

# Reverse Engineering the Apollo 11 Guidance Computer (AGC) Source Code

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# Chapter 1

## Introduction and Notes

I don't know how much time I'm going to spend on this, nor how far I'll take it, but I'll collect my notes here. I started putting comments on my facebook account, and I'll initially copy them here to keep them together.

- Original Apollo 11 guidance computer (AGC) source code, I wrote programs like this in the same time period, however I started using more abstraction with macros and defines in the assembler. ([chrislgarry/Apollo-11](#))
- Today, I would create a literate program in noweb to reverse engineer the code, integrating the documentation and code into a version of the Forth programming language. Forth would be more compact to fit in the small memories of the computers of those days, but I would have to emulate the stack because those old computers hadn't implemented them in the hardware yet. ([wikipedia](#))
- I wrote assemblers in forth to compile (assemble) this type of code on machines before personal computers that didn't have operating systems.
- Such a macro-assembler could be written in several pages of machine code almost directly from the processor reference card.
- I've cloned the Apollo-11 repository and made my first change to the README.md: ([link](#))
- Well, I've got my first stub reverse engineering of the Apollo-11 code in last night. ([link](#))
- There were no file systems with 80 (or more) characters in a file name. There were no file systems at all. The source

had to have been on punch cards or paper tape. I worked at the Federal Reserve Bank in Seattle then on an IBM 360 main frame and we had to order a select chain to put on the printer for the characters that we could print. We had 26 capital letters "A-Z", 10 digits "0-9", and 6 "special characters". In our case the special characters were chosen for accounting applications: "\$", "#", "\_", period, comma, and space. (I think, I can't remember if we had the pound sign.) Notice that there are no lower case letters. That came later, at Bell Labs with UNIX and such, I think.

- There was no floating point arithmetic, only 16 bit integers, from 0 to 65535, or -32767 to 0 to 32767 or possibly -32768 to 32767 depending on whether 0 has a sign and is different from minus zero. Heck there may not have been an integer "divide" operation implemented in the hardware, and probably not even a 16 bit integer multiply. I'll have to look through the source to see. We had to implement multiply and divide in software. Also there was a distinction between "scientific" and "business" computers. My memory is not too good on the details and I have no reference in front of me.
- Aha! I just looked at the first file in my "Apollo-11" book that I just started AND ... "S-ZERO EQUALS NEG0" so plus zero and negative zero were two different numbers!

- I could clone the entire repository and then download it to my Intel Skull Canyon computer from the internet in a fraction of a second. It's 2MB, including all the boiler plate that has been recently added.
- It takes about five seconds to typeset this book. It probably took all night to print the original source listing once.



# Appendices



# Appendix A

## Original Files

### A.1 AGC BLOCK TWO SELF CHECK

```
11  <src/AGC-BLOCK-TWO-SELF-CHECK.s 11>≡
    # Copyright:    Public domain.
    # Filename:     AGC_BLOCK_TWO_SELF_CHECK.agc
    # Purpose:      Part of the source code for Luminary 1A build 099.
    #               It is part of the source code for the Lunar Module's (LM)
    #               Apollo Guidance Computer (AGC), for Apollo 11.
    # Assembler:    yaYUL
    # Contact:       Onno Hommes <ohommes@cmu.edu>.
    # Website:       www.ibiblio.org/apollo.
    # Pages:         1284-1293
    # Mod history:   2009-05-27 OH   Transcribed from page images.
    #
    # This source code has been transcribed or otherwise adapted from
    # digitized images of a hardcopy from the MIT Museum. The digitization
    # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
    # the Museum. Many thanks to both. The images (with suitable reduction
    # in storage size and consequent reduction in image quality as well) are
    # available online at www.ibiblio.org/apollo. If for some reason you
    # find that the images are illegible, contact me at info@sandroid.org
    # about getting access to the (much) higher-quality images which Paul
    # actually created.
    #
    # Notations on the hardcopy document read, in part:
    #
    #       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
    #       16:27 JULY 14, 1969
    #
    # Page 1284
```

```

# PROGRAM DESCRIPTION
# PROGRAM NAME -- SELF-CHECK
# MOD NO -- 1
# MOD BY -- GAUNTT
#
# FUNCTIONAL DESCRIPTION
# PROGRAM HAS TWO MAIN PARTS. THE FIRST IS SELF-CHECK WHICH RUNS AS A ZERO PR
# PART OF THE BACK-UP IDLE LOOP. THE SECOND IS SHOW-BANKSUM WHICH RUNS AS A R
# STARTING VERB.
#
# THE PURPOSE OF SELF-CHECK IS TO CHECK OUT VARIOUS PARTS OF THE COMPUTER AS O
#
# THE PURPOSE OF SHOW-BANKSUM IS TO DISPLAY THE SUM OF EACH BANK, ONE AT A TIME
#
# IN ALL THERE ARE 7 POSSIBLE OPTIONS IN THIS BLOCK II VERSION OF SELF-CHECK.
# FOUND IN E-2065 BLOCK II AGC SELF-CHECK AND SHOW BANKSUM BY EDWIN D. SMALLY I
#
# THE DIFFERENT OPTIONS ARE CONTROLLED BY PUTTING DIFFERENT NUMBERS IN THE SMO
# A DESCRIPTION OF WHAT PARTS OF THE COMPUTER THAT ARE CHECKED BY THE OPTIONS,
# OCTAL, TO LOAD INTO SMODE.
#
# +-4 ERASABLE MEMORY
# +-5 FIXED MEMORY
# +-1,2,3,6,7,10 EVERYTHING IN OPTIONS 4 AND 5.
# -0 SAME AS +-10 UNTIL AN ERROR IS DETECTED.
# +0 NO CHECK, PUTS COMPUTER INTO THE BACKUP IDLE LOOP.
#
# WARNINGS
# USE OF E MEMORY RESERVED FOR SELF-CHECK (EVEN IN IDLE LOOP) AS TEMP STORAGE I
# SMODE SET GREATER THAN OCT 10 PUTS COMPUTER INTO BACKUP IDLE LOOP.
#
# CALLING SEQUENCE
# TO CALL SELF-CHECK KEY IN
# V 21 N 27 E OPTION NUMBER E
# TO CALL SHOW-BANKSUM KEY IN
# V 91 E DISPLAYS FIRST BANK
# V 33 E PROCEED, DISPLAYS NEXT BANK
#
# EXIT MODES, NORMAL AND ALARM
# SELF-CHECK NORMALLY CONTINUES INDEFINITELY UNLESS THERE IS AN ERROR DETECTED
# COMPUTER INTO BACKUP IDLE LOOP, - OPTIONS NUMBERS RESTART THE OPTION.
#
# THE -0 OPTION PROCEEDS FROM THE LINE FOLLOWING THE LINE WHERE THE ERROR WAS I
#
# SHOW-BANKSUM PROCEEDS UNTIL A TERMINATE IS KEYED IN (V 34 E). THE COMPUTER I
#
# OUTPUT

```

# Page 1285

# SELF-CHECK UPON DETECTING AN ERROR LOADS THE SELF-CHECK ALARM CONSTANT (01102) INTO THE  
 # TURNS ON THE ALARM LIGHT. THE OPERATOR MAY THEN DISPLAY THE THREE FAILREGS BY KEYING I  
 # INFORMATION HE MAY KEY IN V 05 N 08 E, THE DSKY DISPLAY IN R1 WILL BE ADDRESS+1 OF WHER  
 # IN R2 THE BBCON OF SELF-CHECK, AND IN R3 THE TOTAL NUMBER OF ERRORS DETECTED BY SELF-CH  
 # INITIATED FRESH START (SLAP1).

#  
 # SHOW-BANKSUM STARTING WITH BANK 0 DISPLAYS IN R1 THE BANK SUM (A +-NUMBER EQUAL TO THE  
 # THE BANK NUMBER, AND IN R3 THE BUGGER WORD.

#  
 # ERASABLE INITIALIZATION REQUIRED  
 # ACCOMPLISHED BY FRESH START  
 # SMODE SET TO +0  
 #

# DEBRIS

# ALL EXITS FROM THE CHECK OF ERASABLE (ERASCHK) RESTORE ORIGINAL CONTENTS TO REGISTERS U  
 # EXCEPTION IS A RESTART. RESTART THAT OCCURS DURING ERASCHK RESTORES ERASABLE, UNLESS T  
 # E MEMORY, IN WHICH CASE PROGRAM THEN DOES A FRESH START (DOFSTART).

BANK 25  
 SETLOC SELFCHEC  
 BANK

COUNT\* \$\$/SELF  
 SBIT1 EQUALS BIT1  
 SBIT2 EQUALS BIT2  
 SBIT3 EQUALS BIT3  
 SBIT4 EQUALS BIT4  
 SBIT5 EQUALS BIT5  
 SBIT6 EQUALS BIT6  
 SBIT7 EQUALS BIT7  
 SBIT8 EQUALS BIT8  
 SBIT9 EQUALS BIT9  
 SBIT10 EQUALS BIT10  
 SBIT11 EQUALS BIT11  
 SBIT12 EQUALS BIT12  
 SBIT13 EQUALS BIT13  
 SBIT14 EQUALS BIT14  
 SBIT15 EQUALS BIT15

S+ZERO EQUALS ZERO  
 S+1 EQUALS BIT1  
 S+2 EQUALS BIT2  
 S+3 EQUALS THREE  
 S+4 EQUALS FOUR  
 S+5 EQUALS FIVE

S+6	EQUALS	SIX	
# Page 1286			
S+7	EQUALS	SEVEN	
S8BITS	EQUALS	LOW8	# 00377
CNTRCON	=	OCT50	# USED IN CNTRCHK
ERASCON1	OCTAL	00061	# USED IN ERASCHK
ERASCON2	OCTAL	01373	# USED IN ERASCHK
ERASCON6	=	OCT1400	# USED IN ERASCHK
ERASCON3	OCTAL	01461	# USED IN ERASCHK
ERASCON4	OCTAL	01773	# USED IN ERASCHK
S10BITS	EQUALS	LOW10	# 01777, USED IN ERASCHK
SBNK03	EQUALS	PRI06	# 06000, USED IN ROPECHK
-MAXADRS	=	HI5	# FOR ROPECHK
SIXTY	OCTAL	00060	
SUPRCON	OCTAL	60017	# USED IN ROPECHK
S13BITS	OCTAL	17777	
CONC+S1	OCTAL	25252	# USED IN CYCLSHFT
CONC+S2	OCTAL	52400	# USED IN CYCLSHFT
ERASCON5	OCTAL	76777	
S-7	=	OCT77770	
S-4	EQUALS	NEG4	
S-3	EQUALS	NEG3	
S-2	EQUALS	NEG2	
S-1	EQUALS	NEGONE	
S-ZERO	EQUALS	NEGO	
	EBANK=	LST1	
ADRS1	ADRES	SKEEP1	
SELFADRS	ADRES	SELFCHK	# SELFCHK RETURN ADDRESS. SHOULD BE PUT # IN SELFRET WHEN GOING FROM SELFCHK TO # SHOWSUM AND PUT IN SKEEP1 WHEN GOING # FROM SHOWSUM TO SELF-CHECK.
PRERRORS	CA	ERESTORE	# IS IT NECESSARY TO RESTORE ERASABLE
	EXTEND		
	BZF	ERRORS	# NO
	EXTEND		
	DCA	SKEEP5	
	INDEX	SKEEP7	
	DXCH	0000	# RESTORE THE TWO ERASABLE REGISTERS
	CA	S+ZERO	
	TS	ERESTORE	
ERRORS	INHINT		
	CA	Q	
	TS	SFAIL	# SAVE Q FOR FAILURE LOCATION
	TS	ALMCADR	# FOR DISPLAY WITH BBANK AND ERCOUNT

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```

TCALARM2      INCR  ERCOUNT      # KEEP TRACK OF NUMBER OF MALFUNCTIONS.
               TC    ALARM2
               OCT    01102      # SELF-CHECK MALFUNCTION INDICATOR
               CCS    SMODE
SIDLOOP       CA    S+ZERO
               TS    SMODE

# Page 1287
               TC    SELFCHK      # GO TO IDLE LOOP
               TC    SFAIL        # CONTINUE WITH SELF-CHECK

-1CHK         CCS    A
               TCF    PRERRORS
               TCF    PRERRORS
               CCS    A
               TCF    PRERRORS
               TC     Q

SMODECHK      EXTEND
               QXCH   SKEEP1
               TC     CHECKNJ      # CHECK FOR NEW JOB
               CCS    SMODE
               TC     SOPTIONS
               TC     SMODECHK +2  # TO BACKUP IDLE LOOP
               TC     SOPTIONS
               INCR   SCOUNT
               TC     SKEEP1      # CONTINUE WITH SELF-CHECK

SOPTIONS      AD     S-7
               EXTEND
               BZMF   +2          # FOR OPTIONS BELOW NINE.
BNKOPTN       TC     SIDLOOP      # ILLEGAL OPTION. GO TO IDLE LOOP.
               INCR   SCOUNT      # FOR OPTIONS BELOW NINE.
               AD     S+7

               INDEX  A
               TC     SOPTION1
SOPTION1      TC     SKEEP1      # WAS TC+TCF
SOPTION2      TC     SKEEP1      # WAS IN:OUT1
SOPTION3      TC     SKEEP1
SOPTION4      TC     ERASCHK
SOPTION5      TC     ROPECHK
SOPTION6      TC     SKEEP1
SOPTION7      TC     SKEEP1
SOPTON10      TC     SKEEP1      # CONTINUE WITH SELF-CHECK

CHECKNJ       EXTEND
```

	QXCH	SELFRET	# SAVE RETURN ADDRESS WHILE TESTING NEWJOB
	TC	POSTJUMP	# TO SEE IF ANY JOBS HAVE BECOME ACTIVE.
	CADR	ADVAN	
SELFCHK	TC	SMODECHK	# ** CHARLEY, COME IN HERE
# SKEEP7 HOLDS LOWEST OF TWO ADDRESSES BEING CHECKED.			
# SKEEP6 HOLDS B(X+1).			
# SKEEP5 HOLDS B(X).			
# SKEEP4 HOLDS C(EBANK) DURING ERASLOOP AND CHECKNJ			
# SKEEP3 HOLDS LAST ADDRESS BEING CHECKED (HIGHEST ADDRESS).			
# Page 1288			
# SKEEP2 CONTROLS CHECKING OF NON-SWITCHABLE ERASABLE MEMORY WITH BANK NUMBERS IN EB			
#			
# ERASCHK TAKES APPROXIMATELY 7 SECONDS.			
ERASCHK	CA	S+1	
	TS	SKEEP2	
OEBANK	CA	S+ZERO	
	TS	EBANK	
	CA	ERASCON3	# 01461
	TS	SKEEP7	# STARTING ADDRESS
	CA	S10BITS	# 01777
	TS	SKEEP3	# LAST ADDRESS CHECKED
	TC	ERASLOOP	
E134567B	CA	ERASCON6	# 01400
	TS	SKEEP7	# STARTING ADDRESS
	CA	S10BITS	# 01777
	TS	SKEEP3	# LAST ADDRESS CHECKED
	TC	ERASLOOP	
2EBANK	CA	ERASCON6	# 01400
	TS	SKEEP7	# STARTING ADDRESS
	CA	ERASCON4	# 01773
	TS	SKEEP3	# LAST ADDRESS CHECKED
	TC	ERASLOOP	
NOEBANK	TS	SKEEP2	# +0
	CA	ERASCON1	# 00061
	TS	SKEEP7	# STARTING ADDRESS
	CA	ERASCON2	# 01373
	TS	SKEEP3	# LAST ADDRESS CHECKED
ERASLOOP	INHINT		
	CA	EBANK	# STORES C(EBANK)



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```
TS      SKEEP4
EXTEND
NDX     SKEEP7
DCA     0000
DXCH    SKEEP5      # STORES C(X) AND C(X+1) IN SKEEP6 AND 5.
CA      SKEEP7
TS      ERESTORE    # IF RESTART, RESTORE C(X) AND C(X+1)
TS      L
INCR    L
NDX     A
DXCH    0000        # PUTS OWN ADDRESS IN X AND X +1
NDX     SKEEP7
CS      0001        # CS X+1
NDX     SKEEP7
AD      0000        # AD X
TC      -1CHK
CA      ERESTORE    # HAS ERASABLE BEEN RESTORED
EXTEND

# Page 1289

BZF     ELOOPFIN    # YES, EXIT ERASLOOP.
EXTEND
NDX     SKEEP7
DCS     0000        # COMPLEMENT OF ADDRESS OF X AND X+1
NDX     SKEEP7
DXCH    0000        # PUT COMPLEMENT OF ADDRESS OF X AND X+1
NDX     SKEEP7
CS      0000        # CS X
NDX     SKEEP7
AD      0001        # AD X+1
TC      -1CHK
CA      ERESTORE    # HAS ERASABLE BEEN RESTORED
EXTEND
BZF     ELOOPFIN    # YES, EXIT ERASLOOP.
EXTEND
DCA     SKEEP5
NDX     SKEEP7
DXCH    0000        # PUT B(X) AND B(X+1) BACK INTO X AND X+1
CA      S+ZERO
TS      ERESTORE    # IF RESTART, DO NOT RESTORE C(X), C(X+1)
RELINT
TC      CHECKNJ     # CHECK FOR NEW JOB
CA      SKEEP4      # REPLACES B(EBANK)
TS      EBANK
INCR    SKEEP7
CS      SKEEP7
AD      SKEEP3
```

```

EXTEND
BZF      +2
TC        ERASLOOP      # GO TO NEXT ADDRESS IN SAME BANK
CCS       SKEEP2
TC        NOEBANK
INCR      SKEEP2      # PUT +1 IN SKEEP2.
CA        EBANK
AD        SBIT9
TS        EBANK
AD        ERASCON5     # 76777, CHECK FOR BANK E2
EXTEND
BZF      2EBANK
CCS       EBANK
TC        E134567B     # GO TO EBANKS 1,3,4,5,6, AND 7
CA        ERASCON6     # END OF ERASCHK
TS        EBANK

# CNTRCHK PERFORMS A CS OF ALL REGISTERS FROM OCT. 60 THROUGH OCT. 10.
# INCLUDED ARE ALL COUNTERS, T6-1, CYCLE AND SHIFT, AND ALL RUPT REGISTERS

CNTRCHK   CA        CNTRCON      # 00050
CNTRLOOP  TS        SKEEP2
          AD        SBIT4      # +10 OCTAL
          INDEX     A
          CS        0000

# Page 1290
          CCS       SKEEP2
          TC        CNTRLOOP

# CYCLSHFT CHECKS THE CYCLE AND SHIFT REGISTERS

CYCLSHFT  CA        CONC+S1     # 25252
          TS        CYR         # C(CYR) = 12525
          TS        CYL         # C(CYL) = 52524
          TS        SR          # C(SR) = 12525
          TS        EDOP        # C(EDOP) = 00125
          AD        CYR         # 37777          C(CYR) = 45252
          AD        CYL         # 00-12524        C(CYL) = 25251
          AD        SR          # 00-25251        C(SR) = 05252
          AD        EDOP        # 00-25376        C(EDOP) = +0
          AD        CONC+S2     # C(CONC+S2) = 52400
          TC        -1CHK
          AD        CYR         # 45252
          AD        CYL         # 72523
          AD        SR          # 77775
          AD        EDOP        # 77775

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AD S+1 # 77776  
TC -1CHK

INCR SCOUNT +1  
TC SMODECHK

# SKEEP1 HOLDS SUM  
# SKEEP2 HOLDS PRESENT CONTENTS OF ADDRESS IN ROPECHK AND SHOWSUM ROUTINES  
# SKEEP2 HOLDS BANK NUMBER IN LOW ORDER BITS DURING SHOWSUM DISPLAY  
# SKEEP3 HOLDS PRESENT ADDRESS (00000 TO 01777 IN COMMON FIXED BANKS)  
# (04000 TO 07777 IN FXXF BANKS)  
# SKEEP3 HOLDS BUGGER WORD DURING SHOWSUM DISPLAY  
# SKEEP4 HOLDS BANK NUMBER AND SUPER BANK NUMBER  
# SKEEP5 COUNTS 2 SUCCESSIVE TC SELF WORDS  
# SKEEP6 CONTROLS ROPECHK OR SHOWSUM OPTION  
# SKEEP7 CONTROLS WHEN ROUTINE IS IN COMMON FIXED OR FIXED FIXED BANKS

ROPECHK CA S-ZERO # \*  
TS SKEEP6 # \* -0 FOR ROPECHK  
STSHOSUM CA S+ZERO # \* SHOULD BE ROPECHK  
  
TS SKEEP4 # BANK NUMBER  
CA S+1  
COMAFX TS SKEEP7  
CA S+ZERO  
TS SKEEP1  
TS SKEEP3  
CA S+1  
TS SKEEP5 # COUNTS DOWN 2 TC SELF WORDS  
COMADRS CA SKEEP4  
TS L # TO SET SUPER BANK  
MASK HI5

# Page 1291

AD SKEEP3  
TC SUPDACAL # SUPER DATA CALL  
TC ADSUM  
AD SBIT11 # 02000  
TC ADRSCHK

FXXF CS A  
TS SKEEP7  
EXTEND  
BZF +3  
CA SBIT12 # 04000, STARTING ADDRESS OF BANK 02  
TC +2  
CA SBNK03 # 06000, STARTING ADDRESS OF BANK 03

	TS	SKEEP3	
	CA	S+ZERO	
	TS	SKEEP1	
	CA	S+1	
	TS	SKEEP5	# COUNTS DOWN 2 TC SELF WORDS
FXADRS	INDEX	SKEEP3	
	CA	0000	
	TC	ADSUM	
	TC	ADRSCHK	
ADSUM	TS	SKEEP2	
	AD	SKEEP1	
	TS	SKEEP1	
	CAF	S+ZERO	
	AD	SKEEP1	
	TS	SKEEP1	
	CS	SKEEP2	
	AD	SKEEP3	
	TC	Q	
ADRSCHK	LXCH	A	
	CA	SKEEP3	
	MASK	LOW10	# RELATIVE ADDRESS
	AD	-MAXADRS	# SUBTRACT MAX RELATIVE ADDRESS = 1777.
	EXTEND		
	BZF	SOPTION	# CHECKSUM FINISHED IF LAST ADDRESS.
	CCS	SKEEP5	# IS CHECKSUM FINISHED
	TC	+3	# NO
	TC	+2	# NO
	TC	SOPTION	# GO TO ROPECHK SHOWSUM OPTION
	CCS	L	# -0 MEANS A TC SELF WORD.
	TC	CONTINU	
	TC	CONTINU	
	TC	CONTINU	
	CCS	SKEEP5	
	TC	CONTINU +1	
	CA	S-1	
# Page 1292			
	TC	CONTINU +1	# AD IN THE BUGGER WORD
CONTINU	CA	S+1	# MAKE SURE TWO CONSECUTIVE TC SELF WORDS
	TS	SKEEP5	
	CCS	SKEEP6	# *
	CCS	NEWJOB	# * +1, SHOWSUM
	TC	CHANG1	# *
	TC	+2	# *
	TC	CHECKNJ	# -0 IN SKEEP6 FOR ROPECHK

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ADRS+1	INCR	SKEEP3	
	CCS	SKEEP7	
	TC	COMADRS	
	TC	COMADRS	
	TC	FXADRS	
	TC	FXADRS	
NXTBNK	CS	SKEEP4	
	AD	LSTBNKCH	# LAST BANK TO BE CHECKED
	EXTEND		
	BZF	ENDSUMS	# END OF SUMMING OF BANKS.
	CA	SKEEP4	
	AD	SBIT11	
	TS	SKEEP4	# 37 TO 40 INCRMTS SKEEP4 BY END RND CARRY
	TC	CHKSUPR	
17T020	CA	SBIT15	
	ADS	SKEEP4	# SET FOR BANK 20
	TC	GONXTBNK	
CHKSUPR	MASK	HI5	
	EXTEND		
	BZF	NXTSUPR	# INCREMENT SUPER BANK
27T030	AD	S13BITS	
	EXTEND		
	BZF	+2	# BANK SET FOR 30
	TC	GONXTBNK	
	CA	SIXTY	# FIRST SUPER BANK
	ADS	SKEEP4	
	TC	GONXTBNK	
NXTSUPR	AD	SUPRCON	# SET BNK 30 + INCR SUPR BNK AND CANCEL
	ADS	SKEEP4	# ERC BIT OF TEH 37 TO 40 ADVANCE.
GONXTBNK	CCS	SKEEP7	
	TC	COMMFY	
	CA	S+1	
	TC	FXFX	
	CA	SBIT7	# HAS TO BE LARGER THAN NO OF FXSW BANKS.
	TC	COMMFY	
SOPTION	CA	SKEEP4	
	MASK	HI5	# = BANK BITS
	TC	LEFT5	
	TS	L	# BANK NUMBER BEFORE SUPER BANK
# Page 1293	CA	SKEEP4	
	MASK	S8BITS	# = SUPER BANK BITS
	EXTEND		

	BZF	SOPT	# BEFORE SUPER BANK
	TS	SR	# SUPER BANK NECESSARY
	CA	L	
	MASK	SEVEN	
	AD	SR	
	TS	L	# BANK NUMBER WITH SUPER BANK
SOPT	CA	SKEEP6	# *
	EXTEND		# *
	BZF	+2	# * ON -0 CONTINUE WITH ROPE CHECK.
	TC	SDISPLAY	# * ON +1 GO TO DISPLAY OF SUM.
	CCS	SKEEP1	# FORCE SUM TO ABSOLUTE VALUE.
	TC	+2	
	TC	+2	
	AD	S+1	
	TS	SKEEP1	
BNKCHK	CS	L	# = - BANK NUMBER
	AD	SKEEP1	
	AD	S-1	
	TC	-1CHK	# CHECK SUM
	TC	NXTBNK	
	EBANK=	NEWJOB	
LSTBNKCH	BBCON*		# * CONSTANT, LAST BANK.

This code is written to file `src/AGC-BLOCK-TWO-SELF--CHECK.s`.

## A.2 AGC BLOCK TWO SELF-CHECK

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*<src/AGC-BLOCK-TWO-SELF-CHECK.s 23>≡*

```
# Copyright:      Public domain.
# Filename:       AGC_BLOCK_TWO_SELF-CHECK.agc
# Purpose:       Part of the source code for Colossus 2A, AKA Comanche 055.
#               It is part of the source code for the Command Module's (CM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:    yaYUL
# Contact:       Ron Burkey <info@sandroid.org>.
# Website:       www.ibiblio.org/apollo.
# Pages:        1394-1403
# Mod history:   2009-05-10 SN    (Sergio Navarro).  Started adapting
#               from the Colossus249/ file of the same
#               name, using Comanche055 page images.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum.  The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum.  Many
# thanks to both.  The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo.  If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#   Assemble revision 055 of AGC program Comanche by NASA
#   2021113-051.  10:28 APR. 1, 1969
#
#   This AGC program shall also be referred to as
#   Colossus 2A

# Page 1394
# PROGRAM DESCRIPTION                                DATE:  20 DECEMBER 1967
# PROGRAM NAME -- SELF-CHECK                        LOG SECTION:  AGC BLOCK TWO SELF-CHECK
# MOD NO -- 1                                       ASSEMBLY SUBROUTINE UTILITYM REV 25
# MOD BY -- GAUNTT
#
# FUNCTIONAL DESCRIPTION
#   PROGRAM HAS TWO MAIN PARTS.  THE FIRST IS SELF-CHECK WHICH RUNS AS A ZERO PRIORITY JOB
#   PART OF THE BACK-UP IDLE LOOP.  THE SECOND IS SHOW-BANKSUM WHICH RUNS AS A REGULAR EXEC
#   STARTING VERB.
#
#   THE PURPOSE OF SELF-CHECK IS TO CHECK OUT VARIOUS PARTS OF THE COMPUTER AS OUTLINED BEL
```

```

#      THE PURPOSE OF SHOW-BANKSUM IS TO DISPLAY THE SUM OF EACH BANK, ONE AT A TIME
#
#      IN ALL THERE ARE 7 POSSIBLE OPTIONS IN THIS BLOCK II VERSION OF SELF-CHECK.
#      FOUND IN E-2065 BLOCK II AGC SELF-CHECK AND SHOW BANKSUM BY EDWIN D. SMALLY
#
#      THE DIFFERENT OPTIONS ARE CONTROLLED BY PUTTING DIFFERENT NUMBERS IN THE SMO
#      A DESCRIPTION OF WHAT PARTS OF THE COMPUTER THAT ARE CHECKED BY THE OPTIONS,
#      OCTAL, TO LOAD INTO SMODE.
#      +-4          ERASABLE MEMORY
#      +-5          FIXED MEMORY
#      +-1,2,3,6,7,10  EVERYTHING IN OPTIONS 4 AND 5.
#      -0          SAME AS +-10 UNTIL AN ERROR IS DETECTED.
#      +0          NO CHECK, PUTS COMPUTER INTO THE BACKUP IDLE LOOP.
#
# WARNINGS
#      USE OF E MEMORY RESERVED FOR SELF-CHECK (EVEN IN IDLE LOOP) AS TEMP STORAGE I
#      SMODE SET GREATER THAN OCT 10 PUTS COMPUTER INTO BACKUP IDLE LOOP.
#
# CALLING SEQUENCE
#      TO CALL SELF-CHECK KEY IN
#          V 21 N 27 E      OPTION NUMBER E
#      TO CALL SHOW-BANKSUM KEY IN
#          V 91 E          DISPLAYS FIRST BANK
#          V 33 E          PROCEED, DISPLAYS NEXT BANK
#
# EXIT MODES, NORMAL AND ALARM
#      SELF-CHECK NORMALLY CONTINUES INDEFINITELY UNLESS THERE IS AN ERROR DETECTED
#      COMPUTER INTO BACKUP IDLE LOOP, - OPTION NUMBERS RESTART THE OPTION.
#
#      THE -0 OPTION PROCEEDS FROM THE LINE FOLLOWING THE LINE WHERE THE ERROR WAS I
#
#      SHOW-BANKSUM PROCEEDS UNTIL A TERMINATE IS KEYED IN (V 34 E).  THE COMPUTER I
#
# OUTPUT
# Page 1395
#      SELF-CHECK UPON DETECTING AN ERROR LOADS THE SELF-CHECK ALARM CONSTANT (01102
#      TURNS ON THE ALARM LIGHT.  THE OPERATOR MAY THEN DISPLAY THE THREE FAILREGS I
#      INFORMATION HE MAY KEY IN V 05 N 08 E, THE DSKY DISPLAY IN R1 WILL BE ADDRESS
#      IN R2 THE BBCON OF SELF-CHECK, AND IN R3 THE TOTAL NUMBER OF ERRORS DETECTED
#      INITIATED FRESH START (SLAP1).
#
#      SHOW-BANKSUM STARTING WITH BANK 0 DISPLAYS IN R1 THE BANK SUM (A +-NUMBER EQ
#      THE BANK NUMBER, AND IN R3 THE BUGGER WORD.
#
# ERASABLE INITIALIZATION REQUIRED
#      ACCOMPLISHED BY FRESH START

```



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```
#          SMODE SET TO +0
#
# DEBRIS
#      ALL EXITS FROM THE CHECK OF ERASABLE (ERASCHK) RESTORE ORIGINAL CONTENTS TO REGISTERS U
#      EXCEPTION IS A RESTART.  RESTART THAT OCCURS DURING ERASCHK RESTORES ERASABLE, UNLESS T
#      E MEMORY, IN WHICH CASE PROGRAM THEN DOES A FRESH START (DOFSTART).

          BANK      25
          SETLOC    SELFCHEC
          BANK

          COUNT     43/SELF

SBIT1      EQUALS   BIT1
SBIT2      EQUALS   BIT2
SBIT3      EQUALS   BIT3
SBIT4      EQUALS   BIT4
SBIT5      EQUALS   BIT5
SBIT6      EQUALS   BIT6
SBIT7      EQUALS   BIT7
SBIT8      EQUALS   BIT8
SBIT9      EQUALS   BIT9
SBIT10     EQUALS   BIT10
SBIT11     EQUALS   BIT11
SBIT12     EQUALS   BIT12
SBIT13     EQUALS   BIT13
SBIT14     EQUALS   BIT14
SBIT15     EQUALS   BIT15

S+ZERO     EQUALS   ZERO
S+1        EQUALS   BIT1
S+2        EQUALS   BIT2
S+3        EQUALS   THREE
S+4        EQUALS   FOUR
S+5        EQUALS   FIVE
# Page 1396
S+6        EQUALS   SIX
S+7        EQUALS   SEVEN
S8BITS     EQUALS   LOW8          # 00377
CNTRCON    =       OCT50         # USED IN CNTRCHK
ERASCON1   OCTAL    00061        # USED IN ERASCHK
ERASCON2   OCTAL    01373        # USED IN ERASCHK
ERASCON6   =       OCT1400       # USED IN ERASCHK
ERASCON3   OCTAL    01461        # USED IN ERASCHK
ERASCON4   OCTAL    01773        # USED IN ERASCHK
S10BITS    EQUALS   LOW10        # 01777, USED IN ERASCHK
```

SBNK03	EQUALS	PRI06	# 06000, USED IN ROPECHK
-MAXADRS	=	HI5	# FOR ROPECHK
SIXTY	OCTAL	00060	
SUPRCON	OCTAL	60017	# USED IN ROPECHK
S13BITS	OCTAL	17777	
CONC+S1	OCTAL	25252	# USED IN CYCLSHFT
CONC+S2	OCTAL	52400	# USED IN CYCLSHFT
ERASCON5	OCTAL	76777	
S-7	=	OCT77770	
S-4	EQUALS	NEG4	
S-3	EQUALS	NEG3	
S-2	EQUALS	NEG2	
S-1	EQUALS	NEGONE	
S-ZERO	EQUALS	NEGO	
	EBANK=	LST1	
ADRS1	ADRES	SKEEP1	
SELFADRS	ADRES	SELFCHK	# SELFCHK RETURN ADDRESS. SHOULD BE PUT # IN SELFRET WHEN GOING FROM SELFCHK TO # SHOWSUM AND PUT IN SKEEP1 WHEN GOING # FROM SHOWSUM TO SELF-CHECK.
PRERRORS	CA	ERESTORE	# IS IT NECESSARY TO RESTORE ERASABLE
	EXTEND		
	BZF	ERRORS	# NO
	EXTEND		
	DCA	SKEEP5	
	INDEX	SKEEP7	
	DXCH	0000	# RESTORE THE TWO ERASABLE REGISTERS
	CA	S+ZERO	
	TS	ERESTORE	
ERRORS	INHINT		
	CA	Q	
	TS	SFAIL	# SAVE Q FOR FAILURE LOCATION
	TS	ALMCADR	# FOR DISPLAY WITH BBANK AND ERCOUNT
	INCR	ERCOUNT	# KEEP TRACK OF NUMBER OF MALFUNCTIONS.
TCALARM2	TC	ALARM2	
	OCT	01102	# SELF-CHECK MALFUNCTION INDICATOR
	CCS	SMODE	
SIDLOOP	CA	S+ZERO	
# Page 1397			
	TS	SMODE	
	TC	SELFCHK	# GO TO IDLE LOOP
	TC	SFAIL	# CONTINUE WITH SELF-CHECK
-1CHK	CCS	A	

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```
TCF      PRERRORS
TCF      PRERRORS
CCS      A
TCF      PRERRORS
TC       Q

SMODECHK  EXTEND
          QXCH  SKEEP1
          TC    CHECKNJ      # CHECK FOR NEW JOB
          CCS   SMODE
          TC    SOPTIONS
          TC    SMODECHK +2  # TO BACKUP IDLE LOOP
          TC    SOPTIONS
          INCR  SCOUNT
          TC    SKEEP1      # CONTINUE WITH SELF-CHECK

SOPTIONS  AD    S-7
          EXTEND
          BZMF  +2          # FOR OPTIONS BELOW NINE.
BNKOPTN   TC    SIDLOOP    # ILLEGAL OPTION. GO TO IDLE LOOP.
          INCR  SCOUNT      # FOR OPTIONS BELOW NINE.
          AD    S+7

          INDEX  A
          TC    SOPTION1
SOPTION1  TC    SKEEP1      # WAS TC+TCF
SOPTION2  TC    SKEEP1      # WAS IN:OUT1
SOPTION3  TC    SKEEP1      # WAS COUNTCHK
SOPTION4  TC    ERASCHK
SOPTION5  TC    ROPECHK
SOPTION6  TC    SKEEP1
SOPTION7  TC    SKEEP1
SOPTON10  TC    SKEEP1      # CONTINUE WITH SELF-CHECK

CHECKNJ   EXTEND
          QXCH  SELFRET      # SAVE RETURN ADDRESS WHILE TESTING NEWJOB
          TC    POSTJUMP     # TO SEE IF ANY JOBS HAVE BECOME ACTIVE.
          CADR  ADVAN

SELFCHK   TC    SMODECHK    # ** CHARLEY, COME IN HERE

# SKEEP7 HOLDS LOWEST OF TWO ADDRESSES BEING CHECKED.
# SKEEP6 HOLDS B(X+1).
# SKEEP5 HOLDS B(X).
# SKEEP4 HOLDS C(EBANK) DURING ERASLOOP AND CHECKNJ
# Page 1398
```

```
# SKEEP3 HOLDS LAST ADDRESS BEING CHECKED (HIGHEST ADDRESS).
# SKEEP2 CONTROLS CHECKING OF NON-SWITCHABLE ERASABLE MEMORY WITH BANK NUMBERS IN EB
#
# ERASCHK TAKES APPROXIMATELY 7 SECONDS.
```

```
ERASCHK      CA      S+1
              TS      SKEEP2
OEBANK       CA      S+ZERO
              TS      EBANK
              CA      ERASCON3      # 01461
              TS      SKEEP7      # STARTING ADDRESS
              CA      S10BITS      # 01777
              TS      SKEEP3      # LAST ADDRESS CHECKED
              TC      ERASLOOP

E134567B     CA      ERASCON6      # 01400
              TS      SKEEP7      # STARTING ADDRESS
              CA      S10BITS      # 01777
              TS      SKEEP3      # LAST ADDRESS CHECKED
              TC      ERASLOOP

2EBANK       CA      ERASCON6      # 01400
              TS      SKEEP7      # STARTING ADDRESS
              CA      ERASCON4      # 01773
              TS      SKEEP3      # LAST ADDRESS CHECKED
              TC      ERASLOOP

NOEBANK      TS      SKEEP2      # +0
              CA      ERASCON1      # 00061
              TS      SKEEP7      # STARTING ADDRESS
              CA      ERASCON2      # 01373
              TS      SKEEP3      # LAST ADDRESS CHECKED

ERASLOOP     INHINT
              CA      EBANK      # STORES C(EBANK)
              TS      SKEEP4
              EXTEND
              NDX      SKEEP7
              DCA      0000
              DXCH     SKEEP5      # STORES C(X) AND C(X+1) IN SKEEP6 AND 5.
              CA      SKEEP7
              TS      ERESTORE      # IF RESTART, RESTORE C(X) AND C(X+1)
              TS      L
              INCR     L
              NDX      A
              DXCH     0000      # PUTS OWN ADDRESS IN X AND X +1
```

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```
# Page 1399
NDX      SKEEP7
CS        0001      # CS X+1
NDX      SKEEP7
AD        0000      # AD X
TC        -1CHK
CA        ERESTORE  # HAS ERASABLE BEEN RESTORED

EXTEND
BZF      ELOOPFIN  # YES, EXIT ERASLOOP.
EXTEND
NDX      SKEEP7
DCS      0000      # COMPLEMENT OF ADDRESS OF X AND X+1
NDX      SKEEP7
DXCH     0000      # PUT COMPLEMENT OF ADDRESS OF X AND X+1
NDX      SKEEP7
CS        0000      # CS X
NDX      SKEEP7
AD        0001      # AD X+1
TC        -1CHK
CA        ERESTORE  # HAS ERASABLE BEEN RESTORED

EXTEND
BZF      ELOOPFIN  # YES, EXIT ERASLOOP.
EXTEND
DCA      SKEEP5
NDX      SKEEP7
DXCH     0000      # PUT B(X) AND B(X+1) BACK INTO X AND X+1
CA        S+ZERO
TS        ERESTORE  # IF RESTART, DO NOT RESTORE C(X), C(X+1)

ELOOPFIN RELINT
TC        CHECKNJ   # CHECK FOR NEW JOB
CA        SKEEP4    # REPLACES B(EBANK)
TS        EBANK
INCR     SKEEP7
CS        SKEEP7
AD        SKEEP3
EXTEND
BZF      +2
TC        ERASLOOP  # GO TO NEXT ADDRESS IN SAME BANK
CCS      SKEEP2
TC        NOEBANK
INCR     SKEEP2      # PUT +1 IN SKEEP2.
CA        EBANK
AD        SBIT9
TS        EBANK
AD        ERASCON5   # 76777, CHECK FOR BANK E2
EXTEND
```



# SKEEP3 HOLDS BUGGER WORD DURING SHOWSUM DISPLAY  
 # SKEEP4 HOLDS BANK NUMBER AND SUPER BANK NUMBER  
 # SKEEP5 COUNTS 2 SUCCESSIVE TC SELF WORDS  
 # SKEEP6 CONTROLS ROPECHK OR SHOWSUM OPTION  
 # SKEEP7 CONTROLS WHEN ROUTINE IS IN COMMON FIXED OR FIXED FIXED BANKS

ROPECHK	CA	S-ZERO	# *
	TS	SKEEP6	# * -0 FOR ROPECHK
STSHOSUM	CA	S+ZERO	# * SHOULD BE ROPECHK
	TS	SKEEP4	# BANK NUMBER
	CA	S+1	
COMAFX	TS	SKEEP7	
	CA	S+ZERO	
	TS	SKEEP1	
	TS	SKEEP3	
	CA	S+1	
	TS	SKEEP5	# COUNTS DOWN 2 TC SELF WORDS
COMADRS	CA	SKEEP4	
	TS	L	# TO SET SUPER BANK
# Page 1401			
	MASK	HI5	
	AD	SKEEP3	
	TC	SUPDACAL	# SUPER DATA CALL
	TC	ADSUM	
	AD	SBIT11	# 02000
	TC	ADRSCHK	
FXFX	CS	A	
	TS	SKEEP7	
	EXTEND		
	BZF	+3	
	CA	SBIT12	# 04000, STARTING ADDRESS OF BANK 02
	TC	+2	
	CA	SBNK03	# 06000, STARTING ADDRESS OF BANK 03
	TS	SKEEP3	
	CA	S+ZERO	
	TS	SKEEP1	
	CA	S+1	
	TS	SKEEP5	# COUNTS DOWN 2 TC SELF WORDS
FXADRS	INDEX	SKEEP3	
	CA	0000	
	TC	ADSUM	
	TC	ADRSCHK	
ADSUM	TS	SKEEP2	

	AD	SKEEP1	
	TS	SKEEP1	
	CAF	S+ZERO	
	AD	SKEEP1	
	TS	SKEEP1	
	CS	SKEEP2	
	AD	SKEEP3	
	TC	Q	
ADRSCHK	LXCH	A	
	CA	SKEEP3	
	MASK	LOW10	# RELATIVE ADDRESS
	AD	-MAXADRS	# SUBTRACT MAX RELATIVE ADDRESS = 1777.
	EXTEND		
	BZF	SOPTION	# CHECKSUM FINISHED IF LAST ADDRESS.
	CCS	SKEEP5	# IS CHECKSUM FINISHED
	TC	+3	# NO
	TC	+2	# NO
	TC	SOPTION	# GO TO ROPECHK SHOWSUM OPTION
	CCS	L	# -0 MEANS A TC SELF WORD.
	TC	CONTINU	
	TC	CONTINU	
	TC	CONTINU	
	CCS	SKEEP5	
	TC	CONTINU +1	
# Page 1402			
	CA	S-1	
	TC	CONTINU +1	# AD IN THE BUGGER WORD
CONTINU	CA	S+1	# MAKE SURE TWO CONSECUTIVE TC SELF WORDS
	TS	SKEEP5	
	CCS	SKEEP6	# *
	CCS	NEWJOB	# * +1, SHOWSUM
	TC	CHANG1	# *
	TC	+2	# *
	TC	CHECKNJ	# -0 IN SKEEP6 FOR ROPECHK
ADRS+1	INCR	SKEEP3	
	CCS	SKEEP7	
	TC	COMADRS	
	TC	COMADRS	
	TC	FXADRS	
	TC	FXADRS	
NXTBNK	CS	SKEEP4	
	AD	LSTBNKCH	# LAST BANK TO BE CHECKED
	EXTEND		



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	BZF	ENDSUMS	# END OF SUMMING OF BANKS.
	CA	SKEEP4	
	AD	SBIT11	
	TS	SKEEP4	# 37 TO 40 INCRMTS SKEEP4 BY END RND CARRY
	TC	CHKSUPR	
17T020	CA	SBIT15	
	ADS	SKEEP4	# SET FOR BANK 20
	TC	GONXTBNK	
CHKSUPR	MASK	HI5	
	EXTEND		
	BZF	NXTSUPR	# INCREMENT SUPER BANK
27T030	AD	S13BITS	
	EXTEND		
	BZF	+2	# BANK SET FOR 30
	TC	GONXTBNK	
	CA	SIXTY	# FIRST SUPER BANK
	ADS	SKEEP4	
	TC	GONXTBNK	
NXTSUPR	AD	SUPRCON	# SET BNK 30 + INCR SUPR BNK AND CANCEL
	ADS	SKEEP4	# ERC BIT OF THE 37 TO 40 ADVANCE.
GONXTBNK	CCS	SKEEP7	
	TC	COMMFY	
	CA	S+1	
	TC	FXFX	
	CA	SBIT7	# HAS TO BE LARGER THAN NO OF FXSW BANKS.
	TC	COMMFY	
SOPTION	CA	SKEEP4	
	MASK	HI5	# = BANK BITS
	TC	LEFT5	
# Page 1403			
	TS	L	# BANK NUMBER BEFORE SUPER BANK
	CA	SKEEP4	
	MASK	S8BITS	# = SUPER BANK BITS
	EXTEND		
	BZF	SOPT	# BEFORE SUPER BANK
	TS	SR	# SUPER BANK NECESSARY
	CA	L	
	MASK	SEVEN	
	AD	SR	
	TS	L	# BANK NUMBER WITH SUPER BANK
SOPT	CA	SKEEP6	# *
	EXTEND		# *
	BZF	+2	# * ON -0 CONTINUE WITH ROPE CHECK.
	TC	SDISPLAY	# * ON +1 GO TO DISPLAY OF SUM.
	CCS	SKEEP1	# FORCE SUM TO ABSOLUTE VALUE.

	TC	+2	
	TC	+2	
	AD	S+1	
	TS	SKEEP1	
BNKCHK	CS	L	# = - BANK NUMBER
	AD	SKEEP1	
	AD	S-1	
	TC	-1CHK	# CHECK SUM
	TC	NXTBNK	
	EBANK=	NEWJOB	
LSTBNKCH	BBCON*		# * CONSTANT, LAST BANK.
	SBANK=	LOWSUPER	

This code is written to file `src/AGC-BLOCK-TWO-SELF-CHECK.s`.

### A.3 AGS INITIALIZATION

35

```

<src/AGS-INITIALIZATION.s 35>≡
# Copyright:      Public domain.
# Filename:       AGS_INITIALIZATION.agc
# Purpose:        Part of the source code for Luminary 1A build 099.
#                It is part of the source code for the Lunar Module's (LM)
#                Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:     yaYUL
# Contact:        Hartmuth Gutsche <hgutsche@explornet.com>.
# Website:        www.ibiblio.org/apollo.
# Pages:          206-210
# Mod history:    2009-05-19 HG   Transcribed from page images.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
#       16:27 JULY 14, 1969
#
# Page 206
#
# PROGRAM NAME:   AGS INITIALIZATION (R47)
#
# WRITTEN BY:     RHODE/KILROY/FOLLETT
#
# MOD NO.:        0
# DATE:           23 MARCH 1967
# MOD BY:         KILROY
#
# MOD NO.:        1
# DATE:           28 OCTOBER 1967
# MOD BY:         FOLLETT
#
# FUNCT. DESC.:   (1) TO PROVIDE THE AGS ABORT ELECTRONICS ASSEMBLY (AEA) WITH THE LEM AND CSM ST
#                 (POSITION,VELOCITY,TIME) IN LEM IMU COORDINATES BY MEANS OF THE LGC DIGITAL DOW
#
#

```

```

#           (2) TO ZERO THE ICDU, LGC, AND AEA GIMBAL ANGLE COUNTER SIMULTANEOUSLY
#           COMMON ZERO REFERENCE FOR THE MEASUREMENT OF GIMBAL (EULER) ANGLES WITH
#
#           (3) TO ESTABLISH THE GROUND ELAPSED TIME OF AEA CLOCK ZERO.  (IF AN AEA
#           REQUESTED DURING THIS PROGRAM
#
# LOG SECTION:  AGS INITIALIZATION
#
# CALLING SEQ:  PROGRAM IS ENTERED WHEN ASTRONAUT KEYS V47E ON DSKY.
#               R47 MAY BE CALLED AT ANY TIME EXCEPT WHEN ANOTHER EXTENDED VERB IS IN
#
# SUBROUTINES
# CALLED:
#
# NORMAL EXIT:  ENDEXT
#
# ALARM/ABORT:  ALARM -- BAD REFSMMAT -- CODE:220
#               OPERATOR ERROR IF V47 SELECTED DURING ANOTHER EXTENDED VERB.
#
# ERASABLES
# USED:         SAMPTIME      (2)      TIME OF :ENTER: KEYSTROKE
#               AGSK          (2)      GROUND ELAPSED TIME OF THE AEA CLOCK :ZERO:
#               AGSBUFF       (140)    CONTAINS AGS INITIALIZATION DATA (SEE :OUTPUT:
#               AGSWORD        (1)     PREVIOUS DOWNLIST SAVED HERE
#
#               EBANK=  AGSBUFF
#
#               BANK      40
#               SETLOC    R47
#               BANK
#
#               COUNT*   $$/R47
#
# AGSINIT      CAF      REFSMBIT
#               MASK     FLAGWRD3      # CHECK REFSMFLG.
#               CCS      A
#
# # Page 207
#               TC       REDSPTEM      # REFSMMAT IS OK
#               TC       ALARM         # REFSMMAT IS BAD
#               OCT      220
#               TC       ENDEXT
#
# NEWAGS       EXTEND
#               DCA      SAMPTIME      # TIME OF THE :ENTER: KEYSTROKE
#               DXCH     AGSK          # BECOMES NEW AEA CLOCK :ZERO:

```

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```

REDSPTM      EXTEND
              DCA      AGSK
              DXCH      DSPTMX
AGSDISPK      CAF      V06N16
              TC        BANKCALL
              CADR      GOMARKF
              TC        ENDEXT
              TC        AGSVCALC
              CS        BIT6
              AD        MPAC
              EXTEND
              BZF       NEWAGS
                                # YES, USE KEYSTROKE TIME FOR NEW AGSK

              EXTEND
              DCA      DSPTMX
              TC        REDSPTM -1
                                # NO, NEW AGSK LOADED VIA V25
                                # LOADED INTO DSPTMX BY KEYING
                                # V25E FOLLOWED BY HRS.,MINS.,SECS.
                                # DISPLAY THE NEW K.

AGSVCALC      TC        INTPRET
              SET
                                # DON'T ALLOW V37
              SET      NODOFLAG
              SET      EXIT
              SET      XDSPFLAG

              CAF      V06N16
              TC        BANKCALL
              CADR      EXDSPRET

              TC        INTPRET
              RTB
                                # EXTRAPOLATE LEM AND CSM STATE VECTORS
                                # TO THE PRESENT TIME
                                # LOAD MPAC WITH TIME2,TIME1
              STCALL   TDEC1
                                # CALCULATE LEM STATE VECTOR
              STCALL   LEMPREC

              CALL
                                # CALL ROUTINE TO CONVERT TO SM COORDS
                                # PROVIDE PROPER SCALING
              STODL    AGSBUFF
                                # (LEMPREC AND CSMPREC LEAVE TDEC1 IN T
              STCALL   TAT
                                # TAT = TIME TO WHICH RATT1 AND VATT1 A
              STCALL   TDEC1
                                # COMPUTED (CSEC SINCE CLOCK START B-28
              STCALL   CSMPREC
                                # CALCULATE CSM STATE VECTOR FOR SAME T
              CALL
              CALL      SCALEVEC

# Page 208
              STODL    AGSBUFF +6
              TAT
              DSU      DDV
                                # CALCULATE AND STORE THE TIME
              DSU      AGSK
```

		TSCALE	
	STORE	AGSBUFF +12D	
	EXIT		
	CAF	LAGSLIST	
	TS	DNLSTCOD	
	CAF	20SEC	# DELAY FOR 20 SEC WHILE THE
	TC	BANKCALL	# DOWNLIST IS TRANSMITTED
	CADR	DELAYJOB	
	CA	AGSWORD	
	TS	DNLSTCOD	# RETURN TO THE OLD DOWNLIST
	CAF	IMUSEBIT	
	MASK	FLAGWRDO	# CHECK IMUSE FLAG.
	CCS	A	
	TC	AGSEND	# IMU IS BEING USED -- DO NOT
CKSTALL	CCS	IMUCADR	# CHECK FOR IMU USAGE WHICH A
	TCF	+3	# IMUSE BIT: I.E., IMU COMPI
	TCF	+6	# FREE. GO AHEAD WITH THE IN
	TCF	+1	
+3	CAF	TEN	# WAIT .1 SEC AND TRY AGAIN.
	TC	BANKCALL	
	CADR	DELAYJOB	
	TCF	CKSTALL	
+6	TC	BANKCALL	# IMU IS NOT IN USE
	CADR	IMUZERO	# SET IMU ZERO DISCRETE FOR 3
	TC	BANKCALL	# WAIT 3 SEC FOR COUNTERS TO
	CADR	IMUSTALL	
	TC	AGSEND	
AGSEND	TC	DOWNFLAG	# ALLOW V37
	ADRES	NODOFLAG	
	CAF	V50N16	
	TC	BANKCALL	
	CADR	GOMARK3	
	TCF	ENDEXT	
	TCF	ENDEXT	
	TC	ENDEXT	
SCALEVEC	VLOAD	MXV	
		VATT1	
		REFSMMAT	
	VXSC	VSL2	
		VSCALE	

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# Page 209

VAD	VAD	# THIS SECTION ROUNDS THE VECTOR, AND
	AGSRND1	# CORRECTS FOR THE FACT THAT THE AGS
	AGSRND2	# IS A 2'S COMPLEMENT MACHINE WHILE THE
RTB		# LGC IS A 1'S COMPLEMENT MACHINE.
	VECSGNAG	
STOVL	VATT1	
	RATT1	
MXV	VXSC	
	REFSMMAT	
	RSCALE	
VSL8	VAD	# AGAIN THIS SECTION ROUNDS. TWO VECTO
	AGSRND1	# ARE ADDED TO DEFEAT ALSIGNAG IN THE
VAD	RTB	# CASE OF A HIGH-ORDER ZERO COUPLED WIT
	AGSRND2	# A LOW ORDER NEGATIVE PART.
	VECSGNAG	
LXA,1		
	VATT1	
SXA,1	LXA,1	
	MPAC +1	
	VATT1 +2	
SXA,1	LXA,1	
	MPAC +4	
	VATT1 +4	
SXA,1	RVQ	
	MPAC +6	

LAGSLIST	=	ONE	
V01N14	VN	0114	
V50N00A	VN	5000	
V00N25	EQUALS	OCT31	
V06N16	VN	0616	
V00N34	EQUALS	34DEC	
V50N16	VN	5016	
TSCALE	2DEC	100 B-10	# CSEC TO SEC SCALE FACTOR
20SEC	DEC	2000	
RSCALE	2DEC	3.280839 B-3	# METERS TO FEET SCALE FACTOR
VSCALE	2DEC	3.280839 E2 B-9	# METERS/CS TO FEET/SEC SCALE FACTOR
AGSRND1	2OCT	0000060000	
	2OCT	0000060000	
	2OCT	0000060000	
AGSRND2	2OCT	0000037777	
	2OCT	0000037777	

S

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2OCT	0000037777
------	------------

40     `Apollo-11.nw`

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`SBANK=   LOWSUPER`

`# FOR SUBSEQUENT LOW 2CADRS.`

This code is written to file `src/AGS-INITIALIZATION.s`.



## A.4 ALARM AND ABORT

```

41  <src/ALARM-AND-ABORT.s 41>≡
    # Copyright:    Public domain.
    # Filename:     ALARM_AND_ABORT.agc
    # Purpose:      Part of the source code for Comanche, build 055. It
    #               is part of the source code for the Command Module's
    #               (CM) Apollo Guidance Computer (AGC), Apollo 11.
    # Assembler:    yaYUL
    # Reference:     pp. 1493-1496
    # Contact:       Ron Burkey <info@sandroid.org>
    # Website:       http://www.ibiblio.org/apollo.
    # Mod history:   2009-05-07 RSB   Adapted from Colossus249 file of the same
    #               name, and page images. Corrected various
    #               typos in the transcription of program
    #               comments, and these should be back-ported
    #               to Colossus249.
    #
    # The contents of the "Comanche055" files, in general, are transcribed
    # from scanned documents.
    #
    # Assemble revision 055 of AGC program Comanche by NASA
    # 2021113-051. April 1, 1969.
    #
    # This AGC program shall also be referred to as Colossus 2A
    #
    # Prepared by
    #
    #           Massachussets Institute of Technology
    #           75 Cambridge Parkway
    #           Cambridge, Massachusetts
    #
    # under NASA contract NAS 9-4065.
    #
    # Refer directly to the online document mentioned above for further
    # information. Please report any errors to info@sandroid.org.
    #
    # Page 1483
    # THE FOLLOWING SUBROUTINE MAY BE CALLED TO DISPLAY A NON-ABORTIVE ALARM CONDITION. IT MAY BE
    # EITHER IN INTERRUPT OR UNDER EXECUTIVE CONTROL.
    #
    # THE CALLING SEQUENCE IS AS FOLLOWS:
    #           TC      ALARM
    #           OCT      NNNNN
    #
    # (RETURNS HERE)
    BLOCK 02

```

```

SETLOC FFTAG7
BANK

EBANK= FAILREG

COUNT 02/ALARM

```

# ALARM TURNS ON THE PROGRAM ALARM LIGHT, BUT DOES NOT DISPLAY.

```

ALARM          INHINT

ALARM2          CA      Q
                TS      ALMCADR
                INDEX   Q
                CA      0
BORTENT         TS      L

PRIOENT         CA      BBANK
+1             EXTEND
                ROR     SUPERBNK      # ADD SUPER BITS.
                TS      ALMCADR +1

LARMENT         CA      Q              # STORE RETURN FOR ALARM
                TS      ITEMP1

                CA      LOC
                TS      LOCALARM
                CA      BANKSET
                TS      BANKALRM

CHKFAIL1        CCS      FAILREG      # IS ANYTHING IN FAILREG
                TCF      CHKFAIL2     # YES TRY NEXT REG
                LXCH     FAILREG
                TCF      PROGLARM      # TURN ALARM LIGHT ON FOR FIRST ALARM

CHKFAIL2        CCS      FAILREG +1
                TCF      FAIL3
                LXCH     FAILREG +1
                TCF      MULTEXIT

FAIL3           CA      FAILREG +2
# Page 1494

                MASK     POSMAX
                CCS      A
                TCF      MULTFAIL
                LXCH     FAILREG +2

```

```

                                TCF      MULTEXIT

PROGLARM      CS      DSPTAB +11D
              MASK    OCT40400
              ADS     DSPTAB +11D

MULTEXIT      XCH      ITEMP1          # OBTAIN RETURN ADDRESS IN A
              RELINT
              INDEX    A
              TC       1

MULTFAIL      CA       L
              AD       BIT15
              TS       FAILREG +2

                                TCF      MULTEXIT

# PRIOLARM DISPLAYS V05N09 VIA PRIODSPR WITH 3 RETURNS TO THE USER FROM THE ASTRONAUT AT CALL L
# AN IMMEDIATE RETURN TO THE USER AT CALL LOC +4.  EXAMPLE FOLLOWS,
#
#          CAF      OCTXX          # ALARM CODE
#          TC       BANKCALL
#          CADR     PRIOLARM
#          ...      ...
#          ...      ...
#          ...      ...          # ASTRONAUT RETURN
#          TC       PHASCHNG       # IMMEDIATE RETURN TO USER.  RESTART
#          OCT      X.1           # PHASE CHANGE FOR PRIO DISPLAY

                                BANK      10
                                SETLOC   DISPLAYS
                                BANK

PRIOLARM      COUNT    10/DSPLA
              INHINT
              TS       L          # * * * KEEP IN DISPLAY ROUTINE'S BANK
                                   # SAVE ALARM CODE

              CA       BUF2          # 2 CADR OF PRIOLARM USER
              TS       ALMCADR
              CA       BUF2 +1
              TC       PRIOENT +1    # * LEAVE L ALONE
-2SEC        DEC      -200          # *** DON'T MOVE
              CAF      V05N09
              TCF      PRIODSPR

```

	BLOCK	02	
	SETLOC	FFTAG13	
	BANK		
	COUNT	02/ALARM	
BAILOUT	INHINT		
	CA	Q	
	TS	ALMCADR	
	TC	BANKCALL	
	CADR	VAC5STOR	
	INDEX	ALMCADR	
	CAF	0	
	TC	BORTENT	
OCT40400	OCT	40400	
	INHINT		
WHIMPER	CA	TWO	
	AD	Z	
	TS	BRUPT	
	RESUME		
	TC	POSTJUMP	# RESUME SENDS CONTROL HERE
	CADR	ENEMA	
	SETLOC	FFTAG7	
	BANK		
POOD00	INHINT		
	CA	Q	
	TS	ALMCADR	
	TC	BANKCALL	
	CADR	VAC5STOR	# STORE ERASABLES FOR DEBUGGING PURPOSES.
	INDEX	ALMCADR	
	CAF	0	
	TC	BORTENT	
ABORT2	OCT	77770	# DON'T MOVE
OCT77770	CA	V37FLBIT	# IS AVERAGE G ON
	MASK	FLAGWRD7	
	CCS	A	
	TC	WHIMPER -1	# YES. DON'T DO POOD00. DO BAILOUT.
	TC	DOWNFLAG	

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TC DOWNFLAG

ADRES	REINTFLG
-------	----------

ADRES      NODOFLAG

CADR MR. KLEAN

TC WHIMPER

## INHINT

TS ALMCADR

TC                      BANKCALL

CADR      VAC5STOR

CA OCT1103

TC ABORT2

OCT 1103

INHINT

CA	Q
----	---

TC ALARM2

OCT 00217

TC	ALMCADR
----	---------

```
# RETURN TO USER
```

EQUALS ENDOFJOB

#	CAF	(ALARM)
---	-----	---------

#	TC	VARALARM
---	----	----------

# Page 1486

```
# VARALARM TURNS ON PROGRAM ALARM LIGHT BUT DOES NOT DISPLAY
```

# INHINT

```
# SAVE USER'S ALARM CODE
```

```
# SAVE USER'S Q
```

TS                      ALMCADR

TC            PRIOENT

OCT 14

# DON'T MOVE

```
TC      ALMCADR      # RETURN TO USER
```

```
ABORT      EQUALS  BAILOUT      # *** TEMPORARY UNTIL ABORT CALLS OUT
```

This code is written to file `src/ALARM-AND-ABORT.s`.

## A.5 ANGLFIND

```

47  <src/ANGLFIND.s 47>≡
# Copyright:    Public domain.
# Filename:     ANGLFIND.agc
# Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
#               It is part of the source code for the Command Module's (CM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:      Ron Burkey <info@sandroid.org>.
# Website:      www.ibiblio.org/apollo.
# Pages:        399-411
# Mod history:  2009-05-09 RSB   Adapted from the Colossus249/ file
#               of the same name, using Comanche055 page
#               images.
#               2009-05-22 RSB   In NOGOM2, TC ZEROEROR corrected to
#               CADR ZEROEROR.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 055 of AGC program Comanche by NASA
#       2021113-051.  10:28 APR. 1, 1969
#
#       This AGC program shall also be referred to as
#               Colossus 2A

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BANK      15
SETLOC    KALCMON1
BANK

EBANK=    BCDU

COUNT    22/KALC

KALCMAN3   TC      INTPRET
          RTB

```

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```

      READCDUK          # PICK UP CURRENT CDU ANGLES
      STORE BCDU        # STORE THE INITIAL S/C ANGLES
      AXC,2 TLOAD       # COMPUTE THE TRANSFORMATION FROM
      MIS              # INITIAL S/C AXES TO STABLE MEMBER AXES
      BCDU             # (MIS)
      CALL
      CDUTODCM
      AXC,2 TLOAD       # COMPUTE THE TRANSFORMATION FROM
      MFS              # FINAL S/C AXES TO STABLE MEMBER AXES
      CPHI             # (MFS)
      CALL
      CDUTODCM
SECAD AXC,1 CALL        # MIS AND MFS ARRAYS CALCULATED          $2
      MIS
      TRANSPOS
      VLOAD
      STADR
      STOVL TMIS        +12D
      STADR
      STOVL TMIS        +6
      STADR
      STORE TMIS        # TMIS = TRANSPOSE(MIS) SCALED BY 2
      AXC,1 AXC,2
      TMIS
      MFS
      CALL
      MXM3
      VLOAD STADR
      STOVL MFI         +12D
      STADR
      STOVL MFI         +6
      STADR
      STORE MFI         # MFI = TMIS MFS (SCALED BY 4)
      SETPD CALL        # TRANSPOSE MFI IN PD LIST
      18D
      TRNSPSPD
      VLOAD STADR
      STOVL TMFI        +12D
      STADR
      STOVL TMFI        +6
# Page 400
      STADR
      STORE TMFI        # TMFI = TRANSPOSE (MFI) SCALED BY 4
# CALCULATE COFSKEW AND MFISYM

```



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```
DLOAD  DSU
        TMFI  +2
        MFI   +2
PDDL   DSU      # CALCULATE COF SCALED BY 2/SIN(AM)
        MFI   +4
        TMFI  +4
PDDL   DSU
        TMFI  +10D
        MFI   +10D
VDEF
STORE  COFSKEW      # EQUALS MFISKEW

# CALCULATE AM AND PROCEED ACCORDING TO ITS MAGNITUDE

DLOAD  DAD
        MFI
        MFI   +16D
DSU     DAD
        DP1/4TH
        MFI   +8D
STORE  CAM      # CAM = (MF10+MFI4+MFI8-1)/2 HALF-SCALE
ARCCOS
STORE  AM      # AM=ARCCOS(CAM)  (AM SCALED BY 2)
DSU     BPL
        MINANG
        CHECKMAX
EXIT      # MANEUVER LESS THAN 0.25 DEG
INHINT    # GO DIRECTLY INTO ATTITUDE HOLD
CS        ONE      # ABOUT COMMANDED ANGLES
TS        HOLDFLAG  # NOGO WILL STOP ANY RATE AND SET UP FOR A
TC        LOADCDUD  # GOOD RETURN
TCF       NOGO

CHECKMAX  DLOAD  DSU
          AM
          MAXANG
BPL       VLOAD
          ALTCALC      # UNIT
          COFSKEW      # COFSKEW
UNIT
STORE     COF      # COF IS THE MANEUVER AXIS
GOTO      # SEE IF MANEUVER GOES THRU GIMBAL LOCK
          LOCKSKIRT
ALTCALC   VLOAD  VAD      # IF AM GREATER THAN 170 DEGREES
          MFI
```

```

                                TMFI
VSR1
STOVL MFISYM
                                MFI +6
VAD VSR1
                                TMFI +6
STOVL MFISYM +6
                                MFI +12D
VAD VSR1
                                TMFI +12D
STORE MFISYM +12D # MFISYM=(MFI+TMFI)/2 SCALED BY 4

# CALCULATE COF

DLOAD SR1
CAM
PDDL DSU # PDO CAM $4
DPHALF
CAM
BOVB PDDL # PD2 1 - CAM $2
SIGNMPAC
MFISYM +16D
DSU DDV
0
2
SQRT PDDL # COFZ = SQRT(MFISYM8-CAM)/(1-CAM)
MFISYM +8D # $ ROOT 2
DSU DDV
0
2
SQRT PDDL # COFY = SQRT(MFISYM4-CAM)/(1-CAM) $ROOT2
MFISYM
DSU DDV
0
2
SQRT VDEF # COFX = SQRT(MFISYM-CAM)/(1-CAM) $ROOT 2
UNIT
STORE COF

# DETERMINE LARGEST COF AND ADJUST ACCORDINGLY

COFMAXGO DLOAD DSU
COF
COF +2
BMN DLOAD # COFY G COFX
COMP12

```

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```
# Page 402

DSU      COF
          BMN
          COF      +4

METHOD3   # COFZ G COFX OR COFY
GOTO

METHOD1   # COFX G COFY OR COFZ
DLOAD    DSU
          COF      +2
          COF      +4
          BMN
          METHOD3   # COFZ G COFY OR COFX

METHOD2   DLOAD    BPL      # COFY MAX
          COFSKEW +2      # UY
          U2POS
          VLOAD    VCOMP
          COF
STORE     COF
U2POS    DLOAD    BPL
          MFISYM  +2      # UX UY
          OKU21
          DLOAD    DCOMP      # SIGN OF UX OPPOSITE TO UY
          COF
STORE     COF
OKU21    DLOAD    BPL
          MFISYM  +10D     # UY UZ
          LOCSKIRT
          DLOAD    DCOMP      # SIGN OF UZ OPPOSITE TO UY
          COF      +4
STORE     COF      +4
GOTO

LOCSKIRT
METHOD1   DLOAD    BPL      # COFX MAX
          COFSKEW      # UX
          U1POS
          VLOAD    VCOMP
          COF
STORE     COF
U1POS    DLOAD    BPL
          MFISYM  +2      # UX UY
          OKU12
          DLOAD    DCOMP
          COF      +2      # SIGN OF UY OPPOSITE TO UX
STORE     COF      +2
OKU12    DLOAD    BPL
```

```

                                MFISYM +4      # UX UZ
                                LOCKSKIRT
                                DLOAD DCOMP      # SIGN OF UZ OPPOSITE TO UY
                                COF      +4
                                STORE COF      +4
                                GOTO
                                LOCKSKIRT
METHOD3      DLOAD BPL      # COFZ MAX
# Page 403
                                COFSKEW +4      # UZ
                                U3POS
                                VLOAD VCOMP
                                COF
                                STORE COF
                                DLOAD BPL
U3POS
                                MFISYM +4      # UX UZ
                                OKU31
                                DLOAD DCOMP
                                COF      # SIGN OF UX OPPOSITE TO UZ
                                STORE COF
                                DLOAD BPL
OKU31
                                MFISYM +10D     # UY UZ
                                LOCKSKIRT
                                DLOAD DCOMP
                                COF      +2      # SIGN OF UY OPPOSITE TO UZ
                                STORE COF      +2
                                GOTO
                                LOCKSKIRT

# Page 404
# MATRIX OPERATIONS

MXM3      SETPD      # MXM3 MULTIPLIES 2 3X3 MATRICES
                                0      # AND LEAVES RESULT IN PD LIST
                                DLOAD* PDDL*      # ADDRESS OF 1ST MATRIX IN XR1
                                12D,2      # ADDRESS OF 2ND MATRIX IN XR2
                                6,2
                                PDDL* VDEF      # DEFINE VECTOR M2(COL 1)
                                0,2
                                MXV* PDDL*      # M1XM2(COL 1) IN PD
                                0,1
                                14D,2
                                PDDL* PDDL*
                                8D,2
                                2,2
                                VDEF MXV*      # DEFINE VECTOR M2(COL 2)

```

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```

                                0,1
PDDL*   PDDL*                   # M1XM2(COL2) IN PD
                                16D,2
                                10D,2
PDDL*   VDEF                     # DEFINE VECTOR M2(COL 3)
                                4,2
MXV*    PUSH                     # M1XM2(COL 3) IN PD
                                0,1
GOTO
                                TRNSPSPD                   # REVERSE ROWS AND COLS IN PD AND

# RETURN WITH M1XM2 IN PD LIST
TRANSPOS  SETPD  VLOAD*          # TRANSPOS TRANSPOSES A 3X3 MATRIX
                                0
                                0,1
                                # AND LEAVES RESULT IN PD LIST
                                # MATRIX ADDRESS IN XR1
PDVL*    PDVL*
                                6,1
                                12D,1
TRNSPSPD  PUSH                   # MATRIX IN PD
DLOAD    PDDL                   # ENTER WITH MATRIX IN PD LIST
                                2
                                6
STODL    2
STADR
STODL    6
                                4
PDDL
                                12D
STODL    4
STADR
STODL    12D
                                10D
PDDL

# Page 405
                                14D
STODL    10D
STADR
STORE    14D
RVQ
                                # RETURN WITH TRANSPOSED MATRIX IN PD LIST
MINANG    DEC    .00069375
MAXANG    DEC    .472222
```

# GIMBAL LOCK CONSTANTS

# D = MGA CORRESPONDING TO GIMBAL LOCK = 60 DEGREES

# NGL = BUFFER ANGLE (TO AVOID DIVISIONS BY ZERO) = 2 DEGREES

```

SD          DEC      .433015      # = SIN(D)          $2
K3S1        DEC      .86603       # = SIN(D)          $2
K4          DEC      -.25         # = -COS(D)         $2
K4SQ        DEC      .125         # = COS(D)COS(D)    $2
SNGLCD      DEC      .008725      # = SIN(NGL)COS(D)  $2
CNGL        DEC      .499695      # = COS(NGL)        $2
READCDUK    INHINT
             CA        CDUZ
             TS        MPAC      +2
             EXTEND
             DCA       CDUX
             RELINT
             TCF       TLOAD     +6
             BANK      16
             SETLOC    KALCMON2
             BANK
             COUNT*    $$/KALC

CDUTODCM    AXT,1    SSP          # SUBROUTINE TO COMPUTE DIRECTION COSINE
             OCT       3          # MATRIX RELATING S/C AXES TO STARLE
             S1        S1        # MEMBER AXES FROM 3 CDU ANGLES IN T(MPAC)
             OCT       1          # SET XR1, S1, AND PD FOR LOOP
             STORE     7
             SETPD
             0
LOOPSIN     SLOAD*   RTB
             10D,1
             CDULOGIC
             STORE     10D        # LOAD PD WITH 0      SIN(PHI)
             SIN       PDDL        #                2      COS(PHI)
             10D        #                4      SIN(THETA)
             COS       PUSH        #                6      COS(THETA)
             TIX,1     DLOAD        #                8      SIN(PSI)
             LOOPSIN    #                10     COS(PSI)
             6
             DMP       SL1
             10D
# Page 406
             STORE     0,2
             DLOAD
             4
             DMP       PDDL
             0          # (PD6 SIN(THETA)SIN(PHI))
             6

```

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DMP	DMP	
	8D	
	2	
SL1	BDSU	
	12D	
SL1		
STORE	2,2	
DLOAD		
	2	
DMP	PDDL	# (PD7 COS(PHI)SIN(THETA)) SCALED 4
	4	
	6	
DMP	DMP	
	8D	
	0	
SL1		
DAD	SL1	
	14D	
STORE	4,2	
DLOAD		
	8D	
STORE	6,2	
DLOAD		
	10D	
DMP	SL1	
	2	
STORE	8D,2	
DLOAD		
	10D	
DMP	DCOMP	
	0	
SL1		
STORE	10D,2	
DLOAD		
	4	
DMP	DCOMP	
	10D	
SL1		
STORE	12D,2	
DLOAD		
DMP	SL1	# (PUSH UP 7)
	8D	
PDDL	DMP	# (PD7 COS(PHI)SIN(THETA)SIN(PSI)) SCALE 4
	6	
	0	

```

DAD      SL1      # (PUSH UP 7)
STADR
STORE    14D,2
DLOAD
DMP      SL1      # (PUSH UP 6)
          8D
PDDL     DMP      # (PD6 SIN(THETA)SIN(PHI)SIN(PSI)) SCALE 4
          6
          2
DSU      SL1      # (PUSH UP 6)
STADR
STORE    16D,2    # C8=-SIN(THETA)SIN(PHI)SIN(PSI)
RVQ      # +COS(THETA)COS(PHI)
ENDOCM    EQUALS

BANK     15
SETLOC   KALCMON1
BANK

# CALCULATION OF THE MATRIX DEL.....
#
#      *      *      __T      *
#      DEL = (IDMATRIX)COS(A)+UU (1-COS(A))+UX SIN(A)          SCALED 1
#
#      -
#      WHERE U IS A UNIT VECTOR (DP SCALED 2) ALONG THE AXIS OF ROTATION.
#      A IS THE ANGLE OF ROTATION (DP SCALED 2).
#
#      -
#      UPON ENTRY THE STARTING ADDRESS OF U IS COF, AND A IS IN MPAC.

COUNT   22/KALC

DELCOMP   SETPD   PUSH      # MPAC CONTAINS THE ANGLE A
          0
          SIN     PDDL      # PD0 = SIN(A)
          COS     PUSH      # PD2 = COS(A)
          SR2     PDDL      # PD2 = COS(A)          $8
          BDSU    BOVB      # PD4 = 1-COS(A)          $2
          DPHALF
          SIGNMPAC

# COMPUTE THE DIAGONAL COMPONENTS OF DEL

PDDL
          COF
DSQ      DMP

```



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```

      4
DAD    SL3

      2
BOVB
      SIGNMPAC
STODL  DEL          # UX UX(U-COS(A)) +COS(A)      $1
      COF          +2
DSQ    DMP
      4
DAD    SL3
      2
BOVB
      SIGNMPAC
STODL  DEL          +8D  # UY UY(1-COS(A)) +COS(A)      $1
      COF          +4
DSQ    DMP
      4
DAD    SL3
      2
BOVB
      SIGNMPAC
STORE  DEL          +16D # UZ UZ(1-COS(A)) +COS(A)      $1
```

# COMPUTE THE OFF-DIAGONAL TERMS OF DEL

```

DLOAD  DMP
      COF
      COF          +2
DMP    SL1
      4
PDDL   DMP          # D6    UX UY (1-COS A)      $ 4
      COF          +4
      0
PUSH   DAD          # D8    UZ SIN A              $ 4
      6
SL2    BOVB
      SIGNMPAC
STODL  DEL          +6
BDSU   SL2
BOVB
      SIGNMPAC
STODL  DEL          +2
      COF
DMP    DMP
      COF          +4
```

```

      4
      SL1  PDDL          # D6    UX UZ (1-COS A)          $ 4
            COF          +2
      DMP  PUSH          # D8    UY SIN(A)
            0
      DAD  SL2
            6
# Page 409
      BOVB
            SIGNMPAC
      STODL DEL          +4    # UX UZ (1-COS(A))+UY SIN(A)
      BDSU  SL2
      BOVB
            SIGNMPAC
      STODL DEL          +12D  # UX UZ (U-COS(A))-UY SIGN(A)
            COF          +2
      DMP  DMP
            COF          +4
            4
      SL1  PDDL          # D6    UY UZ (1-COS(A))          $ 4
            COF
      DMP  PUSH          # D6    UX SIN(A)
            0
      DAD  SL2
            6
      BOVB
            SIGNMPAC
      STODL DEL          +14D  # UY UZ(1-COS(A)) +UX SIN(A)
      BDSU  SL2
      BOVB
            SIGNMPAC
      STORE DEL          +10D  # UY UZ(1-COS(A)) -UX SIN(A)
      RVQ

# DIRECTION COSINE MATRIX TO CDU ANGLE ROUTINE
# X1 CONTAINS THE COMPLEMENT OF THE STARTING ADDRESS FOR MATRIX (SCALED 2)
# LEAVES CDU ANGLES SCALED 2PI IN V(MPAC)
# COS(MGA) WILL BE LEFT IN S1 (SCALED 1)
#
# THE DIRECTION COSINE MATRIX RELATING S/C AXES TO STABLE MEMBER AXES CAN BE WRITTEN
#
#      C =COS(THETA)COS(PSI)
#      0
#
#      C =-COS(THETA)SIN(PSI)COS(PHI)+SIN(THETA)SIN(PHI)
#      1

```

```

#
#      C =COS(THETA)SIN(PSI)SIN(PHI)+SIN(THETA)COS(PHI)
#      2
#
#      C =SIN(PSI)
#      3
#
#      C =COS(PSI)COS(PHI)
#      4
#
#      C =-COS(PSI)SIN(PHI)
#      5
#
#      C =-SIN(THETA)COS(PSI)
#      6
#
#      C =SIN(THETA)SIN(PSI)COS(PHI)+COS(THETA)SIN(PHI)
#      7
# Page 410
#      C =-SIN(THETA)SIN(PSI)SIN(PHI)+COS(THETA)COS(PHI)
#      8
#
#      WHERE   PHI = OGA
#              THETA = IGA
#              PSI = MGA

DCMTOCDU      DLOAD*  ARCSIN
                  6,1
                PUSH   COS           # PD +0          PSI
                SL1     BOVB
                  SIGNMPAC
                STORE   S1
                DLOAD*  DCOMP
                  12D,1
                DDV     ARCSIN
                  S1
                PDDL*   BPL           # PD +2          THETA
                  0,1              # MUST CHECK THE SIGN OF COS(THETA)
                  OKTHETA          # TO DETERMINE THE PROPER QUADRANT
                DLOAD   DCOMP
                BPL     DAD
                  SUHALFA
                  DPHALF
                GOTO
                  CALCPHI
SUHALFA      DSU

```

```

                                DPHALF
CALCPHI      PUSH
OKTHETA      DLOAD*  DCOMP
                                10D,1
                                DDV   ARCSIN
                                S1
                                PDDL*  BPL          # PUSH DOWN PHI
                                8D,1
                                OKPHI
                                DLOAD   DCOMP        # PUSH UP PHI
                                BPL     DAD
                                SUHALFAP
                                DPHALF
                                GOTO
SUHALFAP     DSU      VECOFANG
                                GOTO
                                DPHALF
                                VECOFANG
OKPHI        DLOAD          # PUSH UP PHI
VECOFANG     VDEF   RVQ

```

# Page 411

# ROUTINE FOR TERMINATING AUTOMATIC MANEUVERS

```

NOGOM2       INHINT          # THIS LOCATION ACCESSED BY A BZMF NOGO -2
              TC      BANKCALL
              CADR     ZEROERROR

NOGO          INHINT
              TC      STOPRATE

              CAF      TWO          # TERMINATE MANEUVER
              TC      WAITLIST     # NOTE: ALL RETURNS ARE NOW MADE VIA
              EBANK=   BCDU        # GOODEND
              2CADR    ENDMANU

              TCF      ENDOFJOB

```

This code is written to file src/ANGLFIND.s.

## A.6 AOSTASK AND AOSJOB

```

61  <src/AOSTASK-AND-AOSJOB.s 61>≡
    # Copyright:      Public domain.
    # Filename:       AOSTASK_AND_AOSJOB.agc
    # Purpose:        Part of the source code for Luminary 1A build 099.
    #                 It is part of the source code for the Lunar Module's (LM)
    #                 Apollo Guidance Computer (AGC), for Apollo 11.
    # Assembler:     yaYUL
    # Contact:        Ron Burkey <info@sandroid.org>.
    # Website:        www.ibiblio.org/apollo.
    # Pages:          1485-1506
    # Mod history:    2009-05-27 RSB   Adapted from the corresponding
    #                 Luminary131 file, using page
    #                 images from Luminary 1A.
    #                 2009-06-05 RSB   Corrected a memory-bank error type.
    #                 2009-06-07 RSB   Corrected a typo.
    #
    # This source code has been transcribed or otherwise adapted from
    # digitized images of a hardcopy from the MIT Museum. The digitization
    # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
    # the Museum. Many thanks to both. The images (with suitable reduction
    # in storage size and consequent reduction in image quality as well) are
    # available online at www.ibiblio.org/apollo. If for some reason you
    # find that the images are illegible, contact me at info@sandroid.org
    # about getting access to the (much) higher-quality images which Paul
    # actually created.
    #
    # Notations on the hardcopy document read, in part:
    #
    # Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
    # 16:27 JULY 14, 1969
    #
    # Page 1485
    # PROGRAM NAME:      1/ACCS
    # PROGRAM WRITTEN BY: BOB COVELLI AND MIKE HOUSTON
    # LAST MODIFICATION:  FEB. 14, 1969 BY G. KALAN
    #
    # PROGRAM DESCRIPTION:
    # 1/ACCS PROVIDES THE INTERFACE BETWEEN THE GUIDANCE PROGRAMS AND THE DIGITAL AUTOPILOT.
    # CHANGE IN THE MASS OF THE VEHICLE, IN THE DEADBAND SELECTED, IN THE VEHICLE CONFIGURATION
    # DOCKED), AND DURING A FRESH START OR A RESTART, 1/ACCS IS CALLED TO COMMUNICATE THE DATA
    #
    # THE INPUTS TO 1/ACCS ARE MASS, ACCELERATION (ABDELV), DEADBAND (DB), OFFSET ACCELERATION
    # STAGE VERIFY BIT (CHAN30, BIT2), DOCKED BIT (DAPBOOLS, BIT13), DRIFT BIT (DAPBOOLS, BIT
    # BIT14), AND SURFACE FLAG (FLAGWRDB, BIT8), AND CH5MASK.

```

```

#
# 1/ACCS COMPUTES THE JET ACCELERATIONS (1JACC, 1JACCQ, 1JACCR) AS FUNCTIONS OF
# FORMED BY RESOLVING 1JACCQ AND 1JACCR. IN THE DESCENT CASE, THE DESCENT ENG
# COMPUTED AS A FUNCTION OF MASS. THE RATE OF CHANGE OF ACCELERATION DUE TO RO
# ACCDOTR) IS ALSO COMPUTED IN THE DESCENT CASE.
#
# AFTER THE ABOVE COMPUTATIONS, THE PROGRAM 1/ACCONT COMPUTES THE RECIPROCAL N
# AND V AXES (2 JETS FOR P-AXIS, BOTH 1 AND 2 JETS FOR U AND V AXES), AND THE P
# THE P, U, AND V AXES. THE ACCELERATION FUNCTIONS (ACCFCTZ1 AND ACCFCTZ5) ARE
# FIRE AND COAST DEADBANDS AND AXISDIST ARE COMPUTED FOR EACH AXIS. FLAT AND 2
# MINIMUM IMPULSE ZONE, ARE COMPUTED. 1/ACCONT ALSO SETS ACCSWU AND ACCSWV, WH
# IS NOT SUFFICIENT TO PRODUCE MINIMUM ACCELERATION. AT THE COMPLETION OF 1/A
#
# SUBROUTINES CALLED:
#   TIMEGMBL
#   MAKECADR
#   ROT45DEG
#
# CALLING SEQUENCE:
#           TC      BANKCALL      # (1/ACCS MUST BE CALLED BY BANKCALL)
#           CADR    1/ACCS
#
# NORMAL EXIT: VIA BANKJUMP
#
# ALARM AND EXIT MODES: NONE
#
# INPUT/OUTPUT: SEE PROGRAM DESCRIPTION.
#
# DEBRIS:
#   ALL OF THE EXECUTIVE TEMPORARY REGISTERS, EXCEPT FIXLOC AND OVFIN
#
# RESTRICTIONS:
#   1/ACCS MUST BE CALLED BY BANKCALL
#   EBANK IS SET TO 6, BUT NOT RESTORED.
# Page 1486

```

BANK 20  
SETLOC DAPS3  
BANK

COUNT\* \$\$/DAPAO

EBANK= AOSQ

```

# ENTRY IS THROUGH 1/ACCJOB OR 1/ACCSIT WHEN 1/ACCS IS TO BE DONE AS A SEPARATE NOVA
# IT IS POSSIBLE FOR MORE THAN ONE OF THESE JOBS TO BE SET UP CONCURRENTLY. HOWEVER,

```

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# NEWJOB, A SECOND MANIFESTATION CANNOT BE STARTED UNTIL THE FIRST IS COMPLETED.

1/ACCSET	CAF	ZERO	# ENTRY FROM FRESH START/RESTART CODING.
	TS	AOSQ	# NULL THE OFFSET ESTIMATES FOR 1/ACCS.
	TS	AOSR	
	TS	ALPHAQ	# NULL THE OFFSET ESTIMATES FOR DOWNLIST
	TS	ALPHAR	

1/ACCJOB	TC	BANKCALL	# 1/ACCS ASSUMES ENTRY VIA BANKCALL.
	CADR	1/ACCS +2	# SKIP EBANK SETTING.

TC ENDOFJOB

1/ACCS	CA	EBANK6	# ***** EBANK SET BUT NOT RESTORED *****
	TS	EBANK	
	TC	MAKECADR	# SAVE RETURN SO THAT BUF2 MAY BE USED
	TS	ACCRETRN	

# DETERMINE MASS OF THE LEM.

CA	DAPBOOLS	# IS THE CSM DOCKED
MASK	CSMDOCKD	
TS	DOCKTEMP	# STORE RECORD OF STATE IN TEMP (MPAC +3).
CCS	A	
CS	CSMMASS	# DOCKED: LEMMAS = MASS - CSMMASS
AD	MASS	# LEM ALONE: LEMMASS = MASS
TS	LEMASS	

# ON THE BASIS OF APSFLAG:

# SET THE P-AXIS RATE COMMAND LIMIT FOR 2-JET/2-JET CONTROL

# SET MPAC, WHICH INDICATES THE PROPER SET OF COEFFICIENTS FOR THE LEM-ALONE F(MASS) CALC

# ENSURE THAT THE LEM MASS VALUE IS WITHIN THE ACCEPTABLE RANGE

INHINT		
CAE	FLGWRD10	# DETERMINE WHETHER STAGED.
MASK	APSFLBIT	
EXTEND		
BZF	DPSFLITE	

# Page 1487

CS	POSMAX	# ASCENT (OR ON LUNAR SURFACE)
TS	-2JETLIM	# ALWAYS 2 JETS FOR P-AXIS RATE COMMAND
CAF	OCT14	# INITIALIZE INDEX AT 12.
TS	MPAC	
CS	LEMASS	# CHECK IF MASS TOO HIGH. CATCH STAGING.
AD	HIASCENT	

```

EXTEND
BZMF  MASSFIX
CS    LEMMASS      # CHECK IF MASS TOO LOW.  THIS LIMITS THE
AD    LOASCENT     #      DECREMENTING BY MASSMON.
EXTEND
BZMF  F(MASS)

MASSFIX  ADS    LEMMASS      # STORE THE VIOLATED LIMIT AS LEMMASS.
        ZL      #      ALSO CORRECT TOTAL MASS, ZEROING THE
        CCS    DOCKTEMP     #      LOW-ORDER WORD.
        CAE    CSMASS       #      DOCKED:  MASS = LEMMASS + CS
        AD    LEMMASS       #      LEM ALONE:  MASS = LEMMASS
        DXCH   MASS
        TCF    F(MASS)

DPSFLITE CS    BIT10        # FOUR JETS FOR P-AXIS RATE COMMAND ERRORS
        TS    -2JETLIM     #      EXCEEDING 1.4 DEG/SEC (SCALED AT 45)
        CAF   SIX          # INITIALIZE INDEX AT 6.
        TS    MPAC
        CS    LEMMASS      # CHECK IF MASS TOO HIGH.  SHOULD NEVER
        AD    HIDESCNT     #      OCCUR EXCEPT PERHAPS BEFORE THE PAD
        EXTEND             #      LOAD IS DONE.
        BZMF  MASSFIX
        CS    LEMMASS      # CHECK IF MASS TOO LOW.  THIS LIMITS THE
        AD    LODESCNT     #      DECREMENTING BY MASSMON.
        AD    HIASCENT
        EXTEND
        BZMF  F(MASS)
        TCF   MASSFIX

# COMPUTATION OF FUNCTIONS OF MASS

F(MASS)  RELINT
        CCS    DOCKTEMP
        TCF    DOCKED     # DOCKED:  USE SEPARATE COMPUTATION.
        CA     TWO
STCTR    TS     MPAC      +1 # J=2,1,0 FOR 1JACCR,1JACCQ,1JACC
        CS     TWO
        ADS    MPAC       # JX=10,8,6 OR 4,2,0 TO INDEX COEFS.

STCTR1   CAE    LEMMASS
        INDEX   MPAC
        AD     INERCONC
        TS     MPAC      +2 # MASS + C

```



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```
EXTEND
INDEX  MPAC
DCA    INERCONA
EXTEND
DV     MPAC    +2
INDEX  MPAC
AD     INERCONB
INDEX  MPAC    +1    # 1JACC(J)=A(JX)/(MASS+C(JX) + B(JX)
TS     1JACC        # 1JACC(-1)=L,PVT-CG  SCALED AT 8 FEET

CCS    MPAC    +1
TCF    STCTR
TCF    COMMEQS
TCF    LRES
```

# COEFFQ AND COEFFR ARE COMPUTED IN THIS SECTION. THEY ARE USED TO RESOLVE Q-R COMPONENTS INTO  
# U AND V COMPONENTS (SEE ROT-TOUV SECTION).

```
COMMEQS    CS    1JACCR
           AD    1JACCQ
           EXTEND
           BZMF  BIGIQ
           EXTEND
           DV    1JACCQ    # EPSILON IS A MEASURE OF COUPLING AND IS
           TS    EPSILON   # DEFINED=1-IQ/IR FOR IR GREATER THAN IQ.
           AD    -EPSMAX   # THE COMPUTED EXPRESSION IS EQUIVALENT
           EXTEND
           BZMF  GOODEPS1
           CS    -EPSMAX
           TS    EPSILON   # EPSILON IS LIMITED TO A MAX. OF .42265
GOODEPS1   CA    EPSILON
           EXTEND
           MP    0.35356
           AD    .7071
           TS    COEFFR    # IN THIS CASE WHERE IR IS GREATER THAN
           CS    POSMAX    # IQ, COEFFQ=-.707(1+.5EPSILON)(1-EPSILON)
           AD    EPSILON   # AND COEFFR=.707(1+.5EPSILON)
           EXTEND
           MP    COEFFR
           TS    COEFFQ
           TCF   JACCV
BIGIQ      EXTEND
           DV    1JACCR    # EPSILON IS DEFINED AS 1-IR/IQ FOR IQ
           TS    -EPSILON  # GREATER THAN IR. -EPSILON IS COMPUTED
           CS    -EPSILON  # RATHER THAN EPSILON FOR CONVENIENCE
           AD    -EPSMAX
```

```

EXTEND
BZMF  GOODEPS2
CA    -EPSMAX
TS    -EPSILON      # EPSILON IS LIMITED TO A MAX. OF .42265
# Page 1489
GOODEPS2  CA    -EPSILON
EXTEND
MP     0.35356
AD     -.7071
TS     COEFFQ      # IN THIS CASE WHERE IQ IS GREATER THAN
CS     -EPSILON    # IR, COEFFQ=-.707(1+.5EPSILON) AND
AD     NEGMAX      # COEFFR=.707(1+.5EPSILON)(1-EPSILON)
EXTEND
MP     COEFFQ
TS     COEFFR
JACCUV CS     COEFFQ
EXTEND
MP     1JACCQ      # 1JACCQ IS SCALED AT PI/4
TS     1JACCU      # 1JACCU USED AS TEMPORARY STORAGE
CA     COEFFR
EXTEND
MP     1JACCR
AD     1JACCU
EXTEND
MP     BIT14       # SCALING CHANGED FROM PI/4 TO PI/2
TS     1JACCU
TS     1JACCV      # SCALED AT PI/2 RADIANS/SEC(2)
CCS    MPAC        # COMPUTE L,PVT-CG IF IN DESCENT
CAF    ZERO        # ZERO SWITCHES AND GO TO 1/ACCONT IN
TS     ALLOWGTS    # ASCENT
TCF    1/ACCONT -1

CS     TWO
TS     MPAC
CS     ONE
TS     MPAC      +1
TCF    STCTR1

# THIS SECTION COMPUTES THE RATE OF CHANGE OF ACCELERATION DUE TO THE ROTATION OF THE
# IMPLEMENTED IN BOTH THE Y-X PLANE AND THE Z-X PLANE IS -- D(ALPHA)/DT = TL/I*D(DELTA)
# T = ENGINE THRUST FORCE
# L = PIVOT TO CG DISTANCE OF ENGINE
# I = MOMENT OF INERTIA

LRESC  CAE  ABDELV      # SCALED AT 2(13) CM/SEC(2)
EXTEND

```

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```
MP      MASS      # SCALED AT B+16 KGS
TC      DVOVSUB   # GET QUOTIENT WITH OVERFLOW PROTECTION
ADRES   GFACTM
```

# MASS IS DIVIDED BY ACCELERATION OF GRAVITY IN ORDER TO MATCH THE UNITS OF IXX,IYY,IZZ, WHICH  
# THE RATIO OF ACCELERATION FROM PIPAS TO ACCELERATION OF GRAVITY IS THE SAME IN METRIC OR ENGL  
# THAT IS UNCONVERTED. 2.20462 CONVERTS KG. TO LB. NOW T IN IN A SCALED AT 2(14).

```
EXTEND
MP      L,PVT-CG   # SCALED AT 8 FEET.
# Page 1490
INHINT
TS      MPAC
EXTEND
MP      1JACCR
TC      DVOVSUB   # GET QUOTIENT WITH OVERFLOW PROTECTION
ADRES   TORKJET1

TS      ACCDOTR   # SCALED AT PI/2(7)
CA      MPAC
EXTEND
MP      1JACCQ
TC      DVOVSUB   # GET QUOTIENT WITH OVERFLOW PROTECTION
ADRES   TORKJET1

SPSCONT TS      ACCDOTQ   # SCALED AT PI/2(7)
EXTEND
MP      DGBF      # .3ACCDOTQ SCALED AT PI/2(8)
TS      KQ
CAE     ACCDOTR   # .3ACCDOTR AT PI/2(8)
EXTEND
MP      DGBF
TS      KRDP
EXTEND
READ    CHAN12    # NOW COMPUTE QACCDOT, RACCDOT, THE SIGNED
TS      MPAC      # JERK TERMS. STORE CHANNEL 12. WITH GIMBAL
CAF     BIT2      # DRIVE BITS 9 THROUGH 12 SET LOOP
TCF     LOOP3     # INDEX TO COMPUTE RACCDOT, THEN QACCDOT.
CAF     ZERO
LOOP3  TS      MPAC      # ACCDOTQ AND ACCDOTR ARE NOT NEGATIVE,
CA      MPAC      # BECAUSE THEY ARE MAGNITUDES
INDEX   MPAC      # MASK CHANNEL IMAGE FOR ANY GIMBAL MOTION
MASK    GIMBLBTS
EXTEND
BZF     ZACCDOT   # IF NONE, Q(R)ACCDOT IS ZERO.
CA      MPAC      +1
```

```

INDEX MPAC # GIMBAL IS MOVING. IS ROTATION POSITIVE.
MASK GIMBLBTS +1
EXTEND
BZF FRSTZERO # IF NOT POSITIVE, BRANCH
INDEX MPAC # POSITIVE ROTATION, NEGATIVE Q(R)ACCDOT.
CS ACCDOTQ
TCF STACCDOT
FRSTZERO INDEX MPAC # NEGATIVE ROTATION, POSITIVE Q(R)ACCDOT.
CA ACCDOTQ
TCF STACCDOT
ZACCDOT CAF ZERO
STACCDOT INDEX MPAC
TS QACCDOT # STORE Q(R)ACCDOT.
CCS MPAC
TCF LOOP3 -1 # NOW DO QACCDOT.

# Page 1491
CS DAPBOOLS # IS GIMBAL USABLE?
MASK USEQRJTS
EXTEND
BZF DOWNGTS # NO. BE SURE THE GIMBAL SWITCHES ARE DOWN
CS T5ADR # YES. IS THE DAP RUNNINT?
AD PAXISADR
EXTEND
BZF +2
TCF DOWNGTS # NO. BE SURE THE GIMBAL SWITCHES ARE DOWN
CCS INGTS # YES. IS GTS IN CONTROL?
TCF DOCKTEST # YES. PROCEED WITH 1/ACCS.
TC IBNKCALL # NO. NULL OFFSET AND FIND ALLOWGTS
CADR TIMEGMBL

DOCKTEST CCS DOCKTEMP # BYPASS 1/ACCONT WHEN DOCKED.
TCF 1/ACCRET
TCF 1/ACCONT

# Page 1492
# SUBROUTINE: DVOVSUB
# AUTHOR: C. WORK, MOD 0, 12 JUNE 68
# PURPOSE: THIS SUBROUTINE PROVIDES A SINGLE-PRECISION MACHINE LANGUAGE DIVISION
# (1) THE QUOTIENT, IF THE DIVISION WAS NORMAL.
# (2) NEGMAX, IF THE QUOTIENT WAS IMPROPER AND NEGATIVE.
# (3) POSMAX, IF THE QUOTIENT WAS IMPROPER AND POSITIVE OR IF THERE WAS
# THE CALLING PROGRAM IS PRESUMED TO BE A JOB IN THE F BANK WHICH CONTAINS
# THE DIVISOR FOR THIS ROUTINE MAY BE IN EITHER FIXED OR ERASABLE STORAGE
# ASSUMED BETWEEN THE TWO HALVES OF THE DIVIDEND. (THIS IS CERTAIN IF THE
# RESULT OF A MULTIPLICATION OPERATION.)
# CALL SEQUENCE: L TC DVOVSUB

```

```

#           L +1  ADRES  (DIVISOR)
#           L +2  RETURN HERE, WITH RESULT IN A,L
# INPUT:      DIVIDEND IN A,L (SIGN AGREEMENT ASSUMED), DIVISOR IN LOCATION DESIGNATED BY "AD
#             DIVISOR MAY BE IN THE DVOVSUB FBANK, FIXED-FIXED FBANK, EBANK 6, OR UNSWITCHED ER
# OUTPUT:     QUOTIENT AND REMAINDER, OR POSMAX (NEGMAX), WHICHEVER IS APPROPRIATE.
# DEBRIS:     SCRATCHX, SCRATCHY, SCRATCHZ, A, L  (NOTE: SCRATCHX, Y, Z ARE EQUATED TO MPAC +4, +5,
# ABORTS OR ALARMS:  NONE
# EXITS:      TO THE CALL POINT +2.
# SUBROUTINES CALLED:  NONE.

```

```

DVOVSUB      TS      SCRATCHY      # SAVE UPPER HALF OF DIVIDEND
              TS      SCRATCHX
              INDEX   Q              # OBTAIN ADDRESS OF DIVISOR.
              CA      0
              INCR    Q              # STEP Q FOR PROPER RETURN SEQUENCE.
              INDEX   A
              CA      0              # PICK UP THE DIVISOR.
              EXTEND                      # RETURN POSMAX FOR A ZERO DIVISOR.
              BZF     MAXPLUS

              TS      SCRATCHZ      # STORE DIVISOR.

              CCS     A              # GET ABS(DIVISOR) IN THE A REGISTER.
              AD      BIT1
              TCF     ZEROPLUS
              AD      BIT1

ZEROPLUS     XCH      SCRATCHY      # STORE ABS(DIVISOR).  PICK UP TOP HALF OF
              EXTEND                      # DIVIDENT.
              BZMF    GOODNEG          # GET -ABS(DIVIDEND)

# Page 1493
              CS      A

GOODNEG      AD      SCRATCHY      # ABS(DIVISOR) - ABS(DIVIDEND)
              EXTEND
              BZMF    MAKEMAX          # BRANCH IF DIVISION IS NOT PROPER.

              CA      SCRATCHX      # RE-ESTABLISH THE DIVIDEND
              EXTEND
              DV      SCRATCHZ      # QUOTIENT IN THE A, REMAINDER IN L.
              TC      Q              # RETURN TO CALLER.

MAKEMAX      CCS      SCRATCHX      # DETERMINE THE SIGN OF THE QUOTIENT.
              CCS      SCRATCHZ      # SCRATCHX AND SCRATCHZ ARE NON-ZERO.
              TCF     MAXPLUS
              CCS      SCRATCHZ

```

	CAF	NEGMAX	# +,- OR -,+
	TC	Q	
MAXPLUS	CAF	POSMAX	# -,- OR +,+
	TC	Q	

# COEFFICIENTS FOR THE JET ACCELERATION CURVE FITS

# THE CURVE FITS ARE OF THE FORM --

#

# 1JACC = A/(MASS + C) + B

#

# A IS SCALED AT PI/4 RAD/SEC\*\*2 B+16KG, B IS SCALED AT PI/4 RAD/SEC\*\*2, AND C IS SCA

#

# THE CURVE FIT FOR L,PVT-CG IS OF THE SAME FORM, EXCEPT THAT A IS SCALED AT 8 FT B+

# AND C IS SCALED AT B+16 KG.

	2DEC	+.0410511917	# L	A	DESCENT
INERCONA	2DEC	+.0059347674	# 1JACCP	A	DESCENT
	2DEC	+.0014979264	# 1JACCQ	A	DESCENT
	2DEC	+.0010451889	# 1JACCR	A	DESCENT
	2DEC	+.0065443852	# 1JACCP	A	ASCENT
	2DEC	+.0035784354	# 1JACCQ	A	ASCENT
	2DEC	+.0056946631	# 1JACCR	A	ASCENT
	DEC	+.155044	# L	B	DESCENT
	DEC	-.025233	# L	C	DESCENT
# Page 1494					
INERCONB	DEC	+.002989	# 1JACCP	B	DESCENT
INERCONC	DEC	+.008721	# 1JACCP	C	DESCENT
	DEC	+.018791	# 1JACCQ	B	DESCENT
	DEC	-.068163	# 1JACCQ	C	DESCENT
	DEC	+.021345	# 1JACCR	B	DESCENT
	DEC	-.066027	# 1JACCR	C	DESCENT
	DEC	+.000032	# 1JACCP	B	ASCENT
	DEC	-.006923	# 1JACCP	C	ASCENT
	DEC	+.162862	# 1JACCQ	B	ASCENT
	DEC	+.002588	# 1JACCQ	C	ASCENT
	DEC	+.009312	# 1JACCR	B	ASCENT
	DEC	-.023608	# 1JACCR	C	ASCENT

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GIMBLBTS	OCTAL	01400	
	OCTAL	01000	
	OCTAL	06000	
	OCTAL	04000	
DGBF	DEC	0.6	# .3 SCALED AT 1/2
0.35356	DEC	0.35356	# .70711 SCALED AT 2
GFACTM	OCT	337	# 979.24/2.20462 AT B+15
.7071	DEC	.70711	
-.7071	DEC	-.70711	
-EPSMAX	DEC	-.42265	

# CSM-DOCKED INERTIA COMPUTATIONS

DOCKED	CA	ONE	# COEFTR = 1 FOR INERTIA COEFFICIENTS
SPSLOOP1	TS	COEFCTR	# = 7 FOR CG COEFFICIENTS
	CA	ONE	# MASSCTR = 1 FOR CSM
	TS	MASSCTR	# = 0 FOR LEM

INDEX	COEFCTR	
CA	COEFF	-1 # COEFF -1 = C
EXTEND		
MP	LEMASS	
EXTEND		
MP	CSMASS	# LET X = CSMASS AND Y = LEMASS

INDEX	COEFCTR	
AD	COEFF	# COEFF = F
TS	MPAC	# MPAC = C X Y + F
TCF	+4	

SPSLOOP2	TS	MASSCTR	# LOOP TWICE THROUGH HERE TO OBTAIN
EXTEND			# MPAC = MPAC + (A X +D)X + (B Y +E)Y
DIM	COEFCTR		#
INDEX	COEFCTR		LOOP #1 LOOP #2
CA	COEFF	+2	# COEFF +2 = A OR B
EXTEND			

# Page 1495

INDEX	MASSCTR	
MP	LEMASS	
INDEX	COEFCTR	
AD	COEFF	+4 # COEFF +4 = E OR D
EXTEND		
INDEX	MASSCTR	
MP	LEMASS	
ADS	MPAC	

```

      CCS      MASSCTR
      TCF      SPSLOOP2
      CCS      COEFCTR      # IF COEFCTR IS POS, EXIT FROM LOOP WITH
      TCF      +7           # CG X DELDOT = MPAC X 4 PI RAD-CM/SEC
      TORQCONS 2DEC      0.51443 B-14 # CORRESPONDS TO 500 LB-FT

      CA      MPAC
      TS      MPAC      +1      # INERTIA = (MPAC +1) X 2(38) KG-CM(2)
      CA      SEVEN
      TCF      SPSLOOP1

      CA      1JACCCON      # 1JACC=1JACCCON/MASS
      ZL
      TC      DVOVSUB
      ADRES    MASS
      TS      1JACC      # SCALED AT PI/4

      CA      POSMAX      # SET INVERSE JET ACCELERATIONS TO POSMAX,
      TS      1/ANETP      # WHICH CORRESPONDS TO ACCEL. OF 1.4 D/SS.
      TS      1/ANET2 +1
      TS      1/ANET2 +2
      TS      1/ANET2 +17D
      TS      1/ANET2 +18D
      EXTEND
      DCA      TORQCONS
      EXTEND
      DV      MPAC      +1
      INHINT
      TS      1JACCQ      # SCALED AT PI/4
      TS      1JACCR

      CA      -.7071
      TS      COEFFQ      # COEFFQ AND COEFFR ARE CHOSEN TO MAKE U-
      CA      .7071      # AND V-AXES ORTHOGONAL FOR DOCKED CASE
      TS      COEFFR
      CA      MASS      # SCALED AT 2(16) KG
      EXTEND
      MP      MPAC      # SCALED AT 4 PI RAD-CM/SEC
      EXTEND
      MP      ABDELV      # SCALED AT 2(13) CM/SEC(2)
      TC      DVOVSUB      # GET QUOTIENT WITH OVERFLOW PROTECTION

      ADRES    MPAC      +1

      TS      ACCDOTR
      TCF      SPSCONT      # CONTINUE K, KSQ CALCULATIONS

```



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1JACCCON OCT 00167 # SCALED AT PI/4X2(16) RAD/SEC(2)-KG

#  
# COEFFICIENTS FOR CURVE FIT OF THE FORM  $Z = A X^2 + B Y^2 + C X Y + D X + E Y + F$

COEFF	DEC	.19518	# C	COEFFICIENT OF INERTIA
	DEC	-.00529	# F	"
	DEC	-.17670	# B	"
	DEC	-.03709	# A	"
	DEC	.06974	# E	"
	DEC	.02569	# D	"

	DEC	.20096	# C	COEFFICIENT OF CG
	DEC	.13564	# F	"
	DEC	.75704	# B	"
	DEC	-.37142	# A	"
	DEC	-.63117	# E	"
	DEC	.41179	# D	"

# ASSIGNMENT OF TEMPORARIES FOR 1/ACCS (EXCLUDING 1/ACCONT)

# MPAC, MPAC +1, MPAC +2 USED EXPLICITLY

COEFCTR	EQUALS	MPAC	+4	
MASSCTR	EQUALS	MPAC	+5	
SCRATCHX	EQUALS	MPAC	+4	# SCRATCH AREA FOR DVOVSUB ROUTINE.
SCRATCHY	EQUALS	SCRATCHX	+1	
SCRATCHZ	EQUALS	SCRATCHX	+2	

DOCKTEMP	EQUALS	MPAC	+3	# RECORD OF CSMDOCKED BIT OF DAPBOOLS
EPSILON	EQUALS	MPAC	+1	
-EPSILON	EQUALS	EPSILON		
-.1875	DEC	-.18750		

# Page 1497

BANK 20  
SETLOC DAPS3  
BANK

EBANK= AOSQ

COUNT\* \$\$/DAPAO

-1	TS	INGTS	# ZERO INGTS IN ASCENT
1/ACCONT	CA	DB	# INITIALIZE DBVAL1,2,3
	EXTEND		
	MP	BIT13	

	TS	L	# 0.25 DB
	AD	A	
	TS	DBVAL3	# 0.50 DB
	CS	DBVAL1	
	AD	L	
	TS	DBVAL2	# -.75 DB
GETAOSUV	INHINT		
	CAE	AOSR	# COMPUTE ASOU AND AOSV BY ROTATING
	TS	L	# AOSQ AND AOSR.
	CAE	AOSQ	
	TC	IBNKCALL	
	CADR	ROT-TOUV	
	DXCH	AOSU	
	RELINT		
	CA	DAPBOOLS	
	MASK	DRIFTBIT	# ZERO DURING ULLAGE AND POWERED FLIGHT.
	CCS	A	# IF DRIFTING LIGHT,
	CA	ONE	# SET DRIFTER TO 1
	TS	DRIFTER	# SAVE TO TEST FOR DRIFTING FLIGHT LATER
	AD	ALLOWGTS	# NON-ZERO IF DRIFT OR GTS NEAR
	CCS	A	
	CA	FLATVAL	# DRIFTING FLIGHT, STORE .8 IN FLAT
	TS	FLATEMP	# IN POWERED FLIGHT, STORE ZERO IN FLAT
	EXTEND		
	BZF	DOPAXIS	# IF POWERED AND NO GTS, START P AXIS,
	CCS	DRIFTER	# OTHERWISE SET ZONE3LIM
	CA	ZONE3MAX	# 17.5 MS, SCALED AT 4 SECONDS.
	TS	Z3TEM	
DOPAXIS	CA	1JACC	# 1JACC AT PI/4 = 2JACC AT PI/2 =
	AD	BIT9	# ANET AT PI/2 = ANET/ACOST AT 2(6).
	TS	FUNTEM	# 1 + ANET/ACOST AT 2(6)
# Page 1498	CA	1JACC	
	TC	INVERT	
	INHINT		# P AXIS DATA MUST BE CONSISTENT
	TS	1/ANETP	# SCALED AT 2(7)/PI.
	TS	1/ANETP +1	
	CS	BIT9	# -1 AT 2(6)
	EXTEND		
	MP	1/ANETP	# -1/ANET AT 2(13)/PI

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```
EXTEND
DV      FUNTEM      # -1/(ANET + ANET**2/ACOAST) AT 2(7)/PI
TS      PACCFUN
TS      PACCFUN +1

CA      1/.03      # NO AOS FOR P AXIS, ACOAST = AMIN
TS      1/ACOSTP
TS      1/ACOSTP +1
RELINT

ZL
CCS     DRIFTER
DXCH    AOSU      # ZERO AOSU,V IF IN DRIFT, JUST TO BE SURE

UAXIS   CA      ZERO      # DO U AXIS COMPUTATIONS
        TS      UV        # ZERO FOR U AXIS, ONE FOR V AXIS.

BOTHAXES TS      SIGNAOS   # CODING COMMON TO U,V AXES
        INDEX   UV
        CCS     AOSU      # PICK UP ABS(AOSU OR AOSV)
        AD      ONE      # RESTORE TO PROPER VALUE
        TCF     +3       # AND LEAVE SIGNAOS AT ZERO
        AD      ONE      # NEGATIVE, RESTORE TO PROPER VALUE
        INCR    SIGNAOS   # AND SET SIGNAOS TO ONE TO SHOW AOS NEG
        TS      ABSAOS    # SAVE ABS(AOS)
        CS      SIGNAOS
        TS      -SIGNAOS  # USED AS AN INDEX

        CA      DBVAL1    # SET DB1, DB2 TO DBVAL1 (= DB)
        TS      DBB1
        TS      DBB2

        CA      ABSAOS    # TEST MAGNITUDE OF ABS(AOS)
        AD      -.03R/S2
EXTEND
BZMF    NOTMUCH      # ABS(AOS) LESS THAN AMIN
        CCS     FLATEMP  # AGS(AOS) GREATER THAN AMIN
        TCF     SKIPDB1  # I DRIFT OR GTS, DO NOT COMPUTE DB

        CA      DBVAL1
        INDEX   -SIGNAOS

# Page 1499
ADS     DBB2      # DB2(1) = 2 DB
INDEX   SIGNAOS
TS      DBB4      # DB4(3) = 1 DB
CA      -.1875    # -.1875 PI/2 RAD/SEC(2) SCALED AT PI/2
```

```

                                AD      ABSAOS      # ABSAOS IS SCALED AT PI/2
                                EXTEND
                                BZMF      +3
                                CS      DBVAL3      # -.5 DB
                                TCF      DBONE
                                CS      ABSAOS
                                DOUBLE
                                DOUBLE
                                AD      BIT14
                                DOUBLE      # 1-8 ABSAOS. (8 IS 16/PI SCALED AT 2/PI)
                                EXTEND
                                MP      DB
DBONE      INDEX      SIGNAOS      # DB1(2)=(1-8 ABSAOS) DB. IF ABSAOS IS
                                TS      DBB1      # GREATER THAN .1875 THEN DB1(2) = -.5 DB
                                CA      DBVAL2
                                INDEX      -SIGNAOS
                                TS      DBB3      # DB3(4) = -.75 DB

SKIPDB1      CA      ABSAOS      # ABS(AOS) GREATER THAN AMIN, SO IT IS
                                EXTEND
                                MP      BIT12
                                AD      ABSAOS      # (9/8) ABSAOS.
                                TC      INVERT      # ALL RIGHT TO DIVIDE
                                INDEX      -SIGNAOS
                                TS      1/ACOSTT +1      # 1/ACOSTPOS(NET) = 1/ABS(AOS)
                                CA      1/.03
                                INDEX      SIGNAOS
                                TS      1/ACOSTT      # 1/ACOSTNEG(POS) = 1/AIN

                                CA      ABSAOS
                                AD      1JACCU
                                AD      1JACCU      # 2 JACC + ABS(AOS)
                                AD      BIT9      # MAXIMUM VALUE IN COMPUTATIONS
                                TS      A      # TEST FOR OVERFLOW
                                TCF      SKIPDB2      # NO OVERFLOW, DO NORMAL COMPUTATION

                                CA      ABSAOS      # RESCALE TO PI TO PREVENT OVERFLOW
                                EXTEND
                                MP      BIT14
                                AD      1JACCU      # 1 JACC AT PI/2 = 2JACC AT PI
                                TS      ANET      # ANETPOS(NEG) MAX SCALED AT PI =
                                # ANETPOS(NEG) MAX/ACOSTNEG(POS) AT 2(7)
                                AD      BIT8      # 1 + ANETPOS/ACOSTNEG AT 2(7)
                                XCH      ANET      # SAVE IN ANET, WHILE PICKING UP ANET
                                TC      INVERT
                                EXTEND

```

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# Page 1500

	MP	BIT14	# SCALE 1/ANET AT 2(7)/PI
	TS	1/ANET	
	CA	ACCHERE	# SET UP RETURN FROM COMPUTATION ROUTINE
	TS	ARET	
	CS	BIT8	# -1 AT 2(7)
	TCF	DOACCFUN	# FINISH ACCFUN COMPUTATION
ACCHERE	TCF	ACCTHERE	
NOTMUCH	TS	L	# ABS(AOS) LESS THAN AMIN, SAVE IN L
	CA	1/.03	# ACOASTPOS,NEG = AMIN
	TS	1/ACOSTT	
	TS	1/ACOSTT +1	
	CCS	FLATEMP	
	TCF	SKIPDB2	# DO NOT COMPUTE DB IF DRIFT OR GTS
	CA	.0125RS	# AMIN/2
	AD	L	# L HAS ABS(AOS) - AMIN
	EXTEND		# RESULT IS ABS(AOS)- AMIN/2
	BZMF	NOAOS	# ABS(AOS) LESS THAN AMIN/2
SOMEAOS	CA	DBVAL3	# AMIN/2 LT ABS(AOS) LT AMIN
	INDEX	-SIGNAOS	
	TS	DBB3	# DB3(4) = DB/2
	AD	A	
	INDEX	SIGNAOS	
	TS	DBB4	# DB4(3) = DB
	TCF	SKIPDB2	
NOAOS	CA	DBVAL1	
	TS	DBB3	# DB3,4 = DB
	TS	DBB4	
SKIPDB2	CA	ABSAOS	# ANETPOS(NEG) MAX = 2 JACC + ABS(AOS)
	AD	1JACCU	
	AD	1JACCU	
	TS	ANET	# CANNOT OVERFLOW HERE
CL1/NET+	TC	DO1/NET+	# COMPUTE 1/ANET, ACCFUN
ACCTHERE	INDEX	-SIGNAOS	
	TS	Z5TEM +2	# STORE ACCFUN IN TEMPORARY BUFFER
	CA	1/ANET	
	INDEX	-SIGNAOS	

# Page 1501

TS	1/ATEM2 +2	# STORE 1/ANET IN TEMPORARY BUFFER
CA	ABSAOS	# SEE IF OVERFLOW IN MIN CASE
AD	1JACCU	
AD	BIT9	# MAXIMUM POSSIBLE VALUE
TS	A	# OVERFLOW POSSIBLE BUT REMOTE
TCF	+2	
CA	POS MAX	# IF OVERFLOW, TRUNCATE TO PI/2
AD	-.03R/S2	# RESTORE TO CORRECT VALUE
TS	ANET	
TC	DO1/NET+	# COMPUTE 1/ANET, ACCFUN
INDEX	-SIGNAOS	# STORE MIN VALUES JUST AS MAX VALUES
TS	Z5TEM	
CA	1/ANET	
INDEX	-SIGNAOS	
TS	1/ATEM2	
CS	ABSAOS	# NOW DO NEG(POS) CASES
AD	1JACCU	
AD	1JACCU	# ANETNEG(POS) MAX
TC	1/ANET-	# COMPUTE 1/ANET, ACCFUN, AND ACCSW
INDEX	SIGNAOS	# STORE NEG(POS) VALUES JUST AS POS(NEG)
TS	Z1TEM +2	
TS	L	# SAVE IN L FOR POSSIBLE FUTURE USE
CA	1/ANET	
INDEX	SIGNAOS	
TS	1/ATEM1 +2	
CS	ABSAOS	
AD	1JACCU	# 1/ANETNEG(POS) MIN
TS	ANET	
AD	-.03R/S2	# TEST FOR AMIN
EXTEND		# IF ANET LESS THAN AMIN, STORE MAX JET
BZMF	FIXMIN	# VALUES FOR MIN JETS AND SET ACCSW
TC	1/NETMIN	# OTHERWISE DO MIN JET COMPUTATIONS
INDEX	SIGNAOS	# STORE VALUES
TS	Z1TEM	
CA	1/ANET	
INDEX	SIGNAOS	
TS	1/ATEM1	
INDEX	UV	
CA	+UMASK	
MASK	CH5MASK	# TEST FOR +U (+V) JET FAILURES

STMIN-

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                                EXTEND
                                BZF      FAIL-
                                CA        1/ATEM2      # REPLACE FUNCTION VALUES DEPENDING ON THE
                                TS        1/ATEM2 +2    # FAILED JET PAIR WITH CORRESPONDING ONE-
                                CA        Z5TEM         # JET (OR AMIN) FUNCTION VALUES
                                TS        Z5TEM +2
                                INDEX     UV
                                CA        -UMASK
                                MASK      CH5MASK      # TEST FOR -U (-V) JET FAILURES
                                EXTEND
                                BZF      DBFUN
                                CA        1/ATEM1      # REPLACE FUNCTION VALUES DEPENDING ON THE
                                TS        1/ATEM1 +2    # FAILED JET PAIR WITH CORRESPONDING ONE-
                                CA        Z1TEM         # JET (OR AMIN) FUNCTION VALUES
                                TS        Z1TEM +2
                                DBFUN
                                CS        DBB3          # COMPUTE AXISDIST
                                AD        DBB1
                                AD        FLATEMP
                                TS        AXDSTEM
                                CS        DBB4
                                AD        DBB2
                                AD        FLATEMP
                                TS        AXDSTEM +1
                                INHINT
                                CCS      UV            # TEST FOR U OR V AXIS
                                TCF      STORV         # V AXIS          STORE V VALUES
                                CA        ACCSW         # U AXIS          STORE U VALUES
                                TS        ACCSWU
                                CA        NINE         # TRANSFER 10 WORDS VIA GENTRAN
                                TC        GENTRAN +1
                                ADRES     1/ATEM1      # TEMPORARY BUFFER
                                ADRES     1/ANET1       # THE REAL PLACE
                                RELINT
                                DXCH      DBB1          # SAVE U DBS FOR LATER STORING
                                DXCH      UDB1
                                DXCH      DBB4
                                DXCH      UDB4
                                DXCH      AXDSTEM
                                DXCH      UAXDIST
```

```

CA      ONE      # NOW DO V AXIS
TS      UV
CA      ZERO
TCF     BOTHAXES # AND DO IT AGAIN

STORV   CA      ACCSW      # STORE V AXIS VALUES
        TS      ACCSWV
        CA      NINE
        TC      GENTRAN +1

# Page 1503
        ADRES   1/ATEM1    # TEMPORARY BUFFER
        ADRES   1/ANET1 +16D # THE REAL PLACE

        DXCH    FLATEMP    # NOW STORE DEADBANDS FOR ALL AXES
        DXCH    FLAT      # FLAT AND ZONE3LIM

        CA      DBVAL1    # COMPUTE P AXIS DEADBANDS
        TS      PDB1
        TS      PDB2
        AD      FLAT
        TS      PDB3
        TS      PDB4
        CA      ZERO
        TS      PAXDIST
        TS      PAXDIST +1

        CCS     FLAT
        TCF     DRFDB      # DRIFT OR GTS -- COMPUTE DBS

        DXCH    UDB1      # STORE U DEADBANDS
        DXCH    FIREDDB    # CANNOT USE GENTRAN BECAUSE OF RELINT
        DXCH    UDB4
        DXCH    COASTDB
        DXCH    UAXDIST
        DXCH    AXISDIST
        DXCH    DBB1      # STORE V AXIS DEADBANDS
        DXCH    FIREDDB +16D # COULD USE GENTRAN IF DESIRED
        DXCH    DBB4
        DXCH    COASTDB +16D
        DXCH    AXDSTEM
        DXCH    AXISDIST +16D

        TCF     1/ACCRET +1 # ALL DONE
DRFDB   CA      DBVAL1    # DRIFT DEADBANDS

```



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```
TS      FIREDDB
TS      FIREDDB  +1
TS      FIREDDB  +16D
TS      FIREDDB  +17D
AD      FLAT
TS      COASTDB
TS      COASTDB  +1
TS      COASTDB  +16D
TS      COASTDB  +17D
CA      ZERO
TS      AXISDIST
TS      AXISDIST  +1
TS      AXISDIST  +16D
TS      AXISDIST  +17D
```

# Page 1504  
1/ACCRET

```
INHINT
CS      DAPBOOLS      # SET BIT TO INDICATE DATA GOOD.
MASK    ACCSOKAY
ADS     DAPBOOLS
RELINT
CA      ACCRETRN
TC      BANKJUMP      # RETURN TO CALLER
```

INVERT

```
TS      HOLD          # ROUTINE TO INVERT -INPUT AT PI/2
CA      BIT9          # 1 AT 2(6)
ZL
EXTEND
DV      HOLD
TC      Q              # RESULT AT 2(7)/PI
```

DOWNGTS

```
CAF     ZERO          # ZERO SWITCHES WHEN USEQRJTS BIT IS UP
TS      ALLOWGTS      #          OR DAP IS OFF
TS      INGTS
TCF     DOCKTEST
```

1/ANET-

```
ZL
LXCH    ACCSW          # ZERO ACCSW
TS      ANET           # SAVE ANET
AD      -.03R/S2      # TEST FOR MIN VALUE
EXTEND
```

1/NETMIN

```
BZMF    NETNEG        # ANET LESS THAN AMIN, SO FAKE IT
CA      ANET
EXTEND
INDEX   -SIGNAOS
MP      1/ACOSTT +1    # ANETNEG(POS)/ACOSTPOS(NEG) AT 2(6)
```

# THE FOLLOWING CODING IS VALID FOR BOTH POS OR NEG  
# VALUES OF AOS

DO1/NET+	AD	BIT9	# 1 + ANET/ACOAST AT 2(6)
	XCH	ANET	# SAVE AND PICK UP ANET
	EXTEND		
	QXCH	ARET	# SAVE RETURN
	TC	INVERT	
	TS	1/ANET	# 1/ANET AT 2(7)/PI
	CS	BIT9	# -1 AT 2(6)
DOACCFUN	EXTEND		
	MP	1/ANET	# -1/ANET AT 2(13)/PI
	EXTEND		
	DV	ANET	# ACCFUN AT 2(7)/PI
	TC	ARET	# RETURN
NETNEG	CS	-.03R/S2	# ANET LESS THAN AMIN -- SET EQUAL TO AMIN
	TS	ANET	
# Page 1505			
	TCF	1/NETMIN +1	# CONTINUE AS IF NOTHING HAPPENED.
FIXMIN	CCS	SIGNAOS	
	CA	TWO	# IF AOS NEG, ACCSW = +1
	AD	NEGONE	# IF AOS POS, ACCSW = -1
	TS	ACCSW	
	AD	UV	# IF ACCSW = +1, TEST FOR +U (+V) JET FAIL
	INDEX	A	# IF ACCSW = -1, TEST FOR -U (-V) JET FAIL
	CA	-UMASK +1	
	MASK	CH5MASK	
	EXTEND		
	BZF	+4	
	CS	-.03R/S2	# JET FAILURE -- CANNOT USE 2-JET VALUES
	TS	ANET	# ANET = AMIN
	TCF	STMIN- -1	# CALCULATE FUNCTIONS USING AMIN
	CA	L	# L HAS ACCFUN
	TCF	STMIN-	# STORE MAX VALUES FOR MIN JETS

# ERASABLE ASSIGNMENTS FOR 1/ACCONT

1/ANETP	EQUALS	BLOCKTOP +2
1/ACOSTP	EQUALS	BLOCKTOP +4
PACCFUN	EQUALS	BLOCKTOP +8D
PDB1	EQUALS	BLOCKTOP +10D
PDB2	EQUALS	BLOCKTOP +11D
PDB4	EQUALS	BLOCKTOP +12D

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PDB3	EQUALS	BLOCKTOP +13D	
PAXDIST	EQUALS	BLOCKTOP +14D	
ACCSW	EQUALS	VBUF	# EXECUTIVE TEMPORARIES
			# CANNOT DO CCS NEWJOB DURING 1/ACCS
1/ATEM1	EQUALS	ACCSW +1	# TEMP BUFFER FOR U AND V AXES
1/ATEM2	EQUALS	1/ATEM1 +1	
1/ACOSTT	EQUALS	1/ATEM1 +4	
Z1TEM	EQUALS	1/ATEM1 +6	
Z5TEM	EQUALS	1/ATEM1 +7	
UDB1	EQUALS	1/ATEM1 +10D	# UAXIS DEADBAND BUFFER
UDB2	EQUALS	1/ATEM1 +11D	
UDB4	EQUALS	1/ATEM1 +12D	
UDB3	EQUALS	1/ATEM1 +13D	
UAXDIST	EQUALS	1/ATEM1 +14D	
DBB1	EQUALS	1/ATEM1 +16D	# TEMP DEADBAND BUFFER, ALSO V AXIS
DBB2	EQUALS	1/ATEM1 +17D	
DBB4	EQUALS	1/ATEM1 +18D	
DBB3	EQUALS	1/ATEM1 +19D	
AXDSTEM	EQUALS	1/ATEM1 +20D	
# Page 1506			
FLATEMP	EQUALS	1/ATEM1 +22D	
Z3TEM	EQUALS	1/ATEM1 +23D	# MUST FOLLOW FLATEMP
DBVAL1	EQUALS	DB	
DBVAL2	EQUALS	INTB15+	
DBVAL3	EQUALS	INTB15+ +1	
DRIFTER	EQUALS	INTB15+ +2	
UV	EQUALS	MPAC	
ANET	EQUALS	MPAC +3	
FUNTEM	EQUALS	MPAC +3	
1/ANET	EQUALS	MPAC +4	
ARET	EQUALS	MPAC +5	
ABSAOS	EQUALS	MPAC +6	
SIGNAOS	EQUALS	MPAC +7	
-SIGNAOS	EQUALS	MPAC +8D	
HOLD	EQUALS	MPAC +9D	
ACCRETRN	EQUALS	FIXLOC -1	
ZONE3MAX	DEC	.004375	# 17.5 MS (35 MS FOR 1 JET) AT 4 SECONDS
FLATVAL	DEC	.01778	# .8 AT PI/4 RAD

-.03R/S2	OCT	77377	# -PI/2(7) AT PI/2
.0125RS	EQUALS	BIT8	# PI/2(+8) AT PI/2
1/.03	EQUALS	POSMAX	# 2(7)/PI AT 2(7)/PI
PAXISADR	GENADR	PAXIS	
			# THE FOLLOWING 4 CONSTANTS ARE JET
			# FAILURE MASKS AND ARE INDEXED
-UMASK	OCT	00110	# -U
	OCT	00022	# -V
+UMASK	OCT	00204	# +U
	OCT	00041	# +V

This code is written to file `src/AOSTASK-AND-AOSJOB.s`.

## A.7 AOTMARK

```

85  <src/AOTMARK.s 85>≡
    # Copyright:    Public domain.
    # Filename:     AOTMARK.agc
    # Purpose:      Part of the source code for Luminary 1A build 099.
    #               It is part of the source code for the Lunar Module's (LM)
    #               Apollo Guidance Computer (AGC), for Apollo 11.
    # Assembler:    yaYUL
    # Contact:       Ron Burkey <info@sandroid.org>.
    # Website:       www.ibiblio.org/apollo.
    # Pages:         244-261
    # Mod history:   2009-05-10 SN    (Sergio Navarro).  Started adapting
    #               from the Luminary131/ file of the same
    #               name, using Luminary099 page images.
    #
    # This source code has been transcribed or otherwise adapted from
    # digitized images of a hardcopy from the MIT Museum.  The digitization
    # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
    # the Museum.  Many thanks to both.  The images (with suitable reduction
    # in storage size and consequent reduction in image quality as well) are
    # available online at www.ibiblio.org/apollo.  If for some reason you
    # find that the images are illegible, contact me at info@sandroid.org
    # about getting access to the (much) higher-quality images which Paul
    # actually created.
    #
    # Notations on the hardcopy document read, in part:
    #
    #       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
    #       16:27 JULY 14, 1969

    # Page 244

                BANK      12
                SETLOC    AOTMARK1
                BANK

                EBANK=     XYMARK
                COUNT*     $$/MARK

AOTMARK        INHINT
                CCS        MARKSTAT      # SEE IF AOTMARK BUSY
                TC         +2             # MARK SYSTEM BUSY -- DO ALARM
                TC         EXTVBCHK
                TC         POOD00
                OCT         00105

```

EXTVBCHK	CAF	SIX	# SEE IF EXT. VERB WORKING
	MASK	EXTVBACT	
	CCS	A	
	TCF	MKABORT	# YES -- ABORT
MKVAC	CAF	BIT2	# NO -- DISALLOW SOME EXTENDED VERB ACTION
	ADS	EXTVBACT	# BIT2 RESET IN ENDMARK
	CCS	VAC1USE	# LOOK FOR A VAC AREAD -- DO ABORT IF
	TCF	MKVACFND	# NONE AVAILABLE
	CCS	VAC2USE	
	TCF	MKVACFND	
	CCS	VAC3USE	
	TCF	MKVACFND	
	CCS	VAC4USE	
	TCF	MKVACFND	
	CCS	VAC5USE	
	TCF	MKVACFND	
	DXCH	BUF2	
	TC	BAILOUT1	# ALL VAC AREAS OCCUPIED -- ABORT.
	OCT	01207	
MKVACFND	AD	TWO	
	TS	MARKSTAT	# STORE VAC ADR IN LOW 9 OF MARKSTAT
	CAF	ZERO	
	INDEX	MARKSTAT	
	TS	0 -1	# ZERO IN VACUSE REG TO SHOW VAC OCCUPIED
	CAF	PRI015	
	TC	FINDVAC	# SET UP JOB FOR GETDAT
	EBANK=	XYMARK	
	2CADR	GETDAT	
	RELINT		
# Page 245 MKABORT	TCF	SWRETURN	
	DXCH	BUF2	
	TC	BAILOUT1	# CONFLICT WITH EXTENDED VERB
	OCT	01211	
MKRELEAS	CAF	ZERO	
	XCH	MARKSTAT	# SET MARKSTAT TO ZERO
	MASK	LOW9	# PICK UP VAC AREA AOR
	CCS	A	
	INDEX	A	
	TS	0	# SHOW MKVAC AREA AVAILABLE

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	CAF	ONE	
	TC	IBNKCALL	
	CADR	GOODEND	# GO WAKE UP CALLING JOB
# Page 246			
KILLAOT	CAF	ZERO	
	TS	EXTVBACT	# TERMINATE AOTMARK -- ALLOW EXT VERB
	TC	GOTOP00H	
GETDAT	CS	MARKSTAT	# SET BIT12 TO DISCOURAGE MARKRUPT
	MASK	BIT12	# BIT12 RESET AT GETMARK
	ADS	MARKSTAT	
	CAF	V01N71	# DISPLAY DETENT AND STAR CODE
	TC	BANKCALL	
	CADR	GOMARKF	
	TCF	KILLAOT	# V34 -- DOES GOTOP00H
	TCF	DODAT	# V33 -- PROCEED -- USE THIS STAR FOR MARKS
ENTERDAT	TCF	GETDAT	# ENTER -- REDISPLAY STAR CODE
DODAT	CAF	HIGH9	# PICK DETENT CODE FROM BITS7-9 OF AOTCODE
	MASK	AOTCODE	# AND SEE IF CODE 1 TO 6
	EXTEND		
	MP	BIT9	
	TS	XYMARK	# STORE DETENT
	EXTEND		
	BZMF	GETDAT	# COAS CALIBRATION CODE - NO GOOD HERE
	AD	NEG7	# SEE IF DETENT 7 FOR COAS
	EXTEND		
	BZF	CODE7	
	TCF	CODE1T06	
CODE7	CAF	V06N87*	# CODE 7, COAS SIGHTING, GET OPTIC AXIS
	TC	BANKCALL	# AZ AND EL OF SIGHTING DEVICE FROM ASTRO
	CADR	GOMARKF	
	TCF	KILLAOT	# V34 -- DOES GOTOP00H
	TCF	+2	# PROCEED
	TCF	CODE7	# ON ENTER, RECYCLE
	EXTEND		
	DCA	AZ	# PICK UP AZ AND EL IN SP 25 COMP
	INDEX	FIXLOC	
	DXCH	8D	# STORE IN 8D AND 9D OF LOCAL VAC

```

CAF      ZERO      # BACKUP SYSTEM TO BE USED
TCF      COASCODE  # ZERO APPARENT ROTATION

CODE1T06 INDEX XYMARK      # INDEX AOT POSITION BY DET CODE
CA       AOTEL -1
INDEX    FIXLOC
TS       9D          # STORE ELEVATION IN VAC+9D

# Page 247 INDEX XYMARK      # INDEX DET CODE 1,2 OR 3
CA       AOTAZ -1
INDEX    FIXLOC
TS       8D          # STORE AZIMUTH IN VAC +8D

CA       AOTAZ +1      # COMPENSATION FOR APPARENT ROTATION OF
EXTEND                                # AOT FIELD OF VIEW IN LEFT AND RIGHT
INDEX    FIXLOC        # DETENTS IS STORED IN VAC +10D IN SP
MSU      8D            # PRECISION ONE'S COMPLEMENT
COASCODE INDEX FIXLOC
TS       10D          # ROT ANGLE

TC       INTERPRET     # COMPUTE X AND Y PLANE VECTORS

# Page 248
# THE OPTAXIS SOBROUTINE COMPUTES THE X AND Y MARK PLANE VECs AND
# ROTATES THEM THRU THE APPARENT FIELD OF VIEW ROTATION UNIQUE TO AOT
# OPTAXIS USES OANB TO COMPUTE THE OPTIC AXIS
#
# INPUT -- AZIMUTH ANGLE IN SINGLE PREC AT CDU SCALE IN 8D OF JOB VAC
#           ELEVATION ANGLE IN SINGLE PREC AT CDU SCALE IN 9D OF JOB VAC
#           ROTATION ANGLE IN SINGLE PREC IS COMP SCALED BY PI IN 10D OF
#
# OUTPUT -- OPTIC AXIS VEC IN NG COORDS IN SCAXIS
#           X-MARK PLANE 1/4VEC IN NB COORDS AT 18D OF JOB VAC
#           Y-MARK PLANE 1/4VEC IN NB COORDS AT 12D OF JOB VAC

OPTAXIS  CALL      # GO COMPUTE OA AN X AND Y PLANE VECs
          OANB
          SLOAD    SR1      # LOAD APP ROTATION IN ONES COMP
          10D      # RESCALE BY 2PI
          PUSH     SIN      # 1/2SIN(ROT) 0-1
          PDDL     COS
          PUSH     VXSC     # 1/2COS(ROT) 2-3
          18D
          PDDL     VXSC     # 1/4COS(ROT) UYP 4-9
          0

```



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```

                24D          # 1/4SIN(ROT)UXP
BVSU   STADR          # UP 4-9
STODL   12D          # YPNB=1/4(COS(ROT)UY-P-SIN(ROT)UXP)
VXSC    PDDL          # UP 2-3 UP 0-1 FOR EXCHANGE
                24D          # 1/4COS(ROT)UXP          PUSH 0-5
VXSC    VAD           # 1/4SIN(ROT)UY-P
                18D          # UP 0-5
STADR
STOVL   18D          # XPNB=1/4(COS(ROT)UXP+SIN(ROT)UY-P)
                L06ZEROS      # INITIALIZE AVE STAR VEC ACCUMULATOR
STORE   STARAD +6
EXIT
TCF     GETMKS
```

# Page 249

# THE OANB SUBROUTINE COMPUTES THE OPTIC AXIS OF THE SIGHTING INSTRUMENT  
# FROM AZIMUTH AND ELEVATION INPUT FROM THE ASTRONAUT.

```

#
#      INPUT --      AZIMUTH ANGLE IN SINGLE PREC 2'S COMP IN 8D OF JOB VAC
#                    ELEVATION ANGLE IN SINGLE PREC 2'S COMP IN 9D OF VAC
#
#      OUTPUT --     OPTIC AXIS IN NB COORDS. IN SCAXIS
#                    X-PLANE 1/2VEC IN NB COORDS AT 24D OF VAC
#                    Y-PLANE 1/2VEC IN NB COORDS AT 18D OF VAC
```

```

BANK    05
SETLOC  AOTMARK2
BANK
```

```

COUNT*  $$/MARK
```

```

OANB    SETPD  STQ
                0
                GCTR          # STORE RETURN
SLOAD   RTB
                9D          # PICK UP SP ELV
                CDULOGIC
PUSH    COS
PDDL    SIN          # 1/2COS(ELV)    PD 0-1
STADR
STODL   SCAXIS      # OAX=1/2SIN(ELV)
                8D
RTB
                CDULOGIC
PUSH    COS
STORE   20D          # STORE UYP(Y)    20-21
```

```

PDDL SIN # 1/2COS(AZ) PD 2-3
PUSH DCOMP # PUSH 1/2S IN (AZ) 4-5
STODL 22D # STORE UYP(Z) 22-23
      L06ZEROS
STODL 18D # STORE UYP(X) 18-19
DMP SL1
      0
STODL SCAXIS +2 # OAY=1/2COS(ELV)SIN(AZ)
DMP SL1 # UP 2-3
STADR # UP 0-1
STOVL SCAXIS +4 # OAZ=1/2COS(ELV)COS(AZ)
      18D # LOAD UYP VEC
VXV UNIT
      SCAXIS # UXP VEC=UYP X OA
STORE 24D # STORE UXP
GOTO
      GCTR

# Page 250
# SURFSTAR COMPUTES A STAR VECTOR IN SM COORDINAGES FOR LUNAR
# SURFACE ALIGNMENT AND EXITS TO AVEIT TO AVERAGE STAR VECTORS.
#
# GIVEN X-MARK PLANE 1/4 VEC IN NB AT 18D OF LOCAL VAC
# Y-MARK PLANE 1/4 VEC IN NB AT 12D OF LOCAL VAC
# CURSOR SP 2COMP AT POSITION 1 OF INDEXED MARKVAC
# SPIRAL SP 2COMP AT POSITION 3 OF INDEXED MARKVAC
# CDUY,Z,X AT POSITIONS 0,2,4 OF INDEXED MARKVAC

BANK 15
SETLOC P50S
BANK
COUNT* $$/R59

SURFSTAR VLOAD*
      0,1 # PUT X-MARK CDUS IN CDUSPOT FOR TRG*NBSM
STORE CDUSPOT
SLOAD* RTB
      1,1 # PICK UP YROT
      CDULOGIC
STORE 24D # STORE CURSOR FOR SPIRAL COMP (REVS)
BZE
      YZCHK # IF YROT ZERO -- SEE IF SROT ZERO
JUSTZY PUSH COS
PDDL SIN # 1/2COS(YROT) 0-1
VXSC PDDL # UP 0-1 1/8SIN(YROT)UXP 0-5
      18D
VXSC VSU # UP 0-5

```

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```
UNIT      12D      # UYP
UNIT      VXV
          SCAXIS
UNIT      PUSH
SLOAD*    RTB
          3,1      # PICK UP SPIRAL
          CDULOGIC
STORE     26D      # STORE SPIRAL (REVS)
DSU       DAD
          24D
          ABOUTONE
DMP
          DP1/12
STORE     26D      # SEP=(360 + SPIRAL -CURSOR)/12
SIN       VXSC     # UP      0-5
VSL1     PDDL      # 1/2SIN(SEP)(UPP X OA) 0-5
          26D
COS       VXSC
          SCAXIS
VSL1     VAD       # UP      0-5
UNIT     CALL
          TRG*NBSM
STCALL    24D      # STAR VEC IN SM
          AVEIT     # GO AVERAGE

# Page 251
ABOUTONE 2DEC     .99999999

DP1/12    EQUALS   DEG30      # .08333333
          BANK     7
          SETLOC   AOTMARK1
          BANK
COUNT*   $$/MARK
YZCHK     SLOAD*   BZE       # YROT ZERO AND IF SROT ZERO FORCE STAR
          3,1      # ALONG OPTIC AXIS
          YSZERO
          DLOAD    GOTO
          24D
          JUSTZY   # SROT NOT ZERO -- CONTINUE NORMALLY
YZZERO    VLOAD    GOTO
          SCAXIS
          JUSTOA

# Page 252
# THE GETMKS ROUTINE INITIALIZES THE SIGHTING MARK PROCEDURE

GETMKS    CAF      ZERO      # INITIALIZE MARK ID REGISTER AND MARK CNT
```

	TS	XYMARK	
	TS	MARKCNTR	
	CAF	LOW9	# ZERO BITS10 TO 15 RETAINING MKVAC ADR
	MASK	MARKSTAT	
	TS	MARKSTAT	
	CAF	MKVB54*	# DISPLAY VB54 INITIALLY
PASTIT	TC	BANKCALL	
	CADR	GOMARK4	
	TCF	KILLAOT	# V34 -- DOES GOTOPOOH
	TCF	MARKCHEX	# VB33 -- PROCEED, GOT MARKS, COMPUTE LOS
	TCF	GETDAT	# ENTER -- RECYCLE TO V01N71
MARKCHEX	CS	MARKSTAT	# SET BIT12 TO DISCOURAGE MARKRUPT
	MASK	BIT12	
	ADS	MARKSTAT	
	MASK	LOW9	
	TS	XYMARK	# JAM MARK VAC ADR IN XYMARK FOR AVESTAR
	CAF	ZERO	
	TS	MKDEX	# SET MKDEX ZERO FOR LOS VEC CNTR
	CA	MARKSTAT	
	MASK	PRI03	# SEE IF LAST MK PART COMPLETE
	TS	L	
	CAF	PRI03	# BITS10 AND 11
	EXTEND		
	RXOR	LCHAN	
	EXTEND		
	BZF	AVESTAR	# LAST PAIR COMPLETE -- TO COMPUTE LOS
CNTCHK	CCS	MARKCNTR	# NO PAIR SHOWING -- SEE IF PAIR IN HOLD
	TCF	+2	# PAIR BURIED -- DECREMENT COUNTER
	TCF	MKALARM	# NO PAIR -- ALARM
	TS	MARKCNTR	# STORE DECREMENTED COUNTER
AVESTAR	CAF	BIT12	# INITIALIZE MKDEX FOR STAR LOS COUNTER
	ADS	MKDEX	# MKDEX WAS INITIALIZED ZERO IN MARKCHEX
	CS	MARKCNTR	
	EXTEND		
	MP	SIX	# GET C(L) = -6 MARKCNTR
	CS	XYMARK	
	AD	L	# ADD -- MARK VAC ADR SET IN MARKCHEX
	INDEX	FIXLOC	
	TS	X1	# JAM -- CDU ADR OF X-MARK IN X1
	CA	FIXLOC	# SET PD POINTER TO ZERO
	TS	PUSHLOC	

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```
# Page 253      TC      INTERPRET

BON      VLOAD*
          SURFFLAG      # IF ON SURFACE COMPUTE VEC AT SURFSTAR
          SURFSTAR
          1,1      # PUT Y-MARK CDUS IN CDUSPOT FOR TRG*NBSM
STOVL    CDUSPOT
          12D      # LOAD Y-PLANE VECTOR IN NG
CALL
          TRG*NBSM      # CONVERT IT TO STABLE MEMBER
PUSH     VLOAD*
          0,1      # PUT X-MARK CDUS IN CDUSPOT FOR TRG*NBSM
STOVL    CDUSPOT
          18D      # LOAD X-PLANE VECTOR IN NB
CALL
          TRG*NBSM      # CONVERT IT TO STABLE-MEMBER
VXV      UNIT      # UNIT(XPSM * YPSM)
STADR
STORE    24D

AVEIT     SLOAD    PDVL      # N(NUMBER OF VECs) IN 0-1
          MKDEX
          24D      # LOAD CURRENT VECTOR
VSR3     V/SC
          0
STODL    24D      # VEC/N
          0
DSU      DDV
          DP1/8      # (N-1)/N
VXSC     VAD
          STARAD +6      # ADD VEC TO PREVIOUSLY AVERAGED VECTOR
          24D      # (N-1)/N AVESTVEC + VEC/N
STORE    STARAD +6      # AVERAGE STAR VECTOR
STORE    STARSAV2
EXIT
CCS      MARKCNTR      # SEE IF ANOTHER MARK PAIR IN MKVAC
TCF      AVESTAR -1      # THERE IS -- GO GET IT -- DECREMENT COUNTER
ENDMARKS CAF      FIVE      # NO MORE MARKS -- TERMINATE AOTMARK
          INHINT
          TC      WAITLIST
          EBANK=   XYMARK
          2CADR    MKRELEAS

          TC      ENDMARK

MKALARM   TC      ALARM      # NOT A PAIR TO PROCESS -- DO GETMKS
```

	OCT	111
	TCF	GETMKS

V01N71	VN	171
V06N87*	VN	687

# Page 254

# MARKRUPT IS ENTERED FROM INTERRUPT LEAD-INS AND PROCESSES CHANNEL 16

# CAUSED BY X,Y MARK OR MARK REJECT OR BY THE RATE OF DESCENT SWITCH

MARKRUPT	TS	BANKRUPT	
	CA	CDUY	# STORE CDUS AND TIME NOW -- THEN SEE IF
	TS	ITEMP3	# WE NEED THEM
	CA	CDUZ	
	TS	ITEMP4	
	CA	CDUX	
	TS	ITEMP5	
	EXTEND		
	DCA	TIME2	
	DXCH	ITEMP1	
	XCH	Q	
	TS	QRUPT	
	CAF	OCT34	# SEE IF X OR Y MARK OR MKREJECT
	EXTEND		
	RAND	NAVKEYIN	
	CCS	A	
	TCF	+2	# ITS A LIVE ONE -- SEE IF ITS WANTED
	TCF	SOMEKEY	# ITS SOME OTHER KEY
	CAF	BIT12	# ARE WE ASKING FOR A MARK
	MASK	MARKSTAT	
	CCS	A	
	TC	RESUME	# DON'T WANT MARK OR MKREJECT -- DO NOTHING
	CCS	MARKSTAT	# ARE MARKS BEING ACCEPTED
	TCF	FINDKEY	# THEY ARE -- WHICH ONE IS IT
	TC	ALARM	# MARKS NOT BEING ACCEPTED -- DO ALARM
	OCT	112	
	TC	RESUME	
FINDKEY	CAF	BIT5	# SEE IF MARK REJECT.
	EXTEND		
	RAND	NAVKEYIN	
	CCS	A	
	TCF	MKREJ	# IT'S A MARK REJECT

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```
CAF      BIT4      # SEE IF Y MARK
EXTEND
RAND     NAVKEYIN
CCS      A

TCF      YMKRUPT   # IT'S A Y MARK

CAF      BIT3      # SEE IF X MARK
EXTEND
RAND     NAVKEYIN

# Page 255

CCS      A
TCF      XMKRUPT   # IT'S A X MARK

SOMEKEY  CAF      OCT140      # NOT MARK OR MKREJECT -- SEE IF DESCENT BITS
EXTEND
RAND     NAVKEYIN
EXTEND
BZF      +3        # IF NO BITS

TC       POSTJUMP   # IF DESCENT BITS
CADR     DESCBITS

TC       ALARM      # NO INBITS IN CHANNEL 16.
OCT      113

TC       RESUME

XMKRUPT  CAF      ZERO
TS       RUPTREG1   # SET X MARK STORE INDEX TO ZERO
CAF      BIT10
TCF      +4

YMKRUPT  CAF      ONE
TS       RUPTREG1   # SET Y MARK STORE INDEX TO ONE
CAF      BIT11
TS       XYMARK     # SET MARK IDENTIFICATION

TC       MARKTYPE   # SEE IF SURFACE MARK
TCF      SURFSTOR   # SURFACE MARK -- JUST STORE CDUS

CAF      BIT14      # GOT A MARK -- SEE IF MARK PAIR MADE
MASK     MARKSTAT
EXTEND
BZF      VERIFYMK   # NOT A PAIR, NORMAL PROCEDURE
```

	CS	MARKCNTR	# GO A PAIR, SEE IF ANOTHER CAN BE MADE
	AD	FOUR	# IF SO, INCREMENT POINTER, CLEAR BITS 10,11
	EXTEND		
	BZMF	5MKALARM	# HAVE FIVE MARK PAIRS -- DON'T ALLOW MARK
	INCR	MARKCNTR	# OK FOR ANOTHER PAIR, INCR POINTER
	CS	PRI023	# CLEAR BITS 10,11,14 FOR NEXT PAIR
	MASK	MARKSTAT	
	TS	MARKSTAT	
VERIFYMK	CA	XYMARK	
	MASK	MARKSTAT	
	CCS	A	
	TCF	+2	# THIS MARK NOT DESIRED
	TCF	VACSTOR	# MARK DESIRED -- STORE CDUS
	TC	ALARM	
	OCT	114	
	TC	RESUME	# RESUME -- DISPLAY UNCHANGED -- WAIT FOR ACT
# Page 256			
5MKALARM	TC	ALARM	# ATTEMPTING TO MAKE MORE THAN 5 MK PAIRS
	OCT	107	
	TC	MARKTYPE	# SEE IF SURFACE MARK
	TCF	DSPV6N79	# IT IS
	TC	RESUME	# DON'T CHANGE DISPLAY -- DO NOTHING
# Page 257			
MKREJ	TC	MARKTYPE	# SEE IF SURFACE
	TCF	SURFREJ	# SURFACE -- JUST CHECK MARK COUNTER
	CAF	PRI03	# INFLIGHT -- SEE IF MARKS MADE
	MASK	MARKSTAT	
	CCS	A	
	TCF	REJECT	# MARKS MADE -- REJECT ONE
REJALM	TC	ALARM	# NO MARK TO REJECT -- BAD PROCEDURE -- ALARM
	OCT	115	
	TC	RESUME	# DESIRED ACTION DISPLAYED
REJECT	CS	PRI030	# ZERO BIT14, SHOW REJ., SEE IF MARK SINCE
	MASK	MARKSTAT	# LAST REJECT
	AD	BIT13	
	XCH	MARKSTAT	
	MASK	BIT13	
	CCS	A	
	TCF	REJECT2	# ANOTHER REJECT SET BIT 10+11 TO ZERO
	CS	XYMARK	# MARK MADE SINCE REJECT -- REJECT MARK IN 11



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RENEWMK	MASK	MARKSTAT	
	TS	MARKSTAT	
	TCF	REMARK	# GO REQUEST NEW MARK ACTION
REJECT2	CS	PRI03	# ON SECOND REJECT -- DISPLAY VB53 AGAIN
	TCF	RENEWMK	
SURFREJ	CCS	MARKCNTR	# IF MARK DECREMENT COUNTER
	TCF	+2	
	TCF	REJALM	# NO MARKS TO REJECT -- ALARM
	TS	MARKCNTR	
	TC	RESUME	
# Page 258			
# MARKTYPE TESTS TO SEE IF LEM ON LUNAR SURFACE. IF IT IS RETURN TO LOC+1			
MARKTYPE	CS	FLAGWRD8	# SURFFLAG ***** TEMPORARY *****
	MASK	BIT8	
	CCS	A	
	INCR	Q	# IF SURFACE MARK RETURN TO LOC +1
	TC	Q	# IF INFLIGHT MARK RETURN TO LOC +2
SURFSTOR	CAF	ZERO	# FOR SURFACE MARK ZERO MARK KIND INDEX
	TS	RUPTREG1	
	CS	MARKSTAT	# SET BITS10,11 TO SHOW SURFACE MARK
	MASK	PRI03	# FOR MARKCHEX
	ADS	MARKSTAT	
VACSTOR	CAF	LOW9	
	MASK	MARKSTAT	# STORE MARK VAC ADR IN RUPTREG2
	TS	RUPTREG2	
	EXTEND		
	DCA	ITEMP1	# PICK UP MARKTIME
	DXCH	TSIGHT	# STORE LAST MARK TIME
	CA	MARKCNTR	# 6 X MARKCNTR FOR STORE INDEX
	EXTEND		
	MP	SIX	
	XCH	L	# GET INDEX FROM LOW ORDER PART
	AD	RUPTREG2	# SET CDU STORE INDEX TO MARKVAC
	ADS	RUPTREG1	# INCREMENT VAC PICKUP BY MARK FOR FLIGHT
	TS	MKDEX	# STORE HERE IN CASE OF SURFACE MARK
	CA	ITEMP3	
	INDEX	RUPTREG1	
	TS	0	# STORE CDUY
	CA	ITEMP4	

	INDEX	RUPTREG1	
	TS	2	# STORE CDUZ
	CA	ITEMP5	
	INDEX	RUPTREG1	
	TS	4	# STORE CDUX
	TC	MARKTYPE	# IF SURFACE MARK -- JUST DO SURFJOB
	TCF	SURFJOB	
	CAF	BIT13	# CLEAR BIT13 TO SHOW MARK MADE
	AD	XYMARK	# SET MARK ID IN MARKSTAT
	COM		
	MASK	MARKSTAT	
	AD	XYMARK	
	TS	MARKSTAT	
	MASK	PRI03	# SEE IF X, Y MARK MADE
	TS	L	
# Page 259			
	CA	PRI03	
	EXTEND		
	RXOR	LCHAN	
	CCS	A	
	TCF	REMARK	# NOT PAIR YET, DISPLAY MARK ACTION
	CS	MARKSTAT	# MARK PAIR COMPLETE -- SET BIT14
	MASK	BIT14	
	ADS	MARKSTAT	
	TCF	REMARK	# GO DISPLAY V54
# Page 260			
REMARK	CAF	PRI03	# BITS 10 AND 11
	MASK	MARKSTAT	
	EXTEND		
	MP	BIT6	# SHIFT MARK IDS TO BE 0 TO 3 FOR INDEX
	TS	MKDEX	# STORE VERB INDEX
SURFJOB	CAF	PRI015	
	TC	NOVAC	# ENTER JOB TO CHANGE DISPLAY TO
	EBANK=	XYMARK	# REQUEST NEXT ACTION
	2CADR	CHANGEVB	
	TC	RESUME	
CHANGEVB	TC	MARKTYPE	
	TCF	DSPV6N79	# SURFACE -- DISPLAY V 06 N 79
	INDEX	MKDEX	# INFLIGHT -- PICK UP MARK VB INDEX
	CAF	MKVB54	
	TC	PASTIT	# PASTE UP NEXT MK VERB DISPLAY

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# THE FOUR MKVBS ARE INDEXED -- THEIR ORDER CANNOT BE CHANGED

MKVB54	VN	5471	# MAKE X OR Y MARK
MKVB53	VN	5371	# MAKE Y MARK
MKVB52	VN	5271	# MAKE X MARK
MKVB54*	VN	5471	# MAKE X OR Y MARK
DP1/8	2DEC	.125	

OCT34	OCT	34
V06N71	VN	671
V06N79*	VN	679

# Page 261

# ROUTINE TO REQUEST CURSOR AND SPIRAL MEASUREMENTS

COUNT\* \$\$/R59

DSPV6N79	CAF	V06N79*	# CURSOR -- SPIRAL DISPLAY
	TC	BANKCALL	
	CADR	GOMARKF	
	TCF	KILLAOT	# V34 -- DOES GOTOP00H
	TCF	SURFEND	# V33 -- PROCEED, END MARKING
	CAF	BIT6	# IF V32(OCT40) IN MPAC DO RECYCLE
	MASK	MPAC	# OTHERWISE IT IS LOAD VB ENTER SO
	CCS	A	# RE-DISPLAY V06N79
	TCF	SURFAGAN	# VB32 -- RECYCLE
	TCF	DSPV6N79	# ENTER
SURFEND	CS	BIT14	# SET BIT14 TO SHOW MARK END
	MASK	MARKSTAT	
	AD	BIT14	
	TS	MARKSTAT	
SURFAGAN	CA	CURSOR	
	INDEX	MKDEX	# HOLDS VAC AREA POINTER FOR SURF MARKING
	TS	1	# STORE CURSOR SP 2COMP
	CA	SPIRAL	
	INDEX	MKDEX	
	TS	3	# STORE SPIRAL
	CS	MARKSTAT	# IF BIT 14 SET -- END MARKING
	MASK	BIT14	
	EXTEND		
	BZF	MARKCHEX	
	CA	MARKCNTR	# THIS IS RECYCLE -- SEE IF 5 MARKS ALREADY

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```
AD      ONE
COM
AD      FIVE
EXTEND
BZMF    5MKALARM      # CAN'T RECYCLE -- TOO MANY MARKS -- ALARM
INCR    MARKCNTR      # OF FOR RECYCLE -- INCR COUNTER
TCF     GETMKS +3      # GO DISPLAY MARK VB
```

This code is written to file `src/AOTMARK.s`.

## A.8 ASCENT GUIDANCE

```

101  <src/ASCENT-GUIDANCE.s 101>≡
    # Copyright:    Public domain.
    # Filename:     ASCENT_GUIDNCE.agc
    # Purpose:      Part of the source code for Luminary 1A build 099.
    #               It is part of the source code for the Lunar Module's (LM)
    #               Apollo Guidance Computer (AGC), for Apollo 11.
    # Assembler:    yaYUL
    # Contact:       Hartmuth Gutsche <hgutsche@explornet.com>.
    # Website:       www.ibiblio.org/apollo.
    # Pages:         843-856
    # Mod history:   2009-05-23 HG   Transcribed from page images.
    #               2009-06-05 RSB   Fixed a couple of typos.
    #               2009-06-07 RSB   Corrected a typo.
    #
    # This source code has been transcribed or otherwise adapted from
    # digitized images of a hardcopy from the MIT Museum. The digitization
    # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
    # the Museum. Many thanks to both. The images (with suitable reduction
    # in storage size and consequent reduction in image quality as well) are
    # available online at www.ibiblio.org/apollo. If for some reason you
    # find that the images are illegible, contact me at info@sandroid.org
    # about getting access to the (much) higher-quality images which Paul
    # actually created.
    #
    # Notations on the hardcopy document read, in part:
    #
    #       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
    #       16:27 JULY 14, 1969

    # Page 843

                                BANK      34
                                SETLOC    ASCFILT
                                BANK

                                EBANK=    DVCNTR

                                COUNT*    $$/ASENT

ATMAG                          TC         PHASCHNG
                                OCT        00035
                                TC         INTPRET
                                BON

                                FLRCS
                                ASCENT

```

DLOAD	DSU
	ABDVCONV
	MINABDV
BMN	CLEAR
	ASCTERM4
	SURFFLAG
CLEAR	SLOAD
	RENDWFLG
	BIT3H
DDV	EXIT
	ABDVCONV
DXCH	MPAC
DXCH	1/DV3
DXCH	1/DV2
DXCH	1/DV1
DXCH	1/DV0
TC	INTPRET
DLOAD	DAD
	1/DV0
	1/DV1
DAD	DAD
	1/DV2
	1/DV3
DMP	DMP
	VE
	2SEC(9)
SL3	PDDL
	TBUP
SR1	DAD
DSU	
	6SEC(18)
STODL	TBUP
	VE
SR1	DDV
	TBUP
STCALL	AT

# Page 844

	ASCENT
BIT3H	OCT 4

# Page 845

BANK	30
SETLOC	ASENT
BANK	
COUNT*	\$\$/ASENT

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```
ASCENT      VLOAD  ABVAL
              R
            STOVL  /R/MAG
              ZAXIS1
            DOT    SL1
              V      # Z.V = ZDOT*2(-8).
            STOVL  ZDOT  # ZDOT*2(-7)
              ZAXIS1
            VXV    VSL1
              UNIT/R/  # Z X UR = LAXIS*2(-2)
            STORE  LAXIS  # LAXIS*2(-1)
            DOT    SL1
              V      # L.V = YDOT*2(-8).
            STCALL YDOT  # YDOT * 2(-7)
              YCOMP
            VLOAD
              GDT1/2  # LOAD GDT1/2*2(-7) M/CS.
            V/SC    DOT
              2SEC(18)
              UNIT/R/  # G.UR*2(9) = GR*2(9).
            PDVL    VXV  # STORE IN PDL(0)
              UNIT/R/  # LOAD UNIT/R/ *2(-1)
              V      # UR*2(-1) X V*2(-7) = H/R*2(-8).
            VSQ     DDV  # H(2)/R(2)*2(-16).
              /R/MAG  # H(2)/R(3)*2(9).
            SL1     DAD
            STADR
            STODL   GEFF  # GEFF*2(10)m/CS/CS.
              ZDOTD
            DSU
              ZDOT
            STORE   DZDOT  # DZDOT = (ZDOTD - ZDOT) * 2(7) M/CS.
            VXSC    PDDL
              ZAXIS1
              YDOTD
            DSU
              YDOT
            STORE   DYDOT  # DYDOT = (YDOTD - YDOT) *2(7) M/CS.
            VXSC    PDDL
              LAXIS
              RDOTD
            DSU
              RDOT
            STORE   DRDOT  # DRDOT = (RDOTD - RDOT) * 2(7) M/CS.
            VXSC    VAD
```

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```

UNIT/R/
VAD      VSL1
STADR
STORE    VGVECT      # VG = (DRDOT)R + (DVDOT)L + (DZDOT)Z.
DLOAD    DMP          # LOAD TGO
          TGO          # TGO GEFF
          GEFF
VXSC      VSL1
          UNIT/R/      # TGO GEFF UR
BVSU
          VGVECT      # COMPENSATED FOR GEFF
STORE    VGVECT      # STORE FOR DOWNLINK
MXV      VSL1        # GET VGBODY FOR N85 DISPLAY
          XNBPIP
STOVL    VGBODY
          VGVECT
ABVAL    BOFF        # MAGNITUDE OF VGVECT
          FLRCS        # IF FLRCS=0,DO NORMAL GUIDANCE
          MAINENG
DDV
          AT/RCS
STCALL   TGO          # THIS WILL BE USED ON NEXT CYCLE
          ASCTERM2
MAINENG  DDV          # VG/VE IN PDL(0) (2)
          VE
DMP      BDSU        # 1 - KT VG/VE
          KT1
          NEARONE
DMP      DMP          # TBUP VG(1-KT VG/VE)/VE (0)
          TBUP        # = TGO
DSU
          # COMPENSATE FOR TAILOFF
          TTO
STORE    TGO
SR       DCOMP
          11D
STODL    TTOGO        # TGO *2(-28) CS
          TGO
BON      DSU
          IDLEFLAG
          T2TEST
          4SEC(17)     # ( TGO - 4 ) *2(-17) CS.
BMN
          ENGOFF
T2TEST   DLOAD
          TGO
DSU      BMN          # IF TGO - T2 NEG., GO TO CMPONENT

```



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```

                                T2A
                                CMponent
DLOAD  DSU
        TBUP
        TGO
DDV     CALL      # 1- TGO/TBUP
        TBUP
        LOGSUB
SL      PUSH      # -L IN PDL(0)          (2)
        5
BDDV    BDSU      # -TGO/L*2(-17)
        TGO
        TBUP      # TBUP + TGO/L = D12*2(-17)
PUSH    BON       # STORE IN PDL(2)      (4)
        FLPC      # IF FLPC = 1, GO TO CONST
        NORATES
DLOAD   DSU
        TGO
        T3
BPL     SET       # FLPC=1
        RATES
        FLPC
NORATES DLOAD
        HI6ZEROS
STORE   PRATE     # B = 0
STORE   YRATE     # D = 0
GOTO
RATES   DLOAD     CONST      # GO TO CONST
        DSU
        TGO
        O2D      # TGO - D12 = D21*2(-17)
PUSH    SL1       # IN PDL(4)          (6)
BDSU    SL3       # (1/2TGO - D21)*2(-13) = E * 2(-13)
        TGO      #                      (8)
PDDL    DMP       # IN PDL(6)
        TGO
        RDOT     # RDOT TGO * 2(-24)
DAD     DSU       # R + RDOT TGO
        /R/MAG   # R + RDOT TGO - RCO
        RCO      # MPAC = -DR *2(-24).
PDDL    DMP       # -DR IN PDL(8)      (10)
        DRDOT
        O4D      # D21 DRDOT*2(-24)
DAD     SL2       # (D21 DRDOT-DR)*2(-22)  (8)
DDV     DDV

```

```

                                06D          # (D21 DRDOT-DR)/E*2(-9)
                                TGO
STORE      PRATE          # B * 2(8)
BMN        DLOAD          # B>0 NOT PERMITTED
                                CHKBMAG

#Page 848

                                HI6ZEROS
STCALL     PRATE
                                PROK
CHKBMAG    SR4            DDV          # B*2(4)
                                TBUP      # (B / TAU) * 2(21)
DSU         BPL
                                PRLIMIT   # ( B / TAU ) = 2(21) MAX.
                                PROK
DLOAD       DMP
                                PRLIMIT
                                TBUP      # B MAX. * 2(4)
SL4          # BMAX*2(8)
STORE       PRATE
PROK        DLOAD

                                TGO
DMP         DAD          # YDOT TGO
                                YDOT
Y           # Y + YDOT TGO
DSU         PDDL         # Y + YDOT TGO - YCO
                                YCO       # MPAC = - DY*(-24.) IN PDL(8) (10)
                                DYDOT
DMP         DAD          # D21 DYDOT - DY (8)
                                04D
SL2         DDV          # (D21 DYDOT - DY)/E*2(-9)
DDV         SETPD        # (D21 DYDOT - DY)/E TGO*2(8)
                                TGO       # = D*2(8)
                                04
STORE       YRATE
CONST      DLOAD         DMP          # LOAD B*2(8)
                                PRATE    # B D12*2(-9)
                                02D
PDDL       DDV          # D12 B IN PDL(4) (6)
                                DRDOT     # LOAD DRDOT*2(-7)
                                00D       # -DRDOT/L*2(-7)
SR2        DSU          # (-DRDOT/L-D12 B)=A*2(-9) (4)
STADR
STODL      PCONS
                                YRATE    # D*2(8)
DMP        PDDL         # D12 D,EXCH WITH -L IN PDL(0) (2,2)
BDDV       SR2          # -DYDOT/L*2(-9)

```

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```

                                DYDOT
DSU                               # (-DYDOT/L-D12 D)=C*2(-9)
                                OOD
STORE YCONS
COMPONENT SETPD DLOAD
                                OOD
                                100CS
DMP
                                PRATE
DAD DDV                        # B(T-T0)*2(-9)
                                # (A+B(T-T0))*2(-9)
# Page 849
                                PCONS
                                TBUP
SL1 DSU
                                GEFF
                                # ATR*2(9)
STODL ATR
                                100CS
DMP DAD
                                YRATE
                                YCONS
                                # (C+D(T-T0))*2(-9)
DDV SL1
                                TBUP
STORE ATY                      # ATY*2(9)
VXSC PDDL                      # ATY UY*2(8) (6)
                                LAXIS
                                ATR
VXSC VAD
                                UNIT/R/
VSL1 PUSH                      # AH*2(9) IN PDL(0) (6)
ABVAL PDDL                     # AH(2) IN PDL(34)
                                AT
                                # AHMAG IN PDL(6) (8)
DSQ DSU                        # (AT(2)-AH(2))*2(18)
                                34D
                                # =ATP2*2(18)
PDDL PUSH                      # (12)
                                AT
DSQ DSU                        # (AT(2)KR(2)-AH(2))*2(18) (10)
                                34D
                                # =ATP3*2(18)
BMN DLOAD                      # IF ATP3 NEG,GO TO NO-ATP
                                NO-ATP
                                # LOAD ATP2, IF ATP3 POS
                                8D
SQRT GOTO                      # ATP*2(9)
                                AIMER
NO-ATP DLOAD BDDV              # KR AT/AH = KH (8)
                                6D
VXSC                            # KH AG*2(9)
                                OOD
```

	STODL	OOD	# STORE NEW AH IN PDL(0)
		HI6ZEROS	
AIMER	SIGN		
		DZDOT	
	STORE	ATP	
	VXSC		
		ZAXIS1	# ATP ZAXIS *2(8).
	VSL1	VAD	# AT*2(0)
		OOD	
	STORE	UNFC/2	# WILL BE OVERWRITTEN IF IN VERT. RISE.
	SETPD	BON	
		OOD	
		FLPI	
		P12RET	
	BON		
# Page 850			
		FLVR	
		CHECKALT	
MAINLINE	VLOAD	VCOMP	
		UNIT/R/	
	STODL	UNWC/2	
		TXO	
	DSU	BPL	
		PIPTIME	
		ASCTERM	
	BON		
		ROTFLAG	
		ANG1CHEK	
CLRFLAG	CLEAR	CLEAR	
		NOR29FLG	# START r29 IN ASCENT PHASE.
		XOVINFLG	# ALLOW X-AXIS OVERRIDE
ASCTERM	EXIT		
	CA	FLAGWRD9	
	MASK	FLRCSBIT	
	CCS	A	
	TCF	ASCTERM3	
	TC	INTPRET	
	CALL		
		FINDCDUW -2	
ASCTERM1	EXIT		
+1	CA	FLAGWRD9	# INSURE THAT THE NOUN 63 DISPLAY IS
	MASK	FLRCSBIT	# BYPASSED IF WE ARE IN THE RCS TRIMMING
	CCS	A	# MODE OF OPERATION
	TCF	ASCTERM3	
	CA	FLAGWRD8	# BYPASS DISPLAYS IF ENGINE FAILURE IS
	MASK	FLUNDBIT	# INDICATED.

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	CCS	A	
	TCF	ASCTERM3	
	CAF	V06N63*	
	TC	BANKCALL	
	CADR	GODSPR	
	TCF	ASCTERM3	
ASCTERM2	EXIT		
ASCTERM3	TCF	ENDOFJOB	
ASCTERM4	EXIT		
	INHINT		
	TC	IBNKCALL	# NO GUIDANCE THIS CYCLE -- HENCE ZERO
	CADR	ZATTEROR	# THE DAP COMMANDED ERRORSSs.
	TCF	ASCTERM1 +1	
CHECKALT	DLOAD	DSU	
		/R/MAG	
		/LAND/	
	DSU	BMN	# IF H LT 25K CHECK Z AXIS ORIENTATION
		25KFT	
		CHECKYAW	
# Page 851			
EXITVR	CLEAR	BON	
		FLVR	
		ROTFLAG	
		MAINLINE	
	DLOAD	DAD	
		PIPTIME	
		10SECS	
	STCALL	TXO	
		MAINLINE	
EXITVR1	CLRGO		
		ROTFLAG	
		EXITVR	
	SETLOC	ASENT1	
	BANK		
	COUNT*	\$\$/ASENT	
ANG1CHEK	VLOAD	DOT	
		UNFC/2	
		XNBPIP	
	DSU	BPL	
		COSTHET1	
		OFFROT	
	VLOAD	DOT	
		XNBPIP	

	DSU	UNIT/R/ BMN COSTHET2 KEEPVR1	
OFFROT	CLRGO	ROTFLAG CLRFLAG	
	BANK	7	
	SETLOC	ASENT2	
	BANK		
	COUNT*	\$\$/ASENT	
SETXFLAG	=	CHECKYAW	
CHECKYAW	SET		
		XOVINFLG	# PROHIBIT X-AXIS OVERRRIDE
	DLOAD	VXSC	
		ATY	
		LAXIS	
	PDDL	VXSC	
		ATP	
		ZAXIS1	
	VAD	UNIT	
	PUSH	DOT	
# Page 852			
		YNBPIP	
	ABS	DSU	
		SIN5DEG	
	BPL	DLOAD	
		KEEPVR	
		RDOT	
	DSU	BPL	
		40FPS	
		EXITVR1	
	GOTO		
		KEEPVR	
	BANK	5	
	SETLOC	ASENT3	
	BANK		
	COUNT*	\$\$/ASENT	
SIN5DEG	2DEC	0.08716	B-2
40FPS	2DEC	0.12192	B-7

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	BANK	14	
	SETLOC	ASENT4	
	BANK		
	COUNT*	\$\$/ASENT	
KEEPVR	VLOAD	STADR	# RECALL LOSVEC FROM PUSHLIST
	STORE	UNWC/2	
KEEPVR1	VLOAD		
		UNIT/R/	
	STCALL	UNFC/2	
		ASCTERM	
ENGOFF	RTB		
		LOADTIME	
	DSU	DAD	
		PIPTIME	
		TTOGO	
	DCOMP	EXIT	
	TC	TPAGREE	# FORCH SIGN AGREEMENT ON MPAC, MPAC +1.
	CAF	EBANK7	
	TS	EBANK	
	EBANK=	TGO	
	INHINT		
	CCS	MPAC +1	
	TCF	+3	# C(A) = DT - 1 BIT
	TCF	+2	# C(A) = 0
	CAF	ZERO	# C(A) = 0
	AD	BIT1	# C(A) = 1 BIT OR DT.
# Page 853	TS	ENGOFFDT	
	TC	TWIDDLE	
	ADRES	ENGOFF1	
	TC	PHASCHNG	
	OCT	47014	
	-GENADR	ENGOFFDT	
	EBANK=	TGO	
	2CADR	ENGOFF1	
	TC	INTPRET	
	SET	GOTO	
		IDLEFLAG	# DISABLE DELTA-V MONITOR
		T2TEST	
ENGOFF1	TC	IBNKCALL	# SHUT OFF THE ENGINE.
	CADR	ENGNOF2	

	CAF	PRI017	# SET UP A JOB FOR THE ASCENT GUIDANCE
	TC	FINDVAC	# POSTBURN LOGIC.
	EBANK=	WHICH	
	2CADR	CUTOFF	
	TC	PHASCHNG	
	OCT	07024	
	OCT	17000	
	EBANK=	TGO	
	2CADR	CUTOFF	
	TCF	TASKOVER	
CUTOFF	TC	UPFLAG	# SET FLRCS FLAG.
	ADRES	FLRCS	
-5	CAF	V16N63	
	TC	BANKCALL	
	CADR	GOFLASH	
	TCF	+3	
	TCF	CUTOFF1	
	TCF	-5	
+3	TC	POSTJUMP	
	CADR	TERMASC	
CUTOFF1	INHINT		
	TC	IBNKCALL	# ZERO ATTITUDE ERRORS BEFORE REDUCINT DB.
	CADR	ZATTEROR	
	TC	IBNKCALL	
	CADR	SETMINDB	
	TC	POSTJUMP	
	CADR	CUTOFF2	
# Page 854			
V16N63	VN	1663	
	BANK	30	
	SETLOC	ASENT5	
	BANK		
	COUNT*	\$\$/ASENT	
CUTOFF2	TC	PHASCHNG	
	OCT	04024	
	CAF	V16N85C	
	TC	BANKCALL	



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	CADR	GOFLASH	
	TCF	TERMASC	
	TCF	+2	# PROCEED
	TCF	CUTOFF2	
TERMASC	TC	PHASCHNG	
	OCT	04024	
	INHINT		# RESTORE DEADBAND DESIRED BY ASTRONAUT.
	TC	IBNKCALL	
	CADR	RESTORDB	
	TC	DOWNFLAG	# DISALLOW ABORTS AT THIS TIME.
	ADRES	LETABORT	
	TCF	GOTOP00H	
V16N85C	VN	1685	
	BANK	27	
	SETLOC	ASENT1	
	BANK		
	COUNT*	\$\$/ASENT	
YCOMP	VLOAD	DOT	
		UNIT/R/	
		QAXIS	
	SL2	DMP	
		RCO	
	STORE	Y	
	RVQ		
	BANK	30	
	SETLOC	ASENT	
	BANK		
# Page 855			
100CS	EQUALS	2SEC(18)	
T2A	EQUALS	2SEC(17)	
4SEC(17)	2DEC	400 B-17	
2SEC(17)	2DEC	200 B-17	
T3	2DEC	1000 B-17	
6SEC(18)	2DEC	600 B-18	
BIT4H	OCT	10	
2SEC(9)	2DEC	200 B-9	
V06N63*	VN	0663	
V06N76	VN	0676	
V06N33A	VN	0633	

```

      BANK      33
      SETLOC    ASENT6
      BANK
      COUNT*    $$/ASENT

KT1      2DEC    0.5000
PRLIMIT  2DEC    -.0639      # (B/TBUP)MIN=-.1FT.SEC(-3)
MINABDV  2DEC    .0356 B-5   # 10 PERCENT BIGGER THAN GRAVITY
1/DVO    =       MASS1

# Page 856
# THE LOGARITHM SUBROUTINE

      BANK      24
      SETLOC    FLOGSUB
      BANK

# INPUT ..... X IN MPAC
# OUTPUT ..... -LOG(X) IN MPAC

LOGSUB   NORM    BDSU
          MPAC +6
          NEARONE

          EXIT
          TC      POLY
          DEC      6
          2DEC    .0000000060
          2DEC    -.0312514377
          2DEC    -.0155686771
          2DEC    -.0112502068
          2DEC    -.0018545108
          2DEC    -.0286607906
          2DEC    .0385598563
          2DEC    -.0419361902

          CAF      ZERO
          TS       MPAC +2
          EXTEND
          DCA      CLOG2/32
          DXCH     MPAC
          DXCH     BUF +1
          CA       MPAC +6
          TC       SHORTMP
          DXCH     MPAC +1
          DXCH     MPAC
          DXCH     BUF +1

```

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DAS	MPAC
TC	INTPRET
DCOMP	RVQ

CLOG2/32	2DEC	.0216608494
----------	------	-------------

This code is written to file `src/ASCENT-GUIDANCE.s`.

## A.9 ASSEMBLY AND OPERATION INFORMATION

```

116  <src/ASSEMBLY-AND-OPERATION-INFORMATION.s 116>≡
      # Copyright:      Public domain.
      # Filename:       ASSEMBLY_AND_OPERATION_INFORMATION.agc
      # Purpose:        Part of the source code for Colossus 2A, AKA Comanche 055.
      #                 It is part of the source code for the Command Module's (CM)
      #                 Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:     yaYUL
      # Contact:        Ron Burkey <info@sandroid.org>.
      # Website:        www.ibiblio.org/apollo.
      # Mod history:    2009-05-05 RSB   Adapted from the Colossus249/ file of the
      #                 same name, using Comanche055 page images.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 055 of AGC program Comanche by NASA
      #       2021113-051.  10:28 APR. 1, 1969
      #
      #       This AGC program shall also be referred to as
      #               Colossus 2A

      # Page 2

      # ASSEMBLY AND OPERATIONS INFORMATION
      # TAGS FOR RELATIVE SETLOC AND BLANK BANK CARDS
      # SUBROUTINE CALLS
      #       COMERASE
      #               ERASABLE ASSIGNMENTS
      #       COMAID
      #               INTERRUPT LEAD INS
      #               T4RUPT PROGRAM
      #               DOWNLINK LISTS
      #               FRESH START AND RESTART
      #               RESTART TABLES

```

```
#          SXTMARK
#          EXTENDED VERBS
#          PINBALL NOUN TABLES
#          CSM GEOMETRY
#          IMU COMPENSATION PACKAGE
#          PINBALL GAME BUTTONS AND LIGHTS
#          R60,R62
#          ANGLFIND
#          GIMBAL LOCK AVOIDANCE
#          KALCMANU STEERING
#          SYSTEM TEST STANDARD LEAD INS
#          IMU CALIBRATION AND ALIGNMENT
#          COMEКИSS
#          GROUND TRACKING DETERMINATION PROGRAM -- P21
#          P34-P35, P74-P75
#          R31
#          P76
#          R30
#          STABLE ORBIT -- P38-P39
#          TROUBLE
#          P11
#          TP1 SEARCH
#          P20-P25
#          P30,P37
#          P40-P47
#          P51-P53
#          LUNAR AND SOLAR EPHEMERIDES SUBROUTINES
#          P61-P67
#          SERVICER207
#          ENTRY LEXICON
#          REENTRY CONTROL
#          CM BODY ATTITUDE
#          P37,P70
#          S-BAND ANTENNA FOR CM
#          LUNAR LANDMARK SELECTION FOR CM
#          TVCDAPS
#          TVC INITIALIZE
```

```
# Page 3
```

```
#          TVC EXECUTIVE
#          TVC MASSPROP
#          TVC RESTARTS
#          TVC DAPS
#          TVC STROKE TEST
#          TVC ROLLDAP
```

```
#           MYSUBS
#           RCS-CSM DIGITAL AUTOPILOT
#           AUTOMATIC MANEUVERS
#           RCS-CSM DAP EXECUTIVE PROGRAMS
#           JET SELECTION LOGIC
#           CM ENTRY DIGITAL AUTOPILOT
#   CHIEFTAN
#           DOWN-TELEMETRY PROGRAM
#           INTER-BANK COMMUNICATION
#           INTERPRETER
#           FIXED-FIXED CONSTANT POOL
#           INTERPRETIVE CONSTANTS
#           SINGLE PRECISION SUBROUTINES
#           EXECUTIVE
#           WAITLIST
#           LATITUDE LONGITUDE SUBROUTINES
#           PLANETARY INERTIAL ORIENTATION
#           MEASUREMENT INCORPORATION
#           CONIC SUBROUTINES
#           INTEGRATION INITIALIZATION
#           ORBITAL INTEGRATION
#           INFLIGHT ALIGNMENT ROUTINES
#           POWERED FLIGHT SUBROUTINES
#           TIME OF FREE FALL
#           STAR TABLES
#           AGC BLOCK TWO SELF-CHECK
#           PHASE TABLE MAINTENANCE
#           RESTARTS ROUTINE
#           IMU MODE SWITCHING ROUTINES
#           KEYRUPT, UPRUPT
#           DISPLAY INTERFACE ROUTINES
#           SERVICE ROUTINES
#           ALARM AND ABORT
#           UPDATE PROGRAM
#           RTB OP CODES
# SYMBOL TABLE LISTING
# UNREFERANCES SYMBOL LISTING
# ERASABLE & EQUALS CROSS-REFERENCE TABLE
# SUMMARY OF SYMBOL TABLE LISTINGS
# MEMORY TYPE & AVAILABILITY DISPLAY
# COUNT TABLE
# PARAGRAPHS GENERATED FOR THIS DISPLAY

# Page 4

# OCTAL LISTING
```

# OCCUPIED LOCATIONS TABLE  
# SUBROS CALLED & PROGRAM STATUS

# Page 5  
# VERB LIST FOR CSM

# REGULAR VERBS

# 00 NOT IN USE  
# 01 DISPLAY OCTAL COMP 1 IN R1  
# 02 DISPLAY OCTAL COMP 2 IN R1  
# 03 DISPLAY OCTAL COMP 3 IN R1  
# 04 DISPLAY OCTAL COMP 1,2 IN R1,R2  
# 05 DISPLAY OCTAL COMP 1,2,3 IN R1,R2,R3  
# 06 DISPLAY DECIMAL IN R1 OR R1,R2 OR R1,R2,R3  
# 07 DISPLAY DP DECIMAL IN R1,R2 (TEST ONLY)  
# 08  
# 09  
# 10  
# 11 MONITOR OCTAL COMP 1 IN R1  
# 12 MONITOR OCTAL COMP 2 IN R1  
# 13 MONITOR OCTAL COMP 3 IN R1  
# 14 MONITOR OCTAL COMP 1,2, IN R1,R2  
# 15 MONITOR OCTAL COMP 1,2,3 IN R1,R2,R3  
# 16 MONITOR DECIMAL IN R1 OR R1,R2 OR R1,R2,R3  
# 17 MONITOR DP DECIMAL IN R1,R2 (TEST ONLY)  
# 18  
# 19  
# 20  
# 21 LOAD COMPONENT 1 INTO R1  
# 22 LOAD COMPONENT 2 INTO R2  
# 23 LOAD COMPONENT 3 INTO R3  
# 24 LOAD COMPONENT 1,2 INTO R1,R2  
# 25 LOAD COMPONENT 1,2,3 INTO R1,R2,R3  
# 26  
# 27 DISPLAY FIXED MEMORY  
# 28  
# 29  
# 30 REQUEST EXECUTIVE  
# 31 REQUEST WAITLIST  
# 32 RECYCLE PROGRAM  
# 33 PROCEED WITHOUT DSKY INPUTS  
# 34 TERMINATE FUNCTION  
# 35 TEST LIGHTS  
# 36 REQUEST FRESH START  
# 37 CHANGE PROGRAM (MAJOR MODE)

# 38

# 39

# Page 6

# EXTENDED VERBS

# 40 ZERO CDU'S

# 41 COARSE ALIGN CDU'S

# 42 FINE ALIGN IMU'S

# 43 LOAD IMU ATT ERROR METERS

# 44 SET SURFACE FLAG

# 45 RESET SURFACE FLAG

# 46 ESTABLISH G&amp;C CONTROL

# 47 MOVE LM STATE VECTOR INTO CM STATE VECTOR

# 48 REQUEST DAP DATA LOAD ROUTINE (R03)

# 49 REQUEST CREW DEFINED MANEUVER ROUTINE (R62)

# 50 PLEASE PERFORM

# 51 PLEASE MARK

# 52 MARK ON OFFSET LANDING SITE

# 53 PLEASE PERFORM ALTERNATE LOS MARK

# 54 REQUEST RENDEZVOUS BACKUP SIGHTING MARK ROUTINE (R23)

# 55 INCREMENT AGC TIME (DECIMAL)

# 56 TERMINATE TRACKING (P20 &amp; P25)

# 57 REQUEST RENDEZVOUS SIGHTING MARK ROUTINE (R21)

# 58 RESET STICK FLAG

# 59 PLEASE CALIBRATE

# 60 SET ASTRONAUT TOTAL ATTITUDE (N17) TO PRESENT ATTITUDE

# 61 DISPLAY DAP ATTITUDE ERROR

# 62 DISPLAY TOTAL ATTITUDE ERROR (W.R.T. N22 (THETAD))

# 63 DISPLAY TOTAL ASTRONAUT ATTITUDE ERROR (W.R.T. N17 (CPHIX))

# 64 REQUEST S-BAND ANTENNA ROUTINE

# 65 OPTICAL VERIFICATION OF PRELAUNCH ALIGNMENT

# 66 VEHICLES ARE ATTACHED. MOVE THIS VEHICLE STATE TO OTHER VEHICLE.

# 67

# 68 CSM STROKE TEST ON

# 69 CAUSE RESTART

# 70 UPDATE LIFTOFF TIME

# 71 UNIVERSAL UPDATE - BLOCK ADR

# 72 UNIVERSAL UPDATE - SINGLE ADR

# 73 UPDATE AGC TIME (OCTAL)

# 74 INITIALIZE ERASABLE DUMP VIA DOWNLINK

# 75 BACKUP LIFTOFF

# 76 SET PREFERRED ATTITUDE FLAG

# 77 RESET PREFERRED ATTITUDE FLAG

# 78 UPDATE PRELAUNCH AZIMUTH



```
# 79  REQUEST LUNAR LANDMARK SELECTION ROUTINE (R35)
# 80  UPDATE LEM STATE VECTOR
# 81  UPDATE CSM STATE VECTOR
# 82  REQUEST ORBIT PARAM DISPLAY (R30)
# 83  REQUEST REND  PARAM DISPLAY (R31)
# 84  START TARGET DELTA V (R32)
# 85  REQUEST RENDEZVOUS PARAMETER DISPLAY NO. 2 (R34)
# 86  REJECT RENDEZVOUS BACKUP SIGHTING MARK
# 87  SET VHF RANGE FLAG
```

# Page 7

```
# 88  RESET VHF RANGE FLAG
# 89  REQUEST RENDEZVOUS FINAL ATTITUDE ROUTINE (R63)
# 90  REQUEST RENDEZVOUS OUT OF PLANE DISPLAY ROUTINE (R36)
# 91  DISPLAY BANK SUM
# 92  OPERATE IMU PERFORMANCE TEST (P07)
# 93  ENABLE W MATRIX INITIALIZATION
# 94  PERFORM SYSLUNAR ATTITUDE MANEUVER (P23)
# 95  NO UPDATE OF EITHER STATE VECTOR (P20 OR P22)
# 96  TERMINATE INTEGRATION AND GO TO P00
# 97  PERFORM ENGINE FAIL PROCEDURE
# 98  ENABLE TRANSLUNAR INJECT
# 99  PLEASE ENABLE ENGINE
```

# Page 8

```
# IN THE FOLLOWING NOUN LIST THE 'NO LOAD' RESTRICTION MEANS THE NOUN
# CONTAINS AT LEAST ONE COMONENT WHICH CANNOT BE LOADED, I.E. OF
# SCALE TYPE L (MIN/SEC) OR PP (2 INTEGERS).
```

```
# IN THIS CASE VERBS 24 AND 25 ARE NOT ALLOWED, BUT VERBS 21, 22, OR 23
# MAY BE USED TO LOAD ANY OF THE NOUN'S COMPONENTS WHICH ARE NOT OF THE
# ABOVE SCALE TYPES.
```

```
# THE 'DEC ONLY' RESTRICTION MEANS ONLY DECIMAL OPERATION IS ALLOWED ON
# EVERY COMPONENT IN THE NOUN. (NOT THAT 'NO LOAD' IMPLIES 'DEC ONLY'.)
```

#	NORMAL NOUNS	COMPONENTS	SCALE & DECIMAL POINT	RESTRICTION
# 00	NOT IN USE			
# 01	SPECIFY MACHINE ADDRESS (FRACTIONAL)	3COMP	.XXXXX FOR EACH	
# 02	SPECIFY MACHINE ADDRESS (WHOLE)	3COMP	XXXXX. FOR EACH	
# 03	SPECIFY MACHINE ADDRESS (DEGREES)	3COMP	XXX.XX DEG FOR EACH	
# 04	SPARE			
# 05	ANGULAR ERROR/DIFFERENCE	1COMP	XXX.XX DEG	
# 06	OPTION CODE	2COMP	OCTAL ONLY FOR EACH	

```

# LOADING NOUN 07 WILL SET OR RESET SELECTED BITS IN ANY ERASABLE REGISTER.
# 07 ECADR OF WORD TO BE MODIFIED 3COMP OCTAL ONLY FOR EACH
# ONES FOR BITS TO BE MODIFIED
# 1 TO SET OR 0 TO RESET SELECTED BITS
# 08 ALARM DATA 3COMP OCTAL ONLY FOR EACH
# 09 ALARM CODES 3COMP OCTAL ONLY FOR EACH
# 10 CHANNEL TO BE SPECIFIED 1COMP OCTAL ONLY
# 11 TIG OF CSI 3COMP 00XXX. HRS DEC 0
# 000XX. MIN MUST
# OXX.XX SEC
# 12 OPTION CODE 2COMP OCTAL ONLY FOR EACH
# (USED BY EXTENDED VERBS ONLY)
# 13 TIG OF CDH 3COMP 00XXX. HRS DEC 0
# 000XX. MIN MUST
# OXX.XX SEC
# 14 SPARE
# 15 INCREMENT MACHINE ADDRESS 1COMP OCTAL ONLY
# 16 TIME OF EVENT 3COMP 00XXX. HRS DEC 0
# (USED BY EXTENDED VERBS ONLY) 000XX. MIN MUST
# OXX.XX SEC
# 17 ASTRONAUT TOTAL ATTITUDE 3COMP XXX.XX DEG FOR EACH
# 18 AUTO MANEUVER BALL ANGLES 3COMP XXX.XX DEG FOR EACH
# 19 BYPASS ATTITUDE TRIM MANEUVER 3COMP XXX.XX DEG FOR EACH
# 20 ICDU ANGLES 3COMP XXX.XX DEG FOR EACH
# 21 PIPAS 3COMP XXXXX. PULSES FOR EACH
# 22 NEW ICDU ANGLES 3COMP XXX.XX DEG FOR EACH
# 23 SPARE
# 24 DELTA TIME FOR AGC CLOCK 3COMP 00XXX. HRS. DEC 0
# 000XX. MIN MUST
# OXX.XX SEC
# 25 CHECKLIST 3COMP XXXXX. FOR EACH
# (USED WITH PLEASE PERFORM ONLY)

```

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```

# 26 PRIORITY/DELAY, ADRES, BBON 3COMP OCTAL ONLY FOR EACH
# 27 SELF TEST ON/OFF SWITCH 1COMP XXXXX.
# 28 SPARE
# 29 XSM LAUNCH AZIMUTH 1COMP XXX.XX DEG DEC 0

```

# Page 10

```

# 30 TARGET CODES 3COMP XXXXX. FOR EACH
# 31 TIME OF LANDING SITE 3COMP 00XXX. HRS DEC 0
# 000XX. MIN MUST
# OXX.XX SEC

```

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# 32	TIME FROM PERIGEE	3COMP	00XXX. HRS	DEC ONLY
#			000XX. MIN	MUST LOAD 3 COM
#			0XX.XX SEC	
# 33	TIME OF IGNITION	3COMP	00XXX. HRS	DEC ONLY
#			000XX. MIN	MUST LOAD 3 COM
#			0XX.XX SEC	
# 34	TIME OF EVENT	3COMP	00XXX. HRS	DEC ONLY
#			000XX. MIN	MUST LOAD 3 COM
#			0XX.XX SEC	
# 35	TIME FROM EVENT	3COMP	00XXX. HRS	DEC ONLY
#			000XX. MIN	MUST LOAD 3 COM
#			0XX.XX SEC	
# 36	TIME OF AGC CLOCK	3COMP	00XXX. HRS	DEC ONLY
#			000XX. MIN	MUST LOAD 3 COM
#			0XX.XX SEC	
# 37	TIG OF TPI	3COMP	00XXX. HRS	DEC ONLY
#			000XX. MIN	MUST LOAD 3 COM
#			0XX.XX SEC	
# 38	TIME OF STATE VECTOR	3COMP	00XXX. HRS	DEC ONLY
#			000XX. MIN	MUST LOAD 3 COM
#			0XX.XX SEC	
# 39	DELTA TIME FOR TRANSFER	3COMP	00XXX. HRS	DEC ONLY
#			000XX. MIN	MUST LOAD 3 COM
#			0XX.XX SEC	

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#	MIXED NOUNS	COMPONENTS	SCALE & DECIMAL POINT	RESTRICTION
# 40	TIME FROM IGNITION/CUTOFF	3COMP	XXBXX MIN/SEC	NO LOAD, DEC ON
#	VG		XXXX.X FT/SEC	
#	DELTA V (ACCUMULATED)		XXXX.X FT/SEC	
# 41	TARGET AZIMUTH	2COMP	XXX.XX DEG	
#	ELEVATION		XX.XXX DEG	
# 42	APOGEE	3COMP	XXXX.X NAUT MI	DEC ONLY
#	PERIGEE		XXXX.X NAUT MI	
#	DELTA V (REQUIRED)		XXXX.X FT/SEC	
# 43	LATITUDE	3COMP	XXX.XX DEG	DEC ONLY
#	LONGITUDE		XXX.XX DEG	
#	ALTITUDE		XXXX.X NAUT MI	
# 44	APOGEE	3COMP	XXXX.X NAUT MI	NO LOAD, DEC ON
#	PERIGEE		XXXX.X NAUT MI	
#	TFF		XXBXX MIN/SEC	
# 45	MARKS (VHF - OPTICS)	3COMP	+XXBXX	NO LOAD, DEC ON
#	TFI OF NEXT BURN		XXBXX MIN/SEC	
#	MGA		XXX.XX DEG	

# 46	AUTOPILOT CONFIGURATION	2COMP	OCTAL ONLY FOR EACH	
# 47	THIS VEHICLE WEIGHT	2COMP	XXXXX. LBS	DEC 0
#	OTHER VEHICLE WEIGHT		XXXXX. LBS	
# 48	PITCH TRIM	2COMP	XXX.XX DEG	DEC 0
#	YAW TRIM		XXX.XX DEG	
# 49	DELTA R	3COMP	XXXX.X NAUT MI	DEC 0
#	DELTA V		XXXX.X FT/SEC	
#	VHF OR OPTICS CODE		XXXXX.	
# 50	SPLASH ERROR	3COMP	XXXX.X NAUT MI	NO L
#	PERIGEE		XXXX.X NAUT MI	
#	TFF		XXBXX MIN/SEC	
# 51	S-BAND ANTENNA ANGLES PITCH	2COMP	XXX.XX DEG	DEC 0
#	YAW		XXX.XX DEG	
# 52	CENTRAL ANGLE OF ACTIVE VEHICLE	1COMP	XXX.XX DEG	
# 53	RANGE	3COMP	XXX.XX NAUT MI	DEC 0
#	RANGE RATE		XXXX.X FT/SEC	
#	PHI		XXX.X DEG	
# 54	RANGE	3COMP	XXX.XX NAUT MI	DEC 0
#	RANGE RATE		XXXX.X FT/SEC	
#	THETA		XXX.XX DEG	
# 55	PERIGEE CODE	3COMP	XXXXX.	DEC 0
#	ELEVATION ANGLE		XXX.XX DEG	
#	CENTRAL ANGLE OF PASSIVE VEHICLE		XXX.XX DEG	
# 56	REENTRY ANGLE	2COMP	XXX.XX DEG	DEC 0
#	DELTA V		XXXXX. FT/SEC	
# 57	DELTA R	1COMP	XXXX.X NAUT MI	DEC 0
# 58	PERIGEE ALT (POST TPI)	3COMP	XXXX.X NAUT MI	DEC 0
#	DELTA V TPI		XXXX.X FT/SEC	
#	DELTA V TPF		XXXX.X FT/SEC	
# 59	DELTA VELOCITY LOS	3COMP	XXXX.X FT/SEC FOR EACH	DEC 0
# 60	GMAX	3COMP	XXX.XX G	DEC 0

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#	VPRED		XXXXX. FT/SEC	
#	GAMMA EI		XXX.XX DEG	
# 61	IMPACT LATITUDE	3COMP	XXX.XX DEG	DEC 0
#	IMPACT LONGITUDE		XXX.XX DEG	
#	HEADS UP/DOWN		+/- 00001	
# 62	INERTIAL VEL MAG (VI)	3COMP	XXXXX. FT/SEC	DEC 0
#	ALT RATE CHANGE (HDOT)		XXXXX. FT/SEC	
#	ALT ABOVE PAD RADIUS (H)		XXXX.X NAUT MI	
# 63	RANGE 297,431 TO SPLASH (RTGO)	3COMP	XXXX.X NAUT MI	NO L
#	PREDICTED INERT VEL (VIO)		XXXXX. FT/SEC	
#	TIME FROM 297,431 (TFE)		XXBXX MIN/SEC	
# 64	DRAG ACCELERATION	3COMP	XXX.XX G	DEC 0

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#	INERTIAL VELOCITY (VI)		XXXXX. FT/SEC	
#	RANGE TO SPLASH		XXXX.X NAUT MI	
# 65	SAMPLED AGC TIME	3COMP	00XXX. HRS	DEC ONLY
#	(FETCHED IN INTERRUPT)		000XX. MIN	
#			0XX.XX SEC	
# 66	COMMAND BANK ANGLE (BETA)	3COMP	XXX.XX DEG	DEC ONLY
#	CROSS RANGE ERROR		XXXX.X NAUT MI	
#	DOWN RANGE ERROR		XXXX.X NAUT MI	
# 67	RANGE TO TARGET	3COMP	XXXX.X NAUT MI	DEC ONLY
#	PRESENT LATITUDE		XXX.XX DEG	
#	PRESENT LONGITUDE		XXX.XX DEG	
# 68	COMMAND BANK ANGLE (BETA)	3COMP	XXX.XX DEG	DEC ONLY
#	INERTIAL VELOCITY (VI)		XXXXX. FT/SEC	
#	ALT RATE CHANGE (RDOT)		XXXXX. FT/SEC	
# 69	BETA	3COMP	XXX.XX DEG	
#	DL		XXX.XX G	
#	VL		XXXXX. FT/SEC	
# 70	STAR CODE	3COMP	OCTAL ONLY	
#	LANDMARK DATA		OCTAL ONLY	
#	HORIZON DATA		OCTAL ONLY	
# 71	STAR CODE	3COMP	OCTAL ONLY	
#	LANDMARK DATA		OCTAL ONLY	
#	HORIZON DATA		OCTAL ONLY	
# 72	DELT ANG	3COMP	XXX.XX DEG	DEC ONLY
# 73	ALTITUDE	3COMP	XXXXXB. NAUT MI	
#	VELOCITY		XXXXX. FT/SEC	
#	FLIGHT PATH ANGLE		XXX.XX DEG	
# 74	COMMAND BANK ANGLE (BETA)	3COMP	XXX.XX DEG	
#	INERTIAL VELOCITY (VI)		XXXXX. FT/SEC	
#	DRAG ACCELERATION		XXX.XX G	
# 75	DELTA ALTITUDE CDH	3COMP	XXXX.X NAUT MI	NO LOAD, DEC ON
#	DELTA TIME (CDH-CSI OR TPI-CDH)		XXBXX MIN/SEC	
#	DELTA TIME (TPI-CDH OR TPI-NOMTPI)		XXBXX MIN/SEC	
# 76	SPARE			
# 77	SPARE			
# 78	SPARE			
# 79	SPARE			
# 80	TIME FROM IGNITION/CUTOFF	3COMP	XXBXX MIN/SEC	NO LOAD, DEC ON

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#	VG		XXXXX. FT/SEC	
#	DELTA V (ACCUMULATED)		XXXXX. FT/SEC	
# 81	DELTA V (LV)	3COMP	XXXX.X FT/SEC FOR EACH	DEC ONLY
# 82	DELTA V (LV)	3COMP	XXXX.X FT/SEC FOR EACH	DEC ONLY
# 83	DELTA V (BODY)	3COMP	XXXX.X FT/SEC FOR EACH	DEC ONLY

# 84	DELTA V (OTHER VEHICLE)	3COMP	XXXX.X FT/SEC FOR EACH	DEC 0
# 85	VG (BODY)	3COMP	XXXX.X FT/SEC FOR EACH	DEC 0
# 86	DELTA V (LV)	3COMP	XXXXX. FT/SEC FOR EACH	DEC 0
# 87	MARK DATA	2COMP	XXX.XX DEG	
#	SHAFT		XX.XXX DEG	
#	TRUNION		XX.XXX DEG	
# 88	HALF UNIT SUN OR PLANET VECTOR	3COMP	.XXXXX FOR EACH	DEC 0
# 89	LANDMARK	3COMP	XX.XXX DEG	DEC 0
#	LATITUDE		XX.XXX DEG	
#	LONGITUDE/2		XXX.XX NAUT MI	
#	ALTITUDE			
# 90	Y	3COMP	XXX.XX NM	DEC 0
#	Y DOT		XXXX.X FPS	
#	PSI		XXX.XX DEG	
# 91	OCDU ANGLES	2COMP	XXX.XX DEG	
#	SHAFT		XX.XXX DEG	
#	TRUNION		XX.XXX DEG	
# 92	NEW OPTICS ANGLES	2COMP	XXX.XX DEG	
#	SHAFT		XX.XXX DEG	
#	TRUNION		XX.XXX DEG	
# 93	DELTA GYRO ANGLES	3COMP	XX.XXX DEG FOR EACH	
# 94	NEW OPTICS ANGLES	2COMP	XXX.XX DEG	
#	SHAFT		XX.XXX DEG	
#	TRUNION		XX.XXX DEG	
# 95	PREFERRED ATTITUDE ICDU ANGLES	3COMP	XXX.XX FOR EACH	
# 96	+X-AXIS ATTITUDE ICDU ANGLES	3COMP	XXX.XX DEG FOR EACH	
# 97	SYSTEM TEST INPUTS	3COMP	XXXXX. FOR EACH	
# 98	SYSTEM TEST RESULTS AND INPUTS	3COMP	XXXXX.	
#			.XXXXX	
#			XXXXX.	
# 99	RMS IN POSITION	3COMP	XXX.XX NAUT MI	DEC 0
#	RMS IN VELOCITY		XXXX.X FT/SEC	
#	RMS OPTION		XXXXX.	

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## # REGISTERS AND SCALING FOR NORMAL NOUNS

#	NOUN	REGISTER	SCALE TYPE
#			
# 00	NOT IN USE		
# 01	SPECIFY ADDRESS	H	
# 02	SPECIFY ADDRESS	C	
# 03	SPECIFY ADDRESS	D	
# 04	SPARE		
# 05		DSPTM1	H
# 06		OPTION1	A
# 07		XREG	A
# 08		ALMCADR	A
# 09		FAILREG	A
# 10	SPECIFY CHANNEL	A	

# 11		TCSI	K
# 12		OPTIONX	A
# 13		TCDH	K
# 14	SPARE		
# 15	INCREMENT	ADDRESS	A
# 16		DSPTMX	C
# 17		CPHIX	D
# 18		THETAD	D
# 19		THETAD	D
# 20		CDUX	D
# 21		PIPAX	C
# 22		THETAD	D
# 23	SPARE		
# 24		DSPTM2 +1	K
# 25		DSPTM1	C
# 26		DSPTM1	A
# 27		SMODE	C
# 28	SPARE		
# 29		DSPTM1	D
# 30		DSPTM1	C
# 31		DSPTM1	K
# 32		-TPER	K
# 33		TIG	K
# 34		DSPTM1	K
# 35		TTOGO	K
# 36		TIME2	K
# 37		TTP1	K
# 38		TET	K
# 39		T3TOT4	K

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# REGISTERS AND SCALING FOR MIXED NOUNS

#	NOUN	COMP	REGISTER	SCALE TYPE
#				
# 40	1		TTOGO	L
#	2		VGDISP	S
#	3		DVTOTAL	S
# 41	1		DSPTM1	D
#	2		DSPTM1 +1	E
# 42	1		HAP0	Q
#	2		HPER	Q
#	3		VGDISP	S
# 43	1		LAT	H
#	2		LONG	H

#	3	ALT	Q
# 44	1	HAPOX	Q
#	2	HPERX	Q
#	3	TFF	L
# 45	1	VHFCNT	PP
#	2	TTOGO	L
#	3	+MGA	H
# 46	1	DAPDATR1	A
#	2	DAPDATR2	A
# 47	1	CSMMASS	KK
#	2	LEMMASS	KK
# 48	1	PACTOFF	FF
#	2	YACTOFF	FF
# 49	1	N49DISP	Q
#	2	N49DISP +2	S
#	3	N49DISP +4	C
# 50	1	RSP-RREC	LL
#	2	HPERX	Q
#	3	TFF	L
# 51	1	RHOSB	H
#	2	GAMMASB	H
# 52	1	ACTCENT	H
# 53	1	RANGE	JJ
#	2	RRATE	S
#	3	RTHETA	H
# 54	1	RANGE	JJ
#	2	RRATE	S
#	3	RTHETA	H
# 55	1	NN1	C
#	2	ELEV	H
#	3	CENTANG	H
# 56	1	RTEGAM2D	H
#	2	RTEDVD	P
# 57	1	DELTAR	Q
# 58	1	POSTTPI	Q
#	2	DELVTPI	S

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#	3	DELVTPI	S
# 59	1	DVLOS	S
#	2	DVLOS +2	S
#	3	DVLOS +4	S
# 60	1	GMAX	T
#	2	VPRED	P
#	3	GAMMAEI	H



# 61	1	LAT (SPL)	H
#	2	LNG (SPL)	H
#	3	HEADSUP	C
# 62	1	VMAGI	P
#	2	HDOT	P
#	3	ALTI	Q
# 63	1	RTGO	LL
#	2	VIO	P
#	3	TTE	L
# 64	1	D	MM
#	2	VMAGI	P
#	3	RTGON64	LL
# 65	1	SAMPTIME	K
#	2	SAMPTIME	K
#	3	SAMPTIME	K
# 66	1	ROLLC	H
#	2	XRNGERR	VV
#	3	DNRNGERR	LL
# 67	1	RTGON67	LL
#	2	LAT	H
#	3	LONG	H
# 68	1	ROLLC	H
#	2	VMAGI	P
#	3	RDOT	UU
# 69	1	ROLLC	H
#	2	Q7	MM
#	3	VL	UU
# 70	1	STARCODE	A
#	2	LANDMARK	A
#	3	HORIZON	A
# 71	1	STARCODE	A
#	2	LANDMARK	A
#	3	HORIZON	A
# 72	1	THETZERO	H
# 73	1	P21ALT	Q (MEMORY/100 TO DISPLAY TENS N.M.)
#	2	P21VEL	P
#	3	P21GAM	H
# 74	1	ROLLC	H
#	2	VMAGI	P
#	3	D	MM
# 75	1	DIFFALT	Q
#	2	T1TOT2	L
#	3	T2TOT3	L

# 76	SPARE		
# 77	SPARE		
# 78	SPARE		
# 79	SPARE		
# 80	1	TTOGO	L
#	2	VGDISP	P
#	3	DVTOTAL	P
# 81	1	DEVLVC	S
#	2	DEVLVC +2	S
#	3	DEVLVC +4	S
# 82	1	DEVLVC	S
#	2	DEVLVC +2	S
#	3	DEVLVC +4	S
# 83	1	DELVIMU	S
#	2	DELVIMU +2	S
#	3	DELVIMU +4	S
# 84	1	DELVOV	S
#	2	DELVOV +2	S
#	3	DELVOV +4	S
# 85	1	VGBODY	S
#	2	VGBODY +2	S
#	3	VGBODY +4	S
# 86	1	DEVLVC	P
#	2	DEVLVC +2	P
#	3	DEVLVC +4	P
# 87	1	MRKBUF1 +3	D
#	2	MRKBUF1 +5	J
# 88	1	STARSAV	ZZ
#	2	STARSAV +2	ZZ
#	3	STARSAV +4	ZZ
# 89	1	LANDLAT	G
#	2	LANDLONG	G
#	3	LANDALT	JJ
# 90	1	RANGE	JJ
#	2	RRATE	S
#	3	RTHETA	H
# 91	1	CDUS	D
#	2	CDUT	J
# 92	1	SAC	D
#	2	PAC	J
# 93	1	OGC	G
#	2	OGC +2	G
#	3	OGC +4	G
# 94	1	MRKBUF1 +3	D
#	2	MRKBUF1 +5	J
# 95	1	PRAXIS	D

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#	2	PRAXIS +1	D
#	3	PRAXIS +2	D
# 96	1	CPHIX	D
#	2	CPHIX +1	D

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#	3	CPHIX +2	D
# 97	1	DSPTM1	C
#	2	DSPTM1 +1	C
#	3	DSPTM1 +2	C
# 98	1	DSPTM2	C
#	2	DSPTM2 +1	B
#	3	DSPTM2 +2	C
# 99	1	WWPOS	XX
#	2	WWVEL	YY
#	3	WVOPT	C

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# NOUN SCALES AND FORMATS

#	# -SCALE TYPE-	DECIMAL FORMAT	PRECISION	AGC FORMAT
#	UNITS		--	-----
#	-----	-----	--	-----
#	# -A-			
#	# OCTAL	XXXXX	SP	OCTAL
#	# -B-			
#	# FRACTIONAL	.XXXXX (MAX .99996)	SP	<sup>-14</sup> BIT 1 = 2 UNITS
#	# -C-			
#	# WHOLE	XXXXX. (MAX 16383.)	SP	BIT 1 = 1 UNIT
#	# -D-			
#	# CDU DEGREES	XXX.XX DEGREES (MAX 359.99)	SP	<sup>15</sup> BIT 1 = 360/2 DEGREES (USES 15 BITS FOR MAGNITUDE AND 2'S COMP.)
#	# -E-			
#	# ELEVATION DEGREES	XX.XXX DEGREES (MAX 89.999)	SP	<sup>14</sup> BIT 1 = 90/2 DEGREES
#				
#				

```

# -F-
# DEGREES (180)      XXX.XX DEGREES      SP      BIT 1 = 180/214 DEGREES
#                   (MAX 179.99)
#
# -G-
# DP DEGREES (90)    XX.XXX DEGREES      DP      BIT 1 OF LOW REGISTER =
#                   28
#                   360/2 DEGREES
#
# -H-
# DP DEGREES (360)    XXX.XX DEGREES      DP      BIT 1 OF LOW REGISTER =
#                   (MAX 359.99)          28
#                   360/2 DEGREES
#
# -J-
# Y OPTICS DEGREES    XX.XXX DEGREES      SP      BIT 1 = 90/215 DEGREES
#                   (BIAS OF 19.775      (USES 15 BITS FOR MAGNI-
#                   DEGREES ADDED FOR    TUDE AND S'S COMP.)
#                   DISPLAY, SUBTRACTED
#                   FOR LOAD.)
#                   NOTE: NEGATIVE NUM-
#                   BERS CANNOT BE
#                   LOADED.
#
# -K-

# Page 20

# TIME (HR, MIN, SEC) 00XXX. HR      DP      BIT 1 OF LOW REGISTER =
#                   000XX. MIN      -2
#                   OXX.XX SEC      10 SEC
#                   (DECIMAL ONLY.
#                   MAX MIN COMP = 59
#                   MAX SEC COMP = 59.99
#                   MAX CAPACITY = 745 HRS
#                               39 MINS
#                               14.55 SECS.
#                   WHEN LOADING, ALL 3
#                   COMPONENTS MUST BE
#                   SUPPLIED.)
#
# -L-
# TIME (MIN/SEC)       XXBXX MIN/SEC      DP      BIT 1 OF LOW REGISTER =
#                   (B IS A BLANK      -2
#                   POSITION, DECIMAL    10 SEC
#                   ONLY, DISPLAY OR

```

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```
#          MONITOR ONLY.  CANNOT
#          BE LOADED.
#          MAX MIN COMP = 59
#          MAX SEC COMP = 59
#          VALUES GREATER THAN
#          59 MIN 59 SEC
#          ARE DISPLAYED AS
#          59 MIN 59 SEC.)
#
# -M-
# TIME (SEC)          XXX.XX SEC          SP          BIT 1 = 10-2 SEC
#                   (MAX 163.83)
#
# -N-
# TIME (SEC) DP       XXX.XX SEC          DP          BIT 1 OF LOW REGISTER =
#                   -2
#                   10 SEC
#
# -P-
# VELOCITY 2          XXXXX. FEET/SEC      DP          BIT 1 OF HIGH REGISTER =
#                   (MAX 41994.)          -7
#                   2 METERS/CENTI-SEC
#
# -Q-
# POSITION 4           XXXX.XX NAUTICAL MILES DP          BIT 1 OF LOW REGISTER =
#                   2 METERS.
#
# -S-
# VELOCITY 3          XXXX.X FT/SEC        DP          BIT 1 OF HIGH REGISTER =
#                   -7
#                   2 METERS/CENTI-SEC
#
# Page 21
#
# -T-
# G                   XXX.XX G             SP          BIT 1 = 10-2 G
#                   (MAX 163.83)
#
# -FF-
# TRIM DEGREES        XXX.XX DEG.          SP          LOW ORDER BIT = 85.41 SEC
#                   (MAX 388.69)          OF ARC
#
# -GG-
# INERTIA              XXXXXBB. SLUG FT SQ  SP          FRACTIONAL PART OF
#                   (MAX 07733BB.)          20 2
#                   2 KG M
```

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#				20
# -II-				
# THRUST MOMENT	XXXXXB. FT LBS	SP	FRACTIONAL PART OF 2	
#	(MAX 07733BB.)		NEWTON METER	
#				
# -JJ-				
# POSITION5	XXX.XX NAUT MI	DP	BIT 1 OF LOW REGISTER =	
#			2 METERS	
#				
# -KK-				16
# WEIGHT2	XXXXX. LBS	SP	FRACTIONAL PART OF 2	KG
#				
# -LL-				
# POSITION6	XXXX.X NAUT MI	DP	BIT 1 OF LOW REG =	
#				-28
#			(6,373,338)(2(PI))x2	
#			-----	
#			1852	
#			NAUT MI.	
#				
# -MM-				
# DRAG ACCELERATION	XXX.XX G	DP	BIT 1 OF LOW REGISTER =	
#	MAX (024.99)		-28	
#			25x2 G	
#				
# -PP-				
# 2 INTEGERS	+XXBYY	DP	BIT 1 OF HIGH REGISTER =	
#	(B IS A BLANK		1 UNIT OF XX	
#	POSITION. DECIMAL		BIT 1 OF LOW REGISTER =	
#	ONLY, DISPLAY, OR		1 UNIT OF YY	
#	MONITOR ONLY. CANNOT		(EACH REGISTER MUST	
#	BE LOADED.)		LESS THAN 100.)	
#	(MAX 99B99)			
#				
# -UU-				
# VELOCITY/2VS	XXXXX. FEET/SEC	DP	FRACTIONAL PART OF	
#	(MAX 51532.)		2VS FEET/SEC	
#			(VS = 25766.1973)	
#				
# Page 22				
#				
# -VV-				
# POSITION8	XXXX.X NAUT MI	DP	BIT 1 OF LOW REGISTER =	
#				-28
#			4 x 6,373,338 x 2	
#			-----	

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```
#
#                                     1852
#                                     NAUT MI.
#
# -XX-
# POSITION 9          XXX.XX NAUT MI      DP      BIT 1 OF LOW REGISTER =
#                  (MAX 283.09)          -9
#                                     2  METERS.
#
# -YY-
# VELOCITY 4        XXXX.X FEET/SEC      DP      FRACTIONAL PART OF
#                  (MAX 328.0)          METERS/CENTI-SEC
#
# -ZZ-
# DP FRACTIONAL      .XXXXX              DP      BIT 1 OF HIGH REGISTER =
#                                     -14
#                                     2  UNITS
```

# THAT'S ALL ON THE NOUNS.

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# ALARM CODES FOR 504

# REPORT DEFICIENCIES TO JOHN SUTHERLAND: MIT 617-864-6900 X1458

# *9	*18	*60	*25	CD
#				
# CODE	* TYPE	SET BY	ALARM	R
#				
# 00110	NO MARK SINCE LAST MARK REJECT	SXTMARK	ALARM	
# 00112	MARK NOT BEING ACCEPTED	SXTMARK	ALARM	
# 00113	NO NBITS	SXTMARK	ALARM	
# 00114	MARK MADE BUT NOT DESIRED	SXTMARK	ALARM	
# 00115	OPTICS TORQUE REQUEST WITH SWITCH NOT AT CGC	EXT VERB OPTICS CDU	ALARM	
# 00116	OPTICS SWITCH ALTERED BEFORE 15 SEC ZERO TIME ELAPSED.	T4RUPT	ALARM	
# 00117	OPTICS TORQUE REQUEST WITH OPTICS NOT AVAILABLE (OPTIND=-0)	EXT VERB OPTICS CDU	ALARM	
# 00120	OPTICS TORQUE REQUEST WITH OPTICS NOT ZEROED.	T4RUPT	ALARM	
# 00121	CDUS NO GOOD AT TIME OF MARK	SXTMARK	ALARM	
# 00122	MARKING NOT CALLED FOR	SXTMARK	ALARM	
# 00124	P17 TPI SEARCH - NO SAFE PERICTR HERE.	TPI SEARCH	ALARM	
# 00205	BAD PIPA READING	SERVICER	ALARM	

# 00206	ZERO ENCODE NOT ALLOWED WITH COARSE ALIGN	IMU MODE SWITCHING
#	+ GIMBAL LOCK.	
# 00207	ISS TURNON REQUEST NOT PRESENT FOR 90 SEC	T4RUPT
# 00210	IMU NOT OPERATING	IMU MODE SWITCH,
#		IMU-2, R02, P51
# 00211	COARSE ALIGN ERROR - DRIVE > 2 DEGREES	IMU MODE SWITCH
# 00212	PIPA FAIL BUT PIPA IS NOT BEING USED	IMU MODE SWITCH, T4RUPT
# 00213	IMU NOT OPERATING WITH TURN-ON REQUEST	T4RUPT
# 00214	PROGRAM USING IMU WHEN TURNED OFF	T4RUPT
# 00215	PREFERRED ORIENTATION NOT SPECIFIED	P52,P54
# 00217	BAD RETURN FROM STALL ROUTINES	CURTAINS
# 00220	IMU NOT ALIGNED - NO REFSMMAT	R02,P51
# 00401	DESIRED GIMBAL ANGLES YIELD GIMBAL LOCK	IMF ALIGN, IMU-2
# 00404	TARGET OUT OF VIEW - TRUN ANGLE > 90 DEG	R52
# 00405	TWO STARS NOT AVAILABLE	P52,P54
# 00406	REND NAVIGATION NOT OPERATING	P21,R23
# 00407	AUTO OPTICS REQUEST TRUN ANGLE > 50 DEG.	R52
# 00421	W-MATRIX OVERFLOW	INTEGRV
# 00430	* INTEG. ABORT DUE TO SUBSURFACE S. V.	ALL CALLS TO INTEG
# 00600	IMAGINARY ROOTS ON FIRST ITERATION	P32, P72
# 00601	PERIGEE ALTITUDE LT PMIN1	P32,P72
# 00602	PERIGEE ALTITUDE LT PMIN2	P32,P72
# 00603	CSI TO CDH TIME LT PMIN22	P32,P72,P33,P73
# 00604	CDH TO TPI TIME LT PMIN23	P32,P72
# 00605	NUMBER OF ITERATIONS EXCEEDS LOOP MAXIMUM	P32,P72,P37
# 00606	DV EXCEEDS MAXIMUM	P32,P72
# 00607	* NO SOLN FROM TIME-THETA OR TIME-RADIUS	TIMETHET,TIMERAD
# Page 24		
# 00610	* LAMBDA LESS THAN UNITY	P37
# 00611	NO TIG FOR GIVEN ELEV ANGLE	P34,P74
# 00612	STATE VECTOR IN WRONG SPHERE OF INFLUENCE	P37
# 00613	REENTRY ANGLE OUT OF LIMITS	P37
# 00777	PIPA FAIL CAUSED ISS WARNING.	T4RUPT
# 01102	CMC SELF TEST ERROR	
# 01103	* UNUSED CCS BRANCH EXECUTED	ABORT
# 01104	* DELAY ROUTINE BUSY	EXEC
# 01105	DOWNLINK TOO FAST	T4RUPT
# 01106	UPLINK TOO FAST	T4RUPT
# 01107	PHASE TABLE FAILURE. ASSUME	RESATRT
#	ERASABLE MEMORY IS DESTROYED	
# 01201	* EXECUTIVE OVERFLOW - NO VAC AREAS	EXEC
# 01202	* EXECUTIVE OVERFLOW - NO CORE SETS	EXEC
# 01203	* WAITLIST OVERFLOW - TOO MANY TASKS	WAITLIST
# 01204	* NEGATIVE OR ZERO WAITLIST CALL	WAITLIST



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# 01206	* SECOND JOB ATTEMPTS TO GO TO SLEEP	PINBALL	POODOO
#	VIA KEYBOARD AND DISPLAY PROGRAM		
# 01207	* NO VAC AREA FOR MARKS	SXTMARK	BAILOUT
# 01210	* TWO PROGRAMS USING DEVICE AT SAME TIME	IMU MODE SWITCH	POODOO
# 01211	* ILLEGAL INTERRUPT OF EXTENDED VERB	SXTMARK	BAILOUT
# 01301	ARCSIN-ARCCOS ARGUMENT TOO LARGE	INTERPRETER	ALARM
# 01302	* SQRT CALLED WITH NEGATIVE ARGUMENT. ABORT.	INTERPRETER	POODOO
# 01407	VG INCREASING	S40.8	ALARM
# 01426	IMU UNSATISFACTORY	P61,P62	ALARM
# 01427	IMU REVERSED	P61,P62	ALARM
# 01501	* KEYBOARD AND DISPLAY ALARM DURING	PINBALL	POODOO
#	INTERNAL USE (NVSUB). ABORT.		
# 01502	* ILLEGAL FLASHING DISPLAY	GOPLAY	POODOO
# 01520	V37 REQUEST NOT PERMITTED AT THIS TIME	V37	ALARM
# 01521	* P01 ILLEGALLY SELECTED	P01, P07	POODOO
# 01600	OVERFLOW IN DRIFT TEST	OPT PRE ALIGN CALIB	ALARM
# 01601	* BAD IMU TORQUE - ABORT.	OPT PRE ALIGN CALIB	ALARM
# 01602	BAD OPTICS DURING VERIFICATION	OPTALGN CALIB (CSM)	ALARM
# 01703	INSUF. TIME FOR INTEG., TIG WAS SLIPPED	R41	ALARM
# 03777	ICDU FAIL CAUSED THE ISS WARNING	T4RUPT	VARALAR
# 04777	ICDU, PIPA FAILS CAUSED THE ISS WARNING	T4RUPT	VARALAR
# 07777	IMU FAIL CAUSED THE ISS WARNING	T4RUPT	VARALAR
# 10777	IMU, PIPA FAILS CAUSED THE ISS WARNING	T4RUPT	VARALAR
# 13777	IMU, ICDU FAILS CAUSED THE ISS WARNING	T4RUPT	VARALAR
# 14777	IMU, ICDU, PIPA FAILS CAUSED THE ISS WARNING	T4RUPT	VARALAR
#			
#	* INDICATES ABORT TYPE. ALL OTHERS ARE NON-ABORTIVE		

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# CHECKLIST CODES FOR 504

# PLEASE REPORT ANY DEFICIENCIES IN THIS LIST TO JOHN SUTHERLAND.

# *9	*17	*26 COLUMN
#		
# R1 CODE	ACTION TO BE EFFECTED	
#		
# 00014	KEY IN	FINE ALIGNMENT OPTION
# 00015	PERFORM	CELESTIAL BODY ACQUISITION
# 00016	KEY IN	TERMINATE MARK SEQUENCE
# 00041	SWITCH	CM/SM SEPARATION TO UP
# 00062	SWITCH	AGC POWER DOWN
# 00202	PERFORM	GNCS AUTOMATIC MANEUVER
# 00203	SWITCH	TO CMC-AUTO
# 00204	PERFORM	SPS GIMBAL TRIM

```
# 00403          SWITCH          OPTICS TO MANUAL OR ZERO
#
#              SWITCH DENOTES CHANGE OF POSITION OF A CONSOLE SWITCH
#              PERFORM DENOTES START OF END OF A TASK
#              KEY IN DENOTES KEY IN OF DATA THRU THE DSKY
```

```
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```

```
# OPTION CODES FOR 504
```

```
# PLEASE REPORT ANY DEFICIENCIES IN THIS LIST TO JOHN SUTHERLAND.
```

```
# THE SPECIFIED OPTION CODES WILL BE FLASHED IN COMPONENT R1 IN
# CONJUNCTION WITH VERBO4NOUN06 TO REQUEST THE ASTRONAUT TO LOAD INTO
# COMPONENT R2 THE OPTION HE DESIRES.
```

# *9	*17	#52	#11
#			
# OPTION			
# CODE	PURPOSE	INPUT FOR COMPONENT 2	PROG
#			
# 00001	SPECIFY IMU ORIENTATION	1=PREF 2=NOM 3=REFSMMAT	P50'S
# 00002	SPECIFY VEHICLE	1=THIS 2=OTHER	P21, E
# 00003	SPECIFY TRACKING ATTITUDE	1=PREFERRED 2=OTHER	R63
# 00004	SPECIFY RADAR	1=RR 2=LR	R04
# 00005	SPECIFY SOR PHASE	1=FIRST 2=SECOND	P38
# 00006	SPECIFY RR COARSE ALIGN OPTION	1=LOCKON 2=CONTINUOUS DESIG.	V41N
# 00007	SPECIFY PROPULSION SYSTEM	1=SPS 2=RCS	P37
# 00010	SPECIFY ALIGNEMENT MODE	0=ANY TIME 1=REFSMMAT + G	P57
#		2=TWO BODIES 3=ONE BODY + G	
# 00011	SPEC. SEPARATION MONITOR PHASE	1=DELTAV 2=STATE VECTOR UPDATE	P46
# 00012	SPECIFY CSM ORBIT OPTION	1=NO ORBIT CHANGE 2=CHANGE	P22
#		ORBIT TO PASS OVER LM	

```
This code is written to file src/ASSEMBLY-AND-OPERATION-INFORMATION.s.
```

## A.10 ATTITUDE MANEUVER ROUTINE

139

*<src/ATTITUDE-MANEUVER-ROUTINE.s 139>≡*

```
# Copyright:    Public domain.
# Filename:     ATTITUDE_MANEUVER_ROUTINE.agc
# Purpose:     Part of the source code for Luminary 1A build 099.
#             It is part of the source code for the Lunar Module's (LM)
#             Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:     Ron Burkey <info@sandroid.org>.
# Website:     www.ibiblio.org/apollo.
# Pages:       342-363
# Mod history: 2009-05-16 RSB   Adapted from the corresponding
#                               Luminary131 file, using page
#                               images from Luminary 1A.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
#       16:27 JULY 14, 1969
#
# Page 342
# BLOCK 2 LGC ATTITUDE MANEUVER ROUTINE -- KALCMANU
#
# MOD 2          DATE 5/1/67      BY DON KEENE
#
# PROGRAM DESCRIPTION
#
# KALCMANU IS A ROUTINE WHICH GENERATES COMMANDS FOR THE LM DAP TO CHANGE THE ATTITUDE OF THE S
# DURING FREE FALL. IT IS DESIGNED TO MANEUVER THE SPACECRAFT FROM ITS INITIAL ORIENTATION TO
# ORIENTATION SPECIFIED BY THE PROGRAM WHICH CALLS KALCMANU, AVOIDING GIMBAL LOCK IN THE PROCES
# MOD 2 VERSION, THIS DESIRED ATTITUDE IS SPECIFIED BY A SET OF OF THREE COMMANDED CDU ANGLES S
# SINGLE PRECISION ANGLES IN THE THREE CONSECUTIVE LOCATIONS, CPHI, CTHETA, CPSI, WHERE
#
#       CPHI = COMMANDED OUTER GIMBAL ANGLE
#       CTHETA = COMMANDED INNER GIMBAL ANGLE
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#           CPSI = COMMANDED MIDDLE GIMBAL ANGLE
#
# WHEN POINTING A SPACECRAFT AXIS (I.E., X, Y, Z, THE AOT, THRUST AXIS, ETC.) THE SUR
# USED TO GENERATE THIS SET OF DESIRED CDU ANGLES (SEE DESCRIPTION IN R60).
#
# WITH THIS INFORMATION KALCMANU DETERMINES THE DIRECTION OF THE SINGLE EQUIVALEN RO
# MAGNITUDE OF THE ROTATION (AM) TO BRING THE S/C FROM ITS INITIAL ORIENTATION TO ITS
# THIS DIRECTION REMAINS FIXED BOTH IN INERTIAL COORDINATES AND IN COMMANDED S/C AXES
#
# MANEUVER.  ONCE COF AND AM HAVE BEEN DETERMINED, KALCMANU THEN EXAMINES THE MANEUVER
#
# THE S/C THROUGH GIMBAL LOCK.  IF SO, COF AND AM ARE READJUSTED SO THAT THE S/C WILL
# LOCK ZONE AND ALIGN THE X-AXIS.  IN GENERAL A FINAL YAW ABOUT X WILL BE NECESSARY T
# NEEDLESS TO SAY, NEITHER THE INITIAL NOR THE FINAL ORIENTATION CAN BE IN GIMBAL LOO
#
# FOR PROPER ATTITUDE CONTROL THE DIGITAL AUTOPILOT MUST BE GIVEN AN ATTITUDE REFERE
# KALCMANU DOES THIS BY GENERATING A REFERENCE OF DESIRED GIMBAL ANGLES (CDUXD, CDUYD
# EVERY ONE SECOND DURING THE MANEUVER.  TO ACHIEVE A SMOOTHER SEQUENCE OF COMMANDS
# THE PROGRAM ALSO GENERATES A SET OF INCREMENTAL CDU ANGLES (DELDCDU) TO BE ADDED TO
# AUTOPILOT.  KALCMANU ALSO CALCULATES THE COMPONENT MANEUVER RATES (OMEGAPD, OMEGAQ
#
# BE DETERMINED SIMPLY BY MULTIPLYING COF BY SOME SCALAR (ARATE) CORRESPONDING TO TH
#
# AUTOMATIC MANEUVERS ARE TIMED WTH THE HELP OF WAITLIST SO THAT AFTER A SPECIFIED IN
# DESIRED RATES ARE SET TO ZERO AND THE DESIRED CDU ANGLES (CDUYD, CDUZD) ARE SET EQU
# ANGLES (CTHETA, CPSI).  IF ANY YAW REMAINS DUE TO GIMBAL LOCK AVOIDANCE, THE FINAL
# CALCULATED AND THE DESIRED YAW RATE SET TO SOME FIXED VALUE (ROLLRATE = + OR - 2 DI
# IN THIS CASE ONLY AN INCREMENTAL CDUX ANGLE (DELFROLL) IS SUPPLIED TO THE DAP.  AT
# MANEUVER OR IN THE EVENT THAT THERE WAS NO FINAL YAW, CDUXD IS SET EQUAL TO CPHI AN
# RATE SET TO ZERO.  THUS, UPON COMPLETION OF THE MANEUVER THE S/C WILL FINISH UP IN
# DESIRED GIMBAL ANGLES.
#
# PROGRAM LOGIC FLOW
#
# KALCMANU IS CALLED AS A HIGH PRIORITY JOB WITH ENTRY POINTS AT KALCMAN3 AND VECPOIN
# UP THE CURRENT CDU ANGLES TO BE USED AS THE BASIS FOR ALL COMPUTATIONS INVOLVING TH
# Page 343
# IT THEN DETERMINES THE DIRECTION COSINE MATRICES RELATING BOTH THE INITIAL AND FINA
#
# * *
# MEMBER AXES (MIS,MFS).  IT ALSO COMPUTES THE MATRIX RELATING FINAL S/C AXES TO INIT
# ANGLE OF ROTATION (AM) IS THEN EXTRACTED FROM THIS MATRIX, AND TEST ARE MADE TO DET
#
# A)      AM LESS THAN .25 DEGREES (MINANG)
# B)      AM GREATER THAN 170 DEGREES (MAXANG)
#
# IF AM IS LESS THAN .25 DEGREES, NO COMPLICATED AUTOMATIC MANEUVERING IS NECESSARY.

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```
# SET CDU DESIRED EQUAL TO THE FINAL CDU DESIRED ANGLES AND TERMINATE THE JOB.
#
# IF AM IS GREATER THAN .25 DEGREES BUT LESS THAN 170 DEGREES THE AXES OF THE SINGLE EQUIVALENT
# - *
# (COF) IS EXTRACTED FROM THE SKEW SYMMETRIC COMPONENTS OF MFI.
# * *
# IF AM GREATER THAN 170 DEGREES AN ALTERNATE METHOD EMPLOYING THE SYMMETRIC PART OF MFI (MFISY
# -
# TO DETERMINE COF.
#
# THE PROGRAM THEN CHECKS TO SEE IF THE MANEUVER AS COMPUTED WILL BRING THE S/C THROUGH GIMBAL
# SO, A NEW MANEUVER IS CALCULATED WHICH WILL JUST SKIM THE GIMBAL LOCK ZONE AND ALIGN THE S/C
# METHOD ASSURES THAT THE ADDITIONAL MANEUVERING TO AVOID GIMBAL LOCK WILL BE KEPT TO A MINIMUM
# P AXIS YAW WILL BE NECESSARY, A SWITCH IS RESET (STATE SWITCH 31) TO ALLOW FOR THE COMPUTATIO
# YAW.
#
# AS STATED PREVIOUSLY, KALCMANU GENERATES A SEQUENCE OF DESIRED GIMBAL ANGLES WHICH ARE UPDATE
#
# SECOND. THIS IS ACCOMPLISHED BY A SMALL ROTATION OF THE DESIRED S/C FRAME ABOUT THE VECTOR C
# DESIRED REFERENCE MATRIX IS THEN,
# * * *
# MIS = MIS DEL
# N+1 N
# *
# WHERE DEL IS THE MATRIX CORRESPONDING TO THIS SMALL ROTATION. THE NEW CDU ANGLES CAN THEN BE
# *
# FROM MIS.
#
# AT THE BEGINNING OF THE MANEUVER THE AUTOPILOT DESIRED RATES (OMEGAPD, OMEGAQD, OMEGARD) AND
# MANEUVER TIMINGS ARE ESTABLISHED. ON THE FIRST PASS AND ON ALL SUBSEQUENT UPDATES THE CDU DE
# ANGLES ARE LOADED WITH THE APPROPRIATE VALUES AND THE INCREMENTAL CDU ANGLES ARE COMPUTED. T
# (TIME1 AND TIME2) ARE THEN CHECKED TO SEE IF THE MANEUVER WILL TERMINATE BEFORE THE NEXT UPDA
# NOT, KALCMANU CALLS FOR ANOTHER UPDATE (RUN AS A JOB WITH PRIORITY TBD) IN ONE SECOND. ANY D
# CALLING SEQUENCE ARE AUTOMATICALLY COMPENSATED IN CALLING FOR THE NEXT UPDATE.
#
# IF IT IS FOUND THAT THE MANEUVER IS TO TERMINATE BEFORE THE NEXT UPDATE A ROUTINE IS CALLED (
# LIST TASK) TO STOP THE MANEUVER AT THE APPROPRIATE TIME AS EXPLAINED ABOVE.

# Page 344
# CALLING SEQUENCE
#
# IN ORDER TO PERFORM A KALCMANU SUPERVISED MANEUVER, THE COMMANDED GIMBAL ANGLES MUST BE PRECO
# STORED IN LOCATIONS CPHI, CTHETA, CPSI. THE USER'S PROGRAM MUST THEN CLEAR STATE SWITCH NO 3
# ATTITUDE MANEUVER ROUTINE TO PERFORM ANY FINAL P-AXIS YAW INCURRED BY AVOIDING GIMBAL LOCK.
# THEN INITIATED BY ESTABLISHING THE FOLLOWING EXECUTIVE JOB
# *
```

```
# CAF          PRIO XX
#              --
#
# INHINT
# TC           FINDVAC
# 2CADR        KALCMAN3
# RELINT
#
# THE USER'S PROGRAM MAY EITHER CONTINUE OR WAIT FOR THE TERMINATION OF THE MANEUVER.
# WAIT, HE MAY PUT HIS JOB TO SLEEP WITH THE FOLLOWING INSTRUCTIONS:
#
# L            TC      BANKCALL
# L+1          CADR    ATTSTALL
# L+2          (BAD RETURN)
# L+3          (GOOD RETURN)
#
# UPON COMPLETION OF THE MANEUVER, THE PROGRAM WILL BE AWAKENED AT L+3 IF THE MANEUVER
# SUCCESSFULLY, OR AT L+2 IF THE MANEUVER WAS ABORTED. THIS ABORT WOULD OCCUR IF THE
# WAS IN GIMBAL LOCK.
#
# *** NOTA BENE *** IF IT IS ASSUMED THAT THE DESIRED MANEUVERING RATE (0.5, 2, 5, 10)
# KEYBOARD ENTRY PRIOR TO THE EXECUTION OF KALCMANU.
#
# IT IS ALSO ASSUMED THAT THE AUTOPILOT IS IN THE AUTO MODE. IF THE MODE SWITCH IS ON
# MANEUVER, KALCMANU WILL TERMINATE VIA GOODEND WITHIN 1 SECOND SO THAT R60 MAY REQUIRE
# SUBROUTINES.
#
# KALCMANU USES A NUMBER OF INTERPRETIVE SUBROUTINES WHICH MAY BE OF GENERAL INTEREST.
# WERE PROGRAMMED EXCLUSIVELY FOR KALCMANU, THEY ARE NOT, AS YET, GENERALLY AVAILABLE.
#
# MXM3
# ----
#
# THIS SUBROUTINE MULTIPLIES TWO 3X3 MATRICES AND LEAVES THE RESULT IN THE FIRST 18 I/O
# DOWN LIST, I.E.,
#
#           [ M      M      M ]
#           [ 0       1      2 ]
# *         [             ]
# M   =     [ M      M      M ]   =   M1      X      M2
#           [ 3       4      5 ]
#           [             ]
#           [ M      M      M ]
#           [ 6       7      8 ]
#
# Page 345
#
# INDEX REGISTER X1 MUST BE LOADED WITH THE COMPLEMENT OF THE STARTING ADDRESS FOR M2.
```

```

# LOADED WITH THE COMPLEMENT OF THE STARTING ADDRESS FOR M2.  THE ROUTINE USES THE FIRST 20 LOCATIONS OF THE
# DOWN LIST.  THE FIRST ELEMENT OF THE MATRIX APPEARS IN PDO.  PUSH UP FOR M .
#
# TRANSPOS
# -----
#
# THIS ROUTINE TRANSPOSES A 3X3 MATRIX AND LEAVES THE RESULT IN THE PUSH DOWN LIST, I.E.,
#
#      *      * T
#      M      =      M1
#
# INDEX REGISTER X1 MUST CONTAIN THE COMPLEMENT OF THE STARTING ADDRESS FOR M1.  PUSH UP FOR THE FIRST 20 LOCATIONS OF THE
# SEQUENT COMPONENTS OF M.  THIS SUBROUTINE ALSO USES THE FIRST 20 LOCATIONS OF THE PUSH DOWN LIST.
#
# CDU TO DCM
# -----
#
# THIS SUBROUTINE CONVERTS THREE CDU ANGLES IN T(MPAC) TO A DIRECTION COSINE MATRIX (SCALED BY THE CORRESPONDING S/C
# ORIENTATIONS TO THE STABLE MEMBER FRAME.  THE FORMULAS FOR THIS CONVERSION ARE:
#
#      M      =      COSY COSZ
#      0
#
#      M      =      -COSY SINZ COSX + SINY SINX
#      1
#
#      M      =      COSY SINZ SINX + SINY COSX
#      2
#
#      M      =      SINZ
#      3
#
#      M      =      COSZ COSX
#      4
#
#      M      =      -COSZ SINX
#      5
#
#      M      =      -SINY COSZ
#      6
#
#      M      =      SINY SINZ COSX + COSY SINX
#      7
# Page 346
#      M      =      -SINY SINZ SINX + COSY COSX

```

```

#           8
#
# WHERE      X      =      OUTER GIMBAL ANGLE
#           Y      =      INNER GIMBAL ANGLE
#           Z      =      MIDDLE GIMBAL ANGLE
#
# THE INTERPRETATION OF THIS MATRIX IS AS FOLLOWS:
#
# IF A , A , A REPRESENT THE COMPONENTS OF A VECTOR IN S/C AXES THEN THE COMPONENTS
#   X   Y   Z
# STABLE MEMBER AXES (B , B , B ) ARE
#           X   Y   Z
#
#   [ B ]           [ A ]
#   [ X ]           [ X ]
#   [   ]           [   ]
#   [ B ]           *   [ A ]
#   [ Y ]      =    M   [ Y ]
#   [   ]           [   ]
#   [ B ]           [ B ]
#   [ Z ]           [ Z ]
#
# THE SUBROUTINE WILL STORE THIS MATRIX IN SEQUENTIAL LOCATIONS OF ERASABLE MEMORY AS
#
# PROGRAM. TO DO THIS THE CALLING PROGRAM MUST FIRST LOAD X2 WITH THE COMPLEMENT OF
#
# INTERNALLY, THE ROUTINE USES THE FIRST 16 LOCATIONS OF THE PUSH DOWN LIST, ALSO ST
# REGISTER X2.
#
# DCM TO CDU
# -----
#
# THIS ROUTINE EXTRACTS THE CDU ANGLES FROM A DIRECTION COSINE MATRIX (M SCALED BY 2)
#
# STABLE MEMBER AXES. X1 MUST CONTAIN THE COMPLEMENT OF THE STARTING ADDRESS FOR M.
# CORRESPONDING GIMBAL ANGLES IN V(MPAC) AS DOUBLE PRECISION 1'S COMPLEMENT ANGLES AC
# FOR THIS CONVERSION ARE
#
#   Z      =      ARCSIN (M )
#                       3
#
#   Y      =      ARCSIN (-M /COSZ)
#                       6
#
# IF M IS NEGATIVE, Y IS REPLACED BY PI SGN Y - Y.
#   0

```



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# X = ARCSIN (-M /COSZ)

# 5

#

# IF M IS NEGATIVE, X IS REPLACED BY PI SGN X - X.

# 4

#

# THIS ROUTINE DOES NOT SET THE PUSH DOWN POINTER, BUT USES THE NEXT 8 LOCATIONS OF THE PUSH DOWN

# RETURNS THE POINTER TO ITS ORIGINAL SETTING. THIS PROCEDURE ALLOWS THE CALLER TO STORE THE M

# THE PUSH DOWN LIST.

#

# DELCOMP

# -----

#

# THIS ROUTINE COMPUTES THE DIRECTION COSINE MATRIX (DEL) RELATING ON

#

# IS ROTATED WITH RESPECT TO THE FIRST BY AN ANGLE, A, ABOUT A UNIT VECTOR U. THE FORMULA FOR

#

$$\begin{matrix} * \\ \text{DEL} \end{matrix} = \begin{matrix} * \\ I \end{matrix} \text{COSA} + \begin{matrix} * \\ U \end{matrix} \begin{matrix} - \\ U \end{matrix}^T (1 - \text{COSA}) + \begin{matrix} * \\ V \end{matrix} \begin{matrix} * \\ X \end{matrix} \text{SINA}$$

#

# WHERE

# I =

#

#

#

#

#

#

#

#

#

#

#

#

#

#

#

#

#

#

#

#

#

#

```

#           [   Y           X           ]
#
# Page 348
#
#      -
#      U      =      UNIT ROTATION VECTOR RESOLVED INTO S/C AXES.
#      A      =      ROTATION ANGLE
#
#
#      *
# THE INTERPRETATION OF DEL IS AS FOLLOWS:
#
# IF A , A , A REPRESENT THE COMPONENTS OF A VECTOR IN THE ROTATED FRAME, THEN THE C
#      X   Y   Z
# VECTOR IN THE ORIGINAL S/C AXES (B , B , B ) ARE
#
#      X   Y   Z
#
#
#      [ B ]           [ A ]
#      [ X ]           [ X ]
#      [   ]           [   ]
#      [ B ]           *   [ A ]
#      [ Y ]      =   DEL [ Y ]
#      [   ]           [   ]
#      [ B ]           [ B ]
#      [ Z ]           [ Z ]
#
#
# THE ROUTINE WILL STORE THIS MATRIX (SCALED UNITY) IN SEQUENTIAL LOCATIONS OF ERASAB
#
# THE LOCATION CALLED DEL. IN ORDER TO USE THE ROUTINE, THE CALLING PROGRAM MUST FI
# DOUBLE PRECISION VECTOR) IN THE SET OF ERASABLE LOCATIONS BEGINNING WITH THE ADDRES
# MUST THEN BE LOADED INTO D(MPAC).
#
# INTERNALLY, THE PROGRAM ALSO USES THE FIRST 10 LOCATIONS OF THE PUSH DOWN LIST.
#
# READCDUK
# -----
#
# THIS BASIC LANGUAGE SUBROUTINE LOADS T(MPAC) WITH THE THREE CDU ANGLES.
#
# SIGNMPAC
# -----
#
# THIS IS A BASIC LANGUAGE SUBROUTINE WHICH LIMITS THE MAGNITUDE OF D(MPAC) TO + OR -
#
# PROGRAM STORAGE ALLOCATION
#
#      1)      FIXED MEMORY           1059 WORDS
#      2)      ERASABLE MEMORY        98

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```
#      3)      STATE SWITCHES      3
# Page 349
#      4)      FLAGS      1
#
# JOB PRIORITIES
#
#      1)      KALCMANU      TBD
#      2)      ONE SECOND UPDATE      TBD
#
# SUMMARY OF STATE SWITCHES AND FLAGWORDS USED BY KALCMANU.
#
#      STATE      FLAGWRD 2      SETTING      MEANING
#      SWITCH NO.      BIT NO.
#
#      *
#      31      14      0      MANEUVER WENT THROUGH GIMBAL LOCK
#      1      MANEUVER DID NOT GO THROUGH GIMBAL LOCK
#      *
#      32      13      0      CONTINUE UPDATE PROCESS
#      1      START UPDATE PROCESS
#
#      33      12      0      PERFORM FINAL P AXIS YAW IF REQUIRED
#      1      IGNORE ANY FINAL P-AXIS YAW
#
#      34      11      0      SIGNAL END OF KALCMANU
#      1      KALCMANU IN PROCESS.      USER MUST SET S
#
#      * INTERNAL TO KALCMANU
#
# SUGGESTIONS FOR PROGRAM INTEGRATION
#
# THE FOLLOWING VARIABLES SHOULD BE ASSIGNED TO UNSWITCH ERASABLE:
#
#      CPHI
#      CTHETA
#      CPSI
#      POINTVSM +5
#      SCAXIS +5
#      DELDCDU
#      DELDCDU1
#      DELDCDU2
#      RATEINDX
#
# THE FOLLOWING SUBROUTINES MAY BE PUT IN A DIFFERENT BANK
#
#      MXM3
```

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```
#      TRANSPGS
#      SIGNMPAC
#      READCDUK
#      CDUTODCM
```

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```
BANK      15
SETLOC    KALCMON1
BANK
```

EBANK= BCDU

```
# THE THREE DESIRED CDU ANGLES MUST BE STORED AS SINGLE PRECISION TWO'S COMPLEMENT AND
# LOCATIONS, CPHI, CTHETA, CPSI.
```

```

COUNT*   $$/KALC
KALCMAN3  TC      INTPRET      # PICK UP THE CURRENT CDU ANGLES AND
RTB                      #      COMPUTE THE MATRIX FROM INITIAL S/C
                        READCDUK #      AXES TO FINAL S/C AXES.
STORE      BCDU      # STORE INITIAL S/C ANGLES
SLOAD      ABS      # CHECK THE MAGNITUDE OF THE DESIRED
                        CPSI      # MIDDLE GIMBAL ANGLE
DSU        BPL
                        LOCKANGL  # IF GREATER THAN 70 DEG ABORT MANEUVER
                        TOOBADF
AXC,2      TLOAD
                        MIS
                        BCDU
CALL                      # COMPUTE THE TRANSFORMATION FROM INITIAL
                        CDUTODCM # S/C AXES TO STABLE MEMBER AXES
AXC,2      TLOAD
                        MFS      # PREPARE TO CALCULATE ARRAY MFS
                        CPHI
CALL
                        CDUTODCM
SECAD      AXC,1      CALL      # MIS AND MFS ARRAYS CALCULATED      $2
                        MIS
                        TRANSPOS
VLOAD      STADR
STOVL      TMIS +12D
STADR
STOVL      TMIS +6
STADR
STORE      TMIS      # TMIS = TRANSPOSE(MIS) SCALED BY 2
AXC,1      AXC,2
```

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```

                                TMIS
                                MFS
CALL
                                MXM3
VLOAD  STADR
STOVL  MFI  +12D
STADR
STOVL  MFI  +6
STADR
STORE  MFI          # MFI = TMIS MFS (SCALED BY 4)
SETPD  CALL        # TRANSPOSE MFI IN PD LIST

# Page 352

                                18D
                                TRNSPSPD
VLOAD  STADR
STOVL  TMFI  +12D
STADR
STOVL  TMFI  +6
STADR
STORE  TMFI          # TMFI = TRANSPOSE (MFI) SCALED BY 4

# CALCULATE COFSKEW AND MFISYM

DLOAD  DSU
        TMFI  +2
        MFI  +2
PDDL   DSU          # CALCULATE COF SCALED BY 2/SIN(AM)
        MFI  +4
        TMFI  +4
PDDL   DSU
        TMFI  +10D
        MFI  +10D
VDEF
STORE  COFSKEW      # EQUALS MFISKEW

# CALCULATE AM AND PROCEED ACCORDING TO ITS MAGNITUDE

DLOAD  DAD
        MFI
        MFI  +16D
DSU     DAD
        DP1/4TH
        MFI  +8D
STORE  CAM          # CAM = (MF10+MFI4+MFI8-1)/2 HALF SCALE
ARCCOS
STORE  AM           # AM=ARCCOS(CAM)          (AM SCALED BY 2)
```

```

DSU      BPL
          MINANG
          CHECKMAX

TLOAD    # MANEUVER LESS THAN .25 DEGREES
          CPHI      # GO DIRECTLY INTO ATTITUDE HOLD
STCALL   # ABOUT COMMANDED ANGLES
          CDUXD
          TOOBADI   # STOP RATE AND EXIT

CHECKMAX  DLOAD    DSU
          AM
          MAXANG
          BPL      VLOAD
          ALTALC   # UNIT
          COFSKEW  # COFSKEW

UNIT
STORE    COF      # COF IS THE MANEUVER AXIS

# Page 353 GOTO    # SEE IF MANEUVER GOES THRU GIMBAL LOCK
          LOCKIRT

ALTALC    VLOAD    VAD      # IF AM GREATER THAN 170 DEGREES
          MFI
          TMFI

VSR1
STOVL    MFISYM
          MFI      +6
VAD      VSR1
          TMFI     +6
STOVL    MFISYM   +6
          MFI      +12D
VAD      VSR1
          TMFI     +12D
STORE    MFISYM   +12D   # MFISYM=(MFI+TMFI)/2    SCALED BY 4

# CALCULATE COF

DLOAD    SR1
          CAM
PDDL     DSU      # PDO CAM                                $4
          DPHALF
          CAM
BOVB     PDDL     # PS2 1 - CAM                                $2
          SIGNMPAC
          MFISYM   +16D
DSU      DDV
          0
          2

```

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```

      SQRT  PDDL      # COFZ = SQRT(MFISYM8-CAM)/(1-CAM)
      MFISYM +8D      #
DSU      DDV
      0
      2
      SQRT  PDDL      # COFY = SQRT(MFISYM4-CAM)/(1-CAM) $ROOT2
      MFISYM
DSU      DDV
      0
      2
      SQRT  VDEF      # COFX = SQRT(MFISYM-CAM)/(1-CAM) $ROOT 2
UNIT
STORE    COF

# DETERMINE LARGEST COF AND ADJUST ACCORDINGLY

COFMAXGO      DLOAD  DSU
                COF
                COF      +2
BMN      DLOAD      # COFY G COFX

# Page 354
                COMP12
                COF
DSU      BMN
                COF      +4
                METHOD3      # COFZ G COFX OR COFY
GOTO
                METHOD1      # COFX G COFY OR COFZ
COMP12      DLOAD  DSU
                COF      +2
                COF      +4
BMN
                METHOD3      # COFZ G COFY OR COFX

METHOD2      DLOAD  BPL      # COFY MAX
                COFSKEW +2      # UY
                U2POS
VLOAD      VCOMP
                COF
STORE      COF
U2POS      DLOAD  BPL
                MFISYM +2      # UX UY
                OKU21
DLOAD      DCOMP      # SIGN OF UX OPPOSITE garbled
                COF
STORE      COF
```

OKU21	DLOAD	BPL		
		MFISYM +10D		# UY UZ
		LOCKSKIRT		
	DLOAD	DCOMP		# SIGN OF UZ OPPOSITE TO UY
		COF +4		
	STORE	COF +4		
	GOTO			
		LOCKSKIRT		
METHOD1	DLOAD	BPL		# COFX MAX
		COFSKEW		# UX
		U1POS		
	VLOAD	VCOMP		
		COF		
	STORE	COF		
U1POS	DLOAD	BPL		
		MFISYM +2		# UX UY
		OKU12		
	DLOAD	DCOMP		
		COF +2		# SIGN OF UY OPPOSITE TO UX
	STORE	COF +2		
OKU12	DLOAD	BPL		
		MFISYM +4		# UX UZ
		LOCKSKIRT		
	DLOAD	DCOMP		# SIGN OF UZ OPPOSITE TO UY
		COF +4		
# Page 355				
	STORE	COF +4		
	GOTO			
		LOCKSKIRT		
METHOD3	DLOAD	BPL		# COFZ MAX
		COFSKEW +4		# UZ
		U3POS		
	VLOAD	VCOMP		
		COF		
	STORE	COF		
U3POS	DLOAD	BPL		
		MFISYM +4		# UX UZ
		OKU31		
	DLOAD	DCOMP		
		COF		# SIGN OF UX OPPOSITE TO UZ
	STORE	COF		
OKU31	DLOAD	BPL		
		MFISYM +10D		# UY UZ
		LOCKSKIRT		
	DLOAD	DCOMP		
		COF +2		# SIGN OF UY OPPOSITE TO UZ



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```

                                STORE  COF      +2
                                GOTO
                                LOCSKIRT
# Page 356
# MATRIX OPERATIONS

                                BANK    13
                                SETLOC  KALCMON2
                                BANK
                                EBANK=  BCDU

MXM3                            SETPD   VLOAD*      # MXM3 MULTIPLIES 2 3X3 MATRICES
                                0          # AND LEAVES RESULT IN PD LIST
                                0,1        # AND MPAC
                                VXM*     PDVL*
                                0,2
                                6,1
                                VXM*     PDVL*
                                0,2
                                12D,1
                                VXM*     PUSH
                                0,2
                                RVQ

# RETURN WITH MIXM2 IN PD LIST

TRANSPOS                        SETPD   VLOAD*      # TRANSPOS TRANSPOSES A 3X3 MATRIX
                                0          # AND LEAVES RESULT IN PD LIST
                                0,1        # MATRIX ADDRESS IN XR1
                                PDVL*     PDVL*
                                6,1
                                12D,1
                                PUSH
                                EXIT          # MATRIX IN PD
                                INDEX  FIXLOC      # ENTER WITH MATRIX AT 0 IN PD LIST
                                DXCH    12
                                INDEX  FIXLOC
                                DXCH    16
                                INDEX  FIXLOC
                                DXCH    12
                                INDEX  FIXLOC
                                DXCH    14
                                INDEX  FIXLOC
                                DXCH    4
                                INDEX  FIXLOC
```

```

          DXCH      14
          INDEX     FIXLOC
          DXCH      2
          INDEX     FIXLOC
          DXCH      6
          INDEX     FIXLOC
          DXCH      2
# Page 357
          TC        INTPRET
          RVQ

          BANK      15
          SETLOC    KALCMON1
          BANK

          EBANK=    BCDU

MINANG      2DEC    0.00069375

MAXANG      2DEC    0.472222222

# GIMBAL LOCK CONSTANTS

# D = MGA CORRESPONDING TO GIMBAL LOCK = 60 DEGREES
#      NGL = BUFFER ANGLE (TO AVOID DIVISIONS BY ZERO) = 2 DEGREES

SD          2DEC    .433015          # = SIN(D)          $2
K3S1        2DEC    .86603           # = SIN(D)          $1
K4          2DEC    -.25              # = -COS(D)         $2
K4SQ        2DEC    .125             # = COS(D)COS(D)    $2
SNGLCD      2DEC    .008725          # = SIN(NGL)COS(D)  $2
CNGL        2DEC    .499695          # COS(NGL)          $2
LOCKANGL    DEC     .388889          # = 70 DEGREES

# INTERPRETIVE SUBROUTINE TO READ THE CDU ANGLES

READCDUK    CA      CDUZ              # LOAD T(MPAC) WITH CDU ANGLES
            TS      MPAC      +2
            EXTEND
            DCA     CDUX              # AND CHANGE MODE TO TRIPLE PRECISION

```

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```

TCF      TLOAD  +6

CDUTODCM  AXT,1  SSP
          OCT    3
          S1
          OCT    1      # SET XR1, S1, AND PD FOR LOOP
          STORE  7
          SETPD
          0
LOOPSIN   SLOAD* RTB
          10D,1
          CDULOGIC

# Page 358
          STORE  10D      # LOAD PD WITH 0 SIN(PHI)
          SIN    PDDL      #                2 COS(PHI)
          10D      #                4 SIN(THETA)
          COS    PUSH      #                6 COS(THETA)
          TIX,1  DLOAD      #                8 SIN(PSI)
          LOOPSIN      #                10 COS(PSI)
          6
          DMP     SL1
          10D
          STORE  0,2      # CO = COS(THETA)COS(PSI)
          DLOAD  DMP
          4
          0
          PDDL    DMP      # (PD6 SIN(THETA)SIN(PHI))
          6
          8D
          DMP     SL1
          2
          BDSU    SL1
          12D
          STORE  2,2      # C1=-COS(THETA)SIN(PSI)COS(PHI)
          DLOAD  DMP
          2
          4
          PDDL    DMP      # (PD7 COS(PHI)SIN(THETA)) SCALED 4
          6
          8D
          DMP     SL1
          0
          DAD     SL1
          14D
          STORE  4,2      # C2=COS(THETA)SIN(PSI)SIN(PHI)
          DLOAD

```

```

                                8D
                                STORE 6,2          # C3=SIN(PSI)
                                DLOAD
                                10D
                                DMP SL1
                                2
                                STORE 8D,2          # C4=COS(PSI)COS(PHI)
                                DLOAD DMP
                                10D
                                0
                                DCOMP SL1
                                STORE 10D,2          # C5=-COS(PSI)SIN(PHI)
                                DLOAD DMP
                                4
                                10D
                                DCOMP SL1
                                STORE 12D,2          # C6=-SIN(THETA)COS(PSI)
                                DLOAD
                                DMP SL1              # (PUSH UP 7)
                                8D
                                PDDL DMP             # (PD7 COS(PHI)SIN(THETA)SIN(PSI)) SCALE 4
                                6
                                0
                                DAD SL1              # (PUSH UP 7)
                                STADR                  # C7=COS(PHI)SIN(THETA)SIN(PSI)
                                STORE 14D,2           # +COS(THETA)SIN(PHI)
                                DLOAD
                                DMP SL1              # (PUSH UP 6)
                                8D
                                PDDL DMP             # (PD6 SIN(THETA)SIN(PHI)SIN(PSI)) SCALE 4
                                6
                                2
                                DSU SL1              # (PUSH UP 6)
                                STADR
                                STORE 16D,2          # C8=-SIN(THETA)SIN(PHI)SIN(PSI)
                                RVQ                   # +COS(THETA)COS(PHI)

# CALCULATION OF THE MATRIX DEL.....
#
#      *      *      --T      *
#      DEL = (IDMATRIX)COS(A)+UU (1-COS(A))+UX SIN(A)          SCALED 1
#
#      -
#      WHERE U IS A UNIT VECTOR (DP SCALED 2) ALONG THE AXIS OF ROTATION.
#      A IS THE ANGLE OF ROTATION (DP SCALED 2)
#
#      -

```

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# UPON ENTRY, THE STARTING ADDRESS OF U IS COF, AND A IS IN MPAC

```
DELCOMP      SETPD  PUSH          # MPAC CONTAINS THE ANGLE A
              0
              SIN    PDDL          # PD0 = SIN(A)
              COS    PUSH          # PD2 = COS(A)
              SR2    PDDL          # PD2 = COS(A)
              BDSU   BOVB
              DPHALF
              SIGNMPAC
              PDDL          # PDA = 1-COS(A)
```

\$8

# COMPUTE THE DIAGONAL COMPONENTS OF DEL

```
              COF
DSQ           DMP
              4
DAD           SL3
              2
BOVB
              SIGNMPAC
# Page 360
STODL        KEL          # UX UX(1-COS(A)) +COS(A)
              COF        +2
DSQ           DMP
              4
DAD           SL3
              2
BOVB
              SIGNMPAC
STODL        KEL        +8D    # UY UY(1-COS(A)) +COS(A)
              COF        +4
DSQ           DMP
              4
DAD           SL3
              2
BOVB
              SIGNMPAC
STORE        KEL        +16D   # UZ UZ(1-COS(A)) +COS(A)
```

\$1

\$1

\$1

# COMPUTE THE OFF DIAGONAL TERMS OF DEL

```
DLOAD        DMP
              COF
              COF        +2
DMP           SL1
```

# Page 361

	4				
PDDL	DMP		# D6	UX UY (1-COS A)	\$4
	COF	+4			
	0				
PUSH	DAD		# D8	UZ SIN A	\$4
	6				
SL2	BOVB				
	SIGNMPAC				
STODL	KEL	+6			
BDSU	SL2				
BOVB					
	SIGNMPAC				
STODL	KEL	+2			
	COF				
DMP	DMP				
	COF	+4			
	4				
SL1	PDDL		# D6	UX UZ (1-COS A)	\$4
	COF	+2			
DMP	PUSH		# D8	UY SIN(A)	
	0				
DAD	SL2				
	6				
BOVB					
	SIGNMPAC				
STODL	KEL	+4	# UX UZ (1-COS(A))+UY SIN(A)		
BDSU	SL2				
BOVB					
	SIGNMPAC				
STODL	KEL	+12D	# UX UZ (1-COS(A))-UY SIN(A)		
	COF	+2			
DMP	DMP				
	COF	+4			
	4				
SL1	PDDL		# D6	UY UZ (1-COS(A))	\$ 4
	COF				
DMP	PUSH		# D8	UX SIN(A)	
	0				
DAD	SL2				
	6				
BOVB					
	SIGNMPAC				
STODL	KEL	+14D	# UY UZ(1-COS(A)) +UX SIN(A)		
BDSU	SL2				
BOVB					

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```

                                SIGNMPAC
                                STORE  KEL      +10D      # UY UZ (1-COS(A)) -UX SIN(A)
                                RVQ

# DIRECTION COSINE MATRIX TO CDU ANGLE ROUTINE
# X1 CONTAINS THE COMPLEMENT OF THE STARTING ADDRESS FOR MATRIX (SCALED 2).
# LEAVE CDU ANGLES SCALED 2PI IN V(MPAC).
# COS(MGA) WILL BE LEFT IN S1 (SCALED 1).
#
# THE DIRECTION COSINE MATRIX RELATING S/C AXES TO STABLE MEMBER AXES CAN BE WRITTEN AS:
#
#      C  = COS(THETA) COS(PSI)
#      0
#
#      C  = -COS(THETA) SIN(PSI) COS(PHI) + SIN(THETA) SIN(PHI)
#      1
#
#      C  = COS(THETA) SIN(PSI) SIN(PHI) + SIN(THETA) COS(PHI)
#      2
#
#      C  = SIN(PSI)
#      3
#
#      C  = COS(PSI) COS(PHI)
#      4
#
#      C  = -COS(PSI) SIN(PHI)
#      5
#
#      C  = -SIN(THETA) COS(PSI)
#      6
#
#      C  = SIN(THETA) SIN(PSI) COS(PHI) + COS (THETA) SIN(PHI)
#      7
#
#      C  = -SIN(THETA) SIN(PSI) SIN(PHI) + COS(THETA)COS(PHI)
#      8
# Page 362
#
# WHERE PHI = OGA
#      THETA = IGA
#      PSI  = MGA

DCMTOCDU      DLOAD*  ARCSIN
                  6,1
                  PUSH  COS      # PD +0      PSI
```

```

SL1      BOVB
          SIGNMPAC
STORE    S1
DLOAD*   DCOMP
          12D,1
DDV      ARCSIN
          S1
PDDL*    BPL          # PD +2          THETA
          0,1          # MUST CHECK THE SIGN OF COS(THETA)
          OKTHETA      # TO DETERMINE THE PROPER QUADRANT.
DLOAD    DCOMP
BPL      DAD
          SUHALFA
          DPHALF
GOTO
          CALCPHI
SUHALFA  DSU
          DPHALF
CALCPHI  PUSH
OKTHETA  DLOAD*   DCOMP
          10D,1
DDV      ARCSIN
          S1
PDDL*    BPL          # PUSH DOWN PHI
          8D,1
          OKPHI
DLOAD    DCOMP          # PUSH UP PHI
BPL      DAD
          SUHALFAP
          DPHALF
GOTO
          VECOFANG
SUHALFAP DSU
          GOTO
          DPHALF
          VECOFANG
OKPHI    DLOAD          # PUSH UP PHI
VECOFANG VDEF    RVQ
# Page 363
# ROUTINES FOR TERMINATING THE AUTOMATIC MANEUVER AND RETURNING TO USER.

TOOBADF  EXIT
          TC      ALARM
          OCT     00401

          TCF     NOGO          # DO NOT ZERO ATTITUDE ERRORS

```



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	TC	BANKCALL	
	CADR	ZATTEROR	# ZERO ATTITUDE ERRORS
NOGO	TC	BANKCALL	
	CADR	STOPRATE	# STOP RATES
	CAF	TWO	
	INHINT		# ALL RETURNS ARE NOW MADE VIA GOODEND
	TC	WAITLIST	
	EBANK=	BCDU	
	2CADR	GOODMANU	
	TCF	ENDOFJOB	
TOOBADI	EXIT		
	TCF	NOGO	

This code is written to file `src/ATTITUDE-MANEUVER-ROUTINE.s`.

## A.11 AUTOMATIC MANEUVERS

```

162  <src/AUTOMATIC-MANEUVERS.s 162>≡
      # Copyright:   Public domain.
      # Filename:    AUTOMATIC_MANEUVERS.agc
      # Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
      #              It is part of the source code for the Command Module's (CM)
      #              Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:   yaYUL
      # Contact:      Ron Burkey <info@sandroid.org>.
      # Website:      www.ibiblio.org/apollo.
      # Pages:        1025-1036
      # Mod history:  2009-05-13 RSB   Adapted from the Colossus249/ file of the
      #              same name, using Comanche055 page images.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 055 of AGC program Comanche by NASA
      #       2021113-051.  10:28 APR. 1, 1969
      #
      #       This AGC program shall also be referred to as
      #       Colossus 2A

      # Page 1025

                                BANK      21
                                SETLOC    DAPS3
                                BANK

                                COUNT     21/DAPAM

                                EBANK=    KMPAC
      AHFNOROT  EXTEND
                                READ      CHAN31
                                MASK      BIT14
                                EXTEND
                                BZMF      FREECONT
                                CA         RCSFLAGS      # SEE IF RATE FILTER HAS BEEN INITIALIZED

```

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```

      MASK    BIT14
      CCS      A
      TCF      REINIT
                                     # IF SO, PROCEED WITH ATTITUDE CONTROL
                                     # IF NOT, RECYCLE TO INITIALIZE FILTER
                                     # AUTOMATIC CONTROL YET

      EXTEND
      READ     CHAN31
      MASK     BIT13
      EXTEND
      BZMF     HOLDFUNC

AUTOCONT      CA      HOLDFLAG
               EXTEND
               BZMF     ATTHOLD
               TCF      GRABANG
                                     # IF HOLDFLAG IS +, GO TO GRABANG.
                                     # OTHERWISE, GO TO ATTHOLD.

# MINIMUM IMPULSE CONTROL

FREECONT      CAF      ONE
               TS       HOLDFLAG
                                     # RESET HOLDFLAG
                                     # INHIBIT AUTOMATIC STEERING

               EXTEND
               READ     CHAN32
               TS       L
               COM
               MASK     MANROT
               MASK     CHANTEMP
               LXCH     CHANTEMP
               TC        STICKCHK
               INDEX    RMANNDX
               CA        MINTAU
               TS        TAU
               INDEX    PMANNDX
               CA        MINTAU
               TS        TAU1
               INDEX    YMANNDX
               CA        MINTAU
                                     # MINTAU      +0
                                     #              +1      +14MS MINIMUM IMPULSE
                                     #              +2      -14MS TIME
                                     #              +3      +0

# Page 1026
               TS        TAU2
               TCF      T6PROGM

MINTAU        DEC      0
               DEC      23
               DEC      -23
               DEC      0
                                     # = 14MS
                                     # = -14MS
```

# Page 1027

```

# CALCULATION OF ATTITUDE ERRORS:
#
#      -      *      -      -
#      AK = AMGB (CDUX - THETADX) + BIAS
#
# I.E., *AK *      * 1      SIN(PHI)      0      ** CDUX - THETADX *      *BIAS *
#      *      *      *      **      *      *
#      *AK1* = * 0      COS(PHI)COS(PHI) SIN(PHI)** CDUY - THETADY *      + *BIAS1*
#      *      *      *      **      *      *
#      *AK2*      * 0      -COS(PHI)SIN(PHI) COS(PHI)** CDUZ - THETADZ *      *BIAS2*
#
# THE BIASES ARE ADDED ONLY WHILE PERFORMING AUTOMATIC MANEUVERS (ESP KALCMANU) TO PREVENT
# AND PREVENT OVERSHOOT WHEN STARTING AN AUTOMATIC MANEUVER.  NORMALLY THE REQUIRED BIASES
# BUT DURING HIGH RATE MANEUVERS IT CAN BE AS MUCH AS 7 DEGREES.  THE BIASES ARE COMBINED
# FIXED UNTIL THE MANEUVER IS COMPLETED AT WHICH TIME THEY ARE RESET TO ZERO.

```

```

ATTHOLD      CA      CDUX
EXTEND
MSU      THETADX
TS      ERRORX
CA      CDUY
EXTEND
MSU      THETADY
TS      T5TEMP
EXTEND
MP      AMGB1
ADS      ERRORX
CA      T5TEMP
EXTEND
MP      AMGB4
TS      ERRORY
CA      T5TEMP
EXTEND
MP      AMGB7
TS      ERRORZ
CA      CDUZ
EXTEND
MSU      THETADZ
TS      T5TEMP
EXTEND
MP      AMGB5
ADS      ERRORY
CA      T5TEMP
EXTEND
MP      AMGB8
ADS      ERRORZ
CS      HOLDFLAG

```

```

EXTEND
# Page 1028
BZMF    JETS
CA      BIAS
ADS     ERRORX      # AD BIASES ONLY IF PERFORMING AUTOMATIC
CA      BIAS1
ADS     ERRORY
CA      BIAS2
ADS     ERRORZ
TCF     JETS

HOLDFUNC CCS    HOLDFLAG
TCF      +3
TCF      ATTHOLD
TCF      +1

GRABANG CAF     ZERO      # ZERO WBODYDYS AND BIASES
TS       WBODY
TS       WBODY +1
TS       WBODY1
TS       WBODY1 +1
TS       WBODY2
TS       WBODY2 +1
TS       BIAS
TS       BIAS1
TS       BIAS2

CA      RCSFLAGS
MASK    OCT16000
EXTEND
BZF     ENDDAMP      # IS RATE DAMPING COMPLETED
CAF     ZERO          # IF SO, GO TO ENDDAMP
TS      ERRORX        # OTHERWISE, ZERO ERRORS
TS      ERRORY
TS      ERRORZ
TCF     JETS

ENDDAMP TS      HOLDFLAG      # SET HOLDFLAG +0
EXTEND
DCA     CDUX          # PICK UP CDU ANGLES FOR ATTITUDE HOLD
DXCH    THETADX       # REFERENCES
CA      CDUZ
TS      THETADZ
TCF     ATTHOLD

```

# Page 1029

# JET SWITCHING LOGIC AND CALCULATION OF REQUIRED ROTATION COMMANDS

```

#
# DETERMINE THE LOCATION OF THE RATE ERROR AND THE ATTITUDE ERROR RELATIVE TO THE SW
# PLANE.
#
# COMPUTE THE CHANGE IN RATE CORRESPONDING TO THE ATTITUDE ERROR NECESSARY TO DRIVE T
# APPROPRIATE DEADZONE.
#
#
#
# R22 RATE . ERROR
# WL+H
# ***** SWITCH
# R23 WL *
# ----- DESIRE
# R23 WL-H - *
# ***** -
# * - . * R18 R20 R21 R20, R21, R2
# * . * PLANE FOF COM
# *- . *
# R22 R24*- R23 . *
# * . *
# * . *
# + -ADB . * AF ATTITUDE
# .....+-----+.....
# AF * . +ADB + ERROR
# * . *
# * . -*
# * . -*
# * . -*
# * . *
# * . - *
# . - *****
# .*-
# . * -----
#
#
#
# FIG. 1 PHASE PLANE SWITCHING LOGIC
#
# CONSTANTS FOR JET SWITCHING LOGIC
#
# WLH/SLOP DEC .00463 # = WL+H/SLOPE = .83333 DEG $180
# WL-H/SLP DEC .00277 # = WL-H/SLOPE = .5 DEG $180
# WLH 2DEC .001111111 # = WL+H = 0.5 DEG/SEC $450
#
# WLMH 2DEC .000666666 # = WL-H = 0.3 DEG/SEC $450
#
# WL 2DEC .000888888 # = WL = 0.4 DEG/SEC $450

```

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# Page 1030

SLOPE2	DEC	.32	# = 0.8 DEG/SEC/DEG	\$450/180
JETS	CA	ADB		
	AD	FOUR	# AF = FLAT REGION = .044 DEG	
	TS	T5TEMP	# ADB+AF	
	CAF	TWO		
JLOOP	TS	SPNDX		
	DOUBLE			
	TS	DPNDX		
	EXTEND			
	INDEX	A		
	DCA	ADOT		
	DXCH	EDOT		
	CA	HOLDFLAG	# HOLDFLAG = +0 MEANS THAT DAP IS IN	
	EXTEND		# ATTITUDE HOLD AND RATE DAMPING IS OVER.	
	BZF	INHOLD	# IF THIS IS THE CASE, BYPASS ADDITION	
			# OF WBODY AND GO TO INHOLD	
	EXTEND			
	INDEX	DPNDX		
	DCS	WBODY		
	DAS	EDOT	# = ADOT-WBODY	
INHOLD	INDEX	SPNDX		
	CA	ERRORX		
	TS	AERR	# AERR = BIAS + AK	
	CCS	EDOT		
	TCF	POSVEL		
	TCF	SIGNCK1		
	TCF	NEGVEL		
SIGNCK1	CCS	EDOT +1		
	TCF	POSVEL		
	TCF	POSVEL		
	TCF	NEGVEL		
	TCF	NEGVEL		
POSVEL	EXTEND			
	DCA	EDOT		
	DXCH	EDOTVEL		
	CA	T5TEMP		
	TS	ADBVEL	# +(ADB+AF)	
	CA	AERR		
	TS	AERRVEL		
	TC	J6.		
NEGVEL	EXTEND			
	DCS	EDOT		
	DXCH	EDOTVEL		

	CS	T5TEMP	
	TS	ADBVEL	# -(ADB+AF)
	CS	AERR	
	TS	AERRVEL	
J6.	EXTEND		
# Page 1031	SU	ADB	
	AD	WLH/SLOP	
	EXTEND		
	BZMF	J8	
	CS	T5TEMP	# (ADB+AF)
	AD	AERRVEL	
	EXTEND		
	BZMF	+2	
	TCF	J7	
	EXTEND		
	DCS	EDOTVEL	
	EXTEND		
	DV	SLOPE	
	EXTEND		
	SU	AERRVEL	
	AD	ADB	
	EXTEND		
	BZMF	J18	
	TCF	J23	
J7	CS	WL-H/SLP	
	EXTEND		
	SU	T5TEMP	# (ADB+AF)
	AD	AERRVEL	
	EXTEND		
	BZMF	J20	
	TCF	J21	
J8	EXTEND		
	DCS	WLH	
	DXCH	WTEMP	
	EXTEND		
	DCA	EDOTVEL	
	DAS	WTEMP	
	CCS	WTEMP	
	TCF	J22	
	TCF	SIGNCK2	
	TCF	NJ22	



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SIGNCK2	CCS	WTEMP +1	
	TCF	J22	
	TCF	J22	
	TCF	NJ22	
NJ22	EXTEND		
	DCA	EDOTVEL	
	EXTEND		
	DV	SLOPE	
	AD	T5TEMP	# (ADB+AF)
	AD	AERRVEL	
# Page 1032	CCS	A	
	TCF	J23	
	TCF	J23	
	TCF	+2	
	TCF	J23	
	EXTEND		
	DCS	WLMH	# WL - H
	DXCH	WTEMP	
	EXTEND		
	DCA	EDOTVEL	
	DAS	WTEMP	
	CCS	WTEMP	
	TCF	J23	
	TCF	SIGNCK3	
	TCF	NJ23	
SIGNCK3	CCS	WTEMP +1	
	TCF	J23	
	TCF	J23	
	TCF	NJ23	
NJ23	CA	AERRVEL	
	AD	T5TEMP	# (ADB+AF)
	AD	WL-H/SLP	
	CCS	A	
	TCF	J24	
	TCF	J24	
	TCF	J22	
	TCF	J22	
J18	EXTEND		
	DCS	EDOT	
	DXCH	KMPAC	
	TCF	JTIME	

J20	CS	AERR	
	AD	ADBVEL	
	EXTEND		
	MP	SLOPE2	# (HYSTERESIS SLOPE)
	DXCH	KMPAC	
	EXTEND		
	DCS	EDOT	
	DAS	KMPAC	
	TCF	JTIME	
J21	CCS	EDOT	
	TCF	JP	
	TCF	SIGNCK4	
	TCF	JN	
SIGNCK4	CCS	EDOT +1	
# Page 1033			
	TCF	JP	
	TCF	JP	
	TCF	JN	
JN	EXTEND		
	DCS	EDOT	
	DXCH	KMPAC	
	EXTEND		
	DCA	WL	
	DAS	KMPAC	
	TCF	JTIME	
JP	EXTEND		
	DCS	EDOT	
	DXCH	KMPAC	
	EXTEND		
	DCS	WL	
	DAS	KMPAC	
	TCF	JTIME	
J22	CCS	EDOT	
	TCF	JN	
	TCF	SIGNCK5	
	TCF	JP	
SIGNCK5	CCS	EDOT +1	
	TCF	JN	
	TCF	JN	
	TCF	JP	
	TCF	JP	

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```
J23      INDEX  SPNDX
        CS      BIT13      # RESET RATE DAMPING FLAG
        MASK    RCSFLAGS   # BIT13 FOR ROLL  (SPNDX = 0)
        TS      RCSFLAGS   # BIT12 FOR PITCH (SPNDX = 1)
                                # BIT11 FOR YAW  (SPNDX = 2)

        INDEX  SPNDX
        CAF    OCT01400    # IS THERE TO BE A FORCED FIRING ON THIS
        MASK    RCSFLAGS   # AXIS
        EXTEND
        BZF     DOJET +2    # NO, GO TO DOJET +2 AND DO NOTHING

        TCF     J18        # YES, GO TO J18 AND FORCE A FIRING
```

```
J24      CS      AERR
        EXTEND
        SU      ADBVEL
        EXTEND
        MP      SLOPE2      # (HYSTERESIS SLOPE)
        DXCH    KMPAC
        EXTEND
```

# Page 1034

```
DCS      EDOT
DAS      KMPAC
```

# Page 1035

```
# COMPUTE THE JET ON TIME NECESSARY TO ACCOMPLISH THE DESIRED CHANGE IN RATE, I.E.,
#
#      T = J/M(DELT W)
#      J
#
#      DELTA W = DESIRED CHANGE IN S/C ANGULAR RATE AS DETERMINED BY THE
#                SWITCHING LOGIC, AT THIS POINT STORED IN KMPAC.
#
#      J/M = S/C INERTIA TO TORQUE RATIO SCALED BY
#              (57.3/450)(B24/1600)(1/.8)
#      FOR 1 JET OPERATION (M = 700 FT-LB).
#      I.E., J/M = J(SLUG-FTFT) x 0.00000085601606
#
#      THE CORRESPONDING COMPUTER VARIABLES ESTABLISHED BY
#      KEYBOARD ENTRY ARE
#              J/M (ROLL)
#              J/M1 (PITCH)
#              J/M2 (YAW)
#
#      T = JET-ON TIME      SCALED 16384/1600 SEC
```

```

#           J
#
#           THE COMPUTER VARIABLES ARE
#           TAU  (ROLL)
#           TAU1 (PITCH)
#           TAU2 (YAW)

JTIME      INDEX  SPNDX      # PICK UP S/C INERTIA/TORQUE RATIO
           CA     J/M        # SCALED (57.3/450)(B24/1600)
           TC     SMALLMP    # FOR 1-JET OPERATION
           CA     BIT11
           TC     SMALLMP
           CCS    KMPAC
           TCF    +4
           TCF    TAUNORM
           TCF    +4
           TCF    TAUNORM
           CA     POSMAX
           TCF    DOJET
           CA     NEGMAX
           TCF    DOJET

TAUNORM    CA     KMPAC +1
DOJET      INDEX  SPNDX
           TS     TAU
           CCS    SPNDX
           TCF    JLOOP
           TCF    T6PROG

# Page 1036
ZEROCMDS   CAF    ZERO
           TS     TAU
           TS     TAU1
           TS     TAU2

T6PROG     EXTEND
           DCA    JETADDR    # WHEN THE ROTATION COMMANDS (TAUS)
           DXCH   T5LOC      # HAVE BEEN DETERMINED
           TCF    RESUME     # RESET T5LOC FOR PHASE3

           EBANK= KMPAC
JETADDR    2CADR   JETSLECT

```

This code is written to file `src/AUTOMATIC-MANEUVERS.s`.

## A.12 BURN BABY BURN—MASTER IGNITION ROUTINE

```

173  <src/BURN-BABY-BURN-MASTER-IGNITION-ROUTINE.s 173>≡
    # Copyright:    Public domain.
    # Filename:     BURN_BABY_BURN--MASTER_IGNITION_ROUTINE.agc
    # Purpose:      Part of the source code for Luminary 1A build 099.
    #               It is part of the source code for the Lunar Module's (LM)
    #               Apollo Guidance Computer (AGC), for Apollo 11.
    # Assembler:    yaYUL
    # Contact:       Ron Burkey <info@sandroid.org>.
    # Website:       www.ibiblio.org/apollo.
    # Pages:         731-751
    # Mod history:   2009-05-19 RSB   Adapted from the corresponding
    #               Luminary131 file, using page
    #               images from Luminary 1A.
    #               2009-06-07 RSB   Corrected 3 typos.
    #               2009-07-23 RSB   Added Onno's notes on the naming
    #               of this function, which he got from
    #               Don Eyles.
    #
    # This source code has been transcribed or otherwise adapted from
    # digitized images of a hardcopy from the MIT Museum. The digitization
    # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
    # the Museum. Many thanks to both. The images (with suitable reduction
    # in storage size and consequent reduction in image quality as well) are
    # available online at www.ibiblio.org/apollo. If for some reason you
    # find that the images are illegible, contact me at info@sandroid.org
    # about getting access to the (much) higher-quality images which Paul
    # actually created.
    #
    # Notations on the hardcopy document read, in part:
    #
    #       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
    #       16:27 JULY 14, 1969
    #
    # Page 731
    ## At the get-together of the AGC developers celebrating the 40th anniversary
    ## of the first moonwalk, Don Eyles (one of the authors of this routine along
    ## with Peter Adler) has related to us a little interesting history behind the
    ## naming of the routine.<br>
    ## <br>
    ## It traces back to 1965 and the Los Angeles riots, and was inspired
    ## by disc jockey extraordinaire and radio station owner Magnificent Montague.
    ## Magnificent Montague used the phrase "Burn, baby! BURN!" when spinning the

```

```
## hottest new records. Magnificent Montague was the charismatic voice of
## soul music in Chicago, New York, and Los Angeles from the mid-1950s to
## the mid-1960s.
# BURN, BABY, BURN -- MASTER IGNITION ROUTINE
```

```
BANK    36
SETLOC  P40S
BANK
EBANK=  WHICH
COUNT* $$/P40
```

```
# THE MASTER IGNITION ROUTINE IS DESIGNED FOR USE BY THE FOLLOWING LEM PROGRAMS:  P12
# IT PERFORMS ALL FUNCTIONS IMMEDIATELY ASSOCIATED WITH APS OR DPS IGNITION:  IN PART
# BETWEEN THE PRE-IGNITION TIME CHECK -- ARE WE WITHIN 45 SECONDS OF TIG? -- AND TIG
# PROGRAMS THROTTLE UP.
```

```
#
# VARIATIONS AMONG PROGRAMS ARE ACCOMODATED BY MEANS OF TABLES CONTAINING CONSTANTS (
# WAITLIST, FOR PINBALL) AND TCF INSTRUCTIONS.  USERS PLACE THE ADRES OF THE HEAD OF
# (OF P61TABLE FOR P61LM, FOR EXAMPLE) IN ERASABLE REGISTER 'WHICH' (E4).  THE IGNITION
# WHICH TO OBTAIN OR EXECUTE THE PROPER TABLE ENTRY.  THE IGNITION ROUTINE IS INITIATED
# THROUGH BANKJUMP IF NECESSARY.  THERE IS NO RETURN.
```

```
# THE MASTER IGNITION ROUTINE WAS CONCEIVED AND EXECUTED, AND (NOTA BENE) IS MAINTAINED
```

```
#
# HONI SOIT QUI MAL Y PENSE
```

```
#
# *****
# TABLES FOR THE IGNITION ROUTINE
# *****
```

```
# NOLI SE TANGERE
```

```
P12TABLE  VN      0674      # (0)
          TCF      ULLGNOT   # (1)
          TCF      COMFAIL3  # (2)
          TCF      GOCUTOFF  # (3)
          TCF      TASKOVER  # (4)
          TCF      P12SPOT   # (5)
          DEC      0         # (6)    NO ULLAGE
          EBANK=    WHICH
          2CADR     SERVEXIT  # (7)

          TCF      DISPCHNG  # (11)
          TCF      WAITABIT  # (12)
          TCF      P12IGN    # (13)
```

P40TABLE	VN	0640	# (0)
	TCF	ULLGNOT	# (1)
	TCF	COMFAIL4	# (2)
	TCF	GOPOST	# (3)
	TCF	TASKOVER	# (4)
	TCF	P40SPOT	# (5)
# Page 732	DEC	2240	# (6)
	EBANK=	OMEGAQ	
	2CADR	STEERING	# (7)
	TCF	P40SJUNK	# (11)
	TCF	WAITABIT	# (12)
	TCF	P40IGN	# (13)
	TCF	REP40ALM	# (14)
P41TABLE	TCF	P41SPOT	# (5)
	DEC	-1	# (6)
	EBANK=	OMEGAQ	
	2CADR	CALCN85	# (7)
	TCF	COMMON	# (11)
	TCF	TIGTASK	# (12)
P42TABLE	VN	0640	# (0)
	TCF	WANTAPS	# (1)
	TCF	COMFAIL4	# (2)
	TCF	GOPOST	# (3)
	TCF	TASKOVER	# (4)
	TCF	P42SPOT	# (5)
	DEC	2640	# (6)
	EBANK=	OMEGAQ	
	2CADR	STEERING	# (7)
	TCF	P40SJUNK	# (11)
	TCF	WAITABIT	# (12)
	TCF	P42IGN	# (13)
	TCF	P42STAGE	# (14)
P63TABLE	VN	0662	# (0)
	TCF	ULLGNOT	# (1)
	TCF	COMFAIL3	# (2)
	TCF	V99RECYC	# (3)
	TCF	TASKOVER	# (4)
	TCF	P63SPOT	# (5)
	DEC	2240	# (6)

```

EBANK=  WHICH
2CADR  SERVEXIT      # (7)

TCF    DISPCHNG      # (11)
TCF    WAITABIT      # (12)

# Page 733

TCF    P63IGN        # (13)

ABRTABLE  VN    0663      # (0)
          TCF    ULLGNOT   # (1)
          TCF    COMFAIL3  # (2)
          TCF    GOCUTOFF  # (3)
          TCF    TASKOVER  # (4)
          NOOP                    # (5)
          NOOP                    # (6)
          NOOP                    # (7)
          NOOP
          TCF    DISPCHNG      # (11)
          TCF    WAITABIT      # (12)
          TCF    ABRTIGN      # (13)

# *****
# GENERAL PURPOSE IGNITION ROUTINES
# *****

BURNBABY  TC    PHASCHNG    # GROUP 4 RESTARTS HERE
          OCT    04024

          CAF    ZERO        # EXTIRPATE JUNK LEFT IN DVTOTAL
          TS     DVTOTAL
          TS     DVTOTAL +1

          TC     BANKCALL     # P40AUTO MUST BE BANKCALLED EVEN FROM ITS
          CADR    P40AUTO     # OWN BANK TO SET UP RETURN PROPERLY

B*RNB*B*  EXTEND
          DCA     TIG         # STORE NOMINAL TIG FOR OBLATENESS COMP.
          DXCH    GOBLTIME    # AND FOR P70 OR P71.

          INHINT
          TC     IBNKCALL
          CADR    ENGINOF3
          RELINT

          INDEX   WHICH
          TCF     5

```



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```
P42SPOT      =      P40SPOT      # (5)
P12SPOT      =      P40SPOT      # (5)
P63SPOT      =      P41SPOT      # (5)   IN P63 CLOKTASK ALREADY GOING
P40SPOT      CS      CNTDNDEX      # (5)
# Page 734

              TC      BANKCALL      # MUST BE BANKCALLED FOR GENERALIZED
              CADR      STCLOK2      #      RETURN
P41SPOT      TC      INTPRET      # (5)
              DLOAD      DSU
              TIG
              D29.9SEC
              STCALL      TDEC1
              INITCDUW
              BOFF      CALL
              MUNFLAG
              GOMIDAV
              CSMPREC
              VLOAD      MXV
              VATT1
              REFSMMAT
              VSR1
              STOVL      V(CSM)      # CSM VELOCITY -- M/CS*2(7)
              RATT1
              VSL4      MXV
              REFSMMAT
              STCALL      R(CSM)      # CSM POSITION -- M*2(24)
              MUNGRAV
              STODL      G(CSM)      # CSM GRAVITY VEC. -- M/CS*2(7)
              TAT
              STORE      TDEC1      # RELOAD TDEC1 FOR MIDTOAV.
GOMIDAV      CALRB
              MIDTOAV1
              TCF      CALLT-35      # MADE IT IN TIME.

              EXTEND      # TIG WAS SLIPPED, SO RESET TIG TO 29.9
              DCA      PIPTIME1      # SECONDS AFTER THE TIME TO WHICH WE DID
              DXCH      TIG      # INTEGRATE.
              EXTEND
              DCA      D29.9SEC
              DAS      TIG

CALLT-35      DXCH      MPAC
              DXCH      SAVET-30      # DELTA-T UNTIL TIG-30
              EXTEND
              DCS      5SECDP
```

```

                                DAS      SAVET-30      # DELTA-T UNTIL TIG-35
                                EXTEND
                                DCA       SAVET-30
                                TC        LONGCALL
                                EBANK=    TTOGO
                                2CADR     TIG-35

                                TC        PHASCHNG
                                OCT       20254      # 4.25SPOT FOR TIG-35 RESTART.

# Page 735
                                TC        CHECKMM
                                DEC       63
                                TCF       ENDOFJOB      # NOT P63
                                CS        CNTDNDEX      # P63 CAN START DISPLAYING NOW.
                                TS        DISPDEX
                                TC        INTPRET
                                VLOAD     ABVAL
                                           VN1
                                STORE     ABVEL          # INITIALIZE ABVEL FOR P63 DISPLAY
                                EXIT
                                TCF       ENDOFJOB

# *****

TIG-35      CAF      5SEC
            TC       TWIDDLE
            ADRES    TIG-30

            TC       PHASCHNG
            OCT      40154      # 4.15SPOT FOR TIG-30 RESTART

            CS       BLANKDEX      # BLANK DSKY FOR 5 SECONDS
            TS       DISPDEX

            INDEX    WHICH
            CS       6             # CHECK ULLAGE TIME.
            EXTEND
            BZMF     TASKOVER
            CAF      4.9SEC        # SET UP TASK TO RESTORE DISPLAY AT TIG-30
            TC       TWIDDLE
            ADRES    TIG-30.1

            CAF      PRI017        # A NEGATIVE ULLAGE TIME INDICATES P41, IN
            TC       NOVAC         # WHICH CASE WE HAVE TO SET UP A JOB TO
            EBANK=    TTOGO        # BLANK THE DSKY FOR FIVE SECONDS, SINCE
            2CADR     P41BLANK     # CLOKJOB IS NOT RUNNING DURING P41.
```

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```

                                TCF      TASKOVER

P41BLANK                       TC      BANKCALL      # BLANK DSKY.
                                CADR      CLEANDSP
                                TCF      ENDOFJOB

TIG-30.1                       CAF      PRI017        # SET UP JOB TO RESTORE DISPLAY AT TIG-30
                                TC      NOVAC
                                EBANK=   TTOGO
                                2CADR    TIG-30A

                                TCF      TASKOVER

# Page 736
TIG-30A                       CAF      V16N85B
                                TC      BANKCALL      # RESTORE DISPLAY.
                                CADR      REGODSP      # REGODSP DOES A TCF ENDOFJOB

#      *****

TIG-30                         CAF      S24.9SEC
                                TC      TWIDDLE
                                ADRES    TIG-5

                                CS      CNTDNDEX      # START UP CLOKTASK AGAIN
                                TS      DISPDEX

                                INDEX    WHICH        # PICK UP APPROPRIATE ULLAGE -- ON TIME
                                CA      6              # Was CAF --- RSB 2009.
                                EXTEND
                                BZMF     ULLGNOT        # DON'T SET UP ULLAGE IF DT IS NEG OR ZERO
                                TS      SAVET-30        # SAVE DELTA-T FOR RESTART
                                TC      TWIDDLE
                                ADRES    ULLGTASK

                                CA      THREE          # RESTART PROTECT ULLGTASK (1.3SPOT)
                                TS      L
                                CS      THREE
                                DXCH     -PHASE1
                                CS      TIME1
                                TS      TBASE1

                                INDEX    WHICH
                                TCF      1

WANTAPS                       CS      FLGWRD10      # (1) FOR P42 ENSURE APSFLAG IS SET. IF IT
```

```

                                MASK    APSFLBIT    # WASN'T SET, DAP WILL BE INITIALIZED TO
                                ADS      FLGWRD10    # ASCENT VALUES BY 1/ACCS IN 2 SECONDS.

ULLGNOT                        EXTEND
                                INDEX    WHICH      # (1)
                                DCA       7          # LOAD AVEGEXIT WITH APPROPRIATE 2CADR
                                DXCH      AVEGEXIT

                                CAF       TWO        # 4.2SPOT RESTARTS IMMEDIATELY AT REDO4.2
                                TS        L          #
                                CS        TWO        # AND ALSO AT TIG-5 AT THE CORRECT TIME.
                                DXCH      -PHASE4

                                CS        TIME1
                                TS        TBASE4    # SET TBASE4 FOR TIG-5 RESTART

REDO2.17                      EXTEND
# Page 737

                                DCA       NEG0      # CLEAR OUT GROUP 2 SO LAMBERT CAN START
                                DXCH      -PHASE2    # IF NEEDED.

REDO4.2                       CCS        PHASE5    # IF SERVICER GOING?
                                TCF       TASKOVER   # YES, DON'T START IT UP AGAIN.

                                TC        POSTJUMP
                                CADR      PREREAD    # PREREAD END THIS TASK

# *****

ULLGTASK                      TC        ONULLAGE    # THIS COMES AT TIG-7.5 OR TIG-3.5
                                TC        PHASCHNG
                                OCT       1
                                TCF      TASKOVER

# *****

TIG-5                         EXTEND
                                DCA       NEG0      # INSURE THAT GROUP 3 IS INACTIVE.
                                DXCH      -PHASE3

                                CAF       5SEC
                                TC        TWIDDLE
                                ADRES     TIG-0

                                TC        DOWNFLAG   # RESET IGNFLAG AND ASINFLAG
                                ADRES     IGNFLAG    # FOR LIGHT-UP LOGIC.

```

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	TC	DOWNFLAG	
	ADRES	ASTNFLAG	
	INDEX	WHICH	
	TCF	11	
P40SJUNK	CCS	PHASE3	# (11) P40 AND P42. S40.13 IN PROGRESS?
	TCF	DISPCHNG	# YES
	CAF	PRI020	
	TC	FINDVAC	
	EBANK=	TTOGO	
	2CADR	S40.13	
	TC	PHASCHNG	# 3.5SPOT FOR S40.13
	OCT	00053	
DISPCHNG	CS	VB99DEX	# (11)
	TS	DISPDEX	
# Page 738			
COMMON	TC	PHASCHNG	# RESTART TIG-0 (4.7SPOT)
	OCT	40074	
	TCF	TASKOVER	
#	*****		
TIG-0	CS	FLAGWRD7	# SET IGNFLAG SINCE TIG HAS ARRIVED
	MASK	IGNFLBIT	
	ADS	FLAGWRD7	
	TC	CHECKMM	# IN P63 CASE, THROTTLE-UP IS ZOOMTIME
	DEC	63	# AFTER NOMINAL IGNITION, NOT ACTUAL
	TCF	IGNYET?	
	CA	ZOOMTIME	
	TC	WAITLIST	
	EBANK=	DVCNTR	
	2CADR	P63ZOOM	
	TC	2PHSCHNG	
	OCT	40033	
	OCT	05014	
	OCT	77777	
IGNYET?	CAF	ASTNBIT	# CHECK ASTNFLAG: HAS ASTRONAUT RESPONDED
	MASK	FLAGWRD7	# TO OUR ENGINE ENABLE REQUEST?

	EXTEND		
	INDEX	WHICH	
	BZF	12	# BRANCH IF HE HAS NOT RESPONDED YET
IGNITION	CS	FLAGWRD5	# INSURE ENGONFLG IS SET.
	MASK	ENGONBIT	
	ADS	FLAGWRD5	
	CS	PRI030	# TURN ON THE ENGINE.
	EXTEND		
	RAND	DSALMOUT	
	AD	BIT13	
	EXTEND		
	WRITE	DSALMOUT	
	EXTEND		# SET TEVENT FOR DOWNLINK
	DCA	TIME2	
	DXCH	TEVENT	
	EXTEND		# UPDATE TIG USING TGO FROM S40.13
	DCA	TGO	
	DXCH	TIG	
	EXTEND		
	DCA	TIME2	
	DAS	TIG	
# Page 739	CS	FLUNDBIT	# PERMIT GUIDANCE LOOP DISPLAYS
	MASK	FLAGWRD8	
	TS	FLAGWRD8	
	INDEX	WHICH	
	TCF	13	
P63IGN	EXTEND		# (13) INITIATE BURN DISPLAYS
	DCA	DSP2CADR	
	DXCH	AVGEXIT	
	CA	Z	# ASSASSINATE CLOKTASK
	TS	DISPDEX	
	CS	FLAGWRD9	# SET FLAG FOR P70-P71
	MASK	LETABBIT	
	ADS	FLAGWRD9	
	CS	FLAGWRD7	# SET SWANDISP TO ENABLE R10.
	MASK	SWANDBIT	
	ADS	FLAGWRD7	

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```

CS      PULSES      # MAKE SURE DAP IS NOT IN MINIMUM-IMPULSE
MASK    DAPBOOLS    # MODE, IN CASE OF SWITCH TO P66
TS      DAPBOOLS

EXTEND
DCA      TIME2
DXCH     TIG

CAF      ZERO        # INITIALIZE WCHPHASE, AND FLPASSO
TS      WCHPHASE
TS      WCHPHOLD     # ALSO WHCPHOLD
CA      TWO
TS      FLPASSO

TCF      P42IGN
CS      FLAGWRD5     # (13)
MASK    NOTHRBIT
EXTEND
BZF      P42IGN
CA      ZOOMTIME
TC      WAITLIST
EBANK=   DVCNTR
2CADR    P40ZOOM

P63IGN1  TC      2PHSCHNG
OCT      40033        # 3.3SPOT FOR ZOOM RESTART.
OCT      05014        # TYPE C RESTARTS HERE IMMEDIATELY
OCT      77777

# Page 740
P12IGN   TCF      P42IGN
CAF      EBANK6
TS      EBANK
EBANK=   AOSQ

CA      IGNAOSQ      # INITIALIZE DAP BIAS ACCELERATION
TS      AOSQ         # ESTIMATES AT P12 IGNITION.
CA      IGNAOSR
TS      AOSR

CAF      EBANK7
TS      EBANK
EBANK=   DVCNTR

ABRTIGN  CA      Z      # (13) KILL CLOKTASK
```

	TS	DISPDEX	
	EXTEND		# CONNECT ASCENT GUIDANCE TO SERVICER.
	DCA	ATMAGADR	
	DXCH	AVGEXIT	
	CS	FLAGWRD7	# ENABLE R10.
	MASK	SWANDBIT	
	ADS	FLAGWRD7	
P42IGN	CS	DRIFTBIT	# ENSURE THAT POWERED-FLIGHT SWITCHING
	MASK	DAPBOOLS	# CURVES ARE USED.
	TS	DAPBOOLS	
	CAF	IMPULBIT	# EXAMINE IMPULSE SWITCH
	MASK	FLAGWRD2	
	CCS	A	
	TCF	IMPLBURN	
DVMONCON	TC	DOWNFLAG	
	ADRES	IGNFLAG	# CONNECT DVMON
	TC	DOWNFLAG	
	ADRES	ASTNFLAG	
	TC	DOWNFLAG	
	ADRES	IDLEFLAG	
	TC	PHASCHNG	
	OCT	40054	
	TC	FIXDELAY	# TURN ULLAGE OFF HALF A SECOND AFTER
	DEC	50	# LIGHT UP.
ULLAGOFF	TC	NOULLAGE	
WAITABIT	EXTEND		# KILL GROUP 4
	DCA	NEGO	
# Page 741	DXCH	-PHASE4	
	TCF	TASKOVER	
TIGTASK	TC	POSTJUMP	# (12)
	CADR	TIGTASK1	

# \*\*\*\*\*



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```

SETLOC  P40S3
BANK
COUNT*  $$/P40

TIGTASK1  CAF    PRI016
          TC     NOVAC
          EBANK=  TRKMKCNT
          2CADR   TIGNOW

          TC     PHASCHNG
          OCT     6          # KILL GROUP 6

          TCF     TASKOVER
```

# \*\*\*\*\*

```

P63ZOOM   EXTEND
          DCA     LUNLANAD
          DXCH    AVEGEXIT

          TC     IBNKCALL
          CADR    FLATOUT
          TCF     P40ZOOMA
```

```

P40ZOOM   CAF     BIT13
          TS      THRUST
          CAF     BIT4
```

```

EXTEND
WOR       CHAN14
```

```

P40ZOOMA  TC     PHASCHNG
          OCT     3
          TCF     TASKOVER
```

```

          EBANK=  DVCNTR
LUNLANAD  2CADR   LUNLAND
```

# Page 742

```

ZOOM      =       P40ZOOMA
          BANK     36
          SETLOC   P40S
          BANK
          COUNT*   $$/P40
```

# \*\*\*\*\*

COMFAIL	TC	UPFLAG	# (15)
	ADRES	IDLEFLAG	
	TC	UPFLAG	# SET FLAG TO SUPRESS CONFLICTING DISPLAY
	ADRES	FLUNDISP	
	CAF	FOUR	# RESET DVMON
	TS	DVCNTR	
	CCS	PHASE6	# CLOCTASK ACTIVE?
	TCF	+3	# YES
	TC	BANKCALL	# OTHERWISE, START IT UP
	CADR	STCLOK1	
+3	CS	VB97DEX	
	TS	DISPDEX	
	TC	PHASCHNG	# TURN OFF GROUP 4.
	OCT	00004	
	TCF	ENDOFJOB	
COMFAIL1	INDEX	WHICH	
	TCF	2	
COMFAIL3	CA	Z	# (15) KILL CLOKTASK USING Z
	TCF	+2	
COMFAIL4	CS	CNTDINDEX	
	TS	DISPDEX	
	TC	DOWNFLAG	# RECONNECT DV MONITOR
	ADRES	IDLEFLAG	
	TC	DOWNFLAG	# PERMIT GUIDANCE LOOP DISPLAYS
	ADRES	FLUNDISP	
	TCF	ENDOFJOB	
COMFAIL2	TC	PHASCHNG	# KILL ZOOM RESTART PROTECTION
	OCT	00003	
	INHINT		
	TC	KILLTASK	# KILL ZOOM IN CASE IT'S STILL TO COME
	CADR	ZOOM	
	TC	IBNKCALL	# COMMAND ENGINE OFF
	CADR	ENGNOF4	
	TC	UPFLAG	# SET THE DRIFT BIT FOR THE DAP.
	ADRES	DRIFTDFL	
# Page 743	TC	INVFLAG	# USE OTHER RCS SYSTEM
	ADRES	AORBTFLG	
	TC	UPFLAG	# TURN ON ULLAGE

```

      ADRES  ULLAGFLG
      CAF    BIT1
      INHINT
      TC      TWIDDLE
      ADRES  TIG-5
      TCF     ENDOFJOB

```

```

# *****
# SUBROUTINES OF THE IGNITION ROUTINE
# *****

```

```

INVFLAG      CA      Q
              TC      DEBIT
              COM
              EXTEND
              RXOR    LCHAN
              TCF     COMFLAG

```

```

# *****

```

```

NOULLAGE      CS      ULLAGER      # MUST BE CALLED IN A TASK OR UNDER INHINT
              MASK    DAPBOOLS
              TS      DAPBOOLS
              TC      Q

```

```

# *****

```

```

ONULLAGE      CS      DAPBOOLS      # TURN ON ULLAGE.  MUST BE CALLED IN
              MASK    ULLAGER      # A TASK OR WHILE INHINTED.
              ADS     DAPBOOLS
              TC      Q

```

```

# *****

```

```

STCLOK1      CA      ZERO          # THIS ROUTINE STARTS THE COUNT-DOWN
STCLOK2      TS      DISPDEX       # (CLOKTASK AND CLOKJOB).  SETTING
STCLOK3      TC      MAKECADR      # SETTING DISPDEX POSITIVE KILLS IT.
              TS      TBASE4       # RETURN SAVE (NOT FOR RESTARTS).
              EXTEND
              DCA     TIG
              DXCH    MPAC
              EXTEND
              DCS     TIME2

```

```

# Page 744

```

```

      DAS     MPAC          # HAVE TIG -- TIME2, UNDOUBTEDLY A + NUMBER
      TC      TPAGREE       # POSITIVE, SINCE WE PASSED THE

```

```

CAF      1SEC      # 45 SECOND CHECK.
TS       Q
DXCH     MPAC
MASK     LOW5      # RESTRICT MAGNITUDE OF NUMBER IN A
EXTEND
DV       Q
CA       L         # GET REMAINDER
AD       TWO
INHINT
TC       TWIDDLE
ADRES    CLOKTASK
TC       2PHSCHNG
OCT      40036     # 6.3SPOT FOR CLOKTASK
OCT      05024
OCT      13000

CA       TBASE4
TC       BANKJUMP

CLOKTASK CS       TIME1      # SET TBASE6 FOR GROUP 6 RESTART
        TS       TBASE6

CCS      DISPDEX
TCF      KILLCLOK
NOOP
CAF      PRI027
TC       NOVAC
EBANK=   TTOGO
2CADR    CLOKJOB

TC       FIXDELAY  # WAIT A SECOND BEFORE STARTING OVER
DEC      100
TCF      CLOKTASK

KILLCLOK EXTEND     # KILL RESTART
        DCA      NEG0
        DXCH     -PHASE6
        TCF      TASKOVER

CLOKJOB  EXTEND
        DCS      TIG
        DXCH     TTOGO
        EXTEND

# Page 745
DCA      TIME2
DAS      TTOGO

```

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```

      INHINT
      CCS      DISPDEX      # IF DISPDEX HAS BEEN SET POSITIVE BY A
      TCF      ENDOFJOB      # TASK OR A HIGHER PRIORITY JOB SINCE THE
      TCF      ENDOFJOB      # LAST CLOKTASK, AVOID USING IT AS AN
      COM                      # INDEX.
      RELINT
      INDEX     A            # ***** DISPDEX MUST NEVER B -0 *****
      TCF      DISPNOT -1    # (-1 DUE TO EFFECT OF CCS)

VB97DEX      =      OCT35      # NEGATIVE OF THIS IS PROPER FOR DISPDEX

      -35      CS      ZERO      # INDICATE VERB 97 PASTE
              TS      NVWORD1
              CA      NVWORD +2    # NVWORD+2 CONTAINS V06 & APPROPRIATE NOUN
              TC      BANKCALL
              CADR     CLOCPLAY
              TCF      STOPCLOK      # TERMINATE CLOKTASK ON THE WAY TO POOH
              TCF      COMFAIL1
              TCF      COMFAIL2

      -25      CAF      V06N61      # THIS DISPLAY IS CALLED VIA ASTNCLOK
              TC      BANKCALL      # IT IS PRIMARILY USED BY THE CREW IN P63
              CADR     REFLASH      # TO RESET HIS EVENT TIMER TO AGREE WITH
              TCF      STOPCLOK      # TIG.
              TCF      ASTNRETN
              TCF      -6

CNTDNDEX      =      LOW4      # OCT17:  NEGATIVE PROPER FOR DISPDEX

      -17      INDEX     WHICH      # THIS DISPLAY COMES UP AT ONE SECOND
              # Was CAF --- RSB 2009
              CA      0            # INTERVALS.  IT IS NORMALLY OPERATED
              TC      BANKCALL      # BETWEEN TIG-30 SECONDS AND TIG-5 SECONDS
              CADR     REGODSP      # REGODSP DOES ITS OWN TCF ENDOFJOB

VB99DEX      =      ELEVEN      # OCT13:  NEGATIVE PROPER FOR DISPDEX

V99RECYC      EQUALS

      -13      CS      BIT9      # INDICATE VERB 99 PASTE
              TS      NVWORD1
              INDEX     WHICH      # THIS IS THE "PLEASE ENABLE ENGINE"
              # Was CAF --- RSB 2004
              CA      0            # DISPLAY; IT IS INITIATED AT TIG-5 SEC.
              TC      BANKCALL      # THE DISPLAY IS A V99NXX, WHERE XX IS
```

	CADR	CLOCPLAY	# NOUN THAT HAD PREVIOUSLY BEEN DISPLAYED
	TCF	STOPCLOK	# TERMINATE GOTOPPOH TURNS OFF ULLAGE.
	TCF	*PROCEED	
	TCF	*ENTER	
# Page 746			
BLANKDEX	=	TWO	# NEGATIVE OF THIS IS PROPER FOR DISPDEX
-2	TC	BANKCALL	# BLANK DSKY. THE DSKY IS BLANKED FOR
	CADR	CLEANDSP	# 5 SECONDS AT TIG-35 TO INDICATE THAT
DISPNOT	TCF	ENDOFJOB	# AVERAGE G IS STARTING.
STOPCLOK	TC	NULLCLOK	# STOP CLOKTASK & TURN OFF ULLAGE ON THE
	TCF	GOTOPPOH	# WAY TO P00 (GOTOPPOH RELINTS)
NULLCLOK	INHINT		
	EXTEND		
	QXCH	P40/RET	
	TC	NOULLAGE	# TURN OFF ULLAGE ...
	TC	KILLTASK	# DON'T LET IT COME ON, EITHER ...
	CADR	ULLGTASK	
	TC	PHASCHNG	# NOT EVEN IF THERE'S A RESTART
	OCT	1	
	CA	Z	# KILL CLOKTASK
	TS	DISPDEX	
	TC	P40/RET	
ASTNRETN	TC	PHASCHNG	
	OCT	04024	
	CAF	ZERO	# STOP DISPLAYING BUT KEEP RUNNING
	TS	DISPDEX	
	CAF	PRI013	
	TC	FINDVAC	
	EBANK=	STARIND	
	2CADR	ASTNRET	
	TCF	ENDOFJOB	
*PROCEED	TC	UPFLAG	
	ADRES	ASTNFLAG	
	TCF	IGNITE	
*ENTER	INHINT		
	INDEX	WHICH	
	TCF	3	

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GOPOST	CAF	PRI012	# (3) MUST BE LOWER PRIORITY THAN CLOKJOB
	TC	FINDVAC	
	EBANK=	TTOGO	
	2CADR	POSTBURN	

# Page 747

INHINT		# SET UP THE DAP FOR COASTING FLIGHT.
TC	IBNKCALL	
CADR	ALLCOAST	
TC	NULLCLOK	
TC	PHASCHNG	# 4.13 RESTART FOR POSTBURN
OCT	00134	
TCF	ENDOFJOB	

GOCUTOFF	CAF	PRI017	# (3)
	TC	FINDVAC	
	EBANK=	TGO	
	2CADR	CUTOFF	

TC	DOWNFLAG	
ADRES	FLUNDISP	
INHINT		# SET UP THE DAP FOR COASTING FLIGHT.
TC	IBNKCALL	
CADR	ALLCOAST	
TC	NULLCLOK	
TC	PHASCHNG	
OCT	07024	
OCT	17000	
EBANK=	TGO	
2CADR	CUTOFF	
TCF	ENDOFJOB	

IGNITE	CS	FLAGWRD7	# (2)
	MASK	IGNFLBIT	
	CCS	A	
	TCF	IGNITE1	
	CAF	BIT1	

INHINT	
TC	TWIDDLE
ADRES	IGNITION

CAF	OCT23	# IMMEDIATE RESTART AT IGNITION
-----	-------	---------------------------------

```

                TS      L
                COM
                DXCH    -PHASE4

IGNITE1         CS      CNTDNDX      # RESTORE OLD DISPLAY.
                TS      DISPDEX

                TCF      ENDOFJOB

# Page 748
# *****

P40ALM          TC      ALARM          # PROGRAM SELECTION NOT CONSISTENT WITH
                OCT      1706          # VEHICLE CONFIGURATION

REP40ALM        CAF      V05N09        # (14)
                TC      BANKCALL
                CADR     GOFLASH

                TCF      GOTOPOOH      # V34E          TERMINATE
                TCF      +2            # PROCEED        CHECK FOR P42
                TCF      REP40ALM      # V32E          REDISPLAY ALARM

                INDEX    WHICH        # FOR P42, ALLOW CREW TO PRECEED EVEN
                TCF      14           # THOUGH VEHICLE IS UNSTAGED.

# *****

                BANK      31
                SETLOC    P40S2
                BANK

                COUNT*    $$/P40

P40AUTO         TC      MAKECADR      # HELLO THERE.
                TS      TEMPR60      # FOR GENERALIZED RETURN TO OTHER BANKS.
P40A/P          TC      BANKCALL      # SUBROUTINE TO CHECK PGNC'S CONTROL
                CADR     G+N,AUTO    # AND AUTO STABILIZATION MODES
                CCS      A           # +0 INDICATES IN PGNC'S, IN AUTO
                TCF      TURNITON    # + INDICATES NOT IN PGNC'S AND/OR AUTO
                CAF      APSFLBIT    # ARE WE ON THE DESCENT STAGE?
                MASK     FLGWRD10
                CCS      A
                TCF      GOBACK      # RETURN
                CAF      BIT5        # YES, CHECK FOR AUTO-THROTTLE MODE
                EXTEND

```



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```

                                RAND   CHAN30
                                EXTEND
TURNITON  BZF   GOBACK          # IN AUTO-THROTTLE MODE -- RETURN
          CAF   P40A/PMD        # DISPLAYS V50N25 R1=203 PLEASE PERFORM
          TC    BANKCALL        # CHECKLIST 203 TURN ON PGNC'S ETC.
          CADR  GOPERF1
          TCF   GOTOP00H        # V34E TERMINATE
          TCF   P40A/P          # RECYCLE
GOBACK    CA    TEMPR60
          TC    BANKJUMP        # GOODBYE.  COME AGAIN SOON.

P40A/PMD  OCT    00203
```

# Page 749

```

                                BANK    36
                                SETLOC  P40S
                                BANK
                                COUNT*  $$/P40
```

```

# *****
#   CONSTANTS FOR THE IGNITION ROUTINE
# *****
```

```

SERVCADR      =      P63TABLE +7

P40ADRES      ADRES  P40TABLE

P41ADRES      ADRES  P41TABLE -5

P42ADRES      ADRES  P42TABLE

                                EBANK=  DVCNTR
DSP2CADR      2CADR  P63DISPS -2

                                EBANK=  DVCNTR
ATMAGADR      2CADR  ATMAG

?              =      GOTOP00H

D29.9SEC      2DEC   2990

S24.9SEC      DEC    2490

4.9SEC        DEC    490
```

OCT20 = BIT5

V06N61 VN 0661

# Page 750

# KILLTASK

# MOD NO: NEW PROGRAM

# MOD BY: COVELLI

#

# FUNCTIONAL DESCRIPTION:

#

# KILLTASK IS USED TO REMOVE A TASK FROM THE WAITLIST BY SUBSTITUTING A NULL TASK  
# WHICH MERELY DOES A TC TASKOVER. IF THE SAME TASK IS SCHEDULED MORE THAN ONCE,  
# THE FIRST IS REMOVED. IF THE TASK IS NOT SCHEDULED, KILLTASK TAKES NO ACTION AND  
# LEAVES INTERRUPTS INHIBITED SO CALLER MUST RELINT

#

# CALLING SEQUENCE

#	L	TC	KILLTASK	# IN FIXED-FIXED
#	L+1	CADR	????????	# CADR (NOT 2CADR) OF TASK TO BE REMOVED.
#	L+2	(RELINT)		# RETURN

#

# EXIT MODE: AT L+2 OF CALLING SEQUENCE.

#

# ERASABLE INITIALIZATION: NONE.

#

# OUTPUT: 2CADR OF NULLTASK IN LST2

#

# DEBRIS: ITEMP1 - ITEMP4, A, L, Q.

	EBANK=	LST2	
	BLOCK	3	# KILLTASK MUST BE IN FIXED-FIXED.
	SETLOC	FFTAG6	
	BANK		
	COUNT*	\$\$/KILL	
KILLTASK	CA	KILLBB	
	INHINT		
	LXCH	A	
	INDEX	Q	
	CA	0	# GET CADR.
	LXCH	BBANK	
	TCF	KILLTSK2	# CONTINUE IN SWITCHED FIXED.
	EBANK=	LST2	
KILLBB	BBCON	KILLTSK2	
	BANK	27	

```

SETLOC P40S1
BANK
COUNT* $$/KILL

KILLTSK2      LXCH  ITEMP2      # SAVE CALLER'S BBANK
# Page 751

INCR          Q
EXTEND
QXCH          ITEMP1      # RETURN 2ADR IN ITEMP1,ITEMP2

TS            ITEMP3      # CADR IS IN A
MASK          LOW10
AD            BIT11
TS            ITEMP4      # GENADR OF TASK

CS            LOW10
MASK          ITEMP3
TS            ITEMP3      # FBANK OF TASK

ADRSCAN       ZL
INDEX         L
CS            LST2
AD            ITEMP4      # COMPARE GENADRS
EXTEND
BZF           TSTFBANK     # IF THEY MATCH, COMPARE FBANKS
LETITLIV      CS            LSTLIM
AD            L
EXTEND        # ARE WE DONE?
BZF           DEAD        # YES -- DONE, SO RETURN
INCR          L
INCR          L
TCF           ADRSCAN     # CONTINUE LOOP.

DEAD          DXCH  ITEMP1
DTCB

TSTFBANK      CS            LOW10
INDEX         L
MASK          LST2      +1  # COMPARE FBANKS ONLY.
EXTEND
SU            ITEMP3
EXTEND
BZF           KILLDEAD    # MATCH -- KILL IT.
TCF           LETITLIV    # NO MATCH -- CONTINUE.

```

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```
KILLDEAD      CA      TCTSKOVR
               INDEX   L
               TS      LST2      # REMOVE TASK BY INSERTING TASKOVER
               TCF      DEAD
```

```
LSTLIM        EQUALS  BIT5      # DEC 16
```

This code is written to file `src/BURN-BABY-BURN--MASTER-IGNITION-ROUTINE.s`.

## A.13 CM BODY ATTITUDE

```

197  <src/CM-BODY-ATTITUDE.s 197>≡
# Copyright:    Public domain.
# Filename:     CM_BODY_ATTITUDE.agc
# Purpose:      Part of the source code for Comanche, build 055. It
#               is part of the source code for the Command Module's
#               (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:   yaYUL
# Reference:    pp. 883-889
# Contact:      Ron Burkey <info@sandroid.org>
# Website:      http://www.ibiblio.org/apollo.
# Mod history:  2009-05-12 RSB  Adapted from Colossus249 file of the same
#               name and Comanche 055 page images.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051.  April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#               Massachussets Institute of Technology
#               75 Cambridge Parkway
#               Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.

# Page 883

      BANK      35

      SETLOC    BODYATT
      BANK

      COUNT     37/CMBAT

# PDL 12D - 15D SAFE.

# VALUE OF GIMBAL AND BODY ANGLES VALID AT PIP TIME ARE SAVED DURING READACCS.

      EBANK=    RTINIT          # LET INTERPRETER SET EB

```

CM/POSE	TC	INTPRET	# COME HERE VIA AVEGEXIT.	
	SETPD	VLOAD		
		0		
		VN	# KVSACLE = (12800/ .3048) /2VS	
	VXSC	PDVL		
		-KVSACLE	# KVSACLE = .81491944	
		UNITW	# FULL UNIT VECTOR	
	VXV	VXSC	# VREL = V - WE*R	
		UNITR		
		KWE		
	VAD	STADR		
	STORE	-VREL	# SAVE FOR ENTRY GUIDANCE.	REF COORDS
	UNIT	LXA,1		
		36D	# ABVAL( -VREL) TO X1	
	STORE	UXA/2	# -UVREL	REF COORDS
	VXV	VCOMP		
		UNITR	# .5 UNIT	REF COORDS
	UNIT	SSP	# THE FOLLOWING IS TO PROVIDE A STABLE	
		S1	# UN FOR THE END OF THE TERMINAL PHASE.	
SPVQUIT	DEC	.019405	# 1000/ 2 VS	
	TIX,1	VLOAD	# IF V-VQUIT POS, BRANCH.	
		CM/POSE2	# SAME UYA IN OLDUYA	
		OLDUYA	# OTHERWISE CONTINUE TO USE OLDUYA	
CM/POSE2	STORE	UYA/2	#	REF COORDS
	STORE	OLDUYA	# RESTORE, OR SAVE AS CASE MAY BE.	
	VXV	VCOMP		
		UXA/2	# FINISH OBTAINING TRAJECTORY TRIAD.	
	VSL1			
	STORE	UZA/2	#	REF COORDS
# Page 884	TLOAD		# PICK UP CDUX, CDUY, CDUZ CORRESPONDING	
		AOG/PIP	# TO PIPUP TIME IN 2'S C AND SAVE.	
CM/TRIO	STODL	24D		
		25D	# AIG/PIP	
	RTB	PUSH	# TO PDL0	
		CDULOGIC		
	COS			
	STODL	UBX/2	# CI /2	
			# AIG/PIP FROM PDL 0	

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```
SIN      DCOMP
STODL    UBX/2 +4      # -SI /2
                        # AMG/PIP
RTB      PUSH          # TO PDL 0
                        CDULOGIC
SIN      PDDL          # XCH PDL 0.  SAVE SM /2
COS      PDDL          # CM /2 TO PDL 2
                        # SM /2
DCOMP    VXSC
          UBX/2
VSL1
STODL    UBY/2          # NOISE WON'T OVFL
                        # =(-SMCI, NOISE, SMSI)/2
                        # CM /2 REPLACES NOISE
STODL    UBY/2 +2      # UBY/2=(-SMCI, CM, SMSI)/2
                        # AOG/PIP
RTB      PUSH          # TO PDL 4
                        CDULOGIC
SIN      PDDL          # XCH PDL 4.  SAVE SO /2
COS      VXSC          # CO /2
          UBY/2
STODL    UBY/2          # UBY/2=(-COSMCI, COCM, COSMSI)/4
                        # SO /2
DMP      DCOMP
          UBX/2 +4      # -SI /2
DAD
          UBY/2          # INCREMENT BY (SOSI /4)
STODL    UBY/2
                        # SO /2 FROM PDL 4
DMP      DAD
          UBX/2          # CI /2
          UBY/2 +4
STOVL    UBY/2 +4      # YB/4                                PLATFORM COORDS
                        # YB = (-COSMCI + SOSI , COCM , COSMSI + SOCI )

          UBY/2
VXM      VSL2
          REFSMMAT      # .5 UNIT
STODL    UBY/2          # YB/2 DONE                                REF COORDS
                        # CM /2 FROM PDL 2
VXSC     VSL1
          UBX/2
STODL    UBX/2          # =( CMCI, NOISE, -CMSI)/2
STADR
STOVL    UBX/2 +2      # SM /2 FROM PDL 0
                        # SM /2 REPLACES NOISE
```

```

                                UBX/2                                # XB/2                                PLATFORM COORDINATES
                                # XB = ( CMC1 , SM , -CMSI )

VXM      VSL1
          REFSMMAT                                # .5 UNIT
STORE    UBX/2                                # XB/2 DONE                                REF COORDS

VXV      VSL1
          UBY/2
STOVL    UBZ/2                                # ZB/2 DONE                                REF COORDS

                                # EQUIVALENT TO
                                # ZB = ( SOSMCI + COSI , -SOCM , -SOSMSI + COSM )

VXV      UXA/2                                # -UVREL/2 = -UVA/2
          UNIT                                # GET UNIT(-UVREL*UBY)/2 = UL/2
          UBY/2                                # YB/2
PUSH     DOT                                # UL/2 TO PDL 0,5
          UZA/2                                # UNA/2
STOVL    COSTH                                # COS(ROLL)/4
          0                                    # UL/2

DOT
          UYA/2
STCALL   SINTH                                # -SIN(ROLL)/4
          ARCTRIG
STOVL    6D                                    # -(ROLL/180) /2
          UBY/2
DOT      SL1                                    # -UVA.UBY = -SIN(BETA)
          UXA/2                                # -UVREL/2

ARCSIN
STOVL    7D                                    # -(BETA/180) /2
          UBX/2                                # XB/2
DOT      0                                    # UL.UBX = -SIN(ALFA)
          0                                    # UL/2
STOVL    SINTH                                # -SIN(ALFA)/4
DOT      0                                    # UL/2 FROM PDL 0
          UBZ/2
STCALL   COSTH                                # COS(ALFA)/2
          ARCTRIG
STOVL    8D                                    # -(ALFA/180) /2
          UNITR                                # UR/2                                REF COORDS
DOT      SL1

                                UZA/2                                # MORE ACCURATE AT LARGE ARG.

```



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```

      ARCCOS
STORE  10D          # (-GAMA/180)/2

      TLOAD  EXIT          # ANGLES IN MPAC IN THE ORDER
                        # -( (ROLL, BETA, ALFA) /180)/2
                        # THESE VALUES CORRECT AT PIPUP TIME.
                        6D

# Page 887
# BASIC SUBROUTINE TO UPDATE ATTITUDE ANGLES

      EBANK=  AOG

CM/ATUP      CA      EBAOG
              TS      EBANK
CMTR1        INDEX   FIXLOC
              CS      10D          # (GAMA/180)/2
              XCH     GAMA
              TS      L

      INHINT

                        # MUST REMAIN INHINTED UNTIL UPDATE OF BODY
                        # ANGLES, SO THAT GAMDIFSW IS VALID FIRST PASS
                        # INDICATOR.

      CS      CM/FLAGS
      MASK    BIT11          # GAMDIFSW=94D BIT11      INITLY=0
      EXTEND          # DON'T CALC GAMA DOT UNTIL HAVE FORMD
                        # ONE DIFFERENCE.
      BZF     DOGAMDOT        # IS OK, GO ON.
      ADS     CM/FLAGS        # KNOW BIT IS 0
      TC      NOGAMDOT        # SET GAMDOT = 0

DOGAMDOT     CS      L
              AD      GAMA          # DEL GAMA/360= T GAMDOT/360
              EXTEND
              MP      TCDU          # TCDU = .1 SEC, T = 2 SEC.
              TS      GAMDOT        # GAMA DOT TCDU / 180

              EXTEND          # IGNORE GAMDOT IF LEQ .5 DEG/SEC
              BZMF    +2
              COM
              AD      FIVE
              EXTEND
              BZMF    +3          # SET GAMDOT=+0 AS TAG IF TOO SMALL.

NOGAMDOT     CA      ZERO          # COME HERE INHINTED
```

```

                                TS      GAMDOT
                                # FOR NOW LEAVE IN 2'S C
                                # UPDATE ANGLES BY CORRECTING EULER ANG
                                # FOR ACCRUED INCREMENT SINCE PIPUP
                                # R = R EUIL + R(NOW) - R(PIPUP)
                                CS      MPAC
                                # GET (R EUL/180) /2
                                DOUBLE
                                # POSSIBLE OVERFLOW
                                TC      CORANGOV
                                # CORRECT FOR OVFL IF ANY
                                EXTEND
                                SU      ROLL/PIP
                                # GET INCR SINCE PIPUP
                                AD      ROLL/180
                                # ONLY SINGLE OVFL POSSIBLE.
                                TC      CORANGOV
                                # CORRECT FOR OVFL IF ANY
# Page 888
                                TS      TEMPROLL
                                CS      MPAC +2
                                # GET (ALFA EUL/180) /2
                                DOUBLE
                                # SAME AS FOR ROLL.  NEEDED FOR EXT ATM DAP
                                TC      CORANGOV
                                # CORRECT FOR OVFL IF ANY
                                EXTEND
                                SU      ALFA/PIP
                                AD      ALFA/180
                                TC      CORANGOV
                                # CORRECT FOR OVFL IF ANY
                                TS      TEMPALFA
                                CS      MPAC +1
                                # GET (BETA EUL/180) /2
CMTR2    DOUBLE
                                EXTEND
                                SU      BETA/PIP
                                AD      BETA/180
                                XCH     TEMPBETA
                                # OVFL NOT EXPECTED.
                                CA      EBANK3
                                TS      EBANK
                                EBANK=  PHSNAME5
                                EXTEND
                                DCA     REPOSADR
                                # THIS ASSUMES THAT THE          TC  PHASCHNG
                                DXCH     PHSNAME5
                                # IS NOT CHANGED IN              OCT 10035
                                # SERVICER.
                                CA      EBAOG
                                TS      EBANK
                                EBANK=  AOG
                                # RE-STARTS COME HERE
REDOPOSE  EXTEND
                                DCA     TEMPROLL

```

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```

      DXCH  ROLL/180
      CA    TEMPBETA
      TS    BETA/180

      RELINT

      TC    INTPRET      # CAN'T TC DANZIG AFTER PHASCHNG.
      VLOAD ABVAL        # RETURN FROM CM/ATUP.  (RESTART)
      VN          # 2(-7) M/CS
      STORE  VMAGI       # FOR DISPLAY ON CALL.

      GOTO
      POSEXIT      # ENDEXIT, STARTENT, OR SCALEPOP.

CORANGOV      TS    L
              TC    Q
              INDEX A

# Page 889
              CA    LIMITS
              ADS   L
              TC    Q      # COSTS 2 MCT TO USE.  SEE ANGOVCOR.

-KVSCALE      2DEC  -.81491944  # -12800/(2 VS .3048)

TCDU          DEC    .1      # TCDU = .1 SEC.

              EBANK= AOG
REPOSADR      2CADR  REDOPOSE
```

This code is written to file src/CM-BODY-ATTITUDE.s.

## A.14 CM ENTRY DIGITAL AUTOPILOT

204      *<src/CM-ENTRY-DIGITAL-AUTOPILOT.s 204>≡*

```
# Copyright:      Public domain.
# Filename:       CM_ENTRY_DIGITAL_AUTOPILOT.agc
# Purpose:       Part of the source code for Colossus 2A, AKA Comanche 055.
#               It is part of the source code for the Command Module's (CM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:    yaYUL
# Contact:       Ron Burkey <info@sandroid.org>.
# Website:       www.ibiblio.org/apollo.
# Pages:        1063-1092
# Mod history:   2009-05-13 RSB   Adapted from the Colossus249/ file of the
#               same name, using Comanche055 page images.
#               2009-05-20 RSB   Corrections: Removed an extraneous label
#               EXDAPIN, added a missing instruction in
#               COMPAT.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 055 of AGC program Comanche by NASA
#       2021113-051.  10:28 APR. 1, 1969
#
#       This AGC program shall also be referred to as
#               Colossus 2A
#
# Page 1063
# SUBROUTINE TO READ GIMBAL ANGLES AND FORM DIFFERENCES.  GIMBAL ANGLES ARE SAVED IN
# DIFFERENECES ARE IN 1'S COMP.  ENTER AND READ ANGLES EACH .1 SEC.
#
#       CM/DSTBY = 1 FOR DAP OPERATION
#       CM/DSTBY = 0 TO TERMINATE DAP OPERATION
#
#
#       BANK      15
#
#       SETLOC   ETRYDAP
#       BANK
```

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```
COUNT    15/DAPEN

EBANK=   AOG

READGYMB  CA      TEN      # KEEP RESTART DT GOING RELATIVE TO
          ADS     CM/GYMDT  # PIPTIME.  (GROUP 6)

                                     # IF A RESTART OCCURS, SKIP PRESENT CYCLE.  THE
                                     # PHASCHNG PROTECTION IS IN CM/DAPIC.

          CA      BIT6      # CHECK FOR FINE ALIGN MODE OF CDU.
          MASK     IMODES33  # (PROTECT AOG/PIP ETC AS WELL AS
          EXTEND    # GIMBAL DIFFERENCES)
          BZF      READGYM1  # OK

          CS      BIT1      # NOT IN FINE ALIGN, SO IDLE
          MASK     CM/FLAGS  # SET GYMDIFSW = 0
          TS       CM/FLAGS
          TC       FLUSHJET  # QUENCH JETS, SINCE MAY BE A WHILE.
          TC       CM/GYMIC +2

READGYM1  CA      CDUX
          XCH      AOG
          EXTEND
          MSU      AOG      # -DELAOG=AOG(N-1) - AOG(N)
          TS       -DELAOG

          CA      CDUY
          XCH      AIG
          EXTEND
          MSU      AIG
          TS       -DELAIG

          CA      CDUZ
          XCH      AMG
          EXTEND
          MSU      AMG
          TS       -DELAMG

# Page 1064
DOBRATE?  CS      CM/FLAGS  # CM/DSTBY=103D BIT2  GYMDIFSW=104D BIT1
          MASK     THREE
          INDEX    A
          TC       +1
          TC       DOBRATE  # OK, GO ON
```

	TC	CM/GYMIC	# DON'T CALC BODYRATE ON FIRST PASS.
	NOOP		
	TC	FLUSHJET	# TURN OFF ALL JETS
	TC	PHASCHNG	
	OCT	00006	# DEACTIVATE DAP GROUP 6.
	TC	TASKOVER	
DOBRATE	CA	ONE	# DO BODYRATE
DOBRATE1	TS	JETEM	# SKIP BODYRATE
	CA	TEN	# KEEP CDU READ GOING.
	TC	WAITLIST	
	EBANK=	AOG	
	2CADR	READGYMB	
			# DOES NOT PROTECT TEMK, SQ IN SPSIN/COS
	CCS	JETEM	
	TC	BODYRATE	
	TC	TASKOVER	# SKIP CALC ON INITIAL PASS. (PASSES)
CM/GYMIC	ADS	CM/FLAGS	# GYMDIFSW: C(A)=1, KNOW BIT IS 0
	CAF	ZERO	
	TS	JETAG	
	TS	OLDELP	
	TS	OLDELQ	
	TS	OLDELR	
	TS	GAMDOT	# NO GYM DIF, PROB NO GAM DIF.
	TC	DOBRATE1	
# Page 1065			
# COME HERE TO CORRECT FOR OVERFLOW IN ANGULAR CALCULATIONS			
ANGOVCOR	TS	L	# THIS COSTS 2 MCT TO USE.
	TC	Q	# NO OVFL
	INDEX	A	
	CAF	LIMITS	
	ADS	L	
	TC	Q	
	BLOCK	3	
	COUNT	03/DAPEN	

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```
FLUSHJET      CA      7          # COME HERE TO TURN OFF ALL JETS.
               EXTEND
               WRITE    ROLLJETS  # ZERO CHANNEL 6
               EXTEND
               WRITE    PYJETS    # ZERO CHANNEL 5
               TC       Q

               BANK      15

               COUNT    15/DAPEN

               SETLOC   ETRYDAP
               BANK

RATEAVG       COM          # SUBROUTINE TO ESTIMATE RATES IN PRESENCE
               AD        JETEM  # OF CONSTANT ACCELERATION.
               EXTEND
               MP        HALF    # DELV (EST) = DELV +(DELV-OLDELV)/2
               AD        JETEM
               TC       Q
```

# Page 1066

# THESE ARE CALLED FOR THE VARIOUS INITIALIZATIONS NEEDED.

```
               BANK      20
               SETLOC   DAPS1
               BANK

               COUNT    20/DAPEN
               EBANK=    AOG

CM/DAPON      CA        EBAOG
               TS        EBANK

               TC        DOWNFLAG  # RESET DAPBIT1.  T5 RESTART IDENTIFIER.
               ADRES     DAPBIT1   # BIT 15 FLAG 6          CMFLAGS.
               TC        DOWNFLAG  # RESET DAPBIT2
               ADRES     DAPBIT2   # BIT 14 FLAG 6
               EXTEND
               DCA        T5IDLER1  # DISABLE RCS CALCULATION
               DXCH       T5LOC
               EXTEND
               DCA        T5IDLER1  # DISABLE RCS JET CALLS
               DXCH       T6LOC

               TC        FLUSHJET  # JETS DEPARTED ON SM. ZERO JET BITS.
```

```

                                CS      13,14,15
                                MASK    DAPDATR1      # SET CONFIG BITS=0 FOR ENTRY
                                TS      DAPDATR1
                                TC      +4

NOTYET                        CA      .5SEC
                                TC      BANKCALL
                                CADR    DELAYJOB      # (DELAYJOB DOES INHINT)
                                +4      CA      BIT11  # GAMDIFSW = 94D BIT11, INITLY=0
                                MASK    CM/FLAGS      # IF ZERO, WAIT UNTIL CM/POSE UPDATE.
                                EXTEND
                                BZF     NOTYET

                                CS      ONE          # ACTIVATE CM/DAP
                                TS      RCSFLAGS      # USE BIT3 TO INITIALIZE NEEDLER ON
                                                # NEXT PASS.
                                TS      P63FLAG       # SO WAKEP62 WILL NOT BE INITIATED UNTIL
                                                # HEADSUP IS SET IN P62.

                                                # FLAG TO PREVENT MULTIPLE CALLS TO WAKEP62

                                CA      7
                                TS      JETAG
                                TS      PAXERR1      # KEEP NEEDLES ZERO UNTIL DAP UPDATE
                                                # IN CASE CMDAPMOD IS NOT +1.

# Page 1067
                                INHINT
                                EXTEND
                                DCA     ALFA/180      # DO ATTITUDE HOLD UNTIL KEYBOARD
                                DXCH    ALFACOM        # ESTABLISHES HEADSUP.
                                CA      ROLL/180
                                TS      ROLLHOLD      # FOR ATTITUDE HOLD IN MODE +1.
                                EXTEND
                                MP      HALF
                                TS      ROLLC         # NOT INTERESTED IN LO WORD.

                                CS      CM/FLAGS
                                MASK    BIT12        # CMDAPARM =93D BIT12  INITLY=0
                                ADS     CM/FLAGS      # SET BIT TO 1.

                                CS      FLAGWRD2      # SET  NODOFLAG  TO PREVENT FURTHER
                                MASK    BIT1          # V 37 ENTRIES.
                                ADS     FLAGWRD2

                                RELINT

```



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TC POSTJUMP  
CADR P62.1

# Page 1068

# INITIALIZE CM/DAP. WAITLIST CALL FOR READGYMB. SET SWITCH CM/DSTBY =1  
# SO READACCS WILL ENTER A WTLST CALL FOR SETJTAG .  
# CMDAPARM = 0, SO ONLY BODY RATE AND ATTITUDE CALCULATIONS ARE DONE.  
# SET AVEGEXIT TO CONTINUE AT CM/POSE

CM/DAPIC CA EBAOG  
TS EBANK

CM/DAP2C INHINT  
CS PIPTIME +1

# PRIO OF P62 L PRIO AVG.:PIPTM=PIPTM1.

TS JETEM

CA POS1/2

AD POS1/2

AD TIME1

# OVFL GUARANTEED

ADS JETEM

# C(A) = DELTA TIME SINCE PIPUP

CS FIVE

AD JETEM

CCS A

AD -CDUT+1

TCF -2

NOOP

AD ONE

# SEND NO ZERO TO WTLST

TS CM/GYMDT

# FOR RESTART

TC WAITLIST

EBANK= AOG

2CADR READGYMB

CS CM/SWIC1

# GAMDIFSW, GYMDIFSW, CM/DSTBY

MASK CM/FLAGS

# DAPARM, .05GSW, LATSW, ENTRYDSP

AD CM/SWIC2

# SET CM/DSTBY, LATSW

# DISABLE ENTRY DISPLAY, SINCE DES. GIMB.

# CALC. (P62.3) GOES TO ENDEXIT

TS CM/FLAGS

CA 7

TS BETA/180

# NECESSARY: NO OVFL CORRECTIO

CA ONE

# INITIALIZE THE TM OF BODY RATES VIA

TS SW/NDX

# UPBUFF.

```

TC      2PHSCHNG      # DOES INHINT/RELINT
OCT     40116         # SAVE TBASE6
OCT     05024
OCT     13000

TC      POSTJUMP

# Page 1069

CADR    P62.2

CM/SWIC1 OCT     16017
CM/SWIC2 =       TEN      # 00012: CM/DSTBY, LATSW
-CDUT+1 OCT     77766
EBANK=   T5LOC
T5IDLER1 2CADR    T5IDLOC

```

# Page 1070

```

# THIS SECTION CALCULATES THE ANGULAR BODY RATES EACH .1 SEC.  THE ANGULAR RATES ARE
# XB, YB, ZB, AND ARE NORMALLY DESIGNATED P, Q, R.      REQUIREMENT:  TEMPORARILY ERAS
#
# SINCE RESTARTS ZERO THE JET OUTPUT CHANNELS, NO ATTEMPT IS MADE TO RESTART THE ENT
# THE 0.1 SEC DAPS WILL MISS A CYCLE, AND WILL PICK UP AT THE NEXT 0.1 SEC UPDATE.  N
# ROLL SYSTEM WILL MISS ONLY 0.1 SEC OF CONTROL.  HOWEVER, IF THE RESTART OCCURS AFT
# STARTED, THEN THE ROLL SYSTEM WILL MISS ONE CYCLE.
# THIS IS NECESSARY UNDER THE GROUND-RULE THAT NO JET COMMANDS SHALL BE LESS THAN 14

```

```

EBANK=   AOG
BANK     15
SETLOC   ETRYDAP
BANK

COUNT   15/DAPEN

BODYRATE CA      AMG      # THESE ARE 2'S COMPL NOS, BUT USE ANYWAY.
         TC      SPCOS
         TS      COSM

         CA      AOG      # C(AOG) = AOG/180
         TC      SPSIN    # SINO
         TS      SINO     # SINO = SIN(AOG)

EXTEND
MP       COSM
TS       SINOCOSM      # SO CM

CA       AOG

```

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TC SPCOS # COSO  
TS COSO

EXTEND  
MP COSM  
TS COSOCOSM # CO CM

# PITCHDOT:  $Q \text{ TCDU}/180 = \text{IDOT TCDU}/180 \text{ COSO COSM} + \text{MDOT TCDU}/180 \text{ SINO}$

CS -DELAMG  
EXTEND  
MP SINO  
DXCH JETEM # 2 LOCS  
CS -DELAIG  
EXTEND  
MP COSOCOSM  
DAS JETEM  
CA JETEM  
XCH OLDELQ  
TC RATEAVG  
TS QREL # PITCHDOT =  $Q \text{ TCDU}/180$

# Page 1071

# YAWDOT:  $R \text{ TCDU}/180 = -\text{IDOT TCDU}/180 \text{ COSM SINO} + \text{MDOT TCDU}/180 \text{ COSO}$

CS -DELAMG  
EXTEND  
MP COSO  
DXCH JETEM  
CA -DELAIG  
EXTEND  
MP SINOCOSM  
DAS JETEM  
CA JETEM  
XCH OLDELQ  
TC RATEAVG  
TS RREL # YAWDOT =  $R \text{ TCDU}/180$

# ROLLDOT:  $P \text{ TCDU}/180 = \text{ODOT TCDU}/180 + \text{IDOT TCDU}/180 \text{ SINM}$

CA AMG  
TC SPSIN  
TS SINM  
  
EXTEND  
MP -DELAIG

```

      TS      JETEM
      CA      ZERO
      DDOUBL
      AD      -DELAOG      # ROUND L INTO A
      AD      JETEM
      CS      A
      TS      JETEM
      XCH     OLDELP
      TC      RATEAVG
      TS      PREL      # ROLLDOT = P TCDU/180

                        # IF GAMDOT < 0.5 DEG/SEC, THEN GAMDOT =0

      CCS      GAMDOT
      TC      +2
      TC      NOGAMDUT
      CS      ROLL/180
      TC      SPSIN
      EXTEND
      MP      GAMDOT
      TS      JETEM +1      # -SR GAMDOT
      EXTEND
      MP      SINTRIM      # SIN(-20)      (FOR NOMINAL L/D = .3)
      ADS     PREL      # PREL TCDU/180=(P-SALF SR GAMDOT)TCDU/180

      CA      ROLL/180
      TC      SPCOS

# Page 1072
      COM
      EXTEND
      MP      GAMDOT
      ADS     QREL      # QREL TCDU/180=(Q-CR GAMDOT) TCDU/180

      CS      JETEM +1      # B( ) = -SR GAMDOT
      EXTEND
      MP      COSTRIM      # COS(-20)      (FOR NOMINAL L/D = .3)
      ADS     RREL      # RREL TCDU/180=(R+CALF SR GAMDOT)TCDU/180

NOGAMDUT      CA      BIT12      # CMDAPARM = 93D BIT 12
              MASK     CM/FLAGS
              EXTEND
STBYDUMP      BZF      TASKOVER      # DAP NOT ARMED.

              CA      POSMAX      # PICK UP AT ATTRATES IN 10 MS OR SO.
              TS      TIME5

```

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```

EXTEND
DCA      ATDOTCAD
DXCH     T5LOC
# DOES NOT PROTECT TEMK, SQ IN SPSIN/COS

TC      TASKOVER

EBANK=   AOG
ATDOTCAD 2CADR  ATTRATES

# Page 1073
# CALCULATE BODY ATTITUDE RATES AND INTEGRATE TO OBTAIN ATTITUDE ANGLES.
#
#      CB PHIDOT TCDU/180 = (CA PREL + SA RREL) TCDU/180
#      BETADOT TCDU/180 = (-SA PREL + CA RREL) TCDU/180
#      ALFADOT TCDU = (QREL + SB PHIDOT) TCDU/180

ATTRATES  LXCH   BANKRUPT      # CONTINUE HERE VIA T5
EXTEND    # TASK MAY BE SKIPPED AT RESTART.
QXCH      QRUPT
CA        SR
DOUBLE
TS        CM/SAVE
# DOES NOT PROTECT TEMK, SQ IN SPSIN/COS

CA        QREL
AD        ALFA/180
TC        ANGOVCOR
TS        ALFA/180
TC        SPCOS
TS        CALFA      # CALFA
TS        PHIDOT

EXTEND
MP        PREL
XCH       PHIDOT      # CA PREL
EXTEND
MP        RREL        # CA RREL
TS        BETADOT

CA        ALFA/180
TC        SPSIN
TS        SALFA      # SIN(ALFA)

EXTEND
MP        RREL        # SA RREL
```

```

ADS      PHIDOT      # CB PHIDOT, SAVED.

CS      SALFA
EXTEND
MP      PREL
ADS      BETADOT      # SAVE BETADOT TCDU/180
ADS      BETA/180      # BETA DONE.

TC      SPSIN
EXTEND
MP      PHIDOT      # NEGLECT CB IN CB PHIDOT
AD      ALFA/180
TC      ANGOVCOR
TS      ALFA/180      # ALFA DONE.

# Page 1074
COM
AD      ALFACOM
TC      ANGOVCOR      # JUST IN CASE ...
TS      AK1
TS      QAXERR      # FOR PITCH FDAI AND EDIT.

CA      PHIDOT      # PHIDOT TCDU/180, NEGLECTING CB
AD      ROLL/180
TC      ANGOVCOR
TS      ROLLTM      # ROLL/180 FOR TM.
TS      ROLL/180      # ROLL DONE.

# START YAW AUTOPILOT HERE.  RATE DAMPING WITH ENFORCED COORDINATED ROLL MANEUVER.

CS      BETA/180      # IF IN ATM, SAVE 'RAXERR' FOR TM DNLST.
AD      BETACOM
TS      RAXERR      # IF OUTSIDE ATM, USE TM REGISTER 'RAXERR'
                        # AS A TEMPORARY. (DAP OPERATION IS IN INTER
                        # IS OK.) FINAL C(RAXERR) AT END OF DAP CYCL
                        # BE R-AXIS ERROR.

CA      BIT3      # .05GSW = 102D BIT3      SW=0, LESS .05G
MASK    CM/FLAGS      # SWITCH =1, GREATER THAN .05 G
EXTEND
BZF     EXDAP      # IF G LESS THAN .05
CS      ONE      # IF G GEQ THAN .05
TS      CMDAPMOD      # SAVE -1 FOR USE IN CM/RCS

TS      AK1      # TO ZERO PITCH AND YAW FDAI NEEDLES
TS      AK2      # IN ATM. (MODE ==-1)

```

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```

CS      PREL      # YAW ERROR = RREL - PREL TAN(ALFA)
EXTEND
MP      SINTRIM   # LET SIN(-20) BE APPROX FOR TAN(-20)
AD      RREL
TC      2D/SDZ    # GO TEST DZ.  GET TAG: +0 IF IN DZ
INDEX   A         # +/- 1 IF NOT
CAF     YJETCODE

TS      JETEM

# START PITCH AUTOPILOT HERE.  RATE DAMPING ONLY.

CA      QREL
TC      2D/SDZ
EXDAPIN INDEX A   # COME HERE FROM EX ATM DAP
CAF     P/RJCODE
ADS     JETEM     # COMBINE ALL NEW BITS.

# Page 1075
EXTEND      # DOES NOT REQUIRE SAVING OLD CODES.
WRITE PYJETS # SET PYCHAN TO DESIRED BIT CONFIG.

CCS      JETAG
TC      CM/RCS
TC      CM/FDAI
TC      CM/FDAIR -1 # (JETAG=-1 EQUIVALENT TO CMDAPMOD=+1)

# Page 1076
# DEAD ZONE LOGIC USED BY ENTRY DIGITAL AUTOPILOTS.

3DDZ     CCS      A      # YAWLIM=1.0-3/180=16384-273=16111
          AD      YAWLIM
          TCF     DZCOM
          AD      YAWLIM
          TCF     DZNOCOM

BIASEDZ   TS      JETEM2  # BIASED DZ FOR EXT ATM DAP.
          CCS      A      # SAVE RATE/180.  ERROR/180 IS IN L.
          CS      CM/BIAS  # START ERROR DZ.
          TCF     +2      # = .6/180
          CA      CM/BIAS
          AD      L      # BIAS THE ERROR.
          LXCH    Q      # SAVE CALLER'S RETURN ADDRES.
          TC      3DDZ    # GO GENERATE THE ERROR BIT.
          DXCH    L      # BIT TO L, RESTORE CALLER'S Q.
```

4D/SDZ	CCS	JETEM2	# CAME HERE IN EXT ATM. C(L) = ERROR BIT
	AD	4D/SLIM	# IF RATE GEQ 4D/S, SET L=0 AND TAKE
	TCF	+2	# JET BITS ACCORDING TO SGN OF RATE.
	AD	4D/SLIM	
	TS	A	
	TCF	+2	# RATE OK. CONTINUE
	ZL		# RATE GEQ 4 D/S. OVER RIDE ERROR BIT
	XCH	JETEM2	# AND CONTINUE TO GET SIGN.
2D/SDZ	CCS	A	# COME HERE TO TEST IF A WITHIN 2DEG/S DZ
	AD	YDOTLIM	# 1.0 - YDOT DZ (OR PDOT)
	TCF	+3	
	AD	YDOTLIM	# YDOT DZ = 2 DEG/SEC
DZCOM	COM		
DZNOCOM	TS	JETEM +1	# GENERATE TAG, SET C(A)= +-1 OUTSIDE DZ
	CA	ZERO	# SET C(A) = +0 INSIDE
	TC	Q	

# Page 1077

# EXTRA ATMOSPHERIC DIGITAL AUTOPILOT

#

# 1.	IF ABS(CALF) -C(45) POS, USE	IF CALFA POS, CMDAPMOD= +0
#	BETA: YAW ERROR = SGN(CALF) (BETACOM -BETA)	IF CALFA NEG, CMDAPMOD= -0
#	RATE = BETADOT	IF CMDAPMOD = -0, RATE = RREL
#	R-AXIS = CONTROL	
#	ROLL: ROLL ERROR = SGN(CALF) (ROLLC - ROLL)	IF CMDAPMOD = -0, RATE DAMP
#	RATE = PREL	
#	P-AXIS = CONTROL	
# 2.	IF C(45) GEQ CALFA GEQ -C(45), USE	CMDAPMOD = +1
#	BETA: ROLL ERROR = SGN(-SALF) (BETACOM -BETA)	
#	RATE = BETADOT	
#	P-AXIS = CONTROL	
#	ROLL: YAW ERROR = SGN(SALF) (ROLLC - ROLL)	RATE DAMP ONLY.
#	RATE = RREL	
#	R-AXIS = CONTROL	
# 3.	FOR ALL CASES, USE	
#	ALFA: PITCH ERROR = (ALFACOM - ALFA)	
#	RATE = QREL	
#	Q-AXIS = CONTROL	

EXDAP	TS	CMDAPMOD	# +0 FOR NOW
	CCS	CALFA	



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```
AD      C45LIM      # =1.0-COS(45)
TCF     +2
AD      C45LIM
TS      A
TCF     EXDAP2      # HERE IF ABS(CALFA) L COS(45)

CCS     CALFA      # |CALFA| > 0.707
TCF     +1          # CONTINUE IF POS; GO TO EXDAP4 IF NEG.

CCS     P63FLAG      # VALID VALUES ARE: -1, +1, +0.
TC      EXDAP4
TC      +2
TC      EXDAP4
TC      PHASCHNG      # SINGLE PASS THROUGH HERE.
OCT     40334
CS      ONE
TS      P63FLAG      # SET FLAG TO ASSURE SINGLE PASS.
CA      NSEC
TC      WAITLIST
EBANK=  AOG
2CADR   WAKEP62      # CALL TO TERMINATE P62 IN N SEC.

# Page 1078

# 65 DEG/ 3DEG/SEC = 21 SEC NOMINAL
# TRANSIT TIME FROM ALFA=45 TO ALFA TRIM.

EXDAP4   CCS      JETAG      # ROLLJET INTERFACE TEST BETWEEN .1 SEC
TCF      EXDAP3
TCF      EXDAP3
CA      ZERO
EXTEND
WRITE    ROLLJETS      # TURN OFF ROLL JETS IF ON AND WAIT
TS      JETAG          # UNTIL START OF 2 SEC CM/RCS CYCLE
# RESTORE PROPER VALUE +0

EXDAP3   CCS      CALFA      # ROLL FDAI WILL BE IN ERROR UNTIL NEXT CM/RCS CALL.
CA      RAXERR          # HERE IF ABS(CALFA) GEQ COS(45)
TCF     EXDAP1          # C()= BETACOM - BETA/180
CS      ZERO
TS      CMDAPMOD      # FOR CM/RCS
CS      RAXERR          # COMPLEMENT OF YAW ERROR.
EXDAP1   TS      RAXERR      # FOR YAW FDAI
TS      AK2            # WANT RAXERR FOR TM.
TS      L
CCS     CMDAPMOD      # COORDINATE BETA CONTROL.
TC      +3            # C(CMDAPMOD) CAN BE +1, +0, OR -0.
CA      ONE           # USE BETADOT TO COORD IN MODE +0
```

```

INDEX  A          # OTHERWISE USE RREL.
CA      RREL
TC      BIASEDZ   # GO TEST DZ  +0 IF IN DX, +-1 OTHERWISE
                    # IF GEQ 4D/S, SET ERROR BIT IN L=0

EXTEND
ROR     LCHAN     # L HAS BETA BIT
INDEX   A
CAF     YJETCODE
TS      JETEM

CA      QAXERR    # ALFA ERROR.
TS      L
CA      QREL      # FOR ALPHADOT USE QREL
TC      BIASEDZ
EXTEND
ROR     LCHAN
TCF     EXDAPIN   # CONTINUE ON IN DAP

EXDAP2  INCR      CMDAPMOD  # SET CMDAPMOD TO +1

CS      ONE       # INDICATE CHANGE FROM .1 SEC UPDATE TO
TS      JETAG     # TO 2 SEC FOR ROLL JETS. (IF CMDAPMOD
                    # =0 AND JETAG =-1, QUENCHES JETS IF ON)

CCS     P63FLAG   # IF FLAG WAS +1, SET =0.
TS      P63FLAG

# Page 1079

NOOP

CCS     SALFA     # BETA CONTROL WITH P JETS
CS      RAXERR    # B()= BETACOM - BETA/180
TCF     +2
CA      RAXERR
TS      PAXERR1   # TEMP SAVE.  ERROR/180
EXTEND
MP      HALF      # CM/FDAI EXPECTS ERROR/360.
XCH     PAXERR1   # ERROR/360 FOR FDAI, GET ERROR/180.
TS      L
CCS     SALFA
CS      BETADOT   # USE BETADOT TO COORD IN MODE +1
TC      +2
CA      BETADOT
TC      BIASEDZ
EXTEND
ROR     LCHAN
INDEX   A

```

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	CAF	P/RJCODE	# GET ROLL CODE
	EXTEND		# ROLL CONTROL WITH YAW JETS.
	WRITE	ROLLJETS	# WE'LL SKIP REGULAR ROLL SYST
	CA	ROLLHOLD	# ROLL/180 AT CM/DAPON TIME.
	EXTEND		
	MSU	ROLL/180	# 1'S COMPL, BUT SO WHAT'S A BIT?
	TS	L	# FORCE A LIMIT CYCLE IN YAW RATE.
	CCS	SALFA	
	CA	L	# TO REMOVE ITS BIASING EFFECT ON M DOT.
	TC	EXDAP1	
	CS	L	
	TC	EXDAP1	
NSEC	DEC	2100	# 65 DEG/ 3 DEG/SEC
			# IF NSEC IS CHANGED, REMEMBER TO CHANGE 4.33SPOT.
4D/SLIM	DEC	16348	# 1.0 -4/180 D/S = 4/1800 EXP 14
YDOTLIM	DEC	16366	# =1.0 - YDOT DZ= 16384 -18
			# YDOT DZ = YDOT TCDU/180 = 2/1800 EXP 14
CM/BIAS	DEC	55	# =.6/180 B14 = 55
YAWLIM	DEC	16055	# YAWLIM=1.0-3.6/180=16384-329=16055
C45LIM	DEC	.29289	# =1.0-COS(45)
SINTRIM	DEC	-.34202	# SIN(-20) (FOR NOMINAL L/D = .3)
COSTRIM	DEC	.93969	# COS(-20) (FOR NOMINAL L/D = .3)

# TO MAKE DAP INSENSITIVE TO PITCH ERRORS DUE TO ACCUMULATED NAV ERRORS, USE NOMINAL VALUE (-20)  
# USED DURING ATMOSPHERIC COORDINATION. OUTSIDE ATMOSPHERE, NAV ERRORS WILL BE SLIGHT, BUT ALF  
# FROM TRIM, SO USE ON-BOARD ESTIMATES.

# Page 1080

# JET CODE TABLES FOLLOW

	OCTAL	00120	# POS Y	
YJETCODE	OCTAL	00000	# RCS JET BITS	
	OCTAL	00240	# NEG Y	
	OCTAL	00005	# POS R JET BITS	ALSO POS P JET BITS
P/RJCODE	OCTAL	00000		
	OCTAL	00012	# NEG R	ALSO NEG P

# Page 1081

# RCS THIS SECTION IS ENTERED EACH 2 SEC BY WAITLIST CALL FOLLOWING A DELAY OF 1.2 SE  
# THE TASK SETJTAG SETS A FLAG IN JETAG TO SIGNIFY THAT ROLL UPDATE IS DUE. IN ROUGHLY 5 C  
# EXECUTED AND JETAG WILL CAUSE CM/RCS TO ACT ON ROLLC IMMEDIATELY THEREAFTER. THE  
# TASK SAVES THE CALL TIME SO THAT CM/RCS CAN DETERMINE HOW MUCH OF THE 2 SEC INTERVAL REMAINS

# NEXT UPDATE.

SETJTAG	CS	TIME1	# SAVE NOMINAL UPDATE TIME FOR SYNCH
	TS	TUSED	
			# THE 5 CS APPEARS IN TIMETST.
	CA	ONE	# RATHER THAN INCR, FOR SAFETY
	TS	JETAG	# SET JETAG=1 TO CAUSE CM/RCS TO BE
	TC	PHASCHNG	
	OCT	00001	
	TC	TASKOVER	# EXECUTED AFTER NEXT BODYRATE UPDATE

# PREDICTIVE ROLL SYSTEM ENTRY STEERING PROVIDES ROLL COMMAND IN LOC ROLL. 7  
 # TRAJECTORY TO THE ORIGIN IN PHASE PLANE (X,V). PROGRAM ENTERS JET ON AND OFF CALLS  
 # THE DESIRED TRAJECTORY. ONLY THOSE CALLS WHICH CAN BE EXECUTED WITHIN THE INTERVAL  
 # WTLST, THE REMAINDER ARE RECONSIDERED AT NEXT UPDATE.

HALFPR EQUALS NEG1/2 +1

# CLEAR JETAG BEFORE TIMETST. SET TO +0 TO S  
 # ROLL DAP CALLED. IN EVENT OF RESTART, BODY  
 # MAY MISS A CYCLE. CM/RCS WILL MISS A CYCLE  
 # IF A RESTART OCCURS AFTER TIMETST COMMENCES

CM/RCS	CS	ONE	
	TS	JNDX	# SET NDX FOR POS ROLL, AND CHANGE LATER
	CS	2T/TCDU	# ROLLDOT = DELAOG + DELAIG SINM =DEL R
	EXTEND		
	MP	PREL	# DELR/180 = RDOT TCDU/180 = RDOT/1800
	AD	L	# -2 RDOT T/180 IN L
	TS	-VT/180	# SAVE -2VT/180 HERE
	CS	ROLL/180	
	TS	SR	# SAVE (-R/180) /2
	CS	CM/FLAGS	
	MASK	BIT4	# LATSW = 101D BIT4
	EXTEND		# ROLL OVER TOP \$
	BZF	GETLCX	# NO, TAKE SHORTEST PATH
	ADS	CM/FLAGS	# YES, ENFORCE ROLL OVER TOP.. (BIT =0)
	CA	ROLLC	# (ROLLC/180) /2
	AD	SR	# -(R/180) /2
	XCH	LCX/360	# DIFFERENT X REQD HERE. DISCONT AT 180.
	TCF	COMPAT	# POSSIBLE OVFL ABOVE.

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GETLCX

CA POS1/2  
DOUBLE  
AD ROLLC  
XCH LCX/360

# FORM RCOM/360

# IGNORE POSSIBLE OVFL.

CA SR  
AD NEG1/2  
AD NEG1/2  
XCH LCX/360  
ADS LCX/360

# FORM -R/360

# IGNORE OVFL

# -R/360

#  $LCX/360 = RCOM/360 - R/360$  RANGE (-1,1)

# DOES  $SGN(-VT) (VT/180) (VT/180) (180/(4 A1 TT COSALFA)) + X/360 + SGN(X) / 2$  OVFL ?

CCS -VT/180  
AD ONE  
TCF +2  
AD ONE

# TAKE SHORTEST ANGULAR PATH

# (BASED ON SINGLE JET ACCELERATION)

EXTEND  
MP -VT/180

#  $C(-VT/180) = -2 VT/180$

EXTEND  
MP 1/16A1

#  $= 180/(16 A1 TT)$

EXTEND  
DV CALFA  
TS L  
CCS LCX/360  
CAF POS1/2  
TCF +2

CS POS1/2  
AD LCX/360  
AD L  
TS L

# IS LCX/360 LESS THAN 180 DEGS \$

TCF COMPAT

# YES, GO ON.

TRTAGXPI

INDEX A

# NO, SHIFT X BY - SGN(X) 2 PI

CS HALFPR

# +A YIELDS -1/2

DOUBLE

ADS LCX/360

COMPAT

CA LCX/360

# CORRECT FOR ASSUMED COORD TURN.

EXTEND

MP CALFA

# COS ALFA

TS LCX/360

# SCALED LCX OK HERE.

CCS CMDAPMOD

# FOUR POSSIBILITIES HERE

TC DZCALL1

# EXIT, SETTING JETAG=0. (C(A)=0)

# ALL 3 AXES ALREADY DONE.

```

TC      +1      # G LESS THAN .05.  CA POS. CONTINUE
CA      LCX/360  # G GEQ .05.  CONTINUE IN CM/RCS
TS      LCX/360  # CMDAPMOD=-0.  DAMPING ONLY.  SET LCX=0
TS      ERRORZ   # INITIAL ROLL ERROR (UNREFLECTED) FOR TM.
TS      PAXERR1  # SAVE LCX FOR FDAI AND EDIT.  (/360)

# Page 1083

CA      -VT/180  # GET - 2 VT/180
TS      SR
CA      SR      # GET -VT/180, LEAVE -VT/360 IN SR FOR DZ
TS      -VT/180E #
XCH     -VT/180  # NOW CONTENTS OF -VT/180 AS LABELED
EXTEND
MP      -VT/180  # B(A) = -ZVT/180
EXTEND
MP      180/8ATT
TS      VSQ/4API

# IS SGN(VT) ( (180/4A1 TT) VT/180 VT/180 - .5 BUFLIM/360 ) -X/360 - .5 BUFLIM/360  P

WHICHALF DOUBLE      # FOR SECOND BURN, A1
COM
AD      BUFLIM      # =BUFLIM/(2 360)
TS      L
CCS     -VT/180
CS      L
TCF     +2
CA      L
AD      LCX/360
AD      BUFLIM
EXTEND
BZMF    REFLECT     # POINT (X,V) IN LHP.

# IS SGN(VT) ( (180/4A1 TT) VT/180 VT/180 - .5 BUFLIM/360 ) -X/360 + .5 BUFLIM/360  M

COM
AD      BUFLIM
AD      BUFLIM
EXTEND
BZMF    DZ1         # POINT (X,V) IN RHP

# IS POINT WITHIN VELOCITY DZ?

CS      VSQMIN      # IS VSQ/4API - (VSQ/4API) MIN NEG?
AD      VSQ/4API
EXTEND
BZMF    DZCALL      # YES.

```

# POINT IS IN BUFFER ZONE. THRUST TO X AXIS.

CS JNDX  
TS JNDX1  
TC OVRLINE1

REFLECT CS -VT/180 # RELFECT LHP INTO RHP REL TO TERM CONTR  
TS -VT/180  
TS SR # -VT/360 SAVED FOR DZ.

# Page 1084

CS LCX/360  
TS LCX/360  
CS JNDX  
TS JNDX

# IS VSQ/4API - (VSQ/4API) MIN NEG?

DZ1 CS VSQMIN # IS VSQ/4API - (VSQ/4API) MIN NEG \$  
AD VSQ/4API  
EXTEND  
BZMF DZ2 # YES, GO TEST FURTHER.  
TCF MAXVTEST # NO

# IS X/360 - XMIN/360 -VT/360 NEG?

DZ2 CS XMIN/360 # XMIN/360 = 4/360  
AD LCX/360  
AD SR # C(SR) = -VT/360  
EXTEND # IS X/360 - XMIN/360 -VT/360 NEG \$  
BZMF DZCALL # YES, IN DZ. EXIT SETTING JETAG=0.

# IS XD/360 - VM/360K - XS/360 POS?

MAXVTEST CS JNDX  
TS JNDX1 # NOW CAN SET JNDX1 FOR TON2 JETS.  
CS XS/360 # XS/360 = (XMIN -YMIN/K) /360  
AD VSQ/4API  
AD LCX/360  
TS XD/360 # XD/360= X/360 +VSQ/4API X INTERCEPT  
# BUT C(XD/360) = (XD - XS) /360  
AD -VM/360K # X INTERCEPT FOR MAX V (VM)  
COM  
EXTEND  
BZMF MAXVTIM1 # YES, THRUST TO VM  
CA XD/360

```

EXTEND
MP      KTRCS
DDOUBL                                     # GO SAVE PREDICTED DRIFTING VELOCITY.

TC      GETON1                             # INSURE THAT Q IS POS AS TAG.
MAXVTIM1 EXTEND
ZQ                                             # SET +Q AS TAG
CS      -VMT/180
GETON1  TS      VDT/180                     # VDT/180 OR VMT/180
AD      -VT/180
DOUBLE
EXTEND
MP      180/8ATT
TS      TON1                               # TON1 / 4T
# Page 1085
EXTEND
BZMF    OVRLINE
TC      GETON2                             # RESET Q POS IF CAME FROM MAXVTIM1

OVRLINE CCS      Q
TCF     OVRLINE1
MAXVTIM2 CA      JNDX1                     # ABOVE VM, SO THRUST DOWN
TS      JNDX
CS      TON1
TCF     OVRLINE2 +1

OVRLINE1 CS      -VT/180                   # DRIFT AT V
TS      VDT/180
OVRLINE2 CA      ZERO
TS      TON1
GETON2  CA      VDT/180                   # VDT/180, OR VMT/180 OR VT/180
DOUBLE
EXTEND
MP      180/8ATT
DOUBLE
TS      TON2                               # FOR SECOND BURN, A1
                                           # = TON2 / 4T

COM
EXTEND
BZMF    GETOFF
TS      TON2
CA      JNDX
TS      JNDX1

GETOFF  CS      TON2                       # TON2 / 4T
EXTEND

```



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```
MP      VDT/180      # VDT/180, OR VT/180, OR VMT/180.
TS      XD/360      # USE AS TEMP
CS      VDT/180
EXTEND
BZF     TOFFOVFL     # OMIT THE DIVIDE IF DEN = 0.
AD      -VT/180
EXTEND
MP      TON1         # TON1 / 4T
AD      XD/360      # TEMP = -VDT/180 / 2 TON2
AD      LCX/360
ZL
XCH     L            # TEST THE DIVIDE
EXTEND
DV      VDT/180
EXTEND
BZF     GETOFF2      # DIVIDE OK

TOFFOVFL  CA      2JETT      # OVFL, USE 2T FOR CONVENIENCE.
          TCF      TIMSCAL

# Page 1086
GETOFF2   XCH     L            # GET NUMERATOR.
          EXTEND
          DV      VDT/180     # C(A) = TOFF / 2T
          EXTEND
          MP      2JETT
TIMSCAL   TS      TOFF      # IN CS

          CAF     4JETT
          EXTEND
          MP      TON1      # C(TON1) = TON1 / 4T
          TS      TON1      # IN CS

          CAF     4JETT
          EXTEND
          MP      TON2      # C(TON2) = TON2 / 4T
          TS      TON2      # IN CS

          CA      ZERO      # CANNOT REDO AFTER TIMETST. TUSED GONE
          TS      JETAG     # SET +0 TO SHOW ROLL DAP CALLED.

          # CAUSE THE TM OF BODY RATES VIA UPBUFF TO BE
          # INITIALIZED. ALSO CAUSE NEEDLES TO BE DONE ON EXIT
          # AND ON ALTERNATE PASSES THROUGH CM/DUMPR.

          CA      ONE
```

TS SW/NDX

# Page 1087

# TIMETEST SECTION FOR RCS

#

# ENTER WITH THREE TIME INTERVALS AND THE CORRESPONDING JET CODE INDEXES IN ERASABLE

# JNDX1. SECTION PROCESSES TIME INTERVALS FOR WTLST CALLS AND ASSURES THAT WTLST CALLS

# (1) FOR POS INTERVALS GREATER THAN A SPECIFIED MINIMUM (HERE CHOSEN AS 2 CS) AND

# (2) FOR THE INTERVALS THAT WILL BE EXECUTED WITHIN THE TIME REMAINING IN THE SAMPLE

# TIMETST ESTABLISHES 6 LOCS CONTAINING JET CODES AND CORRESPONDING TIME INTERVALS.

# TOFF, TBITS, TON2, T2BITS. OF THESE THE FIRST 2 LOCS ARE TEMPORARY, FOR IMMEDIATE

# SECTION JETCALL BELOW PROCESSES THIS LIST.

TIMETST	CA	TIME1	# CORRECT FOR POSSIBLE TIME1 OVFL.
	AD	POS1/2	
	AD	POS1/2	# OVFL GUARANTEED.
	ADS	TUSED	# B(TUSED) ==TUSED ==-OLTIME1
	CA	-T-3	# ==-T +2 -5 (SEE SETJTAG)
			# THE +2 REQUIRED FOR PROPER BRANCH.
	ADS	TUSED	# TUSED = TIME(K)-TIME(K-1)-T+2
	CS	TWO	# USE 2 SINCE TIME3 UNCERTAIN TO 1
	AD	TON1	
	EXTEND		
	BZMF	TIMETST1	
	INDEX	JNDX	
	CAF	P/RJCODE	
	TS	T1BITS	
	CA	TON1	
	ADS	TUSED	
	EXTEND		
	BZMF	TOFFTEST	
	CA	ZERO	
	TCF	TIMETST3	
TIMETST1	CS	ONE	
	TS	TON1	
TOFFTEST	CS	TWO	
	AD	TOFF	
	EXTEND		
	BZMF	TIMETST2	
	CA	TOFF	
	ADS	TUSED	
	EXTEND		
	BZMF	TON2TEST	

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```

                                CA      ZERO
                                TCF     TIMETST4
TIMETST2                       CS      ONE
                                TS      TOFF
TON2TEST                       CS      TWO
                                AD      TON2
                                EXTEND
                                BZMF    TIMETST5
# Page 1088
                                INDEX   JNDX1
                                CAF      P/RJCODE
                                TS      T2BITS
                                CA      TON2
                                ADS     TUSED
                                EXTEND
                                BZMF    JETCALL1
                                CA      ZERO
                                TCF     TIMETST5 +1
TIMETST3                       TS      TON1
                                CS      ONE
TIMETST4                       TS      TOFF
TIMETST5                       CS      ONE
                                TS      TON2
```

# SECTION JETCALL EXAMINES CONTENTS OF JET TIMES IN LIST, ESTABLISHES WTLST ENTRIES, AND EXEC  
# JET CODES. A POSITIVE NZ NUMBER IN A TIME REGISTER INDICATES THAT A WTLST CALL IS TO BE MADE  
# EXECUTED. A +0 INDICATES THAT THE TIME INTERVAL DOES NOT APPLY, BUT THE CORRESPONDING JET B  
# EXECUTED. A NEG NUMBER INDICATES THAT THE TIME INTERVAL HAS BEEN PROCESSED. IN EVENT OF +0  
# SUBSEQUENT TIME REGISTER IS EXAMINED FOR POSSIBLE ACTION. THUS JET BITS TO BE EXECUTED MAY C  
# THAN ONE REGISTER.

```

JETCALL1                       CA      ZERO
                                TS      OUTTAG
                                TS      NUJET
                                TS      TBITS
                                DXCH    TON1
                                CCS     A
                                TCF     JETCALL2      # CALL WTLST
JETCALL3                       LXCH    NUJET        # WTLST ENTRIES COME HERE FROM JETCALL
                                CS      ONE
                                DXCH    TOFF
                                CCS     A
                                TCF     JETCALL2      # CALL WTLST
                                LXCH    NUJET
                                CS      ONE
                                DXCH    TON2
```

```

      CCS      A
      TCF      JETCALL2      # CALL WTLST
      LXCH     NUJET
      TC       JETACTN      # C(A) = +0
JETCALL2     XCH      L      # SAVE JET BITS FOR AFTER WTLST CALL
      ADS      NUJET
      XCH      L
      AD       ONE          # RESTORE FOR CCS
      TC       WAITLIST
      EBANK=   AOG
      2CADR    JETCALL

JETACTN      CA       NUJET      # COME HERE WHEN DESIRED JET CODE IS KNOWN
# Page 1089

      EXTEND          # NO NEED TO SAVE OLD CODES
      WRITE     ROLLJETS      # SET RCHAN TO NEW BIT CONFIG.

      CCS      OUTTAG
      TC       TASKOVER
ROLLDUMP     TC       CM/FDAIR

      # EDIT DUMP AT ABOVE LOCATION.

# WAITLIST ENTRIES COME HERE.

JETCALL      CAF      BIT2      # CM/DSTBY =103D BIT2
      TS       OUTTAG      # SIGNIFY WTLST ENTRY
      MASK     CM/FLAGS     # IS SYSTEM DISABLED $
      EXTEND
      BZF      JETACTN +1    # YES, QUENCH ROLL JETS, IF ON AND EXIT.
      ZL              # NO, CONTINUE.
      TCF      JETCALL3     # C(A) POS, C(L) = +0

# DEAD ZONE ENTRIES COME HERE.

DZCALL      CS       CMDAPMOD    # POSSIBLE VALUES OF CMDAPMOD: -1, +0, -0.
      MASK     BIT1
      TS       L          # C(L)=0 FOR -0: C(L)=1 FOR -1 OR +0.
      INDEX    A          # ERASABLE ORDER: ROLLTM, ROLLC, ROLLC +1.
      CA       ROLLTM      # GET ROLL/180 OR ROLLC (/360).
      INDEX    L
      TS       A          # IF C(L)=1, STORE 'ROLLC' IN 'L'.
      AD       L          # (BOTH MUST BE SCALED DEG/180)
      TC       ANGOVCOR    # C(A)=ROLL/180 OR 2 ROLLC.
      TS       ROLLHOLD    # IF CMDAPMOD =-0, SAVE ROLL ANGLE.
      #         OTHERWISE, SAVE ROLL COMMAND.

```

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```

                                CA      ZERO      # COME HERE IF IN DZ, AND CANCEL JETS.
                                EXTEND      # INHINT NOT NEEDED HERE.
                                WRITE    ROLLJETS  # TURN OFF ALL ROLL JETS.
                                TS        VDT/180  # SET =0 TO SHOW IN DEAD ZONE.
DZCALL1      TS        JETAG      # COME HERE WITH C(A)=0.
                                TC        ROLLDUMP
```

# Page 1090

# CM ENTRY FDAI DISPLAY

#

# CALCULATE BY INTEGRATION THE ROLL ERROR BETWEEN THE 2 SEC CM/RCS UPDATES. DISPLAY ATTITUDE E

# ATM DAP: DISPLAY ONLY ROLL ATTITUDE ERROR.

# EXT ATM DAP: PRESENT 3 ATTITUDE ERRORS RELATIVE TO THE APPROPRIATE BODY AXES EACH .1

# ROLL ROLLC-ROLL

# PITCH ALFAC-ALFA

# YAW BETAC-BETA

#

# DURING ENTRY, THE FDAI NEEDLES HAVE FULL SCALE OF 67.5 DEG IN ROLL AND 16.875 DEG IN PITCH AN

# THE SUBROUTINE NEEDLER EXPECTS (ANGLE/180) AND SCALES TO 16.875 DEG FULL SCALE.

CM/FDAI CS PHIDOT # COME HERE EACH .1 SEC. (CMDAPMOD=+1 COMES BELOW)

EXTEND # INTEGRATE ROLL ERROR 'TWEEN 2SEC UPDATES

MP CALFA # FOR ASSUMED COORDINATION.

EXTEND

MP HALF

ADS PAXERR1 # ROLL ERROR/360. OVFL OK.

# EDIT DUMP AT ABOVE LOCATION.

CM/FDAIR CA HALF

EXTEND

MP PAXERR1 # FULL SCALE FOR FDAI (ROLL) IS 67.5 D

TS PAXERR # .25 (ROLL ERROR/180) FOR FDAI NEEDLE.

# PROGRAM TO FILE BODY RATES FOR TM ON ONE PASS AND

# TO UPDATE THE NEEDLE DISPLAY ON THE NEXT.

# SYNCHRONIZATION WITH CM/RCS IS USED SO THAT THE TM

# IS DONE WITH THE ROLL SYSTEM AND NEEDLES START ON

# THE SUBSEQUENT PASS.

CM/DUMPR CS SW/NDX # COMBINED ALTERNATION SWITCH AND FILE

TS SW/NDX

EXTEND # INDEX

BZMF CMTMFILE # FILE STARTS WITH SW/NDX +1 AND GOES TO

# ENDBUF.

# INDEX IS POS FOR NEEDLES.

TC IBNKCALL  
CADR NEEDLER

TC CM/END

# INDEX IS NEG FOR TM FILE

CMTMFILE AD THREE  
EXTEND  
BZMF SAVENDX

# Page 1091

CA TIME1  
TS CMTMTIME  
CS THIRTEEN  
SAVENDX TS SW/NDX  
EXTEND  
DCA PREL  
INDEX SW/NDX  
DXCH ENDBUF -1  
CA RREL  
INDEX SW/NDX  
TS ENDBUF +1

# INITIALIZE THE TM LIST IN UPBUFF.

# INITIALIZE COUNTER

# A NEGATIVE NUMBER.

CM/END CA CM/SAVE  
TS SR

# DOES NOT PROTECT TEMK, SQ IN SPSIN/COS

EXTEND  
DCA T5IDLER2  
DXCH T5LOC  
TC RESUMET5IDLER2 EBANK= T5LOC  
2CADR T5IDLOC# DEFINE THE FOLLOWING 17D REGISTERS IN UPBUFF  
# USED TO TELEMETER CM VEHICLE BODY RATE INFO  
# THE INFORMATION IS FILED EACH 0.2 SEC, GIVING  
# DATA POINTS EACH 1 SEC. TM LIST IS READ TWICE  
# EACH 2 SECONDS.

#

# THE SEQUENCE IS: SP TIME INIT

# SWITCH ALSO

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#	P	ROLL RATE
#	Q	PITCH RATE
#	R	YAW RATE
#	ETC.	

```
#CMTMTIME      =      UPBUFF
#SW/NDX         =      UPBUFF +1
#ENDBUF         =      UPBUFF +16D
```

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# SPACER

#

# CONSTANTS USED IN THE ROLL CONTROL SYSTEM:

# CONSTANTS ARE THE FOLLOWING: A = 9.1 DEG/SECSQ, VM = 20 DEG/SEC, T = 2 SEC, TCDU = .1 SEC,  
# XMIN = 4 DEG, VMIN = 2 DEG/SEC, K = .25, A1 = 4.55 DEG/SECSQ, VI = 1 DEG/SEC, INTERCEPT WITH  
# XBUF = 4DEG

-T-3	DEC	-203	# CS
VSQMIN	DEC	.61050061 E-3	# VSQ MIN/4 A PI = 4/(4 (9.1) 180)
2T/TCDU	=	OCT50	# T/TCDU EXP-14 TCDU = .1SEC
180/8ATT	DEC	.61813187	# 180/(8 (9.1) 4)=(180/ATT) EXP -3
-VM/180	=	-VM/360K	# = 20 (2) / 180
2JETT	=	4SECS	# CS 2 (2) 100 INTEGER
4JETT	DEC	800	# CS 4 (2) 100 INTEGER
XMIN/360	DEC	182	# XMIN/360 = 4/ 360 EXP 14 = 182 INTEGER
-VM/360K	DEC	-.22222222	# =-20/( 360 (.25))
1/16A1	=	180/8ATT	# 1/16A1 = 180/(16 A1 TT)
			# = 180/(16 4.55 4)
XS/360	DEC	91	# = (XMIN +VI (T-1/K))/360 = 2/360 EXP 14
BUFLIM	=	XS/360	# 4/(2 360)
KTRCS	=	HALF	# KT = (.25) 2 = .5

# \*\*\* END OF TVCDAPS .011 \*\*\*

This code is written to file src/CM-ENTRY-DIGITAL-AUTOPILOT.s.

## A.15 CONIC SUBROUTINES

```

232  <src/CONIC-SUBROUTINES.s 232>≡
      # Copyright:      Public domain.
      # Filename:       CONIC_SUBROUTINES.agc
      # Purpose:        Part of the source code for Colossus 2A, AKA Comanche 055.
      #                 It is part of the source code for the Command Module's (CM)
      #                 Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:     yaYUL
      # Contact:        Ron Burkey <info@sandroid.org>.
      # Website:        www.ibiblio.org/apollo.
      # Pages:          1262-1308
      # Mod history:    2009-05-08 RSB   Adapted from the Colossus249/ file of the
      #                 same name, using Comanche055 page images.
      #                 2009-05-20 RSB   Corrected: Fixed four interpreter
      #                 instructions.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 055 of AGC program Comanche by NASA
      #       2021113-051.  10:28 APR. 1, 1969
      #
      #       This AGC program shall also be referred to as
      #       Colossus 2A

      # Page 1262
      # PROGRAM DESCRIPTION -- ENTIRE CONIC SUBROUTINE LOG SECTION      DATE -- 1 SEPTEMBER 1969
      # MOD NO. -- 0                                                    LOG SECTION -- CONIC
      # MOD BY KRAUSE                                                    ASSEMBLY -- COLOSSUS
      #
      # FUNCTIONAL DESCRIPTION --
      #       THE FOLLOWING SET OF SUBROUTINES SOLVE VARIOUS PROBLEMS INVOLVING THE TRAJECTORY OF A POINT MASS
      #       INVERSE-SQUARE FORCE ACTING ON A POINT MASS, AS OUTLINED IN THE CMC AND LGC DOCUMENTS.
      #       5.5.1.2. A GENERAL USAGE POINT-OF-VIEW WAS TAKEN IN FORMULATING, MECHANIZING AND TESTING THE PROGRAMS
      #       RATHER THAN OPTIMIZING EACH FOR A PARTICULAR USE. THEREFORE, MULTIPLE USAGE OF THE PROGRAMS IS
      #       INVOLVING ANY REALISTIC SET OF CONSTRAINTS. IT SHOULD BE NOTED THAT ONLY ONE BODY IS SPECIFIED AS THE
      #       EARTH, MOON, OR ANY OTHER CELESTIAL BODY IS SPECIFIED AS THE CENTRAL BODY OF THE TRAJECTORY.

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# THE INHERENT SCALE CHANGE REQUIRED IN POSITION, VELOCITY, MU, AND TIME, AS OUTLINES IN
# DEFINITION MEMO NO. 10. THIS CAN BE ACCOMPLISHED BY SIMPLY ADDING TO THE MUTABLE AND I
# APPROPRIATELY.
#
# DUE TO THE UNIFORMITY OF THE EQUATIONS INVOLVED, CODING WAS MINIMIZED BY TREATING INDIV
# BLOCKS OF EQUATIONS AS SUBROUTINES OF LOWER RANK WHENEVER POSSIBLE. AS A RESULT, THREE
# DIRECTLY USABLE AS INDEPENDENT SUBROUTINES, WERE GENERATED.
#
# RESTRICTIONS --
# THE ONLY LIMITATION IN THE SCOPE OF THE PROBLEM WHICH CAN BE SOLVED BY A PARTICULAR SUB
# LIMIT OF EACH PARAMETER AS SPECIFIED IN THE GSOP. THESE SCALING LIMITS WERE CHOSEN SO
# COULD BE HANDLED.
#
# SINCE THE SUBROUTINES (EXCEPT KEPLER) USE COMMON SUBROUTINES OF LOWER RANK WHICH USE ER
# THE PUSHLIST (DUE TO ITS LIMITED SIZE) AND COMMON INTERPRETIVE SWITCHES, THE CONIC SUBR
# TO INTERRUPT EACH OTHER. IT IS UP TO THE USER TO GUARANTEE THIS CONDITION.

# Page 1263
# PROGRAM DESCRIPTION -- KEPLER SUBROUTINE DATE -- 11 OCTOBER 1967
# MOD NO. -- 1 LOG SECTION -- CONIC SUBROUTINE
# MOD BY KRAUSE ASSEMBLY -- COLOSSUS 103 AND SU
# MOD NO. -- 2 (AUGUST 1968) BY ROBERTSON: TO PERMIT BACKDATING BY MORE THAN ONE ORBITAL PERIOD
# MOD NO. -- 3 (DEC 1968) BY ROBERTSON: SUPPRESSION OF X-MODULO-ING
# MOD NO. -- 4 (JAN 1969) BY ROBERTSON: CLEAR OVFINDD AT KEPLER ENTRY
#
# FUNCTIONAL DESCRIPTION --
# THIS SUBROUTINE, GIVEN AN INITIAL STATE VECTOR AND THE DESIRED TRANSFER TIME THROUGH WH
# BE UPDATED ALONG A CONIC TRAJECTORY, COMPUTES THE NEW, UPDATED STATE VECTOR. THE TRAJE
# SECTION -- CIRCULAR, ELLIPTIC, PARABOLIC, HYPERPOLIC, OR RECTILINEAR WITH RESPECT TO TH
# USE OF THE SUBROUTINE CAN BE EXTENDED USING OTHER PRIMARY BODIES BY SIMPLE ADDITIONS TO
# INTRODUCING ANY CODING CHANGES, ACCEPTING THE INHERENT SCALE FACTOR CHANGES IN POSITION
# TECHNIQUE IS UTILIZED IN THE COMPUTATION.
#
# IF A NEGATIVE TIME-OF-FLIGHT IS INPUT, THE PROGRAM WILL SOLVE FOR THE STATE WHICH WOULD
# EXTRAPOLATING THE POSITION BACKWARD IN TIME.
#
# IF THE ABSOLUTE VALUE DESIRED TRANSFER TIME EXCEEDS THE ORBITAL PERIOD, THE SUBROUTINE,
# MODULAR TECHNIQUE, WILL COMPUTE THE STATE CORRESPONDING TO THE DESIRED TIME AS USUAL.
#
# THE RESTRICTIONS ARE --
# 1. (PREVIOUS RESTRICTION ON THE NEGATIVE DESIRED TRANSFER TIME IS NOW DELETED.)
# 2. THE PARAMETERS IN THE PROBLEM CANNOT EXCEED THEIR SCALING LIMITS AS SPECIFIED I
# ANY OF THESE LIMITS ARE EXCEEDED, THE RESULTING SOLUTION WILL BE MEANINGLESS.
#
# THE NUMBER OF ITERATIONS AND, THEREFORE, THE COMPUTATION SPEED IS DEPENDENT ON THE ACCU
# GUESS, XKFPNEW. THE AGC COMPUTATION TIME IS APPROXIMATELY .061 SECONDS FOR INITIALIZAT
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#       FINAL COMPUTATIONS, PLUS .083 SECONDS FOR EACH ITERATION.
#
# REFERENCES --
#       R-479, MISSION PROGRAMMING DEFINITION MEMO NO. 10, LUNAR LANDING MISSION GSON
#       MEMO 67-4.
#
# INPUT -- ERASABLE INITIALIZATION REQUIRED
#           SCALE FACTOR
#           VARIABLE      IN POWERS OF 2      DESCRIPTION AND REMARKS
#           -----      -
#           RRECT         +29 FOR EARTH        DP INITIAL POSITION VECTOR IN METERS
#                           +27 FOR MOON
#
# Page 1264
#           VRECT         +7 FOR EARTH         DP INITIAL VELOCITY VECTOR IN METERS,
#                           +5 FOR MOON
#           X1 (38D)       NONE                INDEX REGISTER SET TO -2D OR -10D ACCORDING
#                                           RESPECTIVELY, IS THE CENTRAL
#           TAU            +28                DESIRED TRANSFER TIME IN CENTISECONDS.
#                                           MAY BE POS OR NEG AND ABSOLUTE
#           XKEPNEW        +17 FOR EARTH        DP GUESS OF ROOT X OF KEPLER'S EQN IN
#                           +16 FOR MOON        AND ABS VALUE SHOULD BE LESS THAN
#                                           MAJOR AXIS), FOR SPEED OF COMBINATION
#                                           BY KEPLER TO A POOR BUT VALID GUESS
#           TC             +28                DP PREV. VALUE OF TIME IN CENTISECS.
#           XPREV          +17 FOR EARTH        PRVIOUS VALUE OF X IN SQRT(METERS).
#                           +16 FOR MOON        ORBITAL PERIOD, VIZ, 2PI SQR(METERS)
#
# SUBROUTINES CALLED --
#       DELTIME
#
# CALLING SEQUENCE AND NORMAL EXIT MODES --
#       KEPRTN-2          GOTO                # MUST BE IN INTERPRETIVE MODE BUT OK
#       KEPRTN-1          KEPLER              # RETURNS WITH XPREV IN MPAC.  PL IS
#       KEPRTN            ...                 # CONTINUE
#
#       KEPLER MUST NOT BE CALLED DIRECTLY SINCE AN INTERRUPTION OF IT WOULD DESTROY
#       THE INTERRUPTED JOB.  THEREFORE THE USER MUST CALL CSMCONIC OR LEMCONIC WHICH
#       ALSO CALLS KEPPREP TO COMPUTE A GUESS OF XKEPNEW.
#
# ABORT EXIT MODE --
#       NONE
#
# OUTPUT --
#           SCALE FACTOR
#           VARIABLE      IN POWERS OF 2      DESCRIPTION AND REMARKS
#           -----      -

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#	RCV	+29 FOR EARTH	DP TERMINAL POSITION VECTOR IN METERS
#		+27 FOR MOON	
#	VCV	+7 FOR EARTH	DP TERMINAL VELOCITY VECTOR IN METERS/CENTISEC
#		+5 FOR MOON	
#	TC	+28	DP TRANSFER TIME IN CENTISECS TO WHICH KEPLER C
#	XPREV	+17 FOR EARTH	DP VALUE OF X IN SQRT(METERS) TO WHICH KEPLER C
#		+16 FOR MOON	CORRESPONDING TO ONE PERIOD.

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# FOR OTHER OUTPUT WHICH MAY BE OF USE, SEE DEBRIS.

#

# DEBRIS --

# PARAMETERS WHICH MAY BE OF USE --

#		SCALE FACTOR	
#	VARIABLE	IN POWERS OF 2	DESCRIPTION AND REMARKS
#	-----	-----	-----
#	URRECT	+1	DP UNIT VECTOR OF INITIAL POSITION
#	R1	+29 FOR EARTH	DP MAGNITUDE OF INITIAL POSITION IN METERS
#		+27 FOR MOON	
#	ALPHA	-22 FOR EARTH	DP INVERSE OF SEMI-MAJOR AXIS IN 1/METERS
#		-20 FOR MOON	
#	TMODULO	+28	DP INTEGRAL NUMBER OF PERIODS IN CENTISECS, WHI
#			TAU. OF LESS THAN ONE PERIOD.

#

# PARAMETERS OF NO USE --

# DP PARAMETERS -- FPSILENT, DELX, DELT, RCNORM, XMODULO, PLUS PUSHLIST REGISTERS 0 THROU

# Page 1266

# PROGRAM DESCRIPTION -- LAMBERT SUBROUTINE

DATE -- 1 SEPTEMBER 1967

# MOD NO. -- 0

LOG SECTION -- CONIC SUBROUTINE

# MOD BY KRAUSE

ASSEMBLY -- COLOSSUS REVISION 8

#

# FUNCTIONAL DESCRIPTION --

# THIS SUBROUTINE CALCULATES THE INITIAL VELOCITY REQUIRED TO TRANSFER A POINT-MASS ALONG  
# FROM AN INITIAL POSITION TO A TERMINAL POSITION IN A PRESCRIBED TIME INTERVAL. THE RES  
# A SECTION OF A CIRCLE, ELLIPSE, PARABOLA, OR HYPERBOLA WITH RESPECT TO THE EARTH OR THE  
# SUBROUTINE CAN BE EXTENDED USING OTHER PRIMARY BODIES BY SIMPLE ADDITIONS TO THE MUTABL  
# CODING CHANGES, ACCEPTING THE INHERENT SCALE FACTOR CHANGES IN POSITION AND VELOCITY.  
# UTILIZED IN THE COMPUTATION.

#

# THE RESTRICTIONS ARE: --

- # 1. RECTILINEAR TRAJECTORIES CANNOT BE COMPUTED.
- # 2. AN ACCURACY DEGRADATION OCCURS AS THE COSINE OF THE TRUE ANOMALY DIFFERENCE APPROACH
- # 3. THE ANGLE BETWEEN ANY POSITION VECTOR AND ITS VELOCITY VECTOR MUST BE GREATER THAN 1  
# AND LESS THAN 178 DEGREES 12.5 MINUTES.
- # 4. NEGATIVE TRANSFER TIME IS AMBIGUOUS AND WILL RESULT IN NO SOLUTION.
- # 5. THE PARAMETERS IN THE PROBLEM MUST NOT EXCEED THEIR SCALING LIMITS SPECIFIED IN THE

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#           LIMITS ARE EXCEEDED, THE RESULTING SOLUTION WILL BE MEANINGLESS.
#
#           THE NUMBER OF ITERATIONS AND, THEREFORE, THE COMPUTATION'S SPEED IS DEPENDENT
#           GUESS OF THE INDEPENDENT VARIABLE, COGA.  THE AGC COMPUTATION TIME IS APPROX
#           .105 SECONDS FOR INITIALIZATION, .069 SECONDS FOR FINAL COMPUTATIONS, PLUS .2
#
# REFERENCES --
# R-479, MISSION PROGRAMMING DEFINITION MEMO NO. 10, LUNAR LANDING MISSION GSON
# SGA MEMO 67-4.
#
# INPUT -- ERASABLE INITIALIZATION REQUIRED
#           SCALE FACTOR
#           VARIABLE      IN POWERS OF 2      DESCRIPTION AND REMARKS
#           -----
#           R1VEC          +29 FOR EARTH        DP INITIAL POSITION VECTOR IN METERS
#           R2VEC          +27 FOR MOON
#           R2VEC          +29 FOR EARTH        DP TARGET OR TERMINAL POSITION VECTOR
#           R2VEC          +27 FOR MOON
#           TDESIRED       +28                  DP DESIRED TRANSFER TIME IN CENTISEC
#           X1 (38D)       NONE                 INDEX REGISTER SET TO -2D OR -10D ACC
#                                           RESPECTIVELY, IS THE CENTRAL
#           GEOMSGN        NONE                 SP +.5 IF DESIRED TRANSFER ANGLE IS IN
#           GUESSW         NONE                 AN INTERPRETER SWITCH TO BE SET IF NO
#
# Page 1267
#
#           COGA IS TO BE USED BY LAMBERT
#           COGA           +5                  DP GUESS OF COTANGENT OF FLIGHT PATH
#           NORMSW         NONE                 IGNORED IF GUESSW IS SET.
#           UN             +1                  AN INTERPRETER SWITCH TO BE SET IF UN
#                                           LAMBERT IS TO COMPUTE ITS OWN
#           VTARGETAG      NONE                 DP UNIT NORMAL TO THE DESIRED ORBIT P
#                                           MOMENTUM VECTOR.  THIS WILL B
#           VTARGETAG      NONE                 A S.P. TAG TO BE SET TO ZERO IF LAMBE
#                                           AT R1VEC.
#
# SUBROUTINES CALLED --
# GEOM, GETX, DELTIME, ITERATOR, LAMENTER (PART OF NEWSTATE)
#
# CALLING SEQUENCE AND NORMAL EXIT MODES --
# L      CALL      # MUST BE IN INTERPRETIVE MODE BUT OVFINDE AR
# L+1    LAMBERT   # RETURNS WITH PL AT 0 AND WITH VVEC IN MPAC
#           IN MPAC IF VTARGETAG WAS ZERO
# L+2    BON       # CONTINUE IF SOLNSW CLEAR SINCE SOLUTION IS
# L+3    SOLNSW
# L+4    LAMABORT
#
# IF A LAMBER RESULT IS TO BE A FIRST GUESS FOR THE NEXT LAMBERT CALCULATION, C

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#      GUESSW MUST BE CLEAR FOR EACH SUCCEEDING LAMBERT CALL.
#
# ABORT EXIT MODES --
#      IF SOLNSW WAS SET UPON EXITING, EITHER LAMBERT WAS ASKED TO COMPUTE A TRANSFER TOO NEAR
#      WAS TOO SMALL TO PRODUCE A REALISTIC TRANSFER BETWEEN R1VEC AND R2FEC.  IN EITHER CASE
#      ACCORDING TO THE NEEDS OF THE PARTICULAR USER.  THE ABORT EXIT MODE MAY BE CODED AS ...
#      LAMBERT      DLOAD      ABS      # A MEASURE OF THE PROXIMITY TO 0 OR
#      1-CHTH      # 360 DEGREES.
#      DSU      BWM
#      ONEBIT
#      CHANGER2      # CHANGE R2VEC DIRECTION SLIGHTLY.
#      DLOAD      DAD
#      TDESIRED
#      SOMETIME
#      STCALL      TDESIRED      # INCREASE TDESIRED
#      LAMBERT
#
# OUTPUT --
#      SCALE FACTOR
#      VARIABLE      IN POWERS OF 2      DESCRIPTION AND REMARKS
# Page 1268
#      -----
#      VVEC      +7 FOR EARTH      DP INITIAL VELOCITY VECTOR IN METERS/CENTISECON
#      +5 FOR MOON      PROBLEM.
#      VTARGET      +7 FOR EARTH      DP RESULTANT VELOCITY VECTOR AT R2VEC IN METERS
#      +5 FOR MOON
#      SOLNSW      NONE      INTERPRETER SWITCH WHICH IS SET IF THE SUBROUTI
#      SOLUTION EXISTS.
#
#      FOR OTHER OUTPUT WHICH MAY BE OF USE, SEE DEBRIS.
#
# DEBRIS --
#      PARAMETERS WHICH MAY BE OF USE --
#      SCALE FACTOR
#      VARIABLE      IN POWERS OF 2      DESCRIPTION AND REMARKS
#      -----
#      SNTH      +1      DP SIN OF ANGLE BETWEEN R1VEC AND R2VEC
#      CSTH      +1      DP COSINE OF ANGLE
#      1-CSTH      +2      DP 1-CSTH
#      COGA      +5      DP COTAN OF INITIAL REQUIRED FLIGHT PATH ANGLE
#      P      +4      DP RATIO OF SEMILATUS RECTUM TO INITIAL RADIUS
#      R1A      +6      DP RATIO OF INITIAL RADIUS TO SEMI-MAJOR AXIS
#      R1 (32D)      +29 FOR EARTH      DP INITIAL RADIUS IN METERS
#      +27 FOR MOON
#      UR1      +1      DP UNIT VECTOR OF R1VEC
#      U2      +1      DP UNIT VECTOR OF R2VEC

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#
#   PARAMETERS OF NO USE --
#       DP PARAMETERS -- EPSILONL, CSTDH-RHO, TPREV, TERRLAMB, R2, RTNLAMB (S
#       ADDITIONAL INTERPRETIVE SWITCHES USED -- INFINFLG, 360SW, SLOPESW, O
#
# Page 1269
# PROGRAM DESCRIPTION -- TIME-THETA SUBROUTINE                      DATE -- 1 SEPTEMBER 1
# MOD NO. -- 0                                                    LOG SECTION -- CONIC
# MOD BY KRAUSE                                                    ASSEMBLY -- COLOSSUS
#
# FUNCTIONAL DESCRIPTION --
#   THIS SUBROUTINE, GIVEN AN INITIAL STATE VECTOR AND A DESIRED TRUE-ANOMALY-DI
#   STATE IS TO BE UPDATED ALONG A CONIC TRAJECTORY, CALCULATES THE CORRESPONDING
#   PROVIDES THE OPTION OF COMPUTING THE NEW UPDATED STATE VECTOR.  THE RESULTING
#   CIRCLE, ELLIPSE, PARABOLA, OR HYPERBOLA WITH RESPECT TO THE EARTH OR THE MOON
#   EXTENDED USING OTHER PRIMARY BODIES BY SIMPLE ADDITIONS TO THE MUTABLE WITHOU
#   ACCEPTING THE INHERENT SCALE FACTOR CHANGES IN POSITION AND VELOCITY.
#
# THE RESTRICTIONS ARE --
#   1. THE ANGLE BETWEEN ANY POSITION VECTOR AND ITS VELOCITY VECTOR MUST BE GRE
#       AND LESS THAN 178 DEGREES 12.5 MINUTES.
#   2. THE PARAMETERS IN THE PROBLEM MUST NOT EXCEED THEIR SCALING LIMITS SPECIF
#       ARE EXCEEDED, THE RESULTING SOLUTION WILL BE MEANINGLESS.
#
#   THE AGC COMPUTATION TIME IS APPROXIMATELY .292 SECONDS.
#
# REFERENCES --
#   R-479, MISSION PROGRAMMING DEFINITION MEMO NO. 10, LUNAR LANDING MISSION GSO
#
# INPUT -- ERASABLE INITIALIZATION REQUIRED
#
#           SCALE FACTOR
#   VARIABLE      IN POWERS OF 2      DESCRIPTION AND REMARKS
#   -----      -
#   RVEC          +29 FOR EARTH        DP INITIAL POSITION VECTOR IN METERS
#               +27 FOR MOON
#   VVEC          +7 FOR EARTH         DP INITIAL VELOCITY VECTOR IN METERS,
#               +5 FOR MOON
#   SNTH          +1                   DP SINE OF THE TRUE-ANOMALY-DIFFERENC
#   CSTDH         +1                   DP COSINE OF THE ANGLE
#   RVSW          NONE                 AN INTERPRETIVE SWITCH TO BE SET IF C
#                                   IS TO BE COMPUTED ALSO.
#   X1 (38D)      NONE                 INDEX REGISTER TO BE SET TO -2D OR -3
#                                   RESPECTIVELY, IS THE CENTRAL
#
# SUBROUTINES CALLED --
# Page 1270

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#      PARAM, GEOM, GETX, DELTIME, NEWSTATE
#
# CALLING SEQUENCE AND NORMAL EXIT MODES --
#      IF ONLY TIME IS DESIRED AS OUTPUT --
#      L      SET      CALL      # MUST BE IN INTERPRETIVE MODE BUT OVFLND ARBITRARY.
#      L+1    RVSW
#      L+2    TIMETHET      # RETURN WITH PL AT 0 AND T IN MPAC
#      L+3    ...          # CONTINUE
#
#      IF THE UPDATE STATE VECTOR IS DESIRED AS WELL --
#      L      CLEAR      CALL      # MUST BE IN INTERPRETIVE MODE BUT OVFLND ARBITRARY.
#      L+1    RVSW
#      L+2    TIMETHET      # RETURNS WITH PL AT 6.  THE INITIAL POSITION VECTOR IS
#                          # THE INITIAL VELOCITY VECTOR IN MPAC.
#      L+3    STOVL      NEWVVEC
#      L+4    STADR
#      L+5    STORE      NEWRVEC      # NEWVVEC AND NEWRVEC ARE SYMBOLIC REPRESENTATIONS OF T
#      L+6    ...          # CONTINUE.
#
# ABORT EXIT MODES --
#      IF COGAFLAG AND/OR INFINFLG IS SET AT THE EXIT TO TIME-THETA, TIME-THETA WILL TRANSFER
#      AN ALARM CODE (ORIGINALLY 00607), AND NOT RETURN TO THE CALLING PROGRAM.  (PCR 692 AND
#
# OUTPUT --
#
#      SCALE FACTOR
#      VARIABLE      IN POWERS OF 2      DESCRIPTION AND REMARKS
#      -----
#      T(30D)        +28                  DP TRANSFER TIME IN CENTISECONDS
#      INFINFLG       NONE                 AN INTERPRETIVE SWITCH WHICH IS SET IF THE TRAN
#                                         INFINITY (NO SOLUTION), CLEAR IF A PHYS
#      COGAFLAG       NONE                 AN INTERPRETIVE SWITCH WHICH IS SET IF RESTRICT
#                                         CLEAR IF NOT.
#
#      IN ADDITION, IF RVSW IS CLEAR, THE FOLLOWING ARE OUTPUT --
#      MPAC -        +7 FOR EARTH          DP TERMINAL VELOCITY VECTOR IN METERS/CENTISEC.
#      MPAC+5        +5 FOR MOON
#      OD - 5D       +29 FOR EARTH         DP TERMINAL POSITION VECTOR IN METERS (PL AT 6D
#      +27 FOR MOON
#
#      FOR OTHER OUTPUT WHICH MAY BE OF USE, SEE DEBRIS.
# Page 1271
#
# DEBRIS --
#      PARAMETERS WHICH MAY BE OF USE --
#      SCALE FACTOR
#      VARIABLE      IN POWERS OF 2      DESCRIPTION AND REMARKS

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#          -----
#          R1 (32D)          +29 FOR EARTH          DP MAGNITUDE OF INITIAL POSITION VECTOR
#          +27 FOR MOON
#          R1A              +6                    DP RATIO OF R1 TO SEMI-MAJOR AXIS (NEAR)
#          P                +4                    DP RATIO OF SEMILATUS RECTUM TO R1
#          COGA             +5                    DP COTAN OF ANGLE BETWEEN RVEC AND VEC
#          UR1              +1                    DP UNIT VECTOR OF RVEC
#          U2               +1                    DP UNIT VECTOR OF VVEC
#          UN               +1                    DP UNIT VECTOR OF UR1*U2
#
# PARAMETERS OF NO USE --
#          SP PARAMETERS -- RTNTT, GEOMSGN, RTNPRM, MAGVEC2=R2 (DP), PLUS PUSHLIST LOCATION
#          ADDITIONAL INTERPRETIVE SWITCHES USED -- NORMSW, 360SW

# Page 1272
# PROGRAM DESCRIPTION -- TIME-RADIUS SUBROUTINE          DATE -- 11 OCTOBER 1967
# MOD NO. -1          LOG SECTION -- CONIC SUBROUTINE
# MOD BY KRAUSE          ASSEMBLY -- COLOSSUS REVISION 1
#
# FUNCTIONAL DESCRIPTION --
#          THIS SUBROUTINE, GIVEN AN INITIAL STATE VECTOR AND A DESIRED RADIUS TO WHICH
#          STATE IS TO BE UPDATED ALONG A CONIC TRAJECTORY, CALCULATES THE CORRESPONDING
#          PROVIDES THE OPTION OF COMPUTING THE NEW UPDATED STATE VECTOR.  THE RESULTING
#          CIRCLE, ELLIPSE, PARABOLA, OR HYPERBOLA WITH RESPECT TO THE EARTH OR THE MOON
#          EXTENDED USING OTHER PRIMARY BODIES BY SIMPPE ADDITIONS TO THE MUTABLE WITHOUT
#          ACCEPTING THE INHERENT SCALE FACTOR CHANGES IN POSITION AND VELOCITY.
#
#          IF THE DESIRED RADIUS IS BEYOND THE RADIUS OF APOCENTER OF THE CONIC OR BELOW
#          APSESW WILL BE SET AND THE SUBROUTINE WILL RETURN THE APOCENTER OR PERICENTER
#
# THE RESTRICTIONS ARE --
#          1. THE ANGLE BETWEEN ANY POSITION VECTOR AND ITS VELOCITY VECTOR MUST BE GREATER
#             AND LESS THAN 178 DEGREES 12.5 MINUTES.
#          2. THE PARAMETERS IN THE PROBLEM MUST NOT EXCEED THEIR SCALING LIMITS SPECIFIED
#             EXCEEDED, THE RESULTING SOLUTION WILL BE MEANINGLESS.
#          3. AN ACCURACY DEGRADATION OCCURS AS THE SENSITIVITIES OF TIME AND UPDATED STATE
#             RDESIRED INCREASE.  THIS WILL OCCUR NEAR EITHER APSIS OF THE CONIC AND WHEN
#             PARTICULAR, IF THE CONIC IS AN EXACT CIRCLE, THE PROBLEM IS UNDEFINED AND
#
#          THE AGC COMPUTATION TIME IS APPROXIMATELY .363 SECONDS.
#
# REFERENCES --
#          R-479, MISSION PROGRAMMING DEFINITION MEMO NO. 10, LUNAR LANDING MISSION GSO
#
# INPUT -- ERASABLE INITIALIZATION REQUIRED.
#          SCALE FACTOR

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#      VARIABLE      IN POWERS OF 2      DESCRIPTION AND REMARKS
#      -----      -
#      RVEC          +29 FOR EARTH        DP INITIAL POSITION VECTOR IN METERS
#                  +27 FOR MOON
#      VVEC          +7 FOR EARTH         DP INITIAL VELOCITY VECTOR IN METERS/CENTISECON
#                  +5 FOR MOON
#      RDESIRED      +29 FOR EARTH        DP TERMINAL RADIAL DISTANCE ON CONIC TRAJECTORY
#                  +27 FOR MOON          COMPUTED
#      SGNRDOT       NONE                 SP TAG SET TO +.5 OR -.5 ACCORDING TO WHETHER T
#                                      POSITIVE OR NEGATIVE, RESPECTIVELY.  T
# Page 1273
#
#                                      SINGLE-VALUED PROBLEM.
#      X1 (38D)      NONE                 INDEX REGISTER TO BE SET TO -2D OR -10D ACCORDI
#                                      RESPECTIVELY, IS THE CENTRAL BODY.
#      RVSW          NONE                 AN INTERPRETIVE SWITCH TO BE SET IF ONLY TIME I
#                                      IS TO BE COMPUTED ALSO.
#
# SUBROUTINES CALLED --
#      PARAM, GEOM, GETX, DELTIME, NEWSTATE
#
# CALLING SEQUENCE AND NORMAL EXIT MODES --
#      IF ONLY TIME IS DESIRED AS OUTPUT --
#      L      SET      CALL      # MUST BE IN INTERPRETIVE MODE BUT OVFIN
#      L+1          RVSW
#      L+2          TIMERAD      # RETURN WITH PL AT 0 AND T IN MPAC
#      L+3      ...      # CONTINUE
#
#      IF THE UPDATE STATE VECTOR IS DESIRED AS WELL --
#      L      CLEAR    CALL      # MUST BE IN INTERPRETIVE MODE BUT OVFIN
#      L+1          RVSW
#      L+2          TIMERAD      # RETURNS WITH PL AT 6.  THE INITIAL POSITION VECTOR IS
#      # THE INITIAL VELOCITY VECTOR IN MPAC.
#      L+3      STOVL    NEWVVEC
#      L+4      STADR
#      L+5      STORE    NEWRVEC      # NEWVVEC AND NEWRVEC ARE SYMBOLIC REPRESENTATIONS OF T
#      L+6      ...      # CONTINUE
#
# ABORT EXIT MODES --
#      IF SOLNSW AND/OR COGAFLAG AND/OR INFINFLG IS SET AT THE EXIT TO TIME-RADIUS, TIME-RADIU
#      TO POODOO WITH AN ALARM CODE (ORIGINALLY 00607), AND NOT RETURN TO THE CALLING PROGRAM.
#
# OUTPUT --
#
#      SCALE FACTOR
#      VARIABLE      IN POWERS OF 2      DESCRIPTION AND REMARKS
#      -----      -
#      T (30D)      +28                 DP TRANSFER TIME IN CENTISECONDS.
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#          INFINFLG          NONE          AN INTERPRETIVE SWITCH WHICH IS SET 1
#                                          INFINITY (NO SOLUTION), CLEAR
#          COGAFLAG          NONE          AN INTERPRETIVE SWITCH WHICH IS SET 1
#                                          CLEAR IF NOT.
#          APSESW            NONE          AN INTERPRETIVE SWITCH WHICH IS SET 1
# Page 1274
#                                          LESS THAN RADIUS OF PERICENTR
#                                          WILL THEN BE RETURNED. THE S
#                                          APOCENTER.
#          SOLNSW            NONE          AN INTERPRETIVE SWITCH WHICH IS SET 1
#                                          POINT IS AMBIGUOUS, VIOLATING
#                                          MINUS-18, THE SWITCH IS CLEAR
#
#          IN ADDITION, IF RVSW IS CLEAR, THE FOLLOWING ARE OUTPUT --
#          MPAC -             +7 FOR EARTH      DP TERMINAL VELOCITY VECTOR IN METERS
#          MPAC+5             +5 FOR MOON
#          OD - 5D            +29 FOR EARTH      DP TERMINAL POSITION VECTOR IN METERS
#          +27 FOR MOON
#
#          FOR OTHER OUTPUT WHICH MAY BE OF USE, SEE DEBRIS.
#
# DEBRIS --
#          PARAMETERS WHICH MAY BE OF USE --
#          SCALE FACTOR
#          VARIABLE          IN POWERS OF 2      DESCRIPTION AND REMARKS
#          -----          -
#          R1 (32D)          +29 FOR EARTH      DP MAGNITUDE OF INITIAL POSITION VEC
#          +27 FOR MOON
#          R1A               +6                DP RATIO OF R1 TO SEMI-MAJOR AXIS (N
#          P                 +4                DP RATIO OF SEMILATUS RECTUM TO R1
#          COGA              +5                DP COTAN OF ANGLE BETWEEN RVEC AND V
#          UR1               +1                DP UNIT VECTOR OF RVEC
#          U2                +1                DP UNIT VECTOR OF VVEC
#          UN                +1                DP UNIT VECTOR OF UR1*U2
#          CSTH              +1                DP COSINE OF TRUE ANOMALY DIFFERENCE
#          SNTH              +1                DP SINE OF TRUE ANOMALY DIFFERENCE.
#
#          PARAMETERS OF NO USE --
#          SP PARAMETERS -- RTNTT, GEOMSGN, RTNPRM, MAGVEC2*R2 (DP), PLUS PUSHL
#          ADDITIONAL INTERPRETIVE SWITCHES USED -- NORMSW, 360SW
#
# Page 1275
# PROGRAM DESCRIPTION -- APSIDES SUBROUTINE          DATE -- 1 SEPTEMBER 1967
# MOD NO. -- 0          LOG SECTION -- CONIC SUBROUT
# MOD BY KRAUSE          ASSEMBLY -- COLOSSUS REVISION

```

```

#
# FUNCTIONAL DESCRIPTION --
#     THIS SUBROUTINE, GIVEN AN INITIAL STATE VECTOR, CALCULATES THE RADIUS OF PERICENTER AND
#     ECCENTRICITY OF THE RESULTING CONIC TRAJECTORY, WHICH MAY BE A STRAIGHT LINE,
#     CIRCLE, ELLIPSE, PARABOLA, OR HYPERBOLA WITH RESPECT TO THE EARTH OR THE MOON.  THE USE
#     BE EXTENDED USING OTHER PRIMARY BODIES BY SIMPLE ADDITIONS TO THE MUTABLE WITHOUT INTRO
#     ACCEPTING THE INHERENT SCALE FACTOR CHANGES IN POSITION AND VELOCITY.
#
# THE RESTRICTIONS ARE --
#     1. IF APOCENTER IS BEYOND THE SCALING OF POSITION, THE SCALE FACTOR LIMIT (536,870,910
#         TO THE EARTH OR 134,217,727.5 METERS WITH RESPECT TO THE MOON) WILL BE RETURNED.
#     2. THE PARAMETERS IN THE PROBLEM MUST NOT EXCEED THEIR SCALING LIMITS SPECIFIED IN THE
#         ARE EXCEEDED, THE RESULTING SOLUTION WILL BE MEANINGLESS.
#
#     THE AGC COMPUTATION TIME IS APPROXIMATELY .103 SECONDS.
#
# REFERENCES --
#     MISSION PROGRAMMING DEFINITION MEMO NO. 10, LUNAR LANDING MISSION GSOP-SECTION 5.5.
#
# INPUT -- ERASABLE INITIALIZATION REQUIRED
#           SCALE FACTOR
#           VARIABLE      IN POWERS OF 2      DESCRIPTION AND REMARKS
#           -----
#           RVEC          +29 FOR EARTH        DP INITIAL POSITION VECTOR IN METERS
#                       +27 FOR MOON
#           VVEC          +7 FOR EARTH         DP INITIAL VELOCITY VECTOR IN METERS/CENTISECON
#                       +5 FOR MOON
#           X1 (38D)      NONE                 INDEX REGISTER TO BE SET TO -2D OR -10D ACCORDI
#                                           RESPECTIVELY, IS THE CENTRAL BODY.
#
# SUBROUTINES CALLED --
#     PARAM, GEOM
#
# CALLING SEQUENCE AND NORMAL EXIT MODES --
# Page 1276
#     IF ONLY TIME IS DESIRED AS OUTPUT --
#     L      CALL          # MUST BE IN INTERPRETIVE MODE BUT OV FIND ARBITRARY.
#     L+1    APSIDES      # RETURNS WITH PL AT 0, RADIUS OF APOCENTER IN MPAC AND
#     L+2    STODL        APOAPSE
#     L+3    OD
#     L+4    STORE        PERIAPSE          # APOAPSE AND PERIAPSE ARE SYMBOLIC REPRESENTATIONS OF
#     L+5    ...          # CONTINUE
#
# OUTPUT --
#           SCALE FACTOR
#           VARIABLE      IN POWERS OF 2      DESCRIPTION AND REMARKS

```

```

# -----
# MPAC +29 FOR EARTH DP RADIUS OF APOCENTER IN METERS
# +27 FOR MOON
# OD-1D +29 FOR EARTH DP RADIUS OF PERICENTER IN METERS
# +27 FOR MOON
# ECC +3 DP ECCENTRICITY OF CONIC TRAJECTORY
#
# FOR OTHER OUTPUT WHICH MAY BE OF USE, SEE DEBRIS.
#
# DEBRIS --
# PARAMETERS WHICH MAY BE OF USE --
# SCALE FACTOR
# VARIABLE IN POWERS OF 2 DESCRIPTION AND REMARKS
# -----
# R1 (32D) +29 FOR EARTH DP MAGNITUDE OF INITIAL POSITION VECTOR
# +27 FOR MOON
# R1A +6 DP RATIO OF R1 TO SEMI-MAJOR AXIS (N)
# P +4 DP RATIO OF SEMILATUS RECTUM TO R1
# COGA +5 DP COTAN OF ANGLE BETWEEN RVEC AND V
# UR1 +1 DP UNIT VECTOR OF RVEC
# U2 +1 DP UNIT VECTOR OF VVEC
# UN +1 DP UNIT VECTOR OF UR1*U2
# MAGVEC2 +7 FOR EARTH DP MAGNITUDE OF VVEC
# +5 FOR MOON
#
# PARAMETERS OF NO USE --
# SP PARAMETERS -- RTNAPSE, GOMSGN, RTNPRM, PLUS PUSHLIST LOCATIONS 0-5
# ADDITIONAL INTERPRETIVE SWITCHES USED -- NORMSW

SETLOC CONICS
# Page 1277
BANK
COUNT 12/CONIC
EBANK= UR1
KEPLERN SETPD BOV
0
+1
VLOAD*
MUTABLE,1
STOVL 14D
RRECT
UNIT SSP
ITERCTR
20D

```

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	STODL	URRECT	
		36D	
	STOVL	R1	
		RRECT	
	DOT	SL1R	
		VRECT	
	DMP	SL1R	
		1/ROOTMU	# 1/ROOTMU (-17 OR -14)
	STOVL	KEPC1	# C1=R.V/ROOTMU (+17 OR +16)
		VRECT	
	VSQ	DMPR	
		1/MU	# 1/MU (-34 OR -28)
	DMP	SL3	
		R1	
	DSU	ROUND	
		D1/64	
	STORE	KEPC2	# C2=RV.V/MU -1 (+6)
	BDSU	SR1R	
		D1/64	
	DDV		
		R1	
	STORE	ALPHA	# ALPHA=(1-C2)/R1 (-22 OR -20)
	BPL	DLOAD	# MAXIMUM X DEPENDS ON TYPE OF CONIC
		1REV	
		-50SC	# -50SC (+12)
	DDV	BOV	
		ALPHA	
		STOREMAX	
	SQRT	GOTO	
		STOREMAX	
# Page 1278			
1REV	SQRT	BDDV	
		2PISC	# 2PISC (+6)
	BOV		
		STOREMAX	
STOREMAX	STORE	XMAX	
	DMP	PDDL	
		1/ROOTMU	
		ALPHA	
	NORM	PDDL	
		X1	
	SL*	DDV	
		0	-6,1

	BOV	BMN	
		MODDONE	
		MODDONE	# MPAC=PERIOD
PERIODCH	PDDL	ABS	# OD=PERIOD
		TAU.	
	DSU	BMN	
		OD	
		MODDONE	
	SIGN		
		TAU.	
	STODL	TAU.	
	GOTO		
		PERIODCH	
MODDONE	SETPD	DLOAD	
		O	
		XKEPNEW	
	STORE	X	
	SIGN	BZE	
		TAU.	
		BADX	
	BMN	ABS	
		BADX	
	DSU	BPL	
		XMAX	
		BADX	
STORBND	DLOAD	BPL	
		TAU.	
		STOREMIN	
	DLOAD	DCOMP	
		XMAX	
	STODL	XMIN	
		KEPZERO	
	STCALL	XMAX	
		DXCOMP	
STOREMIN	DLOAD		
		KEPZERO	
	STORE	XMIN	
DXCOMP	DLOAD	DMPR	
# Page 1279			
		TAU.	
		BEE22	
	ABS		
	STODL	EPSILONT	
		XPREV	
XDIFF	BDSU		
		X	

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```

STORE  DELX

KEPLOOP  DLOAD  DSQ
          X      # X=XKEP
NORM     PUSH   # OD=XSQ (+34 OR +32 -N1)      PL AT 2
          X1
DMP      SRR*
          ALPHA
          0      -6,1
STCALL   XI      # XI=ALPHA XSQ (+6)
          DELTIME
BOV      BDSU
          TIMEOVFL  # UNLIKELY
          TAU.
STORE    DELT     # DELT=DELINDEP
ABS      BDSU
          EPSILONT
BPL      DLOAD
          KEPCONVG
          T
DSU      NORM
          TC
          X1
PDDL     NORM
          DELX
          X2
XSU,1    DMP
          X2
          DELT
SLR*     DDV
          1,1
SR1      PUSH     # OD=TRIAL DELX      PL AT 2
BPL      DLOAD
          POSDELX
          X
STORE    XMAX     # MOVE MAX BOUND IN
BDSU     DSU      #
          XMIN
BOV      BPL
          NDXCHNGE
          NDXCHNGE
DLOAD    GOTO
          OD
          NEWDELX
```

# Page 1280

NDXCHNGE	DLOAD	DSU XMIN X	
	DMPR	GOTO DP9/10 NEWDELX	# TO FORCE MPAC +2 TO ZERO
POSDELX	DLOAD	X	
	STORE	XMIN	# MOVE MIN BOUND IN
	BDSU	DSU	# PL AT 0
		XMAX	
	BOV	BMN	
		PDXCHNGE	
		PDXCHNGE	
	DLOAD		
		OD	
NEWDELX	STORE	DELX	
	BZE	DAD	
		KEPCONVG	
		X	
	STODL	X	
		T	
	STORE	TC	
BRNCHCTR	RTB	BHIZ	
		CHECKCTR	
		KEPCONVG	
	GOTO		
		KEPLOOP	# ITERATE
PDXCHNGE	DLOAD	DSU XMAX X	
	DMPR	GOTO DP9/10 NEWDELX	# TO FORCE MPAC +2 TO ZERO
BADX	DLOAD	SR1 XMAX	
	SIGN		
		TAU.	
	STCALL	X	
		STORBND	
# Page 1281			
TIMEOVFL	DLOAD	BMN X	# X WAS TOO BIG



		NEGTOVFL	
	STORE	XMAX	
CMNTOVFL	DLOAD	SR1	
		DELX	
	STORE	DELX	
	BZE	BDSU	
		KEPRTN	
		X	
	STODL	X	
		TC	
	STCALL	T	
		BRNCHCTR	
NEGTOVFL	STCALL	XMIN	
		CMNTOVFL	
KEPCONVG	DLOAD	SR4R	
		R1	
	DSU	VXSC	
		XSQC(XI)	
		URRECT	
	VSL1	PDDL	# OD=(R1-XSQC(XI))URRECT (+33 OR +31)
		X	
	DSQ	NORM	
		X1	
	DMPR	DMPR	
		1/ROOTMU	
		X	
	DMP	SRR*	
		S(XI)	
		0	-7,1
	BDSU		
		T	
	SL1	VXSC	
		VRECT	
	VSL1	VAD	
	VSL4		
	STORE	RCV	# RCV (+29 OR +27)
	ABVAL	NORM	
		X2	
	STODL	RCNORM	
		XI	
	DMPR	DSU	
		S(XI)	
		D1/128	
	DMP	SL1R	
		ROOTMU	

```

# Page 1282
DMP      SLR*
          X
          0      -3,2
DDV      VXSC
          RCNORM
          URRECT
VSL1     PDDL      # OD=URRECT(XI S(XI)-1)X ROOTMU/RCV (+15
          XSQC(XI)  # OR +13)                      PL AT 6
SLR*     DDV
          0      -4,2
          RCNORM
BDSU     VXSC
          D1/256
          VRECT
VAD      VSL8
STADR
STODL    VCV      #
          T      # VCV (+7 OR +5)                      PL AT 0
STODL    TC
          X
STCALL   XPREV
          KEPRTN

# Page 1283
DELTIME  EXIT      # MPAC=XI (+6), OD=XSQ (+34 OR +32 -N1)
          TC      POLY
          DEC      8
          2DEC     .083333334
          2DEC     -.266666684
          2DEC     .406349155
          2DEC     -.361198675
          2DEC     .210153242
          2DEC     -.086221951
          2DEC     .026268812
          2DEC     -.006163316
          2DEC     .001177342

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2DEC -.000199055

TC INTPRET  
STODL S(XI)  
XI

EXIT  
TC POLY  
DEC 8  
2DEC .031250001

2DEC -.166666719

2DEC .355555413

2DEC -.406347410

2DEC .288962094

2DEC -.140117894

2DEC .049247387

2DEC -.013081923

2DEC .002806389

2DEC -.000529414

TC INTPRET

# Page 1284

DMP SRR\* # PL AT 0  
OD  
0 -5,1

STORE XSQC(XI) # XSQC(XI) (+33 OR +31)

DMP SL1  
KEPC1

RTB PDDL # XCH WITH PL. OD=C1 XSQ C(XI) (+49 OR +46)  
TPMODE # PL AT 0,3

DMP SRR\*  
S(XI)  
0 -5,1

DMP SL1  
KEPC2

RTB PDDL # 3D=C2 XSQ S(XI) (+35 OR +33) PL AT 6  
TPMODE  
R1

	SR	TAD	#	PL AT 3
		6		
	NORM	DMP	# TO PRESERVE SIGNIF.	
		X1		
		X		
	SR*	TAD	# X(C2 XSQ S(XI) +R1) (+49 OR +46) PL AT 0	
		0		
		-3,1		
	SL4R	DMPR		
		1/ROOTMU		
	STORE	T		
	RVQ			
# Page 1285				
ITERATOR	BONCLR	DLOAD		
		SLOPESW		
		FIRSTIME		
		DEP		
	DSU	NORM		
		DEPREV		
		X1		
	PDDL	NORM		
		DELINDEP		
		X2		
	XSU,1	DMP		
		X2		
		DELDEP		
	SLR*	DDV	#	PL UP 2
		1,1		
	SR1	BOFF		
		ORDERSW		
		SGNCHECK		
	ABS	SIGN	# IN CASE 2ND DERIV. CHANGED SIGN, MUST	
		DELDEP	# DISREGARD IT TO FIND MIN.	
SGNCHECK	PUSH	BPL	# TRIAL DELINDEP	PL DOWN 2
		POSDEL		
	DLOAD	BON		
		INDEP		
		ORDERSW		
		MINCHECK		
	STORE	MAX	# IF NOT 2ND ORDER, CAN MOVE MAX BOUND IN.	
MINCHECK	BDSU	DSU		
		MIN		
	BOV	BPL		
		MODNGDEL		

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```

                                MODNGDEL
                                GOTO
                                DELOK

MODNGDEL      DLOAD  DSU          # TRIAL DELINDEP WOULD EXCEED MIN BOUND
                MIN
                INDEP
                DMP    GOTO
                DP9/10
                NEWDEL

FIRSTTIME     DLOAD  DMP
                MIN
                TWEKIT          # DLOAD TWEKIT(40D) SENSITIVE TO CHANGE.
                PDDL  DMP      # S2(41D) SHOULDN'T CONTAIN HI ORDER ONES

# Page 1286

                MAX
                TWEKIT
                DSU
                SIGN  GOTO
                DELDEP
                SGNCHECK

POSDEL        DLOAD  BON
                INDEP
                ORDERSW
                MAXCHECK
                STORE  MIN          # IF NOT 2ND ORDER, CAN MOVE MIN BOUND IN.

MAXCHECK      BDSU   DSU
                MAX
                BOV   BMN
                MODPSDEL
                MODPSDEL

DELOK         DLOAD

NEWDEL        STORE  OD
                RVQ   DELINDEP

MODPSDEL      DLOAD  DSU
                MAX
                INDEP
                DMP   GOTO
                DP9/10
                NEWDEL
```

CHECKCTR	CS	ONE	
	INDEX	FIXLOC	
	AD	ITERCTR	
	INDEX	FIXLOC	
	TS	ITERCTR	
	TS	MPAC	
	TC	DANZIG	
# Page 1287			
NEWSTATE	DLOAD	SR4R	
		R1	
	DSU	VXSC	
		XSQC(XI)	
		UR1	
	VSL1	PDDL	# OD=(R1-XSQC(XI))UR1 (+33 OR 31) PL AT 6
		X	
	DSQ	NORM	
		X1	
	DMPR	DMPR	
		1/ROOTMU	
		X	
	DMP	SRR*	
		S(XI)	
		0	-7,1
	BDSU		
		T	
	SL1	VXSC	
		VVEC	
	VSL1	VAD	#
	VSL4	PUSH	PL AT 0
	ABVAL		
LAMENTER	NORM		
		X1	
	STODL	R2	
		XI	
	DMP	DSU	
		S(XI)	
		D1/128	
	DMP	SL1R	
		ROOTMU	
	DMP	SLR*	
		X	
		0	-3,1
	DDV	VXSC	
		R2	
		UR1	

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VSL1	PDDL	# 6D=V2VEC PART (+15 OR 13)	PL AT 12
	XSQC(XI)		
SLR*	DDV		
	0 -4,1		
	R2		
BDSU			
	D1/256		
VXSC	VAD		
	VVEC	#	PL AT 6
VSL8	RVQ		

# Page 1288

SETLOC CONICS1  
BANK

COUNT 04/CONIC

# DO NOT DISTURB THE ORDER OF THESE CDS, OVERLAYS HAVE BEEN MADE.

BEE17 DEC 0 # KEEP WITH D1/8 2DEC 1.0B-17 (0000004000)

D1/8 2DEC 1.0 B-3

D1/128 2DEC 1.0 B-7

D1/64 2DEC 1.0 B-6

D1/4 2DEC 1.0 B-2

D1/16 2DEC 1.0 B-4

D1/32 2DEC 1.0 B-5

D1/1024 2DEC 1.0 B-10

D1/256 2DEC 1.0 B-8

DP9/10 2DEC .9

KEPZERO EQUALS L06ZEROS  
-50SC 2DEC -50.0 B-12

2PISC 2DEC 6.28318530 B-6

BEE19 EQUALS D1/32 -1 # 2DEC 1.0 B-19 (00000 01000)

BEE22 EQUALS D1/256 -1 # 2DEC 1.0 B-22 (00000 00100)

ONEBIT 2DEC 1.0 B-28

COGUPLIM 2DEC .999511597

COGLOLIM 2DEC -.999511597

# Page 1289

SETLOC CONICS  
BANK

COUNT 12/CONIC

TIMETHET STQ SETPD # PL AT 0  
RTNTT  
0

BOV

+1

VLOAD PDVL # SETUP FOR PARAM CALL PL AT 6  
RVEC  
VVEC

CALL

PARAM  
BOV CALL  
COGAOVFL  
GETX

#

PL AT 0

COMMNOUT DLOAD BON  
XI  
INFINFLG  
ABTCONIC  
CLEAR CALL  
COGAFLAG  
DELTIME  
BON CALL  
RVSW  
RTNTT  
NEWSTATE  
GOTO  
RTNTT

COGAOVFL SETGO  
COGAFLAG  
ABTCONIC

BANK 4

SETLOC CONICS1

BANK

COUNT\* \$\$/CONIC

PARAM STQ CLEAR # MPAC=V1VEC, OD=R1VEC PL AT 6  
RTNPRM  
NORMSW



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```
# Page 1290
CLEAR
COGAFLAG
SSP CALL
GEOMSGN
37777 # GAMMA ALWAYS LESS THAN 180DEG
GEOM # MPAC=SNGA (+1), OD=CSGA (+1) PL AT 2
STODL 36D # 36D=SIN GAMMA (+1) PL AT 0

SR DDV
5

36D
STOVL* COGA
MUTABLE,1
STODL 1/MU
MAGVEC2
DSQ NORM
X1
DMPR DMP
1/MU
R1
SRR*
0 -3,1
PUSH BDSU # OD=R1 V1SQ/MU (+6) PL AT 2
D1/32
STODL R1A # R1A (+6) PL AT 0

DMP NORM
36D
X1
DMP SR*
36D
0 -4,1
STCALL P # P (+4)
RTNPRM

# Page 1291
GEOM
UNIT # MPAC=V2VEC, OD=R1VEC PL AT 6
STODL U2 # U2 (+1)
36D
STOVL MAGVEC2 # PL AT 0
UNIT
STORE UR1 # UR1 (+1)
DOT SL1
U2
PDDL # OD=CSTH (+1) PL AT 2
```

		36D		
	STOVL	R1	# R1 (+29 OR +27)	
		UR1		
	VXV	VSL1		
		U2		
	BON	SIGN		
		NORMSW		
		HAVENORM		
		GEOMSGN		
	UNIT	BOV		
		COLINEAR		
UNITNORM	STODL	UN	# UN (+1)	
		36D		
	SIGN	RVQ	# MPAC=SNTH (+1), 34D=SNTH.SNTH (+2)	
		GEOMSGN		
COLINEAR	VSR1	GOTO		
		UNITNORM		
HAVENORM	ABVAL	SIGN		
		GEOMSGN		
	RVQ		# MPAC=SNTH (+1), 34D=SNTH.SNTH (+2)	
# Page 1292				
	BANK	12		
	SETLOC	CONICS		
	BANK			
	COUNT	12/CONIC		
GETX	AXT,2	SSP	# ASSUMES P (+4) IN MPAC	
		3		
		S2		
		1		
	CLEAR			
		360SW		
	SQRT	PDDL	# OD=SQRT(P)	PL AT 2
		CSTH		
	SR1	BDSU		
		D1/4		
	PDDL	SRR	#	PL AT 4D
		SNTH		
		6		
	DDV		#	PL AT 2
	BOV			
		360CHECK		

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	DSU	DMP		
		COGA	#	PL AT 0
	SL2R	BOV		
		360CHECK		
WLOOP	PUSH	DSQ	# OD=W (+5)	PL AT 2
	TLOAD	PDDL	# 2D=WSQ (+10)	PL AT 5
		MPAC		
		R1A		
	SR4	TAD	#	PL AT 2
	BMN	SQRT		
		INFINITY		
	ROUND	DAD	#	PL AT OD
	BOV	TIX,2		
		RESETX2		
		WLOOP		
	BDDV	BOV		
		D1/128		
		INFINITY		
POLYCOEF	BMN	PUSH	# OD=1/W (+2) OR 16/W (+6)	PL AT 2
		INFINITY		
	DSQ			
	NORM	DMP		
		X1		
		R1A		
	SRR*	EXIT		
		0	-10D,1	
# Page 1293				
	TC	POLY		
	DEC	5		
	2DEC	.5		
	2DEC	-.166666770		
	2DEC	.100000392		
	2DEC	-.071401086		
	2DEC	.055503292		
	2DEC	-.047264098		
	2DEC	.040694204		
	TC	INTPRET		
	DMP	SL1R	#	PL AT OD

	PUSH	BON		
		360SW		
		TRUE360X		
XCOMMON	DSQ	NORM		
		X1		
	DMP	SRR*		
		R1A		
		0	-12D,1	
	STODL	XI	# XI (+6)	
		R1		
	SR1	SQRT		
	ROUND	DMP		
	SL4R		#	PL AT 0
	STORE	X	# X (+17 OR +16)	
	DSQ	NORM		
		X1		
	PDDL	DMP	# OD=XSQ (+34 OR +32 -N1)	PL AT 2
		P		
		R1		
	SL3	SQRT		
	DMP	SL3R		
		COGA		
	STODL	KEPC1		
		R1A		
	BDSU	CLEAR		
		D1/64		
		INFINFLG		
	STORE	KEPC2		
# Page 1294				
	RVQ			
RESETX2	AXT,2			
		3		
360CHECK	SETPD	BPL		
		OD		
		INVRSEQN		
	SET			
		360SW		
INVRSEQN	DLOAD	SQRT		
		P		
	PDDL	DMP	# OD=SQRT(P) (+2)	PL AT 2
		SNTH		

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	SL1	COGA PDDL	# 2D=SNTH COGA (+5)	PL AT 4
		CSTH		
	SR4	DAD		
		D1/32		
	DSU	DMP	#	PL AT 2,0
	NORM	BDDV		
		X1		
		SNTH		
	SLR*	ABS	# NOTE: NEAR 360 CASE TREATED DIFFERENTLY	
		0	-5,1	
	PUSH	DSQ	# OD=1/W (-1)	PL AT 2
	STODL	34D		
		D1/16		
1/WLOOP	PUSH	DSQ	# 2D=G (+4)	PL AT 4
	RTB	PDDL	#	PL AT 7
		TPMODE		
		R1A		
	DMP	SR4		
		34D		
	TAD			
	BMN	SQRT	#	PL AT 4
		INFINITY		
	DAD		#	PL AT 2
	TIX,2	NORM		
		1/WLOOP		
		X1		
	BDDV			
	SLR*	GOTO	#	PL AT 0
		0	-7,1	
		POLYCOEF		
# Page 1295 TRUE360X	DLOAD	BMN		
		R1A		
		INFINITY		
	SQRT	NORM		
		X1		
	BDDV	SL*		
		2PISC		
		0	-3,1	
	DSU	PUSH	# OD=2PI/SQRT(R1A) -X	PL AT 0,2
	GOTO			
		XCOMMON		
INFINITY	SETPD	BOV	# NO SOLUTION EXISTS SINCE CLOSURE THROUGH	
		0	# INFINITY IS REQUIRED	

OVFLCLR	SET	OVFLCLR RVQ INFINFLG		
# Page 1296				
LAMBERT	STQ	SETPD RTNLAMB OD		
	BOV			
	SSP	+1 VLOAD* ITERCTR 20D MUTABLE,1		
	STODL	1/MU TDESIRED		
	DMPR			
	STORE	BEE19		
	SET	EPSILONL VLOAD SLOPESW R1VEC		
	PDVL	CALL	# OD=R1VEC (+29 OR +27)	PL AT 6
		R2VEC	# MPAC=R2VEC (+29 OR +27)	
		GEOM		
	STODL	SNTH	# OD=CSTH (+1)	PL AT 2
		MAGVEC2		
	NORM	PDDL	#	PL AT 4
		X1		
		R1		
	SR1	DDV	#	PL AT 2
	SL*	PDDL	# DXCH WITH OD, OD=R1/R2 (+7)	PL AT 0,2
		0	-6,1	
	STADR			
	STORE	CSTH	# CSTH (+1)	
	SR1	BDSU		
		D1/4		
	STORE	1-CSTH	# 1-CSTH (+2)	
	ROUND	BZE		
		360LAMB		
	NORM	PDDL	#	PL AT 4
		X1		
		OD		
	SR1	DDV	#	PL AT 2
	SL*	SQRT		

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```

                                0      -3,1
PDDL    SR                      # 2D=SQRT(2R1/R2(1-CSTH)) (+5)  PL AT 4
        SNTH
        6
DDV     DAD                      #                               PL AT 2
        1-CSTH

STADR
STORE   COGAMAX
BOV     BMN                      # IF OVFL, COGAMAX=COGUPLIM

# Page 1297
        UPLIM                    # IF NEG, USE EVEN IF LT COGLOLIM, SINCE
        MAXCOGA                  #       THIS WOULD BE RESET IN LAMBLOOP
DSU     BMN                      # IF COGAMAX GT COGUPLIM, COGAMAX=COGUPLIM
        COGUPLIM
        MAXCOGA                  # OTHERWISE OK, SO GO TO MAXCOGA

UPLIM   DLOAD
        COGUPLIM                  # COGUPLIM=.999511597 = MAX VALUE OF COGA
STORE   COGAMAX                  #       NOT CAUSING OVFL IN R1A CALCULATION
MAXCOGA DLOAD

        CSTH
SR      DSU                      #                               PL AT 0
        6

STADR
STODL   CSTH-RHO
        GEOMSGN
BMN     DLOAD
        LOLIM
        CSTH-RHO
SL1     DDV
        SNTH
BOV
        LOLIM
MINCOGA STORE COGAMIN            # COGAMIN (+5)
        BON  SSP
        GUESSW
        NOGUESS
        TWEKIT
        00001
        DLOAD
        COGA

LAMBLOOP DMP
        SNTH
SR1     DSU
        CSTH-RHO
NORM    PDDL                    # OD=SNTH COGA-(CSTH-RHO) (+7+C(XI)) PL=2
```

# Page 1298

```

X1
1-CSTH
SL*   DDV          # 1-CSTH (+2)          PL AT 0
      0 -9D,1
BMN   BZE
      NEGP
      NEGP
STODL P          # P=(1-CSTH)/(SNTH COGA-(CSTH-RHO)) (+4)
      COGA
DSQ   DAD
      D1/1024
NORM  DMP
      X1

P
SR*   BDSU
      0          -8D,1
      D1/32
STODL R1A        # R1A=2-P(1+COGA COGA) (+6)

P
BOV   CALL
      HIENERGY
      GETX
DLOAD
T
STODL TPREV
      XI
BON   CALL
      INFINFLG
      NEGP        # HAVE EXCEEDED THEORETICAL BOUNDS
      DELTIME
BOV   BDSU
      BIGTIME
      TDESIRE
STORE TERRLAMB
ABS   BDSU
      EPSILONL
BPL   RTB
      INITV
      CHECKCTR
BHIZ  CALL
      SUFFCHEK
      ITERATOR
DLOAD BZE
      MPAC

```



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```

                                SUFFCHEK
                                DAD
                                COGA
                                STCALL COGA
                                LAMBLOOP

NEGP      DLOAD  BPL          # IMPOSSIBLE TRAJECTORY DUE TO INACCURATE
                                DCOGA    # BOUND CALCULATION.  TRY NEW COGA.
                                LOENERGY

HIENERGY  SETPD  DLOAD          # HIGH ENERGY TRAJECTORY RESULTED.
                                0
                                COGA    # IN OVFL OF P OR R1A, OR XI EXCEEDING 50.
                                STORE    # THIS IS THE NEW BOUND.
COMMONLM  DLOAD  SR1
                                DCOGA

# Page 1299
                                STORE  DCOGA    # USE DCOGA/2 AS DECREMENT
                                BZE    BDSU
                                SUFFCHEK
                                COGA
                                STCALL COGA
                                LAMBLOOP

BIGTIME   DLOAD
                                TPREV
                                STORE  T

LOENERGY  SETPD  DLOAD          # LOW ENERGY TRAJECTORY RESULTED
                                0
                                COGA    # IN OVERFLOW OF TIME.
                                STCALL  COGAMAX # THIS IS THE NEW BOUND.
                                COMMONLM

SUFFCHEK  DLOAD  ABS
                                TERRLAMB
                                PDDL   DMP
                                TDESIED  # PL AT 2D
                                D1/4
                                DAD    DSU    # PL AT 0D
                                ONEBIT
                                BPL    SETGO
                                INITV
                                SOLNSW
                                RTNLAMB
```

360LAMB	SETPD	SETGO 0 SOLNSW RTNLAMB	# LAMBERT CANNOT HANDLE CSTH=1	
NOGUESS	SSP	DLOAD TWEKIT 20000 COGAMIN		
	SR1	PDDL COGAMAX	#	PL AT 2
	SR1	DAD		
	STADR		#	PL AT 0
	STORE	COGA		
	STCALL	DCOGA LAMBLOOP		
# Page 1300				
LOLIM	DLOAD	GOTO COGLOLIM MINCOGA	# COGLOLIM=-.999511597	
INITV	DLOAD	NORM R1 X1		
	PDDL	SR1 P	#	PL AT 2
	DDV		#	PL AT 0
	SL*	SQRT 0		
		-4,1		
	DMP	SL1 ROOTMU		
	PUSH	DMP COGA	# OD=VTAN (+7)	PL AT 2
	SL	VXSC 5 UR1		
	PDDL		# XCH WITH OD	PL AT 0,6
	VXSC	VSL1 UN		
	VXV	VAD UR1	#	PL AT 0
	VSL1	CLEAR SOLNSW		
	STORE	VVEC		
	SLOAD	BZE VTARGETAG		

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		TARGETV		
	GOTO	RTNLAMB		
TARGETV	DLOAD	CALL		
		MAGVEC2		
		LAMENTER		
	STCALL	VTARGET		
		RTNLAMB		
# Page 1301				
TIMERAD	STQ	SETPD	#	PL AT 0
		RTNTR		
		0		
	BOV			
		+1		
	VLOAD	PDVL	#	PL AT 6
		RVEC		
		VVEC		
	CALL			
		PARAM		
	BOV	DLOAD		
		COGAOVFL	#	PL AT 0
		D1/32		
	DSU	DMP		
		R1A		
		P		
	SQRT	DMP		
		COGA		
	SL4	VXSC		
		U2		
	PDDL	DSU	#	PL AT 6
		D1/64		
		R1A		
	VXSC	VSU	#	PL AT 0
		UR1		
	VSL4	UNIT		
	BOV			
		CIRCULAR		
	PDDL	NORM	# 0D=UNIT(ECC) (+3)	PL AT 6
		RDESIRED	# 35D=ECC (+3)	
		X1		
	PDDL	DMP	#	PL AT 8
		R1		
		P		
	SL*	DDV	#	PL AT 6

		0,1		
	DSU	DDV		
		D1/16		
		36D	# 36D=ECC (+3)	
	STORE	COSF		
	BOV	DSQ		
		BADR2		
	BDSU	BMN		
		D1/4		
		BADR2		
	SQRT	SIGN		
		SGNRDOT		
	CLEAR			
		APSESW		
# Page 1302				
TERMNVEC	VXSC	VSL1		
		UN		
	VXV	PDVL	# VXCH WITH OD	PL AT 0,6
		OD		
	VXSC	VAD	#	PL AT 0
		COSF		
	VSL1	PUSH	# OD=U2	PL AT 6
	DOT	DDV	# LIMITS RESULT TO POSMAX OR NEGMAX	
		UR1		
		DP1/4		
	SR1	BOV	# SCALE BACK DOWN TO NORMAL	
		+1	# CLEAR OVFind IF SET	
	STOVL	CSTH	# CSTH (+1)	
		UR1		
	VXV	VSL1		
	DOT	SL1		
		UN		
	STODL	SNTH	# SNTH (+1)	
		P		
	CALL			
		GETX		
	CLRGO			
		SOLNSW		
		COMMNOU		
CIRCULAR	SETPD	SETGO		
		0		
		SOLNSW		
		ABTCONIC		

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BADR2	DLOAD	SIGN		
		LODPHALF		
		COSF		
	STODL	COSF		
		KEPZERO		
	SETGO			
		APSESW		
		TERMNVEC		
# Page 1303				
APSIDES	STQ	SETPD	#	PL AT 0
		RTNAPSE		
		OD		
	BOV			
		+1		
	VLOAD	PDVL	#	PL AT 6
		RVEC		
		VVEC		
	CALL			
		PARAM		
	BOV		#	PL AT 0
		GETECC		
GETECC	DMP	SL4		
		R1A		
	BDSU	SQRT		
		D1/64		
	STORE	ECC		
	DAD	PDDL	#	PL AT 2
		D1/8		
		R1		
	DMP	SL1		
		P		
	DDV		#	PL AT 0
	PDDL	NORM	# OD=RP (+29 OR +27)	PL AT 2
		R1A		
		X1		
	PDDL	SL*	#	PL AT 4
		R1		
		0	-5,1	
	DDV	DSU	#	PL AT 2,0
	BOV	BMN		
		INFINAPO		
		INFINAPO		
	GOTO			
		RTNAPSE		

```

INFINAPO      DLOAD  GOTO      # RETURNS WITH APOAPSIS IN MPAC, PERIAPSIS
                  LDPOS MAX
                  RTNAPSE      # THAT PL IS AT 0.

```

# Page 1304

```

ABTCONIC      EXIT
               TC      P00D00
               OCT     00607

```

# Page 1305

```

               SETLOC  CONICS1
               BANK
               COUNT   04/CONIC

```

```

MUTABLE      2DEC*   3.986032 E10 B-36*      # MUE
               2DEC*   .25087606 E-10 B+34*    # 1/MUE
               2DEC*   1.99650495 E5 B-18*     # SQRT(MUE)
               2DEC*   .50087529 E-5 B+17*     # 1/SQRT(MUE)
               2DEC     4.902778 E8 B-30        # MUM
               2DEC     .203966 E-8 B+28       # 1/MUM
               2DEC*   2.21422176 E4 B-15*     # SQRT(MUM)
               2DEC*   .45162595 E-4 B+14*     # 1/SQRT(MUM)

```

```

LDPOS MAX     EQUALS  LODP MAX      # DPPOS MAX IN LOW MEMORY.

```

# ERASABLE ASSIGNMENTS

# KEPLER SUBROUTINE

# INPUT --

```

# RRECT      ERASE   +5
# VRECT      ERASE   +5
# TAU.       ERASE   +1
# XKEP       ERASE   +1
# TC         ERASE   +1
# XPREV      ERASE   +1
1/MU         EQUALS  14D
ROOTMU       EQUALS  16D

```

```

1/ROOTMU      EQUALS  18D

# OUTPUT --
# RCV          ERASE   +5
# VCV          ERASE   +5
# RC           ERASE   +1
# XPREV        ERASE   +1

# DEBRIS --
ALPHA         EQUALS  8D
XMAX          EQUALS 10D
# Page 1306
XMIN          EQUALS 12D
X             EQUALS 20D
XI            EQUALS 24D
S(XI)         EQUALS 26D
XSQC(XI)      EQUALS 28D
T             EQUALS 30D
R1            EQUALS 32D
KEPC1         EQUALS 34D
KEPC2         EQUALS 36D

# DELX         ERASE   +1
# DELT         ERASE   +1
# URRECT       ERASE   +5
# RCNORM       ERASE   +1
# XPREV        EQUALS  XKEP

# LAMBERT SUBROUTINE
#
# INPUT --
# R1VEC        ERASE   +5
# R2VEC        ERASE   +5
# TDESIRE      ERASE   +1
# GEOMSGN      ERASE   +0
# GUESSW              # 0 IF COGA GUESS AVIABLE, 1 IF NOT
# COGA          ERASE   +1 # INPUT ONLY IF GUESS IS ZERO.
# NORMSW              # 0 IF UN TO BE COMPUTED, 1 IF UN INPUT
# UN            ERASE   +5 # ONLY USED IF NORMSW IS 1
# VTARGETAG     ERASE   +0
# TWEKIT        EQUALS 40D # ONLY USED IF GUESSW IS 0

# OUTPUT --
# VTARGET       ERASE   +5 # AVAILABLE ONLY IF VTARGETAG IS ZERO.
# V1VEC         EQUALS  MPAC

```

```

# DEBRIS --
# RTNLAMB      ERASE   +0
# U2           ERASE   +5
# MAGVEC2      ERASE   +1
# UR1          ERASE   +5
# R1           EQUALS  31D
# UN           ERASE   +5
# SNTH         ERASE   +1
# CSTH         ERASE   +1
# 1-CSTH       ERASE   +1
# CSTH-RHO     ERASE   +1

COGAMAX        EQUALS  14D   # CLOBBERS 1/MU
COGAMIN        EQUALS   8D
DCOGA          EQUALS  12D

# TWEEKIT      EQUALS  40D
# P            ERASE   +1
# Page 1307
# COGA         ERASE   +1
# R1A          ERASE   +1
# X            EQUALS  20D
# XSQ          EQUALS  22D
# XI           EQUALS  24D
# S(XI)        EQUALS  26D
# XSQC(XI)     EQUALS  28D
# T            EQUALS  30D
# KEPC1        EQUALS  34D
# KEPC2        EQUALS  36D
# SLOPSW
# SOLNSW

# OTHERS --
# RVEC         EQUALS  R1VEC
# VVEC         ERASE   +5
# COGAFLAG
# RVSW
# INFINFLG
# APSESW
# 360SW
# RTNTT        EQUALS  RTNLAMB
# ECC          ERASE   +1
# RTNTR        EQUALS  RTNLAMB
# RTNAPSE      EQUALS  RTNLAMB
# R2           EQUALS  MAGVEC2

```



```
COSF          EQUALS  24D

# RTNPRM      ERASE   +0
# SCNRDOT     ERASE   +0
# RDESIRED    ERASE   +1

# ITERATOR SUBROUTINE

# ORDERSW
MAX           EQUALS  14D          # CLOBBERS 1/MU
MIN           EQUALS   8D

# INDEP       ERASE   +1

DELINDEP     EQUALS  12D
ITERCTR      EQUALS  22D
DEP          EQUALS  30D

# DELDEP      ERASE   +1
# DEPREV      ERASE   +1

TWEELIT      EQUALS  40D

# MORE KEPLER

# EPSILONT    ERASE   +1

# Page 1308
# MORE LAMBERT

# TERRLAMB    EQUALS  DELDEP
# TPREV       EQUALS  DEPREV

# EPSILONL    EQUALS  EPSILONT +2  # DOUBLE PRECISION WORD
```

This code is written to file `src/CONIC-SUBROUTINES.s`.

## A.16 CONTRACT AND APPROVALS

```

274  <src/CONTRACT-AND-APPROVALS.s 274>≡
# Copyright:    Public domain.
# Filename:     CONTRACT_AND_APPROVALS.agc
# Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
#               It is part of the source code for the Command Module's (CM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:      Ron Burkey <info@sandroid.org>.
# Website:      www.ibiblio.org/apollo.
# Mod history:  2009-05-06 RSB   Transcribed from page images.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum.  The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum.  Many
# thanks to both.  The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo.  If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 055 of AGC program Comanche by NASA
#       2021113-051.  10:28 APR. 1, 1969
#
# Page 1

#*****
#
#               THIS AGC PROGRAM SHALL ALSO BE REFERRED TO AS:
#
#
#               COLOSSUS 2A
#
#
#       THIS PROGRAM IS INTENDED FOR USE IN THE CM AS SPECIFIED
#       IN REPORT R-577.  THIS PROGRAM WAS PREPARED UNDER DSR
#       PROJECT 55-23870, SPONSORED BY THE MANNED SPACECRAFT
#       CENTER OF THE NATIONAL AERONAUTICS AND SPACE
#       ADMINISTRATION THROUGH CONTRACT NAS 9-4065 WITH THE
#       INSTRUMENTATION LABORATORY, MASSACHUSETTS INSTITUTE OF
#       TECHNOLOGY, CAMBRIDGE, MASS.
#
#*****

```

```
#      SUBMITTED:      MARGARET H. HAMILTON      DATE:  28 MAR 69
#      M.H.HAMILTON, COLOSSUS PROGRAMMING LEADER
#      APOLLO GUIDANCE AND NAVIGATION

#      APPROVED:      DANIEL J. LICKLY      DATE:  28 MAR 69
#      D.J.LICKLY, DIRECTOR, MISSION PROGRAM DEVELOPMENT
#      APOLLO GUIDANCE AND NAVIGATION PROGRAM

#      APPROVED:      FRED H. MARTIN      DATE:  28 MAR 69
#      FRED H. MARTIN, COLOSSUS PROJECT MANAGER
#      APOLLO GUIDANCE AND NAVIGATION PROGRAM

#      APPROVED:      NORMAN E. SEARS      DATE:  28 MAR 69
#      N.E. SEARS, DIRECTOR, MISSION DEVELOPMENT
#      APOLLO GUIDANCE AND NAVIGATION PROGRAM

#      APPROVED:      RICHARD H. BATTIN      DATE:  28 MAR 69
#      R.H. BATTIN, DIRECTOR, MISSION DEVELOPMENT
#      APOLLO GUIDANCE AND NAVIGATION PROGRAM

#      APPROVED:      DAVID G. HOAG      DATE:  28 MAR 69
#      D.G. HOAG, DIRECTOR
#      APOLLO GUIDANCE AND NAVIGATION PROGRAM

#      APPROVED:      RALPH R. RAGAN      DATE:  28 MAR 69
#      R.R. RAGAN, DEPUTY DIRECTOR
#      INSTRUMENTATION LABORATORY
```

This code is written to file `src/CONTRACT-AND-APPROVALS.s`.

## A.17 CONTROLLED CONSTANTS

```

276  <src/CONTROLLED-CONSTANTS.s 276>≡
      # Copyright:      Public domain.
      # Filename:       CONTROLLED_CONSTANTS.agc
      # Purpose:        Part of the source code for Luminary 1A build 099.
      #                 It is part of the source code for the Lunar Module's (LM)
      #                 Apollo Guidance Computer (AGC), for Apollo 11.
      #
      # Assembler:      yaYUL
      # Contact:         Jim Lawton <jim.lawton@gmail.com>
      # Website:         www.ibiblio.org/apollo.
      # Pages:           038-053
      # Mod history:     2009-05-16      JVL      Transcribed from page images.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #   Assemble revision 001 of AGC program LMY99 by NASA 2021112-061
      #   16:27 JULY 14, 1969

      # Page 38
      # DPS AND APS ENGINE PARAMETERS

                                SETLOC  P40S
                                BANK
                                COUNT*  $$/P40

      # *** THE ORDER OF THE FOLLOWING SIX CONSTANTS MUST NOT BE CHANGED ***

      FDPS          2DEC      4.3670 B-7          # 9817.5 LBS FORCE IN NEWTONS
      MDOTDPS       2DEC      0.1480 B-3          # 32.62 LBS/SEC IN KGS/CS
      DTDECAY       2DEC      -38
      FAPS          2DEC      1.5569 B-7          # 3500 LBS FORCE IN NEWTONS
      MDOTAPS       2DEC      0.05135 B-3         # 11.32 LBS/SEC IN KGS/CS
      ATDECAY       2DEC      -10

      # *****

```

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FRCS4	2DEC	0.17792 B-7	# 400 LBS FORCE IN NEWTONS
FRCS2	2DEC	0.08896 B-7	# 200 LBS FORCE IN NEWTONS

SETLOC P40S1  
BANK  
COUNT\* \$\$/P40

# \*\*\* APS IMPULSE DATA FOR P42 \*\*\*\*\*

K1VAL	2DEC	124.55 B-23	# 2800 LB-SEC
K2VAL	2DEC	31.138 B-24	# 700 LB-SEC
K3VAL	2DEC	1.5569 B-10	# FAPS (3500 LBS THRUST)

# \*\*\*\*\*

S40.136	2DEC	.4671 B-9	# .4671 M NEWTONS (DPS)
S40.136_	2DEC	.4671 B+1	# S40.136 SHIFTED LEFT 10.

SETLOC ASENT1  
BANK  
COUNT\* \$\$/P70

(1/DV)A	2DEC	15.20 B-7	# 2 SECONDS WORTH OF INITIAL ASCENT
---------	------	-----------	-------------------------------------

# Page 39

# STAGE ACCELERATION -- INVERTED (M/CS)  
# 1) PREDICATED ON A LIFTOFF MASS OF  
# 4869.9 KG (SNA-8-D-027 7/11/68)  
# 2) PREDICATED ON A CONTRIBUTION TO VEH-  
# ICLE ACCELERATION FROM RCS THRUSTERS  
# EQUIV. TO 1 JET ON CONTINUOUSLY.

K(1/DV)	2DEC	436.70 B-9	# DPS ENGINE THRUST IN NEWTONS / 100 CS.
---------	------	------------	--

(AT)A	2DEC	3.2883 E-4 B9	# INITIAL ASC. STG. ACCELERATION ** M/CS. # ASSUMPTIONS SAME AS FOR (1/DV)A.
-------	------	---------------	---

(TBUP)A	2DEC	91902 B-17	# ESTIMATED BURN-UP TIME OF THE ASCENT STG. # ASSUMPTIONS SAME AS FOR (1/DV)A WITH THE # ADDITIONAL ASSUMPTION THAT NET MASS-FLOW # RATE = 5.299 KG/SEC = 5.135 (APS) + # .164 (1 RCS JET).
---------	------	------------	---

SETLOC ASENT  
BANK  
COUNT\* \$\$/ASENT

AT/RCS	2DEC	.0000785 B+10	# 4 JETS IN A DRY LEM
--------	------	---------------	-----------------------

SETLOC SERVICES  
BANK  
COUNT\* \$\$/SERV

# \*\*\* THE ORDER OF THE FOLLOWING TWO CONSTANTS MUST NOT BE CHANGED \*\*\*\*\*

APSVEX DEC -3030 E-2 B-5 # 9942 FT/SEC IN M/CS.  
DPSVEX DEC\* -2.95588868 E+1 B-05\* # VE (DPS) +2.95588868E+ 3

# \*\*\*\*\*

SETLOC F2DPS\*31  
BANK  
COUNT\* \$\$/F2DPS

TRIMACCL 2DEC\* +3.50132708 E-5 B+08\* # A (T) +3.50132708E- 1

# Page 40

# THROTTLING AND THRUST DETECTION PARAMETERS

SETLOC P40S  
BANK  
COUNT\* \$\$/P40

THRESH1 DEC 24  
THRESH3 DEC 12  
HIRTHROT = BIT13

SETLOC FFTAG5  
BANK  
COUNT\* \$\$/P40

THRESH2 DEC 308

SETLOC FTHROT  
BANK  
COUNT\* \$\$/THROT

FMAXODD	DEC	+3841	# FSAT	+4.81454413 E+4
FMAXPOS	DEC	+3467	# FMAX	+4.34546769 E+4
THROTLAG	DEC	+20	# TAU (TH)	+1.99999999 E-1
SCALEFAC	2DEC*	+7.97959872 E+2 B-16*	# BITPERF	+7.97959872 E-2

SETLOC F2DPS\*32  
BANK  
COUNT\* \$\$/F2DPS

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DPSTHRSH DEC 36 # (THRESH1 + THRESH3 FOR P63)

# Page 41

# LM HARDWARE-RELATED PARAMETERS

SETLOC RADARUPT  
BANK  
COUNT\* \$\$/RRUPT

LVELBIAS DEC -12288 # LANDING RADAR BIAS FOR 153.6 KC.  
RDOTBIAS 2DEC 17000 # BIAS COUNT FOR RR RANGE RATE.

SETLOC LRS22  
BANK  
COUNT\* \$\$/LRS22

RDOTCONV 2DEC -.0019135344 B7 # CONVERTS RR RDOT READING TO M/CS AT 2(7)  
RANGCONV 2DEC 2.859024 B-3 # CONVERTS RR RANGE READING TO M. AT 2(-29)

SETLOC SERVICES  
BANK  
COUNT\* \$\$/SERV

HBEAMANT 2DEC -.4687018041 # RANGE BEAM IN LR ANTENNA COORDINATES.  
2DEC 0  
2DEC -.1741224271

HSCAL 2DEC -.3288792 # SCALES 1.079 FT/BIT TO 2(22)M.

# \*\*\*\*\* THE SEQUENCE OF THE FOLLOWING CONSTANTS MUST BE PRESERVED \*\*\*\*\*

VZSCAL 2DEC +.5410829105 # SCALES .8668 FT/SEC/BIT TO 2(18) M/CS.  
VYSCAL 2DEC +.7565672446 # SCALES 1.212 FT/SEC/BIT TO 2(18) M/CS.  
VXSCAL 2DEC -.4020043770 # SCALES -.644 FT/SEC/BIT TO 2(18) M/CS.

# \*\*\*\*\*

KPIP DEC .0512 # SCALES DELV TO UNITS OF 2(5) M/CS.  
KPIP1 2DEC .0128 # SCALES DELV TO UNITS OF 2(7) M/CS.  
KPIP2 2DEC .0064 # SCALES DELV TO UNITS OF 2(8) M/CS.

# Page 42

ALTCONV 2DEC 1.399078846 B-4 # CONVERTS M\*2(-24) TO BIT UNITS \*2(-28).  
ARCONV1 2DEC 656.167979 B-10 # CONV. ALTRATE COMP. TO BIT UNITS<

```

                SETLOC  R10
                BANK
                COUNT*  $$/R10

ARCONV          OCT      24402          # 656.1679798B-10 CONV ALTRATE TO BIT
ARTOA           DEC      .1066098 B-1   # .25/2.345 B-1 4X/SEC CYCLE RATE.
ARTOA2          DEC      .0021322 B8    # (.5)/(2.345)(100)
VELCONV         OCT      22316          # 588.914 B-10 CONV VEL. TO BIT UNITS
KPIP1(5)        DEC      .0512          # SCALES DELV TO M/CS*2(-5).
MAXVBITS        OCT      00547          # MAX. DISPLAYED VELOCITY 199.9989 FT

```

```

                SETLOC  DAPS3
                BANK
                COUNT*  $$/DAPAO

TORKJET1        DEC      .03757          # 550 / .2 SCALED AT (+16) 64 / 180

```

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# PARAMETERS RELATING TO MASS, INERTIA, AND VEHICLE DIMENSIONS

```

                SETLOC  FRANDRES
                BANK
                COUNT*  $$/START

FULLAPS         DEC      5050 B-16      # NOMINAL FULL ASCENT MASS -- 2(16) K

                SETLOC  LOADDAP1
                BANK
                COUNT*  $$/R03

MINLMD          DEC      -2850 B-16      # MIN. DESCENT STAGE MASS -- 2(16) KG
MINMINLM        DEC      -2200 B-16      # MIN ASCENT STAGE MASS -- 2(16) KG.
MINCSM          =        BIT11          # MIN CSM MASS (OK FOR 1/ACCS) = 9050

```

```

                SETLOC  DAPS3
                BANK
                COUNT*  $$/DAPAD

LOASCENT        DEC      2200 B-16      # MIN ASCENT LEM MASS -- 2(16) KG.
HIDESCNT        DEC      15300 B-16     # MAX DESCENT LEM MASS -- 2(16) KG.
LODESCNT        DEC      1750 B-16      # MIN DESCENT STAGE (ALONE) -- 2(16)

```

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# PHYSICAL CONSTANTS ( TIME - INVARIANT )

```

                SETLOC  IMU2

```



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```
BANK
COUNT*  $$/P07

OMEG/MS      2DEC      .24339048

SETLOC  R30LOC
BANK
COUNT*  $$/R30

# *** THE ORDER OF THE FOLLOWING TWO CONSTANTS MUST BE PRESERVED *****

1/RTMUM      2DEC*      .45162595 E-4 B14*
1/RTMUE      2DEC*      .50087529 E-5 B17*

# *****

SETLOC  P40S1
BANK
COUNT*  $$/S40.9

EARTHMU      2DEC*      -3.986032 E10 B-36*      # M(3)/CS(2)

SETLOC  ASENT1
BANK
COUNT*  $$/P12

MUM(-37)     2DEC*      4.9027780 E8 B-37*
MOONRATE     2DEC*      .26616994890062991 E-7 B+19*      # RAD/CS.

SETLOC  SERVICES
BANK
COUNT*  $$/SERV

# *** THE ORDER OF THE FOLLOWING TWO CONSTANTS MUST BE PRESERVED *****

-MUDT        2DEC*      -7.9720645 E+12 B-44*
-MUDT1       2DEC*      -9.8055560 E+10 B-44*

# *****

-MUDTMUN     2DEC*      -9.8055560 E+10 B-38*
RESQ         2DEC*      40.6809913 E12 B-58*

# Page 45
20J          2DEC      3.24692010 E-2
2J           2DEC      3.24692010 E-3
```

```

                SETLOC  P50S1
                BANK
                COUNT*  $$/LOSAM

RSUBEM          2DEC    384402000 B-29
RSUBM           2DEC    1738090 B-29
RSUBE           2DEC    6378166 B-29
ROE             2DEC    .00257125

                SETLOC  CONICS1
                BANK
                COUNT*  $$/LT-LG

ERAD            2DEC    6373338 B-29      # PAD RADIUS
504RM           2DEC    1738090 B-29      # METERS B-29 (EQUATORIAL MOON RADIUS)

                SETLOC  CONICS1
                BANK
                COUNT*  $$/CONIC

# *** THE ORDER OF THE FOLLOWING CONSTANTS MUST BE PRESERVED *****

MUTABLE         2DEC*   3.986032 E10 B-36*   # MUE
                2DEC*   .25087606 E-10 B+34* # 1/MUE
                2DEC*   1.99650495 E5 B-18*   # SQRT(MUE)
                2DEC*   .50087529 E-5 B+17*   # 1/SQRT(MUE)
                2DEC*   4.902778 E8 B-30*     # MUM
                2DEC*   .203966 E-8 B+28*     # 1/MUM
                2DEC*   2.21422176 E4 B-15*   # SQRT(MUM)
                2DEC*   .45162595 E-4 B+14*   # 1/SQRT(MUM)

# *****

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                SETLOC  INTINIT
                BANK
                COUNT*  $$/INTIN

OMEGMOON        2DEC*   2.66169947 E-8 B+23*

                SETLOC  ORBITAL2
                BANK
                COUNT*  $$/ORBIT

# *** THE ORDER OF THE FOLLOWING CONSTANTS MUST NOT BE CHANGED *****

```

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	2DEC*	1.32715445 E16 B-54*
MUM	2DEC*	4.9027780 E8 B-30*
MUEARTH	2DEC*	3.986032 E10 B-36*
	2DEC	0
J4REQ/J3	2DEC*	.4991607391 E7 B-26*
	2DEC	-176236.02 B-25
2J3RE/J2	2DEC*	-.1355426363 E5 B-27*
	2DEC*	.3067493316 E18 B-60*
J2REQSQ	2DEC*	1.75501139 E21 B-72*
3J22R2MU	2DEC*	9.20479048 E16 B-58*

# \*\*\*\*\*

SETLOC TOF-FF1  
BANK  
COUNT\* \$\$/TFF

1/RTMU	2DEC*	.5005750271 E-5 B17*	# MODIFIED EARTH MU
--------	-------	----------------------	---------------------

SETLOC SBAND  
BANK  
COUNT\* \$\$/R05

REMDIST	2DEC	384402000 B-29	# MEAN DISTANCE BETWEEN EARTH AND MOON.
---------	------	----------------	---

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# PHYSICAL CONSTANTS (TIME - VARIANT)

SETLOC STARTAB  
BANK  
COUNT\* \$\$/STARS

2DEC	+.8342971408 B-1	# STAR 37	X
2DEC	-.2392481515 B-1	# STAR 37	Y
2DEC	-.4966976975 B-1	# STAR 37	Z
2DEC	+.8139832631 B-1	# STAR 36	X
2DEC	-.5557243189 B-1	# STAR 36	Y
2DEC	+.1691204557 B-1	# STAR 36	Z
2DEC	+.4541086270 B-1	# STAR 35	X
2DEC	-.5392368197 B-1	# STAR 35	Y
2DEC	+.7092312789 B-1	# STAR 35	Z
2DEC	+.3201817378 B-1	# STAR 34	X

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2DEC	-.4436021946	B-1	# STAR 34	Y
2DEC	-.8370786986	B-1	# STAR 34	Z
2DEC	+.5520184464	B-1	# STAR 33	X
2DEC	-.7933187400	B-1	# STAR 33	Y
2DEC	-.2567508745	B-1	# STAR 33	Z
2DEC	+.4537196908	B-1	# STAR 32	X
2DEC	-.8779508801	B-1	# STAR 32	Y
2DEC	+.1527766153	B-1	# STAR 32	Z
2DEC	+.2069525789	B-1	# STAR 31	X
2DEC	-.8719885748	B-1	# STAR 31	Y
2DEC	-.4436288486	B-1	# STAR 31	Z
2DEC	+.1217293692	B-1	# STAR 30	X
2DEC	-.7702732847	B-1	# STAR 30	Y
2DEC	+.6259880410	B-1	# STAR 30	Z
2DEC	-.1124304773	B-1	# STAR 29	X
2DEC	-.9694934200	B-1	# STAR 29	Y
2DEC	+.2178116072	B-1	# STAR 29	Z
2DEC	-.1146237858	B-1	# STAR 28	X
2DEC	-.3399692557	B-1	# STAR 28	Y
2DEC	-.9334250333	B-1	# STAR 28	Z
2DEC	-.3516499609	B-1	# STAR 27	X
2DEC	-.8240752703	B-1	# STAR 27	Y
2DEC	-.4441196390	B-1	# STAR 27	Z
2DEC	-.5326876930	B-1	# STAR 26	X
2DEC	-.7160644554	B-1	# STAR 26	Y
2DEC	+.4511047742	B-1	# STAR 26	Z
2DEC	-.7861763936	B-1	# STAR 25	X
2DEC	-.5217996305	B-1	# STAR 25	Y
2DEC	+.3311371675	B-1	# STAR 25	Z
2DEC	-.6898393233	B-1	# STAR 24	X
2DEC	-.4182330640	B-1	# STAR 24	Y
2DEC	-.5909338474	B-1	# STAR 24	Z
2DEC	-.5812035376	B-1	# STAR 23	X
2DEC	-.2909171294	B-1	# STAR 23	Y

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2DEC	+.7599800468 B-1	# STAR 23	Z
2DEC	-.9170097662 B-1	# STAR 22	X
2DEC	-.3502146628 B-1	# STAR 22	Y
2DEC	-.1908999176 B-1	# STAR 22	Z

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2DEC	-.4523440203 B-1	# STAR 21	X
2DEC	-.0493710140 B-1	# STAR 21	Y
2DEC	-.8904759346 B-1	# STAR 21	Z
2DEC	-.9525211695 B-1	# STAR 20	X
2DEC	-.0593434796 B-1	# STAR 20	Y
2DEC	-.2986331746 B-1	# STAR 20	Z
2DEC	-.9656605484 B-1	# STAR 19	X
2DEC	+.0525933156 B-1	# STAR 19	Y
2DEC	+.2544280809 B-1	# STAR 19	Z
2DEC	-.8608205219 B-1	# STAR 18	X
2DEC	+.4636213989 B-1	# STAR 18	Y
2DEC	+.2098647835 B-1	# STAR 18	Z
2DEC	-.7742591356 B-1	# STAR 17	X
2DEC	+.6152504197 B-1	# STAR 17	Y
2DEC	-.1482892839 B-1	# STAR 17	Z
2DEC	-.4657947941 B-1	# STAR 16	X
2DEC	+.4774785033 B-1	# STAR 16	Y
2DEC	+.7450164351 B-1	# STAR 16	Z
2DEC	-.3612508532 B-1	# STAR 15	X
2DEC	+.5747270840 B-1	# STAR 15	Y
2DEC	-.7342932655 B-1	# STAR 15	Z
2DEC	-.4118589524 B-1	# STAR 14	X
2DEC	+.9065485360 B-1	# STAR 14	Y
2DEC	+.0924226975 B-1	# STAR 14	Z
2DEC	-.1820751783 B-1	# STAR 13	X

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2DEC	+.9404899869 B-1	# STAR 13	Y
2DEC	-.2869271926 B-1	# STAR 13	Z
2DEC	-.0614937230 B-1	# STAR 12	X
2DEC	+.6031563286 B-1	# STAR 12	Y

2DEC	-.7952489957 B-1	# STAR 12	Z
2DEC	+.1371725575 B-1	# STAR 11	X
2DEC	+.6813721061 B-1	# STAR 11	Y
2DEC	+.7189685267 B-1	# STAR 11	Z
2DEC	+.2011399589 B-1	# STAR 10	X
2DEC	+.9690337941 B-1	# STAR 10	Y
2DEC	-.1432348512 B-1	# STAR 10	Z
2DEC	+.3507315038 B-1	# STAR 9	X
2DEC	+.8926333307 B-1	# STAR 9	Y
2DEC	+.2831839492 B-1	# STAR 9	Z
2DEC	+.4105636020 B-1	# STAR 8	X
2DEC	+.4988110001 B-1	# STAR 8	Y
2DEC	+.7632988371 B-1	# STAR 8	Z
2DEC	+.7032235469 B-1	# STAR 7	X
2DEC	+.7075846047 B-1	# STAR 7	Y
2DEC	+.0692868685 B-1	# STAR 7	Z
2DEC	+.5450107404 B-1	# STAR 6	X
2DEC	+.5314955466 B-1	# STAR 6	Y
2DEC	-.6484410356 B-1	# STAR 6	Z
2DEC	+.0130968840 B-1	# STAR 5	X
2DEC	+.0078062795 B-1	# STAR 5	Y
2DEC	+.9998837600 B-1	# STAR 5	Z
2DEC	+.4917678276 B-1	# STAR 4	X
2DEC	+.2204887125 B-1	# STAR 4	Y
2DEC	-.8423473935 B-1	# STAR 4	Z
2DEC	+.4775639450 B-1	# STAR 3	X
2DEC	+.1166004340 B-1	# STAR 3	Y
2DEC	+.8708254803 B-1	# STAR 3	Z
2DEC	+.9342640400 B-1	# STAR 2	X
2DEC	+.1735073142 B-1	# STAR 2	Y
2DEC	-.3115219339 B-1	# STAR 2	Z
2DEC	+.8748658918 B-1	# STAR 1	X
2DEC	+.0260879174 B-1	# STAR 1	Y
2DEC	+.4836621670 B-1	# STAR 1	Z

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CATALOG DEC 6970

# \*\*\*\*\*

SETLOC EPHEM1  
BANK  
COUNT\* \$\$/EPHEM

KONMAT	2DEC	1.0 B-1	# *****
	2DEC	0	# *
	2DEC	0	# *
	2DEC	0	# *
	2DEC	.91745 B-1	# K1 COS(OBL) *
	2DEC	-.03571 B-1	# K2 SIN(OBL)SIN(IM) *
	2DEC	0	# *
	2DEC	.39784 B-1	# K3 SIN(OBL) *

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	2DEC	.082354 B-1	# K4 COS(OBL)SIN(IM) *
CSTODAY	2DEC	8640000 B-33	# * NOTE: *
RCB-13	OCT	00002	# * TABLES CONTAIN *
	OCT	00000	# * CONSTANTS FOR *
RATESP	2DEC	.03660098 B+4	# LOMR * 1969 - 1970 *
	2DEC	.00273779 B+4	# LOSR
	2DEC	-.00014719 B+4	# LONR
	2DEC	.815282336	# LOMO
	2DEC	.274674910	# LOSO
	2DEC	.986209499	# LONO
VAL67	2DEC*	.01726666666 B+1*	# AMOD
	2DEC	.530784445	# AARG
	2DEC	.036291712 B+1	# 1/27
	2DEC	.003505277 B+1	# BMOD
	2DEC	.585365625	# BARG
	2DEC	.03125 B+1	# 1/32
	2DEC	.005325277 B+1	# CMOD
	2DEC	-.01106341036	# CARG
	2DEC	.002737925 B+1	# 1/365

# \*\*\*\*\*

SETLOC PLANTIN2  
BANK  
COUNT\* \$\$/LUROT

COSI	2DEC	.99964173 B-1	# COS (5521.5 SEC.) B-1
SINI	2DEC	.02676579 B-1	# SIN (5521.5 SEC.) B-1

```
NODDOT      2DEC    -.457335121 E-2
FDDOT      2DEC     .570863327
# Page 53
BDDOT      2DEC    -3.07500686 E-8
NODIO      2DEC     .986209434
FSUBO      2DEC     .829090536
BSUBO      2DEC     .0651201393
WEARTH     2DEC     .973561595
```

```
# REV/CSEC B+28 = -1.07047011 E-8 RAD
# REV/CSEC B+27 =  2.67240410 E-6 RAD
# REV/CSEC B+28 = -7.19757301 E-14 RAD
# REVS B-D      =  6.19653663041 RAD
# REVS B-D      =  5.20932947829 RAD
# REVS B-D      =  0.40916190299 RAD
# REV/CSEC B+23 =  7.29211494 E-5 RAD
```

This code is written to file `src/CONTROLLED-CONSTANTS.s`.



