P00—LGC IDLING PROGRAM

Purpose:

1. To maintain the LGC in a condition of readiness for entry into other programs.
2. To update the CSM and LM state vectors every four time steps.

Assumptions:

1. This program is automatically selected by V96E, which may be done during any program. State vector integration is permanently inhibited following V96E. Normal integration functions will resume after selection of any program or extended verb. P00 integration will resume when P00 is reselected. Usage of V96 can cause incorrect W-matrix and state vector synchronization.
2. Program changes are inhibited during integration periods and Program Alarm 1520_8 will occur if a change is attempted when inhibited.

Sequence of Events:

V37E00E			
V06N38E		Optional Display.	
	V06N38	Time of State Vector Being Integrated	00XXX. h 000XX. min 0XX.XX s

P06—LGC POWER DOWN PROGRAM

Purpose:

1. To transfer the LGC from the Operate to the Standby program.

Assumptions:

1. If the computer power is switched off, the LGC Update program (P27) would have to be performed to update the LM and CSM state vectors and computer clock time.
2. The LGC is capable of maintaining an accurate value of ground elapsed time (GET) for only 23 hours when in the Standby mode. If the LGC is not brought out of the standby condition to the running condition at least once within 23 hours, the LGC value of GET must be updated.

Sequence of Events:

V37E06E			
	Flashing V50N25	Checklist Code Power Down LGC	0062 CB(11) IMU Operate-Open (No DAP light on)
PRO		Standby light — on	
PGNS Turn On			CB(11) IMU Operate-Close
Standby light — on. PRO until Standby light off. No Att light — on (90 seconds)			
V37E00E		Program P00 Chosen	

P12—POWERED ASCENT PROGRAM

Purpose:

1. To control the PGNS during countdown, ignition, thrusting, and thrust termination of PGNS controlled APS powered ascent maneuver from the lunar surface.

Assumptions:

1. The LGC has stored injection values which define an ascent trajectory that will result in an orbit coplanar with the CSM orbit and an apolune of 30 nmi. These values at orbit insertion are altitude, distance between the LM and CSM orbital planes, LM vertical (V(R)), LM horizontal (V(Y)), and LM downrange (V(Z)) velocities. All altitudes are measured with respect to the LGC stored landing site vector.

   The predefined ascent trajectory may be partially modified during this program by the astronaut.

2. The PGNS will control the LM ascent maneuver such that the LM injection velocity is in the CSM orbital plane or parallel to it at a distance specified by the astronaut inserted crossrange. The injection conditions can be modified by changing the nominal downrange and radial velocities displayed.

   Crossrange should not be specified so that the ascent trajectory crosses through the CSM orbital plane.

3. Engine ignition may be slipped beyond TIG (AS) if desired by the crew or if the state vector integration cannot be completed in time. Variation of the time of ascent ignition (TIG(AS)) changes the relative phasing of the ascent trajectory with respect to the CSM and alters the resultant LM orbit.

4. The initial period of the ascent trajectory consists of two phases:

   a. Vertical Rise Phase. From TIG until the LM radial velocity (V(R)) exceeds 40 ft/s. During this phase, the PGNS holds the LM attitude with the +X axis parallel to the LM position vector at TIG. At TIG, the PGNS commands the LM around its X axis (yaw) until the LM +Z axis points downrange.

   b. Pitchover Phase. When V(R) exceeds 40 ft/s. During this phase, the PGNS commands the LM to pitch down (about the Y axis) an amount defined by the guidance equations.

5. Normally, the Lunar Surface Align program (P57) has been completed and leaves the IMU aligned at a known orientation.

6. The inertial velocity Y axis will be displayed on the lateral velocity cross pointer and the forward velocity cross pointer will be zeroed during ascent.

7. The X-axis override option provides the crew with the ability to exercise manual control about the LM X axis with the attitude controller even though the PGNS Attitude Control mode is Auto. When the controller returns to detent, the DAP damps the yaw rate, stores the yaw attitude when the rate is damped, and then maintains that attitude.

   This option is inhibited from TIG(AS) until 12 seconds after V(R) equals 40 ft/s.

8. Either the Load DAP routine (R03) or the Landing Confirmation program has been performed prior to selection of this program. The DAP will be energized when the PGNS Control mode and the Auto Attitude or Attitude Hold Control mode have been selected. If this occurs prior to the PGNS autocheck in this program, the attitude errors will be zeroed and the attitude deadband will be set to the value specified by P68 (5 degrees) or R03 (astronaut defined), whichever occurred more recently. Immediately prior to the PGNS autocheck, this program will set the attitude deadband to 1 degree.

9. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Auto, the PGNS controls the total vehicle attitude and generates either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise control about only the yaw axis with the ACA (X-axis override) provided the X-axis override capability is permitted (see Assumption 7).

   If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold, the PGNS holds the vehicle attitude and generates either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise manual control about all vehicle axes with the ACA using either the Rate Command or Minimum Impulse mode. However, it is strongly recommended that powered flight not be attempted in the Minimum Impulse mode.

10. Control of the LM RCS and APS is transferred from the PGNS to the Abort Guidance System (AGS) by changing the Guidance Control switch from PGNS to AGS.

    The AGS is capable of taking control of the LM during any phase of the lunar ascent and guiding it to a safe orbit and should be initialized by manual selection of R47, the AGS Initialization routine, prior to the selection of P12.

    If the Guidance Control switch is changed from PGNS to AGS during a thrusting maneuver, the LGC continues computation of position, velocity, desired thrust vector, and desired attitude errors.

11. The PGNS generates two types of errors for display on the FDAI as selected by the astronaut:

    a. Mode 1 – Selected by Verb 61. Autopilot following errors used as a monitor of the DAP's ability to track automatic steering commands.

    b. Mode 2 – Selected by Verb 62. Total attitude errors used to assist the crew in manually maneuvering the vehicle.

12. This program is selected by the astronaut at least 5 minutes prior to ignition.

Sequence of Events:

V37E12E			
	Flashing V06N33	Ascent Time of Ignition	00XXX h 000XX min 0XX.XX s
PRO			V25E Load New TIG
	Flashing V06N76	Desired Downrange Velocity Desired Radial Velocity Crossrange	XXXX.X ft/s XXXX.X ft/s XXXX.X nmi
PRO			V24E Load New Downrange and Radial Velocity or V23E Load New Crossrange.
	Flashing V50N25	Checklist Code	00203
PRO	Switch Guidance Control – PGNS Mode Control – Auto		
	V06N74	Time from Ignition FDAI Yaw – After Vertical Rise FDAI Pitch – After Vertical Rise	XXbXX min/s XXX.XX deg XXX.XX deg
	TFI counts down until TIG -35 seconds, when DSKY blanks for 5 seconds. V06N74 display returns until TIG -5 seconds.		
	Flashing V99N74	Time from Ignition FDAI Yaw – After Vertical Rise FDAI Pitch – After Vertical Rise	XXbXX min/s XXX.XX deg XXX.XX deg
PRO	Astronaut okays ignition. TIG occurs.		
	V06N94	VGX Altitude Rate Computed Altitude	XXXX.X ft/s XXXX.X ft/s XXXXX, ft
N76E			
	V06N76	Desired Downrange Velocity Desired Radial Velocity Crossrange Distance	XXXX.X ft/s XXXX.X ft/s XXXX.X nmi
V16N77E			
	V16N77	Time to Engine Cutoff Velocity Normal to CSM Plane Absolute Value of Velocity	XXbXX min/s XXXX.X ft/s XXXX.X ft/s

KEY REL

Flashing	VGX	XXXX.X ft/s
V16N94	Altitude Rate	XXXX.X ft/s
	Computed Altitude	XXXXX. ft

PRO

Flashing	Velocity to be Gained (X Body)	XXXX.X ft/s
V16N85	Velocity to be Gained (Y Body)	XXXX.X ft/s
	Velocity to be Gained (Z Body)	XXXX.X ft/s

Null Residual Velocities

V83E

Flashing	Range	XXX.XX nmi
V16N54	Range Rate	XXXX.X ft/s
	Theta	XXX.XX deg

KEY REL

Flashing	Velocity to be Gained (X Body)	XXXX.X ft/s
V16N85	Velocity to be Gained (Y Body)	XXXX.X ft/s
	Velocity to be Gained (Z Body)	XXXX.X ft/s

PRO

Flashing V37 Select New Program.

P20—RENDEZVOUS NAVIGATION PROGRAM

Purpose:

1. To control the LM attitude and the Rendezvous Radar (RR) to acquire and track the CSM with the RR while the LM is in flight.
2. To update either the LM or CSM state vector (as specified by the astronaut by DSKY entry) on the basis of RR tracking data or to track the CSM without updating either vehicle state vector.
3. To point the LM optical beacon at the CSM.

Assumptions:

1. The CSM is maintaining a preferred tracking attitude that correctly orients the CSM radar transponder for RR tracking by the LM.
2. At the beginning of the program, the state vector update option is automatically set to the LM. This option may be changed at any time later by one of the following manual entries.
   a. V80E—Update LM state vector,
   b. V81E—Update CSM state vector,
   c. V95E—No state vector update.
3. The initialization of the W matrix is enabled by:
   a. A manual DSKY entry (V93E),
   b. Computer Fresh Start (V36E),
   c. State vector update from the ground (P27) (Except for update of Landing Site vector when the LM is on the lunar surface).
   d. The powered ascent program (P12) invalidates the W matrix used by P22 and causes P20 to reinitialize the W matrix when selected.
4. The RR tracking mark counter counts the number of RR marks processed by the LGC. This counter is zeroed by:
   a. Manual selection of P20/22 (V37E20/22E).
   b. Completion of the State Vector Update Program (P76, P77).

   c. Selection of a new program from a program which had turned on Average G.
   d. Initialization of the W matrix.
   e. Completion of RR search routine (R24) in P20.
5. The crew may manually adjust the LGC-stored values of RR shaft and trunnion bias by a direct load of four registers. However, unless the RR has been jarred, the LGC bias estimate should be more accurate than that from another source.
6. The selection and termination of P20, P22, and P25 are subject to special operating procedures different from all other programs:
   a. Selection
      (1) Always by V37EXXE.
      (2) If any other program is running at the time of P20/22/25 selection the new program will replace the old. This includes P20/22/25 selection whenever either P20, 22, or 25 is running.
      (3) If P20 or P25 is running, selection of any program other than P00 or P22 will result in P20 or P25 continuing and the new program also operating with its number in the DSKY program lights.
      (4) If P20 or P25 is running, selection of P00 or P22 will result in the termination of the old program and operation of the new.
   b. Termination
      (1) By selection of P00, V56E, or by V34E.
      (2) P00 selection will terminate P20, 22, and P25 and any other program in process, and establish P00.
      (3) V56E selection will select the Terminate Tracking routine (R56)) which will terminate only P20 or P25 if either of these programs is running in conjunction with another program. In all other cases R56 will select R00. V56E may be performed any time during P20, 22, or 25 operation.
      (4) The LGC will act upon V34 only in response to a flashing verb-noun. If this display was originated by P20, P22, or P25, V34E will result in an LGC response identical to that of V56E; that is, selection of R56 except in the case of a V06N49 display. If this display was not originated by P20, P22, or P25 (such as P32 running with P20) the LGC will go to R00; however, the program in the background will continue. The new program selected follows the selection rules above.
      (5) Although it is not clearly shown in the program flow below, a V34 response to a priority display must be delayed 2 seconds from display initiation whereas the delay is not necessary for a V56E response. A lamp is lighted in the DSKY for a priority display.
7. The RR Manual Acquisition routine (R23) may be selected only if P20 is not running in conjunction with another program.
8. When P20 is selected any time prior to the landing phase in the lunar mission, this program must be operated in the no update mode to prevent modifying a precision descent targeting for landing.
9. The RSS position and velocity errors computed from the W matrix are available by Extended Verb (V67E). Based upon values in this display and the details of the mission, the astronaut can elect to stop or continue the current navigation procedure or to reinitialize the W matrix and continue navigating. The capability to reinitialize the W matrix is also provided via V67E.
10. State vector integration may be permanently inhibited by V96E. This entry will terminate all present programs and select the LGC Idling program (P00) with the P00 automatic state vector integration permanently inhibited until selection of another program. Use of V96 can cause incorrect W-matrix extrapolation since state vector synchronization is not maintained.

Sequence of Events:

V37E20E
V80E or V81E or V95E
State Vector Option

V80E — LM, V81E — CSM, V95E — None

RR Mode Switch — in LGC

Flashing	RR Trunnion Angle	XXX.XX deg
V50N72	RR Shaft Angle	XXX.XX deg

Verify main lobe lockon

PRO

If RR locked on and tracking. No Track light out, DSKY blanks RR taking marks.

V16N78E

	Range	XXX.XX nmi
	Range Rate	XXXX.X ft/s
	Time from Ignition	XXbXX min/s

KEY REL

Flashing	Delta R	XXX.XX nmi
V06N49	Delta V	XXXX.X ft/s
	Data Source Code	0000X

X = 1 — Range X = 2 — Range Rate X = 3 — Shaft Angle
X = 4 — Trunnion Angle

V32E	Reject partial mark
V34E	Reject total mark
PRO	Update with mark

Flashing	(see above display)
V06N49	

To terminate: V56E or V37E00E or V34E during a flashing display. To keep P20 running in the background: V37EXXE.

If pointing angle greater than 15 degrees.

Flashing	Desired Automaneuver to FDAI Ball	R	XXX.XX deg
V50N18	Angles	P	XXX.XX deg
		Y	XXX.XX deg

Automaneuver: Guidance Control — PGNS
: Mode Control — PGNS Auto

PRO

Monitor maneuver to attitude.
Manual Maneuver: Mode Control — PGNS Attitude Hold, then maneuver.

Flashing	Desired Automaneuver to FDAI Ball	R	XXX.XX deg
V50N18	Angles	P	XXX.XX deg
		Y	XXX.XX deg

When maneuver is complete, by either method, select mode of RR acquisition of CSM.

ENTER

Manual RR acquisition. RR Mode switch: Auto or Slew

Flashing	Checklist Code	00201
V50N25		

ENTER

Choose RR acquisition mode.

Flashing	Checklist Code	00205
V50N25		

Perform manual acquisition of CSM with RR. Slew RR for lockon. RR Mode switch — LGC. No Track light is off. Wait 10 seconds.

PRO

Flashing		
V50N72	Trunnion Angle	XXX.XX deg
	Shaft Angle	XXX.XX deg

Verify main lobe lockon.

PRO

DSKY blanks; No Track light is out; RR taking marks.

Flashing	Delta R	XXX.XX nmi
V06N49	Delta V	XXXX.X ft/s
	Data Source Code (see above)	0000X

V32E	Reject partial mark.
V34E	Reject total mark.
PRO	Update with mark.

Flashing	See above display and response options.
V06N49	

Automatic RR acquisition.

RR Mode switch — LGC.

Flashing	Trunnion Angle	XXX.XX deg
V50N72	Shaft Angle	XXX.XX deg

PRO

No Track light is on.

Flashing	Alarm Code	00503
V05N09		

RR data no good for 30 seconds or Designate fails.

V32E

Redesignate to new V50N72 display.

PRO

Start Search mode.

Flashing		
V16N80	Data Indicator	00000 — Search (42 seconds/scan) 11111 — Lockon
	Angle Between LOS and LM +Z Axis	XXX.XX deg

PRO

When lockon occurs automatically, DSKY blanks; No Track light out; RR taking marks after PRO.

Flashing	Delta R	XXX.XX nmi
V06N49	Delta V	XXXX.X ft/s
	Data Source Code (see above)	0000X

V32E	Reject partial mark.
V34E	Reject total mark.
PRO	Update with mark.

To terminate: V56E or V37E00E, or V34E during a flashing display.

To keep P20 running in the background: V37EXXE.

P21—GROUND TRACK DETERMINATION

Purpose:

1. To provide astronaut with details of his ground track.

Assumptions:

1. Vehicle whose ground track parameters are calculated remains in freefall from start of program until T LAT/LONG.
2. Program may be selected while LM is either in earth or lunar orbit to define ground track of either LM or CSM.

P21 (continued)

Sequence of Events:

V37E21E

Flashing	Option Code ID	00002
V04N06	Vehicle Code	0000X (1—LM 2—CSM)

V22EXXE. Key in vehicle desired.

