

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

Gary Young

July 10, 2016



# Contents

<b>1</b>	<b>Introduction and Notes</b>	<b>7</b>
1.1	References . . . . .	8
	<b>Appendices</b>	<b>11</b>
<b>A</b>	<b>Original Files</b>	<b>13</b>
A.1	AGC BLOCK TWO SELF CHECK . . . . .	13
A.2	AGC BLOCK TWO SELF-CHECK . . . . .	25
A.3	AGS INITIALIZATION . . . . .	37
A.4	ALARM AND ABORT . . . . .	43
A.5	ANGLFIND . . . . .	49
A.6	AOSTASK AND AOSJOB . . . . .	63
A.7	AOTMARK . . . . .	87
A.8	ASCENT GUIDANCE . . . . .	103
A.9	ASSEMBLY AND OPERATION INFORMATION . . . . .	118
A.10	ATTITUDE MANEUVER ROUTINE . . . . .	141
A.11	AUTOMATIC MANEUVERS . . . . .	164
A.12	BURN BABY BURN-MASTER IGNITION ROUTINE . . . . .	175
A.13	CM BODY ATTITUDE . . . . .	199
A.14	CM ENTRY DIGITAL AUTOPILOT . . . . .	206
A.15	CONIC SUBROUTINES . . . . .	234
A.16	CONTRACT AND APPROVALS . . . . .	276
A.17	CONTROLLED CONSTANTS . . . . .	278
A.18	CSM GEOMETRY . . . . .	291
A.19	DAPIDLER PROGRAM . . . . .	301
A.20	DAP INTERFACE SUBROUTINES . . . . .	312
A.21	DISPLAY INTERFACE ROUTINES . . . . .	316
A.22	DOWNLINK LISTS . . . . .	349
A.23	DOWN TELEMETRY PROGRAM . . . . .	358
A.24	DOWN-TELEMETRY PROGRAM . . . . .	368
A.25	ENTRY LEXICON . . . . .	379
A.26	ERASABLE ASSIGNMENTS . . . . .	388
A.27	EXECUTIVE . . . . .	471
A.28	EXTENDED VERBS . . . . .	482

A.29 FINDCDUW-GUIDAP INTERFACE . . . . .	512
A.30 FIXED FIXED CONSTANT POOL . . . . .	529
A.31 FLAGWORD ASSIGNMENTS . . . . .	535
A.32 FRESH START AND RESTART . . . . .	563
A.33 GIMBAL LOCK AVOIDANCE . . . . .	596
A.34 GROUND TRACKING DETERMINATION PROGRAM . . . . .	599
A.35 HeaderTemplate . . . . .	604
A.36 IMU CALIBRATION AND ALIGNMENT . . . . .	605
A.37 IMU COMPENSATION PACKAGE . . . . .	636
A.38 IMU MODE SWITCHING ROUTINES . . . . .	645
A.39 IMU PERFORMANCE TEST 2 . . . . .	669
A.40 IMU PERFORMANCE TESTS 4 . . . . .	679
A.41 INFLIGHT ALIGNMENT ROUTINES . . . . .	687
A.42 INPUT OUTPUT CHANNEL BIT DESCRIPTIONS . . . . .	694
A.43 INTEGRATION INITIALIZATION . . . . .	699
A.44 INTER-BANK COMMUNICATION . . . . .	725
A.45 INTERPRETER . . . . .	730
A.46 INTERPRETIVE CONSTANT . . . . .	797
A.47 INTERPRETIVE CONSTANTS . . . . .	799
A.48 INTERRUPT LEAD INS . . . . .	801
A.49 JET SELECTION LOGIC . . . . .	804
A.50 KALCMANU STEERING . . . . .	825
A.51 KALMAN FILTER . . . . .	831
A.52 KEYRUPT UPRUPT . . . . .	834
A.53 LAMBERT AIMPOINT GUIDANCE . . . . .	838
A.54 LANDING ANALOG DISPLAYS . . . . .	842
A.55 LATITUDE LONGITUDE SUBROUTINES . . . . .	854
A.56 LEM GEOMETRY . . . . .	861
A.57 LUNAR AND SOLAR EPHEMERIDES SUBROUTINES . . . . .	866
A.58 LUNAR LANDING GUIDANCE EQUATIONS . . . . .	871
A.59 LUNAR LANDMARK SELECTION FOR CM . . . . .	904
A.60 MAIN . . . . .	905
A.61 MEASUREMENT INCORPORATION . . . . .	909
A.62 MYSUBS . . . . .	921
A.63 ORBITAL INTEGRATION . . . . .	924
A.64 P11 . . . . .	945
A.65 P12 . . . . .	966
A.66 P20-P25 . . . . .	972
A.67 P30 P37 . . . . .	1049
A.68 P30-P37 . . . . .	1054
A.69 P32-P33 P72-P73 . . . . .	1068
A.70 P32-P35 P72-P75 . . . . .	1099
A.71 P34-35 P74-75 . . . . .	1130
A.72 P37 P70 . . . . .	1168
A.73 P40-P47 . . . . .	1211
A.74 P51-P53 . . . . .	1264

A.75 P61-P67 . . . . .	1313
A.76 P70-P71 . . . . .	1340
A.77 P76 . . . . .	1350
A.78 PHASE TABLE MAINTENANCE . . . . .	1377
A.79 PINBALL GAME BUTTONS AND LIGHTS . . . . .	1386
A.80 PINBALL NOUN TABLES . . . . .	1469
A.81 PLANETARY INERTIAL ORIENTATION . . . . .	1488
A.82 POWERED FLIGHT SUBROUTINES . . . . .	1497
A.83 Q R-AXIS RCS AUTOPILOT . . . . .	1505
A.84 R30 . . . . .	1524
A.85 R31 . . . . .	1535
A.86 R60 62 . . . . .	1542
A.87 R63 . . . . .	1551
A.88 RADAR LEADIN ROUTINES . . . . .	1555
A.89 RCS-CSM DAP EXECUTIVE PROGRAMS . . . . .	1558
A.90 RCS-CSM DIGITAL AUTOPILOT . . . . .	1560
A.91 RCS FAILURE MONITOR . . . . .	1582
A.92 README.md . . . . .	1586
A.93 REENTRY CONTROL . . . . .	1588
A.94 RESTARTS ROUTINE . . . . .	1624
A.95 RESTART TABLES . . . . .	1632
A.96 RT8 OP CODES . . . . .	1645
A.97 RTB OP CODES . . . . .	1653
A.98 S-BAND ANTENNA FOR CM . . . . .	1659
A.99 S-BAND ANTENNA FOR LM . . . . .	1662
A.100SERVICER207 . . . . .	1667
A.101SERVICE ROUTINES . . . . .	1685
A.102SERVICER . . . . .	1691
A.103SINGLE PRECISION SUBROUTINES . . . . .	1729
A.104SPS BACK-UP RCS CONTROL . . . . .	1731
A.105STABLE ORBIT . . . . .	1736
A.106STAR TABLES . . . . .	1746
A.107XTMARK . . . . .	1751
A.108SYSTEM TEST STANDARD LEAD INS . . . . .	1767
A.109T4RUPT PROGRAM . . . . .	1771
A.110T6-RUPT PROGRAMS . . . . .	1803
A.111TAGS FOR RELATIVE SETLOC . . . . .	1807
A.112THE LUNAR LANDING . . . . .	1817
A.113THROTTLE CONTROL ROUTINES . . . . .	1825
A.114TIME OF FREE FALL . . . . .	1830
A.115TJET LAW . . . . .	1846
A.116TPI SEARCH . . . . .	1858
A.117TRIM GIMBAL CNTROL SYSTEM . . . . .	1871
A.118TVCDAPS . . . . .	1885
A.119TVCEXECUTIVE . . . . .	1903
A.120TVCINITIALIZE . . . . .	1910

A.121	IVCMASSPROP . . . . .	1920
A.122	IVCRESTARTS . . . . .	1926
A.123	IVCROLLDAP . . . . .	1932
A.124	IVCSTROKETEST . . . . .	1946
A.125	UPDATE PROGRAM . . . . .	1952
A.126	WAITLIST . . . . .	1965
<b>B</b>	<b>Notes, Bibliography and Indexes</b>	<b>1979</b>
B.1	Chunks . . . . .	1979
B.2	Index . . . . .	1982

# 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.

## 1.1 References

- QUARTZ: "BURN, BABY! BURN!" The code that took America to the moon was just published to GitHub, and its like a 1960s time capsule, Written by Keith Collins, July 09, 2016.
- Apollo Guidance Computer emulation by Dean Koska This Palm Centro program is running the computer software used on the Apollo moon landings. It utilizes Ron Burkey's Virtual AGC engine for the emulation ([www.ibiblio.org/apollo](http://www.ibiblio.org/apollo)).



- Virtual AGC Home Page - Ibiblio
- slashdot: Assembly Code That Took America to the Moon Now Published On GitHub
- Skylab quick-reference card
- Space Guidance Analysis (SGA) memos



# Appendices



# Appendix A

## Original Files

### A.1 AGC BLOCK TWO SELF CHECK

```
13  <src/AGC-BLOCK-TWO-SELF-CHECK.s 13>≡
    # 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                                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 PR
#   PART OF THE BACK-UP IDLE LOOP.  THE SECOND IS SHOW-BANKSUM WHICH RUNS AS A RE
#   STARTING VERB.
#
#   THE PURPOSE OF SELF-CHECK IS TO CHECK OUT VARIOUS PARTS OF THE COMPUTER AS OU
#
#   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



July 10, 2016

Apollo-11.nw 17

```

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)

July 10, 2016

Apollo-11.nw 19

```
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

```

July 10, 2016

Apollo-11.nw 21

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

July 10, 2016

Apollo-11.nw 23

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

25

*<src/AGC-BLOCK-TWO-SELF-CHECK.s 25>≡*

```
# 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
#
# 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

```

July 10, 2016

Apollo-11.nw 27

```
#          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	

```

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

July 10, 2016

Apollo-11.nw 31

```
# 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		

July 10, 2016

Apollo-11.nw 35

	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

37

```

<src/AGS-INITIALIZATION.s 37>≡
# 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:

```

July 10, 2016

Apollo-11.nw 39

```

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	



July 10, 2016

Apollo-11.nw 41

# 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

# Page 210

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

42     Apollo-11.nw

July 10, 2016

SBANK=   LOWSUPER

# FOR SUBSEQUENT LOW 2CADRS.

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

## A.4 ALARM AND ABORT

```

43  <src/ALARM-AND-ABORT.s 43>≡
    # 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
    #           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 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	
ABORT2	TC	BORTENT	
OCT77770	OCT	77770	# DON'T MOVE
	CA	V37FLBIT	# IS AVERAGE G ON
	MASK	FLAGWRD7	
	CCS	A	
	TC	WHIMPER -1	# YES. DON'T DO POOD00. DO BAILOUT.
	TC	DOWNFLAG	

Apollo-11.nw 47

TC DOWNFLAG

ADRES      NODOFLAG

TC WHIMPER

```
# RETURN TO USER
```

# Page 1486

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

```

49  <src/ANGLFIND.s 49>≡
    # 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

    # Page 399

                BANK      15
                SETLOC    KALCMON1
                BANK

                EBANK=    BCDU

                COUNT     22/KALC

KALCMAN3        TC       INTPRET
                RTB

```

July 10, 2016

```

                                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

```

July 10, 2016

Apollo-11.nw 51

```
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
      ALTALC      # UNIT
      COFSKEW     # COFSKEW
UNIT
STORE    COF      # COF IS THE MANEUVER AXIS
GOTO     # SEE IF MANEUVER GOES THRU GIMBAL LOCK
      LOCKSKIRT
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 # 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

```

July 10, 2016

Apollo-11.nw 53

```
# 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
          DLOAD    BPL
          MFISYM   +2      # UX UY
          OKU21
          DLOAD    DCOMP      # SIGN OF UX OPPOSITE TO UY
          COF
          STORE    COF
          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
          DLOAD    BPL
          MFISYM   +2      # UX UY
          OKU12
          DLOAD    DCOMP
          COF      +2      # SIGN OF UY OPPOSITE TO UX
          STORE    COF      +2
          DLOAD    BPL
          OKU12
```

```

                                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
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
                                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)

```

July 10, 2016

Apollo-11.nw 55

```

                                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        # 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

```



July 10, 2016

Apollo-11.nw 57

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       # C7=cos(PHI)sin(THETA)sin(PSI)
      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

```

July 10, 2016

Apollo-11.nw 59

# Page 408

```

      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

63

*<src/AOSTASK-AND-AOSJOB.s 63>≡*

```
# 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,

```



July 10, 2016

Apollo-11.nw 65

# 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

```

July 10, 2016

Apollo-11.nw 67

```
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   JACCUV
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

```

July 10, 2016

Apollo-11.nw 69

```
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,
TS      MPAC      # BECAUSE THEY ARE MAGNITUDES
CA      MPAC      +1
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

```

July 10, 2016

Apollo-11.nw 71

```
#          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



July 10, 2016

Apollo-11.nw 73

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		# LOOP #1 LOOP #2
INDEX	COEFCTR		
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

```

July 10, 2016

Apollo-11.nw 75

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/ACOAST AT 2(6).
	TS	FUNTEM	# 1 + ANET/ACOAST 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)/ $\pi$

July 10, 2016

Apollo-11.nw 77

```
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		

July 10, 2016

Apollo-11.nw 79

# 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	POSMAX	# 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-



July 10, 2016

Apollo-11.nw 81

```

                                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

```

July 10, 2016

Apollo-11.nw 83

```
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                      # ZERO L FOR ACCURACY AND TO PREVENT OVFL0
        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

July 10, 2016

Apollo-11.nw 85

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

```

87  <src/AOTMARK.s 87>≡
    # 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



July 10, 2016

Apollo-11.nw 89

	CAF	ONE	
	TC	IBNKCALL	
	CADR	GOODEND	# GO WAKE UP CALLING JOB
# Page 246			
KILLAUT	CAF	ZERO	
	TS	EXTVBACT	# TERMINATE AOTMARK -- ALLOW EXT VERB
	TC	GOTPOOH	
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	KILLAUT	# V34 -- DOES GOTPOOH
	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	KILLAUT	# V34 -- DOES GOTPOOH
	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

```

July 10, 2016

Apollo-11.nw 91

```

                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)
                LO6ZEROS      # 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

```

July 10, 2016

Apollo-11.nw 93

```
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	

July 10, 2016

Apollo-11.nw 95

```
# 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
```



July 10, 2016

Apollo-11.nw 97

	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

July 10, 2016

Apollo-11.nw 99

```
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

# 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

102     Apollo-11.nw

July 10, 2016

```
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

```

103  <src/ASCENT-GUIDANCE.s 103>≡
    # 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



July 10, 2016

Apollo-11.nw 105

```
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
```

# Page 846

```

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 CMPOENT

```

July 10, 2016

Apollo-11.nw 107

# Page 847

```

                                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          # 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)

```

July 10, 2016

Apollo-11.nw 109

		DYDOT		
	DSU		# (-DYDOT/L-D12 D)=C*2(-9)	
		OOD		
	STORE	YCONS		
CMponent	SETPD	DLOAD		
		OOD		
		100CS		
	DMP			
		PRATE	# B(T-T0)*2(-9)	
	DAD	DDV	# (A+B(T-T0))*2(-9)	
# Page 849				
		PCONS	# (A+B(T-T0))/TBUP*2(8)	
		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.

July 10, 2016

Apollo-11.nw 111

	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 ERRORSSSS.
	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



July 10, 2016

Apollo-11.nw 113

	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	

July 10, 2016

Apollo-11.nw 115

	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

```

July 10, 2016

Apollo-11.nw 117

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

```

118  <src/ASSEMBLY-AND-OPERATION-INFORMATION.s 118>≡
      # 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
#          COMEKISS
#          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)

```

# Page 9

```

# 26 PRIORITY/DELAY, ADRES, BBCON 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

```

July 10, 2016

Apollo-11.nw 125

# 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	

# Page 11

#	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

# Page 12

#	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

July 10, 2016

Apollo-11.nw 127

#	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

# Page 13

#	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.	

# Page 14

## # 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

# Page 15

# 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

# Page 16

#	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

July 10, 2016

Apollo-11.nw 133

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

# Page 18

```
#      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      WWOPT      C
```

# Page 19

# NOUN SCALES AND FORMATS

```
#
# -SCALE TYPE-                PRECISION
# UNITS                        DECIMAL FORMAT  --      AGC FORMAT
# -----                    -----          --      -----
#
# -A-
# OCTAL                        XXXXX           SP      OCTAL
#
# -B-
# FRACTIONAL                   .XXXXX         SP      BIT 1 = 2-14 UNITS
#                               (MAX .99996)
#
# -C-
# WHOLE                         XXXXX.         SP      BIT 1 = 1 UNIT
#                               (MAX 16383.)
#
# -D-
# CDU DEGREES                   XXX.XX DEGREES  SP      BIT 1 = 360/215 DEGREES
#                               (MAX 359.99)      (USES 15 BITS FOR MAGNI-
#                                                    TUDE AND 2'S COMP.)
#
# -E-
# ELEVATION DEGREES             XX.XXX DEGREES  SP      BIT 1 = 90/214 DEGREES
#                               (MAX 89.999)
#
```

```

# -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

```

July 10, 2016

Apollo-11.nw 135

```
#          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
```

July 10, 2016

#				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	
#			-----	



July 10, 2016

Apollo-11.nw 137

```
#
#                                     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.

# Page 23

# 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

July 10, 2016

Apollo-11.nw 139

# 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		

# Page 25

# 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
```

```
# Page 26
```

```
# 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.	V41N7
# 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

141  $\langle \text{src/ATTITUDE-MANEUVER-ROUTINE.s } 141 \rangle \equiv$

```
# 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
```

```

#           CPSI = COMMANDED MIDDLE GIMBAL ANGLE
#
# WHEN POINTING A SPACECRAFT AXIS (I.E., X, Y, Z, THE AOT, THRUST AXIS, ETC.) THE SU
# 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 I
# 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 D
# 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.

```

July 10, 2016

Apollo-11.nw 143

```
# 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

```

# Page 347

# 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  $\bar{U}$ . THE FORMULA FOR

#

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

#

# WHERE

$$\begin{matrix} * \\ I \end{matrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

#

$$\begin{matrix} * \\ \bar{U} \bar{U}^T \end{matrix} = \begin{bmatrix} U^2 & & \\ U X & U U & U U \\ X & X Y & X Z \end{bmatrix}$$

#

$$\begin{matrix} * \\ \bar{U} \bar{U}^T \end{matrix} = \begin{bmatrix} U^2 & & \\ U U & U & U U \\ Y X & Y & Y Z \end{bmatrix}$$

#

$$\begin{matrix} * \\ \bar{U} \bar{U}^T \end{matrix} = \begin{bmatrix} U^2 & & \\ U U & U U & U \\ Z X & Z Y & Z \end{bmatrix}$$

#

$$\begin{matrix} * \\ V \end{matrix} = \begin{bmatrix} 0 & -U & U \\ Z & & Y \end{bmatrix}$$

#

$$\begin{matrix} * \\ X \end{matrix} = \begin{bmatrix} U & 0 & -U \\ Z & & X \end{bmatrix}$$

#

$$\begin{matrix} * \\ X \end{matrix} = \begin{bmatrix} -U & U & 0 \end{bmatrix}$$

#

```

#                                     [   Y           X           ]
#
# Page 348
#
#      -
#      U      =      UNIT ROTATION VECTOR RESOLVED INTO S/C AXES.
#      A      =      ROTATION ANGLE
#
#                                     *
# THE INTERPRETATION OF DEL IS AS FOLLOWS:
#
# IF AX , AY , AZ REPRESENT THE COMPONENTS OF A VECTOR IN THE ROTATED FRAME, THEN THE C
#      X      Y      Z
# VECTOR IN THE ORIGINAL S/C AXES (BX , BY , BZ) ARE
#                                     X      Y      Z
#
#      [ BX ]           [ AX ]
#      [ XX ]           [ XX ]
#      [   ]           [   ]
#      [ BY ]           [ AY ]
#      [ YX ]      =   DEL   [ YX ]
#      [   ]           [   ]
#      [ BZ ]           [ BZ ]
#      [ ZX ]           [ ZX ]
#
# 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

```

July 10, 2016

Apollo-11.nw 149

```
#      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
```

# Page 350

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

# Page 351

```
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      READCDUK     #      COMPUTE THE MATRIX FROM INITIAL S/C
          STORE    BCDU         #      AXES TO FINAL S/C AXES.
          SLOAD    ABS          # STORE INITIAL S/C ANGLES
          CPSI      # CHECK THE MAGNITUDE OF THE DESIRED
          DSU      BPL          # MIDDLE GIMBAL ANGLE
          LOCKANGL
          TOOBADF      # IF GREATER THAN 70 DEG ABORT MANEUVER
          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
```

July 10, 2016

Apollo-11.nw 151

```

                                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

```



July 10, 2016

Apollo-11.nw 153

```

      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

July 10, 2016

Apollo-11.nw 155

```

                                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            # MATRIX IN PD
TRNSPSPD                        EXIT            # ENTER WITH MATRIX AT 0 IN PD LIST
                                INDEX  FIXLOC
                                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

```

July 10, 2016

Apollo-11.nw 157

```
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      # C0 = 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)
#
#      -

```

# 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)	\$8
	BDSU	BOVB		
		DPHALF		
		SIGNMPAC		
	PDDL		# PDA = 1-COS(A)	

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



July 10, 2016

Apollo-11.nw 161

```

                                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(PHI)
#      0
#
#      C  = -COS(THETA) SIN(PHI) COS(PHI) + SIN(THETA) SIN(PHI)
#      1
#
#      C  = COS(THETA) SIN(PHI) SIN(PHI) + SIN(THETA) COS(PHI)
#      2
#
#      C  = SIN(PHI)
#      3
#
#      C  = COS(PHI) COS(PHI)
#      4
#
#      C  = -COS(PHI) SIN(PHI)
#      5
#
#      C  = -SIN(THETA) COS(PHI)
#      6
#
#      C  = SIN(THETA) SIN(PHI) COS(PHI) + COS (THETA) SIN(PHI)
#      7
#
#      C  = -SIN(THETA) SIN(PHI) 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

```

July 10, 2016

Apollo-11.nw 163

	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

```

164  <src/AUTOMATIC-MANEUVERS.s 164>≡
      # 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

```

July 10, 2016

Apollo-11.nw 165

```

      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 COMPLETED
# 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

```



July 10, 2016

Apollo-11.nw 169

# 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

```

July 10, 2016

Apollo-11.nw 171

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	

July 10, 2016

Apollo-11.nw 173

```
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(DELTA 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

```

175  <src/BURN-BABY-BURN-MASTER-IGNITION-ROUTINE.s 175>≡
    # 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

```

July 10, 2016

Apollo-11.nw 179

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

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.
```

July 10, 2016

Apollo-11.nw 181

```

                                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.
```

July 10, 2016

Apollo-11.nw 183

	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	



July 10, 2016

Apollo-11.nw 185

```

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	
#	*****		

July 10, 2016

Apollo-11.nw 187

```

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	NEGO	
	DXCH	-PHASE6	
	TCF	TASKOVER	
CLOKJOB	EXTEND		
	DCS	TIG	
	DXCH	TTOGO	
	EXTEND		
# Page 745	DCA	TIME2	
	DAS	TTOGO	

July 10, 2016

Apollo-11.nw 191

```

      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	



July 10, 2016

Apollo-11.nw 193

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

```

July 10, 2016

Apollo-11.nw 195

```

                                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   GOTOPOOH        # 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

?              =      GOTOPOOH

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.

```

198     Apollo-11.nw

July 10, 2016

```
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

```

199  <src/CM-BODY-ATTITUDE.s 199>≡
# 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	



July 10, 2016

Apollo-11.nw 201

```
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 COORD
                                # XB = ( CMC1 , SM , -CMSI )

VXM      VSL1
          REFMMAT                                # .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.

```

July 10, 2016

Apollo-11.nw 203

```

      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
                                CMTR2
                                CS      MPAC +1
                                # GET (BETA EUL/180) /2
                                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
                                REDOPOSE
                                EXTEND
                                # RE-STARTS COME HERE
                                DCA     TEMPROLL

```

July 10, 2016

Apollo-11.nw 205

```

      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

206      *<src/CM-ENTRY-DIGITAL-AUTOPILOT.s 206>≡*

```
# 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
```

July 10, 2016

Apollo-11.nw 207

```
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	



July 10, 2016

Apollo-11.nw 209

```
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

```

July 10, 2016

Apollo-11.nw 211

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

```

July 10, 2016

Apollo-11.nw 213

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

```

July 10, 2016

Apollo-11.nw 215

```

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)

```



July 10, 2016

Apollo-11.nw 217

```

      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

      TS      JETEM2          # BIASED DZ FOR EXT ATM DAP.
BIASEDZ    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	

July 10, 2016

Apollo-11.nw 219

```
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

```

July 10, 2016

Apollo-11.nw 221

```
CAF      P/RJCODE      # GET ROLL CODE
EXTEND
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

YJETCODE OCTAL 00120      # POS Y
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 =DELR
	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.

July 10, 2016

Apollo-11.nw 223

# Page 1082

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  
EXTEND

# CORRECT FOR ASSUMED COORD TURN.

MP CALFA  
TS LCX/360

# COS ALFA

# SCALED LCX OK HERE.

CCS CMDAPMOD  
TC DZCALL1

# FOUR POSSIBILITIES HERE

# 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

```

July 10, 2016

Apollo-11.nw 227

```
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	

July 10, 2016

Apollo-11.nw 229

```

                                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.