## A.18 CSM GEOMETRY

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*<src/CSM-GEOMETRY.s 289>*≡

```
# Copyright:    Public domain.
# Filename:     CSM_GEOMETRY.agc
# Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
#               It is part of the source code for the Command Module's (CM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:      Ron Burkey <info@sandroid.org>.
# Website:      www.ibiblio.org/apollo.
# Pages:        285-296
# Mod history:  2009-05-08 RSB   Adapted from the Colossus249/ file of the
#                               same name, using Comanche055 page images.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 055 of AGC program Comanche by NASA
#       2021113-051.  10:28 APR. 1, 1969
#
#       This AGC program shall also be referred to as
#               Colossus 2A
#
# Page 285
#
#       BANK      22
#       SETLOC    COMGEOM1
#       BANK
#
# THIS ROUTINE TAKES THE SHAFT AND TRUNNION ANGLES AS READ BY THE CM OPTICAL SYSTEM AND CONVERT
# VECTOR REFERENCED TO THE NAVIGATION BASE COORDINATE SYSTEM AND COINCIDENT WITH THE SEXTANT LI
#
# THE INPUTS ARE:  1) THE SEXTAND SHAFT AND TRUNNION ANGLES ARE STORED SP IN LOCATIONS 3 AND 5
# MARK VAC AREA.  2) THE COMPLEMENT OF THE BASE ADDRESS OF THE MARK VAC AREA IS STORED SP AT LO
# JOB VAC AREA.
#
# THE OUTPUT IS A HALF-UNIT VECTOR IN NAVIGATION BASE COORDINATES AND STORED AT LOCATION 32D OF
# OUTPUT IS ALSO AVAILABLE AT MPAC.
```

```

COUNT 23/GEOM

SXTNB   SLOAD* RTB      # PUSHDOWN 00,02,04,(17D-19D),32D-36D
          5,1          # TRUNNION = TA
          CDULOGIC
          RTB      PUSH
          SXTLOGIC
          SIN      SL1
          PUSH     SLOAD*      # PD2 = SIN(TA)
          3,1      # SHAFT = SA
          RTB      PUSH      # PD4 = SA
          CDULOGIC

          COS      DMP
          2
          STODL    STARM      # COS(SA)SIN(TA)

          SIN      DMP
          STADR
          STODL    STARM  +2   # SIN(SA)SIN(TA)

          COS
          STOVL    STARM  +4
          STARM      # STARM = 32D
          MXV      VSL1
          NB1NB2
          STORE    32D
          RVQ

SXTLOGIC CAF      10DEGS-    # CORRECT FOR 19.775 DEGREE OFFSET
          ADS      MPAC
          CAF      QUARTER
          TC       SHORTMP
          TC       DANZIG

```

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# CALCSXA COMPUTES THE SEXTANT SHAFT AND TRUNNION ANGLES REQUIRED TO POSITION THE OPTICS  
 # OF-SIGHT LIES ALONG THE STAR VECTOR. THE ROUTINE TAKES THE GIVEN STAR VECTOR AND POSITION  
 # REFERENCE TO THE OPTICS COORDINATE SYSTEM. IN ADDITION IT SETS UP THREE UNIT VECTORS  
 # REFERENCED TO THE OPTICS COORDINATE SYSTEM.

#

# THE INPUTS ARE: 1) THE STAR VECTOR REFERRED TO THE PRESENT STABLE MEMBER COORDINATE  
 # INPUT AS \*SMNB\*, I.E., SINES AND COSINES OF THE CDU ANGLES, IN THE ORDER Y Z X, AT  
 # TO CDUTRIG WILL PROVIDE THIS INPUT.

#

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# THE OUTPUT ARE THE SEXTANT SHAFT AND TRUNNION ANGLES STORED DP AT SAC AND PAC RESPECTIVELY.  
# EQUAL TO ZERO).

CALCSXA	ITA	VLOAD	# PUSHDOWN 00-26D, 28D, 30D, 32D-36D
		28D	
		STAR	
	CALL		
		*SMNB*	
	MXV	VSL1	
		NB2NB1	
	STOVL	STAR	
		HIUNITX	
	STOVL	XNB1	
		HIUNITY	
	STOVL	YNB1	
		HIUNITZ	
	STCALL	ZNB1	
		SXTANG1	

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# SXTANG COMPUTES THE SEXTANT SHAFT AND TRUNNION ANGLES REQUIRED TO POSITION THE OPTICS SUCH TH  
# SIGHT LIES ALONG THE STAR VECTOR.

#

# THE INPUTS ARE: 1) THE STAR VECTOR REFERRED TO ANY COORDINATE SYSTEM STORED AT STAR. 2) THE  
# COORDINATES REFERRED TO THE SAME COORDINATE SYSTEM. THESE THREE HALF-UNIT VECTORS ARE STROED  
# ZNB.

#

# THE OUTPUTS ARE THE SEXTANT SHAFT AND TRUNNION ANGLES STORED DP AT SAC AND PAC RESPECTIVELY.  
# EQUAL TO ZERO).

SXTANG	ITA	RTB	# PUSHDOWN 16D,18D,22D-26D,28D
		28D	
		TRANSP1	# EREF WRT NB2
	VLOAD	MXV	
		XNB	
		NB2NB1	
	VSL1		
	STOVL	XNB1	
		YNB	
	MXV	VSL1	
		NB2NB1	
	STOVL	YNB1	
		ZNB	
	MXV	VSL1	
		NB2NB1	
	STORE	ZNB1	

```

                                RTB      RTB
                                TRANSP1
                                TRANSP2

SXTANG1      VLOAD      VXV
                                ZNB1
                                STAR
                                BOV
                                +1
                                UNIT      BOV
                                ZNB=S1
                                STORE      PDA      # PDA = UNIT(ZNB X S)

                                DOT      DCOMP
                                XNB1
                                STOVL      SINTH      # SIN(SA) = PDA . -XNB
                                PDA

                                DOT
                                YNB1
                                STCALL      COSTH      # COS(SA) = PDA . YNB
                                ARCTRIG

# Page 288

                                RTB
                                1STO2S
                                STOVL      SAC
                                STAR
                                BOV
                                +1
                                DOT      SL1
                                ZNB1
                                ACOS
                                BMN      SL2
                                SXTALARM      # TRUNNION ANGLE NEGATIVE
                                BOV      DSU
                                SXTALARM      # TRUNNION ANGLE GREATER THAN 90 DEGREES
                                20DEG-

                                RTB
                                1STO2S
                                STORE      PAC      # FOR FLIGHT USE, CULTFLAG IS ON IF
                                CLRGO      # TRUNION IS GREATER THAN 90 DEG
                                CULTFLAG
                                28D
SXTALARM      SETGO      # ALARM HAS BEEN REMOVED FROM THIS
                                CULTFLAG

```

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```
ZNB=S1          DLOAD          28D          # SUBROUTINE, ALARM WILL BE SET BY MPI
                STODL          270DEG
                STORE          20DEGS-
                CLRGO          PAC
                CULTFLAG
                28D
```

# Page 289

# THESE TWO ROUTINES COMPUTE THE ACTUAL STATE VECTOR FOR LM, CSM BY ADDING  
# THE CONIC R,V AND THE DEVIATIONS R,V. THE STATE VECTORS ARE CONVERTED TO  
# METERS B-29 AND METERS/CSEC B-7 AND STORED APPROPRIATELY IN RN,VN OR  
# R-OTHER, V-OTHER FOR DOWNLINK. THE ROUTINES NAMES ARE SWITCHED IN THE  
# OTHER VEHICLES COMPUTER.

#

# INPUT

# STATE VECTOR IN TEMPORARY STORAGE AREA  
# IF STATE VECTOR IS SCALED POS B27 AND VEL B5  
# SET X2 TO +2  
# IF STATE VECTOR IS SCALED POS B29 AND VEL B7  
# SET X2 TO 0

#

# OUTPUT

# R(T) IN RN, V(T) IN VN, T IN PIPTIME  
# OR  
# R(T) IN R-OTHER, V(T) IN V-OTHER (T IS DEFINED BY T-OTHER)

```
SVDWN1          BANK          23
                SETLOC        COMGEOM2
                BANK
                COUNT          10/GEOM
                BOF            RVQ          # SW=1=AVETOMID DOING W-MATRIX INTEG
                AVEMIDSW
                +1
                VLOAD          VSL*
                TDELTA V
                0              -7,2
                VAD            VSL*
                RCV
                0,2
                STOVL          RN
                TNUV
                VSL*          VAD
                0              -4,2
```

```

                VCV
            VSL*
                0,2
            STODL VN
                TET
            STORE PIPTIME
            RVQ
SVDWN2          VLOAD VSL*
                TDELTA
                0      -7,2
            VAD     VSL*
                RCV

```

# Page 290

```

                0,2
            STOVL R-OTHER
                TNUV
            VSL* VAD
                0      -4,2
                VCV
            VSL*
                0,2
            STORE V-OTHER
            RVQ

```

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# SUBROUTINE TO COMPUTE THE NATURAL LOG OF C(MPAC, MPAC +1).

#

# ENTRY: CALL

# LOG

#

# SUBROUTINE RETURNS WITH -LOG IN DP MPAC.

#

# EBANK IS ARBITRARY.

```

            BANK 14
            SETLOC POWFLIT2
            BANK
            COUNT 23/GEOM

```

```

LOG          NORM BDSU      # GENERATES LOG BY SHIFTING ARG
                MPAC  +3    # UNTIL IT LIES BETWEEN .5 AND 1.
                NEARLY1    # THE LOG OF THIS PART IS FOUND AND THE
            EXIT      # LOG OF THE SHIFTED PART IS COMPUTED
            TC        POLY  # AND ADDED IN.  SHIFT COUNT STORED
            DEC       2     # (N-1, SUPPLIED BY SMERZH)

```

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```
2DEC      0          # IN MPAC +3.
2DEC      .031335467
2DEC      .0130145859
2DEC      .0215738898

CAF      ZERO
TS       MPAC      +2
EXTEND
DCA      CLOG2/32
DXCH     MPAC
DXCH     MPAC      +3
COM
TC       SHORTMP    # LOAD POSITIVE SHIFT COUNT IN A.
                  # MULTIPLY BY SHIFT COUNT.

DXCH     MPAC      +1
DXCH     MPAC
DXCH     MPAC      +3
DAS      MPAC
TC       INTERPRET  # RESULT IN MPAC, MPAC +1

RVQ
```

```
NEARLY1    2DEC      .999999999
```

# Page 292

```
CLOG2/32    2DEC      .0216608494
```

# Page 293

# SUBROUTINE NAME: EARTH ROTATOR (EARROT1 OR EARROT2)

DATE: 15 FEB 67

# MOD NO: N +1

LOG SECTION: POWERED P

# MOD BY: ENTRY GROUP (BAIRNSFATHER)

#

# FUNCTIONAL DESCRIPTION: THIS ROUTINE PROJECTS THE INITIAL EARTH TARGET VECTOR RTINIT AHEAD T  
# THE ESTIMATED TIME OF FLIGHT. INITIAL CALL RESOLVES THE INITIAL TARGET VECTOR RTINIT I  
# AND NORMAL COMPONENTS RTEAST AND RTNORM. INITIAL AND SUBSEQUENT CALLS ROTATE THIS VECT  
# ABOUT THE (FULL) UNIT POLAR AXIS UNITW THROUGH THE ANGLE WIE DTEAROT TO OBTAIN THE RO  
# TARGET VECTOR RT. ALL VECTORS EXCEPT UNITW ARE HALF UNIT.  
# THE EQUATIONS ARE:

```
#      -      -      -
#      RT = RTINIT + RTNORM (COS(WT) - 1) + RTEAST SIN(WT)
```

```
#
# WHERE WT = WIE DTEAROT
```

```
#      RTINIT = INITIAL TARGET VECTOR
```

```
#      -      -      -
#      RTEAST = UNITW * RTINIT
```

```

#
#      -      -      -
#      RTNORM = RTEAST * UNITW
#
#      FOR CONTINUOUS UPDATING, ONLY ONE ENTRY TO EARROT1 IS REQUIRED, WITH SUBSEQUENT
#
# CALLING SEQUENCE:      FIRST CALL                      SUBSEQUENT CALL
#                       STCALL  DTEAROT                  STCALL  DTEAROT
#                       EARROT1                          EARROT2
#                       C(MPAC) UNSPECIFIED              C(MPAC) = DTEAROT
#      PUSHLOC = PDL+0, ARBITRARY.  6 LOCATIONS USED.
#
# SUBROUTINES USED:  NONE
#
# NORMAL EXIT MODES:  RVQ
#
# ALARMS:  NONE
#
# OUTPUT:      RTEAST  (-1)          .5 UNIT VECTOR EAST, COMPNT OF RTINIT  LEFT
#              RTNORM  (-1)          .5 UNIT VECTOR NORML, COMPNT OF RTINIT  LEFT
#              RT      (-1)          .5 UNIT TARGET VECTOR, ROTATED          LEFT
#              DTEAROT (-28) CS      MAY BE CHANGED BY EARROT2, IF OVER 1 DAY
#
# ERASABLE INITIALIZATION REQUIRED:
#              UNITW  (0)            UNIT POLAR VECTOR                      PAD I
#              RTINIT (-1)          .5 UNIT INITIAL TARGET VECTOR          LEFT
#              DTEAROT (-28) CS      TIME OF FLIGHT                        LEFT
#
# DEBRIS:  QPRET, PDL+0 ... PDL+5
# Page 294
#
#      EBANK=  RTINIT
#
# EARROT1      VLOAD  VXV
#              UNITW          # FULL UNIT VECTOR
#              RTINIT         # .5 UNIT
#              STORE  RTEAST   # .5 UNIT
#
#              VXV
#              UNITW          # FULL UNIT
#              STODL  RTNORM   # .5 UNIT
#              DTEAROT        # (-28) CS
#
# EARROT2      BOVB  DDV
#              TCDANZIG      # RESET OVFLND, IF ON
#              1/WIE
#              BOV  PUSH
#              OVERADAY

```



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	COS	DSU	
		HIDPHALF	
	VXSC	PDDL	# XCH W PUSH LIST
		RTNORM	# .5 UNIT
	SIN	VXSC	
		RTEAST	# .5 UNIT
	VAD	VSL1	
	VAD	UNIT	# INSURE THAT RT IS "UNIT".
		RTINIT	# .5 UNIT
	STORE	RT	# .5 UNIT TARGET VECTOR
	RVQ		
OVERADAY	DLOAD	SIGN	
		1/WIE	
		DTEAROT	
	BDSU		
		DTEAROT	
	STORE	DTEAROT	
	GOTO		
		EARROT2	
#WIE	2DEC	.1901487997	
1/WIE	2DEC	8616410	
NB2NB1	2DEC	+.8431756920 B-1	
	2DEC	0	
	2DEC	-.5376381241 B-1	
# Page 295			
ZERINFLT	2DEC	0	
HALFNFLT	2DEC	.5	
	2DEC	0	
	2DEC	+.5376381241 B-1	
	2DEC	0	
	2DEC	+.8431756920 B-1	
NB1NB2	2DEC	+.8431756920 B-1	
	2DEC	0	
	2DEC	+.5376381241 B-1	
	2DEC	0	
	2DEC	.5	
	2DEC	0	
	2DEC	-.5376381241 B-1	
	2DEC	0	
	2DEC	+.8431756920 B-1	
# Page 296			
10DEGS-	DEC	3600	

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270DEG	OCT	60000	# SHAFT 270 DEGREES	25 COMP.
	OCT	00000		
20DEGS-	DEC	-07199		
	DEC	-00000		
20DEG-	DEC	03600		
	DEC	00000		

This code is written to file `src/CSM-GEOMETRY.s`.

## A.19 DAPIDLER PROGRAM

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*<src/DAPIDLER-PROGRAM.s 299>≡*

```
# Copyright:   Public domain.
# Filename:    DAPIDLER_PROGRAM.agc
# Purpose:    Part of the source code for Luminary 1A build 099.
#             It is part of the source code for the Lunar Module's (LM)
#             Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:  yaYUL
# Contact:    Ron Burkey <info@sandroid.org>.
# Website:    www.ibiblio.org/apollo.
# Pages:      1410-1420
# Mod history: 2009-05-10 SN   (Sergio Navarro). Started adapting
#                               from the Luminary131/ file of the same
#                               name, using Luminary099 page images.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
#       16:27 JULY 14, 1969
```

# Page 1410

```
# THE DAPIDLER PROGRAM IS STARTED BY FRESH START AND RESTART.  THE DAPIDLER PROGRAM IS DONE 10
# PER SECOND UNTIL THE ASTRONAUT DESIRES THE DAP TO WAKE UP, AND THE IMU AND CDUS ARE READY FOR
# THE NECESSARY INITIALIZATION OF THE DAP IS DONE BY THE DAPIDLER PROGRAM.
```

```
BANK      16
SETLOC    DAPS1
BANK

EBANK=    AOSQ

COUNT*   $$/DAPID
```

```
CHEKBITS      EXTEND
READ          CHAN31          # IF BOTH BIT13 AND BIT14 ARE ONE, THEN
```



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```

                                BZF      MOREIDLE

STARTDAP      TC      IBNKCALL      # ZERO ATTITUDE ERROR AND DESIRED RATES.
              FCADR    ZATTEROR
              CAF      ZERO          # ***** INITIALIZE: *****
              TS      TJP
              TS      TJU
              TS      TJV
              TS      OMEGAP          # RATES IN BODY (PILOT) COORDINATES.
              TS      OMEGAQ
              TS      OMEGAR
              TS      TRAPEDP
              TS      TRAPEDQ
              TS      TRAPEDR
              TS      AOSQ            # OFFSET ACCELERATION ESTIMATES.
              TS      AOSQ +1
              TS      AOSR
              TS      AOSR +1
              TS      ALPHAQ          # COPIES OF OFFSET ESTIMATES FOR DOWNLIST.
              TS      ALPHAR
              TS      NEGUQ
              TS      NEGUR
              TS      AOSQTERM        # QRAXIS RATE DERIVATION TERMS AND KALMAN
              TS      AOSRTERM        # FILTER INITIALIZATION TERMS.
              TS      QACCDOT         # DESCENT ACCELERATION DERIVATIVE EST.
              TS      RACCDOT

# Page 1412
              TS      ALLOWGTS        # AOSTASK FLAG FOR QRAXIS RCS CONTROL USE.
              TS      COTROLER        # DO TRYGTS ON FIRST PASS (WILL GO TO RCS)
              TS      INGTS           # RECOGNIZE FIRST GTS PASS AS SUCH.
              TS      QGIMTIMR        # STOP GIMBAL DRIVES. (PROBABLY WOULD BE
              TS      RGIMTIMR        #      GOOD ENOUGH JUST TO INACTIVATE TIMERS)
              TS      OLDPMIN         # MINIMUM IMPULSE MODE ERASABLES
              TS      OLDQRMIN
              TS      PJETCTR         # INITIALIZE DOCKED JET INHIBITION
              TS      UJETCTR         # COUNTERS
              TS      VJETCTR

CALLGMBL      EQUALS    BIT5          # RCSFLAGS INITIALIZATION.
              CS      MANFLAG
              MASK     RCSFLAGS        # NEGUQ(R) HAVE BEEN GENERATED.
              TS      RCSFLAGS

# SET UP "OLD" MEASURED CDU ANGLES:

              EXTEND
              DCA      CDUX            # OLDXFORP AND OLDYFORP
```

	DXCH	OLDXFORP	
	CA	CDUZ	
	TS	OLDZFORQ	
	CS	RCSFLAGS	
	MASK	BIT12	
	ADS	RCSFLAGS	# BIT 12 SET TO 1.
	CA	FOUR	
	TS	SKIPU	
	TS	SKIPV	
	CA	POSMAX	
	TS	TIME6	
	TS	T6NEXT	
	TS	T6FURTHA	
	CA	ZERO	
	TS	T6NEXT +1	
	TS	T6FURTHA +1	
	TS	NXT6ADR	
	TS	NEXTP	
	TS	NEXTU	
	TS	NEXTV	
	CS	TEN	
	TS	DAPZRUP	# JASK NOT IN PROGRESS, INITIALIZE NEG.
	CA	TWO	
	TS	NPTRAPS	
	TS	NQTRAPS	
	TS	NRTRAPS	
	EXTEND		
	DCA	PAXADIDL	
SETTIME5	DXCH	T5ADR	
	CAF	MS100	
	TS	TIME5	
# Page 1413			
	TCF	RESUME	
	EBANK=	AOSQ	
IDLERADR	2CADR	DAPIDLER	
MOREIDLE	TC	IBNKCALL	# CALCULATE Q,R-AXES ATTITUDE ERRORS.
	CADR	QERRCALC	
	TC	IBNKCALL	
	CADR	CALCPERR	# CALCULATE P AXIS ATTITUDE ERRORS.
SHUTDOWN	EXTEND		
	DCA	IDLERADR	
	DXCH	T5ADR	

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```
CAF      ZERO      # KILL ANY POSSIBLE JET REQUESTS
TS       NEXTP
TS       NEXTU
TS       NEXTV
EXTEND
WRITE    CHAN5
EXTEND
WRITE    CHAN6
CS       BGIM23     # TURN TRIM GIMBAL OFF
EXTEND
WAND     CHAN12
TCF      SETTIME5   # RETURN IN 100 MSEC.
```

```
MANFLAG  OCT      03021
BGIM23   OCTAL    07400
EBANK=   OMEGAP
PAXADIDL 2CADR    PAXIS
```

```
MS100    =        OCT37766
COSMG     =        ITEMP1
JUMPDSP   EXTEND    # TRANSFER TO BANK 20
DCA       DSPCADR   # FOR ATTITUDE ERROR DISPLAYS
DTCB
```

```
EBANK=   AK
DSPCADR  2CADR    ALTDSPY
```

# Page 1414

```
BANK     20
SETLOC   DAPS3
BANK
COUNT*  $$/NEEDL
```

```
# PROGRAM:      ALTDSPY
# MOD 0.        6 DEC 1967
# AUTHOR:       CRAIG WORK, DON KEENE, MIT IL
# MOD 3 BY DON KEENE AUG 1, 1968 -- MOVED PROGRAM TO BANK 20
#
```

# PROGRAM DESCRIPTION:

```
#       ALTDSPY REVERSES THE DSPLYALT BIT OF RCSFLAGS EACH TIME IT IS CALLED, WHICH IS PRESUMABLY
#       IF THE REVERSED BIT IS ONE, NEEDLER IS CALLED TO DISPLAY ATTITUDE ERRORS.  IF THE BIT IS
#       ORS ARE CALCULATED AS 1) DAP FOLLOWING ERRORS, IF NEEDLFLG = 0, AND 2) TOTAL ATTITUDE ERROR
```

```
#
#
# WARNING:      ALTDSPY MAY ONLY BE CALLED WITH INTERRUPT INHIBITED
#
```

```

# WARNING:      EBANK MUST BE SET TO 6 WHEN USING THIS ROUTINE.
#
# INPUT:        RCSFLAGS AND      1) IF NEEDLFLG = 0, INPUT PERROR, QERROR, RERROR.
#                                     2) IF NEEDLFLG = 1, INPUT CPHI,CTHETA,CPSI,CDUX,CDUY.
#
#
# OUTPUTS:      RCSFLAGS WITH DSPLYALT REVERSED, AK, AK1, AK2, + NEEDLER OUTPUTS.
#
# ENTRY:        TCF      ALTDSPY
#
# EXIT:         TCF      CHEKMORE
#
# ALARM OR ABORT EXITS: NONE
#
# SUBPROGRAMS CALLED:  NEEDLER, OVERSUB2
#
# DEBRIS:       A, L, AND NEEDLER DEBRIS.

ALTDSPY      CA      RCSFLAGS      # INVERT THE DISPLAY ALTERNATION BIT.
              TS      L
              CA      DSPLYALT
              EXTEND
              RXOR    LCHAN
              TS      RCSFLAGS

              MASK    DSPLYALT
              CCS      A              # IS ALTERNATION FLAG ZERO?
              TCF      NEEDLER

              CAE      FLAGWRDO      # NEEDLFLG WILL INDICATE TOTAL OR DAP AT-
# Page 1415
              MASK    NEEDLBIT      # TITUDE ERROR DISPLAY REQUEST.
              CCS      A
              TCF      DSPLYTOT      # TOTAL ERROR IS NEEDED IN AK, AK +1, AK +2

              CS      QERROR          # YES.  DISPLAY ATT ERRORS ON THE -BALL.
              TS      AK +1          # ERROR COMPLEMENTS ARE INPUT TO NEEDLER.
              CS      RERROR
              TS      AK +2
              CS      PERROR
              XCH      AK

              TCF      RETNMORE      # DISPLAY THESE THE NEXT TIME THROUGH

# CALCULATE GIMBAL ANGLE TOTAL ERRORS, RESOLVE INTO PILOT AXES, STORE TOTAL ERRORS FOR

```



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```
DSPLYTOT      EXTEND
                QXCH      ITEMP1      # SAVE Q FOR CHEKBITS RETURN.

                CA        CTHETA      # DESIRED ATTITUDE, Y-AXIS, 2'S COMP.
EXTEND          # SUBTRACT CURRENT ATTITUDE.
                MSU       CDUY        # DIFFERENCE SCALED AT PI, 1'S COMP.
                TS        AK          # SAVE FOR R-ERROR CALCULATION.
EXTEND
                MP        M21        # (CTHETA-CDUY)*M21 SCALED AT PI RADIANS.
                XCH       AK +1      # STORE FIRST TERM OF Q ERROR.
                CA        CPSI        # DESIRED ATTITUDE, Z-AXIS, 2'S COMP.
EXTEND          # SUBTRACT CURRENT ATTITUDE.
                MSU       CDUZ        # DIFFERENCE SCALED AT PI, 1'S COMP.
                TS        AK +2      # SAVE Z-AXIS TERM FOR R ERROR CALCULATION
EXTEND
                MP        M22        # (CPSI-CDUZ)*M22, SCALED AT PI RADIANS.
                AD        AK +1      # Q ERROR COMPLETE          , AT PI RAD.
                TC        OVERSUB2    # PIN NEEDLES IN CASE OF OVERFLOW
                TS        AK +1

# R ERROR CALCULATION NEXT.

                CA        AK          # Y-AXIS DIFFERENCE STORED BY Q-AXIS CALC.
EXTEND
                MP        M31        # (CTHETA-CDUY)*M31, SCALED AT PI RADIANS.
                XCH       AK +2      # FIRST TERM OF R ERROR.
                # Z-AXIS DIFFERENCE, STORED BY A CALC. IS
EXTEND          # RECOVERED BY THE EXCHANGE.
                MP        M32        # (CPSI-CDUZ)*M32, SCALED AT PI RADIANS.
                AD        AK +2      # R ERROR COMPLETE          , AT PI RAD.
                TC        OVERSUB2    # PIN NEEDLES IN CASE OF OVERFLOW.
                TS        AK +2

# NOW CALCULATE P ERROR.  (NOTE THAT M13 = 1, SCALED AT 1, SO THE MULTIPLICATION IS BY-PASSED.)
# Page 1416
                CA        AK          # Y-AXIS DIFFERENCE STORED BY Q AXIS CALC.
EXTEND
                MP        M11        # (CTHETA-CDUY)*M11 SCALED AT PI RADIANS.
                XCH       AK          # FIRST TERM OF P ERROR IN AK, AT PI RAD.
                CAE       CPHI        # DESIRED ATTITUDE, X-AXIS, 2'S COMP.
EXTEND          # SUBTRACT CURRENT X ATTITUDE.
                MSU       CDUX        # X-AXIS DIFFERENCE, 1'S COMP, AT PI RAD.

# M13 = 1, SO BYPASS THE MULTIPLICATION.
#           EXTEND
#           MP        M13          # (CPHI-CDUX)*M13 SCALED AT PI RADIANS.
```

```

AD      AK      # P ERROR COMPLETE      , SCALED AT PI RAD
TC      OVERSUB2  # PIN NEEDLES IN CASE OF OVERFLOW.
TS      AK

EXTEND
QXCH    ITEMP1    # RESTORE Q FOR CHEKBITS RETURN.

TCF     RETNMORE   # DISPLAY THESE THE NEXT TIME THROUGH

# Page 1417
# FDAI ATTITUDE ERROR DISPLAY SUBROUTINE
#
# PROGRAM DESCRIPTION:          D. KEENE          5/24/67
# MOD 1 BY CRAIG WORK, 12 DEC 67
# MOD 2 BY CRAIG WORK, 6 APRIL 68, CONVERTS ATTITUDE ERROR DISPLAY SCALING FROM 16 7/
#
# THIS SUBROUTINE IS USED TO DISPLAY ATTITUDE ERRORS ON THE FDAI VIA THE DIGITAL TO A
# IN THE CDUS. CARE IS TAKEN TO METER OUT THE APPROPRIATE NUMBER OF PULSES TO THE IN
# OVERFLOW, TO CONTROL THE RELAY SEQUENCING, AND TO AVOID INTERFERENCE WITH THE COARS
# THE DACS.
#
# CALLING SEQUENCE:
# DURING THE INITIALIZATION SECTION OF THE USER'S PROGRAM, BIT3 OF RCSFLAGS SH
# TURN-ON SEQUENCE WITHIN THE NEEDLES PROGRAM:
# CS      RCSFLAGS      # IN EBANK6
# MASK    BIT3
# ADS     RCSFLAGS
# THEREAFTER, THE ATTITUDE ERRORS GENERATED BY THE USER SHOULD BE TRANSFERRED T
# AK      SCALED 180 DEGREES      NOTE:  THESE LOCATIONS ARE SUBJECT
# AK1     SCALED 180 DEGREES      TO CHANGE
# AK2     SCALED 180 DEGREES
# FULL SCALED DEFLECTION OF THE NEEDLES CORRESPONDS TO 5 1/16 DEGREES, WHILE 38
# CORRESPONDS TO 42 3/16 DEGREES. (DAC MAXIMUM CAPACITY IS 384 BITS.) 46 BITS
#
# A CALL TO NEEDLER WILL THE UPDATE THE DISPLAY:
# INHINT
# TC      IBNKCALL      # NOTE:  EBANK SHOULD BE SET TO E6
# CADR    NEEDLER
# RELINT
# THIS PROCESS SHOULD BE REPEATED EACH TIME THE ERRORS ARE UPDATED. AT LEAST 3
# REQUIRED BEFORE ANYTHING IS ACTUALLY DISPLAYED ON THE ERROR METERS.
# NOTE:  EACH CALL TO NEEDLER MUST BE SEPARATED BY AT LEAST 50 MS. TO ASSURE PR
#
# ERASABLES USED:
# AK      CDUXCMD

```

```

#      AK1      CDUYCMD
#      AK2      CDUZCMD
#      EDRIX    A,L,Q
#      EDRIY    T5TEMP
#      EDRIEZ    DINDX
# Page 1418
#
# SWITCHES:      RCSFLAGS  BITS 3,2
#
# I/O CHANNELS:  CHAN12  BIT 4 (COARSE ALIGN -- READ ONLY)
#                CHAN12  BIT 6 (IMU ERROR COUNTER ENABLE)
#                CHAN14  BIT 13,14,15 (DAC ACTIVITY)
#
# SIGN CONVENTION:  AK = THETAC - THETA
#                WHERE  THETAC = COMMAND ANGLE
#                THETA = PRESENT ANGLE

NEEDLER      CA      RCSFLAGS
              MASK    SIX
              EXTEND
              BZF     NEEDLES3
              MASK    BIT3
              EXTEND
              BZF     NEEDLER2      # BIT3 = 0, BIT2 = 1

              CS      BIT6          # FIRST PASS BIT3 = 1
              EXTEND          # DISABLE IMU ERROR COUNTER TO ZERO DACS
              WAND     CHAN12      # MUST WAIT AT LEAST 60 MS BEFORE
NEEDLE11     CS      ZERO          # ENABLING COUNTERS.
              TS      AK          # ZERO THE INPUTS ON FIRST PASS
              TS      AK1
              TS      AK2
              TS      EDRIX        # ZERO THE DISPLAY REGISTERS
              TS      EDRIY
              TS      EDRIEZ
              TS      CDUXCMD      # ZERO THE OUT COUNTERS
              TS      CDUYCMD
              TS      CDUZCMD
              CS      SIX          # RESET RCSFLAGS FOR PASS2
              MASK    RCSFLAGS
              AD      BIT2
              TS      RCSFLAGS
              TCF     RETNMORE

NEEDLER2     CAF      BIT6          # ENABLE IMU ERROR COUNTERS
              EXTEND

```

```

                                WOR    CHAN12
                                CS      SIX
                                MASK    RCSFLAGS
                                TS      RCSFLAGS
                                TCF     RETNMORE
                                # RESET RCSFLAGS TO DISPLAY ATTITUDE
                                # ERRORS.  WAIT AT LEAST 4 MS FOR
                                # RELAY CLOSURE.

NEEDLES3                      CAF     BIT6
                                EXTEND
                                RAND    CHAN12
                                # CHECK TO SEE IF IMU ERROR COUNTER
                                # IS ENABLED

# Page 1419
                                CCS     A
                                TCF     NEEDLES
                                # IF NOT, RE-INITIALIZE NEEDLER.

                                CS      RCSFLAGS
                                MASK    BIT3
                                ADS     RCSFLAGS
                                TCF     RETNMORE
                                # SET UP INITIALIZATION FLAG IN RCSFLAGS.

NEEDLES                      CAF     TWO
DACLOOP                      TS      DINDX
                                CS      ONETENTH
                                EXTEND
                                INDEX   DINDX
                                MP      AK
                                TS      L
                                CCS     A
                                CA      DACLIMIT
                                TCF     +2
                                CS      DACLIMIT
                                AD      L
                                TS      T5TEMP
                                TCF     +4
                                # OVFL0 CHK
                                INDEX   A
                                CAF     DACLIMIT
                                TS      L
                                INDEX   DINDX
                                CS      EDRIXEX
                                AD      L
                                # CURRENT VALUE OF DAC
                                INDEX   DINDX
                                ADS     CDUXCMD
                                INDEX   DINDX
                                LXCH    EDRIXEX
                                CCS     DINDX
                                TCF     DACLOOP
                                CAF     13,14,15
                                EXTEND

```

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	WOR	CHAN14	# SET DAC ACTIVITY BITS
	TCF	RETNMORE	
	DEC	-384	
DACLIMIT	DEC	16000	
	DEC	384	
ONETENTH	OCT	03146	# DECIMAL +0.1, SCALED AT 1.
DSPLYALT	EQUALS	BIT4	# 100 MS ALTERNATION BIT IN RCSFLAGS
OVERSUB2	TS	7	# RETURNS A UNCHANGED OR LIMITED TO
	TC	Q	# POSMAX OR NEGMAX IF A HAS OVERFLOW
	INDEX	A	
# Page 1420			
	CS	LIMITS	# DUPLICATE CODING IN BANK 16
	TC	Q	
RETNMORE	EXTEND		# RETURN TO CHEKMORE
	DCA	MORECADR	
	DTCB		
	EBANK=	AOSQ	
MORECADR	2CADR	CHEKMORE	

This code is written to file src/DAPIDLER-PROGRAM.s.

**A.20    DAP INTERFACE SUBROUTINES**

```

310  <src/DAP-INTERFACE-SUBROUTINES.s 310>≡
      # Copyright:    Public domain.
      # Filename:     DAP_INTERFACE_SUBROUTINES.agc
      # Purpose:     Part of the source code for Luminary 1A build 099.
      #              It is part of the source code for the Lunar Module's (LM)
      #              Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:   yaYUL
      # Contact:      Ron Burkey <info@sandroid.org>.
      # Website:      www.ibiblio.org/apollo.
      # Pages:        1406-1409
      # Mod history: 2009-05-10 SN    (Sergio Navarro). Started adapting
      #                                from the Luminary131/ file of the same
      #                                name, using Luminary099 page images.
      #
      # This source code has been transcribed or otherwise adapted from
      # digitized images of a hardcopy from the MIT Museum. The digitization
      # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
      # the Museum. Many thanks to both. The images (with suitable reduction
      # in storage size and consequent reduction in image quality as well) are
      # available online at www.ibiblio.org/apollo. If for some reason you
      # find that the images are illegible, contact me at info@sandroid.org
      # about getting access to the (much) higher-quality images which Paul
      # actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #        Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
      #        16:27 JULY 14, 1969
      #
      # Page 1406
      BANK        20
      SETLOC     DAPS3
      BANK
      EBANK=     CDUXD
      COUNT*     $$/DAPIF
      # MOD 0        DATE    11/15/66        BY GEORGE W. CHERRY
      # MOD 1               1/23/67        MODIFICATION BY PETER ADLER
      #
      # FUNCTIONAL DESCRIPTION
      #        HEREIN IS A COLLECTION OF SUBROUTINES WHICH ALLOW MISSION CONTROL PROGRAMS TO
      #        AND INTERFACE WITH THE DAP.
      #

```

```

# CALLING SEQUENCES
#       IN INTERRUPT OR WITH INTERRUPT INHIBITED
#           TC      IBNKCALL
#           FCADR   ROUTINE
#       IN A JOB WITHOUT INTERRUPT INHIBITED
#           INHINT
#           TC      IBNKCALL
#           FCADR   ROUTINE
#           RELINT
#
# OUTPUT
#       SEE INDIVIDUAL ROUTINES BELOW
#
# DEBRIS
#       A, L, AND SOMETIMES MDUETEMP                ODE      NOT IN PULSES MODE

# Page 1407
# SUBROUTINE NAMES:
#       SETMAXDB, SETMINDB, RESTORDB, PFLITEDB
# MODIFIED:      30 JANUARY 1968 BY P. S. WEISSMAN TO CREATE RESTORDB.
# MODIFIED:      1 MARCH 1968 BY P. S. WEISSMAN TO SAVE EBANK AND CREATE PFLITEDB
#
# FUNCTIONAL DESCRIPTION:
#       SETMAXDB -- SET DEADBAND TO 5.0 DEGREES
#       SETMINDB -- SET DEADBAND TO 0.3 DEGREE
#       RESTORDB -- SET DEADBAND TO MAX OR MIN ACCORDING TO SETTINGS OF DBSELECT BIT OF DAPBOOL
#       PFLITEDB -- SET DEADBAND TO 1.0 DEGREE AND ZERO THE COMMANDED ATTITUDE CHANGE AND COMMA
#
#       ALL ENTRIES SET UP A NOVAC JOB TO DO 1/ACCS SO THAT THE TJETLAW SWITCH CURVES ARE POSIT
#       REFLECT TEH NEW DEADBAND.  IT SHOULD BE NOTED THAT THE DEADBAND REFERS TO THE ATTITUDE
#
# SUBROUTINE CALLED:      NOVAC
#
# CALLING SEQUENCE:      SAME AS ABOVE
#                       OR      TC RESTORDB +1      FROM ALLCOAST
#
# DEBRIS:                A, L, Q, RUPTREG1, (ITEMPS IN NOVAC)

RESTORDB      CAE      DAPBOOLS      # DETERMINE CREW-SELECTED DEADBAND.
              MASK     DBSELECT
              EXTEND
              BZF      SETMINDB

SETMAXDB      CAF      WIDEDB      # SET 5 DEGREE DEADBAND.
              +1      TS      DB

```

	EXTEND		# SET UP JOB TO RE-POSITION SWITCH CURVES.
	QXCH	RUPTREG1	
CALLACCS	CAF	PRI027	
	TC	NOVAC	
	EBANK=	AOSQ	
	2CADR	1/ACCJOB	
	TC	RUPTREG1	# RETURN TO CALLER.
SETMINDB	CAF	NARROWDB	# SET 0.3 DEGREE DEADBAND.
	TCF	SETMAXDB +1	
PFLITEDB	EXTEND		# THE RETURN FROM CALLACCS IS TO RUPTREG1.
	QXCH	RUPTREG1	
	TC	ZATTEROR	# ZERO THE ERRORS AND COMMANDED RATES.
	CAF	POWERDB	# SET DB TO 1.0 DEG.
	TS	DB	
	TCF	CALLACCS	# SET UP 1/ACCS AND RETURN TO CALLER.
NARROWDB	OCTAL	00155	# 0.3 DEGREE SCALED AT 45.
# Page 1408			
WIDEDB	OCTAL	03434	# 5.0 DEGREES SCALED AT 45.
POWERDB	DEC	.02222	# 1.0 DEGREE SCALED AT 45.
ZATTEROR	CAF	EBANK6	
	XCH	EBANK	
	TS	L	# SAVE CALLERS EBANK IN L.
	CAE	CDUX	
	TS	CDUXD	
	CAE	CDUY	
	TS	CDUYD	
	CAE	CDUZ	
	TS	CDUZD	
	TCF	STOPRATE +3	
STOPRATE	CAF	EBANK6	
	XCH	EBANK	
	TS	L	# SAVE CALLERS EBANK IN L.
+3	CAF	ZERO	
	TS	OMEGAPD	
	TS	OMEGAQD	
	TS	OMEGARD	
	TS	DELCDUX	
	TS	DELCDUY	
	TS	DELCDUZ	
	TS	DELPEROR	
	TS	DELQEROR	



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```

        TS      DELREROR
        LXCH     EBANK      # RESTORE CALLERS EBANK.
        TC      Q

# SUBROUTINE NAME:      ALLCOAST
# WILL BE CALLED BY FRESH STARTS AND ENGINE OFF ROUTINES.
#
# CALLING SEQUENCE:      (SAME AS ABOVE)
#
# EXIT:                  RETURN TO Q.
#
# SUBROUTINES CALLED:    STOPRATE, RESTORDB, NOVAC
#
# ZERO:                  (FOR ALL AXES) AOS, ALPHA, AOSTERM, OMEGAD, DELCDU, DELEROR
#
# OUTPUT:                DRIFTBIT/DAPBOOLS, OE, JOB TO DO 1/ACCS
#
# DEBRIS:                A, L, Q, RUPTREG1, RUPTREG2, (ITEMPS IN NOVAC)

ALLCOAST      EXTEND      # SAVE Q FOR RETURN
               QXCH      RUPTREG2

# Page 1409

        TC      STOPRATE  # CLEAR RATE INTERFACE. RETURN WITH A=0
        LXCH     EBANK    # AND L=EBANK6. SAVE CALLER'S EBANK.
        TS      AOSQ
        TS      AOSQ +1
        TS      AOSR
        TS      AOSR +1
        TS      ALPHAQ    # FOR DOWNLIST.
        TS      ALPHAR
        TS      AOSQTERM
        TS      AOSRTERM
        LXCH     EBANK    # RESTORE EBANK (EBANK6 NO LONGER NEEDED)

        CS      DAPBOOLS  # SET UP DRIFTBIT
        MASK     DRIFTBIT
        ADS      DAPBOOLS
        TC      RESTORDB +1 # RESTORE DEADBANK TO CREW-SELECTED VALUE.

        TC      RUPTREG2  # RETURN.
```

This code is written to file src/DAP-INTERFACE-SUBROUTINES.s.

## A.21 DISPLAY INTERFACE ROUTINES

```

314  <src/DISPLAY-INTERFACE-ROUTINES.s 314>≡
# Copyright:    Public domain.
# Filename:     DISPLAY_INTERFACE_ROUTINES.agc
# Purpose:      Part of the source code for Comanche, build 055. It
#               is part of the source code for the Command Module's
#               (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:   yaYUL
# Reference:    pp. 1452-1484
# Contact:      Ron Burkey <info@sandroid.org>
# Website:      http://www.ibiblio.org/apollo.
# Mod history:  2009-05-07 RSB  Adapted from Colossus249 file of the same
#                               name, and page images. Corrected various
#                               typos in the transcription of program
#                               comments, and these should be back-ported
#                               to Colossus249.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#
#           Massachusetts Institute of Technology
#           75 Cambridge Parkway
#           Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.
#
# Page 1452
# DISPLAYS CAN BE CLASSIFIED INTO THE FOLLOWING CATEGORIES --
# 1. PRIORITY DISPLAYS -- DISPLAYS WHICH TAKE PRIORITY OVER ALL OTHER DISPLAYS
#    OUT UNDER CRITICAL ALARM CONDITIONS.
# 2. EXTENDED VERB DISPLAYS -- ALL EXTENDED VERBS AND MARK ROUTINES SHOULD USE
# 3. NORMAL DISPLAYS -- ALL MISSION PROGRAM DISPLAYS WHICH INTERFACE WITH THE
#    SEQUENCE OF EVENTS.
# 4. MISC. DISPLAYS -- ALL DISPLAYS NOT HANDLED BY THE DISPLAY INTERFACE ROUTINE
#    MM DISPLAYS AND SPECIAL PURPOSE DISPLAYS HANDLED BY PINBALL.
# 5. ASTRONAUT INITIATED DISPLAYS -- ALL DISPLAYS INITIATED EXTERNALLY.

```

```

#
# THE FOLLOWING TERMS ARE USED TO DESCRIBE THE STATUS OF DISPLAYS --
#   1. ACTIVE -- THE DISPLAY WHICH IS (1) BEING DISPLAYED TO THE ASTRONAUT AND WAITING FOR
#   (2) WAITING FIRST IN LINE FOR THE ASTRONAUT TO FINISH USING THE DSKY OR (3) BEING D
#   BUT NOT WAITING FOR A RESPONSE.
#   2. INACTIVE -- A DISPLAY WHICH HAS (1) BEEN ACTIVE BUT WAS INTERRUPTED BY A DISPLAY OF
#   (2) BEEN PUT INTO THE WAITING LIST AT TIME IT WAS REQUESTED DUE TO THE FACT A HIGHE
#   WAS ALREADY DOING, (3) BEEN INTERRUPTED BY THE ASTRONAUT (CALLED A PINBRANCH CONDIT
#   OF INACTIVE DISPLAY IS USUALLY REACTIVATED ONLY BY PINBALL) OR (4) A DISPLAY WHICH
#   HAS INFO SAVED FOR RESTART PURPOSES.
#
# DISPLAY PRIORITIES WORK AS FOLLOWS --
#   INTERRUPTS --
#   1. THE ASTRONAUT CAN INTERRUPT ANY DISPLAY WITH AN EXTERNAL DISPLAY REQUEST.
#   2. INTERNAL DISPLAYS CAN NOT BE SENT OUT WHEN THE ASTRONAUT IS USING THE DSKY.
#   3. PRIORITY DISPLAYS INTERRUPT ALL OTHER TYPES OF INTERNAL DISPLAYS. A PRIORI
#   PRIORITY DISPLAY WILL CAUSE AN ABORT UNLESS BIT14 IS SET FOR THE LINUS ROUT
#   4. A MARK DISPLAY INTERRUPTS ANY NORMAL DISPLAY.
#   5. A MARK THAT INTERRUPTS A MARK COMPLETELY REPLACES IT.
#
#   ORDER OF WAITING DISPLAYS --
#   1. ASTRONAUT
#   2. PRIORITY
#   3. INTERRUPTED MARK
#   4. INTERRUPTED NORMAL
#   5. MARK TO BE REQUESTED (SEE DESCRIPTION OF ENDMARK)
#   6. MARK WAITING
#   7. NORMAL WAITING
#
# Page 1453
# THE DISPLAY ROUTINES ARE INTENDED TO SERVE AS AN INTERFACE BETWEEN THE USER AND PINBALL. THE
# FOLLOWING STATEMENTS CAN BE MADE ABOUT NORMAL DISPLAYS AND PRIORITY DISPLAYS (A DESCRIPTION O
# WILL FOLLOW LATER):
#   1. ALL ROUTINES THAT END IN R HAVE AN IMMEDIATE RETURN TO THE USER. FOR ALL FLASHING
#   IS TO THE USER'S CALL CADR +4. FOR THE ONLY NON-FLASHING IMMEDIATE RETURN DISPLAY
#   IS TO THE USER'S CALLING LOC +1.
#   2. ALL ROUTINES NOT ENDING IN R DO NOT DO AN IMMEDIATE RETURN TO THE USER.
#   3. ALL ROUTINES THAT END IN R START A SEPARATE JOB (MAKEPLAY) WITH USER'S JOB PRIORITY
#   4. ALL ROUTIENS NOT ENDING IN R BRANCH DIRECTLY TO MAKEPLAY WHICH MAKES THESE DISPLAYS
#   USER'S JOB.
#   5. ALL DISPLAY ROUTIENS ARE CALLED VIA BANKCALL.
#   6. TO RESTART A DISPLAY THE USER WILL GENERALLY USE A PHASE OF ONE WITH DESIRED RESTAR
#   DESCRIPTION OF RESTARTS).
#   7. ALL FLASHING DISPLAYS HAVE 3 RETURNS TO THE USER FROM ASTRONAUT RESPOSES. A TERMIN
#   TO THE USER'S CALL CADR +1. A PROCEED (V33) BRANCHES TO THE USER'S CALL CADR +2.
#   (V32) BRANCHES TO THE USER'S CALL CADR +3.

```

```

#      8.  ALL ROUTINES MUST BE USED UNDER EXECUTIVE CONTROL
#
# A DESCRIPTION OF EACH ROUTINE WITH AN EXAMPLE FOLLOWS:

#      GODSP IS USED TO DISPLAY A VERB NOUN ARRIVING IN A.  NO RETURN IS MADE TO THE
#      1.  GODSP IS NOT RESTARTABLE
#      2.  A VERB PASTE WITH GODSP ALWAYS TURNS ON THE FLASH.
#
#              CAF      VXXNYY
#              TC       BANKCALL
#              CADR     GODSP
#      VXXNYY OCT      OXXYY

#      GODSPR IS THE SAME AS GODSP ONLY RETURN IS TO THE USER.
#
#              CAF      VXXNYY
#              TC       BANKCALL
#              CADR     GODSPR
#              ...      ...      # IMMEDIATE RETURN OF GODSPR

#      GOFLASH DISPLAYS A FLASHING VERB NOUN WITH NO IMMEDIATE RETURN TO THE USER.
#      THE ASTRONAUT (SEE NO. 7 ABOVE).
#
#              CAF      VXXNYY      # VXX NYY WILL BE A FLASHING
#              TC       BANKCALL
#              CADR     GOFLASH
#              ...      ...      # TERMINATE RETURN
#              ...      ...      # PROCEED RETURN
#              ...      ...      # ENTER OR RECYCLE RETURN

#      GOPERF1 IS ENTERED WITH DESIRED CHECKLIST VALUE IN A.  GOPERF1 WILL DISPLAY T
# Page 1454
#      V01 N25.  A FLASHING PLEASE PERFORM ON CHECKLIST (V50 N25) IS THEN DISPLAYED
#      USER (SEE NO. 7 ABOVE).
#      GOPERF1 BLANKS REGISTERS R2 AND R3
#
#              CAF      OCTXX      # CODE FOR CHECKLIST VALUE XX
#              TC       BANKCALL
#              CADR     GOPERF1
#              ...      ...      # TERMINATE RETURN
#              ...      ...      # PROCEED RETURN
#              ...      ...      # ENTER RETURN

#      GOPERF2 IS ENTERED WITH A VARIABLE NOUN AND V01 (V00 FOR N10 OR N11) IN A.  C
#      REQUESTED NOUN BY MEANS OF A V01NYY OR A VOONYY.  PLEASE PERFORM ON NOUN (V50
#      DISPLAY.  NO IMMEDIATE RETURN IS MADE TO THE USER (SEE NO. 7 ABOVE).
#      GOPERF2 DOES NOT BLANK ANY REGISTERS
#
#              CAF      VXXNYY      # VARIABLE NOUN YY.  XX=0 OR C
#              TC       BANKCALL
#              CADR     GOPERF2
#              ...      ...      # TERMINATE RETURN

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```
#           ...           # PROCEED RETURN
#           ...           # ENTER RETURN
# GOPERF3 IS USED FOR A PLEASE PERFORM ON A PROGRAM NUMBER.  THE DESIRED PROGRAM NO. IS E
# DISPLAYS THE NO. BY MEANS OF A V06 N07 FOLLOWED BY A FLASHING V50 N07 FOR A PLEASE PER
# IS MADE TO THE USER (SEE NO. 7 ABOVE).
# GOPERF3 BLANKS REGISTERS R2 AND R3
#           CAF           DECXX           # REQUEST PERFORM ON PXX
#           TC            BANKCALL
#           CADR          GOPERF3
#           ...           ...           # TERMINATE RETURN
#           ...           ...           # PROCEED RETURN
#           ...           ...           # ENTER RETURN

# GOPERF4 IS USED FOR A PLEASE PERFORM ON AN OPTION.  THE DESIRED OPTION IS ENTERED IN A
# GOPERF4 DISPLAYS R1 AND R2 BY MEANS OF A V04N06 FOLLOWED BY A FLASHING V50N06 FOR A PL
# IMMEDIATE RETURN IS MADE TO THE USER (SEE NO. 7 ABOVE).
#           CAF           OCTXX           # REQUEST PERFORM ON OPTION XX
#           TC            BANKCALL
#           CADR          GOPERF4
#           ...           ...           # TERMINATE RETURN
#           ...           ...           # PROCEED RETURN
#           ...           ...           # ENTER RETURN
# GOPERF4 BLANKS REGISTER R3.
#
# Page 1455
# GODSPRET IS USED TO DISPLAY A VERB NOUN ARRIVING IN A WITH A RETURN TO THE USER AFTER T
# OUT.
#           CAF           VXXXNYY
#           TC            BANKCALL
#           CADR          GODSPRET
#           ...           ...           # RETURN TO USER.

# REGODSP IS USED TO DISPLAY A VERB NOUN ARRIVING IN A.  REGODSP IS THE SAME AS GODSP ONL
# ACTIVE NORMAL DISPLAY IF ONE WAS ACTIVE.
#           CAF           VXXNYY
#           TC            BANKCALL
#           CADR          REGODSP

# REFLASH IS THE SAME AS GOFLASH ONLY REFLASH REPLACES ANY ACTIVE NORMAL DISPLAY IF ONE W
#           CAF           VXXNYY           # VXX NYY WILL BE A FLASHING VERB NOUN
#           TC            BANKCALL
#           CADR          REFLASH
#           ...           ...           # TERMINATE RETURN
#           ...           ...           # PROCEED RETURN
#           ...           ...           # ENTER RETURN
```

```

#      GOFLASHR IF SAME AS GOFLASH ONLY AN IMMEDIATE RETURN IS MADE TO THE USER'S CA
#      CAF      VXXNYY
#      TC      BANKCALL
#      CADR     GOFLASHR
#      ...      ...      # TERMINATE RETURN
#      ...      ...      # PROCEED RETURN
#      ...      ...      # ENTER OR RECYCLE RETURN
#      ...      ...      # IMMEDIATE RETURN FROM GOFLA

#      GOPERF1R IS THE SAME AS GOPERF1 ONLY GOPERF1R HAS AN IMMEDIATE RETURN TO USER
#      GOPERF1R BLANKS REGISTERS R2 AND R3
#      CAF      OCTXX      # CODE FOR CHECKLIST VALUE XX
#      TC      BANKCALL
#      CADR     GOPERF1R
#      ...      ...      # TERMINATE RETURN
#      ...      ...      # PROCEED RETURN
#      ...      ...      # ENTER RETURN
#      ...      ...      # IMMEDIATE RETURN FROM GOPER

#      GOPERF2R IS THE SAME AS GOPERF2 ONLY AN IMMEDIATE RETURN IS MADE TO USER'S CA
# Page 1456
#      GOPERF2R DOES NOT BLANK ANY REGISTERS
#      CAF      VXXXNYY      # VARIABLE NOUN YY REQUESTED
#      TC      BANKCALL
#      CADR     GOPERF2R
#      ...      ...      # TERMINATE RETURN
#      ...      ...      # PROCEED RETURN
#      ...      ...      # ENTER RETURN
#      ...      ...      # IMMEDIATE RETURN HERE FROM

#      GOPERF3R IS THE SAME AS GOPERF3 ONLY AN IMMEDIATE RETURN IS MADE TO USER'S CA
#      GOPERF3R BLANKS REGISTERS R2 AND R3
#      CAF      PROGXX      # PERFORM PROGRAM XX
#      TC      BANKCALL
#      CADR     GOPERF3R
#      ...      ...      # TERMINATE RETURN
#      ...      ...      # PROCEED RETURN
#      ...      ...      # ENTER RETURN
#      ...      ...      # GOPERF3R IMMEDIATELY RETURN

#      GOPERF4R IS THE SAME AS GOPERF4 ONLY AN IMMEDIATE RETURN IS MADE TO USER'S CA
#      CAF      OCTXX      # REQUEST PERFORM ON OPTIONXX
#      TC      BANKCALL
#      CADR     GOPERF4R
#      ...      ...      # TERMINATE RETURN
#      ...      ...      # PROCEED RETURN

```

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```
#           ...      ...      # ENTER RETURN
#           ...      ...      # IMMEDIATE RETURN TO USER
# GOPERF4R BLANKS REGISTER R3.
#
# REFLASHR IS THE SAME AS REFLASH ONLY AN IMMEDIATE RETURN IS MADE TO THE USER'S CALL CAD
#           CAF      VXXNYY      # VXX NYY WILL BE A FLASHING VERB NOUN
#           TC      BANKCALL
#           CADR     REFLASHR
#           ...      ...      # TERMINATE RETURN
#           ...      ...      # PROCEED RETURN
#           ...      ...      # ENTER RETURN
#           ...      ...      # IMMEDIATE RETURN TO USER

# REGODSPR IS THE SAME AS REGODSP ONLY A RETURN (IMMEDIATE) IS MADE TO THE USER.
# Page 1457
#           CAF      VXXNYY
#           TC      BANKCALL
#           CADR     REGODSPR
#           ...      ...      # IMMEDIATE RETURN TO USER

# Page 1458
# GOMARK IS USED TO DISPLAY A MARK VERB NOUN ARRIVING IN A. NO RETURN IS MADE TO THE USER.
# GOXDSP = GOMARK
#           CAF      VXXNYY      # VXXNYY CONTAINS VERB AND NOUN
#           TC      BANKCALL
#           CADR     GOMARK      # OTHER EXTENDED VERBS USE CADR GOXDSP

# GOMARKR IS THE SAME AS GOMARK ONLY RETURN IS TO THE USER.
# GOXDSPR = GOMARKR
#           CAF      VXXNYY
#           TC      BANKCALL
#           CADR     GOMARKR      # OTHER EXTENDED VERBS USE CADR GOXDSPR
#           ...      ...      # IMMEDIATE RETURN OF GOMARKR

# GOMARKF DISPLAYS A FLASHING MARK VERB NOUN WITH NO IMMEDIATE RETURN TO THE USER. 3 RET
# THE ASTRONAUT (SEE NO. 7 ABOVE).
# GOXDSPF = GOMARKF
#           CAF      VXXNYY      # VXXNYY WILL BE A FLASHING MARK VERB NOUN
#           TC      BANKCALL
#           CADR     GOMARKFR      # OTHER EXTENDED VERBS USE CADR GOXDSPFR
#           ...      ...      # TERMINATE RETURN
#           ...      ...      # PROCEED RETURN
#           ...      ...      # ENTER OR RECYCLE RETURN
#           ...      ...      # IMMEDIATE RETURN TO THE USER

# GOMARKFR IS THE SAME AS GOMARKF ONLY AN IMMEDIATE RETURN IS MADE TO THE USER CALL CADR
```

```

#      GOXDSPFR = GOMARKFR
#
#      CAF      VXXNYY      # FLASHING MARK VERB NOUN
#      TCF      BANKCALL
#      CADR      GOMARKFR      # OTHER EXTENDED VERBS USE CA
#      ...      ...      # TERMINATE RETURN
#      ...      ...      # PROCEED RETURN
#      ...      ...      # ENTER OR RECYCLE RETURN
#
#      ...      ...      # IMMEDIATE RETURN TO THE USI

#      GOMARK1 IS USED FOR A PLEASE PERFORM ON A MARK REQUEST WITH ONLY 1 ASTRONAUT
#      RETURN IS MADE.  THE DESIRED MARK PLEASE PERFORM VERB AND DESIRED NOUN IS EN
#      MEANS OF A V05NYY FOLLOWED BY A FLASHING V5XNYY FOR A PLEASE PERFORM.  THE AS
#      OR MARK REJECT OR AN ENTER.  THE ENTER IS THE ONLY ASTRONAUT RESPONSE THAT W
#      CAF      V5XNYY      # X=1,2,3,4      YY=NOUN
#      TC      BANKCALL
# Page 1459
#      CADR      GOMARK1
#      ...      ...      # ENTER RETURN

#      *** IF BLANKING DESIRED ON NON-R ROUTINES, NOTIFY DISPLAYER.
#
#      GOMARK1R IS THE SAME AS A GOMARK1 ONLY AN IMMEDIATE RETURN IS MADE TO THE USI
#      CAF      V5XNYY      # X=1,2,3,4      YY=NOUN
#      TC      BANKCALL
#      CADR      GOMARK1R
#      ...      ...      # ASTRONAUT ENTER RETURN
#      ...      ...      # IMMEDIATE RETURN TO USER

#      GOMARK2 IS THE SAME AS GOMARK1 ONLY 3 RETURNS ARE MADE TO THE USER FROM THE A
#      CAF      V5XNYY      # X=1,2,3,4      YY=NOUN
#      TC      BANKCALL
#      CADR      GOMARK2
#      ...      ...      # TERMINATE RETURN
#      ...      ...      # PROCEED RETURN
#      ...      ...      # ENTER RETURN

#      GOMARK2R IS THE SAME AS GOMARK1R ONLY 3 ASTRONAUT RETURNS ARE MADE TO THE USI
#      CAF      V5XNYY      # X=0,1,2,3,4      YY=NOUN
#      TCF      BANKCALL
#      CADR      GOMARK24
#      ...      ...      # TERMINATE RETURN
#      ...      ...      # PROCEED RETURN
#      ...      ...      # ENTER RETURN
#      ...      ...      # IMMEDIATE RETURN TO THE USI

```



```

# GOMARK3 IS USED FOR A PLEASE PERFORM ON A MARK REQUEST WITH A 3 COMP. DEC DISPLAY. THE
# PERFORM VERB AND NOUN ARE ENTERED IN A. GOMARK3 DISPLAYS R1, R2, R3 BY MEANS OF A VO6N
# V5XNYY FOR A PLEASE PERFORM. GOMARK3 HAS 3 ASTRONAUT RETURNS TO THE USER WITH NO IMMEDIATE
# CAF V5XNYY # X=1,2,3,4 YY=NOUN
# TC BANKCALL
# CADR GOMARK3
# ... .. # TERMINATE RETURN
# ... .. # PROCEED RETURN
# ... .. # ENTER RETURN

# GOMARK4 IS THE SAME AS GOMARK3 ONLY R2 AND R3 ARE BLANKED AND R1 IS DISPLAYED IN OCTAL.
# CAF V5XNYY # X=1,2,3,4 YY=NOUN
# TC BANKCALL
# CADR GOMARK4
# ... .. # TERMINATE RETURN
# ... .. # PROCEED RETURN
# Page 1460
# ... .. # ENTER RETURN
# EXDSPRET IS USED TO DISPLAY A VERB NOUN ARRIVING IN A WITH A RETURN MADE TO THE USER AFTER
# SENT OUT.
# CAF VXNYY
# TC BANKCALL
# CADR EXDSPRET
# ... .. # RETURN TO USER

# KLEENEX CLEANS OUT ALL MARK DISPLAYS (ACTIVE AND INACTIVE). A RETURN IS MADE TO THE USER
# HAVE BEEN CLEANED OUT.
# TC BANKCALL
# CADR KLEENEX
# ... .. # RETURN TO USER

# MARKBRAN IS A SPECIAL PURPOSE ROUTINE USED FOR SAVING JOB VAC AREAS (SEE DESCRIPTION OF
# TC BANKCALL
# CADR MARKBRAN
# ... .. # BAD RETURN IF MARK DISPLAY NOT ACTIVE
# ... .. # (GOOD RETURN TO IMMEDIATE RETURN LOCATION)
# ... .. # LAST FLASHING MARK R ROUTINE)

# PINBRNCH REESTABLISHES THE LAST ACTIVE FLASHING DISPLAY. IF THERE IS NO ACTIVE FLASHING
# BLANKED AND CONTROL IS SENT TO ENDOFJOB.
# TC POSTJUMP
# CADR PINBRNCH

# PRIODSP IS USED AS A PRIORITY DISPLAY. IT WILL DISPLAY A GOFLASH TYPE DISPLAY WITH THREE
# THE ASTRONAUT (SEE NO. 7 ABOVE).
#

```

```

#       THE MAIN PURPOSE OF PRIODSP IS TO REPLACE THE PRESENT DISPLAY WITH A DISPLAY
#       PROVIDE A MEANS FOR RESTORING THE OLD DISPLAY WHEN THE PRIORITY DISPLAY
#       IS RESPONDED TO BY THE ASTRONAUT.
#
#       THE FORMER DISPLAY IS RESTORED BY AN AUTOMATIC BRANCH TO WAKE UP THE DISPLAY
#       PRIO DISPLAY
#
#               CAF      VXXNYY      # VXXNYY WILL BE A FLASHING V
#               TC       BANKCALL
#               CADR      PRIODSP
#               ...      ...
#               ...      ...      # TERMINATE RETURN
#               ...      ...      # PROCEED RETURN
# Page 1461
#               ...      ...      # ENTER OR RECYCLE RETURN
#
#       PRIODSPR IS THE SAME AS PRIODSP ONLY AN IMMEDIATE RETURN IS MADE TO THE USER
#               CAF      VXXNYY      # VXXNYY WILL BE A FLASHING V
#               TC       BANKCALL
#               CADR      PRIODSPR
#               ...      ...      # TERMINATE ACTION
#               ...      ...      # PROCEED RETURN
#               ...      ...      # ENTER OR RECYCLE RETURN
#               ...      ...      # IMMEDIATE RETURN
#
#       PRIOLARM DOES A V05N09 PRIODSPR.
#
#       CLEANDSP CLEANS OUT ALL NORMAL DISPLAYS (ACTIVE AND INACTIVE).  A RETURN IS M
#       DISPLAYS ARE CLEANED OUT.
#               TC       BANKCALL
#               CADR      CLEANDSP
#               ...      ...      # RETURN TO USER
# Page 1462
#
# GENERAL INFORMATION
# -----
#
# ALARM OR ABORT EXIT MODE --
#       PRIOBORT      TC      ABORT
#               OCT      1502
#
#       PRIOBORT IS BRANCHED TO WHEN (1) A NORMAL DISPLAY IS REQUESTED AND ANOTHER NO
#       (REFLASH AND REGODSP ARE EXCEPTIONS) OR (2) A PRIORITY DISPLAY IS REQUESTED W
#       ALREADY ACTIVE (A PRIORITY WITH LINUS BIT14 IS AN EXCEPTION).
#
# ERASABLE INITIALIZATION REQUIRED --
#       ACCOMPLISHED BY FRESH START -- 1. FLAGWRD4 (USED EXCLUSIVELY BY DISPLAY IN
#                                     2. NVSAVE = NORMAL VERB AND NOUN REGISTER.

```

```

#                                     3.  EBANKTEM = NORMAL INACTIVE FLAGWORD (ALSO CONTAINS
#                                     5.  R1SAVE = MARKBRAN CONTROL WORD
#                                     4.  RESTREG = PRIORITY 30 AND SUPERBANK 3.
#
# OUTPUT --
#
#     NVWORD = PRIO VERB AND NOUN
#     NVWORD +1 (MARKNV) = MARK VERB AND NOUN
#     NVWORD +2 (NVSAVE) = NORMAL VERB AND NOUN
#     DSPFLG (EBANKSAV) = PRIO FLAGWORD (INCLUDING EBANK)
#     DSPFLG +1 (MARKEBAN) = MARK FLAGWORD (INCLUDING EBANK)
#     DSPFLG +2 (EBANKTEM) = NORMAL FLAGWORD (INCLUDING EBANK)
#     CADRFLSH = PRIO USER'S CALL CADR +1 LOCATION
#     CADRFLSH +1 (MARKFLSH) = MARK USER'S CALL CADR +1 LOCATION
#     CADRFLSH +2 (TEMPFLSH) = NORMAL USER'S CALL CADR +1 LOCATION
#     PRIOTIME = TIME EACH PRIO REQUEST FIRST SENT OUT
#     OPTION1 = DESIRED OPTION FROM GOPERF4
#     FLAGWRD4 = BIT INFO FOR CONTROL OF ALL DISPLAY ROUTINES
#     DSPTEM1 = R1 INFO FOR ASTRONAUT FROM PERFORM DISPLAYS (NORMAL)
#
# SUBROUTINES USED -- NVSUB, FLAGUP, FLAGDOWN, ENDOFJOB, BLANKSUB, ABORT, JOBWAKE, JOBSLEEP, FI
#     JAMTERM, NVSUBBUSY, FLASHON, ENDIDLE, CHANG1, BANKJUMP, MAKECADR, NOVAC
#
# DEBRIS -- (STORED INTO)
#
#     TEMPORARY TEMPORARIES -- A, Q, L, MPAC +2, MPAC +3, MPAC +4, MPAC +5, MPAC +6, RUPREG2,
#         EBANK, RUPTREG4, LOC, BANKSET, MODE, MPAC, MPAC +1, FACEREG
#     ERASABLES (SHARED AND USED WITH OTHER PROGRAMS) -- CADRSTOR, DSPLIST, LOC, DSPTEM1, OPT
#     ERASABLES (USED ONLY BY DISPLAY ROUTINES) -- NVWORD,+1,+2, DSPFLAG,+1,+2, CADRFLSH,+1,+2
#
# Page 1463
#
#     R1SAVE, MARK2PAC
#
# DEBRIS -- (USED BUT NOT STORED INTO) -- NOUNREG, VERBREG, LOCCTR, MONSAVE1
#
# FLAGWORD DESCRIPTIONS --
#
#     FLAGWRD4 -- SEE DESCRIPTION UNDER LOG SECTION ERASABLE ASSIGNMENTS
#
#     DSPFLG, DSPFLG+1, DSPFLG+2
#     -----
#
#     BITS 1  BLANK R1
#           2  BLANK R2
#           3  BLANK R3
#           4  FLASHING DISPLAY REQUESTED
#           5  PERFORM DISPLAY REQUESTED
#           6  -----          EXDSPRET          GODSPRET
#           7  PRIO DISPLAY          -----          -----
#           8  -----          DEC MARK PERFORM          -----
#           9  EBANK

```

```

#          10 EBANK
#          11 EBANK
#          12 -----
#          13 2ND PART OF PERFORM
#          14 REFLASH OR REDO
#          15 -----
#                                     MARK REQUEST
#                                     -----
#
# RESTARTING DISPLAYS --
#
# RULES FOR THE DSKY OPERATOR --
#   1. PROCEED AND TERMINATE SERVE AS RESPONSES TO REQUESTS FOR OPERATOR RESPONSES
#       AS THERE IS ANY REQUEST AWAITING OPERATOR RESPONSE, ANY USE OF PROCEED OR
#       RESPONSES TO THAT REQUEST. CARE SHOULD BE EXERCISED IN ATTEMPTING TO KILL
#       WITH PROCEED AND TERMINATE FOR THIS REASON.
#   2. THE ASTRONAUT MUST RESPOND TO A PRIORITY DISPLAY NO SOONER THAN 2 SECONDS
#       PROGRAM SENT OUT THE REQUEST FOR OPERATOR RESPONSE (THE ASTRONAUT WOULD S
#       DUE TO TIME IT TAKES TO GET DISPLAY SENT OUT.) IF THE ASTRONAUT RESPONDS
#       IS SENT OUT AGAIN -- AND AGAIN UNTIL AN ACCUMULATED 2 SECS FROM THE TIME
#       OUT. THE SAME 2 SEC. DELAY WILL OCCUR AT 163.84 SECS OR IN ANY MULTIPLE
#       CONSIDERATION.
#   3. KEY RELEASE BUTTON --
#       A) IF THE KEY RELEASE LIGHT IS ON, IT SIMPLY RELEASES THE KEYBOARD AND I
#       B) IF THE KEY RELEASE LIGHT IS OFF, AND IF SOME REQUEST FOR OPERATOR RES
#           AWAITING RESPONSE THEN IT RE-ESTABLISHES THE DISPLAYS THAT ORIGINALLY
#       IF AN OPERATOR WANTS THEREFORE TO RE-ESTABLISH BUT CONDITION (A) IS ENCOU
#       KEY RELEASE BUTTON MAY BE NECESSARY.
#   4. IT IS IMPORTANT TO ANSWER ALL REQUESTS FOR OPERATOR RESPONSE.
#   5. IT IS ALWAYS GOOD PRACTICE TO TERMINATE AN EXTENDED VERB BEFORE ASKING FO
#       OVER AGAIN.
#
# SPECIAL CONSIDERATONS --
# Page 1464
#   1. MPAC +2 SAVED ONLY IN MARK DISPLAYS
#   2. GODSP(R), REGODSP(R), GOMARK(R) ALWAYS TURN ON THE FLASH IF ENTERED WITH
#   3. ALL NORMAL DISPLAYS ARE RESTARTABLE EXCEPT GODSP(R), REGODSP(R)
#   4. ALL EXTENDED VERBS WITH DISPLAYS SHOULD START WITH A TC TESTXACT AND FINI
#   5. GODSP(R) AND REGODSP(R) MUST BE IN THE SAME EBANK AND SUPERBANK AS THE LA
#       BY A .1 RESTART PHASE CHANGE.
#   6. IN ORDER TO SET UP A NON DISPLAY .1 RESTART POINT, THE USER MUST MAKE CEP
#       CORRECT PRIORITY AND SUPERBANK AND THAT EBANKTEM CONTAINS THE CO
#   7. IF CLEANDSP IS RESTARTED VIA A .1 PHASE CHANGE, CAF ZERO SHOULD BE EXECUT
#
# Page 1465
# CALLING SEQUENCE FOR BLANKING
#           CAF      BITX      # X=1,2,3 BLANK R1,R2,R3 RESPECTIVELY
#           TC       BLANKET

```

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```
#          ...          # RETURN TO USER HERE
# IN ORDER TO USE BLANKET CORRECTLY, THE USER MUST USE A DISPLAY ROUTINE THAT ENDS IN R FIRST P
# TO BLANKET AT THE IMMEDIATE RETURN LOC.
      BLOCK  02
      SETLOC FFTAG4
      BANK

      COUNT  02/DSPLA

BLANKET      TS      MPAC +6
             CS      PLAYTEM4
             MASK     MPAC +6
             INDEX    MPAC +5
             ADS      PLAYTEM4

             TC      Q

ENDMARK      TC      POSTJUMP
             CADR     MARKEND

CLEARMRK     CAF      ZERO
             TS      EXTVBACT

             INHINT
             CS      BIT1
             MASK     FLAGWRD4
             TS      FLAGWRD4

             RELINT
             TC      Q

# *** ALL EXTENDED VERB ROUTINES THAT HAVE AT LEAST ONE FLASHING DISPLAY MUST TCF ENDMARK OR TO
# FINISHED.

      BANK  10
      SETLOC DISPLAYS
      BANK

      COUNT  10/DSPLA

# NTERONLY IS USED TO DIFFERENTIATE THE MARK ROUTINE WITH ONLY ONE RETURN TO THE USER FROM THE
# 3 RETURNS TO THE USER.  THIS ROUTINE IS ONLY USED BY GOMARK1 AND GOMARK1R.

MARKEND      TC      CLEARMRK
             TCF     MARKOVER
```

# Page 1466

GOMARK	TS	PLAYTEM1	# ENTRANCE FOR MARK GODSP
GOMARS	CAF TCF	BIT15 GOFLASH2	# BIT15 SET FOR ALL MARK REQUESTS
KLEENEX	CAF	ZERO	# CLEAN OUT EXTENDED VERBS
GOMARKF	TS	PLAYTEM1	# ENTRANCE FOR MARK GOFLASH
	CAF TCF	MARKFMSK GOFLASH2	# MARK, FLASH
GOMARK2	TS	PLAYTEM1	# MARK GOPERFS-3 AST. RETURNS
MARKFORM	CAF TCF	MPERFMSK GOFLASH2	# MARK, PERFORM, FLASH
GOMARK3	TS CAF TCF	PLAYTEM1 MARK3MSK GOFLASH2	# USED FOR 3COMP DECIMAL PERFORM
GOMARK4	TS CAF TCF	PLAYTEM1 MARK4MSK GOFLASH2	# MARK, PERFORM, FLASH, BLANK
GOMARKR	TS	PLAYTEM1	# ENTRANCE FOR MARK GODSPR
	CAF TCF	BIT15 GODSPR2	
GOMARKFR	TS	PLAYTEM1	# ENTRANCE FOR MARK GOFLASHR
	CAF TCF	MARKFMSK GODSPRS	
GOMARK2R	TS CAF TCF	PLAYTEM1 MPERFMSK GODSPRS	# MARK GOPERFS-3 AST. RETS+ IMMEDIATE RET. # MARK, PERFORM, FLASH
GOMARK3R	TS CAF TCF	PLAYTEM1 MARK3MSK GODSPRS	
MAKEMARK	CAF TC	ONE COPIES	
	CA	FLAGWRD4	# IS NORM OR PRIO BUSY OR WAITING

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```

                                MASK    OCT34300
                                CCS      A
                                TCF      CHKPRI0

                                CA       FLAGWRD4      # IS MARK SLEEPING DUE TO ASTRO BUSY?
# Page 1467
                                MASK     BIT9

                                EXTEND
                                BZF      MARKPLAY      # NO
                                TCF      ENDOFJOB

MARKPLAY                      INHINT
                                CS       FIVE          # RESET MARK OVER NORM, SET MARK
                                MASK     FLAGWRD4
                                AD       ONE
                                TS       FLAGWRD4
                                RELINT

GOGOMARK                     CS       MARKFLAG      # PERFORM
                                MASK     BIT5
                                CCS      A
                                TCF      MARKCOP
                                CS       MARKNV
                                TS       MARKNV

MARKCOP                      CAF       ONE          # MARK INDEX
                                TCF      PRIOPLAY

COPYTOGO                     CA       MPAC2SAV
                                TS       MPAC +2

COPYPACS                     INDEX    COPINDEX
                                CAF      PRIOOCT
                                TS      GENMASK

                                INDEX    COPINDEX
                                CA       EBANKSAV      # Was CAF --- RSB 2004.
                                TS       TEMPOR2        # ACTIVE EBANK AND FLAG

                                TS       EBANK

                                TC       Q
```

# PINCHEK CHECKS TO SEE IF THE CURRENT MARK REQUEST IS MADE BY THE ASTRONAUT WHILE INTERRUPTING

```

# (A NORMAL OR A PRIO). IF THE ASTRONAUT TRIES TO MARK DURING A PRIO, THE CHECK FAILS.
# REQUEST IS ENDED. IF HE TRIES TO MARK DURING A NORM, THE MARK IS ALLOWED. IN THIS CASE,
# UNTIL ALL MARKING IS FINISHED.
#
# IF THE MARK REQUEST COMES FROM THE PROGRAM DURING A TIME THE ASTRONAUT IS NOT INTERESTED IN
# PRIO, THE MARK REQUEST IS PUT TO SLEEP UNTIL THE PRESENT ACTIVE DISPLAY IS RESPONDED TO.

```

```

CHKPRIO      CA      FLAGWRD4      # MARK ATTEMPT DURING PRIO
              MASK    OCT24100
              CCS      A
              TCF      MARSLEEP

```

```

# Page 1468

```

```

              CS      FLAGWRD4
              MASK    BIT3          # SET MARK OVER NORM
              INHINT
              ADS      FLAGWRD4
              TCF      SETNORM

```

```

MARKPERF     CA      MARKNV
              MASK    VERBMASK
              TCF      NV50DSP

```

```

GODSP        TS      PLAYTEM1

```

```

GODSP2       CAF      ZERO
              TCF      GOFLASH2

```

```

GODSPRET     TS      PLAYTEM1      # ENTRANCE FOR A GODSP WITH A PASTE
              CAF      BIT6          # SET BIT6 TO GO BACK TO USER AFTER NVSUB
              TCF      GOFLASH2

```

```

GODSPR       TS      PLAYTEM1

```

```

GODSPR1      CAF      ZERO
GODSPR2      TS      PLAYTEM4

```

```

              CAF      ZERO          # * DON'T MOVE
              TCF      GODSPRS1

```

```

# CLEANDSP IS USED FOR CLEARING OUT A NORMAL DISPLAY THAT IS PRESENTLY ACTIVE OR A NORM.
# SET UP TO BE STARTED OR RESTARTED.
#
# NORMALLY THE USER WILL NOT NEED TO USE THIS ROUTINE SINCE A NEW NORMAL DISPLAY AUTOMATICALLY

```



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```
# OLD DISPLAY.
#
# CALLING SEQUENCE FOR CLEANDSP --
#
#           TC      BANKCALL
#           CADR     CLEANDSP

CLEANDSP    CAF      ZERO
REFLASH     TS       PLAYTEM1

           CAF      REDOMASK      # FLASH AND PERMIT
           TCF      GOFLASH2

REGODSP     TS       PLAYTEM1

           CAF      BIT14
           TCF      GOFLASH2

# Page 1469

REGODSPR    TS       PLAYTEM1
           CAF      BIT14
           TCF      GODSPR2

CLOCPLAY    TS       PLAYTEM1
           CAF      CLOCKCON
           TCF      GOFLASH2
GOFLASH     TS       PLAYTEM1

           CAF      BIT4          # LEAVE ONLY FLASH BIT SET
GOFLASH2    TS       PLAYTEM4

           TC       SAVELOCS

           RELINT

           TCF      MAKEPLAY      # BRANCH DIRECT WITH NO SEPARATE JOB CALL

PRIODSPR    TS       PLAYTEM1

           CAF      BITS7+4
           TCF      GODSPRS

PRIODSP     TS       PLAYTEM1

SETPRIO     CAF      BITS7+4
```

	TCF	GOFLASH2	
MAKEPRIO	CAF	ZERO	
	TS	COPINDEX	
	TC	LINUSCHR	
	TCF	HIPRIO	# LINUS RETURN
	CA	FLAGWRD4	
	MASK	OCT20100	# IS PRIO IN ENDIDLE OR BUSY
	CCS	A	
	TCF	PRIOBORT	# YES, ABORT
HIPRIO	CA	FLAGWRD4	# MARK ACTIVE
	MASK	OCT40400	
	EXTEND		
	BZF	ASKIFNRM	# NO
SETMARK	CAF	ZERO	
	TCF	JOBXCHS	
ASKIFNRM	CA	FLAGWRD4	# NORMAL ACTIVE
	MASK	OCT10200	# BITS 13+8
	EXTEND		
# Page 1470			
	BZF	OKTOCOPY	# NO
SETNORM	CAF	ONE	
	TCF	JOBXCHS	
OKTOCOPY	TC	COPYNORM	
	TC	WITCHONE	
	TC	JOBWAKE	
	TC	XCHTOEND	
REDOPRIO	CA	TIME1	# SAVE TIME PRIODSP SENT OUT
	TS	PRIOTIME	
KEEPPRIO	CAF	ZERO	# START UP PRIO DISPLAY
	TCF	PRIOPLAY	
MAKEPLAY	CA	PRIORITY	# SAVE USER'S PRIORITY
	MASK	PRI037	
	TS	USERPRIO	

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	CAF	PRI033	# RAISE PRIORITY FOR FAST JOBS AFTER WAKE
	TC	PRI0CHNG	
	CA	PLAYTEM4	# IS IT MARK OR PRIO OR NORM
	MASK	BITS15+7	
	CCS	A	
	TCF	MAKEPRIO	# ITS PRIO
	TCF	IFLEGAL	
	TCF	MAKEMARK	# ITS MARK
IFLEGAL	CAF	TWO	
	TS	COPINDEX	
	TC	LINUSCHR	
	TCF	OKTOPLAY	# LINUS RETURN
	CS	EBANKTEM	
	MASK	BIT4	
	CCS	A	
	TCF	OKTOPLAY	# NO
	CA	FLAGWRD4	# WAS NORM ASLEEP
	MASK	NBUSMASK	# ARE ANY NORMS ASLEEP
	EXTEND		
	BZF	OKTOPLAY	# NO
PRIOBORT	TC	P00D00	
	OCT	1502	
# Page 1471			
OKTOPLAY	TC	COPIES2	
	CA	USERPRIO	
	EXTEND		
	ROR	SUPERBNK	
	TS	RESTREG	
	CA	FLAGWRD4	# PRIO OR MARK GOING
	MASK	PMMASK	
	CCS	A	
	TCF	GOSLEEPS	# MARK GOING
	TCF	+2	
	TCF	GOSLEEPS	
#	COULD PUT NORM BUSY CHECK HERE TO SAVE TIME		

	TC	WITCHONE	# IS IT NVSUB BUSY, ENDIDLE OR NOONE
	TC	JOBWAKE	
	TC	XCHTOEND	
PLAYJUM1	CAF	TWO	
PRIOPLAY	TS	COPINDEX	
	TCF	GOPLAY	
EXDSPRET	TS	PLAYTEM1	
	CAF	BIT15+6	
	TCF	GOFLASH2	
GOPERF1	TS	NORMTEM1	# STORE DESIRED CHECKLIST VALUE
	CAF	V01N25	# USED TO DISPLAY CHECKLIST VALUE IN R1
GOPERFS	TS	PLAYTEM1	
	CAF	PERFMASK	# LEAVE ONLY FLASH, PERFORM, BLANKING
	TCF	GOFLASH2	
GOPERF2	TS	PLAYTEM1	# DESIRED VERB-NOUN TO DISPLAY R1,R2,R3
	CAF	PERF2MSK	
	TCF	GOFLASH2	
GOPERF4	TC	PURRS4	
	TCF	GOFLASH2	
GOFLASHR	TS	PLAYTEM1	
# Page 1472	CAF	BIT4	# LEAVE ONLY FLASH BIT SET
GODSPRS	TS	PLAYTEM4	
	CAF	THREE	
GODSPRS1	INHINT		# IMMEDIATE RETURN IS CALL CADR +4
	TS	RUPTREG3	
	CA	PRIORITY	# MAKE DISPLAY ONE HIGHER THAN USER
	MASK	PRI037	
	TS	NEWPRIO	

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```

CA      PLAYTEM4      # IS THIS A FLASHING R DISPLAY
MASK    BIT4
CCS      A
TCF      VACDSP      # YES, MAKE DSPLAY JOB A VAC
CA      NEWPRIO      # NO, MAKE DSPLAY JOB A NOVAC
TC      NOVAC
EBANK=   WHOCARES
2CADR    MAKEPLAY

TCF      BOTHJOBS

VACDSP   CA      BBANK
          EXTEND
          ROR      SUPERBNK
          TS       L
          CAF      MAKEGEN
          TC       SPVAC

BOTHJOBS TC      SAVELOCS      # COPY TEMPS INTO PERMANENT REGISTERS

          EXTEND      # SAVE NVWORD AND USER'S MPAC +2
          DCA      MPAC +1
          INDEX    LOCCTR
          DXCH     MPAC +1

          EXTEND      # SAVE USER'S CADR, FLAGS AND EBANK
          DCA      MPAC +3
          INDEX    LOCCTR
          DXCH     MPAC +3

          CA      LOCCTR
          TS      MPAC +5
          TC      SAVELOCR
          RELINT
          TCF     BANKJUMP      # CALL CADR +4

# Page 1473
GOPERF1R TS      NORMTEM1      # DESIRED CHECKLIST VALUE

          CAF      V01N25      # DISPLAYS CHECKLIST VALUE IN R1

GOPERFRS TS      PLAYTEM1

          CAF      PERFMASK      # LEAVE ONLY FLASH, PERFORM, BLANKING
          TCF      GODSPRS
```

GOPERF2R	TS	PLAYTEM1	# DESIRED VERB-NOUN TO DISPLAY R1,R2,R3
	CAF	PERF2MSK	
	TCF	GODSPRS	
GOPERF4R	TC	PURRS4	
	TCF	GODSPRS	
PURRS4	TS	OPTION1	# DESIRED OPTION CODE
	CAF	V04N06	
	TS	PLAYTEM1	
	CAF	PERF4MSK	# FLASH, PERFORM AND EBANK R3
	TC	Q	
SAVELOCS	INHINT		
	CS	OCT3400	# EBANK BITS
	MASK	PLAYTEM4	
	AD	EBANK	
	TS	PLAYTEM4	
SAVELOCR	LXCH	Q	
	TC	MAKECADR	
	TS	PLAYTEM3	
	AD	RUPTREG3	# NOT USED FOR NON R ROUTINES
	TC	L	
COPYNORM	CAF	ZERO	
COPIES	TS	COPINDEX	
COPIES2	INHINT		
	CA	PLAYTEM4	# FLAGWORD
	INDEX	COPINDEX	
	TS	EBANKSAV	# EQUIV TO DSPFLG
	MASK	CADRMASK	# FLASH AND GODSPRET
	EXTEND		
# Page 1474	BZF	SKIPADD	
	CA	PLAYTEM3	

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	INDEX	COPINDEX	
	TS	CADRFLSH	
SKIPADD	CA	PLAYTEM1	# VERB NOUN
	INDEX	COPINDEX	
	TS	NVWORD	
	TCF	RELINTQ	
GOSLEEPS	INDEX	COPINDEX	
	CA	PRIOOCT	
	MASK	WAITMASK	
	TC	UPENT2	
WAITMASK	OCT	3004	
	CS	ONE	
	AD	COPINDEX	
	TS	FACEREG	
XCHSLEEP	INDEX	FACEREG	
	CAF	WAKECADR	
	INHINT		
	TC	JOBWAKE	# FIND CADR IN JOB AREA
	TC	XCHTOEND	# CAUSES AWAKENED JOB TO GO TO ENDOFJOB
	INDEX	FACEREG	# REPLACE SAME CADR BUT NEW JOB AREA
	CAF	WAKECADR	
	TCF	JOBSLEEP	
JOBXCHS	TS	FACEREG	# CONTROLS TYPE OF DISPLAY PUT TO SLEEP
	TC	WITCHONE	
	TC	JOBWAKE	
	CA	FACEREG	
	INDEX	LOCCTR	
	TS	FACEREG	
	CAF	XCHQADD	
	TC	XCHNYLOC	
	INDEX	FACEREG	
	CA	MARKOCT	
	MASK	IDLESLEP	
	TC	DOWNENT2	
IDLEMASK	OCT	74004	# * DON'T MOVE
	INDEX	FACEREG	# BIT SHOWS PRIO INTERRUPTED NORM OR MARK

```

# Page 1475
XCHQADD    CA    BIT5          # BIT5 FOR MARK, BIT4 FOR NORMAL
           AD    FOUR
           TC    UPENT2        # FLAG ROUTINE DOES RELINT
           GENADR XCHSLEEP     # * DON'T MOVE
           CA    FLAGWRD4
           MASK   BIT3        # MARK OVER NORM?
           CCS    A
GENMARK     TC    MARKPLAY     # USED AS GENADR FOR JOBWAKE
           TCF    OKTOCOPY

MARKWAKE    CAF    ZERO
WAKEPLAY    TS    TEMPOR2

           INDEX  TEMPOR2
           CA    BITS5+11
           AD    FOUR
           TC    DOWNENT2
MARKFMSK    OCT    40010      # *** DON'T MOVE

           INDEX  TEMPOR2
           CAF    WAKECADR
           INHINT
           TC    JOBWAKE

           TCF    ENDRET

```

```

# ALL .1 RESTARTS BRANCH DIRECTLY TO INITDSP.  NORMAL DISPLAYS ARE THE ONLY DISPLAYS
# INITDSP FIRST RESTORES THE EBANK AND THE SUPERBANK TO THE MOST RECENT NORMAL EBANK
#
# IF THE MOST RECENT NORMAL DISPLAY REQUEST WAS NOT FINISHED, CONTROL IS SENT BACK TO
# OTHERWISE THE NORMAL DISPLAY SET UP IN THE NORMAL DISPLAY REGS IS STARTED UP IMMEDIATELY

```

```

INITDSP     CA    EBANKTEM     # RESTORE MOST RECENT NORMAL EBANK
           TS    EBANK

           CA    RESTREG       # SUPERBANK AND JOB PRIORITY
           TC    SUPERSW      # RESTORE SUPERBANK

           MASK   PRI037
           TC    PRIOCHNG

           CS    THREE
           AD    TEMPFLSH
           TCF    BANKJUMP

```



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```
PINBRNCH      RELINT      # FOR GOPIN USERS
                CA      MARK2PAC  # NEEDED TO SAVE MPAC +2 FOR MARK USERS
                TS      MPAC +2   # ONLY

                CA      FLAGWRD4  # PINBRANCH CONDITION
                MASK     PINMASK
                CCS      A

# Page 1476    TCF      +3
                TCF      ERASER   # ** NOTHING IN ENDIDLE
                TCF      MARKPLAY

NORMBNCH      TC      UPFLAG      # SET PINBRANCH BIT
                ADRES   PINBRFLG

                CAF      BIT14     # PRIO INTERRUPTED
                MASK     FLAGWRD4
                CCS      A
                TCF      KEEPprio

                TCF      PLAYJUM1

NVDSP         TC      COPYPACS

                CA      TEMPOR2    # SET UP BLANK BITS FOR NVMONOPT IN CASE
                MASK     SEVEN      # USER REQUESTS BLANKING MONITOR
                TS      L

                CS      BIT13
                INDEX   COPINDEX
                MASK     DSPFLG
                INDEX   COPINDEX
                TS      DSPFLG

                MASK     BIT8       # BIT8 SET IF DEC MARK PERFORM DISPLAY
                TS      TEM1

                CA      MPAC +2
                TS      MPAC2SAV

                TS      MARK2PAC    # * FOR DISK ONLY *
                INDEX   COPINDEX
                CCS      NVWORD
                TCF      NVDSP1
                TCF      CLEANEND
                CS      MARKNV
```

	TS	MARKNV	# IN CASE MARKPLAY AWAKENED AFTER SLEEPING
	MASK	LOW7	
	AD	V05NOOM1	
	AD	TEM1	
NVDSP1	AD	ONE	
NV50DSP	TC	NVMONOPT	
	TCF	REST	# IF BUSY
	TC	FLASHOFF	# IN CASE OF EXTENDED VERB NON-FLASH
	TC	COPYTOGO	# MPACS DESTROYED BY NVSUB
	TC	DOWNFLAG	# UNSET SLEEPING BITS
	ADRES	MRKNVFLG	
# Page 1477			
	TC	DOWNFLAG	
	ADRES	NRMNVFLG	
	TC	DOWNFLAG	
	ADRES	PRONVFLG	
BLANKCHK	CA	TEMPOR2	# BLANK BITS 1,2,3 IF SET
	TC	BLANKSUB	
	TCF	NVDSP	
PERFCHEK	CAF	BIT5	# BIT 5 FOR PERFORM
	MASK	TEMPOR2	
	CCS	A	# IS THIS A GOPERF DISPLAY
	TCF	1STOR2ND	# YES
GOANIDLE	CAF	BIT4	
	MASK	TEMPOR2	
	CCS	A	
	TCF	FLASHSUB	# IT IS
	CS	TEMPOR2	# IS THIS A GODSPRET
	MASK	BIT6	
	CCS	A	
	TCF	ISITN00	
	INDEX	COPINDEX	
	CA	CADRFLSH	
	TS	MPAC +3	
	TCF	ENDIT	
ISITN00	INDEX	COPINDEX	# IS THIS A PASTE
	CA	NVWORD	
	MASK	LOW7	# CHECK MADE FOR PINBRNCH AND PRIO ON MARK
	EXTEND		
	BZF	FLASHSUB	# YES, ASSUME PASTE ALWAYS ON FLASH

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	TCF	ENDOFJOB	# NOT FLASH, NOT GOPERF, THEREFORE EXIT
1STOR2ND	CA	TEMPOR2	
	MASK	BIT13	
	CCS	A	
	TCF	GOANIDLE	# SECOND
	CA	BIT13	
	INDEX	COPINDEX	
	ADS	DSPFLG	
	ZL		
	EXTEND		# IS IT MARK
	BZMF	MARKPERF	# YES
	MASK	BIT12	
	EXTEND		
# Page 1478	BZF	V50PASTE	
	CS	NVWORD1	# NVWORD1= -0 IS V97. NVWORD1= -400 IS V99
	AD	V97N00	
	TCF	NV50DSP	
V50PASTE	CAF	V50N00	
	TCF	NV50DSP	# DISPLAY SECOND PART OF GOPERF
WITCHONE	CS	BIT5	# TURN OFF KEY RELEASE LIGHT
	EXTEND		
	WAND	DSALMOUT	
	CA	FLAGWRD4	
	MASK	NVBUSMSK	# IS IT NVSUB ALEEP
	CCS	A	
	CAF	ONE	
	TS	L	
	CAF	ZERO	
	INDEX	L	
	XCH	CADRSTOR	
	INHINT		
	TC	Q	
XCHTOEND	CAF	ENDINST	# TC ENDOFJOB REPLACES GENADR IN LOC FOR
XCHNYLOC	XCH	LOCCTR	# WAS THIS ADDRESS SLEEPING
	EXTEND		
	BZMF	RELINTQ	# NO
	XCH	LOCCTR	# YES

	INDEX	LOCCTR	
	TS	LOC	
RELINTQ	RELINT		
	TC	Q	# BACK TO USER
CLEANEND	CAF	PRI032	# ONE LOWER THAN DISPLAYS SLEEPING
	TC	FINDVAC	
	EBANK=	NVSAVE	
	2CADR	JAMTERM	
	TCF	FLASHSUB +1	
ISITPRIO	CA	FLAGWRD4	
	MASK	ITISMASK	# IS PINBRFLG, MARKIDFLG SET
	EXTEND		
	BZF	PRIOBORT	
	TCF	ENDOFJOB	
REST	CCS	CADRSTOR	# IS SOMEONE IN ENDIDLE
	TCF	ENDOFJOB	# YES
# Page 1479			
	TCF	RESTSLEP	
	TCF	ENDOFJOB	
RESTSLEP	CA	GENMASK	# SET NVSLEEP BITS
	MASK	ASTROMSK	
	TC	UPENT2	
OCT24100	OCT	24100	# *** DON'T MOVE
	INDEX	COPINDEX	
	CAF	NVCADR	
	TC	NVSUBUSY	# BUSY OR ABORT IF ILLEGAL
FLASHSUB	TC	FLASHON	
	CA	COPINDEX	# COPINDEX DESTROYED BY ENDIDLE
	TS	COPMPAC	
	CA	GENMASK	
	MASK	IDLEMASK	
	TC	UPENT2	
ITISMASK	OCT	40040	# *** ENDIDLE ALLOW *** DON'T MOVE
	CA	R1SAVE	# IS THIS A REPEAT AND RETURN DISPLAY
	INDEX	COPINDEX	

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	MASK	BIT3	
	CCS	A	
	TCF	UNSETR1	# YES
	CCS	CADRSTOR	# SEE IF SOMEONE ALREADY IN ENDIDLE
	TCF	ISITPRIO	
	TCF	+2	
	TCF	ISITPRIO	
IDLERET1	TC	ENDIDLE	
	TCF	TERMATE	
	TCF	PROCEED	# ENDIDLE RETURNS HERE ON PROCEED
	CS	LOWLOAD	
	AD	MPAC	# VERBREG
	EXTEND		
	DIM	A	
	EXTEND		
	BZF	LOADITIS	# V21 OR V22 OR V23 ON DSKY
OKTOENT	CAF	TWO	
ENDOUT	TS	OUTHERE	
	CA	FLAGWRD4	# CHECK NATURE OF ENDIDLE RETURN
	MASK	OCT60000	
# Page 1480	CCS	A	
	TCF	TIMECHEK	# PRIO ENDIDLE RETURN
	TCF	NORMRET	# NORMAL ENDIDLE RETURN
	TCF	MARKRET	# MARK ENDIDLE RETURN
TIMECHEK	CS	TIME1	
	AD	PRIOTIME	
	CCS	A	
	COM		
	AD	OCT37776	
	AD	ONE	
	AD	-2SEC	
	EXTEND		
	BZMF	KEEPPRIO	
	TCF	NORMRET	
NORMWAKE	CAF	ONE	
	TCF	WAKEPLAY	

ENDRET	CCS	OUTHERE	
	AD	ONE	
	TCF	+2	# NORMAL ENDIDLE EXIT
	TCF	ENDOFJOB	
	INDEX	COPMPAC	
	AD	CADRFLSH	
	TS	MPAC +3	
	CA	GENMASK	# REMOVE ENDIDLE AND PINBRANCH BITS
	MASK	PINIDMSK	
	TC	DOWNT2	
PINIDMSK	OCT	74044	# *** DON'T MOVE
	CS	THREE	# BLANK EVERYTHING EXCEPT MM
	TC	NVSUB	
	TCF	+1	
ENDIT	CA	USERPRIO	# RETURN TO USER'S PRIORITY
	MASK	PRI037	
	TC	PRI0CHNG	
	CA	MPAC +3	
	TCF	BANKJUMP	
UNSETR1	INDEX	COPINDEX	# RESET REPEAT AND RETURN REQUEST
	CS	BIT3	
	MASK	R1SAVE	
	TS	R1SAVE	
	CAF	ZERO	# *** 205 ONLY MARKBRAN USERS IN
	TC	SUPERSW	# SUPERBANK 0
# Page 1481			
-1	CAF	THREE	# RETURN TO USER'S IMMEDIATE RETURN LOC
IMMEDRET	INDEX	COPINDEX	
	AD	CADRFLSH	
	TCF	BANKJUMP	
TERMATE	CAF	ZERO	# ASTRONAUT TERMINATE (V34) RETURNS TO
	TCF	ENDOUT	
LINUSCHR	CS	PLAYTEM4	# IS THIS A LINUS
	MASK	BIT14	
	CCS	A	
	TCF	Q+1	# NO
	CS	PLAYTEM3	# YES, IS IT ALREADY IN ENDIDLE
	INDEX	COPINDEX	
	AD	CADRFLSH	

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```
EXTEND
BZF      +2          # YES

TC       Q           # NO
CCS      DSPLOCK     # IS THE ASTRONAUT BUSY
TC       ENDOFJOB     # END THE NEW DISPLAY, IT'S ALREADY ACTIVE
TC       Q

# MORE LOGIC COULD BE INCORPORATED HERE TO MAKE SURE A RECYCLE IS A RECYCLE AND CONVERSELY THAT

PROCEED   CAF      ONE          # ASTRONAUT PROCEED (V33) RETURNS
          TCF      ENDOUT

# LASTPLAY CHECKS TO SEE IF (1) THE LAST NORMAL DISPLAY WAS EITHER INTERRUPTED BY A PRIO OR A M
# COULD ONLY HAPPEN DURING PINBRANCH) OR IF (2) THE LAST NORMAL DISPLAY WAS REQUESTED WHILE A H
# DISPLAY WAS GOING, RESULTING IN THE NORMAL BEING PUT TO SLEEP.
#
# IF EITHER OF THE ABOVE 2 CONDITIONS EXISTS, THE NORMAL DISPLAY IS AWAKENED TO GO TO PLAYJUM1
# UP THE MOST RECENT VALID NORMAL DISPLAY. IF THESE 2 CONDITIONS DO NOT EXIST, CONTROL GOES TO
# STARTED IMMEDIATELY WITH THE ASSUMPTION THAT THE MOST RECENT NORMAL DISPLAY IS ALREADY IN END
# PINBRNCH) OR THAT A RESTART HAS OCCURRED AND THE DISPLAY CAN BE STARTED AS A .1 RESTART.

MARKRET   CS        SIX
          MASK      FLAGWRD4
          INHINT    # *** MAY MOVE DISPLAY FLAGWORD OUT OF
          TS        FLAGWRD4

          RELINT    # INHINT REALM
          TCF      ENDRET

MARKOVER  CAF      MINUS1      # RUPTREG2 IS - MEANS ENDOFJOB TO ENDRET
          TS        OUTHERE
          CA        FLAGWRD4   # IS ENDIDFLG SET
          MASK      PRIO30     # IS NORMAL OR PRIO IN ENDIDLE
          CCS      A

# Page 1482
          TCF      NORMBNCH

NORMRET   CA        FLAGWRD4   # IS MARK SLEEPING
          MASK      BITS5+11   # OR WAITING
          CCS      A
          TCF      MARKWAKE

          CA        FLAGWRD4   # NO
          MASK      BITS4+10   # IS NORMAL INTERRUPTED OR WAITING
          CCS      A
```

	TCF	NORMWAKE	# YES
	CA	EBANKTEM	# NO, WAS IT A FLASH REQUEST
	MASK	OCT50	# OR A GODSPRET
	CCS	A	
	TCF	ENDRET	# YES
	CA	NVSAVE	
	EXTEND		
	BZF	ENDRET	
	CAF	PRI015	
	INHINT		
	TC	NOVAC	
	EBANK=	NVWORD	
	2CADR	PLAYJUM1	
	TCF	ENDRET	
MARSLEEP	CA	FLAGWRD4	# IS MARK ALREADY ON
	MASK	BITS5+11	
	CCS	A	
	TCF	ENDOFJOB	# YES
	TCF	GOSLEEPS	
LOADITIS	INDEX	COPMPAC	
	CA	NVWORD	
	MASK	LOW7	
	COM		
	AD	MPAC +1	# NOUNREG
	EXTEND		
	BZF	OKTOENT	# NO, THEN LOAD IS VALID
	TCF	PINBRNCH	# YES, ACCEPT LOAD BUT ASK FOR LAST AGAIN
ERASER	CS	THREE	# BLANK EVERYTHING EXCEPT MM
	TC	NVSUB	
	TCF	ENDOFJOB	
	TCF	ENDOFJOB	
PERFMASK	OCT	0036	# FLASH, PERFORM, BLANK R2 AND R3
# Page 1483			
V01N25	VN	00125	
V06N07	VN	00607	# GOPERF3 VN DISPLAY BEFORE V50
V50N00	VN	5000	
PERF2MSK	OCT	00030	# FLASH, PERFORM
V04N06	VN	00406	
PERF4MSK	OCT	14	# FLASH, BLANK R3



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GOAGIN	EQUALS	PINBRNCH	
REDOMASK	OCT	20010	# BITS 4 AND 14
MARK3MSK	OCT	40230	# MARK, DECIMAL NOUN, PERFORM, FLASH
MARK4MSK	OCT	40036	# MARK, PERFORM, FLASH, BLANK 2 AND 3
NVCADR	CADR	REDOPRIO	
WAKECADR	CADR	MARKPLAY	
	CADR	PLAYJUM1	
OCT3400	OCT	3400	# EBANK MASK
NBUSMASK	OCT	11210	
PMMASK	OCT	66521	
VERBMASK	=	MID7	# (OCT 37600)
V05N00M1	OCT	1177	# V05 MINUS ONE
GOXDSP	EQUALS	GOMARK	
GOXDSPR	EQUALS	GOMARKR	
GOXDSPF	EQUALS	GOMARKF	
GOXDSPFR	EQUALS	GOMARKFR	
ENDEXT	EQUALS	ENDMARK	
MPAC2SAV	EQUALS	BANKSET	
NVBUSMSK	OCT	700	
ASTROMSK	OCT	704	
MPERFMSK	OCT	40030	# BIT 15,5,4 FOR MARK,PERFORM,FLASH
OCT34300	OCT	34300	
BITS15+7	OCT	40100	
BITS7+4	OCT	110	
DSPFLG	EQUALS	EBANKSAV	
MARKFLAG	EQUALS	MARKEBAN	
SAVEFLAG	EQUALS	EBANKTEM	
BITS5+11	OCT	2020	# * DON'T MOVE
BITS4+10	OCT	1010	# * DON'T MOVE
LOWLOAD	DEC	22	
BUSYMASK	OCT	77730	
CADRMASK	OCT	50	
PINMASK	EQUALS	13,14,15	
GOPLAY	EQUALS	NVDSP	
PRIOSAVE	EQUALS	R1SAVE	
COPMPAC	EQUALS	MPAC +3	
TEMPOR2	EQUALS	MPAC +4	
OUTHERE	EQUALS	MPAC +5	
COPINDEX	EQUALS	LOC	
USERPRIO	EQUALS	MODE	
GENMASK	EQUALS	MPAC +6	
PRIOOCT	OCT	20144	# PRIO
MARKOCT	OCT	42424	# MARK
# Page 1484			
	OCT	11254	# NORM

IDLESLEP	OCT	74704	
OCT67777	OCT	67777	
LINUS	EQUALS	BLANKET	
FACEREG	EQUALS	MPAC	
PLAYTEM1	EQUALS	MPAC +1	
PLAYTEM3	EQUALS	MPAC +3	
PLAYTEM4	EQUALS	MPAC +4	
OCT40420	OCT	40420	
MAKEGEN	GENADR	MAKEPLAY	
OCT10200	OCT	10200	
V97N00	VN	09700	# PASTE FOR V97 OR V99
OCT20100	OCT	20100	
CLOCKCON	OCT	24030	

This code is written to file `src/DISPLAY-INTERFACE-ROUTINES.s`.

## A.22 DOWNLINK LISTS

347 *<src/DOWNLINK-LISTS.s 347>≡*

```
# Copyright:   Public domain.
# Filename:    DOWNLINK_LISTS.agc
# Purpose:    Part of the source code for Comanche, build 055. It
#             is part of the source code for the Command Module's
#             (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:  yaYUL
# Reference:   pp. 170-180
# Contact:    Ron Burkey <info@sandroid.org>,
#             Fabrizio Bernardini <fabrizio@spacecraft.it>
# Website:    http://www.ibiblio.org/apollo.
# Mod history: 10/05/09 FB      Transcription of Batch FB-1 Assignment.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#             Massachussets Institute of Technology
#             75 Cambridge Parkway
#             Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.
```

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```
BANK      22
SETLOC    DOWNTLM
BANK
```

```
EBANK=    DNTMBUFF
```

# SPECIAL DOWNLINK OP CODES

#	OP CODE	ADDRESS (EXAMPLE)	SENDS...	BIT 15	BITS 14
#	-----	-----	-----	-----	-----
#	1DNADR	TIME2	(2 AGC WDS)	0	0
#	2DNADR	TEPHEM	(4 AGC WDS)	0	1
#	3DNADR	VGBODY	(6 AGC WDS)	0	2

```

#      4DNADR      STATE      (8 AGC WDS)      0
#      5DNADR      UPBUFF     (10 AGC WDS)     0
#      6DNADR      DSPTAB     (12 AGC WDS)     0
#      DNCHAN      30         CHANNELS        0
#
#      DNPTR       NEXTLIST   POINTS TO NEXT   0
#                               LIST
#
# DOWNLIST FORMAT DEFINITIONS AND RULES --
# 1. END OF A LIST = -XDNADR (X = 1 TO 6), -DNPTR, OR -DNCHAN.
# 2. SNAPSHOT SUBLIST = LIST WHICH STARTS WITH A -1DNADR.
# 3. SNAPSHOT SUBLIST CAN ONLY CONTAIN 1DNADRS.
# 4. TIME2 1DNADR MUST BE LOCATED IN THE CONTROL LIST OF A DOWNLIST.
# 5. ERASABLE DOWN TELEMETRY WORDS SHOULD BE GROUPED IN SEQUENTIAL
#    LOCATIONS AS MUCH AS POSSIBLE TO SAVE STORAGE USED BY DOWNLINK LISTS.
# 6. THE DOWNLINK LISTS (INCLUDING SUBLISTS) ARE ORGANIZED SUCH THAT THE ITEMS LISTED
#    SENT FIRST. EXCEPTION--- SNAPSHOT SUBLISTS. IN THE SNAPSHOT SUBLISTS THE DATA
#    11 1DNADRS IS PRESERVED (IN ORDER) IN DNTMBUFF AND SENT BY THE NEXT 11 DOWNRUPTS
#    LIST IS SENT IMMEDIATELY.

```

```

COUNT 05/DLIST
ERASZERO EQUALS 7
SPARE EQUALS ERASZERO # USE SPARE TO INDICATE AVAIL
LOWIDCOD OCT 77340 # LOW ID CODE

NOMDNLST EQUALS CMCSTADL # FRESH START AND POST P27 DO
UPDNLST EQUALS CMENTRDL # UPDATE PROGRAM (P27) DOWNL

```

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# CSM POWERED FLIGHT DOWNLIST

#

# ----- CONTROL LIST -----

```

CMPOWEDL EQUALS
DNPTR CMPOWE01 # COLLECT SNAPSHOT
6DNADR DNTMBUFF # SEND SNAPSHOT
DNPTR CMPOWE02 # COLLECT SECOND SNAPSHOT
4DNADR DNTMBUFF # SEND SNAPSHOT
DNPTR CMPOWE03 # COMMON DATA
1DNADR TIG # TIG,+1
1DNADR DELLT4 # DELLT4,+1
3DNADR RTARG # RTARG,+1,+2,...+5
1DNADR TGO # TGO,+1
1DNADR PIPTIME1 # PIPTIME1,+1
3DNADR DELV # DELV,+1,...,+4,+5
1DNADR PACTOFF # PACTOFF,YACTOFF

```

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1DNADR	PCMD		# PCMD,YCMD	
1DNADR	CSTEER		# CSTEER,+1	
3DNADR	DELVEET1		# CSI DELTA VELOCITY COMPONENTS	(31-3
6DNADR	REFSMMAT		# REFSMMAT,+1,...+10,+11	
DNPTR	CMPOWE04		# COMMON DATA	
1DNADR	TIME2		# TIME2,TIME1	
DNPTR	CMPOWE05		# COMMON DATA	
6DNADR	DNTMBUFF		# SEND SNAPSHOT	
DNPTR	CMPOWE02		# COLLECT SNAPSHOT	
4DNADR	DNTMBUFF		# SEND SNAPSHOT	
DNPTR	CMPOWE03		#	
DNPTR	CMPOWE06		# COMMON DATA	
1DNADR	ELEV		# ELEV,+1	
1DNADR	CENTANG		# CENTANG,+1	
1DNADR	DELTAR		# DELTAR,+1	
1DNADR	STATE	+10D	# FLAGWORDS 10 AND 11	
1DNADR	TEVENT		# TEVENT,+1	
1DNADR	PCMD		# PCMD,YCMD	
1DNADR	OPTMODES		# OPTMODES,HOLDFLAG	
DNPTR	CMPOWE07		# COMMON DATA	
3DNADR	VGITIG		# VGITIG,+1,...,+4,+5	
-3DNADR	DELVEET2		# CDH DELTA VELOCITY COMPONENTS	(98-1

# ----- SUB LISTS -----

CMPOWE01	-1DNADR RN	+2	# RN +2,+3	SNAPSHO
	1DNADR RN	+4	# RN +4,+5	
	1DNADR VN		# VN, +1	
	1DNADR VN	+2	# VN +2,+3	
	1DNADR VN	+4	# VN +4,+5	
	1DNADR PIPTIME		# PIPTIME, +1	
	-1DNADR RN		# RN, +1	
CMPOWE02	-1DNADR CDUZ		# CDUZ,CDUT	SNAPSHO
# Page 172				
	1DNADR ADOT		# ADOT,+1/OGARATE,+1	
	1DNADR ADOT	+2	# ADOT+2,+3/OMEGAB+2,+3	
	1DNADR ADOT	+4	# ADOT+4,+5/OMEGAB+4,+5	
	-1DNADR CDUX		# CDUX,CDUY	
CMPOWE03	2DNADR AK		# AK,AK1,AK2,RCSFLAGS	COMMON
	-2DNADR THETADX		# THETADX,THETADY,THETADZ,GARBAGE	
CMPOWE04	5DNADR STATE		# FLAGWRD0 THRU FLAGWRD9	COMMON
	-6DNADR DSPTAB		# DISPLAY TABLES	

CMPOWE05	-1DNADR R-OTHER +2	# R-OTHER+2,+3
	1DNADR R-OTHER +4	# R-OTHER+4,+5
	1DNADR V-OTHER	# V-OTHER,+1
	1DNADR V-OTHER +2	# V-OTHER+2,+3
	1DNADR V-OTHER +4	# V-OTHER+4,+5
	1DNADR T-OTHER	# T-OTHER,+1
	-1DNADR R-OTHER	# R-OTHER,+1
CMPOWE06	1DNADR RSBBQ	# RSBBQ,+1
	3DNADR CADRFLSH	# CADRFLSH,+1,+2,FAILREG,+1,-
	-2DNADR CDUS	# CDUS,PIPAX,PIPAY,PIPAZ
CMPOWE07	1DNADR LEMMASS	# LEMMASS,CSMMASS
	1DNADR DAPDATR1	# DAPDATR1,DAPDATR2
	2DNADR ERRORX	# ERRORX,ERRORY,ERRORZ,GARBA
	3DNADR WBODY	# WBODY,...+5/OMEGAC,...+5
	2DNADR REDOCTR	# REDOCTR,THETAD,+1,+2
	1DNADR IMODES30	# IMODES30,IMODES33
	DNCHAN 11	# CHANNELS 11,12
	DNCHAN 13	# CHANNELS 13,14
	DNCHAN 30	# CHANNELS 30,31
	-DNCHAN 32	# CHANNELS 32,33

# -----

# Page 173

# CSM COAST AND ALIGNMENT DOWNLIST

# ----- CONTROL LIST -----

CMCSTADL	EQUALS	# SEND ID BY SPECIAL CODING
	DNPTR CMCSTAO1	# COLLECT SNAPSHOT
	6DNADR DNTMBUFF	# SEND SNAPSHOT
	DNPTR CMCSTAO2	# COLLECT SECOND SNAPSHOT
	4DNADR DNTMBUFF	# SEND SNAPSHOT
	DNPTR CMCSTAO3	# COMMON DATA
	1DNADR TIG	# TIG,+1
	1DNADR BESTI	# BESTI,BESTJ
	4DNADR MARKDOWN	# MARKDOWN,+1,...+5,+6,GARBA
	4DNADR MARK2DWN	# MARK2DWN,+1,...+5,+6
	2DNADR HAPOX	# APOGEE AND PERIGEE FROM R30
	1DNADR PACTOFF	# PACTOFF, YACTOFF
	3DNADR VGTIG	# VGTIG,...+5
	6DNADR REFSMMAT	# REFSMMAT,+1,...+10,+11
	DNPTR CMCSTAO4	# COMMON DATA
	1DNADR TIME2	# TIME2,TIME1
	DNPTR CMCSTAO5	# COLLECT SNAPSHOT

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6DNADR	DNTMBUFF	# SEND SNAPSHOT
DNPTR	CMCSTA02	# COLLECT SNAPSHOT
4DNADR	DNTMBUFF	# SEND SNAPSHOT
DNPTR	CMCSTA03	# COMMON DATA
DNPTR	CMCSTA06	# COMMON DATA
3DNADR	OGC	# OGC,+1,IGC,+1,MGC,+1
1DNADR	STATE +10D	# FLAGWRDS 10 AND 11
1DNADR	TEVENT	# TEVENT,+1
1DNADR	LAUNCHAZ	# LAUNCHAZ,+1
1DNADR	OPTMODES	# OPTMODES,HOLDFLAG
DNPTR	CMCSTA07	# COMMON DATA
-6DNADR	DSPTAB	# DISPLAY TABLES

# ----- SUB LISTS -----

CMCSTA01	EQUALS	CMPOWE01	# COMMON DOWNLIST DATA
CMCSTA02	EQUALS	CMPOWE02	# COMMON DOWNLIST DATA
CMCSTA03	EQUALS	CMPOWE03	# COMMON DOWNLIST DATA
CMCSTA04	EQUALS	CMPOWE04	# COMMON DOWNLIST DATA
CMCSTA05	EQUALS	CMPOWE05	# COMMON DOWNLIST DATA
CMCSTA06	EQUALS	CMPOWE06	# COMMON DOWNLIST DATA
CMCSTA07	EQUALS	CMPOWE07	# COMMON DOWNLIST DATA

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# -----

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# CSM RENDEZVOUS AND PRETHRUST LIST

# ----- CONTROL LIST -----

CMRENDDL	EQUALS	# SEND ID BY SPECIAL CODING
DNPTR	CMREND01	# COLLECT SNAPSHOT
6DNADR	DNTMBUFF	# SEND SNAPSHOT
DNPTR	CMREND02	# COLLECT SECOND SNAPSHOT
4DNADR	DNTMBUFF	# SEND SNAPSHOT
DNPTR	CMREND03	# COMMON DATA
1DNADR	TIG	# TIG,+1
1DNADR	DELLT4	# DELLT4,+1
3DNADR	RTARG	# RTARG,+1,...+4,+5
1DNADR	VHFTIME	# VHFTIME,+1

4DNADR	MARKDOWN	# MARKTIME(DP) , YCDU , SCDU , ZCDU
1DNADR	VHFCNT	# VHFCNT , +1
1DNADR	TTPI	# TTPI , +1
1DNADR	ECSTEER	# ECSTEER , +1
1DNADR	DELVTPI	# DELVTPI , +1
2DNADR	TCDH	# CDH AND CSI TIME
1DNADR	TPASS4	# TPASS4 , +1
3DNADR	DELVSLV	# DELVSLV , +1 . . . +4 , +5
2DNADR	RANGE	# RANGE , +1 , RRATE , +1
DNPTR	CMREND04	# COMMON DATA
1DNADR	TIME2	# TIME2 , TIME1
DNPTR	CMREND05	# COLLECT SNAPSHOT
6DNADR	DNTMBUFF	# SEND SNAPSHOT
DNPTR	CMREND02	# COLLECT SNAPSHOT
4DNADR	DNTMBUFF	# SEND SNAPSHOT
DNPTR	CMREND03	# COMMON DATA
DNPTR	CMREND06	# COMMON DATA
1DNADR	DIFFALT	# CDH DELTA ALTITUDE
1DNADR	CENTANG	# CENTANG , +1
1DNADR	DELTAR	# DELTAR , +1
3DNADR	DELVEET3	# DELVEET3 , +1 , . . . , +4 , +5
1DNADR	OPTMODES	# OPTMODES , HOLDFLAG
DNPTR	CMREND07	# COMMON DATA
1DNADR	RTHETA	# RTHETA , +1
2DNADR	LAT(SPL)	# LAT(SPL) , LNG(SPL) , +1
2DNADR	VPRED	# VPRED , +1 , GAMMAEI , +1
-1DNADR	STATE +10D	# FLAGWRDS 10 AND 11

# ----- SUB LISTS -----

CMREND01	EQUALS	CMPOWE01	# COMMON DOWNLIST DATA
CMREND02	EQUALS	CMPOWE02	# COMMON DOWNLIST DATA
CMREND03	EQUALS	CMPOWE03	# COMMON DOWNLIST DATA
CMREND04	EQUALS	CMPOWE04	# COMMON DOWNLIST DATA
# Page 176			
CMREND05	EQUALS	CMPOWE05	# COMMON DOWNLIST DATA
CMREND06	EQUALS	CMPOWE06	# COMMON DOWNLIST DATA
CMREND07	EQUALS	CMPOWE07	# COMMON DOWNLIST DATA

# -----



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# CSM ENTRY AND UPDATE DOWNLIST

# ----- CONTROL LIST -----

CMENTRDL	EQUALS	# SEND ID BY SPECIAL CODING
	DNPTR CMENTRO1	# COLLECT SNAPSHOT
	6DNADR DNTMBUFF	# SEND SNAPSHOT
	DNPTR CMENTRO2	# COLLECT SNAPSHOT
	4DNADR DNTMBUFF	# SEND SNAPSHOT
	DNPTR CMENTRO3	# COMMON DATA
	2DNADR CMDAPMOD	# CMDAPMOD,PREL,QREL,RREL
	1DNADR L/D1	# L/D1,+1
	6DNADR UPBUFF	# UPBUFF,+1,...+10,+11
	4DNADR UPBUFF +12D	# UPBUFF+12,13,...+18,+19D
	2DNADR COMPNUMB	# COMPNUMB,UPOLDMOD,UPVERB,UPCOUNT
	1DNADR PAXERR1	# PAXERR1,ROLLTM
	3DNADR LATANG	# LATANG,+1,RDOT,+1,THETAH,+1
	2DNADR LAT(SPL)	# LAT(SPL),+1,LNG(SPL),+1
	1DNADR ALFA/180	# ALFA/180,BETA/180
	DNPTR CMENTRO4	# COMMON DATA
	1DNADR TIME2	# TIME2,TIME1
	DNPTR CMENTRO5	# COLLECT SNAPSHOT
	6DNADR DNTMBUFF	# SEND SNAPSHOT
	DNPTR CMENTRO2	# COLLECT SNAPSHOT
	4DNADR DNTMBUFF	# SENT SNAPSHOT
	2DNADR AK	# AK,AK1,AK2,RCSFLAGS
	3DNADR ERRORX	# ERRORX/Y/Z,THETADX/Y/Z
	2DNADR CMDAPMOD	# CMDAPMOD,PREL,QREL,RREL
	6DNADR UPBUFF	# UPBUFF+0,+1,...+10,+11D
	4DNADR UPBUFF +12D	# UPBUFF+12,+13,...+18,+19D
	1DNADR LEMMASS	# LEMMASS,CSMASS
	1DNADR DAPDATR1	# DAPDATR1,DAPDATR2
	1DNADR ROLLTM	# ROLLTM,ROLLC
	1DNADR OPTMODES	# OPTMODES,HOLDFLAG
	3DNADR WBODY	# WBODY,...+5/OMEGAC,...+5
	2DNADR REDOCTR	# REDOCTR,THETAD+0,+1,+2
	1DNADR IMODES30	# IMODES30,IMODES33
	DNCHAN 11	# CHANNELS 11,12
	DNCHAN 13	# CHANNELS 13,14
	DNCHAN 30	# CHANNELS 30,31
	DNCHAN 32	# CHANNELS 32,33
	1DNADR RSBBQ	# RSBBQ,+1
	3DNADR CADRFLSH	# CADRFLSH,+1,+2,FAILREG,+1,+2
	1DNADR STATE +10D	# FLAGWRDS 10 AND 11
	-1DNADR GAMMAEI	# GAMMAEI,+1

## # ----- SUB LISTS -----

CMENTRO1	EQUALS	CMPOWE01	# COMMON DOWNLIST DATA
# Page 178			
CMENTRO2	EQUALS	CMPOWE02	# COMMON DOWNLIST DATA
CMENTRO3	EQUALS	CMPOWE03	# COMMON DOWNLIST DATA
CMENTRO4	EQUALS	CMPOWE04	# COMMON DOWNLIST DATA
CMENTRO5	-1DNADR	DELV	# DELV,+1
	1DNADR	DELV +2	# DELV+2,+3
	1DNADR	DELV +4	# DELV+4,+5
	1DNADR	TTE	# TTE,+1
	1DNADR	VIO	# VIO,+1
	1DNADR	VPRED	# VPRED,+1
	-1DNADR	PIPTIME1	# PIPTIME1,+1
CMENTRO7	EQUALS	CMPOWE07	# COMMON DOWNLIST DATA

## # -----

# Page 179

## # ----- CONTROL LIST -----

CMPG22DL	EQUALS		# SEND ID BY SPECIAL CODING
	DNPTR	CMPG2201	# COLLECT SNAPSHOT
	6DNADR	DNTMBUFF	# SEND SNAPSHOT
	DNPTR	CMPG2202	# COLLECT SNAPSHOT
	4DNADR	DNTMBUFF	# SEND SNAPSHOT
	DNPTR	CMPG2203	# COMMON DATA
	6DNADR	SVMRKDAT	# LANDING SITE MARK DATA
	6DNADR	SVMRKDAT +12D	# SVMRKDAT+0,...+34
	6DNADR	SVMRKDAT +24D	# LANDING SITE MARK DATA
	1DNADR	LANDMARK	# LANDMARK,GARBAGE
	1DNADR	SPARE	
	1DNADR	SPARE	
	1DNADR	SPARE	
	DNPTR	CMPG2204	# COMMON DATA
	1DNADR	TIME2	# TIME2,TIME1
	DNPTR	CMPG2205	# COLLECT SNAPSHOT
	2DNADR	DNTMBUFF	# SEND SNAPSHOT
	1DNADR	SPARE	
	1DNADR	SPARE	
	1DNADR	SPARE	
	1DNADR	SPARE	

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```
DNPTR   CMPG2202           # COLLECT SNAPSHOT
4DNADR  DNTMBUFF          # SEND SNAPSHOT
DNPTR   CMPG2203           # COMMON DATA
DNPTR   CMPG2206           # COMMON DATA
1DNADR  8NN                # 8NN,GARBAGE
1DNADR  STATE   +10D       # FLAGWRDS 10 AND 11
3DNADR  RLS                # RLS,+1,...+4,+5
1DNADR  SPARE
1DNADR  OPTMODES          # OPTMODES,HOLDFLAG
DNPTR   CMPG2207           # COMMON DATA
1DNADR  SPARE
1DNADR  SPARE
1DNADR  SPARE
1DNADR  SPARE
1DNADR  SPARE
-1DNADR SPARE
```

# ----- SUB LISTS -----

```
CMPG2201      EQUALS  CMPOWE01           # COMMON DOWNLIST DATA
CMPG2202      EQUALS  CMPOWE02           # COMMON DOWNLIST DATA
CMPG2203      EQUALS  CMPOWE03           # COMMON DOWNLIST DATA
# Page 180
CMPG2204      EQUALS  CMPOWE04           # COMMON DOWNLIST DATA
CMPG2205      -1DNADR LONG                # LONG,+1
1DNADR  ALT                # ALT,+1
-1DNADR  LAT                # LAT,+1
CMPG2206      EQUALS  CMPOWE06           # COMMON DOWNLIST DATA
CMPG2207      EQUALS  CMPOWE07           # COMMON DOWNLIST DATA
```

# -----

```
DNTABLE      GENADR  CMCSTADL
              GENADR  CMENTRDL
              GENADR  CMRENDDL
              GENADR  CMPOWEDL
              GENADR  CMPG22DL
```

# -----

This code is written to file src/DOWNLINK-LISTS.s.

## A.23    DOWN TELEMETRY PROGRAM

```

356  <src/DOWN-TELEMETRY-PROGRAM.s 356>≡
# Copyright:      Public domain.
# Filename:       DOWN-TELEMETRY-PROGRAM.agc
# Purpose:        Part of the source code for Luminary 1A build 099.
#                It is part of the source code for the Lunar Module's (LM)
#                Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:     yaYUL
# Contact:        Ron Burkey <info@sandroid.org>.
# Website:        www.ibiblio.org/apollo.
# Pages:          988-997
# Mod history:    2009-05-24 RSB   Adapted from the corresponding
#                Luminary131 file, using page
#                images from Luminary 1A.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
#       16:27 JULY 14, 1969
#
# Page 988
# PROGRAM NAME -- DOWN TELEMETRY PROGRAM
# MOD NO. -- 0          TO COMPLETELY REWRITE THE DOWN TELEMETRY PROGRAM AND DOWNLINK
#                      PURPOSE OF SAVING APPROXIMATELY 150 WORDS OF CORE STORAGE.
#                      THIS CHANGE REQUIRES AN ENTIRELY NEW METHOD OF SPECIFYING DOWN
#                      LINK LOG SECTION FOR MORE DETAILS. HOWEVER THIS CHANGE WILL
#                      OF DOWN TELEMETRY DATA.
# MOD BY -- KILROY, SMITH, DEWITT
# DATE -- 02 OCT 67
# AUTHORS -- KILROY, SMITH, DEWITT, DEWOLF, FAGIN
# LOG SECTION -- DOWN-TELEMETRY PROGRAM
#
# FUNCTIONAL DESCRIPTION -- THIS ROUTINE IS INITIATED BY TELEMETRY END
# PULSE FROM THE DOWNLINK TELEMETRY CONVERTER. THIS PULSE OCCURS
# AT 50 TIMES PER SEC (EVERY 20 MS) THEREFORE DODOWNTM IS

```

```
# EXECUTED AT THESE RATES. THIS ROUTINE SELECTS THE APPROPRIATE
# AGC DATA TO BE TRANSMITTED DOWNLINK AND LOADS IT INTO OUTPUT
# CHANNELS 34 AND 35. THE INFORMATION IS THEN GATED OUT FROM THE
# LGC IN SERIAL FASHION.
#
# THIS PROGRAM IS CODED FOR A 2 SECOND DOWNLIST. SINCE DOWNRUPTS
# OCCUR EVERY 20 MS AND 2 AGC COMPUTER WORDS CAN BE PLACED IN
# CHANNELS 34 AND 35 DURING EACH DOWNRUPT THE PROGRAM IS CAPABLE
# OF SENDING 200 AGC WORDS EVERY 2 SECONDS.
#
# CALLING SEQUENCE -- NONE
# PROGRAM IS ENTERED VIA TCF DODOWNTM WHICH IS EXECUTED AS A
# RESULT OF A DOWNRUPT. CONTROL IS RETURNED VIA TCF RESUME WHICH
# IN EFFECT IS A RESUME.
#
# SUBROUTINES CALLED -- NONE
#
# NORMAL EXIT MODE -- TCF RESUME
#
# ALARM OR ABORT EXIT MODE -- NONE
#
# RESTART PROTECTION:
# ON A FRESH START AND RESTART THE 'STARTSUB' SUBROUTINE WILL INITIALIZE THE DOWNLIST POINT
# DNTMGOTO) TO THE BEGINNING OF THE CURRENT DOWNLIST (I.E., CURRENT CONTENTS OF DNLSTADR)
# EFFECT OF IGNORING THE REMAINDER OF THE DOWNLIST WHICH THE DOWN-TELEMETRY PROGRAM WAS W
# THE RESTART (OR FRESH START) OCCURRED AND RESUME DOWN TELEMETRY FROM THE BEGINNING OF T
# DOWNLIST.
#
# ALSO OF INTEREST IS THE FACT THAT ON A RESTART THE AGC WILL ZERO DOWNLINK CHANNELS 13,
#
# DOWNLINK LIST SELECTION:
# THE APPROPRIATE DOWNLINK LISTS ARE SELECTED BY THE FOLLOWING:
# 1. FRESH START
# 2. V37EXXE WHERE XX = THE MAJOR MODE BEING SELECTED.
# 3. UPDATE PROGRAM (P27)
# 4. NON-V37 SELECTABLE TYPE PROGRAMS (E.G., AGS INITIALIZATION (SUNDANCE, LUMINARY)
# TRANSITION (COLOSSUS) ETC.).
#
# DOWNLINK LIST RULES AND LIMITATIONS:
# READ SECTION(S) WHICH FOLLOW 'DEBRIS' WRITEUP.
#
# OUTPUT -- EVERY 2 SECONDS 100 DOUBLE PRECISION WORDS (I.E., 200 LGC
# COMPUTER WORDS) ARE TRANSMITTED VIA DOWNLINK.
#
# ERASABLE INITIALIZATION REQUIRED -- NONE
# 'DNTMGOTO' AND 'DNLSTADR' ARE INITIALIZED BY THE FRESH START PROGRAM.
```

```

#
# DEBRIS (ERASABLE LOCATIONS DESTROYED BY THIS PROGRAM) --
#       LDATA1ST, DNTMBUFF TO DNTMBUFF +21D, TMINDEX, DNQ.
# Page 989 (empty page)
# Page 990
# DODOWNTM IS ENTERED EVERY 20 MS BY AN INTERRUPT TRIGGERED BY THE
# RECEIPT OF AN ENDPULSE FROM THE SPACECRAFT TELEMETRY PROGRAMMER.
#
# NOTES REGARDING DOWNLINK LISTS ASSOCIATED WITH THIS PROGRAM:
# 1.   DOWNLISTS. DOWNLISTS MUST BE COMPILED IN THE SAME BANK AS THE
#       DOWN-TELEMETRY PROGRAM. THIS IS DONE FOR EASE OF CODING, FASTER
#       EXECUTION.
# 2.   EACH DOWNLINK LIST CONSISTS OF A CONTROL LIST AND A NUMBER OF
#       SUBLISTS.
# 3.   A SUBLIST REFERS TO A SNAPSHOT OR DATA COMMON TO THE SAME OR OTHER
#       DOWNLINK LISTS. ANY SUBLIST CONTAINING COMMON DATA NEEDS TO BE
#       CODED ONLY ONCE FOR THE APPLICABLE DOWNLINK LISTS.
# 4.   SNAPSHOT SUBLISTS REFER SPECIFICALLY TO HOMOGENEOUS DATA WHICH MUST BE
#       SAVED IN A BUFFER DURING ONE DOWNRUPT.
# 5.   THE 1DNADR FOR THE 1ST WORD OF SNAPSHOT DATA IS FOUND AT THE END
#       OF EACH SNAPSHOT SUBLIST, SINCE THE PROGRAM CODING SENDS THIS DP WORD
#       IMMEDIATELY AFTER STORING THE OTHERS IN THE SNAPSHOT BUFFER.
# 6.   ALL LISTS ARE COMBINATIONS OF CODED ERASABLE ADDRESS CONSTANTS
#       CREATED FOR THE DOWNLIST PROGRAM.
#       A.   1DNADR           1-WORD DOWNLIST ADDRESS.
#             SAME AS ECADR, BUT USED WHEN THE WORD ADDRESSED IS THE LEFT
#             HALF OF A DOUBLE-PRECISION WORD FOR DOWN TELEMETRY.
#       B.   2DNADR - 6DNADR   N-WORD DOWNLIST ADDRESS, N = 2 - 6.
#             SAME AS 1DNADR, BUT WITH THE 4 UNUSED BITS OF THE ECADR FORMAT
#             FILLED IN WITH 0001-0101. USED TO POINT TO A LIST OF N DOUBLE-
#             PRECISION WORDS, STORED CONSECUTIVELY, FOR DOWN TELEMETRY.
#       C.   DNCHAN           DOWNLIST CHANNEL ADDRESS.
#             SAME AS 1DNADR, BUT WITH PREFIX BITS 0111. USED TO POINT TO
#             A PAIR OF CHANNELS FOR DOWN TELEMETRY.
#       D.   DNPTR           DOWN-TELEMETRY SUBLIST POINTER.
#             SAME AS CAF BUT TAGGED AS A CONSTANT. USED IN CONTROL LIST TO POINT
#             CAUTION --- A DNPTR CANNOT BE USED IN A SUBLIST.
# 7.   THE WORD ORDER CODE IS SET TO ZERO AT THE BEGINNING OF EACH DOWNLIST (I.E.,
#       A '1DNADR TIME2' IS DETECTED IN THE CONTROL LIST (ONLY).
# 8.   IN THE SNAPSHOT SUBLIST ONLY, THE DNADR'S CANNOT POINT TO THE FIRST WORD OF A
#
# DOWNLIST LIST RESTRICTIONS:
# (THE FOLLOWING POINTS MAY BE LISTED ELSEWHERE BUT ARE LISTED HERE SO IT IS CLEAR TH
# DONE)
# 1.   SNAPSHOT DOWNLIST:
#       (A) CANNOT CONTAIN THE FOLLOWING ECADRS (I.E., 1DNADR'S): Q, 400, 1000, 1400.

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```
#      (B) CAN CONTAIN ONLY 1DNADR'S
# 2.    ALL DOWNLINKED DATA (EXCEPT CHANNELS) IS PICKED UP BY A DCA SO DOWNLINK LISTS CANNOT CO
#      EQUIVALENT OF THE FOLLOWING ECADRS (I.E., 1DNADRS): 377, 777, 1377, 1777, 2377, 2777, 3
#      (NOTE: THE TERM 'EQUIVALENT' MEANT THAT THE 1DNADR TO 6DNADR WILL BE PROCESSED LIKE 1 T
# 3.    CONTROL LISTS AND SUBLISTS CANNOT HAVE ENTRIES = OCTAL 00000 OR OCTAL 77777
# Page 991
# 4.    THE '1DNADR TIME2' WHICH WILL CAUSE THE DOWNLINK PROGRAM TO SET THE WORDER CODE TO 3 MU
#      CONTROL SECTION OF THE DOWNLIST.
# 5.    'DNCHAN 0' CANNOT BE USED.
# 6.    'DNPTR 0' CANNOT BE USED.
# 7.    DNPTR CANNOT APPEAR IN A SUBLIST.
#
# EBANK SETTINGS
#      IN THE PROCESS OF SETTING THE EBANK (WHEN PICKING UP DOWNLINK DATA) THE DOWN TELEMETRY
#      'GARBAGE' INTO BITS15-12 OF EBANK.  HUGH BLAIR-SMITH WARNS US THAT BITS15-12 OF EBANK M
#      SIGNIFICANT SOMEDAY IN THE FUTURE.  IF/WHEN THAT HAPPENS, THE PROGRAM SHOULD INSURE (BY
#      THAT BITS 15-12 OF EBANK ARE ZERO.
#
#      INITIALIZATION REQUIRED -- TO INTERRUPT CURRENT LIST AND START A NEW ONE.
#          1. ADRES OF DOWNLINK LIST INTO DNLSTADR
#          2. NEGONE INTO SUBLIST
#          3. NEGONE INTO DNECADR
#
#          BANK      22
#          SETLOC    DOWNTELM
#          BANK
#
#          EBANK=    DNTMBUFF
#
#          COUNT*   $$/DPROG
#          TS       BANKRUPT
#          DODOWNTM
#          EXTEND
#          QXCH     QRUPT          # SAVE Q
#          TCF      WOTEST
#          W01      EXTEND          # SET WORD ORDER BIT TO 1 ONLY IF IT
#          WOR      CHAN13         # ALREADY ISN'T
#          TC       DNTMGOTO       # GOTO APPROPRIATE PHASE OF PROGRAM
#
#          DNPBASE1  CA      NEGONE      # INITIALIZE ALL CONTROL WORDS
#                  TS      SUBLIST      # WORDS TO MINUS ONE
#                  TS      DNECADR
#                  CA      LDNPBASE2    # SET DNTMGOTO = 0 ALL SUSEQUENT DOWRUPTS
#                  TS      DNTMGOTO    # GO TO DNPBASE2
#                  TCF     NEWLIST
#          DNPBASE2  CCS      DNECADR    # SENDING OF DATA IN PROGRESS
#          DODNADR   TC       FETCH2WD   # YES -- THEN FETCH THE NEXT 2 SP WORDS
```

```

MINTIME2      -1DNADR TIME2      # NEGATIVE OF TIME2 1DNADR
TCF           +1                  # (ECADR OF 3776 + 74001 = 77777)

                                CCS   SUBLIST      # IS THE SUBLIST IN CONTROL
                                TCF   NEXTINSL     # YES

# Page 992
DNADRDCR      OCT   74001         # DNADR COUNT AND ECADR DECREMENTER

CHKLIST       CA      CTLIST
EXTEND
BZMF          NEWLIST             # IT WILL BE NEGATIVE AT END OF LIST
TCF           NEXTINCL
NEWLIST       INDEX  DNLSTCOD
CA            DNTABLE             # INITIALIZE CTLIST WITH
TS            CTLIST              # STARTING ADDRESS OF NEW LIST
CS            DNLSTCOD
TCF           SENDID  +3
NEXTINCL      INDEX  CTLIST
CA            0
CCS           A
INCR          CTLIST              # SET POINTER TO PICK UP NEXT CTLIST WORD
TCF           +4                  # ON NEXT ENTRY TO PROG. (A SHOULD NOT =0)
XCH           CTLIST              # SET CTLIST TO NEGATIVE AND PLACE(CODING)
COM           UNCOMPLEMENTED DNADR INTO A. (FOR LA)
XCH           CTLIST              # (ST IN )
+4            INCR   A             # (CTLIST)
TS            DNECADR             # SAVE DNADR
AD            MINTIME2            # TEST FOR TIME2 (NEG. OF ECADR)
CCS           A
TCF           SETWO   +1          # DON'T SET WORD ORDER CODE
MINB1314      OCT   47777         # MINUS BIT 13 AND 14 (CAN'T GET HERE)
TCF           SETWO   +1          # DON'T SET WORD ORDER CODE
SETWO         TC      WOZERO      # GO SET WORD ORDER CODE TO ZERO.
+1            CA      DNECADR     # RELOAD A WITH THE DNADR.
+2            AD      MINB1314    # IS THIS A REGULAR DNADR?
EXTEND
BZMF          FETCH2WD            # YES. (A MUST NEVER BE ZERO)
AD            MINB12              # NO. IS IT A POINTER (DNPTR) OR A
EXTEND        CHANNEL(DNCHAN)    # CHANNEL(DNCHAN)
BZMF          DODNPTR             # IT'S A POINTER. (A MUST NEVER BE ZERO)

DODNCHAN      TC      6           # (EXECUTED AS EXTEND) IT'S A CHANNEL
INDEX         DNECADR
INDEX         0      -4000        # (EXECUTED AS READ)
TS            L
TC            6                   # (EXECUTED AS EXTEND)

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```

INDEX  DNECADR
INDEX  0      -4001  # (EXECUTED AS READ)
TS      DNECADR      # SET DNECADR
CA      NEGONE      #      TO MINUS
XCH     DNECADR      #      WHILE PRESERVING A.
TCF     DNTMEXIT     # GO SEND CHANNELS

WOZERO  CS      BIT7
EXTEND
WAND    CHAN13      # SET WORD ORDER CODE TO ZERO

# Page 993
TC      Q          # RETURN TO CALLER

DODNPTR INDEX  DNECADR      # DNECADR CONTAINS ADRES OF SUBLIST
0      0          # CLEAR AND ADD LIST ENTRY INTO A.
CCS    A          # IS THIS A SNAPSHOT SUBLIST
CA      DNECADR    # NO, IT IS A REGULAR SUBLIST.
TCF     DOSUBLST   # A MUST NOT BE ZERO.

XCH     DNECADR    # YES. IT IS A SNAPSHOT SUBLIST.
TS      SUBLIST    # C(DNECADR) INTO SUBLIST
CAF     ZERO       #      A      INTO      A
XCH     TMINDEX    # (NOTE: TMINDEX = DNECADR)

# THE FOLLOWING CODING (FROM SNAPLOOP TO SNAPEND) IS FOR THE PURPOSE OF TAKING A SNAPSHOT OF 12
# THIS IS DONE BY SAVING 11 DP REGISTERS IN DNTMBUFF AND SENDING THE FIRST DP WORD IMMEDIATELY.
# THE SNAPSHOT PROCESSING IS THE MOST TIME CONSUMING AND THEREFORE THE CODING AND LIST STRUCTURE
# TO MINIMIZE TIME. THE TIME OPTIMIZATION RESULTS IN RULES UNIQUE TO THE SNAPSHOT PORTION OF THE
# THESE RULES ARE .....
#      1. ONLY 1DNADR'S CAN APPEAR IN THE SNAPSHOT SUBLIST
#      2. THE 1DNADR'S CANNOT REFER TO THE FIRST LOCATION IN ANY BANK.

SNAPLOOP TS      EBANK      # SET EBANK
MASK     LOW8      # ISOLATE RELATIVE ADDRESS
EXTEND
INDEX    A
EBANK=   1401
DCA      1401      # PICK UP 2 SNAPSHOT WORDS.
EBANK=   DNTMBUFF
INDEX    TMINDEX
DXCH     DNTMBUFF  # STORE 2 SNAPSHOT WORDS IN BUFFER
INCR     TMINDEX   # SET BUFFER INDEX FOR NEXT 2 WORDS.
INCR     TMINDEX
SNAPAGN  INCR     SUBLIST   # SET POINTER TO NEXT 2 WORDS OF SNAPSHOT
INDEX    SUBLIST
0      0          # = CA SSSS (SSSS = NEXT ENTRY IN SUBLIST)
```

```

LDNPHAS2      CCS      A                # TEST FOR LAST TWO WORDS OF SNAPSHOT.
              TCF      SNAPLOOP          # NOT LAST TWO.
              GENADR   DNPHASE2
              TS       SUBLIST            # YES, LAST.  SAVE A.
              CA       NEGONE             # SET DNECADR AND
              TS       DNECADR            # SUBLIST POINTERS
              XCH      SUBLIST            # TO NEGATIVE VALUES
              TS       EBANK
              MASK     LOW8
              EXTEND
              INDEX    A
              EBANK=   1401
              DCA      1401              # PICK UP FIRST 2 WORDS OF SNAPSHOT.

# Page 994
              EBANK=   DNTMBUFF
SNAPEND        TCF      DNTMEXIT          # NOW TO SEND THEM.

FETCH2WD       CA       DNECADR
              TS       EBANK              # SET EBANK
              MASK     LOW8              # ISOLATE RELATIVE ADDRESS
              TS       L                  # DECREMENT COUNT AND ECADR
              CA       DNADRDRCR
              ADS      DNECADR
              EXTEND
              INDEX    L
              EBANK=   1400
              DCA      1400              # PICK UP 2 DATA WORDS
              EBANK=   DNTMBUFF
              TCF      DNTMEXIT          # NOW GO SEND THEM.

DOSUBLST       TS       SUBLIST            # SET SUBLIST POINTER
NEXTINSL       INDEX    SUBLIST
              0         0                # = CA SSSS (SSSS = NEXT ENTRY IN SUBLIST)
              CCS      A                  # IS IT THE END OF THE SUBLIST
              INCR     SUBLIST            # NO --
              TCF      +4
              TS       SUBLIST            # SAVE A.
              CA       NEGONE             # SET SUBLIST TO MINUS
              XCH      SUBLIST            # RETRIEVE A.
              +4       INCR      A
              TS       DNECADR            # SAVE DNADR
              TCF      SETWO +2           # GO USE COMMON CODING (PROLEMS WOULD
                                          # OCCUR IF THE PROGRAM ENCOUNTERED A
                                          # DNPTR NOW)

DNTMEXIT       EXTEND                    # DOWN-TELEMETRY EXIT

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                WRITE  DNTM1          # TO SEND A + L TO CHANNELS 34 + 35
                CA      L              # RESPECTIVELY
TMEXITL          EXTEND
                WRITE  DNTM2
TMRESUME         TCF    RESUME        # EXIT TELEMTRY PROGRAM VIA RESUME.

MINB12           EQUALS  -1/8
DNECADR          EQUALS  TMINDEX
CTLIST           EQUALS  LDATALST
SUBLIST          EQUALS  DNQ
```

# Page 995

# SUBROUTINE NAME -- DNDUMP

#

# FUNCTIONAL DESCRIPTION -- TO SEND (DUMP) ALL ERASABLE STORAGE 'N' TIMES. (N=1 TO 4). BANKS A  
# EACH BANK IS PRECEDED BY AN ID WORD, SYNCH BITS, ECADR AND TIME1 FOLLOWED BY THE 256D W  
# EBANK. EBANKS ARE DUMPED IN ORDER (I.E., EBANK 0 FIRST, THEN EBANK1 ETC.)

#

# CALLING SEQUENCE -- THE GROUND OR ASTRONAUT BY KEYING V74E CAN INITIALIZE THE DUMP.

# AFTER KEYING IN V74E THE CURRENT DOWNLIST WILL BE IMMEDIATELY TERMINATED AND THE DOWNLI  
# WILL BEGIN.

#

# ONCE INITITIATED THE DOWNLINK ERASABLE DUMP CAN BE TERMINATED (AND INTERRUPTED DOWNLIST  
# BY THE FOLLOWING:

#

# 1. A FRESH START

# 2. COMPLETION OF ALL DOWNLINK DUMPS REQUESTED (ACCORDING TO BITS SET IN DUMPCNT).  
# CAN BE ALTERED BY A V21N01.

# 3. AND INVOLUNTARILY BY A RESTART.

#

# NORMAL EXIT MODE -- TCF DNPHEASE1

#

# ALARM OR ABORT MODE -- NONE

#

# \*SUBROUTINES CALLED -- NONE

#

# ERASABLE INITIALIZATION REQUIRED --

# DUMPCNT OCT 20000 IF 4 COMPLETE ERASABLE DUMPS ARE DESIRED

# DUMPCNT OCT 10000 IF 2 COMPLETE ERASABLE DUMPS ARE DESIRED

# DUMPCNT OCT 04000 IF 1 COMPLETE ERASABLE DUMP IS DESIRED

#

# DEBRIS -- DUMPLOC, DUMPSW, DNTMGOTO, EBANK, AND CENTRAL REGISTERS

#

# TIMING -- TIME (IN SECS) = ((NO.DUMPS)\*(NO.EBANKS)\*(WDSPEREBANK + NO.IDWDS)) / NO.WDSPERS

# TIME (IN SECS) = ( 4 )\*( 8 )\*( 256 + 4 ) / 100

# THUS TIME (IN SECS TO SEND DUMP OF ERASABLE 4 TIMES VIA DOWNLINK) = 83.2 SECONDS

```

#
# STRUCTURE OF ONE EBANK AS IT IS SENT BY DOWNLINK PROGRAM --
# (REMINDER -- THIS ONLY DESCRIBES ONE OF THE 8 EBANKS X 4 (DUMPS) = 32 EBANKS
#
# DOWNLIST
# WORD TAKEN FROM CONTENTS OF EXAMPLE 0 COMMENTS
# 1 ERASID 0177X 0 DOWNLIST I.D. FOR DOWNLINK EBANK
# 2 LOWIDCOD 77340 1 DOWNLINK SYNCH BITS. (SAME 0
# 3 DUMPLOC 13400 1 (SEE NOTES ON DUMPLOC) 1 = 32
# 4 TIME1 14120 1 TIME IN CENTISECONDS
# 5 FIRST WORD OF EBANK X 03400 1 IN THIS EXAMPLE THIS WORD = 0
# 6 2ND WORD OF EBANK X 00142 1 IN THIS EXAMPLE THIS WORD = 0
# 7 3RD WORD OF EBANK X 00142 1 IN THIS EXAMPLE THIS WORD = 0
# .
# .
# .
# 260D 256TH WORD OF EBANK X 03777 1 IN THIS EXAMPLE THIS WORD = 0
#
# NOTE -- DUMPLOC CONTAINS THE COUNTER AND ECADR FOR EACH WORD BEING SENT.
# THE BIT STRUCTURE OF DUMPLOC IS FOLLOW --
# X = NOT USED
# X ABC EEE RRRRRRRR ABC = ERASABLE DUMP COUNTER (I.E. ABC = 0,1,2,3,4,5,6,7)
# COMPLETE ERASABLE DUMP NUMBER 1,2,3,4,5,6,7
# EEE = EBANK BITS
# RRRRRRRR = RELATIVE ADDRESS WITHIN AN EBANK
#
# Page 996
DNDUMPI CA ZERO # INITIALIZE DOWNLINK
TS DUMPLOC # ERASABLE DUMP
+2 TC SENDID # GO SEND ID AND SYNCH BITS
CA LDNDUMP1 # SET DNTMGOTO
TS DNTMGOTO # TO LOCATION FOR NEXT PASS
CA TIME1 # PLACE TIME1
XCH L # INTO L
CA DUMPLOC # AND ECADR OF THIS EBANK INTO A
TCF DNTMEXIT # SEND DUMPLOC AND TIME1

LDNDUMP ADRES DNDUMP
LDNDUMP1 ADRES DNDUMP1

DNDUMP CA TWO # INCREMENT ECADR IN DUMPLOC
ADS DUMPLOC # TO NEXT DP WORD TO BE
MASK LOW8 # DUMPED AND SAVE IT.
CCS A # IS THIS THE BEGINNING OF A NEW EBANK
TCF DNDUMP2 # NO -- THEN CONTINUE DUMPING
CA DUMPLOC # YES -- IS THIS THE END OF THE

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                                MASK    DUMPCNT    # N TH (N = 1 TO 4) COMPLETE ERASABLE
                                MASK    PRI034      # DUMP (BIT14 FOR 4, BIT13 FOR 2 OR BIT12
                                CCS      A          # FOR 1 COMPLETE ERASABLE DUMP(S)).
                                TCF      DNPHASE1    # YES -- START SENDING INTERRUPTED DOWNLIST
                                                # AGAIN
                                TCF      DNDUMPI +2  # NO -- GO BACK AND INITIALIZE NEXT BANK

DNDUMP1      CA      LDNDUMP    # SET DNTMGOTO
              TS      DNTMGOTO  # FOR WORDS 3 TO 256D OF CURRENT EBANK

DNDUMP2      CA      DUMPLOC
              TS      EBANK      # SET EBANK
              MASK    LOW8      # ISOLATE RELATIVE ADDRESS.
              TS      Q          # (NOTE: MASK INSTRUCTION IS USED TO PICK
              CA      NEG0      # UP ERASABLE REGISTERS SO THAT EDITING
              TS      L          # REGISTERS 20-23 WILL NOT BE ALTERED.)
              INDEX   Q
              EBANK=  1400      # PICK UP LOW ORDER REGISTER OF PAIR
              MASK    1401      # OF ERASABLE REGISTERS.
              XCH     L
              INDEX   Q          # PICK UP HIGH ORDER REGISTER OF PAIR
              MASK    1400      # OF ERASABLE REGISTERS.
              EBANK=  DNTMBUFF
              TCF      DNTMEXIT  # GO SEND THEM

SENDID       EXTEND
              QXCH    DNTMGOTO  # ** ENTRANCE USED BY ERASABLE DUMP PROG. **
              CAF     ERASID    # SET DNTMGOTO SO NEXT TIME PROG WILL GO
                                # TO LOCATION FOLLOWING 'TC SENDID'

                                TS      L          # ** ENTRANCE USED BY REGULAR DOWNLINK PG **

# Page 997   TC      WOZERO    # GO SET WORD ORDER CODE TO ZERO
              CAF     LOWIDCOD  # PLACE SPECIAL ID CODE INTO L
              XCH     L          # AND ID BACK INTO A
              TCF     DNTMEXIT  # SEND DOWNLIST ID CODE(S).

WOTEST       CA      BIT7      # AT THE BEGINNING OF THE LIST THE WORD
              EXTEND
              RAND    CHAN13
              CCS     A
              TC      DNTMGOTO
              CA      BIT7
              TCF     W01
```

This code is written to file src/DOWN--TELEMETRY-PROGRAM.s.

## A.24 DOWN-TELEMETRY PROGRAM

```

366  <src/DOWN-TELEMETRY-PROGRAM.s 366>≡
# Copyright:      Public domain.
# Filename:       DOWN-TELEMETRY_PROGRAM.agc
# Purpose:       Part of the source code for Comanche, build 055. It
#               is part of the source code for the Command Module's
#               (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:    yaYUL
# Reference:     pp. 1093-1102
# Contact:       Ron Burkey <info@sandroid.org>
# Website:       http://www.ibiblio.org/apollo.
# Mod history:   2009-05-08 RSB   Adapted from Colossus249/ file of same name
#               and page images. Corrected various typos
#               in the transcription of program comments,
#               and these should be back-ported to
#               Colossus249.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#
#               Massachussets Institute of Technology
#               75 Cambridge Parkway
#               Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.
#
# Page 1093
# PROGRAM NAME -- DOWN TELEMETRY PROGRAM
# MOD NO. -- 0          TO COMPLETELY REWRITE THE DOWN TELEMETRY PROGRAM AND DOWNLINE
#                       PURPOSE OF SAVING APPROXIMATELY 150 WORDS OF CORE STORAGE.
#                       THIS CHANGE REQUIRES AN ENTIRELY NEW METHOD OF SPECIFYING DOWN
#                       LISTS LOG SECTION FOR MORE DETAILS. HOWEVER THIS CHANGES WITH
#                       OF DOWN TELEMETRY DATA.
# MOD BY -- KILROY, SMITH, DEWITT
# DATE -- 02 OCT 67
# AUTHORS -- KILROY, SMITH, DWITT, DEWOLF, FAGIN

```

```
# LOG SECTION -- DOWN-TELEMETRY PROGRAM
#
# FUNCTIONAL DESCRIPTION -- THIS ROUTINE IS INITIATED BY TELEMETRY END
# PULSE FROM THE DOWNLINK TELEMETRY CONVERTER. THIS PULSE OCCURS
# AT 50 TIMES PER SEC (EVERY 20 MS) THEREFORE DODOWNTM IS
# EXECUTED AT THESE RATES. THIS ROUTINE SELECTS THE APPROPRIATE
# AGC DATA TO BE TRANSMITTED DOWNLINK AND LOADS IT INTO OUTPUT
# CHANNELS 34 AND 35. THE INFORMATION IS THEN GATED OUT FROM THE
# LGC IN SERIAL FASHION.
#
# THIS PROGRAM IS CODED FOR A 2 SECOND DOWNLIST. SINCE DOWNRUPTS
# OCCUR EVERY 20 MS AND 2 AGC COMPUTER WORDS CAN BE PLACED IN
# CHANNELS 34 AND 35 DURING EACH DOWNRUPT THE PROGRAM IS CAPABLE
# OF SENDING 200 AGC WORDS EVERY 2 SECONDS.
#
# CALLING SEQUENCE -- NONE
# PROGRAM IS ENTERED VIA TCF DODOWNTM WHICH IS EXECUTED AS A
# RESULT OF A DOWNRUPT. CONTROL IS RETURNED VIA TCF RESUME WHICH
# IN EFFECT IS A RESUME.
#
# SUBROUTINES CALLED -- NONE
#
# NORMAL EXIT MODE -- TCF RESUME
#
# ALARM OR ABORT EXIT MODE -- NONE
#
# RESTART PROTECTION:
# ON A FRESH START AND RESTART THE 'STARTSUB' SUBROUTINE WILL INITIALIZE THE DOWNLIST POINT
# DNTMGOTO) TO THE BEGINNING OF THE CURRENT DOWNLIST (I.E., CURRENT CONTENTS OF DNLSTADR)
# EFFECT OF IGNORING THE REMAINDER OF THE DOWNLIST WHICH THE DOWN-TELEMETRY PROGRAM WAS W
# THE RESTART (OR FRESH START) OCCURRED AND RESUME DOWN TELEMETRY FROM THE BEGINNING OF T
# DOWNLIST.
#
# ALSO OF INTEREST IS THE FACT THAT ON A RESTART THE AGC WILL ZERO DOWNLINK CHANNELS 13,
#
# DOWNLINK LIST SELECTION:
# THE APPROPRIATE DOWNLINK LISTS ARE SELECTED BY THE FOLLOWING:
# 1. FRESH START
# 2. V37EXXE WHERE XX = THE MAJOR MODE BEING SELECTED.
# 3. UPDATE PROGRAM (P27)
# 4. NON-V37 SELECTABLE TYPE PROGRAMS (E.G., AGS INITIALIZATION (SUNDANCE, LUMINARY)
# TRANSITIONS (COLOSSUS) ETC.).
#
# DOWNLINK LIST RULES AND LIMITATIONS:
# READ SECTION(S) WHICH FOLLOW 'DEBRIS' WRITEUP.
#
```

```

# OUTPUT -- EVERY 2 SECONDS 100 DOUBLE PRECISION WORDS (I.E., 200 LGC
#     COMPUTER WORDS) ARE TRANSMITTED VIA DOWNLINK.
#
# ERASABLE INITIALIZATION REQUIRED -- NONE
#     'DNTMGOTO' AND 'DNLSTADR' ARE INITIALIZED BY THE FRESH START PROGRAM.
#
# DEBRIS (ERASABLE LOCATIONS DESTROYED BY THIS PROGRAM) --
#     LDATA1ST, DNTMBUFF TO DNTMBUFF +21D, TMINDEX, DNQ.
# Page 1094
# (No source on this page of the original assembly listing.)

# Page 1095
# DODOWNTM IS ENTERED EVERY 20 MS BY AN INTERRUPT TRIGGERED BY THE
# RECEIPT OF AN ENDPULSE FROM THE SPACECRAFT TELEMETRY PROGRAMMER.
#
# NOTES REGARDING DOWNLINK LISTS ASSOCIATED WITH THIS PROGRAM:
# 1.  DOWNLISTS.  DOWNLISTS MUST BE COMPILED IN THE SAME BANK AS THE
#     DOWN-TELEMETRY PROGRAM.  THIS IS DONE FOR EASE OF CODING, FASTER
#     EXECUTION.
# 2.  EACH DOWNLINK LIST CONSISTES OF A CONTROL LIST AND A NUMBER OF
#     SUBLISTS.
# 3.  A SUBLIST REFERS TO A SNAPSHOT OR DATA COMMON TO THE SAME OR OTHER
#     DOWNLINK LISTS.  ANY SUBLIST CONTAINING COMMON DATA NEEDS TO BE
#     CODED ONLY ONCE FOR THE APPLICABLE DOWNLINK LISTS.
# 4.  SNAPSHOT SUBLISTS REFER SPECIFICALLY TO HOMOGENEOUS DATA WHICH MUST BE
#     SAVED IN A BUFFER DURING ONE DOWNRUPT.
# 5.  THE 1DNADR FOR THE 1ST WORD OF SNAPSHOT DATA IS FOUND AT THE END
#     OF EACH SNAPSHOT SUBLIST, SINCE THE PROGRAM CODING SENDS THIS DP WORD
#     IMMEDIATELY AFTER STORING THE OTHERS IN THE SNAPSHOT BUFFER.
# 6.  ALL LISTS ARE COMBINATIONS OF CODED ERASABLE ADDRESS CONSTANTS
#     CREATED FOR THE DOWNLIST PROGRAM.
#     A.      1DNADR              1-WORD DOWNLIST ADDRESS.
#             SAME AS ECADR, BUT USED WHEN THE WORD ADDRESSED IS THE LEFT
#             HALF OF A DOUBLE-PRECISION WORD FOR DOWN TELEMETRY.
#     B.      2DNADR - 6DNADR      N-WORD DOWNLIST ADDRESS, N = 2 - 6.
#             SAME AS 1DNADR, BUT WITH THE 4 UNUSED BITS OF THE ECADR FORMAT
#             FILLED IN WITH 0001-0101.  USED TO POINT TO A LIST OF N DOUBLE-
#             PRECISION WORDS, STORED CONSECUTIVELY, FOR DOWN TELEMETRY.
#     C.      DNCHAN              DOWNLIST CHANNEL ADDRESS.
#             SAME AS 1DNADR, BUT WITH PREFIX BITS 0111.  USED TO POINT TO
#             A PAIR OF CHANNELS FOR DOWN TELEMETRY.
#     D.      DNPTR              DOWN-TELEMETRY SUBLIST POINTER.
#             SAME AS CAF BUT TAGGES AS A CONSTANT.  USED IN CONTROL LIST TO POINT
#             CAUTION --- A DNPTR CANNOT BE USED IN A SUBLIST.
# 7.  THE WORD ORDER CODE IS SET TO ZERO AT THE BEGINNING OF EACH DOWNLIST (I.E., C
#     A '1DNADR TIME2' IS DETECTED IN THE CONTROL LIST (ONLY).

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# 8.    IN THE SNAPSHOT SUBLIST ONLY, THE DNADR'S CANNOT POINT TO THE FIRST WORD OF ANY EBANK.
#
# DOWNLIST LIST RESTRICTIONS:
# (THE FOLLOWING POINTS MAY BE LISTED ELSEWHERE BUT ARE LISTED HERE SO IT IS CLEAR THAT THESE T
# DONE)
# 1.    SNAPSHOT DOWNLIST:
#        (A) CANNOT CONTAIN THE FOLLOWING ECADRS (I.E., 1DNADR'S): Q, 400, 1000, 1400, 2000, 240
#        (B) CAN CONTAIN ONLY 1DNADR'S
# 2.    ALL DOWNLINKED DATA (EXCEPT CHANNELS) IS PICKED UP BY A DCA SO DOWNLINK LISTS CANNOT CO
#        EQUIVALENT OF THE FOLLOWING ECADRS (I.E., IDNADRS): 377, 777, 1377, 1777, 2377, 2777, 3
#        (NOTE: TE TERM 'EQUIVALENT' MEANT THAT THE IDNADR TO 6DNADR WILL BE PROCESSED LIKE 1 TO
# 3.    CONTROL LISTS AND SUBLISTS CANNOT HAVE ENTRIES = OCTAL 00000 OR OCTAL 77777
# Page 1096
# 4.    THE '1DNADR TIME2' WHICH WILL CAUSE THE DOWNLINT PROGRAM TO SET THE WORDER CODE TO 3 MU
#        CONTROL SECTION OF THE DOWNLIST.
# 5.    'DNCHAN 0' CANNOT BE USED.
# 6.    'DNPTR 0' CANNOT BE USED.
# 7.    DNPTR CANNOT APPEAR IN A SUBLIST.
#
# EBANK SETTINGS
# IN THE PROCESS OF SETTING THE EBANK (WHEN PICKING UP DOWNLINK DATA) THE DOWN TELEMETRY
# 'GARBAGE' INTO BITS15-12 OF EBANK.  HUGH BLAIR-SMITH WARNS US THAT BITS15-12 OF EBANK M
# SIGNIFICANT SOMEDAY IN THE FUTURE.  IF/WHEN THAT HAPPENS, THE PROGRAM SHOULD INSURE (BY
# THAT BITS 15-12 OF EBANK ARE ZERO.
#
# INITIALIZATION REQUIRED -- TO INTERRUPT CURRENT LIST AND START A NEW ONE.
#     1. ADRES OF DOWNLINK LIST INTO DNLSTADR
#     2. NEGONE INTO SUBLIST
#     3. NEGONE INTO DNECADR
#
# BANK      22
# SETLOC    DOWNTELM
# BANK
#
# EBANK=    DNTMBUFF
#
# COUNT     05/DPROG
#
# DODOWNTM  TS      BANKRUPT
#           EXTEND
#           QXCH     QRUPT      # SAVE Q
#           CA       BIT7      # SET WORD ORDER CODE TO 1.  EXCEPTION: AT
#           EXTEND    # THE BEGINNING OF EACH LIST THE WORD
#           WOR      CHAN13     # CODE WILL BE SET BACK TO 0.
#           TC       DNTMGOTO   # GOTO APPROPRIATE PHASE OF PROGRAM
```

DNPHASE1	CA	NEGONE	# INITIALIZE ALL CONTROL WORDS
	TS	SUBLIST	# WORDS TO MINUS ONE
	TS	DNECADR	
	CA	LDNPHAS2	# SET DNTMGOTO = 0 ALL SUSEQUENT DOWRUPTS
	TS	DNTMGOTO	# GO TO DNPBASE2
	TCF	NEWLIST	
DNPHASE2	CCS	DNECADR	# SENDING OF DATA IN PROGRESS
DODNADR	TC	FETCH2WD	# YES -- THEN FETCH THE NEXT 2 SP WORDS
MINTIME2	-1DNADR	TIME2	# NEGATIVE OF TIME2 1DNADR
	TCF	+1	# (ECADR OF 3776 + 74001 = 77777)
	CCS	SUBLIST	# IS THE SUBLIST IN CONTROL
# Page 1097	TCF	NEXTINSL	# YES
DNADRDCR	OCT	74001	# DNADR COUNT AND ECADR DECREMENTER
CHKLIST	CA	CTLIST	
	EXTEND		
	BZMF	NEWLIST	# IT WILL BE NEGATIVE AT END OF LIST
	TCF	NEXTINCL	
NEWLIST	INDEX	DNLSTCOD	
	CA	DNTABLE	# INITIALIZE CTLIST WITH
	TS	CTLIST	# STARTING ADDRESS OF NEW LIST
	CS	DNLSTCOD	
	TCF	SENDID +3	
NEXTINCL	INDEX	CTLIST	
	CA	0	
	CCS	A	
	INCR	CTLIST	# SET POINTER TO PICK UP NEXT CTLIST WORD
	TCF	+4	# ON NEXT ENTRY TO PROG. (A SHOULD NOT =0)
	XCH	CTLIST	# SET CTLIST TO NEGATIVE AND PLACE(CODING)
	COM		# UNCOMPLEMENTED DNADR INTO A. (FOR LA)
	XCH	CTLIST	# (ST IN )
+4	INCR	A	# (CTLIST)
	TS	DNECADR	# SAVE DNADR
	AD	MINTIME2	# TEST FOR TIME2 (NEG. OF ECADR)
	CCS	A	
	TCF	SETWO +1	# DON'T SET WORD ORDER CODE
MINB1314	OCT	47777	# MINUS BIT 13 AND 14 (CAN'T GET HERE)
	TCF	SETWO +1	# DON'T SET WORD ORDER CODE
SETWO	TC	WOZERO	# GO SET WORD ORDER CODE TO ZERO.
+1	CA	DNECADR	# RELOAD A WITH THE DNADR.
+2	AD	MINB1314	# IS THIS A REGULAR DNADR?
	EXTEND		
	BZMF	FETCH2WD	# YES. (A MUST NEVER BE ZERO)
	AD	MINB12	# NO. IS IT A POINTER (DNPTR) OR A

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                                #      CHANNEL(DNCHAN)
                                # IT'S A POINTER.  (A MUST NEVER BE ZERO)
                                # (EXECUTED AS EXTEND)  IT'S A CHANNEL
                                # (EXECUTED AS READ)
                                # (EXECUTED AS EXTEND)
                                # (EXECUTED AS READ)
                                # SET DNECADR
                                #      TO MINUS
                                #      WHILE PRESERVING A.
                                # GO SEND CHANNELS

                                CS      BIT7
                                EXTEND

# Page 1098
                                WAND    CHAN13      # SET WORD ORDER CODE TO ZERO
                                TC      Q           # RETURN TO CALLER

DODNPTR      INDEX    DNECADR      # DNECADR CONTAINS ADRES OF SUBLIST
              0        0           # CLEAR AND ADD LIST ENTRY INTO A.
              CCS      A           # IS THIS A SNAPSHOT SUBLIST
              CA       DNECADR      # NO, IT IS A REGULAR SUBLIST.
              TCF      DOSUBLST     # A MUST NOT BE ZERO.

              XCH      DNECADR      # YES.  IT IS A SNAPSHOT SUBLIST.
              TS       SUBLIST      # C(DNECADR) INTO SUBLIST
              CAF      ZERO         #      A      INTO      A
              XCH      TMINDEX      # (NOTE:  TMINDEX = DNECADR)

# THE FOLLOWING CODING (FROM SNAPLOOP TO SNAPEND) IS FOR THE PURPOSE OF TAKING A SNAPSHOT OF 12
# THIS IS DONE BY SAVING 11 DP REGISTERS IN DNTMBUFF AND SENDING THE FIRST DP WORD IMMEDIATELY.
# THE SNAPSHOT PROCESSING IS THE MOST TIME CONSUMING AND THEREFORE THE CODING AND LIST STRUCTURE
# TO MINIMIZE TIME.  THE TIME OPTIMIZATION RESULTS IN RULES UNIQUE TO THE SNAPSHOT PORTION OF T
# THESE RULES ARE .....
#      1.      ONLY 1DNADR'S CAN APPEAR IN THE SNAPSHOT SUBLIST
#      2.      THE 1DNADR'S CANNOT REFER TO THE FIRST LOCATION IN ANY BANK.

SNAPLOOP     TS       EBANK        # SET EBANK
              MASK     LOW8        # ISOLATE RELATIVE ADDRESS
              EXTEND
              INDEX    A
              EBANK=   1401
              DCA      1401        # PICK UP 2 SNAPSHOT WORDS.
```

	EBANK=	DNTMBUFF	
	INDEX	TMINDEX	
	DXCH	DNTMBUFF	# STORE 2 SNAPSHOT WORDS IN BUFFER
	INCR	TMINDEX	# SET BUFFER INDEX FOR NEXT 2 WORDS.
	INCR	TMINDEX	
SNAPAGN	INCR	SUBLIST	# SET POINTER TO NEXT 2 WORDS OF SNAPSHOT
	INDEX	SUBLIST	
	0	0	# = CA SSSS (SSSS = NEXT ENTRY IN SUBLIST)
	CCS	A	# TEST FOR LAST TWO WORDS OF SNAPSHOT.
	TCF	SNAPLOOP	# NOT LAST TWO.
LDNPHAS2	GENADR	DNPHASE2	
	TS	SUBLIST	# YES, LAST. SAVE A.
	CA	NEGONE	# SET DNECADR AND
	TS	DNECADR	# SUBLIST POINTERS
	XCH	SUBLIST	# TO NEGATIVE VALUES
	TS	EBANK	
	MASK	LOW8	
	EXTEND		
	INDEX	A	
	EBANK=	1401	
# Page 1099			
	DCA	1401	# PICK UP FIRST 2 WORDS OF SNAPSHOT.
	EBANK=	DNTMBUFF	
SNAPEND	TCF	DNTMEXIT	# NOW GO SEND THEM.
FETCH2WD	CA	DNECADR	
	TS	EBANK	# SET EBANK
	MASK	LOW8	# ISOLATE RELATIVE ADDRESS
	TS	L	
	CA	DNADRDRCR	# DECREMENT COUNT AND ECADR
	ADS	DNECADR	
	EXTEND		
	INDEX	L	
	EBANK=	1400	
	DCA	1400	# PICK UP 2 DATA WORDS
	EBANK=	DNTMBUFF	
	TCF	DNTMEXIT	# NOW GO SEND THEM.
DOSUBLST	TS	SUBLIST	# SET SUBLIST POINTER
NEXTINSL	INDEX	SUBLIST	
	0	0	# = CA SSSS (SSSS = NEXT ENTRY IN SUBLIST)
	CCS	A	# IS IT THE END OF THE SUBLIST
	INCR	SUBLIST	# NO --
	TCF	+4	
	TS	SUBLIST	# SAVE A.
	CA	NEGONE	# SET SUBLIST TO MINUS

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```

+4      XCH      SUBLIST      # RETRIEVE A.
        INCR     A
        TS       DNECADR      # SAVE DNADR
        TCF      SETWO +2     # GO USE COMMON CODING (PROBLEMS WOULD
                                # OCCUR IF THE PROGRAM ENCOUNTERED A
                                # DNPTR NOW)

DNTMEXIT      EXTEND          # DOWN-TELEMETRY EXIT
              WRITE  DNTM1     # TO SEND A + L TO CHANNELS 34 + 35
              CA      L        # RESPECTIVELY
TMEXITL      EXTEND
              WRITE  DNTM2
TMRESUME      TCF      RESUME  # EXIT TELEMTRY PROGRAM VIA RESUME.

MINB12        EQUALS  -1/8
DNECADR        EQUALS  TMINDEX
CTLIST         EQUALS  LDATA1ST
SUBLIST        EQUALS  DNQ
```

# Page 1100

# SUBROUTINE NAME -- DNDUMP

#

# FUNCTIONAL DESCRIPTION -- TO SEND (DUMP) ALL 8 BANKS OF ERASABLE STORAGE TWICE. BANKS ARE SE  
# EACH BANK IS PRECEDED BY AN ID WORD, SYNCH BITS, ECADR AND TIME1 FOLLOWED BY THE 256D W  
# EBANK. EBANKS ARE DUMPED IN ORDER (I.E., EBANK 0 FIRST, THEN EBANK1 ETC.)

#

# CALLING SEQUENCE -- THE GROUND OR ASTRONAUT BY KEYING V74E CAN INITIALIZE THE DUMP.

# AFTER KEYING IN V74E THE CURRENT DOWNLIST WILL BE IMMEDIATELY TERMINATED AND THE DOWNLI  
# WILL BEGIN.

#

# ONCE INITITIATED THE DOWNLINK ERASABLE DUMP CAN BE TERMINATED (AND INTERRUPTED DOWNLIST  
# BY THE FOLLOWING:

#

# 1. A FRESH START

# 2. COMPLETION OF ALL DOWNLINK DUMPS REQUESTED (ACCORDING TO BITS SET IN DUMPCNT).  
# CAN BE ALTERED BY A V21N01.

# 3. AND INVOLUNTARILY BY A RESTART.

#

# NORMAL EXIT MODE -- TCF DNPHASE1

#

# ALARM OR ABORT MODE -- NONE

#

# \*SUBROUTINES CALLED -- NONE

#

# ERASABLE INITIALIZATION REQUIRED --

# DUMPCNT OCT 20000 IF 4 COMPLETE ERASABLE DUMPS ARE DESIRED

```

#          DUMPCNT OCT 10000          IF 2 COMPLETE ERASABLE DUMPS ARE DESIRED
#          DUMPCNT OCT 04000          IF 1 COMPLETE ERASABLE DUMP IS DESIRED
#
# DEBRIS -- DUMPLOC, DUMPSW, DNTMGOTO, EBANK, AND CENTRAL REGISTERS
#
# TIMING --      TIME (IN SECS) = ((NO.DUMPS)*(NO.EBANKS)*(WDSPEREBANK + NO.IDWDS)) /
#                  TIME (IN SECS) = (  4  )*(  8  )*( 256  +  4  ) /
#                  THUS TIME (IN SECS TO SEND DUMP OF ERASABLE 4 TIMES VIA DOWNLINK) = 83.2 S
#
# STRUCTURE OF ONE EBANK AS IT IS SENT BY DOWNLINK PROGRAM --
# (REMINDER -- THIS ONLY DESCRIBES ONE OF THE 8 EBANKS X 4 (DUMPS) = 32 EBANKS
#
# DOWNLIST
#          WORD TAKEN FROM CONTENTS OF EXAMPLE 0      COMMENTS
#          1 ERASID                                0177X 0 DOWNLIST I.D. FOR DOWNLINK ERASID
#          2 LOWIDCOD                                77340 1 DOWNLINK SYNCH BITS. (SAME 0
#          3 DUMPLOC                                13400 1 (SEE NOTES ON DUMPLOC) 1 = 3B
#          4 TIME1                                  14120 1 TIME IN CENTISECONDS
#          5 FIRST WORD OF EBANK X                   03400 1 IN THIS EXAMPLE THIS WORD = 0
#          6 2ND WORD OF EBANK X                     00142 1 IN THIS EXAMPLE THIS WORD = 0
#          7 3RD WORD OF EBANK X                     00142 1 IN THIS EXAMPLE THIS WORD = 0
#          .
#          .
#          .
#          260D 256TH WORD OF EBANK X                03777 1 IN THIS EXAMPLE THIS WORD = 0
#
# NOTE --      DUMPLOC CONTAINS THE COUNTER AND ECADR FOR EACH WORD BEING SENT.
#              THE BIT STRUCTURE OF DUMPLOC IS FOLLOW --
#
#              X = NOT USED
#              X ABC EEE RRRRRRRR                    ABC = ERASABLE DUMP COUNTER (I.E. ABC =
#              COMPLETE ERASABLE DUMP NUMBER 1,2
#              EEE = EBANK BITS
#              RRRRRRRR = RELATIVE ADDRESS WITHIN AN EBANK
#
# Page 1101
DNDUMPI      CA      ZERO          # INITIALIZE DOWNLINK
              TS      DUMPLOC       # ERASABLE DUMP
              +2      TC      SENDID  # GO SEND ID AND SYNCH BITS
              CA      LDNDUMP1      # SET DNTMGOTO
              TS      DNTMGOTO      # TO LOCATION FOR NEXT PASS
              CA      TIME1         # PLACE TIME1
              XCH      L            # INTO L
              CA      DUMPLOC       # AND ECADR OF THIS EBANK INTO A
              TCF      DNTMEXIT     # SEND DUMPLOC AND TIME1

LDNDUMP      ADRES  DNDUMP

```

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```
LDNDUMP1      ADRES  DNDUMP1

DNDUMP        CA      TWO          # INCREMENT ECADR IN DUMPLOC
              ADS      DUMPLOC      # TO NEXT DP WORD TO BE
              MASK     LOW8         # DUMPED AND SAVE IT.
              CCS      A           # IS THIS THE BEGINNING OF A NEW EBANK
              TCF      DNDUMP2      # NO -- THEN CONTINUE DUMPING
              CA      DUMPLOC      # YES -- IS THIS THE END OF THE
              MASK     DUMPCNT      # N-TH(N = 1 TO 4) COMPLETE ERASABLE
              MASK     PRI034       # DUMP(BIT14 FOR 4, BIT13 FOR 2 OR BIT12
              CCS      A           # FOR 1 COMPLETE ERASABLE DUMP(S)).
              TCF      DNPHASE1     # YES -- SEND DOWNLIST AGAIN
              # AGAIN
              TCF      DNDUMPI +2   # NO -- GO BACK AND INITIALZE NEXT BANK

DNDUMP1        CA      LDNDUMP      # SET DNTMGOTO
              TS      DNTMGOTO      # FOR WORDS 3 TO 256D OF CURRENT EBANK

DNDUMP2        CA      DUMPLOC
              TS      EBANK         # SET EBANK
              MASK     LOW8         # ISOLATE RELATIVE ADDRESS.
              TS      Q            # (NOTE: MASK INSTRUCTION IS USED TO PICK
              CA      NEG0         # UP ERASABLE REGISTERS TO THAT EDITING
              TS      L            # REGISTERS 20-23 WILL NOT BE ALTERED.)
              INDEX    Q
              EBANK=    1400        # PICK UP LOW ORDER REGISTER OF PAIR
              MASK     1401        # OF ERASABLE REGISTERS.
              XCH      L
              INDEX    Q            # PICK UP HIGH ORDER REGISTER OF PAIR
              MASK     1400        # OF ERASABLE REGISTERS.
              EBANK=    DNTMBUFF
              TCF      DNTMEXIT     # GO SEND THEM

SENDID         EXTEND
              QXCH     DNTMGOTO     # ** ENTRANCE USED BY ERASABLE DUMP PROG. **
              CAF      ERASID       # SET DNTMGOTO SO NEXT TIME PROG WILL GO
              # TO LOCATION FOLLOWING 'TC SENDID'

              TS      L            # ** ENTRANCE USED BY REGULAR DOWNLINK PG **

# Page 1102    TC      WOZERO      # GO SET WORD ORDER CODE TO ZERO
              CAF      LOWIDCOD     # PLACE SPECIAL ID CODE INTO L
              XCH      L            # AND ID BACK INTO A
              TCF      DNTMEXIT     # SEND DOWNLIST ID CODE(S).
```

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This code is written to file `src/DOWN-TELEMETRY-PROGRAM.s`.



## A.25 ENTRY LEXICON

377  $\langle \text{src/ENTRY-LEXICON.s } 377 \rangle \equiv$

```
# Copyright:   Public domain.
# Filename:    ENTRY_LEXICON.agc
# Purpose:    Part of the source code for Comanche, build 055. It
#             is part of the source code for the Command Module's
#             (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:  yaYUL
# Reference:   pp. 837-843
# Contact:    Ron Burkey <info@sandroid.org>
# Website:    http://www.ibiblio.org/apollo.
# Mod history: 2009-05-12 RSB  Adapted from Colossus249 file of the same
#                               name and Comanche 055 page images.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051.  April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#           Massachussets Institute of Technology
#           75 Cambridge Parkway
#           Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.
```

# Page 837

# VARIABLE	DESCRIPTION	MAXIMUM VALUE *	COMPUTER NAME
# -----	-----	-----	-----
# -			
# URTO	INITIAL TARGET VECTOR	2 (UNIT VECTOR)	= RTINIT
# -			
# UZ	UNIT VECTOR NORTH	1	= UNITW
# -			
# V	VELOCITY VECTOR	2 VSAT	= VEL
# -			
# R	POSITION VECTOR	2 EXP 29 METERS	= RN
# -			
# VI	INERTIAL VELOCITY	128 M/CENTISEC	= VN

# _				
# RTE	VECTOR EAST AT INITIAL TARGET	2		= RTE
# _				
# UTR	NORMAL TO RTE AND UZ	2		= RTE
# _				
# URT	TARGET VECTOR	2		= RTE
# _				
# UNI	UNIT NORMAL TO TRAJECTORY PLANE	2		
# _				
# DELV	INTEGRATED ACCEL. FROM PIPAS	5.85 16384 CM/S		
# _				
# G	GRAVITY VECTOR	128 M/CENTISEC		= GDT
#				
# AO	INITIAL DRAG FOR UPCTRL	805 FPSS		FPSS
#				
# AHOOKDV	TERM IN GAMMAL CALC. = AHOOK DVL	16		
#				
# A1	DRAG VALUE IN FACTOR CALCULATION	805 FPSS		
#				
# ALP	CONST FOR UPCTRL	1		
#				
# ASKEP	KEPLER RANGE	21600 NM		NM =
#				
# ASP1	FINAL PHASE RANGE	21600 NM		
#				
# ASPUP	UP-RANGE	21600 NM		
#				
# ASP3	GAMMA CORRECTION	21600 NM		
#				
# ASPDOWN	RANGE DOWN TO PULL-UP	21600 NM		
#				
# ASP	PREDICTED RANGE	21600 NM		NOT S
#				
# COSG	COSINE(GAMMAL)	2		= COS
#				
# C/DO	RECIPROCAL DRAG, -4/DO B-8	64/FPSS		
#				
# D	TOTAL ACCELERATION	805 FPSS		
#				
# DO	CONTROLLED CONSTANT D	805 FPSS		
#				
# DHOOK	TERM IN GAMMAL COMPUTATION	805 FPSS		
#				
# DIFF	THETNM-ASP (RANGE DIFFERENCE)	21600 NM		
#				
# DIFFOLD	PREVIOUS VALUE OF DIFF	21600 NM		

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#				
#	DLEWD	CHANGE IN LEWD	1	
#				
#	DR	REFERENCE DRAG FOR DOWNCONTROL	805 FPSS	NOT STORED
#				
#	DREFR	REFERENCE DRAG	805 FPSS	NOT STORED
#				
#	DVL	VS1-VL	2 VSAT	
#				
#	E	ECCENTRICITY	4	NOT STORED
#				
#	F1	DRANGE/D DRAG (FINAL PHASE)	2700/805	= FX +5
#				
#	F2	DRANGE/D RDOT (FINAL PHASE)	2700/2VS NM/FPS	= FX +4
#	Page 838			
#				
#	F3	DRANGE/D (L/D)	2700 NM	= FX
#				
#	FACT1	CONST FOR UPCONTRL	805 FPSS	
#				
#	FACT2	CONST FOR UPCONTRL	1/805 FPSS	
#				
#	FACTOR	USED IN UPCONTRL	1	* MAXIMUM VALUE
#				VARIABLE VALU
#	GAMMAL	FLIGHT PATH ANGLE AT VL	1 RADIAN	VARIABLE HAS
#				
#	GAMMAL1	SIMPLE FORM OF GAMMAL	1 RADIAN	
#	Page 839			
#				
#	HEADSUP	INDICATOR FOR INITIAL ROLL	1	
#				
#	KA	DRAG TO LIFT UP IF DOWN	805 FPSS	= KAT
#				
#	KLAT	LATERAL SWITCH GAIN	1	(NOM = .0125)
#				
#	K2ROLL	INDICATOR FOR ROLL SWITCH		
#				
#	LAD	MAX L/D (MIN ACTUAL VEHICLE L/D)	1	
#				
#	LADPAD	NOMINAL VEHICLE L/D, SP PAD LOAD	1	(NOM = 0.3)
#				
#	LATANG	LATERAL RANGE	4 RADIANS	
#				
#	LEQ	EXCESS C.F. OVER GRAV=(VSQ-1)GS	128.8 FPSS	
#				
#	LEWD	UPCONTROL REFERENCE L/D	1	

#				
#	LOD	FINAL PHASE L/D	1	(NOM
#				
#	LODPAD	FINAL PHASE L/D, SP PAD LOAD	1	
#				
#	L/D	DESIRED LIFT TO DRAG RATIO	1	
#		(VERTICAL PLANE)		
#				
#	L/D1	TEMP STORAGE FOR L/D IN LATERAL	1	
#				
#	L/DCMINR	LAD COS(15DEG)	1	(NOM
#				
#	PREDANGLE	PREDICTED RANGE (FINAL PHASE)	2700 NM	= PR
#				
#	Q2	FINAL PHASE RANGE -23500 Q3	21600 NM	
#		Q2 = FCN(LAD)		
#				
#	Q7	MINIMUM DRAG FOR UPCONTROL	805FPSS	
#				
#	RDOT	ALTITUDE RATE	2 VSAT	
#				
#	RDOTREF	REFERENCE RDOT FOR UPCONTROL	2 VSAT	
#				
#	RDTR	REFERENCE RDOT FOR DOWNCONT	2 VSAT	NOT S
#				
#	ROLLC	ROLL COMMAND	1 REVOLUTION	
#				
#	RTOGO	RANGE TO GO (FINAL PHASE)	2700 NM	= FX
#				
#	SL	SINE OF LATITUDE	1	NOT S
#				
#	T	TIME	B 28 CENTISEC	= TI
#				
#	THETA	DESIRED RANGE (RADIAN)	2 PI RADIAN	= TH
#				
#	THETNM	DESIRED RANGE (NM)	21600 NM	NON P
#				
#	V	VELOCITY MAGNITUDE	2 VSAT	
#				
#	V1	INITIAL VELOCITY FOR UPCONTROL	2 VSAT	
#				
#	VL	EXIT VELOCITY FOR UPCONTROL	2 VSAT	
#				
#	VREF	REFERENCE VELOCITY FOR UPCONTROL	2 VSAT	
#				
#	VS1	VSAT OR V1, WHICHEVER IS SMALLER	2 VSAT	

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#	2 2		
# VBARS	VL /VSAT	4	
#		2 2	
# VSQ	NORMALIZED VEL. SQUARED = V /VSAT	4	= VSQUARE
#			
# WT	EARTH RATE TIMES TIME	1 REVOLUTION	NOT SAVED
#			
# X	INTERMEDIATE VARIABLE IN G-LIMITER	2 VSAT	NOT SAVED
#			
# Y	LATERAL MISS LIMIT	4 RADIANS	NOT SAVED

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# EXTRA COMPUTER ERASABLE LOCATIONS NOT SHOWN ON FLOW CHARTS

# -----

#	VARIABLE	DESCRIPTION	MAXIMUM VALUE
#	-----	-----	-----
#			
#	GOTOADDR	ADDRESS SELECTED BY SEQUENCER	
#			
#	XPIPBUF	BUFFER TO STORE X PIPA COUNTS	
#			
#	YPIPBUF	BUFFER TO STORE Y PIPA COUNTS	
#			
#	ZPIPBUF	BUFFER TO STORE Z PIPA COUNTS	
#			
#	PIPCTR	COUNTS PASSES THRU PIPA READ ROUTINE	
#			
#	JJ	INDEX IN FINAL PHASE TABLE LOOK-UP	
#			
#	MM	INDEX IN FINAL PHASE TABLE LOOK-U	
#			
#	GRAD	INTERPOLATION FACTOR IN FINAL PHASE	
#			
#	FX	DRANGE/D L/D = F3	2700 NM
#			
#	FX +1	AREF	805 FPSS
#			
#	FX +2	RTOGO	2700 NM
#			
#	FX +3	RDOTREF	VSAT/4
#			
#	FX +4	DRANGE/D RDOT = F2	21600/2VS NM/FPS
#			
#	FX +5	DRANGE/D DRAG = F1	2700/805 NM/FPSS
#			

```

# TEM1B          TEMPORARY LOCATION
#
# TIME/RTO       TIME OF INITIAL TARGET RTINIT          B 28 CENTISEC
#
# DTEAROT        EST TIME BETWEEN RTINIT AND RT          B 28 CENTISEC
# -
# UNITV          UNIT V VECTOR                          2
# -
# UNITR          UNIT R VECTOR                          2
# -
# -VREL          NEGATIVE VELOCITY REL TO ATMOSP        2 VSAT

# COMPUTER SWITCHES          INITIAL STATE          CM/FT
# -----
#
# ENTRYDSP        DO ENTRY DISPLAY, IF SET              NON-BRANCH (1)          92D,
# GONEPAST        INDICATES OVERSHOOT OF TARGET          NON-BRANCH (0)          95D,
# RELVELSW        RELATIVE VELOCITY SWITCH              NON-BRANCH (0)          96D,
# EGSW            FINAL PHASE SWITCH                    NON-BRANCH (0)          97D,
# FIRSTPAS        INITIAL PASS THRU HUNTEST              NON-BRANCH (0)          98D,
# HIND            INDICATES ITERATION IN HUNTEST          NON-BRANCH (0)          99D,
# INRLSW          INDICATES INIT ROLL ATTITUDE SET        NON-BRANCH (0)          100D,
# LATSW           INHIBIT DOWNLIFT SWITCH IF NOT SET      BRANCH (1)              101D,
# .05GSW          INDICATES DRAG EXCEEDS .05 GS          BRANCH (0)              102D,
#
# GONEBY          INDICATES GONE PAST TARGET (SET)        SELF-INITIALIZING      112D,

# Page 841
# CONSTANTS AND GAINS          VALUE
# -----
#
# C1              FACTOR IN ALP COMPUTATION              1.25
# C16             CONSTD GAIN ON DRAG                    .01
# C17             CONSTD GAIN ON RDOT                     .001
# C18             BIAS VEL. FOR FINAL PHASE START        500          FPS
# C20             MAX DRAG FOR DOWN-LIFT                  175          FPSS
# CHOOK           FACTOR IN AHOOK COMPUTATION             .25
# CH1             FACTOR IN GAMMAL COMPUTATION            1.0
# COS15           COS( 15 DEG )                          .965
# DLEWDO          INITIAL VARIATION IN LEWD               -.05
# D2              DRAG TO CHANGE LEWD                    175          FPSS
# DT              COMPUTATION CYCLE TIME INTERVAL         2          SEC.
# GMAX            MAXIMUM ACCELERATION                   257.6        FPSS
# KA1             FACTOR IN KA CALC                      1.3          GS
# KA2             FACTOR IN KA CALC                      .2          GS
# KA3             FACTOR IN DO CALC                      90          FPSS

```

# KA4	FACTOR IN DO CALC	40	FPSS
# KB1	OPTIMIZED UPCONTROL GAIN	3.4	
# KB2	OPTIMIZED UPCONTROL GAIN	.0034	
# KDMIN	INCREMENT ON Q7 TO DETECT END OF KEPLER PHASE	.5	FPSS
# KTETA	TIME OF FLIGHT CONSTANT	1000	
# KLAT1	FACTOR IN KLAT CALC	1/24	
# K44	GAIN USED IN INITIAL ROLL SECTION	19749550	FPS
# LATBIAS	LATERAL SWITCH BIAS TERM	.41252961	NM
# LEWD1	NOMINAL UPCONTROL L/D	.15	
# POINT1	FACTOR TO REDUCE UPCONTROL GAIN	.1	
# Q2	FINAL PHASE RANGE - 23500 Q3	-1002	NM
# Q3	FINAL PHASE DRANGE/D V	.07	NM/FPS
# Q5	FINAL PHASE DRANGE/D GAMMA	7050	NM/RAD
# Q6	FINAL PHASE INITIAL FLIGHT PATH ANGLE	.0349	RAD
# Q7F	MIN DRAG FOR UPCONTROL	6	FPSS
# Q7MIN	IN VALUE FOR Q7 IN FACTOR CALCULATION	40	FPSS
# Q19	FACTOR IN GAMMAL1 CALCULATION	.5	
# Q21	FACTOR IN Q2 CALCULATION	1000	NM
# Q22	FACTOR IN Q2 CALCULATION	-1302	NM
# VFINAL1	VELOCITY TO START FINAL PHASE ON INITIAL ENTRY	27000	FPS
# VFINAL	FACTOR IN INITIAL UP-DOWN CALC	26600	FPS
# VLMIN	MINIMUM VL	18000	FPS
# VMIN	VELOCITY TO SWITCH TO RELATIVE VEL	VSAT/2	
# VRCONTRL	RDOT TO START INTO HUNTEST	700	FPS
#	VRCONT=COMPUTER NAME		
# 25NM	TOLERANCE TO STOP RANGE ITERATION	25	NM
# VQUIT	VELOCITY TO STOP STEERING	1000	FPS

# Page 842

# CONVERSION FACTORS AND SCALING CONSTANTS

# -----

#

# ATK	ANGLE IN RAD TO NM	3437.7468	NM/RAD
# G5	NOMINAL G VALUE FOR SCALING	32.2	FPSS
# H5	ATMOSPHERE SCALE HEIGHT	28500	FT
# J	GRAVITY HARMONIC COEFFICIENT	.00162346	
# KWE	EQUATORIAL EARTH RATE	1546.10168	FPS
# MUE	EARTH GRAVITATIONAL CONSTANT	3.986032233 E14	CUBIC M
# RE	EARTH RADIUS	21202900	FT
# REQ	EARTH EQUATORIAL RADIUS	20925738.2	FT
# VSAT	SATELLITE VELOCITY AT RE	25766.1973	FPS
# WIE	EARTH RATE	.0000729211505	RAD/SEC

# (END GSOP AS-278, VOL 1, FIG. 5.6-3 CONSTANTS, GAINS, ETC.)

# DISPLAY QUANTITIES

```

# -----
#
# (SEE SECTION 4 OF THE GSOP FOR SIGN CONVENTIONS.)
#
# VARIABLE      DESCRIPTION      MAXIMUM VALUE
# -----      -
#
# QMAX          PREDICTED MAXIMUM ENTRY ACCEL      163.84 GS      N 60
# VPRED         PREDICTED VELOCITY AT ALTITUDE     128 M/CENTISEC N 60
#              400K FT ABOVE FISCHER RADIUS.
# GAMMAEI      PREDICTED GAMMA AT ALTITUDE         1 REVOLUTION  N 60
#              400K FT ABOVE FISCHER RADIUS
# D            DRAG ACCELERATION                   805 FPSS      N 64
# VMAGI        INERTIAL VELOCITY MAGNITUDE         128 M/CENTISEC N 64, N 68
# THETAH       DESIRED RANGE ANGLE NM              1 REVOLUTION  N 64, N 67
# LAT          PRESENT LATITUDE                   1 REVOLUTION  N 67
# LONG         PRESENT LONGITUDE                   1 REVOLUTION  N 67
# RTOGO        RANGE ANGLE TO SPLASH FROM          1 REVOLUTION  N 67
#              EMSALT FT ABOVE FISCHER RADIUS (IN NM)
# VIO          PREDICTED VELOCITY AT ALTITUDE     128 M/CENTISEC N 63
#              EMSALT FT ABOVE FISCHER RADIUS.
# TTE          TIME OF FREE FALL TO ALT            B 28 CENTISEC N 63
#              EMSALT FT ABOVE FISCHER RADIUS
# ROLLC        ROLL COMMAND                       1 REVOLUTION  N 68, N 68, 1
# LATANG       CROSS-RANGE ERROR (XRNERR)         4 RADIANS     N 66
# DNRNGERR     DOWN RANGE ERROR                   1 REVOLUTION  N 66
#              (PREDDANG - THETAH IN NM)
# HDOT         ALTITUDE RATE                      128 M/CENTISEC N 68
# QT           MINIMUM DRAG FOR UP-CONTROL         805 FPSS      N 69
# VL           EXIT VELOCITY FOR UP-CONTROL        2 VSAT        N 69

```

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# BODY ATTITUDE QUANTITIES (CM/POSE)

```

# -----
#
# VARIABLE      DECEIPTION      MAXIMUM VALUE
# -----      -
#
# -
# -VREL         NEGATIVE VELOCITY REL TO ATMOS.    2 VSAT
# -
# OLDUYA        USED FOR UYA BELOW 1000 FPS        2
# -
# UXA/2         UNIT VECTOR TRIAD                  2
# -
# UYA/2         BASED ON                            2
# -

```



# UZA/2	THE TRAJECTORY	2
# _		
# UBX/2	UNIT VECTOR	2
# _		
# UBY/2	BODY TRIAD	2
# _		
# UBZ/2	FOR CM.	2

This code is written to file `src/ENTRY-LEXICON.s`.

## A.26 ERASABLE ASSIGNMENTS

```

386  <src/ERASABLE-ASSIGNMENTS.s 386>≡
# Copyright:      Public domain.
# Filename:       ERASABLE_ASSIGNMENTS.agc
# Purpose:        Part of the source code for Colossus 2A, AKA Comanche 055.
#                 It is part of the source code for the Command Module's (CM)
#                 Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:     yaYUL
# Contact:        Ron Burkey <info@sandroid.org>.
# Website:        www.ibiblio.org/apollo.
# Mod history:    2009-05-06 RSB Started adapting from the Colossus249/ file
#                 of the same name, using Comanche055 page
#                 images. Only through page 51 so far.
#                 2009-05-07 RSB Through page 92 so far.
#                 2009-05-07 RSB (Again!) First draft completed.
#                 2009-05-20 RSB Fixed some bugs uncovered in trial assemblies:
#                 EMDOT, STATEXIT, VGDISP, DVPREV, POSTCDH,
#                 RETROFLG not defined correctly, changed the
#                 typing of labels 9X9LOC1 and 9X9LOC2,
#                 R32FLBIT -> R31FLBIT.
#                 2009-05-21 RSB Corrected definition of DELBRTMP, which
#                 chained to quite a lot of off-by-one errors.
#                 Changed a +8 to a +8D.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. 10:28 APR. 1, 1969
#
# This AGC program shall also be referred to as
# Colossus 2A
#
# Page 37
# CONVENTIONS AND NOTATIONS UTILIZED FOR ERASABLE ASSIGNMENTS.

```

```

#      EQUALS IS USED IN TWO WAYS. IT IS OFTEN USED TO CHAIN A GROUP
#      OF ASSIGNMENTS SO THAT THE GROUP MAY BE MOVED WITH THE
#      CHANGING OF ONLY ONE CARD. EXAMPLE:
#
#           X      EQUALS  START
#           Y      EQUALS  X      +SIZE.X
#           Z      EQUALS  Y      +SIZE.Y
#
#      (X, Y, AND Z ARE CONSECUTIVE AND BEGIN AT START.
#      SIZE.X AND SIZE.Y ARE THE RESPECTIVE SIZES OF X AND Y.
#      USUALLY NUMERIC, IE. 1, 2, 6, 18D, ETC.)
#
#      EQUALS OFTEN IMPLIES THE SHARING OF REGISTERS (DIFFERENT NAMES
#      AND DIFFERENT DATA). EXAMPLE:
#
#           X      EQUALS  Y
#
#      =      MEANS THAT MULTIPLE NAMES HAVE BEEN GIVEN TO THE SAME DATA.
#      (THIS IS LOGICAL EQUIVALENCE, NOT SHARING.) EXAMPLE:
#
#           X      =      Y
#
#      THE SIE AND UTILIZATION OF AN ERASABLE ARE OFTEN INCLUDED IN
#      THE COMMENTS IN THE FOLLOWING FORM: M(SIZE)N.
#
#      M      REFERS TO THE MOBILITY OF THE ASSIGNMENT.
#      B      MEANS THAT THE SYMBOL IS REFERENCED BY BASIC
#      INSTRUCTIONS AND THUS IS E-BANK SENSITIVE.
#      I      MEANS THAT THE SYMBOL IS REFERENCED ONLY BY
#      INTERPRETIVE INSTRUCTIONS, AND IS THUS E-BANK
#      INSENSITIVE AND MAY APPEAR IN ANY E-BANK.
#
#      SIZE   IS THE NUMBER OF REGISTERS INCLUDED BY THE SYMBOL.
#
#      N      INDICATES THE NATURE OF PERMANENCE OF THE CONTENTS.
#      PL     MEANS THAT THE CONTENTS ARE PAD LOADED.
#      DSP    MEANS THAT THE REGISTER IS USED FOR A DISPLAY.
#      PRM    MEANS THAT THE REGISTER IS PERMANENT. IE., IT
#      IS USED DURING THE ENTIRE MISSION FOR ONE
#      PURPOSE AND CANNOT BE SHARED.
#      TMP    MEANS THAT THE REGISTER IS USED TEMPORARILY OR
#      IS A SCRATCH REGISTER FOR THE ROUTINE TO WHICH
#      IT IS ASSIGNED. THAT IS, IT NEED NOT BE SET
#      PRIOR TO INVOCATION OF THE ROUTINE NOR DOES IT
#      CONTAIN USEFUL OUTPUT TO ANOTHER ROUTINE. THUS
#
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```

```

#           IT MAY BE SHARED WITHANY OTHER ROUTINE WHICH
#           IS NOT ACTIVE IN PARALLEL
#           IN      MEANS INPUT TO THE ROUTINE AND IT IS PROBABLY
#           TEMPORARY FOR A HIGHER-LEVEL ROUTINE/PROGRAM.
#           OUT    MEANS OUTPUT FROM THE ROUTINE, PROBABLY
#           TEMPORARY FOR A HIGHER-LEVEL ROUTINE/PROGRAM.

```

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# SPECIAL REGISTERS.

```

```

A           EQUALS 0
L           EQUALS 1           # L AND Q ARE BOTH CHANNELS AND REGISTERS
Q           EQUALS 2
EBANK       EQUALS 3
FBANK       EQUALS 4
Z           EQUALS 5           # ADJACENT TO FBANK AND BBANK FOR DXCH Z
BBANK       EQUALS 6           # (DTCB) AND DXCH FBANK (DTCF).
                                   # REGISTER 7 IS A ZERO-SOURCE, USED BY ZL.

ARUPT       EQUALS 10          # INTERRUPT STORAGE
LRUPT       EQUALS 11
QRUPT       EQUALS 12
SAMPTIME    EQUALS 13          # SAMPLED TIME 1 & 2.
ZRUPT       EQUALS 15          # (13 AND 14 ARE SPARES.)
BANKRUPT    EQUALS 16          # USUALLY HOLDS FBANK OR BBANK.
BRUPT       EQUALS 17          # RESUME ADDRESS AS WELL.

CYR         EQUALS 20
SR          EQUALS 21
CYL         EQUALS 22
EDOP        EQUALS 23          # EDITS INTERPRETIVE OPERATION CODE PAIRS.

TIME2       EQUALS 24
TIME1       EQUALS 25
TIME3       EQUALS 26
TIME4       EQUALS 27
TIME5       EQUALS 30
TIME6       EQUALS 31
CDUX        EQUALS 32
CDUY        EQUALS 33
CDUZ        EQUALS 34
CDUT        EQUALS 35          # OPTICS TRUNNION CDU (WAS OPTY).
OPTY        =          CDUT
CDUS        EQUALS 36          # OPTICS SHAFT CDU (WAS OPTX).
OPTX        =          CDUS

```

PIPAX	EQUALS	37
PIPAY	EQUALS	40
PIPAZ	EQUALS	41
BMAGX	EQUALS	42
BMAGY	EQUALS	43
BMAGZ	EQUALS	44
INLINK	EQUALS	45
RNRAD	EQUALS	46
GYROCTR	EQUALS	47
GYROCMD	EQUALS	47
CDUXCMD	EQUALS	50
CDUYCMD	EQUALS	51

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CDUZCMD	EQUALS	52	
CDUTCMD	EQUALS	53	# OPTICS TRUNNION COMMAND (WAS OPTYCMD)
OPTYCMD	=	CDUTCMD	
TVCYAW	EQUALS	CDUTCMD	# SPS YAW COMMAND IN TVC MODE
CDUSCMD	EQUALS	54	# OPTICS SHAFT COMMAND (WAS OPTXCMD).
TVCPITCH	EQUALS	CDUSCMD	# SPS PITCH COMMAND IN TVC MODE
OPTXCMD	=	CDUSCMD	
EMSD	EQUALS	55	
THRUST	EQUALS	55	
LEMONM	EQUALS	56	
LOCALARM	EQUALS	57	
BANKALRM	EQUALS	60	

# INTERPRETIVE REGISTERS ADDRESSED RELATIVE TO VAC AREA.

LVSQUARE	EQUALS	34D	# SQUARE OF VECTOR INPUT TO ABVAL AND UNIT
LV	EQUALS	36D	# LENGTH OF VECTOR INPUT TO UNIT.
X1	EQUALS	38D	# INTERPRETIVE SPECIAL REGISTER RELATIVE
X2	EQUALS	39D	# TO THE WORK AREA.
S1	EQUALS	40D	
S2	EQUALS	41D	
QPRET	EQUALS	42D	

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# INPUT/OUTPUT CHANNELS

# \*\*\* CHANNEL ZERO IS TO BE USED IN AN INDEXED OPERATION ONLY. \*\*\*

LCHAN	EQUALS	L
QCHAN	EQUALS	Q
HISCALAR	EQUALS	3

LOSCALAR	EQUALS	4
PYJETS	EQUALS	5
ROLLJETS	EQUALS	6
SUPERBNK	EQUALS	7
OUTO	EQUALS	10
DSALMOUT	EQUALS	11
CHAN12	EQUALS	12
CHAN13	EQUALS	13
CHAN14	EQUALS	14
MNKEYIN	EQUALS	15
NAVKEYIN	EQUALS	16
CHAN30	EQUALS	30
CHAN31	EQUALS	31
CHAN32	EQUALS	32
CHAN33	EQUALS	33
DNTM1	EQUALS	34
DNTM2	EQUALS	35

# END OF CHANNEL ASSIGNMENTS

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# FLAGWORDS

#

# FLAGWRD0	STATE +0	(000-014)
# FLAGWRD1	STATE +1	(015-029)
# FLAGWRD2	STATE +2	(030-044)
# FLAGWRD3	STATE +3	(045-059)
# FLAGWRD4	STATE +4	(060-074)
# FLAGWRD5	STATE +5	(075-089)
# FLAGWRD6	STATE +6	(090-104)
# FLAGWRD7	STATE +7	(105-119)
# FLAGWRD8	STATE +8D	(120-134)
# FLAGWRD9	STATE +9D	(135-149)

# SORTED LIST OF

# INTERPRETIVE SWITCH BIT ASSIGNMENTS

# INTERPRETIVE SWITCH BIT ASSIGNMENTS

#

# FLAGWORD	DEC NUM	BIT & FLAG	EQUIVALENT FLAGWORDS
#			
# 22DSPFLG	032D	BIT 13 FLAG 2	
# 360SW	134D	BIT 1 FLAG 8	
# 3AXISFLG	084D	BIT 6 FLAG 5	
# ADVTRK	125D	BIT 10 FLAG 8	

# AMOONFLG	13D	BIT 2 FLAG 0	
# APSESW	130D	BIT 5 FLAG 8	
# ASTNFLAG	108D	BIT 12 FLAG 7	
# ATTCHFLG	118D	BIT 2 FLAG 7	
# AVEGFLAG	029D	BIT 1 FLAG 1	
# AVEMIDSW	149D	BIT 1 FLAG 9	
# AVFLAG	040D	BIT 5 FLAG 2	
# CALCMAN2	043D	BIT 2 FLAG 2	
# CMDAPARM	093D	BIT 12 FLAG 6	
# CMOONFLG	123D	BIT 12 FLAG 8	
# CM/DSTBY	103D	BIT 2 FLAG 6	
# COGAFLAG	131D	BIT 4 FLAG 8	
# COMPUTER	082D	BIT 8 FLAG 5	
# CPHIFLAG	000D	BIT 15 FLAG 0	
# CULTFLAG	053D	BIT 7 FLAG 3	
# D6OR9FLG	058D	BIT 2 FLAG 3	
# DAPBIT1	090D	BIT 15 FLAG 6	
# DAPBIT2	091D	BIT 14 FLAG 6	
# DIMOFLAG	059D	BIT 1 FLAG 3	
# DMENFLAG	081D	BIT 9 FLAG 5	
# DRIFTFLG	030D	BIT 15 FLAG 2	
# DSKYFLAG	075D	BIT 15 FLAG 5	
# EGSW	097D	BIT 8 FLAG 6	KNOTNFLAG R57FLAG

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# ENG1FLAG	018D	BIT 12 FLAG 1	
# ENG2FLAG	019D	BIT 11 FLAG 1	
# ENGONFLG	083D	BIT 7 FLAG 5	
# ERADFLAG	017D	BIT 13 FLAG 1	
# ETPIFLAG	038D	BIT 7 FLAG 2	FIRSTFLG OPTNSW
# F2RTE	010D	BIT 5 FLAG 0	
# FINALFLG	039D	BIT 6 FLAG 2	
# FIRSTFLG	038D	BIT 7 FLAG 2	ETPIFLAG OPTNSW
# FREEFLAG	012D	BIT 3 FLAG 0	
# GAMDIFSW	094D	BIT 11 FLAG 6	
# GLOKFAIL	046D	BIT 14 FLAG 3	
# GONEBY	112D	BIT 8 FLAG 7	
# GONEPAST	095D	BIT 10 FLAG 6	
# GRRBKFLG	085D	BIT 5 FLAG 5	
# GUESSW	028D	BIT 2 FLAG 1	
# GYMDIFSW	104D	BIT 1 FLAG 6	
# .05GSW	102D	BIT 3 FLAG 6	
# HIND	099D	BIT 6 FLAG 6	
# IDLEFAIL	024D	BIT 6 FLAG 1	
# IDLEFLAG	113D	BIT 7 FLAG 7	

# IGNFLAG	107D	BIT 13 FLAG 7	
# IMPULSW	036D	BIT 9 FLAG 2	
# IMUSE	007D	BIT 8 FLAG 0	
# INCORFLG	079D	BIT 11 FLAG 5	
# INFINFLG	128D	BIT 7 FLAG 8	
# INRLSW	100D	BIT 5 FLAG 6	
# INTFLAG	151D	BIT 14 FLAG 10	
# INTYPFLG	056D	BIT 4 FLAG 3	
# ITSWICH	106D	BIT 14 FLAG 7	
# KFLAG	014D	BIT 1 FLAG 0	
# KNOWNFLG	097D	BIT 8 FLAG 6	EGSW R57FLAG
# LATSW	101D	BIT 4 FLAG 6	
# LMOONFLG	124D	BIT 11 FLAG 8	
# LUNAFLAG	048D	BIT 12 FLAG 3	
# MAXDBFLG	138D	BIT 12 FLAG 9	
# MGLVFLAG	088D	BIT 2 FLAG 5	
# MID1FLAG	147D	BIT 3 FLAG 9	
# MIDAVFLG	148D	BIT 2 FLAG 9	
# MIDFLAG	002D	BIT 13 FLAG 0	
# MKOVFLAG	072D	BIT 3 FLAG 4	
# MOONFLAG	003D	BIT 12 FLAG 0	
# MRKIDFLG	060D	BIT 15 FLAG 4	
# MRKNVFLG	066D	BIT 9 FLAG 4	
# MRUPTFLG	070D	BIT 5 FLAG 4	
# MWAITFLG	064D	BIT 11 FLAG 4	
# N220RN17	144D	BIT 6 FLAG 9	
# NEEDLFLG	006D	BIT 9 FLAG 0	
# NEWIFLG	122D	BIT 13 FLAG 8	
# NJETSFLG	015D	BIT 15 FLAG 1	
# NODOFLAG	044D	BIT 1 FLAG 2	

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# NODOP01	018D	BIT 12 FLAG 1	
# NORFHOR	004D	BIT 11 FLAG 0	
# NORMSW	110D	BIT 10 FLAG 7	
# NOSWITCH	098D	BIT 7 FLAG 6	
# NRMIDFLG	062D	BIT 13 FLAG 4	
# NRMNVFLG	067D	BIT 8 FLAG 4	
# NRUPTFLG	071D	BIT 4 FLAG 4	
# NWAITFLG	065D	BIT 10 FLAG 4	
# OPTNSW	038D	BIT 7 FLAG 2	ETPIFLAG FIRSTFLG
# ORBWFLAG	054D	BIT 6 FLAG 3	
# ORDERSW	129D	BIT 6 FLAG 8	
# P21FLAG	033D	BIT 12 FLAG 2	
# P22MKFLG	049D	BIT 11 FLAG 3	



# P39/79SW	126D	BIT 9 FLAG 8	
# PDSPFLAG	063D	BIT 12 FLAG 4	
# PFRATFLG	041D	BIT 4 FLAG 2	
# PINBRFLG	069D	BIT 6 FLAG 4	
# PRECIFLG	052D	BIT 8 FLAG 3	
# PRFTRKAT	060D	BIT 10 FLAG 5	
# PRIODFLG	061D	BIT 14 FLAG 4	
# PRONVFLG	068D	BIT 7 FLAG 4	
# QUITFLAG	145D	BIT 5 FLAG 9	
# R21MARK	031D	BIT 14 FLAG 2	
# R22CAFLG	143D	BIT 7 FLAG 9	
# R23FLG	021D	BIT 9 FLAG 1	
# R31FLAG	146D	BIT 4 FLAG 9	
# R53FLAG	009D	BIT 6 FLAG 0	
# R57FLAG	097D	BIT 8 FLAG 6	KNOWNFLG EGSW
# R60FLAG	086D	BIT 4 FLAG 5	
# REFSMFLG	047D	BIT 13 FLAG 3	
# REINTFLG	158D	BIT 7 FLAG 10	
# RELVELSW	096D	BIT 9 FLAG 6	
# RENDWFLG	089D	BIT 1 FLAG 5	
# RNDVZFLG	008D	BIT 7 FLAG 0	
# RPQFLAG	120D	BIT 15 FLAG 6	
# RVSW	111D	BIT 9 FLAG 7	
# SAVECFLG	140D	BIT 10 FLAG 9	
# SKIPVHF	035D	BIT 10 FLAG 2	
# SLOPESW	027D	BIT 3 FLAG 1	
# SOLNSW	087D	BIT 3 FLAG 5	
# SOURCFLG	142D	BIT 8 FLAG 9	
# STATEFLG	055D	BIT 5 FLAG 3	
# STEERSW	034D	BIT 11 FLAG 2	
# STIKFLAG	016D	BIT 14 FLAG 1	
# STRULLSW	092D	BIT 13 FLAG 6	
# SURFFLAG	127D	BIT 8 FLAG 8	
# SWTOVER	135D	BIT 15 FLAG 9	
# TARG1FLG	020D	BIT 10 FLAG 1	

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# TARG2FLG	021D	BIT 9 FLAG 1
# TERMIFLG	105D	BIT 15 FLAG 7
# TFFSW	119D	BIT 1 FLAG 7
# TIMRFLAG	109D	BIT 11 FLAG 7
# TRACKFLG	025D	BIT 5 FLAG 1
# TRM03FLG	026D	BIT 4 FLAG 1
# TRUNFLAG	011D	BIT 4 FLAG 0
# UPDATFLG	023D	BIT 7 FLAG 1

# UNLOCKFL	116D	BIT 4 FLAG 7
# V37FLAG	114D	BIT 6 FLAG 7
# V59FLAG	078D	BIT 12 FLAG 5
# V67FLAG	136D	BIT 14 FLAG 9
# V82EMFLG	137D	BIT 13 FLAG 9
# V94FLAG	139D	BIT 11 FLAG 9
# V96ONFLG	132D	BIT 3 FLAG 8
# VEHUPFLG	022D	BIT 8 FLAG 1
# VERIFLAG	117D	BIT 3 FLAG 7
# VFLAG	050D	BIT 10 FLAG 3
# VHFRFLAG	141D	BIT 9 FLAG 9
# VINTFLAG	057D	BIT 3 FLAG 3
# XDELVFLG	037D	BIT 8 FLAG 2
# XDSPFLAG	074D	BIT 1 FLAG 4

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## # INTERPRETIVE SWITCH BIT ASSIGNMENTS

FLAGWRDO	=	STATE +0	# (000-014)	
			# (SET)	(RESET)
# BIT 15 FLAG 0				
CPHIFLAG	=	000D	# OUTPUT OF CALCGA IS	OUTPUT OF CALCGA IS
			# CPHIX	THETAD
CPHIBIT	=	BIT15		
# BIT 14 FLAG 0				
JSWITCH	=	001D	# INTEGRATION OF W	INTEGRATION OF STATE
			# MATRIX	VECTOR
JSWCHBIT	=	BIT14		
# BIT 13 FLAG 0				
MIDFLAG	=	002D	# INTEGRATION WITH	INTEGRATION WITHOUT
			# SOLAR PERTURBATIONS	SOLAR PERTURBATIONS
MIDFLBIT	=	BIT13		
# BIT 12 FLAG 0				
MOONFLAG	=	003D	# MOON IS SPHERE OF	EARTH IS SPHERE OF
			# INFLUENCE	INFLUENCE
MOONBIT	=	BIT12		
# BIT 11 FLAG 0				
NORFHOR	=	004D	# FAR HORIZON	NEAR HORIZON
NORFBIT	=	BIT11		

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# BIT 10 FLAG 0 ZMEASURE	=	005D	# MEASUREMENT PLANET # AND PRIMARY PLANET # DIFFERENT	MEASUREMENT PLANET AND PRIMARY PLANET SAME
ZMEASBIT	=	BIT10		
# BIT 9 FLAG 0 NEEDLFLG	=	006D	# TOTAL ATTITUDE # ERROR DISPLAYED	A/P FOLLOWING ERROR DISPLAYED
NEEDLBIT	=	BIT9		
# BIT 8 FLAG 0 IMUSE	=	007D	# IMU IN USE	IMU NOT IN USE
# Page 47				
IMUSEBIT	=	BIT8		
# BIT 7 FLAG 0 RNDVZFLG	=	008D	# P20 RUNNING	P20 NOT RUNNING
RNDVZBIT	=	BIT7		
# BIT 6 FLAG 0 R53FLAG	=	009D	# V51 INITIATED	V51 NOT INITIATED
R53FLBIT	=	BIT8		
# BIT 5 FLAG 0 F2RTE	=	010D	# IN TIME CRITICAL # MODE	NOT IN TIME CRITICAL MODE
F2RTEBIT	=	BIT5		
# BIT 4 FLAG 0 TRUNFLAG	=	011D	# DRIVING OF TRUNNION # ALLOWED	DRIVING OF TRUNNION NOT ALLOWED
TRUNBIT	=	BIT4		
# BIT 3 FLAG 0 FREEFLAG	=	012D	# (TEMPORARY FLAG USED IN MANY ROUTINES)	

FREEFBIT	=	BIT3		
# BIT 2 FLAG 0				
AMOONFLG	=	13D	# STATE VECTOR IN	STATE VECTOR IN
AMOONBIT	=	BIT2	# LUNAR SPHERE AT	EARTH SPHERE AT
			# MIDTOAVE	MIDTOAVE
# BIT 1 FLAG 0				
KFLAG	=	014D	# SEARCH SECTOR MORE	SEARCH SECTOR LESS
			# THAN 180 DEGREES	THAN 180 DEGREES
KBIT	=	BIT1		
FLAGWRD1	=	STATE +1	# (015-029)	
			# (SET)	(RESET)
# BIT 15 FLAG 1				
NJETSFLG	=	015D	# TWO JET RCS BURN	FOUR JET RCS BURN
NJETSBIT	=	BIT15		
# Page 48				
# BIT 14 FLAG 1				
STIKFLAG	=	016D	# RHC CONTROL	CMC CONTROL
STIKBIT	=	BIT14		
# BIT 13 FLAG 1				
ERADFLAG	=	017D	# EARTH, COMPUTE	EARTH, USED FIXED
			# FISCHER ELLIPSOID	RADIUS
			# RADIUS	
			# MOON, USE FIXED	MOON, USE RLS FOR
			# RADIUS	LUNAR RADIUS
ERADFBIT	=	BIT13		
# BIT 12 FLAG 1				
NODOP01	=	018D	# P01 NOT ALLOWED	P01 ALLOWD
NOP01BIT	=	BIT12		
# BIT 11 FLAG 1				
ENG2FLAG	=	019D	# RCS BURN	SPS BURN
ENG2BIT	=	BIT11		
# BIT 10 FLAG 1				

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TARG1FLG	=	020D	# SIGHTING LEM	NOT SIGHTING LEM
TARG1BIT	=	BIT10		
# BIT 9 FLAG 1				
TARG2FLG	=	021D	# SIGHTING LANDMARK	SIGHTING STAR
TARG2BIT	=	BIT9		
# BIT 9 FLAG 1				
R23FLG	=	021D	# R23 MARKING	
R23BIT	=	BIT9		
# BIT 8 FLAG 1				
VEHUPFLG	=	022D	# CSM STATE VECTOR # BEING UPDATED	LEM STATE VECTOR BEING UPDATED
VEHUPBIT	=	BIT8		
# BIT 7 FLAG 1				
UPDATFLG	=	023D	# UPDATING BY MARKS # ALLOWED	UPDATING BY MARKS NOT ALLOWED
# Page 49				
UPDATBIT	=	BIT7		
# BIT 6 FLAG 1				
IDLEFAIL	=	024D	# INHIBIT R41	ENABLE R41 (ENGFAIL)
IDLEBIT	=	BIT6		
# BIT 5 FLAG 1				
TRACKFLG	=	025D	# TRACKING ALLOWED	TRACKING NOT ALLOWED
TRACKBIT	=	BIT5		
# BIT 4 FLAG 1				
TRM03FLG	=	026D	# REQUEST TO # TERMINATE P03 HAS # BEEN ENTERED	NO REQUEST TO TERMINATE P03 HAS BEEN ENTERED
TRM03BIT	=	BIT4		
# BIT 3 FLAG 1				
SLOPESW	=	027D	# ITERATE WITH BIAS	ITERATE WITH REGULA

			# METHOD IN ITERATOR	FALSI METHOD IN
			#	ITERATOR
SLOPEBIT	=	BIT3		
# BIT 2 FLAG 1				
GUESSW	=	028D	# NO STARTING VALUE	STARTING VALUE FOR
			# FOR ITERATION	ITERATION EXISTS
GUESSBIT	=	BIT2		
# BIT 1 FLAG 1				
AVEGFLAG	=	029D	# AVERAGEG (SERVICER)	AVERAGEG (SERVICER)
			# TO CONTINUE	TO CEASE
AVEGBIT	=	BIT1		
FLAGWRD2	=	STATE +2	# (030-044)	
			# (SET)	(RESET)
# BIT 15 FLAG 2				
DRIFTFLG	=	030D	# T3RUPT CALLS GYRO	T3RUPT DOES NO GYRO
			# COMPENSATION	COMPENSATION
DRFTBIT	=	BIT15		
# Page 50				
# BIT 14 FLAG 2				
R21MARK	=	031D	# OPTION ONE FOR	OPTION TWO FOR
			# MARKRUPT	MARKRUPT
R21BIT	=	BIT14		
# BIT 13 FLAG 2				
22DSPFLG	=	032D	# DISPLAY DR,DV	DO NOT DISPLAY DR,DV
22DSPBIT	=	BIT13		
# BIT 12 FLAG 2				
P21FLAG	=	033D	# SUCCEEDING PASS	1ST PASS THRU P21,
			# THRU P21, USE BASE	CALCULATE BASE
P21BIT	=	BIT12	# VECTOR FOR CALC.	VECTOR
STEERSW	=	034D	# STEERING TO BE DONE	STEERING OMITTED

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STEERBIT	=	BIT11		
# BIT 10 FLAG 2				
SKIPVHF	=	035D	# DISREGARD RADAR	RADAR READ TO
			# READ BECAUSE OF	PROCEED NORMALLY
SKIPVBIT	=	BIT10	# SFTWRE OR HDWRE	
			# RESTART	
# BIT 9 FLAG 2				
IMPULSW	=	036D	# MINIMUM IMPULSE	STEERING BURN (NO
			# BURN (CUTOFF TIME	CUTOFF TIME YET
			# SPECIFIED)	AVAILABLE)
IMPULBIT	=	BIT9		
# BIT 8 FLAG 2				
XDELVFLG	=	037D	# EXTERNAL DELTAV VG	LAMBERT (AIMPOINT)
			# COMPUTATION	VG COMPUTATION
XDELVBIT	=	BIT8		
# BIT 7 FLAG 2				
ETPIFLAG	=	038D	# ELEVATION ANGLE	TPI TIME SUPPLIED
			# SUPPLIED FOR P34,74	FOR P34,74
# BIT 7 FLAG 2				
FIRSTFLG	=	ETPIFLAG	# FIRST PASS	SUCCEEDING PASS THRU
			# THRU S40.9	S40.9
FIRSTBIT	=	BIT7		
# BIT 7 FLAG 2				
# Page 51				
OPTNSW	=	ETPIFLAG	# SOI PHASE P38/P78	SOR PHASE OF P38/P78
FINALBIT	=	BIT6		
# BIT 6 FLAG 2				
FINALFLG	=	039D	# LAST PASS THROUGH	INTERIM PASS THROUGH
			# RENDEZVOUS PROGRAM	RENDEZVOUS PROGRAM
			# COMPUTATIONS	COMPUTATIONS
AVFLBIT	=	BIT5		
# BIT 5 FLAG 2				

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AVFLAG	=	040D	# LEM IS ACTIVE # VEHICLE	CSM IS ACTIVE VEHICLE
# BIT 4 FLAG 2 PFRATFLG	=	041D	# PREFERRED ATTITUDE # COMPUTED	PREFERRED ATTITUDE NOT COMPUTED
PFRATBIT	=	BIT4		
# BIT 3 FLAG 2	=	042D		
# BIT 2 FLAG 2 CALCMAN2	=	043D	# PERFORM MANEUVER # STARTING PROCEDURE	BYPASS STARTING PROCEDURE
CALC2BIT	=	BIT2		
# BIT 1 FLAG 2 NODOFLAG	=	044D	# V37 NOT PERMITTED	V37 PERMITTED
NODOBIT	=	BIT1		
FLAGWRD3	=	STATE +3	# (045-059) # (SET)	(RESET)
# BIT 15 FLAG 3	=	045D		
# BIT 14 FLAG 3 GLOKFAIL	=	046D	# GIMBAL LOCK HAS # OCCURRED	NOT IN GIMBAL LOCK
GLOKFBIT	=	BIT14		
# Page 52				
# BIT 13 FLAG 3 REFSMFLG	=	047D	# REFSMMAT GOOD	REFSMMAT NO GOOD
REFSMBIT	=	BIT13		
# BIT 12 FLAG 3 LUNAFLAG	=	048D	# LUNAR LAT-LONG	EARTH LAT-LONG
LUNABIT	=	BIT12		



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# BIT 11 FLAG 3 P22MKFLG	=	049D	# P22 DOWNLINKED MARK # DATA WAS JUST TAKEN	P22 DOWNLINK MARK DATA NOT JUST TAKEN
P22MKBIT	=	BIT11		
# BIT 10 FLAG 3 VFLAG	=	050D	# LESS THAN TWO STARS # IN FIELD OF VIEW	TWO STARS IN FIELD OF VIEW
VFLAGBIT	=	BIT10		
# BIT 9 FLAG 3	=	051D		
# BIT 8 FLAG 3 PRECIFLG	=	052D	# CSMPREC OR LEMPREC # OR INTEGRVS CALLED	INTEGRV CALLED
PRECIBIT	=	BIT8		
# BIT 7 FLAG 3 CULTFLAG	=	053D	# STAR OCCULTED	STAR NOT OCCULTED
CULTBIT	=	BIT7		
# BIT 6 FLAG 3 ORBWFLAG	=	054D	# W MATRIX VALID FOR # ORBITAL NAVIGATION	W MATRIX INVALID FOR ORBITAL NAVIGATION
ORBWFBIT	=	BIT6		
# BIT 5 FLAG 3 STATEFLG	=	055D	# PERMANENT STATE # VECTOR UPDATED	PERMANENT STATE VECTOR NOT UPDATED
STATEBIT	=	BIT5		
# BIT 4 FLAG 3 INTYPFLG # Page 53 INTYBIT	=	056D  BIT4	# CONIC INTEGRATION	ENCKE INTEGRATION
# BIT 3 FLAG 3 VINTFLAG	=	057D	# CSM STATE VECTOR	LEM STATE VECTOR

			# BEING INTEGRATED	BEING INTEGRATED
VINTFBIT	=	BIT3		
# BIT 2 FLAG 3 D6OR9FLG	=	058D	# DIMENSION OF W IS 9 # FOR INTEGRATION	DIMENSION OF W IS 6 FOR INTEGRATION
D6OR9BIT	=	BIT2		
# BIT 1 FLAG 3 DIMOFLAG	=	059D	# W MATRIX IS TO BE # USED	W MATRIX IS NOT TO BE USED
FLAGWRD4	=	STATE +4	# (060-074) # (SET)	(RESET)
DIMOBIT	=	BIT1		
# BIT 15 FLAG 4 MRKIDFLG	=	060D	# MARK DISPLAY IN # ENDIDLE	NO MARK DISPLAY IN ENDIDLE
MRKIDBIT	=	BIT15		
# BIT 14 FLAG 4 PRIODFLG	=	061D	# PRIORITY DISPLAY IN # ENDIDLE	NO PRIORITY DISPLAY IN ENDIDLE
PRIODBIT	=	BIT14		
# BIT 13 FLAG 4 NRMIDFLG	=	062D	# NORMAL DISPLAY IN # ENDIDLE	NO NORMAL DISPLAY IN ENDIDLE
NRMIDBIT	=	BIT13		
# BIT 12 FLAG 4 PDSPFLAG	=	063D	# CAN'T INTERRUPT # PRIORITY DISPLAY	SEE M. HAMILTON
PDSPFBIT	=	BIT12		
# BIT 11 FLAG 4 MWAITFLG	=	064D	# HIGHER PRIORITY	NO HIGHER PRIORITY

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MWAITBIT	=	BIT11	# DISPLAY OPERATING # WHEN MARK DISPLAY # INITIATED	DISPLAY OPERATING WHEN MARK DISPLAY INITIATED
# BIT 10 FLAG 4 NWAITFLG	=	065D	# HIGHER PRIORITY # DISPLAY OPERATING # WHEN NORMAL # DISPLAY INITIATED	NO HIGHER PRIORITY DISPLAY OPERATING WHEN NORMAL DISPLAY INITIATED
NWAITBIT	=	BIT10		
# BIT 9 FLAG 4 MRKNVFLG	=	066D	# ASTRONAUT USING # KEYBOARD WHEN MARK # DISPLAY INITIATED	ASTRONAUT NOT USING KEYBOARD WHEN MARK DISPLAY INITIATED
MRKNVBIT	=	BIT9		
# BIT 8 FLAG 4 NRMNVFLG	=	067D	# ASTRONAUT USING # KEYBOARD WHEN # NORMAL DISPLAY # INITIATED	ASTRONAUT NOT USING KEYBOARD WHEN NORMAL DISPLAY INITIATED
NRMNVBIT	=	BIT8		
# BIT 7 FLAG 4 PRONVFLG	=	068D	# ASTRONAUT USING # KEYBOARD WHEN # PRIORITY DISPLAY # INITIATED	ASTRONAUT NOT USING KEYBOARD WHEN PRIORITY DISPLAY INITIATED
PRONVBIT	=	BIT7		
# BIT 6 FLAG 4 PINBRFLG	=	069D	# ASTRONAUT HAS # INTERFERED WITH # EXISTING DISPLAY	ASTRONAUT HAS NOT INTERFERED WITH EXISTING DISPLAY
PINBRBIT	=	BIT6		
# BIT 5 FLAG 4 MRUPTFLG	=	070D	# MARK DISPLAY # INTERRUPTED BY	MARK DISPLAY NOT INTERRUPTED BY

			# PRIORITY DISPLAY	PRIORITY DISPLAY
MRUPTBIT	=	BIT5		
# Page 55				
# BIT 4 FLAG 4				
NRUPTFLG	=	071D	# NORMAL DISPLAY	NORMAL DISPLAY NOT
			# INTERRUPTED BY	INTERRUPTED BY
			# PRIORITY OR MARK	PRIORITY OR MARK
			# DISPLAY	DISPLAY
NRUPTBIT	=	BIT4		
# BIT 3 FLAG 4				
MKOVFLAG	=	072D	# MARK DISPLAY OVER	NO MARK DISPLAY OVER
			# NORMAL	NORMAL
MKOVBIT	=	BIT3		
# BIT 2 FLAG 4			# DISPLAY BIT	
	=	073D	# CLEARED AT INTERVALS	
# BIT 1 FLAG 4				
XDSPFLAG	=	074D	# MARK DISPLAY NOT TO	NO SPECIAL MARK
			# BE INTERRUPTED	INFORMATION
XDSPBIT	=	BIT1		
FLAGWRD5	=	STATE +5	# (075-099)	
			# (SET)	(RESET)
# BIT 15 FLAG 5				
DSKYFLAG	=	075D	# DISPLAYS SENT TO	NO DISPLAYS TO DSKY
			# DSKY	
DSKYBIT	=	BIT15		
# BIT 14 FLAG 5				
RETROFLG	=	076D	# P37 PREMANEUVER	ORBIT NOT RETROGRADE
RETROBIT	=	BIT14	# ORBIT IS RETROGRADE	
# BIT 13 FLAG 5				
SLOWFLG	=	077D	# P37 TRANSEARTH	SLOW DOWN IS NOT
SLOWBIT	=	BIT13	# COAST SLOW DOWN	DESIRED
			# IS DESIRED	
# BIT 12 FLAG 5				

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V59FLAG	=	078D	# CALIBRATING FOR # P23	NORMAL MARKING FOR P23
V59FLBIT	=	BIT12		
# BIT 11 FLAG 5 # Page 56				
INCORFLG	=	079D	# FIRST INCORPORATION	SECOND INCORPORATION
INCORBIT	=	BIT11		
# BIT 10 FLAG 5				
RNGSCFLG	=	080D	# ANOTHER TAG FOR PRFTRKAT	
# BIT 10 FLAG 5				
PRFTRKAT	=	RNGSCFLG	# PREF TRACK ATT	+K AXIS TRACK ATT
PRFTRBIT	=	BIT10		
# BIT 9 FLAG 5				
DMENFLG	=	081D	# DIMENSION OF W IS 9 # FOR INCORPORATION	DIMENSION OF W IS 6 FOR INCORPORATION
DMENFBIT	=	BIT9		
# BIT 8 FLAG 5				
COMPUTER	=	082D	# COMPUTER IS CMC	COMPUTER IS LGC
COMPTBIT	=	BIT8		
# BIT 7 FLAG 5				
ENGONFLG	=	083D	# ENGINE TURNED ON	ENGINE TURNED OFF
ENGONBIT	=	BIT7		
# BIT 6 FLAG 5				
3AXISFLG	=	084D	# MANEUVER SPECIFIED # BY THREE AXES	MANEUVER SPECIFIED BY ONE AXIS
3AXISBIT	=	BIT6		
# BIT 5 FLAG 5				
GRRBKFLG	=	085D	# BACKUP GRR RECEIVED #	BACKUP GRR NOT RECEIVED
GRRBKBIT	=	BIT5		

# BIT 4 FLAG 5				
R60FLAG	=	086D	# R61 MUST USE R60	NORMAL R61
R60FLBIT	=	BIT4		
# BIT 3 FLAG 5				
SOLNSW	=	087D	# LAMBERT DOES NOT	LAMBERT CONVERGES OR
# Page 57				
			# CONVERGE, OR TIME-	TIME-RADIUS NON
			# RADIUS NEARLY CIRC.	CIRCULAR.
SOLNSBIT	=	BIT3		
# BIT 2 FLAG 5				
MGLVFLAG	=	088D	# LOCAL VERTICAL	MIDDLE GIMBAL ANGLE
			# COORDINATES	COMPUTED
			# COMPUTED	
MGLVFBIT	=	BIT2		
# BIT 1 FLAG 5				
RENDWFLG	=	089D	# W MATRIX VALID	W MATRIX INVALID
			# FOR RENDEZVOUS	FOR RENDEZVOUS
			# NAVIGATION	NAVIGATION
RENDWBIT	=	BIT1		
FLAGWRD6	=	STATE +6	# (090-104)	
			# (SET)	(RESET)
# BIT 15 FLAG 6				
DAPBIT1	=	090D	# 1 SATURN 1 TVC	0 RCS 0 NO
DAP1BIT	=	BIT15		
# BIT 14 FLAG 6				
DAPBIT2	=	091D	# 1 A/P 0 A/P	1 A/P 0 A/P
DAP2BIT	=	BIT14		
# BIT 13 FLAG 6				
STRULLSW	=	092D	# DO STEERULL	DO ULAGEOFF ONLY
STRULBIT	=	BIT13		
# BIT 13 FLAG 6				

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ENTRYDSP	=	STRULLSW	# DO ENTRY DISPLAY # VIA ENTRYVN.	OMIT ENTRY DISPLAY
ENDSPBIT	=	BIT13		
# BIT 12 FLAG 6 CMDAPARM	=	093D	# ALLOW ENTRY FIRINGS # AND CALCULATIONS	INHIBIT ENTRY FIRING AND CONTROL FUNCTION
# Page 58 CMDARMBIT	=	BIT12		
# BIT 11 FLAG 6 GAMDIFSW	=	094D	# CALCULATE GAMDOT #	GAMDOT NOT TO BE CALCULATED
GMDIFBIT	=	BIT11		
# BIT 10 FLAG 6 GONEPAST	=	095D	# LATERAL CONTROL # CALCULATIONS TO BE # OMITTED	LATERAL CONTROL CALCULATIONS TO BE DONE
GONEBIT	=	BIT10		
# BIT 9 FLAG 6 RELVELSW	=	096D	# TARGETING USES # EARTH-RELATIVE # VELOCITY.	TARGETING USES INERTIAL VELOCITY
RELVBIT	=	BIT9		
# BIT 8 FLAG 6 EGSW	=	097D	# IN FINAL PHASE	NOT IN FINAL PHASE
EGFLGBIT	=	BIT8		
# BIT 8 FLAG 6 KNOWNFLG	=	EGSW	# LANDMARK KNOWN	LANDMARK UNKNOWN
KNOWNBIT	=	BIT8		
# BIT 8 FLAG 6 R57FLAG	=	KNOWNFLG	# DO NOT DO R57 # TRUNION BIAS HAS # BEEN OBTAINED.	DO R57, TRUNION BIAS NEEDED

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R57BIT = BIT8

# BIT 7 FLAG 6  
NOSWITCH = 098D

# LATERAL ROLL LATERAL ROLL MANEUVER  
# MANEUVER INHIBITED PERMITTED IN ENTRY  
# IN ENTRY

NOSWBIT = BIT7

# BIT 6 FLAG 6  
HIND = 099D

# ITERATING HUNTEST ITERATING OF HUNTEST  
# CALCULATIONS TO BE CALCULATIONS TO BE  
# DONE AFTER RANGE OMITTED AFTER RANGE  
# PREDICTION PREDICTION

# Page 59

HINDBIT = BIT6

# BIT 5 FLAG 6  
INRLSW = 100D

# INITIAL ROLL INITIAL ROLL  
# V(LV) V(LV)

INRLBIT = BIT5

# ATTITUDE NOT HELD ATTITUDE HELD

# BIT 4 FLAG 6  
LATSW = 101D

# DOWNLIFT NOT DOWNLIFT INHIBITED  
# INHIBITED

LATSWBIT = BIT4

# BIT 3 FLAG 6  
.05GSW = 102D

# DRAG OVER .05G DRAG LESS THAN .05G

.05GBIT = BIT3

# BIT 3 FLAG 6  
= 102D

# BIT 2 FLAG 6  
CM/DSTBY = 103D

# ENTRY DAP ACTIVATED ENTRY DAP NOT  
# ACTIVATED

CM/DSBIT = BIT2



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# BIT 1 FLAG 6 GYMDIFSW	=	104D	# CDU DIFFERENCES AND # BODY RATES COMPUTED #	CDU DIFFERENCES AND BODY RATES NOT COMPUTED
GYMDIBIT	=	BIT1		
FLAGWRD7	=	STATE +7	# (105-119) # (SET)	(RESET)
# BIT 15 FLAG 7 TERMIFLG	=	105D	# TERMINATE R52	DO NOT TERMINATE R52
TERMIBIT	=	BIT15		
# BIT 14 FLAG 7 ITSWICH	=	106D	# ACCEPT NEXT LAMBERT # TPI SEARCH SOLUTION	TEST LAMBERT ANSWER AGAINST LIMITS
# Page 60				
ITSWBIT	=	BIT14		
# BIT 13 FLAG 7 IGNFLAG	=	107D	# TIG HAS ARRIVED	TIG HAS NOT ARRIVED
IGNFLBIT	=	BIT13		
# BIT 12 FLAG 7 ASTNFLAG	=	108D	# ASTRONAUT HAS # OKAYED IGNITION	ASTRONAUT HAS NOT OKAYED IGNITION
ASTNBIT	=	BIT12		
# BIT 11 FLAG 7 TIMRFLAG	=	109D	# CLOKTASK OPERATING	CLOKTASK INOPERATIVE
TIMRBIT	=	BIT11		
# BIT 10 FLAG 7 NORMSW	=	110D	# UNIT NORMAL INPUT # TO LAMBERT.	LAMBERT COMPUTE ITS OWN UNIT NORMAL.
NORMSBIT	=	BIT10		
# BIT 9 FLAG 7 RVSW	=	111D	# DO NOT COMPUTE FINAL	COMPUTE FINAL STATE

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			# STATE VECTOR IN	VECTOR IN TIME-THETA
			# TIME-THETA	
RVSDBIT	=	BIT9		
# BIT 8 FLAG 7				
GONEBY	=	112D	# PASSED TARGET	APPROACHING TARGET
GONBYBIT	=	BIT8		
# BIT 7 FLAG 7				
	=	113D		
# BIT 6 FLAG 7				
V37FLAG	=	114D	# AVERAGEG (SERVICER)	AVERAGEG (SERVICER)
			# RUNNING	OFF
V37FLBIT	=	BIT6		
# BIT 5 FLAG 7				
	=	115D		
# Page 61				
	=	BIT5		
# BIT 4 FLAG 7				
UPLOCKFL	=	116D	# K-KBAR-K FAIL	NO K-KBAR-K FAIL
UPLOCBIT	=	BIT4		
# BIT 3 FLAG 7				
VERIFLAG	=	117D	# CHANGED WHEN V33E OCCURS AT END OF P27	
VERIFBIT	=	BIT3		
# BIT 2 FLAG 7				
ATTCHFLG	=	118D	# LM,CM ATTACHED	LM,CM NOT ATTACHED
ATTCHBIT	=	BIT2		
# BIT 1 FLAG 7				
TFFSW	=	119D	# CALCULATE TPERIGEE	CALCULATE TFF
TFFSWBIT	=	BIT1		
FLAGWRD8	=	STATE +8D	# (120-134)	
			# (SET)	(RESET)

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# BIT 15 FLAG 8				
RPQFLAG	=	120D	# RPQ NOT COMPUTED	RPQ COMPUTED
RPQFLBIT	=	BIT15		
# BIT 14 FLAG 8				
	=	121D		
# BIT 13 FLAG 8				
NEWIFLG	=	122D	# FIRST PASS THROUGH	SUCCEEDING ITERATION
			# INTEGRATION	OF INTEGRATION
NEWIBIT	=	BIT13		
# BIT 12 FLAG 8				
CMOONFLG	=	123D	# PERMANENT CSM STATE	PERMANENT CSM STATE
			# IN LUNAR SPHERE	IN EARTH SPHERE
CMOONBIT	=	BIT12		
# BIT 11 FLAG 8				
LMOONFLG	=	124D	# PERMANENT LM STATE	PERMANENT LM STATE
			# IN LUNAR SPHERE	IN EARTH SPHERE
LMOONBIT	=	BIT11		
# Page 62				
# BIT 10 FLAG 8				
ADVTRK	=	125D	# ADVANCE GROUND TRACK	NOT ADVANCED
			# SIGHTING WANTED	GROUND TRACK
ADVTKBIT	=	BIT10		
# BIT 9 FLAG 8				
P39/79SW	=	126D	# P39/79 OPERATING	P38/78 OPERATING
P39SWBIT	=	BIT9		
# BIT 8 FLAG 8				
SURFFLAG	=	127D	# LM ON LUNAR SURFACE	LM NOT ON LUNAR
			#	SURFACE
SURFFBIT	=	BIT8		

# BIT 7 FLAG 8 INFINFLG	=	128D	# NO CONIC SOLUTION # (CLOSURE THROUGH # INFINITY REQUIRED).	CONIC SOLUTION EXISTS.
INFINBIT	=	BIT7		
# BIT 6 FLAG 8 ORDERSW	=	129D	# ITERATOR USES 2ND # ORDER MINIMUM MODE	ITERATOR USES 1ST ORDER STANDARD MODE
ORDERBIT	=	BIT6		
# BIT 5 FLAG 8 APSESW	=	130D	# RDESIRED OUTSIDE # PERICENTER-APOCENTER # RANGE IN TIME-RAD	RDESIRED INSIDE PERICENTER-APOCENTER RANGE IN TIME-RADIUS
APSESBIT	=	BIT5		
# BIT 4 FLAG 8 COGAFLAG	=	131D	# NO CONIC SOLUTION # TOO CLOSE TO # RECTILINEAR (COGA # OVERFLOWS).	CONIC SOLUTION EXISTS (COGA DOES NOT OVERFLOW).
COGAFBIT	=	BIT4		
# Page 63				
# BIT 3 FLAG 8 V96ONFLG	=	132D	# P00 INTEGRATION HAS # BEEN INHIBITED BY # V96	P00 INTEGRATION IS PROCEEDING REGULARLY
# BIT 2 FLAG 8	=	133D		
# BIT 1 FLAG 8 360SW	=	134D	# TRANSFER ANGLE NEAR # 360 DEGREES	TRANSFER ANGLE NOT NEAR 360 DEGREES
360SWBIT	=	BIT1		
FLAGWRD9	=	STATE +9D	# (135-149) # (SET)	(RESET)

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# BIT 15 FLAG 9 SWTOVER	=	135D	# SWITCHOVER HAS # OCCURRED.	NO SWITCHOVER YET
SWTOVBIT	=	BIT15		
# BIT 14 FLAG 9	=	136D		
V67FLBIT	=	BIT14		
# BIT 13 FLAG 9 V82EMFLG	=	137D	# MOON VICINITY	EARTH VICINITY
V82EMBIT	=	BIT13		
# BIT 12 FLAG 9 MAXDBFLG	=	138D	# MAX DB SELECTED	MIN DB SELECTED
MAXDBBIT	=	BIT12		
# BIT 11 FLAG 9 V94FLAG	=	139D	# V94 ALLOWED DURING # P23	V94 NOT ALLOWED
V94FLBIT	=	BIT11		
# BIT 10 FLAG 9 SAVECFLG	=	140D	# P23 DISPLAY AND # DATA STORAGE AFTER	P23 DISPLAY AND DATA STORAGE BEFORE
# Page 64			# MARK IS DONE	MARK IS DONE
SAVECBIT	=	BIT10		
# BIT 9 FLAG 9 VHFRFLAG	=	141D	# ALLOW R22 TO # ACCEPT RANGE # DATA	STOP ACCEPTANCE OF RANGE DATA
VHFRBIT	=	BIT9		
# BIT 8 FLAG 9 SOURCFLG	=	142D	# SOURCE OF INPUT # DATA IS FROM # VHF RADAR	SOURCE OF INPUT DATA IS FROM OPTICS MARK

SOURCBIT = BIT8

# BIT 7 FLAG 9  
R22CAFLG = 143D

# R-22 CALCULATIONS R-22 CALCULATIONS  
# ARE GOING ON ARE NOT GOING ON

R22CABIT = BIT7

# BIT 6 FLAG 9  
N22ORN17 = 144D

# COMPUTE TOTAL COMPUTE TOTAL  
# ATTITUDE ERRORS ATTITUDE ERRORS  
# W.R.T. N22 (V62) W.R.T. N17 (V63)

N2217BIT = BIT6

# BIT 5 FLAG 9  
QUITFLAG = 145D  
QUITBIT = BIT5

# TERMINATE AND EXIT CONTINUE INTEGRATION  
# FROM INTEGRATION

# BIT 4 FLAG 9  
R31FLAG = 146D

# R31 SELECTED (V63) R34 SELECTED (V65)

R31FLBIT = BIT4

# BIT 3 FLAG 9  
MID1FLAG = 147D

# INTEGRATE TO TDEC INTEGRATE TO THE  
# THEN-PRESENT TIME

MID1FBIT = BIT3

# BIT 2 FLAG 9  
MIDAVFLG = 148D

# INTEGRATION ENTERED INTEGRATION WAS  
# FROM ONE OF MIDTOAV NOT ENTERED VIA  
# PORTALS MIDTOAV

# Page 65

MIDAVBIT = BIT2

# BIT 1 FLAG 9  
AVEMIDSW = 149D

# AVETOMID CALLING NO AVETOMID W INTEGE  
# FOR W MATRIX INTEGR ALLOW SET UP RN,VN,  
# DON'T WRITE OVER RN, PIPTIME  
# VN,PIPTIME

AVEMDBIT = BIT1

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FLGWRD10	=	STATE +10D	# (150-164) # (SET)	(RESET)
RASFLAG	=	STATE +10D		
# BIT 15 FLAG 10	=	150D		
# BIT 14 FLAG 10 INTFLAG	=	151D	# INTEGRATION IN # PROGRESS	INTEGRATION NOT IN PROGRESS
INTFLBIT	=	BIT14		
# BIT 13 FLAG 10	=	152D		
# BIT 12 FLAG 10	=	153D		
# BIT 11 FLAG 10	=	154D		
# BIT 10 FLAG 10	=	155D		
# BIT 9 FLAG 10	=	156D		
# BIT 8 FLAG 10	=	157D		
# Page 66				
# BIT 7 FLAG 10 REINTFLG	=	158D	# INTEGRATION ROUTINE # TO BE RESTARTED	INTEGRATION ROUTINE NOT TO BE RESTARTED
REINTBIT	=	BIT7		
# BIT 6 FLAG 10	=	159D		
# BIT 5 FLAG 10	=	160D		
# BIT 4 FLAG 10				

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                                =      161D

# BIT 3 FLAG 10
                                =      162D

# BIT 2 FLAG 10
                                =      163D

# BIT 1 FLAG 10
                                =      164D

FLGWRD11      =      STATE   +11D   # (165-179)
                                           # (SET)                (RESET)

# BIT 15 FLAG 11
S32.1F1      =      165D           # DELTAN AT CSI TIME      DVT1 LESS THAN MAX
S32BIT1      =      BIT15          # ONE EXCEEDS MAX

# BIT 14 FLAG 11
S32.1F2      =      166D           # FIRST PASS OF          REITERATION OF
S32BIT2      =      BIT14          # NEWTON INTEGRATION    NEWTON

# BIT 13 FLAG 11
S32.1F3A     =      167D           # BIT 13 AND BIT 12 FUNCTION AS AN ORDERED
S32BIT3A     =      BIT13          # PAIR (13,12) INDICATING THE POSSIBLE OC-
                                           # CURRENCE OF 2NEWTON ITERATIONS FOR S32.1
# BIT 12 FLAG 11
S32.1F3B     =      168D           # IN THE PROGRAM IN THE FOLLOWING ORDER:
# Page 67
S3229T3B     =      BIT12          # (0,1) (I.E. BIT 13 RESET, BIT 12 SET)
                                           #
                                           #      = FIRST NEWTON ITERATION BEING DONE
                                           # (0,0)= FIRST PASS OF 2ND NEWTON ITER.
                                           # (1,1)= 50 FPS STAGE OF 2ND NEWT ITER.
                                           # (1,0)= REMAINDER OF 2ND NEWT ITER.

# BIT 11 FLAG 11
                                =      169D

# BIT 10 FLAG 11
                                =      170D

# BIT 9 FLAG 11
                                =      171D

# BIT 8 FLAG 11
                                =      172D

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# BIT 7 FLAG 11  
= 173D

# BIT 6 FLAG 11  
= 174D

# BIT 5 FLAG 11  
= 175D

# BIT 4 FLAG 11  
= 176D

# BIT 3 FLAG 11  
= 177D

# BIT 2 FLAG 11  
= 178D

# BIT 1 FLAG 11  
= 179D

# Page 68

# GENERAL ERASABLE ASSIGNMENTS

SETLOC 61

# INTERRUPT TEMPORARY STORAGE POOL. (11D)

# (ITEMP1 THROUGH RUPTREG4)

# ANY OF THESE MAY BE USED AS TEMPORARIES DURING INTERRUPT OR WITH INTERRUPT INHIBITED. THE ITE  
# IS USED DURING CALLS TO THE EXECUTIVE AND WAITLIST -- THE RUPTREGS ARE NOT.

ITEMP1 ERASE  
WAITEXIT EQUALS ITEMP1  
EXECTEM1 EQUALS ITEMP1

ITEMP2 ERASE  
WAITBANK EQUALS ITEMP2  
EXECTEM2 EQUALS ITEMP2

ITEMP3 ERASE  
RUPTSTOR EQUALS ITEMP3  
WAITADR EQUALS ITEMP3  
NEWPRIO EQUALS ITEMP3

ITEMP4 ERASE

LOCCTR	EQUALS	ITEMP4	
WAITTEMP	EQUALS	ITEMP4	
ITEMP5	ERASE		
NEWLOC	EQUALS	ITEMP5	
ITEMP6	ERASE		
NEWLOC+1	EQUALS	ITEMP6	# DP ADDRESS.
	SETLOC	67	
NEWJOB	ERASE		# MUST BE AT LOC 67 DUE TO WIRING.
RUPTREG1	ERASE		
RUPTREG2	ERASE		
RUPTREG3	ERASE		
RUPTREG4	ERASE		
KEYTEMP1	EQUALS	RUPTREG4	
DSRUPTM	EQUALS	RUPTREG4	
# FLAGWORD RESERVATIONS.			(12D)
STATE	ERASE	+11D	
# PAD LOAD FOR DAPS			
EMDOT	ERASE		# I(1)PL (SPS FLOW RATE, SC AT B+3 KG/CS)
# Page 69			
# EXIT FOR V83			
STATEXIT	ERASE		# I(1) STQ ADDRESS FOR STATEXIT
# UNUSED ERASABLES ***** (2)			
ERASFILL	ERASE	+1	
# EXEC TEMPORARIES WHICH MAY BE USED BETWEEN CCS NEWJOBS			
# (INTB15+ THROUGH RUPTMXTM)			(32D)
INTB15+	ERASE		# REFLECTS 15TH BIT OF INDEXABLE ADDRESSES
DSEXIT	EQUALS	INTB15+	# RETURN FOR DSPIN
EXITEM	EQUALS	INTB15+	# RETURN FOR SCALE FACTOR ROUTINE SELECT
BLANKRET	EQUALS	INTB15+	# RETURN FOR 2BLANK
INTBIT15	ERASE		# SIMILAR TO ABOVE.
WRDRET	EQUALS	INTBIT15	# RETURN FOR 5BLANK.
WDRET	EQUALS	INTBIT15	# RETURN FOR DSPWD
DECRET	EQUALS	INTBIT15	# RETURN FOR PUTCOM(DEC LOAD)
21/22REG	EQUALS	INTBIT15	# TEMP FOR CHARIN

# THE REGISTERS BETWEEN ADDRWD AND PRIORITY MUST STAY IN THE FOLLOWING ORDER FOR INTERPRETIVE T

ADDRWD	ERASE		# 12 BIT INTERPRETIVE OPERAND SUB-ADDRESS.
POLISH	ERASE		# HOLDS CADR MADE FROM POLISH ADDRESSE.
UPDATRET	EQUALS	POLISH	# RETURN FOR UPDATNN, UPDATVB
CHAR	EQUALS	POLISH	# TEMP FOR CHARIN
ERCNT	EQUALS	POLISH	# COUNTER FOR ERROR LIGHT RESET
DECOUNT	EQUALS	POLISH	# COUNTER FOR SCALING AND DISPLAY (DEC)
FIXLOC	ERASE		# WORK AREA ADDRESS
OVFIND	ERASE		# SET NON-ZERO ON OVERFLOW.
VBUF	ERASE	+5	# TEMPORARY STORAGE USED FOR VECTORS.
SGNON	EQUALS	VBUF	# TEMP FOR +,- ON
NOUNTEM	EQUALS	VBUF	# COUNTER FOR MIXNOUN FETCH
DISTEM	EQUALS	VBUF	# COUNTER FOR OCTAL DISPLAY VERB
DECTEM	EQUALS	VBUF	# COUNTER FOR FETCH (DEC DISPLAY VERBS)
SGNOFF	EQUALS	VBUF +1	# TEMP FOR +,- ON
NVTEMP	EQUALS	VBUF +1	# TEMP FOR NVSUB
SFTEMP1	EQUALS	VBUF +1	# STORAGE FOR SF CONST HI PART (=SFTEMP2-1)
HITEMIN	EQUALS	VBUF +1	# TEMP FOR LOAD OF HRS,MIN,SEC
			# MUST = LOTEMIN-1.
CODE	EQUALS	VBUF +2	# FOR DSPIN
SFTEMP2	EQUALS	VBUF +2	# STORAGE FOR SF CONST LO PART (=SFTEMP1+1)
LOTEMIN	EQUALS	VBUF +2	# TEMP FOR LOAD OF HRS,MIN,SEC
# Page 70			
			# MUST = HITEMIN+1
MIXTEMP	EQUALS	VBUF +3	# FOR MIXNOUN DATA
SIGNRET	EQUALS	VBUF +3	# RETURN FOR +,- ON

# ALSO MIXTEMP+1 = VBUF+4, MIXTEMP+2 = VBUF+5

BUF	ERASE	+2	# TEMPORARY SCALAR STORAGE
BUF2	ERASE	+1	
INDEXLOC	EQUALS	BUF	# CONTAINS ADDRESS OF SPECIFIED INDEX.
SWWORD	EQUALS	BUF	# ADDRESS OF SWITCH WORD
SWBIT	EQUALS	BUF +1	# SWITCH BIT WITHIN THE SWITCH WORD
MPTEMP	ERASE		# TEMPORARY USED IN MULTIPLY AND SHIFT
DMPNTEMP	EQUALS	MPTEMP	# DMPSUB TEMPORARY
DOTINC	ERASE		# COMPONENT INCREMENT FOR DOT SUBROUTINE
DVSIGN	EQUALS	DOTINC	# DETERMINES SIGN OF DDV RESULT
ESCAPE	EQUALS	DOTINC	# USED IN ARCSIN/ARCCOS.
ENTRET	EQUALS	DOTINC	# EXIT FROM ENTER

DOTRET	ERASE		# RETURN FROM DOT SUBROUTINE
DVNORMCT	EQUALS	DOTRET	# DIVIDENT NORMALIZATION COUNT IN DDV.
ESCAPE2	EQUALS	DOTRET	# ALTERNATE ARCSIN/ARCCOS SWITCH
WDCNT	EQUALS	DOTRET	# CHAR COUNTER FOR DSPWD
INREL	EQUALS	DOTRET	# INPUT BUFFER SELECTION ( X,Y,Z, REG )
MATINC	ERASE		# VECTOR INCREMENT IN MXV AND VXM
MAXDVSW	EQUALS	MATINC	# +0 IF DP QUOTIENT IS NEAR ONE -- ELSE -1.
POLYCNT	EQUALS	MATINC	# POLYNOMIAL LOOP COUNTER
DSPMMTEM	EQUALS	MATINC	# DSPCOUNT SAVE FOR DSPMM
MIXBR	EQUALS	MATINC	# INDICATOR FOR MIXED OR NORMAL NOUN
TEM1	ERASE		# EXEC TEMP
POLYRET	EQUALS	TEM1	
DSREL	EQUALS	TEM1	# REL ADDRESS FOR DSPIN
TEM2	ERASE		# EXEC TEMP
DSMAG	EQUALS	TEM2	# MAGNITUDE STORE FOR DSPIN
IDADITEM	EQUALS	TEM2	# MIXNOUN INDIRECT ADDRESS STORAGE
TEM3	ERASE		# EXEC TEMP
COUNT	EQUALS	TEM3	# FOR DSPIN
TEM4	ERASE		# EXEC TEMP
LSTPTR	EQUALS	TEM4	# LIST POINTER FOR GRABUSY
RELRET	EQUALS	TEM4	# RETURN FOR RELDSP
FREERET	EQUALS	TEM4	# RETURN FOR FREEDSP
DSPWDRET	EQUALS	TEM4	# RETURN FOR DSPSIGN
SEPSCRET	EQUALS	TEM4	# RETURN FOR SEPSEC
SEPMNRET	EQUALS	TEM4	# RETURN FOR SEPMIN
TEM5	ERASE		# EXEC TEMP
# Page 71			
NOUNADD	EQUALS	TEM5	# TEMP STORAGE FOR NOUN ADDRESS
NNADTEM	ERASE		# TEMP FOR NOUN ADDRESS TABLE ENTRY
NNTYPTTEM	ERASE		# TEMP FOR NOUN TYPE TABLE ENTRY
IDAD1TEM	ERASE		# TEMP FOR INDIR ADDRESS TABLE ENTRY (MIXNN)
			# MUST = IDAD2TEM-1, = IDAD3TEM-2
IDAD2TEM	ERASE		# TEMP FOR INDIR ADDRESS TABLE ENTRY (MIXNN)
			# MUST = IDAD1TEM+1, IDAD3TEM-1.
IDAD3TEM	ERASE		# TEMP FOR INDIR ADDRESS TABLE ENTRY (MIXNN)
			# MUST = IDAD1TEM+2, IDAD2TEM+1.
RUTMXTEM	ERASE		# TEMP FOR SF ROUT TABLE ENTRY (MIXNN ONLY)

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```
# AX*SR*T STORAGE. (6D)
DEXDEX      EQUALS  TEM2      # B(1)TMP
DEX1        EQUALS  TEM3      # B(1)TMP
DEX2        EQUALS  TEM4      # B(1)TMP
RTNSAVER    EQUALS  TEM5      # B(1)TMP
TERM1TMP    EQUALS  BUF2      # B(2)TMP
```

```
DEXI        =          DEX1
```

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# DYNAMICALLY ALLOCATED CORE SETS FOR JOBS (84D)

```
MPAC        ERASE    +6      # MULTI-PURPOSE ACCUMULATOR.
MODE        ERASE      # +1 FOR TP, +0 FOR DP, OR -1 FOR VECTOR.
LOC         ERASE      # LOCATION ASSOCIATED WITH JOB.
BANKSET     ERASE      # USUALLY CONTAINS BBANK SETTING.
PUSHLOC     ERASE      # WORD OF PACKED INTERPRETIVE PARAMETERS.
PRIORITY    ERASE      # PRIORITY OF PRESENT JOB AND WORK AREA.

              ERASE    +71D   # SEVEN SETS OF 12 REGISTERS EACH
```

# SPECIAL DOWNLINK BUFFER. -- OVERLAYED BY P27 STORAGE --

# P27 (UPDATE PROGRAM) STORAGE. -- OVERLAYS SPEC DNLNK BUFF -- (24D)

```
COMPNUMB    ERASE    +23D      # B(1)TMP NUMBER OF ITEMS TO BE UPLINKED.
UPOLDMOD    EQUALS  COMPNUMB +1 # B(1)TMP HOLDS INTERRUPTED PROGRAM NUMBER
UPVERB      EQUALS  UPOLDMOD +1 # B(1)TMP VERB NUMBER
UPCOUNT    EQUALS  UPVERB +1  # B(1)TMP UPBUFF INDEX
UPBUFF      EQUALS  UPCOUNT +1  # B(20D)
```

# MORE P27 STORAGE. (2D)

```
UPTMP      ERASE      # B(1)TMP SCRATCH
UPVERBSV   ERASE      # B(1)TMP
INTWAK1Q   EQUALS  UPTMP # (06D)
# (20 REGISTERS OF ENTRY DOWNLINK WILL GO HERE.)
```

# THE FOLLOWING ARE INDEXED FOR TM. IN ENTRY DAP.

```
CMTMTIME    =          UPBUFF      # B(1) (VEHICLE BODY RATE INFO IS
SW/NDX      =          CMTMTIME +1  # B(1)  TELEMETERED EACH 0.2 SEC. DURING
ENDBUF      =          CMTMTIME +16D # B(1)  ENTRY.)

V1          =          ENDBUF +1    # I(2) REENTRY, P64-P65
A0          =          V1 +2        # I(2) REENTRY, P64-P65
```

# HI-ORDER WORD ONLY ON DNLNK.

# ALIGNMENT STORAGE. (5D)

# (CANNOT SHARE WITH PRECISION INTEGRATION OR KEPLER STORAGE.)

QMAJ	EQUALS	COMPNUMB	# B(1)TMP
MARKINDX	EQUALS	QMAJ +1	# B(1)TMP
BESTI	EQUALS	MARKINDX +1	# I(1)TMP
BESTJ	EQUALS	BESTI +1	# I(1)TMP
STARIND	EQUALS	BESTJ +1	# I(1)TMP

# Page 73

# ALIGNMENT/S40.2,3 COMMON STORAGE. (18D)

XSMD	EQUALS	UPBUFF +2	# I(6)TMP
YSMD	EQUALS	XSMD +6	# I(6)TMP
ZSMD	EQUALS	YSMD +6	# I(6)TMP

XSCREF	=	XSMD	# SPACE CRAFT AXES IN REF COORDS.
YSCREF	=	YSMD	
ZSCREF	=	ZSMD	
ZPRIME	=	22D	
PDA	=	22D	
COSTH	=	16D	
SINTH	=	18D	
THETA	=	20D	
STARM	=	32D	

# DOWNLINK STORAGE (18D)

DNLSTADR	EQUALS	DNLSTCOD	# CONTENTS NO LONGER AN ADDR BUT A CODE
DNLSTCOD	ERASE		# B(1)PRM ID CODE OF DOWNLIST
DUMPCNT	ERASE		# B(1)PRM
LDATAST	ERASE		# B(1)
DNTMGOTO	ERASE		# B(1)
TMINDEX	ERASE		# B(1)
DUMPLOC	EQUALS	TMINDEX	# CONTAINS ECADR OF AGC DP WORD BEING DUMPED
			# AND COUNT OF COMPLETE DUMPS ALREADY
			# SENT.
DNQ	ERASE		# B(1)
DNTMBUFF	ERASE	+11D	# B(12)PRM DOWNLINK SNAPSHOT BUFFER

# OPTICS MARKING, UNSHARED. (8D)

MKNDX	ERASE
-------	-------

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MKT2T1           ERASE    +1  
MKCDUY           ERASE  
MKCDUS           ERASE  
MKCDUZ           ERASE  
MKCDUT           ERASE  
MKCDUX           ERASE

# FOR EXCLUSIVE USE OF SYS TEST STANDARD LEAD INS           (2)  
EBUF2            ERASE    +1                   # B(2) UNSHARED

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# UNSWITCHED FOR DISPLAY INTERFACE ROUTINES.           (10D)

RESTREG           ERASE                       # B(1)PRM FOR DISPLAY RESTARTS.  
NVWORD            ERASE  
MARKNV            ERASE  
NVSAVE            ERASE  
# (RETAIN THE ORDER OF CADRFLSH TO FAILREG +2 FOR DOWNLINK PURPOSES)  
CADRFLSH           ERASE                       # B(1)TMP  
CADRMARK           ERASE                       # B(1)TMP  
TEMPFLSH           ERASE                       # B(1)TMP  
FAILREG           ERASE    +2                   # B(3)PRM 3 ALARM CODE REGISTERS

SETLOC 400

# VAC AREAS. -- BE CAREFUL OF PLACEMENT --           (220D)

VAC1USE           ERASE                       # B(1)PRM  
VAC1              ERASE    +42D                # B(43)PRM  
VAC2USE           ERASE                       # B(1)PRM  
VAC2              ERASE    +42D                # B(43)PRM  
VAC3USE           ERASE                       # B(1)PRM  
VAC3              ERASE    +42D                # B(43)PRM  
VAC4USE           ERASE                       # B(1)PRM  
VAC4              ERASE    +42D                # B(43)PRM  
VAC5USE           ERASE                       # B(1)PRM  
VAC5              ERASE    +42D                # B(43)PRM

# WAITLIST REPEAT FLAG.                       (1D)  
RUPTAGN           ERASE                       # B(1)PRM  
KEYTEMP2          =           RUPTAGN

# STARALIGN ERASABLES.                       (13D)

STARCODE           ERASE                       # B(1)DSP NOUN 70 FOR P22,51 AND R52,53  
STARALGN           ERASE    +11D

SINCDU	=	STARALGN
COSCDU	=	STARALGN +6

SINCDUX	=	SINCDU +4
SINCDUY	=	SINCDU
SINCDUZ	=	SINCDU +2
COSCDUX	=	COSCDU +4
COSCDUY	=	COSCDU
COSCDUZ	=	COSCDU +2

# PHASE TABLE AND RESTART COUNTERS (12D)

# Page 75

-PHASE1	ERASE	# B(1)PRM
PHASE1	ERASE	# B(1)PRM
-PHASE2	ERASE	# B(1)PRM
PHASE2	ERASE	# B(1)PRM
-PHASE3	ERASE	# B(1)PRM
PHASE3	ERASE	# B(1)PRM
-PHASE4	ERASE	# B(1)PRM
PHASE4	ERASE	# B(1)PRM
-PHASE5	ERASE	# B(1)PRM
PHASE5	ERASE	# B(1)PRM
-PHASE6	ERASE	# B(1)PRM
PHASE6	ERASE	# B(1)PRM

# A\*\*SR\*T STORAGE (6D)

CDUSPOT	ERASE	+5	# B(6)
---------	-------	----	--------

CDUSPOTY	=	CDUSPOT
CDUSPOTZ	=	CDUSPOT +2
CDUSPOTX	=	CDUSPOT +4

# VERB 37 STORAGE (2D)

MINDEX	ERASE	# B(1)TMP INDEX FOR MAJOR MODE
MMNUMBER	ERASE	# B(1)TMP MAJOR MODE REQUESTED BY V37

# PINBALL INTERRUPT ACTION (1D)

DSPCNT	ERASE	# B(1)PRM COUNTER FOR DSPOUT
--------	-------	------------------------------

# PINBALL EXECUTIVE ACTION (44D)

DSPCOUNT	ERASE	# DISPLAY POSITION INDICATOR
----------	-------	------------------------------



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DECBRNCH	ERASE		# +DEC, -DEC, OCT INDICATOR
VERBREG	ERASE		# VERB CODE
NOUNREG	ERASE		# NOUN CODE
XREG	ERASE		# R1 INPUT BUFFER
YREG	ERASE		# R2 INPUT BUFFER
ZREG	ERASE		# R3 INPUT BUFFER
XREGLP	ERASE		# L0 PART OF XREG (FOR DEC CONV ONLY)
YREGLP	ERASE		# L0 PART OF YREG (FOR DEC CONV ONLY)
HITEMOUT	=	YREGLP	# TEMP FOR DISPLAY OF HRS,MIN,SEC
			# MUST = L0TEMOUT-1.
ZREGLP	ERASE		# L0 PART OF ZREG (FOR DEC CONV ONLY)
LOTEMOUT	=	ZREGLP	# TEMP FOR DISPLAY OF HRS,MIN,SEC
			# MUST = HITEMOUT+1
# Page 76			
MODREG	ERASE		# MODE CODE
DSPLOCK	ERASE		# KEYBOARD/SUBROUTINE CALL INTERLOCK
REQRET	ERASE		# RETURN REGISTER FOR LOAD
LOADSTAT	ERASE		# STATUS INDICATOR FOR LOADTST
CLPASS	ERASE		# PASS INDICATOR FOR CLEAR
NOUT	ERASE		# ACTIVITY COUNTER FOR DSPTAB
NOUNCADR	ERASE		# MACHINE CADR FOR NOUN
MONSAVE	ERASE		# N/V CODE FOR MONITOR. (= MONSAVE1-1)
MONSAVE1	ERASE		# NOUNCADR FOR MONITOR (MATBS) = MONSAVE+1
MONSAVE2	ERASE		# B(1)PRM NVMONOPT OPTIONS
DSPTAB	ERASE	+11D	# 0-100, DISPLAY PANEL BUFF. 11D, C/S LTS.
NVQTEM	ERASE		# NVSUB STORAGE FOR CALLING ADDRESS
			# MUST = NVBNKTEM-1.
NVBNKTEM	ERASE		# NVSUB STORAGE FOR CALLING BANK
			# MUST = NVQTEM+1
VERBSAVE	ERASE		# NEEDED FOR RECYCLE
CADRSTOR	ERASE		# ENDIDLE STORAGE
DSPLIST	ERASE		# WAITING REG FOR DSP SYST INTERNAL USE
EXTVBACT	ERASE		# EXTENDED VERB ACTIVITY INTERLOCK
DSPTM1	ERASE	+2	# BUFFER STORAGE AREA 1 (MOSTLY FOR TIME)
DSPTM2	ERASE	+2	# BUFFER STORAGE AREA 2 (MOSTLY FOR DEG)
DSPTMX	EQUALS	DSPTM2 +1	# B(2) S-S DISPLAY BUFFER FOR EXT. VERBS
NORMTEM1	EQUALS	DSPTM1	# B(3)DSP NORMAL DISPLAY REGISTERS.
# DISPLAY FOR EXTENDED VERBS (2D)			
OPTIONX	EQUALS	DSPTMX	# B(2) EXTENDED VERB OPTION CODE N12(V82)
# TBASE'S AND PHSPRDT'S. (12D)			
TBASE1	ERASE		# B(1)PRM

PHSPRDT1	ERASE	# B(1)PRM
TBASE2	ERASE	# B(1)PRM
PHSPRDT2	ERASE	# B(1)PRM
TBASE3	ERASE	# B(1)PRM
PHSPRDT3	ERASE	# B(1)PRM
TBASE4	ERASE	# B(1)PRM
PHSPRDT4	ERASE	# B(1)PRM
TBASE5	ERASE	# B(1)PRM
PHSPRDT5	ERASE	# B(1)PRM
TBASE6	ERASE	# B(1)PRM
PHSPRDT6	ERASE	# B(1)PRM

# UNSWITCHED FOR DISPLAY INTERFACE ROUTINES. (5D)

# Page 77

EBANKSAV	ERASE
MARKEBAN	ERASE
EBANKTEM	ERASE
MARK2PAC	ERASE
R1SAVE	ERASE

# IMU COMPENSATION UNSWITCHED ERASABLE. (1D)

1/PIPADT	ERASE	# B(1)PRM
OLDBT1	=	1/PIPADT

# SINGLE PRECISION SUBROUTINE TEMPORARIES (3D)

# SPSIN, SPCOS, SPROOT VARIABLES.

# DO NOT SHARE. THESE ARE USED BY DAPS IN I

# AND CURRENTLY ARE NOT PROTECTED. IF OTHER

# MATERIALIZE, THEN THIS CAN BE CHANGED.

HALFY	ERASE
ROOTRET	ERASE
SQRARG	ERASE
TEMK	EQUALS HALFY
SQ	EQUALS ROOTRET

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# UNSWITCHED FOR ORBIT INTEGRATION (21D)

TDEC	ERASE	+20D	# I(2)
COLREG	EQUALS	TDEC +2	# I(1)
LAT	EQUALS	COLREG +1	# I(2)DSP NOUN 43,67 FOR P20,22,51 R52,53.
LANDLAT	=	LAT	# NOUN 89 FOR P22.
LONG	EQUALS	LAT +2	# I(2)DSP NOUN 43,67 FOR P20,22,51 R52,53
ALT	EQUALS	LONG +2	# I(2)DSP NOUN 43 FOR P20,22,51 R52,53.

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YV	EQUALS	ALT +2	# I(6)
ZV	EQUALS	YV +6	# I(6)
# MARK STORAGE.			(2)
VHFCNT	ERASE		# B(1)PRM NO. OF VHF MARKS (P20 (R22)).
TRKMKCNT	ERASE		# B(1)PRM NO. OF VHF MARKS (P20 (R22)).
MARKCTR	=	TRKMKCNT	# B(1) MARK COUNTER USED BY R32
# MISCELLANEOUS UNSWITCHED.			(16D)
IRETURN1	ERASE		# B(1) RET ADDR USED BY MIDTOAV1 AND 2
			# CALLED BY P40,P41,P42, P61,P62
RATEINDX	ERASE		# (1) USED BY KALCMANU
OPTION1	ERASE		# B(1) NOUN 06 USES THIS.
OPTION2	ERASE		# B(1) NOUN 06 USES THIS.
LONGCADR	ERASE	+1	# B(2) LONGCALL REGISTER.
LONGBASE	ERASE	+1	# B(2) LONGCALL REGISTER.
LONGTIME	ERASE	+1	# B(2) LONGCALL REGISTER.
DELAYLOC	ERASE	+3	
NVWORD1	ERASE		# B(1)
TEMPR60	ERASE		# B(1)
PRIOTIME	ERASE		# B(1)
P30/RET	EQUALS	IRETURN1	
# MISC. INCLUDING RESTART COUNTER, GIMBAL ANGLE SAVE AND			
# STANDBY VERB ERASABLES. REDOCTR BEFORE THETAD (DWNLNK)			(16D)
TIME2SAV	ERASE	+1	# B(2)TMP
SCALSAVE	ERASE	+1	# B(2)TMP
REDOCTR	ERASE		# B(1)PRM CONTAINS NUMBER OF RESTARTS
THETAD	ERASE	+2	# B(3)PRM DESIRED GIM ANGLES FOR MANEUVER
CPHI	=	THETAD	# (OUTER)
CTHETA	=	THETAD +1	# (INNER)
CPSI	=	THETAD +2	# (MIDDLE)
# Page 79			
# ENTRY VARIABLES SHARED FOR TM.			
RDOTREF	=	THETAD	# I(2) P65
VREF	=	RDOTREF +2	# I(2) P65 HI-ORDER WORD ONLY DNLNK'D
DESOPTT	ERASE		# B(1)DSP NOUN 92 FOR P20,22,52, R52.
DESOPTS	ERASE		# B(1)DSP NOUN 92 FOR P20,22,52, R52.
DELV	ERASE	+5	# I(6)
DELVX	=	DELV	
DELVY	=	DELV +2	

DELVZ = DELV +4

# P20, CONICS (SHARING WITH TIME 2 SAV AND SCAL SAV ONLY) (3D)  
 POINTEX EQUALS TIME2SAV # I(1) POINT AXS EXIT  
 VHFTIME EQUALS POINTEX +1 # I(2) DOWNLINK OF VHF RANGE TIME +1M

# PERM STATE VECTORS FOR BOOST AND DOWNLINK -- WHOLE MISSION -- (14D)

RN ERASE +5 # B(6)PRM  
 VN ERASE +5 # B(6)PRM  
 PIPTIME ERASE +1 # B(2)PRM (MUST BE FOLLOWED BY GDT/2)

# SERVICER STORAGE. (45D)

# (SERVICER STORAGE AND P11 STORAGE IN UNSWITCHED SHOULD NOT  
 # OVERLAY EACH OTHER AND THE TOTAL ERASABLE REQUIRED SHOULD NOT  
 # EXCEED THE ERASABLE STORAGE REQUIRED BY RENDEZVOUS GUIDANCE.)

GDT/2 EQUALS PIPTIME +2 # B(6)TMP \*\* MUST FOLLOW PIPTIME \*\*  
 GOBL/2 EQUALS GDT/2 +6 # B(6)TMP  
 AVEGEXIT EQUALS GOBL/2 +6 # B(2)TMP  
 AVGEXIT = AVEGEXIT  
 TEMX EQUALS AVEGEXIT +2 # B(1)TMP  
 TEMY EQUALS TEMX +1 # B(1)TMP  
 TEMZ EQUALS TEMY +1 # B(1)TMP  
 PIPCTR EQUALS TEMZ +1 # B(1)TMP  
 PIPAGE EQUALS PIPCTR +1 # B(1)TMP  
 RN1 EQUALS PIPAGE +1 # B(6)TMP  
 VN1 EQUALS RN1 +6 # B(6)TMP  
 PIPTIME1 EQUALS VN1 +6 # B(2)TMP  
 GDT1/2 EQUALS PIPTIME1 +2 # B(6)TMP  
 GOBL1/2 EQUALS GDT1/2 +6 # B(6)TMP

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# ENTRY STORAGE (1D)

ENTRYVN EQUALS GOBL1/2 +6 # B(1)TMP VN CODE FOR ENTRY DISPLAYS P60'S.

# P11 STORAGE. (9D)

PADLONG EQUALS ENTRYVN # (2)PL LONGITUDE OF LAUNCH PAD.  
 LIFTTEMP EQUALS PADLONG +2 # (2)TMP  
 TEPHEM1 EQUALS LIFTTEMP +2 # (3)TMP  
 PGNCALT EQUALS TEPHEM1 +3 # (2)PL ALTITUDE

# RENDEZVOUS NAVIGATION STORAGE. (SEE COMMENT IN SERVICER STORAGE) (58D)

CSMPOS ERASE +57D # I(6)TMP  
 LEMPOS EQUALS CSMPOS +6 # I(6)TMP

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RCL	EQUALS	LEMPOS	+6	# I(2)TMP
MARKTIME	EQUALS	RCL	+2	# B(2)TMP
VTEMP	EQUALS	MARKTIME	+2	# B(6)TMP
UM	EQUALS	VTEMP	+6	# I(6)TMP
MARKDATA	EQUALS	UM	+6	# B(2)TMP
USTAR	EQUALS	MARKDATA	+2	# I(6)TMP
WIXA	EQUALS	USTAR	+6	# B(1)TMP
WIXB	EQUALS	WIXA	+1	# B(1)TMP
ZIXA	EQUALS	WIXB	+1	# B(1)TMP
ZIXB	EQUALS	ZIXA	+1	# B(1)TMP
DELTAX	EQUALS	ZIXB	+1	# I(18)TMP
VHFRANGE	EQUALS	DELTAX		# (2)
UCL	EQUALS	DELTAX	+12D	# (6) LM-CSM LINE OF SIGHT 1/2 UNIT V
# ***** CONICSEX (MEAS INC) *****				
TRIPA	EQUALS	DELTAX		
TEMPVAR	EQUALS	DELTAX	+3	
TEMPOR1	ERASE	+1		# B(2)TMP
# T4RUPT ERASABLE				(6D)
DSRUPTSW	ERASE			
OPTIND	ERASE			
LGYRO	ERASE			
COMMANDO	ERASE	+1		
# Page 81				
ZONE	ERASE			# B(1)PRM USED IN SHAFT STOP MONITOR
LASTYCND	=	OPTY		# DUMMY TO MAKE RR BENCH TEST ASSEMBLE
LASTXCND	=	OPTY		# DUMMY TO MAKE RR BENCH TEST ASSEMBLE
# UNSWITCHED DAP ERASABLE.				(4D)
T6LOC	ERASE			
T6ADR	ERASE			
T5LOC	ERASE	+1		
# MODE SWITCHING ERASABLE				(14D)
SWSAMPLE	ERASE			# B(1)PRM
DESOPMOD	ERASE			# B(1)PRM
WTOPTION	ERASE			# B(1)PRM
ZOPTCNT	ERASE			# B(1)PRM
IMODES30	ERASE			# B(1)PRM
IMODES33	ERASE			# B(1)PRM
MODECADR	ERASE	+2		# B(3)TMP

```

IMUCADR      =      MODECADR
OPTCADR      =      MODECADR +1
RADCADR      =      MODECADR +2
ATTCADR      ERASE   +2      # B(3)PRM
ATTPRIO      =      ATTCADR +2
MARKSTAT     ERASE
OPTMODES     ERASE      # B(1)PRM

# RCSDAP ERASABLE      (1D)
HOLDFLAG     ERASE      # B(1)PRM

# CRS61.1 STORAGE.  -- USED IN R63 (VERB 89) -- (5D)
CPHIX        ERASE   +2      # B(3)DSP NOUN 95 CALCULATED BY CRS61.1

TEVENT       ERASE   +1      # B(2) TIME OF EVENT FOR DOWNLIST
TLIFTOFF     =      TEVENT

# Page 82
# P34-P35 STORAGE      (1D)
NORMEX       ERASE

# SELF-CHECK ASSIGNMENTS      (17D)

SELFERAS     ERASE   1357 - 1377  # *** MUST NOT BE MOVED *** #
SFMAIL       EQUALS  SELFERAS      # B(1)
ERESTORE     EQUALS  SFMAIL +1     # B(1)
SELFRET      EQUALS  ERESTORE +1   # B(1) RETURN
SMODE        EQUALS  SELFRET +1    # B(1)
ALMCADR      EQUALS  SMODE +1      # B(2) ALARM ABORD USER'S 2CADR
ERCOUNT     EQUALS  ALMCADR +2    # B(1)
SCOUNT       EQUALS  ERCOUNT +1    # B(3)
SKEEP1       EQUALS  SCOUNT +3     # B(1)
SKEEP2       EQUALS  SKEEP1 +1     # B(1)
SKEEP3       EQUALS  SKEEP2 +1     # B(1)
SKEEP4       EQUALS  SKEEP3 +1     # B(1)
SKEEP5       EQUALS  SKEEP4 +1     # B(1)
SKEEP6       EQUALS  SKEEP5 +1     # B(1)
SKEEP7       EQUALS  SKEEP6 +1     # B(1)

# USED BY P30 ROUTINES TO WRITE ONLY NEVER READ IN COLOSSUS

DISPDEX      EQUALS  A

# ERASABLE FOR SXTMARK CDU CHECK DELAY.  -- PAD LOADED --      (1D)

CDUCHKWD     ERASE      # B(1)PL

```

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# R57 STORAGE. -- MUST BE UNSHARED EXCEPT IN BOOST OR ENTRY -- (1D)

TRUNBIAS           ERASE                           # B(1)PRM RESULT OF R57 CALIBR OF TRUNION

# KEPLER STORAGE   (6D)

XMODULO           ERASE   +1                   # I(2) GREATER 2PI KEPLER

TMODULO           ERASE   +1                   # I(2) GREATER 2 KEPLER

EPSILONT          ERASE   +1                   # I(2)TMP

# Page 83

# P37   \*\* RETURN TO EARTH (PAD LOAD \*\*\*\*           (2D)

RTED1            ERASE   +1                   # I(2)PL VGAMMA POLY COEF                   B-3

# P40   \*\*\* STEERING ROUTINE \*\*\* PAD LOAD           (1D)

DVTHRESH          ERASE                           # I(1)PL DELTA VTHRESHOLD FOR LOW THRUST  
#   ROUTINE                                   B-2

# P23   \*\*\* PAD LOAD \*\*\*\*                           (2D)

HORIZALT          ERASE   +1                   # I(2)PL HORIZON ALTITUDE                   M B-29

# P20   ALTERNATE LOS VARIANCE   PAD LOAD \*\*\*\*   (1D)

ALTVAR            ERASE                           # I(2)PL MILLARD, SQUARED SCALED 2  
END-UE            EQUALS   SELFERS +16D   # LAST USED UNSWITCHED ERASABLE

-16

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# EBANK-3 ASSIGNMENTS

SETLOC 1400

# WAITLIST TASK LISTS.                           (26D)

LST1            ERASE   +7                   # B(8D)PRM DELTA T'S.

LST2            ERASE   +17D                  # B(18D)PRM TASK 2CADR ADDRESSES.

# RESTART STORAGE.                               (2D)

RSBBQ            ERASE   +1                   # B(2)PRM SAVE BB AND Q FOR RESTARTS

# MORE LONGCALL STORAGE. (MUST BE IN LST1'S BANK.       (2D)

LONGEXIT	ERASE	+1	# B(2)TMP MAY BE SELDOM OVERLAYED
# PHASE-CHANGE LISTS PART II.			(12D)
PHSNAME1	ERASE		# B(1)PRM
PHSBB1	ERASE		# B(1)PRM
PHSNAME2	ERASE		# B(1)PRM
PHSBB2	ERASE		# B(1)PRM
PHSNAME3	ERASE		# B(1)PRM
PHSBB3	ERASE		# B(1)PRM
PHSNAME4	ERASE		# B(1)PRM
PHSBB4	ERASE		# B(1)PRM
PHSNAME5	ERASE		# B(1)PRM
PHSBB5	ERASE		# B(1)PRM
PHSNAME6	ERASE		# B(1)PRM
PHSBB6	ERASE		# B(1)PRM
# IMU COMPENSATION PARAMETERS			(22D)
PBIASX	ERASE		# B(1) PIPA BIAS, PIPA SCALE FACTOR TERMS
PIPABIAS	=	PBIASX	# INTERMIXED.
PIPASCFX	ERASE		
PIPASCF	=	PIPASCFX	
PBIASY	ERASE		
PIPASCFY	ERASE		
PBIASZ	ERASE		
PIPASCFZ	ERASE		
NBDX	ERASE		# GYRO BIAS DRIFT
GBIASX	=	NBDX	
NBDY	ERASE		
# Page 84			
NBDZ	ERASE		
ADIAX	ERASE		# ACCELERATION SENSITIVE DRIFT ALONG THE
ADIAY	ERASE		# INPUT AXIS
ADIAZ	ERASE		
ADSRAX	ERASE		# ACCELERATION SENSITIVE DRIFT ALONG THE
ADSRAY	ERASE		# SPIN REFERENCE AXIS
ADSRAZ	ERASE		
GCOMP	ERASE	+5	# CONTAINS COMPENSATING TORQUES
GCOMP SW	ERASE		



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```
COMMAND      EQUALS  GCOMP
CDUIND        EQUALS  GCOMP  +3
```

# STATE VECTORS FOR ORBIT INTEGRATION. (44D)

```
#          (DIFEQCNT THUR XKEP MUST BE IN THE SAME
#          EBANK AS RRECTCSM, RRECTLEM ETC
#          BECAUSE THE COPY CYCLES (ATOPCSM,
#          PTOACSM ETC) ARE EXECUTED IN BASIC.
#          ALL OTHER REFERENCES TO THIS GROUP
#          ARE BY INTERPRETIVE INSTRUCTIONS.)
#
```

```
DIFEQCNT      ERASE  +43D          # B(1)TMP
# (UPSVFLAG...XKEP MUST BE KEPT IN ORDER).
```

```
UPSVFLAG      EQUALS  DIFEQCNT +1    # B(1)PRM UPDATE FLAG
RRECT          EQUALS  UPSVFLAG +1    # B(6)TMP POS AT RECT      KM*2(-14)
VRECT          EQUALS  RRECT  +6      # B(6)TMP VEL AT RECT      KM(-1/2)*2(6)
TET            EQUALS  VRECT  +6      # B(2)TMP TIME OF STATE VECT  CSPCS*2(-28)
TDELTA        EQUALS  TET    +2      # B(6)TMP POSITION DEVIATION  KM*2(14)
TNUV           EQUALS  TDELTA +6      # B(6)TMP VEL DEVIATION     KM(-1/2)*2(14)
RCV            EQUALS  TNUV   +6      # B(6)TMP CONIC POSITION      KM*2(-14)
VCV            EQUALS  RCV    +6      # B(6)TMP CONIC VELOCITY     KM(-1/2)*2(6)
TC             EQUALS  VCV    +6      # B(2)TMP TIME SINCE RECITIFICATION
XKEP           EQUALS  TC     +2      # B(2)TMP ROOT OF KEPLER EQ  KM(1/2)*2(-10)
```

# \*\*\*\* TEMP -- IN VAC AREA \*\*\*\*

```
RRECT1        EQUALS  18D
VRECT1        EQUALS  24D
TET1          EQUALS  30D
```

# PERMANENT STATE VECTORS AND TIMES. (101D)

# (DO NOT OVERLAY WITH ANYTHING AFTER BOOST)

# Page 86

# (RRECTCSM...XKEPCSM MUST BE KEPT IN THIS ORDER)

```
RRECTCSM      ERASE  +5          # B(6)PRM CSM VARIABLES
RRECTHIS      =      RRECTCSM
VRECTCSM      ERASE  +5          # B(6)PRM
TETCSM        ERASE  +1          # B(2)PRM
TETHIS        =      TETCSM
DELTACSM      ERASE  +5          # B(6)PRM
NUVCMS        ERASE  +5          # B(6)PRM
```

RCVCSM	ERASE	+5	# B(6)PRM
VCVCSM	ERASE	+5	# B(6)PRM
TCCSM	ERASE	+1	# B(2)PRM
XKEPCSM	ERASE	+1	# B(2)PRM

# (RRECTLEM...XKEPLEM MUST BE KEPT IN THIS ORDER)

RRECTLEM	ERASE	+5	# B(6)PRM LEM VARIABLES
RRECTOTH	=	RRECTLEM	
VRECTLEM	ERASE	+5	# B(6)PRM
TETLEM	ERASE	+1	# B(2)PRM
TETOTHER	=	TETLEM	
DELTALEM	ERASE	+5	# B(6)PRM
NUVLEM	ERASE	+5	# B(6)PRM
RCVLEM	ERASE	+5	# B(6)PRM
VCVLEM	ERASE	+5	# B(6)PRM
TCLEM	ERASE	+1	# B(2)PRM
XKEPLEM	ERASE	+1	# B(2)PRM

X789	ERASE	+5	
TEPHEM	ERASE	+2	
AZO	ERASE	+1	
UNITW	ERASE	+5	
-AYO	EQUALS	UNITW	# (2)
AXO	EQUALS	UNITW +2	# (2)

# STATE VECTORS FOR DOWNLINK (12D)

R-OTHER	ERASE	+5	# B(6)PRM POS VECT (OTHER VECH) FOR DNLINK
V-OTHER	ERASE	+5	# B(6)PRM VEL VECT (OTHER VECH) FOR DNLINK
T-OTHER	=	TETLEM	# TIME (OTHER VECH) FOR DNLINK

# REFSMMAT. (18D)

REFSMMAT ERASE +17D # I(18D)PRM

# Page 87

# AVERAGEG INTEGRATOR STORAGE. (8D)

UNITR	ERASE	+5
RMAG	ERASE	+1

# P40 PAD LOADS (6D)

EK1VAL	ERASE	+1	# I(2)PL 1-SEC SPS IMPULSE NEWTSEC/100/B23
EK2VAL	ERASE	+1	# I(2)PL B+23 NEWTON-SEC/E+2
EK3VAL	ERASE		# I(1)PL B+09 NEWTONS/E+4

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FANG ERASE # I(1)PL SPS THRUST USED BY IMPULSIVE BURN

# \*\*\*\*\*LUNAR MODULE CHANGE \*\*\*\*\*

E3J22R2M EQUALS FANG +2

E32C31RM EQUALS E3J22R2M +1

# \*\*\*\* CONICSEX (PLANETARY INERT. ORIEN.) \*\*\*\*

TIMSUBO EQUALS TEPHEM # CSEC B-14 (TRIPLE PREC)

END-E3 EQUALS E32C31RM # NEXT UNUSED E3 ADDRESS

# Page 88

# EBANK-4 ASSIGNMENTS

SETLOC 2000

# P20 STORAGE. -- PAD LOADED -- (4D)

WRENDPOS	ERASE	# B(1)PL	M B-14
WRENDVEL	ERASE	# B(1)PL	M/CSECBO
RMAX	ERASE	# B(1)PL	METERS*2(-19)
VMAX	ERASE	# B(1)PL	M/CSEC*2(-7)

# P22 STORAGE. -- PAD LOADED -- (5D)

WORBPOS	ERASE	# B(1)PL	M B-14
WORBVEL	ERASE	# B(1)PL	M/CSECBO
S22WSUBL	ERASE	# B(1)PL	M B-14
RPVAR	ERASE +1	# B(2)PL	

# CONISEX STORAGE. -- PAD LOADED -- (6D)

504LM ERASE +5 # I(6) MOON LIBRATION VECTOR

# ENTRY STORAGE -- PAD LOADED -- (2D)

EMSALT ERASE +1 # I(2)PL

# P35 CONSTANTS. -- PAD LOADED -- (4D)

ATIGINC	ERASE +1	# B(2)PL
PTIGINC	ERASE +1	# B(2)PL

# LUNAR LANDING SIGHT DATA. -- PAD LOADED -- (6D)

# (USED BY INTEGRATION INITIALIZATION, LAT-LONG SUBROUTINES, P30'S)

RLS ERASE +5 # I(6) LANDING SIGHT VECTOR

# CONISEX (LUNAR AND SOLAR EPHEM) STORAGE. -- PAD LOADED -- (77D)

TIMEMO ERASE +76D

```

VECOEM      EQUALS  TIMEMO  +3
RESO        EQUALS  VECOEM  +60D

```

# Page 89

```

VESO        EQUALS  RESO    +6
OMEGAES     EQUALS  VESO    +6

```

# INTEGRATION STORAGE. (95D)

```

PBODY      ERASE      # I(1)
ALPHAV     EQUALS    PBODY  +1  # I(6)TMP
BETAV      EQUALS    ALPHAV +6  # I(6)TMP
PHIV       EQUALS    BETAV  +6  # I(6)TMP
PSIV       EQUALS    PHIV   +6  # I(6)TMP
FV         EQUALS    PSIV   +6  # I(6)TMP
BETAM      EQUALS    FV     +6  # I(6)TMP
H          EQUALS    BETAM  +2  # I(2)TMP
GMODE      EQUALS    H      +2  # I(1)TMP
IRETURN    EQUALS    GMODE  +1  # I(1)TMP
NORMGAM    EQUALS    IRETURN +1  # I(1)TMP
VECTAB     EQUALS    NORMGAM +1  # I(36)TMP
RPQV       EQUALS    VECTAB +36D # (6)TMP VECTOR PRIMARY TO SECONDARY BODY
ORIGEX     EQUALS    RPQV   +6  # B(1)TMP QSAVE FOR COORD. SWITCH ROUTINE
KEPRTN     EQUALS    ORIGEX  # QSAVE FOR KEPLER
RQVV       EQUALS    ORIGEX +1  # (6) SEC. BODY TO VEH.VETOR (USED P23)
RPSV       EQUALS    RQVV   +6  # (6)TMP SUN TO PRIMARY BODY VECTOR
XKEPNEW    EQUALS    RPSV   +6  # (2)TMP ROOT OF KEPLER'S EQU FOR T

```

# THESE PROBABLY CAN SHARE INTEGRATION VARIABLES (9D)

```

VACX      EQUALS    VECTAB +6  # I(2)TMP
VACY      EQUALS    VACX   +2  # I(2)TMP
VACZ      EQUALS    VACY   +2  # I(2)TMP

```

```

ERADM      EQUALS    VECTAB +18D # I(2)TMP
INCORPEX   EQUALS    ERADM  +2  # I(1)TMP

```

# R31 (V83) STORAGE. -- SHARES WITH INTEGRATION STORAGE -- (24D)

```

BASEOTP    EQUALS    VECTAB +6  # I(6) BASE POS VECTOR OTHER VEH
BASEOTV    EQUALS    VECTAB +18D # I(6) BASE VEL VECTOR OTHER VEH
BASETHP    EQUALS    VECTAB +30D # I(6) BASE POS VECTOR THIS VEH
BASETHV    EQUALS    RPQV      # I(6) BASE VEL VECTOR THIS VEH

```

# CONIC INTEGRATION STORAGE. -- MAY NOT SHARE WITH SERVICER -- (6D)

```

ALPHAM     EQUALS    XKEPNEW +2  # I(2)TMP
TAU.       EQUALS    ALPHAM  +2  # I(2)TMP

```

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# Page 90

# VERB 83 STORAGE. (20D)

# EXTENDED VERB 82 STORAGE. (6D)

# Page 91

```
# REENTRY CONICS                                (6D)
URONE          EQUALS  V82FLAGS                  # I(6) SAVE ACTUAL FOR CALCULATIONS
```

```

# V82 DISPLAY (4D)
HAPOX          EQUALS  THETA(1) +2    # I(2)DSP NOUN 44
HPERX          EQUALS  HAPOX  +2    # I(2)DSP NOUN 44

# P22 DISPLAY REGISTERS (06D)
AOPTIME        EQUALS  HPERX  +2    # I(2)TMP FOR SR52.1.ADVTRACK
LANDLONG       EQUALS  AOPTIME +2    # I(2)DSP NOUN 89 FOR P22
LANDALT        EQUALS  LANDLONG +2   # I(2)DSP NOUN 89 FOR P22

# S34/35.5,P34-P35 STORAGE. (6D)
KT             EQUALS  LANDALT +2    # B(2)
VERBNOUN       EQUALS  KT          +2 # B(1)TMP
QSAVED         EQUALS  VERBNOUN +1   # B(1)TMP HOLDS RETURN
RTRN           EQUALS  QSAVED  +1    # B(1) RETURN
SUBEXIT        EQUALS  RTRN    +1    # B(1)TMP
RGEXIT         EQUALS  SUBEXIT      # RGEXIT CAN'T SHARE WITH HPER,HAPO
# I(1)TMP Q SAVE MODE 1 AND 2 TO RTRN MAIN

# P30 DISPLAY (4D)
HAPO           EQUALS  KT          # I(2)DSP NOUN 42, FOR P30.
HPER           EQUALS  HAPO    +2   # I(2)DSP NOUN 42, FOR P30.

# SOME P34 STORAGE. (OVERLAYS P35.1 STORAGE) (2D)
NOMTPI         EQUALS  KT          # I(2)TMP NOMINAL TPI TIME FOR RECYCLE.

# THE FOLLOWING ARE ERASABLES USED BY THE SYSTEM TESTS. 205 USES TRANSM1. G'S ARE 1
# WHILE 504 USES TRANSM1 AND ALFDK.
# Page 92
# RSB 2009. The definition of TRANSM1 was previously just "TRANSM1 EQUALS 2000",
# this messes up the label typing system in yaYUL.
      SETLOC 2000
TRANSM1        EQUALS                      # (18) INITIALIZATION FOR IMU TESTS
ALFDK          =      TRANSM1 +18D        # (144) ERASABLE LOAD IN 504

# END OF PERF. TEST ERASABLE IN BANK 4

# ***-* V82 ***-* (6D)
VONE'          EQUALS  RGEXIT  +1    # I(6)TMP NORMAL VELOCITY VONE/ SQ RT MU

# PAD LOAD INTEGRATION ERROR INCLUDED IN VARIANCE BY P20 (1D)
INTVAR         EQUALS  VONE'  +6    # I(1)PL          SQUARE OF EXPECTED INTEGRATION
#                                     #                  POSITION EXTRAPOLATION ERROR
#                                     #                  SCALED METERS(2) 2(15)
END-E4         EQUALS  INTVAR      # LAST USED ERASABLE IN E4.

```

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# Page 93  
# EBANK-5 ASSIGNMENTS

SETLOC 2400

# \*- - \*- - \*- OVERLAY 1 IN EBANK 5 \*- - \*- - \*

# W-MATRIX STORAGE. (162D)

# RSB 2009. The following 3 lines have been replaced to be consistent with yaYUL's  
# label-typing system. They \*were\* "W EQUALS 2400", "9X9LOC1 EQUALS 2444",  
# "9X9LOC2 EQUALS 2532".

W EQUALS # B(162)

9X9LOC1 EQUALS W +44

9X9LOC2 EQUALS 9X9LOC1 +66

EMATRIX = W +120D # B(42) USED TO CONVERT W TO 6X6

END-W EQUALS W +162D # \*\*NEXT AVAILABLE LOC AFTER W MATRIX\*\*

# AUTO-OPTICS STORAGE -R52-

# DO NOT MOVE FROM E5,1554. A DELICATE BALANCE EXISTS BETWEEN THIS AND P03

XNB1 EQUALS W +108D # B(6D)TMP

YNB1 EQUALS XNB1 +6 # B(6)TMP

ZNB1 EQUALS YNB1 +6 # B(6)TMP

SAVQR52 EQUALS ZNB1 +6 # I(2)TMP

PLANVEC EQUALS SAVQR52 +2 # B(6) S-S SIGHTING VECTOR IN REF. COOR.

TSIGHT EQUALS PLANVEC +6 # B(2) S-S TIME OF SIGHTING

# RENDEZVOUS -P34-35 (26D)

DVLOS EQUALS TSIGHT +2 # I(6) S-S DELTA VELOCITY, LOS COORD-DISPLAY

DELTAR EQUALS DVLOS # I(2)

TINTSOI EQUALS DELTAR # I(2) INTERCEPT TIME FOR SOI MANEUVER

DELTTIME EQUALS DVLOS +2 # I(2)

TARGTIME EQUALS DVLOS +4 # I(2)

UNRM EQUALS DVLOS +6 # I(6) S-S

ULOS EQUALS UNRM +6 # I(6) S-S UNIT LINE OF SIGHT VECTOR

ACTCENT EQUALS ULOS +6 # I(2) S-S CENTRAL ANGLE BETWEEN ACTIVE

# VEH AT TPI IGNITION TIME AND

# TARGET VECTOR.

DELVTPI EQUALS ACTCENT +2 # I(2) NOUN 58 FOR P34

DELVTPF EQUALS DELVTPI +2 # I(2) NOUN 58,59 FOR P34,35

POSTTPI EQUALS DELVTPF +2 # I(2) NOUN 58 FOR P34.

TDEC2 EQUALS DELVTPI # (2)

```

# ALIGNMENT                                (12D)
# Page 94
STARSAV1      EQUALS  DVLOS                # I(6)TMP RESTART STAR SAVE.
STARSAV2      EQUALS  STARSAV1 +6          # I(6)TMP RESTART STAR SAVE.
US            =       STARSAV2            # (CISLUNAR TAG FOR STARSAV2).

# TPI SEARCH                                (26D)
IT            EQUALS  DVLOS                # (6)
THETZERO      EQUALS  IT      +6          # (2)
TFI           EQUALS  THETZERO +2         # (2)
DELVEE        EQUALS  TFI      +2         # (2)
HP            EQUALS  DELVEE  +2         # (2)
TFO           EQUALS  HP      +2         # (2)
HPO           EQUALS  TFO     +2         # (2)
DELVEO        EQUALS  HPO     +2         # (2)
MAGVTPI       EQUALS  DELVEO  +2         # I(2)TMP MAG OF DELTAVTPI OR VMID
RELDELV       EQUALS  MAGVTPI +2         # I(2)TMP MAG OF DELTAVTPF
T3TOT4        EQUALS  RELDELV +2         # I(2)DSP NOUN 39 FOR P34,35. TPI TO TINT
                                           # (CANNOT SHARE WITH RETURN TO EARTH)

# Page 95
# ALIGNMENT/SYSTEST/CALCSMSC/CRS61.1 COMMON STORAGE      (36D)
# (CALCSMSC IS A SUBSET OF S41.1 AT LEAST)
# (CRS61.1 IS A SUBSET OF P20)

XSM           EQUALS  END-W   +23D       # B(6)
YSM           EQUALS  XSM     +6         # B(6)TMP
ZSM           EQUALS  YSM     +6         # B(6)TMP

XDC           EQUALS  ZSM     +6         # B(6)TMP
YDC           EQUALS  XDC     +6         # B(6)TMP
ZDC           EQUALS  YDC     +6         # B(6)TMP

XNB           =       XDC
YNB           =       YDC
ZNB           =       ZDC

# OVERLAYS WITHIN ALIGNMENT/SYSTEST/CALCSMSC COMMON STORAGE

-COSB         EQUALS  XSM     +2         # (2)TMP
SINB          EQUALS  -COSB   +2         # (2)TMP

# ALIGNMENT/SYSTEST COMMON STORAGE      (18D)

STARAD        EQUALS  ZDC     +6         # I(18D)TMP

# ALIGNMENT/SYSTEST/AUTO OPTICS COMMON STORAGE. (17D)

```



OGC	EQUALS	STARAD	+18D	# I(2)TMP
IGC	EQUALS	OGC	+2	# I(2)TMP
MGC	EQUALS	IGC	+2	# I(2)TMP
STAR	EQUALS	MGC	+2	# I(6)TMP
SAC	EQUALS	STAR	+6	# I(2)TMP
PAC	EQUALS	SAC	+2	# I(2)TMP
QMIN	EQUALS	PAC	+2	# B(1)TMP

# \*\*\*\* COLP50'S \*\*\*\* (1D)  
 CULTRIX EQUALS VEARTH # VEARTH, VSUN, VMOON

# OVERLAYS WITHIN ALIGNMENT/SYSTEST COMMON STORAGE (24D)

VEARTH	EQUALS	STARAD		# (6)TMP
VSUN	EQUALS	VEARTH	+6	# (6)TMP
VMOON	EQUALS	VSUN	+6	# (6)TMP
SAX	EQUALS	VMOON	+6	# (6)TMP

# Page 96

# \*-\*\*\*- OVERLAY NUMBER 2 IN EBANK 5 -\*\*\*-\*

# CONICS ROUTINE STORAGE. (87D)

DELX	EQUALS	END-W		# I(2)TMP
DELT	EQUALS	DELX	+2	# I(2)TMP
URRECT	EQUALS	DELT	+2	# I(6)TMP
RCNORM	EQUALS	URRECT	+6	# I(2)TMP
XPREV	EQUALS	XKEP		# I(2)TMP
R1VEC	EQUALS	RCNORM	+2	# I(6)TMP
R2VEC	EQUALS	R1VEC	+6	# I(6)TMP
TDESIRE	EQUALS	R2VEC	+6	# I(2)TMP
GEOMSGN	EQUALS	TDESIRE	+2	# I(1)TMP
UN	EQUALS	GEOMSGN	+1	# I(6)TMP
VTARGET	EQUALS	UN	+6	# I(1)TMP
VTARGET	EQUALS	VTARGET	+1	# I(6)TMP
RTNLAMB	EQUALS	VTARGET	+6	# I(1)TMP
U2	EQUALS	RTNLAMB	+1	# I(6)TMP
MAGVEC2	EQUALS	U2	+6	# I(2)TMP
UR1	EQUALS	MAGVEC2	+2	# I(6)TMP
SNTH	EQUALS	UR1	+6	# I(2)TMP
CSTH	EQUALS	SNTH	+2	# I(2)TMP
1-CSTH	EQUALS	CSTH	+2	# I(2)TMP
CSTH-RHO	EQUALS	1-CSTH	+2	# I(2)TMP
P	EQUALS	CSTH-RHO	+2	# I(2)TMP
R1A	EQUALS	P	+2	# I(2)TMP

RVEC	EQUALS	R1VEC	# I(6)TMP
VVEC	EQUALS	R1A +2	# I(6)TMP
RTNTT	EQUALS	RTNLAMB	# I(1)TMP
ECC	EQUALS	VVEC +6	# I(2)TMP
RTNTR	EQUALS	RTNLAMB	# I(1)TMP
RTNAPSE	EQUALS	RTNLAMB	# I(1)TMP
R2	EQUALS	MAGVEC2	# I(2)TMP
RTNPRM	EQUALS	ECC +2	# I(1)TMP
SGNRDOT	EQUALS	RTNPRM +1	# I(1)TMP
RDESIRED	EQUALS	SGNRDOT +1	# I(2)TMP
DELDEP	EQUALS	RDESIRED +2	# I(2)TMP
DEPREV	EQUALS	DELDEP +2	# I(2)TMP
TERRLAMB	EQUALS	DELDEP	# I(2)TMP
TPREV	EQUALS	DEPREV	# I(2)TMP

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# \*-\*\*\*- OVERLAY NUMBER 3 IN EBANK 5 -\*\*\*-\*

# MEASUREMENT INCORPORATION STORAGE. (66D)

# (CALLED BY P20, P22, P23)

OMEGAM1	EQUALS	END-W	# I(6)TMP
OMEGAM2	EQUALS	OMEGAM1 +6	# I(6)TMP
OMEGAM3	EQUALS	OMEGAM2 +6	# I(6)TMP
HOLDW	EQUALS	OMEGAM3 +6	# I(18)TMP
TDPOS	EQUALS	HOLDW +18D	# I(6)TMP
TDVEL	EQUALS	TDPOS +6	# I(6)TMP

ZI	EQUALS	TDVEL +6	# I(18)
----	--------	----------	---------

# P22-P23 STORAGE. (8D)

22SUBSCL	EQUALS	ZI +18D	# DE OF ABCDE LANDMARK ID NO.
CXOFF	EQUALS	22SUBSCL +1	# B OF ABCDE OFFSET INDICATOR
8KK	EQUALS	CXOFF +1	# B(1)TMP INDEX OF PRESENT MARK
8NN	EQUALS	8KK +1	# B(1)TMP
S22LOC	EQUALS	8NN +1	# I(1)TMP MARK DATA LOC
LANDMARK	EQUALS	S22LOC +1	# B(1)DSP NOUN 70 FOR P22,51, R52,53
HORIZON	EQUALS	LANDMARK +1	# B(1)DSP NOUN 70 FOR P22,51, R52,53
IDOFLMK	EQUALS	HORIZON +1	# B(1)

# \*\*\*\*\*P23\*\*\* (1D)

TRUNION	EQUALS	IDOFLMK +1	# B(1)
---------	--------	------------	--------

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# \*- - \*- - \*- OVERLAY NUMBER 0 IN EBANK 5 \*- - \*- - \*

# SYSTEM TEST STORAGE. (174)

AZIMUTH	ERASE	+1
LATITUDE	ERASE	+1

TRUNA	EQUALS	DESOPTT
SHAFTA	EQUALS	DESOPTS

ERVECTOR	ERASE	+5
LENGTHOT	ERASE	
LOSVEC	ERASE	+5

SXTOPTN	=	LOSVEC
NDXCTR	ERASE	
PIPINDEX	ERASE	
POSITON	ERASE	
QPLAC	ERASE	
QPLACE	ERASE	
QPLACES	ERASE	
RUN	ERASE	
STOREPL	ERASE	
SOUTHDR	ERASE	
TARG1/2	=	SOUTHDR
TAZEL1	ERASE	+5
TEMPTIME	ERASE	+1
TMARK	ERASE	+1
GENPL	ERASE	+134D
CDUTIMEI	=	GENPL
CDUTIMEF	=	GENPL +2
IMU/OPT	=	GENPL +4
CDUREADF	=	GENPL +5
CDUREADI	=	GENPL +6
CDULIMIT	=	GENPL +7

TEMPADD	=	GENPL +4
TEMP	=	GENPL +5
NOBITS	=	GENPL +6
CHAN	=	GENPL +7

LOS1	=	GENPL +8D
LOS2	=	GENPL +14D

CALCDIR	EQUALS	GENPL +20D
CDFLAG	EQUALS	GENPL +21D

GYTOBETQ	EQUALS	GENPL	+22D	
OPTNREG	EQUALS	GENPL	+23D	
SAVE	EQUALS	GENPL	+24D	# THREE CONSEC LOC
SFCONST1	EQUALS	GENPL	+27D	
# Page 99				
TIMER	EQUALS	GENPL	+28D	
DATAPL	EQUALS	GENPL	+30D	
RDSP	EQUALS	GENPL		# FIX LATER POSSIBLY KEEP1
MASKREG	EQUALS	GENPL	+64D	
CDUNDX	EQUALS	GENPL	+66D	
RESULTCT	EQUALS	GENPL	+67D	
COUNTPL	EQUALS	GENPL	+70D	
CDUANG	EQUALS	GENPL	+71D	
AINLA	=	GENPL		# OPTIMUM CALIB. AND ALIGNMENT
WANGO	EQUALS	AINLA		
WANGI	EQUALS	AINLA	+2D	
WANGT	EQUALS	AINLA	+4D	
TORQNDX	=	WANGT		
DRIFTT	EQUALS	AINLA	+6D	
ALX1S	EQUALS	AINLA	+8D	
CMPX1	EQUALS	AINLA	+9D	
ALK	EQUALS	AINLA	+10D	
VLAUNS	EQUALS	AINLA	+22D	
THETAX	=	ALK	+2	
WPLATO	EQUALS	AINLA	+24D	
INTY	EQUALS	AINLA	+28D	
THETAN	=	THETAX	+6	
ANGZ	EQUALS	AINLA	+30D	
INTZ	EQUALS	AINLA	+32D	
ANGY	EQUALS	AINLA	+34D	
ANGX	EQUALS	AINLA	+36D	
DRIFTO	EQUALS	AINLA	+38D	
DRIFTI	EQUALS	AINLA	+40D	
VLAUN	EQUALS	AINLA	+44D	
FILDELV	=	THETAN	+6	
ACCWD	EQUALS	AINLA	+46D	
INTVEC	=	FILDELV	+2	
POSNV	EQUALS	AINLA	+52D	
DPIPAY	EQUALS	AINLA	+54D	
DPIPAZ	EQUALS	AINLA	+58D	
ALTIM	EQUALS	AINLA	+60D	
ALTIMS	EQUALS	AINLA	+61D	
ALDK	EQUALS	AINLA	+62D	
DELM	EQUALS	AINLA	+76D	

```

WPLATI      EQUALS  AINLA  +84D
RESTARPT    =      AINLA  +91D
GEOSAVED    =      AINLA  +117D
PREMTRXC    =      AINLA  +118D
LAUNHAZ     =      AINLA  +119D
NEWAZMTH    =      AINLA  +121D
OLDAZMTH    =      AINLA  +123D
# Page 100
TOLDAZMT    =      AINLA  +125D
GEOCOMPS    =      AINLA  +127D
1SECXT      =      AINLA  +128D
GTSXTLST    =      AINLA  +129D
ERECTIME    =      AINLA  +130D
ERCOMP      =      AINLA  +131D
ZERONDX     =      AINLA  +137D
GTSOPNDZ    =      ZERONDX

```

# THE FOLLOWING TAGS ARE USED BY THE 504 IMU CALIBRATION AND ALIGNMENT PROGRAM ONLY.

```

THETAX1     EQUALS  ALK      +2
THETAN1     EQUALS  THETAX1 +6
FILDELV1    EQUALS  THETAN1 +6
INTVEC1     EQUALS  FILDELV1 +2
GEOSAVE1    EQUALS  AINLA   +117D
PREMTRX1    EQUALS  AINLA   +118D
LUNHAZ1     EQUALS  AINLA   +119D
NEWAZ1      EQUALS  LUNHAZ1 +2
OLDAZ1      EQUALS  LUNHAZ1 +4
TOLDAZ1     EQUALS  LUNHAZ1 +6
GEOCOMP1    EQUALS  AINLA   +127D
1SECXT1     EQUALS  AINLA   +128D
GTSWTLT1    EQUALS  AINLA   +129D
ERECTIM1    EQUALS  AINLA   +130D
ERCOMP1     EQUALS  AINLA   +131D  # I(6)
ZERONDX1    EQUALS  AINLA   +137D
PERFDLAY    EQUALS  AINLA   +138D  # B(2).....

```

# END OF 504 + ALIGN ERASE.

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# \*-\*-\*-\* OVERLAY 4 IN EBANK 5 \*-\*-\*-\*

#

```

# P32 --- P33                      (26D)
UP1      EQUALS  DVLOS              # I(6)
VPASS2   EQUALS  UP1      +6        # I(6)

```

RPASS2	EQUALS	VPASS2	+6	# I(6)
DIFFALT	EQUALS	RPASS2	+6	# I(2)
TCDH	EQUALS	DIFFALT	+2	# I(2)
TCSI	EQUALS	TCDH	+2	# I(2)
TTPIO	EQUALS	TCSI	+2	# I(2)

## # P32,P33 STORAGE OVERLAYING 9X9 W-MATRIX LOCATIONS (26D)

DELVEET1	EQUALS	9X9LOC1		# I(6) DELV FOR CSI
RACT2	EQUALS	DELVEET1	+6	# I(6) POS. ACTIVE VEH. AT CDH TIME
VACT2	EQUALS	9X9LOC2		# I(6) VEL. ACTIVE VEH. AT CDH TIME
RACT1	EQUALS	VACT2	+6	# I(6) POS. ACTIVE VEH. AT CSI TIME
T1TOT2	EQUALS	RACT1	+6	# I(2) TCDH - TCSI
END-E5	EQUALS	QMIN		# LAST USED E5 ADDRESS

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## # EBANK-6 ASSIGNMENTS.

	SETLOC	3000		
# P23	PAD LOADS ***			(2D).
WMIDPOS	ERASE			# I(1)PL INITIAL VALUES FOR W-MATRIX IN
WMIDVEL	ERASE			# I(1)PL Cislunar (P23) NAVIGATION

# R22	PAD LOADS			(5D).
RVAR	ERASE	+1		# I(2)PL VHF RADAR
RVARMIN	ERASE	+2		# I(3)PL VHF RADAR

## # \*\*\*\*\* PAD LOADED ENTRY DAP STEERING VARIABLES \*\*\*\*\* (3D)

LADPAD	ERASE			# I(1)PL FOR ENTRY. HOLDS CM NOMINAL L/D
LODPAD	ERASE			# I(1)PL FOR ENTRY. HOLDS CM NOMINAL LOD
ALFAPAD	ERASE			# B(1)PL ALFA TRIM / 180

## # \*\*\*\*\* PAD LOADED TVC DAP VARIABLES \*\*\*\*\* (26D)

ETDECAY	ERASE			# I(1)PL
ESTROKER	ERASE			# B(1)PL
EKPRIME	ERASE	+1		# B(2)PL
EKTLX/I	ERASE	+2		# B(3)PL
EREPRAC	ERASE	+1		# B(2)PL
PACTOFF	ERASE			# B(1)PL, DSP N48 R01 = PTRIM, R02 = YTRIM
YACTOFF	ERASE			# B(1)PL, CONSECUTIVE WITH PACTOFF
HBN10	ERASE			# B(1)
HBN11/2	ERASE			# B(1)
HBN12	ERASE			# B(1)
HBD11/2	ERASE			# B(1)
HBD12	ERASE			# B(1)
HBN20	ERASE			# B(1)

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HBN21/2	ERASE	# B(1)
HBN22	ERASE	# B(1)
HBD21/2	ERASE	# B(1)
HBD22	ERASE	# B(1)
HBN30	ERASE	# B(1)
HBN31/2	ERASE	# B(1)
HBN32	ERASE	# B(1)
#Page 103		
HBD31/2	ERASE	# B(1)
HBD32	ERASE	# B(1)

# \*\*\*\* EXCLUSIVE TVC DAP VARIABLES. \*\*\*\*\* (5D)

V97VCNTR	ERASE	# B(1)
TEMPDAP	ERASE +1	# B(2)
MRKRTMP	= TEMPDAP	# ((B(1)))
CNTR	ERASE	# B(1)
OGAD	ERASE	# B(1)

# \*\*\*\* EXCLUSIVE RCS DAP VARIABLES \*\*\*\*\* (13D)

RWORD1	ERASE +12D	# B(1)
RWORD2	EQUALS RWORD1 +1	# B(1)
PWORD1	EQUALS RWORD2 +1	# B(1)
PWORD2	EQUALS PWORD1 +1	# B(1)
YWORD1	EQUALS PWORD2 +1	# B(1)
YWORD2	EQUALS YWORD1 +1	# B(1)
BLAST	EQUALS YWORD2 +1	# B(2)
BLAST1	EQUALS BLAST +2	# B(2)
BLAST2	EQUALS BLAST1 +2	# B(2)
T5PHASE	EQUALS BLAST2 +2	# B(1)

# \*\*\*\* RCS/TVC DAP COMMON STORAGE. \*\*\*\*\* (16D)

DAPDATR1	ERASE	# B(1)DSP NOUN 46(R1)
DAPDATR2	ERASE	# B(1)DSP NOUN 46(R2)

IXX	ERASE	# B(1) CONSECUTIVE WITH IAVG, IAVG/TLX FOR
IAVG	ERASE	# B(1) MASSPROP
IAVG/TLX	ERASE	# B(1)

LEMMASS	ERASE	# B(1)DSP NOUN 47 (R2)
CSMMASS	ERASE	# B(1)DSP NOUN 47 (R1)
WEIGHT/G	ERASE	# B(1)
MASS	= WEIGHT/G	

AK	ERASE
AK1	ERASE
AK2	ERASE

```

RCSFLAGS      ERASE      # B(1) CONSECUTIVE WITH AK2 DOWNLINK
T5TEMP        ERASE      # B(1)
EDRIVEX       ERASE
EDRIVEY       ERASE
# Page 104
EDRIVEZ       ERASE

```

```

# INTMP THRU INTMP+14D ARE RESERVED FOR OVERLAYED TVC/RCS INTERUP TRUE TEMPORARIES
INTTEMP      ERASE    +14D      # (15)

```

```

# TVC/RCS THRU TVCRCS +11D RESERVED FOR DOWNLINKED VARIABLES
TVCRCS      ERASE    +11D      # (12)
                                     # RCS (WBODYS,ADOTS)
                                     # TVC(OMEGACS,OMEGABS)

```

```

# TVC DAP TEMPORARY VARIABLES*****

```

```

# TVC DAP INTERRUPT TRUE TEMPORARIES*****

```

```

PHI333      EQUALS    INTTEMP      # B(1) TEMPORARY REGISTER
PSI333      EQUALS    PHI333  +1    # B(1) COUNTING REGISTER
TEMP333     EQUALS    PSI333  +1    # B(1) COUNTING REGISTER
VARST0      EQUALS    TEMP333  +1    # B(8) BREAKPOINTS AND SLOPES
VARST5      =         VARST0  +5
LASTMASP    EQUALS    VARST0  +9D    # LAST VARSTO WORD
TVCTMP1     EQUALS    LASTMASP +1    # B(1)

```

```

# *****REGULAR TVC TEMPORARIES*****

```

```

# TVC ZEROING STARTS HERE

```

```

OMEGAC      EQUALS    TVCRCS      # I(6)
OMEGAXC     =         OMEGAC
OMEGAYC     =         OMEGAC  +2
OMEGAZC     =         OMEGAC  +4

```

```

OMEGAB      EQUALS    TVCRCS  +6    # B(6)
OMEGAXB     =         OMEGAB
OMEGAYB     =         OMEGAB  +2
OMEGAZB     =         OMEGAB  +4

```

```

PTMP1      EQUALS    OMEGAC  +12D   # B(2)
PTMP2      EQUALS    PTMP1   +2     # B(2)
PTMP3      EQUALS    PTMP2   +2     # B(2)
PTMP4      EQUALS    PTMP3   +2     # B(2)

```



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PTMP5	EQUALS	PTMP4	+2	# B(2)
# Page 105				
PTMP6	EQUALS	PTMP5	+2	# B(2)
YTMP1	EQUALS	PTMP6	+2	# B(2)
YTMP2	EQUALS	YTMP1	+2	# B(2)
YTMP3	EQUALS	YTMP2	+2	# B(2)
YTMP4	EQUALS	YTMP3	+2	# B(2)
YTMP5	EQUALS	YTMP4	+2	# B(2)
YTMP6	EQUALS	YTMP5	+2	# B(2)
ROLLFIRE	EQUALS	YTMP6	+2	# B(1)
ROLLWORD	EQUALS	ROLLFIRE	+1	# B(1)
TEMREG	EQUALS	ROLLWORD	+1	# B(1)
STROKER	EQUALS	TEMREG	+1	# B(1)
PERRB	EQUALS	STROKER	+1	# B(2)
YERRB	EQUALS	PERRB	+2	# B(2)
DELPBAR	EQUALS	YERRB	+2	# B(2)
DELYBAR	EQUALS	DELPBAR	+2	# B(2)
PDELOFF	EQUALS	DELYBAR	+2	# B(2)
YDELOFF	EQUALS	PDELOFF	+2	# B(2)
# TVC ZEROING LOOP ENDS HERE				
TTMP1	EQUALS	YDELOFF	+2	# B(2)
TTMP2	EQUALS	TTMP1	+2	# B(2)
DAP1	EQUALS	TTMP2	+2	# B(2)
DAP2	EQUALS	DAP1	+2	# B(2)
DAP3	EQUALS	DAP2	+2	# B(2)
PCMD	EQUALS	DAP3	+2	# B(1)
YCMD	EQUALS	PCMD	+1	# B(1), CONSECUTIVE WITH PCMD
T5TVCDT	EQUALS	YCMD	+1	# B(1)
MDT	EQUALS	T5TVCDT	+1	# I(6)
KPRIMEDT	EQUALS	MDT	+6	# I(2)
KTLX/I	EQUALS	KPRIMEDT	+2	# B(1)
TENMDOT	EQUALS	KTLX/I	+1	# B(1)
1/CONACC	EQUALS	TENMDOT	+1	# B(1)
VARX	EQUALS	1/CONACC	+1	# B(1)
REPFRAC	EQUALS	VARX	+1	# B(1)
VCNTR	EQUALS	REPFRAC	+1	# B(1)
TVCPHASE	EQUALS	VCNTR	+1	# B(1)
PCDUYPST	EQUALS	TVCPHASE	+1	# B(1)

```
PCDUZPST      EQUALS  PCDUYPST +1      # B(1)
MCDUYDOT      EQUALS  PCDUZPST +1      # B(1)
MCDUZDOT      EQUALS  MCDUYDOT +1      # B(1)
```

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```
TVCEXPHS      EQUALS  MCDUZDOT +1      # B(1)
MASSTMP       EQUALS  TVCEXPHS +1      # B(1)  PROTECT
VCNTRTMP      EQUALS  MASSTMP +1      # B(1)  *PROTECT***
```

## # STROKE TEST VARIABLES

```
STRKTIME      EQUALS  VCNTRTMP +1      # B(1)
CADDY         EQUALS  STRKTIME +1      # B(1)
N             EQUALS  CADDY +1         # B(1)
BUNKER        EQUALS  N +1             # B(1)
REVS          EQUALS  BUNKER +1        # B(1)
CARD          EQUALS  REVS +1          # B(1)
```

## # TVC ROLL DAP VARIABLES

```
OGANOW        EQUALS  CARD +1          # B(1)
OGAPAST       EQUALS  OGANOW +1        # B(1)
OGA           EQUALS  OGAPAST +1       # B(1)TMP
OGAERR        =      OGA               # (ROLL DAP USES OGA, MEANS OGAERROR)
DELOGART      EQUALS  OGA +1          # B(1)TMP
SGNRT         EQUALS  DELOGART +1      # SIGN OF CGA RATE
DELOGA        EQUALS  SGNRT +1        # USED IN ROLL LOGIC
I             EQUALS  DELOGA +1        # USED IN ROLL LOGIC
IOGARATE      EQUALS  I +1            # USED IN ROLL LOGIC
```

## # TVC DAP RESTART TEMPORARIES.

```
PACTTMP       EQUALS  IOGARATE +1      # B(2)
YACTTMP       EQUALS  PACTTMP +2       # B(2)
CNTRTMP       EQUALS  YACTTMP +2       # B(1)
STRKTTMP      EQUALS  CNTRTMP +1       # B(1)
DELBRTMP      EQUALS  STRKTTMP +1      # B(2)
ERRBTMP       EQUALS  DELBRTMP +2      # B(2)
CMDTMP        EQUALS  ERRBTMP +2       # B(2)
```

```
TMP1          EQUALS  CMDTMP +2        # B(2)
TMP2          EQUALS  TMP1 +2          # B(2)
TMP3          EQUALS  TMP2 +2          # B(2)
TMP4          EQUALS  TMP3 +2          # B(2)
TMP5          EQUALS  TMP4 +2          # B(2)
TMP6          EQUALS  TMP5 +2          # B(2)
```

## # TVC DAP FILTER COEFFICIENTS TEMPORARIES

```
COEFFADR      EQUALS  TMP6 +2          # B(1)
N10           EQUALS  COEFFADR +1      # I(15)
```

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# OVERLAYS WITHIN TVC DAP

OGARATE	=	OMEGAB	# B(2)
PHASETMP	=	TTMP1	# B(1) RESTART FOR CSM/LM V46 SWITCH-OVER
RTRNLOC	=	TTMP2	# B(1) RESTART FOR CSM/LM V46 SWITCH-OVER
BZERO	=	ERRBTMP	
CZERO	=	ERRBTMP	
JZERO	=	CMDTMP	
YZERO	=	CMDTMP	

# 540.9 STORAGE .....

NBRCYCLS	EQUALS	N10 +15D	# B(1) COUNTER FOR P40,41 STEERING
NBRCYCLP	EQUALS	NBRCYCLS +1	# B(1) MAINTAIN ORDER
DELVSUM	EQUALS	NBRCYCLP +1	# I(6) P40,P41
DELVSUMP	EQUALS	DELVSUM +6	# I(6) P40,P41

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# \*\*\*\* RCS DAP TEMPORARY VARIABLES. \*\*\*\*\* (95D)

# \*\* RCS INTERRUPT TRUE TEMPS \*\*\*\*\* (15D)

SPNDX	EQUALS	INTTEMP	# B(1)
DPNDX	EQUALS	SPNDX +1	# B(1)TMP
KMPAC	EQUALS	DPNDX +1	# B(2)TMP
KMPTEMP	EQUALS	KMPAC +2	# B(1)TMP
XNDX1	EQUALS	KMPTEMP +1	# B(1)TMP XNDX1 THRU NYJETS ARE OVERLAYED
XNDX2	EQUALS	XNDX1 +1	# B(1)TMP BY OTHER DAP ERASABLES SO
YNDX	EQUALS	XNDX2 +1	# B(1)TMP SHOULD ALWAYS BE DEFINED IN
ZNDX	EQUALS	YNDX +1	# B(1)TMP A BLOCK
RINDEX	EQUALS	ZNDX +1	# B(1)TMP
PINDEX	EQUALS	RINDEX +1	# B(1)TMP
YINDEX	EQUALS	PINDEX +1	# B(1)TMP
NRJETS	EQUALS	YINDEX +1	# B(1)TMP
NPJETS	EQUALS	NRJETS +1	# B(1)TMP
NYJETS	EQUALS	NPJETS +1	# B(1)TMP
WTEMP	EQUALS	XNDX1	# B(2)TMP WTEMP THRU DELTEMPZ OVERLAY
DELTEMPX	EQUALS	WTEMP +2	# B(2)TMP XNDX1 THRU NRJETS AND EDOT THRU
DELTEMPY	EQUALS	DELTEMPX +2	# B(2)TMP ADBVEL
DELTEMPZ	EQUALS	DELTEMPY +2	# B(2)TMP
EDOT	EQUALS	YNDX	# B(2)TMP EDOT THRU ADBVEL OVERLAY

AERR	EQUALS	EDOT	+2	# B(1)TMP YNDX THRU NPJETS AND DELTEMPX
EDOTVEL	EQUALS	AERR	+1	# B(2)TMP THRU DELTEMPZ
AERRVEL	EQUALS	EDOTVEL	+2	# B(1)TMP
ADBVEL	EQUALS	AERRVEL	+1	# B(1)TMP

# \*\*\* REGULAR RCS TEMPS \*\*\*\*\* ( ).

# \*\*\* RCS ZEROING LOOP STARTS HERE \*\*\*\*\* (37)

WBODY	EQUALS	TVCRC		# B(2)TMP
WBODY1	EQUALS	WBODY	+2	# B(2)TMP
WBODY2	EQUALS	WBODY	+4	# B(2)TMP
ADOT	EQUALS	WBODY2	+2	# B(2)TMP
ADOT1	EQUALS	ADOT	+2	# B(2)TMP
ADOT2	EQUALS	ADOT1	+2	# B(2)TMP

MERRORX	EQUALS	ADOT2	+2	# (2)
MERRORY	EQUALS	MERRORX	+2	# (2)
MERRORZ	EQUALS	MERRORY	+2	# (2)
DFT	EQUALS	MERRORZ	+2	# B(1)TMP
DFT1	EQUALS	DFT	+1	# B(1)TMP
DFT2	EQUALS	DFT1	+1	# B(1)TMP
DRHO	EQUALS	DFT2	+1	# B(2)TMP
DRHO1	EQUALS	DRHO	+2	# B(2)TMP

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DRHO2	EQUALS	DRHO1	+2	# B(2)TMP
ATTSEC	EQUALS	DRHO2	+2	# B(1)TMP
TAU	EQUALS	ATTSEC	+1	# B(1)TMP
TAU1	EQUALS	TAU	+1	# B(1)TMP
TAU2	EQUALS	TAU1	+1	# B(1)TMP
BIAS	EQUALS	TAU2	+1	# B(1)TMP
BIAS1	EQUALS	BIAS	+1	# B(1)TMP
BIAS2	EQUALS	BIAS1	+1	# B(1)TMP
ERRORX	EQUALS	BIAS2	+1	# B(1)TMP
ERRORY	EQUALS	ERRORX	+1	# B(1)TMP
ERRORZ	EQUALS	ERRORY	+1	# B(1)TMP

# RCS ZERO LOOP ENDS HERE

# MORE RCS (69D)

THETADX	EQUALS	ERRORZ	+1	# B(1)TMP MUST BE CONSECUTIVE WITH ERRORZ
THETADY	EQUALS	THETADX	+1	# B(1)TMP
THETADZ	EQUALS	THETADY	+1	# B(1)TMP

DELCDUX	EQUALS	THETADZ	+1	# B(2)TMP
DELCDUY	EQUALS	DELCDUX	+2	# B(2)TMP
DELCDUZ	EQUALS	DELCDUY	+2	# B(2)TMP

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DCDU	EQUALS	DELCDUZ +2	# B(6)TMP USED DURING P20
DTHETASM	EQUALS	DCDU +6	# B(6)TMP STEER LOW OUTPUT.
ATTKALMN	EQUALS	DTHETASM +6	# B(1)TMP
KMJ	EQUALS	ATTKALMN +1	# B(1)TMP
KMJ1	EQUALS	KMJ +1	# B(1)TMP
KMJ2	EQUALS	KMJ1 +1	# B(1)TMP
J/M	EQUALS	KMJ2 +1	# B(1)TMP
J/M1	EQUALS	J/M +1	# B(1)TMP
J/M2	EQUALS	J/M1 +1	# B(1)TMP
RACFAIL	EQUALS	J/M2 +1	# B(1)TMP
RBDFAIL	EQUALS	RACFAIL +1	# B(1)TMP
ACORBD	EQUALS	RBDFAIL +1	# B(1)TMP
XTRANS	EQUALS	ACORBD +1	# B(1)TMP
CH31TEMP	EQUALS	XTRANS +1	# B(1)TMP
CHANTEMP	EQUALS	CH31TEMP +1	# B(1)TMP
T5TIME	EQUALS	CHANTEMP +1	# B(1)TMP
RHO	EQUALS	T5TIME +1	# B(1)TMP
RHO1	EQUALS	RHO +1	# B(1)TMP
RHO2	EQUALS	RHO1 +1	# B(1)TMP
AMGB1	EQUALS	RHO2 +1	# B(1)TMP
AMGB4	EQUALS	AMGB1 +1	# B(1)TMP
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AMGB5	EQUALS	AMGB4 +1	# B(1)TMP
AMGB7	EQUALS	AMGB5 +1	# B(1)TMP
AMGB8	EQUALS	AMGB7 +1	# B(1)TMP
CAPSI	EQUALS	AMGB8 +1	# B(1)TMP
CDUXD	EQUALS	CAPSI +1	# B(2)TMP
CDUYD	EQUALS	CDUXD +2	# B(2)TMP
CDUZD	EQUALS	CDUYD +2	# B(2)TMP
SLOPE	EQUALS	CDUZD +2	# B(1)TMP
ADB	EQUALS	SLOPE +1	# B(1)TMP
RMANNDX	EQUALS	ADB +1	# B(1)TMP
PMANNDX	EQUALS	RMANNDX +1	# B(1)TMP
YMANNDX	EQUALS	PMANNDX +1	# B(1)TMP MUST BE LAST VARIABLE IN RCS

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# \*\*\*\*\* ENTRY DAP TEMPORARY VARIABLES. \*\*\*\*\* (69D)

# ANGLE REGISTERS FOR ENTRY DAPS

AOG	EQUALS	BCDU	# 1P
AIG	EQUALS	AOG +1	# 1P
AMG	EQUALS	AIG +1	# 1P
ROLL/180	EQUALS	AMG +1	# 1P
ALFA/180	EQUALS	ROLL/180 +1	# 1P
BETA/180	EQUALS	ALFA/180 +1	# 1P

AOG/PIP	EQUALS	BETA/180 +1	# 1P
AIG/PIP	EQUALS	AOG/PIP +1	# 1P
AMG/PIP	EQUALS	AIG/PIP +1	# 1P
ROLL/PIP	EQUALS	AMG/PIP +1	# 1P
ALFA/PIP	EQUALS	ROLL/PIP +1	# 1P
BETA/PIP	EQUALS	ALFA/PIP +1	# 1P

# GYMBAL DIFFERENCES OVER INTERNAL TCDU = .1 SEC.

-DELAG	EQUALS	BETA/PIP +1	# 1P
-DELAIG	EQUALS	-DELAG +1	# 1P
-DELAMG	EQUALS	-DELAIG +1	# 1P

# ESTIMATED BODY RATES

CMDAPMOD	EQUALS	-DELAMG +1	# 1P GOES BEFORE PREL FOR TM.
----------	--------	------------	-------------------------------

PREL	EQUALS	CMDAPMOD +1	# 1P P TCDU/180	(ROLDDOT)
QREL	EQUALS	PREL +1	# 1P Q TCDU/180	(PITCHDOT)
RREL	EQUALS	QREL +1	# 1P R TCDU/180	(YAWDOT)

BETADOT	EQUALS	RREL +1	# 1P MUST FOLLOW RREL. BETADOT TCDU/180
PHIDOT	EQUALS	BETADOT +1	# 1P

# OLD (UNAVERAGED) BODY RATE MEASURE

OLDELP	EQUALS	PHIDOT +1	# 1P
OLDELQ	EQUALS	OLDELP +1	# 1P
OLDELR	EQUALS	OLDELQ +1	# 1P

JETAG	EQUALS	OLDELR +1	# 1P
TUSED	EQUALS	JETAG +1	# 1P ELAPSED TIME SINCE NOMINAL UPDATE.

# FOLLOWING 3 SP WORDS IN DOWNLINK. ROLLTM SENT EACH 1 SEC.

PAXERR1	EQUALS	TUSED +1	# 1P INTEGRATED ROLL ERROR/360.
ROLLTM	EQUALS	PAXERR1 +1	# 1P ROLL/180 FOR TM.
ROLLC	EQUALS	ROLLTM +1	# 2P ROLLCOM/360 FROM ENTRY (FOR TM)
			# KEEP ROLLC & ROLLHOLD ADJACENT FOR TP

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ROLLHOLD	EQUALS	ROLLC +2	# 1P FOR ATTITUDE HOLD IN CMDAPMOD = +1
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# ENTRY DAP QUANTITIES THAT SHARE WITH RCS DAP.

ALFACOM	EQUALS	DCDU	# 1P KEEP ADJACENT TO BETACOM. <<
BETACOM	EQUALS	ALFACOM +1	# 1P

# JET LIST. DT, JETBITS IN THIS ORDER.

TOFF	EQUALS	BETACOM +1	# 1P DP PAIR
TBITS	EQUALS	TOFF +1	# 1P
TON2	EQUALS	TBITS +1	# 1P DP PAIR

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T2BITS           EQUALS   TON2    +1       # 1P

# MISCELLANEOUS PERMANENT ERASABLE.

OUTTAG           EQUALS   T2BITS   +1       # 1P

NUJET            EQUALS   OUTTAG   +1       # 1P

# MORE ENTRY DAP QUANTITIES THAT DO NOT SHARE WITH RCS DAP.

JETEM            EQUALS   ROLLHOLD +1       # 2P THIS DP USED IN RATEAVG

GAMA             EQUALS   JETEM    +2       # 1P

GAMDOT           EQUALS   GAMA     +1       # 1P

POSEXIT           EQUALS   GAMDOT   +1       # 1P

CM/GYMDT          EQUALS   POSEXIT +1       # 1P

HEADSUP           EQUALS   CM/GYMDT +1       # 1P DSP NOUN 61 FOR P62,63,64,67.

P63FLAG           EQUALS   HEADSUP +1       # 1P INTERLOCK FOR WAKEP62

#>> SHARE BELOW WITH RCS RUPT TEMPS (< 15D) <<<

CALFA            EQUALS   SPNDX       # 1P

SALFA            EQUALS   CALFA    +1       # 1P

SINM             EQUALS   SALFA    +1       # 1P

COSM             EQUALS   SINM     +1       # 1P

SINO             EQUALS   COSM     +1       # 1P

COSO             EQUALS   SINO     +1       # 1P

SINOCOSM          EQUALS   COSO     +1       # 1P

COSOCOSM          EQUALS   SINOCOSM +1       # 1P

#>> SHARE ABOVE WITH RCS RUPT TEMPS <<<

# THE FOLLOWING FEW REGISTERS USED ONCE EACH 2 SEC

-VT/180           EQUALS   NUJET    +1       # 1P

LCX/360           EQUALS   -VT/180 +1       # 1P

XD/360            EQUALS   LCX/360 +1       # 1P

VSQ/4API          EQUALS   XD/360   +1       # 1P

JNDX             EQUALS   VSQ/4API +1       # 1P

JNDX1            EQUALS   JNDX     +1       # 1P

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TON1             EQUALS   JNDX1    +1       # 1P DP PAIR

T1BITS            EQUALS   TON1     +1       # 1P

# MISCELLANEOUS REGISTERS USED EACH UPDATE.

CM/SAVE           EQUALS   T1BITS   +1       # 1P

JETEM2            EQUALS   CM/SAVE +1       # 1P TEMPORARY STORAGE

# DAP QUANTITIES SHARED WITH RCS DAP FOR TM & FLIGHT RECORDER.

VDT/180           =        ERRORX       # 1P (EDIT)

-VT/180E          =        ERRORY       # 1P (EDIT)

PAXERR	EQUALS	AK	# 1P ROLL ERROR FOR NEEDLES
QAXERR	=	THETADX	# 1P SINCE AK1 IS ZEROED IN ATM DAP.
RAXERR	=	QAXERR +1	# 1P SINCE AK2 IS ZEROED IN TM DAP.

# \*\*\* COLMANU (R60,R62) \*\*\*\*  
 VECQTEMP        EQUALS    COFSKEW

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# \*\*\*\*\* KALCMANU VARIABLES. (71D) \*\*\*\*\*

BCDU	EQUALS	YMANNDX +1	# B(3)TMP
KSPNDX	EQUALS	BCDU +3	# B(1)TMP
KDPNDX	EQUALS	KSPNDX +1	# B(1)TMP
TMIS	EQUALS	KDPNDX +1	# I(18) MUST BE IN THE SAME BANK AS RCS DAP
COFSKEW	EQUALS	TMIS +18D	# I(6) MUST BE IN THE SAME BANK AS RCS DAP
CAM	EQUALS	COFSKEW +6	# I(2) MUST BE IN THE SAME BANK AS RCS DAP
MIS	EQUALS	CAM +2	# I(18) (THE REST MAY GO ANYWHERE)
COF	EQUALS	MIS +18D	# I(6)TMP
SCAXIS	EQUALS	COF +6	# I(6)TMP
POINTVSM	EQUALS	SCAXIS +6	# I(6)TMP
AM	EQUALS	POINTVSM +6	# I(2)TMP
RAD	EQUALS	AM +2	# I(2)TMP

# FIRST-ORDER OVERLAYS IN KALCMANU

KV1	EQUALS	TMIS	# I(6)TMP
MFISYM	EQUALS	TMIS	# I    TMP
TMFI	EQUALS	TMIS	# I    TMP
NCDU	EQUALS	TMIS	# B    TMP
NEXTIME	EQUALS	TMIS +3	# B    TMP
TTEMP	EQUALS	TMIS +4	# B    TMP
KV2	EQUALS	TMIS +6	# I(6)TMP
BIASTEMP	EQUALS	TMIS +6	# B    TMP
KV3	EQUALS	TMIS +12D	# I(6)TMP
CGF	EQUALS	TMIS +12D	# I    TMP

BRATE	EQUALS	COFSKEW	# B    TMP
TM	EQUALS	CAM	# B    TMP

# SECOND-ORDER OVERLAYS IN KALCMANU

P21	EQUALS	KV1	# I(2)TMP
D21	EQUALS	KV1 +2	# I(2)TMP
G21	EQUALS	KV1 +4	# I(2)TMP

# SATURN BOOST STORAGE.    SAVE TILL RCS DAP OPERATION.    (17D)  
 POLYNUM        EQUALS    BCDU        # B(15) PAD LOADED



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POLYLOC = POLYNUM +10D  
SATRLRT EQUALS POLYNUM +15D # B(2) PAD LOADED

# MORE P11 STORAGE --PAD LOADED-- (2D)

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# (NOTE: THIS PAD LOAD WILL NOT BE PRESERVED THROUGHOUT THE MISSION AS IT SHARES STORAGE WITH  
# ENTRY DAP AND TVC DAP)

RPSTART EQUALS SATRLRT +2 # B(1) PITCH ROLL START TIME  
POLYSTOP EQUALS RPSTART +1 # B(1) POLY CUT OFF MINUS RPSTART SEC

# STORAGE FOR VHHDOT AND ATTDSP

BODY3 EQUALS POLYSTOP +1 # B(1)OUT  
BODY2 EQUALS BODY3 +1 # B(1)OUT  
BODY1 EQUALS BODY2 +1 # B(1)OUT  
SPOLYARG EQUALS BODY1 +1 # B(1)TMP ARGUMENT FOR POLLY

OLDBODY1 = EDRIVE X # 1 PULSE = 0.0432 DEGREES  
OLDBODY2 = EDRIVE Y  
OLDBODY3 = EDRIVE Z

# STORAGE FOR S11.1

VDISP EQUALS SPOLYARG +1 # I(2)OUT 2(7) M/CS  
HDISP EQUALS VDISP +2 # I(2)OUT 2(29) M  
HDOTDISP EQUALS HDISP +2 # I(2)OUT 2(7) M/CS  
BOOSTEMP EQUALS HDOTDISP +2 # B(3)TEMP

# P11 SATURN I/F (9D)

SATRATE EQUALS BOOSTEMP +3 # B(4)PL MANEUVER RATES FOR SATURN STICK  
SATSW EQUALS SATRATE +4 # B(1)TEM STATUS SW FOR BOOST TAKEOVER  
BIASAK EQUALS SATSW +1 # B(3)TEM STOR AKBIAS FOR BOOST TAKEOVER  
SATSCALE EQUALS BIASAK +3 # B(1) SCALE FACTOR FOR SATURN STEERING

# P21 STORAGE. (1D)

GENRET EQUALS RAD +2 # B(1)TMP

# R61CSM STORAGE. (1D)

SAVBNK EQUALS GENRET +1 # B(1) S-S SAVE EBANK FOR R61 SUBROUTINE

# CRS61.1 STORAGE FOR AUTOPILOT BANK. (3D)

SAVEDCDU EQUALS SAVBNK +1 # B(3)TMP

# R61 STORAGE. (1D)

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R61CNTR EQUALS SAVEDCDU +3 # (1)TMP

# ENTRY RESTART PROTECTION STORAGE. --KEEP TEMPS IN ORDER-- (12D)

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TEMPROLL      EQUALS  GENRET          # B(1)TMP COPY CYCLE REGISTER
TEMPALFA      EQUALS  TEMPROLL +1     # B(1)TMP COPY CYCLE REGISTER
TEMPBETA      EQUALS  TEMPALFA +1     # B(1)TMP COPY CYCLE REGISTER
60GENRET      EQUALS  TEMPBETA +1     # B(1)TMP QSAVE FOR S61.1 AND ENTRY.
S61DT         EQUALS  60GENRET +1     # B(1)TMP VARIABLE DT FOR S61.1 RESTART.

# ENTRY TM SHARING FOR ACCELERATION PROFILE.
XPIBBUF      EQUALS  ADOT             # B(1) PIPA BUFFER FOR TM DURING ENTRY.
YPIBBUF      EQUALS  XPIBBUF +1       # B(1) PIPS FILED HERE EACH .5 SEC APPEAR
ZPIBBUF      EQUALS  YPIBBUF +1       # B(1) ON DOWNLIST ONCE PER SECOND DURING
XOLDBUF      EQUALS  ZPIBBUF +1       # B(1) ENTRY AFTER RCS DAP HAS BEEN DIS-
YOLDBUF      EQUALS  XOLDBUF +1       # B(1) ABLED.  NEWEST PIP VALUE REPLACES
ZOLDBUF      EQUALS  YOLDBUF +1       # B(1) PIPBUF, WHICH IS MOVED INTO OLDBUF.

# REENTRY VARIABLES SHARED WITH RCS DAP FOR TM & FLIGHT RECORDER.
Q7            =        THETADZ        # I(2) HI-WORD ONLY ON DNLIST.
ASPS(TM)      =        WBODY          # I(6)DWN
                                           # ASKEP, ASP1, ASPUP, ASPDN, ASP3, ASP3

# P37 PAD LOADS (1)
P37RANGE      EQUALS  R61CNTR +1      # I(1)PL *****

END-E6        =        P37RANGE +1    # FIRST UNUSED ERASABLE LOCATION IN E6

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# EBANK-7 ASSIGNMENTS

SETLOC 3400

# *--*--*-- OVERLAY NUMBER 0 IN EBANK 7 --*--*--*

# EXTERNAL DELTA-V UPDATE. (21D)
# (MUST BE IN ORDER FOR UPDATE PROGRAM. ALSO ENTRY PROGRAM PICK UP 'LAT(SPL' WITH A

LAT(SPL)      ERASE  +20D             # I(2)DSP NOUN 61 FOR P62,63,64,67
LNG(SPL)      EQUALS  LAT(SPL) +2     # I(2)DSP NOUN 61 FOR P62,63,64,67

DELVSLV      EQUALS  LNG(SPL) +2     # I(6)TMP DELTA VEL VECT, LOC VER COORDS
TIG           EQUALS  DELVSLV +6      # B(2)DSP NOUN 33 FOR X-V84(R32),P30,40.
RTARG        EQUALS  TIG +2          # I(6)IN DESIRED VEHICLE RADIUS VECTOR
DELLT4       EQUALS  RTARG +6        # I(2)IN TIME DIFFERENCE FOR INITVEL
ECSTEER      EQUALS  DELLT4 +2       # I(1)PL FOR P40'S
DELVLVC      =        DELVSLV
END-DELV     ERASE
                                           # *NEXT AVAIL LOC AFTER UNSHARED E7*

# SERVICER STORAGE. (13D)

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DVTOTAL	EQUALS	END-DELV	# B(2)DSP NOUN 40,99 FOR P30,34,35,40
TGO	EQUALS	DVTOTAL +2	# B(2)
DVCNTR	EQUALS	TGO +2	# B(1)TMP
DELVREF	EQUALS	DVCNTR +1	# I(6)TMP

NOMTIG	EQUALS	END-KALC	# I(2) (CANNOT SHARE WITH KALCMANU # OR DELVREF)
END-SVCR	EQUALS	NOMTIG +2	# ***NEXT AVAILABLE AFTER SERVICER

# ALIGNMENT STORAGE.			(25D)
XSCD	EQUALS	END-SVCR	# I(6)TMP
YSCD	EQUALS	XSCD +6	# I(6)TMP
ZSCD	EQUALS	YSCD +6	# I(6)TMP
VEL/C	EQUALS	ZSCD +6	# I(6)TMP
R53EXIT	EQUALS	VEL/C +6	# I(1)TMP

# ALIGNMENT MARKDATA (DOWNLINK) ***** (7D)			
MARK2DWN	EQUALS	R53EXIT +1	# (7) USED BY ALIGNMENT P50'S

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# \*- - \*- - \*- OVERLAY NUMBER 1 IN EBANK 7 - \*- - \*- - \*

# REENTRY ERASABLES.			(206D)
RTINIT	EQUALS	END-SVCR	# 6P
RTEAST	EQUALS	RTINIT +6	# 6P
RTNORM	EQUALS	RTEAST +6	# 6P
RT	EQUALS	RTNORM +6	# 6P
UNI	EQUALS	RT +6	# 6P
UNITV	EQUALS	UNI +6	# 6P
VEL	EQUALS	UNITV +6	# 6P
TIME/RTO	EQUALS	VEL +6	# 2P TIME OF INITIAL TARGET, RTO.
-VREL	EQUALS	TIME/RTO +2	# 6P
OLDUYA	EQUALS	-VREL +6	# 6P USED BY CM/POSE (ENTRY DAP)
UXA/2	EQUALS	OLDUYA +6	# 6P USED BY CM/POSE (ENTRY DAP) -UVA
URH	=	UXA/2	# P67 DISPLAY NOUN
UYA/2	EQUALS	UXA/2 +6	# 6P USED BY CM/POSE (ENTRY DAP) UYA
UZA/2	EQUALS	UYA/2 +6	# 6P USED BY CM/POSE (ENTRY DAP) UNA
UBX/2	EQUALS	UZA/2 +6	# 6P USED BY CM/POSE (ENTRY DAP)
UBY/2	EQUALS	UBX/2 +6	# 6P USED BY CM/POSE (ENTRY DAP)
UBZ/2	EQUALS	UBY/2 +6	# 6P USED BY CM/POSE (ENTRY DAP)
DTEAROT	EQUALS	UBZ/2 +6	# 2P
DIFF	EQUALS	DTEAROT +2	# 2P
DIFFOLD	EQUALS	DIFF +2	# 2P
FACTOR	EQUALS	DIFFOLD +2	# 2P

FACT1	EQUALS	FACTOR	+2	# 2P	
FACT2	EQUALS	FACT1	+2	# 2P	
#Q7	=	THETAD2		# 2P	SHARED FOR TM. P64-P66
VSQUARE	EQUALS	FACT2	+2	# 2P	
LAD	EQUALS	VSQUARE	+2	# 2P	
LOD	EQUALS	LAD	+2	# 2P	
L/DCMINR	EQUALS	LOD	+2	# 2P	
KLAT	EQUALS	L/DCMINR	+2	# 2P	
L/D	EQUALS	KLAT	+2	# 2P	
L/D1	EQUALS	L/D	+2	# 2P	
LEWD	=	VIO		# 2P	SHARED FOR TM. P64-P65
D	EQUALS	L/D1	+2	# 2P	DSP NOUN 64,66,68 FOR P63,64,67
#V1	=	ENDBUF	+1	# 2P	SHARED FOR TM. P64-P65
DLEWD	EQUALS	D	+2	# 2P	
K2ROLL	EQUALS	DLEWD	+2	# 2P	
GOTOADDR	EQUALS	K2ROLL	+2	# 1P	
TEM1B	EQUALS	GOTOADDR	+1	# 2P	
MM	EQUALS	TEM1B	+2	# 2P	
GRAD	EQUALS	MM	+1	# 2P	
FX	EQUALS	GRAD	+1	# 1P	OVERWRITES NEXT 5 LOCS IN P67
LEQ	EQUALS	FX	+1	# 2P	
DHOOK	EQUALS	LEQ	+2	# 2P	
AHOOKDV	EQUALS	DHOOK	+2	# 2P	
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DVL	EQUALS	AHOOKDV	+2	# 2P	
#A0	=	ENDBUF	+3	# 2P	SHARED FOR TM. (HI-WD) P84-P85
A1	EQUALS	DVL	+2	# 2P	
VBARS	EQUALS	A1	+2	# 2P	
COSG/2	EQUALS	VBARS	+2	# 2P	
#GAMMAL	=	GAMMAEI		# 2P	SHARED FOR TM. P64
GAMMAL1	=	22D		# 2P	
VS1	EQUALS	COSG/2	+2	# 2P	
VL	=	VPRED		# 2P	SHARED FOR TM. P64-P65
V	EQUALS	VS1	+2	# 2P	
#VREF	=	THETAD	+2	# 2P	SHARED FOR TM. P65
LATANG	EQUALS	V	+2	# 2P	ADJACENT FOR TM.
RDOT	EQUALS	LATANG	+2	# 2P	ADJACENT FOR TM.
THETAH	EQUALS	RDOT	+2	# 2P	DSP NOUN 64,67 FOR P63,64,67
#RDOTREF	=	THETAD		# 2P	SHARED FOR TM. P65
ALP	EQUALS	THETAH	+2	# 2P	
ASKEP	=	ASPS		# 2P)	THESE ARE STORED IN
ASP1	=	ASPS	+1	# 2P)	SEQUENCE, OVERLAPPING
ASPUP	=	ASPS	+2	# 2P)>HI-WD OF EACH<	HI-WORD ONLY APPEARING
ASPDWN	=	ASPS	+3	# 2P)	ON DOWNLIST, EXCEPT
ASP3	=	ASPS	+4	# 2P)	ASP3 IS COMPLETE.

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C/D0          EQUALS  ALP      +2      # 2P      -1/D0
D0            EQUALS  C/D0     +2      # I(2)    CONSTANT DRAG
Q2            EQUALS  D0       +2      # 2P

# ROLL C IS LOCATED IN EBANK= AOG TO AID ENTRY DAP.
RTGO          EQUALS  Q2       +2      # 2P DSP NOUN 66 FOR P64,P67
DNRNGERR      EQUALS  RTGO     +2      # 2P DSP NOUN 66 FOR P64,67
XRNGERR       =      LATANG    #      FOR DISKY DISPLAY
KAT           EQUALS  DNRNGERR +2      # 2P
GMAX          EQUALS  KAT      +2      # 1P DSP NOUN 60 FOR P61,62,63
                                     # GMAX IS LOADED IN DOUBLE PRECISION.
L/DCALC       =      TTE      # 2P CALCULATED L/D FOR TM: P64-P67.
GAMMAL        =      GAMMAEI  # 2P SHARED FOR TM. P64.
PREDANG       =      GAMMAEI  #      FOR TM IN P67.
JJ            =      PREDANG +1    #      FOR TM IN P67.
VMAGI         EQUALS  GMAX     +1      # 2P DSP NOUN 62,64,66 FOR P11,63,64.
VIO           EQUALS  VMAGI    +2      # 2P DSP NOUN 63 FOR P61.
TTE           EQUALS  VIO      +2      # 2P DSP NOUN 63 FOR P61.
ASPS          EQUALS  TTE      +2      # I(2) HI-WORD ONLY ON DNLIST FOR TEMP
TTE1          EQUALS  ASPS     +2      # I(2) TMP HOLDS UNDECREMENTED TTE VALUE

# **** P60'S ****
RTGON64       EQUALS  RTGO          # RANGE ERRORS NEGATIVE IF FALLS SHORT
# Page 120
RTGON67       EQUALS  RTGO          # DSP NOUN 67

# REENTRY, RETURN TO EARTH COMMON DISPLAY      (4D)
VPRED         EQUALS  BETA12  +2      # DSP NOUN 60 FOR P61,62,63
GAMMAEI       EQUALS  VPRED   +2      # DSP NOUN 60 FOR P61,62,63

# DISPLAY REGISTER FOR VG      (2D)
VGDISP        EQUALS  GAMMAEI +2      # B(2)DSP N.40,42,99 FOR P30,34,35,37,40,
                                     #      41 VG DISPLAY

# SOME P11 DISPLAY REGISTERS      (6D)
ALTI          EQUALS  TTE1     +2      # 2P DSP NOUN 62 FOR P11.
HDOT          EQUALS  ALTI     +2      # 2P DSP NOUN 62 FOR P11.

# Page 121
# ***** OVERLAY NUMBER 2 IN EBANK 7 *****

# KALCMANU STORAGE.      (18D)
MFS           EQUALS  END-DELV    # I(18)
MFI           EQUALS  MFS         # I      TMP
DEL           EQUALS  MFS         # I      TMP
```

END-KALC           EQUALS   MFS       +18D   # \*\*NEXT AVAIL LOC AFTER KALCMANU\*\*

# MEASUREMENT INCORPORATION STORAGE (R22) STORAGE.           (56D)

TX789	EQUALS	END-KALC		# I(6)TMP
GAMMA	EQUALS	TX789	+6	# I(3)TMP
OMEGA	EQUALS	GAMMA	+2	# I(18)TMP
BVECTOR	EQUALS	OMEGA	+18D	# I(18)TMP
DELTAQ	EQUALS	BVECTOR	+18D	# I(2)TMP
VARIANCE	EQUALS	DELTAQ	+2	# I(3)TMP
RCLP	EQUALS	VARIANCE	+3	# I(6)TMP
GRP2SVQ	EQUALS	RCLP	+6	# I(1)TMP QSAVE FOR RESTARTS

# P20, P22, P23 DSP NOUN                                   (5D)

N49DISP	EQUALS	BVECTOR		# B(5)TMP
---------	--------	---------	--	-----------

# S22.1 STORAGE.   (36D)

SVMRKDAT	EQUALS	GRP2SVQ	+1	# I(36)TMP 5 SETS OF MARK DATA +PAD OF ONE
----------	--------	---------	----	--

# \*\*\*\* CISELUNAR NAV. ERAS. (P20'S) \*\*\*\*                   (45D)

TRUNX	EQUALS	SVMRKDAT	+36D	
DATATEST	EQUALS	TRUNX		# (1)
UBAR0	EQUALS	TRUNX	+1	
UBAR1	EQUALS	UBAR0	+6	
UBAR2	EQUALS	UBAR1	+6	
RZC	EQUALS	UBAR2	+6	
VZC	EQUALS	RZC	+6	
UCLSTAR	EQUALS	VZC	+6	
USSTAR	EQUALS	UCLSTAR	+6	
SRRETURN	EQUALS	USSTAR	+6	

# Page 122

# \*\*\*-\*\*\*- OVERLAY NUMBER 3 IN EBANK 7 -\*\*\*-\*\*\*

# RENDEZVOUS GUIDANCE STORAGE. -- P32 ... P35 --           (8D)

DELTEEO	EQUALS	END-KALC		# I(2) S-S BACK VALUES OF DELTA TIME
DELEL	EQUALS	DELTEEO	+2	# I(2) S-S
SECMAX	EQUALS	DELEL	+2	# I(2) S-S MAX STOP SIZE FOR ROUTINE
XXXALT	EQUALS	SECMAX	+2	# I(2)

# S40.9 STORAGE   (16D)

VG	EQUALS	XXXALT	+2	# I(6)TMP
VRPREV	EQUALS	VG	+6	# I(6)
TNIT	EQUALS	VRPREV	+6	# I(2)
TNITPREV	EQUALS	TNIT	+2	# I(2)

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```
# S40.2,3 STORAGE. (1D)
AXISCODE          EQUALS  TNITPREV +2  # I(1)IN

# P30'S-P17 COMMON STORAGE. (24D)
RACT3             EQUALS  GRP2SVQ +1   # I(6)TMP POSITION OF ACTIVE AT TPI TIME.
VACT3             EQUALS  RACT3  +6    # I(6)TMP VELOCITY OF ACTIVE AT TPI TIME.
RPASS3            EQUALS  VACT3  +6    # I(6)TMP POSITION OF PASSIVE AT TPI TIME.
VPASS3            EQUALS  RPASS3 +6    # I(6)TMP VELOCITY OF PASSIVE AT TPI TIME.

# P76, N84 DISPLAY (6D)
DELVOV           EQUALS  RACT3        # I(6)DSP NOUN 84 FOR X-V84, P34-35

# INITVEL/MIDGIM STORAGE. (34D)
# (CALLED BY S34.1,2, S35.1,2, AND S40.9)
# (CALLS LAMBERT, CONIC SUBROUTINES)
RINIT            EQUALS  VPASS3 +6    # I(6)IN ACTIVE VEHICLE RADIUS VECTOR
VINIT            EQUALS  RINIT  +6    # I(6)IN ACTIVE VEHICLE VELOCITY VECTOR
RTARG1           EQUALS  VINIT  +6    # I(6)TMP SHIFTED RTARG
VIPRIME          EQUALS  RTARG1 +6    # I(6)OUT NEW VEL REQ AT INITIAL RADIUS
VTPRIME          EQUALS  VIPRIME +6   # I(6)OUT TOTAL VELOCITY AT DESIRED RADIUS
+MGA             EQUALS  VTPRIME +6   # I(2)DSP NOUN 45 FOR P30,34,35. +MID GIM.
COZY4            EQUALS  +MGA  +2    # I(2)TMP COSINE OF ANGLE WHEN ROT STARTS

# THE FOLLOWING OVERLAYS MEASUREMENT INCORP AND CANNOT SHARE WITH TPI
# Page 123
INTIME           EQUALS  AXISCODE +3
ITCTR           EQUALS  INTIME  +2    # I(1)TMP ITERATION COUNTER
END-IN/M        EQUALS  COZY4  +2    # ** NEXT AVAIL LOC AFTER INITVEL/MIDGIM **

# P34 AND P33 STORAGE. (OVERLAYS INITVEL/MIDGIM) (24D)
VAPREC          EQUALS  RINIT        # I(6) S-S PREC VEC FOR NOM TPI TIME (ACT V)
RAPREC          EQUALS  VINIT        # I(6) S-S PREC VEC FOR NOM TPI TIME (ACT V)
VPPREC          EQUALS  VIPRIME      # I(6) S-S PREC VEC FOR NOM TPI TIME (PASS)
RPPREC          EQUALS  VTPRIME      # I(6) S-S PREC VEC FOR NOM TPI TIME (PASS)

# P30, P40 INTERFACE. (20D)
RTIG            EQUALS  END-IN/M     # I(6)TMP
VTIG            EQUALS  RTIG  +6     # I(6)TMP
DELVSIN         EQUALS  VTIG  +6     # I(6)TMP
DELVEET3        EQUALS  DELVSIN     # TMP DELTA VEL VECT INERTIAL COORDS.
VGTEMP          EQUALS  DELVEET3
DELVSAB         EQUALS  DELVSIN +6   # I(2)TMP

# P35-P40 INTERFACE STORAGE. (OVERLAYS P30-P40 I/F STORAGE) (12D)
RPASS4          EQUALS  RTIG        # I(6)TMP POSITION OF PASSIVE AT INTERCEPT
VPASS4          EQUALS  RPASS4 +6    # I(6)TMP VELOCITY OF PASSIVE AT INTERCEPT
```

```

# TPI SEARCH (P17)                                (6D)
E2                                EQUALS  VPASS4  +6    # I(6)TMP

# P30-P40 COMMON STORAGE.                          (3D)
TPASS4                            EQUALS  DELVSAB +2    # I(2)TMP
TINT                             =        TPASS4      # I(2)
QTEMP                            EQUALS  TPASS4  +2    # I(1)TMP

# P30-P40 STORAGE.                                (4D)
TTOGO                            EQUALS  QTEMP   +1    # B(2)DSP NOUN 35,40,45,59,99
                                     #          FOR P30,34,35,40,41,47, R30.
TTPI                             EQUALS  TTOGO   +2    # B(2)DSP NOUN 37 FOR P34 TPI TIME, CSECS.
# Page 124
END-P30S                         EQUALS  TTPI    +2    # ** NEXT AVAIL LOC AFTER P30-40 STORAGE. **

# P40 STORAGE.                                    (8D)
VGBODY                           EQUALS  END-P30S      # B(6)DSP NOUN 85 FOR P40,41,42 VG-SC COOR
DELVCTL                          =        VGBODY
P40TMP                           EQUALS  VGBODY  +6    # B(2)TMP

# P47 STORAGE.
DV47TEMP                         EQUALS  VG
DELVIMU                          EQUALS  P40TMP  +2    # I(6)DSP NOUN 83 FOR P47 DELTAV(IMU).

# S40.1 STORAGE.                                  (23D)
CSTEER                           EQUALS  DELVIMU +6    # I(2)IN
BDT                              EQUALS  CSTEER  +2    # I(6)IN
UT                               EQUALS  BDT    +6    # I(6)OUT THRUST DIRECTION
VGTIG                           EQUALS  UT     +6    # I(6)OUT
VGPREV                          =        VGTIG
F                               EQUALS  VGTIG  +6    # I(2)OUT S40.3 NEEDS THIS

QTEMP1                           EQUALS  F      +2    # I(1)TMP HOLDS RETURN

# R41                                           (2D)
T-TO-ADD                        EQUALS  QTEMP1  +1    # I(1D) FOR MIDTOAVE

# Page 125
# ***--*- OVERLAY NUMBER 4 IN EBANK 7 -***--*-

# S35.1 STORAGE.                                (2D)
TSTRT                            EQUALS  END-P30S      # I(2)IN MIDCOURSE START TIME

# S34.1 STORAGE. (OVERLAYS S35.1 STORAGE)        (1)
TITER                            EQUALS  TSTRT      # I(1)TMP ITERATION COUNTER

```



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```
# (P30-31 Q-SAVES) (1)
P30/31RT      EQUALS  TITER      # B(1) RETURN POINT

# P22 STORAGE. (6D)
S22WUNL      EQUALS  TSTRT  +2    # 1      WUNL W8 UNKNOWN INIT VALUE.
S22TOFF      EQUALS  S22WUNL +1    # 2      T SUB OFF
S22TPRIM     EQUALS  S22TOFF +2    # 2      SAVE TF
S22EORM      EQUALS  S22TPRIM +2   # 0 = EARTH -- NON-ZERO = MOON

# DOWNLINK ERASABLES FOR P22, P20 MARK DATA. (8D)
MARKDOWN     EQUALS  S22EORM +1    # B(1)
RM           EQUALS  S22RTNEX      # DOWNLINK OF VHF RANGE

# S22.1 (1D)
S22RTNEX     EQUALS  MARKDOWN +7   # B(1)

# P22 STORAGE (6D)
STARSAV3     EQUALS  S22RTNEX +1    # I(6)TMP

# CRS61.1 STORAGE. --A SUBSET OF P20-- (14D)
Q611         EQUALS  RM      +1     # I(1)TMP QSAVE
Q6111        EQUALS  Q611   +1     # I(1)TMP QSAVE
SAVEPOS      EQUALS  Q6111  +1     # I(6)TMP LEM POSITION VECTOR
# Page 126
SAVEVEL      EQUALS  SAVEPOS +6     # I(6)TMP LEM VELOCITY VECTOR

# ATTITUDE MANEUVER -- CALLED BY P20,R61,R63,CRS61.1 (3D)
PRAXIS       EQUALS  SAVEVEL +6     # B(3) S-S DISP RES FOR PREF AXIS N95.

# MARK ROUTINE (R21) STORAGE. -- IS SUBSET OF R22 -- (14D)
MRKBUF1      EQUALS  PRAXIS  +3     # B(7)TMP R21 MARK BUFFER.
MRKBUF2      EQUALS  MRKBUF1 +7     # B(7)TMP R21 MARK BUFFER.

# MORE CONICS STORAGE. (4)
COGA         EQUALS  3774          # I(2) COTAN OF INITIAL FLIGHT PATH ANGLE
INDEP        EQUALS  COGA          # I(1) USED BY SUBROUTINE 'ITERATOR'
EPSILONL     EQUALS  COGA  +2      # I(2)TMP

# RENDEZVOUS GUIDANCE STORAGE. -- P32...P35 -- (10D)
ELEV         EQUALS  MRKBUF2 +7     # I(2)TMP
RTX1         EQUALS  ELEV   +2     # (1)
RTX2         EQUALS  RTX1   +1     # (1)
RTMU         EQUALS  RTX2   +1     # (2)
RTSR1/MU     EQUALS  RTMU   +2     # (2)
CENTANG      EQUALS  RTSR1/MU +2    # I(2) S-S CENTRAL ANGLE COVERED (TPI-TFF)
```

```
# TPI SEARCH (S17.1, S17.2) P17 STORAGE.(10D)
DELTEE      EQUALS  MRKBUF2 +7      # I(2)
XRS         EQUALS  DELTEE +2       # I(2)
THETL      EQUALS  XRS +2          # I(2)
TF          EQUALS  THETL +2       # I(2)
DELHITE     EQUALS  TF +2          # (2)
```

```
# Page 127
```

```
# *- - *- - *- OVERLAY NUMBER 5 IN EBANK 7 - *- - *- - *
```

```
# P17,P34                                     (2D)
NN1      =      NN      # I(2)DSP NOUN 55,R1
```

```
# ***** THE FOLLOWING ARE FOR FLIGHT 504 ONLY *****
```

```
# RETURN-TO-EARTH STORAGE.                  (93D)
RTEDVD      EQUALS  END-IN/M      # I(2)IN DELTA VELOCITY DESIRED      M/CS
RTEGAM2D     EQUALS  RTEDVD +2    # I(2)IN REENTRY ANGLE DESIRED      REVS
RCON         EQUALS  RTEGAM2D +2  # I(2)TMP CONIC R2 RADIUS          M B23
R(T1)/       EQUALS  RCON +2      # I(6)TMP POSITION VECTOR AT TIG    M B23
R(T1)        EQUALS  R(T1)/ +6    # I(2)TMP MAGNITUDE OF R(T1)/     M B23
DT21PR       EQUALS  R(T1) +2     # I(2)TMP PREVIOUS DT21           CS B3
MAMAX1       EQUALS  DT21PR +2    # I(2)TMP MAJ AXIS LOW BOUND LMT   M B30
MAMAX2       EQUALS  MAMAX1 +2    # I(2)TMP MAJ AXIS UP BOUND LMT   M B30
R(T2)/       EQUALS  MAMAX2 +2    # I(6)TMP FINAL POSITION VECTOR     M B23
RD           EQUALS  R(T2)/ +6    # I(2)TMP FINAL R DESIRED         M B23
DRCON        EQUALS  RD +2        # I(2)TMP RCON SLOPE ITERATOR      M B23
RPRE'        EQUALS  DRCON +2     # I(2)TMP PREVIOUS RPRE           M B23
V(T1)/       EQUALS  RPRE' +2     # I(6)TMP VEL VECTOR AT TIG       M/CS
V2(T1)/      EQUALS  V(T1)/ +6    # I(6)TMP POST IMP VEL AT TIG     M/CS
DV           EQUALS  V2(T1)/ +6   # I(2)TMP DELTA VELOCITY AT TIG    M/CS
V(T2)/       EQUALS  DV +2        # I(6)TMP FINAL VELOCITY VECTOR    M/CS
T1           EQUALS  V(T2)/ +6    # I(2)TMP INITIAL VECTOR TIME     CS B2
PCON         EQUALS  T1 +2        # I(2)TMP SEMI-LATUS RECTUM       M B23
X(T1)        EQUALS  PCON +2      # I(2)TMP COTANGENT GAMMA1        B5
T12          EQUALS  X(T1) +2     # I(2)TMP INIT TO FINAL POSIT TIME CS B2
DELTAT       EQUALS  T12 +2      # I(2)TMP DELTA T IN SAVE PERILUNE CS B2
NN1A         EQUALS  DELTAT +2    # I(2)TMP ITERATION COUNTER 1
NN2          EQUALS  NN1A +2      # I(2)TMP ITERATION COUNTER 2
RTENCKEX     EQUALS  NN2 +2      # I(1)TMP RTENCK RETURN ADDRESS
CONICX1      EQUALS  RTENCKEX +1  # I(1)TMP CONICS MU TABLE INDEX
T2           EQUALS  CONICX1 +1   # I(2)TMP FINAL TIME              CS B2
UR1/         EQUALS  T2 +2        # I(6)TMP UNIT R(T1)/             B1
UV1/         EQUALS  UR1/ +6      # I(6)TMP UNIT V(T1)/             B1
BETA1        EQUALS  UV1/ +6      # I(2)TMP 1+X(T2)**2             B1
```

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P(T1)	EQUALS	BETA1	+2	# I(1)TMP PRIMARY BODY STATE TIME 1	B14
CFPA	EQUALS	P(T1)	+1	# I(2)TMP COSINE FLIGHT PATH ANGLE	B1
PHI2	EQUALS	CFPA	+2	# I(2)TMP PERI OR APO INDICATOR	B2
SPRTEX	EQUALS	PHI2	+2	# I(1)TMP ROUTINE RETURN ADDRESS	
VNSTORE	EQUALS	SPRTEX	+1	# I(1)TMP VERBNOUN STORAGE	
BETA12	EQUALS	VNSTORE	+1	# I(2)TMP SIGN FOR TIMERAD	

# OVERLAYS WITHIN RETURN-TO-EARTH STORAGE.

# Page 128

RPRE	EQUALS	24D	# I(2)TMP COMPUTED PREC RADIUS	M B29/B27
P/RPRE	EQUALS	26D	# I(2)TMP P/R	B4
R/APRE	EQUALS	28D	# I(2)TMP R/A	B6
X(T2)PRE	EQUALS	T12	# I(2)TMP PREC COTAN GAMMA2	B0
X(T2)	EQUALS	DELTAT	# I(2)TMP COTAN GAMMA2	B0
UH/	EQUALS	UV1/	# I(2)TMP UNIT HORIZONTAL VECTOR.	B1
SPRTETIG	EQUALS	TIG	# I(2)IN TIME OF IGNITION	CS B28

# Page 129

# \*-\*\*-\*- OVERLAY 6 IN EBANK 7 -\*\*-\*-\*

# P32,P33

# THE FOLLOWING OVERLAY MEAS. INCORP. ARE AND IN USE ONLY WHEN (32D)

POSTCSI	EQUALS	VG	# I(2)	
DELVCSI	EQUALS	POSTCSI +2	# I(2)	
DELDV	EQUALS	DELVCSI +2	# I(2)	
GAMPREV	EQUALS	DELDV +2	# I(2)	
DVPREV	EQUALS	GAMPREV +2	# I(2)	
POSTCDH	EQUALS	DVPREV +2	# I(2)	
HAFPA1	EQUALS	POSTCDH		
VACT4	EQUALS	POSTCDH +2	# I(6)	
RDOTV	EQUALS	VACT4 +6	# I(2)	
VACT1	EQUALS	RDOTV +2	# I(6)	
VPASS1	EQUALS	VACT1 +6	# I(6) VEL. PASSIVE VEH. AT CSI TIME	

UNVEC EQUALS VACT3

T2TOT3 EQUALS TPASS4 # I(2) TPI - TCDH

CSIALRM EQUALS TITER # I(2) ALARM INDEX

DELVEET2 EQUALS S22WUNL # I(6) VACT3 - VACT2 = DVCDH REF. COORD.

# ADDITIONAL CSI - CDH STORAGE. (10D)

RPASS1	EQUALS	CENTANG +2	# I(6) POS. PASSIVE VEH. AT CSI TIME.
LOOPCT	EQUALS	RPASS1 +6	# I(2) ITERATION COUNTER
NN	EQUALS	LOOPCT +2	# I(2)

```
# P21 STORAGE (19D)
P21ORIG EQUALS TRUNX # I(1)
P21BASER EQUALS P21ORIG +1 # I(6)
P21BASEV EQUALS P21BASER +6 # I(6)
P21ALT EQUALS P21BASEV +6 # I(2) NOUN 73 R1 ALTITUDE
P21VEL EQUALS P21ALT +2 # I(2) NOUN 73 R2 VELOCITY
P21GAM EQUALS P21VEL +2 # I(2) NOUN 73 R3 FLIGHT PATH ANGLE

# The following two statements had been just "WHOCARES = 3777".---RSB 2009
SETLOC 3777
WHOCARES EQUALS # A DUMMY FOR E-BANK INSENSITIVE 2CADRS.
END-E7 EQUALS WHOCARES # ***** LAST LOCATION IN E7

# Page 130 ... is empty.
```

This code is written to file `src/ERASABLE-ASSIGNMENTS.s`.

## A.27 EXECUTIVE

```

469  <src/EXECUTIVE.s 469>≡
    # Copyright:   Public domain.
    # Filename:    EXECUTIVE.agc
    # Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
    #              It is part of the source code for the Command Module's (CM)
    #              Apollo Guidance Computer (AGC), for Apollo 11.
    # Assembler:  yaYUL
    # Contact:     Ron Burkey <info@sandroid.org>.
    # Website:     www.ibiblio.org/apollo.
    # Pages:       1208-1220
    # Mod history: 2009-05-14 RSB   Adapted from the Colossus249/ file of the
    #              same name, using Comanche055 page images.
    #
    # This source code has been transcribed or otherwise adapted from digitized
    # images of a hardcopy from the MIT Museum. The digitization was performed
    # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
    # thanks to both. The images (with suitable reduction in storage size and
    # consequent reduction in image quality as well) are available online at
    # www.ibiblio.org/apollo. If for some reason you find that the images are
    # illegible, contact me at info@sandroid.org about getting access to the
    # (much) higher-quality images which Paul actually created.
    #
    # Notations on the hardcopy document read, in part:
    #
    #       Assemble revision 055 of AGC program Comanche by NASA
    #       2021113-051.  10:28 APR. 1, 1969
    #
    #       This AGC program shall also be referred to as
    #               Colossus 2A
    #
    # Page 1208
    #
    #       BLOCK      02
    #
    # TO ENTER A JOB REQUEST REQUIRING NO VAC AREA:
    #
    #       COUNT      02/EXEC
    #
    # NOVAC           INHINT
    # AD              FAKEPRET      # LOC(MPAC +6) - LOC(QPRET)
    # TS              NEWPRIO       # PRIORITY OF NEW JOB + NOVAC C(FIXLOC)
    #
    # EXTEND
    # INDEX           Q             # Q WILL BE UNDISTURBED THROUGHOUT.
    # DCA             0             # 2CADR OF JOB ENTERED.

```

```
DXCH  NEWLOC
CAF    EXECBANK
XCH    FBANK
TS      EXCTEM1
TCF    NOVAC2          # ENTER EXECUTIVE BANK.
```

# TO ENTER A JOB REQUEST REQUIREING A VAC AREA -- E.G., ALL (PARTIALLY) INTERPRETIVE

```
FINDVAC  INHINT
          TS      NEWPRIO
          EXTEND
          INDEX   Q
          DCA     0
SPVACIN  DXCH    NEWLOC
          CAF     EXECBANK
          XCH     FBANK
          TCF     FINDVAC2      # OFF TO EXECUTIVE SWITCHED-BANK.
```

# TO ENTER A FINDVAC WITH THE PRIORITY IN NEWPRIO TO THE 2CADR ARRIVING IN A AND L:  
# USERS OF SPVAC MUST INHINT BEFORE STORING IN NEWPRIO.

```
SPVAC    XCH      Q
          AD       NEG2
          XCH      Q
          TCF      SPVACIN
```

# TO SUSPEND A BASIC JOB SO A HIGHER PRIORITY JOB MAY BE SERVICED:

```
CHANG1   LXCH     Q
          CAF      EXECBANK
          XCH      BBANK
          TCF      CHANJOB
```

# TO SUSPEND AN INTERPRETIVE JOB:

```
CHANG2   CS       LOC          # NEGATIVE LOC SHOWS JOB = INTERPRETIVE.
# ITRACE (4) REFERS TO "CHANG2"
# Page 1209
```

```
          TS      L
+2        CAF     EXECBANK
          TS      BBANK
          TCF     CHANJOB -1
```

# Page 1210

# TO VOLUNTARILY SUSPEND A JOB UNTIL THE COMPLETION OF SOME ANTICIPATED EVENT (I/O EV

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JOBSLEEP	TS	LOC
	CAF	EXECBANK
	TS	FBANK
	TCF	JOBSLP1

# TO AWAKEN A JOB PUT TO SLEEP IN THE ABOVE FASHION:

JOBWAKE	INHINT		
	TS	NEWLOC	
	CS	TWO	# EXIT IS VIA FINDVAC/NOVAC PROCEDURES.
	ADS	Q	
	CAF	EXECBANK	
	XCH	FBANK	
	TCF	JOBWAKE2	

# TO CHANGE THE PRIORITY OF A JOB CURRENTLY UNDER EXECUTION:

PRIOCHNG	INHINT		# NEW PRIORITY ARRIVES IN A. RETURNS TO
	TS	NEWPRIO	# CALLER AS SOON AS NEW JOB PRIORITY IS
	CAF	EXECBANK	# HIGHEST. PREPARE FOR POSSIBLE BASIC-
	XCH	BBANK	# STYLE CHANGE-JOB.
	TS	BANKSET	
	CA	Q	
	TCF	PRIOCH2	

# TO REMOVE A JOB FROM EXECUTIVE CONSIDERATIONS:

ENDOFJOB	CAF	EXECBANK
	TS	FBANK
	TCF	ENDJOB1

ENDFIND	CA	EXECTEM1	# RETURN TO CALLER AFTER JOB ENTRY
	TS	FBANK	# COMPLETE.
	TCF	Q+2	

EXECBANK	CADR	FINDVAC2
----------	------	----------

FAKEPRET	ADRES	MPAC -36D	# LOC(MPAC +6) - LOC(QPRET)
----------	-------	-----------	-----------------------------

# Page 1211

# LOCATE AN AVAILABLE VAC AREA

BANK	01
COUNT	01/EXEC

FINDVAC2	TS	EXECTEM1	# (SAVE CALLER'S BANK FIRST.)
	CCS	VAC1USE	

	TCF	VACFOUND	
	CCS	VAC2USE	
	TCF	VACFOUND	
	CCS	VAC3USE	
	TCF	VACFOUND	
	CCS	VAC4USE	
	TCF	VACFOUND	
	CCS	VAC5USE	
	TCF	VACFOUND	
	TC	BAILOUT	
	OCT	1201	# NO VAC AREAS.
VACFOUND	AD	TWO	# RESERVE THIS VAC AREA BY STORING A ZERO
	ZL		# IN ITS VAC USE REGISTER AND STORE THE
	INDEX	A	# ADDRESS OF THE FIRST WORD OF IT IN THE
	LXCH	0 -1	# LOW NINE BITS OF THE PRIORITY WORD.
	ADS	NEWPRIO	
NOVAC2	CAF	ZERO	# NOVAC ENTERS HERE. FIND A CORE SET.
	TS	LOCCTR	
	CAF	NO.CORES	# SEVEN SETS OF ELEVEN REGISTERS EACH.
NOVAC3	TS	EXECTEM2	
	INDEX	LOCCTR	
	CCS	PRIORITY	# EACH PRIORITY REGISTER CONTAINS -0 IF
	TCF	NEXTCORE	# THE CORRESPONDING CORE SET IS AVAILABLE.
NO.CORES	DEC	6	
	TCF	NEXTCORE	# AN ACTIVE JOB HAS A POSITIVE PRIORITY
			# BUT A DORMANT JOB'S PRIORITY IS NEGATIVE
# Page 1212			
CORFOUND	CA	NEWPRIO	# SET THE PRIORITY OF THIS JOB IN THE CORE
	INDEX	LOCCTR	# SET'S PRIORITY REGISTER AND SET THE
	TS	PRIORITY	# JOB'S PUSH-DOWN POINTER AT THE BEGINNING
	MASK	LOW9	# OF THE WORK AREA AND OVERFLOW INDICATOR.
	INDEX	LOCCTR	
	TS	PUSHLOC	# OFF TO PREPARE FOR INTERPRETIVE PROGRAMS.
	CCS	LOCCTR	# IF CORE SET ZERO IS BEING LOADED, SET UP
	TCF	SETLOC	# OVFINDD AND FIXLOC IMMEDIATELY.
	TS	OVFINDD	
	CA	PUSHLOC	
	TS	FIXLOC	
SPECTEST	CCS	NEWJOB	# SEE IF ANY ACTIVE JOBS WAITING (RARE).
	TCF	SETLOC	# MUST BE AWAKENED OUT UNCHANGED JOB.
	TC	CCSHOLE	



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```

TC      CCSHOLE
TS      NEWJOB      # +0 SHOWS ACTIVE JOB ALREADY SET.
DXCH    NEWLOC
DXCH    LOC
TCF     ENDFIND

SETLOC   DXCH    NEWLOC      # SET UP THE LOCATION REGISTERS FOR THIS
        INDEX   LOCCTR
        DXCH    LOC
        INDEX   NEWJOB      # THIS INDEX INSTRUCTION INSURES THAT THE
        CS      PRIORITY    # HIGHEST ACTIVE PRIORITY WILL BE COMPARED
        AD      NEWPRIO     # WITH THE NEW PRIORITY TO SEE IF NEWJOB
        EXTEND   # SHOULD BE SET TO SIGNAL A SWITCH.
        BZMF     ENDFIND
        CA      LOCCTR      # LOCCTR IS LEFT SET AT THIS CORE SET IF
        TS      NEWJOB      # THE CALLER WANTS TO LOAD ANY MPAC
        TCF     ENDFIND     # REGISTERS, ETC.

NEXTCORE CAF      COREINC
        ADS      LOCCTR
        CCS      EXECTEM2
        TCF     NOVAC3
        TC      BAILOUT     # NO CORE SETS.
        OCT     1202

# Page 1213
# THE FOLLOWING ROUTINE SWAPS CORE SET 0 WITH THAT WHOSE RELATIVE ADDRESS IS IN NEWJOB.

        -2      LXCH    LOC
        -1      CAE     BANKSET      # BANKSET, NOT BBANK, HAS RIGHT CONTENTS.
CHANJOB  INHINT
        EXTEND
        ROR     SUPERBNK      # PICK UP CURRENT SBANK FOR BBCON
        XCH     L           # LOC IN A AND BBCON IN L.
        +4      INDEX   NEWJOB      # SWAP LOC AND BANKSET.
        DXCH    LOC
        DXCH    LOC

        CAE     BANKSET
        EXTEND
        WRITE   SUPERBNK      # SET SBANK FOR NEW JOB.
        DXCH    MPAC          # SWAP MULTI-PURPOSE ACCUMULATOR AREAS.
        INDEX   NEWJOB
        DXCH    MPAC
        DXCH    MPAC
        DXCH    MPAC +2
        INDEX   NEWJOB
```

	DXCH	MPAC +2	
	DXCH	MPAC +2	
	DXCH	MPAC +4	
	INDEX	NEWJOB	
	DXCH	MPAC +4	
	DXCH	MPAC +4	
	DXCH	MPAC +6	
	INDEX	NEWJOB	
	DXCH	MPAC +6	
	DXCH	MPAC +6	
	CAF	ZERO	
	XCH	OVFIND	# MAKE PUSHLOC NEGATIVE IF OVFIND NZ.
	EXTEND		
	BZF	+3	
	CS	PUSHLOC	
	TS	PUSHLOC	
	DXCH	PUSHLOC	
	INDEX	NEWJOB	
	DXCH	PUSHLOC	
	DXCH	PUSHLOC	# SWAPS PUSHLOC AND PRIORITY.
	CAF	LOW9	# SET FIXLOC TO BASE OF VAC AREA.
	MASK	PRIORITY	
	TS	FIXLOC	
	CCS	PUSHLOC	# SET OVERFLOW INDICATOR ACCORDING TO
	CAF	ZERO	
	TCF	ENDPRCHG -1	
# Page 1214			
	CS	PUSHLOC	
	TS	PUSHLOC	
	CAF	ONE	
	XCH	OVFIND	
	TS	NEWJOB	
ENDPRCHG	RELINT		
	DXCH	LOC	# BASIC JOBS HAVE POSITIVE ADDRESSES, SO
	EXTEND		# DISPATCH WITH A DTCB.
	BZMF	+2	# IF INTERPRETIVE, SET UP EBANK, ETC.
	DTCB		
# Page 1215			
	COM		# EPILOGUE TO JOB CHANGE FOR INTERPRETIVE
	AD	ONE	
	TS	LOC	# RESUME

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TCF INTRSM

# COMPLETE JOBSLEEP PREPARATIONS.

JOBSLP1	INHINT		
	CS	PRIORITY	# NNZ PRIORITY SHOWS JOB ASLEEP.
	TS	PRIORITY	
	CAF	LOW7	
	MASK	BBANK	
	EXTEND		
	ROR	SUPERBNK	# SAVE OLD SUPERBANK VALUE.
	TS	BANKSET	
	CS	ZERO	
JOBSLP2	TS	BUF +1	# HOLDS -- HIGHEST PRIORITY.
	TCF	EJSCAN	# SCAN FOR HIGHEST PRIORITY ALA ENDOFJOB.
NUCHANG2	INHINT		# QUICK... DON'T LET NEWJOB CHANGE TO +0.
	CCS	NEWJOB	
	TCF	+3	# NEWJOB STILL PNZ
	RELINT		# NEW JOB HAS CHANGED TO +0. WAKE UP JOB
	TCF	ADVAN +2	# VIA NUDIRECT. (VERY RARE CASE.)
	CAF	TWO	
	EXTEND		
	WOR	DSALMOUT	# TURN ON ACTIVITY LIGHT
	DXCH	LOC	# AND SAVE ADDRESS INFO FOR BENEFIT OF
	TCF	CHANJOB +4	# POSSIBLE SLEEPING JOB.

# Page 1216

# TO WAKE UP A JOB, EACH CORE SET IS FOUND TO LOCATE ALL JOBS WHICH ARE ASLEEP. IF THE FCADR I  
# LOC REGISTER OF ANY SUCH JOB MATCHES THAT SUPPLIED BY THE CALLER, THAT JOB IS AWAKENED. IF N  
# LOCCTR IS SET TO -1 AND NO FURTHER ACTION TAKES PLACE.

JOBWAKE2	TS	EXECTEM1	
	CAF	ZERO	# BEGIN CORE SET SCAN
	TS	LOCCTR	
	CAF	NO.CORES	
JOBWAKE4	TS	EXECTEM2	
	INDEX	LOCCTR	
	CCS	PRIORITY	
	TCF	JOBWAKE3	# ACTIVE JOB -- CHECK NEXT CORE SET.
COREINC	DEC	12	# 12 REGISTERS PER CORE SET.
	TCF	WAKETEST	# SLEEPING JOB -- SEE IF CADR MATCHES.
JOBWAKE3	CAF	COREINC	
	ADS	LOCCTR	

	CCS	EXECTEM2	
	TCF	JOBWAKE4	
	CS	ONE	# EXIT IF SLEEPING JOB NOT FOUND.
	TS	LOCCTR	
	TCF	ENDFIND	
WAKETEST	CS	NEWLOC	
	INDEX	LOCCTR	
	AD	LOC	
	EXTEND		
	BZF	+2	# IF MATCH.
	TCF	JOBWAKE3	# EXAMINE NEXT CORE SET IF NO MATCH.
	INDEX	LOCCTR	# RE-COMPLEMENT PRIORITY TO SHOW JOB AWAKE
	CS	PRIORITY	
	TS	NEWPRIO	
	INDEX	LOCCTR	
	TS	PRIORITY	
	CS	FBANKMSK	# MASK UP THE 2CADR OF THE WAKE ADDRESS
	MASK	NEWLOC	# USING THE CADR IN NEWLOC AND THE EBANK
	AD	2K	# HALF OF BBANK SAVED IN BANKSET.
	XCH	NEWLOC	
	MASK	FBANKMSK	
	INDEX	LOCCTR	
	AD	BANKSET	
	TS	NEWLOC +1	
	CCS	LOCCTR	# SPECIAL TREATMENT IF THIS JOB WAS
	TCF	SETLOC	# ALREADY IN THE RUN (0) POSITION.
	TCF	SPECTEST	

# Page 1217

# PRIORITY CHANGE. CHANGE THE CONTENTS OF PRIORITY AND SCAN FOR THE JOB OF HIGHEST P

PRIOCH2	TS	LOC	
	CAF	ZERO	# SET FLAG TO TELL ENDJOB SCANNER IF THIS
	TS	BUF	# JOB IS STILL HIGHEST PRIORITY.
	CAF	LOW9	
	MASK	PRIORITY	
	AD	NEWPRIO	
	TS	PRIORITY	
	COM		
	TCF	JOBSLP2	# AND TO EJSCAN.

# Page 1218

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# RELEASE THIS CORE SET AND VAC AREA AND SCAN FOR THE JOB OF HIGHEST ACTIVE PRIORITY.

```
ENDJOB1      INHINT
              CS      ZERO
              TS      BUF +1
              XCH      PRIORITY
              MASK     LOW9
              TS      L

              CS      FAKEPRET
              AD      L

              EXTEND
              BZMF     EJSCAN      # NOVAC ENDOFJOB

              CCS      L
              INDEX    A
              TS      0

EJSCAN        CCS      PRIORITY +12D
              TC      EJ1
              TC      CCSHOLE
              TCF      +1

              CCS      PRIORITY +24D  # EXAMINE EACH PRIORITY REGISTER TO FIND
              TC      EJ1              # THE JOB OF HIGHEST ACTIVE PRIORITY.
              TC      CCSHOLE
              TCF      +1

              CCS      PRIORITY +36D
              TC      EJ1
-CCSPR        -CCS     PRIORITY
              TCF      +1

              CCS      PRIORITY +48D
              TC      EJ1
              TC      CCSHOLE
              TCF      +1

              CCS      PRIORITY +60D
              TC      EJ1
              TC      CCSHOLE
              TCF      +1

              CCS      PRIORITY +72D
              TC      EJ1
```

TC CCSHOLE  
TCF +1

# Page 1219

# EVALUATE THE RESULTS OF THE SCAN.

CCS BUF +1 # SEE IF THERE ARE ANY ACTIVE JOBS WAITING  
TC CCSHOLE  
TC CCSHOLE

TCF +2  
TCF DUMMYJOB  
CCS BUF # BUF IS ZERO IS THIS IS A PRIOCHNG AND  
TCF +2 # CHANGED PRIORITY IS STILL HIGHEST.  
TCF ENDPRCHG -1

INDEX A # OTHERWISE, SET NEWJOB TO THE RELATIVE  
# Was CAF --- RSB 2004  
CA 0 -1 # ADDRESS OF THE NEW JOB'S CORE SET.  
AD -CCSPR  
TS NEWJOB  
TCF CHANJOB -2

EJ1 TS BUF +2  
AD BUF +1 # - OLD HIGH PRIORITY.  
CCS A  
CS BUF +2  
TCF EJ2 # NEW HIGH PRIORITY.  
NOOP  
INDEX Q  
TC 2 # PROCEED WITH SEARCH.

EJ2 TS BUF +1  
EXTEND  
QXCH BUF # FOR LOCATING CCS PRIORITY + X INSTR.  
INDEX BUF  
TC 2

# Page 1220

# IDLING AND COMPUTER ACTIVITY (GREEN) LIGHT MAINTENANCE. THE IDLING ROUTIEN IS NOT A  
# BUT RATHER A SUBROUTINE OF THE EXECUTIVE.

EBANK= SELFRET # SELF-CHECK STORAGE IN EBANK.

DUMMYJOB CS ZERO # SET NEWJOB TO -0 FOR IDLING.  
TS NEWJOB

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```

                                RELINT
                                CS      TWO          # TURN OFF THE ACTIVITY LIGHT.
                                EXTEND
                                WAND     DSALMOUT
ADVAN      CCS      NEWJOB          # IS THE NEWJOB ACTIVE?
                                TCF      NUCHANG2      # YES... ONE REQUIRING A CHANGE JOB.
                                CAF      TWO           # NEW JOB ALREADY IN POSITION FOR
                                TCF      NUDIRECT      # EXECUTION

                                CA      SELFRET
                                TS      L              # PUT RETURN ADDRESS IN L.
                                CAF      SELF BANK
                                TCF      SUPDXCHZ +1   # AND DISPATCH JOB.

SEF BANK    EBANK=    SELFRET
            BB CON    SELFCHK

NU DIRECT   EXTEND          # TURN THE GREEN LIGHT BACK ON.
            WOR      DSALMOUT
            DXCH     LOC      # JOBS STARTED IN THIS FASHION MUST BE
            TCF      SUPDXCHZ

            BLOCK    2        # IN FIXED-FIXED SO OTHERS MAY USE.

            COUNT    02/EXEC

# SUPDXCHZ -- ROUTINE TO TRANSFER TO SUPERBANK.
# CALLING SEQUENCE:
#           TCF      SUPDXCHZ          # WITH 2CADR OF DESIRED LOCATION IN A + 1.

SUPDXCHZ    XCH      L          # BASIC.
            +1      EXTEND
            WRITE    SUPERBNK
            TS      BBANK
            TC      L

NEG100      OCT      77677
```

This code is written to file src/EXECUTIVE.s.

## A.28 EXTENDED VERBS

```

480  <src/EXTENDED-VERBS.s 480>≡
    # Copyright:    Public domain.
    # Filename:     EXTENDED_VERBS.agc
    # Purpose:      Part of the source code for Comanche, build 055. It
    #               is part of the source code for the Command Module's
    #               (CM) Apollo Guidance Computer (AGC), Apollo 11.
    # Assembler:    yaYUL
    # Reference:     pp. 236-267
    # Contact:       Ron Burkey <info@sandroid.org>,
    #               Fabrizio Bernardini <fabrizio@spacecraft.it>
    # Website:       http://www.ibiblio.org/apollo.
    # Mod history:   2009-05-18 FB   Transcription Batch 3 Assignment.
    #               2009-05-20 RSB   Corrections:  P00D00 -> P00D00,
    #               GOTOP00H -> GOTOP00H, added a couple of
    #               missing instructions in Verb 96.
    #               2009-05-23 RSB   In SYSTEST, corrected TC FLAGWRD1 to
    #               CA FLAGWRD1.  Added a variety of SBANK=
    #               statements prior to 2CADRs.  One day I'll
    #               have to figure out what yaYUL is doing
    #               wrong with those ....
    #
    # The contents of the "Comanche055" files, in general, are transcribed
    # from scanned documents.
    #
    # Assemble revision 055 of AGC program Comanche by NASA
    # 2021113-051.  April 1, 1969.
    #
    # This AGC program shall also be referred to as Colossus 2A
    #
    # Prepared by
    #
    #               Massachussets Institute of Technology
    #               75 Cambridge Parkway
    #               Cambridge, Massachusetts
    #
    # under NASA contract NAS 9-4065.
    #
    # Refer directly to the online document mentioned above for further
    # information.  Please report any errors to info@sandroid.org.

    # Page 236

    BANK      7
    SETLOC    EXTVERBS
    BANK

```



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EBANK= OGC

COUNT\* \$\$/EXTVB

# FAN-OUT

GOEXTVB	INDEX	MPAC	# VERB-40 IS IN MPAC
	TC	LST2FAN	# FAN AS BEFROE.
LST2FAN	TC	VBZERO	# VB40 ZERO (USED WITH NOUN 20 ONLY)
	TC	VBCOARK	# VB41 COARSE ALIGN (USED WITH NOUN 20 OR 91 ONLY)
	TC	IMUFINEK	# VB42 FINE ALIGN IMU
	TC	IMUATTCK	# VB43 LOAD IMU ATTITUDE ERROR METERS.
	TC	SETSURF	# VB44 SET SURFACE FLAG
	TC	RESTSRF	# VB45 RESET SURFACE FLAG
	TC	STABLISH	# VB46 ESTABLISH G+C CONTROL
	TC	LMTOCMSV	# VB47 MOVE LM STATE VECTOR INTO CM
	TC	DAPDISP	# VB48 LOAD A/P DATA
	TCF	CREWMANU	# VB49 START AUTOMATIC ATTITUDE MANEUVER
	TC	GOLOADLV	# VB50 PLEASE PERFORM
	TC	GOLOADLV	# VB51 PLEASE MARK
	TC	V52	# VB52 SET OFFSET NO. FOR P22
	TC	GOLOADLV	# VB53 PLEASE PERFORM COAS MARK
	TC	GOTOR23	# VB54 PLEASE MARK (R-21 BACKUP)
	TC	ALINTIME	# VB55 ALIGN TIME
	TC	TRACKTRM	# VB56 TERMINATE TRACKING (P20 + P25)
	TC	GOTOR21	# VB57 START R21 REND TRACK SIGHT MARK ROUT
	TC	ENATMA	# VB58 ENABLE AUTOMATIC ATTITUDE MANEUVER
	TC	GOLOADLV	# VB59 PLEASE CALIBRATE
	TC	V60	# VB60 SET CPHIX (N17) EQUAL TO CDU
	TC	V61	# VB61 SELECT MODE I
	TC	V62	# VB62 SELECT MODE II, ERROR WRT N22
	TC	V63	# VB63 SELECT MODE III, ERROR WRT N17
	TC	VB64	# VB64 CALCULATE, DISPLAY S-BAND ANT ANGLES
	TC	CKOPTVB	# V 65 E OPTICAL VERIFICATION FOR PRELAUNC
	TC	ATTACHED	# VB66 ATTACHED. MOVE THIS TO OTHER STATE
	TC	V67	# VB67 W MATRIX MONITOR
	TC	STROKON	# VB68 CSM STROKE TEST ON.
VERB69	TC	VERB69	# VB69 CAUSE RESTART
	TC	V70UPDAT	# VB70 UPDATE LIFTOFF TIME.
	TC	V71UPDAT	# VB71 UNIVERSAL UPDATE -- BLOCK ADDRESS
	TC	V72UPDAT	# VB72 UNIVERSAL UPDATE -- SINGLE ADDRESS
	TC	V73UPDAT	# VB73 UPDATE AGC TIME (OCTAL)
	TC	DNEDUMP	# VB74 INITIALIZE DOWN-TELEMETRY PROGRAM # FOR ERASABLE DUMP.

```

# Page 237
TC      LFTFLGON      # VB75 SET LIFTOFF FLAG.
TC      SETPRFLG      # VB76 SET PREFERRED ATTITUDE FLAG
TC      RESETPRF      # VB77 RESET PREFERRED ATT. FLAG
TC      CHAZFOGC      # CHANGE GYROCOMPASS LAUNCH AZIMUTH V78
TC      ALM/END        # V79 SPARE
TC      LEMVEC         # VB80 UPDATE LEM STATE VECTOR
TC      CSMVEC         # VB81 UPDATE CSM STATE VECTOR
TC      V82PERF        # VB82 REQUEST ORBIT PARAM DISPLAY (R30)
TC      V83PERF        # VB83 RANGE, RANGE RATE, +X AXIS (R31)
TC      ALM/END        # V84 SPARE
TC      V85PERF        # VB85 RANGE, RANGE RATE, SLOS (R32)
TC      V86PERF        # VB86 BACKUP MARK REJECT
TC      SETVHFLG       # VB87 SET VHF RANGE FLAG
TC      RESETVHF       # VB88 RESET VHF RANGE FLAG
TC      V89PERF        # V89-ALIGN X OR PRF CSM AXIS TO LOS (R63)
TC      V90PERF        # VB90-OUT OF PLAN PARAMETERS (R36)
TC      GOSHOSUM       # VB91 TEMP FOR HYBRID AND STG.
TC      SYSTEST        # VB92 OPERATE IMU PERFORMANCE TEST
TC      WMATRXNG       # VB93 CLEAR RENDWFLG
TC      VERB94         # VB94 DO R64
TC      ALM/END        # VB95 SPARE
TCF     VERB96         # VB96 SET QUITFLAG TO STOP INTEGRATION
TC      GOLOADLV       # VB97 PLEASE PERFORM ENGINE-FAIL (R41)
TC      ALM/END        # VB98 SPARE
TC      GOLOADLV       # VB99 PLEASE ENABLE ENGINE

```

```

# END OF EXTENDED VERB FAN

```

```

TESTXACT  CCS      EXTVBACT
TC        ALM/END      # YES, TURN ON OPERATOR ERROR LIGHT
CA        FLAGWRD4     # ARE PRIOS USING DSKY
MASK      OC24100
CCS       A
TC        ALM/END

SETXTACT  CAF      OCT24      # SET BITS 3 AND 5
TS        EXTVBACT      # NO. SET FLAG TO SHOW EXT VERB DISPLAY
                                # SYSTEM BUSY

CA        Q
TS        MPAC +1

CS        TWO          # BLANK EVERYTHING EXCEPT MM AND VERB
TC        NVSUB
TC        +1

```

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	TC	MPAC +1	
XACTALM	TC	FALTON	# TURN ON OPERATOR ERROR LIGHT.
	TC	ENDEXT	# RELEASE MARK AND EXT. VERB DISPLAY SYS.
# Page 238			
TERMEXTV	EQUALS	ENDEXT	
ENDEXTVB	EQUALS	ENDEXT	
XACTO	CAF	ZERO	# RELEASE MARK AND EXT. VERB DISPLAY SYS.
	TC	SETXTACT	
ALM/END	TC	FALTON	# TURN ON OPERATOR ERROR LIGHT
GOPIN	TC	POSTJUMP	
	CADR	PINBRNCH	
OC24100	OCT	24100	
# Page 239			
# VBZERO	VERB 40	DESCRIPTION	
#			
#	1.	REQUIRE NOUN 20 (ICDU ANGLES)	
#	2.	REQUIRE AVAILABILITY OF EXT VERB DISPLAY SYSTEM	
#	3.	IF EITHER OF ABOVE CONDITIONS NOT PRESENT, TURN ON OPERATOR ERROR LIGHT AND GO	
#	4.	SET EXT VERB DISPLAY ACTIVE FLAG.	
#	5.	EXECUTE IMUZERO (ZERO IMU CDU ANGLES).	
#	6.	EXECUTE IMUSTALL (ALLOW TIME FOR DATA TRANSFER).	
#	7.	RELEASE EXT. VERB DISPLAY SYSTEM.	
VBZERO	TC	OP/INERT	
	TC	IMUZEROK	# RETURN HERE IF NOUN = ICDU(20)
	TC	ALM/END	# RETURN HERE IF NOUN = OCDU(91)
			# (NOT IN USE YET)
IMUZEROK	TC	CKMODCAD	# KEYBOARD REQUEST FOR ISS CDUZERO
	TC	BANKCALL	
	CADR	IMUZERO	
	TC	BANKCALL	# STALL
	CADR	IMUSTALL	
	TC	+1	
	TC	GOPIN	
OP/INERT	CS	OCT24	
	AD	NOUNREG	
	EXTEND		

```

          BZF      XACTOQ          # IF = 20.

          INCR     Q
          AD       OPIMDIFF        # -71
          EXTEND
          BZF      XACTOQ

          TC       ALM/END         # ILLEGAL.

OPIMDIFF  DEC      -71

```

# Page 240

# VBCOARK VERB 41 DESCRIPTION

# COARSE ALIGN IMU OR RADAR

#

# 1. REQUIRE NOUN 20 OR NOUN 91 OR TURN ON OPERATOR ERROR.

# 2. REQUIRE EXT VERB DISPLAY SYS AVAILABLE OR TURN ON OPERATOR ERROR LIGHT

#

# CASE 1 NOUN 20 (ICDU ANGLES)

# 3. SET EXT VERB DISPLAY ACTIVE FLAG.

# 4. DISPLAY FLASHING V25,N22 (LOAD NEW ICDU ANGLES).

#

# RESPONSES

#

# A. TERMINATE

#

# 1. RELEASE EXT VERB DISPLAY SYSTEM.

#

# B. PROCEED

#

# 1. DISPLAY FLASHING V25,N23 (LOAD DELTA ICDU ANGLES).

#

# RESPONSES:

#

# A. TERMINATE

#

# 1. RELEASE EXT VERB DISPLAY SYSTEM.

#

# B. PROCEED

#

# 1. EXECUTE ICORK2.

#

# C. ENTER

#

# 1. INCREMENT CDU ANGLES

#

# 2. EXECUTE ICORK2

#

# C. ENTER

#

# 1. EXECUTE ICORK2

#

# ICORK2

#

# 1. RE-DISPLAY VERB 41.

#

# 2. EXECUTE IMUCCARS (IMU COARSE ALIGN).

#

# 3. EXECUTE IMUSTALL (ALLOW TIME FOR DATA TRANSFER).

#

# 4. RELEASE EXT VERB DISPLAY SYSTEM.

#

# CASE 2 NOUN 91 (OCDU ANGLES)

#

# 5. (REQUIRE OPTICS SWITCH TO BE AT COMUTER OR TURN ON OPERATOR ERROR AND

#

# OPTICS AVAILABLE AND DISPLAY FLASHING V24,N92....LOAD NEW OPTICS ANGLE

#

# AND RELEASE EXT VERB DISPLAY SYSTEM).

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```
#      6.      RESPONSES TO V29,N92
#      A.      TERMINATE
#              RELEASE EXT VERB DISPLAY SYS.
#      B.      PROCEED OR ENTER
#              RE-DISPLAY VERB 41,      SET SWITCH TO INDICATE COURSE ALIGN OPTICS WORK
#              RELEASE EXT VERB DISPLAY SYSTEM.
```

```
VBCOARK      TC      OP/INERT
              TC      IMUCOARK      # RETURN HERE IF NOUN = ICDU (20)
              TC      OPTCOARK      # RETURN HERE IF NOUN = OCDU (91)
```

# RETURNS TO L+1 IF NOUN 20 -- TO L+2 IF NOUN 91.

```
IMUCOARK      TC      CKMODCAD      # COARSE ALIGN FROM KEYBOARD
              TC      TESTXACT
              CAF      VNLODCDU      # CALL FOR THETAD LOAD
              TC      BANKCALL
              CADR      GOXDSPF
              TC      TERMEXTV
              TCF      +1
```

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```
ICORK2        CAF      IMUCOARV      # RE-DISPLAY COARSE ALIGN VERB.
              TC      BANKCALL
              CADR      EXDSPRET

              TC      BANKCALL      # CALL MODE SWITCHING PROG
              CADR      IMUCOARS

              TC      BANKCALL      # STALL
              CADR      IMUSTALL
              TC      ENDEXTVB
              TC      ENDEXTVB
```

```
VNLODCDU      VN      2522
IMUCOARV      VN      4100
```

# Page 242

# TEMPORARY ROUTINE TO RUN THE OPTICS CDUS FROM THE KEYBOARD

```
OPTCOARK      CA      OPTCADR
              TC      CKMODCAD +1
              TC      TESTXACT
              CAF      EBANK5
              TS      EBANK
```

	CCS	SWSAMPLE	# SEE IF SWITCH AT COMPUTER
	TC	+5	# SWITCH AT COMPUTER
	TC	+1	# NOT ON COMPUTER
	TC	FALTON	# TURN ON OPERATOR ERR
	TC	ALARM	# AND ALARM
	OCT	00115	
	CCS	OPTIND	# SEE IF OPTICS AVAILABLE
	TC	OPTC1	# IN USE
	TC	OPTC1	# IN USE
	TC	OPTC1	# IN USE
	TC	ALARM	# OPTICS RESERVED (OPTIND=-0)
	OCT	00117	
	TC	ENDEXT	
OPTC1	CAF	VNLDOCDU	# VERB-NOUN TO LOAD OPTICS CDUS
	TC	BANKCALL	
	CADR	GOXDSPF	
	TC	TERMEXTV	
	TC	+1	# PROCEED
	CA	SAC	
	TS	DESOPTS	
	CA	PAC	
	TS	DESOPPT	
	CAF	OPTCOARV	# RE-DISPLAY OUR OWN VERB
	TC	BANKCALL	
	CADR	EXDSPRET	
	CAF	ONE	
	TS	OPTIND	# SET COARS WORKING
	TC	ENDEXTVB	
	TC	ENDEXTVB	
VNLDOCDU	VN	2492	
OPTCOARV	EQUALS	IMUCOARV	# DIFFERENT NOUNS.

# Page 243

# IMUFINEK VERB 42 DESCRIPTION

# FINE ALIGN IMU

#

- # 1. REQUIRE EXT VERB DISPLAY AVAILABLE AND SET BUSY FLAG OR TURN ON OPER
- # 2. DISPLAY FLASHING V25,N93....LOAD DELTA GYRO ANGLES....
- # RESPONSES

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```
#      A.      TERMINATE
#      1.      RELEASE EXT VERB DISPLAY SYSTEM.
#      B.      PROCEED OR ENTER
#      1.      RE-DISPLAY VERB 42
#      2.      EXECUTE IMUFINE (IMU FIVE ALIGN MODE SWITCHING).
#      3.      EXECUTE IMUSTALL (ALLOW FOR DATA TRANSFER)
#      A.      FAILED
#      1.      RELEASE EXT VERB DISPLAY SYSTEM.
#      B.      GOOD
#      1.      EXECUTE IMUPULSE (TORQUE IRIGS).
#      2.      EXECUTE IMUSTALL AND RELEASE EXT VERB DISPLAY S

IMUFINEK      TC      CKMODCAD      # FINE ALIGN WITH GYRO TORQUING.
              TC      TESTXACT
              CAF      VNLODGYR      # CALL FOR LOAD OF GYRO COMMANDS
              TC      BANKCALL
              CADR      GOXDSPF
              TC      TERMEXTV
              TC      +1      # PROCEED WITHOUT A LOAD

              CAF      IMUFINEV      # RE-DISPLAY OUR OWN VERB
              TC      BANKCALL
              CADR      EXDSPRET

              TC      BANKCALL      # CALL MODE SWITCH PROG
              CADR      IMUFINE

              TC      BANKCALL      # HIBERNATION
              CADR      IMUSTALL
              TC      ENDEXTVB

FINEK2        CAF      LGYROBIN      # PINBALL LEFT COMMANDS IN OGC REGISTERS
              TC      BANKCALL
              CADR      IMUPULSE

              TC      BANKCALL      # WAIT FOR PULSES TO GET OUT.
              CADR      IMUSTALL
              TC      ENDEXTVB
              TC      ENDEXTVB

LGYROBIN      ECADR      OGC
VNLODGYR      VN      2593
IMUFINEV      VN      4200      # FINE ALIGN VERB

CKMODCAD      CA      MODECADR
# Page 244
```

```

                                EXTEND
                                BZF    TCQ
                                TC      ALM/END                                # SOMEBODY IS USING MODECADR SO EXIT

# GOLOADLV      VERB 50      DESCRIPTION
#      AND OTHER PLEASE
#      DO SOMETHING VERBS
#
# PLEASE PERFORM, MARK, CALIBRATE, ETC.
#
#      1.      PRESSING ENTER ON DSKY INDICATES REQUESTED ACTION HAS BEEN PERFORMED.
#              SAME RECALL AS A COMPLETED LOAD.
#      2.      THE EXECUTION OF A VERB 33 (PROCEED WITHOUT DATA) INDICATES THE REQUIREMENT

GOLOADLV      TC      FLASHOFF
              CAF      PINSUPBT
              EXTEND
              WRITE    SUPERBNK      # TURN ON FE7
              TC      POSTJUMP
              SBANK=    PINSUPER
              CADR      LOADLV1

# V60      VERB 60
V60            EXTEND                                # SET ASTRONAUT TOTAL ATTITUDE (N17) EQUAL
              DCA      CDUX                                # TO PRESENT ATTITUDE
              DXCH     CPHIX
              CA      CDUZ
              TS      CPHIX    +2
              TC      GOPIN

# V61      VERB 61
V61            TC      DOWNFLAG      # SET NEEDLFLG TO 0 (FLAGWRD0,BIT9), PHASE
              ADRES    NEEDLFLG      # PLANE A/P FOLLOWING ERROR DISPLAYED
              TC      GOPIN

# V62      VERB 62
V62            TC      UPFLAG      # SET NEEDLFLG TO 1 (FLAGWRD0,BIT9),
              ADRES    NEEDLFLG      # TOTAL ATTITUDE ERROR DISPLAYED

              TC      UPFLAG      # SET N22ORN17 TO 1 (FLAGWRD9,BIT6),
              ADRES    N22ORN17      # COMPUTE TOTAL ATTITUDE ERROR WRT N22
              TC      GOPIN

# V63      VERB 63
V63            TC      UPFLAG      # SET NEEDLFLG TO 1 (FLAGWRD0,BIT9),
              ADRES    NEEDLFLG      # TOTAL ATTITUDE ERROR DISPLAYED

```



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# Page 245

TC	DOWNFLAG	# SET N22ORN17 TO 0 (FLAGWRD9,BIT6),
ADRES	N22ORN17	# COMPUTE TOAL ASTRONAUT ATTITUDE ERROR
TC	GOPIN	

# Page 246

# ALINTIME	VERB 55	DESCRIPTION
#		
#	1.	SET EXT VERB DISPLAY BUSY FLAG.
#	2.	DISPLAY FLASHING V25,N24 (LOAD DELTA TIME FOR AGC CLOCK.
#	3.	REQUIRE EXECUTION OF VERB 23.
#	4.	ADD DELTA TIME, RECEIVED FROM INPUT REGISTER, TO THE COMPUTER TIME.
#	5.	RELEASE EXT VERB DISPLAY SYSTEM.

COUNT 04/R33

ALINTIME	TC	TESTXACT	
	CAF	VNLODDT	
	TC	BANKCALL	
	CADR	GOMARKF	
	TC	ENDEXT	# TERMINATE
	TC	ENDEXT	# PROCEED
	CS	DEC23	# DATA IN OR RESEQUENCE (UNLIKELY)
	AD	MPAC	# RECALL LEFT VERB IN MPAC
	EXTEND		
	BZF	UPDATIME	# GO AHEAD WITH UPDATE ONLY IF RECALL
	TC	ENDEXT	# WITH V23 (DATA IN).

UPDATIME	INHINT		# DELTA TIME IS IN DSPTEM1, +1.
	CAF	ZERO	
	TS	MPAC +2	# NEEDED FOR TP AGREE
	TS	L	# ZERO T1 + 2 WHILE ALIGNING.
	DXCH	TIME2	
	DXCH	MPAC	
	DXCH	DSPTEM2 +1	# INCREMENT
	DAS	MPAC	
	TC	TPAGREE	# FORCE SIGN AGREEMENT.
	DXCH	MPAC	# NEW CLOCK.
	DAS	TIME2	
	RELINT		
UPDTMEND	TC	ENDEXT	
DEC23	DEC	23	# V 23

VNLODDT VN 2524 # V25N24 FOR LOAD DELTA TIME

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# SYSTEST VERB 92 DESCRIPTION

# OPERATE SELECTED SYSTEM TEST.

#

# 1. REQUIRE P00 OR P00- OR TURN ON OPERATOR ERROR.

# 2. TURN OFF DAP IF IT IS ON.

# 3. DISPLAY FLASHING V21,N01 (LOAD TEST NUMBER 1 THRU 17).

# 4. UPON ENTRY OF TEST NUMBER, SCHEDULE TSELECT WITH PRIORITY 20.

#

# TSELECT

# 1. IF LOADED TEST NUMBER IS VALID, GO TO THAT TEST ROUTINE, OTHERWISE T  
# REPEAT LOAD REQUEST DISPLAY. (NO. 3 ABOVE)

EBANK= QPLACE

COUNT 04/EXTVB

SYSTEST

TC CHKPOOH

CA FLAGWRD1

# IS NODOP01 FLAGBIT ON? (SET BY P11)

MASK NOP01BIT

EXTEND

BZF V92CONT

# IF IT'S NOT YET SET, CONTINUE

TC P00D00

# IT'S ON. SEND NODO ALARM FOR P07

OCT 1521

V92CONT

TC EXDAPOFF

# TURN DAP OFF IF IT'S ON

CAF PRI020

TC FINDVAC

EBANK= QPLACE

SBANK= IMUSUPER

2CADR REDO

TC GOPIN

# REDO AND TSELECT ARE NOW IN SYSTEM TEST.

COUNT\* \$\$/EXTVB

# CKOPTVB VERB 65 DESCRIPTION

# OPTICAL VERIFICATION FOR PRELAUNCH.

# 1. SCHEDULE GCOMPVER, OPTICAL VERIFICATION SUBPROGRAM, WITH PRIORITY 17

CKOPTVB

TC CHECKMM

MM 02

# I WONDER IF PRELAUNCH IS RUNNING

TC ALM/END

# NOT RUNNING OPERATOR ERROR

INHINT

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```
CAF    PRI016      # PRELAUNCH OPTICAL VERIFICATION
TC     FINDVAC
EBANK= QPLACE
2CADR  COMVER      # STANDARD LEADIN TO GCOMVER.

TC     GOPIN
```

# Page 248  
# V 78 ....

TO CHANGE GYROCOMPASS AZIMUTH

```
CHAZFOGC TC    CHECKMM      # IS IT PRELAUNCH
          MM     02
          TC     ALM/END      # NO -- OPERATOR ERROR
```

```
CAF    PRI016      # PRELAUNCH AZIMUTH CHANGE
TC     FINDVAC
EBANK=  XSM
2CADR  AZMTHCG1

TC     PHASCHNG
OCT    00174
TC     GOPIN
```

# Page 249

# IMUATTCK VERB 43 DESCRIPTION  
# LOAD IMU ATTITUDE ERROR METERS  
#

- # 1. REQUIRE PROGRAM 00 ACTIVE, COARSE ALIGN ENABLE BIT OFF AND ZERO ICDU BIT OFF.  
# 2. IF GUID REF RELEASE OR LIFTOFF HAS OCCURRED REQUIRE EXT VERB DISPLAY AVAILABLE  
# FLAG, OTHERWISE ALLOW CURRENT EXT VERB DISPLAY TO BE OVER-RIDDEN.  
# 3. REMOVE COARSE ALIGN ENABLE AND IMU ERROR COUNTER ENABLE.  
# 4. DISPLAY FLASHING V25,N22 (LOAD NEW ICDU ANGLES).  
# 5. UPON PROCEED OR ENTER RESPONSE, INITIALIZE CURRENT DAC AND COMMAND VALUES, ENAB  
# TRANSFER LOADED VALUES TO REGISTERS, AND SEND COMMANDS.  
# 6. IF BUSY FLAG SET, RESET IT TO RELEASE EXT VERB DISPLAY.

```
IMUATTCK TC    CHKPOOH

CAF    OCTAL30      # SEE IF IMU ZERO AND IMU COARSE ARE ON
EXTEND
RAND   CHAN12
CCS    A
TCF    ALM/END      # NOT ALLOWED IF IMU COARSE OR IMU ZERO ON

TC     CKLFTBTS     # IS IT BEFORE OR AFTER LIFTOFF
TC     TESTXACT      # AFTER
CS     OCT50         # REMOVE COARSE AND ECTR ENABLE
```

```

EXTEND
WAND      CHAN12

CAF       VNLODCDU
TC        BANKCALL
CADR      GOXDSPF
TCF       TRMATTCK
TC        +1
CAF       EBANK6
TS        EBANK      # SET E6 FOR NEEDLES.

EBANK=    AK

TC        BANKCALL      # INITIALIZE CURRENT DAC AND
CADR      NEEDLE11      # COMMAND VALUES.

TC        BANKCALL      # ENABLE ERROR COUNTERS.
CADR      NEEDLER2

CAF       TWO            # 4 MS MIN.
TC        WAITLIST
EBANK=    AK
2CADR     ATTCK1

TRMATTCK  TC        CKLFTBTS      # IS IT BEFORE OR AFTER LIFTOFF
          TCF       ENDEXT      # AFTER
          TC        GOPIN

# Page 250
ATTCK1    EXTEND      # TRANSFER LOADED VALUES TO DESIRED REQS.
          DCA       THETAD
          DXCH      AK
          CAE       THETAD +2
          TS        AK        +2

          TC        IBNKCALL     # SENDS COMMANDS LIMITED TO +,- 384 PULSES
          CADR      NEEDLES      # AND LEAVES ERROR COUNTERS ENABLED.

          TC        TASKOVER

CKLFTBTS  CAF       GRRBKBIT     # HAS LIFTOFF OCCURRED
          MASK      FLAGWRD5
          CCS       A
          TC        Q            # YES
          CAF       BIT5
          EXTEND
          RAND      CHAN30

```

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```

                                CCS      A
                                TCF      Q+1
XACTOQ                          TC       Q          # YES

OCTAL30                         OCT      30
VB64                            TC       CHKPOOH      # DEMAND PROGRAM 00.
                                TC       TESTXACT      # IF DISPLAY SYS. NOT BUSY, MAKE IT BUSY.
                                INHINT
                                CAF      PRI04
                                TC       FINDVAC
                                EBANK=   RHOSB
                                2CADR    SBANDANT      # CALC.,DISPLAY S-BAND ANTENNA ANGLES.
                                TC       ENDOFJOB
```

```
# ENATMA          VERB 58          DESCRIPTION
#      ENABLE AUTOMATIC ATTITUDE MANEUVER
#
# VERB58 RESETS STIKFLAG TO ENABLE R61 TO PERFORM AUTOMATIC TRACKING MANEUVERS, AFTER INTERRUPT
# ACTIVITY.
```

```
ENATMA          TC      DOWNFLAG      # RESET STIKFLAG.
                ADRES   STIKFLAG      # BIT 14 FLAG 1
                TC      GOPIN
```

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```
# STROKON          VERB 68          DESCRIPTION
#      STROKE TEST SETUP/ENABLE
#      1.          SET EXT VERB DISPLAY BUSY FLAG
#      2.          SCHEDULE STRKTST1 WITH PRIORITY 30.
#      3.          RELEASE EXT VERB DISPLAY.
```

```

                                EBANK=   T5TVCDT
STROKON          CS      FLAGWRD6      # V68   PERMITTED ONLY DURING TVC
                                MASK      OCT60000
                                EXTEND
                                BZMF     ALM/END      # NOT TVC....FLASH OP ERROR LIGHT
                                CAF      PRI030      # JOB REQUEST, TO SET UP STROKE TEST,
                                TC      NOVAC      #      INCLUDING INITIALIZATIONS
                                SBANK=   PINSUPER      # Added RSB 2009.
                                EBANK=   STROKER
                                2CADR    STRKTSTI
                                TC      GOPIN
```

```
# STABLISH          VERB 46          DESCRIPTION
```

```
#      ESTABLISH G AND N AUTOPILOT CONTROL
#      1.      SETS UP EITHER RCS, ENTRY, OR SATURN
#      2.      IF TVC IS ON, SETS UP CSM/LM SWITCH-OVER
#              FROM HIGH BW TO LOW BW
```

```
STABLISH      CAF      EBANK6      # V46 - SET EBANK TO E6
              TS      EBANK

              CS      FLAGWRD6      # TEST FOR TVC
              MASK    OCT60000
              EXTEND
              BZMF     +8

              CAE      DAPDATR1      # TET FOR CSM/LM
              MASK    BIT14
              EXTEND
              BZMF     +3

              TC      POSTJUMP      # CSM/LM, SO PERFORM HB TO LB SWITCH-OVER
              CADR    PRESWTCH

+3            TC      ALM/END

+8            TC      POSTJUMP      # SET UP RCS, ENTRY, OR SATURN-STICK DAP
              CADR    DAPFIG
```

```
# Page 252
```

```
# CREMANU      VERB 49      DESCRIPTION
#      START AUTOMATIC ATTITUDE MANEUVER
```

```
#      1.      REQUIRE PROGRAM 00 ACTIVE.
#      2.      SET EXT VERB DISPLAY BUSY FLAG.
#      3.      SCHEDULE R62DISP WITH PRIORITY 10.
#      4.      RELEASE EXT VERB DISPLAY.
```

```
#      R62DISP
```

```
#      1.      DISPLAY FLASHING V06,N22 (DECIMAL DISPLAY NEW ICDU ANGLES). UPON IM
#              4 FOR RESTART OF DISPLAY SEQUENCE.
```

```
#      RESPONSES
```

```
#      A.      TERMINATE
```

```
#              1.      GOTOPOOH
```

```
#      B.      PROCEED
```

```
#              1.      SET 3AXISFLG TO INDICATE MANEUVER IS SPECIFIED BY 3 A
```

```
#              2.      EXECUTE R60CSM (ATTITUDE MANEUVER).
```

```
#              3.      ZERO GROUP 4 (END R62).
```

```
#      C.      ENTER
```

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# 1. REPEAT FLASHING V06,N22.

