APOLLO 11

AC ELECTRONICS
DIVISION OF GENERAL MOTORS CORPORATION
MILWAUKEE, WISCONSIN 53201

	EARTH	MOON
SATELLITE ORBIT	100 x 100 n mi	60 x 60 n mi
SATELLITE ORBIT DURATION	1 hr 28 min	2 hr
SATELLITE ORBIT RATE	4.1 deg/min	3.0 deg/min
V_C (SURFACE)	7,905.4 m/sec	1,679.5 m/sec
I.E. $V_C = \sqrt{\frac{\mu}{R}}$	25,936.0 ft/sec	5,510.2 ft/sec
	15,356.7 n mi/hr	3,262.6 n mi/hr
ESCAPE VELOCITY (SURFACE)	11,027 m/sec	2,380 m/sec
	36,178 ft/sec	7,750 ft/sec
	21,421 n mi/hr	4,572 n mi/hr
VOLUME	1	0.0202
RADIUS	1	0.272
MASS	1	0.0123
DENSITY	1	0.606
SURFACE GRAVITY	1	0.16
ONE DEGREE ON SURFACE	60 n mi	16.4 n mi
μ	0.3986032×10^{15} m^3/sec^2	0.4902778×10^{13} m^3/sec^2
RADIUS	6,378,165 m	1,738,090 m
	20,925,738 ft	5,702,395 ft
	3,444 n mi	938.5 n mi
ORBIT CHARACTERISTICS	EARTH ABOUT SUN	MOON ABOUT EARTH
SEMI MAJOR AXIS	1.496×10^{11} m	384,400,000 m
	4.908×10^{11} ft	1,261,139,500 ft
	8.073×10^{7} n mi	207,430 n mi
ECCENTRICITY	0.0167	0.055
MEAN VELOCITY	29,770 m/sec	1,022 m/sec
	97,702 ft/sec	3,353 ft/sec
	57,888 n mi/hr	1,980 n mi/hr
PERIOD	365.24 days	27.32 days
INCLINATION	23.44 deg	5.15 deg

MOON SURFACE TEMPERATURE -72°F to +214°F (sun side), -238°F (dark side)

$\mu_{SUN} = 0.132715445 \times 10^{21}\ m^3/sec^2$

1 meter = 3.2808 ft
= 5.3961×10^{-4} n mi
= 6.2137×10^{-4} s mi

1 arc-second = 4.8481×10^{-6} rad
= 2.7778×10^{-4} deg

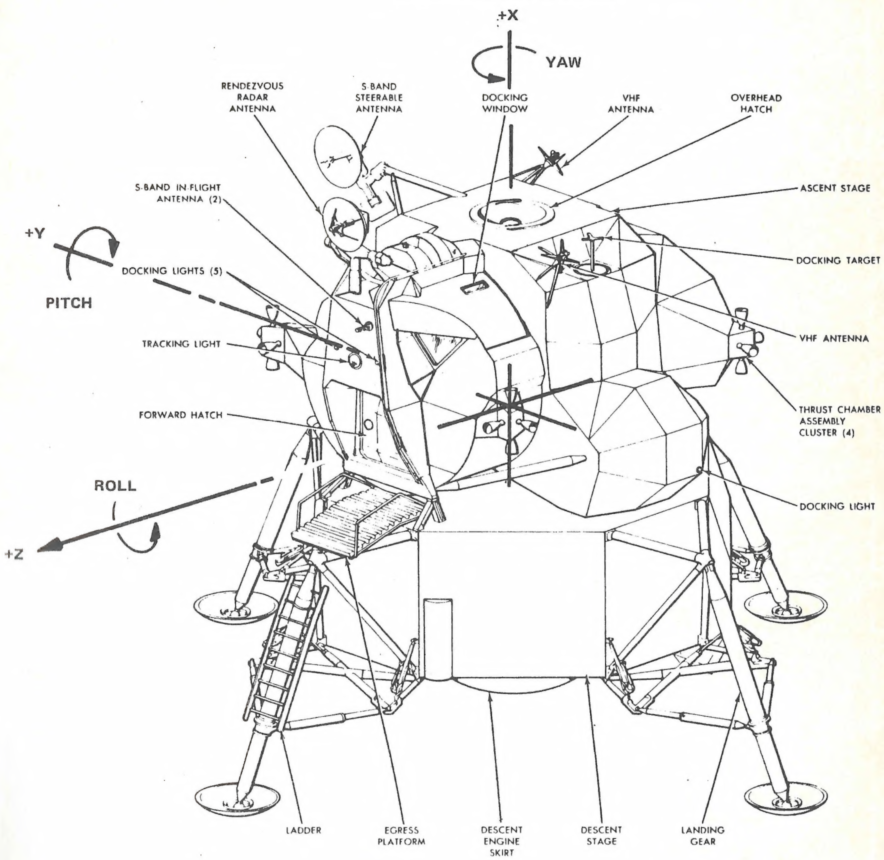
1 meru = 7.292115×10^{-8} rad/sec
= 4.178×10^{-6} deg/sec
= 2.507×10^{-4} arc-min/sec
= 0.01504 arc-sec/sec

1 cm/sec^2 = 3.281×10^{-2} ft/sec^2
= 1.0197×10^{-3} g

GUIDANCE AND NAVIGATION SUMMARY

CM SOFTWARE
LM SOFTWARE
ASPO 45 CRT DISPLAYS
LAUNCH AND BURN SCHEDULE
BURN PERTURBATIONS
PIPA
COARSE ALIGN – FINE ALIGN
OPTICS
DIGITAL AUTOPILOT

LM CONFIGURATION



CM SOFTWARE

COLOSSUS 2A
(REV 055 OF COMANCHE)
CM DSKY
COMPUTER PROGRAMS
COMPUTER ROUTINES
VERB CODES
NOUN CODES
ALARM CODES
OPTION CODES
CHECKLIST CODES
FLAGWORD BIT ASSIGNMENTS
IMODES30 AND IMODES33
OPTMODES
RCSFLAGS
DAPDATR1 AND DAPDATR2
CHANNEL BIT ASSIGNMENTS
COMPUTER PROGRAM DESCRIPTION

UPLINK ACTY Light

1. Is energized by the first character of a digital UPLINK message received by the AGC.
2. Is energized during the Rendezvous Navigation program (P20) when the Tracking Attitude routine (R61) detects that a gimbal angle change of greater than 10 degrees is required to align the CSM to the desired attitude and that the astronaut has disabled automatic tracking of the LM by taking the rotational hand controller out of detent while the SC control switch is at CMC and the thrust controller is not fully clockwise.

NO ATT Light — is energized when the AGC is in the Operate mode and there is no inertial reference; that is, the ISS is off, caged, or in the Coarse Align mode.

STBY Light — is energized when the AGC is in the Standby mode and deenergized when the AGC is in the Operate mode.

KEY REL Light

1. Energized when:
   a. An internal display comes up while astronaut has the DSKY.
   b. An astronaut keystroke is made when an internal flashing display is currently on the DSKY.
   c. The astronaut makes a keystroke on top of (his own) Monitor Verb Display.
2. Deenergized when:
   a. Astronaut relinquishes DSKY by hitting KEY REL button.
   b. Astronaut terminates his current sequence normally, for example,
      (1) With final ENTR of a load sequence.
      (2) The ENTR of a response to a flashing display.
      (3) The ENTR of an extended verb request.

OPR ERR Light — is energized when the DSKY operator performs an improper sequence of key depressions.

TEMP Light — The AGC receives a signal from the IMU when the stable member temperature is in the range 126.3 $^{\circ}$ F to 134.3° F. In the absence of this signal, the TEMP light on the DSKY is actuated.

GIMBAL LOCK Light — is energized when the middle gimbal angle exceeds $\pm$70 degrees from its zero position. When the middle gimbal angle exceeds $\pm$85 degrees from its zero position, the AGC automatically commands the Coarse Align mode in the ISS to prevent gimbal oscillation. The NO ATT light will then be energized.

PROG Light — The program alarm actuates the PROG light on the DSKY. A program alarm is generated under a variety of situations.

RESTART Light — In the event of a RESTART during operation of a program, a latch is set in the AGC which maintains the RESTART light on the DSKY until the latch is manually reset by pressing RSET.

TRACKER Light

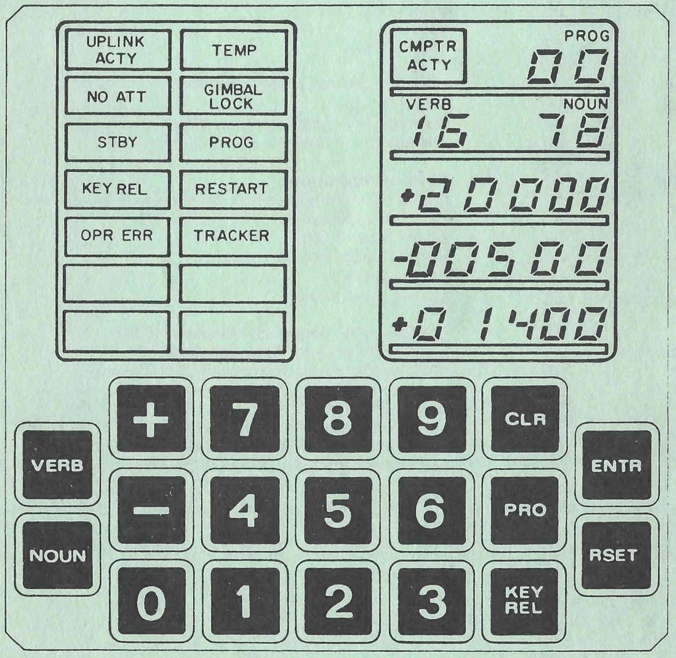
1. The presence of an Optics CDU Fail signal will cause the TRACKER light to be energized.
2. In addition, the TRACKER light is energized during the Rendezvous Navigation program (P20) when the Rendezvous Data Processing routine (R22) reads VHF range data via the VHF DATA link but the DATA GOOD discrete is missing, or the UPDATE flag becomes reset.
3. It is deenergized if the DATA GOOD discrete is present after reading VHF range data and by keying in V88E (shuts off the VHF range data processing section of R22).

COMP ACTY Light — is energized when the AGC is occupied with an internal sequence.

Display Panel — consists of 24 electroluminescent sections. Each section is capable of displaying any decimal character or remaining blank, except the three sign sections. These display a plus sign, a minus sign, or a blank. The numerical sections are grouped to form three data display registers, each of five numerical characters; and three control display registers, each of two numerical characters. The data display registers are referred to as R1, R2, R3. The control display registers are known as VERB, NOUN, and PROGRAM.

Keyboard —contains the following buttons:

1. VERB — pushing this button indicates that the next two numerical characters keyed in are to be interpreted as the Verb Code.
2. NOUN — pushing this button indicates that the next two numerical characters keyed in are to be interpreted as the Noun Code.
3. + and - —are sign keys used for sign convention and to identify decimal data.
4. 0 - 9 —are numerical keys.
5. CLR — Used during a data loading sequence to clear or blank the data display register (R1, R2, R3) being used. It allows the operator to reload the data word.
6. PRO —This pushbutton performs two functions:
   - a. When the AGC is in a Standby mode, pressing this button will put the AGC in the Operate mode, turn off the STBY light, and automatically select Routine 00 in the AGC.
   - b1. When the AGC is in the Operate mode but Program 06 is not selected, pressing the button will provide the "Proceed" function.
   - b2. When the AGC is in the Operate mode and Program 06 is selected, pressing the button will put the AGC in the Standby mode and turn on the STBY light.
7. ENTR —is used in three ways:
   - a. To direct the AGC to execute the Verb/Noun code now appearing on the Verb/Noun lights.
   - b. To direct the AGC to accept a data word just loaded.
   - c. In response to a "please perform" request.
8. RSET —turns off alarm conditions on the DSKY providing the alarm condition has been corrected.



LIST OF PROGRAMS FOR PROGRAM COLOSSUS 2A

PHASE	PROGRAM	PROGRAM TITLE
Pre-launch and Service	00	CMC Idling
	01	Prelaunch or Service-Initialization
	02	Prelaunch or Service-Gyrocompassing
	03	Prelaunch or Service-Optical Verification of Gyrocompassing
	06	CMC Power Down
	07	System Test
Boost	11	Earth Orbit Insertion Monitor
	17	TPI Search
Coast	20	Rendezvous Navigation
	21	Ground Track Determination
	22	Orbital Navigation
	23	Cislunar Midcourse Navigation
	27	CMC Update
Pre-thrusting	30	External Delta V
	31	Lambert Aim Point Guidance
	32	CSM Coelliptic Sequence Initiation (CSI)
	33	CSM Constant Delta Altitude (CDH)
	34	CSM Transfer Phase Initiation (TPI) Targeting
	35	CSM Transfer Phase Midcourse (TPM) Targeting
	37	Return to Earth
	38	CSM Stable Orbit Rendezvous (SOR) Targeting
	39	CSM Stable Orbit Midcourse (SOM) Targeting
Thrusting	40	SPS
	41	RCS
	47	Thrust Monitor
Align-ment	51	IMU Orientation Determination
	52	IMU Realign
	53	Backup IMU Orientation Determination
	54	Backup IMU Realign
Entry	61	Entry—Preparation
	62	Entry—CM/SM Separation and Preentry Maneuver
	63	Entry—Initialization
	64	Entry—Post 0.05G
	65	Entry—Upcontrol
	66	Entry—Ballistic
67	67	Entry—Final Phase
Pre-thrusting Other Vehicle	72	LM Coelliptic Sequence Initiation (CSI)
	73	LM Constant Delta Altitude (CDH)
	74	LM Transfer Phase Initiation (TPI) Targeting
	75	LM Transfer Phase (Midcourse) Targeting
	76	Target Delta V
	77	LM TPI Search
	78	LM Stable Orbit Rendezvous (SOR) Targeting
	79	LM Stable Orbit Midcourse (SOM) Targeting

LIST OF ROUTINES FOR PROGRAM COLOSSUS 2A

ROUTINE	ROUTINE TITLE
00	Final Automatic Request Terminate
02	IMU Status Check
03	Digital Autopilot Data Load
05	S-Band Antenna
21	Rendezvous Tracking Sighting Mark
22	Rendezvous Tracking Data Processing
23	Backup Rendezvous Tracking Sighting Mark
30	Orbit Parameter Display
31	Rendezvous Parameter Display Routine No. 1
33	CMC/LGC Clock Synchronization
34	Rendezvous Parameter Display Routine No. 2
36	Rendezvous Out-of-Plane Display Routine
40	SPS Thrust Fail
41	State Vector Integration (MID to AVE)
50	Coarse Align
52	Automatic Optics Positioning
53	Sighting Mark
54	Sighting Mark Display
55	Gyro Torquing
56	Alternate LOS Sighting Mark
57	Optics Calibration
60	Attitude Maneuver
61	Tracking Attitude
62	Crew-Defined Maneuver
63	Rendezvous Final Attitude

LIST OF VERBS USED IN PROGRAM COLOSSUS 2A

REGULAR VERBS

00	Not in use
01	Display Octal Component 1 in R1
02	Display Octal Component 2 in R1
03	Display Octal Component 3 in R1
04	Display Octal Components 1, 2 in R1, R2
05	Display Octal Components 1, 2, 3 in R1, R2, R3
06	Display decimal in R1 or R1, R2 or R1, R2, R3
07	Display DP decimal in R1, R2 (test only)
08	Spare
09	Spare
10	Spare
11	Monitor Octal Component 1 in R1
12	Monitor Octal Component 2 in R1
13	Monitor Octal Component 3 in R1
14	Monitor Octal Components 1, 2 in R1, R2
15	Monitor Octal Components 1, 2, 3 in R1, R2, R3
16	Monitor decimal in R1 or R1, R2 or R1, R2, R3
17	Monitor DP decimal in R1, R2 (test only)
18	Spare
19	Spare
20	Spare
21	Load Component 1 into R1
22	Load Component 2 into R2
23	Load Component 3 into R3
24	Load Components 1, 2 into R1, R2
25	Load Components 1, 2, 3 into R1, R2, R3
26	Spare
27	Display Fixed Memory
28	Spare
29	Spare
30	Request EXECUTIVE
31	Request WAITLIST

LIST OF VERBS USED IN PROGRAM COLOSSUS 2A

32	Recycle program
33	Proceed without DSKY inputs
34	Terminate function
35	Test lights
36	Request FRESH START
37	Change program (major mode)
38	Spare
39	Spare
	EXTENDED VERBS
40	Zero CDU's (N20 only)
41	Coarse align CDU's (specify N20 or N91)
42	Fine align IMU
43	Load IMU attitude error needles
44	Set Surface flag
45	Reset Surface flag
46	Establish G & N autopilot control
47	Move LM state vector into CM state vector
48	Request DAP Data Load routine (R03)
49	Start automatic attitude maneuver
50	Please perform
51	Please mark
52	Mark on offset landing site
53	Please perform COAS mark
54	Request Rendezvous Backup Sighting Mark routine (R23)
55	Increment CGC time (decimal)
56	Terminate tracking (P20 and P25)
57	Request Rendezvous Sighting Mark routine (R21)
58	Reset Stick flag
59	Please calibrate
60	Set astronaut total attitude (N17) to present attitude
61	Display DAP following attitude errors
62	Display total attitude errors with respect to Noun 22

LIST OF VERBS USED IN PROGRAM COLOSSUS 2A

63	Display total astronaut attitude error with respect to Noun 22
64	Request S-Band Antenna routine (R05)
65	Optical verification of prelaunch alignment
66	Vehicles are attached. Move this vehicle state vector to other vehicle.
67	Spare
68	CSM stroke test on
69	Cause RESTART
70	Update liftoff time (P27)
71	Start CGC update; block address (P27)
72	Start CGC update; single address (P27)
73	Start CGC update; CGC time (P27)
74	Initialize erasable dump via DOWNLINK
75	Backup liftoff
76	Set Preferred Attitude flag
77	Reset Preferred Attitude flag
78	Update prelaunch azimuth
79	Spare
80	Enable LM state vector update
81	Enable CSM state vector update
82	Request Orbit Parameter display (R30)
83	Request Rendezvous Parameter display (R31)
84	Spare
85	Request Rendezvous Parameter Display No. 2 (R34)
86	Reject Rendezvous Backup Sighting Mark
87	Set VHF Range flag
88	Reset VHF Range flag
89	Request Rendezvous Final Attitude maneuver (R63)
90	Request Out of Plane Rendezvous display (R36)
91	Display BANKSUM
92	Start IMU performance tests (ground use)
93	Enable W matrix initialization
94	Perform Cislunar Attitude maneuver
95	Spare

LIST OF VERBS IN PROGRAM COLOSSUS 2A

96	Interrupt integration and go to P00
97	Please perform engine-fail procedure (R40)
98	Spare
99	Please Enable Engine Ignition

LIST OF NOUNS USED IN PROGRAM COLOSSUS 2A

00	Not in use		
01	Specify address (fractional)		.XXXXX fractional .XXXXX fractional .XXXXX fractional
02	Specify address (whole)		XXXXX. integer XXXXX. integer XXXXX. integer
03	Specify address (degree)		XXX.XX deg XXX.XX deg XXX.XX deg
04	Spare		
05	Angular error/difference		XXX.XX deg
06	Option code ID Option code		Octal Octal
07	FLAGWORD operator		
	ECADR BIT ID Action		Octal Octal Octal
08	Alarm data		
	ADRES BBANK ERCOUNT		Octal Octal Octal
09	Alarm codes		
	First Second Last		Octal Octal Octal
10	Channel to be specified		Octal
11	TIG of CSI		00XXX. h 000XX. min 0XX.XX s
12	Option code (extended verbs only)		Octal Octal
13	TIG of CDH		00XXX. h 000XX. min 0XX.XX s
14	Spare		
15	Increment address		Octal
16	Time of event (used by extended verbs only)		00XXX. h 000XX. min 0XX.XX s
17	Astronaut total attitude	R P Y	XXX.XX deg XXX.XX deg XXX.XX deg

LIST OF NOUNS USED IN PROGRAM COLOSSUS 2A

18	Desired automaneuver FDAI ball angles	R P Y	XXX.XX deg XXX.XX deg XXX.XX deg
19	Bypass Attitude Trim maneuver	R P Y	XXX.XX deg XXX.XX deg XXX.XX deg
20	Present ICDU angles	OG IG MG	XXX.XX deg XXX.XX deg XXX.XX deg
21	PIPA's	X Y Z	XXXXX. pulses XXXXX. pulses XXXXX. pulses
22	Desired ICDU angles	OG IG MG	XXX.XX deg XXX.XX deg XXX.XX deg
23	Spare		
24	Delta time for LGC clock		00XXX. h 000XX. min 0XX.XX s
25	CHECKLIST (used with V50)		XXXXX.
26	PRIO/DELAY, ADRES, BBCON		Octal Octal Octal
27	Self-test on/off switch		XXXXX.
28	Spare		
29	XSM launch azimuth		XXX.XX deg
30	Target codes		XXXXX. XXXXX. XXXXX.
31	Time of landing site		00XXX. h 000XX. min 0XX.XX s
32	Time from perigee		00XXX. h 000XX. min 0XX.XX s
33	Time of ignition		00XXX. h 000XX. min 0XX.XX s
34	Time of event		00XXX. h 000XX. min 0XX.XX s
35	Time from event		00XXX. h 000XX. min 0XX.XX s
36	Time of CGC clock		00XXX. h 000XX. min 0XX.XX s

37	Time of ignition (TPI)	00XXX. h 000XX. min 0XX.XX s
38	Time of state being integrated	00XXX. h 000XX. min 0XX.XX s
39	Delta time for transfer	00XXX. h 000XX. min 0XX.XX s
40	Time from ignition/cutoff VG Delta V (accumulated)	XX b XX min/s XXXX.X ft/s XXXX.X ft/s
41	Target	
	Azimuth Elevation	XXX.XX deg XX.XXX deg
42	Apocenter altitude Pericenter altitude Delta V (required)	XXXX.X nmi XXXX.X nmi XXXX.X ft/s
43	Latitude Longitude Altitude	XXX.XX deg (+ north) XXX.XX deg (+ east) XXXX.X nmi
44	Apocenter altitude Pericenter altitude TFF	XXXX.X nmi XXXX.X nmi XX b XX min/s
45	Marks (VHF/optics) Time from ignition of next burn Middle gimbal angle	XX b XX marks XX b XX min/s XXX.XX deg
46	DAP configuration	Octal Octal
47	CSM weight LM weight	XXXXX. lbs XXXXX. lbs
48	Gimbal pitch trim Gimbal roll trim	XXX.XX deg XXX.XX deg
49	Delta R Delta V VHF or optics code	XXXX.X nmi XXXX.X ft/s XXXXX.
50	Splash error Perigee TFF	XXXX.X nmi XXXX.X nmi XX b XX min/s
51	S-band antenna angles	
	Pitch (Alpha) Yaw (Beta)	XXX.XX deg XXX.XX deg
52	Central angle of active vehicle	XXX.XX deg
53	Range Range rate Phi	XXX.XX nmi XXXX.X ft/s XXX.XX deg

LIST OF NOUNS USED IN PROGRAM COLOSSUS 2A

54	Range	XXX.XX nmi
	Range rate	XXXX.X ft/s
	Theta	XXX.XX deg
55	Number of apsidal crossings (N)	0000X.
	Elevation angle (E)	XXX.XX deg
	Central angle of passive vehicle	XXX.XX deg
56	Reentry angle	XXX.XX deg
	Delta V	XXXXX. ft/s
57	Delta R	XXXX.X nmi
58	Pericenter altitude (post TPI)	XXXX.X nmi
	Delta V TPI	XXXX.X ft/s
	Delta V TPF	XXXX.X ft/s
59	Delta V LOS 1	XXXX.X ft/s
	Delta V LOS 2	XXXX.X ft/s
	Delta V LOS 3	XXXX.X ft/s
60	GMAX	XXX.XX g
	VPRED	XXXXX. ft/s
	GAMMA EI	XXX.XX deg
61	Impact	
	Latitude	XXX.XX deg (+ north)
	Longitude	XXX.XX deg (+ east)
	Heads up/down	+/- 00001
62	Inertial velocity magnitude	XXXXX. ft/s
	Altitude rate	XXXXX. ft/s
	Altitude above pad radius	XXXX.X nmi
63	Range from EMS altitude to splash	XXXX.X nmi
	Predicted inertial velocity	XXXXX. ft/s
	Time from EMS altitude	XX b XX min/s
64	Drag acceleration	XXX.XX g
	Inertial velocity	XXXXX. ft/s
	Range to splash	XXXX.X nmi (+ is overshoot)
65	Sampled CGC time	00XXX. h
	(fetched in interrupt)	000XX. min
		0XX.XX s
66	Commanded bank angle	XXX.XX deg
	Crossrange error	XXXX.X nmi (+ south)
	Downrange error	XXXX.X nmi (+ overshoot)
67	Range to target	XXXX.X nmi (+ overshoot)
	Present latitude	XXX.XX deg (+ north)
	Present longitude	XXX.XX deg (+ east)
68	Commanded bank angle	XXX.XX deg
	Inertial velocity	XXXXX. ft/s
	Altitude rate	XXXXX. ft/s
69	Commanded bank angle	XXX.XX deg
	Drag level	XXX.XX g
	Exit velocity	XXXXX. ft/s

LIST OF NOUNS USED IN PROGRAM COLOSSUS 2A

70	Star code		Octal
	Landmark data		Octal
	Horizon data		Octal
71	Star code		Octal
	Landmark data		Octal
	Horizon data		Octal
72	Delta angle (TPI)		XXX.XX deg
	Delta altitude (TPI)		XXXX.X nmi
	Search option		0000X
73	Altitude		XXXXXb. nmi
	Velocity		XXXXX. ft/s
	Flight path angle		XXX.XX deg
74	Commanded bank angle		XXX.XX deg
	Inertial velocity		XXXXX. ft/s
	Drag acceleration		XXX.XX g
75	Delta altitude (CDH)		XXXX.X nmi
	Delta time (CDH-CSI or TPI-CDH)		XX b XX min/s
	Delta time (TPI-CDH or TPI-NOMTPI)		XX b XX min/s
76	Spare		
77	Spare		
78	Spare		
79	Spare		
80	Time from ignition/cutoff		XX b XX min/s
	Velocity to be gained		XXXXX. ft/s
	Delta V (accumulated)		XXXXX. ft/s
81	Delta VX (LV)		XXXX.X ft/s
	Delta VY (LV)		XXXX.X ft/s
	Delta VZ (LV)		XXXX.X ft/s
82	Delta VX (LV)		XXXX.X ft/s
	Delta VY (LV)		XXXX.X ft/s
	Delta VZ (LV)		XXXX.X ft/s
83	Delta VX (body)		XXXX.X ft/s
	Delta VY (body)		XXXX.X ft/s
	Delta VZ (body)		XXXX.X ft/s
84	Delta VX (LV of other vehicle)		XXXX.X ft/s
	Delta VY (LV of other vehicle)		XXXX.X ft/s
	Delta VZ (LV of other vehicle)		XXXX.X ft/s
85	VGX (body)		XXXX.X ft/s
	VGY (body)		XXXX.X ft/s
	VGZ (body)		XXXX.X ft/s
86	Delta VX (LV)		XXXXX. ft/s
	Delta VY (LV)		XXXXX. ft/s
	Delta VZ (LV)		XXXXX. ft/s
87	Mark data		
	Shaft angle		XXX.XX deg
	Trunnion angle		XX.XXX deg
88	Celestial body ½ unit vector	X	.XXXXX
		Y	.XXXXX
		Z	.XXXXX

LIST OF NOUNS USED IN PROGRAM COLOSSUS 2A

89	Landmark latitude		XX.XXX deg (+ north)
	Landmark longitude/2		XX.XXX deg (+ east)
	Landmark altitude		XXX.XX nmi
90	Rendezvous out of plane parameters		
	Y		XXX.XX nmi
	Y dot		XXXX.X ft/s
	PSI		XXX.XX deg
91	Optics angles		
	Shaft		XXX.XX deg
	Trunnion		XX.XXX deg
92	New optics angles		
	Shaft		XXX.XX deg
	Trunnion		XX.XXX deg
93	Delta gyro angles	X	XX.XXX deg
		Y	XX.XXX deg
		Z	XX.XXX deg
94	Mark data		
	Shaft angle		XXX.XX deg
	Trunnion angle		XX.XXX deg
95	Preferred attitude gimbal angles	R	XXX.XX deg
		P	XXX.XX deg
		Y	XXX.XX deg
96	+X axis attitude gimbal angles	R	XXX.XX deg
		P	XXX.XX deg
		Y	XXX.XX deg
97	System test inputs		XXXXX.
			XXXXX.
			XXXXX.
98	System test results and input		XXXXX.
			.XXXXX
			XXXXX.
99	RMS in position		XXXXX. ft
	RMS in velocity		XXXX.X ft/s
	RMS option		XXXXX.

LIST OF ALARM CODES USED WITH V05 N09 FOR PROGRAM COLOSSUS 2A

CODE		PURPOSE	SET BY
00110		No mark since last mark reject	SXTMARK
00112		Mark not being accepted	SXTMARK
00113		No inbits	SXTMARK
00114		Mark made but not desired	SXTMARK
00115		Optics torque request with switch not at CMC	Extended verb optics CDU
00116		Optics switch altered before 15-second ZERO time elapsed	T4RUPT
00117		Optics torque request with optics not available	Extended verb optics CDU
00120		Optics torque request with optics not ZEROED	T4RUPT
00121		CDU's no good at time of mark	SXTMARK
00122		Marking not called for	SXTMARK
00124		P17 TPI search—no safe pericenter here	TPI search
00205		Bad PIPA reading	SERVICER
00206		Zero encode not allowed with coarse align + gimbal lock	IMU mode switch
00207		ISS turn-on request not present for 90 seconds	T4RUPT
00210		IMU not operating	IMU mode switch, IMU-2 R02, P51
00211		Coarse align error-drive > 2 degrees	IMU mode switch
00212		PIPA fail but PIPA is not being used	IMU mode switch, T4RUPT
00213		IMU not operating with turn-on request	T4RUPT
00214		Program using IMU when turned off	T4RUPT
00215		Preferred orientation selected but not specified	P52, P54
00217		Bad return from Stall routines	CURTAINS
00220		IMU not aligned (no REFSMMAT)	R02, P51
00401		Desired gimbal angles yield Gimbal Lock	Fine Align, IMU-2
00404		Target out of view (trunnion angle > 90 degrees)	R52
00405		Two stars not available	P52, P54
00406		Rendezvous navigation not operating	R21, R23
00407		Auto optics request (trunnion angle > 50 degrees)	R52
00421		W-Matrix overflow	INTEGRV
00430	P*	Integration abort due to subsurface state vector	All calls to integration
00600		Imaginary roots on first interation	P32, P72

LIST OF ALARM CODES USED WITH V05 N09
FOR PROGRAM COLOSSUS 2A

CODE		PURPOSE	SET BY
00601		Perigee altitude after CSI < 84 nmi earth orbit, 35,000 feet moon orbit	P32,P72
00602		Perigee altitude after CDH < 84 nmi earth orbit, 35,000 feet moon orbit	P32, P72
00603		CSI to CDH time <10 minutes	P32, P33, P72, P73
00604		CDH to TPI time <10 minutes	P32, P72
00605		Number of iterations exceeds loop maximum	P32, P37, P72
00606		DV exceeds maximum	P32, P72
00607	P*	No solution from Time-Theta or Time-Radius	TIMETHET, TIMERAD
00610	P*	Lambda less than unity	P37
00611		No TIG for given elevation angle	P34, P74
00612		State vector in wrong sphere of influence	P37
00613		Reentry angle out of limits	P37
00777		PIPA fail caused ISS warning	T4RUPT
01102		CMC self-test error	SELF-CHECK
01103	P*	Unused CCS branch executed	ABORT
01104	B*	Delay routine busy	EXECUTIVE
01105		Downlink too fast	T4RUPT
01106		Uplink too fast	T4RUPT
01107		Phase table failure; assume erasable memory is destroyed	RESTART
01201	B*	Executive overflow—no VAC areas available	EXECUTIVE
01202	B*	Executive overflow—no core sets available	EXECUTIVE
01203	B*	WAITLIST overflow—too many tasks	WAITLIST
01204	P*	Negative or zero WAITLIST call	WAITLIST
01206	P*	Second job attempts to go to sleep via Keyboard and Display program	PINBALL
01207	B*	No VAC area for marks	SXTMARK
01210	P*	Two programs using device at same time	IMU Mode Switch
01211	B*	Illegal interrupt of Extended Verb	SXTMARK
01301		ARCSIN-ARCCOS argument too large	INTERPRETER
01302	P*	SQRT called with negative argument	INTERPRETER
01407		VG increasing	S40.8
01426		IMU unsatisfactory	P61, P62

LIST OF ALARM CODES USED WITH V05 N09
FOR PROGRAM COLOSSUS 2A

CODE		PURPOSE	SET BY
01427		IMU reversed	P61, P62
01501	P*	Keyboard and Display alarm during internal use (NVSUB)	PINBALL
01502	P*	Illegal flashing display	GOPLAY
01520		V37 request not permitted at this time	V37
01521	P*	P01, P07 illegally selected	P01, P07
01600		Overflow in Drift Test	Optical Prealignment Calibration
01601		Bad IMU torque	Optical Prealignment Calibration
01602		Bad optics during verification	Optical Alignment Calibration (CSM)
01703		Insufficient time for integration, TIG was slipped	R41
03777		ICDU fail caused the ISS warning	T4RUPT
04777		ICDU, PIPA fails caused the ISS warning	T4RUPT
07777		IMU fail caused the ISS warning	T4RUPT
10777		IMU, PIPA fails caused the ISS warning	T4RUPT
13777		IMU, ICDU fails caused the ISS warning	T4RUPT
14777		IMU, ICDU, PIPA fails caused the ISS warning	T4RUPT

*Indicates abort type. All others are nonabortive.

P Indicates a go-to-Program 00 type abort (unless Average G is on, then P becomes B)

B Indicates a bailout type abort.

Note: For V05 N09 Displays:
R1—XXXXX (first alarm to occur after last reset).
R2—XXXXX (second alarm to occur after last reset).
R3—XXXXX (most recent alarm).

LIST OF OPTION CODES USED WITH V04 N06 FOR PROGRAM COLOSSUS 2A

(The specified option codes will be displayed in R1 in conjunction with Flashing V04 N06 to request the astronaut to load into R2 the option he desires.)

CODE	PURPOSE	INPUT FOR R2	PROGRAM(S
00001	Specify IMU orientation	1 = preferred, 2 = nominal, 3 = REFSMMAT, 4 = landing site	P50's
00002	Specify vehicle	1 = this vehicle, 2 = other vehicle	P21, R30
00003	Specify tracking attitude	1 = preferred, 2 = +X-axis	R63
00005	Specify SOR phase	1 = first, 2 = second	P38
00007	Specify propulsion system	1 = SPS, 2 = RCS	P37

LIST OF CHECKLIST REFERENCE CODES USED WITH V50 N25 FOR PROGRAM COLOSSUS 2A

CODE	ACTION TO BE EFFECTED
00013	Perform coarse alignment
00014	Key in fine alignment option
00015	Perform celestial body acquisition
00016	Key in Terminate Mark sequence
00041	Switch CM/SM separation to UP
00062	Switch AGC power down
00202	Perform GNCS automatic maneuver
00204	Perform SPS gimbal trim

Notes: Switch—denotes change position of a console switch

Perform—denotes start or end of a task

Key In—denotes key-in of data through the DSKY

FLAGWORD BIT ASSIGNMENTS (ALPHABETICAL)
FOR COLOSSUS 2A

ADVTRK	FW8	B10	GAMDIFSW*	FW6	B11
AMOONFLG	FW0	B2	GLOKFAIL	FW3	B14
APSESW	FW8	B5	GLOKFBIT	FW3	B14
ASTENFLAG*	FW7	B12	GONEBY	FW7	B8
ATTCHFLG*	FW7	B2	GONEPAST	FW6	B10
AVEGBIT	FW1	B1	GRRBKBIT	FW5	B5
AVEGFLAG	FW1	B1	GRRBKFLG	FW5	B5
AVEMIDSW	FW9	B1	GUESSW	FW1	B2
AVFLAG	FW2	B5	GYMDIFSW*	FW6	B1
CALCMAN2	FW2	B2	HIND	FW6	B6
CMDAPARM*	FW6	B12	IDLEFAIL	FW1	B6
CMOONFLG	FW8	B12	IGNFLAG*	FW7	B13
CM/DSTBY	FW6	B2	IMPULSW	FW2	B9
COGAFLAG	FW8	B4	IMUSE	FW0	B8
COMPUTER	FW5	B8	IMUSEFLG	FW0	B8
CPHIFLAG	FW0	B15	INCORFLG	FW5	B11
CULTFLAG	FW3	B7	INFINFLG	FW8	B7
D6OR9FLG	FW3	B2	INRLSW	FW6	B5
DAPBIT1	FW6	B15	INTFLBIT	FW10	B14
DAPBIT2	FW6	B14	INTYPFLG	FW3	B4
DIMOFLAG	FW3	B1	ITSWICH	FW7	B14
DMENFLG	FW5	B9	JSWITCH	FW0	B14
DRIFTFLG	FW2	B15	KFLAG	FW0	B1
DSKYFLAG*	FW5	B15	KNOWNFLG	FW6	B8
EGSW	FW6	B8	LATSW	FW6	B4
ENG2FLAG	FW1	B11	LMOONFLG	FW8	B11
ENGONBIT	FW5	B7	LUNAFLAG	FW3	B12
ENTRYDSP	FW6	B13	MAXDBBIT	FW9	B12
ERADFLAG	FW1	B13	MAXDBFLG	FW9	B12
ETPIFLAG	FW2	B7	MGLVFLAG	FW5	B2
FINALFLG	FW2	B6	MID1FLAG	FW9	B3
FIRSTFLG	FW2	B7	MIDAVFLG	FW9	B2
FREEFLAG	FW0	B3	MIDFLAG	FW0	B13
F2RTE	FW0	B5	MKOVFLAG*	FW4	B3

*These switches are never called by name.

FLAGWORD BIT ASSIGNMENTS (ALPHABETICAL) FOR COLOSSUS 2A

MOONFLAG	FW0	B12
MRKIDFLG*	FW4	B15
MRKNVFLG	FW4	B9
MRUPTFLG*	FW4	B5
MWAITFLG*	FW4	B11
NEEDLFLG	FW0	B9
NEWIFLG	FW8	B13
NJETSFLG	FW1	B15
NODOBIT	FW2	B1
NODOFLAG	FW2	B1
NODOP01	FW1	B12
NOP01BIT	FW1	B12
NORFHOR	FW0	B11
NORMSW	FW7	B10
NOSWITCH	FW6	B7
NRMIDFLG*	FW4	B13
NRMNVFLG	FW4	B8
NRUPTFLG*	FW4	B4
NWAITFLG*	FW4	B10
N22ORN17	FW9	B6
OPTNSW	FW2	B7
ORBWFLAG	FW3	B6
ORDERSW	FW8	B6
PDSPFBIT	FW4	B12
PDSPFLAG	FW4	B12
PFRATFLG	FW2	B4
PINBRFLG	FW4	B6
PRECIFLG	FW3	B8
PRFTRKAT	FW5	B10
PRIODFLG*	FW4	B14
PRONVFLG	FW4	B7
P21FLAG	FW2	B12
P22MKFLG	FW3	B11
P39/79SW	FW8	B9
QUITFLAG	FW9	B5
REFSMFLG	FW3	B13
REINTBIT	FW10	B7
REINTFLG	FW10	B7
RELVELSW	FW6	B9
RENDWFLG	FW5	B1
RETROFLG	FW5	B14
RNDVZBIT	FW0	B7
RNDVZFLG	FW0	B7
RNGSCFLG	FW5	B10
RPQFLAG	FW8	B15
RVSW	FW7	B9
R21MARK	FW2	B14
R22CAFLG*	FW9	B7
R23BIT	FW1	B9
R23FLG	FW1	B9
R31FLAG	FW9	B4
R31FLBIT	FW9	B4
R53FLAG	FW0	B6
R57FLAG	FW6	B8
R60FLAG*	FW5	B4
SAVECFLG	FW9	B10
SKIPBIT	FW2	B10
SKIPVHF	FW2	B10
SLOPESW	FW1	B3
SLOWFLG	FW5	B13
SOLNSW	FW5	B3
SOURCBIT	FW9	B8
SOURCFLG	FW9	B8
STATEFLG	FW3	B5

*These switches are never called by name.

FLAGWORD BIT ASSIGNMENTS (ALPHABETICAL)
FOR COLOSSUS 2A

STEERSW	FW2	B11
STIKBIT	FW1	B14
STIKFLAG	FW1	B14
STRULLSW	FW6	B13
SURFFLAG	FW8	B8
SWTOVER*	FW9	B15
S32.1F1	FW11	B15
S32.1F2	FW11	B14
S32.1F3A	FW11	B13
S32.1F3B	FW11	B12
TARG1FLG	FW1	B10
TARG2FLG	FW1	B9
TERMIFLG	FW7	B15
TFFSW	FW7	B1
TIMRFLAG	FW7	B11
TRACKBIT	FW1	B5
TRACKFLG	FW1	B5
TRM03BIT	FW1	B4
TRM03FLG	FW1	B4
TRUNFLAG	FW0	B4
UPDATBIT	FW1	B7
UPDATFLG	FW1	B7
UPLOCKFL*	FW7	B4
VEHUPFLG	FW1	B8
VERIFLAG*	FW7	B3
VFLAG	FW3	B10
VHFRFLAG	FW9	B9
VINTFLAG	FW3	B3
V37FLAG	FW7	B6
V37FLBIT	FW7	B6
V59FLAG	FW5	B12
V67FLBIT*	FW9	B14
V82EMFLG	FW9	B13
V94FLAG	FW9	B11
V94FLBIT	FW9	B11
V96ONFLG	FW8	B3
XDELVFLG	FW2	B8
XDSPFLAG*	FW4	B1
ZMEASURE	FW0	B10
.05GSW	FW6	B3
22DSPFLG	FW2	B13
360SW	FW8	B1
3AXISFLG	FW5	B6

*These switches are never called by name.

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

(FLAGWORD 0)

Bit	Name	1	0
1	KFLAG	Search sector < 180 degrees.	Search sector > 180 degrees.
2	AMOONFLG	State vector in lunar sphere at MIDTOAVE.	State vector in earth sphere at MIDTOAVE.
3	FREEFLAG	(Temporary flag used in many routines.)	
4	TRUNFLAG	Driving of trunnion allowed.	Driving of trunnion not allowed.
5	F2RTE	In time critical mode.	Not in time critical mode.
6	R53FLAG	V51 initiated.	V51 not initiated.
7	RNDVZBIT RNDVZFLG	P20 running.	P20 not running.
8	IMUSE IMUSEFLG	IMU in use.	IMU not in use.
9	NEEDLFLG	Total attitude error displayed.	A/P following error displayed.
10	ZMEASURE	Measurement planet and primary planet different.	Measurement planet and primary planet same.
11	NORFHOR	Far horizon.	Near horizon.
12	MOONFLAG	Moon is sphere of influence.	Earth is sphere of influence.
13	MIDFLAG	Integration with solar perturbations.	Integration without solar perturbations.
14	JSWITCH	Integration of W matrix.	Integration of state vector.
15	CPHIFLAG	Output of CALCGA is CPHIX.	Output of CALCGA is THETAD.

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

(FLAGWORD 1)

Bit	Name	1	0
1	AVEGBIT AVEGFLAG	AVERAGEG (SERVICER) to continue.	AVERAGEG (SERVICER) to cease.
2	GUESSW	No starting value for iteration exists	Starting value for iteration exists.
3	SLOPESW	Iterate with bias method in iterator.	Iterate with Regula Falsi method in iterator.
4	TRM03BIT TRM03FLG	Request to terminate P03 has been entered.	No request to terminate P03 has been entered.
5	TRACKBIT TRACKFLG	Tracking allowed.	Tracking not allowed.
6	IDLEFAIL	Inhibit R40.	Enable R40 (engine fail).
7	UPDATBIT UPDATFLG	Updating by marks allowed.	Updating by marks not allowed.
8	VEHUPFLG	CSM state vector being updated.	LM state vector being updated.
9	R23BIT R23FLG	R23 marking.	R21 marking.
	TARG2FLG	Sighting landmark.	Sighting star.
10	TARG1FLG	Sighting LM.	Not sighting LM.
11	ENG2FLAG	RCS burn.	SPS burn.
12	NODOP01 NOP01BIT	P01 not allowed.	P01 allowed.
13	ERADFLAG	EARTH—compute Fischer ellipsoid radius. MOON—use fixed radius	EARTH—use fixed radius. MOON—use RLS for lunar radius.
14	STIKBIT STIKFLAG	RHC control.	CMC control.
15	NJETSFLG	Two-jet RCS burn.	Four-jet RCS burn.

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

(FLAGWORD 2)

Bit	Name	1	0
1	NODOBIT NODOFLAG	V37 not permitted.	V37 permitted.
2	CALCMAN2	Perform maneuver starting procedure.	Bypass starting procedure.
3	Not Assigned		
4	PFRATFLG	Preferred attitude computed.	Preferred attitude not computed.
5	AVFLAG	LM is active vehicle.	CSM is active vehicle.
6	FINALFLG	Last pass through rendezvous program computations.	Interim pass through rendezvous program computations.
7	OPTNSW	SOI phase of P38/P78.	SOR phase of P38/P78.
	FIRSTFLG	First pass through S40.9.	Succeeding pass through S40.9.
	ETPIFLAG	Elevation angle supplied for P34/P74.	TPI time supplied for P34/P74.
8	XDELVFLG	External Delta V VG computation.	Lambert (AIMPOINT) VG computation.
9	IMPULSW	Minimum impulse burn (cutoff time specified).	Steering burn (no cutoff time yet available).
10	SKIPVBIT SKIPVHF	Disregard radar read because of software or hardware RESTART.	Radar read to proceed normally.
11	STEERSW	Steering to be done.	Steering omitted.
12	P21FLAG	Succeeding pass through P21, use base vector for calculation.	First pass through P21, calculate base vector.
13	22DPSFLG	Display DR, DV.	Do not display DR, DV.
14	R21MARK	Option 1 for MARKRUPT.	Option 2 for MARKRUPT.
15	DRIFTFLG	T3RUPT calls gyro compensation.	T3RUPT does no gyro compensation.

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

(FLAGWORD 3)

Bit	Name	1	0
1	DIMOFLAG	W matrix is to be used.	W matrix is not to be used.
2	D6OR9FLG	Dimension of W is 9 for integration.	Dimension of W is 6 for integration.
3	VINTFLAG	CSM state vector being integrated.	LM state vector being integrated.
4	INTYPFLG	Conic integration.	Encke integration.
5	STATEFLG	Permanent state vector being updated.	Permanent state vector not being updated.
6	ORBWFLAG	W matrix valid for orbital navigation.	W matrix invalid for orbital integration.
7	CULTFLAG	Star occulted.	Start not occulted.
8	PRECIFLG	CSMPREC, LEMPREC, or INTEGRVS called.	INTGRV called.
9	Not Assigned		
10	VFLAG	Less than two stars in the field of view.	Two stars in the field of view.
11	P22MKFLG	P22 downlinked mark data was just taken.	P22 downlinked mark data not just taken.
12	LUNAFLAG	Lunar latitude-longitude.	Earth latitude-longitude.
13	REFSMFLG	REFSMMAT good.	REFSMMAT no good.
14	GLOKFAIL GLOKFBIT	GIMBAL LOCK has occurred.	Not in GIMBAL LOCK.
15	Not Assigned		

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

(FLAGWORD 4)

Bit	Name	1	0
1	XDSPFLAG*	Mark display not to be interrupted.	No special mark information.
2	Not Assigned		
3	MKOVFLAG*	Mark display over normal display.	No mark display over normal display.
4	NRUPTFLG*	Normal display interrupted by priority or mark display.	Normal display not interrupted by priority or mark display.
5	MRUPTFLG*	Mark display interrupted by priority display.	Mark display not interrupted by priority display.
6	PINBRFLG	Astronaut has interferred with existing display.	Astronaut has not interferred with existing display.
7	PRONVFLG	Astronaut using keyboard when priority display initiated.	Astronaut not using keyboard when priority display initiated.
8	NRMNVFLG	Astronaut using keyboard when normal display initiated.	Astronaut not using keyboard when normal display initiated.
9	MRKNVFLG	Astronaut using keyboard when mark display initiated.	Astronaut not using keyboard when mark display initiated.
10	NWAITFLG*	Higher priority display operating when normal display initiated.	No higher priority display operating when normal display initiated.
11	MWAITFLG*	Higher priority display operating when mark display initiated.	No higher priority display operating when mark display initiated.
12	PDSPFBIT PDSPFLAG	Cannot interrupt priority display.	
13	NRMIDFLG*	Normal display in ENDIDLE.	No normal display in ENDIDLE.
14	PRIODFLG*	Priority display in ENDIDLE.	No priority display in ENDIDLE.
15	MRKIDFLG*	Mark display in ENDIDLE.	No mark display in ENDIDLE.

*These switches are never called by name.

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

(FLAGWORD 5)

Bit	Name	1	0
1	RENDWFLG	W matrix valid for rendezvous navigation.	W matrix invalid for rendezvous navigation.
2	MGLVFLAG	Local vertical coordinates computed.	Middle gimbal angle computed.
3	SOLNSW	Lambert does not converge, or time-radius nearly circular.	Lambert converges or time-radius noncircular.
4	R60FLAG*	R61 must use R60.	Normal R61.
5	GRRBKBIT GRRBKFLG	Backup GRR received.	Backup GRR not received.
6	3AXISFLG	Maneuver specified by three axes.	Maneuver specified by one axis.
7	ENGONBIT	Engine turned on.	Engine turned off.
8	COMPUTER	Computer is CMC.	Computer is LGC.
9	DMENFLG	Dimension of W is 9 for incorporation.	Dimension of W is 6 for incorporation.
10	PRFTRKAT RNGSCFLG	Preferred tracking attitude.	+X axis tracking attitude.
11	INCORFLG	First incorporation.	Second incorporation.
12	V59FLAG	Calibrating for P23.	Normal marking for P23.
13	SLOWFLG	P37 transearth coast slowdown is desired.	Slowdown is not desired.
14	RETROFLG	P37 premaneuver orbit is retrograde.	Orbit is not retrograde.
15	DSKYFLAG*	Displays sent to DSKY.	No displays to DSKY.

*These switches are never called by name.

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

(FLAGWORD 6)

Bit	Name	1	0
1	GYMDIFSW*	CDU differences and body rates computed.	CDU differences and body rates not computed.
2	CM/DSTBY	ENTRY DAP activated.	ENTRY DAP not activated.
3	.05GSW	Drag over 0.05 g	Drag less than 0.05 g.
4	LATSW	Downlift not inhibited.	Downlift inhibited.
5	INRLSW	Initial roll V(LV) attitude not held.	Initial roll V(LV) attitude held.
6	HIND	Iterating of HUNTEST calculation to be done after range prediction.	Iterating of HUNTEST calculations to be omitted after range prediction.
7	NOSWITCH	Lateral roll maneuver inhibited in ENTRY.	Lateral roll maneuver permitted in ENTRY.
8	R57FLAG	Do not do R57, trunnion bias has been obtained.	Do R57, trunnion bias needed.
	KNOWNFLG	Landmark known.	Landmark unknown.
	EGSW	In final phase.	Not in final phase.
9	RELVELSW	Targeting uses earth-relative velocity.	Targeting uses inertial velocity.
10	GONEPAST	Lateral control calculations to be omitted.	Lateral control calculations to be done.
11	GAMDIFSW*	Calculate GAMDOT.	GAMDOT not to be calculated.
12	CMDAPARM*	Allow ENTRY firings and calculations.	Inhibit ENTRY firings and control functions.
13	ENTRYDSP	Do ENTRY display via ENTRYVN.	Omit ENTRY display.
	STRULLSW	Do STEERULL.	Do ULAGEOFF only.
14	DAPBIT2	(see below)	DAP selection indicator.
15	DAPBIT1	(see below)	

B14	0	1	1	1
B15	0	0	0	1
A/P	None	RCS	TVC	Saturn

*These switches are never called by name.

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

(FLAGWORD 7)

Bit	Name	1	0
1	TFFSW	Calculate TPERIGEE.	Calculate TFF.
2	ATTCHFLG*	LM, CM attached.	LM, CM not attached.
3	VERIFLAG*	Changed when V33E occurs at end of P27.	
4	UPLOCKFL*	K-$\overline{K}$-K fail.	No K-$\overline{K}$-K fail.
5	Not Assigned		
6	V37FLAG V37FLBIT	AVERAGEG (SERVICER) running.	AVERAGEG (SERVICER) off.
7	Not Assigned		
8	GONEBY	Passed target.	Approaching target.
9	RVSW	Do not compute final state vector in time-theta.	Compute final state vector in time-theta.
10	NORMSW	Unit normal input to Lambert.	Lambert computes its own normal.
11	TIMRFLAG	CLOKTASK operating.	CLOKTASK inoperative.
12	ASTNFLAG*	Astronaut has OKed ignition.	Astronaut has not OKed ignition.
13	IGNFLAG*	TIG has arrived.	TIG has not arrived.
14	ITSWITCH	Accept next Lambert TPI search solution.	Test Lambert answer against limits.
15	TERMIFLG	Terminate R52.	Do not terminate R52.

*These switches are never called by name.

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

(FLAGWORD 8)

Bit	Name	1	0
1	360SW	Transfer angle near 360 degrees.	Transfer angle not near 360 degrees.
2	Not Assigned		
3	V96ONFLG	P00 integration has been inhibited by V96	P00 integration is proceeding regularly.
4	COGAFLAG	No conic solution, too close to rectilinear (COGA overflows).	Conic solution exists, (COGA does not overflow.)
5	APSESW	RDESIRED outside of PERICENTER-APOCENTER range in time-radius.	RDESIRED inside of PERICENTER-APOCENTER range in time-radius.
6	ORDERSW	Iterator uses second order minimum mode.	Iterator uses first order standard mode.
7	INFINFLG	No conic solution (closure through infinity required).	Conic solution exists.
8	SURFFLAG	LM on lunar surface.	LM not on lunar surface.
9	P39/79SW	P39/P79 operating.	P39/P79 not operating.
10	ADVTRK	Advance ground track sighting wanted.	No advanced ground track.
11	LMOONFLG	Permanent LM state vector in lunar sphere.	Permanent LM state vector in earth sphere.
12	CMOONFLG	Permanent CSM state vector in lunar sphere.	Permanent CSM state vector in earth sphere.
13	NEWIFLG	First pass through integration.	Succeeding iteration of integration.
14	Not Assigned		
15	RPQFLAG	RPQ not computed. (RPQ = vector between secondary body and primary body.)	RPQ computed.

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

(FLAGWORD 9)

Bit	Name	1	0
1	AVEMIDSW	AVETOMID calling for W matrix integration. Do not overwrite RN, VN, PIPTIME.	No AVETOMID W matrix integration. Allow setup of RN, VN, PIPTIME.
2	MIDAVFLAG	Integration entered from one of MIDTOAV portals.	Integration was not entered via MIDTOAV.
3	MID1FLAG	Integrate to TDEC.	Integrate to the then-present time.
4	R31FLAG R31FLBIT	R31 selected (V83).	R34 selected (V85).
5	QUITFLAG	Terminate and exit from integration.	Continue integration.
6	N22ORN17	Compute total attitude errors with respect to N22 (V62).	Compute total attitude errors with respect to N17 (V63).
7	R22CAFLG*	R22 calculations are going on.	R22 calculations are not going on.
8	SOURCBIT SOURCFLG	Source of input data is from VHF radar.	Source of input data is from optics mark.
9	VHFRFLAG	Allow R22 to accept range data.	Stop acceptance of range data.
10	SAVECFLG	P23 display and data storage after mark is done.	P23 display and data storage before mark is done.
11	V94FLAG V94FLBIT	V94 allowed during P23.	V94 not allowed.
12	MAXDBBIT MAXDBFLG	Maximum A/P deadband selected.	Minimum A/P deadband selected.
13	V82EMFLG	Moon vicinity.	Earth vicinity.
14	V67FLBIT*	Not Assigned.	
15	SWTOVER*	Switchover has occurred.	No switchover yet.

*These switches are never called by name.

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

(FLAGWORD 10, RASFLAG)

Bit	Name	1	0
1	Not Assigned		
2	Not Assigned		
3	Not Assigned		
4	Not Assigned		
5	Not Assigned		
6	Not Assigned		
7	REINTBIT REINTFLG	Integration routine to be RESTARTED.	Integration routine not to be RESTARTED.
8	Not Assigned		
9	Not Assigned		
10	Not Assigned		
11	Not Assigned		
12	Not Assigned		
13	Not Assigned		
14	INTFLBIT	Integration in progress.	Integration not in progress.
15	Not Assigned		

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

(FLAGWORD 11)

Bit	Name	1	0
1	Not Assigned		
2	Not Assigned		
3	Not Assigned		
4	Not Assigned		
5	Not Assigned		
6	Not Assigned		
7	Not Assigned		
8	Not Assigned		
9	Not Assigned		
10	Not Assigned		
11	Not Assigned		
12 13	S32.1F3B S32.1F3A	(Bits 12 and 13 function as an ordered pair (13, 12) indicating the possible occurrence of two Newton iterations for S32.1: (0, 0) — First pass of second Newton iteration, (0, 1) — First Newton iteration being done, (1, 0) — Remainder of second Newton iteration, (1, 1) — 50 ft/s stage of second Newton iteration.)	
14	S32.1F2	First pass of Newton iteration.	Reiteration of Newton.
15	S32.1F1	Delta V at CSI Time 1 exceeds maximum.	Delta V at CSI Time 1 less than maximum.

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

IMODES30, a flag whose individual bits are used to control the monitoring of IMU functions associated with Channel 30 (and in a few cases Channel 33).

Bit	Meaning
15	Last sampled value of Channel 30, Bit 15 (0 if IMU temperature within limits).
14	Last sampled value of Channel 30, Bit 14 (0 if ISS has been turned on or commanded to be turned on).
13	Last sampled value of Channel 30, Bit 13 (0 if an IMU fail indication has been produced).
12	Last sampled value of Channel 30, Bit 12 (0 if an IMU CDU fail indication has been produced).
11	Last sampled value of Channel 30, Bit 11 (0 if an IMU cage command has been produced by crew).
10	Last sampled value of Channel 33, Bit 10 (0 if a PIPA fail indication has been produced), having the same value as Bit 13 of IMODES33.
9	Last sampled value of Channel 30, Bit 9 (0 if IMU has been turned on and operating with no malfunctions).
8	Bit used to control the IMU turn-on sequencing.
7	Bit used to control the IMU turn-on sequencing.
6	Bit is set to 1 to indicate that IMU initialization is being carried out.
5	Bit is set to 1 to inhibit the generation of program alarm 0212_8 if a PIPA fail signal (Bit 13 of Channel 33) is produced.
4	Bit is set to 1 to inhibit generation of an ISS warning based on receipt of an IMU fail signal.
3	Bit is set to 1 to inhibit generation of an ISS warning based on receipt of an IMU CDU fail signal.
2	Bit is set to 1 to indicate failure of the turn-on delay sequence for IMU turn-on (alarm 0207_8 is also generated).
1	Bit is set to 1 to inhibit generation of an ISS warning based on receipt of a PIPA fail signal (Bit 13 of Channel 33).

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

IMODES33, a flag whose individual bits are used to control the monitoring of functions associated with Channel 33 (and other items).

Bit	Meaning
15	Not assigned.
14	Last sampled value of Channel 32, Bit 14 (0 if a Proceed command is given using the old "standby" button).
13	Last sampled value of Channel 33, Bit 13 (0 if a PIPA fail has been produced).
12	Last sampled value of Channel 33, Bit 12 (0 if a telemetry end pulse has been rejected because the downlink rate is too fast).
11	Last sampled value of Channel 33, Bit 11 (0 if an uplink bit has been rejected because the uplink rate is too fast).
10-7	Not assigned.
6	Bit is set to 1 to indicate that IMU use for vehicle attitude information should not be attempted.
5	Bit is set to 1 in IMU Zeroing routine external to T4RUPT while zeroing is taking place (for an interval of about 10.56 seconds).
4-2	Not assigned.
1	Bit is set to 1 when a Verb 35 ("lamp test") is received, and reset to 0 about 5 seconds later.

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

OPTMODES, a flag whose individual bits are used to control the performance of optics functions within the T4RUPT package.

Bit	Meaning
15-11	Not Assigned
10	Bit is set to 1 to indicate that zeroing of optics has been completed since the last FRESH START or RESTART (both of which set the bit to 0). If an attempt is made to drive the optics and this bit is found to be zero, alarm 0120_8 is generated (but computation proceeds).
9	Bit is set to 1 if optics have been switched from the Computer Control mode (while being driven; that is, "coarse aligned") to another mode. Value is used when switchback to the Computer Control mode is effected to reenable driving. Bit is set to 0 as part of FRESH START and when optics system released (at end of marking); a RESTART preserves the bit (see, however, Bit 10).
8	Not assigned.
7	Last sampled value of Channel 30, Bit 7 (0 if an optics CDU fail indication has been generated by the optics CDU hardware). If Bit 2 of this word is 0, a Tracker alarm (Bit 8 of DSPTAB + 11) is generated if this bit has a 1 to 0 transition. Bit is set to 1 by a FRESH START or RESTART.
6	Not assigned.
5	Last sampled value of Channel 33, Bit 5 (0 if Optics Mode switch set to Computer Control).
4	Last sampled value of Channel 33, Bit 4 (0 if Optics Mode switch set to Zero Optics). If Bits 5-4 = 11_2, the Optics Mode switch has been set to Manual.
3	Bit is set to 1 when the Optics Mode switch is changed from Manual or Computer Control to Zero Optics to indicate that zeroing of the optics is in progress. If bit is 1 and Bit 1 of this word is 0, then a switch out of Zero Optics mode will cause alarm 0116_8 to be generated (if switched to Manual, a "grace period" of about 5.3 seconds is provided before the optics-zeroing time counter is reset, during which time a switchback to optics zeroing can be made). Bit remains 1 for about 16.2 seconds, and is then reset to 0 (at the same time that Bit 10 of this word is set to 1, and Bits 2-1 of this word are set to 0).
2	Bit is set to 1 to inhibit generation of Tracker alarm (Bit 8 of DSPTAB + 11) if Bit 7 of this word goes from 1 to 0. Bit is set and reset at the same time as Bit 3.
1	Bit is set to 1 to indicate that end of optics zeroing delay will occur in 0.4 second (remains 1 for that length of time, and then is reset to 0 at the same time as Bits 3-2). If bit is 1, generation of alarm 0116_8 (see Bit 3) is inhibited.

FLAGWORD BIT ASSIGNMENTS FOR COLOSSUS 2A

RCSFLAGS, a flag whose individual bits are used in monitoring the RCS DAP.

Bit	Meaning
15	Bit is set to 1 to indicate that a high rate (4 deg/s) automaneuver is in progress. Bit is reset to 0 to indicate that a high rate automaneuver is not in progress.
14	Bit is set to 1 if rate estimates are not good and a repeat of the rate filter initialization is required. Bit is reset to 0 if the G & N is in control and the IMU data is usable. Approximately 1 second after the bit is reset to 0 the rate filter initialization is complete.
13	Bit is set to 1 if the rate damping has not been completed on the roll axis. Bit is reset to 0 if the rate damping on the roll axis has been completed.
12	Bit is set to 1 if the damping has not been completed on the pitch axis. Bit is reset to 0 if the rate damping has been completed on the pitch axis.
11	Bit is set to 1 if the rate damping has not been completed on the yaw axis. Bit is reset to 0 if the rate damping has been completed on the yaw axis.
10,9	If either or both bits have been set to 1, there has been a change in the RHC roll command since the last DAP cycle. If both bits are reset to 0, it implies that no change in the RHC roll command has occurred since the last DAP cycle.
8,7	If either or both bits have been set to 1, there has been a change in RHC yaw command since the last DAP cycle. If both bits are reset to 0, it implies that no change in the RHC yaw command has occurred since the last DAP cycle.
6,5	If either or both bits have been set to 1, there has been a change in the RHC pitch command since the last DAP cycle. If both bits are reset to 0, it implies that no change in the RHC pitch command has occurred since the last DAP cycle.
4	Bit is set to 1 to indicate that the AK values should be updated. Bit is reset to 0 to indicate that the Needle Drive routine should be processed with the AK values which have been previously acquired.

3,2	If (Bit 3, Bit 2) = (1,1) or (1,0), it is necessary to follow the initialization path of the Needle Drive routine.
	
	If (Bit 3, Bit 2) = (0, 1), it is necessary to follow Pass 2 of the Needle Drive routine.
	
	If (Bit 3, Bit 2) = (0, 0), it is necessary to follow Pass 3 and greater paths of the Needle Drive routine.

1	Bit is set to 1 to indicate that the initial pass path in the T6 program should not be followed. Bit is reset to 0 if the T6 program should be initialized.

DAPDATR1, a flagword for RCS-CSM DAP interface.

Bit	15-13	12-10	9-7	6-4	3-1
	CONFIG	XTAC	XTDB	DB	RATE

15-13 CONFIG: Configuration

- 0 No DAP or ENTRY DAP
- 1 CSM
- 2 CSM/LM
- 3 CSM/SIVB
- 6 CSM/LM Ascent Stage Only

12-10 XTAC: X-translation using Quads AC

- 0 No AC
- 1 Use AC

9-7 XTBD: X-translation using Quads BD

- 0 No BD
- 1 Use BD

6-4 DB: Deadband

- 0 ± 0.5 degree
- 1 ± 5.0 degrees

3-1 RATE: Response to RHC, automatic maneuvers

- 0 0.05 degree/second
- 1 0.2 degree/second
- 2 0.5 degree/second
- 3 4.0 degrees/second

DAPDATR2, a flagword for RCS-CSM DAP interface.

Bit	15-13	12-10	9-7	6-4	3-1
	AC-Roll	Quad A	Quad B	Quad C	Quad D

15-13 AC-Roll: Roll jet selection

- 0 Use AC Roll
- 1 Use BD Roll

12-10, 9-7, 6-4, 3-1 A, B, C, D Quad fails

- 0 Quad Failed
- 1 Quad OK

CHANNEL BIT ASSIGNMENTS (CM)

OUTPUT CHANNEL 11

BIT	
1	ISS Warning
2	Light Computer Activity Lamp
3	Light Uplink Activity Lamp
4	Light Temp Caution Lamp
5	Light Keyboard Release Lamp
6	Flash Verb and Noun Lamps
7	Light Operator Error Lamp
8	Spare
9	Test Connector Outbit
10	Caution Reset
11	Spare
12	Spare
13	Engine On/Off
14	Spare
15	Spare

OUTPUT CHANNEL 12

1	Zero Optics CDU
2	Enable Optics Error Counter
3	Not Used
4	Coarse Align Enable
5	Zero IMU CDU's
6	Enable IMU Error Counter
7	Spare
8	TVC Enable
9	Enable SIVB Takeover
10	Zero Optics
11	Disengage Optics DAC
12	Spare
13	SIVB Injection Sequence Start
14	SIVB Cutoff
15	ISS Turn-on Delay Complete

CHANNEL BIT ASSIGNMENTS (CM)

OUTPUT CHANNEL 13

1	Range Unit Select c
2	Range Unit Select b
3	Range Unit Select a
4	Range Unit Activity
5	Not Used
6	Block Inlink
7	Downlink Word Order
8	Not Used
9	Spare
10	Test Alarms
11	Enable Standby
12	Reset Trap 31-A
13	Reset Trap 31-B
14	Reset Trap 32
15	Enable T6RUPT

NOTE:

Channel 13 Range Unit Selection: Bits 1 through 4 are assigned control functions for sampling of the VHF range link. These bits must contain 1001_8 in order to obtain control.

OUTPUT CHANNEL 14

BIT	
1	Not Used
2	Spare
3	Spare
4	Spare
5	Spare
6	Gyro Enable
7	Gyro Select b
8	Gyro Select a
9	Gyro Sign Minus
10	Gyro Activity
11	Drive CDU S
12	Drive CDU T
13	Drive CDU Z
14	Drive CDU Y
15	Drive CDU X

Channel 14-Gyro Selection

a	b	Gyro
0	0	–
0	1	X
1	0	Y
1	1	Z

CHANNEL BIT ASSIGNMENTS (CM)

INPUT CHANNEL 15

BIT	
1	Key codes from Main DSKY
2	Key codes from Main DSKY
3	Key codes from Main DSKY
4	Key codes from Main DSKY
5	Key codes from Main DSKY
6	Spare
7	Spare
8	Spare
9	Spare
10	Spare
11	Spare
12	Spare
13	Spare
14	Spare
15	Spare

INPUT CHANNEL 16

1	Key codes from Navigation DSKY
2	Key codes from Navigation DSKY
3	Key codes from Navigation DSKY
4	Key codes from Navigation DSKY
5	Key codes from Navigation DSKY
6	Mark button
7	Mark reject button
8	Spare
9	Spare
10	Spare
11	Spare
12	Spare
13	Spare
14	Spare
15	Spare

CHANNEL BIT ASSIGNMENTS (CM)

INPUT CHANNEL 30

BIT	
1	Ullage Thrust Present
2	SM Separate
3	SPS Ready
4	SIVB Separate, Abort
5	Liftoff
6	Guidance Reference Release
7	Optics CDU Fail
8	Spare
9	IMU Operate
10	S/C Control of Saturn
11	IMU Cage
12	IMU CDU Fail
13	IMU Fail
14	ISS Turn-On Request
15	Temperature in Limits

NOTE:

All of the input signals in Channel 30 are inverted; that is, a ZERO bit indicates that the discrete is ON.

INPUT CHANNEL 31

BIT	
1	+Pitch Manual Rotation
2	-Pitch Manual Rotation
3	+Yaw Manual Rotation
4	-Yaw Manual Rotation
5	+Roll Manual Rotation
6	-Roll Manual Rotation
7	+X Translation
8	-X Translation
9	+Y Translation
10	-Y Translation
11	+Z Translation
12	-Z Translation
13	Hold Function
14	Free Function
15	G & N Autopilot Control

NOTE:

All of the input signals in Channel 31 are inverted; that is, a ZERO bit indicates that the discrete is ON.

CHANNEL BIT ASSIGNMENTS (CM)

INPUT CHANNEL 32

BIT	
1	+Pitch Minimum Impulse
2	-Pitch Minimum Impulse
3	+Yaw Minimum Impulse
4	-Yaw Minimum Impulse
5	+Roll Minimum Impulse
6	-Roll Minimum Impulse
7	Spare
8	Spare
9	Spare
10	Spare
11	LM Attached
12	Spare
13	Spare
14	Proceed
15	Spare

NOTE:
All of the input signals in Channel 32 are inverted; that is, a ZERO bit indicates that the discrete is ON.

INPUT CHANNEL 33

BIT	
1	Spare
2	Range Unit Data Good
3	Spare
4	Zero Optics
5	CMC Control
6	Not Used
7	Not Used
8	Spare
9	Spare
10	Block Uplink Input*
11	Uplink Too Fast
12	Downlink Too Fast
13	PIPA Fail
14	Warning
15	Oscillator Alarm

*This bit reads ONE when accept uplink signal is present at interface.

NOTE:
All of the input signals in Channel 33 are inverted; that is, a ZERO bit indicates that the discrete is ON.

P00—CMC IDLING PROGRAM

Purpose:

1. To provide a program to fulfill the following requirements:
   a. Provide an indication to the crew that the CMC is engaged in no control or computational operations which might require consideration for coordination with other crew tasks in progress.
   b. To maintain the GNCS in a condition where manual attitude maneuvers can be made by the crew with minimal concern for the GNCS.
   c. Maintain the CMC 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. The IMU may or may not be on. If on, the IMU is inertially stabilized but not necessarily aligned to an orientation which is known to the CMC.
2. If non-GNCS controlled attitude maneuvers are made by the crew, care must be taken to avoid IMU gimbal lock. The IMU gimbal angles may be monitored by observing the ICDU's (V16 N20) or by monitoring the FDAI ball.
3. During this program the CMC erasable storage may be initialized by keying in V36E (FRESH START). This would be done only at initial CMC startup or when the content of the CMC erasable storage is in question. If this entry is performed, the CMC's knowledge of the present state vector and the present IMU orientation (REFSMMAT) is invalidated.
4. The program is manually selected by the astronaut by DSKY entry.
5. 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.

Selected Displays:

1. V06 N38

Time of state vector being integrated	00XXX. h
	000XX. min
	0XX.XX s

P01—PRELAUNCH OR SERVICE—INITIALIZATION PROGRAM

Purpose:

1. To initialize the platform for the prelaunch programs.
2. To provide an initial stable member orientation for Gyrocompassing (P02).

Assumptions:

1. The program is manually selected by DSKY entry.
2. Erasable locations have been properly initialized. (Azimuth, +1; Latitude, +1; LAUNCHAZ, +1; IMU compensation parameters).

P02—PRELAUNCH OR SERVICE—GYROCOMPASSING PROGRAM

Purpose:

1. To provide the proper stable member orientation for launch.

Assumptions:

1. This program may be interrupted to perform the Prelaunch or Service—Optical Verification of Gyrocompassing program (P03).
2. V75 will be keyed in and displayed during this program to permit crew backup of the liftoff discrete.

3. The program is automatically selected by the Initialization program (P01).
4. This program has the capability (via V78E) to change the launch azimuth of the stable member while gyrocompassing.

Selected Displays:

1. V06 N29

XSM launch azimuth	XXX.XX deg

P03–PRELAUNCH OR SERVICE–OPTICAL VERIFICATION OF GYROCOMPASSING

Purpose:

1. To provide an optical check for verification of alignment of the stable member during gyrocompassing prior to launch.

Assumptions:

1. The program is manually selected by the DSKY entry.
2. The astronaut has zeroed the optics just prior to program (P03) selection.
3. A minimum of 45 minutes between V78E and P03 (V65E) assures proper damping of transients.
4. In order to prematurely terminate this program and return to P02 the astronaut may key in V34E on any flashing display.

Selected Displays:

1. V06 N41

Target azimuth		XXX.XX deg
Target elevation		XX.XXX deg

2. V51 (please mark)
3. V50 N25 (terminate mark sequence)

Checklist code		00016

4. V06 N93

Gyro torque angles	X	XX.XXX deg
	Y	XX.XXX deg
	Z	XX.XXX deg

P06–CMC POWER DOWN PROGRAM

Purpose:

1. To transfer the CMC from the operate to the standby condition.

Assumptions:

1. When this program is turned on the astronaut must power down the CMC to standby. However, the program is not RESTART protected.
2. The normal condition of readiness of the GNCS when not in use is standby. All the G/N circuit breakers (Panel 5) are closed, the IMU and optics G/N power switches (LEB Panel 100) are off and the CMC standby light (DSKY) is on. In this condition the IMU is in standby with only heater power on, optics power is off, and the CMC is in standby.
3. A possible condition of readiness of the GNCS when not completely on is the same as standby (2) above, except the CMC standby light on the main and LEB DSKY's is off. In this configuration the CMC is running for computational purposes that do not require the IMU or optics.

4. If the computer power is switched off it will be necessary to perform a computer FRESH START (V36E) to initialize the erasable storage. The CMC Update program (P27) would have to be done to update the state vector and computer clock time.
5. The CMC is capable of maintaining an accurate value of ground elapsed time (GET) for only 23 hours when in standby. If the CMC is not brought out of the standby condition to the running condition (see Assumption 3 above) at least once within 23 hours the CMC value of GET must be updated.
6. The program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V50 N25 (CMC power down)

Checklist code	00062

P11—EARTH ORBIT INSERTION MONITOR PROGRAM

Purpose:

1. To indicate to the astronaut that the CMC has received the liftoff discrete.
2. To generate an attitude error indication on the FDAI error needles, scaled for the 50/15 setting; from liftoff to the beginning of pitchover/rollout the attitude error is equal to the difference between the current vehicle attitude and the attitude stored at liftoff. During pitchover/rollout the attitude error is equal to the difference between the current vehicle attitude and the CMC nominal computation of vehicle attitude based on the stored polynomials in pitch and roll.
3. To display CMC computed trajectory parameters.
4. CMC takeover of Saturn during Boost
   a. Automatic Control—All Stages: should the Saturn platform fail (during any stage of earth orbit insertion) the astronaut may set the S/C Control of Saturn switch to the ON position. This stores the current attitude errors as a bias. The Attitude Error routine for each cycle thereafter will compute the attitude error, subtract the bias, and transmit the difference information to the Saturn Instrumentation Unit (IU) for steering.
   b. Manual Control—SII and SIVB Stages only: The astronaut may select the Saturn stick function via V46E (DAP configuration = 3). This will terminate the Attitude Error routine.

Assumptions:

1. The program is normally automatically selected by the Gyrocompassing program (P02) when the CMC receives the liftoff discrete from the SIVB. In the backup case it would have been selected by keying in V75 ENTER.
2. The orbit parameter display routine is available by keying in V82E.

Selected Displays:

1. V06 N62

Inertial velocity magnitude	XXXXX. ft/s
Altitude rate	XXXXX. ft/s
Altitude	XXXX.X nmi

2. V04 N06 (results from V82E)

Option code ID	00002
Option code	0000X (1—this vehicle, 2—other vehicle)

3. V16 N44 (results from V82E)

Apocenter altitude	XXXX.X nmi
Pericenter altitude	XXXX.X nmi
TFF	XX b XX min/s

P17—CSM TRANSFER PHASE INITIALIZATION SEARCH (TPI)

Purpose:

1. To accept a desired time of Transfer Phase Initiation (TIG(TPI)) as a DSKY input from the astronaut, and to compute therefrom the parameters associated with a minimum energy, safe periapsis transfer maneuver at TIG(TPI) and the resultant rendezvous intercept.
2. To provide the astronaut with the option of defining to the CMC the initial transfer trajectory search sector for central angles either greater or less than 180 degrees from the position of the active vehicle (CSM) at TIG(TPI).
3. To display to the astronaut the parameters associated with the transfer (TPI and intercept).

Assumptions:

1. If P20 is in operation while this program is operating, the astronaut may hold at any flashing display and turn on the Rendezvous Sighting Mark routine (either R21 or R23) and take optics marks and/or he may allow VHF ranging marks to accumulate.
2. The operation of this program utilizes the active vehicle flag which designates the vehicle which is doing the rendezvous thrusting maneuvers to the program which calculates the maneuver parameters. Set at the start of each rendezvous prethrusting program.
3. To execute the TPI maneuver select the Transfer Phase Initiation (TPI) program (P34).
4. This program is selected by DSKY entry.

Selected Displays:

1. V06 N37

Time of TPI burn	00XXX. h
	000XX. min
	0XX.XX s

2. V06 N72

Delta angle (TPI)	XXX.XX deg (+ active vehicle ahead)
Delta altitude (TPI)	XXXX.X nmi(+ passive vehicle above)
Search option	0000X (1 intercept at a central angle <180 degrees; 2 intercept at a central angle > 180 degrees)

3. V06 N58

Pericenter altitude (post TPI)	XXXX.X nmi
ΔV (TPI)	XXXX.X ft/s
ΔV (TPF)	XXXX.X ft/s

4. V06 N55

Perigee code	0000X (1—perigee between TPI and TPF 2—perigee after intercept)
Blank	
Central angle of passive vehicles	XXX.XX deg

P20—RENDEZVOUS NAVIGATION PROGRAM

Purpose:

1. Control CSM attitude and optics to acquire the LM in the SXT field and to point the CSM transponder at the LM or to control the CSM attitude to acquire the LM along the +X axis (depends on option code).
2. Update either LM or CSM state vector via optical tracking data.

Assumptions:

1. IMU on and aligned.
2. The GNCS is in control of the vehicle in the auto mode in the nominal case. If the astronaut takes over control of the vheicle with RHC the CSM will remain at the attitude it is driven to. Regardless of mode selection the GNCS will calculate the preferred tracking attitude and the +X-axis tracking attitude.
3. Routine R03 performed prior to programs selection/V46E performed prior to first maneuver.
4. LM maintaining preferred tracking attitude (optical beacon).
5. Program selected by DSKY entry.
6. Terminated by selection of P00, P06, P22, P23 or by V56E.

Selected Displays:

1. V50 N18		
Desired gimbal angles	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg
2. V06 N49		
ΔR		XXXX.X nmi
ΔV		XXXX.X ft/s
Source code		0000X (1—optics, 2—VHF)
3. V06 N94		
Shaft angle		XXX.XX deg
Trunnion angle		XX.XXX deg
4. V51 (please mark)		
5. V50 N25 (terminate mark sequence)		
Checklist code		00016
6. V01 N71 (after mark)		
Celestial body code		000XX
7. V06 N88		
Components of celestial body ½ unit vector		.XXXXX
8. V06 N18		
Final gimbal angles	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

P21—GROUND TRACK DETERMINATION PROGRAM

Purpose:

1. Provide astronaut with details of his ground track.

Assumptions:

1. Program selected by DSKY entry.
2. Can be used while CSM in earth or lunar orbit to determine ground track of either LM or CSM.
3. Vehicle whose ground track parameters are calculated to remain in freefall from the present time until T Lat Long.

Selected Displays:

1. V06 N34

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

2. V06 N43

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

3. V04 N06

Option code ID	00002
Option code ID	0000X (1—this vehicle 2-other vehicle)

P22—ORBITAL NAVIGATION PROGRAM

Purpose:

1. Locate and track landmark suitable for navigation purposes.
2. Obtain sighting marks on chosen landmark.
3. Calculate parameter changes generated by landmark sightings.
4. Update state vector as result of sightings (if sightings ok).
5. Update coordinates of known landmarks.
6. Provide coordinates of unknown landmarks.
7. Track preloaded landing site.
8. Provide coordinates of new landing site.
9. Provide coordinates of an offset landing site.
10. Align optics along an advanced orbit ground track for purpose of tracking and mapping a new landing site.

Assumptions:

1. There are two types of landmark tracking methods:
   a. "Known" Landmark Tracking—The tracking of an earth landmark made known to the CMC by latitude, longitude/2, and altitude, and the tracking of a lunar landmark made known to the CMC by its latitude, longitude/2, and altitude.
   b. "Unknown" Landmark Tracking—The tracking of a landmark or surface feature identified to the CMC as an unknown landmark, one whose coordinates are not known (lunar only).
2. There are two types of landing site mapping methods:
   a. Landing Site Designation—Track and mark on an unknown landmark. Store the resulting coordinates in Landmark Code 01. If mapping only is desired (that is, no state vector calculation or corrections), the astronaut need take only one mark.
   b. Landing Site Offset—While tracking and marking on a primary landmark (known or unknown), point the optics SLOS at the chosen landing site and mark it once, (at least one mark on the primary landmark must have been made prior to this), then continue marking on the primary landmark. Store the resulting coordinates of the offset landing site in Landmark Code 01.
3. Acquisition of a landmark may be aided by the CMC by use of the Automatic Optics Positioning routine (R52).
4. Acquisition of a preloaded landing site may be aided by keying Landmark Code 01 into the V05 N70 display for use by the Automatic Optics Positioning routine (R52).

5. The Ground Track Determination program (P21) is available to aid the crew in choosing appropriate landmarks prior to selection of this program.
6. The Ground Track Determination program (P21) is available to the crew following this program to provide updated ground track information.
7. Possible attitude control methods might be as follows (in all cases care must be taken to monitor possible impending IMU gimbal lock).
   a. Manual control by the pilot or navigator with the rotational hand controller.
   b. Manual rate control by the navigator with the minimum impulse control in the GNC free mode.
8. The program may be performed with SIVB attached if the Launch Vehicle Guidance switch is placed in the CMC position thereby permitting SIVB attitutde control with the rotational hand controller. GNC A/P control is required in this case.
9. The IMU must be on and aligned in order to complete this program.
10. Selection of this program will terminate the Rendezvous Navigation program (P20).
11. The program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N45

R3: Maximum middle gimbal angle	XXX.XX deg

2. V06 N89 (landmark coordinates)

Latitude	XX.XXX deg (+ north)
Longitude/2	XX.XXX deg (+ east)
Altitude	XXX.XX nmi

3. V06 N92

Shaft angle	XXX.XX deg
Trunnion angle	XX.XXX deg

4. V05 N70 (landmark data; before mark)

   R2: ABCDE

   A – 1 if known landmark
   2 if unknown landmark
   B - index of offset designator
   C - not used
   DE - Landmark ID

5. V05 N71 (landmark data; after mark)

   R2: ABCDE (See Item 4 above.)

6. V06 N49

ΔR	XXXX.X nmi
ΔV	XXXX.X ft/s

7. V51 (please mark)
8. V50 N25 (terminate mark sequence)

Checklist code	00016

9. V01 N71 (after mark)

Celestial body code	000XX

10. V06 N88

Components of celestial body ½ unit vector	.XXXXX

11. V16 N91

Shaft angle	XXX.XX deg
Trunnion angle	XX.XXX deg

P23—CISLUNAR MIDCOURSE NAVIGATION PROGRAM

Purpose:

1. To do midcourse navigation by incorporation of star/earth and star/moon optical measurements.

Assumptions:

1. This program does not require that the IMU be on.
2. If the IMU is not aligned the astronaut must acquire the star/LMK or star/HOR manually.
3. If the IMU is:
   a. Aligned, the astronaut may acquire the LMK/HOR automatically.
   b. Aligned, the astronaut may acquire the star automatically.
   c. On, the astronaut must take appropriate precautions to prevent possible IMU gimbal lock.
4. Prior to each mark the program will call for an optics calibration which may be done or bypassed dependent upon the stability history of the calibration.
5. To perform the mark the astronaut should finally select minimum impulse control (either GNCS or SCS) and the optics should be in manual in order to maintain the fix.
6. The optics should be on for 15 minutes prior to marking.
7. The CMC does not check for moon/earth occultation or sun brightness in this program.
8. This program is designed for one man operation within the constraints of mode switching while in the LEB.
9. Nouns 70 and 71 are checked to assure that the codes fall within certain permissible limits. (Check to assure that R2 and R3 do not both equal zero or do not both not equal zero, R1 = 0 to 37 (octal), R2 = ABCDE, C = 1 or 2, R3 = ABCDE, C and D = 1 or 2). Noun 89 is also checked to assure that the values for R1 and R2 fall within certain defined limits (-90 degrees to +90 degrees).
10. Noun 88 allows that any proportional set of components may be loaded for planet direction. However, a unit vector is recommended.
11. The program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V59 (perform calibration mark)	
2. V06 N87	
R2: Trunnion bias angle	XX.XXX deg
3. V51 (please mark)	
4. V50 N25 (terminate mark sequence)	
Checklist code	00016
5. V01 N71 (after mark)	
Celestial body code	000XX
6. V06 N88	
Components of celestial body ½ unit vector	.XXXXX

7. V05 N70 (landmark data, before mark)

   R1: 000DE

   DE—star identification code

   R2: ABCDE
   AB—not used
   C — 1 = earth landmark
   2 = moon landmark
   DE—not used

   R3: 00CD0

   C — 1 = earth horizon
   2 = moon horizon
   D — 1 = near horizon
   2 = far horizon

8. V06 N89 (landmark coordinates)

Latitude	XX.XXX deg (+ north)
Longitude/2	XX.XXX deg (+ east)
Altitude	XXX.XX nmi

9. V50 N25 (perform GNCS auto maneuver)

Checklist code	00202

10. V50 N18

Desired gimbal angles	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

11. V06 N18

Final gimbal angles	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

12. V05 N71 (landmark data, after mark)

   Display same as Item 7 above.

13. V06 N49

ΔR	XXXX.X nmi
ΔV	XXXX.X ft/s

14. V06 N92

Shaft angle	XXX.XX deg
Trunnion angle	XX.XXX deg

P27—CMC UPDATE PROGRAM

Purpose:

1. To insert information into the CMC via the digital uplink by transmission from the ground or via the DSKY keyboard by crew manual input.

Assumptions:

1. The CMC must be in the operate condition. The IMU may be in standby or operate condition.
2. CMC updates are of four categories:
   a. Provide an update for CMC liftoff time (V70).
   b. Provide an octal increment for the CMC clock only (V73).
   c. Provide load capability for a block of sequential erasable locations (1-18 inclusive locations whose address is specified) (V71).
   d. Provide load capability for 1-9 inclusive individually specified erasable locations (V72).

3. Update is allowed in the CSM when the CMC is in P00 or P02, and if the DSKY is available.
4. The UPTEL Accept/Block switch must be in Accept for telemetry update.
5. The program is manually selected by the astronaut by DSKY entry or by the ground by uplink transmission.
6. The automatic mode of update is program selection and update via the ground by uplink transmission. The only difference between this and manual selection by the astronaut is that the DSKY responses are keyed in by the astronaut rather than transmitted.

P30–EXTERNAL DELTA V PROGRAM

Purpose:

1. To accept targeting parameters obtained from a source(s) external to the CMC and compute therefrom the required velocity and other initial conditions required by the CMC for execution of the desired maneuver. The targeting parameters inserted into the CMC are the time of ignition (TIG) and the impulsive ΔV along CSM local vertical axes at TIG.
2. To display to the astronaut and the ground certain specific dependent variables associated with the desired maneuver for approval by the astronaut/ground.

Assumptions:

1. Target parameters (TIG and ΔV(LV)) may have been loaded from the ground during a prior execution of P27.
2. External Delta V flag is set during the program to designate to the thrusting program that external Delta V steering is to be used.
3. ISS need not be on to complete this program.
4. Program is selected by DSKY entry.

Selected Displays:

1. V06 N33

Time of ignition for external ΔV burn	00XXX. h
	000XX. min
	0XX.XX s

2. V06 N81

Components of ΔV (LV)	XXXX.X ft/s

3. V06 N42

Apocenter altitude	XXXX.X nmi
Pericenter altitude	XXXX.X nmi
ΔV	XXXX.X ft/s

4. V16 N45

Marks (VHF/optics)	XX b XX marks
Time from external ΔV ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg

P31—LAMBERT AIM POINT GUIDANCE PROGRAM

Purpose:

1. To accept targeting parameters obtained from a source(s) external to the CMC and compute therefrom the velocity and other initial conditions required by the CMC for execution of the desired maneuver. The targeting parameters inserted into the CMC are the time of ignition (TIG), ECSTEER, the target vector, and the time from TIG until the target is to be reached (Delta T Trans).
2. To display to the astronaut and the ground certain specific dependent variables associated with the desired maneuver for approval by the astronaut/ground.

Assumptions:

1. The target parameters (TIG, Target Vector, ECSTEER, and Delta T Trans) have been loaded from the ground during a prior execution of P27.
2. The external Delta V flag is reset during this program to designate to the thrusting program that Lambert steering is to be used.
3. ISS need not be on to complete this program.
4. This program is selected by DSKY entry.

Selected Displays:

1. V06 N33

Time of ignition for Lambert aim point burn	00XXX. h
	000XX. min
	0XX.XX s

2. V06 N81

Components of ΔV (LV)	XXXX.X ft/s

3. V06 N42

Apocenter altitude	XXXX.X nmi
Pericenter altitude	XXXX.X nmi
ΔV	XXXX.X ft/s

4. V16 N45

Mark (VHF/optics)	XX b XX marks
Time from Lambert aim point ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg

P32—CSM 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 calculate these parameters based upon maneuver data approved and keyed into the LGC by the astronaut.
3. To display to the astronaut and the ground dependent variables associated with the concentric flight plan maneuvers for approval by the astronaut/ground.
4. To store the CSI target parameters for use by the desired thrusting program.

Assumptions:

1. At a selected TPI time the line of sight between the 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 horizontal plane defined by the active vehicle position at CSI ignition.
6. The pericenter altitude of the orbit following CSI and CDH must be greater than 35,000 feet (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 LM orbit. However, crew modification of Delta V (LV) components may result in an out-of-plane CSI maneuver.
8. The ISS need not be on to complete this program.
9. This program is selected by the astronaut by DSKY entry.
10. 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.

Selected Displays:

1.	V06 N11	
	Time of CSI ignition	00XXX. h
		000XX. min
		0XX.XX s
2.	V06 N55	
	Number of apsidal crossings (N)	0000X
	Elevation angle (E)	XXX.XX deg
	Central angle of passive vehicle	XXX.XX deg
3.	V06 N37	
	Time of TPI ignition	00XXX. h
		000XX. min
		0XX.XX s
4.	V06 N75	
	Delta altitude (CDH)	XXXX.X nmi
	ΔT (CDH-CSI)	XX b XX min/s
	ΔT (TPI-CDH)	XX b XX min/s
5.	V06 N13 (astronaut initiated display)	
	Time of CDH ignition	00XXX. h
		000XX. min
		0XX.XX s
6.	V06 N81	
	Components of ΔV(LV) for CSI	XXXX.X ft/s
7.	V06 N82	
	Components of ΔV(LV) for CDH	XXXX.X ft/s
8.	V16 N45	
	Marks (VHF/optics)	XX b XX marks
	Time from CSI ignition	XX b XX min/s
	Middle gimbal angle	XXX.XX deg

9. V04 N12 (results from V90E)	
Option code ID	00002
Option code	0000X (1—this vehicle 2—other vehicle)
10. V06 N16 (results from V90E)	
Time of event	00XXX. h
	000XX. min
	0XX.XX s
11. V06 N90 (results from V90E)	
Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

P33—CSM CONSTANT DELTA ALTITUDE (CDH) PROGRAM

Purpose:

1. To calculate parameters associated with the Constant Delta Altitude maneuver (CDH), for Delta V burns.
2. To calculate these parameters based upon maneuver data approved and keyed into the DSKY by the astronaut.
3. To display to the astronaut and the ground dependent variables associated with the CDH maneuver for approval by the astronaut/ground.
4. To store the CDH target parameters for use by the desired thrusting program.

Assumptions:

1. This program is based upon previous completion of the 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 vehicle position.
   b. The time between CSI ignition and CDH ignition was computed to be greater than 10 minutes.
   c. The time between CDH ignition and TPI ignition was computed to be greater than 10 minutes.
   d. The variation of the altitude difference between the orbits was minimized.
   e. CSI burn is defined such that the impulsive Delta V is in the horizontal plane defined by the active vehicle position at CSI ignition.
   f. The pericenter altitudes of the orbits following CSI and CDH were computed to be greater than 35,000 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.
2. The ISS need not be on to complete tthis program.
3. It is normally required that the ISS be on for 15 minutes prior to a thrusting maneuver.
4. This program is selected by the astronaut by DSKY entry.
5. 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.

Selected Displays:

1. V06 N13

Time of CDH ignition	00XXX h
	000XX min
	0XX.XX s

2. V06 N75

Delta altitude (CDH)	XXXX.X nmi
ΔT (TPI-CDH)	XX b XX min/s
ΔT (TPI-NOMTPI)	XX b XX min/s

3. V06 N81

Components of ΔV(LV) for CDH	XXXX.X ft/s

4. V16 N45

Marks (VHF/optics)	XX b XX mark
Time from CDH ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg

5. V06 N12 (results from V90E)

Option code ID	00002
Option code	0000X (1—this vehicle, 2—other vehicle)

6. V06 N16 (results from V90E)

Time of event	00XXX. h
	000XX. min
	0XX.XX s

7. V06 N90 (results from V90E)

Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

P34—CSM TRANSFER PHASE INITIATION (TPI) TARGETING PROGRAM

Purpose:

1. To calculate the required Delta V and other initial conditions required by the CMC for execution of the Transfer Phase Initiation maneuver. Given:
   a. 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 (TIG(TPF)).
2. To calculate TIG (TPI) given E or E given TIG (TPI).
3. To display to the astronaut and the ground certain dependent variables associated with the maneuver for approval by the astronaut/ground.
4. To store the TPI target parameters for use by the desired thrusting program.

Assumptions:

1. The program must be done over a tracking station for real-time ground participation in CMC data input and output.
2. If P20 is in operation while this program is operating, the astronaut may hold at any flashing display and turn on the Rendezvous Sighting Mark routine (either R21 or R23) and take optics marks, and/or he may allow VHF ranging marks to accumulate.

3. 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.
4. ISS need not be on to complete this program.
5. This program is selected by DSKY entry.
6. The external Delta V flag is reset during this program to designate to the thrusting program that Lambert steering is to be used.

Selected Displays:

1. V06 N37	
Time of TPI ignition	00XXX. 000XX. min 0XX.XX s
2. V06 N55	
R2: Elevation angle	XXX.XX deg
R3: Central angle of passive vehicle	XXX.XX deg
3. V16 N45	
Mark (VHF/optics)	XX b XX marks
Time from TPI ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg
4. V06 N58	
Pericenter altitude	XXXX.X nmi
ΔV (TPI)	XXXX.X ft/s
ΔV (TPF)	XXXX.X ft/s
5. V06 N81	
Components of ΔV (LV) for TPI	XXXX.X ft/s
6. V06 N59	
Components of ΔV (LOS) for TPI	XXXX.X ft/s
7. V06 N52	
Central angle of active vehicle	XXX.XX deg
8. V04 N12 (results from V90E)	
Option code ID	00002
Option code	0000X (1—this vehicle, 2—other vehicle)
9. V06 N16 (results from V90E)	
Time of event	00XXX. h 000XX. min 0XX.XX s
10. V06 N90 (results from V90E)	
Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

P35—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 exectuion of the next midcourse correction of the transfer phase of an active CSM rendezvous.

Assumptions:

1. If P20 is in operation while this program is operating, the astronaut may hold at any flashing display and turn on the Rendezvous Sighting Mark routine (either R21 or R23) and take optics marks and/or he may allow VHF ranging marks to accumulate.
2. 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 the expected maneuver time.
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 CMC storage.
4. ISS need not be on to complete this program.
5. The program is selected by DSKY entry.
6. The external Delta V flag is reset during this program to designate to the thrusting program that Lambert steering is to be used.

Selected Displays:

1. V16 N45	
Mark (VHF/optics)	XX b XX marks
Time from TPM ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg
2. V06 N81	
Components of ΔV (LV) for TPM	XXXX.X ft/s
3. V06 N59	
Components of ΔV (LOS) for TPM	XXXX.X ft/s
4. V06 N52	
Central angle of active vehicle	XXX.XX deg
5. V04 N12 (results from V90E)	
Option code ID	00002
Option code	0000X (1—this vehicle, 2—other vehicle)
6. V06 N16 (results from V90E)	
Time of event	00XXX. h
	000XX. min
	0XX.XX s
7. V06 N90 (results from V90E)	
Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

P37-RETURN TO EARTH

Purpose:

1. This program will compute a return-to-earth trajectory providing the CSM is outside the lunar sphere of influence at the time of ignition.
2. This program computes and displays a preliminary series of parameters based on a conic trajectory and:
   a. Astronaut—specified time of ignition.
   b. Astronaut—specified maximum change in velocity.
   c. Astronaut—specified reentry angle.

   These parameters are:

   a. Time from ignition to reentry.
   b. Reentry inertial velocity.
   c. Reentry flight path angle.
   d. Latitude of splash.
   e. Longitude of splash.
   f. Delta V (LV).
3. When the initial display is satisfactory to the astronaut, the program recomputes the same data, using applicable perturbations to the conic trajectory, and displays the new values.
4. Upon final acceptance by the astronaut, the program computes and stores the target parameters for return to earth for use by the SPS program (P40) or RCS program (P41).
5. Based upon the specified propulsion system the following are displayed:
   a. Middle gimbal angle at ignition.
   b. Time of ignition (TIG).
   c. Time from ignition (TFI).

Assumptions:

1. This program assumes that contact with the ground is unavailable, and is completely self-contained.
2. The ISS need not be on to complete this program.
3. If value of VPRED entered in Noun 60 is less than the minimum required to return to earth, the Delta V required vector will be computed based on a minimum value. If value entered is greater than the minimum required to return to earth, then the astronaut desired value will be used to compute the Delta V required vector. The computed Delta V required vector will be displayed in Noun 81.
4. The DAP Data Load routine (R03) should be performed prior to completion of this program.
5. This program is selected by DSKY entry.
6. The reentry range calculation provided by the AUGE KUGEL routine may be overwritten by a PAD loaded single precision erasable.
7. The external Delta V flag is reset during this program to designate to the thrusting program that Lambert steering is to be used.

Selected Displays:

1. V06 N33

Time of return to earth ignition	00XXX. h
	000XX. min
	0XX.XX s

2.	V06 N60	
	R2: Predicted velocity at 400 k ft	XXXXX. ft/s
	R3: Predicted flight path angle at 400 k ft	XXX.XX deg
3.	V06 N61	
	Impact latitude	XXX.XX deg (+ north)
	Impact longitude	XXX.XX deg (+ east)
4.	V06 N39	
	ΔT for transfer	00XXX. h 000XX. min 0XX.XX s
5.	V06 N81	
	Components of ΔV (LV) for transfer	XXXX.X ft/s
6.	V04 N06 (thrust program option)	
	Option code ID	00007
	Option code	0000X (1-SPS (P-40), 2-RCS (P-41))
7.	V16 N45	
	Marks (VHF/optics)	XX b XX marks
	Time from ignition	XX b XX min/s
	Middle gimbal angle	XXX.XX deg

P38–CSM STABLE ORBIT RENDEZVOUS (SOR) TARGETING PROGRAM

Purpose:

1. To calculate the required Delta V and other initial conditions required by the CMC for CSM execution of the first phase of the Stable Orbit Rendezvous maneuver. Given:
   a. Time of ignition (TIG).
   b. Central angle of transfer (CENTANG) from TIG to intercept time.
   c. The offset of the stable orbit point specified as a distance along the passive vehicle orbit.
2. To calculate the required Delta V and other initial conditions required by the CMC for CSM execution of the second phase of the Stable Orbit Rendezvous maneuver. Given:
   a. A respecification of 1(a) above.
   b. An optional respecification of 1(b) above.
3. To calculate these parameters based upon maneuver data approved and keyed into the CMC by the astronaut.
4. To display to the astronaut and the ground certain dependent variables associated with the maneuver for approval by the astronaut/ground.
5. To store the SOR Phase 1 and Phase 2 target parameters for use by the desired thrusting program.

Assumptions:

1. The stable orbit point is defined as the final position (at completion of the second phase) of the active vehicle relative to the passive vehicle.

2. If P20 is in operation while this program is operating the astronaut may hold at any flashing display and turn on the Rendezvous Sighting Mark routine (either R21 or R23) and take optics marks and/or he may allow VHF ranging marks to accumulate.
3. 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 the expected maneuver time.
4. The second phase of this program requires the TIG input be biased as a function of TPF and any midcourse corrections performed in the Stable Orbit Midcourse (SOM) program (P39).
5. ISS need not be on to complete this program.
6. This program is selected by entry.
7. The external Delta V flag is reset during this program to designate to the thrusting program that Lambert steering is to be used.

Selected Displays:

1. V06 N33	
Time of SOI ignition	00XXX. h 000XX. min 0XX.XX s
2. V06 N55	
R3: Central angle of passive vehicle	XXX.XX deg
3. V04 N06 (specify SOR phase)	
Option code ID	00005
Option code	0000X (1-first pass, 2-second pass)
4. V06 N57	
Offset of the stable orbit point	XXXX.X nmi
5. V06 N34	
Time of arrival at stable orbit	00XXX. h 000XX. min 0XX.XX s
6. V16 N45	
Marks (VHF/optics)	XX b XX marks
Time of SOI ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg
7. V06 N58	
Pericenter altitude (SOR)	XXXX.X nmi
ΔV (SOR)	XXXX.X ft/s
ΔV (SOR-final)	XXXX.X ft/s
8. V06 N81	
Components of ΔV (LV) for SOR	XXXX.X ft/s
9. V06 N52	
Central angle of active vehicle	XXX.XX deg

P39—CSM STABLE ORBIT MIDCOURSE (SOM) TARGETING PROGRAM

Purpose:

1. To calculate the required Delta V and other initial conditions required by the CMC for CSM execution of the next possible midcourse correction of the stable orbit transfer phase of an active CSM rendezvous.
2. To compute and display suitable information to enable the crew to enter the final rendezvous phase at the correct time to complete the required thrusting maneuver.

Assumptions:

1. ISS need not be on to complete this program.
2. If P20 is in operation while this program is operating, the astronaut may hold at any flashing display and turn on the Rendezvous Sighting Mark routine (either R21 or R23) and take optics marks, and/or he may allow VHF ranging marks to accumulate.
3. 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 the expected maneuver time.
4. The time of intercept (T(INT)) was defined by previous completion of the Stable Orbit Rendezvous (SOR) program (P38) and is presently available in CMC storage.
5. This program is selected by DSKY entry.
6. The external Delta V flag is reset during this program to designate to the thrusting program that Lambert steering is to be used.

Selected Displays:

1. V06 N81

Components of ΔV (LV) for SOM	XXXX.X ft/s

2. V16 N45

Marks (VHF/optics)	XX b XX marks
Time from SOM ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg

3. V06 N52

Central angle of active vehicle	XXX.XX deg

P40—SPS PROGRAM

Purpose:

1. To compute a preferred IMU orientation and a preferred vehicle attitude for an SPS thrusting maneuver.
2. To calculate and display the gimbal angles which would result from the present IMU orientation if the vehicle is maneuvered to the preferred vehicle attitude for an SPS thrusting maneuver. The crew is thereby given an opportunity to perform the maneuver with:
   a. The present IMU orientation, if the middle gimbal angle is not greater than 45 degrees, and the IMU has been aligned within the last 3 hours.
   b. A new orientation achieved by selection of P52.
3. To maneuver the vehicle to the thrusting attitude.
4. To control the GNCS during countdown, ignition, thrusting, and thrust termination of a GNCS controlled SPS maneuver.

Assumptions:

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

   For Lambert steering, VG is calculated and updated similarly; however, it is also updated periodically by Lambert solutions to correct for changes in the CSM state vector.
3. It is normally required that the ISS be on for 15 minutes prior to a thrusting maneuver.
4. The TTE clock is set to count to zero at TIG.
5. Engine ignition may be slipped beyond the established TIG if desired by the crew or if integration can not be completed on time.
6. The SPS thrusting program does not monitor the SC control discrete (Channel 31, Bit 15) during thrusting. This means that the CMC will continue to generate engine actuator commands, SPS Engine On discrete, and FDAI attitude erorr needle commands until the CMC solution indicates Engine Off at which time these commands and the Engine On discrete are terminated. However, this program is not written to take into account the situation where control may be taken away from the GNCS and then given back, and it is not recommended. In event control is taken away from the GNCS, the CMC will only be responsible for computation of position and velocity.
7. Routine R03 has been performed prior to selection of this program. In order for the GNCS to perform the attitude maneuver and control the thrusting maneuver the astronaut must key in V46E at some time prior to the attitude maneuver.
8. The value of Delta V required will be stored in the local vertical coordinate system and is available during this program until average g turn-on by keying in V06 N81E.
9. The Orbit Parameter Display routine (R30) may be called during this program by keying in V82E.
10. This program is selected by DSKY entry.
11. The CMC issues an SIVB cutoff command (Channel 12, Bit 14) for possible backup use. This signal is recognized by Saturn only if the Launch Vehicle Guidance switch is set to CMC.