```

July 10, 2016

Apollo-11.nw 231

```

                                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.

```

                                # COME HERE EACH .1 SEC. (CMDAPMOD=+1 COMES BELOW)
CM/FDAI      CS      PHIDOT      # INTEGRATE ROLL ERROR 'TWEEN 2SEC UPDATES
                                EXTEND
                                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



July 10, 2016

Apollo-11.nw 233

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

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

# Page 1092

# 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

```

234  <src/CONIC-SUBROUTINES.s 234>≡
    # 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 SYSTEM.

```

July 10, 2016

Apollo-11.nw 235

```
# 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
```

```

#       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(M)
#
# 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
#           -----      -

```

July 10, 2016

Apollo-11.nw 237

```
#      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.
```

# Page 1265

# 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

```

#           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 1
#           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

```

```

#       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 --
#
#       VARIABLE      SCALE FACTOR
#                   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 --
#
#       VARIABLE      SCALE FACTOR
#                   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

```

```

#
#   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

```



```

#      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 OVFINDB 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 OVFINDB 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

```

```

#          -----
#          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 LOCATED
#       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

```

July 10, 2016

Apollo-11.nw 243

```
#      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.
```

```

#          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 (NR)
#      P             +4                 DP RATIO OF SEMILATUS RECTUM TO R1
#      COGA          +5                 DP COTAN OF ANGLE BETWEEN RVEC AND VVEC
#      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
#      SETPD   BOV
#              0
#              +1
#      VLOAD*
#              MUTABLE,1
#      STOVL   14D
#              RRECT
#      UNIT    SSP
#              ITERCTR
#              20D

```

July 10, 2016

Apollo-11.nw 247

	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	



July 10, 2016

Apollo-11.nw 249

```

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 WAS TOO BIG
		X	

		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

```

July 10, 2016

Apollo-11.nw 253

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		

July 10, 2016

Apollo-11.nw 255

```

                                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
                OD
NEWDEL        STORE  DELINDEP
                RVQ

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	



July 10, 2016

Apollo-11.nw 257

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 # PL AT 0  
COGAOVFL  
GETX

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

July 10, 2016

Apollo-11.nw 259

```
# 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		

July 10, 2016

Apollo-11.nw 261

WLOOP	DSU	DMP		
		COGA	#	PL AT 0
	SL2R	BOV		
		360CHECK		
	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		
POLYCOEF		INFINITY		
	ROUND	DAD	#	PL AT OD
	BOV	TIX,2		
		RESETX2		
		WLOOP		
	BDDV	BOV		
		D1/128		
		INFINITY		
	BMN	PUSH	# OD=1/W (+2) OR 16/W (+6)	PL AT 2
		INFINITY		
# Page 1293	DSQ			
	NORM	DMP		
		X1		
		R1A		
	SRR*	EXIT		
		0	-10D,1	
	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		

July 10, 2016

Apollo-11.nw 263

	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		



July 10, 2016

Apollo-11.nw 265

```

                                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=COGUEPLIM

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

UPLIM   DLOAD
        COGUEPLIM                # COGUEPLIM=.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

```

July 10, 2016

Apollo-11.nw 267

```

                                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		

July 10, 2016

Apollo-11.nw 269

		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		

July 10, 2016

Apollo-11.nw 271

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

# VTARGET           ERASE   +0

# TWEKIT            EQUALS   40D

# ONLY USED IF GUESSW IS 0

# OUTPUT --

# VTARGET           ERASE   +5  
# V1VEC             EQUALS   MPAC

# AVAILABLE ONLY IF VTARGET IS ZERO.

```

# 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

# TWEKIT       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
```

## A.16 CONTRACT AND APPROVALS

```

276  <src/CONTRACT-AND-APPROVALS.s 276>≡
# 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

```

278  <src/CONTROLLED-CONSTANTS.s 278>≡
      # 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

      # *****

```

July 10, 2016

Apollo-11.nw 279

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



July 10, 2016

Apollo-11.nw 281

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 BI
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 F

```

```

                SETLOC  DAPS3
                BANK
                COUNT*  $$/DAPAO

```

```

TORKJET1        DEC      .03757          # 550 / .2 SCALED AT (+16) 64 / 180

```

# Page 43

# PARAMETERS RELATING TO MASS, INERTIA, AND VEHICLE DIMENSIONS

```

                SETLOC  FRANDRES
                BANK
                COUNT*  $$/START

FULLAPS         DEC      5050 B-16      # NOMINAL FULL ASCENT MASS -- 2(16) P

```

```

                SETLOC  LOADDAP1
                BANK
                COUNT*  $$/R03

MINLMD          DEC      -2850 B-16      # MIN. DESCENT STAGE MASS -- 2(16) K
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)

```

# Page 44

# PHYSICAL CONSTANTS ( TIME - INVARIANT )

```

                SETLOC  IMU2

```

July 10, 2016

Apollo-11.nw 283

```

      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)

# *****

# Page 46

                                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 *****

```

July 10, 2016

Apollo-11.nw 285

	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.
---------	------	----------------	---

# Page 47

# 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

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

July 10, 2016

Apollo-11.nw

287

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

# Page 49

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

# Page 50

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



July 10, 2016

Apollo-11.nw 289

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) *

# Page 52

	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

291

*<src/CSM-GEOMETRY.s 291>≡*

```
# 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

```

# Page 286

# 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.

#

July 10, 2016

Apollo-11.nw 293

# 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	

# Page 287

# 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

```

July 10, 2016

Apollo-11.nw 295

```
ZNB=S1          DLOAD      28D          # SUBROUTINE, ALARM WILL BE SET BY MPI
                  STODL      270DEG
                  STORE      SAC
                  CLRG0      20DEGS-
                  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

```

# Page 291

# 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)

```



July 10, 2016

Apollo-11.nw 297

```
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

```

July 10, 2016

Apollo-11.nw 299

	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	

300     Apollo-11.nw

July 10, 2016

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

301

*<src/DAPIDLER-PROGRAM.s 301>≡*

```
# 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
```



July 10, 2016

Apollo-11.nw 303

```

                                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	



July 10, 2016

Apollo-11.nw 305

```
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
#       ZERO, NEEDLER IS CALLED TO DISPLAY ATTITUDE ERRORS.  IF THE BIT IS ONE, NEEDLER IS CALLED TO
#       DISPLAY ATTITUDE ERRORS.  IF THE BIT IS ONE, NEEDLER IS CALLED TO DISPLAY ATTITUDE ERRORS.
#
```

```
# 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

```

July 10, 2016

Apollo-11.nw 307

```
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

```

July 10, 2016

Apollo-11.nw 311

	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

```

312    <src/DAP-INTERFACE-SUBROUTINES.s 312>≡
      # 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	

July 10, 2016

Apollo-11.nw 315

```

        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

```

316    <src/DISPLAY-INTERFACE-ROUTINES.s 316>≡
# 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 OF
# 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 ROUTINES NOT ENDING IN R BRANCH DIRECTLY TO MAKEPLAY WHICH MAKES THESE DISPLAYS
#   USER'S JOB.
#   5. ALL DISPLAY ROUTINES ARE CALLED VIA BANKCALL.
#   6. TO RESTART A DISPLAY THE USER WILL GENERALLY USE A PHASE OF ONE WITH DESIRED RESTART
#   DESCRIPTION OF RESTARTS).
#   7. ALL FLASHING DISPLAYS HAVE 3 RETURNS TO THE USER FROM ASTRONAUT RESPONSES. 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

```

```

#           ...      ...      # 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      VXXNYY
#           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

```



July 10, 2016

Apollo-11.nw 321

```
#           ...      ...      # 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.

```

July 10, 2016

Apollo-11.nw 325

```
#
#
#
#
#
# 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, NVSUBUSY, 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,+
#
# 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 CER
#       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

```

July 10, 2016

Apollo-11.nw 327

```
#          ...          # 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



July 10, 2016

Apollo-11.nw 329

```

                                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     PRI0OCT
                                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 FAIL
# REQUEST IS ENDED. IF HE TRIES TO MARK DURING A NORM, THE MARK IS ALLOWED. IN THIS
# UNTIL ALL MARKING IS FINISHED.
#
# IF THE MARK REQUEST COMES FROM THE PROGRAM DURING A TIME THE ASTRONAUT IS NOT INTER
# PRIO, THE MARK REQUEST IS PUT TO SLEEP UNTIL THE PRESENT ACTIVE DISPLAY IS RESPONDI

```

```

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 NO
# SET UP TO BE STARTED OR RESTARTED.
#
# NORMALLY THE USER WILL NOT NEED TO USE THIS ROUTINE SINCE A NEW NORMAL DISPLAY AUTO

```

July 10, 2016

Apollo-11.nw 331

```
# 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	

July 10, 2016

Apollo-11.nw 333

	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	

July 10, 2016

Apollo-11.nw 335

```

      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	



July 10, 2016

Apollo-11.nw 337

	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

```

July 10, 2016

Apollo-11.nw 339

```
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

July 10, 2016

Apollo-11.nw 341

	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	

July 10, 2016

Apollo-11.nw 343

	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	



July 10, 2016

Apollo-11.nw 345

```
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

July 10, 2016

Apollo-11.nw 347

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

349

<src/DOWNLINK-LISTS.s 349>≡

```
# 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.
```

# Page 170

```
BANK      22
SETLOC    DOWNTELM
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 CMENRDL # UPDATE PROGRAM (P27) DOWNL

```

# Page 171

# 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

```

July 10, 2016

Apollo-11.nw 351

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



July 10, 2016

Apollo-11.nw 353

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

# Page 174

# -----

# Page 175

# 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	DELVSIV	# DELVSIV , +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

# -----

July 10, 2016

Apollo-11.nw 355

# Page 177

# 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	

July 10, 2016

Apollo-11.nw 357

```
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

```

358  <src/DOWN-TELEMETRY-PROGRAM.s 358>≡
# 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.

```



July 10, 2016

Apollo-11.nw 361

```
#      (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
#
#          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 DNPHASE2
#          TCF      NEWLIST
#          DNPHASE2
#          CCS      DNECADR        # SENDING OF DATA IN PROGRESS
#          DODNADR  TC            # 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
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)
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)

```

July 10, 2016

Apollo-11.nw 363

```

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
              CA       DNADRDCR   # 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
              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

```

July 10, 2016

Apollo-11.nw 365

```

                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)
# COMPLETE ERASABLE DUMP NUMBER 1,2,3
# 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

```

July 10, 2016

Apollo-11.nw 367

```

      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      # ** ENTRANCE USED BY ERASABLE DUMP PROG. **
      QXCH    DNTMGOTO    # SET DNTMGOTO SO NEXT TIME PROG WILL GO
      CAF     ERASID      # 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

```

368  <src/DOWN-TELEMETRY-PROGRAM.s 368>≡
# 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, DWWITT, 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).

```

July 10, 2016

Apollo-11.nw 371

```
# 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      LDNPAS2      # SET DNTMGOTO = 0 ALL SUSEQUENT DOWRUPTS
              TS      DNTMGOTO      # GO TO DNPASE2
              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

```

July 10, 2016

Apollo-11.nw 373

```

                                #      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

                                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

July 10, 2016

Apollo-11.nw 375

```

+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 ER
#          2    LOWIDCOD                   77340  1      DOWNLINK SYNCH BITS. (SAME C
#          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 = C
#          6    2ND WORD OF EBANK X       00142  1      IN THIS EXAMPLE THIS WORD = C
#          7    3RD WORD OF EBANK X       00142  1      IN THIS EXAMPLE THIS WORD = C
#          .
#          .
#          .
#          260D  256TH WORD OF EBANK X    03777  1      IN THIS EXAMPLE THIS WORD = C
#
# 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

```



July 10, 2016

Apollo-11.nw 377

```
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).
```

378     `Apollo-11.nw`

July 10, 2016

This code is written to file `src/DOWN-TELEMETRY-PROGRAM.s`.

## A.25 ENTRY LEXICON

379  $\langle \text{src}/\text{ENTRY-LEXICON.s } 379 \rangle \equiv$

```
# 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		
#				
# ASPDWN	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		

July 10, 2016

Apollo-11.nw 381

#				
#	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	

July 10, 2016

Apollo-11.nw 383

#	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

# Page 840

# 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 D0 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
#              (PREANG - 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

```

# Page 843

# 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

```

388  <src/ERASABLE-ASSIGNMENTS.s 388>≡
# 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
#
# Page 38

```

```

#           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.

```

```

# Page 39

```

```

# 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

```

July 10, 2016

Apollo-11.nw 391

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

# Page 40

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	

# Page 41

# 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

# Page 42

# 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

# Page 43

# 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	

# Page 44

# 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	

# Page 45

# 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

# Page 46

## # 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		

July 10, 2016

Apollo-11.nw 397

# 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				

July 10, 2016

Apollo-11.nw 399

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



July 10, 2016

Apollo-11.nw 401

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				

402 Apollo-11.nw

July 10, 2016

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		

July 10, 2016

Apollo-11.nw 403

# 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

July 10, 2016

Apollo-11.nw 405

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				

July 10, 2016

Apollo-11.nw 407

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				



July 10, 2016

Apollo-11.nw 409

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

410 Apollo-11.nw

July 10, 2016

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

July 10, 2016

Apollo-11.nw 411

# 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

			# STATE VECTOR IN	VECTOR IN TIME-THETA
			# TIME-THETA	
RVSBBIT	=	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)

July 10, 2016

Apollo-11.nw 413

# 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)

July 10, 2016

Apollo-11.nw 415

# 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



July 10, 2016

Apollo-11.nw 417

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				

```

                                =      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
                                   # IN THE PROGRAM IN THE FOLLOWING ORDER:
                                   # (0,1) (I.E. BIT 13 RESET, BIT 12 SET)

# BIT 12 FLAG 11
S32.1F3B     =      168D           #
# Page 67
S3229T3B     =      BIT12         #      = 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

```

July 10, 2016

Apollo-11.nw 419

# 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
NNTYPTM	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)

July 10, 2016

Apollo-11.nw 423

```
# 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
```

# Page 72

# 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
LDATA1ST	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
-------	-------



July 10, 2016

Apollo-11.nw 425

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

# Page 74

# 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
----------	-------	------------------------------

July 10, 2016

Apollo-11.nw 427

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

# Page 78

# 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.

July 10, 2016

Apollo-11.nw 429

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

# Page 80
# 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
PGNCSALT       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

```

July 10, 2016

Apollo-11.nw 431

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

```



July 10, 2016

Apollo-11.nw 433

# 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

EPSILON T        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

# Page 84

# 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		

July 10, 2016

Apollo-11.nw 435

```
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 V       EQUALS  TET    +2      # B(6)TMP POSITION DEVIATION  KM*2(14)
TNUV           EQUALS  TDELTA V +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

July 10, 2016

Apollo-11.nw 437

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

VESO	EQUALS	RESO	+6
OMEGAES	EQUALS	VESO	+6

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	

ERADM	EQUALS	VECTAB	+18D	# I(2)TMP
INCORPEX	EQUALS	ERADM	+2	# I(1)TMP

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

```
ALPHAM      EQUALS  XKEPNEW +2      # I(2)TMP
TAU.        EQUALS  ALPHAM  +2      # I(2)TMP
```

Apollo-11.nw 439

# 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.

```



July 10, 2016

Apollo-11.nw 441

# 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

# Page 97

# \*-\*\*-\*- 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)
---------	--------	------------	--------

# Page 98

# \*- - \*- - \*- 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
LAUNCHAZ	=	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.

# Page 101

# \*-\*-\*-\* 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

# Page 102

# 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)



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 VARST0 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)

```

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)
VARK	EQUALS	1/CONACC	+1	# B(1)
REPFRAC	EQUALS	VARK	+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)
```

# Page 106

```
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)
```

# Page 107

# 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

# Page 108

# \*\*\*\* 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  TVCRCS      # 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

```

```
# Page 109
```

```

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

```

July 10, 2016

Apollo-11.nw 455

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
# Page 110			
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

# Page 111

# \*\*\*\*\* 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

# Page 112

ROLLHOLD	EQUALS	ROLLC +2	# 1P FOR ATTITUDE HOLD IN CMDAPMOD = +1
----------	--------	----------	---

# 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



July 10, 2016

Apollo-11.nw 457

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

# Page 113

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

# Page 114

# \*\*\*\*\* 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

July 10, 2016

Apollo-11.nw 459

POLYLOC = POLYNUM +10D  
SATRLRT EQUALS POLYNUM +15D # B(2) PAD LOADED

# MORE P11 STORAGE --PAD LOADED-- (2D)

# Page 115

# (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)

# Page 116

R61CNTR EQUALS SAVEDCDU +3 # (1)TMP

# ENTRY RESTART PROTECTION STORAGE. --KEEP TEMPS IN ORDER-- (12D)

```

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
P37RANGE      EQUALS  R61CNTR +1      # I(1)PL *****

END-E6        =      P37RANGE +1     # FIRST UNUSED ERASABLE LOCATION IN E6

# Page 117
# 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)

```

July 10, 2016

Apollo-11.nw 461

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

# Page 118

# \*- - \*- - \*- 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	
# Page 119					
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.

July 10, 2016

Apollo-11.nw 463

```
C/D0          EQUALS  ALP      +2      # 2P      -1/D0
D0            EQUALS  C/D0     +2      # I(2)    CONSTANT DRAG
Q2            EQUALS  D0       +2      # 2P

# ROLLC 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)



```

# 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

```

July 10, 2016

Apollo-11.nw 467

```
# (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
```

July 10, 2016

Apollo-11.nw 469

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

```

471  <src/EXECUTIVE.s 471>≡
# 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



July 10, 2016

Apollo-11.nw 473

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 CORESPONDING 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	

July 10, 2016

Apollo-11.nw 475

```

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

July 10, 2016

Apollo-11.nw 477

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

July 10, 2016

Apollo-11.nw 479

# 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



July 10, 2016

Apollo-11.nw 481

```

                                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

NUDIRECT                     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**

```

482  <src/EXTENDED-VERBS.s 482>≡
      # 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: POOD00 -> 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 2CADDRs. 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
      #                               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 236

      BANK       7
      SETLOC    EXTVERBS
      BANK

```

July 10, 2016

Apollo-11.nw 483

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	SETSRF	# 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

CAF       OCT24        # SET BITS 3 AND 5
SETXTACT  TS         EXTVBACT
TS        # 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

```

July 10, 2016

Apollo-11.nw 485

	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 COMPUTER OR TURN ON OPERATOR ERROR AND

# OPTICS AVAILABLE AND DISPLAY FLASHING V24,N92....LOAD NEW OPTICS ANGLES

#

# AND RELEASE EXT VERB DISPLAY SYSTEM).

July 10, 2016

Apollo-11.nw 487

```
#      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
```

# Page 241

```
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



July 10, 2016

Apollo-11.nw 489

```
#      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 REQUEST

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

```

July 10, 2016

Apollo-11.nw 491

# 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 DSPTM1, +1.
	CAF	ZERO	
	TS	MPAC +2	# NEEDED FOR TP AGREE
	TS	L	# ZERO T1 + 2 WHILE ALIGNING.
	DXCH	TIME2	
	DXCH	MPAC	
	DXCH	DSPTM2 +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

# Page 247

# 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

July 10, 2016

Apollo-11.nw 493

```
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

```

July 10, 2016

Apollo-11.nw 495

```

                                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
```

# Page 251

```
# 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
```



July 10, 2016

Apollo-11.nw 497

# 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

July 10, 2016

Apollo-11.nw 499

```
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

```

July 10, 2016

Apollo-11.nw 501

# 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	

# Page 258

# 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	

# Page 259

# 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

July 10, 2016

Apollo-11.nw 503

```

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	

July 10, 2016

Apollo-11.nw 507

# 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

```

```

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

```

July 10, 2016

Apollo-11.nw 511

```
# 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**

```

512  <src/FINDCDUW-GUIDAP-INTERFACE.s 512>≡
      # 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

```

```

          VLOAD
          UNFC/2
FINDCDUW  BOV  SETPD
          FINDCDUW
          22
          STQ  EXIT
          QCUDWUSR
          # FINDCDUW -2: ENTRY WHEN UNFC/2 PRE-STORD
          # INPUT VECTORS NEED NOT BE SEMI-UNIT
          # FINDCDUW: ENTRY WHEN UNFC/2 IN MPAC
          # INTERPRETER NOW INITIALIZED
          # LOCS 0 THRU 21 FOR DIRECTION COSINE MAT
          # SAVE RETURN ADDRESS

```

```

# MORE HAUSKEEPING

```

```

CA        ECDUWL
XCH        EBANK
TS        ECDUWUSR
          # SET EBANK
          # SAVE USER'S EBANK

CA        DAPBOOLS
MASK      CSMDOCKD
CCS        A
          # CSMDOCKD MUST NOT BE BIT15
CA        ONE
TS        NDXCDUW
          # INDEX IF CSM DOCKED

CA        XOVINHIB
          # XOVINHIB MUST NOT BE BIT15

```

July 10, 2016

Apollo-11.nw 515

```

                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

```

July 10, 2016

Apollo-11.nw 517

```
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
STORE       UNX/2      # TOTALLY ELIMINATES THRUST POINTING ERROR
VXV         VSL1       # UNX/2
              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         ALARMGA

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

```

# Page 915

# BRANCHES TO NOATTCNT

```

      CCS     FLPAUTNO
      TCF     NOATTCNT +2
      CA      FLAGWRD5
      MASK    ENGONBIT
EXTEND
      BZF     NOATTCNT +2

```

# 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 WITH THE
# AXIS. ATTITUDE ANGLE CHANGES IN THE PRIME SYSTEM ARE RELATED TO SMALL GIMBAL ANGLE CHANGES.
#
# [ -DELATTX ] [ 1 SIN(CDUZD) 0 ] [ -DELGBX ]
# [          ] [          ] [          ]

```

July 10, 2016

Apollo-11.nw 519

```
#      [ -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

```



July 10, 2016

Apollo-11.nw 521

# 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

```
TCQCUDW      CA      ECDUWUSR
              TS      EBANK      # RETURN USER'S EBANK

              TC      INTERPRET
              SETPD    GOTO
                      0
                      QCUDWUSR      # 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

```

July 10, 2016

Apollo-11.nw 523

```
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
```

16OCT OCT 16

# 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

```

July 10, 2016

Apollo-11.nw 525

```

      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

```

July 10, 2016

Apollo-11.nw 527

```
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
```

528     Apollo-11.nw

July 10, 2016

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	

July 10, 2016

Apollo-11.nw 531

# 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	

July 10, 2016

Apollo-11.nw 533

# Page 1203

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		

# Page 1204

# 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

535

*<src/FLAGWORD-ASSIGNMENTS.s 535>≡*

```
# 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
# ATTFLAG	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	
# RCDUFAIL	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

EQUIVALENT FI

EQUIVALENT FI

# 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

# Page 66

# BIT 9 FLAG 0 (S)

P25FLAG = 006D  
 P25FLBIT = BIT9

# P25 OPERATING P25 M

July 10, 2016

Apollo-11.nw 541

# 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)

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	UPDA
# Page 68					
# BIT 5 FLAG 1 (S)					
TRACKFLG	=	025D	#	TRACKING ALLOWED	TRAC
TRACKBIT	=	BIT5			
# BIT 4 FLAG 1					
	=	026D			
	=	BIT4			

July 10, 2016

Apollo-11.nw 543

# 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	FINAL
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



July 10, 2016

Apollo-11.nw 545

# 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 MA
FLAGWRD4	=	STATE +4	#	(060-074)
				USED
# 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

July 10, 2016

Apollo-11.nw 547

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)					

548 Apollo-11.nw

July 10, 2016

MKOVFLAG	=	072D	#	MARK DISPLAY OVER	NO MA
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 SE
XDSPBIT	=	BIT1	#	TO BE INTERRUPTED	INFOR
FLAGWRD5	=	STATE +5	#	(075-089)	
			#	(SET)	(RESI
# 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 SC
			#	OCCURRED DURING	OCCUR
RNGSCBIT	=	BIT10	#	RR READING	RR RE
# BIT 9 FLAG 5 (S)					

July 10, 2016

Apollo-11.nw 549

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 I

## # 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

July 10, 2016

Apollo-11.nw 551

# 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
V67FLBIT	=	BIT8	#	W-MATRIX INITIAL
			#	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



July 10, 2016

Apollo-11.nw 553

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 PERIO
			#	RANGE IN TIME-RADIUS RANG
# 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

July 10, 2016

Apollo-11.nw 555

# 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

556 Apollo-11.nw

July 10, 2016

# 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  
# 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

July 10, 2016

Apollo-11.nw 557

# BIT 8 FLAG 10			#	
	=	157D		
	=	BIT8	#	OH 2009-05-15 Line not in scan
# BIT 7 FLAG 10 (L,C)				
REINTFLG	=	158D	#	INTEGRATION ROUTINE      INTEGRATION ROUTINE
REINTBIT	=	BIT7	#	TO BE RESTARTED      NOT TO BE RESTARTED
# BIT 6 FLAG 10			#	
	=	159D		
	=	BIT6	#	OH 2009-05-15 Line not in scan
# BIT 5 FLAG 10			#	
	=	160D		
	=	BIT5	#	OH 2009-05-15 Line not in scan
# Page 83				
# BIT 4 FLAG 10				
	=	161D	#	
	=	BIT4	#	OH 2009-05-15 Line not in scan
# BIT 3 FLAG 10			#	
	=	162D		
	=	BIT3	#	OH 2009-05-15 Line not in scan
# BIT 2 FLAG 10			#	
	=	163D		
	=	BIT2	#	OH 2009-05-15 Line not in scan
# BIT 1 FLAG 10			#	
	=	164D		
	=	BIT1	#	OH 2009-05-15 Line not in scan
FLGWRD11	=	STATE +11D	#	(165-179)
			#	(SET)      (RESET)
# BIT 15 FLAG 11 (L)(R12)				
LRBYPASS	=	165D	#	BYPASS ALL LANDING      DO NOT BYPASS LANDING
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	UPDAT
			#	UNREASONABLE,	VELO
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	VELO
# BIT 4 FLAG 11 (L)(R12)					

July 10, 2016

Apollo-11.nw 559

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					
REPOS MON	=	184D	#	REPOSITION MONITOR.	NO REPOSITION T

560 Apollo-11.nw

July 10, 2016

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 RE
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 RE



July 10, 2016

Apollo-11.nw 561

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 SCALIN

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