CREWMANU TC CHKPOOH # DEMAND P00

TC TESTXACT

CAF PRI010

TC FINDVAC

EBANK= CPHI

2CADR R62DISP

TC ENDOFJOB

# Page 253

# DAPDISP VERB 48 DESCRIPTION

# LOAD AUTOPILOT DATA (ROUTINE R03)

#

# 0. CHECKFAIL AND RETURN IF TVC.

# 1. REQUIRE EXT VERB DISPLAY AVAILABLE AND SET BUSY FLAG.

# 2. LOWER PRIORITY TO 10.

# 3. DISPLAY FLASHING V04,N46 (DISPLAY AUTOPILOT CONFIGURATION).

# 4. UPON PROCEED RESPONSE, EXECUTE S41.2.

# 5. DISPLAY FLASHING V06,N47 (DISPLAY CSM WGT., LEM WGT.)

# 6. UPON PROCEED RESPONSE EXECUTE S40.14.

# 7. DISPLAY FLASHING V06,N48 (DISPLAY PITCH TRIM, YAW TRIM)

# 8. UPON PROCEED RESPONSE, RELEASE EXTENDED VERB DISPLAY SYSTEM.

COUNT\* \$\$/EXTVB

DAPDISP CS FLAGWRD6

MASK OCT60000

EXTEND

BZMF +2 # TVC = 10, CS YIELDS 01, BZMF TO CONTINUE

TC ALM/END # RETURN IF TVC

TC TESTXACT

TC BANKCALL

CADR DAPDISP1

BANK 42

SETLOC EXTVBS

BANK

COUNT 24/R03

DAPDISP1 CAF EBANK6

TS EBANK

	CAF	PRI010			
	TC	PRI0CHNG			
DONOUN46	CAF	V04N46	#	R1	R2
	TC	BANKCALL	#	DAPDATR1	DAPDATR2
	CADR	GOXDSPF	#	GOXDSP ROUTINES USED FOR EXTENDED VERBS.	
	TC	ENDEXT	#	EXT. VBS GO TO ENDEXT, NOT ENDOFJOB.	
	TC	+2			
	TC	DONOUN46			
	CA	DAPDATR1			
	MASK	BIT4			
	CCS	A			
	TCF	MAXIN			
	TC	DOWNFLAG			
	ADRES	MAXDBFLG			
MAXOUT	TC	BANKCALL			
	CADR	S41.2			
DONOUN47	CAF	V06N47	#	R1	R2
# Page 254	TC	BANKCALL	#	CSM WGT.	LEM WGT.
	CADR	GOXDSPF			R3
	TC	ENDEXT			
	TC	+2			
	TC	DONOUN47			
	CAE	DAPDATR1	#	DO MASS PROPERTIES CALCULATION ONLY IF	
	MASK	PRI030	#	CONFIG = 1(CSM), 2 (CSM/LM), 6(CSM/LMA)	
	EXTEND				
	BZF	DONOUN48	#	SKIP IF 0,4	
	COM				
	MASK	PRI030			
	EXTEND				
	BZF	DONOUN48	#	SKIP IF 3,7	
	INHINT				
	TC	IBNKCALL			
	CADR	MASSPROP	#	UPDATE IXX, IAVG, IAVG/TLX	
	RELINT				
	TC	BANKCALL			
	CADR	S40.14	#	COMPUTE RCS DAP STUFF	
DONOUN48	CAF	V0648	#	R1	R2
	TC	BANKCALL	#	PTRIM	YTRIM
					R3
					BLANK



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```
CADR    GOXDSPF

TC      ENDEXT
TC      ENDEXT
TC      DONOUN48

MAXIN    TC      UPFLAG
        ADRES    MAXDBFLG
        TC      MAXOUT

V0648    VN      0648
V06N47    VN      0647
V04N46    VN      0446
        BANK     43
        SETLOC   EXTVERBS
        BANK

COUNT*  $$/EXTVB
```

```
# V82PERF      VERB82      DESCRIPTION
#      REQUEST ORBIT PARAMETERS DISPLAY (R30)
#
#      1.      IF AVERAGE G IS OFF:
#                  FLASH DISPLAY V04N06.  R2 INDICATES WHICH SHIP'S STATE VECTOR IS
#                  TO BE UPDATED.  INITIAL CHOICE IS THIS SHIP (R2=1).  ASTRONAUT
#                  CAN CHANGE TO OTHER SHIP BY V22EXE, WHERE X NOT EQ I.
#                  SELECTED STATE VECTOR UPDATED BY THISPREC (OTHPREC).
#                  CALLS SR30.1 (WHICH CALLS TFFCONMU + TFFRP/RA) TO CALCULATE
# Page 255
#                  RPER (PERIGEE RADIUS), RAPO (APOGEE RADIUS), HPER (PERIGEE
#                  HEIGHT ABOVE LAUNCH PAD OR LUNAR LANDING SITE), HAPO (APOGEE
#                  HEIGHT AS ABOVE), TPER (TIME TO PERIGEE), TFF (TIME TO
#                  INTERSECT 300 KFT ABOVE PAD OR 35KFT ABOVE LANDING SITE).
#                  FLASH MONITOR V16N44 (HAPO, HPER, TFF).  TFF IS -59M59S IF IT WAS
#                  NOT COMPUTABLE, OTHERWISE IT INCREMENTS ONCE PER SECOND.
#                  ASTRONAUT HAS OPTION TO MONITOR TPER BY KEYING IN N 32 E.
#                  DISPLAY IS IN HMS, IS NEGATIVE (AS WAS TFF), AND INCREMENTS
#                  ONCE PER SECOND ONLY IF TFF DISPLAY WAS -59M59S.
#
#      2.      IF AVERAGE G IS ON:
#                  CALLS SR30.1 APPROX EVERY TWO SECS.  STATE VECTOR IS ALWAYS
#                  FOR THIS VEHICLE.  V82 DOES NOT DISTURB STATE VECTOR.  RESULTS
#                  OF SR30.1 ARE RAPO, RPER, HAPO, HPER, TPER, TFF.
#                  FLASH MONITOR V16N44 (HAPO, HPER, TFF).
#                  IF MODE IS P11, THEN CALL DELRSPL SO ASTRONAUT CAN MONITOR
#                  RESULTS BY N50E.  SPLASH COMPUTATION DONE ONCE PER TWO SECS.
```

```

#
# ADDENDUM:      HAPO AND HPER SHOULD BE CHANGED TO READ HAPOX AND HPERX IN THE
#                ABOVE REMARKS.

V82PERF          TC          TESTXACT

                  CAF        PRI07
                  TC         PRI0CHNG
                  TC         POSTJUMP
                  CADR        V82CALL          # ***** V82CALL MUST NOT BE A FINDVAC JOB.

# VB83PERF        VERB 83          DESCRIPTION
#                REQUEST RENDEZVOUS PARAMETER DISPLAY (R31)
#
#                1.      SET EXT VERB DISPLAY BUSY FLAG.
#                2.      SCHEDULE V83CALL WITH PRIORITY 10.
#                A.      DISPLAY
#                        R1      RANGE
#                        R2      RANGE RATE
#                        R3      THETA

V83PERF          TC          TESTXACT
                  INHINT
                  CS         FLAGWRD9          # SET R31 FLAG-BIT 4 FLAGWRD9
                  MASK        R31FLBIT
                  ADS         FLAGWRD9
                  CAF         PRI05
                  TC         NOVAC
                  SBANK=      LOWSUPER          # Added by RSB 2009
                  EBANK=      SUBEXIT
                  2CADR       R31CALL

                  TC         ENDOFJOB

# Page 256
V85PERF          TC          TESTXACT
                  INHINT
                  CS         R31FLBIT          # RESET R31 FLAG TO INDICATE R34
                  MASK        FLAGWRD9
                  TS         FLAGWRD9
                  TC         V83PERF +5

# Page 257
#                GOTOR21          VERB 57
#                GOTOR23-         VERB 54          DESCRIPTION
# SET UP MARKING FOR R22 (REND TRACK DATA PROC)
# 1.      SET EXT VERB DISPLAY BUSY FLAG

```

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- # 2. IF REND (P20 RUNNING) + TRACK (TRACKING ALLOWED) FLAGS ARE SET,
- # SCHEDULE R21 OR R23 WITH PRIORITY 16, OTHERWISE TURN ON ALARM 406
- # 3. RELEASE EXT VERB DISPLAY SYSTEM

```
GOTOR21      TC      DOWNFLAG      # CLEAR R23FLG
              ADRES    R23FLG      # BIT 9 FLAG 1
              TC      +3
GOTOR23      TC      UPFLAG        # SET R23FLG
              ADRES    R23FLG      # BIT 9 FLAG 1
              TC      TESTXACT
              CA      FLAGWRDO      # VB 57 UNACCEPTABLE UNLESS BOTH
              MASK     RNDVZBIT      # RENDEZVOUS AND TRACK FLAGS ON
              EXTEND
              BZF      R22ALARM

              CA      FLAGWRD1
              MASK     TRACKBIT
              EXTEND
              BZF      R22ALARM

              CA      FLAGWRD1      # TEST R23FLG
              MASK     R23BIT
              EXTEND
              BZF      REGR21      # R21
              CAF      PRI016
              TC      NOVAC
              EBANK=   MRKBUF1
              2CADR    R23CSM

REGR21      TC      ENDOFJOB
             CAF      PRI016
             TC      NOVAC
             EBANK=   MRKBUF1
             2CADR    R21CSM

R22ALARM     TC      ENDOFJOB
             TC      ALARM          # VERB 57 WAS SELECTED AND NEITHER REND
             OCT      00406        # NOR TRACK FLAG WERE ON.
             TC      ENDEXT
```

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# VERB 86 DESCRIPTION

# V86 IS TO R23 AS MARK REJECT IS TO R21

# V86 IS THE MARK REJECT FOR R23 (THE BACKUP MARKING ROUTINE)

EBANK= MRKBUF1

V86PERF	CAF	EBANK7	# BACKUP MARK REJECT (R23)
	XCH	EBANK	
	CA	NEGONE	
	TS	MRKBUF1	
	TC	GOPIN	

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# TRACKTRM VERB 56 DESCRIPTION

# TERMINATE TRACKING (P20)

# 1. KNOCK DOWN RENDEZVOUS, TRACK, AND UPDATE FLAGS.

# 2. REQUIRE P20 NOT RUNNING ALONE OR GO TO GOTOPOOH (REQUEST PROGRAM 00)

# 3. REQUIRE R22 RUNNING OR GO TO PINBRNCH.

# 4. IF INTEGRATION RUNNING, STALL UNTIL IT IS COMPLETED, THEN ZERO GROUPS

# 3. KNOCK DOWN RENDEZFOUS, R22, R21, TRACK, UPDATE, AND TARG1 FLAGS.

# 4. GO TO ENEMA (SOFTWARE RESTART).

# REFERENCE

# P20 RENDEZVOUS NAVIGATION

# R21 RENDEZVOUS TRACKING SIGHTING MARK.

# R22 RENDEZVOUS TRACKING DATA PROCESSING.

TRACKTRM	CA	RNDVZBIT	# IS REND FLAG ON
----------	----	----------	-------------------

MASK	FLAGWRDO
------	----------

EXTEND
--------

BZF	GOPIN	# NO
-----	-------	------

TC	DOWNFLAG
----	----------

ADRES	RNDVZFLG
-------	----------

CA	TRACKBIT	# IS TRACK FLAG ON
----	----------	--------------------

MASK	FLAGWRD1
------	----------

EXTEND
--------

BZF	GOPIN	# NO
-----	-------	------

TC	DOWNFLAG
----	----------

ADRES	TRACKFLG
-------	----------

TC	DOWNFLAG
----	----------

ADRES	UPDATFLG
-------	----------

TC	DOWNFLAG
----	----------

ADRES	IMUSE
-------	-------

CAF	EBANK6
-----	--------

TS	EBANK
----	-------

INHINT

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```

TC      STOPRATE

CAF      NEGONE
TS      OPTIND

TC      INTPRET
CALL
        INTSTALL      # DON'T INTERRUPT INTEGRATION
EXIT

TC      2PHSCHNG

# Page 260
OCT      2      # KILL GROUP 2 TO HALT P20 ACTIVITY
OCT      1      # ALSO KILL GROUP 1

CLEANOUT INHINT
TC      POSTJUMP
CADR     ENEMA      # CAUSE RESTART

# LEMVEC      VERB 80      DESCRIPTION
#      UPDATE LEM STATE VECTOR
#      RESET VEHUPFLG TO 0

LEMVEC    TC      DOWNFLAG
          ADRES    VEHUPFLG      # VEHUPFLG DOWN INDICATES LEM

          TCF      GOPIN

# CSMVEC      VERB 81      DESCRIPTION
#      UPDATE CSM STATE VECTOR
#      SET VEHUPFLG TO 1

CSMVEC    TC      UPFLAG
          ADRES    VEHUPFLG      # VEHUPFLG UP INDICATES CM

          TCF      GOPIN

# DNEDUMP      VERB 74      DESCRIPTION
#      INITIALZE DOWN-TELEMETRY PROGRAM FOR ERASABLE MEMORY DUMP.
#
#      1.      SET EXT VERB DISPLAY BUSY FLAG.
#      2.      REPLACE CURRENT DOWNLIST WITH ERASABLE MEMORY.
#      3.      RELEASE EXT VERB DISPLAY.

          EBANK= 10
DNEDUMP   CAF      LDNDUMPI
```

	TS	DNTMGOTO	
	TC	GOPIN	
V74	EQUALS	DNEDUMP	
LDNDUMPI	REMADR	DNDUMPI	
# LFTFLGON	VERB 75	DESCRIPTION	
#	SET LIFT-OFF FLAG		
#	1.	SETUP GRRBKFLG, GUIDANCE REFERENCE RELEASE BACK-UP FLAG.	
#	2.	RETURN VIA PINBRNCH	
LFTFLGON	TC	UPFLAG	# VB 75 -- SET LIFTOFF FLAG BIT
	ADRES	GRRBKFLG	# BIT 5 FLAG 5
	TC	GOPIN	

# Page 261

CHKPOOH	CA	MODREG	
	EXTEND		
	BZF	TCQ	
	TCF	ALM/END	
EXDAPOFF	EXTEND		
	DCA	IDLECADR	# SET T5 TO IDLE.
	DXCH	T5LOC	
	CS	OCT60000	
	MASK	FLAGWRD6	# RESET DAPBITS 1 AND 2.
	TS	FLAGWRD6	
	TC	Q	
	SBANK=	PINSUPER	# Added RSB 2009
	EBANK=	PACTOFF	
IDLECADR	2CADR	T5IDLOC	

# Page 262

# VERB 89	DESCRIPTION	RENDEZVOUS FINAL ATTITUDE ROUTINE (R63)
#		
#	# CALLED BY VERB 89 ENTER DURING P00. PRIO 10 IS USED. CALCULATES AND	
#	# DISPLAYS FINAL GIMBAL ANGLES TO POINT CSM +X AXIS OR PREFERRED AXIS	
#	# (UNIT(Z)COS55 DEG + UNIT(X)SIN55 DEG) AT LM.	
#		
#	# 1. KEY IN V 89 E ONLY IF IN PROG 00. IF NOT IN P00, OPERATOR ERROR AND	
#	# EXIT R63, OTHERWISE CONTINUE.	
#		
#	# 2. IF IN P00, DO IMU STATUS CHECK ROUTINE (R02BOTH). IF IMU ON AND ITS	
#	# ORIENTATION KNOWN TO CGC, CONTINUE.	
#		

```

# 3. FLASH DISPLAY V 04 N 06.  R2 INDICATES WHICH SPACECRAFT AXIS IS TO
# BE POINTED AT LM.  INITIAL CHOICE IS PREFERRED AXIS (R2=1).
# ASTRONAUT CAN CHANGE TO (+X) AXIS (R2 NOT = 1) BY V 22 E 2 E.  CONTINUE
# AFTER KEYING IN PROCEED.
#
# 4. SET PREFERRED ATTITUDE FLAG ACCORDING TO OPTION DESIRED.  SET FLAG
# FOR PREFERRED AXIS.  RESET FLAG FOR X AXIS.
#
# 5. CURRENT TIME IS STORED AND R63COMP IS CALLED
#
#       R63COMP JOB:
#
#           UPDATES CSM AND LM STATE VECTORS USING CONIC EQUATIONS.
#
#           CALCULATES BOTH PREFERRED AND X AXIS TRACKING ATT FROM CSM TO LM.
#
#           DESIRED GIMBAL ANGLES AS INDICATED BY PREFERRED ATTITUDE FLAG
#           ARE STORED FOR LATER R60CSM CALL.
#
# 6.  FLASH DISPLAY V 06 N18 AND AWAIT RESPONSE.
#
# 7.  RECYCLE:  RETURN TO STEP 5.
#      TERMINATE:  EXIT R63 ROUTINE
#      PROCEED:  RESET 3AXISFLG AND CALL R60CSM FOR ATTITUDE MANEUVER.

```

```

V89PERF      TC      CHKPOOH      # DEMAND P00
              TC      TESTXACT
              INHINT
              CAF      PRI010
              TC      FINDVAC
              SBANK=   LOWSUPER      # Added by RSB 2009.
              EBANK=   P21TIME
              2CADR    V89CALL

```

```

              TCF      ENDOFJOB

```

```

WMATRXNG     TC      DOWNFLAG      # RESET RENDWFLAG
              ADRES    RENDWFLG

```

```

# Page 263

```

```

              TC      DOWNFLAG      # RESET ORBWFLAG
              ADRES    ORBWFLAG
              TC      GOPIN

```

```

GOSHOSUM     EQUALS  SHOWSUM

```

SHOWSUM	TC	CHKPOOH	
	TC	TESTXACT	# *
	CAF	S+1	# *
	TS	SKEEP6	# * SHOWSUM OPTION
	CAF	S+ZERO	# *
	TS	SMODE	# * TURN OFF SELF-CHECK
	CA	SELFADRS	# *
	TS	SELFRET	# *
	TC	STSHOSUM	# * ENTER ROPECHK
SDISPLAY	LXCH	SKEEP2	# * BNK NO FOR DSP
	LXCH	SKEEP3	# * BUGGER WORD FOR DSP
NOKILL	CA	ADRS1	# *
	TS	MPAC +2	# *
	CA	VNCON	# * 0501
	TC	BANKCALL	# *
	CADR	GOXDSPF	# *
	TC	+3	# *
	TC	NXTBNK	# *
	TC	NOKILL	# *
	CA	SELFADRS	
	TS	SKEEP1	
	TC	ENDEXT	# *
VNCON	VN	501	# *
ENDSUMS	CA	SKEEP6	# *
	EXTEND		# *
	BZF	SELFCHK	# * ROPECHK, START SELFCHK AGAIN.
	TC	STSHOSUM	# * START SHOWSUM AGAIN.

# VB 76 --- SET PREFERRED ATTITUDE FLAG --- DRIVE TO PREFERRED.

SETPRFLG	TC	UPFLAG	
	ADRES	PRFTRKAT	# BIT 10 FLAG 5
	TC	GOPIN	

# VB 77 --- RESET PREFERRED ATTITUDE FLAG --- DRIVE TO +X-AXIS ATT.

RESETPRF	TC	DOWNFLAG	
	ADRES	PRFTRKAT	# BIT 10 FLAG 5
	TC	GOPIN	



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# VB 87 --- SET VHF RANGE FLAG --- ALLOWS R22 TO ACCEPT RANGE DATA.

SETVHFLG	TC	INTPRET
	SET	EXIT
		VHFRFLAG
	TC	GOPIN

# VB 88 --- RESET VHF RANGE FLAG --- STOPS ACCEPTANCE OF RANGE DATA.

RESETVHF	TC	INTPRET
	CLEAR	EXIT
		VHFRFLAG
	TC	TRFAILOF # TRACKER FAIL LIGHT
	TC	GOPIN

# VERB 66. VEHICLES ARE ATTACHED. --- MOVE THIS VEHICLE STATE VECTOR TO  
# OTHER VEHICLE STATE VECTOR.

# USE SUBROUTINE GENTRAN.

ATTACHED	EBANK=	RRECTHIS
	CAF	PRI010
	TC	FINDVAC
	EBANK=	RRECTHIS
	2CADR	ATTACHIT

TC	ENDOFJOB
----	----------

ATTACHIT	TC	INTPRET
	CALL	
		INTSTALL
	SET	BON
		MOONOTH
		MOONTHIS
		+3

CLEAR	MOONOTH
-------	---------

EXIT	
CAF	OCT51
TC	GENTRAN
ADRES	RRECTHIS
ADRES	RRECTOTH

# OUR STATE VECTOR INTO OTHER VIA GENTRAN

TACHEXIT	RELINT	
	TC	INTPRET

```

                                CALL          # UPDATE RN, VN, R-OTHER, V-OTHER
                                PTOACSM
# Page 265
                                LXA,2    CALL
                                PBODY
                                SVDWN1
                                CALL      SVDWN2
                                EXIT
                                CAF       TCPINAD
                                INDEX     FIXLOC
                                TS        QPRET
                                TC        POSTJUMP
                                CADR      INTWAKE

TCPIN      RTB
                                PINBRNCH

OCT51      OCT      51
TCPINAD    CADR     TCPIN

# VERB 47.  MOVE LM STATE VECTOR INTO CSM STATE VECTOR

LMTOCMSV   CAF      PRI010
           TC       FINDVAC
           EBANK=   RRECTHIS
           2CADR    LMTOCM

           TC       ENDOFJOB

LMTOCM     TC       INTPRET
           CALL
           INTSTALL
           SET      BON
           MOONTHIS
           MOONOTH
           +3
           CLEAR
           MOONTHIS
           EXIT

           CAF      OCT51
           TC       GENTRAN
           ADRES    RRECTOTH
           ADRES    RRECTHIS          # LM STATE VECTOR INTO CM VIA GENTRAN

```

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```

TCF      TACHEXIT

# VERB 94 --- DO R64 VIA ENEMA TO PICK UP IN P23.

VERB94    CAF      V94FLBIT
          MASK     FLAGWRD9      # IS V94FLAG SET
# Page 266
          EXTEND
          BZF      ALM/END      # NO --- OPERATOR ERROR

          TC       DOWNFLAG
          ADRES    V94FLAG

          TC       CHECKMM      # IS IT P23
          MM       23
          TC       ALM/END      # NO -- OPERATOR ERROR
          TC       PHASCHNG
          OCT      112          # SET GROUP 2 TO DO R64

          TC       CLEANOUT     # CAUSE RESTART

# V90PERF  VERB 90      DESCRIPTION
#          REQUEST RENDEZVOUS OUT-OF-PLANE DISPLAY (R36)
#
#          1.      SET EXT VERB DISPLAY BUSY FLAG.
#          2.      SCHEDULE R36 CALL WITH PRIORITY 10
#          A.      DISPLAY
#                   TIME OF EVENT -- HOURS, MINUTES, SECONDS
#                   Y          OUT-OF-PLANE POSITION -- NAUTICAL MILES
#                   YDOT      OUT-OF-PLANE VELOCITY -- FEET/SECOND
#                   PSI        ANGLE BTW LINE OF SIGHT AND FORWARD
#                   DIRECTION VECTOR IN HORIZONTAL PLANE -- DEGREES

V90PERF    TC       TESTXACT
          CAF      PRI07      # R36,V90
          TC       FINDVAC
          SBANK=    PINSUPER   # Added RSB 2009
          EBANK=    RPASS36
          2CADR     R36

          TCF      ENDOFJOB

# VERB 96  SET QUITFLAG TO STOP INTEGRATION

VERB96     TC       UPFLAG      # QUITFLAG WILL CAUSE INTEGRATION TO EXIT
```

```

                                ADRES  QUITFLAG      #      AT NEXT TIMESTEP

                                TC      UPFLAG
                                ADRES  V96ONFLG
                                CAF     ZERO
                                TC      POSTJUMP
                                CADR    V37            # GO TO P00

                                EBANK=  LANDMARK
V52                             TC      CHECKMM      # IS P22 OPERATING
                                MM      22
                                TC      ALM/END       # NO
                                CAF     LANDBANK
                                TS      EBANK

# Page 267
                                CS      PRI07          # YES  SET BITS 12,11,10 OF LANDMARK =
                                MASK    LANDMARK        #      BITS 14,13,12 OF MARKSTAT AFTER
                                TS      LANDMARK        #      SUBT. THEM FROM 5 TO GET OFFSET
                                CA      MARKSTAT        #      MARK NO.
                                TS      SR
                                CA      SR
                                CA      SR
                                MASK    PRI07
                                CS      A
                                AD      PRI05
                                ADS     LANDMARK
                                TC      GOPIN
LANDBANK                       ECADR    LANDMARK

# VERB 67  ASTRONAUT DISPLAY OF W MATRIX

V67                             TC      TESTXACT
                                CAF     PRI05
                                TC      FINDVAC
                                EBANK=  W
                                2CADR    V67CALL

                                TC      ENDOFJOB

# VB 44.  SET SURFACE FLAG.

SETSURF                       TC      UPFLAG
                                ADRES  SURFFLAG
                                TCF     GOPIN

```

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```
# VB 45. RESET SURFACE FLAG
```

```
RESTSRF      TC      DOWNFLAG  
              ADRES   SURFFLAG  
              TCF     GOPIN
```

This code is written to file `src/EXTENDED-VERBS.s`.

**A.29    FINDCDUW–GUIDAP INTERFACE**

```

510  <src/FINDCDUW-GUIDAP-INTERFACE.s 510>≡
      # Copyright:     Public domain.
      # Filename:      FINDCDUW--GUIDAP_INTERFACE.agc
      # Purpose:       Part of the source code for Luminary 1A build 099.
      #                It is part of the source code for the Lunar Module's (LM)
      #                Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Hartmuth Gutsche <hgutsche@explornet.com>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:          908-925
      # Mod history:   2009-05-28 HG    Transcribed from page images.
      #
      # This source code has been transcribed or otherwise adapted from
      # digitized images of a hardcopy from the MIT Museum. The digitization
      # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
      # the Museum. Many thanks to both. The images (with suitable reduction
      # in storage size and consequent reduction in image quality as well) are
      # available online at www.ibiblio.org/apollo. If for some reason you
      # find that the images are illegible, contact me at info@sandroid.org
      # about getting access to the (much) higher-quality images which Paul
      # actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #                Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
      #                16:27 JULY 14, 1969
      #
      # Page 908
      # PROGRAM NAME:   FINDCDUW
      # MOD NUMBER:     1            68-07-15
      # MOD AUTHOR:     KLUMPP
      #
      # OBJECTS OF MOD:        1.        TO SUPPLY COMMANDED GIMBAL ANGLES FOR NOUN 22.
      #                        2.        TO MAINTAIN CORRECT AND CURRENT THRUST
      #                                   DIRECTION DATA IN ALL MODES. THIS IS DONE BY
      #                                   FETCHING FOR THE THRUST DIRECTION FILTER THE
      #                                   CDUD'S IN PNGCS-AUTO, THE CDU'S IN ALL OTHER
      #                                   MODES.
      #                        3.        TO SUBSTITUTE A STOPRATE FOR THE NORMAL
      #                                   AUTOPILOT COMMANDS WHENEVER
      #                                   1) NOT IN PNGCS-AUTO, OR
      #                                   2) ENGINE IS OFF.
      #
      # FUNCTIONAL DESCRIPTION:

```

```

#
# FINDCDUW PROVIDES THE INTERFACES BETWEEN THE VARIOUS POWERED FLITE GUIDANCE PROGRAMS
# AND THE DIGITAL AUTOPILOT.  THE INPUTS TO FINDCDUW ARE THE THRUST COMMAND VECTOR
# AND THE WINDOW COMMAND VECTOR, AND THE OUTPUTS ARE THE GIMBAL ANGLE
# INCRMENTS, THE COMMANDED ATTITUDE ANGLE RATES, AND THE COMMANDED
# ATTITUDE LAG ANGLES (WHICH ACCOUNT FOR THE ANGLES BY WHICH THE BODY WILL
# LAG BEHIND A RAMP COMMAND IN ATTITUDE ANGLE DUE TO THE FINITE ANGULAR
# ACCELERATIONS AVAILABLE).
#
# FINDCDUW ALIGNS THE ESTIMATED THRUST VECTOR FROM THE THRUST DIRECTION
# FILTER WITH THE THRUST COMMAND VECTOR, AND, WHEN XDVINHIB SET,
# ALIGNS THE +Z HALF OF THE LM ZX PLANE WITH THE WINDOW COMMAND VECTOR.
#
# Page 909
# SPECIFICATIONS:
#
# INITIALIZATION:      A SINGLE INTERPRETIVE CALL TO INITCDUW IS REQUIRED
#                      BEFORE EACH GUIDED MANEUVER USING FINDCDUW.
#
# CALL:                INTERPRETIVE CALL TO FINDCDUW WITH THE THRUST COMMAND
#                      VECTOR IN MPAC.  INTERPRETIVE CALL TO FINDCDUW -2 WITH
#                      THE THRUST COMMAND VECTOR IN UNFC/2 AND NOT IN MPAC.
#
# RETURNS:             NORMAL INTERPRETIVE IN ALL CASES
#                      1.  NORMALLY ALL AUTOPILOT CMDS ARE ISSUED.
#                      2.  IF NOT PNGCS AUTO, DO STOPRATE AND RETURN
#                          WITHOUT ISSUING AUTOPILOT CMDS.
#                      3.  IF ENGINE OFF, DO STOPRATE AND RETURN WITHOUT
#                          ISSUING AUTOPILOT CMDS.
#
# ALARMS:              00401  IF INPUTS DETERMINE AN ATTITUDE IN GIMBAL LOCK.
#                      FINDCDUW DRIVES CDUXD AND CDUYD TO THE RQD VALUES,
#                      BUT DRIVES CDUZD ONLY TO THE GIMBAL LOCK CONE.
#
#                      00402  IF UNFC/2 OR UNWC/2 PRODUCE OVERFLOW WHEN
#                      UNITIZED USING NORMUNIT.  FINDCDUW ISSUES
#                      STOPRATE AS ONLY INPUT TO AUTOPILOT.
#
# INPUTS:              UNFC/2      THRUST COMMAND VECTOR, NEED NOT BE SEMI-UNIT.
#                      UNWC/2      WINDOW COMMAND VECTOR, NEED NOT BE SEMI-UNIT.
#                      OGABIAS     POSSIBLE BIAS FOR OUTER GIMBAL ANGLE (ZEROED IN INITCDU
#                      XOVINHIB    FLAG DENOTING X AXIS OVERRIDE INHIBITED.
#                      CSMDOCKD    FLAG DENOTING CSM DOCKED.
#                      STEERSW     FLAG DENOTING INSUFF THRUST FOR THRUST DIR FLTR.
#
# OUTPUTS:             DELCDUX,Y,Z

```

```

# OMEGAPD,+1,+2
# DELPEROR,+1,+2
# CPHI,+1,+2 FOR NOUN22
#
# DEBRIS: FINDCDUW DESTROYS SINCDUX,Y,Z AND COSCDUX,Y,Z BY
# WRITING INTO THESE LOCATIONS THE SINES AND COSINES
# OF THE CDUD'S IN PNGCS-AUTO, OF THE CDU'S OTHERWISE.

```

```

# Page 910

```

```

# INITIALIZATION FOR FINDCDUW

```

```

BANK 30
SETLOC FCDUW
BANK
EBANK= ECDUW
COUNT* $$/FCDUW

```

```

INITCDUW VLOAD
UNITX
STORE UNFV/2
STORE UNWC/2
RVQ

```

```

# FINDCDUW PRELIMINARIES

```

```

FINDCDUW VLOAD # FINDCDUW -2: ENTRY WHEN UNFC/2 PRE-STORD
UNFC/2 # INPUT VECTORS NEED NOT BE SEMI-UNIT
BOV SETPD # FINDCDUW: ENTRY WHEN UNFC/2 IN MPAC
FINDCDUW # INTERPRETER NOW INITIALIZED
22 # LOCS 0 THRU 21 FOR DIRECTION COSINE MAT
STQ EXIT
QCUDWUSR # SAVE RETURN ADDRESS

```

```

# MORE HAUSKEEPING

```

```

CA ECDUWL
XCH EBANK # SET EBANK
TS ECDWUSR # SAVE USER'S EBANK

CA DAPBOOLS
MASK CSMDOCKD # CSMDOCKD MUST NOT BE BIT15
CCS A
CA ONE # INDEX IF CSM DOCKED
TS NDXCDUW

CA XOVINHIB # XOVINHIB MUST NOT BE BIT15

```



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```

      TS      FLPAUTNO      # SET TO POS-NON-ZERO FLAG PNGCS AUTO NOT

      MASK    DAPBOOLS
      TS      FLAGOODW      # FLAGOODW = ANY PNZ NUMBER IF XOY INHIBTD

# Page 911
# FETCH BASIC DATA
      INHINT      # RELINT AT PAUTNO (TC INTPRET)

      CA      CDUX      # FETCH CDUX,CDUY,CDUZ IN ALL CASES, BUT
      TS      CDUSPOTX      #      REPLACE BELOW IF PNGCS AUTO
      CA      CDUY
      TS      CDUSPOTY
      CA      CDUZ
      TS      CDUSPOTZ

      CA      BIT10      # PNGCS CONTROL BIT
      EXTEND
      RAND    CHAN30
      CCS     A
      TCF     PAUTNO      # NOT PNGCS (BITS INVERTED)

      CA      BIT14      # AUTO MODE BIT
      EXTEND
      RAND    CHAN31
      CCS     A
      TCF     PAUTNO      # NOT AUTO (BITS INVERTED)

      TS      FLPAUTNO      # RESET FLAG PNGCS AUTO NOT

      CA      CDUXD      # PNGCS AUTO:  FETCH CDUXD,CDUYD,CDUZD
      TS      CDUSPOTX
      CA      CDUYD
      TS      CDUSPOTY
      CA      CDUZD
      TS      CDUSPOTZ

# Page 912
# FETCH INPUTS
PAUTNO      TC      INTPRET      # ENTERING THRUST CMD STILL IN MPAC
            RTB
            NORMUNIT
      STOVL    UNX/2      # SEMI-UNIT THRUST CMD AS INITIAL UNX/2
            UNWC/2
      RTB      RTB
            NORMUNIT
```

```

                                QUICTRIG      # ALWAYS RQD TO OBTAIN TRIGS OF CDUD'S
STOVL      UNZ/2                # SEMI-UNIT WINDOW CMD AS INITIAL UNZ/2
                                DELV
BOVB      UNIT
                                NOATTCNT      # AT LEAST ONE ENTERING CMD VCT ZERO
BOV      CALL
                                AFTRFLTR      # IF UNIT DELV OVERFLOWS SKIP FILTER
                                *SMNB*        # YIELDS UNIT(DELV) IN VEH COORDS FOR FLTR

# THRUST DIRECTION FILTER

                                EXIT

                                CA      UNFVY/2      # FOR RESTARTS, UNFV/2 ALWAYS INTACT, MPAC
                                LXCH     MPAC   +3      #      RENEWD AFTER RETURN FROM CALLER,
                                TC      FLTRSUB      #      TWO FILTER UPDATES MAY BE DONE.
                                TS      UNFVY/2      # UNFV/2 NEED NOT BE EXACTLY SEMI-UNIT.

                                CA      UNFVZ/2
                                LXCH     MPAC +5
                                TC      FLTRSUB
                                TS      UNFVZ/2

                                TC      INTERPRET      # COMPLETES FILTER

# Page 913
# FIND A SUITABLE WINDOW POINTING VECTOR

AFTRFLTR      SLOAD      BHIZ      # IF XOY NOT INHIBITED, GO FETCH ZNB
                                FLAGOODW
                                FETCHZNB
                                VLOAD      CALL
                                UNZ/2
                                UNWCTEST

FETCHZNB      VLOAD
                                ZNBPIP
                                STCALL     UNZ/2
                                UNWCTEST

                                VLOAD      VCOMP      # Z AND -X CAN'T BOTH PARALLEL UNFC/2
                                XNBPIP
                                STORE      UNZ/2

# COMPUTE THE REQUIRED DIRECTION COSINE MATRIX

```

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```
DCMCL      VLOAD  VXV
            UNZ/2
            UNX/2
            UNIT  PUSH      # UNY/2 FIRST ITERATION
            VXV   VSL1
            UNX/2
            STORE UNZ/2      # -UNZ/2 FIRST ITERATION
            VXSC  PDVL       # EXCHANGE -UNFVZ/2 UNZ/2 FOR UNY/2
            UNFVZ/2         # MUST BE SMALL
            VXSC  BVSU       # YIELDS -UNFVY/2 UNY/2-UNFVZ/2 UNZ/2
            UNFVY/2         # MUST BE SMALL
            VSL1  VAD
            UNX/2
            UNIT  # TOTALLY ELIMINATES THRUST POINTING ERROR
            STORE UNX/2      # UNX/2
            VXV   VSL1
            UNZ/2           # -UNZ/2 WAS STORED HERE REMEMBER
            STORE UNY/2      # UNY/2
            VCOMP VXV
            UNX/2
            VSL1
            STORE UNZ/2      # UNZ/2

# Page 914
# COMPUTES THE REQUIRED GIMBAL ANGLES

            CALL
            NB2CDUSP        # YIELDS THE RQD GIMBAL ANGLES, 2'S, PI
            EXIT

# LIMIT THE MIDDLE GIMBAL ANGLE & COMPUTE THE UNLIMITED GIMBAL ANGLE CHGS

            CA      MPAC +2      # LIMIT THE MGA
            TS      L            # CAN'T LXCH: NEED UNLIMITED MGA FOR ALARM
            CA      CDUZDLIM
            TC      LIMITSUB     # YIELDS LIMITED MGA. 1 BIT ERROR POSSIBLE
            XCH     MPAC +2      # BECAUSE USING 2'S COMP. WHO CARES?
            EXTEND
            MSU     MPAC +2      # THIS BETTER YIELD ZERO
            EXTEND
            BZF     +2
            TCF     ALARMMGA

MGARET     INHINT              # RELINT AT TC INTPRET AFTER TCQCUDW

            ZL
```

```

      CA      TWO
DELGMBLP TS      TEM2

      CA      L
EXTEND
SQUARE
      AD      HI5
EXTEND
BZMF      +3
      CA      ZERO
      TS      FLAGOODW

      INDEX   TEM2
      CA      MPAC
      INDEX   TEM2
      TS      CPHI
EXTEND
      INDEX   TEM2
      MSU     CDUXD
      COM
      INDEX   TEM2
      TS      -DELGMB
      TS      L
      CCS     TEM2
      TCF     DELGMBLP

```

# TO PREVENT FALSE STARTS ABOUT X, ZERO  
# FLAGOODW IF DELGMBZ OR Y TOO BIG.

# WITHIN 1 BIT OF -(45 DEG SQUARED)

# OUTPUTS TO NOUN22

# NO MATTER THAT THESE SLIGHTLY DIFFERENT  
# FROM WHEN WE INITIALLY FETCHED THEM

# -UNLIMITED GIMBAL ANGLE CHGS, 1'S, PI  
# FOR PRECEDING TEST ON NEXT LOOP PASS

# Page 915

# BRANCHES TO NOATTCNT

```

      CCS     FLPAUTNO
      TCF     NOATTCNT +2

```

# NO PNGCS AUTO

```

      CA      FLAGWRD5
      MASK    ENGONBIT
EXTEND
      BZF     NOATTCNT +2

```

# ENGINE NOT ON

# Page 916

# LIMIT THE ATTITUDE ANGLE CHANGES

#

# THIS SECTION LIMITS THE ATTITUDE ANGLE CHANGES ABOUT A SET OF ORTHOGONAL VEHICLE AXES  
# THESE AXES COINCIDE WITH THE COMMANDED VEHICLE AXES IF AND ONLY IF CDUXD IS ZERO.  
# THE COMMANDED VEHICLE SYSTEM ROTATED ABOUT THE X AXIS TO BRING THE Z AXIS INTO ALIGNMENT  
# AXIS. ATTITUDE ANGLE CHANGES IN THE PRIME SYSTEM ARE RELATED TO SMALL GIMBAL ANGLES

#

```

#      [  -DELATTX  ]  [ 1      SIN(CDUZD)      0 ] [ -DELGBX ]
#      [             ]  [             ] [             ]

```

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```
#      [ -DELATTYPRIME ] = [ 0      COS(CDUZD)      0 ] [ -DELGMBY ]
#      [                  ] [          ] [                ]
#      [ -DELATTZPRIME ] [ 0      0      1 ] [ -DELGMBZ ]

      LXCH      -DELGMB +2      # SAME AS -DELATTZPRIME UNLIMITED
      INDEX      NDXCDUW
      CA          DAZMAX
      TC          LIMITSUB
      TS          -DELGMB +2      # -DELGMBZ

      CA          -DELGMB +1
      EXTEND
      MP          COSCDUZ      # YIELDS -DELATTYPRIME/2 UNLIMITED
      TS          L
      INDEX      NDXCDUW
      CA          DAY/2MAX
      TC          LIMITSUB
      EXTEND
      DV          COSCDUZ
      XCH          -DELGMB +1      # -DELGMBY, FETCHING UNLIMITED VALUE

      EXTEND
      MP          SINCDUZ
      DDOUBL
      COM
      EXTEND      # YIELDS +DELATTX UNLIMITD, MAG < 180 DEG.
      MSU          -DELGMB      #      BASED ON UNLIMITED DELGMBV.
      TS          L      #      ONE BIT ERROR IF OPERANDS IN MSU
      INDEX      NDXCDUW      #      OF MIXED SIGNS. WHO CARES?
      CA          DAXMAX
      TC          LIMITSUB
      TS          -DELGMB      # SAVE LIMITED +DELATTX
      CCS          FLAGOODW
      CS          -DELGMB      # FETCH IT BACK CHGING SIGN IF WINDOW GOOD
      TS          -DELGMB      # OTHERWISE USE ZERO FOR -DELATTX
      CS          -DELGMB +1
      EXTEND
      MP          SINCDUZ
      DDOUBL      # YIELDS -CNTRIB TO -DELATTX FROM -DELGMBY
      ADS          -DELGMB      # -DELGMBX. NO OVERFLOW SINCE LIMITED TO
                                # 20DEG(1+SIN(70DEG)/COS(70DEG)) < 180DEG

# Page 917
# COMPUTE COMMANDED ATTITUDE RATES
#
#      [ OMEGAPD ] [ -2      -4 SINCDUZ      +0      ] [ -DELGMBZ ]
```

```

#      [          ] [
#      [ OMEGAQD ] = [ +0      -8 COSCDUZ COSCDUX      -4 SINCDUX ] [ -DELGMBY ]
#      [          ] [
#      [ OMEGARD ] [ +0      +8 COSCDUZ SINCDUX      -4 COSCDUX ] [ -DELGMBZ ]
#
# ATTITUDE ANGLE RATES IN UNITS OF PI/4 RAD/SEC = K TRIG FCNS IN UNITS OF 2 X GIMBAL
# PI/2 RAD/SEC.  THE CONSTANTS ARE BASED ON DELGMB BEING THE GIMBAL ANGLE CHANGES IN
# AND 2 SECONDS BEING THE COMPUTATION PERIOD (THE PERIOD BETWEEN SUCCESSIVE PASSES T

```

```

CS      -DELGMB
TS      OMEGAPD
CS      -DELGMB +1
EXTEND
MP      SINCDUZ
DDOUBL
ADS     OMEGAPD
ADS     OMEGAPD

CS      -DELGMB +1
EXTEND
MP      COSCDUX
DDOUBL
EXTEND
MP      COSCDUZ
TS      OMEGAQD
CS      -DELGMB +2
EXTEND
MP      SINCDUX
ADS     OMEGAQD
ADS     OMEGAQD
ADS     OMEGAQD

CA      -DELGMB +1
EXTEND
MP      SINCDUX
DDOUBL
EXTEND
MP      COSCDUZ
TS      OMEGARD
CS      -DELGMB +2
EXTEND
MP      COSCDUX
ADS     OMEGARD
ADS     OMEGARD
ADS     OMEGARD

```

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# Page 918

# FINAL TRANSFER

```
CDUWXFR      CA      TWO
              TS      TEM2
              INDEX   TEM2
              CA      -DELGMB
              EXTEND
              MP      DT/DELT      # RATIO OF DAP INTERVAL TO CDUW INTERVAL
              TC      ONESTO2S
              INDEX   TEM2
              TS      DELCDUX      # ANGLE INTERFACE

              INDEX   TEM2
              CCS      OMEGAPD
              AD      ONE
              TCF      +2
              AD      ONE
              EXTEND      # WE NOW HAVE ABS(OMEGAPD,QD,RD)
              INDEX   TEM2
              MP      OMEGAPD
              EXTEND
              MP      BIT11      # 1/16
              EXTEND
              INDEX   TEM2      #
              DV      1JACC      # UNITS PI/4 RAD/SEC
              TS      L
              CA      DELERLIM
              TC      LIMITSUB
              INDEX   TEM2
              TS      DELPEROR      # LAG ANGLE = OMEGA ABS(OMEGA)/2 ACCEL
              CCS      TEM2
              TCF      CDUWXFR
```

# HAUSKEEPING AND RETURN

```
TCQCDUW      CA      ECDUWUSR
              TS      EBANK      # RETURN USER'S EBANK

              TC      INTERPRET
              SETPD   GOTO
                      0
                      QCDUWUSR      # NORMAL AND ABNORMAL RETURN TO USER
```

# Page 919

# THRUST VECTOR FILTER SUBROUTINE

```

FLTRSUB      EXTEND
              QXCH    TEM2
              TS      TEM3      # SAVE ORIGINAL OFFSET
              COM      # ONE MCT, NO WDS, CAN BE SAVED IF NEG OF
              AD      L      # ORIG OFFSET ARRIVES IN A, BUT IT'S
              EXTEND    # NOT WORTH THE INCREASED OBSCURITY.
              INDEX    NDXCDUW
              MP      GAINFLTR
              TS      L      # INCR TO OFFSET, UNLIMITED
              CA      DUNFVLIM # SAME LIMIT FOR Y AND Z
              TC      LIMITSUB # YIELDS INCR TO OFFSET, LIMITED
              AD      TEM3    # ORIGINAL OFFSET
              TS      L      # TOTAL OFFSET, UNLIMITED
              CA      UNFVLIM # SAME LIMIT FOR Y AND Z
              TC      LIMITSUB # YIELDS TOTAL OFFSET, LIMITED
              TC      TEM2

```

# SUBR TO TEST THE ANGLE BETWEEN THE PROPOSED WINDOW AND THRUST CMD VCTS

```

UNWCTEST      DOT      DSQ
                UNX/2
              DSU      BMN
                DOTSWFMX
                DCMCL
              SSP      RVQ      # RVQ FOR ALT CHOICE IF DOT MAGN TOO LARGE
                FLAGOODW    # ZEROING WINDOW GOOD FLAG
                0

```

# Page 920

# NB2CDUSP RETURNS THE 2'S COMPLEMENT, PI, SP CDU ANGLES X,Y,Z IN MPAC,+1,+2 GIVEN T  
 # ARE THE SEMI-UNIT NAV BASE VECTORS X,Y,X EXPRESSED IN STABLE MEMBER COORDINATES, L  
 # NB2CDUSP USES THE ARCTRGSP WHICH HAS A MAXIMUM ERROR OF +-4 BITS.

```

NB2CDUSP      DLOAD    DSQ
                2
              BDSU    BPL
                DP1/4TH
                +3
              DLOAD
                ZEROVECS    # IN CASE SIN WAS SLIGHTLY > 1/2
              SQRT    EXIT    # YIELDS COS(CDUZ) IN UNITS OF 2
              EXTEND
              DCA      MPAC
              DDOUBL

```



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```
TS      TEM5
TCF     +3
CA      POSMAX      # OVERFLOW.  FETCH POSMAX, MPAC ALWAYS POS
TS      TEM5        # COS(CDUZ) IN TEM5, UNITS 1

INDEX   FIXLOC
CA      2
LXCH    MPAC
TC      ARCTRGSP
TS      MPAC +2      # CDUZ

CA      ZERO
TC      DVBYCOSM
CA      FOUR
TC      DVBYCOSM
CS      TEM1
TC      ARCTRGSP
TS      MPAC +1      # CDUY

CA      BIT4
TC      DVBYCOSM
CA      16OCT
TC      DVBYCOSM
CS      TEM1
TC      ARCTRGSP
TS      MPAC          # CDUX

TC      INTERPRET
RVQ
```

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# Page 921

```
# THE ELEMENTS OF THE NAV BASE MATRIX WHICH WE MUST DIVIDE BY COS(MGA)
# ALREADY CONTAIN COS(MGA)/2 AS A FACTOR. THEREFORE THE QUOTIENT SHOULD
# ORDINARILY NEVER EXCEED 1/2 IN MAGNITUDE. BUT IF THE MGA IS NEAR PI/2
# THEN COS(MGA) IS NEAR ZERO, AND THERE MAY BE SOME CHAFF IN THE OTHER
# ELEMENTS OF THE MATRIX WHICH WOULD PRODUCE CHAOS UNDER DIVISION.
# BEFORE DIVIDING WE MAKE SURE COS(MGA) IS AT LEAST ONE BIT LARGER
# THAN THE MAGNITUDE OF THE HIGH ORDER PART OF THE OPERAND.
#
# IF ONE OR MORE DIVIDES CANNOT BE PERFORMED, THIS MEANS THAT THE
# REQUIRED MGA IS VERY NEARLY +-PI/2 AND THEREFORE THE OTHER GIMBAL
# ANGLES ARE INDETERMINATE. THE INNER AND OUTER GIMBAL ANGLES RETURNED
# IN THIS CASE WILL BE RANDOM MULTIPLES OF PI/2.
```

```

DVBYCOSM      AD      FIXLOC
               TS      ADDRWD      # ADRES OF OPERAND

               INDEX   ADDRWD      # FETCH NEG ABS OF OPERAND, AD TEM5, AND
               CA      0           #          SKIP DIVIDE IF RESULT NEG OR ZERO
               EXTEND
               BZMF     +2
               COM
               AD      TEM5        # C(A) ZERO OR NEG, C(TEM5) ZERO OR POS
               EXTEND
               BZMF     TSL&TCQ    # DIFFERENCE ALWAYS SMALL IF BRANCH

               EXTEND            # TEM5 EXCEEDS ABS HIGH ORDER PART OF
               INDEX   ADDRWD    #          OPERAND BY AT LEAST ONE BIT.
               DCA     0         #          THEREFORE IT EXCEEDS THE DP OPERAND
               EXTEND            #          AND DIVISION WILL ALWAYS SUCCEED.
               DV      TEM5
TSL&TCQ        TS      L
               LXCH    TEM1
               TC      Q

```

# Page 922

# ARCTRGSP RETURNS THE 2'S COMPLEMENT, PI, SP ANGLE IN THE A REGISTER GIVEN ITS SINE  
 # UNITS OF 2. THE RESULT IS AN UNAMBIGUOUS ANGLE ANYWHERE IN THE CIRCLE, WITH A MAX.  
 # THE ERROR IS PRODUCED BY THE SUBROUTINE SPARCSIN WHICH IS USED ONLY IN THE REGION -

```

ARCTRGSP      EXTEND
               BZF     SINZERO    # TO AVOID DIVIDING BY ZERO

               EXTEND
               QXCH    TEM4
               TS      TEM2
               CA      L
               TS      TEM3
               CA      ZERO
               EXTEND
               DV      TEM2
               EXTEND
               BZF     USECOS

               CCS     TEM3        # SIN IS SMALLER OR EQUAL
               CA      ZERO
               TCF     +4
               CS      TEM2        # IF COS NEG, REVERSE SIGN OF SIN,
               TS      TEM2        #          ANGLE = PI-ARCSIN(SIN)
               CA      NEGMAX      # PICK UP PI, 2'S COMPLEMENT

```

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```

      TS      TEM3      # WE NO LONGER NEED COS
      CA      TEM2
      TC      SPARCSIN -1
      TC      ONESTO2S
      EXTEND
      MSU      TEM3
1T02&TCQ    TC      ONESTO2S
      TC      TEM4

USECOS      CS      TEM3      # COS IS SMALLER
      TC      SPARCSIN -1      # ANGLE = SIGN(SIN)(FI/2-ARCSIN(COS))
      AD      HALF
      TS      TEM3      # WE NO LONGER NEED COS
      CCS      TEM2
      CA      TEM3
      TCF      1T02&TCQ
      CS      TEM3
      TCF      1T02&TCQ

SINZERO      CCS      L
      CA      ZERO
      TC      Q
      CA      NEGMAX      # PI, 2'S COMP
      TC      Q
```

# Page 923

# SPARCSIN TAKES AN ARGUMENT SCALED UNITY IN A AND RETURNS AN ANGLE SCALED  
# 180 DEGREES IN A. IT HAS BEEN UNIT TESTED IN THE REGION  $\pm .94$  ( $\pm 70$   
# DEGREES) AND THE MAXIMUM ERROR IS  $\pm 5$  BITS WITH AN AVERAGE TIME OF  
# 450 MICROSECONDS. SPARCSIN -1 TAKES THE ARGUMENT SCALED TWO. (BOB CRISP)

```

      DOUBLE
SPARCSIN    TS      SR
      TCF      +4
      INDEX    A
      CS      LIMITS
      TS      SR
      EXTEND
      MP      A
      TS      TEM1
      EXTEND
      MP      DPL9
      AD      DPL7
      EXTEND
      MP      TEM1
      AD      DPL5
```

```

                                EXTEND
                                MP      TEM1
                                AD      DPL3
                                EXTEND
                                MP      TEM1
                                AD      DPL1
                                EXTEND
                                MP      SR
                                TC      Q
DPL1      DEC      10502
DPL3      DEC      432
DPL5      DEC      7300
DPL7      DEC      -11803
DPL9      DEC      8397

```

# Page 924

```

# LIMITSUB LIMITS THE MAGNITUDE OF THE POSITIVE OR NEGATIVE VARIABLE
# ARRIVING IN L TO THE POSITIVE LIMIT ARRIVING IN A.
# THE SIGNED LIMITED VARIABLE IS RETURNED IN A.
#
# VERSION COUTESY HUGH BLAIR-SMITH

```

```

LIMITSUB      TS      TEM1
              CA      ZERO
              EXTEND
              DV      TEM1
              CCS      A
              LXCH     TEM1
              TCF      +2
              TCF      +3
              CA      L
              TC      Q
              CS      TEM1
              TC      Q

```

# SUBROUTINE TO CONVERT 1'S COMP SP TO 2'S COMP

```

ONESTO2S      CCS      A
              AD      ONE
              TC      Q
              CS      A
              TC      Q

```

# NO ATTITUDE CONTROL

```

NOATTCNT      TC      ALARM

```

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```
OCT      00402      # NO ATTITUDE CONTROL

+2      INHINT      # COME HERE FOR NOATTCNT WITHOUT ALARM
      TC      IBNKCALL      # RELINT AT TC INTPRET AFTER TCQCDUW
      FCADR      STOPRATE
      TCF      TCQCDUW      # RETURN TO USER SKIPPING AUTOPILOT CMDS

# MIDDLE GIMBAL ANGLE ALARM

ALARMGA      TC      ALARM
      OCT      00401
      TCF      MGARET

# Page 925
*****
# CONSTANTS
*****

# ADDRESS CONSTANTS

ECDUWL      ECADR      ECDUW

# THRUST DIRECTION FILTER CONSTANTS

GAINFLTR      DEC      .2      # GAIN FILTER SANS CSM
      DEC      .1      # GAIN FILTER WITH CSM

DUNFVLIM      DEC      .007 B-1      # 7 MR MAX CHG IN F DIR IN VEH IN 2 SECS.
      # THIS DOES NOT ALLOW FOR S/C ROT RATE.

UNFVLIM      DEC      .129 B-1      # 129 MR MAX THRUST OFFSET. 105 MR TRAVEL
      # +10MR DEFL+5MR MECH MOUNT+9MR ABLATION.

# CONSTANT RELATED TO GIMBAL ANGLE COMPUTATIONS

DOTSWFMX      DEC      .93302 B-4      # LIM COLNRTY OF UNWC/2 & UNFC/2 TO 85 DEG
      # LOWER PART COMES FROM NEXT CONSTANT

DAXMAX      DEC      .1111111111      # DELATTX LIM TO 20 DEG IN 2 SECS, 1'S, PI
      DEC      .0111111111      # 2 DEG WHEN CSM DOCKED

DAY/2MAX      DEC      .0555555555      # LIKEWISE FOR DELATTY
      DEC      .0055555555

DAZMAX      =      DAXMAX      # LIKEWISE FOR DELATTZ
```

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CDUZDLIM            DEC      .3888888888      # 70 DEG LIMIT FOR MGA, 1'S, PI

# CONSTANTS FOR DATA TRANSFER

DT/DELT            DEC      .05                    # .1 SEC/2 SEC WHICH IS THE AUTOPILOT  
# CONTROL SAMPLE PERIOD/COMPUTATION PERIOD

DELERLIM            =            DAY/2MAX            #            0 DEG LIMIT FOR LAG ANGLES, 1'S, PI

# \*\*\* END OF FLY            .132 \*\*\*

This code is written to file `src/FINDCDUW--GUIDAP-INTERFACE.s`.

### A.30 FIXED FIXED CONSTANT POOL

[illegible]

## # BIT TABLE

BIT15	OCT	40000
BIT14	OCT	20000
BIT13	OCT	10000
BIT12	OCT	04000
BIT11	OCT	02000
BIT10	OCT	01000
BIT9	OCT	00400
BIT8	OCT	00200
BIT7	OCT	00100
BIT6	OCT	00040
BIT5	OCT	00020
BIT4	OCT	00010
BIT3	OCT	00004
BIT2	OCT	00002
BIT1	OCT	00001

# DO NOT DESTROY THIS COMBINATION, SINCE IT IS USED IN DOUBLE PRECISION INSTRUCTIONS

NEGO	OCT	-0	# MUST PRECEDE ZERO
ZERO	OCT	0	# MUST FOLLOW NEGO
# BIT1	OCT	00001	
# NO.WDS	OCT	2	# INTERPRETER
# OCTAL3	OCT	3	# INTERPRETER
# R3D1	OCT	4	# PINBALL
FIVE	OCT	5	
# REVCNT	OCT	6	# INTERPRETER
SEVEN	OCT	7	
# BIT4	OCT	00010	
# R2D1	OCT	11	# PINBALL
OCT11	=	R2D1	# P20S
# BINCON	DEC	10	# PINBALL (OCTAL 12)
ELEVEN	DEC	11	
# OCT14	OCT	14	# ALARM AND ABORT (FILLER)
OCT15	OCT	15	
# R1D1	OCT	16	# PINBALL
# Page 1201			
LOW4	OCT	17	
# BIT5	OCT	00020	
# ND1	OCT	21	# PINBALL
# VD1	OCT	23	# PINBALL
# OCT24	OCT	24	# SERVICE ROUTINES
# MD1	OCT	25	# PINBALL
BITS4&5	OCT	30	
# OCT31	OCT	31	# SERVICE ROUTINES
CALLCODE	OCT	00032	



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# LOW5	OCT	37	# PINBALL
# 33DEC	DEC	33	# PINBALL (OCTAL 41)
# 34DEC	DEC	34	# PINBALL (OCTAL 42)
TBUILDFX	DEC	37	# BUILDUP FOR CONVENIENCE IN DAPTESTING
TDECAYFX	DEC	38	# CONVENIENCE FOR DAPTESTING
# BIT6	OCT	00040	
OCT50	OCT	50	
DEC45	DEC	45	
SUPER011	OCT	60	# BITS FOR SUPERBNK SETTING 011.
.5SEC	DEC	50	
# BIT7	OCT	00100	
SUPER100	=	BIT7	# BITS FOR SUPERBNK SETTING 100
			# (LAST 4K OF ROPE)
SUPER101	OCT	120	# BITS FOR SUPERBNK SETTING 101
# OCT121	OCT	121	# SERVICE ROUTINES
			# (FIRST 8K OF ACM)
SUPER110	OCT	140	# BITS FOR SUPERBNK SETTING 110.
			# (LAST BK OF ACM)
1SEC	DEC	100	
# LOW7	OCT	177	# INTERPRETER
# BIT8	OCT	00200	
# OT215	OCT	215	# ALARM AND ABORT
# 8,5	OCT	00220	# P20-P25 SUNDANCE
2SECS	DEC	200	
# LOW8	OCT	377	# PINBALL
# BIT9	OCT	00400	
GN/CCODE	OCT	00401	# SET S/C CONTROL SWITCH TO G/N
3SECS	DEC	300	
4SECS	DEC	400	
LOW9	OCT	777	
# BIT10	OCT	01000	
# 5.5DEGS	DEC	.03056	# P20-P25 SUNDANCE (OCTAL 00765)
# OCT1103	OCT	1103	# ALARM AND ABORT
C5/2	DEC	.0363551	# (OCTAL 01124)
V05N09	VN	0509	# (SAME AS OCTAL 1211)
OCT1400	OCT	01400	
V06N22	VN	0622	
# MID5	OCT	1740	# PINBALL
BITS2-10	OCT	1776	
LOW10	OCT	1777	
# Page 1202			
# BIT11	OCT	02000	
# 2K+3	OCT	2003	# PINBALL
LOW7+2K	OCT	2177	# OP CODE MASK + BANK 1 FBANK SETTING
EBANK5	OCT	02400	

PRI03	OCT	03000	
EBANK7	OCT	03400	
# LOW11	OCT	3777	# PINBALL
# BIT12	OCT	04000	
# RELTAB	OCT	04025	# T4RUPT
PRI05	OCT	05000	
PRI06	OCT	06000	
PRI07	OCT	07000	
# BIT13	OCT	10000	
#	OCT	10003	# T4RUPT RELTAB +1D
# 13,7,2	OCT	10102	# P20-P25 SUNDANCE
PRI011	OCT	11000	
# PRI012	OCT	12000	# BANKCALL
PRI013	OCT	13000	
PRI014	OCT	14000	
#	OCT	14031	# T4RUPT RELTAB +2D
PRI015	OCT	15000	
PRI016	OCT	16000	
# 85DEGS	DEC	.45556	# P20-P25 SUNDANCE (OCTAL 16450)
PRI017	OCT	17000	
OCT17770	OCT	17770	
# BIT14	OCT	20000	
#	OCT	20033	# T4RUPT RELTAB +3D
PRI021	OCT	21000	
	BLOCK	03	
	COUNT	03/FCONS	
PRI022	OCT	22000	# SERVICE ROUTINES
PRI023	OCT	23000	
PRI024	OCT	24000	
# 5/8+1	OCT	24001	# SINGLE PRECISION SUBROUTINES
#	OCT	24017	# T4RUPT RELTAB +4D
PRI025	OCT	25000	
PRI026	OCT	26000	
PRI027	OCT	27000	
# CHRPRIO	OCT	30000	# PINBALL
#	OCT	30036	# T4RUPT RELTAB +5D
PRI031	OCT	31000	
C1/2	DEC	.7853134	# (OCTAL 31103)
PRI032	OCT	32000	
PRI033	OCT	33000	
PRI034	OCT	34000	
#	OCT	34034	# T4RUPT RELTAB +6D
PRI035	OCT	35000	
PRI036	OCT	36000	

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PRI037	OCT	37000		
63/64+1	OCT	37401		
# MID7	OCT	37600	# PINBALL	
OCT37766	OCT	37766		
OCT37774	OCT	37774		
OCT37776	OCT	37776		
# DPOSMAX	OCT	37777		
# BIT15	OCT	40000		
# OCT40001	OCT	40001	# INTERPRETER (CS 1 INSTRUCTION)	
DLOADCOD	OCT	40014		
DLOAD*	OCT	40015		
#	OCT	40023	# T4RUPT	RELTAB +7D
BIT15+6	OCT	40040		
OCT40200	OCT	40200		
#	OCT	44035	# T4RUPT	RELTAB +8D
#	OCT	50037	# T4RUPT	RELTAB +9D
#	OCT	54000	# T4RUPT	RELTAB +10D
-BIT14	OCT	57777		
# RELTAB11	OCT	60000	# T4RUPT	
C3/2	DEC	-.3216147	#	(OCTAL 65552)
13,14,15	OCT	70000		
-1/8	OCT	73777		
HIGH4	OCT	74000		
-ENDERAS	DEC	-2001	#	(OCTAL 74056)
# HI5	OCT	76000	# PINBALL	
HIGH9	OCT	77700		
# -ENDVAC	DEC	-45	# INTERPRETER	(OCTAL 77722)
# -OCT10	OCT	-10	#	(OCTAL 77767)
# NEG4	DEC	-4	#	(OCTAL 77773)
NEG3	DEC	-3		
NEG2	OCT	77775		
NEGONE	DEC	-1		

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# DEFINED BY EQUALS

# IT WOULD BE TO THE USERS ADVANTAGE TO OCCASIONALLY CHECK ANY OF THESE SYMBOLS IN ORDER TO PRE  
# ACCIDENTAL DEFINITION CHANGES.

MINUS1	=	NEG1
NEG1	=	NEGONE
ONE	=	BIT1
TWO	=	BIT2
THREE	=	OCTAL3

LOW2	=	THREE	
FOUR	=	BIT3	
SIX	=	REVCNT	
LOW3	=	SEVEN	
EIGHT	=	BIT4	
NINE	=	R2D1	
TEN	=	BINCON	
NOUTCON	=	ELEVEN	
OCT23	=	VD1	
OCT25	=	MD1	
PRI01	=	BIT10	
EBANK3	=	OCT1400	
PRI02	=	BIT11	
OCT120	=	SUPER101	
OCT140	=	SUPER110	
2K	=	BIT11	
EBANK4	=	BIT11	
PRI04	=	BIT12	
EBANK6	=	PRI03	
QUARTER	=	BIT13	
PRI010	=	BIT13	
OCT10001	=	CCSL	
POS1/2	=	HALF	
PRI020	=	BIT14	
HALF	=	BIT14	
PRI030	=	CHRPRI0	
BIT13-14	=	PRI030	# INTERPRETER USES IN PROCESSING STORECODE
OCT30002	=	TLOAD +1	
B12T14	=	PRI034	
NEGMAX	=	BIT15	
VLOADCOD	=	BIT15	
VLOAD*	=	OCT40001	
OCT60000	=	RELTAB11	
BANKMASK	=	HI5	

This code is written to file `src/FIXED-FIXED-CONSTANT-POOL.s`.

## A.31 FLAGWORD ASSIGNMENTS

533

*<src/FLAGWORD-ASSIGNMENTS.s 533>≡*

```
# Copyright:    Public domain.
# Filename:     FLAGWORD_ASSIGNMENTS.agc
# Purpose:     Part of the source code for Luminary 1A build 099.
#             It is part of the source code for the Lunar Module's (LM)
#             Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:     Onno Hommes <ohommes@cmu.edu>.
# Website:     www.ibiblio.org/apollo.
# Pages:       0061-0089
# Mod history: 2009-05-15 OH   Transcribed from page images.
#             2009-05-17 RSB   Extended to (blank) p. 89.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
# Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
# 16:27 JULY 14, 1969
```

# Page 61

```
# FLAGWORDS 0-11 ARE DOWNLINKED AND CAN BE SET AND CLEARED BY UP-FLAG AND DOWN-FLAG INST
# INTERPRETER. THESE WERE PREVIOUSLY LISTED UNDER "INTERPRETIVE SWITCH E
# THE ERASABLE LOG SECTION. FLAGWORDS 12 & 13 WERE PREVIOUSLY RADMODES A
# ARE STILL DOWNLINKED UNDER THOSE NAMES.
```

# ALPHABETICAL LIST OF FLAGWORDS

# FLAGWORD	DEC. NUMBER	BIT AND FLAG	BIT NAME
# ACCOKFLG	207	BIT 3 FLAG 13	ACCSOKAY
# ACC4-2FL	199	BIT 11 FLAG 13	ACC4OR2X
# ACMODFLG	032	BIT 13 FLAG 2	ACMODBIT
# ALTSCALE	186	BIT 9 FLAG 12	ALTSCBIT

# ANTENFLG	183	BIT 12 FLAG 12	ANTENBIT
# AORBSFLG	205	BIT 5 FLAG 13	AORBSYST
# AORBTFLG	200	BIT 10 FLAG 13	AORBTRAN
# APSESW	130	BIT 5 FLAG 8	APSESBIT
# APSFLAG	152	BIT 13 FLAG 10	APSFLBIT
# ASTNFLAG	108	BIT 12 FLAG 7	ASTNBIT
# ATTFFLAG	104	BIT 1 FLAG 6	ATTFLBIT
# AUTOMODE	193	BIT 2 FLAG 12	AUTOMBIT
# AUTR1FLG	209	BIT 1 FLAG 13	AUTRATE1
# AUTR2FLG	208	BIT 2 FLAG 13	AUTRATE2
# AUXFLAG	103	BIT 2 FLAG 6	AUXFLBIT
# AVEGFLAG	115	BIT 5 FLAG 7	AVEGFBIT
# AVEMIDSW	149	BIT 1 FLAG 9	AVEMDBIT
# AVFLAG	040	BIT 5 FLAG 2	AVFLBIT
# CALCMAN2	043	BIT 2 FLAG 2	CALC2BIT
# CALCMAN3	042	BIT 3 FLAG 2	CALC3BIT
# CDESFLAG	180	BIT 15 FLAG 12	CDESBIT
# CMOONFLG	123	BIT 12 FLAG 8	CMOONBIT
# COGAFLAG	131	BIT 4 FLAG 8	COGAFBIT
# CSMDKFLG	197	BIT 13 FLAG 13	CSMDOCKD
# CULTFLAG	053	BIT 7 FLAG 3	CULTBIT
# DAPBOOLS		FLGWRD13	
# DBSELFLG	206	BIT 4 FLAG 13	DBSELECT
# DESIGFLG	185	BIT 10 FLAG 12	DESIGBIT
# DIDFLAG	016	BIT 14 FLAG	DIDFLBIT
# DIMOFLAG	059	BIT 1 FLAG 3	DIMOBIT
# DMENFLG	081	BIT 9 FLAG 5	DMENFBIT
# DRIFTDFL	202	BIT 8 FLAG 13	DRIFTBIT
# DRIFTFLG	030	BIT 15 FLAG 2	DRFTBIT
# DSKYFLAG	075	BIT 15 FLAG 5	DSKYFBIT
# Page 62			
# D6OR9FLG	058	BIT 2 FLAG 3	D6OR9BIT
# ENGONFLG	083	BIT 7 FLAG 5	ENGONBIT
# ERADFLAG	017	BIT 13 FLAG 1	ERADFBIT
# ETPIFLAG	038	BIT 7 FLAG 2	ETPIBIT
# FINALFLG	039	BIT 6 FLAG 2	FINALBIT
# FLAGWRD0	(000-014)	(STATE +0)	
# FLAGWRD1	(015-029)	(STATE +1)	
# FLAGWRD2	(030-044)	(STATE +2)	
# FLAGWRD3	(045-059)	(STATE +3)	
# FLAGWRD4	(060-074)	(STATE +4)	
# FLAGWRD5	(075-089)	(STATE +5)	
# FLAGWRD6	(090-104)	(STATE +6)	
# FLAGWRD7	(105-119)	(STATE +7)	
# FLAGWRD8	(120-134)	(STATE +8D)	
# FLAGWRD9	(135-149)	(STATE +9D)	

EQUIVALENT FI

# FLAP	142	BIT 8 FLAG 9	FLAPBIT
# FLGWRD10	(150-164)	(STATE +10D)	
# FLGWRD11	(165-179)	(STATE +11D)	
# FLGWRD12	(180-194)	(STATE +12D)	
# FLGWRD13	(195-209)	(STATE +13D)	
# FLPC	138	BIT 12 FLAG 9	FLPCBIT
# FLPI	139	BIT 11 FLAG 9	FLPIBIT
# FLRCS	149	BIT 10 FLAG 9	FLRCSBIT
# FLUNDISP	125	BIT 10 FLAG 8	FLUNDBIT
# FLVR	136	BIT 14 FLAG 9	FLVRBIT
# FREEFLAG	012	BIT 3 FLAG 0	FREEFBIT
# FSPASFLG	005	BIT 10 FLAG 0	FSPASBIT
# GLOKFAIL	046	BIT 14 FLAG 3	GLOKFBIT
# GMBDRVSW	095	BIT 10 FLAG 6	GMBDRBIT
# GUESSW	028	BIT 2 FLAG 1	GUESSBIT
# HFLSHFLG	179	BIT 1 FLAG 11	HFLSHBIT
# IDLEFLAG	113	BIT 7 FLAG 7	IDLEFBIT
# IGNFLAG	107	BIT 13 FLAG 7	IGNFLBIT
# IMPULSW	036	BIT 9 FLAG 2	IMPULBIT
# IMUSE	007	BIT 8 FLAG 0	IMUSEBIT
# INFINFLG	128	BIT 7 FLAG 8	INFINBIT
# INITALGN	133	BIT 2 FLAG 8	INITABIT
# INTFLAG	151	BIT 14 FLAG 10	INTFLBIT
# INTYPFLG	056	BIT 4 FLAG 3	INTYPBIT
# ITSWICH	105	BIT 15 FLAG 7	ITSWBIT
# JSWITCH	001	BIT 14 FLAG 0	JSWCHBIT
# LETABORT	141	BIT 9 FLAG 9	LETABBIT
# LMOONFLG	124	BIT 11 FLAG 8	LMOONBIT
# LOKONSW	010	BIT 5 FLAG 0	LOKONBIT
# LOSCMFLG	033	BIT 12 FLAG 2	LOSCMBIT
# LRALTFLG	190	BIT 5 FLAG 12	LRALTBIT
# LRBYPASS	165	BIT 15 FLAG 11	LRBYBIT
# LRINH	172	BIT 8 FLAG 11	LRINHBIT
# LRPOSFLG	189	BIT 6 FLAG 12	LRPOSBIT
# LRVELFLG	187	BIT 8 FLAG 12	LRVELBIT
# Page63			
# LUNAFLAG	048	BIT 12 FLAG 3	LUNABIT
# MANUFLAG	106	BIT 14 FLAG 7	MANUFBIT
# MGLVFLAG	088	BIT 2 FLAG 5	MGLVFBIT
# MIDAVFLG	148	BIT 2 FLAG 9	MIDAVBIT
# MIDFLAG	002	BIT 13 FLAG 0	MIDFLBIT
# MID1FLAG	147	BIT 3 FLAG 9	MID1BIT
# MKOVFLAG	072	BIT 3 FLAG 4	MKOVBIT
# MOONFLAG	003	BIT 12 FLAG 0	MOONBIT
# MRKIDFLG	060	BIT 15 FLAG 4	MRKIDBIT
# MRKNVFLG	066	BIT 9 FLAG 4	MRKNVBIT

# MRUPTFLG	070	BIT 5 FLAG 4	MRUPTBIT
# MUNFLAG	097	BIT 8 FLAG 6	MUNFLBIT
# MWAITFLG	064	BIT 11 FLAG 4	MWAITBIT
# NEEDLFLG	011	BIT 4 FLAG 0	NEEDLBIT
# NEWIFLG	122	BIT 13 FLAG 8	NEWIBIT
# NJETSFLG	015	BIT 15 FLAG	NJETSBIT
# NODOFLAG	044	BIT 1 FLAG 2	NODOBIT
# NOLRREAD	170	BIT 10 FLAG 11	NOLRRBIT
# NORMSW	110	BIT 10 FLAG 7	NORMSBIT
# NORRMON	086	BIT 4 FLAG 5	NORRMBIT
# NOR29FLG	049	BIT 11 FLAG 3	NR29FBIT
# NOTHROTL	078	BIT 12 FLAG 5	NOTHRBIT
# NOUPFLAG	024	BIT 6 FLAG 1	NOUPFBIT
# NRMNVFLG	067	BIT 8 FLAG 4	NRMNVBIT
# NRMIDFLG	062	BIT 13 FLAG 4	NRMIDBIT
# NRUPTFLG	071	BIT 4 FLAG 4	NRUPTBIT
# NTARGFLG	102	BIT 3 FLAG 6	NTARGBIT
# NWAITFLG	065	BIT 10 FLAG 4	NWAITBIT
# OLDESFLG	014	BIT 1 FLAG 0	OLDESBIT
# OPTNSW	038	BIT 7 FLAG 2	OPTNBIT
# ORBWFLAG	054	BIT 6 FLAG 3	ORBWFBIT
# ORDERSW	129	BIT 6 FLAG 8	ORDERBIT
# OURRCFLG	198	BIT 12 FLAG 13	OURRCBIT
# PDSPFLAG	063	BIT 12 FLAG 4	PDSPFBIT
# PFRATFLG	041	BIT 4 FLAG 2	PFRATBIT
# PINBRFLG	069	BIT 6 FLAG 4	PINBRBIT
# PRECIFLG	052	BIT 8 FLAG 3	PRECIBIT
# PRIODFLG	061	BIT 14 FLAG 1	PRIODBIT
# PRONVFLG	068	BIT 7 FLAG 4	PRONVBIT
# PSTHIGAT	169	BIT 11 FLAG 11	PSTHIBIT
# PULSEFLG	195	BIT 15 FLAG 13	PULSES
# P21FLAG	004	BIT 11 FLAG 0	P21FLBIT
# P25FLAG	006	BIT 9 FLAG 0	P25FLBIT
# P39/79SW	126	BIT 9 FLAG 8	P39SWBIT
# QUITFLAG	145	BIT 5 FLAG 9	QUITBIT
# RADMODES		FLGWDR12	
# RASFLAG		FLGWDR10	
# RCDUFALL	188	BIT 7 FLAG 12	RCDUFBIT
# RCDUOFLG	182	BIT 13 FLAG 12	RCDUOBIT
# READLR	174	BIT 6 FLAG 11	READLBIT
# Page 64			
# READRFLG	051	BIT 9 FLAG 3	READRBIT
# READVEL	175	BIT 5 FLAG 11	READVBIT
# REDFLAG	099	BIT 6 FLAG 6	REDFLBIT
# REFSMFLG	047	BIT 13 FLAG 3	REFSMBIT
# REINTFLG	158	BIT 7 FLAG 10	REINTBIT

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# REMODFLG	181	BIT 14 FLAG 12	REMODBIT
# RENDWFLG	089	BIT 1 FLAG 5	RENDWBIT
# REPOS MON	184	BIT 11 FLAG 12	REPOSBIT
# RHCSCFLG	203	BIT 7 FLAG 13	RHCSCALE
# RNDVZFLG	008	BIT 7 FLAG 0	RNDVZBIT
# RNGEDATA	176	BIT 4 FLAG 11	RNGEDBIT
# RNGSCFLG	080	BIT 10 FLAG 5	RNGSCBIT
# RODFLAG	018	BIT 12 FLAG 1	RODFLBIT
# ROTFLAG	144	BIT 6 FLAG 9	ROTFLBIT
# RPQFLAG	120	BIT 15 FLAG 8	RPQFLBIT
# RRDATAFL	191	BIT 4 FLAG 12	RRDATA BIT
# RRNBSW	009	BIT 6 FLAG 0	RRNBBIT
# RRRSFLAG	192	BIT 3 FLAG 12	RRRSBIT
# RVSW	111	BIT 9 FLAG 7	RVSWBIT
# R04FLAG	051	BIT 9 FLAG 3	R04FLBIT
# R10FLAG	013	BIT 2 FLAG 0	R10FLBIT
# R61FLAG	020	BIT 10 FLAG 1	R61FLBIT
# R77FLAG	079	BIT 11 FLAG 5	R77FLBIT
# SCALBAD	177	BIT 3 FLAG 11	SCABBIT
# SLOPESW	027	BIT 3 FLAG 1	SLOPEBIT
# SNUFFER	077	BIT 13 FLAG 5	SNUFFBIT
# SOLNSW	087	BIT 3 FLAG 5	SOLNSBIT
# SRCHOPTN	031	BIT 14 FLAG 2	SRCHOBIT
# STATEFLG	055	BIT 5 FLAG 3	STATEBIT
# STEERSW	034	BIT 11 FLAG 2	STEERBIT
# SURFFLAG	127	BIT 8 FLAG 8	SURFFBIT
# SWANDISP	109	BIT 11 FLAG 7	SWANDBIT
# S32.1F1	090	BIT 15 FLAG 6	S32BIT1
# S32.1F2	091	BIT 14 FLAG 6	S32BIT2
# S32.1F3A	092	BIT 13 FLAG 6	S32BIT3A
# S32.1F3B	093	BIT 12 FLAG 6	S32BIT3B
# TFFSW	119	BIT 1 FLAG 7	TFFSWBIT
# TRACKFLG	025	BIT 5 FLAG 1	TRACKBIT
# TURNONFL	194	BIT 1 FLAG 12	TURNONBIT
# ULLAGFLG	204	BIT 6 FLAG 13	ULLAGER
# UPDATFLG	023	BIT 7 FLAG 1	UPDATBIT
# UPLOCKFL	116	BIT 4 FLAG 7	UPLOCBIT
# USEQRFLG	196	BIT 14 FLAG 13	USEQRJTS
# VEHUPFLG	022	BIT 8 FLAG 1	VEHUPBIT
# VELDATA	173	BIT 7 FLAG 11	VELDABIT
# VERIFLAG	117	BIT 3 FLAG 7	VERIFBIT
# VFLAG	050	BIT 10 FLAG 3	VFLAGBIT
# VFLSHFLG	178	BIT 2 FLAG 11	VFLSHBIT
# VINTFLAG	057	BIT 3 FLAG 3	VINTFBIT
# VXINH	168	BIT 12 FLAG 11	VXINHBIT

EQUIVALENT FLAG NAME:

# V37FLAG	114	BIT 6 FLAG 7	V37FLBIT
# V67FLAG	112	BIT 8 FLAG 7	V67FLBIT
# V82EMFLG	118	BIT 2 FLAG 7	V82EMBIT
# XDELVFLG	037	BIT 8 FLAG 2	XDELVBIT
# XDSPFLAG	074	BIT 1 FLAG 4	XDSPBIT
# XORFLG	171	BIT 9 FLAG 11	XORFLBIT
# XOVINFLG	201	BIT 9 FLAG 13	XOVINHIB
# 3AXISFLG	084	BIT 6 FLAG 5	3AXISBIT
# 360SW	134	BIT 1 FLAG 8	360SWBIT

## # ASSIGNMENT AND DESCRIPTION OF FLAGWORDS

FLAGWRDO = STATE +0 # (000-014)

# (SET) (RES)

# BIT 15 FLAG 0 (S)

= 000D  
 = BIT15

# BIT 14 FLAG 0 (S)

JSWITCH = 001D  
 JSWCHBIT = BIT14

# INTEGRATION OF W INTE  
 # MATRIX VECTO

# BIT 13 FLAG 0 (S)

MIDFLAG = 002D  
 MIDFLBIT = BIT13

# INTEGRATION WITH INTE  
 # SECONDARY BODY AND SOLAR  
 # SOLAR PERTURBATIONS

# BIT 12 FLAG 0 (L)

MOONFLAG = 003D  
 MOONBIT = BIT12

# MOON IS SPHERE OF EART  
 # INFLUENCE INFLU

# BIT 11 FLAG 0

P21FLAG = 004D  
 P21FLBIT = BIT11

# USE BASE VECTORS 1ST P  
 # ALREADY CALCULATED ULATI

# BIT 10 FLAG 0

FSPASFLG = 005D  
 FSPASBIT = BIT10

# FIRST PASS THROUGH NOT P  
 # REPOSITION ROUTINE REPOS

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# BIT 9 FLAG 0 (S)

P25FLAG = 006D  
 P25FLBIT = BIT9

# P25 OPERATING P25 M

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# BIT 8 FLAG 0 (S)

IMUSE = 007D

IMUSEBIT = BIT8

# IMU IN USE

IMU NOT IN USE

# BIT 7 FLAG 0 (S)

RNDVZFLG = 008D

RNDVZBIT = BIT7

# P20 RUNNING (RADAR  
# IN USE)

P20 NOT RUNNING

# BIT 6 FLAG 0 (S)

RRNBSW = 009D

RRNBBIT = BIT6

# RADAR TARGET IN  
# NB COORDINATES

RADAR TARGET IN  
SM COORDINATES

# BIT 5 FLAG 0 (S)

LOKONSW = 010D

LOKONBIT = BIT5

# RADAR LOCK-ON  
# DESIRED

RADAR LOCK-ON M  
DESIRED

# BIT 4 FLAG 0 (S)

NEEDLFLG = 011D

NEEDLBIT = BIT4

# TOTAL ATTITUDE  
# ERROR DISPLAYED

A/P FOLLOWING  
ERROR DISPLAYED

# BIT 3 FLAG 0

FREEFLAG = 012D

FREEFBIT = BIT3

# (USED BY P51-53 TEMP IN MANY DIFFERENT  
# ROUTINES & BY LUNAR + SOLAR EPHEMERIDES)

# BIT 2 FLAG 0

R10FLAG = 013D

R10FLBIT = BIT2

# R10 OUTPUTS DATA TO  
# ALTITUDE & ALTITUDE  
# RATE METERS ONLY  
#

BESIDES OUTPUT  
SET, R10 ALSO C  
TO FORWARD & LA  
VELOCITY CROSSF

# BIT 1 FLAG 0 (L)

OLDESFLG = 014D

OLDESBIT = BIT1

# R29 GYRO CMD LOOP  
# REQUESTED

R29 GYRO CMD LO  
NOT REQUESTED

FLAGWRD1 = STATE +1

# (015-029)

# Page 67

# (SET)

(RESET)

# BIT 15 FLAG 1 (S)

NJETSFLG = 015D

NJETSBIT = BIT15

# TWO JET RCS BURN

FOUR JET RCS BU

# BIT 14 FLAG 1 (L)

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DIDFLAG	=	016D	#	INERTIAL DATA IS	PERFO
DIDFLBIT	=	BIT14	#	AVAILABLE	INITI
# BIT 13 FLAG 1 (S)					
ERADFLAG	=	017D	#	COMPUTE REARTH	USE C
ERADFBIT	=	BIT13	#	FISCHER ELLIPSOID	PAD R
# BIT 12 FLAG 1					
RODFLAG	=	018D	#	IF IN P66, NORMAL	IF IN
RODFLBIT	=	BIT12	#	OPERATION CONTINUES.	IALIZ
			#	RESTART CLEARS FLAG	FORM
# BIT 11 FLAG 1					
	=	019D			
	=	BIT11			
# BIT 10 FLAG 1 (L)					
R61FLAG	=	020D	#	RUN R61 LEM	RUN R
R61FLBIT	=	BIT10			
# BIT 9 FLAG 1					
	=	021D			
	=	BIT9			
# BIT 8 FLAG 1 (S)					
VEHUPFLG	=	022D	#	CSM STATE-VECTOR	LEM S
VEHUPBIT	=	BIT8	#	BEING UPDATED	BEING
# BIT 7 FLAG 1 (S)					
UPDATFLG	=	023D	#	UPDATING BY MARKS	UPDAT
UPDATBIT	=	BIT7	#	ALLOWED	NOT A
# BIT 6 FLAG 1 (S)					
NOUPFLAG	=	024D	#	NEITHER CSM	EITH
			#	NOR LM STATE VECTOR	VECT
NOUPFBIT	=	BIT6	#	MAY BE UPDATED	UPDAT
# Page 68					
# BIT 5 FLAG 1 (S)					
TRACKFLG	=	025D	#	TRACKING ALLOWED	TRAC
TRACKBIT	=	BIT5			
# BIT 4 FLAG 1					
	=	026D			
	=	BIT4			

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# BIT 3 FLAG 1 (S)

SLOPESW = 027D

SLOPEBIT = BIT3

# BIT 2 FLAG 1 (S)

GUESSW = 028D

GUESSBIT = BIT2

# BIT 1 FLAG 1

= 029D

= BIT1

FLAGWRD2 = STATE +2

# ITERATE WITH BIAS  
# METHOD IN ITERATOR  
#

ITERATE WITH RE  
FALSI METHOD IN  
ITERATOR

# NO STARTING VALUE  
# FOR ITERATION

STARTING VALUE  
ITERATION EXIST

# OH 2009-05-15 Scan does not have this line

# (030-044)

# (SET) (RESET)

# BIT 15 FLAG 2 (S)

DRIFTFLG = 030D

DRFTBIT = BIT15

# T3RUPT CALLS GYRO  
# COMPENSATION

T3RUPT DOES NO  
COMPENSATION

# BIT 14 FLAG 2 (S)

SRCHOPTN = 031D

SRCHOBIT = BIT14

# RADAR IN AUTOMATIC  
# SEARCH OPTION (R24)

RADAR NOT IN AU  
MATIC SEARCH OF

# BIT 13 FLAG 2 (S)

ACMODFLG = 032D

ACMODBIT = BIT13

# MANUAL ACQUISITION  
# BY RENDEZVOUS RADAR

AUTO ACQUISITIO  
BY RENDEZVOUS R

# BIT 12 FLAG 2 (S)

LOSCMFLG = 033D

LOSCMBIT = BIT12

# LINE OF SIGHT BEING  
# COMPUTED (R21)

LINE OF SIGHT M  
BEING COMPUTED

# Page 69

# BIT 11 FLAG 2 (S)

STEERSW = 034D

STEERBIT = BIT11

# SUFFICIENT THRUST  
# IS PRESENT

INSUFFICIENT TH  
IS PRESENT

# BIT 10 FLAG 2 (S)

= 035D

= BIT10

# OH 2009-05-15 These two line don't appear in

# BIT 9 FLAG 2 (S)

IMPULSW = 036D

# MINIMUM IMPULSE  
# BURN (CUTOFF TIME

STEERING BURN (C  
CUTOFF TIME YET

IMPULBIT	=	BIT9	#	SPECIFIED)	AVAIL
# BIT 8 FLAG 2 (S)					
XDELVFLG	=	037D	#	EXTERNAL DELTAV VG	LAMBE
XDELBVIT	=	BIT8	#	COMPUTATION	VG CO
# BIT 7 FLAG 2 (S)					
ETPIFLAG	=	038D	#	ELEVATION ANGLE	TPI 7
			#	SUPPLIED FOR	FOR P
ETPIBIT	=	BIT7	#	P34,74	ELEVA
# BIT 7 FLAG 2 (L)					
OPTNSW	=	ETPIFLAG	#	SOI PHASE OF P38/78	SOR P
OPTNBIT	=	BIT7			
# BIT 6 FLAG 2 (S)					
FINALFLG	=	039D	#	LAST PASS THROUGH	INTER
			#	RENDEZVOUS PROGRAM	RENDE
FINALBIT	=	BIT6	#	COMPUTATIONS	COMPU
# BIT 5 FLAG 2 (S)					
AVFLAG	=	040D	#	LEM IS ACTIVE	CSM 1
AVFLBIT	=	BIT5	#	VEHICLE	VEHIC
# BIT 4 FLAG 2 (S)					
PFRATFLG	=	041D	#	PREFERRED ATTITUDE	PREFE
PFRATBIT	=	BIT4	#	COMPUTED	NOT C
# BIT 3 FLAG 2 (S)					
# Page 70					
CALCMAN3	=	042D	#	NO FINAL ROLL	FINAI
CALC3BIT	=	BIT3	#		NECES
# BIT 2 FLAG 2 (S)					
CALCMAN2	=	043D	#	PERFORM MANEUVER	BYPAS
CALC2BIT	=	BIT2	#	STARTING PROCEDURE	PROCI
# BIT 1 FLAG 2 (S)					
NODOFLAG	=	044D	#	V37 NOT PERMITTED	V37 P
NODOBIT	=	BIT1			
FLAGWRD3	=	STATE +3	#	(045-059)	
			#	(SET)	(RESI

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# BIT 15 FLAG 3				
	=	045D	#	
	=	BIT15	#	OH 2009-05-15 This line is not in scans
# BIT 14 FLAG 3 (S)				
GLOKFAIL	=	046D	#	GIMBAL LOCK HAS
GLOKFBIT	=	BIT14	#	OCCURRED
				NOT IN GIMBAL L
# BIT 13 FLAG 3 *** PROTECTED FROM FRESH START ***				
REFSMFLG	=	047D	#	REFSMMAT GOOD
REFSMBIT	=	BIT13		REFSMMAT NO GOC
# BIT 12 FLAG 3 (S)				
LUNAFLAG	=	048D	#	LUNAR LAT-LONG
LUNABIT	=	BIT12		EARTH LAT-LONG
# BIT 11 FLAG 3 (L)				
NOR29FLG	=	049D	#	R29 NOT ALLOWED
NR29FBIT	=	BIT11	#	R29 ALLOWED (RR
				IGNATED POWERED
# BIT 10 FLAG 3 (S)				
VFLAG	=	050D	#	LESS THAN TWO STARS
VFLAGBIT	=	BIT10	#	IN FIELD OF VIEW
				TWO STARS IN FI
				OF VIEW
# BIT 9 FLAG 3 (S)				
R04FLAG	=	051D	#	ALARM 521
			#	SUPPRESSED
				ALARM 521 ALLOW
# Page 71				
R04FLBIT	=	BIT9		
# BIT 9 FLAG 3 (L)				
READRFLG	=	R04FLAG	#	READING RR DATA
READRBIT	=	BIT9	#	PURSUANT TO R29
				NOT READING RR
				PURSUANT TO R29
# BIT 8 FLAG 3 (S)				
PRECIFLG	=	052D	#	NORMAL INTEGRATION
			#	IN P00
PRECIBIT	=	BIT8	#	ENGAGES 4-TIME
				(P00) LOGIC IN
				GRATION
# BIT 7 FLAG 3 (S)				
CULTFLAG	=	053D	#	STAR OCCULTED
CULTBIT	=	BIT7		STAR NOT OCCULT
# BIT 6 FLAG 3 (S)				
ORBWFLAG	=	054D	#	W MATRIX VALID FOR
ORBWFBIT	=	BIT6	#	ORBITAL NAVIGATION
				W MATRIX INVALI
				ORBITAL NAVIGAT

# BIT 5 FLAG 3 (S)				
STATEFLG	=	055D	#	PERMANENT STATE
STATEBIT	=	BIT5	#	VECTOR UPDATED
				PERMA
# BIT 4 FLAG 3 (S)				
INTYPFLG	=	056D	#	CONIC INTEGRATION
INTYPBIT	=	BIT4		ENCKE
# BIT 3 FLAG 3 (S)				
VINTFLAG	=	057D	#	CSM STATE VECTOR
VINTFBIT	=	BIT3	#	BEING INTEGRATED
				LEM S
# BIT 2 FLAG 3 (S)				
D6OR9FLG	=	058D	#	DIMENSION OF W IS 9
D6OR9BIT	=	BIT2	#	FOR INTEGRATION
				DIMEN
# BIT 1 FLAG 3 (S)				
DIM0FLAG	=	059D	#	W MATRIX IS TO BE
DIM0BIT	=	BIT1	#	USED
				W MAT
FLAGWRD4	=	STATE +4	#	(060-074)
# Page 72				
			#	(SET)
				(RESI
# BIT 15 FLAG 4 (S)				
MRKIDFLG	=	060D	#	MARK DISPLAY IN
MRKIDBIT	=	BIT15	#	ENDIDLE
				NO MA
# BIT 14 FLAG 4 (S)				
PRIODFLG	=	061D	#	PRIORITY DISPLAY IN
PRIODBIT	=	BIT14	#	ENDIDLE
				NO PR
# BIT 13 FLAG 4 (S)				
NRMIDFLG	=	062D	#	NORMAL DISPLAY IN
NRMIDBIT	=	BIT13	#	ENDIDLE
				NO NO
# BIT 12 FLAG 4 (S)				
PDSPFLAG	=	063D	#	P20 SETS SO AS TO
			#	TURN A NORMAL DIS-
PDSPFBIT	=	BIT12	#	PLAY INTO A PRIORITY
			#	DISPLAY IN R60
				LEAVI
# BIT 11 FLAG 4 (S)				
MWAITFLG	=	064D	#	HIGHER PRIORITY
				NO H



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MWAITBIT	=	BIT11	#	DISPLAY OPERATING	DISPLAY OPERATING
			#	WHEN MARK	WHEN MARK DISPL
			#	DISPLAY INITIATED	INITIATED
# BIT 10 FLAG 4 (S)					
NWAITFLG	=	065D	#	HIGHER PRIORITY	NO HIGHER PRIOR
			#	DISPLAY OPERATING	DISPLAY OPERATI
NWAITBIT	=	BIT10	#	WHEN NORMAL	WHEN NORMAL DIS
			#	DISPLAY INITIATED	INITIATED
# BIT 9 FLAG 4 (S)					
MRKNVFLG	=	066D	#	ASTRONAUT USING	ASTRONAUT NOT U
			#	KEYBOARD WHEN MARK	KEYBOARD WHEN M
MRKNVBIT	=	BIT9	#	DISPLAY INITIATED	DISPLAY INITIAT
# BIT 8 FLAG 4 (S)					
NRMNVFLG	=	067D	#	ASTRONAUT USING	ASTRONAUT NOT U
			#	KEYBOARD WHEN	KEYBOARD WHEN
NRMNVBIT	=	BIT8	#	NORMAL DISPLAY	NORMAL DISPLAY
			#	INITIATED	INITIATED
# BIT 7 FLAG 4 (S)					
PRONVFLG	=	068D	#	ASTRONAUT USING	ASTRONAUT NOT U
# Page 73					
PRONVBIT	=	BIT7	#	KEYBOARD WHEN	KEYBOARD WHEN
			#	PRIORITY DISPLAY	PRIORITY DISPLA
			#	INITIATED	INITIATED
# BIT 6 FLAG 4 (S)					
PINBRFLG	=	069D	#	ASTRONAUT HAS	ASTRONAUT HAS M
			#	INTERFERED WITH	INTERFERED WITH
PINBRBIT	=	BIT6	#	EXISTING DISPLAY	EXISTING DISPLA
# BIT 5 FLAG 4 (S)					
MRUPTFLG	=	070D	#	MARK DISPLAY	MARK DISPLAY NO
			#	INTERRUPTED BY	INTERRUPTED BY
MRUPTBIT	=	BIT5	#	PRIORITY DISPLAY	PRIORITY DISPLA
# BIT 4 FLAG 4 (S)					
NRUPTFLG	=	071D	#	NORMAL DISPLAY	NORMAL DISPLAY
			#	INTERRUPTED BY	INTERRUPTED BY
NRUPTBIT	=	BIT4	#	PRIORITY OR MARK	PRIORITY OR MAR
			#	DISPLAY	DISPLAY
# BIT 3 FLAG 4 (S)					

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MKOVFLAG	=	072D	#	MARK DISPLAY OVER	NO M
MKOVBIT	=	BIT3	#	NORMAL	NORMA
# BIT 2 FLAG 4					
	=	073D			
	=	BIT2		# OH 2009-05-15 Not in scan.	
# BIT 1 FLAG 4 (S)					
XDSPFLAG	=	074D	#	MARK DISPLAY NOT	NO S
XDSPBIT	=	BIT1	#	TO BE INTERRUPTED	INFOR
FLAGWRD5	=	STATE +5	#	(075-089)	
			#	(SET)	(RES
# BIT 15 FLAG 5 (S)					
DSKYFLAG	=	075D	#	DISPLAYS SENT TO	NO D
DSKYFBIT	=	BIT15	#	DSKY	
# BIT 14 FLAG 5					
	=	076D			
	=	BIT14			
# Page 74					
# BIT 13 FLAG 5 (S,L)					
SNUFFER	=	077D	#	U,V JETS DISABLED	U,V J
			#	DURING DPS	DURIN
SNUFFBIT	=	BIT13	#	BURNS (V65)	BURNS
# BIT 12 FLAG 5 (S)					
NOTHROTL	=	078D	#	INHIBIT FULL	PERM
NOTHRBIT	=	BIT12	#	THROTTLE	
# BIT 11 FLAG 5 (S,L)					
R77FLAG	=	079D	#	R77 IS ON,	R77
			#	SUPPRESS ALL RADAR	
			#	ALARMS AND TRACKER	
R77FLBIT	=	BIT11	#	FAILS	
# BIT 10 FLAG 5 (S)					
RNGSCFLG	=	080D	#	SCALE CHANGE HAS	NO S
			#	OCCURRED DURING	OCCUR
RNGSCBIT	=	BIT10	#	RR READING	RR R
# BIT 9 FLAG 5 (S)					

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DMENFLG	=	081D	#	DIMENSION OF W IS 9	DIMENSION OF W
DMENFBIT	=	BIT9	#	FOR INCORPORATION	FOR INCORPORATI
# BIT 8 FLAG 5	(S)				
	=	082D			
	=	BIT8			
# BIT 7 FLAG 5	(S)				
ENGONFLG	=	083D	#	ENGINE TURNED ON	ENGINE TURNED C
ENGONBIT	=	BIT7	#		
# BIT 6 FLAG 5	(S)				
3AXISFLG	=	084D	#	MANEUVER SPECIFIED	MANEUVER SPECIF
			#	BY THREE AXES	BY ONE AXIS; R6
3AXISBIT	=	BIT6	#		CALLS VECPOINT.
# BIT 5 FLAG 5					
	=	085D			
	=	BIT5		# OH 2009-05-15 Not in scan	
# BIT 4 FLAG 5	(S)				
# Page 75					
NORRMON	=	086D	#	BYPASS RR GIMBAL	PERFORM
NORRMBIT	=	BIT4	#	MONITOR	RR GIMBAL MONIT
# BIT 3 FLAG 5	(S)				
SOLNSW	=	087D	#	LAMBERT DOES NOT	LAMBERT CONVERG
			#	CONVERGE, OR TIME-RAD	TIME-RADIUS NON
SOLNSBIT	=	BIT3	#	NEARLY CIRCULAR	CIRCULAR
# BIT 2 FLAG 5	(S)				
MGLVFLAG	=	088D	#	LOCAL VERTICAL	MIDDLE GIMBAL A
			#	COORDINATES	COMPUTED
MGLVFBIT	=	BIT2	#	COMPUTED	
# BIT 1 FLAG 5	(S)				
RENDWFLG	=	089D	#	W MATRIX VALID	W MATRIX INVALI
			#	FOR RENDEZVOUS	FOR RENDEZVOUS
RENDWBIT	=	BIT1	#	NAVIGATION	NAVIGATION
FLAGWRD6	=	STATE +6	#	(090-104)	
			#	(SET)	(RESET)

## # BIT 15 FLAG 6 (S)

S32.1F1 = 090D  
S32BIT1 = BIT15

# DELTA V AT CSI TIME DVT1  
# ONE EXCEEDS MAX

## # BIT 14 FLAG 6 (S)

S32.1F2 = 091D  
S32BIT2 = BIT14

# FIRST PASS OF REITH  
# NEWTON ITERATION NEWTO

## # BIT 13 FLAG 6 (S)

S32.1F3A = 092D  
S32BIT3A = BIT13

# BIT 13 AND BIT 12 FUNCTION AS AN OR  
# PAIR (13,12) INDICATING THE POSSIBL  
# CURRENCE OF 2 NEWTON ITERATIONS FOR  
# IN THE PROGRAM IN THE FOLLOWING OR  
# (0,1) (I.E. BIT 13 RESET, BIT 12 SE  
# = FIRST NEWTON ITERATION BEING  
# (0,0)= FIRST PASS OF SECOND NEWTON  
# (1,1)= 50 FT/SEC STAGE OF SECOND NE  
# (1,0)= REMAINDER OF SECOND NEWTON

## # BIT 12 FLAG 6 (S)

S32.1F3B = 093D  
S32BIT3B = BIT12

## # BIT 11 FLAG 6 (S)

= 094D  
= BIT11

#  
#

## # Page 76

## # BIT 10 FLAG 6 (S)

GMBDRVSW = 095D  
GMBDRBIT = BIT10

# TRIMGIMB OVER TRIM  
#

## # BIT 9 FLAG 6

= 096D  
= BIT9

#  
#

## # BIT 8 FLAG 6 (S)

MUNFLAG = 097D  
MUNFLBIT = BIT8

# SERVICER CALLS SERV  
# MUNRVG CALC

## # BIT 7 FLAG 6 (L)

= 098D  
= BIT7

#  
#

## # BIT 6 FLAG 6 (L)

REDFLAG = 099D  
REDFLBIT = BIT6

# LANDING SITE LAND  
# REDESIGNATION REDES  
# PERMITTED PERM

## # BIT 5 FLAG 6

= 100D  
= BIT5

#  
# OH 2009-05-15 Not in scan

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# BIT 4 FLAG 6			#		
	=	101D			
	=	BIT4	#	OH 2009-05-15 Not in scan	
# BIT 3 FLAG 6 (S)					
NTARGFLG	=	102D	#	ASTRONAUT DID	ASTRONAUT DID M
			#	OVERWRITE DELTA	OVERWRITE DELTA
NTARGBIT	=	BIT3	#	VELOCITY AT TPI	VELOCITY
			#	OR TPM (P34,35)	
# BIT 2 FLAG 6					
AUXFLAG	=	103D	#	PROVIDING IDLEFLAG	SERVICER WILL S
AUXFLBIT	=	BIT2	#	IS NOT SET, SERV-	DVMON ON ITS NE
			#	ICER WILL EXERCISE	PASS EVEN IF TH
			#	DVMON ON ITS NEXT	IDLEFLAG IS NOT
			#	PASS.	IT WILL THEN SE
			#		AUXFLAG.
# BIT 1 FLAG 6 (L)					
ATTFLAG	=	104D	#	LEM ATTITUDE EXISTS	NO LEM ATTITUDE
			#	IN MOON-FIXED	AVAILABLE IN MO
# Page 77					
ATTFLBIT	=	BIT1	#	COORDINATES	FIXED COORDINAT
FLAGWRD7	=	STATE +7	#	(105-119)	
			#	(SET)	(RESET)
# BIT 15 FLAG 7 (S)					
ITSWICH	=	105D	#	R34;TPI TIME TO BE	TPI HAS BEEN
ITSWBIT	=	BIT15	#	COMPUTED	COMPUTED
# BIT 14 FLAG 7 (S)					
MANUFLAG	=	106D	#	ATTITUDE MANEUVER	NO ATTITUDE MAN
			#	GOING DURING RR	DURING RR SEAR
MANUFBIT	=	BIT14	#	SEARCH	
# BIT 13 FLAG 7 (S)					
IGNFLAG	=	107D	#	TIG HAS ARRIVED	TIG HAS NOT ARR
IGNFLBIT	=	BIT13	#		
# BIT 12 FLAG 7 (S)					
ASTNFLAG	=	108D	#	ASTRONAUT HAS	ASTRONAUT HAS M
ASTNBIT	=	BIT12	#	OKAYED IGNITION	OKAYED IGNITION

# BIT 11 FLAG 7 (L)				
SWANDISP	=	109D	#	LANDING ANALOG
SWANDBIT	=	BIT11	#	DISPLAYS ENABLED
# BIT 10 FLAG 7 (S)				
NORMSW	=	110D	#	UNIT NORMAL INPUT
NORMSBIT	=	BIT10	#	TO LAMBERT
# BIT 9 FLAG 7 (S)				
RVS	=	111D	#	DO NOT COMPUTE
RVS	=	111D	#	FINAL STATE VECTOR
RVS	=	111D	#	IN TIME-DELTA
# BIT 8 FLAG 7 (S)				
V67FLAG	=	112D	#	ASTRONAUT OVERWRITE
V67FLAG	=	112D	#	W-MATRIX INITIAL
V67FLBIT	=	BIT8	#	VALUES
# Page 78				
# BIT 7 FLAG 7 (S)				
IDLEFLAG	=	113D	#	NO DV MONITOR
IDLEFBIT	=	BIT7	#	
# BIT 6 FLAG 7 (S)				
V37FLAG	=	114D	#	AVERAGEG (SERVICER)
V37FLBIT	=	BIT6	#	RUNNING
# BIT 5 FLAG 7 (S)				
AVEGFLAG	=	115D	#	AVERAGEG (SERVICER)
AVEGFBIT	=	BIT5	#	DESIRED
# BIT 4 FLAG 7 (S)				
UPLOCKFL	=	116D	#	K-KBAR-K FAIL
UPLOCBIT	=	BIT4	#	
# BIT 3 FLAG 7 (S)				
VERIFLAG	=	117D	#	CHANGED WHEN V33E OCCURS AT END OF
VERIFBIT	=	BIT3	#	
# BIT 2 FLAG 7 (L,C)				
V82EMFLG	=	118D	#	MOON VICINITY
V82EMBIT	=	BIT2	#	
# BIT 1 FLAG 7 (S)				
TFFSW	=	119D	#	CALCULATE TPERIGEE

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TFFSWBIT	=	BIT1	#		
FLAGWRD8	=	STATE +8D	#	(120-134)	
			#	(SET)	(RESET)
# BIT 15 FLAG 8 (S)					
RPQFLAG	=	120D	#	RPQ NOT COMPUTED	RPQ COMPUTED
			#	(RPQ = VECTOR BE-	
RPQFLBIT	=	BIT15	#	TWEEN SECONDARY BODY	
			#	AND PRIMARY BODY)	
# BIT 14 FLAG 8					
	=	121D	#		
	=	BIT14	#		
# Page 79					
# BIT 13 FLAG 8 (S)					
NEWIFLG	=	122D	#	FIRST PASS THROUGH	SUCCEEDING ITER
NEWIBIT	=	BIT13	#	INTEGRATION	OF INTEGRATION
# BIT 12 FLAG 8 *** PROTECTED FROM FRESH START ***					
CMOONFLG	=	123D	#	PERMANENT CSM STATE	PERMANENT CSM S
CMOONBIT	=	BIT12	#	IN LUNAR SPHERE	IN EARTH SPHERE
# BIT 11 FLAG 8 *** PROTECTED FROM FRESH START ***					
LMOONFLG	=	124D	#	PERMANENT LM STATE	PERMANENT LM ST
LMOONBIT	=	BIT11	#	IN LUNAR SPHERE	IN EARTH SPHERE
# BIT 10 FLAG 8 (L)					
FLUNDISP	=	125D	#	CURRENT GUIDANCE	CURRENT GUIDANC
FLUNDBIT	=	BIT10	#	DISPLAYS INHIBITED	DISPLAYS PERMIT
# BIT 9 FLAG 8 (L)					
P39/79SW	=	126D	#	P39/79 OPERATING	P38/78 OPERATIN
P39SWBIT	=	BIT9	#		
# BIT 8 FLAG 8 *** PROTECTED FROM FRESH START ***					
SURFFLAG	=	127D	#	LM ON LUNAR SURFACE	LM NOT ON LUNAR
SURFFBIT	=	BIT8	#		SURFACE
# BIT 7 FLAG 8 (S)					
INFINFLG	=	128D	#	NO CONIC SOLUTION	CONIC SOLUTION
			#	(CLOSURE THROUGH	EXISTS
INFINBIT	=	BIT7	#	INFINITY REQUIRED)	

# BIT 6 FLAG 8 (S)				
ORDERSW	=	129D	#	ITERATOR USES 2ND ITERA
ORDERBIT	=	BIT6	#	ORDER MINIMUM MODE ORDER
# BIT 5 FLAG 8 (S)				
APSESW	=	130D	#	RDESIRED OUTSIDE RDES
APSESBIT	=	BIT5	#	PERICENTER-APOCENTER PERIC
			#	RANGE IN TIME-RADIUS RANGE
# BIT 4 FLAG 8 (S)				
COGAFLAG	=	131D	#	NO CONIC SOLUTION -- CONIC
			#	TOO CLOSE TO RECTI- EXIST
# Page 80				
COGAFBIT	=	BIT4	#	LINEAR (COGA OVERFLWS) OVER
# BIT 3 FLAG 8 (S)				
	=	132D	#	
	=	BIT3	#	OH 2009-05-15 Line not in scan
# BIT 2 FLAG 8 (L)				
INITALGN	=	133D	#	INITIAL PASS THRU SECO
INITABIT	=	BIT2	#	P57 (CHEC
# BIT 1 FLAG 8 (S)				
360SW	=	134D	#	TRANSFER ANGLE NEAR TRANS
360SWBIT	=	BIT1	#	360 DEGREES NEAR
FLAGWRD9	=	STATE +9D	#	(135-149)
			#	(SET) (RESI
# BIT 15 FLAG 9				
	=	135D	#	
	=	BIT15	#	
# BIT 14 FLAG 9 (L)				
FLVR	=	136D	#	VERTICAL RISE NON-V
FLVRBIT	=	BIT14	#	(ASCENT GUIDANCE)
# BIT 13 FLAG 9				
	=	137D	#	
	=	BIT13	#	OH 2009-05-15 Line not in scan



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# BIT 12 FLAG 9 (L)

FLPC = 138D  
FLPCBIT = BIT12

# NO POSITION CONTROL  
# (ASCENT GUIDANCE)

POSITION CONTROL

# BIT 11 FLAG 9 (L)

FLPI = 139D  
FLPIBIT = BIT11

# PRE-IGNITION PHASE  
# (ASCENT GUIDANCE)

REGULAR GUIDANCE

# BIT 10 FLAG 9 (L)

FLRCS = 140D  
FLRCSBIT = BIT10

# RCS INJECTION MODE  
# (ASCENT GUIDANCE)

MAIN ENGINE MODE

# BIT 9 FLAG 9 (L)

# Page 81

LETABORT = 141D  
LETABBIT = BIT9

# ABORT PROGRAMS  
# ARE ENABLED

ABORT PROGRAMS  
ARE NOT ENABLED

# BIT 8 FLAG 9 (L)

FLAP = 142D  
FLAPBIT = BIT8

# APS CONTINUED ABORT  
# AFTER DPS STAGING  
# (ASCENT GUIDANCE)

APS ABORT IS NO  
CONTINUATION

# BIT 7 FLAG 9 (L)

= 143D  
= BIT7

# OH 2009-05-15 Line not in scan

# BIT 6 FLAG 9 (L)

ROTFLAG = 144D  
ROTFLBIT = BIT6

# P70 AND P71 WILL  
# FORCE VEHICLE  
# ROTATION IN THE  
# PREFERRED DIRECTION

P70 AND P71 WILL  
FORCE VEHICLE  
ROTATION IN THE  
PREFERRED DIRECTION

# BIT 5 FLAG 9 (S)

QUITFLAG = 145D  
QUITBIT = BIT5

# DISCONTINUE INTEGR.  
#

CONTINUE INTEGR.

# BIT 4 FLAG 9

= 146D  
= BIT4

#  
#

# BIT 3 FLAG 9 (L)

MID1FLAG = 147D  
MID1FBIT = BIT3

# INTEGRAT TO TDEC  
#

INTEGRATE TO TH  
THEN-PRESENT TI

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# BIT 2 FLAG 9 (L)

MIDAVFLG = 148D

MIDAVBIT = BIT2

# BIT 1 FLAG 9 (S)

AVEMIDSW = 149D

AVEMDBIT = BIT1

RASFLAG EQUALS FLGWRD10

# Page 82

FLGWRD10 = STATE +10D

# BIT 15 FLAG 10 (S)

= 150D

= BIT15

# BIT 14 FLAG 10 (L,C)

INTFLAG = 151D

INTFLBIT = BIT14

# BIT 13 FLAG 10 (S,L)

APSFLAG = 152D

APSFLBIT = BIT13

# BIT 12 FLAG 10

= 153D

= BIT12

# BIT 11 FLAG 10

= 154D

= BIT11

# BIT 10 FLAG 10

= 155D

= BIT10

# BIT 9 FLAG 10

= 156D

= BIT9

# INTEGRATION ENTERED INTE  
# FROM ONE OF MIDTOAV NOT F  
# PORTALS MIDTO

# AVETOMID CALLING NO AV  
# FOR W.MATRIX INTEGR ALLOW  
# DON'T WRITE OVER RN, PIPT  
# VN,PIPTIME

# WAS ONLY AN INSTALL-ERASTALL FLAG

# (150-164)

# (SET) (RES)

#  
# OH 2009-05-15 Line not in scan

# INTEGRATION IN INTE  
# PROGRESS PROGR

# ASCENT STAGE DESC  
# \*\*\* PROTECTED FROM FRESH ST

#  
# OH 2009-05-15 Line not in scan

#  
# OH 2009-05-15 Line not in scan

#  
# OH 2009-05-15 Line not in scan

#  
# OH 2009-05-15 Line not in scan

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# BIT 8 FLAG 10			#	
	=	157D	#	OH 2009-05-15 Line not in scan
	=	BIT8		
# BIT 7 FLAG 10 (L,C)				
REINTFLG	=	158D	#	INTEGRATION ROUTINE INTEGRATION ROU
REINTBIT	=	BIT7	#	TO BE RESTARTED NOT TO BE RESTA
# BIT 6 FLAG 10			#	
	=	159D	#	OH 2009-05-15 Line not in scan
	=	BIT6		
# BIT 5 FLAG 10			#	
	=	160D	#	OH 2009-05-15 Line not in scan
	=	BIT5		
# Page 83				
# BIT 4 FLAG 10			#	
	=	161D	#	OH 2009-05-15 Line not in scan
	=	BIT4		
# BIT 3 FLAG 10			#	
	=	162D	#	OH 2009-05-15 Line not in scan
	=	BIT3		
# BIT 2 FLAG 10			#	
	=	163D	#	OH 2009-05-15 Line not in scan
	=	BIT2		
# BIT 1 FLAG 10			#	
	=	164D	#	OH 2009-05-15 Line not in scan
	=	BIT1		
FLGWRD11	=	STATE +11D	#	(165-179)
			#	(SET) (RESET)
# BIT 15 FLAG 11 (L)(R12)				
LRBYPASS	=	165D	#	BYPASS ALL LANDING DO NOT BYPASS L
LRBYBIT	=	BIT15	#	RADAR UPDATES UPDATES
# BIT 14 FLAG 11			#	
	=	166D		

	=	BIT14	#		
# BIT 13 FLAG 11					
	=	167D	#		
	=	BIT13	#		
# BIT 12 FLAG 11 (L)(R12)					
VXINH	=	168D	#	IF Z VELOCITY DATA	UPDA7
			#	UNREASONABLE,	VELOC
VXINHBIT	=	BIT12	#	BYPASS X VELOCITY	
			#	UPDATE ON NEXT PASS	
# BIT 11 FLAG 11 (L)(R12)					
PSTHIGAT	=	169D	#	PAST HIGATE	PREH
PSTHIBIT	=	BIT11	#		
# BIT 10 FLAG 11 (L)(R12)					
# Page 84					
NOLRREAD	=	170D	#	LANDING RADAR	LR NO
			#	REPOSITIONING;	
NOLRRBIT	=	BIT10	#	BYPASS UPDATE	
# BIT 9 FLAG 11 (L)(R12)					
XORFLG	=	171D	#	BELOW LIMIT	ABOV
			#	INHIBIT X AXIS	NOT
XORFLBIT	=	BIT9	#	OVERRIDE	
# BIT 8 FLAG 11					
LRINH	=	172D	#	LANDING RADAR UP-	LR UP
LRINHBIT	=	BIT8	#	DATES PERMITTED	BY AS
			#	BY ASTRONAUT	
# BIT 7 FLAG 11 (L)(R12)					
VELDATA	=	173D	#	LR VELOCITY	LR VI
VELDABIT	=	BIT7	#	MEASUREMENT MADE	NOT M
# BIT 6 FLAG 11 (L)(R12)					
READLR	=	174D	#	OK TO READ LR	DO NO
READLBIT	=	BIT6	#	RANGE DATA	DATA
# BIT 5 FLAG 11 (L)(R12)					
READVEL	=	175D	#	OK TO READ LR	DO NO
READVBIT	=	BIT5	#	VELOCITY DATA	VELOC
# BIT 4 FLAG 11 (L)(R12)					

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RNGEDATA	=	176D	#	LR ALTITUDE	LR ALTITUDE MEA
RNGEDBIT	=	BIT4	#	MEASUREMENT MADE	NOT MADE
# BIT 3 FLAG 11					
SCALBAD	=	177D	#	LR LOW SCALE DISP-	LS SCALE DISCRE
SCABBIT	=	BIT3	#	CRETE NOT PRESENT	APPEARS OK
			#	WHEN IT SHOULD	
# BIT 2 FLAG 11 (L)(R12)					
VFLSHFLG	=	178D	#	LR VELOCITY FAIL	LR VEL FAIL LAM
			#	LAMP SHOULD BE	SHOULDN'T FLASH
VFLSHBIT	=	BIT2	#	FLASHING	
# BIT 1 FLAG 11 (L)(R12)					
# Page 85					
HFLSHFLG	=	179D	#	LR ALTITUDE FAIL	LR ALTITUDE FAI
HFLSHBIT	=	BIT1	#	LAMP SHOULD BE	LAMP SHOULD NOT
			#	FLASHING	FLASHING
RADMODES	EQUALS	FLGWRD12	#	RADAR FLAG WORD	
FLGWRD12	=	STATE +12D	#	(180-194)	WAS RADMODES
			#	(SET)	(RESET)
# BIT 15 FLAG 12					
CDESFLAG	=	180D	#	CONTINUOUS DESIG-	LGC CHECKS FOR
CDESBIT	=	BIT15	#	NATE, LGC COMMANDS	ON WHEN ANTENNA
			#	RR REGARDLESS OF	BEING DESIGNATE
			#	LOCK-ON	
# BIT 14 FLAG 12					
REMODFLG	=	181D	#	CHANGE IN ANTENNA	NO REMODE REQUE
REMODBIT	=	BIT14	#	MODE BEEN REQUESTED	OR OCCURRING
			#	I.E., REMODE	
# BIT 13 FLAG 12					
RCDUOFLG	=	182D	#	RR CDU'S BEING	RR CDU'S NOT BE
RCDUOBIT	=	BIT13	#	ZEROED	ZEROED
# BIT 12 FLAG 12					
ANTENFLG	=	183D	#	RR ANTENNA MODE IS	RR ANTENNA IN M
ANTENBIT	=	BIT12	#	MODE 2	
# BIT 11 FLAG 12					
REPOSMON	=	184D	#	REPOSITION MONITOR.	NO REPOSITION T

REPOSBIT	=	BIT11	#	RR REPOSITION IS	PLAC
			#	TAKING PLACE	
# BIT 10 FLAG 12					
DESIGFLG	=	185D	#	RR DESIGNATE	RR DE
DESIGBIT	=	BIT10	#	REQUESTED OR IN	REQU
			#	PROGRESS	PROGE
# BIT 9 FLAG 12					
ALTSCALE	=	186D	#	LR ALTITUDE READING	LR AI
ALTSCBIT	=	BIT9	#	IS ON HIGH SCALE	IS ON
# Page 86					
# BIT 8 FLAG 12					
LRVELFLG	=	187D	#	LR VELOCITY DATA	NO LR
LRVELBIT	=	BIT8	#	FAIL	FAIL
# BIT 7 FLAG 12					
RCDUFAIL	=	188D	#	RR CDU FAIL HAS	RR CD
RCDUFBIT	=	BIT7	#	NOT OCCURRED	
# BIT 6 FLAG 12					
LRPOSFLG	=	189D	#	LANDING RADAR	LR PO
LRPOSBIT	=	BIT6	#	POSITION 2	
# BIT 5 FLAG 12					
LRALTFLG	=	190D	#	LR ALTITUDE DATA	NO LR
LRALTBIT	=	BIT5	#	FAIL. COULD NOT BE	FAIL
			#	READ SUCCESSFULLY.	
# BIT 4 FLAG 12					
RRDATAFL	=	191D	#	RR DATA FAIL.	NO RR
RRDATAFT	=	BIT4	#	DATA COULD NOT BE	
			#	READ SUCCESSFULLY	
# BIT 3 FLAG 12					
RRRSFLAG	=	192D	#	RR RANGE READING	RR RA
RRRSBIT	=	BIT3	#	ON THE HIGH SCALE	THE I
# BIT 2 FLAG 12					
AUTOMODE	=	193D	#	RR NOT IN AUTO MODE.	RR IN
AUTOMBIT	=	BIT2	#	AUTO MODE DISCRETE	
			#	IS NOT PRESENT	
# BIT 1 FLAG 12					
TURNONFL	=	194D	#	RR TURN-ON SEQUENCE	NO RR

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TURNONBT	=	BIT1	#	IN PROGRESS. (ZERO	SEQUENCE IN PRO
			#	CDU'S, FIX ANTENNA	
			#	MODE)	
DAPBOOLS	EQUALS	FLGWRD13	#	DIGITAL AUTOPILOT FLAGWORD	
# Page 87					
FLGWRD13	=	STATE +13D	#	(195-209) WAS DAPBOOLS	
			#	(SET)	(RESET)
# BIT 15 FLAG 13					
PULSEFLG	=	195D	#	MINIMUM IMPUSE	NOT IN MINIMUM
PULSES	=	BIT15	#	COMMAND MODE IN	IMPULSE COMMAND
			#	"ATT HOLD" (V76)	(V77)
# BIT 14 FLAG 13					
USEQRFLG	=	196D	#	GIMBAL UNUSABLE.	TRIM GIMBAL MAY
USEQRJTS	=	BIT14	#	USE JETS ONLY.	USED.
# BIT 13 FLAG 13					
CSMDKFLG	=	197D	#	CSM DOCKED. USE	CSM NOT DOCKED
CSMDOCKD	=	BIT13	#	BACKUP DAP	
# BIT 12 FLAG 13					
OURRCFLG	=	198D	#	CURRENT DAP PASS	CURRENT DAP PAS
OURRCBIT	=	BIT12	#	IS RATE COMMAND	NOT RATE COMMAND
# BIT 11 FLAG 13					
ACC4-2FL	=	199D	#	4 JET X-AXIS TRANS-	2 JET X-AXIS TR
ACC4OR2X	=	BIT11	#	LATION REQUESTED	LATION REQUESTED
# BIT 10 FLAG 13					
AORBTF LG	=	200D	#	B SYSTEM FOR X-	A SYSTEM FOR X-
AORBTRAN	=	BIT10	#	TRANSLATION	TRANSLATION PRE
# BIT 9 FLAG 13					
XOVINFLG	=	201D	#	X-AXIS OVERRIDE	X-AXIS OVERRIDE
XOVINHIB	=	BIT9	#	LOCKED OUT	
# BIT 8 FLAG 13					
DRIFTDFL	=	202D	#	ASSUME 0 OFFSET	USE OFFSET ACCE
DRIFTBIT	=	BIT8	#	DRIFTING FLIGHT	ION ESTIMATE
# BIT 7 FLAG 13					
RHCSCFLG	=	203D	#	NORMAL RHC SCALING	FINE RHC SCALING

RHCSCALE	=	BIT7	#	REQUESTED	REQU
# Page 88					
# BIT 6 FLAG 13					
ULLAGFLG	=	204D	#	ULLAGE REQUEST BY	NO ID
ULLAGER	=	BIT6	#	MISSION PROGRAM	REQU
# BIT 5 FLAG 13					
AORBSFLG	=	205D	#	P-AXIS COUPLES 7.15	P-AXI
AORBSYST	=	BIT5	#	AND 8.16 PREFERRED	AND 3
# BIT 4 FLAG 13					
DBSELFLG	=	206D	#	MAX DB SELECTED	MIN I
DBSELECT	=	BIT4	#	BY CREW (5 DEG)	CREW
# BIT 3 FLAG 13					
ACCOKFLG	=	207D	#	CONTROL AUTHORITY	RESTA
ACCSOKAY	=	BIT3	#	VALUES FROM 1/ACCS	SINCE
			#	USABLE	OUTPU
# BIT 2 FLAG 13					
AUTR2FLG	=	208D	#	# THESE FLAGS ARE USED TOGETHER TO ID	
AUTRATE2	=	BIT2	#	# ASTRONAUT-CHOSEN KALCMANU MANEUVER	
# BIT 1 FLAG 13					
AUTR1FLG	=	209D	#	(0,0)=(BIT2,BIT1)=	0.2 DEG/SEC
AUTRATE1	=	BIT1	#	(0,1)=	0.5 DEG/SEC
			#	(1,0)=	2.0 DEG/SEC
			#	(1,1)=	10.0 DEG/SEC

# Page 89 (nothing on this page)

This code is written to file `src/FLAGWORD-ASSIGNMENTS.s`.



## A.32 FRESH START AND RESTART

```

561 {src/FRESH-START-AND-RESTART.s 561}≡
# Copyright:      Public domain.
# Filename:       FRESH_START_AND_RESTART.agc
# Purpose:       Part of the source code for Comanche, build 055. It
#               is part of the source code for the Command Module's
#               (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:    yaYUL
# Reference:     pp. 181-210
# Contact:      Ron Burkey <info@sandroid.org>,
#               Fabrizio Bernardini <fabrizio@spacecraft.it>
# Website:      http://www.ibiblio.org/apollo.
# Mod history:   2009-05-16 FB   Transcription Batch 2 Assignment.
#               2009-05-20 RSB   Removed an extraneous "TC STARTSUB".
#               2009-05-21 RSB   Changed a "TC BANKCALL" to "TC STOPRATE"
#                               in INITSUB.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#
#           Massachussets Institute of Technology
#           75 Cambridge Parkway
#           Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.
#
# Page 181
# PROGRAM DESCRIPTION                                     8 APRIL, 1967
#                                                         SUNDISK REV 120
# FUNCTIONAL DESCRIPTION
#
# SLAP1          MAN INITIATED FRESH START
# 1.             EXECUTE STARTSUB
# 2.             TURN OFF DSKY DISCRETE-LAMPS
# 3.             CLEAR FAIL REGISTERS, SELF-CHECK ERROR COUNTER AND RESTART
#                COUNTER

```

```

#      4.      EXECUTE DOFSTART
#
# DOFSTART    MACHINE INITIATED FRESH START
#
#      1.      CLEAR SELF-CHECK REGISTERS, MODE REGISTER AND CDUZ REGISTER
#      2.      CLEAR PHASE TABLE
#      3.      INITIALIZE IMU FLAGS
#      4.      INITIALIZE FLAGWORDS
#      5.      TRANSFER CONTROL TO IDLE LOOP IN DUMMYJOB
#
# GOPROG      HARDWARE RESTART
#
#      0.      EXECUTE STARTSUB
#      1.      TRANSFER CONTROL TO DOFSTART IF ANY OF THE FOLLOWING CONDITIONS
#                EXIST.
#                A.      RESTART OCCURRED DURING EXECUTION OF ERASCHK.
#                B.      BOTH OSCILLATOR FAIL AND AGC WARNING ARE ON.
#                C.      MARK REJECT AND EITHER NAV OR MAIN DSKY ERROR LIGHT RESET
#                        ARE ON.
#      2.      SCHEDULE A T5RUPT PROGRAM FOR THE DAP
#      3.      SET FLAGWRD5 BITS FOR INTWAKE ROUTINE
#      4.      EXTINGUISH ALL DSKY LAMPS, EXCEPT FOR PROGRAM ALARM, GIMBAL LOCK, AND
#                NO ATT
#      5.      INITIALIZE IMU FLAGS
#      6.      IF ENGINE COMMAND IS ON (FLAGWRD5, BIT 7), SET ENGINE ON (CHANNEL
#                11, BIT 13).
#      7.      TRANSFER CONTROL TO GOPROG3
#
# ENEMA       SOFTWARE RESTART -- INITIATED BY MAJOR MODE CHANGE
#
#      1.      EXECUTE STARTSB2
#      2.      KILL PROGRAMS THAT WERE INTEGRATING OR WAITING FOR INTEGRATION
#                ROUTINE
#      3.      TRANSFER CONTROL TO GOPROG3
#
# GOPROG3     SUBROUTINE COMMON TO GOPROG AND ENEMA
#
#      1.      TEST PHASE TABLES -- IF INCORRECT, DISPLAY ALARM 1107 AND
#                TRANSFER CONTROL TO DOFSTART
#      2.      DISPLAY MAJOR MODE
#      3.      IF ANY GROUPS WERE ACTIVE UPON RESTART, TRANSFER CONTROL TO THE
#
# Page 182    RESTARTS SUBROUTINE TO RESCHEDULE PENDING TASKS, LONGCALLS, AND
#                JOBS (P20 IS RESTARTED VIA FINDVAC)
#      4.      IF NO GROUPS WERE ACTIVE UPON RESTART, DISPLAY ALARM CODE
#                1110 (RESTART WITH NO ACTIVE GROUPS)

```

```

#      5.      TRANSFER CONTROL TO IDLE LOOP IN DUMMYJOB
#
# STARTSUB      SUBROUTINE COMMON TO SLAP1 AND GOPROG
#
#      1.      CLEAR OUTBIT CHANNELS 5 AND 6
#      2.      INITIALIZE TIME5, TIME4, TIME3
#      3.      TRANSFER CONTROL TO STARTSB2
#
# STARTSB2      SUBROUTINE COMMON TO STARTSUB AND ENEMA
#
#      1.      INITIALIZE OUTBIT CHANNELS 11,12,13, AND 14
#      2.      REPLACE ALL TASKS ON WAITLIST WITH ENDTASK
#      3.      MAKE ALL EXECUTEVE REGISTERS AVAILABLE
#      4.      MAKE ALL VAC AREAS AVAILABLE
#      5.      CLEAR DSKY REGISTERS
#      6.      ZERO NUMEROUS SWITCHES
#      7.      INITIALIZE OPTICS FLAGS
#      8.      INITIALIZE PIPA AND TELEMETRY FAIL FLAGS
#      9.      INITIALIZE DOWN TELEMETRY
#
# INPUT/OUTPUT INITIALIZATION
#
#      A.      CALLING SEQUENCE
#
#              SLAP1 --          TC POSTJUMP          OR          VERB 36,ENTER
#                               CADR SLAP1
#
#              ENEMA --         TC POSTJUMP          *** DO NOT CALL ENEMA WITHOUT ***
#                               CADR ENEMA          *** CONSULTING POOH PEOPLE ***
#
#      B.      OUTPUT
#
#              ERASABLE MEMORY INITIALIZATION
#
# PROGRAM ANALYSIS
#
#      A.      SUBROUTINES CALLED
#
#              MR.KLEAN, WAITLIST, DSPMM, ALARM, RESTARTS, FINDVAC
#
#      B.      ALARMS
#
#              1107    PHASE TABLE ERROR
#              1110    RESTART WITH NO ACTIVE GROUPS

```

	BANK	10	
	SETLOC	FRANDRES	
	BANK		
	EBANK=	LST1	
	COUNT	05/START	
SLAP1	INHINT		# FRESH START. COMES HERE FROM PINBALL.
	TC	STARTSUB	# SUBROUTINE DOES MOST OF THE WORK.
STARTSW	TCF	SKIPSIM	# PATCH...TCF STARTSIM...FOR SIMULATION
STARTSIM	CAF	BIT14	
	TC	FINDVAC	
SIM2CADR	OCT	77777	# PATCH 2CADR (AND EBANK DESIGNATION) OF
	OCT	77777	# SIMULATION START ADDRESS.
SKIPSIM	CA	DSPTAB +11D	
	MASK	BITS4&6	
	AD	BIT15	
	TS	DSPTAB +11D	# REQUESTED FRESH START.
	CA	ZERO	# SAME STORY ON ZEROING FAILREG.
	TS	ERCOUNT	
	TS	FAILREG	
	TS	FAILREG +1	
	TS	FAILREG +2	
	TS	REDOCTR	
	CS	PRI012	
	TS	DSRUPTSW	
DOFSTART	CAF	ZERO	# DO A FRESH START.
	TS	ERESTORE	# ***** MUST NOT BE REMOVED FROM DOFSTART
	TS	SMODE	# ***** MUST NOT BE REMOVED FROM DOFSTART
	TS	UPSVFLAG	# UPDATE STATE VECTOR REQUEST FLAGWORD
	EXTEND		
	WRITE	CHAN5	# TURN OFF RCS JETS
	EXTEND		
	WRITE	CHAN6	# TURN OFF RCS JETS
	EXTEND		
	WRITE	DSALMOUT	# ZERO CHANNEL 11
	EXTEND		
	WRITE	CHAN12	# ZERO CHANNEL 12
	EXTEND		
	WRITE	CHAN13	# ZERO CHANNEL 13

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```
EXTEND
WRITE  CHAN14      # ZERO CHANNEL 14
TS     WTOPTION
TS     DNLSTCOD

TS     NVSAVE
TS     EBANKTEM
TS     RATEINDX
TS     TRKMKCNT
TS     VHFCNT
TS     EXTVBACT

CS     DSPTAB +11D
MASK   BITS4&6
CCS    A
TC     +4
CA     BITS4&6
EXTEND
WOR    CHAN12      # THE IMU WAS IN COARSE ALIGN IN GIMBAL
TC     MR.KLEAN    # LOCK, SO PUT IT BACK INTO COARSE ALIGN.

CS     ZERO
TS     MODREG

CAF    PRI030
TS     RESTREG

CAF    IM30INIF     # FRESH START IMU INITIALIZATION.
TS     IMODES30

CAF    NEGONE
TS     OPTIND       # KILL COARSE OPTICS

CAF    OPTINITF
TS     OPTMODES

CAF    IM33INIT
TS     IMODES33

EXTEND
DCA    T5IDLER      # LET T5 IDLE.
DXCH   T5LOC

CA     SWINIT
TS     STATE
```

```

                                CA      FLAGWRD1
                                MASK     NOP01BIT      # LEAVE NODOPO1 FLAG UNTOUCHED
                                AD        SWINIT +1
                                TS        FLAGWRD1

                                CA        SWINIT +2
                                TS        STATE +2

                                CA        FLAGWRD3
# Page 185
                                MASK     BIT13          # REFSMMAT FLAG
                                AD        SWINIT +3
                                TS        FLAGWRD3

                                EXTEND
                                DCA       SWINIT +4
                                DXCH      STATE +4
                                EXTEND
                                DCA       SWINIT +6
                                DXCH      STATE +6
                                CA        FLAGWRD8
                                MASK     OCT6200        # CMOONFLG, LMOONFLG, AND SUFFLAG
                                AD        SWINIT +8D
                                TS        FLAGWRD8

                                CA        SWINIT +9D
                                TS        STATE +9D

                                EXTEND
                                DCA       SWINIT +10D
                                DXCH      STATE +10D

ENDRSTRT                       TC        POSTJUMP
                                CADR      DUMMYJOB +2   # PICKS UP AT RELINT.  (IN A SWITCHED BANK.)

MR.KLEAN                       INHINT
                                EXTEND
                                DCA       NEG0
                                DXCH      -PHASE2

POOKLEAN                       EXTEND
                                DCA       NEG0
                                DXCH      -PHASE4
                                EXTEND
                                DCA       NEG0
                                DXCH      -PHASE1

V37KLEAN                       EXTEND

```

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```
DCA      NEG0
DXCH     -PHASE3
EXTEND
DCA      NEG0
DXCH     -PHASE5
EXTEND
DCA      NEG0
DXCH     -PHASE6
TC        Q
```

OCT6200 OCT 6200

# Page 186

# COMES HERE FROM LOCATION 4000, GOJAM, RESTART ANY PROGRAMS WHICH MAY HAVE BEEN RUNNING AT THE

```
GOPROG      INCR      REDOCTR      # ADVANCE RESTART COUNTER.

LXCH        Q
EXTEND
ROR          SUPERBNK
DXCH         RSBBQ
TC           BANKCALL      # STORE ERASABLES FOR DEBUGGING PURPOSES.
CADR         VAC5STOR
CA           BIT15         # TEST OSC FAIL BIT TO SEE IF WE HAVE
EXTEND       # HAD A POWER TRANSIENT. IF SO, ATTEMPT
WAND         CHAN33        # A RESTART. IF NOT, CHECK THE PRESENT
EXTEND       # STATE OF AGC WARNING BIT.
BZF          BUTTONS

CA           BIT14         # IF AGC WARNING ON (BIT = 0), DO A
EXTEND       # FRESH START ON THE ASSUMPTION THAT
RAND         CHAN33        # WE ARE IN A RESTART LOOP.
EXTEND
BZF          NONAVKEY +1

BUTTONS      TC          LIGHTSET    # MAKE FRESH START CHECKS BEFORE ERESTORE.
```

# ERASCHK TEMPORARILY STORES THE CONTENTS OF TWO ERASABLE LOCATIONS, X  
# AND X+1 INTO SKEEP5 AND SKEEP6. IT ALSO STORES X INTO SKEEP7 AND  
# ERESTORE. IF ERASCHK IS INTERRUPTED BY A RESTART, C(ERESTORE) SHOULD  
# EQUAL C(SKEEP7), AND SHOULD BE A + NUMBER LESS THAN 2000 OCT. OTHERWISE  
# C(ERESTORE) SHOULD EQUAL +0.

```
CAF        HI5
MASK       ERESTORE
EXTEND
```

```

BZF      +2          # IF ERESTORE NOT = +0 OR +N LESS THAN 2K,
TCF      NONAVKEY +1 # DOUBT E MEMORY AND DO A FRESH START
CS        ERESTORE
EXTEND
BZF      ELRSKIP -1
AD        SKEEP7
EXTEND
BZF      +2          # = SKEEP7, RESTORE E MEMORY.
TCF      NONAVKEY +1 # NOT = SKEEP7, DOUBT E MEM, DO FRESH START
CA        SKEEP4
TS        EBANK      # EBANK OF E MEMORY THAT WAS UNDER TEST.
EXTEND    # (NOT DXCH SINCE THIS MIGHT HAPPEN AGAIN)
DCA      SKEEP5
INDEX    SKEEP7
DXCH     0000        # E MEMORY RESTORED
CA        ZERO
TS        ERESTORE

# Page 187
ELRSKIP  TC        STARTSUB      # DO INITIALIZATION AFTER ERASE RESTORE.
          CA        FLAGWRD6     # RESTART AUTOPILOTS
          EXTEND
          MP        BIT3          # BITS 15,14    00      T5IDLOC
          MASK      SIX           #              01      REDORCS
          EXTEND    #              10      REDOTVC
          INDEX     A             #              11      REDOSAT
          DCA      T5IDLER
          DXCH     T5LOC

          CS        INTFLBIT
          MASK      RASFLAG
          TS        RASFLAG

          CA        OPTMODES
          MASK      OPTINITR
          AD        BIT7
          TS        OPTMODES

          CAF       BIT6
          MASK      IMODES33
          AD        IM33INIT
          TS        IMODES33

          CA        9,6,4        # LEAVE PROG ALARM, GIMBAL LOCK, NO ATT
          MASK      DSPTAB +11D   # LAMPS INTACT ON HARDWARE RESTART
          AD        BIT15
          XCH       DSPTAB +11D

```



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```

                                MASK    BIT4          # IF NO ATT LAMP WAS ON, LEAVE ISS IN
                                EXTEND                                # COARSE ALIGN
                                BZF      NOCOARSE
                                TC        IBNKCALL      # IF NO ATT LAMP ON, RETURN ISS TO
                                CADR      SETCOARS      # COARSE ALIGN.

                                CAF        SIX
                                TC        WAITLIST
                                EBANK=    CDUIND
                                2CADR     CA+ECE

NOCOARSE                      CAF        IFAILINH      # LEAVE FAILURE INHIBITS INTACT ON
                                MASK      IMODES30      # HARDWARE RESTART. RESET ALL
                                AD        IM30INIR      # FAILURE CODES.
                                TS        IMODES30

                                CS        FLAGWRD5
                                MASK      ENGONBIT
                                CCS       A
                                TCF      GOPROG3
                                CAF       BIT13
                                EXTEND

# Page 188                    WOR      DSALMOUT      # TURN ENGINE ON
                                TCF      GOPROG3

ENEMA                        INHINT
                                TC       LIGHTSET      # EXIT TO DOFSTART IF ERROR RESET AND
                                TC       STARTSB2      # MARK REJECT DEPRESSED SIMULTANEOUSLY
                                CS       INTMASK      # RESET INTEGRATION BITS
                                MASK     RASFLAG
                                TS       RASFLAG

                                CS       FLAGWRD6      # IS TVC ON
                                MASK     OCT60000
                                EXTEND
                                BZMF     GOPROG3      # NO

                                CAF       .5SEC        # YES, CALL TVCEXEC TASK WHICH WAS KILLED
                                TC       WAITLIST      # IN STARTSB2
                                EBANK=    BZERO
                                2CADR     TVCEXEC

GOPROG3                      CAF        NUMGRPS      # VERIFY PHASE TABLE AGREEMENTS
PCLoop                      TS        MPAC +5
                                DOUBLE
```

```

EXTEND
INDEX    A
DCA      -PHASE1      # COMPLEMENT INTO A, DIRECT INTO L.
EXTEND
RXOR     LCHAN        # RESULT MUST BE -0 FOR AGREEMENT.
CCS      A
TCF      PTBAD        # RESTART FAILURE.
TCF      PTBAD
TCF      PTBAD

CCS      MPAC +5      # PROCESS ALL RESTART GROUPS.
TCF      PCLOOP

TS       MPAC +6      # SET TO +0.
TC       MMDSPRAY     # DISPLAY MAJOR MODE

INHINT                                # RELINT DONE IN MMDSPRAY

CAE      FLAGWRD6     # IS RCS DAP RUNNING (BITS 15 14 OF
MASK     OCT60000     # FLAGWORD6 = 01)
EXTEND
BZMF     NXTRST -1    # NO, SKIP TO NXTRST -1
CAF      EBANK6       # STOPRATE IS DONE IN EBANK 6
TS       EBANK
TC       STOPRATE     # ZERO DELCDUS, WBODYS, AND BIASES THUS
                                # STOPPING AUTOMATIC MANEUVERING

CAF      EBANK3
TS       EBANK

# Page 189
NXTRST   CAF          NUMGRPS      # SEE IF ANY GROUPS RUNNING
          TS          MPAC +5
          DOUBLE
          INDEX       A
          CCS         PHASE1
          TCF         PACTIVE      # PNZ -- GROUP ACTIVE.
          TCF         PINACT       # +0 -- GROUP NOT RUNNING.

PACTIVE  TS          MPAC
          INCR        MPAC        # ABS OF PHASE.
          INCR        MPAC +6     # INDICATE GROUP DEMANDS PRESENT.
          CA          RACTCADR
          TC          SWCALL      # MUST RETURN TO SWRETURN.

PINACT   CCS         MPAC +5      # PROCESS ALL RESTART GROUPS.
          TCF         NXTRST

```

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```

                                CCS      MPAC +6      # NO, CHECK PHASE ACTIVITY FLAG
                                TCF      ENDRSTRT      # PHASE ACTIVE
                                CAF      BIT15         # IS MODE -0
                                MASK     MODREG
                                EXTEND
                                BZF      GOTOPOOH      # NO
                                TCF      ENDRSTRT      # YES
PTBAD                          TC      ALARM          # SET ALARM TO SHOW PHASE TABLE FAILURE.
                                OCT      1107
                                TCF      DOFSTART      # IN R21.

# *****

# DO NOT USE GOPROG2 OR ENEMA WITHOUT CONSULTING POOH PEOPLE.

GOPROG2      EQUALS  ENEMA
OCT10000     =      BIT13
OCT30000     =      PRI030
OCT7777      OCT    7777
RACTCADR     CADR   RESTARTS

LIGHTSET     CAF     BIT7      # DOFSTART IF MARK REJECT AND EITHER
                                EXTEND      # ERROR LIGHT RESET BUTTONS ARE DEPRESSED
                                RAND      NAVKEYIN
                                EXTEND
                                BZF      NONAVKEY      # NO MARK REJECT
                                CAF      OCT37
                                EXTEND
                                RAND      NAVKEYIN      # NAV DSKY KEYCODES, MARK, MARK REJECT
                                AD      -ELR
                                EXTEND
                                BZF      NONAVKEY +1
                                EXTEND

# Page 190
                                READ     MNKEYIN      # MAIN DSKY KEYCODES
                                AD      -ELR
                                EXTEND
                                BZF      +2

NONAVKEY     TC      Q

                                TC      STARTSUB
                                TCF      DOFSTART
STARTSUB     CAF      LDNPAS1      # SET POINTER SO NEXT 20MS DOWNRUPT WILL
```

	TS	DNTMGOTO	# CAUSE THE CURRENT DOWNLIST TO BE # INTERRUPTED AND START SENDING FROM THE # BEGINNING OF THE CURRENT DOWNLIST.
	CAF	POSMAX	
	TS	TIME3	# 37777 TO TIME3.
	AD	MINUS2	
	TS	TIME4	# 37775 TO TIME4.
	AD	NEGONE	
	TS	TIME5	# 37774 TO TIME5.
STARTSB2	CAF	OCT77603	# TURN OFF UPLINK ACTY, TEMP CAUTION, KR,
	EXTEND		# FLASH, OP. ERROR, LEAVE OTHERS UNCHANGED.
	WAND	DSALMOUT	
	CAF	OCT74777	# TURN OFF TEST ALARMS, STANDBY ENABLE.
	EXTEND		
	WAND	CHAN13	
	CS	PRI025	# CLEAR R21MARK, P21FLAG, AND SKIPVHF BIT.
	MASK	FLAGWRD2	
	AD	SKIPVBIT	# NOW SET SKIPVHF FLAG.
	TS	FLAGWRD2	
	EBANK=	LST1	
	CAF	STARTEB	
	TS	EBANK	# SET FOR E3
	CAF	NEG1/2	# INITIALIZE WAITLIST DELTA-TS.
	TS	LST1 +7	
	TS	LST1 +6	
	TS	LST1 +5	
	TS	LST1 +4	
	TS	LST1 +3	
	TS	LST1 +2	
	TS	LST1 +1	
	TS	LST1	
	CS	ENDTASK	
	TS	LST2	
	TS	LST2 +2	
	TS	LST2 +4	
# Page 191	TS	LST2 +6	
	TS	LST2 +8D	
	TS	LST2 +10D	
	TS	LST2 +12D	
	TS	LST2 +14D	
	TS	LST2 +16D	

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```
CS      ENDTASK +1
TS      LST2 +1
TS      LST2 +3
TS      LST2 +5
TS      LST2 +7
TS      LST2 +9D
TS      LST2 +11D
TS      LST2 +13D
TS      LST2 +15D
TS      LST2 +17D

CS      ZERO                # MAKE ALL EXECUTIVE REGISTER SETS
TS      PRIORITY            # AVAILABLE.
TS      PRIORITY +12D
TS      PRIORITY +24D
TS      PRIORITY +36D
TS      PRIORITY +48D
TS      PRIORITY +60D
TS      PRIORITY +72D

TS      DSRUPTSW
TS      NEWJOB              # SHOWS NO ACTIVE JOBS.

CAF     VAC1ADRC            # MAKE ALL VAC AREAS AVAILABLE.
TS      VAC1USE
AD      LTHVACA
TS      VAC2USE
AD      LTHVACA
TS      VAC3USE
AD      LTHVACA
TS      VAC4USE
AD      LTHVACA
TS      VAC5USE

CAF     TEN                 # BLANK DSKY REGISTERS (PROGRAM, VERB, NOUN,
                           # R1, R2, R3)

DSPOFF  TS      MPAC
CS      BIT12
INDEX   MPAC
TS      DSPTAB
CCS     MPAC
TCF     DSPOFF

TS      DELAYLOC

# Page 192
TS      DELAYLOC +1
```

	TS	DELAYLOC +2	
	TS	DELAYLOC +3	
	TS	R1SAVE	
	TS	INLINK	
	TS	DSPCNT	
	TS	CADRSTOR	
	TS	REQRET	
	TS	CLPASS	
	TS	DSPLOCK	
	TS	MONSAVE	# KILL MONITOR
	TS	MONSAVE1	
	TS	VERBREG	
	TS	NOUNREG	
	TS	DSPLIST	
	TS	MARKSTAT	
	TS	IMUCADR	
	TS	OPTCADR	
	TS	RADCADR	
	TS	ATTCADR	
	TS	LGYRO	
	TS	FLAGWRD4	# KILL INTERFACE DISPLAYS
	CAF	NOUTCON	
	TS	NOUT	
	CAF	BIT14	
	MASK	EXTVBACT	
	TS	EXTVBACT	
	CAF	LECHK	# SELF CHECK GO-TO REGISTER.
	TS	SELFRET	
	CS	VD1	
	TS	DSPCOUNT	
	TC	Q	
T5IDLOC	CA	L	# T5RUPT COMES HERE EVERY 163.84 SECS
	TCF	NOQRSM +1	# WHEN NOBODY IS USING IT.
T5IDLER	EBANK=	OGANOW	
	2CADR	T5IDLOC	
	EBANK=	OGANOW	
	2CADR	REDORCS	
	EBANK=	OGANOW	
	2CADR	REDOTVC	

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EBANK= OGANOW  
2CADR REDOSAT

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IFAILINH OCT 435  
LDNPHAS1 GENADR DNPHASE1  
LESCHK GENADR SELFCHK  
VAC1ADRC ADRES VAC1USE  
LTHVACA DEC 44

INTMASK OCT 20100  
OCT77603 OCT 77603  
OCT74777 OCT 74777  
STARTEB ECADR LST1  
NUMGRPS EQUALS FIVE  
-ELR OCT -22  
IM30INIF OCT 37411  
IM30INIR OCT 37000  
IM33INIT = PRI016  
9,6,4 OCT 450  
OPTINITF OCT 130  
OPTINITR OCT 430  
SWINIT OCT 0  
OCT 0  
OCT 0  
OCT 0

# -ERROR LIGHT RESET KEY CODE.  
# INHIBITS IMU FAIL FOR 5 SEC AND PIP ISSW  
# NO PIP OR TM FAIL SIGNALS.

OCT 0  
OCT 00200  
OCT 0  
OCT 0  
OCT 0  
OCT 0  
OCT 0  
OCT 0  
OCT 0

# Page 194

# PROGRAM NAME GOTOP00H ASSEMBLY SUNDISK  
# LOG SECTION FRESH START AND RESTART

#  
# FUNCTIONAL DESCRIPTION

#  
# 1. DISPLAY MAJOR MODE NUMBER 00 IN DSKY REGISTER R1 AND R3. FLASH V50N07 ON DSKY.  
# 2. PERMIT A CURRENT PENDING REQUEST (FLASH ON DSKY) TO BE REPLACED (WITHOUT AN ABC  
# CHANGE REQUEST.  
#

```

# INPUT/OUTPUT INFORMATION
#
#       A. CALLING SEQUENCE           TC GOTOP00H
#       B. ERASABLE INITIALIZATION   NONE
#       C. OUTPUT                     FLASH V 50 NOUN 07 ON DSKY
#       D. DEBRIS                     L
#
# PROGRAM ANALYSIS
#
#       A. SUBROUTINES CALLED         GOPERF3, LINUS
#       B. NORMAL EXIT                TCF ENDOFJOB
#       C. ALARM AND ABORT EXITS      NONE
#
#                               BLOCK   02
#                               SETLOC  FFTAG10
#                               BANK
#
#                               COUNT   02/P00
#
GOTOP00H      TC      PHASCHNG          # RESTART GOTOP00H
              OCT      14
#
              TC      POSTJUMP
              CADR     GOP00FIX
              BANK     10
              SETLOC   VERB37
              BANK
#
              COUNT   04/P00
#
GOP00FIX      TC      INITSUB
              TC      CLEARMRK +2
              CAF      V37N99
              TC      BANKCALL
              CADR     GOFLASH
              TCF      -3
# Page 195
              TCF      -4
              TCF      -5
V37N99        VN      3799
# Page 196
# PROGRAM NAME      V37                ASSEMBLY SUNDISK
#
# LOG SECTION       FRESH START AND RESTART
#

```



## # FUNCTIONAL DESCRIPTION

#

#

# 1. CHECK IF NEW PROGRAM ALLOWED. IF BIT 1 OF FLAGWRD2 (NODOFLAG) IS SET, AN ALARM 1520

# 2. CHECK FOR VALIDITY OF PROGRAM SELECTED. IF AN INVALID PROGRAM IS SELECTED, THE OPER  
# SET AND CURRENT ACTIVITY, IF ANY, CONTINUE.

# 3. SERVICER IS TERMINATED IF IT HAS BEEN RUNNING.

# 4. INSTALL IS EXECUTED TO AVOID INTERRUPTING INTEGRATION.

# 5. THE ENGINE IS TURNED OFF AND THE DAP IS INITIALIZED FOR COAST.

# 6. TRACK, UPDATE, AND TARG1 FLAGS ARE SET TO ZERO.

# 7. DISPLAY SYSTEM IS RELEASED.

# 8. THE FOLLOWING ARE PERFORMED FOR EACH OF THE THREE CASES.

# A. PROGRAM SELECTED IS P00.

# 1. RENDEZVOUS FLAG IS RESET. (KILL P20)

# 2. STATINT1 IS SCHEDULED BY SETTING RESTART GROUP 2.

# 3. MAJOR MODE 00 IS STORED IN THE MODE REGISTER (MODREG).

# 4. SUPERBANK 3 IS SELECTED.

# 5. NODOFLAG IS RESET.

# 6. ALL RESTART GROUPS EXCEPT GROUP2 ARE CLEARED. CONTROL IS TRANSFERRED  
# WHICH CAUSES ALL CURRENT ACTIVITY TO BE DISCONTINUED AND A 9 MINUTE  
# INITIATED.

# B. PROGRAM SELECTED IS P20.

# 1. IF THE CURRENT MAJOR MODE IS THE SAME AS THE SELECTED NEWPROGRAM. T  
# VIA V37XEQ, ALL RESTART GROUPS, EXCEPT GROUP 4 ARE CLEARED.# 2. IF THE CURRENT MAJOR MODE IS NOT EQUAL TO THE NEW REQUEST, A CHECK I  
# ED MAJOR MODE HAS BEEN RUNNING THE BACKGROUND,  
# AND IF IT HAS, NO NEW PROGRAM IS SCHEDULED, THE EXISTING  
# P20 IS RESTARTED TO CONTINUE, AND ITS MAJORE MODE IS SET.

# 3. CONTROL IS TRANSFERRED TO GOPROG2.

# C. PROGRAM SELECTED IS NEITHER P00 NOR P20

# 1. V37XEQ IS SCHEDULED (AS A JOB) BY SETTING RESTART GROUP 4

# 2. ALL CURRENT ACTIVITY EXCEPT RENDEZVOUS AND TRACKING IS DISCONTINUED  
# GROUPS. GROUP 2 IS CLEARED. IF THE RENDEZVOUS FLAG IS ON P20 IS REST  
# TO CONTINUE.

#

## # INPUT/OUTPUT INFORMATION

#

#

# A. CALLING SEQUENCE

# CONTROL IS DIRECTED TO V37 BY THE VERBFAN ROUTINE.

# VERBFAN GOES TO C(VERBTAB+C(VERBREG)). VERB 37 = MMCHANG.

# MMCHANG EXECUTES A TC POSTJUMP, CADR V37.

#

# B. ERASABLE INITIALIZATION NONE

#

# C. OUTPUT

# MAJOR MODE CHANGE

```

#
#      D. DEBRIS
#          MMNUMBER, MPAC +1, MINDEX, BASETEMP +C(MINDEX), FLAGWRD0, FLAGWRD1, I
#          GOLOC, GOLOC +1, GOLOC +2, BASETEMP, -PHASE2, PHASE2, -PHASE4
#
# PROGRAM ANALYSIS
#
#      A. SUBROUTINES CALLED
#          ALARM, RELDSP, PINBRNCH, INTSTALL, ENGINOF2, ALLCOAST, V37KLEAN, GOF
#          DSPMM
#
#      B. NORMAL EXIT                                TC ENDOFJOB
#
#      C. ALARMS                                1520 (MAJOR MODE CHANGE NOT PERMITTED)

          BLOCK    02
          SETLOC   FFTAG10
          BANK

          COUNT    02/V37

OCT24      MM      20
OCT31      MM      25
          BANK     27
          SETLOC   VERB37
          BANK

          COUNT    04/V37

V37        TS      MMNUMBER      # SAVE MAJOR MODE
          CAF      PRI030        # RESTART AT PINBALL PRIORITY
          TS      RESTREG

          CA      IMODES30      # IS IMU BEING INITIALIZED
          MASK    BIT6
          CCS      A
          TCF     CANTROO

          CAF      BIT13      # IS ENGINE ON
          EXTEND
          RAND     DSALMOUT
          CCS      A
          TCF     ROOTOP00    # YES, SET UP FOR P00

          CS      FLAGWRD6      # NO, IS TVC DAP ON
          MASK    OCT60000

```

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```

                                EXTEND
                                BZMF      ISITP00                # NO, CONTINUE WITH ROO

ROOTOP00                      INHINT
                                CAF        EBANK6

# Page 198                    TS        EBANK
                                EBANK=    DAPDATR1
                                CAE        CSMMASS
                                TS        MASSTMP
                                TC        IBNKCALL
                                CADR      SPSOFF
                                TC        IBNKCALL
                                CADR      MASSPROP
                                CAF        3.1SEC
                                TC        IBNKCALL
                                CADR      RCSDAPON +1

                                TC        IBNKCALL
                                CADR      TVCZAP                # DISABLE TVC
                                CAF        ZERO
                                TS        MMNUMBER
                                RELINT
                                CAF        FIVE
                                TC        BANKCALL
                                CADR      DELAYJOB
                                CAF        ZERO
                                EXTEND
                                WRITE     5
                                EXTEND
                                WRITE     6
                                ISITP00   CA        MMNUMBER
                                EXTEND
                                BZF       ISSERVON                # YES, CHECK SERVICER STATUS

                                CS        FLAGWRD2                # NO, IS NODO V37 FLAG SET
                                MASK      NODOBIT
                                CCS       A
                                TCF       CHECKTAB                # NO
                                CANTR00   TC        ALARM
                                OCT       1520

                                V37BAD   TC        RELDSP          # RELEASES DISPLAY FROM ASTRONAUT

                                TC        POSTJUMP                # BRING BACK LAST NORMAL DISPLAY IF THERE
                                CADR      PINBRNCH                # WAS ONE.  OY
```

CHECKTAB	CA	NOV37MM	# THE NO. OF MM
AGAINMM	TS	MPAC +1	
	NDX	MPAC +1	
	CA	PREMM1	# OBTAIN WHICH MM THIS IS FOR
	MASK	LOW7	
	COM		
	AD	MMNUMBER	
	CCS	A	
	CCS	MPAC +1	# IF GR, SEE IF ANY MORE IN LIST
# Page 199	TCF	AGAINMM	# YES, GET NEXT ONE
	TCF	V37NONO	# LAST TIME OR PASSED MM
	CA	MPAC +1	
	TS	MINDEX	# SAVE INDEX FOR LATER
ISSERVON	CS	FLAGWRD7	# V37 FLAG SET -- I.E., IS SERVICER C
	MASK	V37FLBIT	
	CCS	A	
	TCF	CANV37	# NO
	INHINT		
	CS	AVEGBIT	# YES TURN OFF AVERAGE G FLAG AND WA
	MASK	FLAGWRD1	# FOR SERVICER TO RETURN TO CANV37
	TS	FLAGWRD1	
	TCF	ENDOFJOB	
CANV37	CAF	R00AD	
	TS	TEMPFLSH	
	TC	PHASCHNG	
	OCT	14	
ROC	TC	INTPRET	
	CALL		# WAIT FOR INTEGRATION TO FINISH
		INTSTALL	
DUMMYAD	EXIT		
	CS	OCT1400	# CLEAR CAUTION RESET
	EXTEND		# AND TEST CONNECTOR OUTBIT
	WAND	11	
	CAF	OCT44571	# CLEAR ENABLE OPTICS ERROR COUNTER,

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	EXTEND		# TRAKERS ON BIT, TVC ENABLE, ZERO OPTICS,
	WAND	12	# DISENGAGE OPTICS DAP, SIVB IN J SEQUENCE
			# START, AND SIVB CUTOFF BIT.
	CS	OCT600	# CLEAR UNUSED BITS
	EXTEND		
	WAND	13	
	TC	INITSUB	
	TC	CLEARMRK	
	TC	DOWNFLAG	
	ADRES	STIKFLAG	
# Page 200	TC	BANKCALL	
	CADR	UPACTOFF	# TURN OFF UPLINK ACTIV LIGHT
	TC	DOWNFLAG	
	ADRES	VHFRFLAG	
	TC	DOWNFLAG	
	ADRES	R21MARK	
	CCS	MMNUMBER	# IS THIS A POOH REQUEST
	TCF	NOUVEAU	# NO, PICK UP NEW PROGRAM
	COUNT	04/P00	
POOH	TC	RELDSP	# RELEASE DISPLAY SYSTEM
	CAF	PRI05	# SET VARIABLE RESTART REGISTER FOR P00.
	TS	PHSPRDT2	
	INHINT		
	CS	NODOBIT	# TURN OFF NODOFLAG.
	MASK	FLAGWRD2	
	TS	FLAGWRD2	
	CA	FIVE	# SET 2.5 RESTART FOR STATEINT1
	TS	L	
	COM		
	DXCH	-PHASE2	
	CS	BIT7-8	# RESET IMUSE + KILL P20 BY TURNING OFF
	MASK	FLAGWRD0	

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	TS	FLAGWRDO	#	RENDFLG
	CAF	DNLADPOO		
	COUNT	04/V37		
SEUDOP00	TS	DNLSTCOD	#	SET UP APPROPRIATE DOWNLIST CODE
			#	(OLD ONE WILL BE FINISHED FIRST)
	CS	OCT01120	#	TURN OFF TRACK, TARG1, UPDATE FLAG
	TS	EBANKTEM		
	MASK	FLAGWRD1		
	TS	FLAGWRD1		
GROUPKIL	TC	IBNKCALL	#	KILL GROUPS 3,5,6
	CADR	V37KLEAN		
	CCS	MMNUMBER	#	IS IT POOH
	TCF	RENDV00	#	NO
# Page 201				
	TC	IBNKCALL		
	CADR	POOKLEAN	#	REDUNDANT EXCEPT FOR GROUP 4.
GOMOD	CA	MMNUMBER		
	TS	MODREG		
GOGOPROG	TC	POSTJUMP		
	CADR	GOPROG2		
RENDV00	CS	MMNUMBER	#	IS NEW PROG = 20
	AD	OCT24	#	20
	EXTEND			
	BZF	RENDNOO	#	YES
	TCF	POOFIZZ		
RENDNOO	CS	MMNUMBER		
	AD	MODREG		
	EXTEND			
	BZF	KILL20		
	CA	FLAGWRDO	#	IS RENDZV00 FLAG SET
	MASK	RNDVZBIT		
	CCS	A		
	TCF	STATQUO		
POOFIZZ	CAF	RNDVZBIT		
	MASK	FLAGWRDO		

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KILL20	CCS	A	
	TCF	REV37	
	EXTEND		# NO, KILL GROUPS 1 + 2
	DCA	NEGO	
	DXCH	-PHASE1	
	EXTEND		
	DCA	NEGO	
	DXCH	-PHASE2	
REV37	CAF	V37QCAD	# SET RESTART POINT
	TS	TEMPFLSH	
	TCF	GOGOPROG	
STATQUO	CS	FLAGWRD1	# SET TRACKFLAG AND UPDATE FLAG
	MASK	OCT120	
	ADS	FLAGWRD1	
	EXTEND		# KILL GROUP 4
	DCA	NEGO	
	DXCH	-PHASE4	
# Page 202	TCF	GOMOD	
NOUVEAU	CAF	RNDVZBIT	
	MASK	FLAGWRDO	
	CCS	A	
	TCF	+3	
	TC	DOWNFLAG	# NO, RESET IMUINUSE FLAG
	ADRES	IMUSE	# BIT 8 FLAG 0
+3	INDEX	MINDEX	
	CAF	DNLADMM1	# OBTAIN NEW DOWNLIST ADDRESS
	INHINT		
	TCF	SEUDOP00	
V37NONO	TC	FALTON	# COME HERE IF MM REQUESTED DOESN'T EXIST
	TCF	V37BAD	
OCT00010	EQUALS	BIT4	
V37XEQ	INHINT		
	INDEX	MINDEX	
	CAF	PREMM1	

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	TS	MMTEMP	# OBTAIN PRIORITY BITS 15-11
	TS	CYR	# SHIFT RIGHT TO BITS 14-10
	CA	CYR	
	MASK	PRI037	
	TS	PHSPRDT4	# PRESET GROUP 4 RESTART PRIORITY
	TS	NEWPRIO	# STORE PRIO FOR SPVAC
	CA	MMTEMP	# OBTAIN EBANK -- BITS 8, 9, 10 OF MMTEMP
	EXTEND		
	MP	BIT8	
	MASK	LOW3	
	TS	L	
	INDEX	MINDEX	
	CAF	FCADRMM1	
	TS	BASETEMP	
	MASK	HI5	
	ADS	L	
	CA	BASETEMP	# OBTAIN GENADR PORTION OF 2CADR.
	MASK	LOW10	
	AD	BIT11	
	TC	SPVAC	
V37XEQC	CA	MMTEMP	# UPON RETURN FROM FINDVAC PLACE THE
	MASK	LOW7	# NEW MM IN MODREG (THE LOW 7 BITS OF MODREG)
	TC	NEWMODEA	# PHSPRDT1)
# Page 203			
# FOR SUNDISK ONLY			
	TC	RELDSP	# RELEASE DISPLAY
	TC	ENDOFJOB	# AND EXIT
INITSUB	EXTEND		
	QXCH	MPAC +1	
	CAF	EBANK6	# SET E6 FOR DEADBAND CODING
	TS	EBANK	# WILL BE RESET IN STARTSB2
	INHINT		
	TC	STOPRATE	
	CA	FLAGWRD9	# RESTORE DEADBAND
	MASK	MAXDBBIT	
	CCS	A	
	TCF	SETMAXER	# MAX DE SELECTED



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	TC	BANKCALL		# MIN DE SELECTED
	CADR	SETMINDB		
	TCF	RAKE		
SETMAXER	TC	BANKCALL		
	CADR	SETMAXDB		
RAKE	CAF	ELEVEN		# THIS PART CLEARS FLAGWORD BITS.
+1	TS	MPAC		# LOOP COMES HERE
	INDEX	MPAC		
	CS	FLAGTABL		
	INDEX	MPAC		
	MASK	FLAGWRDO		
	INDEX	MPAC		# PUT REVISED FLAGWORD BACK.
	TS	FLAGWRDO		
	CCS	MPAC		
	TCF	RAKE	+1	# GET THE NEXT FLAGWORD
	RELINT			
	TC	UPFLAG		# NOW SET IMPULSW
	ADRES	IMPULSW		
	CA	NEGONE		
	TS	OPTIND		
	TC	MPAC	+1	# RETURN FROM INITSUB
FLAGTABL	OCT	0		
	OCT	00040		# IDLEFAIL
	OCT	06000		# P21FLAG, STEERSW
	OCT	0		
	OCT	0		
	OCT	04140		# V59FLAG, ENGONFLG, 3AXISFLG
	OCT	10000		# STRULLSW
	OCT	16000		
	OCT	0		
# Page 204	OCT	42000		# SWTOVER, V94FLAG
	OCT	0		
	OCT	0		
	SETLOC	VAC5LOC		
	BANK			
VAC5STOR	CA	ZERO		# INITIALIZE INDEX REGISTERS
	TS	ITEMP1		
	TS	ITEMP2		
V5LOOP1	EXTEND			# LOOP TO STORE LOCS, BANKSETS, AND PRIOS.

```

INDEX  ITEMP1
DCA    LOC
INDEX  ITEMP2
DXCH   VAC5

INDEX  ITEMP1
CA     PRIORITY
INDEX  ITEMP2
TS     VAC5 +2

CS     ITEMP2          # HAVE WE STORED THEM ALL?
AD     EIGHTEEN
EXTEND
BZF    V5OUT1          # YES, GET PHASE INFORMATION.

CA     TWELVE          # NO, INCREMENT INDEXES AND LOOP.
ADS    ITEMP1
CA     THREE
ADS    ITEMP2
TCF    V5LOOP1

EBANK= PHSNAME1
V5OUT1 CA    EBANK3     # PHSNAME REGISTERS ARE IN EBANK3.
TS     EBANK

CA     ELEVEN          # GET PHASE 2CADRS.
TC     GENTRAN
ADRES  PHSNAME1
ADRES  VAC5 +21D

CA     ZERO            # NOW INITIALIZE INDEXES AGAIN.
TS     ITEMP1
TS     ITEMP2

V5LOOP2 INDEX  ITEMP1   # LOOP TO GET PHASE TABLES.
CA     PHASE1
INDEX  ITEMP2
TS     VAC5 +33D

# Page 205

CS     ITEMP2          # DO WE HAVE THEM ALL?
AD     FIVE
EXTEND
BZF    V5OUT2          # YES, GO FINISH UP.

CA     TWO             # NO, INCREMENT INDEXES AND LOOP.

```

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	ADS	ITEMP1	
	INCR	ITEMP2	
	TCF	V5LOOP2	
V5OUT2	CA	MPAC +3	
	TS	VAC5 +39D	
	EXTEND		
	DCA	NEWLOC	
	DXCH	VAC5 +40D	
	CA	NEWJOB	
	TS	VAC5 +22D	
	CA	NEWPRIO	
	TS	VAC5 +26D	
	TC	SWRETURN	
EIGHTEEN	OCT	22	
	SETLOC	VERB37	
	BANK		
NEG7	EQUALS	OCT77770	
OCT44571	OCT	44571	# CONSTANTS TO CLEAR CHANNEL BITS IN V37
OCT600	OCT	600	
	EBANK=	PACTOFF	
POODAPAD	2CADR	T5IDLOC	
MMTEMP	EQUALS	PHSPRDT3	
BASETEMP	EQUALS	TBASE4	
BIT7-8	OCT	300	
OCT01120	OCT	01120	
V37QCAD	CADR	V37XEQ +3	
R00AD	CADR	DUMMYAD	
	EBANK=	DAPDATR1	
RCSADDR4	2CADR	RCSATT	
3.1SEC	OCT	37312	# 2.5 + 0.6 SEC

# FOR VERB 37 TWO TABLES ARE MAINTAINED. EACH TABLE HAS AN ENTRY FOR EACH  
# MAJOR MODE THAT CAN BE STARTED FROM THE KEYBOARD. THE ENTRIES ARE PUT  
# INTO THE TABLE WITH THE ENTRY FOR THE HIGHEST MAJOR MODE COMING FIRST,  
# Page 206

```

# TO THE LOWEST MAJOR MODE WHICH IS THE LAST ENTRY IN EACH TABLE.
#
# THE FCADRM TABLE CONTAINS THE FCADR OF THE STARTING JOB OF
# THE MAJOR MODE.  FOR EXAMPLE,
#
#           FCADRM1           FCADR   P79           # START OF P 79
#           FCADR           PROG18          # START OF P 18
#           FCADR           P01            # START OF P 01

```

```

FCADRM1      EQUALS
              FCADR   P79
              FCADR   P78
              FCADR   P77
              FCADR   P76
              FCADR   P75
              FCADR   P74
              FCADR   P73
              FCADR   P72
              FCADR   P62
              FCADR   P61
              FCADR   P54
              FCADR   P53
              FCADR   PROG52
              FCADR   P51
              FCADR   P47CSM
              FCADR   P41CSM
              FCADR   P40CSM
              FCADR   P39
              FCADR   P38
              FCADR   P37
              FCADR   P35
              FCADR   P34
              FCADR   P33
              FCADR   P32
              FCADR   P31
              FCADR   P30
              FCADR   P23
              FCADR   PROG22
              FCADR   PROG21
              FCADR   PROG20
              FCADR   P17
              FCADR   P06
              FCADR   GTSCPSS1

```

```

# GYROCOMPASS STANDARD LEAD 1

```

```

# THE PREMM TABLE CONTAINS THE E-BANK, MAJOR MODE, AND PRIORITY
# INFORMATION, IT IS IN THE FOLLOWING FORM,

```

```

#
#       PPP PPE EEM MMM MMM
#
# Page 207
#       WHERE THE       7 M BITS CONTAIN THE MAJOR MODE NUMBER
#                       3 E BITS CONTAIN THE E-BANK NUMBER
#                       5 P BITS CONTAIN THE PRIORITY AT WHICH THE JOB IS
#                       TO BE STARTED
#
#       FOR EXAMPLE,
#
#           PREMM1           OCT       67213           # PRIORITY       33
#                                           # E-BANK           5
#                                           # MAJOR MODE       11
#           OCT             25437           # PRIORITY       12
#                                           # E-BANK           6
#                                           # MAJOR MODE       31

```

```

PREMM1      EQUALS
OCT  27117      # MM 79      EBANK 4      PRIO 13
OCT  27116      # MM 78      EBANK 4      PRIO 13 (original says
OCT  27115      # MM 77      EBANK 4      PRIO 13
OCT  27714      # MM 76      EBANK 4      PRIO 13
OCT  27113      # MM 75      EBANK 4      PRIO 13
OCT  27112      # MM 74      EBANK 4      PRIO 13
OCT  27111      # MM 73      EBANK 4      PRIO 13
OCT  27110      # MM 72      EBANK 4      PRIO 13
OCT  27476      # MM 62      EBANK 6      PRIO 13
OCT  27475      # MM 61      EBANK 6      PRIO 13
OCT  27266      # MM 54      EBANK 5      PRIO 13
OCT  27265      # MM 53      EBANK 5      PRIO 13
OCT  27264      # MM 52      EBANK 5      PRIO 13
OCT  27263      # MM 51      EBANK 5      PRIO 13
OCT  27657      # MM 47      EBANK 7      PRIO 13
OCT  27451      # MM 41      EBANK 6      PRIO 13
OCT  27450      # MM 40      EBANK 6      PRIO 13
OCT  27047      # MM 39      EBANK 4      PRIO 13
OCT  27046      # MM 38      EBANK 4      PRIO 13
OCT  27645      # MM 37      EBANK 7      PRIO 13
OCT  27043      # MM 35      EBANK 4      PRIO 13
OCT  27042      # MM 34      EBANK 4      PRIO 13
OCT  27041      # MM 33      EBANK 4      PRIO 13
OCT  27040      # MM 32      EBANK 4      PRIO 13
OCT  27637      # MM 31      EBANK 7      PRIO 13
OCT  27636      # MM 30      EBANK 7      PRIO 13
OCT  27227      # MM 23      EBANK 5      PRIO 13

```

OCT	27226	# MM 22	EBANK 5	PRI0 13
OCT	27025	# MM 21	EBANK 4	PRI0 13
OCT	27424	# MM 20	EBANK 6	PRI0 13
OCT	27021	# MM 17	EBANK 6	PRI0 13
OCT	27006	# MM 06	EBANK 4	PRI0 13
OCT	41201	# MM 01	EBANK 5	PRI0 20

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# THE FOLLOWING LIST IS FOR THE PURPOSE OF VERIFYING THAT THE EBA

EBANK= TIG	# EBANK SETTING REQUIRED BY MM 76
EBANK= KT	# EBANK SETTING REQUIRED BY MM 75
EBANK= SUBEXIT	# EBANK SETTING REQUIRED BY MM 74
EBANK= SUBEXIT	# EBANK SETTING REQUIRED BY MM 73
EBANK= SUBEXIT	# EBANK SETTING REQUIRED BY MM 72
EBANK= AOG	# EBANK SETTING REQUIRED BY MM 62
EBANK= AOG	# EBANK SETTING REQUIRED BY MM 61
EBANK= BESTI	# EBANK SETTING REQUIRED BY MM 54
EBANK= STARIND	# EBANK SETTING REQUIRED BY MM 53
EBANK= BESTI	# EBANK SETTING REQUIRED BY MM 52
EBANK= STARIND	# EBANK SETTING REQUIRED BY MM 51
EBANK= P40TMP	# EBANK SETTING REQUIRED BY MM 47
EBANK= DAPDATR1	# EBANK SETTING REQUIRED BY MM 41
EBANK= KMPAC	# EBANK SETTING REQUIRED BY MM 40
EBANK= KT	# EBANK SETTING REQUIRED BY MM 35
EBANK= SUBEXIT	# EBANK SETTING REQUIRED BY MM 34
EBANK= SUBEXIT	# EBANK SETTING REQUIRED BY MM 33
EBANK= SUBEXIT	# EBANK SETTING REQUIRED BY MM 32
EBANK= +MGA	# EBANK SETTING REQUIRED BY MM 30
EBANK= LANDMARK	# EBANK SETTING REQUIRED BY MM 23
EBANK= MARKINDX	# EBANK SETTING REQUIRED BY MM 22
EBANK= WHOCARES	# EBANK SETTING REQUIRED BY MM 21
EBANK= ESTROKER	# EBANK SETTING REQUIRED BY MM 20
EBANK= TIME2SAV	# EBANK SETTING REQUIRED BY MM 06
EBANK= QPLACE	# EBANK SETTING REQUIRED BY MM 01

# NOTE: THE FOLLOWING CONSTANT IS THE NUMBER OF ENTRIES IN EACH OF  
# ----- THE ABOVE LISTS-1 (I.E., THE NUMBER OF MAJOR MODES (EXCEPT P00)  
# THAT CAN BE CALLED FROM THE KEYBOARD MINUS ONE)

EPREMM1	EQUALS	# END OF PREMM1 TABLE
	SETLOC PREMM1	# THIS CODING WILL AUTOMATICALLY CHANGE
NO.MMS	=MINUS EPREMM1	# THE "NOV37MM" CONSTANT AS ENTRIES ARE
	SETLOC VERB37	# INSERTED(IN) OR DELETED(FROM) THE
	BANK	# "PREMM1" TABLE.

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NOV37MM ADRES NO.MMS -1 # ITEMS IN "PREMM1" TABLE - 1. \*DON'T MOVE\*

DNLADMM1 EQUALS  
ADRES RENDEZVU # P79  
ADRES RENDEZVU # P78  
ADRES RENDEZVU # P77  
ADRES RENDEZVU # P76  
ADRES RENDEZVU # P75  
ADRES RENDEZVU # P74  
ADRES RENDEZVU # P73

# Page 209

ADRES RENDEZVU # P72  
ADRES ENTRYUPD # P62  
ADRES POWERED # P61  
ADRES COSTALIN  
ADRES COSTALIN  
ADRES COSTALIN # P52  
ADRES COSTALIN # P51  
ADRES POWERED # P47  
ADRES POWERED # P41  
ADRES POWERED # P40  
ADRES RENDEZVU # P39  
ADRES RENDEZVU # P38  
ADRES RENDEZVU # P37  
ADRES RENDEZVU # P35  
ADRES RENDEZVU # P34  
ADRES RENDEZVU # P33  
ADRES RENDEZVU # P32  
ADRES RENDEZVU  
ADRES RENDEZVU # P30  
ADRES RENDEZVU # P23  
ADRES P22DNLST # P22  
ADRES RENDEZVU # P21  
ADRES RENDEZVU # P20  
ADRES RENDEZVU # P17  
ADRES COSTALIN # P06  
ADRES COSTALIN # P01

DNLADPOO = ZERO  
COSTALIN = 0  
ENTRYUPD = 1  
RENDEZVU = 2  
POWERED = 3

P22DNLST = 4

# ORBITAL INTEGRATION CONSTANTS

# THESE CONSTANTS ARE USED IN COMPUTING THE SETTING OF MIDFLAG.

RMM                2DEC    2538.09 E3 B-27 # 800 KM ABOVE LUNAR SURFACE

RME                2DEC    7178165 B-29    # 800 KM ABOVE EQ. RADIUS

BANK    13  
SETLOC INTINIT  
BANK

COUNT\*    \$\$/INTIN

EBANK=    RRECTCSM

STATEUP        SET    BOF                # EXTRAPOLATE CM STATE VECTOR  
                         VINTFLAG

# Page 210

                         ORBFLAG                # ALSO 6X6 W-MATRIX IF VALID  
                         +3                        #                FOR ORBITAL NAVIGATION

SET                DIMOFLAG

CLEAR    CALL  
                         PRECIFLG  
                         INTEGRV

BON                DLOAD  
                         SURFFLAG  
                         STATEND  
                         TETCSM

STCALL    TDEC1  
                         INTSTALL

CLEAR    CALL                # EXTRAPOLATE LM STATE VECTOR  
                         VINTFLAG

                         SETIFLGS                #                AND 6X6 W-MATRIX IF VALID

BOF                SET                        #                FOR RENDEZVOUS NAVIGATION  
                         RENWFLG  
                         +2

                         DIMOFLAG  
SET                CALL  
                         PRECIFLG  
                         INTEGRV

STATEND        CLRGO  
                         NODOFLAG  
                         ENDINT



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```
# THIS VINT IS CALLED BY MIDTOAV1 AND 2
```

```
THISVINT      SET      RVQ  
                VINTFLAG
```

This code is written to file `src/FRESH-START-AND-RESTART.s`.

### A.33 GIMBAL LOCK AVOIDANCE

```

594  <src/GIMBAL-LOCK-AVOIDANCE.s 594>≡
# Copyright:    Public domain.
# Filename:     GIMBAL_LOCK_AVOIDANCE.agc
# Purpose:     Part of the source code for Comanche, build 055.
#              It is part of the source code for the Command Module's (CM)
#              Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:   yaYUL
# Reference:    pp. 412-413
# Contact:     Onno Hommes <ohommes@cmu.edu>.
# Website:     www.ibiblio.org/apollo.
# Mod history: 05/07/09 OH      Transcription Batch 1 Assignment
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#              Massachusetts Institute of Technology
#              75 Cambridge Parkway
#              Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further information.
# Please report any errors to info@sandroid.org.

# Page 412

BANK      15
SETLOC    KALCMON1
BANK

EBANK=    BCDU

# DETECTING GIMBAL LOCK
LOCKSKIRT    EQUALS    WCALC
WCALC        LXC,1     DLOAD*
                     RATEINDX
                     ARATE,1
SR4          CALL      # COMPUTE THE INCREMENTAL ROTATION MATRIX

```

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```

                                DELCOMP      # DEL CORRESPONDING TO A 1 SEC ROTATION
                                # ABOUT COF
DLOAD*  VXSC
        ARATE,1
        COF
MXV
        QUADROT
STODL   BRATE
        AM
DMP     DDV*
        ANGLTIME
        ARATE,1
SR
        5
STOVL   TM
        BRATE
VXSC
        BIASCALE
STORE   BIASTEMP      # ATTITUDE ERROR BIAS TO PREVENT OVERSHOOT
                                # IN SYSTEM
SETGO   CALCMAN2      # STATE SWITCH CALCMAN2 (43D)
        NEWANGL +1    # 0(OFF) = BYPASS STARTING PROCEDURE
                                # 1(ON) = START MANEUVER

ARATE   2DEC   .0022222222    # = .05 DEG/SEC
        2DEC   .0088888889    # = .2 DEG/SEC
        2DEC   .0222222222    # = .5 DEG/SEC
        2DEC   .0888888889    # = 2 DEG/SEC          $22.5 DEG/SEC

ANGLTIME 2DEC   .000190735    # = 100B - 19
                                # MANEUVER ANGLE TO MANEUVER TIME
QUADROT  2DEC   .1            # ROTATION MATRIX FROM S/C AXES TO CONTROL

# Page 413
        2DEC   0              # AXES (X ROT = -7.25 DEG)
        2DEC   0
        2DEC   0
        2DEC   .099200        # = (.1)COS7.25
```

2DEC      -.012620      # =-(.1)SIN7.25

2DEC      0

2DEC      .012620      # (.1)SIN7.25

2DEC      .099200      # (.1)COS7.25

BIASCALE      2DEC      .0002543132      # = (450/180)(1/0.6)(1/16384)

This code is written to file `src/GIMBAL-LOCK-AVOIDANCE.s`.

## A.34 GROUND TRACKING DETERMINATION PROGRAM

```

597  <src/GROUND-TRACKING-DETERMINATION-PROGRAM.s 597>≡
    # Copyright:    Public domain.
    # Filename:     GROUND_TRACKING_DETERMINATION_PROGRAM.agc
    # Purpose:      Part of the source code for Comanche, build 055.
    #               It is part of the source code for the Command Module's (CM)
    #               Apollo Guidance Computer (AGC), Apollo 11.
    # Assembler:    yaYUL
    # Reference:     pp. 456-459
    # Contact:       Onno Hommes <ohommes@cmu.edu>.
    # Website:       www.ibiblio.org/apollo.
    # Mod history:   2009-05-07 OH   Transcription Batch 1 Assignment
    #               2009-05-20 RSB   Corrected a couple of DIMOFLAG to DIMOFLAG.
    #
    # The contents of the "Comanche055" files, in general, are transcribed
    # from scanned documents.
    #
    # Assemble revision 055 of AGC program Comanche by NASA
    # 2021113-051. April 1, 1969.
    #
    # This AGC program shall also be referred to as Colossus 2A
    #
    # Prepared by
    #               Massachussets Institute of Technology
    #               75 Cambridge Parkway
    #               Cambridge, Massachusetts
    #
    # under NASA contract NAS 9-4065.
    #
    # Refer directly to the online document mentioned above for further information.
    # Please report any errors to info@sandroid.org.
    #
    # Page 456
    # GROUND TRACKING DETERMINATION PROGRAM -- P21
    #
    # PROGRAM DESCRIPTION
    # MOD NO -- 1
    # MOD BY -- N. M. NEVILLE
    #
    # FUNCTIONAL DESCRIPTION --
    # TO PROVIDE THE ASTRONAUT DETAILS OF THE LM OR CSM GROUND TRACK WITHOUT
    # THE NEED FOR GROUND COMMUNICATION (REQUESTED BY DSKY).
    #

```

```

# CALLING SEQUENCE --
#   ASTRONAUT REQUEST THROUGH DSKY V37E21E
#
# SUBROUTINES CALLED --
#   GOPERF4
#   GOFLASH
#   THISPREC
#   OTHPREC
#   LAT-LONG
#
# NORMAL EXIT MODES --
#   ASTRONAUT REQUEST THROUGH DSKY TO TERMINATE PROGRAM V34E
#
# ALARM OR ABORT EXIT MODES --
#   NONE
#
# OUTPUT --
#   OCTAL DISPLAY OF OPTION CODE AND VEHICLE WHOSE GROUND TRACK IS TO BE
#   COMPUTED
#       OPTION CODE      00002
#       THIS              00001
#       OTHER             00002
#   DECIMAL DISPLAY OF TIME TO BE INTEGRATED TO HOURS , MINUTES , SECONDS
#   DECIMAL DISPLAY OF LAT, LONG, ALT
#
# ERASABLE INITIALIZATION REQUIRED
#   AX0      2DEC    4.652459653 E-5   RADIANS      "68-69 CONSTANTS"
#   -AY0     2DEC    2.147535898 E-5   RADIANS
#   AZ0      2DEC    .7753206164      REVOLUTIONS
#   FOR LUNAR ORBITS 504LM VECTOR IS NEEDED
#   504LM    2DEC    -2.700340600 E-5   RADIANS
#   504LM _2 2DEC    -7.514128400 E-4   RADIANS
#   504LM _4 2DEC    _2.553198641 E-4   RADIANS
#
#   NONE
#
# DEBRIS

# Page 457
#   CENTRALS -- A,Q,L
#   OTHER -- THOSE USED BY THE ABOVE LISTED SUBROUTINES
#   SEE LEMPREC, LAT-LONG

```

SBANK= LOWSUPER           # FOR LOW 2CADR'S.

BANK     33

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```

SETLOC P20S
BANK

EBANK= P21TIME
COUNT 24/P21

PROG21 CAF ONE
TS OPTION2 # ASSUMED VEHICLE IS LM, R2 = 00001
CAF BIT2 # OPTION 2
TC BANKCALL
CADR GOPERF4
TC GOTOP00H # TERMINATE
TC +2 # PROCEED VALUE OF ASSUMED VEHICLE OK
TC -5 # R2 LOADED THROUGH DSKY
P21PROG1 CAF V6N34 # LOAD DESIRED TIME OF LAT-LONG.
TC BANKCALL
CADR GOFLASH
TC GOTOP00H # TERM
TC +2 # PROCEED VALUES OK
TC -5 # TIME LOADED THROUGH DSKY
TC INTERPRET
DLOAD
DSPTM1
STCALL TDEC1 # INTEG TO TIME SPECIFIED IN TDEC
INTSTALL
BON SET
P21FLAG
P21CONT # ON...RECYCLE USING BASE VECTOR
VINTFLAG # OFF...1ST PASS CALC BASE VECTOR
SLOAD SR1
OPTION2
BHIZ CLEAR
+2 # ZERO...THIS VEHICLE (CM)
VINTFLAG # ONE...OTHER VEHICLE(LM)
CLEAR CLEAR
DIMOFLAG
INTYPFLG # PRECISION
CALL
INTEGRV # CALCULATE
GOTO # .AND
P21VSAVE # ..SAVE BASE VECTOR
P21CONT VLOAD # RECYCLE...INTEG FROM BASE VECTOR
P21BASER

# Page 458
STOVL RCV # ..POS
P21BASEV
```

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	STODL	VCV	# ..VEL
		P21TIME	
	STORE	TET	# ..TIME
	CLEAR	CLEAR	
		DIMOFBAG	
		MOONFLAG	
	SLOAD	BZE	
		P21ORIG	
		+3	# ZERO = EARTH
	SET		# ...2 = MOON
		MOONFLAG	
	CALL		
		INTEGRVS	
P21VSAVE	DLOAD		# SAVE CURRENT BASE VECTOR
		TAT	
	STOVL	P21TIME	# ..TIME
		RATT1	
	STOVL	P21BASER	# ..POS B-29 OR B-27
		VATT1	
	STORE	P21BASEV	# ..VEL B-7 OR B-5
	ABVAL	SL*	
		0,2	
	STOVL	P21VEL	# /VEL/ FOR N73 DSP
		RATT	
	UNIT	DOT	
		VATT	# U(R).(V)
	DDV	ASIN	# U(R).U(V)
		P21VEL	
	STORE	P21GAM	# SIN-1 U(R).U(V), -90 TO +90
	SXA,2	SET	
		P21ORIG	# 0 = EARTH 2 = MOON
		P21FLAG	
P21DSP	CLEAR	SLOAD	# GENERATE DISPLAY DATA
		LUNAFLAG	
		X2	
	BZE	SET	
		+2	# 0 = EARTH
		LUNAFLAG	
	VLOAD		
		RATT	
	STODL	ALPHAV	
		TAT	
	CLEAR	CALL	
		ERADFLAG	
		LAT-LONG	
	DMP		# MPAC = ALT, METERS B-29



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```
# Page 459
STORE K.01
P21ALT # ALT/100 FOR N73 DSP

EXIT
CAF V06N43 # DISPLAY LAT, LONG, ALT
TC BANKCALL # LAT, LONG = REVS B0 BOTH EARTH/MOON
CADR GOFLASH # ALT = METERS B-29 BOTH EARTH/MOON
TC GOTOP00H # TERM
TC GOTOP00H
TC INTPRET # V32E RECYCLE
DLOAD DAD
P21TIME
600SEC # 600 SECONDS OR 10 MIN
STORE DSPTM1
RTB
P21PROG1

600SEC 2DEC 60000 # 10 MIN

P21ONENN OCT 00001 # NEEDED TO DETERMINE VEHICLE
OCT 00000 # TO BE INTEGRATED
V06N43 VN 00643
V6N34 VN 00634
K.01 2DEC .01
```

This code is written to file src/GROUND-TRACKING-DETERMINATION-PROGRAM.s.

## A.35 HeaderTemplate

```

602  <src/HeaderTemplate.s 602>≡
      # Copyright:   Public domain.
      # Filename:    XXXXXXXX.agc
      # Purpose:     Part of the source code for Luminary 1A build 099.
      #              It is part of the source code for the Lunar Module's (LM)
      #              Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:   yaYUL
      # Contact:      Ron Burkey <info@sandroid.org>.
      # Website:      www.ibiblio.org/apollo.
      # Pages:        XXXX-XXXX
      # Mod history:  2009-05-XX XXX  Adapted from the corresponding
      #              Luminary131 file, using page
      #              images from Luminary 1A.
      #
      # This source code has been transcribed or otherwise adapted from
      # digitized images of a hardcopy from the MIT Museum. The digitization
      # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
      # the Museum. Many thanks to both. The images (with suitable reduction
      # in storage size and consequent reduction in image quality as well) are
      # available online at www.ibiblio.org/apollo. If for some reason you
      # find that the images are illegible, contact me at info@sandroid.org
      # about getting access to the (much) higher-quality images which Paul
      # actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #      Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
      #      16:27 JULY 14, 1969

```

This code is written to file `src/HeaderTemplate.s`.

## A.36 IMU CALIBRATION AND ALIGNMENT

```

603 <src/IMU-CALIBRATION-AND-ALIGNMENT.s 603>≡
# Copyright:      Public domain.
# Filename:       IMU_CALIBRATION_AND_ALIGNMENT.agc
# Purpose:       Part of the source code for Comanche, build 055. It
#               is part of the source code for the Command Module's
#               (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:    yaYUL
# Reference:     pp. 423-455
# Contact:       Onno Hommes <ohommes@cmu.edu>
# Website:      http://www.ibiblio.org/apollo.
# Mod history:   2009-05-10 OH   Batch 1 Assignment Comanche Transcription
#               2009-05-20 RSB   Corrections: P00D00H -> P00D00H, definition
#                               of 25DECML fixed.
#               2009-05-23 RSB   At SPECSTS, corrected to PRI022.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#               Massachussets Institute of Technology
#               75 Cambridge Parkway
#               Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.
#
# Page 423
# NAME --       IMU PERFORMANCE TESTS 2
#
# DATE --       MARCH 20, 1967
#
# BY --         SYSTEM TEST GROUP 864-6900 EXT. 1274
#
# MODNO. --     ZERO
#
# FUNCTIONAL DESCRIPTION
#

```

# POSITIONING ROUTINES FOR THE IMU PERFORMANCE TESTS AS WELL AS SOME OF  
 # THE TESTS THEMSELVES. FOR A DESCRIPTION OF THESE SUBROUTINES AND THE  
 # OPERATING PROCEDURES (TYPICALLY) SEE STG MEMO 685. THEORETICAL REF. E-1973

	BANK	33	
	SETLOC	IMUCAL	
	BANK		
	EBANK=	POSITON	
IMUTEST	CA	ZERO	
	TS	DRIFTT	
	TS	GEOCOMP1	
	CAF	TESTTIME	
	TS	LENGTHOT	
	TC	COAALIGN	# TAKE CARE OF DRIFT FLAG
	CAF	1SECX	
	TS	1SECXT1	
	CA	OC14400	
	TS	1/PIPADT	
GUESS	TC	INTPRET	# CALCULATE -COS LATITUDE AND SIN LATITUDE
	CALL		
		LATAZCHK	
	COS	DCOMP	
	SL1		
	STODL	WANGI	
		LATITUDE	
	SIN	SL1	
	STORE	WANGO	
	EXIT		
GEOIMUTT	TC	BANKCALL	# GYROCOMPASS COMES IN HERE
	CADR	IMUZERO	
	TC	IMUSTLLG	
IMUBACK	CA	ZERO	
	TS	NDXCTR	
	TS	TORQNDX	
	TS	TORQNDX +1	
NBPOSPL	CA	DEC17	
	TS	ZERONDX1	
	CA	XNBADR	
# Page 424			
	TC	ZEROING	
	CA	HALF	
	TS	XNB	
	TC	INTPRET	
	DLOAD	SIN	

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		AZIMUTH	
	STORE	YNB	+2
	STODL	ZNB	+4
		AZIMUTH	
	COS		
	STORE	YNB	+4
	DCOMP		
	STORE	ZNB	+2
	EXIT		
	TC	CHECKMM	
	MM	03	# SEE IF IN OPTICAL VERIFICATION
	TCF	+2	# NO
	TCF	SETNBPOS	+1 # YES
	TC	INTPRET	
	CALL		
		CALCGA	
	EXIT		
	TC	BANKCALL	
	CADR	IMUCOARS	
	CAF	GLOKFBIT	# IF GLOKFAIL SET, GIMBAL LOCK
	MASK	FLAGWRD3	
	EXTEND		
	BZF	+2	
	INCR	NDXCTR	# +1 IF IN GIMBAL LOCK, OTHERWISE 0
	TC	DOWNFLAG	# RESET GIMBAL LOCK FLAG
	ADRES	GLOKFAIL	# BIT 14 FLAG 3
	TC	IMUSTLLG	
	CCS	NDXCTR	# IF ONE GO AND DO A PIPA TEST ONLY
	TC	PIPACHK	# ALIGN AND MEARSUE VERTICAL PIPA RATE
	TC	BANKCALL	
	CADR	IMUFINE	
	TC	IMUSTLLG	
	EXTEND		
	DCA	PERFDLAY	
	TC	LONGCALL	
	SBANK=	LOWSUPER	# RSB 2004, OH 2009: Ask Ron
	EBANK=	POSITON	
	2CADR	GOESTIMS	
	CA	ESTICADR	
	TC	JOBSLEEP	
GOESTIMS	CA	ESTICADR	
	TC	JOBWAKE	
	TC	TASKOVER	
ESTICADR	CADR	ESTIMS	

TORQUE	CA	ZERO	
	TS	DSPTM2	
	CA	DRIFTI	
	TS	DSPTM2 +1	
	INDEX	POSITON	
	TS	SOUTHDR -1	
	TC	SHOW	
PIPACHK	INDEX	NDXCTR	# PIPA TEST
	TC	+1	
	TC	EARTH*	
	CA	DEC57	
	TS	LENGTHOT	
	CA	ONE	
	TS	RESULTCT	
	CA	ZERO	
	INDEX	PIPINDEX	
	TS	PIPAX	
	TS	DATAPL	
	TS	DATAPL +4	
	TC	CHECKG	# PIP PULSE CATCHING ROUTINE
	INHINT		
	CAF	TWO	
	TC	TWIDDLE	
	EBANK=	XSM	
	ADRES	PIPATASK	
	TC	ENDOFJOB	
PIPATASK	EXTEND		
	DIM	LENGTHOT	
	CA	LENGTHOT	
	EXTEND		
	BZMF	STARTPIP	
	CAF	BIT10	
	TC	TWIDDLE	
	EBANK=	XSM	
	ADRES	PIPATASK	
STARTPIP	CAF	PRI020	
	TC	FINDVAC	
	EBANK=	XSM	
	2CADR	PIPJOB	
	TC	TASKOVER	
PIPJOB	INDEX	NDXCTR	
	TC	+1	
	TC	EARTH*	

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AINGOTN

VERTDRFT

PON4

PON2

CA LENGTHOT  
EXTEND  
BZMF +2  
TC ENDOFJOB  
CA FIVE

TS RESULTCT  
TC CHECKG  
EXTEND  
DCS DATAPL  
DAS DATAPL +4

TC INTPRET  
DLOAD DSU  
DATAPL +6  
DATAPL +2  
BPL CALL  
AINGOTN  
OVERFFIX

PDDL DDV  
DATAPL +4  
SL4 DMPR  
DEC585

RTB  
SGNAGREE  
STORE DSPTEM2  
EXIT

CCS NDXCTR  
TC COAALIGN  
TC SHOW

CA 3990DEC  
TS LENGTHOT  
INDEX POSITON  
CS SOUTHDR -2  
TS DRIFTT  
CA XSM +4

EXTEND

BZF PON2  
CS BIT5  
ADS ERCOMP1 +2  
CA BIT5  
ADS ERCOMP1

TCF PONG  
CS BIT5  
ADS ERCOMP1 +2  
CA BIT5

# DEC585 HAS BEEN REDEVINED FOR LEM

# TAKE PLATFORM OUT OF GIMBAL LOCK

# ABOUT 1 HOUR VERTICAL DRIFT TEST

# 0 IF POSN 4

# OFFSET PLATFORM

	ADS	ERCOMP1 +4	
PONG	TC	EARTH* EARTH*	
	CA	ZERO	# ALLOW ONLY SOUTH GYRO EARTH RATE COMPENS
	TS	ERVECTOR	
	TS	ERVECTOR +1	
GUESS1	CAF	POSMAX	
	TS	TORQNDX	
	TS	TORQNDX +1	
	CA	CDUX	
	TS	LOSVEC	
# Page 427			
	TC	ESTIMS	
VALMIS	CA	DRIFT0	
	TS	DSPTM2 +1	
	CA	ZERO	
	TS	DSPTM2	
	TC	SHOW	
ENDTEST1	TC	DOWNFLAG	# IMU NOT IN USE
	ADRES	IMUSE	# BIT 8 FLAG 0
	CS	ZERO	
	TC	NEWMODEX +3	
	TC	BANKCALL	
	CADR	MKRELEAS	
	TC	ENDEXT	
# Page 428			
OVERFFIX	DAD	DAD	
		DPOSMAX	
		ONEDPP	
	RVQ		
COALIGN	EXTEND		# COARSE ALIGN SUBROUTINE
	QXCH	QPLACE	
	CA	ZERO	
	TS	THETAD	
	TS	THETAD +1	
	TS	THETAD +2	
	TC	BANKCALL	
	CADR	IMUCOARS	
	TC	BANKCALL	
	CADR	IMUSTALL	
	TC	SOMERR2	
	TC	QPLACE	
IMUSTLLG	EXTEND		



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```

      QXCH  QPLACE
      TC    COALIGN +10

CHECKG      EXTEND
      QXCH  QPLACE
      TC    +6
CHECKG1     RELINT
      CA    NEWJOB
      EXTEND
      BZMF  +6
      TC    CHANG1
      INHINT
      INDEX PIPINDEX
      CS    PIPAX
      TS    ZERONDX
      INHINT
      INDEX PIPINDEX
      CA    PIPAX
      AD    ZERONDX
      EXTEND
      BZF   CHECKG1
      INDEX PIPINDEX
      CA    PIPAX
      INDEX RESULTCT
      TS    DATAPL
      TC    FINETIME
      INDEX RESULTCT
      TS    DATAPL +1

# Page 429
      INDEX RESULTCT
      LXCH  DATAPL +2
      RELINT
ENDCHKG     TC    QPLACE

ZEROING     TS    L
      TCF   +2
ZEROING1    TS    ZERONDX1
      CAF   ZERO
      INDEX L
      TS    0
      INCR  L
      CCS   ZERONDX1
      TCF   ZEROING1
      TC    Q
```

# Page 430

```

      SETLOC  IMUCAL3
      BANK
ERTHRVSE  DLOAD  PDDL          # PD24 = (SIN (missing) -COS (missing) 0)(
          SCHZEROS
          LATITUDE
      COS    DCOMP
      PDDL   SIN
          LATITUDE
      VDEF   VXSC
          OMEG/MS
      STORE  ERVECTOR
      RTB
          LOADTIME
      STOVL  TMARK
          SCHZEROS
      STORE  ERCOMP1
      RVQ
      SETLOC IMUCAL
      BANK
ERTHR      ITA      RTB          # CALCULATES AND COMPENSATES EARTH RATE
          S2
          LOADTIME
      STORE  TEMPTIME
      DSU    BPL
          TMARK
          ERTHR
      CALL
          OVERFFIX
ERTHR      SL      VXSC
          9D
          ERVECTOR
      MXV    VAD
          XSM
          ERCOMP1
      STODL  ERCOMP1
          TEMPTIME
      STORE  TMARK
      AXT,1  RTB
      ECADR  ERCOMP1
          PULSEIMU
      GOTO
          S2

ERTHR*     EXTEND
      QXCH   QPLACES
      TC     INTPRET

```

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```

CALL
EARTH
PRUIT EXIT
TC IMUSTLLG
TC QPLACES
# Page 431
SHOW EXTEND
QXCH QPLACE
SHOW1 CA POSITON
TS DSPTM2 +2
CA VB06N98
TC BANKCALL
CADR GOFLASH
TC ENDTEST1 # V34
TC QPLACE # V33
TCF SHOW1
OC14400 OCT 14400
3990DEC = OMEG/MS
VB06N98 VN 0698
TESTTIME OCT 01602
DEC17 = ND1
OGCPL ECADR OGC
1SECX = 1SEC
DEC57 = VD1
XNBADR GENADR XNB
XSMADR GENADR XSM
OMEG/MS 2DEC .24339048
P11OUT TC BANKCALL
CADR MATRXJOB # RETURN TO P11
COUNT 02/COMST
BLOCK 2
FINETIME INHINT # RETURNS WITH INTERRUPT INHIBITED
EXTEND
READ LOSCALAR
TS L
EXTEND
RXOR LOSCALAR
EXTEND
BZF +4
EXTEND
READ LOSCALAR
```

```

          TS      L
+4        CS      POSMAX
          AD      L
          EXTEND
          BZF      FINETIME +1
          EXTEND
          READ     HISCALAR
          TC Q

```

# Page 432

# PROGRAM NAME: OPTIMUM PRELAUNCH ALIGNMENT CALIBRATION

# DATE: NOVEMBER 2 1966

# BY: GEORGE SCHMIDT IL 7-146 EXT. 126

# MOD NO 3

#

# FUNCTIONAL DESCRIPTION

#

# THIS SECTION CONSISTS OF PRELAUNCH ALIGNMENT AND GYRO DRIFT TESTS  
 # INTEGRATED TOGETHER TO SAVE WORDS. COMPASS IS COMPLETELY RESTART  
 # PROOFED EXCEPT FOR THE FIRST 30 SECONDS OR SO. PERFORMANCE TESTS OF  
 # THE IRIGS IS RESTART PROOFED ENOUGH TO GIVE 75 PERCENT CONFIDENCE THAT  
 # IF A RESTART OCCURS THE DATA WILL STILL BE GOOD. GOOD PRACTICE TO RECYCL  
 # WHEN A RESTART OCCURS UNLESS IT HAPPENS NEAR THE END OF A TEST -- THEN WAIT  
 # FOR THE DATA TO FLASH.

#

# A RESTART IN GYROCOMPASS DURING GYRO TORQUING CAUSES PULSES TO BE LOST.  
 # THE PRELAUNCH ALIGNMENT TECHNIQUE IS BASICALLY THE SAME AS IN BLOCK 1  
 # EXCEPT THAT IT HAS BEEN SIMPLIFIED IN THE SENSE THAT SMALL ANGLE APPROX.  
 # HAVE BEEN USED. THE DRIFT TESTS USE A UNIQUE IMPLEMENTATION OF THE  
 # OPTIMUM STATISTICAL FILTER. FOR A DESCRIPTION SEE E-1973. BOTH OF THESE  
 # ROUTINES USE STANDARD SYSTEM TEST LEADIN PROCEDURES. THE INITIALIZATION  
 # PROCEDURE THE DRIFT TESTS IS IN THE JDC'S. THE INITIALIZATION METHOD  
 # FOR GYROCOMPASS IS AN ERAS LOAD THEN A MISSION PHASE CALL.  
 # THE COMPASS ALIGNS TO Z DOWN, X DOWNRANGE, HAS THE CAPABILITY  
 # CHANGE AZIMUTH WHILE RUNNING, IS COMPENSATED FOR  
 # COMPONENT ERRORS, IS CAPABLE OF OPTICAL VERIFICATION (CSM ONLY).

#

# COMPASS ERASABLE LOAD REQUIRED

#

- # 1. LAUNCHAZ-DP AZIMUTH IN REV FROM NORTH OF XSM DESIRED (NOM=.2)
- # 2. LATITUDE-DP-OF LAUNCH PAD
- # 3. AZIMUTH-DP-OF ZNB OF VEHICLE
- # 4. IMU COMPENSATION PARAMETERS
- # 5. AZ AND ELEVATION OF TARGETS 1,2 \*\*\*\*\*OPTIONAL\*\*\*\*\*

#

# TO PERFORM AS PART OF COMPASS

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```
#
#      1.      OPTICAL VERIFICATION: V 65 E
#      2.      AXIMUTH CHANGE: V 78 E
#
# SUBROUTINES CALLED
#
# DURING OPTICAL VERIFICATION (CSM ONLY) ESSENTIALLY ALL OF INFLIGHT ALIGN
# IS CALLED IN ONE WAY OR ANOTHER.  SEE THE LISTING.
#
# NORMAL EXIT
#
# DRIFT TESTS.  LENGTHOT GOES TO ZERO-RETURN TO IMU PERF TEST2 CONTROL
# GYROCOMPASS-MANY, SEE THE LISTING.
#
# ALARMS
#
# 1600  OVERFLOW IN DRIFT TEST
# Page 433
# 1601  BAD IMU TORQUE ABORT
# 1602  BAD OPTICS DURING VERIFICATION-RETURN TO COMPASS          CSM ONLY
#
# OUTPUT
#
# DRIFT TESTS:  FLASHING DISPLAYS OF RESULTS-CONTROLLED IN IMU PERF TESTS 2
# COMPASS-PROGRAM MODE LIGHTS TELL YOU WHAT PHAS OF PROGRAM YOU ARE IN
#      01      INITIALIZING THE PLATFORM POSITION AND ERASABLE
#      02      GYROCOMPASSING
#      03      DOING OPTICAL VERIFICATION (CSM)
#
# DEBRIS
#
# ALL CENTRALS, ALL OF EBANK XSM

# Page 434
# MOST OF THE ROUTINES COMMON TO ALIGNMENT AND CALIBRATION APPEAR
# ON THE NEXT FEW PAGES.

COUNT  33/P02

EBANK=   XSM
BANK     33
SETLOC   IMUCAL
BANK

ESTIMS    TC      2PHSCHNG      # COMES HERE FROM IMU2
          OCT     00075
```

```

RSTGTS1      OCT      00004      # TURN OFF GROUP 4 IF ON
              INHINT      # COMES HERE PHASE1 RESTART
              CA          TIME1
              TS          GTSWTLT1
              CAF         ZERO      # ZERO THE PIPAS
              TS          PIPAX
              TS          PIPAY
              TS          PIPAZ
              RELINT
              CA          77DECML    # ZERO ALL NECESSARY LOCATIONS
              TS          ZERONDX1
              CA          ALXXXZ
              TC          ZEROING
              TC          INTPRET
              SLOAD
              SCHZEROS
              STOVL      GCOMPSW -1
              INTVAL +2      # LOAD SOME INITIAL DRIFT GAINS
              STOVL      ALX1S
              SCHZEROS
              STORE      GCOMP
              STORE      DELVX      # GCOMPZER SUBROUTINE NO LONGER NEEDED
              EXIT

              CCS          GEOCOMP1  # NON ZERO IF COMPASS.
              TC          +2
              TC          SLEEPIE +1
              TC          INTPRET
              CALL
              ERTHRVSSE
              EXIT
              CA          LENGTHOT    # TIMES FIVE IS THE NUM OF SEC ERECTING
              TS          ERECTIME

              TC          NEWMODEX
              MM          02
              TC          BANKCALL    # SET UP PIPA FAIL TO CAUSE ISS ALARM

# Page 435
              CADR      PIPUSE      # COMPASS NEVER TURNS THIS OFF
              TC          ANNNNNN    # END OF FIRST TIME THROUGH

# Page 436
# COMES HERE AT THE END OF EVERY ITERATION THROUGH DRIFT TEST OR COMPASS

# SET UP WAITLIST SECTION
SLEEPIE      TS          LENGTHOT    # TEST NOT OVER-DECREMENT LENGHOT

```

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```

TC      PHASCHNG      # CHANGE PHASE
OCT     00135
CCS     TORQNDX       # ARE WE DOING VERTDRIFT
TC      EARTH*        # TRUE TORQUE SOUTH GYRO
WTLISTNT TC      CHKCOMED # SEE IF COMPASS OVER
TC      SETGWLST
TC      ENDOFJOB

SETGWLST EXTEND
QXCH    MPAC          # CALLED EVERY WAITLIST OR AZIMUTH CHANGE
INHINT
CS      TIME1
AD      GTSWTLT1
EXTEND
BZMF    +2
AD      NEGMX         # 10 MS ERROR OK
AD      1SECXT1       # 1 SEC FOR CALIBRATION, .5 SEC IN COMPASS
EXTEND
BZMF    RIGHTGTS
WTGTSMPL TC      TWIDDLE
EBANK=  ALTIM
ADRES   ALLOOP
TC      MPAC
RIGHTGTS CAF      FOUR      # SET UP NEXT WAITLIST-ALLOW SOME TIME
TC      WTGTSMPL      # END OF WAITLIST SECTION
```

# STORE AND LOAD DATA SECTIONS FOR RESTART PROOFING

```

25DECML EQUALS OCT31
STOREDTA CAF      25DECML
TS        MPAC
INDEX     MPAC
CAE       THETAX1
INDEX     MPAC
TS        RESTARPT
CCS       MPAC
TCF       STOREDTA +1
TC        Q

LOADSTD   CAF      25DECML
TS        MPAC
INDEX     MPAC
CA        RESTARPT
INDEX     MPAC
```

# Page 437

```

        TS      THETAX1
        CCS      MPAC
        TCF      LOADSTD +1
        TC      Q

# COMES HERE EVERY ITERATION BY A WAITLIST CALL SET IN SLEEPIE

ALLOOP      CA      TIME1
            TS      GTSWTLT1      # STORE TIME TO SET UP NEXT WAITLIST.
ALLOOP3     CA      ALTIM
            TS      GEOSAVE1
            TC      PHASCHNG
            OCT     00115
ALLOOP1     CAE     GEOSAVE1
            TS      ALTIM
            CCS     A
            CA      A      # SHOULD NEVER HIT THIS LOCATION
            TS      ALTIMS
            CS      A
            TS      ALTIM
            CAF     ZERO
            XCH     PIPAX
            TS      DELVX
            CAF     ZERO
            XCH     PIPAY
            TS      DELVY
            CAF     ZERO
            XCH     PIPAZ
            TS      DELVZ
            CAF     19DECML      # 23 OCT
            TC      NEWPHASE
            OCT     00005
SPECSTS     CAF     PRI022
            TC      FINDVAC
            EBANK=  GEOSAVE1
            2CADR   ALFLT      # START THE JOB

            TC      TASKOVER

# Page 438
# THIS IS PART OF THE JOB DONE EVERY ITERATION

ALFLT      TC      STOREDTA      # STORE DATA IN CASE OF RESTART IN JOB
            TC      PHASCHNG      # THIS IS THE JOB DONE EVERY ITERATION
            OCT     00215
            TCF     +2

```



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```
ALFLT1      TC      LOADSTD      # COMES HERE ON RESTART

            CCS      GEOCOMP1
            TC        +2
            TC        NORMLOP
            TC        CHKCOMED      # SEE IF PRELAUNCH OVER
            TC        BANKCALL      # COMPENSATION IF IN COMPASS
            CADR      1/PIPA
NORMLOP      TC        INTPRET
            DLOAD
            INTVAL
            STOVL      S1
            DELVX
            VXM        VSL1
            XSM
            DLOAD      DCOMP
            MPAC +3
            STODL      DPIPAY
            MPAC +5
            STORE      DPIPZ

            SETPD      AXT,1
            0
            8D
            SLOAD      DCOMP
            GEOCOMP1
            BMN
            ALWAYSG      # DO A QUICK COMPASS

# Page 439
# NOW WE HAVE JUST THE CALIBRATION PARTS OF THE PROGRAM-NEXT PAGES

            COUNT      33/COMST

ALCGKK      SLOAD      BMN
            ALTIMS
            ALFLT3      # NO NEW GAINS NEEDED
ALKCG      AXT,2      LXA,1      # LOADS SLOPES AND TIME CONSTANTS AT RQST
            12D
            ALX1S
ALKCG2      DLOAD*      INCR,1
            ALFDK +144D,1
            DEC        -2
            STORE      ALDK +10D,2
            TIX,2      SXA,1
            ALKCG2
```

```

                                ALX1S

ALFLT3      AXT,1              # MEASUREMENT INCORPORATION ROUTINES
                                8D      # AND GAIN UPDATES
DELMLP      DLOAD* DMP
                                DPIPAY +8D,1
                                PIPASC
                                SLR      BDSU*
                                9D
                                INTY +8D,1
                                STORE    INTY +8D,1
                                PDDL     DMP*
                                VELSC
                                VLAUN +8D,1
                                SL2R
                                DSU      STADR
                                STORE    DELM +8D,1
                                STORE    DELM +10D,1
                                TIX,1    AXT,2
                                DELMLP
                                4
ALILP      DLOAD* DMPR*
                                ALK +4,2
                                ALDK +4,2
                                STORE    ALK +4,2
                                TIX,2    AXT,2
                                ALILP
                                8D
ALKLP      LXC,1    SXA,1
                                CMPX1
                                CMPX1
                                DLOAD* DMPR*
                                ALK +1,1
                                DELM +8D,2

# Page 440
                                DAD*
                                INTY +8D,2
                                STORE    INTY +8D,2
                                DLOAD* DAD*
                                ALK +12D,2
                                ALDK +12D,2
                                STORE    ALK +12D,2
                                DMPR* DAD*
                                DELM +8D,2
                                INTY +16D,2
                                STORE    INTY +16D,2

```

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```

DLOAD* DMP*
      ALSK +1,1
      DELM +8D,2
SL1R   DAD*
      VLAUN +8D,2
STORE  VLAUN +8D,2
TIX,2  AXT,1
      ALKLP
      8D

LOOSE  DLOAD* PDDL*          # EXTRAPOLATE SWAY VARIABLES
      ACCWD +8D,1
      VLAUN +8D,1
PDDL*  VDEF
      POSNV +8D,1
MXV    VSL1
      TRANSM1
DLOAD
      MPAC
STORE  POSNV +8D,1
DLOAD
      MPAC +3
STORE  VLAUN +8D,1
DLOAD
      MPAC +5
STORE  ACCWD +8D,1
TIX,1  LOOSE

      AXT,2  AXT,1          # EVALUATE SINES AND COSINES
      6
      2
BOOP   DLOAD* DMPR
      ANGX +2,1
      GEORGEJ
SR2R
PUSH   SIN

# Page 441
SL3R   XAD,1
      X1
STORE  16D,2
DLOAD
COS
STORE  22D,2          # COSINES
TIX,2  BOOP
```

```

PERFERAS      EXIT
               CA      EBANK7
               EBANK=   LAT(SPL)
               TS      EBANK
               TC      LAT(SPL)      # GOTO ERASABLE ONLY TO RETURN

# CAUTION
#
# THE ERASABLE PROGRAM THAT DOES THE CALCULATIONS MUST BE LOADED
# BEFORE ANY ATTEMPT IS MAKE TO RUN THE IMU PERFORMANCE TEST

ONCEMORE      EBANK=   LENGTHOT
               CCS     LENGTHOT
               TC      SLEEPIE      # TEST NOT OVER SET UP NEXT WAITLIST
               CCS     TORQNDX
               TCF     +2
               TC      SETUPER1
               CA      CDUX
               TS      LOSVEC +1     # FOR TROUBLESHOOTING POSNS 2$4 VD
SETUPER1      TC      INTPRET      # DRIFT TEST OVER
               DLOAD   PDDL          # ANGLES FROM DRIFT TEST ONLY
               ANGZ
               ANGY
               PDDL    VDEF
               ANGX
               VCOMP   VXSC
               GEORGEJ
               MXV     VSR1
               XSM
               STORE   OGC
               EXIT

TORQINCH      TC      PHASCHNG
               OCT     00005
               CA      OGCPL
               TC      BANKCALL
               CADR     IMUPULSE
               TC      IMUSTLLG
               CCS     TORQNDX      # + IF IN VERTICAL DRIFT TEST
               TC      VALMIS      # VERT DRIFT TEST OVER
               TC      INTPRET

# Page 442
               CALL
               ERTHRVS
               EXIT

```

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	TC	TORQUE	# GO TO IMU2 FOR A PIPA TEST AND DISPLAY
SOMEERRR	TC	ALARM	
	OCT	1600	
	TC	+3	
SOMERR2	TC	ALARM	
	OCT	1601	
	TC	PHASCHNG	
	OCT	00005	
	TC	ENDTEST1	

# THE FAMOUS MAGIC NUMBERS OF SCHMIDT ARE NOW PART OF AN ERASABLE LOAD

DEC585	OCT	02222	# 1170 B+14 ORDER IS NOW IMPORTANT
SCHZEROS	2DEC	.00000000	
	2DEC	.00000000	
	OCT	00000	
ONEDPP	OCT	00000	
	OCT	00001	# ABOVE ORDER IS IMPORTANT
INTVAL	OCT	4	
	OCT	2	
	DEC	144	
	DEC	-1	
SOUPLY	2DEC	.93505870	# INITIAL GAINS FOR PIP OUTPUTS
	2DEC	.26266423	# INITIAL GAINS/4 FOR ERECTION ANGLES
77DECML	DEC	77	
ALXXXZ	GENADR	ALX1S -1	

# GYROCOMPASS PORTIONS FINISH THIS LOG SECTION

COUNT 33/P01

# INITIALIZATION SECTION

GTSCPSS	CA	FLAGWRD1	# CALLED BY V37
	MASK	NOP01BIT	
# Page 443	EXTEND		
	BZF	GTSCPSSA	
	TC	P00D00	
	OCT	1521	# NODO ALARM FOR P01 - P11 ALREADY DONE
GTSCPSSA	CAF	ONE	
	TS	GEOCOMP1	# THIS IS THE LEAD IN FOR COMPASS

```

                                CA      1/PIPGT
                                TS      1/PIPADT
NXXTENN                        CA      BIT8
                                TS      LENGTHOT
                                CAF     1/2SECX      # COMPASS IS A .5 SEC LOOP
                                TS      1SECXT1
                                CAF     ONE
                                TS      PREMTRX1
                                TS      PERFDLAY +1
                                CAF     ZERO
                                TS      PERFDLAY
                                EXTEND
                                DCA     LUNHAZ1
                                DXCH    NEWAZ1
                                EXTEND
                                DCA     LUNHAZ1
                                DXCH    OLDAZMTH
SETUPGC                        CA      DEC17
                                TS      ZERONDX1
                                CA      XSMADR
                                TC      ZEROING
                                TC      POSN17C
                                TC      GEOIMUTT      # GO TO IMU2 FOR FURTHER INITIALIZATION

POSN17C                        EXTEND      # COMPASS POSITION Z DOWN, X DOWNRANGE
                                QXCH     QPLACE      # FROM NORTH IN REVOLUTIONS + CLOCKWISE
                                CS      HALF      # ALL THIS TO INITIALIZE MATRIX
                                TS      ZSM
                                TC      INTPRET
                                DLOAD    PUSH
                                NEWAZ1
                                SIN
                                STORE   XSM      +4
                                STODL    YSM      +2
                                COS
                                STORE   YSM      +4
                                DCOMP
                                STORE   XSM      +2
                                EXIT
                                TC      QPLACE

```

# Page 444

# JOB DONE EVERY ITERATION THROUGH COMPASS PROGRAM. SET BY TASK ALLOOP

COUNT 33/P02

ALWAYSG	DLOAD*	DSU*	# COMPASS AND ERECT
		DPIPAY +8D,1	
		FILDELV1 +8D,1	
	DMPR	DAD*	
		GEOCONS1	
		FILDELV1 +8D,1	
	STORE	FILDELV1 +8D,1	
	DAD*		
		INTVEC1 +8D,1	
	STORE	INTVEC1 +8D,1	
	DMPR	DAD*	
		GEOCONS2	
		FILDELV1 +8D,1	
	DMPR	PUSH	
		GEOCONS5	
	TIX,1	SLOAD	
		ALWAYSG	
		ERECTIM1	
	BZE	DLOAD	
		COMPGS	
		THETAN1 +2	
	DSU	STADR	
	STODL	THETAN1 +2	# ERECTION ONLY.
	BDSU		
		THETAN1 +4	
	STORE	THETAN1 +4	
	GOTO		
		ADDINDRF	
COMPGS	DLOAD	DAD	# COMPASS
		THETAN1	
		FILDELV1	
	STODL	THETAN1	
		FILDELV1	
	DMPR	BDSU	
		GEOCONS3	
		THETAN1 +4	
	STODL	THETAN1 +4	
		FILDELV1 +4	
	DMPR	BDSU	
		GEOCONS3	
		THETAN1 +2	
	PDDL	DMPR	
		INTVEC1 +4	
		GEOCONS4	
	BDSU	STADR	

```

# Page 445
ADDINDRF      STORE  THETAN1 +2
               EXIT

ENDGTSAL      CCS    LENGTHOT      # IS 5 SEC OVER-THE TIME TO TORQ PLATFORM
               TC     SLEEP1E      # NO-SET UP NEXT WAITLIST CALL FOR .5 SEC
               TC     CHKCOMED
               CCS    LGYRO        # YES BUT ARE GYROS BUSY
               TCF    SLEEP1E +1   # BUSY-GET THEM .5 SECONDS FROM NOW

LASTGTS       TC     INTPRET
               VLOAD
               ERCOMP1
               STODL  THETAX1
               TMARK
               STORE  ALK
               EXIT      # PREVIOUS SECTION WAS FOR RESTARTS

RESTAIER      TC     PHASCHNG
               OCT    00275
               TC     INTPRET      # ADD COMPASS COMMANDS INTO ERATE
               VLOAD  MXV
               THETAN1
               XSM
               VSL1   VAD
               THETAX1
               STODL  ERCOMP1
               ALK
               STORE  TMARK
               EXIT
               TC     EARTH*      # TORQUE IT ALL IN
               CAE    ERECTIM1
               TS     GEOSAVE1
               TC     PHASCHNG
               OCT    00155
               TC     INTPRET
               VLOAD
               SCHZEROS
               STORE  THETAN1
               EXIT
               CCS    PREMTRXC
               TC     NOCHORLD
               TC     PHASCHNG
               OCT    00255
               TC     INTPRET
RESTEST3

```



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```
# Page 446
DLOAD      LAUNCHAZ
DSU         BZE
           OLDAZMTH
           NOAZCHGE
STORE      OD
SLOAD      DAD
           ONEDPP +1
           PREMTRXC      # DOES NOT CHANGE LAUNCHAZ
STODL      PREMTRXC
           LAUNCHAZ
STODL      NEWAZMTH
           OD
ADERCOMP   STORE      ERCOMP +4
           EXIT
           TC          POSN17C
           TC          PHASCHNG
           OCT         00335
RESCHNG    EXTEND
           DCA         NEWAZMTH
           DXCH        OLDAZMTH
           CA          BIT7      # SPEND 320 SEC ERECTING
           TS          LENGTHOT
           TC          PHASCHNG
           OCT         00075
SPITGYRO   CA          ERCOMPPL
           TC          BANKCALL
           CADR        IMUPULSE
           TC          BANKCALL
           CADR        IMUSTALL
           TC          SOMERR2
           TC          ESTIMS    # RE-INITIALIZE

NOAZCHGE   EXIT
           CA          ONE
           TS          PREMTRXC
NOCHORLD   CCS        GEOSAVE1
           TS          ERECTIM1  # COUNTS DOWN FOR ERECTION.

ANNNNNN    CAF        NINE
           TS          LENGTHOT
           TC          SLEEPIE +1
```

```

CHKCOMED      INHINT
               CS      MODREG      # CHECK FOR MM 07 FIRST
               AD      SEVEN
               EXTEND
               BZF      GOBKALB      # IF MM 07 RETURN TO PERF TEST
               CS      ZERO
               EXTEND
               RXOR     CHAN30      # READ AND INVERT BITS IN CHANNEL 30
               MASK     BIT5        # LIFTOFF BIT
               CCS      A
               TCF      PRELTERM    # LIFTOFF HAS OCCURRED

# Page 447
               CA      GRRBKBIT    # CHECK FOR BACKUP LIFTOFF
               MASK     FLAGWRD5    # BIT5 FLAGWRD5
               CCS      A
               TCF      PRELTERM    # BACKUP RECEIVED

               RELINT
GOBKALB        TC      Q

PRELTERM        CA      PRI022      # PRELAUNCH DONE -- SET UP P11
               TC      PRIOCHNG     # INCREASE PRIORITY HIGHER THAN SERVICER
               INHINT
               TC      POSTJUMP
               CADR     P11

ERCOMPPL        ECADR     ERCOMP

GEOCONS5        EQUALS    HIDPHALF
1/PIPGT         OCT      06200
17DECML         =        ND1        # OCT 21
19DECML         =        VD1        # OCT 23
1/2SECX         =        .5SEC

# Page 448
GEOSTR4         EQUALS    ENDOFJOB

# Page 449
# OPTICAL VERIFICATION ROUTINES FOR GYROCOMPASS

               COUNT     33/P03

GCOMPVER        TC      PHASCHNG    # OPTICAL VERIFICATION ROUTINE

```

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	OCT	00154	
	TC	NEWMODEX	# ENTERED BY VERB 65 ENTER
	MM	03	
SETNBPOS	TC	NBPOSPL	
	TC	BANKCALL	
	CADR	MKRELEAS	
OPTDATA	CAF	BIT1	# CALLS FOR AZIMUTH AND ELEVATION OF TARGET
	ZL		# 1, THEN TARGET 2
	LXCH	RUN	# AZIMUTH CLOCKWISE FROM NORTH TO TARGET
	TS	DSPTM1 +2	# ELEVATION MEASURED FROM HORIZONTAL
	EXTEND		
	INDEX	RUN	
	DCA	TAZEL1	
	DXCH	DSPTM1	
	CAF	V05N30E	
	TC	BANKCALL	
	CADR	GODSPRET	
	CAF	VN0641	
	TC	BANKCALL	
	CADR	GOFLASH	
	TC	GCOMP5	
	TC	+3	
	TC	-8D	
VN0641	VN	0641	
	DXCH	DSPTM1	# TAZEL1 TARGET 1 AZIMUTH
	INDEX	RUN	
	DXCH	TAZEL1	# TAZEL1 +2 TARGET 2 AZIMUTH
	CCS	RUN	
	TCF	+4	
	CAF	TWO	
	TS	L	
	TCF	OPTDATA +2	# MPAC 1ST PASS=0 2ND PASS=2
	TC	CONTIN33	
V05N30E	VN	0530	
	TC	INTPRET	# UNDYNAMIC ASSEMBLER
TAR/EREF	AXT,1	AXT,2	# TARGET VECTOR
		2	# SIN(EL) -COS(AZ)COS(EL) SIN(AZ)COS(EL)
		12D	
	SSP	SETPD	
		S2	
		6	
# Page 450		0	

TAR1	SLOAD*	SR2	# X1=2 X2=12 S2=6 X1=0 X2=6 S2=6
		TAZEL1 +3,1	
	STORE	0	# PD00 ELEVATION PD00
	SIN		
	STORE	18D,2	# PD06 *** SIN(EL) ***PD12
	DLOAD		
		0	
	COS	PUSH	# PD00 COS(EL) PD00
	SLOAD*	RTB	
		TAZEL1 +2,1	
		CDULOGIC	
	STORE	2	# PD02 AZIMUTH PD02
	SIN	DMP	
		0	
	SL1		
	STORE	22D,2	# PD10 *** SIN(AZ)COS(EL) ***PD16
	DLOAD	COS	
		2	
	DMP	SL1	
	DCOMP	AXT,1	
		0	
	STORE	20D,2	# PD08 *** -COS(AZ)COS(EL) ***PD14
	TIX,2	RVQ	
		TAR1	
	BANK	33	
	SETLOC	IMUCAL	
	BANK		
	COUNT*	\$\$/P03	
CONTIN33	CA	ONE	
	TS	STARCODE	
	CA	ZERO	
	TC	TARGDRVE	
	TC	INTPRET	
	CALL		
		TAR/EREF	
NEXTBNKS	VLOAD	MXV	
		6D	
		XSM	
	VSL1		
	STOVL	STARAD	
		12D	
	MXV	VSL1	
		XSM	

```

# Page 451
STCALL  STARAD +6
        LITTLSUB
STORE    LOSVEC

EXIT
TC       BANKCALL
CADR     MKRELEAS

NEXBNKSS
CAF      TWO
TS       STARCODE
CAF      SIX
TC       TARGDRVE
TC       INTPRET
CALL
        LITTLSUB
STOVL    12D
        LOSVEC
STCALL   06D
        AXISGEN
CALL
        CALCGTA
EXIT
CAF      V06N93S
TC       BANKCALL
CADR     GOFLASH
TC       GCOMP5
TCF      +2
TCF      GCOMP4
TC       INTPRET
VLOAD    VAD
        OGC
        ERCOMP1
STORE    ERCOMP1
EXIT
GCOMP5   TC       BANKCALL
        CADR     MKRELEAS
        TC       DOWNFLAG
        ADRES    TRM03FLG

        TC       NEWMODEX
        MM       02
        TC       PHASCHNG
        OCT      00004
        TC       ENDOFJOB
V06N93S  VN       0693

```

GTSOPTCS	TC	ALARM
GTSOPTSS	OCT	01602
	TC	GCOMP5

BANK	34
SETLOC	IMUCAL1
BANK	

# Page 452

COUNT	34/COMST
-------	----------

LATAZCHK	DLOAD	SL2	# CALLS FOR AZIMUTH AND LATITUDE
----------	-------	-----	----------------------------------

		LATITUDE
STODL	DSPTEM1	+1
		AZIMUTH

RTB	EXIT
	1ST02S

XCH	MPAC
TS	DSPTEM1
TC	BANKCALL
CADR	CLEANDSP
CAF	VNG0641
TC	BANKCALL
CADR	GOFLASH

# NOT ALLOWED

TC	+2
TC	+2
TC	-5

TC	INTPRET
SLOAD	RTB
	DSPTEM1
	CDULOGIC
STORE	AZIMUTH
SLOAD	SR2
	DSPTEM1
	+1
STORE	LATITUDE

VNG0641

VN	0641
BANK	33
SETLOC	IMUCAL
BANK	

	COUNT*	\$\$/P03
TARGDRVE	EXTEND	
	QXCH	QPLAC

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TS TARG1/2  
TC INTPRET  
CALL  
LXC,1 TAR/EREF  
VLOAD\*  
TARG1/2  
6D,1  
STCALL STAR  
SXTANG  
EXIT  
CA SAC  
TS DESOPTS

# Page 453

RETARG

CA PAC  
TS DESOPTT  
CAF ZERO  
TS OPTIND  
CAF ONE  
TC BANKCALL  
CADR SXTMARK  
TC BANKCALL  
CADR OPTSTALL  
TC GTSOPTCS  
CAE FLAGWRD1  
MASK TRM03BIT  
CCS A  
TC GCOMP5  
  
INDEX MARKSTAT  
CA QPRET  
EXTEND  
BZF RETARG1  
TC QPLAC

RETARG1

CA ZERO  
XCH MARKSTAT  
CCS A  
INDEX A  
TS A  
TCF RETARG  
BANK 33  
SETLOC IMUCAL  
BANK  
COUNT\* \$\$/P03

# RELEASE PREVIOUSLY GRABBED VAC AREA

# GO DO SXTMARK AGAIN

PIPASC	2DEC	.76376833
VELSC	2DEC	-.52223476
ALSK	2DEC	.17329931
	2DEC	-.00835370
GEORGEJ	2DEC	.63661977
GEOCONS1	2DEC	.1
GEOCONS2	2DEC	.005
GEOCONS3	2DEC	.062
GEOCONS4	2DEC	.0003

# Page 454

LITTLSUB	COUNT	33/P02
	STQ	
		QPLAC
	LXC,1	VLOAD*
		MARKSTAT
		2,1
	STCALL	CDUSPOT
		SXTNB
	CALL	
		TRG*NBSM
GOTO		
		QPLAC

AZMTHCG1	EXIT	
	TC	INTPRET
	DLOAD	RTB
		NEWAZMTH
		1ST02S
	EXIT	
	XCH	MPAC
	TS	DSPTM1
	TC	BANKCALL
	CADR	CLEANDSP
	CAF	VN0629
	TC	BANKCALL



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CADR	GOFLASH
TCF	+2
TCF	+2
TCF	-5
TC	INTPRET
SLOAD	RTB
	DSPTM1
	CDULOGIC
STORE	LAUNCHAZ
EXIT	
CA	ZERO
TS	PREMTRXC
TC	PHASCHNG
OCT	00004
TC	POSTJUMP
CADR	PINBRNCH

VN0629 VN 0629

# Page 455

# \*\*\* END OF COMAID .029 \*\*\*

This code is written to file src/IMU-CALIBRATION-AND-ALIGNMENT.s.

## A.37 IMU COMPENSATION PACKAGE

```

634  <src/IMU-COMPENSATION-PACKAGE.s 634>≡
      # Copyright:    Public domain.
      # Filename:     IMU_COMPENSATION_PACKAGE.agc
      # Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
      #               It is part of the source code for the Command Module's (CM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Ron Burkey <info@sandroid.org>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         297-306
      # Mod history:   2009-05-08 RSB   Adapted from the Colossus249/ file of the
      #               same name, using Comanche055 page images/
      #               2009-05-21 RSB   In IRIGZ, PRI017 corrected to PRI021.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 055 of AGC program Comanche by NASA
      #       2021113-051.  10:28 APR. 1, 1969
      #
      #       This AGC program shall also be referred to as
      #               Colossus 2A

      # Page 297

      BANK      7
      SETLOC    IMUCOMP
      BANK
      EBANK=     NBDX

      COUNT     06/ICOMP

1/PIPA        CAF      LGCOMP      # SAVE EBANK OF CALLING PROGRAM
              XCH      EBANK
              TS        MODE

              CCS       GCOMPSW     # BYPASS IF GCOMPSW NEGATIVE

```

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```
TCF      +3
TCF      +2
TCF      IRIG1      # RETURN

INHINT                                # ASSURE COMPLETE COMPENSATION OF DELV'S
                                      # FOR DOWNLINK.

1/PIPA1  CAF      FOUR      # PIPAZ, PIPAY, PIPAX
          TS      BUF +2

          INDEX    BUF +2
          CA      PIPASCF    # (P.P.M.) X 2(-9)
          EXTEND
          INDEX    BUF +2
          MP      DELVX      # (PP) X 2(+14) NOW (PIPA PULSES) X 2(+5)
          TS      Q          # SAVE MAJOR PART

          CA      L          # MINOR PART
          EXTEND
          MP      BIT6      # SCALE 2(+9)  SHIFT RIGHT 9
          INDEX    BUF +2
          TS      DELVX +1   # FRACTIONAL PIPA PULSES SCALED 2(+14)

          CA      Q          # MAJOR PART
          EXTEND
          MP      BIT6      # SCALE 2(+9)  SHIFT RIGHT 9
          INDEX    BUF +2
          DAS      DELVX     # (PIPAI) + (PIPAI)(SF)

          INDEX    BUF +2
          CS      PIPABIAS   # (PIPA PULSES)/(CS) X 2(-8) *
          EXTEND
          MP      1/PIPADT   # (CS) X 2(+8) NOW (PIPA PULSES) X 2(+0) *
          EXTEND
          MP      BIT1      # SCALE 2(+14) SHIFT RIGHT 14 *
          INDEX    BUF +2
          DAS      DELVX     # (PIPAI) + (PIPAI)(SFE) - (BIAS)(DELTAT)

          CCS      BUF +2    # PIPAZ, PIPAY, PIPAX

# Page 298
          AD      NEG1
          TCF      1/PIPA1 +1
          NOOP
          RELINT

# Page 299
```

IRIGCOMP	TS	GCOMPSW	#	INDICATE COMMANDS 2 PULSES OR LESS.
	TS	BUF	#	INDEX COUNTER. IRIGX, IRIGY, IRIGZ.
IRIGX	EXTEND			
	DCS	DEL VX	#	(PIPA PULSES) X 2(+14)
	DXCH	MPAC		
	CA	ADIA X	#	(GYRO PULSES)/(PIPA PULSE) X 2(-3)
	TC	GCOMPSUB	#	-(ADIA X)(PIPA X) (GYRO PULSES) X 2(+14)
	EXTEND		#	
	DCS	DEL VY	#	(PIPA PULSES) X 2(+14)
	DXCH	MPAC	#	
	CS	ADSRAX	#	(GYRO PULSES)/(PIPA PULSE) X 2(-3)
	TC	GCOMPSUB	#	-(ADSRAX)(PIPA X) (GYRO PULSES) X 2(+14)
#	EXTEND		#	***
#	DCS	DEL VY	#	*** (PIPA PULSES) X 2(+14)
#	DXCH	MPAC	#	***
#	CA	ADOAX	#	*** (GYRO PULSES)/(PIPA PULSE) X 2(-3)
#	TC	GCOMPSUB	#	*** -(ADOAX)(PIPA Z) (GYRO PULSES) X 2(+14)
	CS	NBDX	#	(GYRO PULSES)/(CS) X 2(-3)
	TC	DRIFTSUB	#	-(NBDX)(DELTAT) (GYRO PULSES) X 2(+14)
IRIGY	EXTEND			
	DCS	DEL VY	#	(PIPA PULSES) X 2(+14)
	DXCH	MPAC		
	CA	ADIA Y	#	(GYRO PULSES)/(PIPA PULSE) X 2(-3)
	TC	GCOMPSUB	#	-(ADIA Y)(PIPA Y) (GYRO PULSES) X 2(+14)
	EXTEND			
	DCS	DEL VZ	#	(PIPA PULSES) X 2(+14)
	DXCH	MPAC		
	CS	ADSRAY	#	(GYRO PULSES)/(PIPA PULSE) X 2(-3)
	TC	GCOMPSUB	#	+(ADSRAY)(PIPA Z) (GYRO PULSES) X 2(+14)
#	EXTEND		#	***
#	DCS	DEL VX	#	*** (PIPA PULSES) X 2(+14)
#	DXCH	MPAC	#	***
#	CA	ADOAY	#	*** (GYRO PULSES)/(PIPA PULS) X 2(-3)
#	TC	GCOMPSUB	#	*** -(ADOAY)(PIPA X) (GYRO PULSES) X 2(+14)
	CS	NBDY	#	(GYRO PULSES)/(CS) X 2(-5)
	TC	DRIFTSUB	#	-(NBDY)(DELTAT) (GYRO PULSES) X 2(+14)
IRIGZ	EXTEND			

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```
# Page 300
DCS      DELVY      # (PIPA PULSES) X 2(-14)
DXCH     MPAC
CA       ADSRAZ     # (GYRO PULSES)/(PIPA PULSE) X 2(-3) *
TC       GCOMPSUB   # -(ADSRAZ)(PIPAY)      (GYRO PULSES) X 2(+14)

EXTEND
DCS      DELVZ      # (PIPA PULSES) X 2(+14)
DXCH     MPAC
CA       ADIAZ      # (GYRO PULSES)/(PIPA PULSE) X 2(-3) *
TC       GCOMPSUB   # -(ADIAZ)(PIPAZ)      (GYRO PULSES) X 2(+14)

# EXTEND          # ***
# DCS      DELVX   # *** (PIPA PULSE) X 2(+14)
# DXCH     MPAC    # ***
# CS       ADOAZ   # *** (GYRO PULSES)/(PIPA PULSE) X 2(-3) *
# TC       GCOMPSUB # *** +(ADOAZ)(PIPAZ) (GYRO PULSES) X 2(+14)

CA       NBDZ      # (GYRO PULSES)/(CS) X 2(-5)
TC       DRIFTSUB   # +(NBDZ)(DELTAT) (GYRO PULSES) X 2(+14)

# Page 301
CCS      GCOMPSW    # ARE GYRO COMMANDS GREATER THAN 2 PULSES
TCF      +2         # YES
TCF      IRIG1      # NO

CA       PRI021     # HIGHER THAN SERVICER -- LESS THAN PRELAUNCH
TC       NOVAC
EBANK=   NBDX
2CADR    1/GYRO

IRIG1    RELINT
CA       MODE       # SET EBANK FOR RETURN
TS       EBANK
TCF      SWRETURN

GCOMPSUB XCH       MPAC      # ADIA OR ADSRA COEFFICIENT ARRIVES IN A
EXTEND   # C(MPAC) = (PIPA PULSES) X 2(+14)
MP       MPAC      # (GYRO PULSES)/(PIPA PULSE) X 2(-3) *
DXCH     VBUF      # NOW = (GYRO PULSES) X 2(+11) *

CA       MPAC +1    # MINOR PART OF PIPA PULSES
EXTEND
MP       MPAC      # ADIA OR ADSRA
TS       L
CAF      ZERO
```

```

DAS      VBUF      # NOW = (GYRO PULSES) X 2(+11)

CA      VBUF      # PARTIAL RESULT -- MAJOR
EXTEND
MP      BIT12     # SCALE 2(+3)  SHIFT RIGHT 3
INDEX   BUF       # RESULT = (GYRO PULSES) X 2(+14)
DAS     GCOMP     # HI(ADIA)(PIPAI) OR HI(ADSRA)(PIPAI)

CA      VBUF +1   # PARTIAL RESULT -- MINOR
EXTEND
MP      BIT12     # SCALE 2(+3)  SHIFT RIGHT 3
TS      L
CAF     ZERO
INDEX   BUF       # RESULT = (GYRO PULSES) X 2(+14)
DAS     GCOMP     # (ADIA)(PIPAI) OR (ADSRA)(PIPAI)

TC      Q

# Page 302
DRIFTSUB
EXTEND
QXCH    BUF +1

EXTEND
MP      1/PIPADT  # C(A) = NBD (GYRO PULSES)/(CS) X 2(-5)
LXCH    MPAC +1   # (CS) X 2(+8) NO (GYRO PULSES) X 2(+3)
EXTEND  # SAVE FOR FRACTIONAL COMPENSATION
MP      BIT4      # SCALE 2(+11)  SHIFT RIGHT 11
INDEX   BUF
DAS     GCOMP     # HI(NBD)(DELTAT) (GYRO PULSES) X 2(+14)

CA      MPAC +1   # NOW MINOR PART
EXTEND
MP      BIT4      # SCALE 2(+11)  SHIFT RIGHT 11
TS      L
CAF     ZERO
INDEX   BUF       # ADD IN FRACTIONAL COMPENSATION
DAS     GCOMP     # (NBD)(DELTAT) (GYRO PULSES) X 2(+14)

DRFTSUB2
CAF     TWO       # PIPAX, PIPAY, PIPAZ
AD      BUF
XCH     BUF
INDEX   A
CCS     GCOMP     # ARE GYRO COMMANDS 1 PULSE OR GREATER
TCF     +2        # YES
TC      BUF +1    # NO

```

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```
# Page 303
1/GYRO

MASK      NEGONE
CCS        A
TS         GCOMPSW
TC         BUF +1
# ARE GYRO COMMANDS GREATER THAN 2 PULSES
# YES -- SET GCOMPSW POSITIVE
# NO

CAF        FOUR
TS         BUF
# PIPAZ, PIPAY, PIPAX

INDEX      BUF
CA         GCOMP +1
EXTEND
MP         BIT8
INDEX      BUF
TS         GCOMP +1
# SCALE GYRO COMMANDS FOR IMUPULSE
# FRACTIONAL PULSES

CAF        ZERO
INDEX      BUF
XCH        GCOMP
EXTEND
MP         BIT8
INDEX      BUF
DAS        GCOMP
# SET GCOMP = 0 FOR DAS INSTRUCTION
# GYRO PULSES

# SHIFT RIGHT 7

CAF        ZERO
INDEX      BUF
XCH        GCOMP
EXTEND
MP         BIT8
INDEX      BUF
DAS        GCOMP
# ADD THESE TO FRACTIONAL PULSES ABOVE

CCS        BUF
AD         NEG1
TCF        1/GYRO +1
# PIPAZ, PIPAY, PIPAX

LGCOMP    ECADR    GCOMP
# LESS THAN ZERO IMPOSSIBLE

CAF        LGCOMP
TC         BANKCALL
CADR       IMUPULSE
TC         BANKCALL
CADR       IMUSTALL
TCF        ENDOFJOB
# CALL GYRO TORQUING ROUTINE
# WAIT FOR PULSES TO GET OUT
# TEMPORARY

GCOMP1    CAF        FOUR
TS         BUF
# PIPAZ, PIPAY, PIPAX

INDEX      BUF
CA         GCOMP +1
EXTEND
MP         BIT8
INDEX      BUF
LXCH       GCOMP +1
# RESCALE
# SHIFT MINOR PART LEFT 7 -- MAJOR PART = 0
# BITS 8-14 OF MINOR PART WERE = 0
```

```

                                CCS      BUF          # PIPAZ, PIPAY, PIPAX
                                AD        NEG1
                                TCF       GCOMP1 +1

V06N30S                        VN        0630
                                TCF       ENDOFJOB

# Page 304
NBDONLY                        CCS      GCOMPSW        # BYPASS IF GCOMPSW NEGATIVE
                                TCF       +3
                                TCF       +2
                                TCF       ENDOFJOB

                                INHINT
                                CCS      FLAGWRD2        # PREREAD T3RUPT MAY COINCIDE
                                TCF       ENDOFJOB
                                TCF       ENDOFJOB
                                TCF       +1

                                CA        TIME1          # (CS) X 2(+14)
                                XCH       1/PIPADT        # PREVIOUS TIME
                                RELINT
                                COM
                                AD        1/PIPADT
NBD2                            CCS      A              # CALCULATE ELAPSED TIME.
                                AD        ONE            # NO TIME1 OVERFLOW
                                TCF       NBD3            # RESTORE TIME DIFFERENCE AND JUMP
                                TCF       +2            # TIME1 OVERFLOW
                                TCF       ENDOFJOB        # IF ELAPSED TIME = 0 (DIFFERENCE = -0)

                                COM
                                AD        POSMAX          # CALCULATE ABSOLUTE DIFFERENCE

NBD3                            EXTEND
                                MP        BIT10          # C(A) = DELTAT          (CS) X 2(+14)
                                DXCH      VBUF            # SHIFT RIGHT 5
                                EXTEND
                                DCA       VBUF
                                DXCH      MPAC            # DELTAT NOW SCALED (CS) X 2(+19)

                                CAF       ZERO
                                TS        GCOMPSW        # INDICATE COMMANDS 2 PULSES OR LESS.
                                TS        BUF            # INDEX X, Y, Z.

                                CS        NBDX            # (GYRO PULSES)/(CS) X 2(-5)
                                TC        FBIASSUB        # -(NBOX)(DELTAT)      (GYRO PULSES) X 2(+14)

```



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```
EXTEND
DCS      VBUF
DXCH     MPAC      # DELTAT SCALED (CS) X 2(+19)
CA       NBDY      # (GYRO PULSES)/(CS) X 2(-5)
TC       FBIASSUB  # -(NBDY)(DELTAT)      (GYRO PULSES) X 2(+14)

EXTEND
DCS      VBUF
DXCH     MPAC      # DELTAT SCALED (CS) X 2(+19)
CS       NBDZ      # (GYRO PULSES)/(CS) X 2(-5)
TC       FBIASSUB  # +(NBDZ)(DELTAT)      (GYRO PULSES) X 2(+14)

# Page 305
CCS      GCOMPSW   # ARE GYRO COMMANDS GREATER THAN 2 PULSES
TCF      1/GYRO    # YES
TCF      ENDOFJOB  # NO

# Page 303
FBIASSUB
XCH      Q
TS       BUF +1

CA       Q          # NBD SCALED (GYRO PULSES)/(CS) X 2(-5)
EXTEND
MP       MPAC      # DELTAT SCALED (CS) X 2(+19)
INDEX   BUF
DAS     GCOMP      # HI(NBD)(DELTAT)      (GYRO PULSES) X 2(+14)

CA       Q          # NO FRACTIONAL PART
EXTEND
MP       MPAC +1
TS       L
CAF     ZERO
INDEX   BUF
DAS     GCOMP      # (NBD)(DELTAT)      (GYRO PULSES) X 2(+14)

TCF     DRFTSUB2   # CHECK MAGNITUDE OF COMPENSATION

LASTBIAS
TC       BANKCALL
CADR     PIPUSE

CCS      GCOMPSW   # BYPASS IF GCOMPSW NEGATIVE
TCF      +3
TCF      +2
TCF      ENDOFJOB

CAF      PRI031    # 2 SECONDS SCALED (CS) X 2(+8)
```

```
XCH      1/PIPADT
COM
AD       PIPTIME1 +1      # TIME AT PIPA1 =0
TCF      NBD2
```

This code is written to file `src/IMU-COMPENSATION-PACKAGE.s`.

## A.38 IMU MODE SWITCHING ROUTINES

```

643  <src/IMU-MODE-SWITCHING-ROUTINES.s 643>≡
# Copyright:      Public domain.
# Filename:       IMU_MODE_SWITCHING_ROUTINES.agc
# Purpose:        Part of the source code for Colossus 2A, AKA Comanche 055.
#                It is part of the source code for the Command Module's (CM)
#                Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:     yaYUL
# Contact:        Ron Burkey <info@sandroid.org>.
# Website:        www.ibiblio.org/apollo.
# Pages:          1420-1448
# Mod history:    2009-05-10 SN    (Sergio Navarro). Started adapting from
#                the Colossus249/ file of the same name,
#                using Comanche055 page images.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. 10:28 APR. 1, 1969
#
# This AGC program shall also be referred to as
# Colossus 2A

# Page 1420

BLOCK      02
SETLOC     FFTAG3
BANK

EBANK=     COMMAND

# FIXED-FIXED ROUTINES

COUNT     02/IMODE

ZEROICDU   CAF      ZERO          # ZERO ICDU COUNTERS.
          TS        CDUX

```

```

                TS      CDUY
                TS      CDUZ
                TC      Q

SPSCODE      =      BIT9

# Page 1421
# IMU ZEROING ROUTINE.

                BANK    11
                SETLOC  MODESW
                BANK

                COUNT   07/IMODE

IMUZERO      INHINT
                CS      DSPTAB +11D      # ROUTINE TO ZERO ICDUS.
                MASK    BITS4&6          # DON'T ZERO CDUS IS IMU IN GIMBAL LOCK AND
                CCS      A                # COARSE ALIGN (GIMBAL RUNAWAY PROTECTION)
                TCF      IMUZEROA

                TC      ALARM            # IF SO.
                OCT     00206

                TCF     CAGETSTJ +4      # IMMEDIATE FAILURE.

IMUZEROA     TC      CAGETSTJ

# DO ALL THE WORK.

                CS      IMODES33         # DISABLE DAP AUTO AND HOLD MODES
                MASK    SUPER011         #          BIT5 FOR GROUND
                ADS     IMODES33

                CS      IMODES30         # INHIBIT ICDUFAIL AND IMUFAIL (IN CASE WE
                MASK    BITS3&4          # JUST CAME OUT OF COARSE ALIGN).
                ADS     IMODES30

                CS      BITS4&6          # SEND ZERO ENCODE WITH COARSE AND ERROR
                EXTEND   WAND            # COUNTER DISABLED.
                WAND     CHAN12

                TC      NOATTOFF         # TURN OFF NO ATT LAMP.

                CAF      BIT5
                EXTEND

```

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```

                                WOR      CHAN12

                                TC        ZEROICDU
                                CAF        BIT6      # WAIT 320 MS TO GIVE AGS ADEQUATE TIME TO
                                TC        WAITLIST    # RECEIVE ITS PULSE TRAIN.
                                EBANK=     CDUIND
                                2CADR     IMUZERO2

                                CS        IMODES30    # SEE IF IMU OPERATING AND ALARM IF NOT.
                                MASK       BIT9
                                CCS        A
                                TCF       MODEEXIT

# Page 1422
                                TC        ALARM
                                OCT       210

MODEEXIT      RELINT
TCF          SWRETURN      # GENERAL MODE-SWITCHING EXIT.

IMUZERO2      TC        CAGETEST
TC           ZEROICDU      # ZERO CDUX, CDUY, CDUZ

                                CS        BIT5        # REMOVE ZERO DISCRETE.
                                EXTEND
                                WAND      CHAN12

                                CAF        BIT11      # WAIT 10 SECS FOR CTRS TO FIND GIMBALS
                                TC        VARDELAY

IMUZERO3      TC        CAGETEST
CS           BITS3&4      # REMOVE IMUFAIL AND ICDUFAIL INHIBIT.
MASK        IMODES30
TS          IMODES30

                                CS        SUPER011    # ENABLE DAP AUTO AND HOLD MODES
                                MASK       IMODES33    #          BIT5 FOR GROUND
                                TS        IMODES33

                                TC        IBNKCALL    # SET ISS WARNING IF EITHER OF ABOVE ARE
                                CADR      SETISSW      # PRESENT.

                                TCF       ENDIMU

# Page 1423
# IMU COARSE ALIGN MODE.
```

IMUCOARS	INHINT		
	TC	CAGETSTJ	
	TC	SETCOARS	
	CAF	SIX	
	TC	WAITLIST	
	EBANK=	CDUIND	
	2CADR	COARS	
	TCF	MODEEXIT	
COARS	TC	CAGETEST	
	CAF	BIT6	# ENABLE ALL THREE ISS CDU ERROR COUNTERS
	EXTEND		
	WOR	CHAN12	
COARS1	CAF	TWO	# SET CDU INDICATOR
	TS	CDUIND	
	INDEX	CDUIND	# COMPUTE THETAD -- THETAA IN 1'S
	CA	THETAD	# COMPLEMENT FORM
	EXTEND		
	INDEX	CDUIND	
	MSU	CDUX	
	EXTEND		
	MP	BIT13	# SHIFT RIGHT 2
	XCH	L	# ROUND
	DOUBLE		
	TS	ITEMP1	
	TCF	+2	
	ADS	L	
	INDEX	CDUIND	# DIFFERENCE TO BE COMPUTED
	LXCH	COMMAND	
	CCS	CDUIND	
	TC	COARS1	
	CAF	TWO	# MINIMUM OF 4 MS WAIT
	TC	VARDELAY	
# Page 1424			
COARS2	TC	CAGETEST	# DON'T CONTINUE IF CAGED.
	TS	ITEMP1	# SET TO +0.
	CAF	TWO	# SET CDU INDICATOR.
+3	TS	CDUIND	

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	INDEX	CDUIND	
	CCS	COMMAND	# NUMBER OF PULSES REQUIRED
	TC	COMPOS	# GREATER THAN MAX ALLOWED
	TC	NEXTCDU +1	
	TC	COMNEG	
	TC	NEXTCDU +1	
COMPOS	AD	-COMMAX	# COMMAX = MAX NUMBER OF PULSES ALLOWED
	EXTEND		# MINUS ONE
	BZMF	COMZERO	
	INDEX	CDUIND	
	TS	COMMAND	# REDUCE COMMAND BY MAX NUMBER OF PULSES
	CS	-COMMAX-	# ALLOWED
NEXTCDU	INCR	ITEMP1	
	AD	NEGO	
	INDEX	CDUIND	
	TS	CDUXCMD	# SET UP COMMAND REGISTER.
	CCS	CDUIND	
	TC	COARS2 +3	
	CCS	ITEMP1	# SEE IF ANY PULSES TO GO OUT.
	TCF	SENDPULS	
	TC	FIXDELAY	# WAIT FOR GIMBALS TO SETTLE.
	DEC	150	
CHKCORS	CAF	TWO	# AT END OF COMMAND, CHECK TO SEE THAT
	TS	ITEMP1	# GIMBALS ARE WITHIN 2 DEGREES OF THETAD.
	INDEX	A	
	CA	CDUX	
	EXTEND		
	INDEX	ITEMP1	
	MSU	THETAD	
	CCS	A	
	TCF	COARSERR	
	TCF	CORSCHK2	
	TCF	COARSERR	
# Page 1425			
CORSCHK2	CCS	ITEMP1	
	TCF	CHKCORS	
	TCF	ENDIMU	# END OF COARSE ALIGNMENT
COARSERR	AD	COARSTOL	# 2 DEGREES.

	EXTEND		
	BZMF	CORSCHK2	
	TC	ALARM	# COARSE ALIGN ERROR.
	OCT	211	
	TCF	IMUBAD	
COARSTOL	DEC	-.01111	# 2 DEGREES SCALED AT HALF-REVOLUTIONS
COMNEG	AD	-COMMAX	
	EXTEND		
	BZMF	COMZERO	
	COM		
	INDEX	CDUIND	
	TS	COMMAND	
	CA	-COMMAX-	
	TC	NEXTCDU	
COMZERO	CAF	ZERO	
	INDEX	CDUIND	
	XCH	COMMAND	
	TC	NEXTCDU	
SENDPULS	CAF	13,14,15	
	EXTEND		
	WOR	CHAN14	
	CAF	600MS	
	TCF	COARS2 -1	# THEN TO VARDELAY
CA+ECE	CAF	BIT6	# ENABLE ALL THREE ISS CDU ERROR COUNTERS
	EXTEND		
	WOR	CHAN12	
	TC	TASKOVER	
# Page 1426			
SETCOARS	CAF	BIT4	# BYPASS IF ALREADY IN COARSE ALIGN
	EXTEND		
	RAND	CHAN12	
	CCS	A	
	TC	Q	
	CS	BIT6	# CLEAR ISS ERROR COUNTERS
	EXTEND		
	WAND	CHAN12	



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```
CS      BIT10      # KNOCK DOWN GYRO ACTIVITY
EXTEND
WAND    CHAN14
CS      ZERO
TS      GYROCMD

CAF     BIT4       # PUT ISS IN COARSE ALIGN
EXTEND
WOR     CHAN12

CS      DSPTAB +11D # TURN ON NO ATT LAMP
MASK    OCT40010
ADS     DSPTAB +11D

CS      IMODES33   # DISABLE DAP AUTO AND HOLD MODES
MASK    BIT6
ADS     IMODES33

CS      IMODES30   # DISABLE IMUFAIL
MASK    BIT4
ADS     IMODES30

RNDREFDR CS      BIT5      # KNOCK DOWN TRACK FLAG
MASK    FLAGWRD1
TS      FLAGWRD1

CS      BIT15      # KNOCK DOWN DRIFT FLAG
MASK    FLAGWRD2
TS      FLAGWRD2

CS      BIT13      # KNOCK DOWN REFSMMAT FLAG
MASK    FLAGWRD3
TS      FLAGWRD3

TC      Q

OCT40010 OCT      40010

# Page 1427
# IMU FINE ALIGN MODE SWITCH.

IMUFINE INHINT
TC      CAGETSTJ   # SEE IF IMU BEING CAGED.

CS      BITS4-5    # RESET ZERO AND COARSE
EXTEND
```

	WAND	CHAN12	
	CS	BIT6	# INSURE DAP AUTO AND HOLD MODES ENABLED
	MASK	IMODES33	
	TS	IMODES33	
	TC	NOATTOFF	
	CAF	BIT10	# IMU FAIL WAS INHIBITED DURING THE
	TC	WAITLIST	# PRESUMABLY PRECEDING COARSE ALIGN. LEAVE
	EBANK=	CDUIND	
	2CADR	IFAILOK	# IT ON FOR THE FIRST 5 SECS OF FINE ALIGN
	CAF	2SECS	
	TC	WAITLIST	
	EBANK=	CDUIND	
	2CADR	IMUFINED	
	TCF	MODEEXIT	
IMUFINED	TC	CAGETEST	# SEE THAT NO ONE HAS CAGED THE IMU.
	TCF	ENDIMU	
# Page 1428			
IFAILOK	TC	CAGETSTQ	# ENABLE IMU FAIL UNLESS IMU BEING CAGED.
	TCF	TASKOVER	# IT IS.
	CAF	BIT4	# DON'T RESET IMU FAIL INHIBIT IF SOMEONE
	EXTEND		# HAS GONE INTO COARSE ALIGN.
	RAND	CHAN12	
	CCS	A	
	TCF	TASKOVER	
	CS	IMODES30	# RESET IMUFAIL.
	MASK	BIT13	
	ADS	IMODES30	
	CS	BIT4	
PFAILOK2	MASK	IMODES30	
	TS	IMODES30	
	TC	IBNKCALL	# THE ISS WARNING LIGHT MAY COME ON NOW
	CADR	SETISSW	# THAT THE INHIBIT WAS BEEN REMOVED.
	TCF	TASKOVER	
PFAILOK	TC	CAGETSTQ	# ENABLE PIP FAIL PROG ALARM.
	TCF	TASKOVER	

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```

      CS      IMODES30      # RESET IMU AND PIPA FAIL BITS.
      MASK     BIT10
      ADS      IMODES30

      CS      IMODES33
      MASK     BIT13
      ADS      IMODES33

      CS      BIT5
      TCF      PFAILOK2

NOATTOFF      CS      OCT40010      # SUBROUTINE TO TURN OFF NO ATT LAMP.
              MASK     DSPTAB +11D
              AD       BIT15
              TS       DSPTAB +11D
              TC       Q

# Page 1429
# ROUTINES TO INITIATE AND TERMINATE PROGRAM USE OF THE PIPAS.  NO IMUSTALL REQUIRED IN EITHER

PIPUSE      CS      ZERO
              TS      PIPAX
              TS      PIPAY
              TS      PIPAZ

PIPUSE1      TC      CAGETSTQ      # DO NOT ENABLE PIPA FAIL IF IMU IS CAGED
              TCF     SWRETURN

              INHINT
              CS      BIT1          # IF PIPA FAILS FROM NOW ON (UNTIL
              MASK     IMODES30      # PIPFREE), LIGHT ISS WARNING.
              TS      IMODES30

PIPFREE2      TC      IBNKCALL      # ISS WARNING MIGHT COME ON NOW.
              CADR     SETISSW      # (OR GO OFF ON PIPFREE).

              TCF      MODEEXIT

PIPFREE      INHINT
              CS      IMODES30      # PROGRAM DONE WITH PIPAS.  DON'T LIGHT
              MASK     BIT1          # ISS WARNING.
              ADS      IMODES30

              MASK     BIT10      # IF PIP FAIL ON, DO PROG ALARM AND RESET
              CCS      A          # ISS WARNING.
              TCF      MODEEXIT
```

TC ALARM

OCT 212

INHINT

TCF PIPFREE2

# Page 1430

# THE FOLLOWING ROUTINE TORQUES THE IRIGS ACCORDING TO DOUBLE PRECISION INPUTS IN THE

# BEGINNING AT THE ECADR ARRIVING IN A. THE MINIMUM SIZE OF ANY PULSE TRAIN IS 16 P

# UNSENT PORTION OF THE COMMAND IS LEFT INTACT AT THE INPUT COMMAND REGISTERS.

EBANK= 1400

# VARIABLE, ACTUALLY.

IMUPULSE

TS MPAC +5

# SAVE ARRIVING ECADR.

TC CAGETSTJ

# DON'T PROCEED IF IMU BEING CAGED.

CCS LGYRO

# SEE IF GYROS BUSY.

TC GYROBUSY

# SLEEP.

TS MPAC +2

CAF BIT6

# ENABLE THE POWER SUPPLY.

EXTEND

WOR CHAN14

GWAKE2

CAF FOUR

TC WAITLIST

# (IF A JOB WAS PUT TO SLEEP, THE POWER

EBANK= CDUIND

# SUPPLY IS LEFT ON BY THE WAKING JOB).

2CADR STRTGYRO

CA MPAC +5

# SET UP EBANK, SAVING CALLER'S EBANK FOR

XCH EBANK

# RESTORATION ON RETURN.

XCH MPAC +5

TS LGYRO

# RESERVES GYROS.

MASK LOW8

TS ITEMP1

GYROAGRE

CAF TWO

# FORCE SIGN AGREEMENT ON INPUTS.

TS MPAC +3

DOUBLE

AD ITEMP1

TS MPAC +4

EXTEND

INDEX A

DCA 1400

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DXCH MPAC  
TC TPAGREE  
DXCH MPAC  
INDEX MPAC +4  
DXCH 1400

CCS MPAC +3  
TCF GYROAGRE

CA MPAC +5 # RESTORE CALLER'S EBANK.  
TS EBANK  
TCF MODEEXIT

# Page 1431

# ROUTINES TO ALLOW TORQUING ONLY ONE JOB AT A TIME.

GYROBUSY EXTEND # SAVE RETURN 2FCADR.

DCA BUF2

DXCH MPAC

REGSLEEP CAF LGWAKE  
TCF JOBSLEEP

GWAKE CCS LGYRO # WHEN AWAKENED, SEE IF GYROS STILL BUSY.  
TCF REGSLEEP # IF SO, SLEEP SOME MORE.

TS MPAC +2

EXTEND

DCA MPAC

DXCH BUF2

CAF ONE

TCF GWAKE2

# RESTORE SWRETURN INFO.

LGWAKE CADR GWAKE

# Page 1432

# GYRO-TORQUING WAITLIST TASKS.

STRTGYRO CS GDESELCT # DE-SELECT LAST GYRO.

EXTEND

WAND CHAN14

TC CAGETEST

STRTGYR2 CA LGYRO # JUMP ON PHASE COUNTER IN BITS 13-14.

EXTEND

MP BIT4

	INDEX	A	
	TCF	+1	
	TC	GSELECT	# =0. DO Y GYRO.
	OCT	00202	
	TC	GSELECT	# =1. DO Z GYRO.
	OCT	00302	
	TC	GSELECT -2	# =2. DO X GYRO.
	OCT	00100	
	CAF	ZERO	# =3. DONE
	TS	LGYRO	
	CAF	LGWAKE	# WAKE A POSSIBLE SLEEPING JOB.
	TC	JOBWAKE	
NORESET	TCF	IMUFINED	# DO NOT RESET POWER SUPPLY.
# Page 1433			
-2	CS	FOUR	# SPECIAL ENTRY TO REGRESS LGYRO FOR X.
	ADS	LGYRO	
GSELECT	INDEX	Q	# SELECT GYRO.
	CAF	0	# PACKED WORD CONTAINS GYRO SELECT BITS
	TS	ITEMP4	# AND INCREMENT TO LGYRO.
	MASK	SEVEN	
	AD	BIT13	
	ADS	LGYRO	
	TS	EBANK	
	MASK	LOW8	
	TS	ITEMP1	
	CS	SEVEN	
	MASK	ITEMP4	
	TS	ITEMP4	
	EXTEND		# MOVE DP COMMAND TO RUPTREGS FOR TESTING.
	INDEX	ITEMP1	
	DCA	1400	
	DXCH	RUPTREG1	
	CCS	RUPTREG1	
	TCF	MAJ+	
	TCF	+2	
	TCF	MAJ-	
	CCS	RUPTREG2	

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	TCF	MIN+	
	TCF	STRTYGR2	
	TCF	MIN-	
	TCF	STRTYGR2	
# Page 1434			
MIN+	AD	-GYROMIN	# SMALL POSITIVE COMMAND. SEE IF AT LEAST
	EXTEND		# 16 GYRO PULSES.
	BZMF	STRTYGR2	
MAJ+	EXTEND		# DEFINITE POSITIVE OUTPUT.
	DCA	GYROFRAC	
	DAS	RUPTREG1	
	CA	ITEMP4	# SELECT POSITIVE TORQUING FOR THIS GYRO.
	EXTEND		
	WOR	CHAN14	
	CAF	LOW7	# LEAVE NUMBER OF POSSIBLE 8192 AUGMENTS
	MASK	RUPTREG2	# TO INITIAL COMMAND IN MAJOR PART OF LONG
	XCH	RUPTREG2	# TERM STORAGE AND TRUNCATED FRACTION
GMERGE	EXTEND		# IN MINOR PART. THE MAJOR PART WILL BE
	MP	BIT8	# COUNTED DOWN TO ZERO IN THE COURSE OF
	TS	ITEMP2	# PUTTING OUT THE ENTIRE COMMAND.
	CA	RUPTREG1	
	EXTEND		
	MP	BIT9	
	TS	RUPTREG1	
	CA	L	
	EXTEND		
	MP	BIT14	
	ADS	ITEMP2	# INITIAL COMMAND.
	EXTEND		# SEE IF MORE THAN ONE PULSE TRAIN NEEDED
	DCA	RUPTREG1	# (MORE THAN 16383 PULSES).
	AD	MINUS1	
	CCS	A	
	TCF	LONGGYRO	
-GYROMIN	OCT	-176	# MAY BE ADJUSTED TO SPECIFY MINIMUM CMD
	TCF	+4	
	CAF	BIT14	
	ADS	ITEMP2	
	CAF	ZERO	
+4	INDEX	ITEMP1	

```

# Page 1435
LASTSEG      DXCH      1400
              CA        ITEMP2      # ENTIRE COMMAND.
              TS        GYROCMD
              EXTEND
              MP        BIT10      # WAITLIST DT
              AD        THREE      # TRUNCATION AND PHASE UNCERTAINTIES.
              TC        WAITLIST
              EBANK=    CDUIND
              2CADR     STRTGYRO

GYROEXIT      CAF        BIT10
              EXTEND
              WOR        CHAN14
              TCF        TASKOVER

LONGGYRO      INDEX     ITEMP1
              DXCH      1400      # INITIAL COMMAND OUT PLUS N AUGMENTS OF
              CAF        BIT14      # 8192.  INITIAL COMMAND IS AT LEAST 8192.
              AD        ITEMP2
              TS        GYROCMD

AUG3          EXTEND
              MP        BIT10      # GET WAITLIST DT TO TIME WHEN TRAIN IS
              AD        NEG3      # ALMOST OUT.
              TC        WAITLIST
              EBANK=    CDUIND
              2CADR     8192AUG

              TCF        GYROEXIT

8192AUG       TC        CAGETEST

              CAF        BIT4
              EXTEND
              RAND      CHAN12
              CCS        A
              TCF        IMUBAD
              CA        LGYRO      # ADD 8192 PULSES TO GYROCMD
              TS        EBANK
              MASK      LOW8
              TS        ITEMP1

              INDEX     ITEMP1      # SEE IF THIS IS THE LAST AUG.
              CCS        1400
              TCF        AUG2      # MORE TO COME.

```



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CAF BIT14  
ADS GYROCMD  
TCF LASTSEG +1

# Page 1436

AUG2 INDEX ITEMP1  
TS 1400  
CAF BIT14  
ADS GYROCMD  
TCF AUG3 # COMPUTE DT.

# Page 1437

MIN- AD -GYROMIN # POSSIBLE NEGATIVE OUTPUT.  
EXTEND  
BZMF STRTGYR2

MAJ- EXTEND # DEFINITE NEGATIVE OUTPUT.  
DCS GYROFRAC  
DAS RUPTREG1

CA ITEMP4 # SELECT NEGATIVE TORQUING FOR THIS GYRO.  
AD BIT9  
EXTEND  
WOR CHAN14

CS RUPTREG1 # SET UP RUPTREGS TO FALL INTO GMERGE.  
TS RUPTREG1 # ALL NUMBERS PUT INTO GYROCMD ARE  
CS RUPTREG2 # POSITIVE -- BIT9 OF CHAN 14 DETERMINES  
MASK LOW7 # THE SIGN OF THE COMMAND.  
COM  
XCH RUPTREG2  
COM  
TCF GMERGE

GDESELECT OCT 1700 # TURN OFF SELECT AND ACTIVITY BITS.

GYROFRAC 2DEC .215 B-21

# Page 1438

# IMU MODE SWITCHING ROUTINES COME HERE WHEN ACTION COMPLETE.

ENDIMU EXTEND # MODE IS BAD IF CAGE HAS OCCURRED OR IF  
READ DSALMOUT # ISS WARNING IS ON.  
MASK BIT1  
CCS A

```

                                TCF      IMUBAD

IMUGOOD                        TCF      GOODEND      # WITH C(A) = 0.

IMUBAD                         CAF      ZERO
                                TCF      BADEND

CAGETEST                       CAF      BIT6          # SUBROUTINE TO TERMINATE IMU MODE
                                MASK     IMODES30      # SWITCH IF IMU HAS BEEN CAGED.
                                CCS      A
                                TCF      IMUBAD        # DIRECTLY.
                                TC       Q             # WITH C(A) = +0.

CAGETSTQ                       CS       IMODES30      # SKIP IF IMU NOT BEING CAGED.
                                MASK     BIT6
                                CCS      A
                                INCR     Q
                                TC       Q

CAGETSTJ                       CS       IMODES30      # IF DURING MODE SWITCH INITIALIZATION.
                                MASK     BIT6          # IT IS FOUND THAT THE IMU IS BEING CAGED.
                                CCS      A             # SET IMUCADR TO -0 TO INDICATE OPERATION
                                TC       Q             # COMPLETE BUT FAILED.  RETURN IMMEDIATELY
                                CS       ZERO          # TO SWRETURN.
                                TS       IMUCADR
                                TCF      MODEEXIT

# Page 1439
# GENERALIZED MODE SWITCHING TERMINATION.  ENTER AT GOODEND FOR SUCCESSFUL COMPLETION
# OR AT BADEND FOR AN UNSUCCESSFUL ONE.  C(A) OR ARRIVAL =0 FOR IMU, 1 FOR OPTICS.

BADEND                         TS       RUPTREG2      # DEVICE INDEX.
                                CS       ZERO         # FOR FAILURE.
                                TCF      GOODEND +2

GOODEND                        TS       RUPTREG2
                                CS       ONE          # FOR SUCCESS.

                                TS       RUPTREG3
                                INDEX    RUPTREG2      # SEE IF USING PROGRAM ASLEEP.
                                CCS      MODECADR
                                TCF      +2           # YES -- WAKE IT UP.
                                TCF      ENDMODE        # IF 0, PROGRAM NOT IN YET.

                                CAF      ZERO         # WAKE SLEEPING PROGRAM.
                                INDEX    RUPTREG2

```

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```

XCH    MODECADR
TC      JOBWAKE

CS      RUPTREG3      # ADVANCE LOC IF SUCCESSFUL.
INDEX   LOCCTR
ADS     LOC

TCF     TASKOVER

ENDMODE CA      RUPTREG3      # -0 INDICATES OPERATION COMPLETE BUT
INDEX   RUPTREG2      # UNSUCCESSFUL:  -1 INDICATES COMPLETE AND
TS      MODECADR      # SUCCESSFUL.
TCF     TASKOVER
```

```
# Page 1440
# GENERAL STALLING ROUTINE.  USING PROGRAMS COME HERE TO WAIT FOR I/O COMPLETION.
#
# PROGRAM DESCRIPTION                                DATE -- 21 FEB 1967
#                                                    LOG SECTION IMU MODE SWITCHING
# MOD BY -- R. MELANSON TO ADD DOCUMENTATION      ASSEMBLY SUNDISK REV. 82
#
# FUNCTIONAL DESCRIPTION --
#   TO DELAY FURTHER EXECUTION OF THE CALLING ROUTINE UNTIL ITS SELECTED
#   I/O FUNCTION IS COMPLETE.  THE FOLLOWING CHECKS ON THE CALLING ROUTINES
#   MODEECADR ARE MADE AND ACTED UPON.
#   1) +0 INDICATES INCOMPLETE I/O OPERATION.  CALLING ROUTINE IS PUT TO
#   SLEEP.
#   2) -1 INDICATES COMPLETED I/O OPERATION.  STALL BYPASSES JOBSLEEP
#   CALL AND RETURNS TO CALLING ROUTINE AT L+3.
#   3) -0 INDICATES COMPLETED I/O WITH FAILURE.  STALL CLEARS MODECADR
#   AND RETURNS TO CALLING ROUTINE AT L+2.
#   4) VALUE GREATER THAN 0 INDICATES TWO ROUTINES CALLING FOR USE OF
#   SAME DEVICE.  STALL EXITS TO ABORT WHICH EXECUTES A PROGRAM
#   RESTART WHICH IN TURN CLEARS ALL MODECADR REGISTERS.
#
# CALLING SEQUENCE --
#   L      TC      BANKCALL
#   L+1    CADR    (ONE OF 5 STALL ADDRESSES.  I.E., IMUSTALL, OPTSTALL, RADSTALL,
#   AOTSTALL, OR ATTSTALL)
#
# NORMAL-EXIT MODE --
#   TCF JOBSLEEP   OR      TCF MODEEXIT
#
# ALARM OR ABORT EXIT MODE --
#   TC      ABORT
#
```

```

# OUTPUT --
#     MODECADR=CADR    IF JOBSLEEP
#     MODECADR=+0      IF I/O COMPLETE
#     BUF2=L+3         IF I/O COMPLETE AND GOOD.
#     BUF2=L+2         IF I/O COMPLETE BUT FAILED.
#
# ERASABLE INITIALIZATION --
#     BUF2 CONTAINS RETURN ADDRESS PLUS 1,(L+2)
#     BUF2+1 CONTAINS FBANK VALUE OF CALLING ROUTINE.
#     MODECADR OF CALLING ROUTINE CONTAINS +0,-1,-0 OR CADR RETURN ADDRESS.
#
# DEBRIS --
#     RUPTREG2 AND CALLING ROUTINE MODECADR.

AOTSTALL      CAF      ONE          # AOT.
               TC       STALL

RADSTALL      CAF      TWO
               TCF      STALL

# Page 1441
OPTSTALL      EQUALS   AOTSTALL

IMUSTALL      CAF      ZERO         # IMU.

STALL         INHINT
               TS       RUPTREG2    # SAVE DEVICE INDEX.
               INDEX    A           # SEE IF OPERATION COMPLETE.
               CCS      MODECADR
               TCF      MODABORT     # ALLOWABLE STATES ARE +0, -1, AND -0.
               TCF      MODESLP      # OPERATION INCOMPLETE.
               TCF      MODEGOOD     # COMPLETE AND GOOD IF = -1.

MG2           INDEX    RUPTREG2    # COMPLETE FAILED IF -0.  RESET TO +0.
               TS       MODECADR    # RETURN TO CALLER.
               TCF      MODEEXIT

MODEGOOD      CCS      A           # MAKE SURE INITIAL STATE -1.
               TCF      MODABORT

               INCR     BUF2        # IF SO, INCREMENT RETURN ADDRESS AND
               TCF      MG2         # RETURN IMMEDIATELY, SETTIN CADR = +0.

MODESLP       TC       MAKECADR    # CALL FROM SWITCHABLE FIXED ONLY.
               INDEX    RUPTREG2
               TS       MODECADR

```

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```

                                TCF      JOBSLEEP

MODABORT      TC      POOD00      # TWO PROGRAMS USING THE SAME DEVICE.
                                OCT      1210
```

# Page 1442

# CONSTANTS FOR MODE SWITCHING ROUTINES

```

BITS3&4      =      OCT14
BITS4&6      =      OCT50
BITS4-5      EQUALS  BITS4&5
IMUSEFLG     EQUALS  BIT8      # INTERPRETER SWITCH 7.
-COMMAX      DEC      -191
-COMMAX-     DEC      -192
600MS        DEC      60
IMUFIN20     =      IMUFINE
GOMANUR      CA      ATTCADR      # IS KALCMANU FREE
                                EXTEND
                                BZF      +3
                                TC      POOD00      # NO
                                OCT      1210      # 2 TRYING TO USE SAME DEVICE

+3           EXTEND
                                DCA      BUF2
                                DXCH     ATTCADR      # SAVE FINAL RETURN FOR KALCMAN3

                                CA      BBANK
                                MASK     SEVEN
                                ADS      ATTCADR +1

                                CA      PRIORITY
                                MASK     PRI037
                                TS      ATTPRIO      # SAVE USER'S PRIO

                                CAF      KALEBCON      # SET EBANK FOR KALCMAN3
                                TS      EBANK
                                TC      POSTJUMP
                                CADR     KALCMAN3
KALEBCON     ECADR     BCDU
```

# Page 1443

# PROGRAM DESCRIPTION

# IMU STATUS CHECK ROUTINE R02 (SUBROUTINE UTILITY)

# MOD NO -- 1

# MOD BY -- N.BRODEUR

#

```

# FUNCTIONAL DESCRIPTION
#   TO CHECK WHETHER IMU IS ON AND IF ON WHETHER IT IS ALIGNED TO AN
#   ORIENTATION KNOWN BY THE CMC. TO REQUEST SELECTION OF THE APPROPRIATE
#   PROGRAM IF THE IMU IS OFF OR NOT ALIGNED TO AN ORIENTATION KNOWN BY THE
#   CMC. CALLED THROUGH BANKCALL
#
# CALLING SEQUENCE --
#   L      TC      BANKCALL
#   L+1    CADR    R02BOTH
#
# SUBROUTINES CALLED
#   VARALARM
#   FLAGUP
#
# NORMAL EXIT MODES
#   AT L+2 OF CALLING SEQUENCE
#
# ALARM OR ABORT EXIT MODES
#   GOTOPOOH, WITH ALARM
#
# ERASABLE INITIALIZATION REQUIRED
#   NONE
#
# DEBRIS
#   CENTRALS -- A,Q,L

BANK      34
SETLOC    R02
BANK
COUNT    04/R02      # COUNT*

DEC51     DEC      51
R02BOTH   CAF      BIT13
          MASK     STATE +3      # REFSMFLG
          CCS      A
          TC       R02ZERO      # ZERO IMUS

          CA       IMODES30
          MASK     BIT9        # IS ISS INITIALIZED
          EXTEND
          BZF      +2
          CS       BIT4        # SEND IMU ALARM CODE 210
          AD       OCT220      # SEND REFSMM ALARM
          TC       VARALARM

          TC       GOTOPOOH

```

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# Page 1444

R02ZERO	TC	UPFLAG
	ADRES	IMUSE
	TCF	SWRETURN
OCT220	OCT	220

# Page 1445

# PROGRAM DESCRIPTION: P06 10 FEB 67

#

# TRANSFER THE ISS/CMC FROM THE OPERATE TO THE STANDBY CONDITION.

#

# THE NORMAL CONDITION OF READINESS OF THE GNCS WHEN NOT IN USE IS STANDBY. IN THIS CONDITION  
# HEATER POWER IS ON. THE IMU OPERATE POWER IS OFF. THE COMPUTER POWER IS ON. THE OPTICS POW  
# CMC STANDBY ON THE MAIN AND LEB DISKYS IS ON.

#

# CALLING SEQUENCE:

# ASTRONAUT REQUEST THROUGH DSKY V37E 06E.

#

# SUBROUTINES CALLED:

# GOPERF1

# BANKCALL

# FLAGDOWN

#

# Page 1446

# PRESTAND PREPARES FOR STANDBY BY SNAPSHOTTING THE SCALER AND TIME1 TIME2.

# THE LOW 5 BITS OF THE SCALER ARE INSPECTED TO INSURE COMPATIBILITY

# BETWEEN THE SCALER READING AND THE TIME1 TIME2 READING.

SETLOC P05P06  
BANK

EBANK= TIME2SAV  
COUNT\* \$\$/P06

P06	TC	UPFLAG	# SET NODOV37 BIT
	ADRES	NODOFLAG	

PRESTAND INHINT  
EXTEND

DCA TIME2 # SNAPSHOT TIME1 TIME2

DXCH TIME2SAV

TC SCALPREP

TC PRESTAND # T1,T2,SCALER NOT COMPATIBLE

DXCH MPAC # T1,T2 AND SCALER OK

DXCH SCALSAVE # STORE SCALER

```

      INHINT
      TC      BANKCALL
      CADR     RNDREFDR      # REFSMM, DRIFT, TRACK FLAGS DOWN

      TC      DOWNFLAG
      ADRES    IMUSE         # IMUSE DOWN
      TC      DOWNFLAG
      ADRES    RNDVZFLG      # RNDVZFLG DOWN

      CAF      BIT11
      EXTEND
      WOR      CHAN13        # SET STANDBY ENABLE BIT

      TC      PHASCHNG       # SET RESTART TO POSTAND WHEN STANDBY
      OCT     07024          # RECOVERS
      OCT     20000
      EBANK=   SCALSAVE
      2CADR    POSTAND

      CAF      OCT62
      TC      BANKCALL
      CADR     GOPERF1
      TCF     -3
      TCF     -4
      TCF     -5

OCT62      EQUALS   .5SEC      # DEC 50 = OCT 62

# THE LOW 5 BITS OF THE SCALER READS 10000 FOR THE FIRST INTERVAL AFTER A
# Page 1447.
# T1 INCREMENT. IF SCALPREP DETECTS THIS INTERVAL THE T1,T2 AND SCALER
# DATA ARE NOT COMPATIBLE AND RETURN IS TO L+1 FOR ANOTHER READING OF THE
# DATA. OTHERWISE, THE RETURN IS TO L+2 TO PROCEED. ROUTINE ALSO PREPARES
# THE SCALER READING FOR COMPUTATION OF THE INCREMENT TO UPDATE T1T2. (THE
# 10 MS BIT (BIT 6) OF THE SCALER IS INCREMENTED 5 MS OUT OF PHASE FROM
# T1.) ADDITION OF 5 MS (BIT 5) TO THE SCALER READING HAS THE EFFECT OF
# ADJUSTING BIT 6 IN THE SCALER TO BE IN PHASE WITH BIT 1 OF T1. THE LOW 5
# BITS OF THE SCALER READING ARE THEN SET TO ZERO, TO TRUNCATE THE SCALER
# DATA TO 10 MS. RESULTS ARE STORED IN MPAC, +1.

SCALPREP   EXTEND
           QXCH    MPAC +2
           TC      FINETIME +1
           RELINT
           DXCH    MPAC
           CA      BIT5      # ADD 5 MS TO THE SCALER READING.

```



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```
TS      L
CA      ZERO
DAS     MPAC
CS      LOW5          # SET LOW 5 BITS OF (SCALER+5MS) TO ZERO
MASK    MPAC +1      # AND STORE RESULTS IN MPAC,+1.
XCH     MPAC +1
MASK    LOW5          # TEST LOW 5 BITS OF SCALER FOR THE FIRST
                        # INTERVAL AFTER THE T1 INCREMENT
                        # (NOW = 00000, SINCE BIT 5 ADDED).
CCS     A             # IS IT 1ST INTERVAL AFTER T1 INCREMENT
INCR    MPAC +2       # NO
TC      MPAC +2       # YES
```

```
# POSTAND RECOVERS TIME AFTER STANDBY.  THE SCALER IS SNAPSHOTTED AND THE
# TIME1 TIME2 COUNTER IS SET TO ZERO.  THE LOW 5 BITS OF THE SCALER ARE
# INSPECTED TO INSURE COMPATIBILITY BETWEEN THE SCALER READING AND THE
# CLEARING OF THE TIME COUNTER.  IT THEN COMPUTES THE DIFFERENCE IN SCALER
# VALUES (IN DP) AND ADDS THIS TO THE PREVIOUSLY SNAPSHOTTED VALUES OF
# TIME1 TIME2 AND PLACES THIS NEW TIME INTO THE TIME1 TIME2 COUNTER.
```

```
COUNT*  $$/P05
```

```
POSTAND  CS      BIT11          # RECOVER TIME AFTER STANDBY
          EXTEND
          WAND    CHAN13        # CLEAR STANDBY ENABLE BIT
          INHINT
          CA      ZERO
          TS      L
          DXCH    TIME2         # CLEAR TIME1 TIME2
          TC      SCALPREP      # STORE SCALER IN MPAC, MPAC+1
          TC      POSTAND +3    # T1,T2,SCALER NOT COMPATIBLE
          EXTEND          # T1,T2 AND SCALER OK
          DCS     SCALSAVE
          DAS     MPAC          # FORM DP DIFFERENCE OF POST-STANDBY SCALER
# Page 1448
          CAF     BIT10         # MINUS PRE-STANDBY SCALER AND SHIFT RIGHT
          TC      SHORTMP       # 5 TO ALIGN BITS WITH TIME1 TIME2.
          CAF     ZERO
          TS      MPAC +2       # NEEDED FOR TP AGREE
          TC      TPAGREE       # MAKE DP DIFF AGREE
          CCS     MPAC
          TC      POSTCOM       # IF DP DIFF NET +, NO SCALER OVERFLOW
          TC      POSTCOM       # BETWEEN PRE AND POST STANDBY.
          TC      +1            # IF DP DIFF NET -, SCALER OVERFLOWED.  ADD
          CAF     BIT10         # BIT 10 TO HIGH DIFF TO CORRECT.
          ADS     MPAC
```

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```
POSTCOM      EXTEND      # C(MPAC,+1) IS MAGNITUDE OF DELTA SCALER.
              DCA        TIME2SAV      # PRE-STANDBY TIME1 TIME2
              DAS        MPAC
              TC         TPAGREE        # FORCE SIGN AGREEMENT
              DXCH       MPAC           # UPDATED VALUE FOR T1,T2.
              DAS        TIME2          # LOAD UPDATED VALUE INTO T1,T2, WITH
              TC         DOWNFLAG       # CLEAR NODOFLAG
              ADRES      NODOFLAG

              TC         GOTOPOOH
```

This code is written to file `src/IMU-MODE-SWITCHING-ROUTINES.s`.

## A.39 IMU PERFORMANCE TEST 2

```

667  <src/IMU-PERFORMANCE-TEST-2.s 667>≡
    # Copyright:    Public domain.
    # Filename:     IMU_PERFORMANCE_TEST_2.agc
    # Purpose:      Part of the source code for Luminary 1A build 099.
    #               It is part of the source code for the Lunar Module's (LM)
    #               Apollo Guidance Computer (AGC), for Apollo 11.
    # Assembler:    yaYUL
    # Contact:       Ron Burkey <info@sandroid.org>.
    # Website:       www.ibiblio.org/apollo.
    # Pages:         373-381
    # Mod history:   2009-05-17 RSB   Adapted from the corresponding
    #               Luminary131 file, using page
    #               images from Luminary 1A.
    #
    # This source code has been transcribed or otherwise adapted from
    # digitized images of a hardcopy from the MIT Museum. The digitization
    # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
    # the Museum. Many thanks to both. The images (with suitable reduction
    # in storage size and consequent reduction in image quality as well) are
    # available online at www.ibiblio.org/apollo. If for some reason you
    # find that the images are illegible, contact me at info@sandroid.org
    # about getting access to the (much) higher-quality images which Paul
    # actually created.
    #
    # Notations on the hardcopy document read, in part:
    #
    #       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
    #       16:27 JULY 14, 1969
    #
    # Page 373
    # NAME --        IMU PERFORMANCE TESTS 2
    #
    # DATE --        MARCH 20, 1967
    #
    # BY --          SYSTEM TEST GROUP 864-6900 EXT. 1274
    #
    # MODNO. --      ZERO
    #
    # FUNCTIONAL DESCRIPTION
    #
    # POSITIONING ROUTINES FOR THE IMU PERFORMANCE TESTS AS WELL AS SOME OF
    # THE TESTS THEMSELVES. FOR A DESCRIPTION OF THESE SUBROUTINES AND THE
    # OPERATING PROCEDURES (TYPICALLY) SEE STG MEMO 685. THEORETICAL REF. E-1973

```

	BANK	33
	SETLOC	IMU2
	BANK	
	EBANK=	POSITON
	COUNT*	\$\$/P07
REDO	TC	NEWMODEX
	MM	07
GEOIMUTT	TC	IMUZERR
IMUBACK	CA	ZERO
	TS	NDXCTR
	TS	TORQNDX
	TS	TORQNDX +1
	TS	OVFLOWCK
NBPOSPL	CA	DEC17
	TS	ZERONDY
	CA	XNBADR
	TC	ZEROING
	CA	HALF
	TS	XNB
GUESS	TC	INTPRET
LATAZCHK	DLOAD	SL2
		LATITUDE
	STODL	DSPTM1 +1
		AZIMUTH
	RTB	EXIT
		1ST02S
	XCH	MPAC
	TS	DSPTM1
	CAF	VN0641
	TC	BANKCALL
	CADR	GOFLASH
	TC	ENDTEST1
	TC	+2
	TC	-5
# Page 374	TC	INTPRET
	SLOAD	RTB
		DSPTM1
		CDULOGIC
	STORE	AZIMUTH
	SLOAD	SR2
		DSPTM1 +1
	STORE	LATITUDE
	COS	DCOMP

	SL1		
	STODL	WANGI	
		LATITUDE	
	SIN	SL1	
	STODL	WANGO	
		AZIMUTH	
	PUSH	SIN	
	STORE	YNB	+2
	STODL	ZNB	+4
	COS		
	STORE	YNB	+4
	DCOMP		
POSGMBL	STCALL	ZNB	+2
		CALCGA	
	EXIT		
	TC	BANKCALL	
	CADR	IMUCOARS	
	CAF	BIT14	# IF BIT14 SET, GIMBAL LOCK
	MASK	FLAGWRD3	
	EXTEND		
	BZF	+2	
	INCR	NDXCTR	# +1 IF IN GIMBAL LOCK, OTHERWISE 0
	TC	DOWNFLAG	
	ADRES	GLOKFAIL	# RESET GIMBAL LOCK FLAG
	TC	IMUSLLLG	
	CCS	NDXCTR	# IF ONE GO AND DO A PIPA TEST ONLY
	TC	PIPACHK	# ALIGN AND MEASURE VERTICAL PIPA RATE
	TC	FINIMUDD	
	EXTEND		
	DCA	PERFDLAY	
	TC	LONGCALL	# DELAY WHILE SUSPENSION STABILIZES
	EBANK=	POSITON	
	2CADR	GOESTIMS	
	CA	ESTICADR	
	TC	JOBSLEEP	
GOESTIMS	CA	ESTICADR	
	TC	JOBWAKE	
	TC	TASKOVER	
ESTICADR	CADR	ESTIMS	
TORQUE	CA	ZERO	
# Page 375			
	TS	DSPTM2	
	CA	DRIFTI	
	TS	DSPTM2	+1
	INDEX	POSITON	

	TS	SOUTHDR -1	
	TC	SHOW	
PIPACHK	INDEX	NDXCTR	# PIPA TEST
	TC	+1	
	TC	EARTH*	
	CA	DEC17	# ALLOW PIP COUNTER TO OVERFLOW 17 TIMES
	TS	DATAPL +4	# IN THE ALLOTTED TIME INTERVAL
	CA	DEC58	
	TS	LENGTHOT	
	CA	ONE	
	TS	RESULTCT	
	CA	ZERO	
	INDEX	PIPINDEX	
	TS	PIPAX	
	TS	DATAPL	
	TC	CHECKG	
	INHINT		
	CAF	TWO	
	TC	TWIDDLE	
	EBANK=	XSM	
	ADRES	PIPATASK	
	TC	ENDOFJOB	
PIPATASK	EXTEND		
	DIM	LENGTHOT	
	CA	LENGTHOT	
	EXTEND		
	BZMF	STARTPIP	
	CAF	BIT10	
	TC	TWIDDLE	
	EBANK=	XSM	
	ADRES	PIPATASK	
STARTPIP	CAF	PRI020	
	TC	FINDVAC	
	EBANK=	XSM	
	2CADR	PIPJOB	
	TC	TASKOVER	
PIPJOB	INDEX	NDXCTR	
	TC	+1	
	TC	EARTH*	
	CA	LENGTHOT	
# Page 376	EXTEND		

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	BZMF	+2	
	TC	ENDOFJOB	
	CA	FIVE	
	TS	RESULTCT	
	TC	CHECKG	
	CCS	DATAPL +1	
	TC	+4	
	TC	CCSHOLE	
	CS	DATAPL +4	
	TS	DATAPL +4	
	EXTEND		
	DCS	DATAPL	
	DAS	DATAPL +4	
	TC	INTPRET	
	DLOAD	DSU	
		DATAPL +6	
		DATAPL +2	
	BPL	CALL	
		AINGOTN	
		OVERFFIX	
AINGOTN	PDDL	DDV	
		DATAPL +4	
	DMPR	RTB	
		DEC585	# DEC585 HAS BEEN REDEFINED FOR LEM
		SGNAGREE	
	STORE	DSPTM2	
	EXIT		
	CCS	NDXCTR	
	TC	COAALIGN	# TAKE PLATFORM OUT OF GIMBAL LOCK
	TC	SHOW	
VERTDRFT	CA	3990DEC	# ABOUT 1 HOUR VERTICAL DRIFT TEST
	TS	LENGTHOT	
	INDEX	POSITON	
	CS	SOUTHDR -2	
	TS	DRIFTT	
	CCS	PIPINDEX	# OFFSET PLATFORM TO MISS PIP DEAD-ZONES
	TCF	PON4	# Z-UP IN POS 4
PON2	CS	BIT5	# X-UP
	ADS	ERCOMP +2	
	CA	BIT5	
	ADS	ERCOMP +4	
	TCF	PON	
PON4	CS	BIT5	
	ADS	ERCOMP +2	

	CA	BIT5	
	ADS	ERCOMP	
PON	TC	EARTH*	
# Page 377			
	CA	ZERO	# ALLOW ONLY SOUTH GYRO EARTH RATE COMPENS
	TS	ERVECTOR	
	TS	ERVECTOR +1	
GUESS1	CAF	POSMAX	
	TS	TORQNDX	
	TS	TORQNDX +1	
	CA	CDUX	
	TS	LOSVEC	
	TC	ESTIMS	
VALMIS	CA	DRIFT0	
	TS	DSPTM2 +1	
	CA	ZERO	
	TS	DSPTM2	
	TC	SHOW	
ENDTEST1	TC	DOWNFLAG	
	ADRES	IMUSE	
	CS	ZERO	
	TC	NEWMODEA	
	TC	ENDEXT	
# Page 378			
OVERFFIX	DAD	DAD	
		DPPOSMAX	
		ONEDPP	
	RVQ		
COAALIGN	EXTEND		# COARSE ALIGN SUBROUTINE
	QXCH	ZERONDX	
	CA	ZERO	
	TS	THETAD	
	TS	THETAD +1	
	TS	THETAD +2	
	TC	BANKCALL	
	CADR	IMUCOARS	
ALIGNCOA	TC	BANKCALL	
	CADR	IMUSTALL	
	TC	SOMERR2	
	TC	ZERONDX	
IMUSLLLG	EXTEND		
	QXCH	ZERONDX	



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	TC	ALIGNCOA	
FINIMUDD	EXTEND		
	QXCH	ZERONDX	
	TC	BANKCALL	
	CADR	IMUFINE	
	TC	ALIGNCOA	
IMUZERR	EXTEND		
	QXCH	ZERONDX	
	TC	BANKCALL	
	CADR	IMUZERO	
	TC	ALIGNCOA	
CHECKG	EXTEND		# PIP PULSE CATCHING ROUTINE
	QXCH	QPLACE	
	TC	+6	
CHECKG1	RELINT		
	CA	NEWJOB	
	EXTEND		
	BZMF	+6	
	TC	CHANG1	
	INHINT		
	INDEX	PIPINDEX	
	CS	PIPAX	
	TS	ZERONDX	
	INHINT		
# Page 379	INDEX	PIPINDEX	
	CA	PIPAX	
	AD	ZERONDX	
	EXTEND		
	BZF	CHECKG1	
	INDEX	PIPINDEX	
	CA	PIPAX	
	INDEX	RESULTCT	
	TS	DATAPL	
	TC	FINETIME	
	INDEX	RESULTCT	
	TS	DATAPL +1	
	INDEX	RESULTCT	
	LXCH	DATAPL +2	
	RELINT		
ENDCHKG	TC	QPLACE	
ZEROING	TS	L	

	TCF	+2
ZEROING1	TS	ZERONDX
	CAF	ZERO
	INDEX	L
	TS	0
	INCR	L
	CCS	ZERONDX
	TCF	ZEROING1
	TC	Q

# Page 380

ERTHRVSE	DLOAD	PDDL SCHZEROS LATITUDE	# PD24 = (SIN	-COS	0) (OMEG/MS
	COS	DCOMP			
	PDDL	SIN LATITUDE			
	VDEF	VXSC OMEG/MS			
	STORE	ERVECTOR			
	RTB				
		LOADTIME			
	STOVL	TMARK SCHZEROS			
	STORE	ERCOMP			
	RVQ				
EARTH	ITA	RTB S2 LOADTIME			
	STORE	TEMPTIME			
	DSU	BPL TMARK ERTHR			
	CALL				
ERTHR	SL	OVERFFIX VXSC 9D ERVECTOR			
	MXV	VAD XSM ERCOMP			
	STODL	ERCOMP TEMPTIME			
	STORE	TMARK			
	AXT,1	RTB			

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```

                                ECADR  ERCOMP
                                PULSEIMU
                                GOTO
                                S2

EARTH*  EXTEND
        QXCH  QPLACES
        TC    INTPRET
        CALL
        EARTH
        EXIT
        TC    IMUSLLLG
        TC    QPLACES

SHOW
# Page 381
        EXTEND
        QXCH  QPLACE
        CA    POSITON
        TS    DSPTM2 +2
        CA    VB06N98
        TC    BANKCALL
        CADR  GOFLASH
        TC    ENDTEST1      # V34
        TC    QPLACE        # V33
        TCF   SHOW1

3990DEC  DEC    3990
VB06N98  VN     0698
VN0641   VN     0641
DEC17    =      ND1
DEC58    DEC    58
OGCPL    ECADR  OGC
1SECX    =      1SEC
XNBADR   GENADR XNB
XSMADR   GENADR XSM
        BLOCK  2
        COUNT* $$/P07
FINETIME INHINT      # RETURNS WITH INTERRUPT INHIBITED
        EXTEND
        READ    LOSCALAR
        TS      L
        EXTEND
        RXOR    LOSCALAR
        EXTEND
        BZF     +4
        EXTEND
```

```

                                READ   LOSCALAR
                                TS      L
+4                               CS      POSMAX
                                AD      L
                                EXTEND
                                BZF     FINETIME +1
                                EXTEND
                                READ     HISCALAR
                                TC Q
```

This code is written to file `src/IMU-PERFORMANCE-TEST-2.s`.

## A.40 IMU PERFORMANCE TESTS 4

```

677 <src/IMU-PERFORMANCE-TESTS-4.s 677>≡
# Copyright:      Public domain.
# Filename:       IMU_PERFORMANCE_TESTS_4.agc
# Purpose:       Part of the source code for Luminary 1A build 099.
#               It is part of the source code for the Lunar Module's (LM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:    yaYUL
# Contact:       Ron Burkey <info@sandroid.org>.
# Website:       www.ibiblio.org/apollo.
# Pages:        382-389
# Mod history:   2009-05-17 RSB   Adapted from the corresponding
#               Luminary131 file, using page
#               images from Luminary 1A.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
#       16:27 JULY 14, 1969
#
# Page 382
# PROGRAM --      IMU PERFORMANCE TESTS 4
# DATE --        NOV 15, 1966
# BY --          GEORGE SCHMIDT IL7-146 EXT 1126
# MOD NO-ZERO
#
# FUNCITONAL DESCRIPTION
#
# THIS SECTION CONSISTS OF THE FILTER FOR THE GYRO DRIFT TESTS. NO COMPASS
# IS DONE IN LEM. FOR A DESCRIPTION OF THE FILTER SEE E-1973. THIS
# SECTION IS ENTERED FROM IMU 2. IT RETURNS THERE AT END OF TEST.
#
# EARTH,OGC ZERO,ERTHRVSE
#
# NORMAL EXIT

```

```

#
# LENGTHOT GOES TO ZERO -- RETURN TO IMU PERF TESTS 2 CONTROL
#
# ALARMS
#
# 1600 OVERFLOW IN DRIFT TEST
# 1601 BAD IMU MODING IN ANY ROUTINE THAT USES IMUSTALL
#      OUTPUT
#
# FLASHING DISPLAY OF RESULTS -- CONTROLLED IN IMU PERF TESTS 2
#
# DEBRIS
#
# ALL CENTRALS -- ALL OF EBANK XSM

```

```

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```

```

BANK      33
SETLOC    IMU4
BANK
COUNT*   $$/P07

```

```

EBANK=    XSM

```

```

ESTIMS      INHINT
CAE         1SECXT
TC          TWIDDLE
EBANK=      XSM
ADRES       ALLOOP
CAF         ZERO          # ZERO THE PIPAS
TS          PIPAX
TS          PIPAY
TS          PIPAZ
RELINT
CA          77DECML
TS          ZERONDX
CA          ALXXXZ
TC          ZEROING
TC          INTPRET
SLOAD
           SCHZEROS
STOVL       GCOMP SW -1
           INTVAL  +2
STOVL       ALX1S
           SCHZEROS
STORE       DELVX
STORE       GCOMP

```

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```

                                SLOAD
                                TORQNDX
                                DCOMP BMN
                                VERTSKIP
                                CALL
                                ERTHRVSE
VERTSKIP EXIT
TC      SLEEPIC +1

# Page 384
ALLOOP  CA      OVFLOWCK
        EXTEND
        BZF     +2
        TC      TASKOVER
        CCS     ALTIM
        CA      A                                # SHOULD NEVER HIT THIS LOCATION
        TS      ALTIMS
        CS      A
        TS      ALTIM
        CS      ONE
        AD      GEOCOMPS
        EXTEND
        BZF     +4
        CA      LENGTHOT
        EXTEND
        BZMF    +5
        CAE     1SECXT
        TC      TWIDDLE
        EBANK=   XSM
        ADRES    ALLOOP
        CAF      ZERO
        XCH      PIPAX
        TS      DELVX
        CAF      ZERO
        XCH      PIPAY
        TS      DELVY
        CAF      ZERO
        XCH      PIPAZ
        TS      DELVZ
SPECSTS CAF      PRI020
        TC      FINDVAC
        EBANK=   XSM
        2CADR    ALFLT                                # START THE JOB

        TC      TASKOVER
```

# Page 385

ALFLT	CCS	GEOCOMPS	
	TC	+2	
	TC	NORMLOP	
	TC	BANKCALL	
	CADR	1/PIPA	
NORMLOP	TC	INTPRET	
	DLOAD		
		INTVAL	
	STOVL	S1	
		DELVX	
	VXM	VSL1	
		XSM	
	DLOAD	DCOMP	
		MPAC +3	
	STODL	DPIPAY	
		MPAC +5	
	STORE	DPIPZ	
	SETPD	AXT,1	
		0	
		8D	
	SLOAD	DCOMP	
		GEOCOMPS	
	BMN		
		PERFERAS	
ALCGKK	SLOAD	BMN	
		ALTIMS	
		ALFLT3	
ALKCG	AXT,2	LXA,1	# LOADS SLOPES AND TIME CONSTANTS AT RQST
		12D	
		ALX1S	
ALKCG2	DLOAD*	INCR,1	
		ALFDK +144D,1	
	DEC	-2	
	STORE	ALDK +10D,2	
	TIX,2	SXA,1	
		ALKCG2	
		ALX1S	
ALFLT3	AXT,1		
		8D	
DEMLP	DLOAD*	DMP	
		DPIPAY +8D,1	
		PIPASC	
	SLR	BDSU*	



```

          9D
          INTY      +8D,1
STORE    INTY      +8D,1
PDDL     DMP*
          VELSC

# Page 386

          VLAUN     +8D,1
SL2R
DSU       STADR
STORE     DELM      +8D,1
STORE     DELM      +10D,1
TIX,1     AXT,2
          DELMLP
          4
ALILP     DLOAD*    DMPR*
          ALK        +4,2
          ALDK       +4,2
STORE     ALK        +4,2
TIX,2     AXT,2
          ALILP
          8D
ALKLP     LXC,1     SXA,1
          CMPX1
          CMPX1
DLOAD*    DMPR*
          ALK        +1,1
          DELM       +8D,2
DAD*
          INTY       +8D,2
STORE     INTY       +8D,2
DLOAD*    DAD*
          ALK        +12D,2
          ALDK       +12D,2
STORE     ALK        +12D,2
DMPR*     DAD*
          DELM       +8D,2
          INTY       +16D,2
STORE     INTY       +16D,2
DLOAD*    DMP*
          ALSK       +1,1
          DELM       +8D,2
SL1R      DAD*
          VLAUN      +8D,2
STORE     VLAUN      +8D,2
TIX,2     AXT,1
          ALKLP

```

```

                                8D

LOOSE      DLOAD*  PDDL*
                                ACCWD  +8D,1
                                VLAUN  +8D,1
                                PDDL*  VDEF
                                POSNV  +8D,1
                                MXV    VSL1
                                TRANSM1

# Page 387

                                DLOAD
                                MPAC
STORE      POSNV  +8D,1
DLOAD
                                MPAC  +3
STORE      VLAUN  +8D,1
DLOAD
                                MPAC  +5
STORE      ACCWD  +8D,1
TIX,1
                                LOOSE

                                AXT,2  AXT,1      # EVALUATE SINES AND COSINES
                                6
                                2
BOOP      DLOAD*  DMPR
                                ANGX  +2,1
                                GEORGEJ

SR2R
PUSH      SIN
SL3R      XAD,1
                                X1
STORE      16D,2
DLOAD
COS
STORE      22D,2      # COSINES
TIX,2
                                BOOP

PERFERAS   EXIT
CA          EBANK7
TS          EBANK
EBANK=     ATIGINC
TC          ATIGINC      # GOTO ERASABLE TO CALCULATE ONLY TO RETN

#                                CAUTION

```

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```
#
# THE ERASABLE PROGRAM THAT DOES THE CALCULATIONS MUST BE LOADED
# BEFORE ANY ATTEMPT IS MAKE TO RUN THE IMU PERFORMANCE TEST
```

```
EBANK=  AZIMUTH
CCS      LENGTHOT
TC       SLEEPIE
CCS      TORQNDX
TCF      +2
TC       SETUPER1
CA       CDUX
TS       LOSVEC  +1      # FOR TROUBLESHOOTING VD POSNS 2$4
```

# Page 388

```
SETUPER1  TC      INTPRET
          DLOAD    PDDL          # ANGLES FROM DRIFT TEST ONLY
          ANGZ
          ANGY
          PDDL     VDEF
          ANGX
          VCOMP    VXSC
          GEORGEJ
          MXV      VSR1
          XSM
          STORE    OGC
          EXIT

          CA       OGCPL
          TC       BANKCALL
          CADR     IMUPULSE
          TC       IMUSLLLG
          CCS      TORQNDX      # ONLY POSITIVE IF IN VERTICAL DRIFT TEST
          TC       VALMIS
          TC       INTPRET
          CALL
          ERTHRVSE
          EXIT
          TC       TORQUE

SLEEPIE   TS       LENGTHOT      # TEST NOT OVER-DECREMENT LENGTHOT
          CCS      TORQNDX      # ARE WE DOING VERTDRIFT
          TC       EARTH*
          TC       ENDOFJOB

SOMEERRR  CA       EBANK5
          TS       EBANK
```

	CA	ONE	
	TS	OVFLOWCK	# STOP ALLOOP FROM CALLING ITSELF
	TC	ALARM	
	OCT	1600	
	TC	ENDTEST1	
SOMERR2	CAF	OCT1601	
	TC	VARALARM	
	TC	DOWNFLAG	
	ADRES	IMUSE	
	TC	ENDOFJOB	
OCT1601	OCT	01601	
DEC585	OCT	06200	# 3200 B+14 ORDER IS IMPORTANT
SCHZEROS	2DEC	.00000000	
# Page 389			
	2DEC	.00000000	
	OCT	00000	
ONEDPP	OCT	00000	# ORDER IS IMPORTANT
	OCT	00001	
INTVAL	OCT	4	
	OCT	2	
	DEC	144	
	DEC	-1	
SOUPLY	2DEC	.93505870	# INITIAL GAINS FOR PIP OUTPUTS
	2DEC	.26266423	# INITIAL GAINS/4 FOR ERECTION ANGLES
77DECML	DEC	77	
ALXXXZ	GENADR	ALX1S -1	
PIPASC	2DEC	.13055869	
VELSC	2DEC	-.52223476	# 512/980.402
ALSK	2DEC	.17329931	# SSWAY VEL GAIN X 980.402/4096
	2DEC	-.00835370	# SSWAY ACCEL GAIN X 980.402/4096
GEORGEJ	2DEC	.63661977	
GEORGEK	2DEC	.59737013	

This code is written to file src/IMU-PERFORMANCE-TESTS-4.s.

## A.41 INFLIGHT ALIGNMENT ROUTINES

685

*<src/INFLIGHT-ALIGNMENT-ROUTINES.s 685>≡*

```
# Copyright:      Public domain.
# Filename:       INFLIGHT_ALIGNMENT_ROUTINES.agc
# Purpose:       Part of the source code for Colossus 2A, AKA Comanche 055.
#               It is part of the source code for the Command Module's (CM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:    yaYUL
# Contact:       Ron Burkey <info@sandroid.org>.
# Website:      www.ibiblio.org/apollo.
# Pages:        1355-1364
# Mod history:   2009-05-14 RSB   Adapted from the Colossus249/ file of the
#                               same name, using Comanche055 page images.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 055 of AGC program Comanche by NASA
#       2021113-051.  10:28 APR. 1, 1969
#
#       This AGC program shall also be referred to as
#       Colossus 2A
#
# Page 1355
#
#       BANK      22
#       SETLOC    INFLIGHT
#       BANK
#
#       EBANK=    XSM
#
# CALCGTA COMPUTES THE GYRO TORQUE ANGLES REQUIRED TO BRING THE STABLE MEMBER INTO THE DESIRED
#
# THE INPUT IS THE DESIRED STABLE MEMBER COORDINATES REFERRED TO PRESENT STABLE MEMBER COORDINATE
# HALF-UNIT VECTORS ARE STORED AT XDC, YDC, AND ZDC.
#
# THE OUTPUTS ARE THE THREE GYRO TORQUE ANGLES TO BE APPLIED TO THE Y, Z, AND X GYROS AND ARE STORED
# MGC, AND OGC RESPECTIVELY.
```

	COUNT	23/INFLT	
CALCGTA	ITA	DLOAD	# PUSHDOWN 00-03, 16D-27D, 34D-37D
		S2	# XDC = (XD1 XD2 XD3)
		XDC	# YDC = (YD1 YD2 YD3)
	PDDL	PDDL	# ZDC = (ZD1 ZD2 ZD3)
		HI6ZEROS	
		XDC +4	
	DCOMP	VDEF	
	UNIT		
	STODL	ZPRIME	# ZP = UNIT(-XD3 0 XD1) = (ZP1 ZP2 ZP3)
		ZPRIME	
	SR1		
	STODL	SINTH	# SIN(IGC) = ZP1
		ZPRIME +4	
	SR1		
	STCALL	COSTH	# COS(IGC) = ZP3
		ARCTRIG	
	STODL	IGC	# Y GYRO TORQUING ANGLE FRACTION OF REV.
		XDC +2	
	SR1		
	STODL	SINTH	# SIN(MGC) = XD2
		ZPRIME	
	DMP	PDDL	
		XDC +4	# PD00 = (ZP1)(XD3)
		ZPRIME +4	
	DMP	DSU	
		XDC	# MPAC = (ZP3)(XD1)
	STADR		
	STCALL	COSTH	# COS(MGC) = MPAC - PD00
		ARCTRIG	
# Page 1356	STOVL	MGC	# Z GYRO TORQUING ANGLE FRACTION OF REV.
		ZPRIME	
	DOT		
		ZDC	
	STOVL	COSTH	# COS(OGC) = ZP . ZDC
		ZPRIME	
	DOT		
		YDC	
	STCALL	SINTH	# SIN(OGC) = ZP . YDC

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# ARCTRIG

STCALL OGC # X GYRO TORQUING ANGLE FRACTION OF REV.  
S2

# Page 1357

# ARCTRIG COMPUTES AN ANGLE GIVEN THE SINE AND COSINE OF THIS ANGLE.

#

# THE INPUTS ARE SIN/4 AND COS/4 STORED DP AT SINTH AND COSTH.

#

# THE OUTPUT IS THE CALCULATED ANGLE BETWEEN +.5 AND -.5 REVOLUTIONS AND STORED AT THETA. THE  
# AVAILABLE AT MPAC.

ARCTRIG	DLOAD	ABS SINTH	# PUSHDOWN 16D-21D
	DSU	BMN QTSN45 TRIG1	# ABS(SIN/4) - SIN(45)/4 # IF (-45,45) OR (135,-135)
	DLOAD	SL1 COSTH	# (45,135) OR (-135,-45)
	ACOS	SIGN SINTH	
	STORE RVQ	THETA	# X = ARCCOS(COS) WITH SIGN(SIN)
TRIG1	DLOAD	SL1 SINTH	# (-45,45) OR (135,-135)
	ASIN		
	STODL	THETA COSTH	# X = ARCSIN(SIN) WITH SIGN(SIN)
	BMN	TRIG2	# IF (135,-135)
	DLOAD	RVQ THETA	# X = ARCSIN(SIN) (-45,45)
TRIG2	DLOAD	SIGN HIDPHALF SINTH	# (135,-135)
	DSU	THETA	
	STORE RVQ	THETA	# X = .5 WITH SIGN(SIN) - ARCSIN(SIN) # (+) - (+) OR (-) - (-)

# Page 1358

# SMNB, NBSM, AND AXISROT, WHICH USED TO APPEAR HERE, HAVE BEEN  
 # COMBINED IN A ROUTINE CALLED AX\*SR\*T, WHICH APPEARS AMONG THE POWERED  
 # FLIGHT SUBROUTINES.

# Page 1359

# CALCGA COMPUTES THE CDU DRIVING ANGLES REQUIRED TO BRING THE STABLE MEMBER INTO THE  
 #

# THE INPUTS ARE 1) THE NAVIGATION BASE COORDINATES REFERRED TO ANY COORDINATE SYSTEM  
 # VECTORS ARE STORED AT XNB, YNB, AND ZNB. 2) THE DESIRED STABLE MEMBER COORDINATES  
 # COORDINATE SYSTEM ARE STORED AT XSM, YSM, AND ZSM.

#

# THE OUTPUTS ARE THE THREE CDU DRIVING ANGLES AND ARE STORED SP AT THETAD, THETAD +1

CALCGA	SETPD		# PUSHDOWN 00-05, 16D-21D, 34D-37D
		0	
	VLOAD	VXV	
		XNB	# XNB = OGA (OUTER GIMBAL AXIS)
		YSM	# YSM = IGA (INNER GIMBAL AXIS)
	UNIT	PUSH	# PDO = UNIT(OGA X IGA) = MGA
	DOT	ITA	
		ZNB	
		S2	
	STOVL	COSTH	# COS(OG) = MGA . ZNB
		0	
	DOT		
		YNB	
	STCALL	SINTH	# SIN(OG) = MGA . YNB
		ARCTRIG	
	STOVL	OGC	
		0	
	VXV	DOT	# PROVISION FOR MG ANGLE OF 90 DEGREES
		XNB	
		YSM	
	SL1		
	STOVL	COSTH	# COS(MG) = IGA . (MGA X OGA)
		YSM	
	DOT		
		XNB	
	STCALL	SINTH	# SIN(MG) = IGA . OGA
		ARCTRIG	
	STORE	MGC	
	ABS	DSU	
		.166...	



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```

                                BPL
                                GIMLOCK1      # IF ANGLE GREATER THAN 60 DEGREES

CALCGA1      VLOAD  DOT
                                ZSM
                                0
                                STOVL  COSTH      # COS(IG) = ZSM . MGA
                                XSM

# Page 1360
                                DOT    STADR
                                STCALL  SINTH      # SIN(IG) = XSM . MGA
                                ARCTRIG

                                STOVL  IGC
                                OGC
                                RTB    BONCLR
                                V1STO2S
                                CPHIFLAG
                                S2
                                STCALL  THETAD
                                S2

GIMLOCK1     EXIT
                                TC      ALARM
                                OCT      00401
                                TC      UPFLAG      # GIMBAL LOCK HAS OCCURRED
                                ADRES    GLOKFAIL

                                TC      INTPRET
                                GOTO
                                CALCGA1
```

# Page 1361

```
# AXISGEN COMPUTES THE COORDINATES OF ONE COORDINATE SYSTEM REFERRED TO ANOTHER COORDINATE SYSTEM
#
# THE INPUTS ARE  1) THE STAR1 VECTOR REFERRED TO COORDINATE SYSTEM A STORED AT STARAD.  2) THE
# REFERRED TO COORDINATE SYSTEM A STORED AT STARAD +6.  3) THE STAR1 VECTOR REFERRED TO COORDINATE
# AT LOCATION 6 OF THE VAC AREA.  4) THE STAR2 VECTOR REFERRED TO COORDINATE SYSTEM B STORED AT
# THE VAC AREA.
#
# THE OUTPUT DEFINES COORDINATE SYSTEM A REFERRED TO COORDINATE SYSTEM B.  THE THREE HALF-UNIT
# AT LOCATIONS XDC, XDC +6, XDC +12D, AND STARAD, STARAD +6, STARAD +12D.
```

```
AXISGEN      AXT,1  SSP      # PUSHDOWN 00-30D, 34D-37D
                                STARAD  +6
                                S1
```

```

                                STARAD  -6

                                SETPD
                                0
                                AXISGEN1  VLOAD*  VXV*          # 06D  UA = S1
                                STARAD  +12D,1  #          STARAD  +00D      UB = S1
                                STARAD  +18D,1
                                UNIT          # 12D  VA = UNIT(S1 X S2)
                                STORE  STARAD  +18D,1  #          STARAD  +06D      VB = UNIT(S1 X S2)
                                VLOAD*
                                STARAD  +12D,1

                                VXV*  VSL1
                                STARAD  +18D,1  # 18D  WA = UA X VA
                                STORE  STARAD  +24D,1  #          STARAD  +12D      WB = UB X VB

                                TIX,1
                                AXISGEN1

                                AXC,1  SXA,1
                                6
                                30D

                                AXT,1  SSP
                                18D
                                S1
                                6

                                AXT,2  SSP
                                6
                                S2
                                2

                                AXISGEN2  XCHX,1  VLOAD*
                                30D          # X1=-6 X2=+6  X1=-6 X2=+4  X1=-6 X2=+2
                                0,1

# Page 1362

                                VXSC*  PDVL*          # J=(UA) (UB1)  J=(UA) (UB2)  J=(UA) (UB3)
                                STARAD  +6,2
                                6,1
                                VXSC*
                                STARAD  +12D,2
                                STOVL*  24D          # K=(VA) (VB1)  J=(VA) (VB2)  J=(VA) (VB3)
                                12D,1

```

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```
VXSC*  VAD
        STARAD  +18D,2  # L=(WA) (WB1)    J=(WA) (WB2)    J=(WA) (WB3)
VAD     VSL1
        24D
XCHX,1  UNIT
        30D
STORE   XDC      +18D,1  # XDC = L+J+K    YDC = L+J+K    ZDC = L+J+K

TIX,1
        AXISGEN3

AXISGEN3  TIX,2
          AXISGEN2

VLOAD
        XDC
STOVL   STARAD
        YDC
STOVL   STARAD  +6
        ZDC
STORE   STARAD  +12D

RVQ

# Page 1363
QTSN45  2DEC    .1768
.166... 2DEC    .1666666667

# Page 1364 (empty page)
```

This code is written to file src/INFLIGHT-ALIGNMENT-ROUTINES.s.

## A.42 INPUT OUTPUT CHANNEL BIT DESCRIPTIONS

```

692  <src/INPUT-OUTPUT-CHANNEL-BIT-DESCRIPTIONS.s 692>≡
      # Copyright:   Public domain.
      # Filename:    INPUT_OUTPUT_CHANNEL_BIT_DESCRIPTIONS.agc
      # Purpose:     Part of the source code for Luminary 1A build 099.
      #              It is part of the source code for the Lunar Module's (LM)
      #              Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:   yaYUL
      # Contact:     Onno Hommes <ohommes@cmu.edu>.
      # Website:     www.ibiblio.org/apollo.
      # Pages:       0054-0060
      # Mod history:  2009-05-14 OH   Transcribed from page images.
      #
      # This source code has been transcribed or otherwise adapted from
      # digitized images of a hardcopy from the MIT Museum. The digitization
      # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
      # the Museum. Many thanks to both. The images (with suitable reduction
      # in storage size and consequent reduction in image quality as well) are
      # available online at www.ibiblio.org/apollo. If for some reason you
      # find that the images are illegible, contact me at info@sandroid.org
      # about getting access to the (much) higher-quality images which Paul
      # actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #           Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
      #           16:27 JULY 14, 1969
      #
      # Page 54
      #
      # *** CHANNEL DESCRIPTION WORDS ARE ALLOCATED IN ERASABLE ASSIGNMENTS ***
      #
      # CHANNEL 1      IDENTICAL TO COMPUTER REGISTER L (0001)
      #
      # CHANNEL 2      IDENTICAL TO COMPUTER REGISTER Q (0002)
      #
      # CHANNEL 3      HISCALAR: INPUT CHANNEL; MOST SIGNIFICANT 14 BITS FROM 33 STAGE BINARY
      #                FACTOR IS B23 IN CSEC, SO MAX VALUE ABOUT 23.3 HOURS AND LEAST SIGNIFICANT
      #
      # CHANNEL 4      LOSCALAR: INPUT CHANNEL; NEXT MOST SIGNIFICANT 14 BITS FROM THE 33 STAGE
      #                ASSOCIATED WITH CHANNEL 3. SCALE FACTOR IS B9 IN CSEC. SO MAX VALUE IS
      #                SIGNIFICANT BIT IS 1/3200 SEC. SCALE FACTOR OF D.P. WORD WITH CHANNEL

```

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```
# CHANNEL 5    PYJETS:  OUTPUT CHANNEL; PITCH RCS JET CONTROL.  (REACTION CONTROL SYSTEM) USES
# CHANNEL 6    ROLLJETS: OUTPUT CHANNEL; ROLL RCS JET CONTROL.  (REACTION CONTROL SYSTEM) USES
# CHANNEL 7    SUPERBNK: OUTPUT CHANNEL; NOT RESET BY RESTART; FIXED EXTENSION BITS USED TO SE
#              APPROPRIATE FIXED MEMORY BANK IF FBANK IS 30 OCTAL OR MORE.  USES BITS 5-7.

# CHANNEL 10   OUTO:  OUTPUT CHANNEL; REGISTER USED TO TRANSMIT LATCHING-RELAY DRIVING INFORMAT
#              THE DISPLAY SYSTEM.  BITS 15-12 ARE SET TO THE ROW NUMBER (1-14 OCTAL) OF THE R
#              CHANGED AND BITS 11-1 CONTAIN THE REQUIRED SETTINGS FOR THE RELAYS IN THE ROW.

# CHANNEL 11   DSALMOUT: OUTPUT CHANNEL; REGISTER WHOSE BITS ARE USED FOR ENGINE ON-OFF CONTR
#              DRIVE INDIVIDUAL INDICATORS OF THE DISPLAY SYSTEM.  BITS 1-7 ARE A RELAYS.
#
#              BIT 1          ISS WARNING
#              BIT 2          LIGHT COMPUTER ACTIVITY LAMP
#              BIT 3          LIGHT UPLINK ACTIVITY LAMP
#              BIT 4          LIGHT TEMP CAUTION LAMP
#              BIT 5          LIGHT KEYBOARD RELEASE LAMP
#              BIT 6          FLASH VERB AND NOUN LAMPS
#              BIT 7          LIGHT OPERATOR ERROR LAMP
# Page 55
#              BIT 8          SPARE
#              BIT 9          TEST CONNECTOR OUTBIT
#              BIT 10         CAUTION RESET
#              BIT 11         SPARE
#              BIT 12         SPARE
#              BIT 13         ENGINE ON
#              BIT 14         ENGINE OFF
#              BIT 15         SPARE

# CHANNEL 12   CHAN12: OUTPUT CHANNEL; BITS USED TO DRIVE NAVIGATION AND SPACECRAFT HARDWARE.
#
#              BIT 1          ZERO RR CDU; CDU'S GIVE RRADAR INFORMATION FOR LM
#              BIT 2          ENABLE CDU RADAR ERROR COUNTERS
#              BIT 3          NOT USED
#              BIT 4          COARSE ALIGN ENABLE OF IMU
#              BIT 5          ZERO IMU CDU'S
#              BIT 6          ENABLE IMU ERROR COUNTER, CDU ERROR COUNTER.
#              BIT 7          SPARE
#              BIT 8          DISPLAY INERTIAL DATA
#              BIT 9          -PITCH GIMBAL TRIM (BELL MOTION) DESCENT ENGINE
#              BIT 10         +PITCH GIMBAL TRIM (BELL MOTION) DESCENT ENGINE
#              BIT 11         -ROLL GIMBAL TRIM (BELL MOTION) DESCENT ENGINE
#              BIT 12         +ROLL GIMBAL TRIM (BELL MOTION) DESCENT ENGINE
#              BIT 13         LR POSITION 2 COMMAND
```

```
#          BIT 14      ENABLE RENDEZVOUS RADAR LOCK-ON; AUTO ANGLE TRACK'G
#          BIT 15      ISS TURN ON DELAY COMPLETE
```

```
# Page 56
```

```
# CHANNEL 13  CHAN13: OUTPUT CHANNEL.
```

```
#
#          BIT 1      RADAR C      PROPER SETTING OF THE A,B,C MATRIX
#          BIT 2      RADAR B      SELECTS CERTAIN RADAR
#          BIT 3      RADAR A      PARAMETERS TO BE READ.
#          BIT 4      RADAR ACTIVITY
#          BIT 5      NOT USED (CONNECTS AN ALTERNATE INPUT TO UPLINK)
#          BIT 6      BLOCK INPUTS TO UPLINK CELL
#          BIT 7      DOWNLINK TELEMETRY WORD ORDER CODE BIT
#          BIT 8      RHC COUNTER ENABLE (READ HAND CONTROLLER ANGLES)
#          BIT 9      START RHC READ INTO COUNTERS IS BIT 8 SET
#          BIT 10     TEST ALARMS, TEST DSKY LIGHTS
#          BIT 11     ENABLE STANDBY
#          BIT 12     RESET TRAP 31-A      ALWAYS APPEAR TO BE SET TO 0
#          BIT 13     RESET TRAP 31-B      ALWAYS APPEAR TO BE SET TO 0
#          BIT 14     RESET TRAP 32      ALWAYS APPEAR TO BE SET TO 0
#          BIT 15     ENABLE T6 RUPT
```

```
# CHANNEL 14  CHAN14: OUTPUT CHANNEL; USED TO CONTROL COMPUTER COUNTER CELLS (CDU,
```

```
#
#          BIT 1      OUTLINK ACTIVITY (NOT USED)
#          BIT 2      ALTITUDE RATE OR ALTITUDE SELECTOR
#          BIT 3      ALTITUDE METER ACTIVITY
#          BIT 4      THRUST DRIVE ACTIVITY FOR DESCENT ENGINE
#          BIT 5      SPARE
#          BIT 6      GYRO ENABLE POWER FOR PULSES
#          BIT 7      GYRO SELECT B      PAIR OF BITS IDENTIFIES AXIS
#          BIT 8      GYRO SELECT A      GYRO SYSTEM TO BE TORQUED.
#          BIT 9      GYRO TORQUING COMMAND IN NEGATIVE DIRECTION.
```

```
# Page 57
```

```
#          BIT 10     GYRO ACTIVITY
#          BIT 11     DRIVE CDU S
#          BIT 12     DRIVE CDU T
#          BIT 13     DRIVE CDU Z
#          BIT 14     DRIVE CDU Y
#          BIT 15     DRIVE CDU X
```

```
# CHANNEL 15  MNKEYIN: INPUT CHANNEL; KEY CODE INPUT FROM KEYBOARD OF DSKY, SENSED
#              PROGRAM INTERRUPT #5 IS RECEIVED.  USED BITS 5-1
```

```
# CHANNEL 16  NAVKEYIN: INPUT CHANNEL; OPTICS MARK INFORMATION AND NAVIGATION PANEL
#              CONTROL (LM) SENSED BY PROGRAM THEN PROGRAM INTERRUPT #6 IS RECEIVED
```

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```
#
# BIT 1 NOT ASSIGNED
# BIT 2 NOT ASSIGNED
# BIT 3 OPTICS X-AXIS MARK SIGNAL FOR ALIGN OPTICAL TSCOPE
# BIT 4 OPTICS Y-AXIS MARK SIGNAL FOR AOT
# BIT 5 OPTICS MARK REJECT SIGNAL
# BIT 6 DESCENT+ ; CREW DESIRED SLOWING RATE OF DESCENT
# BIT 7 DESCENT- ; CREW DESIRED SPEEDING UP RATE OF D'CENT
```

```
# NOTE: ALL BITS IN CHANNELS 30-33 ARE INVERTED AS SENSED BY THE PROGRAM, SO THAT A VALUE OF ZERO
# THAT THE INDICATED SIGNAL IS PRESENT.
```

```
# CHANNEL 30 INPUT CHANNEL
```

```
#
# BIT 1 ABORT WITH DESCENT STAGE
# BIT 2 UNUSED
# BIT 3 ENGINE ARMED SIGNAL
# BIT 4 ABORT WITH ASCENT ENGINE STAGE
# BIT 5 AUTO THROTTLE; COMPUTER CONTROL OF DESCENT ENGINE
# Page 58
# BIT 6 DISPLAY INERTIAL DATA
# BIT 7 RR CDU FAIL
# BIT 8 SPARE
# BIT 9 IMU OPERATE WITH NO MALFUNCTION
# BIT 10 LM COMPUTER (NOT AGS) HAS CONTROL OF LM.
# BIT 11 IMU CAGE COMMAND TO DRIVE IMU GIMBAL ANGLES TO 0.
# BIT 12 IMU CDU FAIL (MALFUNCTION OF IMU CDU,S)
# BIT 13 IMU FAIL (MALFUCTION OF IMU STABILIZATION LOOPS)
# BIT 14 ISS TURN ON REQUESTED
# BIT 15 TEMPERATURE OF STABLE MEMBER WITHIN DESIGN LIMITS
```

```
# CHANNEL 31 INPUT CHANNEL; BITS ASSOCIATED WITH THE ATTITUDE CONTROLLER, TRANSLATIONAL CONTROL
# AND SPACECRAFT ATTITUDE CONTROL; USED BY RCS DAP.
```

```
#
# BIT 1 ROTATION (BY RHC) COMMANDED IN POSITIVE PITCH DIRECTION; MUST BE POSITIVE
# ALSO POSITIVE ELEVATION CHANGE FOR LANDING POINT DESIGNATOR
# BIT 2 AS BIT 1 EXCEPT NEGATIVE PITCH AND ELEVATION.
# BIT 3 ROTATION (BY RHC) COMMANDED IN POSITIVE YAW DIRECTION; MUST BE POSITIVE
# BIT 4 AS BIT 3 EXCEPT NEGATIVE YAW
# BIT 5 ROTATION (BY RHC) COMMANDED IN POSITIVE ROLL DIRECTION; MUST BE POSITIVE
# ALSO POSITIVE AZIMUTH CHANGE FOR LANDING POINT DESIGNATOR.
# BIT 6 AS BIT 5 EXCEPT NEGATIVE ROLL AND AZIMUTH
# BIT 7 TRANSLATION IN +X DIRECTION COMMANDED BY THC
# BIT 8 TRANSLATION IN -X DIRECTION COMMANDED BY THC
# BIT 9 TRANSLATION IN +Y DIRECTION COMMANDED BY THC
# BIT 10 TRANSLATION IN -Y DIRECTION COMMANDED BY THC
```

```

#          BIT 11      TRANSLATION IN +Z DIRECTION COMMANDED BY THC
#          BIT 12      TRANSLATION IN -Z DIRECTION COMMANDED BY THC
# Page 59
#          BIT 13      ATTITUDE HOLD MODE ON SCS MODE CONTROL SWITCH
#          BIT 14      AUTO STABILIZATION OF ATTITUDE ON SCS MODE SWITCH
#          BIT 15      ATTITUDE CONTROL OUT OF DETENT (RHC NOT IN NEUTRAL)

# CHANNEL 32  INPUT CHANNEL.
#
#          BIT 1       THRUSTERS 2 & 4 DISABLED BY CREW
#          BIT 2       THRUSTERS 5 & 8 DISABLED BY CREW
#          BIT 3       THRUSTERS 1 & 3 DISABLED BY CREW
#          BIT 4       THRUSTERS 6 & 7 DISABLED BY CREW
#          BIT 5       THRUSTERS 14 & 16 DISABLED BY CREW
#          BIT 6       THRUSTERS 13 & 15 DISABLED BY CREW
#          BIT 7       THRUSTERS 9 & 12 DISABLED BY CREW
#          BIT 8       THRUSTERS 10 & 11 DISABLED BY CREW
#          BIT 9       DESCENT ENGINE DISABLED BY CREW
#          BIT 10      APPARENT DESCENT ENGINE GIMBAL FAILURE
#          BIT 14      INDICATES PROCEED KEY IS DEPRESSED

# CHANNEL 33  CHAN33: INPUT CHANNEL; FOR HARDWARE STATUS AND COMMAND INFORMATION.
#              FLOP BITS RESET BY A CHANNEL "WRITE" COMMAND THAT ARE RESET BY A RES
#
#          BIT 1       SPARE
#          BIT 2       RR AUTO-POWER ON
#          BIT 3       RR RANGE LOW SCALE
#          BIT 4       RR DATA GOOD
#          BIT 5       LR RANGE DATA GOOD
#          BIT 6       LR POS1
#          BIT 7       LR POS2
# Page 60
#          BIT 8       LR VEL DATA GOOD
#          BIT 9       LR RANGE LOW SCALE
#          BIT 10      BLOCK UPLINK INPUT
#          BIT 11      UPLINK TOO FAST
#          BIT 12      DOWNLINK TOO FAST
#          BIT 13      PIPA FAIL
#          BIT 14      WARNING OF REPEATED ALARMS: RESTART, COUNTER FAIL, VO
#          BIT 15      LGC OSCILLATOR STOPPED

# CHANNEL 34  DNT M1: OUTPUT CHANNEL; DOWNLINK 1: FIRST OF TWO WORDS SERIALIZATION
# CHANNEL 35  DNT M2: OUTPUT CHANNEL; DOWNLINK 2: SECOND OF TWO WORDS SERIALIZATION

```



## A.43 INTEGRATION INITIALIZATION

697

*<src/INTEGRATION-INITIALIZATION.s 697>≡*

```
# Copyright:    Public domain.
# Filename:     INTEGRATION_INITIALIZATION.agc
# Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
#              It is part of the source code for the Command Module's (CM)
#              Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:     Ron Burkey <info@sandroid.org>.
# Website:     www.ibiblio.org/apollo.
# Pages:       1309-1333
# Mod history: 2009-05-15 RSB   Adapted from the Colossus249/ file of the
#                   same name, using Comanche055 page images.
#              2009-05-20 RSB   Corrections:  fixed an interpreter instruction,
#                   fixed a SETLOC.
#              2009-05-23 RSB   In SETCOAST, corrected MOONTHIS to AMOONFLG.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum.  The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum.  Many
# thanks to both.  The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo.  If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 055 of AGC program Comanche by NASA
#       2021113-051.  10:28 APR. 1, 1969
#
#       This AGC program shall also be referred to as
#               Colossus 2A
#
# Page 1309
# 1.0 INTRODUCTION
# -----
#
# FROM A USER'S POINT OF VIEW, ORBITAL INTEGRATION IS ESSENTIALLY THE SAME AS THE 278 INTEGRATI
# PROGRAM.  THE SAME ENTRANCES TO THE PROGRAM WILL BE MAINTAINED, THE SAME STALLING ROUTINE WILL
# OUTPUT WILL STILL BE VIA THE PUSHLIST.  THE PRIMARY DIFFERENCES TO A USER INVOLVE THE ADDED C
# TERMINATING INTEGRATION AT A SPECIFIC FINAL RADIUS AND THE DIFFERENCE IN STATE VECTOR SCALING
# THE LUNAR SPHERE OF INFLUENCE.
#
# IN ORDER TO MAKE THE CSM(LEM)PREC AND CSM(LEM)CONIC ENTRANCES SIMILAR TO FLIGHT 278, THE INTE
```

```
# WILL ITSELF SET THE FINAL RADIUS (RFINAL) TO 0 SO THAT REACHING THE DESIRED TIME OF
# INTEGRATION. THE DP REGISTER RFINAL MUST BE SET BY USERS OF INTEGRVS AND INTEGRV,
# CALL TC INTSTALL.
#
# WHEN THE LM IS ON THE LUNAR SURFACE (INDICATED BY LUNAR SURFACE FLAG SET) CALLS TO
# INTEGRV WITH VINFLAG = 0 WILL RESULT IN THE USE OF THE PLANETARY INERTIAL ORIENTATI
# BOTH THE LM'S POSITION AND VELOCITY IN THE REFERENCE COORDINATE SYSTEM.
# THE PROGRAM WILL PROVIDE OUTPUT AS IF INTEGRATION WAS USED. THAT IS, THE PUSHLIST
# THE PERMANENT STATE VECTOR UPDATED WHEN SPECIFIED BY AN INTEGRV CALL.
#
# USERS OF INTEGRVS DESIRING INTEGRATION (INTYPFLG = 0) SHOULD NOTE THAT THE OBLATENESS
# IN LUNAR ORBIT IS TIME DEPENDENT. THEREFORE, THE USER SHOULD SUPPLY AN INITIAL STATE
# TIME AND THE DESIRED TIME (TDEC1) ALSO AT SOME REAL TIME. FOR CONIC "INTEGRATION"
# AS THE INITIAL TIME AND DELTA TIME AS THE DESIRED TIME.
#
# 2.0 CENTRAL DESCRIPTION
# -----
#
# THE INTEGRATION PROGRAM OPERATES AS A CLOSED INTERPRETIVE SUBROUTINE AND PERFORMS THE
# 1) INTEGRATES (PRECISION OR CONIC) EITHER CSM OR LM STATE VECTOR
# 2) INTEGRATES THE W-MATRIX
# 3) PERMANENT OR TEMPORARY UPDATE OF THE STATE VECTOR
#
# THERE ARE SIX ENTRANCES TO THE INTEGRATION PROGRAM. FOUR OF THESE (CSMPREC, LEMPREC,
# ALL THE FLAGS REQUIRED IN THE INTEGRATION PROGRAM ITSELF TO CAUSE THE PRECISION OR
# THE LM OR CSM STATE VECTOR, AS THE NAMES SUGGEST. ONE ENTRANCE (INTEGRVS) PERMITS
# PROVIDE A STATE VECTOR TO BE INTEGRATED. THE CALLING PROGRAM MUST SET THE FLAGS IN
# CONIC INTEGRATION, (2) IN OR OUT OF LUNAR SPHERE, (3) MIDCOURSE OR NOT, AND THE IN
# THE FLAG SETTING TO BYPASS W-MATRIX INTEGRATION. THE LAST ENTRANCE (INTEGRV, USED
# NAVIGATION PROGRAMS) PERMITS THE CALLER TO SET FIVE FLAGS (NOT MOONFLAG OR MIDFLAG)
# VECTOR. ANY PROGRAM WHICH CALLS INTEGRVS OR INTEGRV MUST CALL INTSTALL BEFORE IT
# AND/OR STATE VECTOR.
#
# THREE SETS OF 42 REGISTERS AND 2 FLAGS ARE USED FOR THE STATE VECTORS. TWO SETS, V
# USED FOR THE PERMANENT STATE VECTORS FOR THE CSM AND LM. THE THIRD SET, WHICH MAY
# IS NOT BEING DONE, IS USED IN THE COMPUTATIONS.
#
# THE PERMANENT STATE VECTORS WILL BE PERIODICALLY UPDATED SO THAT THE VECTORS WILL
# THE PERMANENT STATE VECTORS WILL ALSO BE UPDATED WHENEVER THE W-MATRIX IS INTEGRATED
# SETS STATEFLG (THE NAVIGATION PROGRAMS P20, P22.)
#
# Page 1310
# APPENDIX B OF THE USERS' GUIDE LISTS THE STATE VECTOR QUANTITIES.
#
# 2.1 RESTARTS
#
```

```

# PHASE CHANGES WILL BE MADE IN THE INTEGRATION PROGRAM ONLY FOR THE INTEGRV ENTRANCE (I.E., WHEN
# INTEGRATED OR PERMANENT STATE VECTOR IS UPDATED.) THE GROUP NUMBER USED WILL BE THAT FOR THE
# (I.E., GROUP2) SINCE THE INTEGRV ENTRANCE WILL ONLY BE USED BY THESE PROGRAMS. IF A RESTART
# INTEGRATION OF THE STATE VECTOR ONLY, THE RECOVERY WILL BE TO THE LAST PHASE IN THE CALLING PROGRAMS
# PROGRAMS WHICH USE THE INTEGRV OR INTEGRVS ENTRANCE OF INTEGRATION SHOULD ENSURE THAT IF PHASE
# THAT IT IS PRIOR TO SETTING THE INTEGRATION INPUTS IN THE PUSHLIST.
# THIS IS BECAUSE THE PUSHLIST IS LOST DURING A RESTART.
#
# 2.2 SCALING
#
# THE INTEGRATION ROUTINE WILL MAINTAIN THE PERMANENT MEMORY STATE VECTORS IN THE SCALING AND UNITS
# APPENDIX B OF THE USERS' GUIDE. THE SCALING OF THE OUTPUT POSITION VECTOR DEPENDS ON THE ORIGINAL
# SYSTEM AT THE DESIRED INTEGRATION TIME. THE COORDINATE SYSTEM TRANSFORMATION WILL BE DONE AFTER
# MULTIPLE TIMESTEP ENCKE INTEGRATION ONLY. THUS IT IS POSSIBLE TO HAVE OUTPUT FROM SUCCESSIVE
# DIFFERENT SCALING.
# HOWEVER, RATT, VATT WILL ALWAYS BE SCALED THE SAME.
#
# 3.0 INPUT/OUTPUT
# -----
#
# PROGRAM INPUTS ARE THE FLAGS DESCRIBED IN APPENDIX A AND THE PERMANENT STATE VECTOR QUANTITIES
# APPENDIX B OF THE USERS' GUIDE, PLUS THE DESIRED TIME TO INTEGRATE TO IN TDEC1 (A PUSH LIST ENTRY)
# FOR INTEGRVS, THE RCV,VCV,TET OR THE TEMPORARY STATE VECTOR MUST BE SET, PLUS MOONFLAG AND MOON
#
# FOR SIMULATION THE FOLLOWING QUANTITIES MUST BE PRESET ---
#
#                                     EARTH    MOON
#                                     29        27
# RRECTCSM(LEM)      RECTIFIED POSITION VECTOR      METERS      2        2
#
#                                     7        5
# VRECTCSM(LEM)      RECTIFIED VELOCITY VECTOR      M/CSEC      2        2
#
#                                     28        28
# TETCSM(LEM)        TIME STATE VECTOR IS VALID      CSEC        2        2
#                                     CUSTOMARILY 0, BUT NOTE LUNAR
#                                     ORBIT DEPENDENCE ON REAL TIME.
#
#                                     22        18
# DELTAVCSM(LEM)     POSITION DEVIATION      METERS      2        2
#                                     0 IF TCCSM(LEM) = 0
#
#                                     3        -1
# NUVCSSM(LEM)       VELOCITY DEVIATION      M/CSEC      2        2
#                                     0 IF TCCSM(LEM) = 0
# Page 1311
#                                     29        27

```

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#	RCVSM(LEM)	CONIC POSITION	METERS	2
#		EQUALS RRECTCSM(LEM) IF		
#		TCCSM(LEM) = 0		
#				
#	VCVCSM(LEM)	CONIC VELOCITY	M/CSEC	7
#		EQUALS VRECTCSM(LEM) IF		2
#		TCCSM(LEM) = 0		
#				
#	TCCSM(LEM)	TIME SINCE RECTIFICATION	CSECS	28
#		CUSTOMARILY 0		2
#				
#			1/2	17
#	XKEPCSM(LEM)	RDOT OF KEPLER'S EQUATION	M	2
#		0 IF TCCSM(LEM) = 0		
#				
#	CMOONFLG	PERMANENT FLAGS CORRESPONDING		0
#	CMIDFLAG	TO MOONFLAG AND MIDFLAG		0,1
#	LMOONFLG	C = CSM, L = LM		0
#	LMIDFLG			0,1
#				
#	SURFFLAG	LUNAR SURFACE FLAG		0,1
#				
#	# IN ADDITION, IF (L)CMIDFLAG IS SET, THE INITIAL INPUT VALUES FOR LUNAR			
#	# SOLAR EPHEMERIDES SUBROUTINE AND PLANETARY INERTIAL ORIENTATION SUB-			
#	# ROUTINE MUST BE PRESET.			
#	#			
#	# OUTPUT			
#	# AFTER EVERY CALL TO INTEGRATION			
#				
#			EARTH	MOON
#			29	29
#	0D	RATT	POSITION	METERS
#				2
#				
#				7
#	6D	VATT	VELOCITY	M/CSEC
#				2
#				
#				28
#	12D	TAT	TIME	
#				2
#				
#				29
#	14D	RATT1	POSITION	METERS
#				2
#				
#				7
#	20D	VATT1	VELOCITY	M/CSEC
#				2
#				
#				5
#				2

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```
#
#           3   2           36   30
#       26D   MU(P)   MU           M /CS           2   2
#
#       X1           MUTABLE ENTRY           -2   -10D
#
#       X2           COORDINT
#       X2           COORDINATE SYSTEM ORIGIN           0   2
#                   (THIS, NOT MOONFLAG, SHOULD BE
# Page 1312
#                   USED TO DETERMINE ORIGIN.)
#
# IN ADDITION TO THE ABOVE, THE PERMANENT STATE VECTOR IS UPDATED WHENEVER
# STATEFLG WAS SET AND WHENEVER A W-MATRIX IS TO BE INTEGRATED. THE PUSH
# COUNTER IS SET TO 0 AND OVERFLOW IS CLEARED BEFORE RETURNING TO THE
# CALLING PROGRAM.
#
# 4.0 CALLING SEQUENCES AND SAMPLE CODE
# -----
#
#       A) PRECISION ORBITAL INTEGRATION.  CSMPREC, LEMPREC ENTRANCES
#           L-X      STORE TIME TO 96T5791T5 T 95 PUS L9ST (T4531)
#           L        CALL
#           L+1      CSMPREC (OR LEMPREC)
#           L+2      RETURN
#       INPUT                                           28
#           TDEC1 (PD 32D) TIME TO INTEGRATE TO...CENTISECONDS SCALED 2
#       OUTPUT
#           THE DATA LISTED IN SECTION 3.2 PLUS
#           RQVV     POSITION VECTOR OF VEHICLE WITH RESPECT TO SECONDARY
#           BODY... METERS B-29 ONLY IF MIDFLAG = DIMOFLAG = 1
#       B) CONIC INTEGRATION.  CSMCONIC, LEMCONIC ENTRANCES
#           L-X      STORE TIME IN PUSH LIST (TDEC1)
#           L        CALL
#           L+1      CSMCONIC (OR LEMCONIC)
#       INPUT/OUTPUT
#           SAME AS PRECISION INTEGRATION, EXCEPT RQVV NOT SET
#       C) INTEGRATE GIVEN STATE VECTOR.  INTEGRVS ENTRANCE
#           CALL
#
#                   INTSTALL
#
#           VLOAD
#
#                   POSITION VECTOR
#           STOVL    RCV
#
#                   VELOCITY VECTOR
#           STODL    VCV
#
#                   TIME STATE VECTOR VALID
#           STODL    TET
```

```

#                               FINAL RADIUS
#                               STORE          RFINAL
#                               SET(CLEAR)     SET(CLEAR)
#                               INTYPFLAG
#                               MOONFLAG
#                               SET(CLEAR)     DLOAD
#                               DESIRED TIME
#                               STCALL         TDEC1
#                               INTEGRVS
#
# INPUT
# RCV      POSITION VECTOR          METERS
# VCV      VELOCITY VECTOR        M/CSEC
# TET      TIME OF STATE VECTOR (MAY = 0) CSEC B-28
# Page 1313
# TDEC1    TIME TO INTEGRATE TO      CSEC B-28 (PD 32D)
#          (MAY BE INCREMENT IF TET=0)
#
# OUTPUT
# SAME AS FOR PRECISION OR CONIC INTEGRATION,
# DEPENDING ON INTYPFLG.
# D) INTEGRATE STATE VECTOR.  INTGRV ENTRANCE
# L-X      STORE TIME IN PUSH LIST (TDEC1) (MAY BE DONE AFTER CALL TO IN
# L-8      CALL
# L-7
# L-6      SET(CLEAR)              SET(CLEAR)
# L-5      VINTFLAG                1=CSM, 0=LM
# L-4      INTYPFLAG              1=CONIC, 0=PRECISION
# L-3      SET(CLEAR)              SET(CLEAR)
# L-2      DIMOFLAG                1=W-MATRIX, 0=NO W-MATRIX
# L-1      D6OR9FLG               1=9X9, 0=6X6
# L        SET                    DLOAD
# L+1      STATEFLG                DESIRE PERMANENT UPDATE
# L+2      FINAL RAD.              OF STATE VECTOR
# L+3      STCALL                  RFINAL
# L+4      INTEGRV
# L        CALL                    NORMAL USE -- WILL UPDATE STATE
# L+1      INTEGRV                 VECTOR IF DIMOFLAG=1. (STATE
# L+2      RETURN                  ALWAYS RESET IN INTEGRATION A
#                                  IT USED.)
#
# INPUT
# TDEC1 (PD 32D) TIME TO INTEGRATE TO      CSEC B-28
#
# OUTPUT
# SAME AS FOR PRECISION OR CONIC INTEGRATION
# THE PROGRAM WILL SET MOONFLAG, MIDFLAG DEPENDING ON
# THE PERMANENT STATE VECTOR REPRESENTATION.

```

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	SETLOC	INTINIT	
	BANK		
	EBANK=	RRECTCSM	
	COUNT	13/INTIN	
STATEINT	TC	PHASCHNG	
	OCT	00052	
	CAF	PRI05	
	TC	FINDVAC	
	EBANK=	RRECTCSM	
	2CADR	STATINT1	
STATINT1	TC	TASKOVER	
	TC	INTPRET	
	BON	RTB	
		QUITFLAG	
		NOINT	# NO STATEINT IF V96
		LOADTIME	
# Page 1314			
	STORE	TDEC1	
	CLEAR	CALL	
		V96ONFLG	
		INTSTALL	
	SET	CALL	
		NODOFLAG	
		SETIFLGS	
	GOTO		
		STATEUP	
600SECS	2DEC	60000	
ENDINT	CLEAR	EXIT	
		STATEFLG	
	TC	PHASCHNG	
	OCT	20032	
	EXTEND		
	DCA	600SECS	
	TC	LONGCALL	
	EBANK=	RRECTHIS	
	2CADR	STATEINT	
SETIFLGS	TC	ENDOFJOB	
	SET	CLEAR	
		STATEFLG	
		INTYPFLG	
	CLEAR	CLEAR	
		DIMOFLEG	

```

                                D6OR9FLG
                                RVQ
NOINT      EXIT
                                TC      PHASCHNG
                                OCT      2

                                TC      DOWNFLAG
                                ADRES    QUITFLAG

                                TC      ENDOFJOB

# ATOPCSM TRANSFERS RRECT TO RRECT +41 TO RRECTCSM TO RRECTCSM +41
#
# CALLING SEQUENCE
#      L      CALL
#      L+1
#      ATOPCSM
#
# NORMAL EXIT AT L+2

ATOPCSM      STQ      RTB
                                S2
                                MOVEACSM
                                SET      CALL
# Page 1315
                                CMOONFLG
                                SVDWN1
                                BON      CLRG0
                                MOONFLAG
                                S2
                                CMOONFLG
                                S2
MOVEACSM      TC      SETBANK
                                TS      DIFEQCNT      # INITIALIZE INDEX
                                INDEX    DIFEQCNT
                                CA      RRECT
                                INDEX    DIFEQCNT
                                TS      RRECTCSM
                                CCS      DIFEQCNT      # IS TRANSFER COMPLETE
                                TCF      MOVEACSM +1    # NO-LOOP
                                TC      DANZIG          # COMPLETE -- RETURN

# PTOACSM TRANSFERS RRECTCSM TO RRECTCSM +41 TO RRECT TO RRECT +41
#
# CALLING SEQUENCE
#      L      CALL
#      PTOACSM

```



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```
#
# NORMAL EXIT AT L+2

PTOACSM      RTB      BON
                MOVEPCSM
                CMOONFLG
                SETMOON
CLRMOON      CLEAR    SSP
                MOONFLAG
                PBODY
                0
                RVQ
SETMOON      SET      SSP
                MOONFLAG
                PBODY
                2
                RVQ
MOVEPCSM      TC       SETBANK
                TS      DIFEQCNT
                INDEX   DIFEQCNT
                CA      RRECTCSM
                INDEX   DIFEQCNT
                TS      RRECT
                CCS      DIFEQCNT
                TCF     MOVEPCSM +1
                TC      DANZIG
```

# Page 1316

# ATOPLEM TRANSFERS RRECT TO RRECT +41 TO RRECTLEM TO RRECTLEM +41

```
ATOPLEM      STQ      RTB
                S2
                MOVEALEM
                SET     CALL
                LMOONFLG
                SVDWN2
                BON     CLRGO
                MOONFLAG
                S2
                LMOONFLG
                S2
MOVEALEM      TC       SETBANK
                TS      DIFEQCNT
                INDEX   DIFEQCNT
                CA      RRECT
                INDEX   DIFEQCNT
                TS      RRECTLEM
```

CCS DIFEQCNT  
 TCF MOVEALEM +1  
 TC DANZIG

# PTOALEM TRANSFERS RRECTLEM TO RRECTLEM +41 TO RRECT TO RRECT +41

PTOALEM BON RTB  
 SURFFLAG  
 USEPIOS  
 MOVEPLEM  
 BON GOTO  
 LMOONFLG  
 SETMOON  
 CLRMOON  
 MOVEPLEM TC SETBANK  
 TS DIFEQCNT  
 INDEX DIFEQCNT  
 CA RRECTLEM  
 INDEX DIFEQCNT  
 TS RRECT  
 CCS DIFEQCNT  
 TCF MOVEPLEM +1  
 TC DANZIG

USEPIOS SETPD VLOAD  
 0  
 RLS  
 PDDL PUSH  
 TDEC1

# Page 1317

STODL TET  
 5/8  
 CALL  
 RP-TO-R  
 STOVL RCV  
 ZUNIT  
 STODL OD  
 TET  
 STODL 6D  
 5/8  
 SET CALL  
 MOONFLAG  
 RP-TO-R  
 VXV VXSC  
 RCV  
 OMEGMOON

# NEEDED FOR SETTING X1 ON EXIT

```

          STOVL   VCV
              ZEROVEC
          STORE   TDELTA V
          AXT,2   SXA,2
              2
              PBODY
          STCALL  TNUV
              A-PCHK
OMEGMOON      2DEC*  2.66169947 E-8 B+23*

SETBANK       CAF    INTBANK
              TS      BBANK
              CAF     FORTYONE
              TC      Q
              EBANK=  RRECTCSM
INTBANK       BBCON  INTEGRV

```

```

# SPECIAL PURPOSE ENTRIES TO ORBITAL INTEGRATION.  THESE ROUTINES PROVIDE ENTRANCES TO INTEGRATION.
# APPROPRIATE SWITCHES SET OR CLEARED FOR THE DESIRED INTEGRATION.
#

```

```

# CSMPREC AND LEMPREC PERFORM ORBIT INTEGRATION BY THE ENCKE METHOD TO THE TIME INDICATED IN TDEC1.
# ACCELERATIONS DUE TO OBLATENESS ARE INCLUDED.  NO W-MATRIX INT. IS DONE.
# THE PERMANENT STATE VECTOR IS NOT UPDATED.
# CSMCONIC AND LEMCONIC PERFORM ORBIT INTEG. BY KEPLER'S METHOD TO THE TIME INDICATED IN TDEC1.
# NO DISTURBING ACCELERATIONS ARE INCLUDED.  IN THE PROGRAM FLOW THE GIVEN
# STATE VECTOR IS RECTIFIED BEFORE SOLUTION OF KEPLER'S EQUATION.
#

```

```

# THE ROUTINES ASSUME THAT THE CSM (LEM) STATE VECTOR IN P-MEM IS VALID.
# SWITCHES SET PRIOR TO ENTRY TO THE MAIN INTEG. PROG ARE AS FOLLOWS:
#

```

	CSMPREC	CSMCONIC	LEMPREC	LEMCONIC
# VINTFLAG	SET	SET	CLEAR	CLEAR
# INTYPFLG	CLEAR	SET	CLEAR	SET
# DIMOFLAG	CLEAR	CLEAR	CLEAR	CLEAR

```

# Page 1318
#

```

```

# CALLING SEQUENCE
#

```

```

# L-X   STORE   TDEC1
# L     CALL           (STCALL TDEC1)
# L+1   CSMPREC      (CSMCONIC, LEMPREC, LEMCONIC)
#

```

```

# NORMAL EXIT TO L+2
#

```

```

# SUBROUTINES CALLED
#

```

```

# INTEGRV1
# PRECOUT FOR CSMPREC AND LEMPREC
# CONICOUT FOR CSMCONIC AND LEMCONIC

```

```

#
# OUTPUT -- SEE PAGE 2 OF THIS LOG SECTION
#
# INPUT
#      TDEC1          TIME TO INTEGRATE TO.  CSECS B-28

CSMPREC      STQ      CALL
                  X1
                  INTSTALL
                  SXA,1 SET
                  IRETURN
                  VINTFLAG

IFLAGP      SET      CLEAR
                  PRECIFLG
                  DIMOFLAG
                  CLRG0
                  INTYPFLG
                  INTEGRV1

LEMPREC      STQ      CALL
                  X1
                  INTSTALL
                  SXA,1 CLRG0
                  IRETURN
                  VINTFLAG
                  IFLAGP

CSMCONIC     STQ      CALL
                  X1
                  INTSTALL
                  SXA,1 SET
                  IRETURN
                  VINTFLAG

IFLAGC      CLEAR    SETGO
                  DIMOFLAG
                  INTYPFLG
                  INTEGRV1

LEMCONIC     STQ      CALL
                  X1

# Page 1319
                  INTSTALL
                  SXA,1 CLRG0
                  IRETURN
                  VINTFLAG
                  IFLAGC

```

```

INTEGRVS      SET      SSP
                  PRECIFLG
                  PBODY
                  0
                BOF      SSP
                  MOONFLAG
                  +3
                  PBODY
                  2
                STQ      VLOAD
                  IRETURN
                  ZEROVEC
                STORE     TDELTA
                STCALL    TNUV
                  RECTIFY
                CLEAR     SET
                  DIMOFLAG
                  NEWIFLG
                SETGO
                  RPQFLAG
                  ALOADED

```

```

# INTEGRV IS AN ENTRY TO ORBIT INTEGRATION WHICH PERMITS THE CALLER,
# NORMALLY THE NAVIGATION PROGRAM, TO SET THE INTEG. FLAGS.  THE ROUTINE
# IS ENTERED AT INTEGRV1 BY CSMPREC ET. AL. AND AT ALOADED BY INTEGRVS.
# THE ROUTINE SETS UP A-MEMORY IF ENTERED AT INTEGRV,1 AND SETS THE INTEG.
# PROGRAM FOR PRECISION OR CONIC.

```

```

#
# THE CALLER MUST FIRST CALL INTSTALL TO CHECK IF INTEG. IS IN USE BEFORE
# SETTING ANY FLAGS.

```

```

#
# THE FLAGS WHICH SHOULD BE SET OR CLEARED ARE
#      VINTFLAG      (IGNORED WHEN ENTERED FROM INTEGRVS)
#      INTYPFLG
#      DIMOFLAG
#      D6OR9FLG

```

```

# CALLING SEQUENCE

```

```

#      L-X      CALL
#      L-Y      INTSTALL
#      L-1      SET OR CLEAR ALL FOUR FLAGS.  ALSO CAN SET STATEFLG IF DESIRED
#               AND DIMOFLAG IS CLEAR.
#      L        CALL
#      L+1      INTEGRV

```

```

# INITIALIZATION

```

```

#      FLAGS AS ABOVE
#      STORE TIME TO INTEGRATE TO IN TDEC1
#
# Page 1320
# OUTPUT
#      RATT      AS
#      VATT      DEFINED
#      TAT       BEFORE

INTEGRV      STQ
              IRETURN
INTEGRV1     SET      SET
              RPQFLAG
              NEWIFLG
INTEGRV2     SSP
              QPRET
              ALOADED
              BON      GOTO
              VINTFLAG
              PTOACSM
              PTOALEM
              SETLOC   INTINIT1
              BANK
ALOADED      DLOAD
              TDEC1
              STORE    TDEC
              BOFF     GOTO
              INTYPFLG
              TESTLOOP
              RVCON
              SETLOC   INTINIT
              BANK
A-PCHK      BOF      CALL
              MIDFLAG
              ANDOUT   # DON'T MAKE ORIGIN CHANGE CHECK
              CHKSWTCH
              BPL      CALL
              ANDOUT   # NO ORIGIN CHANGE
              ORIGCHNG # MAKE THE SWITCH
ANDOUT      BOFCLR   EXIT
              STATEFLG
              RECTOUT
              TC       PHASCHNG
              OCT      04022
              TC       UPFLAG      # PHASE CHANGE HAS OCCURRED BETWEEN
ADRES      REINTFLG      # INTSTALL AND INTWAKE

```

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```
# Page 1321
PHEXIT      TC      INTPRET
             SSP
             QPRET
             PHEXIT
             BON     GOTO
             VINTFLAG
             ATOPCSM
             ATOPLEM
RECTOUT      CALL
             GRP2PC
             SETPD   CALL
             0
             RECTIFY
             VLOAD   VSL*
             RRECT
             0,2
             PDVL    VSL*      # RATT TO PDO
             VRECT
             0,2
             PDDL    PDVL      # VATT TO PD6   TAT TO PD12
             TET
             RRECT
             PDVL    PDDL*
             VRECT
             MUEARTH,2
             PUSH    AXT,1
             DEC     -10
             BON     AXT,1
             MOONFLAG
             +2
             DEC     -2
INTEXIT      SETPD   BOV
             0
             +1
             CLEAR
             MIDAVFLG
             CLEAR
             AVEMIDSW      # ALLOW UPDATE OF DOWNLINK STATE VECTOR
             PRECIFLG
             SLOAD   EXIT
             IRETURN
             CA      MPAC
             INDEX   FIXLOC
             TS      QPRET
             TC      INTWAKE
```

# RVCON SETS UP ORBIT INTEGRATION TO DO A CONIC SOLUTION FOR POSITION AND  
# VELOCITY FOR THE INTERVAL (TET-TDEC)

```
RVCON      DLOAD  DSU
            TDEC
            TET
            STCALL TAU.
            RECTIFY
            CALL   KEPPREP
            DLOAD  DAD
            TC
```

# Page 1322

```
TET
STCALL    TET
RECTOUT
```

# Page 1323

```
TESTLOOP  BOF      CLRG0
            QUITFLAG
            +3
            STATEFLG
            INEXIT      # STOP INTEGRATION
            +3          SETPD LXA,2
                        10D
                        PBODY
            VLOAD  ABVAL
                        RCV
            PUSH   CLEAR      # RC TO 10D
                        MIDFLAG
            DSU*   BMN        # MIDFLAG=0 IF R G.T. RMP
                        RME,2
                        +3
            SET    MIDFLAG
NORFINAL  DLOAD  DMP
            10D
            34D
            SR1R  DDV*
            MUEARTH,2
            SQRT  DMP
            .3D
            SR3   SR4        # DT IS TRUNCATED TO A MULTIPLE
            DLOAD SL
            MPAC
```



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```

                                15D          #          OF 128 CSECS.
                                PUSH        BOV
                                MAXDT
                                BDSU        BMN
                                DT/2MAX
                                MAXDT
DT/2COMP                      DLOAD        DSU
                                TDEC
                                TET
                                RTB         SL
                                SGNAGREE
                                8D
                                STORE       DT/2          # B-19
                                BOV         ABS
                                GETMAXDT
                                DSU         BMN            # IS TIME TO INTEG. TO GR THAN MAXTIME
                                12D
                                POOHCHK
USEMAXDT                      DLOAD        SIGN
                                12D
                                DT/2
# Page 1324
                                STCALL     DT/2
                                POOHCHK
MAXDT                         DLOAD        PDDL            # EXCHANGE DT/2MAX WITH COMPUTED MAX.
                                DT/2MAX
                                GOTO
                                DT/2COMP
GETMAXDT                      RTB
                                SIGNMPAC
                                STCALL     DT/2
                                USEMAXDT
POOHCHK                      DLOAD        ABS
                                DT/2
                                DSU         BMN
                                DT/2MIN
                                A-PCHK
                                SLOAD      BHIZ
                                MODREG
                                +3
                                GOTO
                                TIMESTEP
                                BON         # WAS THIS CALL VIA CSM(LEM)PREC
                                PRECIFLG
                                TIMESTEP    # YES
                                DLOAD        DSU
```

		DT/2	
		12D	
	BMN	BOFCLR	
		A-PCHK	
		NEWIFLG	
		TIMESTEP	
	DLOAD	DSU	
		TDEC	
		TET	
	BMN		# NO BACKWARD INTEGRATION
		INTEXIT	
	PDDL	SR4	
		DT/2	# IS 4(DT) LS (TDEC - TET)
	SR2R	BDSU	
	BMN	GOTO	
		INTEXIT	
		TIMESTEP	
DT/2MIN	2DEC	3 B-20	
DT/2MAX	2DEC	4000 E2 B-20	
INTSTALL	EXIT		
	CAF	ZERO	
ALLSTALL	TS	L	
	CA	RASFLAG	
	INDEX	L	
# Page 1325			
	MASK	INTBITAB	# IS THIS STALL AREA FREE
	EXTEND		
	BZF	OKTOGRAB	# YES
	INDEX	L	
	CAF	WAKESTAL	
	TC	JOBSLEEP	
INTWAKEO	EXIT		
	TCF	INTWAKE1	
INTWAKE	CS	RASFLAG	# IS THIS INSTALLED ROUTINE TO BE
	MASK	REINTBIT	# RESTARTED
	CCS	A	
	TC	INTWAKE1	# NO
	INDEX	FIXLOC	
	CA	QPRET	
	TS	TBASE2	# YES, DON'T RESTART WITH SOMEONE ELSE'S Q
	TC	PHASCHNG	

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	OCT	04022	
	CA	TBASE2	
	INDEX	FIXLOC	
	TS	QPRET	
	CAF	REINTBIT	
	MASK	RASFLAG	
	EXTEND		
	BZF	GOBAC	# DON'T INTWAKE IF WE CAME HERE VIA RESTART
INTWAKE1	CAF	ZERO	
WAKE	TS	STALTEM	# INDEX OF ANY STALL USER
WAKE1	INDEX	STALTEM	
	CAF	WAKESTAL	
	INHINT		
	TC	JOBWAKE	
	CCS	LOCCTR	
	TCF	WAKE1	# MAY BE MORE TO WAKE UP
FORTYONE	DEC	41	
	INDEX	STALTEM	
	CS	INTBITAB	
	MASK	RASFLAG	
	TS	RASFLAG	# RELEASE STALL AREA
	RELINT		
	TCF	GOBAC	
OKTOGRAB	INDEX	L	# NO, WAIT UNTIL AVAILABLE
	CAF	INTFLBIT	
	ADS	RASFLAG	
GOBAC	TC	INTPRET	
	RVQ		
# Page 1326			
ERASTAL1	EXIT		
	CAF	ONE	
	TCF	ALLSTALL	
ERASTAL2	EXIT		
	CAF	TWO	
	TCF	ALLSTALL	
ERASWAK1	CAF	ONE	
	TCF	WAKE	
ERASWAK2	CAF	TWO	
	TCF	WAKE	
WAKESTAL	CADR	INTSTALL +1	
	CADR	ERASTAL1 +1	
	CADR	ERASTAL2 +1	
STALTEM	EQUALS	MPAC	

```

INTBITAB      OCT      20100
               OCT      10040
               OCT      04020

```

```

# Page 1327

```

```

# AVETOMID

```

```

#

```

```

# THIS ROUTINE PERFORMS THE TRANSITION FROM A THRUSTING PHASE TO THE COAST
# PHASE BY INITIALIZING THIS VEHICLE'S PERMANENT STATE VECTOR WITH THE
# VALUES LEFT BY THE AVERAGEG ROUTINE IN RN,VN,PIPTIME.

```

```

#

```

```

# BEFORE THIS IS DONE THE W-MATRIX, IF IT'S VALID (OR WFLAG OR RENDWFLT IS
# SET) IS INTEGRATED FORWARD TO PIPTIME WITH THE PRE-THRUST STATE VECTOR.

```

```

#

```

```

# IN ADDITION, THE OTHER VEHICLE IS INTEGRATED (PERMANENT) TO PIPTIME.

```

```

#

```

```

# FINALLY TRKMKCNT IS ZEROED.

```

```

      SETLOC  INTINIT2
      BANK

```

```

      COUNT*  $$/INTIN
AVETOMID     STQ    BON
              EGRESS
              RENDWFLG
              INT/W      # W-MATRIX VALID, GO INTEGRATE IT
      BON
              ORBWFLAG
              INT/W      # W-MATRIX VALID, GO INTEGRATE IT.

```

```

SETCOAST     AXT,2  CALL      # NOW MOVE PROPERLY SCALED RN,UN AS WELL AS
                    2        # PIPTIME TO INTEGRATION ERASABLES.

```

```

      INTSTALL
      BON      AXT,2
              AMOONFLG
              +2
              0

```

```

      VLOAD   VSR*
              RN
              0,2

```

```

      STORE   RRECT

```

```

      STODL   RCV
              PIPTIME

```

```

      STOVL   TET
              VN

```

```

      VSR*    CALL

```

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```

                                0,2
                                MINIRECT      # FINISH SETTING UP STATE VECTOR
RTB      SSP
                                MOVATHIS      # PUT TEMP STATE VECTOR INTO PERMANENT
                                TRKMKCNT
                                0
SET      BON
                                CMOONFLG
# Page 1328
                                AMOONFLG
                                +3
CLEAR    CMOONFLG

BON      DLOAD      # NOW DO LM
                                SURFFLAG
                                FAZAB5      # NO COASTING LM
                                PIPTIME
STCALL   TDEC1
                                SETIFLGS
CLEAR    CALL
                                VINTFLAG
                                INTEGRV
GOTO
                                EGRESS
INT/W    DLOAD      CALL
                                PIPTIME      # INTEGRATE W THRU BURN
                                INTSTALL
SET      SET
                                DIMOFLAG      # DO W-MATRIX
                                AVEMIDSW      # SO WON'T CLOBBER RN,VN,PIPTIME
CLEAR    SET
                                D6OR9FLG
                                VINTFLAG
STCALL   TDEC1
                                INTEGRV
GOTO
                                SETCOAST
```

# Page 1329

# MIDTOAV1

#

```
# THIS ROUTINE INTEGRATES (PRECISION) TO THE TIME SPECIFIED IN TDEC1.
# IF, AT THE END OF AN INTEGRATION TIME STEP, CURRENT TIME PLUS A DELTA
# TIME (SEE TIMEDELT....BASED ON THE COMPUTATION TIME FOR ONE TIME STEP)
# IS GREATER THAN THE DESIRED TIME, ALARM 1703 IS SET AND THE INTEGRATION
```

```

# IS DONE TO THE CURRENT TIME.
# RETURN IS IN BASIC TO THE RETURN ADDRESS PLUS ONE.
#
# IF THE INTEGRATION IS FINISHED TO THE DESIRED TIME, RETURN IS IN BASIC
# TO THE RETURN ADDRESS.
#
# IN EITHER CASE, BEFORE RETURNING, THE EXTRAPOLATED STATE VECTOR IS TRANSFERRED
# FROM R,VATT TO R,VN1 -- PIPTIME1 IS SET TO THE FINISHING INTEGRATION
# TIME AND MPAC IS SET TO THE DELTA TIME --
#                               TAT MINUS CURRENT TIME

# MIDTOAV2
#
# THIS ROUTINE INTEGRATES THIS VEHICLE'S STATE VECTOR TO THE CURRENT TIME PLUS
# INCREMENTS OF TIMEDELT SUCH THAT THE DIFFERENCE BETWEEN CURRENT TIME
# AND THE STATE VECTOR TIME AT THE END OF THE LAST STEP IS AT LEAST 5.6
# SECS.
# NO INPUTS ARE REQUIRED OF THE CALLER.  RETURN IS IN BASIC TO THE RETURN
# ADDRESS WITH THE ABOVE TRANSFERS TO R,VN1 -- PIPTIME1 -- AND MPAC DONE

                SETLOC  INTINIT
                BANK
                EBANK=  IRETURN1
MIDTOAV2        STQ      CALL
                  IRETURN1
                  INTSTALL
                DLOAD   CLEAR
                  TIMEDELT
                  MID1FLAG
                STCALL  T-TO-ADD
                  ENTMID2

MIDTOAV1        STQ      CALL
                  IRETURN1
                  INTSTALL
                SET     RTB
                  MID1FLAG
                  LOADTIME
                DAD     BDSU          # INITIAL CHECK, IS TDEC1 IN THE FUTURE
                  TIMEDELT
                  TDEC1
                BPL     CALL
                  ENTMID1

# Page 1330
                NOTIME          # NO, SET ALARM, SWITCH TO MIDTOAV2

```

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```
ENTMID2      RTB      DAD
               LOADTIME
               T-TO-ADD
               STORE   TDEC1

ENTMID1      CLEAR    CALL
               DIMOFLAG      # NO W-MATRIX
               THISVINT
               CLEAR    SET
               INTYPFLG
               MIDAVFLG      # LET INTEG. KNOW THE CALL IS FOR MIDTOAV.
               CALL
               INTEGRV      # GO INTEGRATE
               SXA,2    SXA,1
               RTX2
               RTX1
               CLEAR    SLOAD
               AMOONFLG
               RTX2
               BZE      SET
               +2
               AMOONFLG
               VLOAD
               RATT
               STOVL    RN1
               VATT
               STODL    VN1
               TAT
               STORE    PIPTIME1
               EXIT

               INHINT
               EXTEND
               DCS      TIME2
               DAS      MPAC
               TC        TPAGREE

               CA        IRETURN1
               TC        BANKJUMP
CKMID2      BOF      RTB
               MID1FLAG
               MID2
               LOADTIME
               DAD      BDSU
               TIMEDELT
               TDEC
```

```

                                BPL      CALL
                                TESTLOOP      # YES
# Page 1331
                                NOTIME
TIMEINC      RTB      DAD
                                LOADTIME
                                T-TO-ADD
                                STCALL      TDEC
                                TESTLOOP
MID2      DLOAD      DSU
                                TDEC
                                TET
                                ABS      DSU
                                3CSECS
                                BPL
                                TIMEINC
                                RTB      BDSU
                                LOADTIME
                                TET
                                DSU      BPL
                                5.6SECS
                                A-PCHK      # YES. GET OUT.
                                DLOAD      DAD
                                T-TO-ADD
                                TIMEDELT
                                STCALL      T-TO-ADD
                                TIMEINC
                                CLEAR      EXIT      # TOO LATE
                                MID1FLAG
                                INCR      IRETURN1
                                TC      ALARM      # SET ERROR EXIT (CALLOC +2)
                                OCT      1703      # INSUFFICIENT TIME FOR INTEGRATION --
                                TC      INTPRET      # TIG WILL BE SLIPPED...
                                DLOAD
                                TIMEDELT
                                STORE      T-TO-ADD
                                RVQ
3CSECS      2DEC      3
TIMEDELT      2DEC      1250

```



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5.6SECS 2DEC 560

BANK 27  
SETLOC UPDATE2  
BANK  
EBANK= INTWAKUQ

# Page 1332

COUNT\* \$\$/INTIN

INTWAKUQ = INTWAK1Q # TEMPORARY UNTIL NAME OF INTWAK1Q IS CHNG

INTWAKEU RELINT  
EXTEND  
QXCH INTWAKUQ # SAVE Q FOR RETURN

TC INTPRET

SLOAD BZE # IS THIS A CSM/LEM STATE VECTOR UPDATE  
UPSVFLAG # REQUEST. IF NOT GO TO INTWAKUP.  
INTWAKUP

VLOAD # MOVE PRECT(6) AND VRECT(6) INTO  
RRECT # RCV(6) AND VCV(6) RESPECTIVELY.

STOVL RCV  
VRECT # NOW GO TO 'RECTIFY +13D' TO  
CALL # STORE VRECT INTO VCV AND ZERO OUT  
RECTIFY +13D # TDELTA(6),TNUV(6),TC(2), AND XKEP(2)  
SLOAD ABS # COMPARE ABSOLUTE VALUE OF 'UPSVFLAG'  
UPSVFLAG # TO 'UPDATE MOON STATE VECTOR CODE'  
DSU BZE # TO DETERMINE WHETHER THE STATE VECTOR TO  
UPMNSVCD # BE UPDATED IS IN THE EARTH OR LUNAR  
INTWAKEM # SPHERE OF INFLUENCE.....  
AXT,2 CLRG0 # EARTH SPHERE OF INFLUENCE.  
DEC 0

MOONFLAG  
INTWAKEC

INTWAKEM AXT,2 SET # LUNAR SPHERE OF INFLUENCE.  
DEC 2

MOONFLAG

INTWAKEC SLOAD BMN # COMMON CODING AFTER X2 INITIALIZED AND  
# MOONFLAG SET (OR CLEARED).  
UPSVFLAG # IS THIS A REQUEST FOR A LEM OR CSM  
INTWAKLM # STATE VECTOR UPDATE.....  
CALL # UPDATE CSM STATE VECTOR  
ATOPCSM

```

                                CLEAR  GOTO
                                ORBWFLAG
                                INTWAKEX

INTWAKLM      CALL              # UPDATE LM STATE VECTOR
                                ATOPLEM

INTWAKEX      CLEAR
                                RENDWFLG

INTWAKUP      SSP      CALL      # REMOVE 'UPDATE STATE VECTOR INDICATOR'
# Page 1333      UPSVFLAG
                                0
                                INTWAKEO      # RELEASE 'GRAB' OF ORBIT INTEG.
                                EXIT

                                TC      PHASCHNG
                                OCT      04026
                                TC      INTWAKUQ

UPMNSVCD      OCT      2
                                OCT      0

GRP2PC        STQ      EXIT
                                GRP2SVQ
                                TC      PHASCHNG
                                OCT      04022
                                TC      INTPRET
                                GOTO      GRP2SVQ

```

This code is written to file `src/INTEGRATION-INITIALIZATION.s`.

## A.44 INTER-BANK COMMUNICATION

723

*<src/INTER-BANK-COMMUNICATION.s 723>≡*

```
# Copyright:    Public domain.
# Filename:     INTER-BANK_COMMUNICATION.agc
# Purpose:     Part of the source code for Comanche, build 055. It
#              is part of the source code for the Command Module's
#              (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:   yaYUL
# Reference:    pp. 1103-1106
# Contact:     Ron Burkey <info@sandroid.org>
# Website:     http://www.ibiblio.org/apollo.
# Mod history:  2009-05-08 RSB   Adapted from Colossus249/ file of same name
#              and page images. Corrected various typos
#              in the transcription of program comments,
#              and these should be back-ported to
#              Colossus249.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#           Massachusetts Institute of Technology
#           75 Cambridge Parkway
#           Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.
```

# Page 1103

# THE FOLLOWING ROUTINE CAN BE USED TO CALL A SUBROUTINE IN ANOTHER BANK. IN THE BANKCALL VERSI  
# CADR OF THE SUBROUTINE IMMEDIATELY FOLLOWS THE TC BANKCALL INSTRUCTION, WITH C(A) AND C(L) PR

```
BLOCK    02
COUNT   02/BANK
```

```
BANKCALL    DXCH    BUF2          # SAVE INCOMING A,L.
             INDEX   Q            # PICK UP CADR.
             CA      0
```

```

                                INCR    Q                # SO WE RETURN TO THE LOC. AFTER THE CADR.

# SWCALL IS IDENTICAL TO BANKCALL, EXCEPT THAT THE CADR ARRIVES IN A.

SWCALL      TS      L
            LXCH    FBANK        # SWITCH BANKS, SAVING RETURN.
            MASK    LOW10        # GET SUB-ADDRESS OF CADR.
            XCH     Q            # A,L NOW CONTAINS DP RETURN.
            DXCH    BUF2         # RESTORING INPUTS IF THIS IS A BANKCALL.
            INDEX   Q
            TC      10000        # SETTING Q TO SWRETURN

SWRETURN    XCH     BUF2 +1      # COMES HERE TO RETURN TO CALLER. C(A,L)
            XCH     FBANK        # ARE PRESERVED FOR RETURN.
            XCH     BUF2 +1
            TC      BUF2

# THE FOLLOWING ROUTINE CAN BE USED AS A UNILATERAL JUMP WITH C(A,L) PRESERVED AND TC
# FOLLOWING THE TC POSTJUMP INSTRUCTION.

POSTJUMP    XCH     Q            # SAVE INCOMING C(A).
            INDEX   A            # GET CADR.
            CA      0

# BANKJUMP IS THE SAME AS POSTJUMP, EXCEPT THAT THE CADR ARRIVES IN A.

BANKJUMP    TS      FBANK
            MASK    LOW10
            XCH     Q            # RESTORING INPUT C(A) IF THIS WAS A
Q+10000     INDEX   Q            # POSTJUMP.
PRI012      TCF     10000        # PRI012 = TCF 10000 = 12000

# Page 1104
# THE FOLLOWING ROUTINE GETS THE RETURN CADR SAVED BY SWCALL OR BANKCALL AND LEAVES

MAKECADR    CAF     LOW10
            MASK    BUF2
            AD      BUF2 +1
            TC      Q

SUPDACAL    TS      MPTMP
            XCH     FBANK        # SET FBANK FOR DATA.
            EXTEND
            ROR     SUPERBNK     # SAVE FBANK IN BITS 15-11, AND
            XCH     MPTMP        # SUPERBANK IN BITS 7-5.
            MASK    LOW10

```

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```
XCH      L          # SAVE REL. ADR. IN BANK, FETCH SUPERBITS
INHINT
EXTEND
WRITE    SUPERBNK   # SET SUPERBANK FOR DATA.
INDEX    L
CA       10000      # PINBALL (FIX MEM DISP) PREVENTS DCA HERE
XCH      MPTMP      # SAVE 1ST WD, FETCH OLD FBANK AND SBANK.
EXTEND
WRITE    SUPERBNK   # RESTORE SUPERBANK.
RELINT
TS       FBANK      # RESTORE FBANK.
CA       MPTMP      # RECOVER FIRST WORD OF DATA.
RETURN   # 24 WDS. DATACALL 516 MU, SUPDACAL 432 MU
```

# Page 1105

# THE FOLLOWING ROUTINES ARE IDENTICAL TO BANKCALL AND SWCALL EXCEPT THAT THEY ARE USED IN INTE

```
IBNKCALL  DXCH      RUPTREG3      # USES RUPTREG3,4 FOR DP RETURN ADDRESS.
           INDEX    Q
           # Was CAF --- RSB 2009
           CA       0
           INCR     Q
```

```
ISWCALL   TS       L
           LXCH     FBANK
           MASK     LOW10
           XCH      Q
           DXCH     RUPTREG3
           INDEX    Q
           TC       10000
```

```
ISWRETRN  XCH      RUPTREG4
           XCH      FBANK
           XCH      RUPTREG4
           TC       RUPTREG3
```

# 2. USPRCADR ACCESSES INTERPRETIVE CODING IN OTHER THAN THE USER'S FBANK. THE CALLING SEQUENC

```
#      L      TC      USPRCADR
#      L+1    CADR     INTPRETX      # INTPRETX IS THE INTERPRETIVE CODING
#                                     # RETURN IS TO L+2
```

```
USPRCADR  TS       LOC          # SAVE A
           CA       BIT8
           TS       EDOP        # EXIT INSTRUCTION TO EDOP
           CA       BBANK
           TS       BANKSET     # USER'S BBANK TO BANKSET
```

INDEX	Q	
CA	0	
TS	FBANK	# INTERPRETIVE BANK TO FBANK
MASK	LOW10	# YIELDS INTERPRETIVE RELATIVE ADDRESS
XCH	Q	# INTERPRETIVE ADDRESS TO Q, FETCHING L+1
XCH	LOC	# L+1 TO LOC, RETRIEVING ORIGINAL A
TCF	Q+10000	

# Page 1106

# THERE ARE FOUR POSSIBLE SETTINGS FOR CHANNEL 07. (CHANNEL 07 CONTAINS SUPERBANK S

#

#	SETTING	S-REG. VALUE	PSEUDO-FIXED BANK NUMBERS	OCTAL PSEUDO ADDRESSES
#	-----	-----	-----	-----

# SUPERBANK 3	0XX	2000 - 3777	30 - 37	70000 - 107777
---------------	-----	-------------	---------	----------------

#

# SUPERBANK 4	100	2000 - 3777	40 - 47	110000 - 127777
---------------	-----	-------------	---------	-----------------

#

# SUPERBANK 5	101	2000 - 3777	50 - 57	130000 - 147777
---------------	-----	-------------	---------	-----------------

#

# SUPERBANK 6	110	2000 - 3777	60 - 67	150000 - 167777
---------------	-----	-------------	---------	-----------------

#

# \*\*\* THIS ROUTINE MAY BE CALLED BY ANY PROGRAM LOCATED IN BANKS 00 - 27. I.E., NO P

# SUPERBANK SHOULD USE SUPERSW. \*\*\*

#

# SUPERSW MAY BE CALLED IN THIS FASHION:

#	CAF	ABBCON	WHERE -- ABBCON BBCON SOMETHING --
#	TCR	SUPERSW	(THE SUPERBNK BITS ARE IN THE BBCON)

#

# ...

#

# .

#

# .

#	CAF	SUPERSET	WHERE SUPERSET IS ONE OF THE FOUR AVAILABLE
#	TCR	SUPERSW	SUPERBANK BIT CONSTANTS:
#	...	...	SUPER011 OCTAL 60
#	.	.	SUPER100 OCTAL 100
#	.	.	SUPER101 OCTAL 120
#	.	.	SUPER110 OCTAL 140

SUPERSW

EXTEND

WRITE SUPERBNK

# WRITE BITS 7-6-5 OF THE ACCUMULATOR INTO  
# CHANNEL 07

TC Q

# TC TO INSTRUCTION FOLLOWING

# TC SUPERSW

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This code is written to file `src/INTER-BANK-COMMUNICATION.s`.

## A.45 INTERPRETER

```

728  <src/INTERPRETER.s 728>≡
      # Copyright:   Public domain.
      # Filename:    INTERPRETER.agc
      # Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
      #              It is part of the source code for the Command Module's (CM)
      #              Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:  yaYUL
      # Contact:     Ron Burkey <info@sandroid.org>.
      # Website:     www.ibiblio.org/apollo.
      # Pages:       1107-1199
      # Mod history: 2009-05-08 RSB   Adapted from the Luminary131/ file of the
      #              same name, using Comanche055 page images.
      #              2009-05-20 RSB   Corrections: P00D00 -> P00D00, fixed a
      #              "Page N" reference.
      #              2009-05-21 RSB   Corrected definition of 5B10, which overflowed
      #              integer arithmetic.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 055 of AGC program Comanche by NASA
      #       2021113-051.  10:28 APR. 1, 1969
      #
      #       This AGC program shall also be referred to as
      #
      #               Colossus 2A
      #
      # Page 1107
      # SECTION 1:  DISPATCHER
      #
      # ENTRY TO THE INTERPRETER.  INTPRET SETS LOC TO THE FIRST INSTRUCTION, BANKSET TO THE
      # OBJECT INTERPRETIVE PROGRAM, AND INTBIT15 TO THE BIT15 CONTENTS OF FBANK.  INTERPRETER
      # VIRTUALLY ALL BANKS PRESENT UNDER ANY SUPER-BANK SETTING, WITH THE RESTRICTION THAT
      # (BIT15 OF FBANK = 1) DO NOT REFER TO LOWBANKS, AND VICE-VERSA.  THE INTERPRETER DOES
      # E-BANK SWITCHING OCCURS WHENEVER GENERAL ERASABLE (100-3777) IS ADDRESSED.

```



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```

COUNT*  $$/INTER
INTPRET  RELINT
EXTEND
QXCH     LOC      # SET LOC TO THE WORD FOLLOWING THE TC.
+2       CA       BBANK  # INTERPRETIVE BRANCHES FINISH HERE.
        TS       BANKSET
        MASK     BIT15   # GET 15TH BIT FOR INDEXABLE ADDRESSES.
        TS       INTBIT15

        TS       EDOP    # MAKE SURE NO INSTRUCTIONS LEFT OVER
        TCF      NEWOPS  # PICK UP OP CODE PAIR AND BEGIN.

INTRSM   LXCH     BBANK  # RESUME SUSPENDED INTERPRETIVE JOB
        TCF      INTPRET +3

# DLOAD LOADS MPAC, MPAC +1, LEAVING ZERO IN MPAC +2.

DLOAD    EXTEND
INDEX    ADDRWD
DCA      0      # LOAD DP C(C(ADDRWD)) INT MPAC,MPAC +1
SLOAD2   DXCH    MPAC
CAF      ZERO   # ZERO MPAC +2

# Page 1108
# AT THE END OF MOST INSTRUCTIONS, CONTROL IS GIVEN TO DANZIG TO DISPATCH THE NEXT OPERATION.

        TS       MPAC +2      # AND DECLARE DP MODE

NEWMODE  TS       MODE      # PROLOGUE FOR MODE-CHANGING INSTRUCTIONS.

DANZIG   CA       BANKSET   # SET BBANK BEFORE TESTING NEWJOB SO THAT
        TS       BBANK     # IT MAY BE SAVED DIRECTLY BY CHANJOB.

NOIBNKSW CCS      EDOP      # SEE IF AN ORDER CODE IS LEFT OVER FROM
        TCF      OPJUMP    # THE LAST PAIR RETRIEVED. IF SO, EXECUTE.
                                # EDOP IS SET TO ZERO ON ITS RE-EDITING.

        CCS      NEWJOB    # SEE IF A JOB OF HIGHER PRIORITY IS
        TCF      CHANG2    # PRESENT, AND IF SO, CHANGE JOBS.

        INCR     LOC      # ADVANCE THE LOCATION COUNTER.

# ITRACE (1) REFERS TO "NEWOPS"
NEWOPS   INDEX    LOC      # ENTRY TO BEGIN BY PICKING OP CODE PAIR.
```

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	CA	0	# MAY BE AN OPCODE PAIR OR A STORE CODE
	CCS	A	# TEST SIGN AND GET DABS(A).
	TCF	DOSTORE	# PROCESS STORE CODE.
LOW7	OCT	177	
	TS	EDOP	# OP CODE PAIR. LEAVE THE OTHER IN PLACE
	MASK	LOW7	# WHERE CCS EDOP WILL HONOR IT NEXT.
OPJUMP	TS	CYR	# LOWWD ENTERS HERE IF A RIGHT-HAND CODE
	CCS	CYR	# CODE IS TO BE PROCESSED. TEST PREFIX
	TCF	OPJUMP2	# TEST SECOND PREFIX BIT.
	TCF	EXIT	# +0 OP CODE IS EXIT

# Page 1109

# PROCESS ADDRESSES WHICH MAY BE DIRECT, INDEXED, OR REFERENCE THE PUSHDOWN LIST.

ADDRESS	MASK	BIT1	# SEE IF ADDRESS IS INDEXED. CYR CODE
	CCS	A	# 400XX, SO BIT 1 IS NOW AS IT WAS IN
	TCF	INDEX	# FORM INDEXED ADDRESS.
DIRADRES	INDEX	LOC	# LOOK AHEAD TO NEXT WORD TO SEE IF
OCT40001	CS	1	# ADDRESS IS GIVEN.
	CCS	A	
	TCF	PUSHUP	# IF NOT.
NEG4	DEC	-4	
	INCR	LOC	# IF SO, TO SHOW WE PICKED UP A WORD
	TS	ADDRWD	

# Page 1110

# FINAL DIGESTION OF DIRECT ADDRESSES OF OP CODES WITH 01 PREFIX IS DONE HERE. IN PLACE  
 # REQUIRED 12-BIT SUB-ADDRESS IS LEFT IN ADDRWD, WITH ANY REQUIRED E OR F BANK SWITCHES  
 # THAN 45D ARE TAKEN TO BE RELATIVE TO THE WORK AREA. THE OP CODE IS NOW IN BITS 1-5

	AD	-ENDVAC	# SEE IF ADDRESS RELATIVE TO WORK AREA
	CCS	A	
	AD	-ENDERAS	# IF NOT, SEE IF IN GENERAL ERASABLE
	TCF	IERASTST	
NETZERO	CA	FIXLOC	# IF SO, LEAVE THE MODIFIED ADDRESS IN
	ADS	ADDRWD	# ADDRWD AND DISPATCH.
ITR15	INDEX	CYR	# THIS INDEX MAKES THE NEXT INSTRUCTION
	7	INDJUMP -1	# TCF INDJUMP + OP, EDITING CYR.

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IERASTST	EXTEND		
	BZMF	GEADDR	# GO PROCESS GENERAL-ERASABLE ADDRESS.
	MASK	LOW10	# FIXED BANK ADDRESS. RESTORE AND ADD B15.
	AD	LOW10	# SWITCH BANKS AND LEAVE SUBADDRESS IN
	XCH	ADDRWD	# ADDRWD FOR OPERAND RETRIEVAL. (THIS
	AD	INTBIT15	# METHOD PRECLUDES USE OF THE LAST
	TS	FBANK	# LOCATION IN EACH FBANK.)
ITR12	INDEX	CYR	
	7	INDJUMP -1	
GEADDR	MASK	LOW8	
	AD	OCT1400	
	XCH	ADDRWD	
	TS	EBANK	
ITR10	INDEX	CYR	
	7	INDJUMP -1	

# Page 1111

# THE FOLLOWING ROUTINE PROCESSES INTERPRETIVE INDEXED ADDRESSES. AN INTERPRETER INDEX REGISTER  
# CONTAIN THE ADDRESS OF ANY ERASABLE REGISTER (0-42 BEING RELATIVE TO THE VAC AREA) OR ANY INT  
# BANK, OR ANY INTEGER IN THAT RANGE.

DODLOAD*	CAF	DLOAD*	# STODL* COMES HERE TO PROCESS LOAD ADR.
	TS	CYR	# (STOVL* ENTERS HERE).
INDEX	CA	FIXLOC	# SET UP INDEX LOCATION.
	TS	INDEXLOC	
	INCR	LOC	# (ADDRESS ALWAYS GIVEN).
	INDEX	LOC	
	CS	0	
	CCS	A	# INDEX 2 IF ADDRESS STORED COMPLEMENTED.
	INCR	INDEXLOC	
	NOOP		
	TS	ADDRWD	# 14 BIT ADDRESS TO ADDRWD.
	MASK	HIGH4	# IF ADDRESS GREATER THAN 2K, ADD INTBIT15
	EXTEND		
	BZF	INDEX2	
	CA	INTBIT15	
	ADS	ADDRWD	
INDEX2	INDEX	INDEXLOC	
	CS	X1	
	ADS	ADDRWD	# DO AUGMENT, IGNORING AND CORRECTING OVF.

```

                                MASK    HIGH9                # SEE IF ADDRESS IS IN WORK AREA.
                                EXTEND
                                BZF     INDWORK
                                MASK    HIGH4                # SEE IF IN FIXED BANK.
                                EXTEND
                                BZF     INDERASE

                                CA       ADDRWD                # IN FIXED -- SWITCH BANKS AND CREAT
                                TS       FBANK                  # SUB-ADDRESS
                                MASK    LOW10
                                AD       2K
                                TS       ADDRWD
ITR11  INDEX    CYR
                                3       INDJUMP -1

INDWORK  CA       FIXLOC                # MAKE ADDRWD RELATIVE TO WORK AREA.
        TCF     ITR13 -1

INDERASE CA       OCT1400
        XCH     ADDRWD
        TS      EBANK
        MASK    LOW8
        -1     ADS     ADDRWD
# Page 1112
ITR13  INDEX    CYR
        3       INDJUMP -1

# Page 1113
# PUSH-UP ROUTINES.  WHEN NO OPERAND ADDRESS IS GIVEN, THE APPROPRIATE OPERAND IS TAKEN FROM THE
# LIST.  IN MOST CASES THE MODE OF THE RESULT (VECTOR OR SCALAR) OF THE LAST ARTGHEMATIC OPERATION
# IS THE SAME AS THE TYPE OF OPERAND DESIRED (ALL ADD/SUBTRACT ETC.).  EXCEPTIONS TO THIS RULE ARE
# BELOW (NOTE THAT IN EVERY CASE THE MODE REGISTER IS LEFT INTACT):
#
# 1.    VXSC AND V/SC WANT THE OPPOSITE TYPE OF OPERAND, E.G., IF THE LAST OPERATION WAS A VECTOR
#        RESULT, VXSC WANTS A SCALAR.
#
# 2.    THE LOAD CODES SHOULD LOAD THE ACCUMULATOR INDEPENDENT OF THE RESULT TYPE.  THE LOAD CODES
#        INCLUDES VLOAD, DLOAD, TLOAD, PDDL, AND PDVL (NO PUSHUP WITH SLOAD).
#
# 3.    SOME ARITHMETIC OPERATIONS REQUIRE A STANDARD TYPE OF OPERAND REGARDLESS OF THE TYPE OF
#        THIS INCLUDES SIGN WANTING DP AND TAD REQUIRING TP.

PUSHUP  CAF      OCT23                # IF THE LOW 5 BITS OF CYR ARE LESS THAN
        MASK     CYR                  # 20, THIS OP REQUIRES SPECIAL ATTENTION.
        AD       -OCT10               # (NO -0).
```

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	CCS	A	
	TCF	REGUP	# FOR ALL CODES GREATER THAN OCT 7.
-OCT10	OCT	-10	
	AD	NEG4	# WE NOW HAVE 7 -- OP CODE (MOD4). SEE IF
	CCS	A	# THE OP CODE (MOD4) IS THREE (REVERSE).
	INDEX	A	# NO -- THE MODE IS DEFINITE. PICK UP THE
	CS	NO.WDS	
	TCF	REGUP +2	
	INDEX	MODE	# FOR VXSC AND V/SC WE WANT THE REQUIRED
	CS	REVCNT	# PUSHLOC DECREMENT WITHOUT CHANGING THE
	TCF	REGUP +2	# MODE AT THE IS TIME.
REGUP	INDEX	MODE	# MOST ALL OP CODES PUSHUP HERE.
	CS	NO.WDS	
+2	ADS	PUSHLOC	
	TS	ADDRWD	
ITR14	INDEX	CYR	
	7	INDJUMP -1	# (THE INDEX MAKES THIS A TCF.)
	OCT	2	# REVERSE PUSHUP DECREMENT. VECTOR TAKES 2
REVCNT	OCT	6	# WORDS, SCALAR TAKES 6.
	OCT	6	
NO.WDS	OCT	2	# CONVENTIONAL DECREMENT IS 6 WORDS VECTOR
OCTAL3	OCT	3	# 2 IN DP, AND 3 IN TP.
	OCT	6	

# Page 1114

# TEST THE SECOND PREFIX BIT TO SEE IF THIS IS A MISCELLANEOUS OR A UNARY/SHORT SHIFT OPERATION

OPJUMP2	CCS	CYR	# TEST SECOND PREFIX BIT.
	TCF	OPJUMP3	# TEST THIRD BIT TO SEE IF UNARY OR SHIFT

-ENDVAC DEC -45

# THE FOLLOWING ROUTINE PROCESSES ADDRESSES OF SUFFIX CLASS 10. THEY ARE BASICALLY WORK AREA A  
# IN THE RANGE 0-52, ERASABLE ECADR CONSTANTS FROM 100-3777, AND FCADRS ABOVE THAT. ALL 15 BIT  
# IN CONTRAST TO SUFFIX 1, IN WHICH ONLY THE LOW ORDER 14 ARE AVAILABLE.

15BITADR	INCR	LOC	# (ENTRY HERE FROM STCALL).
	INDEX	LOC	# PICK UP ADDRESS WORD.
	CA	0	
	TS	POLISH	# WE MAY NEED A SUBADDRESS LATER.

	CAF	LOW7+2K	# THESE INSTRUCTIONS ARE IN BANK 1.
	TS	FBANK	
	MASK	CYR	
ITR7	INDEX	A	
	TCF	MISCJUMP	

# Page 1115

# COMPLETE THE DISPATCHING OF UNARY AND SHORT SHIFT OPERATIONS.

OPJUMP3	TS	FBANK	# CALL IN BANK 0 (BITS 11-15 OF A ARE 0.)
	CCS	CYR	# TEST THIRD PREFIX BIT.
	INDEX	A	# THE DECREMENTED UNARY CODE IS IN BITS
	TCF	UNAJUMP	# 1-4 OF A (ZERO, EXIT, HAS BEEN DETECTED)
	CCS	MODE	# IT'S A SHORT SHIFT CODE. SEE IF PRESENT
	TCF	SHORTT	# SCALAR OR VECTOR.
	TCF	SHORTT	
	TCF	SHORTV	# CALLS THE APPROPRIATE ROUTINE.
FBANKMSK	EQUALS	BANKMASK	
LVBUFF	ADRES	VBUF	

# Page 1116

# THE FOLLOWING IS THE JUMP TABLE FOR OP CODES WHICH MAY HAVE INDEXABLE ADDRESSES OR

INDJUMP	TCF	VLOAD	# 00 -- LOAD MPAC WITH A VECTOR.
	TCF	TAD	# 01 -- TRIPLE PRECISION ADD TO MPAC.
	TCF	SIGN	# 02 -- COMPLEMENT MPAC (V OR SC) IF X NEG.
	TCF	VXSC	# 03 -- VECTOR TIMES SCALAR.
	TCF	CGOTO	# 04 -- COMPUTED GO TO.
	TCF	TLOAD	# 05 -- LOAD MPAC WITH TRIPLE PRECISION.
	TCF	DLOAD	# 06 -- LOAD MPAC WITH A DP SCALAR.
	TCF	V/SC	# 07 -- VECTOR DIVIDED BY A SCALAR.
	TCF	SLOAD	# 10 -- LOAD MPAC IN SINGLE PRECISION.
	TCF	SSP	# 11 -- SET SINGLE PRECISION INTO X.
	TCF	PDDL	# 12 -- PUSH DOWN MPAC AND RE-LOAD IN DP.
	TCF	MXV	# 13 -- MATRIX POST-MULTIPLIED BY VECTOR.
	TCF	PDVL	# 14 -- PUSH DOWN AND VECTORLOAD.
	TCF	CCALL	# 15 -- COMPUTED CALL.
	TCF	VXM	# 16 -- MATRIX PRE-MULTIPLIED BY VECTOR.
	TCF	TSLC	# 17 -- NORMALIZE MPAC (SCALAR ONLY).
	TCF	DMPR	# 20 -- DP MULTIPLY AND ROUND.
	TCF	DDV	# 21 -- DP DIVIDE BY.

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TCF	BDDV	# 22 -- DP DIVIDE INTO.
TCF	GSHIFT	# 23 -- GENERAL SHIFT INSTRUCTION
TCF	VAD	# 24 -- VECTOR ADD.
TCF	VSU	# 25 -- VECTOR SUBTRACT.
TCF	BVSU	# 26 -- VECTOR SUBTRACT FROM.
TCF	DOT	# 27 -- VECTOR DOT PRODUCT.
TCF	VXV	# 30 -- VECTOR CROSS PRODUCT.
TCF	VPROJ	# 31 -- VECTOR PROJECTION.
TCF	DSU	# 32 -- DP SUBTRACT.
TCF	BDSU	# 33 -- DP SUBTRACT FROM.
TCF	DAD	# 34 -- DP ADD.
TCF	+0	# 35 -- AVAILABLE
TCF	DMP1	# 36 -- DP MULTIPLY.
TCF	SETPD	# 37 -- SET PUSH DOWN POINTER (DIRECT ONLY)

# CODES 10 AND 14 MUST NOT PUSH UP. CODE 04 MAY BE USED FOR VECTOR DECLARE BEFORE PUSHUP IF DES

# Page 1117

# THE FOLLOWING JUMP TABLE APPLIES TO INDEX, BRANCH, AND MISCELLANEOUS INSTRUCTIONS.

MISCJUMP	TCF	AXT	# 00 -- ADDRESS TO INDEX TRUE.
	TCF	AXC	# 01 -- ADDRESS TO INDEX COMPLEMENTED.
	TCF	LXA	# 02 -- LOAD INDEX FROM ERASABLE.
	TCF	LXC	# 03 -- LOAD INDEX FROM COMPLEMENT OF ERAS.
	TCF	SXA	# 04 -- STORE INDEX IN ERASABLE.
	TCF	XCHX	# 05 -- EXCHANGE INDEX WITH ERASABLE.
	TCF	INCR	# 06 -- INCREMENT INDEX REGISTER.
	TCF	TIX	# 07 -- TRANSFER ON INDEX.
	TCF	XAD	# 10 -- INDEX REGISTER ADD FROM ERASABLE.
	TCF	XSU	# 11 -- INDEX SUBTRACT FROM ERASABLE.
	TCF	BZE/GOTO	# 12 -- BRANCH ZERO AND GOTO
	TCF	BPL/BMN	# 13 -- BRANCH PLUS AND BRANCH MINUS.
	TCF	RTB/BHIZ	# 14 -- RETURN TO BASIC AND BRANCH HI ZERO.
	TCF	CALL/ITA	# 15 -- CALL AND STORE QPRET.
	TCF	SW/	# 16 -- SWITCH INSTRUCTIONS AND AVAILABLE.
	TCF	BOV(B)	# 17 -- BRANCH ON OVERFLOW TO BASIC OR INT.

# Page 1118

# THE FOLLOWING JUMP TABLE APPLIES TO UNARY INSTRUCTIONS

	COUNT*	\$\$/INTER	
	BANK	0	# 00 -- EXIT -- DETECTED EARLIER.
UNAJUMP	TCF	SQRT	# 01 -- SQUARE ROOT.
	TCF	SINE	# 02 -- SIN.
	TCF	COSINE	# 03 -- COS.

TCF	ARCSIN	# 04 -- ARC SIN.
TCF	ARCCOS	# 05 -- ARC COS.
TCF	DSQ	# 06 -- DP SQUARE.
TCF	ROUND	# 07 -- ROUND TO DP.
TCF	COMP	# 10 -- COMPLEMENT VECTOR OR SCALAR
TCF	VDEF	# 11 -- VECTOR DEFINE.
TCF	UNIT	# 12 -- UNIT VECTOR.
TCF	ABVALABS	# 13 -- LENGTH OF VECTOR OR MAG OF SCALAR.
TCF	VSQ	# 14 -- SQUARE OF LENGTH OF VECTOR.
TCF	STADR	# 15 -- PUSH UP ON STORE CODE.
TCF	RVQ	# 16 -- RETURN VIA QPRET.
TCF	PUSH	# 17 -- PUSH MPAC DOWN.

# Page 1119

# SECTION 2 LOAD AND STORE PACKAGE.

#

# A SET OF EIGHT STORE CODES IS PROVIDED AS THE PRIMARY METHOD OF STORING THE MULTI-  
 # ACCUMULATOR (MPAC). IF IN THE DANZIG SECTION LOC REFERS TO AN ALGEBRAICALLY POSITIVE  
 # STORE CODE WITH A CORRESPONDING ERASABLE ADDRESS. MOST OF THESE CODES ARE TWO ADDRESS  
 # FOLLOWING THE STORE CODE IS TO BE USED AS AN ADDRESS FROM WHICH TO RE-LOAD MPAC. IF

#

#	1. STORE	STORE MPAC. THE E ADDRESS MAY BE INDEXED.
#	2. STODL	STORE MPAC AND RE-LOAD IT IN DP WITH THE NEXT ADDRESS (THE LOAD ADDRESS).
#	3. STOVL	STORE MPAC AND RE-LOAD A VECTOR (AS ABOVE).
#	4. STCALL	STORE AND DO A CALL (BOTH ADDRESSES MUST BE DIRECT HERE).

#

# STODL AND STOVL WILL TAKE FROM THE PUSH-DOWN LIST IF NO LOAD ADDRESS IS GIVEN.

BLOCK 3

COUNT 03/INTER

STADR	CA	BANKSET	# THE STADR CODE (PUSHUP UP ON STORE
	TS	FBANK	# ADDRESS) ENTERS HERE.
	INCR	LOC	
ITR1	INDEX	LOC	# THE STORECODE WAS STORED COMPLEMENTED TO
	CS	0	# MAKE IT LOOK LIKE AN OPCODE PAIR.
	AD	NEGONE	# (YUL CAN'T REMOVE 1 BECAUSE OF EARLY CCS)
DOSTORE	TS	ADDRWD	
	MASK	LOW11	# ENTRY FROM DISPATCHER. SAVE THE ERASABLE
	XCH	ADDRWD	# ADDRESS AND JUMP ON THE STORE CODE NO.
	MASK	B12T14	
	EXTEND		
	MP	BIT5	# EACH TRANSFER VECTOR ENTRY IS TWO WORDS.



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ITRO            INDEX    A  
              TCF        STORJUMP

# Page 1120

# STORE CODE JUMP TABLE. CALLS THE APPROPRIATE STORING ROUTINE AND EXITS TO DANZIG OR TO ADDRESS.

# A SUPPLIED OPERATION CODE.

#

# STORE STORE,1 AND STORE,2 RETURN TO DANZIG, THUS RESETTING THE EBANK TO ITS STATE AT INTPRET.

STORJUMP	TC	STORE	# STORE.
	TCF	DANZIG	# PICK UP NEW OP CODE(S).
	TC	STORE,1	
	TCF	DANZIG	
	TC	STORE,2	
	TCF	DANZIG	
	TC	STORE	# STODL.
	TCF	DODLOAD	
	TC	STORE	# STODL WITH INDEXED LOAD ADDRESS.
	TCF	DODLOAD*	
	TC	STORE	# STOVL.
	TCF	DOVLOAD	
	TC	STORE	# STOVL WITH INDEXED LOAD ADDRESS.
	TCF	DOVLOAD*	
	TC	STORE	# STOTC.
	CAF	CALLCODE	
	TS	CYR	
	TCF	15BITADR	# GET A 15 BIT ADDRESS.

# Page 1121

# STORE CODE ADDRESS PROCESSOR.

STORE,1	INDEX	FIXLOC	
	CS	X1	
	TCF	PRESTORE	
STORE,2	INDEX	FIXLOC	
	CS	X2	
PRESTORE	ADS	ADDRWD	# RESULTANT ADDRESS IS IN ERASABLE.
STORE	CS	ADDRWD	
	AD	DEC45	
	CCS	A	# DOES THE ADDRESS POINT TO THE WORK AREA?

	CA	FIXLOC	# YES.
	TCF	AHEAD5	
	CA	OCT1400	# NO. SET EBANK & MAKE UP SUBADDRESS.
	XCH	ADDRWD	
	TS	EBANK	
	MASK	LOW8	
AHEAD5	ADS	ADDRWD	

# Page 1122

# STORING ROUTINES. STORE DP, TP, OR VECTOR AS INDICATED BY MODE.

STARTSTO	EXTEND	# MPAC,+1 MUST BE STORED IN ANY EVENT.
# ITRACE (5) REFERS TO	"STARTSTO".	

DCA	MPAC
INDEX	ADDRWD
DXCH	0

CCS	MODE
TCF	TSTORE
TC	Q

VSTORE	EXTEND
	DCA MPAC +3
	INDEX ADDRWD
	DXCH 2

EXTEND
DCA MPAC +5
INDEX ADDRWD
DXCH 4
TC Q

TSTORE	CA MPAC +2
	INDEX ADDRWD
	TS 2
	TC Q

# Page 1123

# ROUTINES TO BEGIN PROCESSING OF THE SECOND ADDRESS ASSOCIATED WITH ALL STORE-TYPE C  
# ITSELF.

DODLOAD	CAF	DLOADCOD	
	TS	CYR	
	TCF	DIRADRES	# GO GET A DIRECT ADDRESS.

DOVLOAD	CAF	VLOADCOD
---------	-----	----------

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```

          TS      CYR
          TCF      DIRADRES

DOVLOAD*   CAF      VLOAD*
          TCF      DODLOAD* +1      # PROLOGUE TO INDEX ROUTINE.
```

# Page 1124

# THE FOLLOWING LOAD INSTRUCTIONS ARE PROVIDED FOR LOADING THE MULTI-PURPOSE ACCUMULATOR MPAC.

```

TLOAD      INDEX    ADDRWD
          CA        2              # LOAD A TRIPLE PRECISION ARGUMENT INTO
          TS        MPAC +2        # THE FIRST THREE MPAC REGISTERS, WITH THE
          EXTEND     # CONTENTS OF THE OTHER FOUR IRRELEVANT.
          INDEX    ADDRWD
          DCA       0
          DXCH      MPAC
TMODE      CAF      ONE
          TCF      NEWMODE        # DECLEAR TRIPLE PRECISION MODE.

SLOAD      ZL
          INDEX    ADDRWD        # LOAD A SINGLE PRECISION NUMBER INTO
          CA        0            # MPAC, SETTING MPAC+1,2 TO ZERO. THE
          TCF      SLOAD2        # CONTENTS OF THE REMAINING MPAC REGISTERS
                                   # ARE IRRELEVANT.

VLOAD      EXTEND     # LOAD A DOUBLE PRECISION VECTOR INTO
          INDEX    ADDRWD        # MPAC,+1, MPAC+3,4, AND MPAC+5,6. THE
          DCA       0            # CONTENTS OF MPAC +2 ARE IRRELEVANT.
          DXCH      MPAC

ENDVLOAD   EXTEND     # PDVL COMES HERE TO FINISH UP FOR DP, TP.
          INDEX    ADDRWD
          DCA       2
          DXCH      MPAC +3

          +4        EXTEND     # TPDVL FINISHES HERE.
          INDEX    ADDRWD
          DCA       4
          DXCH      MPAC +5

VMODE      CS        ONE        # DECLARE VECTOR MODE.
          TCF      NEWMODE
```

# Page 1125

# THE FOLLOWING INSTRUCTIONS ARE PROVIDED FOR STORING OPERANDS IN THE PUSHDOWN LIST:

```

#      1.      PUSH          PUSHDOWN AND NO LOAD.
#      2.      PDDL          PUSHDOWN AND DOUBLE PRECISION LOAD.
```

```

#          3.          PDVL          PUSHDOWN AND VECTOR LOAD.

PDDL          EXTEND
              INDEX  ADDRWD          # LOAD MPAC,+1, PUSHING THE FORMER
              DCA    0                # CONTENTS DOWN.
              DXCH   MPAC
              INDEX  PUSHLOC
              DXCH   0

              INDEX  MODE          # ADVANCE THE PUSHDOWN POINTER APPRO-
              CAF    NO.WDS         # PRIATELY.
              ADS    PUSHLOC

              CCS     MODE
              TCF     ENDPUSH
              TCF     ENDDPUSH

              TS      MODE          # NOW DP.
ENDVPUSH      TS      MPAC +2
              DXCH   MPAC +3        # PUSH DOWN THE REST OF THE VECTOR HERE.
              INDEX  PUSHLOC
              DXCH   0 -4

              DXCH   MPAC +5
              INDEX  PUSHLOC
              DXCH   0 -2

              TCF     DANZIG

ENDDPUSH      TS      MPAC +2        # SET MPAC +2 TO ZERO AND EXIT ON DP.
              TCF     DANZIG

ENDTPUSH      TS      MODE
              XCH     MPAC +2        # ON TRIPLE, SET MPAC +2 TO ZERO, PUSHING
              +2      INDEX  PUSHLOC  # DOWN THE OLD CONTENTS
              TS      0 -1
              TCF     DANZIG

# Page 1126
# PDVL -- PUSHDOWN AND VECTOR LOAD

PDVL          EXTEND          # RELOAD MPAC AND PUSH DOWN ITS CONTENTS.
              INDEX  ADDRWD
              DCA    0
              DXCH   MPAC
              INDEX  PUSHLOC

```

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```

DXCH      0

INDEX     MODE      # ADVANCE THE PUSHDOWN POINTER.
CAF       NO.WDS
ADS       PUSHLOC

CCS       MODE      # TEST PAST MODE.
TCF       TPDVL
TCF       ENDVLOAD  # JUST LOAD LAST FOUR REGISTERS ON DP.

VPDVL     EXTEND     # PUSHDOWN AND RE-LOAD LAST TWO COMPONENTS
INDEX     ADDRWD
DCA       2
DXCH      MPAC +3
INDEX     PUSHLOC
DXCH      0 -4

EXTEND
INDEX     ADDRWD
DCA       4
DXCH      MPAC +5
INDEX     PUSHLOC
DXCH      0 -2

TCF       DANZIG

TPDVL     EXTEND     # ON TP, WE MUST LOAD THE Y COMPONENT
INDEX     ADDRWD    # BEFORE STORING MPAC +2 IN CASE THIS IS A
DCA       2          # PUSHUP.
DXCH      MPAC +3

CA        MPAC +2
INDEX     PUSHLOC   # IN DP.
TS        0 -1
TCF       ENDVLOAD +4

# SSP (STORE SINGLE PRECISION) IS EXECUTED HERE.

SSP       INCR      LOC      # PICK UP THE WORD FOLLOWING THE GIVEN
INDEX     LOC        # ADDRESS AND STORE IT AT X.
CA        0
STORE1    INDEX     ADDRWD   # SOME INDEX AND MISCELLANEOUS OPS END
TS        0          # HERE.

# Page 1127
TCF       DANZIG
```

# Page 1128

# SEQUENCE CHANGING AND SUBROUTINE CALLING OPTIONS.

#

# THE FOLLOWING OPERATIONS ARE AVAILABLE FOR SEQUENCING CHANGING, BRANCHING, AND CALL

#	1.	GOTO	GO TO.
#	2.	CALL	CALL SUBROUTINE SETTING QPRET.
#	3.	CGOTO	COMPUTED GO TO.
#	4.	CCALL	COMPUTED CALL.
#	7.	BPL	BRANCH IF MPAC POSITIVE OR ZERO.
#	8.	BZE	BRANCH IF MPAC ZERO.
#	9.	BMN	BRANCH IF MPAC NEGATIVE NON-ZERO.

CCALL INCR LOC # MAINTAIN LOC FOR QPRET COMPUTATION

INDEX LOC

# Was CAF --- RSB 2009.

CA 0 # GET BASE ADDRESS OF CADR LIST.

INDEX ADDRWD

AD 0 # ADD INCREMENT.

TS FBANK # SELECT DESIRED CADR.

MASK LOW10

INDEX A

CAF 10000

TS POLISH

CALL CA BANKSET # FOR ANY OF THE CALL OPTIONS, MAKE UP THE

MASK BANKMASK # ADDRESS OF THE NEXT OP-CODE PAIR/STORE

AD BANKMASK # CODE AND LEAVE IT IN QPRET. NOTE THAT

AD LOC # BANKMASK = -(2000 - 1).

INDEX FIXLOC

TS QPRET

GOTO CA POLISH # BASIC BRANCHING SEQUENCE.

+1 MASK HIGH4

EXTEND

BZF GOTOERS # SEE IF ADDRESS POINTS TO FIXED OR ERAS.

+4 CA BANKSET # SET EBANK PART OF BBANK. NEXT, SET UP

TS BBANK # FBANK. THE COMBINATION IS PICKED UP &amp;

CA POLISH # PUT INTO BANKSET AT INTPRET +2.

TS FBANK

MASK LOW10

AD 2K

TS LOC

TCF INTPRET +3

EBANK= 1400 # SO YUL DOESN'T CUSS THE "CA 1400" BELOW.

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GOTOERS	CA	POLISH	# THE GIVEN ADDRESS IS IN ERASABLE -- SEE
	AD	-ENDVAC	# IF RELATIVE TO THE WORK AREA.
	CCS	A	
	CA	POLISH	# GENERAL ERASABLE.
	TCF	GOTOG	

# Page 1129

	CA	FIXLOC	# WORK AREA.
	AD	POLISH	
	INDEX	A	# USE THE GIVEN ADDRESS AS THE ADDRESS OF
	CA	0	# THE BRANCH ADDRESS.
	TS	POLISH	
	TCF	GOTO +1	# ALLOWS ARBITRARY INDIRECTNESS LEVELS.

GOTOG	TS	EBANK	
	MASK	LOW8	
	INDEX	A	# USE THE GIVEN ADDRESS AS THE ADDRESS OF
	CA	1400	# THE BRANCH ADDRESS.
	TS	POLISH	
	TCF	GOTO +1	

CGOTO	INDEX	LOC	# COMPUTED GO TO. PICK UP ADDRESS OF CADR
	CA	1	# LIST
	INDEX	ADDRWD	# ADD MODIFIER.
	AD	0	
	TS	FBANK	# SELECT GOTO ADDRESS
	MASK	LOW10	
	INDEX	A	
	CA	10000	
	TS	POLISH	
	TCF	GOTO +1	# WITH ADDRESS IN A.

SWBRANCH	CA	BANKSET	# SWITCH INSTRUCTIONS WHICH ELECT TO
	TS	FBANK	# BRANCH COME HERE TO DO SO.
	INDEX	LOC	
	CA	1	
	TS	POLISH	
	TCF	GOTO +1	

# Page 1130

# TRIPLE PRECISION BRANCHING ROUTINE. IF CALLING TC IS AT L, RETURN IS AS FOLLOWS:

#	L+1	IF MPAC IS GREATER THAN ZERO.
#	L+2	IF MPAC IS EQUAL TO +0 OR -0.
#	L+3	IF MPAC IS LESS THAN ZERO.

BRANCH	CCS	MPAC
--------	-----	------

```

TC      Q
TCF     +2      # ON ZERO.
TCF     NEG

CCS     MPAC +1
TC      Q
TCF     +2
TCF     NEG

CCS     MPAC +2
TC      Q
TCF     +2
TCF     NEG

Q+1      INDEX  Q
          TC      1

NEG      INDEX  Q      # IF FIRST NON-ZERO REGISTER WAS NEGATIVE.
          TC      2

Q+2      =      NEG

# ITRACE (3) REFERS TO "EXIT".

EXIT      CA      BANKSET      # RESTORE USER'S BANK SETTING, AND LEAVE
          TS      BBANK      # INTERPRETIVE MODE.
          INDEX   LOC
          TC      1

# Page 1131
# SECTION 3 -- ADD/SUBTRACT PACKAGE.
#
# THE FOLLOWING OPERATIONS ARE PROVIDED FOR ADDING TO AND SUBTRACTING FROM THE MULTI-
# MPAC:
#
# 1.      DAD      DOUBLE PRECISION ADD.
# 2.      DSU      DOUBLE PRECISION SUBTRACT.
# 3.      BDSU     DOUBLE PRECISION SUBTRACT FROM.
# 4.      TAD      TRIPLE PRECISION ADD.
# 5.      VAD      VECTOR ADD.
# 6.      VSU      VECTOR SUBTRACT.
# 7.      BVSU     VECTOR SUBTRACT FROM.
# THE INTERPRETIVE OVERFLOW INDICATOR OVFIN IS SET NON-ZERO IF OVERFLOW OCCURS IN AN
#
VSU      CAF      BIT15      # CHANGES 0 TO DCS.
          TCF     +2

```



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VAD	CAF	PRI030	# CHANGES 0 TO DCA.
	ADS	ADDRWD	
	EXTEND		
	INDEX	ADDRWD	
	READ	HISCALAR	# DCA 2 OR DCS 2
	DAS	MPAC +3	
	EXTEND		# CHECK OVERFLOW.
	BZF	+2	
	TC	OVERFLWY	
	EXTEND		
	INDEX	ADDRWD	
	READ	CHAN5	# DCA 4 OR DCS 4
	DAS	MPAC +5	
	EXTEND		
	BZF	+2	
	TC	OVERFLWZ	
	EXTEND		
	INDEX	ADDRWD	
	READ	LCHAN	# DCA 0 OR DCS 0
	TCF	ENDVXV	
DAD	EXTEND		
	INDEX	ADDRWD	
	DCA	0	
ENDVXV	DAS	MPAC	# VXV FINISHES HERE.
	EXTEND		
	BZF	DANZIG	
# Page 1132			
SETOVF	TC	OVERFLOW	
	TCF	DANZIG	
# Page 1133			
DSU	EXTEND		
	INDEX	ADDRWD	
	DCS	0	
	TCF	ENDVXV	
OVERFLWZ	TS	L	# ENTRY FOR THIRD COMPONENT.
	CAF	FIVE	
	TCF	+3	
OVERFLWY	TS	L	# ENTRY FOR SECOND COMPONENT.
	CAF	THREE	

```

                                XCH      L

OVERFLOW      INDEX  A          # ENTRY FOR 1ST COMP OR DP (L=0).
               CS     LIMITS    # PICK UP POSMAX OR NEGMAX.
               TS     BUF
               EXTEND
               AUG     A
               INDEX  L
               ADS     MPAC +1
               TS      7
               CAF     ZERO
               AD      BUF
               INDEX  L
               ADS     MPAC
               TS      7
               TC      Q          # NO OVERFLOW EXIT.
               TCF     SETOVF2    # SET OVFINDD AND EXIT.

BVSU           EXTEND
               INDEX  ADDRWD
               DCA     2
               DXCH    MPAC +3
               EXTEND
               DCOM
               DAS     MPAC +3
               EXTEND
               BZF     +2
               TC      OVERFLWY

               EXTEND
               INDEX  ADDRWD
               DCA     4
               DXCH    MPAC +5
               EXTEND
               DCOM
               DAS     MPAC +5
               EXTEND
               BZF     +2
               TC      OVERFLWZ

# Page 1134
BDSU           EXTEND
               INDEX  ADDRWD
               DCA     0
               DXCH    MPAC
               EXTEND

```

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```
# Page 1135
# TRIPLE PRECISION ADD ROUTINE.
```

```
# Page 1136
# ARITHMETIC SUBROUTINES REQUIRED IN FIXED-FIXED.
#      1.  DMPSUB      DOUBLE PRECISION MULTIPLY, MULTIPLY THE CONTENTS OF MPAC,+1 BY THE DP W
#                      IS IN ADDRWD AND LEAVE A TRIPLE-PRECISION RESULT IN MPAC.
#      2.  ROUNDSUB    ROUND THE TRIPLE PRECISION CONTENTS OF MPAC TO DOUBLE PRECISION.
#      3.  DOTSUB      TAKE THE DOT PRODUCT OF THE VECTOR IN MPAC AND THE VECTOR WHOSE ADDRESS
#                      AND LEAVE THE TRIPLE PRECISION RESULT IN MPAC.
#      4.  POLY        USING THE CONTENTS OF MPAC AS A DP ARGUMENT, EVALUATE THE POLYNOMIAL WH
#                      COEFFICIENTS IMMEDIATELY FOLLOW THE TC POLY INSTRUCTION (SEE ROUTINE F
```

DMPSUB	INDEX	ADDRWD	
	CA	1	# GET MINOR PART OF OPERAND AT C(ADDRWD).
	TS	MPAC +2	# THIS WORKS FOR SQUARING MPAC AS WELL.
	CAF	ZERO	# SET MPAC +1 TO ZERO SO WE CAN ACCUMULATE
	XCH	MPAC +1	# THE PARTIAL PRODUCTS WITH DAS
	TS	MPTMP	# INSTRUCTIONS.
	EXTEND		
	MP	MPAC +2	# MINOR OF MPAC X MINOR OF C(ADDRWD).
	XCH	MPAC +2	# DISCARD MINOR PART OF ABOVE RESULT AND
	EXTEND		# FORM MAJOR OF MPAC X MINOR OF C(ADDRWD).
	MP	MPAC	

```

                                DAS      MPAC +1      # GUARANTEED NO OVERFLOW.

                                INDEX    ADDRWD      # GET MAJOR PART OF ARGUMENT AT C(ADDRWD).
                                CA        0
                                XCH      MPTEMP      # SAVE AND BRING OUT MINOR OF MPAC.
DMPSUB2      EXTEND
                                MP        MPTEMP      # MAJOR OF C(ADDRWD) X MINOR OF MPAC.
                                DAS      MPAC +1      # ACCUMULATE, SETTING A TO NET OVERFLOW.

                                XCH      MPAC        # SETTING MPAC TO 0 OR +-1.
                                EXTEND
                                MP        MPTEMP      # MAJOR OF MPAC X MAJOR OF C(ADDRWD).
                                DAS      MPAC        # GUARANTEED NO OVERFLOW.
                                TC        Q          # 49 MCT = .573 MS. INCLUDING RETURN.

```

# Page 1137

# ROUND MPAC TO DOUBLE PRECISION, SETTING OVFINDD ON THE RARE EVENT OF OVERFLOW.

```

ROUNDSUB      CAF      ZERO      # SET MPAC +2 = 0 FOR SCALARS AND CHANGE
      +1      TS      MODE      # MODE TO DP.

VROUND      XCH      MPAC +2      # BUT WE NEEDN'T TAKE THE TIME FOR VECTORS.
      DOUBLE
      TS      L
      TC      Q

      AD      MPAC +1      # ADD ROUNDING BIT IF MPAC +2 WAS GREATER
      TS      MPAC +1      # THAN .5 IN MAGNITUDE.
      TC      Q

      AD      MPAC        # PROPAGATE INTERFLOW.
      TS      MPAC
      TC      Q

SETOVF2      TS      OVFINDD      # (RARE).
      TC      Q

```

# Page 1138

# THE DOT PRODUCT SUBROUTINE USUALLY FORMS THE DOT PRODUCT OF THE VECTOR IN MPAC WITH  
 # REGISTER VECTOR WHOSE ADDRESS IS IN ADDRWD. IN THIS CASE C(DOTINC) ARE SET TO 2. V  
 # 6 SO THAT DOTSUB DOTS MPAC WITH A COLUMN VECTOR OF THE MATRIX IN QUESTION IN THIS C

```

PREDOT      CAF      TWO      # PROLOGUE TO SET DOTINC TO 2.
      TS      DOTINC

DOTSUB      EXTEND

```

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```

      QXCH  DOTRET      # SAVE RETURN
      TC    DMPSUB      # DOT X COMPONENTS.
      DXCH  MPAC +3     # POSITION Y COMPONENT OF MPAC FOR
      DXCH  MPAC         # MULTIPLICATION WHILE SAVING RESULT IN
      DXCH  BUF          # THREE WORD BUFFER, BUF.
      CA    MPAC +2
      TS    BUF +2

      CA    DOTINC      # ADVANCE ADDRWD TO Y COMPONENT OF
      ADS   ADDRWD      # OTHER ARGUMENT.
      TC    DMPSUB
      DXCH  MPAC +1     # ACCUMULATE PARTIAL PRODUCTS.
      DAS   BUF +1
      AD    MPAC
      AD    BUF
      TS    BUF
      TCF   +2
      TS    OVFLND      # IF OVERFLOW OCCURS.

      DXCH  MPAC +5     # MULTIPLY Z COMPONENTS.
      DXCH  MPAC
      CA    DOTINC
      ADS   ADDRWD
      TC    DMPSUB
      DXCH  BUF +1     # LEAVE FINAL ACCUMULATION IN MPAC.
      DAS   MPAC +1
      AD    MPAC
      AD    BUF
      TS    MPAC
      TC    DOTRET

      TC    OVERFLOW    # ON OVERFLOW HERE.
      TC    DOTRET
```

# Page 1139

# DOUBLE PRECISION POLYNOMIAL EVALUATOR

```

#                                     N      N-1
#      THIS ROUTINE EVALUATES  $A_N X^N + A_{N-1} X^{N-1} + \dots + A_1 X + A_0$  LEAVING THE DP RESULT IN MPAC
#                                     N      N-1      1      0
#
# THE ROUTINE HAS TWO ENTRIES
#
#      1      ENTRY THRU POWRSERS.  THE COEFFICIENTS MAY BE EITHER IN FIXED OR ERASABLE E.  T
#      TC POWRSERS, AND THE RETURN IS TO LOC(TC POWRSERS)+1.  THE ENTERING DATA MUST BE
#      A      SP      LOC-3      ADDRESS FOR REFERENCING COEF TABLE
#      L      SP      N-1      N IS THE DEGREE OF THE POWER SERIES
```

```

#           MPAC   DP   X           ARGUMENT
#           LOC-2N DP   A(0)
#           ...
#           LOC    DP   A(N)
#
#       2.   ENTRY THRU POLY.  THE CALL TO POLY AND THE ENTERING DATA MUST BE AS FOLLOWS:
#           MPAC           DP           X           ARGUMENT
#           LOC           TC           POLY
#           LOC+1         DP           A(0)
#           ...
#           LOC+2N+2      DP           A(N)           RETURN IS TO LOC+2N+2

POWRSERS      EXTEND
QXCH          POLYRET          # RETURN ADDRESS
TS           POLISH           # POWER SERIES ADDRESS
LXCH          POLYCNT          # N-1 TO COUNTER
TCF          POLYCOM          # SKIP SET UP BY POLY

POLY          INDEX   Q
# Was CAF --- RSB 2009.
CA           0
TS          POLYCNT          # N-1 TO COUNTER
DOUBLE
AD          Q
TS          POLISH           # L(A(N))-3 TO POLISH
AD          FIVE
TS          POLYRET          # STORE RETURN ADDRESS

POLYCOM       CAF       LVBUF          # INCOMING X WILL BE MOVED TO VBUF, SO
TS           ADDRWD      # SET ADDRWD SO DMPSUB WILL MPY BY VBUF.

EXTEND
INDEX        POLISH
DCA          3

# Page 1140

DXCH         MPAC           # LOAD A(N) INTO MPAC
DXCH         VBUF           # SAVING X IN VBUF
TCF          POLY2

POLYLOOP      TS          POLYCNT      # SAVE DECREMENTD LOOP COUNTER
CS           TWO
ADS          POLISH           # REGRESS COEFFICIENT POINTER

POLY2         TC          DMPSUB       # MULTIPLY BY X
EXTEND

```

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```

INDEX  POLISH
DCA    1          # ADD IN NEXT COEFFICIENT
DAS    MPAC       # USER'S RESPONSIBILITY TO ASSURE NO OVFLOW

CCS    POLYCNT
TCF    POLYLOOP
TC     POLYRET    # RETURN CALLER

# Page 1141
# MISCELLANEOUS MULTI-PRECISION ROUTINES REQUIRED IN FIXED-FIXED BUT NOT USED BY THE INTERPRETER

DPAGREE    CAF    ZERO          # DOUBLE PRECISION ENTRY --
            TS     MPAC +2       # ZERO LOW-ORDER WORD

TPAGREE    LXCH   Q             # FORCE SIGN AGREEMENT AMONG THE TRIPLE
            TC     BRANCH        # PRECISION CONTENTS OF MPAC.  RETURNING
            TCF    ARG+          # WITH SIGNUM OF THE INPUT IN A.
            TCF    ARGZERO

            CS     POSMAX        # IF NEGATIVE.
            TCF    +2

ARG+       CAF    POSMAX
            TS     Q
            EXTEND
            AUG    A             # FORMS +-1.0.
            AD     MPAC +2
            TS     MPAC +2
            CAF    ZERO
            AD     Q
            AD     MPAC +1
            TS     MPAC +1
            CAF    ZERO
            AD     Q             # Q STILL HAS POSMAX OR NEGMAX IN IT.
            AD     MPAC
ARGZERO2   TS     MPAC          # ALWAYS SKIPPING UNLESS ARGZERO.
            TS     MPAC +1
            TC     L             # RETURN VIA L.

ARGZERO    TS     MPAC +2       # SET ALL THREE MPAC REGISTERS TO ZERO.
            TCF    ARGZERO2

# SHORTMP MULTIPLIES THE TP CONTENTS OF MPAC BY THE SINGLE PRECISION NUMBER ARRIVING IN A.

SHORTMP    TS     MPTMP
            EXTEND
```

	MP	MPAC +2	
	TS	MPAC +2	
SHORTMP2	CAF	ZERO	# SO SUBSEQUENT DAS WILL WORK.
	XCH	MPAC +1	
	TCF	DMPSUB2	

# Page 1142

# DMPNSUB MULTIPLIES THE DP FRACTION ARRIVING IN MPAC BY THE SP  
 # INTEGER ARRIVING IN A. THE DP PRODUCT DEPARTS BOTH IN MPAC AND IN  
 # A AND L. NOTE THAT DMPNSUB NORMALLY INCREASES THE MAGNITUDE OF THE  
 # CONTENTS OF MPAC. THE CUSTOMER MUST INSURE THAT B(A) X B(MPAC,MPAC+1)  
 # AND B(A) X B(MPAC) ARE LESS THAN 1 IN MAGNITUDE, WHERE B, AS IS OBVIOUS,  
 # INDICATES THE ARRIVING CONTENTS.

DMPNSUB	TS	DMPNTEMP	
	EXTEND		
	MP	MPAC +1	
	DXCH	MPAC	# LOW PRODUCT TO MPAC, HIGH FACTOR TO A
	EXTEND		
	MP	DMPNTEMP	
	CA	L	
	ADS	MPAC	# COMPLETING THE PRODUCT IN MPAC
	EXTEND		
	DCA	MPAC	# BRINGING THE PRODUCT INTO A AND L
	TC	Q	

# Page 1143

# MISCELLANEOUS VECTOR OPERATIONS. INCLUDED HERE ARE THE FOLLOWING.

#	1.	DOT	DP VECTOR DOT PRODUCT.
#	2.	VXV	DP VECTOR CROSS PRODUCT.
#	3.	VXSC	DP VECTOR TIMES SCALAR.
#	4.	V/SC	DP VECTOR DIVIDED BY SCALAR.
#	5.	VPROJ	DP VECTOR PROJECTION. ( (MPAC.X)MPAC ).
#	6.	VXM	DP VECTOR POST-MULTIPLIED BY MATRIX.
#	7.	MXV	DP VECTOR PRE-MULTIPLIED BY MATRIX.

DOT	TC	PREDOT	# DO THE DOT PRODUCT AND EXIT, CHANGING
DMODE	CAF	ZERO	# THE MODE TO DP SCALAR.
	TCF	NEWMODE	

MXV	CAF	TWO	# SET UP MATINC AND DOTINC FOR ROW
	TS	MATINC	# VECTORS.
	TCF	VXM/MXV	# GO TO COMMON PORTION.

VXM	CS	TEN	# SET MATINC AND DOTINC TO REFER TO MATRIX
	TS	MATINC	# AS THREE COLUMN VECTORS.



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CAF SIX

# Page 1144

# COMMON PORTION OF MXV AND VXM.

VXM/MXV TS DOTINC

# ITRACE (2) REFERS TO "VXM/MXV".

TC MPACVBUF # SAVE VECTOR IN MPAC FOR FURTHER USE.

TC DOTSUB # GO DOT TO GET X COMPONENT OF ANSWER.

EXTEND

DCA VBUF # MOVE MPAC VECTOR BACK INTO MPAC, SAVING

DXCH MPAC # NEW X COMPONENT IN BUF2.

DXCH BUF2

EXTEND

DCA VBUF +2

DXCH MPAC +3

EXTEND

DCA VBUF +4

DXCH MPAC +5

CA MATINC # INITIALIZE ADDRWD FOR NEXT DOT PRODUCT.

ADS ADDRWD # FORMS HAS ADDRESS OF NEXT COLUMN(ROW).

TC DOTSUB

DXCH VBUF

# MORE GIVEN VECTOR BACK TO MPAC, SAVING Y

DXCH MPAC

# COMPONENT OF ANSWER IN VBUF +2.

DXCH VBUF +2

DXCH MPAC +3

DXCH VBUF +4

DXCH MPAC +5

CA MATINC

# FORM ADDRESS OF LAST COLUMN OR ROW.

ADS ADDRWD

TC DOTSUB

DXCH BUF2

# ANSWER NOW COMPLETE. PUT COMPONENTS INTO

DXCH MPAC

# PROPER MPAC REGISTERS.

DXCH MPAC +5

DXCH VBUF +2

DXCH MPAC +3

TCF DANZIG

# EXIT.

# Page 1145

# VXSC -- VECTOR TIMES SCALAR.

VXSC	CCS	MODE	# TEST PRESENT MODE.
	TCF	DVXSC	# SEPARATE ROUTINE WHEN SCALAR IS IN MPAC.
	TCF	DVXSC	
VVXSC	TC	DMPSUB	# COMPUTE X COMPONENT
	TC	VROUND	# AND ROUND IT.
	DXCH	MPAC +3	# PUT Y COMPONENT INTO MPAC SAVING MPAC IN
	DXCH	MPAC	# MPAC +3.
	DXCH	MPAC +3	
	TC	DMPSUB	# DO SAME FOR Y AND Z COMPONENTS.
	TC	VROUND	
	DXCH	MPAC +5	
	DXCH	MPAC	
	DXCH	MPAC +5	
	TC	DMPSUB	
	TC	VROUND	
VROTATEX	DXCH	MPAC	# EXIT USED TO RESTORE MPAC AFTER THIS
	DXCH	MPAC +5	# TYPE OF ROTATION. CALLED BY VECTOR SHIFT
	DXCH	MPAC +3	# RIGHT, V/SC, ETC.
	DXCH	MPAC	
	TCF	DANZIG	

# Page 1146  
# DP VECTOR PROJECTION ROUTINE.

VPROJ	TC	PREDOT	# (MPAC.X)MPAC IS COMPUTED AND LEFT IN
	CS	FOUR	# MPAC. DO DOT AND FALL INTO DVXSC.
	ADS	ADDRWD	

# VXSC WHEN SCALAR ARRIVES IN MPAC AND VECTOR IS AT X.

DVXSC	EXTEND		# SAVE SCALAR IN MPAC +3 AND GET X
	DCA	MPAC	# COMPONENT OF ANSWER.
	DXCH	MPAC +3	
	TC	DMPSUB	
	TC	VROUND	
	CAF	TWO	# ADVANCE ADDRWD TO Y COMPONENT OF X.
	ADS	ADDRWD	
	EXTEND		
	DCA	MPAC +3	# PUT SCALAR BACK INTO MPAC AND SAVE
	DXCH	MPAC	# X RESULT IN MPAC +5.
	DXCH	MPAC +5	
	TC	DMPSUB	

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```
TC      VROUND

CAF      TWO
ADS      ADDRWD      # TO Z COMPONENT.
DXCH     MPAC +3      # BRING SCALAR BACK, PUTTING Y RESULT IN
DXCH     MPAC          # THE PROPER PLACE.
DXCH     MPAC +3
TC       DMPSUB
TC       VROUND

DXCH     MPAC          # PUT Z COMPONENT IN PROPER PLACE, ALSO
DXCH     MPAC +5      # POSITIONING X.
DXCH     MPAC

TCF      VMODE      # MODE HAS CHANGED TO VECTOR.
```

# Page 1147

```
# VECTOR CROSS PRODUCT ROUTINE CALCULATES (X M -X M ,X M -X M ,X M -X M ) WHERE M IS THE VECTOR
#                                     3 2  2 3  1 3  3 1  2 1  1 2
# MPAC AND X THE VECTOR AT THE GIVEN ADDRESS.
```

```
VXV      EXTEND
DCA      MPAC +5      # FORM UP M3X1, LEAVING M1 IN VBUF.
DXCH     MPAC
DXCH     VBUF
TC       DMPSUB      # BY X1.

EXTEND
DCS      MPAC +3      # CALCULATE -X1M2, SAVING X1M3 IN VBUF +2.
DXCH     MPAC
DXCH     VBUF +2
TC       DMPSUB

CAF      TWO          # ADVANCE ADDRWD TO X2.
ADS      ADDRWD
EXTEND
DCS      MPAC +5      # PREPARE TO GET -X2M3, SAVING -X1M2 IN
DXCH     MPAC          # MPAC +5.
DXCH     MPAC +5
TC       DMPSUB

EXTEND
DCA      VBUF          # GET X2M1, SAVING -X2M3 IN VBUF +4.
DXCH     MPAC
DXCH     VBUF +4
TC       DMPSUB
```

```

CAF      TWO      # ADVANCE ADDRWD TO X3.
ADS      ADDRWD
EXTEND
DCS      VBUF     # GET -X3M1, ADDING X2M1 TO MPAC +5 TO
DXCH     MPAC     # COMPLETE THE Z COMPONENT OF THE ANSWER.
DAS      MPAC +5

EXTEND
BZF      +2
TC       OVERFLWZ

TC       DMPSUB
DXCH     VBUF +2  # MOVE X1M3 TO MPAC +3 SETTING UP FOR X3M2
DXCH     MPAC +3  # AND ADD -X3M1 TO MPAC +3 TO COMPLETE THE
DXCH     MPAC     # Y COMPONENT OF THE RESULT.
DAS      MPAC +3

EXTEND
BZF      +2

# Page 1148
TC OVERFLWY

TC       DMPSUB
DXCH     VBUF +4  # GO ADD -X2M3 TO X3M2 TO COMPLETE THE X
TCF      ENDVXV   # COMPONENT (TAIL END OF DAD).

# THE MPACVBUF SUBROUTINE SAVES THE VECTOR IN MPAC IN VBUF WITHOUT CLOBBERING MPAC.

MPACVBUF  EXTEND      # CALLED BY MXV, VXM, AND UNIT.
DCA      MPAC
DXCH     VBUF
EXTEND
DCA      MPAC +3
DXCH     VBUF +2
EXTEND
DCA      MPAC +5
DXCH     VBUF +4
TC       Q         # RETURN TO CALLER.

# DOUBLE PRECISION SIGN AGREE ROUTINE.  ARRIVE WITH INPUT IN A+L.  OUTPUT IS IN A + L

ALSIGNAG  CCS      A      # TEST UPPER PART.
TCF      UPPOS     # IT IS POSITIVE
TC       Q         # ZERO
TCF      UPNEG     # NEGATIVE

```

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	TC	Q	# ZERO
UPPOS	XCH	L	# SAVE DECREMENTED UPPER PART.
	AD	HALF	
	AD	HALF	
	TS	A	# SKIPS ON OVERFLOW
	TCF	+2	
	INCR	L	# RESTORE UPPER TO ORIGINAL VALUE
	XCH	L	# SWAP A + L BANCK.
	TC	Q	
UPNEG	XCH	L	# SAVE COMPLEMENTED + DECREMENTED UPPER PT
	AD	NEGMAX	
	AD	NEGONE	
	TS	A	
	TCF	+2	# DON'T INCREMENT IF NO OVERFLOW.
	INCR	L	
	XCH	L	
	COM		# MAKE NEGATIVE AGAIN.
	TC	Q	

# Page 1149

# INTERPRETIVE INSTRUCTIONS WHOSE EXECUTION CONSISTS OF PRINCIPALLY CALLING SUBROUTINES.

DMP1	TC	DMPSUB	# DMP INSTRUCTIONS
	TCF	DANZIG	
DMPR	TC	DMPSUB	
	TC	ROUND SUB +1	# (C(A) = +0).
	TCF	DANZIG	
DDV	EXTEND		
	INDEX	ADDRWD	# MOVE DIVIDENT INTO BUF.
	DCA	0	
	TCF	BDDV +4	
BDDV	EXTEND		# MOVE DIVISOR INTO MPAC SAVING MPAC, THE
	INDEX	ADDRWD	# DIVIDEND, IN BUF.
	DCA	0	
	DXCH	MPAC	
+4	DXCH	BUF	
	CAF	ZERO	# DIVIDE ROUTINES IN BANK 0.
	TS	FBANK	
	TCF	DDV/BDDV	
SETPD	CA	ADDRWD	# MUST SET TO WORK AREA, OR EBANK TROUBLE.

	TS	PUSHLOC	
	TCF	NOIBNKSW	# NO FBANK SWITCH REQUIRED.
TSLC	CAF	ZERO	# SHIFTING ROUTINES LOCATED IN BANK 00.
	TS	FBANK	
	TCF	TSLC2	
GSHIFT	CAF	LOW7	# USED AS MASK AT GENSHIFT. THIS PROCESSES
	TS	FBANK	# ANY SHIFT INSTRUCTION (EXCEPT TSLC) WITH
	TCF	GENSHIFT	# AN ADDRESS (ROUTINES IN BANK 0).

# Page 1150

# THE FOLLOWING IS THE PROLOGUE TO V/SC. IF THE PRESENT MODE IS VECTOR, IT SAVES THE  
 # AND CALLS THE V/SC ROUTINE IN BANK 0. IF THE PRESENT MODE IS SCALAR, IT MOVES THE  
 # THE SCALAR IN MPAC IN BUF BEFORE CALLING THE V/SC ROUTINE IN BANK 0.

V/SC	CCS	MODE	
	TCF	DV/SC	# MOVE VECTOR INTO MPAC.
	TCF	DV/SC	
VV/SC	EXTEND		
	INDEX	ADDRWD	
	DCA	0	
V/SC1	DXCH	BUF	# IN BOTH CASES, VECTOR IS NOW IN MPAC AND
	CAF	ZERO	# SCALAR IN BUF.
	TS	FBANK	
	TCF	V/SC2	
DV/SC	EXTEND		
	INDEX	ADDRWD	
	DCA	2	
	DXCH	MPAC +3	
	EXTEND		
	INDEX	ADDRWD	
	DCA	4	
	DXCH	MPAC +5	
	CS	ONE	# CHANGE MODE TO VECTOR.
	TS	MODE	
	EXTEND		
	INDEX	ADDRWD	
	DCA	0	
	DXCH	MPAC	
	TCF	V/SC1	

# Page 1151

# SIGN AND COMPLEMENT INSTRUCTIONS.

SIGN	INDEX	ADDRWD	# CALL COMP INSTRUCTION IF WORD AT X IS
	CCS	0	# NEGATIVE NON-ZERO.
	TCF	DANZIG	
	TCF	+2	
	TCF	COMP	# DO THE COMPLEMENT.
CCSL	INDEX	ADDRWD	
	CCS	1	
	TCF	DANZIG	
	TCF	DANZIG	
	TCF	COMP	
	TCF	DANZIG	
COMP	EXTEND		# COMPLEMENT DP MPAC IN EVERY CASE.
	DCS	MPAC	
	DXCH	MPAC	
	CCS	MODE	# EITHER COMPLEMENT MPAC +3 OR THE REST OF
	TCF	DCOMP	# THE VECTOR ACCUMULATOR.
	TCF	DCOMP	
	EXTEND		# VECTOR COMPLEMENT.
	DCS	MPAC +3	
	DXCH	MPAC +3	
	EXTEND		
	DCS	MPAC +5	
	DXCH	MPAC +5	
	TCF	DANZIG	
DCOMP	CS	MPAC +2	
	TS	MPAC +2	
	TCF	DANZIG	

# Page 1152

# THE FOLLOWING SHORT SHIFT CODES REQUIRE NO ADDRESS WORD:

#	1.	SR1 TO SR4	SCALAR SHIFT RIGHT.
#	2.	SR1R TO SR4R	SCALAR SHIFT RIGHT AND ROUND.
#	3.	SL1 TO SL4	SCALAR SHIFT LEFT.
#	4.	SL1R TO SL4R	SCALAR SHIFT LEFT AND ROUND.
#	5.	VSR1 TO VSR8	VECTOR SHIFT RIGHT (ALWAYS ROUNDS).
#	6.	VSL1 TO VSL8	VECTOR SHIFT LEFT (NEVER ROUNDS).

# THE FOLLOWING CODES REQUIRE AN ADDRESS WHICH MAY BE INDEXED:\*

#	1.	SR	SCALAR SHIFT RIGHT.
#	2.	SRR	SCALAR SHIFT RIGHT AND ROUND.

```

#      3.      SL      SCALAR SHIFT LEFT.
#      4.      SLR     SCALAR SHIFT LEFT AND ROUND.
#      5.      VSR     VECTOR SHIFT RIGHT.
#      6.      VSL     VECTOR SHIFT LEFT.
# * IF THE ADDRESS IS INDEXED, AND THE INDEX MODIFICATION RESULTS IN A NEGATIVE SHIFT.
# ABSOLUTE VALUE OF THE COUNT IS DONE IN THE OPPOSITE DIRECTION.

```

```

BANK      00

```

```

COUNT    00/INTER

```

```

SHORTT    CAF      SIX      # SCALAR SHORT SHIFTS COME HERE.  THE SHIFT
          MASK     CYR      # COUNT-1 IS NOW IN BITS 2-3 OF CYR.  THE
          TS       SR       # ROUNDING BIT IS IN BIT1 AT THIS POINT.

```

```

          CCS      CYR      # SEE IF RIGHT OR LEFT SHIFT DESIRED.
          TCF      TSSL     # SHIFT LEFT.

```

```

SRDDV     DEC      20      # MPTMP SETTING FOR SR BEFORE DDV.

```

```

TSSR      INDEX    SR      # GET SHIFTING BIT.
          CAF      BIT14
          TS       MPTMP

```

```

          CCS      CYR      # SEE IF A ROUND IS DESIRED.
RIGHTR    TC       MPACSRND # YES -- SHIFT RIGHT AND ROUND.
          TCF      NEWMODE  # SET MODE TO DP (C(A) = 0).
MPACSHR   CA       MPTMP    # DO A TRIPLE PRECISION SHIFT RIGHT.

```

```

          EXTEND
          MP       MPAC +2
          +3      TS       MPAC +2      # (EXIT FROM SQRT AND ABVAL).
          CA       MPTMP
          EXTEND

```

```

# Page 1153

```

```

          MP       MPAC      # SHIFT MAJOR PART INTO A,L AND PLACE IN
          DXCH     MPAC      # MPAC,+1.
          CA       MPTMP
          EXTEND
          MP       L         # ORIGINAL C(MPAC +1).
          DAS      MPAC +1   # GUARANTEED NO OVERFLOW.
          TCF      DANZIG

```

```

# MPAC SHIFT RIGHT AND ROUND SUBROUTINES

```

```

MPACSRND  CA       MPAC +2   # WE HAVE TO DO ALL THREE MULTIPLIES SINCE
          EXTEND             # MPAC +1 AND MPAC +2 MIGHT HAVE SIGN

```



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```

      MP      MPTMP      # DISAGREEMENT WITH A SHIFT RIGHT OF L.
      XCH      MPAC +1
      EXTEND
      MP      MPTMP
      XCH      MPAC +1      # TRIAL MINOR PART.
      AD      L

VSHR2      DOUBLE      # (FINISH VECTOR COMPONENT SHIFT RIGHT
      TS      MPAC +2      # AND ROUND.)
      TCF      +2
      ADS      MPAC +1      # GUARANTEED NO OVERFLOW.

      CAF      ZERO
      TS      MPAC +2
      XCH      MPAC      # SETTING TO ZERO SO FOLLOWING DAS WORKS.
      EXTEND
      MP      MPTMP
      DAS      MPAC      # AGAIN NO OVERFLOW.
      TC      Q

VSHRRND      CA      MPTMP      # ENTRY TO SHIFT RIGHT AND ROUND MPAC WHEN
      EXTEND      # MPAC CONTAINS A VECTOR COMPONENT.
      MP      MPAC +1
      TS      MPAC +1
      XCH      L
      TCF      VSHR2      # GO ADD ONE IF NECESSARY AND FINISH.
```

# Page 1154

# ROUTINE FOR SHORT SCALAR SHIFT LEFT (AND MAYBE ROUND).