Selected Displays:

1. V50 N18

Desired gimbal angle	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

2. V06 N18

Final gimbal angles	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

3. V50 N25 (gimbal drive test)

Checklist code	00204

4. V06 N40

Time from SPS ignition/cutoff	XX b XX min/s
Velocity to be gained	XXXX.X ft/s
ΔV (accumulated)	XXXX.X ft/s

5. V99 N40 (request engine on enable)
   Display same as Item 4 above.
6. V97 N40 (perform engine fail procedure)
   Display same as Item 4 above.
7. V16 N85

Components of velocity to be gained (body)	XXXX.X ft/s

8. V16 N40
   Display same as Item 4 above.
9. V04 N06 (results from V82E)

Option code ID	00002
Option code	0000X (1—this vehicle, 2—other vehicle)

10. V16 N44 (results from V82E)

Apocenter altitude	XXXX.X nmi
Pericenter altitude	XXXX.X nmi
TFF	XX b XX min/s

P41—RCS PROGRAM

Purpose:

1. Compute a preferred IMU orientation and preferred vehicle attitude for an RCS thrusting maneuver.
2. Calculate the gimbal angles which would result from the present IMU orientation if the vehicle +X-axis is aligned to the thrust vector. The crew is thereby given an opportunity to perform the maneuver with:
   a. The present IMU orientation (not recommended if middle gimbal angle is greater than 45 degrees). If the IMU has not been aligned within the last 3 hours, realignment is desirable.
   b. A new orientation achieved by selection of P52.
3. Do the vehicle maneuver to the thrusting attitude.
4. Provide suitable displays for manual execution of the thrusting maneuver.

Assumptions:

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

   For Lambert steering, VG is calculated and updated similarly. However, it is also updated periodically by Lambert solutions to correct for changes in the CSM state vector.
3. It is normally required that the ISS be on for 15 minutes prior to a thrusting maneuver.
4. The TTE clock is set to count to zero at TIG.
5. Translation initiation may be slipped beyond the established TIG if desired by the crew or if integration cannot be completed on time.
6. This program is selected by DSKY entry.

7. Routine R03 has been performed prior to selection of this program.
8. The value of Delta V required will be stored in the local vertical coordinate system and is available during this program until Average G turn-on by keying in V06 N81E.
9. The Orbit Parameter Display routine (R30) may be called during this program by keying in V82E.

Selected Displays:

1. V50 N18

Desired gimbal angles	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

2. V06 N18

Final gimbal angles	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

3. V06 N85

   Components of velocity to be gained (body) XXXX.X ft/s

4. V16 N85

   Display same as Item 3 above.

5. V06 N81

   Components of initial velocity to be gained (LV) XXXX.X ft/s

6. V04 N06 (results from V82E)

Option code ID	00002
Option code	0000X (1—this vehicle 2—other vehicle)

7. V16 N44 (results from V82E)

Apocenter altitude	XXXX.X nmi
Pericenter altitude	XXXX.X nmi
TFF	XX b XX min/s

P47—THRUST MONITOR PROGRAM

Purpose:

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

Assumptions:

1. It is normally required that the IMU be on for 15 minutes prior to a thrusting maneuver.
2. The responsibility of avoiding gimbal lock during execution of this program is upon the astronaut.
3. This program is normally used during rendezvous final phase. If the crew desires to do any final phase thrusting maneuvers automatically under GNCS control, they must be accomplished via selection of the Transfer Phase Initiation (TPI) program (P34) and then the SPS Thrusting program (P40) or the RCS Thrusting program (P41).
4. Range, Range Rate, and Theta may be displayed during this program by calling the Rendezvous Parameter Display Routine No. 1 (R31) with V83E.
5. Range, Range Rate, and Phi may be displayed during this program by calling the Rendezvous Parameter Display Routine No. 2 (R34) with V85E.
6. VI, H, and H-dot may be called by keying in V16 N62E. The display of H in lunar orbit will be invalid.
7. The Orbit Parameter Display routine may be called during this program by keying in V82E.

8. This program should be turned on just prior to the planned thrusting maneuver and terminated as soon as possible following the maneuver in order to keep errors of bias and AVERAGE G at a minimum.
9. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V16 N83

Components of ΔV (body)	XXXX.X ft/s

2. V16 N54 (results from V83E)

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

3. V16 N53 (results from V85E)

Range	XXX.XX nmi
Range rate	XXXX.X ft/s
Phi	XXX.XX deg

4. V16 N62

Magnitude of inertial velocity	XXXXX. ft/s
Altitude rate	XXXXX. ft/s
Altitude (invalid in moon orbit)	XXXX.X nmi

5. V04 N06 (results from V82E)

Option code ID	00002
Option code	0000X (1—this vehicle, 2—other vehicle)

6. V16 N44 (results from V82E)

Apocenter altitude	XXXX.X nmi
Pericenter altitude	XXXX.X nmi
TFF	XX b XX min/s

P51-IMU ORIENTATION DETERMINATION PROGRAM

Purpose:

1. To determine the inertial orientation of the IMU using sightings on two celestial bodies using the scanning telescope or the sextant.

Assumptions:

1. The IMU may be:
   a. Off (standby).
   b. On, and aligned or not aligned since turn-on.

   If (a) is true, the IMU must be turned on before this program can be performed.

   If (b) is true, this program can be completed.
2. There are no restraints upon the CSM attitude control modes in this program.
3. 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 required by future CMC programs.
4. The program is selected by DSKY entry.

Selected Displays:

1. V50 N25 (acquire celestial body)

Checklist code		00015

2. V41 N22

Gimbal angles resulting from coarse align	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

3. V51 (please mark)
4. V50 N25 (terminate mark sequence)

Checklist code	00016

5. V01 N71 (after mark)

Celestial body code	000XX

6. V06 N88

Components of celestial body ½ unit vector	.XXXXX

7. V06 N05

Sighting angle difference	XXX.XX deg

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 scanning telescope or the sextant:

   a. Preferred Orientation (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 (00004)

   X_{SM} = Unit (R_{LS})

   Y_{SM} = Unit (Z_{SM} × X_{SM})

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

   where

   The origin is the center of the moon.

   R_{LS} = The position of the most recently defined site at time, T (align) selected by the astronaut.

   H_{CSM} = The angular momentum vector of the CSM (R_{CSM} x V_{CSM}) at time T (align) selected by the astronaut.

   c. Nominal Orientation (00002)

   X_{SM} = Unit (Y_{SM} × Z_{SM})

   Y_{SM} = Unit (V × R)

   Z_{SM} = Unit (-R)

   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 (00003)

Assumptions:

1. The docked configuration may be SIVB/CSM, LM/CSM, or CSM. The present configuration should have been entered into the CMC by completion of the DAP Data Load routine R03.
2. There are no restraints upon the CSM attitude control modes in this program.
3. This program makes no provision for an attitude maneuver to return the vehicle to a specific attitude. Such a maneuver, if desired, must be done manually. An option is provided however to point the sextant at astronaut or CMC selected stars either manually by crew input or automatically under CMC control.
4. The ISS is on and has been aligned to a known orientation which is stored in the CMC (REFSMMAT). The present IMU orientation differs from that to which it was last aligned only due to gyro drift (that is, neither gimbal lock nor IMU power interruption has occurred since the last alignment).
5. The landing site orientation is used for:
   a. Aligning the CSM stable member to the same orientation as the LM stable member prior to LM/CSM separation.
   b. Aligning the CSM stable member to the same orientation as the LM stable member prior to LM ascent from the lunar surface.
6. The program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V04 N06

Option code ID		00001
Option code		0000X (1—preferred, 2—nominal, 3—REFSMMAT, 4—landing site)

2. V06 N34

Time of alignment		00XXX. h
		000XX. min
		0XX.XX s

3. V06 N89 (landing site)

Latitude		XX.XXX deg (+ north)
Longitude/2		XX.XXX deg (+ east)
Altitude		XXX.XX nmi

4. V06 N22

Gimbal angles which will result from selected IMU orientation	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

5. V50 N25 (coarse align)

Checklist code		00013

6. V16 N20

Actual gimbal angles	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

7. V50 N25 (acquire celestial body)

Checklist code		00015

8. V50 N18

Desired gimbal angles	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

9. V06 N18

Final gimbal angles	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

10. V51 (please mark)
11. V50 N25 (terminate mark sequence)

Checklist code	00016

12. V01 N70

Celestial body code (before mark)	000XX

13. V06 N88

Components of celestial body ½ unit vector	.XXXXX

14. V06 N92

Desired shaft angle	XXX.XX deg
Desired trunnion angle	XX.XXX deg

15. V01 N71

Celestial body code (after mark)	000XX

16. V06 N05

Sighting angle difference	XXX.XX deg

17. V06 N93

Gyro torque angles	X	XX.XXX deg
	Y	XX.XXX deg
	Z	XX.XXX deg

18. V50 N25 (fine align)

Checklist code	00014

P53—BACKUP IMU ORIENTATION DETERMINATION PROGRAM

Purpose:

1. To determine the inertial orientation of the IMU using a backup optical device.

Assumptions:

1. The IMU may be:
   a. Off (standby).
   b. On, and aligned or not aligned since turn-on.

   If (a) is true, the IMU must be turned on before this program can be performed.

   If (b) is true, this program can be completed.
2. This program is identical to P51 except that R56 is called in place of R53.
3. The CSM attitude control mode selected is at the option of the crew.
4. 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 required by future CMC programs.
5. The program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V50 N25 (acquire celestial body)

Checklist code	00015

2. V41 N22

Gimbal angles resulting from coarse align	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

3. V06 N92

Shaft angle	XXX.XX deg
Trunnion angle	XX.XXX deg

4. V53 (perform alternate LOS mark)
5. V50 N25 (terminate mark sequence)

Checklist code	00016

6. V01 N71

Celestial body (after mark)	000XX

7. V06 N88

Components of celestial body ½ unit vector	.XXXXX

8. V06 N05

Sighting angle difference	XXX.XX deg

P54—BACKUP 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 a backup optical device:
   a. Preferred Orientation (00001)

      An optimum orientation for a previously claculated maneuver. This orientation must be calculated and stored by a previously selected program.

   b. Landing Site Orientation (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 of the most recently defined landing site at time T(align) selected by the astronaut.

      H_{CSM} = The angular momentum vector of the CSM (R_{CSM} x V_{CSM}) at time T (align) selected by the astronaut.

   c. Nominal Orientation (00002)

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

      Y_{SM} = Unit (V x R)

      Z_{SM} = Unit (-R)

      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 (00003)

Assumptions:

1. The docked configuration may be SIVB/CSM, LM/CSM, or CSM. The present configuration should have been entered into the CMC by completion of the DAP Data Load routine (R03).
2. There are no restraints upon the CSM attitude control modes in this program.
3. This program makes no provision for an attitude maneuver to return the vehicle to a specific attitude. Such a maneuver, if desired, must be done manually. An option is provided however to point the sextant at astronaut or CMC selected stars either manually by crew input or automatically under CMC control.

4. The ISS is on and has been aligned to a known orientation which is stored in the CMC (REFSMMAT). The present IMU orientation differs from that to which it was last aligned only due to gyro drift (that is, neither gimbal lock nor IMU power interruption has occurred since the last alignment).
5. The landing site orientation is used for:
   a. Aligning the CSM stable member to the same orientation as the LM stable member prior to LM/CSM separation.
   b. Aligning the CSM stable member to the same orientation as the LM stable member prior to LM ascent from the lunar surface.
6. This program is identical to P52 except that R56 is called in place of R52 and R53.
7. The program is selected by DSKY entry.

Selected Displays:

1. V04 N06

Option code ID	00001
Option code	0000X (1—preferred, 2—nominal, 3—REFSMMAT, 4—landing site)

2. V06 N34

Timing of alignment	00XXX h
	000XX min
	0XX.XX s

3. V06 N89 (landing site)

Latitude	XX.XXX deg (+ north)
Longitude/2	XX.XXX deg (+ east)
Altitude	XXX.XX nmi

4. V06 N22

Gimbal angles which will result from selected IMU orientation	OG XXX.XX deg
	IG XXX.XX deg
	MG XXX.XX deg

5. V50 N25 (acquire celestial body)

Checklist code	00015

6. V01 N70

Celestial body code (before mark)	000XX

7. V06 N88

Components of celestial body ½ unit vector	.XXXXX

8. V06 N94

Shaft angle	XXX.XX deg
Trunnion angle	XX.XXX deg

9. V53 (perform alternate LOS mark)
10. V50 N25 (terminate mark sequence)

Checklist code	00016

11. V01 N71

Celestial body code (after mark)	000XX

12. V06 N05

Sighting angle difference	XXX.XX deg

13. V06 N93

Gyro torquing angles	X XX.XXX deg
	Y XX.XXX deg
	Z XX.XXX deg

14. V50 N25 (fine align)

Checklist code	00014

P61—ENTRY—PREPARATION PROGRAM

Purpose:

1. To start navigation, check IMU alignment, and provide entry monitor system initialization data.

Assumptions:

1. The program is entered with adequate freefall time to complete the maneuvers from a worst case starting attitude.
2. The ISS is on and precisely aligned to a satisfactory orientation.
3. The program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N61

Impact latitude	XXX.XX deg (+ north)
Impact longitude	XXX.XX deg (+ east)
Heads up/down	00001 (+ heads up/ lift down)

2. V06 N60

Maximum predicted acceleration	XXX.XX g
Predicted velocity at 400 k ft	XXXXX. ft/s
Predicted flight path angle at 400 k ft	XXX.XX deg

3. V06 N63

Range to go from EMS altitude	XXXX.X nmi
Predicted inertial velocity	XXXXX. ft/s
Time to EMS altitude	XX b XX min/s

P62—ENTRY—CM/SM SEPARATION AND PREENTRY MANEUVER PROGRAM

Purpose:

1. To notify crew when the GNCS is prepared for CM/SM separation.
2. To orient the CM to the correct attitude for atmospheric entry.

Assmptions:

1. The program is entered with adequate freefall time to accomplish CM/SM separation and complete the maneuver from a worst case starting attitude.
2. The IMU is satisfactorily aligned for entry.
3. The program is automatically selected by the Entry—Preparation program (P61) or it may be selected manually.

Selected Displays:

1. V50 N25 (CM/SM separation)

Checklist code	00041

2. V06 N61

Impact latitude	XXX.XX deg (+ north)
Impact longitude	XXX.XX deg(+ east)
Heads up/down	00001 (+ heads up/ lift down)

3. V06 N22

Final gimbal angles at EI	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

P63—ENTRY—INITIALIZATION PROGRAM

Purpose:

1. To initialize the entry equations.
2. To continue to hold the CM to the correct attitude with respect to the atmosphere for the onset of entry deceleration.
3. To establish entry DSKY displays.
4. To sense 0.05 g and display this event to the crew by selecting the Entry—Post 0.05 g program (P64).

Assumptions:

1. The program is automatically selected by the Entry—CM/SM Separation and Preentry Maneuver program (P62).
2. The astronaut may monitor N64 (G, VI, RTOTARG) during this program by keying in V16 N64E. He also may monitor N68 (BETA, VI, HDOT) by keying in V16 N68E.

Selected Displays:

1. V06 N64

Drag acceleration	XXX.XX g
Inertial velocity	XXXXX. ft/s
Range to splash	XXXX.X nmi (+ is overshoot)

2. V16 N64

   Displays same as Item 1 above

3. V16 N68

Commanded bank angle	XXX.XX deg
Inertial velocity	XXXXX. ft/s
Altitude rate	XXXX X.ft/s

P64-ENTRY—POST 0.05 G PROGRAM

Purpose:

1. To start entry guidance at 0.05 g selecting roll attitude, constant drag level, and drag threshold, KA, which are keyed to the 0.05 g point.
2. Select final phase (P67) when 0.2 g occurs if V < 27,000 ft/s at 0.05 g.
3. Iterate for upcontrol solution (P65) if V> 27,000 ft/s and if altitude rate and drag level conditions are satisfied.
4. Select final phase (P67) if no upcontrol solution exists with VL > 18,000 ft/s.
5. To establish the 0.05 g mode in SCS.
6. To continue entry DSKY displays.

Assumptions:

1. The program is automatically selected by the Entry—Initialization program (P63).
2. The astronaut may monitor N64 (G, VI, RTOTARG) during this program by keying in V16 N64E. He also may monitor N68 (BETA, VI, HDOT) by keying in V16 N68E.

Selected Displays:

1. V06 N68

Commanded bank angle	XXX.XX deg
Inertial velocity	XXXXX. ft/s
Altitude rate	XXXXX. ft/s

2. V16 N68

   Displays same as Item 1 above

3. V16 N64

Drag acceleration	XXX.XX g
Inertial velocity	XXXXX. ft/s
Range to splash	XXXX.X nmi (+ is overshoot)

P65—ENTRY—UPCONTROL PROGRAM

Purpose:

1. To execute Entry—Upcontrol guidance which steers the CM to a controlled exit (skip out) condition.
2. To establish Entry—Upcontrol displays which are used in conjunction with the EMS to determine for the astronaut if the backup procedures should be implemented.
3. To sense exit (drag acceleration less than Q7 ft/s^2) and thereupon to select the Entry—Ballistic Phase program (P66).
4. Where RDOT is negative and the V is sufficiently low (V-VL-C18 neg), the program will exit directly to P67 (Final Phase).

Assumptions:

1. This program is automatically selected by the Entry—Post 0.05 g program (P64) when constant drag control has brought range prediction to within 25 nmi of the desired range. It is skipped in earth orbit missions.
2. The astronaut may monitor N64 (G, VI, RTOTARG) during this program by keying in V16 N64E. He may also monitor N68 (BETA, VI, HDOT) by keying in V16 N68E.
3. Manual response to N69 is not necessary to terminate P65. Selection of either P66 or P67 by entry guidance provides automatic termination.

Selected Displays:

1. V16 N69

Commanded bank angle	XXX.XX deg
Drag level	XXX.XX g
Skip out velocity	XXXXX. ft/s

2. V06 N68

Commanded bank angle	XXX.XX deg
Inertial velocity	XXXXX. ft/s
Altitude rate	XXXXX. ft/s

3. V16 N64

Drag acceleration	XXX.XX g
Inertial velocity	XXXXX. ft/s
Range to splash	XXXX.X nmi (+ is overshoot)

4. V16 N68

   Displays same as Item 2 above

P66-ENTRY—BALLISTIC PROGRAM

Purpose:

1. To maintain CM attitude during ballistic (skip out) phase for atmospheric reentry.
2. To sense reentry (drag acceleration builds up to Q7 + 0.5 ft/s^2 or approximately 0.2 g) and thereupon to select the Entry—Final Phase program (P67).

Assumptions:

1. This program is automatically selected by the Entry–Upcontrol program (P65) when drag acceleration becomes less than Q7 ft/s^2.
2. The astronaut may monitor N64 (G, VI, RTOTARG) during this program by keying in V16 N64E. He may also monitor N68 (BETA, VI, HDOT) by keying in V16 N68E.

Selected Displays:

1. V06 N22

Desired gimbal angles	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

2. V16 N64

Drag acceleration	XXX.XX g
Inertial velocity	XXXXX. ft/s
Range to splash	XXXX.X nmi (+ is overshoot)

3. V16 N68

Commanded bank angle	XXX.XX deg
Inertial velocity	XXXXX. ft/s
Altitude rate	XXXXX. ft/s

P67–ENTRY–FINAL PHASE PROGRAM

Purpose:

1. To continue entry guidance after Q7 + 0.5 ft/s^2 (or approximately 0.2 g) until termination of steering when the CM velocity WRT earth = 1,000 ft/s (altitude is approximately 65,000 ft).
2. To continue entry DSKY displays.

Assumptions:

1. The program is automatically selected by:
   a. P65 when RDOT is negative and the V is sufficiently low (V-VI-C18 neg).
   b. P66 when drag acceleration builds up to Q7 + 0.5 ft/s^2 (or approximately 0.2 g).
   c. P64 if no upcontrol solution exists with VL > 18,000 ft/s.
2. The astronaut may monitor N64 (G, VI, RTOTARG) during this program by keying in V16 N64E. He also may monitor N68 (BETA, VI, HDOT) by keying in V16 N68E.

Selected Displays:

1. V06 N66

Commanded bank angle	XXX.XX deg
Crossrange error	XXXX.X nmi (+ south)
Downrange error	XXXX.X nmi (+ overshoot)

2. V16 N67

Range to target	XXXX.X nmi (+ overshoot)
Present latitude	XXX.XX (+ north)
Present longitude	XXX.XX (+ east)

3. V16 N64

Drag acceleration	XXX.XX g
Inertial velocity	XXXXX. ft/s
Range to splash	XXXX.X nmi (+ overshoot)

4. V16 N68

Commanded bank angle	XXX.XX deg
Inertial velocity	XXXXX. ft/s
Altitude rate	XXXXX. ft/s

P72–LM COELLIPTIC SEQUENCE INITIATION (CSI) PROGRAM

Purpose:

1. To calculate parameters associated with the following concentric flight plan maneuvers for LM execution of the maneuvers under the control of the LGC; the Coelliptic Sequence Initiation (CSI) and the Constant Delta Altitude maneuver (CDH).
2. To calculate these parameters based upon maneuver data approved and keyed into the CMC by the astronaut.
3. To display to the astronaut and the ground dependent variables associated with the concentric flight plan maneuvers for approval by the astronaut/ground.

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 LM position.
2. The time between CSI ignition and CDH ignition must be computed to be greater than 10 minutes for successful completion of the program.
3. The time between CDH ignition and TPI ignition must be computed to be greater than 10 minutes for successful completion of the program.
4. CDH Delta V is selected to minimize the variation of the altitude difference between the orbits.
5. CSI burn is defined such that the impulsive Delta V is in the horizontal plane defined by the active vehicle position at CSI ignition.
6. The pericenter altitude of the orbit following CSI and CDH must be greater than 35,000 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 CSM orbit. However, crew modification of Delta V(LV) components may result in an out-of-plane CSI maneuver.
8. The ISS need not be on to complete this program.
9. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N11

Time of CSI ignition	00XXX. h
	000XX. min
	0XX.XX s

2. V06 N55

Number of apsidal crossings (N)	0000X
Elevation angle (E)	XXX.XX deg
Central angle of passive vehicle	XXX.XX deg

3. V06 N37

Time of TPI ignition	00XXX. h
	000XX. min
	0XX.XX s

4. V16 N45	
Marks (VHF/optics)	XX b XX marks
Time from CSI ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg
5. V06 N75	
Delta altitude (CDH)	XXXX.X nmi
ΔT (CDH-CSI)	XX b XX min/s
ΔT (TPI-CDH)	XX b XX min/s
6. V06 N13 (astronaut initiated display)	
Time of CDH ignition	00XXX. h
	000XX. min
	0XX.XX s
7. V06 N81	
Components of ΔV(LV) for CSI	XXXX.X ft/s
8. V06 N82	
Components of ΔV(LV) for CDH	XXXX.X ft/s
9. V04 N12 (results from V90E)	
Option code ID	00002
Option code	0000X (1—this vehicle, 2—other vehicle)
10. V06 N16 (results from V90E)	
Time of event	00XXX. h
	000XX. min
	0XX.XX s
11. V06 N90 (results from V90E)	
Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

P73—LM 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 LM execution of the maneuvers under control of the LGC. 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.
2. To calculate these parameters based upon maneuver data approved and keyed into the CMC by the astronaut.
3. To display to the astronaut and the ground dependent variables associated with the concentric flight plan maneuvers for approval by the astronaut/ground.

Assumptions:

1. This program is based upon previous completion of the Coelliptic Sequence Initiation (CSI) 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 active vehicle position.
   b. The time between CSI ignition and CDH ignition was computed to be greater than 10 minutes.
   c. The time between CDH ignition and TPI ignition was computed to be greater than 10 minutes.
   d. The variation of the altitude difference between the orbits was minimized.
   e. CSI burn was defined such that the impulsive Delta V was in the horizontal plane defined by the active vehicle position at CSI ignition.
   f. The pericenter altitudes of the orbits following CSI and CDH were computed to be greater than 35,000 feet (lunar orbit) or 85 nmi (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 ISS need not be on to complete this program.
3. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N13	
Time of CDH ignition	00XXX h
	000XX min
	0XX.XX s
2. V06 N75	
Delta altitude (CDH)	XXXX.X nmi
ΔT (TPI-CDH)	XX b XX min/s
ΔT (TPI-NOMTPI)	XX b XX min/s
3. V06 N81	
Components of ΔV (LV) for CDH	XXXX.X ft/s
4. V16 N45	
Marks (VHF/optics)	XX b XX marks
Time from CDH ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg
5. V04 N12 (results from V90E)	
Option code ID	00002
Option code	0000X (1—this vehicle, 2—other vehicle)
6. V06 N16 (results from V90E)	
Time of event	00XXX. h
	000XX. min
	0XX.XX s
7. V06 N90 (results from V90E)	
Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

P74—LM TRANSFER PHASE INITIATION (TPI) TARGETING 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 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).
3. To display to the astronaut and the ground certain dependent variables associated with the maneuver for approval by the astronaut/ground.

Assumptions:

1. The program must be done over a tracking station for real-time ground participation in CMC data input and output.
2. If P20 is in operation while this program is operating, the astronaut may hold at any flashing display and turn on the Rendezvous Sighting Mark routine (either R21 or R23) and take optics marks, and/or he may allow VHF ranging marks to accumulate.
3. 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.
4. The ISS need not be ON to complete the program.
5. This program is selected by DSKY entry.

Selected Displays:

1.	V06 N37	
	Time of TPI ignition	00XXX. h
		000XX. min
		0XX.XX s
2.	V06 N55	
	R2: Elevation angle	XXX.XX deg
	R3: Central angle of passive vehicle	XXX.XX deg
3.	V16 N45	
	Marks (VHF/optics)	XX b XX marks
	Time until TPI burn	XX b XX min/s
	Middle gimbal angle	XXX.XX deg
4.	V06 N58	
	Pericenter altitude	XXXX.X nmi
	ΔV (TPI)	XXXX.X ft/s
	ΔV (TPF)	XXXX.X ft/s
5.	V06 N81	
	Components of ΔV (LV) for TPI	XXXX.X ft/s

6. V06 N59

Components of ΔV (LOS) for TPI	XXXX.X ft/s

7. V06 N52

Central angle of active vehicle	XXX.XX deg

8. V04 N12 (results from V90E)

Option code ID	00002
Option code	0000X (1—this vehicle, 2—other vehicle)

9. V06 N16 (results from V90E)

Time of event	00XXX. h
	000XX. min
	0XX.XX s

10. V06 N90 (results from V90E)

Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

P75—LM TRANSFER PHASE MIDCOURSE (TPM) TARGETING 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. If P20 is in operation while this program is operating the astronaut may hold at any flashing display and turn on the Rendezvous Sighting Mark routine (either R21 or R23) and take optics marks, and/or he may allow VHF ranging marks to accumulate.
2. 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.
3. The time of intercept (T(INT)) was defined by previous completion of the LM Transfer Phase Initiation (TPI) program (P74) and is presently available in CMC storage.
4. There is no requirement for ISS operation during this program unless automatic state vector updating is desired by the Rendezvous Navigation program (P20).
5. The program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V16 N45

Marks (VHF/optics)	XX b XX marks
Time until TPM ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg

2. V06 N81

Components of ΔV (LV) for TPM	XXXX.X ft/s

3. V06 N59

Components of ΔV (LOS) for TPM	XXXX.X ft/s

4. V06 N52

Central angle of active vehicle	XXX.XX deg

5. V04 N12 (results from V90E)

Option code ID	00002
Option code	0000X (1—this vehicle, 2—other vehicle)

6. V06 N16 (results from V90E)

Time of event	00XXX. h
	000XX. min
	0XX.XX s

7. V06 N90 (results from V90E)

Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

P76—TARGET DELTA V PROGRAM

Purpose:

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

Assumptions:

1. The CSM crew has the Delta V to be applied by the LM in local vertical axes at a specified TIG. These values are displayed prior to TIG by the Prethrust Targeting program in the LM. No provision is made in these thrusting programs to display the results of the maneuver in a form usable by this routine. If the burn is not nominal and this Delta V is not as specified or if TIG is not as originally specified, consult backup procedures.
2. Care should be exercised to incorporate state vector changes via this program in logical order with state vector changes resulting from the Rendezvous Navigation program (P20). A suggested procedure would be to stop optics marking, verify data incorporation by reviewing Noun 45 mark counters, incorporate state vector changes via this program, but do not take optics marks or enable VHF range link until the LM maneuver has taken place.
3. In the event of an uplink failure, the astronaut can create a reasonable LM state vector for LM insertion into orbit from the lunar surface by keying in the expected LM thrusting maneuver from the lunar surface while the surface flag is set. This will cause the computer to take the position vector of the landing site and add the inputted Delta V and store the results in the LM state vector. The landing site will not be altered.
4. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N84

Components of ΔV (OV)	XXXX.X ft/s

2. V06 N33

Time of ignition	00XXX. h
	000XX. min
	0XX.XX s

P77—LM TRANSFER PHASE INITIATION (TPI) SEARCH PROGRAM

Purpose:

1. To accept a desired time of Transfer Phase Initiation (TIG(TPI)) as a DSKY input from the astronaut, and to compute therefrom the parameters associated with a minimum energy, safe periapsis transfer maneuver at TIG (TPI) and the resultant rendezvous intercept for an active LM.
2. To provide the astronaut with the option of defining to the CMC the initial transfer trajectory search sector for central angles either greater than or less than 180 degrees from the position of the active vehicle (LM) at TIG(TPI).
3. To display to the astronaut the parameters associated with the transfer (TPI and intercept).

Assumptions:

1. If P20 is in operation while this program is operating the astronaut may hold at any flashing display and turn on the Rendezvous Sighting Mark routine (either R21 or R23) and take optics marks, and/or he may allow VHF ranging marks to accumulate.
2. To execute the TPI maneuver, select the LM Transfer Phase Initiation Targeting (TPI) program (P74) and transmit maneuver data to the LM.
3. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N37

Time of TPI ignition	00XXX. h
	000XX. min
	0XX.XX s

2. V06 N72

Delta angle (TPI)	XXX.XX deg (+active vehicle ahead)
Delta altitude (TPI)	XXXX.X nmi (+ passive vehicle above)
Search option	0000X (1-central angle $<$ 180 degrees; 2-central angle $>$ 180 degrees)

3. V06 N58

Pericenter altitude	XXXX.X nmi
ΔV (TPI)	XXXX.X ft/s
ΔV (TPF)	XXXX.X ft/s

4. V06 N55

R1: Perigee code	0000X (1—perigee between TPI and TPF, 2—perigee after intercept)
R3: Central angle of passive vehicle	XXX.XX deg

P78—LM STABLE ORBIT RENDEZVOUS (SOR) TARGETING PROGRAM

Purpose:

1. To calculate the required Delta V and other initial conditions required by the LGC for LM execution of the first phase of the Stable Orbit Rendezvous maneuver. Given:
   a. Time of ignition (TIG).
   b. Central angle of transfer (CENTANG) from TIG to intercept time.
   c. The offset of the stable orbit point specified as a distance along the passive vehicle orbit.
2. To calculate the required Delta V and other initial conditions required by the LGC for LM execution of the second phase of the Stable Orbit Rendezvous maneuver. Given:
   a. A respecification of 1.a above.
   b. An optional respecification of 1.b above.
3. To calculate these parameters based upon maneuver data approved and keyed into the CMC by the astronaut.
4. To display to the astronaut and the ground certain dependent variables associated with the maneuver for approval by the astronaut/ground.

Assumptions:

1. The stable orbit point is defined as the final position (at completion of second phase) of the active vehicle relative to the passive vehicle.
2. If P20 is in operation while this program is operating the astronaut may hold at any flashing display and turn on the Rendezvous Sighting Mark routine (either R21 or R23) and take optics marks, and/or he may allow VHF ranging marks to accumulate.
3. Once the parameters required for computation of the maneuver have been completely specified, the value of the active 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.
4. The second phase of this program requires the TIG input be biased as a function of TPF and any midcourse corrections performed in the LM Stable Orbit Midcourse Targeting program (P79).
5. There is no requirement for ISS operation during this program unless automatic state vector updating is desired by the Rendezvous Navigation program (P20).
6. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N33

Time of SOI ignition	00XXX. h
	000XX. min
	0XX.XX s

2. V06 N55

R3: Central angle of passive vehicle	XXX.XX deg

3. V04 N06

Option code ID	00005
Option code	0000X (1-first pass, 2-second pass)

4. V06 N57

Stable orbit offset	XXXX.X nmi

5. V06 N34

Time of arrival at stable orbit	00XXX. h
	000XX. min
	0XX.XX s

6. V16 N45

Marks (VHF/optics)	XX b XX marks
Time of SOI ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg

7. V06 N58

Pericenter altitude (SOR)	XXXX.X nmi
ΔV (SOR)	XXXX.X ft/s
ΔV (SOR-final)	XXXX.X ft/s

8. V06 N81

Components of ΔV (LV) for SOR	XXXX.X ft/s

9. V06 N52

Central angle of active vehicle	XXX.XX deg

P79—LM STABLE ORBIT MIDCOURSE (SOM) TARGETING PROGRAM

Purpose:

1. To calculate the required Delta V and other initial conditions required by the LGC for LM execution of the next possible midcourse correction of the Stable Orbit Transfer Phase of an active LM rendezvous.
2. To compute and display suitable information to enable the crew to enter the Final Rendezvous Phase at the correct time to complete the required thrusting maneuver.

Assumptions:

1. The ISS need not be on to complete this program.
2. If P20 is in operation while this program is operating the astronaut may hold at any flashing display and turn on the Rendezvous Sighting Mark routine (either R21 or R23) and take optics marks, and/or he may allow VHF ranging marks to accumulate.
3. 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.
4. The time of intercept (T(INT)) was defined by previous completion of the LM Stable Orbit Rendezvous Targeting (SOR) program (P78) and is presently available in CMC storage.
5. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N81

Components of ΔV (LV) for SOM	XXXX.X ft/s

2. V16 N45

Marks (VHF/optics)	XX b XX marks
Time from SOM ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg

3. V06 N52

Central angle of active vehicle	XXX.XX deg

LM SOFTWARE

LUMINARY 1A
(REV 001 OF LMY99)
LM DSKY
COMPUTER PROGRAMS
COMPUTER ROUTINES
VERB CODES
NOUN CODES
ALARM CODES
OPTION CODES
CHECKLIST CODES
FLAGWORD BIT ASSIGNMENTS
IMODES30 AND IMODES33
CHANNEL BIT ASSIGNMENTS
COMPUTER PROGRAM DESCRIPTION

UPLINK ACTY light — is energized by the first character of a digital UPLINK message received by the LGC.

NO ATT Light — is energized when the LGC is in the Operate mode and there is no inertial reference; that is, the ISS is off, caged, or in the Coarse Align mode.

STBY Light — is energized when the LGC is in the Standby mode and deenergized when the LGC is in the Operate mode.

KEY REL Light

1. Energized when:
   a. An internal display comes while the astronaut has the DSKY.
   b. An astronaut keystroke is made while an internal flashing display is currently on the DSKY.
   c. The astronaut makes a keystroke on top of (his own) Monitor Verb display.
2. Deenergized when:
   a. Astronaut relinquishes the DSKY by operating the KEY REL button.
   b. Astronaut terminates his current sequence normally, for example:
      (1) With final ENTR of a load sequence.
      (2) The ENTR of a response to a flashing display.
      (3) The ENTR of an extended verb request.

OPR ERR Light — is energized when the DSKY operator performs an improper sequence of key depressions.

TEMP Light — The LGC receives a signal from the IMU when the stable member temperature is in the range 126.3° F to 134.3° F. In the absence of this signal, the TEMP lamp on the DSKY is acutated.

GIMBAL LOCK Light — is energized when the middle gimbal angle exceeds ±70 degrees from its zero position. When the middle gimbal angles exceeds ±85 degrees from its zero position the LGC automatically commands the Coarse Align mode in the ISS to prevent gimbal oscillation. The NO ATT light will then be energized.

PROG Light — Under a variety of situations a program alarm is generated. The program alarm actuates the PROG lamp on the DSKY.

RESTART Light — In the event of a RESTART during operation of a program, a latch is set in the LGC which illuminates the RESTART lamp on the DSKY until the latch is manually reset by pressing RSET.

TRACKER Light — When the Rendezvous or Landing Radars are on, the light is energized when:

1. A RR CDU failed with the RR in the Auto mode and RR CDU's not being zeroed.
2. N samples of LR data could not be taken in 2N tries.
3. N samples of RR data could not be taken in 2N tries.

ALT Light — is energized due to the absence of the LR Range Data Good discrete when reading LR range or when improper scaling of LR range information is detected.

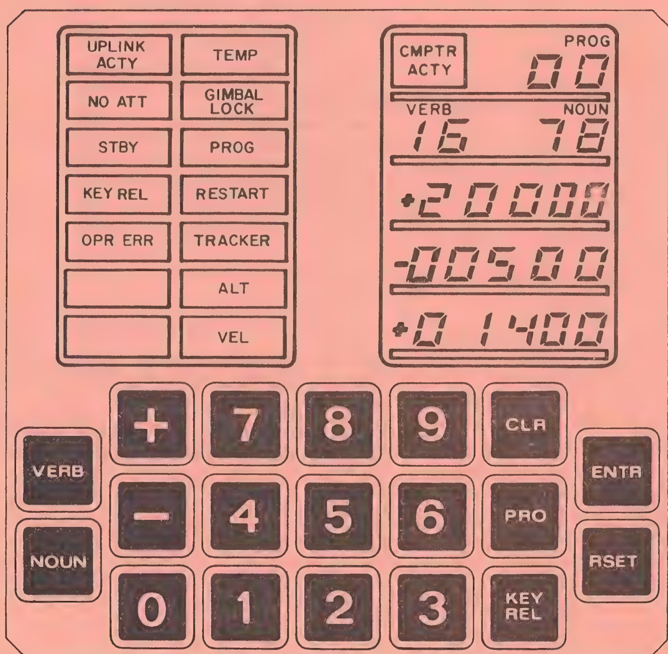
VEL Light — is energized due to the absence of the LR Velocity Data Good discrete when reading LR velocity.

COMP ACTY Light — is energized when the LGC is occupied with an internal sequence.

Display Panel — consists of 24 electroluminescent sections. Each section is capable of displaying a decimal character or remaining blank, except the three sign sections. These display a plus sign, a minus sign, or a blank. The numerical sections are grouped to form three data display registers, each of five numerical characters; and three control display registers, each of two numerical characters. The data display registers are referred to as R1, R2, R3. The control display registers are known as VERB, NOUN, and PROGRAM.

Keyboard —contains the following buttons:

1. VERB — Pushing this button indicates that the next two numerical characters keyed are to be interpreted as the Verb Code.
2. NOUN — Pushing this button indicates that the next two numerical characters keyed are to be interpreted as the Noun Code.
3. + and - — are sign keys used for sign convention and to identify decimal data.
4. 0 - 9 —are numerical keys.
5. CLR — is used during a data loading sequence to blank the data display register (R1, R2, R3) being used. It allows the operator to reload the data word.
6. PRO —This pushbutton performs two functions:
   - a. When the LGC is in the Standby mode, pressing this button will put the LGC in the Operate mode, turn off the STBY light, and automatically select Routine 00 in the LGC, after restoring the clock.
   - b1. When the LGC is in the Operate mode but Program 06 is not selected, pressing the button will provide the "Proceed" function.
   - b2. When the LGC is in the Operate mode and Program 06 is selected, pressing the button will put the LGC in the Standby mode and turn on the STBY light.
7. ENTR —is used in three ways:
   - a. To direct the LGC to execute the Verb/Noun now appearing on the Verb/Noun lights.
   - b. To direct the LGC to accept a data word just loaded.
   - c. To respond to a "Please Perform" request.
8. RSET — turns off alarm indicator on the DSKY providing the alarm condition has been corrected.



PROGRAMS FOR PROGRAM LUMINARY 1A

PHASE	PROGRAM NUMBER	PROGRAM TITLE
Service	00	LGD Idling
	06	LGC Power Down
Ascent	12	Powered Ascent
Coast	20	Rendezvous Navigation
	21	Ground Track Determination
	22	Lunar Surface Navigation
	25	Preferred Tracking Attitude
	27	LGC Update
Pre-thrusting	30	External Delta V
	31	Lambert Aim Point Guidance
	32	Coelliptic Sequence Initiation (CSI)
	33	Constant Delta Altitude (CDH)
	34	Transfer Phase Initiation (TPI)
	35	Transfer Phase Midcourse (TPM)
	38	Stable Orbit Rendezvous (SOR)
	39	Stable Orbit Midcourse (SOM)
Thrusting	40	DPS
	41	RCS
	42	APS
	47	Thrust Monitor
Alignments	51	IMU Orientation Determination
	52	IMU Realign
	57	Lunar Surface Align
Descent	63	Braking Phase
	64	Approach Phase
	65	Landing Phase (Auto)
	66	Landing Phase (ROD)
	67	Landing Phase (Manual)
	68	Landing Configuration
Aborts and Backups	70	DPS Abort
	71	APS Abort
	72	CSM Coelliptic Sequence Initiation (CSI) Targeting
	73	CSM Constant Delta Altitude (CDH) Targeting
	74	CSM Transfer Phase Initiation (TPI) Targeting
	75	CSM Transfer Phase Midcourse (TPM) Targeting
	76	Target Delta V
	78	CSM Stable Orbit Rendezvous (SOR) Targeting
	79	CSM Stable Orbit Midcourse (SOM) Targeting

ROUTINES FOR PROGRAM LUMINARY 1A

ROUTINE	ROUTINE TITLE
00	Final Automatic Request Terminate
01	Erasable Modification
02	IMU Status Check
03	DAP Data Load
04	Rendezvous Radar/Landing Radar Self-Test
05	S-Band Antenna
09	R10/R11/R12 Service
10	Landing Analog Displays
11	Abort Discretes Monitor
12	Descent State Vector Update
13	Landing Auto Modes Monitor
20	Landing Radar/Rendezvous Radar Read
21	Rendevzous Radar Designate
22	Rendezvous Radar Data Read
23	Rendezvous Radar Manual Acquisition
24	Rendezvous Radar Search
25	Rendezvous Radar Monitor
29	Powered Flight Rendezvous Radar Designate
30	Orbit Parameter Display
31	Rendezvous Parameter Display
33	LGC/CMC Clock Synchronization
36	Out-of-Plane Rendezvous Display
40	DPS/APS Thrust Fail
41	State Vector Integration (MIDTOAVE)
47	AGS Initialization
50	Coarse Align
51	In-Flight Fine Align
52	Auto Optics Positioning
53	AOT Mark
54	Sighting Data Display
55	Gyrotorquing
56	Terminate Tracking
57	MARKRUPT
58	Celestial Body Definition
59	Lunar Surface Sighting Mark
60	Attitude Maneuver
61	Preferred Tracking Attitude
62	Crew-Defined Maneuver
63	Rendezvous Final Attitude
65	Fine Preferred Tracking Attitude
76	Extended Verb Interlock
77	LR Spurious Test

LIST OF VERBS USED IN PROGRAM LUMINARY 1A

REGULAR VERBS

00	Not in use
01	Display Octal Component 1 in R1
02	Display Octal Component 2 in R1
03	Display Octal Component 3 in R1
04	Display Octal Components 1, 2 in R1, R2
05	Display Octal Components 1, 2, 3 in R1, R2, R3
06	Display decimal in R1 or R1, R2 or R1, R2, R3
07	Display DP decimal in R1, R2 (test only)
08	Spare
09	Spare
10	Spare
11	Monitor Octal Component 1 in R1
12	Monitor Octal Component 2 in R1
13	Monitor Octal Component 3 in R1
14	Monitor Octal Components 1, 2 in R1, R2
15	Monitor Octal Components 1, 2, 3 in R1, R2, R3
16	Monitor decimal in R1 or R1, R2 or R1, R2, R3
17	Monitor DP decimal in R1, R2 (test only)
18	Spare
19	Spare
20	Spare
21	Load Component 1 into R1
22	Load Component 2 into R2
23	Load Component 3 into R3
24	Load Components 1, 2 into R1, R2
25	Load Components 1, 2, 3 into R1, R2, R3
26	Spare
27	Display Fixed Memory
28	Spare
29	Spare
30	Request EXECUTIVE
31	Request WAITLIST

32 Recycle program

33 Proceed without DSKY inputs

34 Terminate function

35 Test lights

36 Request FRESH START

37 Change program (major mode)

38 Spare

39 Spare

EXTENDED VERBS

40 Zero CDU's (specify N20 or N72)

41 Coarse align CDU's (specify N20 or N72)

42 Fine align IMU

43 Load IMU attitude error needles

44 Terminate RR continuous designate (V41N72 Option 2)

45 Spare

46 Spare

47 Initialize AGS (R47)

48 Request DAP Data Load routine (R03)

49 Request Crew Defined Maneuver routine (R62)

50 Please perform

51 Spare

52 Mark X reticle

53 Mark Y reticle

54 Mark X or Y reticle

55 Increment LGC time (decimal)

56 Terminate tracking (P20 and P25)

57 Permit Landing Radar updates

58 Inhibit Landing Radar updates

59 Spare

60 Command LR to Position 2

61 Display DAP following attitude errors

62 Display total attitude errors with respect to N22

63 Sample radar once per second (R04)

LIST OF VERBS USED IN PROGRAM LUMINARY 1A

64	Request S-Band Antenna routine (R05)
65	Disable U and V jet firings during DPS burns
66	Vehicles are attached. Move this vehicle state vector to other vehicle.
67	Display W matrix
68	Spare
69	Cause RESTART
70	Start LGC update, liftoff time (P27)
71	Start LGC update, block address (P27)
72	Start LGC update, single address (P27)
73	Start LGC update, LGC time (P27)
74	Initialize erasable dump via DOWNLINK
75	Enable U and V jet firings during DPS burns
76	Minimum Impulse Command mode
77	Rate Command and Attitude Hold mode
78	Start LR spurious test (R77)
79	Stop LR spurious test
80	Enable LM state vector update
81	Enable CSM state vector update
82	Request Orbit Parameter display (R30)
83	Request Rendezvous Parameter display (R31)
84	Spare
85	Display Rendezvous Radar LOS azimuth and elevation
86	Spare
87	Spare
88	Spare
89	Request Rendezvous Final Attitude maneuver (R63)
90	Request Out of Plane Rendezvous display (R36)
91	Display BANKSUM
92	Start IMU performance tests (ground use)
93	Enable W matrix initialization
94	Spare
95	No update of either state vector allowed (P20 or P22)
96	Interrupt integration and go to P00
97	Perform Engine Fail procedure (R40)
98	Spare
99	Please Enable Engine Ignition

LIST OF NOUNS USED IN PROGRAM LUMINARY 1A

00	Not in use		
01	Specify address (fractional)		.XXXXX fractional .XXXXX fractional .XXXXX fractional
02	Specify address (whole)		XXXXX. integer XXXXX. integer XXXXX. integer
03	Specify address (degree)		XXX.XX deg XXX.XX deg XXX.XX deg
04	Angular error/difference		XXX.XX deg
05	Angular error/difference		XXX.XX deg
06	Option code ID Option code Dat code		Octal Octal Octal
07	FLAGWORD operator		
	ECADR BIT ID Action		Octal Octal Octal
08	Alarm data		
	ADRES BBANK ERCOUNT		Octal Octal Octal
09	Alarm codes		
	First Second Last		Octal Octal Octal
10	Channel to be specified		Octal
11	TIG of CSI		00XXX. h 000XX. min 0XX.XX s
12	Option code (extended verbs only)		Octal Octal
13	TIG of CDH		00XXX. h 000XX. min 0XX.XX s
14	CHECKLIST (used internally by extended verbs only; N25 is pasted after display)		XXXXX.
15	Increment address		Octal
16	Time of event (used by extended verbs only)		00XXX. h 000XX. min 0XX.XX s
17	Spare		
18	Desired automaneuver FDAI ball angles	R P Y	XXX.XX deg XXX.XX deg XXX.XX deg

19	Spare		
20	Present ICDU angles	OG IG MG	XXX.XX deg XXX.XX deg XXX.XX deg
21	PIPA's	X Y Z	XXXXX. pulses XXXXX. pulses XXXXX. pulses
22	Desired ICDU angles	OG IG MG	XXX.XX deg XXX.XX deg XXX.XX deg
23	Spare		
24	Delta time for LGC clock		00XXX. h 000XX. min 0XX.XX s
25	CHECKLIST (used with V50)		XXXXX.
26	PRIO/DELAY, ADRES, BBCON		Octal Octal Octal
27	Self-test on/off switch		XXXXX.
28	Spare		
29	Spare		
30	Spare		
31	Spare		
32	Time from perigee		00XXX. h 000XX. min 0XX.XX s
33	Time of ignition		00XXX. h 000XX. min 0XX.XX s
34	Time of event		00XXX. h 000XX. min 0XX.XX s
35	Time from event		00XXX. h 000XX. min 0XX.XX s
36	Time of LGC clock		00XXX. h 000XX. min 0XX.XX s
37	Time of ignition (TPI)		00XXX. h 000XX. min 0XX.XX s
38	Time of state being integrated		00XXX. h 000XX. min 0XX.XX s
39	Spare		

LIST OF NOUNS USED IN PROGRAM LUMINARY 1A

40	Time from ignition/cutoff	XX b XX min/s
	VG	XXXX.X ft/s
	Delta V (measured)	XXXX.X ft/s
41	Target	
	Azimuth	XXX.XX deg
	Elevation	XX.XXX deg
42	Apocenter altitude	XXXX.X nmi
	Pericenter altitude	XXXX.X nmi
	Delta V (required)	XXXX.X ft/s
43	Latitude	XXX.XX deg (+ north)
	Longitude	XXX.XX deg (+ east)
	Altitude	XXXX.X nmi
44	Apocenter altitude	XXXX.X nmi
	Pericenter altitude	XXXX.X nmi
	TFF	XX b XX min/s
45	Marks (M)	XXXXX.
	Time from ignition of next burn	XX b XX min/s
	Middle gimbal angle	XXX.XX deg
46	DAP configuration	Octal
47	LM weight	XXXXX. lb
	CSM weight	XXXXX. lb
48	Gimbal pitch trim	XXX.XX deg
	Gimbal roll trim	XXX.XX deg
49	Delta R	XXXX.X nmi
	Delta V	XXXX.X ft/s
	Radar data source code	XXXXX.
50	Spare	
51	S-band antenna angles	
	Pitch (Alpha)	XXX.XX deg
	Yaw (Beta)	XXX.XX deg
52	Central angle of active vehicle	XXX.XX deg
53	Spare	
54	Range	XXX.XX nmi
	Range rate	XXXX.X ft/s
	Theta	XXX.XX deg
55	Number of apsidal crossings (N)	XXXXX.
	Elevation angle (E)	XXX.XX deg
	Central angle	XXX.XX deg
56	RR LOS	
	Azimuth	XXX.XX deg
	Elevation	XXX.XX deg
57	Delta R	XXXX.X nmi
58	Pericenter altitude (post TPI or SOR)	XXXX.X nmi
	Delta V (TPI or SOR)	XXXX.X ft/s
	Delta V (TPF or SOR final)	XXXX.X ft/s

59	Delta V LOS 1	XXXX.X ft/s
	Delta V LOS 2	XXXX.X ft/s
	Delta V LOS 3	XXXX.X ft/s
60	Horizontal velocity	XXXX.X ft/s
	Altitude rate	XXXX.X ft/s
	Computed altitude (H)	XXXXX. ft
61	Time to go in braking phase	XX b XX min/s
	Time from ignition	XX b XX min/s
	Crossrange distance	XXXX.X nmi
62	Absolute value of velocity	XXXX.X ft/s
	Time from ignition	XX b XX min/s
	Delta V (measured)	XXXX.X ft/s
63	Absolute value of velocity	XXXX.X ft/s
	Altitude rate	XXXX.X ft/s
	Computed altitude	XXXXX. ft
64	Time left for redesignations (TR)/LPD	XX b XX seconds/deg
	Altitude rate	XXXX.X ft/s
	Computed altitude	XXXXX. ft
65	Sampled LGC time (fetched in interrupt)	00XXX. h
		000XX. min
		0XX.XX s
66	LR slant range	XXXXX. ft
	LR position	0000X.
67	LR VX	XXXXX. ft/s
	LR VY	XXXXX. ft/s
	LR VZ	XXXXX. ft/s
68	Slant range to landing site	XXXX.X nmi
	Time to go in braking phase	XX b XX min/s
	LR altitude (computed altitude)	XXXXX. ft
69	Spare	
70	AOT detent code/star code (before mark)	Octal
		Octal
		Octal
71	AOT detent code/star code (after mark)	Octal
		Octal
		Octal
72	RR trunnion angle (360 degrees – CDU trunnion angle)	XXX.XX deg
	RR shaft angle	XXX.XX deg
73	Desired RR trunnion angle (360 degrees – CDU trunnion angle)	XXX.XX deg
	Desired RR shaft angle	XXX.XX deg
74	Time from ignition	XX b XX min/s
	Yaw after vehicle rise	XXX.XX deg
	Pitch after vehicle rise	XXX.XX deg
75	Delta altitude (CDH)	XXXX.X nmi
	Delta time (CDH-CSI or TPI-CDH)	XX b XX min/s
	Delta time (TPI-CDH or TPI-NOMTPI)	XX b XX min/s

76	Desired downrange velocity	XXXX.X ft/s
	Desired radial velocity	XXXX.X ft/s
	Crossrange distance	XXXX.X nmi
77	Time to engine cutoff	XX b XX min/s
	Velocity normal to CSM plane	XXXX.X ft/s
78	RR range	XXX.XX nmi
	RR range rate	XXXXX. ft/s
79	Cursor angle	XXX.XX deg
	Spiral angle	XXX.XX deg
	Position code	XXXXX.
80	Data indicator	XXXXX.
	Omega	XXX.XX deg
81	Delta VX (LV)	XXXX.X ft/s
	Delta VY (LV)	XXXX.X ft/s
	Delta VZ (LV)	XXXX.X ft/s
82	Delta VX (LV)	XXXX.X ft/s
	Delta VY (LV)	XXXX.X ft/s
	Delta VZ (LV)	XXXX.X ft/s
83	Delta VX (body)	XXXX.X ft/s
	Delta VY (body)	XXXX.X ft/s
	Delta VZ (body)	XXXX.X ft/s
84	Delta VX (LV of other vehicle)	XXXX.X ft/s
	Delta VY (LV of other vehicle)	XXXX.X ft/s
	Delta VZ (LV of other vehicle)	XXXX.X ft/s
85	VGX (body)	XXXX.X ft/s
	VGY (body)	XXXX.X ft/s
	VGZ (body)	XXXX.X ft/s
86	VGX (LV)	XXXX.X ft/s
	VGY (LV)	XXXX.X ft/s
	VGZ (LV)	XXXX.X ft/s
87	Backup optics LOS	
	Azimuth	XXX.XX deg
	Elevation	XXX.XX deg
88	Components of celestial body 1/2 unit vector	X .XXXXX
		Y .XXXXX
		Z .XXXXX
89	Landmark latitude	XX.XXX deg
	Landmark longitude/2	XX.XXX deg
	Landmark altitude	XXX.XX nmi
90	Rendezvous out of plane parameters	
	Y	XXX.XX nmi
	Y dot	XXXX.X ft/s
	PSI	XXX.XX deg
91	Altitude	XXXXXb. nmi
	Velocity	XXXXX. ft/s
	Flight path angle	XXX.XX deg
92	Spare	

LIST OF NOUNS USED IN PROGRAM LUMINARY 1A

93	Delta gyro angles	X XX.XXX deg Y XX.XXX deg Z XX.XXX deg
94	Spare	
95	Spare	
96	Spare	
97	System test inputs	XXXXX. XXXXX. XXXXX.
98	System test results and input	XXXXX. .XXXXX XXXXX.
99	RMS in position RMS in velocity RMS in bias	XXXXX. ft XXXX.X ft/s XXXXX. milliradians

LIST OF ALARM CODES USED WITH VERB 05 NOUN 09 FOR PROGRAM LUMINARY 1A

CODE		PURPOSE	SET BY
00105	**	AOT mark system in use	R53
00107		More than five mark pairs in flight, five marks on lunar surface	R57
00111		Mark missing	R53
00112		Mark or mark reject not being accepted	R57
00113		No inbits	R57
00114		Mark made but not desired	R57
00115		No marks in last pair to reject	R57
00206		Zero Encode not allowed with Coarse Align plus Gimbal Lock	IMU mode switching
00207		ISS turn-on request not present for 90 seconds	T4RUPT
00210		IMU not operating	IMU mode switching, R02
00211		Coarse Align error	IMU mode switching, P51, P57, R50
00212		PIPA fail but PIPA is not being used	IMU mode switching, T4RUPT
00213		IMU not operating with turn-on request	T4RUPT
00214		Program using IMU when turned off	T4RUPT
00217		Bad return from IMUSTALL	P51, P57, R50
00220		Bad REFSMMAT	R02, R47
00401		Desired gimbal angles yields Gimbal Lock	In-flight alignment FINDCDUW KALCMANU
00402		FINDCDUW routine not controlling attitude because of inadequate pointing vectors	FINDCDUW
00404	M	Two stars not available in any detent	R59
00405	M	Two stars not available	R51
00421		W-matrix overflow	INTEGRV
00430	**	Acceleration overflow in integration	Orbital integration
00501	MP	Radar antenna out of limits	R23
00502		Bad radar gimbal angle input	V41N72
00503	MP	Radar antenna designate fail	R21, non-P in V41 N72
00510		Radar auto discrete not present	R25, V40 N72
00511		LR not in Position 2 or repositioning	R12
00514	P	RR goes out of Auto mode while in use	P20, P22

LIST OF ALARM CODES USED WITH VERB 05 NOUN 09 FOR PROGRAM LUMINARY 1A

CODE		PURPOSE	SET BY
00515		RR CDU Fail discrete present	R25
00520		RADARUPT not expected at this time	Radar read, P20, P22, R12
00521		Could not read radar	R12, R22
00522		LR position change	R12
00523	P	LR antenna did not achieve Position 2	R12, V60 (non-P in V60)
00525	MP	Delta Theta greater than 3 degrees	R22
00526	MP	Range greater than 400 nmi	P20, P22
00527	MP	LOS not in Mode 2 coverage while on lunar surface	R24
		Or vehicle maneuver required	R24
00530	P	LOS not in Mode 2 coverage while on lunar surface after 600 seconds	R21
00600	M	Imaginary roots on first iteration	P32, P72
00601	M	Perigee altitude after CSI < 85 nmi earth orbit, < 35,000 feet moon orbit	P32, P72
00602	M	Perigee altitude after CDH < 85 nmi earth orbit, < 35,000 feet moon orbit	P32, P72
00603	M	CSI to CDH time less than 10 minutes	P32, P33, P72, P73
00604	M	CDH to TPI time less than 10 minutes	P32, P72
00605	M	Number of iterations exceeds P32/P72 loop maximum	P32, P72
00606	M	DV exceeds maximum	P32, P72
00607	**	No solution from TIME-THETA or TIME-RADIUS	TIMETHET, TIMERAD
00611	M	No TIG for given E angle	P33, P34, P73, P74
00701	M	Illegal option code selected	P57
00777		PIPA Fail caused ISS warning	T4RUPT
01102		LGC self-test error	SELFCHECK
01103	**	Unused CCS branch executed	ABORT
01104	*	Delay routine busy	EXECUTIVE
01105		DOWNLINK too fast	T4RUPT
01106		UPLINK too fast	T4RUPT
01107		Phase table failure. Assume erasable memory is suspect.	RESTART

LIST OF ALARM CODES USED WITH VERB 06 NOUN 09 FOR PROGRAM LUMINARY 1A

CODE		PURPOSE	SET BY
01201	*	Executive overflow—no VAC areas	EXECUTIVE
01202	*	Executive overflow—no core sets	EXECUTIVE
01203	*	WAITLIST overflow—too many tasks	WAITLIST
01204	**	WAITLIST, VARDELAY, FIXDELAY, or LONGCALL called with zero or negative delta time	WAITLIST
01206	**	Second job attempts to go to sleep via Keyboard and Display program	PINBALL
01207	*	No VAC area for marks	R53
01210	*	Two programs using device at same time	IMU mode switching
01211	*	Illegal interrupt of extended verb	R53
01301		ARCSIN-ARCCOS input angle too large	INTERPRETER
01302	**	SQRT called with negative argument	INTERPRETER
01406	[1]	Bad return from ROOTSPRS	P63, P64
01407		VG increasing (Delta V accumulated $>$90 degrees away from desired thrust vector)	P40, P42
01410		Unintentional overflow in guidance	P63, P64, P65, P66
01412		Descent ignition algorithm not converging	P63
01501	**	Keyboard and Display alarm during internal use (NVSUB)	PINBALL
01502	**	Illegal flashing display	GOPLAY
01520		V37 request not permitted at this time	R00
01600		Overflow in drift test	Ground Test
01601		Bad IMU torque	Ground Test
01703		Too close to ignition; slip time of ignition	R41
01706	[M]	Incorrect program selected for vehicle configuration	P40, P42
02000	*	DAP still in progress at next T5RUPT	DAP
02001		Jet failures have disabled Y-Z translation	DAP
02002		Jet failures have disabled X translation	DAP
02003		Jet failures have disabled P rotations	DAP
02004		Jet failures have disabled U-V rotations	DAP
03777		ICDU fail caused the ISS warning	T4RUPT
04777		ICDU, PIPA fails caused the ISS warning	T4RUPT

LIST OF ALARM CODES USED WITH VERB 05 NOUN 09 FOR PROGRAM LUMINARY 1A

CODE	PURPOSE	SET BY
07777	IMU fail caused the ISS warning	T4RUPT
10777	IMU, PIPA fails caused the ISS warning	T4RUPT
13777	IMU, ICDU fails caused the ISS warning	T4RUPT
14777	IMU, ICDU, PIPA fails caused the ISS warning	T4RUPT

NOTE: For V05 N09 displays:
R1—0XXXX (first alarm to occur after last Reset)
R2—0XXXX (second alarm to occur after last Reset)
R3—XXXXX (alarm which occurred last)

R3 will be of the form 4XXXX if more than three alarms occured since the last Reset or FRESH START.

*Indicates an Abort code that results in a software RESTART
**Indicates a more serious Abort code that results in the program going to R00

P Indicates a priority alarm.

M Indicates a main alarm.

All others are nonabortive

[1] 01406 is an abort during the ignition algorithm and an alarm during the actual guidance phase.

LIST OF OPTION CODES DISPLAYED IN R1 IN CONJUNCTION WITH VERB 04 NOUN 06 TO REQUEST THE ASTRONAUT TO LOAD INTO R2 THE OPTION HE DESIRES FOR PROGRAM LUMINARY 1A

CODE	PURPOSE	INPUT FOR R2	PROGRAM
00001	Specify IMU Orientation	1 = preferred, 2 = nominal 3 = REFSMMAT, 4 = landing site	P52
00002	Specify vehicle	1 = this, 2 = other	P21, R30
00003	Specify tracking attitude	1 = preferred, 2 = other	R63
00004	Specify radar	1 = RR, 2 = LR	R04
00005	Specify SOR phase	1 = first, 2 = second	P38
00006	Specify RR coarse align option	1 = lockon, 2 = continuous designate	V41N72
00010	Specify alignment mode	0 = anytime, 1 = REFSMMAT + g 2 = two bodies, 3 = one body + g	P57
00012	Specify CSM orbit option	1 = no orbit change, 2 = change orbit to pass over LM	P22

LIST OF CHECKLIST REFERENCE CODES USED WITH VERB 50 NOUN 25 PROGRAM LUMINARY 1A

R1 CODE	ACTION TO BE EFFECTED	PROGRAM
00013	Key in normal or gyro torque coarse align	P52
00014	Proceed: Do fine alignment option	R51, P63, P57
	Enter: Do landing site determination (N89)	P57 Option 2
00015	Perform star acquisition	R51, P51
00062	Switch LGC power down	P06
00201	Swith RR mode to automatic	P20, P22, R04
00203	Switch guidance control to PGNS, mode to Auto, thrust control to Auto	P12, P42, P71, P40, P63, P70
00205	Perform manual acquisition of CSM with RR	R23
00500	Switch LR antenna to Position 1	P63

NOTE: Switch: denotes change position of a console switch
Perform: denotes start or end of a task
Key In: denotes key-in of data through the DSKY

FLAGWORD BIT ASSIGNMENTS (ALPHABETICAL) FOR LUMINARY 1A

ACCSOKAY	FW13	B3
ACC4-2FL	FW13	B11
ACC4OR2X	FW13	B11
ACMODFLG	FW2	B13
ALTSCBIT	FW12	B9
ANTENBIT	FW12	B12
AORBSYST	FW13	B5
AORBTFLG	FW13	B10
AORBTRAN	FW13	B10
APSESW	FW8	B5
APSFLAG	FW10	B13
APSFLBIT	FW10	B13
ASINFBIT	FW7	B12
ASTNFLAG	FW7	B12
ATTFLAG	FW6	B1
ATTFLBIT	FW6	B1
AUTOMODE*	FW12	B2
AUTR1FLG*	FW13	B1
AUTR2FLG*	FW13	B2
AUXFLBIT	FW6	B2
AVEGFBIT	FW7	B5
AVEGFLAG	FW7	B5
AVEMIDSW	FW9	B1
AVFLAG	FW2	B5
CALCMAN2	FW2	B2
CALCMAN3	FW2	B3
CDESBIT	FW12	B15
CDESFLAG	FW12	B15
CMOONBIT	FW8	B12
CMOONFLG	FW8	B12
COGAFLAG	FW8	B4
CSMDOCKD	FW13	B13
CULTFLAG	FW3	B7
DBSELECT	FW13	B4
DESIGBIT	FW12	B10
DIDFLBIT	FW1	B14
DIMOFLAG	FW3	B1
DMENFLG	FW5	B9
DRFTBIT	FW2	B15
DRIFTBIT	FW13	B8
DRIFTDFL	FW13	B8
DRIFTFLG	FW2	B15
DSKYBIT	FW5	B15
D6OR9FLG	FW3	B2
ENGONBIT	FW5	B7
EDRADFLAG	FW1	B13
ETPIFLAG	FW2	B7
FINALFLG	FW2	B6
FLAP	FW9	B8
FLPC	FW9	B12
FLPI	FW9	B11
FLRCS	FW9	B10
FLRCSBIT	FW9	B10
FLUNDBIT	FW8	B10
FLUNDISP	FW8	B10
FLVR	FW9	B14
FREEFBIT	FW0	B3
FREEFLAG	FW0	B3
FSPASFLG	FW0	B10
GLOKFAIL	FW3	B14
GMBDRBIT	FW6	B10
GMBDRVSW	FW6	B10
GUESSW	FW1	B2
HFLSHBIT	FW11	B1
HFLSHFLG	FW11	B1
IDLEFBIT	FW7	B7

*These switches are never called by name.

FLAGWORD BIT ASSIGNMENTS (ALPHABETICAL)
FOR LUMINARY 1A

IDLEFLAG	FW7	B7
IGNFLAG	FW7	B13
IGNFLBIT	FW7	B13
IMPULBIT	FW2	B9
IMPULSW	FW2	B9
IMUSE	FW0	B8
IMUSEBIT	FW0	B8
INFINFLG	FW8	B7
INITABIT	FW8	B2
INITALGN	FW8	B2
INTFLBIT	FW10	B14
INTYPFLG	FW3	B4
ITSWICH	FW7	B15
JSWITCH	FW0	B14
LETABBIT	FW9	B9
LETABORT	FW9	B9
LMOONBIT	FW8	B11
LMOONFLG	FW8	B11
LOKONBIT	FW0	B5
LOKONSW	FW0	B5
LOSCMBIT	FW2	B12
LOSCMFLG	FW2	B12
LRALTBIT	FW12	B5
LRBYBIT	FW11	B15
LRBYPASS	FW11	B15
LRINH	FW11	B8
LRINHBIT	FW11	B8
LRPOSBIT	FW12	B6
LRVELFLG*	FW12	B8
LUNAFLAG	FW3	B12
MANUFLAG*	FW7	B14
MGLVFLAG	FW5	B2
MIDAVFLAG	FW9	B2
MIDFLAG	FW0	B13
MID1FLAG	FW9	B3
MKOVBIT	FW4	B3
MOONFLAG	FW0	B12
MRKIDFLG*	FW4	B15
MRKNVBIT	FW4	B9
MRKNVFLG	FW4	B9
MRUPTFLG*	FW4	B5
MUNFLAG	FW6	B8
MUNFLBIT	FW6	B8
MWAITFLG*	FW4	B11
NEEDLBIT	FW0	B4
NEEDLFLG	FW0	B4
NEWIFLG	FW8	B13
NJETSFLG	FW1	B15
NODOBIT	FW2	B1
NODOFLAG	FW2	B1
NOLRRBIT	FW11	B10
NOLRREAD	FW11	B10
NORMSW	FW7	B10
NORRMBIT	FW5	B4
NORRMON	FW5	B4
NOR29FLG	FW3	B11
NOTHRBIT	FW5	B12
NOTHROTL	FW5	B12
NOUPFBIT	FW1	B6
NOUPFLAG	FW1	B6
NRMNVFLAG	FW4	B8
NRMIDFLG*	FW4	B13
NRUPTFLG*	FW4	B4
NR29FBIT	FW3	B11

*These switches are never called by name.

FLAGWORD BIT ASSIGNMENTS (ALPHABETICAL) FOR LUMINARY 1A

NTARGFLG	FW6	B3	REDFLBIT	FW6	B6
NWAITFLG*	FW4	B10	REFSMBIT	FW3	B13
OLDESBIT	FW0	B1	REFSMFLG	FW3	B13
OPTNSW	FW2	B7	REINTBIT	FW10	B7
ORBWFLAG	FW3	B6	REINTFLG	FW10	B7
ORDERSW	FW8	B6	REMODBIT	FW12	B14
OURRCBIT	FW13	B12	RENDWBIT	FW5	B1
PDSPFBIT	FW4	B12	RENDWFLG	FW5	B1
PDSPFLAG	FW4	B12	REPOSBIT	FW12	B11
PFRATBIT	FW2	B4	RHCSCALE	FW13	B7
PFRATFLG	FW2	B4	RNDVZBIT	FW0	B7
PINBRFLG	FW4	B6	RNDVZFLG	FW0	B7
PRECIFLG	FW3	B8	RNGEDBIT	FW11	B4
PRIODBIT	FW4	B14	RNGSCBIT	FW5	B10
PRONVFLG	FW4	B7	RNGSCFLG	FW5	B10
PSTHIBIT	FW11	B11	RODFLAG	FW1	B12
PULSES	FW13	B15	RODFLBIT	FW1	B12
P21FLAG	FW0	B11	ROTFLAG	FW9	B6
P21FLBIT	FW0	B11	RPQFLAG	FW8	B15
P25FLAG	FW0	B9	RRDATABT	FW12	B4
P25FLBIT	FW0	B9	RRNBSW	FW0	B6
P39/79SW	FW8	B9	RRRSBIT	FW12	B3
QUITFLAG	FW9	B5	RVSW	FW7	B9
RCDUFBIT	FW12	B7	R04FLAG	FW3	B9
RCDU0BIT	FW12	B13	R04FLBIT	FW3	B9
READLBIT	FW11	B6	R10FLG	FW0	B2
READLR	FW11	B6	R10FLBIT	FW0	B2
READRBIT	FW3	B9	R61FLAG	FW1	B10
READRFLG	FW3	B9	R61FLBIT	FW1	B10
READVBIT	FW11	B5	R77FLAG	FW5	B11
READVEL	FW11	B5	R77FLBIT	FW5	B11
REDFLAG	FW6	B6	SCALBBIT	FW11	B3

*These switches are never called by name.

FLAGWORD BIT ASSIGNMENTS (ALPHABETICAL) FOR LUMINARY 1A

SLOPESW	FW1	B3
SNUFFBIT	FW5	B13
SNUFFER	FW5	B13
SOLNSW	FW5	B3
SRCHOBIT	FW2	B14
SRCHOPTN	FW2	B14
STATEBIT	FW3	B5
STATEFLG	FW3	B5
STEERBIT	FW2	B11
STEERSW	FW2	B11
SURFFBIT	FW8	B8
SURFFLAG	FW8	B8
SWANDBIT	FW7	B11
SWANDISP	FW7	B11
S32.1F1	FW6	B15
S32.1F2	FW6	B14
S32.1F3A	FW6	B13
S32.1F3B	FW6	B12
TFFSW	FW7	B1
TRACKBIT	FW1	B5
TRACKFLG	FW1	B5
TURNONBT	FW12	B1
ULLAGER	FW13	B6
ULLAGFLG	FW13	B6
UPDATBIT	FW1	B7
UPDATFLG	FW1	B7
UPLOCBIT	FW7	B4
USEQRJTS	FW13	B14
VEHUPFLG	FW1	B8
VELDABIT	FW11	B7
VERIFBIT	FW7	B3
VFLAG	FW3	B10
VFLSHBIT	FW11	B2
VFLSHFLG	FW11	B2
VINTFLAG	FW3	B3
VXINH	FW11	B12
VXINHBIT	FW11	B12
V37FLAG	FW7	B6
V37FLBIT	FW7	B6
V67FLAG	FW7	B8
V82EMFLG	FW7	B2
XDELVFLG	FW2	B8
XDSPBIT	FW4	B1
XDSPLFAG	FW4	B1
XORFLBIT	FW11	B9
XORFLG	FW11	B9
XOVINFLG	FW13	B9
XOVINHIB	FW13	B9
3AXISBIT	FW5	B6
3AXISFLG	FW5	B6
360SW	FW8	B1

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

(FLAGWORD 0)

Bit	Name	1	0
1	OLDESBIT	R29 gyro command loop requested.	R29 gyro command loop not requested.
2	R10FLAG R10FLBIT	R10 outputs data to altitude and altitude rate meters only.	Besides output when set, R10 also outputs data to forward and lateral velocity crosspointer.
3	FREEFBIT FREEFLAG	Used by P51-53 in many different routines and by lunar and solar ephemerides.	
4	NEEDLBIT NEEDLFLG	Total attitude error displayed.	A/P following error displayed.
5	LOKONBIT LOKONSW	Radar lock-on desired.	Radar lock-on not desired.
6	RRNBSW	Radar target in NB coordinates.	Radar target in SM coordinates.
7	RNDVZBIT RNDVZFLG	P20 running (radar in use).	P20 not running.
8	IMUSE IMUSEBIT	IMU in use.	IMU not in use.
9	P25FLAG P25FLBIT	P25 operating.	P25 not operating
10	FSPASFLG	First pass through resposition routine.	Not first pass through reposition routine.
11	P21FLAG P21FLBIT	Succeeding pass through P21; use base vectors already calculated.	First pass through P21; calculate base vectors.
12	MOONFLAG	Moon is sphere of influence.	Earth is sphere of influence.
13	MIDFLAG	Integration with secondary body and solar perturbations.	Integration without solar perturbations.
14	JSWITCH	Integration of W matrix.	Integration of state vector.
15	Not Assigned		

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

(FLAGWORD 1)

Bit	Name	1	0
1	Not Assigned		
2	GUESSW	No starting value for iterator.	Starting value for iteration exists.
3	SLOPESW	Iterate with bias method in iterator.	Iterate with Regula Falsi method in iterator.
4	Not Assigned		
5	TRACKBIT TRACKFLG	Tracking allowed.	Tracking not allowed.
6	NOUPFBIT NOUPFLAG	Neither CSM nor LM state vector may be updated.	Either state vector may be updated.
7	UPDATBIT UPDATFLG	Updating by marks allowed.	Updating by marks not allowed.
8	VEHUPFLG	CSM state vector being updated.	LM state vector being updated.
9	Not Assigned		
10	R61FLAG R61FLBIT	Run R61 LM.	Run R65 LM.
11	Not Assigned		
12	RODFLAG RODFLBIT	If in P66, normal operation continues.	If in P66, reinitialization is performed.
13	ERADFLAG	Compute REARTH Fischer ellipsoid.	Use constant REARTH pad radius.
14	DIDFLBIT	Inertial data is available.	Perform data display initialization functions.
15	NJETSFLG	Two-jet RCS burn.	Four-jet RCS burn.

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

(FLAGWORD 2)

Bit	Name	1	0
1	NODOBIT NODOFLAG	V37 not permitted.	V37 permitted.
2	CALCMAN2	Perform maneuver starting procedure.	Bypass starting procedure.
3	CALCMAN3	No final roll.	Final roll is necessary.
4	PFRATBIT PFRATFLG	Preferred attitude computed.	Preferred attitude not computed.
5	AVFLAG	LM is active vehicle.	CSM is active vehicle.
6	FINALFLG	Last pass through rendezvous program computations.	Interim pass through rendezvous program computations.
7	OPTNSW	SOI phase of P38/P78.	SOR phase of P38/P78.
	ETPIFLAG	Elevation angle supplied for P34, P74.	TPI time supplied for P34, P74 to compute elevation.
8	XDELVFLG	External Delta V VG computation.	Lambert (AIMPOINT) VG computation.
9	IMPULBIT IMPULSW	Minimum impulse burn (cutoff time specified).	Steering burn (no cutoff time yet available).
10	Not Assigned		
11	STEERBIT STEERSW	Sufficient thrust is present.	Insufficient thrust is present.
12	LOSCMBIT LOSCMFLG	Line of sight being computed (R21). In R29, RR gyro command loop running.	Line of sight not being computed (R21). In R29; RR gyro command loop off.
13	ACMODFLG	Manual acquisition by Rendezvous Radar.	Auto acquisition by Rendezvous Radar.
14	SRCHOBIT SRCHOPTN	Radar in automatic search option (R24).	Radar not in automatic search option.
15	DRFTBIT DRIFTFLG	T3RUPT calls gyro compensation.	T3RUPT does no gyro compensation.

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

(FLAGWORD 3)

Bit	Name	1	0
1	DIMOFLAG	W matrix is to be used.	W matrix is not to be used.
2	D6OR9FLG	Dimension of W is 9 for integration.	Dimension of W is 6 for integration.
3	VINTFLAG	CSM state vector being integrated.	LM state vector being integrated.
4	INTYPFLG	Conic integration.	Encke integration.
5	STATEBIT STATEFLG	Permanent state vector being updated.	Permanent state vector not being updated.
6	ORBWFLAG	W matrix valid for orbital navigation.	W matrix invalid for orbital integration.
7	CULTFLAG	Star occulted.	Star not occulted.
8	PRECIFLG	Normal integration in P00.	Engages four-time step (P00) logic in integration.
9	READRBIT READRFLG	Reading RR data pursuant to R29.	Not reading RR data pursuant to R29.
	R04FLAG R04FLBIT	Alarm 521 suppressed.	Alarm 521 allowed.
10	VFLAG	Less than two stars in the field of view.	Two stars in the field of view.
11	NOR29FLG NR29FBIT	R29 not allowed.	R29 allowed (RR designated, powered flight).
12	LUNAFLAG	Lunar latitude-longitude.	Earth latitude-longitude.
13	REFSMBIT REFSMFLG	REFSMMAT good.	REFSMMAT no good.
14	GLOKFAIL	GIMBAL LOCK has occurred.	Not in GIMBAL LOCK.
15	Not Assigned		

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

(FLAGWORD 4)

Bit	Name	1	0
1	XDSPBIT XDSPFLAG	Mark display not to be interruped.	No special mark information.
2	Not Assigned		
3	MKOVBIT	Mark display over normal.	No mark display over normal.
4	NRUPTFLG*	Normal display interrupted by priority or mark display.	Normal display not interrupted by priority or mark display.
5	MRUPTFLG*	Mark display interrupted by priority display.	Mark display not interrupted by priority display.
6	PINBRFLG	Astronaut has interferred with existing display.	Astronaut has not interferred with existing display.
7	PRONVFLG	Astronaut using keyboard when priority display initiated.	Astronaut not using keyboard when priority display initiated.
8	NRMNVFLG	Astronaut using keyboard when normal display initiated.	Astronaut not using keyboard when normal display initiated.
9	MRKNVBIT MRKNVFLG	Astronaut using keyboard when mark display initiated.	Astronaut not using keyboard when mark display initiated.
10	NWAITFLG*	Higher priority display operating when normal display initiated.	No higher priority display operating when normal display initiated.
11	MWAITFLG*	Higher priority display operating when mark display initiated.	No higher priority display operating when mark display initiated.
12	PDSPFBIT PDSPFLAG	P20 sets so as to turn a normal display into a priority display in R60.	Leave as normal display.
13	NRMIDFLG*	Normal display in ENDIDLE.	No normal display in ENDIDLE.
14	PRIODBIT	Priority display in ENDIDLE.	No priority display in ENDIDLE.
15	MRKIDFLG*	Mark display in ENDIDLE.	No mark display in ENDIDLE.

*Theses switches are never called by name.

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

(FLAGWORD 5)

Bit	Name	1	0
1	RENDWBIT RENDWFLG	W matrix valid for rendezvous navigation.	W matrix invalid for rendezvous navigation.
2	MGLVFLAG	Local vertical coordinates computed.	Middle gimbal angle computed.
3	SOLNSW	Lambert does not converge, or time-radius nearly circular.	Lambert converges or time-radius noncircular.
4	NORRMBIT NORRMON	Bypass RR gimbal monitor.	Perform RR gimbal monitor.
5	Not Assigned		
6	3AXISBIT 3AXISFLG	Maneuver specified by three axes.	Maneuver specified by one axis; R60 call VECPOINT.
7	ENGONBIT	Engine turned on.	Engine turned off.
8	Not Assigned		
9	DMENFLG	Dimension of W is 9 for incorporation.	Dimension of W is 6 for incorporation.
10	RNGSCBIT RNGSCFLG	Scale change has occurred during RR reading.	No scale change has occurred duri RR reading.
11	R77FLAG R77FLBIT	R77 is on; suppress all radar alarms and tracker fails.	R77 is not on.
12	NOTHRBIT NOTHROTL	Inhibit full throttle.	Permit full throttle.
13	SNUFFBIT	U, V jets disabled during DPS burn (V65).	U, V jets enabled during DPS burn (V75).
14	Not Assigned		
15	DSKYFBIT	Displays sent to DSKY.	No displays to DSKY.

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

(FLAGWORD 6)

Bit	Name	1	0
1	ATTFLAG ATTFLBIT	LM attitude exists in moon-fixed coordinates.	No LM attitude available in moon-fixed coordinates.
2	AUXFLBIT	Providing IDLEFLAG is not set, SERVICER will exercise DVMON on its next pass.	SERVICER will skip DVMON on its next pass even if the IDLEFLAG is not set. It will then set AUXFLBIT.
3	NTARGFLG	Astronaut did overwrite Delta V at TPI or TPM (P34, P35).	Astronaut did not overwrite Delta V.
4	Not Assigned		
5	Not Assigned		
6	REDFLAG REDFLBIT	Landing site redesignation permitted.	Landing site redesignation not permitted.
7	Not Assigned		
8	MUNFLAG MUNFLBIT	SERVICER calls MUNRVG.	SERVICER calls CALCRVG.
9	Not Assigned		
10	GMBDRBIT GMBDRVSW	TRIMGIMB over.	TRIMGIMB not over.
11	Not Assigned		
12 13	S32.1F3B S32.1F3A	(Bits 12 and 13 function as an ordered pair (13, 12) indicating the possible occurrence of two Newton iterations for S32.1: (0, 0) — First pass of second Newton iteration, (0, 1) — First Newton iteration being done, (1, 0) — Remainder of second Newton iteration, (1, 1) — 50 ft/s stage of second Newton iteration.)	
14	S32.1F2	First pass of Newton iteration.	Reiteration of Newton.
15	S32.1F1	Delta V at CSI Time 1 exceeds maximum.	Delta V at CSI Time 1 less than maximum.

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

(FLAGWORD 7)

Bit	Name	1	0
1	TFFSW	Calculate TPERIGEE.	Calculate TFF.
2	V82EMFLG	Moon vicinity.	Earth vicinity.
3	VERIFBIT	(Changed when V33E occurs at end of P27).	
4	UPLOCBIT	K-$\overline{K}$-K fail.	No K-$\overline{K}$-K fail.
5	AVEGFBIT AVEGFLAG	AVERAGEG (SERVICER) desired.	AVERAGEG (SERVICER) not desired.
6	V37FLAG V37FLBIT	AVERAGEG (SERVICER) running.	AVERAGEG (SERVICER) off.
7	IDLEFBIT IDLEFLAG	No Delta V monitor.	Connect Delta V monitor.
8	V67FLAG	Astronaut overwrites W-matrix initial values.	Astronaut does not overwrite W-matrix initial values.
9	RVSW	Do not compute final state vector in time-theta.	Compute final state vector in time-theta.
10	NORMSW	Unit normal input to Lambert.	Lambert computes its own normal.
11	SWANDBIT SWANDISP	Landing analog displays enabled.	Landing analog displays suppressed.
12	ASTNBIT ASTNFLAG	Astronaut has OKed ignition.	Astronaut has not OKed ignition.
13	IGNFLAG IGNFLBIT	TIG has arrived.	TIG has not arrived.
14	MANUFLAG*	Attitude maneuver going on during RR search.	No attitude maneuver during RR search.
15	ITSWICH	P34 TPI time to be computed.	TPI has been computed.

*These switches are never called by name.

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

(FLAGWORD 8)

Bit	Name	1	0
1	360SW	Transfer angle near 360 degrees.	Transfer angle not near 360 degrees.
2	INITABIT INITALGN	Initial pass through P57.	Second pass through P57.
3	Not Assigned		
4	COGAFLAG	No conic solution, too close to rectilinear (COGA overflows).	Conic solution exists, (COGA does not overflow.)
5	APSESW	RDESIRED outside of PERICENTER-APOCENTER range in time-radius.	RDESIRED inside of PERICENTER-APOCENTER range in time-radius.
6	ORDERSW	Iterator uses second order minimum mode.	Iterator uses first order standard mode.
7	INFINFLG	No conic solution (closure through infinity required).	Conic solution exists.
8	SURFFBIT SURFFLAG	LM on lunar surface.	LM not on lunar surface.
9	P39/79SW	P39/P79 operating.	P38/P78 operating.
10	FLUNDBIT FLUNDISP	Current guidance displays inhibited.	Current guidance displays permitted.
11	LMOONBIT LMOONFLG	Permanent LM state vector in lunar sphere.	Permanent LM state vector in earth sphere.
12	CMOONBIT CMOONFLG	Permanent CSM state vector in lunar sphere.	Permanent CSM state vector in earth sphere.
13	NEWIFLG	First pass through integration.	Succeeding iteration of integration.
14	Not Assigned		
15	RPQFLAG	RPQ not computed. (RPQ = vector between secondary body and primary body.)	RPQ computed.

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

(FLAGWORD 9)

Bit	Name	1	0
1	AVEMIDSW	AVETOMID calling for W matrix integration. Do not overwrite RN, VN, PIPTIME.	No AVETOMID W matrix integration. Allow setup of RN, VN, PIPTIME.
2	MIDAVFLAG	Integration entered from one of MIDTOAV portals.	Integration was not entered via MIDTOAV.
3	MID1FLAG	Integrate to TDEC.	Integrated to the then-present time.
4	Not Assigned		
5	QUITFLAG	Terminate and exit from integration.	Continue integration.
6	ROTFLAG	P70 and P71 will force vehicle rotation in the preferred direction.	P70 and P71 will not force vehicle rotation in the preferred direction.
7	Not Assigned		
8	FLAP	APS continued abort after DPS staging (ascent guidance).	APS abort is not a continuation.
9	LETABBIT LETABORT	Abort programs are enabled.	Abort programs are not enabled.
10	FLRCS FLRCSBIT	RCS injection mode (ascent guidance).	Main engine mode.
11	FLPI	Preignition phase (ascent guidance).	Regular guidance.
12	FLPC	No position control (ascent guidance).	Position control.
13	Not Assigned		
14	FLVR	Vertical rise (ascent guidance).	Nonvertical rise.
15	Not Assigned		

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

(FLAGWORD 10, RASFLAG)

Bit	Name	1	0
1	Not Assigned		
2	Not Assigned		
3	Not Assigned		
4	Not Assigned		
5	Not Assigned		
6	Not Assigned		
7	REINTBIT REINTFLG	Integration routine to be RESTARTED.	Integration routine not to be RESTARTED.
8	Not Assigned		
9	Not Assigned		
10	Not Assigned		
11	Not Assigned		
12	Not Assigned		
13	APSFLAG APSFLBIT	Ascent stage.	Descent stage.
14	INTFLBIT	Integration in progress.	Integration not in progress.
15	Not Assigned		

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

(FLAGWORD 11)

Bit	Name	1	0
1	HFLSHBIT HFLSHFLG	LR altitude fail lamp should be flashing.	LR altitude fail lamp should not be flashing.
2	VFLSHBIT VFLSHFLG	LR velocity fail lamp should be flashing.	LR velocity fail lamp should not be flashing.
3	SCABBIT	LR low scale discrete not present when it should be.	LR scale discrete appears OK.
4	RNGEDBIT	LR altitude measurement made.	LR altitude measurement not made.
5	READVBIT READVEL	OK to read LR velocity data.	Do not read LR velocity data.
6	READLBIT READLR	OK to read LR range data.	Do not read LR range data.
7	VELDABIT	LR velocity measurement made.	LR velocity measurement not made.
8	LRINH LRINHBIT	LR updates permitted by astronaut.	LR updates inhibited by astronaut.
9	XORFLBIT XORFLG	Below limit inhibit; X-axis override.	Above limit; do not inhibit.
10	NOLRRBIT NOLRREAD	LR repositioning; bypass update.	LR not repositioning.
11	PSTHIBIT	Posthigate.	Prehigate.
12	VXINH VXINHBIT	If Z velocity data unreasonable, bypass X-axis velocity update on next pass.	Update X-axis velocity.
13	Not Assigned		
14	Not Assigned		
15	LRBYBIT LRBYPASS	Bypass all LR updates.	Do not bypass LR updates.

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

(FLAGWORD 12, RADMODES)

Bit	Name	1	0
1	TURNONBT	RR turn-on sequence in progress (zero RR CDU's; fix antenna position).	No RR turn-on sequence in progress.
2	AUTOMODE*	RR not in Auto mode. Auto mode discrete is not present.	RR in Auto mode.
3	RRRSBIT	RR range reading on the high scale.	RR range reading on the low scale.
4	RRDATABT	RR data fail. Data could not be read successfully.	No RR data fail.
5	LRALTBIT	LR altitude data fail. Data could not be read successfully.	No LR altitude data fail.
6	LRPOSBIT	LR in Position 2.	LR in Position 1.
7	RCDUFBIT	RR CDU fail has not occurred.	RR CDU fail has occurred.
8	LRVELFLG*	LR velocity data fail.	No LR velocity data fail.
9	ALTSCBIT	LR altitude reading is on high scale.	LR altitude reading is on low scale.
10	DESIGBIT	RR designate requested or in progress.	RR designate not requested or in progress.
11	REPOSBIT	Reposition monitor, RR reposition is taking place.	No RR resposition taking place.
12	ANTENBIT	RR antenna is in Mode 2.	RR antenna is in Mode 1.
13	RCDU0BIT	RR CDU's being zeroed.	RR CDU's not being zeroed.
14	REMODBIT	Change in antenna mode has been requested.	No remode requested or occurring.
15	CDESBIT CDESFLAG	Continuous designate. LGC commands RR regardless of lock-on.	LGC checks for lock-on when antenna being designated.

*These switches are never called by name.

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

(FLAGWORD 13, DAPBOOLS)

Bit	Name	1	0
1 2	AUTR1FLG* AUTR2FLG*	These flags (2, 1) are used together to indicate astronaut-chosen KALCMANU maneuver rates: (0, 0) = 0.2 deg/second, (0, 1) = 0.5 deg/second, (1, 0) = 2.0 deg/second, (1, 1) = 10.0 deg/second.	
3	ACCSOKAY	Control authority values from 1/ACCS usable.	RESTART or FRESH START since last 1/ACCS; outputs suspect.
4	DBSELECT	Maximum deadband selected by crew (5 degrees).	Minimum deadband selected by crew (0.3 degree).
5	AORBSYST	P-axis couples 7, 15 and 8, 16 preferred.	P-axis couples 3, 11 and 4, 12 preferred.
6	ULLAGER ULLAGFLG	Ullage request by mission program.	No internal ullage request.
7	RHCSCALE	Normal RHC scaling requested.	Fine RHC scaling requested.
8	DRIFTBIT DRIFTDFL	Assume zero offset drifting flight.	Use offset acceleration estimate.
9	XOVINFLG XOVINHIB	X-axis override locked out.	X-axis override OK.
10	AORBTFLG AORBTRAN	B system for X-translation preferred.	A system for X-translation preferred.
11	ACC4-2FL ACC4OR2X	Four-jet X-axis translation requested.	Two-jet X-axis translation requested.
12	OURRCBIT	Current DAP pass is rate command.	Current DAP pass is not rate command.
13	CSMDOCKD	CSM docked; use backup DAP.	CSM not docked to LM.
14	USEQRJTS	Gimbal unusable; use jets only.	Trim gimbal may be used.
15	PULSES	Minimum impulse command mode in "attitude hold" (V76).	Not in minimum impulse command mode (V77).

*These switches are never called by name.

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

IMODES30, a flag whose individual bits are used to control the monitoring of IMU functions associated with Channel 30 (and in a few cases Channel 33).

Bit	Meaning
15	Last sampled value of Channel 30, Bit 15 (0 if IMU temperature within limits).
14	Last sampled value of Channel 30, Bit 14 (0 if ISS has been turned on or commanded to be turned on).
13	Last sampled value of Channel 30, Bit 13 (0 if an IMU fail indication has been produced).
12	Last sampled value of Channel 30, Bit 12 (0 if an IMU CDU fail indication has been produced).
11	Last sampled value of Channel 30, Bit 11 (0 if an IMU cage command has been produced by crew).
10	Last sampled value of Channel 33, Bit 10 (0 if a PIPA fail indication has been produced), having the same value as Bit 13 of IMODES33.
9	Last sampled value of Channel 30, Bit 9 (0 if IMU has been turned on and operating with no malfunctions).
8	Bit used to control the IMU turn-on sequencing.
7	Bit used to control the IMU turn-on sequencing.
6	Bit is set to 1 to indicate that IMU initialization is being carried out.
5	Bit is set to 1 to inhibit the generation of program alarm 0212_8 if a PIPA fail signal (Bit 13 of Channel 33) is produced.
4	Bit is set to 1 to inhibit generation of an ISS warning based on receipt of an IMU fail signal.
3	Bit is set to 1 to inhibit generation of an ISS warning based on receipt of an IMU CDU fail signal.
2	Bit is set to 1 to indicate failure of the turn-on delay sequence for IMU turn-on (alarm 0207_8 is also generated).
1	Bit is set to 1 to inhibit generation of an ISS warning based on receipt of a PIPA fail signal (Bit 13 of Channel 33).

FLAGWORD BIT ASSIGNMENTS FOR LUMINARY 1A

IMODES33, a flag whose individual bits are used to control the monitoring of functions associated with Channel 33 (and other items).

Bit	Meaning
15	Not assigned.
14	Last sampled value of Channel 32, Bit 14 (0 if a Proceed command is given using the old "standby" button).
13	Last sampled value of Channel 33, Bit 13 (0 if an accelerometer fail signal, or PIPA fail, has been produced by hardware).
12	Last sampled value of Channel 33, Bit 12 (0 if a telemetry end pulse has been rejected because the downlink rate is too fast).
11	Last sampled value of Channel 33, Bit 11 (0 if an uplink bit has been rejected because the uplink rate is too fast).
10-7	Not assigned.
6	Bit is set to 1 to indicate that IMU use for vehicle attitude information should not be attempted.
5	Bit is set to 1 in IMU Zeroing routine external to T4RUPT while zeroing is taking place (for an interval of about 10.56 seconds).
4-2	Not assigned.
1	Bit is set to 1 when a Verb 35 ("lamp test") is received, and reset to 0 about 5 seconds later.

CHANNEL BIT ASSIGNMENTS (LM)

OUTPUT CHANNEL 11

BIT	
1	ISS Warning
2	Light Computer Activity Lamp
3	Light Uplink Activity Lamp
4	Light Temp Caution Lamp
5	Light Keyboard Release Lamp
6	Flash Verb and Noun Lamps
7	Light Operator Error Lamp
8	Spare
9	Test Connector Outbit
10	Caution Reset
11	Spare
12	Spare
13	Engine On
14	Engine Off
15	Spare

OUTPUT CHANNEL 12

1	Zero Rendezvous Radar CDU
2	Enable Rendezvous Radar Error Counter
3	Not Used
4	Coarse Align Enable
5	Zero IMU CDU's
6	Enable IMU Error Counter
7	Spare
8	Display Inertial Data
9	+Pitch Vehicle Motion (-Pitch Gimbal Trim, Bell motion)
10	-Pitch Vehicle Motion (+Pitch Gimbal Trim, Bell motion)
11	+Roll Vehicle Motion (-Roll Gimbal Trim, Bell motion)
12	-Roll Vehicle Motion (+Roll Gimbal Trim, Bell motion)
13	Landing Radar Position 2 Command
14	Rendezvous Radar Enable Auto Track
15	ISS Turn-on Delay Complete

CHANNEL BIT ASSIGNMENTS (LM)
OUTPUT CHANNEL 13

BIT	
1	Radar Select c
2	Radar Select b
3	Radar Select a
4	Radar Activity
5	Inhibit Uplink, Enable Crosslink (should not be set to 1)
6	Block Inlink
7	Downlink Word Order
8	RHC Counter Enable
9	Start RHC Read
10	Test Alarms
11	Enable Standby
12	Reset Trap 31-A
13	Reset Trap 31-B
14	Reset Trap 32
15	Enable T6RUPT

Channel 13 Radar Selections

a	b	c	Function
0	0	0	—
0	0	1	Rendezvous Radar range
0	1	0	Rendezvous Radar range rate
0	1	1	—
1	0	0	Landing Radar X velocity
1	0	1	Landing Radar Y velocity
1	1	0	Landing Radar Z velocity
1	1	1	Landing Radar range

CHANNEL BIT ASSIGNMENTS (LM)

OUTPUT CHANNEL 14

BIT	
1	Outlink Activity (should not be set to 1)
2	Altitude Rate Select
3	Altitude Meter Activity
4	Thrust Drive
5	Spare
6	Gyro Enable
7	Gyro Select b
8	Gyro Select a
9	Gyro Sign Minus
10	Gyro Activity
11	Drive CDU S
12	Drive CDU T
13	Drive CDU Z
14	Drive CDU Y
15	Drive CDU X

Channel 14-Gyro Selection

a	b	Gyro
0	0	–
0	1	X
1	0	Y
1	1	Z

INPUT CHANNEL 15

1	Key codes from Main DSKY
2	Key codes from Main DSKY
3	Key codes from Main DSKY
4	Key codes from Main DSKY
5	Key codes from Main DSKY
6	Spare
7	Spare
8	Spare
9	Spare
10	Spare
11	Spare
12	Spare
13	Spare
14	Spare
15	Spare

CHANNEL BIT ASSIGNMENTS (LM)

INPUT CHANNEL 16

Bit	
1	Spare
2	Spare
3	Mark X
4	Mark Y
5	Mark reject
6	Descent +
7	Descent -
8	Spare
9	Spare
10	Spare
11	Spare
12	Spare
13	Spare
14	Spare
15	Spare

INPUT CHANNEL 30

BIT	
1	Abort
2	Descent Stage Attached
3	Engine Armed
4	Abort Stage
5	Auto Throttle
6	Display Inertial Data
7	Rendezvous Radar CDU Fail
8	Spare
9	IMU Operate
10	G/N Control of S/C
11	IMU Cage
12	IMU CDU Fail
13	IMU Fail
14	ISS Turn-On Request
15	Temp in Limits

NOTE:
All of the input signals in Channel 30 are inverted; that is, a ZERO bit indicates that the discrete is ON.

CHANNEL BIT ASSIGNMENTS (LM)

INPUT CHANNEL 31

BIT	
1	+EL (LPD), + PMI
2	-EL (LPD), - PMI
3	+ YMI
4	-YMI
5	+AZ (LPD), +RMI
6	-AZ (LPD), -RMI
7	+X Trans
8	-X Trans
9	+Y Trans
10	-Y Trans
11	+Z Trans
12	-Z Trans
13	Attitude Hold
14	Auto Stabilization
15	Attitude Control Out of Detent

NOTE:

All of the input signals in Channel 31 are inverted; that is, a ZERO bit indicates that the discrete is ON.

INPUT CHANNEL 32

BIT	
1	Thruster 2 — 4 Fail
2	Thruster 5 — 8 Fail
3	Thruster 1 — 3 Fail
4	Thruster 6 — 7 Fail
5	Thruster 14 — 16 Fail
6	Thruster 13 — 15 Fail
7	Thruster 9 — 12 Fail
8	Thruster 10 — 11 Fail
9	Gimbal Off
10	Apparent Gimbal Fail
11	Spare
12	Spare
13	Spare
14	Proceed
15	Spare

NOTE:

All of the input signals in Channel 32 are inverted; that is, a ZERO bit indicates that the discrete is ON.

CHANNEL BIT ASSIGNMENTS (LM)

INPUT CHANNEL 33

BIT	
1	Spare
2	Rendezvous Radar Auto-Power On
3	Rendezvous Radar Range Low Scale
4	Rendezvous Radar Data Good
5	Landing Radar Range Data Good
6	Landing Radar Position 1
7	Landing Radar Position 2
8	Landing Radar Velocity Data Good
9	Landing Radar Range Low Scale
10	Block Uplink Input*
11	Uplink Too Fast
12	Downlink Too Fast
13	PIPA Fail
14	Warning
15	Oscillator Alarm

*This bit reads ONE when accept uplink signal is present at interface.

NOTE:

All of the input signals in Channel 33 are inverted; that is, a ZERO bit indicates that the discrete is ON.

P00—LGC IDLING PROGRAM

Purpose:

1. To provide a program to fulfill the following requirements:
   a. Provide an indication to the crew that the LGC is engaged in no control or computational operations which might require consideration for coordination with other crew tasks in progress.
   b. Maintain the LGC in a condition of readiness for entry into any other program.

Assumptions:

1. The IMU may or may not be on. If on, the IMU is inertially stabilized but not necessarily aligned to an orientation which is known to the LGC.
2. If the IMU is on, the DAP is available for manually controlled attitude maneuvers. If attitude maneuvers are made by the crew, care must be taken to avoid IMU gimbal lock by observing the ICDU's (V16 N20) or by monitoring the FDAI ball.
3. During this program the Coasting Integration routine will periodically update the LM and CSM state vectors to approximately the current time. The capability to select an LGC program (V37 XXE) is inhibited by the LGC during this integration. V37 use at this time will result in a program alarm (1520).
4. 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. Use of V96 can cause incorrect W-matrix extrapolation since state vector synchronization is not maintained.
5. The program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N38

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 condition.

Assumptions:

1. The normal condition of readiness of the PGNCS when not in use is standby. In this condition the IMU standby circuit breaker is on, the IMU operate circuit breaker is off, the LGC/DSKY circuit breaker is on, and the standby light on the DSKY is on. In this configuration both the IMU and LGC are off, with power applied only to the IMU heat control circuitry and the LGC timing circuitry.
2. A possible condition of readiness of the PGNCS when not completely on is the same as standby (Assumption 1) except that the standby light on the DSKY is off. In this configuration the LGC is running for computational purposes that do not require the IMU.
3. If the computer power is switched off it will be necessary to perform a Computer FRESH START (V36E) to initialize the erasable storage. The LGC Update program (P27) would have to be done to update the LM and CSM state vectors and computer clock time.
4. 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.

5. Once the program has been selected the LGC must be shut down. After P06 selection the LGC will not honor a new program request (V37EXXE), a terminate (V34E), or an enter in response to the LGC request for LGC standby.
6. The program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V50 N25 (LGC power down)

   Checklist code 00062

P12—POWERED ASCENT PROGRAM

Purpose:

1. To display to the crew, prior to ascent engine ignition, certain LGC-stored parameters associated with the powered ascent, for possible modification by the crew.
2. To display to the crew, prior to ascent engine ignition, certain FDAI ball readings associated with the early phases of the ascent maneuver.
3. To control the PGNCS during countdown, ignition, thrusting, and thrust termination of a PGNCS-controlled APS powered ascent maneuver from the lunar surface.

Assumptions:

1. The LGC has stored injection values which define an ascent trajectory. These values are altitude of injection, the distance at injection between the LM and the CSM orbital plane, and the LM vertical (V(R)) and horizontal (V(Y)) and (V(Z)) velocities at injection. This trajectory is designed to be coplanar with that of the CSM and to result in an apolune of 30 nmi. All altitudes are measured with respect to the magnitude of the landing site position vector which is an LGC initialization parameter.

   This predefined ascent trajectory may be partially modified during this program by astronaut input.
2. The PGNCS will control the LM ascent maneuver such that the LM velocity at injection is parallel to the CSM orbital plane, either in that plane, or at a specified distance from that plane as controlled by astronaut definition of crossrange. The astronaut can also change the required injection conditions by modifying the nominal initial downrange and radial velocity display values. Crossrange should not be specified such as to cause the ascent trajectory to cross through the CSM orbital plane.
3. The initial period of the ascent trajectory will consist of two phases:
   a. Vertical Rise Phase, from TIG until the radial velocity (V(R)) of the LM exceeds 40 ft/s. During this phase the LM will be held by the PGNCS to an attitude such that the LM +X axis is parallel to the LM position vector at TIG. At TIG the PGNCS will command the LM around its X axis (yaw) until the LM +Z axis points downrange.
   b. Pitchover Phase, when V(R) exceeds 40 ft/s and the LM yaw attitude is within 5 degrees of the desired attitude. During this phase the PGNCS will command the LM to pitch down (about the LM Y axis) an amount defined by the guidance equations.