```

563 <src/FRESH-START-AND-RESTART.s 563>≡
# 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
#
# 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
#
#               8 APRIL, 1967
#               SUNDISK REV 120

```

```

#      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 TIMES5, 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

July 10, 2016

Apollo-11.nw 567

# Page 184

```
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

```



July 10, 2016

Apollo-11.nw 569

```
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

```

July 10, 2016

Apollo-11.nw 571

```

                                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

```

July 10, 2016

Apollo-11.nw 573

```

                                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	

July 10, 2016

Apollo-11.nw 575

```
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	



July 10, 2016

Apollo-11.nw 577

EBANK= OGANOW  
2CADR REDOSAT

# Page 193

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

```

July 10, 2016

Apollo-11.nw 581

```
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,

July 10, 2016

Apollo-11.nw 583

	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	

584 Apollo-11.nw

July 10, 2016

	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		



July 10, 2016

Apollo-11.nw 585

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	

586 Apollo-11.nw

July 10, 2016

	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 M
	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
	TC	NEWMODEA	# PHSBRDT1)
# 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

July 10, 2016

Apollo-11.nw 587

	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.

```

July 10, 2016

Apollo-11.nw 589

	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

# Page 208

# 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.



July 10, 2016

Apollo-11.nw 593

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

                              RENWFLG

#                FOR RENDEZVOUS NAVIGATION

                              +2

                              DIMOFLAG

SET            CALL

                              PRECIFLG

                              INTEGRV

STATEND        CLRGO

                              NODOFLAG

                              ENDINT

July 10, 2016

Apollo-11.nw 595

```
# 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

```

596  <src/GIMBAL-LOCK-AVOIDANCE.s 596>≡
# 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
LOCSKIRT      EQUALS    WCALC
WCALC         LXC,1     DLOAD*
                        RATEINDX
                        ARATE,1
      SR4       CALL          # COMPUTE THE INCREMENTAL ROTATION MATRIX

```

July 10, 2016

Apollo-11.nw 597

```

                                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

```

599  <src/GROUND-TRACKING-DETERMINATION-PROGRAM.s 599>≡
    # 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



July 10, 2016

Apollo-11.nw 601

```

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
```

```

                                STODL  VCV          # ..VEL
                                P21TIME
                                STORE  TET          # ..TIME
                                CLEAR  CLEAR
                                DIMOFLAG
                                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

```

July 10, 2016

Apollo-11.nw 603

```
# 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

```

604  <src/HeaderTemplate.s 604>≡
      # 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

```

605  <src/IMU-CALIBRATION-AND-ALIGNMENT.s 605>≡
# 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	

Apollo-11.nw 607

		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*E	
	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*E	



July 10, 2016

Apollo-11.nw 609

# Page 426

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 DSPTM2  
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	
		DPPOSMAX	
		ONEDPP	
	RVQ		
COAALIGN	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		

July 10, 2016

Apollo-11.nw 611

```

      QXCH  QPLACE
      TC    COAALIGN +10

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
      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

```

July 10, 2016

Apollo-11.nw 613

```
CALL
EARTH
PROUT 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

July 10, 2016

Apollo-11.nw 615

```
#
#      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

```



July 10, 2016

Apollo-11.nw 617

```

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

LOADSTDTC 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

```

July 10, 2016

Apollo-11.nw 619

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	DPIPAZ	
	SETPD	AXT,1	
		0	
		8D	
	SLOAD	DCOMP	
		GEOCOMP1	
	BMN		
		ALWAYS	# 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
DELMPL	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	
		DELMPL	
		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	

July 10, 2016

Apollo-11.nw 621

```

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    ERTHRVSSE
               EXIT

```

July 10, 2016

Apollo-11.nw 623

	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/PIPAGT
                                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     SLEEPIE       # NO-SET UP NEXT WAITLIST CALL FOR .5 SEC
               TC     CHKCOMED
               CCS    LGYRO         # YES BUT ARE GYROS BUSY
               TCF    SLEEPIE +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

```

July 10, 2016

Apollo-11.nw 627

```
# 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

```

July 10, 2016

Apollo-11.nw 629

	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	
GCOMP4	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



July 10, 2016

Apollo-11.nw 633

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

July 10, 2016

Apollo-11.nw 635

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

```

636  <src/IMU-COMPENSATION-PACKAGE.s 636>≡
      # 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

```

July 10, 2016

Apollo-11.nw 637

```
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 X) (GYRO PULSES) X 2(+14)
	CS	NBDX	#	(GYRO PULSES)/(CS) X 2(-3)
	TC	DRIFTSUB	#	-(NBDX)(DEL TAT) (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 X) (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 X) (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)(DEL TAT) (GYRO PULSES) X 2(+14)
IRIGZ	EXTEND			

July 10, 2016

Apollo-11.nw 639

```
# 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       PRIO21    # 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      # C(A) = NBD      (GYRO PULSES)/(CS) X 2(-5)
      MP      1/PIPADT    # (CS) X 2(+8)  NO (GYRO PULSES) X 2(+3)
      LXCH    MPAC +1     # SAVE FOR FRACTIONAL COMPENSATION
      EXTEND
      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

```



July 10, 2016

Apollo-11.nw 641

```
# 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

LGCMP    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	GCOMP5W	# BYPASS IF GCOMP5W 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		# CALCULATE ABSOLUTE DIFFERENCE
	AD	POS MAX	
NBD3	EXTEND		# C(A) = DELTAT (CS) X 2(+14)
	MP	BIT10	# SHIFT RIGHT 5
	DXCH	VBUF	
	EXTEND		
	DCA	VBUF	
	DXCH	MPAC	# DELTAT NOW SCALED (CS) X 2(+19)
	CAF	ZERO	
	TS	GCOMP5W	# 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)

July 10, 2016

Apollo-11.nw 643

```
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

```

645  <src/IMU-MODE-SWITCHING-ROUTINES.s 645>≡
# 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
                MASK     BITS4&6
                CCS      A
                TCF      IMUZEROA

                TC      ALARM
                OCT      00206

                TCF      CAGETSTJ +4

IMUZEROA     TC      CAGETSTJ

# DO ALL THE WORK.

                CS      IMODES33
                MASK     SUPER011
                ADS      IMODES33

                CS      IMODES30
                MASK     BITS3&4
                ADS      IMODES30

                CS      BITS4&6
                EXTEND
                WAND     CHAN12

                TC      NOATTOFF

                CAF      BIT5
                EXTEND

```

# ROUTINE TO ZERO ICDUS.  
# DON'T ZERO CDUS IS IMU IN GIMBAL LOCK AND  
# COARSE ALIGN (GIMBAL RUNAWAY PROTECTION)  
# IF SO.  
# IMMEDIATE FAILURE.

# DISABLE DAP AUTO AND HOLD MODES  
# BIT5 FOR GROUND  
# INHIBIT ICDUFAIL AND IMUFAIL (IN CASE WE  
# JUST CAME OUT OF COARSE ALIGN).  
# SEND ZERO ENCODE WITH COARSE AND ERROR  
# COUNTER DISABLED.  
# TURN OFF NO ATT LAMP.

July 10, 2016

Apollo-11.nw 647

```

                                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	#
	EXTEND		COMPLEMENT FORM
	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	



July 10, 2016

Apollo-11.nw 649

	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	

July 10, 2016

Apollo-11.nw 651

```
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	

July 10, 2016

Apollo-11.nw 653

```

      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

July 10, 2016

Apollo-11.nw 655

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	



July 10, 2016

Apollo-11.nw 657

	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	

	DXCH	1400	
# Page 1435	CA	ITEMP2	# ENTIRE COMMAND.
LASTSEG	TS	GYROCMD	
	EXTEND		
	MP	BIT10	# WAITLIST DT
	AD	THREE	# TRUNCATION AND PHASE UNCERTAINTIES.
	TC	WAITLIST	
	EBANK=	CDUIND	
	2CADR	STRTRYRO	
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		# GET WAITLIST DT TO TIME WHEN TRAIN IS
	MP	BIT10	# ALMOST OUT.
	AD	NEG3	
	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.

July 10, 2016

Apollo-11.nw 659

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

```

July 10, 2016

Apollo-11.nw 661

```

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

```

July 10, 2016

Apollo-11.nw 663

```

                                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     PRIO37
                                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

```



July 10, 2016

Apollo-11.nw 665

# 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.

```

July 10, 2016

Apollo-11.nw 667

```
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
```

668      Apollo-11.nw

July 10, 2016

```
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

```

669  <src/IMU-PERFORMANCE-TEST-2.s 669>≡
# 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	ZERONDX
	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

July 10, 2016

Apollo-11.nw 671

```

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     DSPTEM2
CA     DRIFTI
TS     DSPTEM2 +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		



July 10, 2016

Apollo-11.nw 673

	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	

July 10, 2016

Apollo-11.nw 675

	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				
EARTHR	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			

July 10, 2016

Apollo-11.nw 677

```

                                ECADR  ERCOMP
                                PULSEIMU
                                GOTO    S2

EARTH*  EXTEND
        QXCH  QPLACES
        TC    INTPRET
        CALL
            EARTH
        EXIT
        TC    IMUSLLLG
        TC    QPLACES

SHOW
# Page 381
        EXTEND
SHOW1   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

```

679  <src/IMU-PERFORMANCE-TESTS-4.s 679>≡
# 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

```

```

# Page 383

```

```

BANK    33
SETLOC  IMU4
BANK
COUNT* $$/P07

```

```

EBANK=  XSM

```

```

ESTIMS

```

```

INHINT
CAE     1SECXT
TC      TWIDDLE
EBANK=  XSM
ADRES   ALLOOP
CAF     ZERO
TS      PIPAX
TS      PIPAY
TS      PIPAZ
RELINT

```

```

# ZERO THE PIPAS

```

```

CA      77DECML
TS      ZERONDX
CA      ALXXXZ
TC      ZEROING
TC      INTPRET
SLOAD
SCHZEROS
STOVL   GCOMPSW -1
        INTVAL  +2
STOVL   ALX1S
SCHZEROS
STORE   DELVX
STORE   GCOMP

```



July 10, 2016

Apollo-11.nw 681

```

                                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	
		DEL VX	
	VXM	VSL1	
		XSM	
	DLOAD	DCOMP	
		MPAC +3	
	STODL	DPIPAY	
		MPAC +5	
	STORE	DPIP AZ	
	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

```

July 10, 2016

Apollo-11.nw 685

```
#
# 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	

## A.41 INFLIGHT ALIGNMENT ROUTINES

687

*<src/INFLIGHT-ALIGNMENT-ROUTINES.s 687>≡*

```
# 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



July 10, 2016

Apollo-11.nw 689

# 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...	

July 10, 2016

Apollo-11.nw 691

```

                                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					

July 10, 2016

Apollo-11.nw 693

```
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

```

694  <src/INPUT-OUTPUT-CHANNEL-BIT-DESCRIPTIONS.s 694>≡
      # 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

```

July 10, 2016

Apollo-11.nw 695

```
# 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
```



July 10, 2016

Apollo-11.nw 697

```
#
# 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

699

*<src/INTEGRATION-INITIALIZATION.s 699>≡*

```
# 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 ORIENTAT
# 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 OBLATEN
# IN LUNAR ORBIT IS TIME DEPENDENT. THEREFORE, THE USER SHOULD SUPPLY AN INITIAL ST
# 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
# 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, LEMPRE
# 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 S
# 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 M
# THE PERMANENT STATE VECTORS WILL ALSO BE UPDATED WHENEVER THE W-MATRIX IS INTEGRAT
# 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 PROGRAM.  
 # PROGRAMS WHICH USE THE INTEGRV OR INTEGRVS ENTRANCE OF INTEGRATION SHOULD ENSURE THAT IF PHASE  
 # CHANGES ARE MADE 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 MI

#

# 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
DELTA VCSM(LEM)	POSITION DEVIATION	METERS	2	2
	0 IF TCCSM(LEM) = 0			
			3	-1
NUVCSM(LEM)	VELOCITY DEVIATION	M/CSEC	2	2
	0 IF TCCSM(LEM) = 0			
# Page 1311			29	27

#

```

#          RCVSM(LEM)          CONIC POSITION          METERS          2
#          EQUALS RRECTCSM(LEM) IF
#          TCCSM(LEM) = 0
#
#          VCVCSM(LEM)          CONIC VELOCITY          M/CSEC          7
#          EQUALS VRECTCSM(LEM) IF
#          TCCSM(LEM) = 0
#
#          TCCSM(LEM)          TIME SINCE RECTIFICATION    CSECS          28
#          CUSTOMARILY 0
#
#          XKEPCSM(LEM)          RDOT OF KEPLER'S EQUATION    1/2          17
#          0 IF TCCSM(LEM) = 0
#
#          CMOONFLG          PERMANENT FLAGS CORRESPONDING    0
#          CMIDFLAG          TO MOONFLAG AND MIDFLAG          0,1
#          LMOONFLG          C = CSM, L = LM                  0
#          LMIDFLAG          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
#
#          OD          RATT          POSITION          METERS          EARTH    MOON
#          29          29
#          2          2
#
#          6D          VATT          VELOCITY          M/CSEC          7          7
#          2          2
#
#          12D          TAT          TIME          28          28
#          2          2
#
#          14D          RATT1          POSITION          METERS          29          27
#          2          2
#
#          20D          VATT1          VELOCITY          M/CSEC          7          5
#          2          2
#

```

July 10, 2016

Apollo-11.nw 703

```
#
#           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.

```



July 10, 2016

Apollo-11.nw 705

	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

```

July 10, 2016

Apollo-11.nw 707

```
#
# 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

```



July 10, 2016

Apollo-11.nw 713

```
# Page 1321
PHEXIT      TC      INTERPRET
            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
            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
              INTEXTIT      # 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
```

July 10, 2016

Apollo-11.nw 715

```

                                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	

July 10, 2016

Apollo-11.nw 717

	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

```

July 10, 2016

Apollo-11.nw 719

```

                                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

```



July 10, 2016

Apollo-11.nw 721

```
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

```

July 10, 2016

Apollo-11.nw 723

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

725

*<src/INTER-BANK-COMMUNICATION.s 725>≡*

```
# 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
#               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 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

```

July 10, 2016

Apollo-11.nw 727

```
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

#

#	# SUPERBANK	SETTING	S-REG. VALUE	PSEUDO-FIXED BANK NUMBERS	OCTAL PSEUDO ADDRESSES	
#	-----	-----	-----	-----	-----	
#	SUPERBANK 3	0XX	2000 - 3777	30 - 37	70000 - 107777	(WHE
#						WILL
#	SUPERBANK 4	100	2000 - 3777	40 - 47	110000 - 127777	(AS P
#						ONLY
#						AND A
#	SUPERBANK 5	101	2000 - 3777	50 - 57	130000 - 147777	(PRES
#						THE U
#	SUPERBANK 6	110	2000 - 3777	60 - 67	150000 - 167777	(PRES
#						THE U

# \*\*\* 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)

# ...

# .

# .

# .

# OR IN THIS FASHION:

# 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



July 10, 2016

Apollo-11.nw 729

This code is written to file `src/INTER-BANK-COMMUNICATION.s`.

## A.45 INTERPRETER

```

730  <src/INTERPRETER.s 730>≡
    # 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.

```

July 10, 2016

Apollo-11.nw 731

```

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.
```

	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 BIT.
	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 P.
	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 PLACE.
	ADS	ADDRWD	# ADDRWD AND DISPATCH.
ITR15	INDEX	CYR	# THIS INDEX MAKES THE NEXT INSTRUCTION.
	7	INDJUMP -1	# TCF INDJUMP + OP, EDITING CYR.

July 10, 2016

Apollo-11.nw 733

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).
```

July 10, 2016

Apollo-11.nw 735

	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.



July 10, 2016

Apollo-11.nw 737

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.

July 10, 2016

Apollo-11.nw 739

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
---------	-----	----------

July 10, 2016

Apollo-11.nw 741

```

          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

```

July 10, 2016

Apollo-11.nw 743

```

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.



July 10, 2016

Apollo-11.nw 745

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 OVFind IS SET NON-ZERO IF OVERFLOW OCCURS IN AD
#
VSU      CAF      BIT15      # CHANGES 0 TO DCS.
          TCF     +2

```

July 10, 2016

Apollo-11.nw 747

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

```

July 10, 2016

Apollo-11.nw 749

DCOM  
TCF      ENDVXV

# Page 1135  
# TRIPLE PRECISION ADD ROUTINE.

TAD                    EXTEND  
                      INDEX    ADDRWD  
                      DCA       1                    # ADD MINOR PARTS FIRST.  
                      DAS       MPAC +1  
                      INDEX    ADDRWD  
                      AD        0  
                      AD        MPAC  
                      TS        MPAC  
                      TCF       DANZIG  
  
                      TCF       SETOVF                # SET OVFind IF SUCH OCCURS.

# 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 FC

DMP                    INDEX    Q                    # BASIC SUBROUTINE FOR USE BY PINBALL, ETC  
                      # Was CAF --- RSB 2009.  
                      CA        0  
                      INCR     Q  
                     -1       TS       ADDRWD                # (PROLOGUE FOR SETTING ADDRWD.)

DMPSUB                INDEX    ADDRWD                # GET MINOR PART OF OPERAND AT C(ADDRWD).  
                      CA        1  
                      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

```

July 10, 2016

Apollo-11.nw 751

```

      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 X  + A  X  + ... + A  X + A  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

```



July 10, 2016

Apollo-11.nw 753

```

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.

July 10, 2016

Apollo-11.nw 755

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	

July 10, 2016

Apollo-11.nw 757

```
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

```

July 10, 2016

Apollo-11.nw 759

	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

```

July 10, 2016

Apollo-11.nw 763

```

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	

July 10, 2016

Apollo-11.nw 765

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 # BEGIN NORMALIZATION LOOP.  
TCF TSLCTEST

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     MPTMP      # DECREMENTED SHIFT COUNT TO MPTMP.
               CAF   BIT8       # TEST MEANING OF LOW SEVEN BIT COUNT IN
               EXTEND                                     # MPTMP 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     MPTMP     # SEE IF SHIFT COUNT LESS THAN 14D.
               AD     NEG12
               EXTEND
               BZMF   VSSR      # IF SO, BRANCH AND SHIFT IMMEDIATELY.

               AD     NEGONE    # IF NOT, REDUCE MPTMP BY A TOTAL OF 14.
               TS     MPTMP     # 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

```

July 10, 2016

Apollo-11.nw 767

```

XCH      MPAC +1
TC        SETROUND
DAS      MPAC
# X COMPONENT NOW SHIFTED, SO MAKE UP THE
# ROUNDING QUANTITY (O IN A AND O 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 O.

# Page 1160
# PROCESS SR AND SRR FOR SCALARS.

GENSCR   CA      MPTMP
+1        AD      NEG12
EXTEND
BZMF     DOSSHFT
# 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
# SEE IF FINISHED, DO FINAL DECREMENT.

SLOPEHI  DEC      .5884
CAF      BIT10
# 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.



July 10, 2016

Apollo-11.nw 769

	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

July 10, 2016

Apollo-11.nw 771

	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.
	CA	HALF	# SIGNS DISAGREE. FORCE AGREEMENT.
+6	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  
DDOUBL  
DDOUBL  
DDOUBL  
DDOUBL  
DDOUBL  
DDOUBL  
DDOUBL  
DDOUBL  
DDOUBL  
DDOUBL  
DDOUBL  
DDOUBL  
DDOUBL

DXCH MPAC

MAXTEST CCS MAXDVSU # 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 EQU

#

# 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).

July 10, 2016

Apollo-11.nw 773

```

#
#      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

```

July 10, 2016

Apollo-11.nw 775

```
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

```



July 10, 2016

Apollo-11.nw 777

```

                                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.

```

July 10, 2016

Apollo-11.nw 779

```
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

July 10, 2016

Apollo-11.nw 781

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		

July 10, 2016

Apollo-11.nw 783

```

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-

```



July 10, 2016

Apollo-11.nw 785

	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

```

July 10, 2016

Apollo-11.nw 787

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.

```

July 10, 2016

Apollo-11.nw 789

```

EXTEND                                # IF NEGATIVE, USE THE IDENTITY
DCS      MPAC                        # ARCCOS(X) = PI - ARCCOS(-X), FORCING
DXCH      MPAC                      # ARGUMENT POSITIVE.
CAF      TCSUBTR                    # SET EXIT TO DO ABOVE BEFROE
XCH      ESCAPE                     # ARCSIN/ARCCOS CONSIDERATIONS.
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                  # NOW THAT ARGUMENT IS IN PROPER RANGE,
DCS      MPAC                      # BEGIN COMPUTATION.  USE HASTINGS
AD      HALF                      # APPROXIMATION ARCCOS(X) = SQRT(1-X)P(X)
DXCH      MPAC                    # IN A SCALED VERSION WHERE P(X) IS A
DXCH      BUF2                    # SEVENTH ORDER POLYNOMIAL.

           TC      SQRTSUB        # RETURNS WITH NORMALIZED SQUARE ROOT.

           CCS      MPTEMP        # 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 # ACOS(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
MSTORE1    CA      X1
           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	



July 10, 2016

Apollo-11.nw 793

```

+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).

July 10, 2016

Apollo-11.nw 795

# 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
TEST	+1	CS	Q	# 00 -- BRANCH IF ON.
		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

```

797  <src/INTERPRETIVE-CONSTANT.s 797>≡
    # 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

799  $\langle \text{src}/\text{INTERPRETIVE-CONSTANTS.s } 799 \rangle \equiv$

```

# 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.





## 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	

July 10, 2016

Apollo-11.nw 803

	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

```

804  <src/JET-SELECTION-LOGIC.s 804>≡
      # 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

```

July 10, 2016

Apollo-11.nw 805

```
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
```

# Page 1040

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
---------	-------	-------

July 10, 2016

Apollo-11.nw 807

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	



July 10, 2016

Apollo-11.nw 809

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

# Page 1044

# 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		

July 10, 2016

Apollo-11.nw 811

	BZF	NOACY	# NO Y-TRANSLATION
	CCS	RACFAIL	
	CAF	THREE	
	TCF	+2	
	CAF	SIX	
	INDEX	YNDX	
	AD	XLN1NDX	
	INDEX	A	
	CA	YZTABLE	
	MASK	ACYJETS	# = 34360 OCT
	AD	RWORD1	
	TS	T5TEMP	
	EXTEND		# FOR EXPLANATION SEE CODING ON RTABLE
	MP	BIT4	
	AD	=-4	
	TS	NRJETS	# NO. OF NET ROLL JETS
	EXTEND		
	BZF	TAUCHCK	# IF NRJETS = 0
BDRACZ	CA	T5TEMP	# Y-TRANSLATION ACCEPTED
	TS	RWORD1	
	TCF	ROLLTIME	# BRANCH TO JET ON-TIME CALCULATIONS
TAUCHCK	CCS	TAU	
	TCF	NOACY	
	TCF	BDRACZ	
	TCF	NOACY	
	TCF	BDRACZ	

# Page 1046

NOACY	CA	RWORD1	# Y-TRANSLATION NOT ACCEPTED
	EXTEND		
	MP	BIT4	
	AD	=-2	
	TS	NRJETS	
	TCF	ROLLTIME	

# Page 1047

#  
# 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               -2
#               0   0   1               -1
#               0   1   0               0
#               0   1   1               +1
#               1   0   0               +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 9,10,11
# (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:

```

Apollo-11.nw 813

### Y, Z TRANSLATION TABLE

```
# BITS 9,10,11 ARE CODED TO GIVE THE NET ROLL TORQUE INCURRED BY Z-TRANSLATIONS.  THE WORD SELE
# ADDED TO THE AC-ROLL WORD AND THE RESULTANT ROLL TORQUE DETERMINED FROM THE COMBINED WORD.  S
# 12,13,14 ARE CODED TO GIVE THE NET ROLL TORQUE INCURRED BY Y-TRANSLATIONS WHEN BD-ROLL IS SEL
```

## CALCULATION OF JET ON-TIMES

```
# THE ROTATION COMMANDS (TAU'S), WHICH WERE DETERMINED FROM THE JET SWITCHING LOGIC ON THE BASI
```

```

# 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

```

July 10, 2016

Apollo-11.nw 815

```
# 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
               MP      NPJETS
               LXCH     DFT1
               TS      TAU1
               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



July 10, 2016

Apollo-11.nw 817

```

                                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	

July 10, 2016

Apollo-11.nw 819

# 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.