```

TSSL      CA      SR      # GET SHIFT COUNT FOR SR.
      +1      TS      MPTMP

      +2      EXTEND      # ENTRY HERE FROM SL FOR SCALARS.
      DCA      MPAC +1      # SHIFTING LEFT ONE PLACE AT A TIME IS
      DAS      MPAC +1      # FASTER THAN DOING THE WHOLE SHIFT WITH
      AD      MPAC      # MULTIPLIES ASSUMING THAT FREQUENCY OF
      AD      MPAC      # SHIFT COUNTS GOES DOWN RAPIDLY AS A
      TS      MPAC      # FUNCTION OF THEIR MAGNITUDE.
      TCF      +2
      TS      OVFLND      # OVERFLOW. (LEAVES OVERFLOW-CORRECTED
      # RESULT ANYWAY).
      CCS      MPTMP      # LOOP ON DECREMENTED SHIFT COUNT.
      TCF      TSSL +1

      CCS      CYR      # SEE IF ROUND WANTED.
```

ROUND	TC	ROUNDSUB	# YES -- ROUND AND EXIT.
	TCF	DANZIG	# SL LEAVES A ZERO IN CYR FOR NO ROUND.
	TCF	DANZIG	# NO -- EXIT IMMEDIATELY

# Page 1155

# VECTOR SHIFTING ROUTINES.

SHORTV	CAF	LOW3	# SAVE 3 BIT SHIFT COUNT -- 1 WITHOUT
	MASK	CYR	# EDITING CYR.
	TS	MPTMP	
	CCS	CYR	# SEE IF LEFT OR RIGHT SHIFT.
	TCF	VSSL	# VECTOR SHIFT LEFT.
OCT176	OCT	176	# USED IN PROCESSED SHIFTS WITH - COUNT.
VSSR	INDEX	MPTMP	# (ENTRY FROM SR). PICK UP SHIFTING BIT.
	CAF	BIT14	# MPTMP CONTAINS THE SHIFT COUNT - 1.
	TS	MPTMP	
	TC	VSHRRND	# SHIFT X COMPONENT.
	DXCH	MPAC	# SWAP X AND Y COMPONENTS.
	DXCH	MPAC +3	
	DXCH	MPAC	
	TC	VSHRRND	# SHIFT Y COMPONENT.
	DXCH	MPAC	# SWAP Y AND Z COMPONENTS.
	DXCH	MPAC +5	
	DXCH	MPAC	
	TC	VSHRRND	# SHIFT Z COMPONENT.
	TCF	VROTATEX	# RESTORE COMPONENTS TO PROPER PLACES.

# Page 1156

# VECTOR SHIFT LEFT -- DONE ONE PLACE AT A TIME.

-1	TS	MPTMP	# SHIFTING LOOP.
VSSL	EXTEND		
	DCA	MPAC	
	DAS	MPAC	
	EXTEND		
	BZF	+2	
	TC	OVERFLOW	
	EXTEND		
	DCA	MPAC +3	
	DAS	MPAC +3	

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```
EXTEND
BZF    +2
TC     OVERFLWY
```

```
EXTEND
DCA    MPAC +5
DAS    MPAC +5
EXTEND
BZF    +2
TC     OVERFLWZ
```

```
CCS    MPTMP          # LOOP ON DECREMENTED SHIFT COUNTER.
TCF    VSSL -1
TCF    DANZIG         # EXIT.
```

# Page 1157

# TSLC -- TRIPLE SHIFT LEFT AND COUNT. SHIFTS MPAC LEFT UNTIL GREATER THAN .5 IN MAGNITUDE, LE  
# THE COMPLEMENT OF THE NUMBER OF SHIFTS REQUIRED IN X.

```
TSLC2      TS    MPTMP          # START BY ZEROING SHIFT COUNT (IN A NOW).
            TC    BRANCH        # EXIT WITH NO SHIFTING IF ARGUMENT ZERO.
            TCF   +2
            TCF   ENDTSLC       # STORES ZERO SHIFT COUNT IN THIS CASE.

            TC    TPAGREE       # MAY CAUSE UPSHIFT OF ONE EXTRA PLACE.

            CA    MPAC
            TCF   TSLCTEST      # BEGIN NORMALIZATION LOOP.
```

```
TSLCLOOP    INCR    MPTMP          # INCREMENT SHIFT COUNTER.
            EXTEND
            DCA    MPAC +1
            DAS    MPAC +1
            AD     MPAC
            ADS    MPAC

TSLCTEST     DOUBLE          # SEE IF (ANOTHER) SHIFT IS REQUIRED
            OVSK
            TCF    TSLCLOOP     # YES -- INCREMENT COUNT AND SHIFT AGAIN.

ENDTSLC      CS    MPTMP
            TCF    STORE1       # STORE SHIFT COUNT AND RETURN TO DANZIG.
```

# Page 1158

# THE FOLLOWING ROUTINE PROCESSES THE GENERAL SHIFT INSTRUCTIONS SR, SRR, SL, AND SLR.  
# THE GIVEN ADDRESS IS DECODED AS FOLLOWS:  
# BITS 1-7 SHIFT COUNT (SUBADDRESS) LESS THAN 125 DECIMAL.

```

#      BIT 8      PSEUDO SIGN BIT (DETECTS CHANGE IN SIGN IN INDEXED SHIFTS).
#      BIT 9      0 FOR LEFT SHIFT, AND 1 FOR RIGHT SHIFT.
#      BIT 10     1 FOR TERMINAL ROUND ON SCALAR SHIFTS, 0 OTHERWISE
#      BITS 11-13 0.
#      BIT 14     1.
#      BIT 15     0.
# THE ABOVE ENCODING IS DONE BY THE YUL SYSTEM.

```

```

GENSHIFT      MASK  ADDRWD      # GET SHIFT COUNT, TESTING FOR ZERO.
               CCS   A           # (ARRIVES WITH C(A) = LOW7).
               TCF   GENSHFT2    # IF NON-ZERO, PROCEED WITH DECREMENTED CT

               CAF   BIT10       # ZERO SHIFT COUNT. NO SHIFTS NEEDED BUT
               MASK  ADDRWD       # WE MIGHT HAVE TO ROUND MPAC ON SLR AND
               CCS   A           # SRR (SCALAR ONLY).
               TC    ROUND SUB
               TCF   DANZIG

GENSHFT2      TS    MPTEMP      # DECREMENTED SHIFT COUNT TO MPTEMP.
               CAF   BIT8       # TEST MEANING OF LOW SEVEN BIT COUNT IN
               EXTEND                                     # MPTEMP NOW.
               MP    ADDRWD
               MASK  LOW2       # JUMPS ON SHIFT DIRECTION (BIT8) AND
               INDEX A           #
               TCF   +1         # ORIGINAL SHIFT DIRECTION (BIT 9)
               TCF   RIGHT-     # NEGATIVE SHIFT COUNT FOR SL OR SLR.
               TCF   LEFT      # SL OR SLR.
               TCF   LEFT-     # NEGATIVE SHIFT COUNT WITH SR OR SRR.

```

# Page 1159

# GENERAL SHIFT RIGHT

```

RIGHT         CCS    MODE      # SET IF VECTOR OR SCALAR.
               TCF   GENSCR
               TCF   GENSCR

               CA     MPTEMP    # SEE IF SHIFT COUNT LESS THAN 14D.
               AD     NEG12
               EXTEND
               BZMF   VSSR      # IF SO, BRANCH AND SHIFT IMMEDIATELY.

               AD     NEGONE    # IF NOT, REDUCE MPTEMP BY A TOTAL OF 14.
               TS     MPTEMP    # AND DO A SHIFT RIGHT AND ROUND BY 14.
               CAF    ZERO     # THE ROUND AT THIS STAGE MAY INTRODUCE A
               TS     L        # ONE BIT ERROR IN A SHIFT RIGHT 15D.
               XCH    MPAC

```

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```

XCH      MPAC +1
TC       SETROUND
DAS      MPAC
# X COMPONENT NOW SHIFTED, SO MAKE UP THE
# ROUNDING QUANTITY (0 IN A AND 0 OR +-1
# IN L).
XCH      MPAC +3
XCH      MPAC +4
TC       SETROUND
DAS      MPAC +3
# REPEAT THE ABOVE PROCESS FOR Y AND Z/
# NO OVERFLOW ON THESE ADDS.

XCH      MPAC +5
XCH      MPAC +6
TC       SETROUND
DAS      MPAC +5

CCS      MPTMP
TS       MPTMP
TCF      VRIGHT2
BIASLO   DEC      .2974 B-1
# SEE IF DONE, DOING FINAL DECREMENT.
# Sqrt CONSTANT

TCF      DANZIG

SETROUND  DOUBLE
TS       MPAC +2
CAF      ZERO
XCH      L
TC       Q
# MAKES UP ROUNDING QUANTITY FROM ARRIVING
# C(A). L IS ZERO INITIALLY.
# RETURN AND DO THE DAS, RESETTNG L TO 0.

# Page 1160
# PROCESS SR AND SRR FOR SCALARS.

GENSCR   CA      MPTMP
+1        AD      NEG12
          EXTEND
          BZMF    DOSSHFT
# SEE IF THE ORIGINAL SHIFT COUNT WAS LESS
# THAN 14D.
# DO THE SHIFT IMMEDIATELY IF SO.

+4        AD      NEGONE
          TS      MPTMP
          CAF     ZERO
          XCH     MPAC
          XCH     MPAC +1
          TS      MPAC +2
          CCS     MPTMP
          TS      MPTMP
          TC      GENSCR +1
          DEC     .5884
          CAF     BIT10
# SEE IF FINISHED, DO FINAL DECREMENT.
# Sqrt CONSTANT.
# FINISHED WITH SHIFT. SEE IF ROUND
```

	MASK	ADDRWD	# WANTED.
	CCS	A	
	TC	ROUND SUB	
	TCF	DANZIG	# DO SO AND/OR EXIT.
DOSSHFT	INDEX	MPTMP	# PICK UP SHIFTING BIT.
	CAF	BIT14	
	TS	MPTMP	
	CAF	BIT10	# SEE IF TERMINAL ROUND DESIRED.
	MASK	ADDRWD	
	CCS	A	
	TCF	RIGHTR	# YES.
	TCF	MPACSHR	# JUST SHIFT RIGHT.

# Page 1161

# PROCESS THE RIGHT- (SL(R) WITH A NEGATIVE COUNT), LEFT-, AND LEFT OPTIONS.

RIGHT-	CS	MPTMP	# GET ABSOLUTE VALUE - 1 OF SHIFT COUNT
	AD	OCT176	# UNDERSTANDING THAT BIT8 (PSEUDO-SIGN)
	TS	MPTMP	# WAS 1 INITIALLY.
	TCF	RIGHT	# DO NORMAL SHIFT RIGHT.
LEFT-	CS	OCT176	# SAME PROLOGUE TO LEFT FOR INDEXED RIGHT
	AD	MPTMP	# SHIFT WHOSE NET SHIFT COUNT IS NEGATIVE
	COM		
	TS	MPTMP	
LEFT	CCS	MODE	# SINCE LEFT SHIFTING IS DONE ONE PLACE AT
	TCF	GENSCL	# A TIME, NO COMPARISON WITH 14 NEED BE
	TCF	GENSCL	# DONE. FOR SCALARS, SEE IF TERMINAL ROUND
	TCF	VSSL	# DESIRED. FOR VECTORS, SHIFT IMMEDIATELY.
GENSCL	CS	ADDRWD	# PUT ROUNDING BIT (BIT 10 OF ADDRWD) INTO
	EXTEND		# BIT 15 OF CYR WHERE THE ROUNDING BIT OF
	MP	BIT6	# A SHORT SHIFT LEFT WOULD BE
	TS	CYR	
	TCF	TSSL +2	# DO THE SHIFT.

# Page 1162

# SCALAR DIVISION INSTRUCTIONS, DDV AND BDDV, ARE EXECUTED HERE. AT THIS POINT, THE  
# AND THE DIVISOR IS IN BUF.

DDV/BDDV	CS	ONE	# INITIALIZATION
	TS	DVSIGN	# +-1 FOR POSITIVE QUOTIENT -- -0 FOR NEG.
	TS	DVNORMCT	# DIVIDENT NORMALIZATION COUNT.
	TS	MAXDVSW	# NEAR-ONE DIVIDE FLAG.

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	CCS	BUF	# FORCE BUF POSITIVE WITH THE MAJOR PART
	TCF	BUFPOS	# NON-ZERO.
	TCF	+2	
	TCF	BUFNEG	
BUFZERO	TS	MPAC +2	# ZERO THIS.
	TC	TPAGREE	# FORCE SIGN AGREEMENT BEFORE OVERFLOW
	CCS	MPAC	# TEST TO SEE IF MPAC NON-ZERO. (TOO BIG)
	TCF	OVF+	# MAJOR PART OF DIVIDEND IS POSITIVE NON-0
	TCF	+2	
	TCF	OVF+ -1	# MAJOR PART OF DIVIDEND IS NEG. NON-ZERO
	XCH	BUF +1	# SHIFT DIVIDENT AND DIVISOR LEFT 14
	XCH	BUF	
	XCH	MPAC +1	
	XCH	MPAC	
	CCS	BUF	# TRY AGAIN ON FORMER MINOR PART.
	TCF	BUF+	
	TCF	+2	# OVERFLOW ON ZERO DIVISOR.
	TCF	BUF-	
SGNDVOVF	CS	MPAC	# SIGN OF MPAC DETERMINES SIGN OF RESULT.
	EXTEND		
	BZMF	+2	
	INCR	DVSIGN	# NEGMAX IN MPAC PERHAPS.
DVOVF	CAF	POSMAX	# ON DIVISION OVERFLOW OF ANY SORT, SET
	TS	MPAC	# SET DP MPAC TO +-POSMAX.
	TC	FINALDV +3	
	CAF	ONE	# SET OVEFLOW INDICATOR AND EXIT.
	TS	OVFIND	
	TC	DANZIG	
	INCR	DVSIGN	
OVF+ -1	CS	BUF +1	# LOAD LOWER ORDER PART OF DIVISOR.
	TCF	SGNDVOVF	# GET SIGN OF RESULT.
BUF-	EXTEND		# IF BUF IS NEGATIVE, COMPLEMENT IT AND
	DCS	BUF	# MAINTAIN DVSIGN FOR FINAL QUOTIENT SIGN.
	DXCH	BUF	
	INCR	DVSIGN	# NOW -0.
# Page 1163			
BUF+	CCS	MPAC	# FORCE MPAC POSITIVE, CHECKING FOR ZERO
	TCF	MPAC+	# DIVIDEND IN THE PROCESS.

	TCF	+2	
	TCF	MPAC-	
	CCS	MPAC +1	
	TCF	MPAC+	
	TCF	DANZIG	# EXIT IMMEDIATELY ON ZERO DIVIDEND.
	TCF	MPAC-	
	TCF	DANZIG	
MPAC-	EXTEND		# FORCE MPAC POSITIVE AS BUF IN BUF-.
	DCS	MPAC	
	DXCH	MPAC	
	INCR	DVSIGN	# NOW +1 OR -0.
# Page 1164			
MPAC+	CS	MPAC	# CHECK FOR DIVISION OVERFLOW. IF THE
	AD	NEGONE	# MAJOR PART OF THE DIVIDEND IS LESS THAN
	AD	BUF	# THE MAJOR PART OF THE DIVISOR BY AT
	CCS	A	# LEAST TWO, WE CAN PROCEED IMMEDIATELY
	TCF	DVNORM	# WITHOUT NORMALIZATION PRODUCING A DVMAX.
-1/2+2	OCT	60001	# USED IN SQRTSUB.
	TCF	+1	# IF THE ABOVE DOES NOT HOLD, FORCE SIGN
	CAF	HALF	# AGREEMENT IN NUMERATOR AND DENOMINATOR
	DOUBLE		# TO FACILITATE OVERFLOW AND NEAR-ONE
	AD	MPAC +1	# CHECKING.
	TS	MPAC +1	
	CAF	ZERO	
	AD	POSMAX	
	ADS	MPAC	
	CAF	HALF	# SAME FOR BUF.
	DOUBLE		
	AD	BUF +1	
	TS	BUF +1	
	CAF	ZERO	
	AD	POSMAX	
	ADS	BUF	
	CS	MPAC	# CHECK MAGNITUDE OF SIGN-CORRECTED
	AD	BUF	# OPERANDS.
	CCS	A	
	TCF	DVNORM	# DIVIDE OK -- WILL NOT BECOME MAXOV CASE.
LBUF2	ADRES	BUF2	
	TCF	DVOVF	# DIVISOR NOT LESS THAN DIVIDEND -- OVF.
	TS	MAXDVSW	# IF THE MAJOR PARTS OF THE DIVIDEND AND



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```
CS      MPAC +1      # DIVISOR ARE EQUAL, A SPECIAL APPROXIMA-
AD      BUF +1      # TION IS USED (PROVIDED THE DIVISION IS
EXTEND                      # POSSIBLE, OF COURSE).
BZMF    DVOVF
TCF     DVNORM      # IF NO OVERFLOW.

# Page 1165
BUFNORM      EXTEND      # ADD -1 TO AUGMENT SHIFT COUNT AND SHIFT
AUG          DVNORMCT    # LEFT ONE PLACE.
EXTEND
DCA         BUF
DAS         BUF

DVNORM      CA         BUF      # SEE IF DIVISOR NORMALIZED YET.
DOUBLE
OVSK
TCF         BUFNORM      # NO -- SHIFT LEFT ONE AND TRY AGAIN.

DXCH        MPAC      # CALL DIVIDEND NORMALIZATION SEQUENCE
INDEX       DVNORMCT  # PRIOR TO DOING THE DIVIDE.
TC          MAXTEST

TS          MPAC +2    # RETURNS WITH DIVISION DONE AND C(A) = 0.
TCF        DANZIG

BUFPOS      CCS        A
TCF        BUF+      # TO BUF+ IF BUF IS GREATER THAN +1.

CS          BUF +1    # IF BUF IS +1, FORCING SIGN AGREEMENT
EXTEND      # MAY CAUSE BUF TO BECOME ZERO.
BZMF        BUF+      # BRANCH IF SIGNS AGREE.

+6          CA         HALF    # SIGNS DISAGREE.  FORCE AGREEMENT.
DOUBLE
ADS         BUF +1
CA          ZERO
TS          BUF
TCF        BUFZERO

BUFNEG      CCS        A
TCF        BUF-      # TO BUF- IF BUF IS LESS THAN -1.

CA          BUF +1    # IF BUF IS -1, FORCING SIGN AGREEMENT
EXTEND      # MAY CAUSE BUF TO BECOME ZERO.
BZMF        BUF-      # BRANCH IF SIGNS AGREE.
```

```

CS      HALF      # SIGNS DISAGREE.  FORCE AGREEMENT.
TCF     BUFPOS +6

```

# Page 1166

# THE FOLLOWING ARE PROLOGUES TO SHIFT THE DIVIDEND ARRIVING IN A AND L BEFORE THE D

```

-21D    LXCH      SR      # SPECIAL PROLOGUE FOR UNIT WHEN THE
        EXTEND     # LENGTH OF THE ARGUMENT WAS NOT LESS THAN
        MP         HALF   # .5.  IN THIS CASE, EACH COMPONENT MUST BE
        XCH        L      # SHIFTED RIGHT ONE TO PRODUCE A HALF-UNIT
        AD         SR     # VECTOR.
        XCH        L
        TCF        GENDDV +1  # WITH DP DIVIDEND IN A,L.

```

```

DDOUBL      # PROLOGUE WHICH NORMALIZES THE DIVIDEND
DDOUBL      # WHEN IT IS KNOWN THAT NO DIVISION
DDOUBL      # OVEFLOW WILL OCCUR.

```

```

DDOUBL
DDOUBL
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DDOUBL

```

DXCH MPAC

```

MAXTEST    CCS      MAXDVSW      # 0 IF MAJORS MIGHT BE =, -1 OTHERWISE.
BIASHI     DEC      .4192 B-1    # SQRT CONSTANTS.

```

```

TCF        MAXDV      # CHECK TO SEE IF THAY ARE NOW EQUAL.

```

# Page 1167

```

# THE FOLLOWING IS A GENERAL PURPOSE DOUBLE PRECISION DIVISION ROUTINE.  IT DIVIDES M
# THE RESULT IN MPAC.  THE FOLLOWING CONDITIONS MUST BE SATISFIED:

```

#

```

#      1.      THE DIVISOR (BUF) MUST BE POSITIVE AND NOT LESS THAN .5.

```

#

```

#      2.      THE DIVIDEND (MPAC) MUST BE POSITIVE WITH THE MAJOR PART OF MPAC STR.
#              (A SPECIAL APPROXIMATION, MAXDV, IS USED WHEN THE MAJOR PARTS ARE EQ

```

#

```

# UNDERSTANDING THAT A/B = Q + S(R/B) WHERE S = 2(-14) AND Q AND R ARE QUOTIENT AND R
# TIVELY, THE FOLLOWING APPROXIMATION IS OBTAINED BY MULTIPLYING ABOVE AND BELOW BY C
# ORDER S-SQUARED (POSSIBLY INTRODUCING ERROR INTO THE LOW TWO BITS OF THE RESULT).

```

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```

#
#      A + SB .      (R - CD)      A + SB
#      ----- = Q + S(-----) WHERE Q AND R ARE QUOTIENT AND REMAINDER OF ----- RESPECTIVELY.
#      C + SD      ( C   }      C
#
GENDDV      DXCH      MPAC      # WE NEED A AND B ONLY FOR FIRST DV.
+1          EXTEND      # (SPECIAL UNIT PROLOGUE ENTERS HERE).
            DV      BUF      # A NOW CONTAINS Q AND L, R.
            DXCH      MPAC
#
            CS      MPAC      # FORM DIVIDEND FOR MINOR PART OF RESULT.
            EXTEND
            MP      BUF +1
            AD      MPAC +1      # OVERFLOW AT THIS POINT IS POSITIVE SINCE
            OVSK      # R IS POSITIVE IN EVERY CASE.
            TCF      +5
#
            EXTEND      # OVERFLOW CAN BE REMOVED BY SUBTRACTING C
            SU      BUF      # (BUF) ONCE SINCE R IS ALWAYS LESS THAN C
            INCR      MPAC      # IN THIS CASE. INCR COMPENSATES SUBTRACT.
            TCF      +DOWN      # (SINCE C(A) IS STILL POSITIVE).
#
+5          EXTEND      # C(A) CAN BE MADE LESS THAN C IN MAGNI-
            BZMF      -UP      # TUDE BY DIMINISHING IT BY C (SINCE C IS
# NOT LESS THAN .5) UNLESS C(A) = 0.
#
# Page 1168
+DOWN      EXTEND
            SU      BUF      # IF POSITIVE, REDUCE ONLY IF NECESSARY
            EXTEND      # SINCE THE COMPENSATING INCR MIGHT CAUSE
            BZF      +3      # OVERFLOW.
            EXTEND      # DON'T SUBTRACT UNLESS RESULT IS POSITIVE
            BZMF      ENDMAXDV      # OR ZERO.
#
+3          INCR      MPAC      # KEEP SUBTRACT HERE AND COMPENSATE.
            TCF      FINALDV
#
-UP          EXTEND      # IF ZERO, SET MINOR PART OF RESULT TO
            BZF      FINALDV +3      # ZERO.
#
            EXTEND      # IF NEGATIVE, ADD C TO A, SUBTRACTING ONE
            DIM      MPAC      # TO COMPENSATE. DIM IS OK HERE SINCE THE
ENDMAXDV    AD      BUF      # MAJOR PART NEVER GOES NEGATIVE.
#
# Page 1169
FINALDV     ZL      # DO DV TO OBTAIN MINOR PART OF RESULT.

```

```

                                EXTEND
                                DV      BUF
+3      TS      MPAC +1

                                CCS      DVSIGN      # LEAVE RESULT POSITIVE UNLESS C(DVSIGN).
                                TC      Q
                                TC      Q
                                TC      Q

                                EXTEND
                                DCS      MPAC
                                DXCH     MPAC
                                CAF      ZERO      # SO WE ALWAYS RETURN WITH C(A) = 0.
                                TC      Q

# Page 1170
# IF THE MAJOR PARTS OF THE DIVISOR AND DIVIDEND ARE EQUAL, BUT THE MINOR PARTS ARE S
# DIVIDEND IS STRICTLY LESS THAN THE DIVISOR IN MAGNITUDE, THE FOLLOWING APPROXIMATION
# ARE THE SAME AS THE GENERAL ROUTINE WITH THE ADDITION THAT SIGN AGREEMENT IS NECESS
#
#      C + SB .      (C + B - D)
#      ----- = 37777 + S(-----)
#      C + SD      (    C    )
#
# THE DIVISION MAY BE PERFORMED IMMEDIATELY SINCE B IS STRICTLY LESS THAN D AND C IS

MAXDV      CS      MPAC      # SEE IF MAXDV CASE STILL HOLDS AFTER
            AD      BUF      # NORMALIZATION.
            EXTEND
            BZF     +2
            TCF     GENDDV     # MPAC NOW LESS THAN BUFF -- DIVIDE AS USUAL

+2      CAF      POSMAX      # SET MAJOR PART OF RESULT.
            TS      MPAC

            CS      BUF +1      # FORM DIVIDEND OF MINOR PART OF RESULT.
            AD      MPAC +1
            TCF     ENDMAXDV     # GO ADD C AND DO DIVIDE, ATTACHING SIGN
                                # BEFORE EXITING.

# Page 1171
# VECTOR DIVIDED BY SCALAR, V/SC, IS EXECUTED HERE.  THE VECTOR IS NOW IN MPAC WITH S

V/SC2      CS      ONE      # INITIALIZE DIVIDEND NORMALIZATION COUNT
            TS      DVNORMCT   # AND DIVISION SIGN REGISTER.
            TS      VBUF +5

```

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```
TC      VECAGREE      # FORCE SIGN AGREEMENT IN VECTOR

DXCH    BUF
TC      ALSIGNAG      # SIGN AGREE BUF
DXCH    BUF
CCS     BUF           # FORCE DIVISOR POSITIVE WITH MAJOR PART
TCF     /BUF+         # NON-ZERO (IF POSSIBLE).
TCF     +2
TCF     /BUF-

XCH      BUF +1      # SHIFT VECTOR AND SCALAR LEFT 14.
XCH      BUF
XCH      MPAC +1
XCH      MPAC
EXTEND
BZF      +2
TCF      DVOVF

XCH      MPAC +4
XCH      MPAC +3
EXTEND
BZF      +2
TCF      DVOVF

XCH      MPAC +6
XCH      MPAC +5
EXTEND
BZF      +2
TCF      DVOVF

CCS      BUF
TCF      /BUF+
TCF      DVOVF      # ZERO DIVISOR - OVERFLOW.
TCF      /BUF-
TCF      DVOVF

/BUF-    EXTEND      # ON NEGATIVE, COMPLEMENT BUF AND MAINTAIN
DCS      BUF        # DVSIGN IN VBUF +5.
DXCH     BUF
INCR     VBUF +5

# Page 1172
/BUF+    EXTEND
DCA      BUF        # LEAVE ABS(ORIG DIVISOR) IN BUF2
DXCH     BUF2       # FOR OVERFLOW TESTING
```

```

                                TCF      /NORM      # NORMALIZE DIVISOR IN BUF.

/NORM2      EXTEND
            AUG      DVNORMCT      # IF LESS THAN .5, AUGMENT DVNORMCT AND
            EXTEND      # DOUBLE DIVISOR.
            DCA      BUF
            DAS      BUF

/NORM      CA      BUF      # SEE IF DIVISOR NORMALIZED.
            DOUBLE
            OVSK
            TCF      /NORM2      # DOUBLE AND TRY AGAIN IF NOT.

            TC      V/SCDV      # DO X COMPONENT DIVIDE.
            DXCH     MPAC +3      # SUPPLY ARGUMENTS IN USUAL SEQUENCE.
            DXCH     MPAC
            DXCH     MPAC +3

            TC      V/SCDV      # Y COMPONENT.
            DXCH     MPAC +5
            DXCH     MPAC
            DXCH     MPAC +5

            TC      V/SCDV      # Z COMPONENT.
            TCF      VROTATEX    # GO RE-ARRANGE COMPONENTS BEFORE EXIT.

# Page 1173
# SUBROUTINE USED BY V/SC TO DIVIDE VECTOR COMPONENT IN MPAC,+1 BY THE SCALAR GIVEN

V/SCDV      CA      VBUF +5      # REFLECTS SIGN OF SCALAR.
            TS      DVSIGN

            CCS      MPAC      # FORCE MPAC POSITIVE, EXITING ON ZERO.
            TCF      /MPAC+
            TCF      +2
            TCF      /MPAC-

            CCS      MPAC +1
            TCF      /MPAC+
            TC      Q
            TCF      /MPAC-
            TC      Q

/MPC-      EXTEND      # USUAL COMPLEMENTING AND SETTING OF SIGN.
            DCS      MPAC
            DXCH     MPAC

```

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```

                                INCR    DVSIGN
/MPAC+                          CS      ONE      # INITIALIZE NEAR-ONE SWITCH.
                                TS      MAXDVSW
                                CS      MPAC      # CHECK POSSIBLE OVERFLOW.
                                AD      BUF2      # UNNORMALIZED INPUT DIVISOR.
                                CCS      A
                                TCF      DDVCALL   # NOT NEAR-ONE
                                TCF      +2        # +0 IS JUST POSSIBLE
                                TCF      DVOVF      # NO HOPE
                                TS      MAXDVSW    # SIGNAL POSSIBLE NEAR-ONE CASE
                                CS      MPAC +1     # SEE IF DIVISION CAN BE DONE
                                AD      BUF2 +1
                                EXTEND
                                BZMF     DVOVF
DDVCALL                         DXCH     MPAC      # CALL PRE-DIVIDE NORMALIZATION.
                                INDEX    DVNORMCT
                                TCF      MAXTEST
```

# Page 1174  
SLOPELO

```
DEC      .8324
```

VECAGREE

```

XCH      Q      # SAVE Q IN A
DXCH     MPAC
TC       ALSIGNAG # SIGNAGREE MPAC
DXCH     MPAC
DXCH     MPAC +3
TC       ALSIGNAG # SIGN AGREE MPAC +3
DXCH     MPAC +3
DXCH     MPAC +5
TC       ALSIGNAG # SIGNAGREE MPAC +5
DXCH     MPAC +5
TC       A
```

# Page 1175

# THE FOLLOWING ROUTINE EXECUTES THE UNIT INSTRUCTION, WHICH TAKES THE UNIT OF THE VECTOR IN MP

```

UNIT      TC      VECAGREE      # FORCE SIGN AGREEMENT IN VECTOR
          TC      MPACVBUF      # SAVE ARGUMENT IN VBUF
          CAF      ZERO          # MUST SENSE OVERFLOW IN FOLLOWING DOT.
          XCH      OVFIN
          TS      TEM1
          TC      VSQSUB      # DOT MPAC WITH ITSELF.
          CA      TEM1
```

```

XCH      OVFIN
EXTEND
BZF      +2
TCF      DVOVF
EXTEND
DCA      MPAC      # LEAVE THE SQUARE OF THE LENGTH OF THE
INDEX    FIXLOC    # ARGUMENT IN LVSQUARE.
DXCH     LVSQUARE

TC        SQRTSUB   # GO TAKE THE NORMALIZED SQUARE ROOT.

CCS      MPAC      # CHECK FOR UNIT OVERFLOW.
TCF      +5        # MPAC IS NOT LESS THAN .5 UNLESS
TS        L
INDEX    FIXLOC
DXCH     LV
TCF      DVOVF     # INPUT TO SQRTSUB WAS 0.

CS        FOURTEEN # SEE IF THE INPUT WAS SO SMALL THAT THE
AD        MPTMP     # FIRST TWO REGISTERS OF THE SQUARE WERE 0
CCS      A
COM
TCF      SMALL     # IF SO, SAVE THE NEGATIVE OF THE SHIFT
                        # COUNT -15D.

TCF      LARGE     # (THIS IS USUALLY THE CASE.)

CS        THIRTEEN # IF THE SHIFT COUNT WAS EXACTLY 14, SET
TS        MPTMP     # THE PRE-DIVIDE NORM COUNT TO -13D.

SMALL2    CA        MPAC      # SHIFT THE LENGTH RIGHT 14 BEFORE STORING
            TS        L        # (SMALL EXITS TO THIS POINT).
            CAF      ZERO
            TCF      LARGE2    # GO TO STORE LENGTH AND PROCEED.

LARGE     CCS      MPTMP     # MOST ALL CASES COME HERE.
            TCF      LARGE3    # SEE IF NO NORMALIZATION WAS REQUIRED BY
            CS        SRDDV    # Sqrt, AND IF SO, SET UP FOR A SHIFT
            TS        MPTMP    # RIGHT 1 BEFORE DIVIDING TO PRODUCE
            EXTEND    # THE DESIRED HALF UNIT VECTOR.
            DCA      MPAC

# Page 1176
            TCF      LARGE2

# Page 1177
LARGE3    COM
            TS        MPTMP    # LEAVE NEGATIVE OF SHIFT COUNT-1 FOR
                        # PREDIVIDE LEFT SHIFT.

```



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```
COM                                     # PICK UP REQUIRED SHIFTING BIT TO UNNORM-
INDEX  A                               # ALIZE THE SQRT RESULT.
CAF    BIT14
TS      BUF
EXTEND
MP      MPAC +1
XCH     BUF
EXTEND                                     # (UNNORMALIZE THE SQRT FOR LV).
MP      MPAC
XCH     L
AD      BUF
XCH     L

LARGE2  INDEX  FIXLOC
DXCH    LV                               # LENGTH NOW STORED IN WORK AREA.

CS      ONE
TS      MAXDVSW                          # NO MAXDV CASES IN UNIT.

DXCH    VBUF                             # PREPARE X COMPONENT FOR DIVIDE, SETTING
DXCH    MPAC                             # LENGTH OF VECTOR AS DIVISOR IN BUF.
DXCH    BUF
TC      UNITDV

DXCH    VBUF +2                          # DO Y AND Z IN USUAL FASHION SO WE CAN
DXCH    MPAC                             # EXIT THROUGH VROTATEX.
DXCH    MPAC +3
TC      UNITDV

DXCH    VBUF +4
DXCH    MPAC
DXCH    MPAC +5
TC      UNITDV
TCF     VROTATEX                          # AND EXIT.
```

# Page 1178

# IF THE LENGTH OF THE ARGUMENT VECTOR WAS LESS THAN 2(-28), EACH COMPONENT MUST BE SHIFTED LEFT  
# 14 PLACES BEFORE THE DIVIDE, NOTE THAT IN THIS CASE, THE MAJOR PART OF EACH COMPONENT IS ZERO

```
SMALL    TS      MPTMP                    # NEGATIVE OF PRE-DIVIDE SHIFT COUNT.

CAF      ZERO                               # SHIFT EACH COMPONENT LEFT 14.
XCH      VBUF +1
XCH      VBUF
XCH      VBUF +3
```

XCH VBUF +2  
 XCH VBUF +5  
 XCH VBUF +4

CS MPTEMP  
 INDEX A  
 CAF BIT14  
 EXTEND  
 MP MPAC  
 TCF SMALL2

THIRTEEN = OCT15  
 FOURTEEN = OCT16  
 OCT16 = R1D1

# Page 1179

# THE FOLLOWING ROUTINE SETS UP THE CALL TO THE DIVIDE ROUTINES.

UNITDV	CCS	MPAC	# FORCE MPAC POSITIVE IF POSSIBLE, SETTING
	TCF	UMPAC+	# DVSIGN ACCORDING TO THE SIGN OF MPAC
	TCF	+2	# SINCE THE DIVISOR IS ALWAYS POSITIVE
	TCF	UMPAC-	# HERE.

	CCS	MPAC +1	
	TCF	UMPAC+	
	TC	Q	# EXIT IMMEDIATELY ON ZERO.
	TCF	UMPAC-	
	TC	Q	

UMPAC-	CS	ZERO	# IF NEGATIVE, SET -0 IN DVSIGN FOR FINAL
	TS	DVSIGN	# COMPLEMENT.
	EXTEND		
	DCS	MPAC	# PICK UP ABSOLUTE VALUE OF ARG AND JUMP.
	INDEX	MPTEMP	
	TCF	MAXTEST -1	

UMPAC+	TS	DVSIGN	# SET DVSIGN FOR POSITIVE QUOTIENT.
	DXCH	MPAC	
	INDEX	MPTEMP	
	TCF	MAXTEST -1	

# Page 1180

# MISCELLANEOUS UNARY OPERATIONS.

DSQ	TC	DSQSUB	# SQUARE THE DP CONTENTS OF MPAC.
	TCF	DANZIG	

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ABVALABS	CCS	MODE	# ABVAL OR ABS INSTRUCTION.
	TCF	ABS	# DO ABS ON SCALAR.
	TCF	ABS	
ABVAL	TC	VSQSUB	# DOT MPAC WITH ITSELF.
	LXCH	MODE	# MODE IS NOW DP (L ZERO AFTER DAS).
	EXTEND		# STORE SQUARE OF LENGTH IN WORK AREA.
	DCA	MPAC	
	INDEX	FIXLOC	
	DXCH	LVSQUARE	

# Page 1181

# PROGRAM DESCRIPTION -- SUBROUTINE SQRT

#

# FUNCTIONAL DESCRIPTION -- DOUBLE PRECISION SQUARE ROOT ROUTINE

# THIS PROGRAM TAKES THE SQUARE ROOT OF THE 27 OR 28 MOST SIGNIFICANT BITS IN THE TRIPLE  
# NUMBERS -- MPAC, MPAC+1, AND MPAC+2. THE ROOT IS RETURNED DOUBLE PRECISION IN MPAC AND

#

# WARNING -- THIS SUBROUTINE USES A TRIPLE PRECISION INPUT. THE PROGRAMMER MUST ASSURE THE CON  
# ESPECIALLY IF THE CONTENTS OF MPAC IS SMALL OR ZERO. FOR DETAILS SEE STG MEMO NO.949.

#

# CALLING SEQUENCE -- IN INTERPRETIVE MODE, I.E., FOLLOWING 'TC INTPRET', 'SQRT', NO ADDRESS IS  
# INPUT SCALING: THE BINARY POINT IS ASSUMED TO THE RIGHT OF BIT 15. THE ANSWER IS RETUR

#

# SUBROUTINES -- GENSCR, MPACSHR, SQRTSUB, ABORT

#

# ABORT EXIT MODE -- ABORTS ON NEGATIVE INPUT  $-1.2 \times 10^{-4}$  (77775 OCTAL) OR LESS.

# DISPLAYS ERROR CODE 1302

#	TC	ABORT
---	----	-------

#	OCT	1302
---	-----	------

#

# DEBRIS -- LOCATIONS BUF, MPTEMP, ADDRWD ARE USED

SQRT	TC	SQRTSUB	# TAKE THE SQUARE ROOT OF MPAC.
	CCS	MPTEMP	# RETURNED NORMALIZED SQUARE ROOT. SEE IF
	TCF	+2	# ANY UN-NORMALIZATION REQUIRED AND EXIT
	TCF	DANZIG	# IF NOT.
	AD	NEG12	# A RIGHT SHIFT OF MORE THAN 13 COULD BE
	EXTEND		# REQUIRED IF INPUT WAS ZERO IN MPAC,+1.
	BZMF	SQRTSHFT	# GOES HERE IN MOST CASES.
	ZL		# IF A LONG SHIFT IS REQUIRED, GO TO
	LXCH	ADDRWD	# GENERAL RIGHT SHIFT ROUTINES.
	TCF	GENSCR +4	# ADDRWD WAS ZERO TO PREVENT ROUND.

SQRTSHFT	INDEX	MPTMP	# SELECT SHIFTING BIT AND EXIT THROUGH
	CAF	BIT15	# SHIFT ROUTINES.
	TS	MPTMP	
	CAF	ZERO	# TO ZERO MPAC +2 IN THE PROCESS.
	TCF	MPACSHR +3	
ABS	TC	BRANCH	# TEST SIGN OF MPAC AND COMPLEMENT IF
	TCF	DANZIG	
	TCF	DANZIG	
	TCF	COMP	
# Page 1182			
VDEF	CS	FOUR	# VECTOR DEFINE -- ESSENTIALLY TREATS
	ADS	PUSHLOC	# SCALAR IN MPAC AS X COMPONENT, PUSHES UP
	EXTEND		# FOR Y AND THEN AGAIN FOR Z.
	INDEX	A	
	DCA	2	
	DXCH	MPAC +3	
	EXTEND		
	INDEX	PUSHLOC	
	DCA	0	
	DXCH	MPAC +5	
	TCF	VMODE	# MODE IS NON VECTOR.
VSQ	TC	VSQSUB	# DOT MPAC WITH ITSELF.
	TCF	DMODE	# MODE IS NOW DP.
PUSH	EXTEND		# PUSH DOWN MPAC LEAVING IT LOADED.
	DCA	MPAC	
	INDEX	PUSHLOC	# PUSH DOWN FIRST TWO REGISTERS IN EACH
	DXCH	0	
	INDEX	MODE	# INCREMENT PUSHDOWN POINTER.
	CAF	NO.WDS	
	ADS	PUSHLOC	
	CCS	MODE	
	TCF	TPUSH	# PUSH DOWN MPAC +2.
	TCF	DANZIG	# DONE FOR DP.
	EXTEND		# ON VECTOR, PUSH DOWN Y AND Z COMPONENTS.
	DCA	MPAC +3	
	INDEX	PUSHLOC	
	DXCH	0 -4	
	EXTEND		

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```

      DCA      MPAC +5
      INDEX    PUSHLOC
      DXCH     0 -2
      TCF      DANZIG

TPUSH      CA      MPAC +2
          TCF      ENDTPUSH +2

RVQ        INDEX    FIXLOC      # RVQ -- RETURN IVA QPRET.
          CA      QPRET
          TS      POLISH
          TCF      GOTO +4      # (ASSUME QPRET POINTS TO FIXED ONLY.)
```

# Page 1183

# THE FOLLOWING SUBROUTINES ARE USED IN SQUARING MPAC, IN BOTH THE SCALAR AND VECTOR SENSE. TH  
# SPECIAL CASES OF DMPSUB AND DOTSUB, PUT IN TO SAVE SOME TIME.

```

DSQSUB      CA      MPAC +1      # SQUARES THE SCALAR CONTENTS OF MPAC.
          EXTEND
          SQUARE
          TS      MPAC +2
          CAF     ZERO      # FORM 2(CROSS TERM).
          XCH     MPAC +1
          EXTEND
          MP      MPAC
          DDOUBL      # AND MAYBE OVEFLOW.
          DAS     MPAC +1      # AND SET A TO NET OVERFLOW.
          XCH     MPAC
          EXTEND
          SQUARE
          DAS     MPAC
          TC      Q

VSQSUB      EXTEND      # DOTS THE VECTOR IN MPAC WITH ITSELF.
          QXCH     DOTRET
          TC      DSQSUB      # SQUARE THE X COMPONENT.
          DXCH     MPAC +3
          DXCH     MPAC
          DXCH     BUF      # SO WE CAN END IN DOTSUB.
          CA      MPAC +2
          TS      BUF +2

          TC      DSQSUB      # SQUARE Y COMPONENT.
          DXCH     MPAC +1
          DAS     BUF +1
          AD      MPAC
```

```

AD      BUF
TS      BUF
TCF     +2
TS      OVFINF      # IF OVERFLOW.

```

```

DXCH    MPAC +5
DXCH    MPAC
TC      DSQSUB      # SQUARE Z COMPONENT.
TCF     ENDDOT      # END AS IN DOTSUB.

```

# Page 1184

# DOUBLE PRECISION SQUARE ROOT ROUTINE. TAKE THE SQUARE ROOT OF THE TRIPLE PRECISION  
 # IN NORMALIZATION) CONTENTS OF MPAC AND LEAVE THE NORMALIZED RESULT IN MPAC (C(MPAC)  
 # .5). THE RIGHT SHIFT COUNT (TC UNNORMALIZE) IS LEFT IN MPTMP.

```

SQRTSUB  CAF      ZERO      # START BY ZEROING RIGHT SHIFT COUNT.
          TS      MPTMP

          CCS      MPAC      # CHECK FOR POSITIVE ARGUMENT, SHIFTING
          TCF      SMPAC+    # FIRST SIGNIFICANT MPAC REGISTER INTO
          TCF      +2        # MPAC ITSELF.
          TCF      SQRTNEG   # SEE IF MAG OF ARGUMENT LESS THAN 10(-4).

          XCH      MPAC +2   # MPAC IS ZERO -- SHIFT LEFT 14.
          XCH      MPAC +1
          TS      MPAC
          CAF      SEVEN     # AUGMENT RIGHT SHIFT COUNTER.
          TS      MPTMP

          CCS      MPAC      # SEE IF MPAC NOW PNZ.
          TCF      SMPAC+
          TCF      +2
          TCF      ZEROANS   # NEGATIVE BUT LESS THAN 10(-4) IN MAG.

          XCH      MPAC +1   # XERO -- SHIFT LEFT 14 AGAIN.
          TS      MPAC
          CAF      SEVEN     # AUGMENT RIGHT SHIFT COUNTER.
          ADS      MPTMP

          CCS      MPAC
          TCF      SMPAC+
          TC      Q          # SQRT(0) = 0.
          TCF      ZEROANS
          TCF      FIXROOT   # DO NOT LEAVE SQRTSUB WITH -0 IN MPAC.

SQRTNEG  CCS      A          # ARGUMENT IS NEGATIVE, BUT SEE IF SIGN-

```

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	TCF	SQRTABRT	# CORRECTED ARGUMENT IS LESS THAN 10(-4)
ZEROANS	CCS	MPAC +1	# IN MAGNITUDE. IF SO, CALL ANSWER ZERO.
	CAF	ZERO	# FORCE ANSWER TO ZERO HERE.
	TCF	FIXROOT	
	TCF	SQRTABRT	
	TCF	FIXROOT	
SQRTABRT	TC	POODOO	
	OCT	1302	
# Page 1185			
SMPAC+	AD	-1/2+2	# SEE IF ARGUMENT GREATER THAN OR EQUAL TO
	EXTEND		# .5.
	BZMF	SRTEST	# IF SO, SEE IF LESS THAN .25.
	DXCH	MPAC	# WE WILL TAKE THE SQUARE ROOT OF MPAC/2.
	LXCH	SR	# SHIFT RIGHT 1 AND GO TO THE SQRT ROUTINE
	EXTEND		
	MP	HALF	
	DXCH	MPAC	
	XCH	SR	
	ADS	MPAC +1	# GUARANTEED NO OVERFLOW.
ARGHI	CAF	SLOPEHI	# ARGUMENT BETWEEN .25 AND .5, GET A
	EXTEND		# LINEAR APPROXIMATION FOR THIS RANGE.
	MP	MPAC	
	AD	BIASHI	# $X0/2 = (MPAC/2)(SLOPHI) + BIASHI/2$ .
+4	TS	BUF	# $X0/2$ (ARGLO ENTERS HERE).
	CA	MPAC	# SINGLE-PRECISION THROUGHOUT.
	ZL		
	EXTEND		
	DV	BUF	# $(MPAC/2)/(X0/2)$
	EXTEND		
	MP	HALF	
	ADS	BUF	# $X1 = X0/2 + .5(MPAC/2)/(X0/2)$
	EXTEND		
	MP	HALF	# FORM UP $X1/2$ .
	DXCH	MPAC	# SAVE AND BRING OUT ARGUMENT.
	EXTEND		# TAKE DP QUOTIENT WITH $X1$ .
	DV	BUF	
	TS	BUF +1	# SAVE MAJOR PART OF QUOTIENT.
	CAF	ZERO	# FORM MINOR PART OF QUOTIENT USING
	XCH	L	# (REMAINDER,0).

```

                                EXTEND
                                DV      BUF
                                TS      L      # IN PREPARATION FOR DAS.
                                CA      BUF +1
                                DAS     MPAC    #  $X_2 = X_1/2 + (MPAC/2)X_1$ 

                                EXTEND
                                BZF     TCQBNKOO      # OVERFLOWS IF ARG. NEAR POSMAX.
                                CAF     POSMAX
                                TS      MPAC
                                TS      MPAC +1
                                TCQBNKOO TC      Q      # RETURN TO CALLER TO UNNORMALIZE, ETC.

# Page 1186
SRTEST      AD      QUARTER      # ARGUMENT WAS LESS THAN .5, SEE IF LESS
                                EXTEND      # THAN .25.
                                BZMF     SQRTNORM      # IF SO, BEGIN NORMALIZATION.

                                DXCH     MPAC          # IF BETWEEN .5 AND .25, SHIFT RIGHT 1 AND
                                LXCH     SR            # START AT ARGLO.
                                EXTEND
                                MP      HALF
                                DXCH     MPAC
                                XCH      SR
                                ADS      MPAC +1      # NO OVERFLOW.

                                ARGLO     CAF      SLOPELO      # (NORMALIZED) ARGUMENT BETWEEN .125 AND
                                EXTEND      # .25
                                MP      MPAC
                                AD      BIASLO
                                TCF      ARGHI +4      # BEGIN SQUARE ROOT.

                                SQRTNM2   EXTEND      # SHIFT LEFT 2 AND INCREMENT RIGHT SHIFT
                                DCA      MPAC +1      # COUNT (FOR TERMINAL UNNORMALIZATION).
                                DAS      MPAC +1
                                AD      MPAC
                                ADS      MPAC          # (NO OVERFLOW).

                                SQRTNORM   INCR      MPTMP      # FIRST TIME THROUGH, JUST SHIFT LEFT 1
                                EXTEND      # (PUTS IN EFFECTIVE RIGHT SHIFT SINCE
                                DCA      MPAC +1      # WE WANT MPAC/2).
                                DAS      MPAC +1
                                AD      MPAC
                                ADS      MPAC          # (AGAIN NO OVERFLOW).
                                DOUBLE
                                TS      CYL

```



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NORMTEST	CCS	CYL	# SEE IF ARGUMENT NOW NORMALIZED AT
	CCS	CYL	# GREATER THAN .125.
	TCF	SQRTNM2	# NO -- SHIFT LEFT 2 MORE AND TRY AGAIN.
	TCF	ARGHI	# YES -- NOW BETWEEN .5 AND .25.
	TCF	ARGLO	# ARGUMENT NOW BETWEEN .25 AND .125.

# Page 1187

# TRIGONOMETRIC FUNCTION PACKAGE.

# THE FOLLOWING TRIGONOMETRIC FUNCTIONS ARE AVAILABLE AS INTERPRETIVE OPERATIONS:

#	1.	SIN	COMPUTES (1/2)SINE(2 PI MPAC).
#	2.	COS	COMPUTES (1/2)COSINE(2 PI MPAC).
#	3.	ASIN	COMPUTES (1/2PI)ARCSINE(2 MPAC).
#	4.	ACOS	COMPUTES (1/2PI)ARCCOSINE(2 MPAC).

#

# SIN-ASIN AND COS-ACOS ARE MUTUALLY INVERSE, I.E.,  $\text{SIN}(\text{ASIN}(X)) = X$ .

COSINE	TC	BRANCH	# FINDS COSINE USING THE IDENTITY
	TCF	+3	# $\text{COS}(X) = \text{SIN}(\text{PI}/2 - \text{ABS}(X))$ .
	TCF	PRESINE	
	TCF	PRESINE	

+3	EXTEND
	DCS MPAC
	DXCH MPAC

PRESINE	CAF	QUARTER	# $\text{PI}/2$ SCALED.
	ADS	MPAC	

SINE	DXCH	MPAC	# DOUBLE ARGUMENT.
	DDOUBL		
	OVSK		# SEE IF OVERFLOW PRESENT.
	TCF	+3	# IF NOT, ARGUMENT OK AS IS.
	EXTEND		# IF SO, WE LOST (OR GAINED) PI, SO
	DCOM		# COMPLEMENT MPAC USING THE IDENTITY
			# $\text{SIN}(X-(+)\text{PI}) = \text{SIN}(-X)$ .
	+3	DXCH MPAC	
	CA	MPAC	# SEE IF ARGUMENT GREATER THAN .5 IN
	DOUBLE		# MAGNITUDE. IF SO, REDUCE IT TO LESS THAN
	TS	L	# .5 ( $\pm\text{PI}/2$ SCALED) AS FOLLOWS:
	TCF	SN1	
	INDEX	A	# IF POSITIVE, FORM $\text{PI} - X$ , IF NEGATIVE
	CAF	NEG1/2 +1	# USE $-\text{PI} - X$ .
	DOUBLE		

```

                                EXTEND
                                SU      MPAC      # GUARANTEED NO OVERFLOW.
                                TS      MPAC
                                CS      MPAC +1
                                TS      MPAC +1

# Page 1188
SN1                                EXTEND      # SET UP TO EVALUATE HASTINGS POLYNOMIAL
                                DCA      MPAC
                                DXCH     BUF2
                                TC      DSQSUB   # SQUARE MPAC.

                                TC      POLY      # EVALUATE FOURTH ORDER POLYNOMIAL.
                                DEC      3
                                2DEC     +.3926990796
                                2DEC     -.6459637111
                                2DEC     +.318758717
                                2DEC     -.074780249
                                2DEC     +.009694988

                                CAF      LBUF2     # MULTIPLY BY ARGUMENT AND SHIFT LEFT 2.
                                TC      DMPSUB -1

                                EXTEND
                                DCA      MPAC +1
                                DAS      MPAC +1
                                AD       MPAC
                                ADS      MPAC      # NEITHER SHIFT OVERFLOWS.
                                EXTEND
                                DCA      MPAC +1
                                DAS      MPAC +1
                                AD       MPAC
                                ADS      MPAC
                                TCF      DANZIG

# Page 1189
# ARCSIN/ARCCOS ROUTINE.

ARCSIN      CAF      LASINEX      # COMPUTE ARCSIN BY USING THE IDENTITY
            TCF      +2           # ARCSIN(X) = PI/2 - ARCCOS(X).

ARCCOS      CAF      LDANZIG      # (EXITS IMMEDIATELY).
            TS      ESCAPE
            TC      BRANCH        # TEST SIGN OF INPUT.
            TCF     ACOSST        # START IMMEDIATELY IF POSITIVE.
            TCF     ACOSZERO      # ARCCOS(0) = PI/2 = .25.

```

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```

                                # IF NEGATIVE, USE THE IDENTITY
                                # ARCCOS(X) = PI - ARCCOS(-X), FORCING
                                # ARGUMENT POSITIVE.
                                # SET EXIT TO DO ABOVE BEFROE
                                # ARCSIN/ARCCOS CONSIDERATIONS.
EXTEND
DCS      MPAC
DXCH     MPAC
CAF      TCSUBTR
XCH      ESCAPE
TS       ESCAPE2

ACOSST   CS      HALF      # TEST MAGNITUDE OF INPUT.
         AD      MPAC
         CCS     A
         TCF     ACOSOVF    # THIS IS PROBABLY AN OVERFLOW CASE.

LASINEX  TCF     ASINEX

         TCF     ACOSST2    # NO OVERFLOW -- PROCEED.

         CCS     MPAC +1    # IF MAJOR PART IS .5, CALL ANSWER 0
         CAF     ZERO      # UNLESS MINOR PART NEGATIVE.
         TCF     ACOS=0

         TCF     ACOSST2

ACOS=0   TS      MPAC +1
         TS      MPAC
         TC      ESCAPE

ACOSST2  EXTEND
DCS      MPAC      # NOW THAT ARGUMENT IS IN PROPER RANGE,
AD       HALF      # BEGIN COMPUTATION.  USE HASTINGS
DXCH     MPAC      # APPROXIMATION ARCCOS(X) = SQRT(1-X)P(X)
DXCH     BUF2      # IN A SCALED VERSION WHERE P(X) IS A
                   # SEVENTH ORDER POLYNOMIAL.

         TC      SQRTSUB    # RETURNS WITH NORMALIZED SQUARE ROOT.

         CCS     MPTMP      # SEE IF UN-NORMALIZATION REQUIRED.
         TCF     ACOSHR

# Page 1190
ACOS3    DXCH     MPAC      # SET UP FOR POLYNOMIAL EVALUATION.
         DXCH     BUF2
         DXCH     MPAC

         TC      POLY
         DEC      6
         2DEC     +.353553385  # COEFFICIENTS ARE C 2(+I)/PISQRT(2) WHERE
         2DEC*    -.0483017006 B+1*      # I
```

```

2DEC*  +.0200273085 B+2*      # WEHRE C STANDS FOR ORIGINAL COEFFS
2DEC*  -.0112931863 B+3*
2DEC*  +.00695311612 B+4*
2DEC*  -.00384617957 B+5*
2DEC*  +.001501297736 B+6*
2DEC*  -.000284160334 B+7*

CAF    LBUF2      # DO FINAL MULTIPLY AND GO TO ANY
TC     DMPSUB -1  # EPILOGUE SEQUENCES.
TC     ESCAPE

SUBTR   EXTEND    # EPILOGUE FOR NEGATIVE INPUTS TO ARCCOS.
DCS    MPAC
AD     HALF      # FORMS  $\pi - \arccos(-X) = \arccos(X)$ .
DXCH   MPAC
TC     ESCAPE2   # GO TO POSSIBLE ARCSIN EPILOGUE.

ASINEX  EXTEND
DCS    MPAC      # ARCSIN EPILOGUE -- GET ARCSIN(X)
AD     QUARTER   # =  $\pi/2 - \arccos(X)$ .
DXCH   MPAC
LDANZIG TCF      DANZIG

# Page 1191
ACOSSHR INDEX    A      # THE SHIFT RIGHT IS LESS THAN 14 SINCE
CAF     BIT14      # THE INPUT WAS NON-ZERO DP.
TS      MPTMP
TC      VSHRRND    # DP SHIFT RIGHT AND ROUND.
TCF     ACOS3      # PROCEED.

ACOSOVF EXTEND    # IF MAJOR PART WAS ONLY 1 MORE THAN .5,
BZF     ACOS=0     # CALL ANSWER ZERO.

ACOSABRT TC      ALARM  # IF OVERFLOW, CALL ANSWER ZERO BUT
OCT     1301      # SOUND AN ALARM.

CAF     ZERO
TCF     ACOS=0

ACOSZERO CAF     QUARTER #  $\arccos(0) = \pi/2$ .
TCF     ACOS=0 +1      # SET MPAC AND EXIT VIA ESCAPE.

NEG12   DEC      -12
TCSUBTR TCF      SUBTR

# Page 1192

```

```

# THE FOLLOWING INSTRUCTIONS ARE AVAILABLE FOR SETTING, MODIFYING, AND BRANCHING ON INDEX REGIS
#      1.      AXT      ADDRESS TO INDEX TRUE.
#      2.      AXC      ADDRESS TO INDEX COMPLEMENTED.
#      3.      LXA      LOAD INDEX FROM ERASABLE.
#      4.      LXC      LOAD INDEX COMPLEMENTED FROM ERASABLE.
#      5.      SXA      STORE INDEX IN ERASABLE.
#      6.      XCHX     EXCHANGE INDEX REGISTER WITH ERASABLE.
#      7.      INCR     INCREMENT INDEX REGISTER.
#      8.      XAD      ERASABLE ERASABLE ADD TO INDEX REGISTER.
#      9.      XSU      ERASABLE SUBTRACT FROM INDEX REGISTER.
#     10.      TIX      BRANCH ON INDEX REGISTER AND DECREMENT.

```

```

BANK      01

```

```

COUNT    01/INTER

```

```

AXT        TC      TAGSUB      # SELECT APPROPRIATE INDEX REGISTER.
           CA      POLISH
XSTORE     INDEX   INDEXLOC    # CONTAINS C(FIXLOC) OR C(FIXLOC)+1
           TS      X1
           TCF     DANZIG

```

```

AXC        TC      TAGSUB
           CS      POLISH
           TC      XSTORE

```

```

LXA        TC      15ADRERS     # LOAD INDEX REGISTER FROM ERASABLE.
           INDEX   POLISH
           CA      0
           TCF     XSTORE

```

```

LXC        TC      15ADRERS     # LOAD NDX REG FROM ERASABLE COMPLEMENTED.
           INDEX   POLISH
           CS      0
           TCF     XSTORE

```

```

SXA        TC      15ADRERS     # STORE INDEX REGISTER IN ERASABLE.
           INDEX   INDEXLOC

```

```

           CA      X1
MSTORE1    INDEX   POLISH
           TS      0
           TCF     DANZIG

```

```

# Page 1193

```

```

XCHX       TC      15ADRERS     # EXCHANGE INDEX REGISTER WITH ERASABLE.
           INDEX   POLISH

```

	CA	0	
	INDEX	INDEXLOC	
	XCH	X1	
	TCF	MSTORE1	
XAD	TC	15ADRERS	# ADD ERASABLE TO INDEX REGISTER.
	INDEX	POLISH	
	CA	0	
XAD2	INDEX	INDEXLOC	
	ADS	X1	# IGNORING OVERFLOWS.
	TCF	DANZIG	
INCR	TC	TAGSUB	# INCREMENT INDEX REGISTER.
	CA	POLISH	
	TCF	XAD2	
XSU	TC	15ADRERS	# SUBTRACT ERASABLE FROM INDEX REGISTER.
	INDEX	POLISH	
	CS	0	
	TCF	XAD2	
TIX	TC	TAGSUB	# BRANCH AND DECREMENT ON INDEX.
	INDEX	INDEXLOC	
	CS	S1	
	INDEX	INDEXLOC	
	AD	X1	
	EXTEND		# NO OPERATION IF DECREMENTED INDEX IS
	BZMF	DANZIG	# NEGATIVE OR ZERO.
DOTIXBR	INDEX	INDEXLOC	
	XCH	X1	# IGNORING OVERFLOWS.
	TCF	GOTO	# DO THE BRANCH USING THE CADR IN POLISH.
# Page 1194			
# SUBROUTINE TO CONVERT AN ERASABLE ADDRESS (11 BITS) TO AN EBANK SETTING AND SUBADDRESS			
15ADRERS	CS	POLISH	
	AD	DEC45	
	CCS	A	# DOES THE ADDRESS POINT TO THE WORK AREA?
	CA	FIXLOC	# YES. ADD FIXLOC. EBANK OK AS IS.
	TCF	+5	
	CA	OCT1400	# NO. SET EBANK & MAKE UP SUBADDRESS.
	XCH	POLISH	
	TS	EBANK	

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```

+5      MASK    LOW8
      ADS      POLISH      # FALL INTO TAGSUB, AND RETURN VIA Q.

# SUBROUTINE WHICH SETS THE ADDRESS OF THE SPECIFIED INDEX IN INDEXLOC. (ACTUALLY, THE ADDRESS

TAGSUB      CA      FIXLOC
            TS      INDEXLOC

            CCS      CYR      # BIT 15 SPECIFIES INDEX.
            INCR     INDEXLOC  # 0 MEANS USE X2.
            TC       Q
            TC       Q      # 1 FOR X1.

# Page 1195
# MISCELLANEOUS OPERATION CODES WITH DIRECT ADDRESSES. INCLUDED HERE ARE:
#      1.      ITA      STORE CPRET (RETURN ADDRESS) IN ERASABLE.
#      2.      CALL     CALL A SUBROUTINE, LEAVING RETURN IN QPRET.
#      3.      RTB      RETURN TO BASIC LANGUAGE AT THE GIVEN ADDRESS.
#      4.      BHIZ     BRANCH IF THE HIGHORDER OF MPAC IS ZERO (SINGLE PRECISION).
#      5.      BOV      BRANCH ON OVERFLOW.
#      6.      GOTO     SIMPLE SEQUENCE CHANGE.

RTB/BHIZ     CCS      CYR
RTB           CA      POLISH
            TC      SWCALL  -1      # SO A "TC Q" FROM ROUTINE LEADS TO DANZIG

BHIZ         CCS      MPAC
            TCF      DANZIG
            TCF      GOTO
            TCF      DANZIG
            TCF      GOTO

BOV(B)       CCS      OVFIN      # BRANCH ON OVERFLOW TO BASIC OR INTERP.
            TCF      +2
            TCF      DANZIG
            TS       OVFIN
            CCS      CYR
            TCF      RTB      # IF BASIC.
B5TOBB       OCT      360
            TCF      GOTO

# Page 1196
BZE/GOTO     CCS      CYR      # SEE WHICH OP-CODE IS DESIRED.
            TC       BRANCH    # DO BZE.
            TCF      DANZIG
            TCF      GOTO      # DO GOTO.
```

	TCF	DANZIG	
BPL/BMN	CCS	CYR	
	TCF	BPL	
5B10	#DEC	5	B+10 # SHIFTS OP CODE IN SWITCH INSTRUCTION ADR
	DEC	5	B-4 # RSB 2009
	TC	BRANCH	# DO BMN
	TCF	DANZIG	
	TCF	DANZIG	
	TCF	GOTO	# ONLY IF NNZ.
BPL	TC	BRANCH	
	TCF	GOTO	# IF POSITIVE OR ZERO.
	TCF	GOTO	
	TCF	DANZIG	
CALL/ITA	CCS	CYR	
	TCF	CALL	
	TC	CCSHOLE	
	TC	15ADRERS	# STORE QPRET. (TAGSUB AFTER 15ADRERS IS
	INDEX	FIXLOC	# SLOW IN THIS CASE, BUT SAVES STORAGE.)
	CA	QPRET	
	TCF	MSTORE1	

# Page 1197

# THE FOLLOWING OPERATIONS ARE AVAILABLE FOR ALTERING AND TESTING INTERPRETATIVE SWITCHES:

#	00	BONSET	SET A SWITCH AND DO A GOTO IF IT WAS ON.
#	01	SETGO	SET A SWITCH AND DO A GOTO.
#	02	BOFSET	SET A SWITCH AND DO A GOTO IF IT WAS OFF
#	03	SET	SET A SWITCH.
#	04	BONINV	INVERT A SWITCH AND BRANCH IF IT WAS ON.
#	05	INVGO	INVERT A SWITCH AND DO A GOTO.
#	06	BOFINV	INVERT A SWITCH AND BRANCH IF IT WAS OFF
#	07	INVERT	INVERT A SWITCH.
#	10	BONCLR	CLEAR A SWITCH AND BRANCH IF IT WAS ON.
#	11	CLRGO	CLEAR A SWITCH AND DO A GOTO.
#	12	BOFCLR	CLEAR A SWITCH AND BRANCH IF IT WAS OFF.
#	13	CLEAR	CLEAR A SWITCH.
#	14	BON	BRANCH IF A SWITCH WAS ON.
#	16	BOFF	BRANCH IF A SWITCH WAS OFF.

# THE ADDRESS SUPPLIED WITH THE SWITCH INSTRUCTION IS INTERPRETED AS FOLLOWS:

#	BITS 1-4	SWITCH BIT NUMBER (1-15).
#	BITS 5-8	SWITCH OPERATION NUMBER
#	BITS 9-	SWITCH WORD NUMBER (UP TO 64 SWITCH WORDS).



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# THE ADDRESS ITSELF IS MADE UP BY THE YUL SYSTEM ASSEMBLER. THE BRANCH INSTRUCTIONS REQUIRE T  
# ADDRESSES, THE SECOND TAKEN AS THE DIRECT (OR INDIRECT IF IN ERASABLE) ADDRESS OF THE BRANCH.

SWITCHES           CAF     LOW4           # LEAVE THE SWITCH BIT IN SWBIT.  
                  MASK    POLISH  
                  INDEX   A  
                  CAF     BIT15        # (NUMBER FROM LEFT TO RIGHT.)  
                  TS      SWBIT  
  
                  CAF     BIT7        # LEAVE THE SWITCH NUMBER IN SWWORD.  
                  EXTEND  
                  MP      POLISH  
                  TS      SWWORD  
  
                  INHINT               # DURING SWITCH CHANGE SO RUPT CAN USE TOO  
                  INDEX   A            # LEAVE THE SWITCH WORD ITSELF IN L.  
                  CA      STATE  
                  TS      Q            # Q WILL BE USED AS A CHANNEL.

# Page 1198

                  CAF     BIT11  
                  EXTEND               # DISPATCH SWITCH BIT OPERATION AS IN BITS  
                  MP      POLISH       # 7-8 OF POLISH.  
                  MASK    B3TOB4       # GETS 4X2-BIT CODE.  
                  INDEX   A  
                  TCF     +1  
  
                  +1    CA      SWBIT       # 00 -- SET SWITCH IN QUESTION.  
                          EXTEND  
                          ROR     QCHAN  
                          TCF     SWSTORE  
  
                  +5    CA      SWBIT       # 01 -- INVERT SWITCH.  
                          EXTEND  
                          RXOR    QCHAN  
                          TCF     SWSTORE  
  
                  +9D   CS      SWBIT       # 10 -- CLEAR.  
                          MASK    Q  
SWSTORE           INDEX   SWWORD  
                  TS      STATE        # NEW SWITCH WORD.

# Page 1199

                  +13D RELINT           # 11 -- NOOP.  
                          CAF     BIT13  
                          EXTEND       # DISPATCH SEQUENCE CHANGING OR BRANCING  
                          MP      POLISH       # CODE.

		MASK	B3TOB4	
		INDEX	A	
		TCF	+1	# ORIGINALLY STORED IN BITS 5-6
	+1	CS	Q	# 00 -- BRANCH IF ON.
TEST		MASK	SWBIT	
		CCS	A	
		TCF	SWSKIP	
	+5	TCF	SWBRANCH	# 01 -- GO TO.
		TCF	SWSKIP	# HERE ONLY ON BIT 15.
		TC	CCSHOLE	
		TC	CCSHOLE	
	+9D	CA	Q	# 10 -- BRANCH IF OFF.
		TCF	TEST	
B3TOB4		OCT	0014	
SWSKIP		INCR	LOC	
SW/		EQUALS	SWITCHES	
	+13D	TCF	DANZIG	# 11 -- NOOP.

This code is written to file `src/INTERPRETER.s`.

## A.46 INTERPRETIVE CONSTANT

```

795  <src/INTERPRETIVE-CONSTANT.s 795>≡
    # Copyright:    Public domain.
    # Filename:     INTERPRETIVE_CONSTANT.agc
    # Purpose:      Part of the source code for Luminary 1A build 099.
    #               It is part of the source code for the Lunar Module's (LM)
    #               Apollo Guidance Computer (AGC), for Apollo 11.
    # Assembler:    yaYUL
    # Contact:       Ron Burkey <info@sandroid.org>.
    # Website:       www.ibiblio.org/apollo.
    # Pages:         1100-1101
    # Mod history:   2009-05-25 RSB   Adapted from the corresponding
    #               Luminary131 file, using page
    #               images from Luminary 1A.
    #
    # This source code has been transcribed or otherwise adapted from
    # digitized images of a hardcopy from the MIT Museum. The digitization
    # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
    # the Museum. Many thanks to both. The images (with suitable reduction
    # in storage size and consequent reduction in image quality as well) are
    # available online at www.ibiblio.org/apollo. If for some reason you
    # find that the images are illegible, contact me at info@sandroid.org
    # about getting access to the (much) higher-quality images which Paul
    # actually created.
    #
    # Notations on the hardcopy document read, in part:
    #
    #       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
    #       16:27 JULY 14, 1969

    # Page 1100

                SETLOC  INTPRET1
                BANK

                COUNT*  $$/ICONS
DP1/4TH        2DEC    .25

UNITZ          2DEC    0

UNITY         2DEC    0

UNITX         2DEC    .5

ZEROVECS      2DEC    0

```

	2DEC	0	
	2DEC	0	
DPHALF	=	UNITX	
DPPOSMAX	OCT	37777	
	OCT	37777	
# Page 1101			
# INTERPRETIVE CONSTANTS IN THE OTHER HALF-MEMORY			
	SETLOC	INTPRET2	
	BANK		
	COUNT*	\$\$/ICONS	
ZUNIT	2DEC	0	
YUNIT	2DEC	0	
XUNIT	2DEC	.5	
ZEROVEC	2DEC	0	
	2DEC	0	
	2DEC	0	
	OCT	77777	# -0, -6, -12 MUST REMAIN IN THIS ORDER
DFC-6	DEC	-6	
DFC-12	DEC	-12	
LODPMAX	2OCT	3777737777	# THESE TWO CONSTANTS MUST REMAIN
LODPMAX1	2OCT	3777737777	# ADJACENT AND THE SAME FOR INTEGRATION
ZERODP	=	ZEROVEC	
HALFDP	=	XUNIT	

This code is written to file `src/INTERPRETIVE-CONSTANT.s`.

## A.47 INTERPRETIVE CONSTANTS

```

797  <src/INTERPRETIVE-CONSTANTS.s 797>≡
# Copyright:    Public domain.
# Filename:     INTERPRETIVE_CONSTANTS.agc
# Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
#               It is part of the source code for the Command Module's (CM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:      Ron Burkey <info@sandroid.org>.
# Website:      www.ibiblio.org/apollo.
# Pages:        1205-1206
# Mod history:  2009-05-13 RSB   Adapted from the Colossus249/ file of the
#                               same name, using Comanche055 page images.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 055 of AGC program Comanche by NASA
#       2021113-051.  10:28 APR. 1, 1969
#
#       This AGC program shall also be referred to as
#               Colossus 2A

# Page 1205

          SETLOC  INTPRET1
          BANK

          COUNT   23/ICONS

DP1/4TH    2DEC    .25

UNITZ      2DEC    0

UNITY      2DEC    0

UNITX      2DEC    .5

```

ZEROVECS	2DEC	0	
	2DEC	0	
	2DEC	0	
DPHALF	=	UNITX	
DPPOSMAX	OCT	37777	
	OCT	37777	
# Page 1206			
# INTERPRETIVE CONSTANTS IN THE OTHER HALF-MEMORY			
	SETLOC	INTPRET2	
	BANK		
	COUNT	14/ICONS	
ZUNIT	2DEC	0	
YUNIT	2DEC	0	
XUNIT	2DEC	.5	
ZEROVEC	2DEC	0	
	2DEC	0	
	2DEC	0	
	OCT	77777	# -0, -6, -12 MUST REMAIN IN THIS ORDER
DEC-6	DEC	-6	
DEC-12	DEC	-12	
LODPMAX	2OCT	3777737777	# THESE TWO CONSTANTS MUST REMAIN
LODPMAX1	2OCT	3777737777	# ADJACENT AND THE SAME FOR INTEGRATION
ZERODP	=	ZEROVEC	
HALFDP	=	XUNIT	

This code is written to file `src/INTERPRETIVE-CONSTANTS.s`.

## A.48 INTERRUPT LEAD INS

```

799  <src/INTERRUPT-LEAD-INS.s 799>≡
# Copyright:    Public domain.
# Filename:     INTERRUPT_LEAD_INS.agc
# Purpose:      Part of the source code for Comanche, build 055.
#              It is part of the source code for the Command Module's (CM)
#              Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:   yaYUL
# Reference:    pp. 131-132
# Contact:      Ron Burkey <info@sandroid.org>,
#              Fabrizio Bernardini <fabrizio@spacecraft.it>
# Website:      http://www.ibiblio.org/apollo.
# Mod history:  09/05/09 FB      Transcription of Batch FB-1 Assignment.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#           Massachusetts Institute of Technology
#           75 Cambridge Parkway
#           Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.

# Page 131

      SETLOC 4000

      COUNT 02/RUPTS

      INHINT                      # GO
      CAF    GOBB
      XCH    BBANK
      TCF    GOPROG

      DXCH   ARUPT                # T6RUPT
      EXTEND
      DCA    T6LOC

```

## DTCB

DXCH	ARUPT	# T5RUPT
CS	TIME5	
AD	.5SEC	
TCF	T5RUPT	

DXCH	ARUPT	# T3RUPT
CAF	T3RPTBB	
XCH	BBANK	
TCF	T3RUPT	

DXCH	ARUPT	# T4RUPT
CAF	T4RPTBB	
XCH	BBANK	
TCF	T4RUPT	

DXCH	ARUPT	# KEYRUPT1
CAF	KEYRPTBB	
XCH	BBANK	
TCF	KEYRUPT1	

DXCH	ARUPT	# KEYRUPT2
CAF	MKRUPTBB	
XCH	BBANK	
TCF	MARKRUPT	

DXCH	ARUPT	# UPRUPT
CAF	UPRPTBB	
XCH	BBANK	
TCF	UPRUPT	

DXCH	ARUPT	# DOWNRUPT
CAF	DWNRPTBB	
XCH	BBANK	
TCF	DODOWNTM	

DXCH	ARUPT	# RADAR RUPT
------	-------	--------------

CAF	RDRPTBB	
XCH	BBANK	
TCF	VHFREAD	

DXCH	ARUPT	# HAND CONTROL RUPT
CAF	HCRUPTBB	
XCH	BBANK	



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	TCF	RESUME +3	# NOT USED
GOBB	EBANK=	LST1	# RESTART USES E0,E3
	BBCON	GOPROG	
T3RPTBB	EBANK=	LST1	
	BBCON	T3RUPT	
KEYRPTBB	EBANK=	KEYTEMP1	
	BBCON	KEYRUPT1	
MKRUPTBB	EBANK=	MRKBUF1	
	BBCON	MARKRUPT	
UPRPTBB	=	KEYRPTBB	
DWNRPTBB	EBANK=	DNTMBUFF	
	BBCON	DODOWNTM	
RDRPTBB	EBANK=	DATATEST	
	BBCON	VHFREAD	
HCRUPTBB	EBANK=	TIME1	# NOT USED
	BBCON	RESUME	
T4RPTBB	EBANK=	DSRUPTSW	
	BBCON	T4RUPT	
T5RPTBB	EBANK=	TIME1	
	BBCON	T5RUPT	
T5RUPT	EXTEND		
	BZMF	NOQBRSM	
	EXTEND		
	DCA	T5LOC	
	DTCB		

This code is written to file src/INTERRUPT-LEAD-INS.s.

## A.49 JET SELECTION LOGIC

```

802  <src/JET-SELECTION-LOGIC.s 802>≡
      # Copyright:    Public domain.
      # Filename:     JET_SELECTION_LOGIC.agc
      # Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
      #               It is part of the source code for the Command Module's (CM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Ron Burkey <info@sandroid.org>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         1039-1062
      # Mod history:   2009-05-13 RSB   Adapted from the Colossus249/ file of the
      #               same name, using Comanche055 page images.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 055 of AGC program Comanche by NASA
      #       2021113-051.  10:28 APR. 1, 1969
      #
      #       This AGC program shall also be referred to as
      #               Colossus 2A

      # Page 1039

                        BANK      21
                        SETLOC    DAPS4
                        BANK

                        COUNT     17/DAPJS

                        EBANK=    KMPAC

      # EXAMINE CHANNEL 31 FOR TRANSLATION COMMANDS

      JETSLECT          LXCH      BANKRUPT
                        CAF        DELTATT3      # = 60 MS  RESET TO EXECUTIVE PHASE1
                        AD          T5TIME

```

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```
TS      TIME5
TCF     +3
CAF     DELATT20      # = 20 MS  TO ASSURE A T5RUPT
TS      TIME5
CAF     =14MS         # RESET T6 TO INITIALIZE THE JET CHANNELS
TS      TIME6         # IN 14 MS
CAF     NEGMAX
EXTEND
WOR     CHAN13
EXTEND
QXCH    QRUPT
CAF     XLNMASK       # = 7700 OCT
EXTEND  # EXAMINE THE TRANSLATION
RXOR    CHAN31        # HAND CONTROLLER
MASK    XLNMASK
EXTEND
BZF     NOXLNCMD
TS      T5TEMP
EXTEND
MP      BIT9
MASK    THREE
TS      XNDX1         # AC QUAD  X-TRANSLATION INDEX
TS      XNDX2         # BD QUAD  X-TRANSLATION INDEX
CA      T5TEMP
EXTEND  # 1 = + XLN
MP      BIT7          # 2 = - XLN
MASK    THREE         # 3 = NO XLN
TS      YNDX          # Y-TRANSLATION INDEX

CA      T5TEMP
EXTEND
MP      BIT5
MASK    THREE
TS      ZNDX          # Z-TRANSLATION INDEX

CA      DAPDATR1      # SET ATTKALMN TO PICK UP FILTER GAINS FOR
MASK    BIT14         # TRANSLATIONS.
EXTEND  # CHECK DAPDATR1 BIT 14 FOR LEM ATTACHED.

BZF     NOLEM
CS      THREE         # IF LEM IS ON, SET ATTKALMN = -3
TCF     +2
CS      TWO           # IF LEM IS OFF, SET ATTKALMN = -2.
TS      ATTKALMN
CCS     XTRANS        # (+, -1, 0)
TS      XNDX1         # USING BD-X  ZERO XNDX1
```

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NOLEM

	TCF	PWORD	
	TS	XNDX2	# USING AC-X ZERO XNDX2
	TCF	PWORD	
XLNMASK	OCT	7700	
DELTATT3	DEC	16378	# = 60 MS
DELATT20	DEC	16382	# = 20 MS
NOXLNCMD	TS	XNDX1	# ZERO ALL REQUESTS FOR TRANSLATION
	TS	XNDX2	
	TS	YNDX	
	TS	ZNDX	

# PITCH COMMANDS TIMING(NO X-TRANS, NO QUAD FAILS) 32MCT

PWORD	CCS	TAU1	# CHECK FOR PITCH COMMANDS
	CAF	ONE	
	TCF	+2	# 0 = NO PITCH
	CAF	TWO	# +1 = + PITCH
	TS	PINDEX	# +2 = - PITCH
	CCS	RACFAIL	# FLAG FOR REAL AC QUAD FAILURES
	TCF	AFAILP	
	TCF	TABPCOM	# 0 = NO REAL AC FAILURES
	TCF	CFAILP	# + = A QUAD FAILED
	TCF	TABPCOM	# - = C QUAD FAILED
			# IF FAILURES ARE PRESENT IGNORE
			# X-TRANSLATIONS ON THIS AXIS
AFAILP	CAF	NINE	# IF FAILURE IS PRESENT 1JET OPERATION
	TCF	TABPCOM +2	# IS ASSUMED. IGNORE X-TRANSLATION
CFAILP	CAF	TWELVE	
	TCF	TABPCOM +2	
XLNNDX	DEC	0	# INDICES FOR TRANSLATION COMMANDS
	DEC	3	# FOR USE IN TABLE LOOK UP
	DEC	6	
	DEC	0	
TWELVE	=	OCT14	

# TABLE LOOK UP FOR PITCH COMMANDS WITH AND WITHOUT X-TRANSLATION AND AC QUAD FAILURE  
 # BITS 9, 10 CONTAIN THE NUMBER OF PITCH JETS USED TO PERFORM THE PITCH ROTATION  
 # Page 1041

TABPCOM	INDEX	XNDX1
---------	-------	-------

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CA	XLNNDX	
AD	PINDEX	
INDEX	A	
CA	PYTABLE	
MASK	PJETS	# =1417 OCT
TS	PWORD1	
EXTEND		
MP	BIT7	
TS	NPJETS	# = NO. OF PITCH JETS

# YAW JET COMMANDS TIMING(N X-TRANS, NO QUAD FAILURES) 32MCT

YWORD	CCS	TAU2	# CHECK FOR YAW COMMANDS
	CAF	ONE	
	TCF	+2	
	CAF	TWO	
	TS	YINDEX	# YAW ROTATION INDEX
	CCS	RBDFAIL	# FLAG FOR B OR D QUAD FAILURES
	TCF	BFAILY	# 0 = NO BD FAILURE
	TCF	TABYCOM	# + - B QUAD FAILED
	TCF	DFAILY	# - = D QUAD FAILED
	TCF	TABYCOM	
BFAILY	CAF	NINE	
	TCF	TABYCOM +2	
DFAILY	CAF	TWELVE	
	TCF	TABYCOM +2	

# Page 1042

# TABLE FOR PITCH(YAW) COMMANDS

# BITS 4,3,2,1 = PITCH, X-TRANSLATION JETS SELECTED

# BITS 10,9 = NO. PITCH JETS USED TO PERFORM ROTATION

# BITS 8,7,6,5 = YAW, X-TRANSLATION JETS SELECTED

# BITS 12,11: NO. YAW JETS USED TO PERFORM ROTATION

			# ROT	TRANS	QUAD	BIAS
PYTABLE	OCT	0	# 0	0		0
	OCT	5125	# +	0		0
	OCT	5252	# -	0		0
	OCT	0231	# 0	+		3
	OCT	2421	# +	+		3
	OCT	2610	# -	+		3
	OCT	0146	# 0	-		6
	OCT	2504	# +	-		6
	OCT	2442	# -	-		6

OCT	0	# 0	A(B)	9
OCT	2421	# +	A(B)	9
OCT	2442	# -	A(B)	9
OCT	0	# 0	C(D)	12
OCT	2504	# +	C(D)	12
OCT	2610	# -	C(D)	12

## # MASKS FOR PITCH AND YAW COMMANDS

PJETS	OCT	1417
YJETS	OCT	6360

# TABLE LOOK UP FOR YAW COMMANDS WITH AND WITHOUT X-TRANSLATION AND AC QUAD FAILURES  
 # BITS 11, 12 CONTAIN THE NUMBER OF YAW JETS USED TO PERFORM THE YAW ROTATION

TABYCOM	INDEX	XNDX2	
	CA	XLNNDX	
	AD	YINDEX	
	INDEX	A	
	CA	PYTABLE	
	MASK	YJETS	# = 6360 OCT
	TS	YWORD1	
	EXTEND		
	MP	BIT5	
	TS	NYJETS	# NO. OF YAW JETS USED TO PERFORM ROTATION

# Page 1043

# ROLL COMMANDS TIMING(NO Y,Z TRANS, NO QUAD FAILS) 45MCT

RWORD	CCS	TAU	# CHECK FOR ROLL COMMANDS
	CAF	ONE	
	TCF	+2	
	CAF	TWO	
	TS	RINDEX	
	CCS	ACORBD	# FLAG FOR AC OR BD QUAD SELECTION FOR
	TCF	BDROLL	# ROLL COMMANDS
	TCF	BDROLL	# +, +0 = BD ROLL
	TCF	+1	# -, -0 = AC ROLL
ACROLL	CCS	RACFAIL	# CHECK FOR REAL FAILURES
	TCF	RAFAIL	# ON AC QUADS
	TCF	RXLNS	
	TCF	RCFAIL	
	TCF	RXLNS	

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RAFAIL	CAF	NINE	# QUAD FAILURE WILL GET
	TCF	TABRCOM	# 1-JET OPERATION
RCFAIL	CAF	TWELVE	
	TCF	TABRCOM	
XLN1NDX	DEC	0	
	DEC	1	# INDICES FOR TRANSLATION
	DEC	2	
	DEC	0	

# TABLE LOOK UP FOR AC-ROLL COMMANDS WITH AND WITHOUT Y-TRANSLATION AND ACQUAD FAILURES PRESENT  
# BITS 9,10,11 CONTAIN THE MAGNITUDE AND DIRECTION OF THE ROLL

RXLNS	INDEX	YNDX	# NO AC QUAD FAILURES
	CA	XLNNDX	# INCLUDE +,-,0, Y-TRANSLATION
TABRCOM	AD	RINDEX	
	INDEX	A	
	CA	RTABLE	
	MASK	ACRJETS	# = 3760 OCT
	TS	RWORD1	

# CHECK FOR Z-TRANSLATIONS ON BD

BDZCHECK	CA	ZNDX	
	EXTEND		
	BZMF	NOBDZ	# NO Z-TRANSLATION

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# TABLE LOOK UP FOR BD Z-TRANSLATION WITH AND WITHOUT REAL BD QUAD FAILURES. Z-TRANSLATION WILL  
# BE AS LONG AS ROLL COMMANDS CAN BE SATISFIED WITH THE AC ROLL JETS. CRITERION: IF THE RES  
# COMMANDS = 0 (WITH Z-TRANSLATION) AND IF TAU = 0, THEN INCLUDE THE BD Z-TRANSLATION COMMANDS.  
# ROLL COMMAND = 0, AND IF TAU NZ, THEN IGNORE THE BD Z-TRANSLATION

CCS	RBDFAIL	
CAF	THREE	
TCF	+2	
CAF	SIX	
INDEX	ZNDX	
AD	XLN1NDX	
INDEX	A	
CA	YZTABLE	
MASK	BDZJETS	# = 3417 OCT
AD	RWORD1	# ADD TO ROLL COMMANDS
TS	T5TEMP	# IF POSSIBLE. MUST CHECK TAU FIRST
EXTEND		

	MP	BIT7	# DETERMINE THE NET ROLL COMMAND WITH
	AD	=-4	# Z-TRANSLATION ADDED ON
	TS	NRJETS	# NET NO. OF +,- ROLL JETS ON
	EXTEND		
	BZF	TAUCHECK	
ACRBDZ	CA	T5TEMP	# Z-TRANSLATION ACCEPTED EVEN THO WE MAY
	TS	RWORD1	# HAVE INTRODUCED AN UNDESIRABLE ROLL
	TCF	ROLLTIME	# BRANCH TO JET ON-TIME CALCULATIONS
TAUCHECK	CCS	TAU	
	TCF	NOBDZ	
	TCF	ACRBDZ	
	TCF	NOBDZ	
	TCF	ACRBDZ	
NOBDZ	CA	RWORD1	# Z-TRANSLATION NOT ACCEPTED
	EXTEND		
	MP	BIT7	
	AD	=-2	
	TS	NRJETS	
	TCF	ROLLTIME	# BRANCH TO JET ON-TIME CALCULATION
# Page 1045			
# BD QUAD SELECTION FOR ROLL COMMANDS			
BDROLL	CCS	RBDFAIL	
	TCF	RBFAIL	
	TCF	RZXLNS	
	TCF	RDFAIL	
	TCF	RZXLNS	
RBFAIL	CAF	NINE	
	TCF	TABRZCMD	
RDFAIL	CAF	TWELVE	
	TCF	TABRZCMD	
RZXLNS	INDEX	ZNDX	# NO BD FAILURES
	CA	XLNNDX	# +,-,0 Z-TRANSLATION PRESENT
TABRZCMD	AD	RINDEX	
	INDEX	A	
	CA	RTABLE	
	MASK	BDRJETS	# = 34017 OCT
	TS	RWORD1	
ACYCHECK	CA	YNDX	# ANY Y-TRANSLATION
	EXTEND		



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```
# Page 1046
NOACY          CA          RWORD1          # Y-TRANSLATION NOT ACCEPTED
EXTEND
MP             BIT4
AD             =-2
TS             NRJETS
TCF            ROLLTIME
```

```

#                                     TABLE FOR ROLL, Y AND Z-TRANSLATION COMMANDS
#
# EITHER AC OR BD ROLL MAY BE SELECTED.  IF AC ROLL IS SELECTED, Y-TRANSLATIONS MAY BE SATISFIED
# PROVIDED THAT THERE ARE NO AC QUAD FAILURES.  IF THERE ARE AC FAILURES, Y-TRANSLATION COMMANDS
# IN WHICH CASE THE ASTRONAUT SHOULD SWITCH TO BD ROLL.
#
# IF BDROLL IS SELECTED, Z-TRANSLATIONS MAY BE SATISFIED SIMULTANEOUSLY PROVIDED THAT THERE ARE NO
# FAILURES.  IF THERE ARE BD FAILURES, Z-TRANSLATION COMMANDS WILL BE IGNORED, IN WHICH CASE THE

```

```

# SWITCH TO AC ROLL.
#
# NOTE THAT IF ONE QUAD FAILS (E.G. B FAILED), Z-TRANSLATION IS STILL POSSIBLE AND THE
# INTRODUCED BY THIS TRANSLATION WILL BE COMPENSATED BY THE TWO AC ROLL JETS ACTUATED
#
#                                     WORD MAKE UP...RTABLE
#
# TWO WORDS, CORRESPONDING TO AC OR BD ROLL SELECTION, HAVE BEEN COMBINED INTO ONE TABLE
# TO AC ROLL HAS THE FOLLOWING INTERPRETATION:
#
#       BITS 9,10,11 ARE CODED TO GIVE THE NET ROLL TORQUE FOR THE WORD SELECTED. THE
#
#
#       BIT NO. 11  10   9
#
#
#
#       NO. OF ROLL JETS
#
#
#       0   0   0
#       0   0   1
#       0   1   0
#       0   1   1
#       1   0   0
#
#
#       -2
#       -1
#        0
#        1
#        2
#
# THIS WORD MAY THEN BE ADDED TO THE WORD SELECTED FROM THE YZ-TRANSLATION TABLE, WITH
# CODING AS ABOVE, AND THE NET ROLL DETERMINED BY SHIFTING THE RESULTANT WORD RIGHT 8
#
# THE WORD CORRESPONDING TO THE BD ROLL HAS A SIMILAR INTERPRETATION, EXCEPT THAT BITS
# (AS ABOVE) TO GIVE THE NET ROLL TORQUE.

```

			# ROLL	TRANS	QUADFAIL
RTABLE	OCT	11000	# 0		
	OCT	22125	# +		
	OCT	00252	# -		
	OCT	11231	# 0	+Y(+Z)	
	OCT	15421	# +	+Y(+Z)	
	OCT	04610	# -	+Y(+Z)	
	OCT	11146	# 0	-Y(-Z)	
	OCT	15504	# +	-Y(-Z)	
	OCT	04442	# -	-Y(-Z)	
	OCT	11000	# 0		A(B)
	OCT	15504	# +		A(B)
	OCT	04610	# -		A(B)
	OCT	11000	# 0		C(D)
	OCT	15421	# +		C(D)
	OCT	04442	# -		C(D)

```

# Page 1048
# RTABLE MASKS:

```

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ACRJETS           OCT       03760  
BDRJETS           OCT       34017

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#

#### Y, Z TRANSLATION TABLE

#

# ONCE AC OR BD ROLL IS SELECTED THE QUAD PAIR WHICH IS NOT BEING USED TO SATISFY THE ROLL COMMANDS. HOWEVER, WE MUST MAKE SURE THAT ROLL COMMANDS ARE USED TO SATISFY THE REMAINING TRANSLATION COMMANDS. WHEN THEY OCCUR. THEREFORE, THE Y-Z TRANSLATIONS FROM THIS TABLE WILL BE IGNORED IF THE NET COMBINED WORD IS ZERO AND THE ROLL COMMANDS ARE NON-ZERO. THIS SITUATION WOULD OCCUR, FOR EXAMPLE, IN THE CASE OF COUNTER SIMULTANEOUS +R +Y -Z COMMANDS AND A QUAD D FAILURE WHILE USING AC FOR ROLL.

#

# TO FACILITATE THE LOGIC, THE Y-Z TRANSLATION TABLE HAS BEEN CODED IN A MANNER SIMILAR TO THE ONE ABOVE.

#

# BITS 9,10,11 ARE CODED TO GIVE THE NET ROLL TORQUE INCURRED BY Z-TRANSLATIONS. THE WORD SELECTED IS ADDED TO THE AC-ROLL WORD AND THE RESULTANT ROLL TORQUE DETERMINED FROM THE COMBINED WORD. BITS 12,13,14 ARE CODED TO GIVE THE NET ROLL TORQUE INCURRED BY Y-TRANSLATIONS WHEN BD-ROLL IS SELECTED.

			# TRANSLATION	QUADFAIL	BIAS
YZTABLE	OCT	11000	# 0		0
	OCT	11231	# +Z(+Y)		0
	OCT	11146	# -Z(-Y)		0
	OCT	11000	# 0	B(A)	3
	OCT	04610	# +Z(+Y)	B(A)	3
	OCT	15504	# -Z(-Y)	B(A)	3
	OCT	11000	# 0	D(C)	6
	OCT	15421	# +Z(+Y)	D(C)	6
	OCT	04442	# -Z(-Y)	D(C)	6

# YZ-TABLE MASKS:

BDZJETS           OCT       03417  
ACYJETS           OCT       34360

# ADDITIONAL CONSTANTS

--2               =       NEG2  
--4               =       NEG4

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#

#### CALCULATION OF JET ON-TIMES

#

# THE ROTATION COMMANDS (TAU'S), WHICH WERE DETERMINED FROM THE JET SWITCHING LOGIC ON THE BASIS OF THE FOLLOWING:

```

# OPERATION, MUST NOW BE UPDATED BY THE ACTUAL NUMBER OF JETS TO BE USED IN SATISFYING
# ALSO BE DECREMENTED ACCORDING TO THE EXPECTED TORQUE GENERATED BY THE NEW COMMANDS
# INTERVAL.
#
# IN ORDER TO MAINTAIN ACCURATE KNOWLEDGE OF VEHICLE ANGULAR RATES, WE MUST ALSO PROVIDE
# (DFT'S, ALSO IN TERMS OF 1-JET OPERATION) FOR THE RATE FILTER.
#
# NOTE THAT TRANSLATIONS CAN PRODUCE ROTATIONS EVEN THOUGH NO ROTATIONS WERE CALLED FOR
# UPDATE DFT.
#
# WHEN THE ROTATIONS HAVE FINISHED, WE MUST PROVIDE CHANNEL INFORMATION TO THE T6 PROGRAM
# THE TRANSLATIONS. THIS WILL BE DONE IN THE NEXT SECTION. HOWEVER, TO INSURE THAT
# THAN A MINIMUM IMPULSE (14MS), ALL JET CHANNEL COMMANDS WILL BE HELD FIXED FROM THE
# AT LEAST 14MS UNTIL THE INITIALIZATION OF NEW COMMANDS. MOREOVER, A 14MS ON-TIME
# COMMANDS GENERATED BY THE MANUAL CONTROLS OR THE JET SWITCHING LOGIC, AND ALL TRANSLATIONS
# ACTIVE FOR AT LEAST ONE CYCLE OF THE T5 PROGRAM (.1SEC)

# PITCH JET ON-TIME CALCULATION

PITCHTIM      CCS      TAU1
               TCF      PTAUPOS
               TCF      +2
               TCF      PTAUNEG
               TS       DFT1          # NO PITCH ROTATION
               TCF      PBYPASS       # COMMANDS

PTAUNEG       CS       NPJETS
               TS       NPJETS
PTAUPOS       CA       TAU1
               EXTEND
               INDEX    NPJETS
               MP       NJET
               TS       BLAST1
               AD       =-.1SEC
               EXTEND
               BZMF     AD14MSP
               INDEX    NPJETS
               CA       DFTMAX       # THE PITCH ON-TIME IS GREATER THAN .1 SEC
               TS       DFT1
               COM
               ADS      TAU1          # UPDATE TAU1
               CAF      =+.1SEC      # LIMIT THE LENGTH OF PITCH ROTATION
               TS       BLAST1       # COMMANDS TO 0.1 SEC SO THAT ONLY
               TCF      ASMBLWP      # X-TRANSLATIONS WILL CONTINUE ON SWITCH
               # OVER TO TVC
AD14MSP       CS       BLAST1       # SEE IF JET ON TIME IS LESS THAN

```

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```
# Page 1051
PBLASTOK      AD      =14MS      # MINIMUM IMPULSE TIME
               EXTEND
               BZMF     PBLASTOK  # IF SO LIMIT MINIMUM ON TIME TO 14 MS
               CAF      =14MS

               TS      BLAST1
               CA      BLAST1
               EXTEND      # THE PITCH COMMANDS WILL BE COMPLETED
               MP      NPJETS  # WITHIN THE TS-CYCLE TIME
               LXCH     DFT1   # FOR USE IN UPDATING RATE FILTER
               TS      TAU1   # ZERO TAU1 (ACC CONTAINS ZERO)
               TCF      ASMBLWP

# Page 1052
# YAW JET ON-TIME CALCULATION

YAWTIME      CCS      TAU2
               TCF      YTAUPOS
               TCF      +2
               TCF      YTAUNEG
               TS      DFT2      # NO YAW ROTATION COMMANDS
               TCF      YBYPASS

YTAUNEG      CS      NYJETS
               TS      NYJETS
YTAUPOS      CA      TAU2
               EXTEND
               INDEX   NYJETS
               MP      NJET
               TS      BLAST2
               AD      =-.1SEC
               EXTEND
               BZMF     AD14MSY
               INDEX   NYJETS
               CA      DFTMAX    # YAW COMMANDS WILL LAST LONGER THAN .1SEC
               TS      DFT2
               COM
               ADS      TAU2      # DECREMENT TAU2
               CAF      =+.1SEC  # LIMIT THE LENGTH OF YAW ROTATION COMMAND
               TS      BLAST2    # TO 0.1 SEC SO THAT ONLY X-TRANSLATION
               TCF      ASMBLWY  # WILL CONTINUE ON SWITCH OVER TO TVC

AD14MSY      CS      BLAST2      # SEE IF JET ON-TIME LESS THAN
               AD      =14MS     # MINIMUM IMPULSE TIME
               EXTEND
               BZMF     YBLASTOK  # IF SO, LIMIT MINIMUM ON-TIME TO 14 MS
```

	CAF	=14MS	
	TS	BLAST2	
YBLASTOK	CA	BLAST2	# YAW COMMANDS WILL BE COMPLETED WITHIN
	EXTEND		# THE T5CYCLE TIME
	MP	NYJETS	
	LXCH	DFT2	
	TS	TAU2	# ZERO TAU2
	TCF	ASMBLWY	

# Page 1053  
# ROLL ON-TIME CALCULATION:

ROLLTIME	CCS	TAU	
	TCF	RBLAST	
	TCF	+2	
	TCF	RBLAST	
	INDEX	NRJETS	
	CA	DFTMAX	# UPDATE DFT EVEN THO NO ROLL COMMANDS ARE
	TS	DFT	# PRESENT
	TCF	RBYPASS	

	DEC	-480	# =-.3SEC
	DEC	-320	# =-.2SEC
=-.1SEC	DEC	-160	# =-.1SEC
DFTMAX	DEC	0	# 0
=+.1SEC	DEC	160	# =+.1SEC
	DEC	320	# =+.2SEC
	DEC	480	# =+.3SEC
=14MS	DEC	23	# =14MS

RBLAST	CA	TAU	
	EXTEND		
	INDEX	NRJETS	
	MP	NJET	
	TS	BLAST	# BLAST IS AN INTERMEDIATE VARIABLE
			# USED IN DETERMINING THE JET ON-TIMES

	AD	=-.1SEC	
	EXTEND		
	BZMF	AD14MSR	
	INDEX	NRJETS	# THE ROLL ROTATION WILL LAST LONGER
	CA	DFTMAX	# THAN THE T5 CYCLE TIME
	TS	DFT	
	COM		
	ADS	TAU	
	CAF	=+.1SEC	# LIMIT THE LENGTH OF ROLL ROTATION
	TS	BLAST	# COMMANDS TO 0.1 SEC SO THAT ONLY Y-Z

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```

                                TCF      ASMBLWR      # TRANSLATION COMMANDS CONTINUE

AD14MSR      CS      BLAST      # SEE IF THE JET ON-TIME LESS THAN
              AD      =14MS      # MINIMUM IMPULSE TIME
              EXTEND
              BZMF      RBLASTOK
              CAF      =14MS      # IF SO, LIMIT MINIMUM ON-TIME TO 14 MS
              TS      BLAST
RBLASTOK     CA      BLAST
              EXTEND
              MP      NRJETS
              LXCH      DFT
              TS      TAU      # ZERO TAU
              TCF      ASMBLWR
```

# Page 1054

```

              DEC      -.333333      # = -1/3
              DEC      -.500000      # = -1.2
              DEC      -.999999      # = -1 (NEGMAX)
NJET         DEC      0
              DEC      .999999      # = +1 (POSMAX)
              DEC      .500000      # = +1/2
              DEC      .333333      # = +1/3
```

# Page 1055

```

# WHEN THE ROTATION COMMANDS ARE COMPLETED, IT IS NECESSARY TO REPLACE THESE COMMANDS BY NEW CO
# CONTINUE ON WITH THE TRANSLATIONS IF ANY ARE PRESENT.
#
# IN THIS SECTION THESE NEW COMMANDS ARE GENERATED AND STORED FOR REPLACEMENT OF THE CHANNEL CO
# CORRESPONDING ROTATIONS ARE COMPLETED.
#
# GENERATION OF THE SECOND PITCH(X-TRANS) WORD...PWORD2
```

```

ASMBLWP      CCS      RACFAIL
              TCF      FPX2      # IF FAILURE ON AC IGNORE X-TRANSLATION
              TCF      +2
              TCF      FPX2
              INDEX     XNDX1
              CA      XLNNDX
              INDEX     A
FPX2         CA      PYTABLE
              MASK      PJETS
              TS      PWORD2
              TCF      YAWTIME

PBYPASS      CA      PWORD1      # THE T6 PROGRAM WILL LOAD PWORD2
```

TS	PWORD2	# UPON ENTRY
CAF	ZERO	
TS	BLAST1	# THERE IS NO PWORD2
TCF	YAWTIME	

# Page 1056

# GENERATION OF THE SECOND ROLL (Y,Z) WORD (RWORD2)

ASMBLWR	CCS	YNDX	# CHECK FOR Y-TRANS
	TCF	ACBD2Y	
NO2Y	CAF	ZERO	
	TS	RWORD2	
	CCS	ZNDX	# CHECK FOR Z-TRANS
	TCF	ACBD2Z	
NO2Z	CAF	ZERO	
	ADS	RWORD2	
	TCF	PITCHTIM	# RWORD2 ASSEMBLED
ACBD2Y	CCS	ACORBD	
	TCF	AC2Y	# CAN DO Y-TRANS
	TCF	AC2Y	
	TCF	+1	# USING AC FOR ROLL
	CCS	RACFAIL	
	TCF	NO2Y	# USING AC AND AC HAS FAILED
	TCF	+2	
	TCF	NO2Y	# DITTO
	INDEX	YNDX	# NO FAILURES, CAN DO Y
	CA	XLNNDX	
	INDEX	A	
	CA	RTABLE	
	MASK	ACRJETS	
	TCF	NO2Y +1	
AC2Y	CCS	RACFAIL	
	CAF	THREE	
	TCF	+2	
	CAF	SIX	
	INDEX	YNDX	
	AD	XLN1NDX	
	INDEX	A	
	CA	YZTABLE	
	MASK	ACYJETS	
	TS	RWORD2	
	EXTEND		
	MP	BIT4	



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# Page 1057  
ACBD2Z

AD        =-2  
TS        NRJETS  
CS        BLAST  
AD        =+.1SEC  
EXTEND  
MP        NRJETS  
CA        L  
ADS       DFT  
TCF       NO2Y     +2

CCS       ACORBD  
TCF       BDF2Z  
TCF       BDF2Z  
TCF       +1  
CCS       RBDFAIL  
CAF       THREE  
TCF       +2  
CAF       SIX  
INDEX     ZNDX  
AD        XLN1NDX  
INDEX     A  
CA        YZTABLE  
MASK      BDZJETS  
ADS       RWORD2  
EXTEND  
MP        BIT7  
AD        =-2  
TS        NRJETS  
CS        BLAST  
AD        =+.1SEC  
EXTEND  
MP        NRJETS  
CA        L  
ADS       DFT  
TCF       PITCHTIM

# USING BD-ROLL  
# MUST CHECK FOR BD FAILURES  
# USING AC FOR ROLL, CAN DO Z-TRANS

BDF2Z

CCS       RBDFAIL  
TCF       NO2Z  
TCF       +2  
TCF       NO2Z  
INDEX     ZNDX  
CA        XLNNDX  
INDEX     A  
CA        RTABLE  
MASK      BDRJETS  
TCF       NO2Z +1

# USING BD-ROLL AND BD HAS FAILED  
# DITTO

```

RBYPASS      CA      RWORD1
              TS      RWORD2
              CAF      ZERO
              TS      BLAST
              TCF      PITCHTIM

```

# Page 1058

# GENERATION OF THE SECOND YAW (X-TRANS) WORD...YWORD2

```

ASMBLWY      CCS      RBDFAIL
              TCF      FYX2          # IF FAILURE ON BD IGNORE X-TRANSLATION
              TCF      +2
              TCF      FYX2
              INDEX    XNDX2
              CA      XLNNDX
              INDEX    A
FYX2          CA      PYTABLE
              MASK     YJETS
              TS      YWORD2
              TCF      T6SETUP

YBYPASS      CA      YWORD1
              TS      YWORD2
              CAF      ZERO
              TS      BLAST2

```

# Page 1059

```

#                                     SORT THE JET ON-TIMES
#
# AT THIS POINT ALL THE CHANNEL COMMANDS AND JET ON-TIMES HAVE BEEN DETERMINED.  IN S
#
#      RWORD1
#      RWORD2          BLAST
#
#      PWORD1
#      PWORD2          BLAST1
#
#      YWORD1
#      YWORD2          BLAST2
#
# IN THIS SECTION THE JET ON-TIMES ARE SORTED AND THE SEQUENCE OF T6 INTERRUPTS IS D
# THE SORTING PROCESS AND THE T6 PROGRAM, THE VARIABLES BLAST, BLAST1, BLAST2, ARE RE
# WORDS.  THE LOWER PART OF THESE WORDS CONTAIN A BRANCH INDEX ASSOCIATED WITH THE RO
# ORDER WORD.

```

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T6SETUP	CAF	ZERO	# BRANCH INDEX FOR ROLL
	TS	BLAST +1	
	CAF	FOUR	# BRANCH INDEX FOR PITCH
	TS	BLAST1 +1	
	CAF	ELEVEN	# BRANCH INDEX FOR YAW
	TS	BLAST2 +1	
	CS	BLAST	
	AD	BLAST1	
	EXTEND		
	BZMF	DXCHT12	# T1 OR T2
CHECKT23	CS	BLAST1	
	AD	BLAST2	
	EXTEND		
	BZMF	DXCHT23	
CALCDT6	CS	BLAST1	
	ADS	BLAST2	
	CS	BLAST	
	ADS	BLAST1	# END OF SORTING PROCEDURE
	EXTEND		# RESET T5LOC TO BEGIN PHASE1
	DCA	RCS2CADR	
	DXCH	T5LOC	
ENDJETS	CS	BIT1	# RESET BIT1 FOR INITIALIZATION OF
	MASK	RCSFLAGS	# T6 PROGRAM
	TS	RCSFLAGS	
	CS	ZERO	# RESET T5PHASE FOR PHASE1
	TS	T5PHASE	
	TCF	RESUME	# RESUME INTERRUPTED PROGRAM
	EBANK=	KMPAC	
RCS2CADR	2CADR	RCSATT	
# Page 1060			
DXCHT12	DXCH	BLAST	
	DXCH	BLAST1	
	DXCH	BLAST	
	TCF	CHECKT23	
DXCHT23	DXCH	BLAST1	
	DXCH	BLAST2	
	DXCH	BLAST1	
	CS	BLAST	
	AD	BLAST1	
	EXTEND		
	BZMF	+2	
	TCF	CALCDT6	

```

DXCH  BLAST
DXCH  BLAST1
DXCH  BLAST
TCF   CALCDT6

```

# Page 1061

# T6 PROGRAM AND CHANNEL SETUP

```

BANK  21
SETLOC DAPS5
BANK

T6START  LXCH  BANKRUPT
          EXTEND
          QXCH  QRUPT
          CCS   TIME6      # CHECK TO SEE IF TIME6 WAS RESET
          TCF   RESUME     # AFTER T6RUPT OCCURRED (IN T5RUPT)
          TCF   +2         # IF SO WAIT FOR NEXT T6RUPT BEFORE
          TCF   RESUME     # TAKING ACTION

          CS      RCSFLAGS
          MASK    BIT1     # IF BIT1 IS 0 RESET TO 1
          EXTEND  # AND INITIALIZE CHANNEL
          BZF     T6RUPTOR
          ADS     RCSFLAGS
          CA      RWORD1
          EXTEND  # INITIALIZE CHANNELS 5,6 WITH WORD1
          WRITE   CHAN6
          CA      PWORD1
          AD      YWORD1
          EXTEND
          WRITE   CHAN5

T6RUPTOR  CCS      BLAST
          TCF      ZBLAST  # ZERO BLAST1
          TCF      REPLACE # REPLACE WORD1
          TCF      +2
          TCF      REPLACE

T6L1      CCS      BLAST1
          TCF      ZBLAST1
          TCF      REPLACE1
          TCF      +2
          TCF      REPLACE1

T6L2      CCS      BLAST2
          TCF      ZBLAST2
          TCF      REPLACE2

```

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	TCF	RESUME	
	TCF	REPLACE2	
REPLACE	INDEX	BLAST +1	
	TC	REPLACER	
	CS	ONE	
	TS	BLAST	
	TCF	T6L1	
REPLACE1	INDEX	BLAST1 +1	
# Page 1062	TC	REPLACER	
	CS	ONE	
	TS	BLAST1	
	TCF	T6L2	
REPLACE2	INDEX	BLAST2 +1	
	TC	REPLACER	
	CS	ONE	
	TS	BLAST2	
	TCF	RESUME	
REPLACER	CA	RWORD2	# INITIALIZE CHANNELS 5,6 WITH WORD2
	EXTEND		
	WRITE	CHAN6	
	TC	Q	
REPLACEP	CA	YJETS	
	EXTEND		
	RAND	CHAN5	
	AD	PWORD2	
	EXTEND		
	WRITE	CHAN5	
	TC	Q	
REPLACEY	CA	PJETS	
	EXTEND		
	RAND	CHAN5	
	AD	YWORD2	
	EXTEND		
	WRITE	CHAN5	
	TC	Q	
ZBLAST	CAF	ZERO	
	XCH	BLAST	
	TCF	ENABT6	

```
ZBLAST1      CAF      ZERO
              XCH      BLAST1
              TCF      ENABT6
ZBLAST2      CAF      ZERO
              XCH      BLAST2
ENABT6       TS       TIME6
              CAF      NEGMAX
              EXTEND
              WOR      CHAN13      # ENABLE T6RUPT
              TCF      RESUME

# END OF T6 INTERRUPT

ENDSELECT      EQUALS
```

This code is written to file `src/JET-SELECTION-LOGIC.s`.

## A.50 KALCMANU STEERING

823 *<src/KALCMANU-STEERING.s 823>≡*

```

# Copyright:    Public domain.
# Filename:     KALCMANU_STEERING.agc
# Purpose:      Part of the source code for Comanche, build 055.
#              It is part of the source code for the Command Module's (CM)
#              Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:   yaYUL
# Reference:    pp. 414-419
# Contact:      Onno Hommes <ohommes@cmu.edu>.
# Website:      www.ibiblio.org/apollo.
# Mod history:  05/07/09 OH      Transcription Batch 1 Assignment
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#
#           Massachussets Institute of Technology
#           75 Cambridge Parkway
#           Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further information.
# Please report any errors to info@sandroid.org.
#
# Page 414
# GENERATION OF STEERING COMMANDS FOR DIGITAL AUTOPILOT FREE FALL MANEUVERS
#
# NEW COMMANDS WILL BE GENERATED EVERY ONE SECOND DURING THE MANEUVER
#
# BANK      15
#
# SETLOC    KALCMON1
# BANK
#
# EBANK=    BCDU
#
# COUNT     22/KALC

```

```

NEWDELHI      CS      HOLDFLAG      # SEE IF MANEUVER HAS BEEN INTERRUPTED
EXTEND                                     # BY ASTRONAUT.
BZMF          NOGO      -2          # IF SO, TERMINATE KALCMANU
NEWANGL       TC      INTPRET
AXC,1         AXC,2
MIS                                     # COMPUTE THE NEW MATRIX FROM S/C TO
DEL                                     # STABLE MEMBER AXES
CALL
MXM3
VLOAD         STADR
STOVL         MIS +12D          # CALCULATE NEW DESIRED CDU ANGLES
STADR
STOVL         MIS +6D
STADR
STORE         MIS
AXC,1         CALL
MIS
DCMTOCDU      # PICK UP THE NEW CDU ANGLES FROM MATRIX
RTB
V1STO2S
STORE         NCDU          # NEW CDU ANGLES
BONCLR        EXIT
CALCMAN2
MANUSTAT      # TO START MANEUVER
CAF          TWO          # +0 OTHERWISE
INCRDCDU      TS      KSPNDX
DOUBLE
TS           KDPNDX
INDEX        KSPNDX
CA           NCDU          # NEW DESIRED CDU ANGLES
EXTEND
INDEX        KSPNDX
MSU          BCDU          # INITIAL S/C ANGLE OR PREVIOUS DESIRED
EXTEND      # CDU ANGLES
MP           QUADROT
INDEX        KDPNDX
DXCH         DELCDUX      # ANGEL INCREMENTS TO BE ADDED TO
# Page 415
INDEX        KSPNDX      # DCDU EVERY TENTH SEC
CA           NCDU        # BY LEM DAP
INDEX        KSPNDX
XCH          BCDU
INDEX        KDPNDX
TS           CDUXD
CCS          KSPNDX
TCF          INCRDCDU      # LOOP FOR THREE AXES

```



```

                                RELINT
# COMPARE PRESENT TIME WITH TIME TO TERMINATE MANEUVER

TMANUCHK      TC      TIMECHK
              TC      POSTJUMP
              CADR     CONTMANU

MANUSTAL      CAF      ONE
              TC      WAITLIST
              EBANK=    BCDU
              2CADR     MANUSTOP

                                RELINT
                                TCF      ENDOFJOB

TIMECHK      EXTEND
              DCS      TIME2
              DXCH     TTEMP
              EXTEND
              DCA      TM
              DAS      TTEMP
              CCS      TTEMP
              TC      Q
              TCF      +2
              TCF      2NDRETRN
              CCS      TTEMP +1
              TC      Q
              TCF      MANUOFF
              COM
MANUOFF      AD      1SEC
              EXTEND
              BZMF     2NDRETRN
              INCR     Q
2NDRETRN     INCR     Q
              INCR     Q
              TC      Q

              SETLOC    MANUSTUF
              BANK

# Page 416
MANUSTAT     EXIT
              EXTEND
              DCA      TIME2
              DAS      TM
                                # INITIALIZATION ROUTINE
                                # FOR AUTOMATIC MANEUVERS
                                # TM+TO      MANEUVER COMPLETION TIME

```

```

CS      1SEC
TS      L
CS      ZERO
DAS     TM          # (TM+T0)-1
INHINT
CS      ONE          # ENABLE AUTOPILOT TO PERFORM
TS      HOLDFLAG    # AUTOMATIC MANEUVERS
CS      RATEINDX     # SEE IF MANEUVERING AT HIGH RATE
AD      SIX
EXTEND
BZMF    HIGHGAIN
TCF     +4
HIGHGAIN CS      RCSFLAGS    # IF SO, SET HIGH RATE FLAG (BIT 15 OF
MASK    BIT15        # RCSFLAGS)
ADS     RCSFLAGS
DXCH    BRATE        # X-AXIS MANEUVER RATE
DXCH    WBODY
DXCH    BRATE +2     # Y-AXIS MANEUVER RATE
DXCH    WBODY1
DXCH    BRATE +4     # Z-AXIS MANEUVER RATE
DXCH    WBODY2
CA      BIASTEMP +1  # INSERT ATTITUDE ERROR BIASES
TS      BIAS         # INTO AUTOPILOT
CA      BIASTEMP +3
TS      BIAS1
CA      BIASTEMP +5
TS      BIAS2
CA      TIME1
AD      1SEC
XCH     NEXTIME
TC      POSTJUMP
CADR    INCRDCDU -1

CONTMANU INHINT      # CONTINUE WITH UPDATE PROCESS
CS      TIME1
AD      NEXTIME
CCS     A
AD      ONE
TCF     MANUCALL
AD      NEGMAX
COM
MANUCALL TC      WAITLIST
EBANK=  BCDU
2CADR   UPDTCALL

RELINT

```

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# Page 417

CAF	1SEC	# INCREMENT TIME FOR NEXT UPDATE
ADS	NEXTIME	
TCF	ENDOFJOB	

UPDTCALL	CAF	PRI026	# CALL FOR UPDATE
	TC	FINDVAC	# OF STEERING COMMANDS
	EBANK=	BCDU	
	2CADR	NEWDELHI	
	TC	TASKOVER	

# Page 418

# ROUTINE FOR TERMINATING AUTOMATIC MANEUVERS

	SETLOC	KALCMON3	
	BANK		
MANUSTOP	TC	STOPYZ	
	TC	IBNKCALL	
	CADR	LOADYZ	
ENDROLL	CA	CPHI	
	TS	CDUXD	# SET CDUXD TO THE COMMANDED OUTER GIMBAL
	TC	STOPRATE	
ENDMANU	CA	ATTPRIO	# RESTORE USERS PRIO
	TS	NEWPRIO	
	CA	ZERO	# ZERO ATTCADR
	DXCH	ATTCADR	
	TC	SPVAC	# RETURN TO USER OF GOMANUR
	TC	TASKOVER	
	SETLOC	STOPRAT	
	BANK		
STOPRATE	CAF	ZERO	
	TS	DELCDEX	
	TS	DELCDEX +1	# ZERO ROLL INCREMENTAL ANGLES
	TS	WBODY	# RATE
	TS	WBODY +1	
	TS	BIAS	# BIAS
	CS	BIT15	# MAKE SURE HIGH RATE FLAG (BIT 15 OF

	MASK	RCSFLAGS	# RCSFLAGS) IS RESET.
	TS	RCSFLAGS	
STOPYZ	CAF	ZERO	
	TS	DELCDUY	# ZERO PITCH, YAW
	TS	DELCDUY +1	# INCREMENTAL ANGLES
	TS	DELCDUZ	
	TS	DELCDUZ +1	
	TS	WBODY1	# RATES
	TS	WBODY1 +1	
	TS	WBODY2	
	TS	WBODY2 +1	
	TS	BIAS1	# BIASES
	TS	BIAS2	
	TC	Q	
	SETLOC	MANUSTUF	
	BANK		
# Page 419			
ZEROERROR	CA	CDUX	# PICK UP CDU ANGLES AND STORE IN
	TS	CDUXD	# CDU DESIRED
	CA	CDUY	
	TS	CDUYD	
	CA	CDUZ	
	TS	CDUZD	
	TC	Q	
	SETLOC	KALCMON1	
	BANK		
LOADCDUD	CA	CPHI	# STORE TERMINAL ANGLES INTO
	TS	CDUXD	# COMMAND ANGLES
LOADYZ	CA	CTHETA	
	TS	CDUYD	
	CA	CPSI	
	TS	CDUZD	
	TC	Q	

This code is written to file src/KALCMANU-STEERING.s.

## A.51 KALMAN FILTER

829

*<src/KALMAN-FILTER.s 829>*≡

```
# Copyright:    Public domain.
# Filename:     KALMAN_FILTER.agc
# Purpose:      Part of the source code for Luminary 1A build 099.
#              It is part of the source code for the Lunar Module's (LM)
#              Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:      Ron Burkey <info@sandroid.org>.
# Website:      www.ibiblio.org/apollo.
# Pages:        1470-1471
# Mod history:  2009-05-27 RSB   Adapted from the corresponding
#              Luminary131 file, using page
#              images from Luminary 1A.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
# Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
# 16:27 JULY 14, 1969
```

# Page 1470

```
EBANK= NO.UJETS
BANK   16
SETLOC DAPS1
BANK

COUNT* $$/DAP

RATELOOP CA    TWO
          TS    DAPTEMP6
          DOUBLE
          TS    Q
          INDEX DAPTEMP6
          CCS   TJP
          TCF   +2
```

```

TCF      LOOPRATE
AD        -100MST6
EXTEND
BZMF      SMALLTJU
INDEX     DAPTEMP6
CCS       TJP
CA        -100MST6
TCF       +2
CS        -100MST6
INDEX     DAPTEMP6
ADS       TJP
INDEX     DAPTEMP6
CCS       TJP
CS        -100MS      # 0.1 AT 1
TCF       +2
CA        -100MS
LOOPRATE  EXTEND
INDEX     DAPTEMP6
MP        NO.PJETS
CA        L
INDEX     DAPTEMP6
TS        DAPTEMP1    # SIGNED TORQUE AT 1 JET-SEC FOR FILTER
EXTEND
MP        BIT10       # RESCALE TO 32; ONE BIT ABOUT 2 JET-MSEC
EXTEND
BZMF      NEGTOCK
STORTOCK  INDEX       Q      # INCREMENT DOWNLIST REGISTER.
ADS       DOWNTOCK     #      NOTE:  NOT INITIALIZED; OVERFLOWS.

CCS       DAPTEMP6
TCF       RATELOOP +1
TCF       ROTORQUE
CA        ZERO
SMALLTJU  INDEX       DAPTEMP6
XCH       TJP
EXTEND
# Page 1471
MP        ELEVEN      # 10.24 PLUS
CA        L
TCF       LOOPRATE
CA        DAPTEMP2
AD        DAPTEMP3
EXTEND
MP        1JACCR
TS        JETRATER
CS        DAPTEMP3

```

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	AD	DAPTEMP2
	EXTEND	
	MP	1JACCQ
	TS	JETRATEQ
	TCF	BACKP
-100MST6	DEC	-160
NEGTORK	COM	
	INCR	Q
	TCF	STORTORK

This code is written to file `src/KALMAN-FILTER.s`.

## A.52 KEYRUPT UPRUPT

```

832  <src/KEYRUPT-UPRUPT.s 832>≡
      # Copyright:    Public domain.
      # Filename:     KEYRUPT_UPRUPT.agc
      # Purpose:      Part of the source code for Comanche, build 055. It
      #               is part of the source code for the Command Module's
      #               (CM) Apollo Guidance Computer (AGC), Apollo 11.
      # Assembler:    yaYUL
      # Reference:     pp. 1449-1451
      # Contact:       Ron Burkey <info@sandroid.org>
      # Website:       http://www.ibiblio.org/apollo.
      # Mod history:   2009-05-07 RSB  Adapted from Colossus249 file of the same
      #               name, and page images. Corrected various
      #               typos in the transcription of program
      #               comments, and these should be back-ported
      #               to Colossus249.
      #
      # The contents of the "Comanche055" files, in general, are transcribed
      # from scanned documents.
      #
      # Assemble revision 055 of AGC program Comanche by NASA
      # 2021113-051. April 1, 1969.
      #
      # This AGC program shall also be referred to as Colossus 2A
      #
      # Prepared by
      #
      #               Massachussets Institute of Technology
      #               75 Cambridge Parkway
      #               Cambridge, Massachusetts
      #
      # under NASA contract NAS 9-4065.
      #
      # Refer directly to the online document mentioned above for further
      # information. Please report any errors to info@sandroid.org.

      # Page 1449

      BANK      14
      SETLOC    KEYRUPT
      BANK
      COUNT*    $$/KEYUP

KEYRUPT1      TS      BANKRUPT
              XCH     Q
              TS      QRUPT
              TC      LODSAMPT      # TIME IS SNATCHED IN RUPT FOR NOUN 65.

```



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```

                                CAF    LOW5
                                EXTEND
KEYCOM    RAND    MNKEYIN    # CHECK IF KEYS 5M-1M ON
                                TS      RUPTREG4
                                CS      FLAGWRD5
                                MASK    BIT15
                                ADS     FLAGWRD5

ACCEPTUP    CAF    CHRPRIO    # (NOTE: RUPTREG4 = KEYTEMP1)
                                TC      NOVAC
                                EBANK=  DSPCOUNT
                                2CADR   CHARIN

                                CA      RUPTREG4
                                INDEX   LOCCTR
                                TS      MPAC    # LEAVE 5 BIT KEY CODE IN MPAC FOR CHARIN
                                TC      RESUME

# Page 1450
# UPRUPT PROGRAM

UPRUPT    TS      BANKRUPT
                                XCH     Q
                                TS      QRUPT
                                TC      LODSAMPT    # TIME IS SNATCHED IN RUPT FOR NOUN 65.
                                CAF     ZERO
                                XCH     INLINK
                                TS      KEYTEMP1
                                CAF     BIT3    # TURN ON UPACT LIGHT
                                EXTEND    # (BIT 3 OF CHANNEL 11)
                                WOR     DSALMOUT
UPRPT1    CAF     LOW5    # TEST FOR TRIPLE CHAR REDUNDANCY
                                MASK    KEYTEMP1    # LOW5 OF WORD
                                XCH     KEYTEMP1    # LOW5 INTO KEYTEMP1
                                EXTEND
                                MP      BIT10    # SHIFT RIGHT 5
                                TS      KEYTEMP2
                                MASK    LOW5    # MID 5
                                AD      HI10
                                TC      UPTTEST
                                CAF     BIT10
                                EXTEND
                                MP      KEYTEMP2    # SHIFT RIGHT 5
                                MASK    LOW5    # HIGH 5
                                COM
                                TC      UPTTEST
```

```

UPOK          CS      ELRCODE      # CODE IS GOOD.  IF CODE = 'ERROR RESET',
              AD      KEYTEMP1      # CLEAR UPLOCKFL (SET BIT4 OF FLAGWRD7 = 0)
              EXTEND      # IF CODE DOES NOT = 'ERROR RESET', ACCEPT
              BZF      CLUPLOCK      # CODE ONLY IF UPLOCKFL IS CLEAR (=0).

              CAF      BIT4          # TEST UPLOCKFL FOR 0 OR 1
              MASK     FLAGWRD7
              CCS      A
              TC      RESUME          # UPLOCKFL = 1
              TC      ACCEPTUP        # UPLOCKFL = 0

CLUPLOCK      CS      BIT4          # CLEAR UPLOCKFL (I.E., SET BIT 4 OF
              MASK     FLAGWRD7      # FLAGWRD7 = 0)
              TS      FLAGWRD7
              TC      ACCEPTUP

TMFAIL2      CS      FLAGWRD7        # CODE IS BAD
              MASK     BIT4          # LOCK OUT FURTHER UPLINK ACTIVITY
              ADS      FLAGWRD7      # (BY SETTING UPLOCKFL = 1) UNTIL
              TC      RESUME          # 'ERROR RESET' IS SENT VIA UPLINK.

UPTEST      AD      KEYTEMP1

# Page 1451

              CCS      A
              TC      TMFAIL2
HI10         OCT      77740
              TC      TMFAIL2
              TC      Q

ELRCODE      OCT      22

```

# 'UPLINK ACTIVITY LIGHT' IS TURNED OFF BY .....

- ```

#      1.      VBRELDSP
#      2.      ERROR RESET
#      3.      UPDATE PROGRAM (P27) ENTERED BY V70,V71,V72, AND V73.
#

```

```

# THE RECEPTION OF A BAD CODE (I.E., CCC FAILURE) LOCKS OUT FURTHER UPLINK ACTIVITY
# THIS INDICATION WILL BE TRANSFERRED TO THE GROUND BY THE DOWNLINK WHICH DOWNLINKS A
# WHEN UPLINK ACTIVITY IS LOCKED OUT, IT CAN BE ALLOWED WHEN THE GROUND UPLINKS AND
# (IT IS RECOMMENDED THAT THE 'ERROR LIGHT RESET' CODE IS PRECEDED BY 16 BITS THE F
# BY 15 ZEROS. THIS WILL ELIMINATE EXTRANEIOUS BITS FROM INLINK WHICH MAY HAVE BEEN
# FAILURE).
#

```

```

#
# UPLINK ACTIVITY IS ALSO ALLOWED (UNLOCKED) DURING FRESH START WHEN FRESH START SETS

```

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This code is written to file `src/KEYRUPT-UPRUPT.s`.

## A.53 LAMBERT AIMPOINT GUIDANCE

```

836  <src/LAMBERT-AIMPOINT-GUIDANCE.s 836>≡
      # Copyright:    Public domain.
      # Filename:     LAMBERT_AIMPOINT_GUIDANCE.agc
      # Purpose:      Part of the source code for Luminary 1A build 099.
      #               It is part of the source code for the Lunar Module's (LM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Ron Burkey <info@sandroid.org>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         651-653
      # Mod history:   2009-05-18 RSB   Transcribed from Luminary 099
      #               page images.
      #               2009-06-05 RSB   Corrected 4 typos.
      #               2009-06-07 RSB   Fixed a typo.
      #
      # This source code has been transcribed or otherwise adapted from
      # digitized images of a hardcopy from the MIT Museum. The digitization
      # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
      # the Museum. Many thanks to both. The images (with suitable reduction
      # in storage size and consequent reduction in image quality as well) are
      # available online at www.ibiblio.org/apollo. If for some reason you
      # find that the images are illegible, contact me at info@sandroid.org
      # about getting access to the (much) higher-quality images which Paul
      # actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
      #       16:27 JULY 14, 1969
      #
      # Page 651
      #
      # GENERAL LAMBERT AIMPOINT GUIDANCE **
      # WRITTEN BY RAMA M AIYAWAR
      #
      # PROGRAM P-31 DESCRIPTION **
      #
      # 1.   TO ACCEPT TARGETING PARAMETERS OBTAINED FROM A SOURCE EXTERNAL
      #       TO THE LEM AND COMPUTE THERE FROM THE REQUIRED-VELOCITY AND
      #       OTHER INITIAL CONDITIONS REQUIRED BY LM FOR DESIRED MANEUVER.
      #       THE TARGETING PARAMETERS ARE TIG (TIME OF IGNITION), TARGET
      #       VECTOR (RTARG), AND THE TIME FROM TIG UNTIL THE TARGET IS
      #       REACHED (DELLT4), DESIRED TIME OF FLIGHT FROM RINIT TO RTARG.

```

## # ASSUMPTIONS \*\*

```
#
# 1.    THE TARGET PARAMETERS MAY HAVE BEEN LOADED PRIOR TO THE
#        EXECUTION OF THIS PROGRAM.
# 2.    THIS PROGRAM IS APPLICABLE IN EITHER EARTH OR LUNAR ORBIT.
# 3.    THIS PROGRAM IS DESIGNED FOR ONE-MAN OPERATION, AND SHOULD
#        BE SELECTED BY THE ASTRONAUT BY DSKY ENTRY V37 E31.
```

## # SUBROUTINES USED \*\*

```
#
# MANUPARM, TTG/N35, RO2BOTH, MIDGIM, DISPMGA, FLAGDOWN, BANKCALL,
# GOTOPOOH, ENDOFJOB, PHASCHNG, GOFLASHR, GOFLASH.
#
# MANUPARM      CALCULATES APOGEE, PERIGEE ALTITUDES AND DELTAV DESIRED
#                FOR THE MANEUVER.
#
# TTG/N35       CLOCKTASK - UPDATES CLOCK.
#
# MIDGIM        CALCULATES MIDDLE GIMBAL ANGLE FOR DISPLAY.
#
# RO2BOTH       IMU - STATUS CHECK ROUTINE.
```

## # DISPLAYS USED IN P-31LM \*\*

```
#
# V06N33        DISPLAY SOTRED TIG (IN HRS. MINS. SECS.)
# V06N42        DISPLAY APOGEE, PERIGEE, DELTAV.
# V16N35        DISPLAY TIME FROM TIG.
# V06N45        TIME FROM IGNITION AND MIDDLE GIMBAL ANGLE.
```

## # ERASABLE INITIALIZATION REQUIRED \*\*

```
#
# TIG           TIME OF IGNITION                DP      (B+28) CS.
#
# DELLT4        DESIRED TIME OF FLIGHT           DP      (B+28) CS
#                FROM RINIT TO RTARG.
#
# RTARG         RADIUS VECTOR OF TARGET POSITION VECTOR
#                RADIUS VECTOR SCALED TO (B+29)METERS IF EARTH ORBIT
# Page 652
#                RADIUS VECTOR SCALED TO (B+27)METERS IF MOON ORBIT
```

## # OUTPUT \*\*

```
#
# HAPO          APOGEE ALTITUDE
# HPER          PERIGEE ALTITUDE
# VGDISP        MAG. OF DELTAV FOR DISPLAY, SCALING      B+7 M/CS EARTH
```

```

#          MAG. OF DELTAV FOR DISPLAY, SCALING      B+5 M/CS MOON
# MIDGIM    MIDDLE GIMBAL ANGLE
# XDELVFLG  RESETS XDELVFLG FOR LAMBERT VG COMPUTATIONS

# ALARMS OR ABORTS      NONE **

# RESTARTS ARE VIA GROUP 4 **

          SETLOC  GLM
          BANK

          EBANK=  SUBEXIT

          COUNT*  $$/P31
P31        TC      P20FLGON
          CAF      V06N33      # T16
          TC      VNP00H
          TC      INTPRET
          CLEAR    DLOAD
                   UPDATFLG
                   TIG
          STCALL   TDEC1      # INTEGRATE STATE VECTORS TO TIG
                   LEMPREC
          VLOAD    SETPD
                   RATT
                   OD
          STORE    RTIG
          STOVL    RINIT
                   VATT
          STORE    VTIG
          STODL    VINIT
                   P30ZERO
          PUSH     PDDL      # E4 AND NUMIT = 0
                   DELLT4
          DAD      SXA,1
                   TIG
                   RTX1
          STORE    TPASS4
          SXA,2    CALL
                   RTX2
                   INITVEL
          VLOAD    PUSH

          DELVEET3
          STORE    DELVSIN
          ABVAL    CLEAR

```

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```

                                XDELVFLG
STCALL  VGDISP
                                GET.LVC
VLOAD   PDVL
                                RTIG
                                VIPRIME
CALL
                                PERIAPO1
CALL
                                SHIFTR1
CALL                                     # LIMIT DISPLAY TO 9999.9 N. MI.
                                MAXCHK
STODL    HPER
                                4D
CALL
                                SHIFTR1
CALL                                     # LIMIT DISPLAY TO 9999.9 N. MI.
                                MAXCHK
STORE    HAPO
EXIT
CAF      V06N81                    # DELVLVC
TC       VNP00H
CAF      V06N42                    # HAPO, HPER, VGDISP
TC       VNP00H
TC       INTPRET
REVN1645 SET    CALL                # TRKMKCNT, TTOGO, +MGA
                                FINALFLG
                                VN1645
GOTO
                                REVN1645
```

# \*\*\* END OF LEMP30S .103 \*\*\*

This code is written to file src/LAMBERT-AIMPOINT-GUIDANCE.s.

## A.54 LANDING ANALOG DISPLAYS

```

840  <src/LANDING-ANALOG-DISPLAYS.s 840>≡
      # Copyright:    Public domain.
      # Filename:     LANDING_ANALOG_DISPLAYS.agc
      # Purpose:      Part of the source code for Luminary, build 099. It
      #               is part of the source code for the Lunar Module's
      #               (LM) Apollo Guidance Computer (AGC), Apollo 11.
      # Assembler:    yaYUL
      # Reference:     pp. 898-907
      # Contact:       Ron Burkey <info@sandroid.org>,
      #               Fabrizio Bernardini <fabrizio@spacecraft.it>
      # Website:       http://www.ibiblio.org/apollo.
      # Mod history:   05/06/09 FB      Transcription Batch 4 Assignment.
      #
      # The contents of the "Luminary099" files, in general, are transcribed
      # from scanned documents.
      #
      #       Assemble revision 001 of AGC program Luminary099 by NASA
      #       2021112-061.  July 14, 1969.
      #
      #       Prepared by
      #
      #               Massachussets Institute of Technology
      #               75 Cambridge Parkway
      #               Cambridge, Massachusetts
      #
      #       under NASA contract NAS 9-4065.
      #
      # Refer directly to the online document mentioned above for further
      # information. Please report any errors to info@sandroid.org.

      # Page 898

      BANK      21
      SETLOC    R10
      BANK

      EBANK=     UNIT/R/
      COUNT*    $$/R10

LANDISP      LXCH    PIPCTR1      # UPDATE TBASE2 AND PIPCTR SIMULTANEOUSLY.
              CS      TIME1
              DXCH    TBASE2

              CS      FLAGWRD7    # IS LANDING ANALOG DISPLAYS FLAG SET?
              MASK    SWANDBIT
              CCS      A

```



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```

TCF      DISPRSET      # NO.
CA        IMODES33      # BIT 7 = 0 (DO ALTRATE), =1 (DO ALT.)
MASK      BIT7
CCS       A
TCF      ALTOUT
ALTROUT   TC      DISINDAT      # CHECK MODE SELECT SWITCH AND DIDFLG.
          CS      IMODES33
          MASK     BIT7
          ADS      IMODES33      # ALTERNATE ALTITUDE RATE WITH ALTITUDE.
          CAF      BIT2          # RATE COMMAND IS EXECUTED BEFORE RANGE.
          EXTEND
          WOR      CHAN14      # ALTRATE (BIT2 = 1), ALTITUDE (BIT2 = 0).
          CA        RUNIT      # COMPUTE ALTRATE = RUNIT.VVECT M/CS *(-6).
          EXTEND
          MP        VVECT      # MULTIPLY X-COMPONENTS.
          XCH       RUPTREG1    # SAVE SINGLE PRECISION RESULT M/CS*2(-6)
          CA        RUNIT +1    # MULTIPLY Y-COMPONENTS.
          EXTEND
          MP        VVECT +1
          ADS       RUPTREG1    # ACCUMULATE PARTIAL PRODUCTS.
          CA        RUNIT +2    # MULTIPLY Z-COMPONENTS.
          EXTEND
          MP        VVECT +2
          ADS       RUPTREG1    # ALTITUDE RATE IN M/CS *2(-6).
          CA        ARCONV      # CONVERT ALTRATE TO BIT UNITS (.5FPS/BIT)
          EXTEND
          MP        RUPTREG1
          DDOUBL
          DDOUBL
          XCH       RUPTREG1    # ALTITUDE RATE IN BIT UNITS*2(-14).
          CA        DALTRATE    # ALTITUDE RATE COMPENSATION FACTOR.
          EXTEND
          MP        DT
          AD        RUPTREG1
          TS        ALTRATE      # ALTITUDE RATE IN BIT UNITS*2(-14).
          CS        ALTRATE
# Page 899
          EXTEND      # CHECK POLARITY OF ALTITUDE RATE.
          BZMF      +2
          TCF      DATAOUT      # NEGATIVE -- SEND POS. PULSES TO ALTM REG.
          CA        ALTRATE      # POSITIVE OR ZERO -- SET SIGN BIT = 1 AND
          AD        BIT15        # SEND TO ALTM REGISTER.  *DO NOT SEND +0*
          TS        ALTM          # ACTIVATE THE LANDING ANALOG DISPLAYS
          CAF      BIT3
          EXTEND
          WOR      CHAN14      # BIT3 DRIVES THE ALT/ALTRATE METER.
DATAOUT
```

|            |        |            |                                              |
|------------|--------|------------|----------------------------------------------|
|            | TCF    | TASKOVER   | # EXIT                                       |
| ALTOUT     | TC     | DISINDAT   | # CHECK MODE SELECT SWITCH AND DIDFLG.       |
|            | CS     | BIT7       |                                              |
|            | MASK   | IMODES33   |                                              |
|            | TS     | IMODES33   | # ALTERNATE ALTITUDE RATE WITH ALTITUDE.     |
|            | CS     | BIT2       |                                              |
|            | EXTEND |            |                                              |
|            | WAND   | CHAN14     |                                              |
|            | CCS    | ALTBITS    | # = -1 IF OLD ALT. DATA TO BE EXTRAPOLATED.  |
|            | TCF    | +4         |                                              |
|            | TCF    | +3         |                                              |
|            | TCF    | OLDDATA    |                                              |
|            | TS     | ALTBITS    | # SET ALTBITS FROM -0 TO +0.                 |
|            | CS     | ONE        |                                              |
|            | DXCH   | ALTBITS    | # SET ALTBITS = -1 FOR SWITCH USE NEXT PASS. |
|            | DXCH   | ALTSAVE    |                                              |
|            | CA     | BIT10      | # NEW ALTITUDE EXTRAPOLATION WITH ALTRATE.   |
|            | XCH    | Q          |                                              |
|            | LXCH   | 7          | # ZL                                         |
|            | CA     | DT         |                                              |
|            | EXTEND |            |                                              |
|            | DV     | Q          | # RESCALE DT*2(-14) TO *2(-9) TIME IN CS.    |
|            | EXTEND |            |                                              |
|            | MP     | ARTOA2     | # .0021322 *2(+8)                            |
|            | TCF    | OLDDATA +1 | # RATE APPLIES FOR DT CS.                    |
| ZDATA2     | DXCH   | ALTSAVE    |                                              |
|            | TCF    | NEWDATA    |                                              |
| OLDDATA    | CA     | ARTOA      | # RATE APPLIES FOR .5 SEC. (4X/SEC. CYCLE)   |
|            | EXTEND |            |                                              |
|            | MP     | ALTRATE    | # EXTRAPOLATE WITH ALTITUDE RATE.            |
|            | DDOUBL |            |                                              |
|            | AD     | ALTSAVE +1 |                                              |
|            | TS     | ALTSAVE +1 |                                              |
|            | CAF    | ZERO       |                                              |
|            | ADS    | ALTSAVE    |                                              |
|            | CAF    | POSMAX     | # FORCE SIGN AGREEMENT ASSUMING A            |
|            | AD     | ONE        | # NON-NEGATIVE ALTSAVE.                      |
|            | AD     | ALTSAVE +1 | # IF ALTSAVE IS NEGATIVE, ZERO ALTSAVE       |
|            | TS     | ALTSAVE +1 | # AND ALTSAVE +1 AT ZERODATA.                |
| # Page 900 | CAF    | ZERO       |                                              |
|            | AD     | POSMAX     |                                              |
|            | AD     | ALTSAVE    |                                              |
|            | TS     | ALTSAVE    | # POSSIBLY SKIP TO NEWDATA.                  |

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|          |        |            |                                            |
|----------|--------|------------|--------------------------------------------|
| NEWDATA  | TCF    | ZERODATA   |                                            |
|          | CCS    | ALTSAVE +1 |                                            |
|          | TCF    | +4         |                                            |
|          | TCF    | +3         |                                            |
|          | CAF    | ZERO       | # SET NEGATIVE ALTSAVE +1 TO +0.           |
|          | TS     | ALTSAVE +1 |                                            |
|          | CCS    | ALTSAVE    | # PROVIDE A 15 BIT UNSIGNED OUTPUT.        |
|          | CAF    | BIT15      | # THE HI-ORDER PART IS +1 OR +0.           |
|          | AD     | ALTSAVE +1 |                                            |
|          | TCF    | DATAOUT    | # DISPATCH UNSIGNED BITS TO ALTM REG.      |
| DISINDAT | EXTEND |            |                                            |
|          | QXCH   | LADQSAVE   | # SAVE RETURN TO ALTROUT +1 OR ALTOUT +1   |
|          | CAF    | BIT6       |                                            |
|          | EXTEND |            | # WISHETH THE ASTRONAUT THE ANALOG         |
|          | RAND   | CHAN30     | # DISPLAYS? I.E.,                          |
|          | CCS    | A          | # IS THE MODE SELECT SWITCH IN PGNC'S?     |
|          | TCF    | DISPRSET   | # NO. ASTRONAUT REQUESTS NO INERTIAL DATA  |
|          | CS     | FLAGWRD1   | # YES. CHECK STATUS OF DIDFLAG.            |
|          | MASK   | DIDFLBIT   |                                            |
|          | EXTEND |            |                                            |
|          | BZF    | SPEEDRUN   | # SET. PERFORM DATA DISPLAY SEQUENCE.      |
|          | CS     | FLAGWRD1   | # RESET. PERFORM INITIALIZATION FUNCTIONS. |
|          | MASK   | DIDFLBIT   |                                            |
|          | ADS    | FLAGWRD1   | # SET DIDFLAG.                             |
|          | CS     | BIT7       |                                            |
|          | MASK   | IMODES33   | # TO DISPLAY ALTRATE FIRST AND ALT. SECOND |
|          | TS     | IMODES33   |                                            |
|          | CS     | FLAGWRD0   | # ARE WE IN DESCENT TRAJECTORY?            |
|          | MASK   | R10FLBIT   |                                            |
|          | EXTEND |            |                                            |
|          | BZF    | TASKOVER   | # NO                                       |
|          | CAF    | BIT8       | # YES.                                     |
|          | EXTEND |            |                                            |
|          | WOR    | CHAN12     | # SET DISPLAY INERTIAL DATA OUTBIT.        |
|          | CAF    | ZERO       |                                            |
|          | TS     | TRAKLATV   | # LATERAL VELOCITY MONITOR FLAG            |
|          | TS     | TRAKFWDV   | # FORWARD VELOCITY MONITOR FLAG            |
|          | TS     | LATVMETR   | # LATVEL MONITOR METER                     |
|          | TS     | FORVMETR   | # FORVEL MONITOR METER                     |
|          | CAF    | BIT4       |                                            |
|          | TC     | TWIDDLE    |                                            |
|          | ADRES  | INTLZE     |                                            |
| INTLZE   | TCF    | TASKOVER   |                                            |
|          | CAF    | BIT2       |                                            |
|          | EXTEND |            |                                            |
|          | WOR    | CHAN12     | # ENABLE RR ERROR COUNTER.                 |

# Page 901

```

      CS      IMODES33
      MASK    BIT8
      ADS     IMODES33      # SET INERTIAL DATA FLAG.
      TCF     TASKOVER

SPEEDRUN      CS      PIPTIME +1      # UPDATE THE VELOCITY VECTOR
              AD      TIME1          # COMPUTE T - TN
              AD      HALF          # CORRECT FOR POSSIBLE OVERFLOW OF TIME1.
              AD      HALF
              XCH     DT              # SAVE FOR LATER USE
              CA      1SEC
              TS      ITEMP5        # INITIALIZE FOR DIVISION LATER
              EXTEND
              DCA     GDT/2          # COMPUTE THE X-COMPONENT OF VELOCITY.
              DDOUBL
              DDOUBL
              EXTEND
              MP      DT
              EXTEND
              DV      ITEMP5
              XCH     VVECT          # VVECT = G(T-TN) M/CS *2(-5)
              EXTEND
              DCA     V              # M/CS *2(-7)
              DDOUBL          # RESCALE TO 2(-5)
              DDOUBL
              ADS     VVECT          # VVECT = VN + G(T-TN) M/CS *2(-5)
              CA      PIPAX          # DELV CM/SEC *2(-14)
              AD      PIPATMPX      # IN CASE PIPAX HAS BEEN ZEROED
              EXTEND
              MP      KPIP1(5)      # DELV M/CS *2(-5)
              ADS     VVECT          # VVECT = VN + DELV + GN(T-TN) M/CS *2(-5)
              EXTEND
              DCA     GDT/2 +2      # COMPUTE THE Y-COMPONENT OF VELOCITY.
              DDOUBL
              DDOUBL
              EXTEND
              MP      DT
              EXTEND
              DV      ITEMP5
              XCH     VVECT +1
              EXTEND
              DCA     V +2
              DDOUBL
              DDOUBL
              ADS     VVECT +1

```

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# Page 902

CA PIPAY  
AD PIPATMPY  
EXTEND  
MP KPIP1(5)  
ADS VVECT +1

EXTEND  
DCA GDT/2 +4  
DDOUBL  
DDOUBL  
EXTEND  
MP DT  
EXTEND  
DV ITEMP5  
XCH VVECT +2  
EXTEND  
DCA V +4  
DDOUBL  
DDOUBL  
ADS VVECT +2  
CA PIPAZ  
AD PIPATMPZ  
EXTEND  
MP KPIP1(5)  
ADS VVECT +2

CAF BIT3  
TC VARDELAY

CS FLAGWRD0  
MASK R10FLBIT  
CCS A  
TCF +2  
TC LADQSAVE

CA DELVS  
AD VVECT  
TS ITEMP1  
CA DELVS +2  
AD VVECT +1  
TS ITEMP2  
CA DELVS +4  
AD VVECT +2  
TS ITEMP3  
CA ITEMP1  
EXTEND

# COMPUTE THE Z-COMPONENT OF VELOCITY.

# PAUSE 40 MS TO LET OTHER RUPTS IN.

# ARE WE IN DESCENT TRAJECTORY?

# YES.

# NO.

# HI X OF VELOCITY CORRECTION TERM.

# HI X OF UPDATED VELOCITY VECTOR.

# = VX - DVX M/CS \*2(-5).

# Y

# Y

# = VY - DVY M/CS \*2(-5)

# Z

# Z

# = VZ - DVZ M/CS \*2(-5)

# COMPUTE VHY, VELOCITY DIRECTED ALONG THE

# Y-COORDINATE.

```

      MP      UHYP      # HI X OF CROSS-RANGE HALF-UNIT VECTOR
      XCH     RUPTREG1
      CA      ITEMP2
      EXTEND
      MP      UHYP +2    # Y
      ADS     RUPTREG1    # ACCUMULATE PARTIAL PRODUCTS.
      CA      ITEMP3
      EXTEND
      MP      UHYP +4    # Z
      ADS     RUPTREG1

# Page 903
      CA      RUPTREG1
      DOUBLE
      XCH     VHY        # VHY=VMP.UHYP M/CS*2(-5) .
      CA      ITEMP1      # NO COMPUTE VHZ, VELOCITY DIRECTED ALONG
      EXTEND              # THE Z-COORDINATE.
      MP      UHYP        # HI X OF DOWN-RANGE HALF-UNIT VECTOR.
      XCH     RUPTREG1
      CA      ITEMP2
      EXTEND
      MP      UHYP +2    # Y
      ADS     RUPTREG1    # ACCUMULATE PARTIAL PRODUCTS.
      CA      ITEMP3
      EXTEND
      MP      UHYP +4    # Z
      ADS     RUPTREG1
      CA      RUPTREG1
      DOUBLE
      XCH     VHZ        # VHZ = VMP.UHYP M/CS*2(-5) .
GET22/32  CAF     EBANK6  # GET SIN(AOG),COS(AOG) FROM GPMATRIX.
      TS      EBANK
      EBANK=   M22
      CA      M22
      TS      ITEMP3
      CA      M32
      TS      ITEMP4
      CAF     EBANK7
      TS      EBANK
      EBANK=   UNIT/R/
LATFWDV   CA      ITEMP4    # COMPUTE LATERAL AND FORWARD VELOCITIES.
      EXTEND
      MP      VHY
      XCH     RUPTREG1
      CA      ITEMP3
      EXTEND
      MP      VHZ

```

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```
ADS      RUPTREG1      # = VHY(COS)AOG+VHZ(SIN)AOG M/CS *2(-5)
CA       VELCONV      # CONVERT LATERAL VELOCITY TO BIT UNITS.
EXTEND
MP       RUPTREG1
DDOUBL
XCH      LATVEL      # LATERAL VELOCITY IN BIT UNITS *2(-14).
CA       ITEMP4      # COMPUTE FORWARD VELOCITY.
EXTEND
MP       VHZ
XCH      RUPTREG1
CA       ITEMP3
EXTEND
MP       VHY
CS       A
ADS      RUPTREG1      # =VHZ(COS)AOG-VHY(SIN)AOG M/CS *2(-5).
# Page 904
CA       VELCONV      # CONVERT FORWARD VELOCITY TO BIT UNITS.
EXTEND
MP       RUPTREG1
DDOUBL
XCH      FORVEL      # FORWARD VELOCITY IN BIT UNITS *2(-14).
CS       MAXVBITS      # ACC.=-199.9989 FT./SEC.
TS       ITEMP6      # -547 BIT UNITS (OCTAL) AT 0.5571 FPS/BIT
VMONITOR
CAF      ONE      # LOOP TWICE.
TS       ITEMP5      # FORWARD AND LATERAL VELOCITY LANDING
INDEX    ITEMP5      # ANALOG DISPLAYS MONITOR.
CCS      LATVEL
TCF      +4
TCF      LVLIMITS
TCF      +8D
TCF      LVLIMITS
INDEX    ITEMP5
CS       LATVEL
AD       MAXVBITS      # +199.9989 FT.SEC.
EXTEND
BZMF     CHKLASTY
TCF      LVLIMITS
INDEX    ITEMP5
CA       LATVEL
AD       MAXVBITS
EXTEND
BZMF     +2
TCF      LVLIMITS
CHKLASTY
INDEX    ITEMP5
```

|            |        |             |
|------------|--------|-------------|
|            | CCS    | LATVMETR    |
|            | TCF    | +4          |
|            | TCF    | LASTOK      |
|            | TCF    | +7          |
|            | TCF    | LASTOK      |
|            | INDEX  | ITEMP5      |
|            | CA     | LATVEL      |
|            | EXTEND |             |
|            | BZMF   | LASTPOSY +5 |
|            | TCF    | +5          |
|            | INDEX  | ITEMP5      |
|            | CS     | LATVEL      |
|            | EXTEND |             |
|            | BZMF   | LASTNEGY +4 |
| LASTOK     | INDEX  | ITEMP5      |
|            | CCS    | TRAKLATV    |
|            | TCF    | LASTPOSY    |
|            | TCF    | +2          |
|            | TCF    | LASTNEGY    |
|            | INDEX  | ITEMP5      |
| # Page 905 |        |             |
|            | CA     | LATVEL      |
|            | EXTEND |             |
|            | BZMF   | NEGVMAXY    |
|            | TCF    | POSVMAXY    |
| LASTPOSY   | INDEX  | ITEMP5      |
|            | CA     | LATVEL      |
|            | EXTEND |             |
|            | BZMF   | +2          |
|            | TCF    | POSVMAXY    |
|            | CS     | MAXVBITS    |
|            | TCF    | ZEROLSTY    |
| POSVMAXY   | INDEX  | ITEMP5      |
|            | CS     | LATVMETR    |
|            | AD     | MAXVBITS    |
|            | INDEX  | ITEMP5      |
|            | XCH    | RUPTREG3    |
|            | CAF    | ONE         |
|            | TCF    | ZEROLSTY +3 |
| LASTNEGY   | INDEX  | ITEMP5      |
|            | CA     | LATVEL      |
|            | EXTEND |             |
|            | BZMF   | NEGVMAXY    |
|            | CA     | MAXVBITS    |
|            | TCF    | ZEROLSTY    |
| NEGVMAXY   | INDEX  | ITEMP5      |



|            |        |             |
|------------|--------|-------------|
|            | CA     | LATVMETR    |
|            | AD     | MAXVBITS    |
|            | COM    |             |
|            | INDEX  | ITEMP5      |
|            | XCH    | RUPTREG3    |
|            | CS     | ONE         |
|            | TCF    | ZEROLSTY +3 |
| LVLIMITS   | INDEX  | ITEMP5      |
|            | CCS    | TRAKLATV    |
|            | TCF    | LATVPOS     |
|            | TCF    | +2          |
|            | TCF    | LATVNEG     |
|            | INDEX  | ITEMP5      |
|            | CS     | LATVMETR    |
|            | EXTEND |             |
|            | BZMF   | +2          |
|            | TCF    | NEGLMLV     |
|            | INDEX  | ITEMP5      |
|            | CS     | LATVEL      |
|            | EXTEND |             |
|            | BZMF   | LVMINLM     |
|            | AD     | ITEMP6      |
|            | INDEX  | ITEMP5      |
|            | AD     | LATVMETR    |
|            | EXTEND |             |
| # Page 906 | BZMF   | LVMINLM     |
|            | INDEX  | ITEMP5      |
|            | AD     | LATVEL      |
|            | EXTEND |             |
|            | INDEX  | ITEMP5      |
|            | SU     | LATVMETR    |
|            | TCF    | ZEROLSTY    |
| LATVPOS    | INDEX  | ITEMP5      |
|            | CS     | LATVEL      |
|            | EXTEND |             |
|            | BZMF   | LVMINLM     |
|            | TCF    | +5          |
| LATVNEG    | INDEX  | ITEMP5      |
|            | CA     | LATVEL      |
|            | EXTEND |             |
|            | BZMF   | LVMINLM     |
|            | INDEX  | ITEMP5      |
|            | CS     | LATVMETR    |
|            | TCF    | ZEROLSTY    |

```

NEGLMLV      INDEX  ITEMP5
              CA     LATVEL
              EXTEND
              BZMF   LVMINLM
              CA     MAXVBITS
              INDEX  ITEMP5
              AD     LATVMETR
              COM
              INDEX  ITEMP5
              AD     LATVEL
              EXTEND
              BZMF   LVMINLM
              EXTEND
              INDEX  ITEMP5
              SU     LATVEL
              INDEX  ITEMP5
              AD     LATVMETR
              COM
              TCF    ZEROLSTY
LVMINLM      INDEX  ITEMP5
              CS     LATVMETR
              INDEX  ITEMP5
              AD     LATVEL
ZEROLSTY     INDEX  ITEMP5
              XCH    RUPTREG3
              CAF    ZERO
              INDEX  ITEMP5
              TS     TRAKLATV
              INDEX  ITEMP5
              CA     RUPTREG3
              AD     NEG0      # AVOIDS +0 DINC HARDWARE MALFUNCTION
# Page 907
              INDEX  ITEMP5
              TS     CDUTCMD
              INDEX  ITEMP5
              CA     RUPTREG3
              INDEX  ITEMP5
              ADS    LATVMETR
              CCS    ITEMP5    # FIRST MONITOR FORWARD THEN LATERAL VEL.
              TCF    VMONITOR

              CAF    BITSET    # DRIVE THE X-POINTER DISPLAY.
              EXTEND
              WOR    CHAN14
              TC     LADQSAVE   # GO TO ALTROUT +1 OR TO ALTOUT +1
ZERODATA     CAF    ZERO      # ZERO ALTSAVE AND ALTSAVE +1

```

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```

      TS      L      #      NO NEGATIVE ALTITUDES ALLOWED.
      TCF     ZDATA2

# *****

DISPRSET      CS      FLAGWRD0      # ARE WE IN DESCENT TRAJECTORY?
              MASK    R10FLBIT
              EXTEND
              BZF     ABORTON      # NO.
              CAF     BIT8        # YES.
              MASK    IMODES33     # CHECK IF INERTIAL DATA JUST DISPLAYED.
              CCS     A
              CAF     BIT2        # YES. DISABLE RR ERROR COUNTER
              AD      BIT8        # NO. REMOVE DISPLAY INERTIAL DATA
              COM
              EXTEND
              WAND    CHAN12
ABORTON      CS      BITS8/7      # RESET INERTIAL DATA, INTERLEAVE FLAGS.
              MASK    IMODES33
              TS      IMODES33
              CS      DIDFLBIT
              MASK    FLAGWRD1
              TS      FLAGWRD1    # RESET DIDFLAG.
              TCF     TASKOVER

# *****

BITS8/7      OCT     00300      # INERTIAL DATA AND INTERLEAVE FLAGS.
BITSET       =      PRI06
```

```
# *****
```

This code is written to file src/LANDING-ANALOG-DISPLAYS.s.

**A.55    LATITUDE LONGITUDE SUBROUTINES**

```

852  <src/LATITUDE-LONGITUDE-SUBROUTINES.s 852>≡
      # Copyright:    Public domain.
      # Filename:     LATITUDE_LONGITUDE_SUBROUTINES.agc
      # Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
      #               It is part of the source code for the Command Module's (CM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:   yaYUL
      # Contact:      Ron Burkey <info@sandroid.org>.
      # Website:     www.ibiblio.org/apollo.
      # Pages:       1236-1242
      # Mod history: 2009-05-14 RSB   Adapted from the Colossus249/ file of the
      #                                   same name, using Comanche055 page images.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 055 of AGC program Comanche by NASA
      #       2021113-051.   10:28 APR. 1, 1969
      #
      #       This AGC program shall also be referred to as
      #       Colossus 2A
      #
      # Page 1236
      # SUBROUTINE TO CONVERT RAD VECTOR AT GIVEN TIME TO LAT, LONG AND ALT
      #
      # CALLING SEQUENCE
      #       L-1       CALL
      #       L               LAT-LONG
      #
      # SUBROUTINES USED
      #       R-TO-RP, ARCTAN, SETGAMMA, SETRE
      #
      # ERASABLE INIT. REQ.
      #       AXO, -AYO, AZO, TEPHEM (SET AT LAUNCH TIME)
      #       ALPHAV = POSITION VECTOR METERS B-29
      #       MPAC -- TIME (CSECS B-28)

```

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```

#          ERADFLAG =1, TO COMPUTE EARTH RADIUS, =0 FOR FIXED EARTH RADIUS
#          LUNAFLAG=0 FOR EARTH, 1 FOR MOON
#
# OUTPUT
#          LATITUDE IN LAT          (REVS. B-0)
#          LONGITUDE IN LONG        (REVS. B-0)
#          ALTITUDE IN ALT METERS   B-29
#
#          BANK      30
#          SETLOC    LATLONG
#          BANK
#
#          COUNT     13/LT-LG
#
#          EBANK=    ALPHAV
#          STQ        SETPD
#                   INCORPEX
#                   OD
#          STOVL      6D          # SAVE TIME IN 6-7D FOR R-TO-RP
#                   ALPHAV
#          PUSH       ABVAL        # 0-5D= R FOR R-TO-RP
#          STODL      ALPHAM        # ABS. VALUE OF R FOR ALT FORMULA BELOW
#                   ZEROVEC        # SET MPAC=0 FOR EARTH, NON-ZERO FOR MOON
#          BOFF       COS          # USE COS(0) TO GET NON-ZERO IN MPAC
#                   LUNAFLAG        # 0=EARTH, 1=MOON
#                   CALLRTRP
#
#          CALLRTRP   CALL
#                   R-TO-RP        # RP VECTOR CONVERTED FROM R B-29
#                   UNIT          # UNIT RP B-1
#          STCALL     ALPHAV        # U2= 1/2 SINL FOR SETRE SUBR BELOW
#                   SETGAMMA      #          SET GAMMA=B2/A2 FOR EARTH, =1 FOR MOON
#          CALL       #          SCALED B-1.
#                   SETRE         # CALC RE METERS B-29
#          DLOAD      DSQ
#                   ALPHAV
#          PDDL       DSQ
#                   ALPHAV +2
#
#          DAD        SQRT
#          DMP         SL1R
#                   GAMRP
#          STODL      COSTH          # COS(LAT) B-1
#                   ALPHAV +4
#          STCALL     SINTH          # SIN(LAT) B-1
#                   ARCTAN
#          STODL      LAT            # LAT B0
#
# Page 1237

```

```

      ALPHAV
      STODL  COSTH          # COS(LONG) B-1
              ALPHAV +2
      STCALL SINTH          # SIN(LONG) B-1
              ARCTAN
      STODL  LONG           # LONG. REVS B-0 IN RANGE -1/2 TO 1/2
              ALPHAM
      DSU                      # ALT= R-RE METERS B-29
              ERADM
      STCALL ALT            # EXIT WITH ALT METERS B-29
              INCORPEX

# Page 1238
# SUBROUTINE TO CONVERT LAT, LONG, ALT AT GIVEN TIME TO RADIUS VECTOR
#
# CALLING SEQUENCE
#      L-1      CALL
#      L              LALOTORV
#
# SUBROUTINES USED
#      SETGAMMA, SETRE, RP-TO-R
#
# ERASABLE INIT. REQ.
#      AXO, AYO, AZO, TEPHEM SET AT LAUNCH TIME
#      LAT -- LATITUDE      (REVS B0)
#      LONG -- LONGITUDE    (REVS B0)
#      ALT -- ALTITUDE      (METERS) B-29
#      MPAC -- TIME         (CSECS B-28)
#      ERADFLAG =1 TO COMPUTE EARTH RADIUS, =0 FOR FIXED EARTH RADIUS
#      LUNAFLAG=0 FOR EARTH, 1 FOR MOON
#
# OUTPUT
#      R-VECTOR IN ALPHAV    (METERS B-29)

LALOTORV      STQ      SETPD          # LAT, LONG, ALT TO R VECTOR
              INCORPEX
              OD
      STCALL  6D          #      6-7D = TIME FOR RP-TO-R
              SETGAMMA    #      GAMMA = B2/A2 FOR EARTH, 1 FOR MOON B-1
      DLOAD   SIN         #      COS(LONG)COS(LAT) IN MPAC
              LAT          # UNIT  RP = SIN(LONG)COS(LAT)    2-3D
      DMPR    PDDL        # PD 2      GAMMA*SIN(LAT)        0-1D
              GAMRP
              LAT          #      0-1D = GAMMA*SIN(LAT) B-2
      COS     PDDL        # PD4 2-3D= COS(LAT) B-1 TEMPORARILY
              LONG
      SIN     DMPR        # PD 2

```

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```

      PDDL      COS      # PD 4 2-3D= SIN(LONG)COS(LAT) B-2
                      LAT
      PDDL      COS      # PD 6 4-5D= COS(LAT) B-1 TEMPORARILY
                      LONG
      DMPR      VDEF      # PD4 MPAC = COS(LONG)COS(LAT) B-2
      UNIT      PUSH      #      0-5D = UNIT RP FOR RP-TO-R SUBR.
      STCALL     ALPHAV     # ALPHAV +4= SINL FOR SETRE SUBR.
                      SETRE  # RE METERS B-29
      DLOAD      BOFF      # SET MPAC = 0 FOR EARTH, NON-ZERO FOR MOON
                      ZEROVEC
                      LUNAFLAG
                      CALLRPRT
      COS
CALLRPRT CALL      # USE COS(0) TO GET NON-ZERO IN MPAC
                      RP-TO-R      # EXIT WITH UNIT R VECTOR IN MPAC
      STODL     ALPHAV
                      ERADM
# Page 1239
      DAD      VXSC      # (RE + ALT)(UNIT R) METERS B-30
                      ALT
                      ALPHAV
      VSL1
      STCALL     ALPHAV     # R METERS B-29
                      INCORPEX  # EXIT WITH R IN METERS B-29

# SUBROUTINE TO COMPUTE EARTH RADIUS
#
# INPUT
#      1/2 SIN LAT IN ALPHAV +4
#
# OUTPUT
#      EARTH RADIUS IN ERADM AND MPAC (METERS B-29)

GETERAD      DLOAD      DSQ
                      ALPHAV +4      # SIN**2(L)
      SL1      BDSU
                      DP1/2      # COS**2(L)
      DMPR      BDSU
                      EE
                      DP1/2
      BDDV      SQRT
                      B2XSC
      SR4R
      STORE     ERADM
                      RVQ
```

```
# THE FOLLOWING CONSTANTS WERE COMPUTED WITH A=6378166, B=6356784 METERS
# B2XSC = B**2 SCALED B-51
# B2/A2 = B**2/A**2 SCALED B-1
# EE = (1-B**2/A**2) SCALED B-0
```

```
B2XSC          2DEC      .0179450689      # B**2 SCALED B-51

DP1/2          =          XUNIT
B2/A2          2DEC      .9933064884 B-1 # GAMMA= B**2/A**2 B-1

EE             2DEC      6.6935116 E-3    # (1-B**2/A**2) B-0

ERAD           2DEC      6373338 B-29     # PAD RADIUS
```

```
# Page 1240
# ARCTAN SUBROUTINE
#
# CALLING SEQUENCE
#     SIN THETA IN SINTH B-1
#     COS THETA IN COSTH B-1
#     CALL ARCTAN
#
# OUTPUT
#     ARCTAN THETA IN MPAC AND THETA B-0 IN RANGE -1/2 TO +1/2
```

```
ARCTAN          BOV
                  CLROVFLW
CLROVFLW        DLOAD  DSQ
                  SINTH
                  PDDL  DSQ
                  COSTH
                  DAD
                  BZE   SQRT
                  ARCTANXX      # ATAN=0/0.  SET THETA=0
                  BDDV  BOV
                  SINTH
                  ATAN=90
                  SR1   ASIN
                  STORE  THETA
                  PDDL  BMN
                  COSTH
                  NEGCOS
                  DLOAD  RVQ
NEGCOS          DLOAD  DCOMP
                  BPL   DAD
                  NEGOUT
```



```

          DP1/2
ARCTANXX  STORE  THETA
          RVQ

NEGOUT    DSU    GOTO
          DP1/2
          ARCTANXX
ATAN=90   DLOAD  SIGN
          LODP1/4
          SINTH
          STORE  THETA
          RVQ

2DZERO    =      DPZERO

```

# Page 1241

# \*\*\*\*\* SETGAMMA SUBROUTINE \*\*\*\*\*

# SUBROUTINE TO SET GAMMA FOR THE LAT-LONG AND LALOTORV SUBROUTINES

#

# GAMMA = B\*\*2/A\*\*2 FOR EARTH (B-1)

# GAMMA = 1 FOR MOON (B-1)

#

# CALLING SEQUENCE

# L CALL

# L+1 SETGAMMA

#

# INPUT

# LUNAFLAG=0 FOR EARTH, =1 FOR MOON

#

# OUTPUT

# GAMMA IN GAMRP (B-1)

```

SETGAMMA  DLOAD  BOFF          # BRANCH FOR EARTH
          B2/A2          # EARTH GAMMA
          LUNAFLAG
          SETGMEX

          SLOAD

          1B1            # MOON GAMMA
SETGMEX   STORE  GAMRP
          RVQ

GAMRP     =      8D

```

# Page 1242

# \*\*\*\*\* SETRE SUBROUTINE \*\*\*\*\*

# SUBROUTINE TO SET RE (EARTH OR MOON RADIUS)

#

```

#      RE = RM FOR MOON
#      RE = RREF FOR FIXED EARTH RADIUS OR COMPUTED RF FOR FISCHER ELLIPSOID
#
# CALLING SEQUENCE
#      L      CALL
#      L+1      SETRE
#
# SUBROUTINES USED
#      CETERAD
#
# INPUT
#      ERADFLAG = 0 FOR FIXED RE, 1 FOR COMPUTED RE
#      ALPHAV +4 = 1/2 SINL IF GETERAD IS CALLED
#      LUNAFLAG = 0 FOR EARTH, =1 FOR MOON
#
# OUTPUT
#      ERADM = 504RM FOR MOON (METERS B-29)
#      ERADM = ERAD OR COMPUTED RE FOR EARTH (METERS B-29)

SETRE      STQ      DLOAD
              SETREX
              504RM
              BON      DLOAD      # BRANCH FOR MOON
              LUNAFLAG
              TSTRLSRM
              ERAD
              BOFF      CALL      # ERADFLAG=0 FOR FIXED RE, 1 FOR COMPUTED
              ERADFLAG
              SETRXX
              GETERAD
SETRXX      STCALL   ERADM      # EXIT WITH RE OR RM METERS B-29
              SETREX
TSTRLSRM    BON      VLOAD      # ERADFLAG=0, SET R0=RLS
              ERADFLAG      #      =1      R0=RM
              SETRXX
              RLS
              ABVAL    SR2R      # SCALE FROM B-27 TO B-29
              GOTO
              SETRXX
SETRX      =      S2
504RM      2DEC      1738090 B-29  # METERS B-29 (MOON RADIUS)

```

## A.56 LEM GEOMETRY

```

859  <src/LEM-GEOMETRY.s 859>≡
    # Copyright:    Public domain.
    # Filename:     LEM_GEOMETRY.agc
    # Purpose:      Part of the source code for Luminary 1A build 099.
    #               It is part of the source code for the Lunar Module's (LM)
    #               Apollo Guidance Computer (AGC), for Apollo 11.
    # Assembler:    yaYUL
    # Contact:       Ron Burkey <info@sandroid.org>.
    # Website:       www.ibiblio.org/apollo.
    # Pages:         320-325
    # Mod history:   2009-05-16 RSB   Adapted from the corresponding
    #               Luminary131 file, using page
    #               images from Luminary 1A.
    #
    # This source code has been transcribed or otherwise adapted from
    # digitized images of a hardcopy from the MIT Museum. The digitization
    # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
    # the Museum. Many thanks to both. The images (with suitable reduction
    # in storage size and consequent reduction in image quality as well) are
    # available online at www.ibiblio.org/apollo. If for some reason you
    # find that the images are illegible, contact me at info@sandroid.org
    # about getting access to the (much) higher-quality images which Paul
    # actually created.
    #
    # Notations on the hardcopy document read, in part:
    #
    #       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
    #       16:27 JULY 14, 1969

    # Page 320

                BANK      23
                SETLOC    LEMGEOM
                BANK

                SBANK=    LOWSUPER
                EBANK=    XSM

    # THESE TWO ROUTINES COMPUTE THE ACTUAL STATE VECTOR FOR LM,CSM BY ADDING
    # THE CONIC R,V AND THE DEVIATIONS R,V. THE STATE VECTORS ARE CONVERTED TO
    # METERS B-29 AND METERS/CSEC B-7 AND STORED APPROPRIATELY IN RN,VN OR
    # R-OTHER,V-OTHER FOR DOWNLINK. THE ROUTINES' NAMES ARE SWITCHED IN THE
    # OTHER VEHICLE'S COMPUTER.
    #
    # INPUT

```

```

#      STATE VECTOR IN TEMPORARY STORAGE AREA
#      IF STATE VECTOR IS SCALED POS B27 AND VEL B5
#          SET X2 TO +2
#      IF STATE VECTOR IS SCALED POS B29 AND VEL B7
#          SET X2 TO 0
#
# OUTPUT
#      R(T) IN RN, V(T) IN VN, T IN PIPTIME
# OR
#      R(T) IN R-OTHER, V(T) IN V-OTHER          (T IS DEFINED BY T-OTHER)

COUNT*  $$/GEOM
SVDWN2   BOF      RVQ          # SW=1=AVETOMID DOING W-MATRIX INTEG.
          AVEMIDSW
          +1
          VLOAD   VSL*
          TDELTA
          0        -7,2
          VAD      VSL*
          RCV
          0,2
          STOVL   RN
          TNUV
          VSL*    VAD
          0        -4,2
          VCV
          VSL*
          0,2
          STODL   VN
          TET
          STORE   PIPTIME
          RVQ

# Page 321
SVDWN1   VLOAD   VSL*
          TDELTA
          0        -7,2
          VAD      VSL*
          RCV
          0,2
          STOVL   R-OTHER
          TNUV
          VSL*    VAD
          0        -4,2
          VCV
          VSL*
          0,2

```

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STORE V-OTHER  
RVQ

# Page 322

# THE FOLLOWING ROUTINE TAKES A HALF UNIT TARGET VECTOR REFERRED TO NAV BASE COORDINATES AND FINDS  
# GIMBAL ORIENTATIONS AT WHICH THE RR MIGHT SIGHT THE TARGET. THE GIMBAL ANGLES CORRESPONDING  
# ARE LEFT IN MODEA AND THOSE WHICH WOULD BE USED AFTER A REMODE IN MODEB. THIS ROUTINE ASSUMES  
# ANGLE LESS THAN 90 DEGS IN ABS VALUE WITH ARBITRARY SHAFT, WITH A CORRESPONDING DEFINITION FOR  
# SELECTION AND LIMIT CHECKING ARE DONE ELSEWHERE.

#  
# THE MODE 1 CONFIGURATION IS CALCULATED FROM THE VECTOR AND THEN MODE 2 IS FOUND USING THE RELATIONSHIP  
#

# S(2) = 180 + S(1)

# T(2) = 180 - T(1)

#  
# THE VECTOR ARRIVES IN MPAC WHERE TRG\*SMNG OR \*SMNB\* WILL HAVE LEFT IT.

|          |        |          |                                             |
|----------|--------|----------|---------------------------------------------|
| RRANGLES | STORE  | 32D      |                                             |
|          | DLOAD  | DCOMP    | # SINCE WE WILL FIND THE MODE 1 SHAFT       |
|          |        | 34D      | # ANGLE LATER, WE CAN FIND THE MODE 1       |
|          | SETPD  | ASIN     | # TRUNNION BY SIMPLY TAKING THE ARCSIN OF   |
|          |        | 0        | # THE Y COMPONENT, THE ASIN GIVIN AN        |
|          | PUSH   | BDSU     | # ANSWER WHOSE ABS VAL IS LESS THAN 90 DEG. |
|          |        | LODPHALF |                                             |
|          | STODL  | 4        | # MODE 2 TRUNNION TO 4.                     |
|          |        | LO6ZEROS |                                             |
|          | STOVL  | 34D      | # UNIT THE PROJECTION OF THE VECTOR         |
|          |        | 32D      | # IN THE X-Z PLANE                          |
|          | UNIT   | BOVB     | # IF OVERFLOW, TARGET VECTOR IS ALONG Y     |
|          |        | LUNDESCH | # CALL FOR MANEUVER UNLESS ON LUNAR SURF    |
|          | STODL  | 32D      | # PROJECTION VECTOR.                        |
|          |        | 32D      |                                             |
|          | SR1    | STQ      |                                             |
|          |        | S2       |                                             |
|          | STODL  | SINTH    | # USE ARCTRIG SINCE SHAFT COULD BE ARB.     |
|          |        | 36D      |                                             |
|          | SR1    |          |                                             |
|          | STCALL | COSTH    |                                             |
|          |        | ARCTRIG  |                                             |

# Page 323

|  |       |          |                           |
|--|-------|----------|---------------------------|
|  | PUSH  | DAD      | # MODE 1 SHAFT TO 2.      |
|  |       | LODPHALF |                           |
|  | STOVL | 6        |                           |
|  |       | 4        |                           |
|  | RTB   |          | # FIND MODE 2 CDU ANGLES. |

```

                2V1STO2S
STOVL          MODEB
                0
RTB                                # MODE 1 ANGLES TO MODE A.
                2V1STO2S
STORE          MODEA
EXIT

CS             RADMODES          # SWAP MODEA AND MODEB IF RR IN MODE 2.
MASK          ANTENBIT
CCS           A
TCF           +4

DXCH          MODEA
DXCH          MODEB
DXCH          MODEA

TC            INTPRET
GOTO          S2

# Page 324
# GIVEN RR TRUNNION AND SHAFT (T,S) IN TANGNB,+1, FIND THE ASSOCIATED
# LINE OF SIGHT IN NAV BASE AXES.  THE HALF UNIT VECTOR, .5(SIN(S)COS(T),
# -SIN(T),COS(S)COS(T)) IS LEFT IN MPAC AND 32D.

SETLOC        INFLIGHT
BANK

COUNT*       $$/GEOM

RRNB          SLOAD  RTB
                TANGNB
                CDULOGIC
SETPD         PUSH    # TRUNNION ANGLE TO 0
                0
SIN           DCOMP
STODL         34D      # Y COMPONENT

COS           PUSH    # .5 COS(T) TO 0
SLOAD         RTB
                TANGNB +1
                CDULOGIC
RRNB1         PUSH    COS    # SHAFT ANGLE TO 2
DMP           SL1
                0
STODL         36D      # Z COMPONENT

```

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```
SIN      DMP
SL1
STOVL    32D
          32D
RVQ
```

# THIS ENTRY TO RRNB REQUIRES THE TRUNNION AND SHAFT ANGLES IN MPAC AND MPAC +1 RESPECTIVELY

```
RRNBMPAC      STODL    20D          # SAVE SHAFT CDU IN 21.
                MPAC          # SET MODE TO DP. (THE PRECEEDING STORE
                                # MAY BE DP, TP OR VECTOR.)

                RTB      SETPD
                CDULOGIC
                0
                PUSH     SIN          # TRUNNION ANGLE TO 0
                DCOMP
                STODL    34D          # Y COMPONENT
                COS      PUSH         # .5COS(T) TO 0
                SLOAD    RTB          # PICK UP CDU'S.
                21D
                CDULOGIC
                GOTO
                RRNB1
```

# Page 325

# (This page has nothing on it.)

This code is written to file src/LEM-GEOMETRY.s.

## A.57 LUNAR AND SOLAR EPHEMERIDES SUBROUTINES

```

864  <src/LUNAR-AND-SOLAR-EPHEMERIDES-SUBROUTINES.s 864>≡
      # Copyright:    Public domain.
      # Filename:     LUNAR_AND_SOLAR_EPHEMERIDES_SUBROUTINES.agc
      # Purpose:      Part of the source code for Comanche, build 055. It
      #               is part of the source code for the Command Module's
      #               (CM) Apollo Guidance Computer (AGC), Apollo 11.
      # Assembler:    yaYUL
      # Reference:     pp. 785-788
      # Contact:       Ron Burkey <info@sandroid.org>
      # Website:       http://www.ibiblio.org/apollo.
      # Mod history:   2009-05-12 RSB   Adapted from Colossus249 file of the same
      #               name and Comanche 055 page images.
      #               2009-07-26 RSB   Added annotations related to computation
      #               of the ephemeral(?) polynomials.
      #
      # The contents of the "Comanche055" files, in general, are transcribed
      # from scanned documents.
      #
      # Assemble revision 055 of AGC program Comanche by NASA
      # 2021113-051. April 1, 1969.
      #
      # This AGC program shall also be referred to as Colossus 2A
      #
      # Prepared by
      #
      #               Massachussets Institute of Technology
      #               75 Cambridge Parkway
      #               Cambridge, Massachusetts
      #
      # under NASA contract NAS 9-4065.
      #
      # Refer directly to the online document mentioned above for further
      # information. Please report any errors to info@sandroid.org.
      #
      # Page 785
      # LUNAR AND SOLAR EPHEMERIDES SUBROUTINES
      #
      # FUNCTIONAL DESCRIPTION
      #
      # THESE SUBROUTINES ARE USED TO DETERMINE THE POSITION AND VELOCITY
      # VECTORS OF THE SUN AND THE MOON RELATIVE TO THE EARTH AT THE
      # SPECIFIED GROUND ELAPSED TIME INPUT BY THE USER.
      #

```



```

# THE POSITION OF THE MOON IS STORED IN THE COMPUTER IN THE FORM OF
# A NINTH DEGREE POLYNOMIAL APPROXIMATION WHICH IS VALID OVER A 15
# DAY INTERVAL BEGINNING SHORTLY BEFORE LAUNCH. THEREFORE THE TIME
# INPUT BY THE USER SHOULD FALL WITHIN THIS 15 DAY INTERVAL.
## The 9th-degree polynomial spoken of here is a pad load, meaning
## that it is not actually hardcoded into the software. Additional
## information about calculating the polynomial can be found on the
## <a href="http://nassp.sourceforge.net/wiki/Lunar_Ephemeris_Polynomials">
## <b>Orbiter</b> NASSP wiki</a>, as well as information about calculation
## of the <a href="http://nassp.sourceforge.net/wiki/Solar_Ephemeris">
## solar ephemerides</a>.
#
# LSPOS COMPUTES THE POSITION VECTORS OF THE SUN AND THE MOON.
#
# LUNPOS COMPUTES THE POSITION VECTOR OF THE MOON.
#
# LUNVEL COMPUTES THE VELOCITY VECTOR OF THE MOON.
#
# SOLPOS COMPUTES THE POSITION VECTOR OF THE SUN.
#
# CALLING SEQUENCE
#
# DLOAD CALL
# TIME GROUND ELAPSED TIME
# SUBROUTINE LSPOS OR LUNPOS OR LUNVEL OR SOLPOS
#
# INPUT
#
# 1) SPECIFIED GROUND ELAPSED TIME IN CS x B-28 LOADED IN MPAC.
#
# 2) TIMEMO -- TIME AT THE CENTER OF THE RANGE OVER WHICH THE LUNAR
# POSITION POLYNOMIAL IS VALID IN CS x B-42.
#
# 3) VECOEM -- VECTOR COEFFICIENTS OF THE LUNAR POSITION POLYNOMIAL
# LOADED IN DESCENDING SEQUENCE IN METERS/CS**N x B-2
#
# 4) RESO -- POSITION VECTOR OF THE SUN RELATIVE TO THE EARTH AT
# TIMEMO IN METERS x B-38
#
# 5) VESO -- VELOCITY VECTOR OF THE SUN RELATIVE TO THE EARTH AT
# TIMEMO IN METERS/CS x B-9
#
# 6) OMEGAES -- ANGULAR VELOCITY OF THE VECTOR RESO AT TIMEMO IN
# REV/CS x B+26
#
# ALL EXCEPT THE FIRST INPUT ARE INCLUDED IN THE PRE-LAUNCH

```

```
#          ERASABLE DATA LOAD.
#
# OUTPUT -- LSPOS
# Page 786
#
#          1) 2D OF VAC AREA CONTAINS THE POSITION VECTOR OF THE SUN RELATIVE
#          TO THE EARTH AT TIME INPUT BY THE USER IN METERS x B-38.
#
#          2) MPAC CONTAINS THE POSITION VECTOR OF THE MOON RELATIVE TO THE
#          EARTH AT TIME INPUT BY THE USER IN METERS x B-29
#
# OUTPUT -- LUNPOS
#
#          MPAC CONTAINS THE POSITION VECTOR OF THE MOON RELATIVE TO THE
#          EARTH AT THE TIME INPUT BY USER IN METERS x B-29
#
# OUTPUT -- LUNVEL
#
#          MPAC CONTAINS THE VELOCITY VECTOR OF THE MOON RELATIVE TO THE
#          EARTH AT THE TIME INPUT BY THE USER IN METERS/CS x B-7
#
# OUTPUT -- SOLPOS
#
#          MPAC CONTAINS THE POSITION VECTOR OF THE SUN RELATIVE TO THE EARTH
#          AT TIME INPUT BY THE USER IN METERS x B-38.
#
# SUBROUTINES USED
#
#          NONE
#
# REMARKS
#
#          THE VAC AREA IS USED FOR STORAGE OF INTERMEDIATE AND FINAL RESULTS
#          OF COMPUTATIONS.
#
#          S1, X1, AND X2 ARE USED BY THESE SUBROUTINES.
#
#          PRELAUNCH ERASABLE DATA LOAD ARE ONLY ERASABLE STORAGE USED BY
#          THESE SUBROUTINES.
#
#          RESTARTS DURING OPERATION OF THESE SUBROUTINES MUST BE HANDLED BY
#          THE USER.

BANK      36
SETLOC    EPHEM
BANK
```

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```
COUNT*  $$/EPHEM
EBANK=  END-E7

LSPOS    AXT,2    RESA    # COMPUTES POSITION VECTORS OF BOTH THE
                                # SUN AND THE MOON.  THE POSITION VECTOR
                                # OF THE SUN IS STORED IN 2D OF THE VAC
                                # AREA.  THE POSITION VECTOR OF THE MOON
                                # IS STORED IN MPAC.
LUNPOS    AXT,1    GOTO    # COMPUTES THE POSITION VECTOR OF THE MOON
                                # AND STORES IT IN MPAC.
                                REM
                                LSTIME

# Page 787
LUNVEL    AXT,1    GOTO    # COMPUTES THE VELOCITY VECTOR OF THE MOON
                                # AND STORES IT IN MPAC.
                                VEM
                                LSTIME

SOLPOS    STQ      AXT,1    # COMPUTES THE POSITION VECTOR OF THE SUN
                                # AND STORES IT IN MPAC.
                                X2
                                RES

LSTIME    SETPD    SR
                                OD
                                14D
TAD        DCOMP
TAD        TEPHEM
TAD        DCOMP
TAD        TIMEMO
SL         SSP
                                16D
                                S1
                                6D
GOTO

RES        PUSH     DMP      # PD- 2
                                OMEGAES
PUSH       COS        # PD- 4
VXSC       PDDL       # PD- 8
                                RES0
SIN        PDVL       # PD-10
                                RES0
PUSH       UNIT       # PD-16
VXV        UNIT
                                VES0
VXV        VSL1       # PD-10
VXSC       VAD        # PD-02
VSL1       GOTO      # RES IN METERS x B-38 IN MPAC.
                                X2
RESA       STODL     2D      # RES IN METERS x B-38 IN 2D OF VAC. PD- 0
```

|            |       |               |                                   |       |
|------------|-------|---------------|-----------------------------------|-------|
| REM        | AXT,1 | PDVL          | #                                 | PD- 2 |
|            |       | 54D           |                                   |       |
|            |       | VECOEM        |                                   |       |
| REMA       | VXSC  | VAD*          |                                   |       |
|            |       | OD            |                                   |       |
|            |       | VECOEM +60D,1 |                                   |       |
|            | TIX,1 | VSL2          | # REM IN METERS x B-29 IN MPAC.   |       |
|            |       | REMA          |                                   |       |
|            | RVQ   |               |                                   |       |
| VEM        | AXT,1 | PDDL          | #                                 | PD- 2 |
|            |       | 48D           |                                   |       |
|            |       | NINEB4        |                                   |       |
|            | PUSH  | VXSC          | #                                 | PD- 4 |
|            |       | VECOEM        |                                   |       |
| VEMA       | VXSC  |               |                                   |       |
|            |       | OD            |                                   |       |
| # Page 788 |       |               |                                   |       |
|            | STODL | 4D            | #                                 | PD- 2 |
|            | DSU   | PUSH          | #                                 | PD- 4 |
|            |       | ONEB4         |                                   |       |
|            | VXSC* | VAD           |                                   |       |
|            |       | VECOEM +54D,1 |                                   |       |
|            |       | 4D            |                                   |       |
|            | TIX,1 | VSL2          | # VEM IN METERS/CS x B-7 IN MPAC. |       |
|            |       | VEMA          |                                   |       |
|            | RVQ   |               |                                   |       |
| NINEB4     | 2DEC  | 9.0 B-4       |                                   |       |
| ONEB4      | 2DEC  | 1.0 B-4       |                                   |       |

## A.58 LUNAR LANDING GUIDANCE EQUATIONS

869

*<src/LUNAR-LANDING-GUIDANCE-EQUATIONS.s 869>≡*

```
# Copyright:    Public domain.
# Filename:     LUNAR_LANDING_GUIDANCE_EQUATIONS.agc
# Purpose:     Part of the source code for Luminary 1A build 099.
#             It is part of the source code for the Lunar Module's (LM)
#             Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:     HARTMUTH GUTSCHE <hgutsche@explornet.com>.
# Website:     www.ibiblio.org/apollo.
# Pages:       798-828
# Mod history: 2009-05-23 HG   Transcribed from page images.
#             2009-06-05 RSB   Fixed a goofy thing that was apparently
#                               legal in GAP but not in yaYUL.  Eliminated
#                               a couple of lines of code that shouldn't
#                               have survived from Luminary 131 to here.
#             2009-06-07 RSB   Fixed a typo.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum.  The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum.  Many thanks to both.  The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo.  If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
#       16:27 JULY 14, 1969
#
# Page 798
#
#       EBANK=  E2DPS
#       COUNT*  $$/F2DPS
#
# *****
# LUNAR LANDING FLIGHT SEQUENCE TABLES
# *****
#
# FLIGHT SEQUENCE TABLES ARE ARRANGED BY FUNCTION.  THEY ARE REFERENCED USING AS AN INDEX THE R
#       WCHPHASE = -1 ---> IGNALG
```

```
#      WCHPHASE = 0 ---> BRAKQUAD
#      WCHPHASE = 1 ---> APPRQUAD
#      WCHPHASE = 2 ---> VERTICAL
```

```
*****
```

```
# ROUTINES FOR STARTING NEW GUIDANCE PHASES:
```

```
NEWPHASE      TCF      TTFINCR      # IGNALG
               TCF      TTFINCR      # BRAKQUAD
               TCF      STARTP64     # APPRQUAD
               TCF      P65START     # VERTICAL
```

```
# PRE-GUIDANCE COMPUTATIONS:
```

```
PREGUIDE      TCF      CALCRGVG      # IGNALG
               TCF      RGVGCALC     # BRAKQUAD
               TCF      REDESIG      # APPRQUAD
               TCF      RGVGCALC     # VERTICAL
```

```
# GUIDANCE EQUATIONS:
```

```
WHATGUID      TCF      TTF/8CL      # IGNALG
               TCF      TTF/8CL      # BRAKQUAD
               TCF      TTF/8CL      # APPRQUAD
               TCF      VERTGUID     # VERTICAL
```

```
# POST GUIDANCE EQUATION COMPUTATIONS:
```

```
AFTRGUID      TCF      CGCALC      # IGNALG
               TCF      CGCALC      # BRAKQUAD
               TCF      CGCALC      # APPRQUAD
               TCF      STEER?      # VERTICAL
```

```
# Page 799
```

```
# WINDOW VECTOR COMPUTATIONS:
```

```
WHATEXIT      TCF      EXGSUB      # IGNALG
               TCF      EXBRAK      # BRAKQUAD
               TCF      EXNORM      # APPRQUAD
```

```
# DISPLAY ROUTINES:
```

```
WHATDISP      TCF      P63DISPS     # BRAKQUAD
               TCF      P64DISPS     # APPRQUAD
               TCF      VERTDISP     # VERTICAL
```

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# ALARM ROUTINE FOR TTF COMPUTATION:

|         |     |         |            |
|---------|-----|---------|------------|
|         | TCF | 1406P00 | # IGNALG   |
| WHATALM | TCF | 1406ALM | # BRAKQUAD |
|         | TCF | 1406ALM | # APPRQUAD |

# INDICES FOR REFERENCING TARGET PARAMETERS

|           |     |    |            |
|-----------|-----|----|------------|
|           | OCT | 0  | # IGNALG   |
| TARGETDEX | OCT | 0  | # BRAKQUAD |
|           | OCT | 34 | # APPRQUAD |

\*\*\*\*\*  
# ENTRY POINTS: ?GUIDSUB FOR THE IGNITION ALGORITHM, LUNLAND FOR SERVOUT  
\*\*\*\*\*

# IGNITION ALGORITHM ENTRY: DELIVERS N PASSES OF QUADRATIC GUIDANCE

|          |      |             |         |
|----------|------|-------------|---------|
| ?GUIDSUB | EXIT |             |         |
|          | CAF  | TWO         | # N = 3 |
|          | TS   | NGUIDSUB    |         |
|          | TCF  | GUILDRET +2 |         |

|         |     |          |                                     |
|---------|-----|----------|-------------------------------------|
| GUIDSUB | TS  | NGUIDSUB | # ON SUCCEEDING PASSES SKIP TTFINCR |
|         | TCF | CALCRGVG |                                     |

# NORMAL ENTRY: CONTROL COMES HERE FROM SERVOUT

|         |     |          |                                          |
|---------|-----|----------|------------------------------------------|
| LUNLAND | TC  | PHASCHNG |                                          |
|         | OCT | 00035    | # GROUP 5: RETAIN ONLY PIPA TASK         |
|         | TC  | PHASCHNG |                                          |
|         | OCT | 05023    | # GROUP 3: PROTECT GUIDANCE WITH PRIO 21 |
|         | OCT | 21000    | # JUST HIGHER THAN SERVICER'S PRIORITY   |

# Page 800

\*\*\*\*\*  
# GUILDENSTERN: AUTO-MODES MONITOR (R13)  
\*\*\*\*\*

COUNT\* \$\$/R13

# HERE IS THE PHILOSOPHY OF GUILDENSTERN: ON EVERY APPEARANCE OR DISAPPEARANCE OF THE MAN  
# DISCRETE TO SELECT P67 OR P66 RESPECTIVELY: ON EVERY APPEARANCE OF THE ATTITUDE-HOLD DISCRE  
# UNLESS THE CURRENT PROGRAM IS P67 IN WHICH CASE THERE IS NO CHANGE

|            |                |                                            |
|------------|----------------|--------------------------------------------|
| GUILDEN    | EXTEND         | # IS UN-AUTO-THROTTLE DISCRETE PRESENT?    |
| # STERN    |                | # RSB 2009: Not originally a comment.      |
|            | READ CHAN30    |                                            |
|            | MASK BIT5      |                                            |
|            | CCS A          |                                            |
|            | TCF STARTP67   | # YES                                      |
| P67NOW?    | TC CHECKMM     | # NO: ARE WE IN P67 NOW?                   |
|            | DEC 67         |                                            |
|            | TCF STABL?     | # NO                                       |
| STARTP66   | TC FASTCHNG    | # YES                                      |
|            | TC NEWMODEX    |                                            |
| DEC66      | DEC 66         |                                            |
|            | EXTEND         |                                            |
|            | DCA HDOTDISP   | # SET DESIRED ALTITUDE RATE = CURRENT      |
|            | DXCH VDGVERT   | # ALTITUDE RATE.                           |
| STRTP66A   | TC INTPRET     |                                            |
|            | SLOAD PUSH     |                                            |
|            | PBIASZ         |                                            |
|            | SLOAD PUSH     |                                            |
|            | PBIASY         |                                            |
|            | SLOAD VDEF     |                                            |
|            | PBIASX         |                                            |
|            | VXSC SET       |                                            |
|            | BIASFACT       |                                            |
|            | RODFLAG        |                                            |
|            | STOVL VBIAS    |                                            |
|            | TEMX           |                                            |
|            | VCOMP          |                                            |
|            | STOVL OLDPIPAX |                                            |
|            | ZEROVECS       |                                            |
|            | STODL DELVROD  |                                            |
|            | RODSALE        |                                            |
|            | STODL RODSCAL1 |                                            |
|            | PIPTIME        |                                            |
|            | STORE LASTTPIP |                                            |
|            | EXIT           |                                            |
|            | CAF ZERO       |                                            |
|            | TS FCOLD       |                                            |
|            | TS FWEIGHT     |                                            |
|            | TS FWEIGHT +1  |                                            |
| VRTSTART   | TS WCHVERT     |                                            |
| # Page 801 |                |                                            |
|            | CAF TWO        | # WCHPHASE = 2 ----> VERTICAL: P65,P66,P67 |
|            | TS WCHPHOLD    |                                            |
|            | TS WCHPHASE    |                                            |
|            | TC BANKCALL    | # TEMPORARY, I HOPE HOPE HOPE              |



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```
CADR  STOPRATE      # TEMPORARY, I HOPE HOPE HOPE
TC    DOWNFLAG      # PERMIT X-AXIS OVERRIDE
ADRES XOVINFLG
TC    DOWNFLAG
ADRES REDFLAG
TCF   VERTGUID

STARTP67  TC  NEWMODEX  # NO HARM IN "STARTING" P67 OVER AND OVER
          DEC  67        # SO NO NEED FOR A FASTCHNG AND NO NEED
          CAF  ZERO      # TO SEE IF ALREADY IN P67.
          TS   RODCOUNT
          CAF  TEN
          TCF  VRTSTART

STABL?    CAF  BIT13      # IS UN-ATTITUDE-HOLD DISCRETE PRESENT?
          EXTEND
          RAND  CHAN31
          CCS   A
          TCF   GUILDRET  # YES ALL'S WELL

P66NOW?   CS    MODREG
          AD    DEC66
          EXTEND
          BZF   RESTART?

          CA    RODCOUNT  # NO. HAS THE ROD SWITCH BEEN "CLICKED"?
          EXTEND
          BZF   GUILDRET   # NO. CONTINUE WITH AUTOMATIC LANDING
          TCF   STARTP66   # YES. SWITCH INTO THE ROD MODE.

RESTART?  CA    FLAGWRD1  # HAS THERE BEEN A RESTART?
          MASK  RODFLBIT
          EXTEND
          BZF   STRTP66A   # YES. REINITIALIZE BUT LEAVE VDGVERT AS
                          # IS.

          TCF   VERTGUID   # NO: CONTINUE WITH R.O.D.

# *****
# INITIALIZATION FOR THIS PASS
# *****

COUNT*  $$/F2DPS

GUILDRET  CAF  ZERO
          TS   RODCOUNT
```

# Page 802

+2

```

EXTEND
DCA      TPIP
DXCH     TPIPOLD

```

```

TC      FASTCHNG

```

```

EXTEND
DCA      PIPTIME1
DXCH     TPIP

```

```

EXTEND
DCA      TTF/8
DXCH     TTF/8TMP

```

```

CCS      FLPASSO
TCF      TTFINCR

```

```

BRSPOT1  INDEX  WCHPHASE
          TCF    NEWPHASE

```

```

# *****
# ROUTINES TO START NEW PHASES
# *****

```

```

P65START  TC      NEWMODEX
          DEC      65
          CS       TWO
          TS       WCHVERT
          TC       DOWNFLAG      # PERMIT X-AXIS OVERRIDE
          ADRES    XOVINFLG
          TCF      TTFINCR

```

```

STARTP64  TC      NEWMODEX
          DEC      64
          CA      DELTTFAP      # AUGMENT TTF/8
          ADS     TTF/8TMP
          CA      BIT12         # ENABLE RUPT10
          EXTEND
          WOR     CHAN13
          TC      DOWNFLAG      # INITIALIZE REDESIGNATION FLAG
          ADRES    REDFLAG

```

```

#          (CONTINUE TO TTFINCR)

```

```

# *****
# INCREMENT TTF/8, UPDATE LAND FOR LUNAR ROTATION, DO OTHER USEFUL THINGS
# *****
#
#           TTFINCR COMPUTATIONS ARE AS FOLLOWS --
# Page 803
#           TTF/8 UPDATED FOR TIME SINCE LAST PASS:
#                   TTF/8 = TTF/8 + (TPIP - TPIPOLD)/8
#           LANDING SITE VECTOR UPDATED FOR LUNAR ROTATION:
#
#                   ----          ----          ----          --
#                   LAND = /LAND/ UNIT(LAND - LAND(TPIP - TPIPOLD) * WM)
#           SLANT RANGE TO LANDING SITE, FOR DISPLAY:
#
#                   ----          -
#                   RANGEDSP = ABVAL(LAND - R)

```

|         |        |          |                                          |
|---------|--------|----------|------------------------------------------|
| TTFINCR | TC     | INTPRET  |                                          |
|         | DLOAD  | DSU      |                                          |
|         |        | TPIP     |                                          |
|         |        | TPIPOLD  |                                          |
|         | SLR    | PUSH     | # SHIFT SCALES DELTA TIME TO 2(17) CSECS |
|         |        | 11D      |                                          |
|         | VXSC   | VXV      |                                          |
|         |        | LAND     |                                          |
|         |        | WM       |                                          |
|         | BVSU   | RTB      |                                          |
|         |        | LAND     |                                          |
|         |        | NORMUNIT |                                          |
|         | VXSC   | VSL1     |                                          |
|         |        | /LAND/   |                                          |
|         | STODL  | LANDTEMP |                                          |
|         | EXIT   |          |                                          |
|         | DXCH   | MPAC     |                                          |
|         | DAS    | TTF/8TMP | # NOW HAVE INCREMENTED TTF/8 IN TTF/8TMP |
|         | TC     | FASTCHNG |                                          |
|         | EXTEND |          |                                          |
|         | DCA    | TTF/8TMP |                                          |
|         | DXCH   | TTF/8    |                                          |
|         | EXTEND |          |                                          |
|         | DCA    | LANDTEMP |                                          |
|         | DXCH   | LAND     |                                          |
|         | EXTEND |          |                                          |

```

DCA    LANDTEMP +2
DXCH   LAND      +2
EXTEND
DCA    LANDTEMP +4
DXCH   LAND      +4

```

# Page 804

```

TC      TDISPSET
TC      FASTCHNG      # SINCE REDESIG MAY CHANGE LANDTEMP

```

```

BRSPOT2    INDEX  WCHPHASE
            TCF    PREGUIDE

```

```

# *****
# LANDING SITE PERTURBATION EQUATIONS
# *****

```

```

REDESIG    CA      FLAGWRD6      # IS REDFLAG SET?
            MASK    REDFLBIT
            EXTEND
            BZF     RGVGCALC      # NO:  SKIP REDESIGNATION LOGIC

            CA      TREDES        # YES:  HAS TREDES REACHED ZERO?
            EXTEND
            BZF     RGVGCALC      # YES:  SKIP REDESIGNATION LOGIC

```

```

INHINT
CA      ELINCR1
TS      ELINCR
CA      AZINCR1
TS      AZINCR
TC      FASTCHNG

```

```

CA      ZERO
TS      ELINCR1
TS      AZINCR1
TS      ELINCR  +1
TS      AZINCR  +1

```

```

CA      FIXLOC      # SET PD TO 0
TS      PUSHLOC

```

```

TC      INTPRET
VLOAD   VSU
        LAND
        R

```

#

-----

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```
RTB    PUSH                # PUSH DOWN UNIT (LAND - R)
      NORMUNIT
VXV    VSL1
      YNBPIP                #
VXSC    PDDL                # PUSH DOWN - ELINCR(--- * UNIT(---- - -))
      ELINCR
      AZINCR
VXSC    VSU
      YNBPIP
VAD    PUSH                # RESULTING VECTOR IS 1/2 REAL SIZE
```

# Page 805

```
      DLOAD    DSU          # MAKE SURE REDESIGNATION IS NOT
      0          #      TOO CLOSE TO THE HORIZON.
      DEPRCRIT
BMN    DLOAD
      REDES1
      DEPRCRIT
STORE  0
REDES1 DLOAD    DSU
      LAND
      R
DDV    VXSC
      0
VAD    UNIT
      R
VXSC    VSL1
      /LAND/
STORE  LANDTEMP
EXIT
      # LOOKANGL WILL BE COMPUTED AT RGVGCALC

TC      FASTCHNG

EXTEND
DCA    LANDTEMP
DXCH   LAND
EXTEND
DCA    LANDTEMP +2
DXCH   LAND +2
EXTEND
DCA    LANDTEMP +4
DXCH   LAND +4

TCF    RGVGCALC
```

```

# *****
# COMPUTE STATE IN GUIDANCE COORDINATES
# *****
#
#       RGVGCALC COMPUTATIONS ARE AS FOLLOWS:--
#       VELOCITY RELATIVE TO THE SURFACE
#
#           ----- - - - -
#           ANGTERM = V + R * WM
#       STATE IN GUIDANCE COORDINATES:
#
#           * - - - -
#           RGU = CG (R - LAND)
#
#           * - - - -
#           VGU = CG (V - WM * R)
# Page 806 actually starts one line earlier but that would separate the markers from
#
#       HORIZONTAL VELOCITY FOR DISPLAY
#
#           VHORIZ = 8 ABVAL (0, VG , VG )
#                               2      1
#       DEPRESSION ANGLE FOR DISPLAY:
#
#           LOOKANGL = ARCSIN(UNIT(R - LAND).XMBPIP)

CALCRGVG      TC      INTERPRET      # IN IGNALG, COMPUTE V FROM INTEGRATION
              VLOAD    MXV            #          OUTPUT AND TRIM CORRECTION TERM
              VATT1     #              COMPUTED LAST PASS AND LEFT IN UNFC/2
              REFSMMAT
              VSR1      VAD
              UNFC/2
              STORE     V
              EXIT

RGVGCALC      TC      INTERPRET      # ENTER HERE TO RECOMPUTE RG AND VG
              VLOAD    VXV
              R
              WM
              VAD      VSR2           # RESCALE TO UNITS OF 2(9) M/CS
              V
              STORE     ANGTERM
              MXV
              CG        # NO SHIFT SINCE ANGTERM IS DOUBLE SIZED
              STORE     VGU
              PDDL      VDEF          # FORM (0,VG ,VG ) IN UNITS OF 2(10) M/CS
              ZEROVECS #              2      1
              ABVAL     SL3
              STOVL     VHORIZ        # VHORIZ FOR DISPLAY DURING P65.

```

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```

      R      #      -      ----
VSU    PUSH  # PUSH DOWN R - LAND
      LAND
MXV    VSL1
      CG
STORE  RGU
ABVAL
STOVL  RANGEDSP
RTB    DOT      # NOW IN MPAC IS SINE(LOOKANGL)/4
      NORMUNIT
      XNBPIP
EXIT
CA     FIXLOC      # RESET PUSH DOWN POINTER
TS     PUSHLOC
```

# Page 807

```

CA     MPAC      # COMPUTE LOOKANGLE ITSELF
DOUBLE
TC     BANKCALL
CADR   SPARCSIN -1
AD     1/2DEG
EXTEND
MP     180DEGS
TS     LOOKANGL      # LOOKANGL FOR DISPLAY DURING P64
```

```

BRSPOT3  INDEX  WCHPHASE
          TCF    WHATGUID
```

```

# *****
# TTF/8 COMPUTATION
# *****
```

```

TTF/8CL  TC      INTPRETX
          DLOAD*
          JDG2TTF,1
STODL*   TABLTTF +6      # A(3) = 8 JDG  TO TABLTTF
          ADG2TTF,1      #
          STODL  TABLTTF +4      # A(2) = 6 ADG  TO TABLTTF
          VGU      +4      #
          DMP      DAD*
          3/4DP
          VDG2TTF,1
STODL*   TABLTTF +2      # A(1) = (6 VGU  + 18 VDG )/8 TO TABLTTF
          RDG +4,1      #
          DSU      DMP
```

```

                                RGU +4
                                3/8DP
STORE    TABLTTF                # A(0) = -24 (RGU - RDG )/64 TO TABLTTF
EXIT   #                2        2

CA       BIT8
TS       TABLTTF +10            # FRACTIONAL PRECISION FOR TTF TO TABLE

EXTEND
DCA      TTF/8
DXCH     MPAC                   # LOADS TTF/8 (INITIAL GUESS) INTO MPAC
CAF      TWO                     # DEGREE - ONE
TS       L
CAF      TABLTTF L
TC       ROOTPSRS               # YIELDS TTF/8 IN MPAC
INDEX    WCHPHASE
TCF      WHATALM

EXTEND                                # GOOD RETURN
DCA      MPAC                     # FETCH TTF/8 KEEPING IT IN MPAC
DXCH     TTF/8                     # CORRECTED TTF/8

# Page 808

TC       TDISPSET

#           (CONTINUE TO QUADGUID)

# *****
# MAIN GUIDANCE EQUATION
# *****
#
#       AS PUBLISHED --
#
#               ---      ---      ---      ---
#               6(VDG + VG)  12(RDG - RG)
#       ACG = ADG + ----- + -----
#                       TTF      (TTF)(TTF)
#
#       AS HERE PROGRAMMED --
#
#               ---      ---
#               3 (1/4(RDG - RG)  ---  ---)
#               - (----- + VDG + VG)
#               4 (      TTF/8      )
#       ACG = ----- + ADG
#                       TTF/8

QUADGUID    CS      TTF/8
            AD      LEADTIME        # LEADTIME IS A NEGATIVE NUMBER

```



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```
AD      POSMAX      # SAFEGUARD THE COMPUTATIONS THAT FOLLOW
TS      L            #      BY FORCING -TTF*LEADTIME > OR = ZERO
CS      L
AD      L
ZL
EXTEND
DV      TTF/8
TS      BUF          # - RATIO OF LAG-DIMINISHED TTF TO TTF
EXTEND
SQUARE
TS      BUF +1
AD      BUF
XCH     BUF +1      # RATIO SQUARED - RATIO
AD      BUF +1
TS      MPAC        # COEFFICIENT FOR VGU TERM
AD      BUF +1
INDEX   FIXLOC
TS      26D         # COEFFICIENT FOR RDG-RGU TERM
AD      BUF +1
INDEX   FIXLOC
TS      28D         # COEFFICIENT FOR VDG TERM
AD      BUF
AD      POSMAX

# Page 809

AD      BUF +1
AD      BUF +1
INDEX   FIXLOC
TS      30D         # COEFFICIENT FOR ADG TERM

CAF     ZERO
TS      MODE

TC      INTERPRETX
VXSC    PDDL
        VGU
        28D
VXSC*   PDVL*
        VDG,1
        RDG,1
VSU     V/SC
        RGU
        TTF/8
VSR2    VXSC
        26D
VAD     VAD
V/SC    VXSC
```

```

                                TTF/8
                                3/4DP
                                PDDL VXSC*
                                30D
                                ADG,1
                                VAD
AFCCALC1    VXM    VSL1          # VERGUID COMES HERE
                                CG
                                PDVL V/SC
                                GDT/2
                                GSCALE
                                BVSU STADR
                                STORE UNFC/2          # UNFC/2 NEED NOT BE UNITIZED
                                ABVAL
AFCCALC2    STODL /AFC/          # MAGNITUDE OF AFC FOR THROTTLE
                                UNFC/2          # VERTICAL COMPONENT
                                DSQ    PDDL
                                UNFC/2 +2      # OUT-OF-PLANE
                                DSQ    PDDL
                                HIGHESTF
                                DDV    DSQ
                                MASS          #
                                DSU    DSU          # AMAXHORIZ = SQRT(ATOTAL - A2 - A2)
                                BPL    DLOAD        #
  1    0
                                AFCCALC3
                                ZEROVECS
AFCCALC3    SQRT    DAD
                                UNFC/2 +4
# Page 810
                                BPL    BDSU
                                AFCLEND
                                UNFC/2 +4
                                STORE UNFC/2 +4
AFCCLEND    EXIT
                                TC      FASTCHNG
                                CA      WCHPHASE      # PREPARE FOR PHASE SWITCHING LOGIC
                                TS      WCHPHOLD
                                INCR    FLPASSO      # INCREMENT PASS COUNTER

BRSPOT4     INDEX    WCHPHASE
                                TCF      AFTRGUID

```

```

# *****
# ERECT GUIDANCE-STABLE MEMBER TRANSFORMATION MATRIX
# *****

```

```
CGCALC      CAF      EBANK5
            TS        EBANK
            EBANK=    TCGIBRAK
            EXTEND
            INDEX     WCHPHASE
            INDEX     TARGTDEX
            DCA        TCGFBRAK
            INCR       BBANK
            INCR       BBANK
            EBANK=     TTF/8
            AD          TTF/8
            XCH         L
            AD          TTF/8
            CCS         A
            CCS         L
            TCF         EXTLOGIC
            TCF         EXTLOGIC
            NOOP

            TC          INTERPX
            VLOAD       UNIT
                       LAND
            STODL       CG
                       TTF/8
            DMP*        VXSC
                       GAINBRAK,1    # NUMERO MYSTERIOSO
                       ANGTERM

            VAD
                       LAND
            VSU         RTB
                       R
                       NORMUNIT

            VXV         RTB
                       LAND
                       NORMUNIT
            STOVL       CG +6        # SECOND ROW
                       CG
            VXV         VSL1
                       CG +6
            STORE       CG +14
            EXIT
```

# Page 811

```
#      (CONTINUE TO EXTLOGIC)
#
```

```

# *****
# PREPARE TO EXIT
# *****
#
# DECIDE (1) HOW TO EXIT, AND (2) WHETHER TO SWITCH PHASES
#
EXTLOGIC      INDEX  WCHPHASE      # WCHPHASE = 1  APPRQUAD
              CA     TENDBRAK      # WCHPHASE = 0  BRAKQUAD
              AD     TTF/8
EXSPOT1       EXTEND
              INDEX  WCHPHASE
              BZMF   WHATEXIT
              TC     FASTCHNG
              CA     WCHPHOLD
              AD     ONE
              TS     WCHPHASE
              CA     ZERO
              TS     FLPASSO      # RESET FLPASSO
              INDEX  WCHPHOLD
              TCF    WHATEXIT

# *****
# ROUTINES FOR EXITING FROM LANDING GUIDANCE
# *****
#
# 1.   EXGSUB IS THE RETURN WHEN GUIDSUB IS CALLED BY THE IGNITION ALGORITHM.
# 2.   EXBRAK IN THE EXIT USED DURING THE BRAKING PHASE.  IN THIS CASE UNIT(R) IS T
# 3.   EXNORM IS THE EXIT USED AT OTHER TIMES DURING THE BURN.
# (XOVFLOW IS A SUBROUTINE OF EXBRAK AND EXNORM CALLED WHEN OVERFLOW OCCURRED ANYWH

EXGSUB        TC     INTERPRET      # COMPUTE TRIM VELOCITY CORRECTION TERM.
# Page 812
              VLOAD  RTB
              UNFC/2
              NORMUNIT
              VXSC    VXSC
              ZOOMTIME
              TRIMACCL
              STORE   UNFC/2
              EXIT
              CCS     NGUIDSUB

```

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|            |       |          |                                          |
|------------|-------|----------|------------------------------------------|
|            | TCF   | GUIDSUB  |                                          |
|            | CCS   | NIGNLOOP |                                          |
|            | TCF   | +3       |                                          |
|            | TC    | ALARM    |                                          |
|            | OCT   | 01412    |                                          |
| +3         | TC    | POSTJUMP |                                          |
|            | CADR  | DDUMCALC |                                          |
| EXBRAK     | TC    | INTPRET  |                                          |
|            | VLOAD |          |                                          |
|            |       | UNIT/R/  |                                          |
|            | STORE | UNWC/2   |                                          |
|            | EXIT  |          |                                          |
|            | TCF   | STEER?   |                                          |
| EXNORM     | TC    | INTPRET  |                                          |
|            | VLOAD | VSU      |                                          |
|            |       | LAND     |                                          |
|            |       | R        |                                          |
|            | RTB   |          |                                          |
|            |       | NORMUNIT |                                          |
|            | STORE | UNWC/2   | # UNIT(LAND - R) IS TENTATIVE CHOICE     |
|            | VXV   | DOT      |                                          |
|            |       | XNBPIP   |                                          |
|            |       | CG +6    |                                          |
|            | EXIT  |          | # WITH PROJ IN MPAC 1/8 REAL SIZE        |
|            | CS    | MPAC     | # GET COEFFICIENT FOR CG +14             |
|            | AD    | PROJMAX  |                                          |
|            | AD    | POSMAX   |                                          |
|            | TS    | BUF      |                                          |
|            | CS    | BUF      |                                          |
|            | ADS   | BUF      | # RESULT IS 0 IF PROJMAX - PROJ NEGATIVE |
|            | CS    | PROJMIN  | # GET COEFFICIENT FOR UNIT(LAND - R)     |
|            | AD    | MPAC     |                                          |
|            | AD    | POSMAX   |                                          |
|            | TS    | BUF +1   |                                          |
|            | CS    | BUF +1   |                                          |
| # Page 813 | ADS   | BUF +1   | # RESULT IS 0 IF PROJ - PROJMIN NEGATIVE |
| UNWCLOOP   | CAF   | FOUR     |                                          |
|            | MASK  | SIX      |                                          |
|            | TS    | Q        |                                          |

|          |        |          |                                    |
|----------|--------|----------|------------------------------------|
|          | CA     | EBANK5   |                                    |
|          | TS     | EBANK    |                                    |
|          | EBANK= | CG       |                                    |
|          | CA     | BUF      |                                    |
|          | EXTEND |          |                                    |
|          | INDEX  | Q        |                                    |
|          | MP     | CG +14   |                                    |
|          | INCR   | BBANK    |                                    |
|          | EBANK= | UNWC/2   |                                    |
|          | INDEX  | Q        |                                    |
|          | DXCH   | UNWC/2   |                                    |
|          | EXTEND |          |                                    |
|          | MP     | BUF +1   |                                    |
|          | INDEX  | Q        |                                    |
|          | DAS    | UNWC/2   |                                    |
|          | CCS    | Q        |                                    |
|          | TCF    | UNWCLOOP |                                    |
|          | INCR   | BBANK    |                                    |
|          | EBANK= | PIF      |                                    |
| STEER?   | CA     | FLAGWRD2 | # IF STEERSW DOWN NO OUTPUTS       |
|          | MASK   | STEERBIT |                                    |
|          | EXTEND |          |                                    |
|          | BZF    | RATESTOP |                                    |
| EXVERT   | CA     | OVFIND   | # IF OVERFLOW ANYWHERE IN GUIDANCE |
|          | EXTEND |          | # DON'T CALL THROTTLE OR FINDCDUW  |
|          | BZF    | +13      |                                    |
| EXOVLW   | TC     | ALARM    | # SOUND THE ALARM NON-ABORTIVELY   |
|          | OCT    | 01410    |                                    |
| RATESTOP | CAF    | BIT13    | # ARE WE IN ATTITUDE-HOLD?         |
|          | EXTEND |          |                                    |
|          | RAND   | CHAN31   |                                    |
|          | EXTEND |          |                                    |
|          | BZF    | DISPEXIT | # YES                              |
|          | TC     | BANKCALL | # NO: DO A STOPRATE                |
|          | CADR   | STOPRATE |                                    |
|          | TCF    | DISPEXIT |                                    |
| GDUMP1   | TC     | THROTTLE |                                    |

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```
TC      INTPRET
CALL
        FINDCDUW -2
EXIT

#      (CONTINUE TO DISPEXIT)

# *****
# GUIDANCE LOOP DISPLAYS
# *****

DISPEXIT      EXTEND      # KILL GROUP 3:  DISPLAYS WILL BE
DCA      NEG0      #      RESTORED BY NEXT GUIDANCE CYCLE.
DXCH      -PHASE3

+3      CS      FLAGWRD8      # IF FLUNDISP IS SET, NO DISPLAY THIS PASS
MASK      FLUNDBIT
EXTEND
BZF      ENDLLJOB      # TO PICK UP THE TAG

INDEX      WCHPHOLD
TCF      WHATDISP

-2      TC      PHASCHNG      # KILL GROUP 5
OCT      00035

P63DISPS      CAF      V06N63
DISPCOMN      TC      BANKCALL
CADR      REGODSPR

ENDLLJOB      TCF      ENDOFJOB

P64DISPS      CA      TREDES      # HAS TREDES REACHED ZERO?
EXTEND
BZF      RED-OVER      # YES:  CLEAR REDESIGNATION FLAG

CS      FLAGWRD6      # NO:  IS REDFLAG SET?
MASK      REDFLBIT
EXTEND
BZF      REDES-OK      # YES:  DO STATIC DISPLAY

CAF      V06N64      # OTHERWISE USE FLASHING DISPLAY
TC      BANKCALL
CADR      REFLASHR
TCF      GOTOP00H      # TERMINATE
TCF      P64CEED      # PROCEED      PERMIT REDESIGNATIONS
```

```

# Page 815
TCF      P64DISPS      # RECYCLE
TCF      ENDLLJOB
P64CEED  CAF      ZERO
          TS      ELINCR1
          TS      AZINCR1
          TC      UPFLAG      # ENABLE REDESIGNATION LOGIC
          ADRES   REDFLAG
          TCF      ENDOFJOB
RED-OVER  TC      DOWNFLAG
          ADRES   REDFLAG
REDES-OK  CAF      V06N64
          TCF      DISPCOMN
VERTDISP  CAF      V06N60
          TCF      DISPCOMN

```

```

# *****
# GUIDANCE FOR P65
# *****

```

```

VERTGUID  CCS      WCHVERT
          TCF      P67VERT      # POSITIVE NON-ZERO ---> P67
          TCF      P66VERT      # +0

```

```

#
#      THE P65 GUIDANCE EQUATION IS AS FOLLOWS --
#
#              ----  ---
#              V2FG - VGU
#      ACG = -----
#              TAUVERT

```

```

P65VERT   TC      INTPRET
          VLOAD   VSU
                   V2FG
                   VGU
          V/SC    GOTO
                   TAUVERT
                   AFCCALC1

```

```

# Page 816

```

```

# *****

```



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# GUIDANCE FOR P66

# \*\*\*\*\*

P66VERT TC POSTJUMP  
CADR P66VERTA

P67VERT TC PHASCHNG # TERMINATE GROUP 3.  
OCT 00003

TC INTPRET  
VLOAD GOTO  
V  
VHORCOMP

SETLOC P66LOC  
BANK  
COUNT\* \$\$/F2DPS

RODTASK CAF PRI022  
TC FINDVAC  
EBANK= DVCNTR  
2CADR RODCOMP

TCF TASKOVER

P66VERTA TC PHASCHNG # TERMINATE GROUP 3.  
OCT 00003

CAF 1SEC  
TC TWIDDLE  
ADRES RODTASK

RODCOMP INHINT  
CAF ZERO  
XCH RODCOUNT  
EXTEND  
MP RODSCAL1  
DAS VDGVERT

# UPDATE DESIRED ALTITUDE RATE.

EXTEND # SET OLDPIPAX,Y,Z = PIPAX,Y,Z

DCA PIPAX  
DXCH OLDPIPAX  
DXCH RUPTREG1  
CA PIPAZ  
XCH OLDPIPAZ  
XCH RUPTREG3

# SET RUPTREG1,2,3 = OLDPIPAX,Y,Z

```

EXTEND
DCA      TIME2      # SHAPSHOT TIME OF PIPA READING.

# Page 817
DXCH     THISTPIP

CA       OLDPIPAX
AD       PIPATMPX
TS       MPAC        # MPAC(X) = PIPAX + PIPATMPX
CA       OLDPIPAY
AD       PIPATMPY
TS       MPAC +3     # MPAC(Y) = PIPAY + PIPATMPY
CA       OLDPIPAZ
AD       PIPATMPZ
TS       MPAC +5     # MPAC(Z) = PIPAZ + PIPATMPZ

CS       OLDPIPAX
AD       TEMX
AD       RUPTREG1
TS       DELVROD
CS       OLDPIPAY
AD       TEMY
AD       RUPTREG2
TS       DELVROD +2
CS       OLDPIPAZ
AD       TEMZ
AD       RUPTREG3
TS       DELVROD +4

CAF      ZERO
TS       MPAC +1     # ZERO LO-ORDER MPAC COMPONENTS
TS       MPAC +4
TS       MPAC +6
TS       TEMX        # ZERO TEMX, TEMY, AND TEMZ SO WE WILL
TS       TEMY        #          KNOW WHEN READACCS CHANGES THEM.
TS       TEMZ
CS       ONE
TS       MODE
TC       INTERPRET
ITRPNT1  VXSC      PDDL      # SCALE MPAC TO M/CS *2(-7) AND PUSH      (6)
          KPIP1
          THISTPIP
          DSU
          PIPTIME
STORE    30D        # 30-31D CONTAINS TIME IN CS SINCE PIPTIME
DDV      PDVL      #                                     (8)

```

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# Page 818

|       |          |   |                                   |
|-------|----------|---|-----------------------------------|
|       | 4SEC(28) |   |                                   |
|       | GDT/2    |   |                                   |
| VSU   | VXSC     | # | (6)                               |
|       | VBIAS    |   |                                   |
| VSL2  | VAD      |   |                                   |
|       | V        |   |                                   |
| VAD   | STADR    | # | (0)                               |
| STOVL | 24D      | # | STORE UPDATED VELOCITY IN 24-29D  |
|       | R        |   |                                   |
| UNIT  |          |   |                                   |
| STORE | 14D      |   |                                   |
| DOT   | SL1      |   |                                   |
|       | 24D      |   |                                   |
| STODL | HDOTDISP | # | UPDATE HDOTDISP RATE FOR NOUN 63. |
|       | 30D      |   |                                   |
| SL    | DMP      |   |                                   |
|       | 11D      |   |                                   |
|       | HDOTDISP |   |                                   |
| DAD   | DSU      |   |                                   |
|       | 36D      |   |                                   |
|       | /LAND/   |   |                                   |
| STODL | HCALC1   | # | UPDATE HCALC1 FOR NOUN 63.        |
|       | HDOTDISP |   |                                   |
| BDSU  | DDV      |   |                                   |
|       | VDGVERT  |   |                                   |
|       | TAUROD   |   |                                   |
| PDVL  | ABVAL    | # | (2)                               |
|       | GDT/2    |   |                                   |
| DDV   | SR2      |   |                                   |
|       | GSCALE   |   |                                   |
| STORE | 20D      |   |                                   |
| DAD   |          | # | (0)                               |
| PDVL  | CALL     | # | (2)                               |
|       | UNITX    |   |                                   |
|       | CDU*NBSM |   |                                   |
| DOT   |          |   |                                   |
|       | 14D      |   |                                   |
| STORE | 22D      |   |                                   |
| BDDV  | STADR    | # | (0)                               |
| STOVL | /AFC/    |   |                                   |
|       | DELVRD   |   |                                   |
| VXSC  | VAD      |   |                                   |
|       | KPIP1    |   |                                   |
|       | VBIAS    |   |                                   |
| ABVAL | PDDL     | # | (2)                               |

|            |          |             |                                 |
|------------|----------|-------------|---------------------------------|
|            | THISTPIP |             |                                 |
| DSU        | PDDL     | #           | (4)                             |
|            | LASTTPIP |             |                                 |
|            | THISTPIP |             |                                 |
| STODL      | LASTTPIP | #           | (2)                             |
| DDV        | BDDV     | #           | (0)                             |
|            | SHFTFACT |             |                                 |
| PDDL       | DMP      | #           | (2)                             |
|            | FWEIGHT  |             |                                 |
|            | BIT1H    |             |                                 |
| DDV        | DDV      |             |                                 |
|            | MASS     |             |                                 |
|            | SCALEFAC |             |                                 |
| # Page 819 |          |             |                                 |
| DAD        | PDDL     | #           | (4)                             |
|            | OD       |             |                                 |
|            | 20D      |             |                                 |
| DDV        | DSU      | #           | (2)                             |
|            | 22D      |             |                                 |
| DMP        | DAD      |             |                                 |
|            | LAG/TAU  |             |                                 |
|            | /AFC/    |             |                                 |
| PDDL       | DDV      | #           | (4)                             |
|            | MAXFORCE |             |                                 |
|            | MASS     |             |                                 |
| PDDL       | DDV      | #           | (6)                             |
|            | MINFORCE |             |                                 |
|            | MASS     |             |                                 |
| PUSH       | BDSU     | #           | (8)                             |
|            | 2D       |             |                                 |
| BMN        | DLOAD    | #           | (6)                             |
|            | AFCSPOT  |             |                                 |
| DLOAD      | PUSH     | #           | (6)                             |
| BDSU       | BPL      |             |                                 |
|            | 2D       |             |                                 |
|            | AFCSPOT  |             |                                 |
|            | DLOAD    | #           | (4)                             |
| AFCSPOT    | DLOAD    | #           | (2), (4), OR                    |
|            | SETPD    | #           | (2)                             |
|            | 2D       |             |                                 |
|            | /AFC/    | #           | (0)                             |
| ITRPNT2    | EXIT     |             |                                 |
|            | DXCH     | MPAC        | # MPAC = MEASURED ACCELARATION. |
|            | TC       | BANKCALL    |                                 |
|            | CADR     | THROTTLE +3 |                                 |
|            | TC       | INTPRET     |                                 |

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```

                                # PICK UP UPDATED VELOCITY VECTOR.
                                24D
VHORCOMP  VSL2  VAD
                                DELVS
                                VSR2  PDVL
                                R
                                UNIT  VXSC
                                HDOTDISP
                                VSL1  BVSU
                                ABVAL
                                STORE  VHORIZ
                                EXIT
                                TC      BANKCALL      # PUT UP V06N60 DISPLAY BUT AVOID PHASCHNG
                                CADR    DISPEXIT +3
BIT1H     OCT      00001
SHFTFACT  2DEC     1 B-17
# Page 820
BIASFACT  2DEC     655.36 B-28
```

```
# *****
# REDESIGNATOR TRAP
# *****
```

```

                                BANK      11
                                SETLOC    F2DPS*11
                                BANK
                                COUNT*    $$/F2DPS
PITFALL   XCH      BANKRUPT
                                EXTEND
                                QXCH      QRUPT
                                TC        CHECKMM      # IF NOT IN P64, NO REASON TO CONTINUE
                                DEC        64
                                TCF       RESUME
                                EXTEND
                                READ      CHAN31
                                COM
                                MASK     ALL4BITS
                                TS        ELVIRA
                                CAF       TWO
                                TS        ZERLINA
                                CAF       FIVE
```

|                                               |        |          |                                       |
|-----------------------------------------------|--------|----------|---------------------------------------|
|                                               | TC     | TWIDDLE  |                                       |
|                                               | ADRES  | REDESMON |                                       |
|                                               | TCF    | RESUME   |                                       |
| # REDESIGNATOR MONITOR (INITIATED BY PITFALL) |        |          |                                       |
| PREMON1                                       | TS     | ZERLINA  |                                       |
| PREMON2                                       | CAF    | SEVEN    |                                       |
|                                               | TC     | VARDELAY |                                       |
| REDESMON                                      | EXTEND |          |                                       |
|                                               | READ   | 31       |                                       |
|                                               | COM    |          |                                       |
|                                               | MASK   | ALL4BITS |                                       |
|                                               | XCH    | ELVIRA   |                                       |
|                                               | TS     | L        |                                       |
|                                               | CCS    | ELVIRA   | # DO ANY BITS APPEAR THIS PASS?       |
|                                               | TCF    | PREMON2  | # Y: CONTINUE MONITOR                 |
|                                               | CCS    | L        | # N: ANY LAST PASS?                   |
|                                               | TCF    | COUNT'EM | # Y: COUNT 'EM, RESET RUPT, TERMINATE |
| # Page 821                                    | CCS    | ZERLINA  | # N: HAS ZERLINA REACHED ZERO YET?    |
|                                               | TCF    | PREMON1  | # N: DIMINISH ZERLINA, COUNT          |
| RESETRPT                                      | CAF    | BIT12    | # Y: RESET RUPT. TERMINATE            |
|                                               | EXTEND |          |                                       |
|                                               | WOR    | CHAN13   |                                       |
|                                               | TCF    | TASKOVER |                                       |
| COUNT'EM                                      | CAF    | BIT13    | # ARE WE IN ATTITUDE-HOLD?            |
|                                               | EXTEND |          |                                       |
|                                               | RAND   | CHAN31   |                                       |
|                                               | EXTEND |          |                                       |
|                                               | BZF    | RESETRPT | # YES: SKIP REDESIGNATION LOGIC.      |
|                                               | CA     | L        | # NO.                                 |
|                                               | MASK   | -AZBIT   |                                       |
| -AZ                                           | CCS    | A        |                                       |
|                                               | CS     | AZEACH   |                                       |
|                                               | ADS    | AZINCR1  |                                       |
|                                               | CA     | L        |                                       |
|                                               | MASK   | +AZBIT   |                                       |
|                                               | CCS    | A        |                                       |
| +AZ                                           | CA     | AZEACH   |                                       |
|                                               | ADS    | AZINCR1  |                                       |
|                                               | CA     | L        |                                       |
|                                               | MASK   | -ELBIT   |                                       |

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```
-EL      CCS      A
         CS      ELEACH
         ADS      ELINCR1
         CA      L
         MASK     +ELBIT
         CCS      A
+EL      CA      ELEACH
         ADS      ELINCR1
         TCF      RESETRPT
```

# THESE EQUIVALENCES ARE BASED ON GSOP CHAPTER 4, REVISION 16 OF P64LM

```
+ELBIT    =      BIT2          # -PITCH
-ELBIT    =      BIT1          # +PITCH
+AZBIT    =      BIT5
-AZBIT    =      BIT6
```

# Page 822

```
ALL4BITS  OCT      00063
AZEACH    DEC      .03491      # 2 DEGREES
ELEACH    DEC      .00873      # 1/2 DEGREE
```

```
# *****
# R.O.D. TRAP
# *****
```

```
BANK      20
SETLOC    RODTRAP
BANK
COUNT*   $$/F2DPS          # *****

DESCBITS  MASK      BIT7          # COME HERE FROM MARKRUPT CODING WITH BIT
         CCS      A              #      7 OR 6 OF CHANNEL 16 IN A; BIT 7 MEANS
         CS      TWO            #      - RATE INCREMENT, BIT 6 + INCREMENT.
         AD      ONE
         ADS      RODCOUNT
         TCF      RESUME          # TRAP IS RESET WHEN SWITCH IS RELEASED

BANK      31
SETLOC    F2DPS*31
BANK
COUNT*   $$/F2DPS
```

```
# *****
# DOUBLE PRECISION ROOT FINDER SUBROUTINE (BY ALLAN KLUMPP)
```

```

# *****
#
#                                     N      N-1
#      ROOTPSRS FINDS ONE ROOT OF THE POWER SERIES A X  + A  X  + ... + A X + A
#                                     N      N-1              1      0
# USING NEWTON'S METHOD STARTING WITH AN INITIAL GUESS FOR THE ROOT.  THE ENTERING DA
#      A      SP      LOC-3      ADRES FOR REFERENCING PWR COF TABL
#      L      SP      N-1      N IS THE DEGREE OF THE POWER SERIES
#      MPAC    DP      X      INITIAL GUESS FOR ROOT
#
#      LOC-2N  DP      A(0)
#      ...
#      LOC     DP      A(N)
#      LOC+2   SP      PRECROOT      PREC RQD OF ROOT (AS FRACT OF 1ST GUESS)
#
# Page 823
# THE DP RESULT IS LEFT IN MPAC UPON EXIT, AND A SP COUNT OF THE ITERATIONS TO CONVER
# RETURN IS NORMALLY TO LOC(TC ROOTPSRS)+3.  IF ROOTPSRS FAILS TO CONVERGE TO IN 8 PA
# OUTPUTS ARE NOT TO BE TRUSTED.
#
# PRECAUTION:  ROOTPSRS MAKES NO CHECKS FOR OVERFLOW OR FOR IMPROPER USAGE.  IMPROPER
# PRECLUDE CONVERGENCE OR REQUIRE EXCESSIVE ITERATIONS.  AS A SPECIFIC EXAMPLE, ROOT
# COEFFICIENT TABLE BY MULTIPLYING EACH A(I) BY I, WHERE I RANGES FROM 1 TO N.  IF AD
# COEFFICIENT TABLE = 1 OR >1 IN MAGNITUDE, ONLY THE EXCESS IS RETAINED.  ROOTPSRS MA
# ROOT NONETHELESS, BUT IT MAY TAKE AN EXCESSIVE NUMBER OF ITERATIONS.  THEREFORE TH
#
# 1.  USER'S RESPONSIBILITY TO ASSURE THAT I X A(I) < 1 IN MAGNITUDE FOR ALL I.
#
# 2.  USER'S RESPONSIBILITY TO ASSURE OVERFLOW WILL NOT OCCUR IN EVALUTATING E
#
# POWER SERIES.  THIS OVERFLOW WOULD BE PRODUCED BY SUBROUTINE POWRSERS, CA
#
# PRECLUDE EVENTUAL CONVERGENCE.
#
# 3.  AT PRESENT, ERASABLE LOCATIONS ARE RESERVED ONLY FOR N UP TO 5.  AN N IN
#
# ALL ERASABLES USED BY ROOTPSRS ARE UNSWITCHED LOCATED IN THE REGION FROM
#
# 4.  THE ITERATION COUNT RETURNED IN MPAC+2 MAY BE USED TO DETECT ABNORMAL PER
#
#
#                                     # STORE ENTERING DATA, INITIALIZE ERASABLES
ROOTPSRS      EXTEND
               QXCH  RETROOT      # RETURN ADRES
               TS     PWRPTR      # PWR TABLE POINTER
               DXCH  MPAC +3      # PWR TABLE ADRES, N-1
               CA     DERTABLL
               TS     DERPTR      # DER TABL POINTER
               TS     MPAC +5      # DER TABL ADRES
               CCS    MPAC +4      # NO POWER SERIES DEGREE 1 OR LESS
               TS     MPAC +6      # N-2
               CA     ZERO      # MODE USED AS ITERATION COUNTER.  MODE
               TS     MODE      # MUST BE POS SO ABS WON'T COMP MPAC+3 ETC.

```



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```

# COMPUTE CRITERION TO STOP ITERATING
EXTEND
DCA      MPAC      # FETCH ROOT GUESS, KEEPING IT IN MPAC
DXCH     ROOTPS    # AND IN ROOTPS
INDEX    MPAC +3   # PWR TABLE ADRES
CA       5         # PRECROOT TO A
TC       SHORTMP   # YIELDS DP PRODUCT IN MPAC
TC       USPRCADR
CADR     ABS
DXCH     MPAC
DXCH     DXCRIT    # CRITERION

# SET UP DER COF TABL

# Page 824
EXTEND
INDEX    PWRPTR
DCA      3
DXCH     MPAC      # A(N) TO MPAC

CA       MPAC +4   # N-1 TO A

DERCLOOP TS       PWRCNT    # LOOP COUNTER
AD       ONE
TC       DMPNSUB    # YIELDS DERCOF = I X A(I) IN MPAC
EXTEND
INDEX    PWRPTR
DCA      1
DXCH     MPAC      # (I-1) TO MPAC, FETCHING DERCOF
INDEX    DERPTR
DXCH     3         # DERCOF TO DER TABLE
CS       TWO
ADS      PWRPTR    # DECREMENT PWR POINTER
CS       TWO
ADS      DERPTR    # DECREMENT DER POINTER
CCS      PWRCNT
TCF      DERCLOOP

# CONVERGE ON ROOT
ROOTLOOP EXTEND
DCA      ROOTPS    # FETCH CURRENT ROOT
DXCH     MPAC      # LEAVE IN MPAC
EXTEND
DCA      MPAC +5   # LOAD A, L WITH DER TABL ADRES, N-2
TC       POWRSERS  # YIELDS DERIVATIVE IN MPAC
EXTEND
```

```

DCA      ROOTPS
DXCH     MPAC      # CURRENT ROOT TO MPAC, FETCHING DERIVATIVE
DXCH     BUF       # LEAVE DERIVATIVE IN BUF AS DIVISOR
EXTEND
DCA      MPAC +3    # LOAD A, L WITH PWR TABL ADRES, N-1
TC       POWRSERS   # YIELDS RESIDUAL IN MPAC

TC       USPRCADR
CADR     DDV/BDDV   # YIELDS -DX IN MPAC

EXTEND
DCS      MPAC      # FETCH DX, LEAVING -DX IN MPAC
DAS      ROOTPS    # CORRECTED ROOT NOW IN ROOTPS

TC       USPRCADR
CADR     ABS       # YIELDS ABS(DX) IN MPAC
EXTEND

# Page 825
DCS      DXCRIT
DAS      MPAC      # ABS(DX)-ABS(DXCRIT) IN MPAC

CA       MODE
MASK     BIT4      # KLUMPP SAYS GIVE UP AFTER EIGHT PASSES
CCS      A
BADROOT  TC       RETROOT

INCR     MODE      # INCREMENT ITERATION COUNTER
CCS      MPAC      # TEST HI ORDER DX
TCF      ROOTLOOP
TCF      TESTLODX
TCF      ROOTSTOR
TESTLODX CCS      MPAC +1    # TEST LO ORDER DX
TCF      ROOTLOOP
TCF      ROOTSTOR
TCF      ROOTSTOR
ROOTSTOR DXCH     ROOTPS
DXCH     MPAC
CA       MODE
TS       MPAC +2    # STORE SP ITERATION COUNT IN MPAC+2
INDEX    RETROOT
TCF      2

DERTABLL ADRES     DERCOFN -3

```

```

# *****
# TRASHY LITTLE SUBROUTINES

```

# \*\*\*\*\*

INTPRETX        INDEX    WCHPHASE        # SET X1 ON THE WAY TO THE INTERPRETER  
                  CS        TARGTDEX  
                  INDEX    FIXLOC  
                  TS        X1  
                  TCF        INTPRET

TDISPSET        CA        TTF/8  
                  EXTEND  
                  MP        TSCALINV  
                  DXCH       TTFDISP

                 CA        EBANK5        # TREDES BECOMES ZERO TWO PASSES  
                  TS        EBANK        #        BEFORE TCGFAPPR IS REACHED  
                  EBANK=    TCGFAPPR  
                  CA        TCGFAPPR  
                  INCR       BBANK  
                  INCR       BBANK  
                  EBANK=    TTF/8

# Page 826

                 AD        TTF/8  
                  EXTEND  
                  MP        TREDESCL  
                  AD        -DEC103  
                  AD        NEGMAX  
                  TS        L  
                  CS        L  
                  AD        L  
                  AD        +DEC99  
                  AD        POSMAX  
                  TS        TREDES  
                  CS        TREDES  
                  ADS        TREDES  
                  TC        Q

1406P00        TC        P00D00  
                  OCT        01406  
 1406ALM        TC        ALARM  
                  OCT        01406  
                  TCF        RATESTOP

# \*\*\*\*\*

# SPECIALIZED "PHASCHNG" SUBROUTINE

# \*\*\*\*\*

```

EBANK= PHSNAME2
FASTCHNG CA EBANK3 # SPECIALIZED 'PHASCHNG' ROUTINE
XCH EBANK
DXCH L
TS PHSNAME3
LXCH EBANK
EBANK= E2DPS
TC A

```

```

# *****
# PARAMETER TABLE INDIRECT ADDRESSES
# *****

```

```

RDG = RBRFG
VDG = VBRFG
ADG = ABRFG
VDG2TTF = VBRFG*
ADG2TTF = ABRFG*
JDG2TTF = JBRFG*

```

```

# *****
# LUNAR LANDING CONSTANTS
# *****

```

# Page 827

```

TABLTTF ADRES TABLTTF +3 # ADDRESS FOR REFERENCING TTF TABLE
TTFSCALE = BIT12
TSCALINV = BIT4
-DEC103 DEC -103
+DEC99 DEC +99
TREDESCL DEC -.08
180DEGS DEC +180
1/2DEG DEC +.00278
PROJMAX DEC .42262 B-3 # SIN(25')/8 TO COMPARE WITH PROJ
PROJMIN DEC .25882 B-3 # SIN(15')/8 TO COMPARE WITH PROJ
V06N63 VN 0663 # P63
V06N64 VN 0664 # P64
V06N60 VN 0660 # P65, P66, P67

BANK 22
SETLOC LANDCNST
BANK
COUNT* $$/F2DPS

HIGHESTF 2DEC 4.34546769 B-12
GSCALE 2DEC 100 B-11

```

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|          |      |          |
|----------|------|----------|
| 3/8DP    | 2DEC | .375     |
| 3/4DP    | 2DEC | .750     |
| DEPRCRIT | 2DEC | -.02 B-1 |

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# \*\*\*\*\*  
# \*\*\*\*\*

This code is written to file src/LUNAR-LANDING-GUIDANCE-EQUATIONS.s.

## A.59    LUNAR LANDMARK SELECTION FOR           CM

```

902  <src/LUNAR-LANDMARK-SELECTION-FOR-CM.s 902>≡
      # Copyright:     Public domain.
      # Filename:      LUNAR_LANDMARK_SELECTION_FOR_CM.agc
      # Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
      #                It is part of the source code for the Command Module's (CM)
      #                Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Jim Lawton <jim.lawton@gmail.com>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         936
      # Mod history:   2009-05-11 JVL   Adapted from the Colossus249/ file
      #                                 of the same name, using Comanche055 page
      #                                 images.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #     Assemble revision 055 of AGC program Comanche by NASA
      #     2021113-051. 10:28 APR. 1, 1969
      #
      #     This AGC program shall also be referred to as
      #               Colossus 2A

      # Page 936

      # *** END OF TROUBLE .043 ***

```

This code is written to file `src/LUNAR-LANDMARK-SELECTION-FOR-CM.s`.

## A.60 MAIN

903

*<src/MAIN.s 903>*≡

```
# Copyright:   Public domain.
# Filename:    MAIN.agc
# Purpose:    Part of the source code for Colossus 2A, AKA Comanche 055.
#             It is part of the source code for the Command Module's (CM)
#             Apollo Guidance Computer (AGC) Apollo 11.
# Assembler:  yaYUL
# Contact:    Ron Burkey <info@sandroid.org>.
# Website:    www.ibiblio.org/apollo
# Mod history: 2009-05-05 RSB Adapted from Colossus249/MAIN.agc.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. 10:28 APR. 1, 1969
#
# This AGC program shall also be referred to as
# Colossus 2A
#
# This file is a little different from the other Comanche055 files I'm providing,
# in that it doesn't represent anything that appears directly in the original source.
# What I (RSB) have done for organizational purposes is to split the huge monolithic
# source code into smaller, more manageable chunks--i.e., into individual source
# files. Those files are rejoined within this file as "includes". It just makes
# it a little easier to work with. The code chunks correspond to natural divisions
# into sub-programs. In fact, these divisions are more-or-less specified by
# the source code itself. Refer to the "SUBROUTINE CALLS" at the
# very beginning of the file ASSEMBLY_AND_OPERATION_INFORMATION.agc.
#
# It may be reasonably asked why tens of thousands of lines of source are joined by
# means of inclusion, rather than simply assembling the source files individually and
# then linking them to form the executable. The answer is that the original
# development team had no linker. The builds were monolithic just like this.
# There was a big emphasis on reusability of the code in the original project,
# apparently, but this reusability took the form of inserting your deck of
```

```

# punch-cards at the appropriate position in somebody else's deck of punch-cards.
# (Actually, I think the card-decks were turned into tape libraries, and the modules
# were mixed-and-matched from the tape libraries, but the principle is the same.)
# So, indeed, the method of file-inclusion is a very fair representation of the
# methods used in the original development ... with the improvement, of course,
# that you no longer have to worry about dropping the card deck. On the other hand,
# I wasn't there at the time, so I may have no idea what I'm talking about.
#
# Finally, note that the original Apollo AGC assembler (called "YUL") is no longer
# available (as far as I can tell). Actually, it had already been replaced by another
# assembler (called "GAP") by the time of Apollo 11, but GAP isn't available either.
# The replacement assembler yaYUL accepts a slightly different format for the source
# code from what YUL or GAP accepted, so the source code has been targeted for
# assembly with yaYUL.

# What follows is simply a bunch of file-includes for the individual code chunks.
# I've marked the page numbers to make proof-reading easier. The page images also
# contain a lot of interesting tables (cross-referenced to page numbers) created by (C)
# but not duplicated by yaYUL, so it's still valuable even if the source-files
# listed below are in hand.

$CONTRACT_AND_APPROVALS.agc                # p. 1
$ASSEMBLY_AND_OPERATION_INFORMATION.agc    # pp. 2-26
$TAGS_FOR_RELATIVE_SETLOC.agc              # pp. 27-35

   # p. 36 contains no code.
# COMERASE
$ERASABLE_ASSIGNMENTS.agc                  # pp. 37-130

# COMAID
$INTERRUPT_LEAD_INS.agc                    # pp. 131-132
$T4RUPT_PROGRAM.agc                        # pp. 133-169
$DOWNLINK_LISTS.agc                        # pp. 170-180
$FRESH_START_AND_RESTART.agc               # pp. 181-210
$RESTART_TABLES.agc                        # pp. 211-221
$SXTMARK.agc                               # pp. 222-235
$EXTENDED_VERBS.agc                        # pp. 236-267
$PINBALL_NOUN_TABLES.agc                   # pp. 268-284
$CSM_GEOMETRY.agc                          # pp. 285-296
$IMU_COMPENSATION_PACKAGE.agc               # pp. 297-306
$PINBALL_GAME_BUTTONS_AND_LIGHTS.agc       # pp. 307-389
$R60_62.agc                                # pp. 390-398
$ANGLFIND.agc                              # pp. 399-411
$GIMBAL_LOCK_AVOIDANCE.agc                 # pp. 412-413
$KALCMANU_STEERING.agc                     # pp. 414-419
$SYSTEM_TEST_STANDARD_LEAD_INS.agc         # pp. 420-422

```



|                                               |                 |
|-----------------------------------------------|-----------------|
| \$IMU_CALIBRATION_AND_ALIGNMENT.agc           | # pp. 423-455   |
| # COMEISS                                     |                 |
| \$GROUND_TRACKING_DETERMINATION_PROGRAM.agc   | # pp. 456-459   |
| \$P34-35_P74-75.agc                           | # pp. 460-504   |
| \$R31.agc                                     | # pp. 505-510   |
| \$P76.agc                                     | # pp. 511-513   |
| \$R30.agc                                     | # pp. 514-524   |
| \$STABLE_ORBIT.agc                            | # pp. 525-532   |
| # TROUBLE                                     |                 |
| \$P11.agc                                     | # pp. 533-550   |
| \$TPI_SEARCH.agc                              | # pp. 551-561   |
| \$P20-P25.agc                                 | # pp. 562-634   |
| \$P30-P37.agc                                 | # pp. 635-648   |
| \$P32-P33_P72-P73.agc                         | # pp. 649-683   |
| \$P40-P47.agc                                 | # pp. 684-736   |
| \$P51-P53.agc                                 | # pp. 737-784   |
| \$LUNAR_AND_SOLAR_EPHEMERIDES_SUBROUTINES.agc | # pp. 785-788   |
| \$P61-P67.agc                                 | # pp. 789-818   |
| \$SERVICER207.agc                             | # pp. 819-836   |
| \$ENTRY_LEXICON.agc                           | # pp. 837-843   |
| \$REENTRY_CONTROL.agc                         | # pp. 844-882   |
| \$CM_BODY_ATTITUDE.agc                        | # pp. 883-889   |
| \$P37_P70.agc                                 | # pp. 890-933   |
| \$S-BAND_ANTENNA_FOR_CM.agc                   | # pp. 934-935   |
| \$LUNAR_LANDMARK_SELECTION_FOR_CM.agc         | # pp. 936       |
| # TVCDAPS                                     |                 |
| \$TVCINITIALIZE.agc                           | # pp. 937-944   |
| \$TVCEXECUTIVE.agc                            | # pp. 945-950   |
| \$TVCMASSPROP.agc                             | # pp. 951-955   |
| \$TVCRESTARTS.agc                             | # pp. 956-960   |
| \$TVCDAPS.agc                                 | # pp. 961-978   |
| \$TVCSTROKETEST.agc                           | # pp. 979-983   |
| \$TVCROLLDAP.agc                              | # pp. 984-998   |
| \$MYSUBS.agc                                  | # pp. 999-1001  |
| \$RCS-CSM_DIGITAL_AUTOPILOT.agc               | # pp. 1002-1024 |
| \$AUTOMATIC_MANEUVERS.agc                     | # pp. 1025-1036 |
| \$RCS-CSM_DAP_EXECUTIVE_PROGRAMS.agc          | # pp. 1037-1038 |
| \$JET_SELECTION_LOGIC.agc                     | # pp. 1039-1062 |
| \$CM_ENTRY_DIGITAL_AUTOPILOT.agc              | # pp. 1063-1092 |
| # CHIEFTAN                                    |                 |
| \$DOWN-TELEMETRY_PROGRAM.agc                  | # pp. 1093-1102 |
| \$INTER-BANK_COMMUNICATION.agc                | # pp. 1103-1106 |

|                                      |                 |
|--------------------------------------|-----------------|
| \$INTERPRETER.agc                    | # pp. 1107-1199 |
| \$FIXED_FIXED_CONSTANT_POOL.agc      | # pp. 1200-1204 |
| \$INTERPRETIVE_CONSTANTS.agc         | # pp. 1205-1206 |
| \$SINGLE_PRECISION_SUBROUTINES.agc   | # p. 1207       |
| \$EXECUTIVE.agc                      | # pp. 1208-1220 |
| \$WAITLIST.agc                       | # pp. 1221-1235 |
| \$LATITUDE_LONGITUDE_SUBROUTINES.agc | # pp. 1236-1242 |
| \$PLANETARY_INERTIAL_ORIENTATION.agc | # pp. 1243-1251 |
| \$MEASUREMENT_INCORPORATION.agc      | # pp. 1252-1261 |
| \$CONIC_SUBROUTINES.agc              | # pp. 1262-1308 |
| \$INTEGRATION_INITIALIZATION.agc     | # pp. 1309-1333 |
| \$ORBITAL_INTEGRATION.agc            | # pp. 1334-1354 |
| \$INFLIGHT_ALIGNMENT_ROUTINES.agc    | # pp. 1355-1364 |
| \$POWERED_FLIGHT_SUBROUTINES.agc     | # pp. 1365-1372 |
| \$TIME_OF_FREE_FALL.agc              | # pp. 1373-1388 |
| \$STAR_TABLES.agc                    | # pp. 1389-1393 |
| \$AGC_BLOCK_TWO_SELF-CHECK.agc       | # pp. 1394-1403 |
| \$PHASE_TABLE_MAINTENANCE.agc        | # pp. 1404-1413 |
| \$RESTARTS_ROUTINE.agc               | # pp. 1414-1419 |
| \$IMU_MODE_SWITCHING_ROUTINES.agc    | # pp. 1420-1448 |
| \$KEYRUPT_UPRUPT.agc                 | # pp. 1449-1451 |
| \$DISPLAY_INTERFACE_ROUTINES.agc     | # pp. 1452-1484 |
| \$SERVICE_ROUTINES.agc               | # pp. 1485-1492 |
| \$ALARM_AND_ABORT.agc                | # pp. 1493-1496 |
| \$UPDATE_PROGRAM.agc                 | # pp. 1497-1507 |
| \$RT8_OP_CODES.agc                   | # pp. 1508-1516 |

# pp. 1517-1751: GAP-generated tables

This code is written to file `src/MAIN.s`.

## A.61 MEASUREMENT INCORPORATION

```

907  <src/MEASUREMENT-INCORPORATION.s 907>≡
# Copyright:    Public domain.
# Filename:     MEASUREMENT_INCORPORATION.agc
# Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
#              It is part of the source code for the Command Module's (CM)
#              Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:     Ron Burkey <info@sandroid.org>.
# Website:     www.ibiblio.org/apollo.
# Pages:       1252-1261
# Mod history: 2009-05-14 RSB   Adapted from the Colossus249/ file of the
#                               same name, using Comanche055 page images.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 055 of AGC program Comanche by NASA
#       2021113-051.  10:28 APR. 1, 1969
#
#       This AGC program shall also be referred to as
#       Colossus 2A
#
# Page 1252
# INCORP1 -- PERFORMS THE SIX DIMENSIONAL STATE VECTOR DEVIATION FOR POSITION
# AND VELOCITY OR THE NINE-DIMENSIONAL DEVIATION OF POSITION, VELOCITY, AND
# RADAR OR LANDMARK BIAS. THE OUTPUT OF THE BVECTOR ROUTINE ALONG WITH THE
# ERROR TRANSITION MATRIX (W) ARE USED AS INPUT TO THE ROUTINE. THE DEVIATION
# IS OBTAINED BY COMPUTING AN ESTIMATED TRACKING MEASUREMENT FROM THE
# CURRENT STATE VECTOR AND COMPARING IT WITH AN ACTUAL TRACKING MEASUREMENT
# AND APPLYING A STATISTICAL WEIGHTING VECTOR.
#
# INPUT
#       DMENFLG = 0 (6-DIMENSIONAL BVECTOR), =1 (9-DIMENSIONAL)
#       W = ERROR TRANSITION MATRIX 6X6 OR 9X9
#       VARIANCE = VARIANCE (SCALAR)
#       DELTAQ = MEASURED DEVIATION (SCALAR)

```

```

#          BVECTOR = 6 OR 9 DIMENSIONAL BVECTOR
#
# OUTPUT
#          DELTAX = STATE VECTOR DEVIATIONS 6 OR 9 DIMENSIONAL
#          ZI = VECTOR USED FOR THE INCORPORATION 6 OR 9 DIMENSIONAL
#          GAMMA = SCALAR
#          OMEGA = OMEGA WEIGHTING VECTOR 6 OR 9 DIMENSIONAL
#
# CALLING SEQUENCE
#          L          CALL    INCORP1
#
# NORMAL EXIT
#          L+1 OF CALLING SEQUENCE

          BANK      37
          SETLOC    MEASINC
          BANK

          COUNT*    $$/INCOR

          EBANK=    W

INCORP1    STQ
          EGRESS
          AXT,1     SSP
          54D
          S1
          18D          # IX1 = 54          S1= 18
          AXT,2     SSP
          18D
          S2
          6           # IX2 = 18          S2=6
Z123      VLOAD    MXV*
          BVECTOR    # BVECTOR (0)
          W          +54D,1
          STORE      ZI      +18D,2
          VLOAD
          BVECTOR +6    # BVECTOR (1)

# Page 1253
          MXV*      VAD*
          W +108D,1
          ZI +18D,2
          STORE      ZI +18D,2
          VLOAD
          BVECTOR +12D  # BVECTOR (2)
          MXV*      VAD*

```

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```

                                W      +162D,1
                                ZI      +18D,2  # B(0)*W+B(1)*(W+54)+B(2)*(W+108) FIRST PASS
STORE  ZI      +18D,2  # ZI THEN Z2 THEN Z3
TIX,1
                                INCOR1
INCOR1  TIX,2  BON
                                Z123          # LOOP FOR Z1,Z2,Z3
                                DMENFLG
                                INCOR1A
VLOAD
                                ZEROVECS
STORE  ZI      +12D
SETPD  VLOAD
                                0
                                ZI
VSQ    RTB
                                TPMODE
PDVL   VSQ
                                ZI      +6
RTB    TAD
                                TPMODE
PDVL   VSQ
                                ZI      +12D
RTB    TAD
                                TPMODE
TAD    AXT,2
                                VARIANCE
                                0
STORE  TRIPA          # ZI*2 + Z2*2 + Z3*2 + VARIANCE
TLOAD  BOV
                                VARIANCE      # CLEAR OVFLND
                                +1
STORE  TEMPVAR        # TEMP STORAGE FOR VARIANCE
BZE
                                INCOR1C
INCOR1B  SL2  BOV
                                INCOR1C
STORE  TEMPVAR
INCR,2  GOTO
DEC     1
                                INCOR1B
INCOR1C  TLOAD  ROUND
                                TRIPA
# Page 1254
DMP     SQRT
                                TEMPVAR
```

```

          SL*    TAD
                0,2
                TRIPA
          NORM    INCR,2
                X2
          DEC     -2
          SXA,2   AXT,2
                NORMGAM      # NORMALIZATION COUNT -2 FOR GAMMA
                162D
          BDDV    SETPD
                DP1/4TH
                0
          STORE   GAMMA
          TLOAD   NORM
                TRIPA
                X1
          DLOAD   PDDL      # PD 0-1 = NORM (A)
                MPAC
                DELTAQ
          NORM
                S1
          XSU,1   SR1
                S1
          DDV     PUSH      # PD 0-1 = DELTAQ/A
          GOTO    NEWZCOMP
-3            SSP
                S2
                54D
INCOR2        VLOAD      # COMPUT OMEGA1,2,3
                VXM*
                ZI
                W          +162D,2
          PUSH   VLOAD
                ZI          +6
          VXM*   VAD
                W          +180D,2
          PUSH   VLOAD
                ZI          +12D
          VXM*   VAD
                W          +198D,2
          PUSH   TIX,2      # PD 2-7=OMEGA1, 8-13=OMEGA2, 14-19=OMEGA3
                INCOR2
          VLOAD   STADR
          STORE   OMEGA      +12D
          VLOAD   STADR
          STORE   OMEGA      +6

```

```

                                VLOAD  STADR
                                STORE  OMEGA

# Page 1255
                                BON    VLOAD
   DMENFLG
   INCOR2AB
   ZEROVECS
                                STORE  OMEGA  +12D
INCOR2AB  AXT,2  SSP
   18D
   S2
   6
INCOR3    VLOAD*
                                OMEGA  +18D,2
                                VXSC   VSL*
   0          # DELTAQ/A
   0,1
                                STORE  DELTAX +18D,2
                                TIX,2  VLOAD
   INCOR3
   DELTAX  +6
                                VSL3
                                STORE  DELTAX  +6
                                GOTO
   EGRESS

```

```

# Page 1256
# INCORP2 -- INCORPORATES THE COMPUTED STATE VECTOR DEVIATIONS INTO THE
# ESTIMATED STATE VECTOR.  THE STATE VECTOR UPDATED MAY BE FOR EITHER THE
# LEM OR THE CSM.  DETERMINED BY FLAG VEHUPFLG.  (ZERO = LEM) (1 = CSM)
#
# INPUT
#   PERMANENT STATE VECTOR FOR EITHER THE LEM OR CSM
#   VEHUPFLG = UPDATE VEHICLE C=LEM 1=CSM
#   W = ERROR TRANSITION MATRIX
#   DELTAX = COMPUTED STATE VECTOR DEVIATIONS
#   DMENFLG = SIZE OF W MATRIX (ZERO=6X6) (1=9X9)
#   GAMMA = SCALAR FOR INCORPORATION
#   ZI = VECTOR USED IN INCORPORATION
#   OMEGA = WEIGHTING VECTOR
#
# OUTPUT
#   UPDATED PERMANENT STATE VECTOR
#
# CALLING SEQUENCE
#   L      CALL    INCORP2

```

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SSP DLOAD\*



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```

      S1
      6
      ZI,2
DCOMP  NORM      # CALC UPPER 3X9 PARTITION OF W MATRIX
      S2
VXSC   XCHX,2
      OMEGAM1
      S2
LXC,2  XAD,2
      X2
      NORMGAM
VSL*   XCHX,2
      0,2
      S2
VAD*
      W +54D,1
STORE  HOLDW
DLOAD* DCOMP      # CALC MIDDLE 3X9 PARTITION OF W MATRIX
      ZI,2
NORM   VXSC
      S2
      OMEGAM2
XCHX,2 LXC,2
      S2
      X2
XAD,2  VSL*
      NORMGAM
      0,2
XCHX,2 VAD*
      S2
      W +108D,1
STORE  HOLDW +6
BOFF
      DMENFLG      # BRANCH IF 6 DIMENSIONAL
      FAZB
DLOAD* DCOMP      # CALC LOWER 3X9 PARTITION OF W MATRIX
      ZI,2
NORM   VXSC
      S2
      OMEGAM3
XCHX,2 LXC,2
      S2
      X2
XAD,2  VSL*
      NORMGAM
```

# Page 1258

```

                                0,2
                                XCHX,2 VAD*
                                S2
                                W +162D,1
                                STORE HOLDW +12D
FAZB CALL
                                GRP2PC
                                EXIT
FAZB1 CA WIXA # START 2ND PHASE OF INCORP2 TO TRANSFER
      AD 6DD # TEMP REG TO PERM W MATRIX
      TS WIXB
      CA ZIXA
      AD MINUS2
      TS ZIXB
      TC INTPRET
      LXA,1 SSP
      WIXA
      S1
      6
      VLOAD
      HOLDW
      STORE W +54D,1
      VLOAD
      HOLDW +6
      STORE W +108D,1
      BOFF VLOAD
      DMENFLG
      FAZB5
      HOLDW +12D
      STORE W +162D,1
FAZB2 TIX,1 GOTO
      +2
      FAZC # DONE WITH W MATRIX. UPDATE STATE VECTOR
      RTB
      FAZA
FAZB5 SLOAD DAD
      ZIXB
      12DD
      BHIZ GOTO
      FAZC
      FAZB2
FAZC CALL
      GRP2PC
# Page 1259
      VLOAD VAD # START 3RD PHASE OF INCORP2
      X789 # 7TH, 8TH, 9TH COMPONENTN OF STATE VECTOR

```

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```

                                DELTAX  +12D  # INCORPORATION FOR X789
                                TX789
FAZAB   STORE   BON      RTB
                                VEHUPFLG
                                DOCSM
                                MOVEPLEM
                                BOVB   AXT,2
                                TCDANZIG
                                0
                                BOFF   AXT,2
                                MOONTHIS
                                +2
                                2
                                VLOAD  VSR*
                                DELTAX          # B27 IF MOON ORBIT, B29 IF EARTH
                                0 -7,2
                                VAD      BOV
                                TDELTA V
                                FAZAB1
                                STOVL   TDELTA V
                                DELTAX  +6      # B5 IF MOON ORBIT, B7 IF EARTH
                                VSR*   VAD
                                0 -4,2
                                TNUV
                                BOV
                                FAZAB2
                                STCALL  TNUV
                                FAZAB3
FAZAB1   VLOAD  VAD
                                RCV
                                DELTAX
                                STORE   RCV
FAZAB2   VLOAD  VAD
                                VCV
                                DELTAX  +6
                                STORE   VCV
                                SXA,2   CALL
                                PBODY
                                RECTIFY
FAZAB3   CALL
                                GRP2PC
                                BON     RTB
                                VEHUPFLG
                                DOCSM1
                                MOVEALEM
                                CALL
```

|             |        |            |                               |
|-------------|--------|------------|-------------------------------|
| FAZAB4      | CALL   | SVDWN2     | # STORE DOWNLINK STATE VECTOR |
| # Page 1260 |        |            |                               |
|             | BOFF   | GRP2PC     | # PHASE CHANGE                |
|             |        | VLOAD      |                               |
|             |        | DMENFLG    |                               |
|             |        | FAZAB5     | # 6 DIMENSIONAL               |
|             |        | TX789      | # 9 DIMENSIONAL               |
| FAZAB5      | STORE  | X789       |                               |
|             | LXA,1  | SXA,1      |                               |
|             |        | EGRESS     |                               |
|             |        | QPRET      |                               |
|             | EXIT   |            |                               |
|             | TC     | POSTJUMP   | # EXIT                        |
|             | CADR   | INTWAKE    |                               |
| DOCSM       | RTB    | GOTO       |                               |
|             |        | MOVEPCSM   |                               |
|             |        | FAZAB      |                               |
| DOCSM1      | RTB    | CALL       |                               |
|             |        | MOVEACSM   |                               |
|             |        | SVDWN1     | # STORE DOWNLINK STATE VECTOR |
|             | GOTO   |            |                               |
|             |        | FAZAB4     |                               |
| ZEROD       | =      | ZEROVECS   |                               |
| 54DD        | DEC    | 54         |                               |
| 6DD         | DEC    | -6         |                               |
| 12DD        | DEC    | 12         |                               |
|             | SETLOC | MEASINC2   |                               |
|             | BANK   |            |                               |
|             | COUNT* | \$\$/INCOR |                               |
| NEWZCOMP    | VLOAD  | ABVAL      |                               |
|             |        | ZI         |                               |
|             | STOVL  | NORMZI     |                               |
|             |        | ZI +6      |                               |
|             | ABVAL  | PUSH       |                               |
|             | DSU    | BMN        |                               |
|             |        | NORMZI     |                               |
|             |        | +3         |                               |
|             | DLOAD  | STADR      |                               |
|             | STORE  | NORMZI     |                               |
|             | VLOAD  | ABVAL      |                               |
|             |        | ZI +12D    |                               |
|             | PUSH   | DSU        |                               |
|             |        | NORMZI     |                               |
|             | BMN    | DLOAD      |                               |

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|             |        |           |                 |
|-------------|--------|-----------|-----------------|
|             | STADR  | NEWZCMP1  |                 |
|             | STCALL | NORMZI    | # LARGEST ABVAL |
|             |        | NEWZCMP1  |                 |
|             | SETLOC | MEASINC3  |                 |
|             | BANK   |           |                 |
| # Page 1261 |        |           |                 |
| NEWZCMP1    |        | DLOAD     | SXA,1           |
|             |        | NORMZI    |                 |
|             |        | NORMZI    | # SAVE X1       |
|             | NORM   | INCR,1    |                 |
|             |        | X1        |                 |
|             | DEC    | 2         |                 |
|             | VLOAD  | VSL*      |                 |
|             |        | ZI        |                 |
|             |        | 0,1       |                 |
|             | STOVL  | ZI        |                 |
|             |        | ZI +6     |                 |
|             | VSL*   |           |                 |
|             |        | 0,1       |                 |
|             | STOVL  | ZI +6     |                 |
|             |        | ZI +12D   |                 |
|             | VSL*   | SXA,1     |                 |
|             |        | 0,1       |                 |
|             |        | NORMZI +1 | # SAVE SHIFT    |
|             | STORE  | ZI +12D   |                 |
|             | LXA,1  | XSU,1     |                 |
|             |        | NORMGAM   |                 |
|             |        | NORMZI +1 |                 |
|             | XSU,1  |           |                 |
|             |        | NORMZI +1 |                 |
|             | SXA,1  | LXC,1     |                 |
|             |        | NORMGAM   |                 |
|             |        | NORMZI +1 |                 |
|             | XAD,1  | SETPD     |                 |
|             |        | NORMZI    |                 |
|             |        | 2D        |                 |
|             | GOTO   |           |                 |
|             |        | INCOR2 -3 |                 |
| NORMZI      | =      | 36D       |                 |

This code is written to file `src/MEASUREMENT-INCORPORATION.s`.

## A.62 MYSUBS

```

919  <src/MYSUBS.s 919>≡
    # Copyright:   Public domain.
    # Filename:    MYSUBS.agc
    # Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
    #              It is part of the source code for the Command Module's (CM)
    #              Apollo Guidance Computer (AGC), for Apollo 11.
    # Assembler:  yaYUL
    # Contact:     Ron Burkey <info@sandroid.org>.
    # Website:     www.ibiblio.org/apollo.
    # Pages:       999-1001
    # Mod history: 2009-05-13 RSB   Adapted from the Colossus249/ file of the
    #              same name, using Comanche055 page images.
    #              2009-05-20 RSB   Corrections: EBANK= changed from MPAC to KMPAC.
    #
    # This source code has been transcribed or otherwise adapted from digitized
    # images of a hardcopy from the MIT Museum. The digitization was performed
    # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
    # thanks to both. The images (with suitable reduction in storage size and
    # consequent reduction in image quality as well) are available online at
    # www.ibiblio.org/apollo. If for some reason you find that the images are
    # illegible, contact me at info@sandroid.org about getting access to the
    # (much) higher-quality images which Paul actually created.
    #
    # Notations on the hardcopy document read, in part:
    #
    #       Assemble revision 055 of AGC program Comanche by NASA
    #       2021113-051.  10:28 APR. 1, 1969
    #
    #       This AGC program shall also be referred to as
    #               Colossus 2A

    # Page 999

                                BANK      20
                                SETLOC    MYSUBS
                                BANK

                                EBANK=    KMPAC
SPCOS1                        EQUALS    SPCOS
SPSIN1                        EQUALS    SPSIN
SPCOS2                        EQUALS    SPCOS
SPSIN2                        EQUALS    SPSIN

                                COUNT     21/DAPMS

```

## # ONE AND ONE HALF PRECISION MULTIPLICATION ROUTINE

```

SMALLMP      TS      KMPTMP      # A(X+Y)
             EXTEND
             MP      KMPAC      +1
             TS      KMPAC      +1      # AY
             CAF      ZERO
             XCH      KMPAC
             EXTEND
             MP      KMPTMP      # AX
             DAS      KMPAC      # AX+AY
             TC      Q

```

## # SUBROUTINE FOR DOUBLE PRECISION ADDITIONS OF ANGLES

# A AND L CONTAIN A DP(1S) ANGLE SCALED BY 180 DEGS TO BE ADDED TO KMPAC.

# RESULT IS PLACED IN KMPAC. TIMING = 6 MCT (22 MCT ON OVERFLOW)

```

DPADD        DAS      KMPAC
             EXTEND
             BZF      TSK      +1      # NO OVERFLOW
             CCS      KMPAC
             TCF      DPADD+      # + OVERFLOW
             TCF      +2
             TCF      DPADD-      # - OVERFLOW
             CCS      KMPAC      +1
             TCF      DPADD2+      # UPPER = 0, LOWER +
             TCF      +2
             COM
             AD      POSMAX      # UPPER = 0, LOWER -
             TS      KMPAC      +1      # LOWER = 0, A = 0
             CA      POSMAX      # CAN NOT OVERFLOW
             TSK      TS      KMPAC      # UPPER WAS = 0
             TC      Q

DPADD+        AD      NEGMAX      # KMPAC GREATER THAN 0
             TCF      TSK

# Page 1000
DPADD-        COM
             AD      POSMAX      # KMPAC LESS THAN 0
             TCF      TSK

DPADD2+        AD      NEGMAX      # CAN NOT OVERFLOW
             TS      KMPAC      +1
             CA      NEGMAX      # UPPER WAS = 0
             TCF      TSK

```



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# Page 1001 (empty page)

This code is written to file `src/MYSUBS.s`.

## A.63    ORBITAL INTEGRATION

```

922  <src/ORBITAL-INTEGRATION.s 922>≡
      # Copyright:      Public domain.
      # Filename:       ORBITAL_INTEGRATION.agc
      # Purpose:        Part of the source code for Colossus 2A, AKA Comanche 055.
      #                  It is part of the source code for the Command Module's (CM)
      #                  Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:     yaYUL
      # Contact:        Ron Burkey <info@sandroid.org>.
      # Website:        www.ibiblio.org/apollo.
      # Pages:          1334-1354
      # Mod history:    2009-05-14 RSB   Adapted from the Colossus249/ file of the
      #                  same name, using Comanche055 page images.
      #                  2009-05-20 RSB   Corrections:  DAT -> DAD in one place,
      #                  BWM -> BMN, DEFEQCNT -> DIFEQCNT.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum.  The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum.  Many
      # thanks to both.  The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo.  If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 055 of AGC program Comanche by NASA
      #       2021113-051.  10:28 APR. 1, 1969
      #
      #       This AGC program shall also be referred to as
      #               Colossus 2A

      # Page 1334
      # ORBITAL INTEGRATION

      # DELETE

                                BANK      13
                                SETLOC    ORBITAL
                                BANK
                                COUNT     11/ORBIT

      # DELETE
      KEPPREP                    LXA,2    SETPD
                                PBODY

```

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|        |           |                               |                                     |        |
|--------|-----------|-------------------------------|-------------------------------------|--------|
|        | 0         |                               |                                     |        |
| DLOAD* | SQRT      | # SQRT(MU) (+18 OR +15)       | 0D                                  | PL 2D  |
|        | MUEARTH,2 |                               |                                     |        |
| PDVL   | UNIT      | #                             |                                     | PL 8D  |
|        | RCV       |                               |                                     |        |
| PDDL   | NORM      | # NORM R (+29 OR +27 - N1)    | 2D                                  | PL 4D  |
|        | 36D       |                               |                                     |        |
|        | X1        |                               |                                     |        |
| PDVL   |           |                               |                                     |        |
| DOT    | PDDL      | # F*SQRT(MU) (+7 OR +5)       | 4D                                  | PL 6D  |
|        | VCV       |                               |                                     |        |
|        | TAU.      | # (+28)                       |                                     |        |
| DSU    | NORM      |                               |                                     |        |
|        | TC        |                               |                                     |        |
|        | S1        |                               |                                     |        |
| SR1    |           |                               |                                     |        |
| DDV    | PDDL      |                               |                                     |        |
|        | 2D        |                               |                                     |        |
| DMP    | PUSH      | # FS (+6 +N1-N2)              | 6D                                  | PL 8D  |
|        | 4D        |                               |                                     |        |
| DSQ    | PDDL      | # (FS)SQ (+12 +2(N1-N2))      | 8D                                  | PL 10D |
|        | 4D        |                               |                                     |        |
| DSQ    | PDDL*     | # SSQ/MU (-2 OR +2(N1-N2))    | 10D                                 | PL 12D |
|        | MUEARTH,2 |                               |                                     |        |
| SR3    | SR4       |                               |                                     |        |
| PDVL   | VSQ       | # PREALIGN MU (+43 OR +37)    | 12D                                 | PL 14D |
|        | VCV       |                               |                                     |        |
| DMP    | BDSU      | #                             |                                     | PL 12D |
|        | 36D       |                               |                                     |        |
| DDV    | DMP       | #                             |                                     | PL 10D |
|        | 2D        | # -(1/R-ALPHA) (+12 +3N1-2N2) |                                     |        |
| DMP    | SL*       |                               |                                     |        |
|        | DP2/3     |                               |                                     |        |
|        | 0         | -3,1                          | # 10L(1/R-ALPHA) (+13 +2(N1-N2))    |        |
| XSU,1  | DAD       |                               | # 2(FS)SQ - ETCETERA                | PL 8D  |
|        | S1        |                               | # X1 = N2-N1                        |        |
| SL*    | DSU       |                               | # -FS+2(FS)SQ ETC (+6 +N1-N2)       | PL 6D  |
|        | 8D,1      |                               |                                     |        |
| DMP    | DMP       |                               |                                     |        |
|        | 0D        |                               |                                     |        |
|        | 4D        |                               |                                     |        |
| SL*    | SL*       |                               |                                     |        |
|        | 8D,1      |                               |                                     |        |
|        | 0,1       |                               | # S(-FS(1-2FS)-1/6...) (+17 OR +16) |        |
| DAD    | PDDL      | #                             |                                     | PL 6D  |

```

      XKEP
DMP    SL*          # S(+17 OR +16)
      OD
      1,1
BOVB   DAD
      TCDANZIG
STADR
STORE  XKEPNEW
STQ    AXC,1
      KEPRTN
DEC    10
BON    AXC,1
      MOONFLAG
      KEPLERN
DEC    2
GOTO
      KEPLERN

```

# Page 1336

```

FBR3   LXA,1  SSP
      DIFEQCNT
      S1
DEC    -13
DLOAD  SR
      DT/2
      9D
TIX,1  ROUND
      +1
PUSH   DAD
      TC
STODL  TAU.
DAD
      TET
STCALL TET
      KEPPREP

```

# Page 1337

# AGC ROUTINE TO COMPUTE ACCELERATION COMPONENTS.

```

ACCOMP  LXA,1  LXA,2
      PBODY
      PBODY
VLOAD
      ZEROVEC
STOVL   FV
      ALPHAV

```

```

VSL*   VAD
        0 -7,2
        RCV
STORE   BETAV
BOF     XCHX,2
        DIMOFLAG
        +5
        DIFEQCNT
STORE   VECTAB,2
XCHX,2
        DIFEQCNT
VLOAD   UNIT
        ALPHAV
STODL   ALPHAV
        36D
STORE   ALPHAM
CALL
        GAMCOMP
VLOAD   SXA,1
        BETAV
        S2
STODL   ALPHAV
        BETAM
STORE   ALPHAM
BOF     DLOAD
        MIDFLAG
        OBLATE
        TET
CALL
        LSPOS
AXT,2   LXA,1
        2
        S2
BOF     MOONFLAG
        +3
VCOMP   AXT,2
        0
STORE   BETAV
STOVL   RPQV
        2D
STORE   RPSV
BOF     VLOAD
        DIMOFLAG
        GETRPSV

```

|         |        |             |                                        |
|---------|--------|-------------|----------------------------------------|
|         |        | ALPHAV      |                                        |
|         | VXSC   | VSR*        |                                        |
|         |        | ALPHAM      |                                        |
|         |        | 1,2         |                                        |
|         | VSU    | XCHX,2      |                                        |
|         |        | BETAV       |                                        |
|         |        | DIFEQCNT    |                                        |
|         | STORE  | VECTAB +6,2 |                                        |
|         | XCHX,2 |             |                                        |
| GETRPSV |        | DIFEQCNT    |                                        |
|         | VLOAD  | INCR,1      |                                        |
|         |        | RPQV        |                                        |
|         |        | 4           |                                        |
|         | CLEAR  | BOF         |                                        |
|         |        | RPQFLAG     |                                        |
|         |        | MOONFLAG    |                                        |
|         |        | +5          |                                        |
|         | VSR    | VAD         |                                        |
|         |        | 9D          |                                        |
|         |        | RPSV        |                                        |
|         | STORE  | RPSV        |                                        |
|         | CALL   |             |                                        |
|         |        | GAMCOMP     |                                        |
|         | AXT,2  | INCR,1      |                                        |
|         |        | 4           |                                        |
|         |        | 4           |                                        |
|         | VLOAD  |             |                                        |
|         |        | RPSV        |                                        |
|         | STCALL | BETAV       |                                        |
|         |        | GAMCOMP     |                                        |
|         | GOTO   |             |                                        |
|         |        | OBLATE      |                                        |
| GAMCOMP | VLOAD  | VSR1        |                                        |
|         |        | BETAV       |                                        |
|         | VSQ    | SETPD       |                                        |
|         |        | 0           |                                        |
|         | NORM   | ROUND       |                                        |
|         |        | 31D         |                                        |
|         | PDDL   | NORM        | # NORMED B SQUARED TO PD LIST          |
|         |        | ALPHAM      | # NORMALIZE (LESS ONE) LENGTH OF ALPHA |
|         |        | 32D         | # SAVING NORM SCALE FACTOR IN X1       |
|         | SR1    | PDVL        |                                        |
|         |        | BETAV       | # C(PDL+2) = ALMOST NORMED ALPHA       |
|         | UNIT   |             |                                        |
|         | STODL  | BETAV       |                                        |

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```

                                36D
STORE    BETAM
NORM     BDDV                  # FORM NORMALIZE QUOTIEN ALPHAM/BETAM
                                33D
SR1R     PUSH                  # C(PDL+2) = ALMOST NORMALIZE RHO.
DLOAD*
                                ASCALE,1
STORE    S1
XCHX,2   XAD,2
                                S1
                                32D
XSU,2    DLOAD
                                33D
                                2D
SR*      XCHX,2
                                0      -1,2
                                S1
PUSH     SR1R                  # RHO/4 TO 4D
PDVL     DOT
                                ALPHAV
                                BETAV
SL1R     BDSU                  # (RHO/4) - 2(ALPHAV/2.BETAV/2)
PUSH     DMPR                  # TO PDL+6
                                4
SL1
PUSH     DAD
                                DQUARTER
PUSH     SQRT
DMPR     PUSH
                                10D
SL1      DAD
                                DQUARTER
PDDL     DAD                  # (1/4)+2((Q+1)/4)      TO PD+14D
                                10D
                                HALFDP
DMPR     SL1
                                8D
DAD      DDV
                                THREE/8
                                14D
DMPR     VXSC
                                6
                                BETAV
PDVL     VSR3                  # (G/2)(C(PD+4))B/2 TO PD+16D
                                ALPHAV
VAD      PUSH                  # A12 + C(PD+16D) TO PD+16D
```

# Page 1340

GOBAQUE

```

DLOAD  DMP
        0
        12D
NORM    ROUND

        30D
BDDV    DMP*
        2
        MUEARTH,2
DCOMP   VXSC
XCHX,2  XAD,2
        S1
        S2
XSU,2   XSU,2
        30D
        31D
BOV      # CLEAR OVIND
        +1
VSR*     XCHX,2
        0      -1,2
        S1
VAD
        FV
STORE    FV
BOV      RVQ      # RETURN IF NO OVERFLOW
        +1
VLOAD    ABVAL
        TDELTAV
BZE
        INT-ABRT
DLOAD    SR
        H
        9D
PUSH     BDSU
        TC
STODL    TAU.
        TET
DSU      STADR
STCALL   TET
        KEPPREP
CALL
        RECTIFY
SETGO
        RPQFLAG
        TESTLOOP

```



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```
INT-ABRT      EXIT
               TC      POOD00
               OCT      00430
```

# Page 1341

# THE OBLATE ROUTINE COMPUTES THE ACCELERATION DUE TO OBLATENESS. IT USES THE UNIT OF THE VEHICLE  
# POSITION VECTOR FOUND IN ALPHAV AND THE DISTANCE TO THE CENTER IN ALPHAM. THIS IS ADDED TO THE  
# DISTURBING ACCELERATIONS IN FV AND THE PROPER DIFEQ STAGE IS CALLED VIA X1.

```
OBLATE      LXA,2  DLOAD
              PBODY
              ALPHAM
              SETPD DSU*
              0
              RDE,2
              BPL  BOF      # GET URPV
              NBRANCH
              MOONFLAG
              COSPHIE
              VLOAD PDDL
              ALPHAV
              TET
              PDDL  CALL
              3/5
              R-TO-RP
              STORE URPV
              VLOAD VXV
              504LM
              ZUNIT
              VAD   VXM
              ZUNIT
              MMATRIX
              UNIT  # PROBABLY UNNECESSARY.
COMTERM     STORE  UZ
              DLOAD DMPR
              COSPHI/2
              3/32
              PDDL  DSQ      # P2/64 TO PDO
              COSPHI/2
              DMPR  DSU
              15/16
              3/64
              PUSH  DMPR      # P3/32 TO PD2
              COSPHI/2
              DMP   SL1R
              7/12
```

# Page 1342

```

PDDL  DMPR
      0
      2/3
BDSU  PUSH      # P4/128 TO PD4
DMPR  DMPR
      COSPHI/2   # BEGIN COMPUTING P5/1024
      9/16
PDDL  DMPR
      2
      5/128

BDSU
DMP*
      J4REQ/J3,2
DDV   DAD      # -3
      ALPHAM    # ((P5/256)B 2 /R+P4/32) /R+P3/8)ALPHAV
      4         # 4 3
DMPR* DDV
      2J3RE/J2,2
      ALPHAM
DAD   VXSC
      2
      ALPHAV
STODL TVEC
DMP*  SR1
      J4REQ/J3,2
DDV   DAD
      ALPHAM
DMPR* SR3
      2J3RE/J2,2
DDV   DAD
      ALPHAM
VXSC  VSL1
      UZ
BVSU
      TVEC
STODL TVEC
      ALPHAM
NORM  DSQ
      X1
DSQ   NORM
      S1      # 4
PUSH  BDDV*   # NORMED R TO OD
      J2REQSQ,2
VXSC  BOV
      TVEC

```

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```

                                +1                # (RESET OVERFLOW INDICATOR)
XAD,1  XAD,1
      X1
      X1
XAD,1  VSL*
      S1
      0                -22D,1
VAD    BOV
      FV
      GOBAQUE
STCALL FV
      QUALITY1
QUALITY3 DSQ                # J22 TERM X R**4 IN 2D.  SCALED B61
                                # AS VECTOR.
PUSH    DMP                # STORE COSPHI**2 SCALED B2 IN 8D.
# Page 1343
      5/8                # 5 SCALED B3
PDDL    SR2                # PUT 5 COSPHI**2, D5, IN 8D. GET
                                # COSPHI**2 D2 FROM 8D
DAD     BDSU                # END UP WITH (1-7 COSPHI**2), B5
      8D                # ADDING COSPHI**2 B4 SAME AS COSPHI**2
                                # X 2 D5
                                # 1 SCALED B5
DMP     D1/32
      DMP
      URPV                # X COMPONENT
      5/8                # 5 SCALED B3
VXSC    VSL5                # AFTER SHIFT, SCALED B5
      URPV                # VECTOR, B1.
PDDL    8D                # VECTOR INTO 8D, 10D, 12D, SCALED B5.
                                # GET 5 COSPHI**2 OUT OF 8D
DSU     DAD
      D1/32                # 1 B5
      8D                # X COMPONENT (SAME AS MULTIPLYING
                                # BY UNITX)
STODL   8D
      URPV                # X COMPONENT
DMP     DMP
      URPV                # Z COMPONENT
      5/8                # 5 B3 ANSWER B5
SL1     DAD                # FROM 12D FOR Z COMPONENT (SL1 GIVES 10
                                # INSTEAD OF 5 FOR COEFFICIENT)
PDDL    NORM                # BACK INTO 12D FOR Z COMPONENT
      ALPHAM                # SCALED B27 FOR MOON
      X2
PUSH    SLOAD                # STORE IN 14D, DESTROYING URPV
                                # X COMPONENT
```

|                        |       |           |                                                                              |
|------------------------|-------|-----------|------------------------------------------------------------------------------|
|                        |       | E32C31RM  |                                                                              |
|                        | DDV   | VXSC      | # IF X2 = 0, DIVISION GIVES B53, VXSC<br># out of 8D B5 GIVES B58            |
|                        | VSL*  | VAD       | # SHIFT MAKES B61, FOR ADDITION OF<br># VECTOR IN 2D                         |
|                        |       | 0         | -3,2                                                                         |
|                        | VSL*  | V/SC      | # OPERAND FROM OD, B108 FOR X1 = 0                                           |
|                        |       | 0         | -27D,1                                                                       |
|                        |       |           | # FOR X1 = 0, MAKES B88, GIVING B-20<br># FOR RESULT.                        |
|                        | PDDL  | PDDL      |                                                                              |
|                        |       | TET       |                                                                              |
|                        |       |           | 5/8                                                                          |
|                        | LXA,2 | CALL      | # ANY NON-ZERO CONSTANT<br># POSITION IN OD, TIME IN 6D. X2 LEFT<br># ALONE. |
|                        |       | PBODY     |                                                                              |
|                        |       | RP-TO-R   |                                                                              |
|                        | VAD   | BOV       | # OVERFLOW INDICATOR RESET IN *RP-TO-R*                                      |
|                        |       | FV        |                                                                              |
|                        |       | GOBAQUE   |                                                                              |
|                        | STORE | FV        |                                                                              |
| # Page 1344<br>NBRANCH | SLOAD | LXA,1     |                                                                              |
|                        |       | DIFEQCNT  |                                                                              |
|                        |       | MPAC      |                                                                              |
|                        | DMP   | CGOTO     |                                                                              |
|                        |       | -1/12     |                                                                              |
|                        |       | MPAC      |                                                                              |
|                        |       | DIFEQTAB  |                                                                              |
| COSPHIE                | DLOAD | ALPHAV +4 |                                                                              |
|                        | STOVL | COSPHI/2  |                                                                              |
|                        |       | ZUNIT     |                                                                              |
|                        | GOTO  |           |                                                                              |
|                        |       | COMTERM   |                                                                              |
| DIFEQTAB               | CADR  | DIFEQ+0   |                                                                              |
|                        | CADR  | DIFEQ+1   |                                                                              |
|                        | CADR  | DIFEQ+2   |                                                                              |
| TIMESTEP               | BOF   | CALL      |                                                                              |
|                        |       | MIDFLAG   |                                                                              |
|                        |       | RECTEST   | # SKIP ORIGIN CHANGE LOGIC                                                   |
|                        |       | CHKSWTCH  |                                                                              |
|                        | BMN   |           |                                                                              |
|                        |       | DOSWITCH  |                                                                              |
| RECTEST                | VLOAD | ABVAL     | # RECTIFY IF                                                                 |

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```

                                TDELTA V
BOV
                                CALLRECT
DSU    BPL                     #      1) EITHER TDELTA V OR TNUV EQUALS OR
                                #      EXCEEDS 3/4 IN MAGNITUDE
                                CALLRECT  #
DAD    SL*                     #      OR
                                #
                                0 -7,2   #      2) ABVAL(TDELTA V) EQUALS OR EXCEEDS
DDV    DSU                     #      .01(ABVAL(RCV))
                                10D
                                RECRATIO
BPL    VLOAD
                                CALLRECT
                                TNUV
ABVAL  DSU
                                3/4
BOV
                                CALLRECT
BMN
                                INTEGRATE
CALLRECT CALL
                                RECTIFY
INTEGRATE VLOAD
                                TNUV
# Page 1345
STOVL  ZV
                                TDELTA V
STORE  YV
CLEAR
                                JSWITCH
DIFEQ0 VLOAD  SSP
                                YV
                                DIFEQCNT
                                0
STODL  ALPHAV
                                DPZERO
STORE  H                      # START H AT ZERO.  GOES 0(DELTA/2)DELTA.
BON    GOTO
                                JSWITCH
                                DOW..
                                ACCOMP
CHKSWTCH STQ    BOF
                                ORIGEX
                                RPQFLAG
```

```

                                RPQOK                # MOON POSITION IS AVAILABLE
                                CALL
                                TET
                                LUNPOS                # GET MOON POSITION
                                BOF      VCOMP
                                MOONFLAG
                                +1
                                STORE    RPQV

RPQOK      LXA,2  VLOAD                # RESTORE X2 AFTER USING LUNPOS
                                PBODY
                                TDELTA
                                VSL*    VAD          # -
                                0          -7,2      # |RQC|-RSPHERE WHEN OUTSIDE THE SPHERE.
                                RCV          # - -
                                BOF    ABVAL          # R = RDEVIATION + RCONIC
                                MOONFLAG
                                EARSPH
                                SR2    BDSU          # INSIDE
                                RSPHERE
                                GOTO
                                ORIGEX
EARSPH     VSU    ABVAL                # OUTSIDE
                                RPQV
                                DSU    GOTO
                                RSPHERE
                                ORIGEX

DOSWITCH   CALL
                                ORIGCHNG
                                GOTO
                                INTEGRATE

# Page 1346
ORIGCHNG   STQ    CALL
                                ORIGEX
                                RECTIFY
                                VLOAD  VSL*
                                RCV
                                0,2
                                VSU    VSL*
                                RPQV
                                2,2
                                STORE  RRECT
                                STODL  RCV
                                TET

```

```

CALL
      LUNVEL
BOF   VCOMP
      MOONFLAG
      +1
PDVL  VSL*
      VCV
      0,2
VSU
VSL*
      0 +2,2
STORE VRECT
STORE VCV
LXA,2  SXA,2
      ORIGEX
      QPRET
BON    GOTO
      MOONFLAG
      CLRMOON
      SETMOON

```

# Page 1347

```

# THE RECTIFY SUBROUTINE IS CALLED BY THE INTEGRATION PROGRAM AND OCCASIONALLY BY THE MEASUREME
# ROUTINES TO ESTABLISH A NEW CONIC.

```

```

RECTIFY      LXA,2  VLOAD
              PBODY
              TDELTA V
VSL*         VAD
              0      -7,2
              RCV
STORE        RRECT
STOVL        RCV
              TNUV
VSL*         VAD
              0      -4,2
              VCV
MINIRECT     STORE VRECT
STOVL        VCV
              ZEROVEC
STORE        TDELTA V
STODL        TNUV
              ZEROVEC
STORE        TC
STORE        XKEP
RVQ

```

# Page 1348

# THE THREE DIFEQ ROUTINES -- DIFEQ+0, DIFEQ+12, DIFEQ+24 -- ARE ENTERED TO PROCESS

# BEGINNING, MIDDLE, AND END OF THE TIMESTEP, RESPECTIVELY. THE UPDATING IS DONE BY

```

DIFEQ+0      VLOAD  VSR3
              FV
              STCALL PHIV
              DIFEQCOM
DIFEQ+1      VLOAD  VSR1
              FV
              PUSH   VAD
              PHIV
              STOVL  PSIV
              VSR1   VAD
              PHIV
              STCALL PHIV
              DIFEQCOM
DIFEQ+2      DLOAD  DMPR
              H
              DP2/3
              PUSH   VXSC
              PHIV
              VSL1   VAD
              ZV
              VXSC   VAD
              H
              YV
              STOVL  YV
              FV
              VSR3   VAD
              PSIV
              VXSC   VSL1
              VAD
              ZV
              STORE  ZV
              BOFF   CALL
              JSWITCH
              ENDSTATE
              GRP2PC
              LXA,2  VLOAD
              COLREG
              ZV
              VSL3
              STORE  W      +54D,2
              VLOAD
              YV
# ADJUST W-POSITION FOR STORAGE

```



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```
# Page 1349
VSL3    BOV
        WMATEND
STORE   W,2

CALL
        GRP2PC

LXA,2   SSP
        COLREG
        S2
        0
INCR,2  SXA,2
        6
        YV
TIX,2   CALL
        RELOADSV
        GRP2PC
LXA,2   SXA,2
        YV
        COLREG

NEXTCOL CALL
        GRP2PC
LXA,2   VLOAD*
        COLREG
        W,2

VSR3
STORE   YV
VLOAD*  AXT,1
        W      +54D,2
        0

VSR3
STCALL  ZV
        DIFEQO

ENDSTATE BOV    VLOAD
          GOBAQUE
          ZV
STOVL   TNUV
        YV
STORE   TDELTA V
BON     BOFF
        MIDAVFLG
        CKMID2
        DIMOFLAG
        TESTLOOP

# ADJUST W-POSITION FOR INTEGRATION
# ADJUST W-VELOCITY FOR INTEGRATION
# CHECK FOR MID2 BEFORE GOING TO TIMEINC
```

```

EXIT
TC      PHASCHNG
OCT     04022      # PHASE 1
TC      UPFLAG     # PHASE CHANGE HAS OCCURRED BETWEEN
ADRES   REINTFLG   # INTSTALL AND INTWAKE
TC      INTPRET
SSP
          QPRET
          AMOVED
BON     GOTO
          VINTFLAG

# Page 1350
          ATOPCSM
          ATOPLEM
AMOVED  SET        SSP
          JSWITCH
          COLREG
DEC     -30
BOFF    SSP
          D6OR9FLG
          NEXTCOL
          COLREG
DEC     -48
GOTO    NEXTCOL

RELOADSV DLOAD     # RELOAD TEMPORARY STATE VECTOR
          TDEC      # FROM PERMANENT IN CASE OF
          STCALL    TDEC1
          INTEGRV2  # BY STARTING AT INTEGRV2.
DIFEQCOM DLOAD     # INCREMENT H AND DIFEQCNT.
          DAD
          DT/2
          H
INCR,1  SXA,1
DEC     -12
          DIFEQCNT  # DIFEQCNT SET FOR NEXT ENTRY.
STORE   H
VXSC    VSR1
          FV
VAD     VXSC
          ZV
          H
VAD
          YV
STORE   ALPHAV
BON     GOTO

```

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# Page 1351

```
# ORBITAL ROUTINE FOR EXTRAPOLATION OF THE W MATRIX.  IT COMPUTES THE SECOND DERIVATIVE OF EACH
# VECTOR OF THE MATRIX AND CALLS THE NYSTROM INTEGRATION ROUTINES TO SOLVE THE DIFFERENTIAL EQU
# USES A TABLE OF VEHICLE POSITION VECTORS COMPUTED DURING THE INTEGRATION OF THE VEHICLE'S POS
```

|        |        |           |      |
|--------|--------|-----------|------|
| DOW..  | LXA,2  | DLOAD*    |      |
|        |        | PBODY     |      |
|        |        | MUEARTH,2 |      |
|        | STCALL | BETAM     |      |
|        |        | DOW..1    |      |
|        | STORE  | FV        |      |
|        | BOF    | INCR,1    |      |
|        |        | MIDFLAG   |      |
|        |        | NBRANCH   |      |
|        | DEC    | -6        |      |
|        | LXC,2  | DLOAD*    |      |
|        |        | PBODY     |      |
|        |        | MUEARTH   | -2,2 |
|        | STCALL | BETAM     |      |
|        |        | DOW..1    |      |
|        | BON    | VSR6      |      |
|        |        | MOONFLAG  |      |
|        |        | +1        |      |
|        | VAD    |           |      |
|        |        | FV        |      |
|        | STCALL | FV        |      |
|        |        | NBRANCH   |      |
| DOW..1 | VLOAD  | VSR4      |      |

|             |        |          |
|-------------|--------|----------|
|             |        | ALPHAV   |
|             | PDVL*  | UNIT     |
|             |        | VECTAB,1 |
|             | PDVL   | VPROJ    |
|             |        | ALPHAV   |
|             | VXSC   | VSU      |
|             |        | 3/4      |
|             | PDDL   | NORM     |
|             |        | 36D      |
|             |        | S2       |
|             | PUSH   | DSQ      |
|             | DMP    |          |
|             | NORM   | PDDL     |
|             |        | 34D      |
|             |        | BETAM    |
|             | SR1    | DDV      |
|             | VXSC   |          |
|             | LXA,2  | XAD,2    |
|             |        | S2       |
|             |        | S2       |
|             | XAD,2  | XAD,2    |
|             |        | S2       |
|             |        | 34D      |
|             | VSL*   | RVQ      |
| # Page 1353 |        | 0 -8D,2  |
|             | SETLOC | ORBITAL1 |
|             | BANK   |          |
| 3/5         | 2DEC   | .6 B-2   |
| THREE/8     | 2DEC   | .375     |
| .3D         | 2DEC   | .3 B-2   |
| 3/64        | 2DEC   | 3 B-6    |
| DP1/4       | 2DEC   | .25      |
| DQUARTER    | EQUALS | DP1/4    |
| POS1/4      | EQUALS | DP1/4    |
| 3/32        | 2DEC   | 3 B-5    |
| 15/16       | 2DEC   | 15. B-4  |

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|        |        |             |
|--------|--------|-------------|
| 3/4    | 2DEC   | 3.0 B-2     |
| 7/12   | 2DEC   | .5833333333 |
| 9/16   | 2DEC   | 9 B-4       |
| 5/128  | 2DEC   | 5 B-7       |
| DPZERO | EQUALS | ZEROVEC     |
| DP2/3  | 2DEC   | .6666666667 |
| 2/3    | EQUALS | DP2/3       |
| OCT27  | OCT    | 27          |

BANK 13  
SETLOC ORBITAL2  
BANK

# IT IS VITAL THAT THE FOLLOWING CONSTANTS NOT BE SHUFFLED

|        |     |     |
|--------|-----|-----|
|        | DEC | -11 |
|        | DEC | -2  |
|        | DEC | -9  |
|        | DEC | -6  |
|        | DEC | -2  |
|        | DEC | -2  |
|        | DEC | 0   |
|        | DEC | -12 |
|        | DEC | -9  |
|        | DEC | -4  |
| ASCALE | DEC | -7  |
|        | DEC | -6  |

# Page 1354

|          |       |                       |     |
|----------|-------|-----------------------|-----|
|          | 2DEC* | 1.32715445 E16 B-54*  | # S |
|          | 2DEC* | 4.9027780 E8 B-30*    | # M |
| MUEARTH  | 2DEC* | 3.986032 E10 B-36*    |     |
|          | 2DEC  | 0                     |     |
| J4REQ/J3 | 2DEC* | .4991607391 E7 B-26*  |     |
|          | 2DEC  | -176236.02 B-25       |     |
| 2J3RE/J2 | 2DEC* | -.1355426363 E5 B-27* |     |
|          | 2DEC* | .3067493316 E18 B-60* |     |

|          |        |                      |
|----------|--------|----------------------|
| J2REQSQ  | 2DEC*  | 1.75501139 E21 B-72* |
| 3J22R2MU | 2DEC*  | 9.20479048 E16 B-58* |
| 5/8      | 2DEC   | 5 B-3                |
| -1/12    | 2DEC   | -.1                  |
| MUM      | =      | MUEARTH -2           |
| RECRATIO | 2DEC   | .01                  |
| RSPHERE  | 2DEC   | 64373.76 E3 B-29     |
| RDM      | 2DEC   | 16093.44 E3 B-27     |
| RDE      | 2DEC   | 80467.20 E3 B-29     |
| RATT     | EQUALS | 00                   |
| VATT     | EQUALS | 6D                   |
| TAT      | EQUALS | 12D                  |
| RATT1    | EQUALS | 14D                  |
| VATT1    | EQUALS | 20D                  |
| MU(P)    | EQUALS | 26D                  |
| TDEC1    | EQUALS | 32D                  |
| URPV     | EQUALS | 14D                  |
| COSPFI/2 | EQUALS | URPV +4              |
| UZ       | EQUALS | 20D                  |
| TVEC     | EQUALS | 26D                  |

This code is written to file `src/ORBITAL-INTEGRATION.s`.

## A.64 P11

```

943  <src/P11.s 943>≡
# Copyright:    Public domain.
# Filename:     P11.agc
# Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
#               It is part of the source code for the Command Module's (CM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:      Hartmuth Gutsche <hgutsche@explornet.com>.
# Website:      www.ibiblio.org/apollo.
# Pages:        533-550
# Mod history:  2009-05-13 HG   Started adapting from the Colossus249/ file
#               of the same name, using Comanche055 page
#               images 0533.jpg - 0550.jpg.
#               2009-05-20 RSB  Corrections: ERTHALT -> EARTHALT,
#               STATSW -> SATSW.
#               2009-05-23 RSB  At end of RESCALES, corrected TC 0 to TC Q.
#               Added an SBANK= prior to a 2CADR.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#   Assemble revision 055 of AGC program Comanche by NASA
#   2021113-051. 10:28 APR. 1, 1969
#
#   This AGC program shall also be referred to as
#   Colossus 2A
#
# Page 533
# EARTH ORBIT INSERTION MONITOR PROGRAM
# *****
#
# PROGRAM DESCRIPTION -P11-
#
#   MOD NO. 1
#   MOD BY ELIASSEN
#
# FUNCTIONAL DESCRIPTION

```

```

#
# P11 IS INITIATED BY
#
# A) GYROCOMPASS PRG P02 WHEN LIFTOFF DISCRETE IS RECEIVED OR
# B) BACKUP THRU VERB 75 ENTER
#
# PROGRAM WILL
# 1. ZERO CMC CLOCK AT LIFTOFF (OR UPON RECEIPT OF BACKUP)
# 2. UPDATE TEPHEM TO TIME CMC CLOCK WAS ZEROED
# 3. INITIATE SERVICER AT PREREAD1
# 4. CHANGE MAJOR MODE TO 11
# 5. CLEAR DSKY IN CASE OF V 75
# 6. STORE LIFTOFF IMU-CDU ANGLES FOR ATT. ERROR DISPLAY
# 7. TERMINATE GYROCOMPASSING
# 8. COMPUTE INITIAL VECTORS      -- --
# 9. COMPUTE REFSMMAT FOR PRELAUNCH ALIGNMENT WHERE  $\bar{U}_X, \bar{U}_Y, \bar{U}_Z$  ARE
#
#  $\bar{U} = (\text{UNIT}(-R))$  LOCAL VERTICAL AT TIME OF LIFTOFF
#  $\bar{Z}$ 
#  $\bar{U} = \text{UNIT}(A)$ ,  $A = \text{HOR VECTOR AT LAUNCH AZIMUTH}$ 
#  $\bar{X}$ 
#  $\bar{U} = \bar{U} * \bar{U}$ 
#  $\bar{U}_Z \bar{X}$ 
# 10. SET REFSMMAT KNOWN FLAG
# 11. SET AVGEXIT IN SERVICER TO VHHDOT TO
# COMPUTE AND DISPLAY NOUN 62 EVERY 2 SECONDS
#
# R1 V1 -- INERTIAL VELOCITY MAGNITUDE IN FPS
# R2 HDOT -- RATE OF CHANGE OF VEHICLE VEL IN FPS
# R3 H -- VEHICLE ALTITUDE ABOVE PAD IN NM
#
# 12. DISPLAY BODY AXES ATT. ERRORS ON FDAI NEEDLES
#
# A) FROM L.O. TO RPSTART (APPROX. 0 TO +10SECS AFTER L.O.)
# DESIRED ATTITUDE IS AS STORED AT L.O.
# B) FROM RPSTART TO POLYSTOP (APPROX. +10 TO +133SECS AFTER L.O.)
# DESIRED ATTITUDE IS SPECIFIED BY CMC PITCH AND ROLL
# POLYNOMIALS DURING SATURN ROLLOUT AND PITCHOVER
#
# Page 534
#
# THE DISPLAY IS RUN AS LOW PRIORITY JOB APPROX.
# EVERY 1/2 SEC OR LESS AND IS DISABLED UPON OVFL0 OF TIME1
#
# SUBROUTINES CALLED
#
# 2PHSCHNG BANKCALL CALCGRA CDUTRIG CLEANDSP
# DELAYJOB EARTHRE ENDOFJOB FINDVAC IBNKCALL

```



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```
#      INTPRET      LALOTORV      NEEDLER      NEWMODEX      PHASCHNG
#      POSTJUMP      POWRSERS      PREREAD1      REGODSPR      S11.1
#      SERVEXIT      TASKOVER      TCDANZIG      V1STO2S      WAITLIST
#
# ASTRONAUT REQUESTS (IF ALTITUDE ABOVE 300,000 FT)
#
#      DSKY --
#              MONITOR DISPLAY OF TIME TO PERIGEE R1 HOURS
#                      R2 MINUTES
#
#      DSKY --
#              MONITOR DISPLAY OF R1 APOGEE ALTITUDE IN NAUTICAL MILES
#                      R2 PERIGEE ALTITUDE IN NAUTICAL MILES
#                      R3 TFF IN MINUTES/SECS
#
#      IF ASTRONAUT HAS REQUESTED ANY OF THESE DISPLAYS HE MUST
# HIT PROCEED TO RETURN TO NORMAL NOUN 62 DISPLAY.
# NORMAL EXIT MODE
#
#      ASTRONAUT      VERB 37 ENTER 00 ENTER
#
# ALARM MODES -- NONE
#
# ABORT EXIT MODES --
#
# OUTPUT
#
#      TLIFTOFF (DP)      TEPHEM (TP)
#      REFSMMAT
#      DSKY DISPLAY
#      FDAI DISPLAY
#
# ERASABLE INITIALIZATION
#
#      AZO, AXO, -AYO
#      LATITUDE
#      PADLONG
#      TEPHEM
#      PGNCSTLT
#      POLYNUM THRU POLYNUM +14D
#      RPSTART
#      POLYSTOP
# FLAGS SET OR RESET
# Page 535
#      SET REFSMFLG
#      SET DVMON IDLE FLAG
```

```

#      CLEAR ERADFLAG
#
# DEBRIS
#
#      LIFTTEMP
#      POLYNUM THRU POLYNUM +7
#      SPOLYARG
#      BODY1, BODY2, BODY3
#      VMAG2, ALTI, HDOT
#      CENTRALS, CORE SET, AND VAC AREAS

COUNT    34/P11

BITS5-6    =      SUPER011
           BANK    42
           SETLOC  P11ONE
           BANK

P11         EBANK=  TEPHEM
           CA      EBANK3
           TS      EBANK

           EXTEND
           DCA     REP11S      # DIRECT RESTARTS TO REP11
           DXCH    -PHASE3
           CS      ZERO
           ZL
           TS      LIFTTEMP
           DXCH    -PHASE5      # INACTIVE GROUP 5, PRELAUNCH PROTECTION
P11+7       EXTEND
           DCA     REP11SA
           DXCH    TLIFTOFF

           EXTEND
           DCA     TIME2
           DXCH    LIFTTEMP      # FORE RESTARTS

           CA      ZERO
           ZL
           DXCH    TIME2
REP11A-2    DXCH    TLIFTOFF
REP11A-1    DXCH    -PHASE3      # RESET PHASE

REP11A      INHINT
           EXTEND
           DCA     TEPHEM +1

```

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# Page 536

DXCH TEPHEM1 +1  
CA TEPHEM

XCH TEPHEM1

EXTEND

DCA TLIFTOFF  
DAS TEPHEM1 +1  
ADS TEPHEM1

# CORRECT FOR OVERFLOW

TC PHASCHNG  
OCT 05023  
OCT 22000

INHINT

EXTEND

DCA TEPHEM1  
DXCH TEPHEM  
CA TEPHEM1 +2  
XCH TEPHEM +2

CAF EBDVCNT  
TS EBANK  
EBANK= DVCNTR  
TC IBNKCALL  
CADR PREREAD1

# ZERO PIPS AND INITIALIZE AVERAGEG

TC PHASCHNG  
OCT 05023  
OCT 22000

# CONTINUE HERE ON RESTART

CAF .5SEC  
TC WAITLIST  
EBANK= BODY3  
2CADR ATERTASK

# START ATT ERROR DISPLAY  
# IN .5 SEC

TC NEWMODEX  
MM 11

# DISPLAY MM 11

TC UPFLAG  
ADRES NODOPO1

CA POWDNCOD  
TS DNLSTCOD

# SWITCH TO POWERED FLIGHT DOWNLIST

TC BANKCALL

```

                                CADR    CLEANDSP      # CLEAR DSKY IN CASE OF V75

                                TC        2PHSCHNG
                                OCT        40514        # PROTECT ATERTASK
                                OCT        00073
                                CAF        EBQPLACE

# Page 537

                                TS        EBANK

                                EBANK=    QPLACES
                                CA        P11XIT        # SET EXIT FROM PROUT IN EARTH
                                TS        QPLACES
                                TC        INTPRET
                                VLOAD     MXV
   THETAN
   XSM
                                VSL1     VAD
   ERCOMP
                                STODL     ERCOMP
   TLIFTOFF
                                SSP        GOTO
   S2
                                CADR      PROUT        # RETURN FROM EARTH
   EARTH +3

MATRXJOB  ZL                        # STORE DP GIMBAL ANGLES FOR ATTITUDE
                                CA        CDUX        #
                                DXCH      OGC          # ERROR DISPLAY AFTER LIFTOFF
                                ZL
                                CA        CDUY
                                DXCH      IGC
                                ZL
                                CA        CDUZ
                                DXCH      MGC
                                TC        INTPRET
                                VLOAD     VSR1        # SCALE OGC B-1
   OGC
                                STORE     OGC
                                SSP
   RTX2        # ZERO RTX2
   0            # FOR
   0            # EARTH
                                DLOAD     PDDL
   PGNCALT        # ALTITUDE OF PGNC
   PADLONG        # LONGITUDE
                                PDDL      VDEF
   LATITUDE        # GEODETIC LATITUDE
                                STODL     LAT          # LAT, LONG, ALT ARE CONSECUTIVE

```

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# Page 538

```

      HI6ZEROS      # TIME = 0
CLEAR  CALL
      ERADFLAG
      LALOTORV      # CONVERT TO POSITION VECTOR IN REF. COORDS.

STCALL RN1          #
      GETDOWN        # RETURN WITH VECTOR FOR DOWN DIRECTION
VCOMP  UNIT
STOVL  REFSMMAT +12D # UNITZ = UNIT(GRAV)
      RN1
VXV    VXSC

      UNITW          # SCALED AT 1
      -ERTHRAT       # V = EARTH RATE X R
VSL4   # SCALE TO 2(7) M/CS
STOVL  VN1
      REFSMMAT +12D
VXV    UNIT
      UNITW          # (REF3 X UNITW) = EAST
PUSH   VXV
      REFSMMAT +12D  # (EAST X REF3) = -SOUTH
UNIT   PDDL
      LAUNCHAZ       # COS(AZ)*SOUTH
COS    VXSC
STADR
STODL  REFSMMAT      # TEMPORARY STORAGE
      LAUNCHAZ
SIN    VXSC          # SIN(AZ)*EAST
VAD    UNIT          # SIN(AZ)*EAST - COS(AZ)*SOUTH = REF1
      REFSMMAT
STORE  REFSMMAT

VXV    UNIT          # (REF1 X REF3) = -REF3
      REFSMMAT +12D
VCOMP
STORE  REFSMMAT +6
DLOAD  DSU
      DPHALF         # 1/2 REV
      LAUNCHAZ
DAD    PDDL
      AZIMUTH
      SATRLRT        # SET SATRLRT = -SATRLRT IF
SIGN   STADR         # (1/2REV -LAVNCHAZ +AZIMUTH) IS NEGATIVE
STORE  SATRLRT       # FOR ROLL CALC IN FDAI ATT. ERROR DISPLAY
SET    EXIT
      REFSMFLG       # SET REFSMMAT KNOWN FLAG
```

```
TC      PHASCHNG
OCT     04023

EXTEND
DCA     P11SCADR
DXCH    AVGEXIT      # SET AVGEXIT

CA      PRI031      # 2 SECONDS AT 2(+8)
TS      1/PIPADT

EBANK=   RCSFLAGS
CA       EBANK6
TS       EBANK

INHINT

# Page 539

CS      ZERO
TS      TBASE5      # RESTART READACCS 2 SECONDS AFTER LIFTOFF

CS      TIME1
AD      2SECS      # DO READACCS 2 SECONDS AFTER LIFTOFF

CCS     A          # CHECK TO INSURE DT IS POSITIVE
TCF     +3         # TIME POSITIVE
TCF     +2         # CANNOT GET HERE
CA      ZERO       # TIME NEGATIVE -- SET TO 1
AD      ONE        # RESTORE TIME -- OR MAKE POSITIVE

TC      WAITLIST
EBANK=   AOG
2CADR    READACCS

TC      2PHSCHNG
OCT     00003      # TURN OFF GROUP 3
OCT     00025      # PROTECT NORMLIZE AND READACCS

TC      POSTJUMP
CADR     NORMLIZE   # DO NORMLIZE AND ENDOFJOB

EBANK=   TEPHEM
INHINT
CCS     PHASE5
TC      ENDOFJOB

REP11
```

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```

      CCS      LIFTTEMP
      TCF      +4
      TCF      +3
      TCF      +2
      TCF      P11+7

      CS        TLIFTOFF
      EXTEND
      BZMF      ENDREP11

      CCS      TIME2          # ** TIME2 MUST BE NON-ZERO AT LIFTOFF **
      TCF      REP11A  -5    # T2,T1 NOT YET ZEROED, GO AND DO IT

      EXTEND          # T2,T1 ZEROED, SET TLIFTOFF
      DCA      LIFTTEMP
      TCF      REP11A-2

ENDREP11      EXTEND
              DCA      REP11SA
              TCF      REP11A-1

#Page 540
REP11S      2OCT      7776600011

REP11SA     2OCT      7776400013

P11XIT      GENADR  P11OUT
-ERTHRAT    2DEC*   -7.292115138 E-7 B18*   # - EARTH RATE AT 2(18)

              EBANK=  BODY3
P11SCADR    2CADR   VHHDOT

POWDNCOD    EQUALS  THREE

              EBANK=  BODY3
# VHHDOT IS EXECUTED EVERY 2 SECONDS TO DISPLAY ON DSKY
#      VI      INERTIAL VELOCITY MAGNITUDE
#      HDOT    RATE OF CHANGE OF ALT ABOVE L PAD RADIUS
#      H      ALTITUDE ABOVE L PAD RADIUS

VHHDOT      TC      INTPRET
              CALL          # LOAD VMAGI, ALTI,
              S11.1        # HDOT FOR DISPLAY
              EXIT
              TC      PHASCHNG
              OCT      00035
```

```

CAF      V06N62      # DISPLAY IN R1 R2  R3
TC      BANKCALL    #              VI HDOT H
CADR     REGODSP

ATERTASK  CAF      PRI01      # ESTABLISH JOB TO DISPLAY ATT ERRORS
          TC      FINDVAC     # COMES HERE AT L.O. + .33 SEC
          EBANK=   BODY3
          2CADR    ATERJOB

          CS      RCSFLAGS    # SET BIT3 FOR
          MASK     BIT3       # NEEDLER
          ADS      RCSFLAGS    # INITIALIZATION PASS
          TC      IBNKCALL     # AND GO
          CADR     NEEDLER     # DO IT
          CA      BIT1        # SET SW
          TS      SATSW       # FOR DISPLAY
          TC      TASKOVER
GETDOWN   STQ      SETPD
          INCORPEX
          OD
          DLOAD
          HI6ZEROS

#Page 541

          STODL    6D
          DPHALF
          STCALL   8D
          LALOTORV +5

# THIS SECTION PROVIDES ATTITUDE ERROR DISPLAYS TO THE FDAI DURING SONE BOOST
#
#      COMPUTE DESIRED PITCH W.R.T. PAD LOCAL VERTICAL AT LIFTOFF
#              2      3      4      5      6
#      PITCH = A0+A1T+A2T +A3T +A4T +A5T +A6T
#              SCALED TO 32 REVS. -14
#      IF TL = TIME IN SECS FROM L.O., THEN      T = 100(TL-RPSTART)2
#      WHERE TL GE RPSTART
#              TL LE (-POLYSTOP + RPSTART)
#      COMPUTE DESIRED ROLL WEHRE ROLL EQUALS ANGLE FROM
#      LAUNCHAZ TO -Z(S/C) AS SEEN FROM X(S/C).
#      ROLL = LAUNCHAZ-AZIMUTH-.5+SATRLRT*T      IN REV
#      SATRLRT = RATE OF ROLL IN REV/CENTI-SEC
#      T, IN CENTI-SEC, IS DEFINED AS ABOVE, INCLUSIVE OF TIME RESTRICTIONS
#
#      FOR SIMPLICITY, LET      P = 2*PI*PITCH
#                                R = 2*PI*ROLL
#
#      CONSTRUCT THE TRANSFORMATION MATRIX, TSMV, GIVING DESIRED S/C AXES IN

```



```

#      TERMS OF SM COORDINATES.  LET THE RESULTING ROWS EQUAL THE VECTORS XDC,
#      YDC, AND ZDC.
#
#      *      (      SIN(P)              0              -COS(P)      )      (XDC)
#      TSMV = (-SIN(R)*COS(P)          -COS(R)          -SIN(R)*SIN(P)) = (YDC)
#              (-COS(R)*COS(P)          SIN(R)           -COS(R)*SIN(P))      (ZDC)
#
#      XDC,YDC,ZDC ARE USED AS INPUT TO CALCGTA FOR THE EXTRACTION OF THE
#      EULER SET OF ANGLES WHICH WILL BRING THE SM INTO THE DESIRED
#      ORIENTATION.  THIS EULER SET, OGC, IGC, AND MGC, MAY BE IDENTIFIED
#      AS THE DESIRED CDU ANGLES.
#
#      (XDC)              (OGC)
#      (YDC) ---) CALCGTA ---) (IGC)
#      (ZDC)              (MGC)
#
#      -
#      DEFINE THE VECTOR DELTACDU.
#
#      -      (OGC)      (CDUX)
#      DELTACDU = (IGC) - (CDUY)
#                  (MGC)      (CDUZ)
#
#      COMPUTE ATTITUDE ERRORS, A, WHERE      -      *      -
#                  A = TGSC*DELTACDU
#
#      *      (1              SIN(CDUZ)              0      )      THE GIMBAL ANGLES
#
#Page 542
#      TGSC = (0      COS(CDUX)*COS(CDUZ)      SIN(CDUX)) = TO SPACECRAFT AXES
#              (0      -SIN(CDUX)*COS(CDUZ)      COS(CDUX))      CONVERSION MATRIX
#
#      -
#      THE ATTITUDE ERRORS, A, ARE STORED ONE HALF SINGLE PRECISION IN
#      THE REGISTERS AK, AK1, AK2 AS INPUT TO NEEDLER, THE FDAI ATTITUDE
#      ERROR DISPLAY ROUTINE.
#
#      ATERJOB      CAE      FLAGWRD6      # CHECK FLAGWRD6
#                  MASK      OCT60000      # BITS 14, 15
#                  EXTEND
#                  BZF      +2      # OK -- CONTINUE
#                  TC      ENDOFJOB      # STAURN STICK ON -- KILL JOB
#                  CAF      BIT10      # CHECK IF S/C CONTROL
#                  EXTEND      # OF SATURN PANEL
#                  RAND      CHAN30      # SWITCH IS ON
#                  EXTEND
#                  BZF      STRSAT      # IT IS -- GO STEER
#                  CCS      SATSW      # IT IS NOT -- WAS IT ON LAST CYCLE
#                  TC      ATTDISP      # NO -- CONTINUE
#                  TC      ATRESET      # YES -- REINITIALIZE NEEDLER

```

```

      TC      ATRESET      # YES -- REINITIALIZE NEEDLER
ATTDISP      CS      RPSTART      # PITCH/ROLL START TIME
      AD      TIME1
      EXTEND
      BZMF      NOPOLY      # IF MINUS THEN ATTITUDE HOLD
      TS      MPAC      # MPAC = TIME1 - RPSTART
      TS      SPOLYARG      # SAVE FOR USE IN ROLL CALCULATION
      AD      POLYSTOP      # NEG PITCHOVER TIME IN CSECS
      EXTEND
      BZMF      +2
      TC      NOPOLY      # GO TO ATTITUDE HOLD
      CA      TIME2
      EXTEND
      BZMF      +2
      TC      NOPOLY      # GO TO ATTITUDE HOLD
      CAE      POLYNUM
      TS      L
      CAF      COEFPOLY      # EVALUATE PITCH POLYNOMIAL
      TC      POWRSERS      # SCALED TO 32 REVOLUTIONS
      CA      ZERO      # RETURN WITH PITCH(32REV)
      TS      MODE      # STORED MPAC, MPAC +1
      TC      INTPRET
      SETPD      SL      # 32(PITCH(32REV)) = PITCH(REV)
      0
      5
      PUSH      # LET P(RAD) = 2*PI*PITCH(REV)
      GOTO
      ATTDISP1      # AROUND SETLOC

#Page 543
#
#          *
#          CONSTRUCT SM TO S/C MATRIX, TSMV

      SETLOC      P11TWO
      BANK      # 36 IN COL., 34 IN DISK

      COUNT      36/P11

ATTDISP1      COS      DCOMP
      STODL      14D      # -.5*COS(P)
      SIN
      STODL      10D      # .5*SIN(P)
      ZEROVECS
      STORE      12D      # 0

#          EVALUATE ROLL = LAUNCHAZ-AZIMUTH-.5+SATRLRT*T
      SLOAD      DMP

```

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```

                                SPOLYARG      # TIME1 - RSPSTART, CSECS B-14.
                                SATRLRT
SL      DSU
        14D
        DPHALF
DAD     DSU      # ASSUMING X(SM) ALONG LAUNCH AZIMUTH,
        LAUNHAZ  # LAUNHAZ = ANGLE FROM NORTH TO X(SM).
        AZIMUTH  # AZIMUTH = -ANGLE FROM NORTH TO Z(S/C)
RTB     # DETERMINE IF ROLLOUT
        RLTST    # IS COMPLETED
ATTDISPR  PUSH    COS      # CONTINUE COMPUTING TSMV
        PUSH     # LET R(RAD) = 2*PI*ROLL(REV)
        DMP      SL1
        14D
STODL   22D      # -.5*COS(R)*COS(P)
DCOMP
STORE   18D      # -.5*COS(R)
DMP     SL1
        10D
STODL   26D      # -.5*COS(R)*SIN(P)
SIN     PUSH
STORE   24D      # .5*SIN(R)
DMP     SL1
        14D
STODL   16D      # -.5*SIN(R)*COS(P)
DCOMP
DMP     SL1
        10D
STOVL   20D      # -.5*SIN(R)*SIN(P)
        10D

#      FROM TSMV FIND THE HALF UNIT VECTORS XDC,YDC,ZDC = INPUT TO CALCGTA
# Page 544
        UNIT
STOVL   XDC      # XDC = .5*UNIT(SIN(P),0,-COS(P))
        16D
        UNIT
STOVL   YDC      # YDC = .5*UNIT(-SIN(R)*COS(P),-COS(R),
        22D      #                      -SIN(R)*SIN(P))
        UNIT
STCALL  ZDC      # ZDC = .5*UNIT(-COS(R)*COS(P),SIN(R),
        CALCGTA  #                      -COS(R)*SIN(P))

#      CALL CALCGTA TO COMPUTE DESIRED SM ORIENTATION  OGC,IGC, AND MGC
#
#      FIND DIFFERENCE VECTOR  DELTACDU = OGC-CDUX
```

```

#
#      ENTER HERE IF ATTITUDE HOLD

NOPOLYM      VLOAD  PUSH      #      OGC      IGC
              OGC      # CHANGE IGC TO MGC FOR COMPATIBILITY
              PUSH  CALL      #      MGC      OGC
              CDUTRIG      # WITH Y,Z,X ORDER OF CDUSPOT
              VLOAD  RTB      #      _      DPHI      OGC-CDUX , PD4
              2      # DELTACDU = DTHETA = IGC-CDUY , 0
              V1STO2S      #      DPSI      MGC-CDUZ , 2
              STOVL  BOOSTEMP
              ZEROVECS
              STOVL  0
              CDUSPOT
              RTB      RTB
              V1STO2S
              DELSTOR
              STODL  10D
              SINCDUZ
              DMP      SL1
              0
              DAD      SR2      # CHANGE SCALE OF AK TO 2REVS
              4
              GOTO
              ATTDISP2

              SETLOC P11ONE
              BANK
              COUNT  34/P11

ATTDISP2      STODL  16D      # 16D, .5(DPHI + DTHETA*SIN(CDUZ))
              COSCDUZ
              DMP      PUSH
              0
              DMP      SL1
              COSCDUX
              PDDL  DMP

# Page 545
              SINCDUX
              2
              DAD      SL1
              STADR
              STODL  17D      # 17D, .5(DTHETA*COS(CDUX)*COS(CDUZ))
              DMP      SL1      #
              SINCDUX      +DPSI*SIN(CDUX))
              PDDL  DMP

```

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```

COSCDUX
2
DSU      SL1
STADR
STORE    18D      # 18D,  .5(-DTHETA*SIN(CDUX)*COS(CDUZ)
TLOAD    #
           +DPSI*COS(CDUX))
           16D
STORE    AK        # STORE ATTITUDE ERRORS IN AK,AK1,AK2
EXIT

CA        SATSW
CCS       A        # CHK TAKEOVER STATUS
TC        SATOUT   # POS  -- DISPLAY ONLY
TC        AKLOAD   # 0      STORE BIAS
STEERSAT TC        INTPRET # NEG    STEER L/V
TLOAD     TAD
           BIASAK
           AK
STORE     AK        # AKS = AKS - STORED BIAS
EXIT
CA        AK
TC        RESCALES
TS        AK
CA        AK1
TC        RESCALES
TS        AK1
CA        AK2
TC        RESCALES
TS        AK2
#         DISPLAY ATTITUDE ERRORS ON FDAI VIA NEEDLER

SATOUT    TC        BANKCALL
          CADR       NEEDLER
ATERSET   CAF       OCT31      # DELAY .25 SEC
          TC        BANKCALL   # EXECUTION + DELAY = .56SEC APPROX
          CADR       DELAYJOB
          TC        ATERJOB     # END OF ATT ERROR DISPLAY CYCLE

AKLOAD    CS        AK        # STORE AKS
          TS        BIASAK     # INTO BIAS
          CS        AK1        # COMPLEMENTED
          TS        BIASAK +1

# Page 546
          CS        AK2
          TS        BIASAK +2
          CS        BIT1      # SET SW

```

|          |        |          |                                       |
|----------|--------|----------|---------------------------------------|
|          | TS     | SATSW    | # TO STEER                            |
|          | TC     | STEERSAT | # GO STEER                            |
| STRSAT   | CA     | SATSW    | # CHECK IF NEDLER                     |
|          | EXTEND |          | # HAS BEEN INITIALIZED                |
|          | BZMF   | ATTDISP  | # YES -- CONTINUE                     |
| ATRESET  | CS     | RCSFLAGS | # NO -- SET                           |
|          | MASK   | BIT3     | # INITIALIZATION SW                   |
|          | ADS    | RCSFLAGS | # FOR NEDLER                          |
|          | TC     | BANKCALL | # AND GO                              |
|          | CADR   | NEEDLER  | # DO IT                               |
|          | CAF    | REVCNT   | # OCT 6                               |
|          | TC     | BANKCALL | # DELAY JOB                           |
|          | CADR   | DELAYJOB | # 60 MS --WAIT TILL IMUERRCNTR ZEROED |
|          | CCS    | SATSW    | # CHECK SW STATUS                     |
|          | TC     | TAKEON   | # POS STEER INIT.                     |
|          | TC     | +1       | # 0 RETURN TO DISPLAY                 |
|          | CA     | BIT1     | # NEG RETURN TO DISPLAY               |
|          | TS     | SATSW    | # SW = DISPLAY ON                     |
|          | CS     | BIT9     | # DISABLE                             |
|          | EXTEND |          | # SIVB                                |
|          | WAND   | CHAN12   | # TAKEOVER                            |
|          | TC     | SATOUT   | # DISPLAY                             |
| TAKEON   | CAF    | BIT9     | # ENABLE                              |
|          | EXTEND |          | # SIVB                                |
|          | WOR    | CHAN12   | # TAKEOVER                            |
|          | CA     | ZERO     | # INDICATE NEEDLER                    |
|          | TS     | SATSW    | # WAS INITIALIZED                     |
|          | TC     | SATOUT   |                                       |
| S11.1    | VLOAD  | ABVAL    |                                       |
|          |        | VN       |                                       |
|          | STOVL  | VMAGI    | # VI SCALED 2(7) IN METERS/CSEC       |
|          |        | RN       |                                       |
|          | UNIT   | DOT      |                                       |
|          |        | VN       |                                       |
|          | SL1    |          |                                       |
|          | STODL  | HDOT     |                                       |
|          |        | RPAD     |                                       |
|          | BOF    | VLOAD    |                                       |
|          |        | AMOONFLG |                                       |
|          |        | EARTHALT |                                       |
|          |        | RLS      |                                       |
|          | ABVAL  | SR2      |                                       |
| EARTHALT | BDSU   |          |                                       |
|          |        | 36D      |                                       |
|          | STORE  | ALTI     |                                       |
|          | RVQ    |          |                                       |

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```
DELSTOR      CA      BOOSTEMP
# Page 547

EXTEND
MSU      MPAC
INDEX    FIXLOC
TS        0
CA      BOOSTEMP +1
EXTEND
MSU      MPAC +1
INDEX    FIXLOC
TS        2
CA      BOOSTEMP +2
EXTEND
MSU      MPAC +2
INDEX    FIXLOC
TS        4
TCF      DANZIG
RLTST      CA      MPAC      # DETERMINE IF ROLLOUT
EXTEND      # IS COMPLETED
MP      SATRLRT +1
EXTEND
BZMF      DANZIG      # UNLIKE SIGNS STILL ROLLING
EXTEND      # ROLLOUT COMPLETED
DCA      MBDYTCTL +2  # ZERO OUT ROLL CONTRIBUTION
DXCH      MPAC
TC      DANZIG
NOPOLY      TC      INTPRET      # COMES HERE IF
SETPD      GOTO      # ATTITUDE HOLD
              0
              NOPOLYM
COEFPOLY      ADRES      POLYLOC
V06N62      VN      0662
RESCALES      EXTEND      # RESCALE AK S FOR
              MP      SATSCALE      # NEW HARDWARE
              DDOUBL      # SCALING FOR
              DDOUBL      # STEERING
              TC      Q      # SATURN

# SATURN TAKEOVER FUNCTION
# *****
#
# PROGRAM DESCRIPTION
#
#      MOD NUMBER 1
#      MOD BY ELIASSEN
#
```

```

# FUNCTIONAL DESCRIPTION
#
#     DURING THE COASTING PHASE OF SIVB ATTACHED, THE
#     ASTRONAUT MAY REQUEST SATURN TAKEOVER THROUGH
#     EXTENDED VERB 46 (BITS 13,14 OF DAPDATR1 SET ).
#     THE CMC REGARDS RHC COMMANDS AS BODY-AXES RATE
#     COMMANDS AND IT TRANSMITS THESE TO SATURN AS DC
#Page 548
#     VOLTAGES.  THE VALUE OF THE CONSTANT RATE COMMAND
#     IS 0.5 DEG/SEC.  AN ABSENCE OF RHC ACTIVITY RE-
#     SULTS IN A ZERO RATE COMMAND.
#
#     THE FDAI ERROR NEEDLES WILL INDICATE THE VALUE
#     OF THE RATE COMMAND.
#
# CALLING SEQUENCE
#
#     DAPFIG +9D      TC      POSTJUMP
#                   CADR      SATSTKON
#
# SUBROUTINES CALLED
#
#     ENDEXT
#     IBNKCALL
#     STICKCHK
#     NEEDLER
#     T5RUPT
#     RESUME
#
# ASTRONAUT REQUESTS
#
#     ENTRY --  VERB 46 ENTER
#              (CONDITION -- BITS 13, 14 OF DAPDATR1 SET)
#
#     EXIT --   VERB 48 ENTER (FLASH V06N46)
#              VERB 21 ENTER AXXXX ENTER WHERE A=0 OR 1
#              VERB 34 ENTER
#              VERB 46 ENTER
#
# NORMAL EXIT MODE
#
#     VERB 46 ENTER  (SEE ASTRONAUT ABOVE)
#
# ALARM OR ABORT EXIT MODES
#
#     NONE

```



```

#
# OUTPUT
#
#           SATURN RATES IN CDUXCMD, CDUYCMD, CDUZCMD
#
# ERASABLE INITIALIZATION
#
#           DAPDATR1           (BITS 13, 14 MUST BE SET)
#
# DEBRIS
#
#           CENTRALS
#Page 549
#           CDUXCMD, CDUYCMD, CDUZCMD

                BANK      43
                SETLOC    EXTVERBS
                BANK

SATSTKON        COUNT     23/STTKE
                EXTEND
                DCA        2REDOSAT
                INHINT
                DXCH        T5LOC
                CAF         POSMAX
                TS          TIME5
                CS          FLAGWRD6      # TURN ON BITS 15,14 OF
                MASK        RELTAB11      # FLAGWRD6
                ADS         FLAGWRD6      #           SATSTICK CONTROL OF T5
                TC          IBNKCALL      # ZERO JET CHANNELS IN 14 MS AND THEN
                CADR        ZEROJET       # LEAVE THE T6 CLOCK DISABLED
                RELINT
                TC          GOPIN          # EXIT THUS BECAUSE WE CAME VIA V46

                SBANK=     PINSUPER       # Added RSB 2009
                EBANK=     BODY3
2REDOSAT        2CADR     REDOSAT

                SBANK=     LOWSUPER
                BANK       32
                SETLOC     P11FOUR
                BANK

REDOSAT         LXCH      BANKRUPT        # ALSO COMES HERE FOR RESTARTS
                EXTEND

```

```

      QXCH  QRUPT
      CS    RCSFLAGS      # TURN ON BIT3 OF RCSFLAGX
      MASK  BIT3          # FOR
      ADS   RCSFLAGS      # NEEDLER INITIALIZATION
      TC    IBNKCALL
      CADR  NEEDLER        # DISABLE IMU ERR COUNTERS ETC.
      CAF   BIT9          # SIVB
      EXTEND
      WOR   CHAN12        # TAKEOVER
      EXTEND
      DCA   2SATSTCK      # ENABLE
      DXCH  T5LOC         # SET UP T5 CYCLE
      CAF   100MST5       #
      TS    TIME5
      TCF   RESUME        # IN 100 MSECS
                        # END OF SATURN STICK INITIALIZATION

#          THIS SECTION IS EXECUTED EVERY 100 MSECS.
#Page 550
SATSTICK  LXCH  BANKRUPT
          EXTEND
          QXCH  QRUPT

          CAF   2SATSTCK  # SET UP RUPT
          TS    T5LOC     # LO ORDER LOC SET
          CAF   100MST5   # 100 MSECS
          TS    TIME5
          CAF   STIKBITS
          EXTEND
          RXOR  CHAN31    # CHECK IF MAN ROT BITS SAME
          MASK  STIKBITS
          TC    IBNKCALL  # SET RATE INDICES
          CADR  STICKCHK  # FOR PITCH YAW AND ROLL

          INDEX RMANNDX   # SET SATURN RATES
          CA    SATRATE
          TS    AK
          INDEX PMANNDX
          CA    SATRATE
          TS    AK1       # PITCH
          INDEX YMANNDX
          CA    SATRATE
          TS    AK2       # YAW

          TC    IBNKCALL  # FOR SATURN INTERFACE AND FDAI DISPLAY
          CADR  NEEDLER
          TCF   RESUME    # END OF SATURN STICK CONTROL

```

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|          |        |          |
|----------|--------|----------|
| STIKBITS | OCT    | 00077    |
| 100MST5  | DEC    | 16374    |
|          | EBANK= | BODY3    |
| 2SATSTCK | 2CADR  | SATSTICK |

This code is written to file `src/P11.s`.

## A.65 P12

```

964  <src/P12.s 964>≡
      # Copyright:    Public domain.
      # Filename:     P12.agc
      # Purpose:      Part of the source code for Luminary 1A build 099.
      #               It is part of the source code for the Lunar Module's (LM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Hartmuth Gutsche <hgutsche@explornet.com>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         838-842
      # Mod history:   2009-05-23 HG   Transcribed from page images.
      #
      # This source code has been transcribed or otherwise adapted from
      # digitized images of a hardcopy from the MIT Museum. The digitization
      # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
      # the Museum. Many thanks to both. The images (with suitable reduction
      # in storage size and consequent reduction in image quality as well) are
      # available online at www.ibiblio.org/apollo. If for some reason you
      # find that the images are illegible, contact me at info@sandroid.org
      # about getting access to the (much) higher-quality images which Paul
      # actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
      #       16:27 JULY 14, 1969
      #
      # Page 838
      BANK      24
      SETLOC    P12
      BANK
      EBANK=    DVCNTR
      COUNT*    $$/P12
      P12LM     TC      PHASCHNG
                OCT     04024
                TC      BANKCALL
                CADR     R02BOTH      # CHECK THE STATUS OF THE IMU.
                TC      UPFLAG
                ADRES     MUNFLAG

```

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# Page 839  
P12LMB

|        |          |                                             |
|--------|----------|---------------------------------------------|
| TC     | UPFLAG   | # INSURE 4-JET TRANSLATION CAPABILITY.      |
| ADRES  | ACC4-2FL |                                             |
| TC     | UPFLAG   | # PREVENT R10 FROM ISSUING CROSS-POINTER    |
| ADRES  | R10FLAG  | # OUTPUTS.                                  |
| TC     | CLRADMOD | # INITIALIZE RADMODES FOR R29               |
| TC     | DOWNFLAG | # CLEAR RENDEVOUS FLAG FOR P22              |
| ADRES  | RNDVZFLG |                                             |
| CAF    | THRESH2  | # INITIALIZE DVMON                          |
| TS     | DVTHRUSH |                                             |
| CAF    | FOUR     |                                             |
| TS     | DVCNTR   |                                             |
| CA     | ZERO     |                                             |
| TS     | TRKMKCNT | # SHOW THAT R29 DOWNLINK DATA IS NOT READY. |
| CAF    | V06N33A  |                                             |
| TC     | BANKCALL | # FLASH TIG                                 |
| CADR   | GOFLASH  |                                             |
| TCF    | GOTOPOOH |                                             |
| TCF    | +2       | # PROCEED                                   |
| TCF    | -5       | # ENTER                                     |
| TC     | PHASCHNG |                                             |
| OCT    | 04024    |                                             |
| TC     | INTPRET  |                                             |
| CALL   |          | # INITIALZE WM AND /LAND/                   |
|        | GUIDINIT |                                             |
| SET    | CALL     |                                             |
|        | FLPI     |                                             |
|        | P12INIT  |                                             |
| DLOAD  |          |                                             |
|        | (TGO)A   | # SET TGO TO AN INITIAL NOMINAL VALUE.      |
| STODL  | TGO      |                                             |
|        | TIG      |                                             |
| STCALL | TDEC1    |                                             |
|        | LEMPREC  | # ROTATE THE STATE VECTORS TO THE           |
| VLOAD  | MXV      | # IGNITION TIME.                            |
|        | VATT     |                                             |
|        | REFSMMAT |                                             |
| VSL1   |          |                                             |
| STOVL  | V1S      | # COMPUTE V1S = VEL(TIG)*2(-7) M/CS.        |

```

                                RATT
                                VSL6
                                REFSMMAT
                                R
                                MUNGRAV
                                UNIT
                                R
                                STCALL UNIT/R/
                                YCOMP
                                SR      DCOMP
                                5D
                                STODL  XRANGE
                                VINJNOM
                                STODL  ZDOTD
                                RDOTDNOM
                                STORE   RDOTD
                                EXIT

                                TC      PHASCHNG
                                OCT      04024

NEWLOAD  CAF      V06N76
                                TC      BANKCALL
                                CADR     GOFLASH
                                TCF      GOTOPOOH
                                TCF      +2
                                TCF      NEWLOAD
                                CAF      P12ADRES
                                TS       WHICH

                                TC      PHASCHNG
                                OCT      04024

                                TC      INTPRET
                                DLOAD    SL
                                XRANGE
                                5D
                                DAD

                                Y
                                STOVL   YCO
                                UNIT/R/
                                VXSC     VAD
                                49FPS
                                V1S

```

# COMPUTE R = POS(TIG)\*2(-24) M.  
# COMPUTE GDT1/2(TIG)\*2(-T)M/CS.  
# COMPUTE UNIT/R/ FOR YCOMP.  
# INITIALIZE XRANGE FOR NOUN 76  
# FLASH CROSS-RANGE, AND APOLUNE VALUES.  
# PROCEED  
# ENTER NEW DATA.

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|            |        |          |                                            |
|------------|--------|----------|--------------------------------------------|
|            | STORE  | V        | # V(TIPOVER) = V(IGN) + 57FPS (UNIT/R/)    |
|            | DOT    | SL1      |                                            |
|            |        | UNIT/R/  |                                            |
|            | STOVL  | RDOT     | # RDOT = 2(-7)                             |
|            |        | UNIT/R/  |                                            |
|            | VXV    | UNIT     |                                            |
|            |        | QAXIS    |                                            |
|            | STORE  | ZAXIS1   |                                            |
|            | SETGO  |          |                                            |
|            |        | FLVR     |                                            |
|            |        | ASCENT   |                                            |
| P12RET     | DLOAD  |          |                                            |
|            |        | ATP      | # ATP(2)*2(18)                             |
|            | DSQ    | PDDL     |                                            |
|            |        | ATY      | # ATY(2)*2(18)                             |
|            | DSQ    | DAD      |                                            |
|            | BZE    | SQRT     |                                            |
|            |        | YAWDUN   |                                            |
|            | SL1    | BDDV     |                                            |
|            |        | ATY      |                                            |
|            | ARCSIN |          |                                            |
| YAWDUN     | STOVL  | YAW      |                                            |
|            |        | UNFC/2   |                                            |
|            | UNIT   | DOT      |                                            |
|            |        | UNIT/R/  |                                            |
|            | SL1    | ARCCOS   |                                            |
|            | DCOMP  |          |                                            |
|            | STORE  | PITCH    |                                            |
|            | EXIT   |          |                                            |
|            | TC     | PHASCHNG |                                            |
|            | OCT    | 04024    |                                            |
|            |        |          |                                            |
|            | TC     | DOWNFLAG |                                            |
|            | ADRES  | FLPI     |                                            |
|            |        |          |                                            |
|            | INHINT |          |                                            |
|            | TC     | IBNKCALL |                                            |
|            | CADR   | PFLITEDB |                                            |
|            | RELINT |          |                                            |
|            |        |          |                                            |
|            | TC     | POSTJUMP |                                            |
|            | CADR   | BURNBABY |                                            |
|            |        |          |                                            |
| P12INIT    | DLOAD  |          | # INITIALIZE ENGINE DATA. USED FOR P12 AND |
| # Page 841 |        | (1/DV)A  | # P71.                                     |

|          |        |          |                                            |
|----------|--------|----------|--------------------------------------------|
|          | STORE  | 1/DV3    |                                            |
|          | STORE  | 1/DV2    |                                            |
|          | STODL  | 1/DV1    |                                            |
|          |        | (AT)A    |                                            |
|          | STODL  | AT       |                                            |
|          |        | (TBUP)A  |                                            |
|          | STODL  | TBUP     |                                            |
|          |        | ATDECAY  |                                            |
|          | DCOMP  | SL       |                                            |
|          |        | 11D      |                                            |
|          | STORE  | TTO      |                                            |
|          | SLOAD  | DCOMP    |                                            |
|          |        | APSVEX   |                                            |
|          | SR2    |          |                                            |
|          | STORE  | VE       |                                            |
|          | BOFF   | RVQ      |                                            |
|          |        | FLAP     |                                            |
|          |        | COMMINIT |                                            |
| COMMINIT | DLOAD  | DAD      | # INITIALIZE TARGET DATA. USED BY P12, P70 |
|          |        | HINJECT  | # AND P71 IF IT DOES NOT FOLLOW P70.       |
|          |        | /LAND/   |                                            |
|          | STODL  | RCO      |                                            |
|          |        | HI6ZEROS |                                            |
|          | STORE  | TXO      |                                            |
|          | STORE  | YCO      |                                            |
|          | STORE  | RDOTD    |                                            |
|          | STOVL  | YDOTD    |                                            |
|          |        | VRECTCSM |                                            |
|          | VXV    | MXV      |                                            |
|          |        | RRECTCSM |                                            |
|          |        | REFSMMAT |                                            |
|          | UNIT   |          |                                            |
|          | STORE  | QAXIS    |                                            |
|          | RVQ    |          |                                            |
| P12ADRES | REMADR | P12TABLE |                                            |
|          | SETLOC | P12A     |                                            |
|          | BANK   |          |                                            |
|          | COUNT* | \$\$/P12 |                                            |
| GUIDINIT | STQ    | SETPD    |                                            |
|          |        | TEMPR60  |                                            |
|          |        | OD       |                                            |
|          | VLOAD  | PUSH     |                                            |
|          |        | UNITZ    |                                            |
|          | RTB    | PUSH     |                                            |



# Page 842

CALL

RP-T0-R

MXV

VXSC

REFSMMAT

MOONRATE

STOVL

WM

RLS

ABVAL

SL3

STCALL

/LAND/

TEMPR60

49FPS

2DEC

.149352 B-6

# EXPECTED RDOT AT TIPOVER

VINJNOM

2DEC

16.7924 B-7

# 5509.5 FPS(APO=30NM WITH RDOT=19.5FPS)

RDOTDNOM

2DEC

.059436 B-7

# 19.5 FPS

This code is written to file src/P12.s.

**A.66 P20-P25**

```

970  <src/P20-P25.s 970>≡
# Copyright:   Public domain.
# Filename:    P20-P25.agc
# Purpose:    Part of the source code for Colossus 2A, AKA Comanche 055.
#             It is part of the source code for the Command Module's (CM)
#             Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:  yaYUL
# Contact:    Ron Burkey <info@sandroid.org>.
# Website:    www.ibiblio.org/apollo.
# Pages:      562-534
# Mod history: 2009-05-10 RSB  Adapted from the Colossus249/ file
#                               of the same name, using Comanche055 page
#                               images.
#             2009-05-20 RSB  Corrections: P20S -> P20S, ST0 -> STQ,
#                               GOTOP00H -> GOTOP00H, a duplicated EXTEND
#                               was fixed, P23.10 -> R23.10,
#                               S22BOX44 -> S22BOX44, S22SUBSCL -> 22SUBSCL,
#                               S22DPP -> S22DSPP, changed some instructions in
#                               P23.152.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. 10:28 APR. 1, 1969
#
# This AGC program shall also be referred to as
# Colossus 2A
#
# Page 562
# RENDEZVOUS NAVIGATION PROGRAM 20
#
# PROGRAM DESCRIPTION
#
# MOD NO -- 1
# MOD BY -- N. BRODEUR

```

```

#
# FUNCTIONAL DESCRIPTION
#
#       TO CONTROL THE CSM ATTITUDE AND OPTICS TO ACQUIRE THE LEM IN THE S+T
#       FIELD AND TO POINT THE CSM TRANSPONDER AT THE LEM.  TO UPDATE EITHER THE
#       LEM OR CSM STATE VECTOR (AS SPECIFIED BY THE ASTRONAUT BY THE DSKY
#       ENTRY) ON THE BASIS OF OPTICAL TRACKING DATA (REQUESTED BY DSKY)
#
# CALLING SEQUENCE --
#
#       ASTRONAUT REQUEST THROUGH DSKY V37E20E
#
# SUBROUTINES CALLED
#
#       R02BOTH (IMU STATUS CHECK)                BANKCALL
#       FLAGUP                                2PHCHNG    LOADTIME
#       R61CSM (PREFERRED TRACKING ATTITUDE)        FLAGDOWN
#       R52 (AUTO OPTICS POSITIONING ROUT)           SETINTG
#       R22 (REND TRACK DATA PROC ROUT)           PRIOCHNG
#       ENDOFJOB                                INTEGRV    GRP2PC
#       INTPRET                                MKRLEES      FINDVAC
#
# NORMAL EXIT MODES --
#
#       P20 MAY BE TERMINATED IN TWO WAYS -- ASTRONAUT SELECTION OF IDLING
#       PROGRAM (P00) BY KEYING V37E00E OR BY KEYING IN V56E
#
# ALARM OR ABORT EXIT MODES --
#
#       NONE DIRECTLY FROM P20
#
# OUTPUT
#
#       TRKMKCNT = NO OF RENDEZVOUS TRACKING MARKS TAKEN (COUNTER)
#       VHFCNT = NO OF VHF RANGING MARKS INCORPORATED (COUNTER)
#
# FLAGS SET + RESET
#
#       RNDVZFLG,VEHUPFLG,UPDATFLG,TRACKFLG,TARG1FLG
#       HOLDFLAG,WBODY,WBODY1,WBODY2,DELCDEX,DELCDEUY,DELCDEUZ
#       STIKFLAG,PRFTRKAT,VINTFLAG,DIMOFLEG,R6OFLAG,R61CNTR
#
# BANK    33
# SETLOC  P20S
# BANK

```

```

EBANK= ESTROKER
COUNT* $$/P20

PROG20      TC      BANKCALL
            CADR     R02BOTH      # IMU STATUS CHECK
                                     # BLOCKING OF UPLINK IS DONE BY UPLINK PRG

            CAF      ZERO
            TS        TRKMKCNT     # ZERO REND TRACKING MARK COUNTER
            TS        VHFCNT       # ZERO REND VHF RNG MRK COUNTER
            TC        UPFLAG       # SET PREF TRACK ATT FLAG
            ADRES     PRFTRKAT     # BIT 10 FLAG 5
            TC        DOWNFLAG     # LEM TO BE UPDATED.  VEHUPFLG RESET.
            ADRES     VEHUPFLG     # BIT 8 FLAG 1

# Page 563

            TC        UPFLAG       # SET TRACKFLAG
            ADRES     TRACKFLG     # BIT 5 FLAG 1
            TC        UPFLAG       # SET UPDATFLG
            ADRES     UPDATFLG     # BIT 7 FLAG 1
            TC        UPFLAG       # SET RNDVZFLG
            ADRES     RNDVZFLG     # BIT 7 FLAG 0
            TC        2PHSCHNG
            OCT        4
            OCT        05022
            OCT        26000
            TC        INTPRET
            RTB

            LOADTIME
            STCALL    MARKTIME
            SETINTG   # SET INTEGRATION FLAGS
            BOFF      SET
            RENDWFLG
            P20.1
            DIMOFLAG  # SET TO INTEGRATE THE W MATRIX
            P20.1      BON      CLEAR
            VEHUPFLG
            P20.2
            VINTFLAG  # SET FOR LM INTEGRATION
            P20.2      CALL     INTEGRV
            CALL
            GRP2PC     # GROUP 2 PHASE CHANGE
            CALL
            SETINTG   # SET INTEGRATION FLAGS
            BOFF      CLEAR
            VEHUPFLG
            P20.3

```

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```
P20.3      CALL      VINTFLAG      # SET FOR LM INTEGRATION
           CALL      INTEGRV
           EXIT
           CAF      PRIO26
           TC      FINDVAC
           EBANK=   MRKBUF2
           2CADR    R22

           TC      2PHSCHNG
           OCT      00072
           OCT      00111
PIKUP20    CAF      PRIO14      # ALLOW HIGHER PRIO THAN LAMBERT
           TC      PRIOCHNG
           CAF      BIT5        # IS TRACK FLAG SET
           MASK     STATE      +1
           EXTEND
           BZF      ENDOFJOB      # NO
# Page 564
           CAF      BIT13
           MASK     STATE      +3      # IS REFSMFLG SET
           EXTEND
           BZF      ENDOFJOB
           CAF      ZERO
           TS      R61CNTR      # INITIALIZE R61 COUNTER
           TC      BANKCALL
           CADR     R61CSM
           EBANK=   QMIN
           CAF      EBANK5
           TS      EBANK
           TC      UPFLAG      # SET TARGET FLAG TO LEM
           ADRES    TARG1FLG    # BIT 10 FLAG 1
P20R52JB   TC      INTPRET
           CALL
           R52      # SET UP AUTO OPTICS JOB
           EXIT
           TC      BANKCALL
           CADR     MKRLEES
           CAF      ONE        # HOLD PRESENT ATTITUDE
           TS      HOLDFLAG
           TC      ENDOFJOB
OCT203     OCT      00203
FIRST3     EQUALS   FURST3
```

# Page 565

# ORBITAL NAVIGATION PROGRAM 22

```

      BANK      31
      SETLOC    P20S1
      BANK

      EBANK=    LANDMARK
      COUNT*    $$/P22

PROG22      TC      DOWNFLAG      # RESET RNDVZFLG BIT 7 FLAG 0
            ADRES    RNDVZFLG
            TC      BANKCALL
            CADR     R02BOTH      # IMU STATUS CHECK
            TC      INTPRET      # COMPUTE ANGLE BETWEEN Y AND VXR SM
            RTB
            LOADTIME
            STCALL   TDEC1
            CSMCONIC # INTEGRATE TO PRESENT TIME
            VLOAD    VXV          # CROSS PRODUCT BETWEEN V AND R
            VATT
            RATT
            UNIT     DOT
            REFSMMAT +6
            ABS
            SL1      ARCCOS
            STORE    +MGA
            CLEAR    EXIT
            RENDWFLG
            CAF      V06N45B
            TC      BANKCALL
            CADR     GOFLASHR
            TC      GOTOP00H      # TERM P22
            TC      PROG22A      # PROC
            TC      -5           # ENTER
            CAF      THREE
            TC      BLANKET      # BLANK OUT R1 + R2
            TC      ENDOFJOB
PROG22A     CS      PRI07        # RESULT=70777 SET OFFSET NO.=0
            MASK     LANDMARK
            TS       LANDMARK
            TC      INTPRET
            CLEAR
            P22MKFLG
            SET      BOFF
            ERADFLAG
            CMOONFLG
            PROG22B      # EARTH

```

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```
# Page 566

      SET          # MOON
      LUNAFLAG
DLOAD  CALL        # MPAC=V05N70,MPAC+1=NONZERO FOR N70
      V05N7022
      S22N7071
      GOTO
      CALLR52
PROG22B  CLEAR     SET          # EARTH ORBIT
      LUNAFLAG
      KNOWNFLG
      CALL        # GET LAT/LONG/ALT FROM ASTRO
      P22SUBRB
CALLR52  EXIT
      TC          2PHSCHNG
      OCT         00004
      OCT         05022
      OCT         13000
      CAF         FIVE
      TS          MARKINDX      # SET MARK INDEX=5 FOR R52
      TC          UPFLAG
      ADRES       TARG2FLG      # SET FOR SIGHTING LMK
      TC          DOWNFLAG
      ADRES       TARG1FLG      # CLEAR FOR NON-LEM
      TC          INTPRET
      CALL
      R52
DOV5N71  SLOAD     CALL        # MPAC=V05N71,MPAC+1=0 FOR N71
      V05N7122
      S22N7071
PROG22C  LXC,2     SLOAD*
      MARKSTAT
      QPRET,2
      STCALL      8NN
      S22.1       # ESTABLISH LANDMARK -- COMPUTE ORBITAL
P22OVER  EXIT
      TC          PHASCHNG
      OCT         04022
      TC          PROG22A      # POINT A ON GSOP
V06N45B  VN         0645
V05N7022 VN         00570
V05N7122 VN         00571
      SETLOC      P20S
      BANK
      SETLOC      P20S1
```

```

                                BANK
S22LSITE    RTB                # CONVERT RLS FROM MOON-FIXED TO BASIC REF
                                LOADTIME
                                6D                # 6-7D= TIME
                                RLS
STODL       OD                # 0-5D= LANDING SITE VECTOR
                                HIDPHALF          # MPAC= ANY NON-ZERO FOR MOON
CALL
# Page 567
                                RP-TO-R          # RLS IN BASIC REF B-27 IN MPAC
VSR2
STORE       ALPHAV            # LUNAFLAG AND ERADFLAG SET ABOVE
RTB
                                LOADTIME          # SET PRESENT TIME IN MPAC FOR LAT-LONG
CALL
                                LAT-LONG
GOTO
                                S22TOFF           # EXIT
OBTAINLL    CALL              # GET LAT/LONG/ALT FROM ASTRO
                                P22SUBRB
GOTO
                                S22TOFF           # EXIT
P22SUBRB    STQ               # GET LAT/LONG/ALT FROM ASTRO
                                S22TOFF +1
CAF         V06N89B
TC          BANKCALL
CADR        GOFLASH
TC          GOTOPOOH          # TERMINATE
TC          +2                # PROCEED
TC          -5                # ENTER OR RECYCLE
TC          INTPRET
DLOAD       ABS               # TEST LAT/LONG GREATER THAN 90
                                LANDLAT
BDSU        BMN               # 1/4 REV - LAT
                                DP1/4TH
                                N89ERRX
DLOAD       ABS
                                LANDLONG
BDSU        BPL
                                DP1/4TH
                                +4
N89ERRX     EXIT
TC          FALTON
TC          P22SUBRB +2       # LONG GR. THAN 90  REDISPLAY

```



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```
CALL
LLASRDA
GOTO
S22TOFF +1 # EXIT
S22N7071 STORE 8KK # 8KK=V05N71,V05N70 8KK+1=0 N71, NOT 0 N70
STQ EXIT
S22TOFF
S22DSPPA CA 8KK # V05N70 OR V05N71
TC BANKCALL
CADR GOFLASHR
TC GOTOP00H # V34E TERMINATE
TC +5 # V33E PROCEED
TC -5 # V32E RECYCLE
CAF FIVE # IMMEDIATE RETURN BLANK OUT R1,R3
TC BLANKET

# Page 568
TC ENDOFJOB
CA LANDMARK
MASK PRI07 # 07000
TS CXOFF # 08000 = OFFSET INDICATOR
CS PRI05 # 5 8-5
AD CXOFF
EXTEND
BZMF +2 # OFF=0 THRU 5 OK
TC S22DSPP # OFF=6.7 ILLEGAL REDISPLAY
TC DOWNFLAG
ADRES KNOWNFLG # CLEAR KNOWNFLG
CA LANDMARK # MASK A FROM ABCDE
MASK 13,14,15
EXTEND
BZMF S22DSPP # A=0,4,5,6,7 ILLEGAL REDISPLAY
TS 22SUBSCL # TEMP
CS BIT14
AD 22SUBSCL
CCS A
S22DSPP TC FALTON # + A=3 ILLEGAL REDISPLAY
TC S22DSPPA # COMMON ERROR EXIT BACK TO DISPLAY
TC +2 # - A=1 KNOWN LMK CHECK DE
TC S22ABDE # -0 A=2 UNKNOWN LMK, DE MEANINGLESS
TC UPFLAG
ADRES KNOWNFLG # SET KNOWNFLG
CS HIGH9 # RESULT= 00077
MASK LANDMARK
TS 22SUBSCL # 000DE
CS BIT1
AD 22SUBSCL
```

```

EXTEND
BZMF S22ABDE # DE=0,1 OK FOR BOTH N70,N71
CA 8KK +1 # =0 FOR N71, NOT =0 FOR N70
EXTEND
BZF S22DSPP # N71 REDISPLAY DE MUST= 0 OR 1
CA BIT5 # N70 TEST DE= 50-57 OCTAL FOR ADV. ORBIT
AD OCT50 # SUM=00070
MASK 22SUBSCL # 00D0
CS A
AD OCT50
EXTEND
BZF DE-GR-50 # D=5 OR DE=50-57, OK FOR N70
TC S22DSPP # DE NOT 50-57 ILLEGAL, REDISPLAY
S22ABDE TC INTERPRET
BOFF SLOAD
KNOWNFLG # UNKNOWN LMK, DE MEANINGLESS
S22TOFF
22SUBSCL # =0 GET LLA FROM ASTRO, NOT=0 USE RLS
BHIZ GOTO
OBTAINLL # GET LAT/LONG/ALT FROM ASTRO N89
# Page 569
DE-GR-50 S22LSITE # GET LAT/LONG/ALT FROM RLS
TC 2PHSCHNG
OCT 00004
OCT 05022
OCT 13000
CA FIVE
TS MARKINDX
TC UPFLAG
ADRES TARG2FLG
TC DOWNFLAG
ADRES TARG1FLG
TC INTERPRET
CALL
ADVORB
GOTO
DOV5N71

```

# Page 570

# PROGRAM NAME: OPTICS CALIBRATION ROUTINE

# MOD NO: 1

# MOD BY: TOM KNATT

#

# FUNCTIONAL DESCRIPTION: TO MEASURE THE EFFECT OF SOLAR RADIATION ON

# THE SXT TRUNNON ANGLE AND STORE THE MEASURED TRUNNION BIAS FOR P23

#

```

# CALLING SEQUENCE:      CALL
#                               R57
#
# SUBROUTINES CALLED:  DISPLAY ROUTINES
#
# NORMAL EXIT MODES:  VIA EGRESS
#
# ALARMS:  NONE
#
# ABORT MODES:  P23 ABORT IF MARKING SYSTEM OR EXTENDED VERB ACTIVE
#
# INPUT:  NONE REQUIRES, NORMALLY CALLED BY P23
#
# OUTPUT:  TRUNNION BIAS ANGLE:  ANGLE DETERMINED WHEN SHAFT LINE OF SIGHT
#          (SLOS) AND LANDMARK LINE OF SIGHT (LLOS) ARE SUPERIMPOSED.  THIS ANGLE
#          MAY NOT BE EXACTLY ZERO BECAUSE OF UNEVEN HEATING OF THE OPTICS, FOR
#          EXAMPLE.
#
# ERASABLE INITIALIZATION REQUIRED:  MRKBUF1, EXTVBACT
#
# DEBRIS:  RUPTREGS USED BY MARKRUPT AND ERASABLES USED BY DISPLAYS.

      BANK    33
      SETLOC  P20S
      BANK
      COUNT*  $$/R57
      EBANK=  MRKBUF1
R57      STQ    EXIT
           EGRESS
      CAF     EBANK7
      TS      EBANK
      CAF     SIX           # BIT2 = MARKING SYSTEM IN USE
      MASK    EXTVBACT      # BIT3 = EXTENDED VERB IN PROGRESS
      CCS     A
      TC      P23ABRT       # SET, THEREFORE ABORT
      CAF     BIT2          # NOT SET
      ADS     EXTVBACT      # SET IT
R57A      TC      UPFLAG    # SET V59FLAG (BIT 12 FLAG 5 TO INDICATE
           ADRES  V59FLAG   # CALIBRATION MARK
      CAF     V59NB
      TC      BANKCALL
      CADR    GOMARKFR
      TC      GOTOP00H      # TERMINATE
      TC      ENDR57
      TC      ENDR57
      CAF     SEVEN

```

# Page 571

|                               |        |            |                                       |
|-------------------------------|--------|------------|---------------------------------------|
|                               | TC     | BLANKET    | # BLANK OUT R1,R2,R3                  |
|                               | TC     | ENDOFJOB   |                                       |
| # STORE TRUNNION ANGLE (OCDU) |        |            |                                       |
| MARKDISP                      | CAF    | V06N87NB   |                                       |
|                               | TC     | BANKCALL   |                                       |
|                               | CADR   | GOMARKFR   |                                       |
|                               | TC     | GOTOPOOH   | # TERMINATE                           |
|                               | TC     | R57B       | # PROCEED                             |
|                               | TC     | R57A       | # ENTER (RECYCLE)                     |
|                               | CAF    | FIVE       |                                       |
|                               | TC     | BLANKET    | # BLANK OUT R1,R3                     |
|                               | TC     | ENDOFJOB   |                                       |
| R57B                          | CA     | 19.77DEG   | # PUT FIXED INTO ERASABLE FOR MSU     |
|                               | TS     | L          | # INSTRUCTION COMING UP               |
|                               | CA     | MRKBUF1 +5 | # CONTAINS TRUNNION                   |
|                               | EXTEND |            |                                       |
|                               | MSU    | L          | # CONNECTS TRUNBIAS FROM 2'S TO 1'S   |
|                               | TS     | TRUNBIAS   |                                       |
| ENDR57                        | TC     | DOWNFLAG   | # RESET V59FLAG                       |
|                               | ADRES  | V59FLAG    | # BIT 12 FLAG 5                       |
|                               | CAF    | EBANK5     |                                       |
|                               | TS     | EBANK      |                                       |
|                               | CAF    | PRI014     |                                       |
|                               | TC     | NOVAC      | # THIS JOB CLEARS BIT IN              |
|                               | EBANK= | MARKSTAT   |                                       |
|                               | 2CADR  | ENDMARK    | # MARKING IN R57 SO R53 CAN TAKE OVER |
|                               | TC     | INTPRET    |                                       |
|                               | GOTO   |            |                                       |
|                               |        | EGRESS     |                                       |
| P23ABRT                       | TC     | BAILOUT    |                                       |
|                               | OCT    | 01211      |                                       |
| V06N87NB                      | VN     | 0687       |                                       |
| V59NB                         | VN     | 5900       |                                       |
| V51NB                         | VN     | 5100       |                                       |
| 19.77DEG                      | OCT    | 61740      |                                       |

# Page 572

# PROGRAM DESCRIPTION

# MOD NO: 1

# MOD BY: N. BRODEUR

#

# FUNCTIONAL DESCRIPTION

#

# TO PERFORM SIGHTING MARKS IN CONJUNCTION WITH THE RENDEZVOUS NAVIG-

```

# ATION PROGRAM. CALLED BY ASTRONAUT VIA EXTENDED VERB.
#
# CALLING SEQUENCE:
#
#       R21 VIA V57
#       R23 VIA V 54
#
# SUBROUTINES CALLED:
#
#       FLAGUP           FLAGDOWN           BANKCALL
#       ENDOFJOB         GOMARK2            GOMARKF
#       INTPRET          GENTRAN            KLEENEX
#       ENDMARK
#
# NORMAL EXIT MODES:
#
# MARKRUPT USED BY SXTMARK HAS BEEN MODIFIED TO STORE MARK IN MRKBUF2
# FOR USE BY R22. WHEN ASTRONAUT IS FINISHED TAKING MARKS, HE HITS AN
# PROCEED, R21 IS TERMINATED THUS CAUSING THE FINAL MARK TO BE TRANSFRD
# TO MRKBUF2 FOR PROCESSING BY R22
#
# ALARM OR ABORT EXIT MODES:
#
#       NONE
#
# OUTPUT:
#
#       7 REGISTER MRKBUF2 CONTAINING TIME2,TIME1,CDUY,OPTICS X,CDUZ, OPTICS Y,
#       CDUX.
#
# ERASABLE INTIALIZATION REQUIRED
#
# FLAGS SET AND RESET
#       R21MARK          (COMMUNICATION TO MARKRUPT TO STORE MARKS IN MRKBUF1 +2)
#       R23FLG           INDICATES COAS MARKING
#
# DEBRIS

```

EBANK= MRKBUF1  
SETLOC RENDEZ  
BANK

COUNT\* \$\$/R21

```

R21CSM      TC      UPFLAG      # SET R21MARK
            ADRES   R21MARK      # BIT 14 FLAG 2

```

```

R23CSM      CA      NEGONE
            TS      MRKBUF1
            TS      MRKBUF2
            CA      FLAGWRD1
            MASK    R23BIT      # TEST R23FLG
            EXTEND
            BZF     R21C1      # NOT SET REGULAR R21 MARKING
            CAF     V0694      # R23 BACKUP MARKING
            TC      BANKCALL   # DISPLAY SHAFT + TRUNNION
            CADR    GOMARKF
            TC      R21END      # TERM
            TC      +2          # PROC

# Page 573
            TC      -5          # ENTER
R23CSM1     CAF     V53        # PERFORM ALT LOST SIGHT MARK
            TC      BANKCALL
            CADR    GOMARK2
            TC      R21END      # V34: TERMINATE R23
            TCF     R21CSMA     # PROCEED: END BACK UP MARKING (R23)
            CAF     SIX         # TRANSFER MRKBUF1 TO MRKBUF2
            TC      GENTRAN
            ADRES   MRKBUF1
            ADRES   MRKBUF2
            EXTEND
            DCA     TIME2
            DXCH    MRKBUF1      # READ TIME
            CA      CDUY        # READ CDU ANGLES
            TS      MRKBUF1 +2
            CA      CDUZ
            TS      MRKBUF1 +4
            CA      CDUX
            TS      MRKBUF1 +6
            RELINT
            TC      R23CSM1
R21C1       CAF     V51NB
            TC      BANKCALL
            CADR    GOMARK2
            TC      R21END      # V34: TERMINATE R21
            TCF     R21CSMA     # PROCEED: END R21
            TCF     R21C1      # RECYCLE

R21CSMA     CA      MRKBUF1      # IF -1 NO MARK
            AD      ONE
            EXTEND
            BZF     R21END      # ZERO = NO MARK
            CAF     SIX         # MARK THEREFORE TRANSFER IT TO MRKBUF2

```

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```
R21CSM1      TC      GENTRAN      # TRANSFER MRKBUF1 TO MRKBUF2
              ADRES    MRKBUF1
              ADRES    MRKBUF2
              RELINT
R21END        TC      BANKCALL
              CADR     KLEENEX
              TC      DOWNFLAG      # RESET R21MARK
              ADRES    R21MARK      # BIT 14 FLAG 2
              TC      ENDMARK      # END MARKING AND ENDJOB
V53           VN      5300
V0694         VN      0694
```

```
# Page 574
# PREFERRED TRACKING ATTITUDE ROUTINE R61CSM
#
# PROGRAM DESCRIPTION
#   MOD NO: 2
#   MOD BY: N. BRODEUR
#
# FUNCTIONAL DESCRIPTION:
#
#   TO COMPUTE THE PREFERRED TRACKING ATTITUDE OF THE CSM TO ENABLE OPTICS
#   TRACKING OF THE LM AND TO PERFORM THE MANEUVER TO THE PREFERRED
#   OR X-AXIS TRACKING ATTITUDE.
#
# CALLING SEQUENCE:
#
#   TC      BANKCALL
#   CADR     R61CSM
#
# SUBROUTINE CALLED
#
#   MAKECADR      BANKCALL
#   INTPRET       FLAGUP      FLAGDOWN
#   BANKJUMP      CRS61.1     R60CSM
#   PHASCHNG
#
# NORMAL EXIT MODES:
#
#   NORMAL RETURN TO CALLER + 1
#
# OUTPUT:
#
#   SEE OUTPUT FOR CRS61.1 & ATTITUDE MANEUVER ROUTINE (R60CSM)
#
# ERASABLE INITIALIZATION REQUIRED
```

```

#
#      GENRET USED TO SAVE Q FOR RETURN
#      R61CNTR MUST BE PRESET TO ZERO
#
# FLAGS SET + RESET
#
#      3-AXIS FLAG
#
# DEBRIS
#
#      SEE SUBROUTINES

                                EBANK= GENRET
                                COUNT* $$/R61      # ROUTINES -- NAVIGATION -- PREF. TR. 9TT=

R61CSM      CAF      EBANK6      # SWITCH TO EBANK 6
            XCH      EBANK
            TS       SAVBNK      # SAVE EBANK
            TC       MAKECADR
            TS       GENRET
            CCS      R61CNTR      # TEST R61DNTR
            TC       DECRM61      # NOT READY TO DO R61
            TC       +2           # DO R61
            TC       DECRM61 +1
            TC       INTPRET
            CALL
                                CRS61.1      # LOS DETERMINATION + VEH ATTITUDE
            EXIT
            INDEX    MPAC
            TC       +1
            TC       R61END      # SUBROUTINE DRIVING DAP      (EXIT R61)
                                # OR AUTO MODE NOT SET      (EXIT R61)
                                # OR SKIKFLAG SET      (EXIT R61)
R61C1      TC       DOWNFLAG      # RESET 3-AXIS FLAG
            ADRES    3AXISFLG      # BIT 6 FLAG 5

# Page 575
            CS       ONE          # SET R61CNTR NEG. TO INDICATE KALCMANU
            TS       R61CNTR

            TC       UPFLAG      # SET FLAG FOR PRIORITY DISPLAYS FOR R60
            ADRES    PDSPFLAG      # BIT 12 FLAG 4
            TC       BANKCALL
            CADR     R60CSM
            TC       DOWNFLAG      # RESET FLAG FOR PRIORITY DISPLAYS IN R60
            ADRES    PDSPFLAG      # BIT 12 FLAG 4
            TC       PHASCHNG

```



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```

      OCT      00111
      CAF      ZERO
      TC       DECRM61
R61END      CAF      THREE

DECRM61     TS      R61CNTR

      CAE      GENRET
      LXCH     A          # RETURN IS IN L
      CA       SAVBNK     # RESTORE EBANK
      XCH      EBANK
      LXCH     A          # RETURN IS NOW BACK IN A
      TC       BANKJUMP   # EXIT R61
      BANK     13
      SETLOC   P20S2
      BANK
```

EBANK= MRKBUF1

# Page 576

# BVECTOR PERFORMS COMPUTATIONS FOR

#

# DELTAQ, THE MEASURED DEVIATION BASED ON THE DIFFERENCE BETWEEN THE CSM-LEM  
# STATE VECTOR ESTIMATES AND THE ACTUAL TRACKING MEASUREMENT.

#

# US, THE MODIFIED FICTITIOUS STAR DIRECTION VECTOR  
# GEOMETRY VECTORY B ASSOCIATED WITH EACH TRACKING MEASUREMENT.

#

# INPUT

#

# UM, 1/2 UNIT VECTOR ALONG THE CSM-LM LINE-OF-SIGHT (BASIC REF. SYSTEM)

#

# USTAR, FICTITIOUS STAR DIRECTION (1/2 UNIT VECTOR)

#

# RCLP, RELATIVE CSM TO LM POSITION VECTOR

#

# OUTPUT

#

# USTAR, MODIFIED FICTITIOUS STAR DIRECTION (1/2 UNIT VECTOR)

#

# BVECTOR = 9 DIMENTIONAL BVECTOR (1/2 UNIT VEC.)

#

# DELTAQ = MEASURED DEVIATION

#

# CALLING SEQUENCE

#

# L CALL BVECTORS

```

#
# NORMAL EXIT
#
#           L+1 OF CALLING SEQUENCE

COUNT    23/20SUB

BVECTORS   STQ           EGRESS
           VLOAD        UNIT
           RCLP          # RELATIVE POSITION VECTOR
           STODL        26D      # RCLP UNIT VEC
           36D          # RCLP ABS VALUE
           STOVL        TEMPOR1  # MOVE TO SAFE LOCATION
           USTAR
           VXV          UNIT
           26D          # USTAR = UNIT(US X UCL)
           STCALL       BVECTOR
           GRP2PC        # PHASE CHANGE
           VLOAD
           BVECTOR
           STORE        USTAR
           DOT          SL1
           UM          # USTAR DOT UM
           ACOS         DSU
           DP1/4TH
           NORM         DMP
           X1
           PI/4.0
           DMP          SRR*
           TEMPOR1      # RCLP ABS VALUE
           0 -3,1      # ADJUST SCALING
           STOVL        DELTAQ
           ZEROVECS
           STORE        BVECTOR +6
           STORE        BVECTOR +12D
           GOTO

# Page 577

           EGRESS
PI/4.0     2DEC        .785398164

```

```

# Page 578

```

```

# GETUM: DETERMINES THE LINE OF SIGHT UNIT VECTOR UM IN THE BASIC REFERENCE
# COORDINATE SYSTEM FROM THE OPTICS SHAFT AND TRUNNION ANGLES AND THE IMU
# GIMBAL ANGLES.
#

```

```

# INPUT
#
#      MARKDATA, BASE ADDRESS OF MARK DATA
#      REFSMMAT, ROTATION MATRIX FROM STABLE MEMBER TO BASIC REF. COORD. SYSTEM
#
# SUROUTINES CALLED:
#
#      SXTNB -- SEXT. ANGULAR READINGS TO NAV. BASE COOR.
#      NBSM -- TRANSFORM FROM NAV. BASE TO STABLE MEMBER
#
# OUTPUT
#
#      MPAC = LINE OF SIGHT 1/2 UNIT VECTOR IN BASIC REFERENCE SYSTEM
#
# CALLING SEQUENCE
#
#      L      CALL GETUM
#
# NORMAL EXIT
#
#      L+1 OF CALLING SEQUENCE

GETUM      STQ      SETPD
           EGRESS
           0
           LXC,1    VLOAD*
           MARKDATA      # CONTAINS ADDRESS OF MARK DATA
           1,1
           STODL*    MARKDOWN +1      # TRANSFER DATA FROM WORKING STORAGE
           0,1      # TO MARKDOWN ARRAY FOR DOWNLINK
           STORE    MARKDOWN
           AXT,2
           2
           XSU,2    SXA,2
           X1      # X1 = MARKDATA
           S1      # S1 = MARKDATA(ADR) +2
           CALL
           SXTNB    # SEXT. ANGULAR READINGS TO NAV. BASE COOR.
           CALL
           NBSM     # TRANSFORM FROM NAV. BASE TO STABLE MEM.
           VXM      VSL1
           REFSMMAT
           GOTO     # MPAC = (UM) LINE OF SIGHT VECTOR
           EGRESS   # EXIT

```

```

# RENDEZVOUS TRACKING DATA PROCESSING ROUTINE (R22)
#
# PURPOSE      (1) TO PROCESS RENDEZVOUS SIGHTING MARK DATA TO UPDATE THE STATE VECTOR
#              DEFINED BY THE RENDEZVOUS NAVIGATION PROGRAM (P20).
#
# ASSUMPTIONS  (1) THIS ROUTINE IS MANUALLY SELECTED BY THE ASTRONAUT BY V55E WHENEVER
#              ARE DESIRED.  ITS SELECTION, HOWEVER, IS LIMITED TO PERIODS WHEN THE
#              DATA DISPLAY.  THIS ROUTINE RETURNS TO THE ORIGINAL PROGRAM AT THE END OF
#              THE DATA DISPLAY.

BANK      34
SETLOC    P20S3
BANK

COUNT    34/R22

R22        CAF      PRI026
           TS        PHSPRDT2
           TC        PRIOCHNG
           CA        NEG3
           TS        MRKBUF2
           TC        INTPRET
           RTB

           LOADTIME
STORE      VHFTIME      # PRESENT TIME
REND1      CALL

           GRP2PC
CALL

           WAITONE
REND1A     EXIT
           CA        MRKBUF2
EXTEND
BZF        REND2
EXTEND
BZMF       REND3A
REND2      CAF      SIX
           TC        GENTRAN
ADRES      MRKBUF2
ADRES      MARKTIME    # MARKTIME MUST BE CONTIGUOUS WITH VTEMP
CAF        NEG3        # NEG VALUE TO INDICATE VALUES USED
TS         MRKBUF2
RELINT
TC         INTPRET
CLEAR      CALL
           SOURCFLG    # 0 = OPTICS DATA
           GRP2PC
SSP        GOTO

```

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```

REND3A      ECADR      MARKDATA
REND3        TC        VTEMP -2
# Page 580   CALL      REND4
              INTPRET
              GRP2PC
              CALL      WAITONE
              BOFF      VHFRFLAG
              REND1A
              RTB
              LOADTIME   # PRESENT TIME
              DSU        DSU
              60SECDP    # 1 MIN
              VHFTIME    # LAST READING OF RADAR
              BMN        CALL
              REND1A
              RANGERD    # READ RADAR RANGE
              DLOAD
              MARKTIME
              STORE      VHFTIME   # FOR DOWNLINK
REND4        CALL
              SETINTG    # SET INTEGRV FLAGS
              BON        CALL
              VEHUPFLG
              CSMUPP     # BRANCH IF CSM UPDATE
              INTEGRV
              CALL
              GRP2PC     # PHASE CHANGE
              CALL
              SETINTG    # SET INTEGRV FLAGS
              CLEAR
              VINTFLAG   # SET INTEGRATION VEHICLE TO LM
REND5        BOFF      SET
              RENDWFLG
              REND5A     # DO NOT INTEGRATE W IF FLAG = 0
              DIMOFLAG
REND5A       CALL
              INTEGRV
              CALL
              SHIFTNDX   # SET EARTH MOON SCALING INDEX
              CALL
              CMPOS      # SET CSM POSITION
              SET        CALL
```

```

                                INCORFLG      # SET FOR 1ST PASS
                                LMPOS          # SET LM POSITION
                                CLEAR          BON
                                ORBWFLAG      # CLEAR FOR ORBITAL AND CISLUNAR
                                RENDWFLG
                                REND6
                                DLOAD
                                WRENDPOS
                                STCALL        0      # 0 = WRENDPOS  1 = WRENDVEL
                                INITIALW      # INTIIALIZE W MATRIX
# Page 581
                                DLOAD
                                ZEROVECS
                                STORE          VHFCNT      # ZERO OUT VHFCNT AND TRKMKCNT
REND6      SET
                                RENDWFLG
                                VLOAD          VSU
                                LEMPOS
                                CSMPOS
                                STORE          RCLP      # LM - CSM
REND7      UNIT          BON
                                SOURCFLG
                                REND14      # BRANCH IF DATA IS RADAR
                                STORE          UCL
                                BOFF          CALL
                                INCORFLG
                                REND9
                                GETUM      # CALCULATE UM LINE OF SIGHT
                                STOVL          UM
                                UCL
                                VXV          BOV
                                UM      # UCL X UM
                                REND8
REND8      UNIT          BOV
                                REND3      # BRANCH IF OVERFLOW IGNORE MARK
                                STORE          USTAR
REND9      CALL
                                BVECTORS
                                BON          VLOAD
                                VEHUPFLG
                                REND9A
                                BVECTOR
                                VCOMP
                                STORE          BVECTOR
REND9A      CALL
                                GRP2PC

```

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```

BON
R23FLG
REND15 # BRANCH IF BACKUP OPTICS (R23 WORKING)
DLOAD DAD
SXTVAR
IMUVAR
REND10 STOVL VARIANCE # TEMP STORAGE FOR VARIANCE CALC.
RCLP
ABVAL NORM
X1
DSQ DMP
VARIANCE
XAD,1 CALL
X1
SHIFTNDX # GET EARTH MOON SCALING INDEX
# Page 582
XAD,1 XAD,1
X2
X2
SR* TLOAD
0 -2,1 # ADJUST SCALING TO B-40
MPAC
STORE VARIANCE
SLOAD SR
INTVAR # INTEGRATION VARIANCE SCALED B-15
25D # SCALE IT B-40
TAD RTB
VARIANCE
TPMODE
STORE VARIANCE
BOFF TAD
SOURCFLG # BRANCH IF NOT VHF RADAR
REND10A
RVARMIN # VHF RADAR MIN. VARIANCE
BPL TLOAD
REND10A
RVARMIN
ABS # MIN. VALUE WAS STORED AS NEG.
STORE VARIANCE # STORE MIN. VALUE
REND10A CLEAR CALL
DMENFLG # CLEAR FOR 6 X 6 W MATRIX
INCORP1 # CALCULATE UPDATE
CALL
GRP2PC
BOFF CALL
INCORFLG
```

```

                                REND12
                                SHIFTNDX      # GET EARTH MOON SCALING INDEX
                                ABVAL
VLOAD                          DELTAX +6
                                SR*
                                0,2
                                STOVL          N49DISP +2
                                DELTAX
                                ABVAL          SR*
                                0,2
                                STORE          N49DISP
                                SLOAD
                                RMAX
                                SR             DSU
                                10D
                                N49DISP
                                BMN           SLOAD
                                RENDISP        # BRANCH IF POS UP. GREATER THAN MAX.
                                VMAX
                                DSU           BMN
# Page 583
                                N49DISP +2
                                RENDISP        # BRANCH IF VEL. UPDATE GREATER THAN MAX.
REND12                         CALL
                                INCORP2        # INCORPORATE UPDATE VALUES INTO STATE VEC
                                BON            BOFF
                                SOURCFLG
                                REND16         # BRANCH IF DATA IS RADAR
                                INCORFLG
                                REND17
                                CALL
                                SHIFTNDX      # GET EARTH MOON SCALING INDEX
                                BON            CALL
                                VEHUPFLG
                                REND18         # BRANCH IF CSM UPDATE
                                LMPOS          # GET LM POSITION
REND13                         CALL
                                GRP2PC        # PHASE CHANGE
                                VLOAD          VSU
                                LEMPOS
                                CSMPOS
                                STORE          RCLP      # LM - CSM
                                CLRGO
                                INCORFLG
                                REND7         # BRANCH FOR 2ND PASS THIS OPTICS MARK
CSMUPP                         CLEAR          CALL

```



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| Label      | Operation | Value        | Comment                         |
|------------|-----------|--------------|---------------------------------|
|            |           | VINTFLAG     | # SET INTEGRATION VEHICLE EQ LM |
|            |           | INTEGRV      |                                 |
|            | CALL      | GRP2PC       | # PHASE CHANGE                  |
|            | CALL      | SETINTG      | # SET FLAGS FOR INTEGRATION     |
|            | GOTO      |              |                                 |
|            |           | REND5        |                                 |
| REND14     | STOVL     | BVECTOR      | # VHF RADAR BVECTOR             |
|            |           | ZEROVECS     |                                 |
|            | STORE     | BVECTOR +6   |                                 |
|            | STOVL     | BVECTOR +12D |                                 |
|            |           | RCLP         |                                 |
|            | UNIT      | DLOAD        |                                 |
|            |           | VHFRANGE     | # VHFRANGE SCALED B-27          |
|            | BON       | SR2          |                                 |
|            |           | MOONTHIS     |                                 |
|            |           | +1           |                                 |
|            | DSU       | SET          |                                 |
|            |           | 36D          | # ABVAL (RCLP)                  |
|            |           | INCORFLG     |                                 |
|            | STORE     | DELTAQ       |                                 |
|            | BOFF      | VLOAD        |                                 |
|            |           | VEHUPFLG     |                                 |
|            |           | REND14A      |                                 |
| # Page 584 |           |              |                                 |
|            |           | BVECTOR      |                                 |
|            | VCOMP     |              |                                 |
|            | STORE     | BVECTOR      |                                 |
| REND14A    | CALL      |              |                                 |
|            |           | GRP2PC       |                                 |
|            | DLOAD     | GOTO         |                                 |
|            |           | RVAR         |                                 |
|            |           | REND10       |                                 |
| REND15     | SLOAD     | DAD          | # GET ALT LOS VARIANCE          |
|            |           | ALTVAR       | # BACKUP OPTICS                 |
|            |           | IMUVAR       | # IMU VARIANCE                  |
|            | GOTO      |              |                                 |
|            |           | REND10       |                                 |
| REND16     | LXA,1     | INCR,1       |                                 |
|            |           | VHFCNT       | # VHF RADAR UPDATE COUNT        |
|            | DEC       | 1            |                                 |
|            | SXA,1     | GOTO         |                                 |
|            |           | VHFCNT       | # UPDATE COUNT                  |
|            |           | REND1        |                                 |
| REND17     | LXA,1     | INCR,1       |                                 |

|            |        |            |                                           |
|------------|--------|------------|-------------------------------------------|
|            |        | TRKMKCNT   | # OPTICS MARK COUNT                       |
|            | DEC    | 1          |                                           |
|            | SXA,1  | GOTO       |                                           |
|            |        | TRKMKCNT   | # UPDATE COUNT                            |
|            |        | REND3      |                                           |
| REND18     | CALL   |            |                                           |
|            |        | CMPOS      | # GET CSM POSITION                        |
|            | GOTO   |            |                                           |
|            |        | REND13     |                                           |
| CMPOS      | VLOAD  | VSR*       |                                           |
|            |        | DELTACSM   |                                           |
|            |        | 7,2        |                                           |
|            | VAD    |            |                                           |
|            |        | RCVCSM     |                                           |
|            | STORE  | CSMPOS     | # CSM POSITION SCALED B-27 OR B-29        |
|            | RVQ    |            |                                           |
| LMPOS      | VLOAD  | VSR*       |                                           |
|            |        | DELTALEM   |                                           |
|            |        | 7,2        |                                           |
|            | VAD    |            |                                           |
|            |        | RCVLEM     |                                           |
|            | STORE  | LEMPOS     | # LM POSITION SCALED B-27 OR B-29         |
|            | RVQ    |            |                                           |
| RENDISP    | EXIT   |            |                                           |
|            | CA     | FLAGWRD9   |                                           |
|            | MASK   | SOURCBIT   |                                           |
|            | EXTEND |            |                                           |
|            | BZF    | +3         |                                           |
|            | CA     | BIT2       |                                           |
|            | TC     | +2         |                                           |
| # Page 585 |        |            |                                           |
|            | CA     | BIT1       |                                           |
|            | TS     | N49DISP +4 |                                           |
|            | CAF    | ZERO       | # SET TEMPOR1 > ZERO TO INDICATE          |
|            | TS     | TEMPOR1    | # V06 N49 DISPLAY HASN'T BEEN ANSWERED    |
|            | TC     | PHASCHNG   |                                           |
|            | OCT    | 04022      |                                           |
|            | CAF    | PRI027     | # SET UP DISPLAY JOB WITH HIGHER PRIORITY |
|            | TC     | NOVAC      |                                           |
|            | EBANK= | MRKBUF1    | # THAN PRESENT JOB                        |
|            | 2CADR  | RENDISP2   |                                           |
| RENDISP7   | TC     | INTPRET    |                                           |
|            | STORE  | MPAC       |                                           |
|            | SLOAD  | BZE        |                                           |
|            |        | TEMPOR1    |                                           |

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```

                                RENDISP7 +1    # DISPLAY HAS NOT BEEN ANSWERED YET
                                GOTO
                                REN12          # NEG INDICATES PROCEED
                                RENDISP3        # POS INDICATES RECYCLE
RENDISP2  CAF  V06N49
          TC   BANKCALL
          CADR PRIODSP
          TC   GOTOV56    # TERM EXIT P20 VIA V56
          CS   ONE        # NEG INDICATES PROCEED RENDISP7 JOB
          TS   TEMPOR1    # POS INDICATES RECYCLE RENDISP7 JOB
          TC   ENDOFJOB   # GO COMPLETE ABOVE JOB
RENDISP3  BON
          SOURCFLG
          REN1          # DATA WAS RADAR GO LOOK FOR OPTICS NEXT
          EXIT
          EBANK= MRKBUF1
          INHINT
          CAF  BUFBANK
          TS   BBANK
          CA   NEGONE
          TS   MRKBUF1    # ERASE MARK ONE BUFFER
          TS   MRKBUF2    # ERASE MARK TWO BUFFER
          RELINT
RENDISP4  TC   INTPRET
          GOTO
          REN3
SXTVAR    2DEC  0.04 E-6 B+16  # SXT ERROR VARIANCE = .04 (MR)SQ
IMUVAR    2DEC  0.04 E-6 B+16  # IMU ERROR VARIANCE = .04 (MR)SQ
V06N49    VN   0649
          EBANK= MRKBUF1
          BBCON RENDISP3
          BANK  31
          SETLOC R22S1
# Page 586
          BANK
SETINTG   STQ   CALL
          EGRESS
          INTSTALL    # RESERVE INTEGRATION
          DLOAD SET
          MARKTIME
          STATEFLG
          STORE TDEC1    # MARKTIME
          CLEAR CLEAR
          INTYPFLG    # PRECISION INTEGRATION
```

```

                                DIMOFLAG
                                SET   CLRG0
                                VINTFLAG      # SET VEHICLE EQ. CSM
                                D6OR9FLG      # SET W MATRIX DIM. EQ 6
                                EGRESS        # EXIT
CNTCHK      STQ
                                POINTEX
CONTCHK     BOFF
                                REFSMFLG      # BRANCH TO END OF JOB IF REFSMMAT NO GOOD
                                ENDPLAC
                                SLOAD  BMN
                                R61CNTR
                                WAITONE1
                                BON   BOFF      # IS TRACK FLAG SET
                                UPDATFLG
                                POINTEX
                                TRACKFLG
                                ENDPLAC
                                EXIT
REDOR22     TC   PHASCHNG
                                OCT   00132
                                CAF   PRI026
                                TC   PRIOCHNG
                                TC   WAITONE +3
WAITONE     STQ
                                POINTEX
WAITONE1    EXIT
                                CAF   4SECS      # WAIT 4 SECS.
                                TC   BANKCALL
                                CADR  DELAYJOB
                                TC   INTPRET
                                GOTO
                                CONTCHK      # CHECK AGAIN NOW
RANGERD     EXIT
                                INHINT
                                CS   OCT17
                                EXTEND
                                WAND  CHAN13      # ZERO OUT BITS 1-4 OF CHANNEL 13
                                CAF   OCT11
                                EXTEND
# Page 587
                                WOR   CHAN13      # GENERAGE SHIFT PULSES TO RADR, SET R. BIT
                                RELINT
                                EXTEND
                                DCA   TIME2
                                DXCH  MARKTIME    # READ PRESENT TIME

```

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|          |        |               |                                            |
|----------|--------|---------------|--------------------------------------------|
|          | TC     | DOWNFLAG      |                                            |
|          | ADRES  | SKIPVHF       |                                            |
|          | TC     | BANKCALL      |                                            |
|          | CADR   | RADSTALL      | # WAIT FOR RANGE COMPLETE                  |
|          | TC     | LIGHTON       | # BAD DATA GOOD BIT                        |
|          | TC     | TRFAILOF      | # TURN TRACKER LIGHT OFF                   |
| RANGERD1 | CCS    | RM            | # 15 BIT UNSIGNED RANGE                    |
|          | TC     | RANGERD4      | # GR + 0                                   |
|          | TC     | LIGHTON +4    | # = + 0                                    |
|          | TC     | RANGERD3      | # L - 0                                    |
|          | TC     | RANGERD3      | # = - 0                                    |
| RANGERD4 | TC     | INTPRET       |                                            |
|          | SLOAD  | DMP           |                                            |
|          |        | RM            |                                            |
|          |        | CONVRNGE      | # CONVERT RANGE TO METERS B-27             |
| RANGERD2 | STORE  | VHFRANGE      |                                            |
|          | SET    | RVQ           |                                            |
|          |        | SOURCFLG      | # SOURCE OF DATA TO VHF RADAR              |
| RANGERD3 | CA     | RM            |                                            |
|          | MASK   | POSMAX        |                                            |
|          | TS     | MPAC          | # MASK OUT NEG. SIGN BIT                   |
|          | TC     | INTPRET       |                                            |
|          | DMP    |               |                                            |
|          |        | CONVRNGE      | # CONVERT FROM NM TO METERS AND SCALE B-27 |
|          | DAD    | GOTO          |                                            |
|          |        | RANGEB14      | # VALUE IN METERS OF SIGN BIT SCALED B-27  |
|          |        | RANGERD2      |                                            |
| LIGHTON  | CA     | VHFRANGE      |                                            |
|          | EXTEND |               |                                            |
|          | BZF    | +2            |                                            |
|          | TC     | TRFAILON      |                                            |
|          | TC     | INTPRET       |                                            |
|          | DLOAD  |               |                                            |
|          |        | MARKTIME      |                                            |
|          | STORE  | VHFTIME       |                                            |
|          | GOTO   |               |                                            |
|          |        | REND1         |                                            |
| RANGEB14 | 2DEC   | 303431.7 B-27 | # 16384 X 18.52 SCALED B-27                |
| OCT17    | OCT    | 00017         |                                            |
| OC40200  | OCT    | 40200         |                                            |
| CONVRNGE | 2DEC   | 18.52 B-13    | # VHF INPUT RANGE CONV. FROM .01 NM TO M   |
| VHFREAD  | EXTEND |               |                                            |
|          | ROR    | SUPERBNK      | # MUST SAVE SBANK BECAUSE OF RUPT          |

|          |        |          |                                        |
|----------|--------|----------|----------------------------------------|
|          | TS     | BANKRUPT | # EXITS VIA TASKOVER BADEND OR GOODEND |
|          | CS     | ZERO     |                                        |
|          | TS     | RUPTAGN  |                                        |
|          | EXTEND |          |                                        |
|          | QXCH   | QRUPT    |                                        |
|          | CS     | STATE +2 |                                        |
|          | MASK   | SKIPVBIT | # SKIPVHF FLAG                         |
|          | EXTEND |          |                                        |
|          | BZF    | TASKOVER | # BRANCH IF VHF RESTART BIT SET        |
|          | CAF    | UPDATBIT |                                        |
|          | MASK   | STATE +1 | # UPDATEFLG                            |
|          | EXTEND |          |                                        |
|          | BZF    | BYPASS1  |                                        |
|          | CS     | STATE +4 |                                        |
|          | MASK   | PDSPFBIT | # PDSPFLAG                             |
|          | EXTEND |          |                                        |
|          | BZF    | BYPASS1  |                                        |
|          | CA     | RNRAD    |                                        |
|          | TS     | RM       | # SAVE RANGE                           |
|          | CAF    | BIT2     |                                        |
|          | EXTEND |          |                                        |
|          | RAND   | CHAN33   | # READ DATA GOOD BIT                   |
|          | EXTEND |          |                                        |
|          | BZF    | VHFGOOD  | # BRANCH IF DATA GOOD BIT EQUALS GOOD  |
| BYPASS   | TS     | VHFRANGE | # STORE NON ZERO VALUE                 |
|          | CAF    | TWO      |                                        |
|          | TC     | POSTJUMP |                                        |
|          | CADR   | BADEND   |                                        |
| BYPASS1  | CAF    | ZERO     |                                        |
|          | TC     | BYPASS   |                                        |
| VHFGOOD  | CAF    | TWO      |                                        |
|          | TC     | POSTJUMP |                                        |
|          | CADR   | GOODEND  |                                        |
| SHIFTNDX | AXT,2  | BON      |                                        |
|          |        | 0        |                                        |
|          |        | VEHUPFLG |                                        |
|          |        | SHIFTA   | # VEHICLE IS CSM                       |
|          | BON    | RVQ      |                                        |
|          |        | LMOONFLG |                                        |
|          |        | +1       |                                        |
|          | INCR,2 | RVQ      |                                        |
|          | DEC    | -2       |                                        |
| SHIFTA   | BON    | RVQ      |                                        |
|          |        | CMOONFLG |                                        |
|          |        | +1       | # MOON ORB.                            |
|          | INCR,2 | RVQ      |                                        |

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```
INITIALW      DEC      -2
              AXT,1    SSP
              36D
              S1
# Page 589
              6
              VLOAD
              ZEROVECS
INITA          STORE    W +36D,1      # CLEAR 0 - 35
              TIX,1    AXT,1
              INITA
              36D
INITB          STORE    W +90D,1      # CLEAR 54 - 89
              TIX,1    SLOAD
              INITB
              0          # POSITION VALUE
              STORE    W          # INITIALIZE DIAGONAL W POSITION
              STORE    W +8D
              STORE    W +16D
              SLOAD
              1          # VELOCITY VALUE
              STORE    W +72D      # INITIALIZE DIAGONAL W VELOCITY
              STORE    W +80D
              STORE    W +88D
              RVQ
# Page 590
# CRS61.1      R/10/68
#
# TO COMPUTE THE PREFERRED TRACKING ATTITUDE OF THE CSM WHICH ENABLES
# OPTICS TRACKING OF THE LEM AND LM TRACKING OF THE CSM RADAR TRANSPONDER
# AND TO COMPUTE THE X-AXIS TRACKING ATTITUDE OF THE CSM WHICH ENABLES
# COAS TRACKING OF THE LM.
#
# TO PERFORM THE MANEUVER TO THE SELECTED TRACKING ATTITUDE IF THE
# MANEUVER IS LESS THAN 10 DEGREES BUT TO CALL R60 IF THE MANEUVER IS
# GREATER THAN 10 DEGREES BUT TO CALL R60 IF THE MANEUVER IS
# GREATER THAN 10 DEGREES OR IF THE R60 FLAG IS SET.
#
#      (1)      EXTRAPOLATE LM AND CSM STATE VECTORS TO PRESENT TIME USING
#               CONIC EQUATIONS.
#
#      (2)      CALCULATE LOS FROM CSM TO LM = RL - RC.
#
#      (3)      THE PREFERRED TRACKING ATTITUDE IS DEFINED AS FOLLOWS:
#               THE TRACK AXIS (I) IS ALIGNED ALONG THE LOS TO THE LM.  THE
#               TRACK AXIS (I) IS DEFINED AS:
```

```

#
#          UNIT(I)=UNIT(Z )COS55  &  UNIT(X )SIN55
#          -          -SC          -SC
#
#      (4)    COMPUTE DESIRED CDU ANGLES, USING VECPOINT.
#
# (Sorry, I don't know where (5) and (6) are. --- RSB 2009.)
#      (7)    FORM DIFFERENCE BETWEEN DESIRED AND ACTUAL CDUS.
#             IF ANY OF THE THREE ANGLE DIFFERENCES EXCEEDS 10 DEGREES,
#             GROSS MANEUVER IS REQUIRED.  SIGNAL R61 (SET MPAC=1) TO
#             OPERATE KALCMANU AND EXIT CRS61.1.
#             IF ALL DIFFERENCES ARE LESS THAN 10 DEGREES, CONTINUE.
#
#      (8)    CALCULATE ORTHOGONAL LOS RATE IN REF COORDS AS
#
#             OMEGATH = (UNITLOS(B1) X UNITDV(B1))(ABSDV(B7)/ABSLOS(B29))
#
#             CONVERSION FACTOR OF 100/2PI (B4) REV CSEC PER RAD SEC IS
#             APPLIED TO YIELD UNITS OF REVS/SEC.  SCALE IS CARRIED AS
#             B+1+1+7-29+4+1 PLUS RESULTS OF NORMALIZING ABSDV, ABSLOS.
#             THE EXTRA B+1 RESULTS FROM RESCALING ABSDV B8 AFTER NORM
#             TO AVOID OVFLOW ON DIVIDE.
#
#             UNITLOS = UNIT( RL - RC ) B1.
#             UNITDY  = UNIT( VL - VC ) B1.
#             ABSLOS  = LENGTH OF LOS, METERS B29.
#             ABSDV   = LENGTH OF DV, METERS/CSEC B7.
#
#      (9)    OBTAIN RATE IN SM COORDS.
#
#             OMETATHSM = (REFSMMAT)(OMEGATH).
#
#      (10)   OBTAIN GIMBAL ANGLE INCREMETNS FOR 0.1 SECOND.
#
#             DTHETASM = (0.1)(OMEGATHSM)
#
#      (11)   OBTAIN DELCDUX,Y,Z USING SUBR SMCDURES.
# Page 591
#             INPUT CONSISTS OF
#
#             (A)    VECTOR OF ANGULAR INCREMENTS, DTHETASM, STORED
#                   IN V(DTHETASM).
#             (B)    SIN,COS CDUX,Y,Z FROM SUBR CDUTRIG.
#
#             TRANSFER OUTPUT OF SMCDURES FROM V(DCDU) TO VAC14D.
#

```



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```
#      (12)  CALCULATE ANG LOS RATE IN BODY(NB) COORDS USING SUBR SMNB.
#
#      OMEGANB = (SMNB)(OMETATHSM)
#
#      SUBR SMNB REQUIRES OMEGATHSM IN V(VAC32D) AND ACTUAL CDUS
#      (Y,X,Z ORDER) IN V(VAC20D) WITH S1 OF VAC = BASE ADDRESS
#      OF CDUS (FIXLOC + 20D).
#
#      (13)  CALCULATE ANG LOS RATE IN CONTROL COORDS AS FOLLOWS
#
#      WBODY = (MBDYCTL)(OMEGANB)      UNITS=REVS/SEC(B0) (?).
#
#      ( 0.5      0      0      )  BODY TO
#      MBDYCTL(B1) = ( 0  COS(7.25)B1  -SIN(7.25)B1 ) = CONTROL
#      ( 0  SIN(7.25)B1  COS(7.25)B1 )  AXES
#  CONVERSION
#  MATRIX
#
#      (14)  RESCALE WBODY TO UNITS OF 460 DEG/SEC BY APPLYING FACTOR
#      OF 0.8 TO REVS/SEC.
#
#      (15)  ADDRESS LIVE AUTOPILOT REGISTERS IN BASIC (UNDER INHINT).
#
#      TRANSFER DESIRED CDUS, SCALED 180 DEGREES, FROM T(SAVEDCDU)
#      TO V(CDUXD).
#
#      TRANSFER DELCDUS, SCALED 180 DEG, FROM V(VAC14D)
#      TO V(DELCDUX).
#
#      TRANSFER OMEGA CONTROL, SCALED 450 DEG/SEC, FROM V(MPAC)
#      TO V(WBODY).
#
#      RELINT, SET MPAC=0, EXIT CRS61.1.
#
# CALL:      L      CALL      CRS61.1
#
# RETURNS:   ALL TO L+1.
#
#      (1)    S(MPAC)=0.  NORMAL EXIT.  3 SETS OF INPUTS FED TO DAP.
#      (2)    S(MPAC)=1.  CALCULATED DESIRED CDUS,SP, SET IN T(CPHI)
#      FOR KALCMANU.  ABS(ACDU - DCDU) EXCEEDS 10 DEGREES.
#      (3)    S(MPAC)=2.  GNCS AUTO MODE NOT SELECTED (BIT10=1).
#      (4)    S(MPAC)=3.  DAP HOLD FLAG (HOLDFLAG) NOT EQUAL -1.
#
# Page 592
#
# INPUT:     (1)    TIME2,TIME1.  COMPUTER CLOCK TIME,DP, CENTISEC B28.
```

```

#           (2)      CDUX,Y,Z.  PRESENT CDU ANGLES,SP,2S COMPL HALF-REVS BO.
#           (3)      M(REFSMMAT), STABLE MEMBER COORDS B1.
#
# OUTPUT:      NORMAL.  EXIT WITH S(MPAC) = 0.
#
#           (1)      CDUXD,CDUYD,CDUZD, DESIRED OUTER, INNER, MIDDLE CDU ANGLES,
#                   DP, IS COMPL, SCALED 180 DEGREES (HALF-REVS BO).
#           (2)      DELCDUX,DELCDUY,DELCDUZ.  0.1 SEC DCU ANGULAR INCREMENTS,
#                   DP, IS COMPL, SCALED 180 DEG.
#           (3)      WBODY,WBODY1,WBODY2.  LOS ANGULAR RATE IN CONTROL COORDS,
#                   DP, IS COMPL, SCALED 450 DEG/SEC.
#
# SPECIAL.  EXIT WITH S(MPAC) = 1.
#
#           (1)      CPHI,CTHETA,CPSI.  DESIRED OUTER, INNER, MIDDLE CDU ANGLES,
#                   SP, 2'S COMPL, SCALED 180 DEGREES.
#
# EXTERNAL SUBROUTINES USED      (B)=BASIC
#
#           (1) CALCGA              (5) LOADTIME(B)              (9) SMNB
#           (2) CDUTRIG             (6) MATMOVE
#           (3) CSMCONIC            (7) RCDUS(B)
#           (4) LEMCONIC            (8) SMCDURES
#
# ERASABLE
#
#           (1) S(Q611),EBANK7      CRS61.1 EXIT.
#           (2) S(Q6111),EBANK7     CALCDCDU EXIT.
#           (3) T(SAVEDCDU),E6      SP VECTOR OF CDUDS.
#           (4) V(SAVEPOS),E7       CSM POS VEC AND D(SAVEPOS)= LENGTH OF LOS.
#           (5) V(SAVEVEL),E7       CSM VEL VEC.
#
# FLAGWDS:      HOLDFLAG.  USED, NOT SET.
#
# MISC: (1) ERASABLE ITEMP1 USED TO TEMP STORE EBANK UNDER INHINT.
#       (2) ERASABLE P21TIME USED AS TEMP STORE DURING CRS61.1
#       (3) ERAS DTHETASM USED AS TEMP STORE DURING EARLY CRS61.1
#
# DEBRIS -- CURRENT VAC AREA, CRS61.1 ERASABLES, ITEMP1, P21TIME
#
# BANK      24
# SETLOC    P20S4
# BANK
#
# EBANK=    CDUXD
# COUNT*    $/CRS61

```

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```
CRS61.1      STQ      SETPD
                  Q611
                  0
                  RTB
# Page 593
                  LOADTIME      # LOAD CLOCK TIME2,1 INTO MPAC.

STORT        STCALL  P21TIME      # STORE CLOCK TIME FOR SUBR R63
                  R63            # SUBR TO CALC DCDU (T=PRESENT,PASS1)
                  TLOAD
                  THETAD          # SAVE DCDU(T) FROM CALCDCDU FOR STEP4.
                  STORE  SAVEDCDU

                  EXIT
                  TC      STEP2CK
AUTOCK        CAF      PRI030
                  EXTEND
                  RXOR    CHAN31
                  MASK    FURST3
                  EXTEND      # AUTO MODE SELECTED (BITS 15-13=011)
                  BZF      DAPCK  #      YES -- CONTINUE.
                  TC      ASET

DAPCK        CS      FLAGWRD1      # IS STIKFLAG SET (I.E., IS SOMEONE ON RHC)
                  MASK    STIKBIT
                  CCS      A
                  TC      STEP3CK
ASET         CAF      ZERO
                  TS      MPAC
                  TC      INTPRET    # EXIT CRS61.1
                  GOTO
                  Q611

STEP2CK      TC      BANKCALL
                  CADR    UPACTOFF

CDULOO        CAF      TWO          # SET TEMPORARY INDEX DTHETASM = 2
                  TS      DTHETASM
                  INDEX    DTHETASM
                  CA      CDUX      # SET A = ACTUAL CDU (ACDU).
                  EXTEND
                  INDEX    DTHETASM # SET INDEX TO ACCESS DESIRED CDU (DCDU).
                  MSU      THETAD   # A = DIFF = ACDU - DCDU.
                  TS      MPAC      # RETURN TO INTERPRETER FOR 10 DEGREE CK.
                  TC      INTPRET   # (DP APPROX SP OK FOR ROUGH CHECK)
```

```

          ABS      DSU
          DEGREE10  # IS (ACDU - DCDU) MORE THAN 10 DEGREES.
          BPL      EXIT  # NO -- OK, CONTINUE CHECKING OTHER ANGLES.
          STKTEST  STKTEST # TEST STICK FLAG
          CCS      DTHETASM # HAVE ALL 3 ANGLE DIFFS BEEN CHECKED.
          TC      CDULOOP  # NO -- DIM COUNT, CHECK NEXT ANGLE DIFF.
          TC      AUTOCK
          STKTEST  EXIT
          CS      FLAGWRD1
          MASK     STIKBIT

# Page 594
          CCS      A
          TC      MANUEXIS # STIKFLAG IS NOT SET (DO R63)
          CAF      BIT3
          EXTEND
          WOR      DSALMOUT # STIKFLG IS SET
                                # TURN ON UPACTY LIGHT

          TC      ASET      # EXIT AND SET R61CNTR
          TC      INTPRET
          SETPD
          0                # *
                                # NOW HAVE DCDUS STORED IN T(SAVEDCDU).
                                # GO CALC OTHER DAP INPUTS (DELCDU,WBODY)

CRS61.2  VLOAD     VSU
          DCDU
          SAVEVEL      # DV = VL - VC
          UNIT         # V(MPAC)=-UNITDV. VAC36D=ABSDV.
          VXV          # (-UNITDV)CROSS(UNITLOS).
          SAVEPOS
          RVCS/RDS      # (UNITLOS B1)(UNITDV B1)(CONST B4)=CROSS.
          PUSH         # HOLD CROSS IN PUSHLIST0. SCALED B6.
          DLOAD        # OBTAIN ABS VALUE OF LOS.
          NORM          # P21TIME IS TEMP STORE FOR ABSLOS.
          P21TIME
          X1
          PUSH         # NORM ABSLOS(DENOM) AND HOLD IN PUSH1.

          DLOAD        NORM
          36D          # NORM ABS VALUE OF DV(NUM).
          S1

          XSU,1        SR1      # X1 = X1(N DENOM)-S1(N NUM).
          S1           # SR1 TO AVOID OFLOW ON DOV.
          DDV          VXSC      # ABSDV(MPAC)/ABSLOS(PUSH1) = QUOT.
          SXA,1        # QUOT(MPAC) X CROSS(PUSH0)
          Q6111        # SAVE SCALE OF RESULT (R-15,1X).
                                # X1= NORM OF QUOT. QTUOT SCALE B7-B29=B-22

```

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```
# CROSS IS SCALED B6.  NEED SL1 TO RECOVER
# SR1 SO THAT -22+6+1=-15.  MPAC NOW HOLDS
# ORTHO LOS RATE (OMEGA TH, B-15,X1).
# OBTAIN RATE IN SM COORDS (OMEGTHSM) AND
# ADJUST FOR REFSMMAT SCALE OF B1.
# OMEGTHSM = VAC20D
# DELTA THETA SM = OMEGTHSM * .1B-3.

MXV      VSL1
          REFSMMAT
STORE    20D

VXSC

          TENTH
STORE    DTHETASM
CALL

          CDUTRIG
SETPD    CALL
          0
          SMCDURES

# STORE SM INCREM ANGLES FOR SMCDURES.
# OBTAIN SIN,COSCDUS FOR SMCDURES.
# SMCDURES USES PUSH
# OBTAIN DELCDU IN V(DCDU).

# Page 595
LXA,1

          Q6111
VLOAD    VSL*
          DCDU
          0 -17D,1
STORE    14D

# RELOAD X1
# RECOVER SCALE.
# (B-15,X1) + TENTH(B-3) + HALFREV(SB1)
# EQUALS B-17D,1 TO OBTAIN HALFREV(SB0).
# HOLD DELS IN V(VAC14D) FOR AUTOPILOT.

CALL

          CDUTRIG
VLOAD    CALL
          20D
          *SMNB*
# COMPUTES SINES AND COSINES FOR *SMNB*
# LOAD VECTOR AND CALL TRANSFORMATION
# VECTOR FOR TRG*SMNB INTO MPAC
# OBTAIN ANG. RATE REFERRED TO NB (BODY)

MXV

          MBDYCTL
VXSC

          POINT8
LXA,1    VSL*
          Q6111
          0 -14D,1
# CONVERT RATE(OMEGA) TO CONTROL COORDS.
# MULT. BY 0.8 TO RESCALE REVS TO 450 DEG.
# RECOVER SCALE.
# RELOAD X1 TO RECOVER NORMALIZ.
# (B-15,X1) + MBDYCTL(B1) = B-14D,1 TO
# OBTAIN REVS SCALED AT 450 DEGREES.

CRS61.2A
EXIT
INHINT
CAF      ZERO
          # TRANSFER DESIRED GIMBAL ANGLES
TS        CDUXD  +1
          # FROM T(SAVEDCDU) TO V(CDUXD).
TS        CDUYD  +1
TS        CDUZD  +1
CA        SAVEDCDU
TS        CDUXD
CA        SAVEDCDU +1
TS        CDUYD
```

```

CA      SAVEDCDU +2
TS      CDUZD

EXTEND
DCA      MPAC
DXCH     WBODY
EXTEND
DCA      MPAC      +3
DXCH     WBODY1
EXTEND
DCA      MPAC      +5
DXCH     WBODY2

EXTEND
INDEX    FIXLOC
DCA      14D
DXCH     DELCDUX
EXTEND
INDEX    FIXLOC
DCA      16D

# Page 596
DXCH     DELCDUY
EXTEND
INDEX    FIXLOC
DCA      18D
DXCH     DELCDUZ
CS       ONE
TS       HOLDFLAG
RELINT
TC       ASET
TC       INTERPRET
TLOAD
          SAVEDCDU
STORE    CPHI
SLOAD    GOTO
          LOONE
          Q611

MANUEXIS
MANUEXIT
          # ENTER FROM STEP2.  ACDU-DCDU EXCEEDS
          # 10 DEG. STORE DCDU(T) IN CPHI,CTHETA,
          # CPSI FOR KALCMANU.
          # SPECIAL RETURN (MPAC+0 = 1)
          # OCTAL 00001

R63      STQ      DLOAD
          Q6111
          P21TIME
          STCALL   TDEC1
          CSMCONIC

HOLDATT  VLOAD
          RATT
          STOVL    SAVEPOS

          # SUBR TO CALC DCDUS(T)
          # HOLD EXTRAPOLATED CSM POSITION AND
          # VELOCITY

```

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```

                                VATT
                                SAVEVEL
CALCLEM      STORE
                                DLOAD      # EXTRAPOLATE LEM STATE VECTOR TO SAVE
                                P21TIME    # TIME AS CSM USING LEMCONIC
                                STCALL     TDEC1
                                LEMCONIC
                                VLOAD
                                VATT
                                STOVL     DCDU      # STORE VATT IN DCDU TEMPORARILY
                                RATT      # LOS = RL RC
                                VSU       UNIT
                                SAVEPOS
                                STORE     SAVEPOS    # SAVE UNITLOS FOR CRS61.2 RATE CALC.
                                MXV       VSL1
                                REFSMMAT  # CONVERT TO STABLE MEMBER
                                STODL     POINTVSM
                                36D      # HOLD ABS VAL OF LOS (VAC 36D)
                                STORE     P21TIME    # IN D(P21TIME) FOR CRS61.2 RATE CALC.
                                VLOAD
                                UNITX
                                STCALL    SCAXIS    # TRACK AXIS UNIT VECTOR
                                VECPOINT  # FOR +X-AXIS TRACKING ATTITUDE
                                STORE     CPHIX      # STORE ANGLES FOR N96 DISPLAY
                                VLOAD
                                PRFUNIT
# Page 597
                                STCALL    SCAXIS
                                VECPOINT
                                STORE     PRAXIS    # STORE ANGLES FOR N95 DISPLAY
                                BOFF
                                PRFTRKAT
                                CRSTOR1
CRSTOR      STORE     THETAD      # STORE ANGLES FOR N18 DISPLAY
                                GOTO
                                Q6111
CRSTOR1     VLOAD
                                UNITX
                                STORE     SCAXIS
                                TLOAD     GOTO
                                CPHIX
                                CRSTOR
PRFUNIT     2DEC      .40957602    # 55 DEG TRACK AXIS UNIT VECTOR
                                2DEC      0.0      # FOR USE WITH VECPOINT
                                2DEC      .28678822
```

```

DEGREE10      DEC      .05556      # 10 DEG IN REVS      STEP2
RVCS/RDS      2DEC     15.915494 B-4 # 100/2PI REV-CSEC/RAD-SEC.

TENTH         2DEC     .1 B+3      # .1 B-3 (TO SCALE ANG. RATE TO .1 INREMS)

MAT1B1        2DEC     1.0 B-1

MBDYTCTL      2DEC     .5          #          7.25 DEG NEGATIVE

              2DEC     0          #          X-AXIS ROTATION MATRIX

              2DEC     0          #          CONVERTS BODY TO CTL

              2DEC     0          #          AXES. CAME AS QUADROT

              2DEC     .99200495 B-1 # COS7.25 B1      BUT SCALED B

              2DEC     -.12619897 B-1 # -SIN7.25 B1

              2DEC     0

              2DEC     .12619897 B-1 # SIN7.25 B1

              2DEC     .99200495 B-1 # COS7.25 B1

LOONE         OCT      00001      # TO SET MPAC = 00001 FOR SPECIAL EXIT.
FURST3        EQUALS   13,14,15   # CONSTANT FOR AUTOCK (OCT 70000).

```

# Page 598

# ..... S22.1 ORBITAL NAVIGATION ROUTINE

# MOD 1

#

# FUNCTIONAL DESCRIPTION

# 1. UPDATE CSM STATE VECTOR

# 2. UPDATE LANDMARK POSITION

# 3. CONVERT W MATRIX FROM 9 TO 6 DIMENSIONS

#

# SUBROUTINES CALLED

# INTSTALL,INTEGRV,GETNUM,SETRE,R-TO-TP,RP-TO-R,BVECTORS,INCP1,INCP2

# LALOTRV,S22F2410,LAT-LONG,ROWDOT

#

# ERASABLE INITIALIZATION

# W=9X9 MATRIX

# ORBFLAG=0 FOR INVALID W MATRIX, =1 FOR VALID W MATRIX

# ASTRONAUT ENTRY OF KNOWN,L,OFF



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```
#      8NN= NUMBER OF MARKS, DECIMAL INTEGER B-14
#      REFSMMAT= TRANSFORMATION MATRIX
#      MARKSTAT= ADDRESS OF START OF MARK DATA (MARK DATA OF EACH MARK IS
#                STORED AS FOLLOWS: TIME,AIG,SA,AMG,PA,AOG) TIME IS IN DOUBLE
#                PRECISION, ALL OTHERS ARE IN SINGLE PRECISION
#      CSM STATE VECTOR
#
# OUTPUT
#      UPDATED CSM STATE VECTOR
#      UPDATED LANDMARK POSITION
#      NEW 6 DIMENSIONAL W MATRIX
#
# DEBRIS
#      PUSH LIST,CSMPOS,ALPHAV,ERADM,UM,RCLP,USTAR,VARIANCE,X789,BVECTOR,8KK,
#      S22LOC,SVMRKDAT TABLE,22SUBSCL,LANDMARK,CXOFF,S22C,LAT,LOG,ALT,
#      TEMPOR1,S22TOFF,S221OFF,DSPTM1,S22EORM,S22TPRIM

      BANK      13

      SETLOC    P20S6
      BANK

      EBANK=    LANDMARK
      COUNT     35/LUORB

S22.1      STQ      SSP
           S22RTNEX
           S1
      DEC       6
      SSP       SSP      # SET I=1      ITEM 8KK IS I
           8KK
      DEC       1
           S22LOC
      ECADR     SVMRKDAT      # SET MARK DATA ADDRESS INTO S22LOC

# Page 599
      LXC,2     AXT,1
           MARKSTAT
      DEC       36

S22.111    VLOAD*      # MOVE MARK DATA (5 SETS FROM ADDR. IN
           0,2          # MARKSTAT TO SVMRKDAT TABLE TO AVOID LOSS
      STORE     SVMRKDAT +36D,1 # IF RESTART OCCURS
      INCR,2     TIX,1
      DEC       -6
           S22.111
      SET       EXIT
           P22MKFLG      # DOWNLINKED SVMRKDAT HOLDS PRESENT MARKS
```

```

TC      BANKCALL      # RELEASE VAC AREA WHERE MARK DATA WAS
CADR    MKRELEAS
TC      2PHSCHNG
OCT     00004
OCT     05022
OCT     13000
TC      INTPRET
AXT,1   BOFF
        OD
        CMOONFLG      # =0 EARTH, =1 MOON
        S22SHIFT
        INCR,1
        DEC            -2
S22SHIFT SXA,1   SETPD
        S22EORM        # SET =0 EARTH, =-2 MOON FOR SHIFTING
        OD
FIG2EXIT CALL
        INTSTALL
        CALL
        S22FLGS
#      FLOWCHART D=0   THEN DIMOFLAG=0, D609FLG NOT TESTED
#      FLOWCHART D=6   THEN DIMOFLAG=1, D60R9FLG=0
#      FLOWCHART D=9   THEN DIMOFLAG=1, D60R9FLG=1
        BOFF          CLRG0
        ORBWFLAG
        SETWW5D        # BRANCH TO SET W0-W5, ORBWFLAG, D
        D60R9FLG      # FLOWCHART D=6 PATH
        SETVANDI
SETWW5D CLEAR
        DIMOFLAG      # FLOWCHART D=0 PATH
        AXT,1         SSP
        DEC            108
        S1
        DEC            6
        CLEAR         VLOAD
        RENDWFLG      # GSOP CHANGE 8/18/67
        ZEROVECS
CLEARWW5 STORE    W +108D,1
# Page 600
        TIX,1         SLOAD
        CLEARWW5
        WORBPOS
        STORE         W      # SET DIAGONALS OF W0
        STORE         W +8D
        STORE         W +16D

```

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```

                                SLOAD
                                WORBVEL
                                STORE W +72D      # SET DIAGONALS OF W4
                                STORE W +80D
                                STORE W +88D
SETVANDI                       CLEAR
                                DMENFLG           # 0=6X6W, 1=9X9W
S22NXTIN                       CALL
                                GETTF
                                STCALL TDEC1
                                INTEGRV
                                CALL
                                S22CALRC          # CALC. RC B-29 OR B-27 (CSMPOS)
                                LXA,1 SXA,1
                                S22LOC           # SETUP ADDR. OF MARK DATA FOR GETUM SUBR.
                                MARKDATA
                                CALL              # COMPUTE UM
S2GETUM                       GETUM
                                STORE UM
DMPINTEG                      SLOAD PUSH          # TEST OFF=I
                                8KK
                                SLOAD SR3          # CXOFF SCALED B-5, MUST MOVE TO B-14
                                CXOFF             # BEFORE SUBT.
                                SR3
                                DSU
                                BHIZ BON
                                S22OFF=I         # BRANCH HERE IF OFF=I
                                DMENFLG          # 0=6X6W, 1=9X9W
                                S22D=9
                                CALL
                                GRP2PC
                                SET
                                ORBWFLAG
                                SET
                                DMENFLG         # =0 ON FIRST PASS THRU HERE FOR D=0, OR 6
                                22DSPFLG        # =1 TO DISPLAY DR,DV ON FIRST PASS
                                SET BON
                                ERADFLAG        # =1 TO COMPUTE FISCHER RADIUS
                                KNOWNFLG
                                S22BOX22
                                VLOAD UNIT        # UNIT ALSO PUTS ABVAL(RC) IN 36D
                                CSMPOS
                                STORE ALPHAV     # ALPHAV +4=SINL FOR SETRE
                                CLEAR BOFF
                                LUNAFLAG
# Page 601
```

```

                                CMOONFLG
                                S22C=I
                                SET
                                LUNAFLAG
S22C=I    CALL                  # ERADM= R0 METERS B-29 BOTH EARTH/MOON
                                SETRE
                                CALL                  # COMPUTE RL FROM EQUATION 2.4.10
                                S22F2410              # STORED IN X789,MPAC B-27,B-29
                                BOFF                  # SCALE RL B-29 FOR BOTH EARTH/MOON
                                CMOONFLG
                                +1
                                STORE                S22RL
                                DOT                   SL1
                                UM
                                STOVL                 S22D          # D=UM RL B-29
                                ZEROVECS
                                SETPD                PUSH
                                OD
                                PUSH                 PDDL          # SET 0-18D = I BACKWARDS
                                HIDPHALF              # PD 18
                                SR2                   # B-3
                                STORE                 4D
                                STORE                 8D
                                STOVL                 12D
                                UM                    # B-1
                                STOVL                 S223X1
                                S22RL                 # B-29
                                CALL                   # (UM)(RL T) B-30 STORED IN S22UMRL THRU
                                S2231X13              # S22UMRL +17D
                                AXT,1                 SSP
                                DEC                    18
                                S1
                                DEC                    6
S22NXTU   VLOAD*                VSR2          # (UM)(RL T) B-32
                                S22UMRL +18D,1
                                V/SC
                                S22D                  # D B-29
                                BVSU                 STADR         # SUBTRACT FROM I B-3
                                STORE                 S22UMRL +18D,1 # U MATRIX B-3
                                TIX,1                 AXT,1        # PD 0 AFTER TIX
                                S22NXTU
                                DEC                    36          # S1 STILL 6 FROM ABOVE
S22NXTWI  VLOAD*                MXV
                                W +36D,1             # B-19
                                S22UMRL              # B-3
                                VSL3

```

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# Page 602

S22NXXA

S22NXXB

```
STORE W +144D,1      # W(I+18)= UW(I) B-19
TIX,1  DLOAD
      S22NXTWI

BOFF   S22RHO        # B-28,B-30
      SR2            # MAKE RHO B-30
      CMOONFLG
      +1
NORM   XAD,2
      X2
      X2
DSQ    DMP
      SCTVAR        # B+16
SR1    S22RHO        # ACCOUNTS FOR 1/2 IN NEXT FORMULA
STORE  S22RHO        # 1/2(RHO SQ)(VAR SCT)
AXT,1
DEC    18            # S1 STILL 6 FROM ABOVE
VLOAD* MXV
      S22UMRL +18D,1 # B-3
      S22UMRL      # B-3
VXSC   VSR*
      S22RHO
      0 -12D,2      # WITH VARRP SCALED B-28
STORE  S22UUT +18D,1 # 1/2(RHO SQ)(VAR SCT)(U)(U T)
TIX,1  VLOAD
      S22NXXA
      UM
STCALL S223X1        # UM ALSO IN MPAC FOR S2231X13 SUBR.
      S2231X13      # (UM)(UM T) B-2 IN S22UMRL,P17D
DLOAD  SR3
      ERADM        # B0 B-29
DDV    DSQ
      S22D         # B-29
DMP
      RPVAR        # ***** METERS SQ
STORE  S22RHO        # TEMP (VARRP)(RO/D)
AXT,1
DEC    18            # S1 STILL 6 FROM ABOVE
VLOAD* VXSC
      S22UMRL +18D,1 # (UM)(UM T) B-2
      S22RHO
VAD*
      S22UUT +18D,1
STORE  S22UUT +18D,1 # SMALL E MATRIX
VLOAD
      ZEROVECS
```

```

                                STORE W +162D,1      # CLEAR W8
                                TIX,1    BOV
                                S22NXXB
                                +1
                                DLOAD    BMN
                                S22UUT +16D      # E5
                                S22W76X
                                SQRT    BZE

# Page 603

                                S22W76X
                                STODL   W +148D      # W74= SQ ROOT E5
                                S22UUT +14D      # E4
                                DDV      BOV
                                W +148D
                                S22W72X
                                STORE    W +146D      # W73= E4/W74
S22W72X  DLOAD    DDV
                                S22UUT +12D      # E3
                                W +148D
                                BOV
                                S22W76X
                                STORE    W +144D      # W72= E4/W74
S22W76X  DLOAD    DSQ
                                W +146D      # W73
                                BDSU      BMN
                                S22UUT +8D      # E2
                                S22W78X
                                SQRT    BZE
                                S22W78X
                                STODL   W +152D      # W76= SQ ROOT (E2-W73 SQ)
                                W +144D      # W72
                                DMP      BDSU
                                W +146D      # W73
                                S22UUT +6D      # E1
                                DDV      BOV
                                W +152D      # W76
                                S22W78X
                                STORE    W +150D      # W75= (E1-W72W73)/W76
S22W78X  DLOAD    DSQ
                                W +150D
                                PDDL     DSQ
                                W +144D      # W72
                                DAD
                                BDSU      BMN
                                S22UUT      # E0
                                S22SCLW

```

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```
S22SCLW      SQRT
              STORE W +156D      # W78= SQ RT(E0-W72 SQ-W75 SQ)
              VLOAD VSR1         # SCALE W6 METERS B-19
              W +144D
              STOVL W +144D
              W +150D
              VSR1
              STOVL W +150D
              W +156D
              VSR1
              STORE W +156D
S22SAVET      CALL
              GETTF
# Page 604
S22I=N        STORE S22TPRIM      # SAVE PRESENT TIME FOR PIOS
              EXIT                # TEST I=N
              TC PHASCHNG
              OCT 04022
              CS 8KK
              AD 8NN
              EXTEND
              BZMF S22F244X      # EXIT TO FIGURE 2.4-4
              CA 8KK             # I=I+1
              AD ONE
              TS TEMPOR1
              CA S22LOC          # ADD 7 TO LOC TO GET ADDR. OF NEXT MARK
              AD SEVEN
              TS TEMPOR1 +1
              TC PHASCHNG
              OCT 04022
              CA TEMPOR1
              TS 8KK
              CA TEMPOR1 +1
              TS S22LOC
              TC INTPRET
              CALL                # FOR ALL INTEGRATIONS OTHER THAN FIRST
S2INTS1      INTSTALL
              CALL
              S22FLGS
              BON CLEAR
              DMENFLG
              S22NXTIN          # RETURN ALWAYS EXCEPT OFFSET POINT MARK 1
              DIMOFLAG
              BOFF SET
              ORBWFLAG
              S22NXTIN          # OFFSET POINT MARK 1, NO W INTEGRATION
```

```

                                DIMOFLAG
                                CLRGO
                                D6OR9FLG
                                S22NXTIN      # OFFSET POINT MARK 1, INTEGRATE W 6X6
S22OFF=I      CALL
                                GETTF
                                STOVL      S22TOFF      # TIME SUB OFF
                                UM
                                STCALL      S22UOFF      # U SUB OFF
                                S22I=N      # TEST I=N
S22D=9      VLOAD      # D=9 PATH
                                X789
                                STODL      OD      # CALL PIOS TWICE TO TRANSFORM RL TO TIME
                                S22TPRIM      # T(SUB F) FROM TIME T PRIME
                                STORE      6D
                                SLOAD      CALL
                                S22EORM      # 0=EARTH, NON-ZERO=MOON
S2RTRP      R-TO-RP
# Page 605
                                PUSH      CALL      # R-TO-RP LEAVES PUSHLOC AT 0
                                GETTF
                                STORE      6D
                                SLOAD      CALL
                                S22EORM
S2RPTR      RP-TO-R
S22BOX32      STORE      X789
                                SET      BOV
                                INCORFLG      # FLAG=1
                                +1      # CLEAR OVERFLOW
                                VSU
                                CSMPOS
                                STORE      RCLP      # RCL=RL-RC
                                UNIT      VXV      # USTAR=UNIT(UNIT(RCL)XUM)
                                UM
                                UNIT      BOV
                                S22SAVET      # COMPUTATION OVERFLOW, SAVE TF
                                STORE      USTAR
S22BOX12      SET      SET
                                DMENFLG      # =1 FOR 9X9 W
                                VEHUPFLG      # =1 FOR CSM
                                DLOAD      DAD
                                SCTVAR      # B+18
                                IMUVARR      # B+18
                                STOVL      VARIANCE
                                RCLP      # B-29 OR B-27
                                ABVAL      NORM

```



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```

                                X1
DSQ      DMP
                                VARIANCE
XAD,1    XAD,1
                                X1          # DOUBLE NORM SHIFT SINCE RCLP WAS SQUARED
                                S22EORM      # DOUBLE EARTH OR MOON SHIFT, SAME REASON
XAD,1    SR*
                                S22EORM
                                0,1          # SCALE VARIANCE B-40 FOR BOTH EARTH, MOON
TLOAD    # CHANGE MODE TO TRIPLE
                                MPAC
STCALL   VARIANCE          # CALC B0,B1,DELTAQ, NEW USTAR
                                BVECTORS
S2BVTRS  VLOAD    VCOMP
                                BVECTOR
STCALL   BVECTOR +12D      # B2=-B0
S2INCP1  INCORP1
CALL
                                GRP2PC
BOFF     CLEAR
                                22DSPFLG      # =1 DISPLAY DELTA R,V      =0 DO NOT
                                S22BOX42
                                22DSPFLG
# Page 606
CALL
                                GRP2PC
VLOAD    ABVAL
                                DELTAX          # DELTA R
LXA,1    SR*
                                S22EORM      # SCALE DELTA R ALWAYS METERS B-29
                                0,1
STOVL    N49DISP
                                DELTAX +6      # DELTA V
ABVAL    SR*              # DELTA V=METERS/CSEC B-7 ALWAYS
                                0,1
STORE    N49DISP +2
EXIT
CAF      V06N49EE
TC       BANKCALL
CADR     GOFLASHR
TC       GOTOP00H          # V34E TERMINATE
TC       +5                # INCORPORATE CHANGES
TC       S22EXEX           # V32E RECYCLE
CAF      BIT3
TC       BLANKET
TC       ENDOFJOB
```

|            |        |           |                                         |
|------------|--------|-----------|-----------------------------------------|
|            | TC     | INTPRET   |                                         |
| S22BOX42   | CALL   |           |                                         |
|            |        | INCORP2   |                                         |
|            | CALL   |           | # CSMPOS=RC B-29 OR B-27                |
|            |        | S22CALRC  |                                         |
| DMPINCP2   | BOFF   | CALL      |                                         |
|            |        | INCORFLG  |                                         |
|            |        | S22SAVET  | # SAVE TF AND TEST I=N                  |
|            |        | GRP2PC    |                                         |
|            | CLEAR  | VLOAD     |                                         |
|            |        | INCORFLG  | # FLAG=0                                |
|            |        | X789      |                                         |
|            | VSU    |           |                                         |
|            |        | CSMPOS    |                                         |
|            | STCALL | RCLP      | # RCL=RL-RC                             |
|            |        | S22BOX12  |                                         |
| S22BOX22   | AXT,1  | SSP       | # CLEAR W6,W7,W8. (27 ELEMENTS 54 REGS) |
|            | DEC    | 54        |                                         |
|            |        | S1        |                                         |
|            | DEC    | 6         |                                         |
|            | VLOAD  |           |                                         |
|            |        | ZEROVECS  |                                         |
| CLR678     | STORE  | W +162D,1 |                                         |
|            | TIX,1  | SLOAD     |                                         |
|            |        | CLR678    |                                         |
|            |        | S22WSUBL  |                                         |
|            | STORE  | W +144D   |                                         |
|            | STORE  | W +152D   |                                         |
| # Page 607 |        |           |                                         |
|            | STORE  | W +160D   |                                         |
|            | CLEAR  | BOFF      | # SET LUNAFLAG, TIME FOR LALOTORV       |
|            |        | LUNAFLAG  | # ERADFLAG,LAT, LONG,ALT SET PREVIOUSLY |
|            |        | CMOONFLG  | # CHECK SCALING OF ITEMS,ALT INPUT AND  |
|            |        | S22BX22A  | # RL OUTPUT IN ALPHAV BOTH B-29         |
|            | SET    |           |                                         |
|            |        | LUNAFLAG  |                                         |
| S22BX22A   | CALL   |           |                                         |
|            |        | GETTF     |                                         |
|            | CALL   |           | # COMPUTE RL                            |
|            |        | LALOTORV  |                                         |
|            | VLOAD  | BOFF      |                                         |
|            |        | ALPHAV    | # RL B-29                               |
|            |        | CMOONFLG  |                                         |
|            |        | S22BX22B  |                                         |
|            | VSL2   |           | # SCALE RL B-27 FOR MOON                |
| S22BX22B   | GOTO   |           |                                         |

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|            |        |          |                                        |
|------------|--------|----------|----------------------------------------|
| S22F244X   | TC     | S22BOX32 |                                        |
| S22F244    | SLOAD  | INTPRET  |                                        |
|            |        | BHIZ     | # FIG 2.4-4 TEST OFF=0                 |
|            |        | CXOFF    |                                        |
|            |        | S22BOX44 |                                        |
|            | SR     |          | # SCALE OFFSET B-14 THEN GET GR. 8NN   |
|            |        | 9D       |                                        |
|            | STORE  | ALPHAV   | # TEMP                                 |
|            | SLOAD  | DSU      |                                        |
|            |        | 8NN      |                                        |
|            |        | ALPHAV   |                                        |
|            | BMN    | CALL     | # OFFSET GR. NO. MARKS. FORGET IT      |
|            |        | S22BOX44 |                                        |
|            |        | GRP2PC   | # GROUP 2 PHASE CHANGE                 |
|            | DLOAD  |          |                                        |
|            |        | S22TOFF  |                                        |
|            | STCALL | TDEC1    | # CALC RC AT OFFSET TIME               |
|            |        | CSMPREC  |                                        |
|            | VLOAD  |          |                                        |
|            |        | RATT1    | # RC METERS B-29 OR B-27               |
|            | STOVL  | CSMPOS   |                                        |
|            |        | S22UOFF  |                                        |
|            | STOVL  | UM       | # U=UOFF                               |
|            |        | X789     |                                        |
|            | ABVAL  | BOFF     |                                        |
|            |        | CMOONFLG |                                        |
|            |        | +2       |                                        |
|            | SR2    |          | # SCALE MOON RO B-29 FOR S22F2410 SUBR |
|            | STCALL | ERADM    |                                        |
|            |        | S22F2410 |                                        |
|            | GOTO   |          |                                        |
|            |        | S22BX44A |                                        |
| S22BOX44   | CALL   |          |                                        |
| # Page 608 |        |          |                                        |
|            |        | GETTF    |                                        |
|            | STORE  | S22TOFF  | # PRESENT TIME FOR LAT-LONG SETUP      |
| S22BX44A   | CLEAR  | VLOAD    |                                        |
|            |        | LUNAFLAG |                                        |
|            |        | X789     |                                        |
|            | BOFF   | SET      |                                        |
|            |        | CMOONFLG |                                        |
|            |        | S22BX44B |                                        |
|            |        | LUNAFLAG | # SET = 1 FOR LAT-LONG                 |
|            | VSR2   |          | # SCALE RL MOON B-29 FOR LAT-LONG      |
| S22BX44B   | STODL  | ALPHAV   | # RL SCALED B-29 FOR LAT-LONG          |
|            |        | S22TOFF  | # EITHER PRESENT OR OFFSET TIME        |

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|            |       |          |                                           |                         |
|------------|-------|----------|-------------------------------------------|-------------------------|
|            | CALL  | LAT-LONG | # **** ALT OUTPUT ALWAYS B-29             |                         |
|            | CALL  | LLASRD   | # DISPLAY LAT/LONG/ALT                    |                         |
|            | EXIT  |          |                                           |                         |
|            | CAF   | V06N89B  |                                           |                         |
|            | TC    | BANKCALL |                                           |                         |
|            | CADR  | GOFLASH  |                                           |                         |
|            | TC    | S22GTP   | # V34E TERMINATE                          |                         |
|            | TC    | +2       | # PROCEED                                 | SAVE LANDING SITE COORD |
|            | TC    | S22.981X | # RECYCLE                                 | POINT A IN GSOP         |
|            | TC    | INTPRET  |                                           |                         |
|            | DLOAD |          |                                           |                         |
|            |       | S22TOFF  | # EITHER PRESENT OR OFFSET TIME           |                         |
|            | STOVL | 6D       | # 6-7D= LANDING SITE TIME FOR R-TO-RP     |                         |
|            |       | X789     |                                           |                         |
|            | STORE | OD       | # 0-5D= LANDING SITE VEC FOR R-TO-RP      |                         |
|            | SLOAD | CALL     |                                           |                         |
|            |       | HIDPHALF | # ANY NON-ZERO FOR MOON                   |                         |
|            |       | R-TO-RP  | # CONVERT RLS TO MOON-FIXED COORD         |                         |
|            | STORE | RLS      | # LANDING SITE VECTOR                     |                         |
|            | EXIT  |          |                                           |                         |
| S22.981X   | TC    | INTPRET  |                                           |                         |
|            | CALL  |          |                                           |                         |
|            |       | 9DWT06DW |                                           |                         |
|            | EXIT  |          | # GO TO POINT A IN CHAPTER 5              |                         |
| S22EXEX    | TC    | INTPRET  | # WITHOUT CONVERTING W                    |                         |
|            | GOTO  |          |                                           |                         |
|            |       | S22RTNEX |                                           |                         |
|            |       |          |                                           |                         |
| S22GTP     | TC    | INTPRET  | # CONVERT W BEFORE TC GOTOP00H            |                         |
|            | CALL  |          |                                           |                         |
|            |       | 9DWT06DW |                                           |                         |
|            | EXIT  |          |                                           |                         |
|            | TC    | GOTOP00H |                                           |                         |
| S22F2410   | SETPD | VLOAD    | # COMPUTE FORMULA 2.4.10                  |                         |
|            |       | OD       |                                           |                         |
|            |       | CSMPOS   | # RC B-29 EARTH, B-27 MOON                |                         |
| # Page 609 |       |          |                                           |                         |
|            | UNIT  | DOT      | # UNIT ALSO SETS 36D=ABVAL(RC) USED BELOW |                         |
|            |       | UM       |                                           |                         |
|            | SL1   | DCOMP    | # GSOP CHANGE 8/18/67                     |                         |
|            | PUSH  |          | # PD 2D 8D=COSA=-(UM.RC)/ABVAL(RC)        | B-1                     |
|            | DSQ   | BDSU     |                                           |                         |
|            |       | DEC1B2   |                                           |                         |
|            | PDDL  | BOFF     | # PD 4D 2D=1-COSA SQ=SINA SQ              | B-2                     |

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```

                                ERADM          # R0 ALWAYS B-29 FROM SETRE
                                CMOONFLG
                                +2
S22CALRC  SL2                   # SCALE R0 B-27 FOR MOON
SR1R      DDV                   # (R0/RC)          B-1
          36D
DSQ        DSU                   # PD 2D (RP/RC) SQ - SINA SQ          B-2
SQRT       BDSU                  # PD OD COSA-SQRT((R0/RC)SQ-SINA SQ) B-1
DMP        36D                   # DMP RESULT B-28 MOON, B-30 EARTH
          36D                   # VXSC RESULT B-29 MOON, B-31 EARTH
STORE      S22RHO                # RHO FOR W INIT. OF UNKNOWN LMK B-28,B-30
VXSC
          UM
VSL2       VAD                   # SCALE B-27 MOON, B-29 EARTH AND ADD RC
          CSMPOS
STORE      X789
RVQ
LXA,1      VLOAD                  # B-27 FOR EARTH OR B-29 FOR MOON
          S22EORM                  # COMPUTE RC B-29 OR B-27
          DELTACSM                  # =0 FOR EARTH, -2 FOR MOON
VSR*       VAD
          7,1
          RCVCSM
STORE      CSMPOS
RVQ
SETLOC     P22S
BANK

S2231X13   STORE S221X3          # MULT 3X1 BY 1X3, STORE RESULTING 3X3 IN
SSP         AXT,2                # S22UMRL - S22UMRL+17D
          S2
DEC         2
DEC         6
AXT,1
DEC         18
S2231NXT   VLOAD VXSC*
          S221X3
          S223X1 +6,2
STORE      S22UMRL +18D,1
INCR,1     TIX,2
DEC        -6
          S2231NXT
RVQ

# Page 610
GETTF      LXC,1 DLOAD*          # SET MPAC= TF
          S22LOC
```

```

                                0,1
S22FLGS      RVQ
              SET      SET      # INTEGRATION FLAGS
                                DIMOFLAG
                                D6OR9FLG
              SET      SET
                                VINTFLAG
                                STATEFLG
              CLEAR    RVQ
                                INTYPFLG

# SUBROUTINE TO MODIFY ALT AND STORE LAT TO LAT+5 IN LANDLAT TO LANDLAT+5
# PRIOR TO DISPLAY.

LLASRD      DLOAD      # ALT, LANDALT METERS B-29
              ALT
              STODL     LANDALT
              LONG
              SR1
              STORE     LANDLONG
              RVQ

# SUBROUTINE TO MODIFY LANDALT AND STORE LANDALT TO LANDALT+5 IN LAT TO
# LAT+5 AFTER LMK DATA LOADED BY ASTRONAUT.

LLASRDA      DLOAD      # ALT, LANDALT METERS B-29
              LANDALT
              STODL     ALT
              LANDLONG
              SL1
              STORE     LONG
              RVQ
              SETLOC    P20S6
              BANK

9DWT06DW      STQ      SETPD
              9DWXX
              OD
              VLOAD     PUSH      # CLEAR WORKING AREA OF PUSHLIST
              HI6ZEROS      # INCLUDING P
              PUSH      PUSH      # PD 18D
              SSP
              9DWJ      # J=29  USE 2*29 FOR DP WORDS
              DEC      58
9DWI=J      LXA,1      SXA,1      # SET I=J
              9DWJ

```

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```
9DWEPCAL      CALL      9DWI
# Page 611

                ROWDOT
LXA,1          # P VARIES 0-20 INSTEAD OF 20-0
                9DWP
STORE EMATRIX +40D,1
INCR,1        SXA,1
DEC           2
                9DWP
SLOAD BHIZ      # TEST I=0
                9DWI
                9DWTESTJ
DSU           # I=I-1
                9DWID
STORE 9DWI
DSU BHIZ      # TEST I=26
                9DW26D
                9DWSETI2
GOTO          # NEXT E SUB P
                9DWEPCAL
9DWSETI2      SSP      GOTO      # I=2
                9DWI
DEC           4
                9DWEPCAL
9DWTESTJ      SLOAD BHIZ      # TEST J=0
                9DWJ
                9DWFIG6
DSU
                9DWID
STORE 9DWJ      # J=J-1
DSU BHIZ      # TEST J=26
                9DW26D
                9DWSETJ2
GOTO
                9DWI=J
9DWSETJ2      SSP      GOTO      # SET J=2
                9DWJ
DEC           4
                9DWI=J
9DWFIG6       CALL
                GRP2PC
SSP VLOAD      # START OF FIGURE 2.4-6
                9DWJ      # J=29
DEC           58
                HI6ZEROS
```

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|            |        |                |                   |
|------------|--------|----------------|-------------------|
|            | STORE  | 9DWP           | # P,N,I=0         |
|            | AXT,1  | SSP            |                   |
|            | DEC    | 108            | # CLEAR W0 TO W54 |
|            |        | S1             |                   |
|            |        | 6              |                   |
| CLEARW54   | STORE  | W +108D,1      |                   |
|            | TIX,1  |                |                   |
| # Page 612 |        |                |                   |
|            |        | CLEARW54       |                   |
| 9DWI=JA    | LXA,1  | SXA,1          | # I=J             |
|            |        | 9DWJ           |                   |
|            |        | 9DWI           |                   |
|            | CALL   |                |                   |
|            |        | ROWDOT         |                   |
|            | LXA,1  | BDSU*          |                   |
|            |        | 9DWP           |                   |
|            |        | EMATRIX +40D,1 |                   |
|            | INCR,1 | SXA,1          | # -(P+1)          |
|            |        | 2              |                   |
|            |        | 9DWP           |                   |
|            | LXC,1  | XSU,1          | # -(I+N)          |
|            |        | 9DWI           |                   |
|            |        | 9DWN           |                   |
|            | BPL    | DLOAD          | # TEST WSQ LTE 0  |
|            |        | 9DWAAA         |                   |
|            |        | HI6ZEROS       | # W=0             |
|            | GOTO   |                |                   |
|            |        | 9DWAAB         |                   |
| 9DWAAA     | SQRT   |                | # W= SQRT(WSQ)    |
| 9DWAAB     | STORE  | W,1            |                   |
|            | STODL  | WORKW          |                   |
|            |        | 9DWJ           | # TEST J=0        |
|            | BHIZ   |                |                   |
|            |        | 9DWEXITX       | # EXIT            |
| TST2I=0    | SLOAD  | BHIZ           | # TEST I=0        |
|            |        | 9DWI           |                   |
|            |        | 9DWN=N+3       |                   |
|            | DSU    |                |                   |
|            |        | 9DWID          |                   |
|            | STORE  | 9DWI           | # I=I-1           |
|            | DSU    | BHIZ           | # TEST I=26       |
|            |        | 9DW26D         |                   |
|            |        | 9DWAAC         |                   |
|            | GOTO   |                |                   |
|            |        | 9DWNEXEP       |                   |
| 9DWAAC     | SSP    |                | # I=2             |



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```

                                9DWI
                                4
9DWNEXEP      CALL
                                ROWDOT
LXA,1          BDSU*            # (EP-ROWI*ROWJ)/W
                                9DWP
                                EMATRIX +40D,1
DDV           INCR,1           # P=P+1
                                WORKW
                                2
SXA,1          LXC,1
                                9DWP
# Page 613
                                9DWI
XSU,1          BOV             # -(I+N)
                                9DWN
                                SETWIN=0
GOTO
                                9DWSETWX
SETWIN=0       DLOAD           # W(I+N)=0
                                HI6ZEROS
9DWSETWX       STORE          W,1
GOTO
                                TST2I=0
9DWN=N+3       LXA,1          INCR,1      # N=N+3
                                9DWN
                                6
SXA,1          SLOAD          # J=J-1
                                9DWN
                                9DWJ
DSU
                                9DWID
STORE          9DWJ
DSU           BHIZ             # TEST J=26
                                9DW26D
                                SETJ=2A
GOTO
                                9DWI=JA
SETJ=2A        SSP           GOTO         # J=2
                                9DWJ
                                4
                                9DWI=JA
9DWEXITX       CALL
                                GRP2PC
AXT,1          SSP           # CLEAR W6,W7,W8 USED TEMP FOR EMATRIX
DEC           54
```

```

                                S1
                                6
                                VLOAD
                                HI6ZEROS
9DWEXXA STORE W +162D,1
                                TIX,1 GOTO
                                9DWEXXA
                                9DWXX
ROWDOT SSP BOV
                                XTMP1
                                OCT 377
                                +1
                                LXC,1 LXC,2
                                9DWI
                                9DWJ
                                DLOAD PUSH
                                HI6ZEROS
# Page 614
ROWDOT1 DLOAD* DMPR*
                                W,1
                                W,2
                                DAD PUSH
                                BOV INCR,1
                                ROWDOT3
                                DEC -6
                                INCR,2 SLOAD
                                DEC -6
                                XTMP1
                                BHIZ SR1
                                ROWDOT2
                                STORE XTMP1
                                GOTO
                                ROWDOT1
ROWDOT2 DLOAD
                                RVQ
ROWDOT3 CLRGO
                                ORBWFLAG
                                ROWDOT2
WORKW = OD
XTMP1 = 6D
9DWP = 8D # P
9DWI = 10D # I
9DWN = 12D # N
9DWJ = 14D # J
9DWXX = S22UOFF
S22UMRL = BVECTOR # 18

```

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```
S22UUT      =      DELTAX      # 18
S223X1      =      18D         # 6
S221X3      =      24D         # 6
S22D        =      30D         # 2
S22RHO      =      32D         # 2
S22RL       =      W +156D     # 6
9DW26D      2DEC      52 B-14

9DWID       2DEC      2 B-14

SCTVAR      2DEC      1.0 E-6 B+18

IMUVARR     2DEC      0.04 E-6 B+18

DEC1B2      2DEC      1 B-2

V06N49EE    VN      00649
V06N89B     VN      00689
S22UOFF     =      LEMPOS      # 6      U SUB OFF
            SETLOC P20S2
            BANK
```

# Page 615

# Nothing on this page. --- RSB 2009.

# Page 616

# SUBROUTINE NAME: V89CALL

# MOD NO: 0

DATE: 8 FEB 1968

# MOD BY: DIGITAL DEVEL GROUP

LOG SECTION: P20-P25

#

# FUNCTIONAL DESCRIPTION:

#

# CALLED BY VERB 89 ENTER DURING P00. Prio 10 USED. CALCULATES AND  
# DISPLAYS FINAL GIMBAL ANGLES TO POINT CSM +X AXIS OR PREFERRED AXIS  
# (UNIT(Z)COS55 DEG + UNIT(X)SIN55 DEG) AT LM.

#

# 1. KEY IN V89 E ONLY IF IN PROG 00. IF NOT IN P00, OPERATOR ERROR AND  
# EXIT R63, OTHERWISE CONTINUE.

#

# 2. IF IN P00, DO IMU STATUS CHECK (R02BOTH). IF IMU ON AND ITS  
# ORIENTATION KNOWN TO CGC, CONTINUE.

#

# 3. FLASH DISPLAY V 04 N 06. R2 INDICATES WHICH SPACECRAFT AXIS IS TO  
# BE POINTED AT LM. INITIAL CHOICE IS PREFERRED AXIS. (R2=1).  
# ASTRONAUT CAN CHANGE TO (+X) AXIS (R2 NOT= 1) BY V22 E 2 E. CONTINUE  
# AFTER KEYING IN PROCEED.

#

```

# 4. SET PREFERRED ATTITUDE FLAG ACCORDING TO OPTION DESIRED.  SET FLAG
# FOR PREFERRED AXIS.  RESET FLAG FOR X AXIS.
#
# 5. CURRENT TIME IS STORED AND R63COMP IS CALLED
#
#       R63COMP JOB:
#
#           UPDATE CSM AND LM STATE VECTORS USING CONIC EQUATIONS
#
#           CALCULATES BOTH PREFERRED AND X AXIS TRACKING ATT FROM CSM TO LM.
#
#           DESIRED GIMBAL ANGLES AS INDICATED BY PREFERRED ATTITUDE FLAG
#           ARE STORED FOR LATER R60CSM CALL.
#
# 6. FLASH DISPLAY V 06 N18 AND AWAIT RESPONSE.
#
# 7. RECYCLE: RETURN TO STEP 5.
#   TERMINATE: EXIT R63 ROUTINE
#   PROCEED:  RESET 3AXISFLG AND CALL R60CSM FOR ATTITUDE MANEUVER.
#
# CALLING SEQUENCE:      V 89 E
#
# SUBROUTINES CALLED:  CHKPOOH, R02BOTH, GOXDSPF, R63COMP, R60CSM
#
# ALARMS      1.  OPERATOR ERROR IF NOT IN POO
#              2.  PROGRAM ALARM IF IMU IS OFF
#              3.  PROGRAM ALARM IF IMU ORIENTATION IS UNKNOWN
# Page 617
#
# ERASABLE INITIALIZATION REQUIRED:  NONE
#
# DEBRIS:  OPTION1, OPTION1+1, PRFTEXAT(PREF ATT FLAG), P21TIME, 3AXISFLG

DP1MIN      2DEC      6000

              EBANK=  P21TIME
              BANK    34
              SETLOC  P20S4
              BANK
              COUNT*  $$/R63

V89CALL      TC        BANKCALL      # IMU STATUS CHECK. RETURNS IF ORIENTATION
              CADR      R02BOTH      # KNOWN.  ALARMS IF NOT.
              CAF        THREE      # ALLOW ASTRONAUT TO SELECT DESURED
              TS         OPTION1    # TRACKING ATTITUDE AXIS
              CAF        ONE

```

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```
TS      OPTION1 +1
CAF     VB04N06      # V 04 N 06
TC      BANKCALL
CADR    GOFLASH
TC      ENDEXT      # TERMINATE
TC      +2          # PROCEED
TC      -5          # DATA IN.  OPTION1 +1 = 1 FOR PREF AXIS
                        #
                        # = 2 FOR X AXIS
CS      OPTION1 +1  # 1 FOR PREF AXIS.  2 FOR X AXIS.
AD      ONE
EXTEND
BZF     SETPAF
RSTPAF  TC          DOWNFLAG      # RESET PREF ATT FLAG FOR R63COMP
ADRES   RNGSCFLG    # TO DO X AXIS.  RESET BIT 10 FLAG 5
V89RECL TC          INTPRET
RTB     DAD
        LOADTIME    # READ PRESENT TIME
        DP1MIN      # INTEGRATE TO 1 MIN FROM NOW
STCALL  P21TIME     # STORE TIME FOR CALL TO R63COMP.  R63COMP
        R63COMP     # LEAVES DESIRED GIM ANG IN THETAD, LOS IN
EXIT     # POINTVSM, AND SELECTED AXIS IN SCAXIS.
CAF     VB06N18     # V 06 N 18
TC      BANKCALL    # NOUN 18 REFERS TO THE DESIRED GIMBAL
CADR    GOFLASH
TC      ENDEXT      # TERMINATE
TC      +2          # PROCEED
TC      V89RECL     # RECYCLE
TC      DOWNFLAG    # RESET 3 AXIS FLAG
ADRES   3AXISFLG    # RESET BIT 6 FLAG 5
# Page 618
TC      BANKCALL    # PERFORMS CSM MANEUVER TO ALIGN SELECTED
CADR    R60CSM      # SPACECRAFT AXIS TO LOS.
TCF     ENDEXT
SETPAF  TC          UPFLAG        # SET PREFERRED ATT FLAG FOR R63COMP
ADRES   RNGSCFLG    # TO DO PREF AXIS.  SET BIT 10 FLAG 5.
TC      V89RECL
VB04N06 VN          0406
VB06N18 VN          0618
R63COMP EQUALS     R63
```

# Page 619

# PROGRAM NAME: P23 CISELUNAR MIDCOURSE NAVIGATION

# MOD NO:

```

# MOD BY:  TOM KNATT
#
# FUNCTIONAL DESCRIPTION:  DO MIDCOURSE NAVIGATION BY INCORPORATION OF
# STAR/EARTH AND STAR/MOON OPTICAL MEASUREMENTS.
#
# CALLING SEQUENCE:  ASTRONAUT OPERATED
#
# SUBROUTINES CALLED:  R52,R53,R57,R60,ORBITAL INTEGRATION (INTEGRV)
# INCORP1,INCORP2,LALOTORV,LUNLMKLD, AND DISPLAY INTERFACE ROUTINES.
#
# NORMAL EXIT MODES:  VIA R00
#
# ALARMS:  NONE
#
# ABORT MODES:  NONE
#
# ERASABLE INITIALIZATION REQUIRED:  PAD-LOADED ERASABLES, ORBWFLAG RESET,
# REFSMFLG=0 IF IMU OFF AND REFSMFLG=1 IF IMU ONE
#
# INPUTS BY USER REQUIRED:  STAR NUMBER, LANDMARK LAT, LONG/2, ALT OR ID NUMB.
# IF LANDMARK IS USED, NEAR OR FAR HORIZON IF HORIZON IS USED, AND
# BODY TO BE MARKED ON (EARTH OR MOON).  SEE GSOP CHAPT 4.
#
# OUTPUT:  UPDATED CMC STATE VECTOR.  VECTOR FROM S/C TO HORIZON OR LANDMARK
# IN POINTAXS.  POINTAXS CAN BE USED TO GENERATE THIS VECTOR APART FROM
# P23 IF DESIRED.
#
# DEBRIS:  NO USABLE DEBRIS IS GENERATED.  RENDWFLG IS RESET FOR P20 UPON
# COMPLETION OF P23.  RUPTREGS AND ERASABLES USED BY DISPLAYS ARE DEBRIS.