PRO

Flashing	Time of LAT/LONG	00XXX. h
V06N34		000XX. min
		0XX.XX s

V25E. Load desired time. (time = 0 specifies present time)

PRO

Flashing	Ground Track Latitude	XXX.XX deg (+ north)
V06N43	Ground Track Longitude	XXX.XX deg (+ east)
	Altitude Above Ground	XXXX.X nmi

N91E

Flashing	Altitude	XXXXXb. nmi
V06N91	Velocity	XXXXX. ft/s
	Flight Path Angle	XXX.XX deg

KEY REL

Flashing	Ground Track Latitude	XXX.XX deg (+ north)
V06N43	Ground Track Longitude	XXX.XX deg (+ east)
	Altitude Above Ground	XXXX.X nmi

V32E

Flashing	Repeat program from Time of LAT/
V06N34	LONG with new loaded time.

or

PRO

Flashing	Select New Program.
V37	

P22—LUNAR SURFACE NAVIGATION PROGRAM

Purpose:

1. To control the Rendezvous Radar (RR) to acquire and track the CSM while the LM is on the lunar surface.
2. To update the CSM state vector on the basis of RR tracking data.
3. To track the CSM without updating either vehicle state vector.

Assumptions:

1. Normally the Lunar Surface Alignment program (P57) would be completed before using P22.
2. The CSM may be above or below the horizon, outside the available RR coverage sector, or outside the allowable RR coverage sector.

   The program will always track the CSM with the radar in Mode 2, whose available coverage is always less than horizon to horizon.
3. The CSM is maintaining a preferred tracking attitude that correctly orients the CSM transponder for RR tracking of the LM.

P22 (continued)

4. At the beginning of the program the state vector update option is automatically set to the CSM, which may be inhibited at any time and later restored by the following manual entries:
   a. V81E — Update CSM state vector.
   b. V95E — No state vector update.
5. The initialization of the W matrix is enabled by:
   a. A manual DSKY entry (V93E).
   b. Computer FRESH START (V36E).
   c. State vector update from the ground (P27).
6. The RR tracking mark counter counts the number of RR marks processed by the LGC. This counter is zeroed:
   a. By manual selection of P20/P22 (V37E20/22E)
   b. Completion of the State Vector Update program (P76/P77).
   c. Selection of a new program from a program which had turned on Average G.
   d. Initialization of the W matrix (Assumption 5).
7. The RSS position and velocity errors computed from the W matrix are available by Extended Verb (V67E). Based upon values in this display and the details of the mission, the astronaut can elect to stop or continue the current navigation procedure or to reinitialize the W matrix and continue navigating. The capability to reinitialize the W matrix is also provided via V67E.
8. The selection and termination of P20, P22, and P25 are subject to special operating procedures different from all other programs:
   a. Selection
      (1) Always by V37EXXE.
      (2) If any other program is running at the time of P20/22/25 selection the new program will replace the old. This includes P20/22/25 selection whenever either P20, 22, or 25 is running.
      (3) If P20 or P25 is running, selection of any program other than P00 or P22 will result in P20 or P25 continuing and the new program also operating with its number in the DSKY program lights.
      (4) If P20 or P25 is running, selection of P00 or P22 will result in the termination of the old program and operation of the new.
   b. Termination
      (1) By selection of P00, V56E, or by V34E.
      (2) P00 selection will terminate P20, P22, and P25 and any other program in process and establish P00.
      (3) V56E selection will select the Terminate Tracking routine (R56) which will terminate only P20 or P25 if either of these programs is running in conjunction with another program. In all other cases R56 will select R00. V56E may be performed any time during P20, 22, or 25 operation.
      (4) The LGC will act upon V34E only in response to a flashing verb-noun. If this display was originated by P20, 22, or 25, V34E will result in an identical LGC response to that of V56E; selection of R56.

      If this display was not originated by P20, 22, or 25 (such as P32, while running with P20) the LGC will go to R00; however, the program in the background will continue. The new program selected follows the selection rules shown above.

      (5) Although it is not clearly shown in the program flow below, a V34 response to a priority display must be delayed 2 seconds from display initiation whereas the delay is not necessary for a V56E response. A lamp is lighted on the DSKY for a priority display.
9. State vector integration may be permanently inhibited by V96E. This entry terminates all present programs and selects the LGC Idling program (P00) with the P00 automatic state vector integration permanently inhibited until selection of another program. Use of V96 can cause incorrect W-matrix initialization because state vector synchronization is not maintained.

P22 (continued)

Sequence of Events:

V81E CSM state vector update allowed
or
V95E No update of either state vector allowed.

V37E22E

	Flashing V04N06	Option Code ID	00012 (CSM orbit option)
		Option	0000X (1—No orbit change 2 — Change orbit to passover LM)

V22E load desired option

PRO

00002 Option Only	Flashing V06N33	Time of Ascent Ignition	00XXX. h 000XX. min 0XX.XX s

If range is greater than 400 nmi and range rate is greater than 0, V56E — exit P22. If range is greater than 400 nmi and range rate is less than 0 (closing) wait until range is less than 400 nmi.

PRO

	V16N54E	Range	XXX.XX nmi
		Range Rate	XXXX.X ft/s
		Theta	XXX.XX deg

Automatic Acquisition: RR Mode Switch — LGC; No Track light — out; DSKY — blanks; RR taking marks. (P22 runs in background.)

	V16N78E	Range	XXX.XX nmi
		Range Rate	XXXX.X ft/s
		Time from Ignition	XXbXX min/s

KEY REL

	V16N72E	RR Trunnion Angle	XXX.XX deg
		RR Shaft Angle	XXX.XX deg

KEY REL

	Flashing V06N49	Delta Range	XXX.XX nmi
		Delta Velocity	XXXX.X ft/s
		Radar Data Source Code	0000X (X = 1 range) (X = 2 range rate)

V32E

Reread RR. Flashing V06N49 display repeats. Monitor display, PRO when desired to update state vectors.

PRO

Update — DSKY blanks; RR taking marks; P22 runs in the background.

No Track light is on. RR not tracking.

	Flashing V05N09	Alarm Code	00503 (RR designate fail)
ENTER		Redesignate to Automatic Acquisition.	
or V56E		Terminate	
or PRO		Search.	
	Flashing V16N80	Data Indicator	00000 Search (42 seconds/scan) 11111 Lockon
		Angle Between LOS & LM +Z Axis	XXX.XX deg

PRO

When lockon occurs, return to Automatic Acquisition above.

P25—PREFERRED TRACKING ATTITUDE PROGRAM

Purpose:

1. To compute the preferred tracking attitude of the LM which enables CSM tracking of the beacon and perform the maneuver to that attitude.

Assumptions:

1. During the Rendezvous Navigation program (P20) the LM attitude control is intimately associated with the Rendezvous Radar (RR). Should a RR malfunction preclude correct operation of P20, this program (P25) should be selected to provide a LM preferred tracking attitude.
2. The preferred tracking attitude is defined as follows:
   a. The LM +Z axis is aligned along the LOS to the CSM.
   b. The roll attitude (about LM +Z axis) is unconstrained and is defined as necessary to avoid gimbal lock.
3. Normally the IMU would be on and the IMU Orientation Determination program (P51) completed before using P25. A preferred orientation is not required for this program because the Attitude Maneuver routine (R60) can always calculate a vehicle orientation about the LM +Z axis that can avoid gimbal lock for any IMU inertial orientation.
4. The LM tracking beacon field of view is a 30-degree half-angle cone with the cone axis parallel to the LM +Z axis.
5. The selection and termination of P20, P22, and P25 are subject to special operating procedures different from all other programs.
   a. Selection
      (1) Always by V37EXXE.
      (2) If any other program is running at the time of P20/22/25 selection the new program will replace the old. This includes P20/22/25 selection whenever either P20, 22, or 25 is running.
      (3) If P20 or P25 is running, selection of any program other than P00 or P22 will result in P20 or P25 continuing and the new program also operating with its number in the DSKY program lights.
      (4) If P20 or P25 is running, selection of P00 or P22 will result in the termination of the old program and operation of the new.
   b. Termination
      (1) By selection of P00, V56E, or by V34E.
      (2) P00 selection will terminate P20, 22, and 25 and any other program in process and establish P00.
      (3) V56E will select the Terminate Tracking routine (R56) which will terminate only P20 or P25 if either of these programs is running in conjunction with another program. In all other cases R56 will select R00. V56E may be performed any time during P20, 22, or 25 operation.
      (4) The LGC will act upon V34E only in response to a flashing verb-noun. If this display was originated by P20, 22, or 25, V34E will result in an identical LGC response to that of V56E; that is, selection of R56. If this display was not originated by P20, 22, or 25 (such as P32, while running with P20) the LGC will go to R00. However, the program in the background will continue. The new program selected follows the selection rules above.

Sequence of Events:

V37E25E

When attitude error is greater than 15 degrees.

	Flashing V50N18	Desired Automaneuver FDAI Angles	R XXX.XX deg P XXX.XX deg Y XXX.XX deg

For Automaneuver: Guidance Control — PGNS
Mode Control — PGNS Auto

PRO

For Manual Maneuver: Guidance Control — PGNS
Mode Control — PGNS Attitude Hold and then maneuver

P25 (continued)

Flashing V50N18	Desired Automaneuver FDAI Angles	R XXX.XX deg P XXX.XX deg Y XXX.XX deg

ENTER

P25 continues in background until terminated by V56E.

P27—LGC UPDATE

Purpose

1. To enter data into the LGC via the digital uplink or by crew input via the DSKY.

Assumptions:

1. LGC updates are of four categories:
   a. Provide a decrement for the LGC clock and the orbital integration state vector time tags, and an increment for TEPHEM (V70).
   b. Provide load capability for a block of sequential erasable locations (1 through 18 whose addresses are specified) (V71).
   c. Provide load capability for individual erasable locations (1 through 9) (V72).
   d. Provide an octal increment for the LGC clock only (V73).
2. The uplink may be blocked by placing the Voice/Off/Voice BU switch to Voice BU.
3. Update is allowed in the LM only when the LGC is in the LGC Idling program (P00). P27 exit is always to P00.

P30—EXTERNAL DELTA V PROGRAM

Purpose:

1. To accept targeting parameters obtained from a source(s) external to the LGC and compute therefrom the required velocity and other initial conditions required by the LGC for execution of the desired maneuver. The targeting parameters inserted into the LGC are the time of ignition (TIG) and the impulsive Delta V along LM local vertical axes at TIG.

Assumptions:

1. The target parameters (TIG and Delta V(LV)) may have been loaded from the ground during a prior execution of P27.
2. The External Delta V flag is set during this program to designate to the thrusting program that External Delta V steering is to be used.
3. The ISS need not be on to complete this program unless the Rendezvous Radar is to be used for automatic state vector updating by the Rendezvous Navigation program (P20).
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 ISS should be in operation and the radar should have been 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.
5. This program is applicable in either earth or lunar orbit.

P30 (continued)

Sequence of Events:

V37E30E

Flashing V06N33	Time of Ignition	00XXX. h 000XX. min 0XX.XX s

V25E Load New TIG

PRO

Flashing V06N81	Components of ΔV (LV)	X XXXX.X ft/s Y XXXX.X ft/s Z XXXX.X ft/s

V25E Load Desired ΔV

PRO

Flashing V06N42	Apocenter Altitude Pericenter Altitude ΔV (Required)	XXXX.X nmi XXXX.X nmi XXXX.X ft/s

PRO

Flashing V16N45	Marks Time Until Next Burn Middle Gimbal Angle	XXXXX marks XXbXX min/s XXX.XX deg

PRO Middle gimbal set to -00002 if REFSMMAT flag is not set.

Flashing V37	Select New Program

P32—LM COELLIPTIC SEQUENCE INITIATION (CSI) PROGRAM

Purpose:

1. To calculate parameters associated with the following concentric flight plan maneuvers: the Coelliptic Sequence Initiation (CSI) and the Constant Delta Altitude maneuver (CDH), for Delta V burns.
2. 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 LM and the CSM is selected to be a prescribed angle (E) from the horizontal plane defined at the active 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 LM horizontal plane 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 nmi (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 modification of Delta V (LV) components may result in an out-of-plane CSI maneuver.

8. 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. The rendezvous tracking mark counter is zeroed by the selection of P20 and after each thrusting maneuver.
9. The ISS need not be on to complete this program unless the Rendezvous Radar is to be used for automatic state vector updating by the Rendezvous Navigation program (P20). P20 will define the status of the ISS.

Sequence of Events:

V37E32E

Flashing V06N11	Time of CSI Ignition/T(APOAPSIS)	00XXX. h 000XX. min 0XX.XX s

V25E Load desired CSI TIG

PRO

If zero or negative time, time of APOAPSIS will be computed and displayed by N11.

PRO

Flashing V06N55	Number of Apsidal Crossings	0000X
	Elevation Angle	XXX.XX deg
	Central Angle of Passive Vehicle	XXX.XX deg

V25E. Load desired data.

Apsidal crossing is the future line of apsis of the active vehicle.

Elevation angle is the angle between the LM/CSM LOS and the LM local horizontal plane. CENTANG is an option code where R3 ≠ 0 specifies TIG(CDH) to occur at N(180) degrees from CSI maneuver and N = number entered in R1.

For CSM solution (P72), angle is between CSM/LM LOS and the CSM horizontal.

PRO

Flashing V06N37	Time of TPI Ignition	00XXX. h 000XX. min 0XX.XX s

V25E Load desired TPI TIG.

PRO

Flashing V16N45	Marks	XXXXX
	Time from Ignition of Next Burn	XXbXX min/s
	Middle Gimbal Angle	-00001

PRO Set Final flag.

V32E continues in program but Final flag is not set. Used when another pass is desired.

Alarm codes 00600 through 00606 may occur. If an alarm occurs, V32E recycles to V06N11 where the input parameters may be adjusted for a new solution.

Flashing V06N75	Delta Altitude (CDH)	XXXX.X nmi
	ΔT (CSI - CDH)	XXbXX min/s
	ΔT (CDH - TPI)	XXbXX min/s

PRO

Flashing V06N81	ΔV_X (LV) for CSI	XXXX.X ft/s
	ΔV_Y (LV) for CSI	XXXX.X ft/s
	ΔV_Z (LV) for CSI	XXXX.X ft/s

V90E To correct for out-of-plane velocity on final pass.

Flashing V06N16	Time of Event	00XXX.h 000XX. min 0XX.XX s

V25E Load desired TIG.

PRO

If zero or negative time, time of APOAPSIS will be computed and displayed by N11.

Flashing V06N90	Out-of-Plane Distance	XXX.XX nmi
	Out-of-Plane Velocity (YDOT)	XXXX.X ft/s
	Psi	XXX.XX deg

Record out-of-plane velocity.

PRO

Flashing V06N81	ΔV_X (LV) for CSI	XXXX.X ft/s
	ΔV_Y (LV) for CSI	XXXX.X ft/s
	ΔV_Z (LV) for CSI	XXXX.X ft/s

V22E Load – YDOT recorded above.

PRO

Flashing V06N82	ΔV_X (LV) for CDH	XXXX.X ft/s
	ΔV_Y (LV) for CDH	XXXX.X ft/s
	ΔV_Z (LV) for CDH	XXXX.X ft/s

PRO If Final flag is set, go to previous flashing V16N45.

Flashing V16N45	Marks	XXXXX.
	Time from Ignition	XXbXX min/s
	Middle Gimbal Angle	XXX.XX deg

Middle gimbal angle (MGA) will be MGA at TGI(CSI).

If the IMU is not aligned, MGA will be -00002.

For CSM solution (P72), MGA is always -00002 on the final pass.

PRO

Flashing V37	Select New Program

P33—LM CONSTANT DELTA ALTITUDE (CDH) PROGRAM

Purpose:

1. To calculate parameters associated with the Constant Delta Altitude maneuver (CDH), for Delta V burns.

Assumptions:

1. This program is based upon previous completion of the Coelliptic Sequence Initiation (CSI) program (P32). Therefore:
   a. At a selected TPI time (now in storage) the line of sight between the LM and the CSM was selected to be a prescribed angle (E) (now in storage) from the horizontal plane defined at the active 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 LM horizontal plane at CSI ignition.
   f. The pericenter altitudes of the orbits following CSI and CDH were computed to be greater than 35,000 ft (lunar orbit) or 85 nmi for earth orbit.
   g. The CSI and CDH maneuvers were assumed to be parallel to the plane of the CSM orbit. However, crew modification of Delta V (LV) components may have resulted in an out-of-plane CSI maneuver.
2. The Rendezvous Radar may or may not be used to update the LM or CSM state vectors for this program. If radar use was 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. The rendezvous tracking mark counter is zeroed by the selection of P20 and after each thrusting maneuver.

P33 (continued)

3. The ISS need not be on to complete this program unless automatic state vector updating is desired by the Rendezvous Navigation program (P20). If selected, P20 will define the status of the ISS.

Sequence of Events:

V37E33E

Flashing V06N13	Time of Ignition (CDH)	00XXX h 000XX min 0XX.XXs

V25E Load desired TIG.

PRO

Flashing V16N45	Marks Time from Ignition Middle Gimbal Angle	XXXXX XXbXX min/s -00001

PRO Set Final flag.

V32E continues in program but Final flag is not set. Used when another pass is desired.

If an alarm occurs, a V32E may be used to recycle the V06N13 and readjust TIG.