```

July 10, 2016

Apollo-11.nw 821

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
                                WRITE   CHAN6
                                CA      PWORD1
                                AD      YWORD1
                                EXTEND
                                WRITE   CHAN5          # INITIALIZE CHANNELS 5,6 WITH WORD1

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

```

July 10, 2016

Apollo-11.nw 823

	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

```

825  <src/KALCMANU-STEERING.s 825>≡
# 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

```

July 10, 2016

Apollo-11.nw 829

# 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

```

831  <src/KALMAN-FILTER.s 831>≡
      # 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

```



July 10, 2016

Apollo-11.nw 833

	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

```

834  <src/KEYRUPT-UPRUPT.s 834>≡
      # 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.

```

July 10, 2016

Apollo-11.nw 835

```

                                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 I  
 # FAILURE).

```

#
# UPLINK ACTIVITY IS ALSO ALLOWED (UNLOCKED) DURING FRESH START WHEN FRESH START SETS

```

July 10, 2016

Apollo-11.nw 837

This code is written to file `src/KEYRUPT-UPRUPT.s`.

## A.53 LAMBERT AIMPOINT GUIDANCE

```

838  <src/LAMBERT-AIMPOINT-GUIDANCE.s 838>≡
      # 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

```



July 10, 2016

Apollo-11.nw 841

```

                                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

```

842  <src/LANDING-ANALOG-DISPLAYS.s 842>≡
      # 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

```

July 10, 2016

Apollo-11.nw 843

```

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.

                                CAF      ZERO
                                AD      POSMAX
                                AD      ALTSAVE
                                TS      ALTSAVE      # POSSIBLY SKIP TO NEWDATA.

```

July 10, 2016

Apollo-11.nw 845

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?
	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		
TCF	TASKOVER		
INTLZE	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

```

July 10, 2016

Apollo-11.nw 847

# 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

```



July 10, 2016

Apollo-11.nw 849

```
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	NEGO	# 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

July 10, 2016

Apollo-11.nw 853

```

      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**

```

854  <src/LATITUDE-LONGITUDE-SUBROUTINES.s 854>≡
      # 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)

```

July 10, 2016

Apollo-11.nw 855

```
#      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
LAT-LONG      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

# Page 1237

      DAD        SQRT
      DMP        SL1R
                GAMRP
      STODL      COSTH        # COS(LAT) B-1
                ALPHAV +4
      STCALL     SINTH        # SIN(LAT) B-1
                ARCTAN
      STODL      LAT          # LAT B0
```

```

      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

```



July 10, 2016

Apollo-11.nw 857

```

      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

```

861  <src/LEM-GEOMETRY.s 861>≡
      # 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

```

July 10, 2016

Apollo-11.nw 863

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 RELATION  
#

# 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            INTERPRET
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      # SHAFT ANGLE TO 2
DMP           SL1
                        0
STODL         36D        # Z COMPONENT

```



July 10, 2016

Apollo-11.nw 865

```
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

```

866  <src/LUNAR-AND-SOLAR-EPHEMERIDES-SUBROUTINES.s 866>≡
      # 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
```

July 10, 2016

Apollo-11.nw 869

```

COUNT*  $$/EPHEM
EBANK=    END-E7
LSPOS     AXT,2      RESA      # COMPUTES POSITION VECTORS OF BOTH THE
                                     # SUN AND THE MOON.  THE POSITION VECTOR
AXT,1     GOTO      # OF THE SUN IS STORED IN 2D OF THE VAC
RES      # AREA.  THE POSITION VECTOR OF THE MOON
LSTIME    # IS STORED IN MPAC.
LUNPOS     AXT,1     GOTO      # COMPUTES THE POSITION VECTOR OF THE MOON
REM      # AND STORES IT IN MPAC.
LSTIME
# Page 787
LUNVEL     AXT,1     GOTO      # COMPUTES THE VELOCITY VECTOR OF THE MOON
VEM      # AND STORES IT IN MPAC.
LSTIME
SOLPOS     STQ       AXT,1     # COMPUTES THE POSITION VECTOR OF THE SUN
X2        # AND STORES IT IN MPAC.
RES
LSTIME     SETPD     SR
OD
14D
TAD        DCOMP
TEPHEM
TAD        DCOMP
TIMEMO
SL         SSP
16D
S1
6D
GOTO
X1
RES        PUSH      DMP      # PD- 2
OMEGAES
PUSH      COS      # PD- 4
VXSC      PDDL      # PD- 8
RESO
SIN       PDVL      # PD-10
RESO
PUSH      UNIT      # PD-16
VXV       UNIT
VESO
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
```

870 Apollo-11.nw

July 10, 2016

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		

This code is written to file src/LUNAR-AND-SOLAR-EPHEMERIDES-SUBROUTINES.s.

## A.58 LUNAR LANDING GUIDANCE EQUATIONS

```

871  <src/LUNAR-LANDING-GUIDANCE-EQUATIONS.s 871>≡
      # 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
```



July 10, 2016

Apollo-11.nw 873

# 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

GILDEN	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

July 10, 2016

Apollo-11.nw 875

```
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          #

```

-----

July 10, 2016

Apollo-11.nw 879

```
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.

```



July 10, 2016

Apollo-11.nw 881

```

      R
VSU   PUSH      #      -   ----
      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
          VDGT2TTF,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

```

July 10, 2016

Apollo-11.nw 883

```
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    #
                                AFCCALC3
                                ZEROVECS
AFCCALC3    SQRT    DAD
                                UNFC/2 +4
# Page 810
                                BPL    BDSU
                                AFCCLEND
                                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

# Page 811

            VXV         RTB
                        LAND
                        NORMUNIT
            STOVL       CG +6        # SECOND ROW
                        CG
            VXV         VSL1
                        CG +6
            STORE       CG +14
            EXIT
```

```
#      (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      INTERP      # COMPUTE TRIM VELOCITY CORRECTION TERM.
# Page 812

              VLOAD  RTB
                   UNFC/2
                   NORMUNIT
              VXSC   VXSC
                   ZOOMTIME
                   TRIMACCL
              STORE  UNFC/2
              EXIT

              CCS    NGUIDSUB
```

July 10, 2016

Apollo-11.nw 887

	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	



July 10, 2016

Apollo-11.nw 889

```
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

```

```

# *****

```

July 10, 2016

Apollo-11.nw 891

# 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 OLDPIPAX  
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)

```

July 10, 2016

Apollo-11.nw 893

# 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	

July 10, 2016

Apollo-11.nw 895

```
VLOAD                                # 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 VO6N60 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      QRUP

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	
	CCS	A	
-AZ	CS	AZEACH	
	ADS	AZINCR1	
	CA	L	
	MASK	+AZBIT	
	CCS	A	
+AZ	CA	AZEACH	
	ADS	AZINCR1	
	CA	L	
	MASK	-ELBIT	



July 10, 2016

Apollo-11.nw 897

```
-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.

```

July 10, 2016

Apollo-11.nw 899

```

# 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	TARGETDEX	
	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	POS MAX
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

```

July 10, 2016

Apollo-11.nw 903

3/8DP	2DEC	.375
3/4DP	2DEC	.750
DEPRCRIT	2DEC	-.02 B-1

# Page 828

# \*\*\*\*\*  
# \*\*\*\*\*

This code is written to file `src/LUNAR-LANDING-GUIDANCE-EQUATIONS.s`.

## A.59    LUNAR LANDMARK SELECTION FOR CM

```

904  <src/LUNAR-LANDMARK-SELECTION-FOR-CM.s 904>≡
      # 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

905 `<src/MAIN.s 905>≡`

```
# 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
# COMEIKISS	
\$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

```

909  <src/MEASUREMENT-INCORPORATION.s 909>≡
    # 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*

```

July 10, 2016

Apollo-11.nw 911

```

                                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

```

```

#
# NORMAL EXIT
#          L+1 OF CALLING SEQUENCE
#

          SETLOC  MEASINC1
          BANK

          COUNT*  $$/INCOR

INCRP2    STQ      CALL
          EGRESS
          INTSTALL

          VLOAD    VXSC          # CALC. GAMMA*OMEGA1,2,3
          OMEGA
          GAMMA

          STOVL    OMEGAM1
          OMEGA +6

          VXSC

          GAMMA

          STOVL    OMEGAM2
          OMEGA +12D

          VXSC

          GAMMA

          STORE    OMEGAM3
          EXIT

          CAF      54DD          # INITIAL IX 1 SETTING FOR W MATRIX
          TS       WIXA
          TS       WIXB
          CAF      ZERO

          TS       ZIXA          # INITIAL IX 2 SETTING FOR Z COMPONENT
          TS       ZIXB
          TC       PHASCHNG

FAZA
# Page 1257

          OCT      04022
          TC       UPFLAG
          ADRES    REINTFLG

FAZA1     CA       WIXB          # START FIRST PHASE OF INCRP2
          TS       WIXA          # TO UPDATE 6 OR 9 DIM. W MATRIX IN TEMP
          CA       ZIXB
          TS       ZIXA
          TC       INTPRET
          LXA,1    LXA,2
          WIXA
          ZIXA
          SSP      DLOAD*

```

July 10, 2016

Apollo-11.nw 915

```

      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

```

July 10, 2016

Apollo-11.nw 917

```

                                DELTAX  +12D  # INCORPORATION FOR X789
                                TX789
                                RTB
                                VEHUPFLG
                                DOCSM
                                MOVEPLEM
FAZAB      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
                                STOV L  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
```

		SVDWN2	# STORE DOWNLINK STATE VECTOR
FAZAB4	CALL		
# Page 1260			
		GRP2PC	# PHASE CHANGE
	BOFF	VLOAD	
		DMENFLG	
		FAZAB5	# 6 DIMENSIONAL
		TX789	# 9 DIMENSIONAL
	STORE	X789	
FAZAB5	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	

July 10, 2016

Apollo-11.nw 919

```

                                NEWZCMP1
STADR
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

```

921  <src/MYSUBS.s 921>≡
    # 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

```

July 10, 2016

Apollo-11.nw 923

# Page 1001 (empty page)

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

## A.63    ORBITAL INTEGRATION

```

924  <src/ORBITAL-INTEGRATION.s 924>≡
      # 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

```

July 10, 2016

Apollo-11.nw 925

	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	



July 10, 2016

Apollo-11.nw 929

```

                                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

```

July 10, 2016

Apollo-11.nw 931

```
INT-ABRT      EXIT
               TC      P00D00
               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

```

July 10, 2016

Apollo-11.nw 933

```

                                +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 # out of 8D B5 GIVES B58
	VSL*	VAD	# SHIFT MAKES B61, FOR ADDITION OF # 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 # FOR RESULT.
	PDDL	PDDL	
		TET	
			5/8
	LXA,2	CALL	# ANY NON-ZERO CONSTANT # POSITION IN OD, TIME IN 6D. X2 LEFT # ALONE.
		PBODY	
		RP-TO-R	
	VAD	BOV	# OVERFLOW INDICATOR RESET IN *RP-TO-R*
		FV	
		GOBAQUE	
	STORE	FV	
# Page 1344 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

July 10, 2016

Apollo-11.nw 935

```

                                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
INTGRATE 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 T

# 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

```

July 10, 2016

Apollo-11.nw 939

```
# 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

          # ADJUST W-POSITION FOR INTEGRATION

          # ADJUST W-VELOCITY FOR INTEGRATION

ENDSTATE  BOV      VLOAD
          GOBAQUE
          ZV
STOVL     TNUV
          YV
STORE     TDELTA V
BON       BOFF
          MIDAVFLG
          CKMID2
          DIMOFLAG
          TESTLOOP

          # 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

```

Apollo-11.nw 941

```
# Page 1352
# 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

July 10, 2016

Apollo-11.nw 943

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
COSPHI/2	EQUALS	URPV +4
UZ	EQUALS	20D
TVEC	EQUALS	26D

This code is written to file `src/ORBITAL-INTEGRATION.s`.



## A.64 P11

```

945  <src/P11.s 945>≡
# 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
#       $\bar{Z}$ 
#       $\bar{U} = \text{UNIT}(A)$ ,  $A = \text{HOR VECTOR AT LAUNCH AZIMUTH}$ 
#       $\bar{X} \quad \bar{Y} \quad \bar{Z}$ 
#       $\bar{U} = \bar{U} * \bar{U}$ 
#       $\bar{U} \quad \bar{Z} \quad \bar{X}$ 
# 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

```

July 10, 2016

Apollo-11.nw 947

```
#      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
#      PGNCsalt
#      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

```

July 10, 2016

Apollo-11.nw 949

# 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
                                CA        CDUX          # STORE DP GIMBAL ANGLES FOR ATTITUDE
                                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

```

July 10, 2016

Apollo-11.nw 951

# 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

```



July 10, 2016

Apollo-11.nw 953

```

      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

```

July 10, 2016

Apollo-11.nw 957

```

                                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

```

Apollo-11.nw 959

```

COSCDUX
2
DSU      SL1
STADR
STORE    18D      # 18D,  .5(-DTHETA*SIN(CDUX)*COS(CDUZ)
TLOAD    #
          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		



July 10, 2016

Apollo-11.nw 961

```
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

```

July 10, 2016

Apollo-11.nw 965

STIKBITS	OCT	00077
100MST5	DEC	16374
	EBANK=	BODY3
2SATSTCK	2CADR	SATSTICK

This code is written to file `src/P11.s`.

**A.65 P12**

```

966  <src/P12.s 966>≡
      # 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

```

July 10, 2016

Apollo-11.nw 967

# 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.



July 10, 2016

Apollo-11.nw 969

	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**

```

972  <src/P20-P25.s 972>≡
# 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,DELCDUY,DELCDUZ
#       STIKFLAG,PRFTRKAT,VINTFLAG,DIMOFLLAG,R60FLAG,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	

July 10, 2016

Apollo-11.nw 975

```
P20.3          CALL      VINTFLAG      # SET FOR LM INTEGRATION
                CALL      INTEGRV
                EXIT
                CAF      PRI026
                TC       FINDVAC
                EBANK=   MRKBUF2
                2CADR    R22

                TC       2PHSCHNG
                OCT      00072
                OCT      00111
PIKUP20        CAF      PRI014      # 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

```



July 10, 2016

Apollo-11.nw 977

```
# 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

```

July 10, 2016

Apollo-11.nw 979

```
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 INTPRET
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 INTPRET
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	GOTOP00H	# 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

```



July 10, 2016

Apollo-11.nw 985

```
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

```

July 10, 2016

Apollo-11.nw 987

```

      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
#
#              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

```

July 10, 2016

Apollo-11.nw 991

```

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

```



July 10, 2016

Apollo-11.nw 993

```

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
                                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
                                CLRG0
                                INCORFLG
                                REND7      # BRANCH FOR 2ND PASS THIS OPTICS MARK
CSMUPP                         CLEAR      CALL

```

# Page 583

Apollo-11.nw 995

		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	

July 10, 2016

Apollo-11.nw 997

```

                                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
```

		DIMOF	FLAG	
	SET	CLRG0		
		VINT	FLAG	# SET VEHICLE EQ. CSM
		D60R9	FLG	# SET W MATRIX DIM. EQ 6
		EGRESS		# EXIT
CNTCHK	STQ			
		POINT	EX	
CONTCHK	BOFF			
		REFSM	FLG	# BRANCH TO END OF JOB IF REFSMMAT NO GOOD
		ENDPL	AC	
	SLOAD	BMN		
		R61CN	TR	
		WAITONE	1	
	BON	BOFF		# IS TRACK FLAG SET
		UPDAT	FLG	
		POINT	EX	
		TRACK	FLG	
		ENDPL	AC	
	EXIT			
REDOR22	TC	PHASCH	NG	
	OCT	00132		
	CAF	PRI026		
	TC	PRI0CH	NG	
	TC	WAITONE	+3	
WAITONE	STQ			
		POINT	EX	
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

July 10, 2016

Apollo-11.nw 999

	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	



July 10, 2016

Apollo-11.nw 1001

```
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.
#

```

July 10, 2016

Apollo-11.nw 1003

```
#      (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
#      MBDYTCTL(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

```

July 10, 2016

Apollo-11.nw 1005

```
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
               CAF      PRI030
               EXTEND
               RXOR     CHAN31
               MASK     FURST3
               EXTEND
               BZF      DAPCK      # AUTO MODE SELECTED (BITS 15-13=011)
               TC      ASET        #      YES -- CONTINUE.

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

               CAF      TWO          # SET TEMPORARY INDEX DTHETASM = 2
CDULOO       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     NORM # OBTAIN ABS VALUE OF LOS.
          P21TIME    # P21TIME IS TEMP STORE FOR ABSLOS.
          X1
          PUSH      # NORM ABSLOS(DENOM) AND HOLD IN PUSH1.

          DLOAD     NORM
          36D
          S1        # NORM ABS VALUE OF DV(NUM).

          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

```

July 10, 2016

Apollo-11.nw 1007

```
# 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

# NOW DAP VARIABLES LOADED.  SET HOLDFLAG.
# TO -1.

MANUEXIS
MANUEXIT
          TLOAD
          SAVEDCDU
          CPHI
          GOTO
          LOONE
          Q611

# 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

```



July 10, 2016

Apollo-11.nw 1009

```

                                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

July 10, 2016

Apollo-11.nw 1011

```
#      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

```

July 10, 2016

Apollo-11.nw 1013

```

                                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
```

```

                                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

```

July 10, 2016

Apollo-11.nw 1015

# Page 602

S22NXXA

S22NXXB

```
STORE W +144D,1      # W(I+18)= UW(I) B-19
TIX,1  DLOAD
      S22NXTWI

      S22RHO          # B-28,B-30
BOFF   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

```



July 10, 2016

Apollo-11.nw 1017

```
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
# Page 605    R-TO-RP
                                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

```

July 10, 2016

Apollo-11.nw 1019

```

                                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		

July 10, 2016

Apollo-11.nw 1021

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

	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

July 10, 2016

Apollo-11.nw 1023

```

                                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

```



July 10, 2016

Apollo-11.nw 1025

```
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
```

July 10, 2016

	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

July 10, 2016

Apollo-11.nw 1027

```

                                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

```

July 10, 2016

Apollo-11.nw 1029

```
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

```

July 10, 2016

Apollo-11.nw 1031

```

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

```



July 10, 2016

Apollo-11.nw 1033

```

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
                                LOWMEMRY   # 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

```

July 10, 2016

Apollo-11.nw 1035

	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	GOFLASH	
	TC	GOTOPOOH	# TERMINATE
	TC	P23.65	# STORE DATA
	TC	-5	# REDISPLAY
P23.65	TC	INTPRET	
	SET	EXIT	

July 10, 2016

Apollo-11.nw 1037

```

                                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

```

July 10, 2016

Apollo-11.nw 1039

```
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
SR3    DAD
DAD    DMP
        TRUN19
        32D
DMP    SL3
        PI/4.0
BOFF   SL2
        CMOONFLG
        R23.51
R23.51 STODL DELTAQ
        30D      # RCLL * RCLL
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	
		INCRP2	
	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	



July 10, 2016

Apollo-11.nw 1041

```

                                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

```

July 10, 2016

Apollo-11.nw 1043

		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)

July 10, 2016

Apollo-11.nw 1045

```
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	

July 10, 2016

Apollo-11.nw 1047

```

                                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
                                WWVEL
                                WWPOS
                                Sqrt
                                STORE WWPOS
                                BOV    GOTO
                                      +2
                                      V67XXX
                                DLOAD
                                DPPOS MAX
                                STORE WWPOS
                                STORE WWVEL
V67XXX DLOAD DSU
                                WWPOS
                                FT99999
                                BMN    DLOAD
                                      +3
                                      FT99999
# Page 634
                                STORE WWPOS
                                LXA,1  SXA,1
                                      S2
                                      QPRET
                                EXIT
                                TC      POSTJUMP
                                CADR    INTWAKE
WPOS = RANGE
WVEL = RRATE
WOPT = 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

1049

*<src/P30-P37.s 1049>*≡

```
# 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

```

July 10, 2016

Apollo-11.nw 1051

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

```

July 10, 2016

Apollo-11.nw 1053

```
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**

```

1054  <src/P30-P37.s 1054>≡
      # 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

```

July 10, 2016

Apollo-11.nw 1055

```

                                RGEXIT
                                COMPTGO
                                TC
                                TC
                                CAF    V16N45
                                TC    BANKCALL
                                CADR   GOFLASHR
                                TC    GOTOP00H
                                TC    END45
                                TC    DISP45
                                TC    PHASCHNG
                                OCT    14
                                TCR    ENDOFJOB
                                TC    INTPRET
                                CLEAR  GOTO
                                TIMRFLAG
                                RGEXIT

                                COMPTGO
                                EXTEND
                                QXCH   PHSPRDT6
                                TC      UPFLAG
                                ADRES   TIMRFLAG
                                CAF     ZERO
                                TS      NVWORD1

                                CAF     ONE
                                TC      WAITLIST
                                EBANK=  TIG
                                2CADR   CLOKTASK

                                TC      2PHSCHNG
                                OCT     40036
                                OCT     05024
                                OCT     13000
                                TC      PHSPRDT6
```

# 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

```



July 10, 2016

Apollo-11.nw 1057

	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	GOTOPOOH	
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	GOTOPOOH	
	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	GOTOPOOH	
	TC	P30/RET	
	TCF	CNTNUP30 +2	
PARAM30	XCH	Q	
	TS	P30/31RT	
	CAF	V06N42	
	TC	BANKCALL	
	CADR	GOFLASH	
	TC	GOTOPOOH	# ON TERMINATION GOTOPOOH
	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

July 10, 2016

Apollo-11.nw 1059

```
#      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

```

July 10, 2016

Apollo-11.nw 1061

```
#      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

```

Apollo-11.nw 1063

	BOV	1BITDP 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.
DELRDONE	STCALL	THETA(1) 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

```



July 10, 2016

Apollo-11.nw 1065

	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 \*\*\*\*\*  
#

July 10, 2016

Apollo-11.nw 1067

```
# 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**

```

1068  <src/P32-P33-P72-P73.s 1068>≡
# 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
#              CDHMR.
#
# 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

```

July 10, 2016

Apollo-11.nw 1071

```
#      (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
#      GOTOP00H
# 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

```



July 10, 2016

Apollo-11.nw 1073

	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
```

July 10, 2016

Apollo-11.nw 1077

```
#
#      (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	

July 10, 2016

Apollo-11.nw 1079

	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 *****
```



July 10, 2016

Apollo-11.nw 1081

```
#
# 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

```

July 10, 2016

Apollo-11.nw 1083

	SR1	DDV	#	B38-B31= B7 PLOOD
	SL*	SQRT	#	B7
		0 -7,1		
	PDVL	UNIT	#	PLO2D
		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		
		RVSU	
	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	

July 10, 2016

Apollo-11.nw 1085

		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	

July 10, 2016

Apollo-11.nw 1087

```

      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		
	PUSH	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	#	PLUS
		CSINEXT2		
	SETLOC	CSIPROG6		
	BANK			
CSINEXT2	DLOAD	VXSC	# (SINLOS)(URA3) = U	B2 PL
	VAD	VSL1		
		18D	#	B1
	PUSH	DOT	#	PL
		RACT3	# (U . RA3) = TEMP1	B1 + B29 = B30
	SL1	PUSH	#	B29 PL
	DSQ	TLOAD	# TEMP1**2	B58
		MPAC		
	PDVL	DOT	#	PL
		RACT3		
		RACT3		
	TLOAD	DCOMP	# RA3 . RA3	
# Page 670		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		



July 10, 2016

Apollo-11.nw 1089

		1DPB28		
		1D		
	BZE			
		ALMXITA		
	DLOAD	SR1		
		DELDV		
	STORE	DELDV		
	BDSU			
		DVPREV		
	STCALL	DELVCSI		
		CSI/B1		
K10RK2	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		

1090 Apollo-11.nw

July 10, 2016

```

      STADR      #
      STOVL      12D      # (URP3 X V).(UVP3 X URP3)=TEMP      PL12D
      DOT        SL1      #      PL06D
      ARCCOS     SIGN      #      PL00D
      SR1        12D      #
      BON        DLOAD      # GAMMA = SIGN(TEMP)ARCOS(UNITV.URP3)      B0 PL02D
      S32.1F2
      FRSTPAS
      OOD      # NOT THE FIRST PASS OF A CYCLE
      DSU        PDDL      # GAMMA-GAMPREV      B1 PL04D
      GAMPREV
      DELVCSI
      DSU        NORM      #
      DVPREV      B7
      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
```

July 10, 2016

Apollo-11.nw 1091

# Page 672

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

July 10, 2016

Apollo-11.nw 1093

SCNDSOL	BON	P32/P72C BOFF S32.1F3A ALMXIT S32.1F3B ALMXIT
	SXA,2	DLOAD CSIALRM ZEROVECS
	CLEAR	SET S32.1F1

# Page 674

		S32.1F2
	CLEAR	CLEAR S32.1F3A S32.1F3B
	STCALL	LOOPCT CSI/B

# Page 675

# \*\*\*\*\* ADVANCE \*\*\*\*\*

#

# SUBROUTINES USED

# PRECSET

# ROTATE

SETLOC	CDHTAG3
BANK	

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

	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	

July 10, 2016

Apollo-11.nw 1095

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
```