   The LM attitude will subsequently be controlled by the guidance equations.
4. 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 PGNCS Attitude Control mode is Auto. When the controller is returned to detent, the PGNCS 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 except when the LGC is specifying a desired yaw attitude. Thus the option is inhibited by this program from TIG(AS) until 10 seconds after V(R) equals 40 ft/s and the LM yaw attitude is within 5 degrees of the desired attitude for pitchover initiation.

5. The IMU is on and must be at a known orientation before this program may be completed. Normally, the Lunar Surface Align program (P57) has been completed before selection of this program. It is normally required that the ISS be on for a minimum of 15 minutes prior to a thrusting maneuver.

6. Engine ignition may be slipped beyond TIG(AS) if desired by the crew or if state vector integration cannot be completed in time. Variation of the time of ascent ignition (TIG(AS)) either by design or inadvertent slippage will change the relative phasing with respect to the CSM of the ascent trajectory and the resultant LM orbit.

7. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Auto, the PGNCS will control the total vehicle attitude and generate either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise control around the yaw axis only with the ACA (X-axis override) if the X-axis override capability is permitted by the program in process. This manual control will be in the Rate Command/Attitude Hold mode.

   If a thrusting maneuver is preformed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold, the PGNCS 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. 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 PGNCS will not be responsible if register overflows occur within the LGC.

8. Control of the LM RCS and APS is transferred from the PGNCS 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 phase of the lunar ascent, and guiding it to a safe orbit.

   The AGS may be initialized by the LGC at any time by manual selection of the AGS Initialization routine (R47), which should have been performed prior to selection of P12.

   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 PGNCS will not be responsible if register overflows occur within the LGC.

9. The PGNCS can generate two types of attitude errors for display on the FDAI:

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

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

10. The Rendezvous Radar (RR) was energized and checked out prior to selection of this program.

11. The Landing Analog Displays routine (R10) is enabled at TIG. However, R10 use of the RR CDU's is inhibited by this program. The Powered Flight Designate routine (R29) is enabled after pitchover. R10 and R29 are terminated upon termination of Average G.

12. Either the Load DAP Data routine (R03) or the Landing Confirmation program (P68) has been performed prior to selection of this program.

13. For each burn an ignition total allowable time delay will be specified in the mission rules. This delay time is the total time which the thrusting maneuver may be delayed beyond the LGC calculated time of ignition. If engine restarts are involved, the accounting of this total time delay is up to the crew.

14. The DAP will be energized whenever the PGNS Control mode and the Auto Attitude or Attitude Hold Control mode have been selected. If this occurs prior to the PGNS auto check 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 most recently.

15. LGC and crew procedures in cases of LGC-assumed thrust failure are defined by the DPS/APS Thrust Fail routine (R40). This routine is called at APS ignition by this program.

16. This program is selected by the astronaut by DSKY entry at least 5 minutes before the estimated time of ascent ignition TIG(AS).

Selected Displays:

1. V06 N33

Time of ascent ignition	00XXX. h
	000XX. min
	0XX.XX s

2. V06 N76

Desired downrange velocity	XXXX.X ft/s
Desired radial velocity	XXXX.X ft/s
Crossrange distance	XXXX.X nmi

3. V50 N25 (change guidance mode)

Checklist code	00203

4. V06 N74

Time from ascent ignition	XX b XX min/s
Yaw after vehicle rise	XXX.XX deg
Pitch after vehicle rise	XXX.XX deg

5. V99 N74 (request engine on enable)

   Display same as Item 4 above

6. V16 N63

Absolute value of velocity	XXXX.X ft/s
Altitude rate	XXXX.X ft/s (+ ascent)
Computed altitude	XXXXX. ft

7. V16 N85

Components of VG (LM body axis)	XXXX.X ft/s

8. V16 N77

Time to engine cutoff	XX b XX min/s
LM velocity normal to CSM plane	XXXX.X ft/s

9. V16 N56

RR LOS azimuth	XXX.XX deg
RR LOS elevation	XXX.XX deg

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 ISS may be in standby or operate. The IMU would normally be on and the IMU Orientation Determination program (P51) completed before the selection of this program. No preferred orientation is specified or required for this program as 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. The ISS thus may be:
   a. Off (standby).
   b. On and not aligned since turn-on.

c. On and at an inertial orientation known only inaccurately by the LGC; that is, having been aligned at least once since turn-on but having drifted from the stored alignment.

d. On and at an inertial orientation known accurately by the LGC.

If a is true a program alarm will be made by this program.

If b is true a program alarm will be made by this program.

If c is true the LGC may or may not have a satisfactory inertial reference to accurately complete the program.

If d is true the LGC has a satisfactory inertial reference to accurately complete the program.

2. The CSM is maintaining a preferred tracking attitude for RR tracking by the LM. This preferred attitude correctly orients the CSM radar transponder.
3. 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.
4. The Rendezvous Radar is on, and preliminary checkout has been completed.
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) (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.
6. 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 Target Delta V program (P76),
   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.
7. The crew may manually adjust the LGC-stored values of RR shaft and trunnion bias by a direct load of four registers to be specified. However, unless the RR has been jarred, the LGC bias estimate should be more accurate than that from another source.
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 V37 XXE.
      (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 or V56E or by V34E.
      (2) P00 selection will terminate P20, 22, and 25 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; 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.

9. The RR Manual Acquisition routine (R23) may only be selected if P20 is not running in conjunction with another program.

10. When P20 is selected anytime prior to the landing phase in the lunar mission, this program must be operated in the No Update mode.

11. The RMS 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.

12. 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.

Selected Displays:

1. V50 N25 (change RR mode)

Checklist code		00201

2. V06 N05

Difference angle between RR LOS and state vector		XXX.XX deg

3. V06 N49

ΔR due to RR mark data incorporation		XXXX.X nmi
ΔV due to RR mark data incorporation		XXXX.X ft/s
Source code		0000X (1—RR range, 2—RR range rate, 3—RR shaft angle, 4—RR trunnion angle)

4. V50 N25 (manual RR acquisition of CSM)

Checklist code		00205

5. V16 N80

Data indicator (displays 11111 when search is successful, otherwise blank)		XXXXX
Angle between RR LOS and +Z axis		XXX.XX deg

6. V50 N18

Desired automaneuver FDAI ball angles	R	XXX.XX deg
	P	XXX.XX deg
	Y	XXX.XX deg

7. V06 N18

Final FDAI ball angles	R	XXX.XX deg
	P	XXX.XX deg
	Y	XXX.XX deg

8. V50 N72

RR Trunnion angle (360 degrees – CDU trunnion angle)	XXX.XX deg
RR shaft angle	XXX.XX deg

9. V16 N45

Marks (M)	XXXXX. marks
Time from ignition of next burn	XX b XX min/s
Middle gimbal angle	XXX.XX deg

10. V06 N38

Time of state being integrated	00XXX. h
	000XX. min
	0XX.XX s

P21–GROUND TRACK DETERMINATION

Purpose:

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

Assumptions:

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

Selected Displays:

1. V04 N06

Option code ID	00002
Option code	0000X (1–this vehicle, 2-other vehicle)

2. V06 N34

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

3. V06 N43

Ground track latitude	XXX.XX deg (+ north)
Ground track longitude	XXX.XX deg (+ east)
Altitude above ground	XXXX.X nmi

4. V06 N91

Altitude	XXXXXb. nmi
Velocity	XXXXX. ft/s
Flight path angle	XXX.XX deg

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. The ISS may be in standby or operate. The IMU would normally be on and the Lunar Surface Align program (P57) completed before the selection of this program. The ISS thus may be:
   a. Off (standby).
   b. On and not aligned since turn-on.
   c. On and at an inertial orientation known only inaccurately by the LGC; that is, having been aligned at least once since turn-on but either having been inaccurately aligned or having drifted from the stored alignment.
   d. On and at an inertial orientation known accurately by the LGC.

   If a is true a program alarm will be made by this program.

   If b is true a program alarm will be made by this program.

   If c is true the LGC may not have a satisfactory inertial reference to accurately complete the program.

   If d is true the LGC has a satisfactory inertial reference to accurately complete the program.
2. The CSM may or may not be below the lunar horizon. Although above the horizon, it may still be outside of the available RR coverage sector. Although within the available RR coverage sector, it may be outside the allowable RR coverage sector.

   This program will always track the CSM with the radar in Mode 2. In Mode 2 the available coverage is always less than horizon to horizon.
3. The CSM is maintaining a preferred tracking attitude for RR tracking by the LM. This preferred attitude correctly orients the CSM radar transponder.
4. At the beginning of the program the state vector update option is automatically set to the CSM. This option 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 Rendezvous Radar is on; preliminary checkout has been completed.
6. The initialization of the W matrix is enabled by:
   a. A manual DSKY entry (V98E).
   b. Computer FRESH START (V36E).
   c. State vector update from the ground (P27).
7. 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 Target Delta V program (P76).
   c. Selection of a new program from a program which had turned on Average G.
   d. Initialization of the W matrix (Assumption 6).
8. The RMS 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.
9. 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 V37E XXE.

(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; 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 shown above.

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.

Selected Displays:

1. V04 N06

Option code ID	00012
Option code	0000X (1—no orbit change, 2—change orbit to pass over LM)

2. V06 N33

Time of ascent ignition	00XXX. h
	000XX. min
	0XX.XX s

3. V50 N25 (change RR mode)

Checklist code	00201

4. V06 N05

Difference angle between RR LOS and state vector	XXX.XX deg

5. V06 N49

ΔR due to RR mark data incorporation	XXXX.X nmi
ΔV due to RR mark data incorporation	XXXX.X ft/s
Source code	0000X (1—RR range, 2—RR range rate, 3—RR shaft angle, 4—RR trunnion angle)

6. V50 N25 (manual RR acquisition of CSM)

Checklist code	00205

7. V16 N56

RR LOS azimuth	XXX.XX deg
RR LOS elevation	XXX.XX deg

8. V06 N38

Time of state vector being integrated	00XXX. h
	000XX. min
	0XX.XX s

9. V16 N45

Marks (M)	XXXXX. marks
Time from ignition of next burn	XX b XX min/s
Middle gimbal angle	XXX.XX deg

P25—PREFERRED TRACKING ATTITUDE PROGRAM

Purpose:

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

Assumptions:

1. During the Rendezvous Navigation program (P20) the LM attitude control is intimately associated with the Rendezvous Radar (RR). Should RR malfunction preclude correct operation of P20, this program (P25) should be selected to provide an 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. The ISS may be in standby or operate. The IMU would normally be on and the IMU Orientation Determination program (P51) completed before the selection of this program. No preferred orientation is specified or required for this program as the Fine Preferred Tracking Attitude routine (R65) can always calculate a vehicle orientation about a specified LM +Z vector that can avoid gimbal lock for any inertial IMU orientation. The ISS thus may be:
   a. Off (standby).
   b. On and not aligned since turn-on.
   c. On and at an inertial orientation known only inaccurately by the LGC; that is, having been aligned at least once since turn-on but not within the last 3 hours.
   d. On and at an inertial orientation known accurately by the LGC; that is, having been aligned within the last 3 hours.

   If a is true a program alarm will be made by this program.

   If b is true a program alarm will be made by this program.

   If c is true the LGC may or may not have a satisfactory inertial reference to accurately complete the program.

   If d is true the LGC has a satisfactory inertial reference to accurately complete the program.
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 or V56E or by V34E.

(2) P00 selection will terminate P20, 22, and 25 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 P00. 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.

Selected Displays:

1. V50 N18

Desired automaneuver FDAI ball angles	R XXX.XX deg
	P XXX.XX deg
	Y XXX.XX deg

2. V06 N18

Final FDAI ball angles	R XXX.XX deg
	P XXX.XX deg
	Y XXX.XX deg

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 must be in operate condition; IMU may be in the standby or operate condition.
2. 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 individually specified erasable locations (1 through 9) (V72).
   d. Provide an octal increment for the LGC clock only (V73).
3. The uplink may be blocked by placing the Voice/Off/Voice BU switch to Voice BU.
4. Update is allowed in the LM only when the LGC is in the LGC Idling program (P00). P27 exit is always to P00.
5. The program is manually selected by the astronaut by DSKY entry or by the ground by uplink transmission.

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 implusive Delta V along LM local vertical axes at TIG.
2. To display to the astronaut and the ground certain specific dependent variables associated with the desired maneuver for approval by the astronaut/ground.

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.
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.
6. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N33		
	Time of ignition	00XXX. h
		000XX. min
		0XX.XX s
2. V06 N82		
	Components of ΔV (LV)	XXXX.X ft/s
3. V06 N42		
	Apocenter altitude	XXXX.X nmi
	Pericenter altitude	XXXX.X nmi
	ΔV (required)	XXXX.X ft/s
4. V16 N45		
	Marks (RR)	XXXXX. marks
	Time until next burn	XX b XX min/s
	Middle gimbal angle	XXX.XX deg

P31—LAMBERT AIMPOINT GUIDANCE 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), the target vector, and the time of flight from TIG until the target is to be reached (TF).
2. To display to the astronaut and the ground certain specific dependent variables associated with the desired maneuver, for approval by the astronaut/ground.

Assumptions:

1. The target parameters (TIG, target vector, and TF) have been loaded from the ground during a prior execution of P27.
2. The External Delta V flag is reset during this program to designate to the thrusting program that "ASTEER" is to be used for steering control.
3. The ISS need not be on.
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.
5. This program is applicable in either earth or lunar orbit.
6. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N33

Time of ignition	00XXX. h
	000XX. min
	0XX.XX s

2. V06 N81

Components of ΔV (LV)	XXXX.X ft/s

3. V06 N42

Apocenter altitude	XXXX.X nmi
Pericenter altitude	XXXX.X nmi
ΔV required at TIG	XXXX.X ft/s

4. V16 N45

Marks (RR)	XXXXX.
Time from ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg

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 calculate these parameters based upon maneuver data approved and keyed into the LGC by the astronaut.
3. To display to the astronaut and the ground dependent variables associated with the concentric flight plan maneuvers for approval by the astronaut/ground.
4. To store the CSI target parameters for used 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.
10. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N11

Time of CSI ignition	00XXX. h
	000XX. min
	0XX.XX s

2. V06 N55

Number of apsidal crossings (N)	XXXXX. crossings
Elevation angle (E)	XXX.XX deg
Central angle of passive vehicle	XXX.XX deg

3. V06 N37

Time of TPI ignition	00XXX. h
	000XX. min
	0XX.XX s

4. V06 N75

Delta altitude (CDH)	XXXX.X nmi
ΔT (CSI-CDH)	XX b XX min/s
ΔT (CDH-TPI)	XX b XX min/s

5. V06 N81

Components of ΔV (LV) for CSI	XXXX.X ft/s

6. V06 N82

Components of ΔV (LV) for CDH	XXXX.X ft/s

7. V16 N45

Marks (RR)	XXXXX. marks
Time from CSI ignitiion	XX b XX min/s
Middle gimbal angle	XXX.XX deg

8. V06 N16 (results from V90E)

Time of event	00XXX. h
	000XX. min
	0XX.XX s

9. V06 N90 (results from V90E)

Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

P33–LM CONSTANT DELTA ALTITUDE (CDH) PROGRAM

Purpose:

1. To calculate parameters associated with the Constant Delta Altitude maneuver (CDH), for Delta V burns.
2. To calculate these parameters based upon maneuver data approved and keyed into the LGC by the astronaut.
3. To display to the astronaut and the ground dependent variables associated with the CDH maneuver for approval by the astronaut/ground.
4. To store the CDH target parameters for use by the desired thrusting program.

Assumptions:

1. This program is based upon previous completion of the 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.
3. This 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. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N13

Time of CDH ignition	00XXX. h
	000XX. min
	0XX.XX s

2. V06 N75	
Delta altitude (CDH)	XXXX.X nmi
(CDH-TPI)	XX b XX min/s
(TPI-NOMTPI)	XX b XX min/s
3. V06 N81	
Components of ΔV (LV) for CDH	XXXX.X ft/s
4. V16 N45	
Marks (RR)	XXXXX.
Time from CDH ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg
5. V06 N16 (results from V90E)	
Time of Event	00XXX. h
	000XX. min
	0XX.XX s
6. V06 N90 (results from V90E)	
Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

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)
3. To calculate these parameters based upon maneuver data approved and keyed into the LGC by the astronaut.
4. To display to the astronaut and the ground certain dependent variables associated with the maneuver for approval by the astronaut/ground.
5. To store the TPI target parameters for use by the desired thrusting program.

Assumptions:

1. 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 atronaut should reassess the input targeting parameters based upon Delta V and expected maneuver time.
5. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N37	
Time of TPI ignition	00XXX. h
	000XX. min
	0XX.XX s
2. V06 N55	
R2: Elevation angle	XXX.XX deg
R3: Central angle of passive vehicle	XXX.XX deg
3. V06 N58	
Pericenter altitude	XXXX.X nmi
ΔV (TPI)	XXXX.X ft/s
ΔV (TPF)	XXXX.X ft/s
4. V06 N81	
Components of ΔV (LV) for TPI	XXXX.X ft/s
5. V06 N59	
Components of ΔV (LOS)	XXXX.X ft/s
6. V16 N45	
Marks (RR)	XXXXX. marks
Time from TPI ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg
7. V06 N52	
Central angle of active vehicle	XXX.XX deg
8. V06 N16 (results from V90E)	
Time of event	00XXX. h
	000XX. min
	0XX.XX s
9. V06 N90 (results from V90E)	
Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

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.
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.
5. The program is selected by the astronaut by DSKY entry prior to any anticipated rendezvous midcourse correction.

Selected Displays:

1. V06 N81	
Components of ΔV (LV)	XXXX.X ft/s
2. V06 N59	
Components of ΔV (LOS)	XXXX.X ft/s
3. V16 N45	
Marks (RR)	XXXXX. marks
Time from TPM ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg
4. V06 N52	
Central angle of active vehicle	XXX.XX deg
5. V06 N16 (results from V90E)	
Time of event	00XXX. h
	000XX. min
	0XX.XX s
6. V06 N90 (results from V90E)	
Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

P38—STABLE ORBIT RENDEZVOUS (SOR) PROGRAM

Purpose:

1. To calculate the required Delta V and other initial conditions required by the LGC for LM execution of the first maneuver (SOI) of the Stable Orbit Rendezvous. Given:
   a. Time of ignition (TIG).
   b. Central angle of transfer (CENTANG) from TIG to intercept time.
   c. The displacement of the active vehicle stable orbit point, specified as a distance between the two vehicles along the passive vehicle orbit.
2. To calculate the required Delta V and other initial conditions required by the LGC for LM execution of the second maneuver (SOR) of the Stable Orbit Rendezvous. Given:
   a. A respecification of 1.a above.
   b. An optional respecification of 1.b above.
3. To calculate these parameters based upon maneuver data approved and keyed into the LGC by the astronaut.
4. To display to the astronaut and the ground certain dependent variables associated with the maneuver for approval by the astronaut/ground.
5. To store the SOI and SOR target parameters for use by the desired thrusting program.

Assumptions:

1. The stable orbit point is defined as the final position (at completion of SOR) of the active vehicle relative to the passive vehicle.
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 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.
3. 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.
4. The SOR phase of this program requires the TIG input be biased as a function of TPF and any midcourse corrections performed in the Stable Orbit Midcourse (SOM) program (P39).
5. The ISS need not be on to complete this program (see Assumption 2. above).
6. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N33

Time of ignition for SOI	00XXX. h
	000XX. min
	0XX.XX s

2. V06 N55

Central angle of passive vehicle	XXX.XX deg

3. V04 N06	
Option code ID	00005
Option code	0000X (1—first pass, 2—second pass)
4. V06 N57	
ΔR	XXXX.X nmi
5. V06 N34	
Time of arrival at SOR	00XXX. h
	000XX. min
	0XX.XX s
6. V06 N58	
Pericenter altitude (SOR)	XXXX.X nmi
ΔV (SOR)	XXXX.X ft/s
ΔV (SOR—final)	XXXX.X ft/s
7. V06 N81	
Components of ΔV (LV) for SOR	XXXX.X ft/s
8. V16 N45	
Marks (RR)	XXXXX. marks
Time from SOI ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg
9. V06 N52	
Central angle of active vehicle	XXX.XX deg

P39—STABLE ORBIT MIDCOURSE (SOM) PROGRAM

Purpose:

1. To calculate the required Delta V and other initial conditions required by the LGC for LM execution of the next possible midcourse correction of the stable orbit transfer phase of an active LM rendezvous.
2. To compute and display suitable information to enable the crew to enter the final rendezvous phase at the correct time to complete the required thrusting maneuver.

Assumptions:

1. The ISS need not be on to complete this program (see Assumption 2. below).
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 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.
3. 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.
4. The time of intercept (T(INT)) was defined by previous completion of the Stable Orbit Rendezvous (SOR) program (P38) and is presently available in LGC storage.
5. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N81

Components of ΔV (LV) for SOM	XXXX.X ft/s

2. V16 N45

Marks (RR)	XXXXX. marks
Time from SOM ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg

3. V06 N52

Central angle of active vehicle	XXX.XX deg

P40—DPS PROGRAM

Purpose:

1. To compute a preferred IMU orientation and a vehicle attitude for an LM DPS thrusting maneuver.
2. To maneuver the vehicle to the thrusting attitude.
3. To control the PGNCS during countdown, ignition, thrusting, and thrust termination of a PGNCS 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 Delta 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.

   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. The IMU is on and must be at a known orientation before this program may be completed. It is normally required that the ISS be on for a minimum of 15 minutes prior to a thrusting maneuver.
4. The event timer is set to count to zero at TIG.
5. Engine ignition may be slipped beyond the established TIG if desired by the crew, or if state vector integration cannot be completed in time.
6. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Auto, the PGNCS will control the total vehicle attitude and generate either Mode 1 or Mode 2 attitude errors (See Assumption 7) for display on the FDAI. The crew may exercise control around the yaw axis only with the ACA (X-axis override), if the X-axis override capability is permitted by the program in process. This manual control will be in the Rate Command/Attitude Hold mode.

   If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold the PGNCS 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. 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 PGNCS will not be responsible if register overflows occur within the LGC. 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 PGNCS will not be responsible if register overflows occur within the LGC.

7. The PGNCS can generate two types of attitude errors for display on the FDAI:
   a. Mode 1—Selected by Extended Verb 61. Autopilot following errors used as a monitor of the DAP's ability to track automatic steering commands.
   b. Mode 2—Selected by Extended Verb 62. Total attitude errors used to assist crew in manually maneuvering the vehicle.
8. 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 PGNCS Attitude Control mode is Auto. When the controller is returned to detent the PGNCS 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.
9. 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.
10. 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 required 2 minutes.
11. 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.
12. For each burn an ignition total allowable time delay will be specified in the mission rules. This delay time is the total time which the thrusting maneuver may be delayed beyond the LGC calculated time of ignition. If engine restarts are involved, the accounting of this total time delay is up to the crew.
13. LGC and crew procedures in cases of LGC-assumed thrust failure are defined by the DPS/APS Thrust Fail routine (R40). This routine is called at DPS ignition by this program.
14. The LGC will neither designate nor read the Rendezvous Radar (RR) during this program.
15. This program should be selected by the astronaut by DSKY entry at least 5 minutes before the estimated time of ignition.
16. This program is selected manually by DSKY entry.
17. The Orbit Parameter Display routine (R30) may be called during this program by keying in V82E.

Selected Displays:

1. V06 N86

Components of VG (LV) for thrusting maneuver	XXXX.X ft/s

2. V50 N25 (change guidance control mode)

Checklist code	00203

3. V06 N40

Time from DPS ignition/cutoff	XX b XX min/s
Magnitude of velocity to be gained	XXXX.X ft/s
ΔV (measured)	XXXX.X ft/s

4. V99 N40 (request engine on enable)

   Display same as Item 3 above

5. V16 N85

Components of VG (LM body axes)		XXXX.X ft/s
6. V06 N38		
Time of state vector being integrated		00XXX. h
		000XX. min
		0XX.XX s
7. V50 N18		
Desired automaneuver FDAI ball angles	R	XXX.XX deg
	P	XXX.XX deg
	Y	XXX.XX deg
8. V06 N18		
Final FDAI ball angles	R	XXX.XX deg
	P	XXX.XX deg
	Y	XXX.XX deg
9. V04 N12 (results from V82E)		
Option code ID		00002
Option code		0000X (1—this vehicle, 2—other vehicle)
10. V16 N44 (results from V82E)		
Apocenter altitude		XXXX.X nmi
Pericenter altitude		XXXX.X nmi
TFF		XX b XX min/s

P41—RCS PROGRAM

Purpose:

1. To compute a preferred IMU orientation and a vehicle attitude for an RCS thrusting maneuver.
2. To perform the vehicle maneuver to the thrusting attitude.
3. 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. With the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold the PGNCS will hold the vehicle attitude and will generate either Mode 1 or Mode 2 attitude errors (See Assumption 4) 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. However, it is strongly recommended that powered flight not be attempted in the Minimum Impulse mode. During a thrusting maneuver in the PGNS/Altitude Hold mode the PGNCS will not be responsible if register overflows occur within the LGC.

4. The PGNCS can generate two types of attitude errors for display on the FDAI:
   a. Mode 1—Selected by Extended Verb 61. Autopilot following errors used as a monitor of the DAP's ability to track automatic steering commands.
   b. Mode 2—Selected by Extended Verb 62. Total attitude errors used to assist crew in manually maneuvering the vehicle.
5. The IMU is on and must be at a known orientation before this program may be completed. It is normally required that the ISS be on for a minimum of 15 minutes prior to a thrusting maneuver.
6. The event timer is set to count to zero at TIG.
7. RCS ignition may be slipped beyond the established TIG if desired by the crew, or if state vector integration cannot be completed on time.
8. 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 PGNCS 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.
9. The Load DAP Data routine (R03) has been performed prior to selection of this program.
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 Orbit Parameter Display routine (R30) may be called during this program by keying in V82E.

Selected Displays:

1. V06 N86

Components of VG (LV) for thrusting maneuver		XXXX.X ft/s

2. V16 N85

Components of VG (LM body axis) for thrusting maneuver		XXXX.X ft/s

3. V99 N85 (request engine on enable)

   Display same as Item 2 above
4. V06 N38

Time of state vector being integrated		00XXX. h
		000XX. min
		0XX.XX s

5. V50 N18

Desired automaneuver FDAI ball angles	R	XXX.XX deg
	P	XXX.XX deg
	Y	XXX.XX deg

6. V06 N18

Final FDAI ball angles	R	XXX.XX deg
	P	XXX.XX deg
	Y	XXX.XX deg

7. V04 N12 (results from V82E)

Option code ID		00002
Option code		0000X (1—this vehicle 2—other vehicle)

8. V16 N44 (results from V82E)

Apocenter alitutude	XXXX.X nmi
Pericenter altitude	XXXX.X nmi
TFF	XX b XX min/s

P42—APS PROGRAM

Purpose:

1. To compute a preferred IMU orientation and a vehicle attitude for an LM APS thrusting maneuver.
2. To maneuver the vehicle to the thrusting attitude.
3. To control the PGNCS during countdown, ignition, thrusting, and thrust termination of a PGNCS-controlled APS 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 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. The IMU is on and must be at a known orientation before this program may be completed. It is normally required that the ISS be on for a minimum of 15 minutes prior to a thrusting maneuver.
4. The event timer is set to count to zero at TIG.
5. Engine ignition may be slipped beyond the established TIG if desired by the crew or if state vector integration cannot be completed in time.
6. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Auto, the PGNCS will control the total vehicle attitude and generate either Mode 1 or Mode 2 attitude errors (See Assumption 7) for display on the FDAI. The crew may exercise control around the yaw axis only with the ACA (X-axis override) if the X-axis override capability is permitted by the program in process. This manual control will be in the Rate Command/Attitude Hold mode.

   If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold the PGNCS will hold the vehicle attitude and will generate either Mode 1 or Mode 2 attitude errors for display in 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. However, it is strongly recommended that powered flight not be attempted in the Minimum Impulse mode. During a thrusting maneuver in the PGNCS/Attitude Hold mode the PGNCS will not be responsible if register overflows occur within the LGC.

   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 PGNCS will not be responsible if register overflows occur within the LGC.
7. The PGNCS can generate two types of attitude errors for diaplay on the FDAI:
   a. Mode 1—Selected by Extended Verb 61. Autopilot following errors used as a monitor of the DAP's ability to track automatic steering commands.
   b. Mode 2—Selected by Extended Verb 62. Total attitude errors used to assist crew in manually maneuvering the vehicle.

8. 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 PGNCS Attitude Control mode is Auto. When the controller is returned to detent the PGNCS 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.

9. For each burn an ignition total allowable time delay will be specified in the mission rules. This delay time is the total time which the thrusting maneuver may be delayed beyond the LGC calculated time of ignition. If engine restarts are involved, the accounting of this total time delay is up to the crew.

10. The Load DAP Data routine (R03) may have been performed prior to selection of this program.

11. LGC and crew procedures in cases of LGC-assumed thrust failure are defined by the DPS/APS Thrust Fail routine (R40). This routine is called at APS ignition by this program.

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

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

14. This program is selected manually by DSKY entry.

15. The Orbit Parameter Display routine (R30) may be called during this program by keying in V82E.

Selected Displays:

1. V06 N86		
Components of VG (LV) for thrusting maneuver		XXXX.X ft/s
2. V50 N25 (change guidance control mode)		
Checklist code		00203
3. V06 N40		
Time from APS ignition/cutoff		XX b XX min/s
Magnitude of velocity to be gained		XXXX.X ft/s
ΔV (measured)		XXXX.X ft/s
4. V99 N40 (request engine on enable)		
Display same as Item 3 above		
5. V16 N85		
Components of VG (LM body axes)		XXXX.X ft/s
6. V06 N38		
Time of state vector being integrated		00XXX. h
		000XX. min
		0XX.XX s
7. V50 N18		
Desired automaneuver FDAI ball angles	R	XXX.XX deg
	P	XXX.XX deg
	Y	XXX.XX deg
8. V06 N18		
Final FDAI ball angles	R	XXX.XX deg
	P	XXX.XX deg
	Y	XXX.XX deg

9. V04 N12 (results from V82E)

Option code ID	00002
Option code	0000X (1—this vehicle 2—other vehicle)

10. V16 N44 (results from V82E)

Apocenter altitude	XXXX.X nmi
Pericenter altitude	XXXX.X nmi
TFF	XX b XX min/s

P47—THRUST MONITOR PROGRAM

Purpose:

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

Assumptions:

1. The IMU would normally be on and the IMU Orientation Determination program (P51) completed before selection of this program.
2. The responsibility of avoiding gimbal lock during execution of this program is upon the astronaut.
3. 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 PGNCS control they must be accomplished via selection of the Transfer Phase Initiation (TPI) program (P34) and then the DPS Thrusting program (P40).
4. Range, range rate, and theta may be displayed during this program by calling the Rendezvous Parameter Display routine (R31).
5. 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.
6. The Orbit Parameter Display routine (R30) may be called during this program by keying in V82E.

Selected Displays:

1. V16 N83

Components of ΔV (LM body axes)	XXXX.X ft/s

2. V16 N54 (results from V83E)

Range	XXX.XX nmi
Range rate	XXXX.X ft/s
Angle between LM +Z axis and local horizontal	XXX.XX deg

3. V04 N12 (results from V82E)

Option code ID	00002
Option code	0000X (1—this vehicle, 2—other vehicle)

4. V16 N44 (results from V82E)

Apocenter attitude	XXXX.X nmi
Pericenter attitude	XXXX.X nmi
TFF	XX b XX min/s

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. This program may only be performed while the LM is in flight.
2. The ISS may be:
   a. Off (standby).
   b. On and aligned since turn-on.

   If (a) is true, the IMU must be turned on before this program can be performed.

   If (b) is true, this program can be completed.
3. There are no restraints upon the LM attitude control modes until a PGNCS controlled maneuver is called by a program or the crew wishes to manually maneuver the vehicle.
4. 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.
5. Extended Verbs should not be exercised during this program because of possible interference with R53.
6. The program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V50 N25 (star acquisiton)

   Checklist code — 00015
2. V41 N22

   CDU gimbal angles — OG XXX.XX deg; IG XXX.XX deg; MG XXX.XX deg
3. V01 N71 (after mark)

   R1: ABCDE
   - AB—Blank
   - C—AOT Detent
     - 1—Left
     - 2—Center
     - 3—Right
     - 4—Any rear
     - 5—Backup optical system
   - DE—Celestial Body code
4. V06 N87

   Backup optics LOS azimuth — XXX.XX deg

   Backup otpics LOS elevation — XXX.XX deg
5. V54 N71 (mark X or Y reticle)

   Display same as Item 3 above
6. V52 N71 (mark X reticle)

   Display same as Item 3 above
7. V53 N71 (Mark Y reticle)

   Display same as Item 3 above

8. V06 N05
   Star angle difference — XXX.XX deg
9. V06 N88
   Components of celestial body ½ unit vector — .XXXXX

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 0001). 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 0004)

      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)

Assumptions:

1. This program may only be performed while the LM is in flight.
2. 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).
3. There are no restraints upon the LM attitude control modes until a PGNCS 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 PGNCS 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.

4. This program makes no provision for an attitude maneuver to return the vehicle to a specific 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.
5. The ISS is on and has been aligned to a "known" orientation which is stored in the LGC (REFSMMAT). The present IMU orientation differs from that to which it was last aligned only due to gyro drift; that is, neither gimbal lock nor IMU power interruption has occurred since the last alignment).
6. An option is provided to realign the IMU to the preferred, nominal, or landing site orientations without making celestial body sightings.
7. Extended Verbs should not be exercised during this program because of possible interference with R53.
8. The program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V04 N06

Option code ID		00001
Option code		0000X (1—preferred, 2—nominal, 3—REFSMMAT, 4—landing site)

2. V06 N34

Time of alignment		00XXX. h
		000XX. min
		0XX.XX s

3. V06 N89

Designated landing site latitude		XX.XXX (+ north)
Desginated landing site longitude/2		XX.XXX (+ east)
Designated landing site altitude		XXX.XX nmi

4. V06 N22

IMU gimbal angles at desired orientation	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

5. V50 N25 (coarse align)

Checklist code		00013

6. V16 N20

IMU gimbal angles	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

7. V50 N25 (fine alignment)

Checklist code		00014

8. V50 N25 (star acquisition)

Checklist code		00015

9. V01 N70 (before mark)

    R1: ABCDE
    AB—Blank

    C—AOT Detent

    1—Left
    2—Center
    3—Right
    4—Any rear
    5—Backup optical system

    DE—Celestial Body code

10. V06 N87

Backup optics LOS azimuth		XXX.XX deg
Backup optics LOS elevation		XXX.XX deg

11. V01 N71 (after mark)

    Display same as Item 9 above

12. V54 N71 (Mark X or Y-reticle)

    Display same as Item 9 above

13. V52 N71 (Mark X-reticle)

    Display same as Item 9 above

14. V53 N71 (Mark Y-reticle)

    Display same as Item 9 above

15. V06 N05

Sighting angle difference		XXX.XX deg

16. V06 N93

Gyro torque angles	X	XX.XXX deg
	Y	XX.XXX deg
	Z	XX.XXX deg

17. V06 N88

Components of celestial body ½ unit vector		.XXXXX

18. V50 N18

Desired automaneuver FDAI ball angles	R	XXX.XX deg
	P	XXX.XX deg
	Y	XXX.XX deg

19. V06 N18

Final FDAI ball angles	R	XXX.XX deg
	P	XXX.XX deg
	Y	XXX.XX deg

P57—LUNAR SURFACE ALIGN PROGRAM

Purpose:

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

    a. Landing Site Orientation

    $X_{SM} = \text{Unit}(R_{LS})$

    $Y_{SM} = \text{Unit}(Z_{SM} \times X_{SM})$

    $Z_{SM} = \text{Unit}(H_{CSM} \times X_{SM})$

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

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.

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 (Option 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 R59 portion of this program because of possible interference with R53.
6. No monitor or control of the Rendezvous Radar (RR) will be exercised by the LGC during this program except as defined by the RR Monitor routine (R25).
7. The LM attitude with respect to the lunar surface is available in LGC storage; that is, it will have been stored by the Landing Conformation program (P68). Once this attitude has been stored it will be preserved by the LGC until it is replaced by a more recent value.
8. 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.
9. The DAP should be off during gyro torquing by this program to preclude RCS jet firings due to realignment of the IMU causing attitude errors exceeding the maximum deadband.
10. A determination of the LM position vector while on the lunar surface (R_{LS}) can be accomplished only in conjunction with IMU alignment mode option 2 (using AOT sightings on two celestial bodies). It is valid only if the lunar gravity vector has been previously defined during P57, using IMU alignment mode option 1 (using REFSMMAT or stored LM attitude and determination of lunar gravity vector) or option 3 (using single celetial body sighting and determination of lunar gravity vector).

Selected Displays:

1. V06 N34

GET(ALIGN)	00XXX. h
	000XX. min
	0XX.XX s

2. V05 N06

Option code ID	00010
Option code	0000X (0—Prestored Attitude, 1—Prestored Attitude +g 2—two bodies, 3—ond body +g)
Datcode	00CDE

C—REFSMMAT 1—defined
0—not defined

D—stored LM attitude 1—available
0—not available

E=GETI(AS) 1—defined
0—not defined

3. V06 N04 (angle between present and stored gravity vector)

R1: Angle	XXX.XX deg

4. V01 N70 (before mark)

R1: ABCDE

AB—Blank

C—AOT Detent

1—Left
2—Center
3—Right
4—Any rear
5—Backup optical system

DE—Celestial body code

5. V06 N79

Cursor angle	XXX.XX deg
Spiral angle	XXX.XX deg
Position code	0000X

6. V01 N71

R1: ABCDE (see Item 4 above)

7. V06 N87 (LOS definition)

Azimuth	XXX.XX deg
Elevation	XXX.XX deg

8. V52 (Mark X)
9. V06 N88

Components of celestial body ½ unit vector	.XXXXX

10. V50 N25 (celestial body acquisition)

Checklist code	00015

11. V06 N05

R1: Sighting angle difference	XXX.XX deg

12. V06 N93

Gyro torque angles	X	XX.XXX deg
	Y	XX.XXX deg
	Z	XX.XXX deg

13. V50 N25 (fine align)

Checklist code		00014

14. V06 N22

Desired ICDU angles	OG	XXX.XX deg
	IG	XXX.XX deg
	MG	XXX.XX deg

15. V06 N89

Landing site latitude	XX.XXX deg
Landing site longitude/2	XX.XXX deg
Landing site altitude	XXX.XX nmi

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 PGNCS-controlled, DPS-executed, braking phase of the powered landing maneuver.
2. To align the LM to the thrusting ignition attitude.
3. To control the PGNCS during countdown, ignition, and thrusting of the powered landing maneuver until HI gate.
4. 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.
5. The LGC will neither designate nor read the Rendezvous Radar (RR) during 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.
6. The Landing Analog Displays routine (R10) is enabled at DPS ignition and is terminated upon termination of Average G. The Powered Flight Designate routine (R29) is not enabled during the lunar descent.
7. The entire powered landing maneuver (braking, approach, and landing) will be accomplished using the DPS engine.
8. 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 PGNCS commanded setting.

This program assumes the Throttle Control switch to be in Auto (the DPS receives the sum of the manual and PGNCS 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.

9. 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.

10. 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 PGNCS Mode Control switch is in Auto. When the controller is returned to detent the PGNCS 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.

11. 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, P64, or P65, 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.

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

13. 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), (P65), (P66), or (P67).

    For aborts from the descent orbit injection or the descent coast it is assumed that sufficient time exists to perform a TPI maneuver (see Terminal Phase Initiation (TPI) program (P34)) to intercept the CSM directly.

    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.

14. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Auto, the PGNCS will control the total vehicle attitude and generate either Mode 1 or Mode 2 attitude errors for display on the FDAI. The crew may exercise control around the yaw axis only with the ACA (X-axis override) and only if the X-axis override capability is permitted by the program in process. This manual control will be in the Rate Command/Attitude Hold mode.

    If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold, the PGNCS 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. During a thrusting maneuver in the PGNS/Attitude Hold mode the astronaut is responsible for maintaining small enough attitude errors to achieve guidance objectives.

15. Control of LM DPS, RCS, and APS is transferred from PGNCS 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. However, the PGNCS will not be responsible if register overflows occur within the LGC.

16. The PGNCS can generate two types of attitude errors for display on the FDAI:

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

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

Display selection is always based upon the last entry made in the DSKY.

17. 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.

18. 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.

19. 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.

20. LGC and crew procedures in cases of LGC-assumed thrust failure are defined by the DPS/APS Thrust Fail routine (R40). This routine is enabled at DPS ignition by this program.

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

22. It is normally required that the ISS be on for a minimum of 15 minutes prior to a thrusting maneuver.

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

24. Two alarm conditions may be originated by the PGNCS powered landing equations:

    a. If subroutine ROOTSPRS 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, P65, or P66.

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

    During P63 (P64 and P65) the astronaut can display the PGNCS total guidance error on the FDAI error needles (Attitude Monitor switch in PGNCS) by having keyed in V62E through the DSKY. He can then steer out the PGNCS P63 attitude errors with the PGNCS manually (Guidance Control switch in PGNCS and the PGNCS Mode Control switch in Attitude Hold); or automatically (PGNCS 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 PGNCS Mode Control switch is in Attitude Hold, the LGC will irrevocably transfer him out of the automatic guidance program modes (P63, P64, and P65) into the ROD program (P66).

Selected Displays:

1. V06 N61

TG	XX b XX min/s
TF GETI	XX b XX min/s
Crossrange	XXXX.X nmi

2. V06 N33

Time of PDI ignition	00XXX. h
	000XX. min
	0XX.XX s

3. V50 N25 (fine align)		
Checklist code		00014
4. V50 N18		
Desired automaneuver FDAI ball angles	R	XXX.XX deg
	P	XXX.XX deg
	Y	XXX.XX deg
5. V06 N18		
Final FDAI ball angles	R	XXX.XX deg
	P	XXX.XX deg
	Y	XXX.XX deg
6. V06 N62		
Absolute value of velocity		XXXX.X ft/s
Time from ignition		XX b XX min/s
V (measured)		XXXX.X ft/s
7. V99 N62 (request engine on enable)		
Same display as Item 15 above		
8. V06 N63		
Absolute value of velocity		XXXX.X ft/s
Altitude rate		XXXX.X ft/s (+ ascent)
Computed altitude		XXXXX. ft
9. V50 N25 (reposition LR antenna)		
Checklist code		00500
10. V50 N25 (change guidance mode)		
Checklist code		00203
11. V06 N68 (astronaut initiated display)		
Slant range to landing site		XXXX.X nmi
Time to go in braking phase		XX b XX min/s
LR altitude (computed altitude)		XXXXX. ft
12. V16 N68 (astronaut initiated display)		
Display same as Item 11 above.		

P64—APPROACH PHASE PROGRAM

Purpose:

1. To control the PGNCS 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 PGNCS is guiding the LM.
4. To select P65 automatically when TR is less than TENDAPPR (time to end of approach phase).

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 IMU is on and accurately aligned to a landing site orientation defined for the designated landing site and the nominal time of landing (T(land)).

4. 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.
5. The LGC will neither designate nor read the Rendezvous Radar (RR) during this program.
6. The entire powered landing maneuver (braking, approach, and landing) will be accomplished using the DPS engine.
7. The aim conditions (LO gate) for the approach phase are stored in the LGC.
8. 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 PGNCS commanded setting.

   This program assumes the Throttle Control switch to be in Auto (the DPS receives the sum of the manual and PGNCS 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 redesgination of the landing site (see Assumption 11), 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.
9. 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.
10. The X-axis override option is not provided to the crew whenever the LGC estimated altitude is below 30,000 feet.
11. During most of the approach phase, the LGC provides the crew with the option to redesignate the landing site to which the PGNCS is guiding the LM. This option is called the Landing Point Designator (LPD) mode. The PGNCS 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 as a fixed angular increment (½ degree in elevation, 2 degrees in azimuth) from the present LM/landing site LOS. 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).
12. 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, P64, or P65, 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.

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), (P65), (P66), or (P67).

    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.

15. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Auto, the PGNCS will control the total vehicle attitude and generate either Mode 1 or Mode 2 attitude errors for display on the FDAI.

    If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold the PGNCS 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. During a thrusting maneuver in the PGNS/Attitude Hold mode the PGNCS will not be responsible if register overflows occur within the LGC.

16. Control of the LM DPS, RCS, and APS is transferred from the PGNCS 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 PGNCS will not be responsible if register overflows occur within the LGC.

17. The PGNCS can generate two types of attitude errors for display on the FDAI:

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

    b. Mode 2—Selected by Extended Verb 62. Total attitude errors used to assist 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. LGC and crew procedures in cases of LGC-assumed thrust failure are defined by the DPS/APS Thrust Fail routine (R40). This routine is in effect during this program, having been enabled by P63.

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

21. Two alarm conditions may be originated by the PGNCS powered landing equations:

    a. If Subroutine ROOTSPRS in the RG/VG calculation fails to converge in 7 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, P65, or P66.

22. This program allows manual control of the LM attitude. If manual control is desired, put the PGNCS 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 PGNCS Mode Control switch is in Attitude Hold.

    P67 can be entered by placing the Throttle Control switch to Manual.

    NOTE: Landing Site Redesignation must be completed before either P66 or P67 are selected, since P64 cannot be reentered once it has been exited.

Selected Displays:

1. V06 N64

Time left for redesignations (TR)/LPD	XX b XX s/deg
Altitude rate	XXXX.X ft/s
Computed altitude	XXXXX. ft

P65—LANDING PHASE (AUTO) PROGRAM

Purpose:

1. To control the PGNCS during the thrusting of the powered landing maneuver from the period immediately after completion of the approach phase aim conditions (LO gate) until touchdown on the lunar surface.

Assumptions:

1. The LM is on the powered landing descent having just arrived at the LO gate conditions.

2. The CSM is in a near circular orbit around the moon at a nominal altitude of 60 nautical miles. The CSM's position with respect to the LM is approximately 0 degrees central angle above the LM. The CSM is maintaining a preferred tracking attitude for optical tracking of and RR tracking by the LM.

3. The IMU is on and accurately aligned to a landing site orientation defined for the designated landing site and the nominal time of landing (T(land)).

4. 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.

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

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

7. 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 about 10 percent) and the PGNCS commanded setting.

   This program assumes the Throttle Control switch to be in Auto (the DPS receives the sum of the manual and PGNCS 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 throughout this program.

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.

9. The LPD option is not provided to the crew during this program.

10. The initial maneuver of the auto landing phase is the LM attitude transition from the LM attitude at LO gate to the hover attitude (LM X axis along the local vertical). The final designated landing site remains in the LM X-Z plane during this transition.

    The LM attitude rate is maintained at -3 ft/s until touchdown.

11. The crew can 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 the control of the Landing Analog Displays routine (R10) which is already in process.

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

13. An abort from the lunar descent may be required at any time during descent orbit injection, descent coast, or powered descent (P63), (P64), (P65), (P66), or (P67).

    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.

14. Control of the LM DPS, RCS, and APS is transferred from the PGNCS to the Abort Guidance System (AGS) by placing the Guidance Control switch from PGNCS 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) and guiding 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 PGNCS 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 PGNCS will not be responsible if register overflows occur within the LGC.

15. 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.

16. LGC and crew procedures in cases of LGC-assumed thrust failure are defined by the DPS/APS Thrust Fail routine (R40). This routine is in effect during this program until selection of the Landing Conformation program (P68), having been called by P63.

17. This program is automatically selected by the Approach Phase program (P64) at the completion of the LO gate aim conditions.

18. Two alarm conditions may be originated by the PGNCS powered landing equations:

    a. If Subroutine ROOTSPRS in the RG/VG calculation fails to converge in N(N = 8 for P63, N = 7 for P64) 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, P65, or P66.

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

    During P65 the astronaut can display the PGNCS total guidance error on the FDAI error needles (Attitude Monitor switch in PGNCS) by having keyed in V62E through the DSKY. He can then steer out the PGNCS P65 attitude erorrs with the PGNCS manually (Guidance Control switch in PGNCS and the PGNCS Mode Control switch in Attitude Hold); or automatically (PGNCS 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 PGNCS Mode Control siwtch is in Attitude Hold, the LGC will irrevocably transfer him out of P65 and into the ROD program (P66).

Selected Displays:

1. V06 N60

Horizontal velocity	XXXX.X ft/s
Altitude rate	XXXX.X ft/s
Computed altitude	XXXXX.

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 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. In the absence of manual control inputs, to maintain a constant rate of descent and LM inertial attitude.
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 relatively low inertial velocity.
2. The CSM is in a near circular orbit around the moon at a nominal altitude of 60 nautical miles. The CSM's position with respect to the LM is approximately 0-degrees central angle above the LM. The CSM is maintaining a preferred tracking attitude for optical tracking of and RR tracking by the LM.
3. The IMU is on and accurately aligned to a landing site orientation defined for the designated landing site and the nominal time of landing (T(land)).
   IMU alignment took place during the Braking Phase program (P63) prior to DPS ignition.

4. 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.

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

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

7. 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.

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.

9. The LPD option is not provided to the crew during this program.

10. The LGC assumes all attitude changes to be manual throughout this program. The Mode Control switch may be in Auto or Attitude Hold. The LGC will hold inertial attitude in either mode. However, in the Attitude Hold mode the attitude may be changed by manual control via the attitude controller.

11. 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 the control of the Landing Analog Displays routine (R10) which is already in process.

12. 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-the-window references and LM/DSKY displays.

    Switch operation is on an incremental bias: either -(increase ROD) or +(decrease) ROD). Each command results in an LGC-commanded change of "RODSCALE" in the LM rate of descent. ("RODSCALE" is a value loaded into erasable storage prior to flight).

13. An abort from the lunar descent may be required at any time during descent orbit injection, descent coast, or powered descent (P63), (P64), (P65), (P66), or (P67).

    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.

14. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold the PGNCS 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. During a thrusting maneuver in the PGNS/Attitude Hold mode the PGNCS will not be responsible if register overflows occur within the LGC.

15. Control of the LM DPS, RCS, and APS is transferred from the PGNCS 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 PGNCS will not be responsible if register overflows occur within the LGC.

16. 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.

17. LGC and crew procedures in cases of LGC-assumed thrust failure are defined by the DPS/APS Thrust Fail routine (R40). This routine is in effect during this program until selection of the Landing Conformation program (P68), having been enabled by P63.

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

    a. Rate of Descent switch is operated for the first time with the Attitude Control switch in Attitude Hold and the Throttle Control switch in Auto.

    b. Auto throttle control is selected during the Landing Phase (Manual) program (P67).

    Once this program has been selected it is no longer possible to return to the completely automatic powered landing programs (P63, P64, or P65).

19. Two alarm conditions may be originated by the PGNCS powered landing equations:

    a. If Subroutine ROOTSPRS in the RG/VG calculation fails to converge in N(N = 8 for P63, N = 7 for P64) 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, P65, or P66.

Selected Displays:

1. V06 N60

Horizontal velocity	XXXX.X ft/s
Altitude rate	XXXX.X ft/s
Computed altitude	XXXXX. ft

P67—LANDING PHASE (MANUAL) PROGRAM

Purpose:

1. To update the LM state vector with vehicle acceleration and Landing Radar (LR) data during a non-PGNCS controlled landing maneuver.
2. To display horizontal velcoity, altitude rate, and computed altitude during a non-PGNCS controlled landing maneuver.

Assumptions:

1. The LM could be anywhere on the powered landing descent but nominally it has just completed the second transition.
2. The CSM is in a near circular orbit around the moon at a nominal altitude of 60 nautical miles. The CSM's position with respect to the LM is approximately 0-degrees central angle above the LM. The CSM is maintaining a preferred tracking attitude for optical tracking of and RR tracking by the LM.
3. The IMU is on and accurately aligned to a landing site orientation defined for the designated landing site and the nominal time of landing (T(land)).
4. 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.
5. The LGC will neither designate nor read the Rendezvous Radar (RR) during this program.
6. The entire powered landing maneuver (braking, approach, and landing) will be accomplished using the DPS engine.
7. This program assumes all throttle control to be manual throughout the program.
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 psotion.

   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.
9. The LPD option is not provided the crew during this program.
10. The LGC assumes all attitude changes to be manual throughout this program. The Mode Control switch may be in Auto or Attitude Hold. The LGC will hold inertial attitude in either mode, however, only in the Attitude Hold mode may the attitude be changed by manual control via the attitude controller.
11. 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 the control of the Landing Analog Displays routine (R10) which is already in process.
12. The Rate of Descent (ROD) mode is not enabled during this program.
13. An abort from the lunar descent may be required at any time during descent orbit injection, descent coast, or powered descent (P63), (P64), (P65), (P66), or (P67).

    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.

14. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold, the PGNCS 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. During a thrusting maneuver in the PGNS/Attitude Hold Mode, the PGNCS will not be responsible if register overflows occur within the LGC.

15. Control of the LM DPS, RCS, and APS is transferred from the PGNCS 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 PGNCS will not be responsible if register overflows occur within the LGC.

16. 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.

17. LGC and crew procedures in cases of LGC-assumed thrust failure are defined by the DPS/APS Thrust Fail routine (R40). This routine is in effect during this program until selection of the Landing Conformation program (P68), having been enabled by P63.

18. This program is automatically selected by the Landing Auto Modes Monitor routine (R13) at any time during the powered landing maneuver when the throttle is manual (Thrust Control switch to Manual).

    Once this program has been selected it is no longer possible to return to the completely automatic powered landing programs (P63, P64, or P65).

Selected Displays:

1. V06 N60

Horizontal velocity	XXXX.X ft/s
Altitude rate	XXXX.X ft/s (+ ascent)
Computed altitude	XXXXX. ft

P68—LANDING CONFIRMATION PROGRAM

Purpose:

1. To terminate landing program and DAP functions.
2. To initialize the LGC for lunar surface operation.

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 (Programs P65, P66, or P67).

2. V37E68E selection of P68 will terminate Average G and command the engine off (see R00).
3. 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.

Selected Displays:

1. V06 N43

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

2. V16 N56 (results from V85E)

RR LOS Azimuth	XXX.XX deg
RR LOS Elevation	XXX.XX deg

P70—DPS ABORT PROGRAM

Purpose:

1. To control a PGNCS controlled DPS abort from the powered landing maneuver (P63, P64, P65, P66, or P67) 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 on 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 both of the following conditions are met: the LM Y axis is within 5 degrees of the desired pitchover axis and the LM vertical 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 on an abort orbit.
2. The LM is on the powered landing descent somewhere between DPS iginition for the maneuver (P63) and DPS shutdown on the lunar surface (P65, P66, or P67).
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 Rendezvous Radar (RR) was energized and checked out prior to selection of this program.

7. The Landing Analog Displays routine (R10) is enabled upon entry to this program, having been enabled by P63. R10 use of RR CDU's is inhibited by this program. R29 is enabled after completion of the vertical rise phase (if any). R10 and R29 are terminated upon termination of Average G.

8. 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 PGNCS commanded setting.

   This program assumes the Throttle Control switch to be in Auto (the DPS receives the sum of the manual and PGNCS 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.

9. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Auto, the PGNCS will control the total vehicle attitude and generate either Mode 1 or Mode 2 attitude errors (see Assumption 11) for display on the FDAI.

   If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Attitude Hold the PGNCS 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. During a thrusting maneuver in PGNS/Attitude Hold mode the PGNCS will not be responsible if register overflows occur within the LGC.

10. Control of the LM DPS, RCS, and APS is transferred from the PGNCS 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 PGNCS will not be responsible if register overflows occur within the LGC.

11. The PGNCS can generate two types of attitude errors for display on the FDAI:

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

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

12. 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.

13. 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.

14. 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.

15. 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.

Selected Displays:

1. V16 N77 (astronaut initiated display)

Time to engine cutoff	XX b XX min/s
LM velocity normal to CSM plane	XXXX.X ft/s

2. V16 N85 (astronaut initiated display)

Components of velocity to be gained (body axis)	XXXX.X ft/s

3. V50 N25 (change guidance control mode)

Checklist code	00203

4. V06 N63

Absolute value of velocity	XXXX.X ft/s
Altitude rate	XXXX.X ft/s (+ ascent)
Computed altitude	XXXXX. ft

5. V06 N76 (astronaut initiated display)

Downrange velocity	XXXX.X ft/s
Radial velocity	XXXX.X ft/s
Crossrange	XXXX.X nmi

6. V16 N44 (results from V82E)

Apocenter altitude	XXXX.X nmi
Pericenter altitude	XXXX.X nmi
TFF	XX b XX min/s

P71—APS ABORT PROGRAM

Purpose:

1. To control a PGNCS controlled APS abort from the powered landing maneuver (P63, P64, P65, P66, or P67) 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 both of the following conditions are met: the LM Y axis is within 5 degrees of the desired pitchover axis and the LM vertical 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 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 on 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 IMU is on and accurately aligned to the landing site 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 Rendezvous Radar (RR) was energized and checked out prior to selection of this program.
7. The Landing Analog Displays routine (R10) is enabled upon entry to this program, having been enabled by P63. R10 use of the RR CDU's is inhibited by this program. R29 is enabled after completion of the vertical rise phase (if any). R10 and R29 are terminated upon termination of Average G.
8. If a thrusting maneuver is performed with the Guidance Control switch in PGNS and the Mode Control switch in Auto, the PGNCS will control the total vehicle attitude and generate either Mode 1 or Mode 2 attitude errors for display on the FDAI.

   If a thrusting maneuver is performed with the Guidance Control switch set at PGNS and the Mode Control switch in Attitude Hold, the PGNCS 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. During a thrusting maneuver in the PGNS/Attitude Hold mode, the PGNCS will not be responsible if register overflows occur within the LGC.
9. Control of the LM DPS, RCS, and APS is transferred from the PGNCS 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 PGNCS will not be responsible if register overflows occur within the LGC.
10. The PGNCS can generate two types of attitude errors for display on the FDAI:
    a. Mode 1—Selected by Extended Verb 61. Autopilot following errors used as a monitor of the DAP's ability to track automatic steering commands.
    b. Mode 2—Selected by Extended Verb 62. Total attitude errors used to assist crew in manually maneuvering the vehicle.
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. 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.

Selected Displays:

1. V16 N77 (astronaut initiated display)

Time to engine cutoff	XX b XX min/s
LM velocity normal to CSM plane	XXXX.X ft/s

2. V16 N85 (astronaut initiated display)

Components of velocity to be gained (body axis)	XXXX.X ft/s

3. V50 N25 (change guidance control mode)

Checklist code	00203

4. V06 N63

Absolute value of velocity	XXXX.X ft/s
Altitude rate	XXXX.X ft/s (+ ascent)
Computed altitude	XXXXX. ft

5. V06 N76 (astronaut initiated display)

Downrange velocity	XXXX.X ft/s
Radial velocity	XXXX.X ft/s
Crossrange	XXXX.X nmi

6. V16 N44 (results from V82E)

Apocenter altitude	XXXX.X nmi
Pericenter altitude	XXXX.X nmi
TFF	XX b XX min/s

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).
2. To calculate these parameters based upon maneuver data approved and keyed into the LGC by the astronaut.
3. To display to the astronaut and the ground dependent variables associated with the concentric flight plan maneuvers for approval by the astronaut/ground.

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.
10. This program is selected by the astronaut by the DSKY entry.

Selected Displays:

1. V06 N11

Time of ignition for CSI	00XXX. h
	000XX. min
	0XX.XX s

2. V06 N55

Number of apsidal crossings (N)	0000X
Elevation angle (E) at TPI	XXX.XX deg
Central angle of passive vehicle	XXX.XX deg

3. V06 N37

Time of TPI ignition	00XXX h
	000XX min
	0XX.XX s

4. V06 N75

Delta altitude	XXXX.X nmi
Delta time (CDH-CSI)	XX b XX min/s
Delta time (TPI-CDH)	XX b XX min/s

5. V06 N81

Components of ΔV (LV) for CSI	XXXX.X ft/s

6. V06 N82

Components of ΔV (LV) for CDH	XXXX.X ft/s

7. V16 N45

Marks (RR)	XXXXX.
Time from CSI ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg

8. V06 N16 (results from V90E)

Time of event	00XXX. h
	000XX. min
	0XX.XX s

9. V06 N90 (results from V90E)

Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

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.
2. To calculate these parameters based upon maneuver data approved and keyed into the LGC by the astronaut.
3. To display to the astronaut and the ground dependent variables associated with the concentric flight plan maneuvers for approval by the astronaut/ground.

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 stable 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.
4. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N13

Time of ignition for CDH	00XXX. h
	000XX. min
	0XX.XX s

2. V06 N75

Delta altitude	XXXX.X nmi
Delta time (TPI-CDH)	XX b XX min/s
Delta time (TPI-NOMTPI)	XX b XX min/s

3. V06 N81

Components of ΔV (LV) for CDH	XXXX.X ft/s

4. V16 N45

Marks (RR)	XXXXX.
Time from CDH ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg

5. V06 N16 (results from V90E)

Time of event	00XXX. h
	000XX. min
	0XX.XX s

6. V06 N90 (results from V90E)

Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

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).
3. To calculate these parameters based upon maneuver data approved and keyed into the LGC by the astronaut.
4. To display to the astronaut and the ground certain dependent variables associated with the maneuver for approval by the astronaut/ground.

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.

5. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N37

Time of ignition for TPI	00XXX. h
	000XX. min
	0XX.XX s

2. V06 N55

Blank	00000
Elevation angle (E)	XXX.XX deg
Central angle of passive vehicle	XXX.XX deg

3. V06 N58

Perigee altitude (post TPI)	XXXX.X nmi
ΔV for TPI	XXXX.X ft/s
ΔV for TPF	XXXX.X ft/s

4. V06 N81

Components of ΔV (LV) for TPI	XXXX.X ft/s

5. V06 N59

Components of ΔV (LOS) for TPI	XXXX.X ft/s

6. V16 N45

Marks (RR)	XXXXX.
Time from TPI ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg

7. V06 N52

Central angle of active vehicle	XXX.XX deg

8. V06 N16 (results from V90E)

Time of event	00XXX. h
	000XX. min
	0XX.XX s

9. V06 N90 (results from V90E)

Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

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. The ISS need not be on to complete this program.
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.
5. The program is selected by the astronaut by DSKY entry prior to any anticipated CMC rendezvous midcourse correction requiring LM parameter computation.

Selected Displays:

1. V06 N81

Components of ΔV (LV) for TPM	XXXX.X ft/s

2. V06 N59

Components of ΔV (LOS) for TPM	XXXX.X ft/s

3. V16 N45

Marks (RR)	XXXXX.
Time of TPM ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg

4. V06 N52

Central angle of active vehicle	XXX.XX deg

5. V06 N16 (results from V90E)

Time of event	00XXX. h
	000XX. min
	0XX.XX s

6. V06 N90 (results from V90E)

Y	XXX.XX nmi
YDOT	XXXX.X ft/s
PSI	XXX.XX deg

P76—TARGET DELTA V PROGRAM

Purposes:

1. To provide a means of notifying the LGC that the CSM 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 to enable an updating of the CSM state vector.

Assumptions:

1. The LM crew has the Delta V to be applied to the CSM in local vertical axes at the specified TIG. These values are displayed prior to TIG by the thrusting programs (P40 and P41 in the CMC). No provision is made in these thrusting programs to display the 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.
3. This program is selected by the astornaut by DSKY entry.

Selected Displays:

1. V06 N84

Components of ΔV (other vehicle)	XXXX.X ft/s

2. V06 N33

Time of ignition of other vehicle	00XXX. h
	00XX. min
	0XX.XX s

P78—CSM STABLE ORBIT RENDEZVOUS (SOR) TARGETING PROGRAM

Purpose:

1. To calculate the required Delta V and other initial conditions required by the CMC for CSM execution of the first maneuver (SOI) of the stable orbit rendezvous. Given:
   a. Time of ignition (TIG).
   b. Central angle of transfer (CENTANG) from TIG to intercept time.
   c. The displacement of the stable orbit point of the active vehicle specified as a distance between the two vehicles along the passive vehicle orbit.
2. To calculate the required Delta V and other initial conditions required by the CMC for CSM execution of the second maneuver (SOR) of the Stable Orbit Rendezvous. Given:
   a. A respecification of 1.a above.
   b. An optional respecification of 1.b above.
3. To calculate these parameters based upon maneuver data approved and keyed into the LGC by the astronaut.
4. To display to the astronaut and the ground certain dependent variables associated with the maneuver for approval by the astronaut/ground.
5. To store the SOI and SOR target parameters for use by the desired thrusting program.

Assumptions:

1. The stable orbit point is defined as the final position (at completion of SOR) of the active vehicle relative to the passive vehicle.
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 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.
3. 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 the expected maneuver time.

4. The SOR phase of this program requires the TIG input be biased as a function of TPF and any midcourse corrections performed in the Stable Orbit Midcourse (SOM) program (P39).
5. The ISS need not be on to complete this program (see Assumption 2. above).
6. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N33

Time of ignition for SOI	00XXX. h
	000XX. min
	0XX.XX s

2. V06 N55

R3: Central angle of passive vehicle	XXX.XX deg

3. V04 N06

Option code ID	00005
Option code	0000X (1— first pass, 2-second pass)

4. V06 N57

ΔR	XXXX.X nmi

5. V06 N34

Time of arrival at SOR	00XXX. h
	000XX min
	0XX.XX s

6. V06 N58

Pericenter altitude (SOR)	XXXX.X nmi
ΔV (SOR)	XXXX.X ft/s
ΔV (SOR-final)	XXXX.X ft/s

7. V06 N81

Components of ΔV (LV) for SOR	XXXX.X ft/s

8. V16 N45

Marks (RR)	XXXXX. marks
Time from SOI ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg

9. V06 N52

Central angle of active vehicle	XXX.XX deg

P79—CSM STABLE ORBIT MIDCOURSE (SOM) TARGETING PROGRAM

Purpose:

1. To calculate the required Delta V and other initial conditions required by the CMC for CSM execution of the next possible midcourse correction of the stable orbit transfer phase of an active CSM rendezvous.
2. To compute and display suitable information to enable the crew to enter the final rendezvous phase at the correct time to complete the reuqired thrusting maneuver.

Assumptions:

1. The ISS need not be on to complete this program (see Assumption 2. below).
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 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.
3. 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.
4. The time to intercept (T(INT)) was defined by previous completion of the CSM Stable Orbit Rendezvous (SOR) Targeting program (P78) and is presently available in LGC storage.
5. This program is selected by the astronaut by DSKY entry.

Selected Displays:

1. V06 N81

Components of ΔV (LV) for SOM	XXXX.X ft/s

2. V16 N45

Marks (RR)	XXXXX.
Time from SOM ignition	XX b XX min/s
Middle gimbal angle	XXX.XX deg

3. V06 N52

Central angle of active vehicle	XXX.XX deg

ASPO 45 CRT DISPLAYS

MSK–683 (CM)
MSK–966 (CM)
MSK–1123 (LM)
MSK–1137 (LM)

CSM GNC PRIMARY TAB

GMT	______	SITE	______		
GETA	______				
CTE	______				
CMC	______				
GETC	______				
CMC ΔT	______				
ISS	______	M			
OPT	______	D			
CMC	______	E			
ID	______				

	QUADA	QUADB	QUADC	QUADD
WPU CAL C LBS	______	______	______	______
HE P/T R PCT	______	______	______	______
PKG TEMP °F	______	______	______	______
HE TK P PSIA	______	______	______	______
HE TK T °F	______	______	______	______
HE MN P PSIA	______	______	______	______
FU MN P PSIA	______	______	______	______
OX MN P PSIA	______	______	______	______

VERB	NOUN	PRGM
___	___	___

CM-RCS	SYS A	SYS B
HE TK P PSIA	______	______
HE MN P PSIA	______	______

SPS	
OX TK PSI	______
OX IN PSI	______
EG CH PSI	______
FU TK PSI	______
FU IN PSI	______
HE TK PSI	______

REG 1	______
REG 2	______
REG 3	______

— DAP —

RATE	DB
___	___

VEH ACC	______
VG X	______
VG Y	______
VG Z	______
PIPX	______
PIPY	______
PIPZ	______
TEV	______
TIG	______

	PITCH	YAW	ROLL
ISS ATT	______	______	______
ACDU	______	______	______
FCDU	______	______	______
ERR CMC	______	______	______
ERR SCS	______	______	______
RATE ENT	______	______	______
RATE G/N	______	______	______
RATE SCS	______	______	______
GMB CMD	______	______	______
OCDU DC	______	______	
SPS GMB	______	______	
AT TVC	______	______	
MN TVC	______	______	______

HE TK T °F	______
OX FD LN °F	______
FU FD LN °F	______
OX LN I °F	______
FU LN I °F	______
EG VLV °F	______
N2 T1 PSI	______
N2 T2 PSI	______
OX T1 PCT	______
OX T2 PCT	______
FU T1 PCT	______
FU T2 PCT	______

GMT	-	GREENWICH MEAN TIME	D H M S XX:XX:XX:XX
GETA	-	GROUND ELAPSED TIME ACTUAL	H M S XXXX:XX:XX
CTE	-	CENTRAL TIMING EQUIPMENT TIME	H M S XXXX:XX:XX
CMC	-	CM COMPUTER CLOCK	H M S XXXX:XX:XX
GETC	-	GROUND ELAPSED TIME COMPUTED	H M S XXXX:XX:XX
CMC ΔT	-	DIFFERENCE BETWEEN GETC AND CMC	S XXX.XXX
ISS	-	ISS MODE	OFF/TRN ON/CDU ZR/ CO ALN/FN ALN/ INERTL/CAGE
OPT	-	OPTICS MODE	OFF/ZERO/CMC/MAN
CMC	-	RCS CONTROL MODE	AUTO/HOLD/FREE/SCS
ID	-	IDENTIFICATION OF DOWNLIST BEING TRANSMITTED	
*VERB	-	DSKY VERB DISPLAY	XX
*NOUN	-	DSKY NOUN DISPLAY	XX
*PRGM	-	DSKY PROGRAM NUMBER DISPLAY	XX
REG1, REG2, REG3	-	DSKY ROWS 1, 2, AND 3	±XXXXX
RATE	-	SELECTED MAXIMUM DAP RATE	X.X DEG/SEC
DB	-	SELECTED DAP DEADBAND	X.X DEG
VEH ACC	-	VEHICLE ACCELERATION	±XXX.X FPS^2
VG X, VG Y, VG Z	-	VELOCITY TO BE GAINED IN SM COORDINATES	±XXXX. FPS

*SEE CM SOFTWARE SECTION FOR FURTHER DEFINITION

PIPX, PIPY, PIPZ	-	X, Y, AND Z PIPA COUNTS	±XXXXX COUNTS
TEV	-	TIME OF EVENT	H M S XXXX:XX:XX
TIG	-	TIME TO/FROM IGNITION	H M S XXXX:XX:XX
ISS	-	ISS RESOLVER INDICATED ATTITUDE	+XXX.X DEG
ACDU	-	ACTUAL CDU ANGLES	+XXX.X DEG
FCDU	-	FINAL DESIRED CDU ANGLES	+XXX.X DEG
ERR CMC	-	COMPUTED ATTITUDE ERRORS TO FDAI	±XX.X DEG
ERR SCS	-	SCS ATTITUDE ERRORS	±XX.X DEG
RATE ENT	-	RATES COMPUTED IN ENTRY DAP	±XX.X DEG/SEC
RATE G/N	-	DAP COMPUTED BODY RATES	±XX.X DEG/SEC
RATE SCS	-	SCS DETERMINED BODY RATES	±XX.X DEG/SEC
GMB CMD	-	COMPUTER COMMANDED SPS ENGINE COMMANDS	±XX.XX DEG
OCDU DC	-	OCDU DAC OUTPUT FOR GMB CMD	±XX.XX DEG
SPS GMB	-	SPS GIMBAL POSITION OUTPUTS FOR GMB CMD	±XX.XX DEG
AT TVC	-	SCS AUTOMATIC CONTROL SPS GIMBAL COMMANDS	±X.XX DEG
MN TVC	-	SCS MANUAL CONTROL SPS GIMBAL COMMANDS	±X.XX DEG
SITE	-	SITE FROM WHICH DATA IS BEING RECEIVED	

ID ____ GMT ____ SITE ____ X/ROLL Y/PITCH Z/YAW

CTE ____ PIPA ____ ____ ____
FGWD 0 ____ GETA ____ DELV ____ ____ ____
FGWD 1 ____ GETC ____ VGIMU ____ ____ ____
FGWD 2 ____ GETH ____
FGWD 3 ____ CMC ____ FCDU ____ ____ ____
FGWD 4 ____ TCMSV ____ DCDU ____ ____ ____
FGWD 5 ____ TLMSV ____ ACDU ____ ____ ____
FGWD 6 ____ TGO ____
FGWD 7 ____ TIG ____ ERROR ____ ____ ____
FGWD 8 ____ TEVNT ____ AK ____ ____ ____
FGWD 9 ____ ADOT ____ ____ ____
FGWD 10 ____ OMGAC ____ ____ ____
FGWD 11 ____ BIAS ____ ____ ____

PG __ FL __ WARN __
VB __ NN __ PRG __
KKK __
R1 ____ UPEST __
R2 ____ UPSW __
R3 ____ CMD __

CHNL 11 ____ MASS
CHNL 12 ____ LM ____ ACTOFF ____ ____
CHNL 13 ____ CSM ____ GMBCMD ____ ____
CHNL 14 ____
CHNL 30 ____ REDO DSTB11 ____ HAPO ____ TMRK ____
CHNL 31 ____ ____ FAILRG CDRFL HPER ____ VHFRNG NM ____
CHNL 32 ____ RSBBQ ____ ____ LAT ____ RANGE NM ____
CHNL 33 ____ ____ ____ ____ LONG ____ RRATE FPS ____
____ ____ ____ THETAH DEG ____
IMDE 30 ____ HLDFG CRSTR ____ ELEVN DEG ____
IMDE 33 ____ ____ CDH Δ ALT NM ____ OFSTPT NM ____
OPTMDE ____ RCSFG STARID1 ____ VGTIGX ____ CNTL DEG ____
DPDTR1 ____ ____ STARID2 ____ VGTIGY ____ TRNF ____
DPDTR2 ____ CDU SHFT ____ VGTIGZ ____ TTPI ____
CDU TRUN ____ TTPF ____

ID	-	IDENTIFICATION OF DOWNLIST BEING TRANSMITTED	
GMT	-	GREENWICH MEAN TIME	D H M S XX:XX:XX:XX
CTE	-	CENTRAL TIMING EQUIPMENT TIME	H M S XXXX:XX:XX
GETA	-	GROUND ELAPSED TIME (ACTUAL)	H M S XXXX:XX:XX
GETC	-	GROUND ELAPSED TIME (COMPUTED)	H M S XXXX:XX:XX
GETH	-	GROUND ELAPSED TIME (RTCC)	H M S XXXX:XX:XX
CMC	-	CM COMPUTER CLOCK	H M S XXX:XX:XX.XX
TCMSV	-	TIME OF CM STATE VECTOR	H M S XXX:XX:XX.XX
TLMSV	-	TIME OF LM STATE VECTOR	H M S XXX:XX:XX.XX
TGO	-	TIME TO CUTOFF	H M S XXX:XX:XX
TIG	-	TIME TO/FROM IGNITION	H M S XXX:XX:XX.XX
TEVNT	-	TIME OF EVENT	H M S XXX:XX:XX.XX
SITE	-	SITE FROM WHICH DATA IS BEING RECEIVED	
PIPA	-	PIPA COUNTS	±XXXXX COUNTS
DELV	-	VALUES OF PIPA'S AT LAST READING, CORRECTED FOR SCALE FACTOR ERROR AND BIAS	±XXXXX FPS
VGIMU	-	VELOCITY TO BE GAINED IN SM COORDINATES	±XXXX.X FPS
FCDU	-	FINAL DESIRED CDU ANGLES	+XXX.XX DEG
DCDU	-	DESIRED CDU ANGLES	+XXX.XX DEG
ACDU	-	ACTUAL CDU ANGLES	+XXX.XX DEG
ERROR	-	ATTITUDE ERRORS COMPUTED BY RCS DAP	±XX.XX DEG
CDRFL	-	RETURN ADDRESS INFORMATION ASSOCIATED WITH DSKY DISPLAYS	XXXXX$_8$
AK	-	RCS DAP FOLLOWING ERRORS OR TVC DAP ATTITUDE ERRORS	±XX.XX DEG

ADOT	-	DAP COMPUTED BODY RATES	XX.XX DEG/SEC
OMGAC	-	COMMANDED BODY RATES FROM CROSS PRODUCT STEERING	XX.XX DEG/SEC
BIAS	-	COMPUTED PIPA BIAS	±X.XXXX FT/SEC
*FGWD 0 - FGWD 11	-	COMPUTER FLAGWORDS 0 THRU 11	XXXXX$_8$
*CHAN 11 - CHAN 14	-	COMPUTER OUTPUT CHANNELS	XXXXX$_8$
*CHAN 30 - CHAN 33	-	COMPUTER INPUT CHANNELS	XXXXX$_8$
*IMDE30, IMDE33	-	COMPUTER IMU STATUS REGISTERS	XXXXX$_8$
*OPTMDE	-	COMPUTER OPTICS STATUS REGISTER	XXXXX$_8$
*DPDTR1, DPDTR2	-	DATA FOR DAP SELECTION AND OPERATION	XXXXX$_8$
*PG	-	COMPUTER PROGRAM NUMBER	XX
FL	-	VERB/NOUN FLASHER STATUS	
WARN	-	CMC WARNING LAMP STATUS	
PRG	-	PROGRAM ALARM LAMP STATUS	
KKK	-	UPLINK DATA STATUS	
UPFST	-	BLOCK INLINK DISCRETE STATUS	
UPSW	-	UPLINK ACCEPT/BLOCK SWITCH STATUS	
CMD	-	UPLINK TOO FAST STATUS	
*VB	-	DSKY VERB DISPLAY	XX
*NN	-	DSKY NOUN DISPLAY	XX
R1, R2, & R3	-	DSKY ROW 1, ROW 2, AND ROW 3 DISPLAYS	±XXXXX
REDO	-	NUMBER OF RESTARTS	XXXXX$_8$
RSBBQ	-	VALUE OF BBANK AND Q REGISTERS AT THE TIME OF A RESTART	XXXXX$_8$
DSTB11	-	DISPLAY TABLE OF DSKY STATUS LIGHTS X0400$_8$ = PROGRAM CAUTION, X0200$_8$ = TRACKER WARNING, X0020$_8$ = NO ATTITUDE, X0040$_8$ = GIMBAL LOCK	XXXXX$_8$
*FAIRG	-	1ST, 2ND, AND MOST RECENT ALARM CODES	XXXXX$_8$

*SEE CM SOFTWARE SECTION FOR FURTHER DEFINITION

MSK-966 (CONTINUED)

*HLDFG	STATUS OF ATTITUDE HOLD CONTROL MODE OF CSM RCS DAP	$XXXXX_8$
*RCSFG	DATA FOR RCS DAP	$XXXXX_8$
STARID1	IDENTIFICATION NUMBER OF STAR 1	XXX_8
STARID2	IDENTIFICATION NUMBER OF STAR 2	XXX_8
CDU SHFT	OPTICS SHAFT ANGLE DIVIDED BY TEN	±XX.XXX DEG
CDU TRUN	OPTICS TRUNNION ANGLE	±XX.XXX DEG
LM	PRESENT MASS OF THE LM	XXXXX LBS
CSM	PRESENT MASS OF THE CSM	XXXXX LBS
ACTOFF	SPS GIMBAL TRIMS	±XX.XXX DEG
GMBCMD	COMPUTER COMMANDED SPS ENGINE COMMANDS	±XX.XXX DEG
HAPO	ALTITUDE AT APOGEE	+XXXX.X NM
HPER	ALTITUDE AT PERIGEE	+XXXX.X NM
LAT	LATITUDE OF LANDMARK	±XX.XXX DEG
LONG	LONGITUDE OF LANDMARK	±XXX.XX DEG
CRSTR	CROSS PRODUCT STEERING CONSTANT	±X.XXXX
CDH △ ALT	DIFFERENCE IN ALTITUDE BETWEEN VEHICLES AT CDH	±XX.XX NM

VGTIGX, VGTIGY, VGTIGZ	COMPONENTS OF VELOCITY TO BE GAINED IN ECI COORDINATES	±XXXX.X FPS
TMRK	TIME OF LAST MARK (OPTICS/VHF)	H M S XXX:XX:XX.XX
VHFRNG	RANGE TO OTHER VEHICLE AS DETERMINED BY VHF RANGING SYSTEM	±XXX.XX NM
RANGE	COMPUTED RANGE TO OTHER VEHICLE	±XXX.XX NM
RRATE	COMPUTED RANGE RATE WITH RESPECT TO OTHER VEHICLE	±XXXX.X FPS
THETAH	RANGE BETWEEN PRESENT POSITION AND ESTIMATED LANDING SITE	XXX.X DEG
ELEVN	DESIRED LOS ANGLE AT TPI	±XXX.XX DEG
OFSTPT	DESIRED SEPARATION OF THE TWO VEHICLES AT RENDEZVOUS	±XXX.XX NM
CNTL ANG	ORBITAL CENTRAL ANGLE OF THE PASSIVE VEHICLE DURING TRANSFER FROM TPI TO INTERCEPT	+XXX.XX DEG
TRNF	DESIRED TRANSFER TIME FOR LAMBERT MANEUVER	H M S XXX:XX:XX.XX
TTPI	TIME OF INITIATION OF TPI MANEUVER	H M S XXX:XX:XX.XX
TTPF	TIME OF INTERCEPT	H M S XXX:XX:XX.XX

*SEE CM SOFTWARE SECTION FOR FURTHER DEFINITION

LM GUID, CONTROL AND PROP RT

AEA	LGC	PCM

1123

GET ______ MET ______

AGS ______ LGC ______ LGC FMT ______ SITE ______

TGO ______ TTF/8 ______

	ROLL/Z	PITCH/Y	YAW/X
PGNS RATE	______	______	______
RGA RATE	______	______	______
ASA RATE	______	______	______
ATT CMDS	______	______	______
LOC VER/HOR	______	______	______
RSVR GMBL	______	______	______
ICDUD ATT	______	______	______
CDUA ATT	______	______	______
IMU ATT	______	______	______
AGS ATT	______	______	______
PGNS ERR	______	______	______
AGS ERR	______	______	______
MMNT OFFSET	______	______	
AGS VEL	______	______	______
LGC DEL VEL	______	______	______
AGS DEL VEL	______	______	______

AGS ULL ______ ACT VEL ______

AUTO ___ ___ F0 ______

R ______ ATT H ___ ___ F1 ______

P ______ F2 ______

		LR		DEDA		DSKY	
Y	______	AP	______				
RR	______	VD	______	AD	______	P	___
TRK	______	RD	______	RO	__	V	___
R	______	R	______	CLR	__	N	___
RDT	______	VX	______	M	______	1	______
SH	______	VY	______		______	2	______
TR	______	VZ	______	REDO	______	3	______

GET	-	GROUND ELAPSED TIME	H M S XXX:XX:XX
MET	-	MISSION ELAPSED TIME	H M S XXX:XX:XX
AGS	-	ABORT GUIDANCE SYSTEM TIME	H M S XXX:XX:XX
LGC	-	LM GUIDANCE COMPUTER TIME	H M S XXX:XX:XX
LGC FMT	-	IDENTIFICATION OF DOWNLIST BEING TRANSMITTED	
SITE	-	IDENTIFICATION OF SITE FROM WHICH DATA IS BEING RECEIVED	
TGO	-	TIME TO GO UNTIL ENGINE CUTOFF	M S XX:XX
TTF/8	-	TIME TO GO UNTIL END OF PHASE (DESCENT PROGRAMS)	M S XX:XX
PGNS RATE	-	ROLL, PITCH, YAW DAP RATES	XX.X DEG/SEC
RGA	-	AGS BODY MOUNTED RATE GYRO OUTPUT	XX.X DEG/SEC
ASA	-	AGS ABORT SENSING ASSEMBLY BODY RATES	XX.X DEG/SEC
ATT CMDS	-	LGC ATTITUDE COMMANDS	XX.X DEG
LOC VER/HOR	-	BODY ANGLES FROM THE LOCAL VERTICAL COORDINATE SYSTEM	XX.X DEG
RSVR GMBL	-	1X RESOLVER GIMBAL ANGLES	XXX.X DEG
ICDUD ATT	-	DESIRED CDU ANGLES TO THE DAP	XXX.X DEG
CDUA ATT	-	ACTUAL CDU ANGLES	XXX.X DEG
IMU ATT	-	1X RESOLVER GIMBAL ANGLES	XXX.X DEG
AGS ATT	-	ABORT GUIDANCE SYSTEM BODY ANGLES	XXX.X DEG
PGNS ERR	-	CDU-DAC OUTPUT	XX.X DEG
AGC ERR	-	ABORT GUIDANCE SYSTEM ATTITUDE ERRORS	XXX.X DEG
MMNT OFFSET	-	ANGULAR ACCELERATION ABOUT ROLL AND PITCH	XX.X DEG/SEC^2
AGS VEL	-	ABORT GUIDANCE SYSTEM INDICATED VELOCITY	XXXX FT/SEC
LGC DEL VEL	-	PIPA OUTPUT FOR A 2 SECOND INTERVAL	XX.X FT/SEC

AGS DEL VEL	-	ABORT GUIDANCE SYSTEM MEASURED VELOCITY	XX.X FT/SEC
AGS ULL	-	ABORT GUIDANCE ULLAGE MEASUREMENT	XX.X FT/SEC
ACT VEL	-	ACCUMULATED VELOCITY ALONG THRUST	XX.X FT/SEC
AUTO	-	AUTO STABILIZATION MODE STATUS	XX/BLANK
R P Y	-	ROLL, PITCH AND YAW ACHIEVED FROM PULSES, DIRECT OR AUTO (NORM)	±XXX.X DEG
ATT H	-	ATTITUDE HOLD MODE STATUS	XX/BLANK
*F0 } ALARM CODES	-	FIRST	
*F1	-	SECOND	
*F2	-	MOST RECENT	
*RR	-	RADAR MODE FLAGWORD (RADMODES)	$XXXXX_8$
TRK	-	RADAR TRACK ENABLE	CH 12 B 14
RDT	-	RENDEZVOUS RADAR RANGE RATE	XXXX FT/SEC
R	-	RENDEZVOUS RADAR RANGE	XXX.XX NM
SH	-	RENDEZVOUS RADAR SHAFT ANGLE	±XXX DEG
TR	-	RENDEZVOUS RADAR TRUNNION ANGLE	±XXX DEG
AP	-	LANDING ANTENNA POSITION	1 OR 2
VD	-	LANDING VELOCITY DATA GOOD	GOOD/BAD
RD	-	LANDING RANGE DATA GOOD	GOOD/BAD
R	-	LANDING RADAR RANGE	X NM
V_X V_Y V_Z	-	LANDING RADAR VELOCITIES	±XXXXX FT/SEC
DEDA	-	AGS DSKY	
AD	-	ADDRESS	
RO	-	READOUT	
CLR	-	CLEAR	
M	-	REGISTER 5 DIGIT CONTENTS	
REDO	-	NUMBER OF LGC RESTARTS	
DSKY			
*P	-	PROGRAM	
*V	-	VERB	
*N	-	NOUN	
1 2 3	-	ROW 1, 2, AND 3	

*SEE LM SOFTWARE SECTION FOR FURTHER DEFINITION

1137

GET ______ LGC ______ GMT ______ AEA LGC PCM SITE ______

______ THRT ______ ROLL-R PITCH-Q YAW-P ______ D/L ______

SELECT	______	LGC ERR	___.___	___.___	___.___	WT ______	RTCC	______
DECA	______	AGS ERR	___.___	___.___	___.___	CSM ______	RATE ______	D/S
MAN THR	______	OMEGA-D	___.___	___.___	___.___	RHC ______	X-TRANS	
AUTO THR	______	OFFSET	___.___	___.___		DAP ______	______	CH 30
CMD THR	______	GMBL DR	______	______		CH 11 ______	______	CH 31
VAR ACT	______	SC	TORQ-U	TORQ-V	TORQ-P	CH 12 ______	______	CH 32
GUID CMD	______	AUTO ___	+ ___.___	+ ___.___	+ ___.___	CH 13 ______	______	CH 33
TCP	______	A/H ___	- ___.___	- ___.___	- ___.___	CH 14 ______	______	RAD

ATTITUDES

	ROLL-Z	PITCH-Y	YAW-X
LOCAL	______	______	______
CMD	______	______	______
SERVO	______	______	______
RSVR-S	______	______	______
RSVR-F	______	______	______
ACT-F	______	______	______
IDES-F	______	______	______
FDES-F	______	______	______
AGS-F	______	______	______
ΔERR-S	______	______	______

RATES

PGNS-B	______	______	______
RGA-B	______	______	______

DELTA VELOCITIES

AGS-B	______	______	______
LGC-B	______	______	______
ACT ΔV			______
PIP-S	______	______	______
SM	______	______	______

VEL GAIN

STATUS

___ DAP ___

TIG	______
TGO	______
TEVT	______
T/P	______
LGC	______
ISS	______
PGNS	______
PROG	______
FREG0	______
FREG1	______
FREG2	______
REDO	______
PROG	______
VERB	______
NOUN	______
FL	______
R1	______
R2	______
R3	______

LR

LR RNG ______ VEL ______

	LR	PGNS	AGS
VXB	______	______	______
VYB	______	______	______
VZB	______	______	______

RNG ______ ΔH ______ RNG ______

RR

RR ______ CNTRL ______ ______

DATA ______ MODE ______

	SHFT	TRUN	
______			
LGC	______	______	
RR	______	______	
ERR	______	______	
RANGE	______	______	M
RNGRT	______	______	K

POWER

800 ∿	______
3200∿	______
120V	______
BIAS	______

TEMPS

LR	______
RR	______
PIP	______

GET	- GROUND ELAPSED TIME	H M S XXX:XX:XX
LGC	- LM COMPUTER CLOCK	H M S XXX:XX:XX
GMT	- GREENWICH MEAN TIME	H M S XXX:XX:XX
SITE	- SITE FROM WHICH DATA IS BEING RECEIVED	
D/L	- DOWNLIST IDENTIFICATION	
SELECT	- THROTTLE SELECT SWITCH STATUS	AUTO/BLANK
DECA	- DESCENT THROTTLE COMMAND	±XXX.XX%
MAN THR	- MANUAL THROTTLE COMMAND	XXX%
AUTO THR	- AUTO THROTTLE COMMAND	XXX%
CMD THR	- TOTAL THROTTLE COMMAND (MAN THR + AUTO THR)	XXX%
VAR ACT	- VARIABLE ACTUATOR POSITION	XXX%
GUID CMD	- LGC COMMANDED THRUST	XXX%
TCP	- THRUST CHAMBER PRESSURE	XXX%
LGC ERR	- TOTAL OR DAP FOLLOWING ATTITUDE ERRORS	±XX.X DEG
AGS ERR	- AGS POSITIONAL ERROR	±XXX.X DEG
OMEGA-D	- DESIRED BODY RATES FOR AUTOMATIC MANEUVER	±X.XX DEG/SEC
OFFSET	- COMPUTED ANGULAR ACCELERATION ABOUT Y AND Z BODY AXES DUE TO THE ENGINE	±XX.XXX DEG/SEC^2
GMBL DR	- DIRECTION OF ENGINE BELL MOTION	±R & ±P
A/H	- ATTITUDE HOLD MODE STATUS	XX/BLANK
AUTO	- AUTO STABILIZATION MODE STATUS	XX/BLANK
+ TORQ-U, TORQ-V, TORQ-P	- CUMMULATIVE SUM OF POSITIVE COMMANDED TORQUE ABOUT CONTROL AXES U, V, AND P RESPECTIVELY	XX.XX SECS
- TORQ-U, TORQ-V, TORQ-P	- CUMMULATIVE SUM OF NEGATIVE COMMANDED TORQUE ABOUT CONTROL AXES U, V, AND P RESPECTIVELY	XX.XX SECS
WT	- MASS OF THE LM	XXXXX LBS
RTCC	- RTCC COMPUTED MASS OF THE LM OR LM + CSM	XXXXX LBS
CSM	- MASS OF THE CSM	XXXXX LBS
PIP-S	- PIPA COUNTS	$XXXXX_{10}$
RATE	- DESIRED RATES FOR AUTOMATIC MANEUVERS	±XX.X DEG/SEC
RHC	- SCALING STATUS ON RHC	NORM/FINE
X-TRANS	- RCS FUEL SYSTEM SELECTION/NUMBER OF JETS TO BE USED FOR X-TRANSLATION	A OR B/2 OR 4
*DAP	- DAP FLAGWORD (DAPBOOLS)	$XXXXX_8$
*CH 11 - CH 14	- LM COMPUTER OUTPUT CHANNELS	$XXXXX_8$
*CH 30 - CH 33	- LM COMPUTER INPUT CHANNELS	$XXXXX_8$
*RAD	- RADAR FLAGWORD (RADMODES)	$XXXXX_8$
LOCAL	- BODY ATTITUDE ABOUT LOCAL HORIZONTAL	±XXX.X DEG
CMD	- GIMBAL COMMANDS/GYRO TORQUE COMMANDS/DESIRED CDU ANGLES IN COARSE ALIGN MODE	±XXX.XX DEG
SERVO	- GIMBAL SERVO ERRORS	±XX.X VOLTS
RSVR-S	- GIMBAL RESOLVER INDICATED ANGLES	+XXX.XX DEG
RSVR-F	- GIMBAL RESOLVER INDICATED ANGLES IN FDAI COORDINATES	±XXX.XX DEG
ACT-F	- LM ATTITUDE TRANSFORMED TO FDAI COORDINATES	+XXX.XX DEG
IDES-F	- INTERMEDIATE DESIRED CDU ANGLES TRANSFORMED TO FDAI COORDINATES	+XXX.XX DEG
FDES-F	- FINAL DESIRED CDU ANGLES TRANSFORMED TO FDAI COORDINATES	+XXX.XX DEG
AGS-F	- AGS EULER ANGLES TRANSFORMED TO FDAI COORDINATES	+XXX.XX DEG
ΔERR-S	- DIFFERENCE BETWEEN PGNS EULER ANGLES AND AGS EULER ANGLES	±XX.X DEG

*SEE LM SOFTWARE SECTION FOR FURTHER DEFINITION

PGNS-B	-	DAP COMPUTED BODY RATES	±XX.XX DEG/SEC
RGA-B	-	AGS RATE GYRO OUTPUTS IN BODY COORDINATES	±XX.X DEG/SEC
AGS-B	-	AGS INDICATED LINEAR VELOCITY IN BODY COORDINATES	±XX.X FT/SEC
LGC-B	-	ACCUMULATED PIPA COUNTS WHILE SERVICER IS RUNNING IN BODY AXIS COORDINATES	±XX.X FT/SEC
ACT ΔV	-	ACTUAL DELTA V GAINED (GROUND COMPUTED)	XX.X FT/SEC
SM	-	ACCUMULATED PIPA COUNTS OVER 2 SECONDS IN STABLE MEMBER COORDINATE	±XX.X FT/SEC
DAP	-	LEFT - POSITION OF GUIDANCE AND CONTROL SWITCH	AGS/PGNS
		RIGHT - STATUS OF THE DAP	ON/OFF
TIG	-	TIME OF IGNITION	H M S XXX:XX:XX
TGO	-	TIME TO ENGINE CUTOFF	S XXXXX.
TEVT	-	TIME OF LAST/NEXT SIGNIFICANT EVENT	H M S XXX:XX:XX
T/P	-	TIME TO END OF PHASE (DESCENT ONLY)	S XXXXX.
LGC	-	LGC WARNING LAMP STATUS	
ISS	-	ISS WARNING LAMP STATUS	
PGNS	-	PGNS CAUTION LAMP STATUS	
PROG	-	PROGRAM CAUTION LAMP STATUS	
*FREG0, FREG1, FREG2	-	1ST, 2ND, AND MOST RECENT ALARM CODE	$XXXXX_8$
*REDO	-	NUMBER OF RESTARTS	$XXXXX_8$
*PROG	-	COMPUTER PROGRAM NUMBER	XX
*VERB	-	DSKY VERB DISPLAY	XX
*NOUN	-	DSKY NOUN DISPLAY	XX
FL	-	INDICATES WHETHER OR NOT VERB/NOUN FLASHER IS ON	FLSH/BLANK
*R1, R2, R3	-	DSKY ROW 1, ROW 2, AND ROW 3 DISPLAYS	±XXXXX

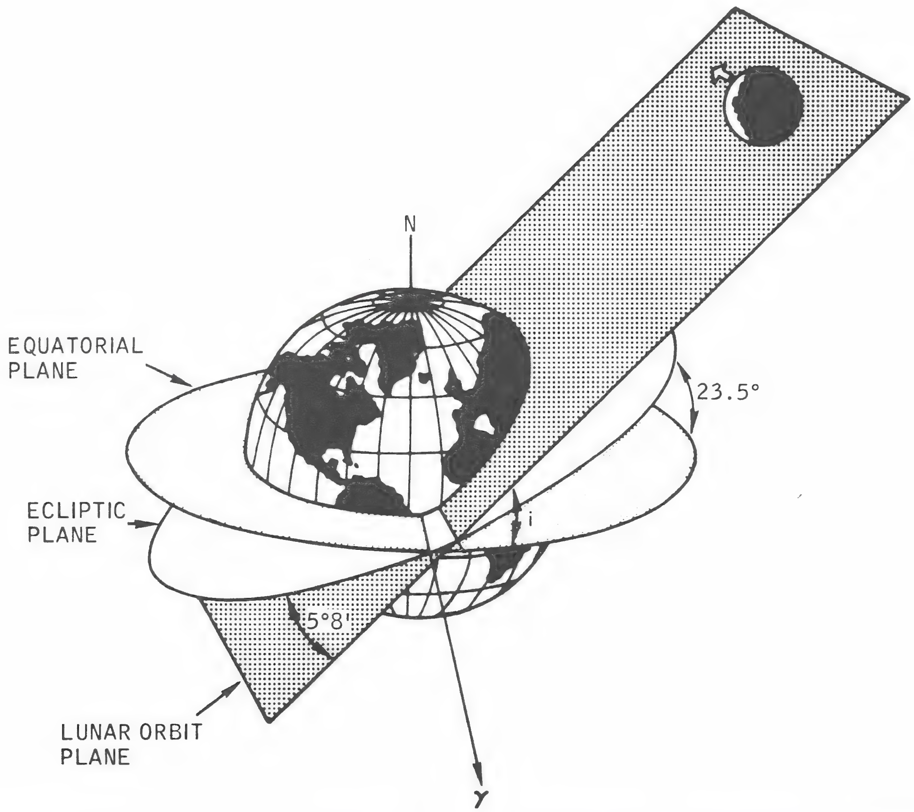
LR RNG	-	STATUS OF LANDING RADAR RANGE DATA	GOOD/BAD
VEL	-	STATUS OF LANDING RADAR VELOCITY DATA	GOOD/BAD
VXB, VYB, VZB	-	VELOCITY DATA IN BODY AXIS COORDINATES	±XXXX FT/SEC
RNG	-	LANDING RADAR SLANT RANGE ALTITUDE	XXXXX FT
ΔH	-	PGNS COMPUTED ALTITUDE	XXXXX FT
RNG	-	AGS COMPUTED ALTITUDE	XX.XX NMI
RR	-	STATUS OF RENDEZVOUS RADAR	ON/OFF
CNTRL	-	MODE STATUS OF RENDEZVOUS RADAR	AUTO/MAN
DATA	-	STATUS OF RENDEZVOUS RADAR DATA	GOOD/BAD
MODE	-	MODE STATUS OF RENDEZVOUS RADAR ANTENNA	1/2
LGC	-	RENDEZVOUS RADAR ANTENNA POSITION (CDU)	±XXX.X DEG
RR	-	RENDEZVOUS RADAR ANTENNA POSITION IN FDAI COORDINATES	±XXX.X DEG
ERR	-	COMPUTER COMMANDED RENDEZVOUS RADAR ANTENNA RATE	±XX.XX DEG/SEC
RANGE	-	RENDEZVOUS RADAR RANGE	XXX.XX NMI
RNGRT	-	RENDEZVOUS RADAR RANGE RATE	±XXXX FT/SEC
800 ∿	-	800 ∿ VOLTAGE	XX.X VOLTS
3200 ∿	-	3200 ∿ VOLTAGE	XX.X VOLTS
120V	-	120 VDC PIPA SUPPLY VOLTAGE	XXX VOLTS
BIAS	-	TM BIAS VOLTAGE	X.XX VOLTS
LR	-	LANDING RADAR ANTENNA TEMPERATURE	±XXX.X °F
RR	-	RENDEZVOUS RADAR ANTENNA TEMPERATURE	±XXX.X °F
PIP	-	PIPA TEMPERATURE	±XXX.X °F

*SEE LM SOFTWARE SECTION FOR FURTHER DEFINITION

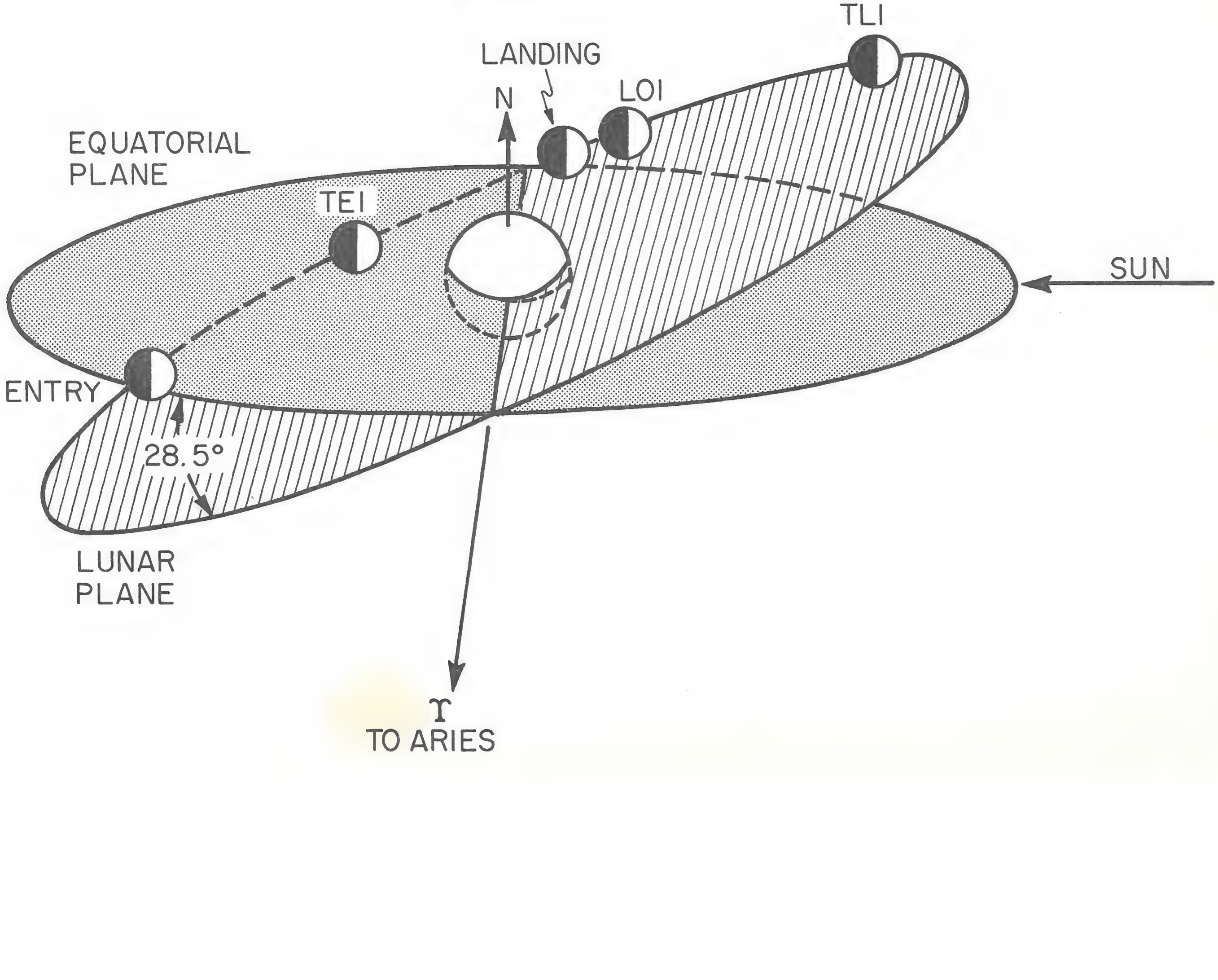
LAUNCH AND BURN SCHEDULE

STABLE MEMBER ORIENTATIONS
TRANSLUNAR INJECTION
EVASIVE MANEUVER
MIDCOURSE CORRECTIONS
LUNAR ORBIT INSERTION (LOI_1)
LUNAR ORBIT CIRCULARIZATION (LOI_2)
LM DESCENT AND LANDING
LM ASCENT AND RENDEZVOUS
TRANSEARTH INJECTION
MIDCOURSE CORRECTIONS
ENTRY

LUNAR ORBIT PLANE IN 1969
INCLINATION ANGLE (i) ~ 28 DEGREES

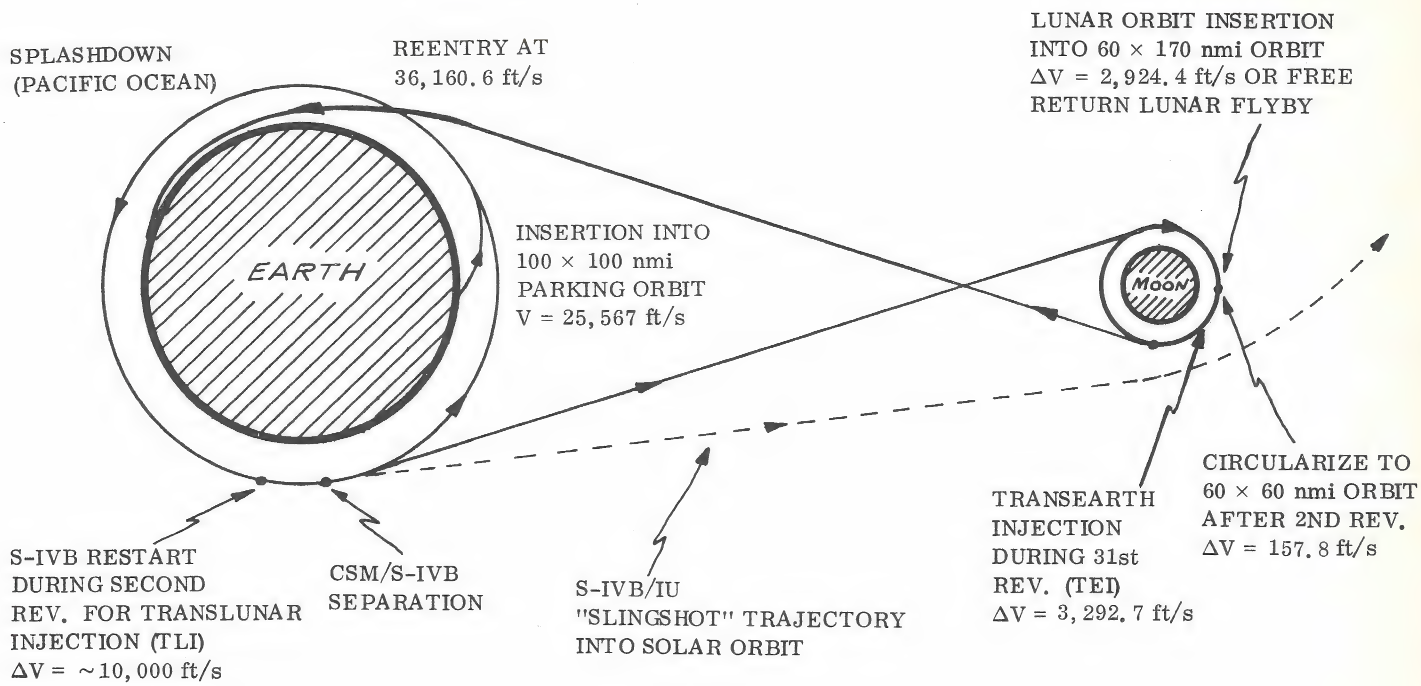


POSITION OF MOON AT VARIOUS STAGES OF APOLLO 11



APOLLO 11 MISSION PROFILE

(TYPICAL)



APOLLO 11 CSM POWERED MANEUVER SUMMARY (TYPICAL)

EVENT	TTNE (h:min:s)	PROPULSION SYSTEM	BURN DURATION (s)	ULLAGE DURATION (s)	TOTAL ΔV (ft/s)	ΔV_X	ΔV_Y	ΔV_Z	RESULTANT* rp/ra (nmi)	GUIDANCE MODE	REFSMMAT
Orbit Insertion	02:32:53	–	-	-	-	-	-	-	100/100	-	Launch Pad
TLI	00:30:00	S-IVB	321.0	-	~10,000	-	-	-	111.5/301,490	S-IVB/IU	Launch Pad
CSM Separation and Docking	01:25:20	SM RCS	-	-	0.8	-	-	-	-	-	Launch Pad
Evasive Maneuver	00:32:00	SPS	2.9	0.0	19.7	5.1	0.0	19.0	119/281,865	Ext ΔV	Launch Pad
S-IVB Slingshot	06:32:40	S-IVB	-	-	120.0	-	-	-	Solar Orbit	S-IVB/IU	-
MCC_1	15:00:00			0.0						Ext ΔV	Launch Pad
MCC_2	27:10:45	SPS/RCS		0.0	Nominally Zero					Ext ΔV	PTC
MCC_3	17:00:00			0.0						Ext ΔV	PTC
MCC_4	05:00:00			0.0						Ext ΔV	Landing Site
LOI_1	04:15:02	SPS	360.0	0.0	2,924.4	-2,892.8	-425.9	-50.3	57.6/168.2	Ext ΔV	Landing Site
LOI_2	20:30:29	SPS	16.4	14.0	157.8				52.0/64.0	Ext ΔV	Landing Site
LM/CSM Separation	06:55:34	SM RCS	8.0	-	2.3	0.0	0.0	2.3	-	Ext ΔV	Landing Site
CSM Plane Change	24:47:32	SPS	0.9	14.0	16.6	0.0	16.6	0.0	56.6/58.8	Ext ΔV	Preferred
LM Jettison and Separation	03:21:29	SM RCS	3.2	-	1.0	-1.0	0.0	0.0	-	Ext ΔV	Liftoff
TEI (Nominal)	15:00:00	SPS	149.0	14.0	3,292.7				N/A	Ext ΔV	Liftoff
MCC_5	29:38:53				Nominally Zero					Ext ΔV	PTC
MCC_6	12:00:00	SPS/RCS								Ext ΔV	PTC
MCC_7	03:00:00									Ext ΔV	Entry
Entry	-	-	-	-	-	-	-	-	-	-	Entry

* R_{Moon} = 938.5 nmi

APOLLO 11 LM POWERED MANEUVER SUMMARY (TYPICAL)

EVENT	TTNE (h:min:s)	PROPULSION SYSTEM	BURN DURATION (s)	ULLAGE DURATION (s)	TOTAL ΔV (ft/s)	ΔV_X	ΔV_Y	ΔV_Z	RESULTANT* rp/ra (nmi)	GUIDANCE MODE	REFSMMAT
DOI	56:25	LM-DPS	28.6	7.5	70.0	-70.0	0.0	0.0	7.1/58.3	Ext ΔV	Landing Site
PDI	11:53 Landing 21:48:13 Ascent	LM-DPS	712.5	7.5	6,774.9					PGNCS	Landing Site
ASCENT	57:53	LM-APS	438.0	-	6,055.4				7.4/44.1	PGNCS	Liftoff
CSI	58:18	LM-RCS	45.0	-	49.5	49.5	0.0	0.0	43.2/43.7	Ext ΔV	Liftoff
CDH	38:31	LM-RCS	1.9	-	4.3	0.0	0.0	4.3	42.6/44.1	Ext ΔV	Liftoff
TPI	41:17	LM-RCS	22.4	-	24.8	22.2	0.0	-11.1	42.1/61.2	Lambert	Liftoff
Braking Maneuvers											
1	01:13	LM-RCS	10.8	-	12.0				47.6/60.0		
2	01:38	LM-RCS	8.8	-	9.8				52.3/59.5		
3	01:19	LM-RCS	4.3	-	4.8				54.8/59.4		
4	15:25	LM-RCS	4.2	-	4.7				57.4/59.2		

*R_{Moon} = 938.5 nmi

STABLE MEMBER ORIENTATION

- IMU IS LEFT ON FOR ENTIRE FLIGHT.