Flashing V06N75	Delta Altitude (CDH) ΔT (TPI - CDH) ΔT (TPI - Nom TPI)	XXXX.X nmi XXbXX min/s XXbXX min/s

PRO

Flashing V06N81	ΔV_X (LV) for CDH ΔV_Y (LV) for CDH ΔV_Z (LV) for CDH	XXXX.X ft/s XXXX.X ft/s XXXX.X ft/s

To correct for out-of-plane velocity on final pass.

V90E

Flashing V06N16	Time of Event	00XXX. h 000XX. min 0XX.XX s

V25E Load desired TIG.

PRO

Flashing V06N90	Out-of-plane Distance Out-of-plane Velocity (YDOT) Psi	XXX.XX nmi XXXX.X ft/s XXX.XX deg

Record out-of-plane velocity.

PRO

Flashing V06N81	ΔV_X (LV) for CSI ΔV_Y (LV) for CSI ΔV_Z (LV) for CSI	XXXX.X ft/s XXXX.X ft/s XXXX.X ft/s

V22E Load – YDOT recorded above.

PRO If Final flag is not set, go to previous flashing V16N45 display.

Flashing V16N45	Marks Time from Ignition Middle Gimbal Angle	XXXXX XXbXX min/s XXX.XX deg

Middle gimbal angle (MGA) will be MGA at TIG(CDH).

If the IMU is not aligned, MGA will be -00002.

For CSM solution (P73) MGA is always -00002 on the final pass.

PRO

Flashing V37	Select New Program

P34—LM TRANSFER PHASE INITIATION (TPI) PROGRAM

Purpose:

1. To calculate the required Delta V and other initial conditions required by the LGC for LM execution of the transfer phase initiation (TPI) maneuver. Given:
   a. Time of ignition (TIG(TPI)) or the elevation angle (E) of the LM/CSM 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).

Assumptions:

1. This program is based upon previous completion of the Constant Delta Altitude (CDH) program (P33). Therefore:
   a. At a selected TPI time (now in storage) the line of sight between the LM and the CSM was selected to be a prescribed angle (E) (now in storage) from the horizontal plane defined at the LM position.
   b. The time between CDH ignition and TPI ignition was computed to be greater than 10 minutes.
   c. The variation of the altitude difference between the orbits was minimized.
   d. The pericenter altitudes of the orbits following CSI and CDH were computed to be greater than 35,000 ft (lunar orbit) or 85 nmi (earth orbit).
   e. The CSI and CDH maneuvers were assumed to be parallel to the plane of the CSM orbit. However, crew modification of Delta V (LV) components may have resulted in an out-of-plane CDH maneuver.
2. 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. The rendezvous tracking mark counter is zeroed by the selection of P20 and after each thrusting maneuver.
3. The ISS need not be on to complete this program unless automatic state vector updating is desired by the Rendezvous Navigation program (P20). If selected, P20 will define the status of the ISS.
4. 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 V06 N52.

   The astronaut would 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.

Sequence of Events:

V37E34E

Flashing V06N37	Time of Ignition (TPI)	00XXX. h 000XX. min 0XX.XX s

V25E Load desired TIG.

PRO

Flashing V06N55	Number of Precision Offsets Elevation Angle Central Angle of Passive Vehicle	0000X XXX.XX deg XXX.XX deg

V25E. Load desired data.

Number of precision offsets is an integration code where X = 0 specifies integration of a conic trajectory to generate the target vector and, if X ≠ 0, specifies precision integration to integrate the target vector. If precision integration is desired, X should = 2.

P34 (continued)

Elevation angle (E) is the angle between the LM/CSM LOS and the LM local horizontal at TIG(TPI). E should be = +00000 if E is to be computed for the specified TIG.

For CSM solution (P74) the angle is between the CSM/LM LOS and the CSM local vertical at TIG.

PRO

Flashing	Marks	XXXXX
V16N45	Time from Ignition	XXbXX min/s
	Middle Gimbal Angle	-00001

V32E continues the program but Final flag is not set. Used when another pass is desired.

PRO Set Final flag.

If elevation angle for given TIG is to be computed.

Flashing	Same as N55 above except elevation angle has been computed.	
V06N55		

TIG for given elevation angle if elevation angle above was ≠ 0.

Flashing	Time of Ignition	00XXX. h
V06N37		000XX. min
		0XX.XX s

PRO

Flashing	Pericenter Altitude	XXXX.X nmi
V06N58	Delta V (TPI)	XXXX.X ft/s
	Delta V (TPF)	XXXX.X ft/s

PRO

Flashing	ΔV_X (LV) for TPI	XXXX.X ft/s
V06N81	ΔV_Y (LV) for TPI	XXXX.X ft/s
	ΔV_Z (LV) for TPI	XXXX.X ft/s

PRO

Flashing	Marks	XXXXX
V16N45	Time from Ignition	XXbXX min/s
	Middle Gimbal Angle	XXX.XX deg

Middle Gimbal Angle (MGA) will be MGA at TIG (TPI).
If the IMU is not aligned, MGA will be -00002.
For CSM solution (P74) MGA is always -00002 on final pass.

PRO

Flashing	Select New Program
V37	

P35—LM TRANSFER PHASE MIDCOURSE (TPM) PROGRAM

Purpose:

1. To calculate the required Delta V and other initial conditions required by the LGC for LM execution of the next midcourse correction of the transfer phase of an active LM rendezvous.

Assumptions:

1. The ISS need not be on to complete this program unless automatic state vector updating is desired by the Rendezvous Navigation program (P20). If selected, P20 will define the status of the ISS.

P35 (continued)

2. 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. The rendezvous tracking mark counter is zeroed by the selection of P20 and after each thrusting maneuver.
3. The time of intercept (T(INT)) was defined by previous completion of the Transfer Phase Initiation (TPI) program (P34) and is presently available in LGC storage.
4. 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 V06 N52.

   The astronaut would 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.

Sequence of Events:

V37E35E

Flashing	Marks	XXXXX
V16N45	Time from Ignition	XXbXX min/s
	Middle Gimbal Angle	-00001

Middle Gimbal Angle (MGA) is -1 until the final pass through the program.

PRO

Flashing	ΔV_X (LV) for TPM	XXXX.X ft/s
V06N81	ΔV_Y (LV) for TPM	XXXX.X ft/s
	ΔV_Z (LV) for TPM	XXXX.X ft/s

PRO

Flashing	Marks	XXXXX
V16N45	Time from Ignition	XXbXX min/s
	Middle Gimbal Angle	XXX.XX deg

Middle Gimbal Angle (MGA) will be MGA at TIG (TPM).

If the IMU is not aligned, MGA will be -00002.

For CSM solution (P75) MGA is always -00002 on final pass.

PRO

Flashing	Select New Program
V37	

P40—DPS PROGRAM

Purpose:

1. To compute a preferred IMU orientation and a vehicle attitude for a LM DPS thrusting maneuver and to maneuver the vehicle to that attitude.
2. To contol the PGNS during countdown, ignition, thrusting, and thrust termination of a PGNS controlled DPS maneuver.

Assumptions:

1. The target parameters have been calculated and stored in the LGC by prior execution of a prethrusting program.
2. The required steering equations are identified by the prior prethrust program, which either reset ("ASTEER") or set (External Delta V) the External V flag. For External Delta V steering, VG is calculated once for the specified time of ignition. Thereafter both during DPS thrusting and until the crew notifies the LGC that RCS trim thrusting has been completed, the LGC updates VG only as a result of accelerometer inputs.

P40 (continued)

For steering control when using "ASTEER," the velocity required is calculated from the most recent intercept trajectory semimajor axis. The Lambert routine periodically recomputes the intercept trajectory semimajor axis for the "ASTEER" calculations. The interval between Lambert solutions is controlled by an erasable load value (UT).

3. Engine ignition may be slipped beyond the established TIG if desired by the crew, or if state vector integration cannot be completed in time.

4. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Auto, the PGNS controls the total vehicle attitude and generates either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise control about only the yaw axis with the ACA (X-axis override) provided the X-axis override capability is permitted.

   If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold, the PGNS holds the vehicle attitude and generates either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise manual control about the vehicle axes with the ACA using either the Rate Command or Minimum Impulse mode. However, it is strongly recommended that powered flight not be attempted in the Minimum Impulse mode.

   If the Guidance Control switch is changed from PGNS to AGS during a thrusting maneuver, the LGC continues computation of position, velocity, desired thrust vector, and desired attitude errors.

5. The PGNS generates two types of errors for display on the FDAI as selected by the astronaut.

   a. Mode 1 — Selected by Verb 61. Autopilot following errors used as a monitor of the DAP's ability to track automatic steering commands.

   b. Mode 2 — Selected by Verb 62. Total attitude errors used to assist the crew in manually maneuvering the vehicle.

6. The X-axis override option provides the crew with the ability to exercise manual control about the LM X axis with the attitude controller even though the PGNS Attitude Control mode is Auto. When the controller is returned to detent the DAP damps the yaw rate, stores the yaw attitude when the yaw rate is damped, and then maintains that attitude.

   The X-axis override option is always available to the crew. However, it should not be exercised when the LGC is specifying a desired yaw attitude; that is, during the attitude maneuver to the thrusting attitude.

7. When the thrust/translation controller is set to minimum thrust position and the LGC throttle command is zero, the DPS will start at 10 percent thrust.

8. The Load DAP Data routine (R03) has been performed prior to selection of this program and the DPS engine gimbal has been previously driven to the correct trim position. If this burn is of sufficient duration that vehicle transients at ignition due to CG/thrust do not affect accomplishment of maneuver aim conditions, then the gimbal need not be driven to the trim position before TIG. Driving the gimbal to the trim position in worst case conditions could require 2 minutes.

9. During DPS burns only, the pitch-roll RCS jet autopilot (U and V jets) may be disabled by (V65) or enabled by (V75). This capability is intended to be used to prevent LM and descent stage thermal constraint violations during CSM-docked DPS burns (P40). The capability exists during P63 and P70 also. Performance of FRESH START (V36E) will always enable the capability in the autopilot.

10. The LGC will neither designate nor read the Rendezvous Radar (RR) during this program.

11. This program should be selected by the astronaut by DSKY entry at least 5 minutes before the estimated time of ignition.

12. The value of Delta V required will be stored in the local vertical coordinate system and is available during this program by keying V06 N81E.

P40 (continued)

Sequence of Events:

V37E40E

	Flashing V50N18	Desired Automaneuver to FDAI Ball Angles	R XXX.XX deg P XXX.XX deg Y XXX.XX deg

Automaneuver: Guidance Control — PGNS
Mode Control — PGNS Auto

PRO

Monitor automatic maneuver to attitude at end of maneuver.

(Flashing) V50N18	Desired Automaneuver to FDAI Ball Angles	R XXX.XX deg P XXX.XX deg Y XXX.XX deg

Manual Maneuver: Guidance Control — PGNS
Mode Control — PGNS Attitude Hold

Maneuver to V50N18 displayed angles.

ENTER

Flashing V50N25	Checklist Code	00203

Please switch to: Guidance Control — PGNS
Attitude Control — Auto
Throttle Switch — Auto

ENTER

V06N40	Time from Ignition (TFI) Magnitude of Velocity to be Gained ΔV (accumulated)	XXbXX min/s XXXX.X ft/s XXXX.X ft/s

TFI counts down until TIG -35 seconds, when DSKY blanks for 5 seconds. V06N40 display returns until TIG -5 seconds.

TIG - 15 seconds. R3 should be less than 00005.
TIG - 7.5 seconds. Verify +X ullage.
TIG -5 seconds

Flashing V99N40	Time from Ignition Magnitude of Velocity to be Gained ΔV (accumulated)	XXbXX min/s XXXX.X ft/s XXXX.X ft/s

PRO Astronaut okays ignition. TIG occurs.

V06N40	Time from Engine Cutoff Velocity to be Gained ΔV (accumulated)	XXbXX min/s XXXX.X ft/s XXXX.X ft/s
Flashing V16N40	Time from Engine Cutoff Velocity to be Gained ΔV (accumulated)	XXbXX min/s XXXX.X ft/s XXXX.X ft/s

Turn off DPS engine:
Push ENG STOP
Switch ENG ARM to OFF

PRO

Flashing V16N85	VG_X (body) VG_Y (body) VG_Z (body)	XXXX.X ft/s XXXX.X ft/s XXXX.X ft/s

Null residual velocities.

PRO

Flashing V37	Select New Program

P41-RCS PROGRAM

Purpose:

1. To compute a preferred IMU orientation and a vehicle attitude for an RCS thrusting maneuver and to perform the vehicle maneuver to that attitude.
2. To provide suitable displays for manual execution of the thrusting maneuver in the Attitude Hold mode.

Assumptions:

1. The target parameters have been calculated and stored in the LGC by prior execution of a prethrusting program.
2. The required steering equations are identified by the prior prethrust program, which either reset ("ASTEER") or set (External Delta V) the External Delta V flag. For External Delta V steering, VG is calculated once for the specified time of ignition. Thereafter until the crew notifies the LGC that RCS thrusting has been completed, the LGC updates VG only as a result of accelerometer inputs.

   For steering control when using "ASTEER," the velocity required is calculated from the most recent intercept trajectory semimajor axis. The Lambert routine periodically recomputes the intercept trajectory semimajor axis for the "ASTEER" calculations. The interval between Lambert solutions is controlled by an erasable load value (UT).
3. RCS ignition may be slipped beyond the established TIG if desired by the crew, or if state vector integration cannot be completed on time.
4. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold, the PGNS holds the vehicle attitude and generates either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise manual control about all vehicle axes with the ACA using either the Rate Command or Minimum Impulse mode. However, it is strongly recommended that powered flight not be attempted in the Minimum Impulse mode.
5. The PGNS generates two types of errors for display on the FDAI as selected by the astronaut.
   a. Mode 1 — Selected by Verb 61. Autopilot following errors used as a monitor of the DAP's ability to track automatic steering commands.
   b. Mode 2 — Selected by Verb 62. Total attitude errors used to assist the crew in manually maneuvering the vehicle.
6. The X-axis override option provides the crew with the ability to exercise manual control about the LM X axis with the attitude controller even though the PGNS Attitude Control mode is Auto. When the controller is returned to detent, the DAP damps the yaw rate, stores the yaw attitude when the yaw rate is damped, and then maintains that attitude.

   The X-axis override option is always available to the crew. However, it should not be exercised when the LGC is specifying a desired yaw attitude; that is, during the attitude maneuver to the thrusting attitude.
7. The Load DAP Data routine (R03) has been performed prior to selection of this program.
8. The LGC will neither designate nor read the Rendezvous Radar (RR) during this program.
9. This program should be selected by the astronaut by DSKY entry at least 5 minutes before the estimated time of ignition.
10. The value of Delta V required will be stored in the local vertical system and is available in this program until Average G turns on by keying in V06N81E.

Sequence of Events

V37E41E

Flashing V50N18	Desired Automaneuver to FDAI Ball Angles	R P Y	XXX.XX deg XXX.XX deg XXX.XX deg

Automaneuver: Guidance Control — PGNS
Mode Control — PGNS Auto

P41 (continued)

Monitor automatic maneuver. At end of maneuver flashing V50N18 display appears.

Manual Maneuver: Guidance Control — PGNS
Mode Control — PGNS Attitude Hold

Maneuver to V50N18 values.

ENTER

V16N85	VG_X (body)	XXXX.X ft/s
	VG_Y (body)	XXXX.X ft/s
	VG_Z (body)	XXXX.X ft/s

Mode Control: Attitude Hold

At TIG - 35 seconds, the DSKY blanks until TIG - 30 seconds and V16N85 display returns.

At TIG - 00 seconds.

Flashing V16N85	VG_X (body)	XXXX.X ft/s
	VG_Y (body)	XXXX.X ft/s
	VG_Z (body)	XXXX.X ft/s

Null components of velocity, when satisfied.

PRO

Flashing V37	Select New Program.

P42—APS PROGRAM

Purpose:

1. To compute a preferred IMU orientation and vehicle attitude for an LM APS thrusting maneuver and maneuver the vehicle to that attitude.
2. To control the S/C during countdown, ignition, thrusting, and thrust termination of a PGNS-controlled APS maneuver.

Assumptions:

1. The target parameters have been calculated and stored in the LGC by prior execution of a prethrusting maneuver.
2. The required steering equations are identified by the prior prethrust program, which either reset ("ASTEER") or set (External Delta V) the External Delta V flag. For External Delta V steering, VG is calculated once for the specified time of ignition. Thereafter both during APS thrusting and until the crew notifies the LGC that RCS trim thrusting has been completed, the LGC updates VG only as a result of accelerometer inputs.

   For steering control when using "ASTEER," the velocity required is calculated from the most recent intercept trajectory semimajor axis. The Lambert routine periodically recomputes the intercept trajectory semimajor axis for the "ASTEER" calculations. The interval between Lambert solutions is controlled by an erasable load value (UT).
3. Engine ignition may be slipped beyond the established TIG if desired by the crew or if state vector integration cannot be completed in time.
4. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Auto, the PGNS controls the total vehicle attitude and generates either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise control about only the yaw axis with the ACA (X-axis override) provided the X-axis override capability is permitted.