      BANK    31
      SETLOC  RT23
      BANK
      COUNT   31/S23
      EBANK=   W
P23      TC     DOWNFLAG
      ADRES    RNDVZFLG

      TC       2PHSCHNG
      OCT      00004      # LEAVE GROUP 4
      OCT      00012      # ENTER GROUP 2
      CAF      PRI013
      TS       PHSPRDT2
      TC       INTPRET
      SSP      CLEAR
            MARKINDX

```

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```

1
TARG2FLG      # TARGET FLAG USED R52 AND R53
CLEAR SSP
TARG1FLG
STARIND
0
SSP CLEAR
BESTI
0
R57FLAG      # SET = DO NOT REPERFORM R57
CLEAR EXIT
V94FLAG      # SET = ALLOW V94
TC INTERPRET

BON CALL
REFSMFLG     # SET NOW AS INPUT, NORMALLY EXTERNAL CONT
P23.05       # WHEN ALIGNED, PERFORM MEASUREMENT
R57          # DO OPTICS CALIBRATION IF IMU NOT ALIGNED.
CALL
R53
GOTO
P23.60
P23.05 CLEAR EXIT
SAVECFLG     # USED TO SAVE SPACE IN P23.65
P23.06 CAF V05N70
TC BANKCALL  # IDENTIFICATION: STAR, HOR IDENT.
CADR GOFLASH
TC GOTOP00H  # TERMINATE
TC P23.15
TC -5        # REDISPLAY
P23.15 CA LANDMARK # IF C=2, LUNAFLAG=1. IF C=1, LUNAFLAG=0
EXTEND
BZF P23.151
CA HORIZON
EXTEND
BZF +2
TC R23.10    # OPERATOR DSKY ERROR
CA LANDMARK
TC P23.152
P23.151 CA HORIZON
EXTEND
BZF R23.10
P23.152 MASK BITS7-9 # IS C EQUAL TO 1 OR 2
AD NEG100
EXTEND
BZF P23.16
```

```

                                AD      NEG100
                                EXTEND
                                BZF      +2
                                TC        R23.10
                                TC        UPFLAG
                                ADRES     LUNAFLAG
                                TCF       +3
P23.16      TC        DOWNFLAG
                                ADRES     LUNAFLAG
                                CA        STARCODE      # IS STARCODE GREATER THAN OR
  # EQUAL TO 0 AND LESS THAN 37
                                EXTEND
                                BZF       P23.176
                                EXTEND
                                BZMF      R23.10
                                AD        NEG37
                                EXTEND
                                BZMF      +2
                                TC        R23.10
# Page 621

                                TC        INTERPRET
P23.17      SLOAD      BZE
                                STARCODE
                                P23.175
                                PUSH
                                SLOAD      DMP
                                SPSIX
                                LXA,1     SXA,1
                                MPAC +1
                                BESTI      # BESTI = 6 X STAR NUMBER
                                CALL
                                LOWMEMORY  # NEEDED TO RETRIEVE STAR VECTOR FROM LOW
                                STORE      STARSAB2  # STORE FOR R53,P23.  US(IN P23)=STARSAB2
P23.175     EXIT
P23.176     CA        HORIZON
                                EXTEND
                                BZF       P23.20
                                MASK      BITS4-6
                                AD        -OCT10
                                EXTEND
                                BZF       P23.18
                                AD        -OCT10
                                EXTEND
                                BZF       +2
                                TC        R23.10
                                TC        UPFLAG

```



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|                       |        |          |                                   |
|-----------------------|--------|----------|-----------------------------------|
|                       | ADRES  | NORFHOR  |                                   |
|                       | TC     | P23.30   |                                   |
| P23.18                | TC     | DOWNFLAG |                                   |
|                       | ADRES  | NORFHOR  |                                   |
|                       | TC     | P23.30   |                                   |
| P23.20                | TC     | INTPRET  |                                   |
|                       | CALL   |          |                                   |
|                       |        | P22SUBRB |                                   |
|                       | EXIT   |          |                                   |
| P23.30                | TC     | INTPRET  |                                   |
|                       | SLOAD  | BZE      |                                   |
|                       |        | STARCODE |                                   |
|                       |        | LDPLANET |                                   |
| P23.31                | BON    | EXIT     |                                   |
|                       |        | SAVECFLG |                                   |
|                       |        | P23.85   |                                   |
|                       | CAF    | V50N25P  |                                   |
|                       | TC     | BANKCALL |                                   |
|                       | CADR   | GOPERF1  | # GOPERF1 BLANKS OUT R2 AND R3    |
|                       | TC     | GOTOP00H |                                   |
|                       | TC     | V94ENTER | # PROCEED. AUTOCONTROL CMC        |
| P23.55                | TC     | INTPRET  |                                   |
|                       | GOTO   |          |                                   |
|                       |        | P23.56   |                                   |
| # Page 622            |        |          |                                   |
| # VERB 94 BEGINS HERE |        |          |                                   |
| V94ENTER              | TC     | INTPRET  |                                   |
|                       | RTB    |          |                                   |
|                       |        | LOADTIME | # READ CLOCK                      |
|                       | STCALL | MARKTIME |                                   |
|                       |        | POINTAXS | # RETURN LOS IN RCLL AND MPAC     |
|                       | MXV    | UNIT     |                                   |
|                       |        | REFSMMAT |                                   |
|                       | STOVL  | POINTVSM |                                   |
|                       |        | JCAXIS   |                                   |
|                       | STORE  | SCAXIS   |                                   |
|                       | EXIT   |          |                                   |
|                       | TC     | DOWNFLAG | # CLEAR AND GO TO VECPOINT IN R60 |
|                       | ADRES  | 3AXISFLG | # BIT 6 FLAG 5                    |
|                       | CAF    | R60ADRS  |                                   |
|                       | TS     | TEMPFLSH |                                   |
|                       | TC     | PHASCHNG |                                   |
|                       | OCT    | 00012    |                                   |
| R60CALL               | TC     | BANKCALL |                                   |
|                       | CADR   | R60CSM   |                                   |

|            |        |             |                        |
|------------|--------|-------------|------------------------|
|            | TC     | PHASCHNG    |                        |
|            | OCT    | 04022       |                        |
|            | TC     | INTPRET     |                        |
|            | BON    |             |                        |
|            |        | R57FLAG     |                        |
|            |        | P23.57      | # DO NOT REPERFORM R57 |
| P23.56     | CALL   |             |                        |
|            |        | R57         |                        |
| P23.57     | SET    | SET         |                        |
|            |        | V94FLAG     |                        |
|            |        | R57FLAG     |                        |
|            | CALL   |             |                        |
|            |        | R52         |                        |
|            | CLEAR  | CLEAR       |                        |
|            |        | V94FLAG     |                        |
|            |        | R57FLAG     |                        |
| P23.60     | EXIT   |             |                        |
|            | INHINT |             |                        |
|            | CA     | MARKSTAT    |                        |
|            | MASK   | LOW10       |                        |
|            | TS     | MARKDATA    |                        |
|            | EXTEND |             |                        |
|            | INDEX  | MARKDATA    |                        |
|            | DCA    | 0           |                        |
|            | DXCH   | MARKTIME    |                        |
|            | INDEX  | MARKDATA    |                        |
|            | CA     | 5           |                        |
|            | XCH    | TRUNION     |                        |
|            | RELINT |             |                        |
|            | TC     | INTPRET     |                        |
| # Page 623 |        |             |                        |
|            | LXC,1  | VLOAD*      |                        |
|            |        | MARKDATA    |                        |
|            |        | 1,1         |                        |
|            | STODL* | MARKDOWN +1 |                        |
|            |        | 0,1         |                        |
|            | STORE  | MARKDOWN    |                        |
|            | EXIT   |             |                        |
|            | CAF    | V05N71      |                        |
|            | TC     | BANKCALL    |                        |
|            | CADR   | GOFFLASH    |                        |
|            | TC     | GOTOPOOH    | # TERMINATE            |
|            | TC     | P23.65      | # STORE DATA           |
|            | TC     | -5          | # REDISPLAY            |
| P23.65     | TC     | INTPRET     |                        |
|            | SET    | EXIT        |                        |

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```

                                SAVECFLG
                                TC      P23.15
P23.85      CLEAR      CALL
                                RENDWFLG
                                POINTAXS
                                GOTO
                                R23.55

# WE BEGIN CALCULATIONS HERE
# POINTAXIS SUBROUTINE

POINTAXS      STQ
R23.05      BON      POINTEX
                                DLOAD
                                ORBWFLAG
                                R23.1
                                WMIDPOS
                                STCALL 0
                                INITIALW      # INITIALIZE W-MATRIX FIRST PASS IN P23
R23.1      CALL
                                SETINTG      # SETUP FOR CSM INTEGRATION
                                BOF      SET
                                ORBWFLAG
                                R23.2
                                DIMOFLAG
R23.2      SET      CALL
                                ORBWFLAG
                                INTEGRV      # INTEGRATE CSM STATE VEC. TO MARKTIME
                                EXIT
                                TC      PHASCHNG
                                OCT      04022
                                TC      INTPRET
                                CALL
                                RECT.1      # PICKUP CSM STATE VECTOR FROM PERM
                                BOFF
                                ZMEASURE      # IN SPHERE OF INFLUENCE OF PRIMARY BODY
                                R23.3

# Page 624
                                DLOAD      CALL
                                MARKTIME
                                LUNPOS
                                BON      VCOMP
                                CMOONFLG
                                +1
                                VAD
                                RZC
```

```

R23.3      STORE  RZC
           SLOAD  BHIZ
           LANDMARK
           R23.4      # IF LANDMARK = 0, USE HORIZ SUBR
           SET
           ERADFLAG
           DLOAD  CALL
           MARKTIME
           LALOTORV
           GOTO
           R23.5
R23.4      CALL
           HORIZ
R23.5      VSU    SETPD
           RZC
           0
           GOTO
           POINTEX
# Page 625
R23.55     UNIT   PUSH      # RCLL IS IN MPAC
           VLOAD
           34D      # RCLL * RCLL
           STOVL   30D      # PUSH 30-31 =RCLL*RCLL 32-33=ABVAL RCLL
           VZC
           VXSC    VSR
           ONE/C
           15D
           VAD      # PUSH UP RCLL(UNIT)
           UNIT
           STOVL   UCLSTAR
           VZC
           VSR2    VSU
           VES0
           VXSC    VSR
           ONE/C
           13D
           VAD     UNIT
           US
           STORE   USSTAR
           DOT     SL1
           UCLSTAR
           PUSH    VLOAD      # PD 0,1 = USSTAR(DOT)UCLSTAR
           UCLSTAR
           VXSC    VCOMP
           VSL1    VAD
           USSTAR

```

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```
UNIT
STOVL  BVECTOR      # USSTAR - COSQ(UCLSTAR)
        ZEROVECS
STORE  BVECTOR +6
STODL  BVECTOR +12D
        0
ACOS   DCOMP
PUSH   DLOAD
        ZEROVECS
EXIT
CA     VARSUBL      # PUT FIXED INTO ERASABLE FOR MSU
TS     L            # INSTRUCTION COMING UP
CA     TRUNION      # REQUIRED TO CHANGE 2'S COMPLEMENT
EXTEND # TRUNION TO 1'S COMPLEMENT
MSU    L            # TRUNION (2'S)-00000 CONVERTS TRUNION TO
TS     MPAC         # 1'S.  VARSUBL=00000.
TC     INTPRET
PUSH   SLOAD        # PUSH IS DP.  WHEN BDSU IS EXECUTED, 2ND
        TRUNBIAS    # HALF OF PUSHLIST IS GUARANTEED ZERO FROM
BDSU   # DLOAD ZEROVECS ABOVE
SR3    DAD
DAD     DMP
        TRUN19
        32D
DMP     SL3
        PI/4.0
BOFF    SL2
        CMOONFLG
        R23.51
R23.51  STODL  DELTAQ      # RCLL * RCLL
        30D
DMP     RTB
        TRUNVAR
        TPMODE
TAD
        VARSUBL
STORE  VARIANCE
CLEAR  CALL
        DMENFLG
        INCORP1
CALL
        GRP2PC
VLOAD  ABVAL
        DELTAX +6
BOF     SR2            # DISPLAY IS 2-27 IF IN LUNAR SPHERE.
```

# Page 626

```

                                CMOONFLG
                                R23.52
R23.52      STOVL      N49DISP +2
                                DELTAX
                                ABVAL
                                BOF      SR2
                                CMOONFLG
                                R23.53
R23.53      STORE     N49DISP
                                EXIT
R23.6       CAF       V6N49
                                TC       BANKCALL
                                CADR     GOFLASHR
                                TC       GOTOP00H
                                TC       R23.7      # INCORPORATE DATA
                                TC       GOTOP00H
                                CAF       BIT3      # BLAN OUT R3
                                TC       BLANKET
                                TC       PHASCHNG
                                OCT      00012
                                TC       ENDOFJOB
R23.7       TC       INTPRET
R23.8       SET      CALL
                                VEHUPFLG
                                INCORP2
                                EXIT
R23.END     TC       GOTOP00H

# Page 622
R23.10      TC       FALTON
                                TC       P23.06
HORIZ       STQ      SETPD
                                SRRETURN
                                0
                                DLOAD     PDDL      # PUSH 0-1 = -AY0 SCALED B0
                                -AY0
                                AX0
                                PDDL      PDVL      # PUSH 2-3 = +AX SCALED B0
                                DPPOS MAX
                                US
                                VXV      UNIT
                                RZC
                                STOVL     UBAR2
                                VXV      UNIT      # PUSH UP
                                UBAR2
                                STOVL     UBAR0

```

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```

                                UBAR2
VXV      UNIT
                                UBAR0
STORE    UBAR1
BON      DOT
                                LUNAFLAG
                                HORIZ.6
                                0
                                # UBAR1 DOT UZ
STCALL   ALPHAV +4
                                GETERAD
DAD      PDDL
                                # MPAC HAS RADIUS OF FISCHER ELLIPSOID
                                HORIZONTALT
                                # PUSH 0-1 = BH SCALED B29
                                AEARTH
DAD      PUSH
                                # PUSH 2-3 = AH B29
                                HORIZONTALT
HORIZ.1  VLOAD  MXV
                                RZC
                                # B29
                                UBAR0
                                # B1
VSL1     PDVL
                                # PUSH 4-9 = RH(XH,YH,ZH) B29
                                US
MXV      VSL1
                                UBAR0
PDDL     # PUSH 10-15 = USH B1
                                2
                                # AH
STODL    34D
                                4
                                # XH
CALL     DIVIDE
SR*      DMP
                                8D,1
                                # NOW SCALED B9
                                MPAC
STODL    30D
                                0
# Page 628
STODL    34D
                                6
                                # YH
CALL     DIVIDE
SR*      DMP
                                8D,1
                                # B9
                                MPAC
                                # B18
DAD      PUSH
                                # PUSH 16-17 =A SCALED B18
                                30D
DSU      SQRT
                                1.0B18
PDDL     # PUSH 18-19 SQRT(A-1) B9
```

```

      16D
STODL  34D
      4          # XH
CALL
      DIVIDE
SR*    PDDL
      17D,1      # PUSH 20-21 = XH/A B29
      6          # YH
CALL
      DIVIDE
SR*    PDDL
      17D,1      # PUSH 22-23 = YH/A B29
      16D        # A
STODL  34D
      18D        # SQRT(A-1)
CALL
      DIVIDE
SR*
      8D,1
STODL  28D
      0          # BH
STODL  34D
      2          # AH
CALL
      DIVIDE
SR*    DMP          # AH/BH SCALED B1
      0,1
      28D          # SQRT(A-1)/A
DMP    SL1
      6          # YH
PDDL
      2          # AH
STODL  34D
      0
CALL
      DIVIDE
SR*    DMP          # BH/AH SCALED B1
      0,1
      28D          # SQRT (A-1)/A
DMP    SL1
      4          # XH
PDDL  DAD
      20D        # XH/A
      24D        # ALPHA
PDDL  DSU

```



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|            |       |          |                                  |
|------------|-------|----------|----------------------------------|
|            |       | 22D      | # YH/A                           |
|            |       | 26D      | # BETA                           |
|            | PUSH  | SETPD    |                                  |
|            |       | 16D      |                                  |
|            | DLOAD | DSU      |                                  |
|            |       | 20D      | # XH/A                           |
|            |       | 24D      | # ALPHA                          |
|            | PDDL  | DAD      |                                  |
|            |       | 22D      | # YH/A                           |
|            |       | 26D      | # BETA                           |
|            | PDDL  | PUSH     |                                  |
|            |       | ZEROVECS |                                  |
|            | STOVL | 32D      | # ZERO THIRD COMP. OF T-0 VECTOR |
|            |       | 28D      |                                  |
|            | VSU   | UNIT     |                                  |
|            |       | 4        | # RH VECTOR                      |
|            | DOT   | PDVL     | # PUSH 22-23 A-SUB-ZERO          |
|            |       | 10D      | # USH VECTOR                     |
|            |       | 16D      | # T1 VECTOR                      |
|            | VSU   | UNIT     |                                  |
|            |       | 4        | # RH VECTOR                      |
|            | DOT   | PUSH     | # PUSH 24-25 A-SUB-ONE           |
|            |       | 10D      |                                  |
|            | BDSU  | BMN      |                                  |
|            |       | 22D      | # A-SUB-ZERO                     |
|            |       | HORIZ.3  |                                  |
|            | BON   |          |                                  |
|            |       | NORFHOR  |                                  |
|            |       | HORIZ.4  |                                  |
| HORIZ.2    | VLOAD | GOTO     |                                  |
|            |       | 28D      | # T-0 VECTOR                     |
|            |       | HORIZ.5  |                                  |
| HORIZ.3    | BON   | GOTO     |                                  |
|            |       | NORFHOR  |                                  |
|            |       | HORIZ.2  |                                  |
|            |       | HORIZ.4  |                                  |
| HORIZ.4    | VLOAD |          |                                  |
|            |       | 16D      | # T1 VECTOR                      |
| HORIZ.5    | VXM   | VSL1     |                                  |
|            |       | UBARO    |                                  |
|            | GOTO  |          |                                  |
|            |       | SRRETURN |                                  |
| HORIZ.6    | DLOAD | PUSH     |                                  |
| # Page 630 |       |          |                                  |
|            |       | RADMOON  |                                  |
|            | PUSH  | GOTO     |                                  |

|        |       |                      |                                           |
|--------|-------|----------------------|-------------------------------------------|
|        |       | HORIZ.1              |                                           |
| DIVIDE | NORM  | SR1                  |                                           |
|        |       | X1                   |                                           |
|        | STODL | 36D                  |                                           |
|        |       | 34D                  |                                           |
|        | NORM  | BDDV                 |                                           |
|        |       | S1                   |                                           |
|        |       | 36D                  |                                           |
|        | XSU,1 | RVQ                  |                                           |
|        |       | S1                   |                                           |
| RECT.1 | BOFF  | AXT,2                | # SR TO SET ZMEASURE = 0 IF MEASUREMENT   |
|        |       | CMOONFLG             | # PLANET AND PRIMARY PLANET ARE THE SAME. |
|        |       | RECT.3               | # OTHERWISE = 1                           |
|        | DEC   | -2                   |                                           |
|        | BOFF  |                      | # VEC. AND SCALE B29 AND B7               |
|        |       | LUNAFLAG             |                                           |
|        |       | RECT.4               |                                           |
| RECT.2 | CLEAR | GOTO                 |                                           |
|        |       | ZMEASURE             |                                           |
|        |       | RECT.5               |                                           |
| RECT.3 | AXT,2 | BOFF                 |                                           |
|        |       | 0                    |                                           |
|        |       | LUNAFLAG             |                                           |
|        |       | RECT.2               |                                           |
| RECT.4 | SET   |                      |                                           |
|        |       | ZMEASURE             |                                           |
| RECT.5 | VLOAD | VSR7                 |                                           |
|        |       | DELTACSM             | # SCALED B22 OR B18                       |
|        | VSR*  | VAD                  |                                           |
|        |       | 0,2                  |                                           |
|        |       | RCVCSM               | # SCALED B29 OR B27                       |
|        | VSR*  |                      |                                           |
|        |       | 0,2                  |                                           |
|        | STOVL | RZC                  | # NOW SCALED B29                          |
|        |       | NUVCSM               | # SCALED B3 OR B-1                        |
|        | VSR4  | VSR*                 |                                           |
|        |       | 0,2                  |                                           |
|        | VAD   | VSR*                 |                                           |
|        |       | VCVCSM               | # SCALED B7 OR B5                         |
|        |       | 0,2                  |                                           |
|        | STORE | VZC                  | # NOW SCALED B7                           |
|        | RVQ   |                      |                                           |
| ONE/C  | 2DEC* | .333564049 E-6 B+21* |                                           |
| AEARTH | 2DEC  | 6378166 B-29         | # A AXIS OF EARTH (METERS B-29)           |

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```
RADMOON      2DEC      1738090 B-29      # RADIUS MOON IN METERS

# Page 631

TRUN19        OCT      01604
TRUN19A        OCT      00000
1.0B18        2DEC      1.0 B-18

VARSUBL        DEC      0
VARSUBL3       2DEC*     3.4299040 E+6 B-26*

TRUNVAR        2DEC      2.5 E-9 B+18

V6N49          VN       0649
V05N70         VN       0570
V05N71         VN       0571
OCT00077       OCT      00077
V50N25P        OCT      00202
SPSIX          OCT      00006
JCAXIS         2DEC      .2688190620      # 1/2(SIN 32.523 DEG)  TRACK AXIS

                2DEC      0

                2DEC      .4215878460      # 1/2(COS 32.523 DEG)

R60ADRS        CADR      R60CALL +3
NEG37          DEC      -37
BITS7-9        OCT      700
BITS4-6        OCT      70
                SETLOC    RT53
                BANK
LOWMEMRY        VLOAD*    RVQ
                CATLOG,1
                BANK      37
                SETLOC    P23S1
                BANK
LDPLANET        EXIT
                CAF        VNPLAN23      # KEEP THIS OPEN SUBROUTINE IN EBANK=5
                TC         BANKCALL      # BECAUSE STAR IS EBANK=5
                CADR        GOFLASH      # LDPLANET ALLOWS VECTOR TO PLANET TO BE
                TC         GOTOP00H      # STORED IN STARS2 IF STORED STARS ARE
                TC         +2            # NOT VISIBLE
                TC         -5
                TC         INTPRET
                VLOAD
                STARS2V3
```

|            |        |            |                                        |
|------------|--------|------------|----------------------------------------|
|            | VXSC   | UNIT       |                                        |
|            |        | 1/SQR3     |                                        |
|            | STORE  | STARSAV2   |                                        |
|            | GOTO   |            |                                        |
|            |        | P23.31     |                                        |
| VNPLAN23   | VN     | 0688       |                                        |
|            | BLOCK  | 02         |                                        |
| GOTOV56    | EXTEND |            | # P20 TERMINATES BY GOTOV56 INSTEAD OF |
| # Page 632 |        |            |                                        |
|            | DCA    | VB56CADR   | # GOTOPOOH                             |
|            | TCF    | SUPDXCHZ   |                                        |
|            | EBANK= | WHOCARES   |                                        |
| VB56CADR   | 2CADR  | TRACKTRM   |                                        |
|            | SETLOC | FFTAG2     |                                        |
|            | BANK   |            |                                        |
|            | COUNT* | \$\$/P20   |                                        |
|            | BANK   | 40         |                                        |
|            | SETLOC | ENDPINS1   |                                        |
|            | BANK   |            |                                        |
|            | COUNT* | \$\$/EXTVB |                                        |
| V67CALL    | TC     | INTPRET    |                                        |
|            | CALL   |            |                                        |
|            |        | V67WW      |                                        |
|            | EXIT   |            |                                        |
| V06N99DS   | CAF    | V06N99A    |                                        |
|            | TC     | BANKCALL   |                                        |
|            | CADR   | GOXDSPF    |                                        |
|            | TCF    | ENDEXT     |                                        |
|            | TC     | V06N9933   |                                        |
|            | TC     | V06N99DS   |                                        |
| V06N9933   | TC     | INTPRET    |                                        |
|            | SLOAD  | BHIZ       | # IF R3 OF V67 = 0 EXIT                |
|            |        | WWOPT      |                                        |
|            |        | +3         |                                        |
|            | GOTO   |            |                                        |
|            |        | V6N99INP   |                                        |
|            | EXIT   |            |                                        |
|            | TCF    | ENDEXT     |                                        |
| V6N99INP   | LXA,1  | LXA,2      |                                        |
|            |        | WWPOS      |                                        |
|            |        | WWVEL      |                                        |
|            | SLOAD  | DSU        |                                        |
|            |        | WWOPT      |                                        |
|            |        | V67DEC2    |                                        |
|            | BHIZ   | BPL        |                                        |

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```

                                V67WORB
                                V67WMID
                                SXA,1 SXA,2
                                WRENDPOS
                                WRENDVEL
                                GOTO
                                V67EXITX
V67WORB      SXA,1 SXA,2
                                WORBPOS
                                WORBVEL
                                GOTO
                                V67EXITX
V67WMID      SXA,1 SXA,2
# Page 633
                                WMIDPOS
                                WMIDVEL
V67EXITX     CLEAR
                                CLEAR
                                ORBWFLAG
                                RENDWFLG
                                EXIT
                                TCF
V67WW        STQ
                                ENDEXT
                                BOV
                                S2
                                +1
                                CALL
                                INTSTALL
                                SSP
                                DLOAD
                                S1
                                DEC
                                6
                                ZEROVECS
                                STORE
                                WWPOS
                                STORE
                                WWVEL
                                STORE
                                WWOPT
                                AXT,1
                                DEC
                                36
NXPOSVEL     VLOAD* VSQ
                                W +36D,1
                                DAD
                                WWPOS
                                STORE
                                WWPOS
                                VLOAD* VSQ
                                W +90D,1
                                DAD
                                WWVEL
                                STORE
                                WWVEL
                                TIX,1 SQRT
```

```

                                NXPOSVEL
                                STODL  WWVEL
                                WWPOS
                                SQR
                                STORE  WWPOS
                                BOV    GOTO
                                +2
                                V67XXX
                                DLOAD
                                DPPOSMAX
                                STORE  WWPOS
                                STORE  WWVEL
                                DLOAD  DSU
                                WWPOS
                                FT99999
                                BMN    DLOAD
                                +3
                                FT99999
                                # Page 634
                                STORE  WWPOS
                                LXA,1  SXA,1
                                S2
                                QPRET
                                EXIT
                                TC    POSTJUMP
                                CADR  INTWAKE
                                =     RANGE
                                =     RRATE
                                =     RTHETA
                                V06N99A VN    0699
                                FT99999 2DEC 30479 B-19

                                V67DEC2 2DEC 2 B-14

                                SBANK=  LOWSUPER

```

This code is written to file src/P20-P25.s.

**A.67 P30 P37**

```

1047  <src/P30-P37.s 1047>≡
# Copyright:   Public domain.
# Filename:    P30_P37.agc
# Purpose:     Part of the source code for Luminary 1A build 099.
#             It is part of the source code for the Lunar Module's (LM)
#             Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:  yaYUL
# Contact:     Ron Burkey <info@sandroid.org>.
# Website:     www.ibiblio.org/apollo.
# Pages:       614-617
# Mod history: 2009-05-17 RSB   Adapted from the corresponding
#                               Luminary131 file, using page
#                               images from Luminary 1A.
#             2009-06-05 RSB   Removed 4 lines of code that shouldn't
#                               have survived from Luminary 131.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
#       16:27 JULY 14, 1969
#
# Page 614
# PROGRAM DESCRIPTION P30          DATE 3-6-67
#
# MOD.1 BY RAMA AIYAWAR
#
# FUNCTIONAL DESCRIPTIONS
#       ACCEPT ASTRONAUT INPUTS OF TIG,DELV(LV)
#       CALL IMU STATUS CHECK ROUTINE (R02)
#       DISPLAY TIME TO GO, APOGEE, PERIGEE, DELV(MAG), MGA AT IGN
#       REQUEST BURN PROGRAM
#
# CALLING SEQUENCE VIA JOB FROM V37
#

```

```

# EXIT VIA V37 CALL OR TO GOTOP00H (V34E)
#
# SUBROUTINE CALLS -- FLAGUP, PHASCHNG, BANKCALL, ENDOFJOB, GOFLASH, GOFLASHR
#                      GOPERF3R, INTPRET, BLANKET, GOTOP00H, R02BOTH, S30.1,
#                      TIG/N35, MIDGIM, DISPMGA
#
# ERASABLE INITIALIZATION -- STATE VECTOR
#
# OUTPUT --          RINIT, VINIT, +MGA, VTIG, RTIG, DELVSIN, DELVSAB, DELVSLV, HAPO,
#                      HPER, TTOGO
#
# DEBRIS -- A, L, MPAC, PUSHLIST

          BANK      32
          SETLOC    P30S
          BANK
          EBANK=     +MGA
          COUNT*    $$/P30
P30        TC      UPFLAG          # SET UPDATE FLAG
          ADRES     UPDATFLG
          TC      UPFLAG          # SET TRACK FLAG
          ADRES     TRACKFLG

P30N33     CAF      V06N33         # T OF IGN
          TC      VNP00H         # RETURN ON PROCEED, POOH ON TERMINATE

          CAF      V06N81         # DISPLAY DELTA V (LV)
          TC      VNP00H         #      REDISPLAY ON RECYCLE

          TC      DOWNFLAG        # RESET UPDATE FLAG
          ADRES     UPDATFLG
          TC      INTPRET
          CALL
          S30.1
          SET      EXIT
          UPDATFLG
PARAM30    CAF      V06N42         # DISPLAY APOGEE, PERIGEE, DELTA V
          TC      VNP00H

# Page 615

          TC      INTPRET
          SETGO
          XDELVFLG          # FOR P40'S: EXTERNAL DELTA-V GUIDANCE.
          REVN1645          # TRKMKCNT, T60, +MGA  DISPLAY

V06N33     VN      0633

```



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V06N42 VN 0642

```
# Page 616
# PROGRAM DESCRIPTION S30.1      DATE 9NOV66
# MOD NO 1                      LOG SECTION P30,P37
# MOD BY RAMA AIYAWAR **
#
# FUNCTIONAL DESCRIPTION
#   BASED ON STORED TARGET PARAMETERS (R OF IGNITION (RTIG), V OF
#   IGNITION (VTIG), TIME OF IGNITION (TIG)), COMPUTE PERIGEE ALTITUDE
#   APOGEE ALTITUDE AND DELTAV REQUIRED (DELVSIN).
#
# CALLING SEQUENCE
#   L      CALL
#   L+1      s30.1
#
# NORMAL EXIT MODE
#   AT L+2 OR CALLING SEQUENCE (GOTO L+2)
#
# SUBROUTINES CALLED
#   LEMPREC
#   PERIAPO
#
# ALARM OR ABORT EXIT MODES
#   NONE
#
# ERASABLE INITIALIZATION REQUIRED
#   TIG      TIME OF IGNITION      DP B28CS
#   DELVSLV   SPECIFIED DELTA-V IN LOCAL VERT.
#             COORDS. OF ACTIVE VEHICLE AT
#             TIME OF IGNITION      VECTOR B+7 METERS/CS
#
# OUTPUT
#   RTIG      POSITION AT TIG      VECTOR B+29 METERS
#   VTIG      VELOCITY AT TIG     VECTOR B+29 METERS/CS
#   PDL 4D     APOGEE ALTITUDE     DP B+29 M, B+27 METERS.
#   HAPO      APOGEE ALTITUDE     DP B+29 METERS
#   PDL 8D     PERIGEE ALTITUDE    DP B+29 M, B+27 METERS.
#   HPER      PERIGEE ALTITUDE    DP B+29 METERS
#   DELVSIN    SPECIFIED DELTA-V IN INTERTIAL
#             COORD. OF ACTIVE VEHICLE AT
#             TIME OF IGNITION      VECTOR B+7 METERS/CS
#   DELVSAB    MAG. OF DELVSIN     VECTOR B+7 METERS/CS
#
# DEBRIS      QTEMP  TEMP.ERASABLE
#             QPRET, MPAC
```

```

#          PUSHLIST

          SETLOC  P30S1
          BANK

          COUNT*  $$/S30S

S30.1      STQ      DLOAD
           QTEMP
           TIG      # TIME IGNITION SCALED AT 2(+28)CS
          STCALL   TDEC1
           LEMPREC  # ENCKE ROUTINE FOR LEM

          VLOAD    SXA,2

# Page 617

           RATT
           RTX2
          STORE    RTIG      # RADIUS VECTOR AT IGNITION TIME
          UNIT     VCOMP
          STOVL    DELVSIN   # ZRF/LV IN DELVSIN SCALED AT 2
           VATT      # VELOCITY VECTOR AT TIG, SCALED 2(7) M/CS
          STORE    VTIG
          VXV      UNIT
           RTIG
          SETPD    SXA,1
           0
           RTX1
          PUSH     VXV      # YRF/LV PDL 0 SCALED AT 2
           DELVSIN
          VSL1     PDVL
          PDVL     PDVL      # YRF/LV PDL 6 SCALED AT 2
           DELVSIN      # ZRF/LV PDL 12D SCALED AT 2
           DELVSLV
          VXM      VSL1
           0
          STORE    DELVSIN   # DELTAV IN INERT. COOR. SCALED TO B+7M/CS
          ABVAL
          STOVL    DELVSAB   # DELTA V MAG.
           RTIG      # (FOR PERIAPO)
          PDVL     VAD      # VREQUIRED = VTIG + DELVSIN (FOR PERIAPO)
           VTIG
           DELVSIN
          CALL
           PERIAPO1
          CALL
           SHIFTR1      # RESCALE IF NEEDED

```

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```
CALL          # LIMIT DISPLAY TO 9999.9 N. MI.
              MAXCHK
STODL  HPER    # PERIGEE ALT 2(29) METERS FOR DISPLAY
      4D
CALL
              SHIFTR1  # RESCALE IF NEEDED
CALL          # LIMIT DISPLAY TO 9999.9 N. MI.
              MAXCHK
STCALL  HAPO   # APOGEE ALT 2(29) METERS FOR DISPLAY
      QTEMP
```

This code is written to file `src/P30--P37.s`.

**A.68 P30-P37**

```

1052  <src/P30-P37.s 1052>≡
      # Copyright:   Public domain.
      # Filename:    P30-P37.agc
      # Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
      #              It is part of the source code for the Command Module's (CM)
      #              Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:   yaYUL
      # Contact:      Ron Burkey <info@sandroid.org>.
      # Website:      www.ibiblio.org/apollo.
      # Pages:        635-648
      # Mod history:  2009-05-10 RSB   Adapted from the Colossus249/ file
      #              of the same name, using Comanche055 page
      #              images.
      #              2009-05-20 RSB   Corrected BDV -> BOV.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      # Assemble revision 055 of AGC program Comanche by NASA
      # 2021113-051. 10:28 APR. 1, 1969
      #
      # This AGC program shall also be referred to as
      # Colossus 2A

      # Page 635

      BANK      32

      SETLOC    P30S1
      BANK

      EBANK=    +MGA

      COUNT     35/P34

      DISPMGA   STQ      EXIT      # USED IN P30

```

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```
# Page 636
# PROGRAM DESCRIPTION P30          DATE 3-6-67
# MOD. I BY S. ZELDIN:  TO ADD P31 AND ADAPT P30 FOR P31 USE.    22DEC67
#
# FUNCTIONAL DESCRIPTION
#      P30      (EXTERNAL DELTA-V TARGETING PROGRAM)
#      ACCEPTS ASTRONAUT INPUTS OF TIG,DELV(LV) AND COMPUTES, FOR DISPLAY,
#      APOGEE, PERIGEE, DELV(MAG), MGA ASSOCIATED WITH DESIRED MANEUVER.
#      P31      (GENERAL LAMBERT AIMPOINT GUIDANCE)
#      A GROUND RULE FOR P31 IS THE ANGLE BETWEEN THE TARGET VECTOR AND
```

```

#           POSITION VECTOR AT TIG IS NOT 165-195 DEGREES APART
#           BASED ON STORED INPUT OF OFFSET TARGET(B+29) AND DELTA T TRANS, AND
#           ASTRONAUT ENTRY OF TIG, P31 COMPUTES REQUIRED VELOCITY FOR MANEUVER
#           AND, FOR DISPLAY, APOGEE, PERIGEE, DELV(7AG), +MGA ASSOCIATED WITH
#           DESIRED MANEUVER.
#
# THE FOLLOWING SUBROUTINES ARE USED IN P30 AND P31
#   S30.1 (P30 ONLY)
#   S31.1 (P31 ONLY)
#   P30/P31 -- DISPLAYS TIG
#   CNTUP30 -- DISPLAYS DELV(LV)
#   PARAM30 -- DISPLAYS APOGEE, PERIGEE, DELV(MAG), MGA, TIME FROM TIG,
#             MARKS SINCE LAST THRUSTING MANEUVER
#
# CALLING SEQUENCE VIA JOB FROM V37
#
# EXIT VIA V37 OR GOTOP00H
#
# OUTPUT FOR POWERED FLIGHT
#   VTIG      X
#   RTIG      X          SEE S30.1
#   DELVSIN   X
#   VGDISP
#   RTARG     X
#   TPASS4    X          SEE S31.1
#           X
#
#           COUNT      35/P30
#
P30          TC        P30/P31
#           TC        CNTNUP30
#           TC        DOWNFLAG      # RESET UPDATFLG
#           ADRES     UPDATFLG      # BIT 7 FLAG 1
#           TC        INTPRET
#           CALL
#           S30.1
#           EXIT
#           TC        PARAM30
#           TC        UPFLAG
#
# Page 637
#           ADRES     XDELVFLG      # SET XDELVFLG BIT 8 FLAG 2
#           TCF       GOTOP00H
#
P31          TC        P30/P31
#           TC        DOWNFLAG
#           ADRES     UPDATFLG      # RESET UPDATFLG BIT 7 FLAG 1

```

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|            |       |             |                              |
|------------|-------|-------------|------------------------------|
|            | TC    | DOWNFLAG    |                              |
|            | ADRES | NORMSW      | # RESET NORMSW BIT 10 FLAG 7 |
|            | TC    | INTPRET     |                              |
|            | CALL  |             |                              |
|            |       | S31.1       |                              |
|            | EXIT  |             |                              |
|            | TC    | CNTNUP30    |                              |
|            | TC    | PARAM30     |                              |
|            | TC    | DOWNFLAG    |                              |
|            | ADRES | XDELVFLG    | # BIT 8 FLAG 2.              |
|            | TCF   | GOTOP00H    |                              |
| P30/P31    | XCH   | Q           |                              |
|            | TS    | P30/31RT    |                              |
|            | TC    | UPFLAG      |                              |
|            | ADRES | UPDATFLG    | # SET UPDATFLG BIT 7 FLAG 1  |
|            | TC    | UPFLAG      |                              |
|            | ADRES | TRACKFLG    | # SET TRACKFLG BIT 5 FLAG 1  |
|            | CAF   | V06N33      | # T OF IGN                   |
|            | TC    | BANKCALL    |                              |
|            | CADR  | GOFLASHR    |                              |
|            | TCF   | GOTOP00H    |                              |
|            | TC    | P30/31RT    |                              |
|            | TCF   | P30/P31 +4  |                              |
|            | TC    | PHASCHNG    |                              |
|            | OCT   | 00014       |                              |
|            | TC    | ENDOFJOB    |                              |
| CNTNUP30   | XCH   | Q           |                              |
|            | TS    | P30/RET     |                              |
|            | CAF   | V06N81      |                              |
|            | TC    | BANKCALL    |                              |
|            | CADR  | GOFLASH     |                              |
|            | TCF   | GOTOP00H    |                              |
|            | TC    | P30/RET     |                              |
|            | TCF   | CNTNUP30 +2 |                              |
| PARAM30    | XCH   | Q           |                              |
|            | TS    | P30/31RT    |                              |
|            | CAF   | V06N42      |                              |
|            | TC    | BANKCALL    |                              |
|            | CADR  | GOFLASH     |                              |
|            | TC    | GOTOP00H    | # ON TERMINATION GOTOP00H    |
|            | TCF   | REFTEST     | # ON PROCEED GO DO REFTEST   |
| # Page 638 | TCF   | PARAM30 +2  |                              |
| REFTEST    | CAF   | BIT13       |                              |

```

                                MASK    STATE +3          # REFSMFLAG
                                EXTEND
                                BZF      NOTSET            # REFSMFLAG =0, THEN BRANCH TO NOTSET
                                TC        INTPRET
                                VLOAD    PUSH
   DELVSIN
                                CALL
   GET+MGA
                                GOTO
   FLASHMGA
NOTSET                          EXTEND
                                DCS      MARSDP
                                DXCH      +MGA             # +MGA, +MGA+1 CONTAINS (-00001)
                                TC        INTPRET
FLASHMGA                        CALL
   DISPMGA
                                EXIT
                                TC        P30/31RT
MARSDP                          OCT      00000           # (00000) (16440) = (+00001)
                                OCT      35100
   # ( .01 ) DEGREES IN THE LOW ORDER REGISTER

V06N33                          VN      0633
V06N42                          VN      0642
V16N35                          VN      1635
V06N45                          VN      0645

```

# Page 639

# PROGRAM DESCRIPTION S30.1      DATE 9NOV66

# MOD NO 1      LOG SECTION P30,P37

# MOD BY RAMA AIYAWAR \*\*

# MOD.2 BY S.ZELDIN -- TO CORRECT MOD.1 FOR COLOSSUS      29DEC67

#

# FUNCTIONAL DESCRIPTION

#      BASED ON STORED TARGET PARAMETERS (R OF IGNITION (RTIG), V OF

#      IGNITION (VTIG), TIME OF IGNITION (TIG)), DELV(LV), COMPUTE PERIGEE ALTITUDE

#      APOGEE ALTITUDE AND DELTA-V REQUIRED IN REF. COORDS. (DELVSIN).

#

# CALLING SEQUENCE

#      L      CALL

#      L+1      S30.1

#

# NORMAL EXIT MODE

#      AT L+2 OR CALLING SEQUENCE (GOTO L+2)

#

# SUBROUTINES CALLED



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```
#      THISPREC
#      PERIAPO
#
# ALARM OR ABORT EXIT MODES
#      NONE
#
# ERASABLE INITIALIZATION REQUIRED
#      TIG          TIME OF IGNITION          DP B28CS
#      DELVSLV      SPECIFIED DELTA-V IN LOCAL VERT.
#                  COORDS. OF ACTIVE VEHICLE AT
#                  TIME OF IGNITION          VCT. B+7 M/CS
#
# OUTPUT
#      RTIG          POSITION AT TIG          VCT.    B+29 M
#      VTIG          VELOCITY AT TIG        VCT.    B+7 M
#      HAPO          APOGEE ALT.            DP      B+29 M
#      HPER          PERIGEE ALT.            DP      B+29 M
#      DELVSIN       DELVSLV IN REF COORDS   VCT.    B+7 M/CS
#      VGDISP        MAG. OF DELVSIN        DP      B+7 M/CS
#
# DEBRIS          QTEMP  TEMP.ERASABLE
#                  QPRET, MPAC
#                  PUSHLIST
#
#                  SETLOC P30S1A
#                  BANK
#
#                  COUNT  35/S30S
#
S30.1      STQ      DLOAD
#                  QTEMP
#                  TIG          # TIME IGNITION SCALED AT 2(+28)CS
#                  STCALL TDEC1
#                  THISPREC     # ENCKE ROUTINE FOR
#
#                  VLOAD  SXA,2
#                  VATT
#                  RTX2
#                  STOVL  VTIG
#
# Page 640
#
#                  RATT
#                  STORE  RTIG
#                  STORE  RACT3
#                  VXV    UNIT
#                  VTIG
#                  STCALL UNRM
```

```

          LOMAT
VLOAD    VXM
          DELVSLV
          0
VSL1     SXA,1
          RTX1
STORE    DELVSIN
ABVAL
STOVL    VGDISP      # MAG DELV
          RTIG
PDVL     VAD
          DELVSIN
          VTIG
CALL
          PERIAPO1
CALL
          SHIFTR1
CALL
          MAXCHK
STODL    HPER        # PERIGEE ALT B+29
          4D
CALL
          SHIFTR1
CALL
          MAXCHK
STCALL   HAPO        # APOGEE ALT B+29
          QTEMP

```

```

# Page 641
# S31.1 PROGRAM DESCRIPTION          28DEC67
# MOD.1 BY S.ZELDIN
#
# S31.1 COMPUTES DELV IN REF AND LV COORDS,MAG OF DELV,INTERCEPT TIME,
# APOGEE AND PERIGEE ALT FOR REQUIRED MANEUVER
#
# CALLING SEQUENCE
#      L      CALL
#      L+1    S31.1
#
# NORMAL EXIT MODE
#      AT L +2 OF CALLING SEQUENCE (GOTO L+2)
#
# SUBROUTINES CALLED
#      AGAIN
#      PERIAPO1
#      SHIFTR1

```

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```
#      MIDGIM
#
# NO ALARM OR ABORT MODES
#
# INPUT
#      DELLT4      DP      +28
#      TIG         DP      +28
#      RTARG       VCT     +29
#
# OUTPUT
#      DELVLVC     VCT     +7
#      VGDISP      DP      +7
#      HAP0        DP      +29
#      HPER        DP      +29
#      TPASS4      DP      +28
#
# DEBRIS -- QTEMP

S31.1      STQ      DLOAD
                        QTEMP
                        TIG
      STCALL  TDEC1
                        AGAIN      # RETURNS RTX2,RTX1,RATT,VATT,VIPRIME
      VLOAD   PDVL      # DELVEET3
                        RTIG
                        VIPRIME
      CALL
                        PERIAP01
      CALL
                        SHIFTR1
      CALL
                        MAXCHK
      STODL   HPER      # B29
                        4D
      CALL
                        SHIFTR1
      CALL
                        MAXCHK
      STOVL   HAP0      # B29
# Page 642
                        DELVEET3
      STORE   0
      SET     CALL
                        AVFLAG
                        MIDGIM      # GET DELVLVC B7 FOR DISPLAY
      ABVAL
```

```

          STODL  VGDISP          # B+7 FOR DISPLAY
          DELLT4
          DAD
          TIG
          STCALL TPASS4          # FOR S40.1
          QTEMP

# Page 643
# SUBROUTINE NAME:      DELRSPL      (CONTINUATION OF V 82 IN CSM IF P11 ACTIVE)
# TRANSFERRED COMPLETELY FROM SUNDISK, P30S REV 33.  9 SEPT 67.
# MOD NO: 0      MOD BY: ZELDIN      DATE:
# MOD NO: 1      MOD BY: RR BAIRNSFATHER DATE: 11 APR 67
# MOD NO: 2      MOD BY: RR BAIRNSFATHER DATE: 12 MAY 67      ADD UR.RT CALC WHEN P
# MOD NO: 2.1    MOD BY: RR BAIRNSFATHER DATE: 5 JULY 67      FIX ERROR ON MOD. 2
# MOD NO: 3      MOD BY: RR BAIRNSFATHER DATE: 12 JUL 67      CHANGE SIGN OF DISPLA
# MOD 4          MOD BY  S.ZELDIN      DATE: 3 APRIL 68      CHANGE EQUATIONS FOR
#
# FUNCTION:      CALCULATE (FOR DISPLAY ON CALL) AN APPROXIMATE MEASURE OF IN-PLANE S
#                ERROR.  IF THE FREE-FALL TRANSFER ANGLE TO 300K FT ABOVE PAD RADIUS I
#                SPLASH ERROR= -RANGE TO TARGET + FREE-FALL TRANSFER ANGLE + ESTIMATED
#                THE TARGET LOCATION AT ESTIMATED TIME OF IMPACT IS USED.  IF THE FRE
#                ANGLE IS NEGATIVE:  SPASH ERROR= -RANGE TO TARGET.
#                THE PRESENT TARGET LOCATION IS USED.
#
# CALLING SEQUENCE: CALLED AFTER SR30.1 IF IN CSM AND IF P11 OPERATING (UNDER CONTROL
#
# SUBROUTINES CALLED:  VGAMCALC, TFF/TRIG, LALOTORV.
#
# EXIT:          RETURN DIRECTLY TO V 82 PROG. AT SPLRET
#
# ERASABLE INITIALIZATION:  LEFT BY SR30.1 AND V82GON1
#
# OUTPUT:        RSP-RREC RANGE IN REVOLUTIONS.      DSKY DISPLAY IN N. M.
#
# DEBRIS:        QPRET, PDL0 ... PDL7, PDL10.

# THETA(1)

          BANK  32
          SETLOC DELRSPL1
          BANK
          COUNT* $$/P30          # PROGRAMS: P30 EXTERNAL DELTA V

DELRSPL    STORE  8D
          BPL    DSU
          CANTDO          # GONE PAST 300K FT ALT

```

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```

                                1BITDP
BOV      CALL
                                CANTDO      # POSMAX INDICATES NO 300K FT SOLUTION.
                                VGAMCALC     # +GAMMA(REV) IN PMAC,V300 MAG(B-7)=PDL 0
PUSH     CALL
                                TFF/TRIG
CALL
                                AUGEKUGL
PDDL     ACOS      # T ENTRY PDL 6
                                CDELF/2
DAD
                                4
GETARG    STOVL     THETA(1)
                                LAT(SPL)
STODL    LAT
                                HI6ZEROS
STODL    ALT      # ALT=0 = LAT +4
                                PIPTIME
# Page 644
BON      DLOAD
                                V37FLAG
                                +2
                                TSTART82
DSU      DAD
                                8D
CLEAR    CALL
                                ERADFLAG
                                LALOTORV     # R RECOV. IN ALPHAV AND MPAC

UNIT     PDVL
                                RONE
UNIT     DOT
SL1      ARCCOS
BDSU
                                # ERROR = THETA EST - THETA TARG
                                # NEGATIVE NUMBER SIGNIFIES THAT WILL FALL SHORT.
                                # POSITIVE NUMBER SIGNIFIES THAT WILL OVERSHOOT.

                                THETA(1)
DELRDONE STCALL    RSP-RREC      # DOWNRANGE RECOVERY RANGE ERROR      /360
                                INTWAKEO
CALL
                                SPLRET
CANTDO   DLOAD     PDDL      # INITIALIZE ERASE TO DOT TARGET AND UR
                                # FOR RANGE ANGLE.
                                HIDPHALF     # TO PDL 0 FOR DEN INDDV.
                                HI6ZEROS
PUSH     # ZERO TO PDL 2 FOR PHI ENTRY
```

```

                                STCALL 8D
                                GETARG      # GO SET RSP-RREC =0

AUGEKUGL      VLOAD
                                X1CON -2
                                STODL  X1 -2
                                0
                                DSU    BMN
                                V(21K)
                                LOOPSET
                                XSU,1  XCHX,2
                                S1
                                X1
                                XCHX,2 DSU
                                S1
                                V(3K)
                                BMN    XCHX,2
                                LOOPSET
                                S1
                                DSU    BMN
                                V(4K)
                                LOOPSET
                                XCHX,2  XCHX,2
# Page 645
                                S1
                                X1
                                DSU    BMN
                                V(400)
                                LOOPSET
                                SXA,1
                                S1
LOOPSET      INCR,1  GOTO
DEC          1
                                K1K2LOOP
K2CALC      SXA,1
                                S1
K1K2LOOP    DLOAD  DSU*
                                0
                                V(32K) +1,1
                                DMP*   DAD*
                                YK1K2 +1,1
                                CK1K2 +1,1
                                PDDL   TIX,1
                                2
                                K2CALC
                                DSU    BDDV

```

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|         |       |           |                                 |
|---------|-------|-----------|---------------------------------|
|         | PUSH  | BOV       |                                 |
|         |       | MAXPHI    |                                 |
|         | BMN   | DSU       |                                 |
|         |       | MAXPHI    |                                 |
|         |       | MAXPHIC   |                                 |
|         | BPL   |           |                                 |
|         |       | MAXPHI    |                                 |
| PHICALC | DLOAD | DSU       | # PHI ENTRY PDL 4D              |
|         |       | 0         |                                 |
|         |       | V(26K)    |                                 |
|         | BPL   | DLOAD     |                                 |
|         |       | TGR26     |                                 |
|         |       | TLESS26   |                                 |
|         | DDV   |           |                                 |
|         |       | 0         |                                 |
| TENT    | DMP   | RVQ       |                                 |
|         |       | 4D        |                                 |
| TGR26   | DLOAD | GOTO      |                                 |
|         |       | TGR26CON  |                                 |
|         |       | TENT      |                                 |
|         |       |           |                                 |
| MAXPHI  | DLOAD | PDDL      |                                 |
|         |       | MAXPHIC   |                                 |
|         | GOTO  |           |                                 |
|         |       | PHICALC   |                                 |
| MAXPHIC | 2DEC  | .09259298 | # 2000 NM FOR MAXIMUM PHI ENTRY |

# Page 646

COUNT\* \$\$/P30

#  
# \*\*\*\*\* TABLE IS INDEXED. KEEP IN ORDER \*\*\*\*\*

# Page 641

|       |      |                |        |
|-------|------|----------------|--------|
|       | 2DEC | 7.07304526 E-4 | # 5500 |
|       | 2DEC | 3.08641975 E-4 | # 2400 |
|       | 2DEC | 3.08641975 E-4 | # 2400 |
|       | 2DEC | -8.8888888 E-3 | # -3.2 |
|       | 2DEC | 2.7777777 E-3  | # 1    |
| CK1K2 | 2DEC | 6.6666666 E-3  | # 2.4  |

|          |       |                     |             |
|----------|-------|---------------------|-------------|
|          | 2DEC  | 0                   | # 0         |
|          | 2DEC* | -1.86909989 E-5 B7* | # -.443     |
|          | 2DEC  | 0                   |             |
|          | 2DEC* | 1.11639691 E-3 B7*  | # .001225   |
|          | 2DEC* | 9.56911636 E-4 B7*  | # .00105    |
| YK1K2    | 2DEC* | 2.59733157 E-4 B7*  | # .000285   |
| V(400)   | 2DEC  | 1.2192 B-7          |             |
| V(28K)   | 2DEC  | 85.344 B-7          |             |
| V(3K)    | 2DEC  | 9.144 B-7           |             |
| V(24K)   | 2DEC  | 73.152 B-7          |             |
|          | 2DEC  | 85.344 B-7          |             |
| V(32K)   | 2DEC  | 97.536 B-7          |             |
| V(4K)    | 2DEC  | 12.192 B-7          |             |
| V(21K)   | 2DEC  | 64.000 B-7          |             |
| TLESS26  | 2DEC* | 5.70146688 E7 B-35* | # 8660PHI/V |
| TGR26CON | 2DEC  | 7.2 E5 B-28         | # PHI/3     |
| V(26K)   | 2DEC  | 79.248 B-7          | # 26000     |

# Page 647

|       |     |    |
|-------|-----|----|
| X1CON | DEC | 10 |
|       | DEC | 8  |
|       | DEC | 6  |

# \*\*\*\* TABLE IS INDEXED. KEEP IN ORDER \*\*\*  
# ABOVE# Page 648  
# \*\*\*\*\* AVFLAG/P \*\*\*\*\*  
#



```

# SUBROUTINES USED
#
#         UPFLAG
#         DOWNFLAG

                SETLOC  P30SUBS
                BANK
                EBANK=  SUBEXIT
AVFLAGA        EXTEND                # AVFLAG = CSM
                QXCH   SUBEXIT
                TC     DOWNFLAG
                ADRES  AVFLAG        # BIT 5 FLAG 2
                CAF    EBANK7
                TS     EBANK
                EBANK= ECSTEER
                CAF    BIT13
                TS     ECSTEER        # SET ECSTEER = 1
                CAF    EBANK4
                TS     EBANK
                EBANK= SUBEXIT
                TC     SUBEXIT
AVFLAGP        EXTEND                # AVFLAG = LEM
                QXCH   SUBEXIT
                TC     UPFLAG
                ADRES  AVFLAG        # BIT 5 FLAG 2
                TC     SUBEXIT
P20FLGON       EXTEND
                QXCH   SUBEXIT
                TC     UPFLAG
                ADRES  TRACKFLG
                TC     UPFLAG
                ADRES  UPDATFLG
                TC     SUBEXIT        # DP B4

```

This code is written to file `src/P30-P37.s`.

**A.69 P32-P33 P72-P73**

```

1066  <src/P32-P33-P72-P73.s 1066>≡
      # Copyright:    Public domain.
      # Filename:     P32-P33_P72-P73.agc
      # Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
      #               It is part of the source code for the Command Module's (CM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Ron Burkey <info@sandroid.org>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         649-683
      # Mod history:   2009-05-09 RSB   Adapted from the Luminary131/ file
      #               P32-P35_P72-P75.agc and Comanche055 page
      #               images.
      #               2009-05-20 RSB   Corrected CSI/COM3 -> CSI/CDH3,
      #               CSI/CDHI -> CSI/CDH1, CDHTAB -> CDHTAG,
      #               changed a SETLOC from CSI/CDH to CSI/CDH1,
      #               a SETLOC CSI/CDH1 to CSIPROG.
      #               2009-05-21 RSB   Changed a P32/P72D to P32/P72E in
      #               P32/P72D.  DP1/4TH changed to DP1/4 in
      #               CDHMVR.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum.  The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum.  Many
      # thanks to both.  The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo.  If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 055 of AGC program Comanche by NASA
      #       2021113-051.  10:28 APR. 1, 1969
      #
      #       This AGC program shall also be referred to as
      #       Colossus 2A
      #
      # Page 649
      # COELLIPTIC SEQUENCE INITIATION (CSI) PROGRAMS (P32 AND P72)
      #
      # MOD NO -1          LOG SECTION -- P32-P35, P72-P75
      # MOD BY WHITE, P.   DATE 1 JUNE 67
      #

```

## # PURPOSE

- # (1) TO CALCULATE PARAMETERS ASSOCIATED WITH THE FOLLOWING  
# CONCENTRIC FLIGHT PLAN MANEUVERS -- THE CO-ELLIPTIC SEQUENCE  
# INITIATION (CSI) MANEUVER AND THE CONSTANT DELTA ALTITUDE  
# (CDH) MANEUVER.
- # (2) TO CALCULATE THESE PARAMETERS BASED UPON MANEUVER DATA  
# APPROVED AND KEYED INTO THE DSKY BY THE ASTRONAUT.
- # (3) TO DISPLAY TO THE ASTRONAUT AND THE GROUND DEPENDENT VARIABLES  
# ASSOCIATED WITH THE CONCENTRIC FLIGHT PLAN MANEUVERS FOR  
# APPROVAL BY THE ASTRONAUT/GROUND.
- # (4) TO STORE THE CSI TARGET PARAMETERS FOR USE BY THE DESIRED  
# THRUSTING PROGRAM.

## # ASSUMPTIONS

- # (1) AT A SELECTED TPI TIME THE LINE OF SIGHT BETWEEN THE ACTIVE  
# AND PASSIVE VEHICLES IS SELECTED TO BE A PRESCRIBED ANGLE (E)  
# FROM THE HORIZONTAL PLANE DEFINED BY THE ACTIVE VEHICLE  
# POSITION.
- # (2) THE TIME BETWEEN CSI IGNITION AND CDH IGNITION MUST BE  
# COMPUTED TO BE GREATER THAN 10 MINUTES FOR SUCCESSFUL  
# COMPLETION OF THE PROGRAM.
- # (3) THE TIME BETWEEN CDH IGNITION AND TPI IGNITION MUST BE  
# COMPUTED TO BE GREATER THAN 10 MINUTES FOR SUCCESSFUL  
# COMPLETION OF THE PROGRAM.
- # (4) CDH DELTA V IS SELECTED TO MINIMIZE THE VARIATION OF THE  
# ALTITUDE DIFFERENCE BETWEEN THE ORBITS.
- # (5) CSI BURN IS DEFINED SUCH THAT THE IMPULSIVE DELTA V IS IN THE  
# HORIZONTAL PLANE DEFINED BY THE ACTIVE VEHICLE POSITION AT CSI  
# IGNITION.
- # (6) THE PERICENTER ALTITUDE OF THE ORBIT FOLLOWING CSI AND CDH  
# MUST BE GREATER THAN 35,000 FT (LUNAR ORBIT) OR 85 NM (EARTH  
# ORBIT) FOR SUCCESSFUL COMPLETION OF THIS PROGRAM.
- # (7) THE CSI AND CDH MANEUVERS ARE ORIGINALLY ASSUMED TO BE  
# PARALLEL TO THE PLANE OF THE CSM ORBIT. HOWEVER, CREW

# Page 650

- # MODIFICATION OF DELTA V (LV) COMPONENTS MAY RESULT IN AN  
# OUT-OF-PLANE CSI MANEUVER
- # (8) STATE VECTOR UPDATES BY P27 ARE DISALLOWED DURING AUTOMATIC  
# STATE VECTOR UPDATING INITIATED BY P20 (SEE ASSUMPTION 10).
- # (9) COMPUTED VARIABLES MAY BE STORED FOR LATER VERIFICATION BY  
# THE GROUND. THESE STORAGE CAPABILITIES ARE NORMALLY LIMITED  
# ONLY TO THE PARAMETERS FOR ONE THRUSTING MANEUVER AT A TIME  
# EXCEPT FOR CONCENTRIC FLIGHT PLAN MANEUVER SEQUENCES.
- # (10) THE RENDEZVOUS RADAR MAY OR MAY NOT BE USED TO UPDATE THE LM  
# OR CSM STATE VECTORS FOR THIS PROGRAM. IF RADAR USE IS  
# DESIRED THE RADAR WAS TURNED ON AND LOCKED BY THE CSM BY

```

#          PREVIOUS SELECTION OF P20.  RADAR SIGHTING MARKS WILL BE MADE
#          AUTOMATICALLY APPROXIMATELY ONCE A MINUTE WHEN ENABLED BY THE
#          TRACK AND UPDATE FLAGS (SEE P20).  THE RENDEZVOUS TRACKING
#          MARK COUNTER IS ZEROED BY THE SELECTION OF P20 AND AFTER EACH
#          THRUSTING MANEUVER.
#          (11)  THE ISS NEED NOT BE ON TO COMPLETE THIS PROGRAM.
#          (12)  THE OPERATION OF THE PROGRAM UTILIZES THE FOLLOWING FLAGS --
#
#                  ACTIVE VEHICLE FLAG -- DESIGNATES THE VEHICLE WHICH IS
#                  DOING RENDEZVOUS THRUSTING MANEUVERS TO THE PROGRAM WHICH
#                  CALCULATES THE MANEUVER PARAMETERS.  SET AT THE START OF
#                  EACH RENDEZVOUS PRE-THRUSTING PROGRAM.
#
#                  FINAL FLAG -- SELECTS FINAL PROGRAM DISPLAYS AFTER CREW HAS
#                  COMPLETED THE FINAL MANEUVER COMPUTATION AND DISPLAY
#                  CYCLE.
#
#                  EXTERNAL DELTA V STEERING FLAG -- DESIGNATES THE TYPE OF
#                  STEERING REQUIRED FOR EXECUTION OF THIS MANEUVER BY THE
#                  THRUSTING PROGRAM SELECTED AFTER COMPLETION OF THIS
#                  PROGRAM.
#
#          (13)  IT IS NORMALLY REQUIRED THAT THE ISS BE ON FOR 1 HOUR PRIOR TO
#                  A THRUSTING MANEUVER.
#
#          (14)  THIS PROGRAM IS SELECTED BY THE ASTRONAUT BY DSKY ENTRY
#
#                  P32 IF THIS VEHICLE IS ACTIVE VEHICLE.
#
#                  P72 IF THIS VEHICLE IS THE PASSIVE VEHICLE.
#
# INPUT
#          (1)    TCSI          TIME OF THE CSI MANEUVER
# Page 651
#          (2)    NN           NUMBER OF APSIDAL CROSSINGS THRU WHICH THE ACTIVE
#                  VEHICLE ORBIT CAN BE ADVANCED TO OBTAIN THE CDH
#                  MANEUVER POINT.
#          (3)    ELEV         DESIRED LOS ANGLE AT TPI
#          (4)    TTPI         TIME OF THE TPI MANEUVER
#
# OUTPUT
#          (1)    TRKMKCNT     NUMBER OF MARKS
#          (2)    TTOGO        TIME TO GO
#          (3)    +MGA         MIDDLE GIMBAL ANGLE
#          (4)    DIFFALT      DELTA ALTITUDE AT CDH
#          (5)    T1TOT2       DELTA TIME FROM CSI TO CDH

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```
#      (6)      T2TOT3      DELTA TIME FROM CDH TO TPI
#      (7)      DELVLVC     DELTA VELOCITY AT CSI -- LOCAL VERTICAL COORDINATES
#      (8)      DELVLVC     DELTA VELOCITY AT CDH -- LOCAL VERTICAL COORDINATES
#
# DOWNLINK
#      (1)      TCSI        TIME OF THE CSI MANEUVER
#      (2)      TCDH        TIME OF THE CDH MANEUVER
#      (3)      TTPI        TIME OF THE TPI MANEUVER
#      (4)      TIG         TIME OF THE CSI MANEUVER
#      (5)      DELVEET1     DELTA VELOCITY AT CSI -- REFERENCE COORDINATES
#      (6)      DELVEET2     DELTA VELOCITY AT CDH -- REFERENCE COORDINATES
#      (7)      DIFFALT      DELTA ALTITUDE AT CDH
#      (8)      NN          NUMBER OF APSIDAL CROSSINGS THRU WHICH THE ACTIVE
#                          VEHICLE ORBIT CAN BE ADVANCED TO OBTAIN THE CDH
#                          MANEUVER POINT
#      (9)      ELEV        DESIRED LOS ANGLE AT TPI
#
# COMMUNICATION TO THRUSTING PROGRAMS
#      (1)      TIG         TIME OF THE CSI MANEUVER
#      (2)      RTIG        POSITION OF ACTIVE VEHICLE AT CSI -- BEFORE ROTATION
#                          INTO PLANE OF PASSIVE VEHICLE
#      (3)      VTIG        VELOCITY OF ACTIVE VEHICLE AT CSE -- BEFORE ROTATION
#                          INTO PLANE OF PASSIVE VEHICLE
#      (4)      DELVSIN      DELTA VELOCITY AT CSI -- REFERENCE COORDINATES
#      (5)      DELVSAB      MAGNITUDE OF DELTA VELOCITY AT CSI
#      (6)      XDELVFLG     SET TO INDICATE EXTERNAL DELTA V VG COMPUTATION
#
# SUBROUTINES USED
#      AVFLAGA
#      AVFLAGP
#      P20FLGON
#      VARALARM
#      BANKCALL
#      GOFLASH
#      GOTOPOOH
# Page 652
#      VNP00H
#      GOFLASHR
#      BLANKET
#      ENDOFJOB
#      SELECTMU
#      ADVANCE
#      INTINT
#      PASSIVE
#      CSI/A
#      S32/33.1
```

```

#      DISDVLVC
#      VN1645

                                BANK 35
                                SETLOC CSI/CDH1
                                BANK
                                EBANK= SUBEXIT
                                COUNT 35/P3272
P32      TC      AVFLAGA
          TC      P32STRT
P72      TC      AVFLAGP
P32STRT  TC      INTPRET
          DLOAD
          ZEROVEC
          STORE   CENTANG
          EXIT
          TC      P32/P72A
ALMXITA  SXA,2
          CSIALRM
ALMXIT   LXC,1
          CSIALRM
          SLOAD*  EXIT
          ALARM/TB -1,1
          CA      MPAC
          TC      VARALARM
          CAF      V05N09
          TC      BANKCALL
          CADR     GOFLASH
          TC      GOTOP00H
          TC      -4
P32/P72A TC      P20FLGON
          TC      INTPRET
          DLOAD
          ZEROVEC
          STORE   NN
          EXIT
          CAF      V06N11      # TCSI
          TC      VNP00H
          CAF      V06N55
# Page 653
          TC      BANKCALL
          CADR     GOFLASH
          TC      GOTOP00H
          TC      +2
          TC      -5
          CAF      V06N37      # TTPI

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|            |        |          |
|------------|--------|----------|
|            | TC     | VNPOOH   |
|            | TC     | INTPRET  |
|            | DLOAD  |          |
|            |        | TCSI     |
|            | STCALL | TIG      |
|            |        | SELECTMU |
| P32/P72B   | CALL   |          |
|            |        | ADVANCE  |
|            | SETPD  | VLOAD    |
|            |        | OD       |
|            |        | VPASS1   |
|            | PDVL   | PDDL     |
|            |        | RPASS1   |
|            |        | TCSI     |
|            | PDDL   | PDDL     |
|            |        | TTPI     |
|            |        | 2PISC    |
|            | SL2    | PUSH     |
|            | CALL   |          |
|            |        | INTINT   |
|            | CALL   |          |
|            |        | PASSIVE  |
|            | CALL   |          |
|            |        | CSI/A    |
| P32/P72C   | BON    | SET      |
|            |        | FINALFLG |
|            |        | P32/P72D |
|            |        | UPDATFLG |
| P32/P72D   | DLOAD  | GOTO     |
|            |        | T1TOT2   |
|            |        | P32/P72E |
|            | SETLOC | CSI/CDH3 |
|            | BANK   |          |
| P32/P72E   | STORE  | T1TOT2   |
|            | DSU    | BPL      |
|            |        | 60MIN    |
|            |        | P32/P72E |
|            | DLOAD  | GOTO     |
|            |        | T2TOT3   |
|            |        | P32/P72F |
|            | SETLOC | CSI/CDH1 |
|            | BANK   |          |
| P32/P72F   | STORE  | T2TOT3   |
|            | DSU    | BPL      |
| # Page 654 |        | 60MIN    |

```

                                P32/P72F
EXIT
CAF      V06N75
TC       VNP00H
TC       INTPRET
VLOAD    CALL
          DELVEET1
          S32/33.1
STOVL    DELVEET1
          RACT2
STOVL    RACT1
          DELVEET2
AXT,1    CALL
VN       0682
          DISDVLVC
DLOAD
          TTPI
STCALL   TTPIO
          VN1645
GOTO
                                P32/P72B

```

# Page 655

# CONSTANT DELTA HEIGHT (CDH) PROGRAMS (P33 AND P73)

# MOD NO -1 LOC SECTION -- P32-P35, P72-P75

# MOD BY WHITE, P. DATE: 1 JUNE 67

#

# PURPOSE

#

# (1) TO CALCULATE PARAMETERS ASSOCIATED WITH THE CONSTANT DELTA  
# ALTITUDE MANEUVER (CDH).

#

# (2) TO CALCULATE THESE PARAMETERS BASED UPON MANEUVER DATA  
# APPROVED AND KEYED INTO THE DSKY BY THE ASTRONAUT.

#

# (3) TO DISPLAY TO THE ASTRONAUT AND THE GROUND DEPENDENT VARIABLES  
# ASSOCIATED WITH THE CDH MANEUVER FOR APPROVAL BY THE  
# ASTRONAUT/GROUND.

#

# (4) TO STORE THE CDH TARGET PARAMETERS FOR USE BY THE DESIRED  
# THRUSTING PROGRAM.

#

# ASSUMPTIONS

#

# (1) THIS PROGRAM IS BASED UPON PREVIOUS COMPLETION OF THE  
# CO-ELLIPTIC SEQUENCE INITIATION (CSI) PROGRAM (P32/P72).



# THEREFORE --

#

# (A) AT A SELECTED TPI TIME (NOW IN STORAGE) THE LINE OF SIGHT

# BETWEEN THE ACTIVE AND PASSIVE VEHICLES WAS SELECTED TO BE

# A PRESCRIBED ANGLE (E) (NOW IN STORAGE) FROM THE

# HORIZONTAL PLANE DEFINED BY THE ACTIVE VEHICLE POSITION.

#

# (B) THE TIME BETWEEN CSI IGNITION AND CDH IGNITION WAS

# COMPUTED TO BE GREATER THAN 10 MINUTES.

#

# (C) THE TIME BETWEEN CDH IGNITION AND TPI IGNITION WAS

# COMPUTED TO BE GREATER THAN 10 MINUTES.

#

# (D) THE VARIATION OF THE ALTITUDE DIFFERENCE BETWEEN THE

# ORBITS WAS MINIMIZED.

#

# (E) CSI BURN WAS DEFINED SUCH THAT THE IMPULSIVE DELTA V WAS

# IN THE HORIZONTAL PLANE DEFINED BY ACTIVE VEHICLE

# POSITION AT CSI IGNITION.

#

# (F) THE PERICENTER ALTITUDES OF THE ORBITS FOLLOWING CSI AND

# CDH WERE COMPUTED TO BE GREATER THAN 35,000 FT FOR LUNAR

# ORBIT OR 85 NM FOR EARTH ORBIT.

#

# (G) THE CSI AND CDH MANEUVERS WERE ASSUMED TO BE PARALLEL TO

# THE PLANE OF THE PASSIVE VEHICLE ORBIT. HOWEVER, CREW

# Page 656

# MODIFICATION OF DELTA V (LV) COMPONENTS MAY HAVE RESULTED

# IN AN OUT-OF-PLANE MANEUVER.

#

# (2) STATE VECTOR UPDATES BY P27 ARE DISALLOWED DURING AUTOMATIC

# STATE VECTOR UPDATING INITIATED BY P20 (SEE ASSUMPTION 4).

#

# (3) COMPUTED VARIABLES MAY BE STORED FOR LATER VERIFICATION BY

# THE GROUND. THESE STORAGE CAPABILITIES ARE NORMALLY LIMITED

# ONLY TO THE PARAMETERS FOR ONE THRUSTING MANEUVER AT A TIME

# EXCEPT FOR CONCENTRIC FLIGHT PLAN MANEUVER SEQUENCES.

#

# (4) THE RENDEZVOUS RADAR MAY OR MAY NOT BE USED TO UPDATE THE LM.

# OR CSM STATE VECTORS FOR THIS PROGRAM. IF RADAR USE IS

# DESIRED THE RADAR WAS TURNED ON AND LOCKED ON THE CSM BY

# PREVIOUS SELECTION OF P20. RADAR SIGHTING MARKS WILL BE MADE

# AUTOMATICALLY APPROXIMATELY ONCE A MINUTE WHEN ENABLED BY THE

# TRACK AND UPDATE FLAGS (SEE P20). THE RENDEZVOUS TRACKING

# MARK COUNTER IS ZEROED BY THE SELECTION OF P20 AND AFTER EACH

# THRUSTING MANEUVER.

```
#
#      (5)      THE ISS NEED NOT BE ON TO COMPLETE THIS PROGRAM.
#
#      (6)      THE OPERATION OF THE PROGRAM UTILIZES THE FOLLOWING FLAGS --
#
#                  ACTIVE VEHICLE FLAG -- DESIGNATES THE VEHICLE WHICH IS
#                  DOING RENDEZVOUS THRUSTING MANEUVERS TO THE PROGRAM WHICH
#                  CALCULATES THE MANEUVER PARAMETERS.  SET AT THE START OF
#                  EACH RENDEZVOUS PRE-THRUSTING PROGRAM.
#
#                  FINAL FLAG -- SELECTS FINAL PROGRAM DISPLAYS AFTER CREW HAS
#                  COMPLETED THE FINAL MANEUVER COMPUTATION AND DISPLAY
#                  CYCLE.
#
#                  EXTERNAL DELTA V STEERING FLAG -- DESIGNATES THE TYPE OF
#                  STEERING REQUIRED FOR EXECUTION OF THIS MANEUVER BY THE
#                  THRUSTING PROGRAM SELECTED AFTER COMPLETION OF THIS
#                  PROGRAM.
#
#      (7)      IT IS NORMALLY REQUIRED THAT THE ISS BE ON FOR 1 HOUR PRIOR TO
#                  A THRUSTING MANEUVER.
#
#      (8)      THIS PROGRAM IS SELECTED BY THE ASTRONAUT BY DSKY ENTRY.
#
#                  P33 IF THIS VEHICLE IS ACTIVE VEHICLE.
#
#                  P73 IF THIS VEHICLE IS PASSIVE VEHICLE.
#
# INPUT
#
#      (1)      TTPIO   TIME OF THE TPI MANEUVER -- SAVED FROM P32/P72
# Page 657
#      (2)      ELEV    DESIRED LOS ANGLE AT TPI -- SAVED FROM P32/P72
#      (3)      TCDH    TIME OF THE CDH MANEUVER
#
# OUTPUT
#
#      (1)      TRKMKCNT      NUMBER OF MARKS
#      (2)      TTOGO         TIME TO GO
#      (3)      +MGA          MIDDLE GIMBAL ANGLE
#      (4)      DIFFALT        DELTA ALTITUDE AT CDH
#      (5)      T2TOT3         DELTA TIME FROM CDH TO COMPUTED TPI
#      (6)      NOMTPI         DELTA TIME FROM NOMINAL TPI TO COMPUTED TPI
#      (7)      DELVLVC        DELTA VELOCITY AT CDH -- LOCAL VERTICAL COORDINATES
#
# DOWNLINK
```

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```
#
#      (1)      TCDH          TIME OF THE CDH MANEUVER
#      (2)      TTPI         TIME OF THE TPI MANEUVER
#      (3)      TIG          TIME OF THE CDH MANEUVER
#      (4)      DELLVEET2    DELTA VELOCITY AT CDH -- REFERENCE COORDINATES
#      (5)      DIFFALT      DELTA ALTITUDE AT CDH
#      (6)      ELEV         DESIRED LOS ANGLE AT TPI
#
# COMMUNICATION TO THRUSTING PROGRAMS
#
#      (1)      TIG          TIME OF THE CDH MANEUVER
#      (2)      RTIG         POSITION OF ACTIVE VEHICLE AT CDH -- BEFORE ROTATION
#                               INTO PLANE OF PASSIVE VEHICLE.
#      (3)      VTIG         VELOCITY OF ACTIVE VEHICLE AT CDH -- BEFORE ROTATION
#                               INTO PLANE OF PASSIVE VEHICLE.
#      (4)      DELVSIN      DELTA VELOCITY AT CDH -- REFERENCE COORDINATES.
#      (5)      DELVSAB      MAGNITUDE OF DELTA VELOCITY AT CDH.
#      (6)      XDELVFLG     SET TO INDICATE EXTERNAL DELTA V VG COMPUTATION.
#
# SUBROUTINES USED
#
#      AVFLAGA
#      AVFLAGP
#      P20FLGON
#      VNPOOH
#      SELECTMU
#      ADVANCE
#      CDHMVR
#      INTINT3P
#      ACTIVE
#      PASSIVE
#      S33/S34.1
#      ALARM
#      BANKCALL
#      GOFLASH
#      GOTOPOOH
#      S32/33.1
# Page 658
#      VN1645
```

COUNT 35/P3373

|          |    |          |
|----------|----|----------|
| P33      | TC | AVFLAGA  |
|          | TC | P33/P73A |
| P73      | TC | AVFLAGP  |
| P33/P73A | TC | P20FLGON |

|            |        |          |        |
|------------|--------|----------|--------|
|            | CAF    | V06N13   | # TCDH |
|            | TC     | VNP00H   |        |
|            | TC     | INTPRET  |        |
|            | DLOAD  |          |        |
|            |        | TTPIO    |        |
|            | STODL  | TTPI     |        |
|            |        | TCDH     |        |
|            | STCALL | TIG      |        |
|            |        | SELECTMU |        |
| P33/P73B   | CALL   |          |        |
|            |        | ADVANCE  |        |
|            | CALL   |          |        |
|            |        | CDHMVR   |        |
|            | SETPD  | VLOAD    |        |
|            |        | OD       |        |
|            |        | VACT3    |        |
|            | PDVL   | CALL     |        |
|            |        | RACT2    |        |
|            |        | INTINT3P |        |
|            | CALL   |          |        |
|            |        | ACTIVE   |        |
|            | SETPD  | VLOAD    |        |
|            |        | OD       |        |
|            |        | VPASS2   |        |
|            | PDVL   | CALL     |        |
|            |        | RPASS2   |        |
|            |        | INTINT3P |        |
|            | CALL   |          |        |
|            |        | PASSIVE  |        |
|            | DLOAD  | SET      |        |
|            |        | ZEROVEC  |        |
|            |        | ITSWICH  |        |
|            | STCALL | NOMTPI   |        |
|            |        | S33/34.1 |        |
|            | BZE    | EXIT     |        |
|            |        | P33/P73C |        |
|            | TC     | ALARM    |        |
|            | OCT    | 611      |        |
|            | CAF    | V05N09   |        |
|            | TC     | BANKCALL |        |
|            | CADR   | GOFLASH  |        |
|            | TC     | GOTOP00H |        |
| # Page 659 |        |          |        |
|            | TC     | +2       |        |
|            | TC     | P33/P73A |        |
|            | TC     | INTPRET  |        |

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|          |        |          |
|----------|--------|----------|
|          | DLOAD  | ZEROVEC  |
|          | STCALL | NOMTPI   |
|          |        | P33/P73C |
|          | SETLOC | CSI/CDH2 |
|          | BANK   |          |
| P33/P73C | BON    | SET      |
|          |        | FINALFLG |
|          |        | P33/P73D |
|          |        | UPDATFLG |
| P33/P73D | DLOAD  | DAD      |
|          |        | NOMTPI   |
|          |        | TTPI     |
|          | STORE  | TTPI     |
|          | DSU    | GOTO     |
|          |        | TCDH     |
|          |        | P33/P73E |
|          | SETLOC | CSI/CDH1 |
|          | BANK   |          |
| P33/P73E | DSU    | BPL      |
|          |        | 60MIN    |
|          |        | P33/P73E |
|          | DAD    |          |
|          |        | 60MIN    |
|          | STODL  | T1TOT2   |
|          |        | TTPI     |
|          | DSU    | PUSH     |
|          |        | TTPIO    |
| P33/P73F | ABS    | DSU      |
|          |        | 60MIN    |
|          | BPL    | DAD      |
|          |        | P33/P73F |
|          |        | 60MIN    |
|          | SIGN   | STADR    |
|          | STORE  | T2TOT3   |
|          | EXIT   |          |
|          | CAF    | V06N75   |
|          | TC     | VNP00H   |
|          | TC     | INTPRET  |
|          | VLOAD  | CALL     |
|          |        | DELVEET2 |
|          |        | S32/33.1 |
|          | STCALL | DELVEET2 |
|          |        | VN1645   |

```
                                GOTO
# Page 660                                P33/P73B

# Page 661
# ***** AVFLAGA/P *****

# Page 662
# ***** DISDVLVC *****
#
# SUBROUTINES USED
#
#          S32/33.X
#          VNPOOH

                                SETLOC  CDHTAG3
                                BANK

DISDVLVC          STORE  DELVLVC
                  STQ    CALL
                              NORMEX
                              S32/33.X
                  VLOAD  MXV
                              DELVLVC
                              OD
                  VSL1   SXA,1
                              VERBNOUN
                  STORE  DELVLVC
                  EXIT
                  CA     VERBNOUN
                  TC     VNPOOH
                  TC     INTPRET
                  GOTO

                              NORMEX
                  SETLOC FFTAG12
                  BANK

V06N11          VN      0611
V06N13          VN      0613
V06N75          VN      0675

V06N50          VN      0650

# Page 663

# ***** CSI/A *****
```

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```
#
# SUBROUTINES USED
#
#      VECSHIFT
#      TIMETHET
#      PERIAPO
#      SHIFTR1
#      INTINT2C
#      CDHMVR
#      PERIAPO1
#      INTINT
#      ACTIVE
```

```
BANK      34
SETLOC    CSIPROG
BANK
EBANK=    SUBEXIT
COUNT    34/CSI
```

```
60MIN      2DEC      360000
```

```
ALARM/TB   OCT      00600      # NO 1
           OCT      00601      #   2
           OCT      00602      #   3
           OCT      00603      #   4
           OCT      00604      #   5
           OCT      00605      #   6
           OCT      00606      #   7
```

```
LOOPMX     2DEC      16
```

```
INITST     2DEC      .03048 B-7      # INITIAL DELDV = 10 FPS
```

```
DVMAX1     2DEC      3.0480 B-7      # MAXIMUM DV1 = 1000 FPS
```

```
DVMAX2     2DEC      3.014472 B-7    #           989 FPS
```

```
1DPB2      2DEC      1.0 B-2
```

```
1DPB28     2DEC      1
```

```
EPSILN1    2DEC      .0003048 B-7    # .1 FPS
```

```
FIFPSDP    2DEC      -.152400 B-7    # 5 FPS
```

```
DELMAX1     2DEC      .6096000 B-7    # 200 FPS
```

```

SETLOC CSI/CDH
BANK
PMINE 2DEC 157420 B-29 # 84 NM -- MUST BE 8 WORDS BEFORE PMINM

# Page 664

NICKELDP 2DEC .021336 B-7 # 7 FPS

INITST1 2DEC .03048 B-7 # INITIAL DELDV = 10 FPS

ONETHTH 2DEC .0001 B-3

PMINM 2DEC 10668 B-29 # 35000 FT -- MUST BE 8 WORDS AFTER PMINE

SETLOC CSIPROG
BANK

CSI/A CLEAR SET # INITIALIZE INDICATORS
S32.1F1 # DVT1 HAS EXCEEDED MAX INDICATOR
S32.1F2 # FIRST PASS FOR NEWTON ITERATION INDICATOR
CLEAR SET
S32.1F3A # 00=1ST 2 PASSES 2ND CYCLE, 01=FIRST CYCLE
S32.1F3B # 10=2ND CYCLE, 11=50 FPS STAGE 2ND CYCLE

DLOAD
ZEROVEC
STORE LOOPCT
STORE CSIALRM
SETPD VLOAD
OD
RACT1
ABVAL PUSH # RA1 B29 PI
NORM SR1 # B29-N2+ B1 PI
X2 #
PDVL ABVAL
RPASS3
NORM BDDV # RA1/RP3 B1 PI
X1
XSU,2 SR* # B2
X1
1,2
DAD DMP # (1+(RA1/RP3))RA1 B29+B2=B31 PI
1DPB2
NORM PDDL # PI
X1
RTMU

```



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|            |        |          |                                  |                   |
|------------|--------|----------|----------------------------------|-------------------|
|            | SR1    | DDV      | #                                | B38-B31= B7 PLOOD |
|            | SL*    | SQRT     | #                                | B7                |
|            |        | 0 -7,1   |                                  |                   |
|            | PDVL   | UNIT     | #                                | PL02D             |
|            |        | RACT1    |                                  |                   |
|            | PDVL   | VXV      |                                  |                   |
|            |        | UP1      |                                  |                   |
|            | UNIT   |          | # UNIT(URP1 X UVP1 X URA1) = UH1 |                   |
|            | DOT    | SL1      | # VA1 . UH1                      | B7                |
|            |        | VACT1    |                                  |                   |
|            | BDSU   | STADR    | #                                | PLOOD             |
| # Page 665 |        |          |                                  |                   |
|            | STODL  | DELVCSI  |                                  |                   |
|            |        | INITST   | # 10 FPS                         |                   |
|            | STORE  | DELDV    |                                  |                   |
| CSI/B1     | DLOAD  | DAD      | # IF LOOPCT = 16                 |                   |
|            |        | LOOPCT   |                                  |                   |
|            |        | 1DPB28   |                                  |                   |
|            | STORE  | LOOPCT   |                                  |                   |
|            | DSU    | AXT,2    |                                  |                   |
|            |        | LOOPMX   |                                  |                   |
|            |        | 6        |                                  |                   |
|            | BPL    | GOTO     |                                  |                   |
|            |        | SCNDSOL  |                                  |                   |
|            |        | CSI/B2   |                                  |                   |
|            | SETLOC | CSIPROG2 |                                  |                   |
|            | BANK   |          |                                  |                   |
| CSI/B2     | SETPD  |          |                                  |                   |
|            |        | OD       |                                  |                   |
|            | DLOAD  | ABS      |                                  |                   |
|            |        | DELVCSI  |                                  |                   |
|            | DSU    | BMN      |                                  |                   |
|            |        | DVMAX1   |                                  |                   |
|            |        | CSI/B23  |                                  |                   |
|            | AXT,2  | BON      |                                  |                   |
|            |        | 7        |                                  |                   |
|            |        | S32.1F1  |                                  |                   |
|            |        | SCNDSOL  |                                  |                   |
|            | BOFF   | BON      |                                  |                   |
|            |        | S32.1F3A |                                  |                   |
|            |        | CSI/B22  | # FLAG 3 NEQ 3                   |                   |
|            |        | S32.1F3B |                                  |                   |
|            |        | SCNDSOL  |                                  |                   |
| CSI/B22    | SET    | DLOAD    |                                  |                   |

|            |        |          |                                   |
|------------|--------|----------|-----------------------------------|
|            |        | S32.1F1  |                                   |
|            |        | DVMAX2   |                                   |
|            | SIGN   |          |                                   |
|            |        | DELVCSI  |                                   |
|            | STCALL | DELVCSI  |                                   |
|            |        | CSI/B23  |                                   |
|            | SETLOC | CSIPROG3 |                                   |
|            | BANK   |          |                                   |
| CSI/B23    | VLOAD  | PUSH     |                                   |
|            |        | RACT1    |                                   |
|            | UNIT   | PDVL     |                                   |
|            |        | UP1      |                                   |
|            | VXV    | UNIT     | # UNIT (URP1 X UVP1 X URA1) = UH1 |
|            | VXSC   | VSL1     |                                   |
| # Page 666 |        |          |                                   |
|            |        | DELVCSI  |                                   |
|            | STORE  | DELVEET1 |                                   |
|            | VAD    | BOV      |                                   |
|            |        | VACT1    |                                   |
|            |        | CSI/B23D |                                   |
| CSI/B23D   | STCALL | VACT4    |                                   |
|            |        | VECSHIFT |                                   |
|            | STOVL  | VVEC     |                                   |
|            | SET    |          |                                   |
|            |        | RVS      |                                   |
|            | STOVL  | RVEC     |                                   |
|            |        | SN359+   |                                   |
|            | STCALL | SNTH     | # ALSO CSTD                       |
|            |        | TIMETHET |                                   |
|            | SR1    | LXA,1    |                                   |
|            |        | RTX1     |                                   |
|            | STCALL | HAFPA1   |                                   |
|            |        | PERIAPO  |                                   |
|            | CALL   |          |                                   |
|            |        | SHIFTR1  |                                   |
|            | STODL  | POSTCSI  |                                   |
|            |        | CENTANG  |                                   |
|            | BZE    | GOTO     |                                   |
|            |        | +2       |                                   |
|            |        | CIRCL    |                                   |
|            | DLOAD  |          |                                   |
|            |        | ECC      |                                   |
|            | DSU    | BMN      |                                   |
|            |        | ONETHTH  |                                   |

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|            |       |          |                        |                       |
|------------|-------|----------|------------------------|-----------------------|
|            |       | CIRCL    |                        |                       |
|            | DLOAD | CALL     |                        |                       |
|            |       | R1       |                        |                       |
|            |       | SHIFTR1  |                        |                       |
|            | SETPD | NORM     |                        |                       |
|            |       | 2D       |                        |                       |
|            |       | X1       |                        |                       |
|            | PDVL  | DOT      | #                      | PL04D                 |
|            |       | RACT1    |                        |                       |
|            |       | VACT4    |                        |                       |
|            | ABS   | DDV      |                        |                       |
|            |       | 02D      | # (/RDOTV/)/R1         | B36-B29= B7           |
|            | SL*   | DSU      |                        |                       |
|            |       | 0,1      |                        |                       |
|            |       | NICKELDP |                        |                       |
|            | BMN   | DLOAD    |                        |                       |
|            |       | CIRCL    |                        |                       |
|            |       | P        |                        |                       |
|            | SL2   | DSU      |                        |                       |
|            |       | 1RTEB2   | # 1.B.2                |                       |
|            | STODL | 14D      |                        |                       |
| # Page 667 |       |          |                        |                       |
|            |       | RTSR1/MU |                        |                       |
|            | SR1   | DDV      | # (1/ROOTMU)/R1        | B-16-B29 = B-45 PL02D |
|            | PDDL  | DMP      |                        |                       |
|            |       | P        |                        |                       |
|            |       | R1       |                        |                       |
|            | CALL  |          |                        |                       |
|            |       | SHIFTR1  |                        |                       |
|            | SL4   | SL1      |                        |                       |
|            | SQRT  | DMP      | # ((P/MU)**.5)/R1      | B14+B-14 = B-31 BL02D |
|            | BOFF  | SL3      |                        |                       |
|            |       | CMOONFLG |                        |                       |
|            |       | CSI/B3   |                        |                       |
| CSI/B3     | PDVL  | DOT      |                        |                       |
|            |       | RACT1    |                        |                       |
|            |       | VACT4    |                        |                       |
|            | STORE | RDOTV    |                        |                       |
|            | ABS   |          |                        |                       |
|            | NORM  | DMP      | # ((P/MU)**.5)RDOTV/R1 | PL02D                 |
|            |       | X2       |                        |                       |
|            | XSU,1 | SL*      | #                      | B-31+B36-B3 = B2      |
|            |       | X2       |                        |                       |
|            |       | 3,1      |                        |                       |
|            | STODL | 12D      |                        |                       |
|            |       | ZEROVECS |                        |                       |

|            |        |              |                          |
|------------|--------|--------------|--------------------------|
|            | STORE  | 16D          |                          |
|            | VLOAD  | UNIT         |                          |
|            |        | 12D          |                          |
|            | STOVL  | SNTH         | # ALSO STORES CSTH AND 0 |
|            |        | RACT1        |                          |
|            | PDVL   | SIGN         |                          |
|            |        | VACT4        |                          |
|            |        | RDOTV        |                          |
|            | VCOMP  | CALL         |                          |
|            |        | VECSHIFT     |                          |
|            | STOVL  | VVEC         |                          |
|            | SETGO  |              |                          |
|            |        | RVSU         |                          |
|            |        | CSINEXT      |                          |
| SN359+     | 2DEC   | - .000086601 |                          |
| CS359+     | 2DEC   | + .499999992 |                          |
|            | SETLOC | CSIPROG4     |                          |
|            | BANK   |              |                          |
| CSINEXT    | STCALL | RVEC         |                          |
|            |        | TIMETHET     |                          |
|            | PDDL   | BPL          |                          |
|            |        | RDOTV        |                          |
| # Page 668 |        |              |                          |
|            |        | NTP/2        |                          |
|            | DLOAD  | DSU          |                          |
|            |        | HAFPA1       |                          |
|            | PUSH   | GOTO         |                          |
|            |        | NTP/2        |                          |
| CIRCL      | SETPD  | DLOAD        |                          |
|            |        | OOD          |                          |
|            |        | ZEROVECS     |                          |
|            | PUSH   |              |                          |
| NTP/2      | DLOAD  | DMP          |                          |
|            |        | NN           |                          |
|            |        | HAFPA1       |                          |
|            | SL     | DSU          |                          |
|            |        | 14D          |                          |
|            | DAD    |              |                          |
|            |        | TCSI         |                          |
|            | STORE  | TCDH         |                          |
|            | BDSU   | AXT, 2       |                          |
|            |        | TTPI         |                          |

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```

      5D
      BMN  SETPD
           SCNDSOL
           OD
      VLOAD PDVL
           VACT4
           RACT1
      CALL
           INTINT2C
      STOVL RACT2
           VATT
      STOVL VACT2
           VPASS1
      SETPD PDVL
           OD
           RPASS1
      GOTO
           CSINEXT1

      SETLOC CSIPROG5
      BANK

CSINEXT1 CALL
           INTINT2C
      STOVL RPASS2
           VATT
      STCALL VPASS2
           CDHMVR
      VLOAD SETPD
           RACT2
           OD

# Page 669 PDVL CALL
           VACT3
           PERIAP01
      CALL
           SHIFTR1
      STOVL POSTCDH
           VACT3
      SETPD PDVL
           OD
           RACT2
      PDDL PDDL
           TCDH
           TTPI
      PDDL SL2
```

```

                                2PISC
                                CALL
                                INTINT
                                CALL
                                ACTIVE
                                DLOAD
                                ELEV
                                SETPD SINE
                                6D
                                PDVL UNIT
                                RACT3
                                STORE OOD          # URA3 AT OOD
                                PDVL VXV          # PL14D, PL08D
                                UP1
                                UNIT
                                PDDL COSINE        # UNIT(URA3 X UVA3 X URA3) = UH3      B1 PL
                                ELEV
                                VXSC STADR        # (COSLOS)(UH3)                    B2 PL
                                STCALL 18D        #
                                CSINEXT2          PLUS
                                SETLOC CSIPROG6
                                BANK
CSINEXT2 DLOAD VXSC          # (SINLOS)(URA3) = U      B2 PL
          VAD VSL1
          18D          #
          PUSH DOT        #
          RACT3          # (U . RA3) = TEMP1      B1 + B29 = B30
          SL1 PUSH        #
          DSQ TLOAD       # TEMP1**2            B29 PL
          MPAC           B58
          PDVL DOT        #
          RACT3
          RACT3
          TLOAD DCOMP     # RA3 . RA3
# Page 670
          MPAC
          PDVL DOT        # RP3 . RP3      B58 PL14D
          RPASS3
          RPASS3          #
          TAD TAD         # TEMP1**2 + RA3.RA3 + RP3.RP3 = TEMP2 PL08D
          BPL DLOAD
          K10RK2
          LOOPCT
          DSU AXT,2

```

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|            |        |          |                            |           |
|------------|--------|----------|----------------------------|-----------|
|            |        | 1DPB28   |                            |           |
|            |        | 1D       |                            |           |
|            | BZE    |          |                            |           |
|            |        | ALMXITA  |                            |           |
|            | DLOAD  | SR1      |                            |           |
|            |        | DELDV    |                            |           |
|            | STORE  | DELDV    |                            |           |
|            | BDSU   |          |                            |           |
|            |        | DVPREV   |                            |           |
|            | STCALL | DELVCSI  |                            |           |
|            |        | CSI/B1   |                            |           |
| K1ORK2     | SQRT   | PUSH     | # TEMP3 = TEMP2** .5       | B29 PL10D |
|            | DCOMP  | DSU      |                            |           |
|            |        | 06D      | # -TEMP1-TEMP3 = K2 AT 10D |           |
|            | STODL  | 10D      | #                          | PL08D     |
|            | DSU    | STADR    | #                          | PL06D     |
|            | STORE  | 12D      | # -TEMP1+TEMP3 = K1 AT 12D |           |
|            | ABS    |          |                            |           |
|            | STODL  | 14D      |                            |           |
|            |        | 10D      |                            |           |
|            | ABS    | DSU      |                            |           |
|            |        | 14D      |                            |           |
|            | BMN    | DLOAD    |                            |           |
|            |        | K2.      |                            |           |
|            |        | 12D      |                            |           |
|            | STCALL | 10D      | # K EQUALS K1              |           |
|            |        | K2.      |                            |           |
|            | SETLOC | CSIPROG7 |                            |           |
|            | BANK   |          |                            |           |
| K2.        | DLOAD  |          |                            |           |
|            |        | 10D      |                            |           |
|            | VXSC   | VSL1     |                            |           |
|            | VAD    | UNIT     | # V = RA3 + KU UNIT        | B1        |
|            |        | RACT3    |                            |           |
|            | PDVL   | UNIT     |                            |           |
|            |        | RPASS3   | #                          | PL06D     |
|            | PDVL   | UNIT     |                            |           |
|            |        | VPASS3   | #                          | PL12D     |
|            | VXV    | PDVL     | # UVP3 X URP3              | PL18D     |
| # Page 671 |        |          |                            |           |
|            |        | 06D      |                            |           |
|            |        | 06D      |                            |           |
|            | VXV    | DOT      |                            |           |
|            |        | 00D      |                            |           |

|         |        |          |   |                                     |              |
|---------|--------|----------|---|-------------------------------------|--------------|
|         | STADR  |          | # |                                     | PL12D        |
|         | STOVL  | 12D      | # | (URP3 X V).(UVP3 X URP3)=TEMP       | PL06D        |
|         | DOT    | SL1      | # |                                     | PL00D        |
|         | ARCCOS | SIGN     |   |                                     |              |
|         |        | 12D      | # |                                     | B0           |
|         | SR1    | PUSH     | # | GAMMA = SIGN(TEMP)ARCOS(UNITV.URP3) | PL02D        |
|         | BON    | DLOAD    |   |                                     |              |
|         |        | S32.1F2  |   |                                     |              |
|         |        | FRSTPAS  |   |                                     |              |
|         |        | OOD      | # | NOT THE FIRST PASS OF A CYCLE       |              |
|         | DSU    | PDDL     | # | GAMMA-GAMPREV                       | B1 PL04D     |
|         |        | GAMPREV  |   |                                     |              |
|         |        | DELVCSI  |   |                                     |              |
|         | DSU    | NORM     | # |                                     | B7           |
|         |        | DVPREV   |   |                                     |              |
|         |        | X1       |   |                                     |              |
|         | BDDV   | PDDL     | # | (GAM-GAMPREV)/(DV-DVPREV)           | B-6+N1 PL06D |
|         |        | O2D      | # | = SLOPE                             |              |
|         |        | DELVCSI  |   |                                     |              |
|         | STORE  | DVPREV   |   |                                     |              |
|         | BOFF   | BOFF     |   |                                     |              |
|         |        | S32.1F3A |   |                                     |              |
|         |        | THRDCHK  |   |                                     |              |
|         |        | S32.1F3B |   |                                     |              |
|         |        | THRDCHK  |   |                                     |              |
|         | DLOAD  | DMP      |   |                                     |              |
|         |        | O2D      |   |                                     |              |
|         |        | GAMPREV  |   |                                     |              |
|         | BPL    | DLOAD    |   |                                     |              |
|         |        | FIFTYFPS |   |                                     |              |
|         |        | INITST1  |   |                                     |              |
|         | SIGN   |          |   |                                     |              |
|         |        | DELDV    |   |                                     |              |
|         | STORE  | DELDV    |   |                                     |              |
|         | SET    | CLEAR    |   |                                     |              |
|         |        | S32.1F3A |   |                                     |              |
|         |        | S32.1F3B |   |                                     |              |
| FRSTPAS | DLOAD  |          |   |                                     |              |
|         |        | OOD      |   |                                     |              |
|         | STODL  | GAMPREV  |   |                                     |              |
|         |        | DELVCSI  |   |                                     |              |
|         | STCALL | DVPREV   |   |                                     |              |
|         |        | CSINEXT3 |   |                                     |              |
|         | SETLOC | CSIPROG8 |   |                                     |              |
|         | BANK   |          |   |                                     |              |



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|          |        |          |
|----------|--------|----------|
| CSINEXT3 | DSU    | CLEAR    |
|          |        | DELDV    |
|          |        | S32.1F2  |
|          | STCALL | DELVCSI  |
|          |        | CSI/B1   |
| THRDCHK  | BON    | BON      |
|          |        | S32.1F3A |
|          |        | NEWTN    |
|          |        | S32.1F3B |
|          |        | NEWTN    |
| FIFTYFPS | DLOAD  | SIGN     |
|          |        | FIFPSDP  |
|          |        | 04D      |
|          | SIGN   |          |
|          |        | GAMPREV  |
|          | STORE  | DELDV    |
|          | DCOMP  | DAD      |
|          |        | DELVCSI  |
|          | STODL  | DELVCSI  |
|          |        | OOD      |
|          | SET    | SET      |
|          |        | S32.1F3B |
|          |        | S32.1F3A |
|          | STCALL | GAMPREV  |
|          |        | CSI/B2   |
| NEWTN    | DLOAD  | NORM     |
|          |        | 04D      |
|          |        | X2       |
|          | BDDV   | XSU,1    |
|          |        | OOD      |
|          |        | X2       |
|          | SR*    |          |
|          |        | 0,1      |
|          | STODL  | DELDV    |
|          |        | OOD      |
|          | STORE  | GAMPREV  |
|          | DLOAD  | ABS      |
|          |        | DELDV    |
|          | PUSH   | DSU      |
|          |        | EPSILN1  |
|          | BMN    | DLOAD    |
|          |        | CSI/SOL  |
|          | DSU    | BMN      |
|          |        | DELMAX1  |

#

PL08D

|            |        |            |
|------------|--------|------------|
|            |        | CSISTEP    |
|            | DLOAD  | SIGN       |
|            |        | DELMAX1    |
|            |        | DELDV      |
|            | STORE  | DELDV      |
| CSISTEP    | DLOAD  | DSU        |
| # Page 673 |        |            |
|            |        | DELVCSI    |
|            |        | DELDV      |
|            | STCALL | DELVCSI    |
|            |        | CSI/B1     |
| CSI/SOL    | DLOAD  | AXT,2      |
|            |        | POSTCSI    |
|            |        | 2          |
|            | LXA,1  | GOTO       |
|            |        | RTX1       |
|            |        | CSINEXT4   |
|            | SETLOC | CSIPROG9   |
|            | BANK   |            |
| CSINEXT4   | DSU*   | BMN        |
|            |        | PMINE -2,1 |
|            |        | SCNDSOL    |
|            | AXT,2  | DLOAD      |
|            |        | 3          |
|            |        | POSTCDH    |
|            | DSU*   | BMN        |
|            |        | PMINE -2,1 |
|            |        | SCNDSOL    |
|            | DLOAD  | DSU        |
|            |        | TCDH       |
|            |        | TCSI       |
|            | STORE  | T1TOT2     |
|            | AXT,2  | DSU        |
|            |        | 4          |
|            |        | 600SEC     |
|            | BMN    | AXT,2      |
|            |        | SCNDSOL    |
|            |        | 5          |
|            | DLOAD  | DSU        |
|            |        | TTPI       |
|            |        | TCDH       |
|            | STORE  | T2TOT3     |
|            | DSU    | BPL        |
|            |        | 600SEC     |

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|         |       |                                                              |
|---------|-------|--------------------------------------------------------------|
| SCNDSOL | BON   | P32/P72C<br>BOFF<br>S32.1F3A<br>ALMXIT<br>S32.1F3B<br>ALMXIT |
|         | SXA,2 | DLOAD<br>CSIALRM<br>ZEROVECS                                 |
|         | CLEAR | SET<br>S32.1F1                                               |

# Page 674

|  |        |                               |
|--|--------|-------------------------------|
|  |        | S32.1F2                       |
|  | CLEAR  | CLEAR<br>S32.1F3A<br>S32.1F3B |
|  | STCALL | LOOPCT<br>CSI/B               |

# Page 675

# \*\*\*\*\* ADVANCE \*\*\*\*\*

#

# SUBROUTINES USED

#       PRECSET

#       ROTATE

|        |         |
|--------|---------|
| SETLOC | CDHTAG3 |
| BANK   |         |

|         |        |                             |
|---------|--------|-----------------------------|
| ADVANCE | STQ    | DLOAD<br>SUBEXIT<br>TIG     |
|         | STCALL | TDEC1<br>PRECSET            |
|         | SET    | VLOAD<br>XDELVFLG<br>VPASS3 |
|         | STORE  | VPASS2                      |
|         | STOVL  | VPASS1<br>RPASS3            |
|         | STORE  | RPASS2                      |
|         | STORE  | RPASS1                      |
|         | UNIT   | VXV<br>VPASS1               |
|         | UNIT   |                             |
|         | STOVL  | UP1                         |

|  |        |         |
|--|--------|---------|
|  | STCALL | RACT3   |
|  |        | RTIG    |
|  |        | ROTATE  |
|  | STORE  | RACT2   |
|  | STOVL  | RACT1   |
|  |        | VACT3   |
|  | STCALL | VTIG    |
|  |        | ROTATE  |
|  | STORE  | VACT2   |
|  | STCALL | VACT1   |
|  |        | SUBEXIT |

# Page 676

# \*\*\*\*\* ROTATE \*\*\*\*\*

|        |        |        |
|--------|--------|--------|
|        | SETLOC | CDHTAG |
|        | BANK   |        |
| ROTATE | PUSH   | PUSH   |
|        | DOT    | VXSC   |
|        |        | UP1    |
|        |        | UP1    |
|        | VSL2   | BVSU   |
|        | UNIT   | PDVL   |
|        | ABVAL  | VXSC   |
|        | VSL1   | RVQ    |

# Page 677

# \*\*\*\*\* INTINTNA \*\*\*\*\*

|          |        |          |
|----------|--------|----------|
|          | SETLOC | CDHTAG2  |
|          | BANK   |          |
| INTINT2C | PDDL   | PDDL     |
|          |        | TCSI     |
|          |        | TCDH     |
|          | PDDL   | PUSH     |
|          |        | TWOPI    |
|          | GOTO   |          |
|          |        | INTINT   |
| INTINT3P | PDDL   | PDDL     |
|          |        | TCDH     |
|          |        | TTPI     |
|          | PDDL   | PUSH     |
|          |        | ZEROVECS |
|          | GOTO   |          |

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INTINT

```
# Page 678
# ***** S32/33.1 *****
#
# SUBROUTINES USED
#       S32/33.X
```

|          |        |          |
|----------|--------|----------|
|          | SETLOC | CSI/CDH  |
|          | BANK   |          |
| S32/33.1 | STQ    | AXT,1    |
|          |        | SUBEXIT  |
|          | VN     | 0681     |
|          | CALL   |          |
|          |        | DISDVLVC |
|          | CALL   |          |
|          |        | S32/33.X |
|          | VLOAD  | VXM      |
|          |        | DELVLVC  |
|          |        | OD       |
|          | VSL1   |          |
|          | STORE  | DELVSIN  |
|          | PUSH   | ABVAL    |
|          | STOVL  | DELVSAB  |
|          | GOTO   |          |
|          |        | SUBEXIT  |

```
# Page 679
# ***** S32/33.X *****
```

|          |        |         |
|----------|--------|---------|
|          | SETLOC | CDHTAGS |
|          | BANK   |         |
| S32/33.X | SETPD  | VLOAD   |
|          |        | 6D      |
|          |        | UP1     |
|          | VCOMP  | PDVL    |
|          |        | RACT1   |
|          | UNIT   | VCOMP   |
|          | PUSH   | VXV     |
|          |        | UP1     |
|          | VSL1   |         |
|          | STORE  | OD      |
|          | RVQ    |         |

```

# Page 680
# ***** CDHMVR *****
#
# SUBROUTINES USED
#      VECSHIFT
#      TIMETHET
#      SHIFTR1

```

```

                                SETLOC  CDHTAG
                                BANK
CDHMVR      STQ      VLOAD
                                SUBEXIT
                                RACT2
                                PUSH     UNIT
                                STOVL    UNVEC      # UR SUB A
                                RPASS2
                                UNIT     DOT
                                UNVEC
                                PUSH     SL1
                                STODL    CSTD
                                DSQ      PDDL
                                DP1/4
                                SR2     DSU
                                SQRT     SL1
                                PDVL     VCOMP
                                VXV
                                RPASS2
                                DOT      PDDL
                                UP1
                                SIGN     STADR
                                STOVL    SNTH
                                RPASS2
                                PDVL     CALL
                                VPASS2
                                VECSHIFT
                                STOVL    VVEC
                                CLEAR
                                RVSW
                                STCALL   RVEC
                                TIMETHET
                                LXA,2    VSL*
                                RTX2
                                0,2
                                STORE    18D
                                DOT      SL1R

```

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# Page 681

|       |         |                                        |                    |     |
|-------|---------|----------------------------------------|--------------------|-----|
|       | UNVEC   |                                        |                    |     |
| PDVL  | ABVAL   | # OD = V SUB PV                        |                    |     |
| SL*   | PDVL    |                                        |                    |     |
|       | 0,2     |                                        |                    |     |
|       | RACT2   |                                        |                    |     |
| ABVAL | PDDL    | # 2D = LENGTH OF R SUB A               |                    |     |
| DSU   |         |                                        |                    |     |
|       | O2D     |                                        |                    |     |
| STODL | DIFFALT | # DELTA H IN METERS                    | B+29               |     |
|       | R1A     |                                        |                    |     |
| NORM  | PDDL    | # 2 - R V**/MU                         |                    | 04D |
|       | X1      |                                        |                    |     |
|       | R1      |                                        |                    |     |
| CALL  |         |                                        |                    |     |
|       | SHIFTR1 |                                        |                    |     |
| SR1R  | DDV     |                                        |                    |     |
| SL*   | PUSH    |                                        |                    |     |
|       | 0 -5,1  |                                        |                    |     |
| DSU   | PDDL    | # A SUB A                              | B+29               | 04D |
|       | DIFFALT |                                        |                    |     |
| SR2   | DDV     | # A SUB P                              | B+31               |     |
|       | 04D     | #                                      | B+2                |     |
| PUSH  | SQRT    | # A SUB P/A SUB A                      |                    | 06D |
| DMPR  | DMP     |                                        |                    |     |
|       | 06D     |                                        |                    |     |
|       | 00D     |                                        |                    |     |
| SL3R  | PDDL    | # V SUB A V METERS/CS                  | B+7                | 08D |
|       | O2D     | # R SUB A MAGNITUDE                    | B+29               |     |
| NORM  | PDDL    |                                        |                    |     |
|       | X1      |                                        |                    |     |
|       | RTMU    |                                        |                    |     |
| SR1   | DDV     | # 2MU                                  | B+38               |     |
| SL*   | PDDL    | # 2 MU/R SUBAA                         | B+14               | 10D |
|       | 0 -5,1  |                                        |                    |     |
|       | 04D     | # ASUBA                                | B+29               |     |
| NORM  | PDDL    |                                        |                    |     |
|       | X2      |                                        |                    |     |
|       | RTMU    |                                        |                    |     |
| SR1   | DDV     |                                        |                    |     |
| SL*   | BDSU    |                                        |                    |     |
|       | 0 -6,2  | # 2U/R - U/A                           | B+14 (METERS/CS)SQ |     |
| PDDL  | DSQ     | #                                      |                    | 10D |
|       | 08D     |                                        |                    |     |
| BDSU  | SQRT    |                                        |                    |     |
| PDVL  | VXV     | # SQRT(MU(2/R SUB A-1/A SUB A)-VSUBA2) |                    | 10D |

```

                                UP1
                                UNVEC
                                UNIT  VXSC
                                10D
                                PDVL  VXSC
                                UNVEC
                                08D
                                VAD    VSL1
                                STADR
# Page 682
                                STORE  VACT3
                                VSU
                                VACT2
                                STCALL DELVEET2
                                SUBEXIT
# DELTA VCDH -- REFERENCE COORDINATES

# Page 683
# ***** COMPTGO *****
#
# SUBROUTINES USED
#     CLOKTASK
#     2PHSCHNG

                                BANK    35
                                SETLOC  CSI/CDH
                                BANK
                                EBANK=  RTRN
                                COUNT*  $$/P3575
```

This code is written to file `src/P32-P33-P72-P73.s`.



**A.70 P32-P35 P72-P75**

```

1097  <src/P32-P35-P72-P75.s 1097>≡
# Copyright:    Public domain.
# Filename:     P32-P35_P72-P75.agc
# Purpose:      Part of the source code for Luminary 1A build 099.
#              It is part of the source code for the Lunar Module's (LM)
#              Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:      Ron Burkey <info@sandroid.org>.
# Website:      www.ibiblio.org/apollo.
# Pages:        618-650
# Mod history:  2009-05-18 RSB   Adapted from the Luminary 131 file of the
#                               same name, as corrected from Luminary 099
#                               page images.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
#       16:27 JULY 14, 1969
#
# Page 618
# COELLIPTIC SEQUENCE INITIATION (CSI) PROGRAMS (P32 AND P72)
#
# MOD NO -1          LOG SECTION -- P32-P35, P72-P75
# MOD BY WHITE, P.   DATE 1 JUNE 67
#
# PURPOSE
#
#       (1)          TO CALCULATE PARAMETERS ASSOCIATED WITH THE TIME FOLLOWING
#                   CONCENTRIC FLIGHT PLAN MANEUVERS -- THE CO-ELLIPTIC SEQUENCE
#                   INITIATION (CSI) MANEUVER AND THE CONSTANT DELTA ALTITUDE
#                   (CDH) MANEUVER.
#
#       (2)          TO CALCULATE THESE PARAMETERS BASED UPON MANEUVER DATA
#                   APPROVED AND KEYED INTO THE DSKY BY THE ASTRONAUT.

```

# (3) TO DISPLAY TO THE ASTRONAUT AND THE GROUND DEPENDENT VARIABLES  
# ASSOCIATED WITH THE CONCENTRIC FLIGHT PLAN MANEUVERS FOR  
# APPROVAL BY THE ASTRONAUT/GROUND.

# (4) TO STORE THE CSI TARGET PARAMETERS FOR USE BY THE DESIRED  
# THRUSTING PROGRAM.

# ASSUMPTIONS

# (1) AT A SELECTED TPI TIME THE LINE OF SIGHT BETWEEN THE ACTIVE  
# AND PASSIVE VEHICLES IS SELECTED TO BE A PRESCRIBED ANGLE (E)  
# FROM THE HORIZONTAL PLANE DEFINED BY THE ACTIVE VEHICLE  
# POSITION.

# (2) THE TIME BETWEEN CSI IGNITION AND CDH IGNITION MUST BE  
# COMPUTED TO BE GREATER THAN 10 MINUTES FOR SUCCESSFUL  
# COMPLETION OF THE PROGRAM.

# (3) THE TIME BETWEEN CDH IGNITION AND TPI IGNITION MUST BE  
# COMPUTED TO BE GREATER THAN 10 MINUTES FOR SUCCESSFUL  
# COMPLETION OF THE PROGRAM.

# (4) CDH DELTA V IS SELECTED TO MINIMIZE THE VARIATION OF THE  
# ALTITUDE DIFFERENCE BETWEEN THE ORBITS.

# (5) CSI BURN IS DEFINED SUCH THAT THE IMPULSIVE DELTA V IS IN THE  
# HORIZONTAL PLANE DEFINED BY THE ACTIVE VEHICLE POSITION AT CSI  
# IGNITION.

# (6) THE PERICENTER ALTITUDE OF THE ORBIT FOLLOWING CSI AND CDH  
# MUST BE GREATER THAN 35,000 FT (LUNAR ORBIT) OR 85 NM (EARTH  
# ORBIT) FOR SUCCESSFUL COMPLETION OF THIS PROGRAM.

# (7) THE CSI AND CDH MANEUVERS ARE ORIGINALLY ASSUMED TO BE  
# PARALLEL TO THE PLANE OF THE CSM ORBIT. HOWEVER, CREW

# Page 619

# MODIFICATION OF DELTA V (LV) COMPONENTS MAY RESULT IN AN  
# OUT-OF-PLANE CSI MANEUVER

# (8) STATE VECTOR UPDATES BY P27 ARE DISALLOWED DURING AUTOMATIC  
# STATE VECTOR UPDATING INITIATED BY P20 (SEE ASSUMPTION 10).

# (9) COMPUTED VARIABLES MAY BE STORED FOR LATER VERIFICATION BY  
# THE GROUND. THESE STORAGE CAPABILITIES ARE NORMALLY LIMITED  
# ONLY TO THE PARAMETERS FOR ONE THRUSTING MANEUVER AT A TIME

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```
#          EXCEPT FOR CONCENTRIC FLIGHT PLAN MANEUVER SEQUENCES.

#      (10)  THE RENDEZVOUS RADAR MAY OR MAY NOT BE USED TO UPDATE THE LM
#            OR CSM STATE VECTORS FOR THIS PROGRAM.  IF RADAR USE IS
#            DESIRED THE RADAR WAS TURNED ON AND LOCKED BY THE CSM BY
#            PREVIOUS SELECTION OF P20.  RADAR SIGHTING MARKS WILL BE MADE
#            AUTOMATICALLY APPROXIMATELY ONCE A MINUTE WHEN ENABLED BY THE
#            TRACK AND UPDATE FLAGS (SEE P20).  THE RENDEZVOUS TRACKING
#            MARK COUNTER IS ZEROED BY THE SELECTION OF P20 AND AFTER EACH
#            THRUSTING MANEUVER.

#      (11)  THE ISS NEED NOT BE ON TO COMPLETE THIS PROGRAM.

#      (12)  THE OPERATION OF THE PROGRAM UTILIZES THE FOLLOWING FLAGS --
#
#            ACTIVE VEHICLE FLAG -- DESIGNATES THE VEHICLE WHICH IS
#            DOING RENDEZVOUS THRUSTING MANEUVERS TO THE PROGRAM WHICH
#            CALCULATES THE MANEUVER PARAMETERS.  SET AT THE START OF
#            EACH RENDEZVOUS PRE-THRUSTING PROGRAM.
#
#            FINAL FLAG -- SELECTS FINAL PROGRAM DISPLAYS AFTER CREW HAS
#            COMPLETED THE FINAL MANEUVER COMPUTATION AND DISPLAY
#            CYCLE.
#
#            EXTERNAL DELTA V STEERING FLAG -- DESIGNATES THE TYPE OF
#            STEERING REQUIRED FOR EXECUTION OF THIS MANEUVER BY THE
#            THRUSTING PROGRAM SELECTED AFTER COMPLETION OF THIS
#            PROGRAM.

#      (13)  IT IS NORMALLY REQUIRED THAT THE ISS BE ON FOR 1 HOUR PRIOR TO
#            A THRUSTING MANEUVER.

#      (14)  THIS PROGRAM IS SELECTED BY THE ASTRONAUT BY DSKY ENTRY
#
#            P32 IF THIS VEHICLE IS ACTIVE VEHICLE.
#
#            P72 IF THIS VEHICLE IS THE PASSIVE VEHICLE.
#
# INPUT

#      (1)   TCSI          TIME OF THE CSI MANEUVER

# Page 620
#      (2)   NN           NUMBER OF APSIDAL CROSSINGS THRU WHICH THE ACTIVE
#            VEHICLE ORBIT CAN BE ADVANCED TO OBTAIN THE CDH
#            MANEUVER POINT.
```

```

#      (3)      ELEV      DESIRED LOS ANGLE AT TPI
#      (4)      TTPI      TIME OF THE TPI MANEUVER
#
# OUTPUT
#
#      (1)      TRKMKCNT   NUMBER OF MARKS
#      (2)      TTOGO      TIME TO GO
#      (3)      +MGA       MIDDLE GIMBAL ANGLE
#      (4)      DIFFALT    DELTA ALTITUDE AT CDH
#      (5)      T1TOT2     DELTA TIME FROM CSI TO CDH
#      (6)      T2TOT3     DELTA TIME FROM CDH TO TPI
#      (7)      DELVLVC    DELTA VELOCITY AT CSI -- LOCAL VERTICAL COORDINATES
#      (8)      DELVLVC    DELTA VELOCITY AT CDH -- LOCAL VERTICAL COORDINATES
#
# DOWNLINK
#
#      (1)      TCSI       TIME OF THE CSI MANEUVER
#      (2)      TCDH       TIME OF THE CDH MANEUVER
#      (3)      TTPI       TIME OF THE TPI MANEUVER
#      (4)      TIG        TIME OF THE CSI MANEUVER
#      (5)      DELVEET1   DELTA VELOCITY AT CSI -- REFERENCE COORDINATES
#      (6)      DELVEET2   DELTA VELOCITY AT CDH -- REFERENCE COORDINATES
#      (7)      DIFFALT    DELTA ALTITUDE AT CDH
#      (8)      NN         NUMBER OF APSIDAL CROSSINGS THRU WHICH THE ACTIVE
#                          VEHICLE ORBIT CAN BE ADVANCED TO OBTAIN THE CDH
#                          MANEUVER POINT
#      (9)      ELEV       DESIRED LOS ANGLE AT TPI
#
# COMMUNICATION TO THRUSTING PROGRAM
#
#      (1)      TIG        TIME OF THE CSI MANEUVER
#      (2)      RTIG       POSITION OF ACTIVE VEHICLE AT CSI -- BEFORE ROTATION
#                          INTO PLANE OF PASSIVE VEHICLE
#      (3)      VTIG       VELOCITY OF ACTIVE VEHICLE AT CSE -- BEFORE ROTATION
#                          INTO PLANE OF PASSIVE VEHICLE
#      (4)      DELVSIN    DELTA VELOCITY AT CSI -- REFERENCE COORDINATES
#      (5)      DELVSAB    MAGNITUDE OF DELTA VELOCITY AT CSI
#      (6)      XDELVFLG   SET TO INDICATE EXTERNAL DELTA V VG COMPUTATION
#
# SUBROUTINES USED
#
#      AVFLAGA
#      AVFLAGP
#      P20FLGON
#      VARALARM
#      BANKCALL

```

```

#      GOFLASH
#      GOTOP00H
# Page 621
#      VNPO0H
#      GOFLASHR
#      BLANKET
#      ENDOFJOB
#      SELECTMU
#      ADVANCE
#      INTINT
#      PASSIVE
#      CSI/A
#      S32/33.1
#      DISDVLVC
#      VN1645

```

```

#      BANK      35
#      SETLOC    CSI/CDH
#      BANK
#      EBANK=     SUBEXIT
#      COUNT*    $$/P3272
P32      TC      AVFLAGA
#      TC      P32STRT
P72      TC      AVFLAGP
P32STRT  EXTEND
#      DCA      P30ZERO
#      DXCH     CENTANG
#      TC      P32/P72A
ALMXITA  SXA,2
#      CSIALRM
ALMXIT   LXC,1
#      CSIALRM
#      SLOAD*   EXIT
#      ALARM/TB -1,1
#      CA      MPAC
#      TC      VARALARM
#      CAF     V05N09
#      TC      BANKCALL
#      CADR    GOFLASH
#      TC      GOTOP00H
#      TC      -4
P32/P72A TC      P20FLGON
#      CAF     P30ZERO
#      TS      NN      +1
#      TS      TCSI
#      TS      TCSI    +1

```

|            |        |           |                   |
|------------|--------|-----------|-------------------|
| VN0611     | CAF    | V06N11    | # TCSI            |
|            | TC     | VNP00H    |                   |
|            | TC     | INTPRET   |                   |
|            | DLOAD  | DCOMP     |                   |
|            |        | TCSI      |                   |
|            | BMN    | DLOAD     |                   |
|            |        | VN0655    |                   |
| # Page 622 |        | TETLEM    |                   |
|            | STCALL | TDEC1     |                   |
|            |        | PRECSET   |                   |
|            | VLOAD  | VSR*      |                   |
|            |        | RACT3     |                   |
|            |        | 0,2       |                   |
|            | STOVL  | RVEC      |                   |
|            |        | VACT3     |                   |
|            | VSR*   | SET       |                   |
|            |        | 0,2       |                   |
|            |        | RVSW      |                   |
|            | STODL  | VVEC      |                   |
|            |        | DPPOS MAX |                   |
|            | STCALL | RDESIRED  |                   |
|            |        | TIMERAD   |                   |
|            | DAD    |           |                   |
|            |        | TDEC2     |                   |
|            | STORE  | TCSI      |                   |
|            | EXIT   |           |                   |
|            | TC     | VN0611    |                   |
| VN0655     | EXIT   |           |                   |
|            | CAF    | V06N55    | # NN, ELEV(RGLOS) |
|            | TC     | BANKCALL  |                   |
|            | CADR   | GOFLASH   |                   |
|            | TC     | GOTOP00H  |                   |
|            | TC     | +2        |                   |
|            | TC     | -5        |                   |
|            | CAF    | V06N37    | # TTPI            |
|            | TC     | VNP00H    |                   |
|            | TC     | INTPRET   |                   |
|            | DLOAD  |           |                   |
|            |        | TCSI      |                   |
|            | STCALL | TIG       |                   |
|            |        | SELECTMU  |                   |
| P32/P72B   | CALL   |           |                   |
|            |        | ADVANCE   |                   |
|            | SETPD  | VLOAD     |                   |
|            |        | OD        |                   |

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|            |       |          |
|------------|-------|----------|
|            |       | VPASS1   |
|            | PDVL  | PDDL     |
|            |       | RPASS1   |
|            |       | TCSI     |
|            | PDDL  | PDDL     |
|            |       | TTPI     |
|            |       | TWOPI    |
|            | PUSH  | CALL     |
|            |       | INTINT   |
|            | CALL  |          |
|            |       | PASSIVE  |
|            | CALL  |          |
| # Page 623 |       |          |
|            |       | CSI/A    |
| P32/P72C   | BON   | SET      |
|            |       | FINALFLG |
|            |       | P32/P72D |
|            |       | UPDATFLG |
| P32/P72D   | DLOAD |          |
|            |       | T1TOT2   |
| P32/P72E   | STORE | T1TOT2   |
|            | DSU   | BPL      |
|            |       | 60MIN    |
|            |       | P32/P72E |
|            | DLOAD |          |
|            |       | T2TOT3   |
| P32/P72F   | STORE | T2TOT3   |
|            | DSU   | BPL      |
|            |       | 60MIN    |
|            |       | P32/P72F |
|            | EXIT  |          |
|            | CAF   | V06N75   |
|            | TC    | VNP00H   |
|            | TC    | INTPRET  |
|            | VLOAD | CALL     |
|            |       | DELVEET1 |
|            |       | S32/33.1 |
|            | STOVL | DELVEET1 |
|            |       | RACT2    |
|            | STOVL | RACT1    |
|            |       | DELVEET2 |
|            | AXT,1 | CALL     |
|            | VN    | 0682     |
|            |       | DISDVLVC |
|            | DLOAD |          |
|            |       | TTPI     |

STCALL TPIO  
VN1645  
GOTO  
P32/P72B

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# CONSTANT DELTA HEIGHT (CDH) PROGRAMS (P33 AND P73)

# MOD NO -1 LOC SECTION -- P32-P35, P72-P75

# MOD BY WHITE, P. DATE: 1 JUNE 67

#

# PURPOSE

#

# (1) TO CALCULATE PARAMETERS ASSOCIATED WITH THE CONSTANT DELTA  
# ALTITUDE MANEUVER (CDH).

#

# (2) TO CALCULATE THESE PARAMETERS BASED UPON MANEUVER DATA  
# APPROVED AND KEYED INTO THE DSKY BY THE ASTRONAUT.

#

# (3) TO DISPLAY TO THE ASTRONAUT AND THE GROUND DEPENDENT VARIABLES  
# ASSOCIATED WITH THE CDH MANEUVER FOR APPROVAL BY THE  
# ASTRONAUT/GROUND.

#

# (4) TO STORE THE CDH TARGET PARAMETERS FOR USE BY THE DESIRED  
# THRUSTING PROGRAM.

#

# ASSUMPTIONS

#

# (1) THIS PROGRAM IS BASED UPON PREVIOUS COMPLETION OF THE  
# CO-ELLIPTIC SEQUENCE INITIATION (CSI) PROGRAM (P32/P72).  
# THEREFORE --

#

# (A) AT A SELECTED TPI TIME (NOW IN STORAGE) THE LINE OF SIGHT  
# BETWEEN THE ACTIVE AND PASSIVE VEHICLES WAS SELECTED TO BE  
# A PRESCRIBED ANGLE (E) (NOW IN STORAGE) FROM THE  
# HORIZONTAL PLANE DEFINED BY THE ACTIVE VEHICLE POSITION.

#

# (B) THE TIME BETWEEN CSI IGNITION AND CDH IGNITION WAS  
# COMPUTED TO BE GREATER THAN 10 MINUTES.

#

# (C) THE TIME BETWEEN CDH IGNITION AND TPI IGNITION WAS  
# COMPUTED TO BE GREATER THAN 10 MINUTES.

#

# (D) THE VARIATION OF THE ALTITUDE DIFFERENCE BETWEEN THE  
# ORBITS WAS MINIMIZED.

#

# (E) CSI BURN WAS DEFINED SUCH THAT THE IMPULSIVE DELTA V WAS



# IN THE HORIZONTAL PLANE DEFINED BY ACTIVE VEHICLE  
# POSITION AT CSI IGNITION.  
#  
# (F) THE PERICENTER ALTITUDES OF THE ORBITS FOLLOWING CSI AND  
# CDH WERE COMPUTED TO BE GREATER THAN 35,000 FT FOR LUNAR  
# ORBIT OR 85 NM FOR EARTH ORBIT.  
#  
# (G) THE CSI AND CDH MANEUVERS WERE ASSUMED TO BE PARALLEL TO  
# THE PLANE OF THE PASSIVE VEHICLE ORBIT. HOWEVER, CREW  
# Page 625  
# MODIFICATION OF DELTA V (LV) COMPONENTS MAY HAVE RESULTED  
# IN AN OUT-OF-PLANE MANEUVER.  
#  
# (2) STATE VECTOR UPDATES BY P27 ARE DISALLOWED DURING AUTOMATIC  
# STATE VECTOR UPDATING INITIATED BY P20 (SEE ASSUMPTION 4).  
#  
# (3) COMPUTED VARIABLES MAY BE STORED FOR LATER VERIFICATION BY  
# THE GROUND. THESE STORAGE CAPABILITIES ARE NORMALLY LIMITED  
# ONLY TO THE PARAMETERS FOR ONE THRUSTING MANEUVER AT A TIME  
# EXCEPT FOR CONCENTRIC FLIGHT PLAN MANEUVER SEQUENCES.  
#  
# (4) THE RENDEZVOUS RADAR MAY OR MAY NOT BE USED TO UPDATE THE LM.  
# OR CSM STATE VECTORS FOR THIS PROGRAM. IF RADAR USE IS  
# DESIRED THE RADAR WAS TURNED ON AND LOCKED ON THE CSM BY  
# PREVIOUS SELECTION OF P20. RADAR SIGHTING MARKS WILL BE MADE  
# AUTOMATICALLY APPROXIMATELY ONCE A MINUTE WHEN ENABLED BY THE  
# TRACK AND UPDATE FLAGS (SEE P20). THE RENDEZVOUS TRACKING  
# MARK COUNTER IS ZEROED BY THE SELECTION OF P20 AND AFTER EACH  
# THRUSTING MANEUVER.  
#  
# (5) THE ISS NEED NOT BE ON TO COMPLETE THIS PROGRAM.  
#  
# (6) THE OPERATION OF THE PROGRAM UTILIZES THE FOLLOWING FLAGS --  
#  
# ACTIVE VEHICLE FLAG -- DESIGNATES THE VEHICLE WHICH IS  
# DOING RENDEZVOUS THRUSTING MANEUVERS TO THE PROGRAM WHICH  
# CALCULATES THE MANEUVER PARAMETERS. SET AT THE START OF  
# EACH RENDEZVOUS PRE-THRUSTING PROGRAM.  
#  
# FINAL FLAG -- SELECTS FINAL PROGRAM DISPLAYS AFTER CREW HAS  
# COMPLETED THE FINAL MANEUVER COMPUTATION AND DISPLAY  
# CYCLE.  
#  
# EXTERNAL DELTA V STEERING FLAG -- DESIGNATES THE TYPE OF  
# STEERING REQUIRED FOR EXECUTION OF THIS MANEUVER BY THE  
# THRUSTING PROGRAM SELECTED AFTER COMPLETION OF THIS

```

#                               PROGRAM.
#
#      (7)      IT IS NORMALLY REQUIRED THAT THE ISS BE ON FOR 1 HOUR PRIOR TO
#               A THRUSTING MANEUVER.
#
#      (8)      THIS PROGRAM IS SELECTED BY THE ASTRONAUT BY DSKY ENTRY.
#
#               P33 IF THIS VEHICLE IS ACTIVE VEHICLE.
#
#               P73 IF THIS VEHICLE IS PASSIVE VEHICLE.
#
# INPUT
#
#      (1)      TTPIO    TIME OF THE TPI MANEUVER -- SAVED FROM P32/P72
# Page 626
#      (2)      ELEV     DESIRED LOS ANGLE AT TPI -- SAVED FROM P32/P72
#      (3)      TCDH     TIME OF THE CDH MANEUVER
#
# OUTPUT
#
#      (1)      TRKMKCNT  NUMBER OF MARKS
#      (2)      TTOGO     TIME TO GO
#      (3)      +MGA      MIDDLE GIMBAL ANGLE
#      (4)      DIFFALT   DELTA ALTITUDE AT CDH
#      (5)      T2TOT3    DELTA TIME FROM CDH TO COMPUTED TPI
#      (6)      NOMTPI    DELTA TIME FROM NOMINAL TPI TO COMPUTED TPI
#      (7)      DELVLVC   DELTA VELOCITY AT CDH -- LOCAL VERTICAL COORDINATES
#
# DOWNLINK
#
#      (1)      TCDH      TIME OF THE CDH MANEUVER
#      (2)      TTPI      TIME OF THE TPI MANEUVER
#      (3)      TIG       TIME OF THE CDH MANEUVER
#      (4)      DELLVEET2 DELTA VELOCITY AT CDH -- REFERENCE COORDINATES
#      (5)      DIFFALT   DELTA ALTITUDE AT CDH
#      (6)      ELEV      DESIRED LOS ANGLE AT TPI
#
# COMMUNICATION TO THRUSTING PROGRAMS
#
#      (1)      TIG       TIME OF THE CDH MANEUVER
#      (2)      RTIG      POSITION OF ACTIVE VEHICLE AT CDH -- BEFORE ROTATION
#               INTO PLANE OF PASSIVE VEHICLE.
#      (3)      VTIG      VELOCITY OF ACTIVE VEHICLE AT CDH -- BEFORE ROTATION
#               INTO PLANE OF PASSIVE VEHICLE.
#      (4)      DELVSIN   DELTA VELOCITY AT CDH -- REFERENCE COORDINATES.
#      (5)      DELVSAB   MAGNITUDE OF DELTA VELOCITY AT CDH.

```

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# (6) XDELVFLG SET TO INDICATE EXTERNAL DELTA V VG COMPUTATION.

#

# SUBROUTINES USED

#

# AVFLAGA

# AVFLAGP

# P20FLGON

# VNPOOH

# SELECTMU

# ADVANCE

# CDHMVR

# INTINT3P

# ACTIVE

# PASSIVE

# S33/S34.1

# ALARM

# BANKCALL

# GOFLASH

# GOTOP00H

# S32/33.1

# Page 627

# VN1645

|          |        |            |        |
|----------|--------|------------|--------|
|          | COUNT* | \$\$/P3373 |        |
| P33      | TC     | AVFLAGA    |        |
|          | TC     | P33/P73A   |        |
| P73      | TC     | AVFLAGP    |        |
| P33/P73A | TC     | P20FLGON   |        |
|          | CAF    | V06N13     | # TCDH |
|          | TC     | VNPOOH     |        |
|          | TC     | INTPRET    |        |
|          | DLOAD  |            |        |
|          |        | TTPIO      |        |
|          | STODL  | TTPI       |        |
|          |        | TCDH       |        |
|          | STCALL | TIG        |        |
|          |        | SELECTMU   |        |
| P33/P73B | CALL   |            |        |
|          |        | ADVANCE    |        |
|          | CALL   |            |        |
|          |        | CDHMVR     |        |
|          | SETPD  | VLOAD      |        |
|          |        | OD         |        |
|          |        | VACT3      |        |
|          | PDVL   | CALL       |        |
|          |        | RACT2      |        |

|            |        |          |
|------------|--------|----------|
|            |        | INTINT3P |
|            | CALL   | ACTIVE   |
|            | SETPD  | VLOAD    |
|            |        | OD       |
|            |        | VPASS2   |
|            | PDVL   | CALL     |
|            |        | RPASS2   |
|            |        | INTINT3P |
|            | CALL   | PASSIVE  |
|            | DLOAD  | SET      |
|            |        | P30ZERO  |
|            |        | ITSWICH  |
|            | STCALL | NOMTPI   |
|            |        | S33/34.1 |
|            | BZE    | EXIT     |
|            |        | P33/P73C |
|            | TC     | ALARM    |
|            | OCT    | 611      |
|            | CAF    | V05N09   |
|            | TC     | BANKCALL |
|            | CADR   | GOFLASH  |
|            | TC     | GOTOP00H |
|            | TC     | +2       |
| # Page 628 |        |          |
|            | TC     | P33/P73A |
|            | TC     | INTPRET  |
|            | DLOAD  |          |
|            |        | P30ZERO  |
|            | STORE  | NOMTPI   |
| P33/P73C   | BON    | SET      |
|            |        | FINALFLG |
|            |        | P33/P73D |
|            |        | UPDATFLG |
| P33/P73D   | DLOAD  | DAD      |
|            |        | NOMTPI   |
|            |        | TTPI     |
|            | STORE  | TTPI     |
|            | DSU    |          |
|            |        | TCDH     |
| P33/P73E   | DSU    | BPL      |
|            |        | 60MIN    |
|            |        | P33/P73E |
|            | DAD    |          |
|            |        | 60MIN    |

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```

                                STODL  T1TOT2
                                TTPI
                                DSU    PUSH
                                TTPIO
P33/P73F  ABS    DSU
                                60MIN
                                BPL    DAD
                                P33/P73F
                                60MIN
                                SIGN   STADR
                                STORE  T2TOT3
                                EXIT
                                CAF    V06N75
                                TC      VNP00H
                                TC      INTPRET
                                VLOAD  CALL
                                DELVEET2
                                S32/33.1
                                STCALL DELVEET2
                                VN1645
                                GOTO
                                P33/P73B
```

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# \*\*\*\*\* ADFLAG/P \*\*\*\*\*

#

# SUBROUTINES USED

#

# UPFLAG

# DOWNFLAG

```

AVFLAGA      EXTEND                # AVFLAG = LEM
              QXCH  SUBEXIT
              TC    UPFLAG
              ADRES AVFLAG
              TC    SUBEXIT
AVFLAGP      EXTEND                # AVFLAG = CSM
              QXCH  SUBEXIT
              TC    DOWNFLAG
              ADRES AVFLAG
              TC    SUBEXIT
P20FLGON     EXTEND
              QXCH  SUBEXIT
              TC    UPFLAG
              ADRES UPDATFLG        # SET UPDATFLG
              TC    UPFLAG
```

|  |       |          |                |
|--|-------|----------|----------------|
|  | ADRES | TRACKFLG | # SET TRACKFLG |
|  | TC    | SUBEXIT  |                |

# Page 630

# \*\*\*\*\* DISDVLVC \*\*\*\*\*

#

# SUBROUTINES USED

#

# S32/33.X

# VNPOOH

  

|          |       |          |  |
|----------|-------|----------|--|
| DISDVLVC | STORE | DELVLVC  |  |
|          | STQ   | CALL     |  |
|          |       | NORMEX   |  |
|          |       | S32/33.X |  |
|          | VLOAD | MXV      |  |
|          |       | DELVLVC  |  |
|          |       | OD       |  |
|          | VSL1  | SXA,1    |  |
|          |       | VERBNOUN |  |
|          | STORE | DELVLVC  |  |
|          | EXIT  |          |  |
|          | CA    | VERBNOUN |  |
|          | TC    | VNPOOH   |  |
|          | TC    | INTPRET  |  |
|          | GOTO  |          |  |
|          |       | NORMEX   |  |

# Page 631

# \*\*\*\*\* CONSTANTS \*\*\*\*\*

  

|          |      |             |        |
|----------|------|-------------|--------|
| V06N11   | VN   | 0611        |        |
| V06N13   | VN   | 0613        |        |
| V06N75   | VN   | 0675        |        |
| SN359+   | 2DEC | -.000086601 |        |
| CS359+   | 2DEC | +.499999992 |        |
| P30ZERO  | 2DEC | 0           |        |
| 60MIN    | 2DEC | 360000      |        |
| ALARM/TB | OCT  | 00600       | # NO 1 |
|          | OCT  | 00601       | # 2    |
|          | OCT  | 00602       | # 3    |
|          | OCT  | 00603       | # 4    |

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|     |       |   |   |
|-----|-------|---|---|
| OCT | 00604 | # | 5 |
| OCT | 00605 | # | 6 |
| OCT | 00606 | # | 7 |

# Page 632

# \*\*\*\*\* CSI/A \*\*\*\*\*

#

# SUBROUTINES USED

#

# VECSHIFT

# TIMETHET

# PERIAPO

# SHIFTR1

# INTINT2C

# CDHMVR

# PERIAPO1

# INTINT

# ACTIVE

|          |        |              |                                           |
|----------|--------|--------------|-------------------------------------------|
|          | BANK   | 34           |                                           |
|          | SETLOC | CSI/CDH1     |                                           |
|          | BANK   |              |                                           |
|          | EBANK= | SUBEXIT      |                                           |
|          | COUNT* | \$\$/CSI     |                                           |
| LOOPMX   | 2DEC   | 16           |                                           |
| INITST   | 2DEC   | .03048 B-7   | # INITIAL DELDV = 10 FPS                  |
| DVMAX1   | 2DEC   | 3.0480 B-7   | # MAXIMUM DV1 = 1000 FPS                  |
| DVMAX2   | 2DEC   | 3.014472 B-7 | # 989 FPS                                 |
| 1DPB2    | 2DEC   | 1.0 B-2      |                                           |
| 1DPB28   | 2DEC   | 1            |                                           |
| PMINE    | 2DEC   | 157420 B-29  | # 85 NM -- MUST BE 8 WORDS BEFORE PMINM   |
| EPSILN1  | 2DEC   | .0003048 B-7 | # .1 FPS                                  |
| NICKELDP | 2DEC   | .021336 B-7  | # 7 FPS (CHANGED FROM .05 FPS)            |
| FIFPSDP  | 2DEC   | -.152400 B-7 | # 50 FPS                                  |
| PMINM    | 2DEC   | 10668 B-29   | # 35000 FT -- MUST BE 8 WORDS AFTER PMINE |

|            |       |              |                                             |                   |
|------------|-------|--------------|---------------------------------------------|-------------------|
| DELMAX1    | 2DEC  | .6096000 B-7 | # 200 FPS                                   |                   |
| ONETHTH    | 2DEC  | .0001 B-3    |                                             |                   |
| TMIN       | 2DEC  | 60000        | # 10 MIN                                    |                   |
| CSI/A      | CLEAR | SET          | # INITIALIZE INDICATORS                     |                   |
|            |       | S32.1F1      | # DVT1 HAS EXCEEDED MAX INDICATOR           |                   |
|            |       | S32.1F2      | # FIRST PASS FOR NEWTON ITERATION INDICATOR |                   |
| # Page 633 |       |              |                                             |                   |
|            | CLEAR | SET          |                                             |                   |
|            |       | S32.1F3A     | # 00=1ST 2 PASSES 2ND CYCLE, 01=FIRST CYCLE |                   |
|            |       | S32.1F3B     | # 10=2ND CYCLE, 11=50 FPS STAGE 2ND CYCLE   |                   |
|            | DLOAD | P30ZERO      |                                             |                   |
|            | STORE | LOOPCT       |                                             |                   |
|            | STORE | CSIALRM      |                                             |                   |
| CSI/B      | SETPD | VLOAD        |                                             |                   |
|            |       | OD           |                                             |                   |
|            |       | RACT1        |                                             |                   |
|            | ABVAL | PUSH         | # RA1                                       | B29 PL02D         |
|            | NORM  | SR1          |                                             |                   |
|            |       | X2           | #                                           | B29-N2+ B1 PL04D  |
|            | PDVL  | ABVAL        |                                             |                   |
|            |       | RPASS3       |                                             |                   |
|            | NORM  | BDDV         | # RA1/RP3                                   | B1 PL02D          |
|            |       | X1           |                                             |                   |
|            | XSU,2 | SR*          | #                                           | B2                |
|            |       | X1           |                                             |                   |
|            |       | 1,2          |                                             |                   |
|            | DAD   | DMP          | # (1+(RA1/RP3))RA1                          | B29+B2=B31 PL00D  |
|            |       | 1DPB2        |                                             |                   |
|            | NORM  | PDDL         | #                                           | PL02D             |
|            |       | X1           |                                             |                   |
|            |       | RTMU         |                                             |                   |
|            | SR1   | DDV          | #                                           | B38-B31= B7 PL00D |
|            | SL*   | SQRT         | #                                           | B7                |
|            |       | 0            | -7,1                                        |                   |
|            | PDVL  | UNIT         | #                                           | PL02D             |
|            |       | RACT1        |                                             |                   |
|            | PDVL  | VXV          |                                             |                   |
|            |       | UP1          |                                             |                   |
|            | UNIT  |              | # UNIT(URP1 X UVP1 X URA1) = UH1            |                   |
|            | DOT   | SL1          | # VA1 . UH1                                 | B7                |
|            |       | VACT1        |                                             |                   |
|            | BDSU  | STADR        | #                                           | PL00D             |



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|            |       |          |                                   |
|------------|-------|----------|-----------------------------------|
|            | STODL | DELVCSI  |                                   |
|            |       | INITST   | # 10 FPS                          |
|            | STORE | DELDV    |                                   |
| CSI/B1     | DLOAD | DAD      | # IF LOOPCT = 16                  |
|            |       | LOOPCT   |                                   |
|            |       | 1DPB28   |                                   |
|            | STORE | LOOPCT   |                                   |
|            | DSU   | AXT,2    |                                   |
|            |       | LOOPMX   |                                   |
|            |       | 6        |                                   |
|            | BPL   |          |                                   |
|            |       | SCNDSOL  |                                   |
| CSI/B2     | SETPD |          |                                   |
|            |       | OD       |                                   |
| # Page 634 |       |          |                                   |
|            | DLOAD | ABS      |                                   |
|            |       | DELVCSI  |                                   |
|            | DSU   | BMN      |                                   |
|            |       | DVMAX1   |                                   |
|            |       | CSI/B23  |                                   |
|            | AXT,2 | BON      |                                   |
|            |       | 7        |                                   |
|            |       | S32.1F1  |                                   |
|            |       | SCNDSOL  |                                   |
|            | BOFF  | BON      |                                   |
|            |       | S32.1F3A |                                   |
|            |       | CSI/B22  | # FLAG 3 NEQ 3                    |
|            |       | S32.1F3B |                                   |
|            |       | SCNDSOL  |                                   |
| CSI/B22    | SET   | DLOAD    |                                   |
|            |       | S32.1F1  |                                   |
|            |       | DVMAX2   |                                   |
|            | SIGN  |          |                                   |
|            |       | DELVCSI  |                                   |
|            | STORE | DELVCSI  |                                   |
| CSI/B23    | VLOAD | PUSH     |                                   |
|            |       | RACT1    |                                   |
|            | UNIT  | PDVL     |                                   |
|            |       | UP1      |                                   |
|            | VXV   | UNIT     | # UNIT (URP1 X UVP1 X URA1) = UH1 |
|            | VXSC  | VSL1     |                                   |
|            |       | DELVCSI  |                                   |
|            | STORE | DELVEET1 |                                   |
|            | VAD   | BOV      |                                   |
|            |       | VACT1    |                                   |
|            |       | CSI/B23D |                                   |

|            |        |          |                |             |
|------------|--------|----------|----------------|-------------|
| CSI/B23D   | STCALL | VACT4    |                |             |
|            |        | VECSHIFT |                |             |
|            | STOVL  | VVEC     |                |             |
|            | SET    |          |                |             |
|            |        | RVS      |                |             |
|            | STOVL  | RVEC     |                |             |
|            |        | SN359+   |                |             |
|            | STCALL | SNTH     | # ALSO C       | STH         |
|            |        | TIMETHET |                |             |
|            | SR1    | LXA,1    |                |             |
|            |        | RTX1     |                |             |
|            | STCALL | HAFPA1   |                |             |
|            |        | PERIAPO  |                |             |
|            | CALL   |          |                |             |
|            |        | SHIFTR1  |                |             |
|            | STODL  | POSTCSI  |                |             |
|            |        | CENTANG  |                |             |
|            | BZE    | GOTO     |                |             |
|            |        | +2       |                |             |
| # Page 635 |        |          |                |             |
|            |        | CIRCL    |                |             |
|            | DLOAD  |          |                |             |
|            |        | ECC      |                |             |
|            | DSU    | BMN      |                |             |
|            |        | ONETHTH  |                |             |
|            |        | CIRCL    |                |             |
|            | DLOAD  | CALL     |                |             |
|            |        | R1       |                |             |
|            |        | SHIFTR1  |                |             |
|            | SETPD  | NORM     |                |             |
|            |        | 2D       |                |             |
|            |        | X1       |                |             |
|            | PDVL   | DOT      | #              | PL04        |
|            |        | RACT1    |                |             |
|            |        | VACT4    |                |             |
|            | ABS    | DDV      |                |             |
|            |        | 02D      | # (/RDOTV/)/R1 | B38-B29= B7 |
|            | SL*    | DSU      |                |             |
|            |        | 0,1      |                |             |
|            |        | NICKELDP |                |             |
|            | BMN    | DLOAD    |                |             |
|            |        | CIRCL    |                |             |
|            |        | P        |                |             |
|            | SL2    | DSU      |                |             |
|            |        | 1DPB2    |                |             |
|            | STODL  | 14D      |                |             |

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|            |        |          |                          |                       |
|------------|--------|----------|--------------------------|-----------------------|
|            |        | RTSR1/MU |                          |                       |
|            | SR1    | DDV      | # (1/ROOTMU)/R1          | B-16-B29 = B-45 PL02D |
|            | PDDL   | DMP      |                          |                       |
|            |        | P        |                          |                       |
|            |        | R1       |                          |                       |
|            | CALL   |          |                          |                       |
|            |        | SHIFTR1  |                          |                       |
|            | SL4    | SL1      |                          |                       |
|            | SQRT   | DMP      | # ((P/MU)**.5)/R1        | B14+B-14 = B-31 PL02D |
|            | BOFF   | SL3      |                          |                       |
|            |        | CMOONFLG |                          |                       |
|            |        | CSI/B3   |                          |                       |
| CSI/B3     | PDVL   | DOT      |                          |                       |
|            |        | RACT1    |                          |                       |
|            |        | VACT4    |                          |                       |
|            | STORE  | RDOTV    |                          |                       |
|            | ABS    |          |                          |                       |
|            | NORM   | DMP      | # ((P/MU)**.5)RDOTV/R1   | PL02D                 |
|            |        | X2       |                          |                       |
|            | XSU,1  | SL*      | #                        | B-31+B36-B3 = B2      |
|            |        | X2       |                          |                       |
|            |        | 3,1      |                          |                       |
|            | STODL  | 12D      |                          |                       |
|            |        | P30ZERO  |                          |                       |
| # Page 636 |        |          |                          |                       |
|            | STORE  | 16D      |                          |                       |
|            | VLOAD  | UNIT     |                          |                       |
|            |        | 12D      |                          |                       |
|            | STOVL  | SNTH     | # ALSO STORES CSTH AND 0 |                       |
|            |        | RACT1    |                          |                       |
|            | PDVL   | SIGN     |                          |                       |
|            |        | VACT4    |                          |                       |
|            |        | RDOTV    |                          |                       |
|            | VCOMP  | CALL     |                          |                       |
|            |        | VECSHIFT |                          |                       |
|            | STOVL  | VVEC     |                          |                       |
|            | SET    |          |                          |                       |
|            |        | RVSU     |                          |                       |
|            | STCALL | RVEC     |                          |                       |
|            |        | TIMETHET |                          |                       |
|            | PDDL   | BPL      |                          |                       |
|            |        | RDOTV    |                          |                       |
|            |        | NTP/2    |                          |                       |
|            | DLOAD  | DSU      |                          |                       |
|            |        | HAFPA1   |                          |                       |
|            | PUSH   | GOTO     |                          |                       |

|       |        |          |
|-------|--------|----------|
|       |        | NTP/2    |
| CIRCL | SETPD  | DLOAD    |
|       |        | OOD      |
|       |        | P30ZERO  |
|       | PUSH   |          |
| NTP/2 | DLOAD  | DMP      |
|       |        | NN       |
|       |        | HAFPA1   |
|       | SL     | DSU      |
|       |        | 14D      |
|       | DAD    |          |
|       |        | TCSI     |
|       | STORE  | TCDH     |
|       | BDSU   | AXT,2    |
|       |        | TTPI     |
|       |        | 5D       |
|       | BMN    | SETPD    |
|       |        | SCNDSOL  |
|       |        | OD       |
|       | VLOAD  | PDVL     |
|       |        | VACT4    |
|       |        | RACT1    |
|       | CALL   |          |
|       |        | INTINT2C |
|       | STOVL  | RACT2    |
|       |        | VATT     |
|       | STOVL  | VACT2    |
|       |        | VPASS1   |
|       | SETPD  | PDVL     |
|       |        | OD       |
|       |        | RPASS1   |
|       | CALL   |          |
|       |        | INTINT2C |
|       | STOVL  | RPASS2   |
|       |        | VATT     |
|       | STCALL | VPASS2   |
|       |        | CDHMVR   |
|       | VLOAD  | SETPD    |
|       |        | RACT2    |
|       |        | OD       |
|       | PDVL   | CALL     |
|       |        | VACT3    |
|       |        | PERIAP01 |
|       | CALL   |          |
|       |        | SHIFTR1  |

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|       |         |                                        |               |
|-------|---------|----------------------------------------|---------------|
| STOVL | POSTCDH |                                        |               |
|       | VACT3   |                                        |               |
| SETPD | PDVL    |                                        |               |
|       | OD      |                                        |               |
|       | RACT2   |                                        |               |
| PDDL  | PDDL    |                                        |               |
|       | TCDH    |                                        |               |
|       | TTPI    |                                        |               |
| PDDL  | PUSH    |                                        |               |
|       | TWOPI   |                                        |               |
| CALL  |         |                                        |               |
|       | INTINT  |                                        |               |
| CALL  |         |                                        |               |
|       | ACTIVE  |                                        |               |
| DLOAD |         |                                        |               |
|       | ELEV    |                                        |               |
| SETPD | SINE    |                                        |               |
|       | 6D      |                                        |               |
| PDVL  | UNIT    |                                        |               |
|       | RACT3   |                                        |               |
| STORE | OOD     | # URA3 AT OOD                          |               |
| PDVL  | VXV     | # PL14D, PL08D                         |               |
|       | UP1     |                                        |               |
| UNIT  |         |                                        |               |
| PDDL  | COSINE  | # UNIT(URA3 X UVA3 X URA3) = UH3       | B1 PL14D      |
|       | ELEV    |                                        |               |
| VXSC  | STADR   | # (COSLOS)(UH3)                        | B2 PL08D      |
| STORE | 18D     | # PLUS                                 |               |
| DLOAD | VXSC    | # (SINLOS)(URA3) = U                   | B2 PL00D      |
| VAD   | VSL1    |                                        |               |
|       | 18D     | #                                      | B1            |
| PUSH  | DOT     | #                                      | PL06D         |
|       | RACT3   | # (U . RA3) = TEMP1                    | B1 +B29 = B30 |
| SL1   | PUSH    | #                                      | B29 PL08D     |
|       |         |                                        |               |
| DSQ   | TLOAD   | # TEMP1**2                             | B58           |
|       | MPAC    |                                        |               |
| PDVL  | DOT     | #                                      | PL11D         |
|       | RACT3   |                                        |               |
|       | RACT3   |                                        |               |
| TLOAD | DCOMP   | # RA3 . RA3                            |               |
|       | MPAC    |                                        |               |
| PDVL  | DOT     | # RP3 . RP3                            | B58 PL14D     |
|       | RPASS3  |                                        |               |
|       | RPASS3  | #                                      | PL11D         |
| TAD   | TAD     | # TEMP1**2 + RA3.RA3 + RP3.RP3 = TEMP2 | PL08D         |

|            |        |         |                            |        |
|------------|--------|---------|----------------------------|--------|
|            | BPL    | DLOAD   |                            |        |
|            |        | K10RK2  |                            |        |
|            |        | LOOPCT  |                            |        |
|            | DSU    | AXT,2   |                            |        |
|            |        | 1DPB28  |                            |        |
|            |        | 1D      |                            |        |
|            | BZE    |         |                            |        |
|            |        | ALMXITA |                            |        |
|            | DLOAD  | SR1     |                            |        |
|            |        | DELDV   |                            |        |
|            | STORE  | DELDV   |                            |        |
|            | BDSU   |         |                            |        |
|            |        | DVPREV  |                            |        |
|            | STCALL | DELVCSI |                            |        |
|            |        | CSI/B1  |                            |        |
| K10RK2     | SQRT   | PUSH    | # TEMP3 = TEMP2** .5       | B29 PI |
|            | DCOMP  | DSU     |                            |        |
|            |        | 06D     | # -TEMP1-TEMP3 = K2 AT 10D |        |
|            | STODL  | 10D     | #                          | PI     |
|            | DSU    | STADR   | #                          | PI     |
|            | STORE  | 12D     | # -TEMP1+TEMP3 = K1 AT 12D |        |
|            | ABS    |         |                            |        |
|            | STODL  | 14D     |                            |        |
|            |        | 10D     |                            |        |
|            | ABS    | DSU     |                            |        |
|            |        | 14D     |                            |        |
|            | BMN    | DLOAD   |                            |        |
|            |        | K2.     |                            |        |
|            |        | 12D     |                            |        |
|            | STORE  | 10D     | # K = K1                   |        |
| K2.        | DLOAD  |         |                            |        |
|            |        | 10D     |                            |        |
|            | VXSC   | VSL1    |                            |        |
|            | VAD    | UNIT    | # V = RA3 + KU UNIT        | B1     |
|            |        | RACT3   |                            |        |
|            | PDVL   | UNIT    |                            |        |
|            |        | RPASS3  | #                          | PI     |
|            | PDVL   | UNIT    |                            |        |
|            |        | VPASS3  | #                          | PI     |
| # Page 639 |        |         |                            |        |
|            | VXV    | PDVL    | # UVP3 X URP3              | PI     |
|            |        | 06D     |                            |        |
|            |        | 06D     |                            |        |
|            | VXV    | DOT     |                            |        |
|            |        | 00D     |                            |        |
|            | STADR  |         | #                          | PI     |

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|            |          |                                       |              |
|------------|----------|---------------------------------------|--------------|
| STOVL      | 12D      | # (URP3 X V).(UVP3 X URP3)=TEMP       | PL06D        |
| DOT        | SL1      | #                                     | PL00D        |
| ARCCOS     | SIGN     |                                       |              |
|            | 12D      | #                                     | B0           |
| SR1        | PUSH     | # GAMMA = SIGN(TEMP)ARCOS(UNITV.URP3) | PL02D        |
| BON        | DLOAD    |                                       |              |
|            | S32.1F2  |                                       |              |
|            | FRSTPAS  |                                       |              |
|            | OOD      | # NOT THE FIRST PASS OF A CYCLE       |              |
| DSU        | PDDL     | # GAMMA-GAMPREV                       | B1 PL04D     |
|            | GAMPREV  |                                       |              |
|            | DELVCSI  |                                       |              |
| DSU        | NORM     | #                                     | B7           |
|            | DVPREV   |                                       |              |
|            | X1       |                                       |              |
| BDDV       | PDDL     | # (GAM-GAMPREV)/(DV-DVPREV)           | B-6+N1 PL06D |
|            | O2D      | # = SLOPE                             |              |
|            | DELVCSI  |                                       |              |
| STORE      | DVPREV   |                                       |              |
| BOFF       | BOFF     |                                       |              |
|            | S32.1F3A |                                       |              |
|            | THRDCHK  |                                       |              |
|            | S32.1F3B |                                       |              |
|            | THRDCHK  |                                       |              |
| DLOAD      | DMP      |                                       |              |
|            | O2D      |                                       |              |
|            | GAMPREV  |                                       |              |
| BPL        | DLOAD    |                                       |              |
|            | FIFTYFPS |                                       |              |
|            | INITST   |                                       |              |
| SIGN       |          |                                       |              |
|            | DELDV    |                                       |              |
| STORE      | DELDV    |                                       |              |
| SET        | CLEAR    |                                       |              |
|            | S32.1F3A |                                       |              |
|            | S32.1F3B |                                       |              |
| FRSTPAS    | DLOAD    |                                       |              |
|            | OOD      |                                       |              |
| STODL      | GAMPREV  |                                       |              |
|            | DELVCSI  |                                       |              |
| STORE      | DVPREV   |                                       |              |
| DSU        | CLEAR    |                                       |              |
|            | DELDV    |                                       |              |
|            | S32.1F2  |                                       |              |
| # Page 640 | STCALL   | DELVCSI                               |              |

|          |        |          |
|----------|--------|----------|
|          |        | CSI/B1   |
| THRDCHK  | BON    | BON      |
|          |        | S32.1F3A |
|          |        | NEWTN    |
|          |        | S32.1F3B |
|          |        | NEWTN    |
| FIFTYFPS | DLOAD  | SIGN     |
|          |        | FIFPSDP  |
|          |        | 04D      |
|          | SIGN   |          |
|          |        | GAMPREV  |
|          | STORE  | DELDV    |
|          | DCOMP  | DAD      |
|          |        | DELVCSI  |
|          | STODL  | DELVCSI  |
|          |        | OOD      |
|          | SET    | SET      |
|          |        | S32.1F3B |
|          |        | S32.1F3A |
|          | STCALL | GAMPREV  |
|          |        | CSI/B2   |
| NEWTN    | DLOAD  | NORM     |
|          |        | 04D      |
|          |        | X2       |
|          | BDDV   | XSU,1    |
|          |        | OOD      |
|          |        | X2       |
|          | SR*    |          |
|          |        | 0,1      |
|          | STODL  | DELDV    |
|          |        | OOD      |
|          | STORE  | GAMPREV  |
|          | DLOAD  | ABS      |
|          |        | DELDV    |
|          | PUSH   | DSU      |
|          |        | EPSILN1  |
|          | BMN    | DLOAD    |
|          |        | CSI/SOL  |
|          | DSU    | BMN      |
|          |        | DELMAX1  |
|          |        | CSISTEP  |
|          | DLOAD  | SIGN     |
|          |        | DELMAX1  |
|          |        | DELDV    |
|          | STORE  | DELDV    |
| CSISTEP  | DLOAD  | DSU      |

#

PI



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```
# Page 641
CSI/SOL      STCALL  DELVCSI
              DELDV
              DELVCSI
              CSI/B1
DLOAD        AXT,2
              POSTCSI
              2
LXA,1
DSU*         RTX1
              BMN
              PMINE  -2,1
              SCNDSOL
AXT,2        DLOAD
              3
              POSTCDH
DSU*         BMN
              PMINE  -2,1
              SCNDSOL
DLOAD        DSU
              TCDH
              TCSI
STORE        T1TOT2
AXT,2        DSU
              4
              TMIN
BMN          AXT,2
              SCNDSOL
              5
DLOAD        DSU
              TTPI
              TCDH
STORE        T2TOT3
DSU          BPL
              TMIN
              P32/P72C
SCNDSOL      BON    BOFF
              S32.1F3A
              ALMXIT
              S32.1F3B
              ALMXIT
SXA,2        DLOAD
              CSIALRM
              P30ZERO
CLEAR        SET
              S32.1F1
```

```

                                S32.1F2
                                CLEAR
                                S32.1F3A
                                S32.1F3B
                                STCALL LOOPCT
                                CSI/B
```

```
# Page 642
# ***** ADVANCE *****
#
# SUBROUTINES USED
#     PRECSET
#     ROTATE
```

```
ADVANCE      STQ      DLOAD
                                SUBEXIT
                                TIG
                                STCALL TDEC1
                                PRECSET
                                SET      VLOAD
                                XDELVFLG
                                VPASS3
                                STORE    VPASS2
                                STOVL    VPASS1
                                RPASS3
                                STORE    RPASS2
                                STORE    RPASS1
                                UNIT      VXV
                                VPASS1
                                UNIT
                                STOVL    UP1
                                RACT3
                                STCALL   RTIG
                                ROTATE
                                STORE    RACT2
                                STOVL    RACT1
                                VACT3
                                STCALL   VTIG
                                ROTATE
                                STORE    VACT2
                                STCALL   VACT1
                                SUBEXIT
```

```
# Page 643
# ***** ROTATE *****
```

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|        |       |      |
|--------|-------|------|
| ROTATE | PUSH  | PUSH |
|        | DOT   | VXSC |
|        |       | UP1  |
|        |       | UP1  |
|        | VSL2  | BVSU |
|        | UNIT  | PDVL |
|        | ABVAL | VXSC |
|        | VSL1  | RVQ  |

# Page 644

# \*\*\*\*\* INTINTNA \*\*\*\*\*

|          |      |         |
|----------|------|---------|
| INTINT2C | PDDL | PDDL    |
|          |      | TCSI    |
|          |      | TCDH    |
|          | PDDL | PUSH    |
|          |      | TWOPI   |
|          | GOTO |         |
|          |      | INTINT  |
| INTINT3P | PDDL | PDDL    |
|          |      | TCDH    |
|          |      | TTPI    |
|          | PDDL | PUSH    |
|          |      | P30ZERO |
|          | GOTO |         |
|          |      | INTINT  |

# Page 645

# \*\*\*\*\* S32/33.1 \*\*\*\*\*

#

# SUBROUTINES USED

# S32/33.X

|          |       |          |
|----------|-------|----------|
| S32/33.1 | STQ   | AXT,1    |
|          |       | SUBEXIT  |
|          | VN    | 0681     |
|          | CALL  |          |
|          |       | DISDVLVC |
|          | CALL  |          |
|          |       | S32/33.X |
|          | VLOAD | VXM      |
|          |       | DELVLVC  |
|          |       | OD       |
|          | VSL1  |          |
|          | STORE | DELVSIN  |
|          | PUSH  | ABVAL    |

STOVL DELVSAB  
 GOTO  
 SUBEXIT

# Page 646  
 # \*\*\*\*\* S32/33.X \*\*\*\*\*

S32/33.X        SETPD    VLOAD  
                       6D  
                       UP1  
                   VCOMP   PDVL  
                          RACT1  
                   UNIT    VCOMP  
                   PUSH    VXV  
                          UP1  
                   VSL1  
                   STORE    OD  
                   RVQ

# Page 647  
 # \*\*\*\*\* CDHMVR \*\*\*\*\*  
 #  
 # SUBROUTINES USED  
 #        VECSHIFT  
 #        TIMETHET  
 #        SHIFTR1

CDHMVR        STQ        VLOAD  
                          SUBEXIT  
                          RACT2  
                   PUSH    UNIT  
                   STOVL   UNVEC        # UR SUB A  
                          RPASS2  
                   UNIT    DOT  
                          UNVEC  
                   PUSH    SL1  
                   STODL   CSTH  
                   DSQ     PDDL  
                          DP1/4TH  
                   SR2     DSU  
                   SQRT    SL1  
                   PDVL    VCOMP  
                   VXV  
                          RPASS2  
                   DOT     PDDL  
                          UP1

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# Page 648

|        |          |                          |      |     |
|--------|----------|--------------------------|------|-----|
| SIGN   | STADR    |                          |      |     |
| STOVL  | SNTH     |                          |      |     |
|        | RPASS2   |                          |      |     |
| PDVL   | CALL     |                          |      |     |
|        | VPASS2   |                          |      |     |
|        | VECSHIFT |                          |      |     |
| STOVL  | VVEC     |                          |      |     |
| CLEAR  |          |                          |      |     |
|        | RVS      |                          |      |     |
| STCALL | RVEC     |                          |      |     |
|        | TIMETHET |                          |      |     |
| LXA,2  | VSL*     |                          |      |     |
|        | RTX2     |                          |      |     |
|        | 0,2      |                          |      |     |
| STORE  | 18D      |                          |      |     |
| DOT    | SL1R     |                          |      |     |
|        | UNVEC    |                          |      |     |
| PDVL   | ABVAL    | # OD = V SUB PV          |      |     |
| SL*    | PDVL     |                          |      |     |
|        | 0,2      |                          |      |     |
|        | RACT2    |                          |      |     |
| ABVAL  | PDDL     | # 2D = LENGTH OF R SUB A |      |     |
| DSU    |          |                          |      |     |
|        | 02D      |                          |      |     |
| STODL  | DIFFALT  | # DELTA H IN METERS      | B+29 |     |
|        | R1A      |                          |      |     |
| NORM   | PDDL     | # 2 - R V**/MU           |      | 04D |
|        | X1       |                          |      |     |
|        | R1       |                          |      |     |
| CALL   |          |                          |      |     |
|        | SHIFTR1  |                          |      |     |
| SR1R   | DDV      |                          |      |     |
| SL*    | PUSH     |                          |      |     |
|        | 0        | -5,1                     |      |     |
| DSU    | PDDL     | # A SUB A                | B+29 | 04D |
|        | DIFFALT  |                          |      |     |
| SR2    | DDV      | # A SUB P                | B+31 |     |
|        | 04D      | #                        | B+2  |     |
| PUSH   | SQRT     | # A SUB P/A SUB A        |      | 06D |
| DMPR   | DMP      |                          |      |     |
|        | 06D      |                          |      |     |
|        | 00D      |                          |      |     |
| SL3R   | PDDL     | # V SUB AV METERS/CS     | B+7  | 08D |
|        | 02D      | # R SUB A MAGNITUDE      | B+29 |     |
| NORM   | PDDL     |                          |      |     |

```

X1
RTMU
SR1 DDV # 2MU B+38
SL* PDDL # 2 MU/R SUBAA B+14 10D
0 -5,1
04D # ASUBA B+29
NORM PDDL
X2
RTMU
SR1 DDV
SL* BDSU
0 -6,2 # 2U/R - U/A B+14 (METERS/CS)SQ
PDDL DSQ # 10D
08D
BDSU SQRT
PDVL VXV # SQRT(MU(2/R SUB A-1/A SUB A)-VSUBA2) 10D
UP1
UNVEC
UNIT VXSC
10D
PDVL VXSC
UNVEC
08D
VAD VSL1
STADR
STORE VACT3
VSU
VACT2
# Page 649
STCALL DELVEET2 # DELTA VCDH -- REFERENCE COORDINATES
SUBEXIT

# Page 650
# ***** COMPTGO *****
#
# SUBROUTINES USED
# CLOKTASK
# 2PHSCHNG

BANK 35
SETLOC CSI/CDH
BANK

EBANK= RTRN

COUNT* $$/P3575

```

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```
COMPTGO      EXTEND
              QXCH   RTRN
              CAF     ZERO
              TS      DISPDEX
              CAF     BIT2
              INHINT
              TC      WAITLIST
              EBANK=  WHICH
              2CADR   CLOKTASK

              TC      2PHSCHNG
              OCT     40036
              OCT     05024
              OCT     13000
              TC      RTRN
```

This code is written to file `src/P32-P35-P72-P75.s`.

**A.71 P34-35 P74-75**

```

1128  <src/P34-35-P74-75.s 1128>≡
      # Copyright:    Public domain.
      # Filename:     P34-35_P74-75.agc
      # Purpose:      Part of the source code for Comanche, build 055. It
      #               is part of the source code for the Command Module's
      #               (CM) Apollo Guidance Computer (AGC), Apollo 11.
      # Assembler:    yaYUL
      # Reference:     pp. 460-504
      # Contact:       Onno Hommes <ohommes@cmu.edu>
      # Website:       http://www.ibiblio.org/apollo.
      # Mod history:   2009-05-10 OH   Batch 2 Assignment Comanche Transcription
      #               2009-05-23 RSB   In DISPLAYE, corrected a CADR GOFLASHR
      #               to CADR GOFLASH.
      #
      # The contents of the "Comanche055" files, in general, are transcribed
      # from scanned documents.
      #
      # Assemble revision 055 of AGC program Comanche by NASA
      # 2021113-051. April 1, 1969.
      #
      # This AGC program shall also be referred to as Colossus 2A
      #
      # Prepared by
      #
      #               Massachussets Institute of Technology
      #               75 Cambridge Parkway
      #               Cambridge, Massachusetts
      #
      # under NASA contract NAS 9-4065.
      #
      # Refer directly to the online document mentioned above for further
      # information. Please report any errors to info@sandroid.org.

      # Page 460
      # TRANSFER PHASE INITITIATION (TPI) PROGRAMS (P34 AND P74)
      # MOD NO -1 LOG SECTION -- P32-P35, P72-P75
      # MOD BY WHITE, P. DATE: 1 JUNE 67
      #
      # PURPOSE
      # (1) TO CALCULATE THE REQUIRED DELTA V AND OTHER INITIAL CONDITIONS
      #     REQUIRED BY THE ACTIVE VEHICLE FOR EXECUTION OF THE TRANSFER
      #     PHASE INITITIATION (TPI) MANEUVER, GIVEN --
      # (A) TIME OF IGNITION TIG (TPI) OR THE ELEVATION ANGLE (E) OF
      #     THE ACTIVE/PASSIVE VEHICLE LOS AT TIG (TPI).

```



```
#          (B)      CENTRAL ANGLE OF TRANSFER (CENTANG) FROM TIG (TPI) TO
#                   INTERCEPT TIME (TIG (TPF)).
#      (2)      TO CALCULATE TIG (TPI) GIVEN E OR E GIVEN TIG (TPI).
#      (3)      TO CALCULATE THESE PARAMETERS BASED UPON MANEUVER DATA
#                   APPROVED AND KEYED INTO THE DSKY BY THE ASTRONAUT.
#      (4)      TO DISPLAY TO THE ASTRONAUT AND THE GROUND CERTAIN DEPENDENT
#                   VARIABLES ASSOCIATED WITH THE MANEUVER FOR APPROVAL BY THE
#                   ASTRONAUT/GROUND.
#      (5)      TO STORE THE TPI TARGET PARAMETERS FOR USE BY THE DESIRED
#                   THRUSTING PROGRAM.
#
# ASSUMPTIONS
#      (1)      LM ONLY -- THIS PROGRAM IS BASED UPON PREVIOUS COMPLETION OF
#                   THE CONSTANT DELTA ALTITUDE (CDH) PROGRAM (P33/P73).
#                   THEREFORE --
#      (A)      AT A SELECTED TPI TIME (NOW IN STORAGE) THE LINE OF SIGHT
#                   BETWEEN THE ACTIVE AND PASSIVE VEHICLES WAS SELECTED TO BE
#                   A PRESCRIBED ANGLE (E) (NOW IN STORAGE) FROM THE
#                   HORIZONTAL PLANE DEFINED BY THE ACTIVE VEHICLE POSITION.
#      (B)      THE TIME BETWEEN CDH IGNITION AND TPI IGNITION WAS
#                   COMPUTED TO BE GREATER THAN 10 MINUTES.
#      (C)      THE VARIATION OF TEH ALTITUDE DIFFERENCE BETWEEN THE
#                   ORBITS WAS MINIMIZED.
#      (D)      THE PERICENTER ALTITUDES OF ORBITS FOLLOWING CSI AND
#                   CDH WERE COMPUTED TO BE GREATER THAN 35,000 FT FOR LUNAR
#
# Page 461
#                   ORBIT OR 85 NM FOR EARTH ORBIT.
#      (E)      THE CSI AND CDH MANEUVERS WERE ASSUMED TO BE PARALLEL TO
#                   THE PLANE OF THE PASSIVE VEHICLE ORBIT. HOWEVER, CREW
#                   MODIFICATION OF DELTA V (LV) COMPONENTS MAY HAVE RESULTED
#                   IN AN OUT-OF-PLANE MANEUVER.
#      (2)      STATE VECTOR UPDATED BY P27 ARE DISALLOWED DURING AUTOMATIC
#                   STATE VECTOR UPDATING INITIATED BY P20 (SEE ASSUMPTION (4)).
#      (3)      THIS PROGRAM MUST BE DONE OVER A TRACKING STATION FOR REAL
#                   TIME GROUND PARTICIPATION IN DATA INPUT AND OUTPUT.  COMPUTED
#                   VARIABLES MAY BE STORED FOR LATER VERIFICATION BY THE GROUND.
#                   THESE STORAGE CAPABILITIES ARE LIMITED ONLY TO THE PARAMETERS
#                   FOR ONE THRUSTING MANEUVER AT A TIME EXCEPT FOR CONCENTRIC
#                   FLIGHT PLAN MANEUVER SEQUENCES.
#      (4)      THE RENDEZVOUS RADAR MAY OR MAY NOT BE USED TO UPDATE THE LM
#                   OR CSM STATE VECTORS FOR THIS PROGRAM.  IF RADAR USE IS
#                   DESIRED THE RADAR WAS TURNED ON AND LOCKED ON THE CSM BY
#                   PREVIOUS SELECTION OF P20.  RADAR SIGHTING MARKS WILL BE MADE
#                   AUTOMATICALLY APPROXIMATELY ONCE A MINUTE WHEN ENABLED BY THE
#                   TRACK AND UPDATE FLAGS (SEE P20).  THE RENDEZVOUS TRACKING
#                   MARK COUNTER IS ZEROED BY TEH SELECTION OF P20 AND AFTER EACH
```

```

#          THRUSTING MANEUVER.
#          (5)    THE ISS NEED NOT BE ON TO COMPLETE THIS PROGRAM.
#          (6)    THE OPERATION OF THE PROGRAM UTILIZES THE FOLLOWING FLAGS --
#
#                  ACTIVE VEHICLE FLAG -- DESIGNATES THE VEHICLE WHICH IS
#                  DOING RENDEZVOUS THRUSTING MANEUVERS TO THE PROGRAM WHICH
#                  CALCULATES THE MANEUVER PARAMETERS.  SET AT THE START OF
#                  EACH RENDEZVOUS PRE-THRUSTING PROGRAM.
#
#                  FINAL FLAG -- SELECTS FINAL PROGRAM DISPLAYS AFTER CREW HAS
#                  SELECTED THE FINAL MANEUVER COMPUTATION CYCLE.
#
#                  EXTERNAL DELTA V FLAG -- DESIGNATES THE TYPE OF STEERING
#                  REQUIRED FOR EXECUTION OF THIS MANEUVER BY THE THRUSTING
#                  PROGRAM SELECTED AFTER COMPLETION OF THIS PROGRAM.
#
#          (7)    ONCE THE PARAMETERS REQUIRED FOR COMPUTATION OF THE MANEUVER
#                  HAVE BEEN COMPLETELY SPECIFIED, THE VALUE OF THE ACTIVE
#                  VEHICLE CENTRAL ANGLE OF TRANSFER IS COMPUTED AND STORED.
#                  THIS NUMBER WILL BE AVAILABLE FOR DISPLAY TO THE ASTRONAUT
#                  THROUGH THE USE OF V06N52.
#
#                  THE ASTRONAUT WILL CALL THIS DISPLAY TO VERIFY THAT THE
#                  CENTRAL ANGLE OF TRANSFER OF THE ACTIVE VEHICLE IS NOT WITHIN
#
# Page 462
#                  170 TO 190 DEGREES.  IF THE ANGLE IS WITHIN THIS ZONE THE
#                  ASTRONAUT SHOULD REASSES THE INPUT TARGETING PARAMETERS BASED
#                  UPON DELTA V AND EXPECTED MANEUVER TIME.
#          (8)    THIS PROGRAM IS SELECTED BY THE ASTRONAUT BY DSKY ENTRY --
#
#                  P34 IF THIS VEHICLE IS ACTIVE VEHICLE.
#
#                  P74 IF THIS VEHICLE IS PASSIVE VEHICLE.
#
# INPUT
#          (1)    TTPI    TIME OF THE TPI MANEUVER.
#          (2)    ELEV    DESIRED LOS ANGLE AT TPI
#          (3)    CENTANG  ORBITAL CENTRAL ANGLE OF THE PASSIVE VEHICLE DURING
#                  TRANSFER FROM TPI TO TIME OF INTERCEPT
#
# OUTPUT
#          (1)    TRKMKCNT    NUMBER OF MARKS
#          (2)    TTOGO    TIME TO GO
#          (3)    +MGA    MIDDLE GIMBAL ANGLE
#          (4)    TTPI    COMPUTED TIME OF TPI MANEUVER
#          OR

```

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```
#          ELEV          COMPUTED LOS ANGLE AT TPI
#      (5)  POSTTPI      PERIGEE ALTITUDE AFTER THE TPI MANEUVER
#      (6)  DELVTPI      MAGNITUDE OF DELTA V AT TPI
#      (7)  DELVTPF      MAGNITUDE OF DELTA V AT INTERCEPT
#      (8)  DVLOS        DELTA VELOCITY AT TPI -- LINE OF SIGHT
#      (9)  DELVLVC      DELTA VELOCITY AT TPI -- LOCAL VERTICAL COORDINATES
#
# DOWNLINK
#      (1)  TTPI         TIME OF TPI MANEUVER
#      (2)  TIG          TIME OF TPI MANEUVER
#      (3)  ELEV         DESIRED LOS ANGLE AT TPI
#      (4)  CENTANG      ORBITAL CENTRAL ANGLE OF THE PASSIVE VEHICLE DURING
#                        TRANSFER FROM TPI TO TIME OF INTERCEPT
#      (5)  DELVEET3     DELTA VELOCITY AT TPI -- REFERENCE COORDINATES
#      (6)  TPASS4       TIME OF INTERCEPT
#
# COMMUNICATION TO THRUSTING PROGRAMS
#      (1)  TIG          TIME OF THE TPI MANEUVER
#      (2)  RTARG        OFFSET TARGET POSITION
#      (3)  TPASS4       TIME OF INTERCEPT
#      (4)  XDELVFLG     RESET TO INDICATE LAMBERT (AIMPOINT) VG COMPUTATION
#
# SUBROUTINES USED
#      AVFLAGA
# Page 463
#      AVFLAGP
#      VNPOOH
#      DISPLAYE
#      SELECTMU
#      PRECSET
#      S33/34.1
#      ALARM
#      BANKCALL
#      GOFLASH
#      GOTOPOOH
#      TIMETHET
#      S34/35.2
#      PERIAP01
#      SHIFTR1
#      S34/35.5
#      VN1645
#
#          SETLOC  CSI/CDH
#          BANK
#          EBANK=  SUBEXIT
#          COUNT   35/P3474
```

|            |        |          |                                        |
|------------|--------|----------|----------------------------------------|
| P34        | TC     | AVFLAGA  |                                        |
|            | TC     | P34/P74A |                                        |
| P74        | TC     | AVFLAGP  |                                        |
| P34/P74A   | TC     | P20FLGON | # SET UPDATFLG, TRACKFLG               |
|            | CAF    | V06N37   | # TTPI                                 |
|            | TC     | VNP00H   | # Onno: The scans look like 0 not zero |
|            | TC     | INTPRET  |                                        |
|            | SSP    | EXIT     |                                        |
|            |        | NN       |                                        |
|            |        | 0        |                                        |
|            | TC     | DISPLA   | # ELEV AND CENTANG                     |
|            | TC     | INTPRET  |                                        |
|            | CLEAR  | DLOAD    |                                        |
|            |        | ETPIFLAG |                                        |
|            |        | TTPI     |                                        |
|            | STODL  | TIG      |                                        |
|            |        | ELEV     |                                        |
|            | BZE    | SET      |                                        |
|            |        | P34/P74B |                                        |
|            |        | ETPIFLAG |                                        |
| P34/P74B   | CALL   |          |                                        |
|            |        | SELECTMU |                                        |
| DELELO     | EQUALS | 26D      |                                        |
| P34/P74C   | DLOAD  | SET      |                                        |
|            |        | ZEROVECS |                                        |
|            |        | ITSWICH  |                                        |
|            | BON    | CLEAR    |                                        |
|            |        | ETPIFLAG |                                        |
| # Page 464 |        |          |                                        |
|            |        | SWCHSET  |                                        |
|            |        | ITSWICH  |                                        |
| SWCHSET    | STORE  | NOMTPI   |                                        |
| INTLOOP    | DLOAD  | DAD      |                                        |
|            |        | TTPI     |                                        |
|            |        | NOMTPI   |                                        |
|            | STCALL | TDEC1    |                                        |
|            |        | PRECSET  |                                        |
|            | CALL   |          |                                        |
|            |        | S33/34.1 |                                        |
|            | BZE    | EXIT     |                                        |
|            |        | SWCHCLR  |                                        |
|            | TC     | ALARM    |                                        |
|            | OCT    | 611      |                                        |
|            | CAF    | V05N09   |                                        |
|            | TC     | BANKCALL |                                        |

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|            |        |          |                            |
|------------|--------|----------|----------------------------|
|            | CADR   | GOFLASH  |                            |
|            | TC     | GOTOP00H |                            |
|            | TC     | P34/P74A | # PROCEED                  |
|            | TC     | -7       | # V32                      |
| SWCHCLR    | BONCLR | BON      |                            |
|            |        | ITSWICH  |                            |
|            |        | INTLOOP  |                            |
|            |        | ETPIFLAG |                            |
|            |        | P34/P74D | # DISPLAY TTPI             |
|            | EXIT   |          |                            |
|            | TC     | DISPLAYE | # DISPLAY ELEV AND CENTANG |
|            | TC     | P34/P74E |                            |
| P34/P74D   | EXIT   |          |                            |
|            | CAF    | V06N37   | # TTPI                     |
|            | TC     | VNP00H   |                            |
| P34/P74E   | TC     | INTPRET  |                            |
|            | SETPD  | DLOAD    |                            |
|            |        | OD       |                            |
|            |        | RTX1     |                            |
|            | STODL  | X1       |                            |
|            |        | CENTANG  |                            |
|            | PUSH   | COS      |                            |
|            | STODL  | CSTH     |                            |
|            | SIN    |          |                            |
|            | STOVL  | SNTH     |                            |
|            |        | RPASS3   |                            |
|            | VSR*   |          |                            |
|            |        | 0,2      |                            |
|            | STOVL  | RVEC     |                            |
|            |        | VPASS3   |                            |
|            | VSR*   | SET      |                            |
|            |        | 0,2      |                            |
|            |        | RVSW     |                            |
| # Page 465 | STCALL | VVEC     |                            |
|            |        | TIMETHET |                            |
|            | DLOAD  |          |                            |
|            |        | TTPI     |                            |
|            | STORE  | INTIME   | # FOR INITVEL              |
|            | DAD    |          |                            |
|            |        | T        | # RENDEZVOUS TIME          |
|            | STCALL | TPASS4   | # FOR INITVEL              |
|            |        | S34/35.2 |                            |
|            | VLOAD  | ABVAL    |                            |
|            |        | DELVEET3 |                            |

```
STOVL  DELVTPI
        VPASS4
VSU     ABVAL
        VTPRIME
STOVL  DELVTPF
        RACT3
PDVL    CALL
        VIPRIME
        PERIAP01
CALL    SHIFTR1
STODL   POSTTPI
        TTPI
STORE   TIG
EXIT
CAF     V06N58
TC      VNP00H
TC      INTPRET
CALL    S34/35.5
CALL    VN1645
GOTO    P34/P74C
```

# Page 466

# RENDEZVOUS MID-COURSE MANEUVER PROGRAMS (P35 AND P75)

# MOD NO -1 LOG SECTION -- P32-P35, P72-P75

# MOD BY WHITE, P. DATE: 1 JUNE 67

#

# PURPOSE

- ```
# (1) TO CALCULATE THE REQUIRED DELTA V AND OTHER INITIAL CONDITIONS
#      REQUIRED BY THE ACTIVE VEHICLE FOR EXECUTION OF THE NEXT
#      MID-COURSE CORRECTION OF THE TRANSFER PHASE OF AN ACTIVE
#      VEHICLE RENDEZVOUS.
# (2) TO DISPLAY TO THE ASTRONAUT AND THE GROUND CERTAIN DEPENDENT
#      VARIABLES ASSOCIATED WITH THE MANEUVER FOR APPROVAL BY THE
#      ASTRONAUT/GROUND.
# (3) TO STORE THE TPM TARGET PARAMETERS FOR USE BY THE DESIRED
#      THRUSTING PROGRAM.
```

#

# ASSUMPTIONS

- ```
# (1) THE ISS NEED NOT BE ON TO COMPLETE THIS PROGRAM.
# (2) STATE VECTOR UPDATES BY P27 ARE DISALLOWED DURING AUTOMATIC
#      STATE VECTOR UPDATING INITIATED BY P20 (SEE ASSUMPTION (3)).
# (3) THE RENDEZVOUS RADAR IS ON AND IS LOCKED ON THE CSM. THIS WAS
```

```

#      DONE DURING PREVIOUS SELECTION OF P20.  RADAR SIGHTING MARKS
#      WILL BE MADE AUTOMATICALLY APPROXIMATELY ONCE A MINUTE WHEN
#      ENABLED BY THE TRACK AND UPDATE FLAGS (SEE P20).  THE
#      RENDEZVOUS TRACKING MARK COUNTER IS ZEROED BY THE SELECTION OF
#      P20 AND AFTER EACH THRUSTING MANEUVER.
#      (4)  THE OPERATION OF THE PROGRAM UTILIZES THE FOLLOWING FLAGS --
#
#           ACTIVE VEHICLE FLAG -- DESIGNATES THE VEHICLE WHICH IS
#           DOING RENDEZVOUS THRUSTING MANEUVERS TO THE PROGRAM WHICH
#           CALCULATES THE MANEUVER PARAMETERS.  SET AT THE START OF
#           EACH RENDEZVOUS PRE-THRUSTING PROGRAM.
#
#           FINAL FLAG -- SELECTS FINAL PROGRAM DISPLAYS AFTER CREW HAS
#           SELECTED THE FINAL MANEUVER COMPUTATION CYCLE.
#
#           EXTERNAL DELTA V FLAG -- DESIGNATES THE TYPE OF STEERING
#           REQUIRED FOR EXECUTION OF THIS MANEUVER BY THE THRUSTING
#           PROGRAM SELECTED AFTER COMPLETION OF THIS PROGRAM.
#
#      (5)  THE TIME OF INTERCEPT (T(INT)) WAS DEFINED BY PREVIOUS
#      COMPLETION OF THE TRANSFER PHASE INITIATION (TPI) PROGRAM
#      (P34/P74) AND IS PRESENTLY AVAILABLE IN STORAGE.
# Page 467
#      (6)  ONCE THE PARAMETERS REQUIRED FOR COMPUTATION OF THE MANEUVER
#      HAVE BEEN COMPLETELY SPECIFIED, THE VALUE OF THE ACTIVE
#      VEHICLE CENTRAL ANGLE OF TRANSFER IS COMPUTED AND STORED.
#      THIS NUMBER WILL BE AVAILABLE FOR DISPLAY TO THE ASTRONAUT
#      THROUGH THE USE OF V06N52
#
#      THE ASTRONAUT WILL CALL THIS DISPLAY TO VERIFY THAT THE
#      CENTRAL ANGLE OF TRANSFER OF THE ACTIVE VEHICLE IS NOT WITHIN
#      170 TO 190 DEGREES.  IF THE ANGLE IS WITHIN THIS ZONE THE
#      ASTRONAUT SHOULD REASSESS THE INPUT TARGETING PARAMETERS BASED
#      UPON DELTA V AND EXPECTED MANEUVER TIME.
#      (7)  THIS PROGRAM IS SELECTED BY THE ASTRONAUT BY DSKY ENTRY --
#
#           P35 IF THIS VEHICLE IS ACTIVE VEHICLE.
#
#           P75 IF THIS VEHICLE IS PASSIVE VEHICLE.
#
# INPUT
#      (1)  TPASS4          TIME OF INTERCEPT -- SAVED FROM P34/P74
#
# OUTPUT
#      (1)  TRKMKCNT        NUMBER OF MARKS
#      (2)  TTOGO           TIME TO GO

```

```

#      (3)      +MGA          MIDDLE GIMBAL ANGLE
#      (4)      DVLOS        DELTA VELOCITY AT MID -- LINE OF SIGHT
#      (5)      DELVLC        DELTA VELOCITY AT MID -- LOCAL VERTICAL COORDINATES
#
# DOWNLINK
#      (1)      TIG          TIME OF THE TPM MANEUVER
#      (2)      DELVEET3      DELTA VELOCITY AT TPM -- REFERENCE COORDINATES
#      (3)      TPASS4        TIME OF INTERCEPT
#
# COMMUNICATION TO THRUSTING PROGRAMS
#      (1)      TIG          TIME OF THE TPM MANEUVER
#      (2)      RTARG         OFFSET TARGET POSITION
#      (3)      TPASS4        TIME OF INTERCEPT
#      (4)      XDELVFLG      RESET TO INDICATE LAMBERT (AIMPOINT) VG COMPUTATION.
#
# SUBROUTINES USED
#      AVFLAGA
#      AVFLAGP
#      LOADTIME
#      SELECTMU
#      PRECSET
#      S34/35.1
#      S34/35.2
# Page 468
#      S34/35.5
#      VN1645

```

```

COUNT 35/P3575
EBANK=  KT

```

```

P35      TC      AVFLAGA
        EXTEND
        DCA      ATIGINC
        TC      P35/P75A
P75      TC      AVFLAGP
        EXTEND
        DCA      PTIGINC
P35/P75A DXCH     KT
        TC      P20FLGON      # SET UPDATFLG, TRACKFLG
        TC      INTPRET
        CALL
        SELECTMU
P35/P75B RTB
        LOADTIME
        STORE    TSTRT
        DAD

```



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```

                                KT
STORE      TIG
STORE      INTIME      # FOR INITVEL
STCALL     TDEC1
                PRECSET      # ADVANCE BOTH VEHICLES
CALL
                S34/35.1      # GET NORM AND LOS FOR TRANSFORM
CALL
                S34/35.2      # GET DELTA V(LV)
CALL
                S34/35.5
CALL
                VN1645
GOTO
                P35/P75B

# Page 469
# ***** S33/34.1 *****

S33/34.1      STQ      SSP
                                NORMEX
                                TITER
OCT           40000
DLOAD        SETPD
                                MAX250
                                OD
STOVL        SECMAX
                                RACT3
STOVL        RAPREC
                                VACT3
STOVL        VAPREC
                                RPASS3
STOVL        RPPREC
                                VPASS3
STORE        VPPREC
ELCALC      CALL
                S34/35.1      # NORMAL AND LOS
VXV          PDVL
                                RACT3      # (RA*VA)*RA OD
PDVL         UNIT      # ULOS AT 6D
                                RACT3
PDVL         VPROJ      # XCHNJ AND UP
VSL2         BVSU
                                ULOS
UNIT         PDVL      # UP AT OD
DOT          PDVL      # UP.UN*RA AT OD
                                OD      # UP IN MPAC
```

|            |       |           |                          |
|------------|-------|-----------|--------------------------|
|            | DOT   | SIGN      |                          |
|            |       | ULOS      |                          |
|            | SL1   | ACOS      |                          |
|            | PDVL  | DOT       | # EA AT OD               |
|            |       | ULOS      |                          |
|            |       | RACT3     |                          |
|            | BPL   | DLOAD     |                          |
|            |       | TESTY     |                          |
|            |       | DPPOS MAX |                          |
| TESTY      | DSU   | PUSH      |                          |
|            | BOFF  | DLOAD     |                          |
|            |       | ITSWICH   |                          |
|            |       | ELEX      |                          |
|            |       | DELEL     |                          |
|            | STODL | DELELO    |                          |
|            | DSU   |           |                          |
|            |       | ELEV      |                          |
|            | STORE | DELEL     |                          |
|            | ABS   | DSU       |                          |
|            |       | ELEPS     |                          |
| # Page 470 |       |           |                          |
|            | BMN   |           |                          |
|            |       | TIMEX     | # COMMERCIALS EVERYWHERE |
| FIGTIME    | SLOAD | SR1       |                          |
|            |       | TITER     |                          |
|            | BHIZ  | LXA,1     |                          |
|            |       | NORMEX    | # TOO MANY ITERATIONS    |
|            |       | MPAC      |                          |
|            | SXA,1 | VLOAD     |                          |
|            |       | TITER     |                          |
|            |       | RPASS3    |                          |
|            | UNIT  | PDDL      |                          |
|            |       | 36D       |                          |
|            | PDVL  | UNIT      |                          |
|            |       | RACT3     |                          |
|            | PDDL  |           |                          |
|            | PDDL  | PUSH      |                          |
|            |       | 36D       |                          |
|            | BDSU  |           |                          |
|            |       | 12D       |                          |
|            | STODL | 30D       | # RP-RA MAGNITUDES       |
|            |       | DPHALF    |                          |
|            | DSU   | PUSH      |                          |
|            |       | ELEV      |                          |
|            | SIGN  | BMN       |                          |
|            |       | 30D       |                          |

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```

                                NORMEX
DLOAD  COS
DMP    DDV
      14D
      12D
DCOMP  # SINCE COS(180-A)=-COS A
STORE  28D
ABS    BDSU
      DPHALF
BMN    VLOAD
      NORMEX
      UNRM
VXV    UNIT
      6D      # UN*RA
DOT    DMP
      VACT3
      12D
PDVL   VXV
      OD
      VPASS3
VXV    UNIT
      OD      # (RP*VP)*RP
DOT    DMP
      VPASS3
      14D
# Page 471
BDSU
NORM   PDVL      # NORMALIZED WA-WP 12D
      X1
      6D
VXV    DOT
      OD
      UNRM      # RA*RP.UN 14D
PDVL   DOT
      OD
      6D
SL1    ACOS
SIGN
DSU    DAD      # ALPHA PI
      DPHALF
      ELEV
PDDL   ACOS
      28D
BDSU   SIGN
      DPHALF
      30D      # CONTAINS RP-RA
```

|            |       |          |                                     |
|------------|-------|----------|-------------------------------------|
|            | DAD   |          |                                     |
|            | DMP   | DDV      |                                     |
|            |       | TWOPI    |                                     |
|            | DMP   |          |                                     |
|            | SL*   | DMP      |                                     |
|            |       | 0 -3,1   |                                     |
|            | PUSH  | ABS      |                                     |
|            | DSU   | BMN      |                                     |
|            |       | SECMAX   |                                     |
|            |       | OKMAX    |                                     |
|            | DLOAD | SIGN     | # REPLACE TIME WITH MAX TIME SIGNED |
|            |       | SECMAX   |                                     |
|            | PUSH  |          |                                     |
| OKMAX      | SLOAD | BPL      | # TEST FIRST ITERATION              |
|            |       | TITER    |                                     |
|            |       | REPETE   |                                     |
|            | SSP   | DLOAD    |                                     |
|            |       | TITER    |                                     |
|            | OCT   | 37777    |                                     |
|            | GOTO  |          |                                     |
|            |       | STORDELT |                                     |
| REPETE     | DLOAD | DMP      |                                     |
|            |       | DELEL    |                                     |
|            |       | DELELO   |                                     |
|            | BPL   | DLOAD    |                                     |
|            |       | NEXTES   |                                     |
|            |       | SECMAX   |                                     |
|            | DMP   |          |                                     |
|            |       | THIRD    |                                     |
|            | STODL | SECMAX   |                                     |
| # Page 472 |       |          |                                     |
|            | ABS   | SR1      | # CROSSED OVER SOLUTION             |
|            | DCOMP | GOTO     | # DT=(-SIGN(DTO)//DT//)/2           |
|            |       | RESIGN   |                                     |
| NEXTES     | DLOAD | ABS      |                                     |
|            |       | DELEL    |                                     |
|            | PDDL  | ABS      |                                     |
|            |       | DELELO   |                                     |
|            | DSU   |          |                                     |
|            | BMN   | DLOAD    |                                     |
|            |       | REVERS   | # WRONG DIRECTION                   |
|            | ABS   |          |                                     |
| RESIGN     | SIGN  | GOTO     |                                     |
|            |       | DELTEEO  |                                     |
|            |       | STORDELT |                                     |
| REVERS     | DLOAD | DCOMP    |                                     |

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```

                                DELTEEO
                                PUSH  SR1
                                STORE DELTEEO
                                DAD
                                GOTO
                                ADTIME
STORDEL T      STORE  DELTEEO
ADTIME        DAD
                                NOMTPI      # SUM OF DELTA T:S
                                STORE  NOMTPI
                                VLOAD  PDVL
                                VAPREC
                                RAPREC
                                CALL
                                GOINT
                                CALL
                                ACTIVE      # STORE NEW RACT3 VACT3
                                VLOAD  PDVL
                                VPPREC
                                RPPREC
                                CALL
                                GOINT
                                CALL
                                PASSIVE     # STORE NEW RPASS3 VPASS3
                                GOTO
                                ELCALC
ELEX          DLOAD  DAD
                                TTPI
                                NOMTPI
                                STODL  TTPI
                                BON
                                ETPIFLAG
                                TIMEX
                                STORE  ELEV
TIMEX         DLOAD  GOTO
# Page 473
                                ZEROVECS
                                NORMEX

# Page 474
# ***** S34/35.1 *****

# COMPUTE UNIT NORMAL AND LINE OF SIGHT VECTORS GIVEN THE ACTIVE AND
# PASSIVE POS AND VEL AT TIME T3
                                SETLOC  S3435LOC
                                BANK
```

```

S34/35.1      VLOAD  VSU
                RPASS3
                RACT3
                UNIT  PUSH
                STOVL  ULOS
                RACT3
                VXV    UNIT
                VACT3
                STORE  UNRM
                RVQ

```

# Page 475

# \*\*\*\*\* S34/35.2 \*\*\*\*\*

```

# ADVANCE PASSIVE VEH TO RENDEZVOUS TIME AND GET REQ VEL FROM LAMBERT
  SETLOC  CSI/CDH
  BANK

```

```

S34/35.2      STQ      VLOAD
                SUBEXIT
                VPASS3
                PDVL    PDDL
                RPASS3
                INTIME
                PDDL    PDDL
                TPASS4
                TWOPI    # CONIC
                PDDL    BHIZ
                NN
                S3435.23
                DLOAD   PDDL
                ZEROVECS # PRECISION

```

```

S3435.23      CALL      INTINT      # GET TARGET VECTOR

```

```

S3435.25      STOVL    RTARG
                VATT
                STOVL    VPASS4
                RTARG

```

# COMPUTE PHI = PI + (ACOS(UNIT RA.UNIT RP) - PI) SIGN(RA\*RP.U)

```

  UNIT  PDVL      # UNIT RP
        RACT3
  UNIT  PUSH      # UNIT RA
  VXV   DOT
        OD
        UNRM      # RA*RP.U

```

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```

      PDVL
      DOT    SL1      # UNIT RA.UNIT RP
              OD
      ACOS    SIGN
      BPL     DAD
              NOPIE
              DPPOSMAX # REASONABLE TWO PI
NOPIE      STODL    ACTCENT
              TPASS4
      DSU
              INTIME
      STORE   DELLT4
      SLOAD   SETPD
              NN      # NUMBER OF OFFSETS
              OD
      PDDL    PDVL
              EPSFOUR
```

# Page 476

```

              RACT3
      STOVL   RINIT
              VACT3
      STCALL  VINIT
              INITVEL
      CALL
              LOMAT
      VLOAD   MXV
              DELVEET3
              OD
      VSL1
      STCALL  DELVLVC
              SUBEXIT
```

# Page 477

# \*\*\*\*\* S34/35.3 \*\*\*\*\*

```

S34/35.3      STQ    CALL
              NORMEX
              LOMAT   # GET MATRIX IN PUSH LIST
      VLOAD    VXN
              DELVLVC # NEW DEL V TPI
              OD
      VSL1
      STORE    DELVEET3 # SAVE FOR TRANSFORM
      VAD      PDVL
              VACT3
              RACT3 # NEW V REQ
```

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|         |        |          |                             |
|---------|--------|----------|-----------------------------|
|         | PDDL   | PDDL     |                             |
|         |        | TIG      |                             |
|         |        | TPASS4   |                             |
|         | PDDL   | PUSH     |                             |
|         |        | DPPOSMAX |                             |
|         | CALL   |          | # INTEG. FOR NEW TARGET VEC |
|         |        | INTINT   |                             |
|         | VLOAD  |          |                             |
|         |        | RATT     |                             |
|         | STORE  | RTARG    |                             |
| NOVRWRT | VLOAD  | PUSH     |                             |
|         |        | ULOS     |                             |
|         | VXV    | VCOMP    |                             |
|         |        | UNRM     |                             |
|         | UNIT   | PUSH     |                             |
|         | VXV    | VSL1     |                             |
|         |        | ULOS     |                             |
|         | PDVL   |          |                             |
|         | PDVL   | MXV      |                             |
|         |        | DELVEET3 |                             |
|         |        | OD       |                             |
|         | VSL1   |          |                             |
|         | STCALL | DVLOS    |                             |
|         |        | NORMEX   |                             |

# Page 478

# \*\*\*\*\* S34/35.4 \*\*\*\*\*

|          |      |         |                        |
|----------|------|---------|------------------------|
| S34/35.4 | STQ  | SETPD   | NO ASTRONAUT OVERWRITE |
|          |      | NORMEX  |                        |
|          |      | OD      |                        |
|          | GOTO |         |                        |
|          |      | NOVRWRT |                        |

# Page 479

# \*\*\*\*\* LOMAT \*\*\*\*\*

|       |       |       |        |
|-------|-------|-------|--------|
| LOMAT | VLOAD | VCOMP |        |
|       |       | UNRM  |        |
|       | STOVL | 6D    | # Y    |
|       |       | RACT3 |        |
|       | UNIT  | VCOMP |        |
|       | STORE | 12D   |        |
|       | VXV   | VSL1  |        |
|       |       | UNRM  | # Z*-Y |
|       | STORE | OD    |        |



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|        |        |          |      |                               |
|--------|--------|----------|------|-------------------------------|
|        | SETPD  | RVQ      |      |                               |
|        |        | 18D      |      |                               |
| GOINT  | PDDL   | PDDL     | # DO |                               |
|        |        | ZEROVECS | #    | NOT                           |
|        |        | NOMTPI   | #    |                               |
|        | PUSH   | PUSH     | #    | ORDER OR INSERT BEFORE INTINT |
| INTINT | STQ    | CALL     |      |                               |
|        |        | RTRN     |      |                               |
|        |        | INTSTALL |      |                               |
|        | CLEAR  | DLOAD    |      |                               |
|        |        | INTYPFLG |      |                               |
|        | BZE    | SET      |      |                               |
|        |        | +2       |      |                               |
|        |        | INTYPFLG |      |                               |
|        | DLOAD  | STADR    |      |                               |
|        | STODL  | TDEC1    |      |                               |
|        | SET    | LXA,2    |      |                               |
|        |        | MOONFLAG |      |                               |
|        |        | RTX2     |      |                               |
|        | BON    | CLEAR    |      |                               |
|        |        | CMOONFLG |      |                               |
|        |        | ALLSET   |      |                               |
|        |        | MOONFLAG |      |                               |
| ALLSET | STOVL  | TET      |      |                               |
|        | VSR*   |          |      |                               |
|        |        | 0,2      |      |                               |
|        | STOVL  | RCV      |      |                               |
|        | VSR*   |          |      |                               |
|        |        | 0,2      |      |                               |
|        | STCALL | VCV      |      |                               |
|        |        | INTEGRVS |      |                               |
|        | VLOAD  | GOTO     |      |                               |
|        |        | RATT     |      |                               |
|        |        | RTRN     |      |                               |

# Page 480

# \*\*\*\*\* S34/35.5 \*\*\*\*\*

#

# SUBROUTINES USED

# BANKCALL

# GOFLASH

# GOTOP00H

# S34/35.3

# S34.35.4

# VNP00H

```

S34/35.5      STQ      BON
                  SUBEXIT
                  FINALFLG
                  FLAGON
                  SET      GOTO
                  UPDATFLG
                  FLAGOFF

FLAGON        VLOAD      DELVLVC
                  STORE     DVLOS      # SAVE DELTA V BEFORE DISPLAY
                  EXIT
                  CAF      V06N81
                  TC      VNPOOH
                  TC      INTPRET
                  VLOAD     VSU      # TEST FOR OVERWRITE OF COMPUTED
                  DELVLVC      #              DELTA V
                  DVLOS
                  ABVAL     BZE
                  NOCHG      # NO OVERWRITE
                  CALL
                  S34/35.3
NOCHG         CLEAR     VLOAD
                  XDELVFLG
                  DELVEET3
                  STORE     DELVSIN
FLAGOFF       CALL
                  S34/35.4
                  EXIT
                  CAF      V06N59
                  TC      VNPOOH
                  TC      INTPRET
                  GOTO
                  SUBEXIT

```

```

# Page 481
# ***** VN1645 *****
#
# SUBROUTINES USED
#   P3XORP7X
#   GET+MGA
#   BANKCALL
#   DELAYJOB
#   COMPTGO
#   GOFLASHR
#   GOTOPOOH
#   FLAGUP

```

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```
VN1645      STQ      DLOAD
              SUBEXIT
              DP-.01
              STORE   +MGA      # MGA = -.01
              BOFF    DLOAD
              FINALFLG
              GET45
              DP-.01
              DAD
              DP-.01
              STORE   +MGA      # MGA = -.02
              BOFF    EXIT
              REFSMFLG
              GET45
              TC      P3XORP7X
              TC      +2        # P3X
              TC      GET45 +1   # P7X
              TC      INTPRET
              VLOAD    PUSH
              DELVSIN
              CALL
              GET+MGA      # COMPUTE MGA
GET45        EXIT
              TC      COMPTGO    # INITIATE TASK TO UPDATE TTOGO
              CA      SUBEXIT
              TS      QSAVED
              CAF     1SEC
              TC      BANKCALL
              CADR    DELAYJOB
              CAF     V16N45     # TRKMKCNT, TTOGO, +MGA
              TC      BANKCALL
              CADR    GOFLASH
              TC      KILCLOCK   # TERMINATE
              TC      N45PROC    # PROCEED
              TC      CLUPDATE   # RECYCLE -- RETURN FOR INITIAL COMPUTATION
KILCLOCK     CA      Z
              TS      DISPDEX
# Page 482
              TC      GOTOP00H
N45PROC      CS      FLAGWRD2
              MASK    BIT6
              EXTEND
              BZF     KILCLOCK   # FINALFLG IS SET -- FLASH V37 -- AWAIT NEW PGM
              TC      PHASCHNG
              OCT     04024
```

|          |       |          |            |
|----------|-------|----------|------------|
|          | TC    | UPFLAG   | # SET      |
|          | ADRES | FINALFLG | # FINALFLG |
| CLUPDATE | CA    | Z        |            |
|          | TS    | DISPDEX  |            |
|          | TC    | PHASCHNG |            |
|          | OCT   | 04024    |            |
|          | TC    | INTPRET  |            |
|          | CLEAR | GOTO     |            |
|          |       | UPDATFLG |            |
|          |       | QSAVED   |            |

```
# Page 483
# ***** DISPLAYE *****
#
# SUBROUTINES USED
#     BANKCALL
#     GOFLASHR
#     GOTOPPOH
#     BLANKET
#     ENDOFJOB
```

|          |        |          |
|----------|--------|----------|
| DISPLAYE | EXTEND |          |
|          | QXCH   | NORMEX   |
|          | CAF    | VO6N55   |
|          | TCR    | BANKCALL |
|          | CADR   | GOFLASH  |
|          | TCF    | GOTOPPOH |
|          | TC     | NORMEX   |
|          | TCF    | -5       |

```
# Page 484
# ***** P3XORP7X *****
```

|          |        |        |
|----------|--------|--------|
| P3XORP7X | CAF    | HIGH9  |
|          | MASK   | MODREG |
|          | EXTEND |        |
|          | BZF    | +2     |
|          | INCR   | Q      |
|          | RETURN |        |

```
# ***** VNPOOH *****
#
# SUBROUTINES USED
#     BANKCALL
#     GOFLASH
#     GOTOPPOH
```

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```

                                SETLOC P30SUBS
                                BANK
VNPOOH      EXTEND
              QXCH   RTRN
              TS     VERBNOUN
              CAF     VNBANK      # ***** THIS ROUTINE MUST REMAIN IN
              XCH     FBANK        #         FIXED-FIXED *****
              TS     TBASE5        # * WATCH OUT *
              CA      VERBNOUN
              TCR     BANKCALL
              CADR    GOFLASH
              TCF     GOTOPPOOH
              TCF     +2
VNBANK      TC      -5
              CA      TBASE5
              TS     FBANK
              TC     RTRN
```

# Page 485

# \*\*\*\*\* CONSTANTS \*\*\*\*\*

```

V06N37      VN      0637
V06N55      VN      0655
V06N58      VN      0658
V06N59      VN      0659
V06N81      VN      0681
V16N45      VN      1645
              SETLOC CSI/CDH
              BANK
TWOPI       2DEC    6.283185307 B-4
MAX250      2DEC    25 E3 B-28      # RSB 2004 added the B-28. OH 2009 leave?
THIRD       2DEC    .333333333
ELEPS       2DEC    .27777777 E-3
DECTWO      OCT     2
DP-.01      OCT     77777          # CONSTANTS
              OCT     61337        # ADJACENT      -.01 FOR MGA DSP
EPSFOUR     2DEC    .0416666666
```

# Page 486

# \*\*\*\*\* INITVEL \*\*\*\*\*

# MOD NO -1

LOG SECTION -- P34-P35, P74-P75

```

# MOD BY WHITE, P.                DATE:  21 NOV 67
#
# FUNCTIONAL DESCRIPTION
#   THIS SUBROUTINE COMPUTES THE REQUIRED INITIAL VELOCITY VECTOR FOR
#   A TRAJECTORY OF SPECIFIC TRANSFER TIME BETWEEN SPECIFIED INITIAL
#   AND TARGET POSITIONS.  THE TRAJECTORY MAY BE EITHER CONIC OR
#   PRECISION DEPENDING ON AN INPUT PARAMETER (NAMELY, NUMBER OF
#   OFFSETS).  IN ADDITION, IN THE PRECISION TRAJECTORY CASE, THE
#   SUBROUTINE ALSO COMPUTES AN OFFSET TARGET VECTOR, TO BE USED
#   DURING PURE-CONIC CROSS-PRODUCT STEERING.  THE OFFSET TARGET
#   VECTOR IS THE TERMINAL POSITION VECTOR OF A CONIC TRAJECTORY WHICH
#   HAS THE SAME INITIAL STATE AS A PRECISION TRAJECTORY WHOSE
#   TERMINAL POSITION VECTOR IS THE SPECIFIED TARGET VECTOR.
#
#   IN ORDER TO AVOID THE INHERENT SINGULARITIES IN THE 180 DEGREE
#   TRANSFER CASE WHEN THE (TRUE OR OFFSET) TARGET VECTOR MAY BE
#   SLIGHTLY OUT OF THE ORBITAL PLANE, THIS SUBROUTINE ROTATES THIS
#   VECTOR INTO A PLANE DEFINED BY THE INPUT INITIAL POSITION VECTOR
#   AND ANOTHER INPUT VECTOR (USUALLY THE INITIAL VELOCITY VECTOR),
#   WHENEVER THE INPUT TARGET VECTOR LIES INSIDE A CONE WHOSE VERTEX
#   IS THE ORIGIN OF COORDINATES, WHOSE AXIS IS THE 180 DEGREE
#   TRANSFER DIRECTION, AND WHOSE CONE ANGLE IS SPECIFIED BY THE USER.
#
#   THE LAMBERT SUBROUTINE IS UTILIZED FOR THE CONIC COMPUTATIONS AND
#   THE COASTING INTEGRATION SUBROUTINE IS UTILIZED FOR THE PRECISION
#   TRAJECTORY COMPUTATIONS.
#
# CALLING SEQUENCE
#   L      CALL
#   L+1    INITVEL
#   L+2    (RETURN -- ALWAYS)
#
# INPUT
#   (1)    RINIT      INITIAL POSITION RADIUS VECTOR
#   (2)    VINIT      INITIAL POSITION VELOCITY VECTOR
#   (3)    RTARG      TARGET POSITION RADIUS VECTOR
#   (4)    DELLT4     DESIRED TIME OF FLIGHT FROM RINIT TO RTARG
#   (5)    INTIME     TIME OF RINIT
#   (6)    OD         NUMBER OF ITERATIONS OF LAMBERT/INTEGRVS
#   (7)    2D         ANGLE TO 180 DEGREES WHEN ROTATION STARTS
#   (8)    RTX1       -2 FOR EARTH, -10D FOR LUNAR
#   (9)    RTX2       COORDINATE SYSTEM ORIGIN -- 0 FOR EARTH, 2 FOR LUNAR
#   PUSHLOC SET AT 4D
#
# Page 487
# OUTPUT

```

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```
#      (1)      RTARG      OFFSET TARGET POSITION VECTOR
#      (2)      VIPRIME     MANEUVER VELOCITY REQUIRED
#      (3)      VTPRIME     VELOCITY AT TARGET AFTER MANEUVER
#      (4)      DELVEET3    DELTA VELOCITY REQUIRED FOR MANEUVER
#
# SUBROUTINES USED
#      LAMBERT
#      INTSTALL
#      INTEGRVS

                SETLOC  INTVEL
                BANK

                COUNT  11/INITV
INITVEL        SET      # COGA GUESS NOT AVAILABLE
                GUESSW
HAVEGUES       VLOAD   STQ
                RTARG
                NORMEX
                STORE  RTARG1
                SLOAD  BHIZ
                RTX2
                INITVEL1
                VLOAD  VSL2
                RINIT      # B29
                STOVL  RINIT  # B27
                VINIT      # B7
                VSL2
                STOVL  VINIT  # B5
                RTARG1
                VSL2
                STORE  RTARG1

# INITIALIZATION

INITVEL1      SSP      DLOAD      # SET ITCTR TO -1,LOAD MPAC WITH E4 (PL 2D)
                ITCTR
                0 -1
                COSINE  SR1      # CALCULATE COSINE (E4) (+2)
                STODL   COZY4    # SET COZY4 TO COSINE (E4) (PL 0D)
                LXA,2    SXA,2
                MPAC
                VTARGETAG      # SET VTARGETAG TO 0D (SP)
                VLOAD
                RINIT
                STOVL  R1VEC      # R1VEC EQ RINIT
```

```

# Page 488
RTARG1
STODL R2VEC # R2VEC EQ RTARG
        DELLT4
STORE TDESIRE # TDESIRE EQ DELLT4
SETPD VLOAD
        OD # INITIALIZE PL TO OD
        RINIT # MPAC EQ RINIT (+29)
UNIT PUSH # UNIT(RI) (+1) (PL 6D)
VXV UNIT
        VINIT # MPAC EQ UNIT(RI) X VI (+8)
STOVL UN
        RTARG1
UNIT DOT # TEMP=URT.URI (+2) (PL 0D)
DAD CLEAR
        COZY4
        NORMSW
STORE COZY4
INITVEL2 BPL SET
        INITVEL3 # UN CALCULATED IN LAMBERT
        NORMSW

# ROTATE RC INTO YC PLANE -- SET UNIT NORMAL TO YC

VLOAD PUSH # (PL 6D)
        R2VEC # RC TO 6D (+29)
ABVAL PDVL # RC TO MPAC, ABVAL(RC) (+29) TO OD(PL 2D)
PUSH VPROJ # (PL 8D)
        UN
VSL2 BVSU
UNIT VXSC # (PL 0D)
VSL1
STORE R2VEC
TLOAD SLOAD
        ZEROVEC
        ITCTR
BPL VLOAD
        INITVEL3
        R2VEC
STORE RTARG1
INITVEL3 DLOAD PDVL # (PL 2D)
        MUEARTH # POSITIVE VALUE
        R2VEC
UNIT PDVL # 2D = UNIT(R2VEC) (PL 8D)
        R1VEC
UNIT PUSH # 8D = UNIT(R1VEC) (PL 14D)

```



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```
# Page 489

      VXV      VCOMP      # -N = UNIT(R2VEC) X UNIT(R1VEC)
                2D
      PUSH
      LXA,1     DLOAD
                RTX1
                18D
      BMN      INCR,1
                +2
      DEC      -8
      INCR,1    SLOAD
                10D
                X1
      BHIZ     VLOAD      # (PL 14D)
                +2
      VCOMP    PUSH      # (PL 20 D)
      VLOAD    # (PL 14D)
      VXV      DOT       # (PL 2D)
      BPL      DLOAD      # (PL 0D)
                INITVEL4
      DCOMP    PUSH      # (PL 2D)
INITVEL4      LXA,2      SXA,2
                OD
                GEOMSGN

# SET INPUTS UP FOR LAMBERT

      LXA,1     CALL
                RTX1
# OPERATE THE LAMBERT CONIC ROUTINE (COASTFLT SUBROUTINE)

      LAMBERT

# ARRIVED AT SOLUTION IS GOOD ENOUGH ACCORDING TO SLIGHTLY WIDER BOUNDS.

      CLEAR     VLOAD
                GUESSW
                VVEC

# STORE CALCULATED INITIAL VELOCITY REQUIRED IN VIPRIME

      STODL     VIPRIME      # INITIAL VELOCITY REQUIRED (+7)

# IF NUMIT IS ZERO, CONTINUE AT INITVELB, OTHERWISE
# SET UP INPUTS FOR ENCKE INTEGRATION (INTEGRVS).
```

```

                                VTARGETAG
                                CALL
                                INITVEL7
                                INTSTALL
                                SLOAD  CLEAR
                                RTX2
                                MOONFLAG
                                BHIZ   SET
                                INITVEL5
                                MOONFLAG
INITVEL5  VLOAD
                                RINIT
                                STORE  R1VEC
# Page 490
                                STOVL  RCV
                                VIPRIME
                                STODL  VCV
                                INTIME
                                STORE  TET
                                DAD    CLEAR
                                DELLT4
                                INTYPFLG
                                STCALL  TDEC1
                                INTEGRVS
                                VLOAD
                                VATT1
                                STORE  VTARGET

# IF ITERATION COUNTER (ITCTR) EQ NO. ITERATIONS (NUMIT), CONTINUE AT
# INITVELC, OTHERWISE REITERATE LAMBERT AND ENCKE

                                LXA,2  INCR,2
                                ITCTR
                                1D      # INCREMENT ITCTR
                                SXA,2  XSU,2
                                ITCTR
                                VTARGETAG
                                SLOAD  BHIZ      # IF SP(MPAC) EQ 0, CONTINUE AT INITVELC
                                X2
                                INITVEL6

# OFFSET CONIC TARGET VECTGOR

                                VLOAD  VSU
                                RTARG1
                                RATT1

```

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```

      VAD
      STODL R2VEC
      COZY4
      GOTO  INITVEL2      # CONTINUE ITERATING AT INITVEL2

# COMPUTE THE DELTA VELOCITY

INITVEL6      VLOAD
               R2VEC
      STORE  RTARG1
INITVEL7      VLOAD  VSU
               VIPRIME
               VINIT
      STOVL  DELVEET3      # DELVEET3 = VIPRIME-VINIT (+7)
               VTARGET
      STORE  VTPRIME
      SLOAD  BHIZ
               RTX2

# Page 491

               INITVELX
      VLOAD  VSR2
               VTPRIME
      STOVL  VTPRIME
               VIPRIME
      VSR2
      STOVL  VIPRIME
               RTARG1
      VSR2
      STOVL  RTARG1
               DELVEET3
      VSR2
      STORE  DELVEET3
INITVELX      SETPD  VLOAD
               OD
               RTARG1
      STCALL RTARG
               NORMEX

# ***** END OF INITVEL ROUTINE *****

# Page 492
# ***** MIDGIM *****
# MOD NO. 0, BY WILLMAN, SUBROUTINE RENDGUID, LOG P34-P35, P74-P75
# REVISION 03, 17 FEB 67
```

```

#
# IF THE ACTIVE VEHICLE IS DOING THE COMPUTATION, MIDGIM COMPUTES
# THE POSITIVE MIDDLE GIMBAL ANGLE OF THE ACTIVE VEHICLE TO THE INPUT
# DELTA VELOCITY VECTOR (OD IN PUSY LIST), OTHERWISE
# MIDGIM CONVERTS THE INPUT DELTA VELOCITY VECTOR FROM INERTIAL COORDIN-
# ATES TO LOCAL VERTICAL COORDINATES OF THE ACTIVE VEHICLE.
#
# ** INPUTS **
#   NAME      MEANING                                     UNITS/SCALING/MODE
#   AVFLAG    INT FLAG -- 0 IS CSM ACTIVE, 1 IS LEM ACTIVE   BIT
#   COMPUTER  INT FLAG -- 0 IS LEM COMPUTER, 1 IS CSM COMPUTER BIT
#   RINIT     ACTIVE VEHICLE RADIUS VECTOR                 METERS/CSEC (+7) VT
#   VINIT     ACTIVE VEHICLE VELOCITY VECTOR               METERS/CSEC (+7) VT
#   OD(PL)    ACTIVE VEHICLE DELTA VELOCITY VECTOR         METERS/CSEC (+7) VT
#
# ** OUTPUTS **
#   NAME      MEANING                                     UNITS/SCALING/MODE
#   +MGA      + MIDDLE GIMBAL ANGLE                       REVOLUTIONS (+0) DP
#   DELVLVC   DELTA VELOCITY VECTOR IN LV COORD.          METERS/CSEC (+7) VT
#   MGLVFLAG  INT FLAG: 0 IS +MGA COMUTED, 1 IS DELVLVC COMP. BIT
#
# ** CALLING SEQUENCE **
#   L          CALL
#   L+1        MIDGIM
#   L+2        (RETURN -- ALWAYS)
#
# ** NO SUBROUTINES CALLED **
#
# ** DEBRIS -- ERASABLE TEMPORARY USAGE **
#   A,Q,L, PUSH LIST, MPAC.
#
# ** ALARMS -- NONE **
#
# Page 493
# MIDDLE GIMBAL ANGLE COMPUTATION
#           SETLOC  MIDGIM
#           BANK
#
#           COUNT*  $$/MIDG
#
# HALFREV    2DEC    1 B-1
#
# MIDGIM      BON     BOFF
#              AVFLAG
#              MIDGIM1
#              COMPUTER

```

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GET.LVC

# COMPUTE +MGA IF AVFLAG AND COMPUTER HAVE OPPOSITE VALUES.

```
GET+MGA      VLOAD  UNIT      # (PL OD) V (+7) TO MPAC UNITIZE UV (+1)
              DOT    SL1       # DOT UV WITH Y(STABLE MEMBER) AND RESCALE
              REFSMMAT +6     # FROM +2 TO +1 FOR ASIN ROUTINE
              ARCSIN BPL
              SETMGA
              DAD     DAD       # CONVERT -MGA TO +MGA BY
              HALFREV      # ADDING ONE REVOLUTION
              HALFREV
SETMGA        STORE  +MGA
              CLR    RVQ       # CLEAR MGLVFLAG TO INDICATE +MGA CALC
              MGLVFLAG      # AND EXIT

MIDGIM1       BOFF
              COMPUTER
              GET+MGA
```

# COMPUTE DELVLVC IF AVFLAG AND COMPUTER HAVE SAME VALUES

```
GET.LVC      VLOAD  UNIT      # (PL 6D) R (+29) IN MPAC UNITIZE UR
              RINIT
              VCOMP      # U(-R)
              STORE  18D   # U(-R) TO 18D
              VXV     UNIT  # U(-R)*V EQ V*U(R), U(V*R)
              VINIT
              STORE  12D   # U(V*R) TO 12D
              VXV     UNIT  # U(V*R)*U(-R), U((V*R)*(-R))
              18D
              STOVL  6D    # TRANSFORMATION MATRIX IS IN 6D (+1)
              OD     # DELTA V (+7) IN OD
              MXV    VSL1  # CONVERT FROM INER COOR TO LV COOR (+8)
              6D     # AND SCALE +7 IN MPAC
              STORE  DELVLVC # STORE IN DELVLVC (+7)
              SET    RVQ    # SET MGLVFLAG TO INDICATE LVC CALC
              MGLVFLAG      # AND EXIT
```

# \*\*\*\*\* END OF MIDGIM ROUTINE \*\*\*\*\*

# Page 494

```
SELECTMU     AXC,1  AXT,2
              2D
              OD
              BOFF
```

```

                                CMOONFLG
                                SETMUER
                                AXC,1  AXT,2
                                10D
                                2D
SETMUER      DLOAD*  SXA,1
                                MUTABLE +4,1
                                RTX1
                                STODL*  RTSR1/MU
                                MUTABLE -2,1
                                BOFF     SR
                                CMOONFLG
                                RTRNMU
                                6D
RTRNMU      STORE   RTMU
                                SXA,2   CLEAR
                                RTX2
                                FINALFLG
                                GOTO
                                VN1645

```

# Page 495

# \*\*\*\*\* PERIAPO \*\*\*\*\*

# MOD NO -1

LOG SECTION -- P34-P35, P74-P75

# MOD BY WHITE, P.

DATE 18 JAN 68

#

# FUNCTIONAL DESCRIPTION

# THIS SUBROUTINE COMPUTES THE TWO BODY APOCENTER AND PERICENTER  
# ALTITUDES GIVEN THE POSITION AND VELOCITY VECTORS FOR A POINT ON  
# THE TRAJECTORY AND THE PRIMARY BODY.

#

# SETRAD IS CALLED TO DETERMINE THE RADIUS OF THE PRIMARY BODY.

#

# APSIDES IS CALLED TO SOVE FOR THE TWO BODY RADII OF APOCENTER AND  
# PERICENTER AND THE ECCENTRICITY OF THE TRAJECTORY.

#

# CALLING SEQUENCE

# L CALL

# L+1 PERIAPO

# L+2 (RETURN -- ALWAYS)

#

# INPUT

# (1) RVEC POSITION VECTOR IN METERS

# SCALE FACTOR -- EARTH +29, MOON +27

# (2) VVEC VELOCITY VECTORY IN METERS/CENTISECOND

# SCALE FACTOR -- EARTH +7, MOON +5

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```
#      (3)    X1      PRIMARY BODY INDICATOR
#                                     EARTH -2, MOON -10
#
# OUTPUT
#      (1)    2D      APOCENTER RADIUS IN METERS
#                                     SCALE FACTOR -- EARTH +29, MOON +27
#      (2)    4D      APOCENTER ALTITUDE IN METERS
#                                     SCALE FACTOR -- EARTH +29, MOON +27
#      (3)    6D      PERICENTER RADIUS IN METERS
#                                     SCALE FACTOR -- EARTH +29, MOON +27
#      (4)    8D      PERICENTER ALTITUDE IN METERS
#                                     SCALE FACTOR -- EARTH +29, MOON +27
#      (5)    ECC     ECCENTRICITY OF CONIC TRAJECTORY
#                                     SCALE FACTOR -- +3
#      (6)    XXXALT  RADIUS OF THE PRIMARY BODY IN METERS
#                                     SCALE FACTOR -- EARTH +29, MOON +27
#      (7)    PUSHLOC EQUALS 10D
#
# SUBROUTINES USED
#      SETRAD
# Page 496
#      APSIDES
```

```
SETLOC  APOPERI
BANK
```

```
COUNT*  $$/PERAP
```

```
RPAD      2DEC      6373338 B-29      # STANDARD RADIUS OF PAD 37-B.
# = 20 909 901.57 FT
```

```
PERIAPO1  LXA,2    VSR*
                                     RTX2
                                     0,2
STOVL      VVEC
LXA,1      VSR*
                                     RTX1
                                     0,2
STORE      RVEC
PERIAPO    STQ      CALL
                                     NORMEX
                                     SETRAD
STCALL     XXXALT
APSIDES
SETPD      PUSH      # 2D = APOCENTER RADIUS
2D
```

B29 OR B27

|            |        |                                   |                          |            |
|------------|--------|-----------------------------------|--------------------------|------------|
|            | DSU    | PDDL<br>XXXALT<br>OD              | # 4D = APOGEE ALTITUDE   | B29 OR B27 |
|            | PUSH   | DSU<br>XXXALT                     | # 6D = PERICENTER RADIUS | B29 OR B27 |
|            | PUSH   | GOTO<br>NORMEX                    | # 8D = PERIGEE ALTITUDE  | B29 OR B27 |
| # Page 497 |        |                                   |                          |            |
| # SETRAD   |        |                                   |                          |            |
| SETRAD     | DLOAD  | PUSH<br>RPAD                      |                          |            |
|            | SXA,1  | INCR,2<br>X2<br>2D                |                          |            |
|            | SLOAD  | BHIZ<br>X2<br>SETRADX             |                          |            |
|            | VLOAD  | ABVAL<br>RLS                      |                          |            |
|            | PDDL   |                                   |                          |            |
| SETRADX    | DLOAD  | RVQ                               |                          |            |
| # Page 498 |        |                                   |                          |            |
| # PRECSET  |        |                                   |                          |            |
| PRECSET    | STQ    |                                   |                          |            |
|            |        | NORMEX                            |                          |            |
|            | STCALL | TDEC2<br>LEMPREC                  |                          |            |
|            | CALL   |                                   |                          |            |
|            |        | LEMSTORE                          |                          |            |
|            | DLOAD  |                                   |                          |            |
|            |        | TDEC2                             |                          |            |
|            | STCALL | TDEC1<br>CSMPREC                  |                          |            |
|            | CALL   |                                   |                          |            |
|            |        | CSMSTORE                          |                          |            |
|            | GOTO   |                                   |                          |            |
|            |        | NORMEX                            |                          |            |
| LEMSTORE   | VLOAD  | BOFF<br>RATT<br>AVFLAG<br>PASSIVE |                          |            |
| ACTIVE     | STOVL  | RACT3<br>VATT                     |                          |            |
|            | STORE  | VACT3                             |                          |            |
|            | RVQ    |                                   |                          |            |



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|          |       |        |
|----------|-------|--------|
| CSMSTORE | VLOAD | BOFF   |
|          |       | RATT   |
|          |       | AVFLAG |
|          |       | ACTIVE |
| PASSIVE  | STOVL | RPASS3 |
|          |       | VATT   |
|          | STORE | VPASS3 |
|          | RVQ   |        |

# Page 499

# VECSHIFT

|          |       |      |
|----------|-------|------|
| VECSHIFT | LXA,2 | VSR* |
|          |       | RTX2 |
|          |       | 0,2  |
|          | LXA,1 | PDVL |
|          |       | RTX1 |
|          | VSR*  | PDVL |
|          |       | 0,2  |
|          | RVQ   |      |

# Page 500

# SHIFTR1

|         |       |      |
|---------|-------|------|
| SHIFTR1 | LXA,2 | SL*  |
|         |       | RTX2 |
|         |       | 0,2  |
|         | RVQ   |      |

# Page 501

# PROGRAM DESCRIPTION

#

# SUBROUTINE NAME R36 OUT-OF-PLANE RENDEZVOUS ROUTINE

# MOD NO. 2 DATE 2 JANUARY 1969

# MOD BY A.W.BANCROFT LOG SECTION EXTENDED VERBS

#

# FUNCTIONAL DESCRIPTION

#

# TO DISPLAY AT ASTRONAUT REQUEST LGC CALCULATED RENDEZVOUS

# OUT-OF-PLANE PARAMETERS (Y, YDOT, PSI). (REQUESTED BY DSKY).

#

# CALLING SEQUENCE

# ASTRONAUT REQUEST THROUGH DSKY V 90 E

#

# SUBROUTINES CALLED

# EXDSPRET

# GOMARKF

# CSMPREC

```

#      LEMPREC
#      SGNAGREE
#      LOADTIME
#
# NORMAL EXIT MODES
#      ASTRONAUT REQUEST THROUGH DSKY TO TERMINATE PROGRAM V 34 E
#
# ALARM OR ABORT EXIT MODES
#      NONE
#
# OUTPUT
#      DECIMAL DISPLAY OF TIME, Y, YDOT AND PSI
#
#      DISPLAYED VALUES Y, YDOT, AND PSI, ARE STORED IN ERASABLE
#      REGISTERS RANGE, RRATE, AND RTHETA RESPECTIVELY.
#
# ERASABLE INITIALIZATION REQUIRED
#      CSM AND LEM STATE VECTORS
#
# DEBRIS
#      CENTRALS A,Q,L
#      OTHER:  THOSE USED BY THE ABOVE LISTED SUBROUTINES

                BANK    20
                SETLOC  R36CM
                BANK
# Page 502
                EBANK=  RPASS36

                SBANK=  R36A
                COUNT*  $$/R36

R36             CAF     TWO
                TS      OPTIONX
                CAF     ONE
                TS      OPTIONX +1
                CAF     OPTION36      # V 04 N 12
                TC      BANKCALL
                CADR    GOXDSPF
                TC      ENDEXT        # TERMINATE
                TC      +2            # PROCEED
                TC      -5            # R2 LOADED VIA DSKY
                TC      POSTJUMP
                CADR    R36A

OPTION36        VN      0412

```

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```

SETLOC R36LM
BANK

R36A      ZL
CAF      ZERO      # SET TIME OF EVENT TO ZERO FOR FIRST
DXCH     DSPTMX    # DISPLAY
LXCH     OPTIONY   # SAVE VEH. OPTION

R36P3     CAF      V06N16N
TC       BANKCALL
CADR     GOMARKF
TCF      ENDEXT    # TERMINATE
TCF      +2        # PROCEED
TCF      -5        # RECYCLE FOR ASTRONAUT INPUT TIME
DXCH     DSPTMX
EXTEND
BZF      LREGCHK   # A-REG ZERO GOTO CHECK L-REG FOR ZERO
DXCH     MPAC      # A-REG NON-ZERO, TIME = ASTRO INPUT TIME
TC       INTPRET
RTB      GOTO
          DPMODE
          R36INT

SETLOC R36LM1
BANK

R36INT    STORE    TDEC1
          SLOAD    SR1
                   OPTIONY
          BHIZ     CALL
                   R36PROG2    # FOR CSM DISPLAY
          THISPREC    # FOR LEM DISPLAY
          GOTO
          R36PROG3
R36PROG2  CALL
          OTHPREC
R36PROG3  VLOAD    PDVL
          VATT
          RATT      # -
          STORE    RPASS36   # R
          UNIT     PDVL      # P
          VXV      UNIT      # -
          STADR
          STODL    UNP36     # U
          TAT
```

# Page 503

```

STORE TDEC1
SLOAD SR1
OPTIONY
BHIZ CALL
      R36PROG4 # FOR CSM DISPLAY
      OTHPREC  # FOR LEM DISPLAY
GOTO
      R36PROG5
R36PROG4 CALL
      THISPREC
R36PROG5 VLOAD PDVL #
          VATT # VELOCITY VECTOR  $\bar{V}$  OOD
          RATT #  $\bar{A}$ 
PDDL
      TAT # SAVE TIME IN LOCATION 30D FOR REDISPLAY
STOVL 30D #
PUSH PUSH # POSITION VECTOR  $\bar{R}$  IN 06D AND 12D
BVSU PDVL #  $\bar{A}$ 
      RPASS36 # LINE OF SIGHT VECTOR  $\bar{R} - \bar{R}$  12D
DOT SL1 #  $\bar{P} \quad \bar{A}$ 
      UNP36 #
STOVL RANGE #  $\bar{Y} = \bar{U} \cdot \bar{R}$ 
      OOD #  $\bar{A}$ 
DOT SL1
      UNP36 #  $\cdot \quad \bar{A}$ 
STOVL RRATE #  $\bar{Y} = \bar{U} \cdot \bar{V}$ 
      06D #  $\bar{A}$ 
UNIT PUSH #  $\bar{U} = \text{UNIT} ( \bar{R} )$  18D
VXV VXV #  $\bar{R} \quad \bar{A}$ 
      OOD #
      18D #  $(\bar{U} \times \bar{V}) \times \bar{U} = \bar{U}$ 
VSL2 UNIT #  $\bar{R} \quad \bar{A} \quad \bar{R} \quad \bar{A}$ 
UNIT GOTO
      R36B

SETLOC R36CM1
# Page 504
BANK
R36B STOVL OOD # UNIT HORIZONTAL IN FORWARD DIR. OOD
      18D
DOT VXSC #  $\bar{U}$ 
      12D #  $\bar{U}$ 
VSL2 #  $\bar{L}$ 
BVSU UNIT
UNIT

```

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```

      PUSH      DOT      # LOS PROJECTED INTO HORIZONTAL 12D
                        OOD # PLANE
      SL1       ARCCOS   #
      STOVL     RTHETA   # PSI = ARCCOS( U- . U- )
      VXV       DOT      #           A    L
                        OOD
      BPL       DLOAD
                        R36TAG2
                        DPPOSMAX
      DSU
                        RTHETA
      STCALL    RTHETA
                        R36TAG2

      SETLOC    R36LM
      BANK

R36TAG2      DLOAD      RTB
                        30D
                        SGNAGREE
      STORE     DSPTMX
      EXIT
      CAF       V06N90N # DISPLAY Y, YDOT, AND PSI.
      TC        BANKCALL
      CADR      GOMARKF
      TCF       ENDEXT  # TERMINATE
      TCF       ENDEXT  # PROCEED, END OF PROGRAM
      TCF       R36P3   # REDISPLAY OUTPUT
LREGCHK      XCH        L
      EXTEND
      BZF       ENTTIM2 # L-REG ZERO, SET TIME = PRESENT TIME
      XCH       L       # L-REG NON ZERO, TIME = ASTRO INPUT TIME
      TCF       ASTROTIM
      TC        INTPRET
      RTB       GOTO
                        LOADTIME
                        R36INT
V06N16N      VN        00616
V06N90N      VN        00690
      SBANK=    LOWSUPER
```

This code is written to file src/P34-35-P74-75.s.

**A.72 P37 P70**1166  $\langle \text{src}/P37\text{-}P70.s \text{ 1166} \rangle \equiv$ 

```

# Copyright:   Public domain.
# Filename:    P37_P70.agc
# Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
#              It is part of the source code for the Command Module's (CM)
#              Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:  yaYUL
# Contact:     Jim Lawton <jim.lawton@gmail.com>.
# Website:     www.ibiblio.org/apollo.
# Pages:       890-933
# Mod history: 2009-05-11 JVL Adapted from the Colossus249/ file
#              of the same name, using Comanche055 page
#              images.
#              2009-05-20 RSB Added missing label V2T179. Fixed P00D00 -> P00D00.
#              2009-05-23 RSB In RTD18, corrected a STOVL DELVLVC to
#              STODL DELVLVC and a STODL 02D to STORE 02D.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. 10:28 APR. 1, 1969
#
# This AGC program shall also be referred to as
# Colossus 2A

# Page 890

BANK      31
SETLOC    RTE1
BANK

EBANK=    RTEDVD
COUNT    31/P37

# PROGRAM DESCRIPTION: P37, RETURN TO EARTH
#

```

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```
# DESCRIPTION
#   A RETURN TO EARTH TRAJECTORY IS COMPUTED PROVIDED THE CSM IS OUTSIDE THE LUNAR SPHERE C
#   TIME OF IGNITION.  INITIALLY A CONIC TRAJECTORY IS DETERMINED AND RESULTING IGNITION AN
#   DISPLAYED TO THE ASTRONAUT.  THEN IF THE ASTRONAUT SO DESIRES, A PRECISION TRAJECTORY I
#   RESULTING IGNITION AND REENTRY PARAMETERS DISPLAYED.  UPON FINAL ACCEPTANCE BY THE ASTR
#   COMPUTES AND STORES THE TARGET PARAMETERS FOR RETURN TO EARTH FOR USE BY SPS PROGRAM (P
#
# CALLING SEQUENCE
#   L      TC      P37
#
# SUBROUTINES CALLED
#   PREC100
#       V2T100
#       RTENCK2
#       RTENCK3
#       TIMERAD
#       PARAM
#   V2T100
#       GAMDV10
#       XT1LIM
#       DVCALC
#   RTENCK1
#       INTSTALL
#       INTEGRVS
#   RTEVN
#       RETDISP
#       TMRAD100
#       AUGKUGL
#       LAT-LONG
#   TMRAD100
#       TIMERAD
#   INVC100
#       CSMPREC
#   GETERAD
#   TIMETHET
#   P37OALRM
#   VN1645
#   POLY
#
# ERASABLE INITIALIZATION REQUIRED
#   CSM STATE VECTOR
# Page 891
#   NJETSFLG      NUMBER OF JETS IF THE RCS PROPULSION SYSTEM SELECTED      STATE FLAG
#
# ASTRONAUT INPUT
#   SPRTEIG      TIME OF IGNITION (OVERLAYS TIG)      DP      B28
```

```

#      VPRED          DESIRED CHANGE IN VELOCITY AT TIG(PROGRM COMPUTED IF 0) DP
#      GAMMAEI        DESIRED FLIGHT PATH ANGLE AT REENTRY (COMPUTED IF 0) DP
#      OPTION2        PROPULSION SYSTEM OPTION SP
#
# OUTPUT
#      CONIC OR PRECISION TRAJECTORY DISPLAY
#      VPRED          VELOCITY MAGNITUDE AT 400,000 FT. ENTRY ALTITUDE DP
#      T3TOT4         TRANSIT TIME TO 400,000 FT. ENTRY ALTITUDE DP
#      GAMMAEI        FLIGHT PATH ANGLE AT 400,00 FT. ENTRY ALTITUDE DP
#      DELVLVC        INITIAL VELOCITY CHANGE VECTOR IN LOCAL VERTICAL COORD. VECTOR
#      LAT(SPL)       LATITUDE OF THE LANDING SITE DP
#      LNG(SPL)       LONGITUDE OF THE LANDING SITE DP
#      TARGETING COMPUTATION DISPLAY
#      TIG            RECOMPUTED TIG BASED ON THRUST OPTION DP
#      TTOGO          TIME FROM TIG DP
#      +MGA           POSITIVE MIDDLE GIMBAL ANGLE DP
#      THRUST PROGRAM COMMUNICATION
#      XDELVFLG       EXTERNAL DELTA V FLAG STAT
#      NORMSW         LAMBERT AIMPT ROTATION SWITCH STAT
#      ECSTEER        CROSS PRODUCT STEERING CONSTANT SP
#      RTARG          CONICALLY INTEGRATED REENTRY POSITION VECTOR VECTOR
#      TPASS4         REENTRY TIME DP

P37      TC          PHASCHNG      # P37 IS NOT RESTARTABLE
        OCT          4

        TC          INTPRET
        AXT,1       SXA,1
        OCT          04000
        ECSTEER
        DLOAD
        ZEROVECS
        STORE       VPRED
        STORE       GAMMAEI
        EXIT
        CAF         V6N33RTE      # INPUT TIG      STORED IN SPRTETIG
        TCR         P37OGOF      #              OVERLAYED WITH TIG
        TCF         -2           # DISPLAY NEW DATA
        CAF         V6N60RTE      # INPUT REENTRY ANGLE IN GAMMAEI
        TCR         P37GFRB1     #              AND DESIRED DELTA V IN RETDVD
        TCF         -2           # DISPLAY NEW DATA

RTE299   TC          INTPRET
        SSP         DLOAD
        OVFIN
        0
        VPRED

```



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# Page 892

```
STODL  RTEDVD
      GAMMAEI
STODL  RTEGAM2D
      1RTEB13
STODL  CONICX1
      C4RTE
STCALL MAMAX1
      INVC100      # GET R(T1)/,V(T1)/,UR1/,UH/
CLEAR  DLOAD
      SLOWFLG
      RTEDVD
BPL    ABS
      RTE317
STORE  RTEDVD
DLOAD  DSU
      R(T1)
      K1RTE
BMN    SET
      RTE317
      SLOWFLG
RTE317 DLOAD  EXIT
      R(T1)
TC     POLY
DEC    2
2DEC   181000434. B-31
2DEC   1.50785145 B-2
2DEC*  -6.49993057 E-9 B27*
2DEC*  9.76938926 E-18 B56*
TC     INTERPRET
SL1
STODL  MAMAX2      # C0+C1*R+C2*R**2+C3*R**3=MAMAX2 B30
      M9RTEB28
STODL  NN1A
      K2RTE
RTE320 STODL  RCON      # RCON=K2
      RTEGAM2D
BZE    BDSU
      RTE340      # GOTORTE340 IF REENTRY ANGLE NOT INPUT
      1RTEB2
PUSH   COS      #
PDDL   SIN
BDDV   STADR     #
STCALL X(T2)      # X(T2)=COT(GAM2D)
      RTE360
RTE340 DLOAD  DSU
```

```

# Page 893
R(T1)
K1RTE
BMN DLOAD
RTE350
K4RTE
STCALL X(T2) # X(T2)=K4
RTE360
RTE350 DLOAD
K3RTE
STORE X(T2) # X(T2)=K3
RTE360 CALL
V2T100
BZE GOTO
RTE367
RTEALRM
RTE367 VLOAD
R(T1)/
STODL RVEC
RCON
STOVL RDESIRED
V2(T1)/
STCALL VVEC
TMRAD100
DAD
T1
STODL T2
RTEGAM2D
BZE GOTO
RTE369
RTE372
RTE369 VLOAD ABVAL
V(T2)/
EXIT
TC POLY
DEC 2
2DEC 0
2DEC -4.8760771 E-2 B4
2DEC 4.5419476 E-4 B11
2DEC -1.4317675 E-6 B18
TC INTERPRET
DAD
RTED1
SL3 GOTO # X(T2),=D1+D2V2+D3V2**2+D4V2**3
RTE373

```

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|            |        |          |                                 |           |
|------------|--------|----------|---------------------------------|-----------|
| RTE372     | DLOAD  |          | # X(T2),=X(T2)                  |           |
|            |        | X(T2)    |                                 |           |
| RTE373     | DSU    | PUSH     | # X(T2)ERR                      | B0 PL02D  |
| # Page 894 |        |          |                                 |           |
|            | VLOAD  | UNIT     |                                 |           |
|            |        | R(T2)/   | #                               | B58       |
|            | STCALL | ALPHAV   |                                 |           |
|            |        | GETERAD  |                                 |           |
|            | DAD    |          |                                 |           |
|            |        | E3RTE    |                                 |           |
|            | PUSH   | DSU      | # RCON,=(E1/1+E2BETA11)**.5)+E3 | B29 PL04D |
|            |        | RCON     |                                 |           |
|            | ABS    | DSU      |                                 |           |
|            |        | EPC2RTE  |                                 |           |
|            | BMN    | GOTO     |                                 |           |
|            |        | RTE374   |                                 |           |
|            |        | RTE375   |                                 |           |
| RTE374     | DLOAD  | ABS      |                                 |           |
|            |        | OOD      |                                 |           |
|            | DSU    | BMN      |                                 |           |
|            |        | EPC3RTE  |                                 |           |
|            |        | P37E     |                                 |           |
| RTE375     | DLOAD  | DAD      |                                 |           |
|            |        | NN1A     |                                 |           |
|            |        | 1RTEB28  |                                 |           |
|            | BMN    | SLOAD    |                                 |           |
|            |        | RTE380   |                                 |           |
|            |        | OCT605   |                                 |           |
|            | GOTO   |          |                                 |           |
|            |        | RTEALRM  | # TOO MANY ITERATIONS           |           |
| RTE380     | STORE  | NN1A     |                                 |           |
|            | DSU    | BZE      |                                 |           |
|            |        | M8RTEB28 |                                 |           |
|            |        | RTE385   |                                 |           |
|            | DLOAD  | DSU      |                                 |           |
|            |        | OOD      |                                 |           |
|            |        | DRCON    |                                 |           |
|            | NORM   | PDDL     | # X(T2)ERR-X(T2)ERR,=Z1         | PL06D     |
|            |        | X1       |                                 |           |
|            |        | RPRE'    |                                 |           |
|            | DSU    | DDV      | # X(T2)PRI-X(T2)=Z2             | PL04D     |
|            |        | X(T2)    |                                 |           |
|            | DMP    | SL*      | # DX(T2)=X(T2)ERR(Z2/Z1)        |           |
|            |        | OOD      |                                 |           |
|            |        | 0,1      |                                 |           |

```

                                GOTO
                                RTE390
RTE385      DLOAD              # DX(T2)=X(T2)ERR
                                OOD
RTE390      STODL             16D      # DX(T2)
                                STADR
                                STODL   RCON      # RCON=RCON,
                                BOV
# Page 895
                                RTE360
                                STODL   DRCON      # X(T2)ERR,=X(T2)ERR
                                X(T2)
                                STODL   RPRE'      # X(T2)PRI=X(T2)
                                16D
                                DAD
                                X(T2)
                                STCALL  X(T2)      # X(T2)=X(T2)+DX(T2)
                                RTE360      # REITERATE
P37E        CALL              # DISPLAY CONIC SOLUTION
                                RTEVN
RTE505      DLOAD             DMP
                                PCON
                                BETA1
                                BDSU      BZE
                                RCON
                                RTE510
                                BMN        DLOAD
                                RTE510
                                1RTEB2
                                GOTO      # ENTRY NEAR APOGEE
                                RTE515
RTE510      DLOAD             DCOMP      # ENTRY NEAR PERIGEE
                                1RTEB2
RTE515      STCALL            PHI2
                                PREC100      # PRECISION TRAJECTORY COMPUTATION
RTE625      BZE
                                P37G
RTEALRM     CALL              P370ALRM
                                EXIT
                                TCF        P37      # RECYCLE AFTER ALARM DISPLAY

# RETURN TO EARTH DISPLAY SUBROUTINE
RTEVN       STQ              CALL
                                VNSTORE

```

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```

                                RTEDISP      # DISPLAY PREPARATION
EXIT
CAF      V6N61RTE              # LATITUDE, LONGITUDE, BLANK
TCR      P370GOFR              #   IN LAT(SPL), LNG(SPL), -
CAF      FOUR
TCR      37BLANK +1
TCF      +5
TCF      P37                    # RECYCLE
CAF      V6N39RTE              # T21 HRS, MIN, SEC IN T3TOT4
TCR      P370GOF
TCF      P37                    # RECYCLE
CAF      V6N60RTE              # DISPLAY BLANK, V(T2), FPA2
TCR      P37GFRB1              #   IN -, VPRED, GAMMAEI

# Page 896
TCF      P37                    # RECYCLE
CAF      V6N81RTE              # DISPLAY DELTA V (LV) IN DELVLVC
TCR      P370GOF
TCF      P37                    # RECYCLE
TCR      INTPRET
GOTO
                                VNSTORE

# PRECISION DISPLAY, TARGETING COMPUTATION AND RTE END PROCESSING

P37G      CALL
                                RTEVN
EXIT
P37N      CAF      SEVEN
TS        OPTION1
CAF      ONE
TS        OPTION2
CAF      V4N06RTE              # DISPLAY RCS OR SPS OPTION  SPS ASSUMED
TCR      P370GOF
TCF      -2                    # RECYCLE
TC        INTPRET              # PROCEED
SETPD     SLOAD
                                OOD
                                OPTION2
DSU       BZE
                                1RTEB13
                                P37Q
SLOAD     NORM                  # SPS
                                EMDOT
                                X1
PDDL      GOTO
                                VCSPS
```

|            |       |                    |                                           |               |       |
|------------|-------|--------------------|-------------------------------------------|---------------|-------|
| P37Q       | DLOAD | P37T<br>BON        | # RCS                                     |               |       |
|            |       | MDOTRCS            |                                           |               |       |
|            |       | NJETSFLG           |                                           |               |       |
|            |       | P37R               |                                           |               |       |
| P37R       | SL1   |                    |                                           |               |       |
|            | SL1   |                    |                                           |               |       |
|            | NORM  | PDDL               |                                           |               |       |
|            |       | X1                 |                                           |               |       |
|            |       | VCRCS              |                                           |               |       |
| P37T       | PDDL  | DDV                | # DV/VC                                   | B7 -B5 = B2   | PL02D |
|            |       | DV                 |                                           |               |       |
|            | EXIT  |                    |                                           |               |       |
|            | TC    | POLY               |                                           |               |       |
|            | DEC   | 1                  |                                           |               |       |
|            | 2DEC  | 5.66240507 E-4 B-3 |                                           |               |       |
|            | 2DEC  | 9.79487897 E-1 B-1 |                                           |               |       |
| # Page 897 |       |                    |                                           |               |       |
|            | 2DEC  | -.388281955 B1     |                                           |               |       |
|            | TC    | INTPRET            |                                           |               |       |
|            | PUSH  | SLOAD              | # (1-E)**(-DV/VC)=A                       | B3            | PL04D |
|            |       | WEIGHT/G           |                                           |               |       |
|            | DMP   | DDV                | # DTB=(M0/MDOT)A                          | B16+B3-B3=B16 | PL00D |
|            | SL*   | DMP                |                                           |               |       |
|            |       | 0 -12D,1           |                                           |               |       |
|            |       | CSUBT              |                                           |               |       |
|            | BDSU  |                    |                                           |               |       |
|            |       | T1                 |                                           |               |       |
|            | STORE | TIG                | # TIG=T1-CT*DTB                           | B28           |       |
|            | EXIT  |                    |                                           |               |       |
|            | CAF   | V6N33RTE           | # DISPLAY BIASED TIG                      |               |       |
|            | TCR   | P370GOF            |                                           |               |       |
|            | TCF   | -2                 |                                           |               |       |
|            | CAF   | ZERO               |                                           |               |       |
|            | TS    | VHFCNT             |                                           |               |       |
|            | TS    | TRKMKCNT           |                                           |               |       |
|            | TC    | INTPRET            |                                           |               |       |
|            | CALL  |                    | # CONICALLY INTEGRATE FROM R1,V1 OVER T12 |               |       |
|            |       | RTENCK1            |                                           |               |       |
|            | VLOAD | UNIT               | #                                         |               | PL00D |
|            |       | R(T2)/             |                                           |               |       |
|            | PDVL  | VXSC               | # UR2                                     | B1            | PL06D |
|            |       | UR1/               |                                           |               |       |
|            |       | MCOS7.5            |                                           |               |       |
|            | PDVL  | VXSC               | # -UR1(COS7.5)                            | B1            | PL12D |
|            |       | UH/                |                                           |               |       |

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```

      MSIN7.5
VAD    DOT      # K/=-UR1(COS7.5)-UH(SIN7.5)  B2    PLOOD
DAD    BMN
      MCOS22.5
      P37W
VLOAD  DOT      # K/ . UR2 GR COS22.5
      UH/
      R(T2)/
BMN    DLOAD
      P37U
      THETA165
PUSH   GOTO
      P37V
P37U   DLOAD    PUSH
      THETA210
P37V   SIN
      STODL    SNTH
      COS      CLEAR
      RVSW
      STOVL    CSTH
      R(T1)/
# Page 898
      STOVL    RVEC
      V2(T1)/
      STCALL   VVEC
      TIMETHET
P37W   CLEAR    CLEAR
      XDELVFLG
      NORMSW
      SET      VLOAD
      FINALFLG
      STADR
      STODL    RTARG
      T
      DAD
      T1
      STOVL    TPASS4
      V2(T1)/
      VSU
      V(T1)/
      STCALL   DELVSIN
      VN1645
      GOTO
      P37W
```

# SUBROUTINE TO GO TO GOFLASHR AND BLANK R1

```

P37GFRB1      EXTEND
               QXCH   SPRTEX
               TCR    P37OGOFR
37BLANK       CAF    ONE
               TCR    BLANKET
               TCF    ENDOFJOB
               TC     SPRTEX      # RECYCLE
               TCF    P37PROC     # PROCEED

# SUBROUTINE TO GO TO GOFLASHR

P37OGOFR      EXTEND
               QXCH   RTENCKEX
               TCR    BANKCALL
               CADR    GOFLASHR
               TCF    GOTOPOOH    # TERMINATE
               TCF    +3
               TCF    +4
               TC     RTENCKEX    # IMMEDIATE RETURN
               INDEX  RTENCKEX    # PROCEED
               TCF    0 +4
               INDEX  RTENCKEX    # RECYCLE
               TCF    0 +3

# SUBROUTINE TO GO TO GOFLASH

# Page 899
P37OGOF      EXTEND
               QXCH   SPRTEX
               TCR    BANKCALL
               CADR    GOFLASH
               TCF    GOTOPOOH
               TCF    +2
               TC     SPRTEX
P37PROC      INDEX  SPRTEX
               TCF    0 +1
V6N33RTE     VN     0633
V4N06RTE     VN     0406
V6N61RTE     VN     0661
V6N39RTE     VN     0639
V6N60RTE     VN     0660
V6N81RTE     VN     0681
               BANK   32
               SETLOC RTE
               BANK

```



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COUNT 32/RTE

# Page 900

# ALARM DISPLAY SUBROUTINE

```
P370ALRM      STQ      EXIT
                  SPRTEX
                  CA      MPAC
                  TC      VARALARM
                  CAF      V5N09RTE
                  TC      BANKCALL
                  CADR      GOFLASH
                  TCF      GOTOPOOH
                  TCF      -4
                  TC      INTPRET
                  GOTO
                  SPRTEX
V5N09RTE      VN      0509
```

# Page 901

# TIME RADIUS CALLING SUBROUTINE

#

# INPUT

|   |          |                                                        |        |     |
|---|----------|--------------------------------------------------------|--------|-----|
| # | RVEC     | INITIAL POSITION VECTOR                                | VECTOR | B29 |
| # | VVEC     | INITIAL VELOCITY VECTOR                                | VECTOR | B7  |
| # | RDESIRED | FINAL RADIUS FOR WHICH TRANSFER TIME IS TO BE COMPUTED | DP     | B29 |
| # | CONICX1  | X1 SETTING FOR CONIC SUBROUTINES -2=EARTH              | SP     | B14 |

#

# OUTPUT

|   |        |                               |        |     |
|---|--------|-------------------------------|--------|-----|
| # | R(T2)/ | FINAL POSITION VECTOR         | VECTOR | B29 |
| # | V(T2)/ | FINAL VELOCITY VECTOR         | VECTOR | B7  |
| # | T12    | TRANSFER TIME TO FINAL RADIUS | DP     | B28 |

```
TMRAD100      STQ      CLEAR
                  RTENCKEX
                  RVSW
                  AXC,2  SXA,2
                  OCT      20000
                  SGNRDOT
                  LXC,1  CALL
                  CONICX1
                  TIMERAD
                  STOVL  V(T2)/
                  STADR
                  STODL  R(T2)/
                  T
```

PL00D

STCALL    T12  
RTENCKEX

```

# Page 902
# DISPLAY CALCULATION SUBROUTINE
#
# DESCRIPTION
#     OUTPUT FOR DISPLAY IS CONVERTED TO PROPER UNITS AND PLACED IN OUTPUT STORAGE
#     COMPUTATION FOR DETERMINING LANDING SITE LATITUDE AND LONGITUDE IS INCLUDED
#
# CALLING SEQUENCE
#     L          CALL
#     L+1        RTEDISP
#
# SUBROUTINES CALLED
#     TMRAD100
#     AUGKUGL
#     LAT-LONG
#
# ERASABLE INITIALIZATION REQUIRED
#     PUSHLIST
#     NONE
#     MPAC
#     NONE
#     OTHER
#     R(T2)/      FINAL POSITION VECTOR          VECTOR
#     V(T2)/      FINAL VELOCITY VECTOR         VECTOR
#     T2          FINAL TIME                    DP
#     V2(T1)/     POST IMPULSE INITIAL VELOCITY VECTOR  VECTOR
#     V(T1)/      INITIAL VELOCITY VECTOR         VECTOR
#     UR1/        UNIT INITIAL VECTOR            VECTOR
#     UH/         UNIT HORIZONTAL VECTOR          VECTOR
#
# OUTPUT
#     VPRED       VELOCITY MAGNITUDE AT 400,000 FT. ENTRY ALTITUDE  DP
#     T3TOT4      TRANSIT TIME TO 400,000 FT. ENTRY ALTITUDE       DP
#     GAMMAEI     FLIGHT PATH ANGLE AT 400,000 FT. ENTRY ALTITUDE  DP
#     DELVLVC     INITIAL VELOCITY CHANGE VECTOR IN LOCAL VERTICAL COORD. VECTOR
#     LAT(SPL)    LATITUDE OF THE LANDING SITE                    DP
#     LNG(SPL)    LONGITUDE OF THE LANDING SITE                   DP
#
RTEDISP          STQ          VLOAD          # DISPLAY
                  SPRTEX
                  V(T2)/
UNIT             PDDL
                  36D

```

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STODL VPRED # V(T2)  
T2  
DSU  
SPRTETIG  
STOVL T3TOT4 # T21  
R(T2)/  
UNIT DOT  
SL1

# Page 903

ARCCOS BDSU  
1RTEB2  
STOVL GAMMAEI # FLIGHT PATH ANGLE T2  
V2(T1)/  
VSU PUSH  
V(T1)/  
DOT DCOMP  
UR1/  
PDVL PUSH  
DLOAD PDVL  
ZERORTE  
DOT VDEF  
UH/

VSL1  
STODL DELVLVC  
DELVLVC  
BOFF DCOMP  
RETROFLG  
RTD18  
STORE DELVLVC # NEGATE X COMPONENT, RETROGRADE  
VLOAD ABVAL  
DELVLVC

RTD18

STOVL VGDISP  
R(T2)/  
STORE RVEC # \*\*\*\*\* LANDING SITE COMPUTATION \*\*\*\*\*  
ABVAL DSU

3048ORTE  
STOVL RDESIRED  
V(T2)/

STCALL VVEC  
TMRAD100 # R3,V3,T23 FROM TIMERAD

VLOAD UNIT  
R(T2)/

PDVL UNIT # UR3

PL06D

DOT SL1 # GAMMAE=ARCSIN(UR3 . UV3)

PL00D

|            |        |          |                                    |       |
|------------|--------|----------|------------------------------------|-------|
|            | ARCSIN | PDDL     | # V(T3)                            | PL02D |
|            |        | 36D      |                                    |       |
|            | PDDL   | ABS      |                                    |       |
|            | PUSH   | CALL     | # /GAMMAE/                         | PL04D |
|            |        | AUGEKUGL | # PHIE                             | PL06D |
|            | DAD    | DAD      |                                    |       |
|            |        | T12      | # T23                              |       |
|            |        | T2       |                                    |       |
|            | STORE  | 02D      | # T(LS)=T2&T23&TE                  |       |
|            | SLOAD  | BZE      |                                    |       |
|            |        | P37RANGE |                                    |       |
|            |        | RTD22    |                                    |       |
|            | STORE  | 04D      | # OVERRIDE RANGE (PCR 261)         |       |
| RTD22      | DLOAD  | SIN      |                                    |       |
| # Page 904 |        |          |                                    |       |
|            |        | 04D      |                                    |       |
|            | STODL  | LNG(SPL) | # LNG(SPL)=SIN(PHIE)               | PL04D |
|            | COS    |          |                                    |       |
|            | STORE  | LAT(SPL) | # LAT(SPL)=COS(PHIE)               |       |
|            | VLOAD  | UNIT     |                                    |       |
|            |        | R(T2)/   |                                    |       |
|            | PUSH   | PUSH     |                                    |       |
|            | PDVL   | UNIT     | #                                  | PL22D |
|            |        | V(T2)/   |                                    |       |
|            | PDVL   | VXV      |                                    |       |
|            | VXV    | UNIT     | # UH3=UNIT(UR3 X UV3 X UR3)        | PL10D |
|            | VXSC   | PDVL     |                                    |       |
|            |        | LNG(SPL) |                                    |       |
|            | VXSC   | VAD      | #                                  | PL04D |
|            |        | LAT(SPL) |                                    |       |
|            | CLEAR  | CLEAR    | # T(LS) IN MPAC                    |       |
|            |        | ERADFLAG |                                    |       |
|            |        | LUNAFLAG |                                    |       |
|            | STODL  | ALPHAV   | # ALPHAV=UR3(COSPHIE)+UH3(SINPHIE) | PL02D |
|            | CALL   |          |                                    |       |
|            |        | LAT-LONG |                                    |       |
|            | DLOAD  |          |                                    |       |
|            |        | LAT      |                                    |       |
|            | STODL  | LAT(SPL) | # LATITUDE LANDING SITE *****      |       |
|            |        | LONG     |                                    |       |
|            | STCALL | LNG(SPL) | # LONGITUDE LANDING SITE *****     |       |
|            |        | SPRTEX   |                                    |       |
|            | COUNT* | \$\$/RTE |                                    |       |

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```
# INITIAL VECTOR SUBROUTINE
#
# DESCRIPTION
#     A PRECISION INTEGRATION OF THE STATE VECTOR TO THE TIME OF IGNITION IS PERFORMED. PRECO
#
# CALLING SEQUENCE
#     L          CALL
#     L+1        INVC100
#
# NORMAL EXIT MODE
#     AT L+2 OF CALLING SEQUENCE WITH MPAC = 0
#
# ALARM EXIT MODE
#     AT L+2 OF CALLING SEQUENCE WITH MPAC = OCTAL 612 FOR STATE VECTOR IN MOONS SPHERE OF IN
#
# SUBROUTINES CALLED
#     CSMPREC
#
# ERASABLE INITIALIZATION REQUIRED
#     PUSHLIST
#     NONE
#     MPAC
#     NONE
#     OTHER
#     SPRTETIG      TIME OF IGNITION                      DP      B28
#     CSM STATE VECTOR
#
# OUTPUT
#     R(T1)/        INITIAL POSITION VECTOR AT TIG          VECTOR  B29
#     V(T1)/        INITIAL VELOCITY VECTOR AT TIG         VECTOR  B7
#     T1            INITIAL VECTOR TIME (TIG)              DP      B28
#     UR1/          UNIT INITIAL VECTOR                   VECTOR  B1
#     UH/           UNIT HORIZONTAL VECTOR                 VECTOR  B1
#     CFPA          COSINE OF INITIAL FLIGHT PATH ANGLE    DP      B1

INVC100      STQ      DLOAD
              SPRTEX
              SPRTETIG
              STCALL  TDEC1
                  CSMPREC      # PRECISION INTEGRATION  R0,V0 TO R1,V1
              VLOAD   SXA,2
                  RATT
                  P(T1)
              STOVL   R(T1)/
                  VATT
              STODL   V(T1)/
```

```

                                TAT
                                STORE T1
                                SLOAD BZE
                                P(T1)
# Page 906
                                INVC109
INVC107      SLOAD      GOTO
                                OCT612
                                RTEALRM      # R1,V1 NOT IN PROPER SPHERE OF INFLUENCE
INVC109      VLOAD      UNIT
                                R(T1)/
                                STODL      UR1/      # UR1/      B1
                                36D
                                STOVL      R(T1)      # R(T1)      B29
                                V(T1)/
                                UNIT
                                STORE UV1/
                                DOT      SL1
                                UR1/
                                STORE CFPA      # CFPA      B1
                                ABS      DSU
                                EPC1RTE
                                BMN      DLOAD
                                INVC115      # NOT NEAR RECTILINEAR
                                1RTEB2
                                PDDL      PUSH
                                ZERORTE
                                VDEF      PUSH      # N/ = (0,0,1)
                                GOTO
                                INVC120
INVC115      VLOAD      VXV
                                UR1/
                                UV1/
                                PUSH      # N/ = UR X UV      B2
INVC120      CLEAR      DLOAD
                                RETROFLG
                                PUSH      BPL
                                INVC125
                                VLOAD      VCOMP      # RETROGRADE ORBIT
                                PUSH      SET
                                RETROFLG
INVC125      VLOAD
                                VXV      UNIT
                                UR1/
                                STORE UH/      # UH/      B1
                                GOTO

```

## SPRTEX

```

# Page 907
# PRECISION TRAJECTORY COMPUTATION SUBROUTINE
#
# DESCRIPTION
#   A NUMERICALLY INTEGRATED TRAJECTORY IS GENERATED WHICH FOR THE RETURN TO EARTH PROBLEM
#   CONSTRAINTS (RCON AND X(T2)) ACHIEVED BY THE INITIAL CONIC TRAJECTORY AND MEETS THE DVD
#   AS POSSIBLE.
#
# CALLING SEQUENCE
#   L          CALL
#   L+1        PREC100
#
# NORMAL EXIT MODE
#   AT L+2 OF CALLING SEQUENCE WITH MPAC = 0
#
# ALARM EXIT MODE
#   AT L+2 OF CALLING SEQUENCE WITH MPAC =
#       OCTAL 605      FOR EXCESS ITERATIONS
#       OCTAL 613      FOR REENTRY ANGLE OUT OF LIMITS
#
# SUBROUTINES CALLED
#   INTSTALL
#   RTENCK2
#   RTENCK3
#   TIMERAD
#   PARAM
#   V2T100
#
# ERASABLE INITIALIZATION REQUIRED
#   PUSHLIST
#   NONE
#   MPAC
#   NONE
#   OTHER
#   R(T1)/      INITIAL POSITION VECTOR          VECTOR  B29/B27
#   V2(T1)/     POST IMPULSE INITIAL VELOCITY VECTOR  VECTOR  B7/B5
#   V(T1)/      INITIAL VELOCITY VECTOR            VECTOR  B7/B5
#   T1          INITIAL VECTOR TIME                 DP      B28
#   T12         INITIAL TO FINAL POSITION TIME        DP      B28
#   RCON        CONIC FINAL RADIUS                   DP      B29/B27
#   R(T1)       MAGNITUDE OF INITIAL POSITION VECTOR   DP      B29/B27
#   X(T2)       COTANGENT OF FINAL FLIGHT PATH ANGLE  DP      B0
#   X(T1)       COTANGENT OF INITIAL FLIGHT PATH ANGLE DP      B5
#   RTEDVD      DELTA VELOCITY DESIRED              DP      B7/B5

```

```

#      MAMAX1      MAJOR AXIS LIMIT FOR LOWER BOUND ON GAMDV ITERATOR      DP
#      MAMAX2      MAJOR AXIS LIMIT FOR UPPER BOUND ON GAMDV ITERATOR      DP
#      UR1/        UNIT INITIAL VECTOR      VECTO
#      UH/         UNIT HORIZONTAL VECTOR      VECTO
#      BETA1       1+X(T2)**2      DP
#      PHI2        PERIGEE OR APOGEE INDICATOR      DP
#
# Page 908
#
# OUTPUT
#      V2(T1)/      POST IMPULSE INITIAL VELOCITY VECTOR      VECTO
#      R(T2)/       FINAL POSITION VECTOR      VECTO
#      V(T2)/       FINAL VELOCITY VECTOR      VECTO
#      T2          FINAL TIME      DP
#
# DEBRIS
#      RD          FINAL R DESIRED      DP
#      R/APRE      R/A      DP
#      P/RPRE      P/R      DP
#      RPRE        MAGNITUDE OF R(T2)/      DP
#      X(T2)PRE    COTANGENT OF GAMMA2      DP
#      DT12        CORRECTION TO FINAL TIME T2      DP
#      RCON        FINAL RADIUS      DP
#      DRCON       DELTA RCON      DP

PREC100      STQ      DLOAD
                SPRTEX
                1ORTE
                STODL  NN1A
                RCON
                STORE  RD
PREC120      DLOAD
                2RTEB1
                STODL  DT21PR      # DT21PR = POSMAX
                M15RTE
                STCALL NN2
                RTENCK3
PREC125      CALL
                PARAM
                DLOAD
                P
                STODL  P/RPRE
                R1A
                STODL  R/APRE
                R1
                STODL  RPRE

```



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COGA  
SL  
5  
STORE X(T2)PRE  
DCOMP DAD  
X(T2)  
ABS DSU  
EPC4RTE  
BOV BMN  
PREC130  
PREC175

# DESIRED REENTRY ANGLE NOT ACHIEVED

# Page 909

PREC130 DLOAD BMN  
NN2  
PREC140  
PREC132 SLOAD GOTO # TOO MANY ITERATIONS  
OCT605 # EXIT WITH ALARM  
PRECX

# DETERMINE RADIUS AT WHICH THE DESIRED REENTRY ANGLE WILL BE ACHIEVED

PREC140 DLOAD BZE  
NN1A  
PREC162  
PREC150 DLOAD SL2 B2  
P/RPRE  
DMP SL1 # BETA2=BETA1\*P/R B2 PL02  
BETA1  
PUSH DLOAD  
R/APRE  
SL4 DMP  
OOD  
BDSU BMN # BETA3=1-BETA2\*R/A  
1RTEB4  
PREC160  
PREC155 SL2 SQRT  
DMP BDSU  
PHI2  
1RTEB3  
NORM PDDL  
X1  
SR1 DDV # BETA4=BETA2/(1-PHI2\*SQRT(BETA3))  
SL\* GOTO B1

|            |       |          |                   |    |
|------------|-------|----------|-------------------|----|
|            |       | 0        | -1,1              |    |
|            |       | PREC165  |                   |    |
| PREC160    | DLOAD | NORM     |                   |    |
|            |       | R/APRE   |                   |    |
|            |       | X1       |                   |    |
|            | BDDV  | SL*      |                   | B1 |
|            |       | 1RTEB1   |                   |    |
|            |       | 0        | -6,1              |    |
|            | GOTO  |          |                   |    |
|            |       | PREC165  |                   |    |
| PREC162    | DLOAD | NORM     |                   |    |
|            |       | RPRE     |                   |    |
|            |       | X1       |                   |    |
|            | BDDV  | SL*      | # BETA4=RD/RPRE   | B1 |
|            |       | RD       |                   |    |
|            |       | 0        | -1,1              |    |
| PREC165    | SETPD | PUSH     |                   |    |
|            |       | 0        |                   |    |
|            | DSU   | DCOMP    |                   |    |
| # Page 910 |       |          |                   |    |
|            |       | 1RTEB1   |                   |    |
|            | STORE | BETA12   |                   |    |
|            | BMN   | DLOAD    |                   |    |
|            |       | PREC168  |                   |    |
|            |       | X(T2)PRE |                   |    |
|            | BMN   | DLOAD    |                   |    |
|            |       | PREC167  |                   |    |
|            |       | BETA12   |                   |    |
|            | DCOMP |          |                   |    |
|            | STORE | BETA12   |                   |    |
| PREC167    | DLOAD |          |                   |    |
|            |       | BETA12   |                   |    |
| PREC168    | ABS   | DSU      |                   |    |
|            |       | EPC6RTE  |                   |    |
|            | BMN   | DLOAD    |                   |    |
|            |       | PREC175  |                   |    |
|            | DMP   | SL1      |                   |    |
|            |       | RPRE     |                   |    |
|            | PUSH  |          | # RF = NEW RADIUS |    |
| PREC170    | DLOAD | DAD      |                   |    |
|            |       | NN2      |                   |    |
|            |       | 1RTEB28  |                   |    |
|            | STORE | NN2      |                   |    |
|            | VLOAD | SET      |                   |    |
|            |       | R(T2)/   |                   |    |
|            |       | RVS      |                   |    |

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```
STOVL  RVEC
        V(T2)/
SIGN
        BETA12
STODL  VVEC
        1RTEB1
SIGN   DCOMP
        BETA12
LXA,2  DLOAD
        MPAC
LXC,1  SXA,2
        CONICX1
        SGNRDOT
STCALL RDESIRED      # COMPUTED DT12 (CORRECTION TO TIME OF
        TIMERAD      #      NEW RADIUS)
DLOAD  SIGN
        T
        BETA12
PDDL   NORM          # DT21=(PHI4)DT21          PL02D
        DT21PR
        X1
BDDV   SL*
        OOD
        0 -3,1
# Page 911
PUSH   BMN          # BETA13=(DT21)/(DT21PR)      R3      PL04D
        PREC172
DLOAD  PDDL          # BETA14=1                B0      PL04D
        2RTEB1
GOTO
        PREC173
PREC172 DLOAD        # BETA14=.6                B0      PL04D
        PDDL
        M.6RTE
PREC173 DDV          DSU
        O2D
        1RTEB3
        BMN          DLOAD
        PREC174
        DMP
        DT21PR
STORE  OOD          # DT21=(BETA14)DT21PR      B28
PREC174 DLOAD        PUSH
        OOD
STCALL DT21PR
        RTENCK2
GOTO
```

```

PREC175      DLOAD  PREC125
                DSU
                RPRE
                RD
                PUSH  ABS      # RPRE-RD = RERR
                DSU    BMN
                EPC7RTE
                PREC220

# DESIRED RADIUS HAS NOT BEEN ACHIEVED

                DLOAD  BZE
                NN1A
                PREC132      # TOO MANY ITERATIONS
                DSU    BZE
                1ORTE
                PREC207
PREC205      DLOAD  DSU      # NOT FIRST PASS OF ITERATION
                RPRE'
                RPRE      # RPRE'-RPRE      B29/B27
                NORM    BDDV
                X2
                DRCON
                SL*    PUSH      # DRCON/(RPRE'-RPRE)=S      B2
                0 -2,2
                DAD    BOV      # S GR +4 OR LS -4
                1RTEB1
                PREC205M
                ABS    DSU
# Page 912
                1RTEB1
                BMN
                PREC206
PREC205M      DLOAD  DCOMP      # S GR 0 OR LS -4
                2RTEB1
                PDDL
PREC206      DLOAD  DMP      # S=-4      B2
                SL2
                STORE  DRCON      # DRCON=S(RERR)      B29
                DAD
                RCON
                STORE  RCON      # RCON+DRCON=RCON
                GOTO
                PREC210
PREC207      DLOAD  DSQ      # FIRST PASS OF ITERATION
                RD

```

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```

                                NORM    SR1
                                X1
                                PDDL    NORM
                                RPRE
                                X2
                                XSU,1   BDDV
                                X2
                                SR*
                                0 -1,1
                                STORE    RCON          # RD**2/RPRE=RCON
                                DSU
                                RD
                                STORE    DRCON          # RCON-RD=DRCON
PREC210  DLOAD          # PREPARE FOR NEXT ITERATION
                                RPRE
                                STODL   RPRE'
                                NN1A
                                DSU
                                1RTEB28
                                STCALL  NN1A
                                V2T100
                                BHIZ    GOTO
                                PREC120
                                PRECX

# DESIRED RADIUS ACHIEVED

                                SETLOC  RTE2
                                BANK
PREC220  DLOAD    DSU
                                X(T2)
                                X(T2)PRE
                                ABS      DSU
                                EPC8RTE

# Page 913
                                BMN      SLOAD
                                PREC225
                                OCT613
                                GOTO
                                PRECX          # IF REENTRY ANGLE OUT OF LIMITS

EPC8RTE  2DEC    .002

OCT613   OCT      613

# DESIRED FINAL ANGLE HAS BEEN REACHED.
```

```

                SETLOC RTE
                BANK
PREC225         DLOAD
                ZERORTE
PRECX           GOTO
                SPRTEX

```

```

# Page 914

```

```

# INTEGRATION CALLING SUBROUTINE

```

```

#

```

```

# DESCRIPTION

```

```

#     PERFORMS CONIC AND PRECISION INTEGRATIONS USING SUBROUTINE INTEGRVS.  THERE A
#     RTENCK2, AND RTENCK3) FOR DIFFERENT SOURCES OF INPUT AND DIFFERENT OPTIONS.
#     WHICH INCLUDES SET UP OF INPUT FOR THE PARAM SUBROUTINE.
#

```

```

# RTENCK1 (CONIC INTEGRATION)

```

```

#

```

```

#     CALLING SEQUENCE

```

```

#     L           CALL
#     L+1         RTENCK1
#

```

```

#     ERASABLE INITIALIZATION REQUIRED

```

```

#     SAME AS FOR THE RTENCK3 ENTRANCE
#

```

```

# RTENCK2 (PRECISION INTEGRATION)

```

```

#

```

```

#     CALLING SEQUENCE

```

```

#     L           CALL
#     L+1         RTENCK2
#

```

```

#     ERASABLE INITIALIZATION REQUIRED

```

```

#     PUSHLIST

```

```

#     PUSHLOC-2   INTEGRATION TIME DT12 (CORRECTION TO T2)

```

```

DP

```

```

#     OTHER

```

```

#     R(T2)/      FINAL POSITION VECTOR
#     V(T2)/      FINAL VELOCITY VECTOR
#     T2          FINAL TIME
#

```

```

VECT

```

```

VECT

```

```

DP

```

```

# RTENCK3 (PRECISION INTEGRATION)

```

```

#

```

```

#     CALLING SEQUENCE

```

```

#     L           CALL
#     L+1         RTENCK3
#

```

```

#     ERASABLE INITIALIZATION REQUIRED

```

```

#      R(T1)/          INITIAL POSITION VECTOR          VECTOR  B29
#      V2(T1)/         POST IMPULSE INITIAL VELOCITY VECTOR  VECTOR  B7
#      T1              INITIAL VECTOR TIME              DP      B28
#      T2              FINAL TIME                      DP      B28
#
# EXIT MODE
#      AT L+2 OF CALLING SEQUENCE
#
# SUBROUTINES CALLED
#      INTSTALL
#      INTEGRVS
#
# OUTPUT
#      PUSHLIST
# Page 915
#      PUSHLOC-6       FINAL POSITION VECTOR R(T2)/          VECTOR  B29
#      X1              CONICS MUTABLE ENTRY FOR EARTH (-2)   SP      B14
#      MPAC
#                      FINAL VELOCITY VECTOR V(T2)/          VECTOR  B7
#      OTHER
#      R(T2)/          AS IN PUSHLIST
#      V(T2)/          AS IN MPAC
#      T2              FINAL TIME                      DP      B28

RTENCK1      SETLOC  RTE3
              BANK
              STQ    CALL
                  RTENCKEX
                  INTSTALL
              VLOAD  SET
                  R(T1)/
                  INTYPFLG
              GOTO   RTENCK3B

RTENCK2      STQ    CALL
                  RTENCKEX
                  INTSTALL
              CLEAR  VLOAD
                  INTYPFLG
                  R(T2)/
              STOVL  RCV
                  V(T2)/
              STODL  VCV
                  T2
              STORE  TET

```

```

                                DAD
                                GOTO
                                RTENCK3D

RTENCK3      STQ      CALL
                                RTENCKEX
                                INTSTALL
RTENCK3A     VLOAD    CLEAR
                                R(T1)/
                                INTYPFLG
RTENCK3B     STOVL    RCV
                                V2(T1)/
                                STODL    VCV
                                T1
                                STODL    TET
                                T2

# Page 916
RTENCK3D     STORE    TDEC1
                                CLEAR    CALL
                                MOONFLAG
                                INTEGRVS
                                VLOAD
                                RATT
                                STORE    R(T2)/
                                PDDL     LXC,1
                                TAT
                                CONICX1
                                STOVL    T2
                                VATT
                                STORE    V(T2)/
                                GOTO
                                RTENCKEX
                                SETLOC   RTE
                                BANK

```

# Page 917

# V2(T1) COMPUTATION SUBROUTINE

#

# DESCRIPTION

# A POST IMPULSE VELOCITY VECTOR (V2(T1)) IS COMPUTED WHICH EITHER

# (1) MEETS THE INPUT VELOCITY CHANGE DESIRED (RTEDVD) IN A MINIMUM TIME

# (2) IF A VELOCITY CHANGE ISN'T SPECIFIED (RTEDVD = 0), A V2(T1) IS COMPUTED  
AND CONSEQUENTLY FUEL.

#

# CALLING SEQUENCE

# L CALL



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```
#          L+1          V2T100
#
# NORMAL EXIT MODE
#       AT L+2 OF CALLING SEQUENCE WITH MPAC = 0
#
# ALARM EXIT MODE
#       AT L+2 OF CALLING SEQUENCE WITH MPAC = OCTAL 605 FOR EXCESS ITERATIONS.
#
# SUBROUTINES CALLED
#       GAMDV10
#       XT1LIM
#       DVCALC
#
# ERASABLE INITIALIZATION REQUIRED
#       PUSHLIST
#       NONE
#       MPAC
#       NONE
#       OTHER
#       R(T1)          MAGNITUDE OF INITIAL POSITION VECTOR          DP          B29/B27
#       RCON           MAGNITUDE OF FINAL POSITION VECTOR           DP          B29/B27
#       V(T1)/         INITIAL VELOCITY VECTOR                     VECTOR   B7/B5
#       RTEDVD         DELTA VELOCITY DESIRED                      DP          B7/B5
#       UR1/           UNIT INITIAL VECTOR                         VECTOR   B1
#       UH/            UNIT HORIZONTAL VECTOR                     VECTOR   B1
#       X(T2)          COTANGENT OF FINAL FLIGHT PATH ANGLE        DP          B0
#       X(T1)          COTANGENT OF INITIAL FLIGHT PATH ANGLE (INPUT FOR PREC) DP          B5
#       CFPA           COSINE OF INITIAL FLIGHT PATH ANGLE        DP          B1
#       MAMAX1         MAJOR AXIS LIMIT FOR LOWER BOUND ON GAMDV ITERATOR DP          B30/B28
#       MAMAX2         MAJOR AXIS LIMIT FOR UPPER BOUND ON GAMDV ITERATOR DP          B30/B28
#       PHI2           REENTRY NEAR PERIGEE OR APOGEE INDICATE (RTE ONLY) DP          B2
#       N1             CONIC OR PRECISION ITERATION OPERATOR      DP          B28
#
# OUTPUT
#       V2(T1)/        POST IMPULSE INITIAL VELOCITY VECTOR       VECTOR   B7/B5
#       DV             INITIAL VELOCITY CHANGE                    DP          B7/B5
#       X(T1)          COTANGENT OF INITIAL FLIGHT PATH ANGLE (POST IMPULSE) DP          B5
#       PCON           SEMI-LATUS RECTUM                          DP          B28/B26
#       BETA1          1+X(T2)**2                                DP          B1
#
# Page 918
#
# DEBRIS
#       PUSHLIST
#       OOD            X(T1),,=PREVIOUS PRECISION X(T1)          DP          B5
#       O2D            THETA1=BETA5*LAMBDA-1                      TP          B17
```

```

#      05D      THETA2=2*R(T1)*(LAMBDA-1)      TP
#      08D      THETA3=MU** .5/R(T1)      DP
#      10D      X(T1)MIN=LOWER BOUND ON X(T1) IN GAMDV ITERATOR      DP
#      12D      DX(T1)MAX=MAXIMUM DELTA X(T1)      DP
#      14D      X(T1)MAX=UPPER BOUND ON X(T1) IN GAMDV ITERATOR      DP
#      16D      DX(T1)=ITERATOR INCREMENT      DP
#      31D      GAMDV10 SUBROUTINE RETURN ADDRESS
#      32D      DVCALC SUBROUTINE RETURN ADDRESS
#      33D      V2T100 SUBROUTINE RETURN ADDRESS

V2T100      STQ      DLOAD
                        33D
                        RCON
                        BMN      DSU      # ABORT IF RCON NEGATIVE
                        V2TERROR
                        R(T1)
                        BMN
                        V2T101
V2TERROR      EXIT      # OR IF LAMBDA LESS THAN ONE
      TC      POOD00      # NO SOLUTION IF LAMBDA LESS THAN 1
      OCT      00610
V2T101      SETPD      CLEAR
                        0      #
                        F2RTE
                        DLOAD      NORM
                        RCON
                        X1
                        PDDL      NORM
                        R(T1)
                        S1
                        STORE      10D
                        SR1      DDV      # R1/RCON = LAMBDA      B1
                        XSU,1      PDDL      #
                        S1
                        X(T2)
                        DSQ
                        SR1      DAD
                        1RTEB1
                        STORE      BETA1      # 1+X(T2)**2 = BETA1      B1
                        DMP
                        00D
                        STORE      28D      # BETAI*LAMBDA = BETA5
                        DMP      SL*
                        00D
                        0 -7,1
                        SL*      DSU

```

PLOOR

PL02I

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# Page 919

```

      0 -7,1
      1RTEB17
RTB   PDDL          # BETA5*LAMBDA-1 = THETA1      B17      PL05D
      TPMODE
      1RTEB1
SR*   DCOMP
      0,1
DAD   DMP
      OOD
      R(T1)
SL*   RTB
      0 -7D,1
      TPMODE
PDDL          # 2*R(T1)*(LAMBDA-1)=THETA2      B38/B36 PL08D
      RTMURTE
NORM   SR1
      X2
XSU,2  DDV
      S1
      10D
SR*   PDDL          # MU**.5/R(T1)=THETA3          B-4/B-5 PL10D
      6,2
      MAMAX1
PUSH   PUSH          # MAMAX1=MA
CALL
      XT1LIM
DCOMP  PUSH          # X(T1)MIN                    B5        PL12D
DCOMP  SR4
PDDL   PUSH          # DX(T1)MAX                    B5        PL14D
      MAMAX2
PUSH   CALL
      XT1LIM
PDDL   BMN          # X(T1)MAX                    B5        PL16D
      NN1A
      V2T102
GOTO
      V2T110
```

# PROCEED HERE IF NOT PRECISION COMPUTATION

```

V2T102      DLOAD
            RTEDVD
BZE         GOTO
            V2T105
            V2T140
```

```

V2T105      DLOAD  BMN
              CFPA
              V2T140
              GOTO  V2T145

```

# Page 920

```

# DURING A PRECISION TRAJECTORY ITERATION CONSTRAIN THE INDEPENDENT
# VARIABLE TO INSURE THAT ALL CONICS PASS THROUGH RCON ON THE SAME PASS
# THROUGH X(T2)

```

```

V2T110      DLOAD  RTB
              1RTEB17
              TPMODE
              DCOMP PDDL      # -1      B17      PL19
              2RTEB1
              SR*   DSU
              0,1
              00D
              DMP   SL*
              28D
              0 -7,1
              SL*   TAD
              0 -7,1
              RTB   PDDL      # BETA5(2-LAMBDA)-1=BETA6      B17      PL19
              TPMODE
              X(T1)
              STORE 00D      # X(T1),,      B5
              TLOAD #
              BMN   BZE
              V2T115
              V2T115
              SL     GOTO
              7
              V2T120
V2T115      DLOAD  BMN
              PHI2
              V2T125
              DCOMP
              STODL PHI2
              1ORTE
              STORE NN1A
              GOTO
              V2T125
V2T120      SQRT  RTB
              DPMODE
              PDDL  BMN      # BETA6**.5=X(T1)LIM      B5      PL18

```

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```

                                PHI2
                                V2T130
                                STADR
                                STORE 14D      # X(T1)LIM = X(T1)MAX
                                DCOMP
                                STORE 10D      # -X(T1)LIM = X(T1)MIN
V2T125                          DLOAD BZE
                                X(T1)
                                V2T140
                                BMN  GOTO
# Page 921
                                V2T140
                                V2T145
V2T130                          DLOAD BZE
                                X(T1)
                                V2T135
                                BMN  DLOAD      #
                                V2T135
                                STADR
                                STORE 10D      # X(T1)LIM = X(T1)MIN
                                GOTO
                                V2T145
V2T135                          DLOAD DCOMP      #
                                STADR
                                STORE 14D      # -X(T1)LIM = X(T1)MAX
V2T140                          DLOAD
                                10D
                                STODL X(T1)      # X(T1)MIN = X(T1)
                                12D
                                PUSH  GOTO      # DX(T1)MAX = DX(T1)
                                V2T150
V2T145                          DLOAD
                                14D
                                STODL X(T1)      # X(T1)MAX = X(T1)
                                12D
                                DCOMP PUSH      # -DX(T1)MAX = DX(T1)
V2T150                          CALL           # GOTO X(T1)-DV ITERATOR
                                GAMDV10
                                DLOAD BZE      # EXIT IF MINIMUM FUEL MODE
                                RTEDVD
                                V2T1X

# CONTINUE IF TIME CRITICAL MODE

                                DSU   BMN
                                DV
```

```

                                V2T155
                                GOTO
V2T155      DLOAD      BMN
                                NN1A
                                V2T160
                                GOTO
                                V2T185

# CONIC TRAJECTORY COMPUTATION

V2T160      DLOAD      BZE
                                X(T1)
                                V2T165
                                BMN      GOTO

# Page 922

                                V2T165
                                V2T300
V2T165      DLOAD      BZE
                                CFPA
                                V2T300
                                BMN      DLOAD
                                V2T300
                                14D
                                STODL    X(T1)      # X(T1)MAX=X(T1)
                                12D
                                DCOMP
                                STCALL    16D      # -DX(T1)MAX=DX(T1)
                                GAMDV10
                                DLOAD      DSU
                                RTEDVD
                                DV
                                BMN
                                V2T300
V2T175      SET      DLOAD
                                F2RTE
                                X(T1)
                                BOFF
                                SLOWFLG
                                V2T177
                                STODL    10D      # X(T1)MIN
                                12D      # DX(T1)MAX
                                GOTO
                                V2T179
V2T177      STODL    14D
                                12D

```

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```

V2T179      DCOMP
            STCALL 16D          # DX(T1)
            GAMDV10
            DLOAD  BMN
            NN1A
            V2T300

# PREVENT A LARGE CHANGE IN INDEPENDENT VARIABLE DURING AN ITERATION FOR A
# PRECISION TRAJECTORY

V2T185      DLOAD  DSU
            X(T1)
            OOD
            ABS    PDDL          # /X(T1)-X(T1),,/ = BETA7
            12D
            SL1    BDSU
            BMN    DLOAD
            V2T300
            OOD          # CONTINUE IF BETA7 LARGER THAN 2DX(T1)MAX
            STORE  X(T1)        # X(T1),, = X(T1)

# Page 923
            DSU    BMN
            14D
            V2T195
            DLOAD
            14D
            STORE  X(T1)        # X(T1)MAX = X(T1)
            GOTO
            V2T205
V2T195      DLOAD  DSU
            X(T1)
            10D
            BMN    GOTO
            V2T200
            V2T205
V2T200      DLOAD
            10D
            STORE  X(T1)        # X(T1)MIN = X(T1)
V2T205      CALL
            DVCALC
V2T300      DLOAD
            ZERORTE
V2T1X       GOTO
            33D
```

# Page 924

```

# X(T1)-DV ITERATOR SUBROUTINE
#
# DESCRIPTION
#     COMPUTES A POST IMPULSE VELOCITY VECTOR (V2(T1)) WHICH REQUIRES A MINIMUM DV
#
# CALLING SEQUENCE
#     L          CALL
#     L+1        GAMDV10
#
# NORMAL EXIT MODE
#     AT L+2 OF CALLING SEQUENCE
#
# ALARM EXIT MODE
#     AT V2T1X WITH MPAC = OCTAL 605 FOR EXCESS ITERATIONS
#
# SUBROUTINES CALLED
#     DVCALC
#
# ERASABLE INITIALIZATION REQUIRED
#     PUSHLIST
#         02D          THETA1=BETA5*LAMBDA-1                      TP
#         05D          THETA2=2*R(T1)*(LAMBDA-1)                  TP
#         08D          THETA3=MU** .5/R(T1)                       DP
#         10D          X(T1)MIN=LOWER BOUND ON INDEPENDENT VARIABLE X(T1)  DP
#         12D          DX(T1)MAX=MAXIMUM DX(T1)                   DP
#         14D          X(T1)MAX=UPPER BOUND ON INDEPENDENT VARIABLE X(T1)  DP
#         16D          DX(T1)=ITERATOR INCREMENT                  DP
#     MPAC
#     NONE
#     OTHER
#         V(T1)/      INITIAL VELOCITY VECTOR                    VECTOR
#         RTEDVD      DELTA VELOCITY DESIRED                      DP
#         UR1/        UNIT INITIAL VECTOR                         VECTOR
#         UH/         UNIT HORIZONTAL VECTOR                      VECTOR
#         X(T1)       COTANGENT OF INITIAL FLIGHT PATH ANGLE (FROM VERTICAL)  DP
#         F2RTE       TIME CRITICAL OR MINIMUM FUEL MODE INDICATOR  STATE
#
# OUTPUT
#         V2(T1)/     POST IMPULSE INITIAL VELOCITY VECTOR        VECTOR
#         DV          INITIAL VELOCITY CHANGE                     DP
#         X(T1)       COTANGENT OF INITIAL FPA MEASURED FROM VERTICAL  DP
#         PCON        SEMI-LATUS RECTUM                            DP
#
# DEBRIS
#     PUSHLIST
#         00D          X(T1),,

```



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|   |          |                                   |    |       |
|---|----------|-----------------------------------|----|-------|
| # | 02D      | THETA1                            |    |       |
| # | 05D      | THETA2                            |    |       |
| # | 08D      | THETA3                            |    |       |
| # | 10D      | X(T1)MIN                          |    |       |
| # | 12D      | DX(T1)MAX                         |    |       |
| # | Page 925 |                                   |    |       |
| # | 14D      | X(T1)MAX                          |    |       |
| # | 16D      | DX(T1)                            |    |       |
| # | 22D      | DV,=PREVIOUS DV                   | DP | B7/B5 |
| # | 24D      | BETA9=X(T1)+1.1DX(T1)             | DP | B5    |
| # | 31D      | GAMDV10 SUBROUTINE RETURN ADDRESS |    |       |
| # | 32D      | DVCALC SUBROUTINE RETURN ADDRESS  |    |       |
| # | 33D      | V2T100 SUBROUTINE RETURN ADDRESS  |    |       |

|         |       |         |                              |          |
|---------|-------|---------|------------------------------|----------|
| GAMDV10 | STQ   | 31D     |                              |          |
|         | SETPD | CALL    |                              |          |
|         |       | 18D     | #                            | PL18D    |
|         |       | DVCALC  |                              |          |
|         | DLOAD | DSU     |                              |          |
|         |       | 14D     |                              |          |
|         |       | 10D     |                              |          |
|         | BOV   |         |                              |          |
|         |       | GAMDV20 |                              |          |
|         | PUSH  | DSU     | # X(T1)MAX-X(T1)MIN=BETA8    | B5 PL20D |
|         |       | EPC9RTE |                              |          |
|         | BMN   | DLOAD   |                              |          |
|         |       | GAMDVX  | # BOUNDS CLOSE TOGETHER      |          |
|         |       | 18D     |                              |          |
|         | DSU   | BMN     | # BETA8-DX(T1)MAX            |          |
|         |       | 12D     |                              |          |
|         |       | GAMDV15 |                              |          |
|         | SETPD | GOTO    | #                            | PL18D    |
|         |       | 18D     |                              |          |
|         |       | GAMDV20 |                              |          |
| GAMDV15 | DLOAD |         | #                            | PL18D    |
|         | SIGN  | SR1     |                              |          |
|         |       | 16D     |                              |          |
|         | STORE | 16D     | # BETA8(SIGNDX(T1))/2=DX(T1) |          |
| GAMDV20 | DLOAD |         |                              |          |
|         |       | M144RTE |                              |          |
|         | STORE | NN2     |                              |          |
| GAMDV25 | DLOAD | DAD     |                              |          |
|         |       | NN2     |                              |          |
|         |       | 1RTEB28 |                              |          |
|         | BMN   | SLOAD   |                              |          |

|                      |        |          |                                  |          |       |
|----------------------|--------|----------|----------------------------------|----------|-------|
|                      |        | GAMDV30  |                                  |          |       |
|                      |        | OCT605   |                                  |          |       |
|                      |        | GOTO     |                                  |          |       |
|                      |        | V2T1X    |                                  |          |       |
| GAMDV30              | STORE  | NN2      | # NN2=NN2+1                      |          |       |
|                      | DLOAD  | PDDL     | # X(T1)=X(T1),                   | B5       | PL201 |
|                      |        | X(T1)    |                                  |          |       |
|                      |        | DV       |                                  |          |       |
|                      | PDDL   | DAD      | # DV=DV,                         | B7/B5    | PL221 |
|                      |        | X(T1)    |                                  |          |       |
|                      |        | 16D      |                                  |          |       |
| # Page 926           |        |          |                                  |          |       |
|                      | STCALL | X(T1)    | # X(T1)+DX(T1)=X(T1)             | B5       |       |
|                      |        | DVCALC   |                                  |          |       |
|                      | BON    | DLOAD    |                                  |          |       |
|                      |        | F2RTE    |                                  |          |       |
|                      |        | GAMDV35  |                                  |          |       |
|                      |        | DV       |                                  |          |       |
|                      | DSU    | BMN      | # CONTINUE IF FUEL CRITICAL MODE |          |       |
|                      |        | 20D      |                                  |          |       |
|                      |        | GAMDV33  |                                  |          |       |
| GAMDV32              | DLOAD  | DCOMP    |                                  |          |       |
|                      |        | 16D      |                                  |          |       |
|                      | SR1    |          |                                  |          |       |
|                      | STORE  | 16D      |                                  |          |       |
| GAMDV33              | SETPD  | GOTO     |                                  |          |       |
|                      |        | 18D      | #                                |          | PL181 |
|                      |        | GAMDV50  |                                  |          |       |
| # TIME CRITICAL MODE |        |          |                                  |          |       |
| GAMDV35              | DLOAD  | DSU      |                                  |          |       |
|                      |        | RTEDVD   |                                  |          |       |
|                      |        | DV       |                                  |          |       |
|                      | PDDL   | PUSH     | # DVD-DV=DVERR                   | B7/B5    | PL221 |
| GAMDV40              | DLOAD  | ABS      | # DV,                            |          | PL241 |
|                      |        | 20D      |                                  |          |       |
|                      | DSU    | BMN      |                                  |          |       |
|                      |        | EPC10RTE |                                  |          |       |
|                      |        | GAMDVX   |                                  |          |       |
| GAMDV45              | BOVB   | DLOAD    | # ASSURE OVFIN IS 0              |          |       |
|                      | BDSU   | NORM     |                                  |          |       |
|                      |        | DV       |                                  |          |       |
|                      |        | X2       |                                  |          |       |
|                      | PDDL   |          | # DV-DV,                         | B7/B5-N2 | PL221 |

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```

NORM    SR1      # DVERR      B8/B6-N1
        X1
DDV     PDDL      # DVERR/ DV - DV
BDSU    DMP        #
        X(T1)      PL18D
XSU,1
        X2
STORE   16D      # PRESERVE SIGN IF OVERFLOW
SR*     BOV
        0 -1,1
        GAMDV47
STORE   16D      # (X(T1)-X(T1),)DVERR/(DV-DV,)=DX(T1)
ABS     DSU
        12D
BMN
        GAMDV50
# Page 927
GAMDV47 DLOAD    SIGN
        12D
        16D
STORE   16D      # DX(T1)MAX(SIGNDX(T1))=DX(T1)

# CHECK TO KEEP INDEPENDENT VARIABLE IN BOUNDS

GAMDV50 DLOAD    DMP
        16D
        1.1RTEB1
SL1     DAD
        X(T1)
STORE   24D      # X(T1)+1.1DX(T1)=BETA9      B5
DSU     BMN
        14D
        GAMDV55
DLOAD   DSU
        14D
        X(T1)
SR1
STCALL  16D      # (X(T1)MAX-X(T1))/2=DX(T1)      B5
        GAMDV65
GAMDV55 DLOAD    DSU
        24D
        10D
BMN     GOTO
        GAMDV60
        GAMDV65
GAMDV60 DLOAD    DSU
```

```

10D
X(T1)
SR1
STORE 16D # (X(T1)MIN-X(T1))/2=DX(T1) B5
GAMDV65 DLOAD ABS
16D
DSU BMN
EPC9RTE
GAMDVX
GOTO GAMDV25
GAMDVX GOTO
31D

# Page 928
# DV CALCULATION SUBROUTINE
#
# INPUT
#   PUSHLIST
#       02D THETA1=BETA5*LAMBDA-1 TP
#       05D THETA2=2*R(T1)*(LAMBDA-1) TP
#       08D THETA3=MU** .5/R(T1) DP
#   OTHER
#       X(T1) COTANGENT OF POST IMPULSE INITIAL FLIGHT PATH ANGLE DP
#       V(T1)/ INITIAL VELOCITY VECTOR (PRE IMPULSE) VECTOR
#       UR1/ UNIT INITIAL VECTOR VECTOR
#       UH/ UNIT HORIZONTAL VECTOR VECTOR
#
# OUTPUT
#       V2(T1)/ POST IMPULSE INITIAL VELOCITY VECTOR VECTOR
#       DV INITIAL VELOCITY CHANGE DP
#       PCON SEMI-LATUS RECTUM DP
#
# DEBRIS
#       28D THETA3*PCON** .5 DP
#       C(PUSHLOC) THETA3(PCON** .5)*X(T1)*UR1/ VECTOR
#       32D DVCALC SUBROUTINE RETURN ADDRESS
#       X1 NORMALIZATION FACTOR FOR VALUE IN 28D
#
# PUSHLOC IS RESTORED TO ITS ENTRANCE VALUE UPON EXITING DVCALC

DVCALC STQ DLOAD
32D
X(T1)
DSQ SR
7

```

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```
DCOMP  TAD
      02D
NORM    PUSH
      X1
TLOAD   NORM
      05D
      X2
RTB     SR1
      DPMODE
XSU,2   DDV
      X1
SR*
      6,2
STORE   PCON          # THETA2/(THETA1-X(T1)**2)=PCON B28/26
SQRT    DMP
      08D
NORM
      X1
STODL   28D          # THETA3*PCON**.5          B10/B8 -N1
# Page 929
      X(T1)
NORM    VXSC
      X2
      UR1/          # X(T1)*UR1/          B5+B1 -N2
XAD,2   VXSC
      X1
      28D
VSR*    PDVL          # THETA3(PCON**.5)X(T1)*UR1/  B7/B5
      0 -9D,2        #
      UH/
VXSC    VSR*          # THETA3(PCON**.5)UH/          B7/B5
      28D
      0 -4,1        #
VAD     STADR
STORE   V2(T1)/        # V2(T1)/          B7/B5
VSU     ABVAL
      V(T1)/
STORE   DV          # ABVAL(V2(T1)/-V1(T)/)=DV  B7/B5
GOTO
      32D
```

# Page 930

# SUBROUTINE TO COMPUTE BOUNDS ON INDEPENDENT VARIABLE X(T1)

#

# INPUT

# PUSHLIST

```

#      PUSHLOC -4      MAJOR AXIS (MA)                      DP
#      PUSHLOC -2      MAJOR AXIS (MA) AGAIN                DP
#      28D              BETA5=LAMBDA*BETA1                  DP
#      OTHER
#      RCON   DP
#      R(T1)  DP
#
# OUTPUT
#      MPAC
#      X(T1)LIM          LIMIT ON INDEPENDENT VARIABLE X(T1)  DP
#
# DEBRIS
#      PUSHLIST
#      C(PUSHLOC)        MA-RCON                             DP
#      C(PUSHLOC) +2     MA                                  DP
#      X1                NORMALIZATION FACTOR FOR MA-RCON
#      20D              XT1LIM SUBROUTINE RETURN ADDRESS
#
# PUSHLOC IS RESTORED TO ITS ENTRANCE VALUE UPON EXITING XT1LIM

XT1LIM      STQ      DLOAD
              20D
              RCON
              SR1     BDSU
              NORM    PDDL          # MA-RCON                B30-N1
              X2
              PDDL    SR1
              R(T1)
              BDSU    DDV
              SL*     DMP
              0        -3,2
              28D
              SL*     DSU          # BETA10=BETA5(MA-RT)/(MA-RC)-1 B11
              0        -6,1
              1RTEB25 +1          # 1.0                      B-11
              SL1     BOV
              XT1LIM2
              BMN     GOTO
              XT1LIM5
              XT1LIM3
XT1LIM2      DLOAD          # BETA10=POS MAX IF OVERFLOW
              2RTEB1
XT1LIM3      SQRT          GOTO          # X(T1)=SQRT(BETA10)
              XT1LIMX
XT1LIM5      DLOAD
              ZERORTE

```

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XT1LIMX           GOTO  
                    20D

# Page 931

# CONSTANTS FOR THE P37 AND P70 PROGRAMS AND SUBROUTINES

BANK     36  
SETLOC   RTECON1  
BANK

1RTEB1       2DEC     1. B-1  
1RTEB2       2DEC     1. B-2  
1RTEB3       2DEC     1. B-3  
1RTEB4       2DEC     1. B-4  
1RTEB10      2DEC     1. B-10  
1RTEB12      2DEC     1. B-12  
1RTEB13      2DEC     1. B-13  
1RTEB17      2DEC     1. B-17  
1RTEB25      2DEC     1. B-25

#

\* \* B25 AND B28 MUST BE CONSECUTIVE \* \*

1RTEB28      2DEC     1. B-28  
ZERORTE      2DEC     0  
M144RTE      2DEC     -144. B-28  
M15RTE       2DEC     -15  
1ORTE        2DEC     10  
M.6RTE       2DEC     -.6  
1.1RTEB1     2DEC     1.1 B-1  
M6RTEB28     2DEC     -6  
2RTEB1       2OCT     3777737777  
M9RTEB28     2DEC     -9  
M8RTEB28     2DEC     -8  
3048ORTE     2DEC     30480. B-29  
VCSPS        2DEC     31.510396 B-5   # (SEE 2VEXHUST)

# Page 932

VCRCS        2DEC     27.0664 B-5  
MDOTRCS      2DEC     .0016375 B-3  
CSUBT        2DEC     .5  
OCT605       OCT     00605  
OCT612       OCT     00612  
MCOS7.5      2DEC     -.99144486  
MSIN7.5      2DEC     -.13052619  
MCOS22.5     2DEC     -.92387953 B-2  
THETA165     2DEC     .4583333333  
THETA210     2DEC     .5833333333  
EPC1RTE      2DEC     .99966 B-1  
EPC2RTE      2DEC     100. B-29

|            |         |                   |
|------------|---------|-------------------|
| EPC3RTE    | 2DEC    | .001              |
| EPC4RTE    | 2DEC    | .00001            |
| EPC5RTE    | 2DEC    | .01 B-6           |
| EPC6RTE    | 2DEC    | .000007 B-1       |
| EPC7RTE    | 2DEC    | 1000. B-29        |
| EPC9RTE    | 2DEC    | 1. B-25           |
| EPC10RTE   | 2DEC    | .0001 B-7         |
|            |         |                   |
| BANK       | 35      |                   |
| SETLOC     | RTECON1 |                   |
| BANK       |         |                   |
|            |         |                   |
| C4RTE      | 2DEC    | -6.986643 E7 B-30 |
| K1RTE      | 2DEC    | 7. E6 B-29        |
| K2RTE      | 2DEC    | 6495000. B-29     |
| K3RTE      | 2DEC    | -.06105           |
| K4RTE      | 2DEC    | -.10453           |
| RTMURTE    | 2DEC    | 199650.501 B-18   |
| # Page 933 |         |                   |
| E3RTE      | 2DEC    | 121920. B-29      |

This code is written to file `src/P37-P70.s`.



## A.73 P40-P47

1209

*<src/P40-P47.s 1209>*≡

```
# Copyright:   Public domain.
# Filename:    P40-P47.agc
# Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
#             It is part of the source code for the Command Module's (CM)
#             Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:  yaYUL
# Contact:     Ron Burkey <info@sandroid.org>.
# Website:     www.ibiblio.org/apollo.
# Pages:       684-736
# Mod history: 2009-05-11 RSB   Adapted from the Colossus249/ file
#             of the same name, using Comanche055 page
#             images.
#             2009-05-20 RSB   In S20.1, a DMP DDV was corrected to DMPR DDV.
#             2009-05-22 RSB   In BESTTRIM, TC PACTOFF corrected to
#             TS PACTOFF.
#             2009-05-23 RSB   Prior to the 2CADR at T5IDLDAP, added an
#             SBANK.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. 10:28 APR. 1, 1969
#
# This AGC program shall also be referred to as
# Colossus 2A
#
# Page 684
# PROGRAM DESCRIPTION ** P40CSM **
```

```
EBANK= DAPDATR1
BANK   31
SETLOC P40S
BANK
```

|            |        |             |                                           |
|------------|--------|-------------|-------------------------------------------|
|            | COUNT  | 24/P40      |                                           |
| P40CSM     | TC     | DOWNFLAG    |                                           |
|            | ADRES  | ENG2FLAG    |                                           |
|            | TC     | INTPRET     |                                           |
|            | SLOAD  | BOFF        |                                           |
|            |        | ECSTEER     | # IS THIS AN EXTERNAL DELTA V BURN        |
|            |        | XDELVFLG    |                                           |
|            |        | P40S/C      | # NO CSTEER = ECSTEER                     |
|            | DLOAD  |             | # YES CSTEER = ZERO                       |
|            |        | HI6ZEROS    |                                           |
| P40S/C     | STODL  | CSTEER      |                                           |
|            |        | FENG        | # SET UP THRUST FOR P40 20,000 LBS        |
| P40S/F     | STODL  | F           | # P41 ENTERS HERE                         |
|            |        | TIG         | # ORIGINAL TIG MAY BE SLIPPED BY P40S/SV  |
|            | STORE  | NOMTIG      | # SET ORIGINAL TIME OF IGNITION FOR S40.9 |
|            | EXIT   |             |                                           |
|            | TC     | BANKCALL    |                                           |
|            | CADR   | R02BOTH     | # IMU STATUS CHECK                        |
| P40PVA     | TC     | INTPRET     |                                           |
|            | CALL   |             |                                           |
|            |        | S40.1       | # COMPUTE VGTIG,UT                        |
|            | CALL   |             |                                           |
|            |        | S40.2,3     | # COMPUTE PREFERRED ATTITUDE              |
|            | SET    | EXIT        |                                           |
|            |        | PFRATFLG    |                                           |
| P40SXTY    | TCR    | SETMINDB -1 | # NARROW DEADBAND FOR MANEUVER (EBANK6)   |
|            | RELINT |             |                                           |
|            | TC     | BANKCALL    |                                           |
|            | CADR   | R60CSM      | # ATTITUDE MANEUVER                       |
|            | CS     | ONE         | # FOR UPDATEVG                            |
|            | TS     | NBRCYCLS    |                                           |
|            | TC     | UPFLAG      |                                           |
|            | ADRES  | TIMRFLAG    | # ALLOW CLOCTASK                          |
|            | TC     | P41/P40     |                                           |
|            | TC     | P41/DSP     | # P41                                     |
| P40TTOG    | CAF    | V06N40      | # INITIALIZE FOR CLOCTASK WHICH IS CALLED |
| # Page 685 | TS     | NVWORD1     | # BELOW                                   |
|            | TC     | INTPRET     |                                           |

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```
VLOAD  ABVAL      # FOR R2
      VGTIG
STODL   VGDISP
      HI6ZEROS
STORE   DVTOTAL
EXIT

EXTEND
DCA     STEERADS   # SET FOR UPDATEVG AND TEST FOR STEERING
DXCH    AVEGEXIT   # AFTER AVERAGE G

P40GMB  CAF        # (4.1 PROTECTION)
      TC          BANKCALL
      CADR        GOPERF1
      TCF         POST41   # V34
      TCF         TST,TRIM # V33
TRIMONLY CS        # SET MRKRTEMP FOR GIMBAL TRIM (-1)
      +1          TS      # ENTRY FROM TST,TRIM
      MRKRTEMP

CAF     ZERO       # SET CNTR      +0 FOR RESTART LOGIC IN S40.6
TS      CNTR       #      +0 SAYS NORMAL ENTRY
      #           #      +1 (PRE40.6) SAYS RESTART ENTRY

CAF     ONE
TC      WAITLIST
EBANK=  DAPDATR1
2CADR   S40.6

CCS     MRKRTEMP   # TEST TO FIND TIME TO WAIT FOR GIMBAL TEST
CAF     18SEC      # PLUS, DELAY FOR 18 SECONDS
TCF     +2         # HOLE
CAF     5SEC       # DELAY FOR TRIM ONLY TASK
TC      BANKCALL
CADR    DELAYJOB
TC      2PHSCHNG
OCT     40026      # 6.2 = PRE40.6(-OCS), CLOKTASK(100CS)
OCT     00234      # 4.23 = P40S/SV (PRIO12)
P40S/RS CAF        ONE
      TC          WAITLIST # P41/SDP
EBANK=  TIG
2CADR   CLOKTASK

RELINT

P40S/SV TCR        E7SETTER # JOB, 4.23 PRETECTS, PRE012
EBANK=  TIG
```

# Page 686

|          |        |          |                                         |
|----------|--------|----------|-----------------------------------------|
|          | TC     | INTPRET  |                                         |
|          | DLOAD  | DSU      |                                         |
|          |        | TIG      |                                         |
|          |        | SEC29.96 |                                         |
|          | STORE  | TDEC1    |                                         |
|          | CALRB  |          | # RETURN IN BASIC                       |
|          |        | MIDTOAV1 |                                         |
|          | TCF    | +2       |                                         |
|          | TC     | P40SNEWM | # INTEGRATION TIME GREATER THAN ALLOWED |
| P40SET   | EXTEND |          |                                         |
|          | DCA    | MPAC     | # DELTA TIME TO PREREAD (INT.INIT.)     |
|          | DXCH   | P40TMP   |                                         |
|          | EXTEND |          |                                         |
|          | DCS    | 5SECDP   | # FOR TIGBLNK                           |
|          | DAS    | P40TMP   |                                         |
|          | EXTEND |          |                                         |
|          | DCA    | P40TMP   |                                         |
|          | TC     | LONGCALL |                                         |
|          | EBANK= | TIG      |                                         |
|          | 2CADR  | TIGBLNK  |                                         |
|          | TC     | PHASCHNG |                                         |
|          | OCT    | 20214    | # 4.21 = TIGBLNK (P40TMP CS)            |
|          | TCF    | ENDOFJOB |                                         |
| P40BLNKR | TC     | BANKCALL |                                         |
|          | CADR   | CLEANDSP | # REMOVE RESIDUE                        |
|          | TCF    | ENDOFJOB |                                         |
|          | EBANK= | TIG      |                                         |
| P40SNEWM | EXTEND |          |                                         |
|          | DCA    | PIPTIME1 |                                         |
|          | DXCH   | TIG      | # SET NEW TIG FOR 06 40                 |
|          | EXTEND |          |                                         |
|          | DCA    | SEC29.96 |                                         |
|          | DAS    | TIG      |                                         |
|          | TCF    | P40SET   | # FOR LONGCALL OF TIG-30 (OR -35)       |
|          | EBANK= | DAPDATR1 |                                         |
| POSTBURN | CAF    | V16N40   |                                         |
|          | TC     | BANKCALL |                                         |
|          | CADR   | REFLASH  |                                         |
|          | TCF    | POST41   | # V34 GO FINISH                         |
|          | TCF    | P40RCS   | # PROCEED                               |
|          | TCF    | POSTBURN | # RECYCLE                               |

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```
P4ORCS      EXTEND      # V99N40 ENTERS HERE ON A P40 BYPASS SPS
              DCA        ACADN85
              DXCH       AVEGEXIT
              CAF        2SECS      # WAIT FOR CALCN85 VIA AVEGEXIT
              TC         BANKCALL

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              CADR       DELAYJOB

P40MINDB     TCR         SETMINDB -1
              RELINT

TIGNOW       TC         PHASCHNG
              OCT        05024      # TYPE C GROUP 4 BELOW FOR NOUN 85
              OCT        20000      # PRIO 20
              CAF        V16N85B
              TC         BANKCALL
              CADR       REFLASH
              TCF        POST41      # FINISH P40/P41
              TCF        POST41      # V03 PROCEED WITH REST OF THE CLEAN-UP
              TCF        TIGNOW      # V32 NOT GSOP RESPONSE BUT REDISPLAY N85

POST41       EXTEND
              DCA        SERVCADR
              DXCH       AVEGEXIT
              TCF        GOTOP00H

MINDB        DEC        46
MAXDB        DEC        455
              EBANK=     DAPDATR1
              -1        INHINT
SETMINDB     CA         CDUX        # ROUTINE FOR SETTING
              TS         THETADX     # THE MINIMUM DEADBAND
              EXTEND      # IN AUTOPILOT
              DCA        CDUY
              DXCH       THETADY
              CA         MINDB       # SHOULD BE CALLED UNDER
              TS         ADB         # INTERRUPT INHIBITED
              CS         BIT4       # EBANK = E6
              MASK       DAPDATR1
              TS         DAPDATR1
              TC         Q

              EBANK=     DAPDATR1
              -1        INHINT
SETMAXDB     CA         MAXDB       # ROUTINE FOR SETTING
              TS         ADB         # THE MAXIMUM DEADBAND IN AUTOPILOT
              CS         DAPDATR1
```

|      |          |                          |
|------|----------|--------------------------|
| MASK | BIT4     | # SHOULD BE CALLED UNDER |
| ADS  | DAPDATR1 | # INTERRUPT INHIBITED    |
| TC   | Q        | # EBANK = E6             |

# Page 688

# PROGRAM DESCRIPTION \*\* P41CSM \*\*

|         |        |          |                              |
|---------|--------|----------|------------------------------|
|         | SETLOC | P40S2    |                              |
|         | BANK   |          |                              |
|         | EBANK= | DAPDATR1 |                              |
|         | COUNT  | 24/P41   |                              |
| P41CSM  | TC     | UPFLAG   |                              |
|         | ADRES  | ENG2FLAG | # SET FOR RCS                |
|         | TC     | INTPRET  |                              |
|         | DLOAD  |          |                              |
|         |        | HI6ZEROS | # FOR P41 CSTEER =0          |
|         | STORE  | CSTEER   |                              |
|         | DLOAD  | BON      |                              |
|         |        | FRCS2    | # 2JET THRUST FOR S40.1      |
|         |        | NJETSFLG |                              |
|         |        | P40S/F   | # NJETS = 1 2-JET            |
|         | DAD    | GOTO     | # NJETS = 0 4-JET            |
|         |        | FRCS2    |                              |
|         |        | P40S/F   |                              |
|         | SETLOC | P40S     |                              |
|         | BANK   |          |                              |
| P41/P40 | CS     | MODREG   |                              |
|         | MASK   | ONE      | # P41EXITS AT CALL LOC +1    |
|         | EXTEND |          |                              |
|         | BZF    | +2       | # P41                        |
|         | INCR   | Q        | # P40 EXITS AT CALL LOC +2   |
|         | TC     | Q        |                              |
| TTG/0   | CAF    | PRI020   | # TASK (4.4 PROTECTS IN P41) |
|         | TC     | NOVAC    |                              |
|         | EBANK= | DAPDATR1 |                              |
|         | 2CADR  | TIGNOW   |                              |
| P40CLK  | TC     | DOWNFLAG |                              |
|         | ADRES  | TIMRFLAG |                              |

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```

                                TCF      TASKOVER

P41/DSP                        CAF      V06N85B      # SET UP FOR NONFLASH V 06 N85 BY CLOCKJOB
                                TS        NVWORD1

                                TC        INTPRET

# Page 689
                                CALL
                                P40CNV85      # COMPUTE
  #          VGTIG IN CTRL COORDS

                                EXIT
                                EXTEND      # DO CONTROL COORD CALCULATION AFTER AVEG
                                DCA        ACADN85
                                DXCH       AVEGEXIT
                                TC        2PHSCHNG
                                OCT        40036      # 6.3=CLOKTASK(100CS)
                                OCT        234        # 4.23=P40S/SV(PRI012)

P41REDSP                       TCF      P40S/RS
                                CAF      V16N85B      # ENTER FROM P41 SIDE OF TIGAVEG
                                TS        NVWORD1      # REDISPLAY NONFLASHING
                                CAF      SEC29.96 +1
                                TC        WAITLIST
                                EBANK=    DAPDATR1
                                2CADR     TTG/0

                                CS        BIT3
                                TCF      TTGPHS
                                STQ       SETPD
                                QTEMP1
                                0
                                VLOAD     PUSH
                                VGPREV    # EQUALS VGTIG (TARGETTING INPUT)
                                CALL
                                S41.1
                                STCALL    VGBODY
                                QTEMP1

                                EBANK=    DAPDATR1
                                TC        INTPRET
                                CALL
                                UPDATEVG      # NEW VG, S40.8 (+MAYBE S40.9)
                                CALL
                                P40CNV85      # COMPUTE VGBODY
                                EXIT
                                TC        SERVXT
```

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|            |        |                 |                                            |
|------------|--------|-----------------|--------------------------------------------|
| FENG       | 2DEC   | 9.1188544 B-7   | # SPS THRUST (20500LBS), SC.AT B+7 NEWT/E4 |
| FRCS2      | 2DEC   | .087437837 B-7  | # RCS ULLAGE (199.6COS10 LBS), SC.AT       |
|            |        |                 | # B+7 NEWTONS/E+4                          |
| SEC24.96   | DEC    | 2496            |                                            |
| SEC29.96   | 2DEC   | 2996            |                                            |
| 18SEC      | DEC    | 1800            |                                            |
| P40CKLS2   | OCT    | 204             |                                            |
| 40CST5     | OCT    | 37730           | # 40 CS FOR THE T5 CLOCK                   |
| OCT12      | =      | TEN             |                                            |
| # Page 690 |        |                 |                                            |
| V1683      | VN     | 1683            |                                            |
| V06N85B    | VN     | 0685            |                                            |
| V16N85B    | VN     | 1685            |                                            |
| V06N40     | VN     | 0640            |                                            |
| V16N40     | VN     | 1640            |                                            |
| OCT27/24   | OCT    | 27              |                                            |
| OCT53      | OCT    | 53              |                                            |
| OCT35      | OCT    | 35              |                                            |
|            | EBANK= | DAPDATR1        |                                            |
| T5IDL24    | 2CADR  | T5IDLOC         |                                            |
| 3MDOT      | DEC    | 86.6175796 B-16 | # 3SEC MASS LOSS (63.8 LBS/SEC), SC.AT     |
|            |        |                 | # B+16 KB/SEC (NOT, EMDOT IS PAD-LOADED,   |
|            |        |                 | # BUT 3MDOT IS NOT A CRITICAL QUANTITY, SO |
|            |        |                 | # IT CAN REMAIN IN FIXED MEMORY)           |
| TST,TRIM   | CAF    | BIT1            | # SET UP FOR GIMB DRIVE TEST AND TRIM (+1) |
|            | TCF    | TRIMONLY +1     |                                            |
| TIGBLNK    | CAF    | 5SEC            | # CALL TIGAVEG IN FIVE SEC AT TIG-30       |
|            | TC     | WAITLIST        |                                            |
|            | EBANK= | TIG             |                                            |
|            | 2CADR  | TIGAVEG         |                                            |
|            | CAF    | ZERO            | # DISABLE HERE, NOT IN P40BLNKR            |
|            | TS     | NVWORD1         |                                            |
|            | CAF    | PRI014          |                                            |
|            | TC     | NOVAC           |                                            |
|            | EBANK= | TIG             |                                            |
|            | 2CADR  | P40BLNKR        | # DON'T PROTECT -- RESTARTS BLANK DSKY     |
| P40TSK     | CS     | OCT37           | # 4.37 = TIGAVEG (500CS)                   |
|            | TC     | NEWPHASE        |                                            |
|            | OCT    | 4               |                                            |



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|          |        |          |
|----------|--------|----------|
|          | TC     | TASKOVER |
|          | EBANK= | TIG      |
| ACADN83  | 2CADR  | CALCN83  |
|          | EBANK= | TIG      |
| SERVCADR | 2CADR  | SERVEXIT |
|          | EBANK= | DAPDATR1 |
| ACADN85  | 2CADR  | CALCN85  |

# Page 691

# PROGRAM DESCRIPTION \*\* P47CSM \*\*

|         |        |          |                                           |
|---------|--------|----------|-------------------------------------------|
|         | COUNT  | 24/P47   |                                           |
|         | EBANK= | TIG      |                                           |
| P47CSM  | TC     | BANKCALL | # IMU STATUS CHECK                        |
|         | CADR   | R02BOTH  |                                           |
|         | TC     | INTPRET  |                                           |
|         | CALRB  |          |                                           |
|         |        | MIDTOAV2 |                                           |
|         | CA     | MPAC +1  | # DELTA TIME TO RPEREAD (LESS THAN 100    |
|         | TS     | P40TMP   | # CS, WITH A TPAGREE, INT.INIT.)          |
|         | TC     | WAITLIST |                                           |
|         | EBANK= | TIG      |                                           |
|         | 2CADR  | TIGON    | # TIGON IS REQUIRED TO MATHCHTAT AND AVEG |
|         | TC     | PHASCHNG |                                           |
|         | OCT    | 40574    | # A, 4.57 = TIGON (P40TMP CS)             |
|         | TCF    | ENDOFJOB |                                           |
|         | EBANK= | P40TMP   |                                           |
| TIGON   | EXTEND |          |                                           |
|         | DCA    | ACADN83  |                                           |
|         | DXCH   | AVEGEXIT |                                           |
|         | CAF    | PRI030   | # FORCE ZEROING OF N83 BEFORE SERVICER    |
|         | TC     | NOVAC    |                                           |
|         | EBANK= | TIG      |                                           |
|         | 2CADR  | P47BODY  |                                           |
|         | CS     | BIT2     | # 4.2 = PRECHECK (-OCS), P47BODY (PRI030) |
|         | TCF    | TTGPHS   |                                           |
|         | EBANK= | TIG      |                                           |
| CALCN83 | TC     | INTPRET  |                                           |

```

                                SETPD                                # SET UP PUSHLIST FOR S41.1
                                0
                                VLOAD                                VAD
                                DELVCTL
                                DELVREF
                                STORE DV47TEMP                      # FOR COPYCYCLE BELOW
                                PUSH  CALL
                                S41.1
                                STCALL DELVIMU
                                S11.1                                # CALC. VI, H, HDOT FOR NOUN 62
                                EXIT
                                TC  PHASCHNG
                                OCT  10035

# Page 692
                                CAF  FIVE
                                TC  GENTRAN
                                ADRES DV47TEMP
                                ADRES DELVCTL

                                TC  SERVXT
P47BODY TC  INTPRET
                                VLOAD
                                HI6ZEROS
                                STORE DELVIMU                        # CLEAR DISPLAY AND ACCUMULATOR STORAGE
                                STORE DELVCTL                        # UPON INITIATION OR ENTER RESPONSE
                                EXIT
P47BOD CAF  PRI015  # LOWER PRIO THAN CALCN83 (20)
                                TC  PRIOCHNG                          #          TO PREVENT INTERRUPTION OF CALCN83
                                TC  PHASCHNG
                                OCT  05024                            # TYPE C GROUP 4 BELOW FOR NOUN 83
                                OCT  15000                            # PRIO 15
P47/DSP CAF  V1683
                                TC  BANKCALL
                                CADR  GOFLASH
                                TC  GOTOP00H
                                TC  GOTOP00H
                                TCF  P47BODY                          # RECYCLE -- CLEAR ACCUMULATED VELOCITY

# Page 693
# ROUTINE ** TIG-30 ** DESCRIPTION

                                EBANK= TIG
                                COUNT 24/P40

TIGAVEG TC  P41/P40  # TASK (4.37 PROTECTS)
                                TCF  P41REDSP

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|          |        |          |                                           |
|----------|--------|----------|-------------------------------------------|
|          | CAF    | V06N40   | # UNBLANK DISPLAY                         |
|          | TS     | NVWORD1  |                                           |
|          | CAF    | SEC24.96 |                                           |
|          | TC     | WAITLIST |                                           |
|          | EBANK= | TIG      |                                           |
|          | 2CADR  | TIG-5    |                                           |
| TTGPHS   | CS     | SIX      | # 4.6 = TIG-5 (2496CS), PRECHECK (-OCS)   |
|          | TC     | NEWPHASE | # ENTRY FROM P41REDSP (P41) WITH A=-4, OR |
|          | OCT    | 4        | # FROM TIGON (P47) WITH A=-1              |
| PRECHECK | CCS    | PHASE5   | # HAS SERVICER BEEN RESTARTED             |
|          | TCF    | TASKOVER | # YES, DON'T START ANOTHER ONE            |
|          | TC     | POSTJUMP |                                           |
|          | CADR   | PREREAD  |                                           |

# Page 694

# ROUTINE \*\* TIG-5 \*\* DESCRIPTION

|       |        |          |                            |
|-------|--------|----------|----------------------------|
| TIG-5 | EBANK= | TIG      |                            |
|       | CAF    | 5SEC     |                            |
|       | TC     | WAITLIST |                            |
|       | EBANK= | DAPDATR1 |                            |
|       | 2CADR  | TIG-0    |                            |
|       | CS     | BIT9     | # WILL CAUSE V99 FLASH     |
|       | TS     | NVWORD1  |                            |
|       | TC     | 2PHSCHNG |                            |
|       | OCT    | 40074    | # A, 4.7 = TIG-0 (500CS)   |
|       | OCT    | 00033    | # A, 3.3 = S40.13 (PRI020) |
|       | CAF    | PRI020   |                            |
|       | TC     | FINDVAC  |                            |
|       | EBANK= | TGO      |                            |
|       | 2CADR  | S40.13   |                            |
|       | TCF    | TASKOVER |                            |

# Page 695

# ROUTINES \*\* TIG-0 \*\* AND \*\* IGNITION \*\* DESCRIPTION

|       |        |          |                                          |
|-------|--------|----------|------------------------------------------|
| TIG-0 | EBANK= | DAPDATR1 | # TASK, 4.7 PHASE, OR 4.77 (-OCS) IN R40 |
|       | CS     | FLAGWRD7 | # SET IGN FLAG                           |

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|          |        |          |                                            |
|----------|--------|----------|--------------------------------------------|
|          | MASK   | BIT13    |                                            |
|          | ADS    | FLAGWRD7 |                                            |
|          | CAE    | FLAGWRD7 | # CHECK ASTN FLAG FOR V99 RESPONSE         |
|          | MASK   | BIT12    |                                            |
|          | EXTEND |          |                                            |
|          | BZF    | TASKOVER | # WAIT FOR V99P                            |
|          | CAF    | V06N40   | # CLEAR THE V99 (IN CASE OF A RESTART      |
|          | TS     | NVWORD1  | # DURING THE V99 SEQUENCE)                 |
|          | TC     | PHASCHNG | # V99P HAS COME ALREADY, DO IGNITION NOW   |
|          | OCT    | 00614    | # A, 4.61 = IGNITION (-OCS) TBASE OLD      |
| IGNITION | CAE    | CDUX     | # SAVE FOR ROLL DAP REFERENCE OGAD         |
|          | TS     | OGAD     | # V99PJOB (CLOCKJOB) SETS UP IGNITION      |
|          | EXTEND |          | # TASK (4.61 PROTECTION)                   |
|          | DCA    | TIME2    | # FOR RESTARTS                             |
|          | DXCH   | TEVENT   |                                            |
|          | CS     | FLAGWRD5 | # SET ENGONFLG                             |
|          | MASK   | BIT7     |                                            |
|          | ADS    | FLAGWRD5 |                                            |
| SPSON    | CAF    | BIT13    | # TURN ON SPS ENGINE                       |
|          | EXTEND |          |                                            |
|          | WOR    | DSALMOUT |                                            |
| IMPULCHK | CAF    | BIT9     | # CHECK FOR IMPULSIVE BURN                 |
|          | MASK   | FLAGWRD2 |                                            |
|          | CCS    | A        |                                            |
|          | TCF    | IMPLBURN | # IMPULSIVE                                |
|          | CS     | FLAGWRD6 | # NON-IMPULSIVE, SET STRULLSW FOR STEERULL |
|          | MASK   | BIT13    |                                            |
|          | ADS    | FLAGWRD6 |                                            |
| PREPTVC  | CS     | OCT60000 | # RESET T5 BITS                            |
|          | MASK   | FLAGWRD6 |                                            |
|          | TS     | FLAGWRD6 |                                            |
|          | EXTEND |          | # KILL RCS                                 |
|          | DCA    | T5IDL24  |                                            |
|          | DXCH   | T5LOC    |                                            |
|          | CS     | THREE    | # 4.3 = DOTVCON (40CS)                     |
|          | TC     | NEWPHASE |                                            |
|          | OCT    | 4        |                                            |

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# Page 696

|          |        |          |                                             |
|----------|--------|----------|---------------------------------------------|
|          | TC     | FIXDELAY |                                             |
|          | DEC    | 40       | # 0.4 SECOND DELAY FOR THRUST BUILDUP       |
| DOTVCON  | CS     | BIT1     | # SET TVCPHASE = TVCDAPON CALL (FRESHDAP)   |
|          | TS     | TVCPHASE |                                             |
|          | CAF    | ZERO     | # SET TVCEXECUTIVE PHASE                    |
|          | TS     | TVCEXPHS |                                             |
|          | CS     | OCT60000 | # SET T5 BITS TO INDICATE TVC TAKEOVER .... |
|          | MASK   | FLAGWRD6 | #       BITS 15,14 = 10                     |
|          | AD     | BIT15    |                                             |
|          | TS     | FLAGWRD6 |                                             |
|          | CAF    | THREE    | # 6.3 = CLOKTASK (100CS), DROPPING PRE40.6  |
|          | TS     | L        | #       WHICH IS HANDLED NOW BY REDOTVC     |
|          | COM    |          |                                             |
|          | DXCH   | -PHASE6  |                                             |
|          | EXTEND |          | # STORE RCS ATTITUDE ERRORS FOR USE IN      |
|          | DCS    | ERRORY   | # INITIALIZING TVC ATTITUDE ERRORS          |
|          | DXCH   | ERRBTMP  |                                             |
|          | CS     | FIVE     | # 4.5 = DOSTRULL (160 CS)                   |
|          | TC     | NEUPHASE |                                             |
|          | OCT    | 4        |                                             |
|          | CAF    | POSMAX   | # SET TIME5 FOR STARTING RIGHT AWAY         |
|          | TS     | TIME5    |                                             |
|          | EXTEND |          |                                             |
|          | DCA    | TVCON2C  | # (TVCDAPON)                                |
|          | DXCH   | T5LOC    | # (KILLS RCS DAP)                           |
|          | TC     | FIXDELAY | # 0.4 + 1.6 = 2.0 SEC FOR ULLAGE-OFF AND    |
|          | DEC    | 160      | #       STEERING (IF NON-IMPULSIVE)         |
| DOSTRULL | CAF    | BIT13    | # CHECK STRULLSW FOR IMPULSIVE BURN         |
|          | MASK   | FLAGWRD6 |                                             |
|          | CCS    | A        |                                             |
|          | TCR    | STEERULL | # NON-IMPULSIVE, STEERING AND ULLAGE OFF    |
|          | TCR    | ULAGEOFF | # ULLAGE OFF (ONLY, OR AGAIN)               |
|          | EXTEND |          |                                             |
|          | DCA    | NEGO     | # KILL GROUP 4 (DP NEG0 = -0,+0)            |
|          | DXCH   | -PHASE4  |                                             |
| ENDIGN   | TCF    | TASKOVER |                                             |

```

STEERULL      CS      FLAGWRD2      # SET STEERSW
               MASK     BIT11
               ADS      FLAGWRD2

# Page 697

ULAGEOFF      CAF      ZERO
               EXTEND
               WRITE    CHAN5      # ZERO CHANNEL 5
               TC        Q

IMPLBURN      CS      BIT13      # RESET STRULLSW (COULD BE AN IMPULSIVE
               MASK     FLAGWRD6  # ENGINE FAIL)
               TS        FLAGWRD6

               TCR      E7SETTER

               EBANK=    TIG
               EXTEND
               DCA      TGO      # PREPARE FOR R1 OF V06N40 (CLOCKTASK)
               DXCH     TIG
               EXTEND
               DCA      TIME2
               DAS       TIG

               TC        2PHSCHNG
               OCT      40153      # A, 3.15 = ENGINOFF (TGO+1) .... NOT GROUP
               OCT      07014      # C, DELTAT NEXT, TASK BELOW, IN
               DEC      -0         # -0 CS
               EBANK=    DAPDATR1
               2CADR     IMPLCONT

               CAE      TGO +1      # (TPAGREE IN S40.13, LESS THAN 600CS)
               TC        WAITLIST
               EBANK=    TGO
               2CADR     ENGINOFF

IMPLCONT      CS      BIT9      # RESET IMPULSW, ENGINOFF IS NOW SET UP
               MASK     FLAGWRD2
               TS        FLAGWRD2

               TCR      E6SETTER
               EBANK=    DAPDATR1

               CAF      ZERO      # SET UP V97VCNTR IN CASE ENGINOFF (MASS=

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|            |        |          |   |                                          |
|------------|--------|----------|---|------------------------------------------|
|            | TS     | V97VCNTR | # | BACK) ARRIVES BEFORE TVCDAPON            |
|            | TCF    | PREPTVC  |   |                                          |
| ENGINEOFF  | EBANK= | TGO      | # | E7 FORCED BY 3.15SPOT VARIABLE DELTA-T   |
|            | TCR    | E6SETTER | # | TASK, 3.15 PHASE (TGO+1 CS) GET E6       |
|            | EBANK= | DAPDATR1 |   |                                          |
|            | CAE    | CSMMASS  |   |                                          |
|            | TS     | MASSTMP  | # | COPYCYCLE FOR MASSBACK                   |
| # Page 698 | TC     | 2PHSCHNG |   |                                          |
|            | OCT    | 00003    | # | KILL GROUP 3 PROTECTION OF ENGINEOFF, DO |
|            | OCT    | 40634    | # | A, 4.63 = DOSPSOFF (-OCS)                |
| DOSPSOFF   | TCR    | SPSOFF   | # | SHUTDOWN SPS, MASS UPDATES, ETC.         |
|            | CS     | OCT27/24 | # | (OCTAL 27)                               |
|            | TC     | NEUPHASE |   |                                          |
|            | OCT    | 4        | # | 4.27 = DOTVCRCS (250 CS)                 |
|            | TC     | FIXDELAY | # | 2.5 SECOND DELAY FOR SPS TAILOFF         |
|            | DEC    | 250      |   |                                          |
| DOTVCRCS   | TCR    | SETMAXDB | # | WIDE DEADBAND FOR CUTOFF TRANSIENT       |
|            | TC     | IBNKCALL | # | SET UP RCS DAP (KILLS TVCDAPS, SETS T5   |
|            | CADR   | RCSDAPON | # | BITS, WAITS 0.6SEC FOR TVCEXEC DIE)      |
|            | TC     | IBNKCALL | # | UPDATE WEIGHT/G AND MASS-PROPERTIES FOR  |
|            | CADR   | MASSPROP | # | RCS DAP STARTUP IN 0.6 SECONDS           |
|            | TCR    | TVCZAP   | # | WIPE OUT TVC, TURN OFF CLOKTASK          |
|            | TC     | PHASCHNG |   |                                          |
|            | OCT    | 00354    | # | A, 4.35 = POSTBURN (NOVAC, PRI012)       |
|            | CAF    | PRI012   | # | SET UP POSTBURN V16N40 JOB               |
|            | TC     | NOVAC    |   |                                          |
|            | EBANK= | DAPDATR1 | # | (SET MAXDB IN POST41)                    |
|            | 2CADR  | POSTBURN |   |                                          |
|            | TCF    | TASKOVER |   |                                          |
| SPSOFF     | EBANK= | DAPDATR1 | # | ESTABLISH SPSOFF TEVENT                  |
|            | EXTEND |          |   |                                          |
|            | DCA    | TIME2    |   |                                          |
|            | DXCH   | TEVENT   |   |                                          |
|            | CS     | BIT7     | # | RESET ENGONFLG                           |
|            | MASK   | FLAGWRD5 |   |                                          |

|            |        |          |                                            |
|------------|--------|----------|--------------------------------------------|
|            | TS     | FLAGWRD5 | # (RESTARTS WILL SHUT DOWN SPS NOW)        |
|            | CS     | BIT13    | # SHUT DOWN SPS ENGINE                     |
|            | EXTEND |          |                                            |
|            | WAND   | DSALMOUT |                                            |
|            | CAF    | BIT14    | # ISSUE SIV CUTOFF COMMAND                 |
|            | EXTEND |          | # FOR POSSIBLE BACK-UP USE                 |
|            | WOR    | CHAN12   |                                            |
| MASSBACK   | CAE    | V97VCNTR | # RESTORE PART OF PRE-DECREMENTED MASS     |
|            |        |          | # V97CNTR = VCNTR UNLESS V97 IS            |
|            |        |          | # ACTIVE. ONLY V97CNTR IS THEN RIGHT.      |
|            | EXTEND |          | # VCNTR COUNTS 1/2-SECONDS IN TVC EXEC     |
|            | MP     | EMDOT    | # MDOT, SC.AT B+3 KG/CS                    |
|            | LXCH   | A        |                                            |
| # Page 699 |        |          |                                            |
|            | EXTEND |          |                                            |
|            | MP     | 1SEC     | # DEC 100                                  |
|            | AD     | MASSTMP  | # CORRECTION IS ACCURATE TO 5 CS OF FLOW   |
|            | TS     | CSMMASS  | # (1.44 KG OR 0.4 BITS)                    |
|            | CA     | TVCPHASE | # CHECK IF OK FOR TRIM UPDATE              |
|            | AD     | ONE      | # THESE CHECKS ARE ONLY NEEDED             |
|            | EXTEND |          | # FOR A LESS THAN 0.4 SEC BURN             |
|            | BZF    | BTRIMR   | # NO. INITIALIZATION NOT COMPLETE          |
|            | CS     | FLAGWRD6 | # YES, CHECK IF TVC                        |
|            | MASK   | OCT60000 |                                            |
|            | EXTEND |          |                                            |
|            | BZMF   | BTRIMR   | # NO, NOT TVC YET                          |
| BESTTRIM   | CAE    | DELPBAR  | # UPDATE TRIMS WITH DELFILTER VALUES       |
|            | TS     | PACTOFF  |                                            |
|            | CAE    | DELYBAR  |                                            |
|            | TS     | YACTOFF  |                                            |
| BTRIMR     | TC     | Q        |                                            |
|            | EBANK= | DAPDATR1 |                                            |
| STEERADS   | 2CADR  | STEERING |                                            |
| .6SECT5    | OCT    | 37703    |                                            |
| 5SECDP     | DEC    | 0        | # MAKE DP 5SEC                             |
| 5SEC       | DEC    | 500      |                                            |
| OCT02202   | OCT    | 02202    | # BITS 2, 8, 11 FOR CHANNEL 12 TVC/OPTICS  |
|            | EBANK= | DAPDATR1 |                                            |
| TVCON2C    | 2CADR  | TVCDAPON |                                            |
| -1         |        |          |                                            |
|            | INHINT |          |                                            |
| TVCZAP     | CS     | OCT02202 | # DISABLE TVC AND OPT ERR CNTRLS, REENGAGE |
|            | EXTEND |          | # OPTICS DAC                               |



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```
WAND    CHAN12
CS      BIT1      # ENABLE T4RUPT OPTICS MONITOR .... PERMIT
TS      OPTIND    #          OPTICS-ZERO BUT NOT OPTICS-DRIVE
CAF     ZERO      # CLEAR NVWORD1 IN CASE CLOCKJOB WAITING
TS      NVWORD1
CS      BIT11     # CLEAR TIMRFLAG TO STOP CLOKTASK
MASK    FLAGWRD7
TS      FLAGWRD7
TC      Q
EBANK=  DAPDATR1
UPDATEVG STQ      BON
          QTEMP1
          XDELVFLG
          CALL40.8

SLOAD    BMN
          NBRCYCLS
          SETUP.9

# Page 700

VLOAD    VAD
          DELVSUM
          DELVREF
STORE    DELVSUMP
EXIT
CA       ONE
AD       NBRCYCLS
TS       NBRCYCLP

TC       PHASCHNG  # TYPE B RESTART RESTART BELOW AND 5.3 REREADACCS
OCT      10035

CA       NBRCYCLP
TS       NBRCYCLS
TC       INTPRET
VLOAD
          DELVSUMP
STORE    DELVSUM

CALL40.8  CALL
          S40.8
          GOTO
          QTEMP1

SETUP.9   BON      SLOAD
          FIRSTFLG
```

```

SURELY.9
NBRCYCLP
NORM    VXSC      # (NORM HANDLES ZERO PROPERLY)
        X1
        BDT
VSR*    VAD
        0 -14D,1
        VGTEMP
VSU
        DELVSUM
STORE   VGPREV
EXIT
CAF     PRI010
TC      FINDVAC
EBANK=  DAPDATR1
2CADR   S40.9

TC      2PHSCHNG
OCT     00051      # A, 1.5 = REDO40.9, PRIO 10
OCT     10035
TC      INTPRET
VLOAD
        RN        # ACTIVE VEHICLE RADIUS VECTOR AT T1
STOVL   RINIT

# Page 701
        VN        # ACTIVE VEHICLE VELOCITY VECTORY AT T1
STODL   VINIT
        PIPTIME
STORE   TNIT
BDSU
        TPASS4
STOVL   DELLT4
        HI6ZEROS
STODL   DELVSUM
        HI6ZEROS
STORE   NBRCYCLS
GOTO
        CALL40.8
EBANK=  DAPDATR1
TC      INTPRET
CALL
        UPDATEVG
EXIT
CAF     BIT9      # CHECK IMPULSW
MASK    FLAGWRD2
CCS     A

```

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```
SERVXT      TCF      +3          # PRE-IGNITE, REQUEST ENG-OFF, OR POST-OFF
             TC       POSTJUMP
             CADR     SERVEXIT
             CAF      BIT13      # CHECK ENGINE-ON/-OFF
             EXTEND
             RAND     DSALMOUT
             EXTEND
             BZF      SERVXT     # ENGINE-OFF, SO PRE-IGNITE OR POST-OFF
             TCR      E7SETTER
             EBANK=   TIG
             INHINT
             EXTEND
             DCA      TIG
             DXCH     MPAC
             EXTEND
             DCS      TIME2
             DAS      MPAC
             TCR      DPAGREE
             CAE      MPAC +1    # (LESS THAN 6 (OR 4) SECONDS TO GO)
             CCS      A          # PROTECT AGAINST NEG/ZRO W.L. CALL
             TCF      +3
             TCF      +2
             CAF      ZERO
             AD       ONE
             XCH      L
             CA       ZERO
             DXCH     TGO
             CA       TGO +1
             TC       WAITLIST

# Page 702   EBANK=   TGO
             2CADR    ENGINOFF

             TC       2PHSCHNG
             OCT      40153      # A, 3.15 = ENGINOFF (TGO+1) .... NOTE GROUP
             OCT      10035      # B, 5.3 = REREADAC, AND START BELOW
             TC       DOWNFLAG   # CLEAR IMPULSW, ENGINOFF IS NOW SET UP
             ADRES    IMPULSW    # RESTARTS OK
             TCF      SERVXT
```

# Page 703

# ROUTINE \*\* CLOKTASK \*\* DESCRIPTION

```
CLOKTASK     EBANK=   TIG
             CAF      BIT11      # IS TIMRFLAG SET
             MASK     FLAGWRD7
```

|            |        |          |                                            |
|------------|--------|----------|--------------------------------------------|
|            | CCS    | A        |                                            |
|            | TCF    | CLOCKON  |                                            |
|            | TC     | PHASCHNG |                                            |
|            | OCT    | 00006    | # KILL RESTART                             |
|            | TC     | TASKOVER |                                            |
| CLOCKON    | EXTEND |          |                                            |
|            | DCA    | TIME2    |                                            |
|            | DXCH   | TTOGO    |                                            |
|            | EXTEND |          |                                            |
|            | DCS    | TIG      |                                            |
|            | DAS    | TTOGO    |                                            |
| SETCLOCK   | CAF    | 1SEC     |                                            |
|            | TC     | WAITLIST |                                            |
|            | EBANK= | TIG      |                                            |
|            | 2CADR  | CLOKTASK |                                            |
|            | CCS    | NVWORD1  |                                            |
|            | TCF    | +3       |                                            |
|            | TCF    | SETTB6   |                                            |
|            | TCF    | +1       |                                            |
|            | CS     | V06N85B  | # CHECK FOR V06N85B (P41)                  |
|            | AD     | NVWORD1  |                                            |
|            | EXTEND |          |                                            |
|            | BZF    | SETUPDYN | # V06N85, SO UPDATE N85 FOR DYNAMIC DISP   |
|            | CAF    | PRI027   |                                            |
|            | TC     | NOVAC    |                                            |
|            | EBANK= | DAPDATR1 |                                            |
|            | 2CADR  | CLOCKJOB |                                            |
| SETTB6     | CS     | TIME1    | # SET GROUP6 TIMEBASE                      |
|            | TS     | TBASE6   |                                            |
|            | TCF    | TASKOVER |                                            |
| SETUPDYN   | CAF    | PRI027   | # SET UP A JOB TO UPDATE N85 (FOR P41=V06) |
|            | TC     | FINDVAC  |                                            |
|            | EBANK= | DAPDATR1 |                                            |
|            | 2CADR  | DYNDISP  |                                            |
|            | TCF    | SETTB6   | # CLOSE OUT CLOKCTASK                      |
| # Page 704 |        |          |                                            |
| DYNDISP    | TC     | INTPRET  | # UPDATE N85 FOR A DYNAMIC V06N85 IN P41.  |
|            | CALL   |          | # PRIOR TO BLANKING AND AVEG (V16N85)      |

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P40CNV85  
EXIT  
TCF CKNVWRD1

# Page 705

# ROUTINE \*\* CLOCKJOB \*\* DESCRIPTION

|          |        |          |                                            |
|----------|--------|----------|--------------------------------------------|
|          | EBANK= | DAPDATR1 |                                            |
| CLOCKJOB | CA     | CDUX     |                                            |
|          | TS     | CDUSPOTX |                                            |
|          | CA     | CDUY     |                                            |
|          | TS     | CDUSPOTY |                                            |
|          | CA     | CDUZ     |                                            |
|          | TS     | CDUSPOTZ |                                            |
|          | TC     | BANKCALL |                                            |
|          | CADR   | QUICTRIG |                                            |
| CKNVWRD1 | INHINT |          |                                            |
|          | CCS    | NVWORD1  | # DETERMINE FUNCTION, INDICATED BY NVWORD1 |
|          | TCF    | NOFLASH  |                                            |
|          | TCF    | ENDOFJOB |                                            |
|          | TCF    | ENGREQST | # SPS ENGINE-ON-ENABLE V99 FLASH           |
| FAILDSP  | CAF    | V06N40   | # SPS ENGINE-FAILED V97 FLASH              |
|          | TC     | BANKCALL |                                            |
|          | CADR   | CLOCPLAY |                                            |
|          | TCF    | V97T     | # TERMINATE                                |
|          | TCF    | V97P     | # PROCEED                                  |
|          | TCF    | V97E     | # ENTER                                    |
| ENGREQST | CAF    | V06N40   |                                            |
|          | TC     | BANKCALL |                                            |
|          | CADR   | CLOCPLAY | # LINUS MAKES IT A REDO, INHINT OK         |
|          | TCF    | V99T     | # TERMINATE                                |
|          | TCF    | V99P     | # PROCEED                                  |
|          | TCF    | V99E     | # ENTER                                    |
| NOFLASH  | CAE    | NVWORD1  | # DISPLAY NVWORD1 NORMALLY                 |
|          | TC     | BANKCALL |                                            |
|          | CADR   | REGODSP  |                                            |
| E7SETTER | CAF    | EBANK7   |                                            |
|          | TS     | EBANK    |                                            |
|          | EBANK= | TIG      |                                            |
|          | TC     | Q        |                                            |
| E6SETTER | CAF    | EBANK6   | # SET UP EBANK6                            |
|          | TS     | EBANK    |                                            |

|            |        |           |                                          |
|------------|--------|-----------|------------------------------------------|
|            | EBANK= | DAPDATR1  |                                          |
|            | TC     | Q         |                                          |
| V99E       | EBANK= | DAPDATR1  |                                          |
|            | TC     | 2PHSCHNG  |                                          |
|            | OCT    | 00006     | # KILL PRE40.6/CLOKTASK PROTECTION       |
|            | OCT    | 05024     | # C, PRIORITY NEXT, JOB BELOW            |
| # Page 706 |        |           |                                          |
|            | OCT    | 27000     |                                          |
| V99EJOB    | TCR    | TVCZAP -1 | # WIPE OUT TVC, CLOKTASK                 |
|            | TCF    | P40RCS    | # V16N85 POST-BURN OPERATIONS            |
|            | EBANK= | DAPDATR1  |                                          |
| V99T       | TC     | 2PHSCHNG  | # (ENTRY FROM V97T FLOW TOO)             |
|            | OCT    | 00006     | # KILL PRE40.6/CLOKTASK PROTECTION       |
|            | OCT    | 05024     | # C, PRIORITY NEXT, JOB BELOW            |
|            | OCT    | 27000     |                                          |
| V99TJOB    | TCR    | TVCZAP -1 | # WIPE OUT TVC, CLOKTASK                 |
|            | TCF    | POST41    | # AVEGEXIT, SETMAXDB, GOTOPOOH           |
| V99P       | INHINT |           |                                          |
|            | CAE    | FLAGWRD7  | # CHECK ASTN FLAG FOR PRIOR V99P         |
|            | MASK   | BIT12     |                                          |
|            | CCS    | A         |                                          |
|            | TCF    | V99P/TIG  | # YES, THIS MUST BE A RESTART ENTRY      |
| ASTNV99P   | CAF    | BIT12     | # SET ASTN FLAG                          |
|            | ADS    | FLAGWRD7  |                                          |
|            | CAE    | FLAGWRD7  | # CHECK IGN FLAG FOR TIG-0 ARRIVAL       |
|            | MASK   | BIT13     |                                          |
|            | EXTEND |           |                                          |
|            | BZF    | V99P/TIG  | # NO, CLEAR THE V99 AND WAIT FOR TIG-0   |
| ENDV99PI   | CAF    | BIT1      | # TIG-0 HAS COME ALREADY                 |
|            | TC     | WAITLIST  | # SET UP IGNITION HERE                   |
|            | EBANK= | DAPDATR1  |                                          |
|            | 2CADR  | IGNITION  |                                          |
| V99P/TIG   | CAF    | V06N40    | # CLEAR THE V99 FLASH AND WAIT FOR TIG-0 |
|            | TS     | NVWORD1   |                                          |
| ENDV99P    | TCF    | ENDOFJOB  |                                          |
|            | EBANK= | CSMMASS   |                                          |
| V97T       | TC     | 2PHSCHNG  |                                          |
|            | OCT    | 00006     | # KILL GROUP 6 (CLOKTASK)                |
|            | OCT    | 40674     | # A, 4.67 = V97TTASK (-0 CS), TBASE NOW  |

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```
CAF      BIT1
TC       TWIDDLE
ADRES    V97TTASK      # KEEP EBANK6 FOR MASSES, SPSOFF, ETC.
TCF      ENDOFJOB

EBANK=   CSMMASS
V97TTASK CAF      ZERO      # DISABLE CLOCKJOB
TS       NVWORD1
CAF      3MDOT          # 3 SECONDS OF MDOT (2-4 SEC ENGFALL
AD        CSMMASS      #      DETECTION) NOT LOST BECAUSE THRUST
TS        MASSTMP      #      FAILED.  COPYCYCLE FOR MASSBACK

# Page 707
TC        PHASCHNG
OCT       05014         # C, DELTAT NEXT, TASK BELOW, IN
DEC       -0           # -0 CS

TCR       SPSOFF        # SHUTDOWN SPS ENGINE, MASS UPDATE, ETC.
TC        PHASCHNG
OCT       00714         # A, 4.71 = V97TRCS (250 CS), TBASE OLD
TC        FIXDELAY      # DELAY 2.5 SECONDS FOR (POSSIBLE) TAIL-
DEC       250          #      OFF (FALSE THRUST-LOSS)

EBANK=   DAPDATR1
V97TRCS  TC        IBNKCALL # RCS DAP IN 0.6SEC, SETTING T5 BITS TO
CADR      RCSDAPON      #      KILL TVCEXEC/TVROLLDAP STARTS
CAF       PRI027         # SET UP V99T FOR TVCZAP AND POST41 (SET-
TC        NOVAC          #      MAXDB AND GOTOPOOH)
EBANK=   DAPDATR1      # EBANK6 FOR SETMAXDB IN POST41
2CADR    V99T

ENDV97T  TCF       TASKOVER

EBANK=   V97VCNTR
V97P     TC        PHASCHNG
OCT       40734         # A, 4.73 = V97PTASK (-0 CS), TBASE NOW
CAF       BIT1
TC        TWIDDLE
ADRES    V97PTASK
TCF      ENDOFJOB

EBANK=   V97VCNTR
V97PTASK CAE       V97VCNTR # GET MASS UPDATES (TVCEXEC) GOING AGAIN
TS        VCNTR         #      (ERRORS IF FLASE THRUST-LOSS AND/OR
                        #      POOR SYNC OF MANUAL ENGINE-ON AND
                        #      THE VERB 97 PROCEED)
CAF       V06N40        # REDISPLAY V06N40
```

|            |        |          |                                          |
|------------|--------|----------|------------------------------------------|
|            | TS     | NVWORD1  |                                          |
|            | TC     | UPFLAG   | # SET IDLEFAIL TO ALLOW R41-BYPASS, IN   |
|            | ADRES  | IDLEFAIL | # CASE OF UNFAVORABLE S40.8 SYNCH        |
|            | TC     | UPFLAG   | # SET STEERSW TO RE-ENABLE STEERING      |
|            | ADRES  | STEERSW  |                                          |
|            | TC     | PHASCHNG |                                          |
|            | OCT    | 00134    | # A, 4.13 = R40ENABL (200 CS), TBASE OLD |
|            | TC     | FIXDELAY | # WAIT 2 SECONDS, THEN                   |
|            | DEC    | 200      |                                          |
|            | EBANK= | WHOCARES |                                          |
| R40ENABL   | TC     | DOWNFLAG | # RE-ENABLE R40 BY CLEARING IDLEFAIL     |
|            | ADRES  | IDLEFAIL |                                          |
|            | TC     | PHASCHNG |                                          |
|            | OCT    | 00004    | # KILL GROUP 4                           |
| # Page 708 |        |          |                                          |
| ENDV97P    | TCF    | TASKOVER |                                          |
|            | EBANK= | WHOCARES |                                          |
| V97E       | TC     | PHASCHNG |                                          |
|            | OCT    | 40534    | # A, 4.53 = V97ETASK (-0 CS), TBASE NOW  |
|            | CAF    | BIT1     |                                          |
|            | TC     | WAITLIST |                                          |
|            | EBANK= | TIG      |                                          |
|            | 2CADR  | V97ETASK |                                          |
|            | TCF    | ENDOFJOB |                                          |
|            | EBANK= | TIG      |                                          |
| V97ETASK   | CS     | OCT24    | # FORCE R1 OF V06N40 TO READ 59X59       |
|            | TS     | TIG      |                                          |
|            | CAF    | V06N40   | # REDISPLAY V06N40                       |
|            | TS     | NVWORD1  |                                          |
|            | TCR    | E6SETTER | # RETURN TO EBANK6 FOR REST OF V97ETASK  |
|            | EBANK= | CSMMASS  |                                          |
|            | CAF    | 3MDOT    | # 3 SECONDS OF MDOT (2-4 SEC ENGFAIL     |
|            | AD     | CSMMASS  | # DETECTION) NOT LOST BECAUSE THRUST     |
|            | TS     | MASSTMP  | # FAILED....COPYCYCLE FOR MASSBACK       |
|            | TC     | PHASCHNG |                                          |
|            | OCT    | 00754    | # A, 4.75 = SPSOFF97 (-0 CS), TBASE OLD  |
| SPSOFF97   | TCR    | SPSOFF   |                                          |
|            | TC     | PHASCHNG |                                          |
|            | OCT    | 00114    | # A, 4.11 = V97E40.6 (250 CS), TBASE OLD |
|            | TC     | FIXDELAY | # DELAY 2.5 SECONDS FOR (POSSIBLE) TAIL- |
|            | DEC    | 250      | # OFF (FALSE THRUST-LOSS)                |



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```
V97E40.6      EBANK= DAPDATR1
               CAF      BIT1
               TC        WAITLIST
               EBANK= CNTR
               2CADR     PRE40.6      # USE S40.6 RESTART ENTRY TO TRIM ENGINE

               TC        IBNKCALL     # RCS DAP IN 0.6SEC, SETTING T5 BITS TO
               CADR      RCSDAPON     #      KILL TVCEXEC/TVCROLLDAP STARTS.
                                   #      LEAVE NARROW DEADBAND FOR REIGNITE.

               TC        2PHSCHNG
               OCT       00026        # A, 6.2 = PRE40.6 (-0 CS), CLOKTASK (1 SEC)
               OCT       05014        # C, DELTAT NEXT, TASK BELOW, IN
               DEC       -0           # -0 CS.

QUICKIGN       CS        PRI014      # CLEAR ASTNFLAG AND SET IGNFLAG FOR
               MASK      FLAGWRD7    #      IMMEDIATE V99 RESPONSE.
               AD        BIT13
               TS        FLAGWRD7
               TC        FIXDELAY     # DELAY TO ALLOW TIME FOR PRE40.6
# Page 709
               DEC       30

V99FLASH       CS        BIT9        # CAUSE V99 TO FLASH
               TS        NVWORD1
               TC        2PHSCHNG
               OCT       40774        # A, 4.77 = TIG-0 (-0 CS) TBASE FOR PREPTVC
               OCT       00033        # A, 3.3 = S40.13 (PRIO 20)
               CAF       PRI020      # SET UP TIMEBURN
               TC        FINDVAC
               EBANK=    TGO
               2CADR     S40.13

ENDV97E        TCF       TASKOVER    # WAIT FOR CLOCKJOB (IMMEDIATE) REACTION
                                   #      TO FLASHING V99 RESPONSE.

# MOD NO2
# MOD BY ZELDIN
#
# FUNCTIONAL DESCRIPTION
#      COMPUTE INITIAL THRUST DIRECTION(UT) AND INITIAL VALUE OF VG
#      VECTOR(VGTIG).
#
# CALLING SEQUENCE
#      L      CALL
#      L+1    S40.1

LOG SECTION P40-P47
```

```

#
# NORMAL EXIT MODE
#       AT L+2 OF CALLING SEQUENCE (GOTO L+2) NORMAL RETURN OR
#       ERROR RETURN IF NOSOFLAG =1
#
# SUBROUTINES CALLED
#       CSMPREC
#       INITVEL
#       CALCGRAV
#       MIDGIM
#
# ALARM OR ABORT EXIT MODES
#       L+2 OF CALLING SEQUENCE, UNSOLVABLE CONIC IF NOSOFLAG=1
#
# ERASABLE INITIALIZATION REQUIRED
#       WEIGHT/G           ANTICIPATED VEHICLE MASS           SP B16 KGM
#       XDELVFLG           1=DELTA-V MANEUVER, 0=AIMPT STEER
#       IF DELTA-V MANEUVER:
#           DELVSIN         SPECIFIED DELTA-V REQUIRED IN
#                           INERTIAL COORDS. OF ACTIVE VEHICLE
#                           AT TIME OF IGNITION                 VECTOR B7 M/CS
#           DELVSAB         MAG. OF DELVSIN                     DP B7 M/CS
#           RTIG            POSITION AT TIME OF IGNITION         VECTOR B29 M
#           VTIG            VELOCITY AT TIME OF IGNITION        VECTOR B7 M/CS.
#           CSTEER = 0   DP
#       IF AIMPOINT STEERING:
#       IF AIMPT STEER
#           TIG             TIME OF IGNITION                     DP B28 CS
#           RTARG           POSITION TARGET TIME                 VECTOR B29 M
#           CSTEER = ECSTEER (GR 0)                             DP B1
# Page 710
#       TPASS4 -- TIME OF ARRIVAL AT AIMPOINT
#
# OUTPUT
#       UT                 1/2 UNIT VECTOR ALIGNED WITH THRUST DIRECTION IN REF COOR
#       VGTIG              INITIAL VALUE OF VELOCITY
#                           TO BE GAINED (INERT. COORD.)         VECTOR B7 M/CS
#       DELVLVC            VGTIG IN LOC. VERT. COORDS.          B7 M/CS
#       F                  NOMINAL THRUST FOR ENG USED FOR S40.13 DP B7 M-NEWT
#       BDT                V REQUIRED AT TIG -V REQUIRED AT (TIG-2SEC)
#       -GDT               FOR S40.13                           VECT B7 M/CS
#       RTIG               CALC IN S40.1B (AIMPT) FOR S40.2,3    VECTOR B29M
#                           POSITION AT TIME OF IGNITION
#
# DEBRIS                  QTEMP1
#                           MPAC, QPRET

```

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```
#          PUSHLIST
#          RTX2,RTX1

          BANK    14
          SETLOC  P40S1
          BANK

          COUNT   16/S40.1

S40.1     SET     VLOAD
          FIRSTFLG
          LO6ZEROS
          STORE   BDT
          STQ     BOF
          QTEMP
          XDELVFLG
          S40.1B      # LAMBERT
          VLOAD   ABVAL  # EXTERNAL DELTA-V
          DELVSIN
          STORE   DELVSAB # COMPUTE FOR P30/P40 INTERFACE
          #       #       #       #       #       #       #       #
          SETPD   VLOAD
          0
          VTIG
          STORE   VINIT
          VXV     UNIT
          RTIG
          STOVL   UT      # UP IN UT
          RTIG
          STORE   RINIT
          VSQ     PDDL
          36D
          DMPR    DDV
          THETACON
          DMP      DMP
          DELVSAB
          WEIGHT/G
          DDV

# Page 711

          F
          STOVL   14D
          DELVSIN

          DOT     VXSC
          UT
          UT
```

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```

                                VSL2  PUSH      # (DELTA V.UP)UP SCALED AT 2(+7) P.D.L.  0
                                BVSU   PDDL      # DELTA VP SCALED AT 2(+7) P.D.L.  6
                                DELVSIN
                                14D
                                SIN     PDVL
                                6D
                                VXV     UNIT
                                UT
                                VXSC    STADR
                                STOVL   VGTIG    # UNIT(VP X UP)SIN(THETAT/2) IN VGTIG.
                                UNIT     PDDL      # UNIT(DELTA VP) IN P.D.L.  6
                                14D
                                COS      VXSC
                                VAD      VXSC
                                VGTIG
                                36D
                                VSL2    VAD
                                STADR
                                STORE    VGTIG    # VG IGNITION SCALED AT 2(+7) M/CS
                                UNIT
                                STOVL    UT        # THRUST DIRECTION SCALED AT 2(+1)
                                VGTIG
                                PUSH     SET
                                AVFLAG
                                CALL
                                MIDGIM    # VGTIG IN LV COOR AT 2(+7)M/CS IN DELVLVC
                                GOTO
                                QTEMP
                                S40.1B  DLOAD    DSU      # LAMBERT
                                TIG
                                TWODT
                                STODL    TDEC1
                                TPASS4
                                DSU
                                TDEC1
                                STCALL    DELLT4
                                AGAIN
                                VLOAD
                                VIPRIME
                                STODL    UT
                                TIG
                                STORE    TDEC1
                                BDSU
                                TPASS4

# Page 712
```

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|          |        |                                 |
|----------|--------|---------------------------------|
|          | STCALL | DELLT4<br>AGAIN                 |
|          | VLOAD  | PUSH<br>DELVEET3                |
|          | STORE  | VGTTG                           |
|          | SET    | CALL<br>AVFLAG<br>MIDGIM        |
|          | SETPD  | GOTO<br>0<br>CALCUT             |
| THETACON | 2DEC   | .31830989 B-8                   |
|          | SETLOC | P40S3                           |
|          | BANK   |                                 |
|          | COUNT  | 24/S40.1                        |
| EP4(45)H | 2DEC   | .125                            |
| EP4(10)H | 2DEC   | .027777777                      |
| AGAIN    | STQ    | CALL<br>QTEMP1<br>THISPREC      |
|          | SXA,2  | SXA,1<br>RTX2<br>RTX1           |
|          | VLOAD  |                                 |
|          |        | RATT                            |
|          | STORE  | RTIG                            |
|          | STOVL  | RINIT<br>VATT                   |
|          | STORE  | VTIG                            |
|          | STORE  | VINIT                           |
|          | SETPD  | SLOAD<br>0<br>HI6ZEROS          |
|          | PDDL   | BON<br>EP4(45)H<br>NORMSW<br>+3 |
|          | DLOAD  |                                 |
|          |        | EP4(10)H                        |
|          | PUSH   | CALL                            |

```

INITVEL
SETPD GOTO
# Page 713
0
QTEMP1
CALCUT VLOAD CALL
RTIG
CALCGRAV # GDELTAT IN MPAC AT 2(+7) M/CS
VSL1 V/SC
200CS # G AT 2(-5) M/CS. CS
PDVL VSU
VIPRIME
UT
V/SC VSU
200CS
VXSC VSL2
CSTEER
STOVL 12D # B.C SCALED AT 2(-15) PDL 12D
VGTIG
UNIT PUSH # UG PDL 0 SCALED AT 2(+1)
DOT VXSC
12D
0
VSL2 BVSU
12D
STODL 12D # Q PDL SCALED AT 2(-5)
F
SRR DDV
4
WEIGHT/G
DSQ PDVL # F/MASS SQUARED PDL 6 AT 2(-10M/(CS.CS))
12D
VSQ
BDSU SQRT
VXSC VSL1
VAD UNIT
12D
STCALL UT
QTEMP
200CS 2DEC 200 B-12

```

# Page 714

# PROGRAM DESCRIPTION S40.2,3

# MOD NO 2

# MOD BY ZELDIN

DATE 15 NOV 66

LOG SECTIONS P40-P47

```

#
# FUNCTIONAL DESCRIPTION
#
#     COMPUTE GIMBAL ANGLES IF THRUSTING OCCURRED WITH PRESENT IMU
#     ORIENTATION, WINGS LEVEL SPACECRAFT, HEADS UP
#     COMPUTE X AXIS OF ENGINE BELL
#     COMPUTE PREFERRED IMU ORIENTATION (XSCREF)
#     FOR THIS CALCULATION, ASSUME X AXIS OF SC ALONG UT INITIALLY,
#     YSC=UNIT(XXR), ZSC=UNIT(XX(XXR)) AND ROTATE ENGINE BELL ALONG UT.
#     NEW SC AXES WILL BE APPROX. WINGS LEVEL AND NEW SC AXES IN REF.
#     COORDS. WILL BE PREFERRED IMU ORIENTATION.
#     COMPUTE DESIRED THRUST DIRECTION IN SM COORDS.
#
# CALLING SEQUENCE
#     L      CALL
#     L+1      S40.2,3
#
# NORMAL EXIT MODE
#     AT L+2 OF CALLING SEQUENCE (GOTO L+2)
#
# SUBROUTINES CALLED
#     CALCGA
#
# ALARM OR ABORT MODES
#     NONE
#
# ERASABLE INITIALIZATION REQUIRED
#     PACTOFF      TOTAL PITCH TRIM ANGLE      SP AT 1.0795111 REV.
#     YACTOFF      TOTAL YAW TRIM ANGLE      SP AT 1.0795111 REV.
#     UT           DESIRED THRUST DIRECTION    VECT. B2 M/(CS.CS)
#     RTIG         POSITION AT TIME OF IGNITION VECT. B29 M
#     ENG2FLAG     ON=RCS OFF=SPS
#
# OUTPUT
#     SCAXIS      UNIT VECT. ALIGNED WITH ENG BELL IN SC COOR.    B1
#     XSCREF      UNIT VECTORS ALIGNED WTH PREFERRED IMU        B1
#     YSCREF
#     ZSCREF
#     GIMBAL ANGLES IN THETAD
#     POINTVSM    UNIT VECT ALONG DESIRED THRUST DIRECTION IN SM  B1
#
# DEBRIS
#     PUSHLIST, QPRET, MPAC
#     QTEMP      TEMP. ERASABLE

```

```

S40.2,3      SETLOC  P40S
              BANK
              COUNT*  $$/S40.2
              VLOAD   MXV
                      UT
                      REFSMMAT
              VSL1    STQ
                      QTEMP
              STORE   POINTVSM      # THRUST IN SM AT 2
              SETPD   BON
                      0
# Page 715
              ENG2FLAG
              S40.2,3B
              DLOAD
              HI6ZEROS
              PUSH    SLOAD          # ZERO PDL 0
                      YACTOFF
              DMP     SL1
                      TRIMSCAL
              DAD     PUSH
                      YBIAS
              COS     PDDL           # COS(Y +Y0) PDL 2
              SIN     PUSH          # SIN(Y +Y0) PDL 4
              SLOAD
                      PACTOFF
              DMP     SL1
                      TRIMSCAL
              DAD     PUSH
                      PBIAS
              COS     PDDL           # COS(P +P0) PDL 6
              SIN     PUSH          # SIN(P +P0) PDL 8D
              STODL   ZSCREF        # SIN(P +P0)
                      6
              DMP     SL1
                      4
              DCOMP   PDDL          # -SIN(Y+Y0)COS(P+P0) PDL 10
                      6
              DMP     SL1
                      2
              VDEF
              STODL   XSCREF        # PD POINTER AT 6 NEW SC X AXIS SCALED AT
                      ZSCREF
              DMP     SL1
                      4

```



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# Page 716

S40.2,3B

|       |         |                                             |
|-------|---------|---------------------------------------------|
| PDDL  | DMP     |                                             |
|       | ZSCREF  |                                             |
|       | 2       |                                             |
| SL1   | DCOMP   |                                             |
| VDEF  |         |                                             |
| STODL | ZSCREF  | # PD POINTER AT 4 NEW SC Z AXIS SCALED AT 2 |
| VDEF  |         |                                             |
| STODL | YSCREF  | # PD POINTER AT 0 NEW SC Y AXIS SCALED AT 2 |
|       | ZSCREF  |                                             |
| PDDL  | PDDL    |                                             |
|       | YSCREF  |                                             |
|       | XSCREF  |                                             |
| VDEF  |         |                                             |
| STOVL | SCAXIS  | # ENGINE BELL SCALED AT 2                   |
|       | UT      |                                             |
| PDVL  | UNIT    |                                             |
|       | RTIG    |                                             |
| VXV   | VCOMP   |                                             |
|       | 0       |                                             |
| UNIT  | PUSH    |                                             |
| CALL  |         |                                             |
|       | TSTRXUT |                                             |
| VXV   | VCOMP   |                                             |
|       | 0       |                                             |
| VSL1  | PDVL    | # 2 RF/SC IN PDL 12D                        |
|       | XSCREF  |                                             |
| VXM   | VSL1    |                                             |
|       | 0       |                                             |
| STOVL | XSCREF  | # X OF PREF. IMU,X OF SC IN REF COOR. AT 2  |
|       | YSCREF  |                                             |
| VXM   | VSL1    |                                             |
|       | 0       |                                             |
| STOVL | YSCREF  | # Y OF PREF. IMU,Y OF SC IN REF COOR. AT 2  |
|       | ZSCREF  |                                             |
| VXM   | VSL1    |                                             |
|       | 0       |                                             |
| STORE | ZSCREF  | # Z OF PREF. IMU,Z OF SC IN REF COOR. AT 2  |
| SETPD | GOTO    |                                             |
|       | 0       |                                             |
|       | QTEMP   |                                             |
| VLOAD |         |                                             |
|       | UNITX   |                                             |
| STOVL | SCAXIS  |                                             |

```

                                UT
                                XSCREF
                                UNIT
                                RTIG
                                6D
                                TSTRXUT
                                YSCREF
                                VCOMP
                                XSCREF
                                VSL1
                                STCALL ZSCREF          # ZNB AXIS IN REF COOR
                                QTEMP
TSTRXUT                        DLOAD BHIZ
                                36D
                                BADVCTOR
                                VLOAD RVQ
                                6D
BADVCTOR                      VLOAD UNIT
                                RTIG
                                PDVL  UNIT
# Page 717
                                VTIG
                                VSR3  VAD
                                VXV    UNIT
                                UT
                                VCOMP
                                STORE  6D
                                RVQ
TRIMSCAL                      2DEC  1.07975111 B-1
YBIAS                         2DEC  +.00263888889  # YAW  MECH BIAS (+0.95 DEG, THRUST ON)
PBIAS                         2DEC  -.00597222222  # PITCH MECH BIAS (-2.15 DEG, THRUST ON)
                                # REFERENCE, TRW 68.6520.3.3-40 27 FEB, 1968
# PROGRAM DESCRIPTION S41.1      DATE 8 DEC 66
# MOD NO 1                      LOG SECTION P40-P47
# MOD BY ZELDIN
#
# FUNCTIONAL DESCRIPTION
#
#      COMPUTE VELOCITY TO BE GAINED INITIALLY IN REF COORDS.
#      TO CONTROL COORDS.
#
# CALLING SEQUENCE

```

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```
#
#      L      CALL
#      L+1      S41.1
#
# NORMAL EXIT MODE
#
#      AT L +2 OF CALLING SEQUENCE
#
# SUBROUTINES CALLED:
#
#      CALCSMSC
#      CDUTRIG
#
# ALARM OR ABORT MODES
#
#      NONE
#
# ERASABLE INITIALIZATION REQUIRED
#
#      VG IN REF. COORD. PDL L POINTER AT L+5.  S41.1 WILL RETURN WITH
#      POINTER AT L (L MUST BE LESS THAN OR = TO 14D)
#
# OUTPUT
#
#      MPAC CONTAINS VG IN CONTROL COORDS          VECT. B7 M/CS
#
# DEBRIS:
#
#      QTEMP      TEMP ERASABLE
#      QPRET
#
#      COUNT      22/S41.1
#
#      SETLOC      P40S5
#      BANK
#
S41.1      STQ      CALL
#           QTEMP
#           CDUTRIG
#
#           VLOAD
#           MXV      CALL
#                   REFSMMAT
#                   *SMNB*
#
# Page 718
#           MXV      VXSC
#                   QUADROT
```

```

TENBNK14      # VG IN CONTROL COORD IN MPAC SCALED AT
VSL5      GOTO      # VG IN CONTROL COORDS. IN MPAC AT 2(+7)
            QTEMP
TENBNK14      2DEC    10. B-4

# Page 719
# NAME      S40.8 -- CROSS PRODUCT STEERING
# FUNCTION  (1) UPDATES THE VELOCITY-TO-BE-GAINED VECTOR.
#           (2) GENERATES ANGULAR RATE STEERING COMMANDS FOR AUTOPILOT.
#           (3) ESTABLISHES ENGINE CUT-OFF SIGNALS AT APPROPRIATE TIMES.
#           (4) INITIATES THRUST-FAIL ROUTINE, R40
# CALLING SEQ CALL S40.6
# INPUT      VGPREV      LAST VALUE OF THE VELOCITY-TO-BE-GAINED VECTOR
#           PRIOR TO UPDATING IN METERS/CS AT +7.
#           DELVREF      CHANGE IN VEHICLE VELOCITY SINCE LAST MEASUREMENT
#           IN METERS/CS AT +7.
#           BDT          EFFECT OF RATE OF CHANGE OF REQUIRED VELOCITY AND
#           GRAVITY DURING DT UPON VELOCITY-TO-BE-GAINED IN
#           METERS/CS AT +7.
#           CSTEER      A SCALAR OF THE STEERING LAW, SC.AT B+1, USED FOR
#           SPS AIMPOINT STEERING MANEUVERS.
#           IDLEFAIL    A FLAG TO INHIBIT (IDLE) THE THRUST-FAIL ROUTINE.
#           STEERSW      A SWITCH TO PRECLUDE NEEDLESS CONDUCT OF STEERING.
#           REFSMMAT, DAPDATR1, PIPTIME
#           EREPFRAC, ETDECAY, KPRIMEDT FOR TVC.
# OUTPUT      TTOGO      TIME REMAINING FOR ENGINE BURN IN CS AT +28.
#           OMEGAC      DP VECTOR RATE COMMAND, SC.AT 1/(2TVCDT) REVS/SEC.
#           VG, VGPREV, VGDISP, TGO, TIG, SCALED AS NOTED IN CODING
#           STEERSW, IMPULSW, NVWORD1
#           REPFRAC, CNTR, VCNTR, VCNTRTMP FOR TVC (R40 INTERFACING)
# DEBRIS      OMEGAXC, +1
# SUBROUTINES USED: *SMNB*, ALARM

SETLOC  P40S1
BANK
EBANK=  DAPDATR1
COUNT  16/S40.8

S40.8      SETPD  STQ
SPBIT1      OOD
            QTEMP
VLOAD      BVSU      # CONSTRUCT DELVG, SC.AT B+7 M/CS
            DELVREF
            BDT
VAD
            VGPREV

```

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# Page 720

TGOCALC

|       |           |                                                 |
|-------|-----------|-------------------------------------------------|
| STORE | VG        | # VELOCITY-TO-BE-GAINED, SC.AT B+7 M/CS         |
| ABVAL |           |                                                 |
| STORE | VGDISP    | # FOR DISPLAY PURPOSES                          |
| EXIT  |           |                                                 |
| TC    | PHASCHNG  |                                                 |
| OCT   | 10035     | # TYPE B RESTART RESTART BELOW AND 5.3 REREADAC |
| TC    | INTPRET   |                                                 |
| VLOAD |           |                                                 |
|       | VG        |                                                 |
| STORE | VGPREV    |                                                 |
| BOFF  | VLOAD     |                                                 |
|       | STEERSW   | # SKIP TGO AND CROSS-PRODUCT                    |
|       | QTEMP     |                                                 |
|       | DELVREF   |                                                 |
| ABVAL | PUSH      | # CHECK FOR LOTHRUST                            |
| SLOAD | DMP       |                                                 |
|       | DVTHRESH  | # SC.AT B-2 M/CS                                |
|       | DPB-9     |                                                 |
| BDSU  |           |                                                 |
| BMN   | EXIT      |                                                 |
|       | LOTHRUST  |                                                 |
| CAE   | DAPDATR1  | # ENABLE TVCDAP CG TRACKING                     |
| MASK  | BIT14     |                                                 |
| CCS   | A         |                                                 |
| CAF   | BIT1      |                                                 |
| INDEX | A         | # LM-OFF, LM-ON VALUE                           |
| CAE   | EREPPFRAC |                                                 |
| TS    | REPFRAC   |                                                 |
| TC    | INTPRET   |                                                 |
| VLOAD | BVSU      | # GET DELVG                                     |
|       | DELVREF   |                                                 |
|       | BDT       |                                                 |
| UNIT  |           |                                                 |
| DOT   | PUSH      | # (OOD)                                         |
|       | VG        |                                                 |
| BPL   | DDV       | # ANGLE SHOULD BE GREATER THAN PI/2             |
|       | INCRSVG   | # DISPLAY ALARM IF NOT                          |
|       | 2VEXHUST  |                                                 |
| DAD   | DMP       | # (DOT PRODUCT UP FROM OOD)                     |
|       | LODPHALF  |                                                 |
| NORM  | SR1       |                                                 |
|       | X1        |                                                 |

```

PDDL  NORM
      36D      # (MAG DELVG)
      X2

BDDV
XSU,2  SL*
      X1
      0 -9D,2
DMP    PUSH      # (OOD)
      -FOURDT

SLOAD  SR
      ETDECAY    # ETDECAY SC.AT B+14 CS
      14D

BDSU   STADR
STORE  TGO      # TIME TO GO IN CS. AT +28
DAD

# Page 721

      PIPTIME
STODL  TIG
      TGO
DSU    BMN
      FOURSEC
      S40.81

XPRODUCT  VLOAD  VXSC
          BDT
          CSTEER
VSL2     VSU
          DELVREF
UNIT     PDVL
          VG
UNIT     VXV
MXV      CALL
          REFSMMAT      # (REFSMMAT/2)
          *SMNB*

          VXSC
          KPRIMEDT      # (KPRIMEDT SCIAT PI/8 RAD)
OMEGACLC STORE  OMEGAC
          GOTO
          QTEMP

          SETLOC  DAPS7
          BANK
COUNT  17/S40.8

TWODT   2DEC    200.0 B-28      # 2 SEC

```

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|            |        |               |                                            |
|------------|--------|---------------|--------------------------------------------|
| -FOURDT    | 2DEC   | -800 B-18     | # -4(200CS), SC.AT B+18CS (-4 FOR SCALING) |
| 2VEXHUST   | 2DEC   | 63.020792 B-7 | # 2(10338.0564 FPS), SC.AT B+7 M/CS        |
| FOURSEC    | 2DEC   | 400.0 B-28    | # 4 SEC                                    |
| DPB-9      | 2DEC   | 1 B-9         |                                            |
|            | SETLOC | DAPS6         |                                            |
|            | BANK   |               |                                            |
|            | COUNT  | 20/S40.8      |                                            |
| S40.81     | SET    | VLOAD         | # TGO LESS THAN 4 SECONDS                  |
|            |        | IMPULSW       | # FOR ENGINE-OFF CALL                      |
|            |        | HI6ZEROS      |                                            |
| RATEZRO    | STORE  | OMEGAC        | # TVC TO ATTITUDE HOLD                     |
|            | EXIT   |               |                                            |
|            | CAF    | POSMAX        | # INHIBIT SWITCHOVER/TVC EG TRACKING       |
|            | TS     | CNTR          |                                            |
| # Page 722 |        |               |                                            |
|            | TC     | INTPRET       |                                            |
|            | CLEAR  | GOTO          |                                            |
|            |        | STEERSW       | # RESTARTS OK                              |
|            |        | QTEMP         |                                            |
| INCRSVG    | EXIT   |               | # ALARM INDICATING THAT THRUST IS POINTING |
|            | TC     | ALARM         | # IN WRONG DIRECTION.                      |
|            | OCT    | 01407         |                                            |
|            | TC     | INTPRET       |                                            |
|            | GOTO   |               |                                            |
|            |        | QTEMP         |                                            |
| LOTHRUST   | BON    | VLOAD         | # THRUST FAILURE (LO-OR-NO) INDICATED      |
|            |        | IDLEFAIL      | # SET BY V97P. ALLOWS 1 BYPASS IN CASE OF  |
|            |        | QTEMP         | # UNFAVORABLE S40.8 SYNCH.                 |
|            |        | HI6ZEROS      | # START OF ENGINE-FAIL (R40) OPERATIONS    |
|            | STORE  | OMEGAC        | # PUT TVC IN ATTITUDE HOLD                 |
|            | EXIT   |               |                                            |
|            | CS     | ZERO          |                                            |
|            | TS     | VCNTR         | # KILL CSMMASS UPDATING                    |
|            | TS     | VCNTRTMP      | # (TVCEXEC LOGIC REQUIRES THIS TOO)        |
|            | TS     | REPFRAC       | # KILL TVCDAP CG TRIM TRACKING             |
|            | TS     | NVWORD1       | # SET UP ENGINE-FAIL V97FLASH (CLOCKJOB)   |
|            | TC     | INTPRET       |                                            |

```

CLEAR  GOTO          # INHIBIT STEERING AND TGO CALC (MANUAL
STEERSW          #      SHUTDOWN IF NOT SET UP AGAIN)
QTEMP          # RESTARTS OK

```

```
# Page 723
```

```

# NAME          S40.9 -- VTOGAIN (AIMPOINT MANEUVERS ONLY)
# FUNCTION      (1) GENERATES REQUIRED VELOCITY AND VELOCITY-TO-BE-GAINED
#               VECTORS FOR USE DURING AIMPOINT MANEUVERS.
#               (2) UPDATES THE B VECTOR WHICH IS USED IN THE FINAL
#               CALCULATION OF EXTRAPOLATING THE VELOCITY-TO-BE-GAINED.
# CALLING SEQ   VIA FINDVEC AS NEW JOB.
# INPUT         RNIT  ACTIVE VEHICLE RADIUS VECTOR IN METERS AT +29.
#               VNIT  ACTIVE VEHICLE VELOCITY VECTOR IN METERS/CS AT +7.
#               VRPREV LAST COMPUTED VELOCITY REQUIRED VECTOR IN
#               METERS/CS AT +7.
#               NONTIG TIME OF IGN. USED IN TARGETTING ROUTINES B+28
#               DELLT4 TRANSFER TIME FROM PIPTIME TO TARGET B+28
#               TNIT   TIME OF RNIT AND VNIT IN CS AT +28
#               GDT/2  HALF OF VELOCITY GAINED IN DELTA T TIME DUE TO
#               ACCELERATION OF GRAVITY IN METERS/CS AT +7.
#               DELVREF CHANGE IN VELOCITY DURING LAST 2 SEC IN
#               METERS/CS AT +7.
#               NORMSW SET=CENTRAL ANGLE BETWEEN RTARG AND RTIG IS BETWEEN
#               165 TO 195 DEGREES.
#               RESET=CENTRAL ANGLE OUTSIDE CONE DESCRIBED ABOVE.
# OUTPUT        VGTEMP VELOCITY TO BE GAINED VECTOR IN METERS/CS AT +7.
#               COGA   INPUT OF INITIAL GUESS FOR LAMBERT FROM S40.1
#               OR PREVIOUS PASS THRU S40.9.
#               GOBL/2 OBLATENESS TERM IN AVG GRAV CALC: GOBL*RSQ/MU
#               VRPREV/ VELOCITY REQUIRED VECTOR IN METERS/CS AT +7.
#               BDT    B VECTOR IN METERS/CS AT +7.
# SUBROUTINES USED -- INITVEL

```

```

SETLOC  P40S1
BANK

```

```

EBANK=  NBRCYCLS
COUNT 16/S40.9

```

```

S40.9      TC      INTPRET
          SETPD    DLOAD
          OOD
          L06ZEROS
          PDDL
          EP4(45)L
          BON      DLOAD

```



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```

                                NORMSW
                                +2
                                EP4(10)L
                                PUSH
                                CLEAR  CALL
                                      GUESSW
                                      HAVEGUES
                                EXIT
                                TC    PHASCHNG      # SAVE TIME BY NOT REDOING LAMBERT CALCS
                                OCT    05021        # C, PRIORITY NEXT, JOB BELOW
# Page 724
                                OCT    10000
                                TC    INTPRET
ENDLAMB
                                BON
                                      FIRSTFLG
                                      FIRSTTME
                                VLOAD  VSU
                                      VIPRIME
                                      VRPREV
                                PDDL   DSU
                                      TNIT
                                      TNITPREV
                                SL     BDDV
                                      17D
                                      200CSHI
                                VXSC
                                VSU   VSL1
                                      GDT/2
                                STORE  BDT
FIRSTTME  SLOAD  DCOMP
                                      RTX2
                                BMN
                                      MOONCASE
                                VLOAD  UNIT
                                      RN
                                DLOAD  DSU
                                      PIPTIME
                                      NOMTIG
                                DMP    DDV
                                      EARTHMU
                                      34D
                                VXSC  VAD
                                      GOBL/2
                                      VGTEMP
                                STORE  VGTEMP      # NOTE: NO TEST IS MADE TO SUBTRACT GOBL
MOONCASE  EXIT      # INSIDE 165-195 DEGREE CONE AREA.
```

```

TC      PHASCHNG
OCT     04021      # C, JOB BELOW

COPY40.9  TC      INTPRET
          DLOAD
          TNIT
          STOVL    TNITPREV
                  VIPRIME
          STORE    VRPREV
          CLEAR    EXIT
                  FIRSTFLG
          -2      CS      ONE      # REDO40.9 (RESTART) ENTRY TO END S40.9
          TS      NBRCYCLS
ENDS40.9  TC      PHASCHNG
          OCT     00001

# Page 725
TCF      ENDOFJOB

REDO40.9  TC      INTPRET      # S40.9 RESTARTS COME HERE TO GRACEFULLY
          VLOAD      #          TERMINATE S40.9 SO THAT IT CAN BE
          L06ZEROS    #          SET UP WITH LATEST R,V,T NEXT PASS
          STODL    DELVSUM    #          (TYPE C PHASE POINTS '04021' WILL
          L06ZEROS    #          FORCE NORMAL S40.9 TERMINATIONS,
          STOVL    NBRCYCLS    #          RATHER THAN LOSE TIME OF BRAND NEW
          VGPREV      #          PASS -- QUICK OLD DATA BETTER THAN
          STORE    VGTEMP      #          NONE) NOW CAN GO THRU SETUP.9
          EXIT      #          WITHOUT DISTURBING VGPREV.
          TCF      ENDS40.9 -2  # STORE 0,0 COVERED NBRCYCLS,P -- FIX UP S

200CSHI   2DEC    200 B-12

EARTHMU   2DEC*   -3.986032 E10 B-36*

EP4(45)L   2DEC    .125

EP4(10)L   2DEC    .027777777

# Page 726
# NAME:      S40.13 -- TIMEBURN
#
# FUNCTION    (1) DETERMINE WHETHER A GIVEN COMBINATION OF VELOCITY-TO-
#              BE-GAINED AND ENGINE CHOICE RESULT IN A BURN TIME SUFFICIENT
#              TO ALLOW STEERING AT THE VEHICLE DURING THE BURN, AND
#              (2) THE MAGNITUDE OF THE RESULTING BURN TIME -- IF IT IS SHOR
#              AND THE ASSOCIATED TIME OF THE ENGINE OFF SIGNAL.
#
```

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```
# CALLING SEQUENCE      VIA FINDVAC AS A NEW JOB
#
# INPUT                  VGTIG -- VELOCITY TO BE GAINED VECTOR (METERS/CS) AT +7
#                        WEIGHT/G -- MASS OF VEHICLE IN KGM AT TIG
#                        F -- ENGINE THRUST IN M.NEWTONS AT +7
#                        MDOT -- RATE OF DECREASE OF VEHICLE MASS DURING ENGINE BURN
#                               IN KILOGRAMS/CENTISECOND AT +3.  THIS SCALING MAY
#                               REQUIRE MODIFICATION FOR SATURN BURNS.
#
# OUTPUT                 IMPULSW      ZERO FOR STEERING
#                        ONE FOR ATTITUDE HOLD
#                        TGO           TIME TO BURN IN CENTISECONDS AT +14
#                        THE QUANTITY M.NEWTON SHALL BE USED TO EXPRESS WEIGHT IN TERMS OF
#                        (KILOGRAM*METER)/(CENTISECOND*CENTISECOND)
#                        (1) M.NEWTON = (10000) NEWTONS.

EBANK= TGO
COUNT 16/40.13

S40.13 TC      INTPRET
      SETPD    SET
              OOD
              IMPULSW      # ASSUME NO STEERING UNTIL FOUND OTHERWISE
VLOAD  ABVAL
              VGTIG        # VELOCITY TO BE GAINED AT +7
      EXIT
      CAF      BIT7        # TEST +X TRANSLATION
      EXTEND
      RXOR     CHAN31
      MASK     BIT7
      EXTEND
      BZF      NOTADDUL
      TC      INTPRET
      PDDL     DDV          # OOD = MAG OF VGTIG AT +7
              S40.135      # COMPENSATION FOR 2 JET ULLAGE AT +24
              WEIGHT/G     # MASS IN KGMS AT +16
      BON      SL1         # DOUBLE CORRECTION IF FOUR JETS
              NJETSFLG
              S40.130

S40.130 BDSU
      PDDL     DDV          # OOD = MAG OF VGTIG CORRECTED FOR ULLAGE
              K1VAL        # M.NEWTON-CS AT +24
              WEIGHT/G
      BDSU     BMN
              OOD
              S40.131      # TGO LESS THAN 100 CS
```

```

# Page 727
PDDL DMP # 02D = TEMP1 AT +7
EMDOT # SPS FLOW RATE SC.AT B+3 KG/CS (SP, NOTE)
3.5SEC # 350 CS AT +14
BDSU PDDL
WEIGHT/G
FANG
DMP SR2
5SECOND # 500 CS AT +14
DDV PUSH # 04D = TEMP2
BDSU BPL
02D
S40.133 # TGO GREATER THAN 600 CS
DLOAD BDDV
DMP DAD
5SECOND # 500 CS AT +14
1SEC2D # 100 CS AT +14
GOTO
S40.131 DLOAD S40.132
DMP # TGO LESS THAN 100 CS
WEIGHT/G
DAD DDV
K2VAL # M.NEWTON CS AT +24
K3VAL # M.NEWTON AT +10
S40.132 EXIT
EBANK= TGO
TC TPAGREE
CA MPAC
XCH L
CA ZERO
DXCH TGO # TGO IN CS AT +28
TC S40.134
S40.133 CLEAR EXIT # WILL STEER VEHICLE
IMPULSW
S40.134 TC PHASCHNG # KILL GROUP 3
OCT 3
TCF ENDOFJOB
NOTADDUL TC INTPRET
GOTO
S40.130 +1 # DO NOT COMPENSATE FOR 7 SEC OF ULLAGE
SETLOC DAPS7
BANK
COUNT 17/40.13

```

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```
K1VAL      =      EK1VAL      # DP PAD LOAD B+23 NEWTON-SEC/E+2
K2VAL      =      EK2VAL      # DP PAD LOAD B+23 NEWTON-SEC/E+2
K3VAL      =      EK3VAL      # DP PAD LOAD B+09 NEWTONS/E+4
1SEC2D     2DEC      100.0 B-14  # 100.0 CS AT +14
# Page 728
3.5SEC     2DEC      350.0 B-13  # 350 CS AT +13

5SECOND    2DEC      500.0 B-14  # 500.0 CS AT +14

S40.135    2DEC      69.6005183 B-23 # IMPULSE FROM 7.96 SECS OF 2-JET FIRING
#          7.96 (199.6)COS(10) LB-SEC, SC.AT
#          B+23 NEWTON-SEC/E+2 (7 SEC ULLAGE
#          TO GO, PLUS 0.96 SEC FROM PIPTIME)
```

# Page 729

```
# NAME          S40.6 GIMBAL DRIVE TEST AND/OR GIMBAL TRIM
# MOD NO 5      DATE 9 MARCH, 1967
# MOD BY ENGEL  LOG SECTION P40-P47
#
```

# FUNCTIONAL DESCRIPTION

```
#   GIMBAL DRIVE TEST....0,+2,-2,0 DEGREE ENGINE COMMANDS, AT 2 SECOND
#   INTERVALS, FIRST IN PITCH, THEN IN YAW.  ASTRONAUT VERIFICATION
#   OF GIMBAL MOTION ON GPI
#   GIMBAL TRIM....AFTER A 4 SECOND DELAY, ENGINE COMMANDED TO
#   PRE-COMPUTED TRIM POSITION.  ASTRONAUT VERIFICATION ON GPI.
#   PRE40.6....RESTART ENTRY TO RE-DO S40.6, ONLY IF RCS IS ON --- IF TVC
#   IS NOT ON --- PRIMARILY TO GET ACTUATORS TRIMMED FOR IGNITION.
#   BYPASS 4 SEC DELAY.  SPEED IS CRITICAL NEAR IGNITION.
#   IF TVC IS ON (TVCDAPON OR LATER) THEN REDOTVC WILL TAKE CARE
#   OF RESTARTING ACTUATORS.
```

# CALLING SEQUENCE....

```
#   WAITLIST, WITH 2CADR FOR S40.6 (OR PRE40.6), WITH EBANK= CNTR
```

# NORMAL EXIT MODE -- FIXDELAY, TASKOVER

# SUBROUTINES CALLED....

```
#   OUTPUT (INTERNAL)
```

```
#   FIXDELAY
```

# ALARM OR ABORT EXIT MODES --- NONE

# ERASABLE INITIALIZATION REQUIRED

```
#   CNTR = +0, NORMALLY SET BY THE P40 CALL AT TST,TRIM.
```

```
#   MRKRTMP....POSITIVE FOR GIMBAL DRIVE TEST AND GIMBAL TRIM (BOTH)
```

```

#           NEGATIVE FOR GIMBAL TRIM ONLY
#   PACTOFF, YACTOFF SC.AT 85.41 ARCSEC/BIT (V48N48 P, YTRIM)
#   "SC CONT" SWITCH AT "CMC" (A/P CONTROL SWITCH AT "GNC")
#   ACTIVE SPS GIMBAL MOTOR POWER(S), PITCH, YAW
#
# OUTPUT
#   TVCYAW, TVCPITCH (BITS RELEASED)
#   TVC ENABLE AND OPTICS ERROR COUNTER ENABLE
#
# DEBRIS
#   TBMPR60, CNTR

#           BANK    17
#           SETLOC  DAPS6
#           BANK

#           EBANK=  CNTR
#           COUNT   20/S40.6

PRE40.6      CS      FLAGWRD6      # RESTART ENTRY TO S40.6 (DO NOT PERMIT
#           MASK    OCT60000      #           IF TVC, BITS 15,14 = 1,0)
#           EXTEND
#           BZMF     +2
#           TCF      TASKOVER      # TVC, REDOTVC WILL REESTABLISH INTERFACE

#           CS      BIT1           # RCS, SO DO S40.6, GIMTRIM ONLY
# Page 730
#           TS      MRKRTMP

#           CAF     BIT1           # FOR REVISED S40.6 TIMING FOR RESTARTS...
#           TS      CNTR           # TO INDICATE A RESTART ENTRY (CNTR 1S
#                                   #           NORMALLY +0, BY S40.6)

#           EBANK=  CNTR
S40.6        CS      ZERO          # INHIBIT OPTICS ACTIVITY
#           TS      OPTIND

#           CS      BIT2           # DISENABLE OPTICS ERROR COUNTERS (ZERO,
#           EXTEND      #           AND INHIBIT PULSE TRANSMISSION --
#           WAND      CHAN12      #           NORMAL STATE)

#           CAF     OCT02200      # TVC ENABLE (SPS SERVO AMPS SEE DAC
#           EXTEND      #           VOLTAGES) AND DISENGAGE OPTICS/DAC
#           WOR      CHAN12

#           TC      FIXDELAY      # 60MS PROCEDURAL DELAY (40MS MINIMUM) FOR

```

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|            |        |            |                                           |
|------------|--------|------------|-------------------------------------------|
|            | DEC    | 6          | # RELAY LATCHING                          |
|            | CAF    | BIT2       | # ENABLE OPTICS ERROR COUNTERS            |
|            | EXTEND |            |                                           |
|            | WOR    | CHAN12     |                                           |
|            | TC     | FIXDELAY   | # 20MS PROCEDURAL DELAY (4MS MINIMUM) FOR |
|            | DEC    | 2          | # RELAY LATCHING                          |
| RSTRTST    | CCS    | CNTR       | # CHECK FOR RESTART ENTRY (PRE40.6)       |
|            | TCF    | GIMTRIM +2 | # RESTART ENTRY...BYPASS 4 SECOND DELAY   |
|            |        |            | # TST,TRIM SETS +0 ON NORMAL ENTRY        |
|            | CAE    | MRKRTMP    | # CHECK FOR TEST/TRIM OR TRIM ONLY        |
|            | TS     | CNTR       | # MRKRTMP SAVES CNTR FOR RESTARTS         |
|            | EXTEND |            |                                           |
|            | BZMF   | GIMTRIM    | # (TRIM ONLY)                             |
| GDTSETUP   | CS     | ZERO       | # GIMBAL DRIVE TEST SETUP, FOR PITCH      |
|            | TS     | CNTR       |                                           |
| GIMDTEST   | CAF    | +2ACTDEG   | # GIMBAL DRIVE TEST, 1ST INCREMENT        |
|            | TC     | OUTPUT     | # (LEAVES GIMBAL AT +2 DEG)               |
|            | CAF    | -4ACTDEG   | # 2ND INCREMENT (LEAVES GIMBAL AT -2)     |
|            | TC     | OUTPUT     |                                           |
|            | CAF    | +2ACTDEG   | # 3RD INCREMENT (LEAVES GIMBAL AT -0)     |
|            | TC     | OUTPUT     |                                           |
|            | CS     | CNTR       | # CHECK FOR COMPLETION OF YAW TEST.       |
| # Page 731 | CCS    | A          |                                           |
|            | TCF    | GIMTRIM    | # COMPLETED, GO TO GIMBAL TRIM ROUTINE    |
|            | CS     | BIT1       | # SET UP YAW TEST                         |
|            | TS     | CNTR       |                                           |
|            | TCF    | GIMDTEST   | # FOR YAW TEST                            |
| OUTPUT     | EXTEND |            | # OUTPUT THE INCREMENT....SAVE Q          |
|            | QXCH   | TEMPR60    |                                           |
|            | INDEX  | CNTR       |                                           |
|            | TS     | TVC PITCH  |                                           |
|            | INDEX  | CNTR       |                                           |
|            | CAF    | BIT11      |                                           |
|            | EXTEND |            |                                           |
|            | WOR    | CHAN14     |                                           |

|                                                                                    |        |          |                                           |
|------------------------------------------------------------------------------------|--------|----------|-------------------------------------------|
|                                                                                    | TC     | FIXDELAY | # WAIT 2SEC, WHILE ASTRONAUT VERIFIES     |
|                                                                                    | DEC    | 200      | # GIMBAL MOTION ON GPI                    |
|                                                                                    | TC     | TEMPR60  |                                           |
| GIMTRIM                                                                            | TC     | FIXDELAY | # WAIT 4 SECONDS BEFORE GIMBAL TRIM       |
|                                                                                    | DEC    | 400      |                                           |
| +2                                                                                 | CS     | ZERO     | # PICK UP TRIM VALUES AND OUTPUT THEM     |
|                                                                                    | AD     | PACTOFF  | # (AVOID +0) ENTRY POINT FROM RSTRTST     |
|                                                                                    | TS     | TVCPITCH | # ON A RESTART, TO AVOID 4SEC DELAY       |
|                                                                                    | CS     | ZERO     |                                           |
|                                                                                    | AD     | YACTOFF  |                                           |
|                                                                                    | TS     | TVCYAW   |                                           |
|                                                                                    | CAF    | PRI06    | # RELEASE THE COUNTERS, BITS 11,12        |
|                                                                                    | EXTEND |          |                                           |
|                                                                                    | WOR    | CHAN14   |                                           |
| ENDS40.6                                                                           | TCF    | TASKOVER |                                           |
| OCT02200                                                                           | OCT    | 02200    | # BITS 8,11 FOR CHANNEL 12 TVC/OPTICS     |
| -4ACTDEG                                                                           | DEC    | -168     | # -2(+2ACTDEG), WHOLE BITS, NO ROUNDUP    |
| +2ACTDEG                                                                           | DEC    | +84      | # +2 DEG, SC.AT 85.41 ARCSEC/BIT (+84D)   |
| # CALLED BY "DONOUN46" (VERB 48), OR DIRECTLY BY "FRESHDAP" (RCS DAP) VIA IBNKCALL |        |          |                                           |
|                                                                                    | COUNT  | 20/S41.2 |                                           |
| S41.2                                                                              | CA     | DAPDATR1 |                                           |
| # Page 732                                                                         | MASK   | THREE    |                                           |
|                                                                                    | AD     | A        |                                           |
|                                                                                    | TS     | RATEINDX |                                           |
|                                                                                    | INHINT |          |                                           |
|                                                                                    | CAE    | DAPDATR1 | # IS LEM ATTACHED (BITS 14,13 OF DAPDATR1 |
|                                                                                    | MASK   | PRI030   | # =10)                                    |
|                                                                                    | AD     | -BIT14   | # (OCT57777)                              |
|                                                                                    | EXTEND |          |                                           |
|                                                                                    | BZF    | TOGETHER | # YES                                     |
|                                                                                    | CS     | BIT2     | # NO, UNSET FLAG                          |
|                                                                                    | MASK   | FLAGWRD7 |                                           |
|                                                                                    | TS     | FLAGWRD7 |                                           |



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```
TCF      +4

TOGETHER  CS      FLAGWRD7      # ATTACHED, SET FLAG FOR INTEGRATION
          MASK     BIT2
          ADS      FLAGWRD7

RELINT

CA        DAPDATR1
MASK      BIT4
EXTEND
BZMF      +2                  # DEC 46 MEANS NARROW DB
CA        DEC409
AD        DEC46              # DEC 455 MEANS WIDE DB
TS        ADB

CA        DAPDATR1
MASK      BIT7              # QUAD BD
EXTEND
BZMF      +2
CA        ONE
TS        XTRANS
CA        DAPDATR1
MASK      BIT10             # QUAD AC
EXTEND
BZMF      +2
CS        ONE
ADS       XTRANS

INHINT
EXTEND
BZF       +5                  # CLEAR NJETSFLG (4 JETS, OR NO JETS)
CS        FLAGWRD1          # SET NJETSFLG (2 JETS, AC OR BD QUADS)
MASK      BIT15             # NJETSFLG = 1 FOR 2 JET ULLAGE (AC OR BD)
ADS       FLAGWRD1

# Page 733

TCF      +4
CS        BIT15              # KJETSFLG = 0 FOR 4 JET (OR 0 JET) ULLAGE
MASK      FLAGWRD1
TS        FLAGWRD1
RELINT
CA        DAPDATR2
MASK      BIT13
EXTEND
BZMF      +2
TCF       +2
```

|        |      |          |                               |
|--------|------|----------|-------------------------------|
|        | CS   | ONE      |                               |
|        | COM  |          |                               |
|        | TS   | ACORBD   | # MINUS FOR A-C, PLUS FOR B-D |
|        | CA   | DAPDATR2 |                               |
|        | MASK | BIT10    |                               |
|        | CCS  | A        |                               |
|        | TCF  | +4       |                               |
|        | CA   | ONE      |                               |
|        | TS   | RACFAIL  |                               |
|        | TCF  | BDFAIL   |                               |
|        | CA   | ZERO     |                               |
|        | TS   | RACFAIL  |                               |
|        | CA   | DAPDATR2 |                               |
|        | MASK | BIT4     |                               |
|        | CCS  | A        |                               |
|        | TCF  | BDFAIL   |                               |
|        | CS   | ONE      |                               |
|        | TS   | RACFAIL  |                               |
| BDFAIL | CA   | DAPDATR2 |                               |
|        | MASK | BIT7     |                               |
|        | CCS  | A        |                               |
|        | TCF  | +4       |                               |
|        | CA   | ONE      |                               |
|        | TS   | RBDFAIL  |                               |
|        | TC   | Q        |                               |
|        | CA   | ZERO     |                               |
|        | TS   | RBDFAIL  |                               |
|        | CA   | DAPDATR2 |                               |
|        | MASK | BIT1     |                               |
|        | CCS  | A        |                               |
|        | TC   | Q        |                               |
|        | CS   | ONE      |                               |
|        | TS   | RBDFAIL  |                               |
|        | TC   | Q        |                               |

# DAPFIG ENTRY VIA TC POSTJUMP AS JOB FROM "STABLISH" (VERB 46)

|  |        |        |
|--|--------|--------|
|  | BANK   | 42     |
|  | SETLOC | EXTVBS |

# Page 734

|        |        |        |
|--------|--------|--------|
|        | BANK   |        |
| DAPFIG | CS     | BIT9   |
|        | EXTEND |        |
|        | WAND   | CHAN12 |

# TURN OFF SIVB TAKEOVER

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```
CAE      DAPDATR1      # DETERMINE VEHICLE CONFIGURATION
EXTEND
MP        BIT3          #      RIGHT SHIFT 4 OCTAL DIGITS
MASK      THREE        #      (IN CASE BIT 15 IS USED)
INDEX     A
TCF       +1           #      BRANCH BASED ON CONFIG...

TCF       NODAPUP       # CM.....ACTIVATE NODAP
TCF       RCSDAPUP      #      CSM.....ACTIVATE RCSDAP
TCF       RCSDAPUP      #      CSM/LEM..ACTIVATE RCSDAP
TC        POSTJUMP
CADR      SATSTKON
RCSAPUP  INHINT         # CALL TO ACTIVATE RCSDAP, AND RETURN
TCR       IBNKCALL
CADR      RCSDAPON
RELINT
TCF       ENDFIG        # CAME IN VIA V46, GO OUT VIA GOPIN
EXTEND    # T5 IDLE FOR NODAP (DON'T WORRY ABOUT T)
DCA       T5IDLDAP
DXCH      T5LOC
TC        DOWNFLAG      # RESET T5-USAGE FLAGS FOR NODAP
ADRES     DAPBIT1       # BIT 15 FLAG 6 = 0
TC        DOWNFLAG
ADRES     DAPBIT2       # BIT 14 FLAG 6 = 0
INHINT
TC        IBNKCALL      # ZERO JET CHANNELS IN 14 MS AND THEN
CADR      ZEROJET       # LEAVE THE T6 CLOCK DISABLED.
RELINT
CAF       BIT1          # KILL KALCMANU JOB
TS        HOLDFLAG
TC        POSTJUMP      # CAME IN VIA V46, GO OUT VIA GOPIN
CADR      GOPIN
SBANK=    PINSUPER      # Added by RSB 2009
EBANK=    PACTOFF
T5IDLDAP  2CADR         T5IDLOC

SBANK=    LOWSUPER
BANK      17
SETLOC    DAPS6
BANK

DEC409    DEC          409
DEC46     DEC          46
```

# CALLED BY "DONOUN47" (VERB 48), OR DIRECTLY BY "FRESHDAP" (RCS DAP)

S40.14 CAE IXX # RCS ENTRY

EXTEND

MP CONTONE

TS J/M

CA IAVG

EXTEND

MP CONTONE

TS J/M1

TS J/M2

EXTEND

DCA CONTTWO

EXTEND

DV IXX

TS KMJ

EXTEND

DCA CONTTWO

EXTEND

DV IAVG

TS KMJ1

TS KMJ2

TC Q

CONTONE DEC .662034 # 2PI/M

CONTTWO 2DEC .00118

COUNT 24/TVNG

BANK 31

SETLOC P40S

BANK

POS-2.5 OCT 37405

EBANK= DAPDATR1

RCSCADR 2CADR RCSUP

6SECT5 OCT 37704

COUNT 21/RCSUP

BANK 20

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```

SETLOC DAPS3
BANK

# Page 736

RCSUP      LXCH  BANKRUPT
            EXTEND
            QXCH  QRUPT

            TCR   RCSDAPON      # ACTIVATE RCS DAP
            TCF   RESUME

            EBANK= DAPDATTR1
RCSADDR    2CADR  RCSATT

0.6SECT5   OCT    37704

RCSDAPON   CAF    0.6SECT5      # RCSDAPON ENTRY MUST BE UNDER INT-INHIBIT
+1          TS     TIME5         # 0.6 SEC ALLOWS TVCEXEC/ROLLDAP TO DIE
            TS     T5PHASE       # ENTRY FROM ROOTPOO
                                     # WILL CAUSE FRESHDAP (+1)

            CS     RCSFLAGS      # SET BIT3 TO REINITIALIZE FDAI ERROR
            MASK   BIT3          #      DISPLAY, IN CASE SC CONT SWITCH
            ADS    RCSFLAGS      #      IN SCS NOT GNC (GUIDEMODE PRIMARY)

            EXTEND
            DCA    RCSADDR      # (RCSATT)
            DXCH   T5LOC

            CS     OCT60000      # SEE BITS 15,14 TO 01 TO INDICATE
            MASK   FLAGWRD6      #      T5 TAKEOVER BY RCSDAP
            AD     BIT14
            TS     FLAGWRD6      # KILLS TVCEXEC AND ROLLDAP STARTS

            TC     Q             # RETURN TO CALLER (TVCDAPOF OR RCSDAPUP)
```

This code is written to file src/P40-P47.s.

## A.74 P51-P53

```

1262  <src/P51-P53.s 1262>≡
# Copyright:   Public domain.
# Filename:    P51-P53.agc
# Purpose:     Part of the source code for Comanche, build 055. It
#              is part of the source code for the Command Module's
#              (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:  yaYUL
# Reference:   pp. 737-784
# Contact:     Ron Burkey <info@sandroid.org>
# Website:     http://www.ibiblio.org/apollo.
# Mod history: 2009-05-12 RSB  Adapted from Colossus249 file of the same
#              name, and Comanche 055 page images.
#              2009-05-20 RSB  Corrections: SETI/PDT -> SET1/PDT,
#              GOTOP00H -> GOTOP00H, R33EXIT -> R53EXIT,
#              V853 -> VB53, R56A -> R56A1 (some places
#              only), added missing R56A1 label, added a
#              missing CAF in COARSTYP, corrected a SETLOC
#              from P50S to P50S3.
#              2009-05-21 RSB  In COARFINE, a TC BANKCALL was corrected to
#              TC PHASCHNG.  In R53C, a CADR GOFLASHR was
#              corrected to CADR GOFLASH.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051.  April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#
#           Massachussets Institute of Technology
#           75 Cambridge Parkway
#           Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.
#
# Page 737
# PROGRAM NAME -- PROG52
# MOD NO -- 2
# MODIFICATION BY -- LONSKE
# DATE -- NOV 30, 1966
# LOG SECTION -- P51-P53
# ASSEMBLY -- SUNDISK REV 30

```

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```
#
# FUNCTIONAL DESCRIPTION --
#
#   ALIGNS THE IMU TO ONE OF THREE ORIENTATIONS SELECTED BY THE ASTRONAUT.  THE PRESENT IMU
#   AND IS STORED IN REFSMMAT.  THE THREE POSSIBLE ORIENTATIONS MAY BE:
#
#   (A)    PREFERRED ORIENTATION
#
#           AN OPTIMUM ORIENTATION FOR A PREVIOUSLY CALCULATED MANEUVER.  THIS ORIENTATION
#           STORED BY A PREVIOUSLY SELECTED PROGRAM.
#
#   (B)    NOMINAL ORIENTATION
#
#           X   = UNIT ( Y   x Z   )
#           -SM           -SM   -SM
#
#           Y   = UNIT ( V X R )
#           -SM           -   -
#
#           Z   = UNIT ( -R )
#           -SM           -
#
#   WHERE:
#
#   R = THE GEOMETRIC RADIUS VECTOR AT TIME T(ALIGN) SELECTED BY THE ASTRONAUT
#   -
#
#   V = THE INERTIAL VELOCITY VECTOR AT TIME T(ALIGN) SELECTED BY THE ASTRONAUT
#   -
#
#   (C)    RERSMMAT ORIENTATION
#
#           THIS SELECTION CORRECTS THE PRESENT IMU ORIENTATION.  THE PRESENT ORIENTATION D
#           WAS LAST ALIGNED ONLY DUE TO GYRO DRIVE (I.E., NEITHER GIMBAL LOCK NOR IMU POWE
#           SINCE THE LAST ALIGNMENT).
#
#   AFTER A IMU ORIENTATION HAS BEEN SELECTED ROUTINE S52.2 IS OPERATED TO COMPUTE THE GIME
#   NEW ORIENTATION AND THE PRESENT VEHICLE ATTITUDE.  CAL52A THEN USES THESE ANGLES, STORE
#   COARSE ALIGN THE IMU.  THE STARS SELECTION ROUTINE, R56, IS THEN OPERATED.  IF 2 STARS
#   IS FLASHED TO NOTIFY THE ASTRONAUT.  AT THIS POINT THE ASTRONAUT WILL MANEUVER THE VEHI
#   EITHER MANUALLY OR AUTOMATICALLY.  AFTER 2 STARS HAVE BEEN SELECTED THE IMU IS FINE ALI
#   THE RENDEZVOUS NAVIGATION PROCESS IS OPERATING (INDICATED BY RNDVZFLG) P20 IS DISPLAYED
#   REQUESTED.
#
# CALLING SEQUENCE --
#
```

```

#       THE PROGRAM IS CALLED BY THE ASTRONAUT BY DSKY ENTRY.
# Page 738
#
# SUBROUTINES CALLED --
#
#       1. FLAGDOWN           7. S52.2           13. NEWMODEX
#       2. R02BOTH           8. CAL53A           14. PRIOLARM
#       3. GOPERF4           9. FLAGUP
#       4. MATMOVE          10. R56
#       5. GOFLASH          11. R51
#       6. S52.3            12. GOPERF3
#
# NORMAL EXIT MODES --
#
#       EXITS TO ENDOFJOB
#
# ALARM OR ABORT EXIT MODES --
#
#       NONE
#
# OUTPUT --
#
#       THE FOLLOWING MAY BE FLASHED ON THE DSKY
#           1. IMU ORIENTATION CODE
#           2. ALARM CODE 215 -- PREFERRED IMU ORIENTATION NOT SPECIFIED
#           3. TIME OF NEXT IGNITION
#           4. GIMBAL ANGLES
#           5. ALARM CODE 405 -- TWO STARS NOT AVAILABLE
#           6. PLEASE PERFORM P00
#       THE MODE DISPLAY MAY BE CHANGED TO 20
#
# ERASABLE INITIALIZATION REQUIRED --
#
#       PFRATFLG SHOULD BE SET IF A PREFERRED ORIENTATION HAS BEEN COMPUTED.  IF IT P
#       XSMD, YSMD, ZSMD.
#
#       RNDVZFLG INDICATES WHETHER THE RENDEZVOUS NAVIGATION PROCESS IS OPERATING.
#
# DEBRIS --
#
#       WORK AREA
#
P54          =          PROG52
              BANK      33
              SETLOC    P50S
              BANK

```



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```

                                SBANK= LOWSUPER
                                EBANK= SAC
                                COUNT  15/P52

PROG52      TC      PHASCHNG
            OCT      00254
            TC      DOWNFLAG
            ADRES    UPDATFLG      # BIT 7 FLAG 1

# Page 739

            TC      DOWNFLAG
            ADRES    TRACKFLG      # BIT 5 FLAG 1
            TC      BANKCALL
            CADR     R02BOTH      # IMU STATUS CHECK
            CAF      BIT4
            MASK     STATE +2      # IS PFRATFLG SET?
            CCS      A
            TC      P52A          # YES
            CAF      BIT2          # NO
            TC      P52A +1
P52A        CAF      BIT1
            TS      OPTION2
P52B        CAF      BIT1
            TC      BANKCALL      # FLASH OPTION CODE AND ORIENTATION CODE
            CADR     GOPERF4R
            TC      GOTOP00H
            TC      +5
            TC      P52B          # NEW CODE -- NEW ORIENTATION CODE INPUT
            TC      PHASCHNG
            OCT      00014
            TC      ENDOFJOB
            CA      OPTION2
            MASK     THREE
            INDEX    A
            TC      +1
            TC      P52T          # L.S.
            TC      P52J          # PREF
            TC      P52T          # NORM
            TCF      P52C          # REF

P52T        EXTEND
            DCA      NEG0
            DXCH     DSPTEM1
            CAF      V06N34
            TC      BANKCALL
            CADR     GOFLASH
            TC      GOTOP00H
```

|            |        |          |                                        |
|------------|--------|----------|----------------------------------------|
|            | TC     | +2       |                                        |
|            | TC     | -5       |                                        |
|            | EXTEND |          |                                        |
|            | DCA    | DSPTM1   |                                        |
|            | EXTEND |          |                                        |
|            | BZF    | +2       |                                        |
|            | TCF    | +4       |                                        |
|            | EXTEND |          |                                        |
|            | DCA    | TIME2    |                                        |
|            | DXCH   | DSPTM1   |                                        |
|            | CA     | OPTION2  |                                        |
|            | MASK   | BIT2     |                                        |
|            | CCS    | A        |                                        |
| # Page 740 | TCF    | +6       | # NOM                                  |
|            | TC     | INTPRET  | # LS                                   |
|            | CALL   |          |                                        |
|            |        | P52LS    |                                        |
|            | GOTO   |          |                                        |
|            |        | P52D     |                                        |
|            | TC     | INTPRET  |                                        |
|            | DLOAD  |          |                                        |
|            |        | DSPTM1   |                                        |
|            | CALL   |          | # COMPUTE NOMINAL IMU                  |
|            |        | S52.3    | # ORIENTATION                          |
| P52D       | CALL   |          | # READ VEHICLE ATTITUDE AND            |
|            |        | S52.2    | # COMPUTE GIMBAL ANGLES                |
|            | EXIT   |          |                                        |
|            | CAF    | VB06N22  |                                        |
|            | TC     | BANKCALL | # DISPLAY GIMBAL ANGLES                |
|            | CADR   | GOFLASH  |                                        |
|            | TC     | GOTOPOOH |                                        |
|            | TC     | COARSTYP |                                        |
| P52J       | TC     | INTPRET  | # RECYCLE: VEHICLE HAS BEEN MANEUVERED |
|            | GOTO   |          |                                        |
|            |        | P52D     |                                        |
|            | TC     | INTPRET  |                                        |
|            | CALL   |          | # DO COARSE ALIGN                      |
|            |        | CAL53A   | # ROUTINE                              |
| CAL53RET   | SET    | EXIT     |                                        |
|            |        | REFSMFLG |                                        |
| P52C       | TC     | PHASCHNG |                                        |
|            | OCT    | 04024    |                                        |
|            | CAF    | ALRM15   |                                        |
|            | TC     | BANKCALL |                                        |

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|            |       |          |                                        |
|------------|-------|----------|----------------------------------------|
|            | CADR  | GOPERF1  |                                        |
|            | TC    | GOTPOOH  |                                        |
|            | TC    | +2       | # V33                                  |
|            | TC    | P52F     | # E                                    |
|            | TC    | INTPRET  |                                        |
|            | RTB   | DAD      |                                        |
|            |       | LOADTIME |                                        |
|            |       | TSIGHT1  |                                        |
|            | CALL  |          |                                        |
|            |       | LOCSAM   |                                        |
|            | EXIT  |          |                                        |
| P52E       | TC    | BANKCALL | # DO STAR SELECTION                    |
|            | CADR  | PICAPAR  |                                        |
|            | TC    | P52I     | # 2 STARS NOT AVAILABLE                |
| P52F       | TC    | INTPRET  | # 2 STARS AVAILABLE                    |
|            | CALL  |          |                                        |
|            |       | R51      |                                        |
| ENDP50S    | EXIT  |          |                                        |
|            | TC    | GOTPOOH  |                                        |
| # Page 741 |       |          |                                        |
| P52I       | TC    | ALARM    |                                        |
|            | OCT   | 405      |                                        |
|            | CAF   | V05N09   |                                        |
|            | TC    | BANKCALL |                                        |
|            | CADR  | GOFLASH  |                                        |
|            | TC    | GOTPOOH  |                                        |
|            | TC    | P52F     | # PROCEED: DO FINE ALIGN-R51           |
|            | TC    | P52C     | # RECYCLE: VEHICLE HAS BEEN MANEUVERED |
| V06N34     | VN    | 0634     |                                        |
| VB06N22    | VN    | 00622    |                                        |
| COARSTYP   | CAF   | OCT13    |                                        |
|            | TC    | BANKCALL |                                        |
|            | CADR  | GOPERF1  |                                        |
|            | TCF   | GOTPOOH  | # V34                                  |
|            | TCF   | P52J +3  | # NORMAL                               |
|            | TC    | INTPRET  | # GYRO COARSE                          |
| GYCRS      | VLOAD | MXV      |                                        |
|            |       | XSMD     |                                        |
|            |       | REFSMMAT |                                        |
|            | UNIT  |          |                                        |
|            | STOVL | XDC      |                                        |
|            |       | YSMD     |                                        |
|            | MXV   | UNIT     |                                        |
|            |       | REFSMMAT |                                        |
|            | STOVL | YDC      |                                        |
|            |       | ZSMD     |                                        |

```

MXV      UNIT
          REFSMMAT
STCALL   ZDC
          CALCGTA
CLEAR    CLEAR
          DRIFTFLG
          REFSMFLG

EXIT
CAF      V16N20
TC       BANKCALL
CADR     GODSPR
CA       R55CDR
TC       BANKCALL
CADR     IMUPULSE
TC       BANKCALL
CADR     IMUSTALL
TC       CURTAINS
TC       PHASCHNG
OCT      04024
TC       INTPRET
AXC,1    AXC,2
          XSMD
          REFSMMAT

CALL

```

# Page 742

```

          MATMOVE
CLEAR    SET
          PFRATFLG
          REFSMFLG
RTB      VLOAD
          SET1/PDT
          ZEROVEC
STORE    GCOMP
SET      GOTO
          DRIFTFLG
          R51K
V16N20   VN      1620
ALRM15   EQUALS  OCT15
          SETLOC  P50S2
          BANK
V06N89*  VN      0689

```

# NAME -- P52LS

#

```

# FUNCTION -- TO DISPLAY THE LANDING SITE LATITUDE,
# LONGITUDE AND ALTITUDE.  TO ACCEPT NEW DATA VIA

```

```

# THE KEYBOARD.  TO COMPUT THE LANDING SITE
# ORIENTATIION FOR P52 OR P54.
#
# LET:
#   RLS = LANDING SITE VECTOR IN REF COORDINATES
#   R   = CSM POSITION VECTOR IN REF COORDINATES
#   V   = CSM VELOCITY VECTOR IN REF COORDINATES
# THEN THE LANDING SITE ORIENTATION IS:
#   XSMD = UNIT(RLS)
#   YSMD = UNIT(ZSMD*XSMD)
#   ZSMD = UNIT((R*V)*RLS)
#
# CALL:      CALL
#              P52LS
#
# INPUTS:     DSPTEM1 = TIME OF ALIGNMENT
#              RLS = LANDING SITE VECTOR IN MOON FIXED COORDINATES
#
# OUTPUTS:    XSMD, YSMD, ZSMD
#
# SUBROUTINES: RP-TO-R, LAT-LONG, LLASRD, LLASRDA, CSMPREC
#
# DEBRIS:     VAC, SEE SUBROUTINES

P52LS      STQ      SET
              QMAJ
              LUNAFLAG
              DLOAD
              DSPTEM1
              STORE  TSIGHT
              VLOAD  SET
              RLS
              ERADFLAG
              STODL  OD
              TSIGHT
              STCALL 6D

# Page 743

              RP-TO-R
              VSR2
              STODL  ALPHAV
              TSIGHT
              CALL
              LAT-LONG
              CALL
              LLASRD
              EXIT

```

```

LSDISP      CAF      V06N89*
            TC        BANKCALL
            CADR      GOFLASH
            TC        GOTOPOOH
            TC        +2
            TC        LSDISP
            TC        INTPRET
            CALL
            LLASRDA
            DLOAD     CALL
            TSIGHT
            LALOTORV
            VLOAD     UNIT
            ALPHAV
            STODL     XSMD
            TSIGHT
            STCALL    TDEC1
            CSMPREC
            VLOAD     VXV
            RATT
            VATT
            VXV       UNIT
            XSMD
            STORE     ZSMD
            VXV       UNIT
            XSMD
            STCALL    YSMD
            QMAJ
            SETLOC    P50S1
            BANK

```

```

# NAME:      AUTOMATIC OPTICS POSITIONING ROUTINE
#

```

```

# FUNCTION:  (1) TO POINT THE STAR LOS OF THE OPTICS AT A STAR OR LANDMARK DEFINED
#            (2) TO POINT THE STAR LOS OF THE OPTICS AT THE LEM DURING RENDEZVOUS
#

```

```

# CALLING:   CALL R52
#

```

```

# INPUT:     1.  TARG1FLG AND TARG2FLG:  PRESET BY CALLER
#            2.  RNDVZFLG AND TRACKFLG:  PRESET BY CALLER
#            3.  STAR CODE:  PRESET BY CALLER.  ALSO INPUT THROUGH DSKY
#            4.  LAT, LONG, AND ALT OF LANDMARK:  INPUT THROUGH DSKY
#

```

```

# Page 744
#

```

```

#            5.  NO. OF MARKS (MARKINDX):  PRESET BY CALLER
#

```

```

# OUTPUT:    DRIVE SHAFT AND TRUNNION CDUS.

```

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```
#
# SUBROUTINES:  1.  FIXDELAY          7.  CLEANDSP
#               2.  GOPERF1          8.  GODSPR
#               3.  GOFLASH          9.  REFLASHR
#               4.  R53             10. R52.2
#               5.  ALARM           11. R52.3
#               6.  SR52.1

COUNT 15/R52

R52      STQ      CLEAR
          SAVQR52
          ADVTRK

R52VRB   EXIT
          EXTEND
          DCA      CDUT
          DXCH     DESOPTT
          TC       INTPRET
          SSP      CLEAR
          OPTIND
          0
          R53FLAG

R52A     EXIT
          TC       INTPRET
          SET      BON
          TRUNFLAG
          TARG1FLG
          R52H
          CLEAR    EXIT
          TERMIFLG

R52C     CA      SWSAMPLE      # IS OPTICS MODE IN AGC
          EXTEND

R52D     BZMF    R52M          # MANUAL
          TC      BANKCALL     # AGC
          CADR    SR52.1
          TCF     R52L          # GR 90 DEGREES
          TCF     R52J          # GR 50 DEGREES
          TC      UPFLAG        # LS 50 DEGREES
          ADRES   TRUNFLAG      # SET TRUNFLAG BIT 4 FLAG 0
R52JA    CAF     BIT10         # IS THIS A LEM
          MASK    STATE +1
          CCS     A
          TC      R52E          # YES
          CAF     BIT6          # NO, IS R53FLAG SET
          MASK    STATE
          CCS     A
```

|            |        |          |                        |
|------------|--------|----------|------------------------|
| # Page 745 | TCF    | R52E     | # YES                  |
|            | CAF    | V06N92   | # NO                   |
|            | TC     | BANKCALL |                        |
|            | CADR   | GODSPR   |                        |
| R52E       | CA     | SWSAMPLE | # IS OSS IN CMC MODE   |
|            | EXTEND |          |                        |
|            | BZMF   | R52F     | # NO                   |
|            | CS     | STATE    | # YES: IS TRUNFLAG SET |
|            | MASK   | BIT4     |                        |
|            | CCS    | A        |                        |
|            | TC     | +3       | # NO                   |
|            | CA     | PAC      | # YES                  |
|            | TS     | DESOPTT  |                        |
|            | CA     | SAC      |                        |
|            | TS     | DESOPTS  |                        |
| R52F       | CAF    | .5SEC    | # WAIT 1/2 SEC         |
|            | TC     | BANKCALL |                        |
|            | CADR   | DELAYJOB |                        |
|            | CAF    | BIT10    |                        |
|            | MASK   | STATE +1 |                        |
|            | CCS    | A        |                        |
|            | TCF    | R52HA    | # YES, LEM             |
|            | CAF    | BIT15    | # NO                   |
|            | MASK   | STATE +7 | # IS TERMIFLG SET      |
|            | EXTEND |          |                        |
|            | BZF    | R52C     | # NO                   |
| R52Q       | TC     | INTPRET  | # YES                  |
|            | GOTO   |          |                        |
|            |        | SAVQR52  |                        |
| R52H       | EXIT   |          | # LEM                  |
| R52HA      | TC     | BANKCALL |                        |
|            | CADR   | R61CSM   |                        |
|            | CA     | STATE +1 |                        |
|            | MASK   | BIT5     |                        |
|            | EXTEND |          | # TRACKFLG             |
|            | BZF    | R52Q     |                        |
|            | CS     | STATE +1 |                        |
|            | MASK   | BIT7     | # UPDATFLG             |
|            | CCS    | A        |                        |
|            | TCF    | R52SYNC  |                        |
| R52I       | CA     | STATE +5 |                        |
|            | MASK   | BIT10    |                        |
|            | CCS    | A        |                        |



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|            |        |                 |                                             |
|------------|--------|-----------------|---------------------------------------------|
| R52SYNC    | TC     | R52D            | # PRFTRKAT = 1                              |
|            | CAF    | 1.8SEC          | # MAKE UP FOR LOST TIME                     |
|            | TCF    | R52F +1         |                                             |
| R52J       | TC     | DOWNFLAG        | # CLEAR TRUNFLAG                            |
|            | ADRES  | TRUNFLAG        | # BIT 4 FLAG 0                              |
| # Page 746 |        |                 |                                             |
|            | TC     | ALARM           | # SET 407 ALARM                             |
|            | OCT    | 407             |                                             |
|            | TC     | R52JA           |                                             |
| R52M       | CAF    | BIT6            | # IS R53FLAG SET                            |
|            | MASK   | STATE           |                                             |
|            | CCS    | A               |                                             |
|            | TC     | R52F            | # YES                                       |
|            | INHINT |                 | # NO                                        |
|            | CAF    | PRI024          |                                             |
|            | TC     | FINDVAC         |                                             |
|            | EBANK= | SAC             |                                             |
|            | 2CADR  | R53JOB          |                                             |
|            | RELINT |                 |                                             |
|            | TCF    | R52F            |                                             |
| R53JOB     | TC     | INTPRET         |                                             |
|            | CALL   |                 |                                             |
|            |        | R53             |                                             |
| ENDPLAC    | EXIT   |                 | # INTERPRETER RETURN TO ENDOFJOB (R22 USES) |
|            | TC     | ENDOFJOB        |                                             |
| V06N92     | VN     | 00692           |                                             |
| V06N89A    | VN     | 0689            |                                             |
| SHAXIS     | 2DEC   | .5376381241 B-1 |                                             |
|            | 2DEC   | 0               |                                             |
|            | 2DEC   | .8431766920 B-1 |                                             |
| R52L       | CAF    | BIT10           | # IS THIS A LEM                             |
|            | MASK   | STATE +1        |                                             |
|            | CCS    | A               |                                             |
|            | TC     | R52J            | # YES                                       |
|            | CAF    | OCT404          |                                             |
|            | TC     | BANKCALL        |                                             |
|            | CADR   | PRIOLARM        |                                             |
|            | TCF    | TERM52          | # TERMINATE                                 |
|            | TCF    | R52F            | # PROCEED                                   |
|            | TCF    | R52F            | # NO PROVISION FOR NEW DATA                 |
|            | TCF    | ENDOFJOB        |                                             |

OCT404            OCT        404  
1.8SEC            DEC        180

TERM52            TC        CLEARMRK

TC            BANKCALL        # KILL MARK SYSTEM  
CADR           MKRELEAS

# Page 747

CAF            ZERO  
TS            OPTCADR

TC            BANKCALL        # CLEAR OUT EXTENDED VERBS  
CADR           KLEENEX

TC            GOTOPOOH        # NO GO TO POO

ADVORB           STQ        SET            # SETS UP ADVANCED ORBIT TRACKING  
                 SAVQR52  
                 ADVTRK  
                 SET        SET  
                 LUNAFLAG  
                 ERADFLAG  
                 GOTO        R52VRB

# Page 748

# NAME -- S50 ALIAS LOCSAM

# NAME: LOCSAM

#

# FUNCTION -- TO COMPUTE QUATITIGS LISTED BELOW, USED IN THE  
# IMU ALIGNMENT PROGRAMS.

#

#        DEFINE:

#

#        RATT = POSITION VECTOR OF CM WRT PRIMARY BODY

#

#        VATT = VELOCITY VECTOR OF CM WRT PRIMARY BODY

#

#        RE = RADIUS OF EARTH

#

#        RM = RADIUS OF MOON

#

#        ECLIPOL = POLE OF ECLIPTIC SCALED BY TANGENTIAL VELOCITY OF EARTH

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```
#           WRT TO SUN OVER THE VELOCITY OF LIGHT
#
#           REM = POSITION OF MOON WRT EARTH
#
#           RES = POSITION OF SUN WRT EARTH
#
#           C = VELOCITY OF LIGHT
#
#           EARTH IS PRIMARY                MOON IS PRIMARY
#
#           VEARTH=-1(RATT)                  VEARTH=-1(REM+RATT)
#
#           VMOON = 1(REM-RATT)              VMOON =-1(RATT)
#
#           VSUN  = 1(RES)                   VSUN  = 1(RES-REM)
#
#           CEARTH=COS(SIN  (RE/RATT)+5)     CEARTH=COS 5
#
#           CMOON =COS 5                     CMOON =COS(SIN  CRM/RATT)+5)
#
#           CSUN  =COS 15                    CSUN  =COS 15
#
#           VEL/C = VSUN x ECLIPOL + VATT/C
#
# CALL:      DLOAD  CALL
#            DESIRED TIME
#            LOCSAM
#
# INPUTS:     MPAC = TIME
#
# OUTPUTS:    VEARTH, VMOON, VSUN, CEARTH, CMOON, CSUN, VEL/C
#
# SUBROUTINES: LSPOS, CSMCONIC
#
# DEBRIS:     VAC AREA, SEE SUBROUTINES.
#
# Page 749
#
#           SETLOC  P50S1
#           BANK
#
#           COUNT*  $$/S50
#
# LOCSAM      =      S50
# S50         STQ
#
#           QMAJ
# STCALL      TSIGHT
```

|            |        |          |
|------------|--------|----------|
|            |        | LSPOS    |
|            | STOVL  | VMOON    |
|            |        | 2D       |
|            | STODL  | VSUN     |
|            |        | TSIGHT   |
|            | STCALL | TDEC1    |
|            |        | CSMCONIC |
|            | SSP    | TIX,2    |
|            |        | S2       |
|            |        | 0        |
|            |        | MOONCNTR |
| EARTCNTR   | VLOAD  | VSU      |
|            |        | VMOON    |
|            |        | RATT     |
|            | UNIT   |          |
|            | STOVL  | VMOON    |
|            |        | RATT     |
|            | UNIT   | VCOMP    |
|            | STODL  | VEARTH   |
|            |        | RSUBE    |
|            | CALL   |          |
|            |        | OCCOS    |
|            | STODL  | CEARTH   |
|            |        | CSS5     |
|            | STOVL  | CMOON    |
|            |        | VSUN     |
|            | UNIT   |          |
|            | STCALL | VSUN     |
|            |        | ENDSAM   |
| MOONCNTR   | VLOAD  | VSR8     |
|            |        | VMOON    |
|            | VSR1   | BVSU     |
|            |        | VSUN     |
|            | UNIT   |          |
|            | STOVL  | VSUN     |
|            |        | VMOON    |
|            | VAD    | UNIT     |
|            |        | RATT     |
|            | VCOMP  |          |
|            | STOVL  | VEARTH   |
| # Page 750 |        |          |
|            |        | RATT     |
|            | UNIT   | VCOMP    |
|            | STODL  | VMOON    |
|            |        | RSUBM    |

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|          |        |                |     |                       |
|----------|--------|----------------|-----|-----------------------|
|          | CALL   |                |     |                       |
|          |        | OCCOS          |     |                       |
|          | STODL  | CMOON          |     |                       |
|          |        | CSS5           |     |                       |
|          | STOVL  | CEARTH         |     |                       |
|          |        | VSUN           |     |                       |
| ENDSAM   | VXV    |                |     |                       |
|          |        | ECLIPOL        |     |                       |
|          | STOVL  | VEL/C          |     |                       |
|          |        | VATT           |     |                       |
|          | VXSC   | VAD            |     |                       |
|          |        | 1/C            |     |                       |
|          |        | VEL/C          |     |                       |
|          | STODL  | VEL/C          |     |                       |
|          |        | CSSUN          |     |                       |
|          | STCALL | CSUN           |     |                       |
|          |        | QMAJ           |     |                       |
| OCCOS    | DDV    | SR1            |     |                       |
|          |        | 36D            |     |                       |
|          | ASIN   | DAD            |     |                       |
|          |        | 5DEGREES       |     |                       |
|          | COS    | SR1            |     |                       |
|          | RVQ    |                |     |                       |
|          | SETLOC | P50S           |     |                       |
|          | BANK   |                |     |                       |
| RSUBM    | 2DEC   | 1738090 B-29   | #   | MOON RADIUS IN METERS |
| RSUBE    | 2DEC   | 6378166 B-29   |     |                       |
| 5DEGREES | 2DEC   | .013888889     | #   | SCALED IN REVS        |
| 1/C      | 2DEC   | .000042699 B-1 | # * |                       |
| ECLIPOL  | 2DEC   | 0              | # * |                       |
|          | 2DEC   | -.00007896 B-1 | # * |                       |
|          | 2DEC   | .00018209 B-1  | # * | * FOR USE BY CSM ONLY |
| TSIGHT1  | 2DEC   | 24000          |     |                       |
| CEARTH   | =      | 14D            |     |                       |
| CSUN     | =      | 16D            |     |                       |
| CMOON    | =      | 18D            |     |                       |
| CSS5     | 2DEC   | .2490475       | #   | (COS 5)/4             |

# Page 751

CSSUN            2DEC    .24148            # (COS 15)/4

# Page 752

# PROGRAM NAME -- PICAPAR

DATE: DEC 20 66

# MOD 1

LOG SECTION: P51-P53

#

ASSEMBLY: SUNDISK REV40

# BY KEN VINCENT

#

# FUNCTION

#        THIS PROGRAM READS THE IMU-CDUS AND COMPUTES THE VEHICLE ORIENTATION  
#        WITH RESPECT TO INERTIAL SPACE. IT THEN COMPUTES THE SHAFT AXIS (SAX)  
#        WITH RESPECT TO REFERENCE INERTIAL. EACH STAR IN THE CATALOG IS TESTED  
#        TO DETERMINE IF IT IS OCCULTED BY EITHER EARTH, SUN OR MOON. IF A  
#        STAR IS NOT OCCULTED THEN IT IS PAIRED WITH ALL STARS OF LOWER INDEX.  
#        THE PAIRED STAR IS TESTED FOR OCCULTATION. PAIRS OF STARS THAT PASS  
#        THE OCCULTATION TESTS ARE TESTED FOR GOOD SEPARATION. A PAIR OF STARS  
#        HAVE GOOD SEPARATION IF THE ANGLE BETWEEN THEM IS LESS THAN 66 DEGREES  
#        AND MORE THAN 40 DEGREES. THOSE PAIRS WITH GOOD SEPARATION  
#        ARE THEN TESTED TO SEE IF THEY LIE IN CURRENT FIELD OF VIEW. (WITHIN  
#        33 DEGREES OF SAX). THE PAIR WITH MAX SEPARATION IS CHOSEN FROM  
#        THOSE WITH GOOD SEPARATION, AND IN FIELD OF VIEW.

