Project Apollo for Orbiter – NASSP/NCPP
Version 6.2

Apollo Guidance Computer (AGC) – Version 2.0

User's guide and reference manual

February 2005

Rodrigo R. Mercê B. Maia

Table of Contents

Section 4 - Other

4.0 - Change log

4.1 - Credits

Section 1 - Getting Started

1.0 - Introduction

The AGC is a fundamental part of the Apollo spacecraft. Without it, going to the moon wouldn't be possible. This particular computer was responsible for controlling the craft through it's most critical maneuvers, which required a precision that only computer control could provide. Although by today's standards it is way too slow, a typical hand calculator has as much if not more processing power, at the time it represented state of the art technology. So, NASSP/NCPP wouldn't be complete without a simulation of an AGC and its software. The AGC 2.0 is embedded into the NASSP/NCPP code, with the intent of simulating the real AGC. It's a work in progress, as there are many more things the real AGC could do that aren't implemented yet. What's implemented so far are the most critical features. Also, in some places, corners were cut from the real one, in order to fit it within Orbiter's capabilities and to make its use more joyful.
This document was written with the intent of providing sort of a user's guide to the AGC 2.0, by describing it's features, providing reference and explaining the procedures.

1.1 - Currently implemented features

So far, for AGC 2.0 the following main features are implemented:

Launch control
Post launch orbit change control
TLI burn control and monitor
Lunar ascent auto-pilot

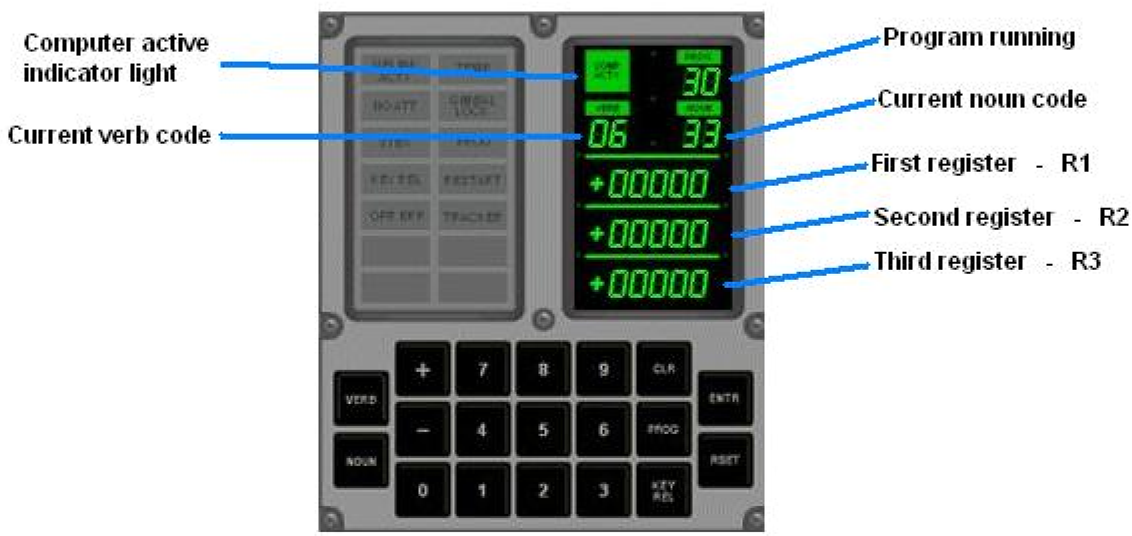
And all the supporting structure required by the features above. A description of this structure can be found in Section 3.