P42 (continued)

If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold, the PGNS holds the vehicle attitude and generates either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise manual control about all vehicle axes with the ACA using either the Rate Command or Minimum Impulse mode. However, it is strongly recommended that powered flight not be attempted in the Minimum Impulse mode.

5. The PGNS generates two types of errors for display on the FDAI as selected by the astronaut:
   a. Mode 1 — Selected by Verb 61. Autopilot following errors used as a monitor of the DAP's ability to track automatic steering commands.
   b. Mode 2 — Selected by Verb 62. Total attitude errors used to assist the crew in manually maneuvering the vehicle.
6. The X-axis override option provides the crew with the ability to exercise manual control about the LM X axis with the attitude controller even though the PGNS Attitude Control mode is Auto. When the controller is returned to detent the PGNS damps the yaw rate, stores the yaw attitude when the yaw rate is damped, and then maintains that attitude.

   The X-axis override option is always available to the crew. However, it should not be exercised when the LGC is specifying a desired yaw attitude; that is, during the attitude maneuver to the thrusting attitude.
7. The Load DAP Data routine (R03) may have been performed prior to selection of this program.
8. The LGC will neither designate nor read the Rendezvous Radar (RR) during the program.
9. This program should be selected by the astronaut by DSKY entry at least 5 minutes before the estimated time of ignition.
10. The value of Delta V required will be stored in the local vertical system and is available in this program until Average G turns on by keying V06N81E.

Sequence of Events:

V37E42E

Flashing V50N18	Desired Automaneuver to FDAI Ball Angles	R P Y	XXX.XX deg XXX.XX deg XXX.XX deg

Automaneuver: Guidance Control — PGNS
Mode Control — PGNS Auto

PRO

Monitor automaneuver. At end of maneuver flashing V50N18 display appears.

Manual Maneuver: Guidance Control — PGNS
Mode Control — PGNS Attitude Hold

Maneuver to V50N18 displayed angles.

ENTER

V06N40	Time from Ignition	XXbXX min/s
	Velocity to be Gained	XXXX.X ft/s
	Δ V (accumulated)	XXXX.X ft/s

TFI counts down until TIG - 35 seconds when DSKY blanks for 5 seconds. V06N40 display returns until TIG - 5 seconds.

P42 (continued)

V06N40 Same as above.

TIG - 15 seconds. R3 should be less than 00005.
TIG - 14 seconds. Manual ullage.
TIG - 10 seconds. Stage switch — Fire MASTER ARM — OFF.
TIG - 6 seconds. Verify +X ullage
TIG - 5 seconds.

Flashing V99N40	Time from Ignition	XXbXX min/s
	Magnitude of Velocity to be Gained	XXXX.X ft/s
	Δ V (accumulated)	XXXX.X ft/s

PRO

V06N40	Time from Engine Cutoff	XXbXX min/s
	Magnitude of Velocity to be Gained	XXXX.X ft/s
	Δ V (accumulated)	XXXX.X ft/s
Flashing V16N40	Time from Engine Cutoff	XXbXX min/s
	Magnitude of Velocity to be Gained	XXXX.X ft/s
	Δ V (accumulated)	XXXX.X ft/s

Engine Arm — OFF. Shutdown APS engine.

PRO

Flashing V16N85	ΔV_X (LM body)	XXXX.X ft/s
	ΔV_Y (LM body)	XXXX.X ft/s
	ΔV_Z (LM body)	XXXX.X ft/s

Null residual velocities.

PRO

Flashing V37 Select New Program

P47—THRUST MONITOR PROGRAM

Purpose:

1. To monitor vehicle acceleration during a non-PGNS controlled thrusting maneuver and display Delta V applied to the vehicle by this thrusting maneuver.

Assumptions:

1. This program is normally used during the final phase of the rendezvous. If the crew desires to do any final phase thrusting maneuvers automatically under PGNS control they must be accomplished via selection of the Transfer Phase Initiation (TPI) program (P34) and then the DPS Thrusting program (P40).
2. Range, range rate, and theta may be displayed during this program by calling the Rendezvous Parameter Display routine (R31).
3. This program should be turned on just prior to the planned thrusting maneuver and terminated as soon as possible after the maneuver in order to keep errors associated with Average G integration at a minimum.
4. The Orbit Parameter Display routine (R30) may be called during this program by keying in V82E.

P47 (continued)

Sequence of Events:

V37E47E

Flashing V16N83	ΔV_X (LM body)	XXXX.X ft/s
	ΔV_Y (LM body)	XXXX.X ft/s
	ΔV_Z (LM body)	XXXX.X ft/s

PRO

Flashing V37	Select New Program.

P51—IMU ORIENTATION DETERMINATION PROGRAM

Purpose:

1. To determine the inertial orientation of the IMU using sightings on two celestial bodies with the AOT or a backup optical system.

Assumptions:

1. There are no restraints upon the LM attitude control modes until a PGNS controlled maneuver is called by a program or the crew wishes to manually maneuver the vehicle.
2. Time and RCS fuel may be saved, and subsequent IMU alignment decisions greatly simplified, if this program is performed in such a way as to leave the IMU inertially stabilized at an orientation as close as possible to the optimum orientation sequence followed by future LGC programs.
3. Extended verbs should not be exercised during this program because of possible interference with the AOT Mark routine (R53).

P51 (continued)

Sequence of Events:

V37E51E

Flashing V50N25	Checklist Code	00015

Perform celestial body acquisition.

To coarse align IMU to 0 - 0 - 0

ENTER

V41N22		+ 000.00 deg
		+ 000.00 deg
		+ 000.00 deg

NO ATT light on; FDAI ball torques; NO ATT light off

PRO

Flashing V01N71	Code	00CDE

C — AOT Detent
0—COAS calibration (not allowed), 1—front left, 2—front center, 3—front right, 4—right rear, 5—rear center, 6—rear left, 7—backup optical system—COAS.
DE—Celestial Body Code
00—planet, 01/45—star from code list, 46—sun, 47—earth, 50—moon

V21E. Load desired star code and detent.
If C = 7, COAS to be used in place of AOT for marks.

PRO

Flashing V06N87	Backup Optics LOS Azimuth	XXX.XX deg
	Backup Optics LOS Elevation	XXX.XX deg

V24E. Load correct data +E, +09000E Overhead Window.

PRO

Flashing V54N71	Code	00CDE
	Mark X/Cursor Counter	XXXXX Octal
	Mark Y/Spiral Counter	XXXXX Octal

Code definition as above V01N71 display.

Mark X or Mark Y using cursor and spiral on AOT with stars positioned.

Last mark defined as A = 1 in R2 or R3. To change A = 1 from R2 or R3 or vice versa ENTER.

After first star, terminate marks with PRO and recycle to V01N71 and repeat. After marking on second star,

PRO

Flashing V06N05	Star Angle Difference	XXX.XX deg

V32E

Recycle to start of program with Flashing V50N25 display.

or

PRO

Flashing V37	Select New Program

P52—IMU REALIGN PROGRAM

Purpose:

1. To align the IMU from a "known" orientation to one of four orientations selected by the astronaut using sightings on two celestial bodies with the AOT or a backup optical system.

   a. Preferred Orientation (Option 00001). An optimum orientation for a previously calculated maneuver. This orientation must be calculated and stored by a previously selected program.

   b. Landing Site Orientation (Option 00004)

   X_{SM} = Unit (R_{LS}) Y_{SM} = Unit (Z_{SM} x X_{SM}) Z_{SM} = Unit (H_{CSM} x X_{SM})

   where:

   The origin is the center of the moon. R_{LS} = The position vector of the LM on the lunar surface at a landing site and a time T(align) selected by the crew.

   H_{CSM} = The angular momentum vector of the CSM (R_{CSM} x V_{CSM}).

   A special case of the landing site orientation occurs when T(align) is defined as the time of lunar landing T(land). This case occurs only if T(land) has been defined by the MSFN, transmitted to the crew, and the crew has then defined T(Align) to be T(land) in this program.

   c. Nominal Orientation (Option 00002)

   X_{SM} = Unit (R) Y_{SM} = Unit (V x R) Z_{SM} = Unit (X_{SM} x Y_{SM})

   where:

   R = The geocentric (earth orbit) or selenocentric (lunar orbit) radius vector at time T(align) selected by the astronaut.

   V = The inertial velocity vector at time T(align) selected by the astronaut.

   d. REFSMMAT (Option 00003). A known orientation stored in the LGC at a previous time.

Assumptions:

1. The configuration may be docked (LM/CSM) or undocked (LM alone). The present configuration should have been entered into the LGC by completion of the DAP Data Load routine (R03).
2. There are no restraints upon the LM attitude control modes until a PGNS controlled maneuver is called by a program or the crew wishes to manually maneuver the vehicle. The Guidance Control switch may be at PGNS or AGS and, if at PGNS, the mode may be Auto or Attitude Hold. Prior to PGNS controlled maneuvers the LGC will request the correct mode if it is not in effect. For manually controlled maneuvers the crew must select the correct modes.
3. This program makes no provision for an attitude maneuver to return the vehicle to a specified attitude. Such a maneuver, if desired, must be done manually. An option is provided however to allow pointing of the AOT at astronaut or LGC selected stars either manually by the crew or automatically by an LGC controlled attitude maneuver.
4. An option is provided to realign the IMU to the preferred, nominal, or landing site orientation without making celestial body sightings.
5. Extended verbs should not be exercised during this program because of possible interference with the AOT Mark routine (R53).

Sequence of Events:

V37E52E

	Flashing V04N06	Option Code ID	00001 IMU Alignment Option 0000X

(1—Preferred, 2—nominal, 3—REFSMMAT,
4—landing site)

V22E. Reload desired option.

P52 (continued)

Landing Site option.

PRO

	Flashing V06N34	Time of Landing	00XXX. h 000XX. min 0XX.XX s

V25E. Reload desired landing time.

PRO

	Flashing V06N89	Designated Landing Site Latitude Designated Landing Site Longitude/2 Designated Landing Site Altitude	XX.XXX deg (+ north) XX.XXX deg (+ east) XXX.XX nmi

V25E. Load corrected landing site coordinates.

PRO Go to Preferred option.

Nominal option

Flashing V06N34	Time of Alignment	00XXX. h 000XX. min 0XX.XX s

V25E. Load desired T_{ALIGN}

PRO Go to Preferred option.

Preferred, Nominal, or Landing Site options continue from this display.

PRO

Flashing V06N22	IMU Gimbal Angles at Desired Orientation	OGA IGA MGA	XXX.XX deg XXX.XX deg XXX.XX deg

To maneuver away from gimbal lock, maneuver with hand controller.

V32E

Flashing V06N22	IMU Gimbal Angles at Desired Orientation	OGA IGA MGA	XXX.XX deg XXX.XX deg XXX.XX deg

PRO

Flashing V50N25	Checklist Code	00013

Gyro Torque Only

Mode Control: PGNS — Attitude Hold, V76E — minimum impulse, No DAP light on.

ENTER

V16N20	Present ICDU Angles	OGA IGA MGA	XXX.XX deg XXX.XX deg XXX.XX deg

when torquing complete

Flashing V50N25	Checklist Code	00014

ENTER

No fine alignment desired.

Flashing V37	Select New Program

Normal alignment and realignment

PRO No Attitude light-on — then off

Flashing V50N25	Checklist Code	00015

Select star acquisition mode.

P52 (Continued)

For Cursor/
Spiral Option

After V50N25 display first time.

V32
ENTER

Flashing V01N70	Code	00CDE

C—AOT Detent
0—COAS calibration (not allowed), 1—front left, 2—front center, 3—front right, 4—right rear, 5—rear center, 6—rear left, 7—backup optical system—COAS
DE—Celestial Body Code
00—Planet, 01/45—star from code list, 46—sun, 47—earth, 50—moon.

V21E. Load desired star code.

V32E

Recycle to Flashing V01N70 display above.

PRO

For DE = 00

Flashing V06N88	Celestial Body Vector	.XXXXX .XXXXX .XXXXX

V25E

Load desired vector components.

PRO

Flashing V06N79	Cursor Angle Spiral Angle Detent Code	XXX.XX XXX.XX 0000X

PRO

Flashing V01N71	Code	00CDE

C—AOT Detent Code
0—COAS calibration (not allowed), 1—front left, 2—front center, 3—front right, 4—right rear, 5—rear center, 6—rear left, 7—backup optical system—COAS
DE—Celestial Body Code
00—Planet, 01/45—star from code list, 46—sun, 47—earth, 50—moon.

If DE = 00

Flashing V06N88	Components of Celestial Body Unit Vector	.XXXXX .XXXXX .XXXXX

Verify components of vector.

PRO

Flashing V52/53 N71	Code Cursor Counter Spiral Counter	00CDE XXXXX XXXXX

To redefine star V32E to Flashing V01N71 display.

If this is to be last mark defined, digit A = 1 in R2 or R3.

To change from V52 or V53 to opposite verb, ENTER

For V52 — Position Cursor, then press mark X, Mark Y, or ROD switch.

For V53 — Position Spiral, then press Mark X, Mark Y, or ROD switch.

Flashing V21/22 N79	Load Cursor or Spiral Angle Data in R1/R2 Detent Code	XXX.XX deg XXX.XX deg 0000X
V21 V22	Cursor Data ENTER Spiral Data ENTER	
Flashing V06N79	Cursor Angle Spiral Angle Detent Code	XXX.XX deg XXX.XX deg 0000X

P52 (Continued)

PRO TO

Flashing V52/53 N71 display with appropriate mark counter incremented.

To terminate marking process

PRO after Flashing V52/53 N71 display.

After first star, program recycles to Flashing V01N70 display.

After second star

Flashing V06N05	Star Angle Difference	XXX.XX deg

PRO to accept

Flashing V06N93	Gyro Torquing Angles	X XX.XXX deg Y XX.XXX deg Z XX.XXX deg

To torque

Mode Control (PGNS) — Attitude Hold
V76E — No DAP Light On
PRO

No torque

V32E to Flashing V50N25 display below.

To reject after Flashing V06N05 display.

V32E

Flashing V50N25	Checklist Code	00014

To recheck — PRO then V50N25 display with R1 00015 will appear and recycle through program.

To terminate — ENTER, V77E, No DAP Light OFF

Flashing V37	Choose New Program

Nominal values for N05 display

AOT: 2 stars $\leq |.12^{\circ}|$
: star and planet $\leq |.21^{\circ}|$

COAS: 2 stars $\leq |.71^{\circ}|$
: star and planet $\leq |.73^{\circ}|$

P52 (continued)

For Mark X, Mark Y Option

PRO

Flashing V01N70	Code	00CDE

C—AOT Detent
0—COAS calibration (not allowed), 1—front left, 2—front center, 3—front right, 4—right rear, 5—rear center, 6—rear left, 7—backup optical system—COAS
DE—Celestial Body Code
00—Planet, 01/45—star from code list, 46—sun, 47—earth, 50—moon.

V21E. Load desired star code and detent.

PRO If C=7, COAS to be used.

Flashing V06N87	Backup Optics LOS Azimuth Backup Optics LOS Elevation	XXX.XX deg XXX.XX deg

V24E. Load correct data.

+E, +E for forward window
+E, +9000E, overhead window

If DE = 00

Flashing V06N88	Components of Celestial Body Unit Vector	.XXXXX .XXXXX .XXXXX

V25E. Load desired vector components.

PRO

Flashing V50N18	Desired Automaneuver to FDAI Ball Angles	R XXX.XX deg P XXX.XX deg Y XXX.XX deg

Automaneuver or trim Guidance Control — PGNS
Mode Control (PGNS) — Auto

PRO — Flashing V50N18 display returns after manual maneuver — Mode Control (PGNS) — Attitude Hold maneuver S/C.

When maneuver complete.

ENTER

Flashing V01N71	Code	00CDE

C—AOT Detent
0—COAS calibration (not allowed), 1—front left, 2—front center, 3—front right, 4—right rear, 5—rear center, 6—rear left, 7—backup optical system—COAS
DE—Celestial Body Code
00—Planet, 01/45—star from code list, 46—sun, 47—earth, 50—moon.

For C = 7, COAS to be used.

Flashing V06N87	Backup Optics LOS Azimuth Backup Optics LOS Elevation	XXX.XX deg XXX.XX deg

For DE = 00 Celestial Body

Flashing V06N88	Celestial Body Vector	.XXXXX .XXXXX .XXXXX

P52 (Continued)

PRO

Flashing V54N71	Code X Mark Counter Y Mark Counter	00CDE XXXXX XXXXX

Position S/C and make X, Y, marks using Mark X, Y buttons. No special order required. The last mark defined by digit A in R2 or R3 = 1. To change A-1 for R2 to R3 or R3 to R2, ENTER.