- ORIENTATION OF PLATFORM

  1. LAUNCH ORIENTATION THROUGH MCC_1.
  2. PTC ORIENTATION THROUGH MCC_3.
  3. LANDING SITE REFSMMAT, FROM MCC_4 THROUGH LM TOUCHDOWN.
  4. PREFERRED THRUSTING ORIENTATION (CSM ONLY) FOR PLANE CHANGE MANEUVER.
  5. MOON LAUNCH ORIENTATION (BOTH VEHICLES) FROM LM ASCENT THROUGH TEI.
  6. PTC ORIENTATION THROUGH MCC_6.
  7. ENTRY REFSMMAT, FROM MCC_7 THROUGH ENTRY.

- REFSMMAT MATRICES

  1. LAUNCH
     U XSM = DOWNRANGE
     U YSM = U ZSM x U XSM
     U ZSM = UNIT (-r LAUNCH)

  2. PTC
     U XSM = IN THE ECLIPTIC PLANE AND PERPENDICULAR TO THE EARTH-MOON LINE PROJECTION IN THE ECLIPTIC PLANE AT THE AVERAGE TIME OF TRANS-EARTH INJECTION FOR THE MONTHLY LAUNCH WINDOW AND AZIMUTH RANGE
     U YSM = U ZSM x U XSM
     U ZSM = PERPENDICULAR TO THE ECLIPTIC PLANE AND DIRECTED SOUTH

  3. LANDING SITE
     U XSM = UNIT (r LANDING)
     U YSM = U ZSM x U XSM
     U ZSM = UNIT [(r CSM x V CSM) x U XSM]

  4. PREFERRED (THRUSTING)
     U XSM = UNIT (ΔV COMPENSATED)
     U YSM = UNIT (U XSM x r TIG)
     U ZSM = U XSM x U YSM

  5. MOON LAUNCH
     U XSM = UNIT (r LAUNCH)
     U YSM = U ZSM x U XSM
     U ZSM = UNIT [(r CSM x V CSM) x U XSM]

  6. ENTRY
     U XSM = U YSM x U ZSM
     U YSM = UNIT (V ENTRY x r ENTRY)
     U ZSM = UNIT (-r ENTRY)

P52—IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 — Preferred, 2 — Nominal,
3 — REFSMMAT, 4 — Landing Site

V51 Flashing — Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0		
+	0	0				Hours (GET)		+	0	0				
+	0	0	0			Minutes (GET)		+	0	0	0			
+	0					Seconds (GET)		+	0					
X	0	0	0			Celestial Body Code	N71	X	0	0	0			
						Star Angle Difference (degrees)	N05							
						X Gyro Torquing Angles (degrees)	N93							
						Y Gyro Torquing Angles (degrees)								
						Z Gyro Torquing Angles (degrees)								
						X Calculated Gyro Drift (meru)								
						Y Calculated Gyro Drift (meru)								
						Z Calculated Gyro Drift (meru)								

X	0	0	0	0		P52 Option		X	0	0	0	0		
+	0	0				Hours (GET)		+	0	0				
+	0	0	0			Minutes (GET)		+	0	0	0			
+	0					Seconds (GET)		+	0					
X	0	0	0			Celestial Body Code	N71	X	0	0	0			
						Star Angle Difference (degrees)	N05							
						X Gyro Torquing Angles (degrees)	N93							
						Y Gyro Torquing Angles (degrees)								
						Z Gyro Torquing Angles (degrees)								
						X Calculated Gyro Drift (meru)								
						Y Calculated Gyro Drift (meru)								
						Z Calculated Gyro Drift (meru)								

NOTES:

P47—THRUST MONITOR

V37 Enter, 47 Enter

V16 N83 Flashing, ΔV XYZ Body Axes

N62 Enter

V16 N62 Flashing, Inertial Velocity, Altitude Rate, Altitude

X						TB 6p* (h:min:s)	X					
X	X	X				R — Predicted Spacecraft IMU Gimbal Angles at TLI Ignition (degrees)	X	X	X			
X	X	X				P	X	X	X			
X	X	X				Y	X	X	X			
X	X					BT Duration of TLI (min:s)	X	X				
						ΔVC'** (ft/s)						
+						VI† (ft/s)	+					
X	X	X				R SEP — Predicted S/C IMU Gimbal Angles at Completion of S-IVB Maneuver to CSM/SIV-B Separation Attitude (degrees)	X	X	X			
X	X	X				P SEP	X	X	X			
X	X	X				Y SEP	X	X	X			
						X — ΔV ft/s — N83						
						Y						
						Z						
						V ft/s — N62						
						HDOT ft/s						
						H nmi						

*Predicted Time of Beginning of S-IVB Restart Preparation for TLI (TB6 = TLI Ignition - 9 minutes)

**Nominal TLI ΔV Set into EMS ΔV Control

†Nominal Inertial Velocity Displayed on DSKY at TLI Cutoff

EVASIVE MANEUVER

P30–EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose							
			/			Prop/Guidance					/		
						Weight (lb)	N47	+					
	0	0				P_{Trim} (degrees)	N48		0	0			
	0	0				Y_{Trim} (degrees)			0	0			
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes GETI		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X LV (ft/s)	N81						
						ΔV_Y LV (ft/s)							
						ΔV_Z LV (ft/s)							
X	X	X				R IMU Gimbal Angles (deg)		X	X	X			
X	X	X				P IMU Gimbal Angles (deg)		X	X	X			
X	X	X				Y IMU Gimbal Angles (deg)		X	X	X			
+						H_{Apogee} nmi	N42	+					
						$H_{Perigee}$ nmi							
+						ΔVT (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X						ΔVC (ft/s)		X					
X	X	X	X			SXT Star		X	X	X	X		
+					0	SFT (degrees)		+					0
+				0	0	TRN (degrees)		+				0	0
X	X	X				BSS (Coas Star)		X	X	X			
X	X					SPA (Coas Pitch, deg)		X	X				
X	X	X				SXP (Coas X Pos, deg)		X	X	X			
	0					LAT (degrees)	N61		0				
						LONG (degrees)							
+						RTGO (nmi) EMS		+					
+						VIO (ft/s)		+					
						GET 0.05 g Hr:min:s							
						SET STARS							
X	X	X				R_{Align}		X	X	X			
X	X	X				P_{Align}		X	X	X			
X	X	X				Y_{Align}		X	X	X			
						ULLAGE							

NOTES:

PRO/GUID		PROPULSION SYSTEM (SPS/RCS)/ GUIDANCE (SCS/G&N)
WT	XXXXX (lbs)	PREMANEUVER VEHICLE WEIGHT
P TRIM	X.XX (DEG)	SPS PITCH GIMBAL OFFSET TO PLACE THRUST
Y TRIM	X.XX (DEG)	SPS YAW GIMBAL OFFSET TO PLACE THRUST
GETI	XX:XX:XX (HRS:MIN:SEC)	TIME OF MNVR IGNITION
ΔVX ΔVY ΔVZ	XXXX.X (fps) XXXX.X (fps) XXXX.X (fps)	P30 VELOCITY TO BE GAINED COMPONENTS IN LOCAL VERTICAL COORDINATES
R P Y	XXX (DEG) XXX (DEG) XXX (DEG)	IMU GIMBAL ANGLES OF MANEUVER ATTITUDE
H_A	XXXX.X (nm)	PREDICTED APOGEE ALTITUDE AFTER MANEUVER
H_P	XXXX.X (nm)	PREDICTED PERIGEE ALTITUDE AFTER MANEUVER
ΔVT	XXXX.X	TOTAL VELOCITY OF MANEUVER
BT	X:XX (MIN:SEC)	MANEUVER DURATION
ΔVC	XXXX.X (fps)	PREMANEUVER ΔV SETTING IN EMS ΔV COUNTER
SXTS	XX (OCTAL)	SEXTANT STAR FOR MANEUVER ATTITUDE CK
SFT	XXX.X (DEG)	SEXTANT SHAFT SETTING FOR MANEUVER ATTITUDE CK
TRN	XX.X (DEG)	SEXTANT TRUNNION SETTING FOR MANEUVER ATTITUDE CK
BSS	XXX (OCTAL)	BORESIGHT STAR FOR MANEUVER ATTITUDE CK USING THE COAS
SPA	XX.X (DEG)	BSS PITCH ANGLE ON COAS
SXP	X.X (DEG)	BSS X POSITION ON COAS
LAT LONG	XX.XX XXX.XX	LATITUDE AND LONGITUDE OF THE LANDING POINT FOR ENTRY GUIDANCE
RTGO	XXXX.X	RANGE TO GO FOR EMS INITIALIZATION
VIO	XXXXXX (fps)	INERTIAL VELOCITY AT .05G FOR EMS INITIALIZATION
GET(.05G)	XX:XX:XX	TIME OF .05G
SET STARS		STARS FOR TELESCOPE FOR BACKUP GDC ALIGN
R, P, Y (ALIGN)		ATTITUDE TO BE SET IN ATTITUDE SET TW FOR BACKUP GDC ALIGN
ULLAGE		NO. OF SM RCS JETS USED AND LENGTH OF TIME OF USSAGE
HORIZON WINDOW		WINDOW MARKING AT WHICH HORIZON IS PLACED AT A SPECIFIED TIG (ATT CK)

P40 – SPS THRUSTING CSM

V37 Enter, 40 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V50 N25 Flashing, R1 = 0 0 2 0 4, Gimbal Actuator Test Option

V06 N40, Time from Ignition, Velocity to be Gained, Measured Change in Velocity

V99 N40 Flashing, Engine On Enable Request

V06 N40, Time from Cutoff, Velocity to be Gained, Measured Change in Velocity

V16 N40 Flashing, Final Values at Engine Cutoff

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

V37 Flashing, V82 Enter

V16 N44 Flashing, Apogee Altitude, Perigee Altitude, Time to Freefall to 35 K ft Moon Orbit, 300 K ft Earth Orbit

50-18	Roll	
	Pitch	(deg)
	Yaw	
06-18	Roll	
	Pitch	(deg)
	Yaw	
06-40	TFI (min:s)	
	VG (ft/s)	
	ΔVM (ft/s)	
06-40	TFC (min:s)	
	VG (ft/s)	
	ΔVM (ft/s)	
16-40	TFC (min:s)	
	VG (ft/s)	
	ΔVM (ft/s)	
85	X	
	Y	Residuals (ft/s)
	Z	
85	X	
	Y	TRIM (ft/s)
	Z	
44	HA (nmi)	
	HP (nmi)	
	TFF (min:s)	

P52–IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 – Preferred, 2 – Nominal,
3 – REFSMMAT, 4 – Landing Site

V51 Flashing – Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

NOTES:

P37 – RETURN TO EARTH

V37 Enter, 37 Enter

V06 N33 Flashing

    Time of Ignition (h, min, 0.01 s)

V06 N60 Flashing

    Blank, ΔV Desired, GAMMA EI Desired (ft/s, 0.01 deg)

V06 N61 Flashing

    Impact Latitude and Longitude (0.01 deg, 0.01 deg)

V06 N39 Flashing

    ΔT of Transfer (h, min, 0.01 s)

V06 N60 Flashing

    Blank, V Predicted GAMMA EI (ft/s, 0.01 deg)

V06 N81 Flashing

    ΔVX (LV), ΔVY (LV), ΔVZ (LV) at TIG (0.1 ft/s)

V04 N06 Flashing

    R1: 0 0 0 0 7

    R2: 0 0 0 0 X (1– SPS, 2–RCS)

V06 N33 Flashing

    Time of Ignition (h, min, 0.01 s)

V16 N45 Flashing

    Marks, TFI, Middle Gimbal Angle (marks, min/s, 0.01 deg)

					Time of Ignition (h, min)	N33					
X					ΔV Required (ft/s)	N60	X				
X					Longitude of Splash Point (deg)		X				
					Time of Entry Interface (h, min)						

					Time of Ignition (h, min)	N33					
X					ΔV Required (ft/s)	N60	X				
X					Longitude of Splash Point (deg)		X				
					Time of Entry Interface (h, min)						

P23—OPTICS CALIBRATION

V37 Enter, 23 Enter

V05 N70 Flashing

R1: 0 0 0 D E Star ID
R2: 0 0 0 0 0
R3: 0 0 C D 0 Hor ID C and D 1 or 2

V59 Flashing, Perform Optics Calibration

+	0	0				Hours		+	0	0			
+	0	0	0			Minutes GET		+	0	0	0		
+	0					Seconds		+	0				
+						Trun Angle Bias	N87 R2	+					
+						Trun Angle Bias	N87 R2	+					
+						Trun Angle Bias	N87 R2	+					

+	0	0				Hours		+	0	0			
+	0	0	0			Minutes GET		+	0	0	0		
+	0					Seconds		+	0				
+						Trun Angle Bias	N87 R2	+					
+						Trun Angle Bias	N87 R2	+					
+						Trun Angle Bias	N87 R2						

NOTES:

P23 CISLUNAR MIDCOURSE NAVIGATION

V37 Enter, 23 Enter

V05 N70 Flashing

R1:	0 0 0 X X	Celestial Body Code
R2:	0 0 X 0 0	0 – Horizon 1 – Earth Landmark 2 – Moon Landmark
R3:	0 0 C D 0	C = 0, D = 0 Landmark C-1 Earth Horizon C-2 Moon Horizon D-1 Near Horizon D-2 Far Horizon

V51 Flashing · Please Mark

+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

NOTES:

P23 CISLUNAR MIDCOURSE NAVIGATION

V37 Enter, 23 Enter

V05 N70 Flashing

R1:	0 0 0 X X	Celestial Body Code
R2:	0 0 X 0 0	0 – Horizon 1 – Earth Landmark 2 – Moon Landmark
R3:	0 0 C D 0	C = 0, D = 0 Landmark C-1 Earth Horizon C-2 Moon Horizon D-1 Near Horizon D-2 Far Horizon

V51 Flashing – Please Mark

+	0	0				Hours GET		+	0	0			
+	0	0	0			Minutes GET		+	0	0	0		
+	0					Seconds GET		+	0				
X	0	0	0			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

+	0	0				Hours GET		+	0	0			
+	0	0	0			Minutes GET		+	0	0	0		
+	0					Seconds GET		+	0				
X	0	0	0			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

NOTES:

P23 CISLUNAR MIDCOURSE NAVIGATION

V37 Enter, 23 Enter

V05 N70 Flashing

R1:	0 0 0 X X	Celestial Body Code
R2:	0 0 X 0 0	0 – Horizon 1 – Earth Landmark 2 – Moon Landmark
R3:	0 0 C D 0	C = 0, D = 0 Landmark C-1 Earth Horizon C-2 Moon Horizon D-1 Near Horizon D-2 Far Horizon

V51 Flashing · Please Mark

+	0	0				Hours		+	0	0			
+	0	0	0			Minutes	GET	+	0	0	0		
+	0					Seconds		+	0				
X	0	0	0			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

+	0	0				Hours		+	0	0			
+	0	0	0			Minutes	GET	+	0	0	0		
+	0					Seconds		+	0				
X	0	0	0			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

NOTES:

P23 CISLUNAR MIDCOURSE NAVIGATION

V37 Enter, 23 Enter

V05 N70 Flashing

R1:	0 0 0 X X	Celestial Body Code
R2:	0 0 X 0 0	0 – Horizon 1 – Earth Landmark 2 – Moon Landmark
R3:	0 0 C D 0	C = 0, D = 0 Landmark C-1 Earth Horizon C-2 Moon Horizon D-1 Near Horizon D-2 Far Horizon

V51 Flashing – Please Mark

+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

NOTES:

P52—IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 — Preferred, 2 — Nominal,
3 — REFSMMAT, 4 — Landing Site

V51 Flashing — Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				GET Hours		+	0	0			
+	0	0	0			GET Minutes		+	0	0	0		
+	0					GET Seconds		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						Gyro Torquing Angles (degrees) X	N93						
						Gyro Torquing Angles (degrees) Y							
						Gyro Torquing Angles (degrees) Z							
						Calculated Gyro Drift (meru) X							
						Calculated Gyro Drift (meru) Y							
						Calculated Gyro Drift (meru) Z							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				GET Hours		+	0	0			
+	0	0	0			GET Minutes		+	0	0	0		
+	0					GET Seconds		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						Gyro Torquing Angles (degrees) X	N93						
						Gyro Torquing Angles (degrees) Y							
						Gyro Torquing Angles (degrees) Z							
						Calculated Gyro Drift (meru) X							
						Calculated Gyro Drift (meru) Y							
						Calculated Gyro Drift (meru) Z							

NOTES:

MCC_1

P30—EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose							
			/			Prop/Guidance					/		
						Weight (lb)	N47	+					
	0	0				P_{Trim} (degrees)	N48		0	0			
	0	0				Y_{Trim}			0	0			
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes GETI		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X	N81						
						ΔV_Y LV							
						ΔV_Z (ft/s)							
X	X	X				R IMU Gimbal Angles (deg)		X	X	X			
X	X	X				P		X	X	X			
X	X	X				Y		X	X	X			
+						H_{Apogee} nmi	N42	+					
						$H_{Perigee}$							
+						ΔVT (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X						ΔVC (ft/s)		X					
X	X	X	X			SXT Star		X	X	X	X		
+					0	SFT (degrees)		+					0
+				0	0	TRN (degrees)		+				0	0
X	X	X				BSS (Coas Star)		X	X	X			
X	X					SPA (Coas Pitch, deg)		X	X				
X	X	X				SXP (Coas X Pos, deg)		X	X	X			
	0					LAT (degrees)	N61		0				
						LONG							
+						RTGO (nmi) EMS		+					
+						VIO (ft/s)		+					
						GET 0.05 g Hr:min:s							
						SET STARS							
X	X	X				R_{Align}		X	X	X			
X	X	X				P_{Align}		X	X	X			
X	X	X				Y_{Align}		X	X	X			
						ULLAGE							

NOTES:

P40 – SPS THRUSTING CSM

V37 Enter, 40 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V50 N25 Flashing, R1 = 0 0 2 0 4, Gimbal Actuator Test Option

V06 N40, Time from Ignition, Velocity to be Gained, Measured Change in Velocity

V99 N40 Flashing, Engine On Enable Request

V06 N40, Time from Cutoff, Velocity to be Gained, Measured Change in Velocity

V16 N40 Flashing, Final Values at Engine Cutoff

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

V37 Flashing, V82 Enter

V16 N44 Flashing, Apogee Altitude, Perigee Altitude, Time to Freefall to 35 K ft Moon Orbit, 300 K ft Earth Orbit

P41 – RCS THRUSTING

V37 Enter, 41 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y, Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V06 N85, X, Y, Z Body Axes Velocity to be Gained

V16 N85 (Average G on at TIG -30) Velocity to be Gained

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

50-18	Roll	
	Pitch	(deg)
	Yaw	
06-18	Roll	
	Pitch	(deg)
	Yaw	
06-40	TFI (min:s)	
	VG (ft/s)	
	ΔVM (ft/s)	
06-40	TFC (min:s)	
	VG (ft/s)	
	ΔVM (ft/s)	
16-40	TFC (min:s)	
	VG (ft/s)	
	ΔVM (ft/s)	
85	X	
	Y	Residuals (ft/s)
	Z	
85	X	
	Y	TRIM (ft/s)
	Z	
44	HA (nmi)	
	HP (nmi)	
	TFF (min:s)	

50-18	Roll	
	Pitch	(deg)
	Yaw	
06-18	Roll	
	Pitch	(deg)
	Yaw	
06-85	X	
	Y	VG (ft/s)
	Z	
16-85	X	
	Y	VG (ft/s)
	Z	
16-85	X	
	Y	Residuals (ft/s)
	Z	
	X	
	Y	Trim (ft/s)
	Z	

P37 – RETURN TO EARTH

V37 Enter, 37 Enter

V06 N33 Flashing

Time of Ignition (h, min, 0.01 s)

V06 N60 Flashing

Blank, ΔV Desired, GAMMA EI Desired (ft/s, 0.01 deg)

V06 N61 Flashing

Impact Latitude and Longitude (0.01 deg, 0.01 deg)

V06 N39 Flashing

ΔT of Transfer (h, min, 0.01 s)

V06 N60 Flashing

Blank, V Predicted GAMMA EI (ft/s, 0.01 deg)

V06 N81 Flashing

ΔVX (LV), ΔVY (LV), ΔVZ (LV) at TIG (0.1 ft/s)

V04 N06 Flashing

R1: 0 0 0 0 7

R2: 0 0 0 0 X (1– SPS, 2–RCS)

V06 N33 Flashing

Time of Ignition (h, min, 0.01 s)

V16 N45 Flashing

Marks, TFI, Middle Gimbal Angle (marks, min/s, 0.01 deg)

					Time of Ignition (h, min) N33						
X					ΔV Required (ft/s) N60	X					
X					Longitude of Splash Point (deg)	X					
					Time of Entry Interface (h, min)						

					Time of Ignition (h, min) N33						
X					ΔV Required (ft/s) N60	X					
X					Longitude of Splash Point (deg)	X					
					Time of Entry Interface (h, min)						

P52—IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 — Preferred, 2 — Nominal,
3 — REFSMMAT, 4 — Landing Site

V51 Flashing — Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

NOTES:

P23–OPTICS CALIBRATION

V37 Enter, 23 Enter

V05 N70 Flashing

R1: 0 0 0 D E Star ID
R2: 0 0 0 0 0
R3: 0 0 C D 0 Hor ID C and D 1 or 2

V59 Flashing, Perform Optics Calibration

+	0	0				Hours		+	0	0			
+	0	0	0			Minutes GET		+	0	0	0		
+	0					Seconds		+	0				
+						Trun Angle Bias	N87 R2	+					
+						Trun Angle Bias	N87 R2	+					
+						Trun Angle Bias	N87 R2	+					

+	0	0				Hours		+	0	0			
+	0	0	0			Minutes GET		+	0	0	0		
+	0					Seconds		+	0				
+						Trun Angle Bias	N87 R2	+					
+						Trun Angle Bias	N87 R2	+					
+						Trun Angle Bias	N87 R2						

NOTES:

P23 CISLUNAR MIDCOURSE NAVIGATION

V37 Enter, 23 Enter

V05 N70 Flashing

R1:	0 0 0 X X	Celestial Body Code
R2:	0 0 X 0 0	0 – Horizon 1 – Earth Landmark 2 – Moon Landmark
R3:	0 0 C D 0	C = 0, D = 0 Landmark C-1 Earth Horizon C-2 Moon Horizon D-1 Near Horizon D-2 Far Horizon

V51 Flashing Please Mark

+	0	0				Hours } GET		+	0	0			
+	0	0	0			Minutes } GET		+	0	0	0		
+	0					Seconds } GET		+	0				
X	0	0	0			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

+	0	0				Hours } GET		+	0	0			
+	0	0	0			Minutes } GET		+	0	0	0		
+	0					Seconds } GET		+	0				
X	0	0	0.			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

NOTES:

P23 CISLUNAR MIDCOURSE NAVIGATION

V37 Enter, 23 Enter

V05 N70 Flashing

R1:	0 0 0 X X	Celestial Body Code
R2:	0 0 X 0 0	0 – Horizon 1 – Earth Landmark 2 – Moon Landmark
R3:	0 0 C D 0	C = 0, D = 0 Landmark C-1 Earth Horizon C-2 Moon Horizon D-1 Near Horizon D-2 Far Horizon

V51 Flashing – Please Mark

+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

NOTES:

P23 CISLUNAR MIDCOURSE NAVIGATION

V37 Enter, 23 Enter

V05 N70 Flashing

R1:	0 0 0 X X	Celestial Body Code
R2:	0 0 X 0 0	0 – Horizon 1 – Earth Landmark 2 – Moon Landmark
R3:	0 0 C D 0	C = 0, D = 0 Landmark C-1 Earth Horizon C-2 Moon Horizon D-1 Near Horizon D-2 Far Horizon

V51 Flashing   Please Mark

+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

NOTES:

P23 CISLUNAR MIDCOURSE NAVIGATION

V37 Enter, 23 Enter

V05 N70 Flashing

R1:	0 0 0 X X	Celestial Body Code
R2:	0 0 X 0 0	0 – Horizon 1 – Earth Landmark 2 – Moon Landmark
R3:	0 0 C D 0	C = 0, D = 0 Landmark C-1 Earth Horizon C-2 Moon Horizon D-1 Near Horizon D-2 Far Horizon

V51 Flashing   Please Mark

+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Star ID	N71	X	0	0	0		
X	0	0		0	0	LMK ID		X	0	0		0	0
X	0	0			0	Hor ID		X	0	0			0
+						Trun Angle Degrees	N92 R2	+					
						ΔR nmi	N49						
						ΔV ft/s							

NOTES:

P52—IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 — Preferred, 2 — Nominal,
3 — REFSMMAT, 4 — Landing Site

V51 Flashing — Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

NOTES:

MCC$_2$

P30–EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose							
		/				Prop/Guidance				/			
						Weight (lb)	N47	+					
	0	0				P_{Trim} (degrees)	N48		0	0			
	0	0				Y_{Trim}			0	0			
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes GETI		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X	N81						
						ΔV_Y LV							
						ΔV_Z (ft/s)							
X	X	X				R IMU Gimbal Angles (deg)		X	X	X			
X	X	X				P		X	X	X			
X	X	X				Y		X	X	X			
+						H_{Apogee} nmi	N42	+					
						$H_{Perigee}$							
+						ΔVT (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X						ΔVC (ft/s)		X					
X	X	X	X			SXT Star		X	X	X	X		
+					0	SFT (degrees)		+					0
+				0	0	TRN (degrees)		+				0	0
X	X	X				BSS (Coas Star)		X	X	X			
X	X					SPA (Coas Pitch, deg)		X	X				
X	X	X				SXP (Coas X Pos, deg)		X	X	X			
	0					LAT (degrees)	N61		0				
						LONG							
+						RTGO (nmi) EMS		+					
+						VIO (ft/s)		+					
						GET 0.05 g Hr:min:s							
						SET STARS							
X	X	X				R_{Align}		X	X	X			
X	X	X				P_{Align}		X	X	X			
X	X	X				Y_{Align}		X	X	X			
						ULLAGE							

NOTES:

P40 – SPS THRUSTING CSM

V37 Enter, 40 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V50 N25 Flashing, R1 = 0 0 2 0 4, Gimbal Actuator Test Option

V06 N40, Time from Ignition, Velocity to be Gained, Measured Change in Velocity

V99 N40 Flashing, Engine On Enable Request

V06 N40, Time from Cutoff, Velocity to be Gained, Measured Change in Velocity

V16 N40 Flashing, Final Values at Engine Cutoff

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

V37 Flashing, V82 Enter

V16 N44 Flashing, Apogee Altitude, Perigee Altitude, Time to Freefall to 35 K ft Moon Orbit, 300 K ft Earth Orbit

	50-18	Roll	
		Pitch	(deg)
		Yaw	
	06-18	Roll	
		Pitch	(deg)
		Yaw	
	06-40	TFI (min:s)	
		VG (ft/s)	
		ΔVM (ft/s)	
	06-40	TFC (min:s)	
		VG (ft/s)	
		ΔVM (ft/s)	
	16-40	TFC (min:s)	
		VG (ft/s)	
		ΔVM (ft/s)	
	85	X	
		Y	Residuals (ft/s)
		Z	
	85	X	
		Y	TRIM (ft/s)
		Z	
	44	HA (nmi)	
		HP (nmi)	
		TFF (min:s)	

P41 – RCS THRUSTING

V37 Enter, 41 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y, Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V06 N85, X, Y, Z Body Axes Velocity to be Gained

V16 N85 (Average G on at TIG -30) Velocity to be Gained

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

	50-18	Roll	
		Pitch	(deg)
		Yaw	
	06-18	Roll	
		Pitch	(deg)
		Yaw	
	06-85	X	
		Y	VG (ft/s)
		Z	
	16-85	X	
		Y	VG (ft/s)
		Z	
	16-85	X	
		Y	Residuals (ft/s)
		Z	
	X		
	Y	Trim (ft/s)	
	Z		

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 – Preferred, 2 – Nominal,
3 – REFSMMAT, 4 – Landing Site

V51 Flashing – Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				GET: Hours		+	0	0			
+	0	0	0			GET: Minutes		+	0	0	0		
+	0					GET: Seconds		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						Gyro Torquing Angles (degrees): X	N93						
						Gyro Torquing Angles (degrees): Y							
						Gyro Torquing Angles (degrees): Z							
						Calculated Gyro Drift (meru): X							
						Calculated Gyro Drift (meru): Y							
						Calculated Gyro Drift (meru): Z							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				GET: Hours		+	0	0			
+	0	0	0			GET: Minutes		+	0	0	0		
+	0					GET: Seconds		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						Gyro Torquing Angles (degrees): X	N93						
						Gyro Torquing Angles (degrees): Y							
						Gyro Torquing Angles (degrees): Z							
						Calculated Gyro Drift (meru): X							
						Calculated Gyro Drift (meru): Y							
						Calculated Gyro Drift (meru): Z							

NOTES:

P52–IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 – Preferred, 2 – Nominal,
3 – REFSMMAT, 4 – Landing Site

V51 Flashing – Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

NOTES:

MCC_3

P30–EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose						
		/				Prop/Guidance			/			
						Weight (lb) N47	+					
	0	0				P_{Trim} (degrees) N48		0	0			
	0	0				Y_{Trim} (degrees)		0	0			
+	0	0				Hours N33	+	0	0			
+	0	0	0			Minutes GETI	+	0	0	0		
+	0					Seconds	+	0				
						ΔV_X N81						
						ΔV_Y LV						
						ΔV_Z (ft/s)						
X	X	X				R IMU Gimbal Angles (deg)	X	X	X			
X	X	X				P	X	X	X			
X	X	X				Y	X	X	X			
+						H_{Apogee} nmi N42	+					
						$H_{Perigee}$						
+						ΔVT (ft/s)	+					
X	X	X				BT (min:s)	X	X	X			
X						ΔVC (ft/s)	X					
X	X	X	X			SXT Star	X	X	X	X		
+					0	SFT (degrees)	+					0
+				0	0	TRN (degrees)	+				0	0
X	X	X				BSS (Coas Star)	X	X	X			
X	X					SPA (Coas Pitch, deg)	X	X				
X	X	X				SXP (Coas X Pos, deg)	X	X	X			
	0					LAT (degrees) N61		0				
						LONG						
+						RTGO (nmi) EMS	+					
+						VIO (ft/s)	+					
						GET 0.05 g Hr:min:s						
						SET STARS						
X	X	X				R_{Align}	X	X	X			
X	X	X				P_{Align}	X	X	X			
X	X	X				Y_{Align}	X	X	X			
						ULLAGE						

NOTES:

P40 – SPS THRUSTING CSM

V37 Enter, 40 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V50 N25 Flashing, R1 = 0 0 2 0 4, Gimbal Actuator Test Option

V06 N40, Time from Ignition, Velocity to be Gained, Measured Change in Velocity

V99 N40 Flashing, Engine On Enable Request

V06 N40, Time from Cutoff, Velocity to be Gained, Measured Change in Velocity

V16 N40 Flashing, Final Values at Engine Cutoff

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

V37 Flashing, V82 Enter

V16 N44 Flashing, Apogee Altitude, Perigee Altitude, Time to Freefall to 35 K ft Moon Orbit, 300 K ft Earth Orbit

	50-18	Roll
		Pitch (deg)
		Yaw
	06-18	Roll
		Pitch (deg)
		Yaw
	06-40	TFI (min:s)
		VG (ft/s)
		ΔVM (ft/s)
	06-40	TFC (min:s)
		VG (ft/s)
		ΔVM (ft/s)
	16-40	TFC (min:s)
		VG (ft/s)
		ΔVM (ft/s)
	85	X
		Y Residuals (ft/s)
		Z
	85	X
		Y TRIM (ft/s)
		Z
	44	HA (nmi)
		HP (nmi)
		TFF (min:s)

P41 – RCS THRUSTING

V37 Enter, 41 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y, Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V06 N85, X, Y, Z Body Axes Velocity to be Gained

V16 N85 (Average G on at TIG -30) Velocity to be Gained

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

	50-18	Roll
		Pitch (deg)
		Yaw
	06-18	Roll
		Pitch (deg)
		Yaw
	06-85	X
		Y VG (ft/s)
		Z
	16-85	X
		Y VG (ft/s)
		Z
	16-85	X
		Y Residuals (ft/s)
		Z
	X	
	Y	Trim (ft/s)
	Z	

MCC$_4$

P30–EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose							
		/				Prop/Guidance				/			
						Weight (lb)	N47	+					
	0	0				P_{Trim} (degrees)	N48		0	0			
	0	0				Y_{Trim}			0	0			
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes GETI		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X	N81						
						ΔV_Y LV							
						ΔV_Z (ft/s)							
X	X	X				R		X	X	X			
X	X	X				P IMU Gimbal Angles (deg)		X	X	X			
X	X	X				Y		X	X	X			
+						H_{Apogee} nmi	N42	+					
						$H_{Perigee}$							
+						ΔVT (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X						ΔVC (ft/s)		X					
X	X	X	X			SXT Star		X	X	X	X		
+					0	SFT (degrees)		+					0
+				0	0	TRN (degrees)		+				0	0
X	X	X				BSS (Coas Star)		X	X	X			
X	X					SPA (Coas Pitch, deg)		X	X				
X	X	X				SXP (Coas X Pos, deg)		X	X	X			
	0					LAT (degrees)	N61		0				
						LONG							
+						RTGO (nmi) EMS		+					
+						VIO (ft/s)		+					
						GET 0.05 g Hr:min:s							
						SET STARS							
X	X	X				R_{Align}		X	X	X			
X	X	X				P_{Align}		X	X	X			
X	X	X				Y_{Align}		X	X	X			
						ULLAGE							

NOTES:

P40 – SPS THRUSTING CSM

V37 Enter, 40 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V50 N25 Flashing, R1 = 0 0 2 0 4, Gimbal Actuator Test Option

V06 N40, Time from Ignition, Velocity to be Gained, Measured Change in Velocity

V99 N40 Flashing, Engine On Enable Request

V06 N40, Time from Cutoff, Velocity to be Gained, Measured Change in Velocity

V16 N40 Flashing, Final Values at Engine Cutoff

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

V37 Flashing, V82 Enter

V16 N44 Flashing, Apogee Altitude, Perigee Altitude, Time to Freefall to 35 K ft Moon Orbit, 300 K ft Earth Orbit

50-18	Roll	
	Pitch	(deg)
	Yaw	
06-18	Roll	
	Pitch	(deg)
	Yaw	
06-40	TFI (min:s)	
	VG (ft/s)	
	ΔVM (ft/s)	
06-40	TFC (min:s)	
	VG (ft/s)	
	ΔVM (ft/s)	
16-40	TFC (min:s)	
	VG (ft/s)	
	ΔVM (ft/s)	
85	X	
	Y	Residuals (ft/s)
	Z	
85	X	
	Y	TRIM (ft/s)
	Z	
44	HA (nmi)	
	HP (nmi)	
	TFF (min:s)	

P41 – RCS THRUSTING

V37 Enter, 41 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y, Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V06 N85, X, Y, Z Body Axes Velocity to be Gained

V16 N85 (Average G on at TIG -30) Velocity to be Gained

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

50-18	Roll	
	Pitch	(deg)
	Yaw	
06-18	Roll	
	Pitch	(deg)
	Yaw	
06-85	X	
	Y	VG (ft/s)
	Z	
16-85	X	
	Y	VG (ft/s)
	Z	
16-85	X	
	Y	Residuals (ft/s)
	Z	
	X	
	Y	Trim (ft/s)
	Z	

P52—IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 00001

R2: 0000X IMU Align Option

1 — Preferred, 2 — Nominal,
3 — REFSMMAT, 4 — Landing Site

V51 Flashing — Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

NOTES:

LOI_1 PAD

P30–EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose							
		/				Prop/Guidance				/			
						Weight (lb)	N47	+					
	0	0				P_{Trim} (degrees)	N48		0	0			
	0	0				Y_{Trim}			0	0			
+	0	0				Hours GETI	N33	+	0	0			
+	0	0	0			Minutes		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X LV (ft/s)	N81						
						ΔV_Y							
						ΔV_Z							
X	X	X				R IMU Gimbal Angles (deg)		X	X	X			
X	X	X				P		X	X	X			
X	X	X				Y		X	X	X			
+						H_{Apogee} nmi	N42	+					
						$H_{Perigee}$							
+						ΔVT (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X						ΔVC (ft/s)		X					
X	X	X	X			SXT Star		X	X	X	X		
+					0	SFT (degrees)		+					0
+				0	0	TRN (degrees)		+				0	0
X	X	X				BSS (Coas Star)		X	X	X			
X	X					SPA (Coas Pitch, deg)		X	X				
X	X	X				SXP (Coas X Pos, deg)		X	X	X			
	0					LAT (degrees)	N61		0				
						LONG							
+						RTGO (nmi) EMS		+					
+						VIO (ft/s)		+					
						GET 0.05 g Hr:min:s							
						SET STARS							
X	X	X				R_{Align}		X	X	X			
X	X	X				P_{Align}		X	X	X			
X	X	X				Y_{Align}		X	X	X			
						ULLAGE							

NOTES:

TEI_1

P30—EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose						
		/				Prop/Guidance			/			
						Weight (lb) N47	+					
	0	0				P_{Trim} (degrees) N48		0	0			
	0	0				Y_{Trim}		0	0			
+	0	0				Hours N33	+	0	0			
+	0	0	0			Minutes GETI	+	0	0	0		
+	0					Seconds	+	0				
						ΔV_X N81						
						ΔV_Y LV						
						ΔV_Z (ft/s)						
X	X	X				R	X	X	X			
X	X	X				P IMU Gimbal Angles (deg)	X	X	X			
X	X	X				Y	X	X	X			
+						H_{Apogee} nmi N42	+					
						$H_{Perigee}$						
+						ΔVT (ft/s)	+					
X	X	X				BT (min:s)	X	X	X			
X						ΔVC (ft/s)	X					
X	X	X	X			SXT Star	X	X	X	X		
+					0	SFT (degrees)	+					0
+				0	0	TRN (degrees)	+				0	0
X	X	X				BSS (Coas Star)	X	X	X			
X	X					SPA (Coas Pitch, deg)	X	X				
X	X	X				SXP (Coas X Pos, deg)	X	X	X			
	0					LAT (degrees) N61		0				
						LONG						
+						RTGO (nmi) EMS	+					
+						VIO (ft/s)	+					
						GET 0.05 g Hr:min:s						
						SET STARS						
X	X	X				R_{Align}	X	X	X			
X	X	X				P_{Align}	X	X	X			
X	X	X				Y_{Align}	X	X	X			
						ULLAGE						

NOTES:

TEI$_4$

P30–EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose							
		/				Prop/Guidance				/			
						Weight (lb)	N47	+					
	0	0				P_{Trim} (degrees)	N48		0	0			
	0	0				Y_{Trim} (degrees)			0	0			
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes GETI		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X LV (ft/s)	N81						
						ΔV_Y LV (ft/s)							
						ΔV_Z LV (ft/s)							
X	X	X				R IMU Gimbal Angles (deg)		X	X	X			
X	X	X				P IMU Gimbal Angles (deg)		X	X	X			
X	X	X				Y IMU Gimbal Angles (deg)		X	X	X			
+						H_{Apogee} nmi	N42	+					
						$H_{Perigee}$ nmi							
+						ΔVT (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X						ΔVC (ft/s)		X					
X	X	X	X			SXT Star		X	X	X	X		
+					0	SFT (degrees)		+					0
+				0	0	TRN (degrees)		+				0	0
X	X	X				BSS (Coas Star)		X	X	X			
X	X					SPA (Coas Pitch, deg)		X	X				
X	X	X				SXP (Coas X Pos, deg)		X	X	X			
	0					LAT (degrees)	N61		0				
						LONG (degrees)							
+						RTGO (nmi) EMS		+					
+						VIO (ft/s)		+					
						GET 0.05 g Hr:min:s							
						SET STARS							
X	X	X				R_{Align}		X	X	X			
X	X	X				P_{Align}		X	X	X			
X	X	X				Y_{Align}		X	X	X			
						ULLAGE							

NOTES:

P52—IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 — Preferred, 2 — Nominal,
3 — REFSMMAT, 4 — Landing Site

V51 Flashing — Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0		
+	0	0				Hours GET		+	0	0				
+	0	0	0			Minutes GET		+	0	0	0			
+	0					Seconds GET		+	0					
X	0	0	0			Celestial Body Code	N71	X	0	0	0			
						Star Angle Difference (degrees)	N05							
						X Gyro Torquing Angles (degrees)	N93							
						Y Gyro Torquing Angles (degrees)								
						Z Gyro Torquing Angles (degrees)								
						X Calculated Gyro Drift (meru)								
						Y Calculated Gyro Drift (meru)								
						Z Calculated Gyro Drift (meru)								

X	0	0	0	0		P52 Option		X	0	0	0	0		
+	0	0				Hours GET		+	0	0				
+	0	0	0			Minutes GET		+	0	0	0			
+	0					Seconds GET		+	0					
X	0	0	0			Celestial Body Code	N71	X	0	0	0			
						Star Angle Difference (degrees)	N05							
						X Gyro Torquing Angles (degrees)	N93							
						Y Gyro Torquing Angles (degrees)								
						Z Gyro Torquing Angles (degrees)								
						X Calculated Gyro Drift (meru)								
						Y Calculated Gyro Drift (meru)								
						Z Calculated Gyro Drift (meru)								

NOTES:

LOI_1 EXECUTION

P30–EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose							
		/				Prop/Guidance				/			
						Weight (lb)	N47	+					
	0	0				P_{Trim} (degrees)	N48		0	0			
	0	0				Y_{Trim}			0	0			
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes GETI		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X	N81						
						ΔV_Y LV							
						ΔV_Z (ft/s)							
X	X	X				R		X	X	X			
X	X	X				P IMU Gimbal Angles (deg)		X	X	X			
X	X	X				Y		X	X	X			
+						H_{Apogee} nmi	N42	+					
						$H_{Perigee}$							
+						ΔVT (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X						ΔVC (ft/s)		X					
X	X	X	X			SXT Star		X	X	X	X		
+					0	SFT (degrees)		+					0
+				0	0	TRN (degrees)		+				0	0
X	X	X				BSS (Coas Star)		X	X	X			
X	X					SPA (Coas Pitch, deg)		X	X				
X	X	X				SXP (Coas X Pos, deg)		X	X	X			
	0					LAT (degrees)	N61		0				
						LONG							
+						RTGO (nmi) EMS		+					
+						VIO (ft/s)		+					
						GET 0.05 g Hr:min:s							
						SET STARS							
X	X	X				R_{Align}		X	X	X			
X	X	X				P_{Align}		X	X	X			
X	X	X				Y_{Align}		X	X	X			
						ULLAGE							

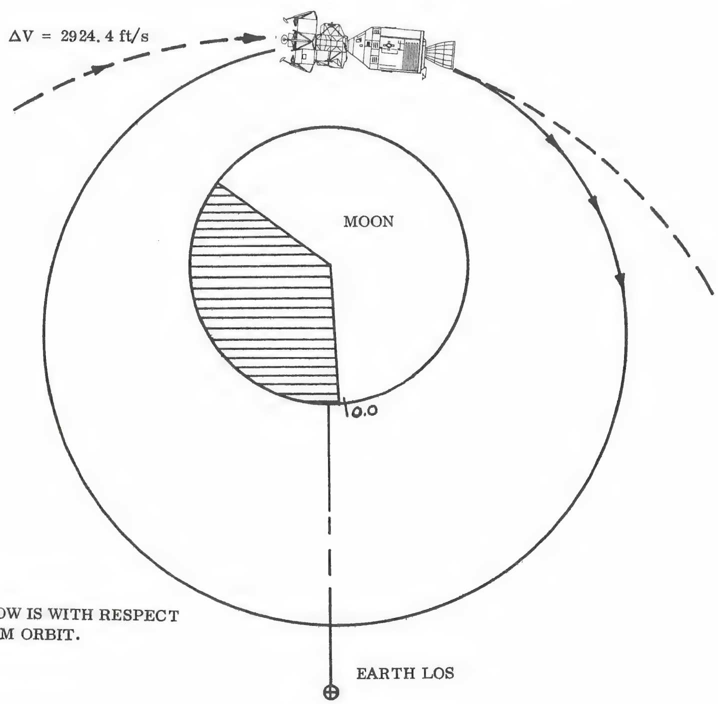
NOTES:

LUNAR ORBIT INSERTION

EVENT	BT/ΔV	TTNE	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
LOI_1 (RETROGRADE)	360.0/ 2924.4	4:15:02	SPS/G & N EXT ΔV (P-40)	P-30

					ΔV_X N85	+	X	X				h
					ΔV_Y RESIDUALS ft/s	+	X	X	X			min GET
					ΔV_Z (BODY AXIS)	+	X					s

— — — • —$V_{X_{TRIM}}$ — — — • — $V_{Y_{TRIM}}$ — — — • — $V_{Z_{TRIM}}$ ft/s



NOTE: SHADOW IS WITH RESPECT TO CSM ORBIT.

P52—IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 00001

R2: 0000X IMU Align Option

1 — Preferred, 2 — Nominal,
3 — REFSMMAT, 4 — Landing Site

V51 Flashing — Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

NOTES:

TEI$_5$

P30–EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose							
			/			Prop/Guidance					/		
						Weight (lb)	N47	+					
	0	0				P_{Trim}	N48		0	0			
	0	0				Y_{Trim} (degrees)			0	0			
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes GETI		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X	N81						
						ΔV_Y LV							
						ΔV_Z (ft/s)							
X	X	X				R		X	X	X			
X	X	X				P IMU Gimbal Angles (deg)		X	X	X			
X	X	X				Y		X	X	X			
+						H_{Apogee}	N42	+					
						$H_{Perigee}$ nmi							
+						ΔVT (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X						ΔVC (ft/s)		X					
X	X	X	X			SXT Star		X	X	X	X		
+					0	SFT (degrees)		+					0
+				0	0	TRN (degrees)		+				0	0
X	X	X				BSS (Coas Star)		X	X	X			
X	X					SPA (Coas Pitch, deg)		X	X				
X	X	X				SXP (Coas X Pos, deg)		X	X	X			
	0					LAT	N61		0				
						LONG (degrees)							
+						RTGO (nmi) EMS		+					
+						VIO (ft/s)		+					
						GET 0.05 g Hr:min:s							
						SET STARS							
X	X	X				R_{Align}		X	X	X			
X	X	X				P_{Align}		X	X	X			
X	X	X				Y_{Align}		X	X	X			
						ULLAGE							

NOTES:

LOI_2

P30–EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose							
		/				Prop/Guidance				/			
						Weight (lb)	N47	+					
	0	0				P_{Trim} (degrees)	N48		0	0			
	0	0				Y_{Trim} (degrees)			0	0			
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes GETI		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X	N81						
						ΔV_Y LV							
						ΔV_Z (ft/s)							
X	X	X				R IMU Gimbal Angles (deg)		X	X	X			
X	X	X				P IMU Gimbal Angles (deg)		X	X	X			
X	X	X				Y IMU Gimbal Angles (deg)		X	X	X			
+						H_{Apogee} nmi	N42	+					
						$H_{Perigee}$ nmi							
+						ΔVT (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X						ΔVC (ft/s)		X					
X	X	X	X			SXT Star		X	X	X	X		
+					0	SFT (degrees)		+					0
+				0	0	TRN (degrees)		+				0	0
X	X	X				BSS (Coas Star)		X	X	X			
X	X					SPA (Coas Pitch, deg)		X	X				
X	X	X				SXP (Coas X Pos, deg)		X	X	X			
	0					LAT (degrees)	N61		0				
						LONG (degrees)							
+						RTGO (nmi) EMS		+					
+						VIO (ft/s)		+					
						GET 0.05 g Hr:min:s							
						SET STARS							
X	X	X				R_{Align}		X	X	X			
X	X	X				P_{Align}		X	X	X			
X	X	X				Y_{Align}		X	X	X			
						ULLAGE							

NOTES:

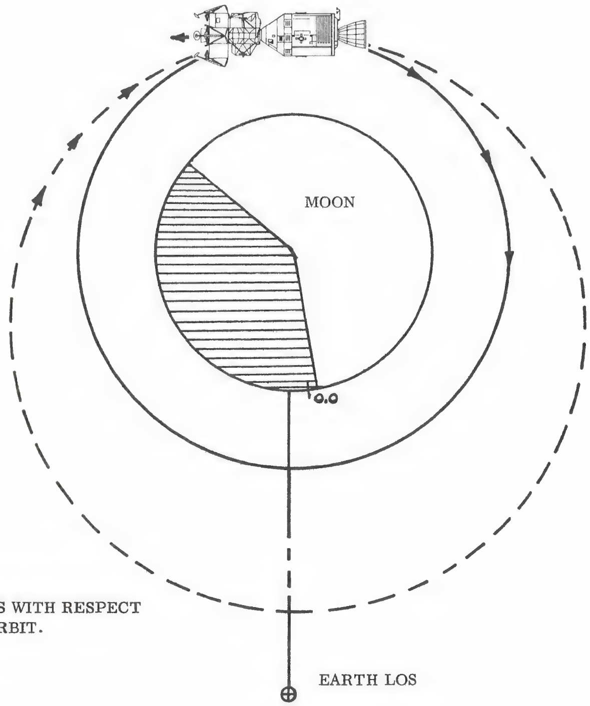
LUNAR ORBIT CIRCULARIZATION

EVENT	BT/ΔV	TTNE	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
LOI_2 (RETROGRADE)	16.4/ 157.8	20:30:29	SPS/G & N EXT ΔV (P-40)	P-30

ΔV_X	N85		+	X	X	h
ΔV_Y	RESIDUALS	ft/s	+	X	X X	min GET
ΔV_Z	(BODY AXIS)		+	X		s

$V_{X_{TRIM}}$ $V_{Y_{TRIM}}$ $V_{Z_{TRIM}}$ ft/s

ΔV = 157.8 ft/s



NOTE: SHADOW IS WITH RESPECT TO CSM ORBIT.

P22—ORBITAL NAVIGATION

V37 Enter, 22 Enter

V06 N45 Flashing, R3: Middle Gimbal Angle

V05 N70 Flashing, R2: A B 0 D E Landmark Code

A1 — Known, A2 — Unknown
B — Index of offset designator
DE — Landmark ID

V06 N89 Flashing Landmark Coordinates

- R1: Latitude
- R2: Longitude/2
- R3: Altitude

V51 Flashing — Please Mark

+	0	0				Hours		+	0	0				
+	0	0	0			Minutes	GET	+	0	0	0			
+	0					Seconds		+	0					
						LAT (+ north)	N89							
						LONG/2 (+ east)								
						ALT (nmi)								
						ΔR nmi	N49							
						ΔV ft/s								

+	0	0				Hours		+	0	0				
+	0	0	0			Minutes	GET	+	0	0	0			
+	0					Seconds		+	0					
						LAT (+ north)	N89							
						LONG/2 (+ east)								
						ALT (nmi)								
						ΔR nmi	N49							
						ΔV ft/s								

NOTES:

P22—ORBITAL NAVIGATION

V37 Enter, 22 Enter

V06 N45 Flashing, R3: Middle Gimbal Angle

V05 N70 Flashing, R2: A B 0 D E Landmark Code

A1 — Known, A2 — Unknown
B — Index of offset designator
DE — Landmark ID

V06 N89 Flashing Landmark Coordinates

R1: Latitude

R2: Longitude/2

R3: Altitude

V51 Flashing — Please Mark

+	0	0				Hours	GET	+	0	0			
+	0	0	0			Minutes		+	0	0	0		
+	0					Seconds		+	0				
						LAT (+ north)	N89						
						LONG/2 (+ east)							
						ALT (nmi)							
						ΔR nmi	N49						
						ΔV ft/s							

+	0	0				Hours	GET	+	0	0			
+	0	0	0			Minutes		+	0	0	0		
+	0					Seconds		+	0				
						LAT (+ north)	N89						
						LONG/2 (+ east)							
						ALT (nmi)							
						ΔR nmi	N49						
						ΔV ft/s							

NOTES:

P52–IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 – Preferred, 2 – Nominal,
3 – REFSMMAT, 4 – Landing Site

V51 Flashing – Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

NOTES:

TEI_{11}

P30—EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose							
		/				Prop/Guidance				/			
						Weight (lb)	N47	+					
	0	0				P_{Trim} (degrees)	N48		0	0			
	0	0				Y_{Trim}			0	0			
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes GETI		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X	N81						
						ΔV_Y LV							
						ΔV_Z (ft/s)							
X	X	X				R IMU Gimbal Angles (deg)		X	X	X			
X	X	X				P		X	X	X			
X	X	X				Y		X	X	X			
+						H_{Apogee} nmi	N42	+					
						$H_{Perigee}$							
+						ΔVT (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X						ΔVC (ft/s)		X					
X	X	X	X			SXT Star		X	X	X	X		
+					0	SFT (degrees)		+					0
+				0	0	TRN (degrees)		+				0	0
X	X	X				BSS (Coas Star)		X	X	X			
X	X					SPA (Coas Pitch, deg)		X	X				
X	X	X				SXP (Coas X Pos, deg)		X	X	X			
	0					LAT (degrees)	N61		0				
						LONG							
+						RTGO (nmi) EMS		+					
+						VIO (ft/s)		+					
						GET 0.05 g Hr:min:s							
						SET STARS							
X	X	X				R_{Align}		X	X	X			
X	X	X				P_{Align}		X	X	X			
X	X	X				Y_{Align}		X	X	X			
						ULLAGE							

NOTES:

P22–ORBITAL NAVIGATION

V37 Enter, 22 Enter

V06 N45 Flashing, R3: Middle Gimbal Angle

V05 N70 Flashing, R2: A B 0 D E Landmark Code

A1 – Known, A2 – Unknown
B – Index of offset designator
DE – Landmark ID

V06 N89 Flashing Landmark Coordinates

R1: Latitude

R2: Longitude/2

R3: Altitude

V51 Flashing – Please Mark

+	0	0				Hours	GET	+	0	0			
+	0	0	0			Minutes		+	0	0	0		
+	0					Seconds		+	0				
						LAT (+ north)	N89						
						LONG/2 (+ east)							
						ALT (nmi)							
						ΔR nmi	N49						
						ΔV ft/s							

+	0	0				Hours	GET	+	0	0			
+	0	0	0			Minutes		+	0	0	0		
+	0					Seconds		+	0				
						LAT (+ north)	N89						
						LONG/2 (+ east)							
						ALT (nmi)							
						ΔR nmi	N49						
						ΔV ft/s							

NOTES:

TEI_{28}

P30–EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose							
		/				Prop/Guidance					/		
						Weight (lb)	N47	+					
	0	0				P_{Trim} (degrees)	N48		0	0			
	0	0				Y_{Trim} (degrees)			0	0			
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes GETI		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X LV (ft/s)	N81						
						ΔV_Y LV (ft/s)							
						ΔV_Z LV (ft/s)							
X	X	X				R IMU Gimbal Angles (deg)		X	X	X			
X	X	X				P IMU Gimbal Angles (deg)		X	X	X			
X	X	X				Y IMU Gimbal Angles (deg)		X	X	X			
+						H_{Apogee} nmi	N42	+					
						$H_{Perigee}$ nmi							
+						ΔVT (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X						ΔVC (ft/s)		X					
X	X	X	X			SXT Star		X	X	X	X		
+					0	SFT (degrees)		+					0
+				0	0	TRN (degrees)		+				0	0
X	X	X				BSS (Coas Star)		X	X	X			
X	X					SPA (Coas Pitch, deg)		X	X				
X	X	X				SXP (Coas X Pos, deg)		X	X	X			
	0					LAT (degrees)	N61		0				
						LONG (degrees)							
+						RTGO (nmi) EMS		+					
+						VIO (ft/s)		+					
						GET 0.05 g Hr:min:s							
						SET STARS							
X	X	X				R_{Align}		X	X	X			
X	X	X				P_{Align}		X	X	X			
X	X	X				Y_{Align}		X	X	X			
						ULLAGE							

NOTES:

P52—IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 — Preferred, 2 — Nominal,
3 — REFSMMAT, 4 — Landing Site

V51 Flashing — Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0		
+	0	0				GET Hours		+	0	0				
+	0	0	0			GET Minutes		+	0	0	0			
+	0					GET Seconds		+	0					
X	0	0	0			Celestial Body Code	N71	X	0	0	0			
						Star Angle Difference (degrees)	N05							
						Gyro Torquing Angles (degrees) X	N93							
						Gyro Torquing Angles (degrees) Y								
						Gyro Torquing Angles (degrees) Z								
						Calculated Gyro Drift (meru) X								
						Calculated Gyro Drift (meru) Y								
						Calculated Gyro Drift (meru) Z								

X	0	0	0	0		P52 Option		X	0	0	0	0		
+	0	0				GET Hours		+	0	0				
+	0	0	0			GET Minutes		+	0	0	0			
+	0					GET Seconds		+	0					
X	0	0	0			Celestial Body Code	N71	X	0	0	0			
						Star Angle Difference (degrees)	N05							
						Gyro Torquing Angles (degrees) X	N93							
						Gyro Torquing Angles (degrees) Y								
						Gyro Torquing Angles (degrees) Z								
						Calculated Gyro Drift (meru) X								
						Calculated Gyro Drift (meru) Y								
						Calculated Gyro Drift (meru) Z								

NOTES:

CSM RENDEZVOUS RESCUE PAD

CSM SEP PAD

33	:	:	
81	X	X	2.5
22	0	18	0

CSI

11	:	:	
81	.	.	.
N			

CSM RESCUE ONE

33	:	:	
81	.	X	X
22	180		0
ΔV_c	.	X	X
11	:	:	
37	:	:	

CDH

13	:	:	
81	.	.	.

DOI P76 PAD

33	:	:	
84	.	.	.

TPI

37	:	:	
81	.	.	.
59	.	.	.

11	GETI	XX:XX:XX	Time of Ignition of CSI (h:min:s)
13	GETI	XX:XX:XX	Time of Ignition of CDH (h:min:s)
22	R P Y	XXX.XX (deg) XXX.XX (deg) XXX.XX (deg)	New ICDU Angles
33	GETI	XX:XX:XX	Time of Ignition (h:min:s)
37	GETI	XX:XX:XX	Time of Ignition of TPI (h:min:s)
59	Delta V LOS 1 Delta V LOS 2 Delta V LOS 3	XX.X (ft/s) XX.X (ft/s) XX.X (ft/s)	Delta V Line of Sight Components
81	Delta VX Delta VY Delta VZ	XX.X (ft/s) XX.X (ft/s) XX.X (ft/s)	Local Vertical Components of Velocity
84	Delta VX (0 VEH) Delta VY (0 VEH) Delta VZ (0 VEH)	XX.X (ft/s) XX.X (ft/s) XX.X (ft/s)	Components of ΔV Applied Along Local Vertical Axis at TIG
	N	XX	The Future Apsidal Crossing (Apolune or Perilune) of the Active Vehicle at Which CDH Should Occur
	ΔV_c	XX.X (ft/s)	Velocity to be Set in EMS Counter

SEPARATION

P30—EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose						
		/				Prop/Guidance			/			
						Weight (lb) N47	+					
	0	0				P_{Trim} (degrees) N48		0	0			
	0	0				Y_{Trim} (degrees)		0	0			
+	0	0				Hours GETI N33	+	0	0			
+	0	0	0			Minutes GETI	+	0	0	0		
+	0					Seconds GETI	+	0				
						ΔV_X LV (ft/s) N81						
						ΔV_Y LV (ft/s)						
						ΔV_Z LV (ft/s)						
X	X	X				R IMU Gimbal Angles (deg)	X	X	X			
X	X	X				P IMU Gimbal Angles (deg)	X	X	X			
X	X	X				Y IMU Gimbal Angles (deg)	X	X	X			
+						H_{Apogee} nmi N42	+					
						$H_{Perigee}$ nmi						
+						ΔVT (ft/s)	+					
X	X	X				BT (min:s)	X	X	X			
X						ΔVC (ft/s)	X					
X	X	X	X			SXT Star	X	X	X	X		
+					0	SFT (degrees)	+					0
+				0	0	TRN (degrees)	+				0	0
X	X	X				BSS (Coas Star)	X	X	X			
X	X					SPA (Coas Pitch, deg)	X	X				
X	X	X				SXP (Coas X Pos, deg)	X	X	X			
	0					LAT (degrees) N61		0				
						LONG (degrees)						
+						RTGO (nmi) EMS	+					
+						VIO (ft/s)	+					
						GET 0.05 g Hr:min:s						
						SET STARS						
X	X	X				R_{Align}	X	X	X			
X	X	X				P_{Align}	X	X	X			
X	X	X				Y_{Align}	X	X	X			
						ULLAGE						

NOTES:

DOI

P30 -- EXTERNAL ΔV (LM)

V37 Enter, 30 Enter
V06 N33 Flashing, Load Desired GETI
V06 N81 Flashing, Load Desired ΔV

						Purpose							
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes GETI		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X	N81						
						ΔV_Y LV							
						ΔV_Z (ft/s)							
+						ΔVR (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X	X	X				R FDAI Inertial Angles		X	X	X			
X	X	X				P (degrees)		X	X	X			
						ΔV_X AGS	N86						
						ΔV_Y Targeting (ft/s)							
						ΔV_Z							
X	X	X	X			COAS Star		X	X	X	X		
X	X					COAS Az (degrees)		X	X				
X	X					COAS EL (degrees)		X	X				
+						H_{Apogee}	N42	+					
						$H_{Perigee}$ (nmi)							
+						ΔVT (ft/s)		+					

NOTES:

P63—BRAKING PHASE

V37 Enter, 63 Enter

V06 N61 Flashing

TG, TFI, crossrange (min/s, min/s, 0.1 nmi)

V50 N25 Flashing

R1: 0 0 0 1 4 Fine align option

V50 N25 Flashing

R1: 0 0 5 0 0 (position LR to Position 1)

V50 N25 Flashing

R1: 0 0 2 0 3 (switch Guidance Control to PGNS, Mode to Auto, Thrust Control to Auto)

V06 N62 Flashing

Inertial velocity, time from ignition, ΔV (accumulated) (0.1 ft/s, min/s, 0.1 ft/s)

V99 N62 Flashing

Enable on enable

V06 N63 Flashing

Inertial velocity, HDOT, H (0.1 ft/s, 0.1 ft/s, ft)

V16 N68

Slant range, TG, LR Alt - computed altitude (0.1 nmi, min/s, ft)

+	0	0				Hours	TIG for PDI		+	0	0			
+	0	0	0			Minutes			+	0	0	0		
+	0					Seconds			+	0				
X	0					min:s	TGO	N61	X	0				
						nmi	Crossrange							
+	0	0				Roll	FDAI inertial angles at PDI (deg)		+	0	0			
+	0	0				Pitch			+	0	0			
+	0	0				Yaw			+	0	0			

P41 — RCS THRUSTING

V37 Enter, 41 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V06 N85, X, Y, Z Body Axes Velocity to be Gained

V16 N85 (Average G on at TIG -30) Velocity to be Gained

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

						50-18	Roll								
							Pitch	(deg)							
							Yaw								
						06-18	Roll								
							Pitch	(deg)							
							Yaw								
						06-85	X								
							Y	VG (ft/s)							
							Z								
						16-85	X								
							Y	VG (ft/s)							
							Z								
						16-85	X								
							Y	Residuals (ft/s)							
							Z								
						X									
						Y	Trim (ft/s)								
						Z									

P52—IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 — Preferred, 2 — Nominal,
3 — REFSMMAT, 4 — Landing Site

V51 Flashing — Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						Gyro Torquing Angles (degrees) X	N93						
						Gyro Torquing Angles (degrees) Y							
						Gyro Torquing Angles (degrees) Z							
						Calculated Gyro Drift (meru) X							
						Calculated Gyro Drift (meru) Y							
						Calculated Gyro Drift (meru) Z							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						Gyro Torquing Angles (degrees) X	N93						
						Gyro Torquing Angles (degrees) Y							
						Gyro Torquing Angles (degrees) Z							
						Calculated Gyro Drift (meru) X							
						Calculated Gyro Drift (meru) Y							
						Calculated Gyro Drift (meru) Z							

NOTES:

P52–IMU REALIGN (LM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 – Preferred, 2 – Nominal
3 – REFSMMAT, 4 – Landing Site

V01 N70 Flashing

R1: 0 0 C D E

C – AOT Detent
1 – L, 2 – F, 3 – R
4 – Any Rear, 5 – COAS
DE – Celestial Body Code

V51 Flashing – Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0				AOT Detent and Star ID	N71	X	0	0			
						Star Angle Difference (degrees)	N05						
						X – Gyro Torquing Angles (degrees)	N93						
						Y – Gyro Torquing Angles (degrees)							
						Z – Gyro Torquing Angles (degrees)							
						X – Calculated Gyro Drift (meru)							
						Y – Calculated Gyro Drift (meru)							
						Z – Calculated Gyro Drift (meru)							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0				AOT Detent and Star ID	N71	X	0	0			
						Star Angle Difference (degrees)	N05						
						X – Gyro Torquing Angles (degrees)	N93						
						Y – Gyro Torquing Angles (degrees)							
						Z – Gyro Torquing Angles (degrees)							
						X – Calculated Gyro Drift (meru)							
						Y – Calculated Gyro Drift (meru)							
						Z – Calculated Gyro Drift (meru)							

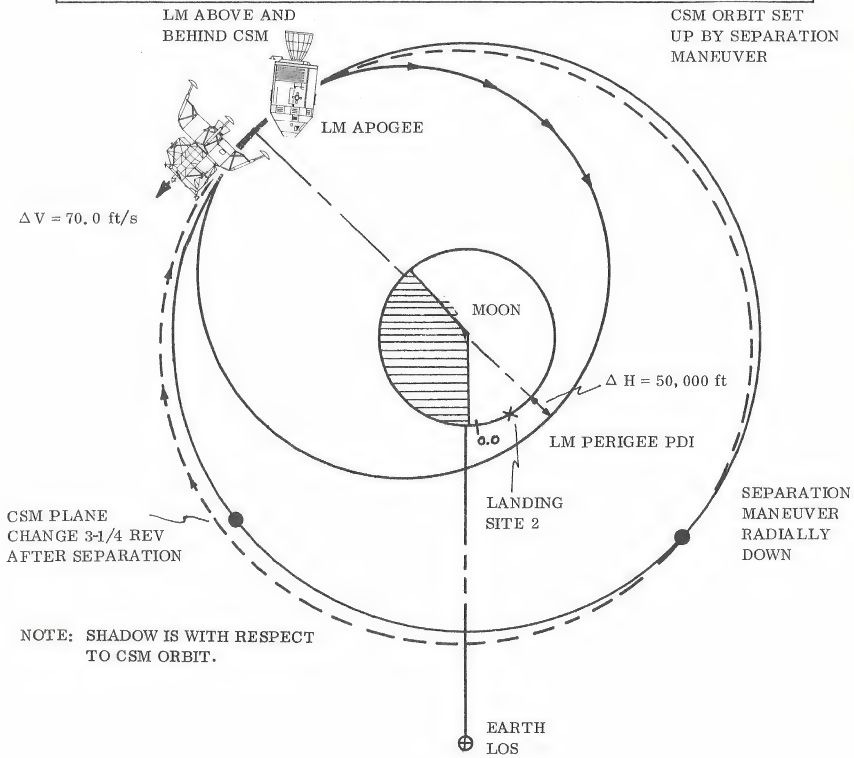
NOTES:

LUNAR SURFACE PAD

0	0				Hours	Liftoff Time Touchdown +11 minutes	0	0			
0	0	0			Minutes		0	0	0		
0					Seconds		0				
0	0				Hours	Liftoff Time Touchdown +1 Revolution	0	0			
0	0	0			Minutes		0	0	0		
0					Seconds		0				
0	0				Hours	CSM Period	0	0			
0	0	0			Minutes		0	0	0		
0	0	0			Seconds		0	0	0		
0	0				Hours	CSM Period Plus the Time Interval Between Closest Approach and Lift-off Time	0	0			
0	0	0			Minutes		0	0	0		
0	0	0			Seconds		0	0	0		
0	0				Hours	Time of Ignition for TPI after Abort from Power Descent	0	0			
0	0	0			Minutes		0	0	0		
0					Seconds		0				

DESCENT ORBIT INITIATION

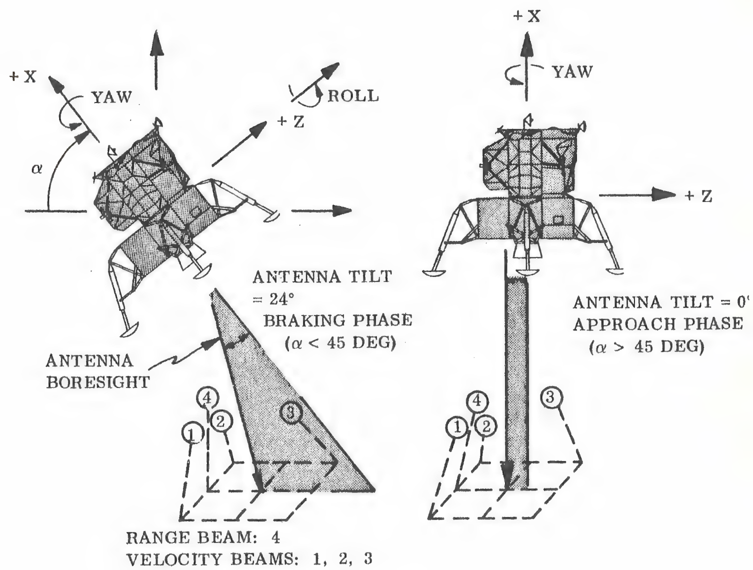
EVENT	BT/ΔV	TTNE	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
DOI (RETROGRADE)	28.6/ 70.0	56:25	LM-DPS/PGNS EXT ΔV (P-40)	P-30
	ΔV_X N85		+ X X	h
	ΔV_Y RESIDUALS ft/s		+ X X X	min GET
	ΔV_Z (BODY AXIS)		+ X	s
$V_{X_{TRIM}}$	$V_{Y_{TRIM}}$	$V_{Z_{TRIM}}$ ft/s		

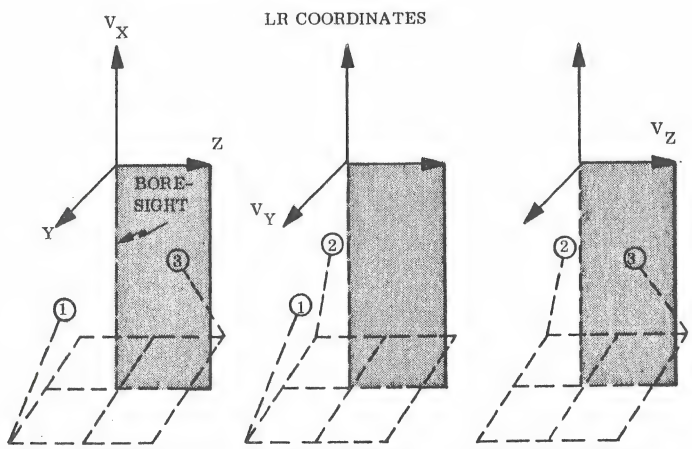


LUNAR LANDING, STAY, AND ASCENT PROGRAMS

- P63 LUNAR LANDING BRAKING PHASE
- P64 LUNAR LANDING APPROACH OR VISIBILITY PHASE
- P65 AUTOMATIC TERMINAL LANDING PHASE
  1. P66 SEMIAUTOMATIC LANDING (RATE OF DESCENT)
  2. P67 MANUAL LANDING PROGRAM
- P68 LANDING CONFIRMATION PROGRAM
- P57 LUNAR SURFACE ALIGNMENT PROGRAM
- P22 LUNAR SURFACE NAVIGATION PROGRAM
- P12 ASCENT PROGRAM
- P20 RENDEZVOUS NAVIGATION
- P32 (CSI), P33 (CDH), P34 (TPI), P35 (TPM) RENDEZVOUS PROGRAMS

LANDING RADAR BEAM CONFIGURATION





$V_X = (D_1 + D_3) K_1$ $V_Y = (D_1 - D_2) K_2$ $V_Z = (D_3 - D_2) K_3$

K_1, K_2, K_3 = VELOCITY BEAM TO BORESIGHT GEOMETRY

LUNAR DESCENT
STATE VECTOR UPDATE ROUTINE

The LM state vector is updated during lunar descent by a recursive filtering process. The state vector extrapolation process is accomplished using PIPA data starting with the DPS ullage and trim and continuing throughout the powered descent maneuver. The state vector updating process is accomplished using Landing Radar range and velocity data subject to the following constraints.

Conditions necessary to update state using LR range data:

- Estimated LM altitude is less than 50,000 feet.
- Landing Radar is not being switched from Position No. 1 to Position No. 2.
- Range data measurement tests are satisfied.
  - Data Good discrete has been present for 4 seconds or more.
  - LR range scale has not been changed within last second.
- Measurement residual (δq) is within specified limits $|\delta q| \leq$ DELQFIX* + 0.125 (q').
- Astronaut approval for updating has been given (V57).

Conditions necessary to update state using LR velocity data:

- Estimated velocity is less than 2,000 ft/s.
- Landing Radar is not being switched from Position No. 1 to Position 2.
- Velocity data measurement tests are satisfied:
  - Data Good discrete has been present for at least 4 seconds.
- Measurement residual is within specified limits $|\delta q_u| \leq 7.5 + 0.125\ (\underline{V}'_u - \underline{\omega}_p \times \underline{r}_p)$.
- Astronaut approval for updating has been given (V57).

*DELQFIX = 200 ft

STATE VECTOR EXTRAPOLATION

State vector extrapolation is accomplished by an Average G routine at 2-second intervals coincident with PIPA ΔV processing.

LM position vector ($\underline{r}_p$) is extrapolated assuming constant velocity and acceleration over the 2-second interval

$$r = r_0 + v_0 \Delta t + \frac{1}{2} a \Delta t^2$$

$$\underline{r}_p = \underline{r}_{n-1} + \underline{v}_{n-1}(t_n - t_{n-1}) + \frac{\Delta \underline{\tilde{v}}_p}{2} \Delta t + \frac{\underline{g}_{n-1}}{2} \Delta t^2$$

where

$\underline{r}_{n-1}$ = position vector ($\underline{r}_p$) at end of previous interval

$\underline{v}_{n-1}$ = velocity vector ($\underline{v}_p$) at end of previous interval

$\Delta \underline{\tilde{v}}_p$ = accumulated PIPA ΔV pulses during 2-second interval

$\underline{g}_{n-1}$ = lunar gravitational acceleration at end of previous interval

LM velocity vector ($\underline{v}_p$) is extrapolated using PIPA ΔV pulses and the average gravitational acceleration over the 2-second interval

$$v = v_0 + a \Delta t$$

$$\underline{v}_p = \underline{v}_{n-1} + \Delta \underline{\tilde{v}}_p + \left[\frac{\underline{g}_{n-1} + \underline{g}_p}{2} \right] \Delta t$$

where

$\underline{v}_{n-1}$ = velocity ($\underline{v}_p$) at end of previous interval

$\Delta \underline{\tilde{v}}_p$ = accumulated PIPA ΔV pulses over 2-second interval

$\underline{g}_{n-1}$ = lunar gravitational acceleration at end of previous interval

$\underline{g}_p$ = lunar gravitational acceleration at end of present interval

$$\underline{g}_p = \frac{-\mu M}{r_p^3} \underline{r}_p$$

In addition to the state vector update, the following terms are computed

Altitude $\quad h' = r_p - r_{Ls}$

where

r_p = magnitude of position, $\underline{r}_p$

r_{LS} = magnitude of landing site, $\underline{r}_{LS}$

Velocity $\quad v' = |\underline{v}_p|$

Mass $\quad m_n = m_{n-1} - |\Delta \underline{\tilde{v}}_p| \, m_{n-1} / V_e$ (V_e = Exhaust Velocity Constant)

Velocity Increment $\quad \Delta V = \Delta V + |\Delta \underline{\tilde{v}}_p|$

UPDATE THE STATE VECTOR USING LR RANGE DATA

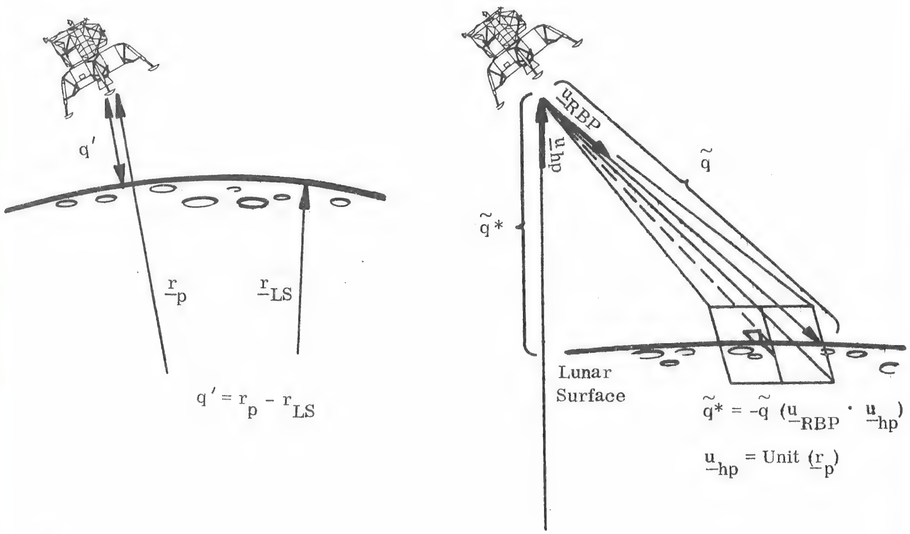
- Compute the measurement residual

$$\delta q = \tilde{q}^* - q'$$

where

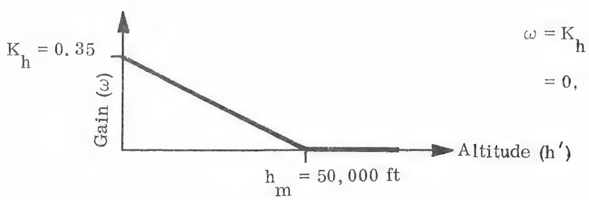
$\tilde{q}^*$ = altitude derived from LR slant range

q' = estimated altitude



- Update the position vector using the precomputed gain and measurement residual

$$\underline{r}_p = \underline{r}_p + \omega\,\delta q\,\underline{u}_{hp}$$

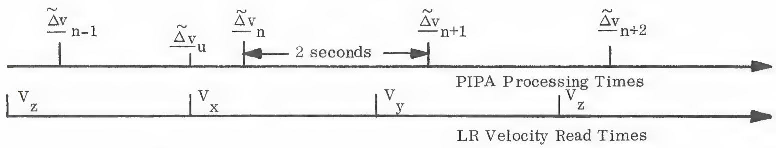


$$\omega = K_h \left(1 - \frac{h'}{h_m}\right),\quad h' \le h_m$$

$$= 0,\quad h' > h_m$$

UPDATE THE STATE VECTOR USING LR VELOCITY DATA

The Landing Radar has three velocity components. They are used (one during each 2-second interval) to update state according to the time line shown below.



$\tilde{q}_u = V_x$ $\quad$ $\tilde{q}_u = V_y$ $\quad$ $\tilde{q}_u = V_z$

$\underline{u}_{AP_u} = [C_{PB_u}]\, \underline{u}_x$ $\quad$ $\underline{u}_{AP_u} = [C_{PB_u}]\, \underline{u}_y$ $\quad$ $\underline{u}_{AP_u} = [C_{PB_u}]\, \underline{u}_z$

- Compute the measurement residual corresponding to the time that the velocity data is read (t_u).

$\delta q = \tilde{q}_u - q'_u$

$\tilde{q}_u$ = LR velocity component read at time t_u

q'_u = estimated component of LM relative velocity in the direction of $\tilde{q}_u$

$q'_u = (\underline{v}'_u - \omega_p \times \underline{r}_p) \cdot \underline{u}_{AP_u}$

where

$\underline{\omega}_p \times \underline{r}_p$ = velocity of lunar surface

$\underline{u}_{AP_u}$ = unit vector in direction of LM velocity data

$\underline{v}'_u - \underline{\omega}_p \times \underline{r}_p$ = velocity of LM relative to lunar surface

$\underline{v}'_u$ = estimated LM velocity at time t_u

$\underline{v}'_u = \underline{v}_{n-1} + \tilde{\Delta \underline{v}}_u + \underline{g}_{n-1}(t_u - t_{n-1})$

where

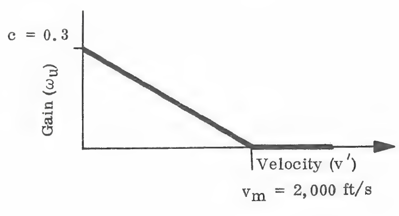
$\underline{v}_{n-1}$ = LM velocity at end of previous update cycle

$\Delta\tilde{\underline{v}}_u$ = PIPA ΔV read at time of LR velocity data t_u

$\underline{g}_{n-1}$ = lunar gravitational acceleration at end of previous cycle

- Update the LM velocity vector at time t_n using measurement residual and extrapolate velocity ($\underline{v}_p$)

$\underline{v}_p = \underline{v}_p + \omega_u \,\delta q\, \underline{u}_{AP_u}$



$\omega_u = 0, \; v' > v_m$

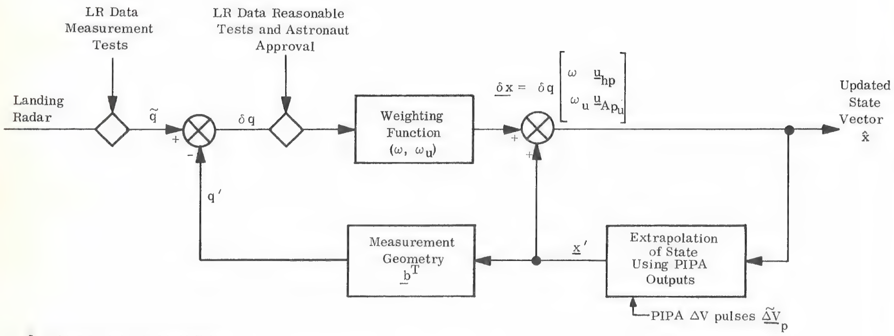
$\omega_u = c\,(1 - v'/v_m), \; v' \le v_m$

$c = K_{vx}, \; \tilde{q}_u = V_x$

$= K_{vy}, \; \tilde{q}_u = V_y$

$= K_{vz}, \; \tilde{q}_u = V_z$

LUNAR DESCENT – STATE VECTOR UPDATE ROUTINE
RECURSIVE FILTER BLOCK DIAGRAM



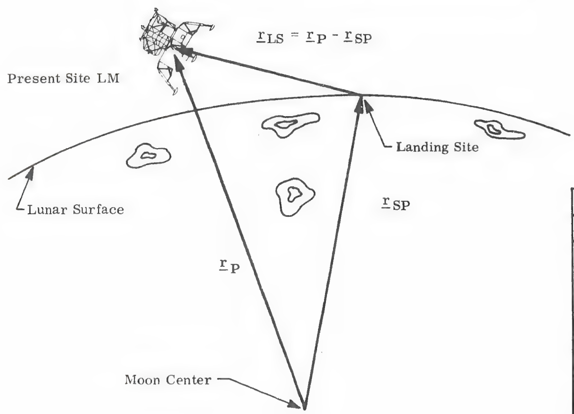
- State Vector Extrapolation

$$\underline{x}' = \begin{bmatrix} \underline{r}_p \\ \underline{V}_p \end{bmatrix} = \begin{bmatrix} \underline{r}_{n-1} + (t_n - t_{n-1})\left(\underline{V}_{n-1} + \dfrac{\Delta \underline{V}_p}{2} + \dfrac{\underline{g}_{n-1}}{2}\,\Delta t\right) \\ \underline{V}_{n-1} + \Delta\underline{\tilde{V}}_p + (\underline{g}_p + \underline{g}_{n-1})\,\dfrac{\Delta t}{2} \end{bmatrix}$$

- State Vector Update Using LR Data

$$\underline{\hat{x}} = \begin{bmatrix} \underline{r}_p \\ \underline{V}_p \end{bmatrix} + \begin{bmatrix} \delta q_h \;\; \omega \;\; \underline{u}_{hp} \\ \delta q_u \;\; \omega_u \;\; \underline{u}_{AP_u} \end{bmatrix}$$

LUNAR GUIDANCE EQUATIONS



Target State (Guidance Coordinate Frame)				
		P63	P64	P65
r_D	X	171.8 ft	111	0
	Y	0 ft	0	0
	Z	-10,678 ft	-26.8	0
v_D	X	-105.8	-5.0	-3.0
	Y	0	0	0
	Z	-1.04	0.25	0
a_D	X	0.624	-0.26	0
	Y	0	0	0
	Z	-9.1	0.51	

P63 AND P64 QUADRATIC MODE

SPECIFIC FORCE $\underline{S}_P = \ddot{\underline{r}}_{LSP} - \frac{\mu_m}{r_P^3}\underline{r}_P = \underline{a}_D - 6(\dot{\underline{r}}_{LS} + \underline{v}_D)/T_{GO} - 12(\underline{r}_{LS} - \underline{r}_D)/T_{GO}^2 - \frac{\mu_m}{r_P^3}\underline{r}_P$

P65 VELOCITY FOLLOWING MODE

SPECIFIC FORCE $\underline{S}_P = \ddot{\underline{r}}_{LSP} - \frac{\mu_m}{r_P^3}\underline{r}_P = (\dot{\underline{r}}_{LS} - \underline{v}_D)/\tau - \frac{\mu_m}{r_P^3}\underline{r}_P$

$\underline{S}_P$ IS THE COMMANDED SPECIFIC FORCE

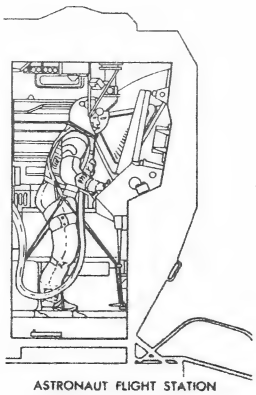
WHERE:

T_{GO} = ESTIMATE OF TIME REMAINING PRIOR TO REACHING TARGET STATE

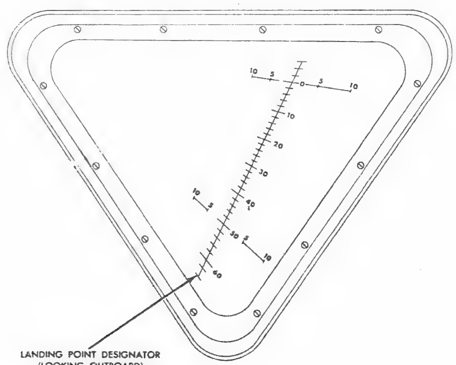
τ = CONSTANT WHICH CONTROLS RATE AT WHICH DESIRED VELOCITY IS REACHED

μ_m = LUNAR GRAVITATIONAL CONSTANT

LANDING POINT DESIGNATION

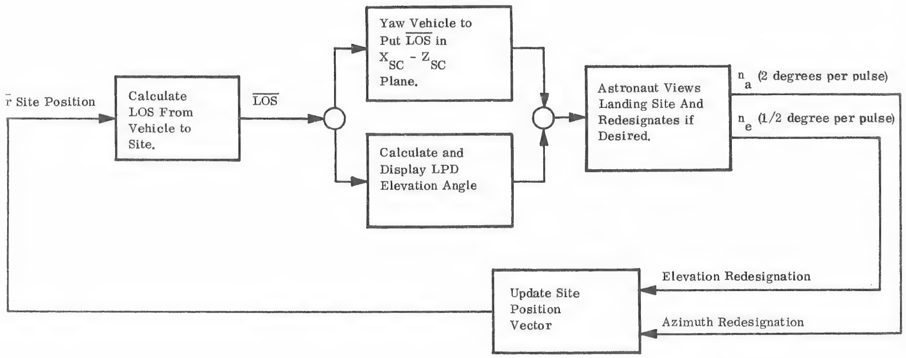


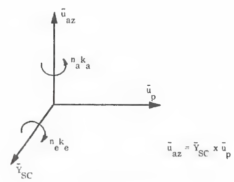
ASTRONAUT FLIGHT STATION

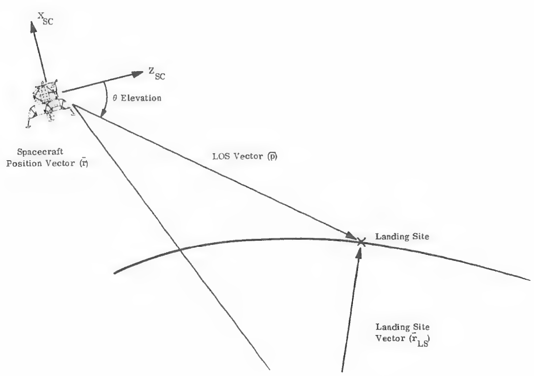


LANDING POINT DESIGNATOR
(LOOKING OUTBOARD)

LANDING SITE REDESIGNATION







SITE REDESIGNATION GEOMETRY

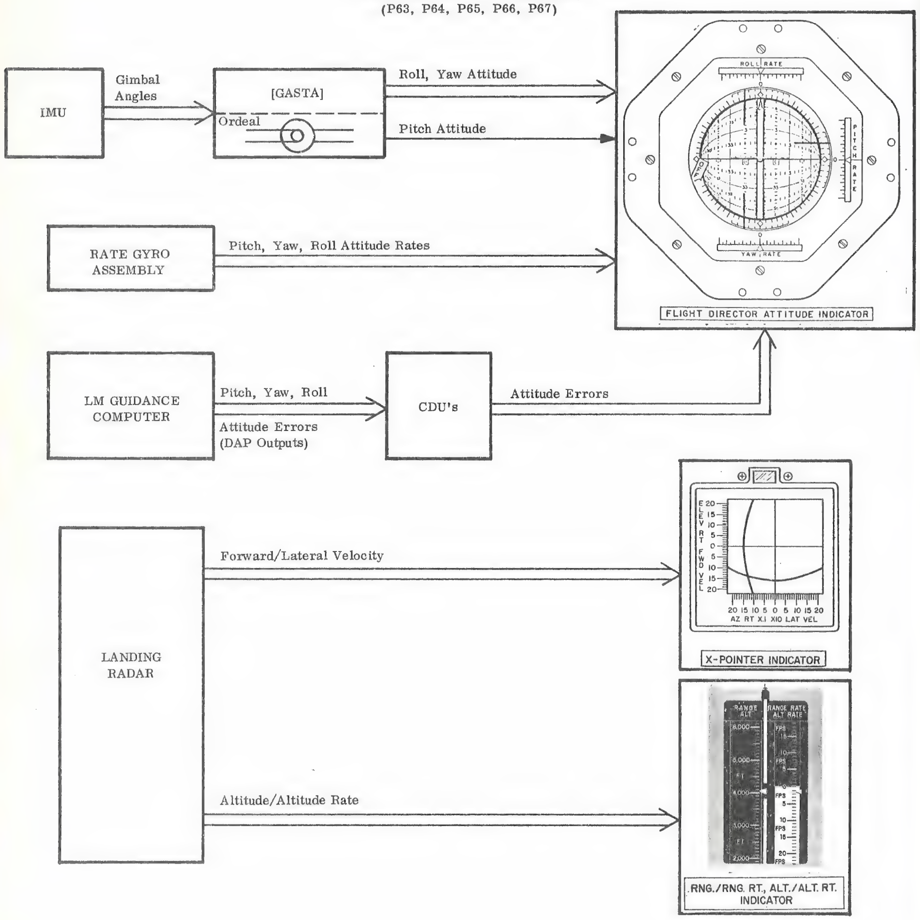
n_a = number of azimuth commands issued by astronaut.

n_e = number of elevation commands issued by astronaut.