1.2 - Getting familiar with the AGC interface: the DSKY

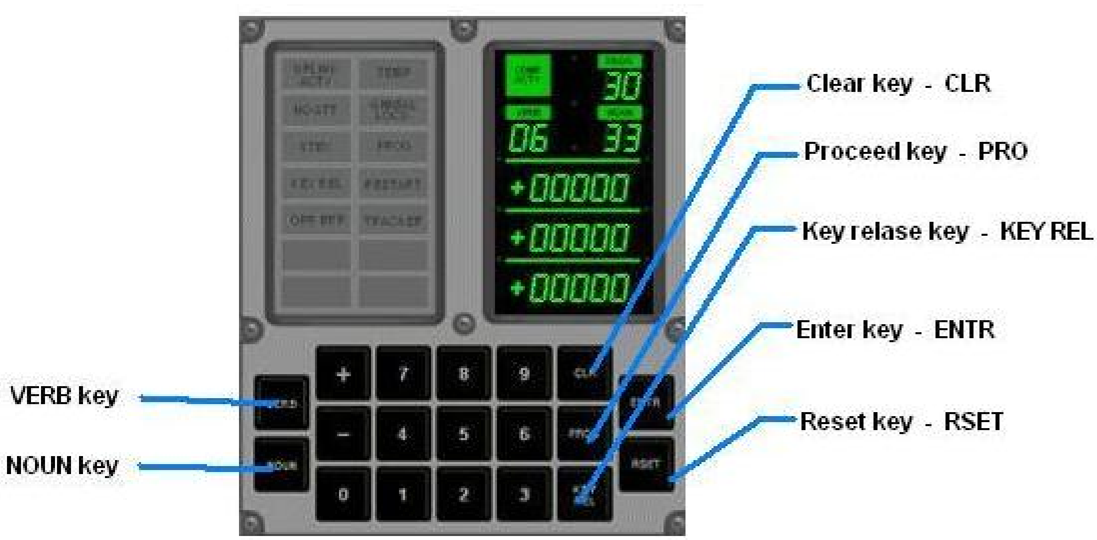
The purpose of this section is to explain the display and keys of the DSKY.
The DSKY is the system AGC uses to display and receive data. If you haven't guessed already, DSKY is an acronym for Display and Keyboard. Here's how it looks like.

The DSKY can be split into 3 main areas:

The display area has several other parts, which are described below:



And the keyboard:



The VERB and NOUN combinations can be a little confusing. Basically VERB codes describe actions to be taken, such as run program, display data, monitor data and so on. The NOUN codes describe where the action will happen. For example, if the run program action (VERB 37) is requested, the computer needs to know which program to run, that's where the noun code comes in. Again, if the monitor data (VERB 16) action is requested, the computer needs to know which data set it will monitor. It is specified in the noun entry. Choosing verb and noun as denomination seems a little pointless at first, but after some thought it makes a lot of sense. Just think grammatically.

To enter a verb and noun combination into the DSKY, press the VERB key, you will notice that verb field in the display will blank. Enter the verb code using the numeric keys then press the NOUN key, now the noun field will blank. Enter the noun code using the numeric keys and after that is done, press the ENTR key.

If you want to enter just the verb code, as is the case if you want to enter one of the verb codes for data entry, just press the VERB key, enter the verb code and press the ENTR key. For noun entry only, the procedure is the same, but instead of pressing the VERB key, you would press the NOUN key.

Another thing is that if the verb desired is already in the Current Verb field, in the display, it's just a matter of entering the desired noun code, there's no need to enter the verb code again. For example, if the verb is already 16 (monitor data) and you want to change just the data set to monitor, press the NOUN key, enter the desired noun code, and press the ENTR key.

The CLR key is used for erasing possible mistakes made during data entry. The RSET key is used for turning off the OPR ERR light, after it lights to indicate that the operation attempted is invalid. And the PRO key is used to proceed at certain points in program execution (mostly after program specific data entry is done).

A few verb codes are worthy to point here, as they are very useful. A more detailed description of them, as well as of all the other implemented verb and noun codes can be found in Section 3.

VERB	ACTION
21	Blank R1, for data entry
22	Blank R2, for data entry
23	Blank R3, for data entry
25	Blank all registers, R1, R2, R3, for data entry
37	Run Program – (noun code then specifies which program to run)

When entering data in the registers, with the use of verbs 21, 22, 23 and 25, remember always to enter the data sign (if positive "+" and "-" if negative) as well as any needed leading zeros, if the number is not 5 digit long (for example, the number 295 should be entered as 00295, the number 15 as 00015 and so on). Also remember to enter it in the expected format, specified together with the data entry request description in the appropriate sections.

1.3 - Main Checklists

To perform some actions, the AGC assumes that the systems involved are correctly set. These checklists describe the switch positions for setting those systems. A description of the exact individual switch locations can be found in the NCPP documentation, as it's not within the scope of this document.

To be able to maneuver the CSM (Command and Service Modules) stack, the SM RCS needs to be activated as the CM RCS is mainly used for reentry maneuvers, when the CM is separated from the SM. For the Lunar Module (LM) it's similar. During the descent phase, the Descent Stage RCS needs to be activated and during the lunar ascent phase, the Ascent Stage RCS is the one that has be activated, as the Descent Stage will be left in the lunar surface.

The LM Descent Stage Activation checklist is used for preparing the LM for the descent phase.

The lunar lift-off checklist assumes the LM Ascent Stage RCS has already been activated.