#

# CALLING SEQUENCE

#        L        TC        BANKCALL

#        L+1      CADR      PICAPAR

#        L+2      ERROR RETURN -- NO STARS IN FIELD OF VIEW

#        L+3      NORMAL RETURN

#

# OUTPUT

#        BESTI, BESTJ -- SINGLE PREC, INTEGERS, STAR NUMBERS TIMES 6

#        VFLAG -- FLAG BIT SET IMPLIES NO STARS IN FIELD OF VIEW

#

# INITIALIZATION

#        1)        A CALL TO LOCSAM MUST BE MADE

#        2)        VEARTH = -UNIT(R) WHERE R HAS BEEN UPDATED TO APPROXIMATE TIME OF  
#        SIGHTINGS.

#

# DEBRIS

#        WORK AREA

#        X,Y,ZNB

#        SINCDU, COSCDU

#        STARAD -- STAR +5

COUNT    14/PICAP

SETLOC   P50S1

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```
PICAPAR      BANK
              TC      MAKECADR
              TS      QMIN
              TC      INTPRET
              CALL
                  CDUTRIG
              CALL
                  CALCSMSC

# Page 753

SETPD
              0
SET      DLOAD      # VFLAG = 1
              VFLAG
              DPZERO
STOVL    BESTI
              XNB
VXSC     PDVL
              SIN33
              ZNB
AXT,1    VXSC
              228D      # X1 = 37 X 6 + 6
              COS33
VAD
VXM      UNIT
              REFSMMAT
STORE    SAX      # SAX = SHAFT AXIS
SSP      SSP      # S1 = S2 = 6
              S1
              6
              S2
              6
PIC1     TIX,1    GOTO      # MAJOR STAR
              PIC2
              PICEND
PIC2     VLOAD*   CALL
              CATLOG,1
              OCCULT
BON      LXA,2
              CULTFLAG
              PIC1
              X1
PIC3     TIX,2    GOTO
              PIC4
              PIC1
PIC4     VLOAD*   CALL
              CATLOG,2
```

```

                                OCCULT
                                VLOAD*
                                CULTFLAG
                                PIC3
                                CATLOG,1
                                DOT*   DSU
                                CATLOG,2
                                CSS66      # SEPARATION LESS THAN 66 DEG.
                                BMN      DAD
                                PIC3
                                CSS6640    # SEPARATION MORE THAN 40 DEG.
                                BPL
                                PIC3
# Page 754
                                VLOAD*   DOT
                                CATLOG,1
                                SAX
                                DSU      BMN      # MAJOR STAR IN CONE
                                CSS33
                                PIC1
                                VLOAD*   DOT
                                CATLOG,2
                                SAX
                                DSU      BPL
                                CSS33
                                STRATGY
                                GOTO
                                PIC3
STRATGY      BONCLR
                                VFLAG
                                NEWPAR
                                XCHX,1   XCHX,2
                                BESTI
                                BESTJ
STRAT      VLOAD*   DOT*
                                CATLOG,1
                                CATLOG,2
                                PUSH      BOFINV
                                VFLAG
                                STRAT -3
                                DLOAD     DSU
                                BPL
                                PIC3
NEWPAR      SXA,1   SXA,2
                                BESTI
                                BESTJ

```



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```

                                GOTO
OCCULT                         MXV    PIC3
                                BVSU
                                CULTRIX
                                CSS
                                BZE
                                CULTED
                                BMN    SIGN
                                CULTED
                                MPAC +3
                                BMN    SIGN
                                CULTED
                                MPAC +5
                                BMN    CLRG0
                                CULTED
                                CULTFLAG
                                QPRET
CULTED                         SETG0
# Page 755
                                CULTFLAG
                                QPRET
CSS                             =      CEARTH
SIN33                          2DEC   .5376381241
COS33                          2DEC   .8431756920
CSS66                          2DEC   .060480472    # (COS76)/4
CSS6640                       2DEC   -.15602587     # (COS76 - COS30)/4
CSS33                          2DEC   .197002688    # (COS(1/2(76)))/4
PICEND                         BOFF   EXIT
                                VFLAG
                                PICGXT
                                TC      PICBXT
PICGXT                         EXIT
                                INCR   QMIN
PICBXT                         CA      QMIN
                                TC      SWCALL
#V1                            =      12D
```

# Page 756

# NAME -- R51 FINE ALIGN

# FUNCTION -- TO ALIGN THE STABLE MEMBER TO REFSSMAT

# CALLING SEQ -- CALL R51

```
# INPUT -- BESTI, BESTJ (PAIR OF STAR NO)
# OUTPUT -- GYRO TORQUE PULSES
# SUBROUTINES -- R52, R54, R55 (SXTNB, NBSM, AXISGEN)
```

```

COUNT 14/R51

R51      EXIT
        CAF  BIT1
        TS   STARIND
        TS   MARKINDX
R51.2    TC   INTPRET
R51.3    CLEAR CLEAR
        TARG2FLG
        TARG1FLG

        EXIT
        TC   PHASCHNG
        OCT  05024      # RESTART GR 4 FOR R52-R53
        OCT  13000
        INDEX STARIND
        CA   BESTI
        EXTEND
        MP   1/6TH
        TS   STARCODE
R51DSP    CAF  V01N70
        TC   BANKCALL
        CADR  GOFLASHR
        TC   GOTOP00H
        TC   +5
        TC   -5
        CAF  SIX
        TC   BLANKET
        TCF  ENDOFJOB
        TC   CHKSCODE
        TC   FALTON
        TC   R51DSP
        TC   INTPRET
        RTB  CALL
        LOADTIME
        PLANET
        SSP  LXA,1
        S1
        0
        STARIND
        TIX,1
        R51ST
        STCALL STARS2V2      # 2ND STAR
```

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```
R51ST      STORE      R51ST +1
# Page 757  STARS AV1    # 1ST STAR

EXIT
CS          MODREG      # IS THIS P54
AD          OCT66
EXTEND
BZF         R51B        # YES
TC          INTPRET
CALL
R51A      CALL      R52      # AOP WILL MAKE CALLS TO SIGHTING
# COMPUTE LOS IN SM FROM MARK DATA

SXTSM
STORE      STARS AV2
EXIT
TC          BANKCALL
CADR       MKRELEAS
TC          INTPRET
DLOAD      CALL
TSIGHT
PLANET

EXIT
CCS        STARIND
TC          R51.4
TC          INTPRET
MXV        UNIT
REFSMMAT
STORE      STARAD
VLOAD
STARS AV2
STOVL      6D
STARS AV1
STOVL      12D
PLANVEC
STCALL     STARAD +6
R54        # STAR DATA TEST
BOFF       CALL
FREEFLAG
R51K
AXISGEN
CALL
R55        # GYRO TORQUE
CLEAR
PFRATFLG
R51K      EXIT
CAF       OCT14
```

```

TC      BANKCALL
CADR    GOPERF1
TC      GOTOPOOH
TC      +2          # V33
TC      +3
TC      BANKCALL
CADR    P52C

# Page 758

TC      INTPRET
GOTO

R51.4   ENDP50S
TC      INTPRET
MXV     UNIT
REFSMMAT
STOVL   PLANVEC
STARSAV2
STORE   STARSAB1
SSP
STARIND
0
GOTO

R51B    R51.3
TC      INTPRET
CALL
R56
GOTO

R51A
OCT66   OCT      00066
V01N70  VN       0170
1/6TH   DEC      .1666667

# Page 759
# NAME:      R55      GYRO TORQUE
# FUNCTION -- COMPUTE AND SEND GYRO PULSES
# CALLING SEQ -- CALL R55
# INPUT -- X,Y,ZDC -- REFSMMAT WRT PRESENT STABLE MEMBER
# OUTPUT -- GYRO PULSES
# SUBROUTINES -- CALCGTA, GOFLASH, GODSPR, IMUFINE, IMUPULSE, GOPERF1

SETLOC  P50S
BANK
COUNT* $$/R55
R55     STQ
QMIN
CALL
CALCGTA

```

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```
PULSEM      EXIT
R55.1        CAF      V06N93
              TC       BANKCALL
              CADR     GOFLASH
              TC       GOTOPOOH
              TC       R55.2
              TC       R55RET
R55.2        TC       PHASCHNG
              OCT      00314
              CA       R55CDR
              TC       BANKCALL
              CADR     IMUPULSE
              TC       BANKCALL
              CADR     IMUSTALL
              TC       CURTAINS
              TC       PHASCHNG
              OCT      05024
              OCT      13000
R55RET       TC       INTPRET
              GOTO
              QMIN
V06N93       VN       0693
R55CDR       ECADR    OGC
R54          =       CHKSDATA
```

```
# ROUTINE NAME -- CHKSDATA          DATE -- JAN 9, 1967
# MOD NO -- 0                      LOG SECTION -- P51-P53
# MODIFICATION BY -- LONSKE        ASSEMBLY --
```

```
#
# FUNCTIONAL DESCRIPTION -- CHECKS THE VALIDITY OF A PAIR OF STAR SIGHTINGS.  WHEN A PAIR OF ST
# BY THE ASTRONAUT THIS ROUTINE OPERATES AND CHECKS THE OBSERVED SIGHTINGS AGAINST STORED STAR
# COMPUTER TO INSURE A PROPER SIGHTING WAS MADE.  THE FOLLOWING COMPUTATIONS ARE PERFORMED --
#      OS1      =      OBSERVED STAR 1 VECTOR
#      OS2      =      OBSERVED STAR 2 VECTOR
#      SS1      =      STORED STAR 1 VECTOR
#      SS2      =      STORED STAR 2 VECTOR
#      A1       =      ARCCOS(OS1 - OS2)
# Page 760
#      A2       =      ARCCOS(SS1 - SS2)
#      A        =      ABS(2(A1 - A2))
```

```
# THE ANGULAR DIFFERENCE IS DISPLAYED FOR ASTRONAUT ACCEPTANCE.
#
# EXIT MODE -- 1. FREEFLAG SET IMPLIES ASTRONAUT WANTS TO PROCEED
#              2. FREEFLAG RESET IMPLIES ASTRONAUT WANTS TO RECYCLE
#
```

```

# OUTPUT --      1. VERB 6,NOUN 3 -- DISPLAYS ANGULAR DIFFERENCE BETWEEN 2 SETS OF ST
#                2. STAR VECTORS FROM STAR CATALOG ARE LEFT IN 6D AND 12D.
#
# ERASABLE INITIALIZATION REQUIRED --
#                1. MARK VECTORS ARE STORED IN STARAD AND STARAD +6.
#                2. CATALOG VECTORS ARE STORED IN 6D AND 12D.
#
# DEBRIS --

                SETLOC P50S1
                BANK
                COUNT* $$/R50
CHKSDATA        STQ      SET
                QMIN
                FREEFLAG

CHKXSAB         AXC,1    # SET X1 TO STORE EPHEMERIS DATA
                STARAD

CHKSB           VLOAD*  DOT*      # CAL. ANGLE THETA
                0,1
                6,1
                SL1      ACOS
                STORE    THETA
                BOFF     INVERT    # BRANCH TO CHKSD IF THIS IS 2ND PASS
                FREEFLAG
                CHKSD
                FREEFLAG          # CLEAR FREEFLAG
                AXC,1  DLOAD      # SET X1 TO MARK ANGLES
                6D
                THETA
                STORE    18D
                GOTO

                CHKSB          # RETURN TO CAL. 2ND ANGLE
CHKSD           DLOAD    DSU
                THETA        # COMPUTE POS DIFF
                18D
                ABS         RTB
                SGNAGREE
                STORE      NORMTEM1
                SET        EXIT
                FREEFLAG
                CAF        ZERO
                TC         BANKCALL
                CADR       CLEANDSP

                CAF        VB6N5

```

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# Page 761

```
TC      BANKCALL
CADR    GOFLASH
TCF     GOTOPOOH
TC      CHKSDA      # PROCEED
TC      INTPRET
CLEAR   GOTO
        FREEFLAG
        QMIN
CHKSDA   TC      INTPRET
        GOTO
        QMIN
VB6N5    VN      605
```

```
# NAME -- CAL53A
# FUNCTION -- COARSE ALIGN THE IMU, IF NECESSARY
# CALLING SEQUENCE -- CALL CAL53A
# INPUT -- PRESENT GIMBAL ANGLES -- CDUX, CDUY, CDUZ
#          DESIRED GIMBAL ANGLES -- THETAD,+1,+2
# OUTPUT -- THE IMU COORDINATES AT STORED IN REFSMMAT
# SUBROUTINES -- 1.IMUCOARS, 2.IMUSTALL, 3CURTAINS
```

```
COUNT  14/R50
```

```
CAL53A   CALL
        S52.2      # MAKE FINAL COMP OF GIMBAL ANGLES
RTB      SSP
        RDCDUS     # READ CDUS
        S1
        1
AXT,1    SETPD
        3
        4
CALOOP   DLOAD*    SR1
        THETAD +3D,1
PDDL*    SR1
        4,1
DSU      ABS
PUSH     DSU
        DEGREE1
BMN      DLOAD
        CALOOP1
DSU      BPL
        DEG359
        CALOOP1
COARFINE EXIT
```

```

TC      PHASCHNG
OCT     04024
TC      BANKCALL
CADR    IMUCOARS      # PERFORM COARSE ALIGNMENT
TC      BANKCALL
CADR    IMUSTALL      # REQUEST MODE SWITCH

# Page 762

TC      CURTAINS
TC      BANKCALL
CADR    IMUFIN20
TC      BANKCALL
CADR    IMUSTALL
TC      CURTAINS      # TEST FOR MALFUNCTION
TC      INTPRET
RTB     VLOAD
        SET1/PDT
        ZEROVEC
STORE   GCOMP
SET     GOTO
        DRIFTFLG
        FINEONLY

CALOOP1 TIX,1
        CALOOP
FINEONLY AXC,1
        AXC,2
        XSM
        REFSMMAT

CALL    MATMOVE
GOTO    CAL53RET

MATMOVE VLOAD*      # TRANSFER MATRIX
        0,1
STORE   0,2
VLOAD*  6D,1
STORE   6D,2
VLOAD*  12D,1
STORE   12D,2
RVQ

DEGREE1 DEC      46
DEG359  DEC      16338
SETLOC  P50S
BANK
RDCDUS  INHINT      # READ CDUS
CA      CDUX

```



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```
INDEX  FIXLOC
TS      1
CA      CDUY
INDEX  FIXLOC
TS      2
CA      CDUZ
INDEX  FIXLOC
TS      3
RELINT
TC      DANZIG
```

# Page 763

# NAME: GIMB

#

# FUNCTION: DETERMINE AND COMPUTE THE DESIRED GIMBAL ANGLES TO BE USED FOR COARSE ALIGNMENT

#

# CALLING SEQUENCE: CALL GIMB

#

# INPUT: DESIRED IMU INERTIAL ORIENTATION VECTORS: XSMD, YSMD, ZSMD

#

# OUTPUT: GIMBAL ANGLES LEFT IN THETAD, +1, +2

#

# SUBROUTINES USED: 1.CDUTRIG 2.CALCSMSC 3.CALCGA

```
SETLOC  P50S2
BANK
COUNT  14/INFLT
```

```
CALCSMSC  DLOAD  DMP
           SINCDUY
           COSCDUZ
          DCOMP
          PDDL   SR1
           SINCDUZ
          PDDL   DMP
           COSCDUY
           COSCDUZ
          VDEF   VSL1
          STORE  XNB
          DLOAD  DMP
           SINCDUX
           SINCDUZ
          SL1
          STORE  26D
          DMP
           SINCDUY
```

```

PDDL    DMP
        COSCDUX
        COSCDUY

DSU
PDDL    DMP
        SINCDUX
        COSCDUZ

DCOMP
PDDL    DMP
        COSCDUX
        SINCDUY

PDDL    DMP
        COSCDUY
        26D

DAD      VDEF
VSL1
STORE    ZNB
VXV      VSL1
        XNB
STORE    YNB
RVQ

```

# NAME -- P51 -- IMU ORIENTATION DETERMINATION

# MOD. NO. 2 21 DEC 66

LOG SECTION -- P51-P53

# Page 764

# MOD BY STURLAUGSON

ASSEMBLY SUNDISK REV15

#

# FUNCTIONAL DESCRIPTION

# DETERMINES THE INERTIAL ORIENTATION OF THE IMU. THE PROGRAM IS SELECTED BY I  
# ROUTINE IS CALLED TO COLLECT THE CDU COUNTERS AND SHAFT AND TRUNNION ANGLES  
# THEN PROCESSED AS FOLLOWS.

#

# 1. SEXTANT ANGLES ARE COMPUTED IN TERMS OF NAVIGATIONAL BASE COORDINATES. I  
# TRUNNION ANGLES, RESPECTIVELY. THEN,

#

# 
$$\begin{matrix} - \\ V \end{matrix} = (\sin(TA) \cdot \cos(SA), \sin(TA) \cdot \sin(SA), \cos(TA)) \quad \text{(A COLUMN VECTOR)}$$

#

# NB  
# THE OUTPUT IS A HALF-UNIT VECTOR STORED IN STARM.

#

# 2. THIS VECTOR IN NAV. BASE COORDS. IS THEN TRANSFORMED TO ONE IN STABLE MEN

#

# 
$$\begin{matrix} - & T & T & T & - \\ V \end{matrix} = Q \begin{matrix} *Q & *Q & *Q \\ 1 & 2 & 3 \end{matrix} \begin{matrix} *V \\ \\ \end{matrix} \begin{matrix} \\ \\ NB \end{matrix}, \quad \text{WHERE}$$

#

# 
$$\begin{pmatrix} \cos(IG) & 0 & -\sin(IG) \end{pmatrix}$$

#

$$\begin{pmatrix} \end{pmatrix}$$

THE C

```

#      Q  = (   0       1       0   ), IG= INNER GIMBAL ANGLE
#      1  (                                     )
#      ( SIN(IG)   0   COS(IG) )
#
#      ( COS(MG) SIN(MG)   0   )
#      (                                     )
#      Q  = (-SIN(MG) COS(MG)   0   ), MG= MIDDLE GIMBAL ANGLE
#      2  (                                     )
#      (   0       0       1   )
#
#      (   1       0       0   )
#      (                                     )
#      Q  = (   0       COS(OG) SIN(OG) ), OG= OUTER GIMBAL ANGLE
#      3  (                                     )
#      (   0      -SIN(OG) COS(OG) )

```

THE CDU COUNTER  
ROT AND CDULOGI

3. THE STAR NUMBER IS SAVED AND THE SECOND STAR IS THEN SIMILARLY PROCESSED.

4. THE ANGLE BETWEEN THE TWO STARS IS THEN CHECKED AT CKSDATA.

5. REFSMMAT IS THEN COMPUTED AT AXISGEN AS FOLLOWS.

```

#      LET  $\bar{S}_1$  AND  $\bar{S}_2$  BE TWO STAR VECTORS EXPRESSED IN TWO COORDINATE SYSTEMS, A AND B
#
# Page 765
#      DEFINE,
#
#       $\bar{U}_A = \bar{S}_{A1}$ 
#
#       $\bar{V}_A = \text{UNIT}(\bar{S}_{A1} \times \bar{S}_{A2})$ 
#
#       $\bar{W}_A = \bar{U}_A \times \bar{V}_A$ 
#
#      AND,
#
#       $\bar{U}_B = \bar{S}_{B1}$ 
#
#       $\bar{V}_B = \text{UNIT}(\bar{S}_{B1} \times \bar{S}_{B2})$ 
#
#       $\bar{W}_B = \bar{U}_B \times \bar{V}_B$ 

```

```

#
#           THEN
#
#            $\bar{X} = U \begin{matrix} \bar{U} \\ B1 \end{matrix} + V \begin{matrix} \bar{V} \\ A \end{matrix} + W \begin{matrix} \bar{W} \\ B1 \end{matrix} + A \begin{matrix} \bar{A} \\ B1 \end{matrix}$ 
#
#            $\bar{Y} = U \begin{matrix} \bar{U} \\ B2 \end{matrix} + V \begin{matrix} \bar{V} \\ A \end{matrix} + W \begin{matrix} \bar{W} \\ B2 \end{matrix} + A \begin{matrix} \bar{A} \\ B2 \end{matrix}$  (REFSMAT)
#
#            $\bar{Z} = U \begin{matrix} \bar{U} \\ B3 \end{matrix} + V \begin{matrix} \bar{V} \\ A \end{matrix} + W \begin{matrix} \bar{W} \\ B3 \end{matrix} + A \begin{matrix} \bar{A} \\ B3 \end{matrix}$ 
#
# THE INPUTS CONSIST OF THE FOUR HALF-UNIT VECTORS STORED AS FOLLOWS
#
#            $\bar{S}$  IN 6-11 OF THE VAC AREA
#           A1
#
#            $\bar{S}$  IN 12-17 OF THE VAC AREA
#           A2
#
#            $\bar{S}$  IN STARAD
#           B1
# Page 766
#            $\bar{S}$  IN STARAD +6
#           B2
#
# CALLING SEQUENCE:
#
#           THE PROGRAM IS CALLED BY THE ASTRONAUT BY DSKY ENTRY.
#
# SUBROUTINES CALLED:
#
#           GOPERF3
#           GOPERF1R
#           GODSPR
#           IMUCOARS
#           IMUFIN20
#           R53
#           SXTNB
#           NBSM
#           MKRELEAS
#           CHKSDATA
#           MATMOVE
#
# ALARMS
#

```

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```
#      NONE
#
# ERASABLE INITIALIZATION:
#
#      IMU ZERO FLAG SHOULD BE SET.
#
# OUTPUT
#
#      REFSMMAT
#      REFSMFLG
#
# DEBRIS
#
#      WORK AREA
#      STARAD
#      STARIND
#      BESTI
#      BESTJ

          SETLOC  P50S1
          BANK
          COUNT   14/P5153

P53      EQUALS  P51
P51      CS      IMODES30
          MASK    BIT9
          CCS     A

# Page 767

          TC      P51A
          TC      ALARM
          OCT     210
          TC      GOTOP00H
P51A     TC      BANKCALL
          CADR    R02ZERO

P51AA    CAF     PRFMSTAQ
          TC      BANKCALL
          CADR    GOPERF1
          TC      GOTOP00H      # TERM.
          TC      P51B          # V33
          TC      PHASCHNG
          OCT     05024
          OCT     13000
          CAF     P51ZERO
          TS      THETAD        # ZERO THE GIMBALS
          TS      THETAD +1
```

|      |           |                                             |
|------|-----------|---------------------------------------------|
| TS   | THETAD +2 |                                             |
| CAF  | V6N22     |                                             |
| TC   | BANKCALL  |                                             |
| CADR | GODSPRET  |                                             |
| CAF  | V41K      | # NOW DISPLAY COARSE ALIGN VERB 41          |
| TC   | BANKCALL  |                                             |
| CADR | GODSPRET  |                                             |
| TC   | BANKCALL  |                                             |
| CADR | IMUCOARS  |                                             |
| TC   | BANKCALL  |                                             |
| CADR | IMUSTALL  |                                             |
| TC   | CURTAINS  | # CAGING OR BAD END                         |
| TC   | BANKCALL  | # SCHEDULE IFAILOK AND IMUFINED TASKS, IN 5 |
| CADR | IMUFIN20  | # AND 20 SECS. DIRECT RETURN AND NO STALL,  |
| TC   | BANKCALL  | # IF CAGING, BUT T4 WILL ZERO C/A ENABLE.   |
| CADR | IMUSTALL  | # IF PUT TO SLEEP, IMUFINED WILL WAKE US    |
| TC   | CURTAINS  | # UP.                                       |
| TC   | PHASCHNG  |                                             |
| OCT  | 05024     |                                             |
| OCT  | 13000     |                                             |
| TCF  | P51AA     | # COARSE ALIGN DONE: RECYCLE FOR FINE       |

# Page 768

# DO STAR SIGHTING AND COMPUTE NEW REFSMMAT

|      |       |          |                                      |
|------|-------|----------|--------------------------------------|
| P51B | TC    | PHASCHNG |                                      |
|      | OCT   | 00014    |                                      |
|      | TC    | INTPRET  |                                      |
|      | SSP   | SETPD    |                                      |
|      |       | STARIND  | # INDEX -- STAR 1 OR 2               |
|      |       | 0        |                                      |
|      |       | 0        |                                      |
|      | RTB   | VLOAD    |                                      |
|      |       | SET1/PDT |                                      |
|      |       | ZEROVEC  |                                      |
|      | STORE | GCOMP    |                                      |
|      | SET   | CLEAR    |                                      |
|      |       | DRIFTFLG | # ENABLE T4 COMPENSATION             |
|      |       | TARG2FLG | # SHOW MARK IS STAR --- NOT LANDMARK |
|      | EXIT  |          |                                      |
|      | CAF   | BIT1     |                                      |
|      | TS    | MARKINDX | # INITIALIZE FOR ONE MARK            |

|      |     |          |
|------|-----|----------|
| P51C | TC  | PHASCHNG |
|      | OCT | 05024    |
|      | OCT | 13000    |
|      | TC  | CHECKMM  |

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|            |       |          |                                    |
|------------|-------|----------|------------------------------------|
|            | MM    | 53       | # BACKUP PROGRAM                   |
|            | TCF   | P51C.1   | # NOT P53                          |
|            | TC    | INTPRET  |                                    |
|            | CALL  |          |                                    |
|            |       | R56      |                                    |
|            | GOTO  |          |                                    |
|            |       | P51C.2   |                                    |
| P51C.1     | TC    | INTPRET  |                                    |
|            | CALL  |          |                                    |
|            |       | R53      | # SIGHTING ROUTINE                 |
| P51C.2     | CALL  |          | # COMPUTE LOS IN SM FROM MARK DATA |
|            |       | SXTSM    |                                    |
|            | PUSH  |          |                                    |
|            | SLOAD | BZE      |                                    |
|            |       | STARIND  |                                    |
|            |       | P51D     |                                    |
|            | VLOAD | STADR    |                                    |
|            | STORE | STARSAV2 | # DOWNLINK                         |
|            | GOTO  |          |                                    |
|            |       | P51E     |                                    |
| P51D       | VLOAD | STADR    |                                    |
|            | STODL | STARSAV1 |                                    |
|            |       | TSIGHT   |                                    |
|            | CALL  |          |                                    |
|            |       | PLANET   |                                    |
|            | STORE | PLANVEC  |                                    |
| # Page 769 |       |          |                                    |
| P51E       | EXIT  |          |                                    |
|            | TC    | PHASCHNG |                                    |
|            | OCT   | 05024    |                                    |
|            | OCT   | 13000    |                                    |
|            | TC    | BANKCALL |                                    |
|            | CADR  | MKRELEAS | # ZERO MARKSTAT                    |
|            | CCS   | STARIND  |                                    |
|            | TCF   | P51F     | # STAR 2                           |
|            | TC    | PHASCHNG |                                    |
|            | OCT   | 05024    |                                    |
|            | OCT   | 13000    |                                    |
|            | CAF   | BIT1     |                                    |
|            | TS    | STARIND  |                                    |
|            | TCF   | P51C     | # GO DO SECOND STAR                |
| P51F       | TC    | PHASCHNG |                                    |
|            | OCT   | 05024    |                                    |
|            | OCT   | 13000    |                                    |
|            | TC    | INTPRET  |                                    |
|            | DLOAD | CALL     |                                    |

```

                                TSIGHT
                                PLANET
                                STOVL 12D
                                PLANVEC
                                STOVL 6D
                                STARS AV1
                                STOVL STARAD
                                STARS AV2
                                STCALL STARAD +6
                                CHKSDATA      # CHECK STAR ANGLES IN STARAD AND
                                BON  EXIT
                                FREEFLAG
                                P51G
                                TC  P51AA
P51G CALL
                                AXISGEN      # COME BACK WITH REFSMMAT IN XDC
                                AXC,1 AXC,2
                                XDC
                                REFSMMAT
                                CLEAR CALL
                                REFSMFLG
                                MATMOVE
                                SET  GOTO
                                REFSMFLG
                                ENDP50S
PRFMSTAQ = OCT15
P51ZERO  = ZERO
P51FIVE  = FIVE
V6N22    VN 0622
V41K     VN 4100
SET1/PDT CA TIME1
# Page 770
                                TS 1/PIPADT
                                TCF DANZIG

```

# Page 771

# SXTSM COMPUTES AN LOS VECTOR IN SM COORD FROM OCDU AND ICDU MARK DATA

```

                                SETLOC P50S3
                                BANK
SXTSM STQ
                                QMAJ
                                LXC,1 DLOAD*
                                MARKSTAT
                                OD,1
                                STORE TSIGHT

```



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```

      LXC,2  SLOAD*
            STARIND
            MKDNCDR,2
      LXC,2  VLOAD*
            MPAC
            0,1
      STORE 0,2
      DLOAD*
            5,1
      STORE 5,2
      CALL
            SXTNB          # COMPUTE LOS VECTOR FROM OCDU IN MKVAC
      LXA,1  INCR,1
            MARKSTAT
            2              # INCREMENT TO BASE ADR OF ICDU
      SXA,1  CALL
            S1
            NBSM          # TRANSFORM LOS TO SM
      GOTO
            QMAJ
MKDNCDR    ECADR  MARKDOWN
           ECADR  MARK2DWN
```

# Page 772

# PROGRAM DESCRIPTION: R53 -- SIGHTING MARK ROUTINE

# MOD. NO. 2

21 DEC 66

# MOD. BY STURLAUGSON

#

# FUNCTIONAL DESCRIPTION:

#

# TO PERFORM A SATISFACTORY NUMBER OF SIGHTING MARKS FOR THE REQUESTING PROGRAM (OR ROUTINE)  
# CAN BE MADE ON A STAR OR LANDMARK. WHEN THE CMC ACCEPTS A MARK IT RECORDS AND STORES 5  
# (OCDUS) AND THE TIME OF THE MARK.

#

# CALLING SEQUENCE:

#

# R53 IS CALLED AND RETURNS IN INTERPRETIVE CODE. RETURN IS VIA QPRET.  
# THERE IS NO ERROR EXIT IN THIS ROUTINE ITSELF.

#

# SUBROUTINES CALLED

#

# SXTMARK  
# OPTSTALL  
# GOFLASH

#

# ERASABLE INITIALIZATION:

```

#
#   TARGET FLAG -- STAR OR LANDMARK
#   MARKINDX -- NUMBER OF MARKS WANTED
#   STARIND -- INDEX TO BESTI OR BESTJ (STAR NUMBER)
#
# OUTPUT
#
#   MARKSTAT CONTAINS INDEX TO VACANT AREA WEHRE MARK DATA IS STORED
#   BESTI (INDEXED BY STARIND) CONTAINS STAR NUMBER SIGHTED.
#
# DEBRIS
#
#   MARKINDX CONTAINS NUMBER OF MARKS DESIRED

                SETLOC  RT53
                BANK

                COUNT   14/R53

R53             STQ      SET              # SET SIGHTING MARK FLAG
                R53EXIT
                R53FLAG

                EXIT
R53A            CA       MARKINDX         # NUMBER OF MARKS
                MASK     LOW3
                TC       BANKCALL
                CADR     SXTMARK
                TC       BANKCALL
                CADR     OPTSTALL
                TC       CURTAINS
                INDEX    MARKSTAT
                CCS      QPRET             # NUMNBER OF MARKS ACTUALLY DONE
                TCF      R53B
                TCF      +2               # ZERO
                TCF      +1               # CCS HOLE
                CAF      ZERO             # HOUSEKEEP VAC AREA SAVE
                XCH      MARKSTAT         #      AND MARKSTAT

# Page 773

                CCS      A
                INDEX    A
                TS       0
                TCF      R53A
R53B            TC       CHECKMM
                MM       22
                TCF      +2
                TCF      R53D

```

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|          |        |          |                         |
|----------|--------|----------|-------------------------|
|          | TC     | CHECKMM  |                         |
|          | MM     | 23       |                         |
|          | TCF    | R53C1    |                         |
|          | TCF    | R53D     |                         |
| R53C1    | CAF    | ZERO     |                         |
|          | TC     | BANKCALL |                         |
|          | CADR   | CLEANDSP |                         |
| R53C     | CAF    | V01N71   |                         |
|          | TC     | BANKCALL |                         |
|          | CADR   | GOFLASH  |                         |
|          | TC     | GOTOP00H | # TERM.                 |
|          | TCF    | R53Z     |                         |
|          | TC     | R53C     | # RECYCLE               |
| R53Z     | TC     | CHKSCODE |                         |
|          | TC     | FALTON   |                         |
|          | TC     | R53C     |                         |
|          | CS     | HIGH9    |                         |
|          | MASK   | STARCODE |                         |
|          | EXTEND |          |                         |
|          | MP     | SIGHTSIX |                         |
|          | XCH    | L        |                         |
|          | INDEX  | STARIND  |                         |
|          | TS     | BESTI    |                         |
| R53D     | TC     | INTPRET  |                         |
| R53OUT   | SETGO  |          |                         |
|          |        | TERMIFLG | # SET TERMINATE FOR R52 |
|          |        | R53EXIT  |                         |
| SIGHTSIX | =      | SIX      |                         |
| V01N71   | VN     | 0171     |                         |

# \*\*\*\*\* KEEP IN SAME BANK AS R51 AND R53 \*\*\*\*\*

|          |       |          |                     |
|----------|-------|----------|---------------------|
| CHKSCODE | CCS   | STARCODE |                     |
|          | AD    | NEG47    |                     |
|          | CCS   | A        |                     |
|          | TC    | Q        | # SC < 0 OR SC > 50 |
|          | TCF   | +2       | # SC = + OR - 0     |
|          | TCF   | +1       | # 0 <= SC < 50      |
|          | INDEX | Q        | # SC = 50           |
|          | TC    | 00002    |                     |
| NEG47    | OCT   | 77730    |                     |

# Page 774

# NAME -- S52.2

# FUNCTION -- COMPUTE GIMBAL ANGLES FOR DESIRED SM AND PRESENT VEHICLE

# CALL -- CALL S52.2

# INPUT -- X,Y,ZSMD

```
# OUTPUT -- OGC,IGC,MGC,THETAD,+1,+2
# SUBROUTINES -- CDUTRIG, CALCSMSC, MATMOVE, CALCGA
```

```

                                SETLOC S52/2
                                BANK
S52.2      COUNT 13/S52.2
            STQ
            QMAJ
            CALL
            CDUTRIG
            CALL
            CALCSMSC
            AXT,1 SSP
            18D
            S1
            6D
S52.2A     VLOAD* VXM
            XNB +18D,1
            REFSMMAT
            UNIT
            STORE XNB +18D,1
            TIX,1
S52.2.1    AXC,1 S52.2A
            XSM
            XSM
            CALL
            MATMOVE
            CALL
            CALCGA
            GOTO
            QMAJ
```

```
# Page 775
```

```
# PROGRAM NAME: SR52.1
```

```
DATE: DEC 20 1968
```

```
# MOD 1
```

```
LOG SEC: P51-P53
```

```
# BY KEN VINCENT
```

```
ASSEMBLY: SUNDISK REV 40
```

```
#
```

```
# FUNCTION
```

```
#
```

```
# TARG1 AND TARG2 FLAGS ARE LOOKED AT TO DETERMINE IF THE TARGET IS THE
# LEM, STAR, OR LANDMARK. IN CASE OF LEM OR LMK, THE PRESENT TIME PLUS
# 2 SECONDS IS SAVED IN AOPTIME (ALIAS STARAD, +1). IF THE LEM IS
# THE TARGET THEN CONIC UPDATES OF TEH CSM AND LEM ARE MADE TO
# THE TIME IN AOPTIME. THE UNIT OF THE DIFFERENCE OF LEM AND CSM
```

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```
# POSITION VECTORS BECOMES THE REFERENCE SIGHTING VECTOR USED IN THE
# COMMON PART OF THE THIS PROGRAM.
#
# IN THE CASE OF LANDMARK, THE CSM IS UPDATED CONICALLY.  THE RADIUS
# VECTOR FOR THE LANDMARK IS OBTAINED FROM LALOTORV.  BOTH OF THESE ARE
# FOUND FOR THE TIME IN AOPTIME.  THE UNIT OF THE DIFFERENCE BETWEEN
# THE LANDMARK AND CSM RADIUS VECTORS BECOMES THE REFERENCE SIGHTING
# VECTOR FOR THE COMMON PART OF THIS ROUTINE.
#
# IF A STAR IS THE TARGET, THE PROPER STAR IS OBTAINED FROM THE CATALOG
# AND THIS VECTOR BECOMES THE REFERENCE SIGHTING VECTOR.
#
# THE COMMON PART OF THIS PROGRAM TRANSFORMS THE REFERENCE SIGHTING
# VECTOR INTO STABLE MEMBER COORDINATES.  IT READS THE IMU-CDUS AND USES
# THIS DATA IN A CALL TO CALCSXA.  ON RETURN FROM CALCSXA A TEST IS
# MADE TO SEE IF THE TRUNNION ANGLE IS GREATER THAN 90DEG OR 38DEG.
# MADE TO SEE IF THE TRUNNION ANGLE IS GREATER THAN 90DEG. OR 50DEG.
#
# CALLING SEQUENCE
#
#           L+4      RETURN WHEN SHAFT OR TRUNION NOT WITHIN 5 DEG OF DESIRED
#           L        TC          BANKCALL
#           L+1      CADR        SR52.1
#           L+2      ERROR RETURN  TRUNNION GREATER THAN 90 DEG.
#           L+3      ERROR RETURN  TRUNNION GREATER THAN 50 DEG
#           L+4      NORMAL RETURN
#
# OUTPUT
#
#           SAC:      SINGLE PREC, 2'S COMP, SCALED AT HALF REVS -- SHAFT ANGLE DESIRED.
#           PAC:      SINGLE PREC, 2'S COMP, SCALED AT EIGHTH REVS -- TRUNNION ANGLE DESIRED.
#
# INITIALIZATION
#
#           IF TARG1FLG =1 THEN TARGET IS LEM -- NO OTHER INPUT REQUIRED.
#
#           IF TARG1FLG =0 AND TARG2FLG =0 THE TARGET IS STAR, STARIND SHOULD
#           0 OR 1 DENOTING BESTI OR BESTJ RESPECTIVELY AS STAR CODE.  STAR CODES
#           ARE 6 TIMES STAR NUMBER.
#
#           IF TARG1FLG =0 AND TARG2FLG =1 THEN TARGET IS LANDMARK.  SETT ROUTINE
#           LALOTORV FOR INPUT REQUIREMENTS.  HERE FIXERAD=1 FOR CONSTANT EARTH
#           RADIUS
#
# DEBRIS
#
```

# WORK AREA  
 # STARAD -- STAR+5 (STAR IS DESIRED LOS IN STABLE MEMBER COORDINATES)

COUNT\* \$\$/SR521  
 # Page 776

SETLOC SR52/1  
 BANK

SR52.1 TC MAKECADR  
 TS QMIN  
 TC INTPRET  
 RTB DAD  
 LOADTIME  
 1.3SECDP  
 STORE AOPTIME  
 BON BON  
 TARG1FLG  
 LEM52  
 TARG2FLG  
 LMK52

GOTO  
 STAR52

LEM52 DLOAD  
 AOPTIME  
 STCALL TDEC1  
 LEMCONIC  
 VLOAD  
 RATT

GOTO  
 LMKLMCOM

LMK52 BON DLOAD  
 ADVTRK  
 ADVTRACK  
 AOPTIME

CALL  
 LALOTORV

VLOAD  
 ALPHAV

LMKLMCOM STODL STAR  
 AOPTIME  
 STCALL TDEC1  
 CSMCONIC

VLOAD VSU  
 STAR  
 RATT

UNIT GOTO

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|            |       |                                       |                                          |
|------------|-------|---------------------------------------|------------------------------------------|
| STAR52     | SSP   | COM52<br>LXA,1<br>S1<br>0<br>STARIND  |                                          |
|            | TIX,1 | ST52ST                                |                                          |
|            | VLOAD | GOTO<br>STARSAV2                      |                                          |
| # Page 777 |       |                                       |                                          |
| ST52ST     | VLOAD | COM52<br>STARSAV1                     |                                          |
| COM52      | MXV   | UNIT<br>REFSMMAT                      |                                          |
|            | STORE | STAR                                  |                                          |
|            | SETPD | CALL<br>0<br>CDUTRIG                  | # COMPUTES SINES AND COSINES FOR CALCSXA |
|            | CALL  |                                       | # NOW EXPECT TO SEE THE CDU ANGLES.      |
|            | BOFF  | CALCSXA<br>EXIT<br>CULTFLAG<br>TRUN38 |                                          |
| TRUN38     | TC    | SR52E1                                |                                          |
|            | DLOAD | DSU<br>PAC<br>38TRDEG                 |                                          |
|            | BPL   | DLOAD<br>SR52E22<br>PAC               |                                          |
|            | DSU   | BPL<br>20DEGSMN<br>SR52E3             |                                          |
| SR52E22    | EXIT  |                                       |                                          |
|            | TC    | SR52E2                                |                                          |
| SR52E3     | EXIT  |                                       |                                          |
|            | INCR  | QMIN                                  |                                          |
| SR52E2     | INCR  | QMIN                                  |                                          |
| SR52E1     | CA    | QMIN                                  |                                          |
|            | TC    | SWCALL                                |                                          |
| 38TRDEG    | 2DEC  | .66666667                             | # CORRESPONDS TO 50 DEGS IN TRUNION      |
| 1.3SECDP   | 2DEC  | 130                                   |                                          |
| 20DEGSMN   | DEC   | -07199                                |                                          |

DEC -0

# Page 778

# THE ADVTRACK ROUTINE IS USED TO COMPUTE AN OPTICS LOS VECTOR TO  
 # A POINT ON THE GROUND TRACK 60 DEGREES FORWARD OF THE LOCAL VERTICAL  
 # OF AN ADVANCED ORBIT A SPECIFIED NUMBER OF REVOLUTIONS FROM NOW.

```

                                SETLOC 26P50S
                                BANK
ADVTRACK SETPD
                                0
                                VLOAD PUSH          # INITIALIZE FOR RP-TO-R
                                UNITZ              # UZ VEC IN PD 0-5
                                RTB PUSH           # TIME IN PD 6-7
                                LOADTIME
                                STCALL AOPTIME      # TIME ALSO IN AOPTIME FOR CSMCONIC
                                RP-TO-R           # GET MOON ROTATION VEC IN REF
                                STODL STAR
                                AOPTIME          # PICK UP TIME
                                STCALL TDEC1       # UPDATE STATE TO TIME
                                CSMCONIC
                                VLOAD VXV
                                VATT
                                RATT
                                UNIT
                                STOVL 24D         # SAVE -UNIT(VxR) FOR 2ND ROTATION
                                RATT
                                UNIT VCOMP
                                SETPD PUSH       # PUSH LOS=-UNIT(RVEC) PD 0-5
                                0
                                EXIT
                                CA LANDMARK
                                MASK SEVEN      # GET NUMBER OF ADVANCE PERIODS
                                EXTEND
                                MP BIT11        # GET N/16
                                XCH L
                                INDEX FIXLOC
                                TS 30D          # TEMP STORE N/16
                                TC INTERPRET
                                SLOAD DMP
                                30D
                                MPERIOD
                                STCALL AOPTIME    # ROTATE ANG ABOUT UR
                                ROTA
                                VLOAD
                                24D             # PICK UP 2ND ROTATION AXIS

```



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```

      STODL  STAR
              DP1/6
      DSU
      AOPTIME      # 2ND RAT ANGLE = 60 - A
      STCALL  AOPTIME
              ROTA      # GO ROTATE 2ND TIME
      VLOAD
# Page 779
      0
      STCALL  STAR      # STORE FINAL LOS IN STAR
              COM52     # RETURN TO SR52.1

ROTA      DLOAD  SIN
              AOPTIME
      PDVL   VXV      # PUSH 1/2SIN(A) PD 6-7
              STAR      #      UR VEC
              0          #      LOS
      VXSC   VSL2     # 1/2SIN(A)(URXLOS) PD 6-11
      PDVL   DOT
              STAR
              0
      VXSC   VSL2
              STAR
      PDDL   COS      # 1/2(UR . LOS)UR 12-17
              AOPTIME
      PDVL   BVSU     # PUSH 1/2COS(A) 18-19
              12D
              0
      VXSC   VSL1     # UP 18-19
      VAD    VAD      # UP 12-17 UP 6011
      UNIT   SETPD
              0
      PUSH   RVQ

DP1/6      2DEC      .16666666

MPERIOD    2DEC      .047619      # APPROX LUNAR ROT ANG IN 2HRS x 16

# Page 780
# NAME -- S52.3
# FUNCTION -- XSMD= UNIT(YSMD x ZSMD)
#             YSMD= UNIT(V X R)
#             ZSMD= UNIT(-R)
# CALL --     DLOAD   CALL
#             TALIGN
#             S52.3
```

```
# INPUT --      TIME OF ALIGNMENT IN MPAC
# OUTPUT --     X,Y,ZSMD
# SUBROUTINES -- CSMCONIC
```

```

                                SETLOC P50S2
                                BANK
S52.3                          COUNT 15/S52.3
                                STQ
                                QMAJ
                                STCALL TDEC1
                                CSMPREC
                                SETPD
                                0
                                VLOAD VCOMP
                                RATT
                                UNIT
                                STOVL ZSMD
                                VATT
                                VXV   UNIT
                                RATT
                                STORE YSMD
                                VXV   UNIT
                                ZSMD
                                STCALL XSMD
                                QMAJ
```

```
# Page 781
```

```
# PROGRAM DESCRIPTION: R56 -- ALTERNATE LOS SIGHTING MARK ROUTINE
```

```
#
```

```
# FUNCTIONAL DESCRIPTION
```

```
#
```

```
# TO PERFORM SIGHTING MARKS FOR THE BACK-UP ALIGNMENT PROGRAMS (P53,P54). THE
# COORDINATES (OPTICS) OF THE ALTERNATE LINE OF SIGHT HE MUST USE FOR THIS ROUT
# ENTER IN RESPONSE TO THE FLASHING V50 N25 R1-XXXXX THE CMC STORES THE THREE
# IN N92.
```

```
#
```

```
# CALLING SEQUENCE
```

```
#
```

```
# CALL
```

```
# R56
```

```
#
```

```
# SUBROUTINES CALLED
```

```
#
```

```
# A PORTION OF SXTMARK (VAC.AREA SEARCH)
```

```
# GOFLASH
```

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```
#      GOPERF1
#
# ERASABLE INITIALIZATION
#
#      STARIND:  INDEX TO STAR NUMBER
#
# OUTPUT
#
#      MARKSTAT:  INDEX TO VAC.AREA WHERE OUTPUT IS STORED.
#      BESTI (INDEXED BY STARIND) CONTAINS STAR NUMBER.
#      ICDU AND OCDU ANGLES IN VAC. AREA AS FOLLOWS:
#          VAC +2  CDUY
#          VAC +3  CDUS
#          VAC +4  CDUZ
#          VAC +5  CDUT
#          VAC +6  CDUX
#
#          COUNT*  $$/R56
#          SETLOC  P50S3
#          BANK
R56      STQ      EXIT
#          R53EXIT
#          CAF      V06N94B
#          TC       BANKCALL
#          CADR     GOFLASH
#          TC       GOTOP00H      # TERM.
#          TC       R56A          # PROCEED:  ANGLES OK
#          TC       -5            # ENTER:   NEW ANGLES
R56A     TC       BANKCALL
#          CADR     SXTMARK +2    # INHIBIR EXT VB ACT AND FIND VAC AREA
#
#          CAF      ZERO
#          TC       BANKCALL
#          CADR     CLEANDSP
#
R56A1    CAF      VB53          # DISPLAY V53 REQUESTING ALTERNATE MARK
#          TC       BANKCALL
# Page 782
#          CADR     GOMARK2
#          TCF      GOTOP00H      # V34:  TERMINATE
#          TCF      R56A1         # V33:  DON'T PROCEED -- JUST ENTER TO MARK
#          TC       INTPRET
#          DLOAD
#          MRKBUF1  +3
#          STODL    SAC
#          MRKBUF1  +5
```

|            |        |          |                                            |
|------------|--------|----------|--------------------------------------------|
|            | STORE  | PAC      |                                            |
|            | EXIT   |          |                                            |
|            | INHINT |          |                                            |
|            | EXTEND |          |                                            |
|            | DCA    | TIME2    |                                            |
|            | INDEX  | MARKSTAT |                                            |
|            | DXCH   | 0        |                                            |
|            | CA     | CDUY     | # ENTER: THIS IS A BACKUP SYSTEM MARK      |
|            | INDEX  | MARKSTAT |                                            |
|            | TS     | 2        |                                            |
|            | CA     | SAC      |                                            |
|            | INDEX  | MARKSTAT |                                            |
|            | TS     | 3        |                                            |
|            | CA     | CDUZ     |                                            |
|            | INDEX  | MARKSTAT |                                            |
|            | TS     | 4        |                                            |
|            | CA     | PAC      |                                            |
|            | INDEX  | MARKSTAT |                                            |
|            | TS     | 5        |                                            |
|            | CA     | CDUX     |                                            |
|            | INDEX  | MARKSTAT |                                            |
|            | TS     | 6        |                                            |
|            | RELINT |          |                                            |
|            | TC     | CLEARMRK | # ENABLE EXTENDED VERBS                    |
|            | CAF    | OCT16    |                                            |
|            | TC     | BANKCALL |                                            |
|            | CADR   | GOPERF1  |                                            |
|            | TC     | GOTOP00H | # TERM.                                    |
|            | TCF    | R56B     | # PROCEED: MARK COMPLETED                  |
|            | TCF    | R56A +2  | # RECYCLE: DO ANOTHER MARK -- LIKE REJECT. |
| R56B       | TC     | BANKCALL |                                            |
|            | CADR   | R53C1    |                                            |
| VB53       | VN     | 05300    | # ALTERNATE MARK VERB                      |
| V06N94B    | VN     | 00694    |                                            |
|            | SETLOC | P50S     |                                            |
|            | BANK   |          |                                            |
| PLANET     | STORE  | TSIGHT   |                                            |
|            | STQ    | CALL     |                                            |
|            |        | QMIN     |                                            |
|            |        | LOCSAM   |                                            |
|            | VLOAD  |          |                                            |
| # Page 783 |        | VEARTH   |                                            |
|            | STOVL  | OD       |                                            |
|            |        | VSUN     |                                            |

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|         |        |                |
|---------|--------|----------------|
|         | STOVL  | VEARTH<br>OD   |
|         | STORE  | VSUN           |
| NOSAM   | EXIT   |                |
|         | CS     | HIGH9          |
|         | MASK   | STARCODE       |
|         | EXTEND |                |
|         | MP     | SIGHTSIX       |
|         | XCH    | L              |
|         | INDEX  | STARIND        |
|         | TS     | BESTI          |
|         | CCS    | A              |
|         | TCF    | NOTPLAN        |
|         | CAF    | VNPLANV        |
|         | TC     | BANKCALL       |
|         | CADR   | GOFLASH        |
|         | TC     | GOTOPOOH       |
|         | TC     | +2             |
|         | TC     | -5             |
|         | TC     | INTPRET        |
|         | VLOAD  | VXSC           |
|         |        | STARSAV3       |
|         |        | 1/SQR3         |
|         | UNIT   | GOTO           |
|         |        | CORPLAN        |
| NOTPLAN | CS     | A              |
|         | AD     | DEC227         |
|         | EXTEND |                |
|         | BZMF   | CALSAM1        |
|         | INDEX  | STARIND        |
|         | CA     | BESTI          |
|         | INDEX  | FIXLOC         |
|         | TS     | X1             |
|         | TC     | INTPRET        |
|         | VLOAD* | GOTO           |
|         |        | CATLOG,1       |
|         |        | CORPLAN        |
| CALSAM1 | TC     | INTPRET        |
|         | LXC,1  | DLOAD*         |
|         |        | STARIND        |
|         |        | BESTI,1        |
|         | LXC,1  | VLOAD*         |
|         |        | MPAC           |
|         |        | STARAD -228D,1 |
| CORPLAN | VAD    | UNIT           |
|         |        | VEL/C          |

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```
                                GOTO
# Page 784
                                QMIN
DEC227                    DEC    227
VNPLANV                  VN     0688
1/SQR3                   2DEC    .57735021
```

This code is written to file `src/P51-P53.s`.

## A.75 P61-P67

1311

*<src/P61-P67.s 1311>≡*

```
# Copyright:   Public domain.
# Filename:    P61-P67.agc
# Purpose:     Part of the source code for Comanche, build 055. It
#              is part of the source code for the Command Module's
#              (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:  yaYUL
# Reference:   pp. 789-818
# Contact:     Ron Burkey <info@sandroid.org>
# Website:     http://www.ibiblio.org/apollo.
# Mod history: 2009-05-12 RSB   Adapted from Colossus249 file of the same
#              name and Comanche 055 page images.
#              2009-05-20 RSB   Corrections:  V06N68 -> V06N74, added missing
#              definition of V06N74, in several
#              interpreter operands fixed stuff like
#              N-M,1 to N -M,1
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#
#           Massachussets Institute of Technology
#           75 Cambridge Parkway
#           Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.

# Page 789
# PROGRAM:     P61
# MOD NO.:     0      MAR. 13, 1967
# MOD BY:      R. HIRSCHKOP
# MOD NO: 1    MOD BY:  RR BAIRNSFATHER      DATE: 22 JUN 67      RESTARTS
# MOD NO: 2    MOD BY:  RR BAIRNSFATHER      DATE: 17 JAN 68      COLOSSUS GSOP CHANGES
# MOD NO: 3    MOD BY:  RR BAIRNSFATHER      DATE:  8 MAY 68      DELETE CMSM MANEUVER (P
# FUNCTION:     TO CALCULATE AND DISPLAY EMS INITIALIZATION DATA
# CALLING SEQUENCE: BY V37
```

```

# EXIT:          TO P62
# SUBROUTINE CALLS: S61.1, S61.3, GOFLASH, FLAGUP, RO2BOTH
# ERASABLE INITIALIZATION:
#       EMSALT (-29) M          .05G ALTITUDE ABOVE FISCHER ELLIPSOID   PAD LOADED.
#       ALFAPAD /180          HYPERSONIC CM TRIM ANGLE OF ATTACK       PAD LOADED
# OUTPUT:        THE FOLLOWING REGISTERS ARE WRITTEN IN FOR USE BY DISPLAYS
#       GMAX      100 GMAX (-14) G,S          MAXIMUM ACCELERATION
#       VPRED     (-7) M/CS                   PREDICTED VELOCITY AT 400K FT
#       GAMMAEI   (GAMMA/360                  PREDICTED GAMMA      AT 400K FT
#       RTGO      THETAH/360                  RANGE ANGLE TO SPLASH FROM EMSALT
#       VIO       (-7) M/CS                   INERTIAL VELOCITY AT      EMSALT
#       TTE       (-28) CS                    TIME TO                      EMSALT
#       LAT(SPL)  /360                        TARGET LOCATION
#       LNG(SPL)  /360                        TARGET LOCATION
#       HEADSUP   (0)                        +1 = LIFT DOWN, -1 = LIFT UP
# DEBRIS:        SEE SUBROUTINES.

BANK      26
SETLOC    P60S
BANK

EBANK=    AOG

COUNT*   $$/P61

P61        CA      BIT14          # EXTENDED VERB SHOULD BE FREE THIS CLOSE
          TS      EXTVBACT        # TO V37
                                     # LOCK OUT EXTENDED VERBS SO CAN USE TFF
                                     # ROUTINES.  EXT VERB ERASE IS USED

          CS      ONE             # REMOVE IF HEADSUP EVER ON UPLINK DATA
          TS      HEADSUP         # PRELOAD

          TC      S61.1           # CHECK STATE VECTOR AND IMU ORIENTATION
                                     # RV 50GENRET. DOES PHASCHNG, GROUP 4.

          CA      V06N61          # LAT(SPL)      LNG(SPL)      HEADSUP
                                     # XXX.XX DEG     XXX.XX DEG     XXXXX.

          TC      BANKCALL
          CADR     GOFLASHR
          TC      GOTOP00H

# Page 790

          TC      P61.4
          TC      -5

P61.3      TC      PHASCHNG

```



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```
OCT      00014

TC      ENDOFJOB

P61.4    ZL
        CCS      HEADSUP      # C(HEADSUP)= +1/-1
        CA      BIT14        # IF HEADSUP POS,ROLLC =180 DEG.(LIFT DWN)
        NOOP        # IF HEADSUP NEG,ROLLC =0 (LIFT UP)
        DXCH      ROLLC      # ROLLC IS USED BY S62.3: GIM ANG AT .05G

NEWRVN   TC      INTPRET
        DLOAD
        PIPTIME      # SAVE TIME OF RN,VN TO DETERMINE IF AN
        STCALL      MM      # UPDATE HAS OCCURRED.
        STARTEN1     # INITIALIZE
        VLOAD
        RN
        STORE      RONE
        UNIT
        STOVL      URONE
        VN
        STORE      VONE
        VXV      UNIT
        URONE
        STORE      UNI
        DLOAD      DSU
        MM          # INITIAL VALUE OF PIPTIME
        PIPTIME
        BMN      CALRB
        NEWRVN     # UPDATED... GO TRY AGAIN
        S61.2      # GET DISPLAY DATA FOR N60 AND N63
                  # AND RETURN IN BASIC, BELOW.

P61.1    TC      CLEARMRK
        CA      V06N60      # GMAX          VPRED          GAMMAEI
                  # XXX.XX G      XXXXX. FPS      XXX.XX DEG

        TC      BANKCALL
        CADR      GOFLASH

        TC      GOTOPOOH
        TC      P61.2      # PROCEED
        TC      -5

P61.2    TC      INTPRET      # CORRECT TTE FOR TIME LAPSE DURING
                  # ABOVE DISPLAY.
        RTB      DSU
        LOADTIME      # CURRENT TIME.
```

# Page 791

```

          MM          # PIPTIME FOR RONE & VONE.
DAD
          TTE1        # NEGATIVE OF FREE FALL TIME.
STORE    TTE         # DECREMENTED

EXIT

CA        V06N63      # RTGO          VIO          TTE
          # XXXX.X NM   XXXXX. FPS      XXBXX M,S

TC        BANKCALL
CADR      GOFLASH
TC        GOTOPOOH
TC        +2
TC        P61.2       # REDO

```

# .... THEN FALL INTO P62

# Page 792

```

# PROGRAM:      P62
# MOD NO.:      0      MAR. 13, 1967
# MOD BY:       R. HIRSCHKOP
# MOD NO:  1    MOD BY:  RR BAIRNSFATHER      DATE: 21 MAR 67
# MOD NO:  2    MOD BY:  RR BAIRNSFATHER      DATE: 22 JUN 67      RESTARTS.
# MOD NO:  3    MOD BY:  RR BAIRNSFATHER      DATE: 17 JAN 68      COLOSSUS GSOI
# MOD NO:  4    MOD BY:  RR BAIRNSFATHER      DATE:  8 MAY 68      MOVE START OF
# FUNCTION:     1) TO NOTIFY CREW WHEN GNC SYSTEM IS PREPARED FOR CM/SM SEPARATION.
#               2) TO ORIENT THE CM TO THE CORRECT ATTITUDE FOR ATMOSPHERIC ENTRY.
# CALLING SEQUENCE: BY V37 OR DIRECTLY FROM P61
# EXIT:         TO P63
# ERASABLE INITIALIZATION:
#   ALFAPAD          LEFT BY PAD LOAD
#   LADPAD           LEFT BY PAD LOAD
#   LODPAD           LEFT BY PAD LOAD
#   LAT(SPL)         (MAY BE CHANGED BELOW)   LEFT BY DSKY, VIA P61
#   LNG(SPL)         (MAY BE CHANGED BELOW)   LEFT BY DSKY, VIA P61
#   HEADSUP          (MAY BE CHANGED BELOW)   LEFT BY DSKY, VIA P61
# SUBROUTINE CALLS:  NEWMODEX, S61.1, CM/DAPIC, CM/DAPON, R02BOTH, GOPERF1, GOFLASH,

```

COUNT\* \$\$/P62

```

TC        NEWMODEX      # MODE CHANGE IF CAME FROM P61.
MM        62            # MODE CHANGE AUTOMATIC VIA V 37.
CA        ONE
TS        DNLSTCOD

```

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|            |        |          |                                                 |
|------------|--------|----------|-------------------------------------------------|
| P62        | TC     | S61.1    | # CHECK STATE VECTOR AND IMU ORIENTATION.       |
|            | TC     | INTPRET  |                                                 |
|            | SSP    | RTB      |                                                 |
|            |        | POSEXIT  |                                                 |
|            |        | P62.3    | # CALCULATE DESIRED .05G GIMBAL ANGLES.         |
|            |        |          | # WITHOUT DISPLAY.                              |
|            |        | CM/DAPIC | # START CM/POSE AND BODY RATE CALC              |
|            |        |          | # DOES 2PHSCHNG, OCT 40116, OCT 05024, OCT 1300 |
|            |        |          | # CM/DAPIC SETS EBANK = EBAOG                   |
|            |        |          | # AND RETURNS IN BASIC TO P62.2.                |
| P62.2      | EXTEND |          |                                                 |
|            | DCA    | POSECADR | # CONTINUE WITH CM/POSE AFTER AV G.             |
|            | DXCH   | AVEGEXIT |                                                 |
|            | CAF    | OCT41    | # REQUEST SEPARATION                            |
|            | TC     | BANKCALL |                                                 |
|            | CADR   | GOPERF1R |                                                 |
|            | TC     | GOTOPOOH |                                                 |
|            | TC     | +3       | # PROCEED                                       |
| # Page 793 |        |          | # NOTE: NODOFLAG WILL BE SET IN CM/DAPON. ***   |
|            | TC     | -5       | # ENTER                                         |
|            | TC     | P61.3    | # FOR PHASCHNG AND ENDOFJOB                     |
|            | +3     | TC       |                                                 |
|            |        | POSTJUMP |                                                 |
|            | CADR   | CM/DAPON | # DISABLE RCS DAP, ENABLE ENTRY DAP AND         |
|            |        |          | # DO ATTITUDE HOLD.                             |
|            |        |          | # WILL IDLE UNTIL CM/POSE DOES ONE UPDATE.      |
|            |        |          | # CM/DAPON DOES NO PHASCHNG.                    |
| P62.1      | CA     | V06N61   | # LAT(SPL) LNG(SPL) HEADSUP                     |
|            |        |          | # XXX.XX DEG XXX.XX DEG 0000X.                  |
|            |        |          | # TERMINATE ATTITUDE HOLD. SET UP COMMANDS:     |
|            |        |          | # ROLL, ALFACOM, BETACOM. BEGIN MANEUVER TO     |
|            |        |          | # ENTRY ATTITUDE.                               |
|            | TC     | BANKCALL |                                                 |
|            | CADR   | GOFLASH  |                                                 |
|            | TC     | -3       |                                                 |
|            | TC     | +2       |                                                 |
|            | TC     | -5       |                                                 |

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SKIP  
# Page 794

WAKEP62

|     |          |
|-----|----------|
| TC  | PHASCHNG |
| OCT | 04024    |

```
# USE ENTRYVN FOR DISPLAY BELOW.
# EBANK WAS SET IN CM/DAPON TO EBAOG
```

|      |         |
|------|---------|
| CCS  | HEADSUP |
| CA   | BIT14   |
| NOOP |         |
| TS   | ROLLC   |
| CA   | ALFAPAD |
| ZL   |         |
| DXCH | ALFACOM |

```
# C(HEADSUP) = +/- 1
# IF HEADSUP POS, ROLL=180 DEG (LIFT)
# IF HEADSUP NEG, ROLL=0 DEG (LIFT)

# NOMINAL ALFATRIM PAD LOADED, NEG.

# SET ALFACOM = ALFA TRIM, BETACOM=0
```

|    |         |
|----|---------|
| CA | ONE     |
| TS | P63FLAG |

```
# PERMITS EXDAP2 TO CHANGE FLAG TO +
# AS INDICATOR.  STARTS UP P63.
```

|    |         |
|----|---------|
| CA | V06N22  |
| TS | ENTRYVN |

```
# SET UP DISPLAY FOR CDU DESIRED VAL
# FROM ENTRY ATTITUDE CALC, THAT IS
# ALREADY GOING.
```

|       |          |
|-------|----------|
| TC    | UPFLAG   |
| ADRES | ENTRYDSP |

```
# TURN ON ENTRY DISPLAY
# ENTRYDSP = 92D BIT 13 FLAG 6
```

|        |          |
|--------|----------|
| CS     | CMDAPMOD |
| MASK   | ONE      |
| EXTEND |          |
| BZF    | P63.1    |

```
# GO DIRECTLY TO P63 IF BODY ATTITUDE
# IS SUCH THAT THE DELAY TASK: WAKEP
# WILL BE OMITTED.
# DISABLE GRP 4, GO TO ENDOFJOB.
# (I.E., CONTINUE IF CMDAPMOD = -1,
```

TC P63

```
# PUT JOB TO SLEEP UNTIL VEHICLE MAN
# REDUCED ALFA TO +/-45 DEG. CONSIDER
# 65 DEG (25 DEG IF ALFA NEG) TO ALF
# OCCUR AT 3 DEG/SEC, AND TERMINATE
# TIME.
```

|        |        |
|--------|--------|
| CA     | PRI013 |
| TC     | NOVAC  |
| EBANK= | AOG    |
| 2CADR  | P63    |

```
# TASK WAKEP62 IS CALLED FROM ENTRY 1
```

TC TASKOVER

```
# EACH 2 SEC, CALCULATE GIMBAL ANGLE
# CONDITIONS THAT WILL HOLD IF REORIENT
# AT PRESENT RN, VN.  COME HERE FROM
```

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```
# IN KEPLER PHASE OF ENTRY.

P62.3      SSP      GOTO      # SET RETURN ADDRESS SO THAT ROUTINE
              QPRET      # GOES DIRECTLY TO ENTRY GUIDANCE EXIT
              ENDEXIT     # THAT DOES ENTRY DISPLAY, GRP 5.
              S62.3       # PUT DESIRED CDU VALUES IN CPHI'S FOR
                          # N22 DISPLAY.

# Page 795
#       P63
# PROGRAM:      P63
# MOD NO:       0      MAR. 13, 1967
# MOD BY:       R. HIRSCHKOP
# MOD NO: 1     MOD BY: RR BAIRNSFATHER      DATE: 22 JUN 67      RESTARTS
# MOD NO: 2     MOD BY: RR BAIRNSFATHER      DATE: 14 JUL 67      REVISED RESTARTS
# FUNCTION:     1) TO INITIALIZE THE ENTRY EQUATIONS.
#               2) TO CONTINUE TO HOLD THE CM TO THE CORRECT ATTITUDE WITH RESPECT TO THE ATMOS
#               THE ONSET OF ENTRY DECELERATION. ROLL ANGLE IS LIFT UP/DOWN AS SPECIFIED BY
#               3) TO SENSE .05G.
# CALLING SEQUENCE: DIRECTLY FROM P62
# EXIT:         TO ENDOFJOB
# SUBROUTINE CALLS: NEWMODEX, GODSPR

COUNT*  $$/P63

P63      TC      NEWMODEX
        MM      63

# ARRIVE WITH EBANK = AOG.

CA      ENTCADR      # CONTINUE AT STARTENT AFTER CM/POSE.

# AT END OF STATEMENT, CHANGE ADDRESS IN GOTOAD
# TO CONTINUE AT SCALEPOP THEREAFTER.

TS      POSEXIT

CA      V06N64      # G      VI      R TO SPLSH
# XXX.XX G      XXXX. FPS      XXXX.X NM
TS      ENTRYVN      # FOR DISPLAY CALL IN OVERNOUT

CS      ONE      # IN CASE FLAG IS LEFT AT +1 BY DAP. THE
TS      P63FLAG      # -1 ASSURES THAT EXO-ATM DAP WILL NOT
# CALL P63 OUT OF SEQUENCE IN P66.

TC      PHASCHNG      # THIS IS REQUIRED TO PRESERVE CLEANDSP
```

```
OCT      00004      # RETURN IN EVENT OF AN EXTENDED VER
TC      BANKCALL    # FLUSH 'N22' DISPLAY, IF ON, (OMIT
CADR     CLEANDSP    # DISPLAY DURING 'STARTENT' PASS.)

P63.1    TC      PHASCHNG
OCT      00004      # DISABLE.  DISPLAY RESTARTED VIA EN

TC      ENDOFJOB

V06N60   VN      0660
V06N61   VN      0661
V06N63   VN      0663
# Page 796
V06N64   VN      0664
ENTCADR  CADR     STARTENT

EBANK=   RTINIT     # TO CARRY OVER INTO ENTRY STEERING.
POSECADR 2CADR     CM/POSE

# Page 797
# PROGRAM: P64
# MOD NO: 1      SEPT. 19, 1967
# MOD BY: R. HIRSCHKOP
# MOD NO: 2    MOD BY: RR BAIRNSFATHER      DATE: 8 MAY 68      REVISED COMM
# FUNCTION: 1.  TO START ENTRY GUIDANCE AT .05G SELECTING ROLL ATTITUDE, CONSTAN
#           DRAG THRESHHOLD, KA, WHICH ARE KEYED TO THE .05G POINT.
#           2.  SELECT FINAL PHASE P67 IF V < 27000 FPS WHEN .2G OCCURS.
#           3.  ITERATE FOR UP-CONTROL SOLUTION P65 IF V > 27000 FPS AND IF ALTI
#           LEVEL CONDITIONS ARE SATISFIED.  ENTER P65 WHEN CONSTANT DRAG CO
#           AS PREDICTED TO WITHIN 25 NM OF DESIRED RANGE.
#           4.  SELECT FINAL PHASE P67 IF NO UP-CONTROL SOLUTION EXISTS WITH VI
# CALLING SEQUENCE: BY RTB FROM REENTRY CONTROL
# EXIT:      BACK TO REENTRY CONTROL.
# SUBROUTINE CALLS: NEWMODEX

BANK     25
SETLOC   P60S1
BANK

# THIS DISPLAY IS CALLED EACH PASS THROUGH STEERING.  RESTART PROTECTION IS VIA STEE

COUNT*  $$/P64

P64      TC      NEWMODEX      # ENTER VIA RTB WHEN .05G IS EXCEEDED
MM      64
```

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```

      CA      V06N74      # ROLLC      VI      D
      TS      ENTRYVN      # XXX.XX DEG      XXXXX. FPS      XXX.XX G
      TC      DANZIG      # DISPLAY VIA OVERNOUT.
      TC      DANZIG      # ... AND CONTINUE IN INITROLL ...

V06N74      VN      0674

# Page 798
# PROGRAM:      P65
# MOD NO:  0      MOD BY:  RR BAIRNSFATHER      DATE:  17 JAN 68      COLOSSUS GSOP ADDITION.
# FUNCTION:      TO CONTINUE ENTRY GUIDANCE, USING THE UP-CONTROL PHASE TO STEER TO A CONTROLLED
#                CONDITION.  THIS PHASE TERMINATES  A) IF D < Q7 FPSS, GOTO TO P66.
#                B) IF RDOT NEG, AND IF V < VL +500 FPS, GO TO P66.
# CALLING SEQUENCE:  BY RTB FROM REENTRY CONTROL
# EXIT:            BACK TO REENTRY CONTROL, OR TO ENDOFJOB.
# SUBROUTINE CALLS:  NEWMODEX

      COUNT*  $$/P65

P65      TC      NEWMODEX      # ENTER VIA RTB WHEN RANGE < 25 N M OF
      MM      65      # TARGET.

      CA      PRI013
      TC      NOVAC
      EBANK=  ENTRYVN
      2CADR   P65.1

      TC      2PHSCHNG      # 2 PHASE CHG REQUIRED TO PREVENT RE-
      OCT      00554      # STARTING FLASHING DISPLAY TWICE.
      OCT      10035      # 4.55 SPOT AND SERVICER, HERE.
      TC      INTPRET
      SSP      RTB
      GTOADDR      # CHANGE ENTRY MODE TO UPCONTRL.
      UPCONTRL
      REFAZE10      # GO HERE TO REESTABLISH ENTRY SEQUENCER.
      # AND CONTINUE AT UPCONTRL...

P65.1      TC      DOWNFLAG
      ADRES   ENTRYDSP      # ENTRYDSP = 92D BIT 13 FLAG 6

      CA      V16N69      # ROLLC      DL (Q7)      VL
      TC      BANKCALL      # XXX.XX DEG      XXX.XX G      XXXXX. FPS
      CADR    GOFLASHR
      TC      -3      # NODOFLAG IS SET ...
      TC      +3
```

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```

TC      -5
TC      P61.3      # EST. GRP 4 FOR DISPLAY AND DO ENDOR
                # IF PROCEED, CONTINUE

TC      UPFLAG
ADRES   ENTRYDSP   # ENTRYDSP = 92D BIT 13 FLAG 6

TC      P63.1      # DISABLE GRP 4, START UP ENTRY DISPI
                # N06V68 VIA OVERNOUT, AS USED IN P64

V16N69   VN      1669
```

```

# Page 799
# PROGRAM:      P66
# MOD NO: 0     MOD BY: RR BAIRNSFATHER      DATE: 17 JAN 68      COLOSSUS GSO
# FUNCTION:     KEEP CM ATTITUDE IN TRIM TO THE RELATIVE VELOCITY VECTOR.  ENTRY GUID
#              ROLL COMMANDS UNTIL DRAG BUILDS UP TO Q7+0.5 FPSS.
# CALLING SEQUENCE: VIA RTB FROM REENTRY CONTROL.
# EXIT:        BACK TO REENTRY CONTROL.
# SUBROUTINE CALLS:  NEWMODEX
```

COUNT\* \$\$/P66

```

P66      TC      NEWMODEX      # ENTER VIA RTB WHEN D < Q7 FPSS
        MM      66

        CA      V06N22      # OGA      IGA      MGA
                # XXX.XX DEG   XXX.XX DEG   XXX.X
        TC      P66END      # IN CASE CAME FROM P65, GO TO DISAB
                # AND SET ENTRYDSP TO DO DISPLAY VIA
                # OVERNOUT.

                # ... AND CONTINUE AT KEP2
```

```

# Page 800
# PROGRAM:      P67
# MOD NO:      0      MAR. 16, 1967
# MOD BY:      R. HIRSCHKOP
# FUNCTION:     TO TERMINATE STEERING WHEN THE CM VELOCITY WRT EARTH = 1000 FT/SEC
# CALLING SEQUENCE:
# EXIT:        TO POOH
# SUBROUTINE CALLS:  GOFLASH
```

# THIS DISPLAY IS CALLED EACH PASS THROUGH STEERING. RESTART PROTECTION IS VIA STEER

COUNT\* \$\$/P67

```

P67      TC      NEWMODEX      # ENTER VIA RTB
```



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|            |        |          |                                             |                       |
|------------|--------|----------|---------------------------------------------|-----------------------|
|            | MM     | 67       |                                             |                       |
|            | CA     | V06N66   | # ROLLC                                     | XRNGERR DNRNGERR      |
|            |        |          | # XXX.XX DEG                                | XXXX.X NM XXXX.X NM   |
| P66END     | TS     | ENTRYVN  | # DISPLAY VIA                               | OVERNOUT.             |
|            | TC     | UPFLAG   | # (IN CASE CAME FROM P65.                   | ENTRY DISPLAY         |
|            | ADRES  | ENTRYDSP | # WILL FLUSH FLASHING DISP.                 | IF STILL ON)          |
|            |        |          | # BIT 13 FLAG 6                             |                       |
| KILLGRP4   | TC     | PHASCHNG | # DISABLE GRP4, IN CASE CAME FROM HUNTEST.  |                       |
|            | OCT    | 00004    | # (COME TO KILLGRP4 VIA RTB, RET TO CALLER) |                       |
|            | TC     | DANZIG   | # ... AND CONTINUE AT PREDICT3 ...          |                       |
| V06N66     | VN     | 0666     |                                             |                       |
|            | BANK   | 26       |                                             |                       |
|            | SETLOC | P60S2    |                                             |                       |
|            | BANK   |          |                                             |                       |
| P67.1      | CA     | V16N67   | # RTOGO                                     | LAT LONG              |
|            |        |          | # XXXX.X NM                                 | XXX.XX DEG XXX.XX DEG |
|            | TC     | BANKCALL |                                             |                       |
|            | CADR   | GOFFLASH |                                             |                       |
|            | TC     | +3       | # EFFECTIVE GOTOP00H                        |                       |
|            | TC     | +2       |                                             |                       |
|            | TC     | P67.1    | # REDO                                      |                       |
|            | CS     | THREE    | # TURN OFF ENTRY DAP                        |                       |
|            | INHINT |          |                                             |                       |
|            | MASK   | CM/FLAGS | # CM/DSTBY, GAMDIFSW                        |                       |
|            | TS     | CM/FLAGS |                                             |                       |
|            | RELINT |          |                                             |                       |
|            | EXTEND |          |                                             |                       |
|            | DCA    | SERVCAD2 |                                             |                       |
| # Page 801 |        |          |                                             |                       |
|            | DXCH   | AVEGEXIT |                                             |                       |
|            | TCF    | GOTOP00H |                                             |                       |
| # Page 802 |        |          |                                             |                       |
| P67.2      | VLOAD  | CLEAR    | # CALC PRESENT LAT, LONG, ALT.              |                       |
|            |        | RN       |                                             |                       |
|            |        | ERADFLAG | # USE PAD RAD FOR ALT. (NOT SEEN ANYWAY)    |                       |
|            | STODL  | ALPHAV   |                                             |                       |
|            |        | PIPTIME  | # USE TIME OF RN                            |                       |

```

          CLEAR      CALL
                      LUNAFLAG
                      LAT-LONG
P67.3      RTB              # ENTRY EXIT THAT OMITTS DISPLAY.
                      SERVNOUT

V16N67     VN          1667
OCT41      =           33DEC
SERVCAD2    =           SERVCAD1

# Page 803
# SUBROUTINE NAME:      S61.1
# MOD NO:      0              DATE:      21 FEB 67
# MOD BY:      RR BAIRNSFATHER    LOG SECTION:  P61-P67
# MOD NO:      1      MOD BY: RR BAIRNSFATHER    DATE:      22 JUN 67
#
# FUNCTIONAL DESCRIPTION:      CALLED BY BOTH P61 AND P62
# FIRST, TEST TO SEE IF AVERAGEG IS ON. IF NOT, UPDATE THE STATE VECTOR TO P
# AND TURN ON AVERAGEG AT THAT TIME, AND CONTINUE. OTHERWISE CONTINUE: SEE
# WITHIN 30 DEG OF VAR. IF YES, EXIT SUBROUTINE S61.1. IF SO, SEE IF -Y AXIS
# 30 DEG OF VAR. IF YES, DISPLAY ALARM: 01427 IMU REVERSED.
# IF NO, DISPLAY ALARM: 01426 IMU UNSATISFACTORY.
# IN EITHER OF THESE LAST 2 CASES, WAIT 10 SEC AND THEN EXIT SUBROUTINE S61.1.
#
# REMARK:      THERE WILL BE A SHORT 10 SEC DELAY IF AN ALARM EXIT IS TAKEN. THE D
# AS SHORT AS CAN BE MADE, BUT IS ARBITRARY SINCE IT DEPENDS ON THE AGE
#
# CALLING SEQUENCE:      CALL
#                          S61.1
#
# C(MPAC) UNSPECIFIED
# PUSHLOC UNSPECIFIED
#
# SUBROUTINES CALLED:      LOADTIME, CSMPREC, TPAGTREE,
#                          WAITLIST, JOBSLEEP, JOBWAKE, PREREAD, ALARM, GODSPR, BANKCAL
#
# NORMAL EXIT MODES:      RVQ
#
# ALARMS:      01426 IMU UNSATISFACTORY
#              01427 IMU REVERSED
#
# OUTPUT:      POSSIBLE ALARMS
#              POSSIBLY TDEC1, RATT, VATT, RN, VN
#
# ERASABLE INITIALIZATION REQUIRED:
# AVEGFLAG      AVERAGEG ON OR OFF

```

LEFT

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```
#      PIPTIME  (-28) CS      TIME OF PIPA UPDATE      LEFT BY READACC
#      RN      (-29) M      STATE VECTOR      LEFT BY AVERAGE
#      VN      (-7) M/CS      STATE VECTOR      LEFT BY AVERAGE
#      REFSMMAT  (-1)      .5 REF TO SM MATRIX      LEFT BY LAST IM
#
# DEBRIS:      QPRET
#      POSSIBLY PIPTIME1, RATT, VATT, TDEC1, RN1, VN1, QTEMP, X1      IF UPDATED
#      PUSH LIST LOCS USED BY CSMPREC

      EBANK=  AOG      # FOR 60GENRET, S61DT
      BANK    26
      SETLOC  P60S3
      BANK

      COUNT*  $$/S61.1

S61.1      EXTEND
      QXCH    60GENRET      # SAVE RET ADDR IN EB 6
      TC      BANKCALL
      CADR    R02BOTH
      TC      INTPRET

# Page 804

      BON     CALRB
      AVEGFLAG      # IS AVERAGEG ON
      S61.1A      # YES
      MIDTOAV2      # GET FUTURE STATE VECTOR SOON AS CAN

      CA      MPAC +1      # RETURN INHINTED ***
      TS      S61DT      # FOR RESTART.
      TC      WAITLIST
      EBANK=   DVCNTR
      2CADR    S61.1C

      TC      PHASCHNG
      OCT     40434
      TC      ENDOFJOB

S61.1C      CA      PRI013
      TC      FINDVAC
      EBANK=   AOG
      2CADR    S61.1A  -1

      EXTEND
      DCA      SERVCAD1      # HE WHO START AVERAGEG MUST SERVICE
      DXCH     AVEGEXIT      # THE EXIT.
```

|            |       |           |                             |
|------------|-------|-----------|-----------------------------|
|            | TC    | 2PHSCHNG  |                             |
|            | OCT   | 00454     |                             |
|            | OCT   | 00415     |                             |
|            | CA    | EBENTRY   | # SET EB= 7 FOR PREREAD.    |
|            | TS    | EBANK     |                             |
|            | TC    | POSTJUMP  |                             |
|            | CADR  | PREREAD   | # PREREAD DOES TC TASKOVER. |
| S61.1A     | TC    | INTPRET   |                             |
|            | BOVB  | VLOAD     |                             |
|            |       | TCDANZIG  | # TURN OFF OVFINd, IF ON    |
|            |       | VN        | # VN (-7) M/CS              |
|            | VXV   | MXV       |                             |
|            |       | RN        | # RN (-29) M                |
|            |       | REFSMMAT  | # .5 UNIT MATRIX            |
|            | UNIT  | DLOAD     |                             |
|            |       | MPAC +3   | # GET COS(THETA)/2          |
|            | BMN   | DAD       |                             |
|            |       | S61.1B    | # DO TEST ON -YSM           |
|            |       | C(30)LIM  | # = 1.0 - .5 COS(30)        |
|            | BOVB  | RTB       |                             |
|            |       | RETRN1    |                             |
|            |       | RETRN3    |                             |
| # Page 805 |       |           |                             |
| S61.1B     | DCOMP | DAD       |                             |
|            |       | C(30)LIM  | # = 1.0 - .5 COS(30)        |
|            | BOVB  | EXIT      |                             |
|            |       | RETRN2    |                             |
| RETRN3     | TC    | ALARM     |                             |
|            | OCT   | 01426     | # IMU UNSATISFACTORY        |
|            | TC    | RETRN2 +2 |                             |
| RETRN2     | TC    | ALARM     |                             |
|            | OCT   | 01427     | # IMU REVERSED              |
| +2         | CAF   | V05N09    |                             |
|            | TC    | BANKCALL  |                             |
|            | CADR  | GODSPR    | # DO DISPLAY                |
|            | CA    | 10SECS    |                             |
|            | TC    | BANKCALL  |                             |
|            | CADR  | DELAYJOB  |                             |
| RETRN1     | TC    | 60GENRET  |                             |

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SERVCAD1           EBANK= DVCNTR  
                  2CADR   SERVEXIT

C(30)LIM           2DEC   .566985           # = 1.0 - .5 COS(30)

10SECS           DEC   1000           # 1000 CS

60SECDP           2DEC   6000 B-28       # 6000 CS

# Page 806

# PROGRAM NAME:           S61.2                   DATE:           14 FEB 67

# MOD NO:           1                   LOG SECTION:    P61-P67

# MOD BY:           NORTH / BAIRNSFATHER

# MOD NO: 2       MOD BY: NORTH/BAIRNSFATHER       DATE: 11 MAY 67

ADD 2ND ITER FOR ERAD A

# MOD NO: 3       MOD BY: RR BAIRNSFATHER       DATE: 21 NOV 67

VARIABLE MU ADDED.

# MOD NO: 4       MOD BY: RR BAIRNSFATHER       DATE: 21 MAR 68

DIFFERENT EARTH/MOON SC

#

# FUNCTIONAL DESCRIPTION: CALLED IN P61. PROVIDES DISPLAYS FOR NOUNS N60 AND N63 .

#       PROGRAM CALCULATES ENTRY DISPLAY OF MAXIMUM ACCELERATION EXPECTED (GMAX) AND ALSO THE

#       INERTIAL VELOCITY (VPRED) AND ENTRY ANGLE (GAMMAEI) THAT WILL OBTAIN AT 400K FT ABOVE

#       ELLIPSOID. PROGRAM ALSO CALCULATES A SECOND DISPLAY RELATIVE TO THE EMSALT ABOVE FIS

#       AND CONSISTS OF RANGE TO SPLASH FOM NOW (RTGO) , PREDICTED INERTIAL VELOCITY (VIO) ,

#       GO FROM NOW (TTE) .

#

# CALLING SEQUENCE:    CALL

#

S61.2

#

C(MPAC) UNSPECIFIED

#

PUSHLOC WILL BE SET TO ZERO.

#

# SUBROUTINES CALLED:   TFFCONIC, CALCTFF, TFF/TRIG, FISHCALC, GETERAD, VGAMCALC

#

# NORMAL EXIT MODES:   RTB, P61.1

#

# ALARMS:           NONE

#

# OUTPUT:           THE FOLLOWING REGISTERS ARE WRITTEN IN FOR USE BY DISPLAYS

#       GMAX   100 GMAX (-14) G,S           MAXIMUM ACCELERATION

#       VPRED   (-7) M/CS           PREDICTED VELOCITY AT 400K FT

#       GAMMAEI GAMMA/360           PREDICTED GAMMA    AT 400K FT

#                                   FOR TM, DP(GAMMAEI) = (GAMMAEI, RTGO) / 360

#       RTGO   THETAH/360           RANGE ANGLE TO SPLASH FROM EMSALT       EMSALT

#       VIO    (-7) M/CS           INTERTIAL VELOCITY AT       EMSALT       EMSALT

#       TTE    (-28) CS           TIME TO                   EMSALT       EMSALT

#

PUSHLOC = 0

#

CONIC PARAMETERS STORED IN VAC AREA (SEE TFF SUBROUTINES)

#

## # ERASABLE INITIALIZATION REQUIRED:

|   |         |                                                    |                                       |
|---|---------|----------------------------------------------------|---------------------------------------|
| # | RONE    | (-29) M                                            | STATE VECTOR                          |
| # | VONE    | (-7) M/CS                                          | STATE VECTOR                          |
| # | URONE   | UR/2                                               |                                       |
| # | UNI     | (-1)                                               | UNIT NORMAL V*R                       |
| # | THETAH  | THETAH/360                                         | RANGE ANGLE                           |
| # | UNITW   | (0)                                                | UNIT POLAR VECTOR                     |
| # | EMSALT  | (-29) M                                            | EMS INTERFACE ALTITUDE                |
| # |         |                                                    | ORBITAL REENTRY: 284843 FT., LUNAR RE |
| # |         |                                                    |                                       |
| # | DEBRIS: | QPRET,                                             |                                       |
| # |         | ALL PDL LOCATIONS ABOVE 12D, INCLUDING X1,X2,S1,S2 |                                       |
| # |         | ALSO PDL+0 ... PDL+5, WHERE INITIAL PUSHLOC = PDL  |                                       |

## # Page 807

# THE FOLLOWING PUSH LIST LOCATIONS HAVE BEEN RESERVED FOR TFF ROUTINES AND ARE REPEATED  
 # OF COURSE FOR S61.2 USAGE, EARTH ORIGIN SCALING IS USED.

|   |           |   |       |                                    |                                |      |
|---|-----------|---|-------|------------------------------------|--------------------------------|------|
| # |           |   | BELOW | E:                                 | IS USED FOR EARTH ORIGIN SCALE |      |
| # |           |   |       | M:                                 | IS USED FOR MOON ORIGIN SCALE  |      |
| # |           |   |       |                                    |                                |      |
| # | RTERM     | = | 18D   | TERMINAL RADIUS M                  | E: (-29)                       | M: 0 |
| # | NRTERM    | = | 16D   | TERMINAL RADIUS M                  | E: (-29+NR)                    |      |
| # |           |   |       |                                    | M: (-27+NR)                    |      |
| # | RMAG1     | = | 12D   | PRESENT RADIUS M                   | E: (-29)                       | M: 0 |
| # | NRMAG     | = | 32D   | PRESENT RADIUS M                   | E: (-29+NR)                    |      |
| # |           |   |       |                                    | M: (-27+NR)                    |      |
| # | SDELF/2   |   |       | SIN(THETA) / 2                     |                                |      |
| # | CDELF/2   | = | 14D   | COS(THETA) / 2                     |                                |      |
| # | TFFX      | = | 34D   | X, ARGUMENT OF SERIES T(X)         |                                |      |
| # | TFFTEM    | = | 36D   | ARG FOR TRANSFER ANGLE CALCULATION |                                |      |
| # | TFFNP     | = | 28D   | LC P M                             | E: (-38+2NR)                   | M: 0 |
| # | TFF/RTMU= |   | 30D   | 1/SQRT(MU)                         | E: (17)                        | M: 0 |
| # | TFFVSQ    | = | 20D   | -(VN.VN/MU) 1/M                    | E: (20)                        | M: 0 |

## # Page 808

BANK 34  
 SETLOC P60S2  
 BANK

COUNT\* \$\$/S61.2

# PDL LEFT AT ZERO BY TARGETING

S61.2 DLOAD DSU  
 EMSALT  
 290KFT

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```
CALLCON      BPL      DLOAD
              LUNENT
              1/RTMU      # ESTABLISH MU FOR ORBITAL ENTRIES
              CALL
              TFFCONIC    # FILL VAC AREA WITH CONIC PARAMETERS
              DLOAD      CALL
              RTRIAL      # 1ST GUESS AT TERMINAL RADIUS  (-29)
              CALCTFF     # SAVES MPAC IN RTERM          (18D)
              CALL
              TFF/TRIG    # CALC SDELFF/2, CDELFF/2
              # RETURN WITH S(THETA) IN MPAC
              CALL
              FISHCALC    # GET FISCHER RADIUS          (-29) M
              # ANS IN MPAC AND IN ERADM
              DAD         CALL
              EMSALT
              CALCTFF     # SAVES MPAC IN RTERM          (18D)
              DCOMP
              STORE      TTE1    # NEGATIVE AS IN COUNTDOWN
              # DECR TTE FROM BASB TTE1.  (RESTART)
              # DNLIST AND DSKY WILL USE TTE.
              STCALL     TTE     # LET MISS CONTRL DECR BY ELAPSED TIME
              # TTE= TIME FROM NOW TO EMSALT +FISCHER
              TFF/TRIG    # S(THETA) IN MPAC ON RETURNING
              # AND THETA= RANGE FROM NOW TO EMSALT
              CALL
              FISHCALC
              CALL
              VRCALC
              CALL
              DISPTARG
              CALL
              DISPTARG
              STCALL     RTGO
              VGAMCALC
              DMP
              # MPAC = GAMMA
              # PDLO HAS VGAM.
              BDDV      DAD
              VEMSCON    # -HS D 180/PI  (-14)
              0          # VGAM FROM PDLO
```

# Page 809

```

          STODL  VIO          # PREDICTED VELOCITY AT EMSALT.

                                # GAMMA AND VGAM AT 300K FT ARE REQUIRED BY C
                                # ALGORITHM.

          ERADM              # EARTH RADIUS FROM GETERAD (-29) M
                                # = FISCHER RADIUS (-29)

          DAD
          300KFT             # M (-29)
          STCALL  RTERM      # TERMINAL RADIUS M (-29)

          PREVGM             # VGAMCALC WITH NEW RTERM

                                # VBAR = (V(FPS) - 36KF/S) / 20 F/S
# GMAX = (4/(1 + 4.8 VBARSQ))(GAM - 6.05 - 2.4 VBARSQ) - 10(L/D - .3) + 10    ASSUM

# GMAXCALC
          PDDL   DSU          # GAM TO PDL2
                                # VGAM IS IN PDL0 (-7)
                                # (-7) M/CS
          DDV    DSQ          # (-6) M/CS
          STORE  0            # VBARSQ (-2) TO PDL0

          DMP     DAD
          KR1
                                # GAM, POS DOWN, FROM PDL2

          DAD     DMP
          -6.05DEG
          KR2
          PDDL    PDDL        # XCH PDL+0 FOR VBARSQ (-2)
          DDV     DAD
          KR4
          DP2(-4)
          BDDV
                                # NUM FROM PDL+0

          DAD     BPL
          KR3
          +3
          DLOAD
          HI6ZEROS
          STODL   GMAX        # 100 GMAX (-14)

# Page 810
# DISPLAY USES GMAX AS SP, SO LO WORD IS WRITTEN OVER BY VPRED.
          ERADM              # = FISCHER RADIUS (-29) M

```



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|          |        |                                             |                                             |
|----------|--------|---------------------------------------------|---------------------------------------------|
|          | DAD    | CALL                                        | # 2 ND ITERATION FOR FISCHER RADIUS         |
|          |        | 400KFT                                      |                                             |
|          |        | CALCTFF                                     | # ESTABLISH TRANSFER ANGLE DATA.            |
|          | CALL   |                                             |                                             |
|          |        | TFF/TRIG                                    | # GET SIN, COS DELF                         |
|          | CALL   |                                             |                                             |
|          |        | FISHCALC                                    | # GET CORRESPONDING FISCHER RADIUS.         |
|          | DAD    | LXA,2                                       | # SAVE HI-WORD FOR DOWNLIST.                |
|          |        | 400KFT                                      | # M (-29)                                   |
|          |        | RTGO                                        | # (RANGE ANGLE FROM EMSALT) / 360           |
|          | STCALL | RTERM                                       |                                             |
|          |        | PREVGAM                                     | # VGAMCALC WITH NEW RTERM                   |
|          | DCOMP  | SXA,2                                       | # HI-WORD OF EACH ON DOWNLIST.              |
|          |        | MPAC +1                                     |                                             |
|          | STODL  | GAMMAEI                                     | # CONIC GAMMA/360 AT 400K FT. (HI-WORD)     |
|          |        |                                             | # CONIC RTGO/360 FROM EMSALT (LOW-WORD)     |
|          |        |                                             | # FOR TM, DP(GAMMAEI) = (GAMMA, RTGO) / 360 |
|          |        |                                             | # VGAM FROM PDL+0 (-7)                      |
|          | STADR  |                                             |                                             |
|          | STORE  | VPRED                                       | # CONIC VELOCITY AT 400K FT                 |
|          | RTB    |                                             |                                             |
|          |        | P61.1                                       |                                             |
|          |        |                                             | # PDL BACK TO ZERO.                         |
| LUNENT   | DLOAD  | GOTO                                        |                                             |
|          |        | 1/RTMUE                                     | # ESTABLISH MU FOR LUNAR TYPE ENTRIES       |
|          |        | CALLCON                                     |                                             |
| 290KFT   | 2DEC   | 88392.0 B-29                                |                                             |
| KTETA1   | 2DEC*  | .421844723 E2 B-14* # 110 2PI/16384(163.84) |                                             |
| 36KFT/S  | 2DEC   | 109.728 B-7                                 | # (-7) M/CS = 36 KFT/S (-7)                 |
| 20KFT/S  | 2DEC   | 121.92 B-7                                  | # (-6) M/CS = 2 20KFT/S (-7)                |
| KR1      | 2DEC   | -.026666667                                 | # = -2.4 4 / 360                            |
| -6.05DEG | 2DEC   | -.016805556                                 | # = -6.05 / 360                             |
| KR2      | 2DEC   | .54931641                                   | # = (360/4) 100 (-14) = 9000 B-14           |
| KR3      | 2DEC   | 1000 B-14                                   | # = 100 (10.0) (-14) G,S                    |

# Page 811

```

# ASSUMES L/D = 0.3, BANK =0.
RTRIAL      2DEC      6460097.18 B-29 # RPAD +264643 FT =21 194 545 FT
400KFT      2DEC      121920 B-29   # RPAD DEFINED AS 20 909 901.57 FT =6 373 330
# METERS
# 300KFT     2DEC      91440 B-29    # (-29) M
# EMSALT     2DEC      86759.2 B-29  # 284643 FT (-29) M      (ORBITAL REENTRY)
# EMSALT     2DEC      90657 B-29    # 297431 FT (-29) M      (LUNAR REENTRY)
KR4          2DEC      .833333333
300KFT       EQUALS    MINPERE
VEMSCON      2DEC      -.0389676 B-14 # = -HS D / 2 PI (-14) M SQ / CS SQ
# = -16369      .05G      32.2      .3048      .3048

```

# Page 812

```

# SUBROUTINE NAME:  FISHCALC      (USED BY S61.2)      DATE:      01.21.67
# MOD NO: 0      LOG SECTION:      P61-P67
# MOD BY: MORTH / BAIRNSFATHER
# MOD NO: 1      MOD BY: RR BAIRNSFATHER      DATE:      11 MAY 67
#
# FUNCTIONAL DESCRIPTION:  GIVEN THE PRESENT POSITION, UNITR, CALCULATE A NEW UNITR
#      TRANSFER ANGLE, THETA, ALONG THE TRAJECTORY.  THEN CALCULATE SIN(LAT) AND USE
#      SINCE FISHCALC USED UNI (LEFT BY ENTRY) EARTH SCALING IS ASSUMED.  (WILL IMPROVE)
#
# CALLING SEQUENCE:      CALL
#      FISHCALC
#      ENTER WITH .5 SIN(THETA) IN MPAC.
#      PUSHLOC IS AT PDL+0, AN ARBITRARY BASE VALUE IF LEQ 8D
#
# SUBROUTINES CALLED:  GET ERAD
#
# NORMAL EXIT MODE:  RVQ
#
# EXIT MODES:  NONE
#
# OUTPUT:      ERADM (-29) M IN MPAC ON RETURNING
#      NEW UNIT VECTOR NOT SAVED.
#      SIN(LAT) NOT SAVED.
#      PUSHLOC AT PDL+0
#
# ERASABLE INITIALIZATION REQUIRED:

```

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```
#          SDELF/2          =SIN(THETA) / 2, IN MPAC          LEFT BY TFF/TRIG
#          CDELF/2          =COS(THETA) / 2, STORED IN PDL 14D  LEFT BY TFF/TRIG
#          RONE             (-29) M          LEFT BY USER
#          VONE             (-7) M/CS        LEFT BY USER
#          URONE            UR/2            LEFT BY USER
#          UNI              .5 UNIT(V*R)     LEFT BY ENTRY / P61
#          UNITW            UNIT NORTH POLE  LEFT BY PAD LOAD
#
# DEBRIS:      QPRET, PDL+0 ... PDL+5
#
FISHCALC      PDVL      VXV          # - - -
              URONE      # URPR = UR CDELF + UHOR SDELF
              UNI
              VXSC      VSL1
              # SIN(THETA) / 2 FROM PDL+0
              PDVL      VXSC          # TO PDL+0, +5
              URONE
              CDELF/2      # COS(THETA) / 2
              VAD      STADR
              STORE      URH          # FOR USE IN RTGO FROM EMS DISPLAY
              DOT      SL1
              UNITW          # PULL UNIT VECTOR          UNIT NORTH
              STORE      ALPHAV +4    # = .5 SIN(LAT)
DUMPFISH      GOTO
              GETERAD          # SAVES FISCHER RAD (-29) M IN ERADM AND
              # IN MPAC. RETURNS TO CALLER VIO QPRET.

# Page 813
# SUBROUTINE NAME:  VGAMCALC      (USED BY S61.2)
# MOD NO: 0
# MOD BY: MORTH / BAIRNSFATHER
# MOD NO: 1      MOD BY: RR BAIRNSFATHER      DATE: 11 APR 67
# MOD NO: 2      MOD BY: RR BAIRNSFATHER      DATE: 21 NOV 67      VARIABLE MU ADDED.
# MOD NO: 3      MOD BY: RR BAIRNSFATHER      DATE: 21 MAR 68      ACCEPT DIFFERENT EARTH/
#
# FUNCTIONAL DESCRIPTION:  EARTH CENTERED VIS VIVA CALCULATION OF TERMINAL VELOCITY AND GAMMA (R
#      HORIZONTAL) GIVEN THE SCALAR QUANTITIES:  PRESENT RADIUS AND VELOCITY AND THE TERMINAL
#      THE USER MUST APPEND PROPER SIGN TO GAMMA, SINCE IT IS CALCULATED AS A POSITIVE NUMBER.
#      THE EQUATIONS ARE
#
#      VGAM = SQRT(VN VN/MU + 2(RN-RTERM)/(RN RTERM) ) RTMU
#
#      COSGAM = H / RTERM VGAM = SQRT (LCP) / (RTERM VGAM/RTMU)
#
#      VGAMCALC ASSUMES THAT THE TERMINAL RADIUS IS LESS THAN THE PRESENT RADIUS.  BOTH CALCTF
#      MAKE THIS ASSUMPTION.
```

```

#
# CALLING SEQUENCE:      CALL          STCALL  RTERM
#                        VGAMCALC      PREVGAM
#      PUSHLOC AT PDL+0, ARBITRARY IF LEQ 12D
#      C(MPAC) UNSPECIFIED          C(MPAC)=NEW RTERM
#
# SUBROUTINES CALLED:  NONE
#
# NORMAL EXIT MODE:  RVQ
#
# ALARMS:            NONE
#
# OUTPUT:            GAMMA / 360 IN MPAC, POSITIVE NUMBER
#                    VGAM   E: (-7)   M: (-5)       M/CS IN PDL+0
#                    PUSHLOC AT PDL+2
#
# ERASABLE INITIALIZATION REQD:
#      TFF/RTMU  E: (17)   M: (14)       1/SQRT(MU)                LEFT
#      RMAG1     E: (-29)  M: (-27)      M  PRESENT RADIUS LENGTH    LEFT
#      NRMAG     E: (-29+NR)             M  NORM LENGTH OF PRESENT POSITION  LEFT
#      M: (-27+NR)
#      RTERM     E: (-29)  M: (-27)      M  TERMINAL RADIUS LENGTH      LEFT
#      NRTERM    E: (-29+NR)             M  NORM LENGTH OF TERMINAL RADIUS  LEFT
#      M: (-27+NR)
#      TFFVSQ    E: (20)   M: (18)      1/M  -(V SQ/MU): PRESENT VELOCITY, NORM  LEFT
#      TFFNP     E: (-38+2NR)             M  LCP, SEMI-LATUS RECTUM, WEIGHT NR  LEFT
#      M: (-36+2NR)
#
# DEBRIS:          QPRET, PDL+0 ... PDL+3
#                  RTERM, NRTERM IF PREVGAM ENTERED.
# Page 814

PREVGAM          SL*                # ENTER WITH NEW RTERM IN MPAC
#                  # E: (-29)  M: (-27)
#                  0,1              # X1 = -NR
#                  STORE  NRTERM    # RTERM M                E: (-29+NR)  M: (-29+NR)

VGAMCALC         DLOAD  DMP
#                  NRMAG          # RMAG M                E: (-29+NR)  M: (-29+NR)
#                  NRTERM         # RTERM M                E: (-29+NR)  M: (-29+NR)
#                  PDDL   DSU      # RMAG RTERM M        E: (-58+2NR)  M: (-58+2NR)
#                  NRMAG          # RMAG M                E: (-29+NR)  M: (-29+NR)
#                  NRTERM         # RTERM M                E: (-29+NR)  M: (-29+NR)
#                  SL*   DDV       # 2(RN-RTERM)         E: (-30+NR)  M: (-30+NR)
#                  0 -8D,1        # (-8+NR)
#                  # PUSH UP PRODUCT.

```

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```

DSU
SQRT    TFFVSQ      # -(V SQ/MU)          E: (20)          M: (18)
        PUSH        # SAVE VGAM/RT(MU) FOR NOW.      E: (10) M: (9)
DDV     PDDL        # XCH PDL+0, LEAVING VGAM FOR OUTPUT.
        PDDL        # VGAM TO PDL M/CS          E: (-7)          M: (-2)
        TFF/RTMU    #                          E: (17)          M: (14)
DMP     PDDL        # RTERM VGAM/RTMU          E: (-19+NR)       M: (-18+NR)
        NRTERM      # RTERM M                  E: (-29+NR)       M: (-27+NR)
        TFFNP       # LC P =H.H/MU M          E: (-38+2NR)      M: (-36+2NR)
SQRT    DDV         #                          E: (-19+NR)       M: (-18+NR)
        DDV         # PUSH UP DEN              E: (-19+NR)       M: (-18+NR)
        DDV         # USE DDV OVFL AS LIMITER (|COS| <1.0)
SR1     ACOS
DUMPVGAM RVQ
        # CALLER MUST SUPPLY OWN SIGN ...
        #                          22W      27MS

# Page 815
# SUBROUTINE NAME:      TFF/TRIG          (USED BY S61.2)      DATE:      01.17.67
# MOD NO: 0                                LOG SECTION:      P61-P67
# MOD BY: RR BAIRNSFATHER
# MOD NO: 1      MOD BY: RR BAIRNSFATHER      DATE: 14 APR 67
# MOD NO: 2      MOD BY: RR BAIRNSFATHER      DATE: 21 MAR 68      ACCEPT DIFFERENT EARTH/
#
# FUNCTIONAL DESCRIPTION: USED BY ENTRY DISPLAY TO CALCULATE SIN(THETA), COS(THETA) FROM DATA
#      PDL BY TFF SUBROUTINES.  THE EQNS ARE
#
#      COS(THETA) = 1-2 ABS(ARG) / (RN RTERM (1+X) )
#
#      SIN(THETA) = SGN(ARG) SQRT(1-COS (THETA) )
#
#      WHERE THETA = TRANSFER ANGLE
#      AND      ARG = P Z ABS(Z)              IF ALFA ZZ LEQ 1
#      ARG = (P / ALFA) SGN(Q1 + R 1/Z)        IF ALFA Z Z G 1
#      AND ARG HAS BEEN AFFIXED WITH THE SIGN OF SIN(THETA)
#
# CALLING SEQUENCE:      CALL
#
#      TFF/TRIG
#      PUSHLOC AT PDL+0, ARBITRARY IF NOT EQ 14D
#      C(MPAC) UNSPECIFIED
#
# SUBROUTINES CALLED:  NONE
#
# NORMAL EXIT MODES:  RVQ
#
# ALARMS:      NONE
```

```

#
# OUTPUT:      C(MPAC) = .5 SIN(THETA)
#              CDELF/2 = .5 COS(THETA)          (IN PDL 14D)
#              PUSHLOC AT PDL+0
#
# ERASABLE INITIALIZATION REQUIRED:
#              TFFX                                X                                LEFT
#              TFFTEM E: (-59+2NR)                ARG                                LEFT
#              M: (-55+2NR)                        WHERE ARG = LCF ZZ SGN(DELF) OR ARG = LCP/AL
#              NRTERM E: (-29+NR)                  M  NORM LENGTH OF TERMINAL RADIUS    LEFT
#              M: (-27+NR)
#              NRMAG E: (-29+NR)                   M  NORM LENGTH OF PRESENT POSITION    LEFT
#              M: (-27+NR)
#
# DEBRIS:      QPRET, CDELF/2
#
#              BANK 27
#              SETLOC P60S5
#              BANK
#              DLOAD SR1
#              TFFX
#              DAD DMP
#              HIDPHALF
#              NRMAG # RMAG M                      E: (-29+NR)    M: (-
#              DMP BDDV
#              NRTERM # RTERM M                      E: (-29+NR)    M: (-
#              TFFTEM # P ZSQ OR P/ALFA              E: (-59+2NR)    M: (-
#              ABS BDSU # THE SIGN IS FOR SDELF.
#              HIDPHALF
#              STORE CDELF/2 # .5 COS(THETA)
#              DSQ DCOMP # KEEP HONEST FOR SQRT.
#
# Page 816
#              DAD SQRT
#              HIDP1/4
#              DUMPTRIG SIGN RVQ
#              TFFTEM # AFFIX SIGN(DELE/2)
#              # RETURN WITH .5 SIN(THETA) IN MPAC
#
#              # 16W 15MS
#
# DISPTARG STQ # C(MPAC = TRGO ESTIMATE
#              60GENRET
#              DMP DSU
#              KTETA1
#              TTE1
#              STCALL DTEAROT

```

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```

                                EARROT2
                                CALL
                                VRCALC
                                GOTO
                                60GENRET
VRCALC      VLOAD      DOT
                                URH
                                RT
                                SL2      ACOS
                                RVQ
```

# END OF PROGRAM S61.2

# Page 817

# PROGRAM DESCRIPTION S62.3 DATE 10JAN67

# MOD NO 1: LOG SECTION P60-P67

# MOD BY ZELDIN

# MOD NO: 2 MOD BY: RR BAIRNSFATHER DATE: 15 MAY 67

CHANGED TO REF COORDS.

# MOD NO: 3 MOD BY: RR BAIRNSFATHER DATE: 17 JAN 68

ALFAPAD CHANGES MADE.

#

# FUNCTIONAL DESCRIPTION

#

# COMPUTE DESIRED GIMBAL ANGLES FOR ENTRY ATTITUDE

# THE FOLLOWING TRAJECTORY TRIAD IS AVAILABLE IN MEMORY AND IS COMPUTED EACH 2 SECONDS BY

# REFERENCE COORDINATES (V = VELOCITY RELATIVE TO EARTH):

#

# UXA = -UNIT(V)

# UYA = UNIT(V\*R)

# UZA = UXA\*UYA

#

# GENERATE A DESIRED BODY TRIAD FOR TRIMMED FLIGHT WITH RESPECT TO THE RELATIVE VELOCITY

# ROLL COMMAND AND TRIM ANGLE OF ATTACK:

#

# UXD = UNIT(UYD\*UXA) SIN(ALFATRIM) + UXA COS(ALFATRIM)

# UYD = UYA COS(ROLLC) + UZA SIN(ROLLC)

# UZD = UXD \* UYD

#

# USE THE DESIRED SET (IN REFERENCE COORDS) AND REFSMMAT TO CALL CALCGA AND OBTAIN GIME

# IN 2S, C IN MPAC, +2 AND THETAD, +2.

#

# CALLING SEQUENCE

#

# L CALL

# L+1 S62.3

#

# NORMAL EXIT MODE

```
#          RETURN VIA QPRET DIRECTLY FROM CALCGA.
#
# SUBROUTINES CALLED
#
#          CALCGA
#
# ALARM OR ABORT MODES
#
#          NONE
#
# ERASABLE INITIALIZATION REQUIRED
#
#          ROLLC    ROLL COMMAND                DP 1'S COMP AT 1REV
#          ALFAPAD SP 1'S C / 180              LEFT BY PAD LOAD           ALFATRIM IS NEGATIVE
#          UXA/2    REF COORDS                  LEFT BY CM/POSE
#          UYA/2    REF COORDS                  LEFT BY CM/POSE
#          UZA/2    REF COORDS                  LEFT BY CM/POSE
#
# OUTPUT
#
#          CPHI      GIMBAL ANGLES (O,I,M) 2'S COMP TP (O,I,M)/180
#
# DEBRIS
#
#          QTEMP, QPRET, PUSHLIST
#
#          BANK      10
#          SETLOC    P60S4
#          BANK
# Page 818
#          COUNT*   $$/S62.3
#
# S62.3            SETPD    SLOAD
#                   0
#                   ALFAPAD        # ALFATRIM / 180, ALFA IS NEG.
# SR1              PUSH
# COS              PDDL             # XCH PDL, COS TO PDL0
# SIN              PDDL             # SIN TO PDL2
#                   ROLLC
# COS              VXSC
#                   UYA/2           #                               REF COORDS
# PDDL             SIN             # PUSH VECTOR INTO PDL4...9
#                   ROLLC
# VXSC             VAD
#                   UZA/2           #                               REF COORDS
```



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```
# VECTOR FROM PDL4...9
VSL1
STORE YNB # = UYD REF COORDS

VXV VSL1
      UX A/2 # REF COORDS
VXSC PDDL

      # SIN TRIM FROM PDL2
      # XCH PDLO FOR COS TRIM
VXSC VAD
      UX A/2 # REF COORDS
      # FROM PDLO

VSL1
STORE XNB # X SC AXIS (.5 UNIT) REF COORDS

VXV VSL1
      YNB
STOVL ZNB # Z SC IN REF COOR. SCALED AT 2
      REFSMMAT
STOVL XSM
      REFSMMAT +6
STOVL YSM
      REFSMMAT +12D
STORE ZSM

CLEAR GOTO
      CPHIFLAG # CAUSE CALCGA TO STORE ANS IN TP CPHI
      CALCGA
      # CALCGA WILL RETURN TO ORIGINAL CALLER
      # VIA QPRET WITH 2'S COMP. ANGLES IN CPHI
```

This code is written to file src/P61-P67.s.

**A.76 P70-P71**

```

1338  <src/P70-P71.s 1338>≡
      # Copyright:   Public domain.
      # Filename:    P70-P71.agc
      # Purpose:     Part of the source code for Luminary 1A build 099.
      #              It is part of the source code for the Lunar Module's (LM)
      #              Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:   yaYUL
      # Contact:      Hartmuth Gutsche <hgutsche@explornet.com>.
      # Website:      www.ibiblio.org/apollo.
      # Pages:        829-837
      # Mod history:  2009-05-23 HG   Transcribed from page images.
      #              2009-06-05 RSB   Fixed a typo.
      #
      # This source code has been transcribed or otherwise adapted from
      # digitized images of a hardcopy from the MIT Museum. The digitization
      # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
      # the Museum. Many thanks to both. The images (with suitable reduction
      # in storage size and consequent reduction in image quality as well) are
      # available online at www.ibiblio.org/apollo. If for some reason you
      # find that the images are illegible, contact me at info@sandroid.org
      # about getting access to the (much) higher-quality images which Paul
      # actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #      Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
      #      16:27 JULY 14, 1969
      #
      # Page 829

      BANK      21
      SETLOC    R11
      BANK

      EBANK=    DVCNTR
      COUNT*    $$/R11

R10,R11      CS      FLAGWRD7      # IS SERVICER STILL RUNNING?
              MASK    AVEGFBIT
              CCS      A
              TCF      TASKOVER      # LET AVGEND TAKE CARE OF GROUP 2.
              CCS      PIPCTR
              TCF      +2
              TCF      LRHTASK      # LAST PASS. CALL LRHTASK.
+2           TS      PIPCTR1

```

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|            |        |          |                                        |
|------------|--------|----------|----------------------------------------|
| PIPCTR1    | =      | LADQSAVE |                                        |
| PIPCTR     | =      | PHSPRDT2 |                                        |
|            | CAF    | OCT31    |                                        |
|            | TC     | TWIDDLE  |                                        |
|            | ADRES  | R10,R11  |                                        |
| R10,R11A   | CS     | IMODES33 | # IF LAMP TEST, DO NTO CHANGE LR LITES |
|            | MASK   | BIT1     |                                        |
|            | EXTEND |          |                                        |
|            | BZF    | 10,11    |                                        |
| FLASHH?    | MASK   | FLGWRD11 | # C(A) = 1 - HFLASH BIT                |
|            | EXTEND |          |                                        |
|            | BZF    | FLASHV?  | # H FLASH OFF, SO LEAVE ALONE          |
|            | CA     | HLITE    |                                        |
|            | TS     | L        |                                        |
|            | TC     | FLIP     | # FLIP H LITE                          |
| FLASHV?    | CA     | VFLSHBIT | # VLASHBIT MUST BE BIT 2.              |
|            | MASK   | FLGWRD11 |                                        |
|            | EXTEND |          |                                        |
|            | BZF    | 10,11    | # V FLASH OFF                          |
|            | CA     | VLITE    |                                        |
|            | TS     | L        |                                        |
|            | TC     | FLIP     | # FLIP V LITE                          |
| 10,11      | CA     | FLAGWRD9 | # IS THE LETABORT FLAG SET ?           |
|            | MASK   | LETABBIT |                                        |
|            | EXTEND |          |                                        |
|            | BZF    | LANDISP  | # NO. PROCEED TO R10.                  |
| P71NOW?    | CS     | MODREG   | # YES. ARE WE IN P71 NOW?              |
| # Page 830 | AD     | 1DEC71   |                                        |
|            | EXTEND |          |                                        |
|            | BZF    | LANDISP  | # YES. PROCEED TO R10.                 |
|            | EXTEND |          | # NO. IS AN ABORT STAGE COMMANDED?     |
|            | READ   | CHAN30   |                                        |
|            | COM    |          |                                        |
|            | TS     | L        |                                        |
|            | MASK   | BIT4     |                                        |
|            | CCS    | A        |                                        |
|            | TCF    | P71A     | # YES.                                 |

|            |        |          |                              |
|------------|--------|----------|------------------------------|
| P7ONOW?    | CS     | MODREG   | # NO. ARE WE IN P70 NOW?     |
|            | AD     | 1DEC70   |                              |
|            | EXTEND |          |                              |
|            | BZF    | LANDISP  | # YES. PROCEED TO R10.       |
|            | CA     | L        | # NO. IS AN ABORT COMMANDED? |
|            | MASK   | BIT1     |                              |
|            | CCS    | A        |                              |
|            | TCF    | P70A     | # YES.                       |
|            | TCF    | LANDISP  | # NO. PROCEED TO R10.        |
|            | COUNT* | \$\$/P70 |                              |
| P70        | TC     | LEGAL?   |                              |
| P70A       | CS     | ZERO     |                              |
|            | TCF    | +3       |                              |
| P71        | TC     | LEGAL?   |                              |
| P71A       | CAF    | TWO      |                              |
| +3         | TS     | Q        |                              |
|            | INHINT |          |                              |
|            | EXTEND |          |                              |
|            | DCA    | CNTABTAD |                              |
|            | DTCB   |          |                              |
|            | EBANK= | DVCNTR   |                              |
| CNTABTAD   | 2CADR  | CONTABRT |                              |
| 1DEC70     | DEC    | 70       |                              |
| 1DEC71     | DEC    | 71       |                              |
|            | BANK   | 05       |                              |
|            | SETLOC | ABORTS1  |                              |
|            | BANK   |          |                              |
|            | COUNT* | \$\$/P70 |                              |
| CONTABRT   | CAF    | ABRTJADR |                              |
|            | TS     | BRUPT    |                              |
|            | RESUME |          |                              |
| # Page 831 |        |          |                              |
| ABRTJADR   | TCF    | ABRTJASK |                              |
| ABRTJASK   | CAF    | OCTAL27  |                              |
|            | AD     | Q        |                              |
|            | TS     | L        |                              |

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```
COM
DXCH    -PHASE4
INDEX   Q
CAF     MODE70
TS      MODREG

TS      DISPDEX      # INSURE DISPDEX IS POSITIVE.

CCS     Q             # SET APSFLAG IF P71.
CS      FLGWRD10      # SET APSFLAG PRIOR TO THE ENEMA.
MASK    APSFLBIT
ADS     FLGWRD10
CS      DAPBITS       # DAPBITS = OCT 640 = BITS 6, 8, 9
MASK    DAPBOOLS      # (TURN OFF ULLAGE, DRIFT, AND KOVINHIB
TS      DAPBOOLS

CS      FLAGWRD5      # SET ENGONFLG.
MASK    ENGONBIT
ADS     FLAGWRD5

CS      PRI030        # INSURE THAT THE ENGINE IS ON, IF ARMED.
EXTEND
RAND    DSALMOUT
AD      BIT13
EXTEND
WRITE   DSALMOUT

CAF     LRBYBIT       # TERMINATE R12.
TS      FLGWRD11

CS      FLAGWRD0      # SET R10FLAG TO SUPPRESS OUTPUTS TO THE
MASK    R10FLBIT      # CROSS-POINTER DISPLAY.
ADS     FLAGWRD0      # THE FOLLOWING ENEMA WILL REMOVE THE
                        # DISPLAY INERTIAL DATA OUTBIT.
TC      CLRADMOD      # INSURE RADMODES PROPERLY SET FOR R29.

EXTEND
DCA     TIME2
DXCH    TEVENT

EXTEND
DCA     SVEXITAD
DXCH    AVGEXIT
```

# Page 832

EXTEND

DCA      NEG0  
DXCH     -PHASE1

EXTEND  
DCA      NEG0  
DXCH     -PHASE3

EXTEND  
DCA      NEG0  
DXCH     -PHASE6

CAF      THREE                    # SET UP 4.3SPOT FOR GOABORT  
TS       L  
COM  
DXCH     -PHASE4

# the 3 in OCT37774 could be something else, garbled

CAF      OCT37774                # SET T5RUPT TO CALL DAPIDLER IN  
TS       TIME5                    # 40 MILLISECONDS.

TC       POSTJUMP  
CADR     ENEMA

SVEXITAD      EBANK= DVCNTR  
                 2CADR    SERVEXIT

MODE70        DEC      70  
OCTAL27       OCT      27  
MODE71        DEC      71

DAPBITS       OCT      00640

BANK        32  
SETLOC      ABORTS  
BANK

COUNT\*      \$\$/P70

GOABORT       TC        INTPRET  
                 CALL  
                 INITCDUW  
                 EXIT  
CAF            FOUR  
TS             DVCNTR  
CAF            WHICHADR

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# Page 833

TS WHICH  
TC DOWNFLAG  
ADRES FLRCS  
TC DOWNFLAG  
ADRES FLUNDISP  
TC DOWNFLAG  
ADRES IDLEFLAG  
TC UPFLAG  
ADRES ACC4-2FL

# INSURE 4-JET TRANSLATION CAPABILITY.

70DEC

TC CHECKMM  
DEC 70  
TCF P71RET

P70INIT

TC INTPRET  
CALL  
TGOCOMP  
DLOAD SL  
MDOTDPS  
4D  
BDDV  
MASS  
STODL TBUP  
MASS  
DDV SR1  
K(1/DV)  
STORE 1/DV1  
STORE 1/DV2  
STORE 1/DV3  
BDDV  
K(AT)  
STODL AT  
DTDECAY  
DCOMP SL  
11D  
STORE TTO  
SLOAD DCOMP  
DPSVEX  
SR2  
STORE VE  
SET CALL  
FLAP

# INITIALIZE DPS EXHAUST VELOCITY

```

                                COMMIT
                                AXC,1  GOTO      # RETURN HERE IN P70, SET X1 FOR DPS COEFF.
                                OD
                                BOTHPOLY
INJTARG      AXC,1              # RETURN HERE IN P71, SET X1 FOR APS COEFF.
                                8D
BOTHPOLY     DLOAD*  DMP        # TGO D
                                ABTCOF,1
                                TGO
# Page 834
                                DAD*   DMP
                                ABTCOF +2,1  #          TGO(C+TGO )
                                TGO
                                DAD*   DMP
                                ABTCOF +4,1  # TGO(B+TGO d))
                                TGO
                                DAD*
                                ABTCOF +6,1  # A+TGO(B+TGO(C+TGO D))
STORE        ZDOTD            # STORE TENTATIVELY IN ZDOTD
DSU          BPL              # CHECK AGAINST MINIMUM
                                VMIN
                                UPRATE      # IF BIG ENOUGH, LEAVE ZDOTD AS IS .
DLOAD
                                VMIN
STORE        ZDOTD            # IF TOO SMALL, REPLCAE WITH MINIMUM.
UPRATE      DLOAD
                                ABTRDOT
STCALL      RDOTD            # INITIALZE RDOTD.
                                YCOMP       # COMPUTE Y
ABS         DSU
                                YLIM        # /Y/-DYMAX
BMN         SIGN            # IF <0, XR<.5DEG, LEAVE YCO AT 0
                                YOK        # IF >0, FIX SIGN OF DEFICIT. THIS IS YCO.
                                Y
STORE       YCO
YOK         DLOAD  DSU
                                YCO
                                Y          # COMPUTE X RANGE IN CASE ASTRONAUT WANTS
SR
                                5D
STORE       XRANGE            # TO LOOK.
UPTHROT     SET    EXIT
                                FLVR
TC          UPFLAG            # SET ROTFLAG
ADRES      ROTFLAG

```



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|            |        |          |                                            |
|------------|--------|----------|--------------------------------------------|
|            | TC     | THROTUP  |                                            |
|            | TC     | PHASCHNG |                                            |
|            | OCT    | 04024    |                                            |
| -3         | TC     | BANKCALL | # VERIFY THAT THE PANEL SWITCHES           |
|            | CADR   | P40AUTO  | # ARE PROPERLY SET.                        |
|            | TC     | THROTUP  |                                            |
| UPTHROT1   | EXTEND |          | # SET SERVICER TO CALL ASCENT GUIDANCE.    |
|            | DCA    | ATMAGAD  |                                            |
|            | DXCH   | AVGEXIT  |                                            |
| # Page 835 |        |          |                                            |
| GRP40FF    | TC     | PHASCHNG | # TERMINATE USE OF GROUP 4.                |
|            | OCT    | 00004    |                                            |
|            | TCF    | ENDOFJOB |                                            |
| P71RET     | TC     | DOWNFLAG |                                            |
|            | ADRES  | LETABORT |                                            |
|            | CAF    | THRESH2  | # SET DVMON THRESHOLD TO THE ASCENT VALUE. |
|            | TS     | DVTHRUSH |                                            |
|            | TC     | INTPRET  |                                            |
|            | BON    | CALL     |                                            |
|            |        | FLAP     |                                            |
|            |        | OLDTIME  |                                            |
|            |        | TGOCOMP  | # IF FLAP=0, TGO=T-TIG                     |
|            | SSP    | GOTO     |                                            |
|            |        | QPRET    |                                            |
|            | CADR   | INJTARG  |                                            |
|            |        | P12INIT  | # WILL EXIT P12INIT TO INJTARG             |
| OLDTIME    | DLOAD  | SL1      | # IF FLAP=1,GTO=2 TGO                      |
|            |        | TGO      |                                            |
|            | STCALL | TG01     |                                            |
|            |        | P12INIT  |                                            |
|            | EXIT   |          |                                            |
|            | TC     | PHASCHNG |                                            |
|            | OCT    | 04024    |                                            |
|            | EXTEND |          |                                            |
|            | DCA    | TG01     |                                            |
|            | DXCH   | TGO      |                                            |

```

                                TCF      UPTHROT1 -3

TGO1      =      VGBODY
# *****

                                BANK      21
                                SETLOC    R11
                                BANK
                                COUNT*   $$/P70

LEGAL?    CS      MMNUMBER      # IS THE DESIRED PGM ALREADY IN PROGRESS?
          AD      MODREG
          EXTEND
          BZF     ABORTALM

          CS      FLAGWRD9      # ARE THE ABORTS ENABLED?
          MASK    LETABBIT
          CCS     A

# Page 836

          TCF     ABORTALM

          CA      FLAGWRD7      # IS SERVICER ON THE AIR?
          MASK    AVEGFBIT
          CCS     A
          TC      Q              # YES. ALL IS WELL.
ABORTALM  TC      FALTON
          TC      RELDSP
          TC      POSTJUMP
          CADR    PINBRNCH

          BANK     32
          SETLOC   ABORTS
          BANK

          COUNT*   $$/P70

# *****

TGOCOMP   RTB      DSU
                                LOADTIME
                                TIG
          SL
                                11D
          STORE    TGO
          RVQ
```

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# \*\*\*\*\*

|         |        |        |
|---------|--------|--------|
| THROTUP | CAF    | BIT13  |
|         | TS     | THRUST |
|         | CAF    | BIT4   |
|         | EXTEND |        |
|         | WOR    | CHAN14 |
|         | TC     | Q      |

# \*\*\*\*\*

|          |        |            |                                    |
|----------|--------|------------|------------------------------------|
| 10SECS   | 2DEC   | 1000       |                                    |
| HINJECT  | 2DEC   | 18288 B-24 | # 60,000 FEET EXPRESSED IN METERS. |
| (TGO)A   | 2DEC   | 37000 B-17 |                                    |
| K(AT)    | 2DEC   | .02        | # SCALING CONSTANT                 |
| WHICHADR | REMADR | ABRTABLE   |                                    |

# \*\*\*\*\*

# Page 837

|          |        |          |
|----------|--------|----------|
|          | EBANK= | DVCNTR   |
| ATMAGAD  | 2CADR  | ATMAG    |
| ORBMANAD | ADRES  | ORBMANUV |

This code is written to file src/P70-P71.s.

**A.77 P76**1348  $\langle src/P76.s\ 1348 \rangle \equiv$ 

```

# Copyright:      Public domain.
# Filename:       P76.agc
# Purpose:        Part of the source code for Colossus 2A, AKA Comanche 055.
#                 It is part of the source code for the Command Module's (CM)
#                 Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:     yaYUL
# Contact:        Hartmuth Gutsche <hgutsche@explornet.com>.
# Website:        www.ibiblio.org/apollo.
# Pages:          pp 511-513
# Mod history:    2009-05-08 HG      Adapting from the Luminary131/ file
#                 of the same name, using Comanche055 page
#                 images 0511.jpg - 0513.jpg.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#   Assemble revision 055 of AGC program Comanche by NASA
#   2021113-051. 10:28 APR. 1, 1969
#
#   This AGC program shall also be referred to as
#   Colossus 2A
#
# Page 511
# 1) PROGRAM NAME -- TARGET DELTA V PROGRAM (P76).
# 2) FUNCTIONAL DESCRIPTION -- UPON ENTRY BY ASTRONAUT ACTION, P76 FLASHES DSKY RE
#   TO PROVIDE VIA DSKY (1) THE DELTA V TO BE APPLIED TO THE OTHER VEHICLE STATE
#   TIME (TIG) AT WHICH THE OTHER VEHICLE VELOCITY WAS CHANGED BY EXECUTION OF A
#   OTHER VEHICLE STATE VECTOR IS INTEGRATED TO TIG AND UPDATED BY THE ADDITION O
#   BEEN TRANSFORMED FROM LV TO REF COSYS). USING INTEGRVS, THE PROGRAM THEN INT
#   VEHICLE STATE VECTOR TO THE STATE VECTOR OF THIS VEHICLE, THUS INSURING THAT
#   STATES CORRESPOND TO THE SAME TIME.
# 3) ERASABLE INITIALIZATION REQUIRED -- NONE.
# 4) CALLING SEQUENCES AND EXIT MODES -- CALLED BY ASTRONAUT REQUEST THRU DSKY V 3
#   EXITS BY TCF ENDOFJOB.
# 5) OUTPUT -- OTHER VEHICLE STATE VECTOR INTEGRATED TO TIG AND INCREMENTED BY DE

```

```

#      THE PUSHLIST CONTAINS THE MATRIX BY WHICH THE INPUT DELTA V MUST BE POST-MULTIPLIED TO
#      TO REF COSYS.
# 6)   DEBRIS -- OTHER VEHICLE STATE VECTOR.
# 7)   SUBROUTINES CALLED -- BANKCALL, GOXDSPF, CSMPREC (OR LEMPREC), ATOPCSM (OR ATOPLEM), IN
#      INTPRET, INTEGRVS, AND MINIRECT.
# 8)   FLAG USE -- MOONFLAG, CMOONFLG, INTYPFLG, RASFLAG, AND MARKCTR.

```

```

      BANK    30
      SETLOC  P76LOC
      BANK

```

```

      COUNT*  $$/P76

```

```

      EBANK=  TIG

```

P76

```

      TC      UPFLAG
      ADRES   TRACKFLG

```

```

      CAF     V06N84      # FLASH LAST DELTA V.
      TC      BANKCALL    # AND WAIT FOR KEYBOARD ACTION.
      CADR    GOFLASH
      TCF     ENDP76
      TC      +2           # PROCEED
      TC      -5           # STORE DATA AND REPEAT FLASHING
      CAF     V06N84 +1    # FLASH VERB 06 NOUN 33, DISPLAY LAST TIG,
      TC      BANKCALL    # AND WAIT FOR KEYBOARD ACTION.
      CADR    GOFLASH
      TCF     ENDP76
      TC      +2
      TC      -5
      TC      INTERPRET    # RETURN TO INTERPRETIVE CODE
      DLOAD   TIG          # SET D(MPAC)=TIG IN CSEC B28

```

```

      STCALL  TDEC1        # SET TDEC1=TIG FOR ORBITAL INTEGRATION
      OTHPREC

```

COMPMAT

```

      VLOAD  UNIT
      RATT

```

# Page 512

```

      VCOMP      # U(-R)
      STORE 24D  # U(-R) TO 24D
      VXV  UNIT  # U(-R) X V = U(V X R)
      VATT
      STORE 18D
      VXV  UNIT  # U(V X R) X U(-R) = U((R X V) X R)
      24D
      STOVL 12D

```

```

                                DELVOV
                                VXM   VSL1      # V(MPAC)=DELTA V IN REFCOSYS
   12D
                                VAD
   VATT
                                STORE  6         # V(PD6)=VATT + DELTA V
                                CALL    # PREVENT WOULD-BE USER OF ORBITAL
   INTSTALL
   # INTEG FROM INTERFERING WITH UPDATING
                                CALL
   P76SUB1
                                VLOAD  VSR*
   6
   0,2
                                STOVL   VCV
   RATT
                                VSR*
   0,2
                                STODL   RCV
   TIG
                                STORE   TET
                                CLEAR   DLOAD
   INTYPFLG
   TETTHIS
INTOTHIS  STCALL  TDEC1
   INTEGRVS
                                CALL
   INTSTALL
                                CALL
   P76SUB1      # SET/CLEAR MOONFLAG
                                VLOAD
   RATT1
                                STORE   RRECT
                                STODL   RCV
   TAT
                                STOVL   TET
   VATT1
                                CALL
   MINIRECT
                                EXIT
                                TC      PHASCHNG
                                OCT      04024
# Page 513
                                TC      UPFLAG
                                ADRES   REINTFLG
                                TC      INTPRET

```

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```

                                CALL
                                ATOPOTH
                                SSP  EXIT
                                QPRET
                                OUT
                                TC   BANKCALL      # PERMIT USE OF ORBITAL INTEGRATION
                                CADR INTWAKE1
                                EXIT
OUT
ENDP76  CAF   ZERO
                                TS   MARKCTR      # CLEAR RR TRACKING MARK COUNTER
                                TS   VHFCNT

                                CAF   NEGONE
                                TS   MRKBUF2      # INVALIDATE MARK BUFFER

                                TCF   GOTOPOOH

V06N84  NV    0684
                                NV    0633
P76SUB1 CLEAR SLOAD
                                MOONFLAG
                                X2
                                BHIZ SET          # X2=0...CLEAR MOONFLAG
                                +2          #   =2.....SET MOONFLAG
                                MOONFLAG

                                RVQ
                                @\r\r
```

\section{P-AXIS RCS AUTOPILOT}

This code is written to file `src/P76.s`.

1352  $\langle \text{src}/P\text{-}AXIS\text{-}RCS\text{-}AUTOPILOT.s \text{ 1352} \rangle \equiv$

```
# Copyright:    Public domain.
# Filename:     P-AXIS_RCS_AUTOPILOT.agc
# Purpose:     Part of the source code for Luminary 1A build 099.
#              It is part of the source code for the Lunar Module's (LM)
#              Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:     Ron Burkey <info@sandroid.org>.
# Website:     www.ibiblio.org/apollo.
# Pages:       1421-1441
# Mod history: 2009-05-27 RSB  Adapted from the corresponding
#                               Luminary131 file, using page
#                               images from Luminary 1A.
#               2009-06-05 RSB  Corrected a relative jump from
#                               +8 to +8D.
#               2009-06-07 RSB  Corrected a typo.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
# Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
# 16:27 JULY 14, 1969
```

# Page 1421

```
BANK      16
SETLOC    DAPS1
BANK

EBANK=    PERROR
COUNT*   $$/DAPP
```

```
# THE FOLLOWING T5RUPT ENTRY BEGINS THE PROGRAM WHICH CONTROLS THE P-AXIS ACTION OF T
# THE NOMINAL TIME BETWEEN THE P-AXIS RUPTS IS 100 MS IN ALL NON-IDLING MODES OF THE
```

```
PAXIS      CA      MS100
           ADS      TIME5      # *** NECESSARY IN ORDER TO ALLOW
                                # SYNCHRONIZATION WITH OTHER INTERRUPTS ***
```



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```

      LXCH   BANKRUPT      # INTERRUPT LEAD IN (CONTINUED)
      EXTEND
      QXCH   QRUPT

# CHECK IF DAP PASS IS PERMISSIBLE

      CCS    DAPZRUP      # IF DAPZRUP POSITIVE, DAP (JASK) IS
      TC     BAILOUT      # STILL IN PROGRESS AND A RESTART IS
      OCT    02000        # CALLED FOR. IT IS NEVER ZERO

      TC     CHEKBITS     # RETURN IS TC I+1 IF DAP SHOULD STAY ON.

      CA     CDUX         # READ AND STORE CDU'S
      TS     DAPTREG4
      CA     CDUY
      TS     DAPTREG5
      CA     CDUZ
      TS     DAPTREG6

# ***** KALCMANU-DAP AND "RATE-HOLD"-DAP INTERFACE *****
#
# THE FOLLOWING SECTION IS EXECUTED EVERY 100 MS (10 TIMES A SECOND) WITHIN THE P-AXIS REACTION
# AUTOPILOT (WHENEVER THE DAP IS IN OPERATION).

      CA     CDUXD
      EXTEND
      MSU    DELCDUX
      TC     1STOTWOS
      TS     CDUXD
      CA     CDUYD
      EXTEND
      MSU    DELCDUY
      TC     1STOTWOS
      TS     CDUYD
      CA     CDUZD
      EXTEND
      MSU    DELCDUZ

# Page 1422

      TC     1STOTWOS
      TS     CDUZD
      EXTEND
      DIM    TCP          # DIMINISH MANUAL CONTROL DIRECT RATE
      EXTEND
      DIM    TCQR         # TIME COUNTERS.
```

```

# RATFLOOP COMPUTES JETRATER, JRATER, AND 1JACC*NO. PJEETS IN ITEMP1.
# RETURNS TO BACKP.
#
# JETRATER = 1JACC*NO.PJETS*TJP          (NOTE TJ IS THE TIME FIRED DURING CSP)
# JETRATER = 1JACCQ(TJU*NO.UJETS - TJV*NO.VJETS)
# JETRATER = 1JACCR(TJU*NO.UJETS + TJV*NO.VJETS)

```

```

1STOTWOS      TCF      PAXFILT      # PROCEEDS TO RATELOOP AFTER SUPERJOB
              CCS      A
              AD      ONE
              TC      Q
              CS      A
              TC      Q
SUBDIVIDE     EXTEND      # OVERFLOW PROTECTION ROUTINE TO GIVE
MP            DAPTEMP3    # POSMAX OR NEGMAX IF THE DIVIDE WOULD
DAS          OMEGAU      # OVERFLOW

              +3      EXTEND
              DCA      OMEGAU
              DXCH     DAPTEMP5
              CCS      OMEGAU
              TCF      +2
              TCF      DIVIDER
              AD      -OCT630
              EXTEND
              BZMF     DIVIDER

              CCS      OMEGAU
              CA      POSMAX      # 45 DEG/SEC
              TC      Q
              CS      POSMAX
              TC      Q
DIVIDER       DXCH      OMEGAU
              EXTEND
              DV      DAPTREG4
              TC      Q
OVERSUB       TS      7          # RETURNS A UNCHANGED OR LIMITED TO
              TC      Q          # POSMAX OR NEGMAX IF A HAS OVERFLOW
              INDEX   A
              CS      BIT15      -1
# Page 1423
              TC      Q
-OCT630       OCT      77147

```

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```
BACKP      CA      DAPTEMP1
           EXTEND
           MP      1JACC
           TS      JETRATE

# BEGINNING OF THE RATE DERIVATION
#      OMEGAP,Q,R    BODY RATES SCALED AT PI/4
#      TRAPEDP,Q,R   BODY ANGLE ERRORS FROM PREDICTED ANGLE (PI/40)
#      NP(QR)TRAPS   NUMBER OF TIMES ANGLE ERROR HAS BEEN ACCUMULATED
#      AOSQ(R)TERM   CHANGE IN RATE DUE TO OFFSET ACCELERATION. (PI/4)
#      JETRATE,Q,R   CHANGE IN RATE DUE TO JET ACCELERATION. (PI/4)
#      TRAPSIZE      NEGATIVE LIMIT OF MAGNITUDE OF TRAPEDP, ETC.
#      OMEGAU        DP-TEMPORARY STORAGE
# OMEGA = OMEGA + JETRATE + AOSTERM (+TRAPED/NTRAPS IF TRAPED BIG)

           CAE      DAPTREG4      # CDUX IS STORED HERE
           TS      L
           EXTEND
           MSU      OLDXFORP      # SCALED AT PI
           LXCH     OLDXFORP
           TS      DAPTEMP1
           CA      1/40
           TS      DAPTREG4
           CS      JETRATE
           EXTEND
           MP      BIT14
           ADS      TRAPEDP
           CA      JETRATEQ
           AD      AOSQTERM
           EXTEND
           MP      -BIT14
           ADS      TRAPEDQ
           CA      JETRATER
           AD      AOSRTERM
           EXTEND
           MP      -BIT14
           ADS      TRAPEDR

           CA      DAPTREG5      # CDUY IS STORED HERE
           TS      L
           EXTEND
           MSU      OLDYFORP      # SCALED AT PI
           LXCH     OLDYFORP
           TS      DAPTEMP2
           EXTEND
```

```

# Page 1424
MP      M11      # M11 SCALED AT 1
AD      DAPTEMP1
DXCH    OMEGAU

TC      SUBDIVDE +3  # RETURNS WITH CDU-RATE AT PI/4

EXTEND
SU      OMEGAP
ADS     TRAPEDP
TC      OVERSUB
TS      TRAPEDP
EXTEND
DCA     DAPTEMP5
DAS     DXERROR
CS      PLAST
EXTEND
MP      1/40
DAS     DXERROR      # MANUAL MODE X-ATTITUDE ERROR (DP)
CA      DAPTRREG6    # CDUZ IS STORED HERE
TS      L
EXTEND
MSU     OLDZFORQ
TS      DAPTEMP3
LXCH    OLDZFORQ
CA      M21
EXTEND
MP      DAPTEMP2
DXCH    OMEGAU
CA      M22
TC      SUBDIVDE

EXTEND
SU      OMEGAQ
ADS     TRAPEDQ
TC      OVERSUB
TS      TRAPEDQ
EXTEND
DCA     DAPTEMP5
DAS     DYERROR
CS      QLAST
EXTEND
MP      1/40
DAS     DYERROR      # MANUAL MODE Y-ATTITUDE ERROR (DP)
CA      M31
EXTEND

```

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```
# Page 1425
MP      DAPTEMP2
DXCH    OMEGAU
CA      M32

TC      SUBDIVDE

EXTEND
SU      OMEGAR
ADS     TRAPEDR
TC      OVERSUB
TS      TRAPEDR      # TRAPEDS HAVE ALL BEEN COMPUTED

EXTEND
DCA     DAPTEMP5
DAS     DZERROR
CS      RLAST
EXTEND
MP      1/40
DAS     DZERROR      # MANUAL MODE Z-ATTITUDE ERROR (DP)
CA      DAPBOOLS     # PICK UP PAD LOADED STATE ESTIMATOR GAINS
MASK    CSMDOCKD
EXTEND
BZF     LMONLY
EXTEND      # DOCKED
DCA     DKOMEGAN
DXCH    DAPTREG4
CA      DKTRAP
TCF     +5
EXTEND      # UNDOCKED
DCA     LMOMEGAN
DXCH    DAPTREG4
CA      LMTRAP
TS      DAPTREG6
CCS     TRAPEDP
TCF     +2
TCF     SMALPDIF
AD      DAPTREG6      # TRAPSIZE > ABOUT 77001 %-1.4DEG/SEC"
EXTEND
BZMF    SMALPDIF
ZL
LXCH    TRAPEDP
CA      ZERO
EXTEND
DV      NPTRAPS
ADS     OMEGAP
TC      OVERSUB
```

|             |        |          |                                        |
|-------------|--------|----------|----------------------------------------|
|             | TS     | OMEGAP   |                                        |
|             | CA     | DAPTRG4  | ABOUT 10 OR 0 FOR DOCKED OR UNDOCKED   |
|             | TS     | NPTRAPS  |                                        |
| SMALPDIF    | INCR   | NPTRAPS  |                                        |
| P-RATE      | CA     | JETRATE  |                                        |
|             | ADS    | OMEGAP   |                                        |
|             | TC     | OVERSUB  |                                        |
|             | TS     | OMEGAP   |                                        |
|             | CCS    | TRAPEDQ  |                                        |
| # Page 1426 | TCF    | +2       |                                        |
|             | TCF    | Q-RATE   |                                        |
|             | AD     | DAPTRG6  | # TRAPSIZE > ABOUT 77001 %-1.4DEG/SEC" |
|             | EXTEND |          |                                        |
|             | BZMF   | Q-RATE   |                                        |
|             | ZL     |          |                                        |
|             | LXCH   | TRAPEDQ  |                                        |
|             | CA     | ZERO     |                                        |
|             | EXTEND |          |                                        |
|             | DV     | NQTRAPS  |                                        |
|             | TS     | DAPTEMP1 | # SAVE FOR OFFSET ESTIMATE             |
|             | ADS    | OMEGAQ   |                                        |
|             | TC     | OVERSUB  |                                        |
|             | TS     | OMEGAQ   |                                        |
|             | CA     | DAPTRG4  | # ABOUT 10 OR 0 FOR DOCKED OR UNDOCKED |
|             | XCH    | NQTRAPS  |                                        |
|             | AD     | DAPTRG5  | # KAOS > ABOUT 60D %N/N_60"            |
|             | XCH    | DAPTEMP1 |                                        |
|             | EXTEND |          |                                        |
|             | MP     | FIVE     |                                        |
|             | EXTEND |          |                                        |
|             | DV     | DAPTEMP1 |                                        |
|             | ADS    | AOSQ     |                                        |
| Q-RATE      | INCR   | NQTRAPS  |                                        |
|             | CA     | JETRATEQ |                                        |
|             | AD     | AOSQTERM |                                        |
|             | ADS    | OMEGAQ   |                                        |
|             | TC     | OVERSUB  |                                        |
|             | TS     | OMEGAQ   |                                        |
|             | CCS    | TRAPEDR  |                                        |
|             | TCF    | +2       |                                        |
|             | TCF    | R-RATE   |                                        |
|             | AD     | DAPTRG6  | # TRAPSIZE > ABOUT 77001 %-1.4DEG/SEC" |
|             | EXTEND |          |                                        |

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```
BZMF      R-RATE
ZL
LXCH      TRAPEDR
CA        ZERO
EXTEND
DV        NRTRAPS
TS        DAPTEMP2      # SAVE FOR OFFSET ESTIMATE
ADS       OMEGAR
TC        OVERSUB
TS        OMEGAR
CA        DAPTREG4      # ABOUT 10 OR 0 FOR DOCKED OR UNDOCKED
XCH       NRTRAPS
AD        DAPTREG5      # KAOS > ABOUT 60D %N/N_60"
XCH       DAPTEMP2
EXTEND

# Page 1427

MP        FIVE
EXTEND
DV        DAPTEMP2
ADS       AOSR
R-RATE    INCR          NRTRAPS
CA        JETRATER
AD        AOSRTERM
ADS       OMEGAR
TC        OVERSUB
TS        OMEGAR

# END OF RATE DERIVATION
# BEGIN OFFSET ESTIMATER
# IN POWERED FLIGHT, AOSTASK WILL BE CALLED EVERY 2 SECONDS.
# AOS = AOS + K*SUMRATE

CS        DAPBOOLS
MASK      DRIFTBIT
CCS       A
TCF       WORKTIME
TS        ALPHAQ      # ZERO THE OFFSET ACCELERATION VALUES.
TS        ALPHAR
TS        AOSQTERM
TS        AOSRTERM
TS        AOSQ
TS        AOSR
TCF       PRETIMCK
KAOS      DEC         60
WORKTIME  CA          QACCDOT
EXTEND
```

```

MP      CALLCODE      # OCTAL 00032 IS DECIMAL .1 AT 2(6).
DAS     AOSQ
CA      AOSQ
TS      ALPHAQ
EXTEND
MP      200MS         # .2 AT 1
TS      AOSQTERM
CA      RACCDOT
EXTEND
MP      CALLCODE      # OCTAL 00032 IS DECIMAL .1 AT 2(6).
DAS     AOSR
CA      AOSR
TS      ALPHAR
EXTEND
MP      200MS         # .2 AT 1
TS      AOSRTERM
TCF     PRETIMCK

# Page 1428
PAXFILT CA      CALLGMBL      # EXECUTE ACDT+C12, IF NEEDED.
MASK    RCSFLAGS
CCS     A           # CALLGMBL IS NOT BIT15, SO THIS TEST IS
TC      ACDT+C12     # VALID.

DXCH    ARUPT
DXCH    DAPARUPT
CA      SUPERJOB      # SETTING UP THE SUPERJOB
XCH     BRUPT
LXCH    QRUPT
DXCH    DAPBQRPT
CA      SUPERADR
DXCH    ZRUPT
DXCH    DAPZRUPT
TCF     NOQBRSM +1    # RELINT (JUST IN CASE) AND RESUME, IN THE
                        # FORM OF A JASK, AT SUPERJOB.

SUPERADR GENADR SUPERJOB +1

# COUNT DOWN GIMBAL DRIVE TIMERS AND TURN OFF DRIVES IF REQUIRED.

SUPERJOB TCF      RATELOOP
PRETIMCK CCS      QGIMTIMR
          TCF      DECQTIMR      # POSITIVE -- COUNTING DOWN
          TCF      TURNOFFQ      # NEGATIVE -- DRIVE SHOULD BE ENDED
CHKRTIMR CCS      RGIMTIMR      # NEGATIVE -- INACTIVE
          TCF      DECRTIMR      # (NEG ZERO -- IMPOSSIBLE)

```



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```

TCF      TURNOFFR      # REPEATED (ABOVE) FOR R AXIS.

EXTEND
DIM      PJETCTR
EXTEND
DIM      UJETCTR
EXTEND
DIM      VJETCTR
CA       BIT12
MASK     RCSFLAGS
EXTEND
BZF      SKIPPAXS
TC       CHKVISFZ
DECQTIMR TS      QGIMTIMR      # COUNT TIMERS DOWN TO POS ZERO.
TCF      CHKRTIMR
DECRTIMR TS      RGIMTIMR
TCF      CHKRTIMR +3

TURNOFFQ TS      NEGUQ        # HALT DRIVES.
TS       QACCDOT
CS       QGIMBITS
EXTEND

# Page 1429
WAND     CHAN12
CAF      NEGMAX
TS       QGIMTIMR
TCF      CHKRTIMR
TURNOFFR TS      NEGUR
TS       RACCDOT
CS       RGIMBITS
EXTEND
WAND     CHAN12
CAF      NEGMAX
TS       RGIMTIMR
TCF      CHKRTIMR +3
QGIMBITS EQUALS  OCT1400      # BITS 9 AND 10 (OF CHANNEL 12).
RGIMBITS EQUALS  PRI06        # BITS 11 AND 12 (OF CHANNEL 12).

SKIPPAXS CS      RCSFLAGS
MASK     BIT12
ADS      RCSFLAGS      # BIT 12 SET TO 1.
TCF      QRAXIS        # GO TO QRAXIS OR TO CTS.

# Y-X TRANSLATION
#
# INPUT:      BITS 9-12 OF CH31 (FROM TRANSLATION CONTROLLER)
```

```

#
# OUTPUT:      NEXTP
#
#             NEXTP IS THE CHANNEL 6 CODE OF JETS FOR THE DESIRED TRANSLATION.
#             IF THERE ARE FAILURES IN THE DESIRED POLICY, THEN
#             (1) FOR DIAGONAL TRANS:      UNFAILED PAIR
#   ALARM (IF NO PAIR)
#             (2) FOR PRINCIPAL TRANS:     TRY TO TACK WITH DIAGONAL PAIRS
#   ALARM (IF DIAGONAL PAIRS ARE FAILED)
#
CHKVISFZ      EXTEND
              READ   CHAN31
              CS     A
              MASK   07400OCT
              EXTEND
              BZF    TSNEXTP
              EXTEND
              MP     BIT7
              INDEX  A
              CA     INDXYZ
              TS     ROTINDEX
TRYUORV       CA     SIX
              TC     SELECTYZ
              CS     SIX
              AD     NUMBERT
              EXTEND
# Page 1430
              BZF    TSNEXTP -1
              CS     FIVE
              AD     ROTINDEX
              EXTEND
              BZMF   ALTERYZ
              CS     NUMBERT
              AD     FOUR
              EXTEND
              BZMF   TSNEXTP -1
ABORTYZ       TC     ALARM
              OCT    02001
              CA     BIT1          # INVERT BIT 1 OF RCSFLAGS.
              LXCH   RCSFLAGS
              EXTEND
              RXOR   1
              TS     RCSFLAGS
              CA     ZERO
              TCF    TSNEXTP
ALTERYZ       CA     BIT1          # INVERT BIT 1 OF RCSFLAGS.

```

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```

                                LXCH   RCSFLAGS
                                EXTEND
                                RXOR    1
                                TS       RCSFLAGS
                                MASK     BIT1
                                AD       FOUR
                                ADS      ROTINDEX
                                TCF      TRYUORV
                                CA       POLYTEMP
TSNEXTP      TS       NEXTP

# STATE LOGIC
#   CHECK IN ORDER:           IF ON
#   LPDPHASE                  GO TO PURGENCY
#   PULSES                    MINIMUM PULSE LOTIC
#   DETENT(BIT15 CH31)       RATE COMMAND
#   GOTO TO PURGENCY

                                CA       BIT13           # CHECK STICK IF IN ATT. HOLD.
                                EXTEND
                                RAND     CHAN31
                                EXTEND
                                BZF      MANMODE

                                CA       DAPBOOLS
                                MASK     XOVINHIB
                                CCS      A
                                TCF      PURGENCY        # ATTITUDE STEER DURING VISIBILITY PHASE

                                TCF      DETENTCK
MANMODE      CA       PULSES        # PULSES IS ONE FOR PULSE MODE
                                MASK     DAPBOOLS

# Page 1431

                                EXTEND
                                BZF      DETENTCK        # BRANCH FOR RATE COMMAND

                                CA       ZERO
                                TS       PERROR

# MINIMUM IMPULSE MODE

                                CA       CDUX
                                TS       CDUXD

                                CCS      OLDPMIN
                                TCF      CHECKP
```

```

FIREP          CA      BIT3
               EXTEND
               RAND     CHAN31
               EXTEND
               BZF      +XMIN

               CA      BIT4
               EXTEND
               RAND     CHAN31
               EXTEND
               BZF      -XMIN

               TCF      JETSOFF

CHECKP         EXTEND
               READ     CHAN31
               CS       A
               MASK     OCT14
               TS       OLDPMIN
               TCF      JETSOFF

-XMIN          CS       TEN           # ANYTHING LESS THAN 14MS. CORRECTED
               TCF      +2           #          IN JET SELECTION ROUTINE
+XMIN          CA       TEN
               TS       TJP
               CA       ONE
               TS       OLDPMIN
               TCF      PJETSLEC -6

#
#                                     MANUAL RATE COMMAND MODE
#                                     =====
#                                     BY ROBERT F. STENGEL
#
# THIS MODE PROVIDES RCAH MANUAL CONTROL THRU 2 CONTROL LAWS:  1) DIRECT RATE AND 2)
# THE DIRECT RATE MODE AFFORDS IMMEDIATE CONTROL WITHOUT OVERSHOOT.  THE PSEUDO-AUTO
# RATE CONTROL AND ATTITUDE HOLD.
#
# Page 1432
# IN DIRECT RATE, JETS ARE FIRED WHEN STICK POSITION CHANGES BY A FIXED NUMBER OF IN
# THE 'BREAKOUT LEVEL' IS .6 D/S FOR LM-ONLY AND .3 D/S FOR CSM-DOCKED.  THIS LAW NU
# THE 'TARGET DEADBAND', WHICH EQUALS THE BREAKOUT LEVEL.
#
# IN PSEUDO-AUTO, BODY-FIXED RATE AND ATTITUDE ERRORS ARE SUPPLIED TO TJETLAW, WHICH
# CONTROL SWITCHES FROM DIRECT RATE TO PSEUDO-AUTO IF THE TARGET DB IS ACHIEVED OR IF
# IF THE INITIAL COMMAND DOES NOT EXCEED THE BREAKOUT LEVEL, CONTROL GOES TO PSEUDO-A

```

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```
#
# SINCE P-AXIS CONTROL IS SEPARATE FROM Q,R AXES CONTROL, IT IS POSSIBLE TO USE (1) IN P-AXIS A
# OR VICE VERSA. THIS ALLOWS A DEGREE OF ATTITUDE HOLD IN UNCONTROLLED AXES. DUE TO U,V CONTR
# R AXES ARE COUPLED AND MUST USE THE SAME CONTROL LAW.
#
# HAND CONTROLLER COMMANDS ARE SCALED BY A LINEAR/QUADRATIC LAW. FOR THE LM-ALONE, MAXIMUM COM
# AND 4 D/S IN NORMAL AND FINE SCALING; HOWEVER, STICK SENSITIVITY AT ZERO COUNTS (OBTAINED AT
# OF 2 DEGREES FROM THE CENTERED POSITION) IS .5 OR .1 D/S PER DEGREE. NORMAL AND FINE SCALING
# CASE IS AUTOMATICALLY SET TO 1/10 THE ABOVE VALUES. SCALING IS DETERMINED IN ROUTINE 3.
#
# ZEROENBL      ENABLES COUNTERS SO THEY CAN BE READ NEXT TIME
# JUSTOUT       FIRST DETECTION OF OUT OF DETENT (BY OURRCBIT)

DETENTCK      EXTEND
              READ    CHAN31
              TS      CH31TEMP
              MASK    BIT15          # CHECK OUT-OF-DETENT BIT.
              EXTEND
              BZF     RHCMOVED        # BRANCH IF OUT OF DETENT.
              CAF     OURRCBIT        # IN DETENT. CHECK THE RATE COMMAND BIT.
              MASK    DAPBOOLS
              EXTEND
              BZF     PURGENCY        # BRANCH IF NOT IN RATE COMMAND LAST PASS.

# .....

              CA      BIT9           # JUST IN DETENT??
              MASK    RCSFLAGS
              EXTEND
              BZF     RUTH
              CAF     BIT13          # CHECK FOR ATTITUDE HOLD.
              EXTEND
              RAND    CHAN31
              EXTEND
              BZF     RATEDAMP        # BRANCH IF IN ATTITUDE HOLD.

              CS      BITS9,11       # IN AUTO.
              MASK    RCSFLAGS        # (X-AXIS OVERRIDE)
              TS      RCSFLAGS        # ZERO ORBIT (BIT 11) AND JUST-IN BIT (9).
              TCF     RATEDAMP

RUTH          CA      RCSFLAGS
              MASK    PBIT           # IN ATTITUDE HOLD.
              EXTEND
              BZF     +2              # BRANCH IF P-RATE DAMPING IS FINISHED.
              TCF     RATEDAMP
```

# Page 1433

|        |          |                                           |
|--------|----------|-------------------------------------------|
| CA     | RCSFLAGS |                                           |
| MASK   | QRBIT    |                                           |
| EXTEND |          |                                           |
| BZF    | RATEDONE | # BRANCH IF Q,R RATE DAMPING IS FINISHED. |
| TCF    | RATEDAMP |                                           |

# =====

|          |        |        |
|----------|--------|--------|
| 1/10SEC  | OCT    | 1      |
| 40CYC    | OCT    | 50     |
| PQRBIT   | OCT    | 74777  |
| BITS9,11 | EQUALS | EBANK5 |
| LINRATP  | DEC    | 46     |

# =====

|          |        |          |                                           |
|----------|--------|----------|-------------------------------------------|
| RATEDONE | CS     | OURRCBIT | # MANUAL COMMAND AND DAMPING COMPLETED IN |
|          | INHINT |          | # ALL AXES.                               |
|          | MASK   | DAPBOOLS |                                           |
|          | TS     | DAPBOOLS |                                           |

# READ CDUS INTO CDU DESIRED REGISTERS

|        |          |                     |
|--------|----------|---------------------|
| CAF    | BIT13    |                     |
| EXTEND |          |                     |
| RAND   | CHAN31   |                     |
| EXTEND |          |                     |
| BZF    | +4       |                     |
| CA     | CDUX     | # (X-AXIS OVERRIDE) |
| TS     | CDUXD    |                     |
| TC     | +3       |                     |
| TC     | IBNKCALL |                     |
| FCADR  | ZATTEROR |                     |
| RELINT |          |                     |
| TCF    | PURGENCY |                     |

|         |     |            |                                        |
|---------|-----|------------|----------------------------------------|
|         | TS  | PERROR     |                                        |
| JUSTOUT | CA  | OURRCBIT   | # INITIALIZATION -- FIRST MANUAL PASS. |
|         | ADS | DAPBOOLS   |                                        |
|         | CA  | ZERO       |                                        |
|         | TS  | DXERROR    |                                        |
|         | TS  | DXERROR +1 |                                        |
|         | TS  | DYERROR    |                                        |
|         | TS  | DYERROR +1 |                                        |

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```
# Page 1434
TS      DZERROR
TS      DZERROR +1
TS      PLAST
TS      QLAST
TS      RLAST
TS      Q-RHCCTR
TS      R-RHCCTR
CA      PQRBIT
MASK    RCSFLAGS
TS      RCSFLAGS      # BITS 10 AND 11 OF RCSFLAGS ARE 0.

CS      RCSFLAGS      # SET 'JUST-IN' BIT TO 1.
MASK    BIT9
ADS     RCSFLAGS
TC      ZEROENBL
TCF     JETSOFF
ZEROENBL LXCH  R-RHCCTR
CA      Q-RHCCTR
DXCH    SAVEHAND
CA      ZERO
TS      P-RHCCTR
TS      Q-RHCCTR
TS      R-RHCCTR
CA      BITS8,9
EXTEND
WOR     CHAN13      # COUNTERS ZEROED AND ENABLED
TC      Q
RATEDAMP CA      ZERO
TS      P-RHCCTR
TCF     RATERROR

RHCMOVED CA      OURRCBIT      # P CONTROL
MASK    DAPBOOLS
EXTEND
BZF     JUSTOUT -1
RATERROR CA      CDUX      # FINDCDUW REQUIRES THAT CDUXD=CDUX DURING
TS      CDUXD      # X-AXIS OVERRIDE
CCS     P-RHCCTR
TCF     +3
TCF     +2
TCF     +1
DOUBLE  # LINEAR/QUADRATIC CONTROLLER SCALING
DOUBLE  # (SEE EXPLANATION OF Q,R-AXES RCS
AD      LINRATP      # AUTOPILOT)
EXTEND
MP      P-RHCCTR
```

```

CA      L
EXTEND
MP      STIKSENS
XCH     PLAST
COM
AD      PLAST
TS      DAPTEMP1
TC      ZEROENBL      # INTERVAL.  ZERO AND ENABLE ACA COUNTERS.
CS      PLAST
AD      OMEGAP
TS      EDOTP
CCS     DAPTEMP1      # IF P COMMAND CHANGE EXCEEDS BREAKOUT
TCF     +3             # LEVEL, GO TO DIRECT RATE CONTROL.  IF NOT
TCF     +8D            # CHECK FOR DIRECT RATE CONTROL LAST TIME.
TCF     +1

# Page 1435

AD      -RATEDB
EXTEND
BZMF    +4
CA      40CYC
TS      TCP
TC      PEGI
CA      RCSFLAGS      # CHECK FOR DIRECT RATE COMMAND LAST TIME.
MASK    PBIT
EXTEND
BZF     +2
TC      PEGI           # TO PURE RATE COMMAND
CA      DXERROR        # PSEUDO-AUTO CONTROL.
TS      E              # X-ATTITUDE ERROR (SP)
TS      PERROR         # LOAD P-AXIS ERROR FOR MODE1 FDAI DISPLAY
TC      PURGENCY +4
PEGI    CA      CDUX    # DIRECT RATE CONTROL.
TS      CDUXD
CA      ZERO
TS      DXERROR
TS      DXERROR +1
TS      PERROR         # ZERO P-AXIS ERROR FOR MODE1 FDAI DISPLAY
CCS     EDOTP
TC      +3
TC      +2
TC      +1
TS      ABSEDOTP
AD      TARGETDB
EXTEND
BZMF    LAST           # IF RATE ERROR IS LESS THAN DEADBANK,
CA      TCP            # FIRE, AN SWITCH TO PSEUDO-AUTO.

```



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```

                                EXTEND                                # IF TIME IN RATE COMMAND EXCEEDS 4 SEC.
                                BZMF      LAST
                                CS        RCSFLAGS
                                MASK      PBIT
                                ADS        RCSFLAGS                    # BIT 10 IS 1.
                                TCF        +4
LAST                                CS        PBIT
                                MASK      RCSFLAGS
                                TS        RCSFLAGS                    # BIT 10 IS 0.
                                CS        EDOTP
                                EXTEND
                                MP        1/ANETP                    # 1/2JTACC SCALED AT 2EXP(7)/PI
                                DAS        A
                                TC        OVERSUB
                                EXTEND
                                MP        25/32                    # A CONTAINS TJET SCALED AT 2EXP(4)(16/25)
                                TS        TJP                        # 4.JET TIME
                                CA        ABSEDOTP
                                AD        -2JETLIM                    # COMPARING DELTA RATE WITH 2 JET LIMIT
                                EXTEND
# Page 1436
                                BZMF      +3
                                CA        SIX
                                TCF        +8D
                                CA        TJP
                                ADS        TJP

# GOES TO PJETSLEC FOR TWO JETS
# P-JET-SELECTION-ROUTINE (ROTATION)
#
# INPUT:          NUMBERT          4,5,6 FOR WHICH PAIR OR 4 JETS
#                 TJP              + FOR +P ROTATION
#
# OUTPUT:         CHANNEL 6
#                 PJUMPADR          FOR P-AXIS SKIP
#                 (JTLST CALL)      (SMALL TJP)
#
# ORDER OF POLICIES TRIED IN CASE OF FAILURE.
#      +P      -P
#      7,15    8,16
#      4,12    3,11
#      4,7     8,11
#      7,12    11,16
#      12,15   3,16
#      4,15    3,8
```

| #        | ALARM  | ALARM    |
|----------|--------|----------|
|          | CA     | AORBSYST |
|          | MASK   | DAPBOOLS |
|          | CCS    | A        |
|          | CA     | ONE      |
|          | AD     | FOUR     |
|          | TS     | NUMBERT  |
| PJETSLEC | CA     | ONE      |
|          | TS     | L        |
|          | CCS    | TJP      |
|          | TCF    | +5       |
|          | TCF    | JETSOFF  |
|          | TCF    | +2       |
|          | TCF    | JETSOFF  |
|          | ZL     |          |
|          | AD     | ONE      |
|          | TS     | ABSTJ    |
|          | LXCH   | ROTINDEX |
|          | TC     | SELECTP  |
|          | CS     | SIX      |
|          | AD     | NUMBERT  |
|          | EXTEND |          |
|          | BZF    | +2       |
|          | CS     | TWO      |

# Page 1437

|        |          |
|--------|----------|
| AD     | FOUR     |
| TS     | NO.PJETS |
| CA     | POLYTEMP |
| TC     | WRITEP   |
| CS     | ABSTJ    |
| AD     | +150MST6 |
| EXTEND |          |
| BZMF   | QRAXIS   |
| AD     | -136MST6 |
| EXTEND |          |
| BZMF   | +5       |
| ADS    | ABSTJ    |
| INDEX  | ROTINDEX |
| CA     | MINTIMES |
| TS     | TJP      |

# GO TO QRAXIS OR TO GTS.

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```

      CA      ABSTJ
      ZL
      INHINT
      DXCH     T6FURTHA
      TC       IBNKCALL
      CADR     JTLST
      CS       BIT12
      MASK     RCSFLAGS
      TS       RCSFLAGS      # BIT 12 SET TO 0.
      TC       ALTSYST
      TCF      QRAXIS

ALTSYST      CA      DAPBOOLS      # ALTERNATE P-AXIS JETS
              TS      L
              CA      AORBSYST
              EXTEND
              RXOR     LCHAN
              TS      DAPBOOLS
              RELINT
              TC      Q

DKALT        TC      ALTSYST

JETSOFF      TC      WRITEP  -1
              CA      ZERO
              TS      TJP
              TCF      QRAXIS

# (NOTE -- M13 = 1 IDENTICALLY IMPLIES NULL MULTIPLICATION.)

CALCPERR     CA      CDUY          # P-ERROR CALCULATION.
              EXTEND
              MSU     CDUYD        # CDU VALUE -- ANGLE DESIRED (Y-AXIS)

# Page 1438
              EXTEND
              MP      M11          # (CDUY-CDUYD)M11 SCALED AT PI RADIANS
              XCH     E            # SAVE FIRST TERM (OF TWO)
              CA      CDUX        # THIRD COMPONENT
              EXTEND
              MSU     CDUXD        # CDU VALUE -- ANGLE DESIRED (X-AXIS)
#              EXTEND
#              MP      M13
              AD      DELPEROR     # KALCMANU INTERFACE ERROR.
              ADS     E            # SAVE SUM OF TERMS.  COULD BE OVERFLOW.
              XCH     PERROR       # SAVE P-ERROR FOR EIGHT-BALL DISPLAY.
              TC      Q            # RETURN TO CALLER
```

## # P-AXIS URGENCY FUNCTION CALCULATION.

|             |        |             |                                            |
|-------------|--------|-------------|--------------------------------------------|
| PURGENCY    | TC     | CALCPERR    | # CALCULATE P-AXIS ERRORS.                 |
|             | CS     | OMEGAPD     | # THIS CODING IS COMMON TO BOTH LM DAP AND |
|             | AD     | OMEGAP      | # SPS-BACKUP MODE.                         |
|             | TS     | EDOTP       | # EDOTP = OMEGAP - OMEGAPD AT PI/4 RAD/SEC |
|             | CS     | ONE         |                                            |
|             | TS     | AXISCTR     |                                            |
|             | CA     | DAPBOOLS    |                                            |
|             | MASK   | CSMDOCKD    |                                            |
|             | EXTEND |             |                                            |
|             | BZF    | HEADTJET    |                                            |
|             | INHINT |             | # IF CSMDOCKD = 1, GOT TO DOCKED RCS LOGIC |
|             | TC     | IBNKCALL    |                                            |
|             | CADR   | SPSRCS      |                                            |
|             | CA     | TJP         |                                            |
|             | EXTEND |             |                                            |
|             | BZF    | DKALT       | # IF TJP = ZERO, CHANGE AORBSYST.          |
|             | RELINT |             |                                            |
|             | TCF    | PJETSLEC -6 | # SELECT AORBSYST AND USE TWO JETS.        |
| HEADTJET    | CA     | ZERO        |                                            |
|             | TS     | SENSETYP    |                                            |
|             | INHINT |             |                                            |
|             | TC     | IBNKCALL    |                                            |
|             | CADR   | TJETLAW     |                                            |
|             | RELINT |             |                                            |
|             | CS     | FIREFCT     |                                            |
|             | AD     | -FOURDEG    |                                            |
|             | EXTEND |             |                                            |
|             | BZMF   | PJETSLEC -6 |                                            |
|             | CCS    | TJP         |                                            |
|             | TCF    | +2          |                                            |
|             | TCF    | JETSOFF     |                                            |
| # Page 1439 | AD     | -160MST6    |                                            |
|             | EXTEND |             |                                            |
|             | BZMF   | PJETSLEC -6 |                                            |
|             | CA     | SIX         |                                            |
|             | TCF    | PJETSLEC -1 |                                            |
| -160MST6    | DEC    | -256        |                                            |
| -FOURDEG    | DEC    | -.08888     |                                            |

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```
# Page 1440
# JET POLICY CONTSTRUCTION SUBROUTINE
#
# INPUT:      ROTINDEX, NUMBERT
#
# OUTPUT:     POLYTEMP (JET POLICY)
#
# THIS SUBROUTINE SELECT A SUBSET OF THE DESIRED JETS WHICH HAS NO FAILURE

SELECTP      CA      SIX
              TS      TEMPNUM
              INDEX   NUMBERT
              CA      TYPEP
              INDEX   ROTINDEX
              MASK     JETSALL
              TS      POLYTEMP
              MASK     CH6MASK
              CCS      A
              TCF      +2
              TC       Q
              CCS      TEMPNUM
              TCF      +4
              TC       ALARM
              OCT      02003
              TCF      JETSOFF      # ***** TCF ALARMJET *****
SELECTYZ      TS      NUMBERT
              TCF      SELECTP +1
              TCF      ABORTYZ +2
-1
JETSALL      OCT      00252
              OCT      00125      # +P
              OCT      00140      # -Y
              OCT      00006      # -Z
              OCT      00220      # +Y
              OCT      00011      # +Z
              OCT      00151      # +V
              TYPEP    OCT      00146      # -U
              OCT      00226      # -V
              OCT      00231      # +U
              OCT      00151      # +V
              OCT      00132      # 1-3
              OCT      00245      # 2-4
              OCT      00377      # ALL
INDXYZ      =      -136MST6
-136MST6    DEC      -218
              DEC      4
              DEC      2
```

```

OCT      07776
DEC      5
DEC      9
DEC     10
OCT     07776
DEC      3

# Page 1441
DEC      8
DEC      7
OCT     07776
OCT     07776
OCT     07776
OCT     07776
OCT     07776
+150MST6 DEC     240
07400OCT OCT     07400

# THESE INDEXES OF MASK JETSALL WILL
# CHANGE THE INSTRUCTION AT SELECTP +4
# TO BE          TC JETSALL -1
# ONLY USED FOR TRANSLATION FAILURE

# T-JET LAW FIXED CONSTANTS

NORMSCL   OCT     266
-100MS    DEC     -.1
200MS     DEC     .2
25/32     =      PRI031
BITS8,9   OCTAL   00600
1/40      DEC     .02500
MINTIMES  DEC     -22
          DEC     22
PSKIPADR  GENADR  SKIPPAXS

# GOES TO Q,R-AXES RCS AUTOPILOT

QRAXIS    CS      OMEGARD
          AD      OMEGAR
          TC      OVERSUB
          TS      EDOTR
          CS      OMEGAQD
          AD      OMEGAQ
          TC      OVERSUB
          TS      EDOTQ
          EXTEND
          DCA      QERRCALL
          DTCB

          EBANK=   AOSQ
QERRCALL  2CADR   CALLQERR

```

This code is written to file `src/P-AXIS-RCS-AUTOPILOT.s`.

## A.78 PHASE TABLE MAINTENANCE

```

1375  <src/PHASE-TABLE-MAINTENANCE.s 1375>≡
# Copyright:   Public domain.
# Filename:    PHASE_TABLE_MAINTENANCE.agc
# Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
#             It is part of the source code for the Command Module's (CM)
#             Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:  yaYUL
# Contact:     Ron Burkey <info@sandroid.org>.
# Website:     www.ibiblio.org/apollo.
# Pages:       1404-1413
# Mod history: 2009-05-10 SN   (Sergio Navarro). Started adapting
#                               from the Colossus249/ file of the same
#                               name, using Comanche055 page images.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#   Assemble revision 055 of AGC program Comanche by NASA
#   2021113-051. 10:28 APR. 1, 1969
#
#   This AGC program shall also be referred to as
#   Colossus 2A

# Page 1404
# SUBROUTINE TO UPDATE THE PROGRAM NUMBER DISPLAY ON THE DSKY.

COUNT 02/PHASE
BLOCK 02
SETLOC FFTAG1
BANK

NEWMODEX INDEX Q # UPDATE MODREG. ENTRY FOR MODE IN FIXED.
CAF 0
INCR Q

NEWMODEA TS MODREG # ENTRY FOR MODE IN A.
```

```

MMDSPY    CAF      +3          # DISPLAY MAJOR MODE.
PREBJUMP   LXCH     BBANK       # PUTS BBANK IN L
           TCF      BANKJUMP    # PUTS Q INTO A
           CADR     SETUPDSP

# RETURN TO CALLER +3 IF MODE = THAT AT CALLER +1.  OTHERWISE RETURN TO CALLER +2.

CHECKMM    INDEX    Q
           CS        0
           AD        MODREG
           EXTEND
           BZF       Q+2
           TCF       Q+1        # NO MATCH

TCQ        =        Q+2 +1

           BANK      14
           SETLOC    PHASETAB
           BANK

           COUNT     10/PHASE

SETUPDSP    INHINT
           DXCH      RUPTREG1   # SAVE CALLER'S RETURN 2CADR
           CAF       PRI030     #     EITHER A TASK OR JOB CAN COME TO
           TC        NOVAC      #     NEWMODEX
           EBANK=    MODREG
           2CADR     DSPMMJOB

           DXCH      RUPTREG1
           RELINT
           DXCH      Z          # RETURN

DSPMMJOB    EQUALS   DSPMMJB

           BLOCK     02

# Page 1405

           SETLOC    FFTAG1
           BANK

# Page 1406
# PHASCHNG IS THE MAIN WAY OF MAKING PHASE CHANGES FOR RESTARTS.  THERE ARE THREE FOR
# A, TYPE B, AND TYPE C.  THEY ARE ALL CALLED AS FOLLOWS, WHERE OCT XXXXX CONTAINS TH
#           TC        PHASCHNG
#           OCT      XXXXX
# TYPE A IS CONCERNED WITH FIXED PHASE CHANGES, THAT IS, PHASE INFORMATION THAT IS ST

```



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```
# OPTIONS ARE, WHERE G STANDS FOR A GROUP AND .X FOR THE PHASE,
#       G.0             INACTIVE, WILL NOT PERMIT A GROUP G RESTART
#       G.1             WILL CAUSE THE LAST DISPLAY TO BE REACTIVATED, USED MAINLY IN MANNED FL
#       G.EVEN          A DOUBLE TABLE RESTART, CAN CAUSE ANY COMBINATION OF TWO JOBS, TASKS, A
#                       LONGCALL TO BE RESTARTED.
#       G.ODD NOT .1    A SINGLE TABLE RESTART, CAN CAUSE EITHER A JOB, TASK, OR LONGCALL RESTA
#
# THIS INFORMATION IS PUT INTO THE OCTAL WORD AFTER TC PHASCHNG AS FOLLOWS
#       TLO OOP PPP PPP GGG
# WHERE EACH LETTER OR NUMBER STANDS FOR A BIT.  THE G'S STAND FOR THE GROUP, OCTAL 1-7, THE P'
# OCTAL 0 - 127.  O'S MUST BE 0.  IF ONE WISHES TO HAVE THE TBASE OF GROUP G TO BE SET AT THIS
# T IS SET TO 1, OTHERWISE IT IS SET TO 0.  SIMILARLY IF ONE WISHES TO SET LONGBASE, THEN L IS
# IT IS SET TO 0.  SOME EXAMLES,
#       TC      PHASCHNG      # THIS WILL CAUSE GROUP 3 TO BE SET TO 0,
#       OCT      00003        # MAKING GROUP 3 INACTIVE
#
#       TC      PHASCHNG      # IF A RESTART OCCURS THIS WOULD CAUSE
#       OCT      00012        # GROUP 2 TO RESTART THE LAST DISPLAY
#
#       TC      PHASCHNG      # THIS SETS THE TBASE OF GROUP 4 AND IN
#       OCT      40064        # CASE OF A RESTART WOULD START UP THE TWO
#                               # THINGS LOCATED IN THE DOUBLE 4.6 RESTART
#                               # LOCATION.
#
#       TC      PHASCHNG      # THIS SETS LONGBASE AND UPON A RESTART
#       OCT      20135        # CAUSES 5.13 TO BE RESTARTED (SINCE
#                               # LONGBASE WAS SET THIS SINGLE ENTRY
#                               # SHOULD BE A LONGCALL)
#
#       TC      PHASCHNG      # SINCE BOTH TBASE4 AND LONGBASE ARE SET,
#       OCT      60124        # 4.12 SHOULD CONTAIN BOTH A TASK AND A
#                               # LONGCALL TO BE RESTARTED
#
# TYPE C PHASCHNG CONTAINS THE VARIABLE TYPE OF PHASCHNG INFORMATION.  INSTEAD OF THE INFORMATI
# PERMANENT FORM, ONE STORES THE DESIRED RESTART INFORMATION IN A VARIABLE LOCATION.  THE BITS
#       TLO 1AD XXX CJW GGG
# WHERE EACH LETTER OR NUMBER STANDS FOR A BIT.  THE G'S STAND FOR THE GROUP, OCTAL 1 - 7.  IF
# BE BY WAITLIST, W IS SET TO 1, IF IT IS A JOB, J IS SET TO 1, IF IT IS A LONGCALL, C IS SET T
# THESE THREE BITS MAY BE SET.  X'S ARE IGNORED, 1 MUST BE 1, AND 0 MUST BE 0.  AGAIN T STANDS
# Page 1407
# AND L FOR LONGBASE.  THE BITS A AND D ARE CONCERNED WITH THE VARIABLE INFORMATION.  IF D IS S
# OR DELTA TIME WILL BE READ FROM THE NEXT LOCATION AFTER THE OCTAL INFORMATION., IF THIS IS TO
# IS, THE NAME OF A LOCATION CONTAINING THE INFORMATION (DELTA TIME ONLY), THEN THIS IS GIVEN A
# THAT LOCATION WHICH CONTAINS THE DELTA TIME.  IF THE OLD PRIORITY OR DELTA TIME IS TO BE USED
# ALREADY IN THE VARIABLE STORAGE, THEN D IS SET TO 0.  NEXT THE A BIT IS USED.  IF IT IS SET T
# THAT WOULD BE RESTARTED DURING A RESTART IS THE NEXT LOCATION AFTER THE PHASE INFORMATION, TH
```

```

# (TC PHASCHNG) +2 OR +3, DEPENDING ON WHETHER D HAD BEEN SET OR NOT.  IF A IS SET T
# WOULD BE RESTARTED IS THE 2CADR THAT IS READ FROM THE NEXT TWO LOCATION.  EXAMPLES,
#      AD      TC      PHASCHNG      # THIS WOULD CAUSE LOCATION AD +3 TO BE
#      AD+1     OCT      05023      # RESTARTED BY GROUP THREE WITH A PRIORITY
#      AD+2     OCT      23000      # OF 23.  NOTE UPON RETURNING IT WOULD
#      AD+3                                     # ALSO GO TO AD+3
#
#      AD      TC      PHASCHNG      # GROUP 1 WOULD CAUSE CALLCALL TO BE
#      AD+1     OCT      27441      # BE STARTED AS A LONGCALL FROM THE TIME
#      AD+2     -GENADR DELTIME      # STORED IN LONGBASE (LONGBASE WAS SET) BY
#      AD+3     2CADR  CALLCALL      # A DELTATIME STORED IN DELTIME.  THE
#      AD+4                                     # BBCON OF THE 2CADR SHOULD CONTAIN THE E
#      AD+5                                     # BANK OF DELTIME.  PHASCHNG RETURNS TO
#                                     # LOCATION AD+5
#
# NOTE THAT IF A VARIABLE PRIORITY IS GIVEN FOR A JOB, THE JOB WILL BE RESTARTED AS A
# NEGATIVE, AS A FINDVAC IF THE PRIORITY IS POSITIVE.
#
# TYPE B PHASCHNG IS A COMBINATION OF VARIABLE AND FIXED PHASE CHANGES.  IT WILL START
# BELOW AND ALSO START UP ONE FIXED RESTART, THAT IS EITHER AN G.1 OR A G.ODD OR THE
# DOUBLE ENTRY.  THE BIT INFORMATION IS AS FOLLOW,
#      TL1 DAP PPP PPP GGG
# WHERE EACH LETTER OR NUMBER STANDS FOR A BIT.  THE G'S STAND FOR THE GROUP, OCTAL 1
# PHASE INFORMATION, OCTAL 0 - 127.  1 MUST BE 1.  AND AGAIN T STANDS FOR THE TBASE A
# TIME STANDS ONLY FOR PRIORITY SINCE THIS WILL BE CONSIDERED A JOB, AND IT MUST BE C
# AGAIN A STANDS FOR THE ADDRESS OF THE LOCATION TO BE RESTARTED, 1 IF THE 2CADR IS C
# THE NEXT LOCATION.  (THE RETURN LOCATION OF PHASCHNG) EXAMPLES,
#      AD      TC      PHASCHNG      # TBASE IS SET AND A RESTART CAUSE GROUP 3
#      AD+1     OCT      56043      # TO START THE JOB AJOBAJOB WITH PRIORITY
#      AD+2     OCT      31000      # 31 AND THE FIRST ENTRY OF 3.4SPOT (WE CAN
#      AD+3     2CADR  AJOBAJOB      # ASSUME IT IS A TASK SINCE WE SET TBASE3)
#      AD+4                                     # UPON RETURN FROM PHASCHNG CONTROL WOULD
#      AD+5                                     # GO TO AD+5
#
#      AD      TC      PHASCHNG      # UPON A RESTART THE LAST DISPLAY WOULD BE
#      AD+1     OCT      10015      # RESTARTED AND A JOB WITH THE PREVIOUSLY
#      AD+2                                     # STORED PRIORITY WOULD BE BEGUN AT AD+2
#                                     # BY MEANS OF GROUP 5
# Page 1408
# THE NOVAC-FINDVAC CHOICE FOR JOBS HOLDS HERE ALSO -- NEGATIVE PRIORITY CAUSES A NOV
#
# SUMMARY OF BITS:
#      TYPE A      TL0 OOP PPP PPP GGG
#      TYPE B      TL1 DAP PPP PPP GGG
#      TYPE C      TL0 1AD XXX CJW GGG

```

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# Page 1409

# 2PHSCHNG IS USED WHEN ONE WISHES TO START UP A GROUP OR CHANGE A GROUP WHILE UNDER THE CONTROL OF A GROUP. FOR EXAMPLE, CHANGE THE PHASE OF GROUP 3 WHILE THE PORTION OF THE PROGRAM IS UNDER GROUP 3. CALLS ARE MADE IN THE FOLLOWING MANNER,

# TC 2PHSCHNG  
# OCT XXXXX  
# OCT YYYYY

# WHERE OCT XXXXX MUST BE OF TYPE A AND OCT YYYYY MAY BE OF EITHER TYPE A OR TYPE B OR TYPE C. # DIFFERENCE --- NOTE: IF LONGBASE IS TO BE SET THIS INFORMATION IS GIVEN IN THE OCT YYYYY INFORMATION. # BE DISREGARDED IF GIVEN WITH THE OCT XXXXX INFORMATION. A COUPLE OF EXAMPLES MAY HELP,

# AD TC 2PHACHNG # SET TBASE3 AND IF A RESTART OCCURS START  
# AD+1 OCT 40083 # THE TWO ENTRIES IN 3.8 TABLE LOCATION  
# AD+2 OCT 05025 # THIS IS OF TYPE C, SET THE JOB TO BE  
# AD+3 OCT 18000 # TO BE LOCATION AD+4, WITH A PRIORITY 18,  
# AD+4 # FOR GROUP 5 PHASE INFORMATION.

COUNT 02/PHASE

2PHSCHNG

INHINT # THE ENTRY FOR A DOUBLE PHASE CHANGE

NDX Q

CA 0

INCR Q

TS TEMPP2

MASK OCT7

DOUBLE

TS TEMPG2

CA TEMPP2

MASK OCT17770 # NEED ONLY 1770, BUT WHY GET A NEW CONST.

EXTEND

MP BIT12

XCH TEMPP2

MASK BIT15

TS TEMPSW2 # INDICATES WHETHER TO SET TBASE OR NOT

TCF PHASCHNG +3

PHASCHNG

INHINT

CA ONE # INDICATES CAME FROM A PHASCHNG ENTRY

TS TEMPSW2

NDX Q

CA 0

INCR Q

```

# Page 1410
TS      TEMPSW
EXTEND
DCA      ADRPCHN2      # OFF TO SWITCHED BANK
DTCB

EBANK=   LST1
ADRPCHN2 2CADR      PHSCHNG2

ONEORTWO LXCH      TEMPBBCN
LXCH      BBANK
LXCH      TEMPBBCN

MASK      OCT14000      # SEE WHAT KIND OF PHASE CHANGE IT IS
CCS      A
TCF      CHECKB      # IT IS OF TYPE 'B'.

CA      TEMPP
MASK      BIT7
CCS      A      # SHALL WE USE THE OLD PRIORITY
TCF      GETPRIO      # NO GET A NEW PRIORITY (OR DELTA T)

OLDPRIO  NDX      TEMPG      # USE THE OLD PRIORITY (OR DELTA T)
CA      PHSPRDT1 -2
TS      TEMPPR

CON1      CA      TEMPP      # SEE IF A 2CADR IS GIVEN
MASK      BIT8
CCS      A
TCF      GETNEWNM

CA      Q
TS      TEMPNM
CA      BB
EXTEND
ROR      SUPERBNK      # PICK UP USER'S SUPERBANK
TS      TEMPBB

TOCON2    CA      CON2ADR      # BACK TO SWITCHED BANK
LXCH      TEMPBBCN
DTCB

CON2ADR    GENADR  CON2

GETPRIO    NDX      Q      # DON'T CARE IF DIRECT OR INDIRECT
CA      0      # LEAVE THAT DECISION TO RESTARTS

```

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|             |        |          |                         |
|-------------|--------|----------|-------------------------|
|             | INCR   | Q        | # OBTAIN RETURN ADDRESS |
|             | TCF    | CON1 -1  |                         |
| GETNEWNM    | EXTEND |          |                         |
| # Page 1411 |        |          |                         |
|             | INDEX  | Q        |                         |
|             | DCA    | 0        |                         |
|             | DXCH   | TEMPNM   |                         |
|             | CA     | TWO      |                         |
|             | ADS    | Q        | # OBTAIN RETURN ADDRESS |
|             | TCF    | TOCON2   |                         |
| OCT14000    | EQUALS | PRI014   |                         |
| TEMPG       | EQUALS | ITEMP1   |                         |
| TEMPP       | EQUALS | ITEMP2   |                         |
| TEMPNM      | EQUALS | ITEMP3   |                         |
| TEMPBB      | EQUALS | ITEMP4   |                         |
| TEMPSW      | EQUALS | ITEMP5   |                         |
| TEMPSW2     | EQUALS | ITEMP6   |                         |
| TEMPPR      | EQUALS | RUPTREG1 |                         |
| TEMPG2      | EQUALS | RUPTREG2 |                         |
| TEMPP2      | EQUALS | RUPTREG3 |                         |
| TEMPBBCN    | EQUALS | RUPTREG4 |                         |
| BB          | EQUALS | BBANK    |                         |
|             | BANK   | 14       |                         |
|             | SETLOC | PHASETAB |                         |
|             | BANK   |          |                         |
|             | EBANK= | PHSNAME1 |                         |
|             | COUNT  | 10/PHASE |                         |
| PHSCHNG2    | LXCH   | TEMPBBCN |                         |
|             | CA     | TEMPSW   |                         |
|             | MASK   | OCT7     |                         |
|             | DOUBLE |          |                         |
|             | TS     | TEMPG    |                         |
|             | CA     | TEMPSW   |                         |
|             | MASK   | OCT17770 |                         |
|             | EXTEND |          |                         |
|             | MP     | BIT12    |                         |
|             | TS     | TEMPP    |                         |

|             |        |            |                                          |
|-------------|--------|------------|------------------------------------------|
|             | CA     | TEMPSW     |                                          |
|             | MASK   | OCT60000   |                                          |
|             | XCH    | TEMPSW     |                                          |
|             | MASK   | OCT14000   |                                          |
|             | CCS    | A          |                                          |
|             | TCF    | ONEORTWO   |                                          |
| # Page 1412 |        |            |                                          |
|             | CA     | TEMPP      | # START STORING THE PHASE INFORMATION    |
|             | NDX    | TEMPPG     |                                          |
|             | TS     | PHASE1 -2  |                                          |
| BELOW1      | CCS    | TEMPSW2    | # IS IT A PHASCHNG OR A 2PHSCHNG         |
|             | TCF    | BELOW2     | # IT'S A PHASCHNG                        |
|             | TCF    | +1         | # IT'S A 2PHSCHNG                        |
|             | CS     | TEMPP2     |                                          |
|             | LXCH   | TEMPP2     |                                          |
|             | NDX    | TEMPPG2    |                                          |
|             | DXCH   | -PHASE1 -2 |                                          |
|             | CCS    | TEMPSW2    |                                          |
|             | NOOP   |            | # CAN'T GET HERE                         |
|             | TCF    | BELOW2     |                                          |
|             | CS     | TIME1      |                                          |
|             | NDX    | TEMPPG2    |                                          |
|             | TS     | TBASE1 -2  |                                          |
| BELOW2      | CCS    | TEMPSW     | # SEE IF WE SHOULD SET TBASE OR LONGBASE |
|             | TCF    | BELOW3     | # SET LONGBASE ONLY                      |
|             | TCF    | BELOW4     | # SET NEITHER                            |
|             | CS     | TIME1      | # SET TBASE TO BEGIN WITH                |
|             | NDX    | TEMPPG     |                                          |
|             | TS     | TBASE1 -2  |                                          |
|             | CA     | TEMPSW     | # SHALL WE NOW SET LONGBASE              |
|             | AD     | BIT14COM   |                                          |
|             | CCS    | A          |                                          |
|             | NOOP   |            | # ***** CAN'T GET HERE *****             |
| BIT14COM    | OCT    | 17777      | # ***** CAN'T GET HERE *****             |
|             | TCF    | BELOW4     | # NO WE NEED ONLY SET TBASE              |
| BELOW3      | EXTEND |            | # SET LONGBASE                           |
|             | DCA    | TIME2      |                                          |

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```

                                DXCH    LONGBASE

BELOW4      CS    TEMPP          # AND STORE THE FINAL PART OF THE PHASE
            NDX    TEMPG
            TS     -PHASE1 -2

            CA     Q
            LXCH   TEMPBBCN
            RELINT
            DTCB
CON2         LXCH   TEMPBBCN
# Page 1413

            CA     TEMPP
            NDX    TEMPG
            TS     PHASE1 -2

            CA     TEMPPR
            NDX    TEMPG
            TS     PHSPRDT1 -2

            EXTEND
            DCA     TEMPNM
            NDX     TEMPG
            DXCH    PHSNAME1 -2

            TCF     BELOW1

            BLOCK   02
            SETLOC  FFTAG1
            BANK

            COUNT   02/PHASE

CHECKB      MASK    BIT12          # SINCE THIS IS OF TYPE B, THIS BIT SHOULD
            CCS     A              # BE HERE IF WE ARE TO GET A NEW PRIORITY
            TCF     GETPRIO        # IT IS, SO GET NEW PRIORITY

            TCF     OLDPRIO        # IT ISN'T, USE THE OLD PRIORITY.
```

This code is written to file src/PHASE-TABLE-MAINTENANCE.s.

## A.79 PINBALL GAME BUTTONS AND LIGHTS

```

1384  <src/PINBALL-GAME-BUTTONS-AND-LIGHTS.s 1384>≡
# Copyright:    Public domain.
# Filename:     PINBALL_GAME_BUTTONS_AND_LIGHTS.agc
# Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
#              It is part of the source code for the Command Module's (CM)
#              Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:     Ron Burkey <info@sandroid.org>.
# Website:     www.ibiblio.org/apollo.
# Pages:       307-389
# Mod history: 2009-05-08 RSB Started adapting from the Colossus249/ file
#              of the same name, using Comanche055 page
#              images. Finished through page 329.
#              2009-05-09 RSB Finished first draft.
#              2009-05-20 RSB Corrected a CHKPOOH to CHKPOOH.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. 10:28 APR. 1, 1969
#
# This AGC program shall also be referred to as
# Colossus 2A
#
# Page 307
# PROGRAM NAME -- KEYBOARD AND DISPLAY PROGRAM
# MOD NO -- 4 DATE -- 27 APRIL 1967 ASSEMBLY -- PINDISK REV 17
# MOD BY -- FILENE
# LOG SECTION -- PINBALL GAME BUTTONS AND LIGHTS
#
# FUNCTIONAL DESCRIPTION
#
# THE KEYBOARD AND DISPLAY SYSTEM PROGRAM OPERATES UNDER EXECUTIVE
# CONTROL AND PROCESSES INFORMATION EXCHANGED BETWEEN THE AGC AND THE
# COMPUTER OPERATOR. THE INPUTS TO THE PROGRAM ARE FROM THE KEYBOARD,

```



```

# FROM INTERNAL PROGRAM, AND FROM THE UPLINK.
#
# THE LANGUAGE OF COMMUNICATION WITH THE PROGRAM IS A PAIR OF WORDS
# KNOWN AS VERB AND NOUN. EACH OF THESE IS REPRESENTED BY A 2 CHARACTER
# DECIMAL NUMBER. THE VERB CODE INDICATES WHAT ACTION IS TO BE TAKEN, THE
# NOUN CODE INDICATES TO WHAT THIS ACTION IS APPLIED. NOUNS USUALLY
# REFER TO A GROUP OF ERASABLE REGISTERS.
#
# VERBS ARE GROUPED INTO DISPLAYS, LOADS, MONITORS (DISPLAYS THAT ARE
# UPDATED ONCE PER SECOND), SPECIAL FUNCTIONS, AND EXTENDED VERBS (THESE
# ARE OUTSIDE OF THE DOMAIN OF PINBALL AND CAN BE FOUND UNDER LOG SECTION
# 'EXTENDED VERBS').
#
# A LIST OF VERBS AND NOUNS IS GIVEN IN LOG SECTION 'ASSEMBLY AND
# OPERATION INFORMATION'.
#
# CALLING SEQUENCES --
#
# KEYBOARD:
# EACH DEPRESSION OF A MAIN (NAVIGATION) KEYBOARD BUTTON ACTIVATES
# INTERRUPT KEYRUPT1 (KEYRUPT2) AND PLACES THE 5 BIT KEY CODE INTO
# CHANNEL 15 (CHANNEL 16). KEYRUPT1 (KEYRUPT2) PLACES THE KEY
# CODE INTO MPAC, ENTERS AN EXECUTIVE REQUEST FOR THE KEYBOARD AND DISPLAY
# PROGRAM (AT 'CHARIN'), AND EXECUTES A RESUME.
#
# UPLINK:
# EACH WORD RECEIVED BY THE UPLINK ACTIVATES INTERRUPT UPRUPT, WHICH
# PLACES THE 5 BIT KEY CODE INTO MPAC, ENTERS AN EXECUTIVE REQUEST FOR THE
# KEYBOARD AND DISPLAY PROGRAM (AT 'CHARIN') AND EXECUTES A RESUME.
#
# INTERNAL PROGRAMS:
# INTERNAL PROGRAMS CALL PINBALL AT 'NVSUB' WITH THE DESIRED VERB/NOUN
# CODE IN A (LOW 7 BITS FOR NOUN, NEXT 7 BITS FOR VERB). DETAILS
# DESCRIBED ON REMARKS CARDS JUST BEFORE 'NVSUB' AND 'NVSBWAIT' (SEE
# SYMBOL TABLE FOR PAGE NUMBERS).
#
# NORMAL EXIT MODES --
#
# IF PINBALL WAS CALLED BY EXTERNAL ACTION, THERE ARE FOUR EXITS:
# 1) ALL BUT (2), (3), AND (4) EXIT DIRECTLY TO ENDOFJOB.
# Page 308
# 2) EXTENDED VERBS TO TO THE EXTENDED VERB FAN AS PART OF THE
# PINBALL EXECUTIVE JOB WITH PRIORITY 30000. IT IS THE
# RESPONSIBILITY OF THE EXTENDED VERB CALLED TO EVENTUALLY
# CHANGE PRIORITY (IF NECESSARY) AND DO AN ENDOFJOB.
# ALSO PINBALL IS A NOVAC JOB. EBANK SET FOR COMMON.

```

```

#           3)      VERB 37.  CHANGE OF PROGRAM (MAJOR MODE) CALLS 'V37' IN THE
#                   SERVICE ROUTINES AS PART OF THE PINBALL EXEC JOB WITH PRIO
#                   30000.  THE NEW PROGRAM CODE (MAJOR MODE) IS LEFT IN A.
#           4)      KEY RELEASE BUTTON CALLS 'PINBRNCH' IN THE DISPLAY INTERFACE
#                   ROUTINES AS PART OF THE PINBALL EXEC JOB WITH PRIO 30000 IF
#                   THE KEY RELEASE LIGHT IS OFF AND 'CADRSTOR' IS NOT 40.
#
# IF PINBALL WAS CALLED BY INTERNAL PROGRAMS, EXIT FROM PINBALL IS BACK
# TO CALLING ROUTINE.  DETAILS DESCRIBED IN REMARKS CARDS JUST BEFORE
# 'NVSUB' AND 'NVSBWAIT' (SEE SYMBOL TABLE FOR PAGE NUMBERS).
#
# ALARM OR ABORT EXIT MODES --
#
#     EXTERNAL INITIATION:
#         IF SOME IMPROPER SEQUENCE OF KEY CODES IS DETECTED, THE OPERATOR
#         ERROR LIGHT IS TURNED ON AND EXIT IS TO 'ENDOFJOB'.
#
#     INTERNAL PROGRAM INITIATION:
#         IF AN ILLEGAL V/N COMBINATION IS ATTEMPTED, AN ABORT IS CAUSED
#         (WITH OCTAL 01501).
#         IF A SECOND ATTEMPT IS MADE TO GO TO SLEEP IN PINBALL, AN ABORT IS
#         CAUSED (WITH OCTAL 01206).  THERE ARE TWO WAYS TO GO TO SLEEP IN PINBALL
#         1)      ENDIDLE OR DATAWAIT.
#         2)      NVSBWAIT, PRENVBSY, OR NVSUBUSY.
#
# CONDITIONS LEADING TO THE ABOVE ARE DESCRIBED IN FORTHCOMING MIT/IL
# E-REPORT DESCRIBING KEYBOARD AND DISPLAY OPERATION FOR 278.
#
# OUTPUT --
#
# INFORMATION TO BE SENT TO THE DISPLAY PANEL IS LEFT IN THE 'DSPTAB'
# BUFFERS REGISTERS (UNDER EXEC CONTROL).  'DSPOUT' (A PART OF T4RUPT)
# HANDLES THE PLACING OF THE 'DSPTAB' INFORMATION INTO OUTPUT CHANNEL 10
# IN INTERRUPT.
#
# ERASABLE INITIALIZATION --
#
# FRESH START AND RESTART INITIALIZE THE NECESSARY E REGISTERS FOR
# PINBALL IN 'STARTSUB'.  REGISTERS ARE:  DSPTAB BUFFER, CADRSTOR,
# REQRET, CLPASS, DSPLOCK, MONSAVE, MONSAVE1, VERBREG, NOUNREG, DSPLIST,
# DSPCOUNT, NOUT.
#
# Page 309
# A COMPLETE LIST OF ALL THE ERASABLES (BOTH RESERVED AND TEMPORARIES) FOR
# PINBALL IS GIVEN BELOW.
#

```

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```
# THE FOLLOWING ARE OF GENERAL INTEREST --
#
# REMARKS CARDS PRECEDE THE REFERENCED SYMBOL DEFINITION.  SEE SYMBOL
# TABLE TO FIND APPROPRIATE PACE NUMBERS.
#
#       NVSUB           CALLING POINT FOR INTERNAL USE OF PINBALL.
#                       OF RELATED INTEREST       NVSBWAIT
#                       NVSUBBUSY
#                       PRENVBSY
#
#       ENDIDLE         ROUTINE FOR INTERNAL PROGRAMS WISHING TO TO SLEEP WHILE
#                       AWAITING OPERATOR'S RESPONSE.
#
#       DSPMM           ROUTINE BY WHICH AN INTERNAL PROGRAM MAY DISPLAY A DECIMAL
#                       PROGRAM CODE (MAJOR MODE) IN THE PROGRAM (MAJOR MODE) LIGHT
#                       (DSPMM DOES NOT DISPLAY DIRECTLY BUT ENTERS EXEC REQUEST
#                       FOR DSPMMJB WITH PRIO 30000 AND RETURNS TO CALLER.)
#
#       BLANKSUB        ROUTINE BY WHICH AN INTERNAL PROGRAM MAY BLANK ANY
#                       COMBINATION OF THE DISPLAY REGISTERS R1, R2, R3.
#
#       JAMTERM         ROUTINE BY WHICH AN INTERNAL PROGRAM MAY PERFORM THE
#       JAMPROC         TERMINATE (V 34) OR PROCEED (V33) FUNCTION.
#
#       MONITOR         VERBS FOR PERIODIC (1 PER SEC) DISPLAY.
#
#       PLEASE PERFORM, PLEASE MARK SITUATIONS
#                       REMARKS DESCRIBING HOW AN INTERNAL ROUTINE SHOULD HANDLE
#                       THESE SITUATIONS CAN BE FOUND JUST BEFORE 'NVSUB' (SEE
#                       SYMBOL TABLE FOR PAGE NUMBER).
#
#       THE NOUN TABLE FORMAT IS DESCRIBED ON A PAGE OF REMARKS CARDS JUST
#       BEFORE 'DSPABC' (SEE SYMBOL TABLE FOR PAGE NUMBER).
#
#       THE NOUN TABLES THEMSELVES ARE FOUND IN LOG SECTION 'PINBALL NOUN
#       TABLES'.
#
# FOR FURTHER DETAILS ABOUT OPERATION OF THE KEYBOARD AND DISPLAY SYSTEM
# PROGRAM, SEE THE MISSION PLAN AND/OR MIT/IL E-2129
# DESCRIBING KEYBOARD AND DISPLAY OPERATION FOR 278.
# (Note that this doc by Green and Filene is/was available online at
# http://hrst.mit.edu/hrs/apollo/public/archive/1706.pdf --- RSB 6/2004.)
#
# THE FOLLOWING QUOTATION IS PROVIDED THROUGH THE COURTESY OF THE AUTHORS.
#
#       "IT WILL BE PROVED TO THY FACE THAT THOU HAST MEN ABOUT THEE THAT
```

# Page 310

# USUALLY TALK OF A NOUN AND A VERB, AND SUCH ABOMINABLE WORDS AS NO  
# CHRISTIAN EAR CAN ENDURE TO HEAR."

# HENRY 6, ACT 2, SCENE 4

# THE FOLLOWING ASSIGNMENTS FOR PINBALL ARE MADE ELSEWHERE

# RESERVED FOR PINBALL EXECUTIVE ACTION

#

|           |       |        |                                              |
|-----------|-------|--------|----------------------------------------------|
| #DSPCOUNT | ERASE |        | # DISPLAY POSITION INDICATOR                 |
| #DECBRNCH | ERASE |        | # +DEC, -DEC, OCT INDICATOR                  |
| #VERBREG  | ERASE |        | # VERB CODE                                  |
| #NOUNREG  | ERASE |        | # NOUN CODE                                  |
| #XREG     | ERASE |        | # R1 INPUT BUFFER                            |
| #YREG     | ERASE |        | # R2 INPUT BUFFER                            |
| #ZREG     | ERASE |        | # R3 INPUT BUFFER                            |
| #XREGLP   | ERASE |        | # LO PART OF XREG (FOR DEC CONV ONLY)        |
| #YREGLP   | ERASE |        | # LO PART OF YREG (FOR DEC CONV ONLY)        |
| #HITEMOUT | =     | YREGLP | # TEMP FOR DISPLAY OF HRS,MIN,SEC            |
| #         |       |        | # MUST = LOTEMOUT-1.                         |
| #ZREGLP   | ERASE |        | # LO PART OF ZREG (FOR DEC CONV ONLY)        |
| #LOTEMOUT | =     | ZREGLP | # TEMP FOR DISPLAY OF HRS,MIN,SEC            |
| #         |       |        | # MUST = HITEMOUT+1                          |
| #MODREG   | ERASE |        | # MODE CODE                                  |
| #DSPLOCK  | ERASE |        | # KEYBOARD/SUBROUTINE CALL INTERLOCK         |
| #REQRET   | ERASE |        | # RETURN REGISTER FOR LOAD                   |
| #LOADSTAT | ERASE |        | # STATUS INDICATOR FOR LOADTST               |
| #CLPASS   | ERASE |        | # PASS INDICATOR FOR CLEAR                   |
| #NOUT     | ERASE |        | # ACTIVITY COUNTER FOR DSPTAB                |
| #NOUNCADR | ERASE |        | # MACHINE CADR FOR NOUN                      |
| #MONSAVE  | ERASE |        | # N/V CODE FOR MONITOR. (= MONSAVE1-1)       |
| #MONSAVE1 | ERASE |        | # NOUNCADR FOR MONITOR (MATBS1) = MONSAVE+1  |
| #MONSAVE2 | ERASE |        | # NVMONOPT OPTIONS                           |
| #DSPTAB   | ERASE | +13D   | # 0-10, DISPLAY PANEL BUFFER 11-13, C RELAYS |
| #CADRSTOR | ERASE |        | # ENDIDLE STORAGE                            |
| #NVQTEM   | ERASE |        | # NVSUB STORAGE FOR CALLING ADDRESS          |
| #         |       |        | # MUST = NVBNKTEM-1.                         |
| #NVBNKTEM | ERASE |        | # NVSUB STORAGE FOR CALLING BANK             |
| #         |       |        | # MUST = NVQTEM+1                            |
| #VERBSAVE | ERASE |        | # NEEDED FOR RECYCLE                         |
| #DSPLIST  | ERASE |        | # WAITING REG FOR DSP SYST INTERNAL USE      |
| #EXTVBACT | ERASE |        | # EXTENDED VERB ACTIVITY INTERLOCK           |
| #DSPTM1   | ERASE | +2     | # BUFFER STORAGE AREA 1 (MOSTLY FOR TIME)    |
| #DSPTM2   | ERASE | +2     | # BUFFER STORAGE AREA 2 (MOSTLY FOR DEG)     |
| #         |       |        |                                              |

# END OF ERASABLES RESERVED FOR PINBALL EXECUTIVE ACTION.

```

#
# TEMPORARIES FOR PINBALL EXECUTIVE ACTION
# Page 311
#DSEXIT      =      INTB15+      # RETURN FOR DSPIN
#EXITEM      =      INTB15+      # RETURN FOR SCALE FACTOR ROUTINE SELECT
#BLANKRET    =      INTB15+      # RETURN FOR 2BLANK
#WRDRET      =      INTBIT15     # RETURN FOR 5BLANK.
#WDRET       =      INTBIT15     # RETURN FOR DSPWD
#DECRET      =      INTBIT15     # RETURN FOR PUTCOM(DEC LOAD)
#21/22REG    =      INTBIT15     # TEMP FOR CHARIN
#UPDATRET    =      POLISH       # RETURN FOR UPDATNN, UPDATVB
#CHAR        =      POLISH       # TEMP FOR CHARIN
#ERCNT       =      POLISH       # COUNTER FOR ERROR LIGHT RESET
#DECOUNT    =      POLISH       # COUNTER FOR SCALING AND DISPLAY (DEC)
#SGNON       =      VBUF         # TEMP FOR +,- ON
#NOUNTEM     =      VBUF         # COUNTER FOR MIXNOUN FETCH
#DISTEM      =      VBUF         # COUNTER FOR OCTAL DISPLAY VERB
#DECTEM      =      VBUF         # COUNTER FOR FETCH (DEC DISPLAY VERBS)
#SGNOFF      =      VBUF +1      # TEMP FOR +,- ON
#NVTEMP      =      VBUF +1      # TEMP FOR NVSUB
#SFTEMP1     =      VBUF +1      # STORAGE FOR SF CONST HI PART (=SFTEMP2-1)
#HITEMIN     =      VBUF +1      # TEMP FOR LOAD OF HRS,MIN,SEC
#            =            MUST = LOTEMIN-1.
#CODE        =      VBUF +2      # FOR DSPIN
#SFTEMP2     =      VBUF +2      # STORAGE FOR SF CONST LO PART (=SFTEMP1+1)
#LOTEMIN     =      VBUF +2      # TEMP FOR LOAD OF HRS,MIN,SEC
#            =            MUST = HITEMIN+1
#MIXTEMP     =      VBUF +3      # FOR MIXNOUN DATA
#SIGNRET     =      VBUF +3      # RETURN FOR +,- ON
# ALSO MIXTEMP+1 = VBUF+4, MIXTEMP+2 = VBUF+5
#ENTRET      =      DOTINC       # EXIT FROM ENTER
#WDONT       =      DOTRET       # CHAR COUNTER FOR DSPWD
#INREL       =      DOTRET       # INPUT BUFFER SELECTOR (X,Y,Z, REG )
#DSPMMTEM    =      MATINC       # DSPCOUNT SAVE FOR DSPMM
#MIXBR       =      MATINC       # INDICATOR FOR MIXED OR NORMAL NOUN
#TEM1        ERASE              # EXEC TEMP
#DSREL       =      TEM1         # REL ADDRESS FOR DSPIN
#TEM2        ERASE              # EXEC TEMP
#DSMAG       =      TEM2         # MAGNITUDE STORE FOR DSPIN
#IDADDTEM    =      TEM2         # MIXNOUN INDIRECT ADDRESS STORAGE
#TEM3        ERASE              # EXEC TEMP
#COUNT     =      TEM3         # FOR DSPIN
# Page 312
#TEM4        ERASE              # EXEC TEMP
#LSTPTR      =      TEM4         # LIST POINTER FOR GRABUSY
#RELRET      =      TEM4         # RETURN FOR RELDSP

```

```

#FREERET      =      TEM4      # RETURN FOR FREEDSP
#DSPWDRET     =      TEM4      # RETURN FOR DSPSIGN
#SEPSCRET     =      TEM4      # RETURN FOR SEPSEC
#SEPMNRET     =      TEM4      # RETURN FOR SEPMIN
#TEM5         ERASE           # EXEC TEMP
#NOUNADD      =      TEM5      # TEMP STORAGE FOR NOUN ADDRESS
#NNADTEM      ERASE           # TEMP FOR NOUN ADDRESS TABLE ENTRY
#NNTYPTTEM    ERASE           # TEMP FOR NOUN TYPE TABLE ENTRY
#IDAD1TEM     ERASE           # TEMP FOR INDIR ADDRESS TABLE ENTRY (MIXNN)
#             # MUST = IDAD2TEM-1, = IDAD3TEM-2
#IDAD2TEM     ERASE           # TEMP FOR INDIR ADDRESS TABLE ENTRY (MIXNN)
#             # MUST = IDAD1TEM+1, IDAD3TEM-1.
#IDAD3TEM     ERASE           # TEMP FOR INDIR ADDRESS TABLE ENTRY (MIXNN)
#             # MUST = IDAD1TEM+2, IDAD2TEM+1.
#RUTMXTEM     ERASE           # TEMP FOR SF ROUT TABLE ENTRY (MIXNN ONLY)
#
# END OF TEMPORARIES FOR PINBALL EXECUTIVE ACTION.
#
# ADDITIONAL TEMPORARIES FOR PINBALL EXECUTIVE ACTION
#
#         MPAC, THRU MPAC +6
#         BUF, +1, +2
#         BUF2, +1, +2
#         MPTEMP
#         ADDRWD
#
# END OF ADDITIONAL TEMPS FOR PINBALL EXEC ACTION
#
# RESERVED FOR PINBALL INTERRUPT ACTION
#
#DSPCNT       ERASE           # COUNTER FOR DSPOUT
#UPLOCK       ERASE           # BIT1 = UPLINK INTERLOCK (ACTIVATED BY
#                                     # RECEPTION OF A BAD MESSAGE IN UPLINK)
#
# END OF ERASABLES RESERVED FOR PINBALL INTERRUPT ACTION
#
# TEMPORARIES FOR PINBALL INTERRUPT ACTION
#
#KEYTEMP1     =      WAITEXIT  # TEMP FOR KEYRUPT, UPRUPT
#DSRUPTTEM    =      WAITEXIT  # TEMP FOR DSPOUT
#KEYTEMP2     =      RUPTAGN   # TEMP FOR KEYRUPT, UPRUPT
#
# END OF TEMPORARIES FOR PINBALL INTERRUPT ACTION

# Page 313
# THE INPUT CODES ASSUMED FOR THE KEYBOARD ARE,

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```
#      0      10000
#      1      00001
#      9      01001
#      VERB   10001
#      ERROR RES 10010
#      KEY RLSE 11001
#      +      11010
#      -      11011
#      ENTER   11100
#      CLEAR   11110
#      NOUN    11111
#
# OUTPUT FORMAT FOR DISPLAY PANEL.  SET OUTO TO AAAABCCCCDDDDDD.
# A'S  SELECTS A RELAYWORD.  THIS DETERMINES WHICH PAIR OF CHARACTERS ARE
#      ENERGIZED.
# B    FOR SPECIAL RELAYS SUCH AS SIGNS ETC.
# C'S  5 BIT RELAY CODE FOR LEFT CHAR OF PAIR SELECTED BY RELAYWORD.
# D'S  5 BIT RELAY CODE FOR RIGHT CHAR OF PAIR SELECTED BY RELAYWORD.
#
# THE PANEL APPEARS AS FOLLOWS,
#      MD1      MD2 (MAJOR MODE)
#      VD1      VD2 (VERB)
#      R1D1     R1D2     R1D3     R1D4     R1D5 (R1)
#      R2D1     R2D2     R2D3     R2D4     R2D5 (R2)
#      R3D1     R3D2     R3D3     R3D4     R3D5 (R3)
#
# EACH OF THESE IS GIVEN A DSPCOUNT NUMBER FOR USE WITHIN COMPUTATION ONLY
#
#      MD1      25      R2D1      11      ALL ARE OCTAL
#      MD2      24      R2D2      10
#      VD1      23      R2D3      7
#      VD2      22      R2D4      6
#      ND1      21      R2D5      5
#      ND2      20      R3D1      4
#      R1D1     16      R3D2      3
#      R1D2     15      R3D3      2
#      R1D3     14      R3D4      1
#      R1D4     13      R3D5      0
#      R1D5     12
#
# THERE IS AN 11-REGISTER TABLE (DSPTAB) FOR THE DISPLAY PANEL.
#
#      DSPTAB      RELAYWD      BIT11      BITS 10-6      BITS 5-1
#      RELADD
#      10          1011          MD1 (25)      MD2 (24)
#      9           1010          VD1 (23)      VD2 (22)
```

|            |   |      |              |           |           |
|------------|---|------|--------------|-----------|-----------|
| #          | 8 | 1001 |              | ND1 (21)  | ND2 (20)  |
| #          | 7 | 1000 |              |           | R1D1 (16) |
| # Page 314 |   |      |              |           |           |
| #          | 6 | 0111 | +R1          | R1D2 (15) | R1D3 (14) |
| #          | 5 | 0110 | -R1          | R1D4 (13) | R1D5 (12) |
| #          | 4 | 0101 | +R2          | R2D1 (11) | R2D2 (10) |
| #          | 3 | 0100 | -R2          | R2D3 (7)  | R2D4 (6)  |
| #          | 2 | 0011 |              | R2D5 (5)  | R3D1 (4)  |
| #          | 1 | 0010 | +R3          | R3D2 (3)  | R3D3 (2)  |
| #          | 0 | 0001 | -R3          | R3D4 (1)  | R3D5 (0)  |
| #          |   | 0000 | NO RELAYWORD |           |           |

#

# THE 5-BIT OUTOUT RELAY CODES ARE:

#

|   |       |       |
|---|-------|-------|
| # | BLANK | 00000 |
| # | 0     | 10101 |
| # | 1     | 00011 |
| # | 2     | 11001 |
| # | 3     | 11011 |
| # | 4     | 01111 |
| # | 5     | 11110 |
| # | 6     | 11100 |
| # | 7     | 10011 |
| # | 8     | 11101 |
| # | 9     | 11111 |

#

# OUTPUT BITS USED BY PINBALL:

#

|   |                      |    |                     |
|---|----------------------|----|---------------------|
| # | KEY RELEASE LIGHT    | -- | BIT 5 OF CHANNEL 11 |
| # | VERB/NOUN FLASH      | -- | BIT 6 OF CHANNEL 11 |
| # | OPERATOR ERROR LIGHT | -- | BIT 7 OF CHANNEL 11 |

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# START OF EXECUTIVE SECTION OF PINBALL

|        |          |
|--------|----------|
| BANK   | 40       |
| SETLOC | PINBALL1 |
| BANK   |          |

|       |        |
|-------|--------|
| COUNT | 40/PIN |
|-------|--------|

|        |     |          |                                           |
|--------|-----|----------|-------------------------------------------|
| CHARIN | CAF | ONE      | # BLOCK DISPLAY SYST                      |
|        | XCH | DSPLOCK  | # MAKE DSP SYST BUSY, BUT SAVE OLD        |
|        | TS  | 21/22REG | # C(DSPLOCK) FOR ERROR LIGHT RESET.       |
|        | CCS | CADRSTOR | # ALL KEYS EXCEPT ER TURN ON KR LITE IF   |
|        | TC  | +2       | # CADRSTOR IS FULL. THIS REMINDS OPERATOR |



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|            |        |          |   |                                        |                   |
|------------|--------|----------|---|----------------------------------------|-------------------|
|            | TC     | CHARIN2  | # | TO RE-ESTABLISH A FLASHING DISPLAY     |                   |
|            | CS     | ELRCODE1 | # | WHICH HE HAS OBSCURED WITH DISPLAYS OF |                   |
|            | AD     | MPAC     | # | HIS OWN (SEE REMARKS PRECEDING ROUTINE |                   |
|            | EXTEND |          | # | VBRELDSP).                             |                   |
|            | BZF    | CHARIN2  |   |                                        |                   |
|            | TC     | RELDSPON |   |                                        |                   |
| CHARIN2    | XCH    | MPAC     |   |                                        |                   |
|            | TS     | CHAR     |   |                                        |                   |
|            | INDEX  | A        |   |                                        |                   |
|            | TC     | +1       | # | INPUT CODE                             | FUNCTION          |
|            | TC     | CHARALRM | # | 0                                      |                   |
|            | TC     | NUM      | # | 1                                      |                   |
|            | TC     | NUM      | # | 2                                      |                   |
|            | TC     | NUM      | # | 3                                      |                   |
|            | TC     | NUM      | # | 4                                      |                   |
|            | TC     | NUM      | # | 5                                      |                   |
|            | TC     | NUM      | # | 6                                      |                   |
|            | TC     | NUM      | # | 7                                      |                   |
|            | TC     | 89TEST   | # | 10                                     | 8                 |
|            | TC     | 89TEST   | # | 11                                     | 9                 |
|            | TC     | CHARALRM | # | 12                                     |                   |
|            | TC     | CHARALRM | # | 13                                     |                   |
|            | TC     | CHARALRM | # | 14                                     |                   |
|            | TC     | CHARALRM | # | 15                                     |                   |
|            | TC     | CHARALRM | # | 16                                     |                   |
|            | TC     | CHARALRM | # | 17                                     |                   |
|            | TC     | NUM -2   | # | 20                                     | 0                 |
|            | TC     | VERB     | # | 21                                     | VERB              |
|            | TC     | ERROR    | # | 22                                     | ERROR LIGHT RESET |
|            | TC     | CHARALRM | # | 23                                     |                   |
|            | TC     | CHARALRM | # | 24                                     |                   |
|            | TC     | CHARALRM | # | 25                                     |                   |
|            | TC     | CHARALRM | # | 26                                     |                   |
|            | TC     | CHARALRM | # | 27                                     |                   |
|            | TC     | CHARALRM | # | 30                                     |                   |
|            | TC     | VBRELDSP | # | 31                                     | KEY RELEASE       |
| # Page 316 | TC     | POSGN    | # | 32                                     | +                 |
|            | TC     | NEGSGN   | # | 33                                     | -                 |
|            | TC     | ENTERJMP | # | 34                                     | ENTER             |
|            | TC     | CHARALRM | # | 35                                     |                   |
|            | TC     | CLEAR    | # | 36                                     | CLEAR             |
|            | TC     | NOUN     | # | 37                                     | NOUN              |
| ELRCODE1   | OCT    | 22       |   |                                        |                   |
| ENTERJMP   | TC     | POSTJUMP |   |                                        |                   |

```

                                CADR    ENTER

89TEST    CCS      DSPCOUNT
          TC        +4              # +
          TC        +3              # +0
          TC        ENDOFJOB        # - BLOCK DATA IN IF DSPCOUNT IS - OR -0
          TC        ENDOFJOB        # -0
          CAF        THREE
          MASK       DECBRNCH
          CCS        A
          TC        NUM              # IF DECBRNCH IS +, 8 OR 9 OK
          TC        CHARALRM        # IF DECBRNCH IS +0, REJECT 8 OR 9

# NUM ASSEMBLES OCTAL 3 BITS AT A TIME.  FOR DECIMAL IT CONVERTS INCOMING
# WORD AS A FRACTION, KEEPING RESULTS TO DP.
# OCTAL RESULTS ARE LEFT IN XREG, YREG, OR ZREG.  HI PART OF DEC IN XREG,
# YREG, ZREG.  THE LOW PARTS IN XREGLP, YREGLP, OR ZREGLP.
# DECBRNCH IS LEFT AT +0 FOR OCT, +1 FOR + DEC, +2 FOR - DEC.
# IF DSPCOUNT WAS LEFT -, NO MORE DATA IS ACCEPTED.

                                CAF      ZERO
                                TS        CHAR
NUM      CCS      DSPCOUNT
          TC        +4              # +
          TC        +3              # +0
          TC        +1              # -BLOCK DATA IN IF DSPCOUNT IS -
          TC        ENDOFJOB        # -0
          TC        GETINREL
          CCS        CLPASS          # IF CLPASS IS + OR +0, MAKE IT +0.
          CAF        ZERO
          TS        CLPASS
          TC        +1
          INDEX      CHAR
          CAF        RELTAB
          MASK       LOW5
          TS        CODE
          CA         DSPCOUNT
          TS        COUNT
          TC        DSPIN

# Page 317

          CAF        THREE
          MASK       DECBRNCH
          CCS        A              # +0, OCTAL.  +1, + DEC.  +2, - DEC.
          TC        DECTOBIN        # +
          INDEX      INREL           # +0 OCTAL
          XCH        VERBREG

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|            |        |           |                                              |
|------------|--------|-----------|----------------------------------------------|
|            | TS     | CYL       |                                              |
|            | CS     | CYL       |                                              |
|            | CS     | CYL       |                                              |
|            | XCH    | CYL       |                                              |
|            | AD     | CHAR      |                                              |
|            | TC     | ENDNMTST  |                                              |
| DECTOBIN   | INDEX  | INREL     |                                              |
|            | XCH    | VERBREG   |                                              |
|            | TS     | MPAC      | # SUM X 2EXP-14 IN MPAC                      |
|            | CAF    | ZERO      |                                              |
|            | TS     | MPAC +1   |                                              |
|            | CAF    | TEN       | # 10 X 2EXP-14                               |
|            | TC     | SHORTMP   | # 10SUM X 2EXP-28 IN MPAC, MPAC+1            |
|            | XCH    | MPAC +1   |                                              |
|            | AD     | CHAR      |                                              |
|            | TS     | MPAC +1   |                                              |
|            | TC     | ENDNMTST  | # NO OF                                      |
|            | ADS    | MPAC      | # OF MUST BE 5TH CHAR                        |
|            | TC     | DECEND    |                                              |
| ENDNMTST   | INDEX  | INREL     |                                              |
|            | TS     | VERBREG   |                                              |
|            | CS     | DSPCOUNT  |                                              |
|            | INDEX  | INREL     |                                              |
|            | AD     | CRITCON   |                                              |
|            | EXTEND |           |                                              |
|            | BZF    | ENDNUM    | # -0, DSPCOUNT = CRITCON                     |
|            | TC     | MORNUM    | # -, DSPCOUNT G/ CRITCON                     |
| ENDNUM     | CAF    | THREE     |                                              |
|            | MASK   | DECBRNCH  |                                              |
|            | CCS    | A         |                                              |
|            | TC     | DECEND    |                                              |
| ENDALL     | CS     | DSPCOUNT  | # BLOCK NUMIN BY PLACING DSPCOUNT            |
|            | TC     | MORNUM +1 | # NEGATIVELY                                 |
| DECEND     | CS     | ONE       |                                              |
|            | AD     | INREL     |                                              |
|            | EXTEND |           |                                              |
|            | BZMF   | ENDALL    | # IF INREL=0,1 (VBREG,NNREG) LEAVE WHOLE     |
|            | TC     | DMP       | # IF INREL=2,3,4 (R1,R2,R3), CONVERT TO FRAC |
|            |        |           | # MULT SUM X 2EXP-28 IN MPAC, MPAC+1 BY      |
|            | ADRES  | DECON     | # 2EXP14/10EXP5, GIVES (SUM/10EXP5)X2EXP-14  |
|            | CAF    | THREE     | # IN MPAC, +1, +2.                           |
|            | MASK   | DECBRNCH  |                                              |
|            | INDEX  | A         |                                              |
|            | TC     | +0        |                                              |
| # Page 318 | TC     | +DECSGN   |                                              |

```

                                EXTEND                # - CASE
                                DCS      MPAC +1
                                DXCH     MPAC +1
+DECSGN                        XCH      MPAC +2
                                INDEX    INREL
                                TS       XREGLP -2
                                XCH      MPAC +1
                                INDEX    INREL
                                TS       VERBREG
                                TC       ENDALL
MORNUM                        CCS      DSPCOUNT      # DECREMENT DSPCOUNT
                                TS       DSPCOUNT
                                TC       ENDOFJOB

CRITCON                       OCT      22              # (DEC 18)
                                OCT      20              # (DEC 16)
                                OCT      12              # (DEC 10)
                                OCT      5
                                OCT      0

DECON                         2DEC      1 E-5 B14      # 2EXP14/10EXP5 = .16384 DEC

# GETINREL GETS PROPER DATA REG REL ADDRESS FOR CURRENT C(DSPCOUNT) AND
# PUTS IN INTO INREL. +0 VERBREG, 1 NOUNREG, 2 XREG, 3 YREG, 4 ZREG.

GETINREL                     INDEX    DSPCOUNT
                                CAF      INRELTAB
                                TS       INREL          # (A TEMP. REG)
                                TC       Q

INRELTAB                     OCT      4                # R3D5 (DSPCOUNT = 0)
                                OCT      4                # R3D4          =(1)
                                OCT      4                # R3D3          =(2)
                                OCT      4                # R3D2          =(3)
                                OCT      4                # R3D1          =(4)
                                OCT      3                # R2D5          =(5)
                                OCT      3                # R2D4          =(6)
                                OCT      3                # R2D3          =(7)
                                OCT      3                # R2D2          =(8D)
                                OCT      3                # R2D1          =(9D)
                                OCT      2                # R1D5          =(10D)
                                OCT      2                # R1D4          =(11D)
                                OCT      2                # R1D3          =(12D)
                                OCT      2                # R1D2          =(13D)
                                OCT      2                # R1D1          =(14D)
                                TC       CCSHOLE          # NO DISCOUNT NUMBER = 15D

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|            |       |           |                                           |        |
|------------|-------|-----------|-------------------------------------------|--------|
| # Page 319 | OCT   | 1         | # ND2                                     | =(16D) |
|            | OCT   | 1         | # ND1                                     | =(17D) |
|            | OCT   | 0         | # VD2                                     | =(18D) |
|            | OCT   | 0         | # VD1                                     | =(19D) |
| VERB       | CAF   | ZERO      |                                           |        |
|            | TS    | VERBREG   |                                           |        |
|            | CAF   | VD1       |                                           |        |
| NVCOM      | TS    | DSPCOUNT  |                                           |        |
|            | TC    | 2BLANK    |                                           |        |
|            | CAF   | ONE       |                                           |        |
|            | TS    | DECBRNCH  | # SET FOR DEC V/N CODE                    |        |
|            | CAF   | ZERO      |                                           |        |
|            | TS    | REQRET    | # SET FOR ENTPASO                         |        |
|            | CAF   | ENDINST   | # IF DSPALARM OCCURS BEFORE FIRST ENTPASO |        |
|            | TS    | ENTRET    | # OR NVSUB, ENTRET MUST ALREADY BE SET    |        |
|            |       |           | # TO TC ENDOFJOB                          |        |
|            | TC    | ENDOFJOB  |                                           |        |
| NOUN       | CAF   | ZERO      |                                           |        |
|            | TS    | NOUNREG   |                                           |        |
|            | CAF   | ND1       | # ND1, OCT 21 (DEC 17)                    |        |
|            | TC    | NVCOM     |                                           |        |
| NEGSGN     | TC    | SIGNTEST  |                                           |        |
|            | TC    | -ON       |                                           |        |
|            | CAF   | TWO       |                                           |        |
| BOTHSGN    | INDEX | INREL     | # SET DEC COMP BIT TO 1 (IN DECBRNCH)     |        |
|            | AD    | BIT7      | # BIT 5 FOR R1. BIT 4 FOR R2.             |        |
|            | ADS   | DECBRNCH  | # BIT 3 FOR R3.                           |        |
| FIXCLPAS   | CCS   | CLPASS    | # IF CLPASS IS + OR +0. MAKE IT +0.       |        |
|            | CAF   | ZERO      |                                           |        |
|            | TS    | CLPASS    |                                           |        |
|            | TC    | +1        |                                           |        |
|            | TC    | ENDOFJOB  |                                           |        |
| POSGN      | TC    | SIGNTEST  |                                           |        |
|            | TC    | +ON       |                                           |        |
|            | CAF   | ONE       |                                           |        |
|            | TC    | BOTHSGN   |                                           |        |
| +ON        | LXCH  | Q         |                                           |        |
|            | TC    | GETINREL  |                                           |        |
|            | INDEX | INREL     |                                           |        |
|            | CAF   | SGNTAB -2 |                                           |        |
|            | TS    | SGNOFF    |                                           |        |

|            |        |           |                                        |
|------------|--------|-----------|----------------------------------------|
|            | AD     | ONE       |                                        |
|            | TS     | SGNON     |                                        |
| SGNCOM     | CAF    | ZERO      |                                        |
|            | TS     | CODE      |                                        |
| # Page 320 |        |           |                                        |
|            | XCH    | SGNOFF    |                                        |
|            | TC     | 11DSPIN   |                                        |
|            | CAF    | BIT11     |                                        |
|            | TS     | CODE      |                                        |
|            | XCH    | SGNON     |                                        |
|            | TC     | 11DSPIN   |                                        |
|            | TC     | L         |                                        |
| -ON        | LXCH   | Q         |                                        |
|            | TC     | GETINREL  |                                        |
|            | INDEX  | INREL     |                                        |
|            | CAF    | SGNTAB -2 |                                        |
|            | TS     | SGNON     |                                        |
|            | AD     | ONE       |                                        |
|            | TS     | SGNOFF    |                                        |
|            | TC     | SGNCOM    |                                        |
| SGNTAB     | OCT    | 5         | # -R1                                  |
|            | OCT    | 3         | # -R2                                  |
|            | OCT    | 0         | # -R3                                  |
| SIGNTTEST  | LXCH   | Q         | # ALLOWS +,- ONLY WHEN DSPCOUNT=R1D1,  |
|            | CAF    | THREE     | # R2D1, OR R3D1. ALLOWS ONLY FIRST OF  |
|            | MASK   | DECBRNCH  | # CONSECUTIVE +/- CHARACTERS.          |
|            | CCS    | A         | # IF LOW2 BITS OF DECBRNCH NOT 0. SIGN |
|            | TC     | ENDOFJOB  | # FOR THIS WORD ALREADY IN. REJECT.    |
|            | CS     | R1D1      |                                        |
|            | TC     | SGNTST1   |                                        |
|            | CS     | R2D1      |                                        |
|            | TC     | SGNTST1   |                                        |
|            | CS     | R3D1      |                                        |
|            | TC     | SGNTST1   |                                        |
|            | TC     | ENDOFJOB  | # NO MATCH FOUND. SIGN ILLEGAL         |
| SGNTST1    | AD     | DSPCOUNT  |                                        |
|            | EXTEND |           |                                        |
|            | BZF    | +2        | # MATCH FOUND                          |
|            | TC     | Q         |                                        |
|            | TC     | L         | # SIGN LEGAL                           |

# CLEAR BLANKS WHICH R1, R2, R3 IS CURRENT OR LAST TO BE DISPLAYED (PERTINENT  
# XREG, YREG, ZREG IS CLEARED). SUCCESSIVE CLEARS TAKE CARE OF EACH RX  
# L/ RC UNTIL R1 IS DONE. THEN NO FURTHER ACTION.

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```
#
# THE SINGLE COMPONENT LOAD VERBS ALLOW ONLY THE SINGLE RC THAT IS
# APPROPRIATE TO BE CLEARED.
#
# CLPASS          +0 PASSO, CAN BE BACKED UP
#                +NZ HIPASS, CAN BE BACKED UP
#                -NZ PASSO, CANNOT BE BACKED UP
# Page 321
CLEAR            CCS      DSPCOUNT
                AD        ONE
                TC        +2
                AD        ONE
                INDEX     A          # DO NOT CHANGE DSPCOUNT BECAUSE MAY LATER
                CAF       INRELTAB   # FAIL LEGALTST.
                TS        INREL      # MUST SET INREL, EVEN FOR HIPASS.
                CCS       CLPASS
                TC        CLPASHI    # +
                TC        +2         # +0   IF CLPASS IS +0 OR -, IT IS PASSO
                TC        +1         # -
                CA        INREL
                TC        LEGALTST
                TC        CLEAR1
CLPASHI          CCS      INREL
                TS        INREL
                TC        LEGALTST
                CAF       DOUBLK +2  # +3 TO - NUMBER, BACKS DATA REQUESTS.
                ADS       REQRET
                CA        INREL
                TS        MIXTEMP    # TEMP STORAGE FOR INREL
EXTEND
                DIM       VERBREG    # DECREMENT VERB AND RE-DISPLAY
                TC        BANKCALL
                CADR      UPDATVB
                CA        MIXTEMP
                TS        INREL      # RESTORE INREL
CLEAR1           TC        CLR5
                INCR      CLPASS     # ONLY IF CLPASS IS + OR +0
                TC        ENDOFJOB   # SET FOR HIGHER PASS.
CLR5             LXCH     Q          # USED 5BLANK BUT AVOIDS ITS TC GETINREL
                TC        5BLANK +2
LEGALTST         AD        NEG2
                CCS       A
                TC        Q          # LEGAL          INREL G/2
                TC        CSHOLE
                TC        ENDOFJOB   # ILLEGAL        INREL=0,1
                TC        Q          # LEGAL          INREL=2
```

# 5BLANK BLANKS 5 CHAR DISPLAY WORD IN R1, R2, OR R3. IT ALSO ZEROES XREG,  
 # YREG, OR ZREG. PLACE ANY + DSPCOUNT NUMBER FOR PERTINENT RC INTO DSPCOUNT.  
 # DSPCOUNT IS LEFT SET TO LEFT MOST DSP NUMB FOR RC JUST BLANKED.

|            |       |             |                                        |
|------------|-------|-------------|----------------------------------------|
|            | TS    | DSPCOUNT    | # NEEDED FOR BLANKSUB                  |
| 5BLANK     | LXCH  | Q           |                                        |
|            | TC    | GETINREL    |                                        |
|            | CAF   | ZERO        |                                        |
|            | INDEX | INREL       |                                        |
|            | TS    | VERBREG     | # ZERO X, Y, Z, REG.                   |
| # Page 322 |       |             |                                        |
|            | INDEX | INREL       |                                        |
|            | TS    | XREGLP -2   |                                        |
|            | TS    | CODE        |                                        |
|            | INDEX | INREL       | # ZERO PERTINENT DEC COMP BIT.         |
|            | CS    | BIT7        | # PROTECT OTHERS                       |
|            | MASK  | DECBRNCH    |                                        |
|            | MASK  | BRNCHCON    | # ZERO LOW 2 BITS.                     |
|            | TS    | DECBRNCH    |                                        |
|            | INDEX | INREL       |                                        |
|            | CAF   | SINBLANK -2 | # BLANK ISOLATED CHAR SEPARATELY       |
|            | TS    | COUNT       |                                        |
|            | TC    | DSPIN       |                                        |
| 5BLANK1    | INDEX | INREL       |                                        |
|            | CAF   | DOUBLK -2   |                                        |
|            | TS    | DSPCOUNT    |                                        |
|            | TC    | 2BLANK      |                                        |
|            | CS    | TWO         |                                        |
|            | ADS   | DSPCOUNT    |                                        |
|            | TC    | 2BLANK      |                                        |
|            | INDEX | INREL       |                                        |
|            | CAF   | R1D1 -2     |                                        |
|            | TS    | DSPCOUNT    | # SET DSPCOUNT TO LEFT MOST DSP NUMBER |
|            | TC    | L           | # OF REG. JUST BLANKED                 |
| SINBLANK   | OCT   | 16          | # DEC 14                               |
|            | OCT   | 5           |                                        |
|            | OCT   | 4           |                                        |
| DOUBLK     | OCT   | 15          | # DEC 13                               |
|            | OCT   | 11          | # DEC 9                                |
|            | OCT   | 3           |                                        |
| BRNCHCON   | OCT   | 77774       |                                        |

# 2BLANK BLANKS TWO CHAR. PLACE DSP NUMBER OF LEFT CHAR OF THE PAIR INTO



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# DSPCOUNT. THIS NUMBER IS LEFT IN DSPCOUNT

|          |        |          |                                 |
|----------|--------|----------|---------------------------------|
| 2BLANK   | CA     | DSPCOUNT |                                 |
|          | TS     | SR       |                                 |
|          | CS     | BLANKCON |                                 |
|          | INHINT |          |                                 |
|          | INDEX  | SR       |                                 |
|          | XCH    | DSPTAB   |                                 |
|          | EXTEND |          |                                 |
|          | BZMF   | +2       | # IF OLD CONTENTS -, NOUT OK    |
|          | INCR   | NOUT     | # IF OLD CONTENTS +, +1 TO NOUT |
|          | RELINT |          | # IF -, NOUT OK                 |
|          | TC     | Q        |                                 |
| BLANKCON | OCT    | 4000     |                                 |

# Page 323

# ENTER PASS 0 IS THE EXECUTE FUNCTION. HIGHER ORDER ENTERS ARE TO LOAD  
# DATA. THE SIGN OF REQRET DETERMINES THE PASS, + FOR PASS 0, - FOR HIGHER  
# PASSES

#

# MACHINE CADR TO BE SPECIFIED (MCTBS) NOUNS DESIRE AN ECADR TO BE LOADED  
# WHEN USED WITH LOAD VERBS, MONITOR VERBS, OR DISPLAY VERBS (EXCEPT  
# VERB = FIXED MEMORY DISPLAY, WHICH REQUIRES AN FCADR).

|        |          |
|--------|----------|
| BANK   | 41       |
| SETLOC | PINBALL2 |
| BANK   |          |

|       |        |
|-------|--------|
| COUNT | 41/PIN |
|-------|--------|

|         |    |        |                                  |
|---------|----|--------|----------------------------------|
| NVSUBB  | TC | NVSUB1 | # STANDARD LEAD INS. DON'T MOVE. |
| LOADLV1 | TC | LOADLV |                                  |

# END OF STANDARD LEAD INS.

|          |        |         |                                      |
|----------|--------|---------|--------------------------------------|
| ENTER    | CAF    | ZERO    |                                      |
|          | TS     | CLPASS  |                                      |
|          | CAF    | ENDINST |                                      |
|          | TS     | ENTRET  |                                      |
|          | CCS    | REQRET  |                                      |
|          | TC     | ENTPASO | # IF +, PASS 0                       |
|          | TC     | ENTPASO | # IF +, PASS 0                       |
|          | TC     | +1      | # IF -, NOT PASS 0                   |
| ENTPASHI | CAF    | MMADREF |                                      |
|          | AD     | REQRET  | # IF L/ 2 CHAR IN FOR MM CODE, ALARM |
|          | EXTEND |         | # AND RECYCLE (DECIDE AT MCHANG+1).  |

|            |        |             |                                           |
|------------|--------|-------------|-------------------------------------------|
|            | BZF    | ACCEPTWD    |                                           |
|            | CAF    | THREE       | # IF DEC, ALARM IF L/ 5 CHAR IN FOR DATA, |
|            | MASK   | DECBRNCH    | # BUT LEAVE REQRET - AND FLASH ON, SO     |
|            | CCS    | A           | # OPERATOR CAN SUPPLY MISSING NUMERICAL   |
|            | TC     | +2          | # CHARACTERS AND CONTINUE.                |
|            | TC     | ACCEPTWD    | # OCTAL. ANY NUMBER OF CHAR OK.           |
|            | CCS    | DSPCOUNT    |                                           |
|            | TC     | GODSPALM    | # LESS THAN 5 CHAR DEC(DSPCOUNT IS +)     |
|            | TC     | GODSPALM    | # LESS THAN 5 CHAR DEC(DSPCOUNT IS +)     |
|            | TC     | +1          | # 5 CHAR IN (DSPCOUNT IS -)               |
| ACCEPTWD   | CS     | REQRET      | # 5 CHAR IN (DSPCOUNT IS -)               |
|            | TS     | REQRET      | # SET REQRET +.                           |
|            | TC     | FLASHOFF    |                                           |
|            | TC     | REQRET      |                                           |
| ENTEXIT    | =      | ENTRET      |                                           |
| MMADREF    | ADRES  | MMCHANG +1  | # ASSUMES TC REQMM AT MMCHANG.            |
| # Page 324 |        |             |                                           |
| LOWVERB    | DEC    | 28          | # LOWER VERB THAT AVOIDS NOUN TEST.       |
| ENTPASO    | CAF    | ZERO        | # NOUN VERB SUB ENTERS HERE               |
|            | TS     | DECBRNCH    |                                           |
|            | CS     | VD1         | # BLOCK FURTHER NUM CHAR, SO THAT STRAY   |
|            | TS     | DSPCOUNT    | # CHAR DO NOT GET INTO VERB OR NOUN LTS.  |
| TESTVB     | CS     | VERBREG     | # IF VERB IS G/E LOWVB, SKIP NOUN TEST.   |
|            | TS     | VERBSAVE    | # SAVE VERB FOR POSSIBLE RECYCLE.         |
|            | AD     | LOWVERB     | # LOWVERB - VB                            |
|            | EXTEND |             |                                           |
|            | BZMF   | VERBFAN     | # VERB G/ E LOWVERB                       |
| TESTNN     | EXTEND |             | # VERB L/ LOWVERB                         |
|            | DCA    | LODNNLOC    | # SWITCH BANKS TO NOUN TABLE READING      |
|            | DXCH   | Z           | # ROUTINE.                                |
|            | INDEX  | MIXBR       |                                           |
|            | TC     | +0          |                                           |
|            | TC     | +2          | # NORMAL                                  |
|            | TC     | MIXNOUN     | # MIXED                                   |
|            | CCS    | NNADTEM     | # NORMAL                                  |
|            | TC     | VERBFAN -2  | # NORMAL IF +                             |
|            | TC     | GODSPALM    | # NOT IN USE IF +0                        |
|            | TC     | REQADD      | # SPECIFY MACHINE CADR IF -               |
|            | INCR   | NOUNCADR    | # AUGMENT MACHINE CADR IF -0              |
|            | TC     | SETNADD     | # ECADR FROM NOUNCADR, SETS ED, NOUNADD.  |
|            | TC     | INTMCTBS +2 |                                           |
| REQADD     | CAF    | BIT15       | # SET CLPASS FOR PASS 0 ONLY              |

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```

TS      CLPASS
CS      ENDINST      # TEST IF REACHED HERE FROM INTERNAL OR
AD      ENTEXIT      #          FROM EXTERNAL
EXTEND
BZF     +2            # EXTERNAL MACH CADR TO BE SPECIFIED
TC      INTMCTBS
TC      REQDATZ      # EXTERNAL MACH CADR TO BE SPECIFIED
CCS     DECBRNCH     # ALARM AND RECYCLE IF DECIMAL USED
TC      ALMCYCLE     # FOR MCTBS.
CS      VD1          # OCTAL USED OK
TS      DSPCOUNT    # BLOCK NUM CHAR IN
CCS     CADRSTOR
TC      +3            # EXTERNAL MCTBS DISPLAY WILL LEAVE FLASH
TC      USEADD        # ON IF ENDIDLE NOT = +0.
TC      +1
TC      FLASHON
USEADD  XCH          ZREG
TC      SETNCADR      # ECADR INTO NOUNCADR.  SET EB, NOUNADD.
EXTEND
DCA     LODNNLOC     # SWITCH BANKS TO NOUN TAB E READING
DXCH    Z            # ROUTINE.
TC      VERBFAN

EBANK=  DSPCOUNT

# Page 325
LODNNLOC 2CADR      LODNNTAB

NEG5     OCT        77772

INTMCTBS CA      MPAC      +2    # INTERNAL MACH CADR TO BE SPECIFIED.
TC      SETNCADR      # ECADR INTO NOUNCADR.  SET EB, NOUNADD.
CS      FIVE          # NVSUB CALL LEFT CADR IN MPAC+2 FOR MACH
AD      VERBREG        # CADR TO BE SPECIFIED.
EXTEND
BZF     VERBFAN      # DON'T DISPLAY CADR IF VB = 05.
CAF     R3D1          # VB NOT = 05.  DISPLAY CADR.
TS      DSPCOUNT
CA      NOUNCADR
TC      DSPOCTWO
TC      VERBFAN

AD      ONE
TC      SETNCADR      # ECADR INTO NOUNCADR.  SETS EB, NOUNADD.
VERBFAN CS      LST2CON
AD      VERBREG      # VERB -- LST2CON
CCS     A
```

|            |       |          |                                          |
|------------|-------|----------|------------------------------------------|
|            | AD    | ONE      | # VERB G/ LST2CON                        |
|            | TC    | +2       |                                          |
|            | TC    | VBFANDIR | # VERB L/ LST2CON                        |
|            | TS    | MPAC     |                                          |
|            | TC    | RELDSP   | # RELEASE DISPLAY SYST                   |
|            | TC    | POSTJUMP | # GO TO GOEXTVB WITH VB=40 IN MPAC.      |
|            | CADR  | GOEXTVB  |                                          |
| LST2CON    | DEC   | 40       | # FIRST LIST2 VERB (EXTENDED VERB)       |
| VBFANDIR   | INDEX | VERBREG  |                                          |
|            | CAF   | VERBTAB  |                                          |
|            | TC    | BANKJUMP |                                          |
| VERBTAB    | CADR  | GODSPALM | # VB00 ILLEGAL                           |
|            | CADR  | DSPA     | # VB01 DISPLAY OCT COMP 1 (R1)           |
|            | CADR  | DSPB     | # VB02 DISPLAY OCT COMP 2 (R1)           |
|            | CADR  | DSPC     | # VB03 DISPLAY OCT COMP 3 (R1)           |
|            | CADR  | DSPAB    | # VB04 DISPLAY OCT COMP 1,2 (R1,R2)      |
|            | CADR  | DSPABC   | # VB05 DISPLAY OCT COMP 1,2,3 (R1,R2,R3) |
|            | CADR  | DECDSP   | # VB06 DECIMAL DISPLAY                   |
|            | CADR  | DSPDPDEC | # VB07 DP DECIMAL DISPLAY (R1,R2)        |
|            | CADR  | GODSPALM | # VB08 SPARE                             |
|            | CADR  | GODSPALM | # VB09 SPARE                             |
|            | CADR  | DSPALARM | # VB10 SPARE                             |
|            | CADR  | MONITOR  | # VB11 MONITOR OCT COMP 1 (R1)           |
|            | CADR  | MONITOR  | # VB12 MONITOR OCT COMP 2 (R1)           |
|            | CADR  | MONITOR  | # VB13 MONITOR OCT COMP 3 (R1)           |
|            | CADR  | MONITOR  | # VB14 MONITOR OCT COMP 1,2 (R1,R2)      |
| # Page 326 |       |          |                                          |
|            | CADR  | MONITOR  | # VB15 MONITOR OCT COMP 1,2,3 (R1,R2,R3) |
|            | CADR  | MONITOR  | # VB16 MONITOR DECIMAL                   |
|            | CADR  | MONITOR  | # VB17 MONITOR DP DEC (R1,R2)            |
|            | CADR  | GODSPALM | # VB18 SPARE                             |
|            | CADR  | GODSPALM | # VB19 SPARE                             |
|            | CADR  | GODSPALM | # VB20 SPARE                             |
|            | CADR  | ALOAD    | # VB21 LOAD COMP 1 (R1)                  |
|            | CADR  | BLOAD    | # VB22 LOAD COMP 2 (R2)                  |
|            | CADR  | CLOAD    | # VB23 LOAD COMP 3 (R3)                  |
|            | CADR  | ABLOAD   | # VB24 LOAD COMP 1,2 (R1,R2)             |
|            | CADR  | ABCLOAD  | # VB25 LOAD COMP 1,2,3 (R1,R2,R3)        |
|            | CADR  | GODSPALM | # VB26 SPARE                             |
|            | CADR  | DSPFMEM  | # VB27 FIXED MEMORY DISPLAY              |
|            |       |          | # THE FOLLOWING VERBS MAKE NO NOUN TEST  |
|            | CADR  | GODSPALM | # VB28 SPARE                             |
|            | CADR  | GODSPALM | # VB29 SPARE                             |
| REQEXLQC   | CADR  | VBRQEXEC | # VB30 REQUEST EXECUTIVE                 |

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|      |          |                                           |
|------|----------|-------------------------------------------|
| CADR | VRQWAIT  | # VB31 REQUEST WAITLIST                   |
| CADR | VBRESEQ  | # VB32 RESEQUENCE                         |
| CADR | VBPROC   | # VB33 PROCEED WITHOUT DATA               |
| CADR | VBTERM   | # VB34 TERMINATE CURRENT TEST OR LOAD REQ |
| CADR | VBSTLTS  | # VB35 TEST LIGHTS                        |
| CADR | SLAP1    | # VB36 FRESH START                        |
| CADR | MMCHANG  | # VB37 CHANGE MAJOR MODE                  |
| CADR | GODSPALM | # VB38 SPARE                              |
| CADR | GODSPALM | # VB39 SPARE                              |

# THE LIST2 VERBFAN IS LOCATED IN THE EXTENDED VERB BANK.

# Page 327

# NNADTAB CONTAINS A RELATIVE ADDRESS, IDADDREL (IN LOW 10 BITS), REFERRING

# TO WHERE 3 CONSECUTIVE ADDRESSES ARE STORED (IN IDADDTAB).

# MIXNOUN GETS DATA AND STORES IN MIXTEMP,+1,+2. IT SETS NOUNADD FOR

# MIXTEMP.

|         |        |          |                                             |
|---------|--------|----------|---------------------------------------------|
| MIXNOUN | CCS    | NNADTEM  |                                             |
|         | TC     | +4       | # + IN USE                                  |
|         | TC     | GODSPALM | # +0 NOT IN USE                             |
|         | TC     | +2       | # - IN USE                                  |
|         | TC     | +1       | # -0 IN USE                                 |
|         | CS     | SIX      |                                             |
|         | AD     | VERBREG  |                                             |
|         | EXTEND |          |                                             |
|         | BZMF   | +2       | # VERB L/E 6                                |
|         | TC     | VERBFAN  | # AVOID MIXNOUN SWAP IF VB NOT = DISPLAY    |
|         | CAF    | TWO      |                                             |
| MIXNN1  | TS     | DECOUNT  |                                             |
|         | AD     | MIXAD    |                                             |
|         | TS     | NOUNADD  | # SET NOUNADD TO MIXTEMP +K                 |
|         | INDEX  | DECOUNT  | # GET IDADDTAB ENTRY FOR COMPONENT K        |
|         | CA     | IDAD1TEM | # OF NOUN.                                  |
|         | TS     | NOUNTEM  |                                             |
|         |        |          | # TEST FOR DP (FOR OCT DISPLAY). IF SO, GET |
|         |        |          | # MINOR PART ONLY.                          |
|         | TC     | SFRUTMIX | # GET SF ROUT NUMBER IN A                   |
|         | TC     | DPTEST   |                                             |
|         | TC     | MIXNN2   | # NO DP                                     |
|         | INCR   | NOUNTEM  | # DP GET MINOR PART                         |
| MIXNN2  | CA     | NOUNTEM  |                                             |
|         | MASK   | LOW11    | # ESUBK (NO DP) OR (ESUBK)+1 FOR DP.        |
|         | TC     | SETEBANK | # SET EBANK, LEAVE EADRES IN A.             |
|         | INDEX  | A        | # PICK UP C(ESUBK) NOT DP.                  |
|         | CA     | 0        | # OR C((ESUBK)+1) FOR DP MINOR PART         |
|         | INDEX  | NOUNADD  |                                             |

|            |       |                                 |                                        |
|------------|-------|---------------------------------|----------------------------------------|
|            | XCH   | 0                               | # STORE IN MIXTEM + K                  |
|            | CCS   | DECOUNT                         |                                        |
|            | TC    | MIXNN1                          |                                        |
|            | TC    | VERBFAN                         |                                        |
| MIXAD      | TC    | MIXTEMP                         |                                        |
| # DPTEST   |       | ENTER WITH SF ROUT NUMBER IN A. |                                        |
| #          |       | RETURNS TO L+1 IF NO DP.        |                                        |
| #          |       | RETURNS TO L+2 IF DP.           |                                        |
| DPTEST     | INDEX | A                               |                                        |
|            | TCF   | +1                              |                                        |
|            | TC    | Q                               | # OCTAL ONLY NO DP                     |
|            | TC    | Q                               | # FRACT NO DP                          |
| # Page 328 |       |                                 |                                        |
|            | TC    | Q                               | # DEG NO DP                            |
|            | TC    | Q                               | # ARITH NO DP                          |
|            | TCF   | DPTEST1                         | # DP1OUT                               |
|            | TCF   | DPTEST1                         | # DP2OUT                               |
|            | TC    | Q                               | # OPDEG NO DP                          |
|            | TCF   | DPTEST1                         | # DP3OUT                               |
|            | TC    | Q                               | # HMS NO DP                            |
|            | TC    | Q                               | # M/S NO DP                            |
|            | TCF   | DPTEST1                         | # DP4OUT                               |
|            | TC    | Q                               | # ARITH1 NO DP                         |
|            | TC    | Q                               | # 2INTOUT NO DP TO GET HI PART IN MPAC |
|            | TCF   | DPTEST1                         | # DPFRACOT                             |
| DPTEST1    | INDEX | Q                               |                                        |
|            | TC    | 1                               | # RETURN TO L+2                        |
| REQDATX    | CAF   | R1D1                            |                                        |
|            | TCF   | REQCOM                          |                                        |
| REQDATY    | CAF   | R2D1                            |                                        |
|            | TCF   | REQCOM                          |                                        |
| REQDATZ    | CAF   | R3D1                            |                                        |
| REQCOM     | TS    | DSPCOUNT                        |                                        |
|            | CS    | Q                               |                                        |
|            | TS    | REQRET                          |                                        |
|            | TC    | BANKCALL                        |                                        |
|            | CADR  | 5BLANK                          |                                        |
|            | TC    | FLASHON                         |                                        |
| ENDRQDAT   | TC    | ENTEXIT                         |                                        |
|            | TS    | NOUNREG                         |                                        |
| UPDATNN    | XCH   | Q                               |                                        |

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```

      TS      UPDATRET
EXTEND
DCA      LODNNLOC      # SWITCH BANKS TO NOUN TABLE READING
DXCH     Z              # ROUTINE.
CCS      NNADTEM
AD        ONE          # NORMAL
TCF      PUTADD
TCF      PUTADD +1     # MCTBS      DON'T CHANGE NOUNADD
TCF      PUTADD +1     # MCTBI      DON'T CHANGE NOUNADD
PUTADD   TC      SETNCADR      # ECADR INTO NOUNCADR.  SETS EB, NOUNADD.
      CAF      ND1
      TS      DSPCOUNT
      CA      NOUNREG
      TCF      UPDAT1

      TS      VERBREG
UPDATVB  XCH      Q
      TS      UPDATRET
      CAF      VD1

# Page 329
      TS      DSPCOUNT
      CA      VERBREG
UPDAT1   TC      POSTJUMP      # CAN'T USE SWCALL TO GO TC DSPDECVN, SINCE
      CADR     GOVNUPDT      # UPDATVB CAN ITSELF BE CALLED BY SWCALL.
      TC      UPDATRET

GOALMCYC TC      ALMCYCLE      # NEEDED BECAUSE BANKJUMP CAN'T HANDLE F/F.

GODSPALM TC      POSTJUMP
      CADR     DSPALARM
```

# Page 330

# NOUN TABLES

#

# NOUN CODE L/40, NORMAL NOUN CASE. NOUN CODE G/E 40, MIXED NOUN CASE.

# FOR NORMAL CASE, NNADTAB CONTAINS ONE ECADR FOR EACH NOUN.

# +0 INDICATES NOUN NOT USED. - ENTRY INDICATES MACHINE CADR (E OR F) TO  
# BE SPECIFIED. -1 INDICATES CHANNEL TO BE SPECIFIED. -0 INDICATES AUGMENT  
# OF LAST MACHINE CADR SUPPLIED.

#

# FOR MIXED CASE, NNADTAB CONTAINS ONE INDIRECT ADDRESS (IDADDREL) IN LOW  
# 10 BITS, AND THE COMPONENT CODE NUMBER IN THE HIGH 5 BITS.

#

# NNTYPTAB IS A PACKED TABLE OF THE FORM MMMMMNNNNPPPPPP.

#

# FOR THE NORMAL CASE, M'S ARE THE COMPONENT CODE NUMBER.

```

#           N'S ARE THE SF ROUTINE CODE NUMBER.
#           P'S ARE THE SF CONSTANT CODE NUMBER.
#
# MIXED-CASE,           M'S ARE THE SF CONSTANT3 CODE NUMBER      3 COMPONENT CASE
#                       N'S ARE THE SF CONSTANT2 CODE NUMBER
#                       P'S ARE THE SF CONSTANT1 CODE NUMBER
#                       N'S ARE THE SF CONSTANT2 CODE NUMBER      2 COMPONENT CASE
#                       P'S ARE THE SF CONSTANT1 CODE NUMBER
#                       P'S ARE THE SF CONSTANT1 CODE NUMBER      1 COMPONENT CASE
#
# THERE IS ALSO AN INDIRECT ADDRESS TABLE (IDADDTAB) FOR MIXED CASE ONLY
# EACH ENTRY CONTAINS ONE ECADR.  IDADDREL IS THE RELATIVE ADDRESS OF
# THE FIRST OF THESE ENTRIES.
#
# THERE IS ONE ENTRY IN THIS TABEL FOR EACH COMPONENT OF A MIXED NOUN
# THEY ARE LISTED IN ORDER OF ASCENDING K.
#
# THERE IS ALSO A SCALE FACTOR ROUTINE NUMBER TABLE (RUTMTAB) FOR MIXED
# CASE ONLY.  THERE IS ONE ENTRY PER MIXED NOUN.  THE FORM IS,
#
#           QQQQRRRRRSSSSS
#
# Q'S ARE THE SF ROUTINE 3 CODE NUMBER           3 COMPONENT CASE
# R'S ARE THE SF ROUTINE 2 CODE NUMBER
# S'S ARE THE SF ROUTINE 1 CODE NUMBER
# R'S ARE THE SF ROUTINE 2 CODE NUMBER           2 COMPONENT CASE
# S'S ARE THE SF ROUTINE 1 CODE NUMBER
#
# IN OCTAL DISPLAY AND LOAD (OCT OR DEC) VERBS, EXCLUDE USE OF VERBS WHOSE
# COMPONENT NUMBER IS GREATER THAN THE NUMBER OF COMONENTS IN NOUN.
# (ALL MACHINE ADDRESS TO BE SPECIFIED NOUNS ARE 3 COMPONENT.)
#
# IN MULTI-COMPONENT LOAD VERBS, NO MIXING OF OCTAL AND DECIMAL DATA
# COMPONENT WORDS IS ALLOWED.  ALARM IF VIOLATION.
#
# IN DECIMAL LOADS OF DATA, 5 NUMERICAL CHARACTERS MUST BE KEYED IN
# BEFORE EACH ENTER.  IF NOT, ALARM.

# Page 331
# DISPLAY VERBS

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DSPABC      CS      TWO
            TC      COMPTST
            INDEX   NOUNADD
            CS      2
            XCH     BUF      +2

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|         |       |          |                                 |
|---------|-------|----------|---------------------------------|
| DSPAB   | CS    | ONE      |                                 |
|         | TC    | COMPTST  |                                 |
|         | INDEX | NOUNADD  |                                 |
|         | CS    | 1        |                                 |
|         | XCH   | BUF      | +1                              |
| DSPA    | TC    | DECTEST  |                                 |
|         | TC    | TSTFORDP |                                 |
|         | INDEX | NOUNADD  |                                 |
|         | CS    | 0        |                                 |
| DSPCOM1 | XCH   | BUF      |                                 |
|         | TC    | DSPCOM2  |                                 |
| DSPB    | CS    | ONE      |                                 |
|         | TC    | DCOMPTST |                                 |
|         | INDEX | NOUNADD  |                                 |
|         | CS    | 1        |                                 |
|         | TC    | DSPCOM1  |                                 |
| DSPC    | CS    | TWO      |                                 |
|         | TC    | DCOMPTST |                                 |
|         | INDEX | NOUNADD  |                                 |
|         | CS    | 2        |                                 |
|         | TC    | DSPCOM1  |                                 |
| DSPCOM2 | CS    | TWO      | # A B C AB ABC                  |
|         | AD    | VERBREG  | # -1 -0 +1 +2 +3 IN A           |
|         | CCS   | A        | # +0 +0 +0 +1 +2 IN A AFTER CCS |
|         | TC    | DSPCOM3  |                                 |
|         | TC    | ENTEXIT  |                                 |
|         | TC    | +1       |                                 |
| DSPCOM3 | TS    | DISTEM   | # +0 +1 +2 INTO DISTEM          |
|         | INDEX | A        |                                 |
|         | CAF   | R1D1     |                                 |
|         | TS    | DSPCOUNT |                                 |
|         | INDEX | DISTEM   |                                 |
|         | CS    | BUF      |                                 |
|         | TC    | DSPCOM2  |                                 |
|         | XCH   | DISTEM   |                                 |
|         | TC    | DSPCOM2  | +2                              |

# COMPTST ALARMS IF COMPONENT NUMBER OF VERB (LOAD OR OCT DISPLAY) IS  
# GREATER THAN THE HIGHEST COMPONENT NUMBER OF NOUN.

|          |      |         |             |
|----------|------|---------|-------------|
| COMPTST  | TS   | SFTEMP1 | # VERB COMP |
|          | LXCH | Q       |             |
| COMPTST1 | TC   | GETCOMP |             |
|          | TC   | LEFT5   |             |
|          | MASK | THREE   | # NOUN COMP |

|          |     |          |                          |
|----------|-----|----------|--------------------------|
|          | AD  | SFTEMP1  | # NOUN COMP -- VERB COMP |
|          | CCS | A        |                          |
|          | TC  | L        | # NOUN COMP G/ VERB COMP |
|          | TC  | CCSHOLE  |                          |
|          | TC  | GODSPALM | # NOUN COMP L/ VERB COMP |
| NDCMPTST | TC  | L        | # NOUN COMP = VERB COMP  |

# DCOMPTST ALARMS IF DECIMAL ONLY BIT (BIT4 OF COMP CODE NUMBER) = 1.  
 # IF NOT, IT PERFORMS REGULAR COMPTST.

|          |      |          |               |
|----------|------|----------|---------------|
| DCOMPTST | TS   | SFTEMP1  | # - VERB COMP |
|          | LXCH | Q        |               |
|          | TC   | DECTEST  |               |
|          | TC   | COMPTST1 |               |

|         |        |          |                                            |
|---------|--------|----------|--------------------------------------------|
| DECTEST | EXTEND |          | # ALARMS IF DEC ONLY BIT = 1 (BIT4 OF COMP |
|         | QXCH   | MPAC +2  | # CODE NUMBER). RETURNS IF NOT.            |
|         | TC     | GETCOMP  |                                            |
|         | MASK   | BIT14    |                                            |
|         | CCS    | A        |                                            |
|         | TC     | GODSPALM |                                            |
|         | TC     | MPAC +2  |                                            |

|          |      |          |                                           |
|----------|------|----------|-------------------------------------------|
| DCTSTCYC | LXCH | Q        | # ALARMS AND RECYCLES IF DEC ONLY BIT = 1 |
|          | TC   | GETCOMP  | # (BIT4 OF COMP CODE NUMBER). RETURNS     |
|          | MASK | BIT14    | # IF NOT. USED BY LOAD VERBS.             |
|          | CCS  | A        |                                           |
|          | TC   | ALMCYCLE |                                           |
|          | TC   | L        |                                           |

# NOUNTEST ALARMS IF NO-LOAD BIT (BIT5 OF COMP CODE NUMBER) = 1.  
 # IF NOT, IT RETURNS.

|          |      |          |
|----------|------|----------|
| NOUNTEST | LXCH | Q        |
|          | TC   | GETCOMP  |
|          | CCS  | A        |
|          | TC   | L        |
|          | TC   | L        |
|          | TC   | GODSPALM |

|          |        |         |                                            |
|----------|--------|---------|--------------------------------------------|
| TSTFORDP | LXCH   | Q       | # TEST FOR DP. IF SO, GET MINOR PART ONLY. |
|          | CA     | NNADTEM |                                            |
|          | AD     | ONE     | # IF NNADTEM = -1, CHANNEL TO BE SPECIFIED |
|          | EXTEND |         |                                            |
|          | BZF    | CHANDSP |                                            |
|          | INDEX  | MIXBR   |                                            |

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# Page 333
TC      +0
TC      +2      # NORMAL

TC      L      # MIXED CASE ALREADY HANDLED IN MIXNOUN
TC      SFRUTNOR
TC      DPTEST
TC      L      # NO DP
INCR    NOUNADD # DP      E+1 INTO NOUNADD FOR MINOR PART.
TC      L

CHANDSP  CA      NOUNCADR
        MASK     LOW9
        EXTEND
        INDEX    A
        READ     0
        CS       A
        TCF      DSPCOM1

COMPICK  ADRES    NNTYPTM
        ADRES    NNADTEM

GETCOMP  INDEX    MIXBR      #      NORMAL      MIXED
        CAF      COMPICK -1  #      ADRES NNTYPTM  ADRES NNADTEM
        INDEX    A
        CA       0      #      C(NNTYPTM)      C(NNADTEM)
        MASK     HI5     #      GET HI5 OF NNTYPTAB (NORM)  OF NNADTAB (MIX
        TC       Q

DECDSP   TC      GETCOMP
        TC      LEFT5
        MASK     THREE
        TS      DECOUNT    # COMP NUMBER INTO DECOUNT
        TS      DECTEM      # PICKS UP DATA
        AD      NOUNADD     # DECTEM 1COMP +0, 2COMP +1, 3COMP +2
        INDEX    A
        CS       0
        INDEX    DECTEM
        XCH      XREG      # CAN'T USE BUF SINCE DMP USES IT.
        CCS      DECTEM
        TC      DSPDCGET    # MORE TO GET
        CAF      ZERO      # DISPLAYS DATA
        TS      MPAC +1    # DECOUNT 1COMP +0, 2COMP +1, 3COMP +2
        TS      MPAC +2
        INDEX    DECOUNT
        CAF      R1D1
        TS      DSPCOUNT
```

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# Page 334
INDEX  DECOUNT
CS      XREG
TS      MPAC
TC      SFCONUM      # 2X (SF CON NUMB) IN A

TS      SFTEMP1
EXTEND
DCA     GTSFOUTL      # SWITCH BANKS TO SF CONSTANT TABLE
DXCH    Z              #      READING ROUTINE.
INDEX   MIXBR          # LOADS SFTEMP1, SFTEMP2
TC      +0
TC      DSPSFNOR
TC      SFRUTMIX
TC      DECDSP3

DSPSFNOR TC      SFRUTNOR
TC      DECDSP3

EBANK=  DSPCOUNT
GTSFOUTL 2CADR    GTSFOUT

DSPDCEND TC      BANKCALL      # ALL SFOUT ROUTINES END HERE
CADR     DSPDECWD
CCS      DECOUNT
TC      +2
TC      ENTEXIT
TS      DECOUNT
TC      DSPDCPUT      # MORE TO DISPLAY

DECDSP3  INDEX    A
CAF      SFOUTABR
TC      BANKJUMP

SFOUTABR CADR     PREDSPAL      # ALARM IF DEC DISP WITH OCTAL ONLY NOUN
CADR     DSPDCEND
CADR     DEGOUTSF
CADR     ARTOUTSF
CADR     DP1OUTSF
CADR     DP2OUTSF
CADR     OPDEGOUT
CADR     DP3OUTSF
CADR     HMSOUT
CADR     M/SOUT
CADR     DP2OUTSF
CADR     AROUT1SF
CADR     2INTOUT

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ENDRTOUT        CADR    DPFACOT  
                 EQUALS

# THE FOLLOWING IS ATYPICAL SF ROUTINE. IT USES MPAC. LEAVES RESULTS  
# IN MPAC, MPAC+1. ENDS WITH TC DSPDCEND

# Page 335

SETLOC BLANKCON +1

COUNT 40/PIN

# DEGOUTSF SCALES BY .18 THE LOW 14 BITS OF ANGLE, ADDING .18 FOR  
# NUMBERS IN THE NEGATIVE (AGC) RANGE.

DEGOUTSF        CAF        ZERO  
                 TS        MPAC +2        # SET INDEX FOR FULL SCALE.  
                 TC        FIXRANGE  
                 TC        +2        # NO AUGMENT NEEDED (SFTEMP1 AND 2 ARE 0)  
                 TC        SETAUG        # SET AUGMENTER ACCORDING TO C(MPAC +2)  
                 TC        DEGCOM

# OPDEGOUT SCALES BY .45 (THE RANGE IS 90 DEGREES) AND ADDS A 20 DEG BIAS.

OPDEGOUT        CCS        MPAC        # RANGE IS 90 DEG  
                 XCH        MPAC        # IF POS OR POS 0 THEN ADD BIAS AND  
                 TC        +3        # CORRECT FOR POSSIBLE OVERFLOW  
                 TC        NEGOPT        # IF NEG NON ZERO  
                 AD        NEG1        # IF NEG ZERO SUBTRACT 1  
                 AD        20BIAS  
BIASCOM        TS        MPAC        # TEST FOR OVEFLOW  
                 TC        +3        # NO OVFLOW  
                 CAF        BIT15        # IF OVFLOW  
                 ADS        MPAC  
                 CAF        TWO        # SET MULTIPLIER TO .45  
                 TC        DEGOUTSF +1  
  
NEGOPT        XCH        MPAC        # NEGATIVE CASE  
                 AD        20BIAS  
                 CCS        A  
                 TC        BIASCOM        # IF POS THEN SUBTRACT 1 BECASUE OF 2SCOM  
                 TC        CCSHOLE  
                 AD        ONE        # IF NEG RESTORE SUM  
                 COM        # IF NEG 0 LEAVE NEG 0  
                 TC        BIASCOM  
  
SETAUG        EXTEND        # LOADS SFTEMP1 AND SFTEMP2 WITH THE

|            |        |          |                                            |
|------------|--------|----------|--------------------------------------------|
|            | INDEX  | MPAC +2  | # DP AUGMENTER CONSTANT                    |
|            | DCA    | DEGTAB   |                                            |
|            | DXCH   | SFTEMP1  |                                            |
|            | TC     | Q        |                                            |
| FIXRANGE   | CCS    | MPAC     | # IF MPAC IS + RETURN TO L+1               |
|            | TC     | Q        | # IF MPAC IS - RETURN TO L+2 AFTER         |
|            | TC     | Q        | # MASKING OUT THE SIGN BIT                 |
|            | TCF    | +1       |                                            |
|            | CS     | BIT15    |                                            |
|            | MASK   | MPAC     |                                            |
| # Page 336 | TS     | MPAC     |                                            |
|            | INDEX  | Q        |                                            |
|            | TC     | 1        |                                            |
| DEGCOM     | EXTEND |          | # LOADS MULTIPLIER, DOES SHORTMP, AND      |
|            | INDEX  | MPAC +2  | # ADDS AUTMENTER.                          |
|            | DCA    | DEGTAB   |                                            |
|            | DXCH   | MPAC     | # ADJUSTED ANGLE IN A                      |
|            | TC     | SHORTMP  |                                            |
|            | DXCH   | SFTEMP1  |                                            |
|            | DAS    | MPAC     |                                            |
|            | TC     | SCOUTEND |                                            |
| DEGTAB     | OCT    | 05605    | # HI PART OF .18                           |
|            | OCT    | 03656    | # LOW PART OF .18                          |
|            | OCT    | 16314    | # HI PART OF .45                           |
|            | OCT    | 31463    | # LO PART OF .45                           |
| 20BIAS     | OCT    | 16040    | # 20 DEG BIAS FOR OPTICS                   |
| ARTOUTSF   | DXCH   | SFTEMP1  | # ASSUMES POINT AT LEFT OF DP SFCON        |
|            | DXCH   | MPAC     |                                            |
|            | TC     | PRSHRTMP | # IF C(A) = -0, SHORTMP FAILS TO GIVE -0.  |
| SCOUTEND   | TC     | POSTJUMP |                                            |
|            | CADR   | DSPDCEND |                                            |
| AROUT1SF   | DXCH   | SFTEMP1  | # ASSUMES POINT BETWEEN HI AND LO PARTS OF |
|            | DXCH   | MPAC     | # DP SFCON. SHIFTS RESULTS LEFT 14, BY     |
|            | TC     | PRSHRTMP | # TAKING RESULTS FROM MPAC+1, MPAC+2.      |
|            | TC     | L14/OUT  |                                            |
| DP10OUTSF  | TC     | DPOUT    | # SCALES MPAC, MPAC +1 BY DP SCALE FACTOR  |
| L14/OUT    | XCH    | MPAC +2  | # IN SFTEMP1, SFTEMP2. THEN SCALE RESULT   |
|            | XCH    | MPAC +1  | # BY B14                                   |

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|          |     |          |                                           |
|----------|-----|----------|-------------------------------------------|
|          | TS  | MPAC     |                                           |
|          | TC  | SCOUTEND |                                           |
| DP2OUTSF | TC  | DPOUT    | # SCALES MPAC, MPAC +1 BY DP SCALE FACTOR |
|          | TC  | SCOUTEND |                                           |
| DP3OUTSF | TC  | DPOUT    | # ASSUMES POINT BETWEEN BITS 7-8 OF HIGH  |
|          | CAF | SIX      | # LEFT BY 7, ROUNDS MPAC+2 INTO MPAC+1    |
|          | TC  | TPLEFTN  | # SHIFT LEFT 7.                           |
|          | TC  | SCOUTEND |                                           |

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|        |       |         |                                      |
|--------|-------|---------|--------------------------------------|
| MPAC+6 | =     | MPAC +6 | # USE MPAC +6 INSTEAD OF OVFIN       |
| DPOUT  | XCH   | Q       |                                      |
|        | TS    | MPAC+6  |                                      |
|        | TC    | READLO  | # GET FRESH DATA FOR BOTH HI AND LO. |
|        | TC    | TPAGREE | # MAKE DP DATA AGREE                 |
|        | TC    | DMP     |                                      |
|        | ADRES | SFTMP1  |                                      |
|        | TC    | MPAC+6  |                                      |

# THE FOLLOWING ROUTINE DISPLAYS TWO CONTIGUOUS SP POSITIVE INTEGERS  
# AS TWO POSITIVE DECIMAL INTEGERS IN RXD1-RXD2 AND RXD4-RXD5 (RXD3 IS  
# BLANKED). THE INTEGER IN THE LOWER NUMBERED ADDRESS IS DISPLAYED IN  
# RXD1-RXD2.

|          |       |             |                                            |
|----------|-------|-------------|--------------------------------------------|
| 2INTOUT  | TC    | 5BLANK      | # TO BLANK RXD3                            |
|          | TC    | +ON         | # TURN ON + SIGN                           |
|          | CA    | MPAC        |                                            |
|          | TC    | DSPDECVN    | # DISPLAY 1ST INTEGER (LIKE VERB AND NOUN) |
|          | CS    | THREE       |                                            |
|          | INDEX | DECOUNT     |                                            |
|          | AD    | R1D1        | # RXD4                                     |
|          | TS    | DSPCOUNT    |                                            |
|          | TC    | READLO      | # GET 2ND INTEGER                          |
|          | CA    | MPAC +1     |                                            |
|          | TC    | DSPDECVN    | # DISPLAY 2ND INTEGER (LIKE VERB AND NOUN) |
|          | TC    | POSTJUMP    |                                            |
|          | CADR  | DSPDCEND +2 |                                            |
| DPFRACOT | TC    | READLO      | # DP FRACTION TO MPAC,+1                   |
|          | TC    | SCOUTEND    |                                            |

# READLO PICKS UP FRESHDATA FOR BOTH HI AND LO AND LEAVES IT IN

# MPAC, MPAC+1. THIS IS NEEDED FOR TIME DISPLAY. IT ZEROES MPAC+2, BUT  
# DOES NOT FORCE TPAGREE.

|         |        |          |                                          |
|---------|--------|----------|------------------------------------------|
| READLO  | XCH    | Q        |                                          |
|         | TS     | TEM4     |                                          |
|         | INDEX  | MIXBR    |                                          |
|         | TC     | +0       |                                          |
|         | TC     | RDONOR   |                                          |
|         | INDEX  | DECOUNT  |                                          |
|         | CA     | IDAD1TEM | # GET IDADDTAB ENTRY FOR COMP K OF NOUN. |
|         | MASK   | LOW11    | # E SUBK                                 |
|         | TC     | SETEBANK | # SET EB, LEAVE EADRES IN A              |
| READLO1 | EXTEND |          | # MIXED NORMAL                           |
|         | INDEX  | A        | # C(ESUBK) C(E)                          |
|         | DCA    | 0        | # C(E SUBK)+1) C(E+1)                    |
|         | DXCH   | MPAC     |                                          |

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|         |     |         |     |
|---------|-----|---------|-----|
|         | CAF | ZERO    |     |
|         | TS  | MPAC    | +2  |
|         | TC  | TEM4    |     |
| RDONOR  | CA  | NOUNADD | # E |
| ENDRDLO | TC  | READLO1 |     |

BANK 42  
SETLOC PINBALL3  
BANK

COUNT 42/PIN

|        |       |            |                                             |
|--------|-------|------------|---------------------------------------------|
| HMSOUT | TC    | BANKCALL   | # READ FRESH DATA FOR HI AND LO INTO MPAC.  |
|        | CADR  | READLO     | # MPAC+1.                                   |
|        | TC    | TPAGREE    | # MAKE DP DATA AGREE.                       |
|        | TC    | SEPSECNR   | # LEAVE FRACT SEC/60 IN MPAC, MPAC+1. LEAVE |
|        |       |            | # WHOLE MIN IN BIT13 OF LOTEMOUT AND ABOVE  |
|        | TC    | DMP        | # USE ONLY FRACT SEC/60 MOD 60              |
|        | ADRES | SECON2     | # MULT BY .06                               |
|        | CAF   | R3D1       | # GIVES CENTI-SEC/10EXP5 MOD 60             |
|        | TS    | DSPCOUNT   |                                             |
|        | TC    | BANKCALL   | # DISPLAY SEC MOD 60                        |
|        | CADR  | DSPDECWD   |                                             |
|        | TC    | SEPMIN     | # REMOVE REST OF SECONDS                    |
|        | CAF   | MINCON2    | # LEAVE FRACT MIN/60 IN MPAC+1. LEAVE       |
|        | XCH   | MPAC       | # WHOLE HOURS IN MPAC.                      |
|        | TS    | HITEMOUT   | # SAVE WHOLE HOURS.                         |
|        | CAF   | MINCON2 +1 |                                             |



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|            |        |                      |                                            |
|------------|--------|----------------------|--------------------------------------------|
|            | XCH    | MPAC +1              | # USE ONLY FRACT MIN/60 MOD 60             |
|            | TC     | PRSHRTMP             | # IF C(A) = -0, SHORTMP FAILS TO GIVE -0.  |
|            |        |                      | # MULT BY .0006                            |
|            | CAF    | R2D1                 | # GIVE MIN/10EXP5 MOD 60                   |
|            | TS     | DSPCOUNT             |                                            |
|            | TC     | BANKCALL             | # DISPLAY MIN MOD 60                       |
|            | CADR   | DSPDECWD             |                                            |
|            | EXTEND |                      | # MINUTES, SECONDS HAVE BEEN REMOVED       |
|            | DCA    | HRCON1               |                                            |
|            | DXCH   | MPAC                 |                                            |
|            | CA     | HITEMOUT             | # USE WHOLE HOURS                          |
|            | TC     | PRSHRTMP             | # IF C(A) = -0, SHORTMP FAILS TO GIVE -0.  |
|            |        |                      | # MULT BY .16384                           |
|            | CAF    | R1D1                 | # GIVES HOURS/10EXP5                       |
|            | TS     | DSPCOUNT             |                                            |
|            | TC     | BANKCALL             | # USE REGULAR DSPDECWD WITH ROUND OFF.     |
|            | CADR   | DSPDECWD             |                                            |
|            | TC     | ENTEXIT              |                                            |
| SECON1     | 2DEC*  | 1.666666666 E-4 B12* | # 2EXP12/6000                              |
| # Page 339 |        |                      |                                            |
| SECON2     | OCT    | 01727                | # .06 FOR SECONDS DISPLAY                  |
|            | OCT    | 01217                |                                            |
| MINCON2    | OCT    | 00011                | # .0006 FOR MINUTES DISPLAY                |
|            | OCT    | 32445                |                                            |
| MINCON1    | OCT    | 02104                | # .06..66 UPPED BY 2EXP-2B                 |
|            | OCT    | 10422                |                                            |
| HRCON1     | 2DEC   | .16384               |                                            |
|            | OCT    | 00000                |                                            |
| RNDCON     | OCT    | 00062                | # .5 SEC                                   |
| M/SOUT     | TC     | BANKCALL             | # READ FRESH DATA FOR HI AND LO INTO MPAC. |
|            | CADR   | READLO               | # MPAC+1.                                  |
|            | TC     | TPAGREE              | # MAKE DP DATA AGREE                       |
|            | CCS    | MPAC                 | # IF MAG OF (MPAC, MPAC+1) G/ 59 M 59 S.   |
|            | TC     | +2                   | # DISPLAY 59B59, WITH PROPER SIGN.         |
|            | TC     | M/SNORM              | # MPAC = +0. L/ 59M58.5S                   |
|            | AD     | M/SCON1              | # - HI PART OF (59M58.5) +1 FOR CCS        |
|            | CCS    | A                    | # MAG OF MPAC - HI PART OF (59M58.5S)      |
|            | TC     | M/SLIMIT             | # G/ 59M58.5S                              |
|            | TC     | M/SNORM              | # ORIGINAL MPAC = -0. L/59M58.5S           |
|            | TC     | M/SNORM              | # L/ 59M58.5S                              |
|            | CCS    | MPAC +1              | # MAG OF MPAC = HI PART OF 59M58.5S        |
|            | TC     | +2                   |                                            |
|            | TC     | M/SNORM              | # MPAC+1 = +0. L/ 59M58.5S                 |
|            | AD     | M/SCON2              | # - LO PART OF (59M58.5S) +1 FOR CCS       |

|            |        |             |                                            |
|------------|--------|-------------|--------------------------------------------|
|            | CCS    | A           | # MAG OF MPAC+1 - LO PART OF (59M58.5S)    |
|            | TC     | M/SLIMIT    | # G/ 59M58.5S                              |
|            | TC     | M/SNORM     | # ORIGINAL MPAC+1 = -0. L/ 49M58.5S        |
|            | TC     | M/SNORM     | # L/ 59M58.5S                              |
| M/SLIMIT   | CCS    | MPAC        | # = 59M58.5S LIMIT                         |
|            | CAF    | M/SCON3     | # MPAC CANNOT BE +/- 0 AT THIS POINT.      |
|            | TC     | +LIMIT      | # FORCE MPAC, MPAC+1 TO +/- 59M58.5S       |
|            | CS     | M/SCON3     |                                            |
|            | TS     | MPAC        | # WILL DISPLAY 59M59S IN DSPDECNR          |
|            | CS     | M/SCON3 +1  |                                            |
| LIMITCOM   | TS     | MPAC +1     |                                            |
|            | CAF    | NORMADR     | # SET RETURN TO M/SNORM+1.                 |
|            | TC     | SEPSECNR +1 |                                            |
| +LIMIT     | TS     | MPAC        |                                            |
|            | CAF    | M/SCON3 +1  |                                            |
|            | TC     | LIMITCOM    |                                            |
| M/SNORM    | TC     | SEPSEC      | # LEAVE FRACT SEC/60 IN MPAC,MPAC+1. LEAVE |
|            |        |             | # WHOLE MIN IN BIT13 OF LOTEMOUT AND ABOVE |
|            | CAF    | HISECON     | # USE ONLY FRACT SEC/60 MOD 60             |
|            | TC     | SHORTMP     | # MULT BY .6 + 2EXP-14                     |
|            | CS     | THREE       | # GIVES SEC/100 MOD 60                     |
|            | ADS    | DSPCOUNT    | # DSPCOUNT ALREADY SET TO RXD1             |
|            | TC     | BANKCALL    | # DISPLAY SEC MOD 60 IN D4D5.              |
| # Page 340 |        |             |                                            |
|            | CADR   | DSPDC2NR    |                                            |
|            | CAF    | ZERO        |                                            |
|            | TS     | CODE        |                                            |
|            | CS     | TWO         |                                            |
|            | INDEX  | DECOUNT     |                                            |
|            | AD     | R1D1        | # RXD3                                     |
|            | TS     | COUNT       |                                            |
|            | TC     | BANKCALL    | # BLANK MIDDLE CHAR                        |
|            | CADR   | DSPIN       |                                            |
|            | TC     | SEPMIN      | # REMOVE REST OF SECONDS                   |
|            | XCH    | MPAC +1     | # LEAVE FRACT MIN/60 IN MPAC+1             |
|            | EXTEND |             | # USE ONLY FRACT MIN/60 MOD 60             |
|            | MP     | HIMINCON    | # MULT BY .6 + 2EXP-7                      |
|            | DXCH   | MPAC        | # GIVES MIN/100 MOD 60                     |
|            | INDEX  | DECOUNT     |                                            |
|            | CAF    | R1D1        | # RXD1                                     |
|            | TS     | DSPCOUNT    |                                            |
|            | TC     | BANKCALL    | # DISPLAY MIN MOD 60 IN D1D2.              |
|            | CADR   | DSPDC2NR    |                                            |
|            | TC     | POSTJUMP    |                                            |
|            | CADR   | DSPDCEND +2 |                                            |

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|            |        |            |                                         |
|------------|--------|------------|-----------------------------------------|
| HISECON    | OCT    | 23147      | # .6 + 2EXP-14                          |
| HIMINCON   | OCT    | 23346      | # .6 + 2EXP-7                           |
| M/SCON1    | OCT    | 77753      | # - HI PART OF (59M58.5S)               |
| M/SCON2    | OCT    | 41126      | # - LO PART OF (59M58.5S)               |
| NORMADR    | ADRES  | M/SNORM +1 |                                         |
| M/SCON3    | OCT    | 00025      | # 59M 59.5S                             |
|            | OCT    | 37016      |                                         |
| SEPSEC     | CCS    | MPAC +1    | # IF +, ROUND BY ADDING .5 SEC          |
|            | TCF    | POSEC      | # IF -, ROUND BY SUBTRACING .5 SEC      |
|            | TCF    | POSEC      | # FINDS TIME IN MPAC, MPAC+1            |
|            | TCF    | +1         | # ROUNDS OFF BY +/- .5 SEC              |
|            | EXTEND |            | # LEAVES WHOLE MIN IN BIT13 OF          |
|            | DCS    | RNDCON -1  | # LOTEMOUT AND ABOVE.                   |
| SEPSEC1    | DAS    | MPAC       | # LEAVES FRACT SEC/60 IN MPAC, MPAC+1.  |
|            | TCF    | SEPSECNR   |                                         |
| POSEC      | EXTEND |            |                                         |
|            | DCA    | RNDCON -1  |                                         |
|            | TCF    | SEPSEC1    |                                         |
| SEPSECNR   | XCH    | Q          | # THIS ENTRY AVOIDS ROUNDING BY .5 SEC  |
|            | TS     | SEPSECRET  |                                         |
|            | TC     | DMP        | # MULT BY 2EXP12/6000                   |
|            | ADRES  | SECON1     | # GIVES FRACT SEC/60 IN BIT12 OF MPAC+1 |
|            | EXTEND |            | # AND BELOW.                            |
|            | DCA    | MPAC       | # SAVE MINUTES AND HOURS                |
|            | DXCH   | HITEMOUT   |                                         |
| # Page 341 |        |            |                                         |
|            | TC     | TPSL1      |                                         |
|            | TC     | TPSL1      | # GIVES FRACT SEC/60 IN MPAC+1, MPAC+2. |
|            | CAF    | ZERO       |                                         |
|            | XCH    | MPAC +2    | # LEAVE FRACT SEC/60 IN MPAC, MPAC+1.   |
|            | XCH    | MPAC +1    |                                         |
|            | XCH    | MPAC       |                                         |
|            | TC     | SEPSECRET  |                                         |
| SEPMIN     | XCH    | Q          | # FIND WHOLE MINUTES IN BIT13           |
|            | TS     | SEPMNRET   | # OF LOTEMOUT AND ABOVE.                |
|            | CA     | LOTEMOUT   | # REMOVES REST OF SECONDS.              |
|            | EXTEND |            | # LEAVES FRACT MIN/60 IN MPAC+1.        |
|            | MP     | BIT3       | # LEAVES WHOLE HOURS IN MPAC.           |
|            | EXTEND |            | # SR 12, THROW AWAY LP.                 |
|            | MP     | BIT13      | # SR 2, TAKE FROM LP. = SL 12.          |
|            | LXCH   | MPAC +1    | # THIS FORCES BITS 12-1 TO 0 IF +.      |
|            |        |            | # FORCES BITS 12-1 TO 1 IF -.           |
|            | CA     | HITEMOUT   |                                         |

```

                TS      MPAC
                TC      DMP          # MULT BY 1/15
                ADRES    MINCON1      # GIVES FRACT MIN/60 IN MPAC+1.
ENDSPMIN        TC      SEPMNRET     # GIVES WHOLE HOURS IN MPAC.

```

```

# THIS IS A SPECIAL PURPOS VERB FOR DISPLAYING A DOUBLE PRECISION AGC
# WORD AS 10 DECIMAL DIGITS ON THE AGC DISPLAY PANEL. IT CAN BE USED WITH
# ANY NOUN, EXCEPT MIXED NOUNS. IT DISPLAYS THE CONTENTS
# OF THE REGISTER NOUNADD IS POINTING TO. IF USED WITH NOUNS WHICH ARE
# INHERENTLY NOT DP SUCH AS THE CDU COUNTERS THE DISPLAY WILL BE GARBAGE.
# DISPLAY IS IN R1 AND R2 ONLY WITH THE SIGN IN R1.

```

```

                SETLOC  ENDRDLO +1

```

```

                COUNT  40/PIN

```

```

DSPDPDEC        INDEX  MIXBR
                TC      +0
                TC      +2          # NORMAL NOUN
                TC      DSPALARM
                EXTEND
                INDEX  NOUNADD
                DCA     0
                DXCH    MPAC
                CAF      R1D1
                TS      DSPCOUNT
                CAF      ZERO
                TS      MPAC +2
                TC      TPAGREE

```

```

# Page 342

```

```

                TC      DSP2DEC
ENDDPDEC        TC      ENTEXTIT

```

```

# Page 343

```

```

# LOAD VERBS          IF ALARM CONDITION IS DETECTED DURING EXECUTE,
# CHECK FAIL LIGHT IS TURNED ON AND ENDOFJOB. IF ALARM CONDITION IS
# DETECTED DURING ENTER OF DATA, CHECK FAIL IS TURNED ON AND IT RECYCLES
# TO EXECUTE OF ORIGINAL LOAD VERB. RECYCLE CAUSED BY          1) DECIMAL MACHINE
# CADR                2) MIXTURE OF OCTAL/DECIMAL DATA        3) OCTAL DATA INTO DECIMAL
# ONLY NOUN           4) DEC DATA INTO OCT ONLY NOUN          5) DATA TOO LARGE FOR SCALE
# 6) FEWER THAN 3 DATA WORDS LOADED FOR HRS, MIN, SEC NOUN.8 (2)-(6) ALARM
# AND RECYCLE OCCUR AT FINAL ENTER OF SET.          (1) ALARM AND RECYCLE OCCUR AT
# ENTER OF CADR.

```

```

                SETLOC  ENDRTOUIT

```

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```
COUNT  41/PIN

ABCLOAD  CS  TWO
          TC  COMPTST
          TC  NOUNTEST      # TEST IF NOUN CAN BE LOADED.
          CAF  VBSP1LD
          TC  UPDATVB -1
          TC  REQDATX
          CAF  VBSP2LD
          TC  UPDATVB -1
          TC  REQDATY
          CAF  VBSP3LD
          TC  UPDATVB -1
          TC  REQDATZ

PUTXYZ   CS  SIX            # TEST THAT THE 3 DATA WORDS LOADED ARE
          TC  ALLDC/OC      # ALL DEC OR ALL OCT.
          EXTEND
          DCA  LODNNLOC     # SWITCH BANKS TO NOUN TABLE READING
          DXCH  Z           # ROUTINE.
          CAF  ZERO        # X COMP
          TC  PUTCOM
          INDEX NOUNADD
          TS   0
          CAF  ONE         # Y COMP
          TC  PUTCOM
          INDEX NOUNADD
          TS   1
          CAF  TWO         # Z COMP
          TC  PUTCOM
          INDEX NOUNADD
          TS   2
          CS  SEVEN        # IF NOUN 7 HAS JUST BEEN LOADED, SET
          AD  NOUNREG      # FLAG BITS AS SPECIFIED.
          EXTEND
          BZF  +2

# Page 344

          TC  LOADLV
          CA  XREG          # ECADR OF ERASABLE CELL
          TC  SETNCADR +1   # SET EBANK, NOUNADD
          CA  ZREG          # ZERO TO RESET BITS. NON-ZERO TO SET BITS
          INHINT
          EXTEND
          BZF  BITSOFF
          INDEX NOUNADD
```

|            |        |            |                                         |
|------------|--------|------------|-----------------------------------------|
|            | CS     | 0          |                                         |
|            | MASK   | YREG       | # BITS TO BE PROCESSED                  |
|            | INDEX  | NOUNADD    |                                         |
|            | ADS    | 0          | # SET BITS.                             |
|            | TC     | BITSOFF1   |                                         |
| BITSOFF    | CS     | YREG       | # BITS TO BE PROCESSED                  |
|            | INDEX  | NOUNADD    |                                         |
|            | MASK   | 0          |                                         |
|            | INDEX  | NOUNADD    |                                         |
|            | TS     | 0          | # RESET BITS                            |
| BITSOFF1   | RELINT |            |                                         |
|            | TC     | LOADLV     |                                         |
| ABLOAD     | CS     | ONE        |                                         |
|            | TC     | COMPTST    |                                         |
|            | TC     | NOUNTEST   | # TEST IF NOUN CAN BE LOADED            |
|            | CAF    | VBSP1LD    |                                         |
|            | TC     | UPDATVB -1 |                                         |
|            | TC     | REQDATX    |                                         |
|            | CAF    | VBSP2LD    |                                         |
|            | TC     | UPDATVB -1 |                                         |
|            | TC     | REQDATY    |                                         |
| PUTXY      | CS     | FIVE       | # TEST THAT THE 2 DATA WORDS LOADED ARE |
|            | TC     | ALLDC/OC   | # ALL DEC OR ALL OCT.                   |
|            | EXTEND |            |                                         |
|            | DCA    | LODNNLOC   | # SWITCH BANKS TO NOUN TABLE READING    |
|            | DXCH   | Z          | # ROUTINE.                              |
|            | CAF    | ZERO       | # X COMP                                |
|            | TC     | PUTCOM     |                                         |
|            | INDEX  | NOUNADD    |                                         |
|            | TS     | 0          |                                         |
|            | CAF    | ONE        | # Y COMP                                |
|            | TC     | PUTCOM     |                                         |
|            | INDEX  | NOUNADD    |                                         |
|            | TS     | 1          |                                         |
|            | TC     | LOADLV     |                                         |
| ALOAD      | TC     | REQDATX    |                                         |
|            | EXTEND |            |                                         |
|            | DCA    | LODNNLOC   | # SWITCH BANKS TO NOUN TABLE READING    |
|            | DXCH   | Z          | # ROUTINE.                              |
|            | CAF    | ZERO       | # X COMP                                |
| # Page 345 | TC     | PUTCOM     |                                         |
|            | INDEX  | NOUNADD    |                                         |

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|          |        |          |                                           |
|----------|--------|----------|-------------------------------------------|
|          | TS     | 0        |                                           |
|          | TC     | LOADLV   |                                           |
| BLOAD    | CS     | ONE      |                                           |
|          | TC     | COMPTST  |                                           |
|          | CAF    | BIT15    | # SET CLPASS FOR PASSO ONLY               |
|          | TS     | CLPASS   |                                           |
|          | TC     | REQDATY  |                                           |
|          | EXTEND |          |                                           |
|          | DCA    | LODNNLOC | # SWITCH BANKS TO NOUN TABLE READING      |
|          | DXCH   | Z        | # ROUTINE.                                |
|          | CAF    | ONE      |                                           |
|          | TC     | PUTCOM   |                                           |
|          | INDEX  | NOUNADD  |                                           |
|          | TS     | 1        |                                           |
|          | TC     | LOADLV   |                                           |
| CLOAD    | CS     | TWO      |                                           |
|          | TC     | COMPTST  |                                           |
|          | CAF    | BIT15    | # SET CLPASS FOR PASSO ONLY               |
|          | TS     | CLPASS   |                                           |
|          | TC     | REQDATZ  |                                           |
|          | EXTEND |          |                                           |
|          | DCA    | LODNNLOC | # SWITCH BANKS TO NOUN TABLE READING      |
|          | DXCH   | Z        | # ROUTINE.                                |
|          | CAF    | TWO      |                                           |
|          | TC     | PUTCOM   |                                           |
|          | INDEX  | NOUNADD  |                                           |
|          | TS     | 2        |                                           |
|          | TC     | LOADLV   |                                           |
| LOADLV   | CAF    | ZERO     |                                           |
|          | TS     | DECBRNCH |                                           |
|          | CS     | ZERO     |                                           |
|          | TS     | LOADSTAT |                                           |
|          | TC     | RELDSP   | # RELEASE FOR PRIORITY DISPLAY PROBLEM.   |
|          | CS     | VD1      | # TO BLOCK NUMERICAL CHARACTERS AND       |
|          | TS     | DSPCOUNT | # CLEARS AFTER A COMPLETED LOAD           |
|          | TC     | POSTJUMP | # AFTER COMPLETED LOAD, GO TO RECALTST    |
|          | CADR   | RECALTST | # TO SEE IF THERE IS RECALL FROM ENDIDLE. |
| VBSP1LD  | DEC    | 21       | # VB21 = ALOAD                            |
| VBSP2LD  | DEC    | 22       | # VB22 = BLOAD                            |
| VBSP3LD  | DEC    | 23       | # VB23 = CLOAD                            |
| ALLDC/OC | TS     | DECOUNT  | # TESTS THAT DATA WORDS LOADED ARE EITHER |

```

# Page 346
CS      DECBRNCH      # ALL DEC OR ALL OCT.  ALARMS IF NOT.

TS      SR
CS      SR
CS      SR      # SHIFTED RIGHT 2
CCS     A      # DEC COMP BITS IN LOW 3
TCF     +2      # SOME ONES IN LOW 3
TC      Q      # ALL ZEROS.  ALL OCTAL.  OK
AD      DECOUNT  # DEC COMP = 7 FOR 3COMP, =6 FOR 2COMP
EXTEND
BZF     +2      # MUST MATCH 6 FOR 3COMP, 5 FOR 2COMP.
TC      ALMCYCLE  # ALARM AND RECYCLE.
GOQ     TC      Q      # ALL REQUIRED ARE DEC.  OK

SFRUTNOR XCH      Q      # GETS SF ROUTINE NUMBER FOR NORMAL CASE
TS      EXITEM      # CAN'T USE L FOR RETURN.  TSTFORDP USES L.
CAF     MID5
MASK    NNTYPTM
TC      RIGHT5
TC      EXITEM      # SF ROUTINE NUMBER IN A

SFRUTMIX XCH      Q      # GETS SF ROUTINE NUMBER FOR MIXED CASE
TS      EXITEM
INDEX   DECOUNT
CAF     DISPLACE      # PUT TC GOQ, TC RIGHT5, OR TC LEFT5 IN L
TS      L
INDEX   DECOUNT
CAF     LOW5      # LOW5, MID5, OR HI5 IN A
MASK    RUTMXTEM      # GET HI5, MID5, OR LOW5 OF RUTMXTAB ENTRY
INDEX   L
TC      0

# DO TC GOQ(DECOUNT=0), DO TC RIGHT5(DECOUNT=1), DO TC LEFT5(DECOUNT=2).

SFRET1   TC      EXITEM      # SF ROUTINE NUMBER IN A

SFCONUM  XCH      Q      # GETS 2X(SF CONSTANT NUMBER)
TS      EXITEM
INDEX   MIXBR
TC      +0
TC      CONUMNOR      # NORMAL NOUN
INDEX   DECOUNT      # MIXED NOUN
CAF     DISPLACE
TS      L      # PUT TC GOQ, TC RIGHT5, OR TC LEFT5 IN L
INDEX   DECOUNT
CAF     LOW5

```



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MASK NNTYPTM  
INDEX L  
TC 0

# DO TC GOQ(DECOUNT=0), DO TC RIGHT5(DECOUNT=1), DO TC LEFT5(DECOUNT=2).

SFRET DOUBLE # 2X(SF CONSTANT NUMBER) IN A  
TC EXITEM

# Page 347

DISPLACE TC GOQ  
TC RIGHT5  
TC LEFT5

CONUMNOR CAF LOW5 # NORMAL NOUN ALWAYS GETS LOW 5 OF  
MASK NNTYPTM # NNTYPTAB FOR SF CONUM.  
DOUBLE  
TC EXITEM # 2X(SF CONSTANT NUMBER) IN A

PUTCOM TS DECOUNT  
XCH Q  
TS DECRET  
CAF ZERO  
TS MPAC+6  
INDEX DECOUNT  
XCH XREGLP  
TS MPAC +1  
INDEX DECOUNT  
XCH XREG  
TS MPAC  
INDEX MIXBR  
TC +0  
TC PUTNORM # NORMAL NOUN

# IF MIXNOUN, PLACE ADDRESS FOR COMPONENT K INTO NOUNADD, SET EBANK BITS.

INDEX DECOUNT # GET IDADDTAB ENTRY FOR COMPONENT K  
CA IDAD1TEM # OF NOUN.  
MASK LOW11 # (ECADR)SUBK FOR CURRENT COMP OF NOUN  
TC SETNCADR # ECADR INTO NOUNCADR. SETS EB, NOUNADD.  
EXTEND # C(NOUNADD) IN A UPON RETURN  
SU DECOUNT # PLACE (ESUBK)-K INTO NOUNADD  
TS NOUNADD  
CCS DECBRNCH  
TC PUTDECSF # + DEC

|            |        |            |                                            |
|------------|--------|------------|--------------------------------------------|
|            | TC     | DCTSTCYC   | # +0 OCTAL                                 |
|            | TC     | SFRUTMIX   | # TEST IF DEC ONLY BIT = 1. IF SO,         |
|            | TC     | DPTTEST    | # ALARM AND RECYCLE. IF NOT, CONTINUE.     |
|            | TC     | PUTCOM2    | # NO DP                                    |
|            |        |            | # TEST FOR DP SCALE FOR OCT LOAD. IF SO,   |
|            |        |            | # +0 INTO MAJOR PART. SET NOUNADD FOR      |
|            |        |            | # LOADING OCTAL WORD INTO MINOR PART.      |
| PUTDPCOM   | INCR   | NOUNADD    | # DP (ESUBK)-K+1 OR E+1                    |
|            | CA     | NOUNADD    | # NOUNADD NOW SET FOR MINOR PART           |
|            | ADS    | DECOUNT    | # (ESUBK)+1 OR E+1 INTO DECOUNT            |
|            | CAF    | ZERO       | # NOUNADD SET FOR MINOR PART               |
|            | INDEX  | DECOUNT    |                                            |
|            | TS     | 0 -1       | # ZERO MAJOR PART(ESUBK OR E)              |
|            | TC     | PUTCOM2    |                                            |
| PUTNORM    | TC     | SETNADD    | # ECADR FROM NOUNCADR. SETS EB, NOUNADD.   |
| # Page 348 |        |            |                                            |
|            | CCS    | DECBRNCH   |                                            |
|            | TC     | PUTDECSF   | # + DEC                                    |
|            | TC     | DCTSTCYC   | # +0 OCTAL                                 |
|            | TC     | SFRUTNOR   | # TEST IF DEC ONLY BIT (garbled). IF SO,   |
|            | TC     | DPTTEST    | # ALARM AND RECYCLE. IF NOT, CONTINUE.     |
|            | TC     | PUTCOM2 -4 | # NO DP                                    |
|            | CAF    | ZERO       | # DP                                       |
|            | TS     | DECOUNT    |                                            |
|            | TC     | PUTDPCOM   |                                            |
|            | CA     | NNADTEM    |                                            |
|            | AD     | ONE        | # IF NNADTEM = -1, CHANNEL TO BE SPECIFIED |
|            | EXTEND |            |                                            |
|            | BZF    | CHANLOAD   |                                            |
| PUTCOM2    | XCH    | MPAC       |                                            |
|            | TC     | DECRET     |                                            |
|            | EBANK= | DSPCOUNT   |                                            |
| GTSFINLC   | 2CADR  | GTSFIN     |                                            |
| CHANLOAD   | CS     | SEVEN      | # DON'T LOAD CHAN 7. (IT'S SUPERBANK).     |
|            | AD     | NOUNCADR   |                                            |
|            | EXTEND |            |                                            |
|            | BZF    | LOADLV     |                                            |
|            | CA     | NOUNCADR   |                                            |
|            | MASK   | LOW9       |                                            |
|            | XCH    | MPAC       |                                            |
|            | EXTEND |            |                                            |
|            | INDEX  | MPAC       |                                            |

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WRITE 0  
TC LOADLV

# PUTDECSF FINDS MIXBR AND DECOUNT STILL SET FROM PUTCOM.

PUTDECSF TC SFCONUM # 2X(SF CON NUMB) IN A  
TS SFTEMP1  
EXTEND # SWITCH BANKS TO SF CONSTANT TABLE  
DCA GTSFINLC # READING ROUTINE.  
DXCH Z # LOADS SFTEMP1, SFTEMP2.  
INDEX MIXBR  
TC +0  
TC PUTSFNOR  
TC SFRUTMIX  
TC PUTDCSF2  
PUTSFNOR TC SFRUTNOR

PUTDCSF2 INDEX A

# Page 349

CAF SFINTABR  
TC BANKJUMP # SWITCH BANKS FOR EXPANSION ROOM  
SFINTABR CADR GOALMCYC # ALARM AND RECYCLE IF DEC LOAD  
# WITH OCTAL ONLY NOUN.  
CADR BINROUND  
CADR DEGINSF  
CADR ARTHINSF  
CADR DPINSF  
CADR DPINSF2  
CADR OPTDEGIN  
CADR DPINSF # SAME AS ARITHDP1  
CADR HMSIN  
CADR DSPALARM # MIN/SEC CAN'T BE LOADED.  
CADR DPINSF4  
CADR ARTIN1SF  
CADR DSPALARM # 2INTOUT CAN'T BE LOADED.  
CADR DPFRACIN  
ENDROUTIN EQUALS

# SCALE FACTORS FOR THOSE ROUTINES NEEDING THEM ARE AVAILABLE IN SFTEMP1.

# ALL SFIN ROUTINES USE MPAC MPAC+1. LEAVE RESULT IN A. END WITH TC DECRET.

SETLOC ENDDPDEC +1

COUNT 40/PIN

# DEGINSF APPLIES  $1000/180 * 5.5555(10) = 5.43434(8)$

```

DEGINSF      TC      DMP      # SF ROUTINE FOR DEC DEGREES
              ADRES    DEGCON1  # MULT BY 5.5 5(10)X2EXP-3
              CCS      MPAC +1   # THIS ROUNDS OFF MPAC+1 BEFORE SHIFT
              CAF      BIT11     # LEFT 3, AND CAUSES 360.00 TO OF/UF
              TC       +2        # WHEN SHIFTED LEFT AND ALARM.
              CS       BIT11
              AD       MPAC +1
              TC       2ROUND +2
              TC       TPSL1     # LEFT 1
DEGINSF2     TC       TPSL1     # LEFT 2
              TC       TESTOFUF
              TC       TPSL1     # RETURNS IF NO OF/UF (LEFT3)
              CCS      MPAC
              TC       SIGNFIX   # IF +, GO TO SIGNFIX
              TC       SIGNFIX   # IF +0, GO TO SIGNFIX
              COM      # IF -, USE -MAGNITUDE +1
              TS       MPAC      # IF -0, USE +0
SIGNFIX      CCS      MPAC+6
              TC       SGNT01    # IF OVERFLOW
              TC       ENDSALE    # NO OVERFLOW/UNDERFLOW
# Page 350
              CCS      MPAC      # IF UF FORCE SIGN TO 0 EXCEPT -180
              TC       CCSHOLE
              TC       NEG180
              TC       +1
              XCH      MPAC
              MASK     POSMAX
              TS       MPAC
ENDSCALE     TC       POSTJUMP
              CADR     PUTCOM2

NEG180       CS       POSMAX
              TC       ENDSALE -1

SGNT01       CS       MPAC      # IF OF FORCE SIGN TO 1
              MASK     POSMAX
              CS       A
              TC       ENDSALE -1

DEGCON1      2DEC     5.55555555 B-3
DEGCON2      2DEC     2.22222222 B-2

NEG.2        OCT      -06250    # = .197753906 I.E., THE BIAS SCALED

```

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```
ARTHINSF      TC      DMP      # SCALES MPAC, +1 BY SFTEMP1, SFTEMP2.
               ADRES    SFTEMP1  # ASSUMES POINT BETWEEN HI AND LO PARTS
               XCH      MPAC +2   # OF SFCON.  SHIFTS RESULTS LEFT BY 14.
               XCH      MPAC +1   # (BY TAKING RESULTS FROM MPAC+1, MPAC+2)
               XCH      MPAC
               EXTEND
               BZF      BINROUND
               TC      ALMCYCLE    # TOO LARGE A LOAD.  ALARM AND RECYCLE.
BINROUND      TC      2ROUND
               TC      TESTOFUF
               TC      ENDSCALE    # RETURNS IF NO OF/UF

ARTIN1SF      TC      DMP      # SCALES MPAC, +1 BY SFTEMP1, SFTEMP2.
               ADRES    SFTEMP1  # ROUNDS MPAC+1 INTO MPAC.
               TC      BINROUND

OPTDEGIN      CCS      MPAC      # OPTICS SCALING ROUTINE
               TC      +4
               TC      +3
               TC      ALMCYCLE    # REJECT -- INPUT.  ALARM AND RECYCLE.
               TC      ALMCYCLE    # REJECT -- INPUT.  ALARM AND RECYCLE.
OPDEGIN2      CAF      NEG.2     # RANGE IS 90 DEG
               ADS      MPAC      # SUBTRACT BIAS

# Page 351
               TC      DMP      # MULT BY 100 / 45 B-2
               ADRES    DEGCON2
               CAF      BIT12     # ROUND AS IN DEGINSF
               AD      MPAC   +1
               TC      2ROUND  +2
               TC      DEGINSF2

DPINSF      TC      DMP      # SCALES MPAC, MPAC +1 BY SFTEMP1,
               ADRES    SFTEMP1  # SFTEMP.  STORES LOW PART OF RESULT
               XCH      MPAC +2   # IN (E SUBK) +1 OR E+1
               DOUBLE
               TS      MPAC +2
               CAF      ZERO
               AD      MPAC +1
               TC      2ROUND +2
               TC      TESTOFUF
DPFRACIN      INDEX    MIXBR     # RETURNS IF NO OF/UF
               TC      +0
               TC      DPINORM
               CA      DECOUNT  # MIXED NOUN
DPINCOM      AD      NOUNADD     #      MIXED      NORMAL
               TS      Q         #      E SUBK      E
```

|            |        |             |                                            |
|------------|--------|-------------|--------------------------------------------|
|            | XCH    | MPAC +1     |                                            |
|            | INDEX  | Q           |                                            |
|            | TS     | 1           | # PLACE LOW PART IN                        |
|            | TC     | ENDSCALE    | # (E SUBK) +1 MIXED                        |
| DPINORM    | CAF    | ZERO        | # E +1 NORMAL                              |
|            | TC     | DPINCOM     |                                            |
| DPINSF2    | TC     | DMP         | # ASSUMES POINT BETWEEN BITS 7-8 OF HIGH   |
|            | ADRES  | SFTEMP1     | # PART OF SF CONST. DPINSF2 SHIFTS RESULTS |
|            | CAF    | SIX         | # LEFT BY 7, ROUNDS MPAC+2 INTO MPAC+1     |
|            | TC     | TPLEFTN     | # SHIFT LEFT 7.                            |
|            | TC     | DPINSF +2   |                                            |
| DPINSF4    | TC     | DMP         | # ASSUMES POINT BETWEEN BITS 11-12 OF HIGH |
|            | ADRES  | SFTEMP1     | # PART OF SF CONST. DPINSF2 SHIFTS RESULTS |
|            | CAF    | TWO         | # LEFT BY 3, ROUNDS MPAC+2 INTO MPAC+1.    |
|            | TC     | TPLEFTN     | # SHIFT LEFT 3.                            |
|            | TC     | DPINSF +2   |                                            |
| TPLEFTN    | XCH    | Q           | # SHIFTS MPAC, +1, +2 LEFT N. SETS OVFLND  |
|            | TS     | SFTEMP2     | # TO +1 FOR OF, -1 FOR UF.                 |
|            | XCH    | Q           | # CALL WITH N-1 IN A.                      |
| LEFTNCOM   | TS     | SFTEMP1     | # LOOP TIME .37 MSEC.                      |
|            | TC     | TPSL1       |                                            |
|            | CCS    | SFTEMP1     |                                            |
| # Page 352 |        |             |                                            |
|            | TC     | LEFTNCOM    |                                            |
|            | TC     | SFTEMP2     |                                            |
| 2ROUND     | XCH    | MPAC +1     |                                            |
|            | DOUBLE |             |                                            |
|            | TS     | MPAC +1     |                                            |
|            | TC     | Q           | # IF MPAC+1 DOES NOT OF/UF                 |
|            | AD     | MPAC        |                                            |
|            | TS     | MPAC        |                                            |
|            | TC     | Q           | # IF MPAC DOES NOT OF/UF                   |
|            | TS     | MPAC+6      |                                            |
| 2RNDEND    | TC     | Q           |                                            |
| TESTOFUF   | CCS    | MPAC+6      | # RETURNS IF NO OF/UF                      |
|            | TC     | ALMCYCLE    | # OF ALARM AND RECYCLE.                    |
|            | TC     | Q           |                                            |
|            | TC     | ALMCYCLE    | # UF ALARM AND RECYCLE.                    |
|            | SETLOC | ENDSPMIN +1 |                                            |

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|            | COUNT  | 42/PIN   |                                          |
|------------|--------|----------|------------------------------------------|
| HMSIN      | TC     | ALL3DEC  | # IF ALL 3 WORDS WERE NOT LOADED, ALARM. |
|            | TC     | DMP      | # XREG, XREGLP (=HOURS) WERE ALREADY PUT |
|            | ADRES  | WHOLECON | # INTO MPAC, MPAC+1.                     |
|            | TC     | RND/TST  | # ROUND OFF TO WHOLE HRS IN MPAC+1.      |
|            | CAF    | ZERO     | # ALARM IF MPAC NON ZERO (G/ 16383).     |
|            | TS     | MPAC +2  |                                          |
|            | CAF    | HRCN     |                                          |
|            | TS     | MPAC     |                                          |
|            | CAF    | HRCN +1  |                                          |
|            | XCH    | MPAC +1  |                                          |
|            | TC     | SHORTMP  |                                          |
|            | TC     | MPACTST  | # ALARM IF MPAC NON ZERO (G/ 745)        |
|            | DXCH   | MPAC +1  | # STORE HOURS CONTRIBUTION               |
|            | DXCH   | HITEMIN  |                                          |
|            | CA     | YREG     | # PUT YREG, YREGLP INTO MPAC, +1.        |
|            | LXCH   | YREGLP   |                                          |
|            | DXCH   | MPAC     |                                          |
|            | TC     | DMP      |                                          |
|            | ADRES  | WHOLECON |                                          |
|            | TC     | RND/TST  | # ROUND OFF TO WHOLE MIN IN MPAC+1       |
|            | CS     | 59MIN    | # ALARM IF MPAC NON ZERO (G/16383)       |
|            | TC     | SIZETST  | # ALARM IF MPAC+1 G/ 59MIN               |
|            | XCH    | MPAC +1  |                                          |
|            | EXTEND |          |                                          |
|            | MP     | MINCON   | # LEAVES MINUTES CONTRIBUTION IN A,L     |
| # Page 353 | DAS    | HITEMIN  | # ADD IN MINUTES CONTRIBUTION            |
|            | EXTEND |          | # IF THIS DAS OVEFLOWS, G/ 745 HR, 39MIN |
|            | BZF    | +2       |                                          |
|            | TC     | ALMCYCLE |                                          |
|            | CA     | ZREG     | # PUT ZREG, ZREGLP INTO MPAC +1.         |
|            | LXCH   | ZREGLP   |                                          |
|            | DXCH   | MPAC     |                                          |
|            | TC     | DMP      |                                          |
|            | ADRES  | WHOLECON |                                          |
|            | TC     | RND/TST  | # ROUND OFF TO WHOLE CENTI-SEC IN MPAC+1 |
|            | CS     | 59.99SEC | # ALARM IF MPAC NON ZERO (G/163.83 SEC)  |
|            | TC     | SIZETST  | # ALARM IF MPAC+1 G/59.99 SEC            |
|            | DXCH   | HITEMIN  | # ADD IN SECONDS CONTRIBUTION            |
|            | DAS    | MPAC     | # IF THIS DAS OVERFLOWS,                 |
|            | EXTEND |          | # G/ 745 HR, 39 MIN, 14.59 SEC.          |
|            | BZF    | +2       |                                          |
|            | TC     | ALMCYCLE | # ALARM AND RECYCLE                      |

|                                                                 |        |          |                                            |
|-----------------------------------------------------------------|--------|----------|--------------------------------------------|
|                                                                 | CAF    | ZERO     |                                            |
|                                                                 | TS     | MPAC +2  |                                            |
|                                                                 | TC     | TPAGREE  |                                            |
|                                                                 | DXCH   | MPAC     |                                            |
|                                                                 | INDEX  | NOUNADD  |                                            |
|                                                                 | DXCH   | 0        |                                            |
|                                                                 | TC     | POSTJUMP |                                            |
|                                                                 | CADR   | LOADLV   |                                            |
| WHOLECON                                                        | OCT    | 00006    | # (10EXP5/2EXP14)2EXP14                    |
|                                                                 | OCT    | 03240    |                                            |
| HRCN                                                            | OCT    | 00025    | # 1 HOUR IN CENTI-SEC                      |
|                                                                 | OCT    | 37100    |                                            |
| MINCON                                                          | OCT    | 13560    | # 1 MINUTE IN CENTI-SEC                    |
| 59MIN                                                           | OCT    | 00073    | # 59 AS WHOLE                              |
| 59.99SEC                                                        | OCT    | 13557    | # 5999 SENTI-SEC                           |
| RND/TST                                                         | XCH    | MPAC +2  | # ROUNDS MPAC+2 INTO MPAC+1.               |
|                                                                 | DOUBLE |          | # ALARMS IF MPAC NOT 0                     |
|                                                                 | TS     | MPAC +2  |                                            |
|                                                                 | CAF    | ZERO     |                                            |
|                                                                 | AD     | MPAC +1  |                                            |
|                                                                 | TS     | MPAC +1  |                                            |
|                                                                 | CAF    | ZERO     |                                            |
|                                                                 | AD     | MPAC     | # CAN'T OVFLOW                             |
|                                                                 | XCH    | MPAC     |                                            |
| MPACTST                                                         | CCS    | MPAC     | # ALARM IF MPAC NON ZERO                   |
|                                                                 | TC     | ALMCYCLE | # ALARM AND RECYCLE                        |
|                                                                 | TC     | Q        |                                            |
|                                                                 | TC     | ALMCYCLE | # ALARM AND RECYCLE                        |
|                                                                 | TC     | Q        |                                            |
| # Page 354                                                      |        |          |                                            |
| SIZETST                                                         | TS     | MPAC +2  | # CALLED WITH - CON IN A                   |
|                                                                 | CCS    | MPAC +1  | # GET MAG OF MPAC+1                        |
|                                                                 | AD     | ONE      |                                            |
|                                                                 | TCF    | +2       |                                            |
|                                                                 | AD     | ONE      |                                            |
|                                                                 | AD     | MPAC +2  |                                            |
|                                                                 | EXTEND |          | # MAG OF MPAC+1 - CON                      |
|                                                                 | BZMF   | +2       |                                            |
|                                                                 | TC     | ALMCYCLE | # MAG OF MPAC+1 G/ CON. ALARM AND RECYCLE. |
|                                                                 | TC     | Q        | # MAG OF MPAC+1 L/= CON                    |
| # ALL3DEC TESTS THAT ALL 3 WORDS ARE LOADED IN DEC (FOR HMSIN). |        |          |                                            |



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# ALARM IF NOT. (TEST THAT BITS 3,4,5 OF DECBRNCH ARE ALL = 1).

|          |        |          |                                           |
|----------|--------|----------|-------------------------------------------|
| ALL3DEC  | CS     | OCT34BAR | # GET BITS 3,4,5 IN A                     |
|          | MASK   | DECBRNCH | # GET BITS 3,4,5 OF DECBRNCH IN A         |
|          | AD     | OCT34BAR | # BITS 3,4,5 OF DECBRNCH MUST ALL = 1     |
|          | CCS    | A        |                                           |
|          | TC     | FORCEV25 |                                           |
| OCT34BAR | OCT    | 77743    |                                           |
|          | TC     | FORCEV25 |                                           |
|          | TC     | Q        |                                           |
| FORCEV25 | CS     | OCT31    | # FORCE VERB 25 TO BE EXECUTED BY RECYCLE |
|          | TS     | VERBSAVE | # IN CASE OPERATOR EXECUTED A LOWER LOAD  |
|          | TC     | ALMCYCLE | # VERB. ALARM AND RECYCLE.                |
| ENDHMSS  | EQUALS |          |                                           |

# Page 355

# MONITOR ALLOWS OTHER KEYBOARD ACTIVITY. IT IS ENDED BY VERB TERMINATE,  
# VERB PROCEED WITHOUT DATA, VERB RESEQUENCE,  
# ANOTHER MONITOR, OR ANY NVSUB CALL THAT PASSES THE DSPLOCK (PROVIDED  
# THAT THE OPERATOR HAS SOMEHOW ALLOWED THE ENDING OF A MONITOR WHICH  
# HE HAS INITIATED THROUGH THE KEYBOARD).  
#  
# MONITOR ACTION IS SUSPENDED, BUT NOT ENDED, BY ANY KEYBOARD ACTION.  
# EXCEPT ERROR LIGHT RESET. IT BEGINS AGAIN WHEN KEY RELEASE IS PERFORMED.  
# MONITOR SAVES THE NOUN AND APPROPRIATE DISPLAY VERB IN MONSAVE. IT SAVES  
# NOUNCADR IN MONSAVE1, IF NOUN = MACHINE CADR TO BE SPECIFIED. BIT 15 OF  
# MONSAVE1 IS THE KILL MONITOR SIGNAL (KILLER BIT). BIT 14 OF MONSAVE1  
# INDICATES THE CURRENT MONITOR WAS EXTERNALLY INITIATED (EXTERNAL  
# MONITOR BIT). IT IS TURNED OFF BY RELDSP AND KILMONON.  
#  
# MONSAVE INDICATES IF MONITOR IS ON (+=ON, +0=OFF)  
# IF MONSAVE IS +, MONITOR ENTERS NO REQUEST, BUT TURNS KILLER BIT OFF.  
# IF MONSAVE IS +0, MONITOR ENTERS REQUEST AND TURNS KILLER BIT OFF.  
#  
# NVSUB (IF EXTERNAL MONITOR BIT IS OFF), VB=PROCEED WITHOUT DATA,  
# VB=RESEQUENCE, AND VB=TERMINATE TURN KILL MONITOR BIT ON.  
#  
# IF KILLER BIT IS ON, MONREQ ENTERS NO FURTHER REQUESTS, ZEROS MONSAVE  
# AND MONSAVE1 (TURNING OFF KILLER BIT AND EXTERNAL MONITOR BIT).  
#  
# MONITOR DOESN'T TEST FOR MATBS SINCE NVSUB CAN HANDLE INTERNAL MATBS NOW.

SETLOC ENDRUTIN

COUNT 41/PIN

```

MONITOR      CS      BIT15/14
              MASK    NOUNCADR
MONIT1       TS      MPAC +1      # TEMP STORAGE
              CS      ENTEXIT
              AD      ENDINST
              CCS     A
              TC      MONIT2
BIT15/14     OCT     60000
              TC      MONIT2
              CAF     BIT14      # EXTERNALLY INITIATED MONITOR.
              ADS     MPAC +1    # SET BIT 14 FOR MONSAVE1.
              CAF     ZERO
              TS      MONSAVE2   # ZERO NVMONOPT OPTIONS
MONIT2       CAF     LOW7
              MASK    VERBREG
              TC      LEFT5
              TS      CYL
              CS      CYL
              XCH     CYL
              AD      NOUNREG
              TS      MPAC      # TEMP STORAGE
# Page 356
              CAF     ZERO
              TS      DSPLOCK    # +0 INTO DSPLOCK SO MONITOR CAN RUN.
              CCS     CADRSTOR   # TURN OFF KR LITE IF CADRSTOR AND DSPLIST
              TC      +2        # ARE BOTH EMPTY. (LITE COMES ON IF NEW
              TC      RELDSP1    # MONITOR IS KEYED IN OVER OLD MONITOR.)
              INHINT
              CCS     MONSAVE
              TC      +5        # IF MONSAVE WAS +, NO REQUEST
              CAF     ONE       # IF MONSAVE WAS 0, REQUEST MONREQ
              TC      WAITLIST
              EBANK=   DSPCOUNT
              2CADR    MONREQ
              DXCH     MPAC      # PLACE MONITOR VERB AND NOUN INTO MONSAVE
              DXCH     MONSAVE   # ZERO THE KILL MONITOR BIT
              RELINT
              TC      ENTRET     # SET UP EXTERNAL MONITOR BIT
MONREQ       TC      LODSAMPT   # CALLED BY WAITLIST
              CCS     MONSAVE1   # TIME IS SNATCHED N RUPT FOR NOUN 65
              TC      +4        # IF KILLER BIT = 0, ENTER REQUESTS
              TC      +3        # IF KILLER BIT = 0, ENTER REQUESTS
              TC      KILLMON    # IF KILLER BIT = 1, NO REQUESTS.

```

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```
TC      KILLMON      # IF KILLER BIT = 1, NO REQUESTS.
CAF     MONDEL
TC      WAITLIST     # ENTER WAITLIST REQUEST FOR MONREQ
EBANK=  DSPCOUNT
2CADR   MONREQ

CAF     CHRPRIO
TC      NOVAC        # ENTER EXEC REQUEST FOR MONDO
EBANK=  DSPCOUNT
2CADR   MONDO

TC      TASKOVER

KILLMON CAF     ZERO      # ZERO MONSAVE AND TURN KILLER BIT OFF
        TS      MONSAVE
        TS      MONSAVE1  # TURN OFF KILL MONITOR BIT.
        TC      TASKOVER  # TURN OFF EXTERNAL MONITOR BIT.
MONDEL  OCT     144       # FOR 1 SEC MONITOR INTERVALS.

MONDO   CCS     MONSAVE1  # CALLED BY EXEC
        TC      +4        # IF KILLER BIT = 0, CONTINUE
        TC      +3        # IF KILLER BIT = 0, CONTINUE
        TC      ENDOFJOB   # IN CASE TERMINATE CAME SINCE LAST MONREQ
        TC      ENDOFJOB   # IN CASE TERMINATE CAME SINCE LAST MONREQ
        CCS     DSPLOCK

# Page 357

TC      MONBUSY      # NVSUB IS BUSY
CAF     LOW7
MASK    MONSAVE
TC      UPDATNN -1   # PLACE NOUN INTO NOUNREG AND DISPLAY IT
CAF     MID7
MASK    MONSAVE      # CHANGE MONITOR VERB TO DISPLAY VERB
AD      MONREF       # -DEC10, STARTING IN BIT8
TS      EDOP         # RIGHT 7
CA      EDOP
TS      VERBREG
CAF     MONBACK      # SET RETURN TO PASTEVB AFTER DATA DISPLAY
TS      ENTRET
CS      BIT15/14
MASK    MONSAVE1     # PUT ECADR INTO MPAC +2.  INTMCTBS WILL
TS      MPAC +2      # DISPLAY IT AND SET NOUNCADR, NOUNADD,
ENDMONDO TC      TESTNN # EBANK.

BLOCK   2

SETLOC  FFTAG8
```

```

                                BANK
                                COUNT  02/PIN

PASTEVB      CAF      MID7
              MASK     MONSAVE2      # NVMONOPT PASTE OPTION
              EXTEND
              BZF      +2
              TC       PASTEOPT      # PASTE PLEASE VERB FOR NVMONOPT
              CA       MONSAVE      # PASTE MONITOR VERB -- PASTE OPTION IS O
PASTEOPT      TS       EDOP          # RIGHT 7
              CA       EDOP          # PLACE MONITOR VERB OR PLEASE VERB INTO
              TC       BANKCALL      # VERBREG AND DISPLAY IT.
              CADR     UPDATVB -1
              CAF      ZERO          # ZERO REQRET SO THAT PASTED VERBS CAN
              TS       REQRET        # BE EXECUTED BY OPERATOR.
              CA       MONSAVE2
              TC       BLANKSUB      # PROCESS NVMONOPT BLANK OPTION IF ANY
              TC       +1
ENDPASTE      TC       ENDOFJOB

MID7          OCT      37600

              SETLOC  ENDMONDO +1
              COUNT   41/PIN

MONREF        OCT      75377      # -DEC10, STARTING IN BIT8
MONBACK       ADRES    PASTEVB

# Page 358
MONBUSY       TC       RELDSPON      # TURN KEY RELEASE LIGHT
              TC       ENDOFJOB

# DSPFMEM IS USED TO DISPLAY (IN OCTAL) ANY FIXED REGISTER.
# IT IS USED WITH NOUN = MACHINE CADR TO BE SPECIFIED.  THE FCADR OF THE
# DESIRED LOCATION IS THEN PUNCHED IN.  IT HANDLES F/F (FCADR 4000-7777)
#
# FOR BANKS L/E 27, THIS IS ENOUGH.
#
# FOR BANKS G/E 30, THE THIRD COMPONENT OF NOUN 26 (PRIO, ADRES, BBCON)
# MUST BE PRELOADED WITH THE DESIRED SUPERBANK BITS (BITS 5,6,7).
# V23N26 SHOULD BE USED.
#
# SUMMARY
# FOR BANKS L/E 27,                                V27N01E(FCADR)E
# FOR BANKS G/E 30,      V23N26E(SUPERBITS)E      V27N01E(FCADR)E

```

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```
DSPFMEM      CAF      R1D1      # IF F/F, DATACALL USES BANK 02 OR 03.
              TS       DSPCOUNT
              CA       DSPTM1 +2  # SUPERBANK BITS WERE PRELOADED INTO
              TS       L          # 3RD COMPONENT OF NOUN 26.
              CA       NOUNCADR   # ORIGINAL FCADR LOADED STILL IN NOUNCADR.
              TC       SUPDACAL   # CALL WITH FCADR IN A, SUPERBITS IN L.
              TC       DSPOCTWO
ENDSPF        TC       ENDOFJOB
```

# Page 359

# WORD DISPLAY ROUTINES

```
SETLOC TESTOFUF +4
COUNT 40/PIN
```

```
DSPSIGN      XCH      Q
              TS       DSPWDRET
              CCS      MPAC
              TC       +8D
              TC       +7
              AD       ONE
              TS       MPAC
              TC       -ON
              CS       MPAC +1
              TS       MPAC +1
              TC       DSPWDRET
              TC       +ON
              TC       DSPWDRET
```

```
DSPRND       EXTEND      # ROUND BY 5 EXP-6
              DCA       DECROUND -1
              DAS       MPAC
              EXTEND
              BZF       +4
              EXTEND
              DCA       DPOSMAX
              DXCH      MPAC
              TC       Q
```

# DSPDECWD CONVERTS C(MPAC,MPAC+1) INTO A SIGN AND 5 CHAR DECIMAL  
# STARTING IN LOC SPECIFIED IN DSPCOUNT. IT ROUNDS BY 5 EXP-6.

```
DSPDECWD     XCH      Q
              TS       WDRET
              TC       DSPSIGN
              TC       DSPRND
```

|                                                                          |       |             |                                   |
|--------------------------------------------------------------------------|-------|-------------|-----------------------------------|
|                                                                          | CAF   | FOUR        |                                   |
| DSPDCWD1                                                                 | TS    | WDCNT       |                                   |
|                                                                          | CAF   | BINCON      |                                   |
|                                                                          | TC    | SHORTMP     |                                   |
| TRACE1                                                                   | INDEX | MPAC        |                                   |
|                                                                          | CAF   | RELTAB      |                                   |
|                                                                          | MASK  | LOW5        |                                   |
|                                                                          | TS    | CODE        |                                   |
|                                                                          | CAF   | ZERO        |                                   |
|                                                                          | XCH   | MPAC +2     |                                   |
|                                                                          | XCH   | MPAC +1     |                                   |
|                                                                          | TS    | MPAC        |                                   |
|                                                                          | XCH   | DSPCOUNT    |                                   |
| TRACE1S                                                                  | TS    | COUNT       |                                   |
| # Page 360                                                               |       |             |                                   |
|                                                                          | CCS   | A           | # DECREMENT DSPCOUNT EXCEPT AT +0 |
|                                                                          | TS    | DSPCOUNT    |                                   |
|                                                                          | TC    | DSPIN       |                                   |
|                                                                          | CCS   | WDCNT       |                                   |
|                                                                          | TC    | DSPDCWD1    |                                   |
|                                                                          | CS    | VD1         |                                   |
|                                                                          | TS    | DSPCOUNT    |                                   |
|                                                                          | TC    | WDRET       |                                   |
|                                                                          | OCT   | 00000       |                                   |
| DECROUND                                                                 | OCT   | 02476       |                                   |
| # DSPDECNR CONVERTS C(MPAC,MPAC+1) INTO A SIGN AND 5 CHAR DECIMAL        |       |             |                                   |
| # STARTING IN LOC SPECIFIED IN DSPCOUNT. IT DOES NOT ROUND               |       |             |                                   |
| DSPDECNR                                                                 | XCH   | Q           |                                   |
|                                                                          | TS    | WDRET       |                                   |
|                                                                          | TC    | DSPSIGN     |                                   |
|                                                                          | TC    | DSPDCWD1 -1 |                                   |
| # DSPDC2NR CONVERTS C(MPAC,MPAC+1) INTO A SIGN AND 2 CHAR DECIMAL        |       |             |                                   |
| # STARTING IN LOC SPECIFIED IN DSPCOUNT. IT DOES NOT ROUND               |       |             |                                   |
| DSPDC2NR                                                                 | XCH   | Q           |                                   |
|                                                                          | TS    | WDRET       |                                   |
|                                                                          | TC    | DSPSIGN     |                                   |
|                                                                          | CAF   | ONE         |                                   |
|                                                                          | TC    | DSPDCWD1    |                                   |
| # DSP2DEC CONVERTS C(MPAC) AND C(MPAC+1) INTO A SIGN AND 10 CHAR DECIMAL |       |             |                                   |
| # STARTING IN THE LOC SPECIFIED IN DSPCOUNT.                             |       |             |                                   |

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```
DSP2DEC      XCH      Q
              TS      WDRET
              CAF      ZERO
              TS      CODE
              CAF      THREE
              TC      11DSPIN      # -R2 OFF
              CAF      FOUR
              TC      11DSPIN      # +R2 OFF
              TC      DSPSIGN
              CAF      R2D1
END2DEC      TC      DSPDCWD1
```

```
# DSPDECVN DISPLAYS C(A) UPON ENTRY AS A 2 CHAR DECIMAL BEGINNING IN THE
# DSP LOC SPECIFIED IN DSPCOUNT.
#
# C(A) SHOULD BE IN FORM N X 2EXP-14. THIS IS SCALED TO FORM N/100 BEFORE
# DISPLAY CONVERSION.
# Page 361
```

```
DSPDECVN      EXTEND
              MP      VNDSPCON      # MULT BY .01
              LXCH     MPAC          # TAKE RESULTS FROM L. (MULT BY 2EXP14).
              CAF      ZERO
              TS      MPAC +1
              XCH      Q
              TS      WDRET
              TC      DSPDC2NR +3    # NO SIGN, NO ROUND, 2 CHAR

VNDSPCON      OCT      00244        # .01 ROUNDED UP

GOVNUPDT      TC      DSPDECVN      # THIS IS NOT FOR GENERAL USE. REALLY PART
              TC      POSTJUMP      # OF UPDATVB.
              CADR     UPDAT1 +2

ENDECVN      EQUALS

              SETLOC   ENDSPF +1
              COUNT    41/PIN
```

```
# DSPOCTWD DISPLAYS C(A) UPON ENTRY AS A 5 CHAR OCT STARTING IN THE DSP
# CHAR SPECIFIED IN DSPCOUNT. IT STOPS AFTER 5 CHAR HAVE BEEN DISPLAYED.
```

```
DSPOCTWO      TS      CYL
              XCH      Q
              TS      WDRET          # MUST USE SAME RETURN AS DSP2BIT.
```

|            |       |          |                                          |
|------------|-------|----------|------------------------------------------|
|            | CAF   | BIT14    | # TO BLANK SIGNS                         |
|            | ADS   | DSPCOUNT |                                          |
|            | CAF   | FOUR     |                                          |
| WDAGAIN    | TS    | WDCNT    |                                          |
|            | CS    | CYL      |                                          |
|            | CS    | CYL      |                                          |
|            | CS    | CYL      |                                          |
|            | CS    | A        |                                          |
|            | MASK  | DSPMSK   |                                          |
|            | INDEX | A        |                                          |
|            | CAF   | RELTAB   |                                          |
|            | MASK  | LOW5     |                                          |
|            | TS    | CODE     |                                          |
|            | XCH   | DSPCOUNT |                                          |
|            | TS    | COUNT    |                                          |
|            | CCS   | A        | # DECREMENT DSPCOUNT EXCEPT AT +0        |
|            | TS    | DSPCOUNT |                                          |
|            | TC    | POSTJUMP |                                          |
|            | CADR  | DSPOCTIN |                                          |
| OCTBACK    | CCS   | WDCNT    |                                          |
|            | TC    | WDAGAIN  | # +                                      |
| DSPLV      | CS    | VD1      | # TO BLOCK NUMERICAL CHARACTERS, CLEARS, |
| # Page 362 |       |          |                                          |
|            | TS    | DSPCOUNT | # AND SIGNS AFTER A COMPLETED DISPLAY.   |
|            | TC    | WDRET    |                                          |
| DSPMSK     | =     | SEVEN    |                                          |

# DSP2BIT DISPLAYS C(A) UPON ENTRY AS A 2 CHAR OCT BEGINNING IN THE DSP  
 # LOC SPECIFIED IN DSPCOUNT BY PRE CYCLING RIGHT C(A) AND USING THE LOGIC  
 # OF THE 5 CHAR OCTAL DISPLAY

|         |     |            |
|---------|-----|------------|
| DSP2BIT | TS  | CYR        |
|         | XCH | Q          |
|         | TS  | WDRET      |
|         | CAF | ONE        |
|         | TS  | WDCNT      |
|         | CS  | CYR        |
|         | CS  | CYR        |
|         | XCH | CYR        |
|         | TS  | CYL        |
|         | TC  | WDAGAIN +5 |

# FOR DSPIN PLACE 0/25 OCT INTO COUNT, 5 BIT RELAY CODE INTO CODE. BOTH  
 # ARE DESTROYED. IF BIT14 OF COUNT IS 1, SIGN IS BLANKED WITH LEFT CHAR.  
 # FOR DSPIN1 PLACE 0,1 INTO BIT11 OF CODE, 2 INTO COUNT, REL ADDRESS OF



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# DSPTAB ENTRY INTO DSREL.

SETLOC ENDECVN

COUNT 40/PIN

DSPIN

XCH Q  
TS DSEXIT  
CAF LOW5  
MASK COUNT  
TS SR  
XCH SR  
TS DSREL  
CAF BIT1  
MASK COUNT  
CCS A  
TC +2  
TC DSPIN1 -1  
XCH CODE  
TC SLEFT5  
TS CODE  
CAF BIT14  
MASK COUNT  
CCS A  
CAF TWO

# CAN'T USE L FOR RETURN, SINCE MANY OF THE  
# ROUTINES CALLING DSPIN USE L AS RETURN.

# LEFT IF COUNT IS ODD  
# RIGHT IF COUNT IS EVEN

# DOES NOT USE CYL

# BIT14 = 1, BLANK SIGN

# Page 363

AD ONE  
TS COUNT

# BIT14 = 0, LEAVE SIGN ALONE  
# +0 INTO COUNT FOR RIGHT  
# +1 INTO COUNT FOR LEFT (SIGN LEFT ALONE)  
# +3 INTO COUNT FOR LEFT (TO BLANK SIGN)

DSPIN1

INHINT  
INDEX DSREL  
CCS DSPTAB  
TC +2  
TC CSHOLE  
AD ONE  
TS DSMAG  
INDEX COUNT  
MASK DSMSK  
EXTEND  
SU CODE  
EXTEND  
BZF DSLV  
INDEX COUNT  
CS DSMSK  
MASK DSMAG

# IF +

# IF -

# SAME

DFRNT

# MASK WITH 77740, 76037, 76777, OR 74037

```

                                AD      CODE
                                CS      A
                                INDEX   DSREL
                                XCH      DSPTAB
                                EXTEND
                                BZMF    DSLV      # DSPTAB ENTRY WAS -
                                INCR     NOUT      # DSPTAB ENTRY WAS +
DSLVLV                        RELINT
                                TC      DSEXIT

DSMSK                        OCT      37
                                OCT      1740
                                OCT      2000
                                OCT      3740

# FOR 11DSPIN, PUT REL ADDRESS OF DSPTAB ENTRY INTO A, 1 IN BIT11 OR 0 IN
# BIT11 OF CODE.

11DSPIN                      TS      DSREL
                                CAF      TWO
                                TS      COUNT
                                XCH      Q      # MUST USE SAME RETURN AS DSPIN
                                TS      DSEXIT
                                TC      DSPIN1

DSPOCTIN                     TC      DSPIN      # SO DSPOCTWD DOESN'T USE SWCALL
                                CAF      +2
                                TC      BANKJUMP

# Page 364
ENDSPOCT                     CADR     OCTBACK

# DSPALARM FINDS TC NVSUBEND IN ENTRET FOR NVSUB INITIATED ROUTINES
# ABORT WITH 01501.
#
# DSPALARM FINDS TC ENDOFJOB IN ENTRET FOR KEYBOARD INITIATED ROUTINES.
# DC TC ENTRET.

PREDSPAL                     CS      VD1
                                TS      DSPCOUNT
DSPALARM                     CS      NVSBENDL
                                AD      ENTEXIT
                                EXTEND
                                BZF      CHARALRM +2
                                CS      MONADR      # IF THIS IS A MONITOR, KILL IT
                                AD      ENTEXIT
                                EXTEND

```

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```

          BZF      +2
          TC      CHARALRM
          TC      KILMONON
          TC      FALTON
          TC      PASTEVB      # PUT MONITOR VERB BACK IN VERBREG
CHARALRM  TC      FALTON      # NOT NVSUB INITATED TURN ON OPR ERROR
          TC      ENDOFJOB
          TC      POODOO
          OCT     01501
MONADR    GENADR  PASTEVB
NVSBENDL  TC      NVSUBEND
```

```

# ALMCYCLE TURNS ON CHECK FAIL LIGHT, REDISPLAYS THE ORIGINAL VERB THAT
# WAS EXECUTED, AND RECYCLES TO EXECUTE THE ORIGINAL VERB/NOUN COMBINATION
# THAT WAS LAST EXECUTED. USED FOR BAD DATA DURING LOAD VERBS AND BY
# MCTBS. ALSO BY MMCHANG IF 2 NUMERICAL CHARACTERS WERE NOT PUNCHED IN
# FOR MM CODE
```

```

          SETLOC   MID7 +1
          COUNT    02/PIN
```

```

ALMCYCLE  TC      FALTON      # TURN ON CHECK FAIL LIGHT.
          CS      VERBSAVE     # GET ORIGINAL VERB THAT WAS EXECUTED
          TS      REQRET       # SET FOR ENTPASO
          TC      BANKCALL     # PUTS ORIGINAL VERB INTO VERBREG AND
CADR      UPDATVB -1          # DISPLAYS IT IN VERB LIGHTS.
          TC      POSTJUMP
ENDALM    CADR      ENTER
```

```

# MMCHANG USES NOUN DISPLAY UNTIL ENTER. THEN IT USES MODE DISP.
# IT GOES TO MODROUT WITH THE NEW M M CODE IN A, BUT NOT DISPLAYED IN
# Page 365
# MM LIGHTS.
#
# IT DEMANDS 2 NUMERICAL CHARACTERS BE PUNCHED IN FOR NEW MM CODE.
# IF NOT, IT RECYCLES.
```

```

          SETLOC   DSP2BIT +10D
          COUNT    41/PIN
```

```

MMCHANG   TC      REQMM      # ENTPASHI ASSUMES THE TC REQMM AT MMCHANG
          # IF THIS MOVES AT ALL, MUST CHANGE
          # MMADREF AT ENTPASHI.
          CAF      BIT5      # OCT20 = ND2.
          AD       DSPCOUNT  # DSPCOUNT MUST = -ND2.
```

```

EXTEND                                # DEMAND THAT 2 NUM CHAR WERE PUNCHED IN.
BZF      +2
TC       ALMCYCLE                      # DSPCOUNT NOT= -ND2.  ALARM AND RECYCLE.
CAF      ZERO                          # DSPCOUNT = -ND2.
XCH      NOUNREG
TS       MPAC
CAF      ND1
TS       DSPCOUNT
TC       BANKCALL
CADR     2BLANK
CS       VD1                          # BLOCK NUM CHAR IN
TS       DSPCOUNT
CA       MPAC
TC       POSTJUMP
CADR     MODROUTB                     # GO THRU STANDARD LOC.

MODROUTB      =      V37
REQMM         CS      Q
              TS      REQRET
              CAF      ND1
              TS      DSPCOUNT
              CAF      ZERO
              TS      NOUNREG
              TC      BANKCALL
              CADR     2BLANK
              TC      FLASHON
              CAF      ONE
              TS      DECBRNCH         # SET FOR DEC
              TC      ENTEXTIT

# VBRQEXEC ENTERS REQUEST TO EXEC FOR ANY ADDRESS WITH ANY PRIORITY.
# IT DOES ENDOFJOB AFTER ENTERING REQUEST.  DISPLAY SYST IS RELEASED.
# IT ASSUMES NOUN 26 HAS BEEN PRELOADED WITH
#      COMPONENT 1      PRIORITY (BITS 10-14) BIT1=0 FOR NOVAC, BIT1=1 FOR FINDVAC.
#      COMPONENT 2      JOB ADRES (12 BIT)
# Page 366
#      COMPONENT 3      BBCON

VBRQEXEC      CAF      BIT1
              MASK     DSPTEM1
              CCS      A
              TC      SETVAC          # IF BIT1 = 1, FINDVAC
              CAF      TCNOVAC        # IF BIT1 = 0, NOVAC
REQEX1        TS      MPAC           # TC NOVAC OR TC FINDVAC INTO MPAC
              CS      BIT1
              MASK     DSPTEM1

```

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```
REQUESTC      TS      MPAC +4      # PRIO INTO MPAC+4 AS A TEMP
              TC      RELDSP
              CA      ENDINST
              TS      MPAC +3      # TC ENDOFJOB INTO MPAC+3
              EXTEND
              DCA      DSPTM1 +1    # JOB ADRES INTO MPAC+1
              DXCH     MPAC +1      # BBCON INTO MPAC+2
              CA      MPAC +4      # PRIO IN A
              INHINT
              TC      MPAC

SETVAC        CAF      TCFINDVC
              TC      REQEX1
```

```
# VBRQWAIT ENTERS REQUEST TO WAITLIST FOR ANY ADDRESS WITH ANY DELAY.
# IT DOES ENDOFJOB AFTER ENTERING REQUEST.  DISPLAY SYST IS RELEASED.
# IT ASSUMES NOUN 26 HAS BEEN PRELOADED WITH
#      COMPONENT 1      DELAY (LOW BITS)
#      COMPONENT 2      TASK ADRES (12 BIT)
#      COMPONENT 3      BBCON
```

```
VBRQWAIT      CAF      TCWAIT
              TS      MPAC          # TC WAITLIST INTO MPAC
              CA      DSPTM1        # TIME DELAY
ENDRQWT        TC      REQUESTC -1
```

```
# REQUESTC WILL PUT TASK ADRES INTO MPAC+1, BBCON INTO MPAC+2,
# TC ENDOFJOB INTO MPAC+3.  IT WILL TAKE TIME DELAY OUT OF MPAC+4 AND
# LEAVE IT IN A, INHINT AND TC MPAC.
```

```
SETLOC NVSBENDL +1
COUNT 40/PIN
```

```
VBPROC        CAF      ONE          # PROCEED WITHOUT DATA
              TS      LOADSTAT
              TC      KILMONON      # TURN ON KILL MONITOR BIT
              TC      RELDSP
              TC      FLASHOFF
              TC      RECALTST      # SEE IF THERE IS ANY RECALL FROM ENDIDLE
```

# Page 367

```
VBTERM        CS      ONE
              TC      VBPROC +1    # TERM VERB SETS LOADSTAT NEG
```

```
# PROCKEY PERFORMS THE SAME FUNCTION AS VBPROC.  IT MUST BE CALLED UNDER
# EXECUTIVE CONTROL, WITH CHRPRIO.
```

```

PROCKEY      CAF      ZERO      # SET REQRET FOR ENTER PASS 0.
              TS      REQRET
              CS      VD1        # BLOCK NUMERICAL CHARACTERS, SIGNS, CLEAR
              TS      DSPCOUNT
              TC      VBPROC

```

```

# VBRESEQ WAKES ENDIDLE AT SAME LINE AS FINAL ENTER OF LOAD (L+3).
# (MAIN USE IS INTENDED AS RESPONSE TO INTERNALLY INITIATED FLASHING
# DISPLAYS IN ENDIDLE. SHOULD NOT BE USED WITH LOAD VERBS, PLEASE PERFORM,
# OR PLEASE MARK VERBS BECAUSE THEY ALREADY USE L+3 IN ANOTHER CONTEXT.)

```

```

VBRESEQ      CS      ZERO      # MAKE IT LOOK LIKE DATA IN.
              TC      VBPROC +1

```

```

# FLASH IS TURNED OFF BY PROCEED WITHOUT DATA, TERMINATE, RESEQUENCE,
# END OF LOAD.
# Page 368

```

```

# KEY RELEASE ROUTINE
#
# THIS ROUTINE ALWAYS TURNS OFF THE UPACT LIGHT AND ALWAYS CLEARS DSPLOCK.
#
# THE HIGHEST PRIORITY FUNCTION OF THE KEY RELEASE BUTTON IS THE
# UNSUSPENDING OF A SUSPENDED MONITOR WHICH WAS EXTERNALLY INITIATED.
# THIS FUNCTION IS ACCOMPLISHED BY CLEARING DSPLOCK AND TURNING OFF
# THE KEY RELEASE LIGHT IF BOTH DSPLIST AND CADRSTOR ARE EMPTY.
#
# IF NO SUCH MONITOR EXISTS, THEN RELDSP IS EXECUTED TO CLEAR DSPLOCK
# AND THE EXTERNAL MONITOR BIT (FREEING THE DISPLAY SYSTEM FOR INTERNAL
# USE), TURN OFF THE KEY RELEASE LIGHT, AND WAKE UP ANY JOB IN DSPLIST.
#
# IN ADDITION IF THERE IS A JOB IN ENDIDLE, THEN CONTROL IS TRANSFERRED
# TO PINBRNCH (IN DISPLAY INTERFACE ROUTINE) TO RE-EXECUTE THE SERIES OF
# NVSUB CALLS ETC. THAT PRECEDED THE ENDIDLE CALL STILL AWAITING RESPONSE.
# THIS FEATURE IS INTENDED FOR USE WHEN THE OPERATOR HAS BEEN REQUESTED TO
# RESPOND TO SOME INTERNAL ACTION THAT USED ENDIDLE, BUT HE HAS WRITTEN
# OVER THE INFORMATION ON THE DISPLAY PANEL BY SOME DISPLAYS OF HIS OWN
# INITIATION WHICH DO NOT SERVE AS RESPONSES. HITTING KEYRLSE WILL
# RE-ESTABLISH THE DISPLAYS TO THE STATE THEY WERE IN BEFORE HE OBSCURED
# THEM, SO THAT HE CAN SEE THE WAITING REQUEST. THIS WORKS ONLY FOR
# INTERNAL PROGRAMS THAT USED ENDIDLE THROUGH MARGARET'S DISPLAY
# SUBROUTINES.

```

```

VBRELDSP     CS      BIT3
              EXTEND

```

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|          |      |          |                                          |
|----------|------|----------|------------------------------------------|
|          | WAND | DSALMOUT | # TURN OF UPACT LITE                     |
|          | CCS  | 21/22REG | # OLD DSPLOCK                            |
|          | CAF  | BIT14    |                                          |
|          | MASK | MONSAVE1 | # EXTERNAL MONITOR BIT (EMB)             |
|          | CCS  | A        |                                          |
|          | TC   | UNSUSPEN | # OLD DSPLOCK AND EMB BOTH 1, UNSUSPEND, |
| TSTLTS4  | TC   | RELDSP   | # NOT UNSUSPENDING EXTERNAL MONITOR      |
|          | CCS  | CADRSTOR | # RELEASE DISPLAY SYSTEM AND             |
|          | TC   | +2       | # DO RE-ESTABLISH IF CADRSTOR IS FULL.   |
|          | TC   | ENDOFJOB |                                          |
|          | TC   | POSTJUMP |                                          |
|          | CADR | PINBRNCH |                                          |
| UNSUSPEN | CAF  | ZERO     | # EXTERNAL MONITOR IS SUSPENDED,         |
|          | TS   | DSPLOCK  | # JUST UNSUSPEND IT BY CLEARING DSPLOCK. |
|          | CCS  | CADRSTOR | # TURN KEY RELEASE LIGHT OFF IF BOTH     |
|          | TC   | ENDOFJOB | # CADRSTOR AND DSPLIST ARE EMPTY.        |
|          | TC   | RELDSP1  |                                          |
|          | TC   | ENDOFJOB |                                          |

ENDRELDS        EQUALS

# Page 369

# NVSUB IS USED FOR SUBROUTINE CALLS FROM WITHIN COMPUTER. IT CAN BE  
# USED TO CALL THE COMBINATION OF ANY DISPLAY, LOAD, OR MONITOR VERB  
# TOGETHER WITH ANY NOUN AVAILABLE TO THE KEYBOARD.  
# PLACE OVVVVVVNNNNNNN INTO A.  
# V'S ARE THE 7-BIT VERB CODE. N'S ARE THE 7-BIT NOUN CODE.  
#  
# IF NVSUB IS CALLED WITH THE FOLLOWING NEGATIVE NUMBERS (RATHER THAN THE  
# VERB-NOUN CODE) IN A, THEN THE DISPLAY IS BLANKED AS FOLLOWS ---  
# -4 FULL BLANK, -3 LEAVE MODE, -2 LEAVE MODE AND VERB, -1 BLANK R'S ONLY.  
#  
# NVSUB CAN BE USED WITH MACHINE CADR TO BE SPECIFIED BY PLACING THE CADR INTO  
# MPAC+2 BEFORE THE STANDARD NVSUB CALL.  
#  
# NVSUB RETURNS TO 2+ CALLING LOC AFTER PERFORMING TASK, IF DISPLAY  
# SYSTEM IS AVAILABLE. THE NEW NOUN AND VERB CODES ARE DISPLAYED.  
# IF V'S =0, THE NEW NOUN CODE IS DISPLAYED ONLY (RETURN WITH NO FURTHER  
# ACTION). IF N'S =0, THE NEW VERB CODE IS DISPLAYED ONLY (RETURN WITH NO  
# FURTHER ACTION).  
#  
# IT RETURNS TO 1+ CALLING LOC WITHOUT PERFORMING TASK, IF DISPLAY  
# SYSTEM IS BLOCKED (NOTHING IS DISPLAYED IN THIS CASE).  
# IT DOES TC ABORT (WITH OCT 01501) IF IT ENCOUNTERS A DISPLAY PROGRAM  
# ALARM CONDITION BEFORE RETURN TO CALLER.  
#

```

# THE DISPLAY SYSTEM IS BLOCKED BY THE DEPRESSION OF ANY
# KEY, EXCEPT ERROR LIGHT RESET.
# IT IS RELEASED BY THE KEY RELEASE BUTTON, ALL EXTENDED VERBS,
# PROCED WITOHOUT DATA, TERMINATE, RESEQUENCE, INITIALIZE EXECUTIVE,
# RECALL PART OF RECALTST IF ENDIDLE WAS USED,
# VB = REQUEST EXECUTIVE, VB = REQUEST WAITLIST,
# MONITOR SET UP.
#
# THE DISPLAY SYSTEM IS ALSO BLOCKED BY THE EXTERNAL MONITOR BIT, WHICH
# INDICATES AND EXTERNALLY INITIATED MONITOR IS RUNNING (SEE MONITOR).
#
# A NVSUB CALL THAT PASSES DSPLOCK AND THE EXTERNAL MONITOR BIT ENDS OLD
# MONITOR.
#
# DSPLOCK IS THE INTERLOCK FOR USE OF KEYBOARD AND DISPLAY SYSTEM WHICH
# LOCKS OUT INTERNAL USE WHENEVER THERE IS EXTERNAL KEYBOARD ACTION.
#
# NVSUB SHOULD BE USED TWICE IN SUCCESSION FOR 'PLEASE PERFORM' SITUATIONS
# (SIMILARLY FOR PLEASE MARK). FIRST PLACE THE CODED NUMBER FOR WHAT
# ACTION IS DESIRED OF OPERATOR INTO THEREGISTERS REFERRED TO BY THE
# 'CHECKLIST' NOUN. GO TO NVSUB WITH A DISPLAY VERB AND THE 'CHECKLIST'
# NOUN. GO TO NVSUB AGAIN WTIH THE 'PLEASE PERFORM' VERB AND ZEROS IN THE
# LOW 7 BITS. THIS 'PASTES UP' THE 'PLEASE PERFORM' VERB INTO THE VERB
# LIGHTS.
#
# NVMONOPT IS AN ENTRY SIMILAR TO NVSUB, BUT REQUIRING AN ADDITIONAL
# Page 370
# PARAMETER IN L. IT SHOULD BE USED ONLY WITH A MONITOR VERB-NOUN CODE IN
# A. AFTER EACH MONITOR DISPLAY A *PLEASE* VERB WILL BE PASED INT THE VERB
# LIGHTS OR DATA WILL BE BLANKED (OR BOTH) ACCORDING TO THE OPTIONS
# SPECIFIED IN L. IF BITS 8-14 OF L ARE OTHER THAN ZERO, THEN THEY WILL
# BE INTERPRETED AS A VERB CODE AND PASTED IN THE VERB LIGHTS. (THIS VERB
# CODE SHOULD DESIGNATE ONE OF THE *PLEASE* VERBS.) IF BITS 1-3 OF L ARE
# OTHER THAN ZERO, THEN THEY WILL BE USED BO BLANK DATA BY BEING FED TO
# BLANKSUB. IF NVMONOPT IS USED WITH A VERB OTHER THAN A MONITOR VERB,
# THE PARAMETER IN L HAS NO EFFECT.
#
# NVSUB IN FIXED-FIXED PLACES 2+CALLING LOC INTO NVQTEM, TC NVSUBEND INTO
# ENTRET. (THIS WILL RESTORE OLD CALLING BANK BITS)

```

SETLOC ENDALM +1

COUNT 02/PIN

|          |      |        |                         |
|----------|------|--------|-------------------------|
| NVSUB    | LXCH | 7      | # ZERO NVMONOPT OPTIONS |
| NVMONOPT | TS   | NVTEMP |                         |



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```
CAF      BIT14
MASK     MONSAVE1      # EXTERNAL MONITOR BIT
AD       DSPLOCK
CCS      A
TC       Q              # DSP SYST BLOCKED.  RET TO 1.  CALLING LOC
CAF      ONE           # DSP SYST AVAILABLE.
NVSBCOM  AD      Q
TS       NVQTEM        # 2+ CALLING LOC INTO NVQTEM
LXCH     MONSAVE2      # STORE NVMONOPT OPTIONS
TC       KILMONON      # TURN ON KILL MONITOR BIT
NVSUBCOM CAF      NVSBBBNK

XCH      BBANK
EXTEND
ROR      SUPERBNK
TS       NVBNKTEM
CAF      PINSUPBT
EXTEND
WRITE    SUPERBNK
TC       NVSUBB        # GO TO NVSUB1 THRU STANDARD LOC
EBANK=   DSPCOUNT
NVSBBBNK BBCON  NVSUB1

PINSUPBT =      NVSBBBNK      # CONTAINS THE PINBALL SUPERBIT.

NVSUBEND DXCH  NVQTEM        # NVBNKTEM MUST = NVQTEM+1
TC       SUPDXCHZ      # DTCB WITH SUPERBIT SWITCHING

SETLOC   ENDRQWT +1

COUNT   41/PIN
```

# Page 371

# BLANKDSP BLANKS DISPLAY ACCORDING TO OPTION NUMBER IN NVTEMP AS FOLLOWS:  
# -4 FULL BLANK, -3 LEAVE MODE, -2 LEAVE MODE AND VERB, -1 BLANK R'S ONLY.

```
BLANKDSP AD      SEVEN      # 7,8,9, OR 10 (A HAD 0,1,2,OR 3)
          INHINT
          TS       CODE      # BLANK SPECIFIED DSPTABS
          CS       BIT12
          INDEX    CODE
          XCH      DSPTAB
          CCS      A
          INCR     NOUT
          TC       +1
          CCS      CODE
```

|            |        |             |                                             |
|------------|--------|-------------|---------------------------------------------|
|            | TC     | BLANKDSP +2 |                                             |
|            | RELINT |             |                                             |
|            | INDEX  | NVTEMP      |                                             |
|            | TC     | +5          |                                             |
|            | TC     | +1          | # NVTEMP HAS -4 (NEVER TOUCH MODREG)        |
|            | TS     | VERBREG     | # -3                                        |
|            | TS     | NOUNREG     | # -2                                        |
|            | TS     | CLPASS      | # -1                                        |
|            | CS     | VD1         |                                             |
|            | TS     | DSPCOUNT    |                                             |
|            | TC     | FLASHOFF    | # PROTECT AGAINST INVISIBLE FLASH           |
|            | TC     | ENTSET -2   | # ZEROS REQRET                              |
| NVSUB1     | CAF    | ENTSET      | # IN BANK                                   |
|            | TS     | ENTRET      | # SET RETURN TO NVSUBEND                    |
|            | CCS    | NVTEMP      | # WHAT NOW                                  |
|            | TC     | +4          | # NORMAL NVSUB CALL (EXECUTE VN OR PASTE)   |
|            | TC     | GODSPALM    |                                             |
|            | TC     | BLANKDSP    | # BLANK DISPLAY AS SPECIFIED                |
|            | TC     | GODSPALM    |                                             |
|            | CAF    | LOW7        |                                             |
|            | MASK   | NVTEMP      |                                             |
|            | TS     | MPAC +3     | # TEMP FOR NOUN (CAN'T USE MPAC. DSPDECVN   |
|            | CA     | NVTEMP      | # USES MPAC, +1, +2).                       |
|            | TS     | EDOP        | # RIGHT 7                                   |
|            | CA     | EDOP        |                                             |
|            | TS     | MPAC +4     | # TEMP FOR VERB (CAN'T USE MPAC+1. DSPDECVN |
|            |        |             | # USES MPAC, +1, +2)                        |
|            | CCS    | MPAC +3     | # TEST NOUN                                 |
|            | TC     | NVSUB2      | # IF NOUN NOT +0, GO ON                     |
|            | CA     | MPAC +4     |                                             |
|            | TC     | UPDATVB -1  | # IF NOUN = +0, DISPLAY VERB. THEN RETURN   |
|            | CAF    | ZERO        | # ZERO REQRET SO THAT PASTED VERBS CAN      |
|            | TS     | REQRET      | # BE EXECUTED BY OPERATOR.                  |
| ENTSET     | TC     | NVSUBEND    |                                             |
| NVSUB2     | CCS    | MPAC +4     | # TEST VERB                                 |
|            | TC     | +4          | # IF VERB NOT +0, GO ON                     |
| # Page 372 | CA     | MPAC +3     |                                             |
|            | TC     | UPDATNN -1  | # IF VERB = +0, DISPLAY NOUN. THEN RETURN   |
|            | TC     | NVSUBEND    |                                             |
|            | CA     | MPAC +2     | # TEMP FOR MACH CADR TO BE SPEC. (DSPDECVN  |
|            | TS     | MPAC +5     | # USES MPAC, +1, +2)                        |
|            | CA     | MPAC +4     |                                             |
|            | TC     | UPDATVB -1  | # IF BOTH NOUN AND VERB NOT +0, DISPLAY     |
|            | CA     | MPAC +3     | # BOTH AND GO TO ENTPAS0.                   |

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```
TC      UPDATNN -1
CAF     ZERO
TS      LOADSTAT      # SET FOR WAITING FOR DATA CONDITION
TS      CLPASS
TS      REQRET         # SET REQRET FOR PASS 0.
CA      MPAC +5        # RESTORES MACH CADR TO BE SPEC TO MPAC+2
TS      MPAC +2        # FOR USE IN INTMCTBS (IN ENTPASO).
ENDNVSBI TC      ENTPASO
```

```
# IF INTERNAL MACH CADR TO BE SPECIFIED, MPAC+2 WILL BE PLACED INTO
# NOUNCADR IN ENTPASO (INTMCTBS).
```

```
SETLOC NVSUBEND +2
COUNT 02/PIN
KILMONON CAF BIT15      # FORCE BIT 15 OF MONSAVE1 TO .
TS      MONSAVE1      # THIS IS THE KILL MONITOR BIT.
TC      Q              # TURN OFF BIT 14, THE EXTERNAL
                        # MONITOR BIT.
```

```
# LOADSTAT +0 INACTIVE (WAITING FOR DATA). SET BY NVSUB
#          +1 PROCEED NO DATA. SET BY SPECIAL VERB
#          -1 TERMINATE. SET BY SPECIAL VERB.
#          -0 DATA IN. SET BY END OF LOAD ROUTINE.
#          OR RESEQUENCE. SET BY VERB 32
```

```
#
# L TO ENDIDLE (FIXED FIXED).
# ROUTINES THAT REQUEST LOADS THROUGH NVSUB SHOULD USE ENDIDLE WHILE
# WAITING FOR THE DATA TO BE LOADED. ENDIDLE PUTS CURRENT JOB TO SLEEP.
# ENDIDLE CANNOT BE CALLED FROM ERASABLE OR F/F MEMORY,
# SINCE JOB SLEEP AND JOBWAKE CAN HANDLE ONLY FIXED BANKS.
# RECALST TESTS LOADSTAT AND WAKES JOB UP TO,
#   L+1 FOR TERMINATE
#   L+2 FOR PROCEED WITHOUT DATA
#   L+3 FOR DATA IN, OR RESEQUENCE
# IT DOES NOTHING IF LOADSTAT INDICATES WAITING FOR DTA.
# Page 373
#
# ENDIDLE ABORTS (WITH CODE 1206) IF A SECOND JOB ATTEMPTS TO GO TO SLEEP
# IN PINBALL. IN PARTICULAR, IF AN ATTEMPT IS MADE TO GO TO ENDIDLE WHEN
#   1) CADRSTOR NOT= +0. THIS IS THE CASE WHERE THE CAPACITY OF ENDIDLE IS
#      EXCEEDED. (+-NZ INDICATES A JOB IS ALREADY ASLEEP DUE TO ENDIDLE.)
#   2) DSPLIST NOT= +0. THIS INDICATES A JOB IS ALREADY ASLEEP DUE TO
#      NVSUBUSY.
```

```
ENDIDLE LXCH Q      # RETURN ADDRESS INTO L.
```

|          |      |          |                                            |
|----------|------|----------|--------------------------------------------|
|          | TC   | ISCADR+0 | # ABORT IF CADRSTOR NOT= +0.               |
|          | TC   | ISLIST+0 | # ABORT IF DSPLIST NOT= +0                 |
|          | CA   | L        | # DON'T SET DSPLOC TO 1 SO CAN USE         |
|          | MASK | LOW10    | # ENDIDLE WITH NVSUB INITIATE MONITOR.     |
|          | AD   | FBANK    | # SAME STRATEGY FOR CADR AS MAKECADR.      |
|          | TS   | CADRSTOR |                                            |
|          | TC   | JOBSLEEP |                                            |
| ENDINST  | TC   | ENDOFJOB |                                            |
| ISCADR+0 | CCS  | CADRSTOR | # ABORTS (CODE 01206) IF CADRSTOR NOT= +0. |
|          | TC   | DSPABORT | # RETURNS IF CADRSTOR = +0.                |
|          | TC   | Q        |                                            |
|          | TC   | DSPABORT |                                            |
| ISLIST+0 | CCS  | DSPLIST  | # ABORTS (CODE 01206) IF DSPLIST NOT= +0.  |
|          | TC   | DSPABORT | # RETURNS IF DSPLIST = +0.                 |
|          | TC   | Q        |                                            |
| DSPABORT | TC   | P00D00   |                                            |
|          | OCT  | 01206    |                                            |

# JAMTERM ALLOWS PROGRAMS TO PERFORM THE TERMINATE FUNCTION.  
# IT DOES ENDOFJOB.

|         |        |          |                                 |
|---------|--------|----------|---------------------------------|
| JAMTERM | CAF    | PINSUPBT |                                 |
|         | EXTEND |          |                                 |
|         | WRITE  | SUPERBNK |                                 |
|         | CAF    | 34DEC    |                                 |
|         | TS     | REQRET   | # LEAVE ENTER SET FOR ENTPASSO. |
|         | CS     | VD1      |                                 |
|         | TS     | DSPCOUNT |                                 |
|         | TC     | POSTJUMP |                                 |
|         | CADR   | VBTERM   |                                 |

|       |     |    |
|-------|-----|----|
| 34DEC | DEC | 34 |
|-------|-----|----|

# JAMPROC ALLOWS PROGRAMS TO PERFORM THE PROCEED/PROCEED WITHOUT DATA  
# FUNCTION. IT DOES ENDOFJOB.  
# Page 374

|         |        |          |                                 |
|---------|--------|----------|---------------------------------|
| JAMPROC | CAF    | PINSUPBT |                                 |
|         | EXTEND |          |                                 |
|         | WRITE  | SUPERBNK |                                 |
|         | CAF    | 33DEC    |                                 |
|         | TS     | REQRET   | # LEAVE ENTER SET FOR ENTPASSO. |
|         | CS     | VD1      |                                 |

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TS DSPCOUNT  
TC POSTJUMP  
CADR VBPROC

33DEC DEC 33

# BLANKSUB BLANKS ANY COMBINATION OF R1, R2, R3.  
# CALL WITH BLANKING CODE IN A.  
# BIT1=1 BLANKS R1, BIT2=1 BLANKS R2, BIT3=1 BLANKS R3.  
# ANY COMBINATION OF THESE BITS IS ACCEPTED.  
#  
# DSPCOUNT IS RESTORED TO STATE IT WAS IN BEFORE BLANKSUB WAS EXECUTED.

BLANKSUB MASK SEVEN  
TS NVTEMP # STORE BLANKING CODE IN NVTEMP.  
CAF BIT14  
MASK MONSAVE1 # EXTERNAL MONITOR BIT  
AD DSPLOCK  
CCS A  
TC Q # DSP SYST BLOCKED. RET TO 1+ CALLING LOC  
INCR Q # DSP SYST AVAILABLE  
# SET RETURN FOR 2+ CALLING LOC  
CCS NVTEMP  
TCF +2  
TC Q # NOTHING TO BLANK. RET TO 2+ CALLING LOC  
LXCH Q # SET RETURN FOR 2 + CALLING LOC  
CAF BLNKBBNK  
XCH BBANK  
EXTEND  
ROR SUPERBNK # SAVE OLD SUPERBITS.  
DXCH BUF  
CAF PINSUPBT  
EXTEND  
WRITE SUPERBNK  
TC BLNKSUB1  
EBANK= DSPCOUNT  
BLNKBBNK BBCON BLNKSUB1  
ENDBLFF EQUALS

SETLOC ENDRELDS  
COUNT 40/PIN

# Page 375

BLNKSUB1 CA DSPCOUNT # SAVE OLD DSPCOUNT FOR LATER RESTORATION  
TS BUF +2

```

CAF      BIT1          # TEST BIT1.  SEE IF R1 TO BE BLANKED.
TC      TESTBIT
CAF      R1D1
TC      5BLANK  -1
CAF      BIT2          # TEST BIT2.  SEE IF R2 TO BE BLANKED.
TC      TESTBIT
CAF      R2D1
TC      5BLANK  -1
CAF      BIT3          # TEST BIT3.  SEE IF R3 TO BE BLANKED.
TC      TESTBIT
CAF      R3D1
TC      5BLANK  -1
CA      BUF      +2    # RESTORE DSPCOUNT TO STATE IT HAD
TS      DSPCOUNT    # BEFORE BLANKSUB.
DXCH    BUF          # CALL L+2 DIRECTORY.
TC      SUPDXCHZ +1    # DTCB WITH SUPERBIT SWITCHING

TESTBIT  MASK  NVTEMP    # NVTEMP CONTAINS BLANKING CODE
          CCS    A
          TC     Q        # IF CURRENT BIT = 1, RETURN TO L+1.
          INDEX  Q        # IF CURRENT BIT = 0, RETURN TO L+3.
          TC     2

ENDBSUB1  EQUALS

# DSPMM DOES NOT DISPLAY MODREG DIRECTLY.  IT PUTS IN EXEC REQUEST WITH
# PRIO 30000 FOR DSPMMJB AND RETURNS TO CALLER.
#
# IF MODREG CONTAINS -0, DSPMMJB BLANKS THE MODE LIGHTS.
#
# DSPMM MUST BE IN BANK 27 OR LOWER, SO IT CAN BE CALLED VIA BANKCALL.

          BANK      7
          SETLOC    PINBALL4
          BANK

          COUNT     07/PIN

DSPMM     XCH      Q
          TS       MPAC
          INHINT
          CAF      CHRPRIO
          TC       NOVAC
          EBANK=   DSPCOUNT
          2CADR    DSPMMJB

```

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```
RELINT
# Page 376
ENDSPMM      TC      MPAC

# DSPMM PLACE MAJOR MODE CODE INTO MODREG

      SETLOC  ENDBSUB1

      COUNT  40/PIN

DSPMMJB      CAF      MD1          # GETS HERE THRU DSPMM
             XCH      DSPCOUNT
             TS        DSPMMTEM    # SAVE DSPCOUNT
             CCS      MODREG
             AD        ONE
             TC        DSPDECVN    # IF MODREG IS + OR +0, DISPLAY MODREG
             TC        +2          # IF MODREG IS -NZ, DO NOTHING
             TC        2BLANK      # IF MODREG IS -0, BLANK MM
             XCH      DSPMMTEM    # RESTORE DSPCOUNT
             TS        DSPCOUNT
             TC        ENDOFJOB

# RECALTST IS ENTERED DIRECTLY AFTER DATA IS LOADED (OR RESEQUENCE VERB IS
# EXECUTED), TERMINATE VERB IS EXECUTED, OR PROCEED WITHOUT DATA VERB IS
# EXECUTED.  IT WAKES UP JOB THAT DID TC ENDIDLE.
#
# IF CADRSTOR NOT= +0, IT PUTS +0 INTO DSPLOCK, AND TURNS OFF KEY RLSE
# LIGHT IF DSPLIST IS EMPTY (LEAVES KEY RLSE LIGHT ALONE IF NOT EMPTY).

RECALTST     CCS      CADRSTOR
             TC        RECAL1
             TC        ENDOFJOB    # NORMAL EXIT IF KEYBOARD INITIATED
RECAL1       CAF      ZERO
             XCH      CADRSTOR
             INHINT
             TC        JOBWAKE
             CCS      LOADSTAT
             TC        DOPROC      # + PROCEED WITHOUT DATA
             TC        ENDOFJOB    # PATHOLOGICAL CASE EXIT
             TC        DOTERM      # - TERMINATE
             CAF      TWO          # -0 DATA IN OR RESEQUENCE
RECAL2       INDEX   LOCCTR
             AD        LOC          # LOC IS + FOR BASIC JOBS
             INDEX   LOCCTR
             TS        LOC
             CA        NOUNREG      # SAVE VERB IN MPAC, NOUN IN MPAC+1 AT
```

|                                                 |                                   |                                          |                                          |
|-------------------------------------------------|-----------------------------------|------------------------------------------|------------------------------------------|
|                                                 | TS                                | L                                        | # TIME OF RESPONSE TO ENDIDLE FOR        |
|                                                 | CA                                | VERBREG                                  | # POSSIBLE LATER TESTING BY JOB THAT HAS |
|                                                 | INDEX                             | LOCCTR                                   | # BEEN WAKED UP.                         |
|                                                 | DXCH                              | MPAC                                     |                                          |
|                                                 | RELINT                            |                                          |                                          |
| # Page 377                                      |                                   |                                          |                                          |
| RECAL3                                          | TC                                | RELDSP                                   |                                          |
|                                                 | TC                                | ENDOFJOB                                 |                                          |
| DOTERM                                          | CAF                               | ZERO                                     |                                          |
|                                                 | TC                                | RECAL2                                   |                                          |
| DOPROC                                          | CAF                               | ONE                                      |                                          |
|                                                 | TC                                | RECAL2                                   |                                          |
|                                                 | SBANK=                            | LOWSUPER                                 |                                          |
| # Page 378                                      |                                   |                                          |                                          |
| # MISCELLANEOUS SERVICE ROUTINES IN FIXED/FIXED |                                   |                                          |                                          |
|                                                 | SETLOC                            | ENDBLFF                                  |                                          |
|                                                 | COUNT                             | 02/PIN                                   |                                          |
| # SETNCADR                                      | E CADR ARRIVES IN A.              | IT IS STORED IN NOUNCADR.                | EBANK BITS                               |
| #                                               | ARE SET.                          | E ADRES IS DERIVED AND PUT INTO NOUNADD. |                                          |
| SETNCADR                                        | TS                                | NOUNCADR                                 | # STORE ECADR                            |
|                                                 | TS                                | EBANK                                    | # SET EBANK BITS                         |
|                                                 | MASK                              | LOW8                                     |                                          |
|                                                 | AD                                | OCT1400                                  |                                          |
|                                                 | TS                                | NOUNADD                                  | # PUT E ADRES INTO NOUNADD               |
|                                                 | TC                                | Q                                        |                                          |
| # SETNADD                                       | GETS E CADR FROM NOUNCADR,        | SETS EBANK BITS,                         | DERIVES                                  |
| #                                               | E ADRES AND PUTS IT INTO NOUNADD. |                                          |                                          |
| SETNADD                                         | CA                                | NOUNCADR                                 |                                          |
|                                                 | TCF                               | SETNCADR +1                              |                                          |
| # SETEBANK                                      | E CADR ARRIVES IN A.              | EBANK BITS ARE SET.                      | E ADRES IS                               |
| #                                               | DERIVED AND LEFT IN A.            |                                          |                                          |
| SETEBANK                                        | TS                                | EBANK                                    | # SET EBANK BITS                         |
|                                                 | MASK                              | LOW8                                     |                                          |
|                                                 | AD                                | OCT1400                                  | # E ADRES LEFT IN A                      |
|                                                 | TC                                | Q                                        |                                          |



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|            |        |          |                                          |
|------------|--------|----------|------------------------------------------|
| R1D1       | OCT    | 16       | # THESE 3 CONSTANTS FORM A PACKED TABLE. |
| R2D1       | OCT    | 11       | # DON'T SEPARATE.                        |
| R3D1       | OCT    | 4        |                                          |
| RIGHT5     | TS     | CYR      |                                          |
|            | CS     | CYR      |                                          |
|            | CS     | CYR      |                                          |
|            | CS     | CYR      |                                          |
|            | CS     | CYR      |                                          |
|            | XCH    | CYR      |                                          |
|            | TC     | Q        |                                          |
| LEFT5      | TS     | CYL      |                                          |
|            | CS     | CYL      |                                          |
|            | CS     | CYL      |                                          |
|            | CS     | CYL      |                                          |
| # Page 379 | CS     | CYL      |                                          |
|            | XCH    | CYL      |                                          |
|            | TC     | Q        |                                          |
| SLEFT5     | DOUBLE |          |                                          |
|            | DOUBLE |          |                                          |
|            | DOUBLE |          |                                          |
|            | DOUBLE |          |                                          |
|            | DOUBLE |          |                                          |
|            | TC     | Q        |                                          |
| LOW5       | OCT    | 37       | # THESE 3 CONSTANTS FORM A PACKED TABLE. |
| MID5       | OCT    | 1740     | # DON'T SEPARATE.                        |
| HI5        | OCT    | 76000    | # MUST STAY HERE                         |
| TCNOVAC    | TC     | NOVAC    |                                          |
| TCWAIT     | TC     | WAITLIST |                                          |
| TCTSKOVR   | TC     | TASKOVER |                                          |
| TCFINDVC   | TC     | FINDVAC  |                                          |
| CHRPRI0    | OCT    | 30000    | # EXEC PRIORITY OF CHARIN                |
| LOW11      | OCT    | 3777     |                                          |
| B12-1      | EQUALS | LOW11    |                                          |
| LOW8       | OCT    | 377      |                                          |
| VD1        | OCT    | 23       | # THESE 3 CONSTANTS FORM A PACKED TABLE. |
| ND1        | OCT    | 21       | # DON'T SEPARATE.                        |

```

MD1          OCT      25

BINCON       DEC      10

FALTON       CA        BIT7      # TURN ON OPERATOR ERROR LIGHT.
             EXTEND
             WOR        DSALMOUT  # BIT 7 OF CHANNEL 11
             TC         Q

FALTOF       CS        BIT7      # TURN OFF OPERATOR ERROR LIGHT
             EXTEND
             WAND       DSALMOUT  # BIT 7 OF CHANNEL 11
             TC         Q

RELDSPON     CAF        BIT5      # TURN ON KEY RELEASE LIGHT
             EXTEND
             WOR        DSALMOUT  # BIT 5 OF CHANNEL 11
             TC         Q

# Page 380
LODSAMPT     EXTEND
             DCA        TIME2
             DXCH       SAMPTIME
             TC         Q

TPSL1        EXTEND              # SHIFTS MPAC, +1, +2 LEFT 1
             DCA        MPAC      +1  # LEAVES OVFIN D SET TO +/- 1 FOR OF/UF
             DAS        MPAC      +1
             AD         MPAC
             ADS        MPAC
             TS         7          # TS A DOES NOT CHANGE A ON OF/UF.
             TC         Q          # NO NET OF/UF
             TS         MPAC+6     # MPAC +6 SET TO +/- 1 FOR OF/UF
             TC         Q

# IF MPAC, +1 ARE EACH +NZ OR +0 AND C(A)=-0, SHORTMP WRONGLY GIVES +0.
# IF MPAC, +1 ARE EACH -NZ OR -0 AND C(A)=+0, SHORTMP WRONGLY GIVES +0.
# PRSHRTMP FIXES FIRST CASE ONLY, BY MERELY TESTING C(A) AND IF IT = -0,
# SETTING RESULT TO -0.
#
# (DO NOT USE PRSHRTMP UNLESS MPAC, +1 ARE EACH +NZ OR +0, AS THEY ARE
# WHEN THEY CONTAIN THE SF CONSTANTS.)

PRSHRTMP     TS         MPTEMP
             CCS        A
             CA         MPTEMP      # C(A) +, DO REGULAR SHORTMP

```

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```
TCF      SHORTMP +1      # C(A) +0, DO REGULAR SHORTMP
TCF      -2              # C(A) -, DO REGULAR SHORTMP
CS       ZERO            # C(A) -0, FORCE RESULT TO -0 AND RETURN.
TS       MPAC
TS       MPAC      +1
TS       MPAC      +2
TC       Q

FLASHON   CAF      BIT6      # TURN ON V/N FLASH
          EXTEND      # BIT 6 OF CHANNEL 11
          WOR      DSALMOUT
          TC       Q

FLASHOFF  CS       BIT6      # TURN OFF V/N FLASH
          EXTEND
          WAND      DSALMOUT  # BIT 6 OF CHANNEL 11
          TC       Q
```

# Page 381

# INTERNAL USE OF KEYBOARD AND DISPLAY PROGRAM.

#

# USER MUST SCHEDULE CALLS TO NVSUB SO THAT THERE IS NO CONFLICT OF USE OR  
# CONFUSION TO OPERATOR. THE OLD CRABLOCK (INTERNAL/INTERNAL INTERLOCK)  
# HAS BEEN REMOVED AND THE INTERNAL USER NO LONGER HAS THE PROTECTION THIS  
# OFFERED.

#

# THERE ARE TWO WAYS A JOB CAN BE PUT TO SLEEP BY THE KEYBOARD + DISPLAY  
# PROGRAM. 1) BY ENDIDLE

# 2) BY NVSUBUSY

# THE BASIC CONVENTION IS THAT ONLY ONE JOB WILL BE PERMITTED ASLEEP VIA  
# THE KEYBOARD + DISPLAY PROGRAM AT A TIME. IF A JOB ATTEMPTS TO GO TO  
# SLEEP BY MEANS OF (1) OR (2) AND THERE IS ALREADY A JOB ASLEEP THAT WAS  
# PUT TO SLEEP BY (1) OR (2), THEN AN ABORT IS CAUSED.

#

# THE CALLING SEQUENCE FOR NVSUB IS

```
#          CAF      V/N
#          L        TC      NVSUB
#          L+1      RETURN HERE IF OPERATOR HAS INTERVENED
#          L+2      RETURN HERE AFTER EXECUTION
```

#

# A ROUTINE CALLED NVSUBUSY IS PROVIDED (USE IS OPTIONAL) TO PUT  
# YOUR JOB TO SLEEP UNTIL THE OPERATOR RELEASES THE KEYBOARD + DISPLAY  
# SYSTEM. NVSUBUSY ALSO TURNS ON THE KEY RELEASE LIGHT.  
# NVSUBUSY CANNOT BE CALLED FROM ERASABLE OR F/F MEMORY,  
# SINCE JOBSLEEP AND JOBWAKE CAN HANDLE ONLY FIXED BANKS.

#

```

# THE CALLING SEQUENCE IS
#     CAF     WAKEFCADR
#     TC      NVSUBUSY
# .
#
# NVSUBUSY IS INTENDED FOR USE WHEN AN INTERNAL PROGRAM FINDS THE OPERATOR
# IS NOT USING THE KEYBOARD + DISPLAY PROGRAM (BY HIS OWN INITIATION). IT IS
# NOT INTENDED FOR USE WHEN ONE INTERNAL PROGRAM FINDS ANOTHER INTERNAL
# PROGRAM USING THE KEYBOARD + DISPLAY PROGRAM.
#
# NVSUBUSY ABORTS (WITH CODE 01206) IF A SECOND JOB ATTEMPTS TO GO TO
# SLEEP IN PINBALL. IN PARTICULAR, IF AN ATTEMPT IS MADE TO GO TO NVSUBUSY
# WHEN
#
#     1)      DSPLIST NOT= +0. THIS IS THE CASE WHERE THE CAPACITY OF THE DSPLIST
#             IS EXCEEDED.
#     2)      CADRSTOR NOT= +0. THIS INDICATES THAT A JOB IS ALREADY USING
# Page 382
# ENDIDLE. (+-NZ INDICATES A JOB IS ALREADY ASLEEP DUE TO ENDIDLE.)

PRENVBSY      CS      2K+3      # SPECIAL ENTRANCE FOR ROUTINES IN FIXED
                AD      Q        # BANKS ONLY DESIRING THE FCADR OF (LOC
                AD      FBANK    # FROM WHICH THE TC PRENVBSY WAS DONE) -2
NVSUBUSY      TC      POSTJUMP   # TO BE ENTERED.
                CADR      NVSUBSY1
2K+3          OCT      2003

# NVSUBSY1 MUST BE IN BANK 27 OR LOWER, SO IT WILL PUT CALLER TO SLEEP
# WITH HIS PROPER SUPERBITS.

                SETLOC  ENDSPMM +1
                COUNT   07/PIN

NVSUBSY1      TS      L
                TC      ISCADR+0   # ABORT IF CADRSTOR NOT= +0.
                TC      ISLIST+0   # ABORT IF DSPLIST NOT= +0.
                TC      RELDSPON
                CA      L
                TS      DSPLIST
ENDNVBSY      TC      JOBSLEEP

# NVSBWAIT IS A SPECIAL ENTRANCE FOR ROUTINES IN FIXED BANKS ONLY. IF
# SYSTEM IS NOT BUSY, IT EXECUTES V/N AND RETURNS TO L+1 (L= LOC FROM
# WHICH THE TC NVSBWAIT WAS DONE). IF SYSTEM IS BUSY, IT PUTS CALLING JOB
# TO SLEEP WITH L-1 GOING INTO LIST FOR EVENTUAL WAKING UP WHEN SYSTEM
# IS NOT BUSY.

```

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```

SETLOC NVSUBUSY +3
COUNT 02/PIN

NVSBWAIT LXCH 7 # ZERO NVMONOPT OPTIONS
TS NVTEMP
CAF BIT14
MASK MONSAVE1 # EXTERNAL MONITOR BIT
AD DSPLOCK
CCS A
TCF NVSBWT1 # BUSY
TCF NVSBCOM # FREE. NVSUB WILL SAVE L+1 FOR RETURN
# AFTER EXECUTION.
NVSBWT1 INCR Q # L+2. PRENVBSY WILL PUT L-1 INTO LIST AND
TCF PRENVBSY # GO TO SLEEP.

# RELDSP IS USED BY VBPROC, VBTERM, VBRQEXEC, VBRQWAIT, VBRELDSP, EXTENDED
# VERB DISPATCHER, VBRESEQ, RECALTST.
#
# RELDSP1 IS USED BY MONITOR SET UP, VBRELDSP.

RELDSP XCH Q # SET DSPLOCK TO +0, TURN RELDSP LIGHT
# Page 383
TS RELRET # OFF, SEARCH DSPLIST
CS BIT14
INHINT
MASK MONSAVE1
TS MONSAVE1 # TURN OFF EXTERNAL MONITOR BIT
CCS DSPLIST
TC +2
TC RELDSP2 # LIST EMPTY
CAF ZERO
XCH DSPLIST
TC JOBWAKE
RELDSP2 RELINT
CS BIT5 # TURN OFF KEY RELEASE LIGHT
EXTEND # (BIT 5 OF CHANNEL 11)
WAND DSALMOUT
CAF ZERO
TS DSPLOCK
TC RELRET
RELDSP1 XCH Q # SET DSPLOCK TO +0. NO DSPLIST SEARCH.
TS RELRET # TURN KEY RLSE LIGHT OFF IF DSPLIST IS
# EMPTY. LEAVE KEY RLSE LIGHT ALONE IF
# DSPLIST IS NOT EMPTY.
CCS DSPLIST
```

|     |         |      |                                      |
|-----|---------|------|--------------------------------------|
| TC  | +2      | # +  | NOT EMPTY. LEAVE KEY RLSE LIGHT ALON |
| TC  | RELDSP2 | # +0 | EMPTY. TURN OFF KEY RLSE LIGHT       |
| CAF | ZERO    | # -  | NOT EMPTY. LEAVE KEY RLSE LIGHT ALON |
| TS  | DSPLOCK |      |                                      |
| TC  | RELRET  |      |                                      |

ENDPINBF        EQUALS

# Page 384

# PINTEST IS NEEDED FOR AUTO CHECK OF PINBALL.

PINTEST        EQUALS    LST2FAN

# Page 385

# VBTSTLTS TURNS ON ALL DISPLAY PANEL LIGHTS. AFTER 5 SEC, IT TURNS

# OFF THE CAUTION AND STATUS LIGHTS.

SETLOC    ENDNVSB1 +1

COUNT    41/PIN

|          |      |          |
|----------|------|----------|
| VBTSTLTS | TC   | BANKCALL |
|          | CADR | CHKPOOH  |

INHINT

|    |      |                                         |
|----|------|-----------------------------------------|
| CS | BIT1 | # SET BIT 1 OF IMODES33 SO IMUMON WON'T |
|----|------|-----------------------------------------|

|      |          |                       |
|------|----------|-----------------------|
| MASK | IMODES33 | # TURN OUT ANY LAMPS. |
|------|----------|-----------------------|

|    |      |
|----|------|
| AD | BIT1 |
|----|------|

|    |          |
|----|----------|
| TS | IMODES33 |
|----|----------|

|     |         |                                            |
|-----|---------|--------------------------------------------|
| CAF | TSTCON1 | # TURN ON UPLINK ACTIVITY, TEMP, KEY RLSE, |
|-----|---------|--------------------------------------------|

|        |  |                              |
|--------|--|------------------------------|
| EXTEND |  | # V/N FLASH, OPERATOR ERROR. |
|--------|--|------------------------------|

|     |          |
|-----|----------|
| WOR | DSALMOUT |
|-----|----------|

|     |         |                                         |
|-----|---------|-----------------------------------------|
| CAF | TSTCON2 | # TURN ON NO ATT, GIMBAL LOCK, TRACKER, |
|-----|---------|-----------------------------------------|

|    |             |             |
|----|-------------|-------------|
| TS | DSPTAB +11D | # PROG ALM. |
|----|-------------|-------------|

|     |       |                             |
|-----|-------|-----------------------------|
| CAF | BIT10 | # TURN ON TEST ALARM OUTBIT |
|-----|-------|-----------------------------|

EXTEND

|     |        |
|-----|--------|
| WOR | CHAN13 |
|-----|--------|

|     |     |
|-----|-----|
| CAF | TEN |
|-----|-----|

|         |    |       |
|---------|----|-------|
| TSTLTS1 | TS | ERCNT |
|---------|----|-------|

|    |         |
|----|---------|
| CS | FULLDSP |
|----|---------|

|       |       |
|-------|-------|
| INDEX | ERCNT |
|-------|-------|

|    |        |
|----|--------|
| TS | DSPTAB |
|----|--------|

|     |       |
|-----|-------|
| CCS | ERCNT |
|-----|-------|

|    |         |
|----|---------|
| TC | TSTLTS1 |
|----|---------|

|    |          |
|----|----------|
| CS | FULLDSP1 |
|----|----------|

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|            |        |             |                                                                                                                |
|------------|--------|-------------|----------------------------------------------------------------------------------------------------------------|
|            | TS     | DSPTAB +1   | # TURN ON 3 PLUS SIGNS                                                                                         |
|            | TS     | DSPTAB +4   |                                                                                                                |
|            | TS     | DSPTAB +6   |                                                                                                                |
|            | CAF    | ELEVEN      |                                                                                                                |
|            | TS     | NOUT        |                                                                                                                |
|            | CAF    | SHOLTS      |                                                                                                                |
|            | TC     | WAITLIST    |                                                                                                                |
|            | EBANK= | DSPTAB      |                                                                                                                |
|            | 2CADR  | TSTLTS2     |                                                                                                                |
|            | TC     | ENDOFJOB    | # DSPLOCK IS LEFT BUSY (FROM KEYBOARD<br># ACTION) UNTIL TSTLTS3 TO INSURE THAT<br># LIGHTS TEST WILL BE SEEN. |
| FULLDSP    | OCT    | 05675       | # DISPLAY ALL 8'S                                                                                              |
| FULLDSP1   | OCT    | 07675       | # DISPLAY ALL 8'S AND +                                                                                        |
| TSTCON1    | OCT    | 00175       |                                                                                                                |
| # Page 386 |        |             |                                                                                                                |
|            |        |             | # UPLINK ACTIVITY, TEMP, KEY RLSE,<br># V/N FLASH, OPERATOR ERROR.                                             |
| TSTCON2    | OCT    | 40650       | # DSPTAB+11D BITS 4,6,8,9,<br># NO ATT, GIMBAL LOCK, TRACKER, PROG ALM.                                        |
| TSTCON3    | OCT    | 00115       | # CHAN 11 BITS 1, 3, 4, 7.<br># UPLINK ACITIVY, TEMP, OPERATOR ERROR.                                          |
| SHOLTS     | OCT    | 764         | # 5 SEC                                                                                                        |
| TSTLTS2    | CAF    | CHRPRI0     | # CALLED BY WAITLIST                                                                                           |
|            | TC     | NOVAC       |                                                                                                                |
|            | EBANK= | DSPTAB      |                                                                                                                |
|            | 2CADR  | TSTLTS3     |                                                                                                                |
|            | TC     | TASKOVER    |                                                                                                                |
| TSTLTS3    | CS     | TSTCON3     | # CALLED BY EXECUTIVE                                                                                          |
|            | INHINT |             |                                                                                                                |
|            | EXTEND |             | # TURN OFF UPLINK ACTIVITY, TEMP,                                                                              |
|            | WAND   | DSALMOUT    | # OPERATOR ERROR.                                                                                              |
|            | CS     | BIT10       | # TURN OFF TEST ALARM OUTBIT                                                                                   |
|            | EXTEND |             |                                                                                                                |
|            | WAND   | CHAN13      |                                                                                                                |
|            | CAF    | BIT4        | # MAKE NO ATT FOLLOW BIT 4 OF CHANNEL 12                                                                       |
|            | EXTEND |             | # (NO TT LIGHT ON IF IN COARSE ALIGN)                                                                          |
|            | RAND   | CHAN12      |                                                                                                                |
|            | AD     | BIT15       | # TURN OFF AUTO, HOLD, FREE, SPARE,                                                                            |
|            | TS     | DSPTAB +11D | # GIMBAL LOCK, SPARE, TRACKER, PROG ALM                                                                        |
|            | CS     | 13-11,1     | # SET BITS TO INDICATE ALL LAMPS OUT. TEST                                                                     |

```

                                MASK    IMODES33      # LIGHTS COMPLETE.
                                AD       PRI016
                                TS       IMODES33

                                CS       OCT55000
                                MASK     IMODES30
                                AD       PRI015      # 15000.
                                TS       IMODES30

                                CS       OPTMODES
                                MASK     BIT7
                                ADS      OPTMODES
                                RELINT

                                TC       BANKCALL      # REDISPLAY C(MODREG)
                                CADR     DSPMM
                                TC       KILMONON      # TURN ON KILL MONITOR BIT.
                                TC       FLASHOFF      # TURN OFF V/N FLASH.
                                TC       POSTJUMP      # DOES RELDSP AND GOES TO PINBRNCH IF
                                CADR     TSTLTS4       # ENDIDLE IS AWAITING OPERATOR RESPONSE.

# Page 387
13-11,1      OCT       16001
OCT55000     OCT       55000
ENDPINS2     EQUALS

# Page 388
# ERROR LIGHT RESET (RSET) TURNS OFF:
# UPLINK ACTIVITY, AUTO, HOLD, FREE, OPERATOR ERROR,
# PROG ALM, TRACKER FAIL.
#
# LEAVES GIMBAL LOCK AND NO ATT ALONE.
#
# IT ALSO ZEROS THE 'TEST ALARM' OUT BIT, WHICH TURNS OFF STBY, RESTART.
# IT ALSO SETS 'CAUTION RESET' TO 1.
# IT ALSO FORCES BIT 12 OF ALL DSPTAB ENTRIES TO 1.

                                SETLOC   DOPROC +2
                                COUNT    40/PIN

ERROR        XCH       21/22REG      # RESTORE ORIGINAL C(DSPLOCK).  THUS ERROR
                                TS       DSPLOCK      # LIGHT RESET LEAVES DSPLOCK CHANGED.
                                INHINT
                                CAF      BIT10      # TURN ON 'CAUTION RESET' OUTBIT
                                EXTEND
                                WOR      DSALMOUT    # BIT10 CHAN 11
                                CAF      GL+NOATT    # LEAVE GIMBAL LOCK AND NO ATT INTACT,

```



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```

MASK    DSPTAB +11D    # TURNING OFF AUTO, HOLD, FREE,
AD       BIT15         # PROG ALARM, AND TRACKER.
TS       DSPTAB +11D
CS       PRI016
MASK     IMODES33      # RESET FAIL BITS WHICH GENERATE PROG
AD       PRI016        # ALARM SO THAT IF THE FAILURE STILL
TS       IMODES33      # EXISTS, THE ALARM WILL COME BACK.
CS       BIT10
MASK     IMODES30
AD       BIT10
TS       IMODES30

CS       OPTMODES
MASK     BIT7
ADS      OPTMODES
CS       BIT10        # TURN OFF 'TEST ALARM' OUTBIT
EXTEND
WAND     CHAN13
CS       ERCON        # TURN OFF UPLINK ACTIVITY,
EXTEND   # OPERATOR ERROR.
WAND     DSALMOUT
CAF      BINCON       # (DEC 10)
TS       ERCNT        # ERCNT = COUNT
INHINT
INDEX    ERCNT
CCS      DSPTAB
AD       ONE
TC       ERPLUS
AD       ONE
ERMINUS  CS           A
MASK     NOTBIT12
TC       ERCOM

# Page 389
ERPLUS   CS           A
MASK     NOTBIT12
CS       A            # MIGHT WANT TO RESET CLPASS, DECBRNCH,
ERCOM    INDEX        ERCNT    # ETC.
TS       DSPTAB
RELINT
CCS      ERCNT
TC       TSTAB  +1
CAF      ZERO
TS       FAILREG
TS       FAILREG +1
TS       FAILREG +2
TS       SFAIL
```

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```

                                TC      ENDOFJOB

ERCON      OCT      104      # CHAN 11 BITS 3,7.
                                # UPLINK ACTIVITY, AND OPERATOR ERROR.

BITS6,8    OCT      240
GL+NOATT   OCT      00050      # NO ATT AND GIMBAL LOCK LAMPS
NOTBIT12    OCT      73777

ENDPINS1    EQUALS

SBANK=     LOWSUPER
```

This code is written to file `src/PINBALL-GAME-BUTTONS-AND-LIGHTS.s`.

## A.80 PINBALL NOUN TABLES

```

1467 <src/PINBALL-NOUN-TABLES.s 1467>≡
# Copyright:    Public domain.
# Filename:     PINBALL_NOUN_TABLES.agc
# Purpose:      Part of the source code for Comanche, build 055. It
#               is part of the source code for the Command Module's
#               (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:   yaYUL
# Reference:    pp. 268-284
# Contact:      Ron Burkey <info@sandroid.org>,
#               Fabrizio Bernardini <fabrizio@spacecraft.it>
# Website:      http://www.ibiblio.org/apollo.
# Mod history:  2009-05-18 FB   Transcription Batch 3 Assignment.
#               2009-05-23 RSB  In NNTYPTAB, corrected former 13 SPARE.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#               Massachussets Institute of Technology
#               75 Cambridge Parkway
#               Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.
#
# Page 268
# THE FOLLOWING REFERS TO THE NOUN TABLES
#
# COMPONENT CODE NUMBER   INTERPRETATION
#
# 00000                   1 COMPONENT
# 00001                   2 COMPONENT
# 00010                   3 COMPONENT
# X1XXX                   BIT 4 = 1.  DECIMAL ONLY
# 1XXXX                   BIT 5 = 1.  NO LOAD
#
# END OF COMPONENT CODE NUMBERS

```

```

#
#      SF ROUTINE CODE NUMBER  INTERPRETATION
#
#      00000      OCTAL ONLY
#      00001      STRAIGHT FRACTIONAL
#      00010      CDU DEGREES (XXX.XX)
#      00011      ARITHMETIC SF
#      00100      ARITH DP1          OUT (MULT BY 2EXP14 AT END)      IN (S
#      00101      ARITH DP2          OUT (STRAIGHT)                  IN (S
#      00110      Y OPTICS DEGREES (XX.XXX MAX 89.999)
#      00111      ARITH DP3          OUT (SL 7 AT END)              IN (S
#      01000      WHOLE HOURS IN R1, WHOLE MINUES (MOD 60) IN R2,
#                      SECONDS (MOD 60) OXX.XX IN R3.  *** ALARMS IF
#      01001      MINUTES (MOD 60) IN D1D2, D3 BLANK, SECONDS (MOD 60)
#                      LIMITS TO 59B59 IF MAG EXCEEDS THIS VALUE.
#                      ALARMS IF USED WITH OCTAL ***** IN (ALARM)
#      01010      ARITH DP4          OUT (STRAIGHT)                  IN (S
#      01011      ARITH1 SF          OUT (MULT BY 2EXP14 AT END)      IN (S
#      01100      2 INTEGERS IN D1D2, D4D5, D3 BLANK.
#                      ALARMS IF USED WITH OCTAL ***** IN (ALARM)
#      01101      DP STRAIGHT FRACTIONAL
#
#      END OF SF ROUTINE CODE NUMBERS
#
#      SF CONSTANT CODE NUMBER INTERPRETATION
#
#      00000      WHOLE                      USE ARITH
#      00000      DP TIME SEC (XXX.XX SEC)    USE ARITHDP1
#      00001      SPARE
#      00010      CDU DEGREES                  USE CDU DEGREES
#      00010      Y OPTICS DEGREES             USE Y OPTICS DEGREES
#      00011      DP DEGREES (90) XX.XXX DEG   USE ARITHDP3
#      00100      DP DEGREES (360) XXX.XX DEG  USE ARITHDP4
#      00101      DEGREES (180) XXX.XX DEG     USE ARITH
#      00110      WEIGHT2 (XXXXX. LBS)         USE ARITH1
#      00111      POSITION5 (XXX.XX NAUTICAL MILES)
#                      USE ARITHDP3
#      01000      POSITION4 (XXXX.X NAUTICAL MILES)
#
# Page 269
#
#                      USE ARITHDP3
#      01001      VELOCITY2 (XXXXX. FT/SEC)    USE ARITHDP4
#      01010      VELOCITY3 (XXXX.X FT/SEC)    USE ARITHDP3
#      01011      ELEVATION DEGREES (89.999 MAX) USE ARITH
#      01100      TRIM DEGREES (XXX.XX DEG)    USE ARITH
#      01101      INERTIA (XXXXXXBB. SLUG FT FT) USE ARITH
#      01101      THRUST MOMENT (XXXXXXBB. FT LBS) USE ARITH

```

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```
#      01110      VELOCITY/2VS (XXXXX. FT/SEC)      USE ARITHDP4
#      01111      POSITION6 (XXXX.X NAUT MI)          USE ARITHDP3
#      10000      DRAG ACCELERATION (XXX.XX)         USE ARITHDP2
#      10001      POSITION8 (XXXX.X NAUT MI)          USE ARITHDP?
#      10010      POSITION9 (XXX.XX NAUT MI)          USE ARITHDP4
#      10011      VELOCITY4 (XXXX.X FT/SEC)          USE ARITHDP2
#
#      END OF SF CONSTANT CODE NUMBERS
```

```
# FOR GREATER THAN SINGLE PRECISION SCALES, PUT ADDRESS IN MAJOR PART INTO
# NOUN TABLES.
```

```
# OCTAL LOADS PLACE +0 INTO MAJOR PART, DATA INTO MINOR PART.
```

```
# OCTAL DISPLAYS SHOW MINOR PART ONLY.
```

```
# TO GET AT BOTH MAJOR AND MINOR PARTS (IN OCTAL), USE NOUN 01.
```

```
# A NOUN MAY BE DECLARED "DECIMAL ONLY" BY MAKING BIT4=1 OF ITS COMPONENT
# CODE NUMBER. IF THIS NOUN IS USED WITH ANY OCTAL DISPLAY VERB, OR IF
# DATA IS LOADED IN OCTAL, IT ALARMS.
```

```
# IN LOADING AN "HOURS, MINUTES, SECONDS" NOUN, ALL 3 WORDS MUST BE
# LOADED, OR ALARM.
```

```
# ALARM IF AN ATTEMPT IS MADE TO LOAD "SPLIT MINUTES/SECONDS" (MMBSS).
# THIS IS USED FOR DISPLAY ONLY.
```

```
# Page 270
```

```
# THE FOLLOWING ROUTINES ARE FOR READING THE NOUN TABLES AND THE SF TABLES
# (WHICH ARE IN A SEPARATE BANK FROM THE REST OF PINBALL). THESE READING
# ROUTINES ARE IN THE SAME BANK AS THE TABLES. THEY ARE CALLED BY DXCH Z.
```

```
# LODNNTAB LOADS NNADTEM WITH THE NNADTAB ENTRY, NNTYPTTEM WITH THE
# NNTYPTAB ENTRY. IF THE NOUN IS MIXED, IDADITEM IS LOADED WITH THE FIRST
# IDADDTAB ENTRY, IDAD2TEM THE SECOND IDADDTAB ENTRY, IDAD3TEM THE THIRD
# IDADDTAB ENTRY, RUTMXTEM WITH THE RUTMXTAB ENTRY. MIXBR IS SET FOR
# MIXED OR NORMAL NOUN.
```

```
BANK      06
SETLOC    PINBALL3
BANK
```

```
COUNT     42/NOUNS
```

```
LODNNTAB      DXCH      IDAD2TEM      # SAVE RETURN INFO IN IDAD2TEM, IDAD3TEM.
```

```

INDEX  NOUNREG
CAF    NNADTAB
TS     NNADTEM
INDEX  NOUNREG
CAF    NNTYPTAB
TS     NNTYPTM
CS     NOUNREG
AD     MIXCON
EXTEND
BZMF   LODMIXNN          # NOUN NUMBER G/E FIRST MIXED NOUN
CAF    ONE              # NOUN NUMBER L/ FIRST MIXED NOUN
TS     MIXBR            # NORMAL.  +1 INTO MIXBR
TC     LODNLV
LODMIXNN CAF    TWO          # MIXED.  +2 INTO MIXBR.
TS     MIXBR
INDEX  NOUNREG
CAF    RUTMXTAB -40D     # FIRST MIXED NOUN = 40.
TS     RUTMXTEM
CAF    LOW10
MASK   NNADTEM
TS     Q                # TEMP
INDEX  A
CAF    IDADDTAB
TS     IDAD1TEM         # LOAD IDAD1TEM WITH FIRST IDADDTAB EN
EXTEND
INDEX  Q                # LOAD IDAD2TEM WITH 2ND IDADDTAB EN
DCA    IDADDTAB +1      # LOAD IDAD3TEM WITH 3RD IDADDTAB EN
LODNLV DXCH  IDAD2TEM     # PUT RETURN INFO INTO A, L.
DXCH   Z

MIXCON =      OCT50      # FIRST MIXED NOUN =40.  (DEC 40)

# GTSFOUT LOADS SFTEMP1, SFTEMP2 WITH THE DP SFOUTAB ENTRIES.
# Page 271

GTSFOUT DXCH  SFTEMP1    # 2X (SFCONUM) ARRIVES IN SFTEMP1.
EXTEND
INDEX  A
DCA    SFOUTAB
SFCOM  DXCH  SFTEMP1
DXCH   Z

# GTSFIN LOADS SFTEMP1, SFTEMP2 WITH THE DP SFINTAB INTRIES.

GTSFIN  DXCH  SFTEMP1    # 2X (SFCONUM) ARIVES IN SFTEMP1.
EXTEND

```

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INDEX A  
DCA SFINTAB  
TCF SFCOM

|         |       | #         | NN   | NORMAL NOUNS                           |
|---------|-------|-----------|------|----------------------------------------|
| NNADTAB | OCT   | 00000     | # 00 | NOT IN USE                             |
|         | OCT   | 40000     | # 01 | SPECIFY MACHINE ADDRESS (FRACTIONAL)   |
|         | OCT   | 40000     | # 02 | SPECIFY MACHINE ADDRESS (WHOLE)        |
|         | OCT   | 40000     | # 03 | SPECIFY MACHINE ADDRESS (DEGREES)      |
|         | OCT   | 0         | # 04 | SPARE                                  |
|         | ECADR | DSPTM1    | # 05 | ANGULAR ERROR/DIFFERENCE               |
|         | ECADR | OPTION1   | # 06 | OPTION CODE                            |
|         | ECADR | XREG      | # 07 | ECADR OF WORD TO BE MODIFIED           |
|         |       |           | #    | ONES FOR BITS TO BE MODIFIED           |
|         |       |           | #    | 1 TO SET OR 0 TO RESET SELECTED BITS   |
|         | ECADR | ALMCADR   | # 08 | ALARM DATA                             |
|         | ECADR | FAILREG   | # 09 | ALARM CODES                            |
|         | OCT   | 77776     | # 10 | CHANNEL TO BE SPECIFIED                |
|         | ECADR | TCSI      | # 11 | TIG OF CSI (HRS,MIN,SEC)               |
|         | ECADR | OPTIONX   | # 12 | OPTION CODE                            |
|         |       |           | #    | (USED BY EXTENDED VERBS ONLY)          |
|         | ECADR | TCDH      | # 13 | TIG OF CDH (HRS,MIN,SEC)               |
|         | OCT   | 0         | # 14 | SPARE                                  |
|         | OCT   | 77777     | # 15 | INCREMENT MACHINE ADDRESS              |
|         | ECADR | DSPTMX    | # 16 | TIME OF EVENT (HRS,MIN,SEC)            |
|         | ECADR | CPHIX     | # 17 | ASTRONAUT TOTAL ATTITUDE               |
|         | ECADR | THETAD    | # 18 | AUTO MANEUVER BALL ANGLES              |
|         | ECADR | THETAD    | # 19 | BYPASS ATTITUDE TRIM MANEUVER          |
|         | ECADR | CDUX      | # 20 | ICDU ANGLES                            |
|         | ECADR | PIPAX     | # 21 | PIPAS                                  |
|         | ECADR | THETAD    | # 22 | NEW ICDU ANGLES                        |
|         | OCT   | 00000     | # 23 | SPARE                                  |
|         | ECADR | DSPTM2 +1 | # 24 | DELTA TIME FOR AGC CLOCK (HRS,MIN,SEC) |
|         | ECADR | DSPTM1    | # 25 | CHECKLIST                              |
|         |       |           | #    | (USED WITH PLEASE PERFORM ONLY)        |
|         | ECADR | DSPTM1    | # 26 | PRIO/DELAY, ADRES, BBCON               |
|         | ECADR | SMODE     | # 27 | SELF TEST ON/OFF SWITCH                |
|         | OCT   | 0         | # 28 | SPARE                                  |
|         | ECADR | DSPTM1    | # 29 | XSM LAUNCH AZIMUTH                     |
|         | ECADR | DSPTM1    | # 30 | TARGET CODES                           |
|         | ECADR | DSPTM1    | # 31 | TIME OF LANDING SITE (HRS,MIN,SEC)     |
|         | ECADR | -TPER     | # 32 | TIME TO PERIGEE (HRS,MIN,SEC)          |
|         | ECADR | TIG       | # 33 | TIME OF IGNITION (HRS,MIN,SEC)         |
|         | ECADR | DSPTM1    | # 34 | TIME OF EVENT (HRS,MIN,SEC)            |

ECADR TTOGO  
 ECADR TIME2  
 ECADR TTPI  
 ECADR TET  
 ECADR T3TOT4

# 35 TIME TO GO TO EVENT (HRS,MIN,SEC)  
 # 36 TIME OF AGC CLOCK (HRS,MIN,SEC)  
 # 37 TIG OF TPI (HRS,MIN,SEC)  
 # 38 TIME OF STATE VECTOR  
 # 39 DELTA TIME TO TRANSFER (HRS,MIN,SEC)

# END OF NNADTAB FOR NORMAL NOUNS

# NN MIXED NOUNS

OCT 64000

# 40 TIME TO IGNITION/CUTOFF  
 # VG

OCT 02003

# DELTA V (ACCUMULATED)  
 # 41 TARGET AZIMUTH  
 # ELEVATION

OCT 24006

# 42 APOGEE  
 # PERIGEE  
 # DELTA V (REQUIRED)

OCT 24011

# 43 LATITUDE  
 # LONGITUDE  
 # ALTITUDE

OCT 64014

# 44 APOGEE  
 # PERIGEE  
 # TFF

OCT 64017

# 45 MARKS (VHF - OPTIC)  
 # TTI OF NEXT BURN  
 # MGA

OCT 02022

# 46 AUTOPILOT CONFIGURATION

OCT 22025

# 47 THIS VEHICLE WEIGHT  
 # OTHER VEHICLE WEIGHT

OCT 22030

# 48 PITCH TRIM  
 # YAW TRIM

OCT 24033

# 49 DELTA R  
 # DELTA V  
 # VHF OR OPTICS CODE

OCT 64036

# 50 SPLASH ERROR  
 # PERIGEE  
 # TFF

OCT 22041

# 51 S-BAND ANTENNA PITCH  
 # YAW

OCT 00044

# 52 CENTRAL ANGLE OF ACTIVE VEHICLE

OCT 24047

# 53 RANGE  
 # RANGE RATE  
 # PHI

# Page 273

OCT 24052

# 54 RANGE



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|     |       |      |                                |
|-----|-------|------|--------------------------------|
|     |       | #    | RANGE RATE                     |
|     |       | #    | THETA                          |
| OCT | 24055 | # 55 | PERIGEE CODE                   |
|     |       | #    | ELEVATION ANGLE                |
|     |       | #    | CENTRAL ANGLE                  |
| OCT | 22060 | # 56 | REENTRY ANGLE,                 |
|     |       | #    | DELTA V                        |
| OCT | 20063 | # 57 | DELTA R                        |
| OCT | 24066 | # 58 | PERIGEE ALT                    |
|     |       | #    | DELTA V TPI                    |
|     |       | #    | DELTA V TPF                    |
| OCT | 24071 | # 59 | DELTA VELOCITY LOS             |
| OCT | 24074 | # 60 | GMAX                           |
|     |       | #    | VPRED                          |
|     |       | #    | GAMMA EI                       |
| OCT | 24077 | # 61 | IMPACT LATITUDE                |
|     |       | #    | IMPACT LONGITUDE               |
|     |       | #    | HEADS UP/DOWN                  |
| OCT | 24102 | # 62 | INERTIAL VEL MAG (V1)          |
|     |       | #    | ALT RATE CHANGE (HDOT)         |
|     |       | #    | ALT ABOVE PAD RADIUS (H)       |
| OCT | 64105 | # 63 | RANGE 297,431 TO SPLASH (RTGO) |
|     |       | #    | PREDICTED INERT VEL (VIO)      |
|     |       | #    | TIME TO GO TO 297,431 (TTE)    |
| OCT | 24110 | # 64 | DRAG ACCELERATION              |
|     |       | #    | INERTIAL VELOCITY (VI)         |
|     |       | #    | RANGE TO SPLASH                |
| OCT | 24113 | # 65 | SAMPLED AGC TIME (HRS,MIN,SEC) |
|     |       | #    | (FETCHED IN INTERRUPT)         |
| OCT | 24116 | # 66 | COMMAND BANK ANGLE (BETA)      |
|     |       | #    | CROSS RANGE ERROR              |
|     |       | #    | DOWN RANGE ERROR               |
| OCT | 24121 | # 67 | RANGE TO TARGET                |
|     |       | #    | PRESENT LATITUDE               |
|     |       | #    | PRESENT LONGITUDE              |
| OCT | 24124 | # 68 | COMMAND BANK ANGLE (BETA)      |
|     |       | #    | INERTIAL VELOCITY (VI)         |
|     |       | #    | ALT RATE CHANGE (RDOT)         |
| OCT | 24127 | # 69 | BETA                           |
|     |       | #    | DL                             |
|     |       | #    | VL                             |
| OCT | 04132 | # 70 | STAR CODE                      |
|     |       | #    | LANDMARK DATA                  |
|     |       | #    | HORIZON DATA                   |
| OCT | 04135 | # 71 | STAR CODE                      |
|     |       | #    | LANDMARK DATA                  |

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|  |       |      |                                 |
|--|-------|------|---------------------------------|
|  |       | #    | HORIZON DATA                    |
|  | OCT   | # 72 | DELT ANG                        |
|  | 24140 | #    | DELT ALT                        |
|  |       | #    | SEARCH OPTION                   |
|  | OCT   | # 73 | ALTITUDE                        |
|  | 04143 | #    | VELOCITY                        |
|  |       | #    | FLIGHT PATH ANGLE               |
|  | OCT   | # 74 | COMMAND BANK ANGLE (BETA)       |
|  | 04146 | #    | INERTIAL VELOCITY (VI)          |
|  |       | #    | DRAG ACCELERATION               |
|  | OCT   | # 75 | DELTA ALTITUDE CDH              |
|  | 64151 | #    | DELTA TIME (CDH-CSI OR TPI-CDH) |
|  |       | #    | DELTA TIME (TPI-CDH OR TPI-NO)  |
|  | OCT   | # 76 | SPARE                           |
|  | 0     | # 77 | SPARE                           |
|  | OCT   | # 78 | SPARE                           |
|  | 0     | # 79 | SPARE                           |
|  | OCT   | # 80 | TIME TO IGNITION/CUTOFF         |
|  | 64170 | #    | VG                              |
|  |       | #    | DELTA V (ACCUMULATED)           |
|  | OCT   | # 81 | DELTA V (LV)                    |
|  | 24173 | # 82 | DELTA V (LV)                    |
|  | OCT   | # 83 | DELTA V (BODY)                  |
|  | 24201 | # 84 | DELTA V (OTHER VEHICLE)         |
|  | OCT   | # 85 | VG (BODY)                       |
|  | 24204 | # 86 | DELTA V (LV)                    |
|  | OCT   | # 87 | MARK DATA                       |
|  | 24207 | #    | SHAFT                           |
|  | OCT   | #    | TRUNION                         |
|  | 24212 | # 88 | HALF UNIT SUN OR PLANET VECTOR  |
|  | OCT   | # 89 | LANDMARK                        |
|  | 02215 | #    | LATITUDE                        |
|  |       | #    | LONGITUDE/2                     |
|  |       | #    | ALTITUDE                        |
|  | OCT   | # 90 | Y                               |
|  | 24226 | #    | Y DOT                           |
|  |       | #    | PSI                             |
|  | OCT   | # 91 | OCDU ANGLES                     |
|  | 02231 | #    | SHAFT                           |
|  |       | #    | TRUNION                         |
|  | OCT   | # 92 | NEW OPTICS ANGLES               |
|  | 02234 | #    | SHAFT                           |
|  |       | #    | TRUNION                         |
|  | OCT   | # 93 | DELTA GYRO ANGLES               |
|  | 04237 | # 94 | NEW OPTICS ANGLES               |
|  | OCT   | #    | SHAFT                           |
|  | 02242 | #    | TRUNION                         |
|  |       | # 95 | PREFERRED ATTITUDE ICDU ANGLES  |
|  | OCT   | # 96 | +X-AXIS ATTITUDE ICDU ANGLES    |
|  | 04245 | # 97 | SYSTEM TEST INPUTS              |
|  | OCT   |      |                                 |
|  | 04250 |      |                                 |
|  | 04253 |      |                                 |

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OCT 04256  
OCT 24261

# 98 SYSTEM TEST RESULTS  
# 99 RMS IN POSITION  
# RMS IN VELOCITY  
# RMS OPTION

# END OF NNADTAB FOR MIXED NOUNS

# Page 275

NNTYPTAB

OCT 00000  
OCT 04040  
OCT 04140  
OCT 04102  
OCT 0  
OCT 00504  
OCT 02000  
OCT 04000  
OCT 04000  
OCT 04000  
OCT 00000  
OCT 24400  
OCT 02000  
OCT 24400  
OCT 0  
OCT 00000  
OCT 24400  
OCT 04102  
OCT 04102  
OCT 04102  
OCT 04102  
OCT 04140  
OCT 04102  
OCT 00000  
OCT 24400  
OCT 04140  
OCT 04000  
OCT 00140  
OCT 00000  
OCT 20102  
OCT 04140  
OCT 24400  
OCT 24400  
OCT 24400  
OCT 24400  
OCT 24400  
OCT 24400  
OCT 24400

# NN NORMAL NOUNS

# 00 NOT IN USE  
# 01 3COMP FRACTIONAL  
# 02 3COMP WHOLE  
# 03 3COMP CDU DEGREES  
# 04 SPARE  
# 05 1COMP DPDEG(360)  
# 06 2COMP OCTAL ONLY  
# 07 3COMP OCTAL ONLY  
# 08 3COMP OCTAL ONLY  
# 09 3COMP OCTAL ONLY  
# 10 1COMP OCTAL ONLY  
# 11 3COMP HMS (DEC ONLY)  
# 12 2COMP OCTAL ONLY  
# 13 3COMP HMS (DEC ONLY)  
# 14 SPARE  
# 15 1COMP OCTAL ONLY  
# 16 3COMP HMS (DEC ONLY)  
# 17 3COMP CDU DEG  
# 18 3COMP CDU DEG  
# 19 3COMP CDU DEG  
# 20 3COMP CDU DEGREES  
# 21 3COMP WHOLE  
# 22 3COMP CDU DEGREES  
# 23 SPARE  
# 24 3COMP HMS (DEC ONLY)  
# 25 3COMP WHOLE  
# 26 3COMP OCTAL ONLY  
# 27 1COMP WHILE  
# 28 SPARE  
# 29 1COMP CDU DEG (DEC ONLY)  
# 30 3COMP WHOLE  
# 31 3COMP HMS (DEC ONLY)  
# 32 3COMP HMS (DEC ONLY)  
# 33 3COMP HMS (DEC ONLY)  
# 34 3COMP HMS (DEC ONLY)  
# 35 3COMP HMS (DEC ONLY)  
# 36 3COMP HMS (DEC ONLY)

OCT 24400  
 OCT 24400  
 OCT 24400

# 37 3COMP HMS (DEC ONLY)  
 # 38 3COMP HMS (DEC ONLY)  
 # 39 3COMP HMS (DEC ONLY)

# END OF NNTYPTAB FOR NORMAL NOUNS

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OCT 24500  
 OCT 00542  
 OCT 24410  
 OCT 20204  
 OCT 00410  
 OCT 10000  
 OCT 00000  
 OCT 00306  
 OCT 00614  
 OCT 00510  
 OCT 00417  
 OCT 00204  
 OCT 00004  
 OCT 10507  
 OCT 10507  
 OCT 10200  
 OCT 00444  
 OCT 00010  
 OCT 24510  
 OCT 24512

# NN MIXED NOUNS

# 40 3COMP MIN/SEC, VEL3, VEL3  
 # (NO LOAD, DEC ONLY)  
 # 41 2COMP CDU DEG, ELEV DEG  
 # 42 3COMP POS4, POS4, VEL3  
 # (DEC ONLY)  
 # 43 3COMP DPDEG(360), DPDEG(360)  
 # (DEC ONLY)  
 # 44 3COMP POS4, POS4, MIN/SEC  
 # (NO LOAD, DEC ONLY)  
 # 45 3COMP 2INT, MIN/SEC, DPDEG  
 # (NO LOAD, DEC ONLY)  
 # 46 2COMP OCTAL ONLY FOR EACH  
 # 47 2COMP WEIGHT2 FOR EACH  
 # (DEC ONLY)  
 # 48 2COMP TRIM DEG, TRIM DEG  
 # (DEC ONLY)  
 # 49 3COMP POS4, VEL3, WHOLE  
 # (DEC ONLY)  
 # 50 3COMP POS6, POS4, MIN/SEC  
 # (NO LOAD, DEC ONLY)  
 # 51 2COMP DPDEG(360), DPDEG(360)  
 # (DEC ONLY)  
 # 52 1COMP DPDEG(360)  
 # 53 3COMP POS5, VEL3, DPDEG(360)  
 # (DEC ONLY)  
 # 54 3COMP POS5, VEL3, DPDEG(360)  
 # (DEC ONLY)  
 # 55 3COMP WHOLE, DPDEG(360), DPDEG(360)  
 # (DEC ONLY)  
 # 56 2COMP DPDEG(360), VEL2  
 # (DEC ONLY)  
 # 57 1COMP POS4  
 # (DEC ONLY)  
 # 58 3COMP POS4, VEL3, VEL3  
 # (DEC ONLY)  
 # 59 3COMP VEL3 FOR EACH  
 # (DEC ONLY)

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|            |     |       |      |       |                                 |
|------------|-----|-------|------|-------|---------------------------------|
|            | OCT | 10440 | # 60 | 3COMP | WHOLE, VEL2, DPDEG(360)         |
|            |     |       | #    |       | (DEC ONLY)                      |
|            | OCT | 00204 | # 61 | 3COMP | DPDEG(360), DPDEG(360), WHOLE   |
|            |     |       | #    |       | (DEC ONLY)                      |
|            | OCT | 20451 | # 62 | 3COMP | VEL2, VEL2, POS4                |
|            |     |       | #    |       | (DEC ONLY)                      |
|            | OCT | 00457 | # 63 | 3COMP | POS6, VEL2, MIN/SEC             |
|            |     |       | #    |       | (NO LOAD, DEC ONLY)             |
|            | OCT | 36460 | # 64 | 3COMP | DRAG ACCEL, VEL2, POS6          |
|            |     |       | #    |       | (DEC ONLY)                      |
|            | OCT | 00000 | # 65 | 3COMP | HMS (DEC ONLY)                  |
|            | OCT | 37044 | # 66 | 3COMP | DPDEG(360), POS8, POS6          |
|            |     |       | #    |       | (DEC ONLY)                      |
|            | OCT | 10217 | # 67 | 3COMP | POS6, DPDEG(360), DPDEG(360)    |
|            |     |       | #    |       | (DEC ONLY)                      |
|            | OCT | 34444 | # 68 | 3COMP | DPDEG(360), VEL2, VEL/2VS       |
|            |     |       | #    |       | (DEC ONLY)                      |
|            | OCT | 35004 | # 69 | 3COMP | DPDEG(360), DRAG ACCEL, VEL/2VS |
|            |     |       | #    |       | (DEC ONLY)                      |
| # Page 277 |     |       |      |       |                                 |
|            | OCT | 00000 | # 70 | 3COMP | OCTAL ONLY FOR EACH             |
|            | OCT | 0     | # 71 | 3COMP | OCTAL ONLY FOR EACH             |
|            | OCT | 00404 | # 72 | 3COMP | DPDEG(360), POS4, WHOLE         |
|            |     |       | #    |       | (DEC ONLY)                      |
|            | OCT | 10450 | # 73 | 3COMP | POS4, VEL2, DPDEG(360)          |
|            | OCT | 40444 | # 74 | 3COMP | DPDEG(360), VEL2, DRAG ACCEL    |
|            | OCT | 00010 | # 75 | 3COMP | POS4, MIN/SEC, MIN/SEC          |
| #          |     |       | #    |       | (NO LOAD, DEC ONLY)             |
|            | OCT | 0     | # 76 | SPARE |                                 |
|            | OCT | 0     | # 77 | SPARE |                                 |
|            | OCT | 0     | # 78 | SPARE |                                 |
|            | OCT | 0     | # 79 | SPARE |                                 |
|            | OCT | 22440 | # 80 | 3COMP | MIN/SEC, VEL2, VEL2             |
|            |     |       | #    |       | (NO LOAD, DEC ONLY)             |
|            | OCT | 24512 | # 81 | 3COMP | VEL3 FOR EACH                   |
|            |     |       | #    |       | (NO LOAD, DEC ONLY)             |
|            | OCT | 24512 | # 82 | 3COMP | VEL3 FOR EACH                   |
|            |     |       | #    |       | (NO LOAD, DEC ONLY)             |
|            | OCT | 24512 | # 83 | 3COMP | VEL3 FOR EACH                   |
|            |     |       | #    |       | (DEC ONLY)                      |
|            | OCT | 24512 | # 84 | 3COMP | VEL3 FOR EACH                   |
|            |     |       | #    |       | (DEC ONLY)                      |
|            | OCT | 24512 | # 85 | 3COMP | VEL3 FOR EACH                   |
|            |     |       | #    |       | (DEC ONLY)                      |
|            | OCT | 22451 | # 86 | 3COMP | VEL2 FOR EACH                   |
|            |     |       | #    |       | (DEC ONLY)                      |

|                                   |     |       |      |                                    |
|-----------------------------------|-----|-------|------|------------------------------------|
|                                   |     |       | #    | (DEC ONLY)                         |
|                                   | OCT | 00102 | # 87 | 2COMP CDU DEG, Y OPTICS DEG        |
|                                   | OCT | 0     | # 88 | 3COMP FRAC FOR EACH                |
|                                   |     |       | #    | (DEC ONLY)                         |
|                                   | OCT | 16143 | # 89 | 3COMP DPDEG(90), DPDEG(90)         |
|                                   |     |       | #    | (DEC ONLY)                         |
|                                   | OCT | 10507 | # 90 | 3COMP POS5, VEL3, DEPDEG(30)       |
|                                   |     |       | #    | (DEC ONLY)                         |
|                                   | OCT | 00102 | # 91 | 2COMP CDUDEG, YOPTICS DEG          |
|                                   | OCT | 00102 | # 92 | 2COMP CDUDEG, YOPTICS DEG          |
|                                   | OCT | 06143 | # 93 | 3COMP DPDEG(90) FOR EACH           |
|                                   | OCT | 00102 | # 94 | 2COMP CDUDEG, YOPTICS DEG          |
|                                   | OCT | 04102 | # 95 | 3COMP CDU DEG FOR EACH             |
|                                   | OCT | 04102 | # 96 | 3COMP CDU DEG FOR EACH             |
|                                   | OCT | 00000 | # 97 | 3COMP WHOLE FOR EACH               |
|                                   | OCT | 00000 | # 98 | 3COMP WHOLE, FRAC, WHOLE           |
|                                   | OCT | 01162 | # 99 | 3COMP POS9, VEL4, WHOLE            |
|                                   |     |       | #    | (DEC ONLY)                         |
| # END OF NNTYPTAB FOR MIXED NOUNS |     |       |      |                                    |
| SFINTAB                           | OCT | 00006 | #    | WHOLE, DP TIME (SEC)               |
|                                   | OCT | 03240 |      |                                    |
|                                   | OCT | 00000 | #    | SPARE                              |
|                                   | OCT | 00000 |      |                                    |
| # Page 278                        |     |       |      |                                    |
|                                   | OCT | 00000 | #    | CDU DEGREES, Y OPTICS DEGREES      |
|                                   | OCT | 00000 | #    | (SFCONS IN DEGINSF, OPTDEGIN)      |
|                                   | OCT | 10707 | #    | DP DEGREES (90)                    |
|                                   | OCT | 03435 | #    | UPPED BY 1                         |
|                                   | OCT | 13070 | #    | DP DEGREES (360) (POINT BETWN BITS |
|                                   | OCT | 34345 | #    | UPPED BY 1                         |
|                                   | OCT | 00005 | #    | DEGREES (180)                      |
|                                   | OCT | 21616 |      |                                    |
|                                   | OCT | 26113 | #    | WEIGHT2                            |
|                                   | OCT | 31713 |      |                                    |
|                                   | OCT | 00070 | #    | POSITION5                          |
|                                   | OCT | 20460 |      |                                    |
|                                   | OCT | 01065 | #    | POSITION4                          |
|                                   | OCT | 05740 |      |                                    |
|                                   | OCT | 11414 | #    | VELOCITY2 (POINT BETWN BITS 11-    |
|                                   | OCT | 31463 |      |                                    |
|                                   | OCT | 07475 | #    | VELOCITY3                          |
|                                   | OCT | 16051 |      |                                    |
|                                   | OCT | 00001 | #    | ELEVATION DEGREES                  |
|                                   | OCT | 03434 |      |                                    |

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|                  |      |            |                                            |
|------------------|------|------------|--------------------------------------------|
|                  | OCT  | 00002      | # TRIM DEGREES                             |
|                  | OCT  | 22245      |                                            |
|                  | OCT  | 00014      | # INERTIA, THRUST MOMENT                   |
|                  | OCT  | 35607      |                                            |
|                  | OCT  | 07606      | # VELOCITY/2VS                             |
|                  | OCT  | 06300      |                                            |
|                  | OCT  | 16631      | # POSITION 6                               |
|                  | OCT  | 11307      |                                            |
|                  | OCT  | 12000      | # DRAG ACCELERATION (POINT BETWN BITS 7-8) |
|                  | OCT  | 00000      |                                            |
|                  | OCT  | 27176      | # POSITION 8                               |
|                  | OCT  | 14235      |                                            |
|                  | 2DEC | 30480 B-19 | # POSITION 9                               |
|                  |      |            |                                            |
|                  | 2DEC | 30.48 B-7  | # VELOCITY4                                |
|                  |      |            |                                            |
| # END OF SFINTAB |      |            |                                            |
| SFOUTAB          | OCT  | 05174      | # WHOLE, DP TIME (SEC)                     |
|                  | OCT  | 13261      |                                            |
|                  | OCT  | 00000      | # SPARE                                    |
|                  | OCT  | 00000      |                                            |
|                  | OCT  | 00000      | # CDU DEGREES, Y OPTICS DEGREES            |
|                  | OCT  | 00000      | # (SFCONS IN DEGOUTSF, OPTDEGOUT)          |
|                  | OCT  | 00714      | # DP DEGREES (90) (POINT BETWN BITS 7-8)   |
|                  | OCT  | 31463      |                                            |
|                  | OCT  | 13412      | # DP DEGREES (360)                         |
|                  | OCT  | 07534      |                                            |
|                  | OCT  | 05605      | # DEGREES (180)                            |
| # Page 279       |      |            |                                            |
|                  | OCT  | 03656      |                                            |
|                  | OCT  | 00001      | # WEIGHT2                                  |
|                  | OCT  | 16170      |                                            |
|                  | OCT  | 00441      | # POSITION5                                |
|                  | OCT  | 34306      |                                            |
|                  | OCT  | 07176      | # POSITION4                                |
|                  | OCT  | 21603      |                                            |
|                  | OCT  | 15340      | # VELOCITY2                                |
|                  | OCT  | 15340      |                                            |
|                  | OCT  | 01031      | # VELOCITY3 (POINT BETWN BITS 7-8)         |
|                  | OCT  | 21032      |                                            |
|                  | OCT  | 34631      | # ELEVATION DETREES                        |
|                  | OCT  | 23146      |                                            |
|                  | OCT  | 14340      | # TRIM DEGREES                             |
|                  | OCT  | 24145      |                                            |
|                  | OCT  | 02363      | # INERTIA, THRUST MOMENT                   |

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|      |                |                                     |
|------|----------------|-------------------------------------|
| OCT  | 03721          |                                     |
| OCT  | 20373          | # VELOCITY/ZVS                      |
| OCT  | 02122          |                                     |
| OCT  | 00424          | # POSITION 6 (POINT BETWN BITS 7-8) |
| OCT  | 30446          |                                     |
| OCT  | 00631          | # DRAG ACCELERATION                 |
| OCT  | 23146          |                                     |
| OCT  | 00260          | # POSITION 8                        |
| OCT  | 06213          |                                     |
| 2DEC | 17.2010499 B-7 | # POSITION 9                        |
| 2DEC | .032808399     | # VELOCITY4                         |

# END OF SFOUTAB

|            |                 | # NN | SF CONSTANT     | SF RO |
|------------|-----------------|------|-----------------|-------|
| IDADDTAB   | ECADR TTOGO     | # 40 | MIN/SEC         | M/S   |
|            | ECADR VGDISP    | # 40 | VEL3            | DP3   |
|            | ECADR DVTOTAL   | # 40 | VEL3            | DP3   |
|            | ECADR DSPTM1    | # 41 | CDU DEG         | CDU   |
|            | ECADR DSPTM1 +1 | # 41 | ELEV DEG        | ARTH  |
|            | OCT 0           | # 41 | SPARE COMPONENT |       |
|            | ECADR HAPO      | # 42 | POS4            | DP3   |
|            | ECADR HPER      | # 42 | POS4            | DP3   |
|            | ECADR VGDISP    | # 42 | VEL3            | DP3   |
|            | ECADR LAT       | # 43 | DPDEG(360)      | DP4   |
|            | ECADR LONG      | # 43 | DPDEG(360)      | DP4   |
|            | ECADR ALT       | # 43 | POS4            | DP3   |
|            | ECADR HAPOX     | # 44 | POS4            | DP3   |
|            | ECADR HPERX     | # 44 | POS4            | DP3   |
|            | ECADR TFF       | # 44 | MIN/SEC         | M/S   |
|            | ECADR VHFCNT    | # 45 | 2INT            | 2INT  |
| # Page 280 | ECADR TTOGO     | # 45 | MIN/SEC         | M/S   |
|            | ECADR +MGA      | # 45 | DPDEG(360)      | DP4   |
|            | ECADR DAPDATR1  | # 46 | OCTAL ONLY      | OCT   |
|            | ECADR DAPDATR2  | # 46 | OCATAL ONLY     | OCT   |
|            | OCT 0           | # 46 | SPARE COMPONENT |       |
|            | ECADR CSMMASS   | # 47 | WEIGHT2         | ARTH  |
|            | ECADR LEMMASS   | # 47 | WEIGHT2         | ARTH  |
|            | OCT 00000       | # 47 | SPARE COMPONENT |       |
|            | ECADR PACTOFF   | # 48 | TRIM DEG2       | ARTH  |
|            | ECADR YACTOFF   | # 48 | TRIM DEG2       | ARTH  |
|            | OCT 00000       | # 48 | SPARE COMPONENT |       |
|            | ECADR N49DISP   | # 49 | POS4            | DP3   |



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|       |            |      |                 |      |
|-------|------------|------|-----------------|------|
| ECADR | N49DISP +2 | # 49 | VEL3            | DP3  |
| ECADR | N49DISP +4 | # 49 | WHOLE           | ARTH |
| ECADR | RSP-RREC   | # 50 | POS6            | DP3  |
| ECADR | HPERX      | # 50 | POS4            | DP3  |
| ECADR | TFF        | # 50 | MIN/SEC         | M/S  |
| ECADR | RHOSB      | # 51 | DPDEG(360)      |      |
| ECADR | GAMMASB    | # 51 | DPDEG(360)      | DP4  |
| OCT   | 0          | # 51 | SPARE COMPONENT |      |
| ECADR | ACTCENT    | # 52 | DPDEG(360)      | DP4  |
| OCT   | 00000      | # 52 | SPARE COMPONENT |      |
| OCT   | 00000      | # 52 | SPARE COMPONENT |      |
| ECADR | RANGE      | # 53 | POS5            | DP1  |
| ECADR | RRATE      | # 53 | VEL3            | DP3  |
| ECADR | RTHETA     | # 53 | DPDEG(360)      | DP4  |
| ECADR | RANGE      | # 54 | POS5            | DP1  |
| ECADR | RRATE      | # 54 | VEL3            | DP3  |
| ECADR | RTHETA     | # 54 | DPDEG(360)      | DP4  |
| ECADR | NN1        | # 55 | WHOLE           | ARTH |
| ECADR | ELEV       | # 55 | DPDEG(360)      | DP4  |
| ECADR | CENTANG    | # 55 | DPDEG(360)      | DP4  |
| ECADR | RTEGAM2D   | # 56 | DPDEG(360)      | DP4  |
| ECADR | RTEDVD     | # 56 | VEL2            | DP4  |
| OCT   | 0          | # 56 | SPARE COMPONENT |      |
| ECADR | DELTAR     | # 57 | POS4            | DP3  |
| OCT   | 0          | # 57 | SPARE COMPONENT |      |
| OCT   | 0          | # 57 | SPARE COMPONENT |      |
| ECADR | POSTTPI    | # 58 | POS4            | DP3  |
| ECADR | DELVTPI    | # 58 | VEL3            | DP3  |
| ECADR | DELVTPI    | # 58 | VEL3            | DP3  |
| ECADR | DVLOS      | # 59 | VEL3            | DP3  |
| ECADR | DVLOS +2   | # 59 | VEL3            | DP3  |
| ECADR | DVLOS +4   | # 59 | VEL3            | DP3  |
| ECADR | GMAX       | # 60 | WHOLE           | ARTH |
| ECADR | VPRED      | # 60 | VEL2            | DP4  |
| ECADR | GAMMAEI    | # 60 | DPDEG(360)      | DP4  |
| ECADR | LAT(SPL)   | # 61 | DPDEG(360)      | DP4  |
| ECADR | LNG(SPL)   | # 61 | DPDEG(360)      | DP4  |
| ECADR | HEADSUP    | # 61 | WHOLE           | ARTH |
| ECADR | VMAGI      | # 62 | VEL2            | DP4  |
| ECADR | HDOT       | # 62 | VEL2            | DP4  |
| ECADR | ALTI       | # 62 | POS4            | DP3  |
| ECADR | RTGO       | # 63 | POS6            | DP3  |
| ECADR | VIO        | # 63 | VEL2            | DP4  |
| ECADR | TTE        | # 63 | MIN/SEC         | M/S  |
| ECADR | D          | # 64 | DRAG ACCEL      | DP2  |

|       |          |      |                              |      |
|-------|----------|------|------------------------------|------|
| ECADR | VMAGI    | # 64 | VEL2                         | DP4  |
| ECADR | RTGON64  | # 64 | POS6                         | DP3  |
| ECADR | SAMPTIME | # 65 | HMS (MIXED ONLY TO KEEP CODE |      |
| ECADR | SAMPTIME | # 65 | HMS                          | HMS  |
| ECADR | SAMPTIME | # 65 | HMS                          | HMS  |
| ECADR | ROLLC    | # 66 | DPDEG(360)                   | DP4  |
| ECADR | XRNGERR  | # 66 | POS8                         | DP3  |
| ECADR | DNRNGERR | # 66 | POS6                         | DP3  |
| ECADR | RTGON67  | # 67 | POS6                         | DP3  |
| ECADR | LAT      | # 67 | DPDEG(360)                   | DP4  |
| ECADR | LONG     | # 67 | DPDEG(360)                   | DP4  |
| ECADR | ROLLC    | # 68 | DPDEG(360)                   | DP4  |
| ECADR | VMAGI    | # 68 | VEL2                         | DP4  |
| ECADR | RDOT     | # 68 | VEL/2VS                      | DP4  |
| ECADR | ROLLC    | # 69 | DPDEG(360)                   | DP4  |
| ECADR | Q7       | # 69 | DRAG ACCEL                   | DP2  |
| ECADR | VL       | # 69 | VEL/2VS                      | DP4  |
| ECADR | STARCODE | # 70 | OCTAL ONLY                   | OCT  |
| ECADR | LANDMARK | # 70 | OCTAL ONLY                   | OCT  |
| ECADR | HORIZON  | # 70 | OCTAL ONLY                   | OCT  |
| ECADR | STARCODE | # 71 | OCTAL ONLY                   | OCT  |
| ECADR | LANDMARK | # 71 | OCTAL ONLY                   | OCT  |
| ECADR | HORIZON  | # 71 | OCTAL ONLY                   | OCT  |
| ECADR | THETZERO | # 72 | DPDEG(360)                   | DP4  |
| ECADR | DELHITE  | # 72 | POS4                         | DP3  |
| ECADR | OPTION2  | # 72 | WHOLE                        | ARTH |
| ECADR | P21ALT   | # 73 | POS4                         | DP3  |
| ECADR | P21VEL   | # 73 | VEL2                         | DP4  |
| ECADR | P21GAM   | # 73 | DPDEG(360)                   | DP4  |
| ECADR | ROLLC    | # 74 | DPDEG(360)                   | DP4  |
| ECADR | VMAGI    | # 74 | VEL 2                        | DP4  |
| ECADR | D        | # 74 | DRAG ACCEL                   | DP2  |
| ECADR | DIFFALT  | # 75 | POS4                         | DP3  |
| ECADR | T1TOT2   | # 75 | MIN/SEC                      | M/S  |
| ECADR | T2TOT3   | # 75 | MIN/SEC                      | M/S  |
| OCT   | 0        | # 76 | SPARE                        |      |
| OCT   | 0        | # 76 | SPARE                        |      |
| OCT   | 0        | # 76 | SPARE                        |      |
| OCT   | 0        | # 77 | SPARE                        |      |
| OCT   | 0        | # 77 | SPARE                        |      |
| OCT   | 0        | # 77 | SPARE                        |      |
| OCT   | 0        | # 78 | SPARE                        |      |
| OCT   | 0        | # 78 | SPARE                        |      |
| OCT   | 0        | # 78 | SPARE                        |      |
| OCT   | 0        | # 79 | SPARE                        |      |
| OCT   | 0        | # 79 | SPARE                        |      |

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|       |             |      |                 |        |
|-------|-------------|------|-----------------|--------|
| OCT   | 0           | # 79 | SPARE           |        |
| OCT   | 0           | # 79 | SPARE           |        |
| ECADR | TTGO        | # 80 | MIN/SEC         | M/S    |
| ECADR | VGDISP      | # 80 | VEL2            | DP4    |
| ECADR | DVTOTAL     | # 80 | VEL2            | DP4    |
| ECADR | DELVLVC     | # 81 | VEL3            | DP3    |
| ECADR | DELVLVC +2  | # 81 | VEL3            | DP3    |
| ECADR | DELVLVC +4  | # 81 | VEL3            | DP3    |
| ECADR | DELVLVC     | # 82 | VEL3            | DP3    |
| ECADR | DELVLVC +2  | # 82 | VEL3            | DP3    |
| ECADR | DELVLVC +4  | # 82 | VEL3            | DP3    |
| ECADR | DELVIMU     | # 83 | VEL3            | DP3    |
| ECADR | DELVIMU +2  | # 83 | VEL3            | DP3    |
| ECADR | DELVIMU +4  | # 83 | VEL3            | DP3    |
| ECADR | DELVOV      | # 84 | VEL3            | DP3    |
| ECADR | DELVOV +2   | # 84 | VEL3            | DP3    |
| ECADR | DELVOV +4   | # 84 | VEL3            | DP3    |
| ECADR | VGBODY      | # 85 | VEL3            | DP3    |
| ECADR | VGBODY +2   | # 85 | VEL3            | DP3    |
| ECADR | VGBODY +4   | # 85 | VEL3            | DP3    |
| ECADR | DELVLVC     | # 86 | VEL3            | DP3    |
| ECADR | DELVLVC +2  | # 86 | VEL3            | DP3    |
| ECADR | DELVLVC +4  | # 86 | VEL3            | DP3    |
| ECADR | MRKBUF1 +3  | # 87 | CDU DEG         | CDU    |
| ECADR | MRKBUF1 +5  | # 87 | Y OPTICS DEG    | YOPT   |
| OCT   | 0           | # 87 | SPARE COMPONENT |        |
| ECADR | STARSAV3    | # 88 | DPFRAC          | DPFRAC |
| ECADR | STARSAV3 +2 | # 88 | DPFRAC          | DPFRAC |
| ECADR | STARSAV3 +4 | # 88 | DPFRAC          | DPFRAC |
| ECADR | LANDLAT     | # 89 | DPDEG(90)       | DP3    |
| ECADR | LANDLONG    | # 89 | DPDEG(90)       | DP3    |
| ECADR | LANDALT     | # 89 | POS5            | DP1    |
| ECADR | RANGE       | # 90 | POS5            | DP1    |
| ECADR | RRATE       | # 90 | VEL3            | DP3    |
| ECADR | RTHETA      | # 90 | DPDEG(360)      | DP4    |
| ECADR | CDUS        | # 91 | CDU DEG         | CDU    |
| ECADR | CDUT        | # 91 | Y OPTICS DEG    | YOPT   |
| OCT   | 0           | # 91 | SPARE COMPONENT |        |
| ECADR | SAC         | # 92 | CDU DEG         | CDU    |
| ECADR | PAC         | # 92 | Y OPTICS DEG    | YOPT   |
| OCT   | 0           | # 92 | SPARE COMPONENT |        |
| ECADR | OGC         | # 93 | DPDEG(90)       | DP3    |
| ECADR | OGC +2      | # 93 | DPDEG(90)       | DP3    |
| ECADR | OGC +4      | # 93 | DPDEG(90)       | DP3    |
| ECADR | MRKBUF1 +3  | # 94 | CDU DEG         | CDU    |
| ECADR | MRKBUF1 +5  | # 94 | Y OPTICS DEG    | YOPT   |

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|       |           |      |         |      |
|-------|-----------|------|---------|------|
| OCT   | 00000     | # 94 | SPARE   |      |
| ECADR | PRAXIS    | # 95 | CDU DEG | CDU  |
| ECADR | PRAXIS +1 | # 95 | CDU DEG | CDU  |
| ECADR | PRAXIS +2 | # 95 | CDU DEG | CDU  |
| ECADR | CPHIX     | # 96 | CDU DEG | CDU  |
| ECADR | CPHIX +1  | # 96 | CDU DEG | CDU  |
| ECADR | CPHIX +2  | # 96 | CDU DEG | CDU  |
| ECADR | DSPTM1    | # 97 | WHOLE   | ARTH |
| ECADR | DSPTM1 +1 | # 97 | WHOLE   | ARTH |
| ECADR | DSPTM1 +2 | # 97 | WHOLE   | ARTH |
| ECADR | DSPTM2    | # 98 | WHOLE   | ARTH |
| ECADR | DSPTM2 +1 | # 98 | FRAC    | FRAC |
| ECADR | DSPTM2 +2 | # 98 | WHOLE   | ARTH |
| ECADR | WWPOS     | # 99 | POS9    | DP3  |
| ECADR | WWVEL     | # 99 | VEL4    | DP2  |
| ECADR | WWOPT     | # 99 | WHOLE   | ARTH |

# END OF IDADDTAB

# NN SF ROUTINES

|         |     |       |      |                |
|---------|-----|-------|------|----------------|
| RUTMTAB | OCT | 16351 | # 40 | M/S, DP3, DP3  |
|         | OCT | 00142 | # 41 | CDU, ARTH      |
|         | OCT | 16347 | # 42 | DP3, DP3, DP3  |
|         | OCT | 16512 | # 43 | DP4, DP4, DP3  |
|         | OCT | 22347 | # 44 | DP3, DP3, M/S  |
|         | OCT | 24454 | # 45 | 2INT, M/S, DP4 |
|         | OCT | 00000 | # 46 | OCT, OCT       |
|         | OCT | 00553 | # 47 | ARITH1, ARITH1 |
|         | OCT | 00143 | # 48 | ARTH, ARTH     |
|         | OCT | 06347 | # 49 | DP3, DP3, ARTH |
|         | OCT | 22347 | # 50 | DP3, DP3, M/S  |
|         | OCT | 00512 | # 51 | DP4, DP4       |
|         | OCT | 00012 | # 52 | DP4            |
|         | OCT | 24344 | # 53 | DP1, DP3, DP4  |
|         | OCT | 24344 | # 54 | DP1, DP3, DP4  |
|         | OCT | 24503 | # 55 | ARTH, DP4, DP4 |
|         | OCT | 00512 | # 56 | DP4, DP4       |
|         | OCT | 00007 | # 57 | DP3            |
|         | OCT | 16347 | # 58 | DP3, DP3, DP3  |
|         | OCT | 16347 | # 59 | DP3, DP3, DP3  |
|         | OCT | 24503 | # 60 | ARTH, DP4, DP4 |
|         | OCT | 06512 | # 61 | DP4, DP4, ARTH |
|         | OCT | 16512 | # 62 | DP4, DP4, DP3  |
|         | OCT | 22507 | # 63 | DP3, DP4, M/S  |

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|            |       |      |                  |
|------------|-------|------|------------------|
| OCT        | 16505 | # 64 | DP2, DP4, DP3    |
| OCT        | 20410 | # 65 | HMS, HMS, HMS    |
| OCT        | 16352 | # 66 | DP4, DP3, DP3    |
| OCT        | 24507 | # 67 | DP3, DP4, DP4    |
| OCT        | 24512 | # 68 | DP4, DP4, DP4    |
| OCT        | 24252 | # 69 | DP4, DP2, DP4    |
| OCT        | 00000 | # 70 | OCT, OCT, OCT    |
| # Page 284 |       |      |                  |
| OCT        | 0     | # 71 | OCT, OCT, OCT    |
| OCT        | 06352 | # 72 | DP4, DP3, ARTH   |
| OCT        | 24507 | # 73 | DPR, DP4, DP4    |
| OCT        | 12512 | # 74 | DP4, DP4, DP2    |
| OCT        | 22447 | # 75 | DP3, M/S, M/S    |
| OCT        | 0     | # 76 | SPARE            |
| OCT        | 0     | # 77 | SPARE            |
| OCT        | 0     | # 78 | SPARE            |
| OCT        | 0     | # 79 | SPARE            |
| OCT        | 24511 | # 80 | M/S, DP4, DP4    |
| OCT        | 16347 | # 81 | DP3, DP3, DP3    |
| OCT        | 16347 | # 82 | DP3, DP3, DP3    |
| OCT        | 16347 | # 83 | DP3, DP3, DP3    |
| OCT        | 16347 | # 84 | DP3, DP3, DP3    |
| OCT        | 16347 | # 85 | DP3, DP3, DP3    |
| OCT        | 24512 | # 86 | DP4, DP4, DP4    |
| OCT        | 00302 | # 87 | CDU, YOPT        |
| OCT        | 32655 | # 88 | DPFRAC FOR EACH  |
| OCT        | 10347 | # 89 | DP3, DP3, DP1    |
| OCT        | 24344 | # 90 | DP1, DP3, DP4    |
| OCT        | 00302 | # 91 | CDU, YOPT        |
| OCT        | 00302 | # 92 | CDU, YOPT        |
| OCT        | 16347 | # 93 | DP3, DP3, DP3    |
| OCT        | 00302 | # 94 | CDU, YOPT        |
| OCT        | 04102 | # 95 | CDU, CDU, CDU    |
| OCT        | 04102 | # 96 | CDU, CDU, CDU    |
| OCT        | 06143 | # 97 | ARTH, ARTH, ARTH |
| OCT        | 06043 | # 98 | ARTH, FRAC, ARTH |
| OCT        | 06247 | # 99 | DP3, DP2, ARTH   |

# END OF RUTMTAB

SBANK= LOWSUPER

This code is written to file src/PINBALL-NOUN-TABLES.s.

## A.81 PLANETARY INERTIAL ORIENTATION

```

1486  <src/PLANETARY-INERTIAL-ORIENTATION.s 1486>≡
      # Copyright:    Public domain.
      # Filename:     PLANETARY_INERTIAL_ORIENTATION.agc
      # Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
      #               It is part of the source code for the Command Module's (CM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Ron Burkey <info@sandroid.org>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         1243-1251
      # Mod history:   2009-05-14 RSB   Adapted from the Colossus249/ file of the
      #               same name, using Comanche055 page images.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 055 of AGC program Comanche by NASA
      #       2021113-051.  10:28 APR. 1, 1969
      #
      #       This AGC program shall also be referred to as
      #               Colossus 2A

      # Page 1243
      # PLANETARY INERTIAL ORIENTATION
      #
      # ***** RP-TO-R SUBROUTINE *****
      # SUBROUTINE TO CONVERT RP (VECTOR IN PLANETARY COORDINATE SYSTEM, EITHER
      # EARTH-FIXED OR MOON-FIXED) TO R (SAME VECTOR IN BASIC REF. SYSTEM)
      #       R = MT(T) * (RP + LP X RP)      MT = M MATRIX TRANSPOSE
      #
      # CALLING SEQUENCE
      #       L          CALL
      #       L+1        RP-TO-R
      #
      # SUBROUTINES USED
      #       EARTHMX, MOONMX, EARTHL

```

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```
#
#       ITEMS AVAILABLE FROM LAUNCH DATA
#       504LM = THE LIBRATION VECTOR L OF THE MOON AT TIME TIMSUBL, EXPRESSED
#       IN THE MOON-FIXED COORD. SYSTEM          RADIANS BO
#
#       ITEMS NECESSARY FOR SUBR. USED (SEE DESCRIPTION OF SUBR.)
#
# INPUT
#       MPAC = 0 FOR EARTH, NON-ZERO FOR MOON
#       0-5D = RP VECTOR
#       6-7D = TIME
#
# OUTPUT
#       MPAC = R VECTOR METERS B-29 FOR EARTH, B-27 FOR MOON

          SETLOC  PLANTIN
          BANK

          COUNT*  $$/LUROT

RP-TO-R    STQ      BHIZ
           RPREXIT
           RPTORA

           CALL          # COMPUTE M MATRIX FOR MOON
           MOONMX        # LP=LM FOR MOON          RADIANS BO
           VLOAD

           504LM
RPTORB     VXV      VAD
           504RPR
           504RPR
           VXM      GOTO
           MMATRIX    # MPAC=R=MT(T)*(RP+LPXRP)
           RPRPXXXX   # RESET PUSHLOC TO 0 BEFORE EXITING
RPTORA     CALL          # EARTH COMPUTATIONS
           EARTHMX    # M MATRIX B-1
           CALL
           EARTHLL    # L VECTOR RADIANS BO
           MXV      VSL1  # LP=M(T)*L      RAD B-0
           MMATRIX

# Page 1244
           GOTO
           RPTORB

# Page 1245
# ***** R-TO-RP SUBROUTINE *****
# SUBROUTINE TO CONVERT R (VECTOR IN REFERENCE COORD. SYSTEM) TO RP
```

```

# (VECTOR IN PLANETARY COORD SYSTEM) EITHER EARTH-FIXED OR MOON-FIXED
#      RP = M(T) * (R - L X R)
#
# CALLING SEQUENCE
#      L      CALL
#      L+1      R-TO-RP
#
# SUBROUTINES USED
#      EARTHMX, MOONMX, EARTHLM
#
# INPUT
#      MPAC = 0 FOR EARTH, NON-ZERO FOR MOON
#      0-5D = R VECTOR
#      6-7D = TIME
#
#      ITEMS AVAILABLE FROM LAUNCH DATA
#      504LM = THE LIBRATION VECTOR L OF THE MOON AT TIME TIMSUBL, EXPRESSED
#      IN THE MOON-FIXED COORD. SYSTEM                                RADIANS BO
#
#      ITEMS NECESSARY FOR SUBROUTINES USED (SEE DESCRIPTION OF SUBR.)
#
# OUTPUT
#      MPAC = RP VECTOR METERS B-29 FOR EARTH, B-27 FOR MOON

R-TO-RP      STQ      BHIZ
              RPREXIT
              RTORPA
              CALL
              MOONMX
              VLOAD    VXM
              504LM      # LP=LM
              MMATRIX
              VSL1      # L = MT(T)*LP      RADIANS BO
RTORPB      VXV      BVSU
              504RPR
              504RPR
              MXV      # M(T)*(R-LXR)      B-2
              MMATRIX
RPRPXXXX    VSL1      SETPD
              OD
              GOTO
              RPREXIT
RTORPA      CALL      # EARTH COMPUTATIONS
              EARTHMX
              CALL
              EARTHLM

```



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GOTO # MPAC=L=(-AX,-AY,0) RAD B-0  
RTORPB

```
# Page 1246
# ***** MOONMX SUBROUTINE *****
# SUBROUTINE TO COMPUTE THE TRANSFORMATION MATRIX M FOR THE MOON
#
# CALLING SEQUENCE
#     L      CALL
#     L+1    MOONMX
#
# SUBROUTINES USED
#     NEWANGLE
#
# INPUT
#     6-7D = TIME
#
#     ITEMS AVAILABLE FROM LAUNCH DATA
#     BSUB0, BDOT
#     TIMSUB0, NODIO, NODDOT, FSUB0, FDOT
#     COSI = COS(I)  B-1
#     SINI = SIN(I)  B-1
#     I IS THE ANGLE BETWEEN THE MEAN LUNAR EQUATORIAL PLANE AND THE
#     PLANE OF THE ECLIPTIC (1 DEGREE 32.1 MINUTES)
#
# OUTPUT
#     MMATRIX = 3X3 M MATRIX          B-1 (STORED IN VAC AREA)

MOONMX      STQ      SETPD
              EARTHMX
              8D
              AXT,1    # B REQUIRES SL 0, SL 5 IN NEWANGLE
              5
DLOAD      PDDL      # PD 10D      8-9D=BSUB0
              BSUB0    #              10-11D=BDOT
              BDOT
PUSH      CALL      # PD 12D
              NEWANGLE # EXIT WITH PD 8D AND MPAC= B  REVS B0
PUSH      COS      # PD 10D
STODL     COB      # PD 8D      COS(B) B-1
SIN      #              SIN(B) B-1
STODL     SOB      #              SETUP INPUT FOR NEWANGLE
              FSUB0    #              8-9D=FSUB0
PDDL      PUSH      # PD 10D THEN 12D      10-11D=FDOT
              FDOT
AXT,1     CALL      # F REQUIRES SL 1, SL 6 IN NEWANGLE.
```

# Page 1247

```

4
NEWANGLE # EXIT WITH PD 8D AND MPAC= F REVS B0
STODL AVECTR +2 # SAVE F TEMP
NODIO # 8-9D=NODIO
PDDL PUSH # PD 10D THEN 12D 10-11D=NODDOT
NODDOT # MPAC=5
AXT,1 CALL # NODE REQUIRES SL 0, SL 5 IN NEWANGLE
5
NEWANGLE # EXIT WITH PD 8D AND MPAC= NODI REVS B0

PUSH COS # PD 10D 8-9D= NODI REVS B0
PUSH # PD 12D 10-11D= COS(NODI) B-1
STORE AVECTR
DMP SL1R
COB # COS(NODI) B-1
STODL BVECTR +2 # PD 10D 20-25D=AVECTR=COB*SIN(NODI)
DMP SL1R # SOB*SIN(NODI)
SOB
STODL BVECTR +4 # PD 8D
SIN PUSH # PD 10D -SIN(NODI) B-1
DCOMP # 26-31D=BVECTR=COB*COS(NODI)
STODL BVECTR # PD 8D SOB*COS(NODI)
AVECTR +2 # MOVE F FROM TEMP LOC. TO 504F
STODL 504F
DMP SL1R
COB
STODL AVECTR +2
SINNODI # 8-9D=SIN(NODI) B-1
DMP SL1R
SOB
STODL AVECTR +4 # 0
HI6ZEROS # 8-13D= CVECTR= -SOB B-1
PDDL DCOMP # PD 10D COB
SOB
PDDL PDVL # PD 12D THEN PD 14D
COB
BVECTR
VXSC PDVL # PD 20D BVECTR*SINI B-2
SINI
CVECTR
VXSC VAD # PD 14D CVECTR*COSI B-2
COSI
VSL1
STOVL MMATRIX +12D # PD 8D M2=BVECTR*SINI+CVECTR*COSI B-1
VXSC PDVL # PD 14D
SINI # CVECTR*SINI B-2

```

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# Page 1248

```

          9D
          10D          # XDOT
SL*      DAD          # PD 8D          SHIFT SUCH THAT THIS PART OF
          10D,1        #                IS SCALED REVS/CSEC B-0
BOV      +1          # TURN OFF OVERFLOW IF SET BY SHIFT
          +1          # INSTRUCTION BEFORE EXITING.
RVQ      # MPAC=X= X0+(XDOT)(T+T0)          REVS B0

# Page 1249
# ***** EARTHMX SUBROUTINE *****
# SUBROUTINE TO COMPUTE THE TRANSFORMATION MATRIX M FOR THE EARTH
#
# CALLING SEQUENCE
#      L      CALL
#      L+1          EARTHMX
#
# SUBROUTINE USED
#      NEWANGLE
#
# INPUT
#      INPUT AVAILABLE FROM LAUNCH DATA          AZO REVS B-0
#  TEPHEM CSEC B-42
#      6-7D= TIME CSEC B-28
#
# OUTPUT
#      MMATRIX= 3X3 M MATRIX B-1 (STORED IN VAC AREA)

EARTHMX      STQ      SETPD          # SET 8-9D=AZO
              EARTHMX
              8D          # 10-11D=WEARTH
              AXT,1      # FOR SL 5, AND SL 10 IN NEWANGLE
              0
DLOAD      PDDL          # LEAVING PD SET AT 12D FOR NEWANGLE
              AZO
              WEARTH
PUSH      CALL
              NEWANGLE
SETPD      PUSH          # 18-19D=504AZ
              18D          #
              COS(AZ)      SIN(AZ)
COS      PDDL          # 20-37D= MMATRIX=      -SIN(AZ)      COS(AZ)
              504AZ          #
              0              0
SIN      PDDL
              HI6ZEROS
PDDL      SIN
              504AZ
DCOMP      PDDL

```

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```

                    504AZ
COS                PDVL
                    HI6ZEROS
PDDL              PUSH
                    HIDPHALF
GOTO              EARTHMX
```

```
# Page 1250
# ***** EARTHL SUBROUTINE *****
# SUBROUTINE TO COMPUTE L VECTOR FOR EARTH
#
# CALLING SEQUENCE
#      L      CALL
#      L+1    EARTHL
#
# INPUT
#      AXO,AYO SET AT LAUNCH TIME WITH AYO IMMEDIATELY FOLLOWING AXO IN CORE
#
# OUTPUT
#      -AX
#      MPAC=  -AY      RADIANS B-0
#              0
```

```
EARTHL      DLOAD  DCOMP
              AXO
STODL       504LPL
              -AYO
STODL       504LPL +2
              HI6ZEROS
STOVL       504LPL +4
              504LPL
RVQ
```

```
# Page 1251
# CONSTANTS AND ERASABLE ASSIGNMENTS

1B1          =      DP1/2      # 1 SCALED B-1
COSI         2DEC    .99964173 B-1 # COS(5521.5 SEC) B-1

SINI         2DEC    .02676579 B-1 # SIN(5521.T SEC) B-1

RPREXIT      =      S1          # R-TO-RP AND RP-TO-R SUBR EXIT
EARTHMX      =      S2          # EARTHMX, MOONMX SUBR. EXITS
504RPR       =      OD          # 6 REGS      R OR RP VECTOR
SINNODI      =      8D          # 2          SIN(NODI)
```

|         |      |                 |                                   |                              |
|---------|------|-----------------|-----------------------------------|------------------------------|
| DVECTR  | =    | 8D              | # 6                               | D VECTOR MOON                |
| CVECTR  | =    | 8D              | # 6                               | C VECTR MOON                 |
| 504AZ   | =    | 18D             | # 2                               | AZ                           |
| TIMSUBM | =    | 14D             | # 3                               | TIME SUB M (MOON) T+10 IN GE |
| 504LPL  | =    | 14D             | # 6                               | L OR LP VECTOR               |
| AVECTR  | =    | 20D             | # 6                               | A VECTOR (MOON)              |
| BVECTR  | =    | 26D             | # 6                               | B VECTOR (MOON)              |
| MMATRIX | =    | 20D             | # 18                              | M MATRIX                     |
| COB     | =    | 32D             | # 2                               | COS(B) B-1                   |
| SOB     | =    | 34D             | # 2                               | SIN(B) B-1                   |
| 504F    | =    | 6D              | # 2                               | F(MOON)                      |
| NODDOT  | 2DEC | -.457335121 E-2 | # REVS/CSEC B+28=-1.07047011 E-8  | RAD/SEC                      |
| FDOT    | 2DEC | .570863327      | # REVS/CSEC B+27= 2.67240410 E-6  | RAD/SEC                      |
| BDOT    | 2DEC | -3.07500686 E-8 | # REVS/CSEC B+28=-7.19757301 E-14 | RAD/SEC                      |
| NODIO   | 2DEC | .986209434      | # REVS B-0 = 6.19653663041        | RAD                          |
| FSUB0   | 2DEC | .829090536      | # REVS B-0 = 5.20932947829        | RAD                          |
| BSUB0   | 2DEC | .0651201393     | # REVS B=0 = 0.40916190299        | RAD                          |
| WEARTH  | 2DEC | .973561595      | # REVS/CSEC B+23= 7.29211494 E-5  | RAD/SEC                      |

This code is written to file `src/PLANETARY-INERTIAL-ORIENTATION.s`.

## A.82 POWERED FLIGHT SUBROUTINES

```

1495  <src/POWERED-FLIGHT-SUBROUTINES.s 1495>≡
      # Copyright:   Public domain.
      # Filename:    POWERED_FLIGHT_SUBROUTINES.agc
      # Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
      #              It is part of the source code for the Command Module's (CM)
      #              Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:   yaYUL
      # Contact:      Ron Burkey <info@sandroid.org>.
      # Website:      www.ibiblio.org/apollo.
      # Pages:        1365-1372
      # Mod history:  2009-05-10 SN    (Sergio Navarro).  Started adapting
      #              from the Colossus249/ file of the same
      #              name, using Comanche055 page images.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum.  The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum.  Many
      # thanks to both.  The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo.  If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #   Assemble revision 055 of AGC program Comanche by NASA
      #   2021113-051.  10:28 APR. 1, 1969
      #
      #   This AGC program shall also be referred to as
      #   Colossus 2A

      # Page 1365

      BANK      14                      # SAME FBANK AS THE FINDCDUD SUB-PROGRAM
      SETLOC    POWFLITE
      BANK

      EBANK=     DEXDEX
      COUNT*    $$/POWFL

      # CDUTRIG, CDUTRIG1, CDUTRIG2, AND CD*GR*GS ALL COMPUTE THE SINES AND
      # COSINES OF THREE 2'S COMPLEMENT ANGLES AND PLACE THE RESULT, DOUBLE
      # PRECISION, IN THE SAME ORDER AS THE INPUTS, AT SINCDU AND COSCDU.  AN
      # ADDITIONAL OUTPUT IS THE 1'S COMPLEMENT ANGLES AT CDUSPOT.  THESE

```

```

# ROUTINES GO OUT OF THEIR WAY TO LEAVE THE MPAC AREA AS THEY FIND IT.
# EXCEPT FOR THE GENERALLY UNIMPORTANT MPAC +2. THEY DIFFER ONLY IN
# WHERE THEY GET THE ANGLES, AND IN METHOD OF CALLING.
#
# CDUTRIG (AND CDUTRIG1, WHICH CAN BE CALLED IN BASIC) COMPUTE THE
# SINES AND COSINES FROM THE CURRENT CONTENTS OF THE CDU REGISTERS.
# THE CONTENTS OF CDUTEMP, ETC., ARE NOT TOUCHED SO THAT THEY MAY
# CONTINUE TO FORM A CONSISTENT SET WITH THE LATEST PIPA READINGS.
#
# CDUTRIG1 IS LIKE CDUTRIG EXCEPT THAT IT CAN BE CALLED IN BASIC.
#
# CD*TR*GS FINDS CDU VALUES IN CDUSPOT RATHER THAN IN CDUTEMP. THIS
# ALLOWS USERS TO MAKE TRANSFORMATIONS USING ARBITRARY ANGLES, OR REAL
# ANGLES IN AN ORDER OTHER THAN X Y Z. A CALL TO THIS ROUTINE IS
# NECESSARY IN PREPARATION FOR A CALL TO AX*SR*T IN EITHER OF ITS TWO
# MODES (SMNB OR NBSM). SINCE AX*SR*T EXPECTS TO FIND THE SINES AND
# COSINES IN THE ORDER Y Z X THE ANGLES MUST HAVE BEEN PLACED IN CDUSPOT
# IN THIS ORDER. CD*TR*GS NEED NOT BE REPEATED WHEN AX*SR*T IS CALLED
# MORE THAN ONCE, PROVIDED THE ANGLES HAVE NOT CHANGED. NOTE THAT SINCE
# IT CLOBBERS BUF2 (IN THE SINE AND COSINE ROUTINES) CD*TR*GS CANNOT BE
# CALLED USING BANKCALL. SORRY.
#
# CD*TR*G IS LIKE CD*TR*GS EXCEPT THAT IT CAN BE CALLED IN
# INTERPRETIVE.

```

|             |        |            |
|-------------|--------|------------|
| CDUTRIG     | EXIT   |            |
|             | TC     | CDUTRIGS   |
|             | TC     | INTPRET    |
|             | RVQ    |            |
| CD*TR*G     | EXIT   |            |
|             | TC     | CD*TR*GS   |
|             | TC     | INTPRET    |
|             | RVQ    |            |
| CDUTRIGS    | CA     | CDUX       |
|             | TS     | CDUSPOT +4 |
|             | CA     | CDUY       |
|             | TS     | CDUSPOT    |
| # Page 1366 |        |            |
|             | CA     | CDUZ       |
|             | TS     | CDUSPOT +2 |
| CD*TR*GS    | EXTEND |            |
|             | QXCH   | TEM2       |
|             | CAF    | FOUR       |



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```
TR*GL**P      MASK      SIX      # MAKE IT EVEN AND SMALLER
               TS        TEM3
               INDEX     TEM3
               CA        CDUSPOT
               DXCH      MPAC      # STORING 2'S COMP ANGLE, LOADING MPAC
               DXCH      VBUF +4    # STORING MPAC FOR LATER RESTORATION
               TC        USPRCADR
               CADR      CDULOGIC
               EXTEND
               DCA       MPAC
               INDEX     TEM3
               DXCH      CDUSPOT    # STORING 1'S COMPLEMENT ANGLE
               TC        USPRCADR
               CADR      COSINE
               DXCH      MPAC
               INDEX     TEM3
               DXCH      COSCDU     # STORING COSINE
               EXTEND
               INDEX     TEM3
               DCA       CDUSPOT    # LOADING 1'S COMPLEMENT ANGLE
               TC        USPRCADR
               CADR      SINE +1    # SINE +1 EXPECTS ARGUMENT IN A AND L
               DXCH      VBUF +4    # BRINGING UP PRIOR MPAC TO BE RESTORED
               DXCH      MPAC
               INDEX     TEM3
               DXCH      SINCDU
               CCS       TEM3
               TCF       TR*GL**P
               TC        TEM2
```

# Page 1367

```
# *****
# QUICTRIG, INTENDED FOR GUIDANCE CYCLE USE WHERE TIME IS CRITICAL, IS A MUCH FASTER VERSION OF
# QUICTRIG COMPUTES AND STORES THE SINES AND COSINES OF THE 2'S COMPLEMENT ANGLES AT CDUSPOT, C
# AND CDUSPOT +4.  UNLIKE CD*TR*GS, QUICTRIG DOES NOT LEAVE THE 1'S COMPLEMENT VERSIONS OF THE
# CDUSPOT.  QUICTRIG'S EXECUTION TIME IS 4.1 MS;  THIS IS 10 TIMES AS FAST AS CD*TR*GS.  QU
# CALLED FROM INTERPRETIVE AS AN RTB OP-CODE, OR FROM BASIC VIA BANKCALL OR IBNKCALL.
```

```
QUICTRIG      INHINT      # INHINT SINCE DAP USES THE SAME TEMPS
               EXTEND
               QXCH      ITEMP1
               CAF       FOUR
               +4      MASK      SIX
               TS        ITEMP2
               INDEX     ITEMP2
               CA        CDUSPOT
               TC        SPSIN
```

```

EXTEND
MP      BIT14          # SCALE DOWN TO MATCH INTERPRETER OUTPUTS
INDEX   ITEMP2
DXCH    SINCDU
INDEX   ITEMP2
CA      CDUSPOT
TC      SPCOS
EXTEND
MP      BIT14
INDEX   ITEMP2
DXCH    COSCDU
CCS     ITEMP2
TCF     QUICTRIG +4
CA      ITEMP1
RELINT
TC      A

# Page 1368
*****
# THESE INTERFACE ROUTINES MAKE IT POSSIBLE TO CALL AX*SR*T, ETC., IN
# INTERPRETIVE.  LATER, WHERE POSSIBLE, THEY WILL BE ELIMINATED.
#
# NBSM WILL BE THE FIRST TO GO.  IT SHOULD NOT BE USED.

NBSM      STQ
          X2
          LXC,1  VLOAD*
          S1          # BASE ADDRESS OF THE CDU ANGLES IS IN S1
          0,1
          STOVL   CDUSPOT
          32D      # VECTOR TO BE TRANSFORMED IS IN 32D
          CALL    TRG*NBSM
          STCALL  32D  # SINCE THERE'S NO STGOTO
          X2

# THESE INTERFACE ROUTINES ARE PERMANENT.  ALL RESTORE USER'S EBANK
# SETTING.  ALL ARE STRICT INTERPRETIVE SUBROUTINES, CALLED USING "CALL",
# RETURNING VIA QPRET.  ALL EXPECT AND RETURN THE VECTOR TO BE TRANSFOR-
# MED INTERPRETER-STYLE IN MPAC: COMPONENTS AT MPAC, MPAC +3, AND MPAC +5.
#
# TRG*SMNB AND TRG*NBSM BOTH EXPECT TO SEE THE 2'S COMPLEMENT ANGLES
# AT CDUSPOT (ORDER Y Z X, AT CDUSPOT, CDUSPOT +2, AND CDUSPOT +4.  ODD
# LOCATIONS NEED NOT BE ZEROED).  TRG*NBSM DOES THE NB TO SM TRANSFOR-
# MATION:  TRG*SMNB, VICE VERSA.
#
# CDU*NBSM DOES ITS TRANSFORMATION USING THE PRESENT CONTENTS OF

```

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# THE CDL COUNTERS. OTHERWISE IT IS LIKE TRG\*NBSM.