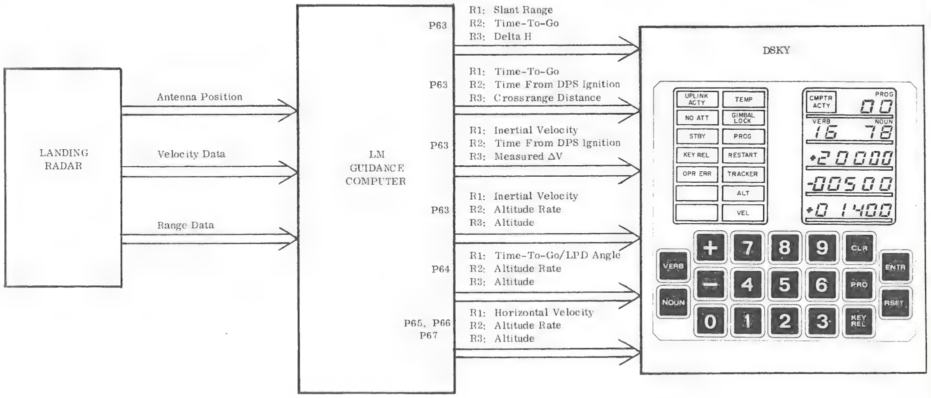
k_a = +2 degrees/pulse

k_e = +0.5 degree/pulse

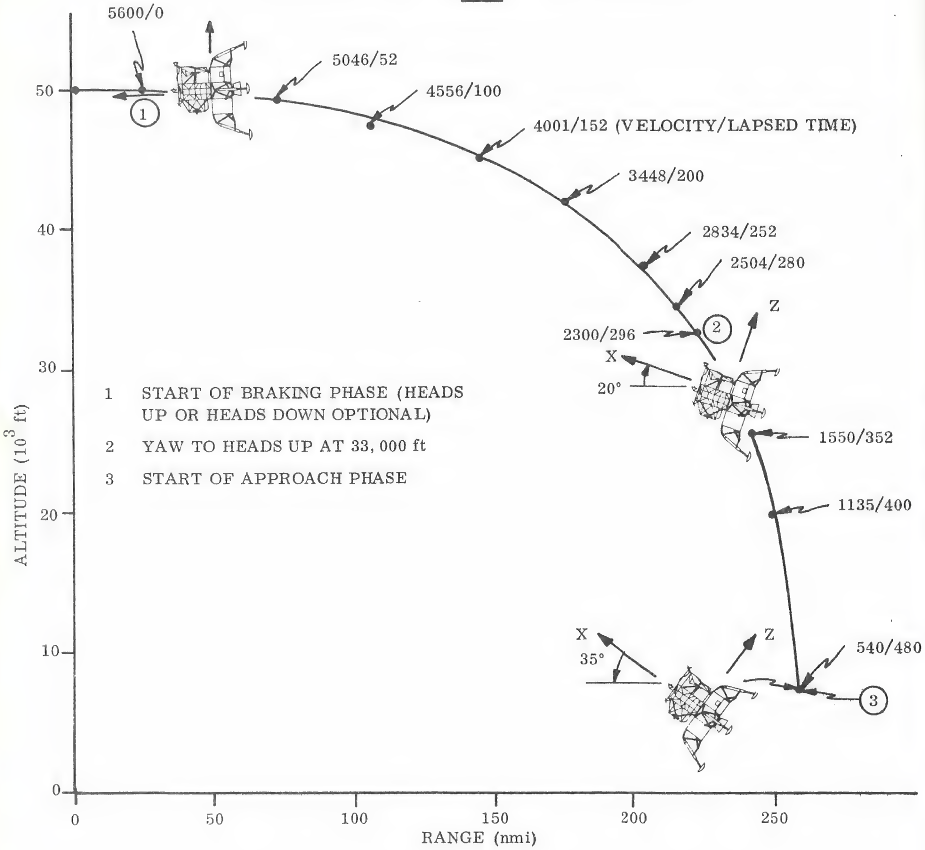
LM LANDING DISPLAYS (ANALOG)
(P63, P64, P65, P66, P67)



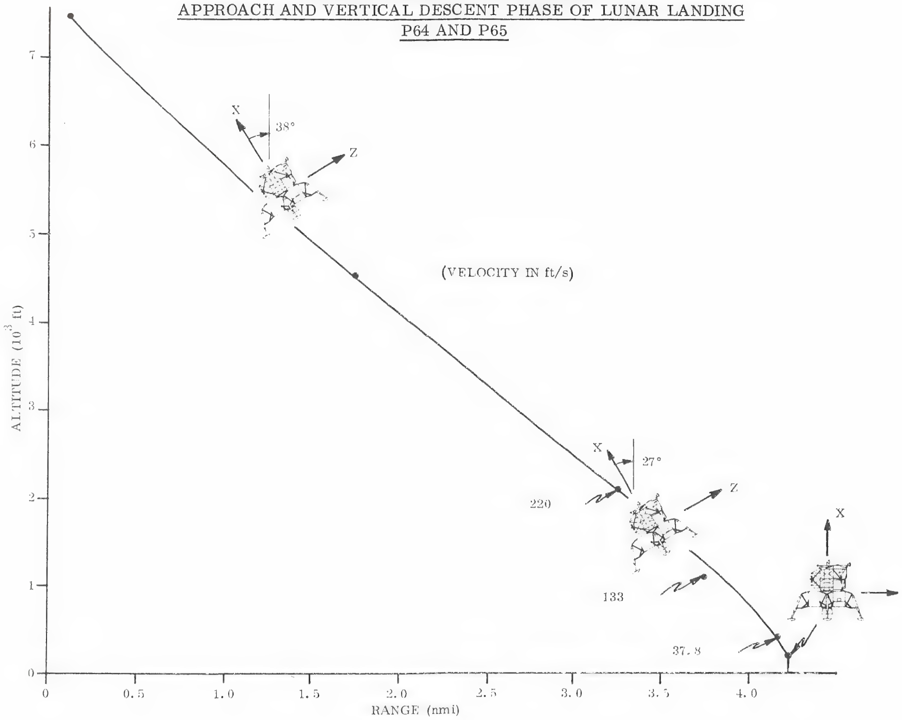
LM LANDING DISPLAYS (DIGITAL)
(P63, P64, P65, P66, P67)



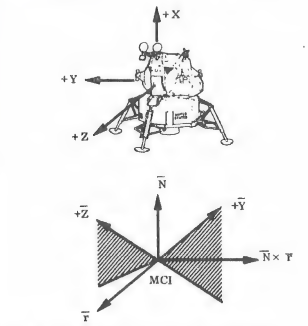
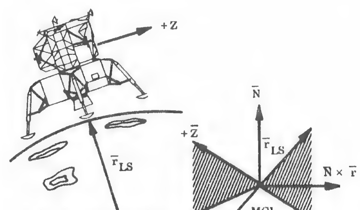
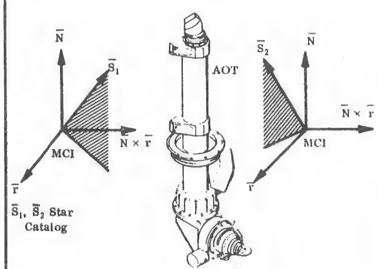
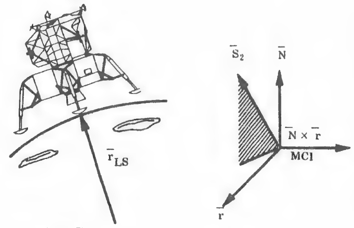
RANGE VERSUS ALTITUDE DURING BRAKING PHASE OF LUNAR LANDING P63



RANGE VERSUS ALTITUDE DURING
APPROACH AND VERTICAL DESCENT PHASE OF LUNAR LANDING
P64 AND P65



LUNAR SURFACE ALIGNMENT - P57

OPTION	LOS DIRECTION IN BASIC REF. COORD.	CALCULATE REFSMMAT
0	 LM + $\bar{Y}$ and $+\bar{Z}$ stored from previous alignment (P57, P68)	$\bar{s}_A = \begin{bmatrix} \bar{Y} \\ (\bar{Y}\times\bar{Z})\times\bar{Y} \\ \bar{Y}\times\bar{Z} \end{bmatrix} \bar{1}_{MCI} \triangleq [A]\,\bar{1}_{MCI}$ (specified) $\bar{s}_B = \begin{bmatrix} \bar{Y}_M \\ (\bar{Y}_M\times\bar{Z}_M)\times\bar{Y}_M \\ \bar{Y}_M\times\bar{Z}_M \end{bmatrix} \bar{1}_{SMCS} \triangleq [B]\,\bar{1}_{SMCS}$ (measured) $\bar{s}_A = [A]\,\bar{1}_{MCI} = \bar{s}_B = [B]\,\bar{1}_{SMCS}$ $\bar{1}_{SMCS} = [REFSMMAT]\,\bar{1}_{MCI} = [B]^{-1}[A]\,\bar{1}_{MCI}$
1	 $\bar{Z}$, $\bar{r}_{LS}$ stored in MCI	$\bar{s}_A = \begin{bmatrix} \bar{r}_{LS} \\ (\bar{r}_{LS}\times\bar{Z})\times\bar{r}_{LS} \\ \bar{r}_{LS}\times\bar{Z} \end{bmatrix} \bar{1}_{MCI} \triangleq [A]\,\bar{1}_{MCI}$ (specified) $\bar{s}_B = \begin{bmatrix} \bar{g}_{LS} \\ (\bar{g}_{LS}\times\bar{Z}_M)\times\bar{g}_{LS} \\ \bar{g}_{LS}\times\bar{Z}_M \end{bmatrix} \bar{1}_{SMCS} \triangleq [B]\,\bar{1}_{SMCS}$ (measured) $\bar{1}_{SMCS} = [REFSMMAT]\,\bar{1}_{MCI} = [B]^{-1}[A]\,\bar{1}_{MCI}$
2	 $\bar{S}_1$, $\bar{S}_2$ Star Catalog	$\bar{s}_A = \begin{bmatrix} \bar{S}_1 \\ (\bar{S}_1\times\bar{S}_2)\times\bar{S}_1 \\ \bar{S}_1\times\bar{S}_2 \end{bmatrix} \bar{1}_{MCI} = [A]\,\bar{1}_{MCI}$ (specified) $\bar{s}_B = \begin{bmatrix} \bar{S}_{1M} \\ (\bar{S}_{1M}\times\bar{S}_{2M})\times\bar{S}_{1M} \\ \bar{S}_{1M}\times\bar{S}_{2M} \end{bmatrix} \bar{1}_{SMCS} = [B]\,\bar{1}_{SMCS}$ (measured) $\bar{1}_{SMCS} = [REFSMMAT]\,\bar{1}_{MCI} = [B]^{-1}[A]\,\bar{1}_{MCI}$
3	 $\bar{r}_{LS}$, $\bar{S}_2$	$\bar{s}_A = \begin{bmatrix} \bar{r}_{LS} \\ (\bar{r}_{LS}\times\bar{S}_2)\times\bar{r}_{LS} \\ \bar{r}_{LS}\times\bar{S}_2 \end{bmatrix} \bar{1}_{MCI} = [A]\,\bar{1}_{MCI}$ (specified) $\bar{s}_B = \begin{bmatrix} \bar{g}_{LS} \\ (\bar{g}_{LS}\times\bar{S}_{2M})\times\bar{g}_{LS} \\ \bar{g}_{LS}\times\bar{S}_{2M} \end{bmatrix} \bar{1}_{SMCS} = [B]\,\bar{1}_{SMCS}$ (measured) $\bar{1}_{SMCS} = [REFSMMAT]\,\bar{1}_{MCI} = [B]^{-1}[A]\,\bar{1}_{MCI}$

MCI = Moon Centered Inertial; SMCS = Stable Member Coordinate System

P57—LUNAR SURFACE ALIGNMENT

V37 Enter, 57 Enter

V06 N34 Flashing

Time of alignment (h, min, 0.01 s)

V05 N06 Flashing

R1: 0 0 0 1 0

R2: 0 0 0 0 X Alignment mode

0—anytime, 1—REFSMMAT + g
2—two bodies, 3—one body + g

R3: 0 0 A B 0 Datcode

A = 0—REFSMMAT not defined
1—REFSMMAT defined

B = 0—LM attitude not available
1—LM attitude available

V06 N04 Flashing

Gravity error angle (0.01 deg)

V06 N93 Flashing

X, Y, and Z gyro torquing angles (0.001 deg)

V50 N25 Flashing

R1: 0 0 0 1 4 Fine align option

V06 N89 Flashing

Latitude, longitude/2, altitude of landing site (0.001 deg, 0.001 deg, 0.01 nmi)

+	0	0				Hours (Time of Alignment)	N34	+	0	0			
+	0	0	0			Minutes (Time of Alignment)		+	0	0	0		
+	0					Seconds (Time of Alignment)		+	0				
X	0	0	0	0		Alignment Mode		X	0	0	0	0	
						Gravity Error Angle (deg)							
X	0	0				Star Code 1	N70	X	0	0			
						Cursor Angle (deg)	N79						
						Spiral Angle (deg) Star No. 1							
X	0	0	0	0		Position Code		X	0	0	0	0	
X	0	0				Star Code 2	N70	X	0	0			
						Cursor Angle (deg)	N79						
						Spiral Angle (deg) Star No. 2							
X	0	0	0	0		Position Code		X	0	0	0	0	
						Star Angle Difference (deg)	N05						
						X Gyro Torquing Angles (deg)	N93						
						Y Gyro Torquing Angles (deg)							
						Z Gyro Torquing Angles (deg)							
						X Calculated Gyro Drifts (meru)							
						Y Calculated Gyro Drifts (meru)							
						Z Calculated Gyro Drifts (meru)							
						Latitude (deg) Landing Site	N89						
						Longitude/2 (deg) Landing Site							
						Altitude (nmi) Landing Site							

P57—LUNAR SURFACE ALIGNMENT

V37 Enter, 57 Enter

V06 N34 Flashing

Time of alignment (h, min, 0.01 s)

V05 N06 Flashing

R1: 0 0 0 1 0

R2: 0 0 0 0 X Alignment mode

0—anytime, 1—REFSMMAT + g
2—two bodies, 3—one body + g

R3: 0 0 A B 0 Datcode

A = 0—REFSMMAT not defined
1—REFSMMAT defined

B = 0—LM attitude not available
1—LM attitude available

V06 N04 Flashing

Gravity error angle (0.01 deg)

V06 N93 Flashing

X, Y, and Z gyro torquing angles (0.001 deg)

V50 N25 Flashing

R1: 0 0 0 1 4 Fine align option

V06 N89 Flashing

Latitude, longitude/2, altitude of landing site (0.001 deg, 0.001 deg, 0.01 nmi)

+	0	0				Hours — Time of Alignment	N34	+	0	0			
+	0	0	0			Minutes		+	0	0	0		
+	0					Seconds		+	0				
X	0	0	0	0		Alignment Mode		X	0	0	0	0	
						Gravity Error Angle (deg)							
X	0	0				Star Code 1	N70	X	0	0			
						Cursor Angle (deg) — Star No. 1	N79						
						Spiral Angle (deg)							
X	0	0	0	0		Position Code		X	0	0	0	0	
X	0	0				Star Code 2	N70	X	0	0			
						Cursor Angle (deg) — Star No. 2	N79						
						Spiral Angle (deg)							
X	0	0	0	0		Position Code		X	0	0	0	0	
						Star Angle Difference (deg)	N05						
						X — Gyro Torquing Angles (deg)	N93						
						Y							
						Z							
						X — Calculated Gyro Drifts (meru)							
						Y							
						Z							
						Latitude (deg) — Landing Site	N89						
						Longitude/2 (deg)							
						Altitude (nmi)							

P22—ORBITAL NAVIGATION

V37 Enter, 22 Enter

V06 N45 Flashing, R3: Middle Gimbal Angle

V05 N70 Flashing, R2: A B 0 D E Landmark Code

A1 – Known, A2 – Unknown
B – Index of offset designator
DE – Landmark ID

V06 N89 Flashing Landmark Coordinates

R1: Latitude

R2: Longitude/2

R3: Altitude

V51 Flashing – Please Mark

+	0	0				Hours	GET	+	0	0			
+	0	0	0			Minutes		+	0	0	0		
+	0					Seconds		+	0				
						LAT (+ north)	N89						
						LONG/2 (+ east)							
						ALT (nmi)							
						ΔR nmi	N49						
						ΔV ft/s							

+	0	0				Hours	GET	+	0	0			
+	0	0	0			Minutes		+	0	0	0		
+	0					Seconds		+	0				
						LAT (+ north)	N89						
						LONG/2 (+ east)							
						ALT (nmi)							
						ΔR nmi	N49						
						ΔV ft/s							

NOTES:

P52—IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 — Preferred, 2 — Nominal,
3 — REFSMMAT, 4 — Landing Site

V51 Flashing — Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X — Gyro Torquing Angles (degrees)	N93						
						Y — Gyro Torquing Angles (degrees)							
						Z — Gyro Torquing Angles (degrees)							
						X — Calculated Gyro Drift (meru)							
						Y — Calculated Gyro Drift (meru)							
						Z — Calculated Gyro Drift (meru)							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X — Gyro Torquing Angles (degrees)	N93						
						Y — Gyro Torquing Angles (degrees)							
						Z — Gyro Torquing Angles (degrees)							
						X — Calculated Gyro Drift (meru)							
						Y — Calculated Gyro Drift (meru)							
						Z — Calculated Gyro Drift (meru)							

NOTES:

CSM PLANE CHANGE

P30–EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose						
		/				Prop/Guidance			/			
						Weight (lb) N47	+					
	0	0				P_{Trim} (degrees) N48		0	0			
	0	0				Y_{Trim}		0	0			
+	0	0				Hours N33	+	0	0			
+	0	0	0			Minutes GETI	+	0	0	0		
+	0					Seconds	+	0				
						ΔV_X N81						
						ΔV_Y LV						
						ΔV_Z (ft/s)						
X	X	X				R IMU Gimbal Angles (deg)	X	X	X			
X	X	X				P	X	X	X			
X	X	X				Y	X	X	X			
+						H_{Apogee} nmi N42	+					
						$H_{Perigee}$						
+						ΔVT (ft/s)	+					
X	X	X				BT (min:s)	X	X	X			
X						ΔVC (ft/s)	X					
X	X	X	X			SXT Star	X	X	X	X		
+					0	SFT (degrees)	+					0
+				0	0	TRN (degrees)	+				0	0
X	X	X				BSS (Coas Star)	X	X	X			
X	X					SPA (Coas Pitch, deg)	X	X				
X	X	X				SXP (Coas X Pos, deg)	X	X	X			
	0					LAT (degrees) N61		0				
						LONG						
+						RTGO (nmi) EMS	+					
+						VIO (ft/s)	+					
						GET 0.05 g Hr:min:s						
						SET STARS						
X	X	X				R_{Align}	X	X	X			
X	X	X				P_{Align}	X	X	X			
X	X	X				Y_{Align}	X	X	X			
						ULLAGE						

NOTES:

P40 – SPS THRUSTING CSM

V37 Enter, 40 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V50 N25 Flashing, R1 = 0 0 2 0 4, Gimbal Actuator Test Option

V06 N40, Time from Ignition, Velocity to be Gained, Measured Change in Velocity

V99 N40 Flashing, Engine On Enable Request

V06 N40, Time from Cutoff, Velocity to be Gained, Measured Change in Velocity

V16 N40 Flashing, Final Values at Engine Cutoff

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

V37 Flashing, V82 Enter

V16 N44 Flashing, Apogee Altitude, Perigee Altitude, Time to Freefall to 35 K ft Moon Orbit, 300 K ft Earth Orbit

	50-18	Roll	
		Pitch (deg)	
		Yaw	
	06-18	Roll	
		Pitch (deg)	
		Yaw	
	06-40	TFI (min:s)	
		VG (ft/s)	
		ΔVM (ft/s)	
	06-40	TFC (min:s)	
		VG (ft/s)	
		ΔVM (ft/s)	
	16-40	TFC (min:s)	
		VG (ft/s)	
		ΔVM (ft/s)	
	85	X Residuals (ft/s)	
		Y	
		Z	
	85	X TRIM (ft/s)	
		Y	
		Z	
	44	HA (nmi)	
		HP (nmi)	
		TFF (min:s)	

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 — Preferred, 2 — Nominal,
3 — REFSMMAT, 4 — Landing Site

V51 Flashing — Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

NOTES:

P22–ORBITAL NAVIGATION

V37 Enter, 22 Enter

V06 N45 Flashing, R3: Middle Gimbal Angle

V05 N70 Flashing, R2: A B 0 D E Landmark Code

A1 – Known, A2 – Unknown
B – Index of offset designator
DE – Landmark ID

V06 N89 Flashing Landmark Coordinates

R1: Latitude

R2: Longitude/2

R3: Altitude

V51 Flashing – Please Mark

+	0	0				Hours		+	0	0			
+	0	0	0			Minutes	GET	+	0	0	0		
+	0					Seconds		+	0				
						LAT (+ north)	N89						
						LONG/2 (+ east)							
						ALT (nmi)							
						ΔR nmi	N49						
						ΔV ft/s							

+	0	0				Hours		+	0	0			
+	0	0	0			Minutes	GET	+	0	0	0		
+	0					Seconds		+	0				
						LAT (+ north)	N89						
						LONG/2 (+ east)							
						ALT (nmi)							
						ΔR nmi	N49						
						ΔV ft/s							

NOTES:

V37 Enter, 57 Enter

V06 N34 Flashing

Time of alignment (h, min, 0.01 s)

V05 N06 Flashing

R1: 0 0 0 1 0

R2: 0 0 0 0 X Alignment mode

0—anytime, 1—REFSMMAT + g
2—two bodies, 3—one body + g

R3: 0 0 A B 0 Datcode

A = 0—REFSMMAT not defined
1—REFSMMAT defined

B = 0—LM attitude not available
1—LM attitude available

V06 N04 Flashing

Gravity error angle (0.01 deg)

V06 N93 Flashing

X, Y, and Z gyro torquing angles (0.001 deg)

V50 N25 Flashing

R1: 0 0 0 1 4 Fine align option

V06 N89 Flashing

Latitude, longitude/2, altitude of landing site (0.001 deg, 0.001 deg, 0.01 nmi)

+	0	0				Hours (Time of Alignment)	N34	+	0	0			
+	0	0	0			Minutes (Time of Alignment)		+	0	0	0		
+	0					Seconds (Time of Alignment)		+	0				
X	0	0	0	0		Alignment Mode		X	0	0	0	0	
						Gravity Error Angle (deg)							
X	0	0				Star Code 1	N70	X	0	0			
						Cursor Angle (deg) (Star No. 1)	N79						
						Spiral Angle (deg) Star No. 1							
X	0	0	0	0		Position Code		X	0	0	0	0	
X	0	0				Star Code 2	N70	X	0	0			
						Cursor Angle (deg) (Star No. 2)	N79						
						Spiral Angle (deg) Star No. 2							
X	0	0	0	0		Position Code		X	0	0	0	0	
						Star Angle Difference (deg)	N05						
						X Gyro Torquing Angles (deg)	N93						
						Y Gyro Torquing Angles (deg)							
						Z Gyro Torquing Angles (deg)							
						X Calculated Gyro Drifts (meru)							
						Y Calculated Gyro Drifts (meru)							
						Z Calculated Gyro Drifts (meru)							
						Latitude (deg) (Landing Site)	N89						
						Longitude/2 (deg) Landing Site							
						Altitude (nmi) (Landing Site)							

P22—LUNAR SURFACE NAVIGATION

V37 Enter, 22 Enter

V04 N06 Flashing

R1: 0 0 0 1 2

R2: 0 0 0 0 X (1—CSM will not change orbit,
2—CSM will change orbit)

V06 N33 Flashing

Time of ascent (h, min, 0.01 s)

V50 N25 Flashing (if RR Auto mode not selected)

R1: 0 0 2 0 1 — switch RR mode to Auto

X	0	0	0	0		Option Code	N06	X	0	0	0	0	
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes — Time of Ascent		+	0	0	0		
+	0					Seconds		+	0				
X	0	0	0	0		Option Code	N06	X	0	0	0	0	
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes — Time of Ascent		+	0	0	0		
+	0					Seconds		+	0				
X	0	0	0	0		Option Code	N06	X	0	0	0	0	
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes — Time of Ascent		+	0	0	0		
+	0					Seconds		+	0				

P12—POWERED ASCENT

V37 Enter, 12 Enter

V06 N33 Flashing
 Time of ascent (h, min, 0.01 s)
V06 N76 Flashing
 Downrange velocity, radial velocity, crossrange (0.1 ft/s, 0.1 ft/s, 0.1 nmi)
V50 N25 Flashing
 R1: 0 0 2 0 3 (switch Guidance Control to PGNS, Mode to Auto, Thrust Control to Auto)
V06 N74 Flashing
 TFI, yaw after rise, pitch after rise (min/s, 0.01 deg, 0.01 deg)
V99 N74 Flashing
 Engine on enable
V06 N63 Flashing
 VI, HDOT, H (0.1 ft/s, 0.1 ft/s, ft)
V16 N85 Flashing
 VGX (LM), VGY (LM), VGZ (LM) (0.1 ft/s)
V82 Enter
 V04 N06 Flashing
 R1: 0 0 0 0 2
 R2: 0 0 0 0 X (1—this vehicle, 2—other vehicle)
 V16 N44 Flashing
 Apocenter altitude, pericenter altitude, TFF (0.1 nmi, 0.1 nmi, min/s)

+	0	0				Hours	TIG of Ascent	N33	+	0	0			
+	0	0	0			Minutes			+	0	0	0		
+	0					Seconds			+	0				
						Desired Downrange Velocity (ft/s)		N76						
						Desired Radial Velocity (ft/s)								
						Crossrange Distance (nmi)								
+	0	0				Roll	FDAI inertial roll, pitch, and yaw angles at TIG		+	0	0			
+	0	0				Pitch			+	0	0			
+	0	0				Yaw			+	0	0			
+	0	0				Hours	TIG of CSI	N11	+	0	0			
+	0	0	0			Minutes			+	0	0	0		
+	0					Seconds			+	0				
+	0	0				Hours	TIG of TPI	N37	+	0	0			
+	0	0	0			Minutes			+	0	0	0		
+	0					Seconds			+	0				

P57–LUNAR SURFACE ALIGNMENT

V37 Enter, 57 Enter

V06 N34 Flashing

Time of alignment (h, min, 0.01 s)

V05 N06 Flashing

R1: 0 0 0 1 0

R2: 0 0 0 0 X Alignment mode

0–anytime, 1–REFSMMAT + g
2–two bodies, 3–one body + g

R3: 0 0 A B 0 Datcode

A = 0–REFSMMAT not defined
1–REFSMMAT defined

B = 0–LM attitude not available
1–LM attitude available

V06 N04 Flashing

Gravity error angle (0.01 deg)

V06 N93 Flashing

X, Y, and Z gyro torquing angles (0.001 deg)

V50 N25 Flashing

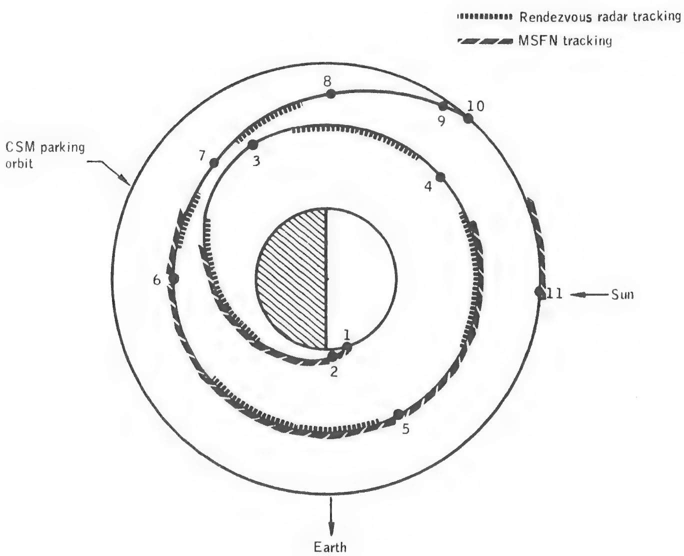
R1: 0 0 0 1 4 Fine align option

V06 N89 Flashing

Latitude, longitude/2, altitude of landing site (0.001 deg, 0.001 deg, 0.01 nmi)

+	0	0				Hours (Time of Alignment)	N34	+	0	0				
+	0	0	0			Minutes (Time of Alignment)		+	0	0	0			
+	0					Seconds (Time of Alignment)		+	0					
X	0	0	0	0		Alignment Mode		X	0	0	0	0		
						Gravity Error Angle (deg)								
X	0	0				Star Code 1	N70	X	0	0				
						Cursor Angle (deg) (Star No. 1)	N79							
						Spiral Angle (deg) Star No. 1								
X	0	0	0	0		Position Code		X	0	0	0	0		
X	0	0				Star Code 2	N70	X	0	0				
						Cursor Angle (deg) (Star No. 2)	N79							
						Spiral Angle (deg) Star No. 2								
X	0	0	0	0		Position Code		X	0	0	0	0		
						Star Angle Difference (deg)	N05							
						X (Gyro Torquing Angles (deg))	N93							
						Y (Gyro Torquing Angles (deg))								
						Z (Gyro Torquing Angles (deg))								
						X (Calculated Gyro Drifts (meru))								
						Y (Calculated Gyro Drifts (meru))								
						Z (Calculated Gyro Drifts (meru))								
						Latitude (deg) (Landing Site)	N89							
						Longitude/2 (deg) (Landing Site)								
						Altitude (nmi) (Landing Site)								

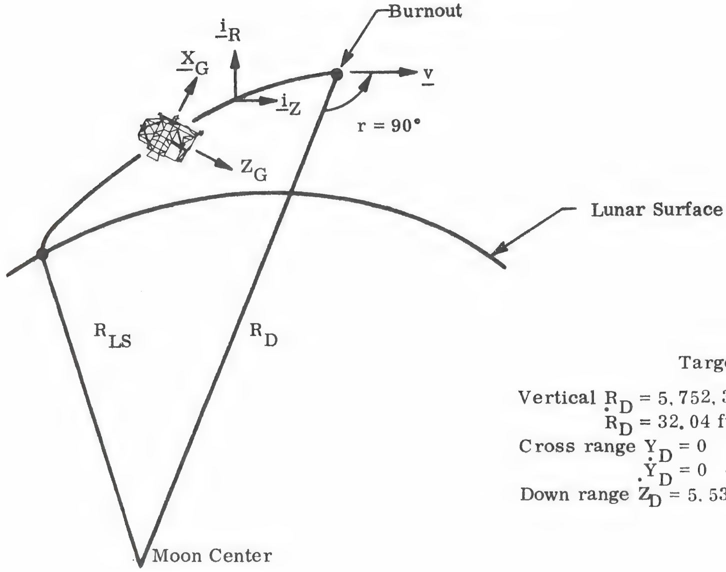
ORBITAL ASCENT THROUGH DOCKING



Event

1. Lift-off
2. LM insertion
3. CSI
4. PC
5. CDH
6. TPI
7. MC1
8. MC2
9. Begin braking
10. Begin stationkeeping
11. Docking

LUNAR ASCENT GUIDANCE



Target Values

Vertical R_D = 5,752,316.9 ft.
$\dot{R}_D$ = 32.04 ft/sec
Cross range Y_D = 0
$\dot{Y}_D$ = 0
Down range $\dot{Z}_D$ = 5,535.62 ft/sec

$a_R = (A+B)/\tau - \mu m/R^2$ Command specific force (vertical)

$a_Y = (C+D)/\tau$ Command specific force (cross range)

$a_Z = (a_T{}^2 - a_h{}^2)^{1/2}\ \mathrm{SGN}\ (\dot{Z}_D - \dot{Z})$ Command specific force (range)

A = Pitch attitude constant = $[-K_1 B - (\dot{R}_D - \dot{R})/L]$

B = Pitch Rate Constant = $[K_2(\dot{R}_D - \dot{R}) - R_D - R - \dot{R}\,T_{GO}]/T_{GO}\,E$

C = Yaw Attitude Constant = $[-K_1 D - (\dot{Y}_D - \dot{Y})/L]$

D = Yaw Rate Constant = $[K_2(\dot{Y}_D - \dot{Y}) - Y_D - Y - \dot{Y}\,T_{GO}]/T_{GO}E$

Where:

a_h = specific force in RY plane.

τ = mass/mass flow rate

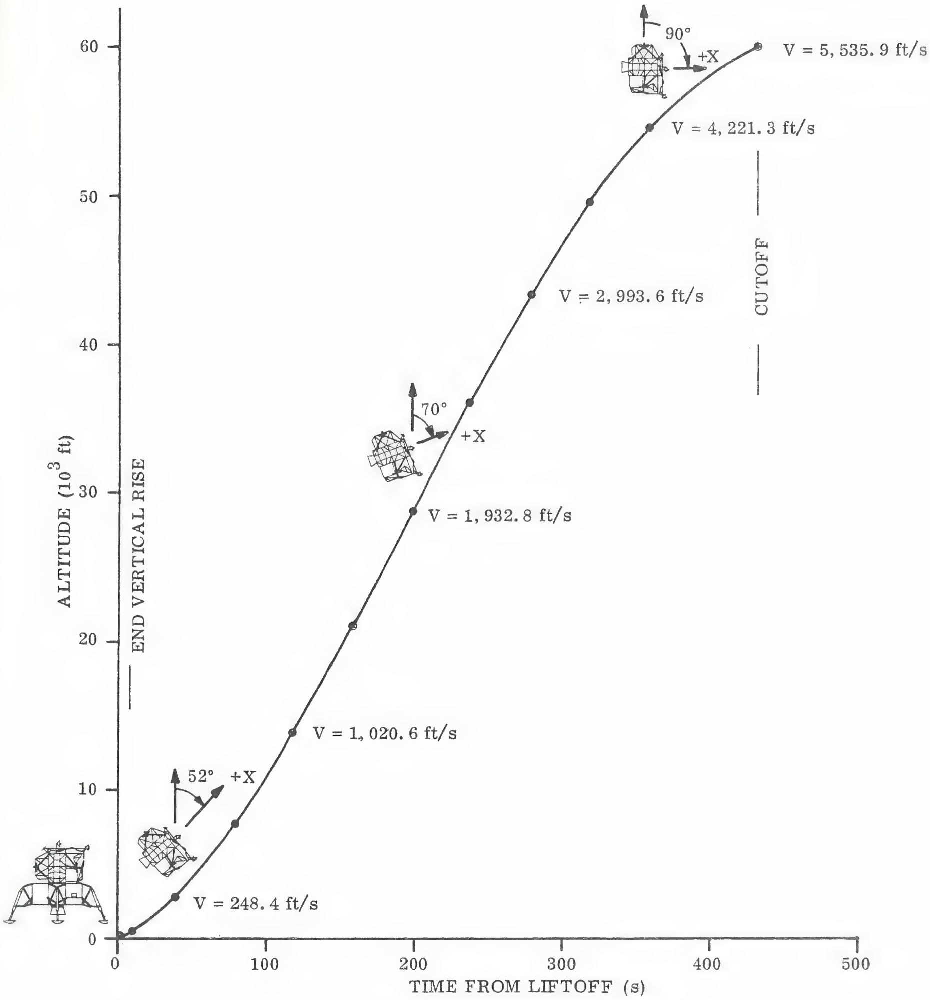
$T_{GO} \approx$ f (APS Tail off. mass/mass flow rate. Exhaust velocity. velocity to be gained)

L, E, K_1, $K_2 \approx$ f (mass/mass flow rate. Exhaust velocity. Time to go)

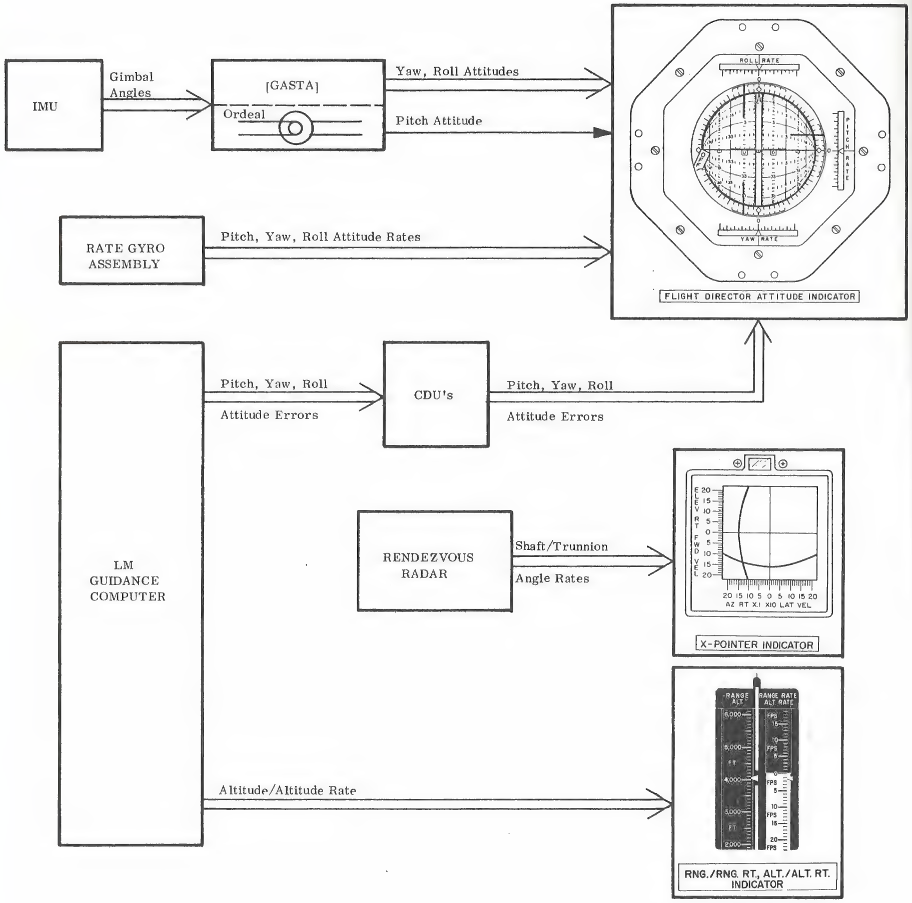
a_T = available specific force

μm lunar gravitational constant

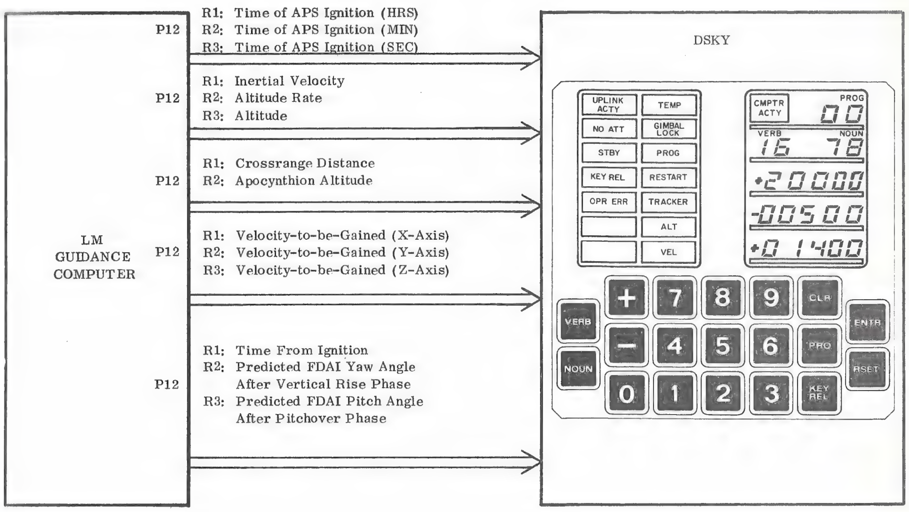
LUNAR ASCENT TO ORBIT INSERTION
(9 × 45 nmi ORBIT)



ASCENT DISPLAYS (ANALOG)
(P12)



LM ASCENT DISPLAYS (DIGITAL)
(P12)

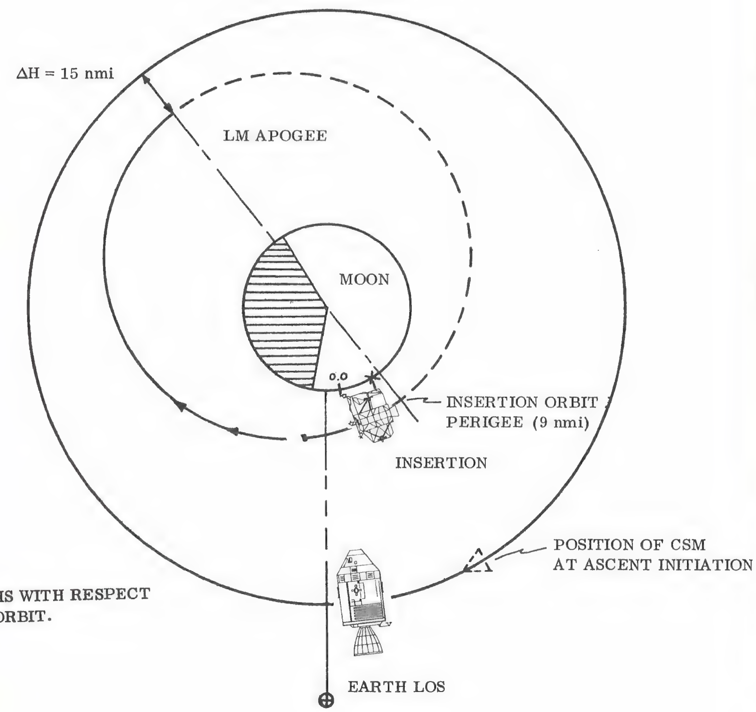


LM INSERTION

EVENT	BT/ΔV	TTNE	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
INSERTION	438/ 6056	57:53	LM-APS/PGNS	P-12

					ΔV_X N85	+	X	X				h
					ΔV_Y RESIDUALS ft/s	+	X	X	X			min GET
					ΔV_Z (BODY AXIS)	+	X					s

— — — . — $V_{X_{TRIM}}$ — — — . — $V_{Y_{TRIM}}$ — — — . — $V_{Z_{TRIM}}$ ft/s



NOTE: SHADOW IS WITH RESPECT TO CSM ORBIT.

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 – Preferred, 2 – Nominal
3 – REFSMMAT, 4 – Landing Site

V01 N70 Flashing

R1: 0 0 C D E

C – AOT Detent
1 – L, 2 – F, 3 – R
4 – Any Rear, 5 – COAS
DE – Celestial Body Code

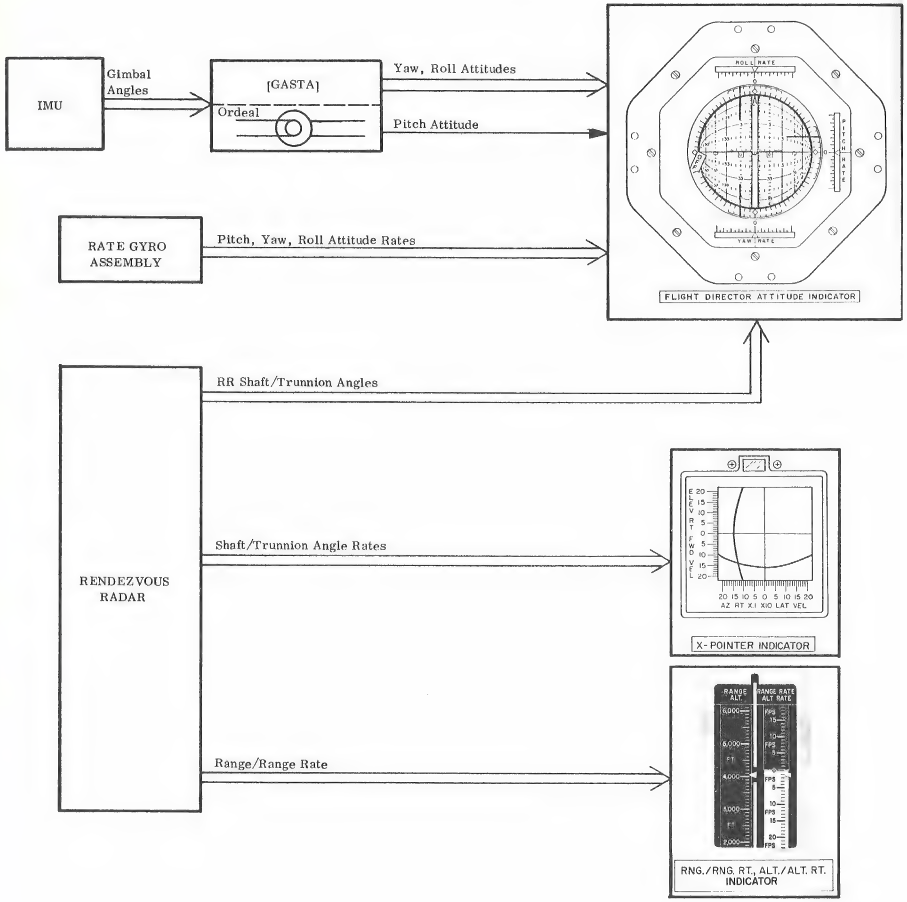
V51 Flashing – Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				GET Hours		+	0	0			
+	0	0	0			GET Minutes		+	0	0	0		
+	0					GET Seconds		+	0				
X	0	0				AOT Detent and Star ID	N71	X	0	0			
						Star Angle Difference (degrees)	N05						
						Gyro Torquing Angles (degrees) X	N93						
						Gyro Torquing Angles (degrees) Y							
						Gyro Torquing Angles (degrees) Z							
						Calculated Gyro Drift (meru) X							
						Calculated Gyro Drift (meru) Y							
						Calculated Gyro Drift (meru) Z							

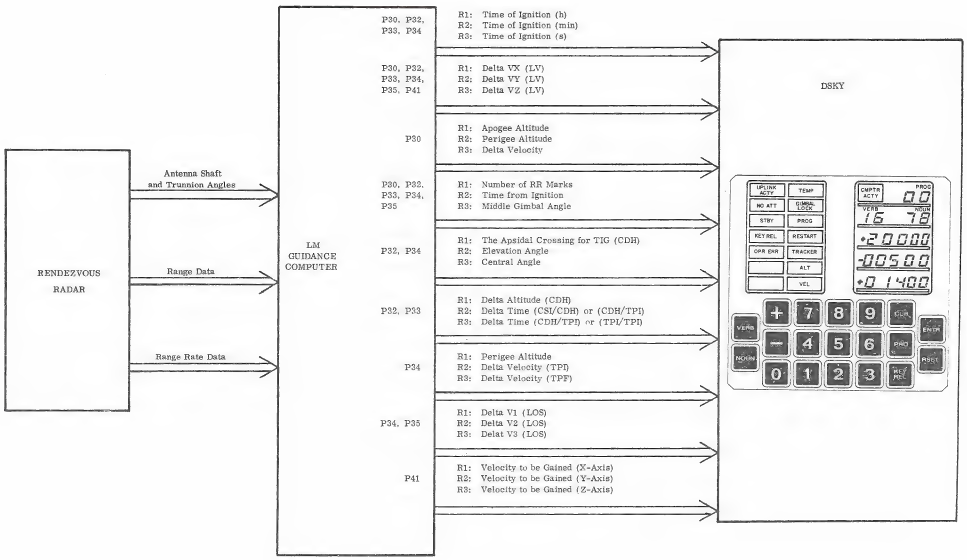
X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				GET Hours		+	0	0			
+	0	0	0			GET Minutes		+	0	0	0		
+	0					GET Seconds		+	0				
X	0	0				AOT Detent and Star ID	N71	X	0	0			
						Star Angle Difference (degrees)	N05						
						Gyro Torquing Angles (degrees) X	N93						
						Gyro Torquing Angles (degrees) Y							
						Gyro Torquing Angles (degrees) Z							
						Calculated Gyro Drift (meru) X							
						Calculated Gyro Drift (meru) Y							
						Calculated Gyro Drift (meru) Z							

NOTES:

RENDEZVOUS DISPLAYS (ANALOG)



LM RENDEZVOUS DISPLAYS (DIGITAL)



P20 – RENDEZVOUS NAVIGATION PROGRAM (LM)

V37 Enter, 20 Enter

V50 N18 Flashing, Request Maneuver to FDAI Angles

V50 N25 Flashing

R1: 0 0 2 0 1 Change RR Mode

V50 N25 Flashing

R1: 0 0 2 0 5 Manual Slew RR for Lock-on

DSKY BLANKS – RR Taking Marks

V06 N49 Flashing

R3: 0 0 0 0 X Source Code

1 – RR range, 2 – RR range rate
3 – RR shaft angle, 4 – RR trunnion angle

						Angle Between RR LOS and State Vector	N05						
						ΔR (nmi)	N49						
						ΔV (ft/s)							
X	0	0	0	0		Source Code		X	0	0	0	0	
+						R	N18	+					
+						P Final FDAI Angles (degrees)		+					
+						Y		+					

						Angle Between RR LOS and State Vector	N05						
						ΔR (nmi)	N49						
						ΔV (ft/s)							
X	0	0	0	0		Source Code		X	0	0	0	0	
+						R	N18	+					
+						P Final FDAI Angles (degrees)		+					
+						Y		+					

P20 – RENDEZVOUS NAVIGATION PROGRAM (LM)

V37 Enter, 20 Enter

V50 N18 Flashing, Request Maneuver to FDAI Angles

V50 N25 Flashing

R1: 0 0 2 0 1 Change RR Mode

V50 N25 Flashing

R1: 0 0 2 0 5 Manual Slew RR for Lock-on

DSKY BLANKS – RR Taking Marks

V06 N49 Flashing

R3: 0 0 0 0 X Source Code

1 – RR range, 2 – RR range rate
3 – RR shaft angle, 4 – RR trunnion angle

						Angle Between RR LOS and State Vector	N05						
						ΔR (nmi)	N49						
						ΔV (ft/s)							
X	0	0	0	0		Source Code		X	0	0	0	0	
+						R	N18	+					
+						P Final FDAI Angles (degrees)		+					
+						Y		+					

						Angle Between RR LOS and State Vector	N05						
						ΔR (nmi)	N49						
						ΔV (ft/s)							
X	0	0	0	0		Source Code		X	0	0	0	0	
+						R	N18	+					
+						P Final FDAI Angles (degrees)		+					
+						Y		+					

P32—COELLIPTIC SEQUENCE INITIATION (CSI)

V37 Enter, 32 Enter

V06 N11 Flashing

  TIG of CSI (h, min, 0.01 s)

V06 N55 Flashing

  Number of apsidal crossings, elevation angle for TPI (+0 0 0 0 X, 0.01 deg)

V06 N37 Flashing

  TIG of TPI (h, min, 0.01 s)

V16 N45 Flashing

  Marks, time from ignition, middle gimbal angle (marks, min/s, 0.01 deg)

V06 N75 Flashing

  ΔH (CDH), ΔT (CDH–CSI), ΔT (TPI–CDH) (0.1 nmi, min/s, min/s)

V06 N81 Flashing

  ΔV_X (LV), ΔV_Y (LV), ΔV_Z (LV) of CSI (0.1 ft/s)

V06 N82 Flashing

  ΔV_X (LV), ΔV_Y (LV), ΔV_Z (LV) of CDH (0.1 ft/s)

V90 Enter (out of plane correction in final computation only)

  V06 N16 Flashing

    Time of event (h, min, 0.01 s)

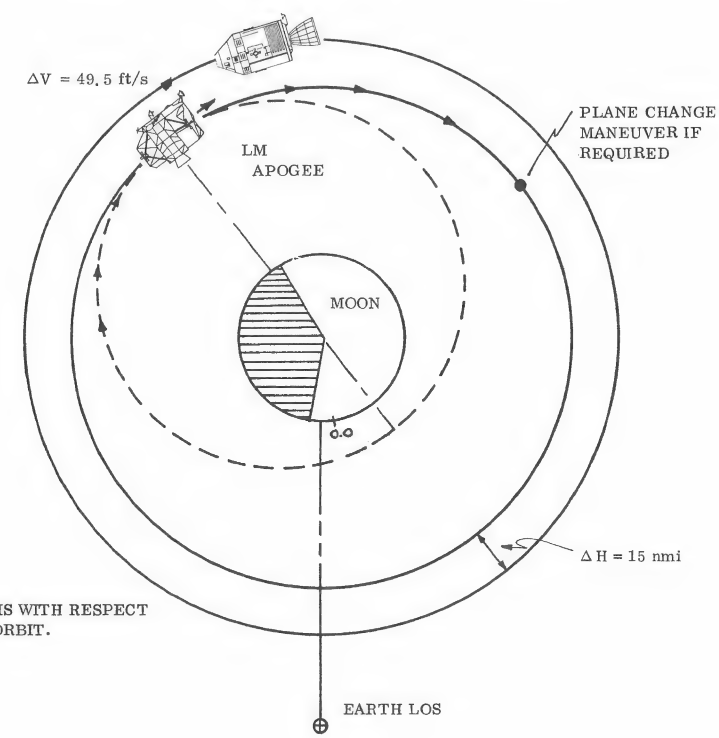
  V06 N90 Flashing

    Y, YDOT, PSI (0.01 min, 0.1 ft/s, 0.01 deg)

+	0	0				Hours TIG for CSI	N11	+	0	0			
+	0	0	0			Minutes		+	0	0	0		
+	0					Seconds		+	0				
+	0	0				Hours TIG for CSI	N37	+	0	0			
+	0	0	0			Minutes		+	0	0	0		
+	0					Seconds		+	0				
	0					ΔV_X Components of ΔV in local vertical coordinates	N81		0				
	0	0				ΔV_Y (ft/s)			0	0			
	0	0				ΔV_X Components of ΔV in local vertical coordinates used in AGS (ft/s)	N86		0	0			
	0	0				ΔV_Y			0	0			
	0	0				ΔV_Z			0	0			
+	0	0				FDAI inertial pitch angle (deg) for CSI		+	0	0			

COELLIPTIC SEQUENCE INITIATION

EVENT	BT/ΔV	TTNE	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
CSI (POSIGRADE)	45.0/ 49.5	58:18	LM-RCS/PGNS EXT ΔV (P-41)	P-32
	ΔV_X N85	ft/s	+ X X	h
	ΔV_Y RESIDUALS	ft/s	+ X X X	min GET
	ΔV_Z (BODY AXIS)	ft/s	+ X	s
$V_{X_{TRIM}}$	$V_{Y_{TRIM}}$	$V_{Z_{TRIM}}$ ft/s		



NOTE: SHADOW IS WITH RESPECT TO CSM ORBIT.

LM PLANE CHANGE

P30 – EXTERNAL ΔV (LM)

V37 Enter, 30 Enter
V06 N33 Flashing, Load Desired GETI
V06 N81 Flashing, Load Desired ΔV

						Purpose							
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes GETI		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X	N81						
						ΔV_Y LV							
						ΔV_Z (ft/s)							
+						ΔVR (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X	X	X				R FDAI Inertial Angles		X	X	X			
X	X	X				P (degrees)		X	X	X			
						ΔV_X AGS	N86						
						ΔV_Y Targeting (ft/s)							
						ΔV_Z							
X	X	X	X			COAS Star		X	X	X	X		
X	X					COAS Az (degrees)		X	X				
X	X					COAS EL (degrees)		X	X				
+						H_{Apogee}	N42	+					
						$H_{Perigee}$ (nmi)							
+						ΔVT (ft/s)		+					

NOTES:

P41 — RCS THRUSTING

V37 Enter, 41 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V06 N85, X, Y, Z Body Axes Velocity to be Gained

V16 N85 (Average G on at TIG -30) Velocity to be Gained

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

						50-18	Roll							
							Pitch	(deg)						
							Yaw							
						06-18	Roll							
							Pitch	(deg)						
							Yaw							
						06-85	X							
							Y	VG (ft/s)						
							Z							
						16-85	X							
							Y	VG (ft/s)						
							Z							
						16-85	X							
							Y	Residuals (ft/s)						
							Z							
						X								
						Y	Trim (ft/s)							
						Z								

P33—CONSTANT DELTA HEIGHT (CDH)

V37 Enter, 33 Enter

V06 N13 Flashing

  TIG of CDH (h, min, 0.01 s)

V16 N45 Flashing

  Marks, time from ignition, middle gimbal angle (marks, min/s, 0.01 deg)

V06 N75 Flashing

  ΔH(CDH), ΔT(TPI-CDH), ΔT(TPI-TPINOM)(0.1 nmi, min/s, min/s)

V06 N81 Flashing

  ΔV_X (LV), ΔV_Y (LV), ΔV_Z (LV) for CDH (0.1 ft/s)

V90 Enter (out of plane correction in final compuation)

  V06 N16 Flashing

    Time of event (h, min, 0.01 s)

  V06 N90 Flashing

    Y, YDOT, PSI (0.01 nmi, 0.1 ft/s, 0.01 deg)

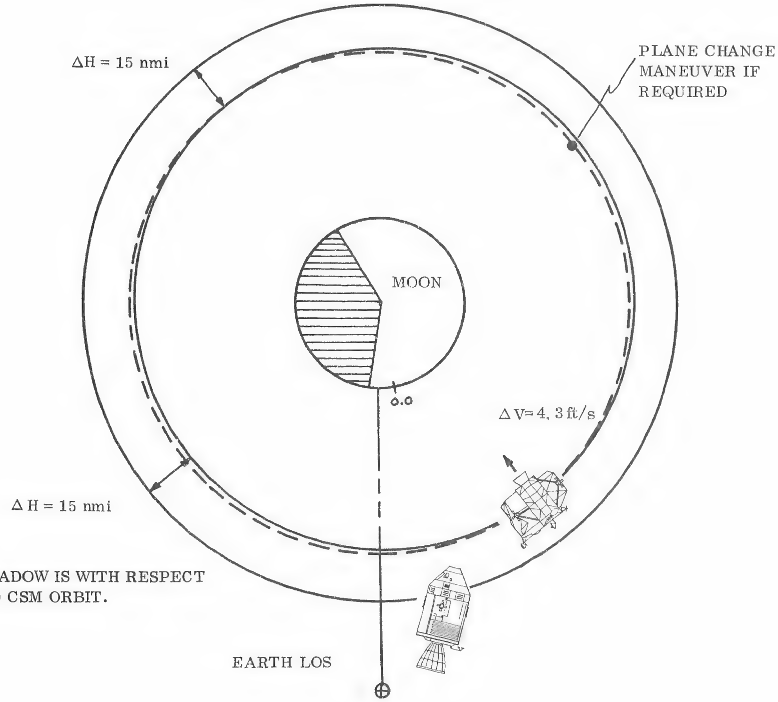
+	0	0				Hours	TIG for CDH	N13	+	0	0				
+	0	0	0			Minutes			+	0	0	0			
+	0					Seconds			+	0					
	0					ΔV_X (LV)	Components of ΔV in local vertical coordinates (ft/s)	N81		0					
	0	0				ΔV_Y (LV)				0	0				
	0	0				ΔV_Z (LV)				0	0				
	0					ΔV_X (LV)	Components of ΔV in local vertical coordinates used in AGS (ft/s)	N86		0					
	0	0				ΔV_Y (LV)				0	0				
	0	0				ΔV_Z (LV)				0	0				
+	0	0				FDAI inertial pitch angle for CDH (deg)			+	0	0				

CONSTANT DELTA HEIGHT

EVENT	BT/ΔV	TTNE	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
CDH (RADIALLY DOWN)	1.9/ 4.3	38:31	LM-RCS/PGNS EXT ΔV (P-41)	P-33

					.	ΔV_X N85	+	X	X			. h
					.	ΔV_Y RESIDUALS	+	X	X	X		. min GET
					.	ΔV_Z (BODY AXIS) ft/s	+	X		.		s

— — — . — $V_{X_{TRIM}}$ — — — . — $V_{Y_{TRIM}}$ — — — . — $V_{Z_{TRIM}}$ ft/s



NOTE: SHADOW IS WITH RESPECT TO CSM ORBIT.

P41 – RCS THRUSTING

V37 Enter, 41 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V06 N85, X, Y, Z Body Axes Velocity to be Gained

V16 N85 (Average G on at TIG -30) Velocity to be Gained

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

50-18	Roll	
	Pitch	(deg)
	Yaw	
06-18	Roll	
	Pitch	(deg)
	Yaw	
06-85	X	
	Y	VG (ft/s)
	Z	
16-85	X	
	Y	VG (ft/s)
	Z	
16-85	X	
	Y	Residuals (ft/s)
	Z	
X		
Y		Trim (ft/s)
Z		

P20 -- RENDEZVOUS NAVIGATION PROGRAM (LM)

V37 Enter, 20 Enter

V50 N18 Flashing, Request Maneuver to FDAI Angles

V50 N25 Flashing

R1: 0 0 2 0 1 Change RR Mode

V50 N25 Flashing

R1: 0 0 2 0 5 Manual Slew RR for Lock-on

DSKY BLANKS – RR Taking Marks

V06 N49 Flashing

R3: 0 0 0 0 X Source Code

1 – RR range, 2 – RR range rate
3 – RR shaft angle, 4 – RR trunnion angle

						Angle Between RR LOS and State Vector	N05						
						ΔR (nmi)	N49						
						ΔV (ft/s)							
X	0	0	0	0		Source Code		X	0	0	0	0	
+						R	N18	+					
+						P Final FDAI Angles (degrees)		+					
+						Y		+					

						Angle Between RR LOS and State Vector	N05						
						ΔR (nmi)	N49						
						ΔV (ft/s)							
X	0	0	0	0		Source Code		X	0	0	0	0	
+						R	N18	+					
+						P Final FDAI Angles (degrees)		+					
+						Y		+					

P34—TRANSFER PHASE INITIATION (TPI)

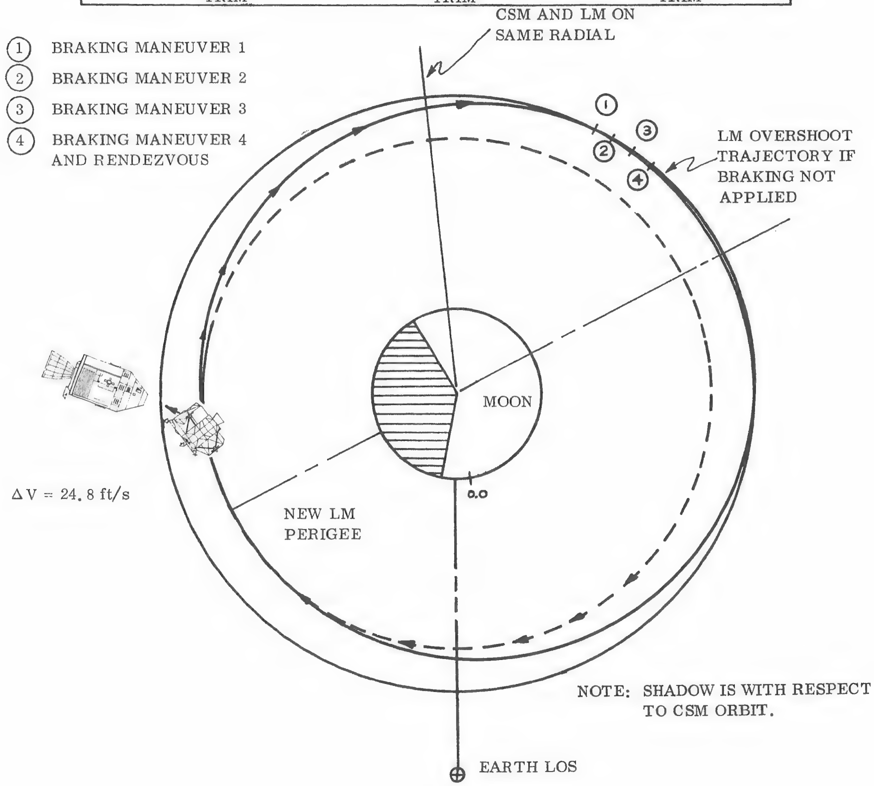
V37 Enter, 34 Enter
V06 N37 Flashing
    TIG of TPI (h, min, 0.01 s)
V06 N35 Flashing
    R2: Elevation angle, R3: Central angle (0.01 deg, 0.01 deg)
V16 N45 Flashing
    Marks, time from ignition, middle gimbal angle (marks, min/s, 0.01 deg)
V06 N58 Flashing
    Pericenter altitude, ΔV (TPI), ΔV (TPF) (0.1 nmi, 0.1 ft/s, 0.1 ft/s)
V06 N81 Flashing
    ΔV_X (LV), ΔV_Y (LV), ΔV_Z (LV) for TPI (0.1 ft/s)
V06 N59 Flashing
    ΔV_X (LOS), ΔV_Y (LOS), ΔV_Z (LOS) for TPI (0.1 ft/s)

+	0	0				Hours (TIG of TPI)	N37	+	0	0			
+	0	0	0			Minutes (TIG of TPI)		+	0	0	0		
+	0					Seconds (TIG of TPI)		+	0				
	0	0				Total ΔV required for TPI (ft/s)	N58		0	0			
	0	0				ΔV_X (LOS) — Components of ΔV in line of sight coordinates (ft/s)	N59		0	0			
	0	0				ΔV_Y (LOS)			0	0			
	0	0				ΔV_Z (LOS)			0	0			
	0	0				ΔV_X (LV) — Components of ΔV in local vertical coordinates (ft/s)	N81		0	0			
	0	0				ΔV_Y (LV)			0	0			
	0	0				ΔV_Z (LV)			0	0			
+	0	0				LM FDAI inertial roll and pitch angles at TPI (deg)		+	0	0			
+	0	0						+	0	0			
+	0					Range at TIG-5 min (nmi)	N54	+	0				
						Range rate at TIG-5 min (ft/s)							
0	0					Burn time (min/s)		0	0				

TERMINAL PHASE INITIATION

EVENT	BT/ΔV	TTNE	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
TPI (ALONG 26.6 DEGREE LINE OF SIGHT)	22.4/ 24.8	41:16	LM-RCS/PGNS LAMBERT (P-41)	P-34

_ _ _ _ . _	ΔV_X N85	+ X X _ _ . _	h
_ _ _ _ . _	ΔV_Y RESIDUALS (BODY AXIS) ft/s	+ X X X _ . _	min GET
_ _ _ _ . _	ΔV_Z	+ X _ _ . _ _	s
———•— $V_{X_{TRIM}}$	———•— $V_{Y_{TRIM}}$	———•— $V_{Z_{TRIM}}$ ft/s	

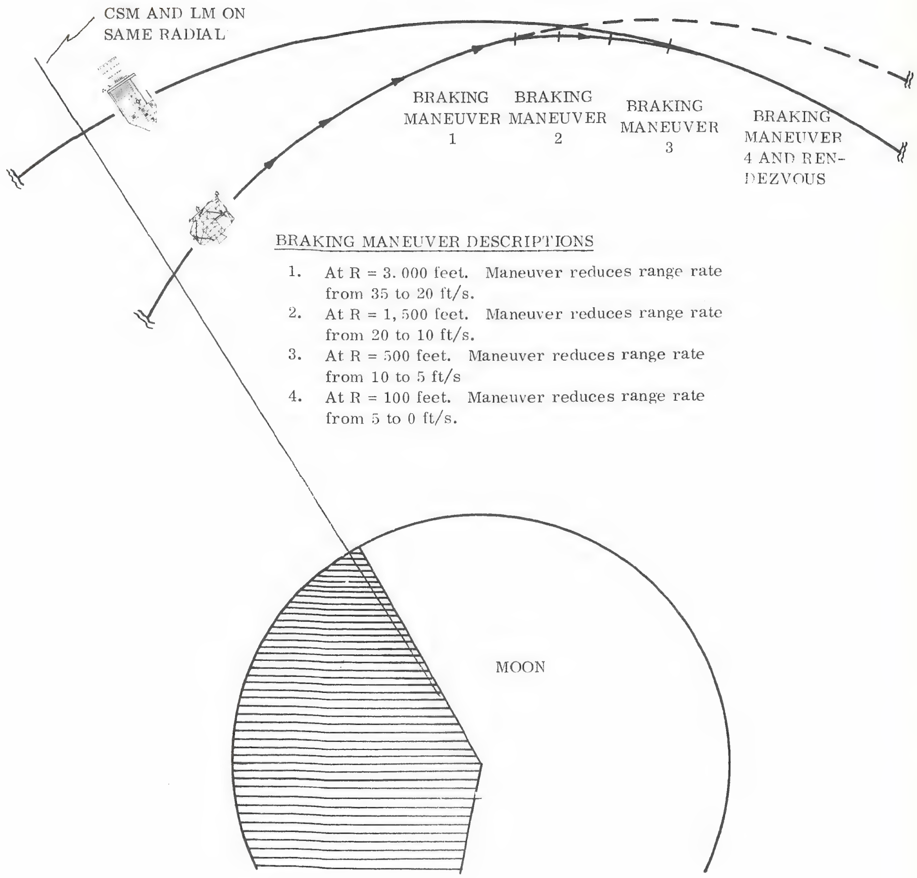


P41 – RCS THRUSTING

V37 Enter, 41 Enter
V50 N18 Flashing, Request Maneuver to FDAI R, P, Y Angles
V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude
V06 N85, X, Y, Z Body Axes Velocity to be Gained
V16 N85 (Average G on at TIG -30) Velocity to be Gained
V16 N85 Flashing, Body Axes Residuals (to be Nulled)

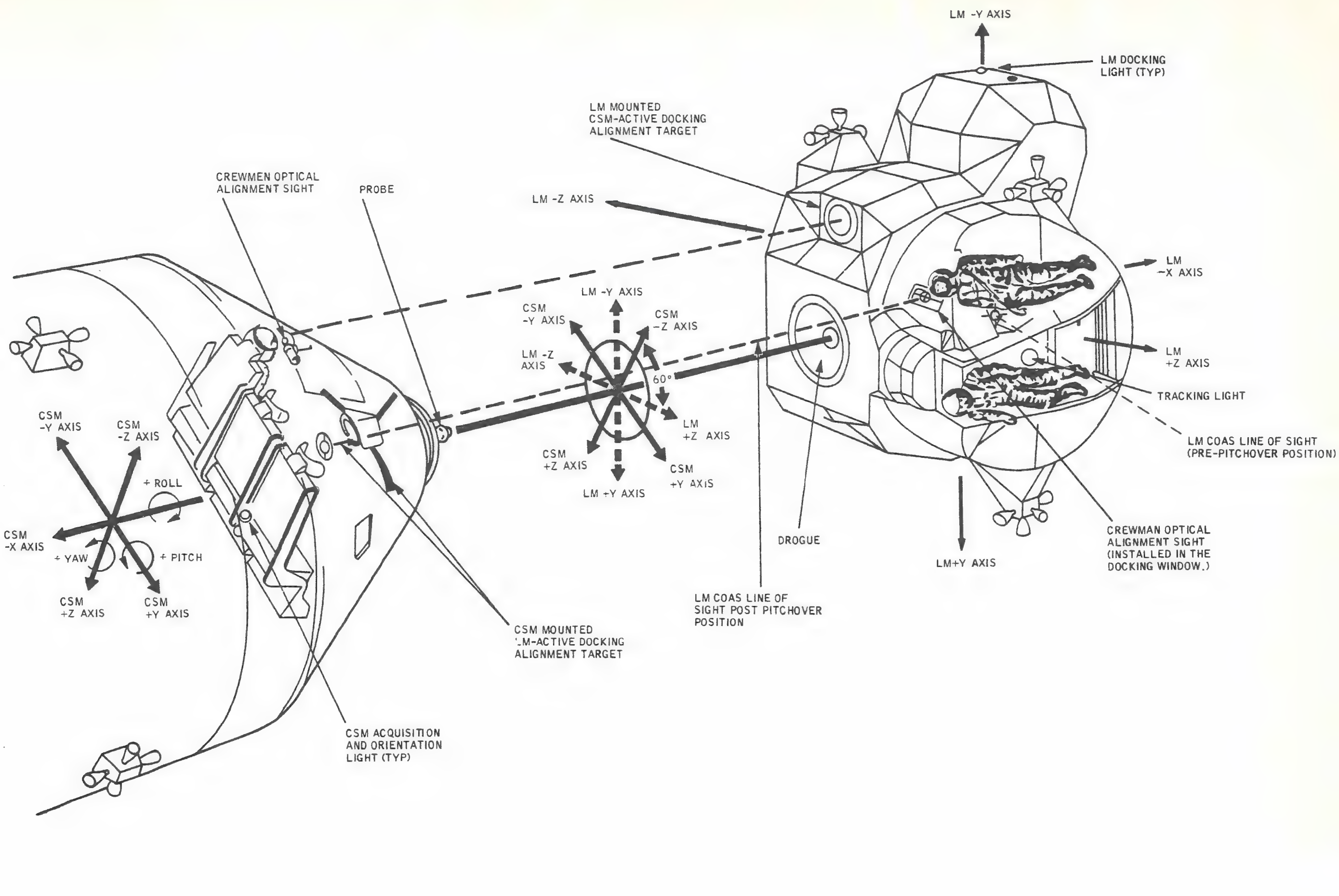
						50-18	Roll							
							Pitch	(deg)						
							Yaw							
						06-18	Roll							
							Pitch	(deg)						
							Yaw							
						06-85	X							
							Y	VG (ft/s)						
							Z							
						16-85	X							
							Y	VG (ft/s)						
							Z							
						16-85	X							
							Y	Residuals (ft/s)						
							Z							
						X								
						Y	Trim (ft/s)							
						Z								

LM RENDEZVOUS FINAL PHASE



BRAKING MANEUVER DESCRIPTIONS

1. At R = 3,000 feet. Maneuver reduces range rate from 35 to 20 ft/s.
2. At R = 1,500 feet. Maneuver reduces range rate from 20 to 10 ft/s.
3. At R = 500 feet. Maneuver reduces range rate from 10 to 5 ft/s
4. At R = 100 feet. Maneuver reduces range rate from 5 to 0 ft/s.



LM -Y AXIS
LM DOCKING
LIGHT (TYP)
LM MOUNTED
CSM-ACTIVE DOCKING
ALIGNMENT TARGET
CREWMEN OPTICAL
ALIGNMENT SIGHT
PROBE
LM -Z AXIS
LM
-X AXIS
LM -Y AXIS
CSM
-Y AXIS
CSM
-Z AXIS
LM -Z
AXIS
60°
LM
+Z AXIS
TRACKING LIGHT
LM
+Z AXIS
CSM
+Z AXIS
CSM
+Y AXIS
LM +Y AXIS
LM COAS LINE OF SIGHT
(PRE-PITCHOVER POSITION)
CSM
-Y AXIS
CSM
-Z AXIS
+ ROLL
CSM
-X AXIS
+ YAW
+ PITCH
CSM
+Z AXIS
CSM
+Y AXIS
DROGUE
LM+Y AXIS
CREWMAN OPTICAL
ALIGNMENT SIGHT
(INSTALLED IN THE
DOCKING WINDOW.)
LM COAS LINE OF
SIGHT POST PITCHOVER
POSITION
CSM MOUNTED
'_M-ACTIVE DOCKING
ALIGNMENT TARGET
CSM ACQUISITION
AND ORIENTATION
LIGHT (TYP)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 – Preferred, 2 – Nominal,
3 – REFSMMAT, 4 – Landing Site

V51 Flashing – Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours } GET		+	0	0			
+	0	0	0			Minutes } GET		+	0	0	0		
+	0					Seconds } GET		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X } Gyro Torquing Angles (degrees)	N93						
						Y } Gyro Torquing Angles (degrees)							
						Z } Gyro Torquing Angles (degrees)							
						X } Calculated Gyro Drift (meru)							
						Y } Calculated Gyro Drift (meru)							
						Z } Calculated Gyro Drift (meru)							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours } GET		+	0	0			
+	0	0	0			Minutes } GET		+	0	0	0		
+	0					Seconds } GET		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X } Gyro Torquing Angles (degrees)	N93						
						Y } Gyro Torquing Angles (degrees)							
						Z } Gyro Torquing Angles (degrees)							
						X } Calculated Gyro Drift (meru)							
						Y } Calculated Gyro Drift (meru)							
						Z } Calculated Gyro Drift (meru)							

NOTES:

TEI (NOMINAL)

P30–EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose							
		/				Prop/Guidance				/			
						Weight (lb)	N47	+					
	0	0				P_{Trim}	N48		0	0			
	0	0				Y_{Trim} (degrees)			0	0			
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes GETI		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X	N81						
						ΔV_Y LV							
						ΔV_Z (ft/s)							
X	X	X				R		X	X	X			
X	X	X				P IMU Gimbal Angles (deg)		X	X	X			
X	X	X				Y		X	X	X			
+						H_{Apogee}	N42	+					
						$H_{Perigee}$ nmi							
+						ΔVT (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X						ΔVC (ft/s)		X					
X	X	X	X			SXT Star		X	X	X	X		
+					0	SFT (degrees)		+					0
+				0	0	TRN (degrees)		+				0	0
X	X	X				BSS (Coas Star)		X	X	X			
X	X					SPA (Coas Pitch, deg)		X	X				
X	X	X				SXP (Coas X Pos, deg)		X	X	X			
	0					LAT (degrees)	N61		0				
						LONG							
+						RTGO (nmi) EMS		+					
+						VIO (ft/s)		+					
						GET 0.05 g Hr:min:s							
						SET STARS							
X	X	X				R_{Align}		X	X	X			
X	X	X				P_{Align}		X	X	X			
X	X	X				Y_{Align}		X	X	X			
						ULLAGE							

NOTES:

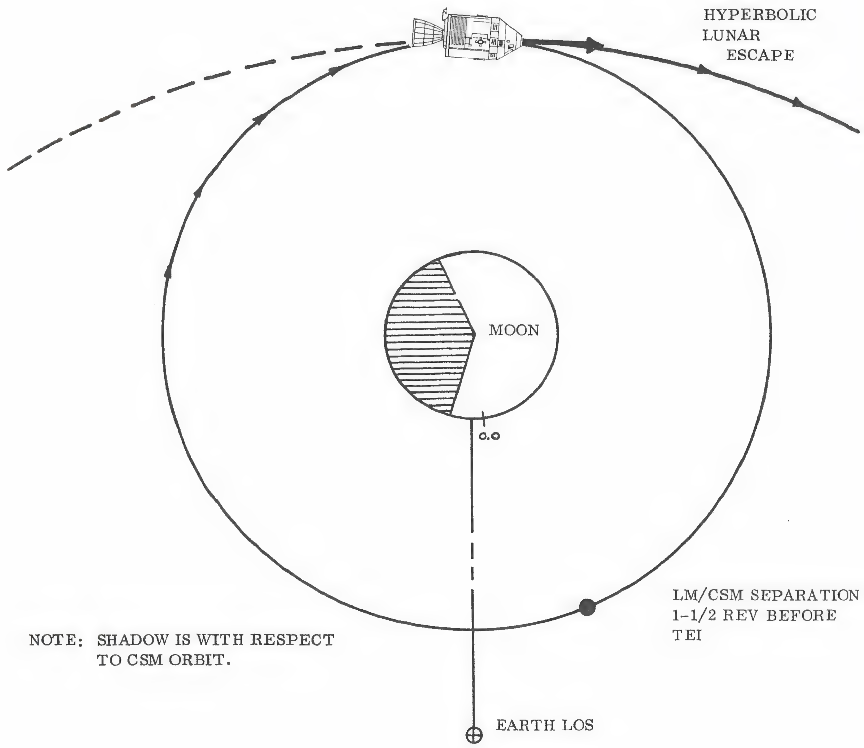
TRANSEARTH INJECTION

EVENT	BT/ΔV	TTNE	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
TEI (NOMINAL) (POSIGRADE)	149.0/ 3292.7	15:00:00	SPS/G & N EXT ΔV (P-40)	P-30

				.	ΔV_X	N85		+	X	X			.	h
				.	ΔV_Y	RESIDUALS	ft/s	+	X	X	X		.	min GET
				.	ΔV_Z	(BODY AXIS)		+	X			.		s

———•— $V_{X_{TRIM}}$	———•— $V_{Y_{TRIM}}$	———•— $V_{Z_{TRIM}}$ ft/s

ΔV = 3292.7 ft/s



NOTE: SHADOW IS WITH RESPECT TO CSM ORBIT.

TEI (OPTIONAL)

P30–EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

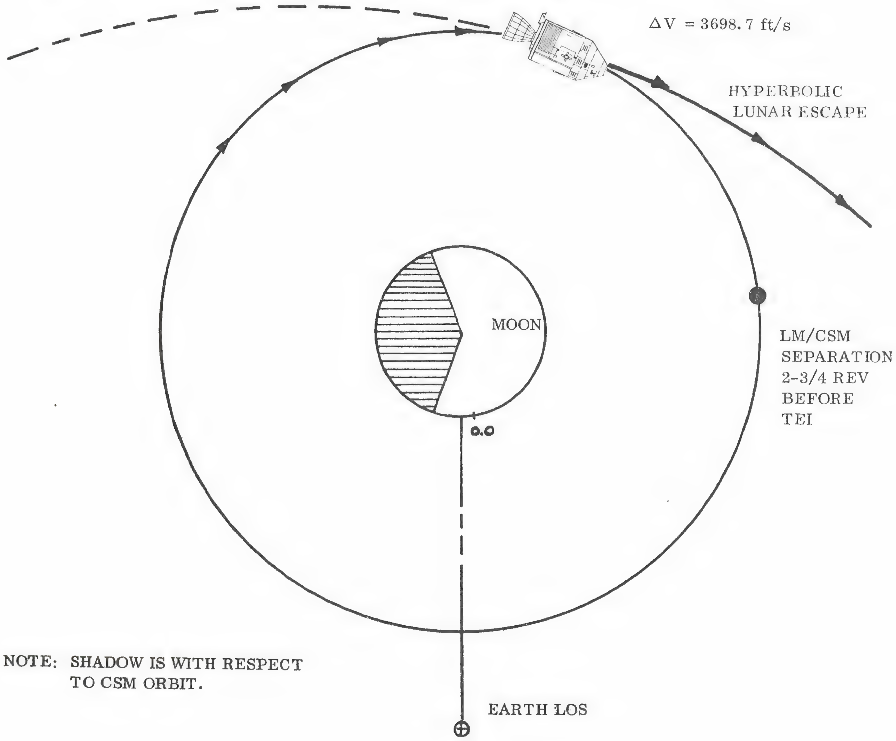
						Purpose							
		/				Prop/Guidance				/			
						Weight (lb)	N47	+					
	0	0				P_{Trim} (degrees)	N48		0	0			
	0	0				Y_{Trim}			0	0			
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes GETI		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X	N81						
						ΔV_Y LV							
						ΔV_Z (ft/s)							
X	X	X				R		X	X	X			
X	X	X				P IMU Gimbal Angles (deg)		X	X	X			
X	X	X				Y		X	X	X			
+						H_{Apogee}	N42	+					
						$H_{Perigee}$ nmi							
+						ΔVT (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X						ΔVC (ft/s)		X					
X	X	X	X			SXT Star		X	X	X	X		
+					0	SFT (degrees)		+					0
+				0	0	TRN (degrees)		+				0	0
X	X	X				BSS (Coas Star)		X	X	X			
X	X					SPA (Coas Pitch, deg)		X	X				
X	X	X				SXP (Coas X Pos, deg)		X	X	X			
	0					LAT (degrees)	N61		0				
						LONG							
+						RTGO (nmi) EMS		+					
+						VIO (ft/s)		+					
						GET 0.05 g Hr:min:s							
						SET STARS							
X	X	X				R_{Align}		X	X	X			
X	X	X				P_{Align}		X	X	X			
X	X	X				Y_{Align}		X	X	X			
						ULLAGE							

NOTES:

OPTIONAL TEI

EVENT	BT/ΔV	TTNE	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
TEI (OPTIONAL) (POSIGRADE)	170/ 3698.7	15:00:00	SPS/G & N EXT ΔV (P-40)	P-30

ΔV$_X$ N85	+ X X	h
ΔV$_Y$ RESIDUALS ft/s	+ X X X	min GET
ΔV$_Z$ (BODY AXIS)	+ X X X	s
----.-- V$_{X_{TRIM}}$ ----.-- V$_{Y_{TRIM}}$ ----.-- V$_{Z_{TRIM}}$ ft/s		



NOTE: SHADOW IS WITH RESPECT TO CSM ORBIT.

P52—IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 — Preferred, 2 — Nominal,
3 — REFSMMAT, 4 — Landing Site

V51 Flashing — Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

NOTES:

MCC$_5$

P30–EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose							
		/				Prop/Guidance				/			
						Weight (lb)	N47	+					
	0	0				P_{Trim} (degrees)	N48		0	0			
	0	0				Y_{Trim}			0	0			
+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes GETI		+	0	0	0		
+	0					Seconds		+	0				
						ΔV_X	N81						
						ΔV_Y LV							
						ΔV_Z (ft/s)							
X	X	X				R		X	X	X			
X	X	X				P IMU Gimbal Angles (deg)		X	X	X			
X	X	X				Y		X	X	X			
+						H_{Apogee}	N42	+					
						$H_{Perigee}$ nmi							
+						ΔVT (ft/s)		+					
X	X	X				BT (min:s)		X	X	X			
X						ΔVC (ft/s)		X					
X	X	X	X			SXT Star		X	X	X	X		
+					0	SFT (degrees)		+					0
+				0	0	TRN (degrees)		+				0	0
X	X	X				BSS (Coas Star)		X	X	X			
X	X					SPA (Coas Pitch, deg)		X	X				
X	X	X				SXP (Coas X Pos, deg)		X	X	X			
	0					LAT (degrees)	N61		0				
						LONG							
+						RTGO (nmi) EMS		+					
+						VIO (ft/s)		+					
						GET 0.05 g Hr:min:s							
						SET STARS							
X	X	X				R_{Align}		X	X	X			
X	X	X				P_{Align}		X	X	X			
X	X	X				Y_{Align}		X	X	X			
						ULLAGE							

NOTES:

P40 – SPS THRUSTING CSM

V37 Enter, 40 Enter
V50 N18 Flashing, Request Maneuver to FDAI R, P, Y Angles
V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude
V50 N25 Flashing, R1 = 0 0 2 0 4, Gimbal Actuator Test Option
V06 N40, Time from Ignition, Velocity to be Gained, Measured Change in Velocity
V99 N40 Flashing, Engine On Enable Request
V06 N40, Time from Cutoff, Velocity to be Gained, Measured Change in Velocity
V16 N40 Flashing, Final Values at Engine Cutoff
V16 N85 Flashing, Body Axes Residuals (to be Nulled)
V37 Flashing, V82 Enter
V16 N44 Flashing, Apogee Altitude, Perigee Altitude, Time to Freefall to 35 K ft Moon Orbit, 300 K ft Earth Orbit

P41 – RCS THRUSTING

V37 Enter, 41 Enter
V50 N18 Flashing, Request Maneuver to FDAI R, P, Y, Angles
V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude
V06 N85, X, Y, Z Body Axes Velocity to be Gained
V16 N85 (Average G on at TIG -30) Velocity to be Gained
V16 N85 Flashing, Body Axes Residuals (to be Nulled)

						50-18	Roll	
							Pitch	(deg)
							Yaw	
						06-18	Roll	
							Pitch	(deg)
							Yaw	
			X			06-40	TFI (min:s)	
							VG (ft/s)	
							ΔVM (ft/s)	
			X			06-40	TFC (min:s)	
							VG (ft/s)	
							ΔVM (ft/s)	
			X			16-40	TFC (min:s)	
							VG (ft/s)	
							ΔVM (ft/s)	
						85	X	
							Y	Residuals (ft/s)
							Z	
						85	X	
							Y	TRIM (ft/s)
							Z	
						44	HA (nmi)	
							HP (nmi)	
			X				TFF (min:s)	

						50-18	Roll	
							Pitch	(deg)
							Yaw	
						06-18	Roll	
							Pitch	(deg)
							Yaw	
						06-85	X	
							Y	VG (ft/s)
							Z	
						16-85	X	
							Y	VG (ft/s)
							Z	
						16-85	X	
							Y	Residuals (ft/s)
							Z	
						X		
						Y	Trim (ft/s)	
						Z		

P52—IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 — Preferred, 2 — Nominal,
3 — REFSMMAT, 4 — Landing Site

V51 Flashing — Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours (GET)		+	0	0			
+	0	0	0			Minutes (GET)		+	0	0	0		
+	0					Seconds (GET)		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y Gyro Torquing Angles (degrees)							
						Z Gyro Torquing Angles (degrees)							
						X Calculated Gyro Drift (meru)							
						Y Calculated Gyro Drift (meru)							
						Z Calculated Gyro Drift (meru)							

NOTES:

MCC$_6$

P30—EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose						
		/				Prop/Guidance			/			
						Weight (lb) N47	+					
	0	0				P_{Trim} (degrees) N48		0	0			
	0	0				Y_{Trim}		0	0			
+	0	0				Hours N33	+	0	0			
+	0	0	0			Minutes GETI	+	0	0	0		
+	0					Seconds	+	0				
						ΔV_X N81						
						ΔV_Y LV						
						ΔV_Z (ft/s)						
X	X	X				R	X	X	X			
X	X	X				P IMU Gimbal Angles (deg)	X	X	X			
X	X	X				Y	X	X	X			
+						H_{Apogee} N42	+					
						$H_{Perigee}$ nmi						
+						ΔVT (ft/s)	+					
X	X	X				BT (min:s)	X	X	X			
X						ΔVC (ft/s)	X					
X	X	X	X			SXT Star	X	X	X	X		
+					0	SFT (degrees)	+					0
+				0	0	TRN (degrees)	+				0	0
X	X	X				BSS (Coas Star)	X	X	X			
X	X					SPA (Coas Pitch, deg)	X	X				
X	X	X				SXP (Coas X Pos, deg)	X	X	X			
	0					LAT N61		0				
						LONG (degrees)						
+						RTGO (nmi) EMS	+					
+						VIO (ft/s)	+					
						GET 0.05 g Hr:min:s						
						SET STARS						
X	X	X				R_{Align}	X	X	X			
X	X	X				P_{Align}	X	X	X			
X	X	X				Y_{Align}	X	X	X			
						ULLAGE						

NOTES:

P40 – SPS THRUSTING CSM

V37 Enter, 40 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V50 N25 Flashing, R1 = 0 0 2 0 4, Gimbal Actuator Test Option

V06 N40, Time from Ignition, Velocity to be Gained, Measured Change in Velocity

V99 N40 Flashing, Engine On Enable Request

V06 N40, Time from Cutoff, Velocity to be Gained, Measured Change in Velocity

V16 N40 Flashing, Final Values at Engine Cutoff

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

V37 Flashing, V82 Enter

V16 N44 Flashing, Apogee Altitude, Perigee Altitude, Time to Freefall to 35 K ft Moon Orbit, 300 K ft Earth Orbit

	50-18	Roll	
		Pitch	(deg)
		Yaw	
	06-18	Roll	
		Pitch	(deg)
		Yaw	
	06-40	TFI (min:s)	
		VG (ft/s)	
		ΔVM (ft/s)	
	06-40	TFC (min:s)	
		VG (ft/s)	
		ΔVM (ft/s)	
	16-40	TFC (min:s)	
		VG (ft/s)	
		ΔVM (ft/s)	
	85	X	
		Y	Residuals (ft/s)
		Z	
	85	X	
		Y	TRIM (ft/s)
		Z	
	44	HA (nmi)	
		HP (nmi)	
		TFF (min:s)	

P41 – RCS THRUSTING

V37 Enter, 41 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y, Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V06 N85, X, Y, Z Body Axes Velocity to be Gained

V16 N85 (Average G on at TIG -30) Velocity to be Gained

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

	50-18	Roll	
		Pitch	(deg)
		Yaw	
	06-18	Roll	
		Pitch	(deg)
		Yaw	
	06-85	X	
		Y	VG (ft/s)
		Z	
	16-85	X	
		Y	VG (ft/s)
		Z	
	16-85	X	
		Y	Residuals (ft/s)
		Z	
	X		
	Y	Trim (ft/s)	
	Z		

ENTRY

P61

V37 Enter, 61 Enter

V06 N61 Flashing

V06 N60 Flashing, Record

V06 N63 Flashing, Used for EMS if no Communication

P62

V50 N25 Flashing, Request CM/SM Separation

V06 N61 Flashing

V06 N22, Monitor

P63

V06 N64, Monitor

						Area							
X	X	X				R 0.05 g		X	X	X			
X	X	X				P 0.05 g		X	X	X			
X	X	X				Y 0.05 g		X	X	X			
						GET Hor Ck							
X	X	X				P EI-17		X	X	X			
	0					Lat	N61		0				
						Long							
X	X	X				Max g		X	X	X			
+						V_{400K}	N60	+					
–	0	0				γ_{400K}		–	0	0			
+						RTGO EMS		+					
+						VIO		+					
						RTT							
X	X					RET 0.05 g*		X	X				
+	0	0				D_L Max*	N69	+	0	0			
+	0	0				D_L Min*		+	0	0			
+						V_L Max*		+					
+						V_L Min*		+					
X	X	X				D_O		X	X	X			
X	X					RET V_{Circ}		X	X				
X	X					RETBBO		X	X				
X	X					RETEBO		X	X				
X	X					RETDRO		X	X				
X	X	X	X			SXTS		X	X	X	X		
+					0	SFT EI-2		+					0
+				0	0	TRN		+				0	0
X	X	X				BSS		X	X	X			
X	X					SPA EI-2		X	X				
X	X	X				SXP		X	X	X			
X	X	X	X			Lift Vector		X	X	X	X		

AREA	XXX	Splashdown Area Defined by Target Line.
R .05G P .05G Y .05G	XXX (deg) XXX (deg) XXX (deg)	Spacecraft IMU Gimbal Angles Required for Aerodynamic Trim at 0.05 g
GET (HOR CK)	XX:XX:XX (h:min:s)	Time of Entry Attitude Horizon Check at EI -17 Minutes.
P (HOR CK)	XXX (deg)	Pitch Attitude for Horizon Check at EI -17 Minutes.
LAT	±XX.XX (deg)	Latitude of Target Point.
LONG	±XXX.XX (deg)	Longitude of Target Point.
MAX G	XX.X (g)	Predicted Maximum Reentry Acceleration.
V_{400K}	XXXXX (ft/s)	Inertial Velocity at Entry Interface.
γ_{400K}	X.XX (deg)	Inertial Flight Path Angle at Entry Interface.
RTGO	XXXX.X (nmi)	Range to Go from 0.05 g to Target for EMS Initialization.
VIO	XXXXX. (ft/s)	Inertial Velocity at 0.05 g for EMS Initialization.
RRT	XX:XX:XX (h:min:s)	Reentry Reference Time Based on GET of Predicted 400K (DET Start).
RET .05G	XX:XX (min:s)	Time of 0.05 g from 400K (RRT).
D_L MAX	X.XX (g)	Maximum Acceptable Value of Predicted Drag Level (from CMC).
D_L MIN	X.XX (g)	Minimum Acceptable Value of Predicted Drag Level (from CMC).
V_L MAX	XXXXX (ft/s)	Maximum Acceptable Value of Exit Velocity (from CMC).
V_L MIN	XXXXX (ft/s)	Minimum Acceptable Value of Exit Velocity (from CMC).
DO	X.XX (g)	Planned Drag Level During Constant g.
RET V_{CIRC}	XX:XX (min:s)	Time from EI that S/C Velocity Becomes Circular.
RETBBO	XX:XX (min:s)	Time from EI to the Beginning of Blackout.
RETEBO	XX:XX (min:s)	Time from EI to the End of Blackout.
RETDRO	XX:XX (min:s)	Time from EI to Drogue Deployment.
SXTS	XX (octal)	Sextant Star for Entry Attitude Check.
SFT	XXX.X (deg)	Sextant Shaft Setting for Entry Attitude Check.
TRN	XX.X (deg)	Sextant Trunnion Setting for Entry Attitude Check.
BSS	XXX (octal)	Boresight Star for Entry Attitude Check Using the COAS.
SPA	XX.X (deg)	BSS Pitch Angle on COAS.
SXP	X.X (deg)	BSS X Position on COAS.
LIFT VECTOR	XX	Lift Vector Desired at 0.05 g Based on Entry Corroidor.

P52—IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 — Preferred, 2 — Nominal,
3 — REFSMMAT, 4 — Landing Site

V51 Flashing — Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				GET Hours		+	0	0			
+	0	0	0			GET Minutes		+	0	0	0		
+	0					GET Seconds		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						Gyro Torquing Angles (degrees) X	N93						
						Gyro Torquing Angles (degrees) Y							
						Gyro Torquing Angles (degrees) Z							
						Calculated Gyro Drift (meru) X							
						Calculated Gyro Drift (meru) Y							
						Calculated Gyro Drift (meru) Z							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				GET Hours		+	0	0			
+	0	0	0			GET Minutes		+	0	0	0		
+	0					GET Seconds		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						Gyro Torquing Angles (degrees) X	N93						
						Gyro Torquing Angles (degrees) Y							
						Gyro Torquing Angles (degrees) Z							
						Calculated Gyro Drift (meru) X							
						Calculated Gyro Drift (meru) Y							
						Calculated Gyro Drift (meru) Z							

NOTES:

MCC$_7$

P30—EXTERNAL ΔV

V37 Enter, 30 Enter

V06 N33 Flashing, Load Desired GETI

V06 N81 Flashing, Load Desired ΔV

						Purpose						
			/			Prop/Guidance				/		
						Weight (lb) N47	+					
	0	0				P_{Trim} N48		0	0			
	0	0				Y_{Trim} (degrees)		0	0			
+	0	0				Hours N33	+	0	0			
+	0	0	0			Minutes GETI	+	0	0	0		
+	0					Seconds	+	0				
						ΔV_X N81						
						ΔV_Y LV						
						ΔV_Z (ft/s)						
X	X	X				R	X	X	X			
X	X	X				P IMU Gimbal Angles (deg)	X	X	X			
X	X	X				Y	X	X	X			
+						H_{Apogee} N42	+					
						$H_{Perigee}$ nmi						
+						ΔVT (ft/s)	+					
X	X	X				BT (min:s)	X	X	X			
X						ΔVC (ft/s)	X					
X	X	X	X			SXT Star	X	X	X	X		
+					0	SFT (degrees)	+					0
+				0	0	TRN (degrees)	+				0	0
X	X	X				BSS (Coas Star)	X	X	X			
X	X					SPA (Coas Pitch, deg)	X	X				
X	X	X				SXP (Coas X Pos, deg)	X	X	X			
	0					LAT N61		0				
						LONG (degrees)						
+						RTGO (nmi) EMS	+					
+						VIO (ft/s)	+					
						GET 0.05 g Hr:min:s						
						SET STARS						
X	X	X				R_{Align}	X	X	X			
X	X	X				P_{Align}	X	X	X			
X	X	X				Y_{Align}	X	X	X			
						ULLAGE						

NOTES:

P40 — SPS THRUSTING CSM

V37 Enter, 40 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V50 N25 Flashing, R1 = 0 0 2 0 4, Gimbal Actuator Test Option

V06 N40, Time from Ignition, Velocity to be Gained, Measured Change in Velocity

V99 N40 Flashing, Engine On Enable Request

V06 N40, Time from Cutoff, Velocity to be Gained, Measured Change in Velocity

V16 N40 Flashing, Final Values at Engine Cutoff

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

V37 Flashing, V82 Enter

V16 N44 Flashing, Apogee Altitude, Perigee Altitude, Time to Freefall to 35 K ft Moon Orbit, 300 K ft Earth Orbit

						50-18	Roll
							Pitch (deg)
							Yaw
						06-18	Roll
							Pitch (deg)
							Yaw
						06-40	TFI (min:s)
							VG (ft/s)
							ΔVM (ft/s)
						06-40	TFC (min:s)
							VG (ft/s)
							ΔVM (ft/s)
						16-40	TFC (min:s)
							VG (ft/s)
							ΔVM (ft/s)
						85	X
							Y Residuals (ft/s)
							Z
						85	X
							Y TRIM (ft/s)
							Z
						44	HA (nmi)
							HP (nmi)
							TFF (min:s)

P41 — RCS THRUSTING

V37 Enter, 41 Enter

V50 N18 Flashing, Request Maneuver to FDAI R, P, Y, Angles

V06 N18, FDAI R, P, Y Angles After Maneuver to Burn Attitude

V06 N85, X, Y, Z Body Axes Velocity to be Gained

V16 N85 (Average G on at TIG -30) Velocity to be Gained

V16 N85 Flashing, Body Axes Residuals (to be Nulled)

						50-18	Roll
							Pitch (deg)
							Yaw
						06-18	Roll
							Pitch (deg)
							Yaw
						06-85	X
							Y VG (ft/s)
							Z
						16-85	X
							Y VG (ft/s)
							Z
						16-85	X
							Y Residuals (ft/s)
							Z
							X
							Y Trim (ft/s)
							Z

P52—IMU REALIGN (CM)

V37 Enter, 52 Enter

V04 N06 Flashing

R1: 0 0 0 0 1

R2: 0 0 0 0 X IMU Align Option

1 — Preferred, 2 — Nominal,
3 — REFSMMAT, 4 — Landing Site

V51 Flashing — Please Mark

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours		+	0	0			
+	0	0	0			Minutes	GET	+	0	0	0		
+	0					Seconds		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y							
						Z							
						X Calculated Gyro Drift (meru)							
						Y							
						Z							

X	0	0	0	0		P52 Option		X	0	0	0	0	
+	0	0				Hours		+	0	0			
+	0	0	0			Minutes	GET	+	0	0	0		
+	0					Seconds		+	0				
X	0	0	0			Celestial Body Code	N71	X	0	0	0		
						Star Angle Difference (degrees)	N05						
						X Gyro Torquing Angles (degrees)	N93						
						Y							
						Z							
						X Calculated Gyro Drift (meru)							
						Y							
						Z							

NOTES:

ENTRY

P61

V37 Enter, 61 Enter
V06 N61 Flashing
V06 N60 Flashing, Record
V06 N63 Flashing, Used for EMS if no Communication

P62

V50 N25 Flashing, Request CM/SM Separation
V06 N61 Flashing
V06 N22, Monitor

P63

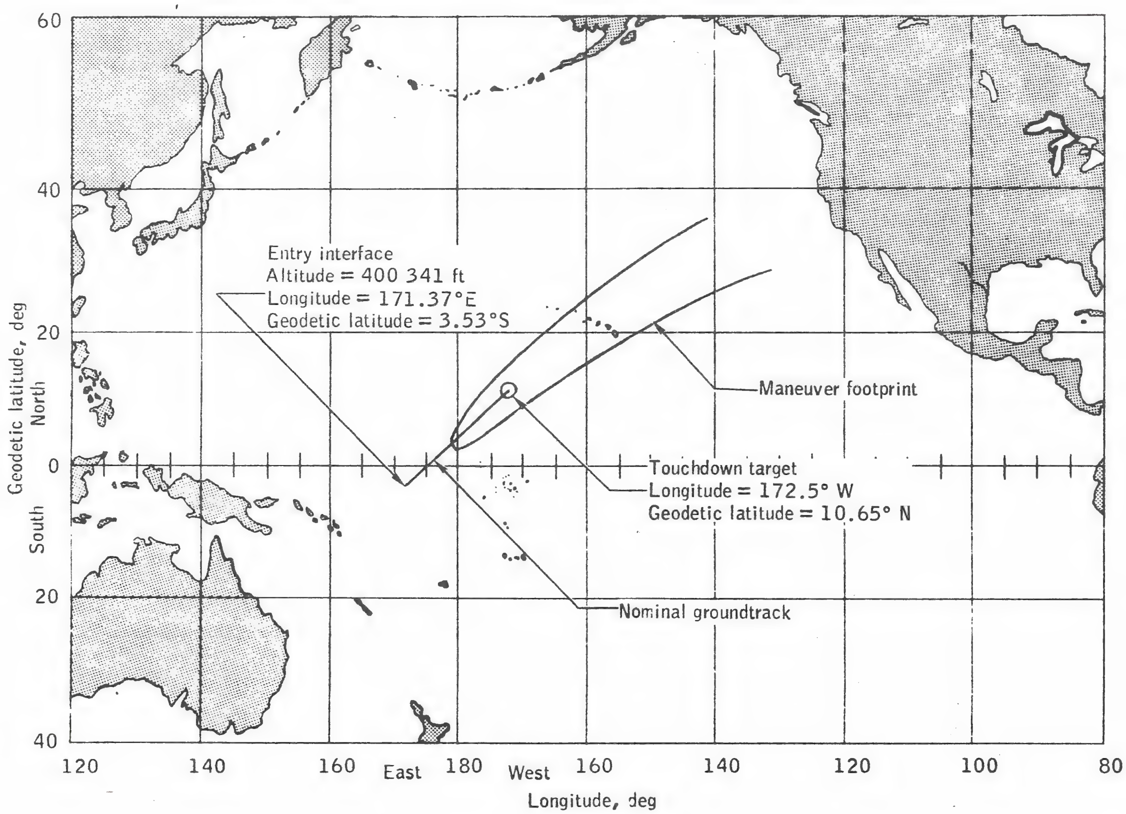
V06 N64, Monitor

						Area							
X	X	X				R 0.05 g		X	X	X			
X	X	X				P 0.05 g		X	X	X			
X	X	X				Y 0.05 g		X	X	X			
						GET Hor Ck							
X	X	X				P EI-17		X	X	X			
	0					Lat	N61		0				
						Long							
X	X	X				Max g		X	X	X			
+						V_{400K}	N60	+					
–	0	0				γ_{400K}		–	0	0			
+						RTGO EMS		+					
+						VIO		+					
						RTT							
X	X					RET 0.05 g*		X	X				
+	0	0				D_L Max*	N69	+	0	0			
+	0	0				D_L Min*		+	0	0			
+						V_L Max*		+					
+						V_L Min*		+					
X	X	X				D_O		X	X	X			
X	X					RET V_{Circ}		X	X				
X	X					RETBBO		X	X				
X	X					RETEBO		X	X				
X	X					RETDRO		X	X				
X	X	X	X			SXTS		X	X	X	X		
+					0	SFT EI-2		+					0
+				0	0	TRN		+				0	0
X	X	X				BSS		X	X	X			
X	X					SPA EI-2		X	X				
X	X	X				SXP		X	X	X			
X	X	X	X			Lift Vector		X	X	X	X		

TYPICAL MISSION G ENTRY

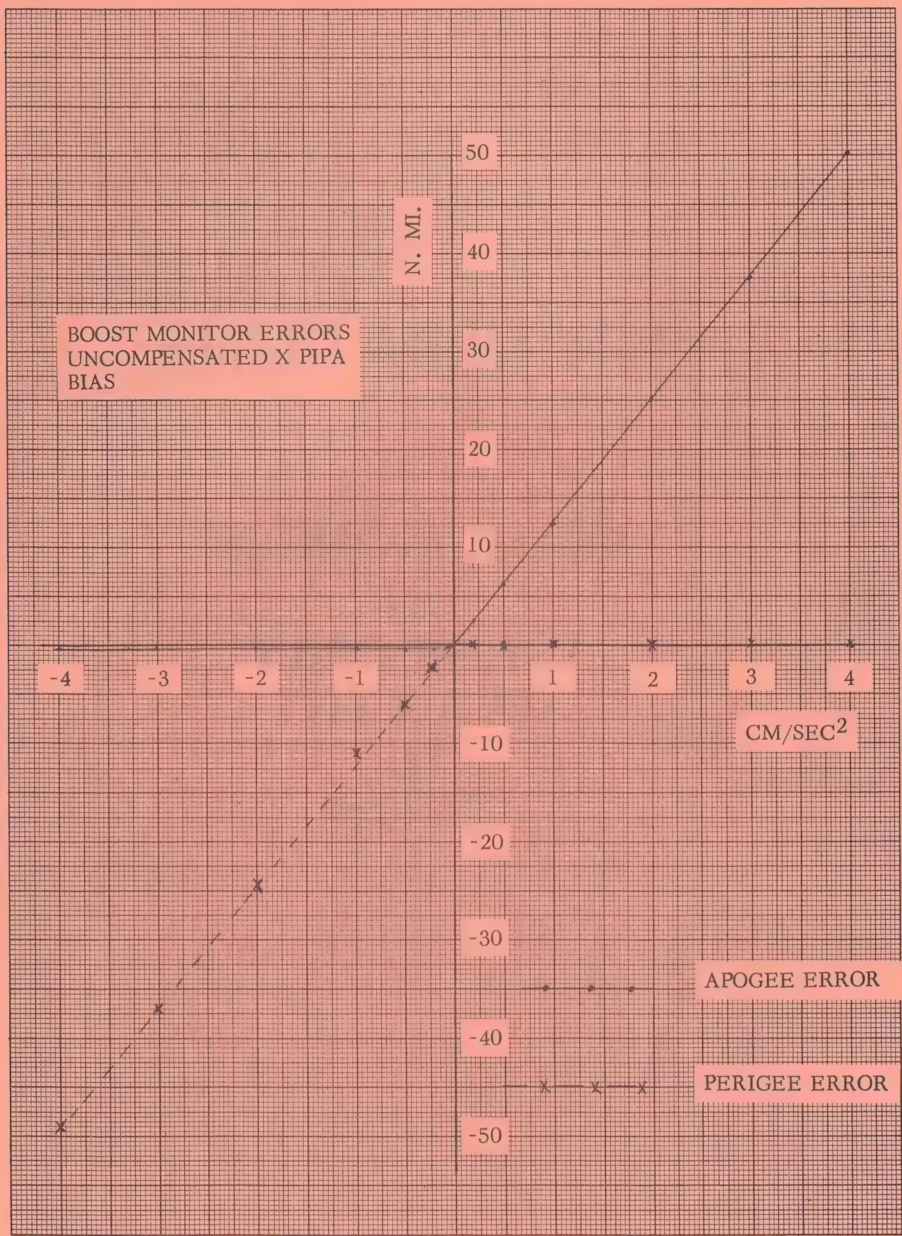
		NOMINAL ENTRY	OPTIONAL ENTRY
INITIAL CONDITIONS AT ENTRY INTERFACE			
Time From Launch (day/h/min/s)		8/3/1/6.5	8/3/13/32.9
Latitude	(deg)	3.527S	3.033S
Longitude	(deg)	171.376E	171.357E
Entry Angle	(deg)	6.500	6.510
Inertial Velocity	(ft/s)	36,160.600	36,246.324
Inertial Azimuth	(deg)	50.128	48.460
Angle Of Attack	(deg)	160.140	160.060 (approx)
Commanded Roll Angle	(deg)	0.000	0.000
SPLASH POINT CONDITIONS			
Time From Launch (day/h/min/s)		8/3/15/4.5	8/3/27/30.9 (approx)
Latitude	(deg)	10.65N	11.13N
Longitude	(deg)	172.50W	172.50W

MANEUVER FOOTPRINT AND NOMINAL GROUNDTRACK

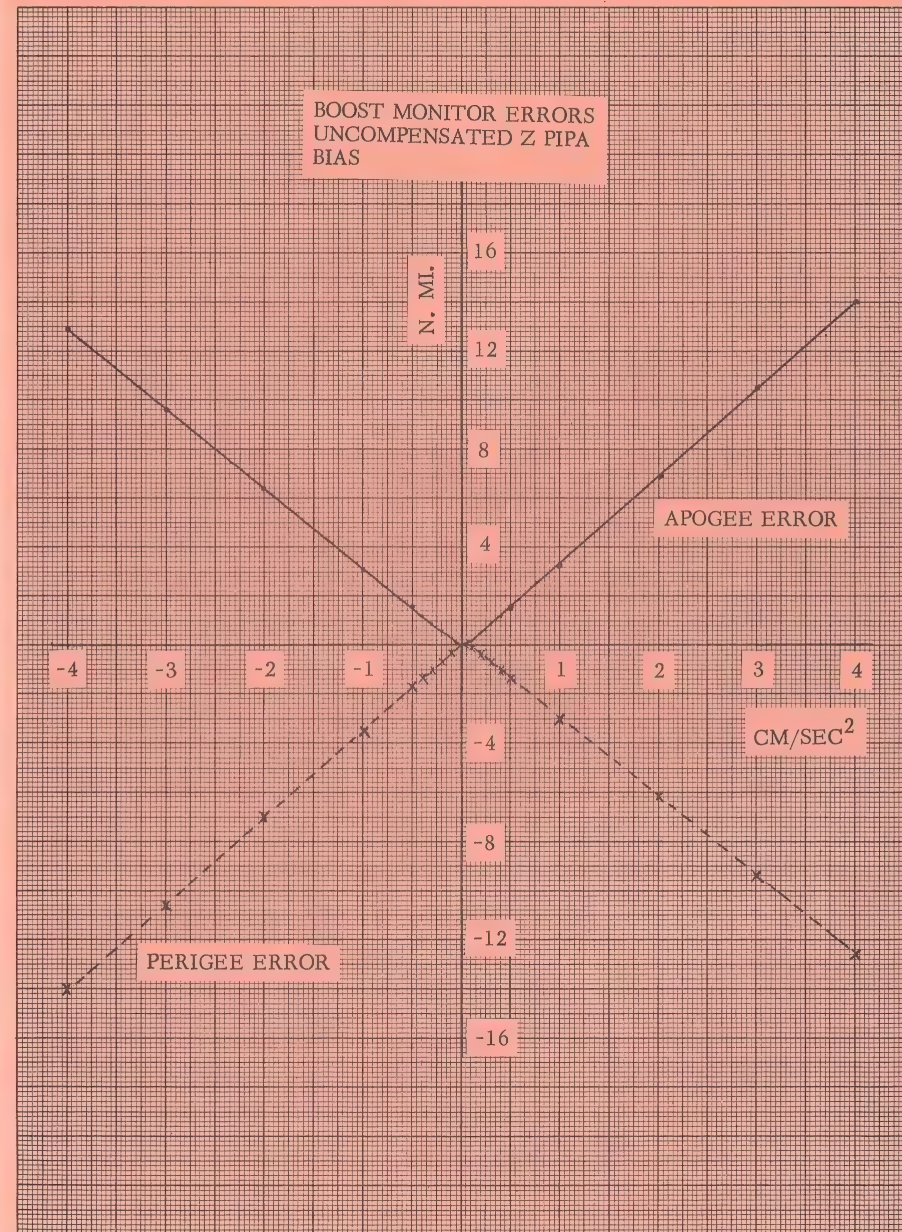


PERTURBATIONS

BOOST MONITOR
TLI
LUNAR ORBIT
LM ASCENT
TEI
ENTRY



BOOST MONITOR ERRORS
UNCOMPENSATED X PIPA
BIAS
N. MI.
50
40
30
20
10
-10
-20
-30
-40
-50
-4
-3
-2
-1
1
2
3
4
CM/SEC2
APOGEE ERROR
PERIGEE ERROR

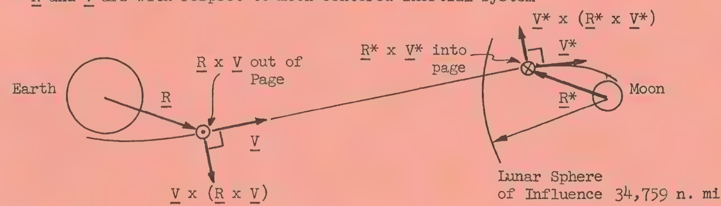

BOOST MONITOR ERRORS
UNCOMPENSATED Z PIPA
BIAS
N. MI.
16
12
8
4
-4
-8
-12
-16
-4
-3
-2
-1
1
2
3
4
APOGEE ERROR
PERIGEE ERROR
CM/SEC²

ERRORS IN PERICYNTHION

DUE TO VELOCITY ERRORS DURING TRANSLUNAR COAST

DIRECTION OF VELOCITY ERROR	ERROR IN PERICYNTHION (n.mi/ft/sec)
ERROR EXISTING AT TLI CUTOFF	(02:44:18 GET)
Along V	112.32
Along R x V	.11
Along V x (R x V)	- 6.76
ERROR EXISTING AT MCC-1 (TLI + 9 hours)	(11:44:18 GET)
Along V	34.54
Along R x V	1.62
Along V x (R x V)	-15.91
ERROR EXISTING AT MCC-2 (TLI + 24 hours)	(26:44:18 GET)
Along V	22.69
Along R x V	1.48
Along V x (R x V)	-13.48
ERROR EXISTING AT MCC-3 (LOI - 22 hours)	(53:55:03 GET)
Along V	10.04
Along R x V	.77
Along V x (R x V)	- 5.98
ERROR EXISTING AT MCC-4 (LOI - 5 hours)	(70:55:03 GET)
Along V*	.40
Along R* x V*	0
Along V* x (R* x V*)	2.71

* R and V are with respect to moon centered inertial system

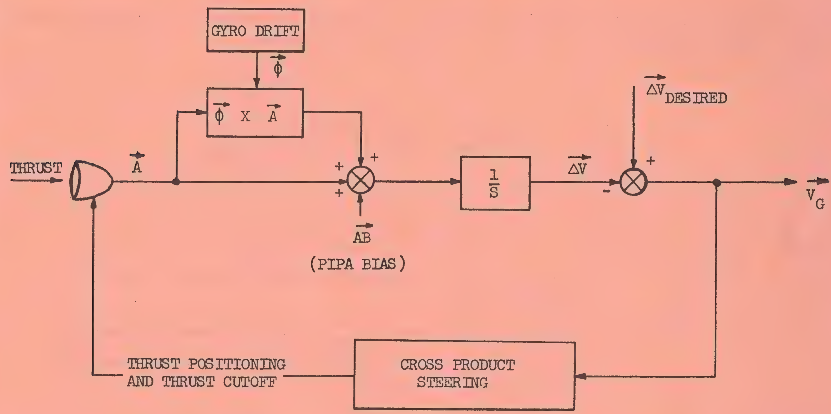


Transformation at TLI from stable member to V, R x V, and V x (R x V).

$$\begin{bmatrix} \text{UNIT } (V) \\ \text{UNIT } (R \times V) \\ \text{UNIT } (V \times (R \times V)) \end{bmatrix} = \begin{bmatrix} .633 & .021 & -.773 \\ .020 & -.999 & -.014 \\ -.774 & -.008 & -.633 \end{bmatrix} \begin{bmatrix} X_{SM} \\ Y_{SM} \\ Z_{SM} \end{bmatrix}$$

EFFECT OF INSTRUMENT ERRORS ON THRUST GUIDANCE

The thrust guidance used on Apollo, in simplified form, is as follows



The above steering loop attemps to drive V_g (velocity to be gained) to zero. The inability of the steering loop to drive V_g to zero will result in velocity residuals at the end of the burn as displayed in P-40.