SIV-B RCS SYSTEM ACTIVATION

PANEL 1

SIVB RCS	- PITCH
SIVB RCS	- YAW
SIVB RCS	- ROLL

SERVICE MODULE (SM) REACTION CONTROL SYSTEM (RCS) ACTIVATION

PANEL 2

SM RCS HELIUM 1 (4)	- CLOSE
SM RCS HELIUM 2 (4)	- CLOSE
PRIM PRPLNT (4)	- OPEN
SEC PRPLNT (4)	- OPEN

PANEL 1

CSM ATTITUDE	- ROLL
CSM ATTITUDE	- PITCH
CSM ATTITUDE	- YAW

COMMAND MODULE (CM) RCS ACTIVATION

PANEL 1

CM RCS LOGIC	- ON (up)
CM ATTITUDE	- ROLL
CM ATTITUDE	- PITCH
CM ATTITUDE	- YAW

PANEL 2

CM RCS PRPLNT (2)	- ON (up)
CM RCS PRESS	- ON (up)

LUNAR MODULE (LM) DESCENT STAGE RCS ACTIVATION

PANEL 2

SYSTEM A/B (4)	- CLOSE
LGC THRUSTER PAIR CMDS A/B (8)	- ENABLE
MAIN SOV SYS A/B (2)	- OPEN

PANEL 8

MASTER ARM	- ON
He PRESS RCS	- FREE

PANEL 3

RCS SYS A/B (4)	- MAN
ATTITUDE CONTROL	- ROLL
ATTITUDE CONTROL	- PITCH
ATTITUDE CONTROL	- YAW

LUNAR MODULE (LM) ASCENT STAGE RCS ACTIVATION

PANEL 2

SYSTEM A/B (4)	- ASC FEED
LGC THRUSTER PAIR CMDS A/B (8)	- ENABLE
MAIN SOV SYS A/B (2)	- OPEN

PANEL 8

MASTER ARM	- ON
He PRESS RCS	- FREE

PANEL 3

RCS SYS A/B (4)	- MAN
ATTITUDE CONTROL	- ROLL
ATTITUDE CONTROL	- PITCH
ATTITUDE CONTROL	- YAW

LUNAR MODULE (LM) DESCENT STAGE ACTIVATION

PANEL 1

DESCENT He (2)	- CLOSE
ENG ARM	- ARM

PANEL 8

MASTER ARM	- ARM
DES VENT	- FREE
He PRESS DES START	- FREE

PANEL 3

ENG GMBL	- ENABLE

LUNAR MODULE (LM) DESCENT ABORT PREPARATION

PANEL 1

ASCENT He (2)	**- CLOSE**

PANEL 8

MASTER ARM	**- ARM**
He PRESS ASCENT	**- FREE**
STAGE SEQ RELAY (2)	**- ON (UP)**

LUNAR MODULE (LM) LUNAR LIFT-OFF PROCEDURE

PANEL_1

ASCENT He (2)	**- CLOSE**
ENG ARM	**- ARM**

PANEL 3

ENG GMBL	**- ENABLE**

PANEL 8

MASTER ARM	**- ARM**
He PRESS ASCENT	**- FREE**
STAGE SEQ RELAY (2)	**- ON (UP)**

Section 2 – Programs

2.0 - Programs description

From the lift-off from Earth to the lunar surface and from there to the reentry on Earth's atmosphere and subsequent splashdown, the Apollo spacecraft was required to perform several maneuvers in order to accomplish its mission. Each of these maneuvers or maneuver sequences were computer controlled and had its own program. Below a listing of the currently implemented programs and a small description of what each one does can be found.
Some programs have their usage described too, as in Section 2.1 they are not listed. For a usage description of the other programs, refer to Section 2.1.

To enter the program, use VERB 37 NOUN XX ENTR, with XX being the program number. For example if you want to run P01, VERB 37 NOUN 01 ENTR would be used.

In the notation used, i.e. V06N33 or V21E:
"V" stands for VERB
"N" stands for NOUN
"E" stands for the ENTR key.
So the change program code would be written as V37NXXE, with XX being the program number.

Programs with the "CSM Specific" remark means that they are only available in the CM AGC and are not available in the LM AGC (sometimes called LGC). In the same manner, programs with the "LM Specific" remark are also only available in the LM AGC. Programs without any remarks are available for both modules.

The LM can sometimes be referred to as LEM, which in fact was its first name. It stands for Lunar Excursion Module, which was shortened later to just Lunar Module (LM).