July 10, 2016

Apollo-11.nw 1097

# 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**

```

1099  <src/P32-P35-P72-P75.s 1099>≡
      # 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

July 10, 2016

Apollo-11.nw 1101

```
#          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	



July 10, 2016

Apollo-11.nw 1105

		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

# Page 624

# 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.

```

July 10, 2016

Apollo-11.nw 1109

# (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

July 10, 2016

Apollo-11.nw 1111

```

                                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
```

# Page 629

# \*\*\*\*\* 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



July 10, 2016

Apollo-11.nw 1113

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

July 10, 2016

Apollo-11.nw 1115

	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			
		RVSW		
	STOVL	RVEC		
		SN359+		
	STCALL	SNTH	# ALSO Csth	
		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	#	PL041
		RACT1		
		VACT4		
	ABS	DDV		
		02D	# (/RDOTV/)/R1	B38-B29= B7
	SL*	DSU		
		0,1		
		NICKELDP		
	BMN	DLOAD		
		CIRCL		
		P		
	SL2	DSU		
		1DPB2		
	STODL	14D		

July 10, 2016

Apollo-11.nw 1117

		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			
		RVSW		
	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

July 10, 2016

Apollo-11.nw 1119

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



July 10, 2016

Apollo-11.nw 1121

	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

July 10, 2016

Apollo-11.nw 1123

```
# 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 *****
```

July 10, 2016

Apollo-11.nw 1125

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

July 10, 2016

Apollo-11.nw 1127

# 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

```



July 10, 2016

Apollo-11.nw 1129

```
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**

```

1130  <src/P34-35-P74-75.s 1130>≡
      # 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 INITITATION (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 INITITATION (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

```

July 10, 2016

Apollo-11.nw 1133

```
#          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	

July 10, 2016

Apollo-11.nw 1135

	CADR	GOFLASH	
	TC	GOTPOOH	
	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	
		RVS	
# 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

```

July 10, 2016

Apollo-11.nw 1139

```

                                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	

July 10, 2016

Apollo-11.nw 1141

```

                                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	

July 10, 2016

Apollo-11.nw 1143

```

                                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

```



July 10, 2016

Apollo-11.nw 1145

```

      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    VXV
              DELVLVC # NEW DEL V TPI
              OD
      VSL1
      STORE    DELVEET3 # SAVE FOR TRANSFORM
      VAD      PDVL
              VACT3
              RACT3 # NEW V REQ
```

1146 Apollo-11.nw

July 10, 2016

	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	

July 10, 2016

Apollo-11.nw 1147

	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

```

July 10, 2016

Apollo-11.nw 1149

```
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
```

July 10, 2016

Apollo-11.nw 1151

```

                                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

```



July 10, 2016

Apollo-11.nw 1153

```
#      (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)

```

July 10, 2016

Apollo-11.nw 1155

```

      VXV      VCOMP      # -N = UNIT(R2VEC) X UNIT(R1VEC)
                      2D
      PUSH
      LXA,1      DLOAD
                      RTX1
                      18D
      BMN      INCR,1
# Page 489
                      +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
          BHIZ  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

```

July 10, 2016

Apollo-11.nw 1157

```

      VAD
      STODL  R2VEC
            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  MIDDGIM
#       BANK
#
#       COUNT*  $$/MIDG
#
# HALFREV      2DEC      1 B-1
#
# MIDGIM        BON      BOFF
#                  AVFLAG
#                  MIDGIM1
#                  COMPUTER

```

July 10, 2016

Apollo-11.nw 1159

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



July 10, 2016

Apollo-11.nw 1161

```
#      (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
```

```
# 2D = APOCENTER RADIUS
```

```
B29 OR B27
```

	DSU	PDDL XXXALT OD	# 4D = APOGEE ALTITUDE	B29 OR B27
	PUSH	DSU XXXALT	# 6D = PERICENTER RADIUS	B29 OR B27
	PUSH	GOTO NORMEX	# 8D = PERIGEE ALTITUDE	B29 OR B27
# Page 497				
# SETRAD				
SETRAD	DLOAD	PUSH RPAD		
	SXA,1	INCR,2 X2 2D		
	SLOAD	BHIZ X2 SETRADX		
	VLOAD	ABVAL RLS		
	PDDL			
SETRADX	DLOAD	RVQ		
# Page 498				
# PRECSET				
PRECSET	STQ			
		NORMEX		
	STCALL	TDEC2 LEMPREC		
	CALL			
		LEMSTORE		
	DLOAD			
		TDEC2		
	STCALL	TDEC1 CSMPREC		
	CALL			
		CSMSTORE		
	GOTO			
		NORMEX		
LEMSTORE	VLOAD	BOFF RATT AVFLAG PASSIVE		
ACTIVE	STOVL	RACT3 VATT		
	STORE	VACT3		
	RVQ			

July 10, 2016

Apollo-11.nw 1163

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

```

July 10, 2016

Apollo-11.nw 1165

```

                                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
          GOTO    THISPREC    # FOR LEM DISPLAY
                   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      -      00D
                                RATT      #                        A
                                PDDL
                                TAT        # SAVE TIME IN LOCATION 30D FOR REDISPLAY
                                STOVL     30D      #
                                PUSH      # POSITION VECTOR      R      IN 06D AND 12D
                                BVSU     PDVL      #
                                RPASS36   # LINE OF SIGHT VECTOR R - R 12D
                                DOT       SL1      # P      A
                                STOVL     RANGE    # Y = U . R
                                OOD        # A
                                DOT       SL1
                                UNP36     # . - -
                                STOVL     RRATE    # Y = U . V
                                O6D        # - A
                                UNIT      PUSH     # U = UNIT ( R )      18D
                                VXV       VXV      # RA      A
                                OOD        #
                                18D        # (U X V ) X U = U
                                VSL2     UNIT      # RA      A      RA      A
                                UNIT      GOTO
                                R36B
                                SETLOC  R36CM1
# Page 504
                                BANK
R36B      STOVL     OOD      # UNIT HORIZONTAL IN FORWARD DIR. 00D
                                18D
                                DOT       VXSC    # -
                                12D          # U
                                VSL2     # L
                                BVSU     UNIT
                                UNIT

```

July 10, 2016

Apollo-11.nw 1167

```

      PUSH    DOT      # LOS PROJECTED INTO HORIZONTAL 12D
                      # 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
                      3OD
                      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**

```

1168  <src/P37-P70.s 1168>≡
      # 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
      #

```



July 10, 2016

Apollo-11.nw 1169

```
# 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. VECTO
#      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 STATI
#      NORMSW         LAMBERT AIMPT ROTATION SWITCH STATI
#      ECSTEER        CROSS PRODUCT STEERING CONSTANT SP
#      RTARG          CONICALLY INTEGRATED REENTRY POSITION VECTOR VECTO
#      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

```

July 10, 2016

Apollo-11.nw 1171

# 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     INTPRET
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

```

July 10, 2016

Apollo-11.nw 1173

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

```

July 10, 2016

Apollo-11.nw 1175

```

                                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 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/			



July 10, 2016

Apollo-11.nw 1177

```

      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
      RVSU
      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

```

July 10, 2016

Apollo-11.nw 1179

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
#     V(T2)/      FINAL VELOCITY VECTOR
#     T2          FINAL TIME
#     V2(T1)/     POST IMPULSE INITIAL VELOCITY VECTOR
#     V(T1)/      INITIAL VELOCITY VECTOR
#     UR1/        UNIT INITIAL VECTOR
#     UH/         UNIT HORIZONTAL VECTOR
#
# OUTPUT
#     VPRED       VELOCITY MAGNITUDE AT 400,000 FT. ENTRY ALTITUDE
#     T3TOT4      TRANSIT TIME TO 400,000 FT. ENTRY ALTITUDE
#     GAMMAEI     FLIGHT PATH ANGLE AT 400,000 FT. ENTRY ALTITUDE
#     DELVLVC     INITIAL VELOCITY CHANGE VECTOR IN LOCAL VERTICAL COORD.
#     LAT(SPL)    LATITUDE OF THE LANDING SITE
#     LNG(SPL)    LONGITUDE OF THE LANDING SITE
#
RTEDISP      STQ      VLOAD      # DISPLAY
              SPRTEX
              V(T2)/
              UNIT    PDDL
              36D
```

July 10, 2016

Apollo-11.nw 1181

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
                   AUGKUGL      # 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          #
                   V(T2)/
          PDVL     VXV
          VXV      UNIT          # UH3=UNIT(UR3 X UV3 X UR3)          PL10D
          VXSC     PDVL
                   LNG(SPL)
          VXSC     VAD          #
                   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

```

Apollo-11.nw 1183

```

# 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 IM
#
# 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      VECTOR
#      UH/         UNIT HORIZONTAL VECTOR      VECTOR
#      BETA1       1+X(T2)**2      DP
#      PHI2        PERIGEE OR APOGEE INDICATOR      DP
#
# Page 908
#
# OUTPUT
#      V2(T1)/      POST IMPULSE INITIAL VELOCITY VECTOR      VECTOR
#      R(T2)/       FINAL POSITION VECTOR      VECTOR
#      V(T2)/       FINAL VELOCITY VECTOR      VECTOR
#      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

```

July 10, 2016

Apollo-11.nw 1187

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		

July 10, 2016

Apollo-11.nw 1189

```
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   PDDL          # BETA14=.6          B0      PL04D
        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

```

July 10, 2016

Apollo-11.nw 1191

```

                                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
```

```
VECT
```

```
# V(T2)/      FINAL VELOCITY VECTOR
```

```
VECT
```

```
# T2          FINAL TIME
```

```
DP
```

```
#
```

```
# RTENCK3 (PRECISION INTEGRATION)
```

```
#
```

```
# CALLING SEQUENCE
```

```
# L      CALL
# L+1          RTENCK3
```

```
#
```

```
# ERASABLE INITIALIZATION REQUIRED
```



July 10, 2016

Apollo-11.nw 1193

```
#      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

July 10, 2016

Apollo-11.nw 1195

```
#          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          # BETA1*LAMBDA = BETA5
DMP         SL*
                        00D
                        0 -7,1
SL*         DSU

```

PLOOR

PL021

July 10, 2016

Apollo-11.nw 1197

# 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

```

July 10, 2016

Apollo-11.nw 1199

```

                                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                                PL16D
                                STADR
                                STORE 10D      # X(T1)LIM = X(T1)MIN
                                GOTO
                                V2T145
V2T135                          DLOAD DCOMP      #
                                STADR                                PL16D
                                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                                PL18D
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                                PL18D
                                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

```



July 10, 2016

Apollo-11.nw 1201

```
DCOMP
V2T179 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),,

```

July 10, 2016

Apollo-11.nw 1203

#	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	PL20
		X(T1)			
		DV			
	PDDL	DAD	# DV=DV,	B7/B5	PL22
		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	#		PL18
		GAMDV50			
# TIME CRITICAL MODE					
GAMDV35	DLOAD	DSU			
		RTEDVD			
		DV			
	PDDL	PUSH	# DVD-DV=DVERR	B7/B5	PL22
GAMDV40	DLOAD	ABS	# DV,		PL24
		20D			
	DSU	BMN			
		EPC10RTE			
		GAMDVX			
GAMDV45	BOVB	DLOAD	# ASSURE OVFIN IS 0		
	BDSU	NORM			
		DV			
		X2			
	PDDL		# DV-DV,	B7/B5-N2	PL22

July 10, 2016

Apollo-11.nw 1205

```

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

```

July 10, 2016

Apollo-11.nw 1207

```
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

```



July 10, 2016

Apollo-11.nw 1209

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

```

1211 <src/P40-P47.s 1211>≡
# 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	

July 10, 2016

Apollo-11.nw 1213

	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	P40CKLS2	# (4.1 PROTECTION)
	TC	BANKCALL	
	CADR	GOPERF1	
	TCF	POST41	# V34
	TCF	TST,TRIM	# V33
TRIMONLY	CS	BIT1	# SET MRKRTEMP FOR GIMBAL TRIM (-1)
+1	TS	MRKRTEMP	# ENTRY FROM TST,TRIM
	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

July 10, 2016

Apollo-11.nw 1215

```
P4ORCS      EXTEND      # V99N40 ENTERS HERE ON A P40 BYPASS SPS
              DCA        ACADN85
              DXCH       AVEGEXIT
              CAF        2SECS      # WAIT FOR CALCN85 VIA AVEGEXIT
              TC         BANKCALL

# Page 687

              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	



July 10, 2016

Apollo-11.nw 1217

```

TCF      TASKOVER

P41/DSP   CAF      V06N85B      # SET UP FOR NONFLASH V 06 N85 BY CLOCKJOB
          TS        NVWORD1

          TC        INTPRET

# Page 689
          CALL      # COMPUTE
                   P40CNV85      #      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
          CALCN85
```

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	

July 10, 2016

Apollo-11.nw 1219

TC TASKOVER

ACADN83 EBANK= TIG  
2CADR CALCN83

SERVCADR EBANK= TIG  
2CADR SERVEXIT

ACADN85 EBANK= DAPDATR1  
2CADR CALCN85

# Page 691

# PROGRAM DESCRIPTION \*\* P47CSM \*\*

COUNT 24/P47

P47CSM EBANK= TIG  
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

TIGON EBANK= P40TMP  
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

CALCN83 EBANK= TIG  
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

```

July 10, 2016

Apollo-11.nw 1221

	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	NEUPHASE	# 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

	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	

July 10, 2016

Apollo-11.nw 1223

# 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=

```



July 10, 2016

Apollo-11.nw 1225

	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	NEWPHASE		
	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

July 10, 2016

Apollo-11.nw 1227

```
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

```

July 10, 2016

Apollo-11.nw 1229

```
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
```

1230 Apollo-11.nw

July 10, 2016

	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 CLOKTASK
# Page 704			
DYNDISP	TC	INTPRET	# UPDATE N85 FOR A DYNAMIC V06N85 IN P41.
	CALL		# PRIOR TO BLANKING AND AVEG (V16N85)

July 10, 2016

Apollo-11.nw 1231

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



July 10, 2016

Apollo-11.nw 1233

```

CAF      BIT1
TC       TWIDDLE
ADRES    V97TTASK
TCF      ENDOFJOB      # KEEP EBANK6 FOR MASSES, SPSOFF, ETC.

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)

July 10, 2016

Apollo-11.nw 1235

```
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

```

July 10, 2016

Apollo-11.nw 1237

```
#          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
          VLOAD     ABVAL
          DELVSIN
          STORE     DELVSAB
          SETPD     VLOAD
          0
          VTIG
          STORE     VINIT
          VXV       UNIT
          RTIG
          STOVL     UT
          RTIG
          STORE     RINIT
          VSQ       PDDL
          36D
          DMPR      DDV
          THETACON
          DMP        DMP
          DELVSAB
          WEIGHT/G
          DDV

          F
          STOVL     14D
          DELVSIN

          DOT       VXSC
          UT
          UT
```

# LAMBERT  
# EXTERNAL DELTA-V  
# COMPUTE FOR P30/P40 INTERFACE  
#       THUS PERMITTING MODULE-ONLY CHANGE  
# UP IN UT

# Page 711

1238 Apollo-11.nw

July 10, 2016

```

                                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
```

July 10, 2016

Apollo-11.nw 1239

	STCALL	DELLT4 AGAIN
	VLOAD	PUSH DELVEET3
	STORE	VGITG
	SET	CALL AVFLAG MIDGIM
	SETPD	GOTO 0 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 QTEMP1 THISPREC
	SXA,2	SXA,1 RTX2 RTX1
	VLOAD	
		RATT
	STORE	RTIG
	STOVL	RINIT VATT
	STORE	VTIG
	STORE	VINIT
	SETPD	SLOAD 0 HI6ZEROS
	PDDL	BON EP4(45)H NORMSW +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

```

July 10, 2016

Apollo-11.nw 1243

# 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	
	STORE	XSCREF	
	VXV	UNIT	
		RTIG	
	STCALL	6D	
		TSTRXUT	
	STORE	YSCREF	
	VXV	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			

July 10, 2016

Apollo-11.nw 1245

```
#
#      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

```

July 10, 2016

Apollo-11.nw 1247

# 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



July 10, 2016

Apollo-11.nw 1249

-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

```

July 10, 2016

Apollo-11.nw 1251

```

                                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.
#

```

July 10, 2016

Apollo-11.nw 1253

```
# 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

```

July 10, 2016

Apollo-11.nw 1255

```
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

```



July 10, 2016

Apollo-11.nw 1257

	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	TVCPITCH	
	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	

July 10, 2016

Apollo-11.nw 1259

```
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

July 10, 2016

Apollo-11.nw 1261

```
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
RCS DAPUP 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

July 10, 2016

Apollo-11.nw 1263

```

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

```

1264  <src/P51-P53.s 1264>≡
# 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

```



July 10, 2016

Apollo-11.nw 1265

```
#
# 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

```

July 10, 2016

Apollo-11.nw 1267

	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	NEGO	
	DXCH	DSPTM1	
	CAF	V06N34	
	TC	BANKCALL	
	CADR	GOFFLASH	
	TC	GOTOP00H	

```

TC      +2
TC      -5
EXTEND
DCA     DSPTEM1
EXTEND
BZF     +2
TCF     +4

EXTEND
DCA     TIME2
DXCH    DSPTEM1
CA      OPTION2
MASK    BIT2
CCS     A

# Page 740
TCF     +6          # NOM
TC      INTERPRET   # LS
CALL
P52LS
GOTO
P52D
TC      INTERPRET
DLOAD
DSPTEM1
CALL
S52.3          # COMPUTE NOMINAL IMU
P52D        CALL    # ORIENTATION
S52.2          # READ VEHICLE ATTITUDE AND
              # COMPUTE GIMBAL ANGLES
EXIT
CAF      VB06N22
TC      BANKCALL    # DISPLAY GIMBAL ANGLES
CADR     GOFLASH
TC      GOTOPPOOH
TC      COARSTYP
P52J      TC        # RECYCLE: VEHICLE HAS BEEN MANEUVERED
GOTO
P52D
TC      INTERPRET
CALL
CAL53A          # DO COARSE ALIGN
SET      EXIT      # ROUTINE
REFSMFLG
P52C      TC      PHASCHNG
OCT      04024
CAF      ALRM15
TC      BANKCALL

```

July 10, 2016

Apollo-11.nw 1269

	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.

```



July 10, 2016

Apollo-11.nw 1273

```
#
# 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	

July 10, 2016

Apollo-11.nw 1275

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

July 10, 2016

Apollo-11.nw 1277

```
#           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

July 10, 2016

Apollo-11.nw 1279

	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

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



July 10, 2016

Apollo-11.nw 1281

```
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

```

July 10, 2016

Apollo-11.nw 1283

```

                                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

```

July 10, 2016

Apollo-11.nw 1285

```
R51ST      R51ST +1
# Page 757  STORE  STARS AV1      # 1ST STAR

EXIT
CS          MODREG      # IS THIS P54
AD          OCT66
EXTEND
BZF         R51B        # YES
TC          INTPRET
CALL
R51A      R52          # AOP WILL MAKE CALLS TO SIGHTING
CALL      # 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

```

July 10, 2016

Apollo-11.nw 1287

```
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

CHKSA      AXC,1                                # SET X1 TO STORE EPHEMERIS DATA
                                STARAD

CHKS      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

                                CHKS      # 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

```



July 10, 2016

Apollo-11.nw 1289

# 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

```

July 10, 2016

Apollo-11.nw 1291

```
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

#

# 
$$\begin{matrix} - & T & T & T & - \\ V \end{matrix} = Q \begin{matrix} *Q & *Q & *Q \\ 1 & 2 & 3 \end{matrix} \begin{matrix} *V \\ \\ \end{matrix} \begin{matrix} \\ \\ \end{matrix} \text{NB} \quad \text{WHERE}$$

#

# 
$$\begin{pmatrix} \cos(IG) & 0 & -\sin(IG) \end{pmatrix}$$

#

$$\begin{pmatrix} \end{pmatrix}$$

THE C

```

#      Q  = (   0       1       0   ), IG= INNER GIMBAL ANGLE      THE CDU COUNTER
#      1  (                                     )      ROT AND CDULOGI
#      ( 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) )
#
#      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
#
#            $\bar{X} = U \begin{matrix} \bar{U} \\ B1 \end{matrix} + V \begin{matrix} \bar{V} \\ A \end{matrix} + W \begin{matrix} \bar{W} \\ B1 \end{matrix} + A \begin{matrix} \bar{A} \\ B1 \end{matrix}$ 
#
#            $\bar{Y} = U \begin{matrix} \bar{U} \\ B2 \end{matrix} + V \begin{matrix} \bar{V} \\ A \end{matrix} + W \begin{matrix} \bar{W} \\ B2 \end{matrix} + A \begin{matrix} \bar{A} \\ B2 \end{matrix}$  (REFSMMAT)
#
#            $\bar{Z} = U \begin{matrix} \bar{U} \\ B3 \end{matrix} + V \begin{matrix} \bar{V} \\ A \end{matrix} + W \begin{matrix} \bar{W} \\ B3 \end{matrix} + A \begin{matrix} \bar{A} \\ B3 \end{matrix}$ 
#
# 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
#

```

July 10, 2016

Apollo-11.nw 1295

```
#      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      GOTOPOOH
P51A     TC      BANKCALL
          CADR    R02ZERO

P51AA    CAF     PRFMSTAQ
          TC      BANKCALL
          CADR    GOPERF1
          TC      GOTOPOOH      # 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



July 10, 2016

Apollo-11.nw 1297

	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

```

July 10, 2016

Apollo-11.nw 1299

```

      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

```

July 10, 2016

Apollo-11.nw 1301

	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
                                AXC,2
                                XSMD
                                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
```

July 10, 2016

Apollo-11.nw 1303

```
# 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



July 10, 2016

Apollo-11.nw 1305

STAR52	SSP	COM52 LXA,1 S1 0 STARIND	
	TIX,1	ST52ST	
	VLOAD	GOTO STARSAV2	
# Page 777			
ST52ST	VLOAD	COM52 STARSAV1	
COM52	MXV	UNIT REFSMMAT	
	STORE	STAR	
	SETPD	CALL 0 CDUTRIG	# COMPUTES SINES AND COSINES FOR CALCSXA
	CALL		# NOW EXPECT TO SEE THE CDU ANGLES.
	BOFF	CALCSXA EXIT CULTFLAG TRUN38	
TRUN38	TC	SR52E1	
	DLOAD	DSU PAC 38TRDEG	
	BPL	DLOAD SR52E22 PAC	
	DSU	BPL 20DEGSMN 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

```

July 10, 2016

Apollo-11.nw 1307

```

      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
```

July 10, 2016

Apollo-11.nw 1309

```
#      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	

July 10, 2016

Apollo-11.nw 1311

	STOVL	VEARTH	
		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	

1312     Apollo-11.nw

July 10, 2016

```

                                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

1313

*<src/P61-P67.s 1313>*≡

```
# 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

```

July 10, 2016

Apollo-11.nw 1315

```
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

```

July 10, 2016

Apollo-11.nw 1317

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	

1318 Apollo-11.nw

July 10, 2016

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: WAKEUP
# WILL BE OMITTED.
# DISABLE GRP 4, GO TO ENDOFJOB.
# (I.E., CONTINUE IF CMDAPMOD = -1, 0)
```

TC P63

```
# PUT JOB TO SLEEP UNTIL VEHICLE MAN
# REDUCED ALFA TO +/-45 DEG. CONSIDER
# 65 DEG (25 DEG IF ALFA NEG) TO ALFA
# OCCUR AT 3 DEG/SEC, AND TERMINATE M
# TIME.
```

CA	PRI013
TC	NOVAC
EBANK=	AOG
2CADR	P63

```
# TASK WAKEP62 IS CALLED FROM ENTRY 1
```

TC TASKOVER

```
# EACH 2 SEC, CALCULATE GIMBAL ANGLES
# CONDITIONS THAT WILL HOLD IF REORIENTED
# AT PRESENT RN, VN.  COME HERE FROM
```

July 10, 2016

Apollo-11.nw 1319

```
# 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
```

1320 Apollo-11.nw

July 10, 2016

```

                                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
```



July 10, 2016

Apollo-11.nw 1321

```

CA      V06N74      # ROLLC      VI      D
# XXX.XX DEG      XXXXX. FPS      XXX.XX G
TS      ENTRYVN      # 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 T
# 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
          GOTOADDR      # 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
```

```

          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

```

July 10, 2016

Apollo-11.nw 1323

	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	GOFLASH		
	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 DELAY
#      AS SHORT AS CAN BE MADE, BUT IS ARBITRARY SINCE IT DEPENDS ON THE AGE OF THE
#
# CALLING SEQUENCE:      CALL
#                          S61.1
#
#                          C(MPAC) UNSPECIFIED
#                          PUSHLOC UNSPECIFIED
#
# SUBROUTINES CALLED:  LOADTIME, CSMPREC, TPAGTREE,
#                      WAITLIST, JOBSLEEP, JOBWAKE, PREREAD, ALARM, GODSPR, BANKCALL
#
# 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

July 10, 2016

Apollo-11.nw 1325

```
#      PIPTIME  (-28) CS      TIME OF PIPA UPDATE      LEFT BY READAC
#      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	

July 10, 2016

Apollo-11.nw 1327

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



July 10, 2016

Apollo-11.nw 1329

```
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 SDELF/2, CDELF/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    DAD          # 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

```

July 10, 2016

Apollo-11.nw 1331

	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 IMP
#
# 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:

```

July 10, 2016

Apollo-11.nw 1333

```
#          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)
# X1 = -NR
# RTERM M          E: (-29+NR)      M: (-29+NR)

VGAMCALC         DLOAD  DMP
# RMAG M          E: (-29+NR)      M: (-29+NR)
# RTERM M          E: (-29+NR)      M: (-29+NR)
PDDL            DSU      # RMAG RTERM M          E: (-58+2NR)      M: (-58+2NR)
# RMAG M          E: (-29+NR)      M: (-29+NR)
# RTERM M          E: (-29+NR)      M: (-29+NR)
SL*            DDV      # 2(RN-RTERM)          E: (-30+NR)      M: (-30+NR)
# (-8+NR)
# PUSH UP PRODUCT.