#

# CDU\*SMNB IS THE COMPLEMENT OF CDU\*NBSM.

CDU\*SMNB        EXIT  
                 TC        CDUTRIGS  
                 TCF        C\*MM\*N1

TRG\*SMNB        EXIT  
                 TC        CD\*TR\*GS  
C\*MM\*N1        TC        MPACVBUF        # AX\*SR\*T EXPECTS VECTOR IN VBUF  
                 CS        THREE        # SIGNAL FOR SM TO NB TRANSFORMATION.  
C\*MM\*N2        TC        AX\*SR\*T  
                 TC        INTPRET  
                 VLOAD    RVQ  
                        VBUF

CDU\*NBSM        EXIT  
                 TC        CDUTRIGS

# Page 1369

TCF        C\*MM\*N3

TRG\*NBSM        EXIT  
                 TC        CD\*TR\*GS  
C\*MM\*N3        TC        MPACVBUF        # FOR AX\*SR\*T  
                 CA        THREE        # SIGNAL FOR NB TO SM TRANSFORMATION  
                 TCF        C\*MM\*N2

# \*NBSM\* AND \*SMNB\* EXPECT TO SEE THE SINES AND COSINES (AT SINCDU  
# AND COSCDU) RATHER THAN THE ANGLES THEMSELVES. OTHERWISE THEY ARE  
# LIKE TRG\*NBSM AND TRG\*SMNB.

#

# NOTE THAT JUST AS CD\*TR\*GS NEED BE CALLED ONLY ONCE FOR EACH SERIES  
# OF TRANSFORMATIONS USING THE SAME ANGLES, SO TOO ONLY ONE OF TRG\*NBSM  
# AND TRG\*SMNB NEED BE CALLED FOR EACH SERIES. FOR SUBSEQUENT TRANFOR-  
# MATIONS USE \*NBSM\* AND \*SMNB\*.

\*SMNB\*        EXIT  
                 TCF        C\*MM\*N1

\*NBSM\*        EXIT  
                 TCF        C\*MM\*N3

# AX\*SR\*T COMBINES THE OLD SMNB AND NBSM. FOR THE NB TO SM

```

# TRANSFORMATION, ENTER WITH +3 IN A.  FOR SM TO NB, ENTER WITH -3.
# THE VECTOR TO BE TRANSFORMED ARRIVES, AND IS RETURNED, IN VBUF.
# AX*SR*T EXPECTS TO FIND THE SINES AND COSINES OF THE ANGLES OF ROTATION
# AT SINCDU AND COSCDU, IN THE ORDER Y Z X.  A CALL TO CD*TR*GS, WITH
# THE 2'S COMPLEMENT ANGLES (ORDER Y Z X) AT CDUSPOT, WILL TAKE CARE OF
# THIS.  HERE IS A SAMPLE CALLING SEQUENCE:--
#           TC      CDUTRIGS
#           CS      THREE          # ("CA THREE" FOR NBSM)
#           TC      AX*SR*T
# THE CALL TO CD*TR*GS NEED NOT BE REPEATED, WHEN AX*SR*T IS CALLED MORE
# THAN ONCE, UNLESS THE ANGLES HAVE CHANGED.
#
# AX*SR*T IS GUARANTEED SAFE ONLY FOR VECTORS OF MAGNITUDE LESS THAN
# UNITY.  A LOOK AT THE CASE IN WHICH A VECTOR OF GREATER MAGNITUDE
# HAPPENS TO LIE ALONG AN AXIS OF THE SYSTEM TO WHICH IT IS TO BE TRANS-
# FORMED CONVINCES ONE THAT THIS IS A RESTRICTION WHICH MUST BE ACCEPTED.

AX*SR*T      TS      DEXDEX          # WHERE IT BECOMES THE INDEX OF INDEXES.
              EXTEND
              QXCH      RTNSAVER

R*TL**P      CCS      DEXDEX          #           +3 --> 0           -3 --> 2
              CS      DEXDEX          #  THUS:      +2 --> 1           -2 --> 1
              AD      THREE          #           +1 --> 2           -1 --> 0

# Page 1370

              EXTEND
              INDEX      A
              DCA      INDEXI
              DXCH      DEXI

              CA      ONE
              TS      BUF
              EXTEND
              INDEX      DEX1
              DCS      VBUF
              TCF      LOOP1          # REALLY BE A SUBTRACT, AND VICE VERSA

LOOP2        DXCH      BUF          # LOADING VECTOR COMPONENT, STORING INDEX

LOOP1        DXCH      MPAC
              CA      SINESLOC
              AD      DEX1
              TS      ADDRWD

              TC      DMPSUB          # MULTIPLY BY SIN(CDUANGLE)
              CCS      DEXDEX

```

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```
DXCH    MPAC          # NBSM CASE
TCF      +3
EXTEND
DCS      MPAC
DXCH     TERM1TMP

CA       SIX          # SINCDU AND COSCDU (EACH 6 WORDS) MUST
ADS      ADDRWD       # BE CONSECUTIVE AND IN THAT ORDER

EXTEND
INDEX    BUF
INDEX    DEX1
DCA      VBUF
DXCH     MPAC
TC        DMPSUB      # MULTIPLY BY COS(CDUANGLE)
DXCH     MPAC
DAS      TERM1TMP
DXCH     TERM1TMP
DDOUBL
INDEX    BUF
INDEX    DEX1
DXCH     VBUF
DXCH     BUF          # LOADING INDEX, STORING VECTOR COMPONENT
CCS      A            # 'CAUSE THAT'S WHERE THE INDEX NOW IS
TCF      LOOP2

EXTEND
DIM      DEXDEX       # DECREMENT MAGNITUDE PRESERVING SIGN

# Page 1371
TSTPOINT CCS    DEXDEX          # ONLY THE BRANCHING FUNCTION IS USED
TCF      R*TL**P
TC        RTNSAVER
TCF      R*TL**P
TC        RTNSAVER

SINESLOC ADRES    SINCDU       # FOR USE IN SETTING ADDRWD

INDEXI   DEC      4            # ***** DON'T *****
          DEC      2            # ***** TOUCH *****
          DEC      0            # ***** THESE *****
          DEC      4            # ***** CONSTANTS *****
```

# \*\*\*\*\*

# Page 1372

# THIS SUBROUTINE COMPUTES INCREMENTAL CHANGES IN CDU(GIMBAL) ANGLES FROM INCREMENTAL CHANGES A

# REQUIRES SM INCREMENTS AS A DP VECTOR SCALED AT ONE REVOLUTION(DTHETASM,+2,+4). S  
 # SINCDU,+2,+4 AND COSCDU,+2,+4 RESPECTIVELY, SCALED TO ONE HALF. CDU INCREMENTS ARE  
 # ONE REVOLUTION.

```
#
#      *  COS(IGA)SEC(MGA)          0          -SIN(IGA)SEC(MGA) *
#      *
#      * -COS(IGA)TAN(MGA)         1          SIN(IGA)TAN(MGA) *
#      *
#      *      SIN(IGA)              0          COS(IGA)      *
```

```
BANK    14
SETLOC  POWFLIT1
BANK
```

SMCDURES

```
DLOAD  DMP
        DTHETASM
        COSCDUY
```

```
PDDL   DMP
        DTHETASM +4
        SINCDUY
```

```
BDSU
DDV
```

```
COSCDUZ
STORE  DCDU
```

```
DMP    SL1          # SCALE
        SINCDUZ
```

BDSU

```
DTHETASM +2
STODL  DCDU +2
        DTHETASM
```

```
DMP    PDDL
        SINCDUY
        DTHETASM +4
```

```
DMP    DAD
        COSCDUY
```

```
SL1
STORE  DCDU +4
RVQ
```

This code is written to file src/POWERED-FLIGHT-SUBROUTINES.s.

## A.83 Q R-AXIS RCS AUTOPILOT

```

1503  <src/Q-R-AXIS-RCS-AUTOPILOT.s 1503>≡
# Copyright:      Public domain.
# Filename:       Q_R-AXIS_RCS_AUTOPILOT.agc
# Purpose:        Part of the source code for Luminary 1A build 099.
#                It is part of the source code for the Lunar Module's (LM)
#                Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:     yaYUL
# Contact:        Ron Burkey <info@sandroid.org>.
# Website:        www.ibiblio.org/apollo.
# Pages:          1442-1459
# Mod history:    2009-05-27 RSB   Adapted from the corresponding
#                Luminary131 file, using page
#                images from Luminary 1A.
#                2009-06-07 RSB   Corrected "DEC 96.0" to "DEC 96", since
#                the former is not compatible with yaYUL.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
# Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
# 16:27 JULY 14, 1969
#
# Page 1442
#
# BANK      17
# SETLOC    DAPS2
# BANK
#
# EBANK=     CDUXD
#
# COUNT*    $$/DAPQR
#
# CALLQERR   CA      BIT13      # CALCULATE Q,R ERRORS UNLESS THESE AXES
#           EXTEND      # ARE IN MANUAL RATE COMMAND.
#           RAND      CHAN31
#           CCS        A

```

```

TCF      +5          # IN AUTO COMPUTE Q,R ERRORS
CS        DAPBOOLS   # IN MANUAL RATE COMMAND?
MASK      OURRCBIT
EXTEND
BZF       Q,RORGTS   # IF SO BYPASS CALCULATION OF ERROS.
TC        QERRCALC

Q,RORGTS  CCS        COTROLER   # CHOOSE CONTROL SYSTEM FOR THIS DAP PASS:
TCF       GOTOGTS    #          GTS (ALTERNATES WITH RCS WHEN DOCKED)
TCF       TRYGTS     #          GTS IF ALLOWED, OTHERWISE RCS
RCS       CAF        ZERO       #          RCS (TRYGTS MAY BRANCH TO HERE)
TS        COTROLER

DXCH      EDOTQ
TC        ROT-TOUV
DXCH      OMEGAU

# X - TRANSLATION
#
# INPUT:      BITS 7,8 OF CH31 (TRANSLATION CONTROLLER)
#            ULLAGER
#            APSFLAG, DRIFTBIT
#            ACC40R2X, ACRBTRAN
#
# OUTPUT:     NEXTU, NEXTV      CODES OF TRANSLATION FOR AFTER ROTATION
#            SENSETYP          TELL ROTATION DIRECTION AND DESIRE
#
# X-TRANS POLICIES ARE EITHER 4 JETS OR A DIAGONAL PAIR.  IN 2-JET TRANSLATION THE S
# WILL OVERRIDE THIS SPECIFICATION.  AN ALARM RESULTS WHEN NO POLICY IS AVAILABLE BEC

SENSEGET   CA        BIT7          # INPUT BITS OVERRIDE THE INTERNAL BITS
EXTEND
RAND       CHAN31
EXTEND
BZF        +XORULGE

# Page 1443

CA        BIT8
EXTEND
RAND       CHAN31
EXTEND
BZF        -XTRANS

CA        ULLAGER
MASK      DAPBOOLS
CCS       A
TCF       +XORULGE

```



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|             |        |          |                                        |
|-------------|--------|----------|----------------------------------------|
|             | TS     | NEXTU    | # STORE NULL TRANSLATION POLICIES      |
|             | TS     | NEXTV    |                                        |
|             | CS     | DAPBOOLS | # BURNING OR DRIFTING?                 |
|             | MASK   | DRIFTBIT |                                        |
|             | EXTEND |          |                                        |
|             | BZF    | TSENSE   |                                        |
|             | CA     | FLGWRD10 | # DPS (INCLUDING DOCKED) OR APS?       |
|             | MASK   | APSFLBIT |                                        |
|             | CCS    | A        |                                        |
|             | CAF    | TWO      | # FAVOR +X JETS DURING AN APS BURN.    |
| TSENSE      | TS     | SENSETYP |                                        |
|             | TCF    | QRCONTRL |                                        |
| +XORULGE    | CAF    | ONE      |                                        |
| -XTRANS     | AD     | FOUR     |                                        |
|             | TS     | ROTINDEX |                                        |
|             | AD     | NEG3     |                                        |
|             | TS     | SENSETYP | # FAVOR APPROPRIATE JETS DURING TRANS. |
|             | CA     | DAPBOOLS |                                        |
|             | MASK   | ACC40R2X |                                        |
|             | CCS    | A        |                                        |
|             | TCF    | TRANS4   |                                        |
|             | CA     | DAPBOOLS |                                        |
|             | MASK   | AORBTRAN |                                        |
|             | CCS    | A        |                                        |
|             | CA     | ONE      | # THREE FOR B                          |
|             | AD     | TWO      | # TWO FOR A SYSTEM 2 JET X TRANS       |
| TSNUMBRT    | TS     | NUMBERT  |                                        |
|             | TC     | SELCTSUB |                                        |
|             | CCS    | POLYTEMP |                                        |
|             | TCF    | +3       |                                        |
|             | TC     | ALARM    |                                        |
|             | OCT    | 02002    |                                        |
|             | CA     | 00314OCT |                                        |
|             | MASK   | POLYTEMP |                                        |
| TSNEXTS     | TS     | NEXTU    |                                        |
| # Page 1444 | CS     | 00314OCT |                                        |
|             | MASK   | POLYTEMP |                                        |
|             | TS     | NEXTV    |                                        |

# Q,R-AXES RCS CONTROL MODE SELECTION

```

#      SWITCHES      INDICATION WHEN SET
#      BIT13/CHAN31  AUTO, GO TO ATTSTEER
#      PULSES        MINIMUM IMPULSE MODE
#      (OTHERWISE)   RATE COMMAND/ATTITUDE HOLD MODE

QRCONTRL      CA      BIT13      # CHECK MODE SELECT SWITCH.
               EXTEND
               RAND     CHAN31     # BITS INVERTED
               CCS      A
               TCF      ATTSTEER
CHKBIT10      CAF      PULSES     # PULSES = 1 FOR MIN IMP USE OF RHC
               MASK     DAPBOOLS
               EXTEND
               BZF      CHEKSTIK   # IN ATT-HOLD/RATE-COMMAND IF BIT10=0

# MINIMUM IMPULSE MODE

               INHINT
               TC       IBNKCALL
               CADR     ZATTEROR
               CA       ZERO
               TS       QERROR
               TS       RERROR     # FOR DISPLAYS
               RELINT

               EXTEND
               READ     CHAN31
               TS       TEMP31     # IS EQUAL TO DAPTEMP1
               CCS      OLDQRMIN
               TCF      CHECKIN

FIREQR        CA       TEMP31
               MASK     BIT1
               EXTEND
               BZF      +QMIN

               CA       TEMP31
               MASK     BIT2
               EXTEND
               BZF      -QMIN

               CA       TEMP31
               MASK     BIT5

# Page 1445

               EXTEND
               BZF      +RMIN

```

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|         |        |          |                                       |
|---------|--------|----------|---------------------------------------|
|         | CA     | TEMP31   |                                       |
|         | MASK   | BIT6     |                                       |
|         | EXTEND |          |                                       |
|         | BZF    | -RMIN    |                                       |
|         | TCF    | XTRANS   |                                       |
| CHECKIN | CS     | TEMP31   |                                       |
|         | MASK   | OCT63    |                                       |
|         | TS     | OLDQRMIN |                                       |
|         | TCF    | XTRANS   |                                       |
| +QMIN   | CA     | 14MS     |                                       |
|         | TS     | TJU      |                                       |
|         | CS     | 14MS     |                                       |
|         | TCF    | MINQR    |                                       |
| -QMIN   | CS     | 14MS     |                                       |
|         | TS     | TJU      |                                       |
|         | CA     | 14MS     |                                       |
|         | TCF    | MINQR    |                                       |
| +RMIN   | CA     | 14MS     |                                       |
|         | TCF    | +2       |                                       |
| -RMIN   | CS     | 14MS     |                                       |
|         | TS     | TJU      |                                       |
| MINQR   | TS     | TJV      |                                       |
|         | CA     | MINADR   |                                       |
|         | TS     | RETJADR  |                                       |
|         | CA     | ONE      |                                       |
|         | TS     | OLDQRMIN |                                       |
| MINRTN  | TS     | AXISCTR  |                                       |
|         | CA     | DAPBOOLS |                                       |
|         | MASK   | CSMDOCKD |                                       |
|         | EXTEND |          |                                       |
|         | BZF    | MIMRET   |                                       |
|         | INDEX  | AXISCTR  | # IF DOCKED, USE 60MS MINIMUM IMPULSE |
|         | CCS    | TJU      |                                       |
|         | CA     | 60MS     |                                       |
|         | TCF    | +2       |                                       |
|         | CS     | 60MS     |                                       |
|         | INDEX  | AXISCTR  |                                       |
|         | TS     | TJU      |                                       |
| MIMRET  | CA     | DAPBOOLS |                                       |
|         | MASK   | AORBTRAN |                                       |
|         | CCS    | A        |                                       |
|         | CA     | ONE      |                                       |

```

                                AD      TWO
                                TS      NUMBERT
# Page 1446
                                TCF      AFTERTJ

60MS      DEC      96          # RSB 2009 -- was 96.0.
MINADR     GENADR  MINRTN
OCT63      OCT      63
14MS       =      +TJMINT6

TRANS4     CA      FOUR
           TCF      TSNUMBRT

# RATE COMMAND MODE:
#
# DESCRIPTION (SAME AS P-AXIS)

CHEKSTIK   TS      INGTS      # NOT IN GTS WHEN IN ATT HOLD
           CS      ONE        # 1/ACCS WILL DO THE NULLING DRIVES
           TS      COTROLER    # COME BACK TO RCS NEXT TIME
           CA      BIT15
           MASK     CH31TEMP
           EXTEND
           BZF      RHCACTIV    # BRANCH IF OUT OF DETENT.
           CA      OURRCBIT     # *****
           MASK     DAPBOOLS    # *IN DETENT*   CHECK FOR MANUAL CONTROL
           EXTEND              # *****   LAST TIME.
           BZF      STILLRCS
           CS      BIT9
           MASK     RCSFLAGS
           TS      RCSFLAGS    # BIT 9 IS 0.
           TCF      DAMPING
40CYCL     OCT      50
1/10S      OCT      1
LINRAT     DEC      46

# =====

DAMPING     CA      ZERO
           TS      SAVEHAND
           TS      SAVEHAND +1
RHCACTIV    CCS      SAVEHAND  # *****
           TCF      +3         # Q,R MANUAL CONTROL   WC = A*(B+|D|)*D
           TCF      +2         # *****
           TCF      +1
           DOUBLE              # WHERE

```

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```
DOUBLE
AD      LINRAT
EXTEND
MP      SAVEHAND
CA      L
EXTEND
MP      STIKSENS
XCH     QLAST
COM
#
# WC = COMMANDED ROTATIONAL RATE
# A = QUADRATIC SENSITIVITY FACTOR
# B = LINEAR/QUADRATIC SENSITIVITY
# |D| = ABS. VALUE OF DEFLECTION
# D = HAND CONTROLLER DEFLECTION
# COMMAND Q RATE, SCALED 45 DEG/SEC

# Page 1447
AD      QLAST
TS      DAPTEMP3
CCS     SAVEHAND +1
TCF     +3
TCF     +2
TCF     +1
DOUBLE
DOUBLE
AD      LINRAT
EXTEND
MP      SAVEHAND +1
CA      L
EXTEND
MP      STIKSENS
XCH     RLAST
COM
AD      RLAST
TS      DAPTEMP4
CS      QLAST
AD      OMEGAQ
TS      QRATEDIF
CS      RLAST
AD      OMEGAR
TS      RRATEDIF
ENTERQR DXCH  QRATEDIF
TC      ROT-TOUV
DXCH    URATEDIF
CCS     DAPTEMP3
TC      +3
TC      +2
TC      +1
AD      -RATEDB
EXTEND
BZMF    +2
TCF     ENTERUV -2
CCS     DAPTEMP4
# CHECK IF Q COMMAND CHANGE EXCEEDS
# BREAKOUT LEVEL. IF NOT, CHECK R.
# TRANSFORM RATES FROM Q,R TO U,V AXES
# BREAKOUT LEVEL EXCEEDED. DIRECT RATE.
# R COMMAND BREAKOUT CHECK.
# INTERVAL.
```

```

TC      +3
TC      +2
TC      +1
AD      -RATEDB
EXTEND
BZMF    +2
TCF     ENTERUV -2      # BREAKOUT LEVEL EXCEEDED.  DIRECT RATE.
CA      RCSFLAGS       # BREAKOUT LEVEL NOT EXCEEDED.  CHECK FOR
MASK     QRBIT          # DIRECT RATE CONTROL LAST TIME.
EXTEND
BZF     +2
TCF     ENTERUV        # CONTINUE DIRECT RATE CONTROL.
TCF     STILLRCS       # PSEUDO-AUTO CONTROL.
CA      40CYCL

# Page 1448
ENTERUV TS      TCQR
        INHINT   # DIRECT RATE CONTROL
        TC      IBNKCALL
        FCADR   ZATTEROR
        RELINT
        CA      ZERO
        TS      DYERROR
        TS      DYERROR +1
        TS      DZERROR
        TS      DZERROR +1
        CCS     URATEDIF
        TCF     +3
        TCF     +2
        TCF     +1
        AD      TARGETDB      # IF TARGET DB IS EXCEEDED, CONTINUE
        EXTEND                # DIRECT RATE CONTROL.
        BZMF    VDB
        CCS     VRATEDIF
        TCF     +3
        TCF     +2
        TCF     +1
        AD      TARGETDB
        EXTEND
        BZMF    +2
        TCF     QRTIME
        CA      ZERO
        TS      VRATEDIF
        TCF     QRTIME
VDB     CCS     VRATEDIF
        TC      +3
        TC      +2

```

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```

TC      +1
AD      TARGETDB      # IF TARGET DB IS EXCEEDED, CONTINUE
EXTEND
BZMF    TOPSEUDO      # DIRECT RATE CONTROL.  IF NOT, FIRE AND
CA      ZERO          # SWITCH TO PSEUDO-AUTO CONTROL ON NEXT
TS      URATEDIF      # PASS.
QRTIME  CA      TCQR      # DIRECT RATE TIME CHECK.
EXTEND
BZMF    +5            # BRANCH IF TIME EXCEEDS 4 SEC.
CS      RCSFLAGS
MASK    QRBIT
ADS     RCSFLAGS      # BIT 11 IS 1.
TC      +4
TOPSEUDO CS      QRBIT
MASK    RCSFLAGS
TS      RCSFLAGS      # BIT 11 IS 0.
CA      HANDADR
TS      RETJADR
CA      ONE

# Page 1449
BACKHAND TS      AXISCTR

CA      FOUR
TS      NUMBERT

INDEX   AXISCTR
INDEX   SKIPU
TCF     +1
CA      FOUR
INDEX   AXISCTR
TS      SKIPU
TCF     LOOPER

INDEX   AXISCTR
CCS     URATEDIF      #      INDEX   AXIS   QUANTITY
CA      ZERO          #      0      -U      1/JETACC-AOSU
TCF     +2            #      1      +U      1/JETACC+AOSU
CA      ONE           #      16     -V      1/JETACC-AOSV
INDEX   AXISCTR       #      17     +V      1/JETACC+AOSV
AD      AXISDIFF      # JETACC = 2 JET ACCELERATION (1 FOR FAIL)

INDEX   A
CS      1/ANET2 +1
EXTEND
INDEX   AXISCTR      # UPRATEDIF IS SCALED AT PI/4 RAD/SEC
```

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```

      MP      URATEDIF      # JET TIME IN A, SCALED 32 SEC
      TS      Q
      DAS     A
      AD      Q
      TS      A      # OVERFLOW SKIP
      TCF     +2
      CA      Q      # RIGHT SIGN AND BIGGER THAN 150MS
SETTIME  INDEX  AXISCTR
      TS      TJU      # SCALED AT 10.67 WHICH IS CLOSE TO 10.24
      TCF     AFTERTJ

ZEROTJ   CA      ZERO
      TCF     SETTIME

HANDADR  GENADR  BACKHAND

# GTS WILL BE TRIED IF
#      1. USEQRJTS = 0,
#      2. ALLOWGTS POS,
#      3. JETS ARE OFF (Q,R-AXES)

TRYGTS   CAF     USEQRJTS      # IS JET USE MANDATORY.      (AS LONG AS
      MASK     DAPBOOLS      # USEQRJTS BIT IS NOT BIT 15, CCS IS SAFE.)
      CCS      A
      TCF      RCS
      CCS      ALLOWGTS      # NO.  DOES AOSTASK OK CONTROL FOR GTS?

# Page 1450
      TCF      +2
      TCF      RCS
      EXTEND
      READ     CHAN5
      CCS      A
      TCF      CHKINGTS
GOTOGTS  EXTEND
      DCA      GTSCADR
      DTCB

CHKINGTS  CCS     INGTS      # WAS THE TRIM GIMBAL CONTROLLING
      TCF      +2      #      YES.  SET UP A DAMPED NULLING DRIVE.
      TCF      RCS      #      NO.  NULLING WAS SET UP BEFORE.  DO P
      INHINT
      TC       IBNKCALL
      CADR     TIMEGMBL
      RELINT
      CAF      ZERO
      TS       INGTS
```



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TCF RCS  
EBANK= CDUXD  
GTSCADR 2CADR GTS

# Page 1451

# SUBROUTINE TO COMPUTE Q,R-AXES ATTITUDE ERRORS FOR USE IN THE RCS AND GTS CONTROL LAWS AND TH

QERRCALC CAE CDUY # Q-ERROR CALCULATION  
EXTEND  
MSU CDUYD # CDU ANGLE -- ANGLE DESIRED (Y-AXIS)  
TS DAPTEMP1 # SAVE FOR RERRCALC  
EXTEND  
MP M21 # (CDUY-CDUYD)\*M21 SCALED AT PI RADIANS  
TS E  
CAE CDUZ # SECOND TERM CALCULATION:  
EXTEND  
MSU CDUZD # CDU ANGLE -ANGLE DESIRED (Z-AXIS)  
TS DAPTEMP2 # SAVE FOR RERRCALC  
EXTEND  
MP M22 # (CDUZ-CDUZD)\*M22 SCALED AT PI RADIANS  
AD DELQEROR # KALCMANU INERFACE ERROR  
AD E  
XCH QERROR # SAVE Q-ERROR FOR EIGHT-BALL DISPLAY.

RERRCALC CAE DAPTEMP1 # R-ERROR CALCULATION:  
EXTEND # CDU ANGLE -ANGLE DESIRED (Y-AXIS)  
MP M31 # (CDUY-CDUYD)\*M31 SCALED AT PI RADIANS  
TS E  
CAE DAPTEMP2 # SECOND TERM CALCULATION:  
EXTEND # CDU ANGLE -ANGLE DESIRED (Z-AXIS)  
MP M32 # (CDUZ-CDUZD)\*M32 SCALED AT PI RADIANS  
AD DELREROR # KALCMANU INERFACE ERROR  
AD E  
XCH RERROR # SAVE R-ERROR FOR EIGHT-BALL DISPLAY.  
TC Q

# Page 1452

# "ATTSTEER" IS THE ENTRY POINT FOR Q,R-AXES (U,V-AXES) ATTITUDE CONTROL USING THE REACTION COM

ATTSTEER EQUALS STILLRCS # "STILLRCS" IS THE RCS EXIT FROM TRYGTS.

STILLRCS CA RERROR  
LXCH A  
CA QERROR  
TC ROT-TOUV

DXCH UERROR

# PREPARES CALL TO TJETLAW (OR SPSRCS(DOCKED))  
 # PREFORMS SKIP LOGIC ON U OR Y AXIS IF NEEDED.

|       |        |          |                                            |
|-------|--------|----------|--------------------------------------------|
| TJLAW | CA     | TJLAWADR |                                            |
|       | TS     | RETJADR  |                                            |
|       | CA     | ONE      |                                            |
|       | TS     | AXISCTR  |                                            |
|       | INDEX  | AXISCTR  |                                            |
|       | INDEX  | SKIPU    |                                            |
|       | TCF    | +1       |                                            |
|       | CA     | FOUR     |                                            |
|       | INDEX  | AXISCTR  |                                            |
|       | TS     | SKIPU    |                                            |
|       | TCF    | LOOPER   |                                            |
|       | INDEX  | AXISCTR  |                                            |
|       | CA     | UERROR   |                                            |
|       | TS     | E        |                                            |
|       | INDEX  | AXISCTR  |                                            |
|       | CA     | OMEGAU   |                                            |
|       | TS     | EDOT     |                                            |
|       | CA     | DAPBOOLS |                                            |
|       | MASK   | CSMDOCKD |                                            |
|       | CCS    | A        |                                            |
|       | TCF    | +3       |                                            |
|       | TC     | TJETLAW  |                                            |
|       | TCF    | AFTERTJ  |                                            |
| +3    | CS     | DAPBOOLS | # DOCKED. IF GIMBAL USABLE DO GTS CONTROL  |
|       | MASK   | USEQRJTS | # ON THE NEXT PASS.                        |
|       | CCS    | A        | # USEQRJTS BIT MUST NOT BE BIT 15.         |
|       | TS     | COTROLER | # GIMBAL USABLE. STORE POSITIVE VALUE.     |
|       | INHINT |          |                                            |
|       | TC     | IBNKCALL |                                            |
|       | CADR   | SPSRCS   | # DETERMINE RCS CONTROL                    |
|       | RELINT |          |                                            |
|       | CAF    | FOUR     | # ALWAYS CALL FOR 2-JET CONTROL ABOUT U,V. |
|       | TS     | NUMBERT  | # FALL THROUGH TO JET SLECTION, ETC.       |

# Q,R-JET-SELECTION-LOGIC

#

|             |          |                                                   |
|-------------|----------|---------------------------------------------------|
| # INPUT:    | AXISCTR  | 0,1 FOR U,V                                       |
| #           | SNUFFBIT | ZERO TJETU,V AND TRANS. ONLY IF SET IN A DPS BURN |
| # Page 1453 |          |                                                   |
| #           | TJU,TJV  | JET TIME SCALED 10.24 SEC.                        |
| #           | NUMBERT  | INDICATES NUMBER OF JETS AND TYPE OF POLICY       |

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```
#          RETJADR          WHERE TO RETURN TO
#
# # OUTPUT:      NO.U(V) JETS      RATE DERIVATION FEEDBACK
#                CHANNEL 5
#                SKIPU,SKIPV      FOR LESS THAN 150MS FIRING
#
# # NOTES:       IN CASE OF FAILURE IN DESIRED ROTATION POLICY, "ALL" UNFAILED
#                JETS OF THE DESIRED POLICY ARE SELECTED.  SINCE THERE ARE ONLY
#                TWO JETS, THIS MEANS THE OTHER ONE OR NONE.  THE ALARM IS SENT
#                IF NONE CAN BE FOUND.
#
#                TIMES LESS THAN 14 MSEC ARE TAKEN TO CALL FOR A SINGLE-JET
#                MINIMUM IMPULSE, WITH THE JET CHOSEN SEMI-RANDOMLY.

AFTERTJ      CA      FLAGWRD5      # IF SNUFFBIT SET DURING A DPS BURN GO TO
MASK         SNUFFBIT      # XTRANS; THAT IS, INHIBIT CONTROL.
EXTEND
BZF          DOROTAT
CS           FLGWRD10
MASK         APSFLBIT
EXTEND
BZF          DOROTAT
CA           DAPBOOLS
MASK         DRIFTBIT
EXTEND
BZF          XTRANS

DOROTAT      CAF      TWO
TS           L
INDEX        AXISCTR
CCS          TJU
TCF          +5
TCF          NOROTAT
TCF          +2
TCF          NOROTAT
ZL
AD           ONE
TS           ABSTJ

CA           AXISCTR
AD           L
TS           ROTINDEX      # 0 1 2 3 = -U -V +U +V

CA           ABSTJ
AD           -150MS
EXTEND
```

```

# Page 1454
BZMF  DOSKIP
TC      SELCTSUB

INDEX  AXISCTR
CA      INDEXES
TS      L

CA      POLYTEMP
INHINT
INDEX  L
TC      WRITEP

RELINT
TCF     FEEDBACK

NOROTAT
INDEX  AXISCTR
CA      INDEXES
INHINT
INDEX  A
TC      WRITEP  -1

RELINT
LOOPER CCS  AXISCTR
TC      RETJADR
TCF     CLOSEOUT
DOSKIP  CS   ABSTJ
AD      +TJMINT6      # 14MS
EXTEND
BZMF    NOTMIN

ADS     ABSTJ
INDEX  AXISCTR
CCS     TJU
CA      +TJMINT6
TCF     +2
CS      +TJMINT6
INDEX  AXISCTR
TS      TJU

CCS     SENSETYP      # ENSURE MIN-IMPULSE NOT AGAINST TRANS
TCF     NOTMIN  -1
EXTEND
READ    LOSCALAR
MASK    ONE
TS      NUMBERT

```

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NOTMIN TC SELCTSUB

INDEX AXISCTR  
CA INDEXES  
INHINT

# Page 1455

TS T6FURTHA +1  
CA POLYTEMP  
INDEX T6FURTHA +1  
TC WRITEP

CA ABSTJ  
TS T6FURTHA  
TC JTLST

# IN QR BANK BY NOW

RELINT

CA ZERO  
INDEX AXISCTR  
TS SKIPU

FEEDBACK CS THREE  
AD NUMBERT  
EXTEND  
BZMF +3

CA TWO  
TCF +2  
CA ONE  
INDEX AXISCTR  
TS NO.UJETS  
TCF LOOPER

XTRANS CA ZERO  
TS TJU  
TS TJV  
CA FOUR  
INHINT  
XCH SKIPU  
EXTEND  
BZF +2  
TC WRITEU -1  
CA FOUR  
XCH SKIPV  
RELINT

```

EXTEND
BZF      CLOSEOUT
INHINT
TC        WRITEV  -1
RELINT

INDEXES   TCF      CLOSEOUT
          DEC      4
          DEC      13
+TJMINT6  DEC      22
# Page 1456
-150MS    DEC      -240
BIT8,9    OCT      00600
SCLNORM   OCT      266
TJLAWADR  GENADR  TJLAW  +3      # RETURN ADDRESS FOR RCS ATTITUDE CONTROL

# THE JET LIST:
# THIS IS A WAITLIST FOR T6RUPTS.
#
# CALLED BY:
#          CA      TJ              # TIME WHEN NEXT JETS WILL BE WRITTEN
#          TS      T6FURTHA
#          CA      INDEX           # AXIS TO BE WRITTEN AT TJ (FROM NOW)
#          TS      T6FURTHA +1
#          TC      JTLST
#
# EXAMPLE -- U-AXIS AUTOPILOT WILL WRITE ITS ROTATION CODE OF
# JETS INTO CHANNEL 5. IF IT DESIRES TO TURN OFF THIS POLICY WITHIN
# 150MS AND THEN FIRE NEXTU, A CALL TO JTLST IS MADE WITH T6FURTHA
# CONTAINING THE TIME TO TURN OFF THE POLICY, T6FURTHA +1 THE INDEX
# OF THE U-AXIS(4), AND NEXTU WILL CONTAIN THE "U-TRANS" POLICY OR ZERO.
#
# THE LIST IS EXACTLY 3 LONG. (THIS LEADS UP TO SKIP LOGIC AND 150MS LIMIT)
# THE INPUT IS THE LAST MEMBER OF THE LIST.
#
# RETURNS BY:
#          +      TC      Q
#
# DEFINITIONS: (OUTPUT)
#          TIME6      TIME OF NEXT RUPT
#          T6NEXT      DELTA TIME TO NEXT RUPT
#          T6FURTHA    DELTA TIME FROM 2ND TO LAST RUPT
#          NXT6ADR      AXIS INDEX      0 -- P-AXIS
#          T6NEXT +1    AXIS INDEX      4 -- U-AXIS
#          T6FURTHA +1  AXIS INDEX     13 -- V-AXIS

```

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```
JTLST      CS      T6FURTHA
           AD      TIME6
           EXTEND
           BZMF     MIDORLST      # TIME6 -- TI IS IN A

           LXCH     NXT6ADR
           DXCH     T6NEXT
           DXCH     T6FURTHA
           TS       TIME6
           LXCH     NXT6ADR
```

```
TURNON     CA      BIT15
           EXTEND
           WOR      CHAN13
           TC       Q
```

# Page 1457

```
MIDORLST   AD      T6NEXT
           EXTEND
           BZMF     LASTCHG      # TIME6 + T6NEXT - T IS IN A

           LXCH     T6NEXT  +1
           DXCH     T6FURTHA
           EXTEND
           SU       TIME6
           DXCH     T6NEXT

           TC       Q
```

```
LASTCHG    CS      A
           AD      NEG0
           TS      T6FURTHA

           TC       Q
```

# ROT-TOUV IS ENTERED WITH THE Q-COMPONENT OF THE QUANTITY TO BE TRANSFORMED IN A AND THE R-COMPONENT IN L.  
# ROT-TOUV TRANSFORMS THE QUANTITY INTO THE NON-ORTHOGONAL U-V AXIS SYSTEM. IN THE U-V SYSTEM  
# PRODUCED FROM RCS JET FIRINGS. AT THE COMPLETION OF ROT-TOUV, THE U-COMPONENT OF THE TRANSFORMED QUANTITY IS IN A  
# A AND THE V-COMPONENT IS IN L.

```
ROT-TOUV   LXCH     ROTEMP2      # (R) IS PUT INTO ROTEMP2
           EXTEND
           MP      COEFFQ
           XCH     ROTEMP2      # (R) GOES TO A AND COEFFQ.(Q) TO ROTEMP2
           EXTEND
```

```

MP      COEFFR
TS      L      # COEFFR.(R) IS PUT INTO L
AD      ROTEMP2
TS      ROTEMP1 # COEFFQ.(Q)+COEFFR.(R) IS PUT IN ROTEMP1
TCF     +4
INDEX   A      # COEFFQ.(Q) + COEFFR.(R) HAS OVERFLOWED
CS      LIMITS # AND IS LIMITED TO POSMAX OR NEGMAX
TS      ROTEMP1
CS      ROTEMP2
AD      L      # -COEFFQ.(Q) + COEFFR.(R) IS NOW IN A
TS      7
TCF     +3
INDEX   A      # -COEFFQ.(Q) + COEFFR.(R) HAS OVERFLOWED
CS      LIMITS # AND IS LIMITED TO POSMAX OR NEGMAX
LXCH    ROTEMP1 # COEFFQ.(Q) + COEFFR.(R) IS PUT INTO L
TC      Q
SELCTSUB INDEX ROTINDEX
CA      ALLJETS
INDEX   NUMBERT
MASK    TYPEPOLY
TS      POLYTEMP
# Page 1458
MASK    CH5MASK
CCS     A
TCF     +2
TC      Q
CA      THREE
FAILLOOP TS      NUMBERT
INDEX   ROTINDEX
CA      ALLJETS
INDEX   NUMBERT
MASK    TYPEPOLY
TS      POLYTEMP
MASK    CH5MASK
EXTEND
BZF     FAILLOOP -2
CCS     NUMBERT
TCF     FAILLOOP
INDEX   AXISCTR
TS      TJU
TC      ALARM
OCT     02004
TCF     NOROTAT
ALLJETS OCT     00110      #      -U      6 13

```



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|          |     |       |   |     |                    |
|----------|-----|-------|---|-----|--------------------|
|          | OCT | 00022 | # | -V  | 2 9                |
|          | OCT | 00204 | # | +U  | 5 14               |
|          | OCT | 00041 | # | +V  | 1 10               |
| TYPEPOLY | OCT | 00125 | # | -X  | 1 5 9 13           |
|          | OCT | 00252 | # | +X  | 2 6 10 14          |
|          | OCT | 00146 | # | A   | 2 5 10 13          |
|          | OCT | 00231 | # | B   | 1 6 9 14           |
|          | OCT | 00377 | # | ALL | 1 2 5 6 9 10 13 14 |

# THE FOLLOWING SETS THE INTERRUPT FLIP-FLOP AS SOON AS POSSIBLE, WHICH PERMITS A RETURN TO THE

|          |    |          |
|----------|----|----------|
| CLOSEOUT | CA | ADRRUPT  |
|          | TC | MAKERUPT |

|         |       |         |
|---------|-------|---------|
| ADRRUPT | ADRES | ENDJASK |
|---------|-------|---------|

|         |      |          |
|---------|------|----------|
| ENDJASK | DXCH | DAPARUPT |
|         | DXCH | ARUPT    |
|         | DXCH | DAPBQRPT |
|         | XCH  | BRUPT    |
|         | LXCH | Q        |
|         | CAF  | NEGMAX   |
|         | DXCH | DAPZRUPT |
|         | DXCH | ZRUPT    |
|         | TCF  | NOQRSM   |

# NEGATIVE DAPZRUPT SIGNALS JASK IS OVER.

# Page 1459

|        |        |
|--------|--------|
| BLOCK  | 3      |
| SETLOC | FFTAG6 |
| BANK   |        |

|        |          |
|--------|----------|
| COUNT* | \$\$/DAP |
|--------|----------|

|          |                 |
|----------|-----------------|
| MAKERUPT | EXTEND          |
|          | EDRUPT MAKERUPT |

This code is written to file src/Q-R-AXIS-RCS-AUTOPILOT.s.

**A.84 R30**1522  $\langle \text{src}/R30.s \text{ 1522} \rangle \equiv$ 

```
# Copyright:      Public domain.
# Filename:       R30.agc
# Purpose:       Part of the source code for Colossus 2A, AKA Comanche 055.
#               It is part of the source code for the Command Module's (CM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:    yaYUL
# Contact:       Hartmuth Gutsche <hgutsche@explornet.com>.
# Website:       www.ibiblio.org/apollo.
# Pages:         514-524
# Mod history:   2009-05-09 HG      Started adapting from the Colossus249/ file
#               of the same name, using Comanche055 page
#               images 0514.jpg - 0524.jpg.
```

```
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
```

```
# Notations on the hardcopy document read, in part:
```

```
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. 10:28 APR. 1, 1969
```

```
# This AGC program shall also be referred to as
# Colossus 2A
```

```
# Page 514
```

```
# SUBROUTINE NAME: V82CALL
```

|                              |                            |                  |               |
|------------------------------|----------------------------|------------------|---------------|
| # MOD NO: 0                  |                            | DATE: 16 FEB 67  |               |
| # MOD BY: R. R. BAIRNSFATHER |                            | LOG SECTION: R30 |               |
| # MOD NO: 1                  | MOD BY: R. R. BAIRNSFATHER | DATE: 11 APR 67  | SR30.1 CHANGE |
| # MOD NO: 2                  | MOD BY: ALONSO             | DATE: 11 DEC 67  | VB82 PROGRAM  |
| # MOD NO: 3                  | MOD BY: ALONSO             | DATE: 26 MAR 68  | PROG MOD TO F |

```
# NEW FUNCTIONAL DESCRIPTION: CALLED BY VERB 82 ENTER. PRIORITY 10.
# USED THROUGHOUT.           CALCULATE AND DISPLAY ORBITAL PARAMETERS
```

```
# 1. IF AVERAGE G IS OFF:
```

```
# FLASH DISPLAY V04N06. R2 INDICATES WHICH SHIP'S STATE VECTOR IS
```

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```
#           TO BE UPDATED.  INITIAL CHOICE IS THIS SHIP (R2=1).  ASTRONAUT
#           CAN CHANGE TO OTHER SHIP BY V22EXE.  WHERE X IS NOT EQ 1.
#           SELECTED STATE VECTOR UPDATED BY THISPREC (OTHPREC).
#           CALLS SR30.1 (WHICH CALLS TFFCONMU + TFFRP/RA) TO CALCULATE
#           RPER (PERIGEE RADIUS), RAPO (APOGEE RADIUS), HPER (PERIGEE
#           HEIGHT ABOVE LAUNCH PAD OR LAUNAR LANDING SITE), HARD (APOGEE
#           HEIGHT AS ABOVE), TPER (TIME TO PERIGEE), TFF (TIME TO
#           INTERSECT 300 KFT ABOVE PAD OR 35KFT ABOVE LANDING SITE).
#           FLASH MONITOR V16N44 (HAPO, HPER, TFF).  TFF IS -59MS59S IF IT WAS
#           NOT COMPUTABLE, OTHERWISE IT INCREMENTS ONCE PER SECOND.
#           ASTRONAUT HAS OPTION TO MONITOR TPER BY KEYING IN N 32 E.
#           DISPLAY IS IN HMS, IS NEGATIVE (AS WAS TFF), AND INCREMENTS
#           ONCE PER SECOND ONLY IF TFF DISPLAY WAS -59M59S.
#           2.  IF AVERAGE G IS ON:
#                   CALLS SR30.1 APPROX EVERY TWO SECS.  STATE VECTOR IS ALWAYS
#                   FOR THIS VEHICLE.  V82 DOES NOT DISTURB STATE VECTOR.  RESULTS
#                   OF SR30.1 ARE RAPO, RPER, HAPO, HPER, TPER, TFF.
#                   FLASH MONITOR V16N44 (HAPO, HPER, TFF).
#                   IF MODE IS P11, THEN CALL DELRSPL SO ASTRONAUT CAN MONITOR
#                   RESULTS BY N50E.  SPLASH COMPUTATION DONE ONCE PER TWO SECS.
#           ADDENDUM:  HAPO AND HPER SHOULD BE CHANGED TO READ HAPOX AND HPERX IN THE
#                   ABOVE REMARKS.
#
# CALLING SEQUENCE:  VERB 82 ENTER.
#
# SUBROUTINES CALLED:  SR30.1, GOXDSPF
#                   MAYBE -- THISPREC, OTHPREC, LOADTIME, DELRSPL
#
# NORMAL EXIT MODES:  TC ENDEXT
#
# ALARMS:  NONE
#
# OUTPUT:           HAPOX   (-29) M
#                   HPERX   (-29) M
#                   RAPO    (-29) M EARTH
#                   (-27) M MOON
# Page 515
#                   RPER    (-29) M EARTH
#                   (-27) M MOON
#                   TFF     (-28) CS           CONTAINS NEGATIVE QUANTITY
#                   -TPER   (-28) CS           CONTAINS NEGATIVE QUANTITY
#                   RSP-RREC(-29) M           IF DELRSPL CALLED
#
# ERASABLE INITIALIZATION REQUIRED:  STATE VECTOR.
#
# DEBRIS:           QPRET, RONE, VONE, TFF/RTMU, HPERMIN, RPADTEM, V82EMFLG.
```

```

#          MAYBE:  TSTART82, V82FLAGS, TDEC1.

          EBANK=  HAPOX
          BANK    31
          SETLOC  R30LOC
          BANK
          COUNT*  $$/R30

V82CALL   TC      INTPRET
          BON      GOTO
                   AVEGFLAG
                   V82GON      # IF AVERAGE G ON
                   V82GOFF     # IF AVERAGE G OFF

V82GOFF   EXIT
          CAF      TWO          # ALLOW ASTRONAUT TO SELECT VEHICLE
                   TS          # DESIRED FOR ORBITAL PARAMETERS
                   CAF      ONE
                   TS          OPTIONX +1
                   CAF      OPTIONVN      # V 04 N 06
                   TC      BANKCALL
                   CADR     GOXDSPF
                   TC      ENDEXT      # TERMINATE
                   TC      +2          # PROCEED
                   TC      -5          # DATA IN.  OPTIONX +1 = 1 FOR THIS VEHIC.
                                     #
                                     #      UNEQ 1 FOR OTHER VEHICLE.
                                     # 80 MS
          CAF      BIT4
          TC      WAITLIST
          EBANK=  TFF
          2CADR   TICKTEST

          RELINT
V82GOFLP  CAF      TFFBANK      # MAJOR RECYCLE LOOP ENTRY
          TS      EBANK
          CAF      ZERO
          TS      V82FLAGS      # ZERO FLAGS FOR TICKTEST, INHIBITS
                                     # DECREMENTING OF TFF AND -TPER.
          CAF      PRI07
          TC      FINDVAC      # V82GOFF1 WILL EXECUTE STATE VECTOR

# Page 516
          EBANK=  TFF          # UPDATE AND ORBIT CALCULATIONS FOR
          2CADR   V82GOFF1     # SELECTED VEHICLE ABOUT PROPER BODY.

          RELINT
V82STALL  CAF      THREE      # STALL IN THIS LOOP AND WITHOLD V 16 N 44
          MASK     V82FLAGS    # UNTIL STATE VECTOR UPDATE SETS ONE OF

```

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|          |        |            |                                                         |
|----------|--------|------------|---------------------------------------------------------|
|          | CCS    | A          | # OUR FLAG BITS.                                        |
|          | TC     | FLAGGON    | # EXIT FROM STALL LOOP.                                 |
|          | CAF    | 1SEC       |                                                         |
|          | TC     | BANKCALL   |                                                         |
|          | CADR   | DELAYJOB   |                                                         |
|          | TC     | V82STALL   |                                                         |
| FLAGGON  | CAF    | V16N44     | # MONITOR HAPO, HPER, TFF.                              |
|          | TC     | BANKCALL   |                                                         |
|          | CADR   | GOXDSPF    |                                                         |
|          | TC     | B5OFF      | # TERM THIS TELLS TICKTEST TO KILL ITSELF               |
|          | TC     | B5OFF      | # PROCEED DITTO                                         |
|          | TC     | V82GOFLP   | # RECYCLE RECOMPUTE STATE VECT + DISPLAY                |
| OPTIONVN | VN     | 0412       |                                                         |
| V16N44   | VN     | 1644       |                                                         |
| TFFBANK  | ECADR  | TFF        |                                                         |
| V82GOFF1 | TC     | INTPRET    |                                                         |
|          | RTB    |            |                                                         |
|          |        | LOADTIME   |                                                         |
|          | STORE  | TDEC1      | # TIME FOR STATE VECTOR UPDATE.                         |
|          | STORE  | TSTART82   | # TIME FOR INTERNAL USE.                                |
|          | EXIT   |            |                                                         |
|          | CS     | OPTIONX +1 | # 1 FOR THIS VEHICLE, NOT 1 FOR OTHER                   |
|          | AD     | ONE        |                                                         |
|          | EXTEND |            |                                                         |
|          | BZF    | THISSHIP   |                                                         |
| OTHSHIP  | TC     | INTPRET    |                                                         |
|          | CALL   |            | # CALL STATE VECTOR UPDATE FOR OTHER SHIP.              |
|          |        | OTHPREC    |                                                         |
| BOTHSHIP | VLOAD  |            | # MOVE RESULTS INTO TFFCONIC STORAGE AREAS              |
|          |        | RATT       | # TO BE CALLED BY SR30.1.                               |
|          | STOVL  | RONE       | # RATT AT (-29)M FOR EARTH OR MOON                      |
|          |        | VATT       |                                                         |
|          | STORE  | VONE       | # VATT AT (-7)M/CS FOR EARTH OR MOON                    |
|          | DLOAD* |            |                                                         |
|          |        | 1/RTMUE,2  | # X2 IS 0 FOR EARTH CENTERED STATE VEC                  |
|          |        |            | # HG remark: In Comanche055 scan this line (5324) looks |
|          |        |            | # as it is in start source                              |
|          | STORE  | TFF/RTMU   | # X2 IS 2 FOR MOON                                      |
|          | DLOAD* |            | # AS LEFT BY THISPREC OR OTHPREC.                       |
|          |        | MINPERE,2  |                                                         |
|          | STORE  | HPERMIN    | # TFFRTMU, HPERMIN, AND RPADTEM ARE ALL                 |
|          | SLOAD  | BHIZ       | # EARTH/MOON PARAMETERS AS SET HERE.                    |

```

                                X2
                                EARTHPAD
                                GOTO
THISSHIP TC MOONPAD
          CALL INTPRET          # CALL STATE VECTOR UPDATE FOR THIS SHIP.
                                THISPREC
                                GOTO
                                BOTHSHIP

# THE FOLLOWING CONSTANTS ARE PAIRWISE INDEXED.  DO NOT SEPARATE PAIRS.

1/RTMUM      2DEC*   .45162595 E-4 B14*
1/RTMUE      2DEC*   .50087529 E-5 B17*

MINPERM      2DEC    10668 B-27      # 35 KFT MIN PERIGEE HEIGHT FOR MOON(-27)M
MINPERE      2DEC    91440 B-29      # 300 KFT (-29)M FOR EARTH

EARTHPAD     DLOAD   CLRGO          # PAD 37-B RADIUS.  SCALED AT (-29)M
                                RPAD
                                V82EMFLG      # INDICATE EARTH SCALING FOR SR30.1
                                BOTHPAD

MOONPAD      VLOAD   ABVAL          # COMPUTE MOON PAD RADIUS FROM RLS VECTOR.
                                RLS           # SCALED AT (-27)M.
                                SET

                                V82EMFLG      # INDICATE MOON SCALING FOR SR30.1
BOTHPAD      STCALL  RPADTEM
                                SR30.1       # CALCULATE ORBITAL PARAMETERS
                                EXIT
                                CA           # ARE WE IN POO
                                EXTEND
                                BZF         # YES, DO DELRSPL
SPLRET1      TC      INTPRET
                                RTB         DSU
                                LOADTIME
                                TSTART82    # PRESENT TIME -- TIME V82GOFF1 BEGAN
                                STORE       # SAVE IT
                                DLOAD      BZE
                                -TPER      # SR30.1 SETS -TPER=0 IF HPER L/
                                TICKTFF    # HPERMIN (300 OR 35) KFT.
                                -TPER      # (-TPER = 0)
TICKTPER     DLOAD   DAD           # (-TPER NON ZERO) TFF WAS NOT COMPUTED.
                                -TPER      # BUT WAS SET TO 59M59S.  DON'T DICK TFF, DO
                                TSTART82    # TICK -TPER.  DISPLAY BOTH.
                                STORE      -TPER
                                EXIT       # -TPER CORRECTED FOR TIME SINCE V82GOFF1
                                BEGIN.

```

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# Page 518

|          |        |          |                                              |
|----------|--------|----------|----------------------------------------------|
|          | CAF    | BIT1     |                                              |
|          | TS     | V82FLAGS | # INFORMS TICKTEST TO INCREMENT ONLY -TPER   |
|          | TC     | ENDOFJOB |                                              |
| TICKTFF  | DLOAD  | DAD      | # (-TPER=0) TFF WAS COMPUTED. TICK TFF.      |
|          |        | TFF      | # DO NOT TICK -TPER. DISPLAY TFF, BUT NOT    |
|          |        | TSTART82 | # -TPER                                      |
|          | STORE  | TFF      | # TFF CORRECTED FOR TIME SINCE V82GOFF1      |
|          | EXIT   |          | # BEGAN.                                     |
|          | CAF    | BIT2     |                                              |
|          | TS     | V82FLAGS | # INFORMS TICKTEST TO INCREMENT ONLY TFF.    |
|          | TC     | ENDOFJOB |                                              |
| TICKTEST | CAF    | BIT5     | # THIS WAITLIST PROGRAM PERPETUATES ITSELF   |
|          | MASK   | EXTVBACT | # ONCE A SEC UNTIL BIT 5 OF EXTVBACT =0.     |
|          | CCS    | A        |                                              |
|          | TC     | DOTICK   |                                              |
|          | CAF    | PRI025   |                                              |
|          | TC     | NOVAC    | # TERMINATE V 82. CAN'T CALL ENDEXT IN RUPT. |
|          | EBANK= | EXTVBACT |                                              |
|          | 2CADR  | ENDEXT   |                                              |
| DOTICK   | TC     | TASKOVER |                                              |
|          | CAF    | 1SEC     | # RE-REQUEST TICKTEST.                       |
|          | TC     | WAITLIST |                                              |
|          | EBANK= | TFF      |                                              |
|          | 2CADR  | TICKTEST |                                              |
|          | CAF    | THREE    |                                              |
|          | MASK   | V82FLAGS |                                              |
|          | INDEX  | A        |                                              |
|          | TC     | +1       |                                              |
|          | TC     | TASKOVER | # IF NO FLAGBITS SET DONT' CHANGE TFF OR     |
|          |        |          | # -TPER, BUT CONTINUE LOOP.                  |
|          | TC     | TPERTICK | # ONLY BIT 1 SET. INCR -TPER BY 1 SEC.       |
| TFFTICK  | CAF    | 1SEC     | # ONLY BIT 2 SET. INCR TFF BY 1 SEC.         |
|          | TS     | L        |                                              |
|          | CAF    | ZERO     |                                              |
|          | DAS    | TFF      |                                              |
|          | TC     | TASKOVER |                                              |
| TPERTICK | CAF    | 1SEC     |                                              |
|          | TS     | L        |                                              |
|          | CAF    | ZERO     |                                              |
|          | DAS    | -TPER    |                                              |

```

# Page 519
V82GON      TC      TASKOVER

EXIT

CAF      PRI07
TC      FINDVAC
EBANK=    TFF
2CADR    V82GON1

RELINT
CCS      NEWJOB
TC      CHANG1

V82REDSP    CAF      V16N44
            TC      BANKCALL
            CADR    GOXDSPF
            TC      B50FF
            TC      B50FF
            TC      V82REDSP

V82GON1     TC      INTERPRET

            VLOAD   GOTO
            RN
            NEXTLINE
NEXTLINE    STOVL   RONE
            VN
            STORE   VONE
            BON     GOTO
            AMOONFLG
            MOONGON
            EARTHGON

MOONGON     SET     DLOAD
            V82EMFLG
            1/RTMUM
            STODL   TFF/RTMU
            MINPERM
            STOVL   HPERMIN
            RLS
            ABVAL   GOTO
            V82GON2
EARTHGON    CLEAR   DLOAD
            V82EMFLG
            1/RTMUE

# AVERAGE G ON.  USE CURRENT STATE VECTOR
# FOR ORBITAL PARAMETER CALCULATIONS.
# LESS THAN LAMBERT
# V82GON1 WILL PERFORM ORBIT CALCULATIONS
# ABOUT PROPER BODY APPROX ONCE PER SEC.

# WITHOLD V16 N44 UNTIL FIRST ORBIT CALC
# IS DONE.  NOTE:  V82GON1 (PRI07, FINDVAC
# JOB) IS COMPLETED BEFORE V82GON (PRI07,
# NOVAC JOB).
# MONITOR HAPO, HPER, TFF

# TERM THIS TELLS V82GON1 TO KILL ITSELF.
# PROC DITTO.
# RECYCLE

# THIS EXEC PROGRAM PERPETUATES ITSELF
# ONCE A SEC UNTIL BIT 5 OF EXTVBACT =0.
# HOLDS OFF CCS NEWJOB BETWEEN RN AND
# VN FETCH SO RN, VN ARE FROM SAME
# STATE VECTOR UPDATE.
# RN AT (-29)M FOR EARTH OR MOON
# VN AT (-7)M/CS FOR EARTH OR MOON
# FLAG INDICATES BODY ABOUT WHICH ORBITAL
# CALCULATIONS ARE TO BE PERFORMED.
# IF SET - MOON, IF RESET - EARTH.

# INDICATE MOON SCALING FOR SR30.1
# LUNAR PARAMETERS LOADED HERE FOR SR30.1

# SCALED AT (-27)M

# INDICATE EARTH SCALING FOR SR30.1
# EARTH PARAMETERS LOADED HERE FOR SR30.1

```



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```

                                STODL  TFF/RTMU
                                MINPERE
                                STODL  HPERMIN
                                RPAD
V82GON2  STCALL  RPADTEM      # COMMON CODE FOR EARTH & MOON.
                                SR30.1
# Page 520
                                EXIT
                                TC      CHECKMM
                                DEC      11
                                TC      V82GON3      # NOT IN MODE 11.
CANDEL   TC      INTPRET      # IN MODE 11 OR 00
                                CALL
                                INTSTALL      # DELRSPL DOES INTWAKE
                                DLOAD  CALL
                                TFF
                                DELRSPL      # RETURN IS TO NEXT LINE (SPLRET).
SPLRET   EXIT
                                CA      MODREG
                                EXTEND
                                BZF     SPLRET1
V82GON3  CAF     BIT5
                                MASK    EXTVBACT      # SEE IF ASTRONAUT HAS SIGNALLED TERMINATE
                                EXTEND
                                BZF     ENDEXT      # YES, TERMINATE VB 82 LOOP
                                CAF     1SEC
                                TC      BANKCALL      # WAIT ONE SECOND BEFORE REPEATING
                                CADR     DELAYJOB      # ORBITAL PARAMETER COMPUTATION.
                                TC      V82GON1
```

# Page 521

# SUBROUTINE NAME: SR30.1

# MOD NO: 0

# MOD BY: R. R. BAIRNSFATHER

# MOD NO: 1 MOD BY: R. R. BAIRNSFATHER

DATE: 11 APR 67

# MOD NO: 2 MOD BY: R. R. BAIRNSFATHER

DATE: 14 APR 67

# MOD NO: 3 MOD BY ALONSO

DATE: 11 DEC 67

# MOD NO: 4 MOD BY ALONSO

DATE: 26 MAR 68

# MOD NO: 5 MOD BY: R. R. BAIRNSFATHER

DATE: 6 AUG 68

DATE: 16 FEB 67

LOG SECTION: R32

SR30.1 CHANGED TO ALLOW

ADD OVFL CK FOR RAPO

SUBROUTINE REWRITTEN

PROG MOD TO HANDLE DIF

OVFL CK FOR HAPO & HPER

#

# NEW FUNCTIONAL DESCRIPTION: ORBITAL PARAMETERS DISPLAY FOR NOUNS 32 AND 44.

# SR30.1 CALLS TFFCONMU AND TFFRP/RA TO CALCULATE RPER (PERIGEE RADIUS),

# RAPO (APOGEE RADIUS), HPER (PERIGEE HEIGHT ABOVE LAUNCH PAD OR LUNAR

# LANDING SITE), HAPO (APOGEE HEIGHT AS ABOVE), TPER (TIME TO PERIGEE),

# TFF (TIME TO INTERSECT 300 KFT ABOVE PAD OR 35KFT ABOVE LANDING SITE).

```

# IF HPER IS GREATER THAN OR EQUAL TO HPERMIN, CALCULATES TPER AND STORES
# NEGATIVE. IN -TPER. OTHERWISE STORES +0 IN -TPER. WHENEVER TPER IS
# CALCULATED, TFF IS NOT COMPUTABLE AND DEFAULTS TO -59MIN 59SEC. IF HAPO
# WOULD EXCEED 9999.9 NM, IT IS LIMITED TO THAT VALUE FOR DISPLAY.
#
# ADDENDUM:      HAPO AND HPER SHOULD BE CHANGED TO READ HAPOX AND HPERX IN THE
#                ABOVE REMARKS.
#
# CALLING SEQUENCE:      CALL
#                        SR30.1
#
# SUBROUTINES CALLED:    TFFCONMU, TFFRP/RA, CALCTPER, CALCTFF
#
# NORMAL EXIT MODE:      CALLING LINE +1 (STILL IN INTERPRETIVE MODE)
#
# ALARMS:               NONE
#
# OUTPUT:               RAPO      (-29) M EARTH      APOGEE RADIUS      EARTH CENTERED COORD.
#                        (-27) M MOON                  MOON CENTERED COORD.
#                        RPER      (-29) M EARTH      PERIGEE RADIUS      EARTH CENTERED COORD.
#                        (-27) M MOON                  MOON CENTERED COORD.
#                        HAPOX     (-29) M            APOGEE ALTITUDE ABOVE PAD OR LAND. SITE MAX V
#                        HPERX     (-29) M            PERIGEE ALT. ABOVE PAD OR LAND. SITE      MAX V
#                        TFF       (-28) CS           TIME TO 300KFT OR 35KFT ALTITUDE
#                        -TPER     (-28) CS           TIME TO PERIGEE
#
# ERASABLE INITIALIZATION REQUIRED -
#      TFF/RTMU          (+17) EARTH      RECIPROCAL OF PROPER GRAV CONSTANT FOR
#                        (+14) MOON        EARTH OR MOON = 1/SQRT(MU).
#      RONE              (-29) M          STATE VECTOR
#      VONE              (-7) M/CS        STATE VECTOR
#      RPADTEM           (-29) M EARTH    RADIUS OF LAUNCH PAD OR LUNAR LANDING
#                        (-27) M MOON      SITE.
#      HPERMIN           (-29) M EARTH    (300 OR 35) KFT MINIMUM PERIGEE ALTITUDE
#                        (-27) M MOON      ABOVE LAUNCH PAD OR LUNAR LANDING SITE.
#      V82EMFLG          (INT SW BIT)     RESET FOR EARTH, SET FOR MOON.
#
# DEBRIS:               QPRET, PDL, S2
#
# Page 522
#
# COUNT*  $$/SR30S
#
SR30.1      SETPD  STQ          # INITIALIZE PUSHDOWN LIST.
            0
            S2
# SR30.1 INPUT: RONE AT (-29)M EARTH/MOON

```

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```
#          VONE AT (-7)M/CS
# TFFCONMU, TFFRP/RA, CALCTPER, AND CALCTFF
# CALLS REQUIRE:
# EARTH CENTERED (NO RESCALING REQUIRED)
#     RONE SCALED TO B-29 M
#     VONE SCALED TO B-7 M/CS
# MOON CENTERED (RESCALING REQUIRED)
#     RONE SCALED TO B-27 M
#     VONE SCALED TO B-5 M/CS

BOFF    VLOAD
        V82EMFLG
        TFFCALLS
        RONE
        # OFF FOR EARTH, ON FOR MOON.

VSL2
STOVL   RONE
        VONE

VSL2
STORE   VONE
TFFCALLS CALL
        TFFCONMU
        CALL
        TFFRP/RA
        # TFFRP/RA COMPUTES RAPO,RPER.
        # RETURNS WITH RAPO IN D(MPAC).

DSU
        RPADTEM
BOFF    SR2R
        # NEED HAPO AT (-29)M FOR DISPLAY.
        # IF MOON CENTERED, RESCALE FROM (-27)M.
        # IF EARTH CENTERED ALREADY AT (-29)M.
        # OFF FOR EARTH, ON FOR MOON.

        V82EMFLG
        +1
CALL    # IF HAPO > MAXNM, SET HAPO =9999.9 NM.
        MAXCHK
        # OTHERWISE STORE (RAPO-RPADTEM) IN HAPO.
STODL   HAPOX
        RPER

DSU
        RPADTEM
STORE   MPAC +4
BOFF    SR2R
        # GIVES HPER AT (-29)M EARTH, (-27)M MOON.
        # SAVE THIS FOR COMPARISON TO HPERMIN.
        # NEED HPER AT (-29)M FOR DISPLAY.
        # IF MOON CENTERED, RESCALE FROM (-27)M.
        # IF EARTH CENTERED ALREADY AT (-29)M.
        # OFF FOR EARTH, ON FOR MOON.

        V82EMFLG
        +1
CALL    # IF HPER > MAXNM, SET HPER = 9999.9 NM.
        MAXCHK

# Page 523
STORHPER STODL HPERX
        # STORE (RPER - RPADTEM) INTO HPERX.
```

```

                                MPAC +4
                                DSU   BPL
                                HPERMIN
                                DOTPER
                                DLOAD GOTO
                                HI6ZEROS
                                SKIPTPER
DOTPER      DLOAD  CALL
                                RPER
                                CALCTPER

                                DCOMP
SKIPTPER    STODL  -TPER
                                HPERMIN
                                DAD   CALL
                                RPADTEM
                                CALCTFF
                                DCOMP
                                STCALL TFF
                                S2
                                # HPERMIN AT (-29)M FOR EARTH, (-27)M MOON
                                # IF HPER L/ HPERMIN (300 OR 35) KFT,
                                # THEN ZERO INTO -TPER.
                                # OTHERWISE CALCULATE TPER.

                                # TPER IS PUT NEG INTO -TPER.
                                # HPERMIN AT (-29)M FOR EARTH, (-27)M MOON
                                # RPADTEM AT (-29)M FOR EARTH, (-27)M MOON
                                # GIVES 59M59S FOR TFF IF RPER G/
                                # HPERMIN + RPADTEM. (TPER WAS NON ZERO)
                                # OTHERWISE COMPUTES TFF.      (GOTO)

MAXCHK      DSU   BPL
                                MAXNM
                                +3
                                DAD   RVQ
                                MAXNM
+3          DLOAD RVQ
                                MAXNM

MAXNM       2OCT  0106505603

```

# Page 524

# There is no source code on this page --- HG 2009

This code is written to file src/R30.s.

**A.85 R31**

```

1533  <src/R31.s 1533>≡
      # Copyright:   Public domain.
      # Filename:    R31.agc
      # Purpose:     Part of the source code for Comanche, build 055. It
      #              is part of the source code for the Command Module's
      #              (CM) Apollo Guidance Computer (AGC), Apollo 11.
      # Assembler:   yaYUL
      # Reference:    pp. 505-510
      # Contact:      Onno Hommes <ohommes@cmu.edu>
      # Website:      http://www.ibiblio.org/apollo.
      # Mod history:  2009-05-11 OH   Batch 2 Assignment Comanche Transcription
      #              2009-05-20 RSB   Corrected INSTALL -> INTSTALL
      #
      # The contents of the "Comanche055" files, in general, are transcribed
      # from scanned documents.
      #
      # Assemble revision 055 of AGC program Comanche by NASA
      # 2021113-051. April 1, 1969.
      #
      # This AGC program shall also be referred to as Colossus 2A
      #
      # Prepared by
      #              Massachussets Institute of Technology
      #              75 Cambridge Parkway
      #              Cambridge, Massachusetts
      #
      # under NASA contract NAS 9-4065.
      #
      # Refer directly to the online document mentioned above for further
      # information. Please report any errors to info@sandroid.org.

      # Page 505

      BANK      34
      SETLOC    R31
      BANK

      COUNT*    $$/R31

R31CALL        CAF      PRI03
               TC       FINDVAC
               EBANK=    SUBEXIT
               2CADR     V83CALL

```

|          |        |          |                                          |       |
|----------|--------|----------|------------------------------------------|-------|
| DSPDELAY | CAF    | 1SEC     |                                          |       |
|          | TC     | BANKCALL |                                          |       |
|          | CADR   | DELAYJOB |                                          |       |
|          | CA     | EXTVBACT |                                          |       |
|          | MASK   | BIT12    |                                          |       |
|          | EXTEND |          |                                          |       |
|          | BZF    | DSPDELAY |                                          |       |
| DISPN5X  | CA     | FLAGWRD9 | # TEST R31FLAG (IN SUNDANCE R31FLAG WILL |       |
|          | MASK   | BIT4     | # ALWAYS BE SET AS R34 DOES NOT EXIST.   |       |
|          | EXTEND |          |                                          |       |
|          | BZF    | +3       |                                          |       |
|          | CAF    | V16N54   | # R31 USE NOUN 54                        |       |
|          | TC     | +2       |                                          |       |
|          | CAF    | V16N53   | # R34 USE NOUN 53                        |       |
|          | TC     | BANKCALL |                                          |       |
|          | CADR   | GOMARKF  |                                          |       |
|          | TC     | B5OFF    |                                          |       |
|          | TC     | B5OFF    |                                          |       |
|          | TCF    | DISPN5X  |                                          |       |
| V83      | TC     | INTPRET  |                                          |       |
|          | GOTO   |          |                                          |       |
|          |        | HAVEBASE | # INTEG STATE VECTORS                    |       |
| V83CALL  | TC     | INTPRET  |                                          |       |
|          | GOTO   |          |                                          |       |
|          |        | STATEXTP | # EXTRAPOLATE STATE VECTORS              |       |
| COMPDISP | VLOAD  | VSU      |                                          |       |
|          |        | RATT     |                                          |       |
|          |        | RONE     |                                          |       |
|          | PUSH   | ABVAL    | # RATT-RONE TO OD                        | PD= 6 |
|          | STORE  | RANGE    | # METERS B-29                            |       |
|          | NORM   | VLOAD    |                                          |       |
|          |        | X1       | # RATT-RONE                              | PD= 0 |
|          | VSR1   |          |                                          |       |
|          | VSL*   | UNIT     |                                          |       |
|          |        | 0,1      |                                          |       |
|          | PDVL   | VSU      | # UNIT(LOS) TO OD                        | PD= 6 |
|          |        | VATT     |                                          |       |
|          |        | VONE     |                                          |       |
|          | DOT    |          | # (VATT-VONE).UNIT(LOS)                  | PD= 0 |
|          | SL1    |          |                                          |       |
|          | STCALL | RRATE    | # RANGE RATE M/CS B-7                    |       |
|          |        | CDUTRIG  | # TO INITIALIZE FOR *NBSM*               |       |
|          | CALL   |          |                                          |       |

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```
R34ANG      VLOAD      R34LOS      # NOTE.  PDL MUST = 0.
              UNIT
              RONE

              PDVL      # UR TO OD          PD= 6
              THISAXIS  # UNITX FOR CM, UNITZ FOR LM
              BON       VLOAD      # CHK R31FLAG.  ON=R31 THETA, OFF=R34 PHI
              R31FLAG
              +2         # R31-THETA
              12D

              CALL      *NBSM*

              VXM       PUSH      # UXORZ TO 6D          PD=12D
              REFSMMAT

              VPROJ     VSL2
              OD

              BVSU      UNIT
              6D

              PDVL      VXV      # UP/2 TO 12D          PD=18D
              RONE
              VONE

              UNIT      VXV
              RONE

              DOT       PDVL      # SIGN TO 12D, UP/2 TO MPAC      PD=18D
              12D

              VSL1     DOT      # UP.UXORZ
              6D

              SIGN      SL1
              12D

              ACOS

              STOVL     RTHETA
              RONE

              DOT       BPL
              6D
              +5

              DLOAD     BDSU      # IF UXORZ.R NEG, RTHETA = 1 - RTHETA
              RTHETA
              DPPOSMAX

              STORE     RTHETA    # RTHETA BETWEEN 0 AND 1 REV.
              EXIT

              CAF       BIT5      # HAVE WE BEEN ANSWERED
              MASK      EXTVBACT

              EXTEND

              BZF       ENDEXT    # YES, DIE

              CS        EXTVBACT
              MASK      BIT12
```

|        |     |          |
|--------|-----|----------|
|        | ADS | EXTVBACT |
|        | TCF | V83      |
| V16N54 | VN  | 1654     |
| V16N53 | VN  | 1653     |

# Page 508

```
# STATEXTP DOES AN INITIAL PRECISION EXTRAPOLATION OF THE
# LEM STATE VECTOR TO PRESENT TIME OR TO PIPTIME IF AV G.
# IS ON AND SAVES AS BASE VECTOR. IF AV G IS ON RN + VN
# ARE USED AS THE CM STATE VECTOR AND THE INITIAL R RDOT
# RTHETA ARE COMPUTED WITH NO FURTHER INTEGRATION. IF AV
# G IS OFF A PRECISION EXTRAPOLATION IS MADE OF THE CM
# STATE VECTOR TO PRESENT TIME AND.....
```

```
#
# THE CM + LM STATE VECTORS ARE INTEGRATED TO PRES TIME
# USING PRECISION OR CONIC AS SURFFLAG IS SET OR CLEAR.
#
# IF AV G IS ON THEN
# SUBSEQUENT PASSES WILL PROVIDE
# USE OF RN + VN AS CM STATE VECTOR AND THE LM STATE
# VECTOR WILL BE PRECISION INTEGRATED USING LEMPREC
#
# IF SURFFLAG IS SET.
# CM STATE VECTOR RONE VONE + LM STATE VECTOR RATT
# VATT ARE USED IN COMPUTING R RDOT RTHETA.
#
```

|          |        |          |                                        |
|----------|--------|----------|----------------------------------------|
| STATEXTP | RTB    | BOF      | # INITIAL INTEGRATION                  |
|          |        | LOADTIME |                                        |
|          |        | V37FLAG  |                                        |
|          |        | +3       | # AV G OFF, USE PRES TIME              |
|          | CALL   | GETRVN   | # ON, USE RN VN PIPTIME                |
|          | STORE  | BASETIME | # PRES TIME OR PIPTIME                 |
|          | STCALL | TDEC1    |                                        |
|          |        | LEMPREC  |                                        |
|          | VLOAD  |          | # BASE VECTOR, LM                      |
|          |        | RATT1    |                                        |
|          | STOVL  | BASE0TP  | # POS.                                 |
|          |        | VATT1    |                                        |
|          | STORE  | BASE0TV  | # VEL.                                 |
|          | BON    | DLOAD    |                                        |
|          |        | V37FLAG  |                                        |
|          |        | COMPDISP | # COMPUTE R RDOT RTHETA FROM           |
|          |        |          | # RONE(RN) VONE(VN) RATT+VATT(LEMPREC) |



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```

                                TAT
STCALL  TDEC1
                                CSMPREC
VLOAD                                     # BASE VECTOR, CM
                                RATT1
STOVL   BASETHP                    # POS.
                                VATT1
STORE   BASETHV                    # VEL.
HAVEBASE BON  RTB                  # SUBSEQUENT INTEGRATIONS
                                V37FLAG
                                GETRVN5
                                LOADTIME
STCALL  TDEC1                    # AV G OFF, SET INTEG, OF CM
                                INTSTALL
VLOAD   CLEAR
                                BASETHP
# Page 509
                                MOONFLAG
STOVL   RCV
                                BASETHV
STODL   VCV
                                BASETIME
BOF     SET                      # GET APPROPRIATE MOONFLAG SETTING
                                MOONTHIS
                                +2
                                MOONFLAG
CLEAR
                                INTYPFLG
BON     SET
                                SURFFLAG
                                +2
                                INTYPFLG
STCALL  TET                      # CONIC IF LM NOT DOWN
                                INTEGRVS
                                # INTEGRATION --- AT LAST ---
VLOAD
                                RATT
STOVL   RONE
                                VATT
STODL   VONE                    # GET SET FOR CONIC EXTRAP., OTHER.
                                TAT
BON     CALL
                                SURFFLAG
                                GETRVN6
                                INTSTALL
SET     # LEMPREC IF LM DOWN
                                # ..CONIC IF NOT DOWN
                                INTYPFLG
```

```

OTHINT      STORE  TDEC1      # ENTERED IF AV G ON TO INTEG LM
            VLOAD  CLEAR
            BASEOTP
            MOONFLAG
            STOVL  RCV
            BASEOTV
            STODL  VCV
            BASETIME
            BOF    SET
            MOONTHIS
            +2
            MOONFLAG
            STCALL TET
            INTEGRVS
            GOTO
            COMPDISP      # COMPUTE R RDOT RTHETA
GETRVN5     CALL      # AV G ON
            GETRVN
            BON  CALL
            SURFFLAG
            GETRVN6      # LM DOWN, LMPREC
# Page 510
            INTSTALL
            CLEAR  GOTO
            INTYPFLG
            OTHINT
GETRVN6     STCALL  TDEC1
            LEMPREC
            GOTO
            COMPDISP      # COMPUTE R RDOT RTHETA
GETRVN      STQ
            OD
            VLOAD  GOTO      # AV G ON, RONE = RN VONE = VN
            RN      # AND USE PIPTIME
            +1
            STCALL RONE
            +1
            VLOAD  GOTO
            VN
            +1
            STODL  VONE
            PIPTIME
            GOTO
            OD
            SETLOC R34
            BANK

```

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```
R34LOS      EXIT
             CA      CDUS
             INDEX    FIXLOC
             TS      9D
             CA      CDUT
             INDEX    FIXLOC
             TS      11D
             CA      FIXLOC
             AD      SIX
             COM
             INDEX    FIXLOC
             TS      X1
             TC      INTERPRET
             CALL
             SXTNB
             STCALL  12D
             R34ANG
```

This code is written to file `src/R31.s`.

**A.86 R60 62**

```

1540  <src/R60-62.s 1540>≡
      # Copyright:   Public domain.
      # Filename:    R60_62.agc
      # Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
      #              It is part of the source code for the Command Module's (CM)
      #              Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:   yaYUL
      # Contact:      Ron Burkey <info@sandroid.org>.
      # Website:      www.ibiblio.org/apollo.
      # Pages:        390-398
      # Mod history:  2009-05-09 RSB   Adapted from the Colossus249/ file
      #              of the same name, using Comanche055 page
      #              images.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 055 of AGC program Comanche by NASA
      #       2021113-051.  10:28 APR. 1, 1969
      #
      #       This AGC program shall also be referred to as
      #               Colossus 2A

      # Page 390

                        BANK      34
                        SETLOC    MANUVER
                        BANK

                        EBANK=    TEMPR60

                        COUNT     27/R60

      # CONFORMS TO GSOP CHAPTER FOUR REVISION LOGIC 09          JAN 18, 1968

      R60CSM           TC        MAKECADR
                        TS        TEMPR60

```

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# INSERT PRIODSP CHECK WITH R22 (V06N49) WITH JENNINGS BRODEUR

|          |       |           |                                            |
|----------|-------|-----------|--------------------------------------------|
| REDOMANN | CAF   | BIT6      |                                            |
|          | MASK  | FLAGWRD5  | # IS 3-AXIS FLAG SET                       |
|          | CCS   | A         |                                            |
|          | TCF   | TOBALL    | # YES                                      |
|          | TC    | INTPRET   |                                            |
|          | CALL  |           |                                            |
|          |       | VECPPOINT | # TO COMPUTE FINAL ANGLES                  |
|          | STORE | CPHI      | # STORE FINAL ANGLES -- CPHI, CTHETA, CPSI |
|          | EXIT  |           |                                            |

|        |      |          |                                        |
|--------|------|----------|----------------------------------------|
| TOBALL | CAF  | V06N18   |                                        |
|        | TC   | BANKCALL |                                        |
|        | CADR | GOPERF2R | # DISPLAY PLEASE PERFORM AUTO MANEUVER |
|        | TC   | R61TEST  |                                        |
|        | TC   | REDOMANC | # PROCEED                              |
|        | TCF  | ENDMANU1 | # ENTER I.E., FINISHED WITH R60        |
|        |      |          |                                        |
|        | TC   | CHKLINUS | # TO CHECK FOR PRIORITY DISPLAYS       |
|        | TC   | ENDOFJOB |                                        |

|          |       |           |                           |
|----------|-------|-----------|---------------------------|
| REDOMANC | CAF   | BIT6      |                           |
|          | MASK  | FLAGWRD5  | # IS 3-AXIS FLAG SET      |
|          | CCS   | A         |                           |
|          | TCF   | TOBALLC   | # YES                     |
|          | TC    | INTPRET   |                           |
|          | CALL  |           |                           |
|          |       | VECPPOINT | # TO COMPUTE FINAL ANGLES |
|          | STORE | CPHI      | # STORE ANGLES            |
|          | EXIT  |           |                           |

|            |        |          |                                  |
|------------|--------|----------|----------------------------------|
| TOBALLC    | CAF    | PRI030   | # IS MODE AUTO AND CTL GNC       |
| # Page 391 |        |          |                                  |
|            | EXTEND |          |                                  |
|            | RXOR   | CHAN31   |                                  |
|            | MASK   | 13,14,15 |                                  |
|            | EXTEND |          |                                  |
|            | BZF    | +2       | # AUTO, NON-FLASH N18            |
|            | TCF    | TOBALL   | # NOT AUTO                       |
|            |        |          |                                  |
|            | CAF    | V06N18   | # STATIC UP NON-FLASHING V06 N18 |
|            | TC     | BANKCALL |                                  |
|            | CADR   | GODSPR   |                                  |
|            | TC     | CHKLINUS |                                  |

|            |        |          |                                    |
|------------|--------|----------|------------------------------------|
| STARTMNV   | TC     | BANKCALL |                                    |
|            | CADR   | GOMANUR  |                                    |
| ENDMANUV   | TCF    | TOBALL   | # FINISHED MANEUVER.               |
| ENDMANU1   | TC     | DOWNFLAG | # RESET 3-AXIS FLAG                |
|            | ADRES  | 3AXISFLG | # BIT 6 FLAG 5                     |
|            | CAE    | TEMPR60  |                                    |
|            | TC     | BANKJUMP |                                    |
| CHKLINUS   | CS     | FLAGWRD4 |                                    |
|            | MASK   | BIT12    | # IS PRIORITY DISPLAY FLAG SET?    |
|            | CCS    | A        |                                    |
|            | TC     | Q        | # NO -- EXIT                       |
|            | CA     | Q        |                                    |
|            | TS     | MPAC +2  | # SAVE RETURN                      |
|            | CS     | THREE    | # OBTAIN LOCATION FOR RESTART      |
|            | AD     | BUF2     | # HOLD Q OF LAST DISPLAY           |
|            | TS     | TBASE1   |                                    |
|            | TC     | PHASCHNG |                                    |
|            | OCT    | 71       | # 1.7SPOT FOR RELINUS              |
|            | CAF    | BIT7     |                                    |
|            | TC     | LINUS    | # GO SET BITS FOR PRIORITY DISPLAY |
|            | TC     | MPAC +2  |                                    |
| RELINUS    | CAF    | BIT5     | # IS TRACK FLAG ON                 |
|            | MASK   | FLAGWRD1 |                                    |
|            | EXTEND |          |                                    |
|            | BZF    | GORED020 | # NO                               |
|            | TC     | UPFLAG   |                                    |
|            | ADRES  | PDSPFLAG | # R60 PRIODSP FLAG                 |
|            | TC     | UPFLAG   |                                    |
|            | ADRES  | TARG1FLG | # FOR R52                          |
|            | CAF    | ZERO     | # RESET TO ZERO, SINCE             |
| # Page 392 | TS     | OPTIND   | # OPTIND WAS SET TO -1 BY V379     |
|            | CAF    | PRI014   | # RESTORE ORIGINAL PRIORITY        |
|            | TC     | PRI0CHNG |                                    |
|            | TC     | TBASE1   |                                    |

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```

GORED020      TC      PHASCHNG
               OCT      111          # 1.11 FOR PIKUP20

               TC      ENDOFJOB

R61TEST       CA      MODREG          # ARE WE IN P00.  IF YES THIS MUST BE
               EXTEND          #          VERB49 OR VERB89 SO DO ENDEXT.
               BZF      ENDMANU1      # RESET 3-AXIS & RETURN.  USER DOES ENDEXT
               CA      FLAGWRD4      # ARE WE IN R61 (P20)
               MASK     BIT12
               EXTEND
               BZF      GOTOPOOH      # NO
               TC      GOTOV56        # YES

BIT14+7       OCT      20100
V06N18        VN      0618
```

# Page 393

# PROGRAM DESCRIPTION -- VECPOINT

#

# THIS INTERPRETIVE SUBROUTINE MAY BE USED TO POINT A SPACECRAFT AXIS IN A DESIRED DIRECTION.  
# TO BE POINTED MUST APPEAR AS A HALF UNIT DOUBLE PRECISION VECTOR IN SUCCESSIVE LOCATIONS OF E  
# BEGINNING WITH THE LOCATION CALLED SCAXIS. THE COMPONENTS OF THIS VECTOR ARE GIVEN IN SPACEC  
# THE DIRECTION IN WHICH THIS AXIS IS TO BE POINTED MUST APPEAR AS A HALF UNIT DOUBLE PRECISION  
# SUCCESSIVE LOCATIONS OF ERASABLE MEMORY BEGINNING WITH THE ADDRESS CALLED POINTVSM. THE COMP  
# VECTOR ARE GIVEN IN STABLE MEMBER COORDINATES. WITH THIS INFORMTION VECPOINT COMPUTES A SET  
# ANGLES (2'S COMPLEMENT) CORRESPONDING TO THE CROSS-PRODUCT ROTATION BETWEEN SCAXIS AND POINTV  
# IN T(MPAC) BEFORE RETURNING TO THE CALLER.

#

# THIS ROTATION, HOWEVER, MAY BRING THE S/C INTO GIMBAL LOCK. WHEN POINTING A VECTOR IN THE Y-  
# THE TRANSPONDER AXIS, OR THE AOT FOR THE LEM, THE PROGRAM WILL CORRECT THIS PROBLEM BY ROTATI  
# PRODUCT ATTITUDE ABOUT POINTVSM BY A FIXED AMOUNT SUFFICIENT TO ROTATE THE DESIRED S/C ATTITU  
# LOCK. IF THE AXIS TO BE POINTED IS MORE THAN 40.6 DEGREES BUT LESS THAN 60.5 DEG FROM THE +X  
# THE ADDITIONAL ROTATION TO AVOID GIMBAL LOCK IS 35 DEGREES. IF THE AXIS IS MORE THAN 60.5 DE  
# THE ADDITIONAL ROTATION IS 35 DEGREES. THE GIMBAL ANGLES CORRESPONDING TO THIS ATTITUDE ARE  
# STORED AS 2'S COMPLEMENT ANGLES N T(MPAC) BEFORE RETURNING TO THE CALLER.

#

# WHEN POINTING THE X-AXIS, OR THE THRUST VECTOR, OR ANY VECTOR WITHIN 40.6 DEG OF THE X-AXIS,  
# CANNOT CORRECT FOR A CROSS-PRODUCT ROTATION INTO GIMBAL LOCK. IN THIS CASE A PLATFORM REALIG  
# REQUIRED TO POINT THE VECTOR IN THE DESIRED DIRECTION. AT PRESENT NO INDICATION IS GIVEN FOR  
# EXCEPT THAT THE FINAL MIDDLE GIMBAL ANGLE IN MPAC +2 IS GREATER THAN 59 DEGREES.

#

# CALLING SEQUENCE

#

# 1) LOAD SCAXIS, POINTVSM

```

#      2)      CALL
#                               VECPOINT
#
# RETURNS WITH
#
#      1)      DESIRED OUTER GIMBAL ANGLE IN MPAC
#      2)      DESIRED INNER GIMBAL ANGLE IN MPAC +1
#      3)      DESIRED MIDDLE GIMBAL ANGLE IN MPAC +2
#
# ERASABLES USED --
#
#      1)      SCAXIS          6
#      2)      POINTVSM        6
#      3)      MIS              18
#      4)      DEL              18
#      5)      COF              6
#      6)      VECQTEMP         1
#      7)      ALL OF VAC AREA  43
#
#                               TOTAL    99
#
# SETLOC  VECPT
# BANK
# Page 394
# EBANK=  BCDU
# COUNT   27/VECPT
#
VECPOINT  STQ    BOV          # SAVE RETURN ADDRESS
          VECQTEMP
          VECLEAR          # AND CLEAR OVFIN
VECLEAR   AXC,2  RTB
          MIS              # READ THE PRESENT CDU ANGLES AND
          READCDUK         # STORE THEM IN PD25, 26, 27
          STCALL  25D
          CDUTODCM         # S/C AXES TO STABLE MEMBER AXES (MIS)
          VLOAD   VXI
          POINTVSM        # RESOLVE THE POINTING DIRECTION VF INTO
          MIS            # INITIAL S/C AXES (VF = POINTVSM)
          UNIT
          STORE  28D
          VXV    UNIT      # PD 28 29 30 31 32 33
          SCAXIS          # TAKE THE CROSS PRODUCT VF X VI
          BOV    VCOMP     # WHERE VI = SCAXIS
          PICKAXIS

```



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|            |       |          |                                             |     |
|------------|-------|----------|---------------------------------------------|-----|
|            | STODL | COF      | # CHECK MAGNITUDE                           |     |
|            |       | 36D      | # OF CROSS PRODUCT                          |     |
|            | DSU   | BMN      | # VECTOR, IF LESS                           |     |
|            |       | DPB-14   | # THAN B-14 ASSUME                          |     |
|            |       | PICKAXIS | # UNIT OPERATION                            |     |
|            | VLOAD | DOT      | # INVALID.                                  |     |
|            |       | SCAXIS   |                                             |     |
|            |       | 28D      |                                             |     |
|            | SL1   | ARCCOS   |                                             |     |
| COMPMATX   | CALL  |          | # NO COMPUTE THE TRANSFORMATION FROM        |     |
|            |       | DELCOMP  | # FINAL S/C AXES TO INITIAL S/C AXES MFI    |     |
|            | AXC,1 | AXC,2    |                                             |     |
|            |       | MIS      | # COMPUTE THE TRANSFORMATION FROM FINAL     |     |
|            |       | DEL      | # S/C AXES TO STABLE MEMBER AXES            |     |
|            | CALL  |          | # MFS = MIS MFI                             |     |
|            |       | MXM3     | # (IN PD LIST)                              |     |
|            | DLOAD | ABS      |                                             |     |
|            |       | 6        | # MFS6 = SIN(CPSI)                          | \$2 |
|            | DSU   | BMN      |                                             |     |
|            |       | SINGIMLC | # = SIN(59 DEGS)                            | \$2 |
|            |       | FINDGIMB | # /CPSI/ LESS THAN 59 DEGS.                 |     |
|            |       |          | # I.E., DESIRED ATTITUDE NOT IN GIMBAL LOCK |     |
|            | DLOAD | ABS      | # CHECK TO SEE IF WE ARE POINTING           |     |
|            |       | SCAXIS   | # THE THRUST AXIS                           |     |
|            | DSU   | BPL      |                                             |     |
|            |       | SINVEC1  | # SIN 49.4 DEGS                             | \$2 |
| # Page 395 |       | FINDGIMB | # IF SO, WE ARE TRYING TO POINT IT INTO     |     |
|            | VLOAD |          | # GIMBAL LOCK, ABORT COULD GO HERE          |     |
|            | STADR |          |                                             |     |
|            | STOVL | MIS +12D |                                             |     |
|            | STADR |          | # STORE MFS (IN PD LIST) IN MIS             |     |
|            | STOVL | MIS +6   |                                             |     |
|            | STADR |          |                                             |     |
|            | STOVL | MIS      |                                             |     |
|            |       | MIS +6   | # INNER GIMBAL AXIS IN FINAL S/C AXES       |     |
|            | BPL   | VCOMP    | # LOCATE THE IG AXIS DIRECTION CLOSEST TO   |     |
|            |       | IGSAMEX  | # FINAL X S/C AXIS                          |     |
| IGSAMEX    | VXV   | BMN      | # FIND THE SHORTEST WAY OF ROTATING THE     |     |
|            |       | SCAXIS   | # S/C OUT OF GIMBAL LOCK BY A ROTATION      |     |
|            |       | U=SCAXIS | # ABOUT +- SCAXIS, I.E., IF (IG (SGN MFS3)  |     |
|            |       |          | # X SCAXIS . XF) LESS THAN Q, U = SCAXIS    |     |
|            |       |          | # OTHERWISE U = -SCAXIS.                    |     |

```

                                VLOAD  VCOMP
                                SCAXIS
                                STCALL  COF          # ROTATE ABOUT -SCAXIS
                                CHEKAXIS
U=SCAXIS                        VLOAD
                                SCAXIS
                                STORE   COF          # ROTATE ABOUT + SCAXIS
CHEKAXIS                        DLOAD   ABS
                                SCAXIS          # SEE IF WE ARE POINTING THE AOT
                                DSU      BPL
                                SINVEC2          # SIN 29.5 DEGS                      $2
                                PICKANG1          # IF SO, ROTATE 50 DEGS ABOUT +- SCAXIS
                                DLOAD   GOTO          # IF NOT, MUST BE POINTING THE TRANSPONDER
                                VECANG2          # OR SOME VECTOR IN THE Y, OR Z PLANE
                                COMPMFSN          # IN THIS CASE ROTATE 35 DEGS TO GET OUT
                                # OF GIMBAL LOCK (VECANG2 $360)
PICKANG1                        DLOAD
                                VECANG1          # = 50 DEGS.                      $360
COMPMFSN                        CALL
                                DELCOMP          # COMPUTE THE ROTATION ABOUT SCAXIS TO
                                AXC,1  AXC,2          # BRING MFS OUT OF GIMBAL LOCK
                                MIS
                                DEL
                                CALL
                                MXM3          # COMPUTE THE NEW TRANSFORMATION FROM
                                # DESIRED S/C AXES TO STABLE MEMBER AXES
                                # WHICH WILL ALIGN VI WITH VF AND AVOID
                                # GIMBAL LOCK
FINDGIMB                        AXC,1  CALL
                                0          # EXTRACT THE COMMANDED CDU ANGLES FROM
                                DCMTOCDU          # THIS MATRIX
                                RTB      SETPD
                                V1ST02S          # CONVERT TO 2'S COMPLEMENT
# Page 396
                                0
                                GOTO
                                VECQTEMP          # RETURN TO CALLER
PICKAXIS                        VLOAD  DOT          # IF VF X VI = 0, FIND VF, VI
                                28D
                                SCAXIS
                                BMN      TLOAD
                                ROT180
                                25D
                                GOTO
                                VECQTEMP          # IF VF = VI, CDU DESIRED = PRESENT CDU
                                # PRESENT CDU ANGLES

```

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```

ROT180      VLOAD  VXV          # IF VF, VI ANTI-PARALLEL, 180 DEG ROTATION
              MIS +6          # IS REQUIRED. Y STABLE MEMBER AXIS IN
              HIUNITX         # INITIAL S/C AXES.
              UNIT   VXV          # FIND Y(SM) X X(I)
              SCAXIS         # FIND UNIT(VI X UNIT(Y(SM) X X(I)))
              UNIT   BOV          # I.E., PICK A VECTOR IN THE PLANE OF X(I),
              PICKX          # Y(SM) PERPENDICULAR TO VI
              STODL  COF
              36D            # CHECK MAGNITUDE
              DSU   BMN          # OF THIS VECTOR.
              DPB-14         # IF LESS THAN B-14,
              PICKX          # PICK X-AXIS.
              VLOAD
              COF
XROT        STODL  COF
              HIDPHALF
              GOTO
              COMPMATX
PICKX       VLOAD  GOTO          # PICK THE XAXIS IN THIS CASE
              HIUNITX
              XROT
              BANK   35
              SETLOC MANUVER1
              BANK

SINGIMLC    2DEC   .4285836003   # = SIN(59)                                $2
SINVEC1     2DEC   .3796356537   # = SIN(49.4)                              $2
SINVEC2     2DEC   .2462117800   # = SIN(29.5)                              $2
VECANG1     2DEC   .1388888889   # = 50 DEGREES                             $360
VECANG2     2DEC   .0972222222   # = 35 DEGREES                             $360

1BITDP      OCT    0              # KEEP THIS BEFORE DPB(-14)          *****
DPB-14      OCT    00001
# Page 397
              OCT    00000
              BANK   34
              SETLOC MANUVER
              BANK
```

# Page 398

# ROUTINE FOR INITIATING AUTOMATIC MANEUVER VIA KEYBOARD (V49)

```
EBANK=  CPHI

COUNT  27/R62

R62DISP  CAF    V06N22      # DISPLAY COMMAND ICDUS CPHI, CTHETA, CPHI
          TC     BANKCALL
          CADR   GOFLASH
          TCF    ENDEXT
          TCF    GOMOVE      # PROCEED
          TCF    R62DISP     # ENTER

                                # ASTRONAUT MAY LOAD NEW ICDUS AT THIS
                                # POINT.
                                # SET FOR 3-AXIS MANEUVER

GOMOVE   TC     UPFLAG
          ADRES  3AXISFLG

          TC     BANKCALL
          CADR   R60CSM
          TCF    ENDEXT
```

This code is written to file src/R60-62.s.

## A.87 R63

1549

*<src/R63.s 1549>*≡

```

# Copyright:      Public domain.
# Filename:       R63.agc
# Purpose:       Part of the source code for Luminary 1A build 099.
#               It is part of the source code for the Lunar Module's (LM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:    yaYUL
# Contact:       Ron Burkey <info@sandroid.org>.
# Website:       www.ibiblio.org/apollo.
# Pages:        338-341
# Mod history:   2009-05-16 RSB   Adapted from the corresponding
#               Luminary131 file, using page
#               images from Luminary 1A.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
#       16:27 JULY 14, 1969
#
# Page 338
# SUBROUTINE NAME:      V89CALL
# MOD NO:              0          DATE:          9 JAN 1968
# MOD BY:              DIGITAL DEVEL GROUP    LOG SECTION:    R63
#
# FUNCTIONAL DESCRIPTION:
#
# CALLED BY VERB 89 ENTER DURING P00.  PRIO 10 USED.  CALCULATES AND
# DISPLAYS FINAL FDAI BALL ANGLES TO POINT LM +X OR +Z AXIS AT CSM.
#
# 1. KEY IN V 89 E ONLY IF IN PROG 00.  IF NOT IN P00, OPERATOR ERROR AND
# EXIT R63, OTHERWISE CONTINUE.
#
# 2. IF IN P00, DO IMU STATUS CHECK ROUTINE (R02BOTH).  IF IMU ON AND ITS
# ORIENTATION KNOWN TO LGC, CONTINUE.

```

```

#
# 3. FLASH DISPLAY V 04 N 06.  R2 INDICATES WHICH SPACECRAFT AXIS IS TO
# BE POINTED AT CSM.  INITIAL CHOICE IS PREFERRED (+Z) AXIS (R2=1).
# ASTRONAUT CAN CHANGE TO (+X) AXIS (R2 NOT =1) BY V 22 E 2 E.  CONTINUE
# AFTER KEYING IN PROCEED.
#
# 4. BOTH VEHICLE STATE VECTORS UPDATED BY CONIC EQS.
#
# 5. HALF MAGNITUDE UNIT LOS VECTOR (IN STABLE MEMBER COORDINATES) AND
# HALF MAGNITUDE UNIT SPACECRAFT AXIS VECTOR (IN BODY COORDINATES)
# PREPARED FOR VECPOINT.
#
# 6. GIMBAL ANGLES FROM VECPOINT TRANSFORMED INTO FDAI BALL ANGLES BY
# BALLANGS.  FLASH DISPLAY V 06 N 18 AND AWAIT RESPONSE.
#
# 7      RECYCLE -- RETURN TO STEP 4.
#      TERMINATE -- EXIT R63
#      PROCEED -- RESET 3AXISFLAG AND CALL R60LEM FOR ATTITUDE MANEUVER.
#
# CALLING SEQUENCE:      V 89 E.
#
# SUBROUTINES CALLED:    CHECKPOOH, R02BOTH, GOXDSPF, CSMCONIC, LEMCONIC,
#                        VECPOINT, BALLANGS, R60LEM.
#
# NORMAL EXIT MODES:     TC ENDEXT
#
# ALARMS:                1. OPERATOR ERROR IF NOT IN POO.
#                        2. PROGRAM ALARM IF IMU IS OFF.
#                        3. PROGRAM ALARM IF IMU ORIENTATION IS UNKNOWN.
#
# OUTPUT:                NONE
#
# ERASABLE INITIALIZATION REQUIRED:  NONE
#
# DEBRIS:                OPTION1, +1, TDEC1, PCINTVSM, SCAXIS, CPHI, CTHETA, CPSI,
# Page 339
#                        3AXISFLAG.

EBANK=  RONE
BANK    32
SETLOC  BAWLANGS
BANK

COUNT*  $$/R63
V89CALL  TC      BANKCALL      # IMU STATUS CHECK.  RETURNS IF ORIENTATION
CADR     R02BOTH      # KNOWN.  ALARMS IF NOT.

```

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```
V89RECL      CAF      THREE      # ALLOW ASTRONAUT TO SELECT DESIRED
              TS        OPTIONX    # TRACKING ATTITUDE AXIS.
              CAF        ONE
              TS        OPTIONX    +1
              CAF        VB04N12    # V 04 N 12.
              TC        BANKCALL
              CADR       GOFLASH
              TC        ENDEXT      # TERMINATE
              TC        +2          # PROCEED
              TC        -5          # DATA IN.  OPTION1+1 = 1 FOR Z AXIS
              TC        INTPRET     #                2 FOR X AXIS
              RTB        DAD
              LOADTIME      # READ PRESENT TIME
              DP1MIN
              STORE      TSTART82    # SAVE TIME FOR LEMCONIC CALL
              STCALL     TDEC1       # STORE TIME FOR CSMCONIC CALL
              CSMCONIC     # CSM STATE VECTOR UPDATE
              VLOAD      # CSMCONIC LEFT R VECTOR IN RATT
              RATT
              STODL      RONE        # SAVE FOR LINE OF SIGHT (LOS) COMPUTATION
              TSTART82
              STCALL     TDEC1       # STORE TIME FOR LEMCONIC CALL
              LEMCONIC     # LEM STATE VECTOR UPDATE
              VLOAD      VSU         # CSM POSITION -- LEM POSITION -- LOS
              RONE        # LOS VECTOR LEFT IN MPAC
              RATT
              MXV        RTB         # (REFSMAT X LOS).  TRANSFORMS LOS FROM
              REFSMMAT     # REFERENCE COORD TO STAB MEMB COORD.
              NORMUNIT
              STORE      POINTVSM    # STORE LOS FOR VECPOINT CALCULATION
              EXIT
              CS         OPTIONX    +1  # 1 FOR Z AXIS.  2 FOR X AXIS.
              AD         ONE
              EXTEND
              BZF        ALINEZ
              TC         INTPRET     # X AXIS ALIGNMENT
              VLOAD
              UNITX      # READ (.5, 0, 0)
              # Page 340
              V89CALL1    STCALL     SCAXIS      # STORE SELECTED ALIGNMENT AXIS
              VECPOINT    # PUTS DESIRED GIM ANG (OG,IG,MG) IN TMPAC
              STORE      CPHI        # STOR GIMBAL ANGLES FOR BALLANGS CALL
              EXIT
              TC         BANKCALL
              CADR       BALLANGS    # PUTS DESIRED BALL ANGLE IN FDAIX,Y,Z
              CAF        VB06N18    # V 06 N 18
```

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|            |       |          |                                           |
|------------|-------|----------|-------------------------------------------|
|            | TC    | BANKCALL | # NOUN 18 REFERS TO FDAIX,Y,Z             |
|            | CADR  | GOFLASH  |                                           |
|            | TC    | ENDEXT   | # TERMINATE                               |
|            | TC    | +2       | # PROCEED                                 |
|            | TC    | V89RECL  | # RECYCLE                                 |
|            | TC    | DOWNFLAG | # RESET 3 AXIS FLAG                       |
|            | ADRES | 3AXISFLG | # RESET BIT6 FLAG WORD 5                  |
|            | TC    | BANKCALL | # PERFORMS LEM MANEUVER TO ALIGN SELECTED |
|            | CADR  | R60LEM   | # SPACECRAFT AXIS TO CSM.                 |
|            | TCF   | ENDEXT   | # TERMINATE R63                           |
| ALINEZ     | TC    | INTPRET  | # Z AXIS ALIGNMENT                        |
|            | VLOAD | GOTO     |                                           |
|            |       | UNITZ    | # READ (0, 0, .5)                         |
|            |       | V89CALL1 |                                           |
| VB04N12    | VN    | 412      |                                           |
| VB06N18    | VN    | 0618     |                                           |
| # Page 341 |       |          |                                           |
| DP1MIN     | 2DEC  | 6000     |                                           |

This code is written to file src/R63.s.



## A.88 RADAR LEADIN ROUTINES

```

1553  <src/RADAR-LEADIN-ROUTINES.s 1553>≡
      # Copyright:    Public domain.
      # Filename:     RADAR_LEADIN_ROUTINES.agc
      # Purpose:      Part of the source code for Luminary 1A build 099.
      #               It is part of the source code for the Lunar Module's (LM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Ron Burkey <info@sandroid.org>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         490-491
      # Mod history:   2009-05-17 RSB   Adapted from the corresponding
      #               Luminary131 file, using page
      #               images from Luminary 1A.
      #
      # This source code has been transcribed or otherwise adapted from
      # digitized images of a hardcopy from the MIT Museum. The digitization
      # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
      # the Museum. Many thanks to both. The images (with suitable reduction
      # in storage size and consequent reduction in image quality as well) are
      # available online at www.ibiblio.org/apollo. If for some reason you
      # find that the images are illegible, contact me at info@sandroid.org
      # about getting access to the (much) higher-quality images which Paul
      # actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
      #       16:27 JULY 14, 1969

      # Page 490

      BANK      25
      SETLOC    RRLEADIN
      BANK

      EBANK=    RSTACK

      # RADAR SAMPLING LOOP.

      COUNT*    $$/RLEAD
      RADSAMP    CCS      RSAMPDT      # TIMES NORMAL ONCE PER SECOND SAMLING
      TCF        +2
      TCF        TASKOVER      # +0 INSERTED MANUALLY TERMINATES TEST.

      TC         WAITLIST

```

```

EBANK= RSTACK
2CADR  RADSAMP

CAF     PRI025
TC      NOVAC
EBANK=  RSTACK
2CADR  DORSAMP

CAF     BIT14          # FOR CYCLIC SAMPLING, RTSTDEX=
EXTEND          # RTSTLOC/2 + RTSTBASE
MP      RTSTLOC
AD      RTSTBASE      # 0 FOR RR, 2 FOR LR.
TS      RTSTDEX
TCF     TASKOVER

# DO THE ACTUAL RADAR SAMPLE.

DORSAMP      TC      VARADAR      # SELECTS VARIABLE RADAR CHANNEL.
              TC      BANKCALL
              CADR     RADSTALL

              INCR     RFAILCNT      # ADVANCE FAIL COUNTER BUT ACCEPT BAD DATA

DORSAMP2     INHINT
              CA      FLAGWRD5      # DON'T UPDATE RSTACK IF IN R77.
              MASK    R77FLBIT
              CCS      A
              TCF      +4

              DXCH     SAMPLSUM
              INDEX    RTSTLOC
              DXCH     RSTACK

              CS      RTSTLOC      # CYCLE RTSTLOC.
              AD      RTSTMAX
              EXTEND

# Page 491

              BZF      +3
              CA      RTSTLOC
              AD      TWO          # STORAGE IS DP
              TS      RTSTLOC
              TCF     ENDOFJOB      # CONTINUOUS SAMPLING AND 2N TRIES -- GONE.

# VARIABLE RADAR DATA CALLER FOR ONE MEASUREMENT ONLY.

```

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|         |       |         |                                         |
|---------|-------|---------|-----------------------------------------|
| VARADAR | CAF   | ONE     | # WILL BE SENT TO RADAR ROUTINE IN A BY |
|         | TS    | BUF2    | # SWCALL                                |
|         | INDEX | RTSTDEX |                                         |
|         | CAF   | RDRLOCS |                                         |
|         | TCF   | SWCALL  | # NOT TOUCHING Q.                       |
| RDRLOCS | CADR  | RRRANGE | # = 0                                   |
|         | CADR  | RRRDOT  | # = 1                                   |
|         | CADR  | LRVELX  | # = 2                                   |
|         | CADR  | LRVELY  | # = 3                                   |
|         | CADR  | LRVELZ  | # = 4                                   |
|         | CADR  | LRALT   | # = 5                                   |

This code is written to file `src/RADAR-LEADIN-ROUTINES.s`.

## A.89 RCS-CSM DAP EXECUTIVE PROGRAMS

```

1556  <src/RCS-CSM-DAP-EXECUTIVE-PROGRAMS.s 1556>≡
# Copyright:    Public domain.
# Filename:     RCS-CSM_DAP_EXECUTIVE_PROGRAMS.agc
# Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
#              It is part of the source code for the Command Module's (CM)
#              Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:     Ron Burkey <info@sandroid.org>.
# Website:     www.ibiblio.org/apollo.
# Pages:       1037-1038
# Mod history: 2009-05-13 RSB   Adapted from the Colossus249/ file of the
#                      same name, using Comanche055 page images.
#              2009-05-20 RSB   A "Page N" comment was corrected.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 055 of AGC program Comanche by NASA
#       2021113-051.  10:28 APR. 1, 1969
#
#       This AGC program shall also be referred to as
#       Colossus 2A
#
# Page 1037
# CALCULATION OF  AMGB, AMBG  ONCE EVERY SECOND
#
#       AMGB = 1      SIN(PSI)              0
#              0      COS(PSI)COS(PHI)      SIN(PHI)
#              0      -COS(PSI)SIN(PHI)     COS(PHI)
#
#       AMBG = 1      -TAN(PSI)COS(PHI)     TAN(PSI)SIN(PHI)
#              0      COS(PHI)/COS(PSI)     -SIN(PHI)/COS(PSI)
#              0      SIN(PHI)              COS(PHI)
#
# WHERE PHI AND PSI ARE CDU ANGLES

```

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Apollo-11.nw 1557

```
BANK      20
SETLOC    DAPS8
BANK

COUNT*   $$/DAPEX
EBANK=    KMPAC
AMBGUPDT  CA      FLAGWRD6      # CHECK FOR RCS AUTOPILOT
EXTEND
BZMF      ENDOFJOB      # BIT15 = 0, BIT14 = 1
MASK      BIT14      # IF NOT RCS, EXIT
EXTEND
BZF       ENDOFJOB      # TO PROTECT TVC DAP ON SWITCHOVER

CA        CDUZ
TC        SPSIN2
TS        AMGB1      # CALCULATE AMGB
CA        CDUZ
TC        SPCOS2
TS        CAPSI      # MUST CHECK FOR GIMBAL LOCK
CAF       QUADANGL    # = 7.25 DEGREES JET QUAD ANGULAR OFFSET
EXTEND
MSU       CDUX
COM       # CDUX - 7.25 DEG
TC        SPCOS1
TS        AMGB8
EXTEND
MP        CAPSI
TS        AMGB4
CAF       QUADANGL
EXTEND
MSU       CDUX
COM       # CDUX - 7.25 DEG
TC        SPSIN1
TS        AMGB5
EXTEND
MP        CAPSI
COM

# Page 1038
TS        AMGB7
TCF       ENDOFJOB
QUADANGL  DEC      660      # = 7.25 DEGREES
```

This code is written to file src/RCS-CSM-DAP-EXECUTIVE-PROGRAMS.s.

## A.90 RCS-CSM DIGITAL AUTOPILOT

```

1558      <src/RCS-CSM-DIGITAL-AUTOPILOT.s 1558>≡
      # Copyright:      Public domain.
      # Filename:        RCS-CSM_DIGITAL_AUTOPILOT.agc
      # Purpose:         Part of the source code for Colossus 2A, AKA Comanche 055.
      #                  It is part of the source code for the Command Module's (CM)
      #                  Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:      yaYUL
      # Contact:         Ron Burkey <info@sandroid.org>.
      # Website:         www.ibiblio.org/apollo.
      # Pages:           1002-1024
      # Mod history:     2009-05-13 RSB   Adapted from the Colossus249/ file of the
      #                  same name, using Comanche055 page images.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum.  The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum.  Many
      # thanks to both.  The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo.  If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #      Assemble revision 055 of AGC program Comanche by NASA
      #      2021113-051.  10:28 APR. 1, 1969
      #
      #      This AGC program shall also be referred to as
      #
      #                  Colossus 2A
      #
      # Page 1002
      # T5 INTERRUPT PROGRAM FOR THE RCS-CSM AUTOPILOT
      #
      # START OF T5 INTERRUPT PROGRAM
      #
      #      BANK      20
      #      SETLOC    DAPS3
      #      BANK
      #
      #      COUNT    21/DAPRC
      #
      #      EBANK=    KMPAC
      #
      # REDORCS      LXCH      BANKRUPT      # RESTART OF AUTOPILOT COMES HERE
      #              CA        T5PHASE      # ON A T5 RUPT

```

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```
EXTEND
BZMF +2 # IF T5PHASE +0, -0, OR -, RESET TO -
TCF +3 # IF T5PHASE +, LEAVE IT +. DO A FRESHDAP
CS ONE
TS T5PHASE
EXTEND
DCA RCSLOC
DXCH T5LOC # HOOK UP T5RUPT TO AUTOPILOT
TCF RCSATT +1
EBANK= KMPAC
RCSLOC 2CADR RCSATT

RCSATT LXCH BANKRUPT # SAVE BB
EXTEND # SAVE Q
QXCH QRUPT
CAF BIT15 # BIT15 CHAN31 = 0 IF IMU POWER IS ON AND
EXTEND # S/C CONT SW IS IN CMC (I.E., IF G/C AUTO
RAND CHAN31 # PILOT IS FULLY ENABLED)
EXTEND
BZF SETT5 # IF G/C AUTOPILOT IS FULLY ENABLED,
# GO TO SETT5

CS RCSFLAGS # IF G/C AUTOPILOT IS NOT FULLY ENABLED,
MASK BIT14
ADS RCSFLAGS # SET NORATE FLAG,
CAF POSMAX
TS HOLDFLAG # SET HOLDFLAG +,
CAF ZERO # ZERO ERRORX, ERRORY, AND ERRORZ,
TS ERRORX
TS ERRORY
TS ERRORZ
CAF BIT14
EXTEND
RAND CHAN31 # AND CHECK FREE FUNCTION (BIT14 CHAN31).
EXTEND

# Page 1003
BZF SETT5 # IF IN FREE MODE, GO TO SETT5.

TS T5PHASE # IF NOT IN FREE MODE,
CAF OCT37766 # SCHEDULE REINITIALIZATION (FRESHDAP)
TS TIME5 # IN 100 MS VIA T5RUPT

TCR ZEROJET # ZERO JET CHANNELS IN 14 MS VIA ZEROJET

DELTATT TCF KMATRIX
OCT 37770 # 80MS (TIME5)
```

|          |        |        |                |
|----------|--------|--------|----------------|
| DELTATT2 | OCT    | 37776  | # 20MS (TIME5) |
| ONESEK   | DEC    | 16284  | # 1 SEC(TIME5) |
| CHAN5    | EQUALS | 5      |                |
| CHAN6    | EQUALS | 6      |                |
| PRI034A  | =      | PRI034 |                |

```
# CHECK PHASE OF T5 PROGRAM
#
# BECAUSE OF THE LENGTH OF THE T5 PROGRAM,IT HAS BEEN DIVIDED INTO
# THREE PARTS, T5PHASE1, T5PHASE2, AND THE JET SELECTION LOGIC,
# TO ALLOW FOR THE EXECUTION OF OTHER
# INTERRUPTS. T5PHASE IS ALSO USED IN THE INITIALIZATION OF THE AUTOPILOT
# VARIABLES AT TURN ON.
```

```
#
# THE CODING OF T5PHASE IS...
#
#           + = INITIALIZE T5 RCS-CSM AUTOPILOT
#   T5PHASE = +0 = PHASE2 OF THE T5 PROGRAM
#           - = RESTART DAP
#           -0 = PHASE1 OF THE T5 PROGRAM
```

|       |     |          |                                         |
|-------|-----|----------|-----------------------------------------|
| SETT5 | CCS | T5PHASE  |                                         |
|       | TCF | FRESHDAP | # TURN ON AUTOPILOT                     |
|       | TCF | T5PHASE2 | # BRANCH TO PHASE2 OF PROGRAM           |
|       | TCF | REDAP    | # RESTART AUTOPILOT                     |
|       | TS  | T5PHASE  | # PHASE 1 RESET FOR PHASE 2             |
|       | CA  | TIME5    |                                         |
|       | TS  | T5TIME   | # USED IN COMPENSATING FOR DELAYS IN T5 |
|       | CAF | DELTATT2 | # RESET FOR T5RUPT IN 20MS FOR PHASE2   |
|       | TS  | TIME5    | # OF PROGRAM                            |

```
# Page 1004
# IMU STATUS CHECK
```

|         |      |          |                                            |
|---------|------|----------|--------------------------------------------|
|         | CS   | IMODES33 | # CHECK IMU STATUS                         |
|         | MASK | BIT6     | # BIT6 = 0 IMU OK                          |
|         | CCS  | A        | # BIT6 = 1 NO IMU                          |
|         | TCF  | RATEFILT |                                            |
| FREECHK | CS   | RCSFLAGS | # BIT14 INDICATES THAT RATES HAVE NOT BEEN |
|         | MASK | BIT14    | # INITIALIZED                              |
|         | ADS  | RCSFLAGS |                                            |
|         | CAF  | BIT14    | # NO ATTITUDE REFERENCE                    |
|         | TS   | HOLDFLAG | # STOP ANY AUTOMATIC STEERING AND PREPARE  |
|         |      |          | # TO PICK UP CDU ANGLES UPON RESUMPTION OF |
|         |      |          | # ATTITUDE HOLD                            |



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```

                                EXTEND
                                RAND  CHAN31      # CHECK FOR FREE MODE
                                EXTEND
                                BZF   KRESUME1     # IN FREE MODE PROVIDE FREE CONTROL ONLY
                                TCF   REINIT       # .....TILT.....
BITS4,5  OCT 30

RATEFILT  CA  RCSFLAGS      # SEE IF RATEFILTER HAS BEEN INITIALIZED
          MASK BIT14
          EXTEND             # IF SO, PROCEED WITH RATE DERIVATION
          BZF  +2
          TCF  KMATRIX       # IF NOT, SKIP RATE DERIVATION

#      RATE FILTER      TIMING = 7.72 MS
#
# RATE FILTER EQUATIONS
#
#
#  $DRHO = DELRHO - (.1)ADOT + (1 = GAIN1)DRHO$ 
#                                     -1
#
#  $ADOT = ADOT -1 + GAIN2 DRHO + KMJ DFT$ 
#
#      *
# WHERE  $DEL RHO = AMGB (CDU - CDU)$ 
#                                     -1

DRHOLOOP  CAF  TWO
          TS   SPNDX
          DOUBLE
          TS   DPNDX
          INDEX DPNDX
          CS   DRHO      # DRHO SCALED 180 DEGS
          EXTEND
          INDEX ATTKALMN  # PICK UP DESIRED FILTER GAIN
          MP   GAIN1
          INDEX DPNDX
          DAS  DRHO      # (1 -.064) DRHO
          EXTEND

# Page 1005
          INDEX DPNDX
          DCS   ADOT
          DXCH  KMPAC      #  $-(.1)ADOT$ 
          CA   QUARTER
          TC   SMALLMP
          DXCH  KMPAC
```

```

INDEX  DPNDX
DAS    DRHO
CCS    SPNDX
TCF    DRHOLoop

CA      CDUX
XCH     RHO
EXTEND
MSU     RHO
COM
# MEASURED BODY RATES--
# _      *      _      _
# DELRHO = AMGB (CDU - CDU )
#                                     -1

ZL
DXCH    DELTEMPX
CA      CDUY
XCH     RH01
EXTEND
MSU     RH01
COM
TS      T5TEMP
EXTEND
MP      AMGB1
DAS     DELTEMPX
# (CDUY - RH01)    SCALED 90 DEGS
# DELTEMPX = (CDUX-RHO) + AMGB1(CDUY-RH01)
# MUST BE DOUBLE PRECISION OR WILL LOSE
# PULSES

CA      AMGB4
EXTEND
MP      T5TEMP
DXCH    DELTEMPY
CA      AMGB7
EXTEND
MP      T5TEMP
DXCH    DELTEMPZ
CA      CDUZ
XCH     RH02
EXTEND
MSU     RH02
COM
TS      T5TEMP
EXTEND
MP      AMGB5
DAS     DELTEMPY
# (CDUZ - RH02)    SCALED 90 DEGS
# DELTEMPY = AMGB4(CDUY-RH01)
#                                     + AMGB5(CDUZ-RH02)

CA      AMGB8
EXTEND

```

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```
ADOTLOOP
MP      T5TEMP
DAS     DELTEMPZ      # DELTEMPZ = AMBG7(CDUY-RH01)
                        #                + AMGB8(CDUZ-RH02)
CAF     TWO
TS      SPNDX
DOUBLE
TS      DPNDX
EXTEND
INDEX   DPNDX
DCA     DELTEMPX
INDEX   DPNDX
DAS     DRHO
EXTEND
INDEX   DPNDX
DCA     DELTEMPX
INDEX   DPNDX
DAS     MERRORX
INDEX   DPNDX
CA      DRHO
DOUBLE  # N.B.
DOUBLE  # N.B.
EXTEND
INDEX   ATTKALMN      # PICK UP DESIRED FILTER GAINS
MP      GAIN2
INDEX   DPNDX          # ADOT  + (.16)(.1)DRHO
DAS     ADOT            #      -1
INDEX   SPNDX          # S/C TORQUE TO INERTIA RATIO
CA      KMJ             # SCALED (450)(1600)/(57.3)(16384)=1/1.3
EXTEND
INDEX   SPNDX
MP      DFT
INDEX   DPNDX
DAS     ADOT            # KMJ(DFT)
CCS     SPNDX
TCF     ADOTLOOP        # END CALCULATION OF VEHICLE RATES
CA      ATTSEC
MASK    LOW4
CCS     A
TCF     TENTHSEK
CAF     PRI034          # CALL FOR 1 SEC UPDATE OF TRANSFORMATION
TC      NOVAC           # MATRIX FROM GIMBAL AXES TO BODY AXES
EBANK=  KMPAC
2CADR   AMBGUPDT

CAF     NINE
```

TENTHSEK            TS            ATTSEC

# Page 1007

# WHEN AUTOMATIC MANEUVERS ARE BEING PERFORMED, THE FOLLOWING ANGLE ADDITION MUST BE  
# SEQUENCE OF ANGULAR COMMANDS TO THE AUTOPILOT--

#

#            CDUXD = CDUXD + DELCDUX            (DOUBLE PRECISION)

#            CDUYD = CDUYD + DELCDUY            (DOUBLE PRECISION)

#            CDUZD = CDUZD + DELCDUZ            (DOUBLE PRECISION)

#

# THE STEERING PROGRAMS:

#            1) ATTITUDE MANEUVER ROUTINE

#            2) LEM TRACKING

#

# SHOULD GENERATE THE DESIRED ANGLES (CDUXD, CDUYD, CDUZD) AS WELL AS THE INCREMENTAL  
# DELCDUZ) SO THAT THE GIMBAL ANGLE COMMANDS CAN BE INTERPOLATED BETWEEN UPDATES.

#

# HOLDFLAG CODING:

#

#            + = GRAB PRESENT CDU ANGLES AND STORE IN THETADX, THETADY, THETADZ  
#            AND PERFORM ATTITUDE HOLD ABOUT THESE ANGLES  
#            ALSO IGNORE AUTOMATIC STEERING

#            SET = + BY

#            1) INITIALIZATION PHASE OF AUTOPILOT

#            2) OCCURANCE OF RHC COMMANDS

#            3) FREE MODE

#            4) SWITCH OVER TO ATTITUDE HOLD FROM AUTO

#            WHILE DOING AUTOMATIC STEERING (IN THIS CASE  
#            HOLDFLAG IS NOT ACTUALLY SET TO +, BUT THE LOGIC  
#            FUNCTIONS AS IF IT WERE.)

#            5) S/C CONTROL SWITCH IS SCS

#            6) IMU POWER OFF

#            +0 = IN ATTITUDE HOLD ABOUT A PREVIOUSLY ESTABLISHED REFERENCE

#            - = PERFORMING AUTOMATIC MANEUVER

#            -0 = NOT USED AT PRESENT

#

# NOTE THAT THIS FLAG MUST BE SET = - BY THE STEERING PROGRAM IF IT IS TO COMMAND THE

# SINCE ASTRONAUT ACTION MAY CHANGE THE HOLDFLAG SETTING, IT SHOULD BE MONITORED BY THE

# DETERMINE IF THE AUTOMATIC SEQUENCE HAS BEEN INTERRUPTED AND IF SO, TAKE THE APPROPRIATE

CS            HOLDFLAG

EXTEND

BZMF        DACNDLS

# IF HOLDFLAG +0,-0,+, BYPASS AUTOMATIC  
# COMMANDS.

DCDUINCR     CAF        TWO

DELOOP       TS        SPNDX

```
DOUBLE
TS      DPNDX
EXTEND
INDEX   A
DCA     CDUXD

# Page 1008

DXCH    KMPAC
EXTEND
INDEX   DPNDX
DCA     DELCDUX
TC      DPADD
EXTEND
DCA     KMPAC
INDEX   SPNDX
TS      THETADX
INDEX   DPNDX
DXCH    CDUXD
CCS     SPNDX
TCF     DELOOP
```

```
# Page 1009
```

```
# RCS-CSM AUTOPILOT ATTITUDE ERROR DISPLAY
```

```
#
```

```
# THREE TYPES OF ATTITUDE ERRORS MAY BE DISPLAYED ON THE FDAI:
```

```
#
```

```
#      MODE 1) AUTOPILOT FOLLOWING ERRORS                SELECTED BY V61E
#              GENERATED INTERNALLY BY THE AUTOPILOT
```

```
#
```

```
#      MODE 2) TOTAL ATTITUDE ERRORS                    SELECTED BY V62E
#              WITH RESPECT TO THE CONTENTS OF N22
```

```
#
```

```
#      MODE 3) TOTAL ASTRONAUT ATTITUDE ERRORS          SELECTED BY V63E
#              WITH RESPECT TO THE CONTENTS OF N17
```

```
#
```

```
# MODE 1 IS PROVIDED AS A MONITOR OF THE RCS DAP AND ITS ABILITY TO TRACK AUTOMATIC STEERING CO
```

```
# MODE THE ATTITUDE ERRORS WILL BE ZEROED WHEN THE CMC MODE SWITCH IS IN FREE.
```

```
#
```

```
# MODE 2 IS PROVIDED TO ASSIST THE CREW IN MANUALLY MANEUVERING THE S/C TO THE ATTITUDE (GIMBAL
# IN N22. THE ATTITUDE ERRORS WRT THESE ANGLES AND THE CURRENT CDU ANGLES ARE RESOLVED INTO S/
# AS A FLY-TO INDICATOR.
```

```
#
```

```
# MODE 3 IS PROVIDED TO ASSIST THE CREW IN MANUALLY MANEUVERING THE S/C TO THE ATTITUDE (GIMBAL
# IN N17. THE ATTITUDE ERRORS WRT THESE ANGLES AND THE CURRENT CDU ANGLES ARE RESOLVED INTO S/
# AS A FLY-TO INDICATOR.
```

```
#
```

```
# V60 IS PROVIDED TO LOAD N17 WITH A SNAPSHOT OF THE CURRENT CDU ANGLES, THUS SYNCHRONIZING THE
```

# WITH THE CURRENT S/C ATTITUDE. THIS VERB MAY BE USED AT ANY TIME.

#

# THESE DISPLAYS WILL BE AVAILABLE IN ANY MODE (AUTO, HOLD, FREE, G+N, OR SCS) ONCE T

# INITIATED VIA V46E. MODE 1, HOWEVER, WILL BE MEANINGFUL ONLY IN G+N AUTO OR HOLD.

# V25N17) AN ATTITUDE REFERENCE (DESIRED GIMBAL ANGLES) INTO N17 AT ANY TIME.

|         |        |          |                                           |
|---------|--------|----------|-------------------------------------------|
| DACNDLS | CS     | RCSFLAGS | # ALTERNATE BETWEEN FDAIDSP1 AND FDAIDSP2 |
|         | MASK   | BIT4     |                                           |
|         | EXTEND |          |                                           |
|         | BZF    | FDAIDSP2 |                                           |

|          |     |          |
|----------|-----|----------|
| FDAIDSP1 | ADS | RCSFLAGS |
|          | TC  | NEEDLER  |

|          |     |        |               |
|----------|-----|--------|---------------|
| KRESUME1 | TCF | RESUME | # END PHASE 1 |
|----------|-----|--------|---------------|

# Page 1010

# FDAI ATTITUDE ERROR DISPLAY SUBROUTINE

#

# PROGRAM DESCRIPTION: D. KEENE 5/24/67

#

# THIS SUBROUTINE IS USED TO DISPLAY ATTITUDE ERRORS ON THE FDAI VIA THE DIGITAL TO A

# IN THE CDUS. CARE IS TAKEN TO METER OUT THE APPROPRIATE NUMBER OF PULSES TO THE IN

# OVERFLOW, TO CONTROL THE RELAY SEQUENCING, AND TO AVOID INTERFERENCE WITH THE COAR

# THE DACS.

#

# CALLING SEQUENCE:

#

# DURING THE INITIALIZATION SECTION OF THE USER'S PROGRAM, BIT3 OF RCSFLAGS SHOULD BE

# TURN-ON SEQUENCE WITHIN THE NEEDLES PROGRAM:

#

|   |      |          |             |
|---|------|----------|-------------|
| # | CS   | RCSFLAGS | # IN EBANK6 |
| # | MASK | BIT3     |             |
| # | ADS  | RCSFLAGS |             |

#

# THEREAFTER, THE ATTITUDE ERRORS GENERATED BY THE USER SHOULD BE TRANSFERRED TO THE P

#

|   |     |                    |                                   |
|---|-----|--------------------|-----------------------------------|
| # | AK  | SCALED 180 DEGREES | NOTE: THESE LOCATIONS ARE SUBJECT |
| # | AK1 | SCALED 180 DEGREES | TO CHANGE                         |
| # | AK2 | SCALED 180 DEGREES |                                   |

#

# FULL SCALED DEFLECTION CORRESPONDS TO 16 7/8 DEGREES OF ATTITUDE ERROR

# (= 384 BITS IN IMU ERROR COUNTER)

#

# A CALL TO NEEDLER WILL THEN UPDATE THE DISPLAY:

#

# INHINT

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```
#          TC      IBNKCALL      # NOTE: EBANK SHOULD BE SET TO E6
#          CADR     NEEDLER
#          RELINT
#
# THIS PROCESS SHOULD BE REPEATED EACH TIME THE ERRORS ARE UPDATED.  AT LEAST 3 PASSES THRU THE
# REQUIRED BEFORE ANYTHING IS ACTUALLY DISPLAYED ON THE ERROR METERS.
# NOTE:  EACH CALL TO NEEDLER MUST BE SEPARATED BY AT LEAST 50MS TO ASSURE PROPER RELAY SEQUENC
#
# ERASABLE USED:
#          AK              CDUXCMD
#          AK1             CDUYCMD
#          AK2             CDUZCMD
#          EDRIX           A,L,Q
#          EDRIY           T5TEMP
#          EDRIZ           SPNDX
#
# SWITCHES;  RCSFLAGS      BITS 3,2
#
# I/O CHANNELS: CHAN12      BIT 4          (COARSE ALIGN - READ ONLY)
# Page 1011
#          CHAN12          BIT 6          (IMU ERROR COUNTER ENABLE)
#          CHAN14          BIT 13,14,15   (DAC ACTIVITY)
#
# SIGN CONVENTION:  AK = THETAC - THETA
#          WHERE  THETAC = COMMAND ANGLE
#          THETA = PRESENT ANGLE

NEEDLER      CAF      BIT4          # CHECK FOR COARSE ALIGN ENABLE
EXTEND
RAND      CHAN12      # IF IN COARSE ALIGN DO NOT USE IMU
EXTEND
BZF      NEEDLER1
CS      RCSFLAGS      # SET BIT3 FOR INITIALIZATION PASS
MASK      BIT3
ADS      RCSFLAGS
TC      Q

NEEDLER1     CA      RCSFLAGS
MASK      SIX
EXTEND
BZF      NEEDLES3
MASK      BIT3
EXTEND
BZF      NEEDLER2      # BIT3 = 0, BIT2 = 1

CS      BIT6          # FIRST PASS BIT3 = 1
```

|             |        |            |                                          |
|-------------|--------|------------|------------------------------------------|
|             | EXTEND |            | # DISABLE IMU ERROR COUNTER TO ZERO DACS |
|             | WAND   | CHAN12     | # MUST WAIT AT LEAST 60 MS. BEFORE       |
| NEEDLE11    | CS     | ZERO       | # ENABLING COUNTERS.                     |
|             | TS     | AK         | # ZERO THE INPUTS ON FIRST PASS          |
|             | TS     | AK1        |                                          |
|             | TS     | AK2        |                                          |
|             | TS     | EDRIVEX    | # ZERO THE DISPLAY REGISTERS             |
|             | TS     | EDRIVEY    |                                          |
|             | TS     | EDRIVEZ    |                                          |
|             | TS     | CDUXCMD    | # ZERO THE OUT COUNTERS                  |
|             | TS     | CDUYCMD    |                                          |
|             | TS     | CDUZCMD    |                                          |
|             | CS     | SIX        | # RESET RCSFLAGS FOR PASS2               |
|             | MASK   | RCSFLAGS   |                                          |
|             | AD     | BIT2       |                                          |
|             | TS     | RCSFLAGS   |                                          |
|             | TC     | Q          | # END PASS1                              |
| NEEDLER2    | CAF    | BIT6       | # ENABLE IMU ERROR COUNTERS              |
|             | EXTEND |            |                                          |
|             | WOR    | CHAN12     |                                          |
|             | CS     | SIX        | # RESET RCSFLAGS TO DISPLAY ATTITUDE     |
| # Page 1012 |        |            |                                          |
|             | MASK   | RCSFLAGS   | # ERRORS WAIT AT LEAST 4 MS FOR          |
|             | TS     | RCSFLAGS   | # RELAY CLOSURE                          |
|             | TC     | Q          |                                          |
| NEEDLES3    | CAF    | BIT6       | # CHECK TO SEE IF IMU ERROR COUNTER      |
|             | EXTEND |            | # IS ENABLED                             |
|             | RAND   | CHAN12     |                                          |
|             | EXTEND |            | # IF NOT RECYCLE NEEDLES                 |
|             | BZF    | NEEDLER +5 |                                          |
| NEEDLES     | CAF    | TWO        |                                          |
| DACLOOP     | TS     | SPNDX      |                                          |
|             | CS     | QUARTER    |                                          |
|             | EXTEND |            |                                          |
|             | INDEX  | SPNDX      |                                          |
|             | MP     | AK         |                                          |
|             | TS     | L          |                                          |
|             | CCS    | A          |                                          |
|             | CA     | DACLIMIT   |                                          |
|             | TCF    | +2         |                                          |
|             | CS     | DACLIMIT   |                                          |
|             | AD     | L          |                                          |
|             | TS     | T5TEMP     | # OVFL0 CHK                              |



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```
TCF      +4
INDEX    A          # ON OVERFLOW LIMIT OUTPUT TO +-384
CAF      DACLIMIT
TS        L
INDEX    SPNDX
CS        EDRIX     # CURRENT VALUE OF DAC
AD        L
INDEX    SPNDX
ADS      CDUXCMD
INDEX    SPNDX
LXCH     EDRIX
CCS      SPNDX
TCF      DACLOOP
CAF      13,14,15
EXTEND
WOR      CHAN14     # SET DAC ACTIVITY BITS
TC        Q
REINIT   CAF      DELAY200    # .....TILT LOGIC
          TS        TIME5     # REINITIALIZE DAP IN 200MS
          TS        T5PHASE
          TCF      RESUME
DELAY200 DEC      16364      # 200MS
          DEC      -384
```

# Page 1013

```
DACLIMIT DEC      16000
          DEC      384
```

# Page 1014

# INITIALIZATION PROGRAM FOR RCS-CSM AUTOPILOT

#

# THE FOLLOWING QUANTITIES WILL BE ZEROED AND SHOULD APPEAR IN CONSECUTIVE LOCATIONS IN MEMORY

#

```
#      WBODY  (+1)          DFT              TAU2
#      WBODY1 (+1)          DFT1             BIAS
#      WBODY2 (+1)          DFT2             BIAS1
#      ADOT   (+1)          DRHO  (+1)        BIAS2
#      ADOT1  (+1)          DRHO1 (+1)        ERRORX
#      ADOT2  (+1)          DRHO2 (+1)        ERRORY
#      MERRORX (+1)         ATTSEC            ERRORZ
#      MERRORY (+1)         TAU
#      MERRORZ (+1)         TAU1
```

```
FRESHDAP CAF      ONE          # RESET HOLDFLAG TO STOP AUTOMATIC
```

|             |                                                      |                                                                           |                                                                                                                                                                                                                          |
|-------------|------------------------------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             | TS                                                   | HOLDFLAG                                                                  | # STEERING AND PREPARE TO PICK UP AN<br># ATTITUDE HOLD REFERENCE                                                                                                                                                        |
| REDAP       | TC<br>CADR                                           | IBNKCALL<br>S41.2                                                         | # DECODE DAPDATR1, DAPDATR2 FOR DEADBANDS<br># RATES, QUADFAILS, QUAD MANAGEMENT                                                                                                                                         |
|             | TC<br>CADR                                           | IBNKCALL<br>S40.14                                                        | # DECODE IXX, IAVG, AND CONVERT<br># TO AUTOPILOT GAINS                                                                                                                                                                  |
| ZEROT5      | CAF<br>TS<br>CAF<br>INDEX<br>TS<br>CCS<br>TCF<br>TCR | NO.T5VAR<br>SPNDX<br>ZERO<br>SPNDX<br>WBODY<br>SPNDX<br>ZEROT5<br>ZEROJET | # NO. LOCATIONS TO BE ZEROED MINUS ONE<br># ZERO ALL NECESSARY ERASABLE REGISTERS                                                                                                                                        |
|             | CS<br>TS                                             | ZERO<br>CHANTEMP                                                          | # INITIALIZE MINIMUM IMPULSE CONTROL                                                                                                                                                                                     |
|             | TS                                                   | CH31TEMP                                                                  | # INITIALIZE RHC POSITION MEMORY FOR<br># MANUAL RATE MODES                                                                                                                                                              |
|             | CAF<br>TS                                            | =.24<br>SLOPE                                                             | # INITIALIZE SWITCHING LOGIC SLOPE                                                                                                                                                                                       |
|             | CAF<br>TS                                            | FOUR<br>T5TIME                                                            | # PHASE 0 RESETS FOR PHASE 2 INTERRUPT IN<br># 60 MS. PHASE 2 RESETS FOR PHASE 1 RUPT<br># IN (80MS - T5TIME(40MS)). THEREFORE<br># PHASE 1 (RATEFILTER) BEGINS CYCLING 100<br># MS FROM NOW AND EVERY 100MS THEREAFTER. |
|             | CAF<br>TS                                            | ELEVEN<br>ATTKALMN                                                        | # RESET TO PICK UP KALMAN FILTER TAINS<br># TO INITIALIZE THE S/C ANGULAR RATES                                                                                                                                          |
| # Page 1015 | CA<br>TS<br>CA<br>TS<br>CA<br>TS<br>CAF<br>TS        | CDUX<br>RHO<br>CDUY<br>RH01<br>CDUZ<br>RH02<br>ZERO<br>T5PHASE            | # RESET AUTOPILOT TO BEGIN EXECUTING<br># PHASE2 OF PROGRAM                                                                                                                                                              |

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```

      CS      IMODES33      # CHECK IMU STATUS
      MASK    BIT6         # IF BIT6 = 0 IMU IN FINE ALIGN
      CCS     A            # IF BIT6 = 1 IMU NOT READY
      TCF     IMUAOK
      TS      ATTKALMN     # CANNOT USE IMU
      CAF     RCSINITB     # PROVIDE FREE CONTROL ONLY
      TCF     RCSSWIT      # DON'T START UP RATE FILTER
                        # SIGNAL NO RATE FILTER

IMUAOK      CAF     PRI034      # START MATRIX INITIALIZATION
            TC      NOVAC      # BYPASS IF IMU NOT IN FINE ALIGN
            EBANK=  KMPAC
            2CADR   AMBGUPDT

RCSSWIT     CAF     RCSINIT     # CLEAR BIT14 --ASSUME WE HAVE A GOOD IMU
            TS      RCSFLAGS    # CLEAR BIT1  --INITIALIZE T6 PROGRAM
                        # SET BIT3  --INITIALIZE NEEDLES
                        # CLEAR BIT4 --RESET FOR FDAIDSP1
            CAF     T5WAIT60    # NEXT T5RUPT 60 MS FROM NOW TO ALLOW IMU
                        # ERROR COUNTER TO ZERO.
                        # (MINIMUM DELAY = 15 MS)
            TS      TIME5       # SINCE ATTKALMN IS +11, PROGRAM WILL THEN
            TC      RESUME      # PICK UP THE KALMAN FILTER GAINS.  RATE
                        # FILTER WILL BEGIN OPERATING ZOOMS FROM
                        # NOW

# CONSTANTS USED IN INITIALIZATION PROGRAM

NO.T5VAR    DEC      36
=.24        DEC      .24      # = SLOPE OF 0.6/SEC
RCSINIT     OCT      00004
RCSINITB    OCT      20004
T5WAIT60    DEC      16378    # = 6 CS
            EBANK=  KMPAC
T6ADDR      2CADR    T6START

ZEROJET     CAF     ELEVEN     # ZERO BLAST2, BLAST1, BLAST, YWORD2,
            TS      SPNDX      # YWORD1, PWORD2, PWORD1, RWORD2,
            CAF     ZERO       # AND RWORD1

# Page 1016
            INDEX   SPNDX
            TS      RWORD1
            CCS     SPNDX
            TCF     ZEROJET +1
```

```

CAF      FOUR
TS       BLAST1 +1
CAF      ELEVEN
TS       BLAST2 +1

CS       BIT1
MASK     RCSFLAGS
TS       RCSFLAGS      # RESET BIT1 OF RCSFLAGS TO 0

EXTEND
DCA      T6ADDR
DXCH     T6LOC
CAF      =+14MS        # ENABLE T6RUPT TO SHUT OFF JETS IN 14 MS.
TS       TIME6
CAF      BIT15
EXTEND
WOR      CHAN13

TC       Q

T5PHASE2 CCS      ATTKALMN      # IF (+) INITIALIZE RATE ESTIMATE
TCF      KALUPDT

TCF      +2            # ONLY IF ATTKALMN POSITIVE
TCF      +1
CA       DELTATT2      # RESET FOR PHASE3 IN 20 MS
XCH      TIME5         # (JET SELECTION LOGIC)
ADS      T5TIME        # TO COMPENSATE FOR DELAYS IN T5RUPT

CA       RCSFLAGS      # IF A HIGH RATE AUTO MANEUVER IS IN
MASK     BIT15          # PROGRESS (BIT 15 OF RCSFLAGS SET), SET
EXTEND   # ATTKALMN TO -1
BZF      NOHIAUTO      # OTHERWISE SET ATTKALMN TO 0.
CS       ONE
NOHIAUTO TS      ATTKALMN

# Page 1017
# MANUAL ROTATION COMMANDS

CS       OCT01760      # RESET FORCED FIRING BITS (BITS 10 TO 5
MASK     RCSFLAGS      # OF RCSFLAGS) TO ZERO
TS       RCSFLAGS

EXTEND
READ     CHAN31

```

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```
TS      L
CA      CH31TEMP
EXTEND
RXOR    LCHAN
MASK    MANROT      # = OCT00077
EXTEND
BZMF    NOCHANGE

LXCH    A
TS      CH31TEMP    # SAVE CONTENTS OF CHANNEL 31 IN CH31TEMP

CA      L
EXTEND
MP      BIT5        # PUT BITS 6-1 OF A IN BITS 10-5 OF L
CA      L
ADS     RCSFLAGS    # SET FORCED FIRING BITS FOR AXES WITH
                   # CHANGES IN COMMAND. BITS 10,9 FOR
                   # ROLL, BITS 8,7 FOR YAW, BITS 6,5 FOR
                   # PITCH

CS      RCSFLAGS    # SET RATE DAMPING FLAGS (BITS 13,12, AND
MASK     OCT16000    # 11 OF RCSFLAGS)
ADS     RCSFLAGS

NOCHANGE CS      CH31TEMP
MASK     MANROT
EXTEND
BZMF     AHFNOROT    # IF NO MANUAL COMMANDS, GO TO AHFNOROT

TS      HOLDFLAG    # SET HOLDFLAG +

TC      STICKCHK     # WHEN THE RHC IS OUT OF DETENT, PMANNDX,
                   # YMANNDX, AND RMANNDX ARE ALL SET, BY
                   # MEANS OF STICKCHK, TO 0, 1, OR 2 FOR NO,
                   # +, OR - ROTATION RESPECTIVELY AS
                   # COMMANDED BY THE RHC.
                   #
                   # HOWEVER, IT IS WELL TO NOTE THAT AFTER
                   # THE RHC IS RETURNED TO DETENT, THE
                   # PROGRAM BRANCHES TO AHFNOROT AND AVOIDS
                   # STICKCHK SO PMANNDX, YMANNDX, AND
                   # RMANNDX ARE NOT RESET TO ZERO BUT RATHER
                   # LEFT SET TO THEIR LAST OUT OF DETENT
                   # VALUES.
```

```

      CS      FLAGWRD1      # SET STIKFLAG TO INFORM STEERING
      MASK    BIT14        # PROGRAMS (P20) THAT ASTRONAUT HAS
      ADS     FLAGWRD1      # ASSUMED ROTATIONAL CONTROL OF SPACECRAFT

      CAF     BIT14
      EXTEND
      RAND    CHAN31
      EXTEND
      BZMF    FREEFUNC

      CA      RCSFLAGS      # EXAMINE RCSFLAGS TO SEE IF RATE FILTER
      MASK    BIT14        # HAS BEEN INITIALIZED
      CCS     A             # IF SO, PROCEED WITH MANUAL RATE COMMANDS
      TCF     REINIT        # .....TILT, RECYCLE TO INITIALIZE FILTER

      CS      FIVE          # IF MANUAL MANEUVER IS AT HIGH RTE, SET
      AD      RATEINDX      # ATTKALMN TO -1.
      EXTEND
      BZMF    +3            # OTHERWISE, LEAVE ATTKALMN ALONE.
      CS      ONE
      TS      ATTKALMN

      CAF     TWO           # AUTO-HOLD MANUAL ROTATION
      TS      SPNDX
      DOUBLE
      TS      DPNDX
      INDEX   SPNDX         # RMANNDX = 0 NO ROTATION
      CA      RMANNDX       #           = 1  + ROTATION
      EXTEND
      BZF     NORATE        #           = 2  - ROTATION
                           # IF NO ROTATION COMMAND ON THIS AXIS,
                           # GO TO NORATE.

      AD      RATEINDX      # RATEINDX = 0  0.05 DEG/SEC
      TS      Q             #           = 2  0.2  DEG/SEC
      INDEX   Q             #           = 4  0.5  DEG/SEC
      CA      MANTABLE -1   #           = 6  2.0  DEG/SEC
      EXTEND
      MP      BIT9          # MULTIPLY MANTABLE BY 2 TO THE -6
      INDEX   DPNDX        # TO GET COMMANDED RATE.
      DXCH    WBODY        # SET WBODY TO COMMANDED RATE.

      CA      RCSFLAGS
      MASK    OCT16000      # IS RATE DAMPING COMPLETED (BITS 13,12 AND
      EXTEND
      BZF     MERUPDAT      # 11 OF RCSFLAGS ALL ZERO.) IF SO, GO TO
                           # MERUPDAT TO UPDATE CUMULATIVE ATTITUDE
                           # ERROR.

```

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# Page 1019

```
ZEROER      CA      ZERO      # ZEROER ZEROS MERRORS
            ZL
            INDEX    DPNDX
            DXCH     MERRORX
            TCF      SPNDXCHK

NORATE      ZL
            INDEX    DPNDX
            DXCH     WBODY      # ZERO WBODY FOR THIS AXIS
            CA       RCSFLAGS
            MASK      OCT16000
            EXTEND    # IS RATE DAMPING COMPLETED
            BZF      SPNDXCHK    # YES, KEEP CURRENT MERRORX GO TO SPNDXCHK
            TCF      ZEROER      # NO, GO TO ZEROER

MERUPDAT    INDEX    Q          # MERRORX=MERRORX+MEASURED CHANGE IN ANGLE
            CS       MANTABLE -1 # -COMMANDED CHANGE IN ANGLE
            EXTEND    # THE ADDITION OF MEASURED CHANGE IN ANGLE
            MP        BIT7      # HAS ALREADY BEEN DONE IN THE RATE FILTER
            INDEX    DPNDX      # COMMANDED CHANGE IN ANGLE = WBODY TIMES
            DAS       MERRORX    # .1SEC = MANTABLE ENTRY TIMES 2 TO THE -8

SPNDXCHK    INDEX    DPNDX
            CA       MERRORX
            INDEX    SPNDX
            TS        ERRORX     # ERRORX = HIGH ORDER WORD OF MERRORX
            CCS       SPNDX
            TCF      SETWBODY
            TCF      JETS

OCT01760    OCT      01760      # FORCED FIRING BITS MASK

OCT01400    OCT      01400      # ROLL FORCED FIRING MASK
OCT00060    OCT      00060      # PITCH FORCED FIRING MASK
OCT00300    OCT      00300      # YAW FORCED FIRING MASK
            #
            #
            # ORDER OF
            # DEFINITION
            # MUST BE
            # PRESERVED
            # FOR INDEXING

MANROT      OCT      77
OCT16000    OCT      16000      # RATE DAMPING FLAGS MASK
MANTABLE    DEC      .0071111
            DEC      -.0071111
            DEC      .028444
            DEC      -0.028444
            DEC      .071111
```

```

                                DEC      -.071111
                                DEC      .284444
                                DEC      -.284444
    =+14MS                      DEC      23
    FREEFUNC                    INDEX    RMANNDX      # ACCELERATION
    # Page 1020
                                CA       FREETAU      # COMMANDS
                                TS       TAU
                                INDEX    PMANNDX
                                CA       FREETAU      # FREETAU      0 SEC
                                TS       TAU1         # +1          +0.10 SEC
                                INDEX    YMANNDX      # +2          -0.10 SEC
                                CA       FREETAU      # (+3)         0 SEC
                                TS       TAU2
                                TCF      T6PROGM

    FREETAU                    DEC      0
                                DEC      480
                                DEC      -480
                                DEC      0

    T6PROGM                    CAF      ZERO          # FOR MANUAL ROTATIONS
                                TS      ERRORX
                                TS      ERRORY
                                TS      ERRORZ
                                TCF      T6PROG

    # Page 1021
                                DEC      .2112      # FILTER GAIN FOR TRANSLATION, LEM ON
                                DEC      .8400      # FILTER GAIN FOR TRANSLATION 2(ZETA)WN DT
                                DEC      .2112      # FILTER GAIN FOR 4 DEGREE/SEC MANEUVERS
    GAIN1                      DEC      .0640      # KALMAN FILTER GAINS FOR INITIALIZATION
                                DEC      .3180      # OF ATTITUDE RATES
                                DEC      .3452
                                DEC      .3774
                                DEC      .4161
                                DEC      .4634
                                DEC      .5223
                                DEC      .5970
                                DEC      .6933
                                DEC      .8151
                                DEC      .9342

                                DEC      .0174      # FILTER GAIN FOR TRANSLATION, LEM ON
                                DEC      .3600      # FILTER GAIN FOR TRANSLATION (WN)(WN)DT
                                DEC      .0174      # FILTER GAIN FOR 4 DEGREE/SEC MANEUVERS

```



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|             |        |          |                                          |
|-------------|--------|----------|------------------------------------------|
| GAIN2       | DEC    | .0016    | # SCALED 10                              |
|             | DEC    | .0454    |                                          |
|             | DEC    | .0545    |                                          |
|             | DEC    | .0666    |                                          |
|             | DEC    | .0832    |                                          |
|             | DEC    | .1069    |                                          |
|             | DEC    | .1422    |                                          |
|             | DEC    | .1985    |                                          |
|             | DEC    | .2955    |                                          |
|             | DEC    | .4817    |                                          |
|             | DEC    | .8683    |                                          |
| STICKCHK    | TS     | T5TEMP   |                                          |
|             | MASK   | THREE    | # INDICES FOR MANUAL ROTATION            |
|             | TS     | PMANNDX  |                                          |
|             | CA     | T5TEMP   |                                          |
|             | EXTEND |          | # MAN RATE 0 0 RATE (DP)                 |
|             | MP     | QUARTER  | # +1 + RATE (DP)                         |
|             | TS     | T5TEMP   | # +2 - RATE (DP)                         |
|             | MASK   | THREE    | # (+3) 0 RATE (DP)                       |
|             | TS     | YMANNDX  |                                          |
|             | CA     | T5TEMP   |                                          |
|             | EXTEND |          |                                          |
|             | MP     | QUARTER  |                                          |
|             | TS     | RMANNDX  |                                          |
|             | TC     | Q        |                                          |
| KALUPDT     | TS     | ATTKALMN | # INITIALIZATION OF ATTITUDE RATES USING |
|             |        |          | # KALMAN FILTER TAKES 1.1 SEC            |
|             | CA     | DELTATT  | # =1SEC - 80MS                           |
|             | AD     | T5TIME   | # + DELAYS                               |
| # Page 1022 | TS     | TIME5    |                                          |
|             | TCF    | +3       |                                          |
|             | CAF    | DELTATT2 | # SAFETY PLAY TO ASSURE                  |
|             | TS     | TIME5    | # A T5RUPT                               |
| KRESUME2    | CS     | ZERO     | # RESET FOR PHASE1                       |
|             | TS     | T5PHASE  | # RESUME INTERRUPTED PROGRAM             |
|             | TCF    | RESUME   |                                          |
| FDAIDSP2    | CS     | BIT4     | # RESET FOR FDAIDSP1                     |
|             | MASK   | RCSFLAGS |                                          |
|             | TS     | RCSFLAGS |                                          |
|             | CS     | FLAGWRDO | # ON - DISPLAY ONE OF THE TOTAL ATTITUDE |
|             | MASK   | BIT9     | # ERRORS                                 |

```

EXTEND
BZF      FDAITOTL
EXTEND
DCS      ERRORX      # OFF - DISPLAY AUTOPILOT FOLLOWING ERROR
DXCH     AK
CS       ERRORZ
TS       AK2
TCF      RESUME      # END PHASE 1

FDAITOTL  CA      FLAGWRD9
          MASK    BIT6
          EXTEND
          BZF      WRTN17      # IS N22ORN17 (BIT6 OF FLAGWRD9) = 0
                                # IF SO, GO TO WRTN17
WRTN22    EXTEND      # OTHERWISE, CONTINUE ON TO WRTN22 AND
          DCA      CTHETA    # GET SET TO COMPUTE TOTAL ATTITUDE
          DXCH     WTEMP      # ERROR WRT N22 BY PICKING UP THE THREE
          CA       CPHI      # COMPONENTS OF N22

GETAKS    EXTEND      # COMPUTE TOTAL ATTITUDE ERROR FOR
          MSU      CDUX      # DISPLAY ON FDAI ERROR NEEDLES
          TS       AK
          CA       WTEMP
          EXTEND
          MSU      CDUY
          TS       T5TEMP
          EXTEND
          MP       AMGB1
          ADS      AK
          CA       T5TEMP
          EXTEND
          MP       AMGB4
          TS       AK1
          CA       T5TEMP
          EXTEND
          MP       AMGB7
          TS       AK2
          CA       WTEMP +1
          EXTEND
          MSU      CDUZ
          TS       T5TEMP
          EXTEND
          MP       AMGB5
          ADS      AK1
          CA       T5TEMP

```

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```

      EXTEND
      MP      AMGB8
      ADS      AK2
      TCF      RESUME      # END PHASE1 OF RCS DAP

WRTN17      EXTEND      # GET SET TO COMPUTE TOTAL ASTRONAUT
      DCA      CPHIX +1  # ATTITUDE ERROR WRT N17 BY PICKING UP
      DXCH      WTEMP    # THE THREE COMPONENTS OF N17
      CA      CPHIX
      TCF      GETAKS
```

# Page 1024 (empty page)

This code is written to file `src/RCS-CSM-DIGITAL-AUTOPILOT.s`.

## A.91 RCS FAILURE MONITOR

```

1580  <src/RCS-FAILURE-MONITOR.s 1580>≡
      # Copyright:    Public domain.
      # Filename:     RCS_FAILURE_MONITOR.agc
      # Purpose:      Part of the source code for Luminary 1A build 099.
      #               It is part of the source code for the Lunar Module's (LM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Hartmuth Gutsche <hgutsche@explornet.com>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:        190-192
      # Mod history:   2009-05-19 HG   Transcribed from page images.
      #
      # This source code has been transcribed or otherwise adapted from
      # digitized images of a hardcopy from the MIT Museum. The digitization
      # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
      # the Museum. Many thanks to both. The images (with suitable reduction
      # in storage size and consequent reduction in image quality as well) are
      # available online at www.ibiblio.org/apollo. If for some reason you
      # find that the images are illegible, contact me at info@sandroid.org
      # about getting access to the (much) higher-quality images which Paul
      # actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
      #       16:27 JULY 14, 1969
      #
      # Page 190
      # PROGRAM DESCRIPTION:
      #
      # AUTHOR: J. S. MILLER
      #
      # MODIFIED 6 MARCH 1968 BY P. S. WEISSMAN TO SET UP JOB FOR 1/ACCS WHEN THE MASKS ARE
      #
      # THIS ROUTINE IS ATTACHED TO T4RUPT, AND IS ENTERED EVERY 480 MS. ITS FUNCTION IS TO
      # OF CHANNEL 32 TO SEE IF ANY ISOLATION-VALVE CLOSURE BITS HAVE APPEARED OR DISAPPEARED
      # FAILURES BY LAMPS LIT BY THE GRUMMAN FAILURE-DETECTION CIRCUITRY; THEY MAY RESPOND
      # ISOLATE PAIRS OF JETS FROM THE PROPELLANT TANKS AND SET BITS IN CHANNEL 32). IN THE
      # DIFFER FROM 'PVALVEST', THE RECORD OF ACTIONS TAKEN BY THIS ROUTINE, THE APPROPRIATE
      # 'CH6MASK', USED BY THE DAP JET-SELECTION LOGIC, ARE UPDATED, AS IS 'PVALVEST'. TO
      # ROUTINE, NO MORE THAN ONE CHANGE IS ACCEPTED PER ENTRY. THE HIGHEST-NUMBERED BIT IN
      # ACTION IS THE ONE PROCESSED.
      #
      # THE CODING IN THE FAILURE MONITOR HAS BEEN WRITTEN SO AS TO HAVE ALMOST COMPLETE RE

```

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```
# EXAMPLE, NO ASSUMPTION IS MADE WHEN SETTING A 'CH5MASK' BIT TO 1 THAT THE PREVIOUS STATE IS C
# COURSE SHOULD BE. ONE CASE WHICH MAY BE SEEN TO EVADE PROTECTION IS THE OCCURRENCE OF A REST
# ONE OR BOTH DAP MASK-WORDS BUT BEFORE UPDATING 'PVALVEST', COUPLED WITH A CHANGE IN THE VALVE
# FORMER STATE. THE CONSEQUENCE OF THIS IS THAT THE NEXT ENTRY WOULD NOT SEE THE CHANGE INCOM
# ORATED BY THE LAST PASS (BECAUSE IT WENT AWAY AT JUST THE RIGHT TIME), BUT THE DAP MASK-WORDS
# THIS COMBINATION OF EVENTS SEEMS QUITE REMOTE, BUT NOT IMPOSSIBLE UNLESS THE CREW OPERATES TH
# SECOND INTERVALS OR LONGER. IN ANY EVENT, A DISAGREEMENT BETWEEN REALITY AND THE DAP MASKS W
# THE MISINTERPRETED SWITCH IS REVERSED AND THEN RESTORED TO ITS CORRECT POSITION (SLOWLY).
#
# CALLING SEQUENCE:
#
#           TCF      RCSMONIT                # (IN INTERRUPT MODE, EVERY 480 MS.)
#
# EXIT: TCF RCSMONEX (ALL PATHS EXIT VIA SUCH AN INSTRUCTION)

RCSMONEX      EQUALS  RESUME

# ERASABLE INITIALIZATION REQUIRED:
#
#           VIA FRESH START:      PVALVEST      =      +0      (ALL JETS ENABLED)
#                                   CH5MASK,CH6MASK =      +0      (ALL JETS OK)
#
# OUTPUT:      CH5MASK & CH6MASK UPDATED (1'S WHERE JETS NOT TO BE USED, IN CHANNEL 5 & 6 FORM
#               PVALTEST UPDATED (1'S WHEN VALVE CLOSURES HAVE BEEN TRANSLATED INTO CH5MASK & C
#               JOB TO DO 1/ACCS.
#
# DEBRIS:  A, L, AND Q AND DEBRIS OF NOVAC.
#
# SUBROUTINE CALLED:  NOVAC.

                EBANK=  CH5MASK

                BANK    23
                SETLOC  RCSMONT
                BANK

# Page 191

                COUNT*  $$/T4RCS

RCSMONIT      EQUALS  RCSMON

RCSMON        CS      ZERO
                EXTEND
                RXOR    CHAN32                # PICK UP + INVERT INVERTED CHANNEL 32.
                MASK    LOW8                  # KEEP JET-FAIL BITS ONLY.
                TS      Q
```

```

CS      PVALVEST      #      -      -
MASK    Q              # FORM PC + PC.
TS      L              #      (P = PREVIOUS ISOLATION VALVE
CS      Q              #      C = CURRENT VALVE STATE (CH
MASK    PVALVEST
ADS     L              # RESULT NZ INDICATES ACTION REQUIRED

EXTEND
BZF     RCSMONEX      # QUIT IF NO ACTION REQUIRED.

EXTEND
MP      BIT7           # MOVE BITS 8-1 OF A TO 14-7 OF L.
XCH     L              # ZERO TO L IN THE PROCESS.

-3      INCR      L
DOUBLE
OVSK
TCF     -3

INDEX   L
CA      BIT8 -1       # SAVE THE RELEVANT BIT (8-1).
TS      Q
MASK    PVALVEST      # LOOK AT PREVIOUS VALVE STATE BIT.
CCS     A
TCF     VOPENED       # THE VALVE HAS JUST BEEN OPENED.

CS      CH5MASK       # THE VALVE HAS JUST BEEN CLOSED.
INDEX   L
MASK    5FAILTAB
ADS     CH5MASK       # SET INHIBIT BIT FOR CHANNEL 5 JET.

CS      CH6MASK
INDEX   L
MASK    6FAILTAB
ADS     CH6MASK       # SET INHIBIT BIT FOR CHANNEL 6 JET

CA      Q
ADS     PVALVEST      # RECORD ACTION TAKEN.

TCF     1/ACCFIX      # SET UP 1/ACCJOB AND EXIT.

# Page 192
VOPENED INDEX   L      # A VALVE HAS JUST BEEN OPENED.
CS      5FAILTAB
MASK    CH5MASK
TS      CH5MASK       # REMOVE INHIBIT BIT FOR CHANNEL 5 JET

```

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```

                                INDEX  L
                                CS      6FAILTAB
                                MASK     CH6MASK
                                TS       CH6MASK                # REMOVE INHIBIT BIT FOR CHANNEL 6 JET.

                                CS      Q
                                MASK     PVALVEST
                                TS       PVALVEST                # RECORD ACTION TAKEN.

1/ACCFIX                      CAF      PRI027                # SET UP 1/ACCS SO THAT THE SWITCH CURVES
                                TC       NOVAC                #           FOR TJETLAW CAN BE MODIFIED IF CH5MASK
                                EBANK=    AOSQ                #           HAS BEEN ALTERED.
                                2CADR     1/ACCJOB

                                TCF       RCSMONEX                # EXIT.

5FAILTAB                      EQUALS   -1                # CH 5 JET BIT CORRESPONDING TO CH 32 BIT:
                                OCT       00040                # 8
                                OCT       00020                # 7
                                OCT       00100                # 6
                                OCT       00200                # 5
                                OCT       00010                # 4
                                OCT       00001                # 3
                                OCT       00004                # 2
                                OCT       00002                # 1

6FAILTAB                      EQUALS   -1                # CH 6 JET BIT CORRESPONDING TO CH 32 BIT:
                                OCT       00010                # 8
                                OCT       00020                # 7
                                OCT       00004                # 6
                                OCT       00200                # 5
                                OCT       00001                # 4
                                OCT       00002                # 3
                                OCT       00040                # 2
                                OCT       00100                # 1
```

This code is written to file src/RCS-FAILURE-MONITOR.s.

```

1584      <src/README.md 1584>≡
        Apollo-11
        =====
        proundiv: See my [facebook post](https://www.facebook.com/gary.young.9480/posts/102
        -----

```

### Attribution

Copyright: Public domain.  
Filename: CONTRACT\_AND\_APPROVALS.agc  
Purpose: Part of the source code for Colossus 2A, AKA Comanche 055.  
It is part of the source code for the Command Module's (CM)  
Apollo Guidance Computer (AGC), for Apollo 11.  
Assembler: yaYUL  
Contact: Ron Burkey <info@sandroid.org>.  
Website: [www.ibiblio.org/apollo](http://www.ibiblio.org/apollo).  
Mod history: 2009-05-06 RSB Transcribed from page images.

This source code has been transcribed or otherwise adapted from digitized images of a hardcopy from the MIT Museum. The digitization was performed by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many thanks to both. The images (with suitable reduction in storage size and consequent reduction in image quality as well) are available online at [www.ibiblio.org/apollo](http://www.ibiblio.org/apollo). If for some reason you find that the images are illegible, contact me at [info@sandroid.org](mailto:info@sandroid.org) about getting access to the (much) higher-quality images which Paul actually created.

Notations on the hardcopy document read, in part:

Assemble revision 055 of AGC program Comanche by NASA  
2021113-051. 10:28 APR. 1, 1969

Page 1

```

#*****
#
#      THIS AGC PROGRAM SHALL ALSO BE REFERRED TO AS:
#
#
#      COLOSSUS 2A
#
#
#*****

```



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```
# THIS PROGRAM IS INTENDED FOR USE IN THE CM AS SPECIFIED *
# IN REPORT R-577. THIS PROGRAM WAS PREPARED UNDER DSR *
# PROJECT 55-23870, SPONSORED BY THE MANNED SPACECRAFT *
# CENTER OF THE NATIONAL AERONAUTICS AND SPACE *
# ADMINISTRATION THROUGH CONTRACT NAS 9-4065 WITH THE *
# INSTRUMENTATION LABORATORY, MASSACHUSETTS INSTITUTE OF *
# TECHNOLOGY, CAMBRIDGE, MASS. *
# *
#*****
```

SUBMITTED: MARGARET H. HAMILTON           DATE: 28 MAR 69  
M.H.HAMILTON, COLOSSUS PROGRAMMING LEADER  
APOLLO GUIDANCE AND NAVIGATION

APPROVED: DANIEL J. LICKLY           DATE: 28 MAR 69  
D.J.LICKLY, DIRECTOR, MISSION PROGRAM DEVELOPMENT  
APOLLO GUIDANCE AND NAVIGATION PROGRAM

APPROVED: FRED H. MARTIN           DATE: 28 MAR 69  
FRED H. MARTIN, COLOSSUS PROJECT MANAGER  
APOLLO GUIDANCE AND NAVIGATION PROGRAM

APPROVED: NORMAN E. SEARS           DATE: 28 MAR 69  
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APPROVED: RICHARD H. BATTIN       DATE: 28 MAR 69  
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APPROVED: DAVID G. HOAG           DATE: 28 MAR 69  
D.G. HOAG, DIRECTOR  
APOLLO GUIDANCE AND NAVIGATION PROGRAM

APPROVED: RALPH R. RAGAN           DATE: 28 MAR 69  
R.R. RAGAN, DEPUTY DIRECTOR  
INSTRUMENTATION LABORATORY

This code is written to file src/README.md.

## A.93 REENTRY CONTROL

```

1586  <src/REENTRY-CONTROL.s 1586>≡
      # Copyright:    Public domain.
      # Filename:     REENTRY_CONTROL.agc
      # Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
      #               It is part of the source code for the Command Module's (CM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Ron Burkey <info@sandroid.org>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         844-882
      # Mod history:   2009-05-08 RSB   Adapted from the Colossus249/ file of the
      #               same name, using Comanche055 page images.
      #               2009-05-23 RSB   In a couple of 2OCT statements, removed the
      #               space between the first and second octal words.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      # Assemble revision 055 of AGC program Comanche by NASA
      # 2021113-051. 10:28 APR. 1, 1969
      #
      # This AGC program shall also be referred to as
      # Colossus 2A
      #
      # Page 844
      # ENTRY INITIALIZATION ROUTINE
      # -----
      #
      # BANK      25
      # SETLOC    REENTRY
      # BANK
      #
      # COUNT*    $$/ENTRY
      # EBANK=    RTINIT
      #
      # EBENTRY   =      EBANK7

```

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```
EBAOG      EQUALS  EBANK6
NTRYPRIO    EQUALS  PRIO20      # (SERVICER)
CM/FLAGS    EQUALS  STATE +6

STARTENT    EXIT              # MM = 63

                                # COME HERE FROM CM/POSE.  RESTARTED IN CM/POSE.
                                # INITIALIZE ALL SWITCHES TO ZERO
                                # EXCEPT LATSW, ENTRYDSP, AND GONEPAST.
                                # GONEBY 112D BIT8 FLAG7, SELF-INITIALIZING.

                                # ENTRYDSP = 92D B13
                                # GONEPAST=95D B10      RELVELSW=96D B9
                                # EGSW = 97D B8
                                # HIND=99D B6          INRLSW=100D B5
                                # LATSW=101D B4         .05GSW=102D B3

                                # L/DCMINR = LAD COS(15)

                                # KLAT = LAD/24

                                # Q7 = Q7F
                                # 1.0 -1BIT

                                # 1.0 -1BIT
```

AD ENTRYSW  
TS CM/FLAGS

RELINT

TC INTPRET

SLOAD

LODPAD

STORE LOD

SLOAD

LADPAD

STORE LAD

DMP

STODL L/DCMINR

LATSLOPE

DMP SR1

LAD

STODL KLAT

Q7F

STODL Q7

NEARONE

STODL FACTOR

LAD

# Page 845

```

SIGN      DCOMP
HEADSUP
STCALL    L/D      # MAY BE NOISE FOR DISPLAY P61
              # L/D = - LAD SGN(HEADSUP)

              STARTEN1      # RETURN VIA GOTOADDR
VLOAD     VXV
              VN              # (-7) M/CS
              UNITR          # .5 UNIT              REF COORDS
UNIT       DOT
              RT              # RT/2 TARGET VECTOR      REF COORDS
STORE      LATANG      # LATANG = UNI.RT /4
DCOMP      RTB
              SIGNMPAC
STODL      K2ROLL      # K2ROLL = -SGN(LATANG)

              LAD
DMP         DAD
              Q21
              Q22
STORE      Q2          # Q2 = -1152 + 500 LAD

SSP         SSP
              GOTOADDR      # SET SELECTOR FOR INITIAL PASS
              INITROLL
              POSEXIT
              SCALEPOP      # SET CM/POSE TO CONTINUE AT SCALEPOP

RTB
              SERVNOOUT      # OMIT INITIAL DISPLAY, SINCE 1ST GUESSBAD

# CALCULATE THE INITIAL TARGET VECTOR: RTINIT, ALSO RTEAST, RTNORM, AND RT.  ALL ARE
# REFERENCE COORDINATES.

STARTEN1    STQ      VLOAD
              GOTOADDR
              LAT(SPL)      # TARGET COORDINATES
              CLEAR        # DO CALL USING PAD RADIUS.  WILL UNIT IT.
              ERADFLAG      # ANYWAY.
              LUNAFLAG
STODL       LAT
              3ZEROS

STODL       LAT +4      # SET ALT=0.
              PIPTIME      # ESTABLISH RTINIT AT TIME OF PRESENT

# Page 846

              # RN AND VN.

```

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```

      STCALL  TIME/RTO      # SAVE TIME BASE OF RTINIT.
                LALOTORV    # C(MPAC) =TIME  (PIPTIME)
      UNIT                                # ANSWER IN ALPHAV ALSO
      STODL   RTINIT        # .5 UNIT TARGET          REF COORDS
                500SEC      # NOMINAL ENTRY TIME FOR P63
                                # TIME/RTO = PIPTIME, STILL.
      STCALL  DTEAROT        # INITIALIZE EARROT
                EARROT1      # GET R5
      DOT     SL1
                UNITR        # RT/2 IN MPAC
      ACOS
      STCALL  THETAH        # RANGE ANGLE /360
                GOTOADDR     # RETURN TO CALLER

500SEC      2DEC    50000 B-28    # CS.

ENTMASK     OCT     11774
ENTRYSW     OCT     11010        # ENTRYDSP B13.  GONEPAST B10.  LATSW B4
# Page 847

SCALEPOP    CALL
                TARGETNG

      EXIT

REFAZE10    TC     PHASCHNG
            OCT     10035        # SERVICER 5.3 RESTART AT REFAZE10

            TC     INTPRET

# JUMP TO PARTICULAR RE-ENTRY PHASE:
#                               SEQUENCE
      GOTO
                GOTOADDR

# GOTOADDR CONTAINS THE ADDRESS OF THE ROLL COMMAND EQUATIONS TO THE CURRENT PHASE OF
# RE-ENTRY.  SEQUENCING IS AS FOLLOWS:
#
# INITROLL   ADDRESS IS SET HERE INITIALLY.  HOLDS INITIAL ROLL ATTITUDE UNTIL  KAT  IS EXCE
#            ATTITUDE UNTIL  VRTHRESH  IS EXCEEDED.  THEN BRANCHES TO
#
# HUNTEST    THIS SECTION CHECKS TO SEE IF THE PREDICTED RANGE AT NOMINAL  L/D FROM PRESENT
#            THAN THE DESIRED RANGE.
#            IF NOT --- A ROLL COMMAND IS GENERATED BY THE CONSTANT DRAG CONTROLLER.
#            IF SO --- CONTROL AND GOTOADDR ARE SET TO UPCONTRL.
#            USUALLY NO ITERATION IS INVOLVED EXCEPT IF THE RANGE DESIRED IS TOO LONG ON THE
```

```

#           HUNTEST.
#
# UPCONTRL   CONTROLS ROLL DURING THE SUPER-CIRCULAR PHASE.  UPCONTRL IS TERMINATED
#             (A) WHEN THE DRAG (AS MEASURED BY THE PIPAS) FALLS BELOW Q7,
#             (B) IF RDOT IS NEGATIVE AND REFERENCE VL EXCEEDS V.
#           IN CASE (A), GOTOADDR IS SET TO KEP2 AND IN CASE (B), TO PREDICT3
#           ENTRY.
#
# KEP2       GOTOADDR IS SET HERE DURING THE KEPLER PHASE TO MONITOR DRAG.  THE SP
#             TRIMMED IN PITCH AND YAW TO THE COMPUTED RELATIVE VELOCITY.  THE LAST
#             WHEN THE MEASURED DRAG EXCEEDS Q7 +0.5, GOTOADDR IS SET TO
#
# PREDICT3   THIS CONTROLS THE FINAL SUB-ORBITAL PHASE.  ROLL COMMANDS CEASE
#             WHEN V IS LESS THAN VQUIT .  AN EXIT IS MADE TO
#
# P67.1      THE LAST COMPUTED ROLL ANGLE IS MAINTAINED.  RATE DAMPING IS DONE IN
#             AND LONGITUDE ARE COMPUTED FOR DISPLAY.
#           ENTRY IS TERMINATED WHEN DISKY RESPONSE IS MADE TO THIS FINAL FLASHING

```

# Page 848

# PROCESS AVERAGE G OUTPUT...SCALE IT AND GET INPUT DATA

# \* START TARGETING ...

EBANK= RTINIT

# TARGETNG IS CALLED BY P61, FROM GROUP 4.  
 # TARGETNG IS CALLED BY ENTRY, FROM GROUP 5.

|          |       |                                      |                                                                                                                                                                |
|----------|-------|--------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TARGETNG | BOFF  | VLOAD<br>RELVELSW<br>GETVEL<br>-VREL | # ALL MM COME HERE.<br># ENTER WITH PROPER EB FROM CM/POSE(TEST)<br># RELVELSW = 96D BIT9<br># WANT INERTIAL VEL.  GO GET IT.<br># NEW V IS RELATIVE, CONTINUE |
|          | VCOMP | GOTO<br>GETUNITV -1                  | # (VREL) = (V) + KWE UNITR*UNITW<br># - VREL WAS LEFT BY CM/POSE                                                                                               |
| GETVEL   | VLOAD | VXSC<br>VN<br>KVSCALE                | # INERTIAL V WANTED<br># KVSCALE = (12800 / .3048) / 2VS<br># KVSCALE = .81491944                                                                              |
|          | STORE | VEL                                  | # V/2 VS                                                                                                                                                       |
| GETUNITV | UNIT  | STQ<br>60GENRET                      |                                                                                                                                                                |
|          | STODL | UNITV                                |                                                                                                                                                                |

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```

                                34D
STORE    VSQUARE                # VSQ/4

                                36D
DSU      V                      # LEQ = VSQUARE - 1
                                FOURTH
STODL    LEQ                    # 4 G'S FULL SCALE
                                LEQ
                                # LEQ/4

                                36D
STOVL    V                      # V/2 VS = VEL/2 VS

                                VEL
DOT      SL1                    # RDOT= V.UNITR
                                UNITR
STOVL    RDOT                  # RDOT /2 VS

                                DELV
ABVAL    DMP                    # PIPA COUNTS IN PLATFORM COORDS.
                                KASCALE
SL1      BZE
                                SETMIND
DSTORE   STOVL    D              # ACCELERATION USED TO APPROX DRAG
                                VEL
                                VXV    UNIT              # UNI = UNIT(V*R)

# Page 849
                                UNITR
STORE    UNI                    # .5 UNI                      REF COORDS.

BOFF     DLOAD
                                RELVELSW
                                GETETA
                                3ZEROS
UPDATERT DSU    DAD              # PIPTIME-TIME/RTO =ELAPSED TIME SINCE
                                # RTINIT WAS ESTABLISHED.
                                TIME/RTO
                                PIPTIME
STCALL   DTEAROT                # GET PREDICTED TARGET VECTOR RT

                                EARROT2
DOT      SETPD                  # SINCE (RT) UNIT VECT, THIS IS 1/4 MAX
                                UNI
                                0
                                # LATANG = RT.UNI
STOVL    LATANG                 # LATANG = MAC LATANG / 4

                                RT
CLEAR    GONEBY                 # SHOW HAVE NOT GONE PAST TARGET.
```

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```

                                VXV    DOT      # IF RT*UNITR.UNI NEG, GONEBY=1
                                UNITR    # GONEPAST IS CONDITIONAL SW SET IN
                                UNI      # FINAL PHASE.
                                BPL    SET
                                +2
                                GONEBY    # SHOW HAVE GONE PAST TARGET.

                                VLOAD
                                RT
GETANGLE    DOT    DSU      # THETA = ARCCOS(RT.UNITR)
                                UNITR
                                NEAR1/4  # TO IMPROVE ACCURACY, CALC RANGE BY
                                BPL    DAD  # TINYTHET IF HIGH ORDER PART OF
                                TINYTHET  # ARCCOS ARGUMENT IS ZERO
                                NEAR1/4
                                SL1    ACOS
THETDONE    STORE   THETAH    # THETAH/360
                                # HI WORD, LO BIT =1.32 NM=360 60/16384

                                BON    DCOMP
                                GONEBY    # =1 IF HAVE GONE PAST TARGET.
                                # (SIGN MAY BECOME ERRATIC VERY NEAR
                                # TARGET DUE TO LOSS OF PRECISION.)
                                +1
                                STODL    RTGON67  # RANGE ERROR: NEG IF WILL FALL SHORT.

                                D
                                DSU    BMN

                                .05G
                                NO.05G
                                SET    VLOAD
                                .05GSW
                                DELVREF
                                PUSH    DOT
                                UXA/2
                                SL1    DSQ
                                PDVL    VSQ      # EXCHANGE WITH PDL.
                                DSU    DDV
                                0
                                BOV    SQRT
                                NOLDCALC    # OVFL LAST CLEARED IN EARROT2 ABOVE.
                                STORE    L/DCALC

NOLDCALC    GOTO
                                60GENRET
```

# Page 850



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```
NO.05G      CLEAR  GOTO      # THIS WAY FOR DAP. (MAY INTERRUPT)
              .05GSW      # .05GSW = 102D B3
              NOLDALC      # KEEP SINGLE EXIT FOR TARGETING
```

# Page 851

# SUBROUTINES CALLED BY SCALEPOP (TARGETING):

```
              BANK    26
              SETLOC  REENTRY1
              BANK
              COUNT*  $$/ENTRY

GETETA      DLOAD  DDV      # D = D +D(-RDOT/HS -2D/V)  DT/2
              RDOT      # DT/2 = 2/2 =1
              -HSCALED
PDDL        DMP
              D
              -KSCALE
DDV         DAD
              V
              # -RDOT/HS FROM PDL.
DMP         DAD
              D
              D
STORE      D

BON         DLOAD      # EGSW INDICATES FINAL PHASE
              EGSW
              SUBETA
              THETAH
DMP         GOTO
              KTETA      # = 1000x2PI/(2)E14 163.84
              UPDATERT

SUBETA      DLOAD  DSU      # SWITCH FROM INERTIAL TO RELATIVE VEL.
              V
              VMIN
BPL         SET
              SUBETA2
              RELVELSW

SUBETA2     DLOAD  DMP
```

```

                                THETAH
                                KT1      # KT1 = KT
                                DDV      GOTO
                                V        # KT = RE(2 PI)/2 VS 16384 163.84/ 2 VSAT
                                UPDATERT

SETMIND      DLOAD      GOTO
                                1BITDP
                                DSTORE

# Page 852
TINYTHET      DSU      ABS      # ENTER WITH X-.249
                                1BITDP +1  # GET 1/4 - MPAC
                                SL      SQRT  # SCALE UP BEFORE SQRT
                                13D      # HAS FACTOR FOR UP SCALING
                                DMP      GOTO
                                KACOS
                                THETDONE

# Page 853
# * START      INITIAL ROLL ...

                                BANK      25
                                SETLOC REENTRY
                                BANK

                                COUNT*  $$/ENTRY

INITROLL      BON      BOFF      # MM = 63, 64, ...
                                INRLSW    # IF D- .05G NEG, GO TO LIMITL/D
                                INITRL1
                                .05GSW
                                LIMITL/D

                                # MM = 64, NOW
                                #          3
                                # KA = KA1 LEG + KA2

                                DLOAD      DSQ
                                LEQ
                                DMP      DDV
                                LEQ
                                1/KA1    # = 25 /(64 1.8)
                                DAD      RTB
                                KA2      # = .2
                                P64      # ROLLC          VI          RDOT

```

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```
# XXX.XX DEG      XXXXX. FPS      XXXXX. FPS

STORE  KAT

DSU    BMN
       KALIM
       +4

DLOAD  KALIM

STORE  KAT
DLOAD  DSU      # IF V-VFINAL1 NEG, GO TO FINAL PHASE.
       V
       VFINAL1

CLEAR  BPL      # (CAN'T CLEAR INRLSW AFTER HERE: RESTARTS)
       GONEPAST # GONEPAST WAS INITIALLY SET=1 TO FORCE
                # ROLLC TO REMAIN AS DEFINED BY HEADSUP
                # UNTIL START OF P64.  (UNTIL D > .05G)

SSP    DOEQ
       GOTO
       GOTOADDR
       KEP2      # AND IDLE UNTIL D > 0.2 G.  (NO P66 HERE)
       INROLOUT  # GO TO LIMITL/D AFTER SETTING INRLSW.

DOEQ   DLOAD    DMP      # D0 = KA3 LEQ + KA4
# Page 854      LEQ
                KA3

DAD     KA4

STORE  D0      # D0/805
BDDV   BOV
       C001     # (-4/25 G) B-8
       +1       # CLEAR OVFLND, IF ON.
STODL  C/D0     # (-4/D0) B-8
       LAD      # IF V-VFINAL +K(RDOT/V)CUBED POS,L/D=-LAD
STODL  L/D
       RDOT
DDV    PUSH
       V
DSQ    DMP
DDV    DSU
       1/K44
       VFINAL

#                                     3
# V-VFINAL +(RDOT/V)  / K44      OVFL $

DAD    BOV
```

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|            |               |          |                                            |
|------------|---------------|----------|--------------------------------------------|
|            |               | V        |                                            |
|            |               | INROLOUT | # GO TO LIMITL/D AFTER SETTING INRLSW.     |
|            | BMN           | DLOAD    |                                            |
|            |               | INROLOUT | # GO TO LIMITL/D AFTER SETTING INRLSW.     |
|            |               | LAD      |                                            |
|            | DCOMP         |          |                                            |
|            | STORE         | L/D      |                                            |
|            |               |          | # SET INRLSW AT END FOR RESTART PROTECTION |
| INROLOUT   | BOFSET        |          | # END OF PRE .05G PATH OF INITROLL.        |
|            |               | INRLSW   | # SWITCH IS ZERO INITIALLY.                |
|            |               | LIMITL/D | # (GO TO)                                  |
| KATEST     | DLOAD         | DSU      | # IF KAT - D POS, GO TO CONSTD             |
|            |               | KAT      |                                            |
|            |               | D        | # IF POS, OUT WITH COMMAND VIA LIMITL/D    |
|            | BPL           | GOTO     |                                            |
|            |               | LIMITL/D |                                            |
|            |               | CONSTD   |                                            |
| INITRL1    | DLOAD         | DAD      | # IF RDOT + VRCONT POS, GO TO HUNTEST      |
|            |               | RDOT     |                                            |
|            |               | VRCONT   |                                            |
|            | BMN           | CALL     | # IF POSITIVE, FALL INTO HUNTEST.          |
|            |               | KATEST   |                                            |
|            |               | FOREHUNT | # INITIALIZE HUNTEST.                      |
| # Page 855 |               |          |                                            |
| # * START  | HUNT TEST ... |          |                                            |
|            |               |          | # MM = 64                                  |
|            | SSP           |          | # INITIALIZE HUNTEST ON FIRST PASS         |
|            |               | GOTOADDR |                                            |
|            |               | HUNTEST  | # MUST GO AFTER FOREHUNT FOR RESTARTS.     |
| HUNTEST    | DLOAD         |          |                                            |
|            |               | D        |                                            |
|            | STODL         | A1       | # A1/805 = A1/25G                          |
|            |               | LAD      |                                            |
|            | STODL         | TEM1B    |                                            |
|            |               | RDOT     |                                            |
|            | BMN           | DLOAD    | # IF RDOT NEG, TEM1B=LAD, OTHERWISE = LEWD |
|            |               | AOCALC   |                                            |
|            |               | LEWD     |                                            |
|            | STODL         | TEM1B    |                                            |

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```
AOCALC      DDV      RDOT
              DAD      # V1 = V + RDOT/TEM1B
              TEM1B
              V
      STODL    V1      # V1/2 VS

              RDOT
      DSQ      DDV      # A0=(V1/V)SQ(D+RDOT SQ/(TEM1B 2 C1 HS)
              TEM1B
      DDV      DAD
              2C1HS
      DMP      DMP
              V1
              V1
      DDV
      STODL    VSQUARE
              A0      # A0/805 = A0/25G

              RDOT
      BPL      DLOAD
              V1LEAD
              A0
      STORE    A1      # A1/25G

V1LEAD      DLOAD    BPL      # IF L/D NEG, V1=V1 - 1000
              L/D
              HUNTEST1

              DLOAD    DSU
              V1

# Page 856

              VQUIT
      STORE    V1

HUNTEST1    DLOAD    DMP      # ALP = 2 C1 HS A0/LEWD V1 V1
              A0
              2C1HS
      DDV      SETPD
              V1
              0
      DDV      DDV
              V1
              LEWD
      STORE    ALP
```

```

BDSU   BDDV           # FACT1 = V1 / (1 - ALP)
        BARELY1
        V1
STODL   FACT1         # FACT1 / 2VS

        ALP
DSU     DMP           # FACT2 = ALP(ALP - 1) / A0
        BARELY1
        ALP
DDV
        A0
STORE   FACT2         # FACT2 (25G)

DMP     DAD
        Q7           # Q7 / 805 = Q7 / 25G
        ALP          # VL=FACT1 (1-SQRT(Q7 FACT2 +ALP) )
SQRT    BDSU
        BARELY1
DMP
        FACT1
STORE   VL           # VL / 2 VS

BDSU    DMP           # GAMMAL1 = LEWD (V1-VL)/VL
        V1
        LEWD
DDV
        VL
STODL   GAMMAL1      # GAMMAL1 USED IN UPCONTROL.

        # GAMMAL1 = PDL 22D.

        VL
DSU     BMN           # IF VL-VLMIN NEG, GO TO PREFINAL
        VLMIN
        PREFINAL

DLOAD   DSQ

        VL
STODL   VBARS        # VBARS / 4 VS VS

        HALVE
DSU     BMN           # IF VSAT-VL NEG, GO TO CONSTD
        VL
        BECONSTD
STODL   DVL          # SET MODE=HUNTEST, CONTINUE IN CONSTD
        # DVL / 2VS

```

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```

                                HALVE
STORE    VS1                    # VS1 = VSAT

DSU      BMN                    # IF V1 GREATER THAN VSAT, GO ON
          V1
          GETDHOOK

BDSU

          DVL
STODL    DVL                    # DVL = DVL - (VSAT-V1) = V1 - VL
          V1
STORE    VS1                    # VS1 = V1, IN THIS CASE

GETDHOOK DLOAD    CALL          # DHOOK=((1-VS1/FACT1) SQ -ALP)/FACT2
          VS1          # VS1 / 2 VS
          DHOOKYQ7     # GO CALC DHOOK
STORE    DHOOK          # DHOOK / 25G

SR        DDV
          6              # CHOOK
          Q7

DSU

          CHOOK          # = .25/16 = (-6)
STORE    AHOOKDV

DAD        DMP              # GAMMAL= GAMMAL1-CH1 DVL SQ(1+AHOOK DVL)
          1/16TH
          CH1
DMP        DMP
          DVL
          DVL
DDV        DDV
          DHOOK
          VBARS
BDSU       BMN
          GAMMAL1
          NEGAMA
HUNTEST3  STORE    GAMMAL

DSU              # GAMMAL1=GAMMAL1 +Q19 (GAMMAL-GAMMAL1)
          GAMMAL1
DMP          DAD

          Q19
          GAMMAL1
STODL       GAMMAL1
```

# Page 858

## GAMMAL

# Page 859

# \*START

RANGE PREDICTION ...

# C(MPAC) = GAMMAL.

# COSG = 1-GAMMAL SQ/2, TRUNCATED SERIES

RANGER

DSQ

SR2

BDSU

HALVE

STODL

COSG/2

VBARS

# E=SQRT(1+VBARS.....

DSU

DMP

HALVE

VBARS

DMP

DMP

COSG/2

COSG/2

SL2

DAD

C1/16

# C1/16 = 1/16

SQRT

PDDL

# E/4 INTO PDL

VBARS

DMP

DMP

# ASKEP/2 = ARCSIN(VBARS COSG SING/E)

COSG/2

GAMMAL

DDV

ASIN

SL1

PUSH

# ASKEP TO PDL 0.

STODL

ASKEP

# BALLISTIC RANGE ASKEP/2PI

# FOR TM, STORE RANGE COMPONENTS OVERLAPPING

VL

DMP

DAD

# ASP1 = Q2 + Q3 VL

Q3

Q2

STORE

ASP1

# FINAL PHASE RANGE ASP1/2 PI

PDDL

DSQ

# ASP1 TO PDL 2.

V1

#

2

# ASPUP= -C12 LOG(V1 Q7/VBARS A0)/GAMMAL1

DMP

DDV

Q7

VBARS

DDV

CALL

A0

LOG

# RETURN WITH -LOG IN MPAC



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# Page 860

```
DMP      DDV
          C12
          GAMMAL1
STORE    ASPUP      # UP PHASE RANGE      ASPUP / 2 PI

PDDL     DMP      # ASPUP TO PDL 4.
          KC3      # KC3 = -4 VS VS / 2 PI 805 RE
                   # ASPDWN = KC3 RDOT V / A0
          RDOT
DMP      DDV
          V
          A0
DDV      PUSH      # ASPDWN TO PDL 6.
          LAD
STODL    ASPDWN     # RANGE TO PULL OUT      ASPDWN /2 PI

          Q6
DSU      DMP      # ASP3 = Q5(Q6-GAMMAL)
          GAMMAL
          Q5
STOVL    ASP3      # GAMMA CORRECTION      ASP3/2PI

          ASKEP     # GET HI-WD AND
STODL    ASPS(TM)  # SAVE HI-WORD OF ASP'S FOR TM.

          ASP3
DAD      DAD

          # ASPDWN FROM PDL 6.
          # ASPUP FROM PDL 4.

DAD      DAD

          # ASP1 FROM PDL 2.
          # ASKEP FROM PDL 0.
          # CLEAR OVFind.
DSU      BOVB
          THETAH
          TCDANZIG
STORE    DIFF      # DIFF = (ASP-THETAH) / 2 PI
                   # ASP=ASKEP+ASP1+ASPUP+ASP3+ASPDWN = TOTAL RANGE

ABS      DSU      # IF ABS(THETAH-ASP) -25NM NEG, GO TO UPSY
          25NM
BMN      BON
          GOTOUPSY
          HIND
          GETLEWD
```

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```

      DLOAD      BPL
                  DIFF
                  DCONSTD      # EVENTUALLY SETS MODE = HUNTEST.
GETLEWD      DLOAD      DMP
                  # DLEWD = DLEWD (DIFF/(DIFFOLD-DIFF))
                  DLEWD
                  DIFF
      PDDL      DSU
                  DIFFOLD
                  DIFF
# Page 861
      BDDV
LWDSTORE      STADR
      STORE      DLEWD
      DAD      BMN      # IF LEWD+DLEWD NEG, DLEWD=-LEWD/2
                  LEWD
                  LEWDPTR
      BOV
                  LEWDOVFL
      STORE      LEWD

SIDETRAK      EXIT

      CA      EBENTRY
      TS      EBANK

      CA      PRI016      # DROP GRP 5 RESTART PRIO TO 1 LESS THAN
      TS      PHSPRDT5      # GRP 4.

      TC      PHASCHNG
      OCT      00474      # RESTART GRP 4 AT PRE-HUN.
                  # FORCE RESTART TO PICK UP IN GRP 4:
                  # USE PRIO 17 FOR GRP 4 (< SERVICER PRIO)
      CA      PRI016      # CONTINUE GRP 5 AT LOWER PRIO THAN EITHER
                  # GRP 4 OR SERVICER.

      TC      PRIOCHNG

      CAF      ADENDEXT      # SIDETRACK NEXT PASS UNTIL THIS ONE DONE.
      TS      GOTOADDR      # ONLY AFTER RESTART IS LEFT AFTER DETOUR.

      TC      INTPRET

      DLOAD      SET
                  DIFF
                  HIND
      STODL      DIFFOLD      # DIFFOLD / 2 PI

```

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```

                                Q7F
STCALL  Q7                     # Q7 / 805 FPSS
                                HUNTEST                # (GO TO)

LEWDOVFL  DLOAD
                                NEARONE
STCALL  LEWD
                                DCONSTD                # (GO TO)  ALSO WILL SET MODE = HUNTEST

LEWDPTR   DLOAD  SR1
                                LEWD
DCOMP     GOTO
                                LWDSTORE

# Page 862
NEGAMA    DMP      DMP                     # ENTER WITH GAMMAL IN MPAC

                                VL
                                1/3RD
PDDL      DMP                     # PUSH GAMMAL VL/3
                                LEWD
                                1/3RD
PDDL      DAD                     # PUSH LEWD/3
                                AHOOKDV
                                1/24TH
DMP        DMP                     # DEL VL = (GAMMAL VL/3)/(LEWD/3-DVL
                                DVL                     # (2/3 + AHOOKDV)(CH1 GS/DHOOK VL))
                                CH1
DDV        DDV
                                DHOOK
                                VL
BDSU       BDDV

                                # LEWD/3
                                # GAMMAL VL /3

DAD
                                VL
STCALL    VL                     # VL/2 VS

                                DHOOKYQ7                # GO CALC Q7
                                # Q7=((1-VL/FACT1)SQ - ALP)/FACT2
STODL     Q7                     # Q7 / 25G

                                VL
DSQ
STODL     VBARS                  # VBARS / 4 VS VS
```

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[illegible]

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```
UPCONTRL      DLOAD  DSU          # IF D-140 POS, NOSWITCH =1
                D          # (SUPPRESS LATERAL SWITCH)
                C21
BMN            SET
                +2
                NOSWITCH

                DLOAD  DSU          # IF V-V1 POS, GO TO DOWN CONTROL.
                V
                V1
BPL            DLOAD
                DOWNCNTL
                D
DSU            BMN          # IF D- Q7 NEG, GO TO KEP
                Q7
                KEP
DLOAD          BPL          # IF RDOT NEG, DO VLTEST
                RDOT
                CONT1

VLTEST         DLOAD  DSU          # IF V-VL-C18 NEG,EGSW=1,MODE=PREDICT3
                V
                VL
DSU            BMN
                C18
                PREFINAL

CONT1          DLOAD          # IF D-A0 POS, L/D = LAD, GO TO LIMITL/D
                D
DSU            BMN
                A0
                CONT3
DLOAD          GOTO
                LAD
                STOREL/D

CONT3          DLOAD  DMP          # VREF=FACT1(1-SQRT(FACT2 D + ALP))
                D
                FACT2

# Page 865
DAD            SQRT
                ALP
BDSU           DMP
                BARELY1
                FACT1
```

```

        STORE    VREF          # VREF / 2VS

        BDSU     DMP           # RDOTREF = LEWD(V1-VREF)
                V1
                LEWD
        STODL    RDOTREF      # RDOTREF / 2VS

        DSU      VS1
                BMN           # IF VSAT-VREF NEG, GO TO CONTINU2
                VREF
                CONTINU2

        PUSH     PUSH         # VS1-VREF TO PDL TWICE
        DMP      DDV          # RDHOOK=CHI1(1+DV AHOOKDV/DVL) DV DV
                AHOOKDV      # /DHOOK VREF
                DVL          # WHERE DV = (VS1-VREF)

        DAD      DMP
                1/16TH
                CH1
        DMP      DMP
                # VS1-VREF FROM PDL TWICE.

        DDV
                DHOOK
        DDV      BDSU
                VREF
                RDOTREF      # C(RDOTREF)= LEWD (V1-VREF)
        STORE    RDOTREF      # RDOTREF = RDOTREF - RDHOOK

CONTINU2      DLOAD    DSU
                D
                Q7MIN
        BOVB     BMN
                TCDANZIG    # CLEAR OVFL IND, IF ON.
                UPCNTRL3
        DLOAD    DSU
                A1
                Q7
        PDDL     DSU
                D
                Q7
        DDV      STADR
        STORE    FACTOR      # FACTOR / 25G

# Page 866
# SKIPPER

# DELTA L/D=--((RDOT-RDOTREF)F1 KB1+V-VREF)F1

```

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# WHERE F1 = FACTOR

```
UPCNTRL3      DLOAD      RDOT
                DSU        DMP      # L/D = LEWD
                RDOTREF    # -((RDOT-RDOTREF)F1/KB1+V-VREF)F1/KB2
                FACTOR
                DDV        DAD
                1/KB1
                V
                DSU        DMP
                VREF
                FACTOR
                DDV        PUSH

                -1/KB2      # DELTA L/D INTO PDL
                BOV        ABS      # NONLINEAR CIRCUIT FOR REDUCING HIGH GAIN
                GOMAXL/D
                DSU        BMN
                PT1/16
                NEXT1
                DMP        DAD
                POINT1
                PT1/16
                SIGN       PUSH      # ATTACH SIGN OF PUSH TO MPAC THEN PUSH

NEXT1          DLOAD      SL4
                DAD
                LEWD
NEGTESTS       BOV        PUSH      # L/D TO PDL FOR USE IN NEGTESTS.
                GOMAXL/D
                STODL      L/D
                D
                DSU        BMN
                C20
                LIMITL/D
                CLEAR      DLOAD
                LATSW      # =21D. ROLL OVER TOP, REGARDLESS.
                BPL        DLOAD      # L/D FROM PDL.
                LIMITL/D
                3ZEROS
```

```

                                STCALL  L/D
                                LIMITL/D      # (GO TO)

# Page 867
DCONSTD      DLOAD              # TWO RANGER ENTRIES TO CONSTD HERE
                                DIFF
                                # SAVE OLD VALUE OF DIFF FOR NEXT PASS.
                                STODL   DIFFOLD  # DIFFOLD / 2 PI
                                Q7F
                                STORE   Q7

BECONSTD      SSP      RTB          # A HUNTEST ENTRY INTO CONSTD.
                                GOTOADDR      # RESET MODE TO HUNTEST
                                HUNTEST
                                KILLGRP4      # DEACTIVATE GRP4 FROM HUNTEST.

CONSTD        BOVB
                                TCDANZIG      # CLEAR OVF IND IF ON.

                                DLOAD  DMP
                                LEQ
                                C/DO          # C/DO = -4/DO B-8
                                PDDL   DMP      # LEQ C/DO INTO PDL
                                2HS          # 2HS / 4 VS VS
                                DO
                                DDV   DAD          # RDOTREF = -2 HS DO/V
                                V
                                RDOT
                                DMP   DAD
                                K2D          # C/DO LEQ + K2D(RDOT-RDOTREF) INTO PD
                                PDDL
                                DO          # DO /805

CONSTD1       BDSU              # ENTER WITH DREF IN MPAC
                                D
                                DMP   DAD
                                K1D          # K2D TERM FROM PUSH
                                SL    GOTO
                                8D
                                NEGTESTS      # (GO TO)

DOWNCNTL      BOVB              # INITIAL PART OF UPCONTROL.
                                TCDANZIG      # CLEAR OVFFIND, IF ON.

                                DLOAD  SR

```



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```
# Page 868
      LAD
      8D
PDDL  DSU      # RDTR = LAD(V1-V)
      V
      V1
DMP   DAD
      LAD

      RDOT
DMP   DAD
      K2D
      # PUSH UP LAD.
PDDL  DSU      # LAD + K2D(RDOT-RDTR) INTO PD
      V1
      V
DSQ   DMP
      LAD
DDV   PDDL      # (V1-V)SQ LAD/(2 C1 HS) INTO PD
      2C1HS
      V1
DSQ   DDV
      VSQUARE
BDDV  DSU      # DREF = (V/V1)SQ A0 - PD
      A0
      # PUSH UP HERE
GOTO  # C(MPAC) = DREF
      CONSTD1

      #
      2          2
      # DREF = (V/V1) A0 -(V-V1) LAD/2 C1 HS

# Page 869
# * START BALLISTIC PHASE ...
      # MM = 66          UPCONTRL ENTRY INTO KEP2
KEP   RTB      SSP
      P66
      GOTOADDR
      KEP2
      # DISPLAY TRIM GIMBAL ANGLE VALUES.
      # SET GOTOADDR TO KEPLER PHASE.

      # KEP2 CAN ALSO BE STARTED UP DIRECTLY FROM INITROLL
      # IN P64. PROGRAM WILL IDLE IN P64 UNTIL D EXCEEDS
      # .2 G BEFORE GOING ON TO P67.

KEP2  DLOAD    DSU      # IF Q7F+KDMIN -D NEG, GO TO FINAL PHASE.
      Q7FKDMIN
      D
      # (Q7F + KDMIN)/805
BMN   TLOAD
```

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```

# Page 870
# START FINAL PHASE ...

PREFINAL          SSP      RTB
                   GOTOADDR
                   PREFINAL
                   P67
                   # MM = 67
                   # RESTART PROTECT: RESET GOTOADDR IF CAME
                   # FROM HUNTEST.
                   # DISABLES GRP4. FINE IF FROM HUNTEST, BUT
                   # MAY ALSO REMOVE RESTART PROTECTION OF
                   # N69 (P65).
                   # ROLLC          XRUNGERR          DNRNGERR
                   # XXX.XX DEG      XXXX.X NM        XXXX.XX NM

                   SET      SSP
                   EGSW
                   GOTOADDR
                   PREDICT3

PREDICT3          DLOAD    DSU
                   V
                   VQUIT
                   BMN      EXIT
                   STEEROFF

                   CA        EBENTRY
                   TS        EBANK
                   # PRECAUTIONARY.

                   CA        TWELVE
BACK              TS        JJ

                   CS        V
                   INDEX     JJ
                   AD        VREFER
                   CCS        A
                   CCS        JJ
                   TCF        BACK
                   # VREF - V, HIGHEST VREF AT END OF TABLE.
                   # IF VREF-V POS LOOP BACK
                   # DECREMENT JJ, JJ CANNOT BE ZERO

```

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```
AD      ONE
TS      TEM1B      # V-VREF IN TEM1B (MUST BE POSITIVE NUM)

INDEX   JJ
CS      VREFER
INDEX   JJ
AD      VREFER +1  # V(K+1) - V(K) (POS NUM)
XCH     TEM1B
ZL
EXTEND
DV      TEM1B
TS      GRAD      # GRAD = (V-VREF)/(VK+1 - VK) (POS NUM)

CAF     FIVE
```

# Page 871  
BACK2

```
TS      MM
CAF     THIRTEEN
ADS     JJ
INDEX   A
CS      VREFER
INDEX   JJ
AD      VREFER +1  # X(K+1) - X(K)
EXTEND
MP      GRAD
INDEX   JJ
AD      VREFER
INDEX   MM
TS      FX      # FX = AK + GRAD (AK+1 - AK)
CCS     MM
TCF     BACK2
XCH     FX      +1  # ZERO FX +1 AND GET DREFR
AD      D
EXTEND
MP      FX      +5  # F1
DXCH    MPAC     # MPAC = F1(D-DREF)

EXTEND
DCS     RDOT     # FORM RDOTREF - RDOT
DDOUBL
DDOUBL
DDOUBL  # SCALE UP BY 8 FOR THIS PHASE.
AD      FX      +3  # RDOTREF
EXTEND
MP      FX      +4  # F2
AD      FX      +2  # RTOGO
```

```

      DAS      MPAC      # ADD F2(DADV1-DADVR)
      CA       MPAC
      TS       PREDANG
                                # L/D = LOD + (THETA- PREDANG)/ Y
      TC       INTERPRET

      SR3      DSU
                THETAH
      BON      BOFF
                GONEPAST
                GONEGLAD
                GONEBY
                HAVDNRNG
      DLOAD    SET      # SET GONEPAST IF GONEBY SET & LATCH IN-PLAC
                MAXRNG   # DISPLAY = 9999.9 IF GONEBY
                GONEPAST
      STCALL   DNRNGERR
                GONEGLAD

HAVDNRNG      STORE    DNRNGERR      # = (PREDANG - THETA) /360
# Page 872

      DCOMP
      BOVB     DDV
                TCDANZIG      # FALLS SHORT IF NEG, OVERSHOOT IF POS
                FX            # CLEAR OVFINDD IF ON.
                                # FX= DRANGE/D L/D = Y
      SL       BOV
                5
                GOMAXL/D
      DAD      BOV
                LOD
                GOMAXL/D
      STCALL   L/D
                GLIMITER      # (GO TO)

# GONEGLAD AND GOPOSMAX ENTRY POINTS FOR GLIMITER ...

GONEGLAD      DLOAD    # SET L/D = -LAD
                GONEGLAD   # (ANY NEGATIVE NUMBER WILL DO)

GOMAXL/D      RTB      DMP      L/D = LAD SIGN(MPAC)
                SIGNMPAC
                LAD
      STORE    L/D      # AND FALL INTO GLIMITER SECTION

GLIMITER      DLOAD    DSU      # IF GMAX/2-D POS, GO TO LIMITL/D
                GMAX/2

```

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```

      D
BPL   DAD      # IF GMAX -D NEG, GO TO GOPOSLAD
      LIMITL/D
      GMAX/2
BMN   DMP
      GOPOSLAD
      2HS
PDDL  DMP      # 2HS(GMAX-D) INTO PD
      LEQ
      1/GMAX
DAD   DMP
      LAD
PDDL  DDV      # 2HS(GMAX-D) (LEQ/GMAX+LAD) INTO PD
      2HSGMXSQ
      VSQUARE
DAD   SQRT     # XLIM = SQRT(PD+(2HSGMAX/V)SQ)
DAD   BPL      # IF RDOT+XLIM POS, GO TO LIMITL/D
      RDOT
      LIMITL/D

GOPOSLAD  DLOAD
          LAD
STOREL/D  STORE  L/D

# Page 873
LIMITL/D  DLOAD
          L/D
          STODL  L/D1
          VSQUARE

BON       # NO LATERAL CONTROL IF PAST TARGET
          GONEPAST
          L355
DMP       DAD      # Y= KLAT VSQUARE + LATBIAS
          KLAT
          LATBIAS  # Y INTO PD
L350      PDDL     # IF ABS(L/D)-L/DCMINR NEG, GO TO L353
          ABS
          L/D
          DSU      BMN
          L/DCMINR
          L353
          DLOAD    SIGN      # IF K2ROLL LATANG NEG, GO TO L357
          LATANG
          K2ROLL
          BMN      DLOAD
          L357
```

```

L353      SR1      PUSH      # Y = Y/2
          DLOAD    SIGN      # IF LATANG SIGN(K2ROLL)-Y POS, SWITCH
          LATANG
          K2ROLL

          DSU
          BMN      DLOAD
          L355
          K2ROLL

          BONCLR   DCOMP      # IF NOSWITCH =1, K2ROLL= K2ROLL
          NOSWITCH
          L355
          STORE    K2ROLL     # K2ROLL = -K2ROLL

L355      DLOAD    DDV        # ROLL C = ACOS( (L/D1) / LAD)
          L/D1
          LAD       # MPAC SET TO +-1 IF OVERFLOW***
          SR1      ACOS
          SIGN      CLEAR
          K2ROLL
          NOSWITCH
          STORE    ROLL C

ENDEXIT   EXIT

OVERNOUT  CA       BIT13     # ENTRYDSP =92D B13
          MASK     CM/FLAGS
          EXTEND
          BZF      NODISKY   # OMIT DISPLAY.

# Page 874
          CA       ENTRYVN   # ALL ENTRY DISPLAYS ARE DONE HERE.
          TC       BANKCALL
          CADR      REGODSPR # NO ABORT IF DISKY IN USE

NODISKY   INHINT

          CCS      NEWJOB    # PROTECT READACCS GRP 5, IF SIDETRACKED.
          TC       CHANG1
SERVNOUT  TC       POSTJUMP  # ( COME HERE FROM P67.3 )
          CADR      SERVEXIT # AND END AVERAGEG JOB VIA ENDOJOB.

# Page 875
# DISPLAY WHEN V IS LESS THAN VQUIT.

STEEROFF  EXIT
          CA       EBENTRY   # PRECAUTIONARY.
          TS       EBANK

```

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```
CA      PRI016      # 2 LESS THAN NTRYPRIO.
TC      NOVAC
EBANK=  AOG        # ANY EB HERE
2CADR   P67.1      # START UP REMAINDER OF P67

                        # RTOGO          LAT          LONG
                        # XXXX.X NM      XXX.XX DEG      XXX.XX DEG

TC      2PHSCHNG    # INHINT/RELINT DONE.
OCT     00414      # 4.41 RESTART FOR P67.1 DISPLAY JOB.
OCT     10035      # SERVICER 5.3 RESTART.

CA      P67.2CAD    # HEREAFTER, DO LAT, LONG.
TS      GOTOADDR

TC      INTPRET
GOTO

P67.2CAD      P67.2      # CONTINUE FOR LAT, LONG THIS TIME.

L357      DLOAD     SIGN      # L/D = L/DCMINR SIGN(L/D)
          L/DCMINR
          L/D
          STCALL    L/D1
          L355      # (GO TO)

# Page 876
# TABLE USED FOR SUB-ORBITAL REFERENCE TRAJECTORY CONTROL.

VREFER    DEC      .019288    # REFERENCE VELOCITY SCALED V/51532.3946
          DEC      .040809    # 13 POINTS ARE STORED AS THE INDEPENDENT
          DEC      .076107    # VARIABLE AND THEN SIX 13-POINT FUNCTIONS
          DEC      .122156    # OF V ARE STORED CONSECUTIVELY
          DEC      .165546
          DEC      .196012
          DEC      .271945
          DEC      .309533
          DEC      .356222
          DEC      .404192
          DEC      .448067
          DEC      .456023
          DEC      .67918      # HIGHVELOCITY FOR SAFETY.

          DEC      -.010337    # DRANGE/DA      SCALED DRDA/(2700/805)
          DEC      -.016550
          DEC      -.026935
          DEC      -.042039
```

DEC -.058974  
 DEC -.070721  
 DEC -.098538  
 DEC -.107482  
 DEC -.147762  
 DEC -.193289  
 DEC -.602557  
 DEC -.99999  
 DEC -.99999

DEC -.0478599 B-3 # -DRANGE/DRDOT  
 DEC -.0683663 B-3 # SCALED ((2VS/8 2700) DR/DRDOT)  
 DEC -.1343468 B-3  
 DEC -.2759846 B-3  
 DEC -.4731437 B-3  
 DEC -.6472087 B-3  
 DEC -1.171693 B-3  
 DEC -1.466382 B-3  
 DEC -1.905171 B-3  
 DEC -2.547990 B-3  
 DEC -4.151220 B-3  
 DEC -5.813617 B-3  
 DEC -5.813617 B-3

# Page 877

DEC -.0134001 B3 # RDOTREF SCALED (8 RDT/2VS)  
 DEC -.013947 B3  
 DEC -.013462 B3  
 DEC -.011813 B3  
 DEC -.0095631 B3  
 DEC -.00806946 B3  
 DEC -.006828 B3  
 DEC -.00806946 B3  
 DEC -.0109791 B3  
 DEC -.0151498 B3  
 DEC -.0179817 B3  
 DEC -.0159061 B3  
 DEC -.0159061 B3

DEC .0008067 # RANGE TO GO SCALED RTGO/2700  
 DEC .0032963 # 8.9  
 DEC .0081852 # 22.1  
 DEC .017148  
 DEC .027926  
 DEC .037  
 DEC .063298



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DEC .077889  
DEC .098815  
DEC .127519  
DEC .186963  
DEC .238148  
DEC .294185185

DEC -.051099 # -AREF/805  
DEC -.074534  
DEC -.101242  
DEC -.116646  
DEC -.122360  
DEC -.127081  
DEC -.147453  
DEC -.155528  
DEC -.149565  
DEC -.118509  
DEC -.034907  
DEC -.007950  
DEC -.007950

# Page 878

DEC .004491 # DRANGE/D L/D SCALED Y/2700  
DEC .008081  
DEC .016030  
DEC .035815  
DEC .069422  
DEC .104519  
DEC .122  
DEC .172407  
DEC .252852  
DEC .363148  
DEC .512963  
DEC .558519  
DEC .558519 # END OF STORED REFERENCE

# Page 879

# REENTRY CONSTANTS.

# DEFINED BY EQUALS

DEC15 = LOW4  
#GAMMAL1 = 22D

MAXRNG 20CT 1663106755 # DNRNGERR = 9999.9 IF GONEPAST=1

|                                        |        |             |                                              |
|----------------------------------------|--------|-------------|----------------------------------------------|
|                                        | BANK   | 26          |                                              |
|                                        | SETLOC | REENTRY1    |                                              |
|                                        | BANK   |             |                                              |
|                                        | COUNT* | \$\$/ENTRY  |                                              |
| BARELY1                                | =      | NEARONE     | # COMMON TO BOTH DISK,DANCE, DEFND IN TFF    |
| #1BITDP                                |        |             | # COMMON TO BOTH DISK AND DANCE. DEFND IN VE |
| 1/12TH                                 | DEC    | .083333     | # DP 1/12 USES HI WORD IN 1/3 BELOW          |
| 1/3RD                                  | 2DEC   | .3333333333 | # DP 1/3                                     |
| 1/16TH                                 | =      | DP2(-4)     |                                              |
| # BELOW: VS = VSAT = 25766.1973 FT/SEC |        |             |                                              |
| # RE = 21,202,900 FEET                 |        |             |                                              |
| LEWD1                                  | 2DEC   | .15         |                                              |
| POINT1                                 | 2DEC   | .1          |                                              |
| POINT2                                 | 2DEC   | .2          | # .2                                         |
| DLEWD0                                 | 2DEC   | -.05        | # -.05                                       |
| GMAX/2                                 | 2DEC   | .16         | # 8 GS / 2                                   |
| 3ZEROS                                 | EQUALS | HI6ZEROS    |                                              |
| NEAR1/4                                | 2OCT   | 0777700000  | # 1/4 LESS 1 BIT IN UPPER PART.              |
| C18                                    | 2DEC   | .0097026346 | # 500/2VS                                    |
| Q7FKDMIN                               | 2DEC   | .0080745342 | # 6.5/805 (Q7F +KDMIN) = 6 + .5)             |
| C1/16                                  | =      | DP2(-4)     |                                              |
| Q3                                     | 2DEC   | .167003132  | # .07 2VS/21600                              |
| # Page 880                             |        |             |                                              |
| Q5                                     | 2DEC   | .326388889  | # .3 23500/21600                             |
| Q6                                     | 2DEC   | .0349       | # 2 DEG. APPROX 820/23500                    |
| Q7F                                    | 2DEC   | .0074534161 | # 6/805 (VALUE OF Q7 IN FIXED MEM.)          |
| Q19                                    | =      | HALVE       | # Q19 = .5                                   |

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|                      |       |                     |                                   |
|----------------------|-------|---------------------|-----------------------------------|
| Q21                  | 2DEC  | .0231481481         | # 500/21600                       |
| Q22                  | 2DEC  | -.053333333         | # -1152/21600                     |
| VLMIN                | 2DEC  | .34929485           | # 18000/2 VS                      |
| VMIN                 | =     | FOURTH              | # (VS/2) / 2VS                    |
| C12                  | 2DEC  | .00684572901        | # 32 28500/(21202900 2 PI)        |
| 1/KB1                | 2DEC  | .29411765           | # 1 / 3.4                         |
| -1/KB2               | 2DEC  | -.0057074322 B4     | # - 1/(.0034 2 VS) EXP +4         |
| VQUIT                | 2DEC  | .019405269          | # 1000 /2VS                       |
| C20                  | 2DEC  | .21739130           | # (175 FPSS) LIFT UP IF ABOVE C20 |
| C21                  | 2DEC  | .17391304           | # 140/805                         |
| 25NM                 | 2DEC  | .0011574074         | # 25/21600 (25 NAUT MILES)        |
| K1D                  | 2DEC  | .0314453125         | # =C16 805/256 = .01 805/256      |
| K2D                  | 2DEC  | -.201298418         | # -C17 2VS/256 = -.001 2VS/256    |
| KVSCALE              | 2DEC  | .81491944           | # 12800/(2 VS .3048)              |
| KASCALE              | 2DEC  | .97657358           | # 5.85 16384/(4 .3048 100 805)    |
| KTETA                | 2DEC* | .383495203 E2 B-14* | # 1000 2PI/16384(163.84)          |
| KT1                  | 2DEC* | .157788327 E2 B-14* | # RE(2PI)/2 VS(16384) 163.84      |
| .05G                 | 2DEC  | .002                | # .05/25                          |
| LATBIAS              | 2DEC  | .00003              | # APPRX .5 NM/ 4(21600/2 PI)      |
| KWE                  | 2DEC  | .120056652 B-1      |                                   |
| KACOS                | 2DEC  | .004973592          | # 1/32(2PI)                       |
| CHOOK                | 2DEC  | 1 B-6               | # .25/16                          |
| # Page 881<br>1/24TH | 2DEC  | .0833333333 B-1     |                                   |

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|          |        |              |                               |
|----------|--------|--------------|-------------------------------|
| CH1      | 2DEC   | .32 B1       | # 16 CH1/25 = 16 (1) /25      |
| KC3      | 2DEC   | -.0247622232 | # -(4 VS VS/ 2 PI 805 RE)     |
| VRCONT   | 2DEC   | .0135836886  | # 700/2 VSAT                  |
| HALVE    | EQUALS | HIDPHALF     |                               |
| FOURTH   | EQUALS | HIDP1/4      |                               |
| 1/GMAX   | EQUALS | HALVE        | # 4/GMAX = 4 / 8              |
| 2HS      | 2DEC   | .0172786611  | # 2 28500 25 32.2/(4 VS VS)   |
| 2HSGMXSQ | 2DEC   | .0000305717  | # (2 28500 8 32.2/ 4 VS VS)SQ |
| C001     | 2DEC   | -.000625     | # -(4/25)/256 LEQ/DO CONST    |
| POINT8   | 2DEC   | .8           |                               |
| 2C1HS    | 2DEC   | .0215983264  | # 2 1.25 28500 805/(2 VS)SQ   |
| PT1/16   | 2DEC   | .1 B-4       |                               |
| 1/K44    | 2DEC   | .00260929464 | # 2 VS/19749550               |
| VFINAL   | 2DEC   | .51618016    | # 26600/2 VS                  |
| VFINAL1  | 2DEC   | .523942273   | # = 27000 / 2 VS              |
| 1/KA1    | 2DEC   | .30048077    | # 25/(1.3 64)                 |
| KA2      | 2DEC   | .008         | # .2/25                       |
| KA3      | 2DEC   | .44720497    | # = 90 4/805                  |
| KA4      | 2DEC   | .049689441   | # 40/805                      |
| KALIM    | 2DEC   | .06          | # 1.5/25                      |
| Q7MIN    | =      | KA4          | # = 40/805 = .049689441       |
| -HSCALED | 2DEC   | -.55305018   | # -28500/2 VS                 |
| -KSCALE  | 2DEC   | -.0312424837 | # -805/VS                     |
| COS15    | 2DEC   | .965         |                               |
| LATSLOPE | EQUALS | 1/12TH       |                               |

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```
# ... END OF RE-ENTRY CONSTANTS ...
```

This code is written to file `src/REENTRY-CONTROL.s`.

## A.94 RESTARTS ROUTINE

```

1622  <src/RESTARTS-ROUTINE.s 1622>≡
      # Copyright:    Public domain.
      # Filename:     RESTARTS_ROUTINE.agc
      # Purpose:      Part of the source code for Comanche, build 055. It
      #               is part of the source code for the Command Module's
      #               (CM) Apollo Guidance Computer (AGC), Apollo 11.
      # Assembler:    yaYUL
      # Reference:     pp. 1414-1419
      # Contact:       Ron Burkey <info@sandroid.org>
      # Website:       http://www.ibiblio.org/apollo.
      # Mod history:   2009-05-07 RSB  Adapted from Colossus249 file of the same
      #               name, and page images. Corrected various
      #               typos in the transcription of program
      #               comments, and these should be back-ported
      #               to Colossus249.
      #
      # The contents of the "Comanche055" files, in general, are transcribed
      # from scanned documents.
      #
      # Assemble revision 055 of AGC program Comanche by NASA
      # 2021113-051. April 1, 1969.
      #
      # This AGC program shall also be referred to as Colossus 2A
      #
      # Prepared by
      #
      #               Massachusetts Institute of Technology
      #               75 Cambridge Parkway
      #               Cambridge, Massachusetts
      #
      # under NASA contract NAS 9-4065.
      #
      # Refer directly to the online document mentioned above for further
      # information. Please report any errors to info@sandroid.org.

      # Page 1414

      BANK      01
      SETLOC    RESTART
      BANK

      EBANK=     PHSNAME1          # GOPROG MUST SWITCH TO THIS EBANK

      COUNT     01/RSROU

      RESTARTS   CA      MPAC +5          # GET GROUP NUMBER -1

```

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```
DOUBLE      # SAVE FOR INDEXING
TS          TEMP2G

CA          PHS2CADR      # SET UP EXIT IN CASE IT IS AN EVEN
TS          TEMPSWCH      # TABLE PHASE

CA          RTRNCADR      # TO SAVE TIME ASSUME IT WILL GET NEXT
TS          GOLOC +2      # GROUP AFTER THIS

CA          TEMPPHS
MASK        OCT1400
CCS         A              # IS IT A VARIABLE OR TABLE RESTART
TCF        ITSAVAR        # IT'S A VARIABLE RESTART

GETPART2    CCS          TEMPPHS      # IS IT AN X.1 RESTART
            CCS          A
            TCF          ITSATBL      # NO, IT'S A TABLE RESTART

CA          PRI014        # IT IS AN X.1 RESTART, THEREFORE START
TC          FINDVAC        # THE DISPLAY RESTART JOB
EBANK=     LST1
2CADR      INITDSP

TC          RTRNCADR      # FINISHED WITH THIS GROUP, GET NEXT ONE

ITSAVAR     MASK        OCT1400      # IS IT TYPE B ?
            CCS         A
            TCF          ITSLIKEB    # YES, IT IS TYPE B

            EXTEND        # STORES THE JOB (OR TASK) 2CADR FOR EXIT
            NDX          TEMP2G
            DCA          PHSNAME1
            DXCH         GOLOC

CA          TEMPPHS      # SEE IF THIS IS A JOB, TASK, OR A LONGCALL
MASK        OCT7
AD          MINUS2
CCS         A
TCF        ITSLNGCL      # IT'S A LONGCALL

# Page 1415
RTRNCADR    TC          SWRETURN      # CAN'T GET HERE.
            TCF          ITSAWAIT

TCF        ITSAJOB      # IT'S A JOB
```

|          |      |          |                                 |
|----------|------|----------|---------------------------------|
| ITSAWAIT | CA   | WILTCADR | # SET UP WAITLIST CALL          |
|          | TS   | GOLOC -1 |                                 |
|          | NDX  | TEMP2G   | # DIRECTLY STORED               |
|          | CA   | PHSPRDT1 |                                 |
| TIMETEST | CCS  | A        | # IS IT AN IMMEDIATE RESTART    |
|          | INCR | A        | # NO.                           |
|          | TCF  | FINDTIME | # FIND OUT WHEN IT SHOULD BEGIN |
|          | TCF  | ITSINDIR | # STORED INDIRECTLY             |
|          | TCF  | IMEDIATE | # IT WANTS AN IMMEDIATE RESTART |

# \*\*\*\*\* THIS MUST BE IN FIXED FIXED \*\*\*\*\*

|          |        |          |                                          |
|----------|--------|----------|------------------------------------------|
|          | BLOCK  | 02       |                                          |
|          | SETLOC | FFTAG2   |                                          |
|          | BANK   |          |                                          |
|          | COUNT  | 02/RSROU |                                          |
| ITSINDIR | LXCH   | GOLOC +1 | # GET THE CORRECT E BANK IN CASE THIS IS |
|          | LXCH   | BB       | # SWITCHED ERASABLE                      |
|          | NDX    | A        | # GET THE TIME INDIRECTLY                |
|          | CA     | 1        |                                          |
|          | LXCH   | BB       | # RESTORE THE BB AND GOLOC               |
|          | LXCH   | GOLOC +1 |                                          |
|          | TCF    | FINDTIME | # FIND OUT WHEN IT SHOULD BEGIN          |

# \*\*\*\*\* YOU MAY RETURN TO SWITCHED FIXED \*\*\*\*\*

|          |        |          |                                             |
|----------|--------|----------|---------------------------------------------|
|          | BANK   | 01       |                                             |
|          | SETLOC | RESTART  |                                             |
|          | BANK   |          |                                             |
|          | COUNT  | 01/RSROU |                                             |
| FINDTIME | COM    |          | # MAKE NEGATIVE SINCE IT WILL BE SUBTRACTED |
|          | TS     | L        | # AND SAVE                                  |
|          | NDX    | TEMP2G   |                                             |
|          | CS     | TBASE1   |                                             |
|          | EXTEND |          |                                             |



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|          |        |          |                                           |
|----------|--------|----------|-------------------------------------------|
|          | SU     | TIME1    |                                           |
|          | CCS    | A        |                                           |
|          | COM    |          |                                           |
|          | AD     | OCT37776 |                                           |
|          | AD     | ONE      |                                           |
|          | AD     | L        |                                           |
|          | CCS    | A        |                                           |
|          | CA     | ZERO     |                                           |
|          | TCF    | +2       |                                           |
|          | TCF    | +1       |                                           |
| IMEDIATE | AD     | ONE      |                                           |
|          | TC     | GOLOC -1 |                                           |
| ITSLIKEB | CA     | RTRNCADR | # TYPE B, SO STORE RETURN IN              |
|          | TS     | TEMPSWCH | # TEMPSWCH IN CASE OF AN EVEN PHASE       |
|          | CA     | PRT2CADR | # SET UP EXIT TO GET TABLE PART OF THIS   |
|          | TS     | GOLOC +2 | # VARIABLE TYPE OF PHASE                  |
|          | CA     | TEMPPHS  | # MAKE THE PHASE LOOK RIGHT FOR THE TABLE |
|          | MASK   | OCT177   | # PART OF THIS VARIABLE PHASE             |
|          | TS     | TEMPPHS  |                                           |
|          | EXTEND |          |                                           |
|          | NDX    | TEMP2G   | # OBTAIN THE JOB'S 2CADR                  |
|          | DCA    | PHSNAME1 |                                           |
|          | DXCH   | GOLOC    |                                           |
| ITSAJOB  | NDX    | TEMP2G   | # NOW ADD THE PRIORITY AND LET'S GO       |
|          | CA     | PHSPRDT1 |                                           |
| CHKNOVAC | TS     | GOLOC -1 | # SAVE PRIO UNTIL WE SEE IF IT'S          |
|          | EXTEND |          | # A FINDVAC OR A NOVAC                    |
|          | BZMF   | ITSNOVAC |                                           |
|          | CAF    | FVACCADR | # POSITIVE, SET UP FINDVAC CALL.          |
|          | XCH    | GOLOC -1 | # PICK UP PRIO                            |
|          | TC     | GOLOC -1 | AND GO                                    |
| ITSNOVAC | CAF    | NOVACADR | # NEGATIVE,                               |
|          | XCH    | GOLOC -1 | # SET UP NOVAC CALL,                      |
|          | COM    |          | # CORRECT PRIO,                           |
|          | TC     | GOLOC -1 | # AND GO                                  |
| ITSATBL  | TS     | CYR      | # FIND OUT IF THE PHASE IS ODD OR EVEN    |
|          | CCS    | CYR      |                                           |
|          | TCF    | +1       | # IT'S EVEN                               |
|          | TCF    | ITSEVEN  |                                           |

```

# Page 1417
CA      RTRNCADR      # IN CASE THIS IS THE SECOND PART OF A
TS      GOLOC +2      # TYPE B RESTART, WE NEED PROPER EXIT

CA      TEMPPHS      # SET UP POINTER FOR FINDING OUR PLACE IN
TS      SR            # THE RESTART TABLES
AD      SR
NDX     TEMP2G
AD      SIZETAB +1
TS      POINTER

CONTBL2 EXTEND        # FIND OUT WHAT'S IN THE TABLE
NDX     POINTER
DCA     CADRTAB      # GET THE 2CADR

LXCH    GOLOC +1      # STORE THE BB INFORMATION

CCS     A            # IS IT A JOB OR IT IT TIMED
INCR    A            # POSITIVE, MUST BE A JOB
TCF     ITSAJOB2

INCR    A            # MUST BE EITHER A WAITLIST OR LONGCALL
TS      GOLOC        # LET'S STORE THE CORRECT CADR

CA      WTLTCADR      # SET UP OUR EXIT TO WAITLIST
TS      GOLOC -1

CA      GOLOC +1      # NOW FIND OUT IF IT IS A WAITLIST CALL
MASK    BIT10        # THIS SHOULD BE ONE IF WE HAVE -BB
CCS     A            # FOR THAT MATTER SO SHOULD BE BITS 9,8,7,
                        # 6,5, AND LAST BUT NOT LEAST (PERHAPS NOT
                        # IN IMPORTANCE ANYWAY. BUT 4
TCF     ITSWTLST      # IT IS A WAITLIST CALL

NDX     POINTER      # OBTAIN THE ORIGINAL DELTA T
CA      PRDTTAB      # ADDRESS FOR THIS LONGCALL

TCF     ITSLGCL1      # NOW GO GET THE DELTA TIME

# ***** THIS MUST BE IN FIXED FIXED *****

BLOCK   02
SETLOC  FFTAG2
BANK

COUNT  02/RSROU

```

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```
ITSLGCL1      LXCH  GOLOC +1      # OBTAIN THE CORRECT E BANK
               LXCH  BB
               LXCH  GOLOC +1      # AND PRESERVE OUR E AND F BANKS

               EXTEND
               NDX    A            # GET THE DELTA TIME
               DCA    0

# Page 1418
               LXCH  GOLOC +1      # RESTORE OUR E AND F BANK
               LXCH  BB            # RESTORE THE TASKS E AND F BANKS
               LXCH  GOLOC +1      # AND PRESERVE OUR L
               TCF    ITSLGCL2      # NOT GET'S PROCESS THIS LONGCALL

# ***** YOU MAY RETURN TO SWITCHED FIXED *****

               BANK    01
               SETLOC  RESTART
               BANK

ITSLGCL2      COUNT  01/RSROU
               DXCH   LONGTIME

               EXTEND
               DCS    TIME2        # CALCULATE TIME LEFT
               DAS    LONGTIME
               EXTEND
               DCA    LONGBASE
               DAS    LONGTIME

               CCS    LONGTIME      # FIND OUT HOW THIS SHOULD BE RESTARTED
               TCF    LONGCLCL
               TCF    +2
               TCF    IMEDIATE -3
               CCS    LONGTIME +1
               TCF    LONGCLCL

               NOOP
               TCF    IMEDIATE -3   # CAN'T GET HERE *****
               TCF    IMEDIATE

LONGCLCL      CA     LGCLCADR      # WE WILL GO TO LONGCALL
               TS     GOLOC -1

               EXTEND
               DCA    LONGTIME      # PREPARE OUR ENTRY TO LONGCALL
               TC     GOLOC -1
```

|             |        |          |                                            |
|-------------|--------|----------|--------------------------------------------|
| ITSLNGCL    | CA     | WILTCADR | # ASSUME IT WILL GO TO WAITLIST            |
|             | TS     | GOLOC -1 |                                            |
|             | NDX    | TEMP2G   |                                            |
|             | CS     | PHSPRDT1 | # GET THE DELTA T ADDRESS                  |
|             | TCF    | ITSLGCL1 | # NOW GET THE DELTA TIME                   |
| ITSWTLST    | CS     | GOLOC +1 | # CORRECT THE BBCON INFORMATION            |
|             | TS     | GOLOC +1 |                                            |
| # Page 1419 | NDX    | POINTER  | # GET THE DT AND FIND OUT IF IT WAS STORED |
|             | CA     | PRDTTAB  | # DIRECTLY OR INDIRECTLY                   |
|             | TCF    | TIMETEST | # FIND OUT HOW THE TIME IS STORED          |
| ITSAJOB2    | XCH    | GOLOC    | # STORE THE CADR                           |
|             | NDX    | POINTER  | # ADD THE PRIORITY AND LET'S GO            |
|             | CA     | PRDTTAB  |                                            |
|             | TCF    | CHKNOVAC |                                            |
| ITSEVEN     | CA     | TEMPSWCH | # SET FOR EITHER THE SECOND PART OF THE    |
|             | TS     | GOLOC +2 | # TABLE, OR A RETURN FOR THE NEXT GROUP    |
|             | NDX    | TEMP2G   | # SET UP POINTER FOR OUR LOCATION WITHIN   |
|             | CA     | SIZETAB  | # THE TABLE                                |
|             | AD     | TEMPPHS  | # THIS MAY LOOK BAD BUT LET'S SEE YOU DO   |
|             | AD     | TEMPPHS  | # BETTER IN TIME OR NUMBER OF LOCATIONS    |
|             | AD     | TEMPPHS  |                                            |
|             | TS     | POINTER  |                                            |
|             | TCF    | CONTBL2  | # NO PROCESS WHAT IS IN THE TABLE          |
| PHSPART2    | CA     | THREE    | # SET THE POINTER FOR THE SECOND HALF OF   |
|             | ADS    | POINTER  | # THE TABLE                                |
|             | CA     | RTRNCADR | # THIS WILL BE OUR LAST TIME THROUGH THE   |
|             | TS     | GOLOC +2 | # EVEN TABLE, SO AFTER IT GET THE NEXT     |
|             |        |          | # GROUP                                    |
|             | TCF    | CONTBL2  | # SO LET'S GET THE SECOND ENTRY IN THE TBL |
| TEMPPHS     | EQUALS | MPAC     |                                            |
| TEMP2G      | EQUALS | MPAC +1  |                                            |

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|          |        |           |
|----------|--------|-----------|
| POINTER  | EQUALS | MPAC +2   |
| TEMPSWCH | EQUALS | MPAC +3   |
| GOLOC    | EQUALS | VAC5 +20D |
| MINUS2   | EQUALS | NEG2      |
| OCT177   | EQUALS | LOW7      |

|          |        |          |
|----------|--------|----------|
| PHS2CADR | GENADR | PHSPART2 |
| PRT2CADR | GENADR | GETPART2 |
| LGCLCADR | GENADR | LONGCALL |
| FVACCADR | GENADR | FINDVAC  |
| WTLTCADR | GENADR | WAITLIST |
| NOVACADR | GENADR | NOVAC    |

This code is written to file `src/RESTARTS-ROUTINE.s`.

## A.95 RESTART TABLES

```

1630  <src/RESTART-TABLES.s 1630>≡
# Copyright:    Public domain.
# Filename:     RESTART_TABLES.agc
# Purpose:      Part of the source code for Comanche, build 055. It
#               is part of the source code for the Command Module's
#               (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:   yaYUL
# Reference:    pp. 211-221
# Contact:      Ron Burkey <info@sandroid.org>,
#               Fabrizio Bernardini <fabrizio@spacecraft.it>
# Website:      http://www.ibiblio.org/apollo.
# Mod history:  2009-05-16 FB   Transcription Batch 2 Assignment.
#               2009-05-20 RSB   Added a missing comment mark.  Corrected mismarked
#                               Page 217 -> 220.
#               2009-05-21 RSB   Fixed value of 5.21SPOT.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051.  April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#
#               Massachusetts Institute of Technology
#               75 Cambridge Parkway
#               Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.
#
# Page 211
# RESTART TABLES
# -----
#
# THERE ARE TWO FORMS OF RESTART TABLES FOR EACH GROUP.  THEY ARE KNOWN AS THE EVEN P
# RESTART TABLES.  THE ODD TABLES HAVE ONLY ONE ENTRY OF THREE LOCATIONS WHILE THE EV
# EACH USING THREE LOCATIONS.  THE INFORMATION AS TO WHETHER IT IS A JOB, WAITLIST, C
# WAY THINGS ARE PUT IN TO THE TABLES.
#
# A JOB HAS ITS PRIORITY STORED IN A PRDTTAB OF THE CORRECT PHASE SPOT -- A POSITIVE

```

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```
# FINDVAC JOB, A NEGATIVE PRIORITY A NOVAC.  THE 2CADR OF THE JOB IS STORED IN THE CADRTAB.
# FOR EXAMPLE,
#
#           5.7SPOT           OCT      23000
#                               2CADR    SOMEJOB
#
# A RESTART OF GROUP 5 WITH PHASE SEVEN WOULD THEN CAUSE SOMEJOB TO BE RESTARTED AS A FINDVAC W
#
#           5.5SPOT           OCT      -23000
#                               2CADR    ANYJOB
#
# HERE A RESTART OF GROUP 5 WITH PHASE 7 WOULD CAUSE ANYJOB TO BE RESTARTED AS A NOVAC WITH PRI
# A LONGCALL HAS ITS GENADR OF ITS 2CADR STORED NEGATIVELY AND ITS BBCON STORED POSITIVELY.  IN
# PLACED THE LOCATION OF A DP REGISTER THAT CONTAINS THE DELTA TIME THAT LONGCALL HAD BEEN ORIG
# WITH.  EXAMPLE,
#
#           3.6SPOT           GENADR  DELTAT
#                               -GENADR LONGTASK
#                               BBCON   LONGTASK
#
#                               OCT      31000
#                               2CADR    JOBAGAIN
#
# THIS WOULD START UP LONGTASK AT THE APPROPRIATE TIME, OR IMMEDIATELY IF THE TIME HAD ALREADY
# BE NOTED THAT IF DELTAT IS IN A SWITCHED E BANK, THIS INFORMATION SHOULD BE IN THE BBCON OF T
# TASK.  FROM ABOVE, WE SEE THAT THE SECOND PART OF THIS PHASE WOULD BE STARTED AS A JOB WITH A
#
# WAITLIST CALLS ARE IDENTIFIED BY THE FACT THAT THEIR 2CADR IS STORED NEGATIVELY.  IF PRDTTAB
# IS POSITIVE, THEN IT CONTAINS THE DELTA TIME, IF PRDTTAB IS NEGATIVE THEN IT IS THE -GENADR C
# LOCATION CONTAINING THE DELTA TIME, THAT IS, THE TIME IS STORED INDIRECTLY.  IT SHOULD BE NOTE
# IF THE TIME IS STORED INDIRECTLY, THE BBCON MUST CONTAIN THE NECESSARY E BANK INFORMATION IF
# WAITLIST WE HAVE ONE FURTHER OPTION, IF -0 IS STORED IN PRDTTAB, IT WILL CAUSE AN IMMEDIATE R
# TASK.  EXAMPLES,
#
#                               OCT      77777           # THIS WILL CAUSE AN IMMEDIATE RESTART
#                               -2CADR  ATASK             # OF THE TASK "ATASK"
#
#                               DEC      200             # IF THE TIME OF THE 2 SECONDS SINCE DU
#                               -2CADR  DUMMY            # WAS PUT ON THE WAITLIST IS UP, IT WILL
#   # IN 10 MS, OTHERWISE IT WILL BEGIN WHE
#   # IT NORMALLY WOULD HAVE BEGUN.
#
# Page 212
#                               -GENADR DTIME           # WHERE DTIME CONTAINS THE DELTA TIME
#                               -2CADR  TASKTASK         # OTHERWISE THIS IS AS ABOVE
#
# ***** NOW THE TABLES THEMSELVES *****
```

|                                                        |        |                |                                       |
|--------------------------------------------------------|--------|----------------|---------------------------------------|
|                                                        | BANK   | 01             |                                       |
|                                                        | SETLOC | RESTART        |                                       |
|                                                        | BANK   |                |                                       |
|                                                        | COUNT  | 01/RSTAB       |                                       |
| PRDTTAB                                                | EQUALS | 12000          | # USED TO FIND THE PRIORITY OR DELTA  |
| CADRTAB                                                | EQUALS | 12001          | # THIS AND THE NEXT RELATIVE LOC CONT |
|                                                        |        |                | # RESTART 2CADR                       |
| SIZETAB                                                | TC     | 1.2SPOT -12006 |                                       |
|                                                        | TC     | 1.3SPOT -12004 |                                       |
|                                                        | TC     | 2.2SPOT -12006 |                                       |
|                                                        | TC     | 2.3SPOT -12004 |                                       |
|                                                        | TC     | 3.2SPOT -12006 |                                       |
|                                                        | TC     | 3.3SPOT -12004 |                                       |
|                                                        | TC     | 4.2SPOT -12006 |                                       |
|                                                        | TC     | 4.3SPOT -12004 |                                       |
|                                                        | TC     | 5.2SPOT -12006 |                                       |
|                                                        | TC     | 5.3SPOT -12004 |                                       |
|                                                        | TC     | 6.2SPOT -12006 |                                       |
|                                                        | TC     | 6.3SPOT -12004 |                                       |
| 1.2SPOT                                                | EQUALS | 3.2SPOT        |                                       |
| # ANY MORE GROUP 1.EVEN RESTART VALUES SHOULD GO HERE. |        |                |                                       |
| 1.3SPOT                                                | DEC    | 120            | # THIS NUMBER MUST BE EQUAL C(JTAGTIN |
|                                                        | EBANK= | AOG            |                                       |
|                                                        | -2CADR | SETJTAG        |                                       |
| 1.5SPOT                                                | OCT    | 10000          |                                       |
|                                                        | EBANK= | DAPDATR1       |                                       |
|                                                        | 2CADR  | RED040.9       |                                       |
| 1.7SPOT                                                | OCT    | 10000          |                                       |
|                                                        | EBANK= | ESTROKER       |                                       |
|                                                        | 2CADR  | RELINUS        |                                       |
| 1.11SPOT                                               | OCT    | 10000          |                                       |
|                                                        | EBANK= | ESTROKER       |                                       |
|                                                        | 2CADR  | PIKUP20        |                                       |
| # ANY MORE GROUP 1.ODD RESTART VALUES SHOULD GO HERE.  |        |                |                                       |
| 2.2SPOT                                                | EQUALS | 1.2SPOT        |                                       |



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# ANY MORE GROUP 2.EVEN RESTART VALUES SHOULD GO HERE

# Page 213

2.3SPOT            GENADR 600SECS  
                  -GENADR STATEINT  
                  EBANK= RRECTCSM  
                  BBCON STATEINT

2.5SPOT            OCT        05000  
                  EBANK= RRECTCSM  
                  2CADR STATINT1

2.7SPOT            OCT        10000  
                  EBANK= MRKBUF2  
                  2CADR R22

2.11SPOT           OCT        14000  
                  EBANK= LANDMARK  
                  2CADR V94ENTER

2.13SPOT           OCT        10000  
                  EBANK= MRKBUF2  
                  2CADR REDOR22

# ANY MORE GROUP 2.ODD RESTART VALUES SHOULD GO HERE.

3.2SPOT            EQUALS 4.2SPOT

# ANY MORE GROUP 3.EVEN RESTART VALUES SHOULD GO HERE

3.3SPOT            OCT        20000  
                  EBANK= TGO  
                  2CADR S40.13

3.5SPOT            DEC        0  
                  DEC        0  
                  DEC        0

3.7SPOT            OCT        22000  
                  EBANK= TEPHEM  
                  2CADR MATRXJOB

3.11SPOT           OCT        22000  
                  EBANK= TEPHEM  
                  2CADR REP11

3.13SPOT        OCT       22000  
                 EBANK=   TEPHEM  
                 2CADR    REP11A

3.15SPOT       -GENADR TGO       +1  
                 EBANK=   TGO  
                 -2CADR   ENGINOFF

# Page 214

# ANY MORE GROUP 3.ODD RESTART VALUES SHOULD GO HERE

4.2SPOT        OCT       77777  
                 EBANK=   TIG  
                 -2CADR   PRECHECK

                 OCT       30000  
                 EBANK=   DELVIMU  
                 2CADR    P47BODY

4.4SPOT        OCT       77777  
                 EBANK=   TIG  
                 -2CADR   PRECHECK

                 DEC       2996  
                 EBANK=   DAPDATR1  
                 -2CADR   TTG/0

4.6SPOT        OCT       77777  
                 EBANK=   TIG  
                 -2CADR   PRECHECK

                 DEC       2496  
                 EBANK=   TIG  
                 -2CADR   TIG-5

# ANY MORE GROUP 4.EVEN RESTART VALUES SHOULD GO HERE

4.3SPOT        DEC       40  
                 EBANK=   PACTOFF  
                 -2CADR   DOTVCON

4.5SPOT        DEC       160  
                 EBANK=   PACTOFF  
                 -2CADR   DOSTRULL

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|            |         |          |                                            |
|------------|---------|----------|--------------------------------------------|
| 4.7SPOT    | DEC     | 500      |                                            |
|            | EBANK=  | PACTOFF  |                                            |
|            | -2CADR  | TIG-0    |                                            |
| 4.11SPOT   | DEC     | 250      |                                            |
|            | EBANK=  | DAPDATR1 |                                            |
|            | -2CADR  | V97E40.6 |                                            |
| 4.13SPOT   | DEC     | 200      |                                            |
|            | EBANK=  | WHOCARES |                                            |
|            | -2CADR  | R40ENABL |                                            |
| 4.15SPOT   | OCT     | 16000    | # PRELAUNCH OPTICAL VERIFICATION           |
|            | EBANK=  | OGC      |                                            |
| # Page 215 |         |          |                                            |
|            | 2CADR   | COMPVER  | # CALLS FOR OPTICS DATA AGAIN (STD LEADIN) |
| 4.17SPOT   | OCT     | 16000    |                                            |
|            | EBANK=  | XSM      |                                            |
|            | 2CADR   | AZMTHCG1 |                                            |
| 4.21SPOT   | GENADR  | P40TMP   | # DELTA TIME USED IN SETTING UP            |
|            | -GENADR | TIGBLNK  | # LONG CALL OF TIGBLNK BY P40,P41          |
|            | EBANK=  | P40TMP   |                                            |
|            | BBCON   | TIGBLNK  |                                            |
| 4.23SPOT   | OCT     | 12000    | # PROTECT P40S/SV BY P40 P41               |
|            | EBANK=  | TIG      |                                            |
|            | 2CADR   | P40S/SV  |                                            |
| 4.25SPOT   | OCT     | 24000    |                                            |
|            | EBANK=  | BESTI    |                                            |
|            | 2CADR   | PROG52   |                                            |
| 4.27SPOT   | DEC     | 250      |                                            |
|            | EBANK=  | PACTOFF  |                                            |
|            | -2CADR  | DOTVCRCS |                                            |
| 4.31SPOT   | OCT     | 13000    |                                            |
|            | EBANK=  | STAR     |                                            |
|            | 2CADR   | R51 +1   |                                            |
| 4.33SPOT   | DEC     | 2100     | # PROTECT CONTINUING JOB TO START P63      |
|            | EBANK=  | AOG      |                                            |
|            | -2CADR  | WAKEP62  |                                            |

|            |         |           |                                        |
|------------|---------|-----------|----------------------------------------|
| 4.35SPOT   | OCT     | 12000     |                                        |
|            | EBANK=  | DAPDATR1  |                                        |
|            | 2CADR   | POSTBURN  |                                        |
| 4.37SPOT   | DEC     | 500       |                                        |
|            | EBANK=  | TIG       |                                        |
|            | -2CADR  | TIGAVEG   |                                        |
| 4.41SPOT   | OCT     | 17000     | # PROTECT DISPLAY JOB IN P67           |
|            | EBANK=  | AOG       |                                        |
|            | 2CADR   | P67.1     |                                        |
| 4.43SPOT   | -GENADR | S61DT     | # PROTECT TASK TO START PREREAD,ENTRY  |
|            | EBANK=  | S61DT     | # S61.1C WILL CHANGE EBANK=EB7 FOR P67 |
|            | -2CADR  | S61.1C    |                                        |
| 4.45SPOT   | OCT     | 13000     | # PROTECT CONTINUING JOB S61.1         |
|            | EBANK=  | AOG       | # (ENTRY IMU ALIGNMENT)                |
| # Page 216 |         |           |                                        |
|            | 2CADR   | S61.1A -1 |                                        |
| 4.47SPOT   | OCT     | 17000     | # PROTECT HUNTEST ITERATION            |
|            | EBANK=  | AOG       |                                        |
|            | 2CADR   | PRE-HUNT  |                                        |
| 4.51SPOT   | OCT     | 77777     | # PROTECT FDAI ATTITUDE                |
|            | EBANK=  | BODY3     | # ERROR DISPLAY IN P11                 |
|            | -2CADR  | ATERTASK  |                                        |
| 4.53SPOT   | DEC     | -0        |                                        |
|            | EBANK=  | END-E7    | # EBANK7 FOR TIG                       |
|            | -2CADR  | V97ETASK  |                                        |
| 4.55SPOT   | OCT     | 13000     | # PROTECT P65 RESPONSIVE DISPLAY.      |
|            | EBANK=  | RTINIT    |                                        |
|            | 2CADR   | P65.1     |                                        |
| 4.57SPOT   | -GENADR | P40TMP    |                                        |
|            | EBANK=  | P40TMP    |                                        |
|            | -2CADR  | TIGON     |                                        |
| 4.61SPOT   | OCT     | 77777     |                                        |
|            | EBANK=  | PACTOFF   |                                        |
|            | -2CADR  | IGNITION  |                                        |
| 4.63SPOT   | OCT     | 77777     |                                        |

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EBANK= PACTOFF  
-2CADR DOSPSOFF

4.65SPOT DEC 10  
EBANK= TIG  
-2CADR TIG-5

4.67SPOT DEC -0  
EBANK= CSMMASS  
-2CADR V97TTASK

4.71SPOT DEC 250  
EBANK= DAPDATR1 # (FOR RCSDAPON)  
-2CADR V97TRCS

4.73SPOT DEC -0  
EBANK= V97VCNTR  
-2CADR V97PTASK

4.75SPOT DEC -0  
EBANK= DAPDATR1  
-2CADR SPSOFF97

# Page 217

4.77SPOT DEC -0  
EBANK= PACTOFF  
-2CADR TIG-0

# ANY MORE GROUP 4.ODD RESTART VALUES SHOULD GO HERE

5.2SPOT OCT 32000  
EBANK= DVCNTR  
2CADR NORMLIZE

DEC 200  
EBANK= AOG  
-2CADR REREADAC

5.4SPOT OCT 20000  
EBANK= DVCNTR  
2CADR SERVICER

DEC 200  
EBANK= AOG  
-2CADR REREADAC

# ANY MORE GROUP 5.EVEN RESTART VALUES SHOULD GO HERE

5.3SPOT           DEC       200  
                  EBANK=   AOG  
                  -2CADR   REREADAC

5.5SPOT           OCT       77777  
                  EBANK=   AOG  
                  -2CADR   RED05.5

5.7SPOT           OCT       20000                   # USED BY PRELAUNCH  
                  EBANK=   XSM  
                  2CADR   RSTGTS1

5.11SPOT          OCT       77777  
                  EBANK=   XSM  
                  -2CADR   ALLOOP1

5.13SPOT          OCT       20000  
                  EBANK=   XSM  
                  2CADR   WTLISTNT

5.15SPOT          OCT       20000  
                  EBANK=   XSM  
                  2CADR   RETEST1

5.17SPOT          OCT       20000  
                  EBANK=   XSM

# Page 218  
                  2CADR   GEOSTRT4

5.21SPOT          OCT       22000  
                  EBANK=   XSM  
                  2CADR   ALFLT1

5.23SPOT          OCT       77777  
                  EBANK=   XSM  
                  -2CADR   SPECSTS

5.25SPOT          OCT       20000  
                  EBANK=   XSM  
                  2CADR   RETEST3

5.27SPOT          OCT       20000  
                  EBANK=   XSM  
                  2CADR   RESTAIER

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5.31SPOT        DEC       0  
                 DEC       0  
                 DEC       0

5.33SPOT        OCT       20000  
                 EBANK=   XSM  
                 2CADR   RESCHNG

5.35SPOT        DEC       0  
                 2DEC       0

5.37SPOT        OCT       77777  
                 EBANK=   AOG  
                 -2CADR   CHEKAVEG

5.41SPOT        OCT       77777                    # TO PROTECT PREREAD AT TIG-30A  
                 EBANK=   DVCNTR                   #                   TIG-15 T+60  
                 -2CADR   PREREAD

# ANY MORE GROUP 5.ODD RESTART VALUES SHOULD GO HERE

6.2SPOT        OCT       77777                    # USED BY P40 AFTER GIMB DR TST TO REPOS'N  
                 EBANK=   AK                        # ENGINE UNTIL TVCDAPON  
                 -2CADR   PRE40.6  
  
                 DEC       100  
                 EBANK=   TTOGO  
                 -2CADR   CLOKTASK

# ANY MORE 6.ODD RESTART VALUES SHOULD GO HERE

# Page 219

6.3SPOT        DEC       100  
                 EBANK=   TIG  
                 -2CADR   CLOKTASK

6.5SPOT        OCT       30000                    # PROTECT INCREMENTING OF TIME2,TIME1 BY  
                 EBANK=   TEPHEM                   # P27(UPDATE PROGRAM)  
                 2CADR   TIMEDIDR

6.7SPOT        OCT       0  
                 OCT       0  
                 OCT       0

6.11SPOT       -GENADR CM/GYMDT                    # PROTECT TASK TO READ CDUS.

EBANK= CM/GYMDT  
-2CADR READGYMB

# FOR ENTRY DAP

6.13SPOT DEC 0  
DEC 0  
DEC 0

# Page 220

# PROGRAM DESCRIPTION: NEWPHASE

# MOD: 1

# MOD BY: COPPS

#

# FUNCTIONAL DESCRIPTION:

#

# NEWPHASE IS THE QUICK WAY TO MAKE A NON VARIABLE PHASE CHANGE. IT INCLUDES T  
# TBASE OF THE GROUP. IF TBASE IS TO BE SET, -C(TIME1) IS STORED IN THE TBASE

#

# (L-1) TBASE0  
# (L) TBASE1 (IF GROUP=1)  
# (L+1)  
# (L+2) TBASE2 (IF GROUP=2)  
# -----  
# (L+6) TBASE4 (IF GROUP=4)  
# (L+7)  
# (L+8) TBASE5 (IF GROUP=5)  
#

# IN ANY CASE, THE NEGATIVE OF THE PHASE, FOLLOWED (IN THE NEXT REGISTER) BY T  
# PHASE TABLE AS FOLLOWS:

#

# (L) -PHASE1 (IF GROUP=1)  
# (L+1) PHASE1  
# (L+2) -PHASE2 (IF GROUP=2)  
# (L+3) PHASE2  
# -----  
# (L+7) PHASE4  
# (L+8) -PHASE5 (IF GROUP=5)  
# (L+9) PHASE5  
#

# CALLING SEQUENCE:

#

# EXAMPLE IS FOR PLACING A PHASE OF FIVE INTO GROUP THREE:

#

# 1) IF TBASE IS NOT TO BE SET:

# L-1 CA FIVE  
# L TC NEWPHASE  
# L+1 OCT 00003

DATE: 11 NOV

ASSEMBLY: SU

LOG SECTION:



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```
#
#      2)      IF TBASE IS TO BE SET:
#                L-1      CS      FIVE
#                L        TC      NEWPHASE
#                L+1      OCT      00003
#
# SUBROUTINES CALLED:  NONE
#
# NORMAL EXIT MODE:  AT L+2 OF CALLING SEQUENCE
#
# ALARM OR ABORT EXITS:  NONE
#
# OUTPUT:  PHASE TABLE AND TBASE TABLE UPDATED
#
# ERASABLE INITIALIZATION REQ'D:  NONE
# Page 221
# DEBRIS:  A,L,TEMPG

# *** WARNING *** THIS PROGRAM IS TO BE PLACED IN FIXED-FIXED AND UNSWITCHED ERASABLE.

      BLOCK      02
      SETLOC     FFTAG1
      BANK

      COUNT*     $$/PHASE

NEWPHASE      INHINT

      TS          L                      # SAVE FOR FURTHER USE

      NDX          Q                      # OBTAIN THE GROUP NUMBER
      CA          0
      INCR         Q                      # OBTAIN THE RETURN ADDRESS
      DOUBLE
      TS          TEMPG                  # INDEXING

      CCS          L                      # SEE IF WE ARE TO SET TBASE
      TCF          +7                    # NO, THE DELTA T WAS POSITIVE
      TCF          +6

NUFAZ+10      INCR          A              # SET TBASE AND STORE PHASE CORRECTLY
      TS          L

      CS          TIME1                  # SET TBASE
      NDX          TEMPG
      TS          TBASE1 -2
```

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```
CS      L
NDX     TEMPG
DXCH    -PHASE1 -2
```

# NOW PUT THE PHASE IN THE RIGHT TAB

```
RELINT
```

```
TC      Q
```

# NOW RETURN TO CALLER

This code is written to file `src/RESTART-TABLES.s`.

## A.96 RT8 OP CODES

```

1643  <src/RT8-OP-CODES.s 1643>≡
# Copyright:   Public domain.
# Filename:    RT8_OP_CODES.agc
# Purpose:     Part of the source code for Comanche, build 055. It
#              is part of the source code for the Command Module's
#              (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:  yaYUL
# Reference:   pp. 1508-1516
# Contact:     Ron Burkey <info@sandroid.org>
# Website:     http://www.ibiblio.org/apollo.
# Mod history: 2009-05-07 RSB  Adapted from Colossus249/RT8_OP_CODES.agc
#              and page images.
#              2009-05-07 RSB  Oops! Left out the entire last page before.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#           Massachusetts Institute of Technology
#           75 Cambridge Parkway
#           Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.

# Page 1508

BANK      22
SETLOC    RTBCODES
BANK

EBANK=    XNB
COUNT*   $$/RTB

# LOAD TIME2, TIME1 INTO MPAC:

LOADTIME      EXTEND
DCA           TIME2

```

TCF SLOAD2

# CONVERT THE SINGLE PRECISION 2'S COMPLEMENT NUMBER ARRIVING IN MPAC (SCALED IN HALF-REVOLUTIONS)  
# DP 1'S COMPLEMENT NUMBER SCALED IN REVOLUTIONS.

CDULOGIC

CCS MPAC

CAF ZERO

TCF +3

NOOP

CS HALF

TS MPAC +1

CAF ZERO

XCH MPAC

EXTEND

MP HALF

DAS MPAC

TCF DANZIG # MODE IS ALREADY AT DOUBLE-PRECISION

# READ THE PIPS INTO MPAC WITHOUT CHANGING THEM:

READPIPS

INHINT

CA PIPAX

TS MPAC

CA PIPAY

TS MPAC +3

CA PIPAZ

RELINT

TS MPAC +5

CAF ZERO

TS MPAC +1

TS MPAC +4

TS MPAC +6

VECMODE

TCF VMODE

# FORCE TP SIGN AGREEMENT IN MPAC:

SGNAGREE

TC

TPAGREE

# Page 1509

TCF DANZIG

# CONVERT THE DP 1'S COMPLEMENT ANGLE SCALED IN REVOLUTIONS TO A SINGLE PRECISION 2'S  
# SCALED IN HALF-REVOLUTIONS.

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```
1ST02S      TC      1T02SUB
             CAF      ZERO
             TS       MPAC +1
             TCF      NEWMODE
```

# DO 1ST02S ON A VECTOR OF ANGLES:

```
V1ST02S      TC      1T02SUB      # ANSWER ARRIVES IN A AND MPAC.

             DXCH     MPAC +5
             DXCH     MPAC
             TC       1T02SUB
             TS       MPAC +2

             DXCH     MPAC +3
             DXCH     MPAC
             TC       1T02SUB
             TS       MPAC +1

             CA       MPAC +5
             TS       MPAC
```

```
TPMODE      CAF      ONE          # MODE IS TP.
             TCF      NEWMODE
```

# V1ST02S FOR 2 COMPONENT VECTOR. USED BY RR.

```
2V1ST02S      TC      1T02SUB
             DXCH     MPAC +3
             DXCH     MPAC
             TC       1T02SUB
             TS       L
             CA       MPAC +3
             TCF      SLOAD2
```

# SUBROUTINE TO DO DOUBLING AND 1'S TO 2'S CONVERSION:

```
1T02SUB      DXCH     MPAC          # FINAL MPAC +1 UNSPECIFIED.
             DDOUBL
             CCS      A
             AD       ONE
             TCF      +2
             COM                      # THIS WAS REVERSE OF MSU.

             TS       MPAC          # AND SKIP ON OVERFLOW.
```

# Page 1510

TC Q

INDEX A  
 CAF LIMITS  
 ADS MPAC  
 TC Q

# OVERFLOW UNCORRECT AND IN MSU.

# Page 1511

# SUBROUTINE TO INCREMENT CDUS

INCRCDUS CAF LOCTHETA  
 TS BUF  
 CAE MPAC  
 TC CDUINC

# PLACE ADRES(THETA) IN BUF.

# INCREMENT IN 1'S COMPL.

INCR BUF  
 CAE MPAC +3  
 TC CDUINC

INCR BUF  
 CAE MPAC +5  
 TC CDUINC

TCF VECMODE

LOCTHETA ADRES THETAD

# THE FOLLOWING ROUTINE INCREMENTS IN 2'S COMPLEMENT THE REGISTER WHOSE ADDRESS IS IN  
 # QUANTITY FOUND IN TEM2. THIS MAY BE USED TO INCRMENT DESIRED IMU AND OPTICS CDU AD  
 # (+0 UNEQUAL TO -0) QUANTITY. MAY BE CALLED BY BANKCALL/SWCALL.

CDUINC TS TEM2  
 INDEX BUF  
 CCS 0  
 AD ONE  
 TCF +4  
 AD ONE  
 AD ONE  
 COM  
 AD TEM2  
 CCS A  
 AD ONE  
 TCF +2  
 COM

# 1'S COMPL. QUANT. ARRIVES IN ACC. STORE IT

# CHANGE 2'S COMPLE. ANGEL (IN BUF) INTO 1'S

# OVEFLOW HERE IF 2'S COMPL. IS 180 DEG.

# SULT MOVES FROM 2ND TO 3D QUAD. (OR BACK)  
 # BACK TO 2'S COMPL.

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|       |        |                                           |
|-------|--------|-------------------------------------------|
| TS    | TEM2   | # STORE 14-BIT QUANTITY WITH PRESENT SIGN |
| TCF   | +4     |                                           |
| INDEX | A      | # SIGN.                                   |
| CAF   | LIMITS | # FIX IT, BY ADDING IN 37777 OR 40000     |
| AD    | TEM2   |                                           |
| INDEX | BUF    |                                           |
| TS    | 0      | # STORE NEW ANGLE IN 2'S COMPLEMENT.      |
| TC    | Q      |                                           |

# Page 1512

# RTB TO TORQUE GYROS, EXCEPT FOR THE CALL TO IMUSTALL. ECADR OF COMMANDS ARRIVES IN X1.

|          |       |          |                                            |
|----------|-------|----------|--------------------------------------------|
| PULSEIMU | INDEX | FIXLOC   | # ADDRESS OF GYRO COMMANDS SHOULD BE IN X1 |
|          | CA    | X1       |                                            |
|          | TC    | BANKCALL |                                            |
|          | CADR  | IMUPULSE |                                            |
|          | TCF   | DANZIG   |                                            |

# Page 1513

# EACH ROUTINE TAKES A 3X3 MATRIX STORED IN DOUBLE PRECISION IN A FIXED AREA OF ERASABLE MEMORY  
# WITH THE TRANSPOSE MATRIX. TRANSP1 USES LOCATIONS XNB+0,+1 THROUGH XNB+16D,+17D AND TRANSP2  
# XNB1+0,+1 THROUGH XNB1+16D,+17D. EACH MATRIX IS STORED BY ROWS.

|         |        |          |
|---------|--------|----------|
| XNBEB   | ECADR  | XNB      |
| XNB1EB  | ECADR  | XNB1     |
|         | EBANK= | XNB      |
| TRANSP1 | CAF    | XNBEB    |
|         | TS     | EBANK    |
|         | DXCH   | XNB +2   |
|         | DXCH   | XNB +6   |
|         | DXCH   | XNB +2   |
|         | DXCH   | XNB +4   |
|         | DXCH   | XNB +12D |
|         | DXCH   | XNB +4   |
|         | DXCH   | XNB +10D |
|         | DXCH   | XNB +14D |
|         | DXCH   | XNB +10D |
|         | TCF    | DANZIG   |
|         | EBANK= | XNB1     |
| TRANSP2 | CAF    | XNB1EB   |

```

TS      EBANK
DXCH    XNB1 +2
DXCH    XNB1 +6
DXCH    XNB1 +2

DXCH    XNB1 +4
DXCH    XNB1 +12D
DXCH    XNB1 +4

DXCH    XNB1 +10D
DXCH    XNB1 +14D
DXCH    XNB1 +10D
TCF     DANZIG

```

# Page 1514

# THE SUBROUTINE SIGNMPAC SETS C(MPAC, MPAC +1) TO SIGN(MPAC).

# FOR THIS, ONLY THE CONTENTS OF MPAC ARE EXAMINED. ALSO +0 YIELDS POSMAX AND -0 YI

#

# ENTRY MAY BE BY EITHER OF THE FOLLOWING:

# 1. LIMIT THE SIZE OF MPAC ON INTERPRETIVE OVERFLOW:

# ENTRY: BOVB

#

SIGNMPAC

# 2. GENERATE IN MPAC THE SIGNUM FUNCTION OF MPAC:

# ENTRY: RTB

#

SIGNMPAC

# IN EITHER CASE, RETURN IS TO THE NEXT INTERPRETIVE INSTRUCTION IN THE CALLING SEQU

SIGNMPAC EXTEND

DCA DPOSMAX

DXCH MPAC

CCS A

DPMODE CAF ZERO # SETS MPAC +2 TO ZERO IN THE PROCESS

TCF SLOAD2 +2

TCF +1

EXTEND

DCS DPOSMAX

TCF SLOAD2

# RTB OP CODE NORMUNIT IS LIKE INTERPRETIVE INSTRUCTION UNIT, EXCEPT THAT IT CAN BE I

# UP WHEN THE VECTOR BEING UNITIZED IS VERY SMALL -- IT WILL BLOW UP WHEN ALL COMPON

# IS USED AND THE UPPER ORDER HALVES OF ALL COMPONENTS ARE ZERO, THE MAGNITUDE RETUR

# BY A FACTOR OF 2(13) AND THE SQUARED MAGNITUDE RETURNED AT 34D WILL BE TOO BIG BY A

NORMUNX1 CAF ONE

TCF NORMUNIT +1

NORMUNIT CAF ZERO



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```
AD      FIXLOC
TS      MPAC +2
TC      BANKCALL      # GET SIGN AGREEMENT IN ALL COMPONENTS
CADR    VECAGREE
CCS     MPAC
TCF     NOSHIFT
TCF     +2
TCF     NOSHIFT
CCS     MPAC +3
TCF     NOSHIFT
TCF     +2
TCF     NOSHIFT
CCS     MPAC +5
TCF     NOSHIFT
TCF     +2
TCF     NOSHIFT

# Page 1515
CA      MPAC +1      # SHIFT ALL COMPONENTS LEFT 13
EXTEND
MP      BIT14
DAS     MPAC      # DAS GAINS A LITTLE ACCURACY
CA      MPAC +4
EXTEND
MP      BIT14
DAS     MPAC +3
CA      MPAC +6
EXTEND
MP      BIT14
DAS     MPAC +5
CAF     THIRTEEN
INDEX   MPAC +2
TS      37D
OFFTUNIT TC      POSTJUMP
CADR    UNIT +1      # SKIP THE "TC VECAGREE" DONE AT UNIT

NOSHIFT CAF     ZERO
TCF     OFFTUNIT -2

# RTB VECSGNAG ... FORCES SIGN AGREEMENT OF VECTOR IN MPAC.

VECSGNAG TC      BANKCALL
CADR     VECAGREE
TC       DANZIG
```

# Page 1516

# MODULE CHANGE FOR NEW LUNAR GRAVITY MODEL

|          |        |          |    |                                           |
|----------|--------|----------|----|-------------------------------------------|
|          | SETLOC | MODCHG3  |    |                                           |
|          | BANK   |          |    |                                           |
| QUALITY1 | BOF    | DLOAD    |    |                                           |
|          |        | MOONFLAG |    |                                           |
|          |        | NBRANCH  |    |                                           |
|          |        | URPV     |    |                                           |
|          | DSQ    | GOTO     |    |                                           |
|          |        | QUALITY2 |    |                                           |
|          | SETLOC | MODCHG2  |    |                                           |
|          | BANK   |          |    |                                           |
| QUALITY2 | PDDL   | DSQ      |    | # SQUARE INTO 2D, B2                      |
|          |        | URPV     | +2 | # Y COMPONENT, B1                         |
|          | DSU    |          |    |                                           |
|          | DMP    | VXSC     |    | # 5(Y**2-X**2)UR                          |
|          |        | 5/8      |    | # CONSTANT, 5B3                           |
|          |        | URPV     |    | # VECTOR, RESULT MAXIMUM IS 5, SCALING    |
|          |        |          |    | # HERE B6                                 |
|          | VSL3   | PDDL     |    | # STORE SCALED B3 IN 2D, 4D, 6D FOR XYZ   |
|          |        | URPV     |    | # X COMPONENT, B1                         |
|          | SR1    | DAD      |    | # 2 X X COMPONENT FOR B3 SCALING          |
|          |        | 2D       |    | # ADD TO VECTOR X COMPONENT OF ANSWER.    |
|          |        |          |    | # SAME AS MULTIPLYING BY UNITX. MAX IS 7. |
|          | STODL  | 2D       |    |                                           |
|          |        | URPV     | +2 | # Y COMPONENT, B1                         |
|          | SR1    | BDSU     |    | # 2 X Y COMPONENT FOR B3 SCALING          |
|          |        | 4D       |    | # SUBTRACT FROM VECTOR Y COMPONENT OF     |
|          |        |          |    | # ANSWER, SAME AS MULTIPLYING BY UNITY.   |
|          |        |          |    | # MAX IS 7.                               |
|          | STORE  | 4D       |    | # 2D HAS VECTOR, B3.                      |
|          | SLOAD  | VXSC     |    | # MULTIPLY COEFFICIENT TIMES VECTOR IN 2D |
|          |        | E3J22R2M |    |                                           |
|          | PDDL   | RVQ      |    | # J22 TERM X R**4 IN 2D, SCALED B61       |
|          |        | COSPHI/2 |    | # SAME AS URPV +4, Z COMPONENT            |

# \*\*\* END OF CHIEFTAN.028 \*\*\*

This code is written to file src/RT8-OP-CODES.s.

## A.97 RTB OP CODES

1651

*<src/RTB-OP-CODES.s 1651>*≡

```
# Copyright:    Public domain.
# Filename:     RTB_OP_CODES.agc
# Purpose:      Part of the source code for Luminary 1A build 099.
#               It is part of the source code for the Lunar Module's (LM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:      Ron Burkey <info@sandroid.org>.
# Website:      www.ibiblio.org/apollo.
# Pages:        1397-1401
# Mod history:  2009-05-10 SN    (Sergio Navarro).  Started adapting
#               from the Luminary131/ file of the same
#               name, using Luminary099 page images.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum.  The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum.  Many thanks to both.  The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo.  If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
#       16:27 JULY 14, 1969
```

# Page 1397

```
BANK      22
SETLOC    RTBCODES
BANK
```

```
EBANK=    XNB
COUNT*   $$/RTB
```

# LOAD TIME2, TIME1 INTO MPAC:

```
LOADTIME      EXTEND
               DCA      TIME2
               TCF      SLOAD2
```

# CONVERT THE SINGLE PRECISION 2'S COMPLEMENT NUMBER ARRIVING IN MPAC (SCALED IN HALF-REVOLUTION

# DP 1'S COMPLEMENT NUMBER SCALED IN REVOLUTIONS.

|          |        |         |                                       |
|----------|--------|---------|---------------------------------------|
| CDULOGIC | CCS    | MPAC    |                                       |
|          | CAF    | ZERO    |                                       |
|          | TCF    | +3      |                                       |
|          | NOOP   |         |                                       |
|          | CS     | HALF    |                                       |
|          | TS     | MPAC +1 |                                       |
|          | CAF    | ZERO    |                                       |
|          | XCH    | MPAC    |                                       |
|          | EXTEND |         |                                       |
|          | MP     | HALF    |                                       |
|          | DAS    | MPAC    |                                       |
|          | TCF    | DANZIG  | # MODE IS ALREADY AT DOUBLE-PRECISION |

# FORCE TP SIGN AGREEMENT IN MPAC:

|          |     |         |
|----------|-----|---------|
| SGNAGREE | TC  | TPAGREE |
|          | TCF | DANZIG  |

# CONVERT THE DP 1'S COMPLEMENT ANGLE SCALED IN REVOLUTIONS TO A SINGLE PRECISION 2'S  
# SCALED IN HALF-REVOLUTIONS.

|        |     |         |
|--------|-----|---------|
| 1ST02S | TC  | 1T02SUB |
|        | CAF | ZERO    |
|        | TS  | MPAC +1 |
|        | TCF | NEWMODE |

# DO 1ST02S ON A VECTOR OF ANGLES:

|         |    |         |                                 |
|---------|----|---------|---------------------------------|
| V1ST02S | TC | 1T02SUB | # ANSWER ARRIVES IN A AND MPAC. |
|---------|----|---------|---------------------------------|

|  |      |         |
|--|------|---------|
|  | DXCH | MPAC +5 |
|  | DXCH | MPAC    |
|  | TC   | 1T02SUB |

# Page 1398

|  |    |         |
|--|----|---------|
|  | TS | MPAC +2 |
|--|----|---------|

|  |      |         |
|--|------|---------|
|  | DXCH | MPAC +3 |
|  | DXCH | MPAC    |
|  | TC   | 1T02SUB |
|  | TS   | MPAC +1 |

|  |    |         |
|--|----|---------|
|  | CA | MPAC +5 |
|  | TS | MPAC    |

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```
TPMODE      CAF      ONE      # MODE IS TP.
             TCF      NEWMODE
```

# V1STO2S FOR 2 COMPONENT VECTOR. USED BY RR.

```
2V1STO2S    TC      1TO2SUB
             DXCH    MPAC +3
             DXCH    MPAC
             TC      1TO2SUB
             TS      L
             CA      MPAC +3
             TCF     SLOAD2
```

# SUBROUTINE TO DO DOUBLING AND 1'S TO 2'S CONVERSION:

```
1TO2SUB      DXCH    MPAC      # FINAL MPAC +1 UNSPECIFIED.
             DDOUBL
             CCS      A
             AD      ONE
             TCF     +2
             COM      # THIS WAS REVERSE OF MSU.

             TS      MPAC      # AND SKIP ON OVERFLOW.
             TC      Q

             INDEX    A      # OVERFLOW UNCORRECT AND IN MSU.
             CAF      LIMITS
             ADS      MPAC
             TC      Q
```

# THE FOLLOWING ROUTINE INCREMENTS IN 2S COMPLEMENT THE REGISTER WHOSE ADDRESS IS IN BUF BY THE  
# QUANTITY FOUND IN TEM2. THIS MAY BE USED TO INCRMENT DESIRED IMU AND OPTICS CDU ANGLES OR AN  
# (+0 UNEQUAL TO -0) QUANTITY. MAY BE CALLED BY BANKCALL/SWCALL.

```
CDUINC      TS      TEM2      # 1S COMPL.QUANT. ARRIVES IN ACC. STORE IT
             INDEX    BUF
             CCS      0      # CHANGE 2S COMPL. ANGLE(IN BUF)INTO 1S
             AD      ONE
             TCF     +4
             AD      ONE

# Page 1399

             AD      ONE      # OVEFLOW HERE IF 2S COMPL. IS 180 DEG.
             COM

             AD      TEM2      # SULT MOVES FROM 2ND TO 3D QUAD. (OR BACK)
```

```

CCS      A          # BACK TO 2S COMPL.
AD        ONE
TCF      +2
COM
TS        TEM2      # STORE 14BIT QUANTITY WITH PRESENT SIGN
TCF      +4
INDEX    A          # SIGN.
CAF      LIMITS     # FIX IT, BY ADDING IN 37777 OR 40000
AD        TEM2

INDEX    BUF
TS        0          # STORE NEW ANGLE IN 2S COMPLEMENT.
TC        Q

```

# Page 1400

# RTB TO TORQUE GYROS, EXCEPT FOR THE CALL TO IMUSTALL. ECADR OF COMMANDS ARRIVES IN

```

PULSEIMU INDEX  FIXLOC      # ADDRESS OF GYRO COMMANDS SHOULD BE IN X1
CA        X1
TC        BANKCALL
CADR      IMUPULSE
TCF      DANZIG

```

# Page 1401

# THE SUBROUTINE SIGNMPAC SETS C(MPAC, MPAC +1) TO SIGN(MPAC).

# FOR THIS, ONLY THE CONTENTS OF MPAC ARE EXAMINED. ALSO +0 YIELDS POSMAX AND -0 YIELD

#

# ENTRY MAY BE BY EITHER OF THE FOLLOWING:

# 1. LIMIT THE SIZE OF MPAC ON INTERPRETIVE OVERFLOW:

# ENTRY: BOVB

#

SIGNMPAC

# 2. GENERATE IN MPAC THE SIGNUM FUNCTION OF MPAC:

# ENTRY: RTB

#

SIGNMPAC

# IN EITHER CASE, RETURN IS TO THE NEXT INTERPRETIVE INSTRUCTION IN THE CALLING SEQU

```

SIGNMPAC EXTEND
DCA      DPOSMAX
DXCH     MPAC
CCS      A
DPMODE   CAF      ZERO      # SETS MPAC +2 TO ZERO IN THE PROCESS
TCF      SLOAD2 +2
TCF      +1
EXTEND
DCS      DPOSMAX
TCF      SLOAD2

```

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# RTB OP CODE NORMUNIT IS LIKE INTERPRETIVE INSTRUCTION UNIT, EXCEPT THAT IT CAN BE DEPENDED ON  
# UP WHEN THE VECTOR BEING UNITIZED IS VERY SMALL -- IT WILL BLOW UP WHEN ALL COMPONENT ARE ZERO  
# IS USED AND THE UPPER ORDER HALVES OF ALL COMPONENTS ARE ZERO, THE MAGNITUDE RETURNED IN 36D  
# BY A FACTOR OF 2(13) AND THE SQUARED MAGNITUDE RETURNED ATE 34D WILL BE TOO BIG BY A FACTOR C

```
NORMUNX1      CAF      ONE
              TCF      NORMUNIT +1
NORMUNIT      CAF      ZERO
              AD       FIXLOC
              TS       MPAC +2
              TC       BANKCALL      # GET SIGN AGREEMENT IN ALL COMPONENTS
              CADR     VECAGREE
              CCS      MPAC
              TCF      NOSHIFT
              TCF      +2
              TCF      NOSHIFT
              CCS      MPAC +3
              TCF      NOSHIFT
              TCF      +2
              TCF      NOSHIFT
              CCS      MPAC +5
              TCF      NOSHIFT
              TCF      +2
              TCF      NOSHIFT
# Page 1402
              CA       MPAC +1      # SHIFT ALL COMPONENTS LEFT 13
              EXTEND
              MP       BIT14
              DAS      MPAC      # DAS GAINS A LITTLE ACCURACY
              CA       MPAC +4
              EXTEND
              MP       BIT14
              DAS      MPAC +3
              CA       MPAC +6
              EXTEND
              MP       BIT14
              DAS      MPAC +5
              CAF      THIRTEEN
              INDEX    MPAC +2
              TS       37D
OFFTUNIT      TC       POSTJUMP
              CADR     UNIT +1      # SKIP THE "TC VECAGREE" DONE AT UNIT
NOSHIFT      CAF      ZERO
              TCF      OFFTUNIT -2
```

```
# RTB VECSGNAG ... FORCES SIGN AGREEMENT OF VECTOR IN MPAC.
```

```
VECSGNAG      TC      BANKCALL
               CADR     VECAGREE
               TC      DANZIG
```

```
# *** END OF SKIPPER .087 ***
```

This code is written to file `src/RTB-OP-CODES.s`.



## A.98 S-BAND ANTENNA FOR CM

```

1657 <src/S-BAND-ANTENNA-FOR-CM.s 1657>≡
# Copyright:      Public domain.
# Filename:       S-BAND_ANTENNA_FOR_CM.agc
# Purpose:       Part of the source code for Colossus 2A, AKA Comanche 055.
#               It is part of the source code for the Command Module's (CM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:    yaYUL
# Contact:       Jim Lawton <jim.lawton@gmail.com>.
# Website:       www.ibiblio.org/apollo.
# Pages:        934-935
# Mod history:   2009-05-11 JVL   Adapted from the Colossus249/ file
#               of the same name, using Comanche055 page
#               images.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. 10:28 APR. 1, 1969
#
# This AGC program shall also be referred to as
# Colossus 2A

# Page 934
# S-BAND ANTENNA FOR CM

BANK      23
SETLOC    SBAND
BANK

COUNT*   $$/R05
EBANK=     EMSALT

SBANDANT   TC      BANKCALL      # V 64 E GETS US HERE
          CADR     R02BOTH      # CHECK IF IMU IS ON AND ALIGNED
          TC      INTPRET

```

```

RTB      CALL
          LOADTIME      # PICKUP CURRENT TIME SCALED B-28
          CDUTRIG        # COMPUTE SINES AND COSINES OF CDU ANGLES
STCALL   TDEC1          # ADVANCE INTEGRATION TO TIME IN TDEC1
          CSMCONIC       # USING CONIC INTEGRATION
SLOAD    BHIZ           # ORIGIN OF REFERENCE INERTIAL SYSTEM IS
          X2              # EARTH = 0, MOON = 2
          EISOI
VLOAD
          RATT
STORE    RCM            # MOVE RATT TO PREVENT WIPEOUT
DLOAD    CALL           # MOON, PUSH ON
          TAT            # GET ORIGINAL TIME
          LUNPOS         # COMPUTE POSITION VECTOR OF MOON
VAD      VCOMP          # R= -(REM+RCM) = NEG. OF S/C POS. VEC
          RCM
GOTO
          EISOI +2
EISOI    VLOAD          # EARTH, R= -RCM
          RATT
SETPD    MXV            # RCS TO STABLE MEMBER: B-1X B-29X B+1
          2D             # 2D
          REFMMAT        # STABLE MEMBER.  B-1X B-29X B+1= B-29
VSL1     PDDL           # 8D
          HI6ZEROS
STOVL    YAWANG         # ZERO OUT YAWANG, SET UP FOR SMNB
          RCM            # TRANSFORMATION.  SM COORD.  SCALED B-29
CALL
          *SMNB*
STORE    R              # SAVE NAV. BASE COORDINATES
UNIT     PDVL           # 14D
          R
VPROJ    VSL2           # COMPUTE PROJECTION OF VECTOR INTO CM
          HIUNITZ        # XY-PLANE, R-(R.UZ)UZ
BVSU     BOV            # CLEAR OVERFLOW INDICATOR IF SET
          R
          COVCNV
COVCNV   UNIT           # TEST OVERFLOW FOR INDICATION OF NULL
          BOV            # VECTOR
          NOADJUST
          DOT            # 20D
          DOT
          HIUNITX
SL1      ACOS           # COMPUTE YAW ANGLE = ACOS (URP.UX)
          DOT            # REVOLUTIONS SCALED BO
          URP            # 22D YAWANG
          HIUNITY        # COMPUTE FOLLOWING: URP.UY

```

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```
NOADJUST      SL1      BPL          # POSITIVE
               NOADJUST    # YES, 0-180 DEGREES
DLOAD         DSU          # NO, 181-360 DEGREES 20D
               DPPOSMAX    # COMPUTE 2 PI MINUS YAW ANGLE
PUSH          # 22D YAWANG
VLOAD         DOT          # COMPUTE PITCH ANGLE
               UR          # ACOS (UR.UZ) - PI/2
               HIUNITZ
SL1           ACOS         # REVOLUTIONS BO
DSU
               HIDP1/4
STODL         RHOSB
               YAWANG
STORE         GAMMASB     # PATCH FOR CHECKOUT
EXIT
CA            EXTVBACT    # IS BIT 5 STILL ON
MASK         BIT5
EXTEND
BZF          ENDEXT       # NO, WE HAVE BEEN ANSWERED
CAF          V06N51       # DISPLAY ANGLES
TC           BANKCALL
CADR         GOMARKFR
TC           B5OFF        # TERMINATE
TC           B5OFF
TC           ENDOFJOB     # RECYCLE
CAF          BIT3         # IMMEDIATE RETURN
TC           BLANKET      # BLANK R3
CAF          BIT1         # DELAY MINIMUM TIME TO ALLOW DISPLAY IN
TC           BANKCALL
CADR         DELAYJOB
TCF          SBANDANT +2
V06N51       VN           0651
RCM          EQUALS      2D
UR           EQUALS      8D
URP          EQUALS      14D
YAWANG       EQUALS      20D
PITCHANG     EQUALS      22D
R            EQUALS      RCM
SBANK=       LOWSUPER
```

This code is written to file `src/S-BAND-ANTENNA-FOR-CM.s`.

## A.99 S-BAND ANTENNA FOR LM

```

1660  <src/S-BAND-ANTENNA-FOR-LM.s 1660>≡
      # Copyright:    Public domain.
      # Filename:     S-BAND_ANTENNA_FOR_LM.agc
      # Purpose:      Part of the source code for Luminary 1A build 099.
      #               It is part of the source code for the Lunar Module's (LM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Ron Burkey <info@sandroid.org>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         486-489
      # Mod history:   2009-05-17 RSB   Adapted from the corresponding
      #               Luminary131 file, using page
      #               images from Luminary 1A.
      #               2009-06-07 RSB   Corrected a misprint.
      #
      # This source code has been transcribed or otherwise adapted from
      # digitized images of a hardcopy from the MIT Museum. The digitization
      # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
      # the Museum. Many thanks to both. The images (with suitable reduction
      # in storage size and consequent reduction in image quality as well) are
      # available online at www.ibiblio.org/apollo. If for some reason you
      # find that the images are illegible, contact me at info@sandroid.org
      # about getting access to the (much) higher-quality images which Paul
      # actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
      #       16:27 JULY 14, 1969
      #
      # Page 486
      # SUBROUTINE NAME: R05 -- S-BAND ANTENNA FOR LM
      #
      # MOD0 BY T. JAMES
      # MOD1 BY P. SHAKIR
      #
      # FUNCTIONAL DESCRIPTION
      #
      # THE S-BAND ANTENNA ROUTINE, R05, COMPUTES AND DISPLAYS THE PITCH AND
      # YAW ANTENNA GIMBAL ANGLES REQUIRED TO POINT THE LM STEERABLE ANTENNA
      # TOWARD THE CENTER OF THE EARTH. THIS ROUTINE IS SELECTED BY THE ASTRO-
      # NAUT VIA DSKY ENTRY DURING COASTING FLIGHT OR WHEN THE LM IS ON THE MOON
      # SURFACE. THE EARTH OR MOON REFERENCE COORDINATE SYSTEM IS USED DEPENDING
      # ON WHETHER THE LM IS ABOUT TO ENTER OR HAS ALREADY ENTERED THE MOON

```

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```
# SPHERE OF INFLUENCE, RESPECTIVELY.
#
# TO CALL SUBROUTINE, ASTRONAUT KEYS IN V 64 E
#
# SUBROUTINES CALLED ---
#     R02BOTH
#     INTPRET
#     LOADTIME
#     LEMCONIC
#     LUNPOS
#     CDUTRIG
#     *SMNB*
#     BANKCALL
#     B500FF
#     ENDOFJOB
#     BLANKRET
#
# RETURNS WITH
#     PITCH ANGLE IN PITCHANG          REV. BO
#     YAW ANGLE IN YAWANG              REV. BO
#
# ERASABLES USED
#     PITCHANG
#     YAWANG
#     RLM
#     VAC AREA

                                BANK    41
                                SETLOC  SBAND
                                BANK

                                EBANK=  WHOCARES
                                COUNT*  $$/R05
SBANDANT TC      BANKCALL
# Page 487

                                CADR    R02BOTH          # CHECK IF IMU IS ON AND ALIGNED
                                TC      INTPRET
                                SETPD   RTB
                                OD
                                LOADTIME          # PICK UP CURRENT TIME
                                STCALL  TDEC1          # ADVANCE INTEGRATION TO TIME IN TDEC1
                                LEMCONIC          # USING CONIC INTEGRATION
                                SLOAD   BHIZ
                                X2          # X2 =0 EARTH SPHERE, X2 =2 MOON SPHERE
                                CONV4
                                VLOAD
```

```

                                RATT
                                RLM
                                TAT
CONV3      CALL                LUNPOS      # UNIT POSITION VECTOR FROM EARTH TO MOON
                                VXSC
                                VMOON
                                REMDIST     # MEAN DISTANCE FROM EARTH TO MOON
                                VAD
                                RLM
                                GOTO
                                CONV5
CONV4      VLOAD
CONV5      SETPD              RATT          # UE = -UNIT(RATT)          EARTH SPHERE
                                UNIT         # UE = -UNIT((REM)(UEM) + RL)  MOON SPHERE
                                OD           # SET PL POINTER TO 0
                                VCOMP        CALL
                                CDUTRIG     # COMPUTE SINES AND COSINES OF CDU ANGLES
                                MXV          VSL1      # TRANSFORM REF. COORDINATE SYSTEM TO
                                REFMMAT     # STABLE MEMBER B-1 X B-1 X B+1 = B-1
                                PUSH         DLOAD      # 8D
                                HI6ZEROS
                                STORE        PITCHANG
                                STOVL        YAWANG     # ZERO OUT ANGLES
                                CALL
                                *SMNB*
                                STODL        RLM          # PRE-MULTIPLY RLM BY (NBSA) MATRIX(BO)
                                RLM          +2
                                PUSH         DSU
                                RLM
                                DMP
                                10VSQRT2
                                STODL        RLM          +2
                                DAD          DMP
                                RLM
                                10VSQRT2
                                STOVL        RLM          # R B-1
                                RLM
                                UNIT        PDVL
                                RLM
                                VPROJ        VSL2        # PROJECTION OF R ONTO LM XZ PLANE.
                                HIUNITY
                                BVSU         BOV          # CLEAR OVERFLOW INDICATOR IF ON
                                RLM
                                COVCNV

```

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|            |        |          |                                   |        |
|------------|--------|----------|-----------------------------------|--------|
| COVCNV     | UNIT   | BOV      | # EXIT ON OVERFLOW                |        |
|            |        | SBANDEX  |                                   |        |
|            | PUSH   | VXV      | # URP VECTOR B-1                  |        |
|            |        | HIUNITZ  |                                   |        |
|            | VSL1   | VCOMP    | # UZ X URP = -(URP X UZ)          |        |
|            | STORE  | RLM      | # X VEC B-1                       |        |
|            | DOT    | PDVL     | # SGN(X.UY) UNSCALED              |        |
|            |        | HIUNITY  |                                   |        |
|            |        | RLM      |                                   |        |
|            | ABVAL  | SIGN     |                                   |        |
|            | ASIN   |          | # ASIN((SGN(X.UY))ABV(X))         | REV BO |
|            | STOVL  | PITCHANG |                                   |        |
|            |        | URP      |                                   |        |
|            | DOT    | BPL      |                                   |        |
|            |        | HIUNITZ  |                                   |        |
|            |        | NOADJUST | # YES, -90 TO +90                 |        |
|            | DLOAD  | DSU      |                                   |        |
|            |        | HIDPHALF |                                   |        |
|            |        | PITCHANG |                                   |        |
|            | STORE  | PITCHANG |                                   |        |
| NOADJUST   | VLOAD  | VXV      |                                   |        |
|            |        | UR       | # Z = (UR X URP)                  |        |
|            |        | URP      |                                   |        |
|            | VSL1   |          |                                   |        |
|            | STODL  | RLM      | # Z VEC B-1                       |        |
|            |        | PITCHANG |                                   |        |
|            | SIN    | VXSC     |                                   |        |
|            |        | HIUNITZ  |                                   |        |
|            | PDDL   | COS      |                                   |        |
|            |        | PITCHANG |                                   |        |
|            | VXSC   | VSU      |                                   |        |
|            |        | HIUNITX  | # (UX COS ALPHA) - (UZ SIN ALPHA) |        |
|            | DOT    | PDVL     | # YAW.Z                           |        |
|            |        | RLM      |                                   |        |
|            |        | RLM      |                                   |        |
|            | ABVAL  | SIGN     |                                   |        |
|            | ASIN   |          |                                   |        |
|            | STORE  | YAWANG   |                                   |        |
| SBANDEX    | EXIT   |          |                                   |        |
|            | CA     | EXTVBACT |                                   |        |
|            | MASK   | BIT5     | # IS BIT5 STILL ON                |        |
|            | EXTEND |          |                                   |        |
|            | BZF    | ENDEXT   | # NO                              |        |
|            | CAF    | PRI05    |                                   |        |
| # Page 489 | TC     | PRI0CHNG |                                   |        |

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```

CAF      V06N51      # DISPLAY ANGLES
TC       BANKCALL
CADR     GOMARKFR
TC       B5OFF       # TERMINATE
TC       B5OFF       # PROCEED
TC       ENDOFJOB    # RECYCLE
CAF      BIT3        # IMMEDIATE RETURN
TC       BLANKET     # BLANK R3
CAF      PRIO4
TC       PRIOCHNG
TC       SBANDANT +2  # YES, CONTINUE DISPLAYING ANGLES.
V06N51   VN          0651
10VSQRT2 2DEC        .7071067815 # 1/SQRT(2)

UR       EQUALS      0D
URP      EQUALS      6D
SBANK=   LOWSUPER
```

# END OF LNYAIDE .001 \*\*\*

This code is written to file src/S-BAND-ANTENNA-FOR-LM.s.



**A.100 SERVICER207**

1665

*<src/SERVICER207.s 1665>*≡

```

# Copyright:    Public domain.
# Filename:     SERVICER207.agc
# Purpose:      Part of the source code for Comanche, build 055. It
#               is part of the source code for the Command Module's
#               (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:   yaYUL
# Reference:    pp. 819-836
# Contact:      Ron Burkey <info@sandroid.org>
# Website:      http://www.ibiblio.org/apollo.
# Mod history:  2009-05-12 RSB   Adapted from Colossus249 file of the same
#               name and Comanche 055 page images.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#               Massachussets Institute of Technology
#               75 Cambridge Parkway
#               Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.
#
# Page 819
# SERVICER207
#
# PROGRAM NAME: PREREAD, READACCS, SERVICER, AVERAGE G.
# MOD NO. 00 BY M. HAMILTON      DEC. 12, 1966
#
# FUNCTIONAL DESCRIPTION
#
# THE ROUTINES DESCRIBED BELOW ARE USED TO CALCULATE VALUES OF RN, VN, AND GDT/2 DURING ACCELER
# THE SEVERAL ROUTINES COMPRISE A PACKAGE AND ARE NOT MEANT TO BE USED AS SEPARATE SUBROUTINES.
#
# GENERAL REFERENCES TO SERVICER OR AVERAGE G ARE UNDERSTOOD TO REFER TO THE ENTIRE SET OF
# RRADACCS, SERVICER, AVERAGE G, INTEREAD, SMOOTHER, AND ANY ADDITIONAL ROUTINES ATTACHED AT AV

```

```

#
# PROGRAMS INITIATING SERVICER ARE REQUIRED TO MAKE A WAITLIST CALL FOR PREREAD (OR,
# AT 2 SECONDS BEFORE THE FIRST AVERAGE G UPDATE IN ORDER TO INITIALIZE THE SEQUENCE.
# 2 SECONDS FROM THAT TIME ON AS LONG AS AVEGFLAG REMAINS SET.
#
# THE USE OF ERASABLE AVGEXIT ALLOWS VARIOUS ROUTINES TO BE PERFORMED AS PART OF THE
# EXPLANATION OF AVGEXIT BELOW).
#
# DESCRIPTIONS OF INDIVIDUAL ROUTINES FOLLOW.
#
# PREREAD
#
# PREVIOUSLY EXTRAPOLATED VALUES COPIED FROM RN1, VN1, AND PIPTIME1 INTO
# LASTBIAS JOB SCHEDULED.
# PIPS READ AND CLEARED VIA PIPASR SUBROUTINE.
# AVERAGE G FLAG SET ON.
# DRIFT FLAG SET OFF.
# V37 FLAG SET ON.
# INITIALIZATION OF      1) THRUST MONITOR (DVMON) -- DVCNTR SET TO ON
#                        2) TOTAL ACCUMULATED DELV VALUE (DVTOTAL) --
#                        3) AXIS VECTOR (AXIS) -- SET TO (.5,0,0).
# NORMLIZE JOB SCHEDULED.
# READACCS TASH CALLED IN 2 SECONDS.
#
# NORMLIZE
#
# GDT/2 INITIALIZED VIA CALCGRAV ROUTINE.
#
# READACCS
#
# IF ONMON FLAG SET QUIKREAD ROUTINE IS PERFORMED BEFORE PIPASR ZEROS 7
# ONMONITOR LOOP IS INITIATED TO PROVIDE DOWNLINK INFORMATION DURING E
# PIPS READ AND CLEARED BY PIPASR SUBROUTINE.
# IF CM/DSTBY IS ON, ENTRY VARIABLES INITIALIZED AND SETJTAG TASK CALLED
# Page 820
#
# SERVICER207
#
# IF AVERAGEG FLAG ON      READACCS CALLED TO RECYCLE IN 2 SECONDS.
# IF AVERAGEG FLAG OFF    AVERAGE G EXIT (AVGEXIT) SET TO 2CADR AVGEND
# SERVICER JOB SCHEDULED.
# TEST CONNECTOR OUTBIT TURNED ON.
#
# ONMNITOR
#
# A SEQUENCE OF THREE PASSES THROUGH QUIKREAD FOLLOWING A CALL TO READ

```

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```
#          SEC INTERVALS.  INTERVALS ARE COUNTED OUT BY PIPCTR, INITIALIZED AT 3 BY READAC
#
#      QUIKREAD
#
#          READS CURRENT PIPS INTO X,Y,ZPIPBUFF.  READS OLD X,Y,ZPIPBUFF INTO X,Y,ZOLDBUFF.
#          DOWNLIST DURING ENTRY.
#
#      SERVICER
#
#          DELV VALUES CHECKED TO DETECT RUNAWAY PIP:
#              IF BAD PIP      1) ALARM SENT.
#                              2) COMPENSATION, DVTOTAL ACCUMULATION, AND DVMON BYPASS
#                              TRANSFERRED TO AVERAGE G.
#          PIPS COMPENSATED VIA 1/PIPA SUBROUTINE.
#          DVTOTAL INCREMENTED BY ABSOLUTE VALUE OF DELV.
#          THRUST MONITOR (DVMON) PERFORMED UNLESS IDLE FLAG IS ON.
#          CONTROL TRANSFERRED TO AVERAGE Q.
#
#      DVMON
#
#          THRESHOLD VALUD (PLACED IN DVTHRUSH BY USER) CHECKED AGAINST ABSOLUTE VALUE OF
#          THRUST LEVEL.
#
#              IF THRUST      1) ULLAGE OFF ROUTINE PERFORMED.
#                              2) STEERING FLAG TURNED ON AT FIRST DETECTION OF THRUST
#                              3) CONTROL TRANSFERRED TO AVERAGE G.
#              IF NO THRUST   1) ON FIRST PASS THROUGH MONITOR, CONTROL TRANSFERRED T
#                              2) ON SUBSEQUENT PASSES, CONTROL TRANSFERRED TO ENGINE
#                              HAS FAILED FOR 3 CONSECUTIVE PASSES.
#
#      ENGINE FAIL
#
#          ENGFAIL1 TASK CALLED IN 2.5 SECONDS.  THIS WILL RETURN CONTROL TO TIG-5 SO THAT
#          SEQUENCE MAY BE REPEATED.
#          ENGINOF3 PERFORMED.
#          DAP SET UP FOR RCS.
#
#      AVERAGE G
# Page 821
#          RN1, VN1, GDT1/2 CALCULATED VIA CALCRVG ROUTINE BY UPDATING RN, VN WITH DELV AN
#          OF GDT/2
#          RN1, VN1, GDT1/2, PIPTIME1 COPIED INTO RN, VN, GDT/2, PIPTIME FOR RESTART PROTE
#          CONTROL TRANSFERRED TO ADDRESS SPECIFIED BY USER (OR BY READACCS FOR LAST PASS)
#          LAST PASS (AVGEND)  1) FREE FALL GYRO COMPENSATION SET UP.
#                              2) DRIFT FLAG TURNED ON.
#                              3) STATE VECTOR TRANSFERRED VIA AVETOMID ROUTINE.
```

```

#                               4) ONMONITOR FLAG RESET.
#                               5) V37 FLAG RESET.
#                               6) TEST CONNECTOR OUTBIT RESET.
#                               7) CONTROL TRANSFERRED TO CANV37 TO CONTINUE
#
# CALLING SEQUENCE
#
#     PREREAD ENTERED DIRECTLY FROM TIG-30 VIA POSTJUMP.
#     READACCS CALLED AS WAITLIST TASK.
#
# SUBROUTINES CALLED
#
#     UTILITY ROUTINES:  PHASCHNG FLAGUP FLAGDOWN NOVAC FINDVAC WAITLIST ALARM NEW
#
#     OTHER:  PIPASR 1/PIPA CALCGRAV CALCRVG AVETOMID
#
# NORMAL EXIT MODES
#
#     ENDOFJOB          TASKOVER          CANV37
#
#     AVGEXIT:          THIS IS A DOUBLE PRECISION ERASABLE LOCATION BY WHICH CONTROL
#                       OF EACH CYCLE OF AVERAGE G.
#                       THE 2CADR OF A ROUTINE TO BE PERFORMED AT THAT TIME (E.G., ST
#                       AT 2 SECOND INTERVALS) MAY BE SET BY THE USER INTO AV
#                       ALL SUCH ROUTINES SHOULD RETURN TO SERVEXIT, WHICH IS THE NO
#
#     SERVEXIT:         DOES A PHASE CHANGE FOR RESTART PROTECTION AND GOES TO ENDOF
#                       THE 2CADR OF SERVEXIT IS SET INTO AVGEXIT BY THE USERI F NO C
#
#     AVGEND:           LAST PASS OF AVERAGE G EXITS HERE, BYPASSING SPECIAL ROUTINE
#                       FINAL EXIT IS TO CANV37.                                F AVI
#
# OUTPUT
#
#     DVTOTAL(2)  PIPTIME(2)  XPIPBUF(2)  YPIPBUF(2)  ZPIPBUF(2)
#     RN(6)       REFERENCE COORD.          SCALED AT 2(+29) M/CS
#     VN(6)       REFERENCE COORD.          SCALED AT 2(+7) M/CS
#     GDT/2(6)    REFERENCE COORD.          SCALED AT 2(+7) M/CS
#     DELV(6)     STABLE MEMB. COORD.        SCALED AT 2(+14)*5.85*10(-4) M/CS (KI
# Page 822
#     DELVREF(6)  REFERENCE COORD.          SCALED AT 2(+7) M/CS
#
# INITIALIZATION
#
#     ONMONITOR FLAG SET BY ENTRY TO SHOW PIPBUF VALUES REQUIRED.
#     IDLE FLAG ON IF DVMON TO BE BYPASSED.

```

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```
# DVTHRUSH SET TO APPROPRIATE VALUE FOR DVMON.
# AVGEXIT SET TO 2CADR OF ROUTINE, IF ANY, TO BE PERFORMED AFTER EACH CYCLE OF AVERAGE G.
# TO BE DONE, AVGEXIT SET TO SERVEXIT.
# VALUES NEEDED
# REFSMMAT
# UNITW: FULL UNIT VECTOR, IN REFERENCE COORD., OF EARTH'S ROTATIONAL VECTOR
# RN1, VN1, PIPTIME1: IN REFERENCE COORD., CONSISTENT WITH TIME OF EXECUTION OF
#
# DEBRIS
#
# CENTRALS      A, L, Q
# OTHER         INTERNAL: DVCNTR(1) PIPAGE(1) PIPCTR(1) AVGEXIT(2)
#               EXTERNAL: ITEMP1(1) ITEMP2(1) RUPTREG1(1) TEMX(1) TEMY(1) TEMZ(1)
#               USEFUL DEBRIS
#                   RN1(0) VN1(0) GDT1/0 PIPTIME1(2?)
#                   THESE LOCATIONS USED AS BUFFER STORAGE FOR NEWLY CALCUL
#                   AND PIPTIME DURING PERFORMANCE OF SERVICER ROUTINES.
#                   UNITR: HALF UNIT VECTOR OF RN, REFERENCE COORD.
#                   RMAG SCALED AT 2(+58) IN 36D.
#                   RMAGSQ SCALED AT 2(+58) IN 34D.
#                   (RE/RMAG)SQ IN 32D
#
# BANK      27
# SETLOC    SERVICES
# BANK
#
# EBANK= DVCNTR
# ***** PREREAD *****
#
# COUNT      37/SERV
#
# PREREAD    CAF      PRI021      # CALLER MUST PROTECT PREREAD
#            TC       NOVAC
#            EBANK= NBDX
#            2CADR   LASTBIAS      # DO LAST GYRO COMPENSATION IN FREE FALL
#
#            # CALL-TO AND LASTBIAS ITSELF ARE NOT
#            # PROTECTED. REREADAC SETS 1/PIPADT
#            # TO 2.0 SECS IN CASE LASTBIAS LOST.
#            # (REDUNDANT IF LASTBIAS IS AOK.)
#
# Page 823
# RED05.31   TC       PREREAD1
#
#            CAF      PRI032
#            TC       FINDVAC      # SET UP NORMLIZE JOB REQUIRED PRIOR TO
#            EBANK= DVCNTR      # FIRST AVERAGE G PASS
```

```

                2CADR  NORMLIZE

                CAF    2SECS
                TC      WAITLIST
                EBANK=  AOG
                2CADR  READACCS

                CS      TWO
                TC      NEWPHASE
                OCT     5

                TCF     TASKOVER

PREREAD1      EXTEND
                QXCH    RUPTREG1

                TC      PIPASR          # CLEAR + READ PIPS LAST TIME IN FREE FALL

                CAF     ONE              # SET UP PIPAGE FOR REREADAC IN CASE A
                TS      PIPAGE          #          RESTART OCCURS BEFORE READACCS

                CS      FLAGWRD1        # SET AVEG FLAG
                MASK    BIT1
                ADS     FLAGWRD1

                CA      POSMAX
                MASK    FLAGWRD2
                TS      FLAGWRD2        # KNOCK DOWN DRIFT FLAG

                CS      FLAGWRD7        # SET V37 FLAG
                MASK    BIT6
                ADS     FLAGWRD7

                CAF     ZERO
                TS      DVTOTAL          # CLEAR DVTOTAL
                TS      DVTOTAL +1

                TC      RUPTREG1

# Page 824
# ***** READACCS *****
                EBANK=  AOG
READACCS      TC      PIPASR

PIPSDONE      CAF     FIVE
                TS      L

```

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```
COM
DXCH  -PHASE5

RED05.5  CAF  ONE      # SHOW PIPS HAVE BEEN READ
        TS  PIPAGE

        CA  TWO      # SET PIPCTR FOR ONMINTOR
        TS  PIPCTR    # AFTER ABOVE PHASCHNG

        CS  CM/FLAGS
        MASK BIT2     # CM/DSTBY
        CCS  A
        TC  CHEKAVEG

        CS  PIPTIME1 +1
        TS  TBASE6    # FOR RESTARTS
        EXTEND      # CONTINUE FOR ENTRY DAP
        DCA  AOG
        DXCH  AOG/PIP
        CA  AMG
        XCH  AMG/PIP
        EXTEND
        DCA  ROLL/180
        DXCH  ROLL/PIP
        CA  BETA/180
        XCH  BETA/PIP
        CA  CM/FLAGS
        MASK BIT12    # CM/DAPARM 93D BIT12
        EXTEND      # DURING ENTRY, WHEN RCS DAP IS INACTIVE,
        BZF  NOSAVPIP # SAVE PIPAS EACH 0.5 SEC FOR TM.

        CA  0.5SEC
        TC  WAITLIST
        EBANK= XPIPBUF
        2CADR  QUIKREAD

        CA  DELVX      # NO NEED TO RESTART PROTECT THIS.
        XCH  XPIPBUF    # SAVE PIPAS AS READ (BUT NOT COMPENSATED)
        TS  XOLDBUF

        CA  DELVY
        XCH  YPIPBUF
        TS  YOLDBUF

        CA  DELVZ
```

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|          |        |          |                                         |
|----------|--------|----------|-----------------------------------------|
|          | XCH    | ZPIBUF   |                                         |
|          | TS     | ZOLDBUF  |                                         |
| NOSAVPIP | CA     | FIVE     |                                         |
|          | TS     | CM/GYMDT |                                         |
|          | CA     | JTAGTIME | # ACTIVATE CM/RCS AFTER PIPUP TO GO     |
|          |        |          | # IN JTAGTIME +5 CS.                    |
|          | TC     | WAITLIST |                                         |
|          | EBANK= | AOG      |                                         |
|          | 2CADR  | SETJTAG  |                                         |
|          | CS     | THREE    | # 1.3SPOT FOR SETJTAG                   |
|          | TC     | NEWPHASE |                                         |
|          | OCT    | 1        |                                         |
|          | CAF    | OCT37    |                                         |
|          | TS     | L        |                                         |
|          | COM    |          |                                         |
|          | DXCH   | -PHASE5  |                                         |
| CHEKAVEG | CS     | FLAGWRD1 |                                         |
|          | MASK   | BIT1     |                                         |
|          | CCS    | A        | # IF AVEG FLAG DOWN SET FINAL EXIT AVEG |
|          | TC     | AVEGOUT  |                                         |
|          | CAF    | 2SECS    |                                         |
|          | TC     | WAITLIST |                                         |
|          | EBANK= | AOG      |                                         |
|          | 2CADR  | READACCS |                                         |
| MAKESERV | CAF    | PRI020   | # ESTABLISH SERVICER ROUTINE            |
|          | TC     | FINDVAC  |                                         |
|          | EBANK= | DVCNTR   |                                         |
|          | 2CADR  | SERVICER |                                         |
|          | CS     | FOUR     | # RESTART SERVICER AND READACCS         |
|          | TC     | NEWPHASE |                                         |
|          | OCT    | 5        |                                         |
|          | CAF    | BIT9     |                                         |
|          | EXTEND |          |                                         |
|          | WOR    | DSALMOUT | # TURN TEST CONNECTOR OUTBIT ON         |
|          | TCF    | TASKOVER | # END PREVIOUS READACCS WAITLIST TASK   |



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# Page 826

```
AVEGOUT      EXTEND
              DCA      AVOUTCAD
              DXCH     AVGEXIT
              TCF      MAKESERV

              EBANK=   DVCNTR
AVOUTCAD      2CADR   AVGEND
```

# Page 827

```
# ROUTINE NAME: ONMNITOR
# MOD 04 BY BAIRNSFATHER 30 APR 1968      REDO ONMNITOR TO SAVE PIPS EACH 0.5 SEC FOR TM,ENTRY.
# MOD 03 BY FISHER DECEMBER 1967
# MOD 02 BY RYE SEPT 1967
# MOD 01 BY KOSMALA 23 MAR 1967
# MOD 00 BY KOSMALA 27 FEB 1967
#
# FUNCTIONAL DESCRIPTION
#
#       THE PURPOSE OF ONMONITOR IS TO PROVIDE 1/2 SEC. READING OF PIPAS FOR DOWNLIST DURING EN
#       X,Y,XPIPBUF CONTAIN PRESET VALUES X,Y,ZOLDBUF CONTAIN VALUES FROM PREVIOUS READING.
#
# CALLING SEQUENCE
#
#       CALL AS WAITLIST TASK. TERMINATES ITSELF IN TASKOVER
#
# INITIALIZATION
#
#       PIPCTR = 2 (FOR DT = 0.5 SEC)
#       X,Y,ZPIPBUF SET TO PREVIOUS PIPAX,Y,Z
#
# OUTPUT
#
#       X,Y,ZPIPBUF, X,Y,ZOLDBUF
#
# DEBRIS
#
#       X,Y,ZPIPBUF CONTAIN LAST PIPAX,Y,Z VALUES
#       X,Y,ZOLDBUF CONTAIN LAST-BUT-ONE PIPAX,Y,Z VALUES
#       RUPTREG1
#       PIPCTR

ONMNITOR      TS      PIPCTR

              TC      FIXDELAY      # WAIT
0.5SEC        DEC     50
```

```

QUIKREAD      CAF      TWO
               TS       RUPTREG1
               INDEX    A
               CA       PIPAX      # SAVE ACTUAL PIPAS FOR TM.
               INDEX    RUPTREG1
               XCH      XPIPBUF    # UPDATE X,Y,ZPIPBUF
               INDEX    RUPTREG1
               TS       XOLDBUF    # AND X,Y,ZOLDBUF
CHKCTR        CCS       RUPTREG1
               TCF      QUIKREAD +1 # LOOP AGAIN
               CCS      PIPCTR
               TCF      ONMNITOR
               TC       TASKOVER

```

# Page 828

# \*\*\*\*\* SERVICER \*\*\*\*\*

```

               EBANK=   DVCNTR

SERVICER      CAF      TWO
               INHINT
PIPCHECK      TS       RUPTREG1

               DOUBLE
               INDEX    A
               CCS      DELVX
               TC       +2
               TC       PIPLOOP

               AD       -MAXDELV   # DO PIPA-SATURATION TEST BEFORE
               EXTEND
               BZMF     PIPLOOP    # COMPENSATION.

               TC       ALARM
               OCT      00205      # SATURATED-PIPA ALARM   ***CHANGE LATER
               TC       AVERAGEG

PIPLOOP       CCS      RUPTREG1
               TCF      PIPCHECK

               TC       PHASCHNG   # RESTART REREADAC + SERVICER
               OCT      16035
               OCT      20000
               EBANK=   DVCNTR
               2CADR    DVTOTUP

```

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|            |        |            |                                        |
|------------|--------|------------|----------------------------------------|
|            | TC     | BANKCALL   | # PIPA COMPENSATION CALL               |
|            | CADR   | 1/PIPA     |                                        |
| DVTOTUP    | TC     | INTPRET    |                                        |
|            | VLOAD  | ABVAL      | # GET ABS VALUE OF DELV                |
|            |        | DELV       |                                        |
|            | DMP    | EXIT       |                                        |
|            |        | KPIP1      | # SCALE AT 2(+7)                       |
|            | EXTEND |            |                                        |
|            | DCA    | MPAC       |                                        |
|            | DAS    | DVTOTAL    | # ACCUMULATE DVTOTAL                   |
| AVERAGEG   | TC     | PHASCHNG   |                                        |
|            | OCT    | 10035      |                                        |
|            | TC     | INTPRET    |                                        |
|            | CALL   |            |                                        |
| # Page 829 |        | CALCRVG    |                                        |
|            | EXIT   |            |                                        |
|            | TC     | PHASCHNG   |                                        |
|            | OCT    | 10035      |                                        |
|            | CAF    | OCT31      | # COPY RN1,VN1,GOT102,GOBL1/2,PIPTIME1 |
|            | TC     | GENTRAN    | # INTO RN, VN, GDT/12, GOBL/2,PIPTIME  |
|            | ADRES  | RN1        |                                        |
|            | ADRES  | RN         |                                        |
|            | RELINT |            | # GENTRAN DOES AN INHINT               |
|            | TC     | PHASCHNG   |                                        |
|            | OCT    | 10035      |                                        |
|            | EXTEND |            |                                        |
|            | DCA    | AVGEXIT    |                                        |
|            | DXCH   | Z          | # AVERAGEG EXIT                        |
| AVGEND     | CA     | PIPTIME +1 | # FINAL AVERAGE G EXIT                 |
|            | TS     | OLDBT1     | # SET UP FREE FALL GYRO COMPENSATION   |
|            | TC     | UPFLAG     | # SET DRIFTFLG                         |
|            | ADRES  | DRIFTFLG   | # BIT 15 FLAG 2                        |
|            | TC     | 2PHSCHNG   |                                        |
|            | OCT    | 5          | # GROUP 5 OFF                          |
|            | OCT    | 05022      | # GROUP 2 ON FOR AVETOMID              |
|            | OCT    | 20000      |                                        |

|            |        |          |                                                                                                   |
|------------|--------|----------|---------------------------------------------------------------------------------------------------|
|            | TC     | INTPRET  |                                                                                                   |
|            | CALL   |          |                                                                                                   |
|            |        | AVETOMID | # CONVERT STATE VECTOR TO REFERENCE SCALE.                                                        |
|            | EXIT   |          |                                                                                                   |
|            | CAF    | ZERO     | # ZERO MARK COUNTERS.                                                                             |
|            | TS     | VHFCNT   |                                                                                                   |
|            | TS     | TRKMKCNT |                                                                                                   |
|            | TC     | BANKCALL |                                                                                                   |
|            | CADR   | PIPFREE  |                                                                                                   |
|            | CS     | BIT9     |                                                                                                   |
|            | TS     | MRKBUF2  | # INVALIDATE MARK BUFFER                                                                          |
|            | EXTEND |          |                                                                                                   |
|            | WAND   | DSALMOUT |                                                                                                   |
|            | TC     | DOWNFLAG |                                                                                                   |
|            | ADRES  | CM/DSTBY |                                                                                                   |
|            | TC     | DOWNFLAG |                                                                                                   |
|            | ADRES  | V37FLAG  |                                                                                                   |
| # Page 830 |        |          |                                                                                                   |
|            | CAF    | BIT7     | # RESTORE GROUP 1 + 2 IF P20 IS RUNNING.                                                          |
|            | MASK   | FLAGWRDO |                                                                                                   |
|            | EXTEND |          |                                                                                                   |
|            | BZF    | +4       |                                                                                                   |
|            | TC     | 2PHSCHNG |                                                                                                   |
|            | OCT    | 111      | # 1.11SPOT                                                                                        |
|            | OCT    | 132      | # 2.13SPOT                                                                                        |
|            | TC     | POSTJUMP |                                                                                                   |
|            | CADR   | CANV37   |                                                                                                   |
| SERVEXIT   | TC     | PHASCHNG |                                                                                                   |
|            | OCT    | 00035    | # A, 5.3 = REREADAC (ONLY)                                                                        |
|            | TCF    | ENDOFJOB |                                                                                                   |
| DVTHRUSH   | EQUALS | ELEVEN   | # 15 PERCENT OF 2SEC PIPA ACCUMULATION,<br># FOR 503-FULL CSM/LEM....DELV SC.AT<br># 5.85 CM/SEC. |

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```
-MAXDELV      DEC      -6398      # 3200 PPS FOR 2 SEC CCS TAKES 1

JTAGTIME      DEC      120        # = 1 SEC + T CDU, T CDU = .1 SEC

2.5SEC        DEC      250
MDOTFAIL      DEC      144.0 B-16  # 5 SEC MASS LOSS AT 28.8 KG/SEC
   # SHOULD BE 2-4 SECS FOR NO START
   #           6-8 SECS FOR FAILURE
```

# Page 831

# NORMLIZE PERFORMS THE INITIALIZATION REQUIRED PRIOR TO THE FIRST ENTRY TO AVERAGE, AND SCALE  
# HAS 1 LEADING BINARY ZERO. IN MOST MISSIONS, RN WILL BE SCALED AT 2(+29), BUT IN THE 206 MIS  
# SCALED AT 2(+24) M.

```
NORMLIZE      CAF      THIRTEEN    # SET UP TO COPY 14 REGS: RN1,VN1,PIPTIME1
              TC       GENTRAN      # INTO RN,VN,PIPTIME
              ADRES    RN1          # FROM HERE
              ADRES    RN           # TO HERE

              RELINT
              TC       INTPRET
              VLOAD    CALL          # LOAD RN FOR CALCGRAV
                               RN
                               CALCGRAV # INITIALIZE UNITR RMAG GDT1

              STOVL    GDT/2
                               GOBL1/2
              STORE    GOBL/2
              EXIT
              TCF      ENDOFJOB
```

# Page 832

# \*\*\*\*\* PIPA READER \*\*\*\*\*

# MOD NO. 00 BY D. LICKLY DEC. 9 1966

#

# FUNCTIONAL DESCRIPTION

#

# SUBROUTINE TO READ PIPA COUNTERS, TRYING TO BE VERY CAREFUL SO THAT IT WILL BE RESTARTABLE.  
# PIPA READINGS ARE STORED IN THE VECTOR DELV. THE HIGH ORDER PART OF EACH COMPONENT CONTAINS  
# RESTARTS BEGIN AT REREADAC.

#

# AT THE END OF THE PIPA READER THE CDUS ARE READ AND STORED AS A  
# VECTOR IN CDUTEMP. THE HIGH ORDER PART OF EACH COMPONENT CONTAINS  
# THE CDU READING IN 2'S COMP IN THE ORDER CDUX,Y,Z. THE THRUST  
# VECTOR ESTIMATOR IN FINDCDUD REQUIRES THE CDUS BE READ AT PIPTIME.

#

```

# CALLING SEQUENCE AND EXIT
#
#       CALL VIA TC, ISWCALL, ETC.
#
#       EXIT IS VIA Q.
#
# INPUT
#
#       INPUT IS THROUGH THE COUNTERS PIPAX, PIPAY, PIPAZ, AND TIME2.
#
# OUTPUT
#
#       HIGH ORDER COMPONENTS OF THE VECTOR DELV CONTAIN THE PIPA READINGS.
#
#       PIPTIME CONTAINS TIME OF PIPA READING.
#
# DEBRIS (ERASABLE LOCATIONS DESTROYED BY THE PROGRAM)
#
#       LOW ORDER DELV'S ARE ZEROED FOR TM INDICATION.
#       TEMX      TEMY      TEMZ      PIPAGE

PIPASR          EXTEND
                 DCA      TIME2
                 DXCH     PIPTIME1      # CURRENT TIME  POSITIVE VALUE
                 CS       ZERO          # INITIALIZE THESE AT NEG ZERO.
                 TS       TEMX
                 TS       TEMY
                 TS       TEMZ

# Page 833
                 CA       ZERO
                 TS       DELVZ          # OTHER DELVS OK INCLUDING LOW ORDER
                 TS       DELVY

                 TS       DELVX +1      # LOW ORDER DELV'S ARE ZEROED FOR TM:  THIS
                 TS       DELVY +1      # IF DNLNK=D LOW ORDER DELVS ARE NZ, THEY
                 TS       DELVZ +1      # CONTAIN PROPER COMPENSATION.  IF=0, THEN
                                     # THE TM VALUES ARE BEFORE COMPENSATION.

                 TS       PIPAGE        # SHOW PIPA READING IN PROGRESS

REPIP1          EXTEND
                 DCS      PIPAX          # X AND Y PIPS READ
                 DXCH     TEMX
                 DXCH     PIPAX          # PIPAS SET TO NEG ZERO AS READ.
                 TS       DELVX
                 LXCH     DELVY

```

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```
REPIP3      CS      PIPAZ      # REPEAT PROCESS FOR Z PIP
            XCH      TEMZ
            XCH      PIPAZ
DODELVZ     TS      DELVZ
            TC        Q
            EBANK=    AOG

REREADAC    CCS      PHASE5     # LAST PASS CHECK
            TCF      +2
            TCF      TASKOVER

            CAF      PRI031     # RESTART MAY HAVE WIPE OUT LASTBIAS, AN
            TS      1/PIPADT    # UNPROTECTED NOVAC FROM PREREAD,
                                # WHICH SET(S) UP 1/PIPADT (THUSLY)
                                # FOR NON-COASTING COMPENSATION...BE
                                # SURE 1/PIPADT IS AOK. (PRI031 IS
                                # 2.0SEC SC.AT B+8(CS)

            CCS      PIPAGE
            TCF      READACCS    # PIP READING NOT STARTED. GO TO BEGINNING

            CAF      DONEADR     # SET UP RETURN FROM PIPASR
            TS      Q

            CCS      DELVZ
            TC        Q          # Z DONE, GO DO CDUS
            TCF      +3          # Z NOT DONE, CHECK Y.
            TC        Q
            TC        Q

# Page 834   ZL
            CCS      DELVY
            TCF      +3
            TCF      CHKTEMX     # Y NOT DONE, CHECK X.
            TCF      +1
            LXCH     PIPAZ       # Y DONE, ZERO Z PIP.

            CCS      TEMZ
            CS      TEMZ         # TEMZ NOT = -0, CONTAINS -PIPAZ VALUE.
            TCF      DODELVZ
            TCF      -2
            LXCH     DELVZ       # TEMZ = -0, L HAS ZPIP VALUE.
            TC        Q
```

```

CHKTEMX      CCS      TEMX      # HAS THIS CHANGED
              CS       TEMX      # YES
              TCF      +3        # YES
              TCF      -2        # YES
              TCF      REPIP1     # NO
              TS       DELVX

              CS       TEMY
              TS       DELVY

              CS       ZERO      # ZERO X AND Y PIPS
              DXCH     PIPAX     # L STILL ZERO FROM ABOVE

              TCF      REPIP3

DONEADR      GENADR  PIPSDONE

```

```
# Page 835
```

```

*****
#
# ROUTINE CALCRVG INTEGRATES THE EQUATIONS OF MOTION BY AVERAGING THE THRUST AND GRAV
# ACCELERATIONS OVER A TIME INTERVAL OF 2 SECONDS.
#
# FOR THE EARTH-CENTERED GRAVITATIONAL FIELD, THE PERTURBATION DUE TO OBLATENESS IS C
# HARMONIC COEFFICIENT J.
#
# ROUTINE CALCRVG REQUIRES...
#      1) THRUST ACCELERATION INCREMENTS IN DELV SCALED SAME AS PIPAX,Y,Z IN STABLE
#      2) VN SCALED 2(+7) M/CS IN REFERENCE COORDS.
#      3) RN SCALED AT 2(+29) METERS IN REFERENCE COORDS.
#      4) UNITW THE EARTH'S UNIT ROTATIONAL VECTOR (SCALED AS A FULL UNIT VECTOR) IN
#
# IT LEAVES RN1 UPDATED (SCALED AT 2(+29)M, VN1 (SCALED AT 2(+7)M/CS), AND GDT1/2 (SC
# UNIT VECTOR UNITR, RMAG IN 36D SCALED AT 2(+29)M, R MAG SQ. IN 34D SCALED AT 2(+58)

```

```

CALCGRAV     UNIT     PUSH      # ENTER WITH RN IN MPAC
              STORE    UNITR
              LXC,1    SLOAD
                  RTX2
                  X1
              BMN     VLOAD
                  ITISMOON
              DOT     PUSH
                  UNITW
              DSQ     BDSU

```



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|            |        |            |                                           |
|------------|--------|------------|-------------------------------------------|
|            | PDDL   | DP1/20     |                                           |
|            |        | DDV        |                                           |
|            |        | RESQ       |                                           |
|            |        | 34D        | # (RN)SQ                                  |
|            | STORE  | 32D        | # TEMP FOR (RE/RN)SQ                      |
|            | DMP    | DMP        |                                           |
|            |        | 20J        |                                           |
|            | VXSC   | PDDL       |                                           |
|            |        | UNITR      |                                           |
|            | DMP    | DMP        |                                           |
|            |        | 2J         |                                           |
|            |        | 32D        |                                           |
|            | VXSC   | VAD        |                                           |
|            |        | UNITW      |                                           |
|            | STADR  |            |                                           |
|            | STORE  | GOBL1/2    |                                           |
|            | VAD    | PUSH       |                                           |
|            |        | UNITR      |                                           |
| ITISMOON   | DLOAD  | NORM       |                                           |
|            |        | 34D        |                                           |
|            |        | X2         |                                           |
|            | BDDV*  | SLR*       |                                           |
| # Page 836 |        |            |                                           |
|            |        | -MUDT(E),1 |                                           |
|            |        | 0 -21D,2   |                                           |
|            | VXSC   | STADR      |                                           |
|            | STORE  | GDT1/2     | # SCALED AT 2(+7) M/CS                    |
|            | RVQ    |            |                                           |
| CALCRVG    | VLOAD  | VXSC       |                                           |
|            |        | DELV       |                                           |
|            |        | KPIP1      |                                           |
|            | VXM    | VSL1       |                                           |
|            |        | REFSMMAT   |                                           |
|            | STORE  | DELVREF    | # DELV IN REF COORDS AT 2(+7)             |
|            | VSR1   | PUSH       |                                           |
|            | VAD    | PUSH       | # (DV-OLDGDT)/2 TO PD SCALED AT 2(+7)M/CS |
|            |        | GDT/2      |                                           |
|            | VAD    | VXSC       |                                           |
|            |        | VN         |                                           |
|            |        | 2SEC(22)   |                                           |
|            | VAD    | STQ        |                                           |
|            |        | RN         |                                           |
|            |        | 31D        |                                           |
|            | STCALL | RN1        | # TEMP STORAGE OF RN SCALED 2(+29)M       |
|            |        | CALCGRAV   |                                           |

|          |        |                       |                                            |
|----------|--------|-----------------------|--------------------------------------------|
|          | VAD    | VAD                   |                                            |
|          | VAD    |                       |                                            |
|          |        | VN                    |                                            |
|          | STCALL | VN1                   | # TEMP STORAGE OF VN SCALED 2(+7) M/CS.    |
|          |        | 31D                   |                                            |
| KPIP     | 2DEC   | .1024                 | # SCALES DELV TO 2(+4)                     |
| KPIP1    | 2DEC   | 0.074880              | # 207 DELV SCALING. 1 PULSE = 5.85 CM/SEC. |
| -MUDT(E) | 2DEC*  | -7.9720645 E+12 B-44* |                                            |
| -MUDT(M) | 2DEC*  | -9.805556 E+10 B-44*  |                                            |
| 2SEC(22) | 2DEC   | 200 B-22              |                                            |
| DP1/20   | 2DEC   | 0.05                  |                                            |
| RESQ     | 2DEC*  | 40.6809913 E12 B-59*  |                                            |
| 20J      | 2DEC*  | 3.24692010 E-2 B1*    |                                            |
| 2J       | 2DEC*  | 3.24692010 E-3 B1*    |                                            |

This code is written to file `src/SERVICER207.s`.

## A.101 SERVICE ROUTINES

1683

*<src/SERVICE-ROUTINES.s 1683>*≡

```
# Copyright:   Public domain.
# Filename:    SERVICE_ROUTINES.agc
# Purpose:     Part of the source code for Comanche, build 055. It
#              is part of the source code for the Command Module's
#              (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:  yaYUL
# Reference:   pp. 1485-1492
# Contact:     Ron Burkey <info@sandroid.org>
# Website:     http://www.ibiblio.org/apollo.
# Mod history: 2009-05-07 RSB   Adapted from Colossus249 file of the same
#                               name, and page images. Corrected various
#                               typos in the transcription of program
#                               comments, and these should be back-ported
#                               to Colossus249.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#
#           Massachussets Institute of Technology
#           75 Cambridge Parkway
#           Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.

# Page 1485

BLOCK      3
SETLOC     FFTAG6
BANK
COUNT     03/FLAG

UPENT2     TS      L           # WHICH FLAGWORD IS IT
           MASK     OCT7
           XCH      L           # SAVE IN L FOR INDEXING
```

```

                                MASK    OCT77770      # OBTAIN THE BIT INFORMATION
                                INHINT                                # PREVENT INTERRUPTS
                                TS       ITEMP1         # STORE THE BIT INFORMATION TEMPORARILY

                                NDX      L
                                CS       FLAGWRDO
                                MASK     ITEMP1
                                NDX      L
                                ADS      FLAGWRDO
                                RELINT                                # RELEASE INTERRUPT INHIBIT

                                INCR     Q              # OBTAIN THE CORRECT RETURN ADDRESS
                                TC       Q              # RETURN

DOWNENT2                       TS       L              # WHICH FLAGWORD IS IT
                                MASK     OCT7
                                XCH      L              # SAVE IN L FOR INDEXING

                                MASK     OCT77770      # OBTAIN THE BIT INFORMATION
                                COM   # START TO PROCESS THE INFORMATION

                                INHINT                                # PREVENT INTERRUPTS
                                NDX      L
                                MASK     FLAGWRDO
                                NDX      L
                                TS       FLAGWRDO
                                RELINT                                # RELEASE INTERRUPT INHIBIT

                                INCR     Q              # OBTAIN THE CORRECT RETURN ADDRESS
                                TC       Q

OCT7                           EQUALS   SEVEN
                                BANK     10

```

# Page 1486

# UPFLAG AND DOWNFLAG ARE ENTIRELY GENERAL FLAG SETTING AND CLEARING SUBROUTINES. US  
 # NOT IN INTERRUPT, ONE MAY SET OR CLEAR ANY SINGLE, NAMED BIT IN ANY ERASABLE REGISTER  
 # EBANK SETTING. A "NAMED" BIT, AS THE WORD IS USED HERE, IS ANY BIT WITH A NAME FOR  
 # ASSEMBLER.

#

# AT PRESENT THE ONLY NAMED BITS ARE THOSE IN THE FLAGWORDS. ASSEMBLER CHANGES WILL  
 # NAME ANY BIT IN ERASABLE MEMORY.

#

# CALLING SEQUENCES ARE AS FOLLOWS --

```

#           TC      UPFLAG                TC      DOWNFLAG
#           ADRES   NAME OF FLAG          ADRES   NAME OF FLAG

```

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#  
# RETURN IS TO THE LOCATION FOLLOWING THE "ADRES" ABOUT .58 MS AFTER THE "TC".  
# UPON RETURN A CONTAINS THE CURRENT FLAGWRD SETTING.

|             |        |           |                               |
|-------------|--------|-----------|-------------------------------|
|             | BLOCK  | 02        |                               |
|             | SETLOC | FFTAG1    |                               |
|             | BANK   |           |                               |
|             | COUNT* | \$\$/FLAG |                               |
| UPFLAG      | CA     | Q         |                               |
|             | TC     | DEBIT     |                               |
|             | COM    |           | # +(15 - BIT)                 |
|             | EXTEND |           |                               |
|             | ROR    | LCHAN     | # SET BIT                     |
| COMFLAG     | INDEX  | ITEMP1    |                               |
|             | TS     | FLAGWRD0  |                               |
|             | LXCH   | ITEMP3    |                               |
|             | RELINT |           |                               |
|             | TC     | L         |                               |
| DOWNFLAG    | CA     | Q         |                               |
|             | TC     | DEBIT     |                               |
|             | MASK   | L         | # RESET BIT                   |
|             | TCF    | COMFLAG   |                               |
| DEBIT       | AD     | ONE       | # CET DE BITS                 |
|             | INHINT |           |                               |
|             | TS     | ITEMP3    |                               |
|             | CA     | LOW4      | # DEC15                       |
|             | TS     | ITEMP1    |                               |
|             | INDEX  | ITEMP3    |                               |
|             | CA     | 0 -1      | # ADRES                       |
|             | TS     | L         |                               |
|             | CA     | ZERO      |                               |
| # Page 1487 | EXTEND |           |                               |
|             | DV     | ITEMP1    | # A = FLAGWRD, L = (15 - BIT) |
|             | DXCH   | ITEMP1    |                               |
|             | INDEX  | ITEMP1    |                               |
|             | CA     | FLAGWRD0  |                               |
|             | TS     | L         | # CURRENT STATE               |
|             | INDEX  | ITEMP2    |                               |
|             | CS     | BIT15     | # -(15 - BIT)                 |
|             | TC     | Q         |                               |

# Page 1488

```

# DELAYJOB -- A GENERAL ROUTINE TO DELAY A JOB A SPECIFIC AMOUNT OF TIME BEFORE PICK
#
# ENTRANCE REQUIREMENTS ...
#          CAF      DT          # DELAY JOB FOR DT CENTISECS
#          TC       BANKCALL
#          CADR     DELAYJOB

          BANK      06
          SETLOC    DLAYJOB
          BANK

# THIS MUST REMAIN IN BANK 0 *****

COUNT    00/DELAY

DELAYJOB   INHINT
          TS      Q          # STORE DELAY DT IN Q FOR DLY -1 IN
          CAF     DELAYNUM    # WAITLIST
DELOOP     TS      RUPTREG1
          INDEX   A
          CA      DELAYLOC    # IS THIS DELAYLOC AVAILABLE
          EXTEND
          BZF     OK2DELAY     # YES

          CCS     RUPTREG1    # NO, TRY NEXT DELAYLOC
          TCF     DELOOP

          TC      BAILOUT     # NO AVAILABLE LOCS.
          OCT     1104

OK2DELAY    CA      TCSLEEP    # SET WAITLIST IMMEDIATE RETURN
          TS      WAITEXIT

          CA      FBANK
          AD      RUPTREG1    # STORE BBANK FOR TASK CALL
          TS      L

          CAF     WAKECAD     # STORE CADR FOR TASK CALL
          TCF     DLY2 -1     # DLY IS IN WAITLIST ROUTINE

TCGETCAD    TC      MAKECADR   # GET CALLER'S FCADR

          INDEX   RUPTREG1
          TS      DELAYLOC    # SAVE DELAY CADRS

          TC      JOBSLEEP

```

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```
WAKER      CAF      ZERO
            INDEX    BBANK
            XCH      DELAYLOC      # MAKE DELAYLOC AVAILABLE
```

# Page 1489

```
TC          JOBWAKE
TC          TASKOVER
```

```
TCSLEEP     GENADR  TCGETCAD -2
WAKECAD      GENADR  WAKER
```

# Page 1490

```
# GENTRAN, A BLOCK TRANSFER ROUTINE
# WRITTEN BY D. EYLES
```

```
# MOD 1 BY KERNAN
```

UTILITYM REV 17 11/18/67

```
# MOD 2 BY SCHULENBERG -- (REMOVE RELINT) -- SKIPPER REV 4 2/28/68
```

#

```
# THIS ROUTINE IS USEFUL FOR TRANSFERRING N CONSECUTIVE ERASABLE OR FIXED QUANTITIES TO SOME OTHER
# CONSECUTIVE ERASABLE LOCATIONS.  IF BOTH BLOCKS OF DATA ARE IN SWITCHABLE EBANKS, THEY MUST BE
```

#

```
# GENTRAN IS CALLABLE IN A JOB AS WELL AS A RUPT.  THE CALLING SEQUENCE IS:
```

```
#      I      CA      N-1      # NO. NUMBER OF QUANTITIES MINUS ONE.
#      I +1    TC      GENTRAN  # IN FIXED-FIXED.
#      I +2    ADRES  L        # STARTING ADRES OF DATA TO BE MOVED.
#      I +3    ADRES  M        # STARTING ADRES OF DUPLICATION BLOCK.
#      I +4                      # RETURNS HERE.
```

#

```
# GENTRAN TAKES 25 MCT'S (300 MICROSECONDS) PER ITEM + 5 MCT'S (60 MICS) FOR ENTERING AND EXITING.
# A, L, AND ITEMP1 ARE NOT PRESERVED.
```

```
BLOCK      02
SETLOC     FFTAG4
BANK
```

```
EBANK=     ITEMP1
```

```
COUNT*     $$/TRAN
```

```
GENTRAN    INHINT
TS          ITEMP1      # SAVE N-1
INDEX      Q            # C(Q) = ADRES L.
AD         0            # ADRES (L + N - 1).
INDEX      A
CA         0            # C(ABOVE).
TS         L            # SAVE DATA.
```

```

CA      ITEMP1
INDEX   Q
AD      1          # ADRES (M + N - 1).
INDEX   A
LXCH    0          # STUFF IT.
CCS     ITEMP1     # LOOP UNTIL N-1 = 0.
TCF     GENTRAN +1
TCF     Q+2        # RETURN TO CALLER.

```

# Page 1491

```

# B50FF      ZERO BIT 5 OF EXTVBACK, WHICH IS SET BY TESTXACT.
# MAY BE USED AS NEEDED BY ANY EXTENDED VERB WHICH HAS DONE TESTXACT

```

COUNT\* \$\$/EXTVB

```

B50FF      CS      BIT5
           MASK     EXTVBACT
           TS       EXTVBACT
           TC       ENDOFJOB

```

# Page 1492

# SUBROUTINES TO TURN OFF AND TURN ON TRACKER FAIL LIGHT.

```

TRFAILOF   INHINT
           CS      OCT40200      # TURN OFF TRACKER LIGHT
           MASK     DSPTAB +11D
           AD      BIT15
           TS      DSPTAB +11D
           CS      OPTMODES      # TO INSURE THAT OCDU FAIL WILL GO ON
           MASK     BIT7         # AGAIN IF IT WAS ON IN ADDITION TO
           ADS      OPTMODES      # TRACKER FAIL.

```

```

REQ         RELINT
           TC      Q

```

```

TRFAILON   INHINT
           CS      DSPTAB +11D    # TURN ON
           MASK     OCT40200
           ADS      DSPTAB +11D
           TCF     REQ

```



## A.102 SERVICER

1689

<src/SERVICER.s 1689>≡

```
# Copyright:   Public domain.
# Filename:    SERVICER.agc
# Purpose:     Part of the source code for Luminary, build 099. It
#              is part of the source code for the Lunar Module's
#              (LM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:  yaYUL
# Reference:   pp. 857-897
# Contact:     Ron Burkey <info@sandroid.org>,
#              Fabrizio Bernardini <fabrizio@spacecraft.it>
# Website:     http://www.ibiblio.org/apollo.
# Mod history: 2009-06-01 FB   Transcription Batch 4 Assignment.
#              2009-06-05 RSB   Fixed a couple of typos, plus a goofy relative
#                               label reference from the original source.
#
# The contents of the "Luminary099" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 001 of AGC program Luminary099 by NASA
# 2021112-061.  July 14, 1969.
#
# Prepared by
#
#           Massachussets Institute of Technology
#           75 Cambridge Parkway
#           Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.

# Page 857

      BANK      37
      SETLOC    SERV1
      BANK

      EBANK=    DVCNTR

# ***** PREREAD *****

      COUNT*    $$/SERV

PREREAD      CAF      SEVEN      # 5.7 SPOT TO SKIP LASTBIAS AFTER
              TC       GNUFAZE5   # RESTART.
```

|          |        |           |                                                                                  |
|----------|--------|-----------|----------------------------------------------------------------------------------|
|          | CAF    | PRI021    |                                                                                  |
|          | TC     | NOVAC     |                                                                                  |
|          | EBANK= | NBDX      |                                                                                  |
|          | 2CADR  | LASTBIAS  | # DO LAST GYRO COMPENSATION IN FREE FALL                                         |
| BIBIBIAS | TC     | PIPASR +3 | # CLEAR + READ PIPS LAST TIME IN FRE5+F133<br># DO NOT DESTROY VALUE OF PIPTIME1 |
|          | CS     | FLAGWRD7  |                                                                                  |
|          | MASK   | SUPER011  | # SET V37FLAG AND AVEGFLAG (BITS 5 AND 6                                         |
|          | ADS    | FLAGWRD7  | # OF FLAGWRD7)                                                                   |
|          | CS     | DRFTBIT   |                                                                                  |
|          | MASK   | FLAGWRD2  | # RESET DRIFTFLAG                                                                |
|          | TS     | FLAGWRD2  |                                                                                  |
|          | CAF    | FOUR      | # INITIALIZE DV MONITOR                                                          |
|          | TS     | PIPAGE    |                                                                                  |
|          | CAF    | ENDJBCAD  | # POINT OUTROUTE TO END-OF-JOB.                                                  |
|          | TS     | OUTROUTE  |                                                                                  |
|          | CAF    | PRI022    |                                                                                  |
|          | TC     | FINDVAC   | # TO FIRST ENTRY TO AVERAGE G                                                    |
|          | EBANK= | DVCNTR    |                                                                                  |
|          | 2CADR  | NORMLIZE  |                                                                                  |
| GOREADAX | CA     | TWO       | # 5.2SPOT FOR REREADAC AND NORMLIZE                                              |
|          | TC     | GNUTFAZ5  |                                                                                  |
|          | CA     | 2SECS     | # WAIT TWO SECONDS FOR READACCS                                                  |
|          | TC     | VARDELAY  |                                                                                  |

# Page 858

# \*\*\*\*\* READACCS \*\*\*\*\*

|          |     |          |                                           |
|----------|-----|----------|-------------------------------------------|
| READACCS | CS  | OCT37771 | # THIS PIECE OF CODING ATTEMPTS TO        |
|          | AD  | TIME5    | # SYNCHRONIZE READACCS WITH THE DIGITAL   |
|          | CCS | A        | # AUTOPILOT SO THAT A PAXIS RUPT WILL     |
|          | CS  | ONE      | # OCCUR APPROXIMATELY 70 MILLISECONDS     |
|          | TCF | +2       | # FOLLOWING THE READACCS RUPT. THE 70 MS  |
|          | CA  | ONE      | # OFFSET WAS CHOSEN SO THAT THE PAXIS     |
| +2       | ADS | TIME5    | # RUPT WOULD NOT OCCUR SIMULTANEOUSLY     |
|          |     |          | # WITH ANY OF THE 8 SUBSEQUENT R10,R11    |
|          |     |          | # INTERRUPTS -- THUS MINIMIZING THE POSS- |
|          |     |          | # IBILITY OF LOSING DOWNRUPTS.            |

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```

TC      PIPASR      # READ THE PIPAS.

PIPSDONE CA      FIVE
TC      GNUFAZE5
RED05.5 CAF      ONE
TS      PIPAGE

CA      PRI020
TC      FINDVAC
EBANK=  DVCNTR
2CADR   SERVICER      # SET UP SERVICER JOB

CA      BIT9
EXTEND
WOR      DSALMOUT      # TURN ON TEST CONNECTOR OUTBIT

CA      FLAGWRD7
MASK     AVEGFBIT
EXTEND
BZF      AVEGOUT      # AVEGFLAG DOWN -- SET UP FINAL EXIT

CA      FLAGWRD6
MASK     MUNFLBIT
EXTEND
BZF      MAKEACCS      # MUNFLAG CLEAR -- BYPASS LR AND DISP.

CCS      PHASE2
TCF      MAKEACCS      # PHASE 2 ACTIVATED -- AVOID MULTIPLE R10.

CAF      SEVEN
TS      PIPCTR      # SET PIPCTR FOR 4X/SEC RATE.

CS      TIME1      # SET TBASE2 .05 SECONDS IN THE PAST.
AD      FIVE
AD      NEG1/2
AD      NEG1/2
XCH      TBASE2

CAF      DEC17      # 2.21SPOT FOR R10,R11
TS      L
COM
DXCH     -PHASE2

CAF      OCT24      # FIRST R10,R11 IN .200 SECONDS
TC      WAITLIST
EBANK=  UNIT/R/
```

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```

                2CADR  R10,R11

MAKEACCS      CA      FOUR
              TCF      GOREADAX      # DO PHASE CHANGE AND RECALL READACCS

AVEGOUT       EXTEND
              DCA      AVOUTCAD      # SET UP FINAL SERVICER EXIT
              DXCH     AVGEXIT

              CA      FOUR      # SET 5.4 SPOT FOR REREADAC AND SERVICER
              TC      GNUTFAZ5    # IF REREADAC IS CALLED, IT WILL EXIT
              TC      TASKOVER    # END TASK WITHOUT CALLING READACCS

GNUTFAZ5      TS      L          # SAVE INPUT IN L
              CS      TIME1
              TS      TBASE5      # SET TBASE5
              TCF     +2

GNUFAZE5      TS      L          # SAVE INPUT IN L
              CS      L          # -PHASE IN A, PHASE IN L.
              DXCH    -PHASE5    # SET -PHASE5,PHASE5
              TC      Q

              EBANK=  DVCNTR
AVOUTCAD      2CADR    AVGEND

ENDJBCAD      CADR     SERVEXIT +2

OCT37771      OCT      37771

              BANK     33
              SETLOC   SERVICES
              BANK

              COUNT*   $$/SERV

```

# Page 860

# \*\*\*\*\* SERVICER \*\*\*\*\*

```

SERVICER      TC      PHASCHNG      # RESTART REREADAC + SERVICER
              OCT      16035
              OCT      20000
              EBANK=   DVCNTR
              2CADR    GETABVAL

              CAF      PRI031      # INITIALIZE 1/PIPADT IN CASE RESTART HAS

```

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```

      TS      1/PIPADT      # CAUSED LASTBIAS TO BE SKIPPED.

      TC      BANKCALL
      CADR    1/PIPA      # PIPA COMPENSATION CALL

GETABVAL      TC      INTPRET
      VLOAD    ABVAL
              DELV

      EXIT
      CA      MPAC
      TS      ABDELV      # ABDELV = CM/SEC*2(-14) .
      EXTEND
      MP      KPIP
      DXCH    ABDVCONV      # ABDVCONV = M/CS * 2(-5) .
      EXTEND
      DCA     MASS
      DXCH    MASS1      # INITIALIZE MASS1 IN CASE WE SKIP MASSMON
      CS      FLAGWRD8    # ARE WE ON THE SURFACE?
      MASK    SURFFBIT
      EXTEND
      BZF     MOONSPOT    # YES:  BYPASS MASS MESS

      CA      FLGWRD10    # NO:  WHICH VEX SHOULD BE USED?
      MASK    APSFLBIT
      CCS     A
      EXTEND    # IF EXTEND IS EXECUTED, APSVEX --> A,
      DCA     APSVEX      #      OTHERWISE DPSVEX --> A
      TS      Q

      EXTEND
      DCA     ABDVCONV
      EXTEND
OCT10002      DV      Q      # WHERE APPROPRIATE VEX RESIDES
      EXTEND
      MP      MASS
      DAS     MASS1

MOONSPOT      CA      KPIP1      # TP MPAC = ABDELV AT 2(14) CM/SEC
      TC      SHORTMP      # MULTIPLY BY KPIP1 TO GET

# Page 861
      DXCH    MPAC      # ABDELV AT 2(7) M/CS
      DAS     DVTOTAL    # UPDATE DVTOTAL FOR DISPLAY

      TC      TMPTOSPT

      TC      BANKCALL
```

|            |        |          |                                         |
|------------|--------|----------|-----------------------------------------|
|            | CADR   | QUICTRIG |                                         |
|            | CAF    | XNBPIPAD |                                         |
|            | TC     | BANKCALL |                                         |
|            | CADR   | FLESHPOT |                                         |
|            | TC     | INTPRET  |                                         |
| AVERAGEG   | BON    | CALL     |                                         |
|            |        | MUNFLAG  |                                         |
|            |        | RVBOTH   |                                         |
|            |        | CALCRVG  |                                         |
|            | EXIT   |          |                                         |
| GOSERV     | TC     | QUIKFAZ5 |                                         |
| COPYCYCL   | TC     | COPYCYC  |                                         |
| #          | CA     | ZERO     | # A IS ZERO ON RETURN FROM COPYCYC      |
|            | TS     | PIPATMPX |                                         |
|            | TS     | PIPATMPY |                                         |
|            | TS     | PIPATMPZ |                                         |
|            | CS     | STEERBIT | # CLEAR STEERSW PRIOR TO DVMON.         |
|            | MASK   | FLAGWRD2 |                                         |
|            | TS     | FLAGWRD2 |                                         |
|            | CAF    | IDLEFBIT | # IS THE IDLE FLAG SET?                 |
|            | MASK   | FLAGWRD7 |                                         |
|            | CCS    | A        |                                         |
|            | TCF    | NODVMON1 | # IDLEFLAG = 1, HENCE SET AUXFLAG TO 0. |
|            | CS     | FLAGWRD6 |                                         |
|            | MASK   | AUXFLBIT |                                         |
|            | CCS    | A        |                                         |
|            | TCF    | NODVMON2 | # AUXFLAG = 0, HENCE SET AUXFLAG TO 1.  |
| DVMON      | CS     | DVTHRUSH |                                         |
|            | AD     | ABDELV   |                                         |
|            | EXTEND |          |                                         |
|            | BZMF   | LOTHRUST |                                         |
|            | CS     | FLAGWRD2 | # SET STEERSW.                          |
|            | MASK   | STEERBIT |                                         |
|            | ADS    | FLAGWRD2 |                                         |
| DVCNTSET   | CAF    | ONE      | # ALLOW TWO PASSES MAXIMUM NOW THAT     |
| # Page 862 | TS     | DVCNTR   | # THRUST HAS BEEN DETECTED.             |

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|          |        |          |                             |
|----------|--------|----------|-----------------------------|
|          | CA     | FLGWRD10 | # BRANCH IF APSFLAG IS SET. |
|          | MASK   | APSFLBIT |                             |
|          | CCS    | A        |                             |
|          | TCF    | USEJETS  |                             |
|          | CA     | BIT9     | # CHECK GIMBAL FAIL BIT     |
|          | EXTEND |          |                             |
|          | RAND   | CHAN32   |                             |
|          | EXTEND |          |                             |
|          | BZF    | USEJETS  |                             |
| USEGTS   | CS     | USEQRJTS |                             |
|          | MASK   | DAPBOOLS |                             |
|          | TS     | DAPBOOLS |                             |
|          | TCF    | SERVOUT  |                             |
| NODVMON1 | CS     | AUXFLBIT | # SET AUXFLAG TO 0.         |
|          | MASK   | FLAGWRD6 |                             |
|          | TS     | FLAGWRD6 |                             |
|          | TCF    | USEJETS  |                             |
| NODVMON2 | CS     | FLAGWRD6 | # SET AUXFLAG TO 1.         |
|          | MASK   | AUXFLBIT |                             |
|          | ADS    | FLAGWRD6 |                             |
|          | TCF    | USEJETS  |                             |
| LOTHRUST | TC     | QUIKFAZ5 |                             |
|          | CCS    | DVCNTR   |                             |
|          | TCF    | DECCNTR  |                             |
|          | CCS    | PHASE4   | # COMFAIL JOB ACTIVE?       |
|          | TCF    | SERVOUT  | # YES: WON'T NEED ANOTHER.  |
|          | TC     | PHASCHNG | # 4.37SPOT FOR COMFAIL.     |
|          | OCT    | 00374    |                             |
|          | CAF    | PRI025   |                             |
|          | TC     | NOVAC    |                             |
|          | EBANK= | WHICH    |                             |
|          | 2CADR  | COMFAIL  |                             |
|          | TCF    | SERVOUT  |                             |
| DECCNTR  | TS     | DVCNTR1  |                             |
|          | TC     | QUIKFAZ5 |                             |
|          | CA     | DVCNTR1  |                             |

```

# Page 863
USEJETS
SERVOUT
    TS      DVCNTR
    INHINT
    TC      IBNKCALL      # IF THRUST IS LOW, NO STEERING IS DONE
    CADR    STOPRATE      # AND THE DESIRED RATES ARE SET TO ZERO.
    CS      DAPBOOLS
    MASK    USEQRJTS
    ADS     DAPBOOLS
    RELINT
    TC      BANKCALL
    CADR    1/ACCS
    CA      PRIORITY
    MASK    LOW9
    TS      PUSHLOC
    ZL
    DXCH    FIXLOC      # FIXLOC AND DVFIND
    TC      QUIKFAZ5
    EXTEND
    DCA     AVGEXIT      # EXIT TO SELECTED ROUTINE WHETHER THERE
    DXCH    Z            # IS THRUST OR NOT.  THE STATE OF STEERSW
                        # WILL CONVEY THIS INFORMATION.
XNBPIPAD
    ECADR   XNBPIP
    BANK    32
    SETLOC  SERV2
    BANK
    COUNT*  $$/SERV
AVGEND
    CA      PIPTIME +1    # FINAL AVERAGE G EXIT
    TS      1/PIPADT      # SET UP FREE FALL GYRO COMPENSATION.
    TC      UPFLAG      # SET DRIFT FLAG.
    ADRES   DRIFTFLG
    TC      BANKCALL
    CADR    PIPFREE
    CS      BIT9
    EXTEND
    WAND    DSALMOUT
    TC      2PHSCHNG
    OCT     5            # GROUP 5 OFF
    OCT     05022        # GROUP 2 ON

```



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```
OCT      20000

TC      INTPRET
SET      CLEAR
          NOR29FLG      # SHUT OFF R29 WHEN SERVICER ENDS.
          SWANDISP      # SHUT OFF R10 WHEN SERVICER ENDS.
CLEAR    CALL          # RESET MUNFLAG.
          MUNFLAG

# Page 864

          AVETOMID
CLEAR    EXIT
          V37FLAG

AVERTRN  CA      OUTROUTE      # RETURN TO DESIRED POINT.
          TC      BANKJUMP

OUTGOAVE =      AVERTRN
DVCNTR1  =      MASS1

# Page 865

SETLOC   SERV3
BANK
COUNT*  $$/SERV

SERVIDLE EXTEND
          DCA      SVEXTADR
          DXCH     AVGEXIT

          CS      FLAGWRD7      # DISCONNECT THE DELTA-V MONITOR
          MASK     IDLEFBIT
          ADS      FLAGWRD7

          CAF      LRBYBIT      # TERMINATE R12 IS RUNNING.
          TS      FLGWRD11

          EXTEND
          DCA      NEG0
          DXCH     -PHASE1

          CA      FLAGWRD6      # DO NOT TURN OFF PHASE 2 IF MUNFLAG SET.
          MASK     MUNFLBIT
          CCS      A
          TCF      +4

          EXTEND
          DCA      NEG0
          DXCH     -PHASE2
```

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|            |        |           |                                                                                                                                                                                                |
|------------|--------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| +4         | EXTEND |           |                                                                                                                                                                                                |
|            | DCA    | NEGO      |                                                                                                                                                                                                |
|            | DXCH   | -PHASE3   |                                                                                                                                                                                                |
|            | EXTEND |           |                                                                                                                                                                                                |
|            | DCA    | NEGO      |                                                                                                                                                                                                |
|            | DXCH   | -PHASE6   |                                                                                                                                                                                                |
|            | CAF    | OCT33     | # 4.33SPOT FOR GOP00FIX                                                                                                                                                                        |
|            | TS     | L         |                                                                                                                                                                                                |
|            | COM    |           |                                                                                                                                                                                                |
|            | DXCH   | -PHASE4   |                                                                                                                                                                                                |
|            | TCF    | WHIMPER   | # PERFORM A SOFTWARE RESTART AND PROCEED<br># TO GOTOP00H WHILE SERVICER CONTINUES TO<br># RUN, ALBEIT IN A GROUND STATE WHERE<br># ONLY STATE-VECTOR DEPENDENT FUNCTIONS<br># ARE MAINTAINED. |
|            | EBANK= | DVCNTR    |                                                                                                                                                                                                |
| # Page 866 | 2CADR  | SERVEXIT  |                                                                                                                                                                                                |
|            | BANK   | 32        |                                                                                                                                                                                                |
|            | SETLOC | SERV      |                                                                                                                                                                                                |
|            | BANK   |           |                                                                                                                                                                                                |
|            | COUNT* | \$\$/SERV |                                                                                                                                                                                                |
| SERVEXIT   | TC     | PHASCHNG  |                                                                                                                                                                                                |
|            | OCT    | 00035     |                                                                                                                                                                                                |
| +2         | TCF    | ENDOFJOB  |                                                                                                                                                                                                |
|            | BANK   | 23        |                                                                                                                                                                                                |
|            | SETLOC | NORMLIZ   |                                                                                                                                                                                                |
|            | BANK   |           |                                                                                                                                                                                                |
|            | COUNT* | \$\$/SERV |                                                                                                                                                                                                |
| # Page 867 | TC     | INTPRET   |                                                                                                                                                                                                |
| NORMLIZE   | VLOAD  | BOFF      |                                                                                                                                                                                                |
|            |        | RN1       |                                                                                                                                                                                                |
|            |        | MUNFLAG   |                                                                                                                                                                                                |
|            |        | NORMLIZ1  |                                                                                                                                                                                                |

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```

VSL6      MXV
          REFSMMAT
STCALL    R
          MUNGRAV
VLOAD     VSL1
          VN1
MXV
          REFSMMAT
STOVL     V
          V(CSM)
VXV       UNIT
          R(CSM)
STORE     UHYP
ASCSPOT   EXIT
          EXTEND
          DCA      NEG0
          DXCH     -PHASE2

          TC       POSTJUMP
          CADR     NORMLIZ2

          BANK     33
          SETLOC   SERVICES
          BANK
          COUNT*   $$/SERV

NORMLIZ1  CALL
          CALCGRAV
          EXIT

NORMLIZ2  CA       EIGHTEEN
          TC       COPYCYC +1
          TC       ENDOFJOB
          # DO NOT COPY MASS IN NORMLIZE

COPYCYC   CA       OCT24
          +1      INHINT
          +2      MASK    NEG1
          TS       ITEMP1
          # REDUCE BY 1 IF ODD
          EXTEND
          INDEX    ITEMP1
          DCA      RN1
          INDEX    ITEMP1

# Page 868
          DXCH     RN
          CCS      ITEMP1
          TCF      COPYCYC +2
```

```

                                TC      Q      # RETURN UNDER INHINT

EIGHTEEN      DEC      18

# Page 869
# ***** PIPA READER *****
# MOD NO. 00 BY D. LICKLY, DEC. 9 1966
#
# FUNCTIONAL DESCRIPTION
#     SUBROUTINE TO READ PIPA COUNTERS, TRYING TO BE VERY CAREFUL SO THAT WILL BE P
#     PIPA READINGS ARE STORED IN THE VECTOR DELV.  THE HIGH ORDER PART OF EACH COM
#     RESTARTS BEGIN AT REREADAC.
#
#     AT THE END OF THE PIPA READER THE CDUS ARE READ AND STORED AS A
#     VECTOR IN CDUTEMP.  THE HIGH ORDER PART OF EACH COMPONENT CONTAINS
#     THE CDU READING IN 25 COMP IN THE ORDER CDUX,Y,Z.  THE THRUST
#     VECTOR ESTIMATOR IN FINDCDUD REQUIRES THE CDUS BE READ AT PIPTIME.
#
# CALLING SEQUENCE AND EXIT
#     CALL VIA TC, ISWCALL, ETC.
#     EXIT IS VIA Q.
#
# INPUT
#     INPUT IS THROUGH THE COUNTERS PIPAX, PIPAY, PIPAZ, AND TIME2.
#
# OUTPUT
#     HIGH ORDER COMPONENTS OF THE VECTOR DELV CONTAIN THE PIPA READINGS.
#     PIPTIME CONTAINS TIME OF PIPA READING.
#
# DEBRIS (ERASABLE LOCATIONS DESTROYED BY PROGRAM)
#     TEMX, TEMY, TEMZ, PIPAGE

                                BANK      37
                                SETLOC    SERV1
                                BANK

                                COUNT*   $$/SERV

PIPASR      EXTEND
# Page 870

                                DCA      TIME2
                                DXCH     PIPTIME1      # CURRENT TIME POSITIVE VALUE
                                +3      CS      ZERO      # INITIALIZE THESE AT NEG. ZERO.
                                TS      TEMX
                                TS      TEMY
                                TS      TEMZ

```

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```

      CA      ZERO
      TS      DELVZ
      TS      DELVZ +1
      TS      DELVY
      TS      DELVY +1
      TS      DELVX +1
      TS      PIPAGE      # SHOW PIPA READING IN PROGRESS

REPIP1      EXTEND
      DCS      PIPAX      # X AND Y PIPS READ
      DXCH      TEMX
      DXCH      PIPAX      # PIPAS SET TO NEG ZERO AS READ.
      TS      DELVX
      LXCH      DELVY

REPIP3      CS      PIPAZ      # REPEAT PROCESS FOR Z PIP
      XCH      TEMZ
      XCH      PIPAZ
DODELVZ      TS      DELVZ

REPIP4      EXTEND      # COMPUTE GUIDANCE PERIOD
      DCA      PIPTIME1
      DXCH      PGUIDE
      EXTEND
      DCS      PIPTIME
      DAS      PGUIDE

      CA      CDUX      # READ CDUS INTO HIGH ORDER CDUTEMPS
      TS      CDUTEMPX
      CA      CDUY
      TS      CDUTEMPY
      CA      CDUZ
      TS      CDUTEMPZ
      CA      DELVX
      TS      PIPATMPX
      CA      DELVY
      TS      PIPATMPY
      CA      DELVZ
      TS      PIPATMPZ

      TC      Q

# Page 871
REREADAC      CCS      PIPAGE
      TCF      READACCS      # PIP READING NOT STARTED.  GO TO BEGINNING
```

|            |        |          |                                         |
|------------|--------|----------|-----------------------------------------|
|            | CAF    | DONEADR  | # SET UP RETURN FROM PIPASR             |
|            | TS     | Q        |                                         |
|            | CCS    | DELVZ    |                                         |
|            | TCF    | REPIP4   | # Z DONE, GO DO CDUS                    |
|            | TCF    | +3       | # Z NOT DONE, CHECK Y.                  |
|            | TCF    | REPIP4   |                                         |
|            | TCF    | REPIP4   |                                         |
|            | ZL     |          |                                         |
|            | CCS    | DELVY    |                                         |
|            | TCF    | +3       |                                         |
|            | TCF    | CHKTEMX  | # Y NOT DONE, CHECK X.                  |
|            | TCF    | +1       |                                         |
|            | LXCH   | PIPAZ    | # Y DONE, ZERO Z PIP.                   |
|            | CCS    | TEMZ     |                                         |
|            | CS     | TEMZ     | # TEMZ NOT = -0, CONTAINS -PIPAZ VALUE. |
|            | TCF    | DODELVZ  |                                         |
|            | TCF    | -2       |                                         |
|            | LXCH   | DELVZ    | # TEMZ = -0, L HAS ZPIP VALUE.          |
|            | TCF    | REPIP4   |                                         |
| CHKTEMX    | CCS    | TEMX     | # HAS THIS CHANGED                      |
|            | CS     | TEMX     | # YES                                   |
|            | TCF    | +3       | # YES                                   |
|            | TCF    | -2       | # YES                                   |
|            | TCF    | REPIP1   | # NO                                    |
|            | TS     | DELVX    |                                         |
|            | CS     | TEMY     |                                         |
|            | TS     | DELVY    |                                         |
|            | CS     | ZERO     | # ZERO X AND Y PIPS                     |
|            | DXCH   | PIPAX    | # L STILL ZERO FROM ABOVE               |
|            | TCF    | REPIP3   |                                         |
| DONEADR    | GENADR | PIPSDONE |                                         |
| # Page 872 |        |          |                                         |
|            | BANK   | 33       |                                         |
|            | SETLOC | SERVICES |                                         |
|            | BANK   |          |                                         |

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```

COUNT*  $$/SERV

TMPTOSPT  CA      CDUTEMPY      # THIS SUBROUTINE, CALLED BY AN RTB FROM
          TS      CDUSPOTY      # INTERPRETIVE, LOADS THE CDUS CORRESPON-
          CA      CDUTEMPZ      # DING TO PIPTIME INTO THE CDUSPOT VECTOR.
          TS      CDUSPOTZ
          CA      CDUTEMPX
          TS      CDUSPOTX
          TC      Q

# LRHTASK IS A WAITLIST TASK SET BY READACCS DURING THE DESCENT BRAKING
# PHASE WHEN THE ALT TO THE LUNAR SURFACE IS LESS THAN 25,000 FT.  THIS
# TASK CLEARS THE ALTITUDE MEASUREMENT MADE DISCRETE AND INITIATES THE
# LANDING RADAR MEASUREMENT JOB (LRHJOB) TO TAKE A ALTITUDE MEASUREMENT
# 50 MS PRIOR TO THE NEXT READACCS TASK.

          BANK     21
          SETLOC   R10
          BANK

COUNT*  $$/SERV

LRHTASK   CS      FLGWRD11
          MASK     LRBYBIT
          EXTEND
          BZF      GRP2OFF      # LR BYPASS SET -- BYPASS ALL LR READING.

          CA      READLBIT
          MASK     FLGWRD11      # IS READLR FLAG SET?
          EXTEND
          BZF      GRP2OFF      # NO.  BYPASS LR READ.

          CS      FLGWRD11
          MASK     NOLRRBIT      # IS LR READ INHIBITED?
          EXTEND
          BZF      GRP2OFF      # YES.  BYPASS LR READ.

          CA      PRI032      # LR READ OK.  SET JOB TO DO IT
          TC      NOVAC      # ABOUT 50 MS. PRIOR TO PIPA READ.
          EBANK=   HMEAS
          2CADR    LRHJOB

GRP2OFF   EXTEND
          DCA      NEG0
          DXCH     -PHASE2
          TCF      R10,R11A
```

BANK 33  
 SETLOC SERVICES  
 BANK

# Page 873

COUNT\* \$\$/SERV

# HIGATASK IS ENTERED APPROXIMATELY 6 SECS PRIOR TO HIGATE DURING THE  
 # DESCENT PHASE. HIGATASK SETS THE HIGATE FLAG (BIT11) AND THE LR INHIBIT  
 # FLAG (BIT10) IN LRSTAT. THE HIGATJOB IS SET UP TO REPOSITION THE LR  
 # ANTENNA FROM POSITION 1 TO POSITION 2. IF THE REPOSITIONING IS  
 # SUCCESSFUL THE ALT BEAM AND VELOCITY BEAMS ARE TRANSFORMED TO THE NEW  
 # ORIENTATION IN NB COORDINATES AND STORED IN ERASABLE.

|          |          |                                   |
|----------|----------|-----------------------------------|
| HIGATASK | INHINT   |                                   |
| CS       | PRI03    | # SET HIGATE AND LR INHIBIT FLAGS |
| MASK     | FLGWRD11 |                                   |
| AD       | PRI03    |                                   |
| TS       | FLGWRD11 |                                   |
| CAF      | PRI032   |                                   |
| TC       | FINDVAC  | # SET LR POSITIONING JOB (POS2)   |
| EBANK=   | HMEAS    |                                   |
| 2CADR    | HIGATJOB |                                   |
| TCF      | CONTSERV | # CONTINUE SERVICER               |

# Page 874

# MUNRETRN IS THE RETURN LOC FROM SPECIAL AVE G ROUTINE (MUNRVG)

|          |          |                                         |
|----------|----------|-----------------------------------------|
| MUNRETRN | EXIT     |                                         |
| CS       | FLGWRD11 |                                         |
| MASK     | LRBYBIT  |                                         |
| EXTEND   |          |                                         |
| BZF      | COPYCYC1 | # BYPASS LR LOGIC IF BIT15 IS SET.      |
| CA       | READLBIT | # SEE IF ALT < 35000 FT LAST CYCLE      |
| MASK     | FLGWRD11 |                                         |
| EXTEND   |          |                                         |
| BZF      | 35KCHK   | # ALT WAS > 35000 FT LAST CYCLE CHK NOW |
| CAF      | XORFLBIT | # WERE WE BELOW 30000 FT LAST PASS?     |
| MASK     | FLGWRD11 |                                         |
| EXTEND   |          |                                         |
| BZF      | XORCHK   | # NO -- TEST THIS PASS                  |
| HITEST   | CAF      | PSTHIBIT # CHECK FOR HIGATE             |



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```

                                MASK    FLGWRD11
                                EXTEND
                                BZF      HIGATCHK      # NOT AT HIGATE LAST CYCLE -- CHK THIS CYCLE

POS2CHK                        CAF      BIT7           # VERIFY LR IN POS2
                                EXTEND
                                RAND      CHAN33
                                EXTEND
                                BZF      UPDATCHK      # IT IS -- CHECK FOR LR UPDATE
                                CAF      BIT13
                                EXTEND
                                RAND      CHAN12
                                EXTEND
                                BZF      LRPOSALM      # LR NOT IN POS2 OR REPOSITIONING -- BAD
                                TCF      CONTSERV      # LR BEING REPOSITIONED -- CONTINUE SERV

HIGATCHK                      CA        TTF/8         # IS TTF > CRITERION? (TTF IS NEGATIVE)
                                AD        RPCRTIME
                                EXTEND
                                BZMF     POS1CHK       # NO

                                CA        EBANK4       # MUST SWITCH EBANKS
                                XCH      EBANK
                                TS       L            # SAVE IN L

                                EBANK=   XNBPIP
                                CS       XNBPIP       # UXBXP IN GSOP CH5
                                EBANK=   DVCNTR
                                LXCH     EBANK        # RESTORE EBANK
                                AD       RPCRTQSW     # QSW - UXBXP

# Page 875

                                EXTEND
                                BZMF     HIGATASK      # IF UXBXP > QSW, THEN REPOSITION

POS1CHK                       CAF      BIT6           # HIGATE NOT IN SIGHT -- DO POS1 CHK
                                EXTEND
                                RAND      33
                                EXTEND
                                BZF      UPDATCHK      # LR IN POS1 -- CHECK FOR LR UPDATE

LRPOSALM                      TC        ALARM        # LR NOT IN PROPER POS-ALARM-BYPASS UPDATE
                                OCT      511          # AND CONTINUE SERVICER

CONTSERV                      INHINT
                                CS       BITS4-7
                                MASK     FLGWRD11     # CLEAR LR MEASUREMENT MADE DISCRETES.
```

|                        |        |          |                                            |
|------------------------|--------|----------|--------------------------------------------|
|                        | TS     | FLGWRD11 |                                            |
|                        | TC     | IBNKCALL | # SET LR LITES PROPERLY                    |
|                        | CADR   | R12LITES |                                            |
| # Page 876<br>COPYCYC1 | TC     | QUIKFAZ5 |                                            |
| R29?                   | CA     | FLAGWRD3 |                                            |
|                        | MASK   | NR29&RDR |                                            |
|                        | CCS    | A        | # IS NOR29FLG OR READRFLG SET?             |
|                        | TCF    | R29NODES | # YES, SO DON'T DESIGNATE.                 |
|                        | CA     | RADMODES | # NO, SO R29 IS CALLED FOR.                |
|                        | MASK   | OCT10002 | # IS THE RR NOT ZEROING ITS CDUS, AND      |
|                        | CCS    | A        | # IS THE RENDEZVOUS RADAR IN AUTO MODE?    |
|                        | TCF    | R29NODES | # NO, SO DON'T DESIGNATE.                  |
|                        | CA     | RADMODES |                                            |
|                        | MASK   | PRI022   |                                            |
|                        | CCS    | A        | # IS RR REPOSITIONING OR REMODING?         |
|                        | TCF    | NOR29NOW | # YES: COME BACK IN 2 SECONDS & TRY AGAIN. |
|                        | TCF    | R29      |                                            |
| R29NODES               | INHINT |          | # R29 NOT ALLOWED THIS CYCLE.              |
|                        | CS     | DESIGBIT | # SHOW THAT DESIGNATION IS OFF.            |
|                        | MASK   | RADMODES |                                            |
|                        | TS     | RADMODES |                                            |
| NOR29NOW               | TC     | INTPRET  | # INTERPRET DOES A RELINT.                 |
|                        | VLOAD  | ABVAL    | # MPAC = ABVAL( NEW SM. POSITION VECTOR )  |
|                        |        | R1S      |                                            |
|                        | PUSH   | DSU      | # (2)                                      |
|                        |        | /LAND/   |                                            |
|                        | STORE  | HCALC    | # NEW HCALC*2(24)M.                        |
|                        | STORE  | HCALC1   |                                            |
|                        | DMPR   | RTB      |                                            |
|                        |        | ALTCONV  |                                            |
|                        |        | SGNAGREE |                                            |
|                        | STOVL  | ALTBITS  | # ALTITUDE FOR R10 IN BIT UNITS.           |
|                        |        | UNIT/R/  |                                            |
|                        | VXV    | UNIT     |                                            |
|                        |        | UHYP     |                                            |
|                        | STOVL  | UHYP     | # DOWNRANGE HALF-UNIT VECTOR FOR R10.      |
|                        |        | R1S      |                                            |

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```

VXM      VSR4
          REFSMMAT
STOVL    RN1      # TEMP. REF. POSITION VECTOR*2(29)M.
          V1S
VXM      VSL1
          REFSMMAT
STOVL    VN1      # TEMP. REF. VELOCITY VECTOR 2(7) M/CS.
          UNIT/R/
VXV      ABVAL

# Page 877

          V1S
SL1      DSQ
DDV
DMPR     RTB
          ARCONV1
          SGNAGREE

COPYCYC2 EXIT      # LEAVE ALTITUDE RATE COMPENSATION IN MPAC
          INHINT
CA       UNIT/R/   # UPDATE RUNIT FOR R10.
TS       RUNIT
CA       UNIT/R/ +2
TS       RUNIT +1
CA       UNIT/R/ +4
TS       RUNIT +2
CA       MPAC      # LOAD NEW DALTRATE FOR R10.
TS       DALTRATE

EXTEND
DCA      R1S
DXCH     R
EXTEND
DCA      R1S +2
DXCH     R +2
EXTEND
DCA      R1S +4
DXCH     R +4
EXTEND
DCA      V1S
DXCH     V
EXTEND
DCA      V1S +2
DXCH     V +2
EXTEND
DCA      V1S +4
DXCH     V +4
```

TCF COPYCYCL # COMPLETE THE COPYCYCL.

# Page 878

# ALTCHK COMPARES CURRENT ALTITUDE (IN HCALC) WITH A SPECIFIED ALTITUDE FROM A TABLE  
# ITS CALLING SEQUENCE IS AS FOLLOWS:-

#  
# L CAF N  
# L+1 TC BANKCALL  
# L+2 CADR ALTCHK  
# L+3 RETURN HERE IF HCALC STILL > SPECIFIED CRITERION. C(L) = +0.  
# L+4 RETURN HERE IF HCALC < OR = SPECIFIED CRITERION. C(A) = C(L) = +0  
#  
# ALTCHK MUST BE BANKCALLED EVEN FROM ITS OWN BANK. N IS THE LOCATION, RELATIVE TO  
# OF THE BEGINNING OF THE DP CONSTANT TO BE USED AS A CRITERION.

|          |        |            |                               |
|----------|--------|------------|-------------------------------|
| ALTCHK   | EXTEND |            |                               |
|          | INDEX  | A          |                               |
|          | DCA    | ALTCRIT    |                               |
|          | DXCH   | MPAC +1    |                               |
|          | EXTEND |            |                               |
|          | DCS    | HCALC      |                               |
|          | DAS    | MPAC +1    |                               |
|          | TC     | BRANCH +4  |                               |
|          | CAF    | ZERO       | # BETTER THAN A NOOP, PERHAPS |
|          | INCR   | BUF2       |                               |
|          | TCF    | SWRETURN   |                               |
| ALTCRIT  | =      | 25KFT      |                               |
| 25KFT    | 2DEC   | 7620 B-24  | # (0)                         |
| 50KFT    | 2DEC   | 15240 B-24 | # (2)                         |
| 50FT     | 2DEC   | 15.24 B-24 | # (4)                         |
| 30KFT    | 2DEC   | 9144 B-24  | # (6)                         |
| 2KFT/SEC | DEC    | 6.096 B-7  | # 2000 FT/SEC AT 2(7) M/CS    |

# (A remark was likely to be needed here to explain XORCHK) 4/Jun/09,FB

|        |      |          |                          |
|--------|------|----------|--------------------------|
| XORCHK | CAF  | SIX      | # ARE WE BELOW 30000 FT? |
|        | TC   | BANKCALL |                          |
|        | CADR | ALTCHK   |                          |
|        | TCF  | HITEST   | # CONTINUE LR UPDATE     |

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|        |       |          |                                |
|--------|-------|----------|--------------------------------|
|        | TC    | UPFLAG   | # YES: INHIBIT X-AXIS OVERRIDE |
|        | ADRES | XOVINFLG |                                |
|        | TC    | UPFLAG   |                                |
|        | ADRES | XORFLG   |                                |
|        | TCF   | HITEST   | # CONTINUE LR UPDATE           |
| 35KCHK | CAF   | TWO      | # ARE WE BELOW 35000 FT?       |

# Page 879

|  |       |          |                                         |
|--|-------|----------|-----------------------------------------|
|  | TC    | BANKCALL |                                         |
|  | CADR  | ALTCHK   |                                         |
|  | TCF   | CONTSERV |                                         |
|  | TC    | UPFLAG   |                                         |
|  | ADRES | READLR   | # SET READLR FLAG TO ENABLE LR READING. |
|  | TCF   | CONTSERV |                                         |

# Page 880

# \*\*\*\*\*

|         |       |          |                                         |      |
|---------|-------|----------|-----------------------------------------|------|
| CALCGRV | UNIT  | PUSH     | # SAVE UNIT/R/ IN PUSHLIST              | (18) |
|         | STORE | UNIT/R/  |                                         |      |
|         | LXC,1 | SLOAD    | # RTX2 = 0 IF EARTH ORBIT, =2 IF LUNAR. |      |
|         |       | RTX2     |                                         |      |
|         |       | RTX2     |                                         |      |
|         | DCOMP | BMN      |                                         |      |
|         |       | CALCGRV1 |                                         |      |
|         | VLOAD | DOT      | #                                       | (12) |
|         |       | UNITZ    |                                         |      |
|         |       | UNIT/R/  |                                         |      |
|         | SL1   | PUSH     | #                                       | (14) |
|         | DSQ   | BDSU     |                                         |      |
|         |       | DP1/20   |                                         |      |
|         | PDDL  | DDV      |                                         |      |
|         |       | RESQ     |                                         |      |
|         |       | 34D      | # (RN)SQ                                |      |
|         | STORE | 32D      | # TEMP FOR (RE/RN)SQ                    |      |
|         | DMP   | DMP      |                                         |      |
|         |       | 20J      |                                         |      |
|         | VXSC  | PDDL     |                                         |      |
|         |       | UNIT/R/  |                                         |      |
|         | DMP   | DMP      |                                         |      |
|         |       | 2J       |                                         |      |
|         |       | 32D      |                                         |      |
|         | VXSC  | VSL1     |                                         |      |
|         |       | UNITZ    |                                         |      |
|         | VAD   | STADR    |                                         |      |

```

                                STORE  UNITGOBL
                                VAD    PUSH
CALCGRV1                      DLOAD  NORM      # MPAC = UNIT GRAVITY VECTOR.  (18)
                                34D      # PERFORM A NORMALIZATION ON RMAGSQ IN
                                X2       # ORDER TO BE ABLE TO SCALE THE MU FOR
                                BDDV*   SLR*      # MAXIMUM PRECISION.
                                -MUDT,1
                                0 -21D,2
                                VXSC    STADR
                                STORE   GDT1/2    # SCALED AT 2(+7) M/CS
                                RVQ

CALCRVG                      VLOAD  VXM
                                DELV
                                REFSMMAT
                                VXSC    VSL1
                                KPIP1
                                STORE   DELVREF
                                VSR1    PUSH
                                VAD     PUSH      # (DV-OLDGDT)/2 TO PD SCALED AT 2(+7) M/CS.

# Page 881

                                GDT/2
                                VAD     PDDL
                                VN
                                PGUIDE
                                SL      VXSC
                                6D
                                VAD     STQ
                                RN
                                31D
                                STCALL  RN1      # TEMP STORAGE OF RN SCALED 2(+29) M
                                CALCGRAV

                                VAD     VAD
                                VAD
                                VN
                                STCALL  VN1      # TEMP STORAGE OF VN SCALED 2(+7) M/CS
                                31D

DP1/20                      2DEC    0.05
SHIFT11                     2DEC    1 B-11

```

# Page 882

```

*****
# MUNRVG IS A SPECIAL AVERAGE G INTEGRATION ROUTINE USED BY THRUSTING
# PROGRAMS WHICH FUNCTION IN THE VICINITY OF AN ASSUMED SPHERICAL MOON.

```

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# THE INPUT AND OUTPUT QUANTITIES ARE REFERENCED TO THE STABLE MEMBER  
# COORDINATE SYSTEM.

|        |        |          |                                           |
|--------|--------|----------|-------------------------------------------|
| RVBOTH | VLOAD  | PUSH     |                                           |
|        |        | G(CSM)   |                                           |
|        | VAD    | PDDL     |                                           |
|        |        | V(CSM)   |                                           |
|        |        | PGUIDE   |                                           |
|        | DDV    | VXSC     |                                           |
|        |        | SHIFT11  |                                           |
|        | VAD    |          |                                           |
|        |        | R(CSM)   |                                           |
|        | STCALL | R1S      |                                           |
|        |        | MUNGRAV  |                                           |
|        | VAD    | VAD      |                                           |
|        |        | V(CSM)   |                                           |
|        | STADR  |          |                                           |
|        | STORE  | V1S      |                                           |
|        | EXIT   |          |                                           |
|        | TC     | QUIKFAZ5 |                                           |
|        | TC     | INTPRET  |                                           |
|        | VLOAD  |          |                                           |
|        |        | GDT1/2   |                                           |
|        | STOVL  | G(CSM)   |                                           |
|        |        | R1S      |                                           |
|        | STOVL  | R(CSM)   |                                           |
|        |        | V1S      |                                           |
|        | STORE  | V(CSM)   |                                           |
|        | EXIT   |          |                                           |
|        | TC     | QUIKFAZ5 |                                           |
|        | TC     | INTPRET  |                                           |
| MUNRVG | VLOAD  | VXSC     |                                           |
|        |        | DELV     |                                           |
|        |        | KPIP2    |                                           |
|        | PUSH   | VAD      | # 1ST PUSH: DELV IN UNITS OF 2(8) M/CS    |
|        |        | GDT/2    |                                           |
|        | PUSH   | VAD      | # 2ND PUSH: (DELV + GDT)/2, UNITS OF 2(7) |
|        |        | V        | # (12)                                    |
|        | PDDL   | DDV      |                                           |
|        |        | PGUIDE   |                                           |
|        |        | SHIFT11  |                                           |
|        | VXSC   |          |                                           |
|        | VAD    |          |                                           |
|        |        | R        |                                           |
|        | STCALL | R1S      | # STORE R SCALED AT 2(+24) M              |
|        |        | MUNGRAV  |                                           |

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|          |        |            |                                            |
|----------|--------|------------|--------------------------------------------|
|          | VAD    | VAD        |                                            |
|          | VAD    |            |                                            |
|          |        | V          |                                            |
|          | STORE  | V1S        | # STORE V SCALED AT 2(+7) M/CS.            |
|          | ABVAL  |            |                                            |
|          | STOVL  | ABVEL      | # STORE SPEED FOR LR AND DISPLAYS.         |
|          |        | UNIT/R/    |                                            |
|          | DOT    | SL1        |                                            |
|          |        | V1S        |                                            |
|          | STOVL  | HDOTDISP   | # HDOT = V. UNIT(R)*2(7) M/CS.             |
|          |        | R1S        |                                            |
|          | VXV    | VSL2       |                                            |
|          |        | WM         |                                            |
|          | STODL  | DELVS      | # LUNAR ROTATION CORRECTON TERM*2(5) M/CS. |
|          |        | 36D        |                                            |
|          | DSU    |            |                                            |
|          |        | /LAND/     |                                            |
|          | STCALL | HCALC      | # FOR NOW, DISPLAY WHETHER POS OR NEG      |
|          |        | MUNRETRN   |                                            |
| MUNGRAV  | UNIT   |            | # AT 36D HAVE ABVAL(R), AT 34D R.R         |
|          | STODL  | UNIT/R/    |                                            |
|          |        | 34D        |                                            |
|          | SL     | BDDV       |                                            |
|          |        | 6D         |                                            |
|          |        | -MUDTMUN   |                                            |
|          | DMP    | VXSC       |                                            |
|          |        | SHIFT11    |                                            |
|          |        | UNIT/R/    |                                            |
|          | STORE  | GDT1/2     | # 1/2GDT SCALED AT 2(7) M/CS.              |
|          | RVQ    |            |                                            |
| 1.95SECS | DEC    | 195        |                                            |
| 7.5      | 2DEC   | .02286 B-6 | # 7.5 FT/SEC AT 2(6) M/CS                  |
| 2SEC(18) | 2DEC   | 200 B-18   |                                            |
| 2SEC(28) | 2OCT   | 0000000310 | # 2SEC AT 2(28)                            |
| 4SEC(28) | 2DEC   | 400 B-28   |                                            |
| BITS4-7  | OCT    | 110        |                                            |

# Page 884

|          |     |          |                               |
|----------|-----|----------|-------------------------------|
| UPDATCHK | CAF | NOLRRBIT | # SEE IF LR UPDATE INHIBITED. |
|----------|-----|----------|-------------------------------|



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```

                                MASK    FLGWRD11
                                CCS      A
                                TCF      CONTSERV      # IT IS -- NO LR UPDATE
                                CAF      RANGEDBIT      # NO INHIBIT -- SEE ALT MEAS. THIS CYCLE.
                                MASK      FLGWRD11
                                EXTEND
                                BZF      VMEASCHK      # NO ALT MEAS THIS CYCLE -- CHECK FOR VEL

POSUPDAT      CA      FIXLOC      # SET PUSHLIST TO ZERO
              TS      PUSHLOC

              TC      INTPRET
              VLOAD    VXM
                   HBEAMNB
                   XNBPIP      # HBEAM SM AT 2(2)
              PDVL    VSL2      # STORE HBEAM IN PD 0-5
                   V1S        # SCALE V AT 2(5) M/CS
              VAD      DOT
                   DELVS      # V RELATIVE TO SURFACE AT 2(5) M/CS
                   OD        # V ALONG HBEAM AT 2(7) M/CS.
              DMP      EXIT
                   RADSKAL    # SCALE TO RADAR COUNTS X 5

              CS      FLGWRD12      # TEST LR ALTITUDE SCALE FACTOR
              MASK      ALTSCBIT
              EXTEND
              BZF      +3      # BRANCH IF HIGH SCALE

              CA      SKALSKAL      # RESCALE IF LOW SCALE
              TC      SHORTMP

+3            TC      INTPRET
              DAD      SL
                   HMEAS
                   7D
              DMP      VXSC      # SLANT RANGE AT 2(21), PUSH UP FOR HBEAM
                   HSCAL      # SLANT RANGE VECTOR AT 2(23) M
              DOT      DSU
                   UNIT/R/      # ALTITUDE AT 2(24) M
                   HCALC      # DELTA H AT 2(24) M
              STORE    DELTAH
              EXIT

              CA      FLGWRD11
              MASK      PSTHIBIT
              EXTEND      # DO NOT PERFORM DATA REASONABLENESS TEST
```

```

# Page 885
BZF      NOREASON      # UNTIL AFTER HIGATE

TC        INTPRET
ABS       DSU
          DELQFIX      # ABS(DELTAH) - DQFIX    50 FT NOM
SL3       DSU          # SCALE TO 2(21)
          HCALC        # ABS(DELTAH) - (50 + HCALC/8) AT 2(21)
EXIT

INCR      LRLCTR
TC        BRANCH
TCF       HFAIL        # DELTA H TOO LARGE
TCF       HFAIL        # DELTA H TOO LARGE
TC        DOWNFLAG     # TURN OFF ALT FAIL LAMP
ADRES     HFLSHFLG

NOREASON  CS          FLGWRD11
          MASK        LRINHBIT
          CCS         A
          TCF         VMEASCHK      # UPDATE INHIBITED -- TEST VELOCITY ANYWAY

          TC          INTPRET      # DO POSITION UPDATE
          DLOAD       SR4
          HCALC        # RESCALE H TO 2(28)M
EXIT
EXTEND
DCA       DELTAH      # STORE DELTAH IN MPAC AND
DXCH      MPAC        # BRING HCALC INTO A,L
TC        ALSIGNAG
EXTEND
BZF       +2          # IF HIGH PART OF HCALC IS NON-ZERO, THEN
          TCF         VMEASCHK     # HCALC > HMAX,
          TS          MPAC +2      # SO UPDATE IS BYPASSED
                                   # FOR LATER SHORTMP

          CS          L           # -H AT 2(14) M
          AD          LRHMAX      # HMAX - H
EXTEND
BZMF      VMEASCHK    # IF H >HMAX, BYPASS UPDATE
EXTEND
MP        LRWH        # WH(HMAX - H)
EXTEND
DV        LRHMAX      # WH(1 - H/HMAX)
TS        MPTMP
TC        SHORTMP2    # DELTAH (WH)(1 - H/HMAX) IN MPAC
TC        INTPRET     # MODE IS DP FROM ABOVE
SL1

```

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```
# Page 886

VXSC      VAD
          UNIT/R/
          R1S      # DELTAR = DH(WH)(1 - H/HMAX) UNIT/R/
STCALL    GNUR
          MUNGRAV
EXIT

TC        QUIKFAZ5

CA        ZERO
RUPDATED  TC      GNURVST

VMEASCHK  TC      QUIKFAZ5      # RESTART AT NEXT LOCATION
          CS      FLGWRD11
          MASK    VELDABIT      # IS V READING AVAILABLE?
          CCS     A
          TCF     VALTCHK      # NO:  SEE IF V READING TO BE TAKEN

VELUPDAT  CS      VSELECT      # PROCESS VELOCITY DATA
          TS      L
          ADS     L      # -2 VSELECT IN L
          AD      L
          AD      L      # -6 VSELECT IN A
          INDEX   FIXLOC
          DXCH    X1      # X1 = -6 VSELECT, X2 = -2 VSELECT

          CA      EBANK4
          TS      EBANK
          EBANK=  LRXCDU

          CA      LRYCDU      # STORE LRCDUS IN CDUSPOTS
          TS      CDUSPOT
          CA      LRZCDU
          TS      CDUSPOT +2
          CA      LRXCDU
          TS      CDUSPOT +4

          TC      BANKCALL
          CADR    QUICTRIG      # GET SINES AND COSINES FOR NBSM

          CA      FIXLOC
          TS      PUSHLOC      # SET PD TO ZERO

          TC      INTERPRET
          VLOAD*  CALL
          VZBEAMNB,1      # CONVERT VBEAM FROM NB TO SM
```

# Page 887

```

                                *NBSM*
PDDL    SL                      # STORE IN PD 0-5
        VMEAS                  # LOAD VELOCITY MEASUREMENT
        12D
DMP*    PUSH                   # SCALE TO M/CS AT 2(6)
        VZSCAL,2              # AND STORE IN PD 6-7

EXIT
CS      ONE
TS      MODE                   # CHANGE STORE MODE TO VECTOR

CA      PIPTM                  # STORE DELV IN MPAC

ZL
DXCH    MPAC

CA      PIPTM +1
ZL
DXCH    MPAC +3

CA      PIPTM +2
ZL
DXCH    MPAC +5

CA      EBANK7
TS      EBANK                  # RESTORE EBANK 7
EBANK=  DVCNTR
TC      INTPRET
VXSC    PDDL
        KPIP1                  # SCALE DELV TO 2(7) M/CS AND PUSH
        LRVTIME                # TIME OF DELV AT 2(28) CS
DSU     DDV
        PIPTIME                 # TU - T(N-1)
        2SEC(28)
VXSC    VSL1                   # G(N-1)(TU - T(N-1))
        GDT/2                   # SCALED AT 2(7) M/CS
VAD     VAD                     # PUSH UP FOR DELV
        V                       # VU = V(N-1) + DELVU + G(N-1) DTU
VSL2    VAD                     # SCALE TO 2(5) M/CS AND SUBTRACT
        DELVS                   # MOON ROTATION.
PUSH    ABVAL                  # STORE IN PD
SR4     DAD                     # ABS(VM)/8 + 7.5 AT 2(6)
        7.5
STOVL   20D                     # STORE IN 20D AND PICK UP VM
DOT     BDSU                    # V(EST) AT 2(6)
        0                       # DELTAV = VMEAS - V(EST)
PUSH    ABS

```

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```

DSU      EXIT      # ABS(DV) - (7.5 + ABS(VM)/8))
          20D

INCR      LRMCTR
TC         BRANCH
TCF        VFAIL   # DELTA V TOO LARGE.      ALARM
TCF        VFAIL   # DELTA V TOO LARGE.      ALARM

TC         DOWNFLAG # TURN OFF VEL FAIL LAMP
ADRES      VFLSHFLG

CA         FLGWRD11
MASK       VXINHBIT
EXTEND
BZF        VUPDAT   # IF VX INHIBIT RESET, INCORPORATE DATA.

# Page 888
TC         DOWNFLAG
ADRES      VXINH    # RESET VX INHIBIT

CA         VSELECT
AD         NEG2      # IF VSELECT = 2 (X AXIS).
EXTEND     # BYPASS UPDATE
BZF        ENDVDAT

VUPDAT
CS         FLGWRD11
MASK       LRINHBIT
CCS        A
TCF        VALTCHK   # UPDATE INHIBITED

TS         MPAC +1

CA         ABVEL     # STORE E7 ERASABLES NEEDED IN TEMPS
TS         ABVEL*
CA         VSELECT
TS         VSELECT*
CA         EBANK5
TS         EBANK     # CHANGE EBANKS

EBANK=     LRVF
CS         LRVF
AD         ABVEL*    # IF V < VF, USE WVF
EXTEND
BZMF       USEVF

CS         ABVEL*
AD         LRVMAX    # VMAX - V
```

```

EXTEND
BZMF  WSTOR -1      # IF V > VMAX, W = 0

EXTEND
INDEX  VSELECT*
MP     LRWVZ        # WV(VMAX - V)

EXTEND
DV     LRVMAX       # WV( 1 - V/VMAX )
TCF    WSTOR

USEVF  INDEX  VSELECT*
CA     LRWVFZ       # USE APPROPRIATE CONSTANT WEIGHT
TCF    WSTOR

      -1  CA     ZERO
WSTOR  TS     MPAC
      CS     BIT7    # (=64D)
      AD     MODREG
      # Page 889
      BZMF   +3      # IF IN P65,P66,P67, USE ANOTHER CONSTANT

      CA     LRWVFF
      TS     MPAC

      +3  CA     EBANK7
      TS     EBANK   # CHANGE EBANKS

      EBANK= ABVEL
      TC     INTERP
      DMP    VXSC    # W(DELTA V)(VBEAMSM) UP 6-7, 0-5
      VAD

      V1S      # ADD WEIGHTED DELTA V TO VELOCITY
      STORE   GNUV
      EXIT

      TC     QUIKFAZ5  # DO NOT RE-UPDATE

      CA     SIX
      VUPDATED TC     GNURVST  # STORE NEW VELOCITY VECTOR
      ENDVDAT  =     VALTCHK

      VALTCHK TC     QUIKFAZ5  # DO NOT REPEAT ABOVE

      CAF    READVBIT  # TEST READVEL TO SEE IF VELOCITY READING

```

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```

      MASK    FLGWRD11      # IS DESIRED.
      CCS      A
      TCF      READV        # YES -- READ VELOCITY
      CS       ABVEL        # NO -- SEE IF VELOCITY < 2000 FT/SEC
      AD       2KFT/SEC
      EXTEND
      BZMF     CONTSERV     # V > 2000 FT/SEC  DO NOT READ VEL

      TC       UPFLAG      # V < 2000 FT/SEC  SET READVEL AND READ.
      ADRES    READVEL

READV      CAF      PRI032  # SET UP JOB TO READ VELOCITY BEAMS.
           TC       NOVAC
           EBANK=    HMEAS
           2CADR     LRVJOB

           TCF      CONTSERV  # CONTINUE WITH SERVICER

GNURVST    TS       BUF     # STORE GNUR (=GNUV) IN R1S OR V1S
           EXTEND
           DCA      GNUR
           INDEX    BUF
           DXCH     R1S
           EXTEND

# Page 890
           DCA      GNUR +2
           INDEX    BUF
           DXCH     R1S +2
           EXTEND
           DCA      GNUR +4
           INDEX    BUF
           DXCH     R1S +4
           TC       Q

QUIKFAZ5   CA       EBANK3
           XCH      EBANK    # SET EBANK 3
           DXCH     L        # Q TO A, A TO L
           EBANK=    PHSNAME5
           TS       PHSNAME5
           LXCH     EBANK
           EBANK=    DVCNTR
           TC       A

HFAIL      CS       LRRCTR
           EXTEND
           BZF      NORLITE  # IF R = 0, DO NOT TURN ON TRK FAIL
```

```

                                AD      LRLCTR
                                MASK     NEG3
                                EXTEND
                                BZF      +2
                                TCF      NORLITE
                                # IF L-R LT 4, DO NOT TURN ON TRK FAIL

                                TC      UPFLAG
                                ADRES    HFLSHFLG
                                # AND SET BIT TO TURN ON TRACKER FAIL LITE

NORLITE                        CA      LRLCTR
                                TS      LRRCTR
                                # SET R = L

                                TCF      VMEASCHK

VFAIL                          CS      LRSCTR
                                EXTEND
                                BZF      NOLITE
                                AD      LRMCTR
                                MASK     NEG3
                                # M-S
                                # TEST FOR M-S > 3
                                EXTEND
                                BZF      +2
                                TCF      NOLITE
                                # IF M-S > 3, THEN TWO OR MORE OF THE
                                #          LAST FOUR V READINGS WERE BAD,
                                #          SO TURN ON VELOCITY FAIL LIGHT

                                TC      UPFLAG
                                ADRES    VFLSHFLG
                                # AND SET BIT TO TURN ON TRACKER FAIL LITE

# Page 891
NOLITE                        CA      LRMCTR
                                TS      LRSCTR
                                # SET S = M

                                CCS      VSELECT
                                TCF      ENDVDAT
                                # TEST FOR Z COMPONENT
                                # NOT Z, DO NOT SET VX INHIBIT

                                TC      UPFLAG
                                ADRES    VXINH
                                TCF      ENDVDAT
                                # Z COMPONENT - SET FLAG TO SKIP X
                                # COMPONENT, AS ERROR MAY BE DUE TO CROSS
                                # LOBE LOCK UP NOT DETECTED ON X AXIS.

# Page 892
# *****
# LRVJOB IS SET WHEN THE LEM IS BELOW 15000 FT DURING THE LANDING PHASE
# THIS JOB INITIALIZES THE LANDING RADAR READ ROUTINE FOR 5 VELOCITY
# SAMPLES AND GOES TO SLEEP WHILE THE SAMPLING IS DONE -- ABOUT 500 MS.
# WITH A GOODEND RETURN THE DATA IS STORED IN VMEAS AND BIT7 OF LRSTAT
# IS SET.  THE GIMBAL ANGLES ARE READ ABOUT MIDWAY IN THE SAMPLINGS.

170MS                        EQUALS   ND1

```



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```
LRVJOB      CA      170MS      # SET TASK TO READ CDUS + PIPAS
            TC      WAITLIST
            EBANK=   LRVTIME
            2CADR    RDGIMS

            CCS      VSELECT      # SEQUENCE LR VEL BEAM SELECTOR
            TCF      +2
            CAF      TWO          # IF ZERO, RESET TO TWO
            DOUBLE   # 2XVSELECT USED FOR VBEAM INDEX IN LRVEL
            TC      BANKCALL      # GO INITIALIZE LR VEL READ ROUTINE
            CADR     LRVEL
            TC      BANKCALL      # PUT LRVJOB TO SLEEP ABOUT 500 MS
            CADR     RADSTALL
            TCF      VBAD
            CCS      STILBADV      # IS DATA GOOD JUST PRESENT?
            TCF      VSTILBAD      # JUST GOOD -- MUST WAIT 4 SECONDS.

            INHINT
            EXTEND
            DCA      SAMPLSUM      # GOOD RETURN -- STOW AWAY VMEAS
            DXCH     VMEAS
            CA      EBANK4        # FOR DOWNLINK
            TS      EBANK
            EBANK=   LRVTIME

            EXTEND
            DCA      LRVTIME
            DXCH     LRVTIMDL
            EXTEND
            DCA      LRXCDU
            DXCH     LRXCDUDL
            CA      LRZCDU
            TS      LRZCDUDL
            CA      EBANK7
            TS      EBANK
            EBANK=   VSELECT

            CS      FLGWRD11      # SET BIT TO INDICATE VELOCITY
            MASK     VELDABIT      # MEASUREMENT MADE

# Page 893

            ADS      FLGWRD11
            CCS      VSELECT      # UPDATE VSELECT
            TCF      +2
            CA      TWO
            TS      VSELECT
```

```

                                TCF      ENDOFJOB

VBAD          CAF      TWO          # SET STILBAD TO WAIT 4 SECONDS
VSTILBAD      TS       STILBADV
                                TCF      ENDLRV

# LRHJOB IS SET BY LRHTASK WHEN LEM IS BELOW 25000 FT.  THIS JOB
# INITIALIZES THE LR READ ROUTINE FOR AN ALT MEASUREMENT AND GOES TO
# SLEEP WHILE THE SAMPLING IS DONE -- ABOUT 95 MS.  WITH A GOODEND RETURN
# THE ALT DATA IS STORED IN HMEAS AND BIT7 OF LRSTAT IS SET.

                                BANK      34
                                SETLOC    R12STUFF
                                BANK

                                COUNT*   $$/SERV

LRHJOB        TC        BANKCALL      # INITIATE LR ALT MEASUREMENT
              CADR      LRALT
              TC        BANKCALL      # LRHJOB TO SLEEP ABOUT 95MS
              CADR      RADSTALL
              TCF       HBAD
              CCS       STILBADH      # IS DATA GOOD JUST PRESENT?
              TCF       HSTILBAD      # JUST GOOD -- MUST WAIT 4 SECONDS.

              INHINT
              EXTEND
              DCA       SAMPLSUM      # GOOD RETURN -- STORE AWAY LRH DATA
              DXCH      HMEAS         # LRH DATA 1.079 FT/BIT
              EXTEND     # FOR DOWNLINK
              DCA       PIPTIME1
              DXCH      MKTIME

              EXTEND
              DCA       CDUTEMPY      # CDUY,Z = AIG,AMG
              DXCH      AIG

              CA        CDUTEMPX      # CDUX = AOG
              TS        AOG

              CS        FLGWRD11      # SET BIT TO INDICATE RANGE
              MASK      RNGEDBIT      # MEASUREMENT MADE.
              ADS       FLGWRD11
ENDLRH        TC        ENDOFJOB      # TERMATE LRHJOB

# Page 894

```

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```
HBAD      CA      FLAGWRD5
          MASK     RNGSCBIT      # IS BAD RETURN DUE TO SCALE CHANGE?
          EXTEND
          BZF      HSTILBAD -1    # NO  RESET HSTILBAD
          TC       DOWNFLAG      # YES  RESET SCALE CHANGE BIT AND IGNORE
          ADRES    RNGSCFLG
          TC       ENDOFJOB
```

```
HSTILBAD  CAF      TWO           # SET STILBAD TO WAIT 4 SECONDS
          TS       STILBADH
          TC       ENDOFJOB
```

```
BANK      34
SETLOC    SERV4
BANK
COUNT*   $$/SERV
```

```
# RDGIMS IS A TASK SET UP BY LRVJOB TO PICK UP THE IMU CDUS AND TIME
# AT ABOUT THE MIDPOINT OF THE LR VEL READ ROUTINE WHEN 5 VEL SAMPLES
# ARE SPECIFIED.
```

```
RDGIMS    EBANK=   LRVTIME
          EXTEND
          DCA      TIME2          # PICK UP TIME2, TIME1
          DXCH     LRVTIME        #      AND SAVE IN LRVTIME

          EXTEND
          DCA      CDUX           # PICK UP CDUX AND CDUY
          DXCH     LRXCDU        #      AND SAVE IN LRXCDU AND LRYCDU

          CA       CDUZ
          TS       LRZCDU        # SAVE CDUZ IN LRZCDU

          CA       PIPAX
          TS       PIPTM         # SAVE PIPAX IN PIPTM

          EXTEND
          DCA      PIPAY          # PICK UP PIPAY AND PIPAZ
          DXCH     PIPTM +1      #      AND SAVE IN PIPTM +1 AND PIPTM +2
          TC       TASKOVER

          BANK      33
          SETLOC    SERVICES
          BANK
```

COUNT\* \$\$/SERV

EBANK= DVCNTR

# Page 895

# HIGATJOB IS SET APPROXIMATELY 6 SECONDS PRIOR TO HIGH GATE DURING  
 # THE DESCENT BURN PHASE OF LUNAR LANDING. THIS JOB INITIATES THE  
 # LANDING RADAR REPOSITIONING ROUTINE AND GOES TO SLEEP UNTIL THE  
 # LR ANTENNA MOVES FROM POSITION 1 TO POSITION 2. IF THE LR ANTENNA  
 # ACHIEVES POSITION 2 WITHIN 22 SECONDS THE ALTITUDE AND VELOCITY  
 # BEAM VECTORS ARE RECOMPUTED TO REFLECT THE NEW ORIENTATION WITH  
 # RESPECT TO THE NB. BIT10 OF LRSTAT IS CLEARED TO ALLOW LR  
 # MEASUREMENTS AND THE JOB TERMINATES.

|          |       |          |                                            |
|----------|-------|----------|--------------------------------------------|
| HIGATJOB | TC    | BANKCALL | # START LRPOS2 JOB                         |
|          | CADR  | LRPOS2   |                                            |
|          | TC    | BANKCALL | # PUT HIGATJOB TO SLEEP UNTIL JOB IS DONE  |
|          | CADR  | RADSTALL |                                            |
|          | TCF   | POSALARM | # BAD END ALARM                            |
| POSGOOD  | CA    | PRI023   | # REDUCE PRIORITY FOR INTERPRETIVE COMPS.  |
|          | TC    | PRI0CHNG |                                            |
|          | TC    | SETPOS2  | # LR IN POS2 -- SET UP TRANSFORMATIONS     |
|          | TC    | DOWNFLAG |                                            |
|          | ADRES | NOLRREAD | # RESET NOLRREAD FLAG TO ENABLE LR READING |
|          | TC    | ENDOFJOB |                                            |
| POSALARM | CA    | OCT523   |                                            |
|          | TC    | BANKCALL |                                            |
|          | CADR  | PRIOLARM | # FLASH ALARM CODE                         |
|          | TCF   | GOTOPOOH | # TERMINATE                                |
|          | TCF   | +3       | # PROCEED -- TRY AGAIN                     |
|          | TCF   | ENDOFJOB | # V 32 E TERMINATE R12                     |
|          | TC    | ENDOFJOB |                                            |
|          | +3    | CA       | BIT7                                       |
|          |       | EXTEND   | # SEE IF IN POS2 YET                       |
|          |       | RAND     | CHAN33                                     |
|          |       | EXTEND   |                                            |
|          | BZF   | POSGOOD  | # POS2 ACHIEVED SET UP ANTENNA BEAMS       |
|          | TCF   | POSALARM | # STILL DIDN'T MAKE IT REALARM             |
| OCT523   | OCT   | 00523    |                                            |

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```
SETPOS1      TC      MAKECADR      # MUST BE CALLED BY BANKCALL
              TS      LRADRET1     # SAVE RETURN CADR.  SINCE BUP2 CLOBBBERED

              CAF      TWO
              TS      STILBADH      # INITIALIZE STILBAD
              TS      STILBADV      # INITIALIZE STILBAD

              CA      ZERO          # INDEX FOR LRALPHA, LRBETA IN POS 1.

# Page 896    TS      LRLCTR        # SET L,M,R, ANS S TO ZERO
              TS      LRMCTR
              TS      LRRCTR
              TS      LRSCTR
              TS      VSELECT      # INITIALIZE VSELECT

              TC      SETPOS        # CONTINUE WITH COMPUTATIONS.

              CA      LRADRET1
              TC      BANKJUMP      # RETURN TO CALLER

SETPOS2      CA      TWO          # INDEX FOR POS2
SETPOS       XCH      Q            # SAVE INDEX IN Q
              TS      LRADRET      # SAVE RETURN

              CA      EBANK5
              TS      EBANK
EBANK=       LRALPHA

EXTEND
INDEX        Q
DCA          LRALPHA              # LRALPHA IN A, LRBETA IN L
TS           CDUSPOT +4           # ROTATION ABOUT X
LXCH         CDUSPOT              # ROTATION ABOUT Y
CA           ZERO
TS           CDUSPOT +2           # ZERO ROTATION ABOUT Z.

              CA      EBANK7
              TS      EBANK
EBANK=       LRADRET

              TC      INTPRET
VLOAD        CALL
              UNITY              # CONVERT UNITY(ANTENNA) TO NB
              TRG*SMNB
STOVL        VYBEAMNB
```

```
UNITX          # CONVERT UNITX(ANTENNA) TO NB
CALL
*SMNB*
STORE VXBEAMNB
VXV VSL1
VYBEAMNB
STOVL VZBEAMNB # Z = X * Y
HBEAMANT
CALL
*SMNB*          # CONVERT TO NB
STORE HBEAMNB
EXIT
```

# Page 897

TC LRADRET

This code is written to file src/SERVICER.s.

## A.103 SINGLE PRECISION SUBROUTINES

```

1727 <src/SINGLE-PRECISION-SUBROUTINES.s 1727>≡
# Copyright:      Public domain.
# Filename:       SINGLE_PRECISION_SUBROUTINES.agc
# Purpose:       Part of the source code for Colossus 2A, AKA Comanche 055.
#               It is part of the source code for the Command Module's (CM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:    yaYUL
# Contact:       Ron Burkey <info@sandroid.org>.
# Website:       www.ibiblio.org/apollo.
# Pages:        1207
# Mod history:   2009-05-13 RSB   Adapted from the Colossus249/ file of the
#                               same name, using Comanche055 page images.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 055 of AGC program Comanche by NASA
#       2021113-051.  10:28 APR. 1, 1969
#
#       This AGC program shall also be referred to as
#       Colossus 2A

# Page 1207

BLOCK    02

# SINGLE PRECISION SINE AND COSINE

COUNT  02/INTER

SPCOS    AD      HALF      # ARGUMENTS SCALED AT PI
SPSIN    TS      TEMK
          TCF      SPT
          CS      TEMK
SPT      DOUBLE
          TS      TEMK
          TCF      POLLEY

```

|        |        |        |                       |
|--------|--------|--------|-----------------------|
|        | XCH    | TEMK   |                       |
|        | INDEX  | TEMK   |                       |
|        | AD     | LIMITS |                       |
|        | COM    |        |                       |
|        | AD     | TEMK   |                       |
|        | TS     | TEMK   |                       |
|        | TCF    | POLLEY |                       |
|        | TCF    | ARG90  |                       |
| POLLEY | EXTEND |        |                       |
|        | MP     | TEMK   |                       |
|        | TS     | SQ     |                       |
|        | EXTEND |        |                       |
|        | MP     | C5/2   |                       |
|        | AD     | C3/2   |                       |
|        | EXTEND |        |                       |
|        | MP     | SQ     |                       |
|        | AD     | C1/2   |                       |
|        | EXTEND |        |                       |
|        | MP     | TEMK   |                       |
|        | DDOUBL |        |                       |
|        | TS     | TEMK   |                       |
|        | TC     | Q      |                       |
| ARG90  | INDEX  | A      |                       |
|        | CS     | LIMITS |                       |
|        | TC     | Q      | # RESULT SCALED AT 1. |

# SPROOT WAS DELETED IN REV 51 OF MASTER. ASS. CONT. HAS CARDS.

This code is written to file `src/SINGLE-PRECISION-SUBROUTINES.s`.



## A.104 SPS BACK-UP RCS CONTROL

1729

*<src/SPS-BACK-UP-RCS-CONTROL.s 1729>≡*

```
# Copyright:      Public domain.
# Filename:       SPS_BACK-UP_RCS_CONTROL.agc
# Purpose:       Part of the source code for Luminary 1A build 099.
#               It is part of the source code for the Lunar Module's (LM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:    yaYUL
# Contact:       Ron Burkey <info@sandroid.org>.
# Website:       www.ibiblio.org/apollo.
# Pages:        1507-1510
# Mod history:   2009-05-27 RSB   Adapted from the corresponding
#               Luminary131 file, using page
#               images from Luminary 1A.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
#       16:27 JULY 14, 1969
#
# Page 1507
# PROGRAM NAME:      SPSRCS
# AUTHOR:            EDGAR M. OSHIKA (AC ELECTRONICS)
# MODIFIED:          TO RETURN TO ALL AXES VIA Q BY P. S. WEISSMAN, OCT 7, 1968
# MODIFIED TO IMPROVE BENDING STABILITY BY G. KALAN, FEB. 14, 1969
#
# FUNCTIONAL DESCRIPTION:
#       THE PROGRAM CONTROLS THE FIRING OF ALL RCS JETS IN THE DOCKED CONFIGURATION ACCORDING TO
#       PLANE LOGIC.
#
#       1. JET SENSE TEST (SPSRCS)
#           IF JETS ARE FIRING NEGATIVELY, SET OLDSENSE NEGATIVE AND CONTINUE
#           IF JETS ARE FIRING POSITIVELY, SET OLDSENSE POSITIVE AND CONTINUE
#           IF JETS ARE NOT FIRING, SET OLDSENSE TO ZERO AND GO TO OUTER RATE LIMIT TEST
#
```

```

#       2. RATE DEAD BAND TEST
#       IF JETS ARE FIRING NEGATIVELY AND RATE IS GREATER THAN TARGET RATE, I
#       JETS ON AND GO TO INHIBITION LOGIC.  OTHERWISE, CONTINUE.
#       IF JETS ARE FIRING POSITIVELY AND RATE IS LESS THAN TARGET RATE, I
#       JETS ON AND GO TO INHIBITION LOGIC.  OTHERWISE, CONTINUE.
#
#       3. OUTER RATE LIMIT TEST (SPSSTART)
#       IF MAGNITUDE OF EDOT IS GREATER THAN 1.73 DEG/SEC SET JET FIRING TIME
#       TO REDUCE RATE AND GO TO INHIBITION LOGIC.  OTHERWISE, CONTINUE.
#
#       4. COAST ZONE TEST
#       IF STATE (E,EDOT) IS BELOW LINE  $E + 4 \times EDOT > -1.4$  DEG AND EDOT IS I
#       POSITIVE AND CONTINUE.  OTHERWISE, SET JET FIRING TIME TO ZERO
#       IF STATE IS ABOVE LINE  $E + 4 \times EDOT > +1.4$  DEG AND EDOT IS GREATER TH
#       AND CONTINUE.  OTHERWISE, SET JET FIRING TIME TO ZERO AND CONTINUE.
#
#       5. INHIBITION LOGIC
#       IF OLDSENSE IS NON-ZERO:
#           A) RETURN IF JET TIME AS THE SAME SIGN AS OLDSENSE
#           B) SET INHIBITION COUNTER* AND RETURN IF JET TIME IS ZERO
#           C) SET INHIBITION COUNTER,* SET JET TIME TO ZERO AND RETURN I
#               OF JET TIME IS OPPOSITE TO THAT OF OLDSENSE
#       IF OLDSENSE IS ZERO:
#           A) RETURN IF INHIBITION COUNTER IS NOT POSITIVE
#           B) SET JET TIME TO ZERO AND RETURN IF INHIBITION COUNTER IS I
#
#       *NOTE: INHIBITION COUNTERS CAN BE SET TO 4 OR 10 FOR THE P AND UV AXES
#       RESPECTIVELY, IN SPSRCS.  THEY ARE DECREMENTED BY ONE AT THE BEGINNING
#
# Page 1508
#       EACH DAP PASS.
#
#       THE MINIMUM PULSE WIDTH OF THIS CONTROLLER IS DETERMINED BY THE REPETITION RATE
#       AND IS NOMINALLY 100 MS FOR ALL AXES IN DRIFTING FLIGHT.  DURING POWERED FLIGHT
#       P AXIS AND 200 MS FOR THE CONTROL OF THE U AND V AXES.
#
# CALLING SEQUENCE:
#       INHINT
#       TC      IBNKCALL
#       CADR     SPSRCE
#
# EXIT:
#       TC      Q
#
# ALARM/ABORT MODE:  NONE
#
# SUBROUTINES CALLED:  NONE
#

```

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```
# INPUT:          E, EDOT
#                 TJP, TJV, TJU          TJ MUST NOT BE NEGATIVE ZERO
#
# OUTPUT:         TJP, TJV, TJU

BANK 21
SETLOC DAPS4
BANK

COUNT* $$/DAPBU

EBANK= TJU
RATELIM2 OCT 00632          # 1.125 DEG/SEC
POSTHRST CA HALF

NDX AXISCTR
TS TJU
CCS OLDSENSE
TCF POSCHECK          # JETS FIRING POSITIVELY
TCF CTRCHECK          # JETS OFF. CHECK INHIBITION CTR
NEGCHECK INDEX AXISCTR  # JETS FIRING NEGATIVELY
CS TJU
CCS A
TC Q          # RETURN
TCF +2
TCF +1          # JETS COMMANDED OFF. SET CTR AND RETURN
SETCTR INDEX AXISCTR  # JET FIRING REVERSAL COMMANDED. SET CTR,
CA UTIME          # SET JET TIME TO ZER, AND RETURN

# Page 1509

INDEX AXISCTR
TS UJETCTR
ZAPTJ CA ZERO
INDEX AXISCTR
TS TJU
TC Q
POSCHECK INDEX AXISCTR
CA TJU
TCF NEGCHECK +2
CTRCHECK INDEX AXISCTR  # CHECK JET INHIBITION COUNTER
CCS UJETCTR
TCF +2
TC Q          # CTR IS NOT POSITIVE. RETURN
TCF ZAPTJ     # CTR IS POSITIVE. INHIBIT FIRINGS
TC Q          # CTR IS NOT POSITIVE. RETURN
OCT 00004
UTIME OCT 00012
```

|             |        |             |                                            |
|-------------|--------|-------------|--------------------------------------------|
|             | OCT    | 00012       |                                            |
| OLDSENSE    | EQUALS | DAPTRG1     |                                            |
| NEGFIRE     | CS     | ONE         | # JETS FIRING NEGATIVELY                   |
|             | TS     | OLDSENSE    |                                            |
|             | CA     | EDOT        |                                            |
|             | TCF    | +4          |                                            |
| PLUSFIRE    | CA     | ONE         |                                            |
|             | TS     | OLDSENSE    |                                            |
|             | CS     | EDOT        | # RATE DEAD BAND TEST                      |
|             | LXCH   | A           |                                            |
|             | CS     | DAPBOOLS    | # IF DRIFTBIT = 1, USE ZERO TARGET RATE    |
|             | MASK   | DRIFTBIT    | # IF DRIFTBIT = 0, USE 0.10 RATE TARGET    |
|             | CCS    | A           |                                            |
|             | CA     | RATEDB1     |                                            |
|             | AD     | L           |                                            |
|             | EXTEND |             |                                            |
|             | BZMF   | SPSSTART    |                                            |
|             | TCF    | POSTHRST +3 |                                            |
| SPSRCS      | INDEX  | AXISCTR     | # JET SENSE TEST                           |
|             | CCS    | TJU         |                                            |
|             | TCF    | PLUSFIRE    | # JETS FIRING POSITIVELY                   |
|             | TCF    | +2          |                                            |
|             | TCF    | NEGFIRE     | # JETS FIRING NEGATIVELY                   |
|             | TS     | OLDSENSE    | # JETS OFF                                 |
| SPSSTART    | CA     | EDOT        | # OUTER RATE LIMIT TEST                    |
|             | EXTEND |             |                                            |
|             | MP     | RATELIM1    |                                            |
|             | CCS    | A           |                                            |
|             | TCF    | NEGTHRST    | # OUTER RATE LIMIT EXCEEDED                |
|             | TCF    | +2          |                                            |
|             | TCF    | POSTHRST    | # OUTER RATE LIMIT EXCEEDED                |
|             | CA     | EDOT        | # COAST ZONE TEST                          |
| # Page 1510 | AD     | E           |                                            |
|             | EXTEND |             |                                            |
|             | MP     | DKDB        | # PAD LOADED DEADBAND. FRESHSTART: 1.4 DEG |
|             | EXTEND |             |                                            |
|             | BZF    | TJZERO      |                                            |
|             | EXTEND |             |                                            |
|             | BZMF   | +7          |                                            |
|             | CA     | EDOT        |                                            |
|             | AD     | RATELIM2    |                                            |
|             | EXTEND |             |                                            |
|             | BZMF   | TJZERO      |                                            |

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```
NEGTHRST      CS      HALF
               TCF      POSTHRST +1
               CS      RATELIM2
               AD      EDOT
               EXTEND
               BZMF      POSTHRST
TJZERO        CA      ZERO
               TCF      POSTHRST +1

RATELIM1      =      CALLCODE      # = 00032, CORRESPONDING TO 1.73 DEG/SEC
RATEDB1       =      TBUILDFX      # = 00045, CORRESPONDS TO 0.101 DEG/SEC

# *** END OF LMDAP .015 ***
```

This code is written to file `src/SPS-BACK-UP-RCS-CONTROL.s`.

## A.105 STABLE ORBIT

```

1734  <src/STABLE-ORBIT.s 1734>≡
      # Copyright:    Public domain.
      # Filename:     STABLE_ORBIT.agc
      # Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
      #               It is part of the source code for the Command Module's (CM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Hartmuth Gutsche <hgutsche@explornet.com>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         525-532
      # Mod history:   2009-05-10 HG      Started adapting from the Colossus249/ file
      #               of the same name, using Comanche055 page
      #               images 0525.jpg - 0532.jpg.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #   Assemble revision 055 of AGC program Comanche by NASA
      #   2021113-051. 10:28 APR. 1, 1969
      #
      #   This AGC program shall also be referred to as
      #   Colossus 2A
      # Page 525
      # STABLE ORBIT RENDEZVOUS PROGRAMS (P38 AND P78)
      #
      # MOD NO -1          LOG SECTION - STABLE ORBIT - P38-P39
      # MOD BY RUDNICKI.S   DATE 25JAN68
      #
      # FUNCTIONAL DESCRIPTION
      #
      #   P38 AND P78 CALCULATE THE REQUIRED DELTA V AND OTHER INITIAL
      #   CONDITIONS REQUIRED BY THE AGC TO (1) PUT THE ACTIVE VEHICLE
      #   ON A TRANSFER TRAJECTORY THAT INTERCEPTS THE PASSIVE VEHICLE
      #   ORBIT A GIVEN DISTANCE, DELTA R, EITHER AHEAD OF OR BEHIND THE
      #   PASSIVE VEHICLE AND (2) ACTUALLY PLACE THE ACTIVE VEHICLE IN THE
      #   PASSIVE VEHICLE ORBIT WITH A DELTA R SEPARATION BETWEEN THE TWO

```

```

#       VEHICLES
#
# CALLING SEQUENCE
#
#       ASTRONAUT REQUEST THRU DSKY
#
#       V37E38E      IF THIS VEHICLE IS ACTIVE VEHICLE
#       V37E78E      IF OTHER VEHICLE IS ACTIVE VEHICLE
#
# INPUT
#
#       (1)      SOI MANEUVER
#
#               (A)  TIG      TIME OF SOI MANEUVER
#               (B)  CENTANG  ORBITAL CENTRAL ANGLE OF THE PASSIVE VEHICLE
#                           DURING THE TRANSFER FROM TIG TO TIME OF INTERCEPT
#               (C)  DELTAR   THE DESIRED SEPARATION OF THE TWO VEHICLES
#                           SPECIFIED AS A DISTANCE ALONG THE PASSIVE VEHICLE
#                           ORBIT
#               (D)  OPTION   EQUALS 1 FOR SOI
#
#       (2)      SOR MANEUVER
#
#               (A)  TIG      TIME OF SOR MANEUVER
#               (B)  CENTANG  AN OPTIONAL RESPECIFICATION OF 1 (B) ABOVE
#               (C)  OPTION   EQUALS 2 FOR SOR
#               (D)  DELTTIME THE TIME REQUIRED TO TRAVERSE DELTA R WHEN
#                           TRAVELING AT A VELOCITY EQUAL TO THE HORIZONTAL
#                           VELOCITY OF THE PASSIVE VEHICLE - SAVED FROM
#                           SOI PHASE
#               (E)  TINT     TIME OF INTERCEPT (SOI) - SAVED FROM SOI PHASE
#
# OUTPUT
#
#       (1)  TRMKCNT  NUMBER OF MARKS
#       (2)  TTOGO    TIME TO GO
#       (3)  +MGA     MIDDLE GIMBAL ANGLE
# Page 526
#       (4)  DSPTM1   TIME OF INTERCEPT OF PASSIVE VEHICLE ORBIT
#                           (FOR SOI ONLY)
#       (5)  POSTTPI  PERIGEE ALTITUDE OF ACTIVE VEHICLE ORBIT AFTER
#                           THE SOI (SOR) MANEUVER
#       (6)  DELVTPI  MAGNITUDE OF DELTA V AT SOI (SOR) TIME
#       (7)  DELVTPF  MAGNITUDE OF DELTA V AT INTERCEPT TIME
#       (8)  DELTA    VELOCITY AT SOI (AND SOR) - LOCAL VERTICAL
#                           COORDINATES

```

```

#
# SUBROUTINES USED
#
# AVFLAGA
# AVFLAGP
# VNDSPLY
# BANKCALL
# GOFLASHR
# GOTOPPOH
# BLANKET
# ENDOFJOB
# PREC/TT
# SELECTMU
# INTRPVP
# MAINRTNE

```

```

BANK 04
SETLOC STBLEORB
BANK

```

```

EBANK= SUBEXIT
COUNT* $$/P3879

```

```

P38 TC AVFLAGA # THIS VEHICLE ACTIVE
TC +2
P78 TC AVFLAGP # OTHER VEHICLE ACTIVE
TC P20FLGON # SET UPDATFLG, TRACKFLG
CAF V06N33SR # DISPLAY TIG
TC VNDSPLY
CAF V06N55SR # DISPLAY CENTANG
TCR BANKCALL
CADR GOFLASHR
TCF GOTOPPOH # TERMINATE
TCF +5 # PROCEED
TCF -5 # RECYCLE
CAF THREE # IMMEDIATE RETURN -- BLANK R1, R2
TCR BLANKET
TCF ENDOFJOB
CAF FIVE
TS OPTION1
CAF ONE
TS OPTION2 # OPTION CODE IS SET TO 1

# Page 527
CAF V04N06SR # DISPLAY OPTION CODE -1 = SOI, 2 = SOR
TCR BANKCALL
CADR GOFLASHR

```



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|         |       |          |                                           |
|---------|-------|----------|-------------------------------------------|
|         | TCF   | GOTOP00H | # TERMINATE                               |
|         | TCF   | +5       | # PROCEED                                 |
|         | TCF   | -5       | # RECYCLE                                 |
|         | CAF   | BIT3     | # IMMEDIATE RETURN -- BLANK R3            |
|         | TCR   | BLANKET  |                                           |
|         | TCF   | ENDOFJOB |                                           |
|         | TC    | INTPRET  |                                           |
|         | SSP   |          |                                           |
|         |       | NN       |                                           |
|         |       | 2        |                                           |
|         | SLOAD | SR1      |                                           |
|         |       | OPTION2  |                                           |
|         | BHIZ  | DLOAD    |                                           |
|         |       | OPTN1    |                                           |
|         |       | TINT     |                                           |
|         | STORE | TINTSOI  | # STORE FOR SOR PHASE                     |
|         | CLRGO |          |                                           |
|         |       | OPTNSW   | # OPTNSW: ON = SOI. OFF = SOR             |
|         |       | JUNCTN1  |                                           |
| OPTN1   | SET   | CLEAR    | # SOI                                     |
|         |       | OPTNSW   |                                           |
|         |       | UPDATFLG |                                           |
|         | CALL  |          |                                           |
|         |       | PREC/TT  |                                           |
|         | SET   | DAD      |                                           |
|         |       | UPDATFLG |                                           |
|         |       | TIG      |                                           |
|         | STORE | TINT     | # TI = TIG + TF                           |
|         | STORE | DSPTM1   | # FOR DISPLAY                             |
|         | EXIT  |          |                                           |
|         | CAF   | V06N57SR | # DISPLAY DELTA R                         |
|         | TCR   | BANKCALL |                                           |
|         | CADR  | GOFLASHR |                                           |
|         | TCF   | GOTOP00H | # TERMINATE                               |
|         | TCF   | +5       | # PROCEED                                 |
|         | TCF   | -5       | # RECYCLE                                 |
|         | CAF   | SIX      | # IMMEDIATE RETURN - BLANK R2, R3         |
|         | TCR   | BLANKET  |                                           |
|         | TCF   | ENDOFJOB |                                           |
|         | CAF   | V06N34SR | # DISPLAY TIME OF INTERCEPT               |
|         | TC    | VNDSPLY  |                                           |
|         | TC    | INTPRET  |                                           |
| JUNCTN1 | CLEAR | CALL     |                                           |
|         |       | P39/79SW |                                           |
|         |       | SELECTMU | # SELECT MU, CLEAR FINALFLG, GO TO VN1645 |
| RECYCLE | CALL  |          |                                           |

```

PREC/TT
# Page 528
      BOFF  DLOAD
            OPTNSW
            OPTN2
            TINT
      STCALL TDEC1      # PRECISION UPDATE PASSIVE VEHICLE TO
            INTRPVP    # INTERCEPT TIME
      VLOAD  UNIT
            RATT      # RP/(RP)
      PDVL   VXV
            VATT
      ABVAL  NORM      # (VP X RP/(RP))
            X1
      PDDL   DDV
            DELTAR
      SL*    # DELTA R / (VP X RP/RP)
            0 -7,1
      STCALL DELTTIME  # DELTA T = (RP) DELTA R / (VP X RP)
            JUNCTN2
OPTN2      DLOAD  DAD
            TINTSOI
            T
      STORE  TINT      # TI = TI + TF
JUNCTN2    DLOAD  DSU
            TINT
            DELTTIME
      STORE  TARGTIME  # TT = TI - DELTA T

# .... MAINRTNE ....
#
# SUBROUTINES USED
#
#      S3435.25
#      PERIAP01
#      SHIFTR1
#      VNDSPLY
#      BANKCALL
#      GOFLASH
#      GOTOP00H
#      VN1645

MAINRTNE   STCALL  TDEC1      # PRECISION UPDATE PASSIVE VEHICLE TO
            INTRPVP    # TARGET TIME
            DLOAD
            TIG

```

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```

STORE  INTIME
SSP     VLOAD
        SUBEXIT
        TEST3979
        RATT
CALL
        S3435.25
TEST3979 BOFF  BON
# Page 529
        P39/79SW
        MAINRTN1
        FINALFLG
        P39P79
SET
        UPDATFLG
P39P79  EXIT
TC      DSPLY81      # FOR P39 AND P79
VLOAD   ABVAL
        DELVEET3
STOVL   DELVTPI      # DELTA V
        VPASS4
VSU     ABVAL
        VTPRIME
STOVL   DELVTPI      # DELTA V (FINAL) = V-T - VT
        RACT3
PDVL    CALL
        VIPRIME
        PERIAP01    # GET PERIGEE ALTITUDE
CALL
        SHIFTR1
STORE   POSTTPI
BON     SET
        FINALFLG
        DSPLY58
        UPDATFLG
DSPLY58 EXIT
CAF     V06N58SR      # DISPLAY HP, DELTA V, DELTA V (FINAL)
TC      VNDSPLY
DSPLY81 CAF     V06N81SR      # DISPLAY DELTA V (LV)
TC      VNDSPLY
TC      INTPRET
CLEAR   VLOAD
        XDELVFLG
        DELVEET3
STCALL  DELVSIN
        VN1645      # DISPLAY TRKMKCNT, TTOGO, +MGA
```

BON GOTO  
P39/79SW  
P39/P79B  
RECYCLE

# STABLE ORBIT MIDCOURSE PROGRAM (P39 AND P79)  
#  
# MOD NO -1 LOG SECTION - STABLE ORBIT - P38-P39  
# MOD BY RUDNICKI, S DATE 25JAN68  
#  
# FUNCTIONAL DESCRIPTION  
#  
# P39 AND P79 CALCULATE THE REQUIRED DELTA V AND OTHER INITIAL  
# CONDITIONS REQUIRED BY THE AGC TO MAKE A MIDCOURSE CORRECTION  
# Page 530  
# MANEUVER AFTER COMPLETING THE SOI MANEUVER BUT BEFORE MAKING  
# THE SOR MANEUVER.  
#  
# CALLING SEQUENCE  
#  
# ASTRONAUT REQUEST THRU DSKY  
#  
# V37E39E IF THIS VEHICLE IS ACTIVE VEHICLE  
# V37E79E IF OTHER VEHICLE IS ACTIVE VEHICLE  
#  
# INPUT  
#  
# (1) TPASS4 TIME OF INTERCEPT -- SAVED FROM P38/P78  
# (2) TARGTIME TIME THAT PASSIVE VEHICLE IS AT INTERCEPT POINT --  
# SAVED FROM P38/P78  
#  
# OUTPUT  
#  
# (1) TRKMKCNT NUMBER OF MARKS  
# (2) TTOGO TIME TO GO  
# (3) +MGA MIDDLE GIMBAL ANGLE  
# (4) DELVLVC DELTA VELOCITY AT MID -- LOCAL VERTICAL COORDINATES  
#  
# SUBROUTINES USED  
#  
# AVFLAGA  
# AVFLAGP  
# LOADTIME  
# SELECTMU  
# PRECSET  
# S34/35.1

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```
#      MAINRTNE

P39      TC      AVFLAGA      # THIS VEHICLE ACTIVE
        EXTEND
        DCA      ATIGINC
        TC      P39/P79A
P79      TC      AVFLAGP      # OTHER VEHICLE ACTIVE
        EXTEND
        DCA      PTIGINC
P39/P79A DXCH      KT          # TIME TO PREPARE FOR BURN
        TC      P20FLGON      # SET UPDATFLG, TRACKFLG
        TC      INTPRET
        SET      CALL
        P39/79SW
        SELECTMU
P39/P79B RTB      DAD
        LOADTIME
        KT
        STORE    TIG          # TIG = T (PRESENT) + PREPARATION TIME
# Page531
        STCALL   TDEC1        # PRECISION UPDATE ACTIVE AND PASSIVE
        PRECSET
        CALL
        S34/35.1      # GET UNIT NORMAL
        DLOAD      GOTO
        TARGTIME
        MAINRTNE      # CALCULATE DELTA V AND DELTA V (LV)

# .... PREC/TT ....
#
# SUBROUTINES USED
#
#      PRECSET
#      TIMETHET
#      S34/35.1

PREC/TT      STQ      DLOAD
                RTRN
                TIG
                STCALL  TDEC1      # PRECISION UPDATE ACTIVE AND PASSIVE
                PRECSET      #      VEHICLES TO TIG
                VLOAD      VSR*
                RPASS3
                0,2
                STODL      RVEC
                CENTANG
```

```

        PUSH    COS
        STODL   CSTH
        SIN     SET
              RVSW
        STOVL   SNTH
              VPASS3
        VSR*    0,2
        STCALL  VVEC          # GET TRANSFER TIME BASED ON CENTANG OF
              TIMETHET       # PASSIVE VEHICLE
        CALL    S34/35.1     # GET UNIT NORMAL
        DLOAD   GOTO
              T
              RTRN

# .... INTRPVP ....
#
# SUBROUTINES USED
#
#       CSMPREC
#       LEMPREC

INTRPVP      STQ    BOFF          # PRECISION UPDATE PASSIVE VEHICLE TO
              RTRN          # TDEC1
              AVFLAG
              OTHERV
              CALL
# Page 532
              CSMPREC
              GOTO
              RTRN
OTHERV       CALL    LEMPREC
              GOTO
              RTRN

# .... VNDSPLY ....
#
# SUBROUTINES USED
#
#       BANKCALL
#       GOFLASH
#       GOTOPOOH

VNDSPLY      EXTEND          # FLASH DISPLAY

```

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|          |      |          |             |
|----------|------|----------|-------------|
|          | QXCH | RTRN     |             |
|          | TS   | VERBNOUN |             |
|          | CA   | VERBNOUN |             |
|          | TCR  | BANKCALL |             |
|          | CADR | GOFLASH  |             |
|          | TCF  | GOTOPOOH | # TERMINATE |
|          | TC   | RTRN     | # PROCEED   |
|          | TCF  | -5       | # RECYCLE   |
| V06N33SR | VN   | 0633     |             |
| V06N55SR | VN   | 0655     |             |
| V04N06SR | VN   | 0406     |             |
| V06N57SR | VN   | 0657     |             |
| V06N34SR | VN   | 0634     |             |
| V06N58SR | VN   | 0658     |             |
| V06N81SR | VN   | 0681     |             |

# \*\*\* END OF COMEKISS.020 \*\*\*

This code is written to file src/STABLE-ORBIT.s.

## A.106 STAR TABLES

```

1744  <src/STAR-TABLES.s 1744>≡
      # Copyright:    Public domain.
      # Filename:     STAR_TABLES.agc
      # Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
      #               It is part of the source code for the Command Module's (CM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Ron Burkey <info@sandroid.org>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         1389-1393
      # Mod history:   2009-05-10 SN    (Sergio Navarro).  Started adapting
      #               from the Colossus249/ file of the same
      #               name, using Comanche055 page images.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum.  The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum.  Many
      # thanks to both.  The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo.  If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #   Assemble revision 055 of AGC program Comanche by NASA
      #   2021113-051.  10:28 APR. 1, 1969
      #
      #   This AGC program shall also be referred to as
      #   Colossus 2A

      # Page 1389

      BANK      32
      SETLOC    STARTAB
      BANK

      COUNT     14/STARS

      2DEC      +.8342971408 B-1      # STAR 37      X
      2DEC      -.2392481515 B-1      # STAR 37      Y
      2DEC      -.4966976975 B-1      # STAR 37      Z

      2DEC      +.8139832631 B-1      # STAR 36      X
      2DEC      -.5557243189 B-1      # STAR 36      Y

```



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# Page 1390

|      |                  |           |   |
|------|------------------|-----------|---|
| 2DEC | +.1691204557 B-1 | # STAR 36 | Z |
| 2DEC | +.4541086270 B-1 | # STAR 35 | X |
| 2DEC | -.5392368197 B-1 | # STAR 35 | Y |
| 2DEC | +.7092312789 B-1 | # STAR 35 | Z |
| 2DEC | +.3201817378 B-1 | # STAR 34 | X |
| 2DEC | -.4436021946 B-1 | # STAR 34 | Y |
| 2DEC | -.8370786986 B-1 | # STAR 34 | Z |
| 2DEC | +.5520184464 B-1 | # STAR 33 | X |
| 2DEC | -.7933187400 B-1 | # STAR 33 | Y |
| 2DEC | -.2567508745 B-1 | # STAR 33 | Z |
| 2DEC | +.4537196908 B-1 | # STAR 32 | X |
| 2DEC | -.8779508801 B-1 | # STAR 32 | Y |
| 2DEC | +.1527766153 B-1 | # STAR 32 | Z |
| 2DEC | +.2069525789 B-1 | # STAR 31 | X |
| 2DEC | -.8719885748 B-1 | # STAR 31 | Y |
| 2DEC | -.4436288486 B-1 | # STAR 31 | Z |
| 2DEC | +.1217293692 B-1 | # STAR 30 | X |
| 2DEC | -.7702732847 B-1 | # STAR 30 | Y |
| 2DEC | +.6259880410 B-1 | # STAR 30 | Z |
| 2DEC | -.1124304773 B-1 | # STAR 29 | X |
| 2DEC | -.9694934200 B-1 | # STAR 29 | Y |
| 2DEC | +.2178116072 B-1 | # STAR 29 | Z |
| 2DEC | -.1146237858 B-1 | # STAR 28 | X |
| 2DEC | -.3399692557 B-1 | # STAR 28 | Y |
| 2DEC | -.9334250333 B-1 | # STAR 28 | Z |
| 2DEC | -.3516499609 B-1 | # STAR 27 | X |
| 2DEC | -.8240752703 B-1 | # STAR 27 | Y |
| 2DEC | -.4441196390 B-1 | # STAR 27 | Z |
| 2DEC | -.5326876930 B-1 | # STAR 26 | X |
| 2DEC | -.7160644554 B-1 | # STAR 26 | Y |
| 2DEC | +.4511047742 B-1 | # STAR 26 | Z |
| 2DEC | -.7861763936 B-1 | # STAR 25 | X |
| 2DEC | -.5217996305 B-1 | # STAR 25 | Y |
| 2DEC | +.3311371675 B-1 | # STAR 25 | Z |

# Page 1391

|      |                  |           |   |
|------|------------------|-----------|---|
| 2DEC | -.6898393233 B-1 | # STAR 24 | X |
| 2DEC | -.4182330640 B-1 | # STAR 24 | Y |
| 2DEC | -.5909338474 B-1 | # STAR 24 | Z |
| 2DEC | -.5812035376 B-1 | # STAR 23 | X |
| 2DEC | -.2909171294 B-1 | # STAR 23 | Y |
| 2DEC | +.7599800468 B-1 | # STAR 23 | Z |
| 2DEC | -.9170097662 B-1 | # STAR 22 | X |
| 2DEC | -.3502146628 B-1 | # STAR 22 | Y |
| 2DEC | -.1908999176 B-1 | # STAR 22 | Z |
| 2DEC | -.4523440203 B-1 | # STAR 21 | X |
| 2DEC | -.0493710140 B-1 | # STAR 21 | Y |
| 2DEC | -.8904759346 B-1 | # STAR 21 | Z |
| 2DEC | -.9525211695 B-1 | # STAR 20 | X |
| 2DEC | -.0593434796 B-1 | # STAR 20 | Y |
| 2DEC | -.2986331746 B-1 | # STAR 20 | Z |
| 2DEC | -.9656605484 B-1 | # STAR 19 | X |
| 2DEC | +.0525933156 B-1 | # STAR 19 | Y |
| 2DEC | +.2544280809 B-1 | # STAR 19 | Z |
| 2DEC | -.8608205219 B-1 | # STAR 18 | X |
| 2DEC | +.4636213989 B-1 | # STAR 18 | Y |
| 2DEC | +.2098647835 B-1 | # STAR 18 | Z |
| 2DEC | -.7742591356 B-1 | # STAR 17 | X |
| 2DEC | +.6152504197 B-1 | # STAR 17 | Y |
| 2DEC | -.1482892839 B-1 | # STAR 17 | Z |
| 2DEC | -.4657947941 B-1 | # STAR 16 | X |
| 2DEC | +.4774785033 B-1 | # STAR 16 | Y |
| 2DEC | +.7450164351 B-1 | # STAR 16 | Z |
| 2DEC | -.3612508532 B-1 | # STAR 15 | X |
| 2DEC | +.5747270840 B-1 | # STAR 15 | Y |
| 2DEC | -.7342932655 B-1 | # STAR 15 | Z |
| 2DEC | -.4118589524 B-1 | # STAR 14 | X |
| 2DEC | +.9065485360 B-1 | # STAR 14 | Y |
| 2DEC | +.0924226975 B-1 | # STAR 14 | Z |

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# Page 1392

|      |                  |           |   |
|------|------------------|-----------|---|
| 2DEC | -.1820751783 B-1 | # STAR 13 | X |
| 2DEC | +.9404899869 B-1 | # STAR 13 | Y |
| 2DEC | -.2869271926 B-1 | # STAR 13 | Z |
| 2DEC | -.0614937230 B-1 | # STAR 12 | X |
| 2DEC | +.6031563286 B-1 | # STAR 12 | Y |
| 2DEC | -.7952489957 B-1 | # STAR 12 | Z |
| 2DEC | +.1371725575 B-1 | # STAR 11 | X |
| 2DEC | +.6813721061 B-1 | # STAR 11 | Y |
| 2DEC | +.7189685267 B-1 | # STAR 11 | Z |
| 2DEC | +.2011399589 B-1 | # STAR 10 | X |
| 2DEC | +.9690337941 B-1 | # STAR 10 | Y |
| 2DEC | -.1432348512 B-1 | # STAR 10 | Z |
| 2DEC | +.3507315038 B-1 | # STAR 9  | X |
| 2DEC | +.8926333307 B-1 | # STAR 9  | Y |
| 2DEC | +.2831839492 B-1 | # STAR 9  | Z |
| 2DEC | +.4105636020 B-1 | # STAR 8  | X |
| 2DEC | +.4988110001 B-1 | # STAR 8  | Y |
| 2DEC | +.7632988371 B-1 | # STAR 8  | Z |
| 2DEC | +.7032235469 B-1 | # STAR 7  | X |
| 2DEC | +.7075846047 B-1 | # STAR 7  | Y |
| 2DEC | +.0692868685 B-1 | # STAR 7  | Z |
| 2DEC | +.5450107404 B-1 | # STAR 6  | X |
| 2DEC | +.5314955466 B-1 | # STAR 6  | Y |
| 2DEC | -.6484410356 B-1 | # STAR 6  | Z |
| 2DEC | +.0130968840 B-1 | # STAR 5  | X |

# Page 1393

|      |                  |          |   |
|------|------------------|----------|---|
| 2DEC | +.0078062795 B-1 | # STAR 5 | Y |
| 2DEC | +.9998837600 B-1 | # STAR 5 | Z |
| 2DEC | +.4917678276 B-1 | # STAR 4 | X |
| 2DEC | +.2204887125 B-1 | # STAR 4 | Y |
| 2DEC | -.8423473935 B-1 | # STAR 4 | Z |
| 2DEC | +.4775639450 B-1 | # STAR 3 | X |
| 2DEC | +.1166004340 B-1 | # STAR 3 | Y |
| 2DEC | +.8708254803 B-1 | # STAR 3 | Z |

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|      |              |     |          |   |
|------|--------------|-----|----------|---|
| 2DEC | +.9342640400 | B-1 | # STAR 2 | X |
| 2DEC | +.1735073142 | B-1 | # STAR 2 | Y |
| 2DEC | -.3115219339 | B-1 | # STAR 2 | Z |
| 2DEC | +.8748658918 | B-1 | # STAR 1 | X |
| 2DEC | +.0260879174 | B-1 | # STAR 1 | Y |
| 2DEC | +.4836621670 | B-1 | # STAR 1 | Z |

CATALOG      DEC      6970

This code is written to file `src/STAR-TABLES.s`.