During execution of the programs, except Idling and Standby ones, time acceleration use is strongly advised against. Even use of 10x acceleration can cause loss of control and subsequent tumbling.

AGC Idle - P00

This is the AGC idling program. It basically blanks the three registers as well as the verb and noun fields, and puts the AGC "to sleep".
To "wake up" the AGC again, just press the PRO key. Then the verb field will flash a 37. That's a suggestion to run another program, but another verb and noun combination (given that it's valid, otherwise the OPR ERR light will be turned on) can be entered if desired.

IMU Alignment - P01 - CSM Specific

This program is run when the AGC is started up. It does nothing more than light up the NO ATT light for a brief period and then automatically switches to P02.

Pre-launch setup - P02 - CSM Specific

This program allows you to check the launch data and if desired, change it.
At execution, it changes to V06N29. The display format is described below:

V06N29	**R1**	**Desired Azimuth (degrees * 100)**	**XXX.XX degs**

To change R1, use V21E.
Remember the value sign (plus or minus) as well as the format. So, if 89 degrees value is desired, the input should look like +08900.
Then, to proceed, press the PRO key.

Now, the mode will change to V06N44.

P02 (continued)

V06N44	R1	Desired apogee (meters / 10)	XXXXX meters
	R2	Desired perigee (meters / 10)	XXXXX meters

To change R1, use V21E
To change R2, use V22E
To change R1 and R2, use V24E

Remember the sign and the format. So, if 189Km apogee is desired, R1 after data entry should look like +18900.
Press the PRO key to continue.

The display will then go to V06N33

V06N33	R1	Countdown time (hours)	00XXX hours
	R2	Countdown time (minutes)	000XX mins
	R3	Countdown time (seconds * 100)	0XX.XX secs

To change R1, use V21E
To change R2, use V22E
To change R1, R2 and R3, use V25E
Press the PRO key to proceed.

Then the program will wait until the launch time (countdown reaches zero) and will automatically start the engines and switch to P11.

AGC Standby - P06

This is an alternative for P00, intended for use when the AGC will be unused for a long period of time.
When it is run, the display will change into V50N25 with R1 displaying 00062. That's a coded message which means press the PRO key to send the AGC into standby. Press the PRO key, and all data fields will blank and the STDBY light will be turned on, that's the AGC in standby mode.
To bring the AGC back from standby mode, press the PRO key again.

Launch control - P11 - CSM Specific

This program is responsible for monitoring the Saturn V flight profile from lift-off to orbit.

It will change the display to V16N62:

V16N62	R1	Absolute velocity	XXXXX m/s
	R2	Vertical velocity	XXXXX m/s
	R3	Altitude	XXXXX km

No input is taken at this point, it just displays the information. Also free change of nouns in order to have other information changed is allowed. For example, to monitor orbit data, V16N44E can be entered. Refer to section 3.1 for a complete list of the available nouns.

When orbit insertion is achieved, the program will automatically shut-down the SIV-B engine, turn the auto-pilot off (this can also be done manually at any point during launch by entering V46E) and the display will change to a flashing V37, which makes it ready for another program input.

Powered Ascent - P12 - LM Specific

This is the program that takes care of the lunar lift-off and ascent into orbit. It is part of the so called Lunar Module Ascent Auto-Pilot (LMAAP), now in version 4. This program will insert the LM into a pre-defined orbit, called the insertion orbit. This orbit geometry can't be defined by the user. It is pre-set within the program. After the insertion orbit is achieved, a series of maneuvers are performed to bring the orbit to a geometry defined by the user.

P12 (continued)

The ascent phase is divided in three parts:

- Vertical rise
- Pitch over
- Acceleration to orbit

The vertical rise phase consists of the time since lunar lift-off until the pitch over, which occurs when the LM reaches 15.5 m/s vertical velocity, usually at 12 seconds after lift-off. For the first 2 seconds since lunar lift-off no maneuvering is performed, as this interval is designed to allow the LM Ascent Stage to clear the Descent Stage (which is left on the lunar surface). After these 2 seconds, yawing to bring the current azimuth to the launch azimuth begins. This yawing must end before the pitch over phase begins, so there's a limit of 26 degrees to either side. If the desired launch azimuth is outside this limit, the program automatically corrects it to be within the limit, i.e. to 26 degrees in the desired direction from the current azimuth.

The pitch over phase begins when the LM reaches 15.5 m/s vertical speed, which is also when the vertical rise ends. In this phase, the LM pitches down to -52 degrees and maintains this attitude until the vertical speed reaches 70 m/s. The purpose of the pitch over is to begin building horizontal speed, and reducing the vertical acceleration increase rate.