```

July 10, 2016

Apollo-11.nw 1335

```

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) )
#                      2
#      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)
#              CDEL/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(DEL/2) 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, CDEL/2

BANK          27
SETLOC        P60S5
BANK
TFF/TRIG      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 SDEL/2.
                HIDPHALF
STORE         CDEL/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

```



July 10, 2016

Apollo-11.nw 1337

```

                                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
#
#          ROLL C      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
#                   ROLL C
# COS             VXSC
#                   UYA/2          #                               REF COORDS
# PDDL            SIN             # PUSH VECTOR INTO PDL4...9
#                   ROLL C
# VXSC            VAD
#                   UZA/2          #                               REF COORDS
```

July 10, 2016

Apollo-11.nw 1339

```
# 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**

```

1340  <src/P70-P71.s 1340>≡
      # 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

```

July 10, 2016

Apollo-11.nw 1341

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	

July 10, 2016

Apollo-11.nw 1343

```
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 XOVINHIB
TS      DAPBOOLS

CS      FLAGWRD5      # SET ENGONFLG.
MASK    ENGONBIT
ADS     FLAGWRD5

CS      PRIO30        # 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

EBANK=   DVCNTR
SVEXITAD 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

```



July 10, 2016

Apollo-11.nw 1345

# 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
                                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        X RANGE    # TO LOOK.
UPTHROT     SET        EXIT
                                FLVR
TC          UPFLAG      # SET ROTFLAG
ADRES      ROTFLAG

```

July 10, 2016

Apollo-11.nw 1347

	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

TG01      =      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
```

July 10, 2016

Apollo-11.nw 1349

# \*\*\*\*\*

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**1350  $\langle src/P76.s \ 1350 \rangle \equiv$ 

```

# 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

```



July 10, 2016

Apollo-11.nw 1353

```

                                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`.

1354 *<src/P-AXIS-RCS-AUTOPILOT.s 1354>≡*

```
# 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 ***
```

July 10, 2016

Apollo-11.nw 1355

```

      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 = 1JACCQ(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

```

July 10, 2016

Apollo-11.nw 1357

```
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
```

July 10, 2016

Apollo-11.nw 1359

```
# 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		



July 10, 2016

Apollo-11.nw 1361

```
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)

```

July 10, 2016

Apollo-11.nw 1363

```
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.

```

July 10, 2016

Apollo-11.nw 1365

```

LXCH    RCSFLAGS
EXTEND
RXOR     1
TS       RCSFLAGS
MASK     BIT1
AD       FOUR
ADS      ROTINDEX
TCF      TRYUORV
CA       POLYTEMP
TSNEXTTP 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

```

July 10, 2016

Apollo-11.nw 1367

```
#
# 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	



July 10, 2016

Apollo-11.nw 1369

```
# 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.

```

July 10, 2016

Apollo-11.nw 1371

```

                                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.

July 10, 2016

Apollo-11.nw 1373

```

      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	

July 10, 2016

Apollo-11.nw 1375

```
# 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

```

1377 <src/PHASE-TABLE-MAINTENANCE.s 1377>≡
# 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

```

July 10, 2016

Apollo-11.nw 1379

```
# 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

```

July 10, 2016

Apollo-11.nw 1381

# 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

```

July 10, 2016

Apollo-11.nw 1383

	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	



July 10, 2016

Apollo-11.nw 1385

```

                                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

```

1386  <src/PINBALL-GAME-BUTTONS-AND-LIGHTS.s 1386>≡
# 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.
#

```

```
# 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
#DSPTEM1	ERASE	+2	# BUFFER STORAGE AREA 1 (MOSTLY FOR TIME)
#DSPTEM2	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,

```



July 10, 2016

Apollo-11.nw 1393

```
#      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

# Page 315

# 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

July 10, 2016

Apollo-11.nw 1395

	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	

July 10, 2016

Apollo-11.nw 1397

	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

```

July 10, 2016

Apollo-11.nw 1399

# 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
SIGNTST	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.



July 10, 2016

Apollo-11.nw 1401

```
#
# 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        CCSHOLE
            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

July 10, 2016

Apollo-11.nw 1403

# 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

July 10, 2016

Apollo-11.nw 1405

```

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

July 10, 2016

Apollo-11.nw 1407

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	



July 10, 2016

Apollo-11.nw 1409

```

      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 (RUTMXTAB) 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

```

```

DSPABC      CS      TWO
            TC      COMPTTEST
            INDEX   NOUNADD
            CS      2
            XCH     BUF      +2

```

July 10, 2016

Apollo-11.nw 1411

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	

July 10, 2016

Apollo-11.nw 1413

```
# 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
```

```

# 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
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

```

July 10, 2016

Apollo-11.nw 1415

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



July 10, 2016

Apollo-11.nw 1417

	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	

# Page 337

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	RDLONOR	
	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	

# Page 338

	CAF	ZERO	
	TS	MPAC	+2
	TC	TEM4	
RDLONOR	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	

July 10, 2016

Apollo-11.nw 1419

	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	

July 10, 2016

Apollo-11.nw 1421

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

```

July 10, 2016

Apollo-11.nw 1423

```
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	



July 10, 2016

Apollo-11.nw 1425

	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      # (BUT IT HAS BEEN DECREMENTED BY CCS)
TC      ALMCYCLE  # MUST MATCH 6 FOR 3COMP, 5 FOR 2COMP.
GOQ     TC      Q      # ALARM AND RECYCLE.
                        # 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

```

July 10, 2016

Apollo-11.nw 1427

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	

July 10, 2016

Apollo-11.nw 1429

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

```

July 10, 2016

Apollo-11.nw 1431

```
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 OVFIN
	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	



July 10, 2016

Apollo-11.nw 1433

```
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 HRCON
TS MPAC
CAF HRCON +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).			

July 10, 2016

Apollo-11.nw 1435

# 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.

```

July 10, 2016

Apollo-11.nw 1437

```
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

```

July 10, 2016

Apollo-11.nw 1439

```
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.			



July 10, 2016

Apollo-11.nw 1441

```
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

July 10, 2016

Apollo-11.nw 1443

# 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 CCSHOLE

AD ONE

TS DSMAG

INDEX COUNT

MASK DSMSK

EXTEND

SU CODE

EXTEND

BZF DSLV

# SAME

DFRNT

INDEX COUNT

CS DSMSK

MASK DSMAG

# 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

```

July 10, 2016

Apollo-11.nw 1445

```

          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

```

July 10, 2016

Apollo-11.nw 1447

```
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

```



July 10, 2016

Apollo-11.nw 1449

	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	

July 10, 2016

Apollo-11.nw 1451

```
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.

July 10, 2016

Apollo-11.nw 1453

```
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.
#          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      POOD00
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

```

July 10, 2016

Apollo-11.nw 1455

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

```



July 10, 2016

Apollo-11.nw 1457

```
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	

July 10, 2016

Apollo-11.nw 1459

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

```

July 10, 2016

Apollo-11.nw 1461

```
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.

```

July 10, 2016

Apollo-11.nw 1463

```

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, RECALST.
#
# 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



July 10, 2016

Apollo-11.nw 1465

	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 # ACTION) UNTIL TSTLTS3 TO INSURE THAT # 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, # V/N FLASH, OPERATOR ERROR.
TSTCON2	OCT	40650	# DSPTAB+11D BITS 4,6,8,9, # NO ATT, GIMBAL LOCK, TRACKER, PROG ALM.
TSTCON3	OCT	00115	# CHAN 11 BITS 1, 3, 4, 7. # 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,

July 10, 2016

Apollo-11.nw 1467

```

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
```

1468     Apollo-11.nw

July 10, 2016

```

                                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

1469

*<src/PINBALL-NOUN-TABLES.s 1469>≡*

```
# 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

```

July 10, 2016

Apollo-11.nw 1471

```
#      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

```



July 10, 2016

Apollo-11.nw 1473

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)

OCT 24006

# 41 TARGET AZIMUTH  
 # ELEVATION

OCT 24011

# 42 APOGEE  
 # PERIGEE  
 # DELTA V (REQUIRED)

OCT 64014

# 43 LATITUDE  
 # LONGITUDE  
 # ALTITUDE

OCT 64017

# 44 APOGEE  
 # PERIGEE  
 # TFF

OCT 02022

# 45 MARKS (VHF - OPTIC)  
 # TTI OF NEXT BURN

OCT 22025

# MGA  
 # 46 AUTOPILOT CONFIGURATION

OCT 22030

# 47 THIS VEHICLE WEIGHT  
 # OTHER VEHICLE WEIGHT

OCT 24033

# 48 PITCH TRIM  
 # YAW TRIM

OCT 64036

# 49 DELTA R  
 # DELTA V  
 # VHF OR OPTICS CODE

OCT 22041

# 50 SPLASH ERROR  
 # PERIGEE  
 # TFF

OCT 00044

# 51 S-BAND ANTENNA PITCH  
 # YAW

OCT 24047

# 52 CENTRAL ANGLE OF ACTIVE VEHICLE

# 53 RANGE  
 # RANGE RATE  
 # PHI

# Page 273

OCT 24052

# 54 RANGE

July 10, 2016

Apollo-11.nw 1475

		#	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

# Page 274

		#	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
	02215	# 88	HALF UNIT SUN OR PLANET VECTOR
	OCT	# 89	LANDMARK
	24220	#	LATITUDE
	OCT	#	LONGITUDE/2
	24223	#	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
	OCT	# 95	PREFERRED ATTITUDE ICDU ANGLES
	04245	# 96	+X-AXIS ATTITUDE ICDU ANGLES
	OCT	# 97	SYSTEM TEST INPUTS
	04250		
	04253		

July 10, 2016

Apollo-11.nw 1477

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

# Page 276

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)

July 10, 2016

Apollo-11.nw 1479

	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		



July 10, 2016

Apollo-11.nw 1481

	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

1482 Apollo-11.nw

July 10, 2016

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	40	MIN/SEC	M/S
	ECADR	40	VEL3	DP3
	ECADR	40	VEL3	DP3
	ECADR	41	CDU DEG	CDU
	ECADR	41	ELEV DEG	ARTH
	OCT	41	SPARE COMPONENT	
	ECADR	42	POS4	DP3
	ECADR	42	POS4	DP3
	ECADR	42	VEL3	DP3
	ECADR	43	DPDEG(360)	DP4
	ECADR	43	DPDEG(360)	DP4
	ECADR	43	POS4	DP3
	ECADR	44	POS4	DP3
	ECADR	44	POS4	DP3
	ECADR	44	MIN/SEC	M/S
	ECADR	45	2INT	2INT
# Page 280	ECADR	45	MIN/SEC	M/S
	ECADR	45	DPDEG(360)	DP4
	ECADR	46	OCTAL ONLY	OCT
	ECADR	46	OCATAL ONLY	OCT
	OCT	46	SPARE COMPONENT	
	ECADR	47	WEIGHT2	ARTH
	ECADR	47	WEIGHT2	ARTH
	OCT	47	SPARE COMPONENT	
	ECADR	48	TRIM DEG2	ARTH
	ECADR	48	TRIM DEG2	ARTH
	OCT	48	SPARE COMPONENT	
	ECADR	49	POS4	DP3

July 10, 2016

Apollo-11.nw 1483

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	

July 10, 2016

Apollo-11.nw 1485

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	DEVLVC	# 81	VEL3	DP3
ECADR	DEVLVC +2	# 81	VEL3	DP3
ECADR	DEVLVC +4	# 81	VEL3	DP3
ECADR	DEVLVC	# 82	VEL3	DP3
ECADR	DEVLVC +2	# 82	VEL3	DP3
ECADR	DEVLVC +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	DEVLVC	# 86	VEL3	DP3
ECADR	DEVLVC +2	# 86	VEL3	DP3
ECADR	DEVLVC +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

# Page 283

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

July 10, 2016

Apollo-11.nw 1487

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

```

1488  <src/PLANETARY-INERTIAL-ORIENTATION.s 1488>≡
      # 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, EARHL

```



July 10, 2016

Apollo-11.nw 1489

```
#
#       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
           EARTHXL      # 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, EARTH
#
# 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
              EARTH

```

July 10, 2016

Apollo-11.nw 1491

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

```

July 10, 2016

Apollo-11.nw 1493

```

      BVECTR
VXSC  VSU      # PD 8D      BVECTR*COSI B-2
      COSI
VSL1  PDDL     # PD 14D
      504F     # 8-13D=DVECTR=BVECTR*COSI-CVECTR*SINI B-1
COS   VXSC
      DVECTR
PDDL  SIN      # PD 20D  14-19D= DVECTR*COSF B-2
      504F
VXSC  VSU      # PD 14D      AVECTR*SINF B-2
      AVECTR
VSL1
STODL MMATRIX +6 # M1= AVECTR*SINF-DVECTR*COSF B-1
      504F
# Page 1248
SIN   VXSC     # PD 8D
PDDL  COS      # PD 14D  8-13D=DVECTR*SINF B-2
      504F
VXSC  VAD      # PD 8D      AVECTR*COSF B-2
      AVECTR
VSL1  VCOMP
STCALL MMATRIX # M0= -(AVECTR*COSF+DVECTR*SINF) B-1
      EARTHMX
# COMPUTE X=X0+(XDOT)(T+T0)
# 8-9D= X0 (REVS B-0), PUSHLOC SET AT 12D
# 10-11D=XDOT (REVS/CSEC) SCALED B+23 FOR WEARTH,B+28 FOR NODDOT AND BDOT
#          AND B+27 FOR FDOT
# X1=DIFFERENCE IN 23 AND SCALING OF XDOT, =0 FOR WEARTH, 5 FOR NDDOT AND
#          BDOT AND 4 FOR FDOT
# 6-7D=T (CSEC B-28), TIMSUB0= (CSEC B-42 TRIPLE PREC.)
NEWANGLE DLOAD SR      # ENTER PD 12D
          6D
          14D
TAD      TLOAD      # CHANGE MODE TO TP
          TIMSUB0
          MPAC
STODL    TIMSUBM     # T+T0 CSEC B-42
          TIMSUBM +1
DMP
SL*      DAD        # PD 10D      MULT BY XDOT IN 10-11D
          5,1       # PD 8D      ADD X0 IN 8-9D AFTER SHIFTING
          #          SUCH THAT SCALING IS B-0
PUSH     SLOAD      # PD 10D  SAVE PARTIAL (X0+XDOT*T) IN 8-9D
          TIMSUBM
SL       DMP
```

```

          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      +1          # 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

```

July 10, 2016

Apollo-11.nw 1495

```

                    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

```

1497 <src/POWERED-FLIGHT-SUBROUTINES.s 1497>≡
# 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

July 10, 2016

Apollo-11.nw 1499

```
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

```

July 10, 2016

Apollo-11.nw 1501

# 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

```

July 10, 2016

Apollo-11.nw 1503

```
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

```

1505  <src/Q-R-AXIS-RCS-AUTOPILOT.s 1505>≡
# 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 ST
# WILL OVERRIDE THIS SPECIFICATION.  AN ALARM RESULTS WHEN NO POLICY IS AVAILABLE BEC

SENSEGET   CA        BIT7          # INPUT BITS OVERRIDE THE INTERNAL BITS
          EXTEND      # SENSETYP WILL NOT OPPOSE ANYTRANS
          RAND        CHAN31
          EXTEND
          BZF         +XORULGE

# Page 1443

          CA        BIT8
          EXTEND
          RAND        CHAN31
          EXTEND
          BZF         -XTRANS

          CA        ULLAGER
          MASK       DAPBOOLS
          CCS        A
          TCF        +XORULGE

```

July 10, 2016

Apollo-11.nw 1507

	TS	NEXTU	# STORE NULL TRANSLATION POLICIES
	TS	NEXTV	
	CS	DAPBOOLS	# BURNING OR DRIFTING?
	MASK	DRIFTBIT	
	EXTEND		
	BZF	TSSENSE	
	CA	FLGWRD10	# DPS (INCLUDING DOCKED) OR APS?
	MASK	APSFLBIT	
	CCS	A	
	CAF	TWO	# FAVOR +X JETS DURING AN APS BURN.
TSSENSE	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

```

July 10, 2016

Apollo-11.nw 1509

	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

```

July 10, 2016

Apollo-11.nw 1511

```
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
```

# INTERVAL.

# TRANSFORM RATES FROM Q,R TO U,V AXES

# CHECK IF Q COMMAND CHANGE EXCEEDS  
# BREAKOUT LEVEL. IF NOT, CHECK R.

# BREAKOUT LEVEL EXCEEDED. DIRECT RATE.  
# R COMMAND BREAKOUT CHECK.

```

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

```



July 10, 2016

Apollo-11.nw 1513

```

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
```

	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	

July 10, 2016

Apollo-11.nw 1515

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 CON

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

July 10, 2016

Apollo-11.nw 1517

```
#          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
          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

```

July 10, 2016

Apollo-11.nw 1519

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

```



July 10, 2016

Apollo-11.nw 1521

```
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
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

```

July 10, 2016

Apollo-11.nw 1523

	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**1524  $\langle \text{src}/R30.s \text{ 1524} \rangle \equiv$ 

```
# 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
```

July 10, 2016

Apollo-11.nw 1525

```
#          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      OPTIONX # 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.
                  CAF      BIT4      # 80 MS
                  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

```

July 10, 2016

Apollo-11.nw 1527

	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.

July 10, 2016

		X2	
		EARTHPAD	
	GOTO		
		MOONPAD	
THISSHIP	TC	INTPRET	
	CALL		# 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	CLRG0	# 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	MODREG	# ARE WE IN P00
	EXTEND		
	BZF	CANDEL	# YES, DO DELRSPL
SPLRET1	TC	INTPRET	
	RTB	DSU	
		LOADTIME	
		TSTART82	# PRESENT TIME -- TIME V82GOFF1 BEGAN
	STORE	TSTART82	# SAVE IT
	DLOAD	BZE	# SR30.1 SETS -TPER=0 IF HPER L/
		-TPER	# HPERMIN (300 OR 35) KFT.
		TICKTFF	# (-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	# -TPER CORRECTED FOR TIME SINCE V82GOFF1
	EXIT		# BEGAN.



July 10, 2016

Apollo-11.nw 1529

# 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      B5OFF
            TC      B5OFF
            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.

# WITHHOLD 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

```

July 10, 2016

Apollo-11.nw 1531

```

      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

```

July 10, 2016

Apollo-11.nw 1533

```
#          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**

```

1535  <src/R31.s 1535>≡
      # 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
# Page 506				
		VATT		
		VONE		
	DOT		# (VATT-VONE).UNIT(LOS)	PD= 0
	SL1			
	STCALL	RRATE	# RANGE RATE M/CS B-7	
		CDUTRIG	# TO INITIALIZE FOR *NBSM*	
	CALL			



July 10, 2016

Apollo-11.nw 1537

```
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
              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)

July 10, 2016

Apollo-11.nw 1539

```

                                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     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

```

July 10, 2016

Apollo-11.nw 1541

```
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**

```

1542  <src/R60-62.s 1542>≡
      # 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

```

July 10, 2016

Apollo-11.nw 1543

# 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	GOREDO20	# 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	PRIOCHNG	
	TC	TBASE1	



July 10, 2016

Apollo-11.nw 1545

```

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

```

Apollo-11.nw 1547

	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
		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.	

Apollo-11.nw

July 10, 2016

# Page 396

July 10, 2016

Apollo-11.nw 1549

```

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

```

1551  <src/R63.s 1551>≡
      # 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.

```



July 10, 2016

Apollo-11.nw 1553

```
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
```

1554 Apollo-11.nw

July 10, 2016

	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

```

1555  <src/RADAR-LEADIN-ROUTINES.s 1555>≡
      # 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
RADAMP      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.

```

July 10, 2016

Apollo-11.nw 1557

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

```

1558  <src/RCS-CSM-DAP-EXECUTIVE-PROGRAMS.s 1558>≡
      # 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

```

July 10, 2016

Apollo-11.nw 1559

```
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

```

1560  <src/RCS-CSM-DIGITAL-AUTOPILOT.s 1560>≡
      # 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

```



July 10, 2016

Apollo-11.nw 1561

```
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)
```

July 10, 2016

```

FREECHK      CS      IMODES33      # CHECK IMU STATUS
             MASK     BIT6         # BIT6 = 0 IMU OK
             CCS      A             # BIT6 = 1 NO IMU
             TCF      RATEFILT
             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

```

July 10, 2016

Apollo-11.nw 1563

```

                                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
#
#  $ADOT = ADOT -1 + GAIN2 DRHO + KMJ DFT$ 
#
#  $WHERE \ DELRHO = AMGB \ (CDU - CDU) \ -1$ 
#
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

```

July 10, 2016

Apollo-11.nw 1565

```
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
               DOUBLE
               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
KMATRIX        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

July 10, 2016

Apollo-11.nw 1567

```
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 TRANFERRED 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



July 10, 2016

Apollo-11.nw 1569

```
#          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
#          EDRIE           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

July 10, 2016

Apollo-11.nw 1571

```
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 # ATTITUDE HOLD REFERENCE
REDAP	TC CADR	IBNKCALL S41.2	# DECODE DAPDATR1, DAPDATR2 FOR DEADBANDS # RATES, QUADFALLS, QUAD MANAGEMENT
	TC CADR	IBNKCALL S40.14	# DECODE IXX, IAVG, AND CONVERT # TO AUTOPILOT GAINS
ZEROT5	CAF TS CAF INDEX TS CCS TCF TCR	NO.T5VAR SPNDX ZERO SPNDX WBODY SPNDX ZEROT5 ZEROJET	# NO. LOCATIONS TO BE ZEROED MINUS ONE # ZERO ALL NECESSARY ERASABLE REGISTERS
	CS TS	ZERO CHANTEMP	# INITIALIZE MINIMUM IMPULSE CONTROL
	TS	CH31TEMP	# INITIALIZE RHC POSITION MEMORY FOR # MANUAL RATE MODES
	CAF TS	=.24 SLOPE	# INITIALIZE SWITCHING LOGIC SLOPE
	CAF TS	FOUR T5TIME	# PHASE 0 RESETS FOR PHASE 2 INTERRUPT IN # 60 MS. PHASE 2 RESETS FOR PHASE 1 RUPT # IN (80MS - T5TIME(40MS)). THEREFORE # PHASE 1 (RATEFILTER) BEGINS CYCLING 100 # MS FROM NOW AND EVERY 100MS THEREAFTER.
	CAF TS	ELEVEN ATTKALMN	# RESET TO PICK UP KALMAN FILTER TAINS # TO INITIALIZE THE S/C ANGULAR RATES
# Page 1015	CA TS CA TS CA TS CAF TS	CDUX RHO CDUY RHO1 CDUZ RHO2 ZERO T5PHASE	# RESET AUTOPILOT TO BEGIN EXECUTING # PHASE2 OF PROGRAM

July 10, 2016

Apollo-11.nw 1573

```

      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

```

July 10, 2016

Apollo-11.nw 1575

```
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.

```



July 10, 2016

Apollo-11.nw 1577

# 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	ORDER OF
OCT00060	OCT	00060	# PITCH FORCED FIRING MASK	DEFINITION
OCT00300	OCT	00300	# YAW FORCED FIRING MASK	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

```

July 10, 2016

Apollo-11.nw 1579

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	FLAGWRD0	# 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

# Page 1023
          TS       AK1
          CA       T5TEMP
          EXTEND
          MP       AMGB7
          TS       AK2
          CA       WTEMP +1
          EXTEND
          MSU      CDUZ
          TS       T5TEMP
          EXTEND
          MP       AMGB5
          ADS      AK1
          CA       T5TEMP

```

July 10, 2016

Apollo-11.nw 1581

```

      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

```

1582  <src/RCS-FAILURE-MONITOR.s 1582>≡
      # 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

```

July 10, 2016

Apollo-11.nw 1583

```
# 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
```

July 10, 2016

```

      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

```



July 10, 2016

Apollo-11.nw 1585

```

                                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.

## A.92 README.md

1586 `<src/README.md 1586>≡`  
 Apollo-11  
 =====

Original Apollo 11 guidance computer (AGC) source code, in assembly, for Command Modu

### ####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                                           *
#                                                                 *
#                                                                 *
#          THIS PROGRAM IS INTENDED FOR USE IN THE CM AS SPECIFIED *
#          IN REPORT R-577.  THIS PROGRAM WAS PREPARED UNDER DSR  *
```

July 10, 2016

Apollo-11.nw 1587

```
# 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/README.md.