To terminate marking

PRO

If after first star the program recycles to the Flashing V01N70 display.

If after the second star

Flashing V06N05	Star Angle Difference	XXX.XX deg

PRO

To accept

Flashing V06N93	Gyro Torquing Angles	X XX.XXX deg Y XX.XXX deg Z XX.XXX deg

To torque

Mode Control (PGNS) — Attitude Hold
V76E — No DAP Light On
PRO

No torque

V32E to Flashing V50N25 display below

To reject after Flashing V06N05 display

V32E

Flashing V50N25	Checklist Code	00014

To recheck — PRO then V50N25 display with R1 00015 will appear and recycle through program.

To terminate — ENTER, V77E, NO DAP Light.
OFF

Flashing V37	Choose New Program

Nominal values for N05 display

AOT: 2 stars $\leq |.12^{\circ}|$
: star and planet $\leq |.21^{\circ}|$

COAS: 2 stars $\leq |.71^{\circ}|$
: star and planet $\leq |.73^{\circ}|$

P57—LUNAR SURFACE ALIGN PROGRAM

Purpose:

1. While on the surface of the moon to align or realign the IMU to one of three types of orientations:

   a. Landing Site Orientation (Option 4)

   X_{SM} = Unit (R_{LS}) Y_{SM} = Unit ($Z_{SM} \times X_{SM}$) Z_{SM} = Unit ($H_{CSM} \times X_{SM}$)

   where:

   The origin is the center of the moon.

   R_{LS} = The position vector of the LM on the lunar surface at the most recently designated landing site and a time T(align) selected by the crew.

   H_{CSM} = The angular momentum vector of the CSM ($R_{CSM} \times V_{CSM}$).

   b. Preferred Orientation (Option 1)

   An IMU orientation specified by the ground and loaded into the LGC by the LGC Update program (P27). When such an orientation is loaded by the ground the preferred orientation flag will be also set during P27.

   c. REFSMMAT (Option 3).

Assumptions:

1. There are several methods available to the crew for completing an IMU alignment. The resultant accuracy of the IMU to the specified desired orientation (that is, that orientation defined by the final REFSMMAT) is dependent upon the mode of alignment which the crew selects. This selection will be dictated by the circumstances at the time of alignment.
2. The LM has landed on the lunar surface. The LM yaw angle with respect to the inertial orientation of the IMU at landing was not constrained during landing.
3. All possible efforts have been made by the crew to assure that the LM will not shift its position with respect to the lunar surface. No provision has been made to incorporate in the LGC any measurement of LM settling on the lunar surface. However, a shifting of the LM will result in a misaligned IMU only in the case where an alignment is made from a stored LM attitude with respect to the lunar surface (Technique Codes 00000 and 00001) and the IMU is not subsequently aligned by reference to celestial bodies and/or lunar gravity.
4. The ISS is on and may be:
   a. At an inertial orientation "unknown" to the LGC; that is, having been shut down and restarted since landing without subsequent orientation determination.
   b. At an inertial orientation "known" by the LGC; that is, neither gimbal lock nor IMU power interruption has occurred since the last IMU alignment or orientation determination. Therefore the present orientation differs from that stored in REFSMMAT only due to gyro drift and/or the initial misalignment of the IMU to the stored REFSMMAT.
5. Extended verbs should not be exercised during the Lunar Surface Sighting Mark routine (R59) because of possible interference with the AOT Mark routine (R53).
6. The LM attitude with respect to the lunar surface is available in LGC storage; that is, it will have been stored by the Landing Confirmation program (P68). Once this attitude has been stored it will be preserved by the LGC until it is replaced by a more recent value.
7. This program is selected by the astronaut by DSKY entry. It will normally be selected to perform an alignment of the IMU immediately after landing on the lunar surface, prior to selection of the RR Lunar Surface Navigation program (P22), prior to AGS initialization, and approximately 15 minutes prior to ascent. This program may also be used to provide an IMU alignment in time-critical emergencies prior to ascent.

P57 (continued)

8. The DAP should be off during gyro torquing by this program to preclude RCS je firings due to realignment of the IMU causing attitude errors exceeding th maximum deadband.
9. A determination of the LM position vector while on the lunar surface (R_{LS}) can b accomplished only in conjunction with IMU alignment Technique 2 (using AO sightings on two celestial bodies). It is valid only if the lunar gravity vector has bee previously defined during P57, using IMU alignment Technique 1 (usin REFSMMAT or stored LM attitude and determination of lunar gravity vector) c Technique 3 (using single celestial body sighting and determination of lunar gravit vector).

Sequence of Events:

V37E57E

	Flashing V04N06	Option Code ID	00001 Specify Align- ment mode
		Option Code	0000X
		1—preferred, 2—nominal (not valid) 3—REFSMMAT, 4—landing site	

V22E. Load desired option.

Landing Site Only

PRO

	Flashing V06N34	Time of Alignment	00XXX. h 000XX. min 0XX.XX s

V25E. Load desired alignment time.

Preferred and REFSMMAT

	Flashing V05N06	Specify Alignment Technique Alignment Technique	00010 0000X
		0—prestored attitude, 1—prestored attitude +g 2—two celestial bodies, 3—one celestial body + g	
		DataCode	00CD0
		C=1 — REFSMMAT defined C=0 — REFSMMAT not defined D=1 — Stored LM attitude available D=0 — Stored LM attitude not available	

For alignment technique REFSMMAT +g or one celestial body +g.

PRO

	V16N20	Present ICDU Angle	OGA +042.00 deg IGA +318.00 deg MGA +035.26 deg

No Attitude and No DAP light on, then off twice.

Flashing V06N04	Angle Between Present and Stored Gravity Vector	XXX.XX deg

For Alignment technqiue stored or REFSMMAT Attitude or two celestial bodies and IMU not aligned.

Flashing V06N22	Desired ICDU Angles	OGA IGA MGA	XXX.XX deg XXX.XX deg XXX.XX deg

P57 (continued)

PRO No Attitude light off

For alignment techniques
Two celestial bodies or one celestial body +g and IMU aligned.

Flashing V01N70	Code	00CDE

C—AOT Detent
0—COAS calibration (not allowed), 1—front left
2—front center, 3—front right, 4—right rear,
5—rear center, 6—rear left, 7—backup optical system — COAS
DE—Celestial Body Code
00—planet, 01/45—star from star code list,
46—sun, 47—earth, 50—moon.

V21E. Load desired star code and detent.

For DE = 00

Flashing V06N88	Components of Celestial Body Unit Vector	X Y Z	.XXXXX .XXXXX .XXXXX

V32E

PRO

Flashing V06N79	Cursor Angle Spiral Angle Position Code	XXX.XX deg XXX.XX deg 0000X

V32E (To redefine star)

Flashing V01N70	(Same as above V01N70.)	00CDE

or
PRO

Flashing V01N71	Code	00CDE

PRO

Flashing V52N71	Code	00CDE
or	Cursor Counter	XXXXX
V53N71	Spiral Counter	XXXXX

To change V52N71 to V53N71 or vice versa, key ENTER.

For Verb 52, position Cursor, and punch Mark X, Mark Y or click ROD switch.

For Verb 53, position Spiral and punch Mark X, Mark Y, or click ROD switch.

Last mark defined by digit A = 1 in R2 or R3.

Flashing V21/V22 N79	Load Cursor or Spiral Angle Data in R1 or R2 as Requested by V21/V22	XXX.XX deg XXX.XX deg 0000X Position Code

V21 — Cursor Data R1
V22 — Spiral Data R2

P57 (continued)

PRO If alignment technique is two celestial bodies, repeat sequence starting with Flashing V01N70 display and then continue. If alignment technique is one celestial body and gravity continue.

Flashing V06N05	Star Angle Difference	XXX.XX deg

PRO

Flashing V06N93	X Gyro Torquing Angle Y Gyro Torquing Angle Z Gyro Torquing Angle	XX.XXX deg XX.XXX deg XX.XXX deg

PRO

Flashing V50N25	Checklist Code	00014 00014—choose fine align or landing site determination

PRO Recycles program to Flashing V01N70

ENTER

Flashing V06N89	Latitude Longitude/2 Altitude	XX.XXX deg XX.XXX deg XXX.XX nmi

PRO

Flashing V37	Select New Program	

P63—BRAKING PHASE PROGRAM

Purpose:

1. To calculate the required time of DPS ignition (TIG) and other initial conditions required by the LGC for a PGNS-controlled, DPS-executed, braking phase of the powered landing maneuver.
2. To provide option to fine align the IMU to an existing REFSMMAT.
3. To align the LM to the thrusting ignition attitude.
4. To control the PGNS during countdown, ignition, and thrusting of the powered landing maneuver until HI gate.
5. To indicate to the crew that HI gate has been reached by automatic selection of the Approach Phase program (P64).

Assumptions:

1. The LM is on a descent coast orbit (Hohmann transfer) approaching the braking ignition point which is nominally 50,000 feet above the lunar radius at the designated landing site. The descent coast orbit is approximately coplanar with the CSM orbital plane. If the designated landing site is not in the descent coast plane at the nominal time of landing the plane change will be accomplished by the powered landing maneuver (Braking program, P63, and Approach program, P64).
2. The CSM is in a near-circular orbit around the moon at a nominal altitude of 60 nautical miles. The CSM is maintaining a preferred tracking attitude for optical tracking of the LM.
3. The IMU is on and aligned to a landing site orientation defined for the designated landing site and the nominal time of landing (T(land)), but should be fine aligned to this orientation as closely as possible prior to DPS ignition. The LM has not yet been aligned to the correct attitude for ignition for the powered landing maneuver.

4. The Landing Radar (LR) was energized, checked out, and made ready at LR Position No. 1 prior to selection of this program. Radar data will not be incorporated into the LM state vector until the astronaut sets the LR permit flag via V57E indicating he is satisfied with the quality of the data. V58E will reset the LR permit flag.

5. The Landing Analog Displays routine (R10) is enabled 2 seconds after AverageG is enabled and is terminated upon termination of Average G.

6. The entire powered landing maneuver (braking, approach, and landing) will be accomplished using the DPS engine.

7. The aim conditions for braking phase are stored in the LGC.

8. The following parameters required by this program have been stored by the LGC since LGC initialization by erasable load.

   a. The LM and CSM state vectors. The LGC has updated these as required. No further state vector updates from any external source other than the LR will be accepted by this program.

   b. The nominal landing time at the designated landing site T(land) and the position R_{LS}. Corrections to the landing site position R_{LS} may be made by keying V21 through V25 N69 and entering the appropriate correction.

9. The DPS is not throttlable over the whole range (0 to maximum). It must be operated either at maximum throttle or over a specific throttle range of lower settings. These throttle settings are total throttle settings; that is, the sum of the manual setting (whose minimum is about 10 percent) and the PGNS commanded setting.

   This program assumes the Throttle Control switch to be in Auto (the DPS receives the sum of the manual and PGNS commanded settings) and the manual throttle to be set at minimum for ZOOMTIME seconds of thrusting, and thereafter at a level less than that required by the LGC. The value ZOOMTIME is in erasable storage, having been loaded prior to launch or by P27.

   Due to the region of forbidden throttling, thrust command logic in conjunction with the interim terminal conditions assures that the commanded throttle remains at maximum until the guidance equations first require it to be within the allowable throttle range. Thereafter it should remain within the allowable throttle range.

   Furthermore, the DPS must be started in the following sequence: (1) +X axis 2-jet ullage for 7.5 seconds, (2) ignition at minimum throttle, (3) ullage off 0.5 seconds after ignition, (4) ZOOMTIME seconds at minimum thrust, and (5) maximum throttle. The throttle setting then becomes controlled by the guidance equations.

10. During the powered landing maneuver, the LGC will monitor the presence or absence of the Auto Stabilization discrete. This discrete is issued to the LGC when the Mode Control switch is in the Auto position.

    The LGC will also monitor the presence or absence of the Auto Throttle discrete. This discrete is issued to the LGC when the Thrust Control switch is in the Auto position.

    Should either of these discretes be interrupted during the powered landing maneuver, the LGC assumes that it no longer has complete automatic control of the maneuver.

    The monitor and the associated LGC logic is included in the Landing Auto Modes Monitor routine (R13) which will be called by this program.

    The LGC can be forced to ignore the absence of the Auto Throttle discrete and continue issuing normal throttle commands by setting the CHANBKUP location (0374) in the computer to $0001X_8$. This location can only be set by astronaut or ground loading and is not changed by Fresh Start or Restart. The location is also R2 of N46 used during the DAP DATA load routine (V48).

11. The X-axis override option provides the crew with the ability to exercise manual control about the LM X axis with the attitude controller even though the PGNS Mode Control switch is in Auto. When the controller is returned to detent the PGNS damps the yaw rate, stores the yaw attitude when the yaw is damped, and then maintains that attitude.

    The X-axis override option is available to the crew (until the estimated altitude is below 30,000 feet); however, it should not be exercised when the LGC is specifying a desired yaw attitude; that is, during the attitude maneuver to the thrusting attitude. The option is inhibited by this program from midway in the program to the end.

12. The LGC specifies LM attitude during the powered landing maneuver based upon the requirements of thrust vector control, landing site visibility, and LR orientation. After DPS ignition, thrust vector control is required through the remainder of this program. The landing site becomes visible at the beginning of the approach phase.

    Thrust vector control does not constrain the LM orientation about the thrust axis (yaw attitude). Rotation about the LM Y and LM Z axes is used to point the measured thrust vector along the desired thrust vector.

    The first restraint upon the LM yaw attitude to occur is that of LR orientation. The LGC will not attempt to use LR data until the LGC estimation of altitude is 50,000 feet. Automatic X-axis override lockout and yaw attitude specification by the LGC will not occur until the LGC estimated altitude is 30,000 feet. Before this time, the astronaut must maneuver to a roughly-window-up yaw orientation to prevent subsequent loss of S-band lock-on. The LGC will then command the vehicle to the LGC-specified yaw attitude.

    Subsequent to X-axis override lockout, control of the vehicle about the LM X axis is governed by LR orientation requirements during this program. The landing site becomes visible to the command pilot if the "look" angle (the angle between the LM -X axis and the LOS to the landing site) is greater than 25 degrees and the LOS is in or near the LM X/Z plane.

    At any time during P63 or P64, the magnitude of the look angle and the orientation of the look angle plane (that plane containing the LOS and the LM X axis) are defined by the inertial orientation of the LM X axis and the position of the LM with respect to the landing site.

13. The crew has the capability to display LGC calculated values of forward velocity, lateral velocity, altitude, and altitude rate on certain LM meters during this program. The calculations of these parameters is under the control of the Landing Analog Displays routine.

14. The crew can select a display of the LGC computed throttle setting by keying V16 N92E.

15. The Rate of Descent (ROD) mode is not enabled during this program.

16. An abort from the lunar descent may be required at any time during the descent orbit injection, the descent coast, or the powered descent (P63), (P64), or (P66).

    For aborts after DPS ignition for the powered landing maneuver, time is critical. During this period an abort is nominally commanded by pushing one of two buttons in the LM. The abort may be commanded to use the descent stage (Abort button) or the ascent stage (Abort Stage button). If the descent stage is selected, and the DPS propellant approaches exhaustion, control must be switched to the ascent stage by the crew by ascent stage selection (Abort Stage button).

    During the powered landing maneuver, the LGC will continuously monitor the Abort and Abort Stage discretes, and upon receipt of either will terminate the program in process and call the appropriate abort program (DPS Abort program (P70) or APS Abort program (P71)). Both abort programs will guide the LM to an acceptable orbit.

    The monitor of the Abort and Abort Stage buttons is controlled by the Abort Discretes Monitor routine (R11) which will be enabled by this program.

    This step can be locked out by setting the CHANBKUP location (0374) in the computer to 000X1$_8$. This location can only be set by astronaut or ground loading and is not changed by Fresh Start or Restart. The location is R2 of N46 which is used in the DAP Data Load Routine (V48).

17. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Auto, the PGNS controls the total vehicle attitude and generates either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise control about only the yaw axis with the ACA (X-axis override) provided the X-axis override capability is permitted.

    If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold, the PGNS holds the vehicle attitude and generates either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise manual control about all vehicle axes with the ACA using either the Rate Command or Minimum Impulse mode. However, it is strongly recommended that powered flight not be attempted in the Minimum Impulse mode.

    During a thrusting maneuver in the PGNS/Attitude Hold mode the astronaut is responsible for maintaining small enough attitude errors to achieve guidance objectives.

18. Control of LM DPS, RCS, and APS is transferred from PGNS to the Abort Guidance System (AGS) by changing the Guidance Control switch from PGNS to AGS.

    The AGS will be capable of taking over control of the LM during any portion of the lunar descent or ascent or during either of the abort programs (P70 or P71). The AGS will guide the LM to a safe orbit.

    The AGS may be initialized by the LGC at any time by manual selection of the AGS Initialization routine (R47).