The acceleration to orbit phase is the final phase. It begins at the end of the pitch over phase and goes until the orbit insertion is achieved and the LM ascent engine (APS) is cut off. In this phase, constant corrections to the LM pitch are made to adjust the acceleration components to ensure that at the end of the burn time (which is calculated to allow for some 9% fuel left for the other orbital maneuvers) the proper insertion conditions (vertical and horizontal velocities) are met.

Since there's always some error margin, after the APS is cut off, the residual speed trim begins. This process is aimed at trimming any velocity difference between the actual and target that may result after orbit insertion. The lunar gravity is very weak, so differences as little as 5 m/s can have a significant effect in the final orbit geometry, thus the importance of this trimming process.
First the residual vertical velocity is trimmed then the residual horizontal velocity. This process is accomplished through RCS thruster firings.

Here's a very important note concerning this program, during ascent, the automated control only acts upon the pitch RCS thrusters. This means that manual override in the roll axis is possible. When pitched down, this has an effect of changing the azimuth by changing the thrust line direction. So, if at the beginning the desired launch azimuth wasn't possible to achieve due to the yawing limit, this is an option to correct it during the ascent. But note that this is purely manual, no computer control or assist is given. If the desired action is to bring the orbital plane difference between the LM and the CSM to a minimum, the Align Plane MFD can be used at this point as a guideline for adjusting the roll.

And finally, before running this program, be sure to have the LM Ascent Stage RCS activated as well as the LM ready for lift-off, refer to Section 1.3 for the checklists on these procedures.

TLI burn monitor - P15 - CSM Specific

This program is used for performing an automated TLI burn. It takes care of keeping the spacecraft in the proper orientation, firing the engine at the proper time, and cutting it off once the desired Delta V has been achieved.

This program assumes the SIV-B RCS is enabled. Refer to Section 1.3 for the checklist on this procedure.

This program doesn't calculate the needed Delta V or the correct time for burn. This must be calculated in an external program or Orbiter MFD, which is the most practical way. You can use any MFD that allows you to calculate these parameters. A good suggestion would be TransX, although explaining how to use it is beyond the scope of this document. If needed, refer to its documentation, which can be found in Orbiter's default documentation folder.

Calculate the burn to be a considerable time ahead, something greater than 20 minutes. This way, a burn countdown time of 20 minutes can be input into V06N33 display when the program asks for it, but the real time can be monitored with the MFD countdown feature. When this value reaches 1200 seconds (20 minutes), the PRO key can then be pressed, to store into the AGC the countdown to burn. This is a very effective way of getting a precise TLI burn.

P15 (continued)

The AGC doesn't have access to the MFD data, the user must provide this bridge by inputting the MFD data into the AGC when it requests. But since both countdowns (AGC and MFD) have been synchronized with the procedure described above, the burn will be precisely on time.

Also, when you finish inputting the MFD data into the AGC (it will first ask for burn time, then it will ask the Delta V), the program will make some calculations to adjust the actual burn time, and display this value together with other data through V06N95. The goal of this calculation is to bring the burn time to happen earlier, to allow the original burn time to be halfway through the burn.

This process is required by the sheer physics of the spaceflight. Once you have a finite Delta V to be imparted, for maximum efficiency, when the spacecraft gets to the primary desired burn time, it should already have half of that Delta V imparted. That means that the time the engines will run, which can be calculated once the desired Delta V is known, has to be equally split before and after the initial time to initiate the burn. Thus the actual burn time will be earlier than the desired one.

Once the desired Delta V is reached, the engine takes care of engine shutdown. Then the program execution ends.

Automated Orbit Change - P33 - CSM Specific

This program is implemented for the LM also, but with a different interface and working, although does the same thing. This part describes the one implemented for the CSM.

The purpose of this program is to provide means of raising the orbit, both apoapsis and periapsis, with computer automatic control. The desired apoapsis and periapsis values are requested and stored, then the program takes care of the firing the engine at the appropriate time and maintaining the proper orientation.

Once the program is run, the burn is set to occur at the next approaching apsis, which can be the periapsis or the apoapsis. When the burn happens, the effect happens on the opposite apsis. So for modifying both apsides, two burns are required. The program takes all that into account, and only ends its execution after the target conditions are met.

Please note that this program assumes that the CSM RCS system is activated. Refer to Section 1.3 for the checklist on this procedure.