## A.93 REENTRY CONTROL

```

1588  <src/REENTRY-CONTROL.s 1588>≡
      # 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

```

July 10, 2016

Apollo-11.nw 1589

```
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 INTERPRET

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

```

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.

```

July 10, 2016

Apollo-11.nw 1591

```

      STCALL  TIME/RTO      # SAVE TIME BASE OF RTINIT.
                LALOTORV    # C(MPAC) =TIME  (PIPTIME)
UNIT
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.

```

```

# ALL MM COME HERE.
# ENTER WITH PROPER EB FROM CM/POSE(TEST)
# RELVELSW = 96D BIT9
# WANT INERTIAL VEL.  GO GET IT.
# NEW V IS RELATIVE, CONTINUE

TARGETNG    BOFF    VLOAD
              RELVELSW
              GETVEL
              -VREL

              VCOMP    GOTO
              GETUNITV -1

# (VREL) = (V) + KWE UNITR*UNITW
# - VREL WAS LEFT BY CM/POSE

GETVEL      VLOAD    VXSC
              VN
              KVSCALE
              STORE    VEL

# INERTIAL V WANTED
# KVSCALE = (12800 / .3048) / 2VS
# KVSCALE = .81491944
# V/2 VS

GETUNITV    UNIT     STQ
              60GENRET
              STODL    UNITV

```



July 10, 2016

Apollo-11.nw 1593

```

                                34D
STORE    VSQUARE                # VSQ/4

DSU                                # LEQ = VSQUARE - 1
                                # 4 G'S FULL SCALE
STODL    FOURTH
                                # LEQ/4
                                LEQ

                                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.
```

1594 Apollo-11.nw

July 10, 2016

```

                                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

July 10, 2016

Apollo-11.nw 1595

```
NO.05G      CLEAR  GOTO      # THIS WAY FOR DAP. (MAY INTERRUPT)
              .05GSW      # .05GSW = 102D B3
              NOLDCALC     # 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

```

July 10, 2016

Apollo-11.nw 1597

```
# 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)

      DOEQ
SSP     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
```

Apollo-11.nw

July 10, 2016

		V	
		INROLOUT	# GO TO LIMITL/D AFTER SETTING INRLSW.
	BMN	DLOAD	
		INROLOUT	# GO TO LIMITL/D AFTER SETTING INRLSW.
		LAD	
	DCOMP		
	STORE	L/D	
INROLOUT	BOFSET		# SET INRLSW AT END FOR RESTART PROTECTION
			# 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	

July 10, 2016

Apollo-11.nw 1599

```
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      D
      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

```



July 10, 2016

Apollo-11.nw 1601

```

                                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=GAMMAL1 +Q19 (GAMMAL-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

July 10, 2016

Apollo-11.nw 1603

# 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
```

July 10, 2016

```

      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

```

July 10, 2016

Apollo-11.nw 1605

```

                                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
```

July 10, 2016

[illegible]

July 10, 2016

Apollo-11.nw 1607

```
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

          VS1
DSU       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

```



July 10, 2016

Apollo-11.nw 1609

# 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
                                TCDANZIG     # INITIAL PART OF UPCONTROL.
                                # CLEAR OVFFIND, IF ON.

                                DLOAD  SR

```

July 10, 2016

Apollo-11.nw 1611

```
# 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
```

```

                                PREFINAL
                                ROLLC
                                BON  TLOAD
                                .05GSW
                                +2
                                3ZEROS
                                +2    STCALL ROLLC
                                P62.3

# Page 870
# START FINAL PHASE ...

PREFINAL    SSP    RTB
              GOTOADDR
              PREFINAL
              P67

                                SET    SSP
                                EGSW
                                GOTOADDR
                                PREDICT3

PREDICT3    DLOAD  DSU
              V
              VQUIT
              BMN   EXIT
              STEEROFF

              CA    EBENTRY
              TS    EBANK

              CA    TWELVE
BACK        TS    JJ

              CS    V
              INDEX JJ
              AD    VREFER
              CCS   A
              CCS   JJ
              TCF   BACK

# SET ROLLHOLD = ROLLC, IN CASE CMDAPMOD
# = +1 EVER ENTERED.
# IF D > .05G, KEEP PRESENT ROLL COMMAND.
# IF D < .06G, SET ROLL COMMAND = 0.

# SET ROLLC & ROLLHOLD =0.
# (SP ROLLHOLD FOLLOWS DP ROLLC)
# CALC DESIRED GIMBAL ANGLES AT PRESENT
# RN, VN TO YIELD TRIM ATTITUDE.
# AVAILABLE IN CPHI'S FOR N22.

# 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          XRNGERR          DNRNGERR
# XXX.XX DEG     XXXX.X NM        XXXX.XX NM

# IF V-VQUIT NEG, STOP STEERING

# PRECAUTIONARY.

# VREF - V, HIGHEST VREF AT END OF TABLE.
# IF VREF-V POS LOOP BACK
# DECREMENT JJ, JJ CANNOT BE ZERO

```

July 10, 2016

Apollo-11.nw 1613

```
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

TC        INTERPRET      # L/D = LOD + (THETA- PREDANG)/ Y

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          # FALLS SHORT IF NEG, OVERSHOOT IF POS
          TCDANZIG
          FX           # CLEAR OVFINDD IF ON.
          SL          # FX= DRANGE/D L/D = Y
          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        L/D = LAD SIGN(MPAC)
          SIGNMPAC
          LAD
          STORE      L/D      # AND FALL INTO GLIMITER SECTION

GLIMITER  DLOAD      # IF GMAX/2-D POS, GO TO LIMITL/D
          GMAX/2

```

July 10, 2016

Apollo-11.nw 1615

```

      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

```



July 10, 2016

Apollo-11.nw 1617

```

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      INTERPRET
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

July 10, 2016

Apollo-11.nw 1619

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

July 10, 2016

Apollo-11.nw 1621

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 1/24TH	2DEC	.0833333333 B-1	

1622 Apollo-11.nw

July 10, 2016

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	

July 10, 2016

Apollo-11.nw 1623

```
# ... END OF RE-ENTRY CONSTANTS ...
```

This code is written to file `src/REENTRY-CONTROL.s`.

## A.94 RESTARTS ROUTINE

```

1624  <src/RESTARTS-ROUTINE.s 1624>≡
      # 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

```



July 10, 2016

Apollo-11.nw 1625

```
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		

July 10, 2016

Apollo-11.nw 1627

	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

```

July 10, 2016

Apollo-11.nw 1629

```
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	

July 10, 2016

Apollo-11.nw 1631

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

```

1632  <src/RESTART-TABLES.s 1632>≡
      # 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

```



July 10, 2016

Apollo-11.nw 1633

```
# 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	

July 10, 2016

Apollo-11.nw 1635

# 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

July 10, 2016

Apollo-11.nw 1637

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	

July 10, 2016

Apollo-11.nw 1639

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   GEOSTR14

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



July 10, 2016

Apollo-11.nw 1641

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:

July 10, 2016

Apollo-11.nw 1643

```
#
#      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     # SAVE THE GROUP IN A FORM USED FOR
      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
```

1644     Apollo-11.nw

July 10, 2016

```
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

```

1645  <src/RT8-OP-CODES.s 1645>≡
# 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
#              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 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.

July 10, 2016

Apollo-11.nw 1647

```
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
             TS       MPAC          # 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.



July 10, 2016

Apollo-11.nw 1649

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

```

July 10, 2016

Apollo-11.nw 1651

```
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

1653

*<src/RTB-OP-CODES.s 1653>*≡

```
# 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

July 10, 2016

Apollo-11.nw 1655

```
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

```



July 10, 2016

Apollo-11.nw 1657

# 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

```

1659  <src/S-BAND-ANTENNA-FOR-CM.s 1659>≡
# 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
# Page 935
          HIUNITX        # COMPUTE YAW ANGLE = ACOS (URP.UX)
SL1      ACOS           # REVOLUTIONS SCALED BO
PDVL     DOT            # 22D YAWANG
          URP
          HIUNITY        # COMPUTE FOLLOWING: URP.UY

```

July 10, 2016

Apollo-11.nw 1661

```

                                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
NOADJUST 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

```

1662  <src/S-BAND-ANTENNA-FOR-LM.s 1662>≡
# 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

```

July 10, 2016

Apollo-11.nw 1663

```
# 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

```



July 10, 2016

Apollo-11.nw 1665

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		

1666      Apollo-11.nw

July 10, 2016

```

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**

1667

*<src/SERVICER207.s 1667>*≡

```

# 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

```

July 10, 2016

Apollo-11.nw 1669

```
#          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
#
#     AVGEN:            LAST PASS OF AVERAGE G EXITS HERE, BYPASSING SPECIAL ROUTINE
#                       FINAL EXIT IS TO CANV37.                                F AVI
#
# OUTPUT
#
#     DVTOTAL(2)  PIPTIME(2)  XPIPBUFF(2)  YPIPBUFF(2)  ZPIPBUFF(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.

```

July 10, 2016

Apollo-11.nw 1671

```
# 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

```



July 10, 2016

Apollo-11.nw 1673

```
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
```

1674 Apollo-11.nw

July 10, 2016

	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

July 10, 2016

Apollo-11.nw 1675

# 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      XPIPBUFF   # UPDATE X,Y,ZPIPBUFF
               INDEX    RUPTREG1
               TS       XOLDBUFF   # AND X,Y,ZOLDBUFF
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

```

July 10, 2016

Apollo-11.nw 1677

	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, # FOR 503-FULL CSM/LEM....DELV SC.AT # 5.85 CM/SEC.

July 10, 2016

Apollo-11.nw 1679

```
-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

```



July 10, 2016

Apollo-11.nw 1681

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	

# 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)

```

CALCGRV	UNIT	PUSH	# ENTER WITH RN IN MPAC
	STORE	UNITR	
	LXC,1	SLOAD	
		RTX2	
		X1	
	BMN	VLOAD	
		ITISMOON	
	DOT	PUSH	
		UNITW	
	DSQ	BDSU	

July 10, 2016

Apollo-11.nw 1683

	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

```

1685  <src/SERVICE-ROUTINES.s 1685>≡
      # 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
      #
      #           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 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

```

July 10, 2016

Apollo-11.nw 1687

#  
# 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     DELLOOP

          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

```



July 10, 2016

Apollo-11.nw 1689

```
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 IN THE SAME

#

# 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

```

1691  <src/SERVICER.s 1691>≡
      # 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 # 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.

July 10, 2016

Apollo-11.nw 1693

```

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/
```

# Page 859

```

                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

```

July 10, 2016

Apollo-11.nw 1695

```

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.



July 10, 2016

Apollo-11.nw 1697

	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
TC      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
DXCH    Z      # EXIT TO SELECTED ROUTINE WHETHER THERE
              # 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

```

July 10, 2016

Apollo-11.nw 1699

```
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
```

```
+4      EXTEND
        DCA      NEG0
        DXCH     -PHASE3

        EXTEND
        DCA      NEG0
        DXCH     -PHASE6

        CAF      OCT33      # 4.33SPOT FOR GOP00FIX
        TS       L
        COM
        DXCH     -PHASE4

        TCF      WHIMPER    # PERFORM A SOFTWARE RESTART AND PROCEED
                                # TO GOTOP00H WHILE SERVICER CONTINUES TO
                                # RUN, ALBEIT IN A GROUND STATE WHERE
                                # ONLY STATE-VECTOR DEPENDENT FUNCTIONS
                                # ARE MAINTAINED.

# Page 866
SVEXTADR      EBANK= DVCNTR
                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
NORMLIZE      TC      INTPRET
                VLOAD  BOFF
                        RN1
                        MUNFLAG
                        NORMLIZ1
```

July 10, 2016

Apollo-11.nw 1701

```

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

```

July 10, 2016

Apollo-11.nw 1703

```

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		



July 10, 2016

Apollo-11.nw 1705

```

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

July 10, 2016

Apollo-11.nw 1707

```

                                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 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	

July 10, 2016

Apollo-11.nw 1709

```

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

July 10, 2016

Apollo-11.nw 1711

```
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      #
          UNITZ
          UNIT/R/
SL1      PUSH      #
DSQ      BDSU      (14)
          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      # MPAC = UNIT GRAVITY VECTOR.   (18)
CALCGRV1                      DLOAD  NORM      # PERFORM A NORMALIZATION ON RMAGSQ IN
                                34D          # ORDER TO BE ABLE TO SCALE THE MU FOR
                                X2           # MAXIMUM PRECISION.
                                BDDV*  SLR*
                                -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.

```



July 10, 2016

Apollo-11.nw 1713

# 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	QUICKFAZ5		
	TC	INTPRET		
	VLOAD			
		GDT1/2		
	STOVL	G(CSM)		
		R1S		
	STOVL	R(CSM)		
		V1S		
	STORE	V(CSM)		
	EXIT			
	TC	QUICKFAZ5		
	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			

# Page 883

	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.
----------	-----	----------	-------------------------------

July 10, 2016

Apollo-11.nw 1715

```

                                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      INTERPRET
              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      INTERPRET
              DAD      SL          # CORRECT HMEAS FOR DOPPLER EFFECT
                   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      # IF HIGH PART OF HCALC IS NON-ZERO, THEN
          BZF         +2          # HCALC > HMAX,
          TCF         VMEASCHK    # SO UPDATE IS BYPASSED
          TS          MPAC +2     #          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

```

July 10, 2016

Apollo-11.nw 1717

```
# 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

```

July 10, 2016

Apollo-11.nw 1719

```

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.

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
```

# Page 888

```

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
      EXTEND

# 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

```



July 10, 2016

Apollo-11.nw 1721

```

      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

```

July 10, 2016

Apollo-11.nw 1723

```
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

```

July 10, 2016

Apollo-11.nw 1725

```
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	GOTPOOH	# 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	

July 10, 2016

Apollo-11.nw 1727

```
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
```

1728      Apollo-11.nw

July 10, 2016

```
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

1729  $\langle \text{src}/\text{SINGLE-PRECISION-SUBROUTINES.s } 1729 \rangle \equiv$

```
# 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

1731

*<src/SPS-BACK-UP-RCS-CONTROL.s 1731>≡*

```
# 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
#

```

July 10, 2016

Apollo-11.nw 1733

```
# 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 CTCHECK          # 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	DAPTREG1	
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	

July 10, 2016

Apollo-11.nw 1735

```
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

```

1736  <src/STABLE-ORBIT.s 1736>≡
      # 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

```



July 10, 2016

Apollo-11.nw 1737

```
#      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

```

July 10, 2016

Apollo-11.nw 1739

	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*    0 -7,1    # DELTA R / (VP X RP/RP)
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

```

July 10, 2016

Apollo-11.nw 1741

```

                                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
                                STOVL    DELVEET3
                                      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

July 10, 2016

Apollo-11.nw 1743

```
#      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      # SELECT MU, CLEAR FINALFLG, GO TO VN1645
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

```



July 10, 2016

Apollo-11.nw 1745

	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

```

1746  <src/STAR-TABLES.s 1746>≡
      # 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

```

July 10, 2016

Apollo-11.nw 1747

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 1390

# 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

July 10, 2016

Apollo-11.nw 1749

# 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

1750      Apollo-11.nw

July 10, 2016

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

1751

<src/SXTMARK.s 1751>≡

```
# 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
# PROGRAM MODIFIED BY 258/278 PROGRAMMERS
# MOD BY: R. MELANSON TO ADD DOCUMENTATION
#
# 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:
```

DATE: 5 APRIL 1967  
LOG SECTION SXTMARK  
ASSEMBLY SUNDISK REV. 116

```

#
#      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

```



July 10, 2016

Apollo-11.nw 1753

	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.

July 10, 2016

Apollo-11.nw 1755

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            # ALARM IF NO INBITS
            OCT     113

```

July 10, 2016

Apollo-11.nw 1757

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

```

July 10, 2016

Apollo-11.nw 1759

	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 1761

```
#      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 DESCRIPTOR 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

July 10, 2016

Apollo-11.nw 1763

	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
	TC	WAITLIST
EBANK=	MRKBUF1	
2CADR	MARKDIF	

# 10 MS IF NO CHECK

	TCF	RESUME
--	-----	--------

SETLOC	SXTMARK1
BANK	

July 10, 2016

Apollo-11.nw 1765

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)
```

1766      Apollo-11.nw

July 10, 2016

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**

```

1767 <src/SYSTEM-TEST-STANDARD-LEAD-INS.s 1767>≡
# 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

```



July 10, 2016

Apollo-11.nw 1769

```
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

```

1771  <src/T4RUPT-PROGRAM.s 1771>≡
      # 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
      #
      #              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 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

July 10, 2016

Apollo-11.nw 1773

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      DSPORTSB
                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

```

July 10, 2016

Apollo-11.nw 1775

	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.

```

#



July 10, 2016

Apollo-11.nw 1777

# 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

```

July 10, 2016

Apollo-11.nw 1779

```
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.

July 10, 2016

Apollo-11.nw 1781

```
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

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

```

July 10, 2016

Apollo-11.nw 1783

```

      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 WITH 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

# Page 148
                                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

```



July 10, 2016

Apollo-11.nw 1785

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
EXTEND	
WOR	DSALMOUT
TCF	NXTIFAIL

# TURN ON LAMP.

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
# REQUEST) IS DETECTED.  UPON ENTRY, ITURNON CHECKS IF A TURN-ON DELAY SEQUENCE HAS
# IF NOT, IT CHECKS WHETHER THE TURN-ON REQUEST CHANGE IS TO ON OR OFF.  IF ON, IT
# THAT TNONTEST WILL INITIATE THE ISS INITIALIZATION SEQUENCE.  IF OFF, THE TURN-ON
# 15, IS CHECKED AND IF IT IS ON, ITURNON EXITS.  IF THE DELAY SIGNAL IS OFF, PROGRAM
# OF IMODES30 IS SET TO 1 AND THE PROGRAM EXITS.
#
# THE SETTING OF BIT 2 OF IMODES30 (ISS DELAY SEQUENCE FAIL) INHIBITS THIS ROUTINE AND
# PROCESSING ANY CHANGES.  THIS BIT WILL BE RESET BY THE ENDTNON ROUTINE WHEN THE CUR
# 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
# AND BIT 14 OF IMODES30 TO 1.
#
# ALARMS:  PROGRAM ALARM 00207 IS ISSUED IF THE ISS TURN-ON REQUEST SIGNAL IS NOT PRESENT.
#
# EXIT:  NXTIFAIL.
#
# OUTPUT:  BIT 7 OF IMODES30 TO START ISS INITIALIZATION, OR BIT 2 OF IMODES30 AND BIT 15
# 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		

July 10, 2016

Apollo-11.nw 1787

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 ICPU 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.

July 10, 2016

Apollo-11.nw 1789

```
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.
#

```

July 10, 2016

Apollo-11.nw 1791

# 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	



July 10, 2016

Apollo-11.nw 1793

	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	
30RDMSK	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

July 10, 2016

Apollo-11.nw 1795

	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		

1796 Apollo-11.nw

July 10, 2016

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		

July 10, 2016

Apollo-11.nw 1797

	WAND	CHAN12	
	CS	OPTMODES	# SET RETURN-TO-COARS BIT
	MASK	BIT9	
	ADS	OPTMODES	
OPTZERO	TC	SETDESMD	
	TC	INITZOPT	# INITIALIZE ZERO OPTICS
SETCNT	CA	OCT40	# SET UP 32 SAMPLE WAIT
SETDESMD	TS	ZOPTCNT	
	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

July 10, 2016

Apollo-11.nw 1799

```

                                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             # ABS(CDUS) - 45 DEG
            TCF     +2
            TCF     -2
            EXTEND
            BZMF    OZONE
            CA      ZONE                  # LESS THAN 45 DEG-SET ZONE 0
            EXTEND                          # IF ZONE ZERO, CHANGE TO + OR - OTHERWISE
            BZF     +2                      # DON'T MESS WITH ZONE
            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

CONTRDRVE   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
```

1800 Apollo-11.nw

July 10, 2016

```

                                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
                                TS         OPTIND
                                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
```



July 10, 2016

Apollo-11.nw 1801

```
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
```

	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	

## A.110 T6-RUPT PROGRAMS

1803

*<src/T6-RUPT-PROGRAMS.s 1803>≡*

```
# 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      T6NEZ
#             T6FURTHA    T6FURTHA +1  T6FURTHA    T6FUR
#
# 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

```

July 10, 2016

Apollo-11.nw 1805

# 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

```

1807  <src/TAGS-FOR-RELATIVE-SETLOC.s 1807>≡
# 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



July 10, 2016

Apollo-11.nw 1809

# 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

July 10, 2016

Apollo-11.nw 1811

	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)

July 10, 2016

Apollo-11.nw 1813

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
P11ONE	EQUALS	
P20S3	EQUALS	
P20S4	EQUALS	
RTECON	EQUALS	
	BNKSUM	34

	BANK	35
RTECON1	EQUALS	
CSI/CDH	EQUALS	
P30S1	EQUALS	
P30S	EQUALS	
P17S1	EQUALS	
MEASINC3	EQUALS	

INTINIT2	EQUALS	
	BNKSUM	35

# MODULE 6 CONTAINS BANKS 36 THROUGH 43

	BANK	36
MEASINC	EQUALS	
MEASINC1	EQUALS	
P17S	EQUALS	
RTE1	EQUALS	
S3435LOC	EQUALS	
	BNKSUM	36

	BANK	37
P20S	EQUALS	
BODYATT	EQUALS	
RENDEZ	EQUALS	
SERVICES	EQUALS	
P11TWO	EQUALS	
CDHTAG3	EQUALS	
	BNKSUM	37

	BANK	40
PINSUPER	EQUALS	

# Page 34

SELSUPR	EQUALS	
PINBALL1	EQUALS	
R36CM1	EQUALS	
	BNKSUM	40

	BANK	41
PINBALL2	EQUALS	
R36LM	EQUALS	
	BNKSUM	41

	BANK	42
SBAND	EQUALS	
PINBALL3	EQUALS	
EXTVBS	EQUALS	
R36LM1	EQUALS	
	BNKSUM	42

	BANK	43
SELFCHEC	EQUALS	

July 10, 2016

Apollo-11.nw 1815

```
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

\*\*\*\*\*

# Page 36

# \*\*\* END OF MAIN PROGRAM \*\*\*

This code is written to file `src/TAGS-FOR-RELATIVE-SETLOC.s`.