    In the event that the Guidance Control switch is changed from PGNS to AGS during a thrusting maneuver, the LGC will continue computation of position and velocity, the desired thrust vector, and the desired attitude errors.

19. The PGNS generates two types of errors for display on the FDAI as selected by the astronaut.

    a. Mode 1—Selected by Verb 61. Autopilot following errors used as a monitor of the DAP's ability to track automatic steering commands.

    b. Mode 2 — Selected by Verb 62. Total attitude errors used to assist the crew in manually maneuvering the vehicle.

    Display selection is always based upon last entry mode in the DSKY or Mode 2 by the Attitude Maneuver Routine R60.

20. The event timer was set prior to selection of this program to count to zero at T BRAK based on a time from ignition provided by the ground.

21. The Load DAP Data routine (R03) has been performed prior to selection of this program. At that time the DPS engine gimbal should have been driven to the correct trim position.

22. During DPS burn only, the pitch-roll RCS jet autopilot (U and V jets) may be disabled (V65E) or enabled (V75) by Extended Verb as shown. This capability is intended to be used to prevent LM and descent stage thermal constraint violations during CSM-docked DPS burns (P40). The capability exists during P70 also. Performance of FRESH START (V36E) will always enable the pitch-roll jets.

23. This program is selected by the astronaut by DSKY entry. It should be selected at least 20 minutes before the nominal time of ignition for the powered landing maneuver (T BRAK).

24. Engine ignition may be slipped beyond the established TIG if desired by the crew or if state vector integration cannot be completed in time.

25. Two alarm conditions may be originated by the PGNS powered landing equations:

    a. If subroutine ROOTPSRS in the RG/VG calculation fails to converge in 8 passes the LGC will turn on the Program Alarm light, store Alarm Code 1406, and go immediately to the final Automatic Request routine (R00). This alarm can occur only in P63 or P64.

    b. If an overflow occurs anywhere in the landing equations the LGC will turn on the Program Alarm light, store Alarm Code 1410, stop all vehicle attitude rates, and continue. This alarm can occur only in P63, P64, or P66.

26. This program allows manual control of LM attitude and the selection of P66.

    During P63 (P64) the astronaut can display the PGNS total guidance error on the FDAI error needles (Attitude Monitor switch in PGNS) by having keyed in V62E through the DSKY. He can then steer out the PGNS P63 attitude errors with the PGNS manually (Guidance Control switch in PGNS and the PGNS Mode Control switch in Attitude Hold); or automatically (PGNS Mode Control switch in Auto); or with the AGS manually (Guidance Control switch in AGS and the AGS Mode Control switch in Attitude Hold).

    NOTE: If the astronaut hits the ROD (Rate of Descent) switch while the PGNS Mode Control switch is in Attitude Hold, the LGC will irrevocably transfer him out of the automatic guidance program modes (P63 and P64) into the ROD program (P66).

Sequence of Events:

V37E63E

Flashing	Time to Go in Braking Phase	XXbXX min/s
V06N61	Time from Ignition	XXbXX min/s
	Crossrange Distance	XXXX.X nmi
		(+ Landing Site north of S/C)

N33E

Flashing	Time of Ignition	00XXX. h
V06N33		000XX. min
		0XX.XX s

KEY REL

P63 (continued)

PRO

Flashing V50N18	Desired Automaneuver FDAI Ball Angles	R XXX.XX deg P XXX.XX deg Y XXX.XX deg

Automaneuver Guidance Control – PGNS
Mode Control (PGNS) – Auto

Monitor automatic maneuver to attitude.

At end of maneuver

Flashing V50N18	Desired Automaneuver FDAI Ball Angles	R XXX.XX deg P XXX.XX deg Y XXX.XX deg

Manual maneuver: Guidance Control – PGNS
Mode Control (PGNS) – Attitude Hold

Maneuver to V50N18 displayed angles

ENTER

Flashing V50N25	Checklist Code	00203

Please switch to
Guidance Control – PGNS
Attitude Control (PGNS) – Auto
Throttle Control – Auto

ENTER

V06N62	Absolute Value of Velocity Time from Ignition (TFI) Delta V Accumulated	XXXX.X ft/s XXbXX min/s XXXX.X ft/s

Time from ignition keeps counting down until TIG - 35 seconds. DSKY blanks for 5 seconds. V06N62 display returns until TIG - 5 seconds.

TIG - 30 seconds – ENG ARM – DES
TIG - 15 seconds – R3 should be less than 00005
TIG - 7.5 seconds – Verify +X ullage
TIG - 5 seconds – ENGINE ON ENABLE

Flashing V99N62	Absolute Value of Velocity Time from Ignition Delta V Accumulated	XXXX.X ft/s XXbXX min/s XXXX.X ft/s

PRO Astronaut okays ignition.

Flashing V06N63	Delta Altitude Altitude Rate Computed Altitude	XXXXX. ft XXXX.X ft/s XXXXX. ft

At approximately 42,000 feet computed altitude, ALT, and VEL Lights – Off

V57E

V06N63	Delta Altitude Altitude Rate Computed Altitude	XXXX.X ft XXXX.X ft/s XXXXX. ft

At approximately +9:30 P64 displayed.

P64—APPROACH PHASE PROGRAM

Purpose:

1. To control the PGNS during the thrusting of the powered landing maneuver between HI gate and LO gate.
2. To control the DPS thrust and attitude between HI gate and LO gate.
3. To provide the crew with the capability of redesignating the landing site to which the PGNS is guiding the LM.

Assumptions:

1. The LM is on the powered landing descent between HI gate and LO gate.
2. The CSM is in a near circular orbit around the moon at a nominal altitude of 60 nautical miles. The CSM is maintaining a preferred tracking attitude for optical tracking of the LM.
3. The Landing Radar (LR) is on, checked out, and should have been providing to the LGC velocity and range information with respect to the moon. This information should have been incorporated into the LM state vector. The LGC/LR operation is under the control of the Descent State Vector Update routine (R12) which is already in process.
4. The entire powered landing maneuver (braking, approach, and landing) will be accomplished using the DPS engine.
5. The aim conditions (LO gate) for the approach phase are stored in the LGC.
6. The LM state vector has been stored in the LGC since initialization by ERASABLE register load. The LGC has updated this as required during thrusting. No further state vector updates from any source other than the LR will be accepted by this program.
7. The DPS is not throttlable over the whole range from 0 to maximum. It must be operated either at maximum throttle or over a specific throttle range of lower settings. These throttle settings are total throttle settings; that is, the sum of the manual setting (whose minimum is about 10 percent) and the PGNS commanded setting.

   This program assumes the Throttle Control switch to be in Auto (the DPS receives the sum of the manual and PGNS commanded settings) and the manual throttle to be set at a level less than that required by the LGC.

   Nominally, if the Approach Phase program is completed without any redesignation of the landing site (see Assumption 10), the throttle will remain within the allowable throttle range throughout the phase. Excessive target redesignations during this program, however, may result in required throttle excursions outside the allowable range. In such cases the LGC will command maximum throttle for at least 2 seconds, and until the required throttle setting returns to the permitted throttle region.
8. During the powered landing maneuver, the LGC will monitor the presence or absence of the Auto Stabilization discrete. This discrete is issued to the LGC when the Mode Control switch is in the Auto position.

   The LGC will also monitor the presence or absence of the Auto Throttle discrete. This discrete is issued to the LGC when the Thrust Control switch is in the Auto position.

   Should either of these discretes be interrupted during the powered landing maneuver, the LGC assumes that it no longer has complete automatic control of the maneuver.

   The monitor and the associated LGC logic is included in the Landing Auto Modes Monitor routine (R13) which is already in process.

   The LGC can be forced to ignore the absence of the Auto Throttle discrete and continue issuing normal throttle commands by setting the CHANBKUP location (0374) in the computer to 0001X$_8$. This location can only be set by astronaut or ground loading and is not changed by Fresh Start or Restart. This location is R2 of N46 used in the DAP Data Load Routine (R48).
9. The X-axis override option is not provided to the crew whenever the LGC estimated altitude is below 30,000 feet.

10. During most of the approach phase, the LGC provides the crew with the option to redesignate the landing site to which the PGNS is guiding the LM. This option is called the Landing Point Designator (LPD) mode. The PGNS Mode Control switch must be in Auto for the ACA to function as a landing site redesignator.

    The landing point redesignation, if exercised, is based upon visual assessment of the lunar terrain with respect to the presently designated landing site. During the LPD mode the present landing site is displayed on the DSKY in terms of coordinates on the LPD sighting grid on the left hand LM window (LPD angle). Landing site redesignations are manually put into the computer via the attitude controller on an incremental basis; that is, a limit switch actuation in the attitude controller causes the LGC to redesignate the landing site at a fixed angular increment (1 degree in elevation, 1 degree in azimuth) from the present LM/landing site. The applicable attitude controller polarities are:

    a. -Pitch Rotation gives -LPD Elevation (new site beyond present site).

    b. +Pitch Rotation gives +LPD Elevation (new site short of present site).

    c. +Roll Rotation gives +LPD Azimuth (new site to right of present site).

    d. -Roll Rotation gives -LPD Azimuth (new site to left of present site).

11. The initial maneuver of the approach phase is the LM attitude transition from the LM attitude at the start of P64 to a satisfactory attitude for landing site visibility. After the completion of this maneuver the LM attitude is constrained by thrust pointing requirements and is controlled about the thrust axis so as to maintain the current landing site in the LM X-Z plane. The conditions achieved at the start of P64 should be such that the thrust pointing requirements of the approach phase will yield satisfactory visibility and radar orientations.

    The landing site becomes visible to the command pilot if the "look" angle (the angle between the -X LM axis and the LOS to the landing site) is greater than 25 degrees and the LOS is in or near the LM X-Z plane.

    At any time during P63 or P64, the magnitude of the look angle and the orientation of the look angle plane (that plane containing the LOS and the LM X axis) are defined by the inertial orientation of the LM X axis and the position of the LM with respect to the landing site.

    The inertial orientation of the LM X axis is controlled by requirements of thrust vector control. The orientation of the LM windows with respect to the look angle plane is controlled by rotation of the vehicle about the LM X axis.

12. The crew has the capability to display LGC calculated values of forward velocity, lateral velocity, altitude, and altitude rate on certain LM meters during this program. The calculation of these parameters is under control of the Landing Analog Display routine which is already in process.

13. The Rate of Descent (ROD) mode is not enabled during this program.

14. An abort from the lunar descent may be required at any time during the descent orbit injection, the descent coast, or the powered descent (P63), (P64), or (P66).

    For aborts after DPS ignition for the powered landing maneuver, time is critical. During this period an abort is nominally commanded by pushing one of two buttons in the LM. The abort may be commanded to use the descent stage (Abort button) or the ascent stage (Abort Stage button). If the descent stage is selected, and the DPS propellant approaches exhaustion, control must be switched to the ascent stage by the crew by ascent stage selection (Abort Stage button).

    During the powered landing maneuver the LGC will continuously monitor the Abort and the Abort Stage discretes, and upon receipt of either will terminate the program in process and call the appropriate abort program (DPS Abort program (P70) or APS Abort program (P71)). Both abort programs will guide the LM to an acceptable orbit.

    Monitoring the Abort and Abort Stage buttons is controlled by the Abort Discretes Monitor routine (R11) which is already in process.

    This step can be locked out by setting the CHANBKUP location (0374) in the computer to 000X1$_B$. This location can only be set by astronaut or ground loading and is not changed by Fresh Start or Restart. This location is R2 of N46 which is used in the DAP Data Load Routine (V48).

15. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Auto, the PGNS controls the total vehicle attitude and generates either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise control about only the yaw axis with the ACA (X-axis override) provided the X-axis override capability is permitted.

    If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold, the PGNS holds the vehicle attitude and generates either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise manual control about all vehicle axes with the ACA using either the Rate Command or Minimum Impulse mode. However, it is strongly recommended that powered flight not be attempted in the Minimum Impulse mode.

16. Control of the LM DPS, RCS, and APS is transferred from the PGNS to the Abort Guidance System (AGS) by placing the Guidance Control switch from PGNS to AGS.

    The AGS will be capable of taking over control of the LM during any portion of the lunar descent or ascent or during either of the abort programs (P70 or P71). The AGS will guide the LM to a safe orbit.

    The AGS may be initialized by the LGC at any time during this program by manual selection of the AGS Initialization routine (R47).

    In the event that the Guidance Control switch is changed from PGNS to AGS during a thrusting maneuver, the LGC will continue computation of position and velocity, the desired thrust vector, and the desired attitude errors. However, the PGNS will not be responsible if register overflows occur within the LGC.

17. The PGNS generates two types of errors for display on the FDAI as selected by the astronaut:

    a. Mode 1—Selected by Verb 61. Autopilot following errors are used as a monitor of the DAP's ability to track automatic steering commands.

    b. Mode 2—Selected by Verb 62. Total attitude errors used to assist the crew in manually maneuvering the vehicle.

18. The Load DAP Data routine (R03) has been performed prior to the start of the powered landing maneuver and should not be required during this program.

19. This program is automatically selected by the Braking Phase program (P63) at the completion of the P63 aim conditions.

20. Two alarm conditions may be originated by the PGNS powered landing equations:

    a. If Subroutine ROOTPSRS in the RG/VG calculation fails to converge in 8 passes the LGC will turn on the Program Alarm light, store Alarm Code 1406, and go immediately to the Final Automatic Request routine (R00). This alarm can occur only in P63 or P64.

    b. If an overflow occurs anywhere in the landing equations the LGC will turn on the Program Alarm light, store Alarm Code 1410, stop all vehicle attitude rates, and continue. This alarm can occur only in P63, P64, or P66.

21. This program allows manual control of the LM attitude. If manual control is desired, put the PGNS Mode Control switch in Attitude Hold and use the ACA to control the LM attitude.

    If P66 is desired, click the ROD switch while the PGNS Mode Control switch is in Attitude Hold. The ACA does not redesignate the landing site while the Mode Control switch is in Attitude Hold. To use the ACA to redesignate the landing site, put the Mode Control in Auto and rotate the ACA in the desired direction.

    NOTE: Landing Site Redesignation must be completed before P66 is selected because P64 cannot be reentered once it has been exited.

22. The crew can select a display of the LGC computed throttle setting by keying V16 N92E.

P64 (continued)

Sequence of Events:

Flashing	Time Left for Redesignations/LPD Angle	XXbXX s/deg
V06N64	Altitude Rate	XXXX.X ft/s
	Computed Altitude	XXXXX. ft

Manual Throttle Control

TTCA — Advance until thrust = 10%, throttle control — MAN

V16N92E

Flashing	Percent of Full Thrust (10,500 lb)	00XXX%
V16N92	Altitude Rate	XXXX.X ft/s
	Computed Altitude	XXXXX. ft

To return to auto throttle
Throttle Control — AUTO
TTCA — minimum position

KEY REL

Flashing	Same display as above.
V06N64	

Manual Attitude Check
Mode Control (PGNS — Attitude Hold)

To use Landing Point designator
Verify Mode Control PGNS — AUTO

PRO

V06N64	Time Left for Redesignations/LPD Angle	XXbXX s/deg
	Altitude Rate	XXXX.X ft/s
	Computed Altitude	XXXXX. ft

Redesignate landing site as described (+ pitch redesignates landing site toward LM by 1 degree) (+ roll redesignates new site to right of present site by 1 degree in azimuth.) V06N64 changes the elevation LPD angle accordingly.

Manual Rate of Descent Control

PGNS — Attitude Hold. Activate ROD switch. Automatic Transfer to P66.

Automatic Transfer to ROD Control

When time remaining is zero — Automatic transfer to P66 occurs.

P66—LANDING PHASE (ROD) PROGRAM

Purpose:

1. To modify the rate of descent of the LM (with respect to the lunar surface) in response to astronaut originated inputs via the LM Rate of Descent (ROD) switch to the LGC.
2. To modify the inertial attitude of the LM in response to astronaut originated inputs via the attitude controller only if the Mode Control switch is in Attitude Hold.
3. To null the forward and lateral surface velocities of the LM when the Mode Control switch is in Auto and still respond to the Rate of Descent (ROD) switch inputs.
4. To update the LM state vector with vehicle acceleration and Landing Radar (LR) data.

Assumptions:

1. The LM is in the late stages of landing, with a low inertial velocity.
2. The Landing Radar (LR) is on, checked out, and providing to the LGC velocity and range information with respect to the moon. This information has been incorporated into the LM State Vector. The LGC/LR operation is under the control of the Descent State Vector Update routine (R12) which is already in process.
3. The entire powered landing maneuver (braking, approach, and landing) will be accomplished using the DPS engine.
4. The LM State Vector has been stored in the LGC since initialization by erasable register load. The LGC has updated this as required during thrusting. No further state vector updates from any source other than the LR will be accepted by this program.
5. The DPS is not throttlable over the whole range from 0 percent to maximum. It must be operated either at maximum throttle or over a specific throttle range of lower settings. These throttle settings are total throttle settings; that is, the sum of the manual setting (whose minimum is 10 percent) and the PGNS commanded setting.