2.1 - Program reference

Section 2.0 provided a description of what each program does, as well as some details of the logic behind them. This section will provide a description of the interface used. What displays mode will be used, what they mean, what format the data displayed is in, what is the expected format of the data input and so on. This is basically a walkthrough of each program use.

The notation used will be same as the used in the previous section, i.e. in V37N01E:
- “V” means VERB key
- “37” is the VERB code
- “N” means NOUN key
- “01” is the noun code
- “E” means the ENTR key
The keys should be pressed in that sequence.

Again, the remarks mean the same. If “CSM specific”, it’s only available in the CM AGC. If “LM Specific”, only available in the LM AGC, and if no remark, available for both AGC.

Also, the same note regarding time acceleration usage:
During execution of the programs, except Idling (P00) and Standby (P06) ones, time acceleration use is strongly advised against. Even use of 10x acceleration can cause loss of control and subsequent tumbling.

TLI burn monitor - P15 - CSM Specific

For a better understanding of this program, be sure to read the P15 description in Section 2.0.

To execute: V37N15E
At execution, the display will change to V06N33:

V06N33	**R1**	**Countdown time (hours)**	**00XXX hours**
	R2	**Countdown time (minutes)**	**000XX mins**
	R3	**Countdown time (seconds * 100)**	**0XX.XX secs**

To change R1, use V21E
To change R2, use V22E
To change R1, R2 and R3, use V25E
Press the PRO key to proceed

Now, the display will go into V06N14:

V06N14	**R1**	**Delta V for TLI burn**	**XXXXX m/s**

To change, use V21E
Press PRO to proceed

Now, it will go into V06N95:

V06N95	**R1**	**Time to ignition (TIG)**	**XX XX min/sec**
	R2	**TLI burn Delta V**	**XXXXX m/s**
	R3	**Engine cut-off velocity**	**XXXXX m/s**

No input is taken at this point.
To update data roughly 10 times per second, use V16E

At TIG - 1 min 45 sec - the display will blank for a brief moment. When it returns, automatic switch to V16N95
At TIG - 1 min 30 sec – the SIV-B prograde orientation begins.
At TIG the V16N95 will change a little, so:

	R1	Countdown to engine shut off	XX XX min/sec
	R2	Remaining Delta V	XXXXX m/s
	R3	Cut off velocity	XXXXX m/s

No input taken at this point.

After engine shut off, R1 will be +00 00, and to end the program execution (actually there's nothing more for it to do), press the PRO key. The display will blank and then flash the familiar V37.

Powered Ascent - P12 - LM Specific

For a better understanding of this program, be sure to read the P12 description in Section 2.0.

Execution: V37N12E
At execution, the display will change to V06N76 mode.

V06N76	R1	Insertion downrange (horizontal) velocity	XXXXX m/s
	R2	Insertion radial (vertical) velocity	XXXXX m/s
	R3	Launch azimuth	XXX.XX degs

To change R3, use V23E
Note: remember the 26 degrees difference limit for the azimuth.
Press PRO to proceed

Now, the mode will be changed to V06N33:

V06N33	R1	Countdown time (hours)	00XXX hours
	R2	Countdown time (minutes)	000XX mins
	R3	Countdown time (seconds * 100)	0XX.XX secs

To change R1, use V21E
To change R2, use V22E
To change R1, R2 and R3, use V25E
Press the PRO key to proceed

At TIG - 35 secs - the display will blank
At TIG - 30 secs - the display will come back, this time in mode V50N25:

V50N25	R1	Checklist code	XXXXX code

Press PRO to proceed.

R1 will be displaying 00203, which is a code to remind that the guidance should be set to auto. It is automatically set, so at this point just press PRO. Note that if PRO isn't pressed within 30 seconds (which is the time left for lift-off), the lift-off will be canceled and the program will end its execution.

The display will then go into V16N74

V16N74	R1	Time to lift off	XX XX min/sec
	R2	Angle to desired azimuth	XXX.XX degs
	R3	Desired azimuth	XXX.XX degs

No input taken.

Remember that other noun codes can be chosen at any time after data input.
From now on, the countdown will reach zero and lift off will occur. Program execution will end when the orbit insertion conditions are met.

Orbit altitude change - P33 - CSM Specific

For a better understanding of this program, be sure to read the P33 CSM description in Section 2.0.