## A.107 SXTMARK

1749

*<src/SXTMARK.s 1749>*≡

```
# Copyright:   Public domain.
# Filename:    SXTMARK.agc
# Purpose:    Part of the source code for Comanche, build 055. It
#             is part of the source code for the Command Module's
#             (CM) Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:  yaYUL
# Reference:   pp. 222-235
# Contact:    Ron Burkey <info@sandroid.org>,
#             Fabrizio Bernardini <fabrizio@spacecraft.it>
# Website:    http://www.ibiblio.org/apollo.
# Mod history: 16/05/09 FB      Transcription Batch 2 Assignment.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#             Massachussets Institute of Technology
#             75 Cambridge Parkway
#             Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.

# Page 222
# PROGRAM NAME:  SXTMARK                      DATE:  5 APRIL 1967
# PROGRAM MODIFIED BY 258/278 PROGRAMMERS      LOG SECTION SXTMARK
# MOD BY: R. MELANSON TO ADD DOCUMENTATION     ASSEMBLY SUNDISK REV. 116
#
# FUNCTIONAL DESCRIPTION:
#
# SXTMARK IS CALLED FROM INTERNAL ROUTINES WHICH MAY REQUIRE STAR OR LANDMARK MARKINGS BY
# THE MARK SYSTEM IS NOT IN USE, SXTMARK RESERVES A VAC AREA FOR MARKING AND REQUESTS EXE
# ROUTINE VIA THE EXECUTIVE JOB PRIORITY LIST. R21 USES THIS ROUTINE TO DETERMINE IF THE
# USED. IF YES, SXTMARK RETURNS TO R21 TO PERFORM ITS OWN MARK REQUESTS VIA THE V51 FLAS
#
# CALLING SEQUENCE:
```

```

#
#      CAF      (NO. MARK REQUESTS IN BITS 1-3 OF A)
#      TC       BANKCALL
#      CADR      SXTMARK
#
# NORMAL EXIT MODE:
#
#      SWRETURN
#
# ALARM OR ABORT EXIT MODE:
#
#      ABORT
#
# OUTPUT:
#
#      1)      MARKSTAT CONTAINS MARK VALUE (BITS 14-12) AND VAC AREA ADDRESS
#      2)      QPRET = VAC AREA POINTER VALUE
#      3)      1ST WORD OF RESERVED VAC AREA SET TO +0
#      4)      PRIO32 PLACED IN A REGISTER
#
# ERASABLE INITIALIZATION:
#
#      1)      BITS 1-3 OF A = NO. MARKS REQUESTED
#      2)      BITS 2,3 OF EXTVBACT = 0
#      3)      A VAC AREA MUST BE AVAILABLE (WORD 1 = ADDRESS OF VAC AREA)
#
# DEBRIS:
#
#      A,Q,L, RUPTREG1, MARKSTAT, QPRET, BIT2 OF EXTVBACT
#
#      BANK      13
#      SETLOC     SXTMARKE
#      BANK
#
#      EBANK=     MRKBUF1
#      COUNT      07/SXTMK
#
# SXTMARK      INHINT
#              TS      RUPTREG1      # NUMBER OF MARKS WANTED
#
#              CAF      SIX          # BIT2 = MARKING SYSTEM IN USE
#              MASK     EXTVBACT     # BIT3 = EXTENDED VERB IN PROGRESS
#              CCS      A
#              TC       MKABORT
#
# Page 223
#              CAF      BIT2          # NOT SET

```

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|          |        |          |                                    |
|----------|--------|----------|------------------------------------|
|          | ADS    | EXTVBACT | # SET IT, RESET IN ENDMARK         |
|          | TC     | MARKOK   | # YES, FIND VAC AREA               |
| MKABORT  | TC     | BAILOUT  |                                    |
|          | OCT    | 01211    |                                    |
| MARKOK   | CCS    | VAC1USE  | # FIND VAC AREA                    |
|          | TC     | MKVACFND |                                    |
|          | CCS    | VAC2USE  |                                    |
|          | TC     | MKVACFND |                                    |
|          | CCS    | VAC3USE  |                                    |
|          | TC     | MKVACFND |                                    |
|          | CCS    | VAC4USE  |                                    |
|          | TC     | MKVACFND |                                    |
|          | CCS    | VAC5USE  |                                    |
|          | TC     | MKVACFND |                                    |
|          | TC     | BAILOUT  |                                    |
|          | OCT    | 01207    |                                    |
| MKVACFND | AD     | TWO      | # ADDRESS OF VAC AREA              |
|          | TS     | MARKSTAT |                                    |
|          | INDEX  | A        |                                    |
|          | TS     | QPRET    | # STORE NEXT AVAILABLE MARK SLOT   |
|          | CAF    | ZERO     | # STORE VAC AREA OCCUPIED          |
|          | INDEX  | MARKSTAT |                                    |
|          | TS     | 0 -1     |                                    |
|          | TC     | CHECKMM  | # BACKUP MARK ROUTINE USES SXTMARK |
|          | MM     | 53       |                                    |
|          | TCF    | +2       |                                    |
|          | TCF    | SWRETURN |                                    |
|          | TC     | CHECKMM  |                                    |
|          | MM     | 54       |                                    |
|          | TCF    | +2       |                                    |
|          | TCF    | SWRETURN |                                    |
|          | CAF    | BIT12    | # DESIRED NUMBER OF MARKS IN 12-14 |
|          | EXTEND |          |                                    |
|          | MP     | RUPTREG1 |                                    |
|          | XCH    | L        |                                    |
|          | ADS    | MARKSTAT |                                    |
|          | CAF    | PRI032   | # ENTER MARK JOB                   |
|          | TC     | NOVAC    |                                    |
|          | EBANK= | MARKSTAT |                                    |
|          | 2CADR  | MKVB51   |                                    |

RELINT

TCF SWRETURN

# SAME AS MODEEXIT

# Page 224

# PROGRAM NAME: MKRELEAS

DATE: 5 APRIL 1967

# PROGRAM MODIFIED BY 248/278 PROGRAMMERS

LOG SECTION SXTMARK

# MOD BY: R. MELANSON TO ADD DOCUMENTATION

ASSEMBLY SUNDISK REV

#

# FUNCTIONAL DESCRIPTION:

#

# MKRELEAS IS EXECUTED BY INTERNAL ROUTINES TO RELEASE THE MARK SYSTEM TO MAKE  
# SYSTEM ROUTINES. IT ALSO CLEARS THE COARSE OPTICS FLAG BIT AND DISABLES THE

#

# CALLING SEQUENCE:

#

# TC BANKCALL

# CADR MKRELEAS

#

# NORMAL EXIT MODE:

#

# SWRETURN

#

# ALARM OR EXIT MODE: NONE

#

# OUTPUT:

#

# 1) BIT9 OPTMODES SET TO 0

# 2) OPTIND SET TO -1

# 3) 1ST WORD OF VAC AREA SET TO VAC ADDRESS TO SIGNIFY AVAILABILITY

# 4) MARKSTAT CLEARED

# 5) BIT2 CHANNEL 12 SET TO 0

#

# ERASABLE INITIALIZATION: NONE

#

# DEBRIS:

#

# A,MARKSTAT,BIT9,OPTMODES OPTIND,BIT2 CHANNEL 12

MKRELEAS

CAF ZERO

# SHOW MARK SYSTEM NOW AVAILABLE

XCH MARKSTAT

MASK LOW9

CCS A

INDEX A

TS 0

MKRLEES

INHINT

CS BIT9

# COARSE OPTICS RETURN FLAG.



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MASK OPTMODES  
TS OPTMODES

CA NEGONE  
TS OPTIND

# KILL COARSE OPTICS

CS BIT2  
EXTEND  
WAND CHAN12

# DISABLE OPTICS ERROR COUNTER

RELINT  
TC SWRETURN

# Page 225

# PROGRAM NAME: MARKRUPT

DATE: 5 APRIL 1967

# PROGRAM MODIFIED BY 258/278 PROGRAMMERS

LOG SECTION SXTMARK

# MOD BY: R. MELANSON TO ADD DOCUMENTATION

ASSEMBLY SUNDISK REV. 116

#

# FUNCTIONAL DESCRIPTION:

#

# MARKRUPT STORES CDUS,OPTICS AND TIME AND TRANSFERS CONTROL TO THE MARKIT,MARK REJECT OR  
# BITS IN CHANNEL 16 ARE SET AS REQUIRED.

#

# CALLING SEQUENCE:

#

# ROUTINE ENTERED VIA KEYRUPT2 WHEN MARK,MARK REJECT OR DSKY KEYS DEPRESSED BY THE OPERAT

#

# NORMAL EXIT MODE:

#

# MARKIT, MKREJECT, OR POSTJUMP ROUTINES (MARK, MARK REJECT, OR DSKY CODE)

#

# ALARM OR ABORT EXIT MODE:

#

# ALARM AND RESUME

#

# OUTPUT:

#

# RUPTSTOR+5 = CDUT, RUPTSTOR+3 = CDUS, RUPTSTOR+2 = CDUY,  
# RUPTREG3 = CDUZ, RUPTSTOR+6 = CDUX, RUPTSTOR+1 AND SAMPTIME+1 = TIME1,  
# RUPTSTOR AND SAMPTIME = TIME2

#

# ERASABLE INITIALIZATION:

#

# CDUT,CDUS,CDUY,CDUZ,CDUX,TIME2,TIME1,CHANNEL 16 BITS 6,7 OR 1-5.

#

# DEBRIS:

#

```

#           A,QRUPT,RUPTREG3,SAMPTIME,SAMPTIME+1,RUPTSTOR TO RUPTSTOR+6 EXCEPT RUPTSTOR+
MARKRUPT    TS      BANKRUPT                # STORE CDUS AND OPTICS NOW
            CA      CDUT
            TS      MKCDUT
            CA      CDUS
            TS      MKCDUS
            CA      CDUY
            TS      MKCDUY
            CA      CDUZ
            TS      MKCDUZ
            CA      CDUX
            TS      MKCDUX
            EXTEND
            DCA      TIME2                    # GET TIME
            DXCH      MKT2T1
            EXTEND
            DCA      MKT2T1
            DXCH      SAMPTIME                # RUPT TIME FOR NOUN 65.

            XCH      Q
            TS      QRUPT

            CAF      BIT6                    # SEE IF MARK OR MKREJECT
# Page 226
            EXTEND
            RAND      NAVKEYIN
            CCS      A
            TC      MARKIT                    # IT'S A MARK

            CAF      BIT7                    # NOT A MARK, SEE IF MKREJECT
            EXTEND
            RAND      NAVKEYIN
            CCS      A
            TC      MKREJECT                # IT'S A MARK REJECT

KEYCALL      CAF      OCT37                  # NOT MARK OR MKREJECT, SEE IF KEYCOM
            EXTEND
            RAND      NAVKEYIN
            EXTEND
            BZF      +3                      # IF NO INBITS
            TC      POSTJUMP
            CADR      KEYCOM                # IT'S A KEY CODE, NOT A MARK.

            +3      TC      ALARM
            OCT      113                    # ALARM IF NO INBITS

```

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Apollo-11.nw 1755

TC RESUME

# Page 227

# PROGRAM NAME: MARKCONT

DATE: 19 SEPT 1967

# PROGRAM MODIFIED BY 258/278 PROGRAMMERS

LOG SECTION SXTMARK

# MOD BY: R. MELANSON TO ADD DOCUMENTATION

ASSEMBLY SUNDISK REV. 116

#

# FUNCTIONAL DESCRIPTION:

#

# MARKCONT IS USED TO PERFORM A SPECIAL MARK FUNCTION FOR R21, TO EXECUTE A SPECIAL DISPLAY  
# TO PERFORM A MARK OF THE STAR OR LAND SIGHTING BASED UPON FLASHING V-N.

#

# CALLING SEQUENCE:

#

# FROM MARKDIF

#

# NORMAL EXIT MODE:

#

# TASKOVER

#

# ALARM OR ABORT EXIT MODE:

#

# ALARM AND TASKOVER

#

# OUTPUT:

#

# 1) FOR R21:

# EBANK=EBANK7

# MRKBUF1 TO MRKBUF1+6 = TIME2,TIME1,CDUY,OPTICX,CDUZ,OPTICSY,CDUX OF CURRENT R21

# MRKBUF2 TO MRKBUF2+6 CONTAINS PREVIOUS R21 MARK VALUES.

# 2) FOR SPECIAL DISPLAY JOB:

# RUPTREG1 AND MRKBUF1 = CDUS, RUPTREG2, AND MRKBUF1+1 = CDUT.

# RUPTREG3 AND MRKBUF1+2 = TIME2, RUPTREG4, AND MRKBUF1+3 = TIME1.

# 3) FOR NORMAL MARKING:

# DECREMENT BITS14-12 OF MARKSTAT BY 1,

# BIT10 MARKSTAT SET TO 1, INCREMENT QPRET BY 7,

# STORE TIME2,TIME1,CDUY,CDUS,CDUZ,CDUT, AND CDUX IN VAC+1 TO VAC+7.

#

# ERASABLE INITIALIZATION:

#

# 1) FOR R21:

# BIT14 OF STATE+2 =1, MRKBUF1 TO MRKBUF1+6, ITEMP1, RUPTREG3,

# RUPTSTOR TO RUPTSTOR+6 EXCEPT RUPTSTOR+4.

# 2) FOR SPECIAL DISPLAY JOB:

# BIT14 OF STATE+2 =0, MARKSTAT =+0, RUPTREG1, RUPTREG2, RUPTREG3

# RUPTREG4, RUPTSTOR, RUPTSTOR+1, RUPTSTOR+3, RUPTSTOR+5,

```

#          BIT12 OF STATE+5 (V59 FLAG), MRKBUF1 THRU MRKBUF1+3
#          3)  FOR NORMAL MARKING:
#          BIT14 OF STATE+2 =0, MARKSTATE =VAC ADDRESS, A REG, ITEMP1, RUPTREG3,
#          RUPTSTOR TO RUPTSTOR+6 EXCEPT RUPTSTOR+4.
#
# DEBRIS:
#
#          1)  FOR R21:
#          A, ITEMP1, MRKBUF1, MRKBUF2
#          2)  FOR SPECIAL DISPLAY JOB:
#          A, RUPTREG1, RUPTREG2, RUPTREG3, RUPTREG4, MPAC TO MPAC+3.
#          3)  FOR NORMAL MARKING:
#          A, MARKSTAT, ITEMP1, QPRET, VAC+1 TO VAC+7 OF VAC AREA IN USE.

```

# Page 228

```

MARKCONT  CAF      BIT14
           MASK     STATE   +2          # R21 MARK (SPECIAL MARKING FOR R21)
           EXTEND
           BZF      MARKET          # NOT SET THEREFORE REGULAR MARKING
MARKIT1    CAF      SIX              # SPECIAL FOR R21
           TC       GENTRAN          # TRANSFER MRKBUF1 TO MRKBUF2
           ADRES    MRKBUF1
           ADRES    MRKBUF2

           CAF      SIX              # TRANSFER CURRENT MARK DATE TO MARK
           TC       GENTRAN
           ADRES    MKT2T1
           ADRES    MRKBUF1

           TCF      TASKOVER

MARKET     CCS      MARKSTAT          # SEE IF MARKS CALLED FOR
           TC       MARK2            # COLLECT MARKS

           CAF      TWO              # IS MARKING SYSTEM IN USE (BIT2)
           MASK     EXTVBACT
           EXTEND
           BZF      MARKET3          # MARKING NOT CALLED FOR
           CAF      BIT12
           MASK     STATE   +5        # V59FLAG
           EXTEND
           BZF      MARKET3          # IF V59FLAG NOT SET-MARK UNCALLED FOR
           CAF      PRI05            # CALIBRATION MARK (SET) FOR P23
           TC       NOVAC            # SPECIAL DISPLAY JOB
           EBANK=   MRKBUF1
           2CADR    MARKDISP

```

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|         |       |          |                                         |
|---------|-------|----------|-----------------------------------------|
|         | CAF   | SIX      |                                         |
|         | TC    | GENTRAN  | # TRANSFER MARK DATE TO MARKDOWN        |
|         | ADRES | MKT2T1   |                                         |
|         | ADRES | MARKDOWN |                                         |
|         | CAF   | SIX      |                                         |
|         | TC    | GENTRAN  | # TRANSFER MARK DATA TO MRKBUF1 FOR     |
|         | ADRES | MKT2T1   | # SPECIAL DISPLAY OF SHAFT AND TRUNNION |
|         | ADRES | MRKBUF1  | # IF V59 ACTING                         |
|         | TCF   | TASKOVER |                                         |
| MARKET3 | TC    | ALARM    |                                         |
|         | OCT   | 122      | # MARKING NOT CALLED FOR                |
|         | TCF   | TASKOVER |                                         |
| 114ALM  | TC    | ALARM    | # MARK NOT WANTED                       |
|         | OCT   | 114      |                                         |
|         | TCF   | TASKOVER |                                         |

# Page 229

# STORE MARK DATA IN MKVAC AND INCREMENT POINTER

|         |        |          |                                           |
|---------|--------|----------|-------------------------------------------|
| MARK2   | AD     | 74K      | # SEE IF MARKS WANTED-REDUCE MARKS WANTED |
|         | EXTEND |          |                                           |
|         | BZMF   | 114ALM   | # MARK NOT WANTED-ALARM                   |
|         | TS     | MARKSTAT |                                           |
|         | COM    |          |                                           |
|         | MASK   | BIT10    | # SET BIT10 TO ENABLE REJECT              |
|         | ADS    | MARKSTAT |                                           |
|         | MASK   | LOW9     |                                           |
|         | TS     | ITEMP1   |                                           |
|         | INDEX  | A        |                                           |
|         | XCH    | QPRET    | # PICK UP MARK SLOT-POINTER               |
|         | TS     | ITEMP2   | # SAVE CURRENT POINTER                    |
|         | AD     | SEVEN    | # INCREMENT POINTER                       |
|         | INDEX  | ITEMP1   |                                           |
|         | TS     | QPRET    | # STORE ADVANCED POINTER                  |
| VACSTOR | EXTEND |          |                                           |
|         | DCA    | MKT2T1   |                                           |
|         | INDEX  | ITEMP2   |                                           |
|         | DXCH   | 0        |                                           |
|         | CA     | MKCDUY   |                                           |
|         | INDEX  | ITEMP2   |                                           |
|         | TS     | 2        |                                           |
|         | CA     | MKCDUS   |                                           |
|         | INDEX  | ITEMP2   |                                           |

```

TS      3
CA      MKCDUZ
INDEX   ITEMP2
TS      4
CA      MKCDUT
INDEX   ITEMP2
TS      5
CA      MKCDUX
INDEX   ITEMP2
TS      6

```

```

CAF      PRI034
MASK     MARKSTAT
EXTEND
BZF      +2
TCF      TASKOVER
CAF      PRI032
TC       NOVAC
EBANK=   MARKSTAT
2CADR    MKVB50

```

# IF ALL MARKS MADE FLASH VB50

TCF TASKOVER

# Page 230

# PROGRAM NAME: MKREJECT

# PROGRAM MODIFIED BY 258/276 PROGRAMMERS

# MOD BY: R. MELANSON TO ADD DOCUMENTATION

#

# FUNCTIONAL DESCRIPTION:

#

# ROUTINE ALLOWS OPEATOR TO REJECT MARK MADE PRIOR TO ACCEPTANCE AND ALLOWS A M

#

# CALLING SEQUENCE:

#

# FROM MARKRUPT IF BIT7 OF CHANNEL 16 IS 1.

#

# NORMAL EXIT MODE:

#

# RESUME

#

# ALARM OR ABORT EXIT MODE:

#

# ALARM AND RESUME

#

# OUTPUT:

#

DATE: 5 APRIL 1967

LOG SECTION SXTMARK

ASSEMBLY SUNDISK REV

July 10, 2016

Apollo-11.nw 1759

```
#      1)      FOR R21:
#              MRKRUP1 SET TO -1
#      2)      FOR NORMAL MARKING:
#              BIT10 MARKSTAT =0, INCREMENT NO. MARKS BY 1, DECREMENT QPRET BY 7
#
# ERASABLE INITIALIZATION:
#
#      1)      FOR R21:
#              BIT14 OF STATE+2 SET TO 1
#      2)      FOR NORMAL MARKING:
#              BIT14 OF STATE+2 SET TO 0, MARKSTAT,QPRET
#
# DEBRIS:
#
#      1)      FOR R21:
#              A,MARKSTAT,EBANK
#      2)      FOR NORMAL MARKING:
#              A,MARKSTAT,ITEMP1,QPRET

MKREJECT      CAF      BIT14
               MASK     STATE   +2          # R21 MARK (SPECIAL MARKING FOR R21)
               EXTEND
               BZF      MRKREJCT          # NOT SET THEREFORE REGULAR REJECT
               CA       NEGONE            # -1 (FOR R22)
               TS       MRKBUF1           # -0 IN TIME IS FLAG TO R22 SIGNIFYING A
               TC       RESUME            # REJECTED MARK
MRKREJCT      CCS      MARKSTAT          # SEE IF MARKS BEING ACCEPTED
               TC       REJECT2
               TC       ALARM             # MARKS NOT BEING ACCEPTED
               OCT      112
               TC       RESUME

REJECT2       CS       BIT10             # SEE IF MARK HAD BEEN MADE SINCE LAST
               MASK     MARKSTAT         # REJECT, AND SET BIT10 TO ZERO TO
               XCH      MARKSTAT         # SHOW MARK REJECT

# Page 231

               MASK     BIT10
               CCS      A
               TC       REJECT3

               TC       ALARM             # DON'T ACCEPT TWO REJECTS TOGETHER
               OCT      110
               TC       RESUME

REJECT3       CAF      LOW9              # DECREMENT POINTER TO REJECT MARK
               MASK     MARKSTAT
```

TS ITEMP1  
 CS SEVEN  
 INDEX ITEMP1  
 ADS QPRET

# NEW POINTER

CAF BIT12  
 AD MARKSTAT  
 XCH MARKSTAT  
 MASK PRI034  
 CCS A  
 TC RESUME  
 CAF PRI032  
 TC NOVAC  
 EBANK= MARKSTAT  
 2CADR MKVB51

# INCREMENT MARKS WANTED AND IF FIELD  
 # IS NOW NON-ZERO, CHANGE TO VB51 TO  
 # INDICATE MORE MARKS WANTED  
 # INDICATE MORE MARKS WANTED

TC RESUME

# Page 232

# PROGRAM DESCRIPTON MKVB51 AND MKVB50

#

# AUTHOR: BARNERT DATE: 2-15-67 MOD: 0

# PURPOSE: FLASH V51N70,V51N43, OR V51 TO REQUEST MARKING,  
 # AND V50N25 R1=16 TO REQUEST TERMINATE MARKING.

#

# CALLING SEQUENCE: AS JOB WITHIN SXTMARK

#

# EXIT TO ENDMARK UPON RECEIPT OF V33, V34 CAUSES GOTOP00H, ENTER  
 # RECYCLES THE DISPLAY

#

# NOTE: SXTMARK AUTOMATICALLY CHANGES FROM CALLING MKVB51 TO MKVB50 WHEN  
 # SUFFICIENT MARKS HAVE BEEN MADE, AND THE REVERSE WHEN A MARK  
 # REJECT REDUCES THE NUMBER MADE BELOW THAT REQUIRED

#

# SUBROUTINES CALLED: BANKCALL, GOMARK2, GOODEND, ENDMARK, WAITLIST

#

# ALARM OR ABORT MODES: NONE

#

# ERASABLE USED: VERBREG, MARKSTAT, QPRET, DSPTEM1

#

# OUTPUT MARKSTAT = VAC ADDRESS

# QPRET = NO. MARKS

MKVB51 TC BANKCALL  
 CADR KLEENEX

# CLEAR DISPLAY FOR MARK VERB



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|            |        |          |                                            |
|------------|--------|----------|--------------------------------------------|
|            | CAF    | VB51     | # DISPLAY MARK VB51                        |
|            | TC     | BANKCALL |                                            |
|            | CADR   | GOMARK4  |                                            |
|            | TCF    | TERMSXT  | # VB34-TERMINATE                           |
|            | TCF    | ENTANSWR | # V33-PROCEED-MARKING DONE                 |
|            | TCF    | MKVB5X   | # ENTER-RECYCLE TO INITIAL MARK DISPLAY    |
| TERMSXT    | TC     | CLEARMRK | # CLEAR MARK ACTIVITY.                     |
|            | TC     | CHECKMM  |                                            |
|            | MM     | 03       |                                            |
|            | TCF    | +2       |                                            |
|            | TC     | TERMP03  |                                            |
|            | TC     | POSTJUMP |                                            |
|            | CADR   | TERM52   |                                            |
| TERMP03    | TC     | UPFLAG   |                                            |
|            | ADRES  | TRM03FLG |                                            |
| ENTANSWR   | CAF    | LOW9     | # PUT VAC ADR IN MARKSTAT AND NO. OF       |
|            | MASK   | MARKSTAT | # MARKS MADE IN QPRET BEFORE LEAVING       |
|            | TS     | MARKSTAT | # SXTMARK                                  |
|            | COM    |          |                                            |
|            | INDEX  | MARKSTAT |                                            |
|            | AD     | QPRET    |                                            |
| # Page 233 |        |          |                                            |
|            | EXTEND |          |                                            |
|            | BZMF   | JAMIT    | # NO MARKS MADE, SHOW IT IN QPRET, R53     |
|            | EXTEND |          | # WILL PICK IT UP AND RECYCLE              |
|            | MP     | BIT12    | # THIS PUTS NUMBER MARKS-1 IN A            |
|            | AD     | ONE      |                                            |
| JAMIT      | INDEX  | MARKSTAT | # STORE NO OF MARKS MADE                   |
|            | TS     | QPRET    |                                            |
|            | INHINT |          | # SERVICE OPTSTALL INTERFACE WITH          |
|            | CAF    | FIVE     |                                            |
|            | TC     | WAITLIST |                                            |
|            | EBANK= | MARKSTAT |                                            |
|            | 2CADR  | ENDMARKS |                                            |
|            | TC     | ENDMARK  | # KNOCKS DOWN MARKING FLAG + DOES ENDOFJOB |
| ENDMARKS   | CAF    | ONE      |                                            |
|            | TC     | IBNKCALL |                                            |
|            | CADR   | GOODEND  |                                            |
| MKVB5X     | CAF    | PRI034   |                                            |
|            | MASK   | MARKSTAT | # RE-DISPLAY VB51 IF MORE MARKS WANTED     |
|            | CCS    | A        | # AND VB50 IF ALL IN                       |

|        |     |           |          |
|--------|-----|-----------|----------|
|        | TCF | MKVB51    |          |
| MKVB50 | CAF | R1D1      | # OCT 16 |
|        | TS  | DSPTM1    |          |
|        | CAF | V50N25    |          |
|        | TCF | MKVB51 +3 |          |

|        |    |      |
|--------|----|------|
| V50N25 | VN | 5025 |
| VB51   | VN | 5100 |
| OCT37  | =  | LOW5 |

# PROGRAM NAME: MARKIT DATE: 19 SEPT 1967

#

# CALLING SEQUENCE:

#

# FROM MARKRUPT IF CHAN 16 BIT 6 = 1

#

# EXIT

#

# RESUME

#

# INPUT

#

# CDUCHKWD. ALSO ALL INITIALIZATION FOR MARKCONT

#

# OUTPUT

#

# MKT2T1,MKCDUX,MKCDUY,MKCDUZ,MKCDUS,MKCDUT

#

# ALARM EXIT

#

# NONE

MARKIT CCS CDUCHKWD

TCF +3

# DELAY OF CDUCHKWD CS IF PNZ

# Page 234

TCF +2

CAF ZERO

AD ONE

# 10 MS IF NO CHECK

TC WAITLIST

EBANK= MRKBUF1

2CADR MARKDIF

TCF RESUME

SETLOC SXTMARK1

BANK

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COUNT 20/SXTMK

```
# PROGRAM NAME: MARKDIF
#
# CALLING SEQUENCE
#
#     WAITLIST FROM MARKIT
#
# EXIT
#
#     TASKOVER TO IBNKCALL TO MARKCONT
#
# INPUT
#
#     OUTPUT FROM MARKIT, INPUT TO MARKCONT, CDUCHKWD
#
# OUTPUT
#
#     RUPTSTOR - RUPTSTOR+3, RUPTREG3, RUPTSTOR+5 - RUPTSTOR+6
#
# ALARM EXIT
#
#     ALARM AND TASKOVER

MARKDIF      CA      CDUCHKWD      # IF DELAY CHECK IS ZERO OR NEG, ACP MARK
            EXTEND
            BZMF     MKACPT
            CS       BIT1
            TS       MKNDX      # SET INDEX -1
            CA       MKCDUX
            TC       DIFCHK      # SEE IF VEHICLE RATE TOO MUCH AT MARK
            CA       MKCDUY
            TC       DIFCHK
            CA       MKCDUZ
            TC       DIFCHK

MKACPT      TC       IBNKCALL
            CADR     MARKCONT      # MARK DATA OK, WHAT DO WE DO WITH IT

DIFCHK      INCR     MKNDX      # INCREMENT INDEX

            EXTEND
            INDEX    MKNDX

# Page 235
            MSU      CDUX      # GET MARK(ICDU) - CURRENT(ICDU)
```

1764      Apollo-11.nw

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CCS      A  
TCF      +4  
TC       Q  
TCF      +2  
TC       Q  
AD       NEG2  
EXTEND  
BZMF     -3

# SEE IF DIFFERENCE GREATER THAN 3 B

# NOT GREATER

TC       ALARM  
OCT      00121

# COUPLED WITH PROGRAM ALARM

TCF      TASKOVER

# DO NOT ACCEPT

This code is written to file `src/SXTMARK.s`.

**A.108 SYSTEM TEST STANDARD LEAD INS**

```

1765  <src/SYSTEM-TEST-STANDARD-LEAD-INS.s 1765>≡
# Copyright:    Public domain.
# Filename:     SYSTEM_TEST_STANDARD_LEAD_INS.agc
# Purpose:     Part of the source code for Comanche, build 055.
#             It is part of the source code for the Command Module's (CM)
#             Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:   yaYUL
# Reference:    pp. 420-422
# Contact:     Onno Hommes <ohommes@cmu.edu>.
# Website:     www.ibiblio.org/apollo.
# Mod history: 05/07/09 OH      Transcription Batch 1 Assignment
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#             Massachussets Institute of Technology
#             75 Cambridge Parkway
#             Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further information.
# Please report any errors to info@sandroid.org.

# Page 420

EBANK=  XSM

BANK    33
SETLOC  E/PROG1
BANK

COUNT*  $$/P07

# SPECIAL PROGRAMS TO EASE THE PANGS OF ERASABLE MEMORY PROGRAMS.
#
# E/BKCALL      FOR DOING BANKCALLS FROM AND RETURNING TO ERASABLE.
#

```

```

# THIS ROUTINE IS CALLABLE FROM ERASABLE OR FIXED.  LIKE BANKCALL, HOWEVER, SWITCHING
# IS NOT POSSIBLE.
#
# THE CALLING SEQUENCE IS:
#
#      TC      BANKCALL
#      CADR     E/BKCALL
#      CADR     ROUTINE      # WHERE TO WANT TO GO IN FIXED.
#      RETURN HERE FROM DISPLAY TERMINATE, BAD STALL OR TC Q.
#      RETURN HERE FROM DISPLAY PROCEED OR GOOD RETURN FROM STALL.
#      RETURN HERE FROM DISPLAY ENTER OR RECYCLE.
#
# THIS ROUTINE REQUIRES TWO ERASABLES (EBUF2, +1) IN UNSWITCHED WHICH ARE UNSHARED BY
# OTHER EMEMORY PROGRAMS.
#
# A + L ARE PRESERVED THROUGH BANKCALL AND E/BKCALL.

E/BKCALL      DXCH      BUF2      # SAVE A,L AND GET DP RETURN.
              DXCH      EBUF2     # SAVE DP RETURN.
              INCR      EBUF2     # RETURN +1 BECAUSE DOUBLE CADR.
              CA        BBANK
              MASK      LOW10     # GET CURRENT EBANK.  (SBANK SOMEDAY)
              ADS       EBUF2     +1 # FORM BBCON.  (WAS FBANK)
              NDX       EBUF2
              CA        0 -1      # GET CADR OF ROUTINE.
              TC        SWCALL    # GO TO ROUTINE, SETTING Q TO SWRETURN
                                # AND RESTORING A + L.
              TC        +4        # TX Q, V34, OR BADD STALL RETURN.
              TC        +2        # PROCEED OR GOOD STALL RETURN.
              INCR      EBUF2     # ENTER OR RECYCLE RETURN.
              INCR      EBUF2
E/SWITCH      DXCH      EBUF2
              DTCB

# Page 421
# E/CALL      FOR CALLING A FIXED MEMORY INTERPRETIVE SUBROUTINE FROM ERASABLE AND
#
# THE CALLING SEQUENCE IS...
#
#      RTB
#
#      CADR     E/CALL
#      CADR     ROUTINE      # THE INTERPRETIVE SUBROUTINE YOU WANT
#                          # RETURNS HERE IN INTERPRETIVE.

E/CALL      LXCH      LOC      # ADRES -1 OF CADR.
              INDEX    L

```

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```
CA      L          # CADR IN A.
INCR    L
INCR    L          # RETURN ADRES IN L.
DXCH    EBUF2      # STORE CADR AND RETURN.
TC      INTERPRET
CALL
          EBUF2      # INDIRECTLY EXECUTE ROUTING. IT MUST
EXIT          # LEAVE VIA RVQ OR EQUIVALENT.
LXCH    EBUF2 +1    # PICK UP RETURN.
TCF     INTERPRET +2 # SET LOC AND RETURN TO CALLER.
```

# Page 422

# E/JOBWAK FOR WAKING UP ERASABLE MEMORY JOBS.

#

# THIS ROUTINE MUST BE CALLED IN INTERRUPT OR WITH INTERRUPTS INHIBITED.

#

# THE CALLING SEQUENCE IS

#

# INHINT

# ...

# CA WAKEADR # ADDRESS OF SLEEPING JOB

# TC IBNKCALL

# CADR E/JOBWAK

# ... # RETURNS HERE

# RELINT # IF YOU DID AND INHINT

BANK 33

SETLOC E/PROG

BANK

COUNT\* \$\$/P07

E/JOBWAK TC JOBWAKE # ARRIVE IWTH ADRES IN A.

CS BIT11

NDX LOCCTR

ADS LOC # KNOCK FIXED MEMORY BIT OUT OF ADRES.

TC RUPTREG3 # RETURN

# THESE PROGRAMS ARE PROVIDED TO ALLOW OVERLAY OF BANKS 30 THRU 33 OF THE 205 VERSIONS OF SYSTEM  
# PRELAUNCH ALIGN. THE INTENT IS TO ALLOW THE STG AND HYBRID LABS TO RUN ALL THE TESTS WITH CO

BANK 33

SETLOC TESTLEAD

BANK

|          |        |          |                      |
|----------|--------|----------|----------------------|
|          | COUNT  | 33/COMST |                      |
|          | EBANK= | QPLACE   |                      |
| COMPVER  | TC     | GCOMPVER | # MUST BE 33,2000.   |
| GTSCPSS1 | TC     | GTSCPSS  | # MUST BE AT 33,2001 |
| REDO     | TC     | NEWMODEX | # DISPLAY MM 07.     |
|          | MM     | 07       | # FALL INTO IMUTEST  |

This code is written to file `src/SYSTEM-TEST-STANDARD-LEAD-INS.s`.



## A.109 T4RUPT PROGRAM

```

1769 <src/T4RUPT-PROGRAM.s 1769>≡
# Copyright:    Public domain.
# Filename:     T4RUPT_PROGRAM.agc
# Purpose:      Part of the source code for Comanche, build 055.
#              It is part of the source code for the Command Module's (CM)
#              Apollo Guidance Computer (AGC), Apollo 11.
# Assembler:   yaYUL
# Reference:    pp. 133-169
# Contact:      Ron Burkey <info@sandroid.org>,
#              Fabrizio Bernardini <fabrizio@spacecraft.it>
# Website:      http://www.ibiblio.org/apollo.
# Mod history:  10/05/09 FB      Transcription of Batch FB-1 Assignment.
#
# The contents of the "Comanche055" files, in general, are transcribed
# from scanned documents.
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. April 1, 1969.
#
# This AGC program shall also be referred to as Colossus 2A
#
# Prepared by
#           Massachusetts Institute of Technology
#           75 Cambridge Parkway
#           Cambridge, Massachusetts
#
# under NASA contract NAS 9-4065.
#
# Refer directly to the online document mentioned above for further
# information. Please report any errors to info@sandroid.org.

# Page 133

BANK      12
SETLOC    T4RUP
BANK

COUNT    06/T4RPT

T4RUPT    TS      BANKRUPT
          EXTEND
          QXCH     QRUPT

          CCS      DSRUPTSW      # GOES 7(-1)0 AROUND AND AROUND
          TCF      NORMT4 +1

```

|        |       |          |
|--------|-------|----------|
|        | TCF   | NORMT4   |
|        | TCF   | QUIKDSP  |
| NORMT4 | CAF   | SEVEN    |
|        | TS    | RUPTREG1 |
|        | TS    | DSRUPTSW |
|        | COUNT | 02/T4RPT |
| 74K    | =     | HIGH4    |

# RELTAB IS A PACKED TABLE. RELAYWORD CODE IN UPPER 4 BITS, RELAY CODE  
# IN LOWER 5 BITS.

|          |        |         |
|----------|--------|---------|
|          | BLOCK  | 02      |
|          | SETLOC | FFTAG12 |
|          | BANK   |         |
| RELTAB   | OCT    | 04025   |
|          | OCT    | 10003   |
|          | OCT    | 14031   |
|          | OCT    | 20033   |
|          | OCT    | 24017   |
|          | OCT    | 30036   |
|          | OCT    | 34034   |
|          | OCT    | 40023   |
|          | OCT    | 44035   |
|          | OCT    | 50037   |
|          | OCT    | 54000   |
| RELTAB11 | OCT    | 60000   |

# Page 134  
# SWITCHED-BANK PORTION

|       |        |             |
|-------|--------|-------------|
|       | BANK   | 12          |
|       | SETLOC | T4RUP       |
|       | BANK   |             |
|       | COUNT  | 06/T4RPT    |
| CDRVE | CCS    | DSPTAB +11D |
|       | TC     | DSPOUT      |
|       | TC     | DSPOUT      |
|       | XCH    | DSPTAB +11D |

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MASK LOW11  
TS DSPTAB +11D  
AD RELTAB11  
EXTEND  
WRITE OUT0  
TC HANG20

# Page 135

# DSPOUT PROGRAM, PUTS OUT DISPLAYS

```
DSPOUTSB      TS      NOUT
              CS      ZERO
              TS      DSRUPTM      # SET TO -0 FOR 1ST PASS THRU DSPTAB
              XCH     DSPCNT
              AD      NEG0      # TO PREVENT +0
              TS      DSPCNT
DSPSCAN        INDEX   DSPCNT
              CCS      DSPTAB
              CCS      DSPCNT      # IF DSPTAB ENTRY +, SKIP
              TCF     DSPSCAN -2   # IF DSPCNT +, AGAIN
              TCF     DSPLY      # IF DSPTAB ENTRY -, DISPLAY
TABLNTH        OCT     12      # DEC 10 LENGTH OF DSPTAB
              CCS      DSRUPTM      # IF DSRUPTM=+0, 2ND PASS THRU DSPTAB
120MRUPT       DEC     16372     # (DSPCNT = 0). +0 INTO NOUT.
              TS      NOUT
              TC      Q
              TS      DSRUPTM      # IF DSRUPTM=-0, 1ST PASS THRU DSPTAB
              CAF     TABLNTH      # (DSPCNT=0).+0 INTO DSRUPTM. PASS AGAIN
              TCF     DSPSCAN -1

DSPLY          AD      ONE
              INDEX   DSPCNT
              TS      DSPTAB      # REPLACE POSITIVELY
              MASK    LOW11      # REMOVE BITS 12 TO 15
              TS      DSRUPTM
              CAF     HI5
              INDEX   DSPCNT
              MASK    RELTAB      # PICK UP BITS 12 TO 15 OF RELTAB ENTRY
              AD      DSRUPTM
              EXTEND
              WRITE   OUT0      # WRITE CHANNEL 10
              TCF     Q+1      # *** NORMAL RETURN SKIPS ONE

DSPOUT         CCS     FLAGWRD5   # DON'T DISPLAY UNLESS DSKY FLAG ON
              CAF     ZERO
              TCF     NODSPOUT
```

```

                CCS    NOUT
                TC      DSPOUTSB
                TCF     NODSPOUT      # NO DISPLAY REQUESTS

HANG20          CS      11,14,9
                ADS     DSRUPTSW

                CAF     20MRUPT

SETTIME4        TS      TIME4

```

# Page 136

```

# THE STATUS OF THE PROCEED PUSHBUTTON IS MONITORED EVERY 120 MILLISECONDS VIA THE C
# THE STATE OF THIS INBIT IS COMPARED WITH ITS STATE DURING THE PREVIOUS T4RUPT AND
#       IF PREV ON AND NOW ON    -- BYPASS
#       IF PREV ON AND NOW OFF   -- UPDATE IMODES33
#       IF PREV OFF AND NOW ON   -- UPDATE IMODES33 AND PROCESS VIA PINBALL
#       IF PREV OFF AND NOW OFF  -- BYPASS
# THE LOGIC EMPLOYED REQUIRES ONLY 9 MCT (APPROX. 108 MICROSECONDS) OF COMPUTER TIME

```

```

PROCEEDE        CA      IMODES33      # MONITOR FOR PROCEED BUTTON
                EXTEND
                RXOR     CHAN32      # CHECK IF BIT 14 DIFFERENT
                MASK     BIT14
                EXTEND
                BZF      T4JUMP      # NO CHANGE

                LXCH     IMODES33
                EXTEND
                RXOR     LCHAN
                TS        IMODES33    # UPDATE IMODES33
                MASK     BIT14
                CCS       A
                TCF       T4JUMP      # WAS ON -- NOW OFF

                CAF      CHRPRIO      # WAS OFF -- NOW ON
                TC        NOVAC
                EBANK=    DSPCOUNT
                2CADR     PROCKEY

```

# Page 137

# JUMP TO APPROPRIATE ONCE-PER SECOND (0.96 SEC ACTUALLY) ACTIVITY

```

T4JUMP          INDEX    RUPTREG1
                TCF      +1

```

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|          |        |          |                                         |
|----------|--------|----------|-----------------------------------------|
|          | TCF    | OPTTEST  |                                         |
|          | TCF    | OPTMON   |                                         |
|          | TCF    | IMUMON   |                                         |
|          | TCF    | RESUME   |                                         |
|          | TCF    | OPTTEST  |                                         |
|          | TCF    | OPTMON   |                                         |
|          | TCF    | IMUMON   |                                         |
|          | TCF    | RESUME   |                                         |
| OPTTEST  | TC     | IBNKCALL |                                         |
|          | CADR   | OPTDRIVE |                                         |
| 20MRUPT  | =      | OCT37776 | # (DEC 16382)                           |
| NODSPOUT | EXTEND |          | # TURN OFF RELAYS                       |
|          | WRITE  | OUTO     |                                         |
|          | CAF    | 120MRUPT | # SET FOR NEXT CDRVE                    |
|          | TCF    | SETTIME4 |                                         |
| QUIKDSP  | CAF    | BIT14    |                                         |
|          | MASK   | DSRUPTSW |                                         |
|          | EXTEND |          |                                         |
|          | BZF    | QUIKOFF  | # WROTE LAST TIME, NOW TURN OFF RELAYS. |
|          | CCS    | NOUT     |                                         |
|          | TC     | DSPOUTSB |                                         |
|          | TCF    | NODSPY   | # NOUT=0 OR BAD RETURN FROM DSPOUTSB    |
|          | CS     | BIT14    | # GOOD RETURN (WE DISPLAYED SOMETHING)  |
| QUIKRUPT | ADS    | DSRUPTSW |                                         |
|          | CAF    | 20MRUPT  |                                         |
|          | TS     | TIME4    |                                         |
|          | CAF    | BIT9     |                                         |
|          | ADS    | DSRUPTSW |                                         |
|          | TC     | RESUME   |                                         |
| NODSPY   | EXTEND |          |                                         |
|          | WRITE  | OUTO     |                                         |
| SYNCT4   | CAF    | 20MRUPT  |                                         |
|          | ADS    | TIME4    |                                         |
|          | CAF    | BIT9     |                                         |

# Page 138

```

          ADS      DSRUPTSW
          CCS      DSRUPTSW
          TC       RESUME
OCT37737  OCT      37737
          TC       SYNCT4
          TC       RESUME

QUIKOFF   EXTEND
          WRITE    OUTO
          CAF      BIT14      # RESET DSRUPTSW TO SEND DISPLAY NEXT PASS
          TCF      QUIKRUP

```

```

11,14,9   OCT      22400

```

# Page 139

# PROGRAM NAME: IMUMON

#

```

# FUNCTIONAL DESCRIPTION:  THIS PROGRAM IS ENTERED EVERY 480 MS.  IT DETECTS CHANGES
# CHANNEL 30 AND CALLS THE APPROPRIATE SUBROUTINES.  THE BITS PROCESSED AND THEIR RE

```

#

| FUNCTION            | BIT | SUBROUTINE CALLED  |
|---------------------|-----|--------------------|
| -----               | --- | -----              |
| TEMP IN LIMITS      | 15  | TLIM               |
| ISS TURN-ON REQUEST | 14  | ITURNON            |
| IMU FAIL            | 13  | IMUFAIL (SETISSW)  |
| IMU CDU FAIL        | 12  | ICDUFAIL (SETISSW) |
| IMU CAGE            | 11  | IMUCAGE            |
| IMU OPERATE         | 9   | IMUOP              |

#

```

# THE LAST SAMPLED STATE OF THESE BITS IS LEFT IN IMODES30.  ALSO, EACH SUBROUTINE CA
# VALUE OF THE BIT IN A, WITH Q SET TO THE PROPER RETURN LOCATION NXTIFAIL.

```

#

```

# CALLING SEQUENCE:  T4RUPT EVERY 480 MILLISECONDS.

```

#

```

# JOBS OR TASKS INITIATED:  NONE.

```

#

```

# SUBROUTINES CALLED:  TLIM, ITURNON, SETISSW, IMUCAGE, IMUOP.

```

#

```

# ERASABLE INITIALIZATION:

```

```

# FRESH START OR RESTART WITH NO GROUPS ACTIVE:  C(IMODES30) = OCT 37411.

```

```

# RESTART WITH ACTIVE GROUPS:      C(IMODES30) = (B(IMODES30)AND(OCT 00035)) PL
# THIS LEAVES IMU FAIL BITS INTACT.

```

#

```

# ALARMS:  NONE.

```

#

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# EXIT: TNONTEST.

#

# OUTPUT: UPDATED IMODES30 WITH CHANGES PROCESSED BY APPROPRIATE SUBROUTINE.

|        |        |          |                                         |
|--------|--------|----------|-----------------------------------------|
| IMUMON | CA     | IMODES30 | # SEE IF THERE HAS BEEN A CHANGE IN THE |
|        | EXTEND |          | # RELEVANT BITS OF CHAN 30.             |
|        | RXOR   | CHAN30   | # CHECK IF BITS 9,11-15 CHANGED         |
|        | MASK   | 3ORDMSK  |                                         |
|        | EXTEND |          |                                         |
|        | BZF    | TNONTEST | # NO CHANGE IN STATUS                   |

|      |          |                                 |
|------|----------|---------------------------------|
| TS   | RUPTREG1 | # SAVE BITS WHICH HAVE CHANGED. |
| LXCH | IMODES30 | # UPDATE IMODES30.              |

|        |          |
|--------|----------|
| EXTEND |          |
| RXOR   | LCHAN    |
| TS     | IMODES30 |

|        |          |
|--------|----------|
| CS     | ONE      |
| XCH    | RUPTREG1 |
| EXTEND |          |

# Page 140

|      |          |                       |
|------|----------|-----------------------|
| BZMF | TLIM     | # CHANGE IN IMU TEMP. |
| TCF  | NXTIFBIT | # BEGIN BIT SCAN.     |

|          |      |          |                                   |
|----------|------|----------|-----------------------------------|
| -1       | AD   | ONE      | # (RE-ENTERS HERE FROM NXTIFAIL.) |
| NXTIFBIT | INCR | RUPTREG1 | # ADVANCE BIT POSITION NUMBER.    |

|     |          |                     |
|-----|----------|---------------------|
| +1  | DOUBLE   |                     |
| TS  | A        | # SKIP IF OVERFLOW. |
| TCF | NXTIFBIT | # LOOK FOR BIT.     |

|       |          |                                 |
|-------|----------|---------------------------------|
| XCH   | RUPTREG2 | # SAVE OVERFLOW-CORRECTED DATA. |
| INDEX | RUPTREG1 | # SELECT NEW VALUE OF THIS BIT. |

|       |          |
|-------|----------|
| CAF   | BIT14    |
| MASK  | IMODES30 |
| INDEX | RUPTREG1 |
| TC    | IFAILJMP |

|          |     |             |                                   |
|----------|-----|-------------|-----------------------------------|
| NXTIFAIL | CCS | RUPTREG2    | # PROCESS ANY ADDITIONAL CHANGES. |
|          | TCF | NXTIFBIT -1 |                                   |

# Page 141

# PROGRAM NAME: TNONTEST.

#

# FUNCTIONAL DESCRIPTION: THIS PROGRAM HONORS REQUESTS FOR ISS INITIALIZATION. ISS TURN-ON (C  
# AND ISS OPERATE (CHANNEL 30 BIT 9) REQUESTS ARE TREATED AS A PAIR AND PROCESSING TAKES PLACE  
# AFTER EITHER ONE APPEARS. THIS INITIALIZATION TAKES ON ONE OF THE FOLLOWING THREE FORMS:

```

#
# 1) ISS TURN-ON: IN THIS SITUATION THE COMPUTER IS OPERATING WHEN THE ISS IS
# BOTH ISS TURN-ON AND ISS OPERATE APPEAR. THE PLATFORM IS CAGED FOR 90 SECONDS
# SO THAT AT THE END OF THE PROCESS THE GIMBAL LOCK MONITOR WILL FUNCTION PROPERLY.
#
# 2) ICDU INITIALIZATION: IN THIS CASE THE COMPUTER WAS PROBABLY TURNED ON WITH
# A FRESH START WAS DONE WITH THE ISS IN OPERATE. IN THIS CASE ONLY ISS OPERATE
# ZEROED SO THE GIMBAL LOCK MONITOR WILL FUNCTION. AN EXCEPTION IS IF THE ISS
# A RESTART, THE ICDU'S WILL NOT BE ZEROED.
#
# 3) RESTART WITH RESTARTABLE PROGRAM USING THE IMU: IN THIS CASE, NO INITIAL
# IT IS ASSUMED THAT THE USING PROGRAM DID THE INITIALIZATION AND THEREFORE T4
#
# IMODES30 BIT 7 IS SET = 1 BY THE FIRST BIT (CHANNEL 30 BIT 14 OR 9) WHICH ARRIVES.
# ENTERED, FINDS BIT 7 = 1 BUT BIT 8 = 0, SO IT SETS BIT 8 = 1 AND EXITS. THE NEXT
# PROCEEDS, SETTING BITS 8 AND 7 = 0. AT PROCTNON, IF ISS TURN-ON REQUEST IS PRESENT
# COARSE). IF ISS OPERATE IS NOT PRESENT PROGRAM ALARM 00213 IS ISSUED. AT THE END
# OF IMODES30 IS TESTED. IF IT IS = 1, ISS TURN-ON WAS NOT PRESENT FOR THE ENTIRE 90
# THE ISS TURN-ON REQUEST IS PRESENT THE 90 SECOND WAIT IS REPEATED, OTHERWISE NO AC
# WAS WAITING FOR THE INITIALIZATION IN WHICH CASE THE PROGRAM IS GIVEN AN IMUSTALL
# WENT PROPERLY, THE ISS DELAY OUTBIT IS SENT AND THE ICDU'S ZEROED. A TASK IS INITI
# INHIBIT BIT IN 10.24 SECONDS. IF A MISSION PROGRAM WAS WAITING IT IS INFORMED VIA
#
# AT PROCTNON, IF ONLY ISS OPERATE IS PRESENT (OPONLY), THE CDU'S ARE ZEROED UNLESS
# ALIGN (= GIMBAL LOCK HERE) OR A MISSION PROGRAM IS USING THE IMU (INUSEFLG = 1).
#
# CALLING SEQUENCE: T4RUPT EVERY 480 MILLISECONDS AFTER IMUMON.
#
# JOBS OR TASKS INITIATED: 1) ENDTNON, 90 SECONDS AFTER CAGING STARTED. 2) ISSUP, 4
# 3) PFAILOK, 10.24 SECONDS AFTER INITIALIZATION COMPLETED. 4) UNZ2, 320 MILL
# STARTED.
#
# SUBROUTINES CALLED: CAGESUB, CAGESUB2, ZEROICDU, ENDIMU, IMUBAD, NOATTOFF, SETISSW
#
# ERASABLE INITIALIZATION: SEE IMUMON.
#
# ALARMS: PROGRAM ALARM 00213 IF ISS TURN-ON REQUESTED WITHOUT ISS OPERATE.
#
# EXIT: ENDTNON EXITS TO C33TEST. TASKS HAVING TO DO WITH INITIALIZATION EXIT AS F
# WAITING AND INITIALIZATION COMPLETE, EXIT TO ENDIMU, MISSION PROGRAM WAITING AND I
# IMUBAD, IMU NOT IN USE, EXIT TO TASKOVER.
#
# OUTPUT: ISS INITIALIZED.

```

```

TNONTEST          CS          IMODES30          # AFTER PROCESSING ALL CHANGES, SEE 1
# Page 142

```



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```

MASK    BIT7          # IS TIME TO ACT ON A TURN-ON SEQUENCE.
CCS     A
TCF     C33TEST      # NO -- EXAMINE CHANNEL 33.

CAF     BIT8          # SEE IF FIRST SAMPLE OR SECOND.
MASK    IMODES30
CCS     A
TCF     PROCTNON     # REACT AFTER A SECOND SAMPLE.

CAF     BIT8          # IF FIRST SAMPLE, SET BIT TO REACT NEXT
ADS     IMODES30      # TIME.
TCF     C33TEST

# PROCESS IMU TURN-ON REQUESTS AFTER WAITING 1 SAMPLE FOR ALL SIGNALS TO ARRIVE.

PROCTNON    CS    BITS7&8
            MASK   IMODES30
            TS     IMODES30
            MASK   BIT14      # SEE IF TURN-ON REQUEST.
            CCS    A
            TCF    OPONLY     # OPERATE ON ONLY.

            CS     IMODES30    # IF TURN-ON REQUEST, WE SHOULD HAVE IMU
            MASK   BIT9        # OPERATE.
            CCS    A
            TCF    +3

            TC     ALARM       # ALARM IF NOT
            OCT    213

+3          TC     CAGESUB

            CAF    90SECS
            TC     WAITLIST
            EBANK= CDUIND
            2CADR  ENDTNON

            TCF    C33TEST

RETNON      CAF    90SECS
            TC     VARDELAY

ENDTNON     CS     BIT2        # RESET TURN-ON REQUEST FAIL BIT.
            MASK   IMODES30
            XCH    IMODES30
            MASK   BIT2        # IF IT WAS OFF, SEND ISS DELAY COMPLETE.
```

# Page 143

|          |        |          |                                       |
|----------|--------|----------|---------------------------------------|
|          | EXTEND |          |                                       |
|          | BZF    | ENDTNON2 |                                       |
|          | CAF    | BIT14    | # IF IT WAS ON AND TURN-ON REQUEST NO |
|          | MASK   | IMODES30 | # PRESENT, RE-ENTER 90 SEC DELAY IN V |
|          | EXTEND |          |                                       |
|          | BZF    | RETNON   |                                       |
|          | CS     | STATE    | # IF IT IS NOT ON NOW, SEE IF A PROG  |
|          | MASK   | IMUSEFLG | # WAITING.                            |
|          | CCS    | A        |                                       |
|          | TCF    | TASKOVER |                                       |
|          | TC     | POSTJUMP |                                       |
|          | CADR   | IMUBAD   | # UNSUCCESSFUL TURN-ON.               |
| ENDTNON2 | CAF    | BIT15    | # SEND ISS DELAY COMPLETE.            |
|          | EXTEND |          |                                       |
|          | WOR    | CHAN12   | # TURN OFF ISS DELAY COUNTER          |
|          | TC     | IBNKCALL | # TURN OFF NO ATT LAMP.               |
|          | CADR   | NOATTOFF |                                       |
| UNZ2     | TC     | ZEROICDU |                                       |
|          | CS     | BITS4&5  | # REMOVE ZERO AND COARSE.             |
|          | EXTEND |          |                                       |
|          | WAND   | CHAN12   |                                       |
|          | CAF    | BIT11    | # WAIT 10 SECS FOR CTRS TO FIND GIMBA |
|          | TC     | VARDELAY |                                       |
| ISSUP    | CS     | OCT54    | # REMOVE CAGING, IMU FAIL INHIBIT, AD |
|          | MASK   | IMODES30 | # ICDUFAIL INHIBIT FLAGS.             |
|          | TS     | IMODES30 |                                       |
|          | CS     | BIT6     | # ENABLE DAP                          |
|          | MASK   | IMODES33 |                                       |
|          | TS     | IMODES33 |                                       |
|          | TC     | SETISSW  | # ISS WARNING MIGHT HAVE BEEN INHIBIT |
|          | CS     | BIT15    | # REMOVE IMU DELAY COMPLETE DISCRETE  |
|          | EXTEND |          |                                       |
|          | WAND   | CHAN12   |                                       |
|          | CAF    | 4SECS    | # DONT ENABLE PROG ALARM ON PIP FAIL  |
|          | TC     | WAITLIST | # ANOTHER 4 SECS.                     |

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```
EBANK= CDUIND
2CADR PFAILOK

TCF TASKOVER

OPONLY
# Page 144

CAF BIT4

EXTEND
RAND CHAN12
CCS A
TCF C33TEST

CAF IMUSEFLG
MASK STATE
CCS A
TCF C33TEST

TC CAGESUB2

ISSZERO
TC IBNKCALL
CADR NOATTOFF

CAF BIT5
EXTEND
WOR CHAN12

TC ZEROICDU
CAF BIT6
TC WAITLIST
EBANK= OPTMODES
2CADR UNZ2
TCF C33TEST

# IF OPERATE ON ONLY AND WE ARE IN COARSE
# ALIGN, DON'T ZERO THE CDUS BECAUSE WE
# MIGHT BE IN GIMBAL LOCK. USE V41N20 TO
# RECOVER.

# OTHERWISE, ZERO THE COUNTERS
# UNLESS SOMEONE IS USING THE IMU.

# SET TURNON FLAGS.

# TURN OFF NO ATT LAMP.
# IMU CAGE OFF ENTRY.

# ISS CDU ZERO

# WAIT 300 MS FOR AGS TO RECEIVE SIGNAL.

# Page 145
# PROGRAM NAME: C33TEST
#
# FUNCTIONAL DESCRIPTION: THIS PROGRAM MONITORS THREE FLIP-FLOP INBITS OF CHANNEL 33 AND CALLS
# SUBROUTINE TO PROCESS A CHANGE. IT IS ANALOGOUS TO IMUMON, WHICH MONITORS CHANNEL 30, EXCEPT
# CHANNEL 33 WITH A WAND INSTRUCTION BECAUSE A 'WRITE' PULSE IS REQUIRED TO RESET THE FLIP-FLOP
# PROCESSED AND THE SUBROUTINES CALLED ARE:
# BIT FUNCTION SUBROUTINE
# ---
# 13 PIPA FAIL PIPFAIL
# 12 DOWNLINK TOO FAST DNTMFAST
# 11 UPLINK TOO FAST UPTMFAST
```

```

#
# UPON ENTRY TO THE SUBROUTINE, THE NEW BIT STATE IS IN A.
#
# CALLING SEQUENCE:  EVERY 480 MILLISECONDS AFTER TNONTEST.
#
# JOBS OR TASKS INITIATED:  NONE.
#
# SUBROUTINES CALLED:  PIPFAIL, DNTMFAST AND UPTMFAST ON BIT CHANGES.
#
# ERASABLE INITIALIZATION:  C(IMODES33) = OCT 16000 ON A FRESH START OR RESTART, THEN
# REAPPEAR IF THE CONDITIONS PERSIST.
#
# ALARMS:  NONE.
#
# EXIT:  GLOCKMON.
#
# OUTPUT:  UPDATED BITS 13, 12, AND 11 OF IMODES33 WITH CHANGES PROCESSED.

C33TEST      CA      IMODES33      # SEE IF RELEVANT CHAN33 BITS HAVE
              MASK    33RDMSK
              TS      L            # CHANGED.
              CAF     33RDMSK
              EXTEND
              WAND    CHAN33      # RESETS FLIP-FLOP INPUTS
              EXTEND
              RXOR    LCHAN
              EXTEND
              BZF     GLOCKMON    # ON NO CHANGE.

              TS      RUPTREG1    # SAVE BITS WHICH HAVE CHANGED
              LXCH    IMODES33
              EXTEND
              RXOR    LCHAN
              TS      IMODES33    # UPDATED IMODES33.

              CAF     ZERO
              XCH     RUPTREG1
              DOUBLE

# Page 146
              TCF     NXTIBT +1   # SCAN FOR BIT CHANGES.

              -1      AD      ONE
NXTIBT        INCR    RUPTREG1
              +1      DOUBLE
              TS      A          # (CODING IDENTICAL TO CHAN 30).
              TCF     NXTIBT

```

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```

XCH      RUPTREG2
INDEX    RUPTREG1          # GET NEW VALUE OF BIT WHICH CHANGED.
CAF      BIT13
MASK     IMODES33
INDEX    RUPTREG1
TC       C33JMP

NXTFL33   CCS      RUPTREG2          # PROCESS POSSIBLE ADDITIONAL CHANGES.
TCF      NXTIBT -1

# Page 147
# PROGRAM NAME:  GLOCKMON
#
# FUNCTIONAL DESCRIPTION:  THIS PROGRAM MONITORS THE CDUZ COUNTER TO DETERMINE WHETHER THE ISS
# AND TAKES ACTION IF IT IS.  THREE REGIONS OF MIDDLE GIMBAL ANGLE (MGA) ARE USED:
#
#       1) ABS(MGA) LESS THAN OR EQUAL TO 70 DEGREES -- NORMAL MODE.
#       2) ABS(MGA) GREATER THAN 70 DEGREES AND LESS THAN OR EQUAL TO 85 DEGREES -- GIMBAL LOCK
#       3) ABS(MGA) GREATER THAN 85 DEGREES -- ISS PUT IN COARSE ALIGN AND NO ATT LAMP TURNED C
#
# CALLING SEQUENCE:  EVERY 480 MILLISECONDS AFTER C33TEST.
#
# JOBS OR TASKS INITIATED:  NONE.
#
# SUBROUTINES CALLED:  1) SETCOARS WHEN ABS(MGA) GREATER THEN 85 DEGREES AND ISS NOT IN COARSE
#                      2) LAMPTST BEFORE TURNING OFF GIMBAL LOCK LAMP.
#
# ERASABLE INITIALIZATION:
#       1) FRESH START OR RESTART WITH NO GROUPS ACTIVE:  C(CDUZ) = 0, IMODES30 BIT 6 =
#       2) RESTART WTIH GROUPS ACTIVE:  SAME AS FRESH START EXCEPT C(CDUZ) NOT CHANGED
#                                     PROCEEDS AS BEFORE.
#
# ALARMS:  1) MGA REGION (2) CAUSES GIMBAL LOCK LAMP TO BE LIT.
#          2) MGA REGION (3) CAUSES THE ISS TO BE PUT IN COARSE ALIGN AND THE NO ATT LAMP
#          SO ALREADY.

GLOCKMON   CCS      CDUZ
TCF      GLOCKCHK          # SEE IF MAGNITUDE OF MGA IS GREATER THAN
TCF      SETGLOCK          # 70 DEGREES.
TCF      GLOCKCHK
TCF      SETGLOCK

GLOCKCHK   AD       -70DEGS
EXTEND
BZMF     SETGLOCK -1          # NO LOCK.
```

```

                                AD      -15DEGS          # SEE IF ABS(MGA) GREATER THAN 85 DEG
                                EXTEND
                                BZMF     NOGIMRUN

                                CAF      BIT4             # IF SO, SYSTEM SHOULD BE IN COARSE A
                                EXTEND          # TO PREVENT GIMBAL RUNAWAY.
                                RAND     CHAN12
                                CCS      A
                                TCF      NOGIMRUN

                                TC       IBNKCALL          # GO INTO COARSE ALIGN.
                                CADR     SETCOARS

                                CAF      SIX              # ENABLE ISS ERROR COUNTERS IN 60 MS
                                TC       WAITLIST

                                EBANK=   CDUIND
                                2CADR    CA+ECE

                                NOGIMRUN

                                CAF      BIT6             # TURN ON GIMBAL LOCK LAMP.
                                TCF      SETGLOCK

                                -1
                                SETGLOCK

                                CAF      ZERO
                                AD       DSPTAB +11D      # SEE IF PRESENT STATE OF GIMBAL LOCK
                                MASK     BIT6              # AGREES WITH DESIRED STATE BY HALF A
                                EXTEND          # THE TWO.
                                BZF      GLOCKOK           # OK AS IS.

                                MASK     DSPTAB +11D      # IF OFF, DON'T TURN ON IF IMU BEING
                                CCS      A
                                TCF      GLAMPTST         # TURN OFF UNLESS LAMP TEST IN PROGR

                                CAF      BIT6
                                MASK     IMODES30
                                CCS      A
                                TCF      GLOCKOK

                                GLINVERT

                                CS       DSPTAB +11D      # INVERT GIMBAL LOCK LAMP.
                                MASK     BIT6
                                AD       BIT15           # TO INDICATE CHANGE IN DSPTAB +11D.
                                XCH      DSPTAB +11D
                                MASK     OCT37737
                                ADS      DSPTAB +11D
                                TCF      GLOCKOK

```

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|          |     |          |                                           |
|----------|-----|----------|-------------------------------------------|
| GLAMPTST | TC  | LAMPTST  | # TURN OFF UNLESS LAMP TEST IN PROGRESS.  |
|          | TCF | GLOCKOK  |                                           |
|          | TCF | GLINVERT |                                           |
| -70DEGS  | DEC | -.38888  | # -70 DEGREES SCALED IN HALF-REVOLUTIONS. |
| -15DEGS  | DEC | -.08333  |                                           |

# Page 149

# PROGRAM NAME: TLIM.

#

# FUNCTIONAL DESCRIPTION: THIS PROGRAM MAINTAINS THE TEMP LAMP (BIT 4 OF CHANNEL 11) ON THE DS  
# THE TEMP SIGNAL FROM THE ISS (BIT 15 OF CHANNEL 30). HOWEVER, THE LIGHT WILL NOT BE TURNED C  
# IS IN PROGRESS.

#

# CALLING SEQUENCE: CALLED BY IMUMON ON A CHANGE OF BIT 15 OF CHANNEL 30.

#

# JOBS OR TASKS INITIATED: NONE.

#

# SUBROUTINES CALLED: LAMPTST.

#

# ERASABLE INITIALIZATION: FRESH START AND RESTART TURN THE TEMP LAMP OFF.

#

# ALARMS: TEMP LAMP TURNED ON WHEN THE IMU TEMP GOES OUT OF LIMITS.

#

# EXIT: NXTIFAIL.

#

# OUTPUT: SERVICE OF TEMP LAMP. IN A, EXCEPT FOR TLIM.

|      |      |          |                                           |
|------|------|----------|-------------------------------------------|
| TLIM | MASK | POSMAX   | # REMOVE BIT FROM WORD OF CHANGES AND SET |
|      | TS   | RUPTREG2 | # DSKY TEMP LAMP ACCORDINGLY.             |

|     |          |
|-----|----------|
| CCS | IMODES30 |
| TCF | TEMPOK   |
| TCF | TEMPOK   |

|        |          |                 |
|--------|----------|-----------------|
| CAF    | BIT4     | # TURN ON LAMP. |
| EXTEND |          |                 |
| WOR    | DSALMOUT |                 |
| TCF    | NXTIFAIL |                 |

|        |     |          |                                          |
|--------|-----|----------|------------------------------------------|
| TEMPOK | TC  | LAMPTST  | # IF TEMP NOW OK, DON'T TURN OFF LAMP IF |
|        | TCF | NXTIFAIL | # LAMP TEST IN PROGRESS.                 |

|        |          |                 |
|--------|----------|-----------------|
| CS     | BIT4     |                 |
| EXTEND |          |                 |
| WAND   | DSALMOUT | # TURN OFF LAMP |

TCF NXTIFAIL

```

# Page 150
# PROGRAM NAME:  ITURNON.
#
# FUNCTIONAL DESCRIPTION:  THIS PROGRAM IS CALLED BY IMUMON WHEN A CHANGE OF BIT 14 OF IMODES30 (ISS TURN-ON REQUEST) IS DETECTED.  UPON ENTRY, ITURNON CHECKS IF A TURN-ON DELAY SEQUENCE HAS BEEN INITIATED.  IF NOT, IT CHECKS WHETHER THE TURN-ON REQUEST CHANGE IS TO ON OR OFF.  IF ON, IT STARTS A DELAY SEQUENCE THAT TNONTEST WILL INITIATE THE ISS INITIALIZATION SEQUENCE.  IF OFF, THE TURN-ON REQUEST IS INITIATED.  IF BIT 15, IS CHECKED AND IF IT IS ON, ITURNON EXITS.  IF THE DELAY SIGNAL IS OFF, PROGRAM EXITS.  IF IMODES30 IS SET TO 1 AND THE PROGRAM EXITS.
#
# THE SETTING OF BIT 2 OF IMODES30 (ISS DELAY SEQUENCE FAIL) INHIBITS THIS ROUTINE AND PREVENTS IT FROM PROCESSING ANY CHANGES.  THIS BIT WILL BE RESET BY THE ENDTNON ROUTINE WHEN THE CURRENT DELAY SEQUENCE ENDS.
#
# CALLING SEQUENCE:  FROM IMUMON WHEN ISS TURN-ON REQUEST CHANGES STATE.
#
# JOBS OR TASKS INITIATED:  NONE.
#
# SUBROUTINES CALLED:  ALARM, IF THE ISS TURN-ON REQUEST IS NOT PRESENT FOR 90 SECONDS.
#
# ERASABLE INITIALIZATION:  FRESH START AND RESTART SET BIT 15 OF CHANNEL 12 AND BITS 13 AND 14 OF IMODES30 TO 1.
#
# ALARMS:  PROGRAM ALARM 00207 IS ISSUED IF THE ISS TURN-ON REQUEST SIGNAL IS NOT PRESENT FOR 90 SECONDS.
#
# EXIT:  NXTIFAIL.
#
# OUTPUT:  BIT 7 OF IMODES30 TO START ISS INITIALIZATION, OR BIT 2 OF IMODES30 AND BIT 15 OF IMODES30 TO INDICATE A FAILED TURN-ON SEQUENCE.

```

|         |        |          |                                           |
|---------|--------|----------|-------------------------------------------|
| ITURNON | CAF    | BIT2     | # IF DELAY REQUEST HAS GONE OFF           |
|         | MASK   | IMODES30 | # PREMATURELY, DO NOT PROCESS ANY CHANGES |
|         | CCS    | A        | # UNTIL THE CURRENT 90 SEC WAIT EXPIRES.  |
|         | TCF    | NXTIFAIL |                                           |
|         | CAF    | BIT14    | # SEE IF JUST ON OR OFF.                  |
|         | MASK   | IMODES30 |                                           |
|         | EXTEND |          |                                           |
|         | BZF    | ITURNON2 | # IF JUST ON.                             |
|         | CAF    | BIT15    |                                           |
|         | EXTEND |          | # SEE IF DELAY PRESENT DISCRETE HAS BEEN  |
|         | RAND   | CHAN12   | # SENT.  IF SO, ACTION COMPLETE           |
|         | EXTEND |          |                                           |



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BZF +2  
TCF NXTIFAIL

CAF BIT2 # IF NOT, SET BIT TO INDICATE REQUEST NOT  
ADS IMODES30 # PRESENT FOR FULL DURATION.  
TC ALARM  
OCT 207  
TCF NXTIFAIL

# Page 151

ITURNON2 CS IMODES30 # SET BIT7 TO INDICATE WAIT OF 1 SAMPLE  
MASK BIT7  
ADS IMODES30  
TCF NXTIFAIL

# Page 152

# PROGRAM NAME: IMUCAGE.

#

# FUNCTIONAL DESCRIPTION: THIS PROGRAM PROCESSES CHANGES OF THE IMUCAGE INBIT, CHANNEL 30 BITS  
# CHANGES TO 0 (CAGE BUTTON PRESSED), THE ISS IS CAGED (ICDU ZERO + COARSE ALIGN + NO ATT LAMP)  
# ASTRONAUT SELECTS ANOTHER PROGRAM TO ALIGN THE ISS. ANY PULSE TRAINS TO THE ICDU'S AND GYRO'S  
# THE ASSOCIATE OUTCOUNTERS ARE ZEROED AND THE GYRO'S ARE DE-SELECTED. NO ACTION OCCURS WHEN T  
# RELEASED (INBIT CHANGES TO 1).

#

# CALLING SEQUENCE: BY IMUMON WHEN IMU CAGE BIT CHANGES.

#

# JOBS OR TASKS INITIATED: NONE.

#

# SUBROUTINES CALLED: CAGESUB.

#

# ERASABLE INITIALZATION: FRESH START AND RESTART SET BIT 11 OF IMODES30 TO 1.

#

# ALARMS: NONE.

#

# EXIT: NXTIFAIL.

#

# OUTPUT: ISS CAGED, COUNTERS ZEROED, PULSE TRAINS TERMINATED AND NO ATT LAMP LIT.

IMUCAGE CCS A # NO ACTION IF GOING OFF.  
TCF ISSZERO  
CS OCT77000 # TERMINATE ICDU, OPTICS, GYRO PULSE TRAINS  
EXTEND  
WAND CHAN14  
  
CS OCT272 # KNOCK DOWN TVC ENABLE, IMU ERROR COUNTER  
EXTEND # ENABLE, ZERO ICDU, COARSE ALIGN

```

WAND  CHAN12      #  ENABLE, OPTICS ERR CNTR ENABLE

CS    BIT13      #  TURN OFF ENGINE
EXTEND
WAND  DSALMOUT

TC    CAGESUB1

TC    IBNKCALL   #  KNOCK DOWN TRACK, REFSMMAT, DRIFT FLAGS
CADR  RNDREFDR

CS    ZERO       #  ZERO COMMAND OUT-COUNTERS
TS    CDUXCMD
TS    CDUYCMD
TS    CDUZCMD
TS    GYROCMD

CS    OCT740     #  HAVING WAITED AT LEAST 27 MCT FROM
EXTEND          #  GYRO PULSE TRAIN TERMINATION, WE CAN
WAND  CHAN14     #  DE-SELECT THE GYROS.

# Page 153
TCF   NXTIFAIL

```

# Page 154

# PROGRAM NAME: IMUOP.

#

```

# FUNCTIONAL DESCRIPTION: THIS PROGRAM PROCESSES CHANGES IN THE ISS OPERATE DISCRETI
# IF THE INBIT CHANGES TO 0, INDICATING ISS ON, IMUOP GENERALLY SETS BIT 7 OF IMODES30
# INITIALIZATION VIA TNONTEST. AN EXCEPTION IS DURING A FAILED ISS DELAY DURING WHICH
# TO 1 AND NO FURTHER INITIALIZATION IS REQUIRED. WHEN THE INBIT CHANGES TO 1, INDI
# TESTED TO SEE IF ANY PROGRAM WAS USING THE ISS. IF SO, PROGRAM ALARM 00214 IS ISSU
#

```

# CALLING SEQUENCE: BY IMUMON WHEN BIT 9 OF CHANNEL 30 CHANGES.

#

# JOBS OR TASKS INITIATED: NONE.

#

# SUBROUTINES CALLED: ALARM, IF ISS IS TURNED OFF WHILE IN USE.

#

```

# ERASABLE INITIALIZATION: ON FRESH START AND RESTART, BIT 9 OF IMODES30 IS SET TO 1
# LAMP IS ON, IN WHICH CASE IT IS SET TO 0. THIS PREVENTS ICDU ZERO BY TNONTEST WITH
#

```

# ALARMS: PROGRAM ALARM 00214 IF THE ISS IS TURNED OFF WHILE IN USE.

#

# EXIT: NXTIFAIL.

#

# OUTPUT: ISS INITIALIZATION REQUEST (IMODES30 BIT 7) OR PROGRAM ALARM 00214.

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|        |        |          |                                           |
|--------|--------|----------|-------------------------------------------|
| IMUOP  | EXTEND |          | # IF OPERATE JUST ON, WAIT 1 SAMPLE.      |
|        | BZF    | IMUOP2   |                                           |
|        | CS     | IMODES33 | # DISABLE DAP                             |
|        | MASK   | BIT6     |                                           |
|        | ADS    | IMODES33 |                                           |
|        | TC     | IBNKCALL | # KNOCK DOWN TRACK, REFSMMAT, DRIFT FLAGS |
|        | CADR   | RNDREFDR |                                           |
|        | CS     | BITS7&8  | # KNOCK DOWN RENDEZVOUS, IMUUSE FLAGS     |
|        | MASK   | STATE    |                                           |
|        | XCH    | STATE    | # IF GOING OFF, ALARM IF PROG USING IMU.  |
|        | COM    |          |                                           |
|        | MASK   | IMUSEFLG |                                           |
|        | CCS    | A        |                                           |
|        | TCF    | NXTIFAIL |                                           |
|        | TC     | ALARM    |                                           |
|        | OCT    | 214      |                                           |
|        | TCF    | NXTIFAIL |                                           |
| IMUOP2 | CAF    | BIT2     | # SEE IF FAILED ISS TURN-ON SEQ IN PROG.  |
|        | MASK   | IMODES30 |                                           |
|        | CCS    | A        |                                           |
|        | TCF    | NXTIFAIL | # IF SO, DON'T PROCESS UNTIL PRESENT 90   |
|        | TCF    | ITURNON2 | # SECONDS EXPIRES                         |

# Page 155

# PROGRAM NAME: PIPFAIL

#

# FUNCTIONAL DESCRIPTION: THIS PROGRAM PROCESSES CHANGES OF BIT 13 OF CHANNEL 33, PIPA FAIL.

# IMODES30 TO AGREE. IT CALLS SETISSW IN CASE A PIPA FAIL NECESSITATES AN ISS WARNING. IF NOT

# BIT 1 = 1, AND A PIPA FAIL IS PRESENT AND THE ISS NOT BEING INITIALIZED, PROGRAM ALARM 0212 I

#

# CALLING SEQUENCE: BY C33TEST ON CHANGES OF CHANNEL 33 BIT 13.

#

# JOBS OR TASKS INITIATED: NONE.

#

# SUBROUTINES CALLED: 1) SETISSW, AND 2) ALARM (SEE FUNCTIONAL DESCRIPTION).

#

# ERASABLE INITIALIZATION: SEE IMUMON FOR INITIALIZATION OF IMODES30. THE RELEVANT BITS ARE 5

#

# ALARMS: PROGRAM ALARM 00212 IF PIPA FAIL IS PRESENT BUT NEITHER ISS WARNING IS TO BE ISSUED

# BEING INITIALIZED.

```

#
# EXIT:  NXTFL33.
#
# OUTPUT:  PROGRAM ALARM 00212 AND ISS WARNING MAINTENANCE.

PIPFail      CCS      A                # SET BIT10 IN IMODES30 SO ALL ISS W
          CAF      BIT10              # INFO IS IN ONE REGISTER.
          XCH      IMODES30
          MASK     -BIT10
          ADS      IMODES30

          TC       SETISSW

          CS       IMODES30           # IF PIP FAIL DOESN'T LIGHT ISS WARN
          MASK     BIT1               # A PROGRAM ALARM IF IMU OPERATING BU
          CCS      A                  # CAGED OR BEING TURNED ON.
          TCF      NXTFL33

          CA       IMODES30
          MASK     OCT1720
          CCS      A
          TCF      NXTFL33           # ABOVE CONDITION NOT MET.

          TC       ALARM
          OCT      212
          TCF      NXTFL33

# Page 156
# PROGRAM NAMES:  DNTMFAST, UPTMFAST
#
# FUNCTIONAL DESCRIPTION:  THESE PROGRAMS PROCESS CHANGES OF BITS 12 AND 11 OF CHANNEL
# 0, A PROGRAM ALARM IS ISSUED.  THE ALARMS ARE:
#
#      BIT      ALARM  CAUSE
#      ---      -
#      12      01105  DOWNLINK TOO FAST
#      11      01106  UPLINK TOO FAST
#
# CALLING SEQUENCE:  BY C33TEST ON A BIT CHANGE.
#
# SUBROUTINES CALLED:  ALARM, IF A BIT CHANGES TO A 0.
#
# ERASABLE INITIALIZATION:  FRESH START OR RESTART, BITS 12 AND 11 OF IMODES33 ARE SET
#
# ALARMS:  SEE FUNCTIONAL DESCRIPTION.
#

```

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# EXIT: NXTFL33.

#

# OUTPUT: PROGRAM ALARM ON A BIT CHANGE TO 0.

|          |     |         |                                 |
|----------|-----|---------|---------------------------------|
| DNTMFAST | CCS | A       | # DO PROG ALARM IF TM TOO FAST. |
|          | TCF | NXTFL33 |                                 |

|  |     |         |
|--|-----|---------|
|  | TC  | ALARM   |
|  | OCT | 1105    |
|  | TCF | NXTFL33 |

|          |     |         |                                          |
|----------|-----|---------|------------------------------------------|
| UPTMFAST | CCS | A       | # SAME AS DNLINK TOO FAST WITH DIFFERENT |
|          | TCF | NXTFL33 | # ALARM CODE.                            |

|  |     |         |
|--|-----|---------|
|  | TC  | ALARM   |
|  | OCT | 1106    |
|  | TCF | NXTFL33 |

# Page 157

# PROGRAM NAME: SETISSW

#

# FUNCTIONAL DESCRIPTION: THIS PROGRAM TURNS THE ISS WARNING LAMP ON AND OFF (CHANNEL 11 BIT 1  
# 0 FOR OFF) DEPENDING ON THE STATUS OF IMODES30 BITS 13 (IMU FAIL) AND 4 (INHIBIT IMU FAIL), 1  
# 3 (INHIBIT ICDU FAIL), AND 10 (PIPA FAIL) AND 1 (INHIBIT PIPA FAIL). THE LAMP IS LEFT ON IF  
# PROGRESS.

#

# CALLING SEQUENCE: CALLED BY IMUMON ON CHANGES TO IMU FAIL AND ICDU FAIL. CALLED BY IFAILOK  
# REMOVAL OF THE FAIL INHIBITS. CALLED BY PIPFAIL WHEN THE PIPA FAIL DISCRETE CHANGES. IT IS  
# SINCE THE PIPA FAIL PROGRAM ALARM MAY NECESSITATE AN ISS WARNING, AND LIKEWISE BY PIPFREE WHEN  
# AND IT IS CALLED BY IMUZERO3 AND ISSUP AFTER THE FAIL INHIBITS HAVE BEEN REMOVED.

#

# JOBS OR TASKS INITIATED: NONE.

#

# SUBROUTINES CALLED: NONE.

#

# ERASABLE INITIALIZATION:

#

# 1) IMODES30 -- SEE IMUMON.

# 2) IMODES33 BIT 1 = 0 (LAMP TEST NOT IN PROGRESS).

#

# ALARMS: ISS WARNING.

#

# EXIT: VIA Q.

#

# OUTPUT: ISS WARNING LAMP SET PROPERLY.

|            |        |             |                                       |
|------------|--------|-------------|---------------------------------------|
| SETISSW    | CAF    | OCT15       | # SET ISS WARNING USING THE FAIL BITS |
|            | MASK   | IMODES30    | # BITS 13, 12, AND 10 OF IMODES30 AND |
|            | EXTEND |             | # FAILURE INHIBIT BITS IN POSITIONS   |
|            | MP     | BIT10       | # 4, 3, AND 1.                        |
|            | CA     | IMODES30    |                                       |
|            | EXTEND |             |                                       |
|            | ROR    | LCHAN       | # 0 INDICATES FAILURE                 |
|            | COM    |             |                                       |
|            | MASK   | OCT15000    |                                       |
|            | CCS    | A           |                                       |
|            | TCF    | ISSWON      | # FAILURE.                            |
| ISSWOFF    | CAF    | BIT1        | # DON'T TURN OFF ISS WARNING IF LAMP  |
|            | MASK   | IMODES33    | # IN PROGRESS.                        |
|            | CCS    | A           |                                       |
|            | TC     | Q           |                                       |
|            | CS     | BIT1        |                                       |
|            | EXTEND |             |                                       |
|            | WAND   | DSALMOUT    | # TURN OFF ISS WARNING.               |
|            | TC     | Q           |                                       |
| ISSWON     | EXTEND |             |                                       |
| # Page 158 | QXCH   | ITEMP6      |                                       |
|            | TC     | VARALARM    | # TELL EVERYONE WHAT CAUSED THE ISS V |
|            | CAF    | BIT1        |                                       |
|            | EXTEND |             |                                       |
|            | WOR    | DSALMOUT    | # TURN ON ISS WARNING                 |
|            | TC     | ITEMP6      |                                       |
| CAGESUB    | CS     | BIT15+6     | # SET OUTBITS + INTERNAL FLAGS FOR    |
|            | EXTEND |             | # SYSTEM TURN-ON OR CAGE. DISABLE T   |
|            | WAND   | CHAN12      | # ERROR COUNTER AND REMOVE THE IMU D  |
|            | CAF    | BITS4&5     | # SEND ZERO AND COARSE.               |
|            | EXTEND |             |                                       |
|            | WOR    | CHAN12      |                                       |
| CAGESUB1   | CS     | DSPTAB +11D | # TURN ON NO ATT LAMP                 |
|            | MASK   | OC40010     |                                       |
|            | ADS    | DSPTAB +11D |                                       |
| CAGESUB2   | CS     | IMODES30    | # SET FLAGS TO INDICATE CAGING OR TU  |
|            | MASK   | OCT75       | # AND INHIBIT ALL ISS WARNING INFO    |
|            | ADS    | IMODES30    |                                       |

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```

        CS      IMODES33      # DISABLE DAP AUTO AND HOLD MODES
        MASK    BIT6
        ADS      IMODES33

        TC      Q

IMUFAIL      EQUALS  SETISSW
ICDUFail     EQUALS  SETISSW

# Page 159
# JUMP TABLES AND CONSTANTS.

IFAILJMP     TCF      ITURNON      # CHANNEL 30 DISPATCH.
              TCF      IMUFAIL
              TCF      ICDUFail
              TCF      IMUCAGE
3ORDMSK      OCT      76400        # (BIT 10 NOT SAMPLED HERE).
              TCF      IMUOP

C33JMP       TCF      PIPFAIL      # CHANNEL 33 DISPATCH.
              TCF      DNTMFAST
              TCF      UPTMFAST

# SUBROUTINE TO SKIP IF LAMP TEST NOT IN PROGRESS.

LAMPTEST     CS      IMODES33      # BIT 1 OF IMODES33 = 1 IF LAMP TEST IN
              MASK    BIT1          # PROGRESS.
              TCF      ZOPFIN3

33RDMSK      EQUALS  PRI016
OC40010      OCT      40010
OCT54        OCT      54
OCT75        OCT      75
OCT272       OCT      00272
BITS7&8      OCT      300
OCT1720      OCT      1720
OCT740       OCT      00740
OCT15000     EQUALS  PRI015
OCT77000     OCT      77000
-BIT10       OCT      -1000

90SECS       DEC      9000
120MS        =        OCT14      # (DEC12)
GLOCKOK      EQUALS  RESUME

# Page 160
```

## # OPTICS MONITORING AND ZERO ROUTINES

|            |        |          |                                        |
|------------|--------|----------|----------------------------------------|
| OPTMON     | CA     | OPTMODES | # MONITOR OPTICS INBITS IN CHAN 30 AND |
|            | EXTEND |          |                                        |
|            | RXOR   | CHAN30   | # LOOK FOR OCDU FAIL BIT CHANGE        |
|            | MASK   | BIT7     |                                        |
|            | TS     | RUPTREG1 | # STORE CHANGE BIT                     |
|            | CCS    | A        |                                        |
|            | TC     | OCDUFTST | # PROCESS OCDUFAIL BIT CHANGE          |
| 330OPTMON  | CCS    | OPTIND   | # BYPASS IF TVC TAKEOVER               |
|            | TCF    | +4       |                                        |
|            | TCF    | +3       |                                        |
|            | TCF    | +2       |                                        |
|            | TCF    | RESUME   |                                        |
|            | CA     | OPTMODES | # LOOK FOR OPTICS MODE SWITCH CHANGE   |
|            | EXTEND |          |                                        |
|            | RXOR   | CHAN33   |                                        |
|            | MASK   | OCTHIRTY |                                        |
|            | ADS    | RUPTREG1 | # STORE INBIT CHANGES                  |
|            | LXCH   | OPTMODES |                                        |
|            | EXTEND |          |                                        |
|            | RXOR   | LCHAN    |                                        |
|            | TS     | OPTMODES | # UPDATE OPTMODES TO SHOW BIT CHANGES  |
|            | COM    |          | # SAMPLE CURRENT SWITCH SETTING        |
|            | MASK   | OCTHIRTY |                                        |
|            | EXTEND |          |                                        |
|            | BZF    | SETSAMP  | # MANUAL-SET ZERO IN SWSAMPLE          |
|            | MASK   | BIT5     | # SEE IF CSC                           |
|            | CCS    | A        |                                        |
|            | TC     | +2       | # CSC-SET SWSAMPLE POS                 |
|            | CAF    | NEGONE   | # ZOPTICS-SET SWSAMPLE (-1)            |
| SETSAMP    | TS     | SWSAMPLE | # CURRENT OPTICS SWITCH SETTING        |
| PROCESSW   | CCS    | DESOPMOD | # BRANCH ON PREVIOUS SETTING           |
|            | TC     | CSCDES   | # CSC                                  |
|            | TC     | MANUDES  | # MANUAL                               |
|            | TC     | ZOPTDES  | # ZERO OPTICS                          |
| # Page 161 |        |          |                                        |
| ZOPTDES    | CCS    | SWSAMPLE | # IS SWITCH STILL AT ZOPTICS           |
|            | TC     | ZTOCSC   | # NOW AT CSC                           |
|            | TC     | ZTOMAN   | # MANUAL                               |
|            | TC     | ZOPFIN1  | # ZOPTICS-SEE IF ZOPT PROCESSING       |
|            | TC     | SETDESMD | # ZOPT NOT PROCESSING-NO ACTION        |



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|          |        |             |                                            |                 |
|----------|--------|-------------|--------------------------------------------|-----------------|
|          | CCS    | ZOPTCNT     | # ZOPT PROCESSING-CHECK COUNTER            |                 |
|          | TC     | SETCNT      | # 32 SAMPLE NOT FINISHED-SET COUNTER       |                 |
|          | TC     | SETZOEND    | # 32 SAMPLE WAIT COMPLETED-SET UP ZOP END  |                 |
| ZTOMAN   | TC     | ZOPFIN1     | # ZOP TO MANUAL-IS ZOPT DONE               | // Shou         |
|          | TC     | SETDESMD    | # YES-NORMAL EXIT                          |                 |
| ZOPALARM | TC     | ALARM       | # ALARM-SWITCHED ALTERED WHILE ZOPTICS     |                 |
|          | OCT    | 00116       |                                            |                 |
|          | CAF    | OCT13       | # PROCESSING-SET RETURN OPTION             |                 |
|          | TS     | WTOPTION    |                                            |                 |
|          | TC     | CANZOPT     | # CANCEL ZOPT                              |                 |
|          | TC     | SETDESMD    |                                            |                 |
| ZTOCSC   | TC     | ZOPFIN1     | # SEE IF ZOPT PROCESSING                   | // Shou         |
|          | TC     | MANTOCSC +3 | # NO-CHECK RETURN TO COARS OPT             |                 |
|          | TC     | ALARM       | # ZOPT PROCESSING-ALARM                    |                 |
|          | OCT    | 00116       |                                            |                 |
|          | TC     | CANZOPT     | # CANCEL ZOPT                              |                 |
|          | TC     | MANTOCSC    | # ZERO CNT-LOOK FOR COARS OPT RETURN       |                 |
| COARSLOK | CAF    | BIT9        | # IF COARS OPT SINCE FSTART GO TO L+2      |                 |
|          | TCF    | ZOPFIN2     | # IF NOT GO TO L+1                         |                 |
| ZOPFIN1  | CAF    | BIT1        | # SEE IF END ZOPT TASK WORKING             | // Label should |
|          | MASK   | OPTMODES    |                                            |                 |
|          | CCS    | A           |                                            |                 |
|          | TC     | RESUME      | # ZOPT TASK WORKING-WAIT ONE SAMPLE PERIOD |                 |
|          | CAF    | BIT3        | # TEST IF ZOPTICS PROCESSING               |                 |
| ZOPFIN2  | MASK   | OPTMODES    | # RETURNS TO L+1 PROCESSING AND            |                 |
| ZOPFIN3  | CCS    | A           |                                            |                 |
|          | INCR   | Q           | # L+2 IF NOT                               |                 |
|          | TC     | Q           |                                            |                 |
| CANZOPT  | CS     | SIX         | # CANCEL ZERO OPTICS                       |                 |
|          | MASK   | OPTMODES    | # ZERO ZOPT PROCESSING BIT-ENABLE OCDUFAIL |                 |
|          | TS     | OPTMODES    |                                            |                 |
|          | CS     | BIT1        | # MAKE SURE ZERO OCDU IS OFF               |                 |
|          | EXTEND |             |                                            |                 |
|          | WAND   | CHAN12      |                                            |                 |
|          | TC     | Q           |                                            |                 |

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|            |          |          |                                       |
|------------|----------|----------|---------------------------------------|
| MANUDES    | CCS      | SWSAMPLE | # SEE IF SWITCH STILL IN MANUAL MODE  |
|            | TC       | MANTOCSC | # NOW AT CSC                          |
|            | TC       | MANTOMAN | # STILL MANUAL                        |
|            | CCS      | WTOPTION | # ZOPTICS-LOOK AT ZOPTICS RETURN OPT  |
|            | TC       | +2       | # 5 SEC RETURN GOOD-CONTINUE ZOPTICS  |
|            | TC       | OPTZERO  | # ZOPTICS MUST START ANEW             |
|            | TC       | INITZOPT | # SHOW ZERO OPTICS PROCESSING         |
|            | TC       | SETDESMD | # NORMAL EXIT                         |
| MANTOMAN   | CCS      | WTOPTION | # DECREMENT RETURN OPTION TIME        |
|            | TS       | WTOPTION |                                       |
|            | TC       | SETDESMD |                                       |
| MANTOCSC   | CAF      | ZERO     | # CANCEL ZOPT RETURN OPTION IF SET    |
|            | TS       | WTOPTION |                                       |
|            | TS       | ZOPTCNT  |                                       |
|            | TC       | COARSLOK | # CHECK FOR COARS OPT RETURN          |
|            | TC       | SETDESMD | # NO COARS TASK-NO ACTION             |
|            | CAF      | ONE      | # SET COARS OPT WORKING               |
|            | TS       | OPTIND   |                                       |
|            | CAF      | BIT2     | # ENABLE OPTICS CDU ERROR CNTS        |
|            | EXTEND   |          |                                       |
|            | WOR      | CHAN12   |                                       |
| TC         | SETDESMD |          |                                       |
| CSCDES     | CCS      | SWSAMPLE | # SEE IF SWITCH STILL AT CSC          |
|            | TC       | SETDESMD | # STILL AT CSC                        |
|            | TC       | CSCTOMAN | # MANUAL                              |
| CSCTOZOP   | CAF      | OCT40    | # ZOPTICS-INITIALIZE FOR ZOPT         |
|            | TS       | ZOPTCNT  |                                       |
|            | TC       | INITZOPT |                                       |
| CSCTOMAN   | CCS      | OPTIND   | # SEE IF COARS WORKING                |
|            | TC       | CANCOARS | # COARS WORKING-SWITCH NOT CSC-KILL C |
|            | TC       | CANCOARS |                                       |
|            | TC       | +1       | # NO COARS-NORMAL EXIT                |
|            | TC       | SETDESMD |                                       |
| # Page 163 |          |          |                                       |
| CANCOARS   | CA       | NEGONE   |                                       |
|            | TS       | OPTIND   | # SET OPTIND (-1) TO SHOW NOT WORKING |
|            | CS       | BIT2     | # DISABLE OCDU ERR CNTS               |
|            | EXTEND   |          |                                       |

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|            |        |          |                                         |
|------------|--------|----------|-----------------------------------------|
|            | WAND   | CHAN12   |                                         |
|            | CS     | OPTMODES | # SET RETURN-TO-COARS BIT               |
|            | MASK   | BIT9     |                                         |
|            | ADS    | OPTMODES |                                         |
|            | TC     | SETDESMD |                                         |
| OPTZERO    | TC     | INITZOPT | # INITIALIZE ZERO OPTICS                |
|            | CA     | OCT40    | # SET UP 32 SAMPLE WAIT                 |
| SETCNT     | TS     | ZOPTCNT  |                                         |
| SETDESMD   | CA     | SWSAMPLE | # SET CURRENT SWITCH INDICATION-RESUME  |
|            | TS     | DESOPMOD |                                         |
|            | TC     | RESUME   |                                         |
| SETZOEND   | CAF    | BIT1     | # SEND ZERO OPTICS CDU                  |
|            | EXTEND |          |                                         |
|            | WOR    | CHAN12   |                                         |
|            | CA     | 200MS    | # HOLD ZERO CDU FOR 200 MS              |
|            | TC     | WAITLIST |                                         |
|            | EBANK= | OPTMODES |                                         |
|            | 2CADR  | ENDZOPT  |                                         |
|            | CS     | OPTMODES | # SHOW ZOPTICS TASK WORKING             |
|            | MASK   | BIT1     |                                         |
|            | ADS    | OPTMODES |                                         |
|            | TC     | SETDESMD |                                         |
| ENDZOPT    | TC     | ZEROPCDU | # ZERO OCDU COUNTERS                    |
|            | CS     | BIT1     | # TURN OFF ZERO OCDU                    |
|            | EXTEND |          |                                         |
|            | WAND   | CHAN12   |                                         |
|            | CAF    | 200MS    | # DELAY 200MS FOR CDUS TO RESYNCHRONIZE |
|            | TC     | VARDELAY |                                         |
|            | CS     | OPTMODES | # SHOW ZOPTICS SINCE LAST FRESH START   |
|            | MASK   | BIT10    | # OR RESTART                            |
|            | ADS    | OPTMODES |                                         |
|            | CS     | SEVEN    | # ENABLE OCDUFAIL-SHOW OPTICS COMPLETE  |
|            | MASK   | OPTMODES |                                         |
|            | TS     | OPTMODES |                                         |
|            | TC     | OCDUFTST | # CHECK OCDU FAIL BIT AFTER ENABLE.     |
| # Page 164 | TC     | TASKOVER |                                         |

|            |        |             |                                       |
|------------|--------|-------------|---------------------------------------|
| ZEROPCDU   | CAF    | ZERO        |                                       |
|            | TS     | CDUS        | # ZERO IN CDUS, -20 IN CDUT           |
|            | TS     | ZONE        | # INITIALZE SHAFT MONITOR ZONE.       |
|            | CS     | 20DEGS      |                                       |
|            | TS     | CDUT        |                                       |
|            | TC     | Q           |                                       |
| INITZOPT   | CAF    | ZERO        | # INITIALIZE ZOPTICS-INHIBIT OCDUFAIL |
|            | TS     | WTOPTION    | # AND SHOW OPTICS PROCESSING          |
|            | CS     | OPTMODES    | # SET ZERO OPTICS PROCESSING          |
|            | MASK   | SIX         | # OPTICS CDU FAIL INHIBITED           |
|            | ADS    | OPTMODES    |                                       |
|            | TC     | Q           |                                       |
| # Page 165 |        |             |                                       |
| OCDUFTST   | CAF    | BIT7        | # SEE IF OCDUFAIL ON OR OFF           |
|            | EXTEND |             |                                       |
|            | RAND   | CHAN30      |                                       |
|            | CCS    | A           |                                       |
|            | TCF    | OPFAILOF    | # OCDUFAIL LIGHT OFF                  |
|            | CAF    | BIT2        | # OCDUFAIL LIGHT ON UNLESS INHIBITED  |
|            | MASK   | OPTMODES    |                                       |
|            | CCS    | A           |                                       |
|            | TC     | Q           | # OCDUFAIL INHIBITED                  |
| OPFAILON   | CAF    | BIT8        | # ON BIT                              |
|            | AD     | DSPTAB +11D |                                       |
|            | MASK   | BIT8        |                                       |
| SETOFF     | EXTEND |             |                                       |
|            | BZF    | TCQ         | # NO CHANGE                           |
|            | TS     | L           |                                       |
|            | CA     | DSPTAB +11D |                                       |
|            | EXTEND |             |                                       |
|            | RXOR   | LCHAN       |                                       |
|            | MASK   | POSMAX      |                                       |
|            | AD     | BIT15       | # SHOW ACTION WANTED                  |
|            | TS     | DSPTAB +11D |                                       |
|            | TC     | Q           |                                       |
| OPFAILOF   | CAF    | BIT1        | # DON'T TURN OFF IF LAMP TEST         |
|            | MASK   | IMODES33    |                                       |
|            | CCS    | A           |                                       |
|            | TC     | Q           | # LAMP TEST IN PROGRESS               |

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```

                                CAF    BIT8                # TURN OFF OCDUFAIL LIGHT
                                MASK    DSPTAB  +11D
                                TCF     SETOFF

OCT13      =      ELEVEN
OCTHIRTY   EQUALS  BITS4&5
20DEGS     DEC     7199
OCT40      EQUALS  BIT6
200MS      EQUALS  OCT24

# Page 166
# OPTICS CDU DRIVING PROGRAM

                                BANK    10
                                SETLOC   OPTDRV
                                BANK
                                COUNT*   $$/SXT

# SHAFT STOP MONITOR-ZONE UPDATE

OPTDRIVE    CA      CDUS                # GRAB OPTIC SHAFT CDU
            TS      L
            CCS     A                    # GET ABS(CDUS)
            AD      13,14,15
            TCF     +2                    # ABS(CDUS) - 45 DEG
            TCF     -2
            EXTEND
            BZMF    OZONE
            CA      ZONE
            EXTEND
            BZF     +2
            TCF     CONTDRVE             # JUST CONTINUE
            XCH     L                    # GREATER THAN 45 DEG-SET ZONE TO SIGN CDU
            TCF     OZONE  +1
OZONE       CAF     ZERO                # ABS(CDUS) LESS THAN 90 DEG-ZONE ZERO
            TS      ZONE
            COUNT*  $$/T4RUPT
CONTDRVE    CCS     OPTIND
            TC      +4                    # WORK COARS OPTICS
            TC      +3                    # WORK COARS OPTICS
            TC      RESUME               # NO OPT
            TC      RESUME               # NO OPT

            CA      SWSAMPLE             # SEE IF SWITCH AT CMC
            EXTEND
```

|                        |        |          |                                       |
|------------------------|--------|----------|---------------------------------------|
|                        | BZMF   | RESUME   | # ZERO (-1)      MANUAL (+0)          |
|                        | CAF    | BIT10    | # SEE IF OCDUS ZEROED SINCE LAST FSTA |
|                        | MASK   | OPTMODES |                                       |
|                        | CCS    | A        |                                       |
|                        | TC     | +3       |                                       |
|                        | TC     | ALARM    | # OPTICS NOT ZEROED                   |
|                        | OCT    | 00120    |                                       |
|                        | CA     | BIT2     | # SEE IF ERR CNTS ENABLED             |
|                        | EXTEND |          |                                       |
|                        | RAND   | CHAN12   |                                       |
|                        | EXTEND |          |                                       |
|                        | BZF    | SETBIT   | # CNTS NOT ENABLED-DO IT AND RESUME   |
|                        | CAF    | ONE      | # INITIALIZE OPTIND                   |
| # Page 167             | TS     | OPTIND   |                                       |
| OPT2                   | EXTEND |          |                                       |
|                        | BZF    | TRUNCMD  | # CHECK TRUNION COMMAND               |
| GETOPCMD               | INDEX  | OPTIND   |                                       |
|                        | CA     | DESOPTT  | # PICK UP DESIRED OPT ANGLE           |
|                        | EXTEND |          |                                       |
|                        | INDEX  | OPTIND   |                                       |
|                        | MSU    | CDUT     | # GET DIFFERENCE                      |
|                        | EXTEND |          |                                       |
|                        | MP     | BIT13    |                                       |
|                        | XCH    | L        |                                       |
|                        | DOUBLE |          |                                       |
|                        | TS     | ITEMP1   |                                       |
|                        | TCF    | +2       | # NO OVFL                             |
|                        | ADS    | L        | # WITH OVFL                           |
| STORCMD                | INDEX  | OPTIND   |                                       |
|                        | LXCH   | COMMANDO | # STORE COMMAND                       |
|                        | CCS    | OPTIND   |                                       |
|                        | TCF    | OPT2     | # GET NEXT COMMAND                    |
|                        | TS     | ITEMP1   | # INITIALIZE SEND INDICATOR TO ZERO   |
|                        | COUNT* | \$\$/SXT |                                       |
| # SHAFT STOP AVOIDANCE |        |          |                                       |
|                        | CCS    | CDUS     | # IF CDUS GREATER THAN + OR - 90 DEG  |
|                        | AD     | NEG1/2   | # FOR POSSIBLE STOP PROBLEM           |

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```
TCF      +2
TCF      -2
EXTEND
BZMF     CMDSETUP          # CDU LESS THAN 90 DEG, NO PROBLEMS

CA       ZONE
EXTEND
BZF      CMDSETUP          # ZONE=3, NORMAL COMMAND
MASK     BIT15             # GRAB SIGN OF ZONE
TS       L
CA       COMMANDO +1
MASK     BIT15             # GRAB SIGN OF SHAFT COMMAND
EXTEND
RXOR     LCHAN
CCS      A
TCF      CMDSETUP          # SIGN ZONE NOT EQUAL TO SIGN COMMAND
CCS      DESOPTS           # SEE IF DESOPTS BETWEEN -90 AND +90
AD       NEG1/2
TCF      +2                # ABS(DESOPTS) - 90 DEG
TCF      -2
EXTEND

# Page 168
BZMF     +2                # DESOPTS IN FIRST OR FOURTH QUAD
TCF      CMDSETUP
CS       COMMANDO +1       # REVERSE REGULAR COMMAND
TS       COMMANDO +1

COUNT*  $$/T4RPT

CMDSETUP CAF      ONE      # SET OPTIND
        TS       OPTIND
        INDEX    A
        CCS      COMMANDO  # GET SIGN OF COMMAND
        TC       POSOPCMD
        TC       NEXTOPT +1 # ZERO COMMAND-SKIP SEND INDICATOR
        TC       NEGOPCMD
        TC       NEXTOPT +1 # ZERO COMMAND

TRUNCMD  CS       CDUT     # IF COMMAND GREATER THAN 45 DEG-COMMAND
        AD       DESOPTT   # 45 DEG
        TS       Q
        TC       GETOPCMD  # LESS THAN 45 DEG-NORMAL OPERATION

        CCS      A         # GREATER THAN 45 DEG-USE OPSMAX WITH
        CA       POSMAX    # CORRECT SIGN
        TC       +2
```

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|            |        |             |                                      |
|------------|--------|-------------|--------------------------------------|
|            | CS     | POSMAX      |                                      |
|            | TS     | L           |                                      |
|            | TC     | STORCMD     |                                      |
| POSOPCMD   | AD     | MAXPLS1     |                                      |
|            | EXTEND |             |                                      |
|            | BZMF   | DELOPCMD    | # COMMAND LESS THAN MAX PULSE        |
|            | CS     | MAXPLS      | # GREATER THAN MAX PULSE-USE MAX PUL |
| NEXTOPT    | INCR   | ITEMP1      | # SET SEND INDICATOR                 |
|            | AD     | NEGO        | # MAKE SURE ZERO COMMAND IS -ZERO    |
|            | INDEX  | OPTIND      |                                      |
|            | TS     | CDUTCMD     | # STORE PULSE IN SEND REG            |
|            | CCS    | OPTIND      |                                      |
|            | TC     | CMDSETUP +1 | # GET NEXT OPT                       |
|            | CCS    | ITEMP1      | # ARE ANY PULSES TO GO               |
|            | TCF    | SENDOCMD    | # YES-SEND EM                        |
|            | TC     | RESUME      | # NO                                 |
| NEGOPCMD   | AD     | MAXPLS1     |                                      |
|            | EXTEND |             |                                      |
|            | BZMF   | DELOPCMD    | # LESS THAN MAX PULSE                |
|            | CA     | MAXPLS      | # MAX PULSES                         |
|            | TCF    | NEXTOPT     |                                      |
| # Page 169 |        |             |                                      |
| DELOPCMD   | INDEX  | OPTIND      |                                      |
|            | XCH    | COMMANDO    | # SET UP SMALL COMMAND               |
|            | TCF    | NEXTOPT     |                                      |
| SENDOCMD   | CAF    | 11,12       | # SEND OCDU DRIVE COMMANDS           |
|            | EXTEND |             |                                      |
|            | WOR    | CHAN14      |                                      |
|            | TC     | RESUME      |                                      |
| SETBIT     | CAF    | BIT2        | # ENABLE OCDU ERR CNTS               |
|            | EXTEND |             |                                      |
|            | WOR    | CHAN12      |                                      |
|            | TC     | RESUME      | # START COARS NEXT TIME AROUND       |
| MAXPLS     | DEC    | -165        | # WAS -80                            |
| MAXPLS1    | DEC    | -164        | # WAS -79                            |
| 11,12      | EQUALS | PRI06       |                                      |

This code is written to file src/T4RUPT-PROGRAM.s.



## A.110 T6-RUPT PROGRAMS

1801

*<src/T6-RUPT-PROGRAMS.s 1801>≡*

```
# Copyright:    Public domain.
# Filename:     T6-RUPT_PROGRAMS.agc
# Purpose:     Part of the source code for Luminary 1A build 099.
#             It is part of the source code for the Lunar Module's (LM)
#             Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:     Ron Burkey <info@sandroid.org>.
# Website:     www.ibiblio.org/apollo.
# Pages:       1403-1405
# Mod history: 2009-05-10 SN    (Sergio Navarro).  Started adapting
#             from the Luminary131/ file of the same
#             name, using Luminary099 page images.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum.  The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum.  Many thanks to both.  The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo.  If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
#       16:27 JULY 14, 1969
#
# Page 1403
# PROGRAM NAMES:      (1) T6JOBCHK      MOD. NO. 5      OCTOBER 2, 1967
#                   (2) DOT6RUPT
# MODIFICATION BY:    LOWELL G. HULL (A.C.ELECTRONICS)
#
# THESE PROGRAMS ENABLE THE LM DAP TO CONTROL THE THRUST TIMES OF THE REACTION CONTROL SYSTEM J
# SINCE THE LM DAP MAINTAINS EXCLUSIVE CONTROL OVER TIME6 AND ITS INTERRUPTS, THE FOLLOWING CON
# ESTABLISHED AND MUST NOT BE TAMPERED WITH:
#     1.      NO NUMBER IS EVER PLACED INTO TIME6 EXCEPT BY LM DAP.
#     2.      NO PROGRAM OTHER THAN LM DAP ENABLES THE TIME6 COUNTER.
#     3.      TO USE TIME6, THE FOLLOWING SEQUENCE IS ALWAYS EMPLOYED:
#             A.      A POSITIVE (NON-ZERO) NUMBER IS STORED IN TIME6.
#             B.      THE TIME6 CLOCK IS ENABLED.
#             C.      TIME6 IS INTERROGATED AND IS:
#                     I.      NEVER FOUND NEGATIVE (NON-ZERO) OR +0.
```

```

#           II.      SOMETIMES FOUND POSITIVE (BETWEEN 1 AND 240D) INDICAT
#           III.     SOMETIMES FOUND POSMAX INDICATING THAT IT IS INACTIV
#           IV.      SOMETIMES FOUND NEGATIVE ZERO INDICATING THAT:
#                   A.      A T6RUPT IS ABOUT TO OCCUR AT THE NEXT DINC,
#                   B.      A T6RUPT IS WAITING IN THE PRIORITY CHAIN, OR
#                   C.      A T6RUPT IS IN PROCESS NOW.
#       4.      ALL PROGRAMS WHICH OPERATE IN EITHER INTERRUPT MODE OR WITH INTERRUPT
#              EVERY 5 MILLISECONDS TO PROCESS A POSSIBLE WAITING T6RUPT BEFORE IT C
#       (5.      PROGRAM JTLST, IN Q,R-AXES, HANDLES THE INPUT LIST.)
#
# T6JOBCHK CALLING SEQUENCE:
#           L      TC      T6JOBCHK
#           L+1    (RETURN)
#
# DOT6RUPT CALLING SEQUENCE:
#           DXCH    ARUPT      # T6RUPT LEAD IN AT LOCATION 4004.
#           EXTEND
#           DCA     T6ADR
#           DTCB
#
# SUBROUTINES CALLED:  DOT6RUPT CALLS T6JOBCHK.
#
# NORMAL EXIT MODES:  T6JOBCHK RETURNS TO L +1.
#                    DOT6RUPT TRANSFERS CONTROL TO RESUME.
#
# ALARM/ABORT MODES:  NONE.
#
# INPUT:      TIME6      NXT6ADR      OUTPUT:      TIME6      NXT6A
#            T6NEXT      T6NEXT +1      T6NEXT      T6NE
#            T6FURTHA     T6FURTHA +1      T6FURTHA     T6FU
#
# DEBRIS:      T6JOBCHK CLOBBERS A.  DOT6RUPT CLOBBERS NOTHING.
#
# Page 1404
#           BLOCK  02
#
#           BANK   17
#           SETLOC DAPS2
#           BANK
#           EBANK=  T6NEXT
#           COUNT*  $$/DAPT6
#
# T6JOBCHK    CCS      TIME6      # CHECK TIME6 FOR WAITING T6RUPT:
#            TC      Q          # NONE: CLOCK COUNTING DOWN.
#            TC      CCSHOLE
#            TC      T6JOBCHK +3

```

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# CONTROL PASSES TO T6JOB ONLY WHEN C(TIME6) = -0 (I.E., WHEN A T6RUPT MUST BE PROCESSED).

|       |        |        |                                           |
|-------|--------|--------|-------------------------------------------|
| T6JOB | CAF    | POSMAX | # DISABLE CLOCK: NEEDED SINCE RUPT OCCURS |
|       | EXTEND |        | # 1 DINC AFTER T6 = 77777. FOR 625 MUSECS |
|       | WAND   | CHAN13 | # MUST NOT HAVE T6 = +0 WITH ENABLE SET   |

|      |          |
|------|----------|
| CA   | POSMAX   |
| ZL   |          |
| DXCH | T6FURTHA |
| DXCH | T6NEXT   |
| LXCH | NXT6ADR  |
| TS   | TIME6    |

|          |        |           |
|----------|--------|-----------|
|          | AD     | PRI037    |
|          | TS     | A         |
|          | TCF    | ENABLET6  |
|          | CA     | POSMAX    |
|          | TS     | TIME6     |
| ENABLET6 | TCF    | GOCH56    |
|          | CA     | BIT15     |
|          | EXTEND |           |
|          | WOR    | CHAN13    |
|          | CA     | T6NEXT    |
|          | AD     | PRI037    |
|          | TS     | A         |
|          | TCF    | GOCH56    |
|          | CA     | POSMAX    |
|          | TS     | T6NEXT    |
| GOCH56   | INDEX  | L         |
|          | TCF    | WRITEP -1 |

|        |            |
|--------|------------|
| BLOCK  | 02         |
| SETLOC | FFTAG9     |
| BANK   |            |
| EBANK= | CDUXD      |
| COUNT* | \$\$/DAPT6 |

|        |        |       |
|--------|--------|-------|
|        | CA     | NEXTP |
| WRITEP | EXTEND |       |
|        | WRITE  | CHAN6 |

# Page 1405

|    |   |
|----|---|
| TC | Q |
|----|---|

|        |    |          |
|--------|----|----------|
|        | CA | NEXTU    |
| WRITEU | TS | L        |
|        | CS | 003140CT |

```

                                EXTEND
                                RAND   CHAN5
                                AD      L
                                EXTEND
                                WRITE   CHAN5
                                TC       Q

                                CA       NEXTV
WRITEV                          TS      L
                                CA       00314OCT
                                TCF      -9D
00314OCT                        OCT     00314

                                BANK     17
                                SETLOC   DAPS2
                                BANK

                                EBANK=   T6NEXT
                                COUNT*   $$/DAPT6

DOT6RUPT                        LXCH     BANKRUPT      # (INTERRUPT LEAD INS CONTINUED)
                                EXTEND
                                QXCH     QRUPT

                                TC        T6JOBCHK      # CALL T6JOBCHK.

                                TCF       RESUME         # END TIME6 INTERRUPT PROCESSOR.

```

This code is written to file `src/T6-RUPT-PROGRAMS.s`.

## A.111 TAGS FOR RELATIVE SETLOC

```

1805 <src/TAGS-FOR-RELATIVE-SETLOC.s 1805>≡
# Copyright:      Public domain.
# Filename:       TAGS_FOR_RELATIVE_SETLOC.agc
# Purpose:       Part of the source code for Colossus 2A, AKA Comanche 055.
#               It is part of the source code for the Command Module's (CM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:    yaYUL
# Contact:       Ron Burkey <info@sandroid.org>.
# Website:       www.ibiblio.org/apollo.
# Mod history:   2009-05-05 RSB Adapted from the Colossus249/ file of the
#               same name, using Comanche055 page images.
#               2009-05-20 RSB Corrected R32 -> R31.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
# Assemble revision 055 of AGC program Comanche by NASA
# 2021113-051. 10:28 APR. 1, 1969
#
# This AGC program shall also be referred to as
# Colossus 2A

# Page 27
# TAGS FOR RELATIVE SETLOC AND BLANK BANK CARDS

FIXED          MEMORY 120000 - 167777
                COUNT  BANKSUM

# MODULE 1 CONTAINS BANKS 0 THROUGH 5

                BLOCK  02
FFTAG1         EQUALS
FFTAG2         EQUALS
FFTAG3         EQUALS
FFTAG4         EQUALS
FFTAG7         EQUALS

```

|         |        |    |
|---------|--------|----|
| FFTAG8  | EQUALS |    |
| FFTAG9  | EQUALS |    |
| FFTAG10 | EQUALS |    |
| FFTAG12 | EQUALS |    |
| P30SUBS | EQUALS |    |
| STOPRAT | EQUALS |    |
| P23S    | EQUALS |    |
|         | BNKSUM | 02 |

|         |        |    |
|---------|--------|----|
|         | BLOCK  | 03 |
| FFTAG5  | EQUALS |    |
| FFTAG6  | EQUALS |    |
| DAPS9   | EQUALS |    |
| FFTAG13 | EQUALS |    |
|         | BNKSUM | 03 |

|         |        |    |
|---------|--------|----|
|         | BANK   | 00 |
| DLAYJOB | EQUALS |    |
|         | BNKSUM | 00 |

|         |        |    |
|---------|--------|----|
|         | BANK   | 01 |
| RESTART | EQUALS |    |
|         | BNKSUM | 01 |

|          |        |   |
|----------|--------|---|
|          | BANK   | 4 |
| VERB37   | EQUALS |   |
| CONICS1  | EQUALS |   |
| PINBALL4 | EQUALS |   |
| CSI/CDH1 | EQUALS |   |
| INTPRET2 | EQUALS |   |
| IMUCAL1  | EQUALS |   |

# Page 28

|          |        |    |
|----------|--------|----|
| STBLEORB | EQUALS |    |
| E/PROG   | EQUALS |    |
| MIDDGIM  | EQUALS |    |
|          | BNKSUM | 04 |

|          |        |    |
|----------|--------|----|
|          | BANK   | 5  |
| FRANDRES | EQUALS |    |
| DOWNTLM  | EQUALS |    |
| DAPMASS  | EQUALS |    |
| CDHTAG   | EQUALS |    |
|          | BNKSUM | 05 |

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# MODULE 2 CONTAINS BANKS 6 THROUGH 13

|         |        |    |
|---------|--------|----|
|         | BANK   | 6  |
| IMUCOMP | EQUALS |    |
| T4RUP   | EQUALS |    |
| IMUCAL2 | EQUALS |    |
| CSIPROG | EQUALS |    |
|         | BNKSUM | 06 |

|          |        |    |
|----------|--------|----|
|          | BANK   | 7  |
| SXTMARKE | EQUALS |    |
| R02      | EQUALS |    |
| MODESW   | EQUALS |    |
| XANG     | EQUALS |    |
| KEYRUPT  | EQUALS |    |
| CSIPROG6 | EQUALS |    |
|          | BNKSUM | 07 |

|          |        |    |
|----------|--------|----|
|          | BANK   | 10 |
| DISPLAYS | EQUALS |    |
| PHASETAB | EQUALS |    |
| COMGEOM2 | EQUALS |    |
| SXTMARK1 | EQUALS |    |
| P60S4    | EQUALS |    |
| OPTDRV   | EQUALS |    |
| CSIPROG8 | EQUALS |    |
|          | BNKSUM | 10 |

|          |        |    |
|----------|--------|----|
|          | BANK   | 11 |
| ORBITAL  | EQUALS |    |
| ORBITAL1 | EQUALS |    |

# CONSTANTS

# Page 29

|          |        |    |
|----------|--------|----|
| INTVEL   | EQUALS |    |
| S52/2    | EQUALS |    |
| CSIPROG5 | EQUALS |    |
| INTINIT1 | EQUALS |    |
|          | BNKSUM | 11 |

|          |        |    |
|----------|--------|----|
|          | BANK   | 12 |
| CONICS   | EQUALS |    |
| CSIPROG2 | EQUALS |    |
| CSI/CDH2 | EQUALS |    |
| MODCHG2  | EQUALS |    |

|          |        |    |
|----------|--------|----|
|          | BNKSUM | 12 |
|          | BANK   | 13 |
| P76LOC   | EQUALS |    |
| LATLONG  | EQUALS |    |
| INTINIT  | EQUALS |    |
| SR52/1   | EQUALS |    |
| ORBITAL2 | EQUALS |    |
| CDHTAGS  | EQUALS |    |
| E/PROG1  | EQUALS |    |
| MODCHG3  | EQUALS |    |
|          | BNKSUM | 13 |

# MODULE 3 CONTAINS BANKS 14 THROUGH 21

|          |        |    |
|----------|--------|----|
|          | BANK   | 14 |
| STARTAB  | EQUALS |    |
| RT53     | EQUALS |    |
| P50S1    | EQUALS |    |
| MEASINC2 | EQUALS |    |
| CSI/CDH3 | EQUALS |    |
|          | BNKSUM | 14 |

|         |        |    |
|---------|--------|----|
|         | BANK   | 15 |
| P50S    | EQUALS |    |
| ETRYDAP | EQUALS |    |
| S52/3   | EQUALS |    |
|         | BNKSUM | 15 |

|       |        |    |
|-------|--------|----|
|       | BANK   | 16 |
| P40S1 | EQUALS |    |

# Page 30

|         |        |    |
|---------|--------|----|
| DAPROLL | EQUALS |    |
| P50S2   | EQUALS |    |
| P23S1   | EQUALS |    |
| RTE2    | EQUALS |    |
|         | BNKSUM | 16 |

|       |        |    |
|-------|--------|----|
|       | BANK   | 17 |
| DAPS4 | EQUALS |    |
| DAPS5 | EQUALS |    |
| DAPS7 | EQUALS |    |
| P50S3 | EQUALS |    |
|       | BNKSUM | 17 |



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|          |        |    |
|----------|--------|----|
|          | BANK   | 20 |
| DAPS6    | EQUALS |    |
| DAPS1    | EQUALS |    |
| DAPS2    | EQUALS |    |
| MANUSTUF | EQUALS |    |
| R36CM    | EQUALS |    |
| VAC5LOC  | EQUALS |    |
|          | BNKSUM | 20 |

|          |        |    |
|----------|--------|----|
|          | BANK   | 21 |
| DAPS3    | EQUALS |    |
| MYSUBS   | EQUALS |    |
| KALCMON3 | EQUALS |    |
|          | BNKSUM | 21 |

# MODULE 4 CONTAINS BANKS 22 THROUGH 27

|          |        |    |
|----------|--------|----|
|          | BANK   | 22 |
| RTBCODES | EQUALS |    |
| RTBCODE1 | EQUALS |    |
| DAPS8    | EQUALS |    |
| AOPERI   | EQUALS |    |
| P40S5    | EQUALS |    |
| KALCMON2 | EQUALS |    |
| KALCMON1 | EQUALS |    |
| CSIPROG3 | EQUALS |    |
|          | BNKSUM | 22 |

# Page 31

|          |        |    |
|----------|--------|----|
|          | BANK   | 23 |
| P20S2    | EQUALS |    |
| INFLIGHT | EQUALS |    |
| COMGEOM1 | EQUALS |    |
| POWFLITE | EQUALS |    |
| POWFLIT1 | EQUALS |    |
| RENDGUID | EQUALS |    |
| POWFLIT2 | EQUALS |    |
| R30LOC   | EQUALS |    |
| P11FOUR  | EQUALS |    |
| CSIPROG4 | EQUALS |    |
|          | BNKSUM | 23 |

|         |        |    |
|---------|--------|----|
|         | BANK   | 24 |
| LOADDAP | EQUALS |    |

P40S                   EQUALS  
CSIPROG7               EQUALS  
                      BNKSUM   24

                      BANK     25  
REENTRY               EQUALS  
CDHTAG1               EQUALS  
                      BNKSUM   25

                      BANK     26  
INTPRET1               EQUALS  
REENTRY1               EQUALS  
P60S                   EQUALS  
P60S1                  EQUALS  
P60S2                  EQUALS  
P60S3                  EQUALS  
PLANTIN                EQUALS  
EPHEM                  EQUALS  
P05P06                 EQUALS  
26P50S                 EQUALS  
                      BNKSUM   26

# LUNAR ROT

                      BANK     27  
TOF-FF                 EQUALS  
TOF-FF1                EQUALS  
MANUVER                EQUALS  
MANUVER1               EQUALS

# Page 32

VECPT                  EQUALS  
UPDATE1                EQUALS  
UPDATE2                EQUALS  
R22S1                  EQUALS  
P60S5                  EQUALS  
P40S2                  EQUALS  
                      BNKSUM   27

# MODULE 5 CONTAINS BANKS 30 THROUGH 35

                      BANK     30  
IMUSUPER               EQUALS  
LOWSUPER               EQUALS  
FCSTART                EQUALS  
LOPC                    EQUALS  
P20S1                  EQUALS

# STANDARD LOCATION FOR THIS. (FOR EXTV8)

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P20S6           EQUALS  
P40S3           EQUALS  
R35A            EQUALS  
                 BNKSUM   30

                 BANK     31  
R35            EQUALS  
RT23           EQUALS  
P30S1A        EQUALS  
R34            EQUALS  
CDHTAG2       EQUALS  
CSIPROG9      EQUALS  
R31            EQUALS  
P22S           EQUALS  
RTE3           EQUALS  
                 BNKSUM   31

                 BANK     32  
MSGSCAN1      EQUALS  
RTE            EQUALS  
DELRSP1       EQUALS  
IMUCAL3       EQUALS  
                 BNKSUM   32

                 BANK     33  
TESTLEAD      EQUALS

# Page 33

IMUCAL        EQUALS  
                 BNKSUM   33

                 BANK     34  
P110NE        EQUALS  
P20S3        EQUALS  
P20S4        EQUALS  
RTECON        EQUALS  
                 BNKSUM   34

                 BANK     35  
RTECON1       EQUALS  
CSI/CDH       EQUALS  
P30S1        EQUALS  
P30S          EQUALS  
P17S1        EQUALS  
MEASINC3      EQUALS

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# MODULE 6 CONTAINS BANKS 36 THROUGH 43

# Page 34

|          |        |    |
|----------|--------|----|
|          | BANK   | 43 |
| SELFCHEC | EQUALS |    |

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```
EXTVERBS      EQUALS
BNKSUM      43

HI6ZEROS      EQUALS  ZEROVECS      # ZERO VECTOR ALWAYS IN HIGH MEMORY
LO6ZEROS      EQUALS  ZEROVEC      # ZERO VECTOR ALWAYS IN LOW MEMORY
HIDPHALF      EQUALS  UNITX
LODPHALF      EQUALS  XUNIT
HIDP1/4       EQUALS  DP1/4TH
LODP1/4       EQUALS  D1/4          # 2DEC .25
HIUNITX       EQUALS  UNITX
HIUNITY       EQUALS  UNITY
HIUNITZ       EQUALS  UNITZ
LOUNITX       EQUALS  XUNIT        # 2DEC .5
LOUNITY       EQUALS  YUNIT        # 2DEC 0
LOUNITZ       EQUALS  ZUNIT        # 2DEC 0
3/4LOWDP      EQUALS  3/4          # 2DEC 3.0 B-2
```

SBANK= LOWSUPER

# ROPE-SPECIFIC ASSIGNS OBVIATING NEED TO CHECK COMPUTER FLAG IN DETERMINING(?) INTEGRATION ARE

```
OTHPREC      EQUALS  LEMPREC
ATOPOTH      EQUALS  ATOPLEM
ATOPTHIS     EQUALS  ATOPCSM
MOONTHIS     EQUALS  CMOONFLG
```

# Page 35

```
MOONOTH      EQUALS  LMOONFLG
MOVATHIS     EQUALS  MOVEACSM
STATEST      EQUALS  V83CALL      # * TEMPORARY
THISPREC     EQUALS  CSMPREC
THISAXIS     =      UNITX
ERASID       EQUALS  LOW10        # DOWNLINK ERASABLE DUMP ID
DELAYNUM     EQUALS  THREE
```

\*\*\*\*\*

# THE FOLLOWING ECADRS ARE DEFINED TO FACILITATE EBANK SWITCHING. THEY ALSO MAKE IT EASIER FOR  
# ERASABLE CONTROL TO REARRANGE ERASABLE MEMORY WITHOUT DISRUPTING THE PROGRAMS WHICH SET EBANK  
# PRIOR TO ROPE RELEASE FIXED MEMORY CAN BE SAVED BY SETTING EACH EBXXXX =EBANKX (X=4,5,6,7).  
# WILL BE THE BANK WHERE THE ERASABLES REFERENCED IN EBXXXX WILL BE STORED.

```
BANK      7
EBANK=    MARKDOWN
EBMARKDO  ECADR  MARKDOWN
```

|          |        |         |
|----------|--------|---------|
|          | EBANK= | MRKBUF1 |
| EBMRKBUF | ECADR  | MRKBUF1 |

|          |        |        |
|----------|--------|--------|
|          | BANK   | 24     |
|          | EBANK= | DVCNTR |
| EBDVCNTR | ECADR  | DVCNTR |
|          | EBANK= | P40TMP |
| EBP40TMP | ECADR  | P40TMP |

|          |        |         |
|----------|--------|---------|
|          | BANK   | 34      |
|          | EBANK= | DVCNTR  |
| EBDVCNT  | ECADR  | DVCNTR  |
|          | EBANK= | QPLACES |
| EBQPLACE | ECADR  | QPLACES |

|       |        |     |
|-------|--------|-----|
|       | BANK   | 37  |
|       | EBANK= | RN1 |
| EBRN1 | ECADR  | RN1 |

\*\*\*\*\*

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# \*\*\* END OF MAIN PROGRAM \*\*\*

This code is written to file `src/TAGS-FOR-RELATIVE-SETLOC.s`.

## A.112 THE LUNAR LANDING

```

1815  <src/THE-LUNAR-LANDING.s 1815>≡
      # Copyright:   Public domain.
      # Filename:    THE_LUNAR_LANDING.agc
      # Purpose:     Part of the source code for Luminary 1A build 099.
      #              It is part of the source code for the Lunar Module's (LM)
      #              Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:   yaYUL
      # Contact:      Hartmuth Gutsche<hgutsche@explornet.com>.
      # Website:      www.ibiblio.org/apollo.
      # Pages:        785-792
      # Mod history:  2009-05-20 HG   Transcribed from page images.
      #
      # This source code has been transcribed or otherwise adapted from
      # digitized images of a hardcopy from the MIT Museum.  The digitization
      # was performed by Paul Fjeld, and arranged for by Deborah Douglas of
      # the Museum.  Many thanks to both.  The images (with suitable reduction
      # in storage size and consequent reduction in image quality as well) are
      # available online at www.ibiblio.org/apollo.  If for some reason you
      # find that the images are illegible, contact me at info@sandroid.org
      # about getting access to the (much) higher-quality images which Paul
      # actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
      #       16:27 JULY 14, 1969

      # Page 785

              BANK      32
              SETLOC    F2DPS*32
              BANK

              EBANK=    E2DPS

      # *****
      # P63: THE LUNAR LANDING, BRAKING PHASE
      # *****

              COUNT*    $$/P63

P63LM          TC      PHASCHNG
                OCT      04024

                TC      BANKCALL          # DO IMU STATUS CHECK ROUTINE R02

```

```

                                CADR    R02BOTH

                                CAF      P63ADRES    # INITIALIZE WHICH FOR BURNBABY
                                TS        WHICH

                                CAF      DPSTHRSH     # INITIALIZE DVMON
                                TS        DVTHRUSH
                                CAF      FOUR
                                TS        DVCNTR

                                CS        ONE          # INITIALIZE WCHPHASE AND FLPASSO
                                TS        WCHPHASE

                                CA        ZERO
                                TS        FLPASSO

                                CS        BIT14
                                EXTEND
                                WAND      CHAN12        # REMOVE TRACK-ENABLE DISCRETE.

FLAGORGY    TC        INTERPRET    # DIONYSIAN FLAG WAVING
             CLEAR    CLEAR
             CLEAR    NOTHROTL
             CLEAR    REDFLAG
             CLEAR    SET
             CLEAR    LRBYPASS
             CLEAR    MUNFLAG
             CLEAR    CLEAR
             CLEAR    P25FLAG        # TERMINATE P25 IF IT IS RUNNING.
             CLEAR    RNDVZFLG      # TERMINATE P20 IF IT IS RUNNING.

                                # *****

IGNALG      SETPD     VLOAD        # FIRST SET UP INPUTS FOR RP-TO-R:
# Page 786
                                O
                                RLS        # AT 0D LANDING SITE IN MOON FIXED FRAME
                                PDDL      PUSH        # AT 6D ESTIMATED TIME OF LANDING
                                TLAND     # MPAC NON-ZERO TO INDICATE LUNAR CASE

                                STCALL    TPIP        # ALSO SET TPIP FOR FIRST GUIDANCE PASS
                                RP-TO-R
                                VSL4     MXV
                                REFMMAT
                                STCALL    LAND
                                GUIDINIT    # GUIDINIT INITIALIZES WM AND /LAND/
                                DLOAD     DSU

```



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```

                                TLAND
                                GUIDDURN
STCALL  TDEC1                  # INTEGRATE STATE FORWARD TO THAT TIME
                                LEMPREC
SSP      VLOAD
                                NIGNLOOP
                                40D
                                UNITX
STOVL    CG
                                UNITY
STOVL    CG +6
                                UNITZ
STODL    CG +14
                                99999CON
STOVL    DELTAH                # INITIALIZE DELTAH FOR V16N68 DISPLAY
                                ZEROVECS
STODL    UNFC/2                # INITIALIZE TRIM VELOCITY CORRECTION TERM
                                HI6ZEROS
STORE    TTF/8

IGNALOOP  DLOAD
                                TAT
STOVL    PIPTIME1
                                RATT1
VSL4     MXV
                                REFSMMAT
STCALL    R
                                MUNGRAV
STCALL    GDT/2
                                ?GUIDSUB                # WHICH DELIVERS N PASSES OF GUIDANCE

# DDUMCALC IS PROGRAMMED AS FOLLOWS:
#
#                                2
#                                (RIGNZ - RGU )/16 + 16(RGU )KIGNY/B8 + (RGU - RIGNX)KIGNX/B4 + (ABVAL(VGU) - VI
#                                2                1                0
# DDUM = -----
#                                10
#                                2 (VGU - 16 VGU KIGNX/B4)
#                                2      0
# Page 787 new page is actually one line earlier but this would put the indices on a seperate l
# disconnected from their respective variables
# THE NUMERATOR IS SCALED IN METERS AT 2(28). THE DENOMINATOR IS A VELOCITY IN UNITS OF 2(10)
# THE QUOTIENT IS THUS A TIME IN UNITS OF 2(18) CENTISECONDS. THE FINAL SHIFT RESCALES TO UNIT
# THERE IS NO DAMPING FACTOR. THE CONSTANTS KIGNX/B4, KIGNY/B8 AND KIGNV/B4 ARE ALL NEGATIVE I

DDUMCALC      TS      NIGNLOOP
```

|       |          |                                        |
|-------|----------|----------------------------------------|
| TC    | INTPRET  |                                        |
| DLOAD | DMPR     | # FORM DENOMINATOR FIRST               |
|       | VGU      |                                        |
|       | KIGNX/B4 |                                        |
| SL4R  | BDSU     |                                        |
|       | VGU +4   |                                        |
| PDDL  | DSU      |                                        |
|       | RIGNZ    |                                        |
|       | RGU +4   |                                        |
| SR4R  | PDDL     |                                        |
|       | RGU +2   |                                        |
| DSQ   | DMPR     |                                        |
|       | KIGNY/B8 |                                        |
| SL4R  | PDDL     |                                        |
|       | RGU      |                                        |
| DSU   | DMPR     |                                        |
|       | RIGNX    |                                        |
|       | KIGNX/B4 |                                        |
| PDVL  | ABVAL    |                                        |
|       | VGU      |                                        |
| DSU   | DMPR     |                                        |
|       | VIGN     |                                        |
|       | KIGNV/B4 |                                        |
| DAD   | DAD      |                                        |
| DAD   | DDV      |                                        |
| SRR   |          |                                        |
|       | 10D      |                                        |
| PUSH  | DAD      |                                        |
|       | PIPTIME1 |                                        |
| STODL | TDEC1    | # STORE NEW GUESS FOR NEXT INTEGRATION |
| ABS   | DSU      |                                        |
|       | DDUMCRIT |                                        |
| BMN   | CALL     |                                        |
|       | DDUMGOOD |                                        |
|       | INTSTALL |                                        |
| SET   | SET      |                                        |
|       | INTYPFLG |                                        |
|       | MOONFLAG |                                        |
| DLOAD |          |                                        |
|       | PIPTIME1 |                                        |
| STOVL | TET      | # HOPEFULLY ?GUIDSUB DID NOT           |
|       | RATT1    | # CLOBBER RATT1 AND VATT1              |
| STOVL | RCV      |                                        |
|       | VATT1    |                                        |

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```

                STCALL  VCV
                        INTEGRVS
                GOTO     IGNALoop

DDUMGOOD        SLOAD   SR
                        ZOOMTIME
                        14D
                BDSU
                        TDEC1
                STOVL   TIG
                        V
                VXV     UNIT
                        R
                DOT      SL1
                        LAND
R60INIT          STOVL   OUTFPLN
                        UNFC/2
                STORE   R60VSAVE
                EXIT
                        # STORE UNFC/2 TEMPORARILY IN R60SAVE
                        # *****

IGNALGRT        TC      PHASCHNG
                OCT      04024
                        # PREVENT REPEATING IGNALG

ASTNCLOK        CS      ASTNDEX
                TC      BANKCALL
                CADR     STCLOK2
                TCF      ENDOFJOB
                        # RETURN IN NEW JOB AND IN EBANK FIVE

ASTNRET         TC      INTPRET
                SSP      RTB
                        # GO PICK UP DISPLAY AT END OF R51:
                        # "PROCEED" WILL DO A FINE ALIGNMENT
                FCADR     P63SPOT2
                        # "ENTER" WILL RETURN TO P63SPOT2
                        R51P63
P63SPOT2        VLOAD   UNIT
                        R60VSAVE
                STOVL   POINTVSM
                        UNITX
                STORE   SCAXIS
                EXIT
                CAF      EBANK7
                TS       EBANK
                INHINT
```

```
# Page 789

TC      IBNKCALL
CADR    PFLITEDB

RELINT

TC      BANKCALL
CADR    R60LEM

TC      PHASCHNG      # PREVENT RECALLING R60
OCT     04024

P63SPOT3  CA      BIT6      # IS THE LR ANTENNA IN POSITION 1 YET
          EXTEND
          RAND     CHAN33
          EXTEND
          BZF      P63SPOT4  # BRANCH IF ANTENNA ALREADY IN POSITION 1

          CAF      CODE500   # ASTRONAUT:  PLEASE CRANK THE
          TC       BANKCALL  #
          CADR     GOPERF1   #
          TCF      GOTOPOOH  # TERMINATE
          TCF      P63SPOT3  # PROCEED      SEE IF HE'S LYING

P63SPOT4  TC      BANKCALL   # ENTER      INITIALIZE LANDING RADAR
          CADR     SETPOS1

          TC      POSTJUMP   # OFF TO SEE THE WIZARD ...
          CADR     BURNBABY

# -----

# CONSTANTS FOR P63LM AND IGNALG

P63ADRES      GENADR  P63TABLE

ASTNDEX      =      MD1      # OCT 25:  INDEX FOR CLOKTASK

CODE500      OCT     00500

99999CON      2DEC    30479.7 B-24

GUIDDURN      2DEC    +66440      # GUIDDURN +6.64400314 E+2
DDUMCRIT      2DEC    +8 B-28     # CRITERION FOR IGNALG CONVERGENCE

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# -----
```

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# \*\*\*\*\*  
# P68: LANDING CONFIRMATION  
# \*\*\*\*\*

|          |        |            |                                           |
|----------|--------|------------|-------------------------------------------|
|          | BANK   | 31         |                                           |
|          | SETLOC | F2DPS*31   |                                           |
|          | BANK   |            |                                           |
|          | COUNT* | \$\$/P6567 |                                           |
| LANDJUNK | TC     | PHASCHNG   |                                           |
|          | OCT    | 04024      |                                           |
|          | INHINT |            |                                           |
|          | TC     | BANKCALL   | # ZERO ATTITUDE ERROR                     |
|          | CADR   | ZATTEROR   |                                           |
|          | TC     | BANKCALL   | # SET 5 DEGREE DEADBAND                   |
|          | CADR   | SETMAXDB   |                                           |
|          | TC     | INTPRET    | # TO INTERPRETIVE AS TIME IS NOT CRITICAL |
|          | SET    | CLEAR      |                                           |
|          |        | SURFFLAG   |                                           |
|          |        | LETABORT   |                                           |
|          | SET    | VLOAD      |                                           |
|          |        | APSFLAG    |                                           |
|          |        | RN         |                                           |
|          | STODL  | ALPHAV     |                                           |
|          |        | PIPTIME    |                                           |
|          | SET    | CALL       |                                           |
|          |        | LUNAFLAG   |                                           |
|          |        | LAT-LONG   |                                           |
|          | SETPD  | VLOAD      | # COMPUTE RLS AND STORE IT AWAY           |
|          |        | 0          |                                           |
|          |        | RN         |                                           |
|          | VSL2   | PDDL       |                                           |
|          |        | PIPTIME    |                                           |
|          | PUSH   | CALL       |                                           |
|          |        | R-TO-RP    |                                           |
|          | STORE  | RLS        |                                           |
|          | EXIT   |            |                                           |
|          | CAF    | V06N43*    | # ASTRONAUT: NOW LOOK WHERE TO ENDED UP   |
|          | TC     | BANKCALL   |                                           |
|          | CADR   | GOFLASH    |                                           |

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```

                                TCF      GOTOPOOH      # TERMINATE
                                TCF      +2            # PROCEED
                                TCF      -5            # RECYCLE

                                TC        INTPRET

# Page 792
                                VLOAD
                                UNITX                # INITIALIZE GSAV AND (USING REFMF)
                                STCALL  GSAV           # YNBSAV, ZNBSAV AND ATTFLAG FOR P57
                                REFMF
                                EXIT

                                TCF      GOTOPOOH      # ASTRONAUT:  PLEASE SELECT P57

V06N43*      VN      0643
```

This code is written to file `src/THE-LUNAR-LANDING.s`.

## A.113 THROTTLE CONTROL ROUTINES

1823 *<src/THROTTLE-CONTROL-ROUTINES.s 1823>≡*

```
# Copyright:   Public domain.
# Filename:    THROTTLE_CONTROL_ROUTINES.agc
# Purpose:    Part of the source code for Luminary 1A build 099.
#             It is part of the source code for the Lunar Module's (LM)
#             Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:  yaYUL
# Contact:    HARTMUTH GUTSCHE <hgutsche@explornet.com>.
# Website:    www.ibiblio.org/apollo.
# Pages:      793-797
# Mod history: 2009-05-20 HG   Transcribed from page images.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
#       16:27 JULY 14, 1969
```

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```
BANK      31
SETLOC    FTHROT
BANK
EBANK=    PIF
COUNT*   $$/THROT
```

```
# * * * * *
# HERE FC, DESIRED THRUST, AND FP, PRESENT THRUST, UNWEIGHTED, ARE COMPUTED.
```

```
THROTTLE      CA      ABDELV      # COMPUTE PRESENT ACCELERATION IN UNITS OF
EXTEND        /AF/CNST      # 2(-4) M/CS/CS, SAVING SERVICER TROUBLE
+3            EXTEND
QXCH          RTNHOLD
AFDUMP        TC      MASSMULT
DXCH          FP          # FP = PRESENT THRUST
```

```

EXTEND
DCA      /AFC/
TC       MASSMULT
TS       FC          # FC = THRUST DESIRED BY GUIDANCE
DXCH     FCODD       # FCODD = WHAT IT IS GOING TO GET

# IF IT HAS BEEN LESS THAN 3 SECONDS SINCE THE LAST THROTTLING, AUGMENT FP USING THE

CS       TTHROT      # THIS CODING ASSUMES A FLATOUT WITHIN
AD       TIME1       #          80 SECONDS BEFORE FIRST THROTTLE CALL
MASK     POSMAX
COM
AD       3SECS
EXTEND
BZMF     WHERETO     # BRANCH IF (TIME1-TTHROT +1) > 3 SECONDS
EXTEND
DCA      FWEIGHT
DAS      FP

# THIS LOGIC DETERMINES THE THROTTLING IN THE REGION 10% - 94%.  THE MANUAL THROTTLE
# MINIMUM BY ASTRONAUT OR MISSION CONTROL PROGRAMS, PROVIDES THE LOWER BOUND.  A STOP
# PROVIDES THE UPPER.

WHERETO   CA      EBANK5      # INITIALIZE L*WCR*T AND H*GHCR*T FROM
          TS      EBANK       #          PAD LOADED ERASABLES IN W-MATRIX

#Page 794
          EBANK=   LOWCRIT
EXTEND
DCA      LOWCRIT
DXCH     L*WCR*T
CA       EBANK7
TS       EBANK
EBANK=   PIF
CS       ZERO        # INITIALIZE PIFPSET
TS       PIFPSET
CS       H*GHCR*T
AD       FCOLD
EXTEND
BZMF     LOWFCOLD     # BRANCH IF FCOLD < OR = HIGHCRIT
CS       L*WCR*T
AD       FCODD
EXTEND
BZMF     FCOMPSET     # BRANCH IF FC < OR = LOWCRIT
CA       FP          # SEE NOTE 1
TCF      FLATOUT1

```



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```
FCOMPSET      CS      FMAXODD      # SEE NOTE 2
              AD      FP
              TCF      FLATOUT2

LOWFCOLD      CS      H*GHCR*T
              AD      FCODD
              EXTEND
              BZMF     DOPIF      # BRANCH IF FC < OR = HIGHCRIT

              CA      FMAXPOS      # NO:  THROTTLE-UP
FLATOUT1      DXCH     FCODD
              CA      FEXTRA
FLATOUT2      TS      PIFPSET

# NOTE 1      FC IS SET EQUAL TO FP SO PIF WILL BE ZERO.  THIS IS DESIRABLE
#              AS THERE IS ACTUALLY NO THROTTLE CHANGE.
#
# NOTE2      HERE, SINCE WE ARE ABOUT TO RETURN TO THE THROTTLEABLE REGION
#              (BELOW 55%) THE QUANTITY -(FMAXODD-FP) IS COMPUTED AND PUT
#              INTO PIFPSET TO COMPENSATE FOR THE DIFFERENCE BETWEEN THE
#              NUMBER OF BITS CORRESPONDING TO FULL THROTTLE (FMAXODD) AND THE
#              NUMBER CORRESPONDING TO ACTUAL THRUST (FP).  THUS THE TOTAL
#              THROTTLE COMMAND PIF = FC - FP - (FMAXODD - FP) = FC - FMAXODD.

DOPIF         TC      FASTCHNG
              EXTEND
              DCA      FCODD
              TS      FCOLD
              DXCH     PIF
              EXTEND

#Page 795     DCS      FP
              DAS      PIF      # PIF = FC - FP, NEVER EQUALS +0

DOIT          CA      PIF
              AD      PIFPSET      # ADD IN PIFPSET, WITHOUT CHANGING PIF
              TS      PSEUDO55
              TS      THRUST
              CAF      BIT4
              EXTEND
              WOR      CHAN14
              CA      TIME1
              TS      TTHROT
```

```
# SINCE /AF/ IS NOT AN INSTANTANEOUS ACCELERATION, BUT RATHER AN "AVERAGE" OF THE ACCELERATION I
# THE PRECEEDING PIPA INTERVAL, AND SINCE FP IS COMPUTED DIRECTLY FROM /AF/, FP IN ORDER TO COR
```

# ACTUAL THRUST LEVEL AT THE END OF THE INTERVAL MUST BE WEIGHTED BY

#

#  
#  
#
$$\text{FWEIGHT} = \frac{\text{PIF}(\text{PPROCESS} + \text{TL})}{\text{PGUID}} + \frac{\text{PIF} / \text{PIF/}}{2 \text{ PGUID FRATE}}$$
  
#

# WHERE PROCESS IS THE TIME BETWEEN PIPA READING AND THE START OF THROTTLING, PGUID IS

# FRATE IS THE THROTTLING RATE (32 UNITS PER CENTISECOND). PGUID IS EITHER 1 OR 2 SE

# FIRST TERM REPRESENTS THE ENGINE'S RESPONSE LAG. HERE FWEIGHT IS COMPUTED FOR USE

CA THISTPIP +1 # INITIALIZE FWEIGHT COMP AS IF FOR P  
TS BUF

CS MODREG # ARE WE IN FACT IN P66?  
AD DEC66

EXTEND  
BZF FWCOMP # YES

CA PIPTIME +1 # NO: INITIALIZE FOR TWO SECOND PER.  
TS BUF  
CAF 4SECS  
TCF FWCOMP +1

FWCOMP CAF 2SECS  
+1 TS Q

EXTEND  
MP BIT6  
LXCH BUF +1  
CS BUF # TIME OF LAST PIPA READING.

AD TIME1  
AD THROTLAG # COMPENSATE FOR ENGINE RESPONSE LAG  
MASK LOW8 # MAKE SURE SMALL AND POSITIVE

ZL  
EXTEND

#Page 796

DV Q  
EXTEND  
MP PIF  
DOUBLE  
DXCH FWEIGHT  
CCS PIF  
AD ONE  
TCF +2  
AD ONE  
EXTEND  
MP PIF

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```

                                EXTEND
                                DV      BUF +1
                                ZL
                                DAS      FWEIGHT

THDUMP      TC      RTNHOLD
```

# FLATOUT THROTTLES UP THE DESCENT ENGINE, AND IS CALLED AS A BASIC SUBROUTINE.

```

FLATOUT      CAF      BIT13      # 4096 PULSES
WHATOUT      TS      PIFPSET      # USE PIFPSET SO FWEIGHT WILL BE ZERO
                                CS      ZERO
                                TS      FCOLD
                                TS      PIF
                                EXTEND
                                QXCH      RTNHOLD
                                TCF      DOIT
```

# MASSMULT SCALES ACCELERATION, ARRIVING IN A AND L IN UNITS OF 2(-4) M/CS/CS, TO FORCE IN PULSES

```

MASSMULT      EXTEND
                                QXCH      BUF
                                DXCH      MPAC
                                TC      DMP
                                ADRES      MASS
                                TC      DMP      # LEAVES PROPERLY SCALED FORCE IN MPAC
                                ADRES      SCALEFAC
                                TC      TPAGREE
                                CA      MPAC
                                EXTEND
                                BZF      +3
                                CAF      POSMAX
                                TC      BUF
                                DXCH      MPAC +1
                                TC      BUF
```

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# CONSTANTS --

```

FEXTRA      =      BIT13      # FEXT +5.13309020 E+4
```

```

/AF/CNST      DEC      .13107
```

# \* \* \* \* \*

This code is written to file src/THROTTLE-CONTROL-ROUTINES.s.

## A.114 TIME OF FREE FALL

```

1828  <src/TIME-OF-FREE-FALL.s 1828>≡
      # Copyright:    Public domain.
      # Filename:     TIME_OF_FREE_FALL.agc
      # Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
      #               It is part of the source code for the Command Module's (CM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Ron Burkey <info@sandroid.org>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         1373-1388
      # Mod history:   2009-05-10 SN    (Sergio Navarro).  Started adapting
      #               from the Colossus249/ file of the same
      #               name, using Comanche055 page images.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum.  The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum.  Many
      # thanks to both.  The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo.  If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #   Assemble revision 055 of AGC program Comanche by NASA
      #   2021113-051.  10:28 APR. 1, 1969
      #
      #   This AGC program shall also be referred to as
      #   Colossus 2A

      # Page 1373
      # THE TFF SUBROUTINES MAY BE USED IN EITHER EARTH OR MOON CENTERED COORDINATES.  THE
      # KNOW WHICH ORIGIN APPLIES.  IT IS THE USER WHO KNOWS, AND WHO SUPPLIES RONE, VONE,
      # APPROPRIATE SCALE LEVEL FOR THE PROPER PRIMARY BODY.
      #
      #           EARTH ORIGIN      POSITION          -29      METERS
      #                               VELOCITY          -7      METERS/CENTISECOND
      #                               1/SQRT(MU)         +17      SQRT(CS SQ/METERS CUBED)
      #
      #           MOON ORIGIN       POSITION          -27      METERS
      #                               VELOCITY          -5      METERS/CENTISECONDS
      #                               1/SQRT(MU)         +14      SQRT(CS SQ/METERS CUBED)
      #

```

```

# ALL DATA PROVIDED TO AND RECEIVED FROM ANY TFF SUBROUTINE WILL BE AT ONE OF THE LEVELS ABOVE.
# THE FREE FALL TIME IS RETURNED IN CENTISECONDS AT (-28). PROGRAM TFF/CONIC WILL GENERATE VONE
# LEAVE IT IN VONE' AT (+10) IF EARTH ORIGIN AND (+9) IF MOON ORIGIN.
#
# THE USER MUST STORE THE STATE VECTOR IN RONE, VONE, AND MU IN THE FORM 1/SQRT(MU) IN TFF/RTMU
# AT THE PROPER SCALE BEFORE CALLING TFF/CONIC. SINCE RONE, VONE ARE IN THE EXTENDED VERB STORAGE
# THE USER MUST ALSO LOCK OUT THE EXTENDED VERBS, AND RELEASE THEM WHEN FINISHED.
#
# PROGRAMS CALC/TFF AND CALC/TPER ASSUME THAT THE TERMINAL RADIUS IS LESS THAN THE PRESENT
# RADIUS. THIS RESTRICTION CAN BE REMOVED BY A 15 W CODING CHANGE, BUT AT PRESENT IT IS NOT DONE.
#
# THE FOLLOWING ERASABLE QUANTITIES ARE USED BY THE TFF ROUTINES, AND ARE LOCATED IN THE PUSH DOWN STACK
#
#                               BELOW  E: IS USED FOR EARTH ORIGIN SCALE
#                               M: IS USED FOR MOON ORIGIN SCALE
#
#TFFSW          =      119D  # BIT1  0 = CALCTFF          1 = CALCTPER
TFFDELQ         =      10D  #      Q2-Q1          E: (-16) M: (-15)
RMAG1           =      12D  #      ABVAL(RN) M      E: (-29) M: (-27)
#RPER           =      14D  #      PERIGEE RADIUS M    E: (-29) M: (-27)
TFFQ1           =      14D  #      R.V / SQRT(MUE)    E: (-16) M: (-15)
#SDELF/2        =          #      SIN(THETA) /2
CDELF/2         =      14D  #      COS(THETA) /2
#RAPO           =      16D  #      APOGEE RADIUS M      E: (-29) M: (-27)
NRTERM          =      16D  #      TERMINAL RADIUS M    E: (-29+NR)
#                               #                               M: (-27+NR)
RTERM           =      18D  #      TERMINAL RADIUS M    E: (-29) M: (-27)
TFFVSQ          =      20D  #      -(V SQUARED/MU) 1/M  E: (20) M: (18)
TFF1/ALF        =      22D  #      SEMI MAJ AXIS M      E: (-22-2 NA)
#                               #                               M: (-20-2 NA)
TFFRTALF        =      24D  #      SQRT(ALFA)          E: (10+NA) M: (9+NA)
TFFALFA         =      26D  #      ALFA 1/M            E: (26-NR) M: (24-NR)
TFFNP           =      28D  #      SEMI LATUS RECTUM M  E: (-38+2 NR)
#                               #                               M: (-36+2 NR)
TFF/RTMU        =      30D  #      1/SQRT(MU)          E: (17) M: (14)
NRMAG           =      32D  #      PRESENT RADIUS M    E: (-29+NR)
#                               #                               M: (-27+NR)
TFFX            =      34D  #
TFFTEM          =      36D  #      TEMPORARY
# Page 1374
#
# REGISTERS S1, S2 ARE UNTOUCHED BY ANY TFF SUBROUTINE
#
# INDEX REGISTERS X1, X2 ARE USED BY ALL TFF SUBROUTINES. THEY ARE ESTABLISHED IN TFF/CONIC AND MUST BE PRESERVED BETWEEN CALLS TO SUBSEQUENT SUBROUTINES.
#
# -NR                               C(X1) = NORM COUNT OF RMAG
# -NA                               C(X2) = NORM COUNT OF SQRT(ABS(ALFA))

```

```

# Page 1375
# SUBROUTINE NAME:  TFFCONIC                                DATE:  01.29.67
# MOD NO:  0  LOG SECTION:  TIME OF FREE FALL
# MOD BY:  RR BAIRNSFATHER
# MOD NO:  1      MOD BY:  RR BAIRNSFATHER                DATE:  11 APR 67
# MOD NO:  2      MOD BY:  RR BAIRNSFATHER                DATE:  21 NOV 67      ADD MOON MU.
# MOD NO:  3      MOD BY:  RR BAIRNSFATHER                DATE:  21 MAR 68      ACCEPT DIFFER
#
# FUNCTIONAL DESCRIPTION:  THIS SUBROUTINE IS CALLED TO COMPUTE THOSE CONIC PARAMETERS
#                          SUBROUTINES AND TO ESTABLISH THEM IN THE PUSH LIST AREA.  THE PARAMETERS ARE
#                          THE EQUATIONS ARE:
#
#                          
$$\bar{H} = \bar{R}\bar{N}\bar{V}\bar{N}$$
                                ANGULAR MOMENTUM
#
#                          
$$LCP = \bar{H}.\bar{H} / \mu$$
                                SEMI LATUS RECTUM
#
#                          
$$ALFA = 2/\bar{R}\bar{N} - \bar{V}\bar{N}.\bar{V}\bar{N} / \mu$$
                RECIPROCAL SEMI MAJ AXIS, SIGNED
#
#                          AND ALFA IS POS FOR ELLIPTIC ORBITS
#                          0 FOR PARABOLIC ORBITS
#                          NEG FOR HYPERBOLIC ORBITS.
#                          SUBROUTINE ALSO COMPUTES AND SAVES RMAG.
#
# CALLING SEQUENCE:
# TFFCONIC EXPECTS CALLER TO ENTER WITH CORRECT GRAVITATIONAL CONSTANT IN MPAC,
# 1/SQRT(MU).  THE PROGRAM WILL SAVE IN TFF/RTMU.  THE SCALE IS DETERMINED BY V
# ORIGIN IS USED.  THE CALLER MUST LOCK OUT THE EXTENDED VERBS BEFORE PROVIDING
# VONE AT PROPER SCALE.  THE EXTENDED VERBS MUST BE RESTORED WHEN THE CALLER IS
# TFF ROUTINES.
#
# ENTRY POINT TFFCONMU EXPECTS THAT TFF/RTMU IS ALREADY LOADED.
#
# TO SPECIFY MU:  DLOAD  CALL      # IF MU ALREADY STORED:      CALL
#                  YOURMU      # 1/RTMU E:(17) M:(14)
#                  TFFCONIC
# PUSHLOC = PDL+0, ARBITRARY IF LEQ 18D
#
# SUBROUTINES CALLED:  NONE
#
# NORMAL EXIT MODES:  RVQ
#
# ALARMS:  NONE
#
# OUTPUT:          THE FOLLOWING ARE STORED IN THE PUSH LIST AREA.
#                  RMAG1          E:(-29) M:(-27)          M RN, PRESENT RADIUS LENGTH

```

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```
#          NRMAG          E: (-29+NR)          M  RMAG, NORMALIZED
#          M: (-27+NR)
#          X1              -NR, NORM COUNT
#          TFFNP          E: (-38+2NR)          M  LCP, SEMI LATUS RECTUM, WEIGHTED BY
#          M: (-36+2NR)
#          TFF/RTMU       E: (17) M: (14)        1/SQRT(MU)
#          TFFVSQ         E: (20) M: (18)        1/M  -(V SQ/MU):  PRESENT VELOCITY, NOR
#          TFFALFA        E: (26-NR)            1/M  ALFA, WEIGHTED BY NR
#          M: (24-NR)
#          TFFRTALF       E: (10+NA)            SQRT(ALFA), NORMALIZED
#          M: (9+NA)
# Page 1376
#          X2              -NA, NORM COUNT
#          TFF1/ALF       E: (-22-2NA)          SIGNED SEMI MAJ AXIS, WEIGHTED BY NA
#          M: (-20-2NA)
#          PUSHLOC AT PDL+0
#
#          THE FOLLOWING IS STORED IN GENERAL ERASABLE
#          VONE'          E: (10) M: (9)        V/RT(MU), NORMALIZED VELOCITY
#
# ERASABLE INITIALIZATION REQUIRED:
#          RONE           E: (-29) M: (-27)      M  STATE VECTOR          LEFT BY CALLER
#          VONE           E: (-7) M: (-5)       M/CS  STATE VECTOR        LEFT BY CALLER
#          TFF/RTMU       E: (17) M: (14)       1/RT(CS SQ/M CUBE)      IF ENTER VIA TR
#
# DEBRIS:      QPRET      PDL+0 ... PDL+3
#
#          BANK    33
#          SETLOC  TOF-FF
#          BANK
#
#          COUNT*  $$/TFF
#
# TFFCONIC      STORE    TFF/RTMU      # 1/SQRT(MU)      E: (17) M: (14)
#
# TFFCONMU      VLOAD    UNIT          # COME HERE WITH TFFRTMU LOADED.
#                  RONE      # SAVED RN.  M  E: (-29) M: (-27)
#          PDDL      # UR/2 TO PDL+0, +5
#                  36D      # MAGNITUDE
#          STORE    RMAG1      # M  E: (-29) M: (-27)
#
#          NORM
#                  X1          # -NR
#          STOVL    NRMAG      # RMAG  M  E: (-29+NR) M: (-27+NR)
#                  VONE      # SAVED VN.  M/CS  E: (-7) M: (-5)
#          VXSC
```

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|             |       |          |                                        |
|-------------|-------|----------|----------------------------------------|
|             |       | TFF/RTMU | # E:(17) M:(14)                        |
|             | STORE | VONE'    | # VN/SQRT(MU) E:(10) M:(9)             |
|             | VXSC  | VXV      |                                        |
|             |       | NRMAG    | # E:(-29+NR) M:(-27+NR)                |
|             |       |          | # UR/2 FROM PDL                        |
|             | VSL1  | VSQ      | # BEFORE: E:(-19+NR) M:(-18+NR)        |
|             | STODL | TFFNP    | # LC P M E:(-38+2NR) M:(-36+2NR)       |
|             |       |          | # SAVE ALSO FOR VGAMCALC               |
|             |       | TFF1/4   |                                        |
|             | DDV   | PDVL     | # (2/RMAG) 1/M E:(26-NR) M:(24-NR)     |
|             |       | NRMAG    | # RMAG M E:(-29+NR) M:(-27+NR)         |
|             |       | VONE'    | # SAVED VN. E:(10) M:(9)               |
|             | VSQ   | DCOMP    | # KEEP MPAC+2 HONEST FOR SQRT.         |
|             | STORE | TFFVSQ   | # -(V SQ/MU) E:(20) M:(18)             |
|             |       |          | # SAVE FOR VGAMCALC                    |
|             | SR*   | DAD      |                                        |
| # Page 1377 |       | 0 -6,1   | # GET -VSQ/MU E:(26-NR) M:(24-NR)      |
|             | STADR |          |                                        |
|             |       |          | # 2/RMAG FROM PDL+2                    |
|             | STORE | TFFALFA  | # ALFA 1/M E:(26-NR) M:(24-NR)         |
|             | SL*   | PUSH     | # TEMP SAVE ALFA E:(20) M:(18)         |
|             |       | 0 -6,1   |                                        |
|             | ABS   | SQRT     | # E:(10) M:(9)                         |
|             | NORM  |          |                                        |
|             |       | X2       | # X2 = -NA                             |
|             | STORE | TFFRTALF | # SQRT( ABS(ALFA) ) E:(10+NA) M:(9+NA) |
|             | DSQ   | SIGN     | # NOT SO ACCURATE, BUT OK              |
|             |       |          | # ALFA FROM PDL+2 E:(20) M:(18)        |
|             | BZE   | BDDV     | # SET 1/ALFA =0, TO SHOW SMALL ALFA    |
|             |       | +2       |                                        |
|             |       | TFF1/4   |                                        |
| +2          | STORE | TFF1/ALF | # 1/ALFA E:(-22-2NA) M:(-20-2NA)       |
| DUMPCNIC    | RVQ   |          |                                        |
|             |       |          | #                                      |
|             |       |          | 39 W                                   |

# Page 1378

```
# SUBROUTINE NAME:  TFFRP/RA
```

DATE: 01.17.67

# MOD NO: 0

LOG SECTION: TIME OF FREE FALL

# MOD NO: 1 MOD BY: RR BAIRNSFATHER

DATE: 11 APR 67

# MOD NO: 2 MOD BY: RR BAIRNSFATHER

DATE: 21 MAR 68

ACCEPT DIFFER

#

ALSO IMPROVE

#

```
# FUNCTIONAL DESCRIPTION:  USED BY CALCTPER AND TFF DISPLAYS TO CALCULATE PERIGEE RA
```

# APOGEE RADIUS FOR A GENERAL CONIC.

```
#
# PROGRAM GIVES PERIGEE RADIUS AS          APOGEE RADIUS IS GIVEN BY
```



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```
#          RP = P/(1+E)                      RA = (1+E) / ALFA
#      WHERE      2
#          E = 1 - P ALFA
#      IF RA IS NEGATIVE OR SHOWS DIVIDE OVERFLOW, THEN RA = POSMAX BECAUSE
#          1. APOGEE RADIUS IS NOT MEANINGFUL FOR HYPERBOLA
#          2. APOGEE RADIUS IS NOT DEFINED FOR PARABOLA
#          3. APOGEE RADIUS EXCEEDS THE SCALING FOR ELLIPSE.
#
#      THIS SUBROUTINE REQUIRED THE SIGNED RECIPROCAL SEMI MAJ AXIS, ALFA, AND SEMI LATUS RECT
#
#      CALLING SEQUENCE:      CALL
#                              TFFRP/RA
#      PUSHLOC = PDL+0, ARBITRARY IF LEQ 10D
#      C(MPAC) UNSPECIFIED
#
#      SUBROUTINES CALLED:    NONE
#
#      NORMAL EXIT MODE:      RVQ
#      IF ELLIPSE, WITHIN NORMAL SCALING, RAPO IS CORRECT.
#      OTHERWISE, RAPO = POSMAX.
#
#      ALARMS:                NONE
#
#      OUTPUT:                STORED IN PUSH LIST AREA.  SCALE OF OUTPUT AGREES WITH DATA SUPPLIED TO TFF/CON
#      RPER      E:(-29) M:(-27)      M      PERIGEE RADIUS      DESTROYED BY CALCTFF/CA
#      RAPO      E:(-29) M:(-27)      M      APOGEE RADIUS      WILL BE DESTROYED BY CA
#      PUSHLOC AT PDL+0
#
#      ERASABLE INITIALIZATION REQUIRED:
#      TFFALFA E:(26-NR)      M      1/SEMI MAJ AXIS LEFT BY TFFCONIC
#      M:(24-NR)
#      TFFNP   E:(-38+2NR)    M      LC P, SEMI LATUS RECTUM LEFT BY TFFCONIC
#      M:(-36+2NR)
#      X1      -NR, NORM COUNT OF RMAG      LEFT BY TFFCONIC
#      X2      -NA, NORM COUNT OF ALFA      LEFT BY TFFCONIC
#
#      DEBRIS:                QPRET, PDL+0 ... PDL+1

# Page 1379
RAPO      =      16D      # APOGEE RADIUS  M  E:(-29) M:(-27)
RPER      =      14D      # PERIGEE RADIUS  M  E:(-29) M:(-27)

TFFRP/RA  DLOAD  DMP
           TFFALFA  # ALFA  1/M  E:(26-NR) M:(24-NR)
           TFFNP    # LC P  M  E:(-38+2NR) M:(-36+2NR)
SR*       DCOMP    # ALFA P (-12+NR)
```

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```

DAD      0 -8D,1      # ALFA P (-4)
          ABS          # (DCOMP GIVES VALID TP RESULT FOR SQRT)
          # (ABS PROTECTS SQRT IF E IS VERY NEAR 0)

          DP2(-4)
SQRT     DAD          # E SQ = (1- P ALFA) (-4)
          TFF1/4
PUSH     BDDV         # (1+E) (-2) TO PDL+0
          TFFNP        # LCP M E:(-38+2NR) M:(-36+2NR)
SR*      SR*          # (DOES SR THEN SL TO AVOID OVFL)
          0,1          # X1=-NR
          0 -7,1       # (EFFECTIVE SL)
STODL    RPER         # PERIGEE RADIUS M E:(-29) M:(-27)
          # (1+E) (-2) FROM PDL+0

DMP      BOVB
          TFF1/ALF     # E:(-22-2NA) M:(-20-2NA)
          TCDANZIG     # CLEAR OVFLND, IF ON.
BZE      SL*
          MAXRA        # SET POSMAX IF ALFA=0
          0 -5,2       # -5+NA
SL*      BOV
          0,2
          MAXRA        # SET POSMAX IF OVFL.
BPL      # CONTINUE WITH VALID RAPO.
          +3

MAXRA    DLOAD        # RAPO CALC IS NOT VALID. SET RAPO =
          NEARONE      # POSMAX AS A TAG.
          +3           # APOGEE RADIUS M E:(-29) M:(-27)
DUMPRPRA STORE RAPO
          RVQ

#
#
# Page 1380
# SUBROUTINE NAME: CALCTPER / CALCTFF      DATE: 01.29.67
# MOD NO: 0                                LOG SECTION: TIME OF FREE FALL
# MOD BY: RR BAIRNSFATHER
# MOD NO: 1 MOD BY: RR BAIRNSFATHER        DATE: 21 MAR 67
# MOD NO: 2 MOD BY: RR BAIRNSFATHER        DATE: 14 APR 67
# MOD BY: 3 MOD BY: RR BAIRNSFATHER        DATE: 8 JUL 67 NEAR EARTH MO
# MOD BY: 4 MOD BY: RR BAIRNSFATHER        DATE: 21 NOV 67 ADD VARIABLE
# MOD BY: 5 MOD BY: RR BAIRNSFATHER        DATE: 21 MAR 68 ACCEPT DIFFER
#
# FUNCTIONAL DESCRIPTION: PROGRAM CALCULATES THE FREE-FALL TIME OF FLIGHT FROM PRES
# VELOCITY VN TO A RADIUS LENGTH SPECIFIED BY RTERM, SUPPLIED BY THE USER. THE
# RN MAY BE ON EITHER SIDE OF THE CONIC, BUT RTERM IS CONSIDERED ON THE INBOUND
# THE EQUATIONS ARE:
#
# Q2 = -SQRT(RTERM (2-RTERM ALFA) - LCP) (INBOUND SIDE) LEQ +- LCE/SO
#

```

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```
#          Q1 = RN.VN / SQRT(MU)                                LEQ +- LCE/SQRT(ALFA)
#
#          Z = NUM / DEN  LEQ +- 1/SQRT(ALFA)
#
# WHERE, IF INBOUND
#          NUM = RTERM -RN   LEQ +- 2 LCE/ALFA
#          DEN = Q2+Q1   LEQ +- 2 LCE/SQRT(ALFA)
#
# AND, IF OUTBOUND
#          NUM = Q2-Q1   LEQ +- 2 LCE/SQRT(ALFA)
#          DEN = 2 - ALFA (RTERM + RN).                          LEQ +- 2 LCE
#
# IF      ALFA ZZ < 1.0              (FOR ALL CONICS EXCEPT ELLIPSES HAVING ABS(DEL ECC ANOM
# THEN    X = ALFA Z Z
# AND     TFF = (RTERM +RN -2 ZZ T(X) ) Z/SQRT(MU)
#         EXCEPT IF ALFA PNZ, AND IF TFF NEG,
#         THEN     TFF = 2 PI /(ALFA SQRT(ALFA)) + TFF
# OR      IF ALFA ZZ GEQ 1.0        (FOR ELLIPSES HAVING ABS(DEL ECC ANOM) GEQ 90 DEG)
# THEN    X = 1/ALFA Z Z
# AND     TFF = (PI/SQRT(ALFA) -Q2 +Q1 +2(X T(X) -1) /ALFA Z) /ALFA SQRT(MU)
# WHERE   T(X) IS A POLYNOMIAL APPROXIMATION TO THE SERIES
#               2       3           2
#             1/3 - X/5 + X /7 - X /8 ...      (X < 1.0)
#
# CALLING SEQUENC:      TIME TO RTERM                TIME TO PERIGEE
#                       CALL                        CALL
#
#                       CALCTFF                      CALCTPER
#
#                       C(MPAC) = TERMNL RAD M        C(MPAC) = PERIGEE RAD M
#
# FOR EITHER, E:(-29) M:(-27)
# FOR EITHER, PUSHLOC = PDL+0, ARBITRARY IF LEQ 8D.
# Page 1381
#
# SUBROUTINES CALLED:   T(X), VIA RTB
#
# NORMAL EXIT MODE:     RVQ
#
# HOWEVER, PROGRAM EXITS WITH ONE OF THE FOLLOWING VALUES FOR TFF (-28) CS IN MPAC. USER
# A. TFF = FLIGHT TIME.  NORMAL CASE FOR POSITIVE FLIGHT TIME LESS THAN ONE ORBIT
# B. (THIS OPTION IS NO LONGER USED.)
# C. TFF = POSMAX. THIS INDICATES THAT THE CONIC FROM THE PRESENT POSITION WILL
#    THE SPECIFIED ALTITUDE. ALSO INDICATES OUTBOUND PARABOLA OR HYPERBOLA.
#
# OUTPUT:      C(MPAC)      (-28) CS      TIME OF FLIGHT, OR TIME TO PERIGEE
#              TFFX        (0)            X,                               LEFT FO
#              NRTERM      E:(-29+NR) M    RTERM, WEIGHTED BY NR          LEFT FO
#                                  M:(-27+NR)
#              TFFTTEM     E:(-59+2NR)     LCP Z Z SGN(SDELF)            LEFT FO
```

```

#                                     M:(-55+2NR)      LCP /ALFA SGN(SDELF)
# NOTE:   TFFTEM = PDL 36D AND WILL BE DESTROYED BY .:UNIT:.
# RMAG1      E:(-29) M:(-27) PDL 12 NOT TOUCHED.
# TFFQ1      E:(-16) M:(-15) PDL 14D
# TFFDELQ    E:(-16) M:(-15) PDL 10D
# PUSHLOC AT PDL+0
#
# ERASABLE INITIALIZATION REQUIRED:
# RONE      E:(-29) M:(-27) M STATE VECTOR
# VONE'     E:(+10) M:(+9)  VN/SQRT(NU)
# RMAG1     E:(-29) M:(-27) PRESENT RADIUS, M
# C(MPAC)   E:(-29) M:(-27) RTERM, TERMINAL RADIUS LENGTH, M
#
# THE FOLLOWING ARE STORED IN THE PUSH LIST AREA.
# TFF/RTMU  E:(17) M:(14)  1/SQRT(MU)
# NRMAG     E:(-29+NR)      M RMAG, NORMALIZED
#           M:(-27+NR)
# X1        -NR, NORM COUNT
# TFFNP     E:(-38+2NR)     M LCP, SEMI LATUS RECTUM, WEIGHT NR
#           M:(-36+2N4)
# TFFALFA   E:(26-NR)      1/M ALFA, WEIGHT NR
#           M:(24-NR)
# TFFRTALF  E:(10+NA)      SQRT(ALFA), NORMALIZED
#           M:(9+NA)
# X2        -NA, NORM COUNT
# TFF1/ALF  E:(-22-2NA)    SIGNED SEMIMAJ AXIS, WEIGHTED BY NA
#           M:(-20-2NA)
#
# DEBRIS:   QPRET, PDL+0 ... PDL+3
# RTERM     E:(-29) M(-27)  RTERM, TERMINAL RADIUS LENGTH
# RAPO      E:(-29) M(-27)  PDL 16D (=NRTERM)
# RPER      E:(-29) M(-27)  PDL 14D (=TFFQ1)
#
# Page 1382
CALCTPER    SETGO          # ENTER WITH RPER IN MPAC
              TFFSW
              +3
CALCTFF     CLEAR          # ENTER WITH RTERM IN MPAC
              TFFSW
              +3 STORE     RTERM      # E:(-29) M:(-27)
              SL*
              0,1          # X1=-NR
              STORE      NRTERM      # RTERM E:(-29+NR) M:(-27+NR)
              DMP        BDSU
              TFFALFA     # ALFA E:(26-NR) M:(24-NR)
              TFF1/4

```

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```

PUSH    DMP                # (2-ALFA RTERM) (-3) TO PDL+0
        NRTERM            # E: (-29+NR) M: (-27+NR)
PDDL    SR*                # RTERM(2-ALFA RTERM) TO PDL+2
        SR*                # E: (-32+NR) M: (-30+NR)
        TFFNP             # LC P E: (-38+2NR) M: (-36+2NR)
        0 -6,1            # X1 = -NR
DCOMP   DAD                # DUE TO SHIFTS, KEEP PRECISION FOR SQRT
        DAD                # RTERM(2-ALFA RTERM) FROM PDL +2
        SR*                # E: (-32+NR) M: (-30+NR)
        SR*                # LEAVE E: (-32) M: (-30)
        0,1                # X1 = -NR
BOFF    DLOAD              # CHECK TFF /TPER SWITCH
        TFFSW
        +2                # IF TFF, CONTINUE
        TFFZEROS          # IF TPER, SET Q2 = 0
+2      BMN                # E: (-16) M: (-15)
        SQRT              # NO FREE FALL CONIC TO RTERM FROM HERE
        MAXTFF1           # RESET PDL, SET TFF=POSMAX, AND EXIT.

DCOMP   BOVB               # RT IS ON INBOUND SIDE. ASSURE OVFIN=0
        TCDANZIG          # ANY PORT IN A STORM.
STOVL   TFFTEM             # Q2 E: (-16) M: (-15)
        VONE'             # VN/SQRT(MU) E: (10) M: (9)
DOT     SL3                # SAVED RN. E: (-29) M: (-27)
        RONE              # Q1, SAVE FOR GONEPAST TEST.
STORE   TFFQ1              # E: (-16) M: (-15)

BMN     BDSU               # USE ALTERNATE Z
        INBOUND           # Q2 E: (-16) M: (-15)
        TFFTEM

# OUTBOUND Z CALC CONTINUES HERE

STODL   TFFX               # NUM=Q2-Q1 E: (-16) M: (-15)
        TFFALFA           # ALFA E: (26-NR) M: (24-NR)
DMP     BDSU

# Page 1383

        NRMAG             # RMAG E: (-29+NR) M: (-27+NR)
        (2-RTERM ALFA)    # (2-RTERM ALFA) (-3) FROM PDL+0
SAVEDEN PUSH ABS           # DEN TO PDL+0 E: (-3) OR (-16)
        M: (-3) OR (-15)
        DAD BOV           # INDETERMINANCY TEST
        LIM(-22)          # =1.0-B(-22)
        TFFXTEST          # GO IF DEN >= B(-22)
DLOAD   PDDL              # SET DEN=0 OTHERWISE
        TFFZEROS
```

```

                                # XCH ZERO WITH PDL+0
                                # ALFA  E:(26-NR) M:(24-NR)
                                # FOR TPER:  Z INDET AT DELE/2=0 AND 90.
                                # ASSUME 90, AND LEAVE 0 IN PDL: 1/Z=D/N

                                # Z INDET. AT PERIGEE FOR PARAB OR HYPERB.
                                # RETURN TFF =0

DUMPTFF1      RVQ

# INBOUND Z CALC CONTINUES HERE

INBOUND      DLOAD      DCOMP      # RESET PDL+0
              DLOAD      DSU        # ALTERNATE Z CALC
              RTERM      # E:(-29) M:(-27)
              RMAG1      # E:(-29) M:(-27)
              STODL      TFFX      # NUM=RTERM-RN  E:(-29) M:(-27)
              TFFTEM      # Q2  E:(-16) M:(-15)
              DAD        GOTO
              TFFQ1      # Q1  E:(-16) M:(-15)
              SAVEDEN    # DEN = Q2+Q1  E:(-16) M:(-15)

TFFXTEST      DAD        PDDL      # (ABS(DEN) TO PDL+2)  E:(-3) OR (-16)
              DP(-22)      # M:(-3) OR (-15)
              TFFX      # RESTORE ABS(DEN) TO MPAC
              SR*          # NUM  E:(-16) OR (-29)  M:(-15) OR (-27)
              TFFRTALF    # SQRT(ALFA)  E:(10+NA) M:(9+NA)
              0 -3,2      # X2=-NA
              DDV          # C(MPAC) =NUM SQRT(ALFA)      E:(-3) OR (-16)
              # M:(-3) OR (-15)
              # ABS(DEN) FROM PDL+2  E:(-3) OR (-16)
              # M:(-3) OR (-15)
              DLOAD      BOV      # (THE DLOAD IS SHARED WITH TFFELL)
              TFFX      # NUM  E:(-16) OR (-29)  M:(-15) OR (-27)
              TFFELL      # USE EQN FOR DELE GEQ 90, LEQ -90

# OTHERWISE, CONTINUE FOR GENERAL CONIC FOR TFF EQN

              DDV      STADR      # DEN FROM PDL+0      E:(-3) OR (-16)
              # M:(-3) OR (-15)
              STORE      TFFTEM    # Z SAVE FOR SIGN OF SDELF.

# Page 1384
              # E:(-13) M:(-12)
              PUSH      DSQ      # Z TO PDL+0
              PUSH      DMP      # Z SQ TO PDL+2  E:(-26) M:(-24)

```

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```

      TFFNP      # LC P  E:(-38+2NR) M:(-36+NR)
SL      SIGN
      5
      TFFTEM      # AFFIX SIGN FOR SDELF (ENTRY DISPLAY)
STODL    TFFTEM      # P ZSQ  E:(-59+2NR) M:(-55+2NR)
      # (ARG IS USED IN TFF/TRIG)
      # ZSQ FROM PDL+2  E:(-26) M:(-24)
PUSH     DMP      # RESTORE PUSH LOC
      TFFALFA      # ALFA  E:(26-NR) M:(24-NR)
SL*
      0,1      # X1=-NR
STORE    TFFX      # X
RTB      DMP
      T(X)      # POLY
      # ZSQ FROM PDL+2  E:(-26) M:(-24)
SR2      BDSU      # 2 ZSQ T(X)  E:(-29) M:(-27)
      RTERM      # RTERM  E:(-29) M:(-27)
DAD      DMP
      RMAG1      # E:(-29) M:(-27)
      # Z FROM PDL+0  E:(-13) M:(-12)
SR3      BPL      # TFF SQRT(MU)  E:(-45) M:(-42)
      ENDTFF      # (NO PUSH UP)
PUSH     SIGN      # TFF SQRT(MU) TO PDL+0
      TFFQ1      # Q1 FOR GONEPAST TEST
BPL      DLOAD      # GONE PAST ?
      NEGTTFF      # YES. TFF < 0.
      TFF1/ALF      # 1/ALFA  E:(-22-2NA) M:(-20-2NA)
DCOMP    BPL      # ALFA > 0 ?
      NEGTTFF      # NO. TFF IS NEGATIVE.

# CORRECT FOR ORBITAL PERIOD.

DCOMP      # YES.  CORRECT FOR ORB PERIOD.
DMP      DDV
      PI/16      # 2 PI (-5)
      TFFRTALF      # SQRT(ALFA)  E:(10+NA) M:(9+NA)
SL*      SL*
      0 -4,2      # X2=-NA
      0 -4,2
SL*      DAD
      0,2
      # TFF SQRT(MU) FROM PDL+0      E:(-45) M:(-42)
ENDTFF    DMP      BOV      # TFF SQRT(MU) IN MPAC      E:(-45) M:(-42)
      TFF/RTMU      # E:(17) M:(14)
      MAXTFF      # SET POSMAX IN OVFL.
```

```

DUMPTFF2      RVQ      # RETURN TFF (-28) CS IN MPAC.

# Page 1385
NEGTTFF      DLOAD
              GOTO      # TFF SQRT(MU) FROM PDL+0, NEGATIVE.
              ENDTFF

MAXTFF1      DLOAD      # RESET PDL
MAXTFF      DLOAD      RVQ
              NEARONE

# TIME OF FLIGHT ELLIPSE WHEN DEL (ECCENTRIC ANOM) GEQ 90 AND LEQ -90.

              # NUM FROM TFFX.      E: (-16) OR (-29)
              #                      M: (-15) OR (-27)
TFFELL      SL2      # NUM E: (-14) OR (-27) M: (-13) OR (-25)
              BDDV    PUSH      # TEMP SAVE D/N IN PDL+0
              # DEN FROM PDL+0 E: (-3)/(-16) M: (-3)/(-15)
              # N/D TO PDL+0 E: (11) M: (10)
TFFEL1      DLOAD    DSU      # (ENTER WITH D/N=0 IN PDL+0)
              TFFTEM    # Q2 E: (-16) M: (-15)
              TFFQ1     # Q1 E: (-16) M: (-15)
              STODL     TFFDELQ # Q2-Q1 E: (-16) M: (-15)
              # D/N FROM PDL+0

              STADR
              STORE    TFFTEM    # D/N E: (11) M: (10)
              DMP      SL*
              TFF1/ALF    # 1/ALFA E: (-22-2NA) M: (-20-2NA)
              0,2        # 1/ALFA Z E: (-11-NA) M: (-10-NA)
              PUSH      DMP      # TO PDL+0
              TFFTEM    # 1/Z E: (11) M: (10)
              SL*      BOVB
              0,2        # X2= -NA
              SIGNMPAC   # IN CASE X= 1.0, CONTINUE
              STORE     TFFX      # X=1/ALFA ZSQ
              RTB       DMP
              T(X)      # POLY
              TFFX
              SR3      DSU
              DP2(-3)
              DMP      PUSH      # 2(X T(X)-1) /Z ALFA E: (-15-NA)
              #                      M: (-14-NA)
              # 1/ALFA Z FROM PDL+0 E: (-11-NA)
              #                      M: (-10-NA)
              DLOAD     DMP      # GET SIGN FOR SDELF

```



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```
# Page 1386
          TFFTEM          # 1/Z  E:(11) M:(10)
          RMAG1           # E:(-29) M:(-27)
SL2      DAD
          TFFQ1           # Q1  E:(-16) M:(-15)
STODL    TFFTEM          # (Q1+R 1/Z) =SGN OF SDELF  E:(-16) M:(-15)
          TFFNP           # LC P  E:(-38+2NR) M:(-36+2NR)
DMP      SL*             # CALC FOR ARG FOR TFF/TRIG.

          TFF1/ALF        # 1/ALFA  E:(-22-2NA) M:(-20-2NA)
          1,2             # X2=-NA
SIGN     SL*
          TFFTEM          # AFFIX SIGN FOR SDELF
          0,2
STODL    TFFTEM          # P/ALFA  E:(-59+2NR) M:(-55+2NR)
          TFF1/ALF        # (ARG FOR USE IN TFF/TRIG)
          DMP             # 1/ALFA  E:(-22-2NA) M:(-20-2NA)
SQRT     PI/16           # PI  (-4)
DAD
          # 2(XT(X)-1)/Z ALFA FROM PDL      E:(-15-NA)
          #                                     M:(-14-NA)
SL*      DSU
          0 -1,2
          TFFDELQ         # Q2-Q1  E:(-16) M:(-15)
DMP      SL*
          TFF1/ALF        # 1/ALFA  E:(-22-2NA) M:(-20-2NA)
          0 -3,2
SL*      GOTO
          0 -4,2
          ENDTFF         # TFF SQRT(MU) IN MPAC E:(-145) M:(-42)
```

# Page 1387

# PROGRAM NAME: T(X)

DATE: 01.17.67

# MOD NO: 0

LOG SECTION: TIME OF FREE FALL

# MOD BY: RR BAIRNSFATHER

#

# FUNCTIONAL DESCRIPTION: THE POLYNOMIAL T(X) IS USED BY TIME OF FLIGHT SUBROUTINES CALCTFF AND

# CALCTPER TO APPROXIMATE THE SERIES

```
#          2      3
#          1/3 -X/5 +X /7 -X /9 ...
```

#

```
#      WHERE  X = ALFA Z Z          IF ALFA Z Z LEQ 1
#             X = 1/(ALFA Z Z)      IF ALFA Z Z G 1
```

#

# ALSO X IS NEG FOR HYPERBOLIC ORBITS

# X = 0 FOR PARABOLIC ORBITS

```

#           X IS POSITIVE FOR ELLIPTIC ORBITS
#
#   FOR FLIGHT 278, THE POLYNOMIAL T(X) IS FITTED OVER THE RANGE (0,+1) AND HAS A
#   DEVIATION FROM THE SERIES OF 2 E-5. (T(X) IS A CHEBYCHEV TYPE FIT AND WAS ON
#   MAC PROGRAM AUTCURFIT294RRB AND IS VALID TO THE SAME TOLERANCE OVER THE RANGE
#
# CALLING SEQUENCE:      RTB
#                       T(X)
#   C(MPAC) = X
#
# SUBROUTINE CALLED:  NONE
#
# NORMAL EXIT MODE:  TC DANZIG
#
# ALARMS:  NONE
#
# OUTPUT:  C(MPAC) = T(X)
#
# ERASABLE INITIALIZATION REQUIRED:
#   C(MPAC) = X
#
# DEBRIS:  NONE

T(X)          TC      POLY
              DEC      4          # N-1
              2DEC      3.333333333 E-1
              2DEC*     -1.999819135 E-1*
              2DEC*     1.418148467 E-1*
              2DEC*     -1.01310997 E-1*
              2DEC*     5.609004986 E-2*
              2DEC*     -1.536156925 E-2*

ENDT(X)        TC      DANZIG

TCDANZIG       =      ENDT(X)

# Page 1388
# TFF CONSTANTS

              BANK      32

              SETLOC    TOF-FF1
              BANK

#
#MUE           =      3.990815471 E10          # NOTE _ NOTE _ ADJUSTED MUE FOR NE
# M CUBE/CS SQ

```

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|          |        |                      |                                                |
|----------|--------|----------------------|------------------------------------------------|
| #RTMUE   | =      | 1.997702549 E5 B-18* | # MODIFIED EARTH MU                            |
| 1/RTMU   | 2DEC*  | .5005750271 E-5 B17* | # MODIFIED EARTH MU                            |
| #        |        |                      | # NOTE _ NOTE _ ADJUSTED MUE FOR NEAR EARTH TR |
| #MUM     | =      | 4.902778 E8          | # M CUBE/CS SQ                                 |
| #RTMUM   | 2DEC*  | 2.21422176 E4 B-18*  |                                                |
| PI/16    | 2DEC   | 3.141592653 B-4      |                                                |
| LIM(-22) | 20CT   | 3777737700           | # 1.0 -B(-22)                                  |
| DP(-22)  | 20CT   | 0000000100           | # B(-22)                                       |
| DP2(-3)  | 2DEC   | 1 B-3                |                                                |
| DP2(-4)  | 2DEC   | 1 B-4                | # 1/16                                         |
| # RPAD1  | 2DEC   | 6373338 B-29         | # M (-29) = 20909901.57 FT                     |
| RPAD1    | =      | RPAD                 |                                                |
| R300K    | 2DEC   | 6464778 B-29         | # (-29) M                                      |
| NEARONE  | 2DEC   | .999999999           |                                                |
| TFFZEROS | EQUALS | HI6ZEROS             |                                                |
| TFF1/4   | EQUALS | HIDP1/4              |                                                |

This code is written to file src/TIME-OF-FREE-FALL.s.

## A.115 TJET LAW

1844  $\langle \text{src}/\text{TJET-LAW.s } 1844 \rangle \equiv$ 

```

# Copyright:      Public domain.
# Filename:       TJET_LAW.agc
# Purpose:        Part of the source code for Luminary 1A build 099.
#                It is part of the source code for the Lunar Module's (LM)
#                Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:     yaYUL
# Contact:        Ron Burkey <info@sandroid.org>.
# Website:        www.ibiblio.org/apollo.
# Pages:          1460-1469
# Mod history:    2009-05-27 RSB   Adapted from the corresponding
#                Luminary131 file, using page
#                images from Luminary 1A.
#                2009-06-06 RSB   Eliminated a stray instruction that had crept
#                in somehow.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
# Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
# 16:27 JULY 14, 1969
#
# Page 1460
# PROGRAM DESCRIPTION
# DESIGNED BY:   R. D. GOSS AND P. S. WEISSMAN
# CODED BY:      P. S. WEISSMAN, 28 FEBRUARY 1968
#
# TJETLAW IS CALLED AS A SUBROUTINE WHEN THE LEM IS NOT DOCKED AND THE AUTOPILOT IS IN
# ATTITUDE-HOLD MODE TO CALCULATE THE JET-FIRING-TIME (TJET) REQUIRED FOR THE AXIS IN
#
#      -1      INDICATES THE P-AXIS
#      +0      INDICATES THE U-AXIS
#      +1      INDICATES THE V-AXIS
#
# THE REGISTERS E AND EDOT CONTAIN THE APPROPRIATE ATTITUDE ERROR AND ERROR RATE AND
# UNBALANCED COUPLES ARE PREFERRED. TJETLAW ALSO USES VARIOUS FUNCTIONS OF ACCELERATION
# COMPUTED IN THE 1/ACCONT SECTION OF 1/ACCS AND ARE STORED IN SUCH AN ORDER THAT THE

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```
# ACCESSED BY INDEXING.
#
# THE SIGN OF THE REQUIRED ROTATION IS CARRIED THROUGH TJETLAW AS ROTSENSE AND IS FINALLY APPLIED
# PREVIOUS TO ITS STORAGE IN THE LOCATION CORRESPONDING TO THE AXIS (TJP, TJU, OR TJV). THE NUMBER
# TJETLAW ASSUMES WILL BE USED AS INDICATED BY THE SETTING OF NUMBERT FOR THE U- OR V-AXIS. TWO
# ASSUMED FOR THE P-AXIS ALTHOUGH FOUR JETS WILL BE FIRED WHEN FIREFCT IS MORE NEGATIVE THAN -4
# (FIREFCT IS THE DISTANCE TO A SWITCH CURVE IN THE PHASE PLANE) AND A LONG FIRING IS CALLED FOUR
#
# IN ORDER TO AVOID SCALING DIFFICULTIES, SIMPLE ALGORITHMS TAGGED RUFLAW1, -2 AND -3 ARE RESORTED TO
# ERROR AND/OR ERROR RATE ARE LARGE.
#
# CALLING SEQUENCE:
#          TC          TJETLAW          # (MUST BE IN JASK)
#          OR
#          INHINT          # (MUST BE IN JASK)
#          TC          IBNKCALL
#          CADR          TJETLAW
#          RELINT
#
# EXIT:          RETURN TO Q.
#
# INPUT:
#          FROM THE CALLER:  E, EDOT, AXISCTR, SENSETYP, TJP, -U, -V.
#          FROM 1/ACCONT:  48 ERASABLES BEGINNING AT BLOCKTOP (INCLUDING FLAT, ZONE3LIM AND ACCSWITCH)
#
# OUTPUT:
#          TJP, -U OR -V, NUMBERT (DAPTEMP5), FIREFCT (DAPTEMP3).
#
# DEBRIS:
#          A, L, Q, E, EDOT, DAPTEMP1-6, DAPTEMP1-4.
#
# ALARM:  NONE

          BANK      17
          SETLOC    DAPS2
          BANK
          EBANK=    TJP

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          COUNT*    $$/DAPTJ

TJETLAW          EXTEND          # SAVE Q FOR RETURN.
          QXCH      HOLDQ

# SET INDEXERS TO CORRESPOND TO THE AXIS AND TO THE SIGN OF EDOT

          INDEX     AXISCTR          # AXISDIFF(-1)=NO OF LOCATIONS BET P AND U
```

```

CAF      AXISDIFF      # AXISDIFF(0)=0
TS       ADRSDIF1      # AXISDIFF(+1)=NO OF LOCATIONS BET V AND U

CAE      EDOT          # IF EDOT NEGATIVE, PICK UP SET OF VALUES
EXTEND                      # THAT ALLOW USE OF SAME CODING AS FOR
BZMF     NEGEDOT        # POSITIVE EDOT.
CAE      ADRSDIF1      # SET A SECOND INDEXER WHICH MAY BE
TS       ADRSDIF2      # MODIFIED BY A DECISION FOR MAX JETS.
CAF      SENSOR        # FOR POSITIVE EDOT, ROTSENSE IS
TCF      SETSENSE      # INITIALIZED POSITIVE.

NEGEDOT  CS      E      # IN ORDER FOR NEG EDOT CASE TO USE CODING
TS       E              # OF POS EDOT, MUST MODIFY AS FOLLOWS:
CS       EDOT          # 1. COMPLEMENT E AND EDOT.
TS       EDOT          # 2. SET SENSE OF ROTATION TO NEGATIVE
CAF      BIT1          # (REVERSED LATER IF NECESSARY).
ADS      ADRSDIF1      # 3. INCREMENT INDEXERS BY ONE SO THAT
TS       ADRSDIF2      # THE PROPER PARAMETERS ARE ACCESE
CS       SENSOR
SETSENSE TS      ROTSENSE

# TEST MAGNITUDE OF E (ATTITUDE ERROR, SINGLE-PRECISION, SCALED AT PI RADIANS):
# IF GREATER THAN (OR EQUAL TO) PI/16 RADIANS, GO TO THE SIMPLIFIED TJET ROUTIN
# IF LESS THAN PI/16 RADIANS, RESCALE TO PI/4

CAE      E              # PICK UP ATTITUDE ERROR FOR THIS AXIS
EXTEND
MP       BIT5           # SHIFT RIGHT TEN BITS: IF A-REGISTER IS
CCS      A              # ZERO, RESCALE AND TEST EDOT.
TCF      RUFLAW2
TCF      SCALEE
TCF      RUFLAW1
SCALEE   CAF      BIT13 # ERROR IS IN L SCALED AT PI/16. RESCALE
EXTEND                      # IT TO PI/4 AND SAVE IT.
MP       L
TS       E

# TEST MAGNITUDE OF EDOT (ERROR RATE SCALED AT PI/4 RADIANS/SECOND)
# IF GREATER THAN (OR EQUAL TO) PI/32 RADIANS/SECOND, GO TO THE SIMPLIFIED TJET
# IF LESS THAN PI/32 RADIANS/SECOND, THEN RESCALE TO PI/32 RADIANS/SECOND.

CAE      EDOT          # PICK UP SINGLE-PRECISION ERROR-RATE
# Page 1462
EXTEND                      # FOR THIS AXIS=
MP       BIT4          # SHIFT RIGHT ELEVEN BITS, IF THE A-REG IS
EXTEND                      # ZERO, THEN RESCALE AND USE FINELAW.

```

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BZF SCALEDOT  
TCF RUFLAW3

# \*\*\* FINELAW STARTS HERE \*\*\*

|          |        |          |                                             |
|----------|--------|----------|---------------------------------------------|
| SCALEDOT | LXCH   | EDOT     | # EDOT IS SCALED AT PI/32 RADIANS/SECOND.   |
|          | CAE    | EDOT     | # COMPUTE (EDOT)(EDOT)                      |
|          | EXTEND |          |                                             |
|          | SQUARE |          | # PRODUCT SCALED AT PI(2)/2(10) RAD/SEC.    |
|          | EXTEND |          |                                             |
|          | MP     | BIT13    | # SHIFT RIGHT TWO BITS TO RESCALE TO EDOTSQ |
|          | TS     | EDOTSQ   | # TO PI(2)/2(8) RAD(2)/SEC(2).              |
| ERRTEST  | CCS    | E        | # DOES BIG ERROR (THREE DEG BEYOND THE      |
|          | AD     | -3DEG    | # DEADBAND) REQUIRE MAXIMUM JETS?           |
|          | TCF    | +2       |                                             |
|          | AD     | -3DEG    |                                             |
|          | EXTEND |          |                                             |
|          | INDEX  | ADRSDIF1 |                                             |
|          | SU     | FIREDB   |                                             |
|          | EXTEND |          |                                             |
|          | BZMF   | SENSTEST | # IF NOT: ARE UNBALANCED JETS PREFERRED?    |
| MAXJETS  | CAF    | TWO      | # IF YES: INCRMENT ADDRESS LOCATOR AND      |
|          | ADS    | ADRSDIF2 | # SET SWITCH FOR JET SELECT LOGIC TO 4.     |
|          | CAF    | FOUR     | # (ALWAYS DO THIS FOR P-AXIS)               |
|          | TCF    | TJCALC   |                                             |
| SENSTEST | CCS    | SENSETYP | # DOES TRANSLATION PREFER MIN JETS.         |
|          | TCF    | TJCALC   | # YES. USE MIN-JET PARAMETERS               |
|          | TCF    | MAXJETS  | # NO. GET THE MAX-JET PARAMETERS.           |
| TJCALC   | TS     | NUMBERT  | # SET TO +0,1,4 FOR (U,V-AXES) JET SELECT.  |

# BEGINNING OF TJET CALCULATIONS:

|        |          |                                           |
|--------|----------|-------------------------------------------|
| CS     | EDOTSQ   | # SCALED AT PI(2)/2(8).                   |
| EXTEND |          |                                           |
| INDEX  | ADRSDIF2 |                                           |
| MP     | 1/ANET1  | # .5/ACC SCALED AT 2(6)/PI SEC(2)/RADIAN. |
| INDEX  | ADRSDIF1 |                                           |
| AD     | FIREDB   | # DEADBAND SCALED AT PI/4 RADIAN.         |
| EXTEND |          |                                           |
| SU     | E        | # ATTITUDE ERROR SCALED AT PI/4 RADIAN.   |
| TS     | FIREFCT  | # -E-.5(EDOTSQ)/ACC-DB AT PI/4 RADIAN.    |
| EXTEND |          |                                           |
| BZMF   | ZON1,2,3 |                                           |

```

ZONE4,5      INDEX  ADRSDIF1
              CAE    1/ACOAST      # .5/ACC SCALED AT 2(6)/PI WHERE

# Page 1463

              EXTEND
              MP      EDOTSQ        # ACC = MAX(AMIN, AOS-).
              AD      E             # SCALED AT PI/2(8).
              INDEX  ADRSDIF1      # SCALED AT PI/4
              AD      COASTDB       # SCALED AT PI/4 POS. FOR NEG. INTERCEPT.
              EXTEND
              BZMF    ZONE5         # TEST E+.5(EDOTSQ)/ACC+DB AT PI/4 RADIAN.
                                   # IF FUNCTION NEGATIVE, FIND TJET.
                                   # IF FUNCTION POSITIVE, IN ZONE 4.

# ZONE 4 IS THE COAST REGION.  HOWEVER, IF THE JETS ARE ON AND DRIVING TOWARD
#     A. THE AXIS WITHIN + OR - (DB + FLAT) FOR DRIFTING FLIGHT, OR
#     B. THE USUAL TARGET PARABOLA FOR POWERED FLIGHT
# THEN THE THRUSTERS ARE KEPT ON.

ZONE4         INDEX  AXISCTR      # IS THE CURRENT VALUE IN TJET NON-ZERO
              CS      TJETU        #     WITH SENSE OPPOSITE TO EDOT,
              EXTEND
              MP      ROTSENSE     #     (I.E., ARE JETS ON AND FIRING TOWARD
              EXTEND
              BZMF    COASTTJ      #     THE DESIRABLE STATE).

              # NO.  COAST.

JETSON        CCS      FLAT        # YES.  IS THIS DRIFTING OR POWERED FLIGHT?
              TCF      DRIFT/ON    # DRIFTING.  GO MAKE FURTHER TEST.

              CS      FIREFCT      # POWERED (OR ULLAGE).  CAN TARGET PARABOLA
              INDEX  ADRSDIF1      #     BE REACHED FROM THIS POINT IN THE
              AD      AXISDIST     #     PHASE PLANE?
              EXTEND
              BZMF    COASTTJ      # NO.  SET TJET = 0.
              TC      Z123COMP     # YES.  CALCULATE TJET AS THOUGH IN ZONE 1
              CAE      FIREFCT     #     AFTER COMPUTING THE REQUIRED
              TCF      ZONE1       #     PARAMETERS.

DRIFT/ON      INDEX  ADRSDIF1      # CAN TARGET STRIP OF AXIS BE REACHED FROM
              CS      FIREDDB      #     THIS POINT IN THE PHASE PLANE?
              DOUBLE
              AD      FIREFCT
              EXTEND
              BZMF    +3
              COASTTJ  CAF      ZERO      # NO.  SET TJET = 0.
              TCF      RETURN TJ
              TC      Z123COMP     # YES.  CALCULATE TJET AS THOUGH IN ZONE 2

```



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```

                                TCF      ZONE2,3      #      OR 3 AFTER COMPUTING REQUIRED VALUES.

ZONE5                          TS      L              # TEMPORARILY STORE FUNCTION IN L.
                                CCS      ROTSENSE      # MODIFY ADRSDIF2 FOR ACCESSING 1/ANET2
                                TCF      +4              # AND ACCFCTZ5, WHICH MUST BE PICKED UP
                                TC      CSHOLE      # FROM THE NEXT LOWER REGISTER IF THE
                                CS      TWO              # (ACTUAL) ERROR RATE IS NEGATIVE.

# Page 1464

                                ADS      ADRSDIF2

                                +4      CAE      L
                                EXTEND
                                INDEX      ADRSDIF2      # TTOAXIS AND HH ARE THE PARAMETERS UPON
                                MP      ACCFCTZ5      # WHICH THE APPROXIMATIONS TO TJET ARE
                                DDOUBL      # ABASED.
                                DDOUBL
                                DXCH      HH              # DOUBLE PRECISION H SCALED AT 8 SEC(2).
                                INDEX      ADRSDIF2
                                CAE      1/ANET2      # SCALED AT 2(7)/PI SEC(2)/RAD.
                                EXTEND
                                MP      EDOT      # SCALED AT PI/2(5)
                                TS      TTOAXIS      # SCALED AT 4 SEC.

# TEST WHETHER TJET GREATER THAN 50 MSEC.

                                EXTEND
                                MP      -.05AT2      # H - .05 TTOAXIS - .00125 G.T. ZERO
                                AD      HH              # (SCALED AT 8 SEC(2) ).
                                AD      NEG2
                                EXTEND
                                BZMF      FORMULA1

# TEST WHETHER TJET GREATER THAN 150 MSEC.

                                CAE      TTOAXIS
                                EXTEND
                                MP      -.15AT2      # H - .15 TTOAXIS - .01125 G.T. ZERO
                                AD      HH              # (SCALED AT 8 SEC(2) )
                                AD      -.0112A8
                                EXTEND
                                BZMF      FORMULA2

# IF TJET GREATER THAN 150 MSEC, ASSIGN IT VALUE OF 250 MSEC, SINCE THIS
# IS ENOUGH TO ASSURE NO SKIP NEXT CSP (100 MSEC).

FULLTIME      CAF      BIT11      # 250 MSEC SCALED AT 4 SEC.
```

# RETURN TO CALLING PROGRAM WITH JET TIME SCALED AS TIME6 AND SIGNED.

```

RETURN TJ      EXTEND      # ALL BRANCHES TERMINATE HERE WITH TJET
                MP        ROTSENSE      # (SCALED AT 4 SEC) IN THE ACCUMULATOR.
                INDEX     AXISCTR      # ROTSENSE APPLIES SIGN AND CHANGES SCALE.
                TS        TJETU
                EXTEND
                INDEX     AXISCTR
                MP        ACCSWU      # SET SWITCH FOR JET SELECT IF ROTATION IS
                CAE       L
                EXTEND      # IN A SENSE FOR WHICH 1/ACCS HAS FORCE
                BZMF      +3          # A MAX-JET CALCULATION.
                CAF       FOUR
# Page 1465
                TS        NUMBERT
                TC        HOLDQ      # RETURN VIA SAVED Q.

```

# TJET = H/(.025 + TTOAXIS) FOR TJET LESS THAN 50 MSEC.

```

FORMULA1      CS        -.025AT4      # .025 SEC SCALED AT 4.
                AD        TTOAXIS      # SCALED AT 4 SECONDS.
                DXCH      HH          # STORE DENOMINATOR IN FIRST WORD OF H,
                EXTEND      # WHICH NEED NOT BE PRESERVED. PICK UP
                DV        HH          # DP H AND DIVIDE BY DENOMINATOR.
                EXTEND
                MP        BIT14      # RESCALE TJET FROM 2 TO USUAL 4 SEC.
                TCF       CHKMINTJ    # CHECK THAT TJET IS NOT LESS THAN MINIMUM

```

# TJET = (H + .00375)/(0.1 + TTOAXIS) FOR TJET GREATER THAN 50 MSEC.

```

FORMULA2      EXTEND
                DCA       .00375A8    # .00375 SEC(2) SCALED AT 8.
                DAS       HH          # STORE NUMERATOR IN DP H, WHICH NEED NOT
                #         BE PRESERVED.
                CAE       TTOAXIS      # SCALED AT 4 SEC.
                AD        .1AT4      # 0.1 SEC SCALED AT 4.
                DXCH      HH          # STORE DENOMINATOR IN FIRST WORD OF H,
                EXTEND      # WHICH NEED NOT BE PRESERVED. PICK UP
                DV        HH          # DP NUMERATOR AND DIVIDE BY DENOMINATOR
                EXTEND
                MP        BIT14      # RESCALE TJET FROM 2 TO USUAL 4 SEC.
                TCF       RETURN TJ    # END SUBROUTINE.

```

# SUBROUTINIZED COMPUTATIONS REQUIRED FOR ALL ENTRIES INTO CODING FOR ZONES 1, 2, AND 3  
# REACHED BY TC FROM 3 POINTS IN TJETLAW.

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```
Z123COMP      CS      ROTSENSE      # USED IN RETURN TJ SECTION TO RESCALE TJET
               TS      ROTSENSE      #           AS TIME6 AND GIVE IT PROPER SIGN.
               CAE      EDOT          # SCALED AT PI/2(5) RAD/SEC.
               EXTEND
               INDEX    ADRSDIF2
               MP        1/ANET1      # SCALED AT 2(7)/PI SEC(2)/RAD.
               TS        TTOAXIS      # STORE TIME-TO-AXIS SCALED AT 4 SECONDS.
               AD        -TJMAX
               EXTEND
               BZMF      +2            # IS TIME TO AXIS LESS THAN 150 MSEC.
               TCF       FULLTIME     # NO. FIRE JETS, DO NOT CALCULATE TJET.
               RETURN    # YES. GO ON TO FIND TJET

ZON1,2,3       TC        Z123COMP     # SUBROUTINIZED PREPARATION FOR ZONE1,2,3.

# IF THE (NEG) DISTANCE BEYOND PARABOLA IS LESS THAN FLAT, USE SPECIAL
# LOGIC TO ACQUIRE MINIMUM IMPULSE LIMIT CYCLE. DURING POWERED FLIGHT
# Page 1466
# OR ULLAGE, FLAT = 0

               CAE      FIREFCT      # SCALED AT PI/4 RAD.
               AD        FLAT
               EXTEND
               BZMF      ZONE1        # NOT IN SPECIAL ZONES.

# FIRE FOR AXIS OR, IF CLOSE, FIRE MINIMUM IMPULSE. IF ON AXIS, COAST.

ZONE2,3        CS        ZONE3LIM     # HEIGHT OF MIN-IMPULSE ZONE SET BY 1/ACCS
               AD        TTOAXIS      #           35 MSEC IN DRIFTING FLIGHT
               EXTEND      #           ZERO WHEN TRYING TO ENTER GTS CONTROL.
               BZMF      ZONE3
ZONE2           CAE      TTOAXIS      # FIRE TO AXIS.
               TCF       RETURN TJ
ZONE3          CCS      EDOT          # CHECK IF EDOT IS ZERO.
               CAF       BIT6         # FIRE A ONE-JET MINIMUM IMPULSE.
               TCF       RETURN TJ    # TJET = +0.
               TC        CSHOLE       # CANNOT BE BECAUSE NEG EDOT COMPLEMENTED.
               TCF       RETURN TJ    # TJET = +0.

ZONE1          EXTEND
               INDEX    ADRSDIF1
               SU        AXISDIST     # SCALED AT PI/4 RAD.
               EXTEND
               INDEX    ADRSDIF2
               MP        ACCFCTZ1     # SCALED AT 2(7)/PI SEC(2)/RAD.
```

```

                                DDOUBL
                                DDOUBL
                                DXCH    HH          # DOUBLE PRECISION H SCALED AT 8 SEC(2).

# TEST WHETHER TOTAL TIME REQUIRED GREATER THAN 150 MSEC:
#                                2                                2
#      IS .5(.150 - TTOAXIS) - H  NEGATIVE (SCALED AT 8 SECONDS )

                                CAE    TTOAXIS        # TTOAXIS SCALED AT 4 SECONDS.
                                AD      -TJMAX        # -.150 SECOND SCALED AT 4.
                                EXTEND
                                SQUARE
                                EXTEND
                                SU      HH          # HIGH WORD OF H SCALED AT 8 SEC(2).
                                EXTEND
                                BZMF    FULLTIME      # YES.  NEED NOT CALCULATE TJET.

# TEST WHETHER TIME BEYOND AXIS GREATER THAN 50 MSEC TO DETERMINE WHICH APPROXIMATION

                                CAE    HH
                                AD      NEG2
                                EXTEND
                                BZMF    FORMULA3

# Page 1467
# TJET = H/0.1 + TTOAXIS + .0375      FOR APPROXIMATION OVER MORE THAN 50 MSEC.

                                CAF      .1AT2        # STORE .1 SEC SCALED AT 2 FOR DIVISION.
                                DXCH    HH          # DP H SCALED AT 8 SEC(2) NEED NOT BE
                                EXTEND                # PRESERVED.
                                DV      HH          # QUOTIENT SCALED AT 4 SECONDS.
                                AD      TTOAXIS        # SCALED AT 4 SEC.
                                AD      .0375AT4      # .0375 SEC SCALED AT 4.
                                TCF      RETURN TJ      # END COMPUTATION.

# TJET - H/.025 + TTOAXIS      FOR APPROXIMATION OVER LESS THAN 50 MSEC.

FORMULA3    CS      -.025AT2        # STORE +.25 SEC SCALED AT 2 FOR DIVISION
            DXCH    HH          # PICK UP DP H AT 8, WHICH NEED NOT BE
            EXTEND                # PRESERVED.
            DV      HH          # QUOTIENT SCALED AT 4 SECONDS.
            AD      TTOAXIS        # SCALED AT 4 SEC.

# IF COMPUTED JET TIME IS LESS THAN TJMIN, TJET IS SET TO ZERO.
# MINIMUM IMPULSES REQUIRED IN ZONE 3 ARE NOT SUBJECT TO THIS CONSTRAINT, NATURALLY.

```

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```
CHKMINTJ      AD      -TJMIN      # IS COMPUTED TIME LESS THAN THE MINIMUM.
               EXTEND
               BZMF     COASTTJ      # YES, SET TIME TO ZERO.
               AD       TJMIN      # NO, RESTORE COMPUTED TIME.
               TCF      RETURN TJ    # END COMPUTATION.
```

# Page 1468

# \*\*\* ROUGHLAW \*\*\*

#

# BEFORE ENTRY TO RUFLAW:

# 1. INDEXERS ADRSDIF1 AND ADRSDIF2 ARE SET ON BASIS OF AXIS, AND SIGN OF EDOT.

# 2. IF EDOT WAS NEGATIVE, E AND EDOT ARE ROTATED INTO UPPER HALF-PLANE AND ROTSENSE IS M

# 3. E IS SCALED AT PI RADIANS AND EDOT AT PI/4 RAD/SEC.

# (EXCEPT THE RUFLAW3 ENTRY WHEN E IS AT PI/4)

#

# RUFLAW1: ERROR MORE NEGATIVE THAN PI/16 RAD. FIRE TO A RATE OF 6.5 DEG/SEC (IF JET TIME

# RUFLAW2: ERROR MORE POSITIVE THAN PI/16 RAD. FIRE TO AN OPPOSING RATE OF 6.5 DEG/SEC.

# RUFLAW3: ERROR RATE GREATER THAN PI/32 RAD/SEC AND ERROR WITHIN BOUNDS. COAST IF BELOW

```
RUFLAW1      CS      RUFRATE      # DECREMENT EDOT BY .1444 RAD/SEC AT PI/4
               ADS     EDOT        # WHICH IS THE TARGET RATE
               EXTEND
               BZMF     SMALRATE    # BRANCH IF RATE LESS THAN TARGET.
               TC       RUFSETUP    # REVERSE ROTSENSE AND INDICATE MAX JETS.
               CAE      EDOT        # PICK UP DESIRED RATE CHANGE.
```

```
RUFLAW12     EXTEND      # COMPUTE TJET
               INDEX     ADRSDIF2  # = (DESIRED RATE CHANGE)/(2-JET ACCEL.)
               MP        1/ANET1 +2
               AD        -1/8      # IF TJET, SCALED AT 32 SEC, EXCEEDS
               EXTEND      # 4 SECONDS, SET TJET TO TJMAX.
               BZMF      +2
               TCF       FULLTIME
               EXTEND
               BZF       FULLTIME
               AD        BIT12      # RESTORE COMPUTED TJET TO ACCUMULATOR
               DAS       A
               DAS       A
               DAS       A          # RESCALED TJET AT 4 SECONDS.
               TCF       CHKMINTJ   # RETURN AS FROM FINELAW.
```

```
SMALRATE     TC        RUFSETUP +2 # SET NUMBERT AND FIREFCT FOR MAXIMUM JETS
               CCS      ROTSENSE
               CAF       ONE        # MODIFY INDEXER TO POINT TO 1/ANET
               TCF      +2          # CORRESPONDING TO THE PROPER SENSE.
               CAF      NEGONE
```

```

                                ADS      ADRSDIF2

                                CS      EDOT      # (.144 AT PI/4 - EDOT) = DESIRED RATE CHNG.
                                TCF      RUFLAW12

RUFLAW2      TC      RUFSETUP      # REVERSE ROTSENSE AND INDICATE MAX JETS.
              CAF      RUFRATE
              AD      EDOT      # (.144 AT PI/4 + EDOT) = DESIRED RATE CHNG.
              TS      A      # IF OVERFLOW SKIP, FIRE FOR FULL TIME.
              TCF      RUFLAW12      # OTHERWISE, COMPUTE JET TIME.
              TCF      FULLTIME

# Page 1469
RUFLAW3      TC      RUFSETUP      # EXECUTE COMMON RUFLAW SUBROUTINE.
              INDEX    ADRSDIF1
              CS      FIREDDB      # CALCULATE DISTANCE FROM SWITCH CURVE
              AD      E      #      1/ANET1*EDOT*EDOT +E - FIREDDB = 0
              EXTEND      #      SCALED AT 4 PI RADIANS
              MP      BIT11
              XCH      EDOT
              EXTEND
              SQUARE
              EXTEND
              INDEX    ADRSDIF1
              MP      1/ANET1 +2
              AD      EDOT
              EXTEND
              BZMF      COASTTJ      # COAST IF BELOW IT.
              TCF      FULLTIME      # FIRE FOR FULL PERIOD IF ABOVE IT.

# SUBROUTINE USED IN ALL ENTRIES TO ROUGHLAW.

RUFSETUP      CS      ROTSENSE      # REVERSE ROTSENSE WHEN ENTER HERE.
              TS      ROTSENSE
              +2      CAF      FOUR      # REQUIRE MAXIMUM (2) JETS IN U,V-AXES.
              TS      NUMBERT
              CAF      NEGMAX      # SUGGEST MAXIMUM (4) JETS IN P-AXIS.
              TS      FIREFCT
              TC      Q

# CONSTANTS FOR TJETLAW

              DEC      -16      # AXISDIFF(INDEX) = NUMBER OF REGISTERS
AXISDIFF      DEC      +0      #      BETWEEN STORED 1/ACCS PARAMETERS FOR
              DEC      16      #      THE INDEXED AXIS AND THE U-AXIS.
SENSOR        OCT      14400      # RATIO OF TJET SCALING WITHIN TJETLAW

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|          |      |            |                                            |
|----------|------|------------|--------------------------------------------|
| -3DEG    | DEC  | -.06667    | # (4 SEC) TO SCALING FOR T6 (10.24 SEC).   |
| -.0112A8 | DEC  | -.00141    | # -3.0 DEGREES SCALED AT 45.               |
| .1AT4    | DEC  | .025       | # -.01125 SEC(2) SCALED AT 8.              |
| .1AT2    | DEC  | .05        | # 0.1 SECOND SCALED AT 4.                  |
| .0375AT4 | DEC  | .00938     | # .1 SEC SCALED AT 2.                      |
| -.025AT2 | DEC  | -.0125     | # .0375 SEC SCALED AT 4.                   |
| -.025AT4 | DEC  | -.00625    | # -.025 SEC SCALED AT 2.                   |
| -.05AT2  | DEC  | -.025      |                                            |
| -.15AT2  | DEC  | -.075      |                                            |
| .00375A8 | 2DEC | .00375 B-3 |                                            |
| -TJMAX   | DEC  | -.0375     | # LARGEST CALCULATED TIME. .150 SEC AT 4.  |
| TJMIN    | DEC  | .005       | # SMALLEST ALLOWABLE TIME. .020 SEC AT 4.  |
| -TJMIN   | DEC  | -.005      |                                            |
| RUFRATE  | DEC  | .1444      | # CORRESPONDS TO TARGET RATE OF 6.5 DEG/S. |

This code is written to file src/TJET-LAW.s.

## A.116 TPI SEARCH

```

1856  <src/TPI-SEARCH.s 1856>≡
      # Copyright:   Public domain.
      # Filename:    TPI_SEARCH.agc
      # Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
      #              It is part of the source code for the Command Module's (CM)
      #              Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:   yaYUL
      # Contact:      Ron Burkey <info@sandroid.org>.
      # Website:      www.ibiblio.org/apollo.
      # Pages:        551-561
      # Mod history:  2009-05-15 RSB   Adapted from the Colossus249/ file of the
      #              same name, using Comanche055 page images.
      #              2009-05-20 RSB   Corrections:  On p. 551, "SETLOC P17S" -> P17S1.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum.  The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum.  Many
      # thanks to both.  The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo.  If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 055 of AGC program Comanche by NASA
      #       2021113-051.  10:28 APR. 1, 1969
      #
      #       This AGC program shall also be referred to as
      #               Colossus 2A
      #
      # Page 551
      # TPI SEARCH
      #
      # PROGRAM DESCRIPTION S17.1 AND S17.2
      #
      # FUNCTIONAL DESCRIPTION
      #
      # THE TPI SEARCH ROUTINE DETERMINES THE MINIMUM TOTAL VELOCITY TRANSFER TRAJECTORY FOR
      # MANEUVER TIME WITHIN THE CONSTRAINT OF A SAFE PERICENTER.  THIS VELOCITY IS THE SUM
      # FOR THE TPI AND TPF MANEUVERS.
      #
      # THE S17.1 ROUTINE EXTRAPOLATES THE STATE VECTORS OF BOTH VEHICLES TO THE TPI TIME AND
      # RELATIVE PHASE ANGLE BETWEEN THE VEHICLES, THE ALTITUDE DIFFERENCE (I.E., THE MAGNITUDE

```



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```
# POSITION VECTORS) AND SELECTS A SEARCH SECTOR BASED ON THE SIGN OF THE ALTITUDE DIFFERENCE.
#
# THE S17.2 ROUTINE FURTHER DEFINES THE SEARCH SECTOR BY COMPUTING ANGULAR LIMITS AND USES THE
# SUBROUTINE TO COMPUTE THE SEARCH START AND END TIMES. THE SEARCH IS THEN MADE IN AN ITERATIVE
# LAMBERT SUBROUTINE TO COMPUTE THE VELOCITIES REQUIRED AT TPI TIME AND AT TPF TIME. EXIT FROM
# IS MADE WHEN SOLUTION CRITERIA ARE MET (NORMAL EXIT) OR AS SOON AS IT IS EVIDENT THAT NO SOLUTION
# THE SECTOR SEARCHED.
#
# CALLING SEQUENCE
#
#       BOTH ROUTINES ARE CALLED IN INTERPRETIVE CODE AND RETURN VIA QPRET. S17.1 HAS ONLY A NORMAL
#       S17.2 RETURNS VIA QPRET FOR NORMAL EXIT AND TO ALARMS FOR ERROR EXIT.
#
# SUBROUTINES CALLED
#
#       CSMCONIC
#       LEMCONIC
#       TIMETHET
#       INITVEL
#
#       BANK      36
#       SETLOC    P17S1
#       BANK
#
#       COUNT     36/TPI
#
#       EBANK=    RACT3
#
# ***** TEMPORARY *****
#
# HPE           2DEC      157420.0 B-29           # EARTH'S MIN. PERICENTER ALTITUDE 85 N.M.
#
# HPL           2DEC      10668.0213 B-29         # MOON'S MIN. PERICENTER ALTITUDE 35000 FT.
#
# CDSEC         2DEC      40000
#
# CLSEC         2DEC      15000
#
# PIINVERS      2DEC      .3183098862
#
# SEC1THET      2DEC      .1944444444
#
# # Page 552
# SEC2THET      2DEC      .9166666667
#
# MANYFEET      2DEC      -1.0 B-2
```

|         |         |               |                                  |      |
|---------|---------|---------------|----------------------------------|------|
| LIMVEL  | 2DEC    | .6096 E-2 B-7 | # 2FPS                           |      |
| DFTMOON | 2DEC    | .1524 E3 B-29 | # 500 FEET                       |      |
| DP-.002 | 2DEC    | 0.002         |                                  |      |
| S17.1   | SETLOC  | P17S          |                                  |      |
|         | BANK    |               |                                  |      |
|         | STQ     | DLOAD         |                                  |      |
|         |         | NORMEX        |                                  |      |
|         |         | TTPI          |                                  |      |
|         | STCALL  | TDEC1         | # ADVANCE PASSIVE VEHICLE TO TPI |      |
|         |         | LEMCONIC      |                                  |      |
|         | CALL    |               |                                  |      |
|         |         | LEMSTORE      |                                  |      |
|         | DLOAD   |               |                                  |      |
|         |         | TTPI          |                                  |      |
|         | STCALL  | TDEC1         | # ADVANCE ACTIVE VEHICLE TO TPI  |      |
|         |         | CSMCONIC      |                                  |      |
|         | CALL    |               |                                  |      |
|         |         | CSMSTORE      |                                  |      |
|         | VLOAD   |               |                                  |      |
|         |         | RACT3         |                                  |      |
| ABVAL   | PDVL    |               | # /RA/ OD                        | PL 2 |
|         | RPASS3  |               |                                  |      |
| UNIT    | PDDL    |               | # UNIT RP OD                     | PL 6 |
| BDSU    | SET     |               |                                  |      |
|         | 36D     |               | # /RP/ -/RA/                     |      |
|         | KFLAG   |               | # OFF = +                        |      |
| BMN     | CLEAR   |               |                                  |      |
|         | +2      |               |                                  |      |
|         | KFLAG   |               | # ON = -                         |      |
| STOVL   | DELHITE |               |                                  |      |
|         | OD      |               |                                  |      |
| VXV     | UNIT    |               |                                  |      |
|         | VPASS3  |               |                                  |      |
| STOVL   | E2      |               | # ALMOST IT SAVE FOR 17.2        |      |
|         | RACT3   |               |                                  |      |
| PUSH    | VPROJ   |               |                                  |      |
|         | E2      |               |                                  |      |
| VSL2    | BVSU    |               | # RPA                            |      |
| UNIT    | DOT     |               |                                  |      |
|         | OD      |               |                                  |      |
| SL1     | ACOS    |               |                                  |      |
| PDVL    |         |               |                                  |      |

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```
# Page 553
VXV      DOT
          RACT3
          E2
PDDL     SIGN
STADR
STODL    THETZERO      # CENTRAL ANGLE
          X1
STCALL   XRS           # SAVE INDICES FOR FURTHER USE
          NORMEX        # += ACTIVE AHEAD -= ACTIVE BEHIND
S17.2    STQ           # COMPUTE SEARCH SECTOR LIMITS
          VLOAD
          QTEMP
          RACT3
UNIT     DOT
          E2
ABS      SQRT
SL1      DAD
          DP-.002       # ADD .002 RADIANS TO IT
          DCOMP         # GIVES CORRECT SINE, COSINE MUST BE
          KFLAG         # COMP. ADD .5 FOR ANGLE
          +1
# PHI(0)=180-(-(THETAZERO +K5IT)), PHI(I)=180-(-(THETAZERO+K2IT))
# SIN(180-ALPHA)=SIN(ALPHA) ETC
DMP      SETPD
          PIINVERS      # REVOLUTIONARY HERES TWO IT
          OD
PUSH     DSU
          THETZERO
STORE    IT           # PHI(I) , -(THETZERO + K2IT)
PDDL     PUSH
SR1      DAD
DAD      PUSH         # PHI(0) , -(THETZERO + K5IT)
SIN      SET
          RVSW
STODL    SNTH
COS      BMN
          +2
DCOMP
STODL    CSTH
          XRS
STOVL    X1
          RPASS3
VSR*
          0,2
STOVL    RVEC
          VPASS3
```

```

                                VSR*
                                0,2
                                STCALL VVEC
                                TIMETHET
                                DLOAD
                                T
                                # SAVE START TIME AND GET END TIME
# Page 554
                                STORE TF
                                STODL TFO
                                IT
                                PUSH SIN
                                STODL SNTH
                                COS BMN
                                +2
                                DCOMP
                                STORE Csth
                                LXA,1 CALL
                                XRS
                                TIMETHET
# INITIALIZE LOOP
                                DLOAD CLEAR
                                T
                                ITSWICH
                                STODL TFI
                                # SAVE TIME FOR LOOP TEST
                                DPOS MAX
                                STODL DELVEE
                                MANYFEET
                                STODL HP
                                SEC1THET
                                # 70 DEGREES
                                BON DLOAD
                                KFLAG
                                +2
                                SEC2THET
                                # 330 DEGREES
                                STCALL THETL
                                CONCAUL
                                DLOAD SR1
                                Csth
                                STODL COSTH
                                SNTH
                                SR1
                                STCALL SINTH
                                # GET 4 QUADRANT THETA
                                ARCTRIG
                                BPL DAD
                                +2
                                DPOS MAX
                                # PUT THETA BETWEEN 0,1
                                BDSU PDDL

```

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```

                                THETL
                                TF
                                DSU    SIGN    # FAST TIMES
                                TFI
                                BMN
                                RNGTHTEST    # TIME MUST HAVE A STOP
# ADVANCE PASSIVE FOR TARGET VECTOR
CONCAUL    DLOAD
                                TTPI
                                DAD    BON
                                TF
# Page 555
                                AVFLAG
                                ADVCSM
                                STCALL    TDEC1
                                LEMCONIC
                                GOTO
                                JUNCT3
ADVCSM    STCALL    TDEC1
                                CSMCONIC
# SAVE BACK VALUES OF HP AND DELVEE
JUNCT3    VLOAD
                                VATT
                                STOVL    VPASS4
                                RATT
                                STORE    RPASS4
                                STODL    RTARG
                                TF
                                STODL    DELLT4
                                HP
                                STODL    HPO
                                DELVEE
                                STODL    DELVEO
# PREPARE FOR LAMBERT
                                TTPI
                                STODL    INTIME
                                XRS
                                STODL    RTX1
                                HI6ZEROS
                                SETPD    PDDL
                                OD
                                EPSFOUR
                                PDVL
                                RACT3
                                STOVL    RINIT
                                VACT3
```

```

                STCALL  VINIT
                INITVEL
# COMPUTE H ET CETERA
                VLOAD   VSU
                VTPRIME
                VPASS4
                ABVAL   PUSH
                STOVL   RELDELV           # /V2-VP(TPI+TF)/
                DELVEET3                 # V1-VA
                ABVAL   # /V1-VA/
                STORE   MAGVTPI
                DAD      STADR
                STODL   DELVEE
                XRS
                STOVL   X1
                VIPRIME
# Page 556
                VSR*
                0,2
                STOVL   VVEC
                RACT3
                VSR*
                0,2
                STCALL  RVEC
                PERIAPO
                LXA,2   DLOAD
                XRS      +1
                SL*
                0,2
                STORE   HP
# ITSWICH DENOTES INTERPOLATION -- SOLUTION ACCEPTANCE IS FORCED
                BON     DLOAD
                ITSWICH
                ENDEN
                HPERMIN
                DSU      BMN
                HP
                HALFSAFE
                PDDL     DSU           # WAS PERICENTER ALT SAFE
                HPERMIN
                HPO
                BMN      DSU           # (HPLIM-HPO)-(HPLIM-HP)=HP-HPO
                INTERP   # SOLUTION AT HAND
                BMN      DLOAD
                ALARUMS   # IT'S GETTING WORSE -- SOUND THE AL
                CDSEC

```

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|            |        |         |      |                              |
|------------|--------|---------|------|------------------------------|
| JUNCT1     | BOFF   | DCOMP   |      | # OFF IS PLUS, ON IS MINUS   |
|            |        | KFLAG   |      |                              |
|            |        | +1      |      |                              |
| JUNCT2     | STORE  | DELTEE  |      |                              |
|            | DLOAD  | DAD     |      |                              |
|            |        | DELTEE  |      |                              |
|            |        | TF      |      |                              |
|            | STCALL | TF      |      |                              |
|            |        | BIS     |      | # RECYCLE                    |
| INTERP     | SET    | DSU     |      | # HP-HPO                     |
|            |        | ITSWICH |      |                              |
|            | NORM   | PDDL    |      |                              |
|            |        | X1      |      |                              |
|            |        | DFTMOON |      |                              |
|            | DAD    | DSU     |      |                              |
|            |        | HPERMIN |      |                              |
|            |        | HP      |      |                              |
|            | NORM   | SR1     |      |                              |
|            |        | X2      |      |                              |
|            | XSU,2  | DDV     |      |                              |
|            |        | X1      |      |                              |
| # Page 557 |        |         |      |                              |
|            | DMP    | SR*     |      |                              |
|            |        | DELTEE  |      |                              |
|            |        | 0       | -1,2 |                              |
|            | STCALL | DELTEE  |      |                              |
|            |        | JUNCT2  |      |                              |
| HALFSAFE   | PDDL   | DSU     |      | # SAVE HP-HPLIM FOR POSSIBLE |
|            |        | DELVEE  |      |                              |
|            |        | DELVEO  |      | # SAVE THIS TOO              |
|            | PUSH   | ABS     |      |                              |
|            | DSU    | BMN     |      |                              |
|            |        | LIMVEL  |      | # 2 FT PS                    |
|            |        | ENDEN   |      |                              |
|            | DLOAD  | DSU     |      |                              |
|            |        | HPERMIN |      |                              |
|            |        | HPO     |      |                              |
|            | PDDL   |         |      |                              |
|            | BMN    | DLOAD   |      |                              |
|            |        | LRGRDVO |      |                              |
|            | BPL    | DLOAD   |      |                              |
|            |        | INTERP  |      |                              |
|            |        | DELTEE  |      |                              |
|            | SR1    | DCOMP   |      |                              |
|            | STCALL | DELTEE  |      |                              |
|            |        | JUNCT2  |      |                              |

```

LRGRDVO      DLOAD
              BMN      DLOAD
                  JUNCT2
                  CLSEC
              GOTO      JUNCT1
# TIME RAN OUT ASSUME SOLUTION IF SAVE PERICENTER
RNGETEST     DLOAD     DSU
              HP
              HPERMIN
              BMN      DLOAD
                  ALARUMS
                  TF
              DSU
                  DELTEE
              STORE    TF      # TIME OF SOLUTION
              VLOAD
                  VTPRIME
              DOT      PDDL      # SG2 WITH MAGNITUDE
                  RPASS4
                  RELDELV
              SIGN     STADR      # NOW SIGN(RELDELV)=SIGN(SG2)
              STCALL   RELDELV
                  TRANSANG      # COMPUTE OMEGA T, CENTRAL ANGLE
              VLOAD    DOT
                  RACT3
# Page 558
              VIPRIME      # SG1
              SIGN     BPL      # IF POSITIVE THEN SG1 = SG2 OTHERWISE
                  RELDELV
                  USEKAY      # SIGN(SG2-SG1)=SIGN(SG2)=SIGN(RELDELV)
              SLOAD    DCOMP
                  DECTWO
              SIGN     BPL
                  RELDELV
                  NEXUS
              DCOMP    GOTO
                  USEKAY +4
              USEKAY   SLOAD    BON
                  DECTWO
                  KFLAG
                  NEXUS
              DSU
                  P210NENN
              NEXUS    STODL    NN1
                  HP

```



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STCALL POSTTPI  
QTEMP  
BANK 07  
SETLOC XANG  
BANK  
COUNT 07/XANG

# CENTRAL ANGLE SUBROUTINE

#

# THIS SUBROUTINE COMPUTES THE CENTRAL ANGLE OF TRAVEL OF THE  
# PASSIVE VEHICLE DURING THE TRANSFER.

|            |        |           |      |                        |                  |
|------------|--------|-----------|------|------------------------|------------------|
| TRANSANG   | STQ    | SETPD     |      |                        |                  |
|            |        | SUBEXIT   |      |                        |                  |
|            |        | 0         |      |                        |                  |
|            | LXA,1  | LXA,2     |      |                        |                  |
|            |        | XRS       |      |                        |                  |
|            |        | XRS       | +1   |                        |                  |
|            | VLOAD  | VSR*      |      |                        |                  |
|            |        | VPASS4    |      |                        |                  |
|            |        | 0,2       |      |                        |                  |
|            | STODL* | VVEC      |      |                        |                  |
|            |        | MUTABLE   | +2,1 |                        |                  |
|            | PDVL   | VSR*      |      | # SQRT MU (+18 OR +15) | 00D              |
|            |        | RPASS4    |      |                        |                  |
|            |        | 0,2       |      |                        |                  |
|            | ABVAL  | PDDL*     |      | # MAGNITUDE OF R       | (+29 OR +27) 02D |
|            |        | MUTABLE,1 |      |                        |                  |
|            | PDVL   | VSQ       |      | # 1/MU                 | (+34 OR +28) 04D |
|            |        | VVEC      |      |                        |                  |
|            | NORM   | DMPR      |      | # PUSH LIST AT 02D     |                  |
|            |        | X1        |      |                        |                  |
| # Page 559 |        |           |      |                        |                  |
|            | DMP    | SRR*      |      |                        |                  |
|            |        | 02D       |      |                        |                  |
|            |        | 0         | -3,1 |                        |                  |
|            | BDSU   |           |      | # R V**/MU             | (+6)             |
|            |        | D1/32     |      |                        |                  |
|            | NORM   | PDDL      |      |                        |                  |
|            |        | X1        |      | # (2 - R V**/MU)       | (+6-N)           |
|            | SR1R   | DDV       |      | # MAGNITUDE OF R       | (+30 OR +28)     |
|            | SL*    | PUSH      |      | # R/(2 - R V**/MU)     | (+29 OR +27) 02D |
|            |        | 0         | -5,1 |                        |                  |
|            | SR1    | SQRT      |      |                        |                  |
|            | DMP    |           |      |                        |                  |
|            | NORM   | PDDL      |      | # ASUBP***             | 00D              |

```

                                X1
                                DDV
                                SL*
                                TF
                                0,1
                                PDDL NORM
                                2PISC
                                X1
                                PDDL DDV
                                SL*
                                0      -3,1      # CENTANG = (SQRT(MU/ASUP***)TF)
                                STCALL CENTANG      # IN REVOLUTIONS B-0
                                SUBEXIT
                                BANK 35
                                SETLOC P17S1
                                BANK
                                COUNT 35/P17

# TPI SEARCH DISPLAY ROUTINE

P17      TC      AVFLAGA      # AVFLAG = CSM, SET TRACK + UPDATE FI
        TC      P17.1
P77      TC      AVFLAGP      # AVFLAG = LEM, SET TRACK + UPDATE FI
P17.1    TC      P20FLGON      #      SET UPDATE FLAG
        CAF      V06N37      #      DISPLAY TTPI TIME
        TC      VNP00H
        TC      INTPRET
        CLEAR    CALL
                UPDATFLG
                S17.1      # UPDATE STATE VECTORS TO TTPI
        SET      AXT,1
                UPDATFLG
        DEC      2      # DELTA H = 2 K POSITIVE, KFLAG OFF
        BOFF     AXT,1
                KFLAG
                +2
        DEC      1      # DELTA H = 1 K NEGATIVE, KFLAG ON

# Page 560
        SXA,1    EXIT
                OPTION2
        CAF      V06N72      # DISPLAY PHI, DELTA H, SEARCH OPTION
        TC      VNCOMP17
        TC      INTPRET
        CLEAR    SET
                UPDATFLG
                KFLAG

```

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```

SLOAD  DSU
        OPTION2          # RESET KFLAG ON FOR OPTION =1
        P21ONENN         #           OFF FOR OPTION =2
BHIZ    CLEAR
        +2
        KFLAG
SLOAD  BHIZ
        XRS      +1
        +4
DLOAD  GOTO
        HPL
        P17.2
DLOAD
        HPE
P17.2  STCALL HPERMIN
        S17.2
SET    EXIT
        UPDATFLG
P17.3  CAF    V06N58          # DISPLAY DELTA VTPI, DELTA VTPF, AND H
        TC    VNCOMP17
        CAF    V06N55          # DISPLAY PERICENTER CODE AND CENTRAL ANG,
        TC    BANKCALL
        CADR   GOFLASHR
        TC    GOTOP00H        # TERMINATE PROGRAM
        TC    GOTOP00H        # END PROGRAM
        TC    P17.1           # RECYCLE WITH NEW TTPI OR SEARCH OPTION
        CAF    TWO            # BLANK R2
        TC    BLANKET
        TCF    ENDOFJOB
        EBANK= RTRN

VNCOMP17 EXTEND
        QXCH   QSAVED
        TS     VERBNOUN
        CA     VERBNOUN
        TCR    BANKCALL
        CADR   GOFLASH
        TC     -3              # TERMINATE ILLEGAL REDISPLAY
        TC     QSAVED          # PROCEED
        CS     MPAC            # RECYCLE WITH NEW TPI TIME
        AD     BIT6            # OR PROCEED WITH NEW SEARCH OPTION
        EXTEND

# Page 561
BZF    P17.1
TC      VNCOMP17 +3
ALARUMS SET  EXIT
```

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|        |     |          |                                     |
|--------|-----|----------|-------------------------------------|
|        |     | UPDATFLG |                                     |
|        | TC  | ALARM    |                                     |
|        | OCT | 00124    | # NO SAFE PERICENTER IN THIS SECTOR |
|        | CAF | V05N09   |                                     |
|        | TC  | VNCOMP17 |                                     |
|        | TC  | GOTOP00H | # PROCEED ILLEGAL TERMINATE PROGRAM |
| V06N72 | VN  | 0672     |                                     |

This code is written to file `src/TPI-SEARCH.s`.

## A.117 TRIM GIMBAL CNTROL SYSTEM

1869

*<src/TRIM-GIMBAL-CNTROL-SYSTEM.s 1869>≡*

```
# Copyright:    Public domain.
# Filename:     TRIM_GIMBAL_CNTLROL_SYSTEM.agc
# Purpose:     Part of the source code for Luminary 1A build 099.
#             It is part of the source code for the Lunar Module's (LM)
#             Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:     Ron Burkey <info@sandroid.org>.
# Website:     www.ibiblio.org/apollo.
# Pages:       1472-1485
# Mod history: 2009-05-27 RSB   Adapted from the corresponding
#                               Luminary131 file, using page
#                               images from Luminary 1A.
#
# This source code has been transcribed or otherwise adapted from
# digitized images of a hardcopy from the MIT Museum. The digitization
# was performed by Paul Fjeld, and arranged for by Deborah Douglas of
# the Museum. Many thanks to both. The images (with suitable reduction
# in storage size and consequent reduction in image quality as well) are
# available online at www.ibiblio.org/apollo. If for some reason you
# find that the images are illegible, contact me at info@sandroid.org
# about getting access to the (much) higher-quality images which Paul
# actually created.
#
# Notations on the hardcopy document read, in part:
#
# Assemble revision 001 of AGC program LMY99 by NASA 2021112-61
# 16:27 JULY 14, 1969
```

# Page 1472

```
BANK      21
EBANK=    QDIFF
SETLOC    DAPS4
BANK

COUNT*   $$/DAPGT
```

```
# CONTROL REACHES THIS POINT UNDER EITHER OF THE FOLLOWING TWO CONDITIONS ONCE THE DESCENT ENGI
# AUTOPILOT ARE BOTH ON:
#   A) THE TRIM GIMBAL CONTROL LAW WAS ON DURING THE PREVIOUS Q,R-AXIS TIME5 INTERRUPT (OR
#      INITIALIZATION WAS SET FOR TRIM GIMBAL CONTROL AND THIS IS THE FIRST PASS), OR
#   B) THE Q,R-AXES RCS AUTOPILOT DETERMINED THAT THE VEHICLE WAS ENTERING (OR HAD JUST ENT
#      ZONE WITH A SMALL OFFSET ANGULAR ACCELERATION.
# GTS IS THE ENTRY TO THE GIMBAL TRIM SYSTEM FOR CONTROLLING ATTITUDE ERRORS AND RATES AS WELL
```

```

GTS          CAF    NEGONE      # MAKE THE NEXT PASS THROUGH THE DAP BE
              TS     COTROLER    #           THROUGH RCS CONTROL,
              CAF    FOUR        #           AND ENSURE THAT IT IS NOT A SKIP.
              TS     SKIPU
              TS     SKIPV

              CAF    TWO
              TS     INGTS        # SET INDICATOR OF GTS CONTROL POSITIVE.
              TS     QGIMTIMR     # SET TIMERS TO 200 MSEC TO AVOID BOTH
              TS     RGIMTIMR     # RUNAWAY AND INTERFERENCE BY NULLING.

# THE DRIVE SETTING ALGORITHM
#
#      DEL = SGN(OMEGA + ALPHA*ABS(ALPHA)/(2*K))
#
#      NEGUSUM = ERROR*K + ALPHA*(DEL*OMEGA + ALPHA / (3*K)) + DEL*K    (DEL*OMEGA + A
#
#      DRIVE = -SGN(NEGUSUM)

              CA      SR          # SAVE THE SR.  SHIFT IT LEFT TO CORRECT
              AD      A           # FOR THE RIGHT SHIFT DUE TO EDITING.
              TS      SAVESR

GTSGO+DN      CAF    TWO          # SET INDEXER FOR R-AXIS CALCULATIONS.
              TCF     GOQTRIMG +1

GOQTRIMG      CAF    ZERO         # SET INDEXER FOR Q-AXIS CALCULATIONS
              TS     QRCNTR

# Page 1473
# RSB 2009 -----
# Everything between this line and the similar line below was simply filled-in
# as-is from Luminary 131, and then verified to assemble to the proper binary
# values.  This area is blank on the Luminary 099 print-out, as if the
# printer ribbon had run out.
              INDEX   QRCNTR      # AOS SCALED AT PI/2
              CA      AOSQ
              EXTEND
              MP      BIT2        # RESCALE AOS TO PI/4
              EXTEND
              BZF     GTSQAXIS -3  # USE FULL SCALE FOR LARGER AOS ESTIMATES.

              INDEX   A
              CS      LIMITS      # LIMITS +1 CONTAINS NEGMAX.
              XCH     L           # LIMITS -1 CONTAINS POSMAX.

```

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```
GTSQAXIS      CCS      QRCNTR      # PICK UP RATE FOR THIS AXIS.  RATE CELLS
              INDEX     A          # USE ADJACENT, NOT SEPARATED.  AT PI/4
              CA        EDOTQ
              DXCH      WCENTRAL

              INDEX     QRCNTR      # COLLECT K FOR THIS AXIS
              CA        KQ
              TS        KCENTRAL

              EXTEND
              BZF      POSDRIVE +1  # CONTROL AUTHORITY ZERO.  AVOID DRIVING
                                   # ENGINE BELL TO THE STOPS.

              INDEX     QRCNTR      # QDIFF, RDIFF ARE STORED IN D.P.
              CAE      QDIFF

ALGORITHM     EXTEND
              MP      KCENTRAL      # Q(R)DIFF IS THETA (ERROR) SCALED AT PI.
              LXCH    K2THETA      # FORM K*ERROR AT PI(2)/2(8), IN D.P.
              EXTEND
              MP      BIT5          # RESCALE TO 4*PI(2)
              DXCH    K2THETA
              EXTEND
              MP      BIT5          # FIRST TERM OF NEGUSUM IN K2THETA.
              ADS     K2THETA +1    # NO CARRY NEEDED          D.P. AT 4*PI(2)

              CS      ACENTRAL      # FORM ALPHA(2)/(2*K) AT 16*PI, IN D.P.,
              EXTEND                                     # LIMITING QUOTIENT TO AVOID OVERFLOW.
              MP      BIT14         # -ALPHA/2 IN A, SCALED AT PI/4
              EXTEND
              MP      ACENTRAL      # -ALPHA(2)/2 IN A,L, SCALED AT PI(2)/16)
              AD      KCENTRAL
              EXTEND
              BZMF     HUGEQUOT     # K-ALPHA(2)/2 SHOULD BE PNZ FO DIVISION

              EXTEND
              DCS      A            # ALPHA(2)/2 - K
              AD      KCENTRAL

# RSB 2009 -----
              EXTEND
              DV      KCENTRAL      # HIGH ORDER OF QUOTIENT.
              XCH     A2CNTRAL
              CA      L            # SHIFT UP THE REMAINDER.
              LXCH    7            # ZERO LOW-ORDER DIVIDEND.
              EXTEND

# Page 1474
              DV      KCENTRAL
```

|          |        |             |                                           |
|----------|--------|-------------|-------------------------------------------|
|          | XCH    | A2CNTRAL +1 | # QUOTIENT STORED AT 16*PI, D.P.          |
|          | TCF    | HAVEQUOT    |                                           |
| HUGEQUOT | CA     | POSMAX      |                                           |
|          | TS     | L           |                                           |
|          | DXCH   | A2CNTRAL    | # LIMITED QUOTIENT STORED AT 16*PI, D.P.  |
| HAVEQUOT | CA     | WCENTRAL    |                                           |
|          | EXTEND |             |                                           |
|          | MP     | BIT9        | # RESCALE OMEGA AT 16*PI IN D.P.          |
|          | DXCH   | K2CNTRAL    | # LOWER WORD OVERLAYS OMEGA IN WCENTRAL   |
|          | EXTEND |             |                                           |
|          | DCA    | K2CNTRAL    |                                           |
|          | DXCH   | FUNCTION    |                                           |
|          | CA     | ACENTRAL    | # GET ALPHA*ABS(ALPHA)/(2*K)              |
|          | EXTEND |             |                                           |
|          | BZMF   | +4          |                                           |
|          | EXTEND |             |                                           |
|          | DCA    | A2CNTRAL    |                                           |
|          | TCF    | +3          |                                           |
|          | EXTEND |             |                                           |
|          | DCS    | A2CNTRAL    |                                           |
|          | DAS    | FUNCTION    | # OMEGA + ALPHA*ABS(ALPHA)/(2*K) AT 16*PI |
|          | CCS    | FUNCTION    | # DEL = +1 FOR FUNCT1 GREATER THAN ZERO.  |
|          | TCF    | POSFNCT1    | # OTHERWISE DEL = -1                      |
|          | TCF    | +2          |                                           |
|          | TCF    | NEGFNCT1    |                                           |
| POSFNCT1 | CCS    | FUNCTION +1 | # USE LOW ORDER WORD SINCE HIGH IS ZERO   |
|          | CAF    | BIT1        |                                           |
|          | TCF    | +2          |                                           |
| NEGFNCT1 | CS     | BIT1        |                                           |
|          | TS     | DEL         |                                           |
|          | CCS    | DEL         | # REPLACE OMEGA BY DEL*OMEGA              |
|          | TCF    | FUNCT2      | # POSITIVE DEL VALUE. PROCEED.            |
|          | TCF    | DEFUNCT     |                                           |
|          | TCF    | NEGFNCT2    |                                           |
| DEFUNCT  | TS     | K2CNTRAL    |                                           |



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```

TS      K2CNTRAL +1
TCF     FUNCT2

# Page 1475
NEG1/3  DEC      -.33333

NEGFUNCT2  EXTEND
DCS      K2CNTRAL
DXCH     K2CNTRAL

FUNCT2    EXTEND
DCA      A2CNTRAL
DAS      K2CNTRAL      # DEL*OMEGA + ALPHA(2)/(2*K) AT 16*PI, D.P.

FUNCT3    CA      A2CNTRAL
EXTEND
MP       NEG1/3
DXCH     A2CNTRAL
CA       L
EXTEND
MP       NEG1/3
ADS      A2CNTRAL +1
TS       L
TCF      +2            # A2CNTRAL NOW CONTAINS -ALPHA(2)/(6*K),
ADS      A2CNTRAL      # SCALED AT 16*PI, IN D.P.

EXTEND
DCA      K2CNTRAL      # DEL*OMEGA + ALPHA(2)/(3*K) IN A2CNTRAL,
DAS      A2CNTRAL      # SCALED AT 16*PI, D.P.

CA      A2CNTRAL
EXTEND
MP      ACENTRAL
DAS     K2THETA
CA      A2CNTRAL +1
EXTEND
MP      ACENTRAL      # ACENTRAL MAY NOW BE OVERLAID.
ADS     K2THETA +1
TS      L
TCF     +2            # TWO TERMS OF NEGUSUM ACCUMULATED, SO FAR
ADS     K2THETA      # SCALED AT 4*PI(2), IN D.P.

GETROOT  CA      K2CNTRAL      # K*(DEL*OMEGA + ALPHA(2)/(2*K)) IS THE
EXTEND   EXTEND      # TERM FOR WHICH A SQUARE ROOT IS NEEDED.
MP       KCENTRAL      # K AT PI/2(8)
DXCH     FUNCTION
```

```

      CA      K2CNTRAL +1
      EXTEND
      MP      KCENTRAL
      ADS     FUNCTION +1
      TS      L
      TCF     +2
      ADS     FUNCTION      # DESIRED TERM IN FUNCTION, AT PI(2)/16
# Page 1476

```

```

      CCS     DEL
      TCF     RSTOFGTS
      TCF     NEGUSUM
      TCF     NEGATE
      TCF     NEGUSUM

```

```

NEGATE      EXTEND
      DCS     K2CNTRAL
      DXCH    K2CNTRAL
      TCF     RSTOFGTS

```

```

      BANK    16
      EBANK=  NEGUQ
      SETLOC  DAPS1
      BANK

```

```

# THE WRCHN12 SUBROUTINE SETS BITS 9,10,11,12 OF CHANNEL 12 ON THE BASIS OF THE CONT
# THE NEGATIVES OF THE DESIRED ACCELERATION CHANGES.  ACDT+C12 SETS Q(R)ACCDOT TO RE
#
# WARNING:  ACDT+C12 AND WRCHN12 MUST BE CALLED WITH INTERRUPT INHIBITED.

```

```

BGIM      OCTAL    07400
CHNL12    EQUALS   ITEMP6
ACDT+C12  CS       NEGUQ
      EXTEND      # GIMBAL DRIVE REQUESTS.
      MP         ACCDOTQ
      LXCH       QACCDOT
      CS         NEGUR
      EXTEND
      MP         ACCDOTR
      LXCH       RACCDOT

      CCS        NEGUQ
      CAF        BIT10
      TCF        +2
      CAF        BIT9
      TS         CHNL12

```

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```
CCS      NEGUR
CAF      BIT12
TCF      +2
CAF      BIT11
ADS      CHNL12          # (STORED RESULT NOT USED AT PRESENT)
```

```
CS      BGIM
EXTEND
RAND     CHAN12
AD       CHNL12
EXTEND
WRITE    CHAN12
```

# Page 1477

```
CS      CALLGMBL          # TURN OFF REQUEST FOR ACDT+C12 EXECUTION.
MASK    RCSFLAGS
TS      RCSFLAGS
```

```
TC      Q                  # RETURN TO CALLER.
```

```
BANK    21
EBANK=   QDIFF
SETLOC   DAPS4
BANK
```

# Page 1478

# SUBROUTINE TIMEGMBL: MOD 0, OCTOBER 1967, CRAIG WORK

#

# TIMEGMBL COMPUTES THE DRIVE TIME NEEDED FOR THE TRIM GIMBAL TO POSITION THE DESCENT ENGINE NO  
# THE OFFSET ANGULAR ACCELERATION ABOUT THE Q (OR R) AXIS. INSTEAD OF USING AOSQ(R), TIMEGMBL  
# SCALED AT PI/8. FOR EACH AXIS, THE DRIVE TIME IS COMPUTED AS ABS(ALPHA/ACCDOT). A ZERO  
# ALPHA OR ACCDOT OR A ZERO QUOTIENT TURNS OFF THE GIMBAL DRIVE IMMEDIATELY. OTHERWISE, THE GI  
# DRIVING IN THE CORRECT DIRECTION. THE Q(R)GIMTIMR IS SET TO TERMINATE THE DRIVE AND Q(R)ACCD  
# IS STORED TO REFLECT THE NEW ACCELERATION DERIVATIVE. NEGUQ(R) WILL CONTAIN +1,+0,-1 FOR A Q  
# WHICH IS NEGATIVE, ZERO, OR POSITIVE.

#

# INPUTS: AOSQ,AOSR, SCALED AT P1/2, AND ACCDOTQ, ACCDOTR AT PI/2(7). PI/2(7).

#

# OUTPUTS: NEW GIMBAL DRIVE BITS IN CHANNEL 12, NEGUQ, NEGUR, QACCDOT, AND RACCDOT, THE LA  
# Q(R)GIMTIMR WILL BE SET TO TIME AND TERMINATE GIMBAL DRIVE(S).

#

# DEBRIS: A, L, Q, ITEMPS 2, 3, 6, AND RUPTREG2 AND ACDT+C12 DEBRIS.

#

# EXITS: VIA TC Q.

#

# ALARMS, ABORTS: NONE.

#

```

# SUBROUTINES:  ACDT+C12, IBNKCALL
#
# WARNING:      THIS SUBROUTINE WRITES INTO CHANNEL 12 AND USES THE ITEMS.  THEREFOR
#               INTERRUPT INHIBITED.
#
# ERASABLE STORAGE CONFIGURATION (NEEDED BY THE INDEXING METHODS):
#   NEGUQ          ERASE   +2          # NEGATIVE OF Q-AXIS GIMBAL DRIVE
#   (SPWORD)       EQUALS  NEGUQ +1     # ANY S.P. ERASABLE NUMBER, NOW THRS
#   NEGUR          EQUALS  NEGUQ +2     # NEGATIVE OF R-AXIS GIMBAL DRIVE
#   ACCDOTQ        ERASE   +2          # Q-JERK TERM SCALED AT PI/2(7) RAD/S
#   (SPWORD)       EQUALS  ACCDOTQ +1   # ANY S.P. ERASABLE NUMBER NOW QACCD
#   ACCDOTR        EQUALS  ACCDOTQ +2   # R-JERK TERM SCALED AT PI/2(7) RAD/S
#               # ACCDOTQ, ACCDOTR ARE MAGNITUDES.
#   AOSQ           ERASE   +4          # Q-AXIS ACC., D.P. AT PI/2 R/SEC(2)
#   AOSR           EQUALS  AOSQ +2     # R-AXIS ACCELERATION SCALED AT PI/2

QRNDXER          EQUALS  ITEMP6
OCT23146         OCTAL   23146        # DECIMAL .6
NZACCDOT         EQUALS  ITEMP3

TIMEGMBL         CAF     ONE          # INITIALZE ALLOWGTS.
                 TS      ALLOWGTS

                 CAF     TWO          # SET UP LOOP FOR R AXIS.
                 LXCH    Q            # SAVE RETURN ADDRESS.
                 LXCH    RUPTREG2

# Page 1479

TIMQGMBL         TCF     +2
                 CAF     ZERO         # NOW DO THE Q-AXIS
                 TS      QRNDXER
                 INDEX   QRNDXER
                 CA      ACCDOTQ      # ACCDOT IS PRESUMED TO BE AT PI/2(7)
                 EXTEND
                 BZMF    TGOFFNOW     # IS ACCDOT LESS THAN OR EQUAL TO 0?
                 TS      NZACCDOT     # NO.  STORE NON-ZERO, POSITIVE ACCD

ALPHATRY         INDEX   QRNDXER
                 CS      AOSQ
                 EXTEND
                 BZF     TGOFFNOW     # IS ALPHA ZERO?

                 TS      Q            # SAVE A COPY OF -AOS.
                 EXTEND              # NO.  RESCALE FOR TIMEGMBL USE.
                 MP      OCT23146     # OCTAL 23146 IS DECIMAL .6
                 AD      Q            # -1.6*AOS AT PI/2 = -.4*AOS AT PI/8
                 TS      L            # WAS THERE OVERFLOW?

```

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|             |        |            |                                         |
|-------------|--------|------------|-----------------------------------------|
|             | TCF    | SETNEGU    | # NO. COMPUTE DRIVE TIME.               |
|             | CS     | A          | # RECOVER -SGN(AOS) IN THE A REGISTER.  |
|             | INDEX  | QRNDXER    | # YES. START DRIVE WITHOUT WAITLIST.    |
|             | XCH    | NEGUQ      |                                         |
|             | TCF    | NOTALLOW   | # KNOCK DOWN THE ALLOWGTS FLAG.         |
| SETNEGU     | EXTEND |            |                                         |
|             | BZMF   | POSALPH    |                                         |
|             | COM    |            |                                         |
|             | TS     | ITEMP2     | # STORE -ABS(.4*AOS) SCALED AT PI/8.    |
|             | CS     | BIT1       |                                         |
|             | TCF    | POSALPH +2 |                                         |
| POSALPH     | TS     | ITEMP2     | # STORE -ABS(.4*AOS) SCALED AT PI/8.    |
|             | CA     | BIT1       |                                         |
| +2          | INDEX  | QRNDXER    | # SGN(AOS) INTO NEGU                    |
|             | TS     | NEGUQ      | # STORE SGN(ALPHA) AS NEGU              |
|             | CA     | NZACCDOT   |                                         |
|             | EXTEND |            |                                         |
|             | MP     | BIT12      | # 2*ACCDOT, SCALED AT PI/8.             |
|             | AD     | ITEMP2     | # -ABS(ALPHS) + 2*ACCDOT, AT PI/8.      |
|             | EXTEND |            |                                         |
|             | BZMF   | NOTALLOW   | # IS DRIVE TIME MORE THAN TWO SECONDS?  |
|             | CS     | ITEMP2     | # NO. COMPUTE DRIVE TIME.               |
|             | EXTEND |            | # ABS(ALPHA) AT PI/8.                   |
|             | MP     | OCT00240   | # DECIMAL 10/1024                       |
|             | EXTEND |            | # QUOTIENT IS DRIVE TIME AT WAITLIST.   |
|             | DV     | NZACCDOT   | # ABS(ALPHA)/ACCDOT AT 2(14)/100        |
| # Page 1480 | EXTEND |            |                                         |
|             | BZF    | TGOFFNOW   | # DRIVE TIME MUST BE GREATER THAN ZERO. |
|             | TCF    | DRIVEON    |                                         |
| TGOFFNOW    | CAF    | ZERO       | # TURN OFF GIMBAL NOW.                  |
|             | INDEX  | QRNDXER    |                                         |
|             | TS     | NEGUQ      |                                         |
|             | TCF    | DONEYET    |                                         |
| NOTALLOW    | CAF    | OCT31      |                                         |
|             | INDEX  | QRNDXER    |                                         |
|             | TS     | QGIMTIMR   |                                         |
|             | CAF    | ZERO       | # DRIVE TIME IS MORE THAN 2 SECONDS, SO |

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|          |       |          |                                       |
|----------|-------|----------|---------------------------------------|
|          | TS    | ALLOWGTS | # DO NOT PERMIT FURTHER GTS ATTITUDE  |
|          | TCF   | DONEYET  | # CONTROL UNTIL AOSTASK APPROVES.     |
|          |       |          | # NO WAITLIST CALL IS MADE.           |
| DRIVEON  | INDEX | QRNDXER  |                                       |
|          | TS    | QGIMTIMR | # CHOOSE Q OR R AXIS.                 |
| DONEYET  | CCS   | QRNDXER  |                                       |
|          | TCF   | TIMQGMBL |                                       |
|          | DXCH  | RUPTREG3 | # PROTECT IBNKCALL ERASABLES. ACDT+C  |
|          | DXCH  | ITEMP2   | # LEAVES ITEMS2,3 ALONE.              |
|          | TC    | IBNKCALL | # TURN OFF CHANNEL BITS, SET Q(R)ACCD |
|          | CADR  | ACDT+C12 |                                       |
|          | DXCH  | ITEMP2   | # RESTORE ERASABLES FOR IBNKCALL.     |
|          | DXCH  | RUPTREG3 |                                       |
|          | TC    | RUPTREG2 | # RETURN TO CALLER.                   |
| OCT00240 | OCTAL | 00240    | # DECIMAL 10/1024                     |

# Page 1481

# THE FOLLOWING SECTION IS A CONTINUATION OF THE TRIM GIMBAL CONTROL FROM THE LAST G  
 # IS COMPUTED FOR EACH AXIS (Q,R),  $.707 * \Delta * \text{FUNCTION}(3/2) + K2\theta = \text{NEGUSUM}$ . NEW I  
 #  
 # THE SUBROUTINE GTSQRT ACCEPTS A DOUBLE PRECISION VALUE IN FUNCTION, FUNCTION +1 AND  
 # SQUARE ROOT OF THE FOURTEEN MOST SIGNIFICANT BITS OF THE ARGUMENT. ALSO, THE CELL  
 # EXPONENT S, SUCH THAT THE SQUARE ROOT (RETURNED IN THE A REGISTER) MUST BE SHIFTED  
 # POWER (-S)) IN ORDER TO BE THE TRUE SQUARE ROOT OF THE FOURTEEN MOST SIGNIFICANT B  
 # SQUARE ROOT ERROR IS NOT MORE THAN 2 IN THE 14TH SIGNIFICANT BIT. CELLS CLOBBE  
 # HALFARG, SCRATCH, SR, FUNCTION, FUNCTION +1. GTSQRT IS CALLED BY TC GTSQRT AND RE  
 # ZERO OR NEGATIVE ARGUMENTS YIELD ZERO FOR SQUARE ROOTS.

|         |        |             |                                           |
|---------|--------|-------------|-------------------------------------------|
| GTSQRT  | CCS    | FUNCTION    |                                           |
|         | TCF    | GOODARG     | # FUNCTION IS POSITIVE. TAKE SQUARE ROOT. |
|         | TCF    | +2          | # HIGH ORDER WORD IS ZERO. TRY THE LOWER. |
|         | TCF    | ZERROOT     | # NEGATIVE. USE ZERO FOR 1/2 POWER.       |
|         | CA     | FUNCTION +1 |                                           |
|         | EXTEND |             |                                           |
|         | BZMF   | ZERROOT     |                                           |
|         | TCF    | ZEROHIGH    | # PROCEED.                                |
| ZERROOT | CA     | ZERO        |                                           |

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|             |        |             |                                            |
|-------------|--------|-------------|--------------------------------------------|
|             | TS     | SHFTFLAG    |                                            |
|             | TC     | Q           |                                            |
| ZEROHIGH    | XCH    | FUNCTION    | # 14 MOST SIGNIFICANT BITS ARE IN THE      |
|             | XCH    | FUNCTION +1 | # LOWER WORD. EXCHANGE THEM.               |
|             | CA     | SEVEN       |                                            |
|             | TCF    | GOODARG +1  |                                            |
| GOODARG     | CA     | ZERO        |                                            |
|             | TS     | SHFTFLAG    |                                            |
|             | CA     | TWELVE      | # INITIALIZE THE SCALING LOOP.             |
|             | TS     | ININDEX     |                                            |
|             | TCF    | SCALLOOP    |                                            |
| SCALSTRT    | CA     | FUNCTION    |                                            |
|             | TCF    | SCALDONE    |                                            |
| MULBUSH     | CA     | NEG2        | # IF ARG IS NOT LESS THAN 1/4, INDEX IS    |
|             | ADS    | ININDEX     | # ZERO, INDICATING NO SHIFT NEEDED.        |
|             | EXTEND |             | # BRANCH IF ARG IS NOT LESS THAN 1/4.      |
|             | BZMF   | SCALSTRT    | # OTHERWISE COMPARE ARG WITH A REFERENCE   |
|             |        |             | # WHICH IS 4 TIMES LARGER THAN THE LAST.   |
| SCALLOOP    | CS     | FUNCTION    |                                            |
|             | INDEX  | ININDEX     |                                            |
|             | AD     | BIT15       | # REFERENCE MAGNITUDE LESS OR EQUAL TO 1/4 |
|             | EXTEND |             |                                            |
|             | BZMF   | MULBUSH     | # IF ARG IS NOT LESS THAN REFERENCE, GO    |
|             |        |             | # AROUND THE MULBERRY BUSH ONCE MORE.      |
| # Page 1482 |        |             |                                            |
|             | INDEX  | ININDEX     |                                            |
|             | CA     | BIT15       | # THIS IS THE SCALE MAGNITUDE              |
|             | XCH    | HALFARG     | # 2*(-ININDEX) IS THE SHIFT DIVISOR.       |
|             | EXTEND |             | # RESCALE ARGUMENT.                        |
|             | DCA    | FUNCTION    |                                            |
|             | EXTEND |             |                                            |
|             | DV     | HALFARG     |                                            |
|             |        |             | # ININDEX AND SHFTFLAG PRESERVE INFO FOR   |
|             |        |             | # RESCALING AFTER ROOT PROCESS.            |
| SCALDONE    | EXTEND |             |                                            |
|             | QXCH   | FUNCTION +1 | # SAVE Q FOR RETURN                        |
|             | EXTEND |             |                                            |
|             | MP     | BIT14       |                                            |
|             | TS     | HALFARG     |                                            |
|             | MASK   | BIT13       |                                            |
|             | CCS    | A           |                                            |
|             | CA     | OCT11276    |                                            |

```

AD      ROOTHALF      # INITIAL GUESS IS ROOT 1/2 OR POSMAX
TC      ROOTCYCL
TC      ROOTCYCL
TC      ROOTCYCL
TC      FUNCTION +1

```

```

# *****

```

```

RSTOFGTS      TC      GTSQRT
PRODUCT      XCH      K2CNTRAL
EXTEND
MP      K2CNTRAL
DXCH      K2CNTRAL
EXTEND
MP      L      # THE PRODUCT OF
ADS      K2CNTRAL +1 # 1/2 2 1/2
TS      L      # K *(DEL*OMEGA + ALPHA /(2*K))
TCF      +2      # AND
ADS      K2CNTRAL # 2
# DEL*(DEL*OMEGA + ALPHA /(2*K)) NOW IN
# K2CNTRAL

```

```

DOSHIFT      CA      ININDEX
EXTEND      # MULTIPLY IN THE FACTOR 2(-S), RETURNED
MP      BIT14      # BY THE GTSQRT SUBROUTINE
ADS      SHFTFLAG
EXTEND
BZF      ADDITIN
INDEX      SHFTFLAG
CA      BIT15

```

```

# Page 1483

```

```

XCH      K2CNTRAL
EXTEND
MP      K2CNTRAL
DAS      K2THETA
XCH      K2CNTRAL
EXTEND
MP      K2CNTRAL +1
ADS      K2THETA +1
TS      L
TCF      +2
ADS      K2THETA

```

```

TCF      NEGUSUM

```

```

ADDITIN      EXTEND
DCA      K2CNTRAL

```



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|             |        |            |                                           |
|-------------|--------|------------|-------------------------------------------|
| NEGUSUM     | DAS    | K2THETA    | # NO ADD IN THE K2THETA TERM.             |
|             | CCS    | K2THETA    | # TEST SIGN OF HIGH ORDER PART.           |
|             | TCF    | NEGDRIVE   |                                           |
|             | TCF    | +2         |                                           |
|             | TCF    | POSDRIVE   |                                           |
| NEGDRIVE    | CCS    | K2THETA +1 | # SIGN TEST FOR LOW ORDER PART.           |
|             | CA     | BIT1       |                                           |
| POSDRIVE    | TCF    | +2         | # STOP GIMBAL DRIVE FOR A ZERO NEGUSUM.   |
|             | CS     | BIT1       |                                           |
|             | TS     | L          | # SAVE FOR DRIVE REVERSAL TEST.           |
|             | INDEX  | QRCNTR     |                                           |
|             | XCH    | NEGUQ      |                                           |
|             | EXTEND |            |                                           |
|             | MP     | L          | # MULTIPLY OLD NEGU AND NEW NEGU.         |
|             | CCS    | L          |                                           |
|             | TCF    | LOUPE      | # NON-ZERO GIMBAL DRIVE BEING CONTINUED.  |
|             | TCF    | ZEROLOUP   | # NO REVERSAL PROBLEM HERE.               |
|             | TCF    | REVERSAL   | # NON-ZERO GIMBAL DRIVE BEING REVERSED.   |
|             | TCF    | ZEROLOUP   | # NO REVERSAL PROBLEM HERE.               |
| REVERSAL    | INDEX  | QRCNTR     | # A ZERO-DRIVE PAUSE IS NEEDED HERE. ZERO |
|             | TS     | QACCDOT    | # IS IN A REGISTER FROM CCS ON (-1).      |
|             | INDEX  | QRCNTR     |                                           |
|             | CS     | GMBLBITA   |                                           |
|             | EXTEND |            |                                           |
|             | WAND   | CHAN12     |                                           |
| ZEROLOUP    | CS     | RCSFLAGS   | # SET UP REQUEST FOR ACDT+C12 CALL.       |
|             | MASK   | CALLGMBL   |                                           |
|             | ADS    | RCSFLAGS   |                                           |
| # Page 1484 |        |            |                                           |
| LOUPE       | CCS    | QRCNTR     | # HAVE BOTH AXES BEEN PROCESSED?          |
|             | TCF    | GOQTRIMG   | # NO. DO Q AXIS NEXT.                     |
|             | CA     | SAVESR     | # RESTORE THE SR                          |
|             | TS     | SR         |                                           |
| GOCLOSE     | EXTEND |            | # TERMINATE THE JASK.                     |
|             | DCA    | CLOSEADR   |                                           |
|             | DTCB   |            |                                           |
|             | EBANK= | AOSQ       |                                           |

```

CLOSEADR      2CADR  CLOSEOUT      # TERMINATE THE JASK.

TWELVE        EQUALS  OCT14
ROOTHALF      OCTAL  26501          # SQUARE ROOT OF 1/2
GMBLBITA      OCTAL  01400          # INDEXED WRT GMBLBITB  DO NOT MOVE *****
OCT11276      OCTAL  11276          # POSMAX -- ROOTHALF
GMBLBITB      OCTAL  06000          # INDEXED WRT GMBLBITA  DO NOT MOVE *****

# SUBROUTINE ROOTCYCL:  BY CRAIG WORK, 3 APRIL 68
#
# ROOTCYCL IS A SUBROUTINE WHICH EXECUTS ONE NEWTON SQUARE ALGORITHM ITERATION.  THE
# SQUARE ROOT IS PRESUMED TO BE IN THE A REGISTER AND ONE-HALF THE SQUARE IS TAKEN FR
# TO THE SQUARE ROOT IS RETURNED IN THE A REGISTER.  DEBRIS:  A, L, SR, SCRATCH.  RO
# LOCATION (LOC) BY A TC ROOTCYCL, AND RETURNS (TC Q) TO LOC +1.
#
# WARNING:  IF THE INITIAL GUESS IS NOT GREATER THAN THE SQUARE, DIVIDE OR ADD OVERFI

ROOTCYCL      TS      SCRATCH        # STORE X
              TS      SR              # X/2 NOW IN SR
              CA      HALFARG         # ARG/2 IN THE A REG
              ZL
              EXTEND
              DV      SCRATCH         # (ARG/X)/2
              AD      SR              # (X + ARG/X)/2 IN THE A REG
              TC      Q

```

This code is written to file `src/TRIM-GIMBAL-CNTROL-SYSTEM.s`.

## A.118 TVCDAPS

1883

*<src/TVCDAPS.s 1883>*≡

```

# Copyright:    Public domain.
# Filename:     TVCDAPS.agc
# Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
#               It is part of the source code for the Command Module's (CM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:      Ron Burkey <info@sandroid.org>.
# Website:      www.ibiblio.org/apollo.
# Pages:        961-978
# Mod history:  2009-05-13 RSB   Adapted from the Colossus249/ file of the
#               same name, using Comanche055 page images.
#               2009-05-20 RSB   Corrections:  Eliminated an extraneous EXTEND,
#               added a missing instruction to PFORWARD.
#               2000-05-21 RSB   Wrong opcode was used with DELBRTMP and
#               DELBRTMP +1 operands in 4 places.  Corrected
#               an MP operation in 2CASFLTR.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum.  The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum.  Many
# thanks to both.  The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo.  If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 055 of AGC program Comanche by NASA
#       2021113-051.  10:28 APR. 1, 1969
#
#       This AGC program shall also be referred to as
#               Colossus 2A
#
# Page 961
# PROGRAM NAME....TVCDAP, CONSISTING OF PITCHDAP, YAWDAP, ETC.
# LOG SECTION....TVCDAPS                                SUBROUTINE....DAPCSM
# MODIFIED BY SCHLUNDT                                21 OCTOBER 1968
#
# FUNCTIONAL DESCRIPTION
#
#       SELF-PERPETUATING T5 TASKS WHICH GENERATE THE COMMAND SIGNALS
#       FOR THE PITCH AND YAW SPS GIMBAL ACTUATORS DURING TVC (SPS) BURNS,

```

```
#      IN RESPONSE TO BODY-AXIS RATE COMMANDS FROM CROSS-PRODUCT STEERING
#      (S40.8).  IF NO STEERING (IMPULSIVE BURNS) MAINTAINS ATTITUDE-HOLD
#      ABOUT THE REFERENCE (INITIAL) DIRECTIONS (ZERO RATE COMMANDS).
#
#      THE PITCH AND YAW LOOPS ARE SEPARATE, BUT STRUCTURED IDENTICALLY.
#      EACH ATTITUDE-RATE LOOP INCLUDES GIMBAL ANGLE RATE DERIVATION,
#      GIMBAL/BODY AXIS TRANSFORMATION, BODY-AXIS ATTITUDE ERROR
#      INTEGRATION WITH ERROR LIMITING, THE GENERALIZED 6TH-ORDER FILTERS
#      FOR CSM OR CSM/LM OPERATION. A FILTER OUTPUT LIMITER.
#      CG-OFFSET TRACKER FILTER, AND THE CG-TRACKER MINOR LOOP.
#
#      THE DAPS ARE CYCLIC, CALLING EACH OTHER AT 1/2 THE DAP SAMPLE
#      TIME, AS DETERMINED BY T5TVCDT.  THE ACTUATOR COMMANDS ARE
#      REGENERATED AS ANALOG VOLTAGES BY THE OPTICS ERROR COUNTERS, WHICH
#      TRANSMIT THE SIGNAL TO THE ACTUATOR SERVOS WHEN THERE IS PROPER CDU
#      MODING.
#
# CALLING SEQUENCE.... (TYPICALLY)
#
#      T5 CALL OF TVCDAPON (TVCINITIALIZE) BY DOTVCON (P40)
#      T5 CALL OF DAPINIT (TVCDAPS) BY TVCINIT4 (TVCINITIALIZE)
#      T5 CALL OF PITCHDAP BY DAPINIT
#      T5 CALL OF YAWDAP BY PITCHDAP
#      T5 CALL OF PITCHDAP BY YAWDAP
#      ETC.
#      (AUTOMATIC SEQUENCING FROM TVCDAPON)
#
# NORMAL EXIT MODE....RESUME
#
# ALARM OR ABORT EXIT MODES....NONE
#
# SUBROUTINES CALLED....
#
#      HACK FOR STROKE TEST (V68) WAVEFORM GENERATION
#      PCOPY, YCOPY FOR COPY-CYCLES (USED ALSO BY TVC RESTART PACKAGE)
#      DAPINIT FOR INITIAL CDUS FOR RATE MEASUREMENTS
#      ERRORLIM, ACTLIM FOR INPUT (ATTITUDE-ERROR INTEGRATION) AND
#      OUTPUT (ACTUATOR COMMAND) LIMITING, COMMON TO PITCH AND
#      YAW DAPS
#      FWDFLTR (INCLUDING OPTVARK) AND PRECOMP, TO COMPUTE FILTER
#      OUTPUTS AND STORAGE VALUES
#      RESUME
#
# Page 962
# OTHER INTERFACES
#
```

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```
# S40.8 CROSS-PRODUCT STEERING FOR BODY AXIS RATE COMMANDS OMEGAY,ZC
# S40.15 FOR THE INITIAL DAP GAINS VARK AND 1/CONACC
# TVCEXECUTIVE FOR DAP GAIN UPDATES AND TMC LOOP OPERATIONS
# TVCRESTART PACKAGE FOR TVC RESTART PROTECTION.
#
# ERASABLE INITIALIZATION REQUIRED....
#
# PAD-LOAD ERASABLES (SEE ERASABLE ASSIGNMENTS)
# CONFIGURATION BITS (14, 13) OF DAPDATR1 AS IN R03
# ENGINE-ON BIT (11.13) FOR RESTARTS
# TVCPHASE FOR RESTARTS (SEE DOTVCON, AND TVCINIT4)
# T5 BITS (15,14 OF FLAGWRD6) FOR RESTARTS
# MISCELLANEOUS VARIABLES SET UP OR COMPUTED BY TVCDAPON...TVCINIT4,
# INCLUDING THE ZEROING OF TEMPORARIES BY MRCLEAN
# CDUX,Y,Z AND SINCDEX... COSCDUX AS PREPARED BY QUICTRIG1 (WITH
# UPDATES EVERY 1/2 SECOND)
# ALSO G+N PRIMARY, TVC ENABLE, AND OPTICS ERROR COUNTER ENABLE
# UNLESS BENCH-TESTING.
#
# OUTPUT....
#
# TVCPITCH AND TVCYAW WITH COUNTER RELEASE (11.14 AND 11.13 INCREMENTAL
# COMMANDS TO OPTICS ERROR COUNTERS), FILTER NODES, BODY-
# AXIS ATTITUDE ERROR INTEGRATOR, TOTAL ACTUATOR COMMANDS,
# OFFSET-TRACKER-FILTER OUTPUTS, ETC.
#
# DEBRIS....
#
# MUCH, SHAREABLE WITH RCS/ENTRY, IN EBANK6 ONLY
#
# BANK 17
# SETLOC DAPS2
# BANK
#
# EBANK= BZERO
#
# COUNT* $$/DAPS
#
# Page 963
# PITCH TVCDAP STARTS HERE....(INCOPORATES CSM/LEM DAP FILTER, MODOR DESIGN)
#
# PITCHDAP LXCH BANKRUPT # T5 ENTRY, NORMAL OR VIA DAPINIT
# EXTEND
# QXCH QRUPT
#
# CAF YAWT5 # SET UP T5 CALL FOR YAW AUTOPILOT (LOW-
```

|            |        |           |   |                                          |
|------------|--------|-----------|---|------------------------------------------|
|            | TS     | T5LOC     | # | ORDER PART OF 2CADR ALREADY THERE)       |
|            | CAE    | T5TVCDT   |   |                                          |
|            | TS     | TIME5     |   |                                          |
| PSTROKER   | CCS    | STROKER   | # | (STRKFLG) CHECK FOR STROKE TEST          |
|            | TC     | HACK      | # | TEST-START OR TEST-IN-PROGRESS           |
|            | TCF    | +2        | # | NO-TEST                                  |
|            | TC     | HACK      | # | TEST-IN-PROGRESS                         |
| PCDUDOTS   | CAE    | CDUY      | # | COMPUTE CDUYDOT (USED BY PITCH AND YAW)  |
|            | XCH    | PCDUYPST  |   |                                          |
|            | EXTEND |           |   |                                          |
|            | MSU    | PCDUYPST  |   |                                          |
|            | TCR    | RLIMTEST  | # | RATE TEST                                |
|            | TS     | MCDUYDOT  | # | (MINUS, SC.AT 1/2TVCDT REVS/SEC)         |
|            | CAE    | CDUZ      | # | COMPUTE CDUZDOT (USED BY PITCH AND YAW)  |
|            | XCH    | PCDUZPST  |   |                                          |
|            | EXTEND |           |   |                                          |
|            | MSU    | PCDUZPST  |   |                                          |
|            | TCR    | RLIMTEST  | # | RATE TEST                                |
|            | TS     | MCDUZDOT  | # | (MINUS, SC.AT 1/2TVCDT REVS/SEC)         |
|            | TCF    | PINTEGRAL |   |                                          |
| RLIMTEST   | TS     | TTMP1     | # | TEST FOR EXCESSIVE CDU RATES (GREATER    |
|            | EXTEND |           | # | THAN 2.33 DEG IN ONE SAMPLE PERIOD       |
|            | MP     | 1/RTLIM   |   |                                          |
|            | EXTEND |           |   |                                          |
|            | BZF    | +3        |   |                                          |
|            | CAF    | ZERO      |   |                                          |
|            | TS     | TTMP1     |   |                                          |
|            | CAE    | TTMP1     |   |                                          |
|            | TC     | Q         |   |                                          |
| PINTEGRAL  | EXTEND |           | # | COMPUTE INTEGRAL OF BODY-AXIS PITCH-RATE |
|            | DCA    | PERRB     | # | ERROR, SC.AT B-1 REVS                    |
|            | DXCH   | ERRBTMP   |   |                                          |
|            | EXTEND |           |   |                                          |
|            | DCA    | OMEGAYC   |   |                                          |
|            | DAS    | ERRBTMP   |   |                                          |
| # Page 964 | CS     | COSCDUZ   | # | PREPARE BODY-AXIS PITCH RATE, OMEGAYB    |
|            | EXTEND |           |   |                                          |
|            | MP     | COSCDUX   |   |                                          |

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|          |        |          |                                            |
|----------|--------|----------|--------------------------------------------|
|          | DDOUBL |          |                                            |
|          | EXTEND |          |                                            |
|          | MP     | MCDUYDOT |                                            |
|          | DDOUBL |          |                                            |
|          | DXCH   | OMEGAYB  |                                            |
|          | CS     | MCDUZDOT |                                            |
|          | EXTEND |          |                                            |
|          | MP     | SINCDEX  |                                            |
|          | DDOUBL |          |                                            |
|          | DAS    | OMEGAYB  | # (COMPLETED OMEGAYB, SC.AT 1/2TVCDT REVS) |
|          | EXTEND |          | # PICK UP -OMEGAYB (SIGN CHNG, INTEGRATE)  |
|          | DCS    | OMEGAYB  |                                            |
|          | DAS    | ERRBTMP  |                                            |
| PERORLIM | TCR    | ERRORLIM | # PITCH BODY-AXIS-ERROR INPUT LIMITER      |
| PFORWARD | EXTEND |          | # PREPARE THE FILTER STORAGE LOCATIONS     |
|          | DCA    | PTMP1    | # FOR THE PITCH CHANNEL                    |
|          | DXCH   | TMP1     |                                            |
|          | EXTEND |          |                                            |
|          | DCA    | PTMP3    |                                            |
|          | DXCH   | TMP3     |                                            |
|          | EXTEND |          |                                            |
|          | DCA    | PTMP5    |                                            |
|          | DXCH   | TMP5     |                                            |
|          | TCR    | FWDFLTR  | # GO COMPUTE PRESENT OUTPUT                |
|          |        |          | # (INCLUDES VARIABLE GAIN PACKAGE)         |
| POFFSET  | EXTEND |          |                                            |
|          | DCA    | PDELOFF  |                                            |
|          | DAS    | CMDTMP   | # NO SCALED AT B+0 ASCREV                  |
| PACLIM   | TCR    | ACTLIM   | # ROUND OFF & LIMIT PITCH ACTUATOR COMMAND |
| POUT     | CS     | PCMD     | # INCREMENTAL PITCH COMMAND                |
|          | AD     | CMDTMP   |                                            |
|          | ADS    | TVCPITCH | # UPDATE THE ERROR COUNTER (NO RESTART-    |
|          |        |          | # PROTECT. SINCE ERROR CNTR ZEROED)        |
|          | CAF    | BIT11    | # BIT FOR TVCPITCH COUNT RELEASE           |
|          | EXTEND |          |                                            |
|          | WOR    | CHAN14   |                                            |

```

PPRECOMP      EXTEND      #      PREPARE THE FILTER STORAGE FOR PITCH
# Page 965

      DCA      PTMP2
      DXCH     TMP2
      EXTEND
      DCA      PTMP4
      DXCH     TMP4
      EXTEND
      DCA      PTMP6
      DXCH     TMP6

      TCR      PRECOMP     #      TO THE FILTER FOR PRECOMPUTATION

DELBARP        CAE      DELPBAR +1
      EXTEND
      MP      E(-AT)
      TS      DELBRTMP +1
      CAE      DELPBAR
      EXTEND
      MP      E(-AT)
      DAS      DELBRTMP
      CAE      CMDTMP
      EXTEND
      MP      1-E(-AT)
      DAS      DELBRTMP

PCOPYCYC      TCR      PCOPY      # PITCH COPYCYCLE

PDAPEND      TCF      RESUME      # PITCH DAP COMPLETED
# Page 966
# PITCH TVCDAP COPYCYCLE SUBROUTINE (CALLED VIA PITCH TVCDAP OR TVC RESTART PACKAGE)

PCOPY        INCR      TVCPHASE      # RESTART-PROTECT THE COPYCYCLE.          (1)
      #      NOTE POSSIBLE RE-ENTRY FROM RESTART
      #      PACKAGE, SHOULD A RESTART OCCUR
      #      DURING PITCH COPYCYCLE.

      EXTEND
      DCA      TMP1
      DXCH     PTMP1
      EXTEND
      DCA      TMP2
      DXCH     PTMP2
      EXTEND
      DCA      TMP3
      DXCH     PTMP3

```



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```
EXTEND
DCA      TMP4
DXCH     PTMP4
EXTEND
DCA      TMP5
DXCH     PTMP5
EXTEND
DCA      TMP6
DXCH     PTMP6

PMISC    EXTEND          # MISC...PITCH-RATE-ERROR INTEGRATOR
DCA      ERRBTMP
TS       AK1             #          FOR PITCH NEEDLES, SC.AT B-1 REVS
DXCH     PERRB

CAE      CMDTMP          #          PITCH ACTUATOR COMMAND
TS       PCMD

EXTEND          #          PITCH OFFSET-TRACKER-FILTER
DCA      DELBRTMP
DXCH     DELPBAR

INCR     TVCPHASE        # PITCH COPYCYCLE COMPLETED          (2)

TC       Q

# Page 967
# YAW TVCDAP STARTS HERE...(INCORPORATES CSM/LEM DAP FILTER, MODOR DESIGN)

YAWDAP    LXCH    BANKRUPT      # T5 ENTRY, NORMAL
EXTEND
QXCH     QRUP

CAF      PITCHT5      # SET UP T5 CALL FOR PITCH AUTOPILOT (LOW-
TS       T5LOC        #          ORDER PART OF 2CADR ALREADY THERE)
CAE      T5TVCDT
TS       TIME5

YSTROKER  CCS      STROKER      # (STRKFLG) CHECK FOR STROKE TEST
TC       HACK        # TEST-START OR TEST-IN-PROGRESS
TCF      +2          # NO-TEST
TC       HACK        # TEST-IN-PROGRESS

# USE BODY RATES FROM PITCHDAP (PCDUDOTS)

YINTEGRL  EXTEND          # COMPUTE INTEGRAL OF BODY-AXIS YAW-RATE
```

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|            |        |          |   |                                          |
|------------|--------|----------|---|------------------------------------------|
|            | DCA    | YERRB    | # | ERROR, SC.AT B-1 REVS                    |
|            | DXCH   | ERRBTMP  |   |                                          |
|            | EXTEND |          |   |                                          |
|            | DCA    | OMEGAZC  |   |                                          |
|            | DAS    | ERRBTMP  |   |                                          |
|            | CAE    | COSCDUZ  | # | PREPARE BODY-AXIS YAW-RATE, OMEGAZB      |
|            | EXTEND |          |   |                                          |
|            | MP     | SINCDEX  |   |                                          |
|            | DDOUBL |          |   |                                          |
|            | EXTEND |          |   |                                          |
|            | MP     | MCDUYDOT |   |                                          |
|            | DDOUBL |          |   |                                          |
|            | DXCH   | OMEGAZB  |   |                                          |
|            | CS     | MCDUZDOT |   |                                          |
|            | EXTEND |          |   |                                          |
|            | MP     | COSCDUX  |   |                                          |
|            | DDOUBL |          |   |                                          |
|            | DAS    | OMEGAZB  | # | (COMPLETED OMEGAZB, SC.AT 1/2TVCDT REVS) |
|            | EXTEND |          | # | PICK UP -OMEGAZB (SIGN CHNG, INTEGRATE)  |
|            | DCS    | OMEGAZB  |   |                                          |
|            | DAS    | ERRBTMP  |   |                                          |
| YERORLIM   | TCR    | ERRORLIM | # | YAW BODY-AXIS-ERROR INPUT LIMITER        |
| YFORWARD   | EXTEND |          | # | PREPARE THE FILTER STORAGE LOCATIONS     |
|            | DCA    | YTMP1    | # | FOR THE YAW CHANNEL                      |
| # Page 968 | DXCH   | TMP1     |   |                                          |
|            | EXTEND |          |   |                                          |
|            | DCA    | YTMP3    |   |                                          |
|            | DXCH   | TMP3     |   |                                          |
|            | EXTEND |          |   |                                          |
|            | DCA    | YTMP5    |   |                                          |
|            | DXCH   | TMP5     |   |                                          |
|            | TCR    | FWDFLTR  | # | GO COMPUTE PRESENT OUTPUT                |
|            |        |          | # | (INCLUDES VARIABLE GAIN PACKAGE)         |
| YOFFSET    | EXTEND |          |   |                                          |
|            | DCA    | YDELOFF  |   |                                          |
|            | DAS    | CMDTMP   | # | NOW SCALED AT B+0 ASCREV                 |

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|                                                                              |        |             |                                                                                |
|------------------------------------------------------------------------------|--------|-------------|--------------------------------------------------------------------------------|
| YACLIM                                                                       | TCR    | ACTLIM      | # YAW ACTUATOR-COMMAND-LIMITER                                                 |
| YOUT                                                                         | CS     | YCMD        | # INCRMENTAL YAW COMMAND                                                       |
|                                                                              | AD     | CMDTMP      |                                                                                |
|                                                                              | ADS    | TVCYAW      | # UPDATE THE ERROR COUNTER (NO RESTART-<br># PROTECT, SINCE ERROR CNTR ZEROED) |
|                                                                              | CAF    | BIT12       | # BIT FOR TVCYAW COUNT RELEASE                                                 |
|                                                                              | EXTEND |             |                                                                                |
|                                                                              | WOR    | CHAN14      |                                                                                |
| YPRECOMP                                                                     | EXTEND |             | # PREPARE THE FILTER STORAGE FOR YAW                                           |
|                                                                              | DCA    | YTMP2       |                                                                                |
|                                                                              | DXCH   | TMP2        |                                                                                |
|                                                                              | EXTEND |             |                                                                                |
|                                                                              | DCA    | YTMP4       |                                                                                |
|                                                                              | DXCH   | TMP4        |                                                                                |
|                                                                              | EXTEND |             |                                                                                |
|                                                                              | DCA    | YTMP6       |                                                                                |
|                                                                              | DXCH   | TMP6        |                                                                                |
|                                                                              | TCR    | PRECOMP     | # TO THE FILTER FOR PRECOMPUTATION                                             |
| DELBARY                                                                      | CAE    | DELYBAR +1  | # UPDATE YAW OFFSET-TRACKER-FILTER                                             |
|                                                                              | EXTEND |             |                                                                                |
|                                                                              | MP     | E(-AT)      |                                                                                |
|                                                                              | TS     | DELBRTMP +1 |                                                                                |
|                                                                              | CAE    | DELYBAR     |                                                                                |
|                                                                              | EXTEND |             |                                                                                |
|                                                                              | MP     | E(-AT)      |                                                                                |
|                                                                              | DAS    | DELBRTMP    |                                                                                |
|                                                                              | CAE    | CMDTMP      |                                                                                |
|                                                                              | EXTEND |             |                                                                                |
|                                                                              | MP     | 1-E(-AT)    |                                                                                |
|                                                                              | DAS    | DELBRTMP    |                                                                                |
| # Page 969                                                                   |        |             |                                                                                |
| YCOPYCYC                                                                     | TCR    | YCOPY       | # YAW COPYCYCLE                                                                |
| YDAPEND                                                                      | TCF    | RESUME      | # YAW DAP COMPLETED                                                            |
| # Page 970                                                                   |        |             |                                                                                |
| # TVCDAP COPYCYCLE SUBROUTINE (CALLED VIA YAW TVCDAP OR TVC RESTART PACKAGE) |        |             |                                                                                |
| YCOPY                                                                        | INCR   | TVCPHASE    | # RESTART-PROTECT THE COPYCYCLE. (3)                                           |
|                                                                              |        |             | # NOTE POSSIBLE RE-ENTRY FROM RESTART                                          |

```
# PACKAGE, SHOULD A RESTART OCCUR
# DURING YAW COPYCYCLE.
```

```
EXTEND
DCA    TMP1
DXCH   YTMP1
EXTEND
DCA    TMP2
DXCH   YTMP2
EXTEND
DCA    TMP3
DXCH   YTMP3
EXTEND
DCA    TMP4
DXCH   YTMP4
EXTEND
DCA    TMP5
DXCH   YTMP5
EXTEND
DCA    TMP6
DXCH   YTMP6
```

```
YMISC    EXTEND    # MISC...YAW-RATE-ERROR INTEGRATOR
          DCA      ERRBTMP
          TS       AK2    # FOR YAW NEEDLES, SC.AT B-1 REVS
          DXCH     YERRB

          CAE      CMDTMP
          TS       YCMD

          EXTEND
          DCA      DELBRTMP
          DXCH     DELYBAR

          CAF      ZERO    # YAW COPYCYCLE COMPLETED
          TS       TVCPHASE # RESET TVCPHASE

          TC       Q
```

```
# Page 971
```

```
# SUBROUTINES COMMON TO BOTH PITCH AND YAW DAPS....
```

```
# INITIALIZATION PACKAGE FOR CDURATES....
```

```
DAPINIT    LXCH    BANKRUPT    # T5 RUPT ENTRY (CALLED BY TVCINT4)
```

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```
CAF    NEGONE      #      SET UP
AD     T5TVCDT     #      T5 CALL FOR PITCHDAP IN TVCDT SECS
AD     NEGMAX      #      (T5TVCDT = POSMAX - TVCDT/2 +1)
AD     T5TVCDT
TS     TIME5
CAF    PITCHT5     #      (BBCON ALREADY THERE)
TS     T5LOC

CAE    CDUY        # READ AND STORE CDUS FOR DIFFERENTIATOR
TS     PCDUYPST    #      PAST-VALUES
CAE    CDUZ
TS     PCDUZPST

TCF    NOQRSM
```

# BODY-AXIS-ERROR INPUT LIMITER PACKAGE....

```
ERRORLIM  CAE    ERRBTMP      # CHECK FOR INPUT-ERROR LIMIT
           EXTEND      #      CHECKS UPPER WORD ONLY
           MP      1/ERRLIM
           EXTEND
           BZF      +6
           CCS      ERRBTMP
           CAF      ERRLIM
           TCF      +2
           CS      ERRLIM
           TS      ERRBTMP      # LIMIT WRITES OVER UPPER WORD ONLY

           TC      Q
```

# ACTUATOR-COMMAND LIMITER PACKAGE....

```
ACTLIM    CAE    CMDTMP  +1    # ROUND UP FOR OUTPUT
           DOUBLE
           TS      L
           CAF      ZERO
           AD      CMDTMP

           EXTEND      # CHECK FOR ACTUATOR COMMAND LIMIT
           MP      1/ACTSAT
           EXTEND
```

# Page 972

```
BZF      +6
CCS      CMDTMP      # APPLY LIMITS
CAF      ACTSAT
TCF      +2
```

|    |        |                            |
|----|--------|----------------------------|
| CS | ACTSAT |                            |
| TS | CMDTMP | # LIMITS WRITE OVER CMDTMP |
| TC | Q      |                            |

# FILTER COMPUTATIONS FOR PRESENT OUTPUT.....

|         |     |          |
|---------|-----|----------|
| FWDFLTR | CAF | ZERO     |
|         | TS  | DAP1     |
|         | TS  | DAP2     |
|         | TS  | DAP3     |
|         | TS  | CMDTMP   |
|         | TS  | DELBRTMP |

|         |        |            |                     |
|---------|--------|------------|---------------------|
| 1DAPCAS | CAE    | ERRBTMP +1 | # FIRST DAP CASCADE |
|         | EXTEND |            |                     |
|         | MP     | N10        | # N10               |
|         | TS     | DAP1 +1    |                     |
|         | CA     | ERRBTMP    |                     |
|         | EXTEND |            |                     |
|         | MP     | N10        | # N10               |
|         | DAS    | DAP1       |                     |
|         | DXCH   | TMP1       |                     |
|         | DAS    | DAP1       |                     |

|         |        |         |                      |
|---------|--------|---------|----------------------|
| 2DAPCAS | CAE    | DAP1 +1 | # SECOND DAP CASCADE |
|         | EXTEND |         |                      |
|         | MP     | N10 +5  | # N20                |
|         | TS     | DAP2 +1 |                      |
|         | CA     | DAP1    |                      |
|         | EXTEND |         |                      |
|         | MP     | N10 +5  | # N20                |
|         | DAS    | DAP2    |                      |
|         | DXCH   | TMP3    |                      |
|         | DAS    | DAP2    |                      |

|        |          |                          |
|--------|----------|--------------------------|
| CAE    | DAPDATR1 | # TEST FOR LEM ON OR OFF |
| MASK   | BIT14    |                          |
| CCS    | A        |                          |
| TCF    | 3DAPCAS  | # LEM ON                 |
| EXTEND |          | # LEM OFF                |
| DCA    | DAP2     |                          |
| DXCH   | DAP3     |                          |
| TCF    | OPTVARK  |                          |

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# Page 973

3DAPCAS

```
CAE      DAP2      +1      # THIRD DAP CASCADE
EXTEND
MP       N10       +10D     #          N30
TS       DAP3      +1
CA       DAP2
EXTEND
MP       N10       +10D     #          N30
DAS      DAP3
DXCH     TMP5
DAS      DAP3
```

OPTVARK

```
CS       DAP3      +1      # VARIABLE GAIN PACKAGE
EXTEND                                     # (ALSO, SIGN CHANGE IN FORWARD LOOP)
MP       VARK                                     # SCALED AT 1/(8 ASCREV) OF ACTUAL VALUE
TS       CMDTMP    +1
CS       DAP3
EXTEND
MP       VARK
DAS      CMDTMP

DXCH     CMDTMP                                # FIX UP SCALING -- SCALED B+3 ASCREVS
DDOUBL
DDOUBL
DXCH     CMDTMP                                #          -- SCALED B+1 ASCREVS
# NOTE -- THERE IS AN INHERENT GAIN OF
# (B+1 ASCREVS) ON THE OUTPUT DACS.
```

TC Q

# FILTER PRECOMPUTATIONS FOR NEXT PASS.....

PRECOMP

```
CAF      ZERO      # **** FIRST CASCADE FILTER *****
TS       TTMP1
TS       TTMP2

CA       ERRBTMP   +1      # MULTIPLY INPUT BY
EXTEND
MP       N10       +1      #          N11/2
TS       TTMP1     +1
CA       ERRBTMP
EXTEND
MP       N10       +1      #          N11/2
DAS      TTMP1

CS       DAP1      +1      # MULTIPLY OUTPUT BY
```

EXTEND

|    |       |    |   |       |
|----|-------|----|---|-------|
| MP | N10   | +3 | # | D11/2 |
| TS | TTMP2 | +1 |   |       |
| CS | DAP1  |    |   |       |

# Page 974

EXTEND

|     |       |    |   |       |
|-----|-------|----|---|-------|
| MP  | N10   | +3 | # | D11/2 |
| DAS | TTMP2 |    |   |       |

DXCH TTMP2

DAS TTMP1

DXCH TTMP1

DDOUBL

DAS TMP2

DXCH TMP2

DXCH TMP1

CAF ZERO

TS TTMP1

TS TMP2

CA ERRBTMP +1

EXTEND # MULTIPLY INPUT BY

MP N10 +2 # SECOND-ORDER NUMERATOR COEFF.

TS TTMP1 +1 # N12

CA ERRBTMP

EXTEND

MP N10 +2 # N12

DAS TTMP1

CS DAP1 +1

EXTEND # MULTIPLY OUTPUT BY

MP N10 +4 # D12

TS TMP2 +1

CS DAP1

EXTEND

MP N10 +4 # D12

DAS TMP2

DXCH TTMP1

DAS TMP2

2CASFLTR

CAF ZERO

TS TTMP1

# \*\*\*\* SECOND CASCADE FILTER \*\*\*\*



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# Page 975

```
TS      TTMP2

CA      DAP1      +1      # MULTIPLY INPUT BY
EXTEND
MP      N10       +6      #      N21/2
TS      TTMP1     +1
CA      DAP1
EXTEND
MP      N10       +6      #      N21/2

DAS     TTMP1

CS      DAP2      +1      # MULTIPLY OUTPUT BY
EXTEND
MP      N10       +8D     #      D21/2
TS      TTMP2     +1
CS      DAP2
EXTEND
MP      N10       +8D     #      D21/2
DAS     TTMP2

DXCH    TTMP2
DAS     TTMP1
DXCH    TTMP1
DDOUBL
DAS     TMP4

DXCH    TMP4
DXCH    TMP3

CAF     ZERO
TS      TTMP1
TS      TMP4

CA      DAP1      +1      # MULTIPLY INPUT BY
EXTEND                                # SECOND-ORDER NUMERATOR COEFF.
MP      N10       +7      #      N22
TS      TTMP1     +1
CA      DAP1
EXTEND
MP      N10       +7      #      N22
DAS     TTMP1

CS      DAP2      +1      # MULTIPLY OUTPUT BY
EXTEND
MP      N10       +9D     #      D22
```

```

      TS      TMP4      +1
      CS      DAP2
      EXTEND
      MP      N10      +9D      #      D22
      DAS      TMP4

      DXCH     TTMP1
      DAS      TMP4

      CAE      DAPDATR1      # TEST FOR LEM ON OR OFF
      MASK     BIT13
      CCS      A
      TC       Q      # EXIT IF LEM OFF

# Page 976
3CASFLTR      CAF      ZERO      # **** THIRD CASCADE FILTER ****
               TS      TTMP1
               TS      TTMP2

               CA      DAP2      +1      # MULTIPLY INPUT BY (1/2)
               EXTEND
               MP      N10      +11D      #      N31/2
               TS      TTMP1      +1
               CA      DAP2
               EXTEND
               MP      N10      +11D      #      N31/2
               DAS      TTMP1

               CS      DAP3      +1
               EXTEND
               MP      N10      +13D      #      D31/2
               TS      TTMP2      +1
               CS      DAP3
               EXTEND
               MP      N10      +13D      #      D31/2
               DAS      TTMP2

               DXCH     TTMP2
               DAS      TTMP1
               DXCH     TTMP1
               DDOUBL
               DAS      TMP6

               DXCH     TMP6
               DXCH     TMP5

```

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```
CAF      ZERO
TS       TTMP1
TS       TMP6

CA       DAP2    +1    # MULTIPLY INPUT BY
EXTEND
MP       N10     +12D   #          N32
TS       TTMP1   +1
CA       DAP2
EXTEND
MP       N10     +12D   #          N32
DAS      TTMP1

CS       DAP3    +1
EXTEND
MP       N10     +14D   #          D32
TS       TMP6    +1
CS       DAP3
EXTEND

MP       N10     +14D   #          D32
DAS      TMP6

DXCH     TTMP1
DAS      TMP6

TC       Q
```

# Page 977

# Page 978

# CONSTANTS FOR AUTOPILOTS

# NOTE....1 ASCREV (ACTUATOR CMD SCALING) = 85.41 ARCSEC/BIT OR 1.07975111 REVS (85.41x16384/360)  
# 1 SPASCREV (SPECIAL ACTUATOR CMD SCALING) = 1.04620942 REVS

```
ACTSAT    DEC      253          # ACTUATOR LIMIT (6 DEG), SC.AT 1ASCREV
1/ACTSAT   DEC      .0039525692 # RECIPROCAL (1/253)

ERRLIM     EQUALS  BIT13        # FILTER INPUT LIMIT....B-3 REVS (45DEG),
1/ERRLIM    EQUALS  BIT3         #          SC.AT B-1 REV, AND ITS RECIPROCAL

PITCHT5    GENADR   PITCHDAP     # UPPER WORDS OF T5 2CADRS, LOWER WORDS
DAPT5      GENADR   DAPINIT      #          (BBCON) ALREADY THERE. ORDER IS
YAWT5      GENADR   YAWDAP       #          REQUIRED.

1/RTLIM     DEC      0.004715    # .004715(CDUDIF) = 0 IF CDUIF < 2.33 DEG
1-E(-AT)    OCT      00243       # AT = .01SEC....EITHER(1/A=4SEC, T=40MS),
```

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E(-AT)                      OCT            37535                      #                                      OR(1/A=8SEC, T=80MS)

This code is written to file `src/TVCDAPS.s`.

## A.119 TVCEEXECUTIVE

```

1901  <src/TVCEEXECUTIVE.s 1901>≡
# Copyright:      Public domain.
# Filename:       TVCEEXECUTIVE.agc
# Purpose:        Part of the source code for Colossus 2A, AKA Comanche 055.
#                It is part of the source code for the Command Module's (CM)
#                Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:     yaYUL
# Contact:        Ron Burkey <info@sandroid.org>.
# Website:        www.ibiblio.org/apollo.
# Pages:          945-950
# Mod history:    2009-05-12 RSB   Adapted from the Colossus249/ file of the
#                same name, using Comanche055 page images.
#                2009-05-20 RSB   Corrections:  CAE -> CAF in one place.
#                2009-05-21 RSB   In 1SHOTCHK, a CAF SEVEN was corrected to
#                CAF SIX.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum.  The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum.  Many
# thanks to both.  The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo.  If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 055 of AGC program Comanche by NASA
#       2021113-051.  10:28 APR. 1, 1969
#
#       This AGC program shall also be referred to as
#       Colossus 2A
#
# Page 945
# PROGRAM NAME....      TVCEEXECUTIVE, CONSISTING OF TVCEXEC, NEEDLEUP, VARGAINS
#                       1SHOTCHK, REPCHEK, CG.CORR, COPYCYCLES, ETC.
# LOG SECTION....      TVCEEXECUTIVE                SUBROUTINE ...DAPCSM
# MOD BY SCHLUNDT                      21 OCTOBER 1968
#
# FUNCTIONAL DESCRIPTION....
#       *A SELF-PERPETUATING WAITLIST TASK AT 1/2 SECOND INTERVALS WHICH:
#       PREPARES THE ROLL WITH OGA (CDUX)
#       PREPARES THE ROLL FDAI NEEDLE (FLY-TO  OGA ERROR)
#       PREPARES THE ROLL PHASE PLANE  OGAERR  (FLY-FROM  OGA ERROR)

```

```

#     PREPARES THE TVC ROLLDAP TASK WAITLIST CALL (3 CS DELAY)
#     UPDATES THE NEEDLES DISPLAY
#     UPDATES THE VEHICLE MASS AND CALLS MASSPROP TO UPDATE INERTIA DATA
#     UPDATES PITCH, YAW, AND ROLL DAP GAINS FROM MASSPROP DATA
#     PERFORMS ONE-SHOT CORRECTION FOR TMC LOOP 0-3 SEC AFTER IGNITION
#     PERFORMS REPETITIVE UPDATES FOR THE TMC LOOP AFTER THE ONE-SHOT CORR.
#
# CALLING SEQUENCE....
#     *TVCEXEC CALLED AS A WAITLIST TASK, IN PARTICULAR BY TVCINIT4 AND BY
#     ITSELF, BOTH AT 1/2 SECOND INTERVALS
#
# NORMAL EXIT MODE.... TASKOVER
#
# ALARM OR ABORT EXIT MODES.... NONE
#
# SUBROUTINES CALLED....NEEDLER, S40.15, MASSPROP, TASKOVER, IBNKCALL
#
# OTHER INTERFACES....
#     *TVCRESTART PACKAGE FOR RESTARTS
#     *PITCHDAP, YAWDAP FOR VARIABLE GAINS AND ENGINE TRIM ANGLES
#
# ERASABLE INITIALIZATION REQUIRED....
#     *SEE TVCDAPON....TVCINIT4
#     *VARK AND 1/CONACC (S40.15 OF R03)
#     *PAD LOAD EREPFRAC
#     *BITS 15,14 OF FLAGWRD6 (T5 BITS)
#     *TVCEXPHS FOR RESTARTS
#     *ENGINE-ON BIT (11.13) FOR RESTARTS
#     *CDUX, OGAD
#
# OUTPUT....
#     *ROLL DAP OGANOW, FDAI NEEDLE= (AK). AND PHASE PLANE OGAERR
#     *VARIABLE GAINS FOR PITCH/YAW AND ROLL TVC DAPS
#     *SINGLE-SHOT AND REPETITIVE CORRECTIONS TO ENGINE TRIM ANGLES
#     PACTOFF AND YACTOFF
#
# DEBRIS....     MUCH, BUT SHAREABLE WITH RCS/ENTRY, ALL IN EBANK6

# Page 946
#     BANK      16
#     SETLOC    DAPROLL
#     BANK
#     EBANK=    BZERO
#     COUNT*    $$/TVCX

TVCEXEC      CS      FLAGWRD6      # CHECK FOR TERMINATION (BITS 15,14 READ

```

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```

MASK    OCT60000      #      10 FROM TVCDAPON TO RCSDAPON)
EXTEND
BZMF    TVCEXFIN      # TERMINATE

CAF      .5SEC        # W.L. CALL TO PERPETUATE TVCEXEC
TC       WAITLIST
EBANK=   BZERO
2CADR    TVCEXEC

ROLLPREP  CAE      CDUX      # UPDATE ROLL LADDERS (NO NEED TO RESTART-
XCH      OGANOW      #      PROTECT, SINCE ROLL DAPS RE-START)
XCH      OGAPAST

CAF      OGAD         # PREPARE ROLL FDAI NEEDLE WITH FLY-TO
EXTEND   ERROR (COMMAND - MEASURED)
MSU      OGANOW
TS       AK          # FLY-TO OGA ERROR, SC.AT B-1 REVS

EXTEND   # PREPARE ROLL DAP PHASE PLANE OGAERR
MP       -BIT14
TS       OGAERR      # PHASE-PLANE (FLY-FROM) OGAERROR,
#      SC.AT B+0 REVS

CAF      THREE        # SET UP ROLL DAP TASK (ALLOW SOME TIME)
TC       WAITLIST
EBANK=   BZERO
2CADR    ROLLDAP

NEEDLEUP  TC      IBNKCALL  # DO A NEEDLES UPDATE (RETURNS AFTER CADR)
CADR     NEEDLER  #      (NEEDLES RESTARTS ITSELF)

VARGAINS  CAF      BIT13    # CHECK ENGINE-ON BIT TO INHIBIT VARIABLE
EXTEND    #      GAINS AND MASS IF ENGINE OFF
RAND      DSALMOUT  # CHANNEL 11
CCS       A
TCF       +4        #      ON, SO OK TO UPDATE GAINS AND MASS
+5        CAF      TWO      #      OFF, SO BYPASS MASS/GAIN UPDATES,
TS        TVCEXPHS  #      ALSO ENTRY FROM CCS BELOW WITH
TCF       1SHOTCHK  #      VCNTR = -0 (V97 R40 ENGFAIL)
CCS       VCNTR     #      TEST FOR GAIN OF UPDATE TIME
TCF       +4        #      NOT YET

# Page 947
TCF       GAINCHNG  #      NOW
TCF       +0        #      NOT USED
TCF       VARGAINS +5 #      NO, LOTHURST (S40.6 R40)
```

|          |    |        |            |   |                                          |     |
|----------|----|--------|------------|---|------------------------------------------|-----|
|          | +4 | TS     | VCNTRTMP   | # | PROTECT VCNTR AND                        |     |
|          |    | CAE    | CSMMASS    | # | CSMMASS DURING AN IMPULSIVE BURN         |     |
|          |    | TS     | MASSTMP    |   |                                          |     |
|          |    | TCF    | EXECCOPY   |   |                                          |     |
| GAINCHNG |    | TC     | IBNKCALL   | # | UPDATE IXX, IAVG, IAVG/TLX               |     |
|          |    | CADR   | FIXCW      | # | MASSPROP ENTRY (ALREADY INITIALIZED)     |     |
|          |    | TC     | IBNKCALL   | # | UPDATE 1/CONACC, VARK                    |     |
|          |    | CADR   | S40.15     | # | (S40.15 IS IN TVCINITIALIZE)             |     |
|          |    | CS     | TENMDOT    | # | UPDATE MASS FOR NEXT 10 SEC. OF BURN     |     |
|          |    | AD     | CSMMASS    |   |                                          |     |
|          |    | TS     | MASSTMP    | # | KG B+16                                  |     |
|          |    | CAF    | NINETEEN   | # | RESET THE VARIABLE-GAIN UPDATE COUNTER   |     |
|          |    | TS     | VCNTRTMP   |   |                                          |     |
| EXECCOPY |    | INCR   | TVCEXPHS   | # | RESTART-PROTECT TEH COPYCYCLE            | (1) |
|          |    | CAE    | MASSTMP    | # | CSMMASS KG B+16                          |     |
|          |    | TS     | CSMMASS    |   |                                          |     |
|          |    | CAE    | VCNTRTMP   | # | VCNTR                                    |     |
|          |    | TS     | VCNTR      |   |                                          |     |
|          |    | TS     | V97VCNTR   | # | FOR ENGFALL (R41) MASS UPDATES AT SPSOFF |     |
|          |    | INCR   | TVCEXPHS   | # | COPYCYCLE OVER                           | (2) |
| 1SHOTCHK |    | CCS    | CNTR       | # | CHECK FOR ONE-SHOT OR REPCORR            |     |
|          |    | TCF    | +4         | # | NOT YET                                  |     |
|          |    | TCF    | 1SHOTOK    | # | NOW                                      |     |
|          |    | TCF    | REPCHEK    | # | ONE-SHOT OVER, ON TO REPCORR             |     |
|          |    | TCF    | 1SHOTOK    | # | NOW (ONE-SHOT ONLY, NO REPCORR)          |     |
|          | +4 | TS     | CNTRTMP    | # | COUNT DOWN                               |     |
|          |    | CAF    | SIX        | # | SETUP TVCEXPHS FOR ENTRY AT CNTRCOPY     |     |
|          |    | TS     | TVCEXPHS   |   |                                          |     |
|          |    | TCF    | CNTRCOPY   |   |                                          |     |
| REPCHEK  |    | CAE    | REPFRAC    | # | CHECK FOR REPETITIVE UPDATES             |     |
|          |    | EXTEND |            |   |                                          |     |
|          |    | BZMF   | TVCEXFIN   | # | NO (NEG OR +-ZERO)                       |     |
|          |    | TS     | TEMPDAP +1 | # | YES, SET UP CORRECTION FUNCTION          |     |
|          |    | CAF    | FOUR       | # | SET UP TVCEXPHS FOR ENTRY AT CORSETUP    |     |
|          |    | TS     | TVCEXPHS   |   |                                          |     |
|          |    | TCF    | CORSETUP   |   |                                          |     |



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```
1SHOTOK      CAF      BIT13      # CHECK ENGINE-ON BIT, NOT PERMITTING
              EXTEND      #          SWITCHOVER DURING ENGINE-SHUTDOWN
              RAND      DSALMOUT
              CCS      A
              TCF      +2      #          ONE-SHOT OK
              TCF      TVCEXFIN      #          NO, TERMINATE

              INCR      TVCEXPHS      #          (3)
```

# RSB 2009. The following instruction was previously "CAE FCORFRAC", but FCORFRAC  
# is not in erasable memory as implied by the use of CAE. I've accordingly changed  
# it to CAF instead to indicate fixed memory.

```
TEMPSET      CAF      FCORFRAC      #          SET UP CORRECTION FRACTION
              TS      TEMPDAP +1

              INCR      TVCEXPHS      # ENTRY FROM REPCHECK AT NEXT LOCATION (4)

CORSETUP      CAE      DAPDATR1      # CHECK FOR LEM-OFF/ON
              MASK      BIT13      # (NOTE, SHOWS LEM-OFF)
              EXTEND
              BZF      +2      # LEM IS ON, PICK UP TEMPdap+1
              CAE      TEMPdap +1      # LEM IS OFF, PICK UP 2(TEMPdap+1)
              AD      TEMPdap +1
              TS      TEMPdap      # CG.CORR USES TEMPdap

              CAF      NEGONE      # SET UP FOR CNTR = -1 (SWTCHOVR DONE)
              TS      CNTRTMP      #          (COPYCYCLE AT "CNTRCOPY")
```

```
CG.CORR      EXTEND      # PITCH TMC LOOP
              DCA      PDELOFF
              DXCH      PACTTMP
              EXTEND
              DCS      PDELOFF
              DDOUBL
              DDOUBL
              DXCH      TTMP1
              EXTEND
              DCA      DELPBAR
              DDOUBL
              DDOUBL
              DAS      TTMP1
              EXTEND
              DCA      TTMP1
              EXTEND
              MP      TEMPdap
              DAS      PACTTMP
```

```

EXTEND
DCA      YDELOFF
DXCH     YACTTMP
EXTEND
DCS      YDELOFF
DDOUBL

# Page 949

DDOUBL
DXCH     TTMP1
EXTEND
DCA      DELYBAR
DDOUBL
DDOUBL
DAS      TTMP1
EXTEND
DCA      TTMP1
EXTEND
MP       TEMPDAP
DAS      YACTTMP

CORCOPY  INCR    TVCEXPHS      # RESTART-PROTECT THE COPYCYCLE      (5)

EXTEND
DCA      PACTTMP
TS       PACTOFF
DXCH     PDELOFF

EXTEND
DCA      YACTTMP
TS       YACTOFF
DXCH     YDELOFF

INCR     TVCEXPHS      # ENTRY FROM 1SHOTCHK AT NEXT LOCATION  (6)

CNTRCOPY CAE      CNTRTMP      # UPDATE CNTR (RESTARTS OK, FOLLOWS CPYCY)
TS       CNTR

TVCEXFIN CAF      ZERO        # RESET TVCEXPHS
TS       TVCEXPHS
TCF      TASKOVER      # TVCEXECUTIVE FINISHED

FCORFRAC OCT      10000       # ONE-SHOT CORRECTION FRACTION

# Page 950 (page is empty)

```

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This code is written to file `src/TVCEXECUTIVE.s`.

## A.120 TVCINITIALIZE

```

1908  <src/TVCINITIALIZE.s 1908>≡
      # Copyright:    Public domain.
      # Filename:     TVCINITIALIZE.agc
      # Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
      #               It is part of the source code for the Command Module's (CM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Jim Lawton <jim.lawton@gmail.com>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         936-944
      # Mod history:   2009-05-11 JVL  Adapted from the Colossus249/ file
      #               of the same name, using Comanche055 page
      #               images.
      #               2009-05-20 RSB  Corrections: +80 -> +8D, added 4 missing
      #               lines in TVCINIT1, changed the capitalization
      #               of a couple of the "Page N" comments,
      #               corrected a couple of lines in LOADCOEFF.
      #               2009-05-22 RSB  In LOADCOEF, DXCH N10 +14D corrected to
      #               TS N10 +14D. Also, various comment-marks
      #               were added to comments following this
      #               change.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #   Assemble revision 055 of AGC program Comanche by NASA
      #   2021113-051. 10:28 APR. 1, 1969
      #
      #   This AGC program shall also be referred to as
      #   Colossus 2A

      # Page 937
      # NAME          TVCDAPON (TVC DAP INITIALIZATION AND STARTUP CALL)
      # LOG SECTION...TVCINITIALIZE          SUBROUTINE...DAPCSM
      # MODIFIED BY SCHLUNDT                  21 OCTOBER 1968
      # FUNCTIONAL DESCRIPTION

```

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```
# PERFORMS TVCDAP INITIALIZATION (GAINS, TIMING PARAMETERS, FILTER VARIABLES, ETC.)
# COMPUTES STEERING (S40.8) GAIN KPRIMEDT, AND ZEROES PASTDELV,+1 VARIABLE
# MAKES INITIALIZATION CALL TO "NEEDLER" FOR TVC DAP NEEDLES-SETUP
# PERFORMS INITIALIZATION FOR ROLL DAP
# CALLS TVCEXECUTIVE AT TVCEXEC, VIA WAITLIST
# CALLS TVCDAP CDU-RATE INITIALIZATION PKG AT DAPINIT VIA T5
# PROVIDES FOR LOADING OF LOW-BANDWIDTH COEFFS AND GAINS AT SWICHOVR
# CALLING SEQUENCE - T5LOC=2CADR(TVCDAPON,EBANK=BZERO), T5=.6SECT5
# IN PARTICULAR, CALLED BY "DOTVCON" IN P40
# MRCLEAN AND TVCINIT4 ARE POSSIBLE TVC-RESTART ENTRY POINTS
# NORMAL EXIT MODE
# TCF RESUME
# SUBROUTINES CALLED
# NEEDLER, MASSPROP
# ALARM OR ABORT EXIT MODES
# NONE
# ERASABLE INITIALIZATION REQUIRED
# CSMMASS, LEMMASS, DAPDATR1 (FOR MASSPROP SUBROUTINE)
# TVC PAD LOADS (SEE EBANK6 IN ERASABLE ASSIGNMENTS)
# PACTOFF, YACTOFF, CDUX
# TVCPHASE AND THE T5 BITS OF FLAGWRD6 (SET AT DOTVCON IN P40)
# OUTPUT
# ALL TVC AND ROLL DAP ERASABLES, FLAGWRD6 (BITS 13,14), T5, WAITLIST
# DEBRIS
# NONE

COUNT*  $$/INIT
BANK      17
SETLOC    DAPS7
BANK

EBANK=    BZERO

TVCDAPON  LXCH   BANKRUPT      # T5 RUPT ARRIVAL (CALL BY DOTVCON - P40)
          EXTEND # SAVE Q REQUIRED IN RESTART (MRCLEAN AND
          QXCH   QRUPT         # TVCINIT4 ARE ENTRIES)
MRCLEAN   CAF    NZERO        # NUMBER TO ZERO, LESS ONE (MUST BE ODD)
          # TVC RESTARTS ENTER HERE (NEW BANK)

          +1    CCS    A
          TS     CNTR
          CAF    ZERO
          TS     L
          INDEX  CNTR
          DXCH   OMEGAYC      # FIRST (LAST) TWO LOCATIONS
          CCS    CNTR
          TCF    MRCLEAN +1
```

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|          |        |          |                                             |
|----------|--------|----------|---------------------------------------------|
|          | EXTEND |          | # SET UP ANOTHER T5 RUPT TO CONTINUE        |
|          | DCA    | INITLOC2 | #       INITIALIZATION AT TVCINIT1          |
|          | DXCH   | T5LOC    | # THE PHSCHK2 ENTRY (REDOTVC) AT TVCDAPON   |
|          | CAF    | POSMAX   | #       +3 IS IN ANOTHER BANK. MUST RESET   |
|          | TS     | TIME5    | #       BBCON TOO (FULL 2CADR), FOR THAT    |
| ENDMRC   | TCF    | RESUME   | #       ENTRY.                              |
| TVCINIT1 | LXCH   | BANKRUPT |                                             |
|          | EXTEND |          |                                             |
|          | QXCH   | QRUPT    |                                             |
|          | TC     | IBNKCALL | # UPDATE IXX, IAVG/TLX FOR DAP GAINS (R03   |
|          | CADR   | MASSPROP | #       OR NOUNS 46 AND 47 MUST BE CORRECT) |
|          | CAE    | EMDOT    | # SPS FLOW RATE, SCALED B+3 KG/CS           |
|          | EXTEND |          |                                             |
|          | MP     | ONETHOU  |                                             |
|          | TS     | TENMDOT  | # 10-SEC MASS LOSS B+16 KG                  |
|          | COM    |          |                                             |
|          | AD     | CSMMASS  |                                             |
|          | TS     | MASSTMP  | # DECREMENT FOR FIRST 10 SEC OF BURN        |
|          | CAE    | DAPDATR1 | # CHECK LEM-ON/OFF                          |
|          | MASK   | BIT14    |                                             |
|          | CCS    | A        |                                             |
|          | CAF    | BIT1     | # LEM-ON (BIT1)                             |
|          | TS     | CNTR     | # LEM-OFF (ZERO)                            |
|          | INDEX  | CNTR     | # LOAD THE FILTER COEFFICIENTS              |
|          | CAF    | CSMCFADR |                                             |
|          | TS     | COEFFADR |                                             |
|          | TC     | LOADCOEF |                                             |
|          | INDEX  | CNTR     | # PICK UP LM-OFF,-ON KTLX/I                 |
|          | CAE    | EKTLX/I  | # SCALED AT 1/(8 ASCREV) OF ACTUAL VALUE    |
|          | TS     | KTLX/I   |                                             |
|          | TCR    | S40.15   | # COMPUTE 1/CONACC, VARK                    |
| TVCINIT2 | CS     | CNTR     | # PICK LM-OFF,-ON VALUE FOR FILTER PERIOD   |
|          | INDEX  | A        | # DETERMINATION:                            |
|          | CAF    | BIT2     | #       BIT2 FOR CSM ONLY 40MS FILTER       |
|          | TS     | KPRIMEDT | #       BIT3 FOR CSM/LM 80MS FILTER         |
|          | COM    |          | # PREPARE T5TVCDT                           |

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|          |        |           |                                          |
|----------|--------|-----------|------------------------------------------|
|          | AD     | POSMAX    |                                          |
|          | AD     | BIT1      |                                          |
|          | TS     | T5TVCDT   |                                          |
|          | CS     | BIT15     | # RESET SWTOVER FLAG                     |
|          | MASK   | FLAGWRD9  |                                          |
|          | TS     | FLAGWRD9  |                                          |
|          | INDEX  | CNTR      | # PICK UP LEM-OFF,-ON KPRIME             |
|          | CAE    | EKPRIME   | # SCALED (100 PI)/16                     |
|          | EXTEND |           |                                          |
|          | MP     | KPRIMEDT  | # (TVCDT/2, SC.AT B+14 CS)               |
|          | LXCH   | A         | # SC.AT PI/8 (DIMENSIONLESS)             |
|          | DXCH   | KPRIMEDT  |                                          |
|          | INDEX  | CNTR      | # PICK UP LEM-OFF,-ON REPFRAC            |
|          | CAE    | EREPPFRAC |                                          |
|          | TS     | REPFRAC   |                                          |
|          | INDEX  | CNTR      | # PICK UP ONE-SHOT CORRECTION TIME       |
|          | CAF    | TCORR     |                                          |
|          | TS     | CNTR      |                                          |
|          | CAF    | NEGONE    | # PREVENT STROKE TEST UNTIL CALLED       |
|          | TS     | STRKTIME  |                                          |
|          | CAF    | NINETEEN  | # SET VCNTR FOR VARIABLE-GAIN UPDATES IN |
|          | TS     | VCNTR     | # 10 SECONDS (TVCEXEC 1/2 SEC RATE)      |
|          | TS     | V97VCNTR  | # FOR ENGFAIL (R41) LOGIC                |
| TVCINIT3 | CAE    | PACTOFF   | # TRIM VALUES TO TRIM-TRACKERS, OUTPUT   |
|          | TS     | PDELOFF   | # TRACKERS, OFFSET-UPDATES, AND          |
|          | TS     | PCMD      | # OFFSET-TRACKER FILTERS                 |
|          | TS     | DELPBAR   | # NOTE, LO-ORDER DELOFF,DELBAR ZEROED    |
|          | CAE    | YACTOFF   |                                          |
|          | TS     | YDELOFF   |                                          |
|          | TS     | YCMD      |                                          |
|          | TS     | DELYBAR   |                                          |
| ATTINIT  | CAE    | DAPDATR1  | # ATTITUDE-ERROR INITIALIZATION LOGIC    |
|          | MASK   | BIT13     | # TEST FOR CSM OR CSM/LM                 |
|          | EXTEND |           |                                          |
|          | BZF    | NEEDLEIN  | # BYPASS INITIALIZATION FOR CSM/LM       |

```

+5      CAF      BIT1      #      SET UP TEMPORARY COUNTER
      TS      TTMP1

      INDEX      TTMP1
      CA      ERRTMP      # ERRTMP CONTAINS RCS ATTITUDE ERRORS
      EXTEND      #      ERROR & ERRORZ (P40 AT DOTVCON)
      MP      1/ATTLIM      # .007325(ERROR) = 0 IF ERROR < 1.5 DEG
      EXTEND
      BZF      +8D      #      |ERROR| LESS THAN 1.5 DEG
      EXTEND

# Page 940
      BZMF      +3      #      |ERROR| > 1.5 DEG, AND NEG
      CA      ATTLIM      #      |ERROR| > 1.5 DEG, AND POS
      TCF      +2
+3      CS      ATTLIM
+2      INDEX      TTMP1
      TS      ERRTMP
+8      CCS      TTMP1      #      TEST TEMPORARY COUNTER
      TCF      ATTINIT +5      #      BACK TO REPEAT FOR PITCH ERROR

      CA      ERRTMP      # ERROS ESTABLISHED AND LIMITED
      TS      PERRB
      CA      ERRTMP +1
      TS      YERRB

NEEDLEIN      CS      RCSFLAGS      # SET BIT 3 FOR INITIALIZATION PASS AND GO
      MASK      BIT3      #      TO NEEDLER. WILL CLEAR FOR TVC DAP
      ADS      RCSFLAGS      #      (RETURNS AFTER CADR)
      TC      IBNKCALL
      CADR      NEEDLER

TVCINIT4      CAF      ZERO      # SET TVCPHASE TO INDICATE TVCDAPON-THRU-
      TS      TVCPHASE      #      NEEDLEIN INITIALIZATION FINISHED.
      #      (POSSIBLE TVC-RESTART ENTRY)

      CAE      CDUX      # PREPARE ROLL DAP
      TS      OGANOW

      CAF      BIT13      # IF ENGINE IS ALREADY OFF, ENGINOFF HAS
      EXTEND      #      ALREADY ESTABLISHED THE POST-BURN
      RAND      DSALMOUT      #      CSMMASS (MASSBACK DOES IT). DON'T
      EXTEND      #      TOUCH CSMMASS. IF ENGINE IS ON,
      BZF      +3      #      THEN IT'S OK TO DO THE COPYCYCLE
      #      EVEN BURNS LESS THAN 0.4 SEC ARE AOK

      CAE      MASSTMP      # COPYCYCLE

```



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```

      TS      CSMMASS

+3    CAF      .5SEC      # CALL TVCEXECUTIVE (ROLLDAP CALL, ETC)
      TC      WAITLIST
      EBANK=   BZERO
      2CADR    TVCEXEC

      EXTEND      # CALL FOR DAPINIT
      DCA      DAPINIT5
      DXCH     T5LOC
      CAE      T5TVCDT      # (ALLOW TIME FOR RESTART COMPUTATIONS)
      TS      TIME5

# Page 941
ENDTVCIN      TCF      RESUME

PRESWTCH      TCR      SWICHOVR      # ENTRY FROM V46

      TC      POSTJUMP      # THIS PROVIDES AN EXIT FROM SWITCH-OVER
      CADR     PINBRNCH      # (PINBRNCH DOES A RELINT)

SWICHOVR      INHINT
      CA      TVCPHASE      # SAVE TVCPHASE
      TS      PHASETMP
      CS      BIT2      # SET TVCPHASE = -2 (INDICATES SWITCH-OVER
      TS      TVCPHASE      # TO RESTART LOGIC)

+5    EXTEND      # SAVE Q FOR RETURN (RESTART ENTRY POINT,
      QXCH     RTRNLOC      # TVCPHASE AND PHASETMP ALREADY SET)

      CAF      NZEROJR      # ZEROING LOOP FOR FILTER STORAGE LOCS
+8    TS      CNTRTMP

MCLEANJR      CA      ZERO
      TS      L
      INDEX   CNTRTMP
      DXCH    PTMP1 -1
      CCS     CNTRTMP
      CCS     A
      TCF     SWICHOVR +8D

      CS      FLAGWRD9      # SET SWITCHOVER FLAG FOR DOWNLINK
      MASK    BIT15
      ADS     FLAGWRD9

      CAE     ECTLX/I +2      # LOW BANDWIDTH GAINS - DAP
      TS      KTLX/I
```

```

TCR      S40.15  +7

CAF      FKPRIMDT      #
TS      KPRIMEDT

CAF      FREPFRAC      #
TS      REPFRAC        - TMC LOOP

EXTEND
DCA      DELPBAR
DXCH     PDELOFF
EXTEND
DCA      DELYBAR
DXCH     YDELOFF

CA      LBCFADR

# Page 942
TS      COEFFADR
TC      LOADCOEF

CAE      PHASETMP      # RESTORE TVCPHASE
TS      TVCPHASE

TC      RTRNLOC        # BACK TO PRESWTCH OR TVCRESTARTS

LOADCOEF EXTEND        # LOAD DAP FILTER COEFFICIENTS
INDEX    COEFFADR      # FROM: ERASABLE FOR CSM/LM HB
DCA      0              # FIXED FOR CSM/LM LB
DXCH     N10            # FIXED FOR CSM

EXTEND
INDEX    COEFFADR      # NOTE: FOR CSM/LM, NORMAL COEFFICIENT
DCA      2              # LOAD WILL BE HIGH BANDWIDTH PAD LOAD
DXCH     N10            # ERASABLES. DURING CSM/LM SWITCHOVER,
                        # THIS LOGIC IS USED TO LOAD LOW BANDWIDTH
                        # COEFFICIENTS FROM FIXED MEMORY.

EXTEND
INDEX    COEFFADR
DCA      4
DXCH     N10            +4

EXTEND
INDEX    COEFFADR
DCA      6
DXCH     N10            +6

```

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EXTEND  
INDEX COEFFADR  
DCA 8D  
DXCH N10 +8D

EXTEND  
INDEX COEFFADR  
DCA 10D  
DXCH N10 +10D

EXTEND  
INDEX COEFFADR  
DCA 12D  
DXCH N10 +12D

INDEX COEFFADR  
CA 14D  
TS N10 +14D

TC Q

# Page 943  
S40.15

CAE IXX # GAIN COMPUTATIONS (1/CONACC, VARK)  
EXTEND # ENTERED FROM TVCINITIALIZE AND TVCEXEC  
MP 2PI/M # 2PI/M SCALED 1/(B+8 N M)  
DDOUBL # IXX SCALED B+20 KG-MSQ  
DDOUBL  
DDOUBL  
TS 1/CONACC # SCALED B+9 SEC-SQ/REV

+7 CAE KTLX/I # ENTRY FROM CSM/LM V46 SWITCH-OVER  
EXTEND # SCALED (B+3 ASCREV) 1/SECSQ  
MP IAVG/TLX # SCALED B+2 SECSQ  
DDOUBL  
DDOUBL  
TS VARK # SCALED (B+3 ASCREV)  
TC Q

CSMN10 DEC .99999 # N10 CSM ONLY FILTER COEFFICIENTS  
DEC -.2549 # N11/2  
DEC .0588 # N12  
DEC -.7620 # D11/2  
DEC .7450 # D12  
  
DEC .99999 # N20  
DEC -.4852 # N21/2  
DEC 0 # N22

|            |        |               |                                           |
|------------|--------|---------------|-------------------------------------------|
|            | DEC    | -.2692        | # D22/2                                   |
|            | DEC    | 0             | # D22                                     |
| LBN10      | DEC    | +.99999       | # N10 LOW BANDWIDTH FILTER COEFFICIENTS   |
|            | DEC    | -.3285        | # N11/2                                   |
|            | DEC    | -.3301        | #N12                                      |
|            | DEC    | -.9101        | #D11/2                                    |
|            | DEC    | +.8460        | #D12                                      |
|            | DEC    | +.03125       | #N20                                      |
|            | DEC    | 0             | #N21/2                                    |
|            | DEC    | 0             | #N22                                      |
|            | DEC    | -.9101        | #D21/2                                    |
|            | DEC    | +.8460        | #D22                                      |
|            | DEC    | +.50000       | #N30                                      |
|            | DEC    | -.47115       | #N31/2                                    |
|            | DEC    | +.4749        | #N32                                      |
|            | DEC    | -.9558        | #D31/2                                    |
|            | DEC    | +.9372        | #D32                                      |
| CSMCFADR   | GENADR | CSMN10        | # CSM ONLY COEFFICIENTS ADDRESS           |
| HBCFADR    | GENADR | HBN10         | # HIGH BANDWIDTH COEFFICIENTS ADDRESS     |
| # Page 944 |        |               |                                           |
| LBCFADR    | GENADR | LBN10         | # LOW BANDWIDTH COEFFICIENTS ADDRESS      |
| NZERO      | DEC    | 51            | # MUST BE ODD FOR MRCLEAN                 |
| NZEROJR    | DEC    | 23            | # MUST BE ODD FOR MCLEANJR                |
| ATTLM      | DEC    | 0.00833       | # INITIAL ATTITUDE EROR LIMIT (1.5 DEG)   |
| 1/ATTLM    | DEC    | 0.007325      | # .007325(ERROR) = 0 IF ERROR < 1.5 DEG   |
| TCORR      | OCT    | 00005         | # CSM                                     |
| +1         | OCT    | 00000         | # CSM/LM (HB, LB)                         |
| FKPRIMDT   | DEC    | .0102         | # CSM/LM (LB), (.05 X .08) SCALED AT PI/8 |
| FREPFRAC   | DEC    | .0375 B-2     | # CSM/LM (LB), 0.0375 SCALED AT B+2       |
| NINETEEN   | =      | VD1           |                                           |
| 2PI/M      | DEC    | .00331017 B+8 | # 2PI/M, SCALED AT 1/(B+8 N-M)            |
| ONETHOU    | DEC    | 1000 B-13     | # KG/CS B3 TO KG/10SEC B16 CONVERSION     |
|            | EBANK= | BZERO         |                                           |
| DAPINIT5   | 2CADR  | DAPINIT       |                                           |

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```
EBANK= BZERO
INITLOC2 2CADR TVCINIT1
```

This code is written to file `src/TVCINITIALIZE.s`.

## A.121 TVCMASSPROP

```

1918  <src/TVCMASSPROP.s 1918>=
      # Copyright:    Public domain.
      # Filename:     TVCMASSPROP.agc
      # Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
      #               It is part of the source code for the Command Module's (CM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Ron Burkey <info@sandroid.org>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         951-955
      # Mod history:   2009-05-13 RSB   Adapted from the Colossus249/ file of the
      #               same name, using Comanche055 page images.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 055 of AGC program Comanche by NASA
      #       2021113-051.  10:28 APR. 1, 1969
      #
      #       This AGC program shall also be referred to as
      #               Colossus 2A
      #
      # Page 951
      # PROGRAM NAME...MASSPROP
      # LOG SECTION...TVCMASSPROP                PROGRAMMER...MELANSON (ENGEL, SCHLUNDT)
      #
      # FUNCTIONAL DESCRIPTION:
      #
      #       MASSPROP OPERATES IN TWO MODES: (1) IF LEM MASS OR CONFIGURATION ARE UPDATED
      #       FOR THIS) THE ENTIRE PROGRAM MUST BE RUN THROUGH, BREAKPOINT VALUES AND DERIV
      #       RESPECT TO CSM MASS BEING CALCULATED PRIOR TO CALCULATION OF THE OUTPUTS. (2
      #       CALCULATED USING PREVIOUSLY COMPUTED BREAKPOINT VALUES AND DERIVATIVES.
      #
      # CALLING SEQUENCES
      #
      #       IF LEM MASS OR CONFIGURATION HAS BEEN UPDATED, TRANSFER TO MASSPROP, OTHERWIS

```

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```
#          L      TC      BANKCALL or IBNKCALL
#          L+1    CADR    MASSPROP
#          OR
#          L+1    CADR    FIXCW
#          L+2    RETURNS VIA Q
#
# CALLED:  IN PARTICULAR BY DONOUN47 (JOB) AND TVCEXECUTIVE (TASK)
#
# JOBS OR TASKS INITIATED:  NONE
#
# SUBROUTINES CALLED:  NONE
#
# ERASABLE INITIALIZATION REQUIRED
#
#          LEMMASS MUST CONTAIN LEM MASS SCALED AT B+16 KILOGRAMS
#          CSMMASS MUST CONTAIN CSM MASS SCALED AT B+16 KILOGRAMS
#          DAPDATR1 MUST BE SET TO INDICATE VEHICLE CONFIGURATION.
#          BITS (15,14,13) = ( 0 , 0 , 1 )          LEM OFF
#                          ( 0 , 1 , 0 )          LEM ON (ASCNT,DSCNT)
#                          ( 1 , 1 , 0 )          LEM ON (ASCNT ONLY)
#
# ALARMS:  NONE
#
# EXIT:          TC      Q
#
# OUTPUTS:
#
#          (1)      IXX, SINGLE PRECISION SCALED AT B+20 IN KG-M SQ.
#          (2)      IAVG, SINGLE PRECISION SCALED AT B+20 IN KG-M SQ.
#          (3)      IAVG/TLX, SINGLE PRECISION, SCALED AT B+2 SEC-SQD
#
#          THEY ARE STORED IN CONSECUTIVE REGISTERS IXX0, IXX1, IXX2
#          CONVERSION FACTOR:  (SLUG-FTSQ) = 0.737562 (KG-MSQ)
# Page 952
#
# OUTPUTS ARE CALCULATED AS FOLLOWS:
#
#          (1)      IF LEM DOCKED, LEMMASS IS FIRST ELIMINATED AS A PARAMETER
#
#          VARST0 = INTVALUE0 + LEMMASS(SLOPEVAL0)          IXX          BREAKPOINT VALU
#          VARST1 = INTVALUE1 + LEMMASS(SLOPEVAL1)          IAVG          BREAKPOINT VALU
#          VARST2 = INTVALUE2 + LEMMASS(SLOPEVAL2)          IAVG/TLX        BREAKPOINT VALU
#
#          VARST3 = INTVALUE3 + LEMMASS(SLOPEVAL3)          IAVG/TLX        SLOPE FOR CSMMA
#          VARST4 = INTVALUE4 + LEMMASS(SLOPEVAL4)          IAVG          SLOPE FOR CSMMA
#
```

```

#          VARST5 = INTVALUE5 + LEMMASS(SLOPEVAL5)          IXX          SLOPE
#
#          VARST6 = INTVALUE6 + LEMMASS(SLOPEVAL6)          IAVG          SLOPE
#          VARST7 = INTVALUE7 + LEMMASS(SLOPEVAL7)          IAVG/TLX        SLOPE
#
#          VARST8 = INTVALUE8 + LEMMASS(SLOPEVAL8)          IAVG          DECRE
#          VARST9 = INTVALUE9 + LEMMASS(SLOPEVAL9)          IAVG/TLX        DECRE
#
# (2)      IF LEM NOT DOCKED
#
#          VARST0 = NOLEMVAL0      WHERE THE MEANING AND SCALING OF VARST0
#          .                      TO VARST9 ARE THE SAME AS GIVEN ABOVE
#          .
#          .                      NOTE... FOR THIS CASE, VARST8,9 HAVE NO
#          VARST9 = NOLEMVAL9      MEANING (THEY ARE COMPUTED BUT NOT USED)
#
# (3)      THE FINAL OUTPUT CALCULATIONS ARE THEN DONE
#
#          IXX0 = VARST0 + (CSMASS + NEGBPW)VARST5          IXX
#
#          IXX1 = VARST1 + (CSMASS + NEGBPW)VARST(4 OR 6)    IAVG
#
#          IXX2 = VARST2 + (CSMASS + NEGBPW)VARST(3 OR 7)    IAVG/TLX
#
# THE DATA USED CAME FROM THE CSM/LM SPACECRAFT OPERATIONAL DATA BOOK
# VOL. 3, NASA DOCUMENT SNA-8-D-027 (MARCH 1968)
#
# PERTINENT MASS DATA:          CSM WEIGHT      (FULL)  64100 LBS.
#                                (EMPTY) 23956 LBS.
#                                LEM WEIGHT      (FULL)  32000 LBS.
#                                (EMPTY) 14116 LBS.
#
# (WEIGHTS ARE FROM AMMENDMENT #1 (APRIL 24, 1968) TO ABOVE DATA BOOK)
# Page 953

```

```

BANK      25
SETLOC    DAPMASS
BANK
EBANK=    BZERO
COUNT*   $$/MASP

```

```

MASSPROP  CAF      NINE          # MASSPROP USES TVC/RCS INTERRUPT TEMPS
          TS       PHI333        # SET UP TEN PASSES

LEMTEST   CAE      DAPDATR1      # DETERMINE LEM STATUS
          MASK     BIT13

```



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```

EXTEND
BZF      LEMYES

LEMNO     INDEX  PHI333      # LEM NOT ATTACHED
          CAF    NOLEMVAL
          TCF    STOINST

LEMYES    CAE    LEMMASS    # LEM IS ATTACHED
          DOUBLE
          EXTEND
          INDEX  PHI333
          MP     SLOPEVAL
          DDOUBL
          INDEX  PHI333
          AD     INTVALUE

STOINST   INDEX  PHI333      # STORAGE INST BEGIN HERE
          TS     VARSTO
          CCS    PHI333      # ARE ALL TEN PASSES COMPLETED
          TCF    MASSPROP +1 # NO: GO DECREMENT PHI333

DXTEST    CCS    DAPDATR1    # IF NEG, BIT15 IS 1, LEM DSCNT STAGE OFF
          TCF    FIXCW
          TCF    FIXCW
          DXCH   VARSTO +8D
          DAS    VARSTO +1
          CA     DXITFIX
          ADS    VARSTO +7

FIXCW     CAF    BIT2        # COMPUTATION PHASE BEGINS HERE. SET UP
          TS     PHI333      # THREE PASSES
          TS     PSI333

          CAE    CSMMASS     # GET DELTA CSM WEIGHT:  SIGN DETERMINES
          AD     NEGBPW      # SLOPE LOCATIONS.
          DOUBLE
          TS     TEMP333

# Page 954

          EXTEND
          BZMF   PEGGY       # DETERMINE CORRECT SLOPE
          CAF    NEG2
          TS     PHI333

PEGGY     INDEX  PHI333      # ALL IS READY:  CALCULATE OUTPUTS NOW
          CAE    VARST5      # GET SLOPE
          EXTEND
```

|            |        |                  |                                          |
|------------|--------|------------------|------------------------------------------|
|            | MP     | TEMP333          | # MULT BY DELTA CSM WEIGHT               |
|            | DOUBLE |                  |                                          |
|            | INDEX  | PSI333           |                                          |
|            | AD     | VARSTO           | # ADD BREAKPOINT VALUE                   |
|            | INDEX  | PSI333           |                                          |
|            | TS     | IXX              | # ***** OUTPUTS (IXX0, IXX1, IXX2) ***** |
|            | CCS    | PSI333           | # BOOKKEEPING: MASSPROP FINISHED OR NOT  |
|            | TCF    | BOKKEP2          | # NO: GO TAKE CARE OF INDEXING REGISTERS |
|            | CAE    | DAPDATR1         | # UPDATE WEIGHT/G                        |
|            | MASK   | BIT14            |                                          |
|            | CCS    | A                |                                          |
|            | CA     | LEMMASS          |                                          |
|            | AD     | CSMMASS          |                                          |
|            | TS     | WEIGHT/G         | # SCALED AT B+16 KILOGRAMS               |
| ENDMASSP   | TC     | Q                |                                          |
| BOKKEP2    | TS     | PSI333           | # REDUCE PSI BY ONE                      |
|            | EXTEND |                  |                                          |
|            | DIM    | PHI333           |                                          |
|            | TCF    | PEGGY            |                                          |
| # Page 955 |        |                  |                                          |
| NOLEMVAL   | DEC    | 25445 B-20       |                                          |
|            | DEC    | 87450 B-20       |                                          |
|            | DEC    | .30715 B-2       |                                          |
|            | DEC    | 1.22877 E-5 B+12 |                                          |
|            | DEC    | 1.6096 B-6       |                                          |
|            | DEC    | 1.54 B-6         |                                          |
|            | DEC    | 7.77177 B-6      |                                          |
|            | DEC    | 3.46458 E-5 B+12 |                                          |
| INTVALUE   | DEC    | 26850 B-20       |                                          |
|            | DEC    | 127518 B-20      |                                          |
|            | DEC    | .54059 B-2       |                                          |
|            | DEC    | .153964 E-4 B+12 |                                          |
|            | DEC    | -.742923 B-6     |                                          |
|            | DEC    | 1.5398 B-6       |                                          |
|            | DEC    | 9.68 B-6         |                                          |
|            | DEC    | .647625 E-4 B+12 |                                          |
|            | DEC    | -27228 B-20      |                                          |
|            | DEC    | -.206476 B-2     |                                          |
| SLOPEVAL   | DEC    | 1.96307 B-6      |                                          |
|            | DEC    | 27.5774 B-6      |                                          |

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|         |                         |
|---------|-------------------------|
| DEC     | 2.3548 E-5 B+12         |
| DEC     | 2.1777 E-9 B+26         |
| DEC     | 1.044 E-3 B+8           |
| DEC     | 0                       |
| DEC     | 2.21068 E-3 B+8         |
| DEC     | 1.5166 E-9 B+26         |
| DEC     | -1.284 B-6              |
| DEC     | 2 E-5 B+12              |
| NEGBPW  | DEC -15402.17 B-16      |
| DXITFIX | DEC* -1.88275 E-5 B+12* |

This code is written to file `src/TVCMASSPROP.s`.

## A.122 TVCRESTARTS

1924  $\langle \text{src}/\text{TVCRESTARTS}.s \text{ 1924} \rangle \equiv$

```
# Copyright:    Public domain.
# Filename:     TVCRESTARTS.agc
# Purpose:     Part of the source code for Colossus 2A, AKA Comanche 055.
#              It is part of the source code for the Command Module's (CM)
#              Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:     Ron Burkey <info@sandroid.org>.
# Website:     www.ibiblio.org/apollo.
# Pages:       956-960
# Mod history: 2009-05-13 RSB   Adapted from the Colossus249/ file of the
#                               same name, using Comanche055 page images.
#               2009-05-20 RSB   Corrections:  TCF -> BZF in one place.
#               2009-05-21 RSB   In PHSCHK2, CS TVCPHASE corrected to
#                               CCS TVCPHASE and CCS 4 corrected to CCS A.
#                               Page 924 corrected to 961.  CORCOPY +2
#                               corrected to CORCOPY +1.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum.  The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum.  Many
# thanks to both.  The images (with suitable reduction in storage size and
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# www.ibiblio.org/apollo.  If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 055 of AGC program Comanche by NASA
#       2021113-051.  10:28 APR. 1, 1969
#
#       This AGC program shall also be referred to as
#       Colossus 2A
#
# Page 956
# NAME...TVCRESTART PACKAGE, CONSISTING OF REDOTVC, ENABL1, 2, CMDSOUT, PHSCHK2, ET
# LOG SECTION...TVCRESTARTS                               SUBROUTINE...DAPCSM
# MODIFIED BY SCHLUNDT                                     21 OCTOBER 1968
#
# FUNCTIONAL DESCRIPTION....
#
#       *RESTART-PROCESS THE TVC DAPS, INCLUDING PITCHDAP, YAWDAP,
#       TVCEXECUTIVE, ROLLDAP, TVCINIT4, TVCDAPON, AND CSM/.M V46 SWTCHOVR.
```

```
#
# *TVC RESTARTS DESERVE SPECIAL CONSIDERATION IN SEVERAL AREAS.
# RESTART DOWN-TIME IS IMPORTANT BECAUSE OF THE TRANSIENTS INTRODUCED
# BY THE THRUST VECTOR RETURN TO THE ACTUATOR MECHANICAL NULLS
# FOLLOWING TVC- AND OPTICS-ERROR-COUNTER-DISENABLES (CHANNEL 12).
# TVC USES A MIXTURE OF WAITLIST, T5, T6, AND JOB CALLS. THERE IS
# FILTER MEMORY (UP TO 6TH ORDER) TO BE PROTECTED IF WILD TRANSIENTS
# ARE TO BE AVOIDED. COUNTERS ARE INVOLVED FOR ONE-SHOT
# CORRECTIONS AND GAIN UPDATES. THE GIMBAL TRIM ESTIMATORS AND THE
# BODY AXIS ATTITUDE ERROR INTEGRATORS INVOLVE DIGITAL SUMMATION.
# DIGITAL DIFFERENTIATORS ARE INVOLVED IN THE BODY AXIS RATE ESTIMA-
# TIONS AND IN THE OUTPUTTING OF ACTUATOR COMMANDS. THERE IS AN
# OFFSET-TRACKER-FILTER TO PROTECT. ETC., ETC.
#
# *THOSE QUANTITIES WHICH MUST BE PROTECTED ARE STORED IN TEMPORARY
# REGISTERS AS THEY ARE COMPUTED, FOR UPDATING THE REAL REGISTERS
# DURING COPYCYCLES.
#
# *THE SEVERAL COPYCYCLES ARE EACH PROTECTED BY PHASE POINTS AT THEIR
# BEGINNING AND AT THEIR TERMINATION. THE PHASE POINTS ARE SIMPLY
# "INCR" INSTRUCTIONS, EITHER "INCR TVCEXPHS" FOR COPYCYCLES
# IN THE TVCEXECUTIVE, OR "INCR TVCPHASE" FOR THE PITCH AND YAW
# COPYCYCLES. INDEXING ON EACH OF THESE POINTERS THEN PERMITS A
# RETURN TO THE APPROPRIATE RESTART POINTS.
#
# *IF A RESTART OCCURS DURING EITHER COPYCYCLE, THAT COPYCYCLE IS
# COMPLETED. THEN THE NORMAL TVCINIT4...DAPINIT...PITCHDAP STARTUP
# SEQUENCE IS CALLED UPON TO GET THINGS GOING AGAIN.
#
# *TVC-ENABLE AND OPTICS-ERROR-COUNTER ENABLE MUST BE SET ASAP
# (ALLOWING FOR PROCEDURAL DELAYS). THEN THE ENGINES ARE COMMANDED
# TO THE P,YACTOFF TRIM VALUES. THE DAPS ARE THEN READY TO GO ON THE
# AIR, WITH THE REGULAR STARTUP SEQUENCE, EITHER AT MRCLEAN FOR A
# COMPLETE INITIALIZATION OR AT TVCINIT4 FOR A PARTIAL INITIALIZATION.
#
# *FOR RESTARTS PRIOR TO THE SETTING OF THE T5 BITS AT DOTVCON THE
# PRE40.6 SECTION OF S40.6 TAKES CARE OF RE-ESTABLISHING TRIMS.
#
# *IF A RESTART OCCURS DURING THE TVCEXEC...TVCEXFIN SEQUENCE THE
# COMPUTATIONS WILL BE COMPLETED, STARTING AT THE APPROPRIATE RESTART
# POINT, AFTER THE DAPS ARE READY TO GO ON THE AIR.
#
# *IF A RESTART OCCURS PRIOR TO TVCINIT4 (TVCPHAS = -1) E.G. DURING
# THE EARLY DAP INITIALIZATION PHASE, THE DAP STARTUP SEQUENCE IS
# ENTERED AT MRCLEAN FOR A FULL INITIALIZATION.
#
```

```

#      *FOR RESTARTS DURING CSM/LM V46 SWITCH-VER, TVCPHASE IS SET TO -2.
#      AND THE RESTART LOGIC GOES BACK TO REDO SWITCH-OVER (AFTER THE
#      NORMAL DAP RESTART SEQUENCE IS FOLLOWED.)
#
#      *RESTARTS ARE NOT CRITICAL TO THE ROLL DAP PERFORMANCES HENCE THE
#      ROLL DAP IS MERELY RESTARTED.
#
#      *RESTARTS DURING A STROKE TEST (STROKER IS NON-ZERO) WILL CAUSE THE
# Page 957
#      STROKE TEST TO BE TERMINATED. A NEW V68 ENTRY WILL BE REQUIRED
#      TO GET IT GOING AGAIN (NO AUTOMATIC RESTART).
#
#      *REDOTVC IS REACHED FOLLOWING ANY RESTART WHICH FINDS THE T5 BITS
#      (BITS 15,14 OF FLAGWRD6) SET FOR TVC. DOTVCON TVCPHASE = -1
#      AND TVC EXPHS = 0 JUST BEFORE SETTING THESE BITS, JUST BEFORE
#      MAKING THE T5 CALL TO TVCDAPON. ON A NORMAL SHUTDOWN DOTVCRCS
#      CALLS RCSDAPON, WHICH RESETS THE T5 BIT FOR RCS
#
# CALLING SEQUENCE....T5, IN PARTICULAR BY ELRSKIP OF FRESH START/RESTART
#
# NORMAL EXIT MODES....RESUME, NOQRSM, POSTJUMP (TO TVCINIT4 OR MRCLEAN)
#
# ALARM OR ABORT EXIT MODES....NONE
#
# SUBROUTINES CALLED....
#
#      *PCOPY+1, YCOPY+1 (PITCH AND YAW COPYCYCLES)
#      *ENABLE1,2, CMDSOUT (RE-ESTABLISH ACTUATOR TRIMS)
#      *MRCLEAN OR TVCINIT4 (TVCDAP INITIALIZATIONS)
#      *SWITCHOVR +5 (CSM/LM V46 SWITCH-OVER)
#      *EXRSTRT AND TVCEXECUTIVE PHASE POINTS 1 THRU 6
#      *WAITLIST, IBNKCALL, POSTJUMP, ISWCALL
#
# OTHER INTERFACES....DOTVCON AND RCSDAPON (T5 BITS), ELRSKIP (CALLS IT)
#
# ERASABLE ININITIALIZATION REQUIRED....
#
#      *T5 BITS (1,0), TVCPHASE (-2,-1,0,1,2,3), TVCEXPHS (1 THRU 6)
#      *TVC DAP VARIABLES
#      *OPERATIONS PERFORMED BY REDOTVC ARE BASED ON THE ASSUMPTION THAT
#      THE TVC DAPS ARE RUNNING NORMALLY
#
# OUTPUT....
#
#      *PITCH AND YAW TVC DAP COPYCYCLES COMPLETED IF INTERRUPTED
#      *TVCEXECUTIVE COMPLETED IF INTERRUPTED

```

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```
# *STROKE TEST TERMINATED IF INTERRUPTED
# *CSM/LM V46 SWITCH-OVER REPEATED IF INTERRUPTED
# *ACTUATOR TRIMS RE-ESTABLISHED (ACTUATORS BACK ON THE AIR)
# *TVC DAP INITIALIZATION AS REQUIRED
# *ALL TVC DAP OPERATIONS ON THE AIR
#
# DEBRIS...TVC TEMPORARIES IN EBANK6
```

#Page 958

```

BANK      16
SETLOC    DAPROLL
BANK
EBANK=    TVCPHASE
COUNT*   $$/RSRT

REDOTVC    LXCH    BANKRUPT    # TVC RESTART PACKAGE
           EXTEND
           QXCH    QRUPRT      # ("TCR" IN "FINCOPY")

EXECPHS    CCS     TVCEXPHS    # CHECK TVCEXECUTIVE PHASE
           TCF     +2          #      MUST RESTART TVCEXECUTIVE
           TCF     TVCDAPHS    #      NO NEED TO RESTART TVCEXECUTIVE

           CAF     NINE        # 9CS DELAY TO FORCE EXRSTRT TO OCCUR
           TC      WAITLIST    #      BEFORE PITCHDAP, AFTER CMDSOUT
           EBANK=   TVCEXPHS
           2CADR    EXRSTRT

TVCDAPHS   CS      OCT37776    # CHECK BITS 15 AND 1 OF TVCPHASE TO SEE
           MASK    TVCPHASE    #      DAP RESTART LOCATION (-1,1,2,3)
           CCS     A           #
           TCF     FINCOPY     #      FINISH THE COPYCYCLE FIRST
           TCF     ENABL1      #      JUST PREPARE THE OUTCOUNTERS AND GO

           CS      TVCPHASE    # TEST FOR TVCPHASE = -2
           MASK    BIT2        #      (THIS INDICATES RESTART OCCURRED
           EXTEND   #      DURING CSM/LM V46 SWITCH-OVER)
           BZF     TRIM/CMD    # NO. TVCPHASE = -1. RSTRT WAS IN TVCINIT

ENABL1     CAF     BIT8        # TVC ENABLE, FOLLOWED BY 40 MS (MIN) WAIT
           AD      BIT11      #      SET BIT FOR OPTICS-DAC-ENABLE ALSO
           EXTEND   #      (ENABL1 ENTERED FROM TVCDAPHS / FINCOPY)
           WOR     CHAN12
           CAF     TVCADDR     # WAIT, CALLING ENABL2 (BBCON THERE)
           TS      T5LOC
```

|            |        |            |   |                                        |
|------------|--------|------------|---|----------------------------------------|
|            | CAF    | TVCADDR +4 | # | 60 MS (TVCEXADR)                       |
|            | TS     | TIME5      |   |                                        |
|            | TCF    | RESUME     |   |                                        |
| ENABL2     | LXCH   | BANKRUPT   | # | CONTINUE PREPARATION OF OUTCOUNTERS    |
|            | CAF    | BIT2       | # | OPTICS ERROR CNTR ENABLE, 4MS MIN WAIT |
|            | EXTEND |            |   |                                        |
|            | WOR    | CHAN12     |   |                                        |
| # Page 959 |        |            |   |                                        |
|            | CAF    | TVCADDR +2 | # | WAIT, CALLING CMDROUT (BBCON THERE)    |
|            | TS     | T5LOC      |   |                                        |
|            | CAF    | OCT37776   | # | 20MS                                   |
|            | TS     | TIME5      |   |                                        |
|            | TCF    | NOQRSM     |   |                                        |
| CMDROUT    | LXCH   | BANKRUPT   | # | CONTINUE PREPARATION OF OUTCOUNTERS    |
|            | EXTEND |            |   |                                        |
|            | QXCH   | QRUP       |   |                                        |
|            | CS     | ZERO       | # | MOST RECENT ACTUATOR COMMANDS          |
|            | AD     | PCMD       | # | (AVOID +0)                             |
|            | TS     | TVCPTCH    |   |                                        |
|            | CS     | ZERO       |   |                                        |
|            | AD     | YCMD       |   |                                        |
|            | TS     | TVCYAW     |   |                                        |
|            | CAF    | PRI06      | # | RELEASE THE COUNTERS (BITS 11,12)      |
|            | EXTEND |            |   |                                        |
|            | WOR    | CHAN14     |   |                                        |
| PHSCHK2    | CCS    | TVCPTCH    | # | CHECK TVCPTCH AGAIN                    |
|            | TCF    | CHKSTRK    |   |                                        |
|            | TCF    | CHKSTRK    |   |                                        |
|            | CCS    | A          | # | A CONTAINS THE DIMINISHED ABSOLUTE OF  |
|            | TC     | +3         | # | TVCPTCH (-2 BECOMES +1. -1 BECOMES +0) |
|            | TC     | POSTJUMP   | # | REPEAT TVC INITIALIZATION              |
|            | CADR   | MRCLEAN    | # | (DO NOT RETURN)                        |
|            |        |            |   |                                        |
|            | +3     | TC         | # | REPEAT CSM/LM V46 SWITCH-OVER          |
|            |        | CADR       | # | (RETURN TO CHECK FOR STROKE TEST)      |
|            |        |            |   |                                        |
| CHKSTRK    | CCS    | STROKER    | # | CHECK FOR STROKE TEST IN PROGRESS      |



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|                                                                                                |        |             |                                            |
|------------------------------------------------------------------------------------------------|--------|-------------|--------------------------------------------|
|                                                                                                | TCF    | TSTINITJ    | # YES, KILL IT                             |
|                                                                                                | TCF    | +2          | # NO, PROCEED                              |
|                                                                                                | TCF    | TSTINITJ    | # YES, KILL IT                             |
| +4                                                                                             | TC     | POSTJUMP    | # IF POSITIVE OR ZERO, RESTART AT          |
|                                                                                                | CADR   | TVCINIT4    | # TVCINIT4 (ZEROS TVCPHASE, AND            |
|                                                                                                |        |             | # CALLS TVC DAPS VIA DAPINIT)              |
| FINCOPY                                                                                        | INDEX  | TVCPHASE    | # PICK UP THE APPROPRIATE COPYCYCLE        |
|                                                                                                | CAF    | TVCCADR     |                                            |
|                                                                                                | TCR    | ISWCALL     | # RE-ENTER THE COPYCYCLE, RETURN AT END    |
|                                                                                                | TCF    | ENABL1      | # NOW PREPARE THE OUTCOUNTERS              |
| TRIM/CMD                                                                                       | EXTEND |             | # TVCDAPON INITIALIZATION NOT COMPLETED,   |
| # Page 960                                                                                     |        |             |                                            |
|                                                                                                | DCA    | PACTOFF     | # EG. P,YCMD MAY NOT BE SET. SET...        |
|                                                                                                | DXCH   | PCMD        |                                            |
|                                                                                                | TCF    | ENABL1      | # NOW PREPARE THE OUTCOUNTERS              |
| TSTINITJ                                                                                       | CAF    | ZERO        | # DISABLE STROKE TEST (-0 SHOWS PRIOR V68) |
|                                                                                                | TS     | STROKER     | # (+0 MEANS NEW V68 REQUIRED FOR STARTUP)  |
|                                                                                                | TCF    | CHKSTRK +4  |                                            |
| EXRSTRT                                                                                        | INDEX  | TVCEXPHS    | # TVCEXECUTIVE RESTARTS...GO TO            |
|                                                                                                | CAF    | TVCEXADR    | # APPROPRIATE RESTART POINT                |
|                                                                                                | INDEX  | A           |                                            |
|                                                                                                | TCF    | 0           |                                            |
| # Page 961                                                                                     |        |             |                                            |
| # TVC RESTART TABLES.... ORDER IS REQUIRED. HI-ORDER WORDS ONLY, OF 2CADRS, SINCE BBCON IS ALP |        |             |                                            |
| TVCADDR                                                                                        | =      | TVCCADR     | # TABLE OF CADRS, UNUSED LOCS FOR GENADRS  |
| TVCCADR                                                                                        | GENADR | ENABL2      | # (FOR T5 CALL, UNUSED TABLE LOC)          |
| +1                                                                                             | CADR   | PCOPY +1    | # PITCH COPYCYCLE                          |
| +2                                                                                             | GENADR | CMDSOUT     | # (FOR T5 CALL, UNUSED TABLE LOC)          |
| +3                                                                                             | CADR   | YCOPY +1    | # YAW COPYCYCLE                            |
| TVCEXADR                                                                                       | OCT    | 37772       | # (UNUSED TABLE LOC, FILL WITH 60MS, T5)   |
| +1                                                                                             | GENADR | EXECCOPY +1 | # TVCEXECUTIVE RESTART POINTS (ORDERED)    |
| +2                                                                                             | GENADR | 1SHOTCHK    |                                            |
| +3                                                                                             | GENADR | TEMPSET     |                                            |
| +4                                                                                             | GENADR | CORSETUP    |                                            |
| +5                                                                                             | GENADR | CORCOPY +1  |                                            |
| +6                                                                                             | GENADR | CNTRCOPY    |                                            |

This code is written to file src/TVCRESTARTS.s.

## A.123 TVCROLLDAP

```

1930  <src/TVCROLLDAP.s 1930>≡
# Copyright:    Public domain.
# Filename:     TVCROLLDAP.agc
# Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
#               It is part of the source code for the Command Module's (CM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:      Ron Burkey <info@sandroid.org>.
# Website:      www.ibiblio.org/apollo.
# Pages:        984-998
# Mod history:  2009-05-13 RSB   Adapted from the Colossus249/ file of the
#                               same name, using Comanche055 page images.
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#       2021113-051.  10:28 APR. 1, 1969
#
#       This AGC program shall also be referred to as
#               Colossus 2A
#
# Page 984
# PROGRAM NAME....TVC ROLL AUTOPILOT
# LOG SECTION....TVCROLLDAP                                SUBROUTINE....DAPCSM
# MOD BY SCHLUNDT   21 OCTOBER 1968
#
# FUNCTIONAL DESCRIPTION....
#
#       *AN ADAPTATION OF THE LEM P-AXIS CONTROLLER
#       *MAINTAIN OGA WITHIN 5 DEG DEADBND OF OGAD, WHERE OGAD = OGA AS SEEN
#       BY IGNOVER (P40)
#       *MAINTAIN OGA RATE LESS THAN 0.1 DEG/SEC LIMIT CYCLE RATE
#       *SWITCHING LOGIC IN PHASE PLANE.... SEE GSOP CHAPTER 3
#       *USES T6 CLOCK TO TIME JET FIRINGS.
#       *MAXIMUM JET FIRING TIME = 2.56 SECONDS, LIMITED TO 2.5 IF GREATER

```

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```
#      *MINIMUM JET FIRING TIME = 15 MS
#      *JET PAIRS FIRE ALTERNATELY
#      *AT LEAST 1/2 SECOND DELAY BEFORE A NEW JET PAIR IS FIRED
#      *JET FIRINGS MAY NOT BE EXTENDED, ONLY SHORTENED, WHEN RE-EVALUATION
#      OF A JET FIRING TIME IS MADE ON A LATER PASS
#
# CALLING SEQUENCE....
#
#      *ROLLDAP CALL VIA WAITLIST, IN PARTICULAR BY TVCEXEC (EVERY 1/2 SEC)
#      WITH A 3CS DELAY TO ALLOW FREE TIME FOR OTHER RUPTS (DWNRPRT, ETC.)
#
# NORMAL EXIT MODES.... ENDOFJOB
#
# ALARM OR ABORT EXIT MODES.... NONE
#
# SUBROUTINES CALLED.....NONE
#
# OTHER INTERFACES....
#
#      *TVCEXEC SETS UP ROLLDAP TASK EVERY 1/2 SECOND AND UPDATES 1/CONACC
#      EVERY 10 SECONDS (VIA MASSPROP AND S40.15)
#      *RESTARTS SUSPEND ROLL DAP COMPUTATIONS UNTIL THE NEXT 1/2 SEC
#      SAMPLE PERIOD. (THE PART OF TVCEXECUTIVE THAT CALLS ROLL DAP IS
#      NOT RESTARTED.) THE OGAD FROM IGNITION IS MAINTAINED.
#
# ERASABLE INITIALIZATION REQUIRED
#
#      *1/CONACC                      (S40.15)
#      *OGAD                          (CDUX, AT IGNITION)
#      *OGANOW                        (CDUX AT TVCINIT4 AND TVCEXECUTIVE)
#      *OGAPAST                       (OGANOW AT TVCEXECUTIVE)
#      *ROLLFIRE = TEMREG = ROLLWORD = 0 (MRCLEAN LOOP IN TVCDAPON)
#
# OUTPUT....
#
#      *ROLL JET PAIR FIRINGS
#
# Page 985
# DEBRIS.... MISCELLANEOUS, SHAREABLE WITH RCS/ENTRY, IN EBANK6 ONLY
#
# Page 986
# SOME NOTES ON THE ROLL AUTOPILOT, AND IN PARTICULAR, ON ITS SWITCHING
# LOGIC. SEE SECTION THREE OF THE GSOP (SUNDISK/COLOSSUS) FOR DETAILS.
#
# SWITCHING LOGIC IN THE PHASE PLANE....
#
```

```

#                                     OGARATE
#                                     *
#                                     *
# *
#                                     * (REGION 1, SEE TEXT BELOW)
#                                     *
# *
#                                     * ...PARABOLA (SWITCHING = CONTROL)
#                                     *
#                                     * *
#                                     * (FIRE NEG ROLL JETS)
#                                     *
#                                     * *
# (-DB,+LMCRATE)....*
#                                     *
#                                     * *
#                                     *
#                                     * OGAERROR
# *****
#                                     * * (-AK, OGAERR)
#                                     * * (REGION 6-PRIME)
#                                     * * (SEE TEXT BELOW)
#                                     * *
#                                     * * ...STRAIGHT LINE
# (FIRE POS ROLL JETS) * * * * *
#                                     * (COAST) *
#                                     *
#                                     * -MINLIM
#                                     *
#                                     *
#                                     *
#                                     * -MAXLIM
#                                     *
#                                     *
#
# SWITCHING PARABOLAS ARE CONTROL PARABOLAS, THUS REQUIRING KNOWLEDGE OF
# CONTROL ACCELERATION CONACC, OR ITS RECIPROCAL, 1/CONACC, THE TVC
# ROLL DAP GAIN (SEE TVCEXECUTIVE VARIABLE GAIN PACKAGE). JET
# FIRING TIME IS SIMPLY THAT REQUIRED TO ACHIEVE THE DESIRED OGARATE,
# SUBJECT TO THE LIMITATIONS DISCUSSED UNDER FUNCTIONAL DESCRIPTION,
# ABOVE.
#
# THE THREE CONTROL REGIONS (+, -, AND ZERO TORQUE) ARE COMPRISED OF
# TWELVE SUBSET REGIONS ( 1...6, AND THE CORRESPONDING 1-PRIME...
# 5-PRIME ) SEE SECTION 3 OF THE GSOP (SUNDISK OR COLOSSUS)
# Page 987
#
# GIVEN THE OPERATING POINT NOT IN THE COAST REGION, THE DESIRED OGARATE
# IS AT THE POINT OF PENETRATION OF THE COAST REGION BY THE CONTROL

```

```

# PARABOLA WHICH PASSES THROUGH THE OPERATING POINT. FOR REGION 3
# DESIRED OGARATE IS SIMPLY +-MAXLIM. FOR REGIONS 1 OR 6 THE SOLUTION
# TO A QUADRATIC IS REQUIRED (THE PENETRATION IS ALONG THE STRAIGHT
# LINE OR MINLIM BOUNDARY SWITCH LINES). AN APPROXIMATION IS MADE
# INSTEAD. CONSIDER AN OPERATING POINT IN REGION 6'. PASS A TANGENT TO
# THE CONTROL PARABOLA THROUGH THE OPERATING POINT, AND FIND ITS
# INTERSECTION WITH THE STRAIGHT LINE SECTION OF THE SWITCH CURVE...
# THE INTERSECTION DEFINES THE DESIRED OGARATE. IF THE OPERATING POINT IS
# CLOSE TO THE SWITCH LINE, THE APPROXIMATION IS QUITE GOOD (INDEED
# THE APPROXIMATE AND QUADRATIC SOLUTIONS CONVERGE IN THE LIMIT AS
# THE SWITCH LINE IS APPROACHED). IF THE OPERATING POINT IS NOT CLOSE
# TO THE SWITCH LINE, THE APPROXIMATE SOLUTION GIVES VALID TREND
# INFORMATION (DIRECTION OF DESIRED OGARATE) AT LEAST. THE
# RE-EVALUATION OF DESIRED OGARATE IN SUBSEQUENT ROLL DAP PASSES (1/2
# SECOND INTERVALS) WILL BENEFIT FROM THE CONVERGENT NATURE OF THE
# APPROXIMATION.
#
# FOR LARGE OGAERROR THE TANGENT INTERSECTS +-MINLIM SWITCH BOUNDARY BEFORE
# INTERSECTING THE STRAIGHT LINE SWITCH. HOWEVER THE MINLIM IS
# IGNORED IN COMPUTING THE FIRING TIME, SO THAT THE EXTENSION (INTO
# THE COAST REGION) OF THE STRAIGHT LINE SWITCH IS WHAT IS FIRED TO.
# IF THE ROLL DAP FINDS ITSELF IN THE COAST REGION BEFORE REACHING
# THE DESIRED INTERSECTION (I.E., IN THE REGION BETWEEN THE MINLIM
# AND THE STRAIGHT LINE SWITCH) IT WILL EXHIBIT NORMAL COAST-REGION
# BEHAVIOR AND TURN OFF THE JETS. THE PURPOSE OF THIS FIRING POLICY
# IS TO MAINTAIN STATIC ROLL STABILITY IN THE EVENT OF A JET
# FAILED-ON.
#
# WHEN THE OPERATING POINT IS IN REGION 1 THE SAME APPROXIMATION IS
# MADE, BUT AT AN ARTIFICIALLY-CREATED OR DUMMY OPERATING POINT,
# DEFINED BY: OGAERROR = INTERSECTION OF CONTROL PARABOLA AND
# OGAERROR AXIS, OGARATE = +-LMCRATE WHERE SIGN IS OPPOSITE THAT OF
# REAL OPERATING POINT RATE. WHEN THE OPERATING POINT HAS PASSED
# FROM REGION 1 TO REGION 6', THE DUMMY POINT IS NO LONGER REQUIRED,
# AND THE SOLUTION REVERTS TO THAT OF A REGULAR REGION 6' POINT.
#
# EQUATION FOR SWITCHING PARABOLA (SEE FIGURE ABOVE)....
#
# 
$$SOGAERROR = (DB - (SOGARATE) (1/CONACC)/2) SGN(SOGARATE)$$

#
# EQUATION FOR SWITCHING STRAIGHT LINE SEGMENT....
#
# 
$$SOGARATE = -(-SLOPE)(SOGAERROR) - SGN(SOGARATE) INTERCEP$$

#
# WHERE INTERCEP = DB(-SLOPE) - LMCRATE
# Page 988

```

```

#
# EQUATION FOR INTERSECTION, CONTROL PARABOLA, AND STRAIGHT SWITCH LINE....
#
#      DOGADOT = NUM/DEN, WHERE
#
#      NUM = (-SLOPE)(OGARATE) (1/CONACC)
#            +SGN(DELOGA)(-SLOPE)(OGAERROR - SGN(DELOGA)(DB))
#            +LMCRATE
#
#      DEN = (-SLOPE)(LMCRATE)(1/CONACC) = SGN(DELOGA)
#
#      DELOGA = OGAERROR - (DB - (OGADOT) (1/CONACC)/2)SGN(OGARATE)
#
# FOR REGIONS 6 AND 6-PRIME, USE ACTUAL OPERATING POINT (OGA, OGARATE)
# FOR OGAERROR AND OGARATE IN THE INTERSECTION EQUATIONS ABOVE.
# FOR REGIONS 1 AND 1-PRIME USE DUMMY OPERATING POINT FOR OGAERROR
# AND OGARATE, WHERE THE DUMMY POINT IS GIVEN BY....
#
#      OGAERROR = DELOGA + DB SGN(OGARATE)
#
#      OGARATE = -LMCRATE SGN(OGARATE)
#
# NOTE, OGAERROR = OGA - OGAD USES DUMMY REGISTER OGA IN ROLL DAP CODING
# ALSO, AT POINT WHERE DOGADOT IS COMPUTED, REGISTER DELOGA IS USED
# AS A DUMMY REGISTER FOR THE OGAERROR IN THE NUM EQUATION ABOVE.
# Page 989

# ROLLDAP CODING....

          SETLOC  DAPROLL
          BANK
          EBANK=  OGANOW
          COUNT*  $$/ROLL
ROLLDAP    CAE    OGANOW          # OGA RATE ESTIMATOR...SIMPLE FIRST-ORDER
          EXTEND                                     #      DIFFERENCE (SAMPLE TIME = 1/2 SEC)
          MSU     OGAPAST
          EXTEND
          MP      BIT5
          LXCH    A
          TS      OGARATE          # SC.AT B-4 REV/SEC

# COMPUTATIONS WHICH FOLLOW USE OGA FOR OGAERR (SAME REGISTER)
# EXAMINE DURATION OF LAST ROLL FIRING IF JETS ARE NOW ON.

DURATION   CA      ROLLFIRE          # SAME SGN AS PRESENT TORQ,MAGN=POSMAX
          EXTEND

```

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```

      BZF      +2          # ROLL JETS ARE NOW OFF.
      TCF      ROLLOGIC    # ENTER LOGIC, JETS NOW ON.

      CAE      TEMREG      # EXAMINE LAST FIRING INTERVAL
      EXTEND                    # IF POSITIVE, DON'T FIRE
      BZF      ROLLOGIC    # ENTER LOGIC, JETS NOW OFF.

      CAF      ZERO        # JETS HAVE NOT BEEN OFF FOR 1/2 SEC. WAIT
      TS       TEMREG      # RESET TEMREG
WAIT1/2  TCF      TASKOVER  # EXIT ROLL DAP

# COMPUTE DB-(1/2 CONACC) (OGARATE)SQ (1/2 IN THE SCALING)

ROLLOGIC  CS       OGARATE  # SCALED AT 2(-4) REV/SEC
          EXTEND
          MP       1/CONACC  # SCALED AT 2(+9) SEC SQ /REV
          EXTEND
          MP       OGARATE
          AD       DB        # SCALED AT 2(+0) REV
          TS       TEMREG    # QUANTITY SCALED AT 2(+0) REV.

# GET SIGN OF OGARATE

          CA       OGARATE
          EXTEND
          BZMF     +3        # LET SGN(0) BE NEGATIVE
          CA       BIT1
          TCF      +2
          CS       BIT1
          TS       SGNRT     # + OR - 2(-14)

# Page 990
# CALCULATE DISTANCE FROM SWITCH PARABOLA,DELOGA
          EXTEND
          MP       TEMREG    # SGN(OGARATE) TEMREG NOW IN L
          CS       L
          AD       OGA       # SCALED AT 2(+0) REV
DELOGAC   TS       DELOGA    # SC.AT B+0 REV, PLUS TO RIGHT OF C-PARAB

# EXAMINE SGN(DELOGA) AND CREATE CA OR CS INSTR. DEPENDING UPON SIGN.

          EXTEND
          BZMF     +3
          CAF      PRI030    # = CA (30000)
          TCF      +2
          CAF      BIT15     # = CS (40000)
```

```

      TS      I

      INDEX   I      # TSET ON I SGN(OGARATE)
      0       SGNRT  # CA OR CS
      COM
      EXTEND
REG1TST      BZMF   ROLLON      # IF REGION 1 (DELOGA OGARATE SAME SIGN)

# NO JET FIRE YET.  TEST FOR MAX OGARATE.

      INDEX   I
      0       OGARATE      # CA OR CS...BOTH MUST BE NEG. HERE
      TS      IOGARATE     # I.E., I OGARATE
      AD      MAXLIM       # SCALED AT 2(-4) REV/SEC
      EXTEND
REG3TST      BZMF   RATELIM     # IF REGION 3 (RATES TOO HIGH, FIRE JETS)

# COMPUTATION OF I((-SLOPE)OGA + OGARATE) - INTERCEPT:  NOTE THAT STR. LINE
# SWITCH SLOPE IS (SLOPE) DEG/SEC/DEG, A NEG. QUANTITY

      CA      OGARATE
      EXTEND
      MP      BIT14
      TS      TEMREG
      CA      OGA
      EXTEND
      MP      -SLOPE
      DDOUBL
      DDOUBL
      DDOUBL      # (OGA ERROR MUST BE LESS THAN +-225 DEG)
      AD      TEMREG

      INDEX   I
      0       A      # I((-SLOPE)OGA+OGARATE) AT 2(-3)REV/SEC
      COM
# Page 991
      AD      INTERCEP     # SCALED AT 2(-3) REV.
      COM
      EXTEND
REG2TST      BZMF   NOROLL     # IP REGION 2 (COAST SIDE OF STRT LINE)

# CHECK TO SEE IF OGARATE IS ABOVE MINLIM

      CA      IOGARATE     # ALWAYS NEGATIVE
      AD      MINLIM      # SCALED AT 2(-4) REV/SEC.
      EXTEND

```



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REG4TST            BZMF        NOROLL            # IF REGION 4 (COAST SIDE OF MINLIM)

# ALL AREAS CHECKED EXCEPT LAST AREA...NO FIRE IN THIS SMALL SEGMENT

INDEX    I  
O        OGA  
COM  
AD       DB  
COM  
EXTEND

REG5TST            BZMF        NOROLL            # IF REGION 5 (COAST SIDE OF DB)

# JETS MUST FIRE NOW. OGARATE IS NEG. (OR VICE VERSA). USE DIRECT STR. LINE.  
# DELOGA AND DELOGART ARE USED AS DUMMY VARIABLES IN THE SOLUTION OF A  
# STRAIGHT LINE APPROXIMATION TO A QUADRATIC SOLUTION OF THE INTERSECTION  
# OF THE CONTROL PARABOLA AND THE STRAIGHT-LINE SWITCH LINE. THE STRAIGHT  
# LINE IS THE TANGENT TO THE CONTROL PARABOLA AT THE OPERATING POINT. (FOR  
# OPERATING POINTS IN REGIONS 6 AND 6')

REGION6            CAE        OGA            # USE ACTUAL OPERATING POINT FOR TANGENT  
TS        DELOGA            # ACTUAL STATE  
CA        OGARATE  
TS        DELOGART        # ACTUAL STATE, I.E., DEL OGARATE  
TCF        ONROLL

# JETS ALSO FIRE FROM HERE EXCEPT OGARATE IS POS (VICE VERSA), USE INDIRECT  
# STRAIGHT LINE ESTABLISHED BY TANGENT TO A CONTROL PARABOLA AT ((DELOGA  
# + DB SGN(DELOGA) ), -LMCRATE SGN(DELOGA) )        (THIS IS THE DUMMY  
# OPERATING POINT FOR OPERATING POINTS IN REGIONS 1 AND 1')

ROLLON            INDEX    I  
O        DB  
ADS        DELOGA            # DELOGA WAS DIST. FROM SWITCH PARABOLA  
  
CS        LMCRATE            # LIMIT CYCLE RATE AT 2(-4) REV/SEC  
INDEX    I  
O        A  
TS        DELOGART        # EVALUATE STATE FOR INDIRECT LINE.

# Page 992

# SOLVE STRAIGHT LINES SIMULTANEOUSLY TO OBTAIN DESIRED OGARATE.

ONROLL            EXTEND            # DELOGART IN ACC. ON ARRIVAL  
MP        1/CONACC  
DOUBLE  
EXTEND

|            |        |          |                                           |
|------------|--------|----------|-------------------------------------------|
|            | MP     | -SLOPE   |                                           |
|            | TS     | TEMREG   | # 2(-SLOPE)RATE /CONACC                   |
|            | EXTEND |          |                                           |
|            | MP     | DELOGART |                                           |
|            | TS     | DELOGART | # 2(-SLOPE)(RATESQ)/CONACC                |
|            | CS     | BIT11    |                                           |
|            | INDEX  | I        |                                           |
|            | O      | A        |                                           |
| RATEDEN    | ADS    | TEMREG   | # DENOMINATOR COMPLETED                   |
|            | INDEX  | I        |                                           |
|            | O      | DELOGA   |                                           |
|            | COM    |          |                                           |
|            | AD     | DB       |                                           |
|            | COM    |          |                                           |
|            | EXTEND |          |                                           |
|            | MP     | -SLOPE   |                                           |
|            | ADS    | DELOGART |                                           |
|            | CA     | LMCRATE  |                                           |
|            | EXTEND |          |                                           |
|            | MP     | BIT11    |                                           |
| RATENUM    | AD     | DELOGART | # NUMERATOR COMPLETED                     |
|            | XCH    | L        | # PLACE NUMERATOR IN L FOR OVERFL. CHECK  |
|            | CA     | ZERO     |                                           |
|            | EXTEND |          |                                           |
|            | DV     | TEMREG   | # OVERFLOW, IF ANYTHING, NOW APPEARS IN A |
|            | EXTEND |          |                                           |
|            | BZF    | DVOK     | # NO OVERFLOW...(0,L)/TEMREG = 0,L        |
| MINLIMAP   | CCS    | A        |                                           |
|            | CAF    | POSMAX   | # POSITIVE OVERFLOW                       |
|            | TCF    | ROLLSET  |                                           |
|            | CS     | POSMAX   | # NEGATIVE OVERFLOW                       |
|            | TCF    | ROLLSET  |                                           |
| DVOK       | LXCH   | A        | # PUT NUMERATOR BACK INTO A, 0 INTO L     |
|            | EXTEND |          |                                           |
|            | DV     | TEMREG   | # RESULT OF DIVISION IS DESIRED OGARATE   |
|            | TCF    | ROLLSET  | # (SCALED AT B-4 REV/SEC)                 |
| RATELIM    | CS     | MAXLIM   |                                           |
|            | INDEX  | I        |                                           |
| # Page 993 | O      | A        | # IF I = CA, DESIRED RATE IS -MAXLIM      |

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# COMPUTE JET FIRE TIME, BASED ON DESIRED RATE MINUS PRESENT RATE

```
ROLLSET      TS      TEMREG      # STORE DESIRED OGARATE (SCALED B-4)
EXTEND
SU           OGARATE      # RATE DIFF. SCALED AT 2(-4) REV/SEC
TS           TEMREG      #      OVERFLOW PROTECT
TCF         +3           #      "      "
INDEX       A           #      "      "
CS          LIMITS      #      "      "
EXTEND
MP          T6SCALE      # T6SCALE = 8/10.24
EXTEND
MP          1/CONACC      # SCALED AT B+9 SECSQ/REV (MAX < .60)
DDOUBL
DDOUBL
TS          TEMREG      #      OVERFLOW PROTECT
TCF         +3           #      "      "
INDEX       A           #      "      "
CS          LIMITS      #      "      "
TS          TEMREG      # JET FIRE TIME AT 625 MICROSEC/BIT
EXTEND
BZF        NOROLL
```

# JET FIRE TIME IS NZ, TEST FOR JETS NOW ON.

```
CAE          TEMREG      # DESIRED CHANGE IN OGARATE
EXTEND
MP          ROLLFIRE      # (SGN OF TORQUE: ZERO IF JETS NOW OFF)
CCS         A
TCF        MOREROLL      # CONTINUE FIRING WITH PRESENT POLARITY
TCF        NEWROLL      # START NEW FIRING NOW, PLUS
TCF        NOROLL      # TERMINATE OLD FIRING, NEW SIGN REQUESTED
TCF        NEWROLL      # START NEW FIRING NOW, MINUS
```

# CONTINUE PRESENT FIRING

```
MOREROLL     CAF        ZERO
TS           I          # USE TEMP. AS MOREROLL SWITCH
TCF         MAXTFIRE
```

# START NEW FIRING BUT CHECK IF GREATER THAN MIN FIRE TIME.

```
NEWROLL      CCS        TEMREG      # CALL THIS T6FIRE
AD           ONE
TCF         +2
AD           ONE
```

```

COM      # -MAG(T6FIRE)
AD      TMINFIRE  # TMINFIRE-MAG(T6FIRE)
# Page 994
COM
EXTEND
MINTST  BZMF  NOROLL      # IF NOT GREATER THAN TMINFIRE (NEW FIRE)

# PROCEED WITH NEW FIRING BUT NOT LONGER THAN TMAXFIRE

MAXTFIRE  CA      TEMREG
EXTEND
MP      1/TMXFIR      # I.E., 1/TMAXFIRE
EXTEND
MAXTST  BZF      NOMXFIRE      # IF LESS THAN TMAXFIRE

CCS      A
CAF      TMAXFIRE      # USE MAXIMUM
TCF      +2
CS      TMAXFIRE      # USE MAXIMUM
TS      TEMREG

# SET UP SIGN OF REQUIRED TORQUE

NOMXFIRE  CCS      TEMREG      # FOR TORQUE SIGN
CA      POSMAX      # POSITIVE TORQUE REQUIRED
TCF      +2
CA      NEGMAX      # NEGATIVE TORQUE REQUIRED
TS      ROLLFIRE      # SET ROLLFIRE FOR + OR - TORQUE

COM      # COMPLEMENT... POS. FOR NEG. TORQUE
EXTEND
BZMF      +3      # POSITIVE TORQUE REQUIRED
CS      TEMREG
TS      TEMREG

FIRELOOK  CA      I      # IS IT MOREROLL
EXTEND
BZF      FIREPLUG      # YES
TCF      JETROLL      # MAG(T6FIRE) NOW IN TEMREG

FIREPLUG  CAE      TIME6      # CHECK FOR EXTENDED FIRING
EXTEND
SU      TEMREG
EXTEND
EXTENTST  BZMF      TASKOVER      # IF EXTENSION WANTED, DON'T, EXIT ROLL DAP
TCF      JETROLL

```

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```
NOROLL      CS      ZERO      # COAST...(NEG ZERO FOR TIME6)
            TS      ROLLFIRE   # NOTE, JETS CAN FIRE NEXT PASS
            TS      TEMREG

JETROLL      EXTEND
            DCA      NOROL1T6

# Page 995   DXCH      T6LOC
            CA      TEMREG      # ENTER JET FIRING TIME
            TS      TIME6

            CA      I          # I=0 IF MOREROLL, KEEP SAME JETS ON
            EXTEND
SAMEJETS     BZF      TASKOVER  # IF JETS ON KEEP SAME JETS.  EXIT ROLL DAP

            CCS      ROLLFIRE
            TCF      +TORQUE
            TCF      T6ENABL
            TCF      -TORQUE
            TCF      T6ENABL

# PROCEED WITH + TORQUE

+TORQUE      CA      ROLLWORD   # WHAT WAS THE LAST +TORQUE COMBINATION
            MASK     BIT1       # WAS IT NO.9-11
            EXTEND
            BZF      NO.9-11    # NOT 9-11, SO USE IT THIS TIME

NO.13-15     CS      BIT1
            MASK     ROLLWORD
            TS      ROLLWORD    # CHANGE BIT 1 TO ZERO
            CAF      +ROLL2
            EXTEND
            WRITE    CHAN6
            TCF      T6ENABL

NO.9-11      CAF      BIT1      # 1ST + JETS TO FIRE (MRCLEAN OS ROLLWORD)
            ADS      ROLLWORD   # CHANGE BIT 1 TO ONE
            CAF      +ROLL1
            EXTEND
            WRITE    CHAN6
            TCF      T6ENABL

-TORQUE      CA      ROLLWORD   # WHAT WAS LAST -TORQUE COMBINATION
            MASK     BIT2       # WAS IT NO.12-10
```

```

                                EXTEND
                                BZF      NO.12-10      # NOT 12-10, SO USE IT THIS TIME

NO.16-14      CS      BIT2
                                MASK     ROLLWORD
                                TS       ROLLWORD      # CHANGE BIT 2 TO ZERO
                                CAF      -ROLL2
                                EXTEND
                                WRITE    CHAN6
                                TCF      T6ENABL

NO.12-10      CAF      BIT2      # 1ST -JETS TO FIRE (MRCLEAN OS ROLLWORD)
# Page 996
                                ADS      ROLLWORD      # CHANGE BIT 2 TO ONE
                                CAF      -ROLL1
                                EXTEND
                                WRITE    CHAN6

T6ENABL       CAF      BIT15
                                EXTEND
                                WOR      CHAN13
RDAPEND       TCF      TASKOVER  # EXIT ROLL DAP

# Page 997
# THIS T6 TASK SHUTS OFF ALL ROLL JETS

NOROLL1       LXCH     BANKRUPT  # SHUT OFF ALL (ROLL) JETS, (A T6 TASK
                                CAF      ZERO          # CALLED BY "JETROLL")
                                TS       ROLLFIRE      # ZERO INDICATES JETS NOW OFF
                                EXTEND
KILLJETS      WRITE    CHAN6
                                TCF      NOQRSM

# Page 998
# CONSTANTS FOR ROLL AUTOPILOT....

                                EBANK=   BZERO
NOROL1T6      2CADR    NOROLL1

DB            DEC      .01388889  # DEAD BAND (5 DEG), SC.AT B+0 REV

-SLOPE        DEC      0.2        # -SWITCHLINE SLOPE(0.2 PER SEC) SC.AT B+0
                                # PER SEC
LMCRATE       DEC      .00027778 B+4 # LIMIT CYCLE RATE (0.1 DEG/SEC) SC.AT
                                # B-4 REV/SEC
INTERCEP      DEC      .0025 B+3   # DB(-SLOPE) - LMCRATE, SC.AT B-3 REV/SC

```

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```
MINLIM      DEC      .00277778 B+4  # RATELIM,MIN (1DEG/SEC), SC.AT B-4 REV/SC

1/MINLIM    DEC      360 B-18      # RECIPROCAL THEREOF, SHIFTED 14 RIGHT

MAXLIM      DEC      .01388889 B+4  # RATELIM,MAX (5DEG/SEC), SC.AT B-4 REV/SC

# The following two were B+4.---RSB 2009.
TMINFIRE    DEC      1.5 B-10      # 15 MS. (14MIN), SC.AT 16 BITS/CS

TMAXFIRE    DEC      250 B-10      # 2.5 SEC, SC.AT 16 BITS/CS

1/TMXFIR    =        BIT3          # RECIPROCAL THEREOF, SHIFTED 14 RIGHT,
                                     #      ROUNDS TO OCT00004, SO ALLOWS 2.56
                                     #      SEC FIRINGS BEFORE APPLYING LIMIT
T6SCALE     =        PRI031        # (B+3) (16 BITS/CS) (100CS/SEC)

+ROLL1      =        FIVE          # ONBITS FOR JETS 9 AND 11
+ROLL2      =        OCT120        # ONBITS FOR JETS 13 AND 15
-ROLL1      =        TEN           # ONBITS FOR JETS 12 AND 10
-ROLL2      OCT      240           # ONBITS FOR JETS 16 AND 14
```

This code is written to file `src/TVCROLLDAP.s`.

## A.124 TVCSTROKETEST

```

1944  <src/TVCSTROKETEST.s 1944>≡
      # Copyright:    Public domain.
      # Filename:     TVCSTROKETEST.agc
      # Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
      #               It is part of the source code for the Command Module's (CM)
      #               Apollo Guidance Computer (AGC), for Apollo 11.
      # Assembler:    yaYUL
      # Contact:       Ron Burkey <info@sandroid.org>.
      # Website:       www.ibiblio.org/apollo.
      # Pages:         979-983
      # Mod history:   2009-05-13 RSB   Adapted from the Colossus249/ file of the
      #               same name, using Comanche055 page images.
      #
      # This source code has been transcribed or otherwise adapted from digitized
      # images of a hardcopy from the MIT Museum. The digitization was performed
      # by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
      # thanks to both. The images (with suitable reduction in storage size and
      # consequent reduction in image quality as well) are available online at
      # www.ibiblio.org/apollo. If for some reason you find that the images are
      # illegible, contact me at info@sandroid.org about getting access to the
      # (much) higher-quality images which Paul actually created.
      #
      # Notations on the hardcopy document read, in part:
      #
      #       Assemble revision 055 of AGC program Comanche by NASA
      #       2021113-051.  10:28 APR. 1, 1969
      #
      #       This AGC program shall also be referred to as
      #               Colossus 2A

      # Page 979
      # NAME          STROKE TEST PACKAGE                      (INCLUDING INITIALIZATION PACKAGE)
      # LOG SECTION...TVCSTROKETEST                          SUBROUTINE...DAPCSM
      # MODIFIED BY SCHLUNDT                                  21 OCTOBER 1968
      #
      # FUNCTIONAL DESCRIPTION....
      #       STROKE TEST PACKAGE GENERATES A WAVEFORM DESIGNED TO EXCITE BENDING
      #       STRKTSTI (STROKE TEST INITIALIZATION) IS CALLED AS A JOB BY VB68.
      #               IT INITIALIZES ALL ERASABLES REQD FOR A STROKE TEST, AND
      #               THEN TESTS FOR CSM/LM (BIT 13 OF DAPDATR1). IF CSM/LM,
      #               IN EITHER HIGH OR LOW-BANDWIDTH MODE, THE TEST IS STARTED
      #               IMMEDIATELY. IF NOT CSM/LM, PROGRAM EXITS WITH NO ACTION.
      #       HACK (STROKE TEST) GENERATES THE WAVEFORM BY DUMPING PULSE BURSTS
      #               OF PROPER SIGN AND IN PROPER SEQUENCE DIRECTLY INTO

```



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```
#          TVCPITCH, WORKING IN CONJUNCTION WITH BOTH PITCH AND YAW
#          TVC DAPS, WITH INTERMEDIATE WAITLIST CALLS.  NOTE, HOWEVER
#          THAT THE STROKE TEST IS PERFORMED ONLY IN THE PITCH AXIS.
#          AN EXAMPLE WAVEFORM IS GIVEN BELOW, TO DEMONSTRATE STROKE-
#          TEST PARAMETER SELECTION.
#          RESTARTS CAUSE TEST TO BE TERMINATED.  ANOTHER V68 REQD IF TEST
#          IS TO BE RE-RUN.
#          PULSE BURST SIZE IS PAD-LOADED (ESTROKER) SO THAT AMPLITUDE OF
#          WAVEFORM CAN BE CHANGED.  THERE ARE TEN PULSE BURSTS IN
#          THE HALF-AMPLITUDE OF THE FIRST FREQUENCY SET IN THE
#          STANDARD WAVEFORM.  AMPLITUDE IS 10(ESTROKER)(1/42.15),
#          NOMINALLY 50/42.15 = 1.185 DEG
#
# CALLING SEQUENCE....
#     EXTENDED VERB 68 SETS UP STRKTSTI JOB
#     PITCH AND YAW TVCDAPS, FINDING STROKER NON-ZERO, DO A "TC HACK"
#     AN INTERNALLY-GENERATED WAITLIST CALL ENTERS AT "HACKWLST"
#
# NORMAL EXIT MODES....
#     TC BUNKER ("Q" IF ENTRY FROM DAP, "TCTSKOVR" IF FROM WAITLIST) LIST
#
# SUBROUTINES CALLED....
#     WAITLIST
#
# ALARM OR ABORT EXIT MODES....
#     NONE
#
# ERASABLE INITIALIZATION REQUIRED....
#     ESTROKER (PAD-LOAD)
#     STROKER, CADDY, REVS, CARD, N
#
# OUTPUT....
#     STRKTSTI...INITIALIZATION FOR STROKE TEST
#     HACK, HACKWLST...PULSE BURSTS INTO TVCPITCH VIA "ADS"
#     RESETS STROKER = +0 WHEN TEST COMPLETED
#
# DEBRIS....
#     N = CADDY = +0, CARD = -0, REVS = -1
#     BUNKER
# Page 980
#
# EXAMPLE STROKE TEST WAVE FORM, DEMONSTRATING PARAMETER SELECTION
#
# NOTE....THIS IS NOT THE OFFICIAL WAVEFORM....
#
#          **          **
```

[illegible]

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```
BANK      17
SETLOC    DAPS2
BANK

COUNT*   $$/STRK
EBANK=    CADDY

STRKTSTI   TCR      TSTINIT      # STROKE TEST INITIALIZATION PKG (CALLED
                                     # AS A JOB BY VERB68)

STRKCHK     INHINT

CAE        DAPDATR1      # CHECK FOR CSM/LM CONFIGURATION
MASK       BIT14
EXTEND
BZF        +3

CAE        ESTROKER      # BEGIN ON NEXT DAP PASS (PITCH OR YAW)
TS         STROKER       # (STROKING DONE IN PITCH ONLY, HOWEVER)

TCF        ENDOFJOB

TSTINIT    CS          FCADDY      # NORMAL ENTRY FROM STRKTSTI
           TS          CADDY
           TS          N           # NOTE SGN CHNG FCADDY(+) TO CADDY(-)

CAF        FREVS
TS         REVS

CS         FCARD         # NOTE SGN CHNG FCARD(+) TO CARD(-)
TS         CARD

TC         Q             # RETURN TO STRKTSTI+1 (OR CHKSTRK+2 OR +4)

# Page 982
# THE OFFICIAL STROKE TEST WAVEFORM (3 JAN, 1967) CONSISTS OF FOUR STROKE SETS, AS FOLLOWS....
#
# SET 1...10 BURSTS IN 1/2 AMP, 4 REVERSALS
# SET 2... 6 BURSTS IN 1/2 AMP, 6 REVERSALS
# SET 3... 5 BURSTS IN 1/2 AMP, 10 REVERSALS
# SET 4... 4 BURSTS IN 1/2 AMP, 14 REVERSALS
#
# THE PULSE BURST SIZE (ESTROKER) IS PAD-LOADED (5 BITS AS OF 3 JAN, 1967)
# THE REMAINING WAVEFORM-GENERATING PARAMETERS ARE AS FOLLOWS....

FCADDY     DEC        10          # NO. PULSE BURSTS IN 1/2 AMP, SET1..(+10)
```

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```
FREVS          DEC      3          # NO. REVERSALS MINUS 1, SET1.....( 3)

FCARD          DEC      4          # NO. STROKE SETS.....(+ 4)

FCARD1         DEC      5          # NO. REVERSALS MINUS 1, SET2.....( 5)

FCARD2         DEC      9          #
FCARD3         DEC     13          #
                                     3.....( 9)
                                     4.....( 13)

FCARD4         DEC      6          # NO. PULSE BURSTS IN 1/2 AMP, SET2..(+ 6)
FCARD5         DEC      5          #
FCARD6         DEC      4          #
                                     3..(+ 5)
                                     4..(+ 4)

20MS           =        BIT2

# STROKE TEST PACKAGE PROPER....

                EBANK=  BUNKER

HACK           EXTEND
                QXCH   BUNKER          # ENTRY (IN T5 RUPT) FROM TVCDAPS
                                     # SAVE Q FOR DAP RETURN

                CAF     20MS          # 2DAPSx2(PASSES/DAP)x2(CS/PASS)=8CS=TVCDT
                TC      WAITLIST
                EBANK=  BUNKER
                2CADR   HACKWLST

                TCF     +3

HACKWLST       CAF     TCTSKOVR        # ENTRY FROM WAITLIST
                TS      BUNKER          # BUNKER IS TC TASKOVER

                CA      STROKER        # STROKE
                ADS     TVCPITCH

                CAF     BIT11          # RELEASE THE ERROR COUNTERS
                EXTEND
                WOR     CHAN14
                INCR    CADDY          # COUNT DOWN THE NO. BURSTS, THIS SLOPE

# Page 982

                CS      CADDY
                EXTEND
                BZMF    +2
                TC      BUNKER          # EXIT, WHILE ON A SLOPE

                CCS     REVS
```

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|          |        |          |                                           |
|----------|--------|----------|-------------------------------------------|
|          | TCF    | REVUP    | # POSITIVE REVS                           |
|          | TCF    | REVUP +4 | # FINAL REVERSAL, THE SET                 |
|          | INCR   | CARD     | # NEGATIVE REVS SET LAST PASS, READY FOR  |
|          | CS     | CARD     | # THE NEXT SET. CHECK IF NO MORE SETS     |
|          | EXTEND |          |                                           |
|          | BZF    | STROKILL | # ALL SETS COMPLETED                      |
|          | INDEX  | CARD     |                                           |
|          | CAF    | FCARD +4 | # PICK UP NO. REVERSALS (-), NEXT SET     |
|          | TS     | REVS     | # REINITIALIZE                            |
|          | INDEX  | CARD     |                                           |
|          | CS     | FCARD +7 | # PICK UP NO. BURSTS IN 1/2AMP, NEXT SET  |
|          | TS     | N        | # REINITIALIZE                            |
|          | TS     | CADDY    |                                           |
|          | TC     | BUNKER   | # EXIT, AT END OF SET                     |
| STROKILL | TS     | STROKER  | # RESET (TO +0) TO END TEST               |
|          | TC     | BUNKER   | # EXIT, STROKE TEST FINIS                 |
| REVUP    | TS     | REVS     | # ALL REVERSALS EXCEPT LAST OF SET        |
|          | CA     | N        |                                           |
|          | DOUBLE |          | # 2 x 1/2AMP                              |
|          | TCF    | +4       |                                           |
| +4       | CS     | ONE      | # FINAL REVERSAL, THIS SET                |
|          | TS     | REVS     | # PREPARE TO BRANCH TO NEW BURST          |
|          | CA     | N        | # JUST RETURN TO ZERO, FINAL SLOPE OF SET |
|          | TS     | CADDY    | # CADUP                                   |
|          | CS     | STROKER  | # CHANGE SIGN OF SLOPE                    |
|          | TS     | STROKER  |                                           |
|          | TC     | BUNKER   | # EXIT AT A REVERSAL (SLOPE CHANGE)       |

This code is written to file src/TVCSTROKETEST.s.

## A.125 UPDATE PROGRAM

```

1950  <src/UPDATE-PROGRAM.s 1950>≡
      # Copyright:    Public domain.
      # Filename:     UPDATE_PROGRAM.agc
      # Purpose:      Part of the source code for Comanche, build 055. It
      #               is part of the source code for the Command Module's
      #               (CM) Apollo Guidance Computer (AGC), Apollo 11.
      # Assembler:    yaYUL
      # Reference:     pp. 1497-1507
      # Contact:       Ron Burkey <info@sandroid.org>
      # Website:       http://www.ibiblio.org/apollo.
      # Mod history:   2009-05-07 RSB  Adapted from Colossus249/UPDATE_PROGRAM.agc
      #               and page images. Corrected various typos
      #               in the transcription of program comments,
      #               and these should be back-ported to
      #               Colossus249.
      #
      # The contents of the "Comanche055" files, in general, are transcribed
      # from scanned documents.
      #
      # Assemble revision 055 of AGC program Comanche by NASA
      # 2021113-051. April 1, 1969.
      #
      # This AGC program shall also be referred to as Colossus 2A
      #
      # Prepared by
      #
      #               Massachussets Institute of Technology
      #               75 Cambridge Parkway
      #               Cambridge, Massachusetts
      #
      # under NASA contract NAS 9-4065.
      #
      # Refer directly to the online document mentioned above for further
      # information. Please report any errors to info@sandroid.org.

      # Page 1497
      # PROGRAM NAME:      P27
      # WRITTEN BY:        KILROY/ DE WOLF
      #
      # MOD NO:             0
      # MOD BY:             KILROY
      # DATE:               01DEC67
      #
      # LOG SECTION:       UPDATE PROGRAM.
      #

```

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```
# FUNCT. DESCR.:      P27 (THE UPDATE PROGRAM) PROCESSES COMMANDS AND DATA
#                      INSERTIONS REQUESTED BY THE GROUND VIA UPLINK.
#                      THE P27 PROGRAM WILL ACCEPT UPDATES
#                      ONLY DURING P00 FOR THE LM, AND ONLY DURING P00,
#                      P02, AND FRESH START FOR THE CSM.
#
# CALLING SEQ:         PROGRAM IS INITIATED BY UPLINK ENTRY OF VERBS 70, 71, 72, AND 73.
#
# SUBROUTINES:         TESTXACT, NEWMODEX, NEWMODEX +3, GOXDSPF, BANKCALL, FINDVAC, INTPRET, I
#                      INTWAKEU, ENDEXT, POSTJUMP, FALTON, NEWPHASE, PHASCHNG
#
# NORMAL EXIT:         TC ENDEXT
#
# ALARM/ABORT:         TC FALTON FOLLOWED BY TC ENDEXT
#
# RESTARTS:            P27 IS RESTART PROTECTED IN TWO WAYS ...
#                      1. PRIOR TO VERIFLAG INVERSION (WHICH IS CAUSED BY THE GROUND/ASTR
#                      DATA BY SENDING A V33E WHEN V21N02 IS FLASHING)---
#                      NO PROTECTION EXCEPT PRE-P27 MODE IS RESTROED, COAST + ALIGN DO
#                      ACTIVITY LIGHT IS TURNED OFF. (JUST AS IF A V34E WAS SENT DURI
#                      V70,V71,V72, OR V73 WILL HAVE TO BE COMPLETELY RESENT BY USER.
#                      2. AFTER VERIFLAG INVERSION (WHEN UPDATE OF THE SPECIFIED ERASABLE
#                      PROTECTED AGAINST RESTARTS.
#
# DEBRIS:              UPBUFF (20D) TEMP STORAGE FOR ADDRESSES AND CONTENTS.
#                      UPVERB (1) VERB NUMBER MINUS 70D (E.G., FOR V72, UPVERB = 72D - 70
#                      UPOLDMOD(1) FOR MAJOR MODE INTERRUPTED BY P27.
#                      COMPNUMB(1) TOTAL NUMBER OF COMPONENTS TO BE TRANSMITTED.
#                      UPCOUNT (1) ACTUAL NUMBER OF COMPONENTS RECEIVED.
#                      UPTEMP (1) SCRATCH, BUT USUALLY CONTAINS COMPONENT NUMBER TO BE CH
#
# INPUT:
#
# ENTRY                DESCRIPTION
# V70EXXXXXEXXXXXE    (LIFTOFF TIME INCREMENT) DOUBLE PRECISION OCTAL TIME INCREMENT,
#                      IS ADDED TO TEPHEM, SUBTRACTED FROM AGC CLOCK(TIME2,TIME1), SUB
#                      VECTOR TIME(TETCSM) AND SUBTRACTED FROM LEM STATE VECTOR TIME(T
#                      THE DP OCTAL TIME INCREMENT IS SCALED AT 2(28).
#
# Page 1498
# V71EIIIAAAAE        (CONTIGUOUS BLOCK UPDATE) II-2 OCTAL COMPONENTS, XXXXX,
# XXXXXE              ARE LOADED INTO ERASABLE STARTING AT ECADR, AAAA.
# XXXXXE              IT IS .GE. 3 .AND. .LE. 20D.,
#                      AND (AAAA + II -3) DOES NOT PRODUCE AN ADDRESS IN THE
# 9 NEXT BANK
# .
# V72EIIIE             SCALING IS SAME AS INTERNAL REGISTERS.
#                      (SCATTER UPDATE) (II-1)/2 OCTAL COMPONENTS, XXXXX, ARE
```

```
#      AAAAEXXXXXE      LOADED INTO ERASABLE LOCATIONS, AAAA.
#      AAAAEXXXXXE      II IS .GE. 3 .AND. .LE. 19D, AND MUST BE ODD.
#      .                  SCALING IS SAME AS INTERNAL REGISTERS.
#
#      V73EXXXXXEXXXXXE  (OCTAL CLOCK INCREMENT) DOUBLE PRECISION OCTAL TIME
#                          INCREMENT XXXXX XXXXX, IS ADDED TO THE AGC CLOCK, IN
#                          CENTISECONDS SCALED AT (2)28).
#                          THIS LOAD IS THE OCTAL EQUIVALENT OF V55.
#
# OUTPUT:                IN ADDITION TO THE ABOVE REGISTER LOADS, ALL UPDATES
#                          COMPLEMENT BIT3 OF FLAGWORD7.
#
# ADDITIONAL NOTES:      VERB 71, JUST DEFINED ABOVE WILL BE USED TO PERFORM BUT NOT I
#                          1. CSM/LM STATE VECTOR UPDATE
#                          2. REFSMMAT UPDATE
#
#      THE FOLLOWING COMMENTS DELINEATE EACH SPECIAL UPDATE ---
#
#      1. CSM/LM STATE VECTOR UPDATE (ALL DATA ENTRIES IN OCTAL)
#          ENTRIES:        DATA DEFINITION:                SCALING
#          V71E            CONTIGUOUS BLOCK UPDATE VERB
#          21E            NUMBER OF COMPONENTS FOR STATE VECTOR UPDATE
#          AAAAE            ECADR OF 'UPSVFLAG'
#          XXXXXE          STATE VECTOR IDENTIFIER: 00001 FOR CSM, 77776 FOR LM
#                               00002 FOR CSM, 77775 FOR LM
#          XXXXXEXXXXXE    X POSITION
#          XXXXXEXXXXXE    Y POSITION
#          XXXXXEXXXXXE    Z POSITION
#          XXXXXEXXXXXE    X VELOCITY
#          XXXXXEXXXXXE    Y VELOCITY
#          XXXXXEXXXXXE    Z VELOCITY
#          XXXXXEXXXXXE    TIME FROM AGC CLOCK ZERO
#          V33E            VERB 33 TO SIGNAL THAT THE STATE VECTOR IS READY TO B
#
#      2. REFSMMAT (ALL DATA ENTRIES IN OCTAL)
#          ENTRIES        DATA DEFINITIONS                SCALING
#
# Page 1499
#          V71E            CONTIGUOUS BLOCK UPDATE VERB
#          24E            NUMBER OF COMPONENTS FOR REFSMMAT UPDATE
#          AAAAE            ECADR OF 'REFSMMAT'
#          XXXXXEXXXXXE    ROW 1 COLUMN 1                2(-1)
#          XXXXXEXXXXXE    ROW 1 COLUMN 2                2(-1)
#          XXXXXEXXXXXE    ROW 1 COLUMN 3                2(-1)
#          XXXXXEXXXXXE    ROW 2 COLUMN 1                2(-1)
#          XXXXXEXXXXXE    ROW 2 COLUMN 2                2(-1)
#          XXXXXEXXXXXE    ROW 2 COLUMN 3                2(-1)
```



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```
#      XXXXXEXXXXXE      ROW 3 COLUMN 1      2(-1)
#      XXXXXEXXXXXE      ROW 3 COLUMN 2      2(-1)
#      XXXXXEXXXXXE      ROW 3 COLUMN 3      2(-1)
#      V33E              VERB 33 TO SIGNAL THAT REFSMMAT IS READY TO BE STORED
```

```
BANK      07
SETLOC    EXTVERBS
BANK
```

```
EBANK=    TEPHEM
```

```

COUNT*   $$/P27
V70UPDAT   CAF      UP70      # COMES HERE ON V70E
           TCF      V73UPDAT +1
V71UPDAT   CAF      UP71      # COMES HERE ON V71E
           TCF      V73UPDAT +1
V72UPDAT   CAF      UP72      # COMES HERE ON V72E
           TCF      V73UPDAT +1
V73UPDAT   CAF      UP73      # COMES HERE ON V73E
+1         TS      UPVERBSV    # SAVE UPVERB UNTIL IT'S OK TO ENTER P27
           TC      TESTXACT    # GRAB DISPLAY IF AVAILABLE, OTHERWISE
                               # TURN *OPERATOR ERROR* ON AND TERMINATE JOB
           CA      MODREG      # CHECK IF UPDATE ALLOWED
           EXTEND    # FIRST CHECK FOR MODREG = +0, -0
           BZF      +2        # (+0 = P00, -0 = FRESHSTART)
           TC      CKMDMORE    # NOW CHECK FOR PROGRAM WHICH CAN BE
                               # INTERRUPTED BY P27.
           CAE      MODREG      # UPDATE ALLOWED
           TS      UPOLDMOD     # SAVE CURRENT MAJOR MODE
# Page 1500
           CAE      UPVERBSV    # SET UPVERB TO INDICATE TO P27
           TS      UPVERB      # WHICH EXTENDED VERB CALLED IT.
           CAF      ONE
           TS      UPCOUNT      # INITIALIZE UPCOUNT TO 1
           TC      POSTJUMP     # LEAVE EXTENDED VERB BANK AND
           CADR      UPART2     # GO TO UPDATE PROGRAM (P27) BANK.
```

|             |        |             |                                            |
|-------------|--------|-------------|--------------------------------------------|
| CKMDMORE    | CS     | FLAGWRD5    |                                            |
|             | MASK   | BIT8        | # CHECK IF COMPUTER IS LGC                 |
|             | CCS    | A           | # IS COMPUER LGC OR AGC                    |
| UPERLEM     | TCF    | UPERROR     | # ERROR: IT'S THE LEM + MODE IS NOT P00.   |
|             | CS     | TWO         |                                            |
|             | MASK   | MODREG      |                                            |
|             | CCS    | A           |                                            |
| UPERCMC     | TCF    | UPERROR     | # ERROR: IT'S THE CMC AND MODE IS NOT      |
|             |        |             | # P00 OR P02.                              |
|             | TC     | Q           | # ALLOW UPDATE TO PROCEED.                 |
| UPERROR     | TC     | POSTJUMP    | # TURN ON 'OPERATOR ERROR' LIGHT           |
|             | CADR   | UPERROUT +2 | # GO TO COMMON UPDATE PROGRAM EXIT         |
|             | SBANK= | LOWSUPER    |                                            |
| UP70        | EQUALS | ZERO        |                                            |
| UP71        | EQUALS | ONE         |                                            |
| UP72        | EQUALS | TWO         |                                            |
| UP73        | EQUALS | THREE       |                                            |
|             | BANK   | 04          |                                            |
|             | SETLOC | UPDATE2     |                                            |
|             | BANK   |             |                                            |
|             | COUNT* | \$\$/P27    |                                            |
| UPPART2     | EQUALS |             | # UPDATE PROGRAM -- PART 2                 |
|             | TC     | PHASCHNG    | # SET RESTART GROUP 6 TO RESTORE OLD MODE  |
|             | OCT    | 07026       | # AND DOWNLIST AND EXIT IF RESTART OCCURS. |
|             | OCT    | 30000       | # PRIORITY SAME AS CHRPRIO                 |
|             | EBANK= | UPBUFF      |                                            |
|             | 2CADR  | UPOUT +1    |                                            |
|             | CAF    | ONE         |                                            |
|             | TS     | DNLSTCOD    | # DOWNLIST                                 |
|             | TC     | NEWMODEX    | # SET MAJOR MODE = 27                      |
| # Page 1501 | DEC    | 27          |                                            |
|             | INDEX  | UPVERB      | # BRANCH DEPENDING ON WHETHER THE UPDATE   |
|             | TCF    | +1          | # VERB REQUIRES A FIXED OR VARIABLE NUMBER |
|             | TCF    | +3          | # V70 FIXED (OF COMPONENTS)                |
|             | TCF    | OHWELL1     | # V71 VARIABLE -- GO GET NO. OF COMPONENTS |
|             | TCF    | OHWELL1     | # V72 VARIABLE -- GO GET NO. OF COMPONENTS |

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```

      CA      TWO      # V73 (AND V70) FIXED
      TS      COMPNUMB # SET NUMBER OF COMPONENTS TO 2.
      TCF     OHWELL2  # GO GET THE TWO UPDATE COMPONENTS

OHWELL1      CAF      ADUPBUFF      # * REQUEST USER TO SEND NUMBER *
      TS      MPAC +2      # * OF COMPONENTS PARAMETER(II) *
      +2      CAF      UPLOADNV      # (CKV432 RETURNS HERE IF V32 ENCOUNTERED)
      TC      BANKCALL      # DISPLAY A FLASHING V21N01
      CADR     GOXDSPF      # TO REQUEST II.
      TCF     UPOUT4      # V32 TERMINATE UPDATE (P27) RETURN
      TCF     OHWELL1 +2
      TC      CK4V32      # DATA OR V32 RETURN
      CS      BIT2
      AD      UPBUFF      # IS II (NUMBER OF COMPONENTS PARAMETER)
      EXTEND      # .GE. 3 AND .LE. 20D.
      BZMF     OHWELL1 +2
      CS      UPBUFF
      AD      UP21
      EXTEND
      BZMF     OHWELL1 +2
      CAE      UPBUFF
      TS      COMPNUMB      # SAVE II IN COMPNUMB

# UPBUFF LOADING SEQUENCE

      INCR     UPCOUNT      # INCREMENT COUNT OF COMPONENTS RECEIVED.
OHWELL2      CAF      ADUPBFM1      # CALCULATE LOCATION (ECADR) IN UPBUFF
      AD      UPCOUNT      # WHERE NEXT COMPONENT SHOULD BE STORED
      +2      TS      MPAC +2      # PLACE ECADR INTO R3.
      +3      CAF      UPLOADNV      # (CK4V32 RETURNS HERE IF V32 ENCOUNTERED)
      TC      BANKCALL      # DISPLAY A FLASHING V21N01
      CADR     GOXDSPF      # TO REQUEST DATA.
      TCF     UPOUT4      # V34 TERMINATE UPDATE (P27) RETURN.
      TCF     OHWELL2 +3      # V33 PROCEED RETURN
      TC      CK4V32      # DATA OR V32 RETURN
      CS      UPCOUNT      # HAVE WE FINISHED RECEIVING ALL
      AD      COMPNUMB      # THE DATA WE EXPECTED.
      EXTEND
      BZMF     UPVERIFY      # YES -- GO TO VERIFICATION SEQUENCE
      TCF     OHWELL2 -1      # NO -- REQUEST ADDITIONAL DATA.

# Page 1502
# VERIFY SEQUENCE
UPVERIFY      CAF      ADUPTMP      # PLACE ECADR WHERE COMPONENT NO. INDEX
      TS      MPAC +2      # IS TO BE STORED INTO R3.
      CAF      UPVRFYNV      # (CK4V32 RETURNS HERE IF V32 ENCOUNTERED)
```

```

TC      BANKCALL      # DISPLAY A FLASHING V21N02 TO REQUEST
CADR    GOXDSPF      # DATA CORRECTION OR VERIFICATION.
TCF     UPOUT4        # V34 TERMINATE UPDATE (P27) RETURN
TCF     UPSTORE       # V33 DATA SENT IS GOOD. GO STORE IT.
TC      CK4V32        # COMPONENT NO. INDEX OR V32 RETURN
CA      UPTEMP        # DOES THE COMPONENT NO. INDEX JUST SENT
EXTEND                      # SPECIFY A LEGAL COMPONENT NUMBER?
BZMF    UPVERIFY      # NO, IT IS NOT POSITIVE NONZERO
CS      UPTEMP
AD      COMPNUMB
AD      BIT1
EXTEND
BZMF    UPVERIFY      # NO
CAF     ADUPBFM1      # YES -- BASED ON THE COMPONENT NO. INDEX
AD      UPTEMP        # CALCULATE THE ECADR OF LOCATION IN
TCF     OHWELL2 +2    # UPBUFF WHICH USER WANTS TO CHANGE.

UPOUT4      EQUALS    UPOUT +1      # COMES HERE ON V34 TC TERMINATE UPDATE.

# CHECK FOR VERB 32 SEQUENCE

CK4V32      CS      MPAC      # ON DATA RETURN FROM 'GOXDSPF'
            MASK    BIT6      # ON DATA RETURN FROM "GOXDSP" & THE CON-
            CCS     A          # TENTS OF MPAC = VERB. SO TEST FOR V32.
            TC      Q          # IT'S NOT A V32, IT'S DATA. PROCEED.
            INDEX   Q
            TC      0 -6      # V32 ENCOUNTERED -- GO BACK AND GET DATA

ADUPTEMP    ADRES    UPTEMP      # ADDRESS OF TEMP STORAGE FOR CORRECTIONS
ADUPBUFF    ADRES    UPBUFF      # ADDRESS OF UPDATE DATA STORAGE BUFFER
UPLOADNV    VN      2101        # VERB 21 NOUN 01
UPVRFYNV    VN      2102        # VERB 21 NOUN 02
UP21        =      MD1          # DEC 21 = MAX NO OF COMPONENTS +1
UPDTPHAS    EQUALS   FIVE

# PRE-STORE AND FAN TO APPROPRIATE BRANCH SEQUENCE

UPSTORE      EQUALS                      # GROUND HAS VERIFIED UPDATE. STORE DATA.

            INHINT

            CAE      FLAGWRD7      # INVERT VERIFLAG (BIT 3 OF FLAGWRD7) TO
            XCH      L              # INDICATE TO THE GROUND (VIA DOWNLINK)
            CAF      BIT3           # THAT THE V33 (WHICH THE GROUND SENT TO

# Page 1503
            EXTEND                  # VERIFY THE UPDATE) HAS BEEN SUCCESSFULLY

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```

RXOR    LCHAN    # RECEIVED BY THE UPDATE PROGRAM
TS      FLAGWRD7

TC      PHASCHNG  # SET RESTART GROUP 6 TO REDO THE UPDATE
OCT     04026    # DATA STORE IF A RESTART OCCURS.
INHINT  # (BECAUSE PHASCHNG DID A RELINT)

CS      TWO      # GO TO UPFNDVAC IF INSTALL IS REQUIRED.
AD      UPVERB   # THAT IS, IF IT'S A V70 - V72.
EXTEND  # GO TO UPEND73 IF IT'S A V73.
BZMF    UPFNDVAC

# VERB 73 BRANCH

UPEND73  EXTEND   # V73 -- PERFORM DP OCTAL AGC CLOCK INCREMENT
          DCA     UPBUFF
          DXCH    UPBUFF +8D
          TC      TIMEDIDL
          TC      FALTON    # ERROR -- TURN ON *OPERATOR ERROR* LIGHT
          TC      UPOUT +1  # GO TO COMMON UPDATE PROGRAM EXIT

UPFNDVAC  CAF     CHRPRIO  # (USE EXTENDED VERB PRIORITY)
          TC      FINDVAC  # GET VAC AREA FOR 'CALL INTSTALL'
          EBANK=  TEPHEM
          2CADR   UPJOB    # (NOTE: THIS WILL ALSO SET EBANK FOR
          TC      ENDOFJOB # 'TEPHEM' UPDATE BY V70)

UPJOB    TC      INTERPRET # THIS COULD BE A STATE VECTOR UPDATE -- SO
          CALL    INTSTALL  # WAIT (PUT JOB TO SLEEP) IF ORBIT INT(OI)
                              # IS IN PROGRESS -- OR -- GRAB OI AND RETURN
                              # TO UPWAKE IF OI IS NOT IN PROGRESS.

UPWAKE    EXIT

          TC      PHASCHNG # RESTART PROTECT (GROUP 6)
          OCT     04026

          TC      UPFLAG   # SET INTEGRATION RESTART BIT
          ADRES   REINTFLG
          INHINT
UPPART3  EQUALS

          INDEX   UPVERB   # BRANCH TO THE APPROPRIATE UPDATE VERB
          TCF     +1       # ROUTINE TO ACTUALLY PERFORM THE UPDATE
          TCF     UPEND70  # V70
          TCF     UPEND71  # V71
```

```

TCF      UPEND72      # V72

# Page 1504
# ROUTINE TO INCREMENT CLOCK (TIME2,TIME1) WITH CONTENTS OF DP WORD AT UPBUFF.
TIMEDIDL      EXTEND
QXCH      UPTMP      # SAVE Q FOR RETURN
CAF      ZERO      # ZERO AND SAVE TIME2,TIME1
ZL
DXCH      TIME2
DXCH      UPBUFF +18D      # STORE IN CASE OF OVERFLOW

CAF      UPDTPHAS      # DO
TS      L      # A
COM      # QUICK
DXCH      -PHASE6      # PHASCHNG

TIMEDIDR      INHINT
CAF      ZERO
ZL      # PICK UP INCRMENTER (AND ZERO
TS      MPAC +2      # IT IN CASE OF RESTARTS) AND
DXCH      UPBUFF +8D      # STORE IT
DXCH      MPAC      # INTO MPAC FOR TPAGREE.

EXTEND
DCA      UPBUFF +18D
DAS      MPAC      # FORM SUM IN MPAC
EXTEND
BZF      DELTAOK      # TEST FOR OVERFLOW
CAF      ZERO
DXCH      UPBUFF +18D      # OVERFLOW, RESTORE OLD VALUE OF CLOCK
DAS      TIME2      # AND TURN ON OPERATOR ERROR

TC      PHASCHNG      # RESTART PROTECT (GROUP 6)
OCT      04026

TC      UPTMP      # GO TO ERROR EXIT

DELTAOK      TC      TPAGREE      # FORCE SIGN AGREEMENT
DXCH      MPAC
DAS      TIME2      # INCREMENT TIME2,TIME1

TC      PHASCHNG      # RESTART PROTECT (GROUP 6)
OCT      04026

INHINT
INDEX      UPTMP      # (CODED THIS WAY FOR RESTART PROTECTION)

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```

TC      1      # NORMAL RETURN

# VERB 71 BRANCH

UPEND71  CAE    UPBUFF +1    # SET EBANK
          TS     EBANK        #      AND

# Page 1505

          MASK   LOW8         # CALCULATE
          TS     UPTMP        # S-REG VALUE OF RECEIVING AREA
          AD     NEG3         # IN THE PROCESS OF
          AD     COMPNUMB     # PERFORMING
          EXTEND  # THIS UPDATE
          BZF    STORLP71     # WILL WE
          MASK   BIT9         # OVERFLOW
          CCS     A           # INTO THE NEXT EBANK...
          TCF    UPERROUT     # YES

          CA     NEG3         # NO -- CALCULATE NUMBER OF
          AD     COMPNUMB     # WORDS TO BE STORED MINUS ONE
STORLP71 TS     MPAC         # SAVE NO. OF WORDS REMAINING MINUS ONE
          INDEX  A           # TAKE NEXT UPDATE WORD FROM
          CA     UPBUFF +2    # UPBUFF AND
          TS     L           # SAVE IT IN L
          CA     MPAC         # CALCULATE NEXT
          AD     UPTMP        # RECEIVING ADDRESS
          INDEX  A
          EBANK= 1400
          LXCH   1400        # UPDATE THE REGISTER BY CONTENTS OF L
          EBANK= TEPHEM
          CCS     MPAC        # ARE THERE ANY WORDS LEFT TO BE STORED
          TCF    STORLP71     # YES
          TCF    UPOUT        # NO -- THEN EXIT UPDATE PROGRAM
ADUPBFM1 ADRES  UPBUFF -1    # SAME AS ADUPBUFF BUT LESS 1 (DON'T MOVE)
          TCF    UPOUT        # NO -- EXIT UPDATE (HERE WHEN COMPNUMB = 3)

# VERB 72 BRANCH

UPEND72  CAF     BIT1        # HAVE AN ODD NO. OF COMPONENTS
          MASK   COMPNUMB     # BEEN SENT FOR A V72 UPDATE ...
          CCS     A
          TCF    +2          # YES
          TCF    UPERROUT     # ERROR -- SHOULD BE ODD NO. OF COMPONENTS
          CS     BIT2
          AD     COMPNUMB
LDLOOP72 TS     MPAC        # NOW PERFORM THE UPDATE
          INDEX  A
```

```

      CAE      UPBUFF +1      # PICK UP NEXT UPDATE WORD
      LXCH     A
      CCS      MPAC           # SET POINTER TO ECADR (MUST BE CCS)
      TS       MPAC
      INDEX    A
      CAE      UPBUFF +1      # PICK UP NEXT ECADR OF REG TO BE UPDATED
      TS       EBANK          # SET EBANK
      MASK     LOW8           # ISOLATE RELATIVE ADDRESS
      INDEX    A

# Page 1506
      EBANK=   1400
      LXCH     1400           # UPDATE THE REGISTER BY CONTENTS OF L
      EBANK=   TEPHEM
      CCS      MPAC           # ARE WE THOROUGH THE V72 UPDATE...
      TCF      LDLOOP72       # NO

# NORMAL FINISH OF P27

UPOUT      EQUALS
      TC       INTWAKEU       # RELEASE GRAB OF ORBITAL INTEGRATION
      +1      CAE      UPOLDMOD # RESTORE PRIOR P27 MODE
      TC       NEWMODEX +3
      CAF      ZERO
      TS       DNLSTCOD
      TC       UPACTOFF       # TURN OFF 'UPLINK ACTIVITY' LIGHT
      EXTEND    # KILL GROUP 6
      DCA      NEG0
      DXCH     -PHASE6

      TC       ENDEXT         # EXTENDED VERB EXIT

# VERB TO BRANCH

UPEND70     EXTEND           # V70 DOES THE FOLLOWING WITH DP DELTA
      DCS      UPBUFF       # TIME IN UPBUFF
      DXCH     UPBUFF +8D
      TC       TIMEDIDL      # DECREMENT AGC CLOCK

      TC       UPERROUT      # ERROR WHILE DECREMENTING CLOCK -- EXIT

      EBANK=   TEPHEM
      EXTEND
      DCS      UPBUFF       # COPY DECREMENTERS FOR
      DXCH     UPBUFF +10D   # RESTART PROTECTION
      EXTEND

```



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Apollo-11.nw 1961

```
DCS      UPBUFF
DXCH      UPBUFF +12D

TC      PHASCHNG      # RESTART PROTECT (GROUP 6)
OCT      04026

CAF      ZERO
ZL
DXCH      UPBUFF +10D      # DECREMENT CSM STATE VECTOR TIME
DAS      TETCSM

CAF      ZERO
```

# Page 1507

```
ZL
DXCH      UPBUFF +12D      # DECREMENT LEM STATE VECTOR TIME
DAS      TETLEM
CAF      ZERO
ZL
DXCH      UPBUFF
DAS      TEPHEM +1      # INCREMENT TP TEPHEM
ADS      TEPHEM

TC      PHASCHNG      # RESTART PROTECT (GROUP 6)
OCT      04026

EBANK=    UPBUFF

TC      UPOUT      # GO TO STANDARD UPDATE PROGRAM EXIT
```

# ERROR SEQUENCE

```
UPERROUT      TC      FALTON      # TURN ON *OPERATOR ERROR* LIGHT
               TCF      UPOUT      # GO TO COMMON UPDATE PROGRAM EXIT

               +2      TC      FALTON      # TURN ON 'OPERATOR ERROR' LIGHT
               TC      UPACTOFF      # TURN OFF 'UPLINK ACTIVITY' LIGHT
               TC      ENDEXT      # EXTENDED VERB EXIT
                                   # (THE PURPOSE OF UPERROUT +2 EXIT IS
                                   # TO PROVIDE AN ERROR EXIT WHICH DOES NOT
                                   # RESET ANY RESTART GROUPS)
```

# 'UPACTOFF' IS A ROUTINE TO TURN OFF UPLINK ACTIVITY LIGHT ON ALL EXITS FROM UPDATE PROGRAM (P

```
UPACTOFF      CS      BIT3
EXTEND      # TURN OFF UPLINK ACTIVITY LIGHT
```

1962      Apollo-11.nw

July 10, 2016

|      |          |                         |
|------|----------|-------------------------|
| WAND | DSALMOUT | # (BIT 3 OF CHANNEL 11) |
| TC   | Q        |                         |

This code is written to file `src/UPDATE-PROGRAM.s`.

July 10, 2016

Apollo-11.nw 1963

## A.126 WAITLIST

1963

*<src/WAITLIST.s 1963>*≡

```
# Copyright:    Public domain.
# Filename:     WAITLIST.agc
# Purpose:      Part of the source code for Colossus 2A, AKA Comanche 055.
#               It is part of the source code for the Command Module's (CM)
#               Apollo Guidance Computer (AGC), for Apollo 11.
# Assembler:   yaYUL
# Contact:      Ron Burkey <info@sandroid.org>.
# Website:      www.ibiblio.org/apollo.
# Pages:        1221-1235
# Mod history:  2009-05-14 RSB   Adapted from the Colossus249/ file of the
#               same name, using Comanche055 page images.
#
# This source code has been transcribed or otherwise adapted from digitized
# images of a hardcopy from the MIT Museum. The digitization was performed
# by Paul Fjeld, and arranged for by Deborah Douglas of the Museum. Many
# thanks to both. The images (with suitable reduction in storage size and
# consequent reduction in image quality as well) are available online at
# www.ibiblio.org/apollo. If for some reason you find that the images are
# illegible, contact me at info@sandroid.org about getting access to the
# (much) higher-quality images which Paul actually created.
#
# Notations on the hardcopy document read, in part:
#
#       Assemble revision 055 of AGC program Comanche by NASA
#       2021113-051.  10:28 APR. 1, 1969
#
#       This AGC program shall also be referred to as
#               Colossus 2A
#
# Page 1221
# PROGRAM DESCRIPTION                                DATE -- 10 OCTOBER 1966
# MOD NO -- 2   LOG SECTION -- WAITLIST
# MOD BY -- MILLER      (DTMAX INCREASED TO 162.5 SEC) ASSEMBLY -- SUNBURST REV 5
# MOD 3 BY KERNAN       (INHINT INSERTED AT WAITLIST) 2/28/68 SKIPPER REV 4
# MOD 4 BY KERNAN       (TWIDDLE IN 54) 3/28/68 SKIPPER REV 13.
#
# FUNCTIONAL DESCRIPTION --
#       PART OF A SECTION OF PROGRAMS -- WAITLIST, TASKOVER, T3RUPT, USED TO CALL A PROGRAM (CA
#       WHICH IS TO BEGIN IN C(A) CENTISECONDS. WAITLIST UPDATES TIME3, LST1, AND LST2. THE M
#       FOLLOW.
#
#               C(TIME3) = 16384 -(T1-T) CENTISECONDS, (T=PRESENT TIME, T1-TIME FOR TASK1)
#
```

July 10, 2016

[illegible]

July 10, 2016

Apollo-11.nw 1965

```
#
# OUTPUT --
#     LST1 AND LST2 UPDATED WITH NEW TASK AND ASSOCIATED TIME.
#
# DEBRIS --
#     CENTRALS -- A,Q,L
#     OTHER     -- WAITEXIT, WAITADR, WAITTEMP, WAITBANK
#
# DETAILED ANALYSIS OF TIMING --
#     CONTROL WILL NOT BE RETURNED TO THE SPECIFIED ADDRESS (2CADR) IN EXACTLY DELTA T CENTIS
#     THE APPROXIMATE TIME MAY BE CALCULATED AS FOLLOWS:
#         LET TO = THE TIME OF THE TC WAITLIST
#         LET TS = TO +147U + COUNTER INCREMENTS (SET UP TIME)
#         LET X  = TS -(100TS)/100 (VARIANCE FROM COUNTERS)
#         LET Y  = LENGTH OF TIME OF INHIBIT INTERRUPT AFTER T3RUPT
#         LET Z  = LENGTH OF TIME TO PROCESS TASKS WHICH ARE DUE THIS T3RUPT BUT DISPATCH
#         (Z=0, USUALLY).
#         LET DELTD = THE ACTUAL TIME TAKEN TO GIVE CONTROL TO 2CADR
#     THEN DELTD = TS+DELTA T -X +Y +Z +1.05MS* +COUNTERS*
#     *THE TIME TAKEN BY WAITLIST ITSELF AND THE COUNTER TICKING DURING THIS WAITLIST
#     IN SHORT, THE ACTUAL TIME TO RETURN CONTROL TO A 2CADR IS AUGMENTED BY THE TIME TO SET
#     INTERRUPT, ALL COUNTERS TICKING, THE T3RUPT PROCESSING TIME, THE WAITLIST PROCESSING TI
#     OF OTHER TASKS INHIBITING THE INTERRUPT.
```

BLOCK 02

# Page 1223

EBANK= LST1 # TASK LISTS IN SWITCHED E BANK.

COUNT 02/WAIT

TWIDDLE

INHINT

TS L # SAVE DELAY TIME IN L

CA POSMAX

ADS Q # CREATING OVERFLOW AND Q-1 IN Q

CA BBANK

EXTEND

ROR SUPERBNK

XCH L

WAITLIST

INHINT

EXTEND

BZMF WATLSTO-

XCH Q SAVE DELTA T IN Q AND RETURN IN  
TS WAITEXIT WAITEXIT.

EXTEND

INDEX WAITEXIT # IF TWIDDLING, THE TS SKIPS TO HERE

1966 Apollo-11.nw

July 10, 2016

```

                                DCA      0          # PICK UP 2CADR OF TASK.
                                TS      WAITADR      # BBCON WILL REMAIN IN L
DLY2      -1      CAF      WAITBB      # ENTRY FROM FIXDELAY AND VARDELAY.
                                XCH      BBANK
                                TCF      WAIT2

WATLSTO-      TC      POODOO
                                OCT      1204      # WAITLIST CALL WITH ZERO OR NEG DT

# RETURN TO CALLER AFTER TASK INSERTION:

LVWTLIST      DXCH      WAITEXIT
                                AD      TWO
                                DTCB

                                EBANK=  LST1
WAITBB      BBCON      WAIT2

# RETURN TO CALLER +2 AFTER WAITING DT SPECIFIED AT CALLER +1.

FIXDELAY      INDEX      Q          # BOTH ROUTINES MUST BE CALLED UNDER
                                # Was CAF --- RSB 2004.
                                CA      0          # WAITLIST CONTROL AND TERMINATE THE TASK
                                INCR      Q          # IN WHICH THEY WERE CALLED.

# RETURN TO CALLER +1 AFTER WAITING THE DT AS ARRIVING IN A.

VARDELAY      XCH      Q          # DT TO Q.  TASK ADRES TO WAITADR.
                                TS      WAITADR
                                CA      BBANK      # BBANK IS SAVED DURING DELAY.
                                EXTEND

# Page 1224
                                ROR      SUPERBNK      # ADD SBANK TO BBCON.
                                TS      L
                                CAF      DELAYEX
                                TS      WAITEXIT      # GO TO TASKOVER AFTER TASK ENTRY.
                                TCF      DLY2

DELAYEX      TCF      TASKOVER -2      # RETURNS TO TASKOVER.

# Page 1225
# ENDTASK MUST ENTERED IN FIXED-FIXED SO IT IS DISTINGUISHABLE BY ITS ADRES ALONE.

                                EBANK=  LST1
ENDTASK      -2CADR      SVCT3
```

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Apollo-11.nw 1967

```
SVCT3      CCS  FLAGWRD2      # DRIFT FLAG
           TCF  TASKOVER
           TCF  TASKOVER
           TCF  +1

           CCS  IMUCADR      # DON'T DO NBDONLY IF SOMEONE ELSE IS IN
           TCF  SVCT3X
           TCF  +3
           TCF  SVCT3X
           TCF  SVCT3X
+3          CAF  PRI035      # COMPENSATE FOR NBD COEFFICIENTS ONLY.
           TC   NOVAC      #      ENABLE EVERY 81.93 SECONDS
EBANK=     NBDX
2CADR     NBDONLY

           TCF  TASKOVER

SETLOC     FFTAG6
BANK

SVCT3X     TC   FIXDELAY      # DELAY MAX OF 2 TIMES FOR IMU ZERO
           DEC  500
           TC   SVCT3

# Page 1226
# BEGIN TASK INSERTION.

           BANK  01
           COUNT 01/WAIT

WAIT2      TS   WAITBANK      # BBANK OF CALLING PROGRAM.
           CS   TIME3
           AD   BIT8          # BIT 8 = OCT 200
           CCS  A             # TEST 200 - C(TIME3). IF POSITIVE,
                               # IT MEANS THAT TIME3 OVERFLOW HAS OCCURRED PRIOR TO CS
                               # C(TIME3) = T - T1, INSTEAD OF 1.0 - (T1 - T). THE FC
                               # ORDERS SET C(A) = TD - T1 + 1 IN EITHER CASE.

           AD   OCT40001      # OVERFLOW HAS OCCURRED. SET C(A) =
           CS   A             # T - T1 + 1.0 - 201

# NORMAL CASE (C(A) NNZ) YIELDS SAME C(A): -( -(1.0-(T1-T)) + 200) - 1

           AD   OCT40201
           AD   Q             # RESULT = TD - T1 + 1.
```

```

      CCS      A          # TEST TD - T1 +1.

      AD      LST1        # IF TD - T1 POS, GO TO WTLST5 WITH
      TCF     WTLST5      # C(A) = (TD - T1) + C(LST1) = TD-T2+1

      NOOP
      CS      Q

```

```

# NOTE THAT THIS PROGRAM SECTION IS NEVER ENTERED WHEN T-T1 G/E -1,
# SINCE TD-T1+1 = (TD-T) + (T-T1+1), AND DELTA T = TD-T G/E +1. (G/E
# SYMBOL MEANS GREATER THAN OR EQUAL TO). THUS THERE NEED BE NO CON-
# CERN OVER A PREVIOUS OR IMMINENT OVEFLOW OF TIME3 HERE.

```

```

      AD      POS1/2      # WHEN TD IS NEXT, FORM QUANTITY
      AD      POS1/2      #      1.0 - DELTA T = 1.0 - (TD - T)
      XCH     TIME3
      AD      NEGMAX
      AD      Q           # 1.0 - DELTAT T NOW COMPLETE.
      EXTEND          # ZERO INDEX Q.
      QXCH    7          # (ZQ)

```

# Page 1227

WTLST4

```

      XCH     LST1
      XCH     LST1      +1
      XCH     LST1      +2
      XCH     LST1      +3
      XCH     LST1      +4
      XCH     LST1      +5
      XCH     LST1      +6
      XCH     LST1      +7

```

```

      CA      WAITADR     # (MINOR PART OF TASK CADR HAS BEEN IN L.)
      INDEX   Q
      TCF     +1

```

```

      DXCH    LST2
      DXCH    LST2      +2
      DXCH    LST2      +4
      DXCH    LST2      +6
      DXCH    LST2      +8D
      DXCH    LST2      +10D # AT END, CHECK THAT C(LST2 +10) IS STD
      DXCH    LST2      +12D
      DXCH    LST2      +14D
      DXCH    LST2      +16D
      AD      ENDTASK     # END ITEM, AS CHECK FOR EXCEEDING
                        # THE LENGTH OF THE LIST.

```



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|             |        |          |                                          |
|-------------|--------|----------|------------------------------------------|
|             | EXTEND |          | # DUMMY TASK ADRES SHOULD BE IN FIXED-   |
|             | BZF    | LVWTLIST | # FIXED SO ITS ADRES ALONE DISTINGUISHES |
|             | TCF    | WTABORT  | # IT.                                    |
| # Page 1228 |        |          |                                          |
| WTLST5      | CCS    | A        | # TEST TD - T2 + 1                       |
|             | AD     | LST1 +1  |                                          |
|             | TCF    | +4       |                                          |
|             | AD     | ONE      |                                          |
|             | TC     | WTLST2   |                                          |
|             | OCT    | 1        |                                          |
| +4          | CCS    | A        | # TEST TD - T3 + 1                       |
|             | AD     | LST1 +2  |                                          |
|             | TCF    | +4       |                                          |
|             | AD     | ONE      |                                          |
|             | TC     | WTLST2   |                                          |
|             | OCT    | 2        |                                          |
| +4          | CCS    | A        | # TEST TD - T4 + 1                       |
|             | AD     | LST1 +3  |                                          |
|             | TCF    | +4       |                                          |
|             | AD     | ONE      |                                          |
|             | TC     | WTLST2   |                                          |
|             | OCT    | 3        |                                          |
| +4          | CCS    | A        | # TEST TD - T5 + 1                       |
|             | AD     | LST1 +4  |                                          |
|             | TCF    | +4       |                                          |
|             | AD     | ONE      |                                          |
|             | TC     | WTLST2   |                                          |
|             | OCT    | 4        |                                          |
| +4          | CCS    | A        | # TEST TD - T6 + 1                       |
|             | AD     | LST1 +5  |                                          |
|             | TCF    | +4       |                                          |
|             | AD     | ONE      |                                          |
|             | TC     | WTLST2   |                                          |
|             | OCT    | 5        |                                          |
| +4          | CCS    | A        | # TEST TD - T7 + 1                       |
|             | AD     | LST1 +6  |                                          |
|             | TCF    | +4       |                                          |
|             | AD     | ONE      |                                          |
|             | TC     | WTLST2   |                                          |
|             | OCT    | 6        |                                          |

# Page 1229

```

      +4      CCS      A
            AD      LST1 +7
            TCF      +4
            AD      ONE
            TC      WTLST2
            OCT      7

      +4      CCS      A
WTABORT    TC      BAILOUT      # NO ROOM IN THE INN
            OCT      1203

            AD      ONE
            TC      WTLST2
            OCT      10

OCT40201    OCT      40201

```

# Page 1230

```

# THE ENTRY TC WTLST2 JUST PRECEDING OCT N IS FOR T LE TD LE T  -1.
#                                     N          N+1
#
# (LE MEANS LESS THAN OR EQUAL TO).  AT ENTRY, C(A) = -(TD - T  + 1)
#                                     N+1
#
# THE LST1 ENTRY-(T  -T +1) IS TO BE REPLACED BY -(TD - T  + 1), AND
#               N+1  N                                     N
#
# THE ENTRY-(T  - TD + 1) IS TO BE INSERTED IMMEDIATELY FOLLOWING.
#               N+1

```

```

WTLST2      TS      WAITTEMP      # C(A) = -(TD - T  + 1)
            INDEX    Q
            # Was CAF --- RSB 2004.
            CA      0
            TS      Q      # INDEX VALUE INTO Q.

            CAF      ONE
            AD      WAITTEMP
            INDEX    Q      # C(A) = -(TD - T  ) + 1.
            ADS      LST1 -1  #                                     N

            CS      WAITTEMP
            INDEX    Q
            TCF      WTLST4

```

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Apollo-11.nw 1971

# Page 1231

# ENTERS HERE ON T3 RUPT TO DISPATCH WAITLISTED TASK.

```
T3RUPT      EXTEND
             ROR      SUPERBNK      # READ CURRENT SUPERBANK VALUE AND
             TS       BANKRUPT      # SAVE WITH E AND F BANK VALUES.
             EXTEND
             QXCH     QRUPT

T3RUPT2     CAF      NEG1/2          # DISPATCH WAITLIST TASK.
             XCH      LST1 +7
             XCH      LST1 +6
             XCH      LST1 +5
             XCH      LST1 +4        # 1. MOVE UP LST1 CONTENTS, ENTERING
             XCH      LST1 +3        #   A VALUE OF 1/2 +1 AT THE BOTTOM
             XCH      LST1 +2        #   FOR T6-T5, CORRESPONDING TO THE
             XCH      LST1 +1        #   INTERVAL 81.91 SEC FOR ENDTASK.
             XCH      LST1
             AD       POSMAX          # 2. SET T3 = 1.0 - T2 - T USING LIST 1.
             ADS      TIME3          #   SO T3 WON'T TICK DURING UPDATE.
             TS       RUPTAGN
             CS       ZERO
             TS       RUPTAGN        # SETS RUPTAGN TO +1 ON OVERFLOW.

             EXTEND                  # DISPATCH TASK.
             DCS      ENDTASK
             DXCH     LST2 +16D
             DXCH     LST2 +14D
             DXCH     LST2 +12D
             DXCH     LST2 +10D
             DXCH     LST2 +8D
             DXCH     LST2 +6
             DXCH     LST2 +4
             DXCH     LST2 +2
             DXCH     LST2
             XCH      L
             EXTEND
             WRITE    SUPERBNK      # SET SUPERBANK FROM BBCON OF 2CADR
             XCH      L              # RESTORE TO L FOR DXCH Z.
             DTCB
```

# Page 1232

# RETURN, AFTER EXECUTION OF T3 OVERFLOW TASK:

```

                                BLOCK 02
                                COUNT 02/WAIT

TASKOVER  CCS  RUPTAGN          # IF +1 RETURN TO T3RUPT, IF -0 RESUME.
          CAF  WAITBB
          TS   BBANK
          TCF  T3RUPT2          # DISPATCH NEXT TASK IF IT WAS DUE.

          CA   BANKRUPT
          EXTEND
          WRITE SUPERBNK        # RESTORE SUPERBANK BEFORE RESUME IS DONE

RESUME    EXTEND
          QXCH  QRUPT
NOQRSM    CA   BANKRUPT
          XCH   BBANK
NOQBRSM   DXCH  ARUPT
          RELINT
          RESUME

```

# Page 1233

# LONGCALL

# PROGRAM DESCRIPTION

DATE -- 17 MARCH 1967

# PROGRAM WRITTEN BY W.H.VANDEVER

LOG SECTION WAITLIST

# MOD BY -- R. MELANSON TO ADD DOCUMENTATION

ASSEMBLY SUNDISK REV. 100

#

# FUNCTIONAL DESCRIPTION --

# LONGCALL IS CALLED WITH THE DELTA TIME ARRIVING IN A,L SCALED AS TIME2,TIME1

# IMMEDIATELY FOLLOWING THE TC LONGCALL. FOR EXAMPLE, IT MIGHT BE DONE AS FOL

# A DP REGISTER CONTAINING A DELTA TIME AND WHERE TASKTODO IS THE NAME OF THE I

# START.

#

# CALLING SEQUENCE --

# EXTEND

# DCA TIMELOC

# TC LONGCALL

# 2CADR TASKTODO

#

# NORMAL EXIT MODE --

# 1) TC WAITLIST

# 2) DTCB (TC L+3 OF CALLING ROUTINE 1ST PASS THRU LONGCYCL)

# 3) DTCB (TO TASKOVER ON SUBSEQUENT PASSES THRU LONGCYCL)

#

# ALARM OR ABORT EXIT MODE --

# NONE

#

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Apollo-11.nw 1973

```
# OUTPUT --
#     LONGTIME AND LONGTIME+1 = DELTA TIME
#     LONGEXIT AND LONGEXIT+1 = RETURN 2CADR
#     LONGCADR AND LONGCADR+1 = TASK 2CADR
#     A = SINGLE PRECISION TIME FOR WAITLIST
#
# ERASABLE INITIALIZATION --
#     A = MOST SIGNIFICANT PART OF DELTA TIME
#     L = LEAST SIGNIFICANT PART OF DELTA TIME
#     Q = ADDRESS OF 2CADR TASK VALUE
#
# DEBRIS --
#     A,Q,L
#     LONGCADR AND LONGCADR+1
#     LONGEXIT AND LONGEXIT+1
#     LONGTIME AND LONGTIME+1
#
# *** THE FOLLOWING IS TO BE IN FIXED-FIXED AND UNSWITCHED ERASIBLE **

                BLOCK    02
                EBANK=   LST1
LONGCALL        DXCH     LONGTIME      # OBTAIN THE DELTA TIME

                EXTEND                    # OBTAIN THE 2CADR
# Page 1234
                NDX      Q
                DCA      0
                DXCH     LONGCADR

                EXTEND                    # NO GO TO THE APPROPRIATE SWITCHED BANK
                DCA      LGCL2CDR        # FOR THE REST OF LONGCALL
                DTCB

                EBANK=   LST1
LGCL2CDR        2CADR   LNGCALL2

# *** THE FOLLOWING MAY BE IN A SWITCHED BANK, INCLUDING ITS ERASABLE ***

                BANK     01
                COUNT    01/WAIT

LNGCALL2        LXCH     LONGEXIT +1    # SAVE THE CORRECT BB FOR RETURN
                CA       TWO            # OBTAIN THE RETURN ADDRESS
                ADS      Q
                TS       LONGEXIT
```

## # \*\*\* WAITLIST TASK LONGCYCL \*\*\*

```

LONGCYCL      EXTEND      # CAN WE SUCCESSFULLY TAKE ABOUT 1.25
                  DCS      DPBIT14      # MINUTES OFF OF LONGTIME
                  DAS      LONGTIME

                  CCS      LONGTIME +1    # THE REASONING BEHIND THIS PART IS
                  TCF      MUCHTIME      # INVOLVED, TAKING INTO ACCOUNT THAT THE
  # WORDS MAY NOT BE SIGNED CORRECTED (DP
  # BASIC INSTRUCTIONS
  # DO NOT SIGN CORRECT) AND THAT WE SUBTRAC-
  # TED BIT14 (1 OVER HALF THE POS. VALUE
  # REPRESENTABLE IN SINGLE WORD)
  # CAN'T GET HERE *****

                  NOOP
                  TCF      +1
                  CCS      LONGTIME
                  TCF      MUCHTIME
DPBIT14        OCT      00000
                  OCT      20000

LASTTIME       CA      BIT14      # LONGCALL
                  ADS      LONGTIME +1  # GET BACK THE CORRECT DELTA TFOR WAITLIST
                  TC      WAITLIST
                  EBANK=   LST1
                  2CADR    GETCADR      # THE ENTRY TO OUR LONGCADR

LONGRTRN       CA      TSKOVCDR      # SET IT UP SO THAT ONLY THE FIRST EXIT IS
# Page 1235
                  DXCH    LONGEXIT    # TO THE CALLER OF LONGCALL
                  DTCB    # THE REST ARE TO TASKOVER

MUCHTIME       CA      BIT14      # WE HAVE OVER OUR ABOUT 1.25 MINUTES
                  TC      WAITLIST    # SO SET UP FOR ANOTHER CYCLE THROUGH HERE
                  EBANK=   LST1
                  2CADR    LONGCYCL

                  TCF      LONGRTRN    # NOW EXIT PROPERLY

# *** WAITLIST TASK GETCADR ***

GETCADR        DXCH    LONGCADR      # GET THE LONGCALL THAT WE WISHED TO START
                  DTCB    # AND TRANSFER CONTROL TO IT

TSKOVCDR       GENADR    TASKOVER

```

July 10, 2016

Apollo-11.nw 1975

This code is written to file `src/WAITLIST.s`.

1976      Apollo-11.nw

July 10, 2016



## Appendix B

# Notes, Bibliography and Indexes

### B.1 Chunks

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