## A.112 THE LUNAR LANDING

```

1817  <src/THE-LUNAR-LANDING.s 1817>≡
# 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            INTPRET      # DIONYSIAN FLAG WAVING
          CLEAR         CLEAR
          NOTHRCTL
          REDFLAG
          CLEAR         SET
          LRBYPASS
          MUNFLAG
          CLEAR         CLEAR
          P25FLAG        # TERMINATE P25 IF IT IS RUNNING.
          RNDVZFLG       # TERMINATE P20 IF IT IS RUNNING.

          # *****

IGNALG    SETPD         VLOAD        # FIRST SET UP INPUTS FOR RP-TO-R:
# Page 786
          0              #          AT 0D LANDING SITE IN MOON FIXED FRAM
          RLS            #          AT 6D ESTIMATED TIME OF LANDING
          PDDL           #          MPAC NON-ZERO TO INDICATE LUNAR CASE
          TLAND
          STCALL         TPIP          # ALSO SET TPIP FOR FIRST GUIDANCE PASS
          RP-TO-R
          VSL4           MXV
          REFSMMAT
          STCALL         LAND
          GUIDINIT       # GUIDINIT INITIALIZES WM AND /LAND/
          DLOAD          DSU
```

July 10, 2016

Apollo-11.nw 1819

```

                                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      INTERPRET
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

```

July 10, 2016

Apollo-11.nw 1821

```

                STCALL  VCV
                        INTEGRVS
                GOTO    IGNALoop

DDUMGOOD        SLOAD  SR
                        ZOOMTIME
                        14D
                BDSU
                        TDEC1
                STOVL  TIG
                        V
                VXV    UNIT
                        R
                DOT    SL1
                        LAND
R60INIT          STOVL  OUTOFPLN
                        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   #                   SILLY THING AROUND
          CADR    GOPERF1
          TCF     GOTOP00H   # 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

# Page 790
# -----
```

July 10, 2016

Apollo-11.nw 1823

# Page 791

# \*\*\*\*\*  
# 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	

1824      Apollo-11.nw

July 10, 2016

```

                                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

1825 *<src/THROTTLE-CONTROL-ROUTINES.s 1825>≡*

```
# 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
```

# Page 793

```
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        # 2(-4) M/CS/CS, SAVING SERVICER TROUBLE
MP            /AF/CNST
+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

```

July 10, 2016

Apollo-11.nw 1827

```
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

AD DEC66

EXTEND

BZF FWCOMP

CA PIPTIME +1

TS BUF

CAF 4SECS

TCF FWCOMP +1

FWCOMP

+1

CAF 2SECS

TS Q

EXTEND

MP BIT6

LXCH BUF +1

CS BUF

AD TIME1

AD THROTLAG

MASK LOW8

ZL

EXTEND

DV Q

EXTEND

MP PIF

DOUBLE

DXCH FWEIGHT

CCS PIF

AD ONE

TCF +2

AD ONE

EXTEND

MP PIF

#Page 796

July 10, 2016

Apollo-11.nw 1829

```

                                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
```

#Page 797

# 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

```

1830  <src/TIME-OF-FREE-FALL.s 1830>≡
      # 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)
      #

```

Apollo-11.nw 1831

```
#
# 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 STOR
# THE USER MUST ALSO LOCK OUT THE EXTENDED VERBS, AND RELEASE THEM WHEN FINISHED.
```

```
# THE FOLLOWING ERASABLE QUANTITIES ARE USED BY THE TFF ROUTINES, AND ARE LOCATED IN THE PUSH L
```

#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		

```
# REGISTERS S1, S2 ARE UNTOUCHED BY ANY TFF SUBROUTINE
# INDEX REGISTERS X1, X2 ARE USED BY ALL TFF SUBROUTINES.  THEY ARE ESTAB-
# LISHED 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

```



July 10, 2016

Apollo-11.nw 1833

```
#          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
```

July 10, 2016

```

STORE      TFF/RTMU          # E:(17) M:(14)
           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 DIFFE
#                                                    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
```

July 10, 2016

Apollo-11.nw 1835

```
#          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)
```

```

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
          #
          30 W

# 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
#

```

July 10, 2016

Apollo-11.nw 1837

```
#          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,
#                  NRTERM        E:(-29+NR) M   RTERM, WEIGHTED BY NR
#                  M:(-27+NR)
#                  TFFTEM        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

```

July 10, 2016

Apollo-11.nw 1839

```

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
        TFFNP             # E: (-32+NR) M: (-30+NR)
        0 -6,1            # LC P E: (-38+2NR) M: (-36+2NR)
        DAD               # X1 = -NR
DCOMP   DAD               # DUE TO SHIFTS, KEEP PRECISION FOR SQRT
        SR*               # RTERM(2-ALFA RTERM) FROM PDL +2
        0,1              # E: (-32+NR) M: (-30+NR)
BOFF    DLOAD             # LEAVE E: (-32) M: (-30)
        TFFSW            # X1 = -NR
        +2               # CHECK TFF /TPER SWITCH
        TFFZEROS         # IF TFF, CONTINUE
        SQRT             # IF TPER, SET Q2 = 0
+2      BMN              # E: (-16) M: (-15)
        MAXTFF1          # NO FREE FALL CONIC TO RTERM FROM HERE
                        # 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) (-3) FROM PDL+0
SAVEDEN PUSH ABS          # DEN TO PDL+0 E: (-3) OR (-16)
                        # M: (-3) OR (-15)
        DAD             # INDETERMINANCY TEST
        BOV             # =1.0-B(-22)
        LIM(-22)        # GO IF DEN >= B(-22)
        TFFXTEST        # SET DEN=0 OTHERWISE
DLOAD   PDDL
        TFFZEROS
```

July 10, 2016

```

DLOAD      DCOMP      # XCH ZERO WITH PDL+0
            TFFALFA    # ALFA  E:(26-NR) M:(24-NR)
BMN        DLOAD      # FOR TPER:  Z INDET AT DELE/2=0 AND 90.
            TFFEL1     # ASSUME 90, AND LEAVE 0 IN PDL: 1/Z=D/N

DUMPTFF1    RVQ        # Z INDET. AT PERIGEE FOR PARAB OR HYPERB.
            # RETURN TFF =0

# INBOUND Z CALC CONTINUES HERE

INBOUND     DLOAD      # 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)
            # M:(-3) OR (-15)
            DP(-22)    # RESTORE ABS(DEN) TO MPAC
            TFFX       # NUM  E:(-16) OR (-29)  M:(-15) OR (-27)
DMP         SR*        #
            TFFRTALF   # SQRT(ALFA)  E:(10+NA) M:(9+NA)
            0 -3,2     # X2=-NA
DDV         # C(MPAC) =NUM SQRT(ALFA)      E:(-3) OR (-
            # M:(-3) OR (-
            # 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)

```



July 10, 2016

Apollo-11.nw 1841

```

      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

```

July 10, 2016

Apollo-11.nw 1843

```
# 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 OBTAINED BY THE
#   MAC PROGRAM AUTCURFIT294RRB AND IS VALID TO THE SAME TOLERANCE OVER THE RANGE (0,+1)
#
# 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 NEARBY
# M CUBE/CS SQ

```

July 10, 2016

Apollo-11.nw 1845

#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

1846  $\langle \text{src}/\text{TJET-LAW.s } 1846 \rangle \equiv$ 

```

# 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

```

July 10, 2016

Apollo-11.nw 1847

```
# 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

# Page 1461

          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.

```



July 10, 2016

Apollo-11.nw 1849

```

      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
      EXTEND      # PRODUCT SCALED AT PI(2)/2(10) RAD/SEC.
      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

```

July 10, 2016

Apollo-11.nw 1851

```

                                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.

July 10, 2016

Apollo-11.nw 1853

```
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       CCSHOLE      # 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.

```

July 10, 2016

Apollo-11.nw 1855

```
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

```



July 10, 2016

Apollo-11.nw 1857

-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

```

1858  <src/TPI-SEARCH.s 1858>≡
      # 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

```

July 10, 2016

Apollo-11.nw 1859

```
# 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
```

1860 Apollo-11.nw

July 10, 2016

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			

July 10, 2016

Apollo-11.nw 1861

```
# 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     VLOAD        # COMPUTE SEARCH SECTOR LIMITS
      QTEMP
      RACT3
      UNIT     DOT
      E2
      ABS      SQRT
      SL1      DAD
      DP-.002   # ADD .002 RADIANS TO IT
      BON      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
# 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
                                DPOS MAX
                                STODL DELVEE
                                MANYFEET
                                STODL HP
                                SEC1THET
                                BON DLOAD
                                KFLAG
                                +2
                                SEC2THET
                                STCALL THETL
                                CONCAUL
                                DLOAD SR1
                                CSTH
                                STODL COSTH
                                SNTH
                                SR1
                                STCALL SINTH
                                ARCTRIG
                                BPL DAD
                                +2
                                DPOS MAX
                                BDSU PDDL
# SAVE START TIME AND GET END TIME
# SAVE TIME FOR LOOP TEST
# 70 DEGREES
# 330 DEGREES
# GET 4 QUADRANT THETA
# PUT THETA BETWEEN 0,1

```

July 10, 2016

Apollo-11.nw 1863

```

                                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

```



July 10, 2016

Apollo-11.nw 1865

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

```

July 10, 2016

Apollo-11.nw 1867

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
                                NORM
                                2PISC
                                X1
                                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

```

July 10, 2016

Apollo-11.nw 1869

```

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
```

1870      Apollo-11.nw

July 10, 2016

		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

1871 *<src/TRIM-GIMBAL-CNTROL-SYSTEM.s 1871>≡*

```
# 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.

```



July 10, 2016

Apollo-11.nw 1873

```
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
              MP      BIT14         # LIMITING QUOTIENT TO AVOID OVERFLOW.
                                   # -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	

July 10, 2016

Apollo-11.nw 1875

	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		# 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

```

July 10, 2016

Apollo-11.nw 1877

```
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?

```

July 10, 2016

Apollo-11.nw 1879

	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

1880 Apollo-11.nw

July 10, 2016

	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	ZEROOT	# NEGATIVE. USE ZERO FOR 1/2 POWER.
	CA	FUNCTION +1	
	EXTEND		
	BZMF	ZEROOT	
	TCF	ZEROHIGH	# PROCEED.
ZEROOT	CA	ZERO	



July 10, 2016

Apollo-11.nw 1881

	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

```

July 10, 2016

Apollo-11.nw 1883

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

1885

*<src/TVCDAPS.s 1885>*≡

```
# 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
#
```

July 10, 2016

Apollo-11.nw 1887

```
# 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		



July 10, 2016

Apollo-11.nw 1889

	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

```

July 10, 2016

Apollo-11.nw 1891

```
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
```

1892 Apollo-11.nw

July 10, 2016

	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

July 10, 2016

Apollo-11.nw 1893

YACLIM	TCR	ACTLIM	# YAW ACTUATOR-COMMAND-LIMITER
YOUT	CS	YCMD	# INCRMENTAL YAW COMMAND
	AD	CMDTMP	
	ADS	TVCYAW	# UPDATE THE ERROR COUNTER (NO RESTART- # 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
DELBAR	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)
```

July 10, 2016

Apollo-11.nw 1895

```
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



July 10, 2016

Apollo-11.nw 1897

# 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 \*\*\*\*

July 10, 2016

Apollo-11.nw 1899

# 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

```

July 10, 2016

Apollo-11.nw 1901

```
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),
```

1902     Apollo-11.nw

July 10, 2016

E(-AT)                    OCT        37535                    #                    OR(1/A=8SEC, T=80MS)

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

## A.119 TVCEEXECUTIVE

1903

*<src/TVCEEXECUTIVE.s 1903>≡*

```
# 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

```



July 10, 2016

Apollo-11.nw 1905

```

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, LOTHRUST (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			

July 10, 2016

Apollo-11.nw 1907

```
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)

```

July 10, 2016

Apollo-11.nw 1909

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

**A.120 TVCINITIALIZE**

```

1910  <src/TVCINITIALIZE.s 1910>≡
      # 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

```

July 10, 2016

Apollo-11.nw 1911

```
# 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
```

# Page 938

	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



July 10, 2016

Apollo-11.nw 1913

# Page 939

	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

	CAF	BIT1	#	SET UP TEMPORARY COUNTER
+5	TS	TTMP1		
	INDEX	TTMP1		
	CA	ERRBTMP	#	ERRBTMP CONTAINS RCS ATTITUDE ERRORS
	EXTEND		#	ERRORY & 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	ERRBTMP		
+8	CCS	TTMP1	#	TEST TEMPORARY COUNTER
	TCF	ATTINIT +5	#	BACK TO REPEAT FOR PITCH ERROR
	CA	ERRBTMP	#	ERROS ESTABLISHED AND LIMITED
	TS	PERRB		
	CA	ERRBTMP +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

July 10, 2016

Apollo-11.nw 1915

```

      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      +2  # 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

```

July 10, 2016

Apollo-11.nw 1917

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	

July 10, 2016

Apollo-11.nw 1919

```
EBANK= BZERO
INITLOC2 2CADR TVCINIT1
```

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

## A.121 TVCMASSPROP

1920  $\langle \text{src}/\text{TVCMASSPROP.s } 1920 \rangle \equiv$

```
# 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, OTHERWISE
```



July 10, 2016

Apollo-11.nw 1921

```
#          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

```

July 10, 2016

Apollo-11.nw 1923

```

                                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	VARST0	# 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	

July 10, 2016

Apollo-11.nw 1925

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

1926  $\langle \text{src}/\text{TVCRESTARTS}.s \text{ 1926} \rangle \equiv$

```
# 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
# 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 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

```



July 10, 2016

Apollo-11.nw 1929

```
#      *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 CMDSOUT (BBCON THERE)
	TS	T5LOC		
	CAF	OCT37776	#	20MS
	TS	TIME5		
	TCF	NOQRSM		
CMDSOUT	LXCH	BANKRUPT	#	CONTINUE PREPARATION OF OUTCOUNTERS
	EXTEND			
	QXCH	QRUP		
	CS	ZERO	#	MOST RECENT ACTUATOR COMMANDS
	AD	PCMD	#	(AVOID +0)
	TS	TVC PITCH		
	CS	ZERO		
	AD	YCND		
	TS	TVCYAW		
	CAF	PRI06	#	RELEASE THE COUNTERS (BITS 11,12)
	EXTEND			
	WOR	CHAN14		
PHSCHK2	CCS	TVC PHASE	#	CHECK TVC PHASE AGAIN
	TCF	CHKSTRK		
	TCF	CHKSTRK		
	CCS	A	#	A CONTAINS THE DIMINISHED ABSOLUTE OF
	TC	+3	#	TVC PHASE (-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

July 10, 2016

Apollo-11.nw 1931

	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

```

1932  <src/TVCROLLDAP.s 1932>≡
# 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.
#
# 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 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

```

July 10, 2016

Apollo-11.nw 1933

```
#      *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)....
#
# 
$$SOGAERROR = (DB - (SOGARATE)^2 / (CONACC/2)) \operatorname{SGN}(SOGARATE)$$

#
# EQUATION FOR SWITCHING STRAIGHT LINE SEGMENT....
#
# 
$$SOGARATE = -(-SLOPE)(SOGAERROR) - \operatorname{SGN}(SOGARATE) \operatorname{INTERCEP}$$

#
# WHERE  $\operatorname{INTERCEP} = DB(-SLOPE) - \operatorname{LMCRATE}$ 
# 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

```



July 10, 2016

Apollo-11.nw 1937

```

      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

```

July 10, 2016

Apollo-11.nw 1939

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... (O,L)/TEMREG = 0,L
MINLIMAP	CCS	A	
	CAF	POS MAX	# POSITIVE OVERFLOW
	TCF	ROLLSET	
	CS	POS MAX	# NEGATIVE OVERFLOW
	TCF	ROLLSET	
DVOK	LXCH	A	# PUT NUMERATOR BACK INTO A, 0 INTO L
	EXTEND		
	DV	TEMREG	# RESULT OF DIVISION IS DESIRED OGRATE
	TCF	ROLLSET	# (SCALED AT B-4 REV/SEC)
RATELIM	CS	MAXLIM	
	INDEX	I	
# Page 993	O	A	# IF I = CA, DESIRED RATE IS -MAXLIM

July 10, 2016

Apollo-11.nw 1941

# 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

```

July 10, 2016

Apollo-11.nw 1943

```
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

```



July 10, 2016

Apollo-11.nw 1945

```
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

```

1946  <src/TVCSTROKETEST.s 1946>≡
      # 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

```

July 10, 2016

Apollo-11.nw 1947

```
#          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....
#
#          **          **
```

```
#          **                **
#          **                **              EXAMPLE WAVEFORM (EACH * REPRESENTS
#          *  *                *  *        (85.41 ARCSEC OF ACTUATOR CMD)
#          *  *                *  *
#          *  *                *  *
#          *  *                *  *
#          *    *            *    *      **      **      **      **      **
#          *    *            *    *      **      **      **      **      **
#          *    *            *    *      **      **      **      **      **
#          *      *          *      *      *  *   *  *   *  *   *  *   *  *
#          *      *          *      *      *  *   *  *   *  *   *  *   *  *
#          *      *          *      *      *  *   *  *   *  *   *  *   *  *
# -----
#          *      *          *      *      *  *   *  *   *  *   *  *   *  *
#          *      *          *      *      *  *   *  *   *  *   *  *   *  *
#          *      *          *      *      *  *   *  *   *  *   *  *   *  *
#          *      *          *      *      **      **      **      **      **
#          *      *          *      *      **      **      **      **      **
#          *      *          *      *      **      **      **      **      **
#          *      *          *      *
#          *      *          *      *
#          *      *          *      *
#          **               **
#          **               **
#          **               **
#
# FOR THIS (UNOFFICIAL, EXAMPLE) WAVEFORM, THE REQUIRED PARAMETERS ARE AS FOLLOWS...
#
# FCARD      = +3           (NUMBER OF SETS)
# ESTROKER   = +3           (PULSE BURST SIZE, SC.AT 85.41 ARCSEC/BIT)
#
# SET1:
# FREVS      = +3           (NUMBER REVERSALS MINUS 1)
# FCADDY     = +4           (NUMBER OF PULSE BURSTS IN 1/2 AMPLITUDE)
# SET2:
# FCARD1     = +9           (NUMBER REVERSALS MINUS 1)
# FCARD4     = +2           (NUMBER OF PULSE BURSTS IN 1/2 AMPLITUDE)
# SET3:
# FCARD2     = +9           (NUMBER REVERSALS MINUS 1)
# FCARD5     = +1           (NUMBER OF PULSE BURSTS IN 1/2 AMPLITUDE)
# SET4:
# FCARD3     = +0           (NUMBER OF REVERSALS MINUS 1)
# FCARD6     = +0           (NUMBER OF PULSE BURSTS IN 1/2 AMPLITUDE)
```

July 10, 2016

Apollo-11.nw 1949

```
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)
```

1950 Apollo-11.nw

July 10, 2016

```
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
```

July 10, 2016

Apollo-11.nw 1951

	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

```

1952  <src/UPDATE-PROGRAM.s 1952>≡
      # 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.
      #

```



July 10, 2016

Apollo-11.nw 1953

```
# 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
# .                  SCALING IS SAME AS INTERNAL REGISTERS.
# V72EIIIE           (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)
```

July 10, 2016

Apollo-11.nw 1955

```
#      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.
```

1956 Apollo-11.nw

July 10, 2016

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

July 10, 2016

Apollo-11.nw 1957

```

      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

```

July 10, 2016

Apollo-11.nw 1959

```

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                      # 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 UTEMP

# 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 UTEMP

# 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 UTEMP

# (CODED THIS WAY FOR RESTART PROTECTION)



July 10, 2016

Apollo-11.nw 1961

```

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

```

July 10, 2016

Apollo-11.nw 1963

```
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
```

1964      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`.

## A.126 WAITLIST

1965

*<src/WAITLIST.s 1965>*≡

```

# 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 1967

```
#
# 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  
WAITEXIT.

TS WAITEXIT

EXTEND

INDEX WAITEXIT

# IF TWIDDLING, THE TS SKIPS TO HERE

1968 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
```



July 10, 2016

Apollo-11.nw 1969

```
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.

```

July 10, 2016

Apollo-11.nw 1971

	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

```

July 10, 2016

Apollo-11.nw 1973

# 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

#

July 10, 2016

Apollo-11.nw 1975

```
# 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
```

1976 Apollo-11.nw

July 10, 2016

# \*\*\* 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 1977

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

1978      Apollo-11.nw

July 10, 2016

## Appendix B

# Notes, Bibliography and Indexes

### B.1 Chunks

*<src/AGC-BLOCK-TWO-SELF-CHECK.s 13>*  
*<src/AGC-BLOCK-TWO-SELF-CHECK.s 25>*  
*<src/AGS-INITIALIZATION.s 37>*  
*<src/ALARM-AND-ABORT.s 43>*  
*<src/ANGLFIND.s 49>*  
*<src/AOSTASK-AND-AOSJOB.s 63>*  
*<src/AOTMARK.s 87>*  
*<src/ASCENT-GUIDANCE.s 103>*  
*<src/ASSEMBLY-AND-OPERATION-INFORMATION.s 118>*  
*<src/ATTITUDE-MANEUVER-ROUTINE.s 141>*  
*<src/AUTOMATIC-MANEUVERS.s 164>*  
*<src/BURN-BABY-BURN-MASTER-IGNITION-ROUTINE.s 175>*  
*<src/CM-BODY-ATTITUDE.s 199>*  
*<src/CM-ENTRY-DIGITAL-AUTOPILOT.s 206>*  
*<src/CONIC-SUBROUTINES.s 234>*  
*<src/CONTRACT-AND-APPROVALS.s 276>*  
*<src/CONTROLLED-CONSTANTS.s 278>*  
*<src/CSM-GEOMETRY.s 291>*  
*<src/DAP-INTERFACE-SUBROUTINES.s 312>*  
*<src/DAPIDLER-PROGRAM.s 301>*  
*<src/DISPLAY-INTERFACE-ROUTINES.s 316>*  
*<src/DOWN-TELEMETRY-PROGRAM.s 358>*  
*<src/DOWN-TELEMETRY-PROGRAM.s 368>*  
*<src/DOWNLINK-LISTS.s 349>*  
*<src/ENTRY-LEXICON.s 379>*  
*<src/ERASABLE-ASSIGNMENTS.s 388>*

*<src/EXECUTIVE.s 471>*  
*<src/EXTENDED-VERBS.s 482>*  
*<src/FINDCDUW-GUIDAP-INTERFACE.s 512>*  
*<src/FIXED-FIXED-CONSTANT-POOL.s 529>*  
*<src/FLAGWORD-ASSIGNMENTS.s 535>*  
*<src/FRESH-START-AND-RESTART.s 563>*  
*<src/GIMBAL-LOCK-AVOIDANCE.s 596>*  
*<src/GROUND-TRACKING-DETERMINATION-PROGRAM.s 599>*  
*<src/HeaderTemplate.s 604>*  
*<src/IMU-CALIBRATION-AND-ALIGNMENT.s 605>*  
*<src/IMU-COMPENSATION-PACKAGE.s 636>*  
*<src/IMU-MODE-SWITCHING-ROUTINES.s 645>*  
*<src/IMU-PERFORMANCE-TEST-2.s 669>*  
*<src/IMU-PERFORMANCE-TESTS-4.s 679>*  
*<src/INFLIGHT-ALIGNMENT-ROUTINES.s 687>*  
*<src/INPUT-OUTPUT-CHANNEL-BIT-DESCRIPTIONS.s 694>*  
*<src/INTEGRATION-INITIALIZATION.s 699>*  
*<src/INTER-BANK-COMMUNICATION.s 725>*  
*<src/INTERPRETER.s 730>*  
*<src/INTERPRETIVE-CONSTANT.s 797>*  
*<src/INTERPRETIVE-CONSTANTS.s 799>*  
*<src/INTERRUPT-LEAD-INS.s 801>*  
*<src/JET-SELECTION-LOGIC.s 804>*  
*<src/KALCMANU-STEERING.s 825>*  
*<src/KALMAN-FILTER.s 831>*  
*<src/KEYRUPT-UPRUPT.s 834>*  
*<src/LAMBERT-AIMPOINT-GUIDANCE.s 838>*  
*<src/LANDING-ANALOG-DISPLAYS.s 842>*  
*<src/LATITUDE-LONGITUDE-SUBROUTINES.s 854>*  
*<src/LEM-GEOMETRY.s 861>*  
*<src/LUNAR-AND-SOLAR-EPHEMERIDES-SUBROUTINES.s 866>*  
*<src/LUNAR-LANDING-GUIDANCE-EQUATIONS.s 871>*  
*<src/LUNAR-LANDMARK-SELECTION-FOR-CM.s 904>*  
*<src/MAIN.s 905>*  
*<src/MEASUREMENT-INCORPORATION.s 909>*  
*<src/MYSUBS.s 921>*  
*<src/ORBITAL-INTEGRATION.s 924>*  
*<src/P-AXIS-RCS-AUTOPILOT.s 1354>*  
*<src/P11.s 945>*  
*<src/P12.s 966>*  
*<src/P20-P25.s 972>*  
*<src/P30-P37.s 1049>*  
*<src/P30-P37.s 1054>*  
*<src/P32-P33-P72-P73.s 1068>*  
*<src/P32-P35-P72-P75.s 1099>*  
*<src/P34-35-P74-75.s 1130>*

*<src/P37-P70.s 1168>*  
*<src/P40-P47.s 1211>*  
*<src/P51-P53.s 1264>*  
*<src/P61-P67.s 1313>*  
*<src/P70-P71.s 1340>*  
*<src/P76.s 1350>*  
*<src/PHASE-TABLE-MAINTENANCE.s 1377>*  
*<src/PINBALL-GAME-BUTTONS-AND-LIGHTS.s 1386>*  
*<src/PINBALL-NOUN-TABLES.s 1469>*  
*<src/PLANETARY-INERTIAL-ORIENTATION.s 1488>*  
*<src/POWERED-FLIGHT-SUBROUTINES.s 1497>*  
*<src/Q-R-AXIS-RCS-AUTOPILOT.s 1505>*  
*<src/R30.s 1524>*  
*<src/R31.s 1535>*  
*<src/R60-62.s 1542>*  
*<src/R63.s 1551>*  
*<src/RADAR-LEADIN-ROUTINES.s 1555>*  
*<src/RCS-CSM-DAP-EXECUTIVE-PROGRAMS.s 1558>*  
*<src/RCS-CSM-DIGITAL-AUTOPILOT.s 1560>*  
*<src/RCS-FAILURE-MONITOR.s 1582>*  
*<src/README.md 1586>*  
*<src/REENTRY-CONTROL.s 1588>*  
*<src/RESTART-TABLES.s 1632>*  
*<src/RESTARTS-ROUTINE.s 1624>*  
*<src/RT8-OP-CODES.s 1645>*  
*<src/RTB-OP-CODES.s 1653>*  
*<src/S-BAND-ANTENNA-FOR-CM.s 1659>*  
*<src/S-BAND-ANTENNA-FOR-LM.s 1662>*  
*<src/SERVICE-ROUTINES.s 1685>*  
*<src/SERVICER.s 1691>*  
*<src/SERVICER207.s 1667>*  
*<src/SINGLE-PRECISION-SUBROUTINES.s 1729>*  
*<src/SPS-BACK-UP-RCS-CONTROL.s 1731>*  
*<src/STABLE-ORBIT.s 1736>*  
*<src/STAR-TABLES.s 1746>*  
*<src/SXTMARK.s 1751>*  
*<src/SYSTEM-TEST-STANDARD-LEAD-INS.s 1767>*  
*<src/T4RUPT-PROGRAM.s 1771>*  
*<src/T6-RUPT-PROGRAMS.s 1803>*  
*<src/TAGS-FOR-RELATIVE-SETLOC.s 1807>*  
*<src/THE-LUNAR-LANDING.s 1817>*  
*<src/THROTTLE-CONTROL-ROUTINES.s 1825>*  
*<src/TIME-OF-FREE-FALL.s 1830>*  
*<src/TJET-LAW.s 1846>*  
*<src/TPI-SEARCH.s 1858>*  
*<src/TRIM-GIMBAL-CNTROL-SYSTEM.s 1871>*

*<src/TVCDAPS.s 1885>*  
*<src/TVCEXECUTIVE.s 1903>*  
*<src/TVCINITIALIZE.s 1910>*  
*<src/TVCMASSPROP.s 1920>*  
*<src/TVCRESTARTS.s 1926>*  
*<src/TVCROLLDAP.s 1932>*  
*<src/TVCSTROKETEST.s 1946>*  
*<src/UPDATE-PROGRAM.s 1952>*  
*<src/WAITLIST.s 1965>*

## **B.2    Index**