To execute: V37N33E
The display will then go to V06N44:

V06N44	**R1**	**Desired apogee (meters / 100)**	**XXXX.X km**
	R2	**Desired perigee (meters / 100)**	**XXXX.X km**

To change R1, use V21E
To change R2, use V22E
To change R1 and R2, use V24E
Press PRO to proceed

Now the display will change to V06N95, for the first burn:

V06N95	**R1**	**Time to ignition (TIG)**	**XX XX min/sec**
	R2	**Burn Delta V**	**XXXXX m/s**
	R3	**Engine cut-off velocity**	**XXXXX m/s**

No input taken at this point.

Important: make sure to have the SPS DIRECT switch in panel 1 activated.

After the first burn is completed, the display will go into V06N95 again, this time displaying the data for the second burn. If a countdown is desired, V16E can be used.

When the second burn ends, the program execution does the same. Then the familiar flashing V37 will display.

2.2 - General program use

Up to now, all the currently implemented programs have been described, but when should they be used? This section is aimed at answering this question, although not in an extensive manner, as it's merely an appendix to the data contained in this document.

Remember that for running a program, V37NXXE, with XX being the program number.

To begin everything, actually you need to enter just P01, the other ones will be loaded automatically as the process develops
Program sequence:
P01 - Manual load through V37N01E
P02 - Loaded by P01
P11 - Loaded by P02

After P11 ends, orbit has been achieved and the next program to run, at the appropriate time is the TLI program.

TLI burn:
P15 - Load manually through V37N15E

When P15 ends the Apollo spacecraft is already en route to the.

Currently for landing at the moon there's no auto-pilot.

Then at the LM AGC, from lunar surface to rendezvous with the CSM:
P12 - Load manually with V37N12E

For the Earth's atmosphere reentry, there's no auto-pilot implemented also. So this would be pretty much the end of program usage.

Section 3 - AGC functions listing

3.0 - List of verb codes

A list of the currently implemented verb codes can be found below.

VERB	DESCRIPTION
01	Display contents of erasable memory location (with NOUN 02)
03	Octal display in R1
04	Octal display in R2
05	Octal display in R1, R2 and R3
06	Decimal data display
11	Monitor contents of erasable memory (with NOUN 02)
16	Decimal data monitor
21	Data entry in R1
22	Data entry in R2
23	Data entry in R3
24	Data entry in R1 and R2
25	Data entry in R1, R2 and R3
33	Proceed without data
34	Terminate program
37	Run program
46	Saturn V launch auto-pilot toggle on/off
69	Restart the AGC
75	Force run launch program (P11)
82	Orbit information display during launch
91	Memory checksum display

3.1 - List of implemented noun codes

Below is a list of all the noun codes available for use. They are split into 3 groups:

- **Common - Available for both the CM and LM AGC**
- **CSM specific - Available only for the CM AGC.**
- **LM specific - Available only for the LM AGC.**

Common nouns

09	R1	Program alarms	XXXXX octal
	R2	Program alarms	XXXXX octal
	R3	Program alarms	XXXXX octal
16	R1	Target Roll	XXX.XX deg (+ right)
	R2	Target Pitch	XXX.XX deg
	R3	Target Yaw	XXX.XX deg
17	R1	Current bank	XXX.XX deg (+ right)
	R2	Current pitch	XXX.XX deg
	R3	Current heading	XXX.XX deg
28	R1	Current Angle of Attack (relative to flight path)	XXX.XX deg
	R2	Current slip angle (relative to flight path)	XXX.XX deg (+ right)
29	R1	Desired azimuth	XXX.XX deg
32	R1	Time from periapsis	00XXX hours
	R2	Time from periapsis	000XX min
	R3	Time from periapsis	0XX.XX sec
33	R1	Time to burn	00XXX hours
	R2	Time to burn	000XX min
	R3	Time to burn	0XX.XX sec
34	R1	Time of Next Event	00XXX hours
	R2	Time of Next Event	000XX min
	R3	Time of Next Event	0XX.XX sec
35	R1	Time to Next Event	00XXX hours
	R2	Time to Next Event	000XX min
	R3	Time to Next Event	0XX.XX sec
38	R1	Time since AGC startup	00XXX hours
	R2	Time since AGC startup	000XX min
	R3	Time since AGC startup	0XX.XX sec
42	R1	Apocenter altitude	XXX.XX km
	R2	Pericenter altitude	XXX.XX km
	R3	Absolute value of Delta V	XXXXX m/s
43	R1	Latitude	XXX.XX deg (+ north)
	R2	Longitude	XXX.XX deg (+ west)
	R3	Altitude	XXXX.X km
44	R1	Desired apogee (meters / 100)	XXXX.X km
	R2	Desired perigee (meters / 100)	XXXX.X km