   This program assumes the Throttle Control switch to be in Auto (the DPS receives the sum of the manual and PGNS commanded settings) and the manual throttle to be set at a level less than that required by the LGC.

   Nominally the throttle will remain within the allowable throttle range through this program.
6. During the powered landing maneuver, the LGC will monitor the presence or absence of the Auto Stabilization discrete. This discrete is issued to the LGC when the Mode Control switch is in the Auto position.

   In the Auto Stabilization mode, the PGNS will operate to null the forward and lateral surface velocities by controlling the inertial attitude of the spacecraft.

   In the Attitude Hold mode, the LGC will hold an inertial attitude. However, the attitude may be changed by manual control via the attitude controller.
7. The LPD option is not provided to the crew during this program.
8. The crew can display LGC calculated value of forward velocity, lateral velocity altitude, and altitude rate during this program. The calculation of these parameters is under the control of the Landing Analog Displays routine (R10) which is already in process.
9. During this program the LGC monitors the output of the Rate of Descent (ROD) switch in the LM. This switch is operated by the astronaut in response to his assessment of the present LM rate of descent based on out-of-window references and LM/DSKY displays.

   Switch operation is on an incremental basis: - (increase ROD) or + (decrease ROD). Each command results in an LGC—commanded change of "ROD SCALE" in LM rate of descent. (ROD SCALE is a value loaded into erasable storage prior to flight. Presently 1 foot per second.)
10. An abort from the lunar descent may be required at any time during descent coast or powered descent (P63, P64, or P66).

For aborts after DPS ignition for the powered landing maneuver, time is critical. During this period an abort is commanded by pushing one of two buttons in the LM. The abort may be commanded to use the descent stage (Abort button) or the ascent stage (Abort Stage button). If the descent stage is selected, and the DPS propellant approaches exhaustion, control must be switched to the ascent stage by the crew by ascent stage selection (Abort Stage button).

During the powered landing maneuver, the LGC will continuously monitor the Abort and Abort Stage discretes, and upon receipt of either will terminate the program in process and call the appropriate abort program (DPS Abort program (P70) or APS Abort program (P71)). Both abort programs will guide the LM to an acceptable orbit.

Monitoring the Abort and Abort Stage buttons is controlled by the Abort Discretes Monitor routine (R11) which is already in process.

This step can be locked out by setting the CHANBKUP location (0374) in the computer to $000X1_8$. This location can only be set by astronaut or ground loading and is not changed by Fresh Start or Restart. This location is R2 of N46 used during DAP Data Load Routine (V48).

11. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold, the PGNS will hold the vehicle attitude and will generate either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise manual attitude control about all vehicle axes with the ACA in either the Rate Command or Minimum Impulse mode. It is strongly recommended that powered flight not be attempted in the Minimum Impulse mode.

    The LGC is not permitted to compute body rates via V60 during this program. The attitude will always be available for astronaut display so that they are aware of the impending S/C motion when switching from Attitude Hold to Auto.

12. Control of the LM DPS, RCS, and APS is transferred from the PGNS to the Abort Guidance System (AGS) by placing the Guidance Control switch from PGNS to AGS.

    The AGS will be capable of taking over control of the LM during any portion of the lunar descent or ascent or during either of the abort programs (P70 or P71). The AGS will guide the LM to a safe orbit.

    The AGS may be initialized by the LGC at any time by manual selection of the AGS Initialization routine (R47).

    In the event the Guidance Control switch is changed from PGNS to AGS during a thrusting maneuver, the LGC will continue computation of position and velocity, the desired thrust vector, and the desired attitude errors; however, the PGNS will not be responsible if register overflows occur within the LGC.

13. The Load DAP Data routine (R03) has been performed prior to the start of the powered landing maneuver and should not be required during this program.

14. This program is automatically selected by the Landing Auto Modes Monitor routine (R13) during the powered landing maneuver when:

    a. The targeted conditions for P64 are met (either automatically or astronaut flown)

    b. When the Rate of Descent (ROD) switch is activated by the astronaut after P63 throttle up in Attitude Hold.

    Once this program has been selected it is no longer possible to return to the completely automatic powered landing programs (P63 or P64).

15. The crew has the capability to select a display of the LGC computed throttle setting by keying in V16 N92E.

Sequence of Events:

Flashing	Forward Velocity	XXXX.X ft/s
V06N60	Altitude Rate	XXXX.X ft/s
	Computed Altitude	XXXXX. ft

Use ROD switch as desired.

To manually null forward and lateral velocities

Mode Control: PGNS – Attitude Hold

Forward (pitch) and lateral (roll) cross pointers

Manual Throttle

TTCA – Advance until thrust = 10%
Throttle Control – Manual

V16N92E

Flashing	Percent of Full Thrust	00XXX%
V16N92	Altitude Rate	XXXX.X ft/s
	Altitude	XXXXX. ft

To return to auto throttle
Throttle Control – Auto

TTCA – minimum position

KEY REL

Flashing	Forward Velocity	XXXX.X ft/s
V06N60	Altitude Rate	XXXX.X ft/s
	Computed Altitude	XXXXX. ft

At height actual = 5.6 ft., lunar contact light – ON

ENGINE STOP–PUSH

PRO

ENGINE ARM–OFF

P68—LANDING CONFIRMATION PROGRAM

Purpose:

1. To terminate landing program and DAP functions.
2. To initialize the LGC for lunar surface operation.
3. To permit the astronaut to prevent RCS jet firings on the lunar surface.

Assumptions:

1. This program is selected by the astronaut by DSKY entry. It is to be selected only after the LM has landed on the lunar surface (Program P66).
2. V37E68E selection of P68 will terminate Average G and command the engine off (see R00).
3. The selection of this program places the DAP in the Minimum Impulse mode. As long as the astronaut keeps the mode control in Attitude Hold, RCS jet firings will not occur, even while the platform is being torqued (in P57).
4. This program will not shut off the DAP. However, the attitude errors are zeroed and the maximum deadband is set. No jet firings should result until one of the following occurs in sufficient magnitude to cause the attitude errors to exceed the deadband:
   a. The moon rotates,
   b. The LM shifts on the lunar surface,
   c. The IMU gyros are torqued for alignment by P57,
   d. The IMU drifts.

   The DAP may be shut off by setting the Mode-Control-PGNS switch to Off.

Sequence of Events:

V37E68E

Flashing V06N43	Latitude	XXX.XX deg (+ north)
	Longitude	XXX.XX deg (+ east)
	Altitude	XXXX.X nmi

PRO Mode Control (PGNS)—Attitude Hold, No DAP light on.

Flashing V37	Select New Program.

P70—DPS ABORT PROGRAM

Purpose:

1. To control a PGNS controlled DPS abort from the powered landing maneuver (P63, P64, or P66) when required.

Assumptions:

1. This program will control a DPS abort in one of two ways:
   a. If the altitude is greater than 25,000 feet, this program will command maximum DPS throttle, continue DPS thrusting, perform an attitude maneuver (using the RCS) to the correct attitude to continue the abort ascent, and complete the abort ascent to insert the LM into an abort orbit.
   b. If the altitude is less than 25,000 feet, this program will command maximum DPS throttle and enter a vertical rise phase which will terminate either when the LM altitude exceeds 25,000 feet or when LM velocity is greater than 40 ft/s.

   During the vertical rise phase, the vehicle is maneuvered to align the LM +X axis with the local vertical (using the RCS), and the LM +Y axis normal to the anticipated pitch maneuvers plane. The program will then pitch the LM to the correct attitude for ascent and complete the abort ascent to insert the LM into an abort orbit.

P70 (continued)

2. The LM is on the powered landing descent somewhere between DPS iginition for the maneuver (P63) and DPS shutdown on the lunar surface (P66).
3. The CSM is in a near circular orbit around the moon at a nominal altitude of 60 nautical miles. The CSM is maintaining a preferred tracking attitude for optical tracking of and RR tracking by the LM.
4. The IMU is on and accurately aligned to the landing orientation.
5. The Landing Radar (LR) is on and was checked out when in Position No. 1. The LGC/LR operation is under the control of the Descent State Vector Update routine (R12).
6. The Landing Analog Displays routine (R10) is enabled upon entry into this program, having been enabled by P63.
7. The DPS is not throttlable over the whole range from zero to maximum. It must be operated either at maximum throttle or over a specific throttle range of lower settings. These throttle settings are total throttle settings; that is, the sum of the manual setting (whose minimum is 10 percent) and the PGNS commanded setting.

   This program assumes the Throttle Control switch to be in Auto (the DPS receives the sum of the manual and PGNS commanded settings) and the manual throttle to be set at a level less than that required by the LGC. The LGC will command maximum throttle for all DPS thrusting controlled by this program.
8. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Auto, the PGNS controls the total vehicle attitude and generates either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise control about only the yaw axis with the ACA (X-axis override) provided the X-axis-override capability is permitted.

   If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold, the PGNS holds the vehicle attitude and generates either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise manual control about all vehicle axes with the ACA using either the Rate Command or Minimum Impulse mode. However, it is strongly recommended that powered flight not be attempted in the Minimum Impulse mode.
9. Control of the LM DPS, RCS, and APS is transferred from the PGNS to the Abort Guidance System (AGS) by placing the Guidance Control switch from PGNS to AGS.

   The AGS will be capable of taking over control of the LM during any portion of the lunar descent or ascent or during either of the abort programs (P70 or P71). The AGS will guide the LM to a safe orbit.

   The AGS may be initialized by the LGC at any time by manual selection of the AGS Initialization routine (R47).

   In the event that the Guidance Control switch is changed from PGNS to AGS during a thrusting maneuver, the LGC will continue computation of position and velocity, the desired thrust vector, and the desired attitude errors. However, the PGNS will not be responsible if register overflows occur within the LGC.
10. The PGNS generates two types of errors for display on the FDAI as selected by the astronaut:
    a. Mode 1—Selected by Verb 61. Autopilot following errors used as a monitor of the DAP's ability to track automatic steering commands.
    b. Mode 2—Selected by Verb 62. Total attitude errors used to assist the crew in manually maneuvering the vehicle.

P70 (continued)

11. The Load DAP Data routine (R03) was completed prior to DPS ignition for the powered landing maneuver and should not be selected during this program.

12. During DPS burns only, the Pitch-Roll RCS jet autopilot (U and V jets) may be disabled (V65) or enabled (V75) by Extended Verb as shown. This capability is intended to be used to prevent LM and descent stage thermal constraint violations during CSM-docked DPS burns (P40). The capability exists during P63 also. Performance of FRESH START (V36E) will always enable the capability of the autopilot.

13. This program may be called in two ways:

    a. Abort button—If the Abort button is used during the powered descent it will be detected by the Abort Discretes Monitor routine (R11). R11 will then call this program.

    b. V37E 70E—This program may be called by the same procedure as other programs are manually called.

14. The LGC will not automatically select the APS Abort program (P71) if DPS fuel exhaustion occurs during execution of P70. The crew must anticipate DPS fuel exhaustion and select P71 by the Abort Stage button or by V37E 71E.

Sequence of Events:

ABORT PUSH (DURING P63, P64, or P66)

or

V37E70E

V06N94	VGX (LM) (+Up)	XXXX.X ft/s
	Altitude Rate	XXXX.X ft/s
	Computed Altitude	XXXXX. ft

To monitor Time-to-Go and cross range velocity.

V16N77E

V16N77	Time to Engine Cutoff	XXbXX min/s
	LM Velocity Normal to CSM Plane (VGY)	XXXX.X ft/s
	Absolute Value of Inertial Velocity	XXXX.X ft/s

If burn is greater than 400 seconds, descent regulators close at PDI + 6:20. Then when VG_X = 100 ft/s, shut down DPS engine. DES ENG CMD OVRD and ENG ARM are OFF. NULL components of V16N85 display.

KEY REL

Flashing	VGX (LM) (+Up)	XXXX.X ft/s
V16N94	Altitude Rate	XXXX.X ft/s
	Computed Altitude	XXXXX. ft

ENG STOP – PUSH, ENG ARM—OFF, ABORT – Reset

PRO

Flashing	VG_X (body)	XXXX.X ft/s
V16N85	VG_Y (body)	XXXX.X ft/s
	VG_Z (body)	XXXX.X ft/s

V82E Display Orbital parameters.

Flashing	Apocenter Altitude	XXXX.X nmi
V16N44	Pericenter Altitude	XXXX.X nmi
	Time from Interface Altitude	XXbXX min/s

PRO

Flashing	Same as above.
V16N85	

PRO

Flashing	Select New Program.
V37	

P71—APS ABORT PROGRAM

Purpose:

1. To control a PGNS controlled APS abort from the powered landing maneuver (P63, P64, or P66) or a DPS Abort (P70) when required.

Assumptions:

1. The program will control an APS abort in one of two ways:

    a. If the altitude is greater than 25,000 feet this program will ignite the APS, continue APS thrusting, perform an attitude maneuver (using the RCS) to the correct attitude to continue the abort ascent, and complete the abort ascent to insert the LM into an abort orbit.

    b. If the altitude is less than 25,000 feet this program will ignite the APS, continue APS thrusting, enter a vertical rise phase which will terminate either when the LM altitude exceeds 25,000 feet or when LM vertical velocity exceeds 40 ft/s.

    During the vertical rise phase the vehicle is maneuvered to align the LM +X axis with the local vertical (using the RCS) and the LM +Y axis normal to the anticipated pitch maneuver plane. The program will then pitch the LM to the correct attitude for ascent, and then complete the abort ascent to insert the LM into an abort orbit.

2. This program does not check to see if the DPS has been staged. Thus if P71 is selected via V37 and the descent stage has not been manually staged this program may command engine on (Assumption 1.a or 1.b above). In such cases the command will go to the DPS.

3. The CSM is in a near circular orbit around the moon at a nominal altitude of 60 nautical miles. The CSM is maintaining a perferred tracking attitude for optical tracking of and RR tracking by the LM.

4. The Landing Radar (LR) is on and was checked out when in Position No. 1. The LGC/LR operation is under the control of the Descent State Vector Update routine (R12).

5. The Landing Analog Displays routine (R10) is enabled upon entry to this program, having been enabled by P63.

6. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Auto, the PGNS controls the total vehicle attitude and generates either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise control about only the yaw axis with the ACA (X-axis override) provided the X-axis override capability is permitted.

    If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold, the PGNS holds the vehicle attitude and generates either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise manual control about all vehicle axes with the ACA using either the Rate Command or Minimum Impulse mode. However, it is strongly recommended that powered flight not be attempted in the Minimum Impulse mode.

P71 (continued)

7. Control of the LM DPS, RCS, and APS is transferred from the PGNS to the Abort Guidance System (AGS) by placing the Guidance Control switch from PGNS to AGS.

   The AGS will be capable of taking over control of the LM during any portion of the lunar descent or ascent or during either of the abort programs (P70 or P71). The AGS will guide the LM to a safe orbit.

   The AGS may be initialized by the LGC at any time by manual selection of the AGS Initialization routine (R47).

   In the event that the Guidance Control switch is changed from PGNS to AGS during a thrusting maneuver, the LGC will continue computation of position and velocity, the desired thrust vector, and the desired attitude errors. However, the PGNS will not be responsible if register overflows occur within the LGC.

8. The PGNS generates two types of errors for display on the FDAI as selected by the astronaut.

   a. Mode 1—Selected by Verb 61. Autopilot following errors used as a monitor of the DAP's ability to track automatic steering comands.

   b. Mode 2—Selected by Verb 62. Total attitude errors used to assist the crew in manually maneuvering the vehicle.

9. The Load DAP Data routine (R03) was completed prior to DPS ignition for the powered landing maneuver and should not be selected during this program.

10. This program may be called in two ways:

    a. Abort Stage button—If the Abort Stage button is used during the powered descent or the DPS Abort program (P70), it will be detected by the Abort Discretes Monitor routine (R11). R11 will then call this program.

    b. V37E71E—This program may be called by the same procedure as other programs are manually called.

Sequence of Events:

ABORT STAGE—Push (During P63, P64, P66, or P70)

or

V37E71E

V06N94	VGX (LM) (+ Up)	XXXX.X ft/s
	Altitude Rate	XXXX.X ft/s
	Computed Altitude	XXXXX. ft

ENG START — Push, ENG ARM — ASC, RESET ENG STOP — if on.

To monitor time to go and cross range velocity.

V16N77E

V16N77	Time to Engine Cutoff	XXbXX min/s
	LM Velocity Normal to CSM Plane (VGY)	XXXX.X ft/s
	Absolute Value of Inertial Velocity	XXXX.X ft/s

At VG_X = 200 ft/s enable automatic shutdown ENG — ARM — OFF.