Since the thrust guidance loop performs its calculations on the difference between ΔV measured and ΔV desired, the velocity residuals displayed by P-40 at the end of each burn are not caused by instrument errors but by the inability of the steering loop to drive V_g to zero.

Instrument errors result in a difference between the measured incremental velocity change and the true incremental velocity change. Assuming perfect cross product steering ($V_{Residuals}$ = 0 in P-40) the resultant orbit will differ from the planned orbit. A measure of the difference between the actual and planned orbits is the error between actual and planned apogee and perigee.

The following tables relate incremental spacecraft velocity errors, during lunar orbit maneuvers, to errors in apogee and perigee. Knowing apogee and perigee errors, the table is used to obtain the required error in velocity, expressed in body axes coordinates. This velocity error is then converted to possible instrument errors by using the table relating PIPA bias and gyro drift to spacecraft velocity.

For example: Assume a perigee error of +5.0 n mi and zero spacecraft residuals, as shown in P-40, after the DOI maneuver.

1. From the "Lunar Orbit Maneuver Perturbation" table, the most sensitive spacecraft velocity error is ΔV_X.

2. The required velocity error is

$$\Delta V_X = \frac{5.0 \text{ n mi}}{-.700 \text{ n mi/ft/sec}} = -7.14 \text{ ft/sec}$$

3. The weighting factors relating instrument errors to velocity errors yield

$$-0.84 \times 10^{-2} \, AB_X \times 58.6 - 3.17 \times 10^{-2} \, AB_Z \times 58.6 = -7.14 \text{ ft/sec}$$

$$-0.49 \, AB_X - 1.86 \, AB_Z = -7.14 \text{ ft/sec}$$

Therefore:

Uncompensated AB_X = +14.6 cm/sec^2 assuming AB_Z = 0

Uncompensated AB_Z = +3.8 cm/sec^2 assuming AB_X = 0

or a combination of the above could have caused the 5 n mi error in perigee.

The "Lunar Orbit Maneuver Perturbation" table also gives the transformation from stable member space to spacecraft body control axes space as follows:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{S/C\ CSM} = \left[R_X(-7.25°)\right]\left[SM\text{-}NB\right]\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{SM}$$

where:

$\left[SM\text{-}NB\right]$ = Transformation from stable member to the nav base using gimbal angles

$\left[R_X(-7.25°)\right]$ = Rotation matrix about X_{NB} of -7.25 degrees to transform from nav base space to spacecraft control axes space for the CSM.

For the LM

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{S/C\ LM} = \left[SM\text{-}NB\right]\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{SM}$$

The purpose of this transformation is to indicate the location of the stable member with respect to thrust. The assumed gimbal angles are as follows:

	OUTER GIMBAL (degrees)	INNER GIMBAL (degrees)	MIDDLE GIMBAL (degrees)
LOI_1	358	227	345
LOI_2	0	239	358
LM DOI	180	285	0
LM CSI	0	188	0
LM CDH	0	8	0
LM TPI	0	276	0
TEI	182	302	13

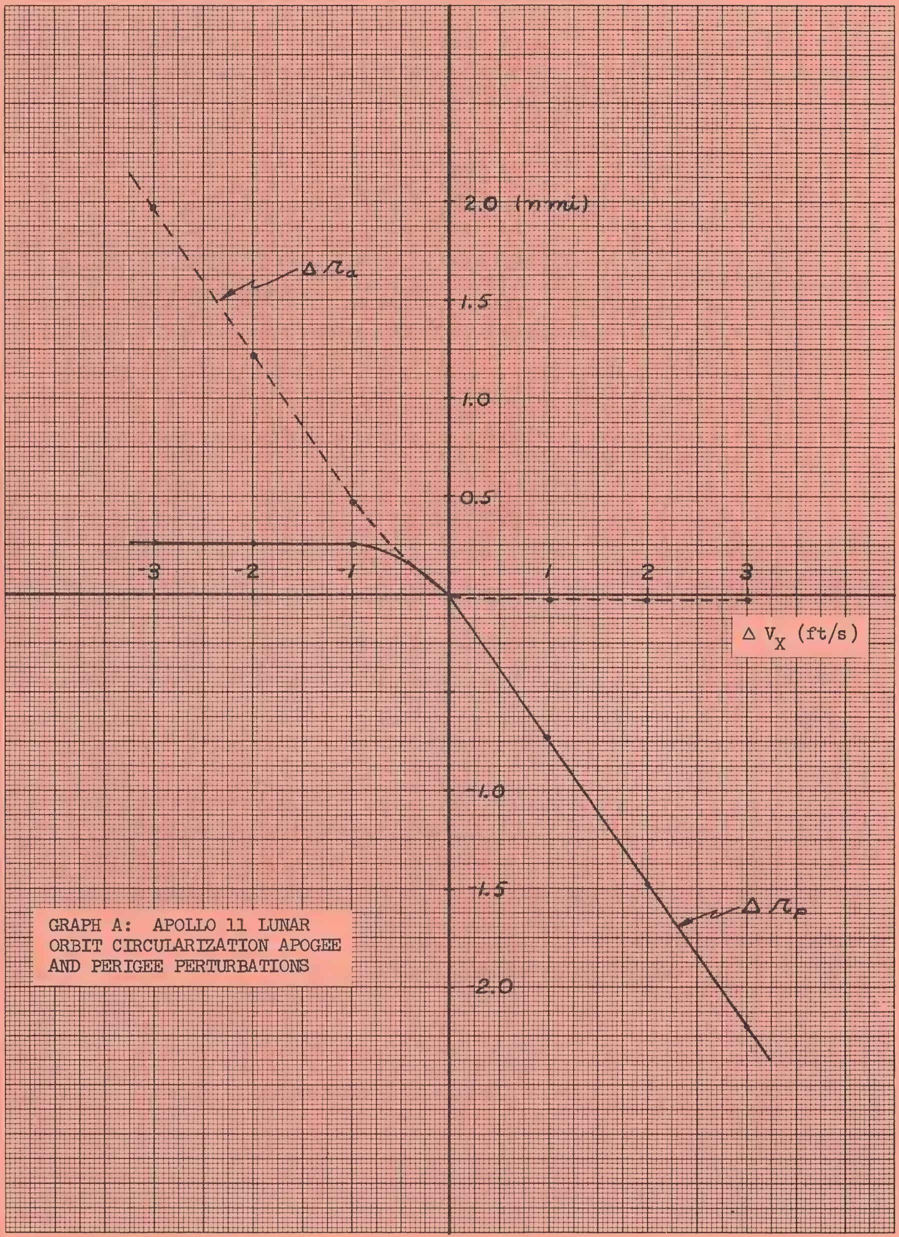
For all maneuvers thrust is assumed along $+X_{S/C}$ axis with the exceptions of the CDH maneuver where thrust was assumed along the $-X_{S/C}$ axis, and the CSI and TPI maneuvers where thrust was assumed along the $+Z_{S/C}$ axis.

APOLLO 11 LUNAR ORBIT MANEUVER PERTURBATIONS

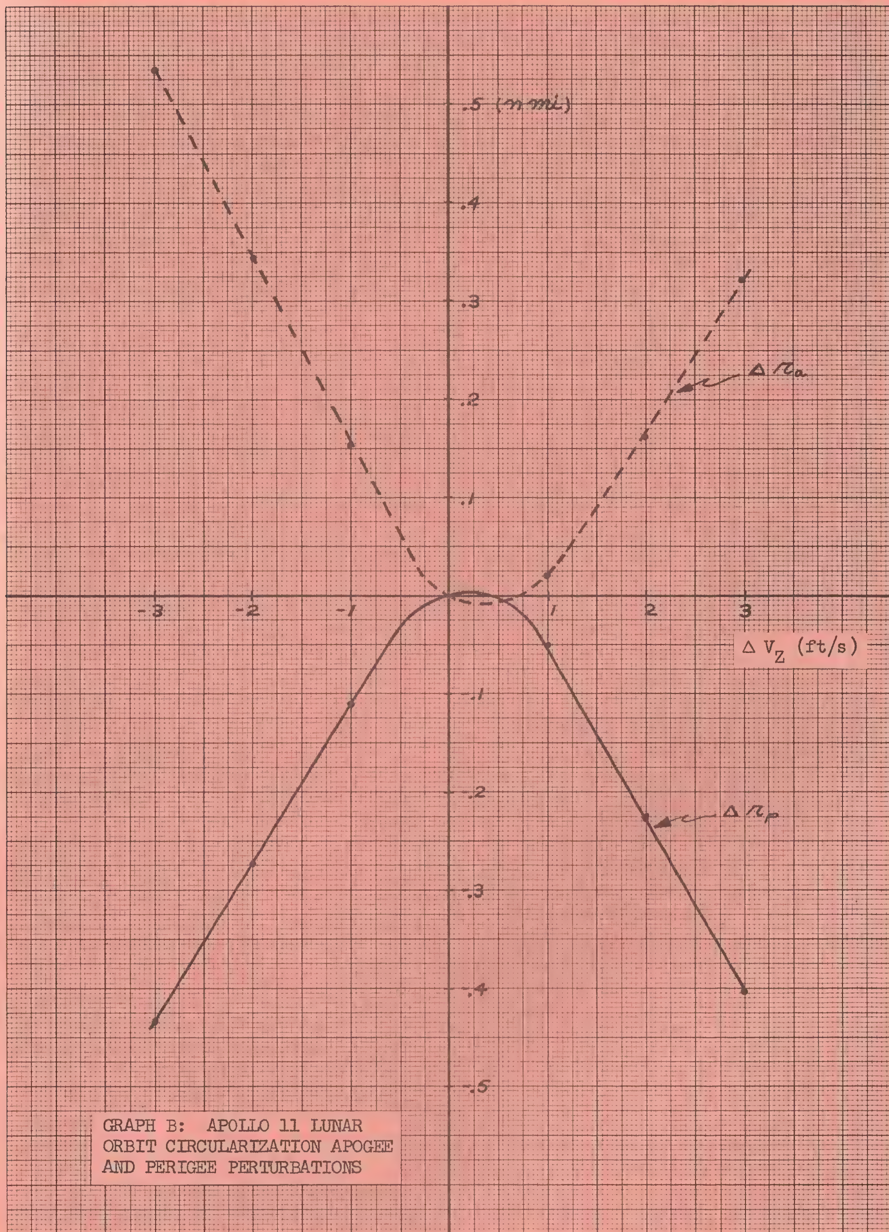
MANEUVER	BODY AXES VELOCITY ERRORS	ERROR IN PERIGEE (nmi/ft/s)	ERROR IN APOGEE (nmi/ft/s)	STABLE MEMBER TO SPACECRAFT CONTROL AXES TRANSFORMATION [SC] = [M] [SM]		
LOI_1	ΔV_x	—	-0.802	-0.659	-0.257	0.706
	ΔV_y	—	-0.201	-0.054	0.953	0.296
	ΔV_z	-0.063	-0.095	-0.750	0.157	-0.642
LOI_2	ΔV_x	Graph A	Graph A	-0.510	-0.042	0.859
	ΔV_y	—	—	0.086	0.991	0.099
	ΔV_z	Graph B	Graph B	-0.855	0.124	-0.502
LM DOI	ΔV_x	-0.700	—	0.257	0	0.966
	ΔV_y	—	—	0	1	0
	ΔV_z	—	—	0.966	0	-0.257
LM* CSI	ΔV_x	Graph C	Graph C	-0.991	0	0.132
	ΔV_y	—	—	0	1	0
	ΔV_z	Graph D	Graph D	-0.132	0	-0.991
LM** CDH	ΔV_x	Graph E	Graph E	0.991	0	-0.132
	ΔV_y	—	—	0	1	0
	ΔV_z	Graph F	Graph F	0.132	0	0.991
LM* TPI	ΔV_x	—	-0.30	0.106	0	0.994
	ΔV_y	—	—	0	1	0
	ΔV_z	—	0.67	-0.994	0	0.106

NOTES:

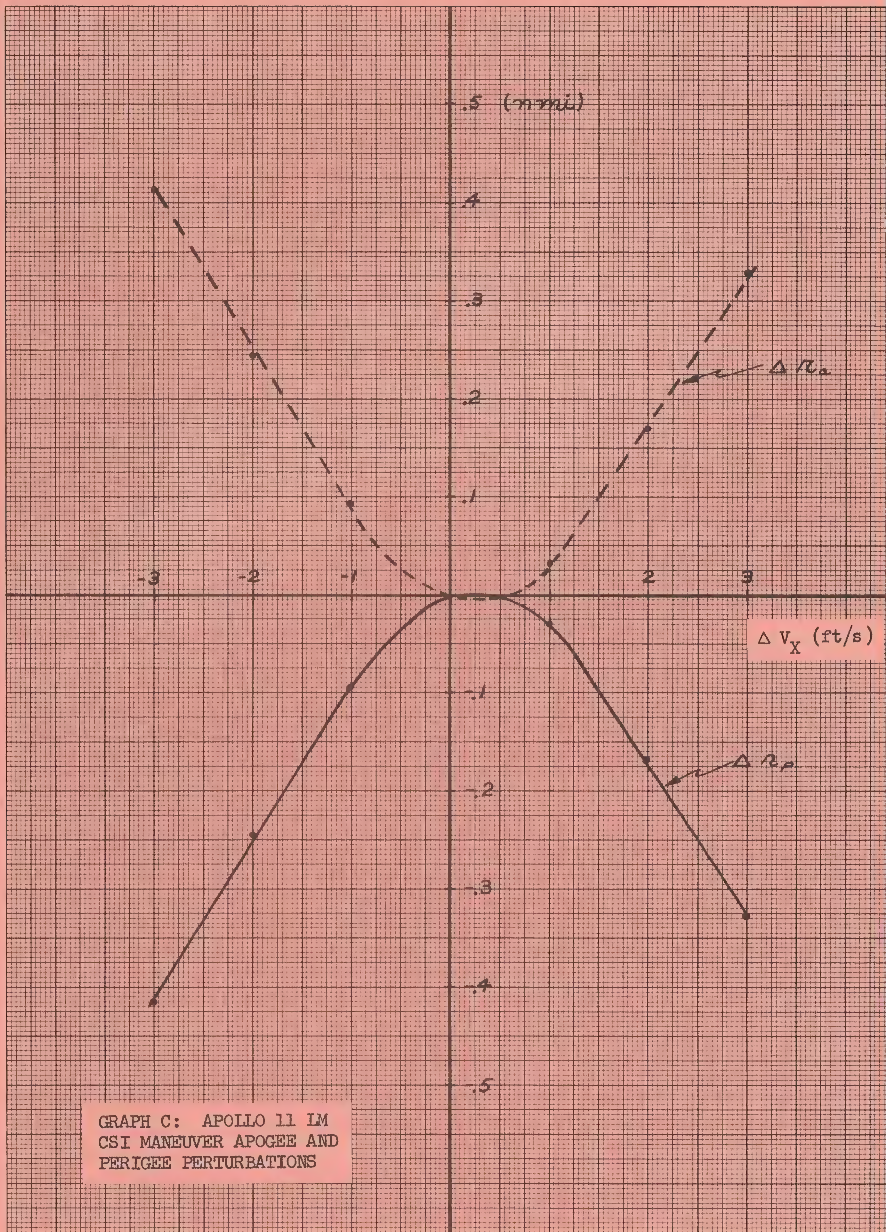
* Thrust is along +Z SC axis.
** Thrust is along -X SC axis.
— Indicates coefficient is less than 0.06 nmi/ft/s



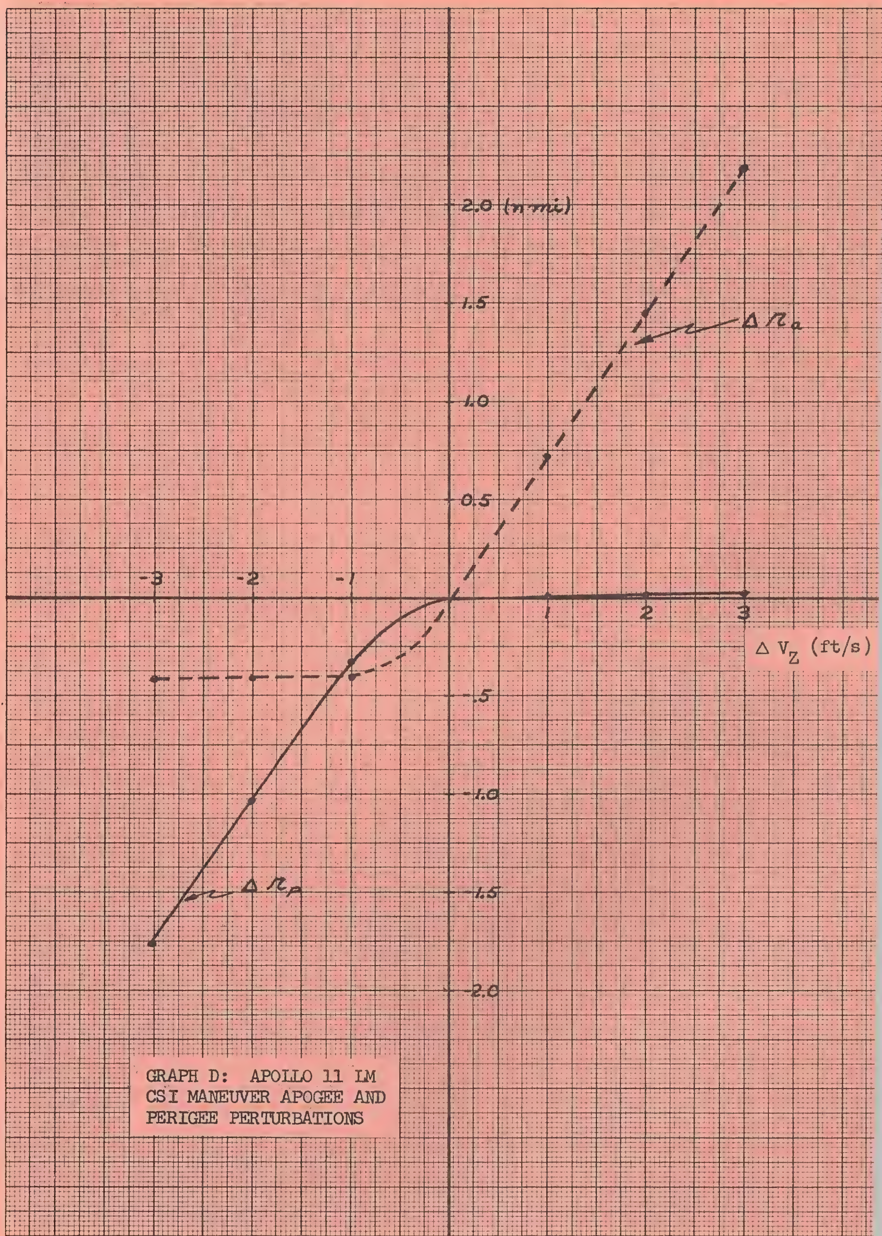
GRAPH A: APOLLO 11 LUNAR ORBIT CIRCULARIZATION APOGEE AND PERIGEE PERTURBATIONS



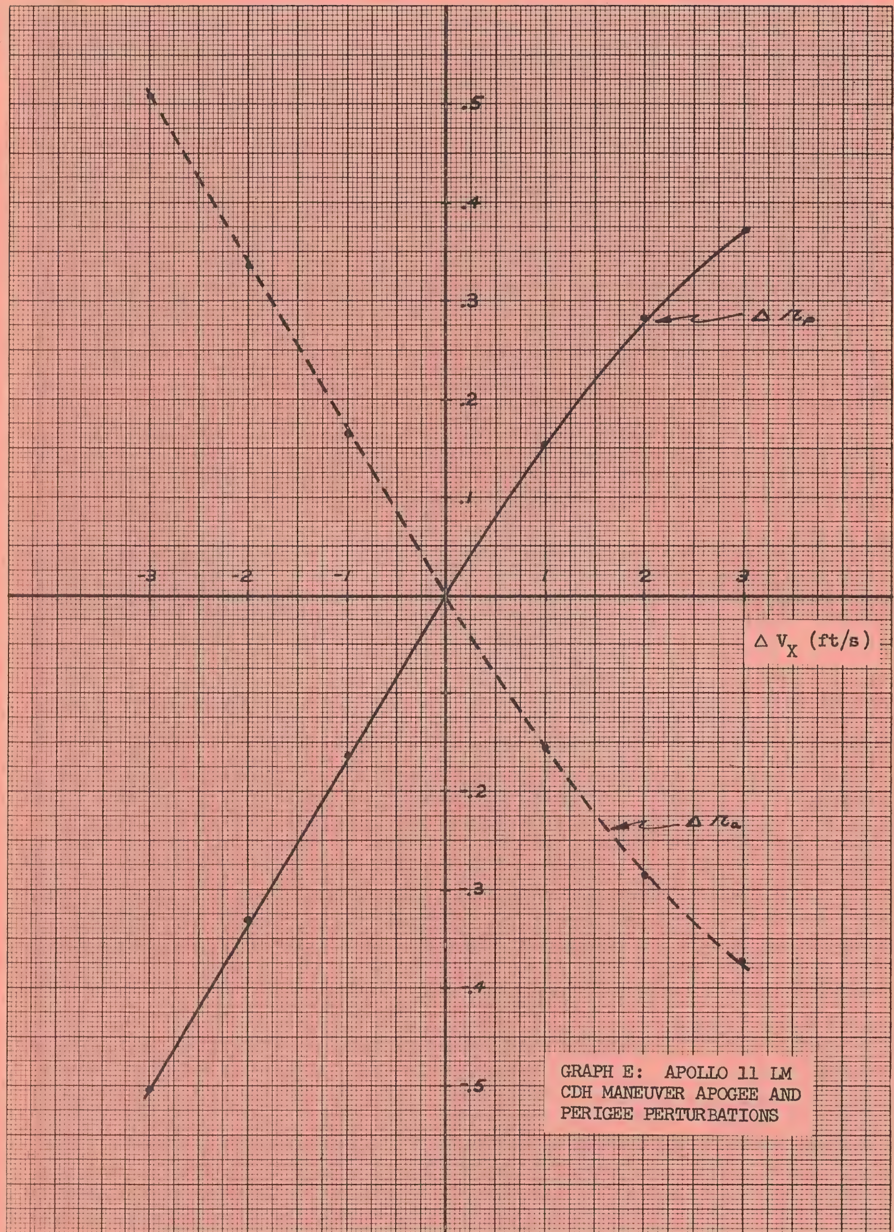
GRAPH B: APOLLO 11 LUNAR ORBIT CIRCULARIZATION APOGEE AND PERIGEE PERTURBATIONS



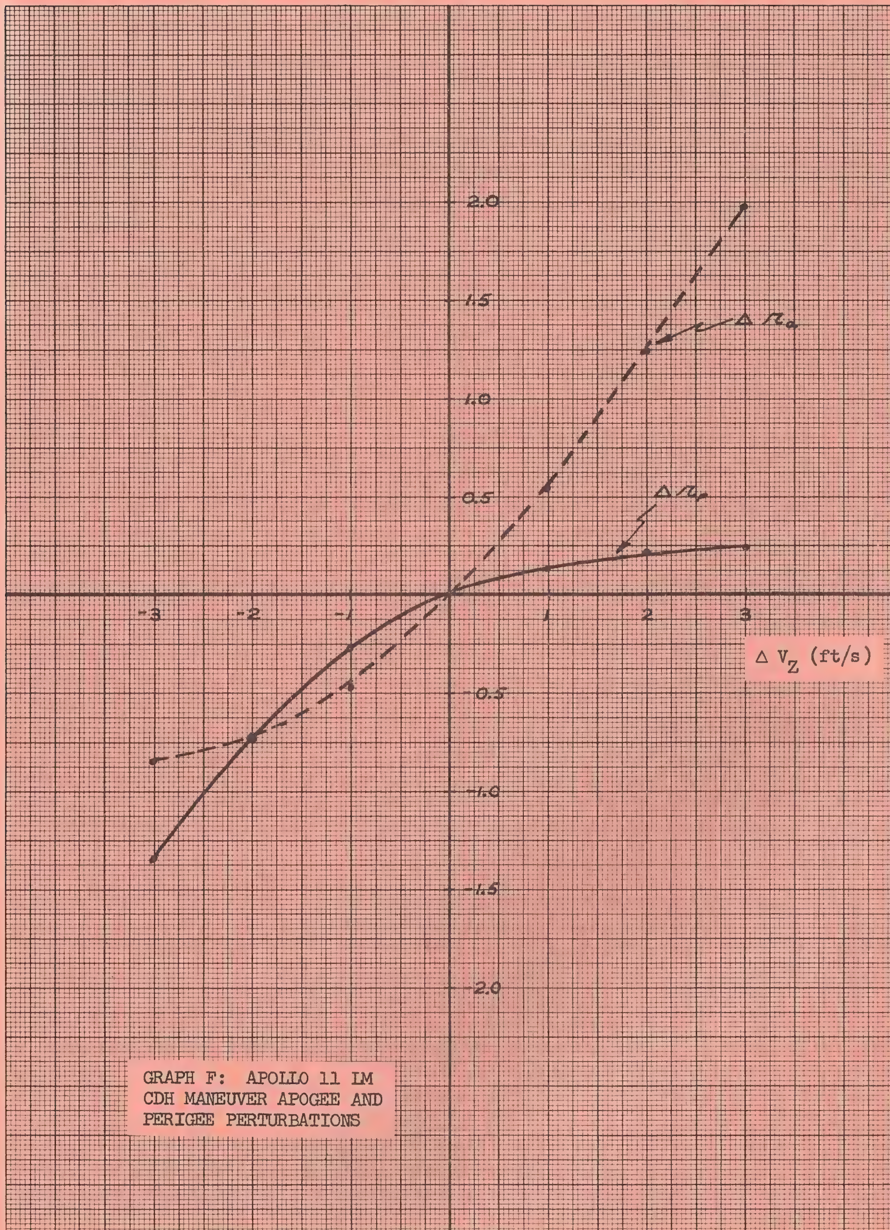
GRAPH C: APOLLO 11 LM CSI MANEUVER APOGEE AND PERIGEE PERTURBATIONS



GRAPH D: APOLLO 11 LM CSI MANEUVER APOGEE AND PERIGEE PERTURBATIONS



GRAPH E: APOLLO 11 LM CDH MANEUVER APOGEE AND PERIGEE PERTURBATIONS



GRAPH F: APOLLO 11 LM CDH MANEUVER APOGEE AND PERIGEE PERTURBATIONS

ΔV_{SC} ERRORS CAUSED BY GYRO DRIFTS $[\vec{\phi} \times \vec{A}]$ AND PIPA BIASES

GYRO DRIFTS - MERU

PIPA BIASES - CM/SEC^2

ΔV_{SC} - FT/SEC

ΔT_P - SEC (LENGTH OF BURN + 30 SECONDS FOR STARTUP OF AVERAGEG ROUTINE)

ΔT_G - SEC (TIME FROM LAST ALIGNMENT TO BURN)

WEIGHT FACTORS RELATE PIPA BIAS AND GYRO DRIFTS TO VELOCITY ERROR.

LOI_1

$$\Delta V_{X_{SC}} = + 5.48 \times 10^{-5}\ NBDZ\ \Delta T_G + 2.16 \times 10^{-2}\ AB_X\ \Delta T_P + 0.84 \times 10^{-2}\ AB_Y\ \Delta T_P - 2.32 \times 10^{-2}\ AB_Z\ \Delta T_P$$

$$\Delta V_{Y_{SC}} = - 1.99 \times 10^{-4}\ NBDZ\ \Delta T_G + 0.18 \times 10^{-2}\ AB_X\ \Delta T_P - 3.28 \times 10^{-2}\ AB_Y\ \Delta T_P - 0.97 \times 10^{-2}\ AB_Z\ \Delta T_P$$

$$\Delta V_{Z_{SC}} = + 5.48 \times 10^{-5}\ NBDX\ \Delta T_G - 1.99 \times 10^{-4}\ NBDY\ \Delta T_G + 2.46 \times 10^{-2}\ AB_X\ \Delta T_P - 0.51 \times 10^{-2}\ AB_Y\ \Delta T_P + 2.11 \times 10^{-2}\ AB_Z\ \Delta T_P$$

LOI_2

$$\Delta V_{X_{SC}} = + 1.67 \times 10^{-2}\ AB_X\ \Delta T_P - 2.82 \times 10^{-2}\ AB_Z\ \Delta T_P$$

$$\Delta V_{Y_{SC}} = - 1.01 \times 10^{-5}\ NBDZ\ \Delta T_G - 3.25 \times 10^{-2}\ AB_Y\ \Delta T_P$$

$$\Delta V_{Z_{SC}} = - 1.01 \times 10^{-5}\ NBDY\ \Delta T_G + 2.81 \times 10^{-2}\ AB_X\ \Delta T_P + 1.65 \times 10^{-2}\ AB_Z\ \Delta T_P$$

LM DOI

$$\Delta V_{X_{SC}} = - 0.84 \times 10^{-2}\ AB_X\ \Delta T_P - 3.17 \times 10^{-2}\ AB_Z\ \Delta T_P$$

$$\Delta V_{Y_{SC}} = - 5.20 \times 10^{-6}\ NBDZ\ \Delta T_G + 3.28 \times 10^{-2}\ AB_Y\ \Delta T_P$$

$$\Delta V_{Z_{SC}} = - 5.20 \times 10^{-6}\ NBDY\ \Delta T_G - 3.17 \times 10^{-2}\ AB_X\ \Delta T_P + 0.84 \times 10^{-2}\ AB_Z\ \Delta T_P$$

LM CSI

$$\Delta V_{X_{SC}} = + 3.65 \times 10^{-6}\ NBDY\ \Delta T_G + 3.25 \times 10^{-2}\ AB_X\ \Delta T_P - 0.43 \times 10^{-2}\ AB_Z\ \Delta T_P$$

$$\Delta V_{Y_{SC}} = - 3.65 \times 10^{-6}\ NBDX\ \Delta T_G - 3.28 \times 10^{-2}\ AB_Y\ \Delta T_P$$

$$\Delta V_{Z_{SC}} = + 0.43 \times 10^{-2}\ AB_X\ \Delta T_P + 3.25 \times 10^{-2}\ AB_Z\ \Delta T_P$$

LM CDH

$$\Delta V_{X_{SC}} = - 3.25 \times 10^{-2}\ AB_X\ \Delta T_P + 0.43 \times 10^{-2}\ AB_Z\ \Delta T_P$$

$$\Delta V_{Y_{SC}} = + 4.38 \times 10^{-7}\ NBDZ\ \Delta T_G - 3.28 \times 10^{-2}\ AB_Y\ \Delta T_P$$

$$\Delta V_{Z_{SC}} = + 4.38 \times 10^{-7}\ NBDY\ \Delta T_G - 0.43 \times 10^{-2}\ AB_X\ \Delta T_P - 3.25 \times 10^{-2}\ AB_Z\ \Delta T_P$$

LM TPI

$$\Delta V_{X_{SC}} = + 1.87 \times 10^{-6}\ NBDY\ \Delta T_G - 0.35 \times 10^{-2}\ AB_X\ \Delta T_P - 3.26 \times 10^{-2}\ AB_Z\ \Delta T_P$$

$$\Delta V_{Y_{SC}} = - 1.87 \times 10^{-6}\ NBDX\ \Delta T_G - 3.28 \times 10^{-2}\ AB_Y\ \Delta T_P$$

$$\Delta V_{Z_{SC}} = + 3.26 \times 10^{-2}\ AB_X\ \Delta T_P + 0.35 \times 10^{-2}\ AB_Z\ \Delta T_P$$

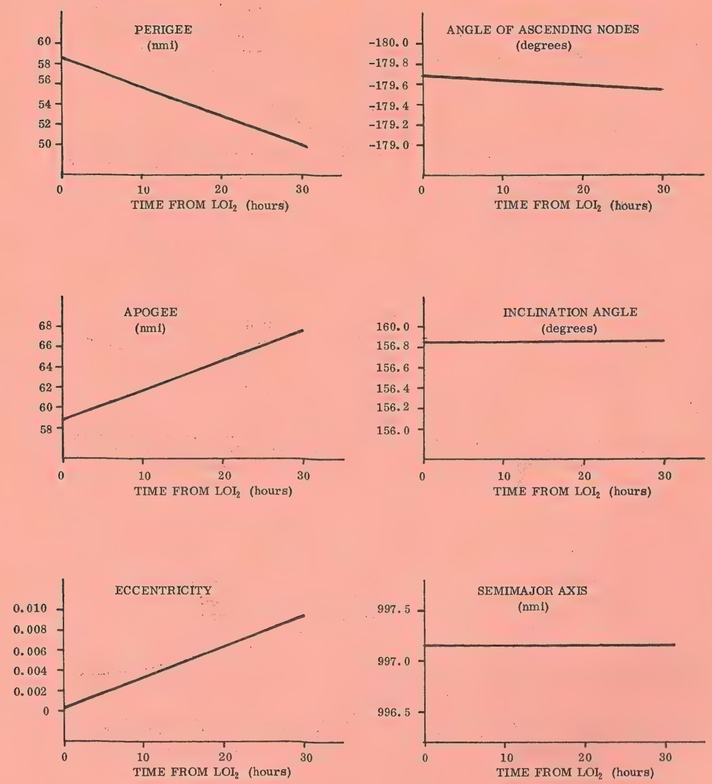
TEI

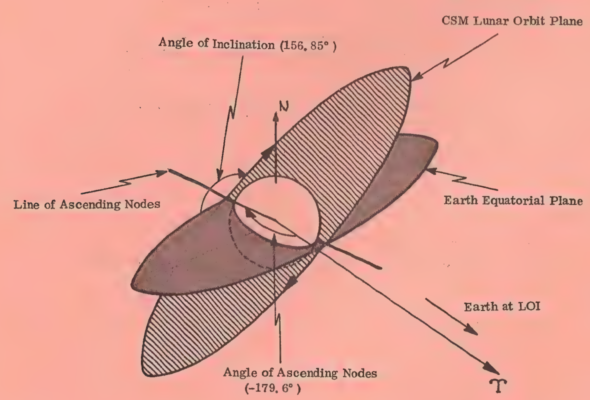
$$\Delta V_{X_{SC}} = + 4.50 \times 10^{-5}\ NBDZ\ \Delta T_G - 1.71 \times 10^{-2}\ AB_X\ \Delta T_P - 0.75 \times 10^{-2}\ AB_Y\ \Delta T_P + 2.70 \times 10^{-2}\ AB_Z\ \Delta T_P$$

$$\Delta V_{Y_{SC}} = - 2.62 \times 10^{-4}\ NBDZ\ \Delta T_G - 0.68 \times 10^{-2}\ AB_X\ \Delta T_P + 3.18 \times 10^{-2}\ AB_Y\ \Delta T_P + 0.45 \times 10^{-2}\ AB_Z\ \Delta T_P$$

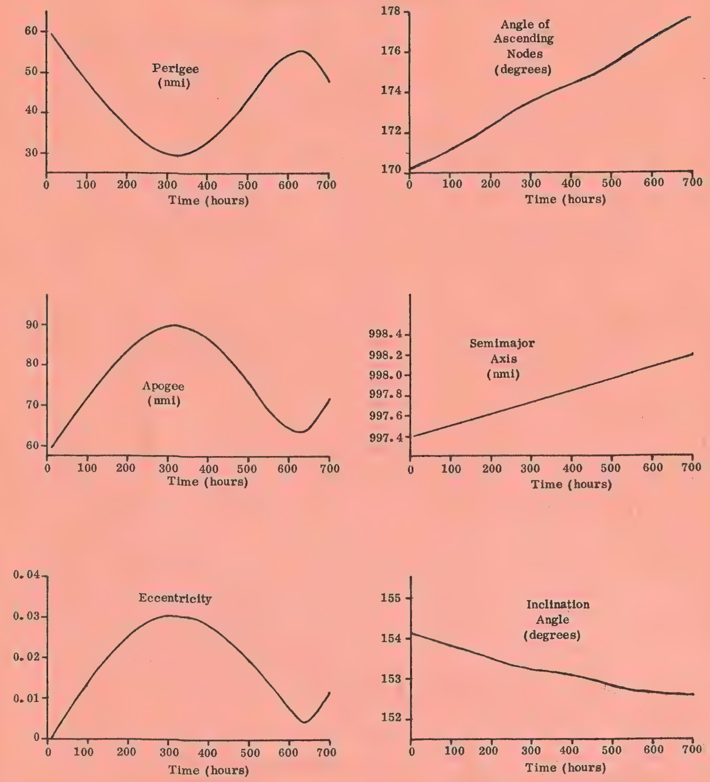
$$\Delta V_{Z_{SC}} = - 2.62 \times 10^{-4}\ NBDY\ \Delta T_G + 4.50 \times 10^{-5}\ NBDX\ \Delta T_G + 2.72 \times 10^{-2}\ AB_X\ \Delta T_P + 0.32 \times 10^{-2}\ AB_Y\ \Delta T_P + 1.81 \times 10^{-2}\ AB_Z\ \Delta T_P$$

APOLLO 11
LUNAR ORBIT PARAMETERS
(TYPICAL)





EFFECT OF LUNAR DISTURBANCE ACCELERATION
ON LUNAR ORBITAL PARAMETERS (TYPICAL)



$$
\begin{aligned}
\underline{a}_{dM} = \frac{\mu_M}{r^2}\Bigg\{ & \sum_{i=2}^{4} J_{iM}\left(\frac{r_M}{r}\right)^i \left[P'_{i+1}(\cos\phi)\,\underline{u}_r - P'_i(\cos\phi)\,\underline{u}_Z\right] \\
& + 3J_{22}\left(\frac{r_M}{r}\right)^2\left[\frac{-5(X_M^2 - Y_M^2)}{r^2}\,\underline{u}_Z + \frac{2X_M}{r}\,\underline{i}_M - \frac{2Y_M}{r}\,\underline{j}_M\right] \\
& + \frac{3}{2}C_{31}\left(\frac{r_M}{r}\right)^3\left[\frac{5X_M}{r}(1 - 7\cos^2\phi)\,\underline{u}_r + (5\cos^2\phi - 1)\,\underline{j}_M\right. \\
& \left. + \frac{10X_M Z_M}{r^2}\,\underline{k}_M\right]\Bigg\}
\end{aligned}
$$

where

r_M = mean lunar radius

$\underline{r}$ = $X_M\,\underline{i}_M + Y_M\,\underline{j}_M + Z_M\,\underline{k}_M$ = spacecraft position vector in moon-fixed coordinates

$\cos\phi = \underline{u}_r \cdot \underline{u}_Z$

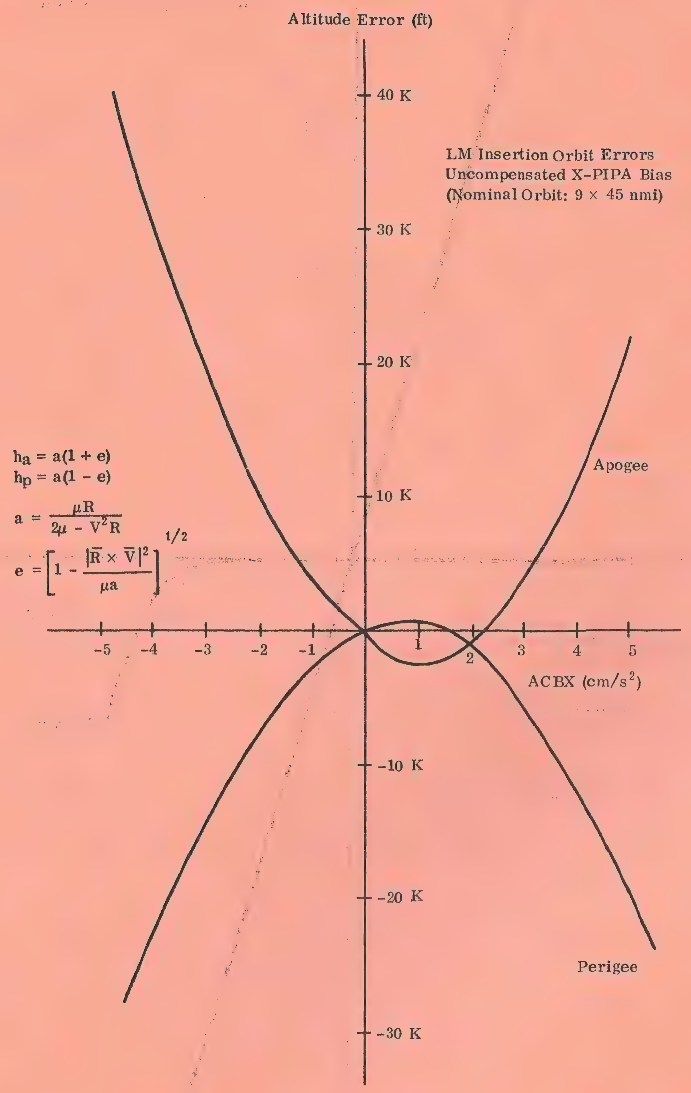
$J_{2M} = 2.07108 \times 10^{-4}$

$J_{3M} = -2.1 \times 10^{-5}$

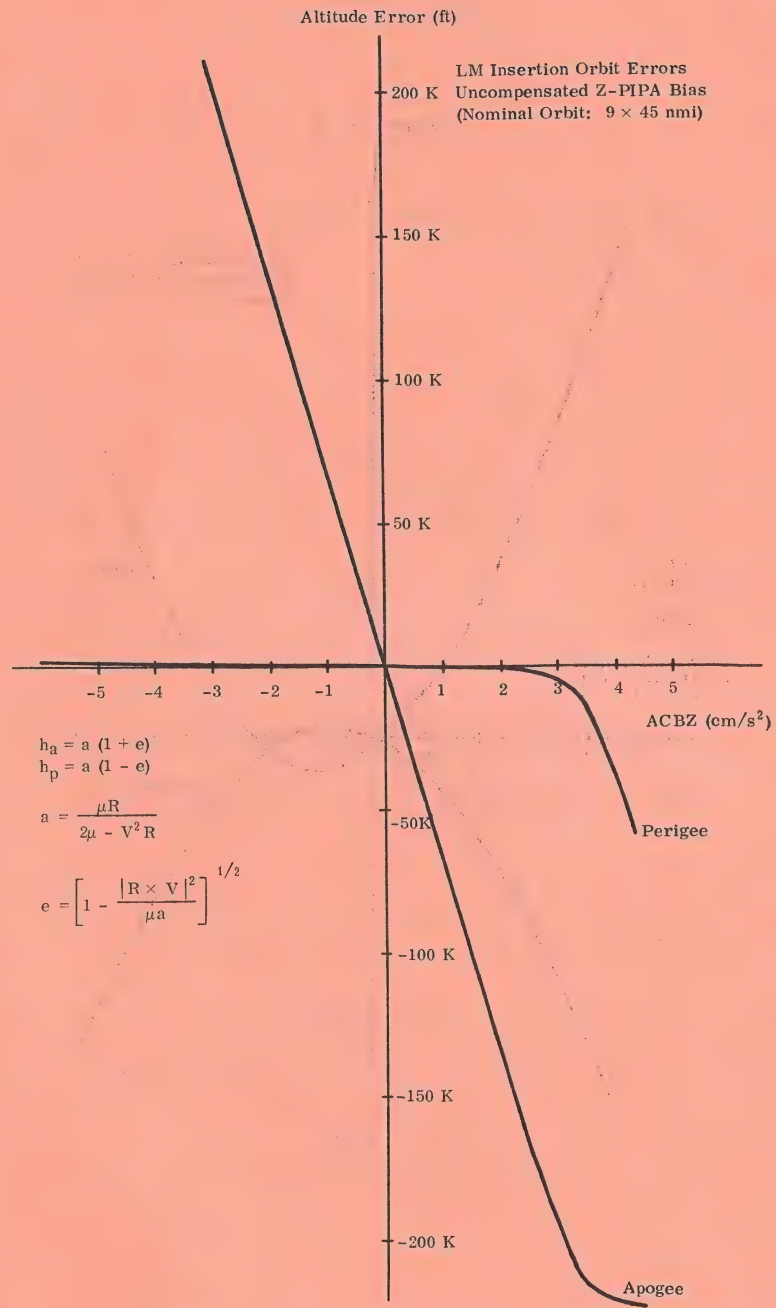
$J_{4M} = 0$

$J_{22} = 2.0716 \times 10^{-5}$

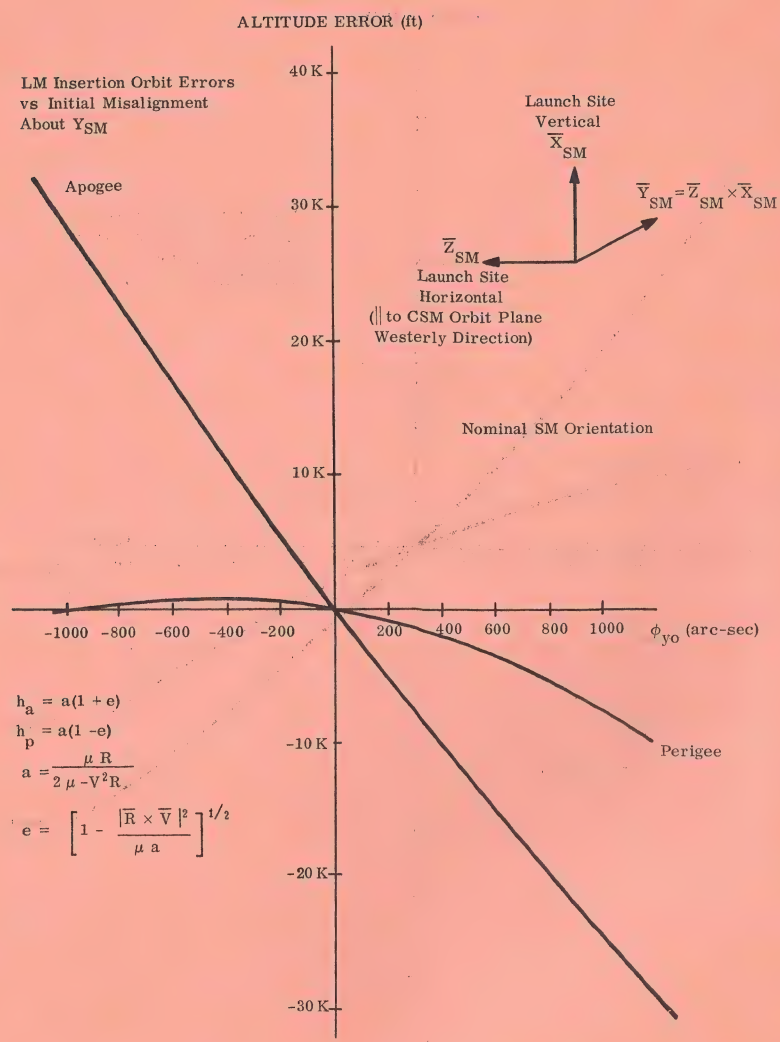
$C_{31} = 3.82 \times 10^{-5}$

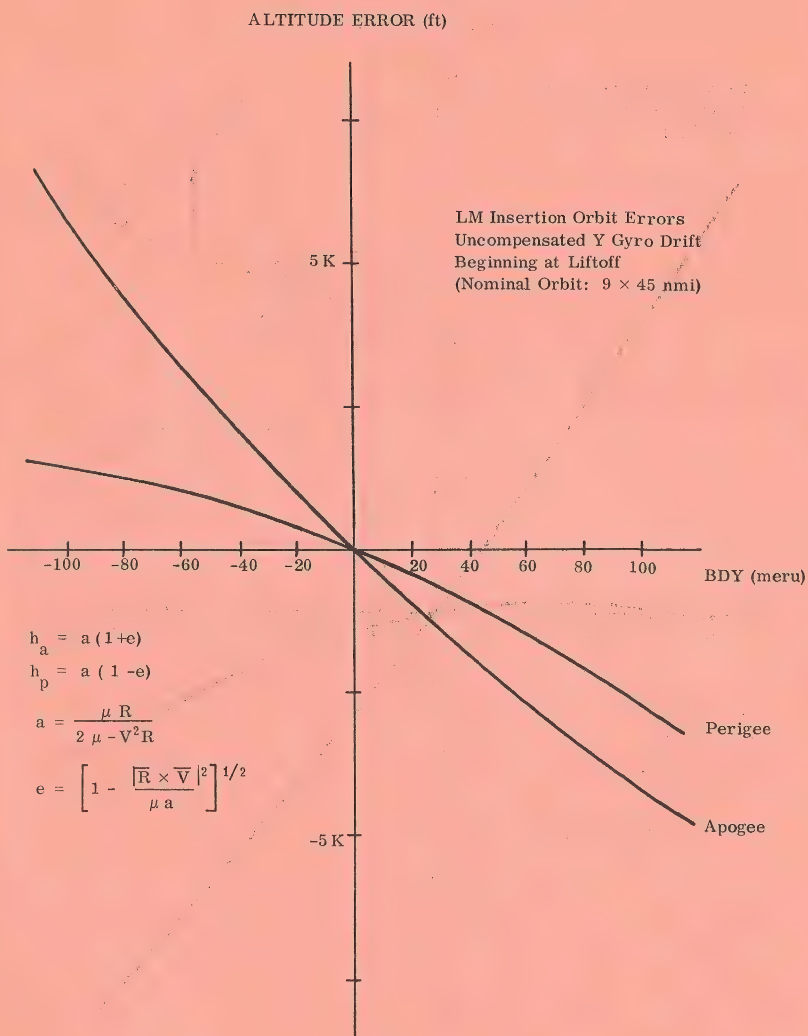


Altitude Error (ft)
40 K
30 K
20 K
10 K
-10 K
-20 K
-30 K
LM Insertion Orbit Errors
Uncompensated X-PIPA Bias
(Nominal Orbit: 9 × 45 nmi)
$h_a = a(1 + e)$
$h_p = a(1 - e)$
$a = \frac{\mu R}{2\mu - V^2 R}$
$e = \left[1 - \frac{|\bar{R} \times \bar{V}|^2}{\mu a}\right]^{1/2}$
Apogee
Perigee
-5
-4
-3
-2
-1
1
2
3
4
5
ACBX (cm/s^2)



$$h_a = a\,(1 + e)$$
$$h_p = a\,(1 - e)$$
$$a = \frac{\mu R}{2\mu - V^2 R}$$
$$e = \left[1 - \frac{|R \times V|^2}{\mu a}\right]^{1/2}$$


ALTITUDE ERROR (ft)
LM Insertion Orbit Errors
vs Initial Misalignment
About Y_{SM}
Apogee
Launch Site
Vertical
$\overline{X}_{SM}$
$\overline{Y}_{SM} = \overline{Z}_{SM} \times \overline{X}_{SM}$
$\overline{Z}_{SM}$
Launch Site
Horizontal
(|| to CSM Orbit Plane
Westerly Direction)
Nominal SM Orientation
40 K
30 K
20 K
10 K
-10 K
-20 K
-30 K
-1000
-800
-600
-400
-200
200
400
600
800
1000
ϕ_{yo} (arc-sec)
Perigee
$h_a = a(1 + e)$
$h_p = a(1 - e)$
$a = \frac{\mu R}{2\mu - V^2 R}$
$e = \left[1 - \frac{|\overline{R} \times \overline{V}|^2}{\mu a}\right]^{1/2}$


ALTITUDE ERROR (ft)
LM Insertion Orbit Errors
Uncompensated Y Gyro Drift
Beginning at Liftoff
(Nominal Orbit: 9 × 45 nmi)
5 K
-5 K
-100
-80
-60
-40
-20
20
40
60
80
100
BDY (meru)
Perigee
Apogee
$h_a = a(1+e)$
$h_p = a(1-e)$
$a = \frac{\mu R}{2\mu - V^2 R}$
$e = \left[1 - \frac{|\overline{R} \times \overline{V}|^2}{\mu a}\right]^{1/2}$

LM Insertion Orbit Errors
Versus Computer Error in μ.

$$\overline{g}(t) = -\frac{\mu}{R^3}\,\overline{R(t)}$$

$$\overline{R}(t+\Delta t) = \overline{R}(t) + \Delta t\left[\overline{V}(t) + \overline{g}(t)\,\frac{\Delta t}{2} + \frac{\overline{\Delta V}(\Delta t)}{2}\right]$$

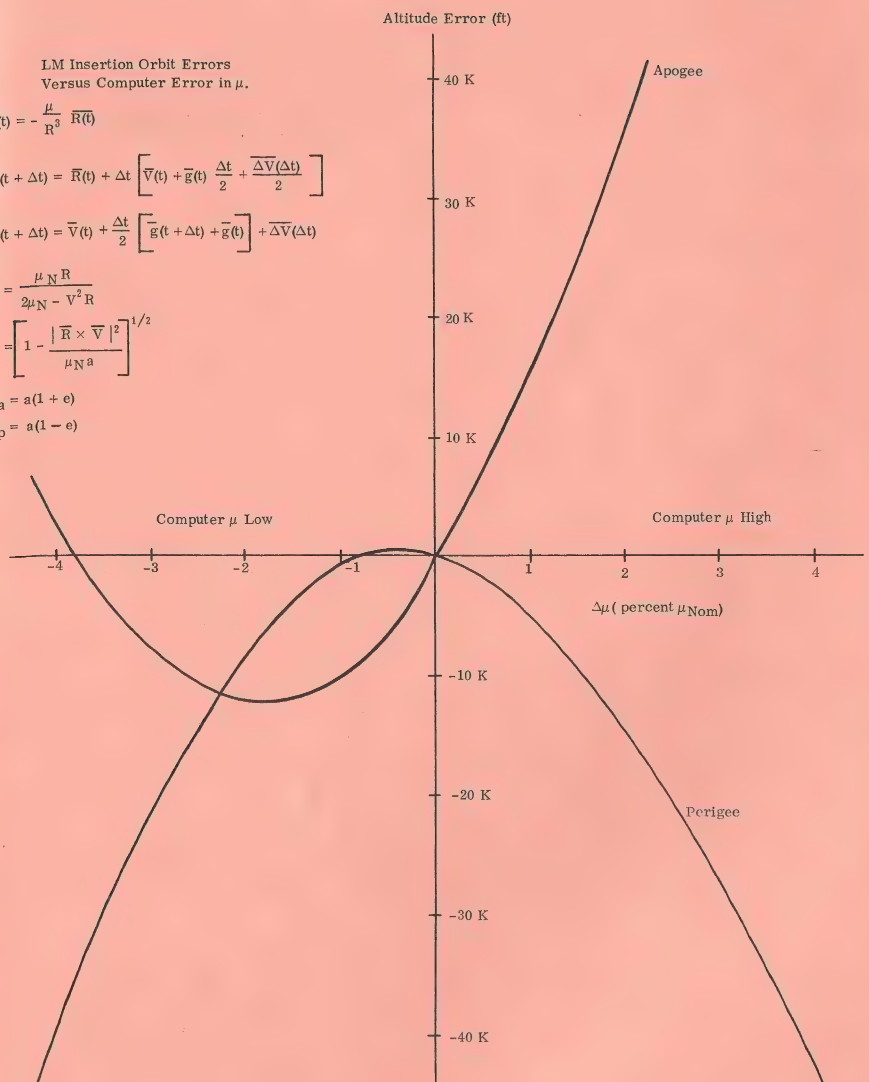
$$\overline{V}(t+\Delta t) = \overline{V}(t) + \frac{\Delta t}{2}\left[\overline{g}(t+\Delta t) + \overline{g}(t)\right] + \overline{\Delta V}(\Delta t)$$

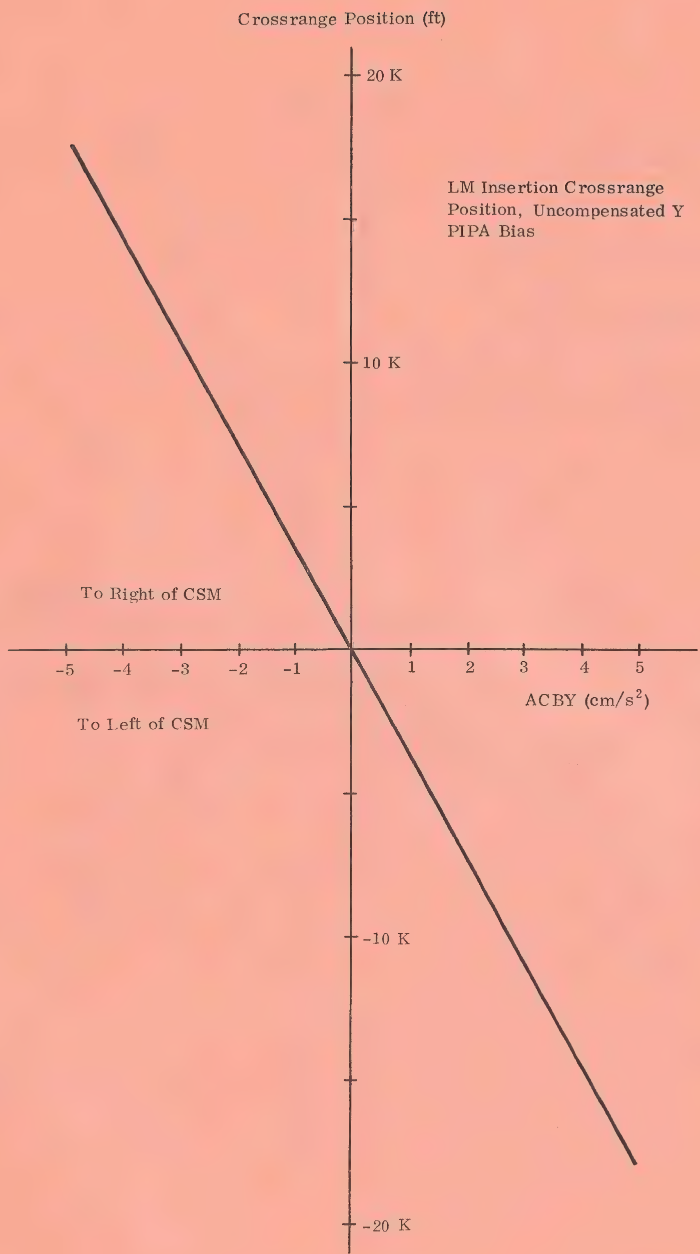
$$a = \frac{\mu_N R}{2\mu_N - V^2 R}$$

$$e = \left[1 - \frac{|\overline{R}\times\overline{V}|^2}{\mu_N a}\right]^{1/2}$$

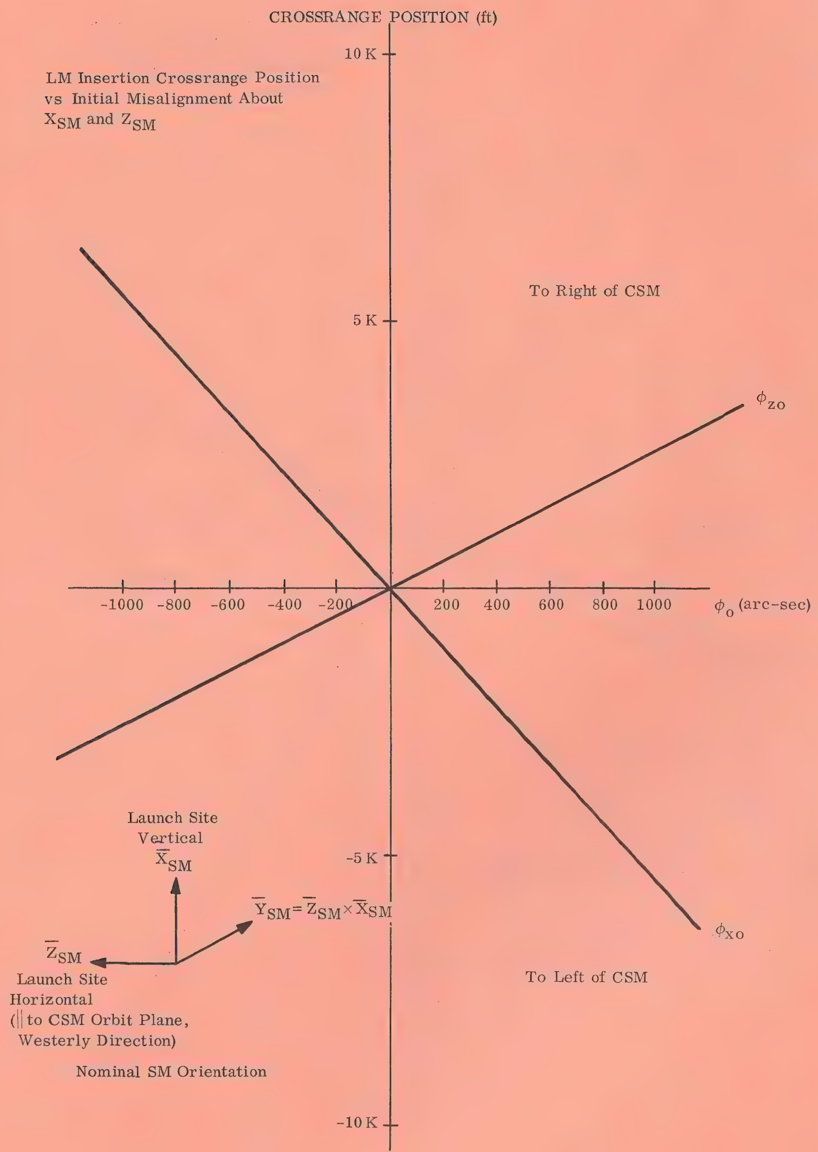
$$h_a = a(1+e)$$

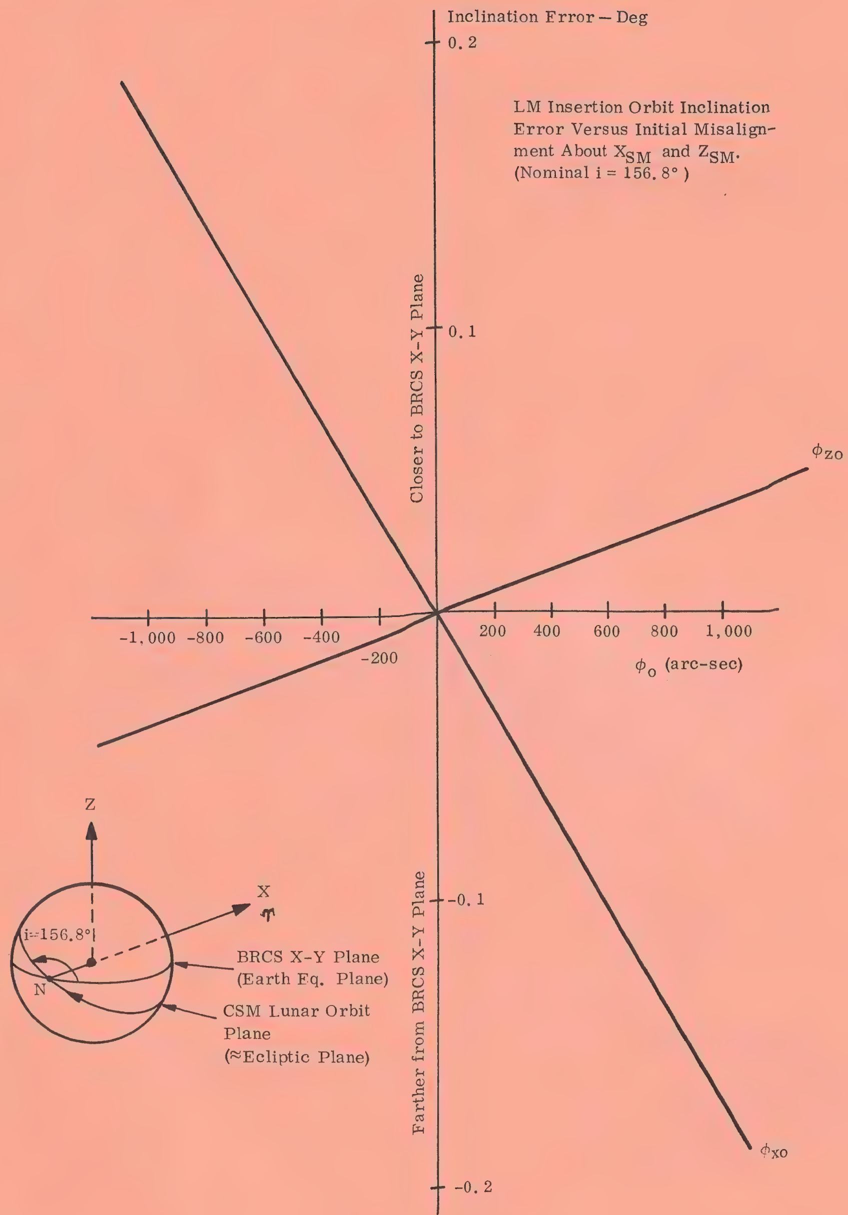
$$h_p = a(1-e)$$

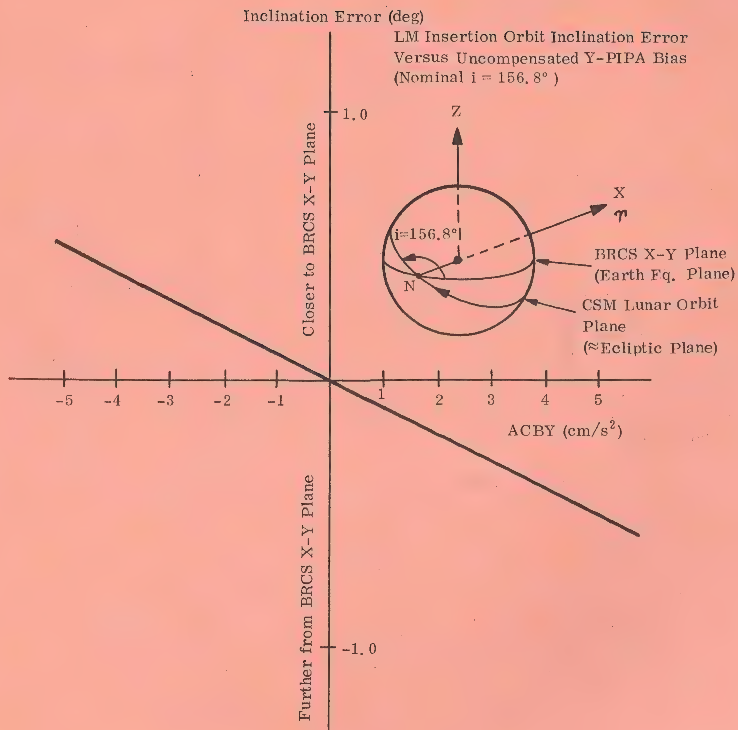


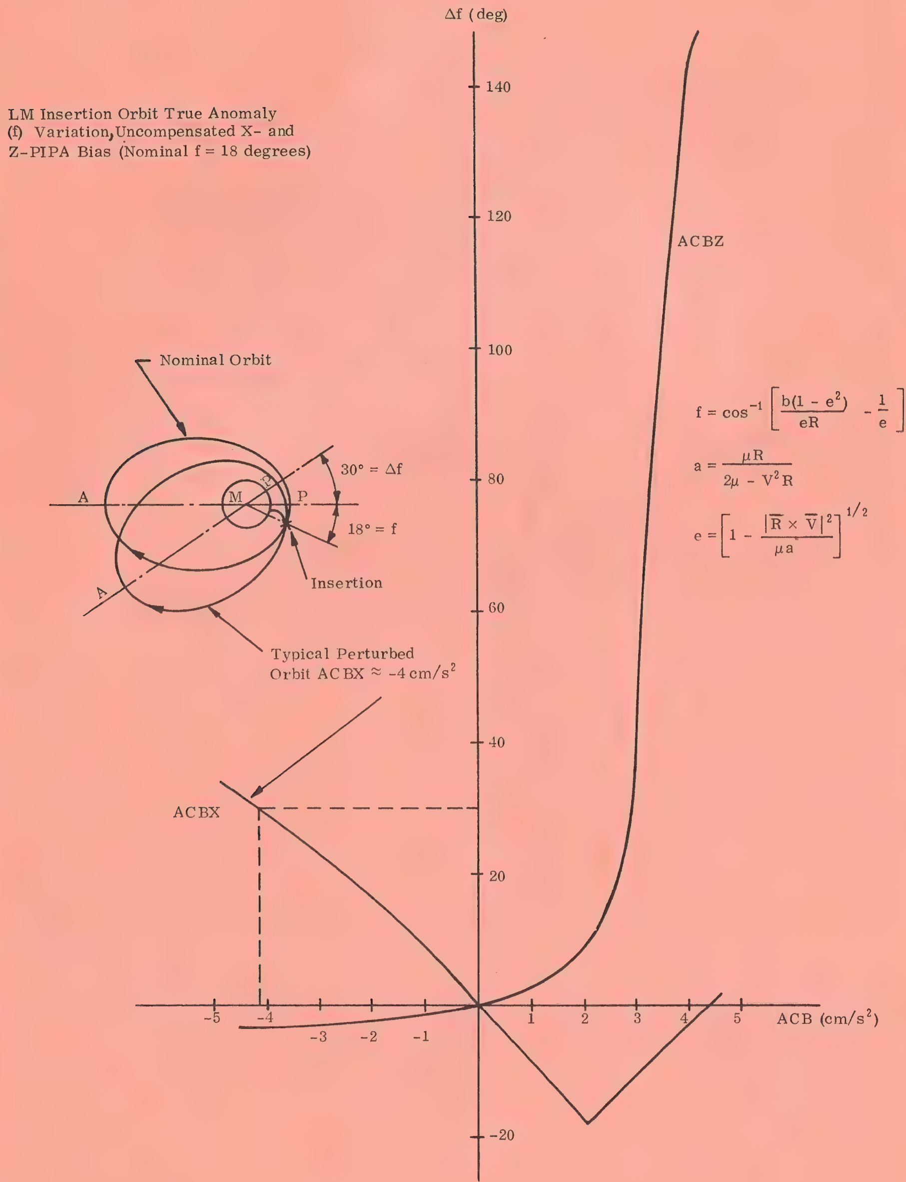


Crossrange Position (ft)
20 K
LM Insertion Crossrange Position, Uncompensated Y PIPA Bias
10 K
To Right of CSM
-5
-4
-3
-2
-1
1
2
3
4
5
ACBY (cm/s^2)
To Left of CSM
-10 K
-20 K


CROSSRANGE POSITION (ft)
10 K
5 K
-5 K
-10 K
LM Insertion Crossrange Position vs Initial Misalignment About X_{SM} and Z_{SM}
To Right of CSM
To Left of CSM
ϕ_{zo}
ϕ_{xo}
-1000 -800 -600 -400 -200 200 400 600 800 1000
ϕ_o (arc-sec)
Launch Site Vertical $\overline{X}_{SM}$
$\overline{Y}_{SM} = \overline{Z}_{SM} \times \overline{X}_{SM}$
$\overline{Z}_{SM}$
Launch Site Horizontal (|| to CSM Orbit Plane, Westerly Direction)
Nominal SM Orientation


Inclination Frror — Deg
0.2
LM Insertion Orbit Inclination Error Versus Initial Misalignment About X_{SM} and Z_{SM}.
(Nominal i = 156.8°)
Closer to BRCS X-Y Plane
0.1
ϕ_{zo}
-1,000
-800
-600
-400
-200
200
400
600
800
1,000
ϕ_o (arc-sec)
Z
X
i=156.8°
N
BRCS X-Y Plane
(Earth Eq. Plane)
CSM Lunar Orbit Plane
(≈Ecliptic Plane)
Farther from BRCS X-Y Plane
-0.1
ϕ_{xo}
-0.2


Inclination Error (deg)
LM Insertion Orbit Inclination Error
Versus Uncompensated Y-PIPA Bias
(Nominal i = 156.8°)
1.0
-1.0
Closer to BRCS X-Y Plane
Further from BRCS X-Y Plane
Z
X
i=156.8°
N
BRCS X-Y Plane
(Earth Eq. Plane)
CSM Lunar Orbit
Plane
(≈Ecliptic Plane)
-5
-4
-3
-2
-1
1
2
3
4
5
ACBY (cm/s²)

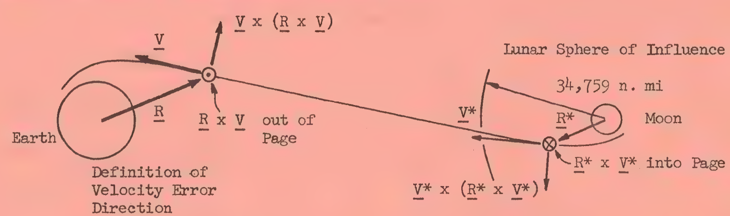


LM Insertion Orbit True Anomaly (f) Variation, Uncompensated X- and Z-PIPA Bias (Nominal f = 18 degrees)

ERRORS AT THE ENTRY INTERFACE (400,000 FT. ALT.)
DUE TO VELOCITY ERRORS DURING TRANSEARTH COAST

DIRECTION OF VELOCITY ERROR	ERROR IN VACUUM PERIGEE (n.mi/ft/sec)	ERROR IN TIME OF ARRIVAL (sec/ft/sec)	ERROR IN VELOCITY AT EI (ft/sec/ft/sec)	ERROR IN FLIGHT PATH ANGLE AT EI (degrees/ft/sec)
ERROR EXISTING AT TEI CUTOFF		(131:28:46 GET)		
Along V*	-26.76	-102.75	6.55	-2.44
Along R* x V*	.90	3.2	.11	.06
Along V* x (R* x V*)	- 5.93	3.95	-.02	- .42
ERROR EXISTING AT MCC-5 (TEI + 15 hours)		(146:28:46 GET)		
Along V	1.46	- 20.45	-.43	.10
Along R x V	.31	.85	-.03	.02
Along V x (R x V)	9.75	29.80	.51	.69
ERROR EXISTING AT MCC-6 (EI - 15 hours)		(180:01:07 GET)		
Along V	1.05	- 2.55	.18	.07
Along R x V	0	0	0	0
Along V x (R x V)	4.60	10.65	-.13	.32
ERROR EXISTING AT MCC-7 (EI - 3 hours)		(192:01:07 GET)		
Along V	.50	.30	.30	.03
Along R x V	0	0	0	0
Along V x (R x V)	1.46	2.65	-.03	.10

* R and V are with respect to moon centered inertial system



Transformation at TEI from stable member to V, R x V and V x (R x V).

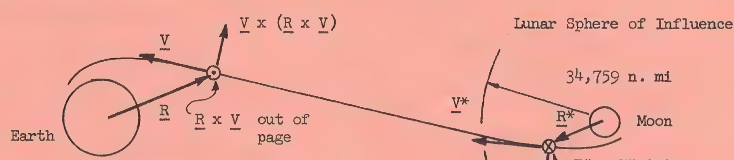
$$\begin{bmatrix} \text{UNIT } (\underline{V}) \\ \text{UNIT } (\underline{R} \times \underline{V}) \\ \text{UNIT } (\underline{V} \times (\underline{R} \times \underline{V})) \end{bmatrix} = \begin{bmatrix} .530 & .083 & -.843 \\ .041 & -.996 & -.073 \\ -.846 & +.004 & -.531 \end{bmatrix} \begin{bmatrix} X_{SM} \\ Y_{SM} \\ Z_{SM} \end{bmatrix}$$

ERRORS AT THE ENTRY INTERFACE (400,000 FT. ALT.)

DUE TO VELOCITY ERRORS DURING OPTIONAL TRANSEARTH COAST

DIRECTION OF VELOCITY ERROR	ERROR IN VACUUM PERIGEE (n.mi/ft/sec)	ERROR IN TIME OF ARRIVAL (sec/ft/sec)	ERROR IN VELOCITY AT EI (ft/sec/ft/sec)	ERROR IN FLIGHT PATH ANGLE AT EI (degrees/ft/sec)
ERROR EXISTING AT TEI CUTOFF (143:26:35 GET)				
Along V*	-20.24	-76.9	.21	-1.75
Along R* x V*	1.21	3.45	.02	.09
Along V* x (R* x V*)	- 7.63	- 7.15	-.06	- .56
ERROR EXISTING AT MCC-5 (TEI + 15 hours) (158:26:35 GET)				
Along V	1.24	-12.55	.19	.09
Along R x V	.11	.25	-.09	.01
Along V x (R x V)	8.83	23.45	-.16	.65
ERROR EXISTING AT MCC-6 (EI - 15 hours) (180:13:33 GET)				
Along V	.96	- 2.65	.09	.07
Along R x V	0	0	-.01	0
Along V x (R x V)	4.79	10.95	-.06	.35
ERROR EXISTING AT MCC-7 (EI - 3 hours) (192:13:33 GET)				
Along V	.49	.30	.34	.03
Along R x V	0	0	0	0
Along V x (R x V)	1.49	2.75	-.06	.11

* R and V are with respect to moon centered inertial system

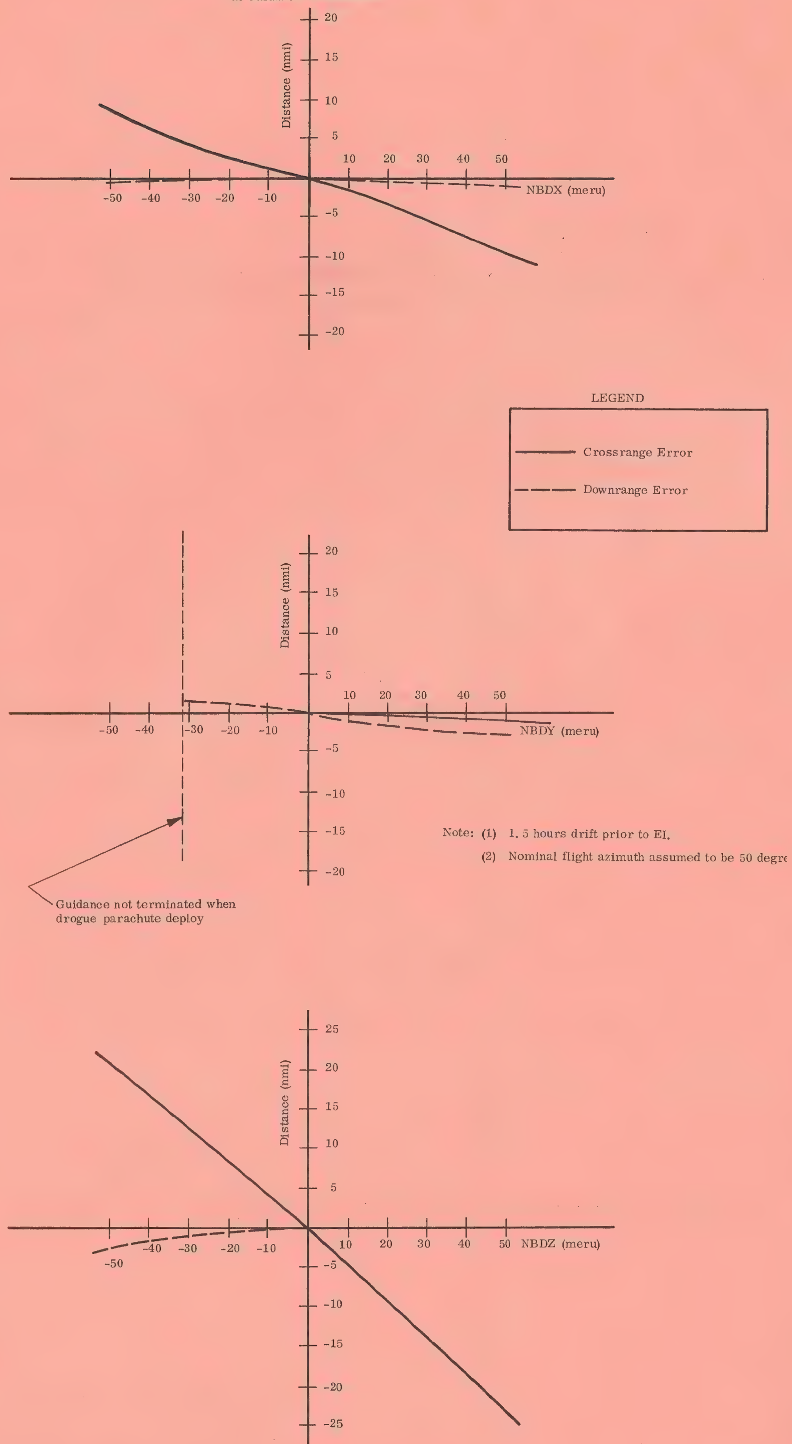


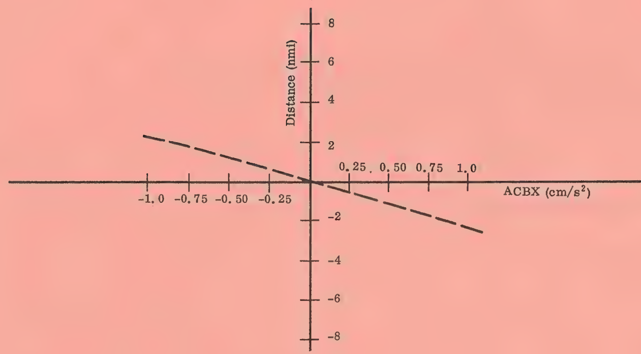
Definition of Velocity Error Direction

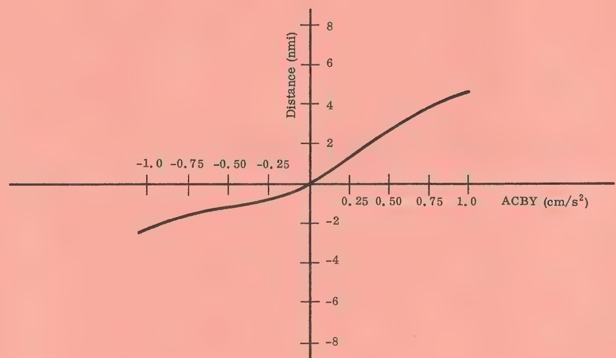
Transformation at TEI from stable member to V, R x V and V x (R x V).

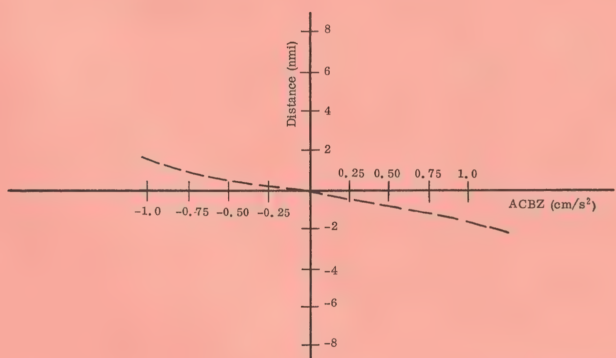
$$\begin{bmatrix} \text{UNIT } (\underline{V}) \\ \text{UNIT } (\underline{R} \times \underline{V}) \\ \text{UNIT } (\underline{V} \times (\underline{R} \times \underline{V})) \end{bmatrix} = \begin{bmatrix} +.701 & +.080 & -.708 \\ +.053 & -.996 & -.061 \\ -.711 & +.006 & -.703 \end{bmatrix} \begin{bmatrix} X_{SM} \\ Y_{SM} \\ Z_{SM} \end{bmatrix}$$

Earth Entry Position Perturbation Plots
at Guidance Termination









Note: (3) Crossrange error due to ACBX and ACBZ is negligible.

(4) Downrange error due to ACBY is negligible.

(5) Accelerometers assumed on 15 minutes prior to EI.

Typical Mission G

Entry Position Error Sensitivities at Guidance Termination

ERROR SOURCE (ϵ)	CROSSRANGE ERROR (nmi/ϵ)	DOWNRANGE ERROR (nmi/ϵ)
NBDX (meru)	-0.17	0.0
NBDY (meru)	0.0	-0.08
NBDZ (meru)	-0.44	0.0
ACBX (cm/sec^2)	0.0	-2.67
ACBY (cm/sec^2)	4.00	0.0
ACBZ (cm/sec^2)	0.0	-1.60

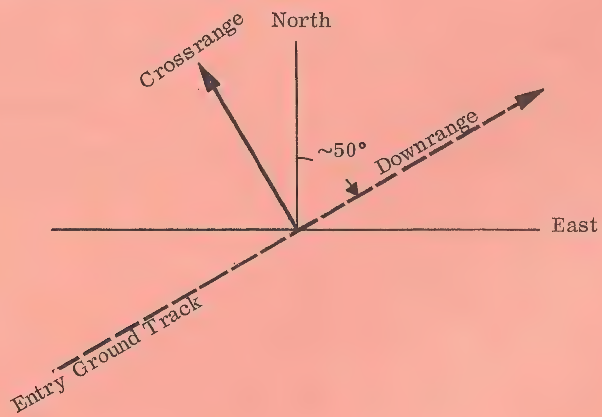
Notes:

(1) All sensitivities represent the slopes about the origin of those perturbation graphs presented previously.

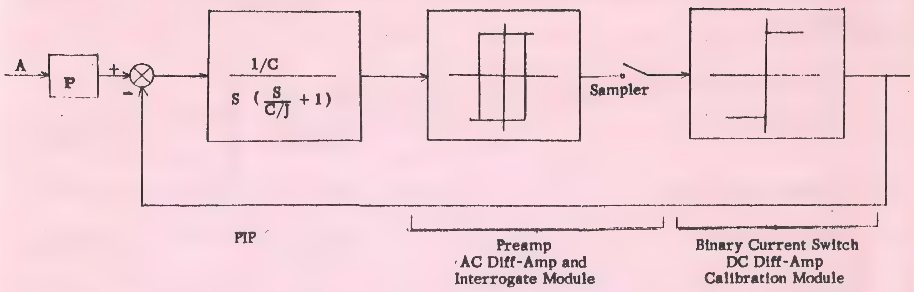
(2) Assumed accelerometer operation began 15 minutes prior to EI.

(3) Assumed IMU drift 1.5 hours prior to EI.

(4) Crossrange-downrange definition:



PIPA LOOP



P = Pendulosity
C = Coefficient of Viscous Damping
J = Float Inertia

The PIP Signal Generator Ducosyn provides information on rotor position in the form of a 3200 hertz output. The stable limit cycle in rotor position is converted to an AC suppressed carrier modulated signal.

The PIP Preamp amplifies the SG output (14 V/V gain) and phase shifts the 3200 hertz carrier 45° lag.

The AC Diff-Amp and Interrogate Module provides additional amplification (3050 V/V), peak detects float position, and sets a flip-flop. One state of the flip-flop indicates float position on the plus side of null and the other state means float position on the minus side of null.

The Binary Current Switch provides discrete current pulse outputs of appropriate phase as determined by the state of the flip-flop in the AC Diff-Amp Module.

The Calibration Module is the passive circuit interface between the BCS and the PIP torquer. The circuitry introduces bias and scale factor adjust capability into the PIPA loop.

The PIP Torque Ducosyn converts current pulses from the Calibration Module to torque about the PIP OA axis.

The DC Diff-Amp and PVR Module is the mechanism which regulates current and hence PIP torque to precisely controlled values.

PIPA CHARACTERISTICS

PARAMETER			CM		LM	
1.	Maximum measurable acceleration		19.1	g's	3.26	g's
2.	Pendulosity	P	0.25	$\frac{\text{dyne cm}}{\text{cm/sec}^2}$	0.25	$\frac{\text{dyne cm}}{\text{cm/sec}^2}$
3.	Torque to balance	T	4680	dyne cm	800	dyne cm
4.	PIP float inertia	J	14.0	$\frac{\text{dyne cm}}{\text{rad/sec}^2}$	14.0	$\frac{\text{dyne cm}}{\text{rad/sec}^2}$
5.	PIP viscous damping	C	12×10^4	$\frac{\text{dyne cm}}{\text{rad/sec}}$	12×10^4	$\frac{\text{dyne cm}}{\text{rad/sec}}$
6.	PIP break point	C/J	8550	rad/sec	8550	rad/sec
7.	PIP time constant	J/C	.117	ms	.117	ms
8.	Total torque constant		.42	dyne cm/ma^2	.42	dyne cm/ma^2
9.	Nominal torque current		105	ma	44	ma

SUSPENSION CHARACTERISTICS

1. Radial Force — 2.3 grams per .0001" min
2. Suspension current — 65 ± 6 ma

   the two ends (SG & TG) matched within 3 ma
3. Phase angle of current — lags 45° ± 2.8°
4. Suspension stiffness — 30×10^{-3} grams/micro-inch

TYPICAL TEMPERATURE CHARACTERISTICS

1. Scale Factor — 150 ppm/°F CM; 300 ppm/°F LM
2. Bias — .05 cm/sec^2/°F LM/CM

°F Actual PIPA Temperature

PIPA PARAMETERS

Primary PIPA parameters are scale factor and bias. Specification values across ISS, G&N, and S/C testing are as shown in Table I-1.

Table I-1

PIPA Coefficient Stability Criteria				
Coefficient	Units	D_1	D_2	D_3
PIPA Bias (A_B)	cm/sec^2	0.50	0.70	0.90
PIPA Scale Factor SF	ppm	400	500	600

PIPA bias in a unity gravity field (A_b) must be within 0.30 cm/sec^2 of that evaluated in a zero gravity (a_b) field at the ISS level of test.

The maximum value of PIPA parameters which can be compensated for by the computer is as shown in Table I-2.

Table I-2

Coefficient	Units	Max Value (CM)	Max Value (LM)
A_b	cm/sec^2	±2.28	±3.12
SF	ppm	±1900	±1900

PIPA COMPENSATION

	Register
X PIPA Bias	1452
Y PIPA Bias	1454
Z PIPA Bias	1456

PIPA Bias CM = (.0013923) (Reg Contents in Decimal) cm/sec^2
PIPA Bias LM = (.0001907) (Reg Contents in Decimal) cm/sec^2

The correction to the PIPA's is

$$PIPA_C = (1 + SFE_I)\ PIPA_I - BIAS_I \Delta t$$

where

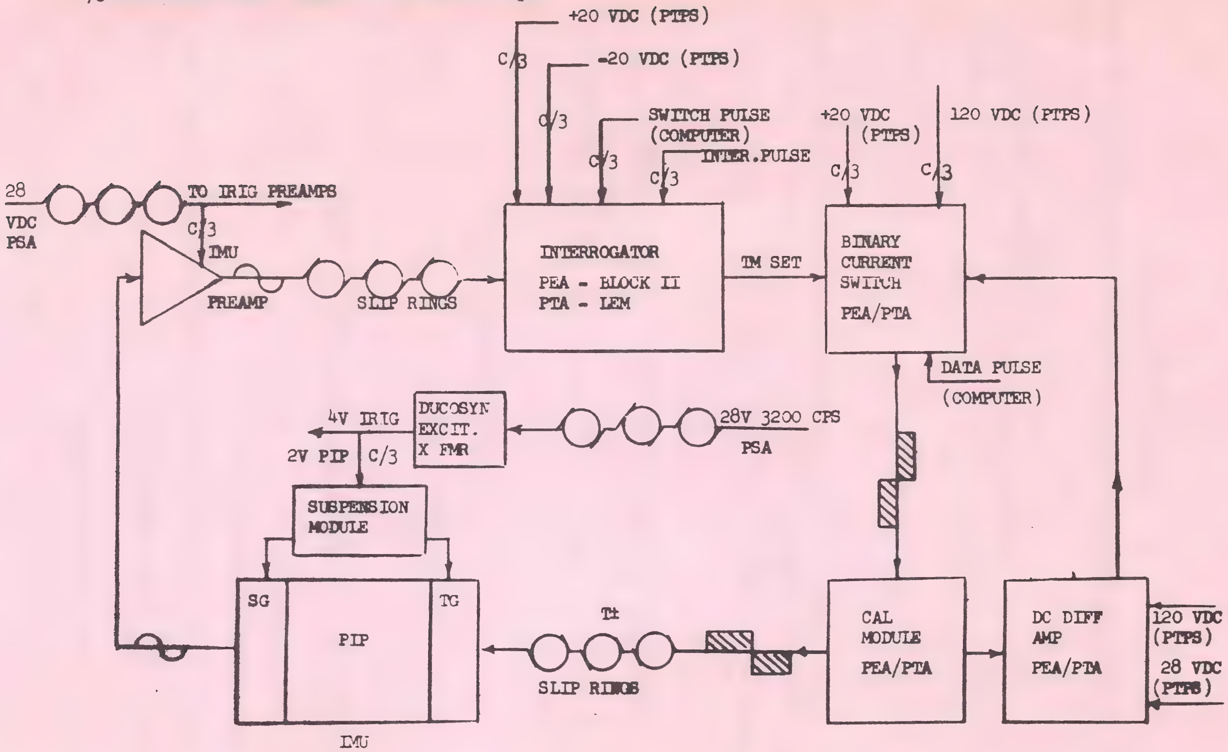
$PIPA_C$ is the compensated data for the I^{th} PIPA denoted $PIPAX_C$, $PIPAY_C$, $PIPAZ_C$

$$SFE = \frac{SF - SF_{nom}}{SF_{nom}} \quad \text{(erasable load)}$$

$$SF = \text{Scale-factor } \frac{CM/Sec}{Pulse}$$

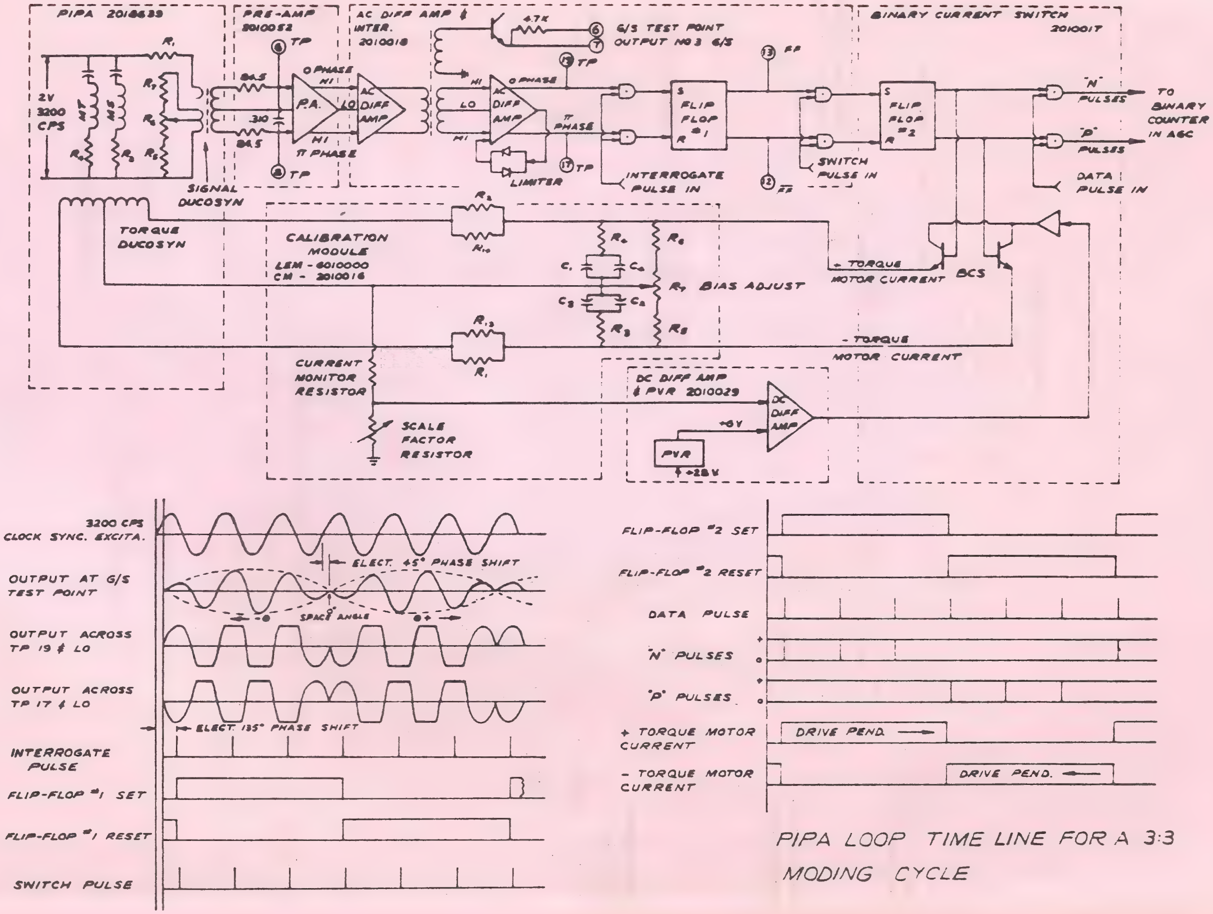
$BIAS_I$ is the bias for the I^{th} PIPA (an erasable load)

C/3 indicates assets common to all three loops.

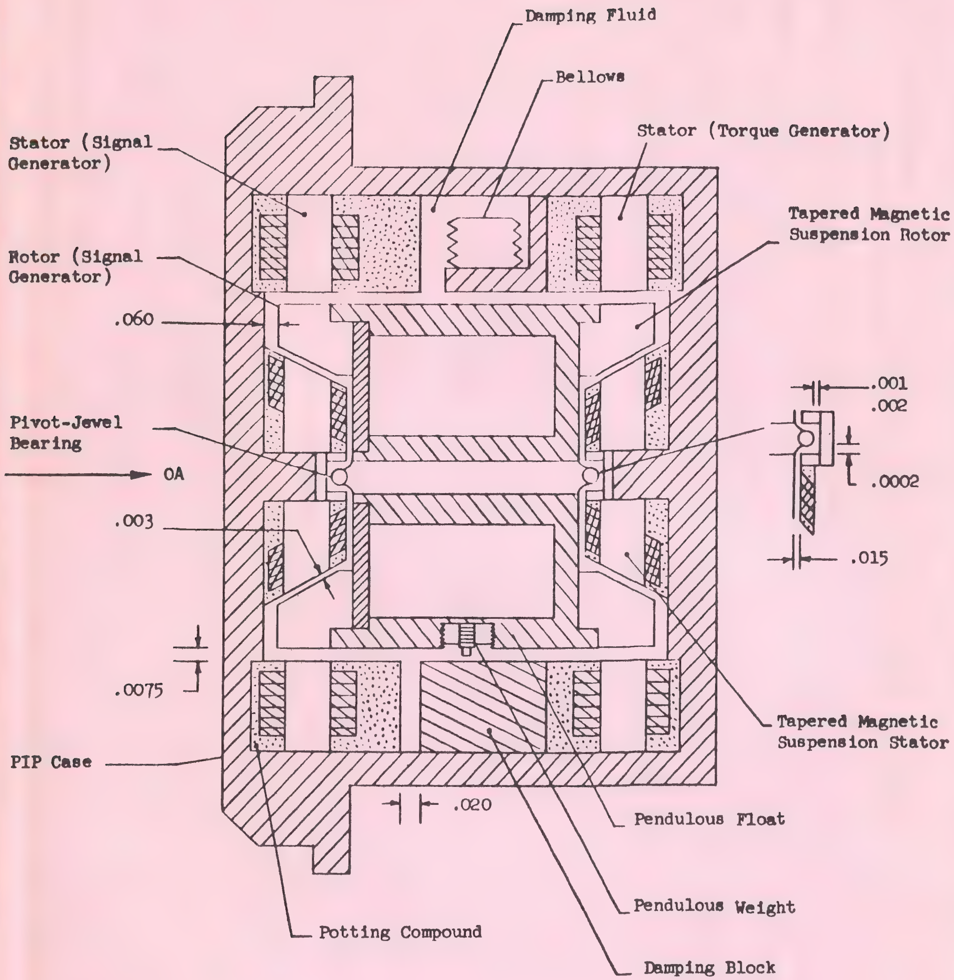


PTPS = Pulse Torque Power Supply. For Block II PTPS is in the PSA
For LEM PTPS is in the PTA
PEA = PIPA Electronics Header Assembly (CM); PTA = Pulse Torque Header Assembly (LEM).