List of common nouns

46	R1	Target Delta V	XXXXX m/s
	R2	Remaining Delta V	XXXXX m/s
	R3	Time to ignition	XX XX min/sec
73	R1	Altitude	XXXXX km
	R2	Current velocity	XXXXX m/s
	R3	Flight path angle (AoA)	XXX.XX deg
81	R1	Desired Delta V X axis (LV)	XXXXX m/s
	R2	Desired Delta V Y axis (LV)	XXXXX m/s
	R3	Desired Delta V Z axis (LV)	XXXXX m/s
82	R1	Desired Delta V X axis (horizon)	XXXXX m/s
	R2	Desired Delta V Y axis (horizon)	XXXXX m/s
	R3	Desired Delta V Z axis (horizon)	XXXXX m/s
95	R1	Time to ignition	XX XX min/sec
	R2	Expected Delta V	XXXXX m/s
	R3	Accumulated Delta V	XXXXX m/s

CSM specific

14	R1	Desired Delta V (TLI burn)	XXXXX m/s
44	R1	(Only available if P11 is running) Apogee	XXXXX km
	R2	(Only available if P11 is running) Perigee	XXXXX km
	R3	Time to fall back to 300 000 ft	XX XX min/sec
62	R1	Absolute velocity	XXXXX m/s
	R2	Vertical velocity	XXXXX m/s
	R3	Altitude	XXXXX km

LM specific

11	R1	Time to apoapsis (CSI TIG)	00XXX hours
	R2	Time to apoapsis (CSI TIG)	000XX min
	R3	Time to apoapsis (CSI TIG)	0XX.XX sec
45	R1	Desired Longitude of Ascending Node (LAN)	
50	R1	Apoapsis	XXX.XX km
	R2	Periapsis	XXX.XX km
	R3	Fuel left	XXX.XX %
74	R1	Time to lift off	XX XX min/sec
	R2	Azimuth difference	XXX.XX deg
	R3	Desired Azimuth	XXX.XX deg
75	R1	Time to CSI burn	XX XX min/sec
	R2	Target LAN	XXX.XX deg
	R3	Desired plane change	00000 deg
76	R1	Insertion downrange (horizontal) velocity	XXXXX m/s
	R2	Insertion radial (vertical) velocity	XXXXX m/s
	R3	Launch azimuth	XXX.XX deg
89	R1	Landing site latitude	XXX.XX deg (+ north)
	R2	Landing site longitude	XXX.XX deg (+ west)
	R3	Landing site altitude	XX.XXX km

3.2 - List of programs

The list below contains all the currently implemented programs.

Also split into 3 groups:

- Common	-	Available for both the CM and LM AGC
- CSM specific	-	Available only for the CM AGC.
- LM specific	-	Available only for the LM AGC.

Common

PROGRAM	DESCRIPTION
00	AGC Idle
06	AGC Standby

CSM specific

PROGRAM	DESCRIPTION
01	Pre-launch IMU alignment
02	Pre-launch setup
11	Saturn V launch control
15	TLI burn monitor
33	Orbit altitude change

LM specific

PROGRAM	DESCRIPTION
11	Powered Ascent

Section 4 - Other

4.0 - Change log

For this version, 2.0, I basically used the already existing AGC code authored by Mark Grant, and added the following things.

- LMAAP V4:
This is the Lunar Module Ascent Auto-Pilot I have developed. The version included with this release is the latest, Version 4. It is implemented as the P12 in the LM AGC.

- New noun codes. These include:
Noun 16, Noun 17, Noun 28, Noun 32, Noun 42, Noun 46, Noun 81 and Noun 82 for both the CM and LM AGC
Noun 11, Noun 45, Noun 74, Noun 75 and Noun 76 for the LM AGC

As well as some other minor code modifications.

4.2 - Credits

Jean-Luc Rocca-Serra	**-**	**Original NASSP code**
Mark Grant	**-**	**New COSTAM code and most of the AGC**
Moonwalker	**-**	**Control panels**
Chris Knestrick	**-**	**Some guidance code and CDK library**
Rodrigo R. Mercê B. Maia	**-**	**AGC upgrades to version 2.0**
Eric Weber	**-**	**On-line HTML help file**

If you have helped develop the wonderful package NASSP/NCPP 6.2 is, and your name has been left out, please contact me and I will as soon as possible add you name to this list.

I can be contacted at the following e-mails:

rmaia@extreme-aero.com.br
rmaia3d@ibestvip.com.br