Null velocities with RCS using V16N85 displays.

P71 (continued)

KEY REL

Flashing	VGX (LM) (+Up)	XXXX.X ft/s
V16N94	Altitude Rate	XXXX.X ft/s
	Computed altitude	XXXXX. ft

ENG — STOP — reset

PRO

Flashing	VG_X (body)	XXXX.X ft/s
V16N85	VG^Y (body)	XXXX.X ft/s
	VG_Z^Y (body)	XXXX.X ft/s

Display orbital parameters.

V82E

Flashing	Apocenter Altitude	XXXX.X nmi
V16N44	Pericenter Altitude	XXXX.X nmi
	Time from Interface Altitude	XXbXX min/s

PRO

Flashing	Select New Program
V37	

P72—CSM COELLIPTIC SEQUENCE INITIATION (CSI) TARGETING PROGRAM

Purpose:

1. To calculate parameters associated with the following concentric flight plan maneuvers for CSM execution of the maneuvers under the control of the CMC: the Coelliptic Sequence Initiation (CSI) and the Constant Delta Altitude maneuver (CDH).

Assumptions:

1. At a selected TPI time the line of sight between the CSM and the LM is selected to be a prescribed angle (E) from the horizontal plane defined at the CSM 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 CSM horizontal plane at CSI ignition.
6. The pericenter altitude of the orbit following CSI and CDH must be greater than 35,000 feet (lunar orbit) or 85 nmi (earth orbit) for successful completion of this program.
7. The CSI and CDH maneuvers are assumed to be parallel to the plane of the LM orbit, however crew modification of Delta V(LV) components may result in an out-of-plane CSI maneuver.
8. The Rendezvous Radar may or may not be used to update the LM or CSM 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. The rendezvous tracking mark counter is zeroed by the selection of P20 and after each thrusting maneuver.
9. The ISS need not be on to complete this program unless automatic state vector updating is desired by the Rendezvous Navigation program (P20). If selected, P20 will define the status of the ISS.

Sequence of Events:

This sequence of events is identical to P32. Record maneuvers and transmit to CSM.

P73—CSM CONSTANT DELTA ALTITUDE (CDH) TARGETING PROGRAM

Purpose:

1. To calculate parameters associated with the concentric flight plan maneuvers with the exception of Coelliptic Sequence Initiation (CSI) for CSM execution of the maneuvers under control of the CMC. The concentric flight plan maneuvers are the Coelliptic Sequence Initiation (CSI), the Constant Delta Altitude maneuver (CDH), the Transfer Phase Initiation (TPI), and the Transfer Phase Final (TPF) or braking maneuver.

Assumptions:

1. This program is based upon previous completion of the Coelliptic Sequence Initiation (CSI) Targeting program (P72). Therefore:
   a. At a selected TPI time the line of sight between the CSM and the LM was selected to be a prescribed angle (E) from the horizontal plane defined at the CSM 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 CSM horizontal plane at CSI ignition.
   f. The pericenter altitudes of the orbits following CSI and CDH were computed to be greater than 35,000 feet (lunar orbit) or 85 nmi (earth orbit).
   g. The CSI and CDH maneuvers were assumed to be parallel to the plane of the LM orbit. However, crew modification of Delta V(LV) components may have resulted in an out-of-plane CSI maneuver.

   Unless the inputs to this program are changed from those values inserted in P72, the calculated parameters for the remaining maneuvers of the concentric flight plan will vary from those originally calculated and displayed only due to the continuous radar updating of the LM or CSM orbit.
2. 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 should have been 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. The rendezvous tracking mark counter is zeroed by the selection of P20 and after each thrusting maneuver.
3. The ISS need not be on to complete this program unless automatic state vector updating is required by the Rendezvous Navigation program (P20). If selected, P20 will define the status of the ISS.

Sequence of Events:

This sequence of events is identical to P33. Record maneuver parameters and transmit to CSM.

P74—CSM TRANSFER PHASE INITIATION (TPI) TARGETING PROGRAM

Purpose:

1. To calculate the required Delta V and other initial conditions required by the CMC for CSM execution of the Transfer Phase Initiation (TPI) maneuver. Given:
   a. Time of ignition (TIG(TPI)) or the elevation angle (E) of the CSM/LM LOS at TIG(TPI).
   b. Central angle of transfer (CENTANG) from TIG(TPI) to intercept time.
2. To calculate TIG(TPI) given E or E given TIG(TPI).

Assumptions:

1. This program is based upon previous completion of the Constant Delta Altitude (CDH) Targeting program (P73). Therefore:
   a. At a selected TPI time (now in storage) the line of sight between the CSM and the LM was selected to be a prescribed angle (E) (now in storage) from the horizontal plane defined at the CSM position.
   b. The time between CDH ignition and TPI ignition was computed to be greater than 10 minutes.
   c. The variation of the altitude difference between the orbits was minimized.
   d. The pericenter altitudes of the orbits following CSI and CDH were computed to be greater than 35,000 feet (lunar orbit) or 85 nmi (earth orbit).
   e. The CSI and CDH maneuvers were assumed to be parallel to the plane of the LM orbit. However, crew modification of Delta V(LV) components may have resulted in an out-of-plane CDH maneuver.

   Unless the inputs to this program are changed from those inserted in P72 and/or P73, the calculated parameters for the remaining maneuvers of the concentric flight plan will vary from those originally calculated and displayed only due to the continuous radar updating of the LM or CSM orbit.
2. 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 should be 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. The rendezvous tracking mark counter is zeroed by the selection of P20 and after each thrusting maneuver.
3. There is no requirement for ISS operation during this program unless automatic state vector updating is desired by the Rendezvous Navigation program (P20). If selected, P20 will define the status of the ISS.
4. 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 V06 N52.

   The astronaut would 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.

Sequence of Events:

This sequence of events is identical to P34. Record maneuver parameters and transmit to CSM.

P75—CSM TRANSFER PHASE MIDCOURSE (TPM) TARGETING PROGRAM

Purpose:

1. To calculate the required Delta V and other initial conditions required by the CMC for CSM execution of the next midcourse correction of the transfer phase of an active CSM rendezvous.

Assumptions:

1. There is no requirement for ISS operating during this program, unless automatic state vector updating is desired by the Rendezvous Navigation program (P20). If selected, P20 will define the status of the ISS.
2. 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. The rendezvous tracking mark counter is zeroed by the selection of P20 and after each thrusting maneuver.
3. The time of intercept (T(INT)) was defined by previous completion of the Transfer Phase Initiation (TPI) Targeting program (P74) and is presently available in LGC storage.
4. 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 V06 N52.

   The astronaut would 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.

Sequence of Events:

This sequence is identical to P35 sequence. Record maneuver parameters and transmit to CSM.

P76/P77 CSM/LM State Vector Update Program

Purposes:

1. To provide a means of notifying the LGC that the CSM/LM has changed its orbital parameters by the execution of a thrusting maneuver.
2. To provide to the LGC the Delta V applied to the CSM/LM to enable an updating of the CSM or LM state vector.

Assumptions:

1. The LM crew has the Delta V to be applied to the CSM/LM in local vertical axes at the specified TIG.

   These values are displayed prior to TIG by the thrusting programs.

   No provision is made in these thrusting programs to display results of the maneuver in a form usable by this program.
2. If the Rendezvous Navigation program (P20) or the Lunar Surface Navigation program (P22) is in process this program must be selected prior to the CSM thrusting maneuver. This can be assured by voice communication between the LM and CSM.

Sequence of Events:

V37E76E (CSM), V37E77E (LM)

Flashing V06N33	Time of Ignition of Other Vehicle	00XXX. h 000XX. min 0XX.XX s

PRO

Flashing V06N84 or Flashing V06N81	ΔV_X (LV of other vehicle)	XXXX.X ft/s
	ΔV_Y (LV of other vehicle)	XXXX.X ft/s
	ΔV_Z (LV of other vehicle)	XXXX.X ft/s
	ΔV_X (LV of this vehicle)	XXXX.X ft/s
	ΔV_Y (LV of this vehicle)	XXXX.X ft/s
	ΔV_Z (LV of this vehicle)	XXXX.X ft/s

PRO

Flashing V37	Select New Program.

P99—GUIDED RCS BURN (ERASABLE MEMORY PROGRAM)

Purpose:

1. To provide for a guided RCS burn that will be used to deorbit the LM ascent stage into a precise moon impact.

Assumptions:

1. The LM is the ascent stage only.
2. The erasable program for P99 has been previously uplinked and loaded into the computer.
3. A targeting program (P30—External Delta V Program or similar) has been performed prior to calling P99 for use.
4. The digital autopilot has been properly configured with a 5-degree deadband and correct ascent weight prior to use of this program.
5. The control of the spacecraft is PGNS in Auto with the Ascent Engine Arm switch at Off.
6. No more IMU alignments are allowed because the program overlays the AOT Mark and landing radar pad loads in EBANK7.

Sequence of Events:

(Via uplink)

V30E

P99 in mode light

Flashing V50N18	Desired Automaneuver FDAI Angle	R XXX.XX deg P XXX.XX deg Y XXX.XX deg

V33E (Proceed) for trim
or
ENTER For no trim

V06N40	Time from Ignition	XXbXX min/s
	Velocity to be Gained	XXXX.X ft/s
	ΔV (accumulated)	XXXX.X ft/s

TFI counts down until TIG -35 seconds when DSKY blanks for 5 seconds. V06N40 display returns.

At TIG ullage begins
At cutoff ullage stops

Flashing V16N40	Time from Ignition	XXbXX min/s
	Velocity go be Gained	XXXX.X ft/s
	ΔV (accumulated)	XXXX.X ft/s

V33E (Proceed)

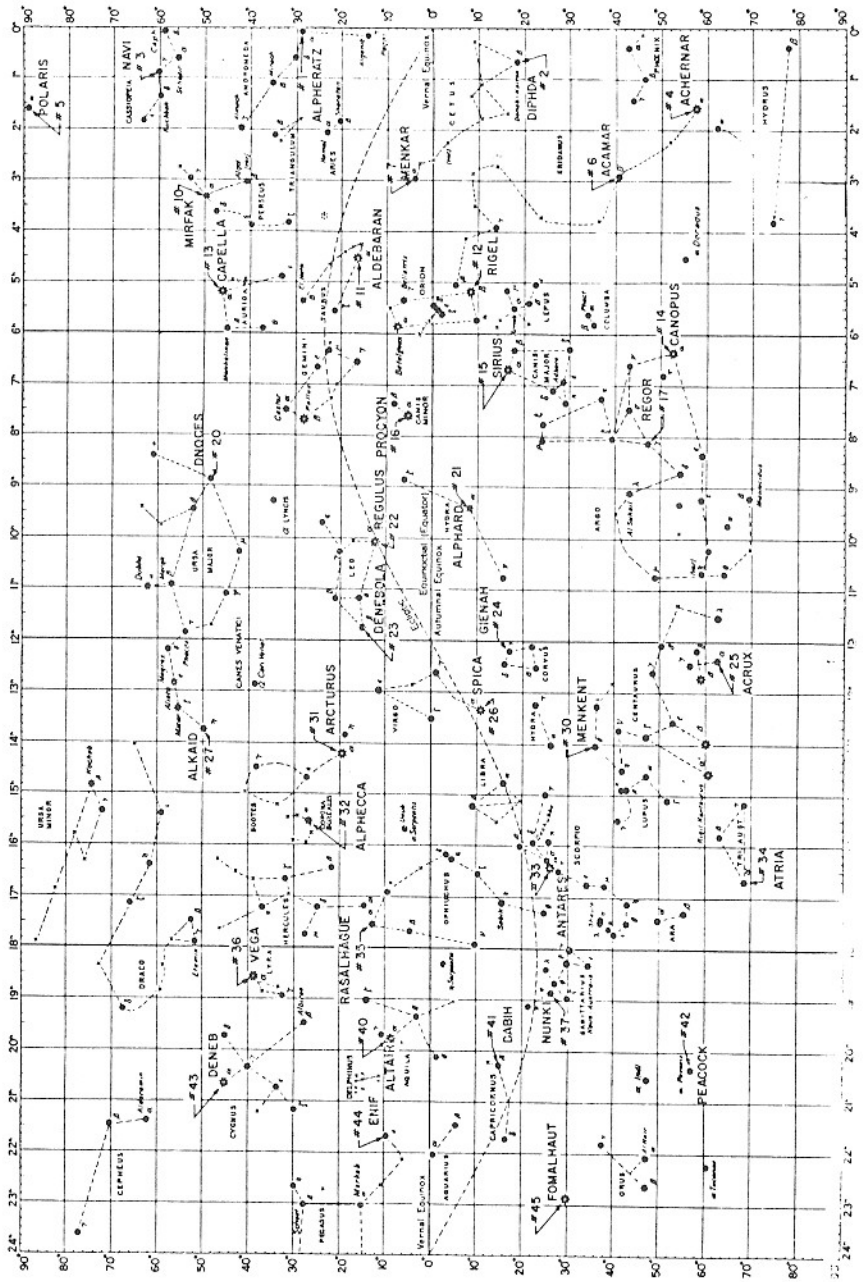
Flashing V16N85	ΔV_X (LM body)	XXXX.X ft/s
	ΔV_Y (LM body)	XXXX.X ft/s
	ΔV_Z (LM body)	XXXX.X ft/s

V33E (Proceed)

Flashing
V37

00E

Go to Program P00



LGC ERASABLE PROCEDURES

Erasable Memory Programs

LEP 001 (EMP 102)	Cause a Software Restart Using V31 Request for Waitlist. This procedure allows a software restart to be placed in the WAITLIST and used when needed or desired.
LEP 002 (EMP 100)	An Erasable Memory Program to Allow Some Use of the DSKY with a Failed Key. A program can be entered via the uplink that will allow a limited use of the DSKY with a failed key. This requires the use of the PRO key on the DSKY.
LEP 011 (EMP 110)	Backup Event Timer. This program would allow the DSKY to be used as an event timer when the vehicle event timer is not usable.
LEP 104 (EMP 108)	Inhibiting T4RUPT Coarse Alignment of the IMU. The T4RUPT coarse alignment of the IMU can be inhibited thereby allowing continuous gyro torquing of the platform and vehicle. Also will prevent a bad followup lag in gimbal lock recovery.
LEP 106 (EMP 104)	P20 Operation with the IMU Off. Allows use of P20 for navigation without the requirement of having the IMU on.
LEP 108 (EMP 103)	Performing Descent with Failed CDU's. Allows some use of P63, P64, and P66 during descent without some combinations of CDU's. Procedure varies with which CDU has been failed.
LEP 107	Ascent with Failed CDU. Allows a modification of the ascent programs (P12, P70, P71) for use with failed CDU's. Procedure varies with which CDU has been failed.
LEP 109	IMU Orientation Determination (P51, P57) with a Failed CDU. Allows use of P51, P57 with some combinations of failed CDU's. Procedures vary with which CDU is failed.
LEP 110	IMU Realignment (P52, P57) with Failed CDU. Allows use of P52, P57 with some combinations of failed CDU's. Procedures vary with which CDU is failed.
LEP 111	P40, P41, P42 with Failed CDU. Allows use of the major burn programs with some combinations of failed CDU's. Procedure varies with which CDU is failed.
LEP 201 (EMP 107)	Displaying Raw LR H and H DOT on the DSKY. Allows use of raw landing radar data to be used and checked on the DSKY.
LEP 203	RR CDU Failure Workarounds.
LEP 301 (EMP 99)	EMP for Guided RCS Translational Maneuvers (P99). See description in LM Software Section.
LEP 302	EMP for P47 with DPS/GTS (Gimbal Trim System). Allows use of P47 with the DPS engine as the S/C propulsion source.

LGC Erasable Memory Procedures

LEP 003	N79 Detent Overwrite. Flight Crew G&N dictionary page 1-40.
LEP 004	State Vector Readout for Transfer to the CMC. Flight Crew G&N dictionary page 1-75.
LEP 005	V36 Recovery.
LEP 006	General Systems Checkout. Flight Crew G&N dictionary page 1-15.
LEP 007	LGC Thruster Inhibit/Reenable. Flight Crew G&N dictionary page 1-65.
LEP 008	Crew Defined Docked Deadband. Flight Crew G&N dictionary page 1-66.
LEP 009	LPD Bias Load/Alternate Bias Load. Flight Crew G&N dictionary page 1-66.
LEP 010	RMAX/VMAX Loading to Force all N49's. Flight Crew G&N dictionary page 1-66.
LEP 105	Rapid IMU Align. Flight Crew G&N dictionary page 3-1.
LEP 112	PIPA Bias Measurement and Loading. Flight Crew G&N dictionary page 1-60.
LEP 113	Enable V40N20E (Coarse Alignment) in Apparent Gimbal Lock.
LEP 114	Onboard Computation of NBDX.
LEP 202	Radar Bias Determination/Initialization. Flight Crew G&N dictionary page 4-8 and page 1-65.