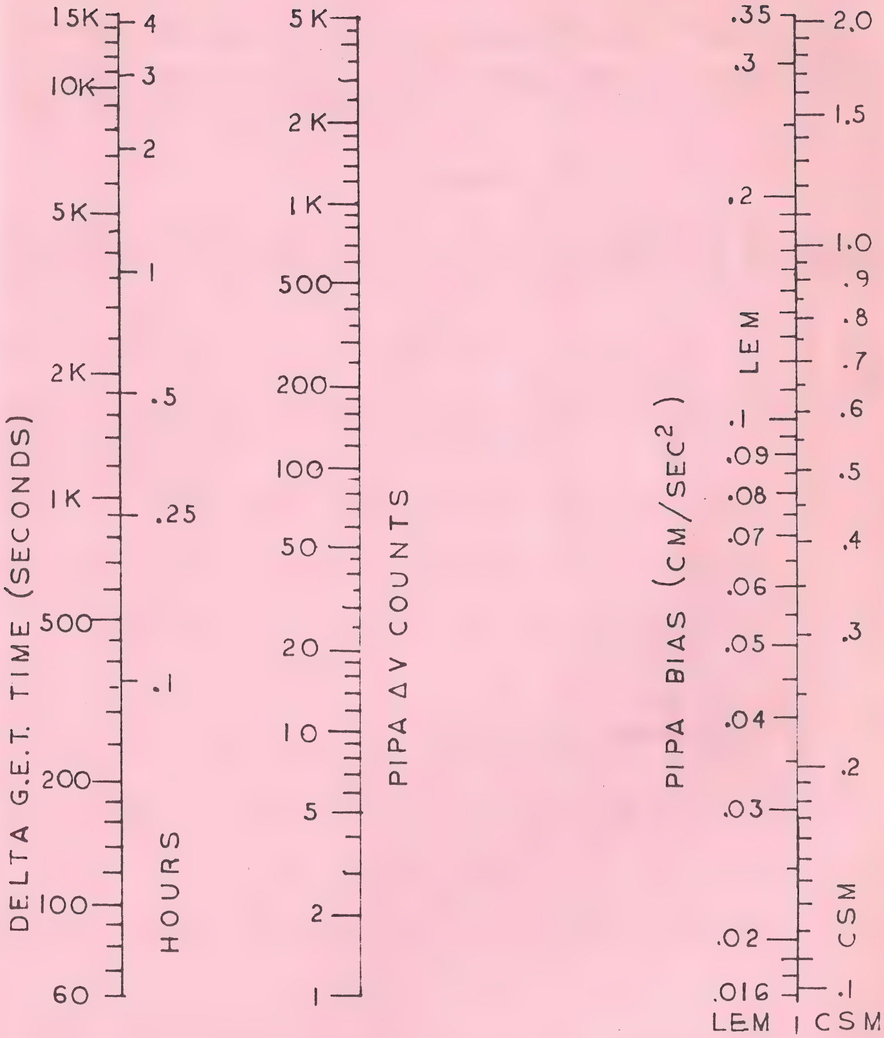
PIPA LOOP



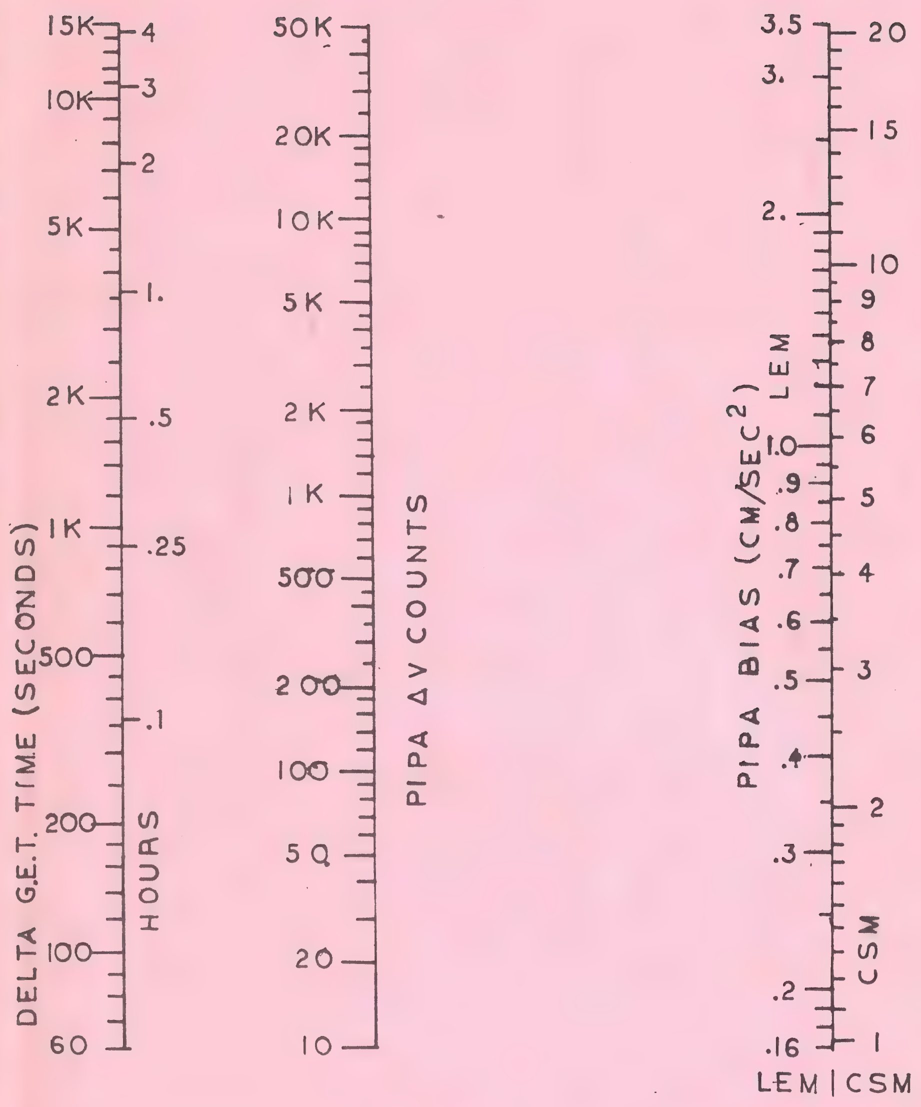
PIPA LOOP TIME LINE FOR A 3:3 MODING CYCLE


Damping Fluid
Bellows
Stator (Signal Generator)
Stator (Torque Generator)
Tapered Magnetic Suspension Rotor
Rotor (Signal Generator)
.060
.001
.002
Pivot-Jewel Bearing
OA
.0002
.003
.015
.0075
Tapered Magnetic Suspension Stator
PIP Case
.020
Pendulous Float
Pendulous Weight
Potting Compound
Damping Block

APOLLO PIP



NOMOGRAPH FOR ZERO GRAVITY PIPA BIAS



NOMOGRAPH FOR ZERO GRAVITY PIPA BIAS

IMU COARSE ALIGN LOOP

The coarse align loop drives the IMU gimbals to the angles commanded by the computer with an accuracy of ± 1.5°. The coarse align mode also acts as a caging mode when a gimbal lock condition is approached

The three basic elements of the coarse align loop are the Digital Computer which issues angle commands ($\Delta\theta_C$) and moding discretes, the IMU, and the ECDU which encodes gimbal position and provides position and rate feedback for proper loop operation.

IMU FINE ALIGN LOOP

The fine align loop drives the IMU gimbals to the computer commanded angles ± 80" by pulse torquing the gyros. Pulse torquing is a computer controlled switching of a constant current source to a gyro torquer winding. The current produces gyro torque, a corresponding precession rate, and hence, gimbal position.

IMU INERTIAL MODE

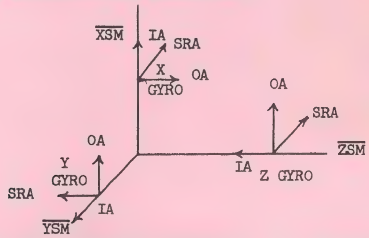
The elements of the inertial mode are the gyro, stabilization amplifier, and gimbal torque motor. The gyro senses inertial rotation about its input axis and supplies torquing to the gimbal via the stabilization amplifier to compensate for the motion.

APOLLO INERTIAL INSTRUMENTATION/STABLE MEMBER ORIENTATION DIAGRAM

Gyro drift is positive when the SM drift rate is about the positive gyro input (IA) axis.

Drift Rate About SM Axes	Gyro Drift Coefficient		
	NBD	ADIA	ADSRA
W_{XSM}	+NBDX	+ADIAX (a_{XSM})	-ADSRAX (a_{YSM})
W_{YSM}	+NBDY	+ADIAY (a_{YSM})	-ADSRAY (a_{ZSM})
W_{ZSM}	-NBDZ	+ADIAZ (a_{ZSM})	+ADSRAZ (a_{YSM})

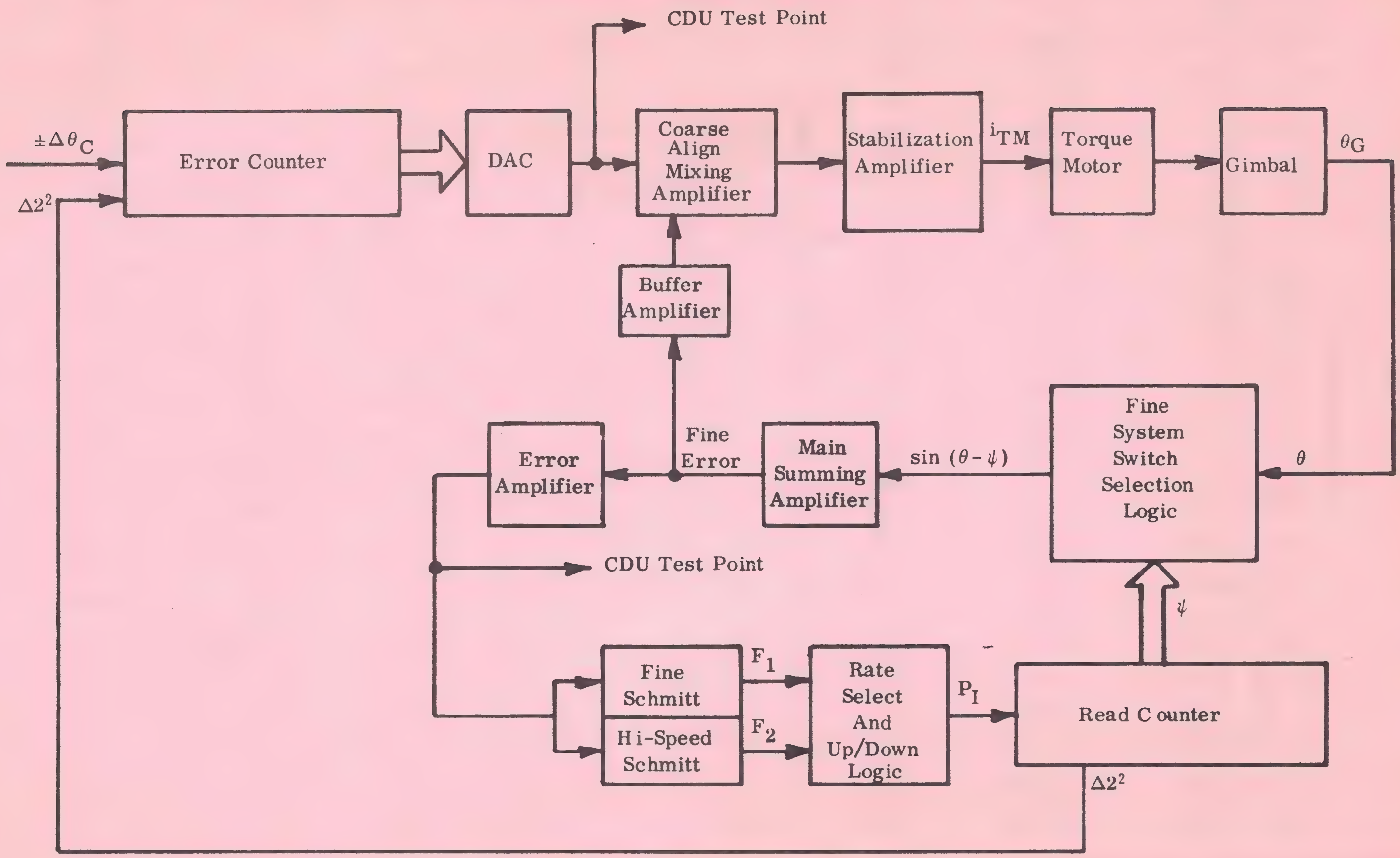
a_{XSM}, a_{YSM}, a_{ZSM} is positive along positive stable member axes.



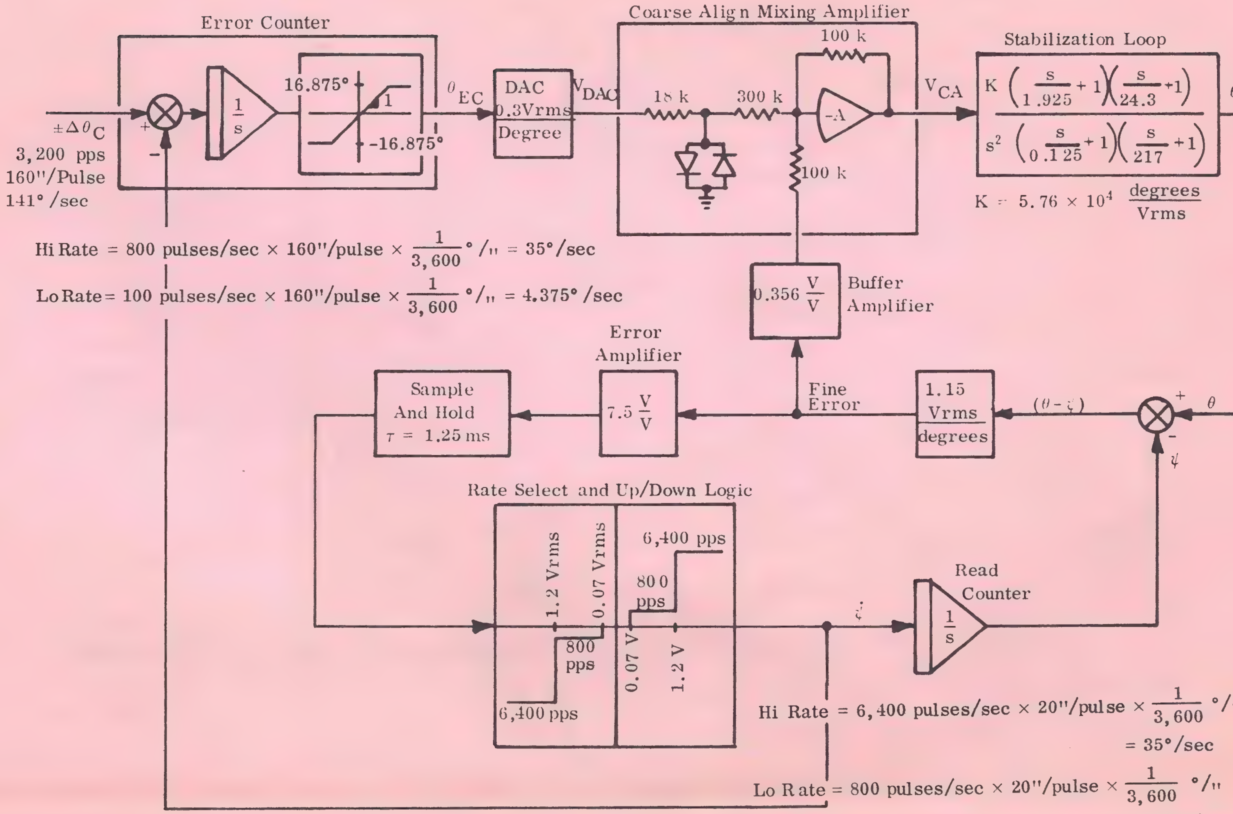
Gyro	IA Along	SRA Along	OA Along
X	$+\overline{XSM}$	$-\overline{YSM}$	$+\overline{ZSM}$
Y	$+\overline{YSM}$	$-\overline{ZSM}$	$+\overline{XSM}$
Z	$-\overline{ZSM}$	$-\overline{YSM}$	$+\overline{XSM}$

Input axes of the X, Y, Z accelerometers lie respectively along positive XSM, YSM, ZSM axes.

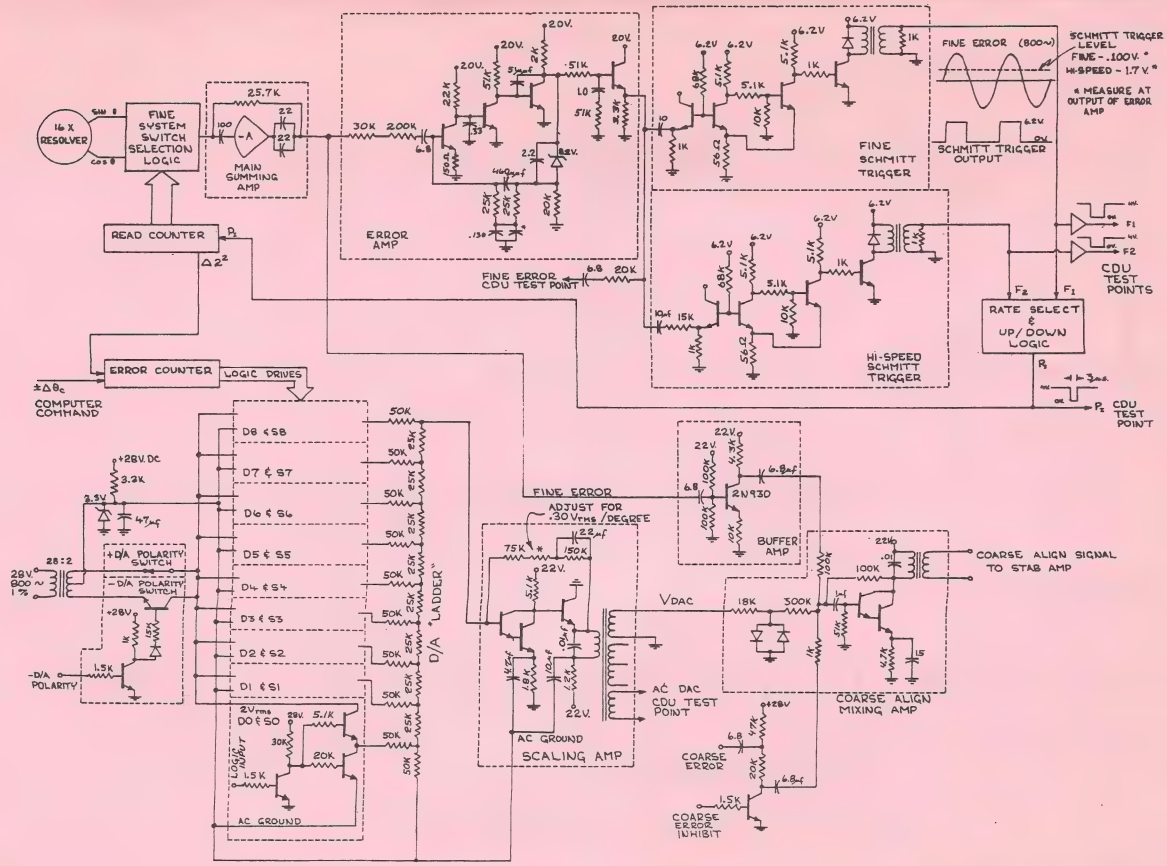
IMU COARSE ALIGN BLOCK DIAGRAM



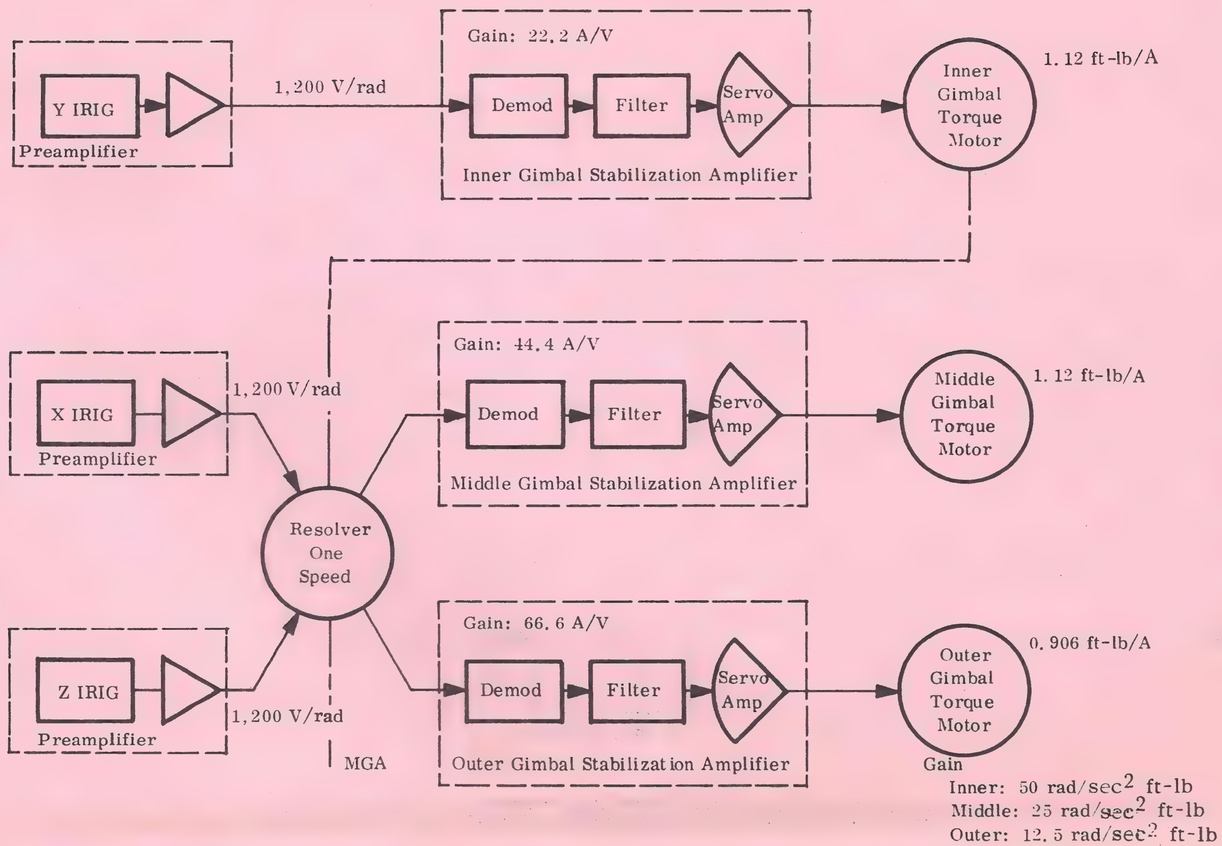
IMU COARSE ALIGN FUNCTIONAL BLOCK DIAGRAM



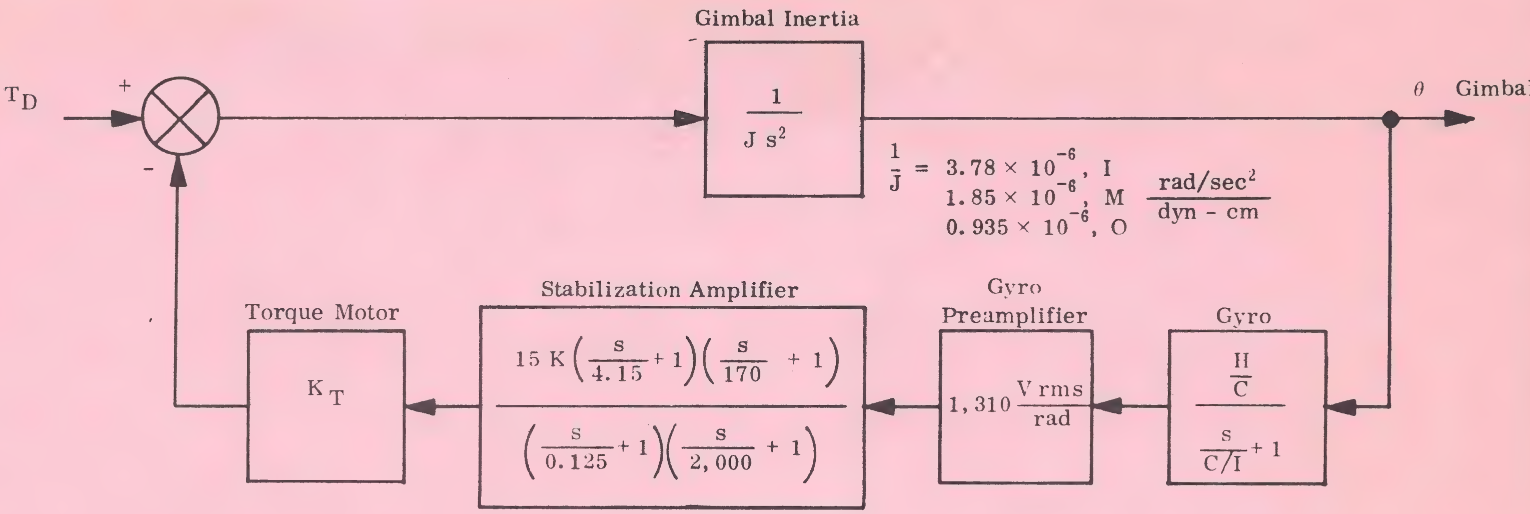
ECDU COARSE ALIGN NETWORK



IMU "INERTIAL MODE" BLOCK DIAGRAM



IMU "INERTIAL MODE" FUNCTIONAL BLOCK DIAGRAM



$K_T = 1.52 \times 10^7 \ \frac{\text{dyn - cm}}{\text{A}}$, I

$1.52 \times 10^7 \ \frac{\text{dyn - cm}}{\text{A}}$, M

$1.23 \times 10^7 \ \frac{\text{dyn - cm}}{\text{A}}$, O

$K = 1 \ \frac{\text{A}}{\text{V rms}}$, I

$2 \ \frac{\text{A}}{\text{V rms}}$, M

$3 \ \frac{\text{A}}{\text{V rms}}$, O

$H = 0.434 \times 10^6 \ \frac{\text{dyn - cm}}{\text{rad/sec}}$

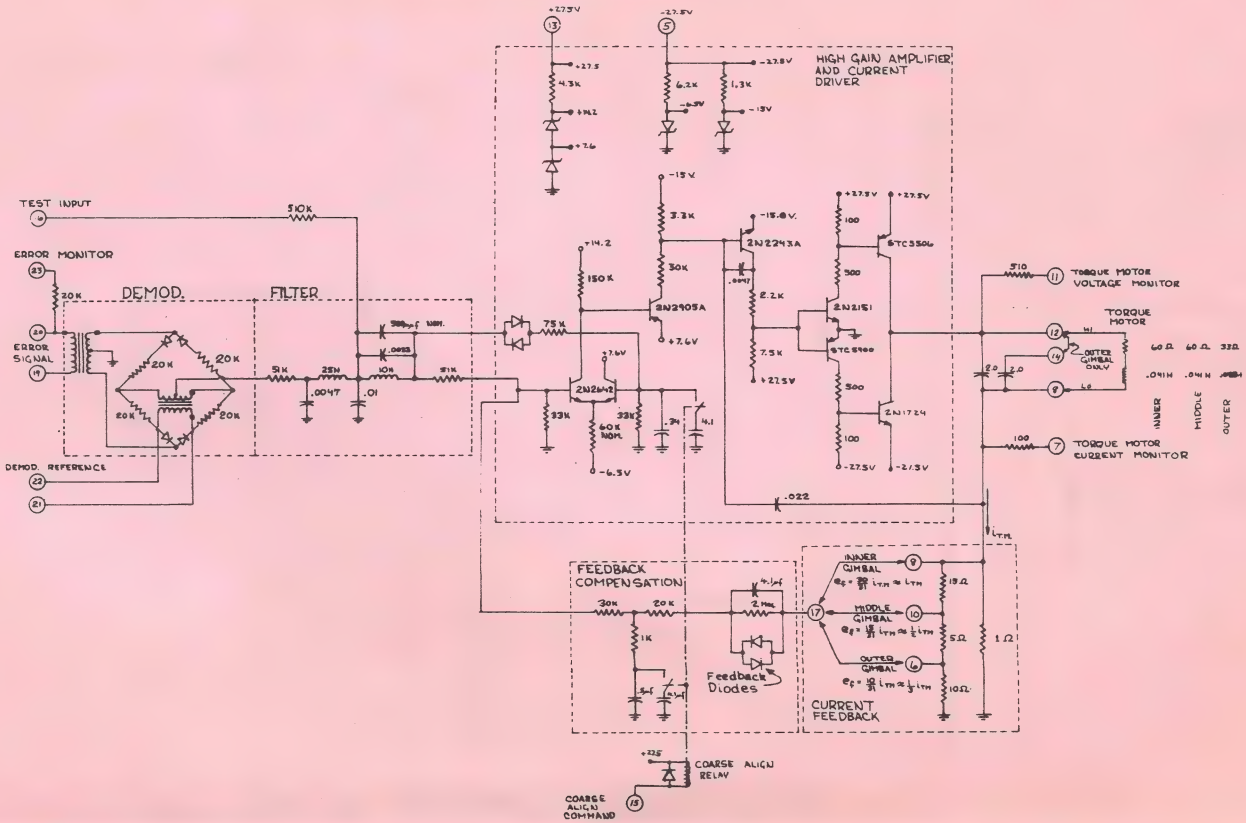
$C = 0.475 \times 10^6 \ \frac{\text{dyn - cm}}{\text{rad/sec}}$

$I = 367 \text{ gm - cm}^2$

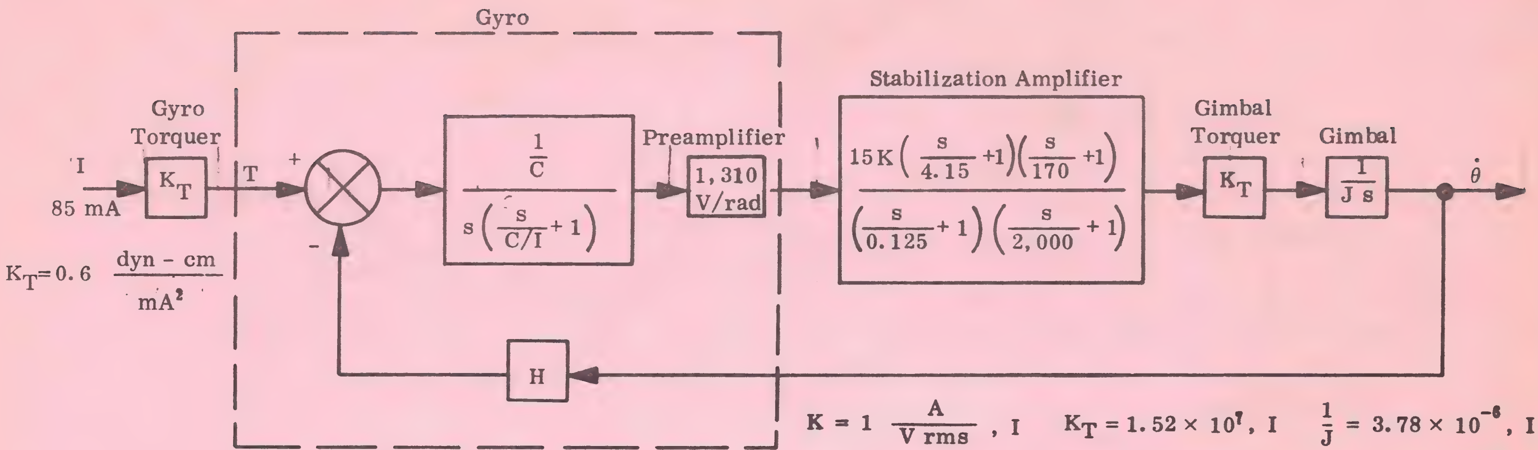
$H/C = 0.915$

$C/I = 1,290 \text{ rad/sec}$

IMU STABILIZATION AMPLIFIER



IMU FINE ALIGN FUNCTIONAL BLOCK DIAGRAM



$K = 1 \; \frac{A}{V\,rms}$, I

$K = 2$, M

$K = 3$, O

$K_T = 1.52 \times 10^7$, I

$= 1.52 \times 10^7$, M

$= 1.23 \times 10^7$, O

$\frac{dyn - cm}{A}$

$\frac{1}{J} = 3.78 \times 10^{-6}$, I

$= 1.85 \times 10^{-6}$, M

$= 0.935 \times 10^{-6}$, O

$\frac{rad/sec^2}{dyn - cm}$

$H = 0.434 \times 10^6 \; \frac{dyn - cm}{rad/sec}$

$C = 0.475 \times 10^6 \; \frac{dyn - cm}{rad/sec}$

$I = 367 \; gm - cm^2$

Gyro Torque $= K_T I^2 = 0.6(85)^2 = 4,335$ dyn - cm

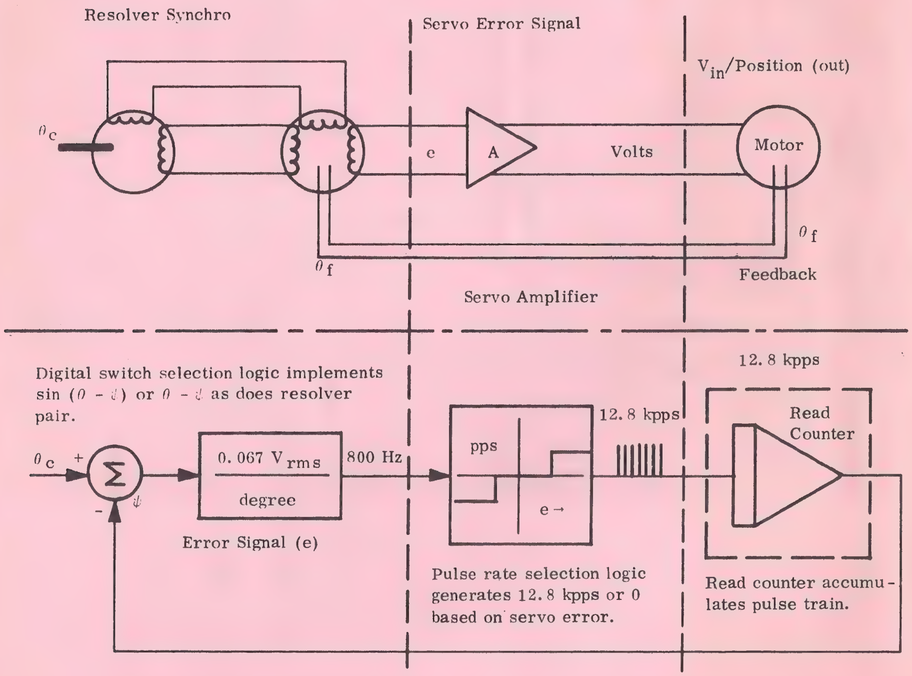
ELECTRONICS COUPLING DISPLAY UNIT (ECDU)

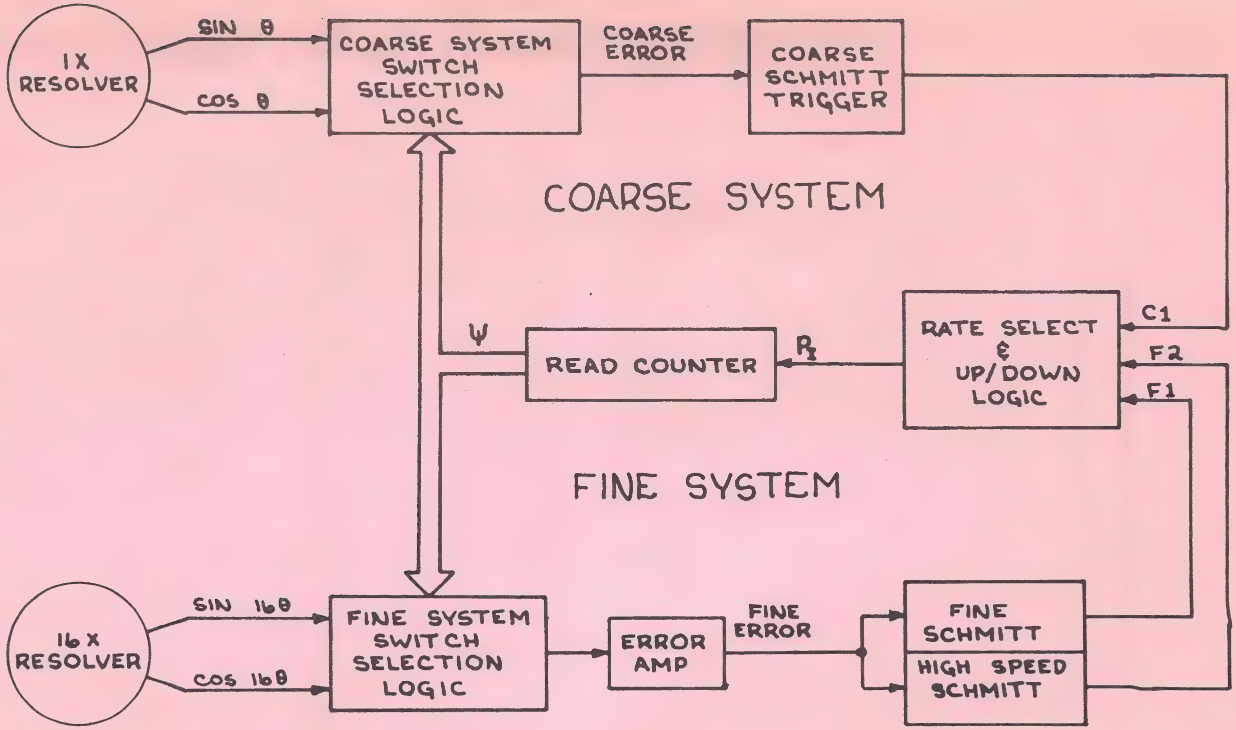
The ECDU encodes and scales the IMU gimbal angles and transfers the angles to the computer in the proper format.

The ECDU is an analog-to-digital converter which utilizes two encoding loops and one read counter which can be accessed by the computer.

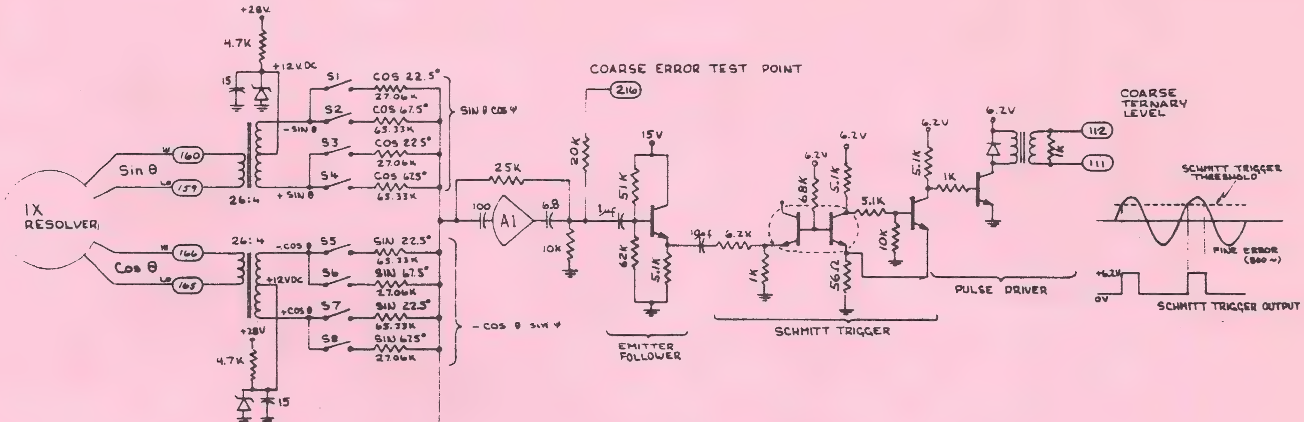
One encoding loop is used with the 16 × gimbal resolver (the fine system); the other encoding loop is used with the 1 × gimbal resolver (the coarse system).

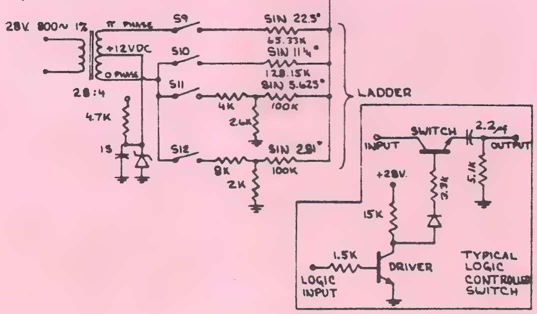
The ECDU digital servo is analogous to a resolver synchro illustrated by the following diagram.





ECDU
READ COUNTER LOOP
BLOCK DIAGRAM



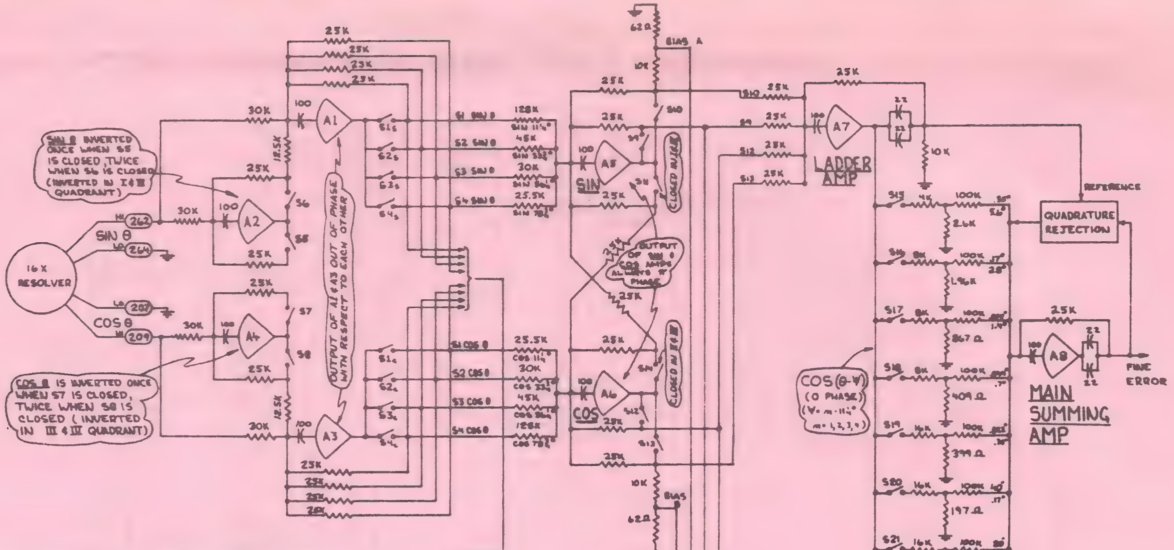


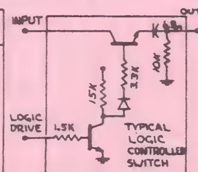
COARSE SYSTEM READ COUNTER WEIGHT FACTOR	
2^0	
2^1	
2^2	
2^3	
2^4	
2^5	
2^6	
2^7	
2^8	
2^9	2.8125°
2^{10}	5.625°
2^{11}	11.25°
2^{12}	22.5°
2^{13}	45°
2^{14}	90°
2^{15}	180°

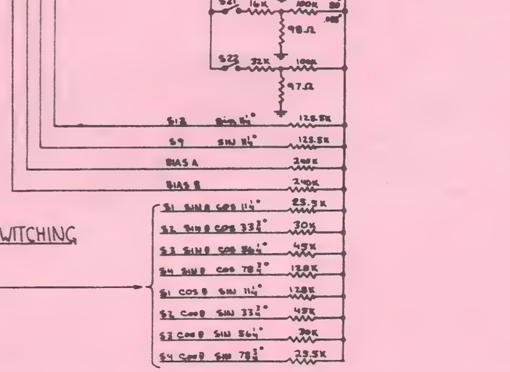
COARSE SYSTEM SWITCH CONTROL LOGIC *
$S1 = 13 \cdot 14 \cdot \overline{15} + \overline{13} \cdot \overline{14} \cdot \overline{15}$
$S2 = 13 \cdot \overline{14} \cdot 15 + \overline{13} \cdot 14 \cdot \overline{15}$
$S3 = 13 \cdot 14 \cdot 15 + \overline{13} \cdot \overline{14} \cdot \overline{15}$
$S4 = \overline{13} \cdot 14 \cdot 15 + 13 \cdot \overline{14} \cdot \overline{15}$
$S5 = 13 \cdot 14 \cdot \overline{15} + \overline{13} \cdot \overline{14} \cdot \overline{15}$
$S6 = \overline{13} \cdot 14 \cdot \overline{15} + 13 \cdot \overline{14} \cdot \overline{15}$
$S7 = 13 \cdot 14 \cdot 15 + \overline{13} \cdot \overline{14} \cdot 15$
$S8 = \overline{13} \cdot 14 \cdot 15 + 13 \cdot \overline{14} \cdot 15$
$S9 = \overline{12}$
S10 = 11
S11 = 10
S12 = 9

* NUMBERS IN LOGIC EQUATIONS REFER TO READ COUNTER POSITIONS i.e. 13 = LOGIC "1" WHEN THERE IS A BIT IN THE 2^{13} POSITION

ECDU
COARSE SYSTEM
SWITCHING NETWORK







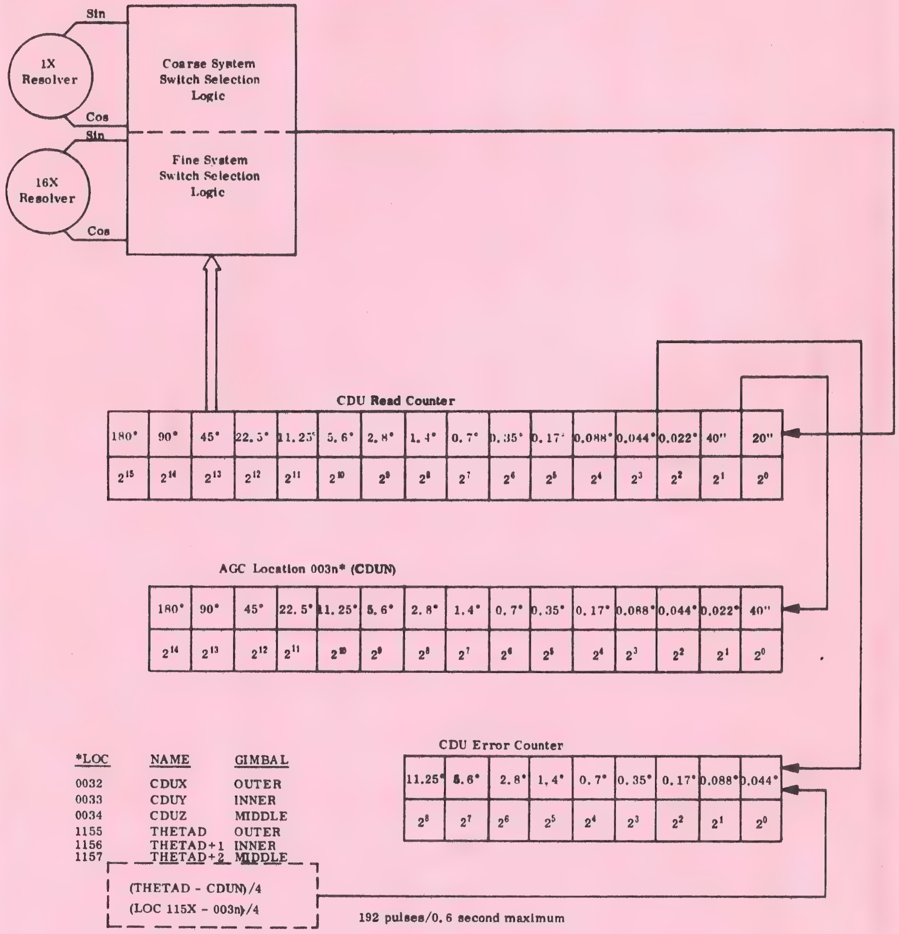
READ COUNTER WEIGHT FACTOR			
	.1X	16 X	TRUNNION
2^0	20"	.088°	2.5"
2^1	40"	.17°	5"
2^2	.022°	.35°	10"
2^3	.044°	.7°	20"
2^4	.088°	1.41°	40"
2^5	.17°	2.82°	.022°
2^6	.35°	5.62°	.044°
2^7	.70°	11.25°	.088°
2^8	1.41°	22.5°	.17°
2^9	2.82°	45°	.35°
2^{10}	5.62°	90°	.70°
2^{11}	11.25°	180°	1.41°
2^{12}	22.5°		2.82°
2^{13}	45°		5.625°
2^{14}	90°		11.25°
2^{15}	180°		22.5°

SWITCH CONTROL LOGIC*
$S1 = \overline{10}\cdot\overline{9}\cdot\overline{8} + 10\cdot 9\cdot 8$
$S2 = \overline{10}\cdot\overline{9}\cdot 8 + 10\cdot 9\cdot\overline{8}$
$S3 = 10\cdot\overline{9}\cdot 8 + \overline{10}\cdot 9\cdot\overline{8}$
$S4 = \overline{10}\cdot 9\cdot 8 + 10\cdot\overline{9}\cdot\overline{8}$
$S5 = 10\cdot 11 + \overline{10}\cdot\overline{11}$
$S6 = 10\cdot\overline{11} + \overline{10}\cdot 11$
$S7 = 11$
$S8 = \overline{11}$
$S9 = 10\cdot\overline{7}$
$S10 = 10\cdot 7$
$S11 = \overline{10}$
$S12 = \overline{10}\cdot\overline{7}$
$S13 = \overline{10}\cdot 7$
$S14 = 10$
$S15 = 6$
$S16 = 5$
$S17 = 4$
$S18 = 3$
$S19 = 2$
$S20 = 1$
$S21 = 0$
S22 (TRUNNION ONLY)

* NUMBERS IN LOGIC EQUATIONS REFER TO READ COUNTER POSITIONS i.e., 10 = LOGIC "1" WHEN THERE IS A BIT IN THE 2^{10} POSITION (IMU & OPTICS SHAFT ONLY)

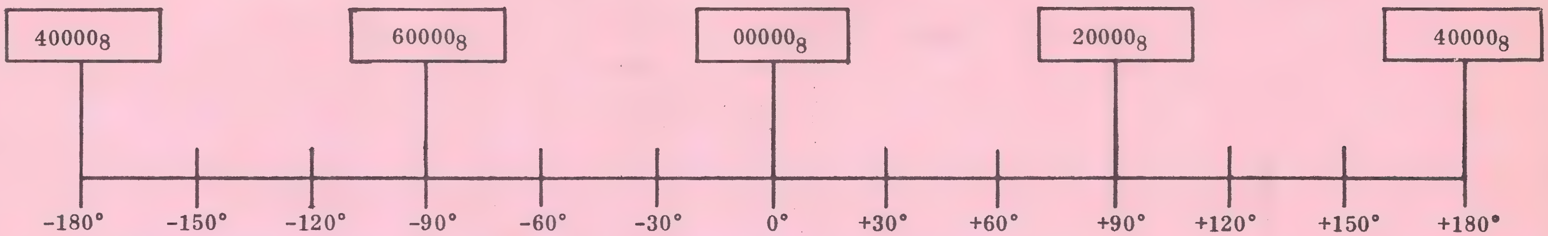
ECDU FINE SYSTEM SWITCHING NETWORK

IMU/CDU/AGC INTERFACE DIAGRAM



IMU GIMBAL ANGLE AND OPTICS SHAFT SCALING DIAGRAM

Contents of Respective Location in AGC



Actual Optics Shaft Angle or IMU Gimbal Angle

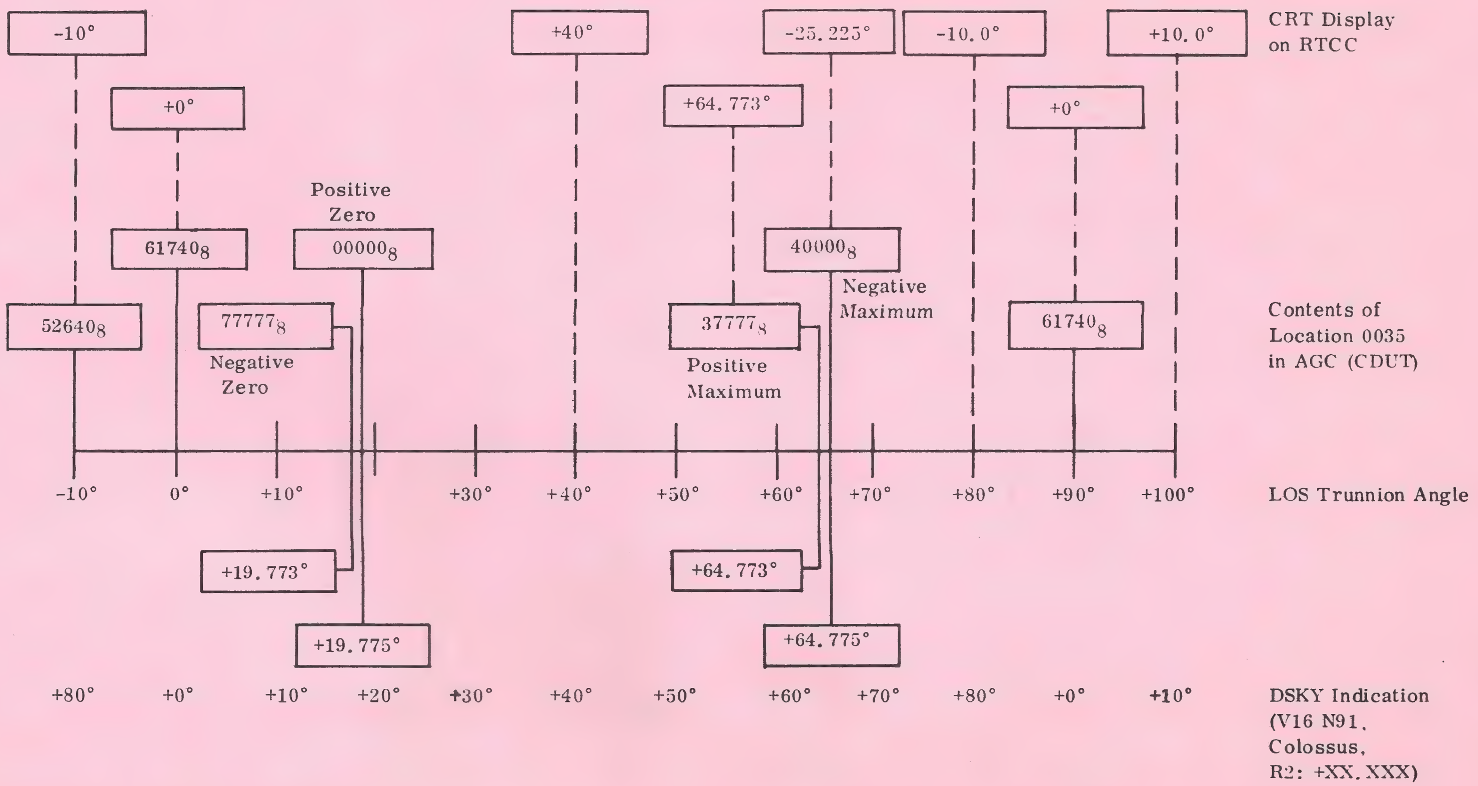
DSKY Indication and CRT Display on RTCC

+180° +210° +240° +270° +300° +330° 0° +30° +60° +90° +120° +150° +180°

NOTE: For Colossus, V16 N91 monitors the optics shaft angle in R1 (+XXX.XX); V16 N20 monitors the IMU gimbal angles as follows:

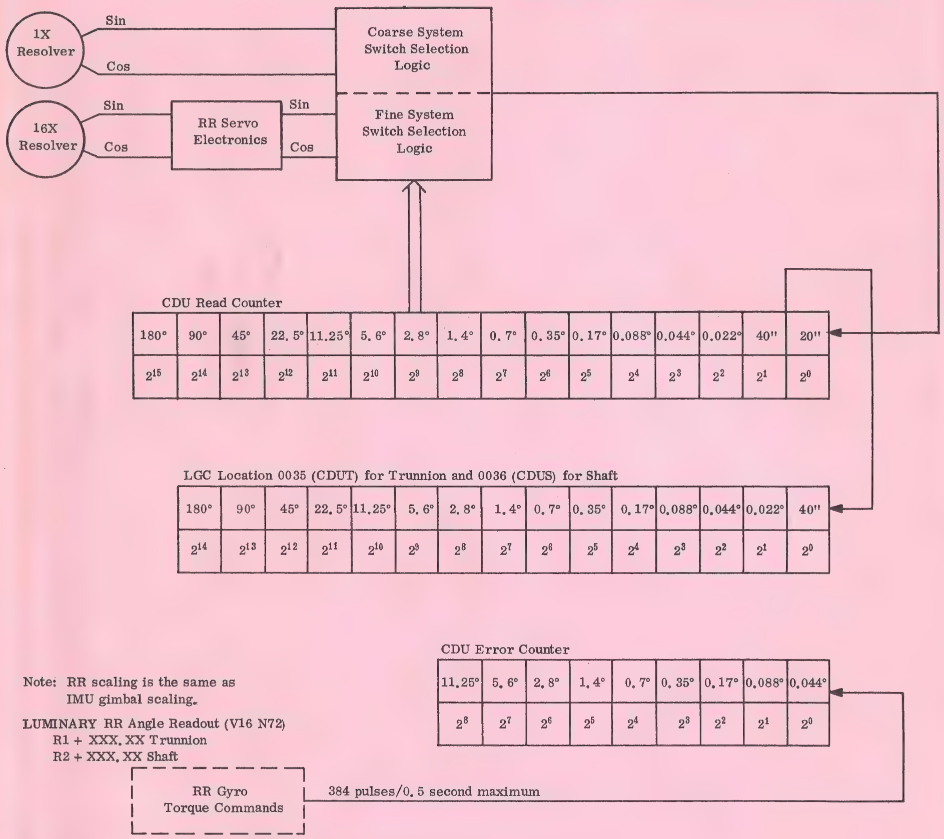
R1: Outer Gimbal (+XXX.XX)
R2: Inner Gimbal (+XXX.XX)
R3: Middle Gimbal (+XXX.XX)

OPTICS TRUNNION SCALING DIAGRAM

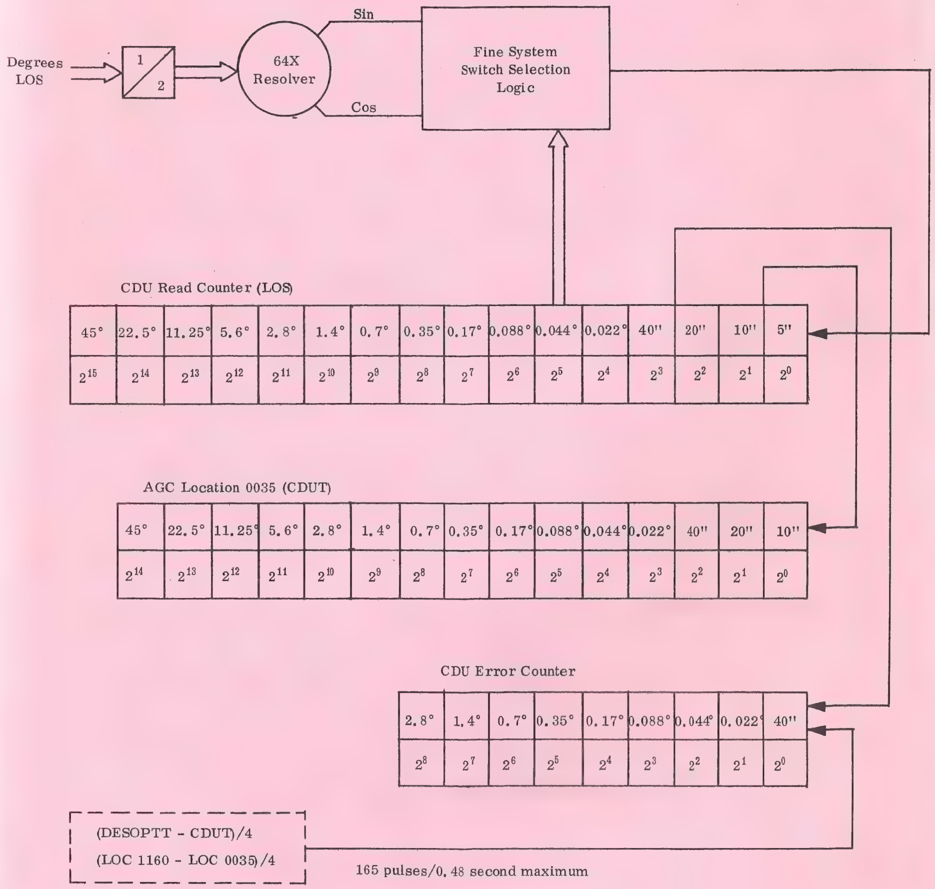


NOTE: CDUT (LOC 0035) is loaded with a -19.775° bias during ZERO OPTICS. This bias produces positive driving commands for angles up to +64.775° in the CMC mode. Without the bias, the CMC mode would drive the trunnion to the negative stop for command angles of 45° or greater.

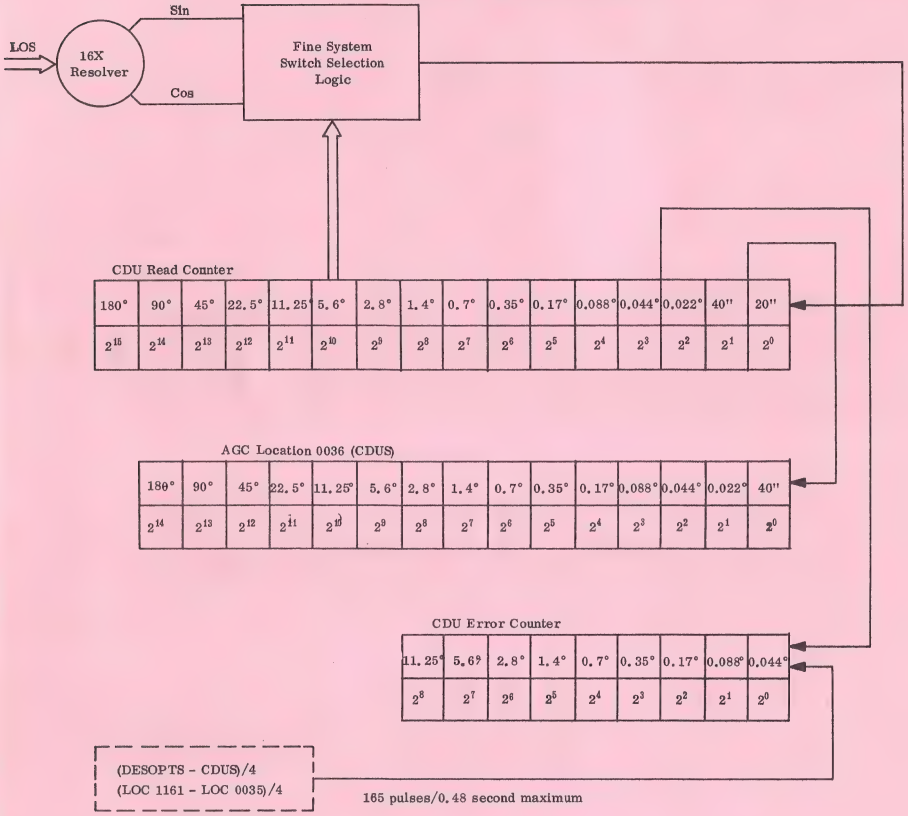
RENDEZVOUS RADAR/CDU/LGC INTERFACE DIAGRAM



OPTICS TRUNNION/CDU/AGC INTERFACE DIAGRAM



OPTICS SHAFT/CDU/AGC INTERFACE DIAGRAM



APOLLO 25 IRIG

Moments of Inertia:

- about OA: 367.3 gram-cm^2
- about IA: 650.8 gram-cm^2
- about SRA: 724.9 gram-cm^2

Damping Coefficients:

- about OA: 4.75×10^5 dyne-cm/rad/sec
- about IA: 1.5×10^9 dyne-cm/rad/sec
- about SRA: 1.5×10^9 dyne-cm/rad/sec

Wheel Excitation: 28 volts, 800 cps, 4.5 watts at synchronism

Wheel Speed: 24,000 rpm

Angular Momentum at 24,000 rpm: 434×10^3 gram-cm^2 sec

Signal Generator:

- Input: 4 volts, 3200 cps
- Sensitivity: 10 mv/mrad

Torque Generator Sensitivity: 0.6 dyne-cm/ma^2

Pulse Torque Scale Factor: $\pi/2^{20}$ rad/pulse at 3200 pps

Magnetic Suspension:

- Input: 4 volts, 3200 cps
- Stiffness: 6 gm/0.0001 inches Radial
  0.8 gm/0.0001 inches Axial

Typical Temperature Sensitivity

- Scale Factor: 400 ppm/$^\circ$ F
- Drift: 0.2 meru/$^\circ$ F

Actual IRIG temperature

GYRO PARAMETERS

Primary gyro parameters are ADIA, ADSRA, NBD and scale factor. Specification values across ISS, G&N, and S/C testing are as shown in Table II-1.

Table II-1

Gyro Coefficient Stability Criteria					
Coefficient	Units	D1	D2	D3	Max
Acceleration Drift along the IA (ADIA)	meru/g	17	33	40	100
Acceleration Drift along the SRA (ADSRA)	meru/g	14	21	25	40
Non-Acceleration Bias Drift (NBD)	meru	6	9	11	15

Gyro scale factor limits are ± 1750 ppm.

The maximum value of gyro performance parameters which can be compensated for by the computer is shown in Table II-2.

Table II-2

Coefficient	Units	Max Value CM/LM
ADIA	meru/g	862
ADSRA	meru/g	862
NBD	meru	128.7

IMU GYRO COMPENSATION

The compensated PIPA data is used to compute the IRIG torquing necessary to cancel the NBD, ADIA and ADSRA gyro coefficients. The computations are

$$XIRIG = -ADIAX\ PIPAX_C + ADSRAX\ PIPAY_C - NBDX\ \Delta t$$

$$YIRIG = -ADIAY\ PIPAY_C + ADSRAY\ PIPAZ_C - NBDY\ \Delta t$$

$$ZIRIG = -ADIAZ\ PIPAZ_C - ADSRAZ\ PIPAY_C + NBDZ\ \Delta t$$

where

XIRIG, YIRIG, ZIRIG are gyro drift compensations

NBDX, NBDY, NBDZ are gyro bias drifts (an erasable load)

ADSRAX, ADSRAY, ADSRAZ are gyro drifts due to acceleration in spin reference axis (an erasable load)

ADIAX, ADIAY, ADIAZ are gyro drifts due to acceleration in the input axis (an erasable load)

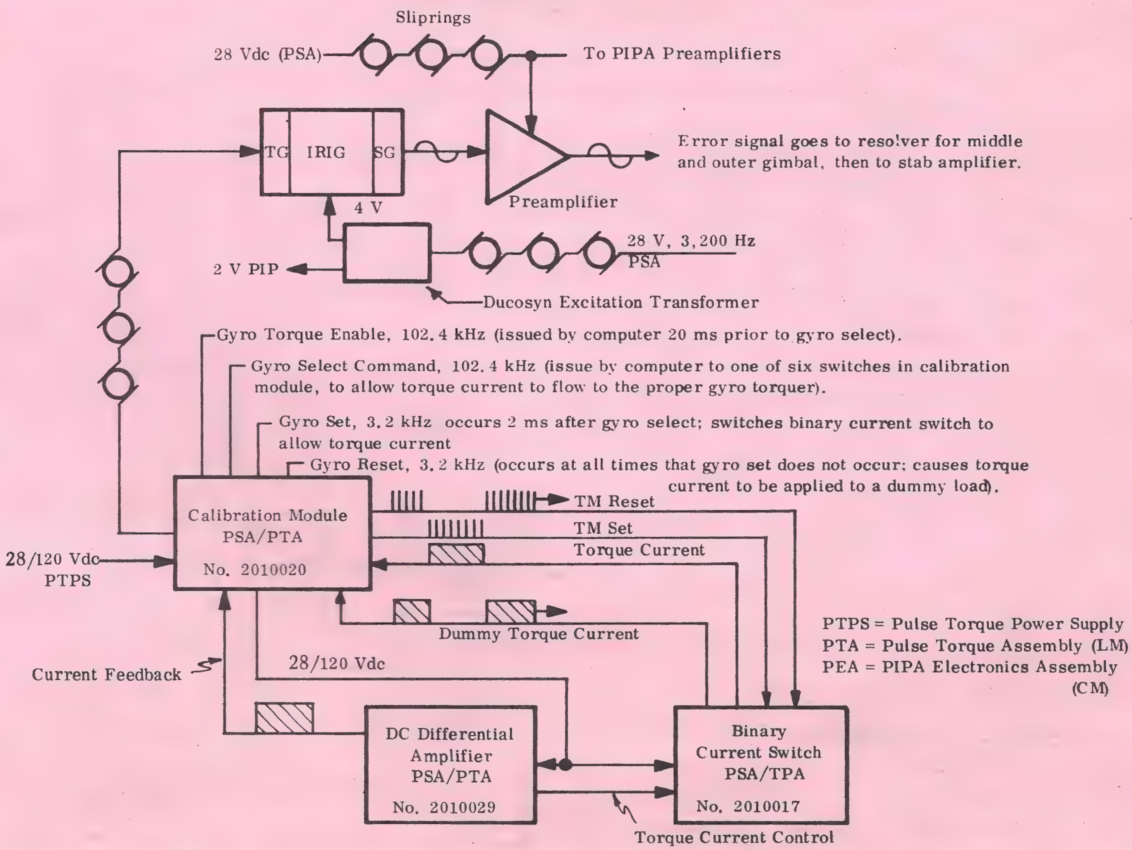
When the magnitude of any IRIG command exceeds two pulses, the commands are sent to the gyros.

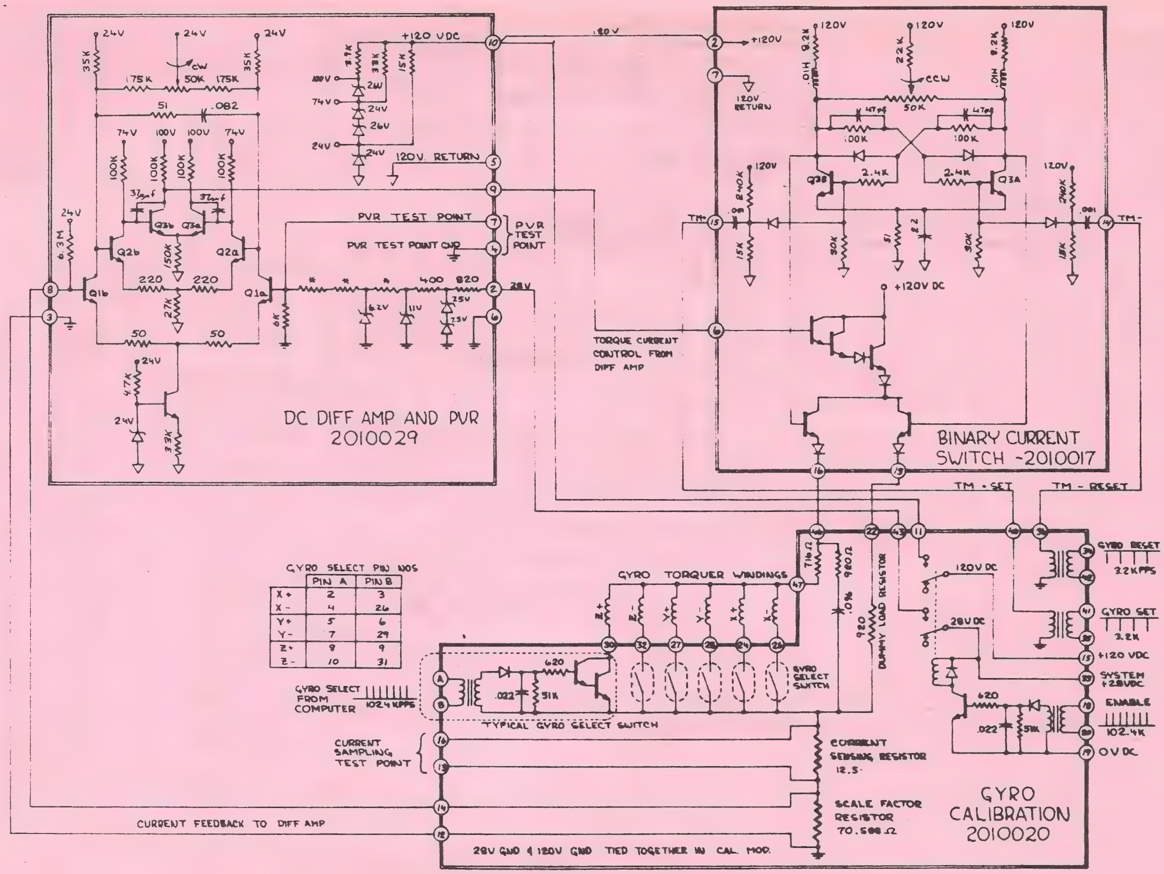
During free-fall only the NBDX, NBDY, NBDZ are the relevant coefficients and the routine is so ordered that only these terms are calculated for the gyro compensation.

The computer NBD registers are 1460, 1461, and 1462 for the X, Y, and Z gyros respectively.

GYRO DRIFT NBD = (.007835) (Reg Contents in Decimal) MERU

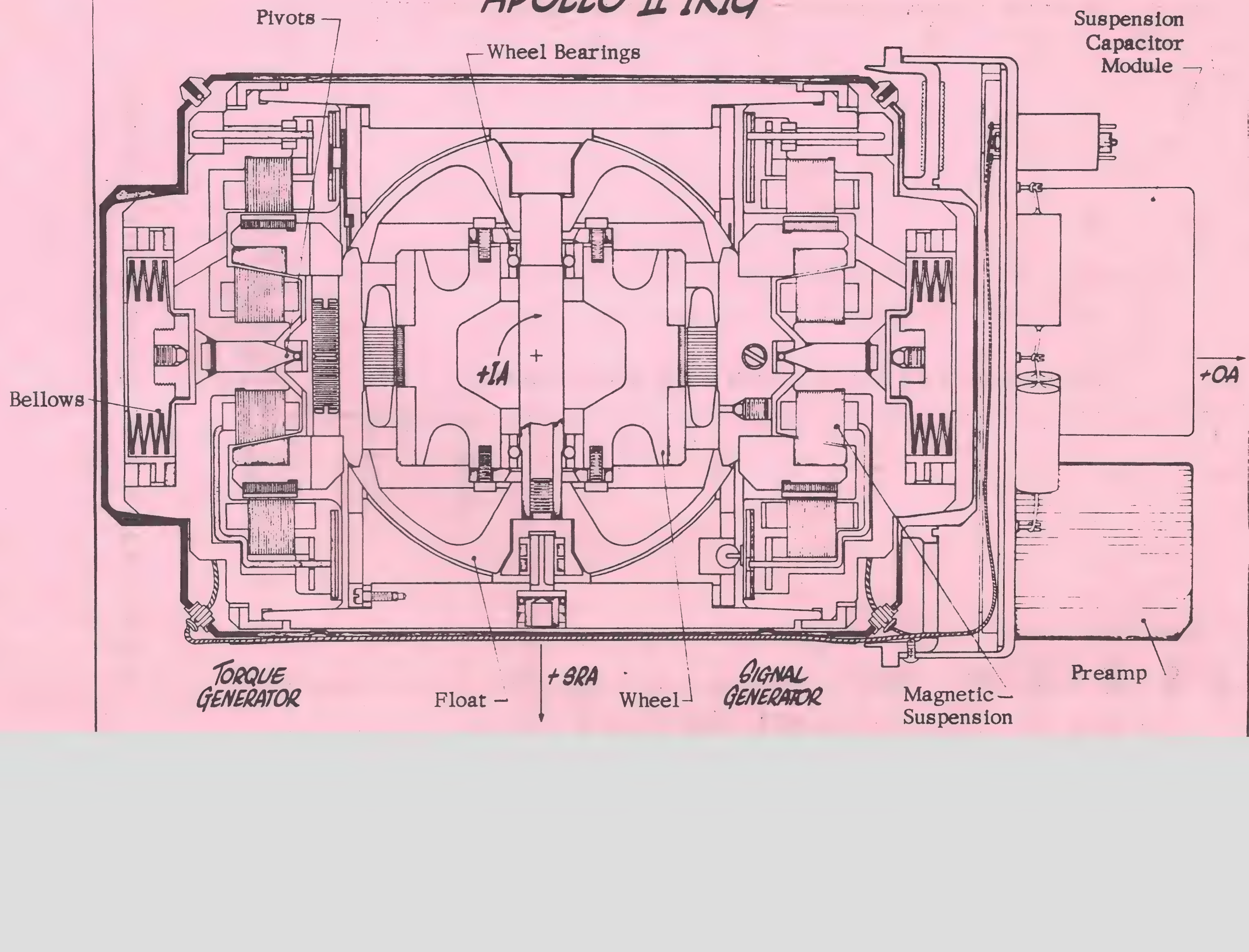
GYRO PULSE TORQUING LOOP

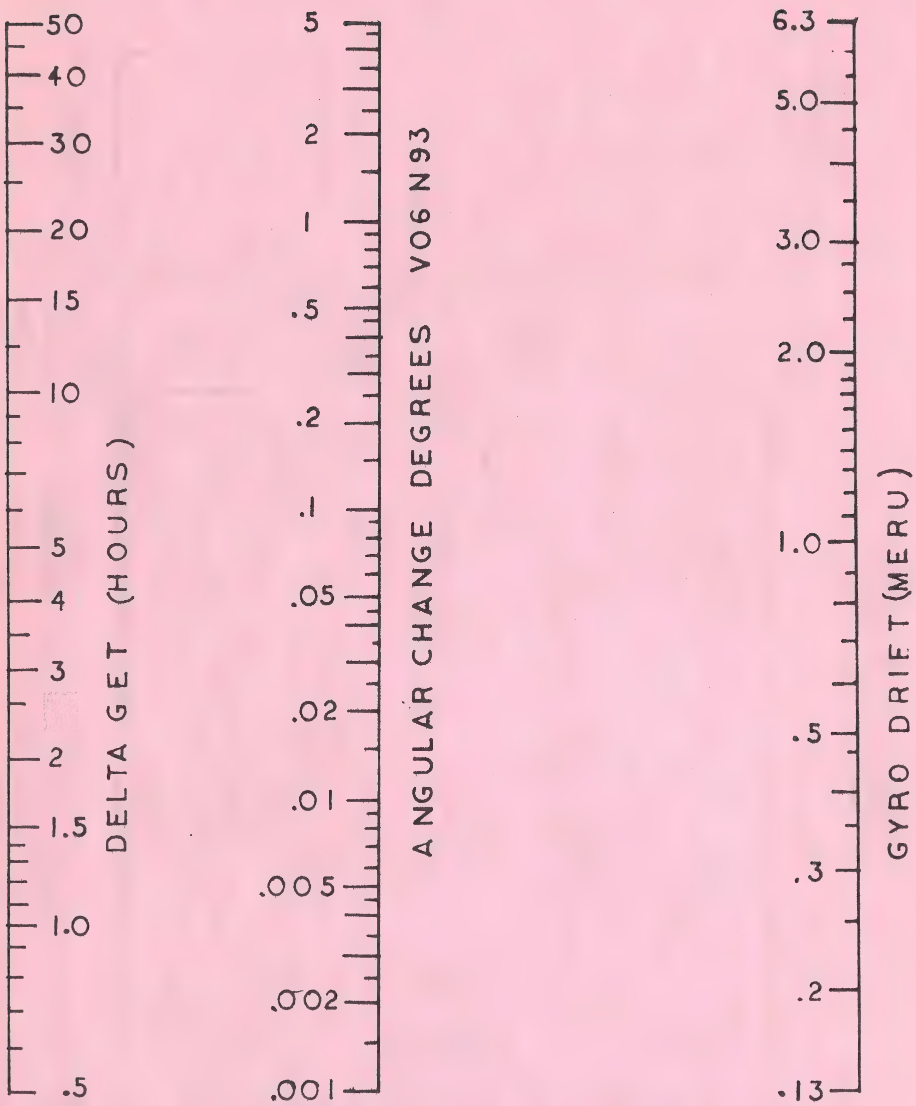




GYRO PULSE TORQUING LOOP

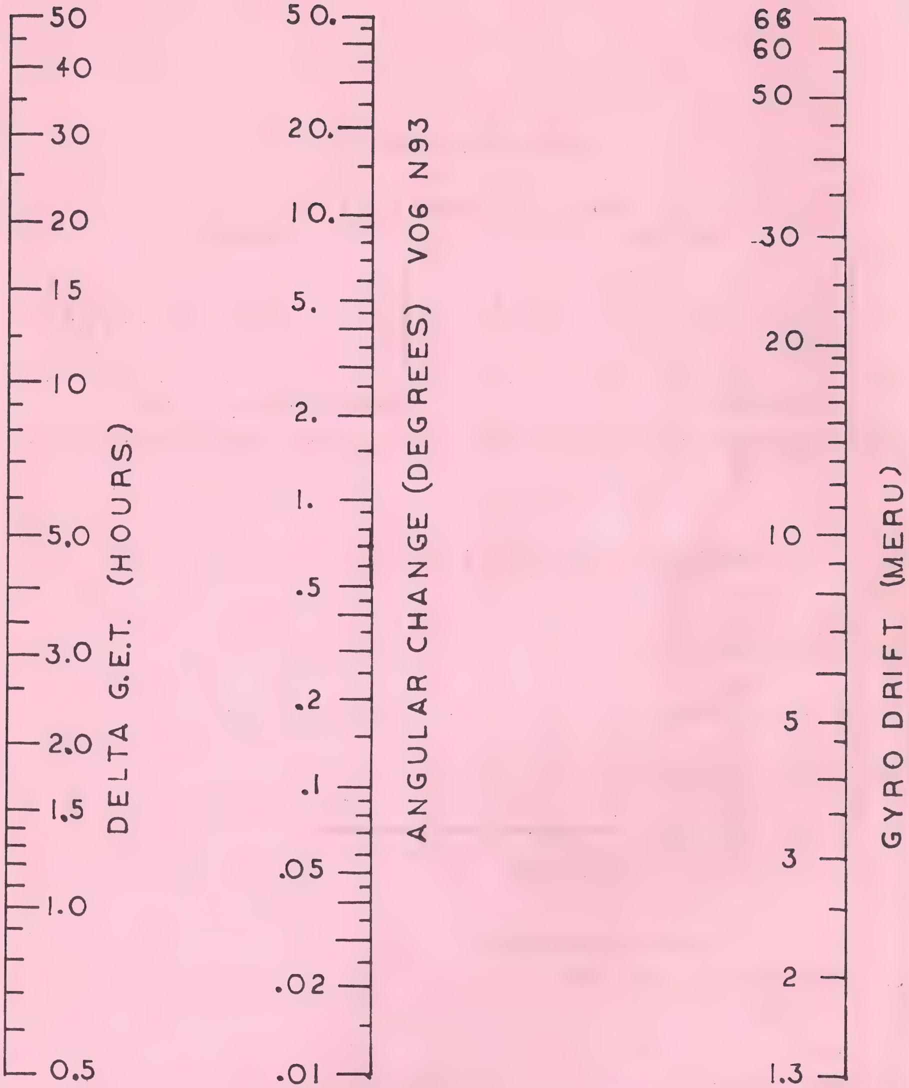
APOLLO II IRIG





GYRO TORQUING ANGLES
PROGRAM 52

NOMOGRAPH FOR GYRO DRIFT(NBD)

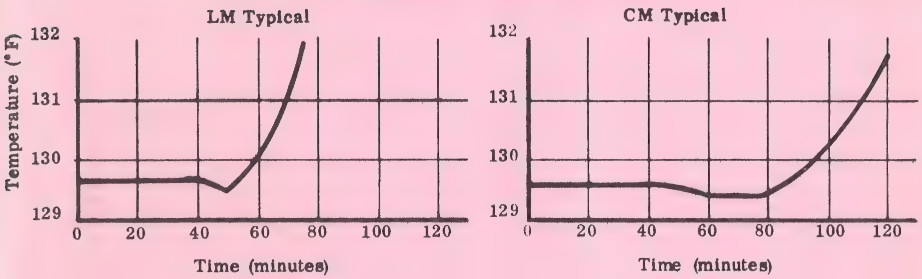


GYRO TORQUING ANGLES
PROGRAM 52

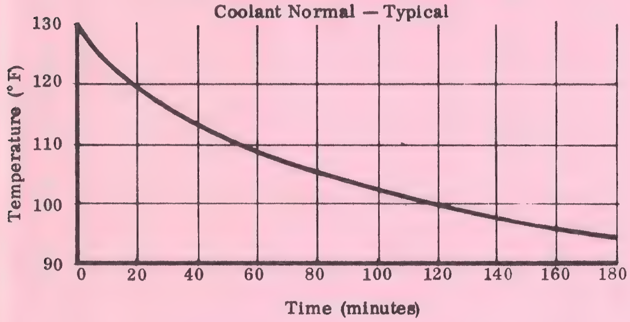
NOMOGRAPH FOR GYRO DRIFT (NBD)

TYPICAL IMU TEMPERATURE

PIPA Temperature After Coolant Loss



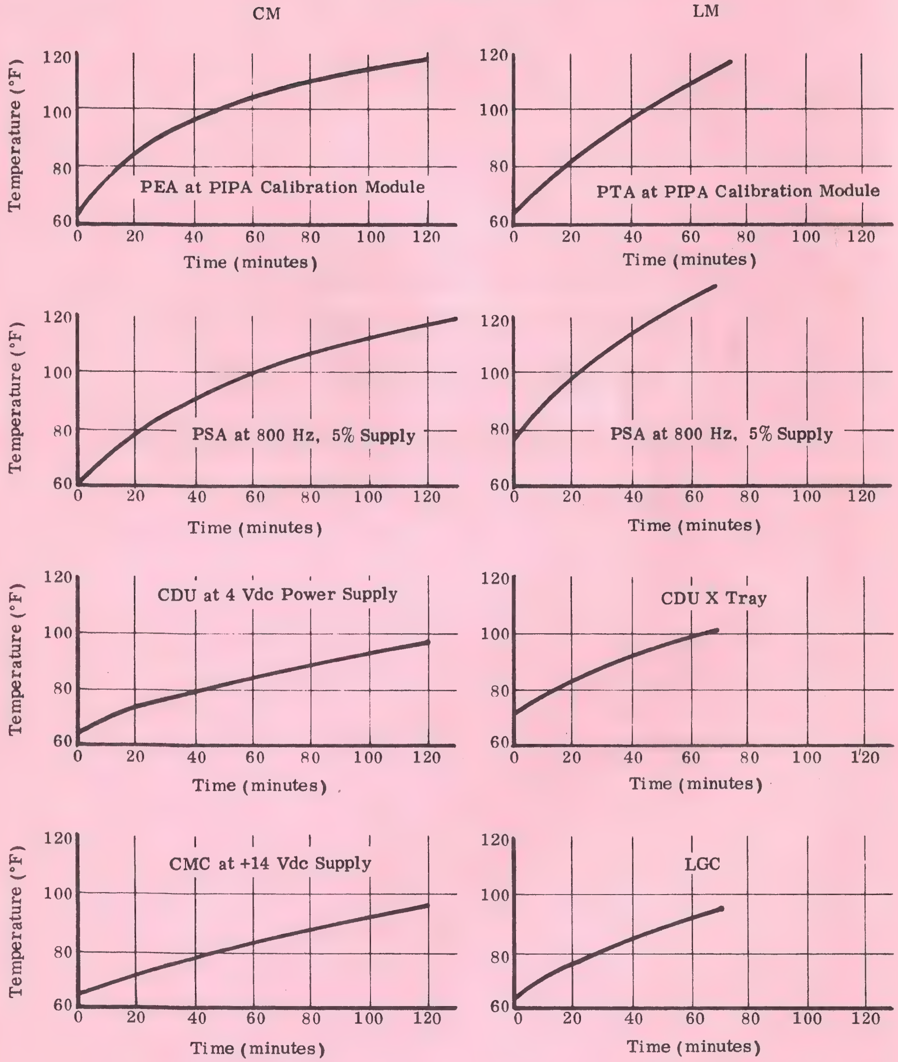
PIPA Temperature After Power Loss
Coolant Normal — Typical



NOMINAL PARAMETERS

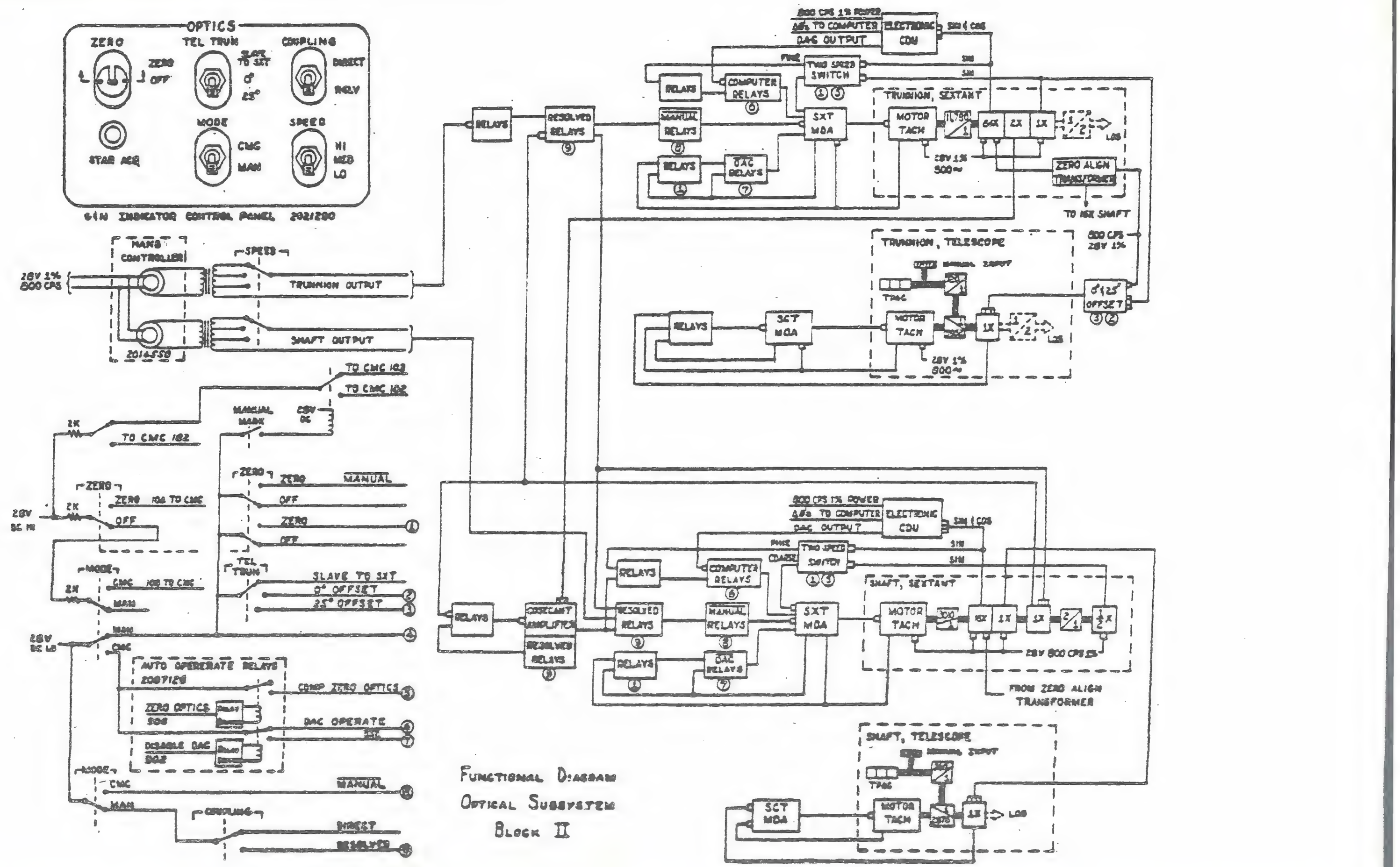
- PIPA Temperature — 130 ± 1.5°F
- Low Temperature Alarm — 126 ± 2.5°F (PIPA Temperature)
- High Temperature Alarm — 135 ± 2.5°F (PIPA Temperature)
- Safety Thermostat Opens — 140^{+5}_{-2} °F (PIPA Temperature)
- Safety Thermostate Hysteresis — 2 - 5°F

TYPICAL HEADER TEMPERATURES AFTER
COOLANT LOSS



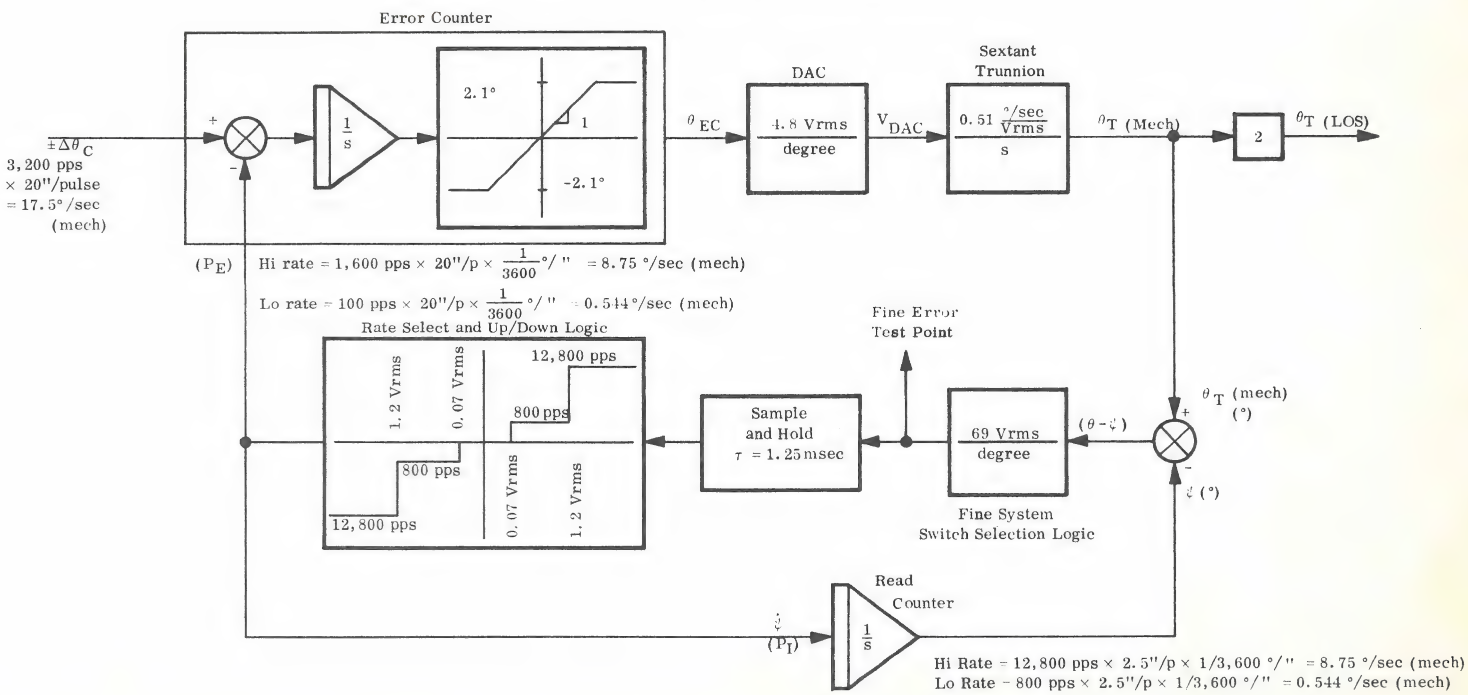
OPTICS

FUNCTIONAL DIAGRAM
CELESTIAL BODY CODES
IMU REALIGNMENT
CISLUNAR NAVIGATION
LANDMARK TRACK

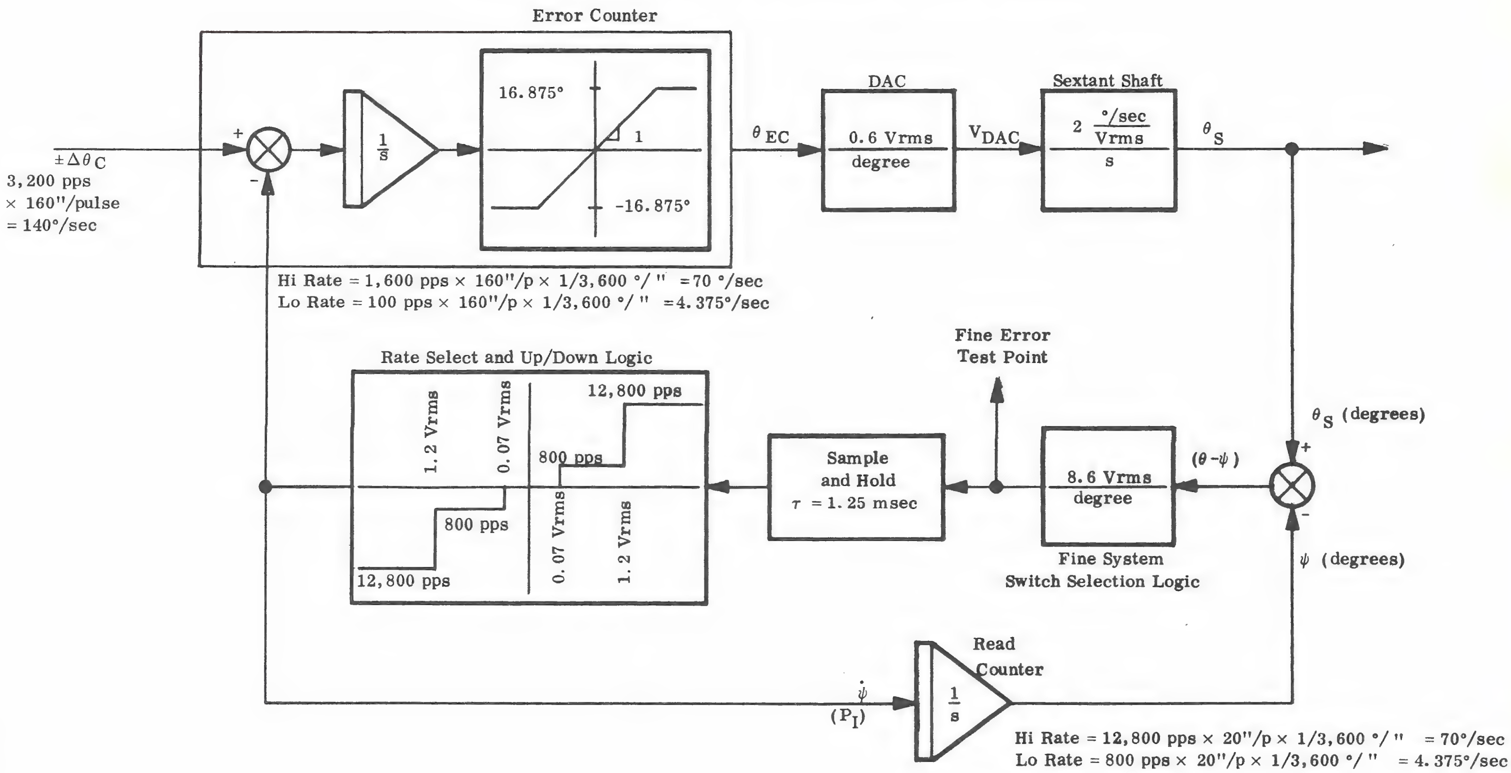


Functional Diagram
Optical Subsystem
Block II

TRUNNION COMPUTER OPERATE MODE FUNCTIONAL BLOCK DIAGRAM



SHAFT COMPUTER OPERATE MODE FUNCTIONAL BLOCK DIAGRAM



NOUN 70 CODES

R1: CELESTIAL BODY CODE 000XX

00	PLANET	27	ALKAID
01	ALPHERATZ	30	MENKENT
02	DIPHDA	31	ARCTURUS
03	NAVI	32	ALPHECCA
04	ACHERNAR	33	ANTARES
05	POLARIS	34	ATRIA
06	ACAMAR	35	RASALHAGUE
07	MENKAR	36	VEGA
10	MIRFAK	37	NUNKI
11	ALDEBARAN	40	ALTAIR
12	RIGEL		
13	CAPELLA		
14	CANOPUS		
15	SIRIUS		
16	PROCYON		
17	REGOR	41	DABIH
20	DNOCES	42	PEACOCK
21	ALPHARD	43	DENEB
22	REGULUS	44	ENIF
23	DENEBOLA	45	FOMALHAUT
24	GIENAH	46	SUN
25	ACRUX	47	EARTH
26	SPICA	50	MOON

R2: LANDMARK DATA ABCDE

A = 1 IF KNOWN LDMK
A = 2 IF UNKNOWN LDMK
B = INDEX OF OFFSET DESIG
C = NOT USED
DE = LDMK ID NO

R3: HORIZON DATA 00CD0

C = 1 FOR EARTH HORIZON
C = 2 FOR MOON HORIZON
D = 1 FOR NEAR HORIZON
D = 2 FOR FAR HORIZON

CHECKLIST REF CODES (V50N25)

R1 CODE	ACTION
00013	PERFORM COARSE ALIGN
00014	PERFORM FINE ALIGN
00015	ACQUIRE CELESTIAL BODY
00016	TERMINATE MARKS
00041	CM/SM SEP
00062	KEY CMC TO STBY
00202	G&N AUTO MNVR
00204	SPS GMBL TRIM

ALARM CODES (V05N09)

CODE	DESCRIPTION	CORRECTIVE ACTION
00110	MARK REJECT UNNECESSARY	RSET/CONT
00112	MARK NOT ACCEPTED	RSET/CONT
00113	NO INBITS	RSET/REATTEMPT ENTRY
00114	MARK NOT DESIRED	RSET/CONT
00115	TOR REQ-OSS NOT IN CMC	SET OSS TO CMC/RSET/CONT
00116	OSS SW BEFORE 15 SEC	SET OSS TO ZERO/RSET/CONT
00117	TOR REQ-OSS NOT AVAIL	RSET
00120	TOR REQ-OSS NOT ZEROED	SET OSS TO ZERO/RSET/CONT
00121	CDUS NO GO AT MARK	RSET/REPEAT MARK
00122	MARKING NOT CALLED FOR	RSET/CONT
00124	NO SOLUTION TO TPI	RSET/V32E
00205	PIPA SATURATED	RSET/SWITCH TO SCS
00206	ZERO ENCODE NOT ALLOWED	RSET/V41/V40
00211	COARSE ALIGN ERROR	RSET/REPEAT AND/OR FA CK
00217	ISS MODE SWITCH FAIL	RSET/REINITIATE PROG, CONT
00220	IMU NOT ALIGNED	RSET/P51 OR SET FLAG
00401	DESIRED ANGLES GMBL LOCK	RSET/AVOID GMBL LOCK
00404#	TARGET OUT OF 90 DEG	RSET/MNVR NEW TGT
00405	TWO STARS NOT AVAIL	MNVR/RSET/V32E/NEW STAR
00406	P20 NOT OPERATING	RSET
00407	TARGET OUT OF 50 DEG	RSET/MNVR
00421	W MATRIX OVERFLOW	RSET/NOTIFY MSFN, CONT
00430**	ACC OVERFLOW IN INTEG	RSET/REINITIATE PROG
00600	IMAG ROOTS FIRST ITER	RSET/V32E ADJUST INPUT PARAMETERS (00600–00606)
00601	HP POST CSI LOW	
00602	HP POST CDH LOW	
00603	TIG CSI-CDH < 10 MIN	
00604	TIG CDH-TPI < 10 MIN	
00605	ITER > LOOP MAX	
00606	ΔV EXCEEDS MAX	
00607**	NO SOL TIME θ OR R	RSET/REINITIATE PROG
00611	NO TIG FOR ELEV ANGLE	PRO NEW ELEV/RSET
01105	DOWN TEL TOO FAST	RSET
01106	UP TEL TOO FAST	RSET/RETRANSMIT
01207*	NO VAC AREA FOR MARKS	RSET/TERM, REINITIATE P51/P52
01211*	ILLEGAL RUPT OF EXTD VERB	RSET/TERM, REINITIATE PROG
01302**	NO SOLUTION	RSET/N08, NOTIFY MSFN, CONT
01407	VG INCREASING	TERMINATE THRUST/RSET
01426	IMU UNSAT	RSET/REALIGN IMU
01427	IMU REVERSED	RSET/CONT/0 DEG = LIFT DN
01520	V37 NOT ALLOWED	RSET/RESELECT V37
01521**	P01 ILLEG SELECT	RSET/REINITIATE PROG
01703	CANNOT INTEG SV TO TIG	RSET/AUTO TIG SLIP

AUTO DISPLAY   * RESTART   ** POODOO

P23 (CALIBRATE FIRST) CMC-FREE
OPT ZRO-MAN-DIR-LO
MAN TO ACQUIRE STAR IN SXT
F05 70 (STAR.LDMK.HOR ID)LD&PRO
F50 25 00202 E F59
OPT ZRO-OFF-MARK
F06 87 (R2=BIAS)
V32 TIL 2 <.003° PRO. V37E 23E
OPT ZRO. OPT MODE-CMC
F05 70 (110EN.120F:210LN.220F)PRO
F50 25 00202 PRO
F50 18 CMC. AUTO-PRO
WHEN MANEUVER COMPLETE. E
F59-OPT ZRO OFF-E 06 92
(FREE-IF MIC REQD)
OPT-MAN-F51-MARK
F50 25 00016 -PRO
F05 71 VERIFY & PRO
F06 49 ΔR.I. ΔV.I. RCD
REJ-V37E 23E. ACC-PRO
F37 23E NEXT STAR. 00E

P22 (AUTO OPT)
RESOLVED-MED-ZRO-CMC
F06 45 (R3=MGA) PRO
F05 70 LD 10000CP/1000IRLS PRO
F06 89 LAT.LONG/2.ALT(CP ONLY)
OPT ZRO-OFF PRO
06 92 SHAFT TRUN MODE-MAN
F51 5 MARKS 30 SEC APART
F50 25 00016-PRO
F05 71 CONFIRM-PRO
F06 89 CONFIRM-PRO
F06 49 ΔR. ΔV (.1NM. .1FPS)
WAIT 30 SEC. PRO OR V32E
F06 89 RCD. V34E

P52 (NO PLANETS) CMC-FREE
OPT ZRO. OPT MODE-CMC
F04 06: V22E LD 1 OR 3-PRO
PREF. NOM. REFSMMAT. LDG SITE
F06 22 (NEW GIMBAL ANG)
PRO IF MGA OK. OR MANEUVER
F50 25 00013 (TOR)
GYRO TOR-E
COARSE ALIGN-PRO
16 20 WHILE MOVING
F50 25 00014 (ALIGN CK)
(TO BYPASS. E TO F37)
PRO (FOR OPT VERIF)
F50 25 00015 STAR SEL
(TO ACQ MANUALLY. E)
PRO-PICAPAR(ZRO-OFF)
F01 70 LD STAR PRO
06 92 SHAFT&TRUN
OPT-MAN-F51-MARK
F50 25 00016 PRO
F01 71 STAR#-PRO 1ST. 2ND
F06 05 STAR ANG DIFF
ACC. PRO(REJ. V32E)
F06 93 TOR ANGLES
TOR.PRO:BYPASS.V32E
F50 25 00014. E(F37) RECK PRO

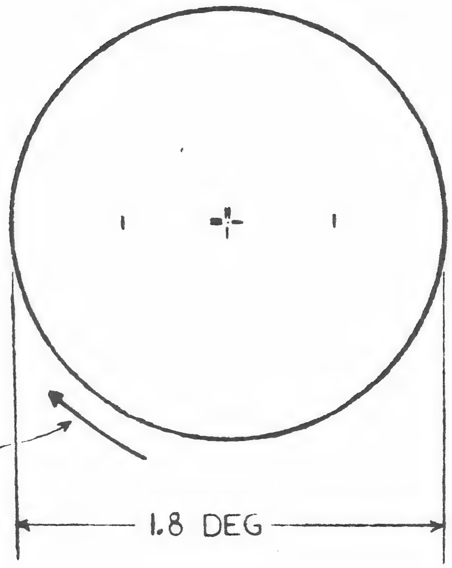
DAP V48E	A/C X	B/D X	D/B	RATE
0-NONE	0 FAIL	0 FAIL	0-0.5	.05°/S
1-CSM	1 USE	1 USE	1-5.0	.2°/S
2-CSM/LM				.5°/S
3-CSM/SIVB				2.0°/S

ROLL	QUAD A	B	C	D
0 B/D	0 FAIL	0 FAIL	0 FAIL	0 FAIL
1 A/C	1 USE	1 USE	1 USE	1 USE

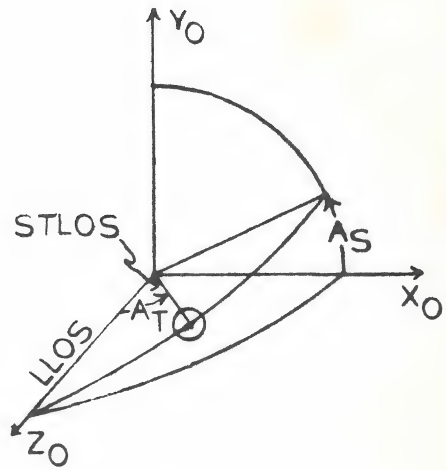
DRIVE RATES

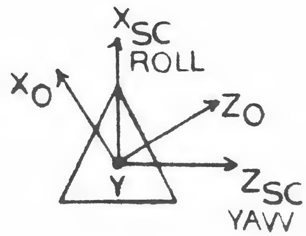
	TRUNNION	SHAFT
HI	10.0 DEG/S	19.5 DEG/S
MED	1.0 DEG/S	2.0 DEG/S
LO	0.1 DEG/S	0.2 DEG/S
MIN	25 SEC/S	50 SEC/S
CMC	3.8 DEG/S	15.1 DEG/S

SXT FIELD OF VIEW



RETICLE ROTATION WITH OPTICS HAND CONTROLLER FULL RIGHT (MANUAL DIRECT MODE)



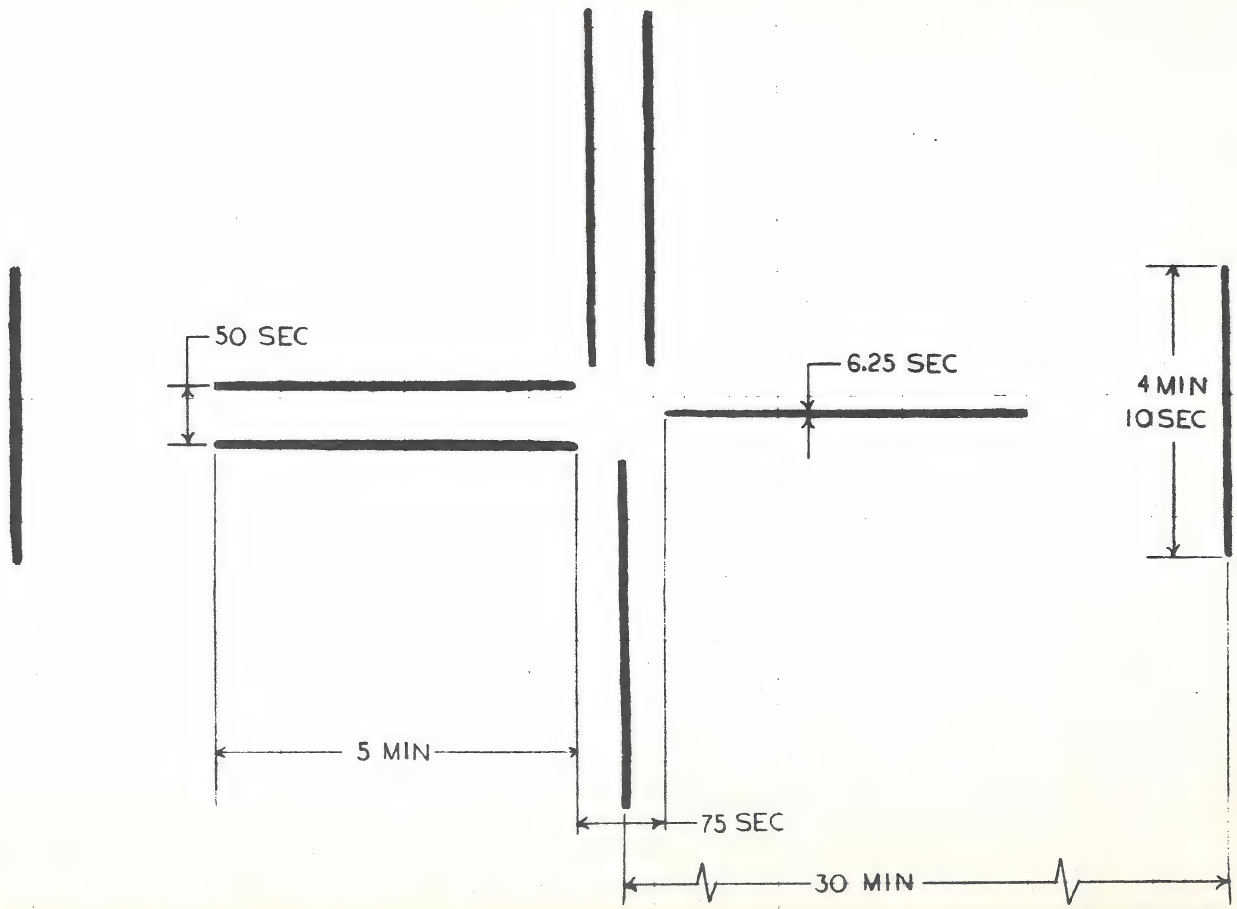


SXT LOS MECHANICAL LIMITS

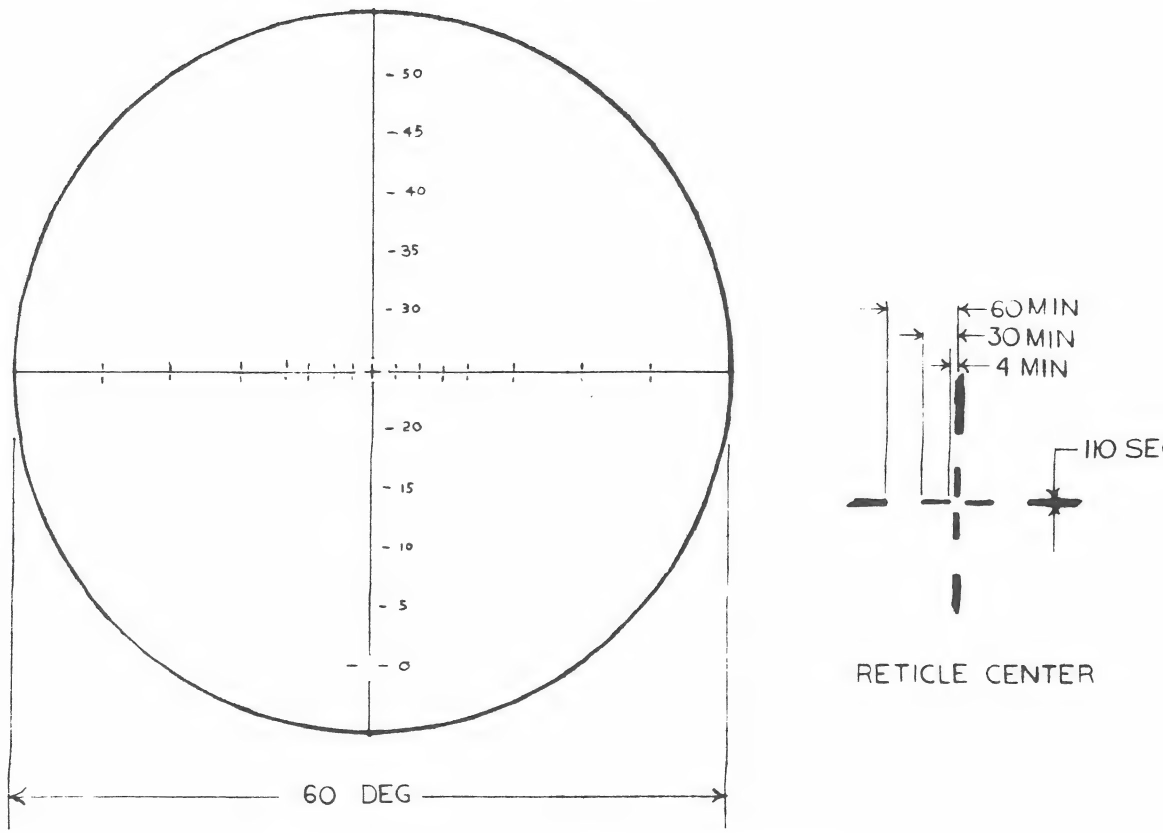
TRUNNION 0(0,-10) TO 90(10,0) DEG

SHAFT 270(0,-10) TO -270(-10,0) DEG

SXT VACUUM RETICLE

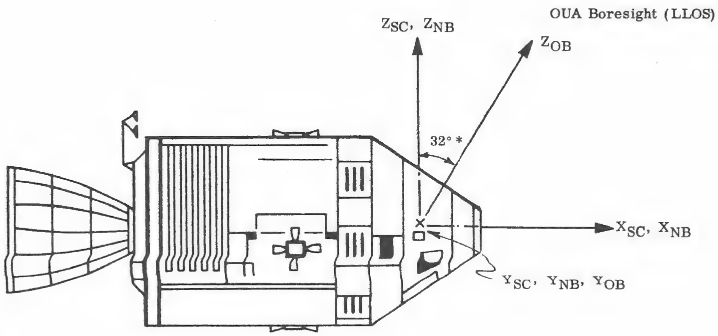


SCT RETICLE



RETICLE CENTER

OUA LINE OF SIGHT TO IMU STABLE MEMBER TRANSFORMATIONS



$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{SM} = \begin{bmatrix} \cos AI & 0 & \sin AI \\ 0 & 1 & 0 \\ -\sin AI & 0 & \cos AI \end{bmatrix} \begin{bmatrix} \cos AM & -\sin AM & 0 \\ \sin AM & \cos AM & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos AO & -\sin AO \\ 0 & \sin AO & \cos AO \end{bmatrix} \begin{bmatrix} \cos 32^* & 0 & \sin 32^* \\ 0 & 1 & 0 \\ -\sin 32^* & 0 & \cos 32^* \end{bmatrix} \begin{bmatrix} \cos AS & -\sin AS & 0 \\ \sin AS & \cos AS & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos AT & 0 & \sin AT \\ 0 & 1 & 0 \\ -\sin AT & 0 & \cos AT \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ St\ LOS \end{bmatrix}$$

* Nominal Angle 32° 31' 23"

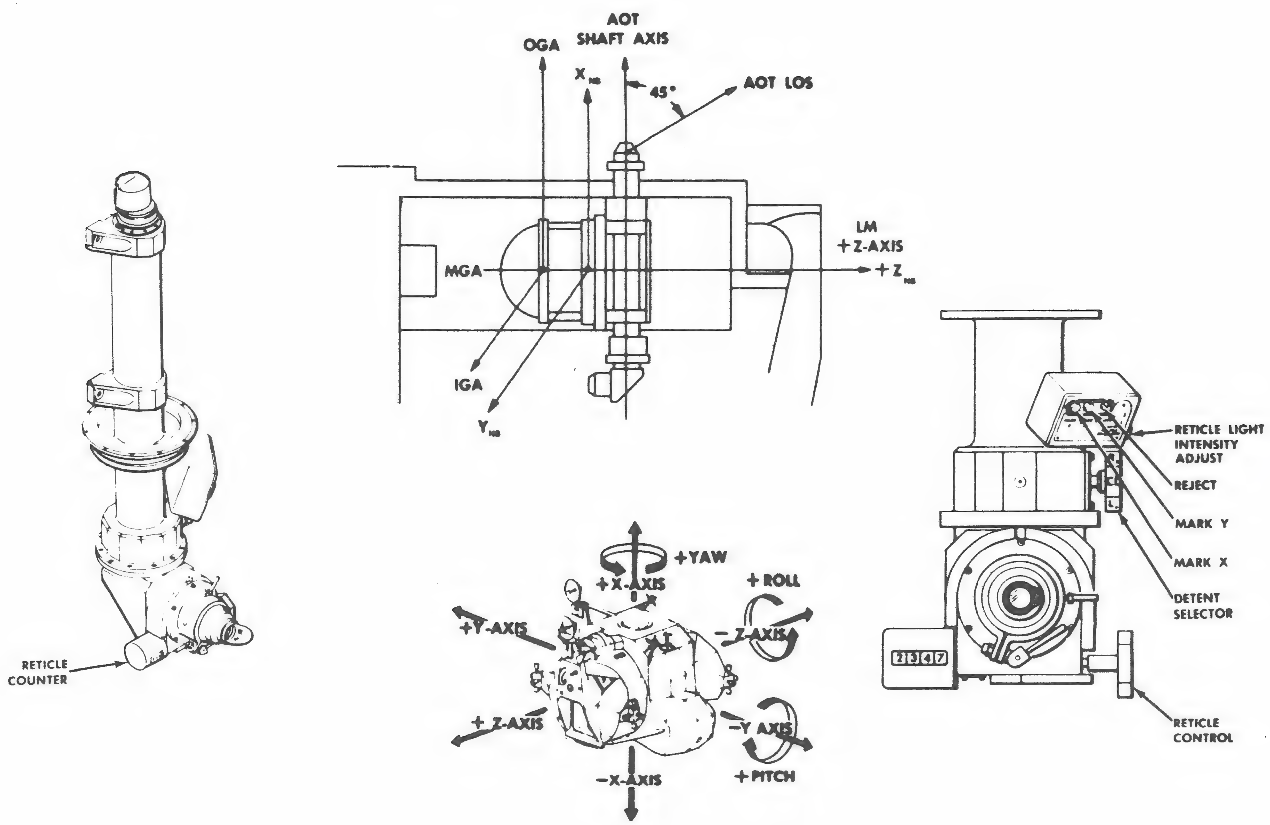
$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{SM} = \begin{bmatrix} \cos AI & 0 & \sin AI \\ 0 & 1 & 0 \\ -\sin AI & 0 & \cos AI \end{bmatrix} \begin{bmatrix} \cos AM & -\sin AM & 0 \\ \sin AM & \cos AM & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos AO & -\sin AO \\ 0 & \sin AO & \cos AO \end{bmatrix} \begin{bmatrix} \cos 32^* & 0 & \sin 32^* \\ 0 & 1 & 0 \\ -\sin 32^* & 0 & \cos 32^* \end{bmatrix} \begin{bmatrix} \cos AS \ \sin AT \\ \sin AS \ \sin AT \\ \cos AT \end{bmatrix}$$

where

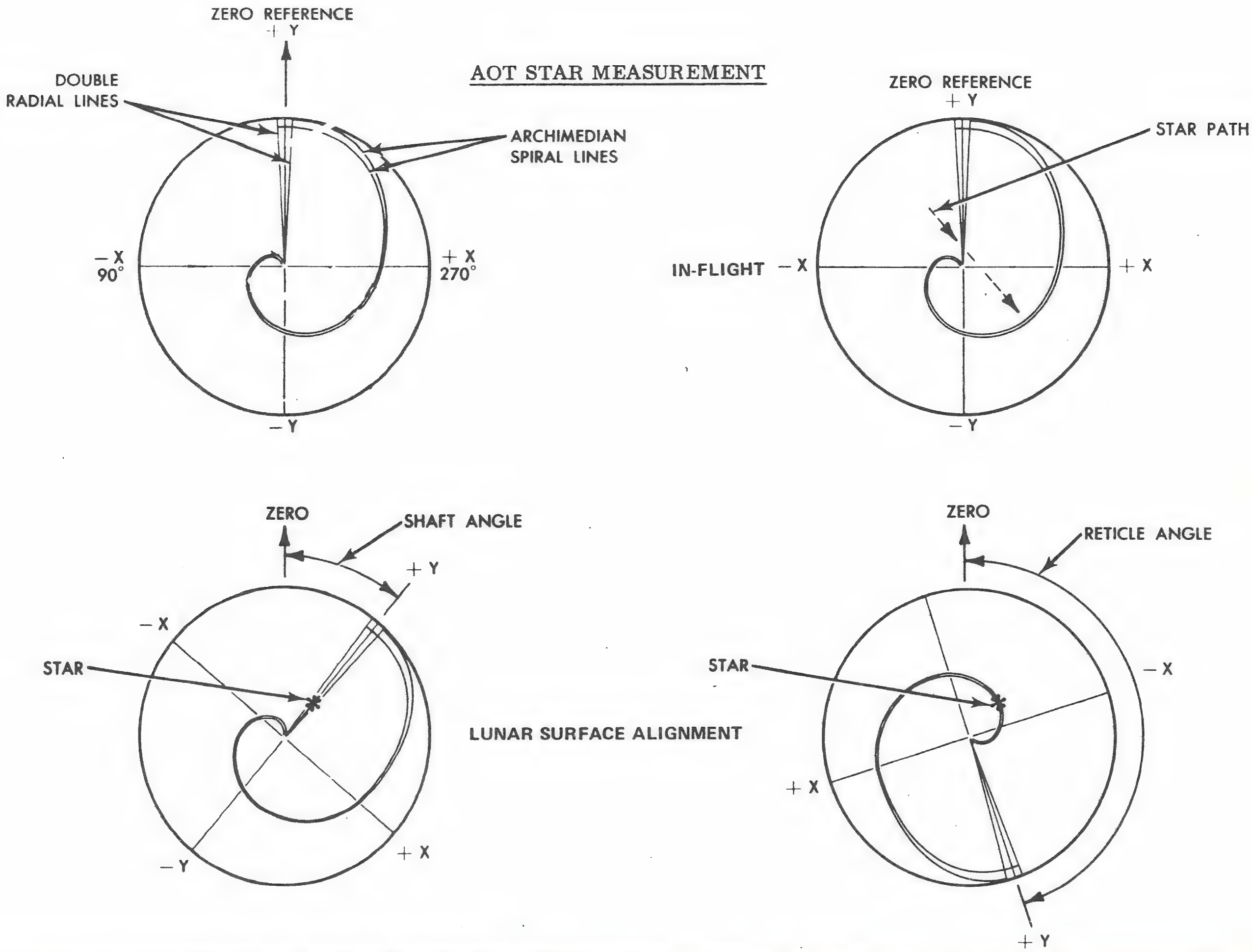
AI, AM and AO are the inner, middle, and outer gimbal angles as indicated by the CMC

AS and AT are the SXT LOS shaft and trunnion angles

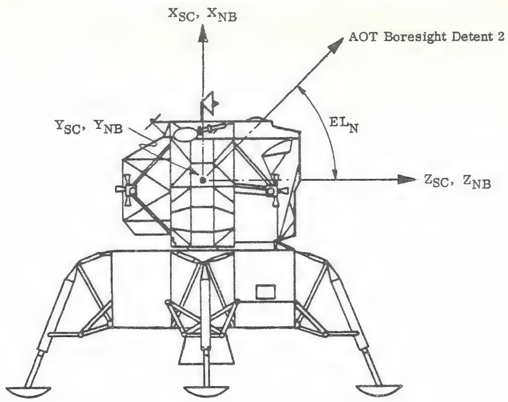
ALIGNMENT OPTICAL TELESCOPE



AOT STAR MEASUREMENT



AOT LINE OF SIGHT TO IMU STABLE MEMBER TRANSFORMATIONS



Orbital Alignment

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{SM} = \begin{bmatrix} \cos AI & 0 & \sin AI \\ 0 & 1 & 0 \\ -\sin AI & 0 & \cos AI \end{bmatrix} \begin{bmatrix} \cos AM & -\sin AM & 0 \\ \sin AM & \cos AM & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos AO & -\sin AO \\ 0 & \sin AO & \cos AO \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos AZ_N & \sin AZ_N \\ 0 & -\sin AZ_N & \cos AZ_N \end{bmatrix} \begin{bmatrix} \cos EL_N & 0 & \sin EL_N \\ 0 & 1 & 0 \\ -\sin EL_N & 0 & \cos EL_N \end{bmatrix} \begin{bmatrix} \cos R_N & -\sin R_N & 0 \\ \sin R_N & \cos R_N & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_{Reticle\ Plane} \\ Y_{Reticle\ Plane} \\ LOS \end{bmatrix}$$

N = Detent Position

$R_N = AZ_2 - AZ_N$

(Note: R_N is a correction for the apparent rotation of the star field about the optical axis when the AOT is moved to different detent positions.)

Lunar Surface Alignment

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{SM} = \begin{bmatrix} \cos AI & 0 & \sin AI \\ 0 & 1 & 0 \\ -\sin AI & 0 & \cos AI \end{bmatrix} \begin{bmatrix} \cos AM & -\sin AM & 0 \\ \sin AM & \cos AM & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos AO & -\sin AO \\ 0 & \sin AO & \cos AO \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos AZ_N & \sin AZ_N \\ 0 & -\sin AZ_N & \cos AZ_N \end{bmatrix} \begin{bmatrix} \cos EL_N & 0 & \sin EL_N \\ 0 & 1 & 0 \\ -\sin EL_N & 0 & \cos EL_N \end{bmatrix} \begin{bmatrix} \cos R_N & -\sin R_N & 0 \\ \sin R_N & \cos R_N & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos AS & -\sin AS & 0 \\ \sin AS & \cos AS & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos AT & 0 & \sin AT \\ 0 & 1 & 0 \\ -\sin AT & 0 & \cos AT \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ LOS \end{bmatrix}$$

where

AI, AM, and AO are the inner, middle, and outer gimbal angles as indicated by the LGC

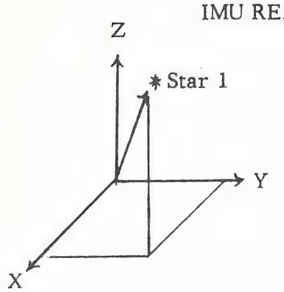
AZ_N and EL_N are the AOT azimuth and elevation angles at the Nth detent.

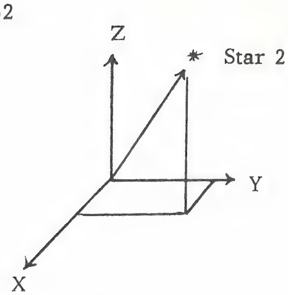
$EL_N \approx 45°$. N = 1, 2, ---, 6; $AZ_1 \approx -60°$; $AZ_2 \approx 0°$; $AZ_3 \approx 60°$; $AZ_4 \approx 120°$; $AZ_5 \approx 180°$; $AZ_6 \approx -120°$

AS = Y Reticle Angle

$$AT = \frac{360 + \text{S Reticle Angle} - \text{Y Reticle Angle}}{12}$$

IMU REALIGNMENT - P52





$$\underline{U}_{S1} = \begin{bmatrix} X_1 \\ Y_1 \\ Z_1 \end{bmatrix}_{ECI} \qquad \underline{U}_{S2} = \begin{bmatrix} X_2 \\ Y_2 \\ Z_2 \end{bmatrix}_{ECI}$$

$\underline{U}_{S1}$ and $\underline{U}_{S2}$ are known unit vectors in ECI space of the stars and are stored in the AGC.

$$\underline{U}_{S1M} = \begin{bmatrix} X_{1M} \\ Y_{1M} \\ Z_{1M} \end{bmatrix}_{SM} \qquad \underline{U}_{S2M} = \begin{bmatrix} X_{2M} \\ Y_{2M} \\ Z_{2M} \end{bmatrix}_{SM}$$

$\underline{U}_{S1M}$ and $\underline{U}_{S2M}$ are the measured unit vectors (optics mark) in stable member (SM) space of the stars.

$$[S_A] = \begin{bmatrix} \underline{U}_{S1} \\ (\underline{U}_{S1} \times \underline{U}_{S2}) \times \underline{U}_{S1} \\ \underline{U}_{S1} \times \underline{U}_{S2} \end{bmatrix} [ECI] \qquad [S_B] = \begin{bmatrix} \underline{U}_{S1M} \\ (\underline{U}_{S1M} \times \underline{U}_{S2M}) \times \underline{U}_{S1M} \\ \underline{U}_{S1M} \times \underline{U}_{S2M} \end{bmatrix} [SM]$$

$$[S_A] = [A]\,[ECI] \qquad [S_B] = [B]\,[SM]$$

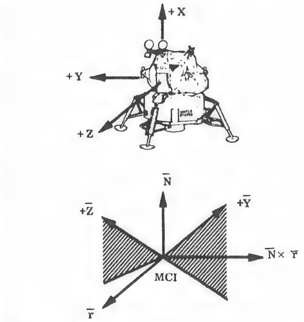
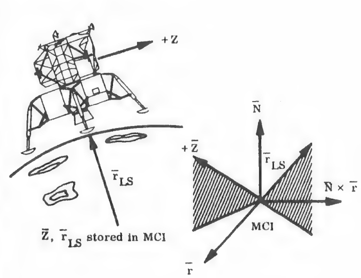
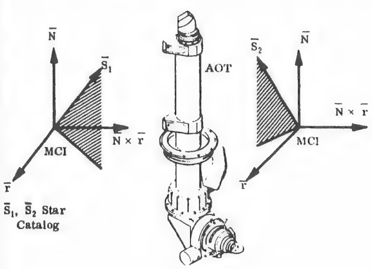
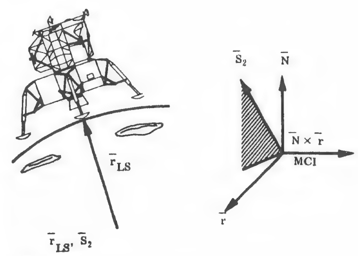
$$[S_A] = [S_B]$$

$$[A]\,[ECI] = [B]\,[SM]$$

$$[SM] = [B]^{-1}\,[A]\,[ECI]$$

$$[REFSMMAT] = [B]^{-1}\,[A]$$

LUNAR SURFACE ALIGNMENT - P57

OPTION	LOS DIRECTION IN BASIC REF. COORD.	CALCULATE REFSMMAT
0	 LM + $\bar{Y}$ and $+\bar{Z}$ stored from previous alignment (P57, P68)	$\bar{S}_A =$ (specified) $\begin{bmatrix} \bar{Y} \\ (\bar{Y}\times\bar{Z})\times\bar{Y} \\ \bar{Y}\times\bar{Z} \end{bmatrix} \bar{1}_{MCI} \triangleq [A]\ \bar{1}_{MCI}$ $\bar{S}_B =$ (measured) $\begin{bmatrix} \bar{Y}_M \\ (\bar{Y}_M\times\bar{Z}_M)\times\bar{Y}_M \\ \bar{Y}_M\times\bar{Z}_M \end{bmatrix} \bar{1}_{SMCS} \triangleq [B]\ \bar{1}_{SMCS}$ $\bar{S}_A = [A]\ \bar{1}_{MCI} = \bar{S}_B = [B]\ \bar{1}_{SMCS}$ $\bar{1}_{SMCS} = [REFSMMAT]\ \bar{1}_{MCI} = [B]^{-1}\ [A]\ \bar{1}_{MCI}$
1		$\bar{S}_A =$ (specified) $\begin{bmatrix} \bar{r}_{LS} \\ (\bar{r}_{LS}\times\bar{Z})\times\bar{r}_{LS} \\ \bar{r}_{LS}\times\bar{Z} \end{bmatrix} \bar{1}_{MCI} \triangleq [A]\ \bar{1}_{MCI}$ $\bar{S}_B =$ (measured) $\begin{bmatrix} \bar{g}_{LS} \\ (\bar{g}_{LS}\times\bar{Z}_M)\times\bar{g}_{LS} \\ \bar{g}_{LS}\times\bar{Z}_M \end{bmatrix} \bar{1}_{SMCS} \triangleq [B]\ \bar{1}_{SMCS}$ $\bar{1}_{SMCS} = [REFSMMAT]\ \bar{1}_{MCI} = [B]^{-1}\ [A]\ \bar{1}_{MCI}$
2		$\bar{S}_A =$ (specified) $\begin{bmatrix} \bar{S}_1 \\ (\bar{S}_1\times\bar{S}_2)\times\bar{S}_1 \\ \bar{S}_1\times\bar{S}_2 \end{bmatrix} \bar{1}_{MCI} = [A]\ \bar{1}_{MCI}$ $\bar{S}_B =$ (measured) $\begin{bmatrix} \bar{S}_{1M} \\ (\bar{S}_{1M}\times\bar{S}_{2M})\times\bar{S}_{1M} \\ \bar{S}_{1M}\times\bar{S}_{2M} \end{bmatrix} \bar{1}_{SMCS} = [B]\ \bar{1}_{SMCS}$ $\bar{1}_{SMCS} = [REFSMMAT]\ \bar{1}_{MCI} = [B]^{-1}\ [A]\ \bar{1}_{MCI}$
3		$\bar{S}_A =$ (specified) $\begin{bmatrix} \bar{r}_{LS} \\ (\bar{r}_{LS}\times\bar{S}_2)\times\bar{r}_{LS} \\ \bar{r}_{LS}\times\bar{S}_2 \end{bmatrix} \bar{1}_{MCI} = [A]\ \bar{1}_{MCI}$ $\bar{S}_B =$ (measured) $\begin{bmatrix} \bar{g}_{LS} \\ (\bar{g}_{LS}\times\bar{S}_{2M})\times\bar{g}_{LS} \\ \bar{g}_{LS}\times\bar{S}_{2M} \end{bmatrix} \bar{1}_{SMCS} = [B]\ \bar{1}_{SMCS}$ $\bar{1}_{SMCS} = [REFSMMAT]\ \bar{1}_{MCI} = [B]^{-1}\ [A]\ \bar{1}_{MCI}$

MCI = Moon Centered Inertial; SMCS = Stable Member Coordinate System

CISLUNAR NAVIGATION STAR/LANDMARK MEASUREMENT PROCESSING

The guidance computer utilizes a modified Kalman filter to incorporate the star/landmark measurement into estimates of the Spacecraft state vector. The state vector in this case is the deviation of the Spacecraft position and velocity from a reference conic.

$$\text{State Vector} = \underline{x}(t) = \begin{bmatrix} \underline{\delta r} \\ \underline{\delta v} \end{bmatrix} = \begin{bmatrix} \delta r_x \\ \delta r_y \\ \delta r_z \\ \delta v_x \\ \delta v_y \\ \delta v_z \end{bmatrix} = \begin{bmatrix} \text{Deviations from conic position} \\ \text{Deviations from conic velocity} \end{bmatrix}$$

Deviations from the reference conic are assumed to be Gaussian distributed with a known mean and variance. The mean is estimated via the precision integration routines or obtained from MSFN. The variance is given by the error covariance matrix, which is precomputed and entered via erasable data load.

The basic recursive procedure of Kalman Filtering is as follows.

STAR/LANDMARK MEASUREMENT PROCESSING (CONTINUED)

1. Extrapolate the state vector ahead to time t_n, using the best estimate of the state at time t_{n-1}.

$$\hat{\underline{X}}'_n = [\phi_{n-1}]\hat{\underline{X}}_{n-1}$$

2. Extrapolate the error covariance matrix in a similar manner.

$$[E'_n] = [\phi_{n-1}]\,[E_{n-1}]\,[\phi_{n-1}]^T + [U_{n-1}] \quad (U_{n-1} = \text{process noise})$$

3. Compute the optimal gain matrix.

$$[K^*_n] = [E'_n]\,[H_n]^T\,[H_n\,E'_n\,H_n{}^T + V_n]^{-1} \quad (V_n = \text{measurement noise})$$

4. Calculate a measurement vector for time t_n.

$$\hat{\underline{Y}}'_n = [H_n]\,\hat{\underline{X}}'_n$$

5. Update the estimate of the state vector, using the extrapolated state $\hat{\underline{X}}'_n$, the optimal gain $[K^*_n]$, the extrapolated measurement $\hat{\underline{Y}}'_n$, and the actual measurement at time t_n, $\underline{Y}_n$.

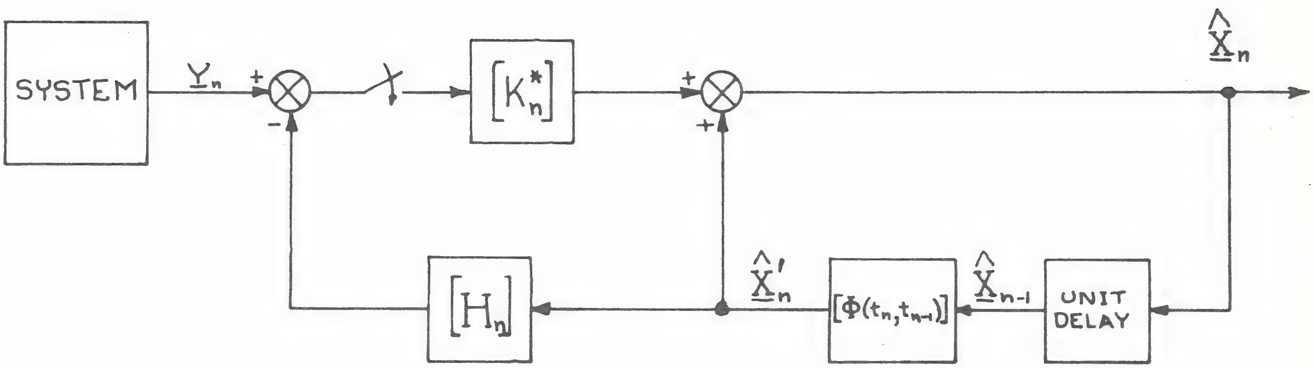
$$\hat{\underline{X}}_n = \hat{\underline{X}}'_n + [K^*_n]\,(\underline{Y}_n - \hat{\underline{Y}}'_n)$$

6. Update the error covariance matrix in a similar manner.

$$[E_n] = [E'_n] - [K^*_n]\,[H_n]\,[E'_n]$$

The following diagram illustrates this procedure.

BASIC RECURSIVE PROCEDURE OF KALMAN FILTERING



EXTRAPOLATE THE STATE VECTOR AND ERROR COVARIANCE MATRIX.

$$\hat{\underline{X}}'_n = [\Phi(t_n, t_{n-1})]\, \hat{\underline{X}}_{n-1}$$

$$[E'_n] = [\Phi(t_n, t_{n-1})][E_{n-1}][\Phi(t_n, t_{n-1})]^T + [U_{n-1}]$$

UPDATE THE STATE VECTOR AND ERROR COVARIANCE MATRIX.

$$\hat{\underline{X}}_n = \hat{\underline{X}}'_n + [K_n^*](\underline{Y}_n - [H_n]\hat{\underline{X}}'_n)$$

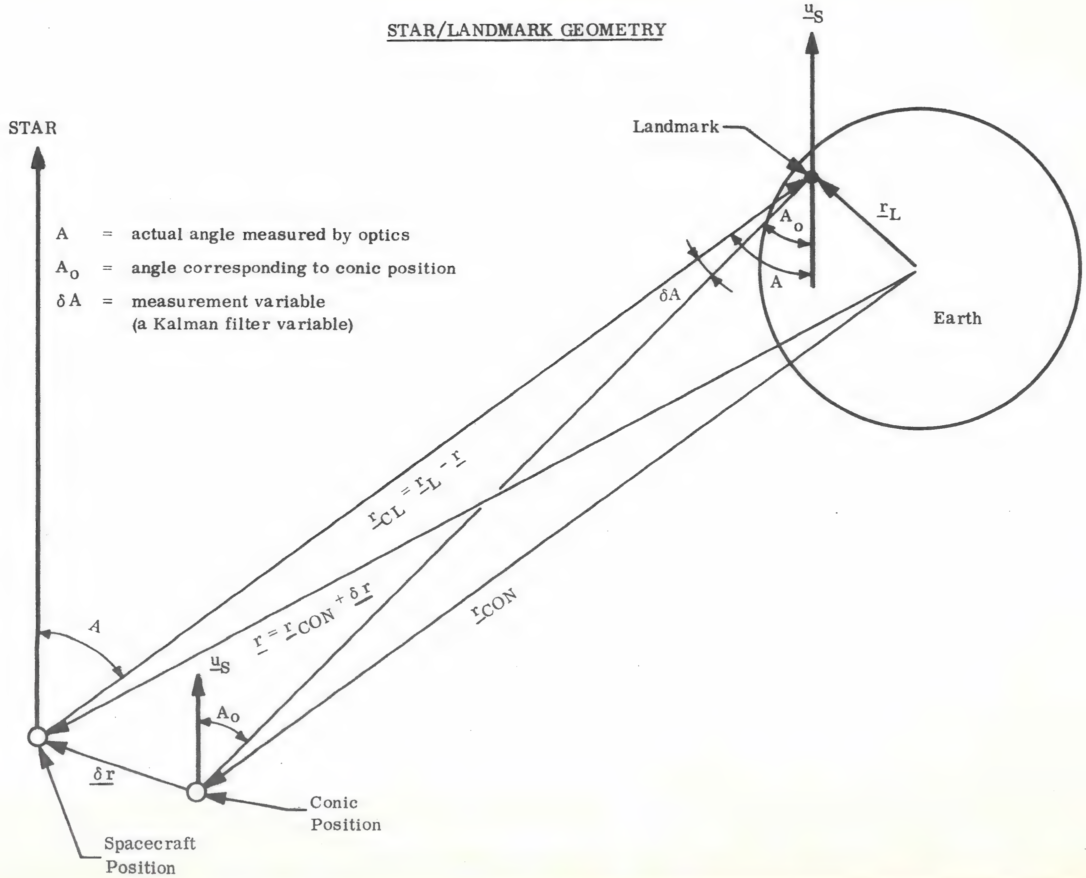
$$[E_n] = [E'_n] - [K_n^*][H_n][E'_n]$$

CORRELATION BETWEEN KALMAN FILTER TERMINOLOGY AND CELESTIAL NAVIGATION TERMINOLOGY

THIS TABLE AND THE FOLLOWING FIGURE SHOW THE DIFFERENCE BETWEEN CLASSIC KALMAN FILTERING TERMINOLOGY AND THE ACTUAL APOLLO NAVIGATION PROCEDURE.

Celestial Navigation Terminology	Kalman Filter Terminology	Correlation
$\underline{b}$ = geometry vector of dimension "D"	$[H]$ = measurement matrix	$\underline{b}^T \Rightarrow [H]$
$\underline{\omega}$ = weighting vector of dimension "D"	$[K_n^*]$ = optimal gain matrix	$\underline{\omega} \Rightarrow [K_n^*]$
$[W]$ = error transition matrix of dimension "D x D"	$[E]$ = error covariance matrix	$[E] \Rightarrow [WW^T]$
$\underline{x}$ = state vector	$\underline{x}$ = state vector	$\underline{x} \Rightarrow \underline{x}$
$\bar{\alpha}^2$ = a priori measurement error variance (scalar)	$[V]$ = covariance of the measurement noise	$\bar{\alpha}^2 \Rightarrow [V]$
δQ = measurement deviation (scalar)	$(\hat{\underline{Y}}'_n - \underline{Y}_n)$ = measurement residual	$\delta Q \Rightarrow (\hat{\underline{Y}}'_n - \underline{Y}_n)$

STAR/LANDMARK GEOMETRY



STAR/LANDMARK GEOMETRY (cont)

The relationship between the state vector and measurement variable can be determined by redrawing part of the preceding figure.

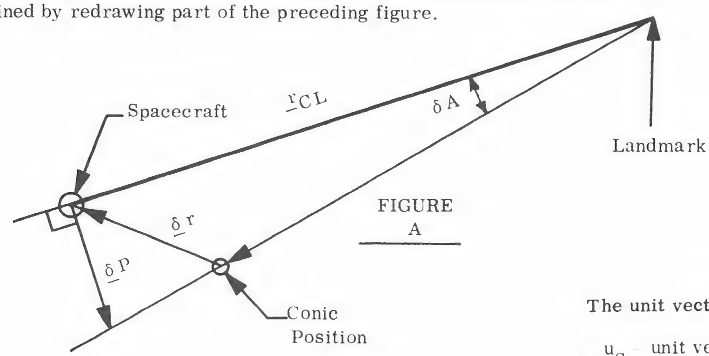
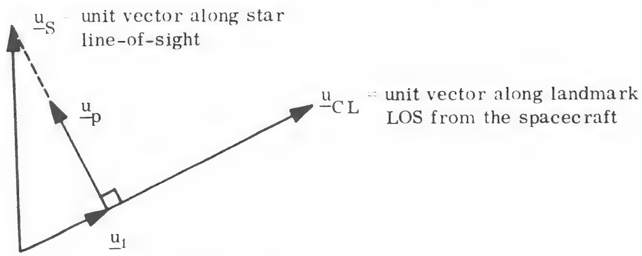


FIGURE A

$$\delta A = \frac{|\delta \underline{P}|}{|\underline{r}_{CL}|} = \frac{\underline{u}_p^T \, \delta \underline{r}}{|\underline{r}_{CL}|} = \frac{\underline{u}_p^T}{|\underline{r}_{CL}|} \quad \delta \underline{r} = \underline{b}^T \, \delta \underline{x}$$

where $\underline{u}_p$ is a unit vector prependicular to $\underline{r}_{CL}$

The unit vector, $\underline{u}_p$, can be determined from Figure A



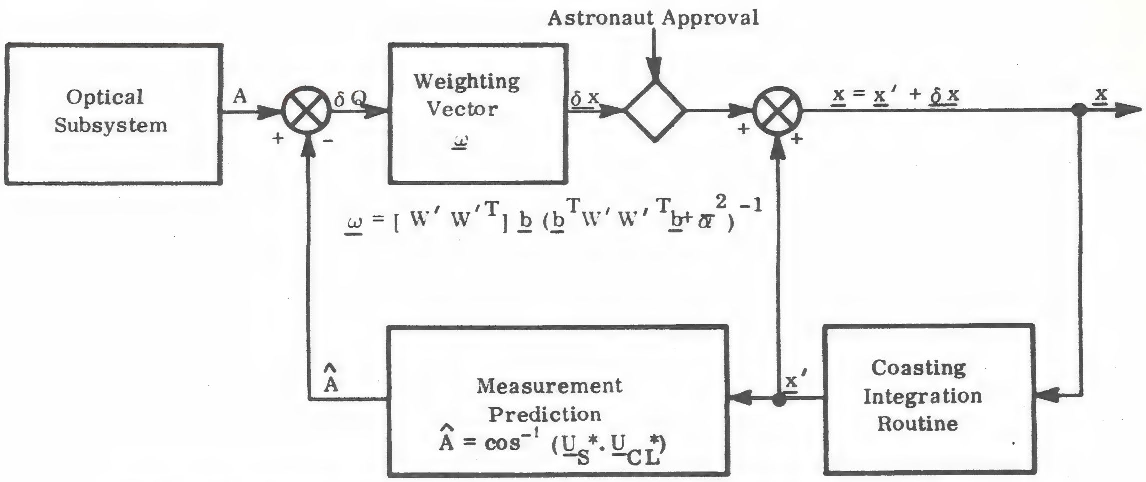
$\underline{u}_p$ = Unit $(\underline{u}_S - \underline{u}_1)$

$\underline{u}_1$ = Component of $\underline{u}_S$ along $\underline{u}_{CL} = (\underline{u}_S \cdot \underline{u}_{CL}) \, \underline{u}_{CL}$

$\underline{u}_p$ = Unit $(\underline{u}_S - (\underline{u}_S \cdot \underline{u}_{CL}) \, \underline{u}_{CL})$

$$\therefore \quad \underline{b} = \frac{1}{|\underline{r}_{CL}|} \begin{bmatrix} \text{Unit } (\underline{u}_S - (\underline{u}_S \cdot \underline{u}_{CL}) \, \underline{u}_{CL} \\ \underline{0} \end{bmatrix}$$

CISLUNAR NAVIGATION (P23) – INFORMATION PROCESSING



EXTRAPOLATE THE STATE VECTOR AND ERROR TRANSITION MATRIX:

Extrapolation is accomplished via the Coasting Integration routine.

UPDATE THE STATE VECTOR AND ERROR TRANSITION MATRIX:

$$\underline{x} = \underline{x}' + \underline{\delta x} = \underline{x}' + \underline{\omega}\ \delta Q$$

$$[W] = [W'] - \frac{\underline{\omega} \underline{Z}^T}{1 + \sqrt{\frac{\bar{\alpha}^2}{Z^2 + \bar{\alpha}^2}}}$$

ORBITAL NAVIGATION — STATE VECTOR DEFINITION

FOR LANDMARK TRACKING THE STATE VECTOR IS DEFINED AS FOLLOWS.

$$\underline{X} = \begin{bmatrix} \underline{r}_c \\ \underline{v}_c \\ \underline{r}_L \end{bmatrix} = \begin{bmatrix} \text{POSITION OF SPACECRAFT} \\ \text{VELOCITY OF SPACECRAFT} \\ \text{INERTIAL POSITION OF LANDMARK} \end{bmatrix}$$

WHERE:

$\underline{r}_c$ = SPACECRAFT POSITION VECTOR

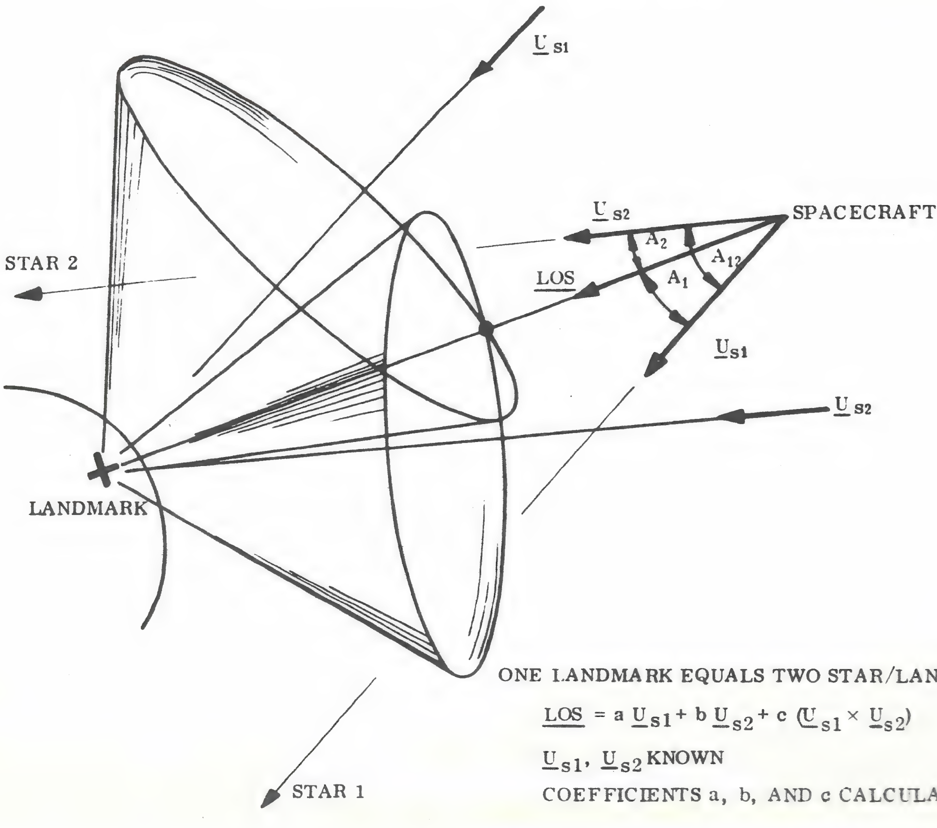
$= \underline{r}_{con} + \underline{\delta r}$

$\underline{v}_c$ = SPACECRAFT VELOCITY VECTOR

$= \underline{v}_{con} + \underline{\delta v}$

$\underline{r}_L$ = LANDMARK POSITION VECTOR

ORBITAL NAVIGATION — LANDMARK TRACK



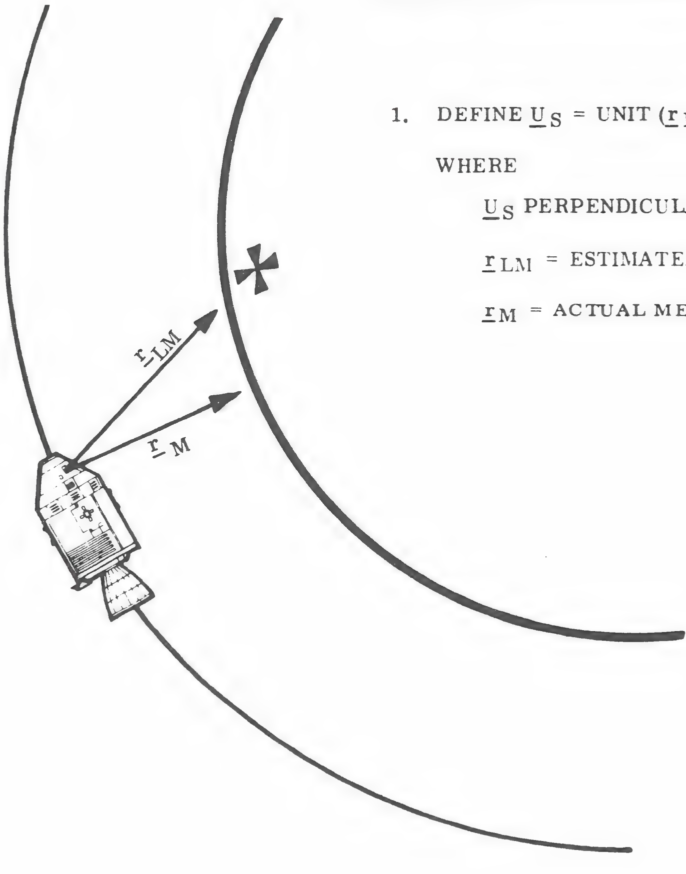
ONE LANDMARK EQUALS TWO STAR/LANDMARK SIGHTINGS.

$\underline{LOS} = a\,\underline{U}_{s1} + b\,\underline{U}_{s2} + c\,(\underline{U}_{s1} \times \underline{U}_{s2})$

$\underline{U}_{s1}$, $\underline{U}_{s2}$ KNOWN

COEFFICIENTS a, b, AND c CALCULATED

ORBITAL NAVIGATION — LANDMARK TRACK



1. DEFINE $\underline{U}_S$ = UNIT ($\underline{r}_{LM} \times \underline{r}_M$)

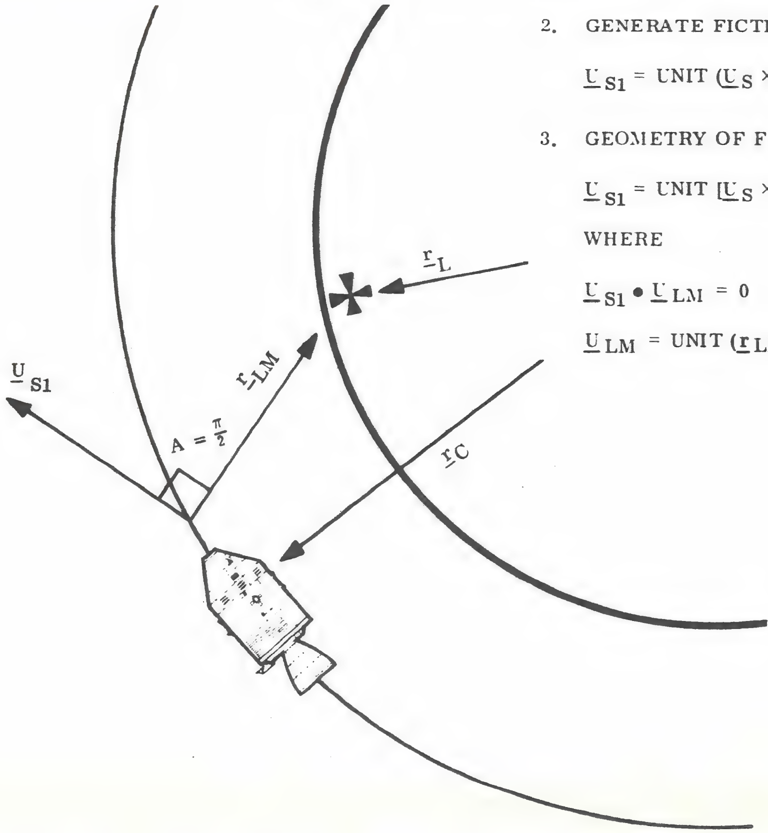
   WHERE

   $\underline{U}_S$ PERPENDICULAR TO MEASUREMENT PLANE

   $\underline{r}_{LM}$ = ESTIMATED LOS FROM SPACECRAFT TO LANDMARK

   $\underline{r}_M$ = ACTUAL MEASURED LOS FROM SPACECRAFT TO LANDMARK

ORBITAL NAVIGATION — LANDMARK TRACK (CONTINUED)



2. GENERATE FICTITIOUS STAR

$\underline{U}_{S1} = \text{UNIT}\ (\underline{U}_S \times \underline{r}_{LM})$ $\left\{ \begin{array}{l} \underline{U}_{S1} \text{ PERPENDICULAR TO } \underline{r}_{LM} \\ \underline{U}_{S1} \text{ IN MEASUREMENT PLANE} \end{array} \right.$

3. GEOMETRY OF FICTITIOUS STAR AND STATE VECTOR

$\underline{U}_{S1} = \text{UNIT}\ [\underline{U}_S \times (\underline{r}_L - \underline{r}_C)]$

WHERE

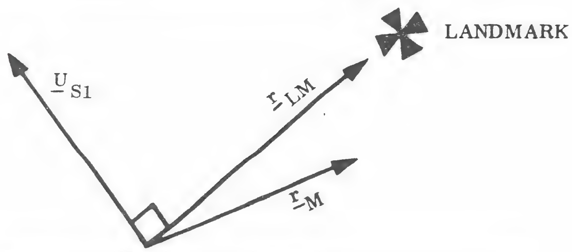
$\underline{U}_{S1} \bullet \underline{U}_{LM} = 0$

$\underline{U}_{LM} = \text{UNIT}\ (\underline{r}_{LM})$

4. IN TERMS OF STATE VECTOR

$$\underline{U}_{S1} \bullet \underline{U}_{LM} = 0 = \frac{1}{|r_{LM}|} \begin{bmatrix} -\underline{U}_{S1} \\ 0 \\ +\underline{U}_{S1} \end{bmatrix} \bullet \begin{bmatrix} \underline{r}_C \\ \underline{V}_C \\ \underline{r}_L \end{bmatrix}$$

5. CONSIDERING ACTUAL MEASUREMENT $\underline{r}_M$



6. MEASUREMENT RESIDUAL IN TERMS OF STATE VECTOR

$\underline{U}_{S1M}$ = UNIT $(\underline{U}_S \times \underline{r}_M)$

$$\delta Q = 0 - \frac{1}{|r_M|} \begin{bmatrix} -\underline{U}_{S1M} \\ 0 \\ \underline{U}_{S1M} \end{bmatrix} \bullet \begin{bmatrix} \underline{r}_C \\ \underline{V}_C \\ \underline{r}_L \end{bmatrix}$$ A SCALAR DEVIATION FROM ZERO.

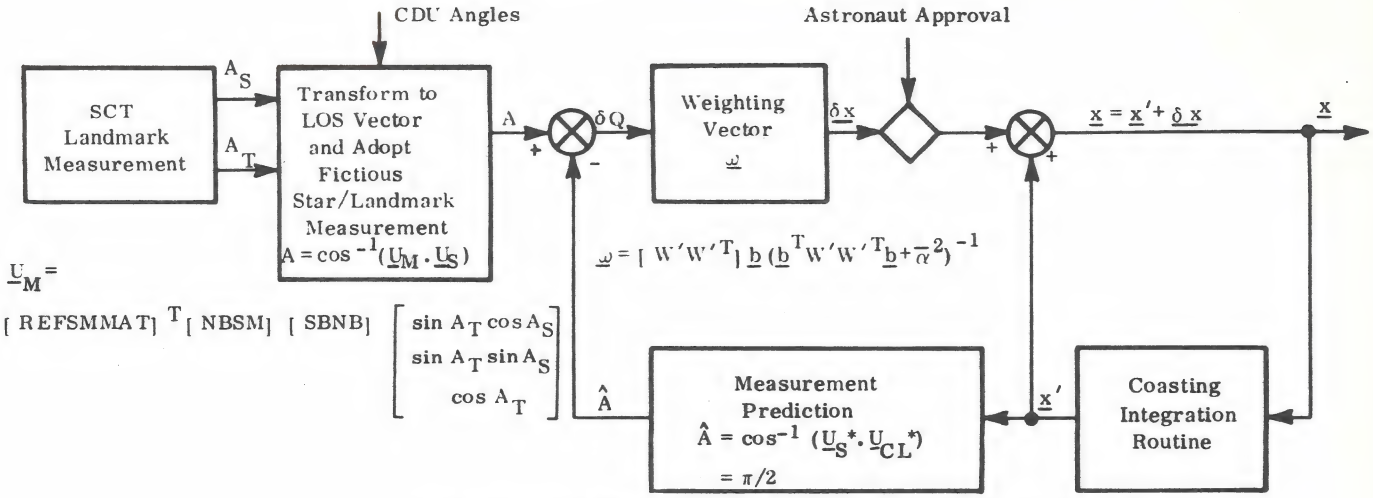
UPDATE STATE

$\underline{X} = \underline{X}' + \underline{\omega}\,\delta Q$

$\underline{X}'$ = EXTRAPOLATED ESTIMATE OF STATE

$\underline{\omega}$ = OPTIMAL WEIGHT FACTOR

ORBITAL NAVIGATION (P22) – INFORMATION PROCESSING



EXTRAPOLATE THE STATE VECTOR AND ERROR TRANSITION MATRIX.

Extrapolation is accomplished via the Coasting Integration routine.

UPDATE THE STATE VECTOR AND ERROR TRANSITION MATRIX.

$$\underline{x} = \underline{x}' + \underline{\delta x} = \underline{x}' + \underline{\omega}\, \delta Q$$

$$[W] = [W'] - \frac{\underline{\omega} \underline{z}^T}{1 + \sqrt{\dfrac{\overline{\alpha}^2}{Z^2 + \overline{\alpha}^2}}}$$

MEASUREMENT VARIANCE

OPTICAL TRACKING

$$\overline{\alpha}^2 = Var_{SXT} + Var_{IMU} + \frac{Var^*_{INT}}{r_{CL}^2}$$

$$= (0.2\,mr)^2 + (0.2\,mr)^2 + \frac{(14\,m)^2}{r_{CL}^2}$$

VHF RANGING

$$\overline{\alpha}^2 = Max \left\{ Var^*_R, \frac{Var^*_{R\,min}}{r_{CL}^2} \right\}$$

$$= Max \left\{ 0.0\%, \frac{-83.6127\,m^2}{r_{CL}^2} \right\}$$

ALTERNATE LOS

$$\overline{\alpha}^2 = Var^*_{ALT} + Var_{IMU}$$

$$= 12\,mr^2 + (0.2\,mr)^2$$

INITIAL "W" MATRIX

$$[W] = \left[\begin{array}{c|c} w_{rr}I & 0 \\ \hline 0 & w_{rv}I \end{array} \right]$$

$$w^*_{rr} = 3,048\,m = 10^4\,ft/s$$

$$w^*_{rv} = 3.048\,m/s = 10\,ft/s$$

*These values are stored in erasable memory.

MEASUREMENT VARIANCE

RANGE MEASUREMENT

$$\bar{\alpha}^2 = \text{Max}\left\{ \text{Var}_R^*, \frac{\text{Var}^*_{R\,min}}{r_{CL}^2} \right\} = \text{Max}\left\{ 0.111111 \times 10^{-4}, \frac{66\,m^2}{r_{CL}^2} \right\}$$

RANGE RATE MEASUREMENT

$$\bar{\alpha}^2 = \text{Max}\left\{ \dot{r}^2\,\text{Var}_V^*, \text{Var}^*_{V\,min} \right\} = \text{Max}\left\{ \dot{r}^2\, 1.8777 \times 10^{-6}, 0.017445\ m^2/s^2 \right\}$$

SHAFT ANGLE MEASUREMENT

$$\bar{\alpha}^2 = \text{Var}_\beta^* + \text{Var}_{IMU} = (1\,mr)^2 + (0.2\,mr)^2$$

TRUNNION ANGLE MEASUREMENT

$$\bar{\alpha}^2 = \text{Var}_\theta^* + \text{Var}_{IMU} = (1\,mr)^2 + (0.2\,mr)^2$$

INITIAL "W" MATRICES

FOR RENDEZVOUS

$$[W] = \left[\begin{array}{c|c|ccc} w_{rr}I & 0 & & 0 & \\ \hline 0 & w_{rv}I & & 0 & \\ \hline & & w_\beta & 0 & 0 \\ 0 & 0 & 0 & w_\theta & 0 \\ & & 0 & 0 & 0 \end{array}\right]$$

$w_{rr}^* = 3,048\ m = 10^4\ ft$

$w_{rv}^* = 3.048\ m/s = 10\ ft/s$

$w_\beta^* = 15\ mrad$

$w_\theta^* = 15\ mrad$

FOR LUNAR SURFACE NAVIGATION

$$[W] = \left[\begin{array}{c|c} w_{\ell r}I & 0 \\ \hline 0 & w_{\ell v}I \end{array}\right]$$

$w_{\ell r}^* = 1,524\ m = 5,000\ ft$

$w_{\ell v}^* = 1.524\ m/s = 5\ ft/s$

*These values are stored in erasable memory.

MEASUREMENT VARIANCE

$$\overline{\alpha}^2 = \text{Var}_{SCT} + \text{Var}_{IMU}$$
$$= (1\,\text{mr})^2 + (0.2\,\text{mr})^2$$

INITIAL "W" MATRIX

$$[W] = \begin{bmatrix} w_{\ell r} I & 0 & 0 \\ 0 & w_{\ell v} I & 0 \\ 0 & 0 & w_{\ell} I \end{bmatrix}$$

$w^*_{\ell r} = 0.0$

$w^*_{\ell v} = 0.0$

$w^*_{\ell} = 10{,}000$ meters

*These values are stored in erasable memory.

CISLUNAR MIDCOURSE NAVIGATION ROUTINE
P-23

MEASUREMENT VARIANCE

$$\overline{\alpha}^2 = \text{Var}_{Trun} + \text{Var}_{L}/r_{CL}^2$$
$$= (0.05\,\text{mr})^2 + \frac{1\ \text{nmi}^2}{r_{CL}^2}$$

INITIAL "W" MATRIX

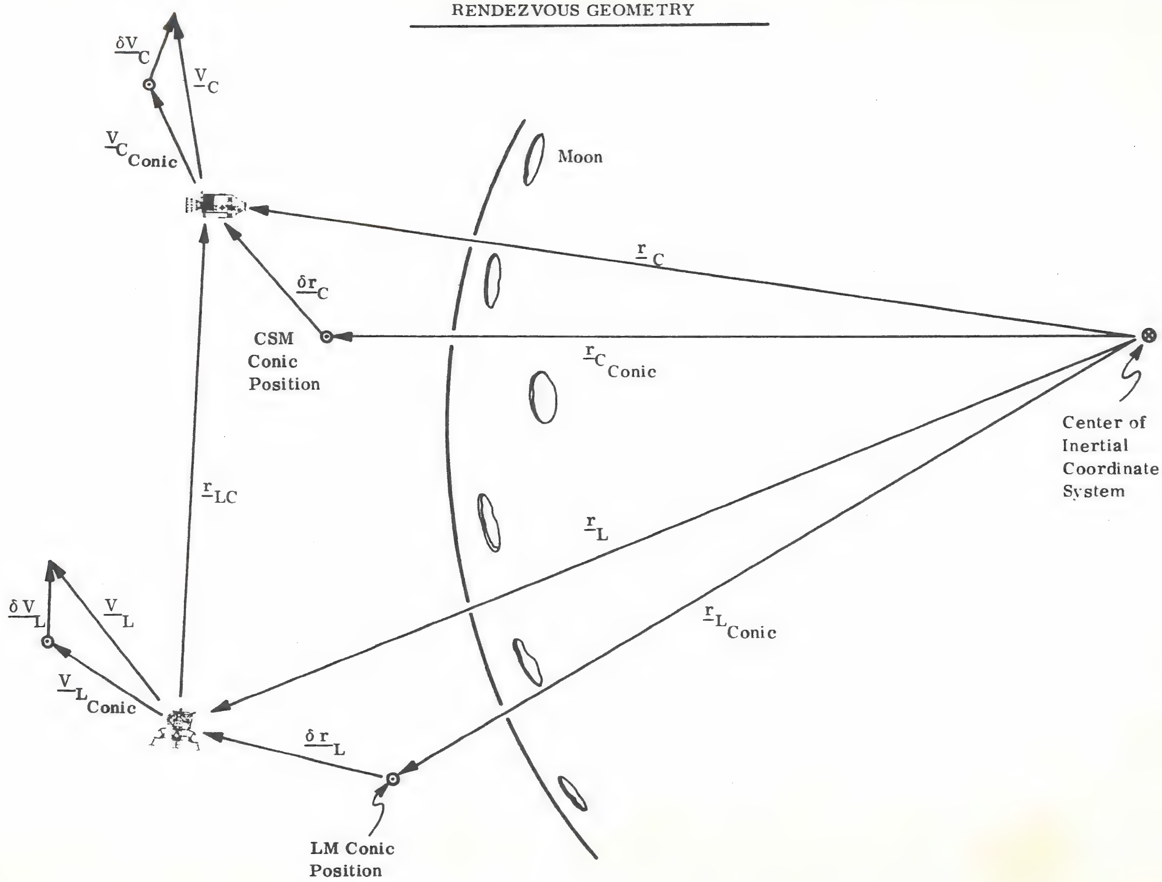
$$[W] = \begin{bmatrix} w_{mr} I & 0 \\ 0 & w_{mv} I \end{bmatrix}$$

$w^*_{mr} = 1{,}005.84\ \text{m} = 3{,}300$ ft

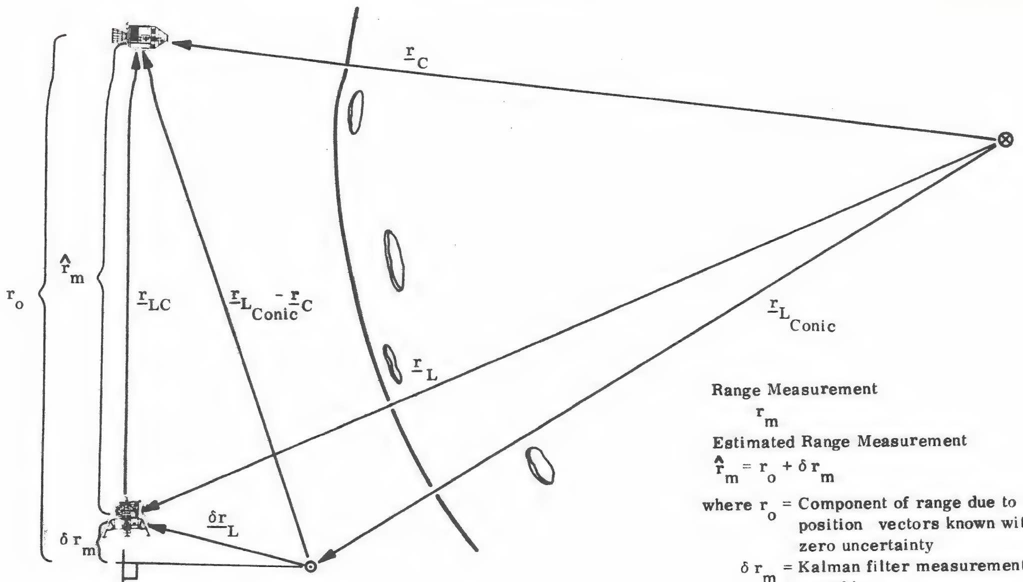
$w^*_{mv} = 1.00584\ \text{m/s} = 3.3$ ft/s

*These values are stored in erasable memory.

RENDEZVOUS GEOMETRY



RENDEZVOUS RANGE (r_m) MEASUREMENT



Range Measurement

r_m

Estimated Range Measurement

$\hat{r}_m = r_o + \delta r_m$

where r_o = Component of range due to position vectors known with zero uncertainty

δr_m = Kalman filter measurement variable

$= \underline{b}^T \underline{x}$

$$\hat{r}_m = \underline{u}_{LC} \cdot \underline{r}_{LC} = \underline{u}_{LC} \cdot (\underline{r}_C - \underline{r}_{L_{Conic}} - \delta\underline{r}_L)$$

$$= \underline{u}_{LC} \cdot (\underline{r}_C - \underline{r}_{L_{Conic}}) - \underline{u}_{LC} \cdot \delta\underline{r}_L$$

$$= r_o - \underline{u}_{LC} \cdot \delta\underline{r}_L$$

$$\delta r_m = -\underline{u}_{LC} \cdot \delta\underline{r}_L = \underline{b}^T \underline{x}$$

$$\underline{b} = \begin{bmatrix} -\underline{u}_{LC} \\ \underline{0} \\ \underline{0} \end{bmatrix} \quad \underline{x} = \begin{bmatrix} \delta\underline{r}_L \\ \delta\underline{V}_L \\ \delta\beta \\ \delta\theta \\ 0 \end{bmatrix}$$

RENDEZVOUS RANGE RATE (V_m) MEASUREMENT

Rendezvous range rate measurement has a term due to deviation from conic velocity ($\delta\underline{V}_L$) and a term due to deviation from conic position ($\delta\underline{r}_L$). The term due to velocity deviation ($\delta\underline{V}_L$) is:

$$\hat{V}_m = \underline{V}_{LC} \cdot \underline{u}_{LC}$$

$$= \underline{u}_{LC} \cdot (\underline{V}_C - \underline{V}_{L_{Conic}} - \delta\underline{V}_L) = \underline{u}_{LC} \cdot (\underline{V}_C - \underline{V}_{L_{Conic}}) - \underline{u}_{LC} \cdot \delta\underline{V}_L$$

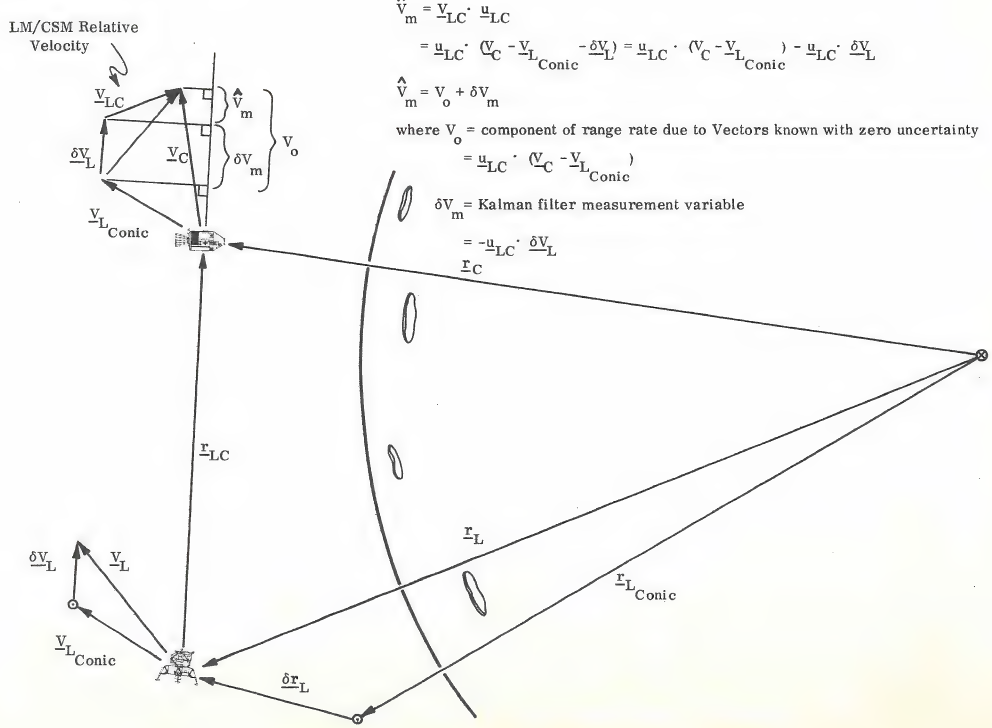
$$\hat{V}_m = V_o + \delta V_m$$

where V_o = component of range rate due to Vectors known with zero uncertainty

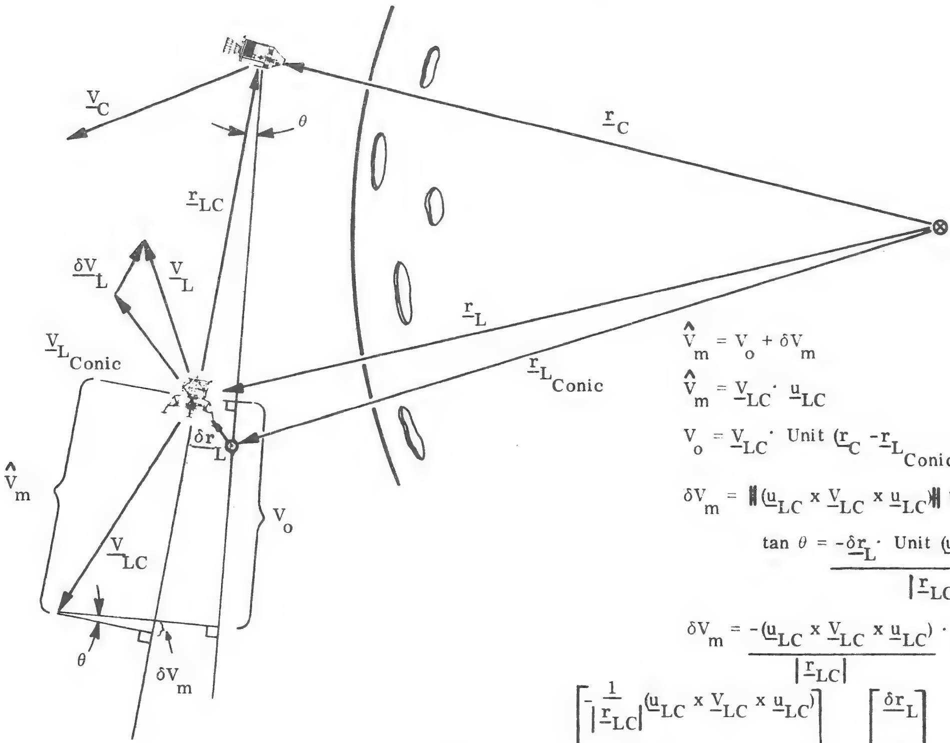
$$= \underline{u}_{LC} \cdot (\underline{V}_C - \underline{V}_{L_{Conic}})$$

δV_m = Kalman filter measurement variable

$$= -\underline{u}_{LC} \cdot \delta\underline{V}_L$$



RENDEZVOUS RANGE RATE (V_m) MEASUREMENT continued



$$\hat{V}_m = V_o + \delta V_m$$

$$\hat{V}_m = \underline{V}_{LC} \cdot \underline{u}_{LC}$$

$$V_o = \underline{V}_{LC} \cdot \text{ Unit } (\underline{r}_C - \underline{r}_{L_{Conic}})$$

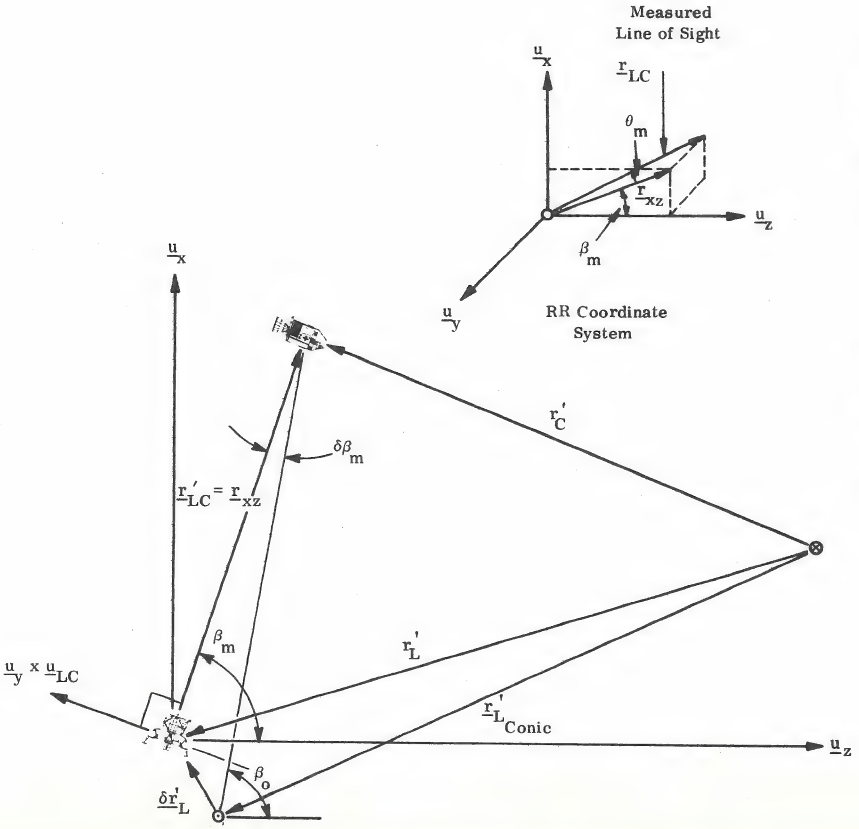
$$\delta V_m = \| (\underline{u}_{LC} \times \underline{V}_{LC} \times \underline{u}_{LC}) \| \tan \theta$$

$$\tan \theta = \frac{-\delta \underline{r}_L \cdot \text{ Unit } (\underline{u}_{LC} \times \underline{V}_{LC} \times \underline{u}_{LC})}{|\underline{r}_{LC}|}$$

$$\delta V_m = \frac{-(\underline{u}_{LC} \times \underline{V}_{LC} \times \underline{u}_{LC}) \cdot \delta \underline{r}_L}{|\underline{r}_{LC}|}$$

$$\delta V_m = \underline{b}^T \underline{x} = \begin{bmatrix} -\frac{1}{|\underline{r}_{LC}|} (\underline{u}_{LC} \times \underline{V}_{LC} \times \underline{u}_{LC}) \\ -\underline{u}_{LC} \\ \underline{0} \end{bmatrix} \cdot \begin{bmatrix} \delta \underline{r}_L \\ \delta \underline{V}_L \\ \delta \beta \\ \delta \theta \\ 0 \end{bmatrix}$$

RENDEZVOUS RADAR SHAFT ANGLE (β_m) MEASUREMENTS



The Rendezvous Radar shaft angle is defined in the radar X-Z coordinate plane. The effect of LM and CSM position vectors on the shaft angle can be determined by looking at the projection of these vectors on the x-z plane:

$$\beta_m = \beta_o + \delta\beta_m$$

where β_m = estimate of RR shaft angle due to $\underline{r}_{LC}$

β_o = portion of RR shaft angle due to $\underline{r}_C$ and $\underline{r}_{L_{Conic}}$

$$\delta\beta_m = \frac{1}{\underline{r}_{xz}} \left[\text{Unit} \left(\underline{u}_y \times \underline{u}_{LC}\right) \cdot \underline{\delta r}_L \right]$$

The actual measured shaft angle has two components a nominal one due to spacecraft position and an additional deviation term ($\delta\beta$) which is an element of the state vector.

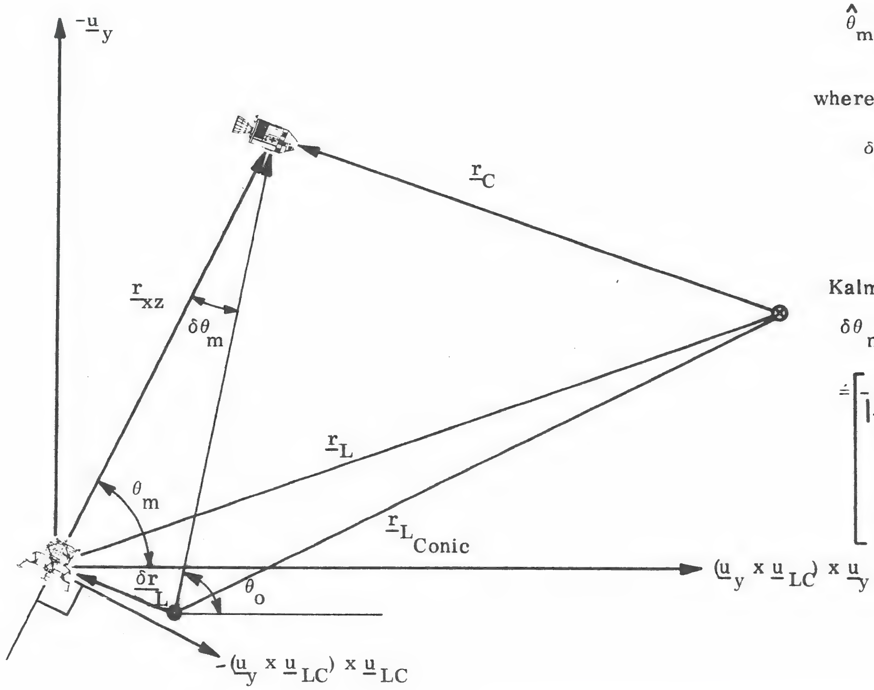
$$\hat{\beta}_m = \beta_m + \delta\beta = \beta_o + \delta\beta_m + \delta\beta$$

The Kalman filter measurement variable. $= \delta\beta_m + \delta\beta_o = \underline{b}^T \ \underline{x}$

$$= \begin{bmatrix} \frac{1}{\underline{r}_{xz}} \left[\text{Unit} \left(\underline{u}_y \times \underline{u}_{LC}\right) \right. \\ 0 \\ 1 \\ 0 \\ 0 \end{bmatrix} \cdot \begin{bmatrix} \underline{\delta r}_L \\ \underline{\delta V}_L \\ \delta\beta \\ \delta\theta \\ 0 \end{bmatrix}$$

RENDEZVOUS RADAR TRUNNION ANGLE (θ) MEASUREMENTS

The rendezvous radar trunnion angle is defined in the $\underline{u}_{LC}$, $\underline{u}_y$ plane and can be illustrated by projecting the spacecraft position vectors onto this plane. Like the shaft angle it is divided into two components, a nominal one due to spacecraft positions and a deviation term ($\delta\theta$) which is an element of the state vector.



$$\hat{\theta}_m = \theta_m + \delta\theta$$

$$= \theta_o + \delta\theta_m + \delta\theta$$

where θ_o = component of θ_m due to $\underline{r}_C - \underline{r}_{L_{Conic}}$

$\delta\theta_m$ = component of θ_m due to $\delta\underline{r}_L$

$$= \delta\underline{r}_L \cdot \frac{-1}{|\underline{r}_{xz}|} \text{Unit } [(\underline{u}_y \times \underline{u}_{LC}) \times \underline{u}_{LC}] \cdot$$

Kalman filter measurement variable =

$$\delta\theta_m + \delta\theta = \underline{b}^T \underline{x}$$

$$\doteq \begin{bmatrix} -\frac{1}{|\underline{r}_{xz}|} \text{ Unit } [(\underline{u}_y \times \underline{u}_{LC}) \times \underline{u}_{LC}] \\ \underline{0} \\ 0 \\ 1 \\ 0 \end{bmatrix} \cdot \begin{bmatrix} \delta\underline{r}_L \\ \delta\underline{V}_L \\ \delta\beta \\ \delta\theta \\ 0 \end{bmatrix}$$

CSM DAP CONTROL

Flashing V04 N46

Register 1:

A	B	C	D	E
CONFIG	XTAC	XTBD	DB	RATE

CONFIG - Vehicle Configuration

0 = No DAP is requested
1 = CSM alone
2 = CSM and LM
3 = SIVB, CSM and LM (SIVB control)
6 = CSM and LM (ascent stage only)

XTAC - X-Translations Using Quads AC

0 = Do not use AC
1 = Use AC

XTBD - X-Translations Using Quads BD

0 = Do not use BD
1 = Use BD

DB - Angular Deadband for Attitude Hold and Automatic Maneuvers

0 = ± 0.5 degree
1 = ± 5.0 degrees

RATE - Rotational Rate for RHC in HOLD or AUTO Mode and for Automatic Maneuvers.

0 = 0.05 deg/s
1 = 0.2 deg/s
2 = 0.5 deg/s
3 = 4.0 deg/s

Register 2:

AC Roll	Quad A	Quad B	Quad C	Quad D

AC Roll - Roll-Jet selection

0 = Use BD roll Quads
1 = Use AC roll Quads

A, B, C, D - Quad fails

0 = Quad has failed
1 = Quad operational

Flashing V06 N47

Register 1: CSM weight in pounds

Register 2: LM weight in pounds

Flashing V06 N48

Register 1: Pitch-trim gimbal offset, in 1/100 degree

Register 2: Yaw-trim gimbal offset, in 1/100 degree

AUTOMATIC MODE

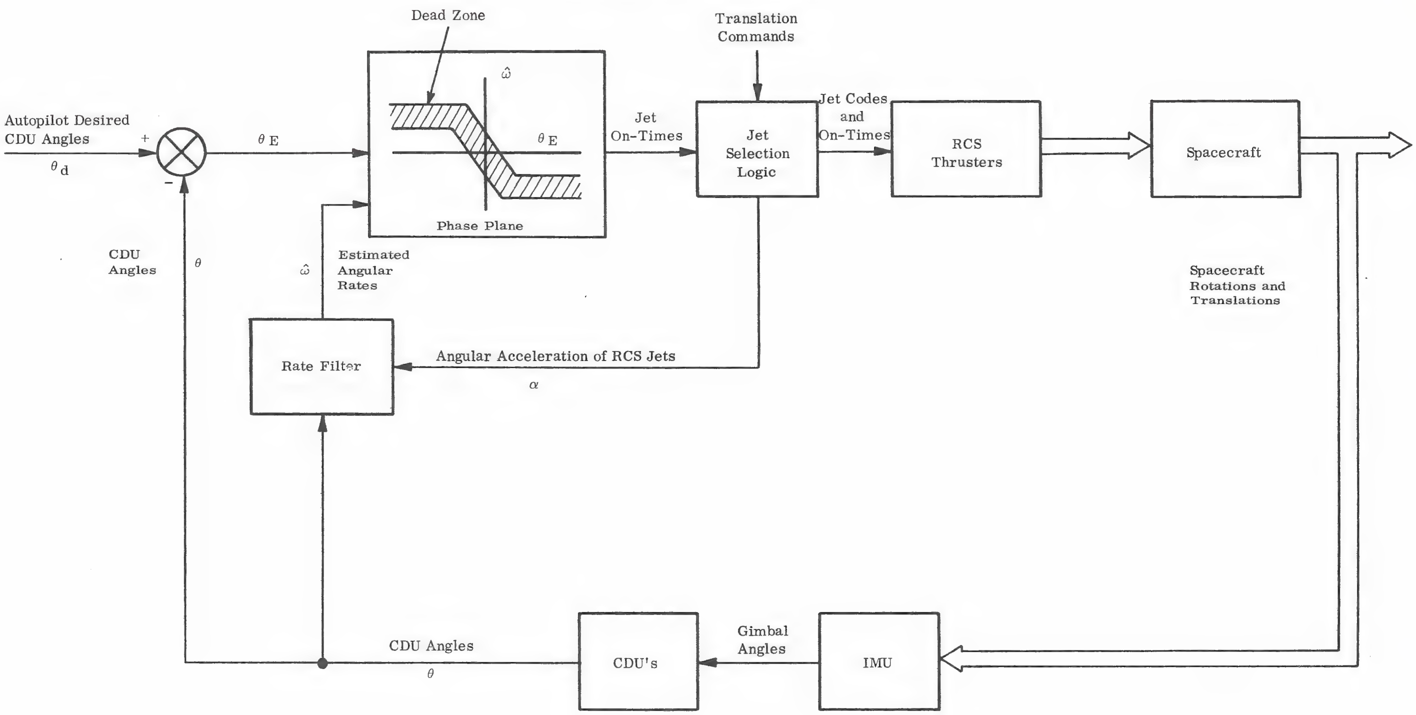
1. Automatic three-axis rotation.
2. Manual three-axis rotation and translation
3. Attitude hold to program or manual defined attitude.
4. Automatic rate damping.

ATTITUDE HOLD MODE

1. Manual three-axis rotation and translation.
2. RHC produces a rotational rate as specified by N46 while out of detent.
3. Attitude hold to attitude selected via hand controller.
4. Automatic rate damping.

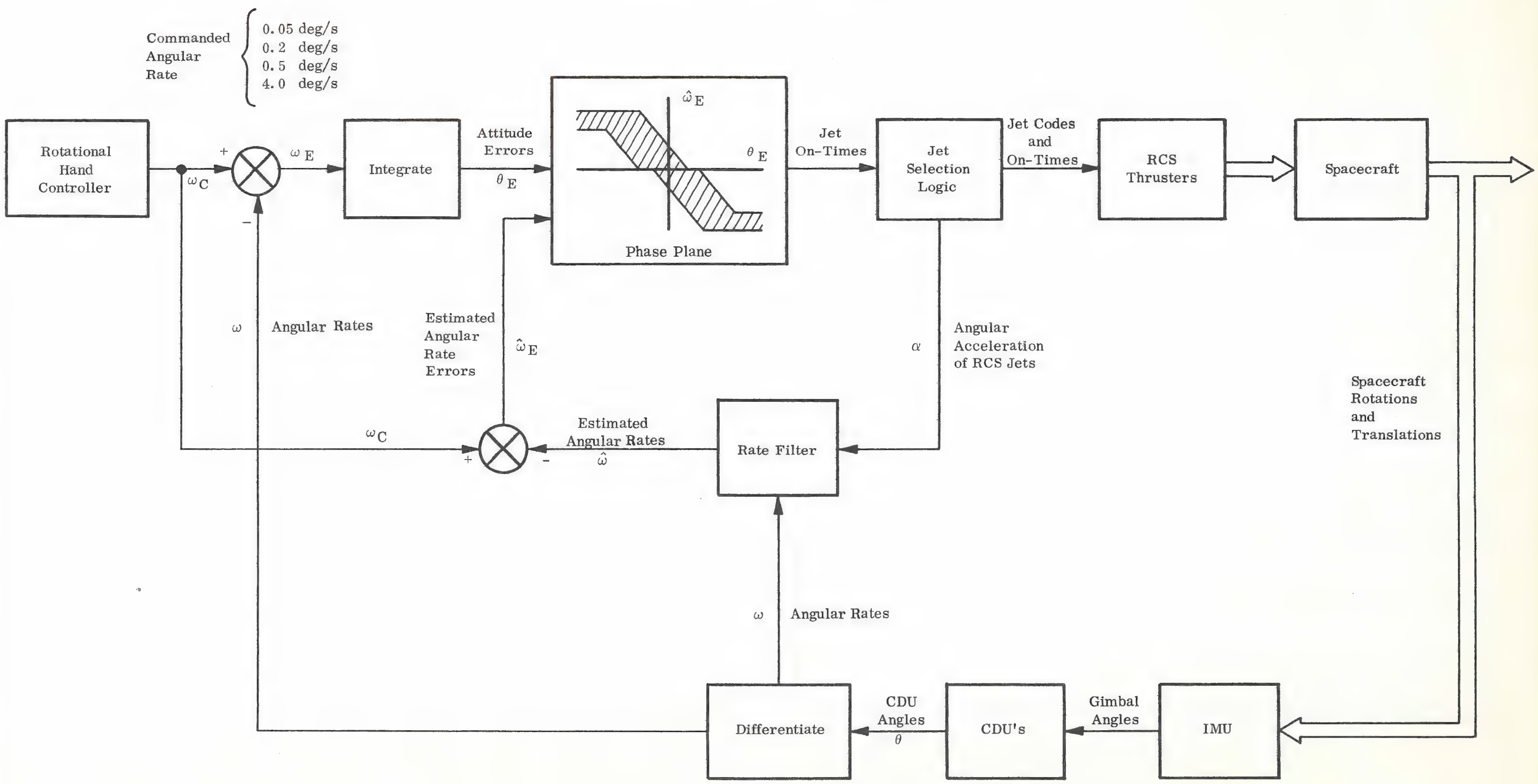
CSM DIGITAL AUTOPILOT
COASTING FLIGHT

AUTOMATIC ATTITUDE HOLD MODE



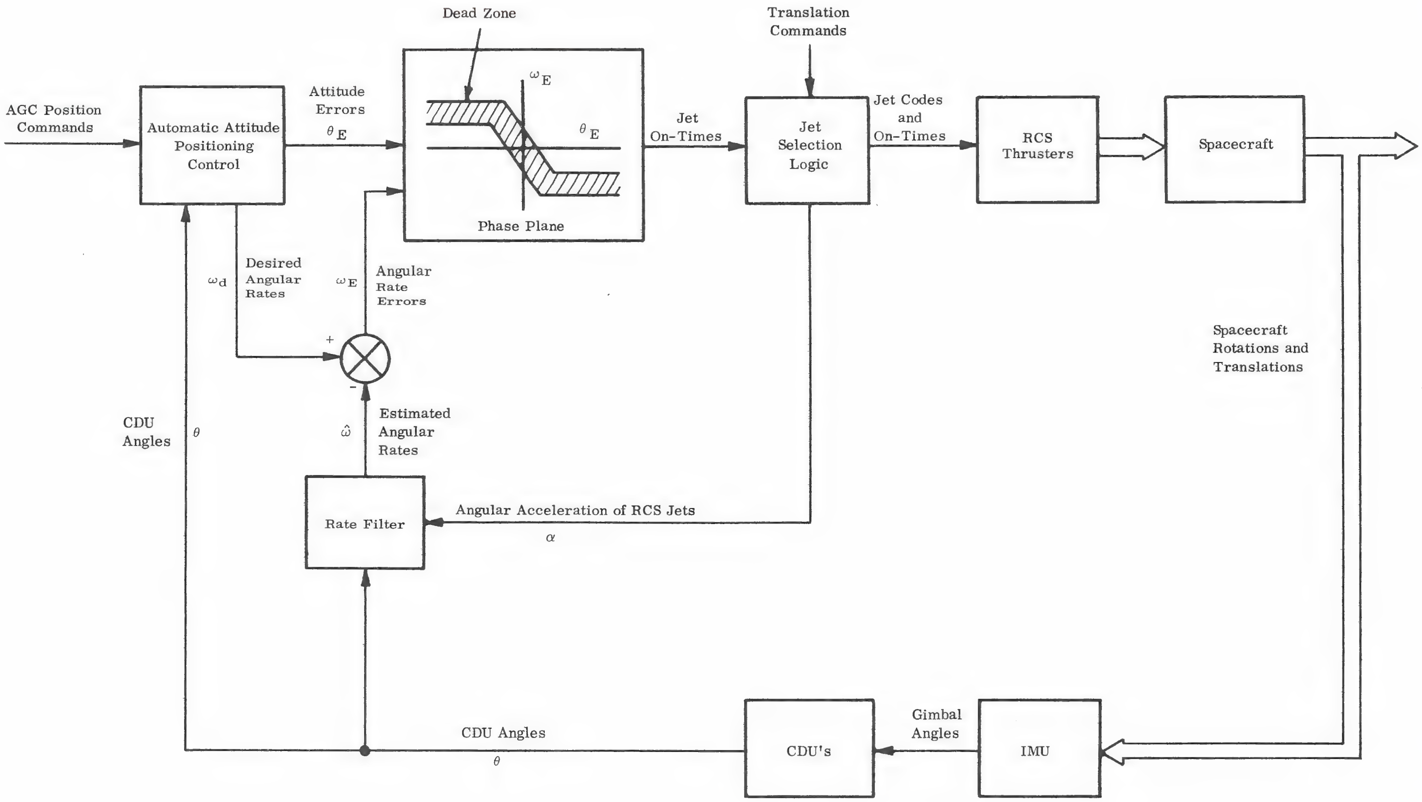
CSM DIGITAL AUTOPILOT
COASTING FLIGHT

MANUAL ANGULAR RATE CONTROL MODE



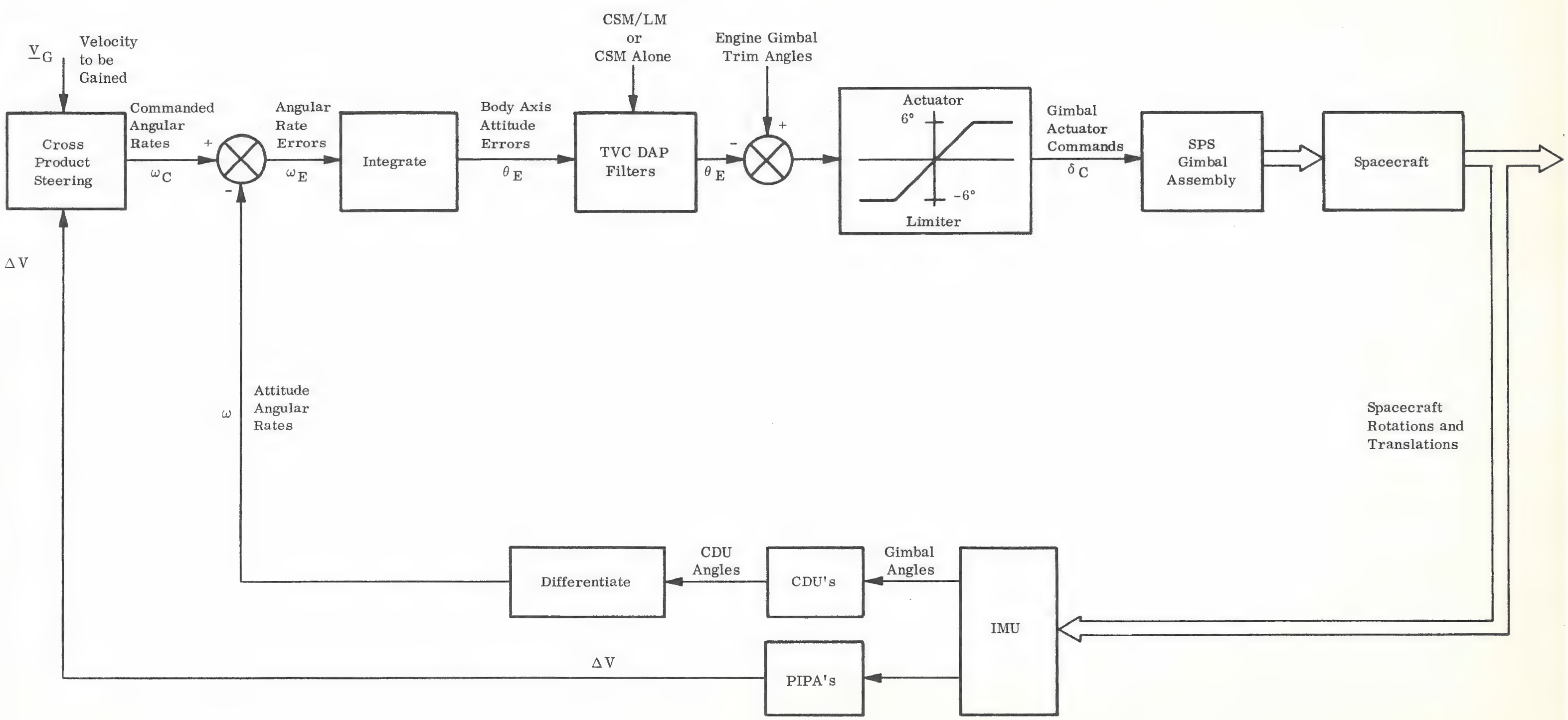
CSM DIGITAL AUTOPILOT
COASTING FLIGHT

AUTOMATIC ATTITUDE POSITIONING MODE



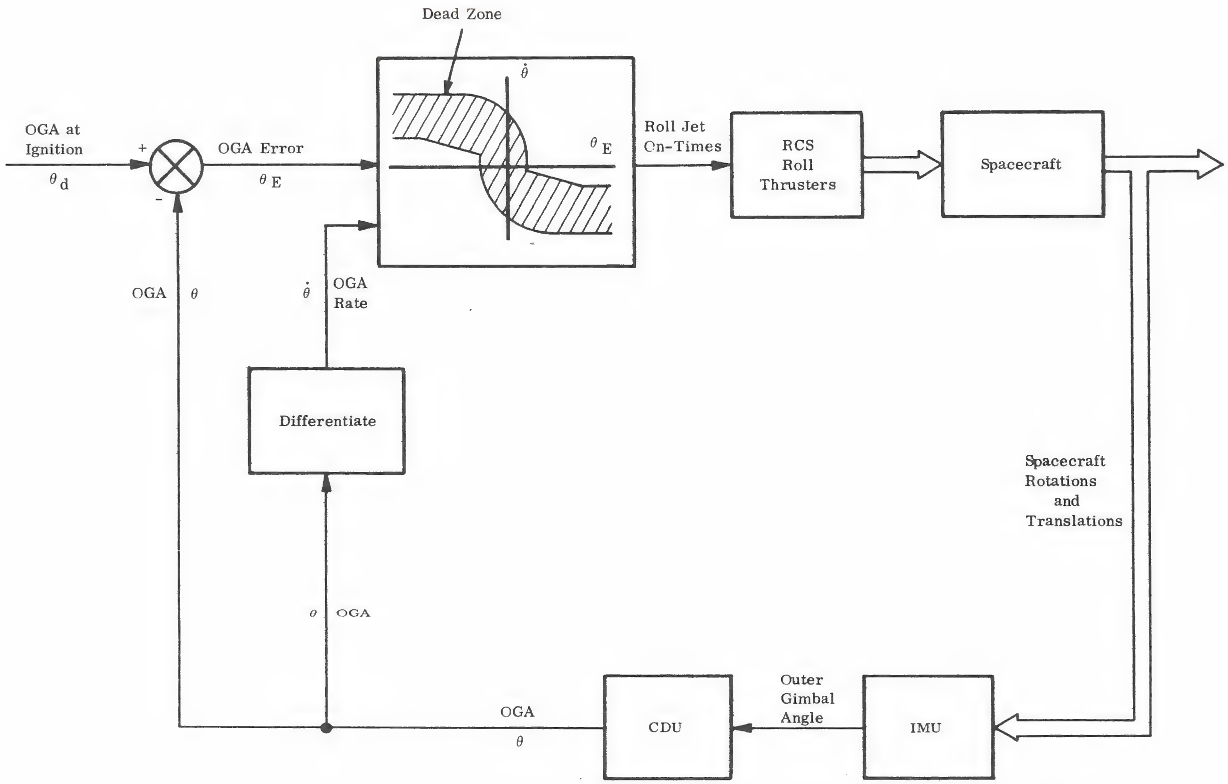
CSM DIGITAL AUTOPILOT
POWERED FLIGHT

THRUST VECTOR ATTITUDE CONTROL



CSM DIGITAL AUTOPILOT
POWERED FLIGHT

TVC ROLL ATTITUDE HOLD CONTROL



LM DAP CONTROL

Flashing V01 N46

	A	B	C	D	E
Register 1:	CONFIG	ACC	ACA	DB	RATE

CONFIG - Vehicle Configuration

1 = Ascent stage only
2 = Ascent and descent stages
3 = LM and CSM docked

ACC - Acceleration Code

0 = Two-jet translation (RCS System A)
1 = Two-jet translation (RCS System B)
2 = Four-jet translation (RCS System A and B)

ACA - ACA Scaling

0 = Docked (4 deg/s, max. rate)
1 = Normal (20 deg/s, max. rate)

DB - Deadband

0 = 0.3 degree
1 = 5.0 degrees

RATE - Maneuver Rate (Automatic Mode)

0 = 0.2 deg/s
1 = 0.5 deg/s
2 = 2.0 deg/s
3 = 10.0 deg/s

Flashing V06 N47

Register 1: LM weight in pounds

Register 2: CSM weight in pounds

Flashing V06 N48

Register 1: Pitch-trim engine gimbal angle, in 1/100 degree

Register 2: Roll-trim engine gimbal angle, in 1/100 degree

AUTOMATIC MODE

1. Automatic three-axis rotation and translation.
2. Manual three-axis translation.
3. Manual X-axis rate command (inhibited in LPD phase)
4. Attitude hold to program defined attitude
5. Automatic rate damping

ATTITUDE HOLD MODE

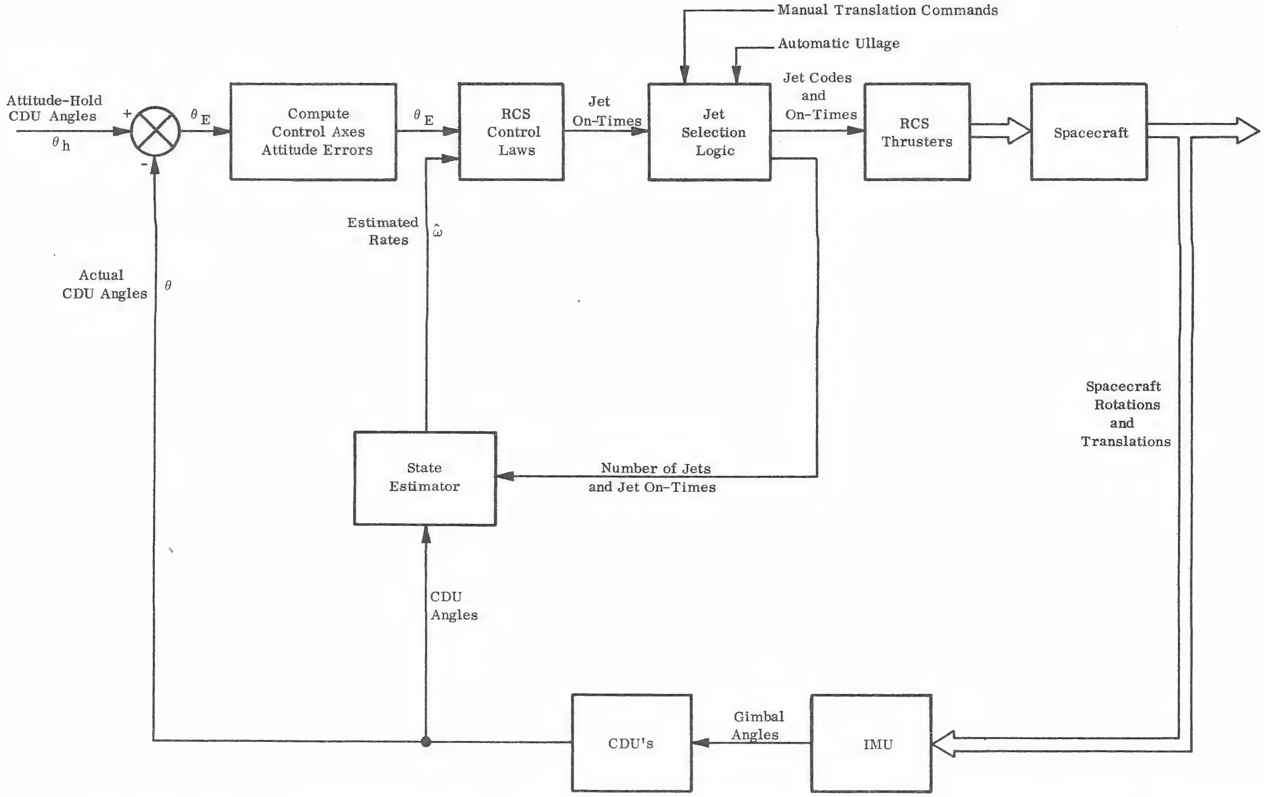
1. Manual three-axis translation.
2. Manual three-axis rate command using V77
3. Manual minimum impulse command using V76.
4. Attitude hold to attitude selected via hand controller
5. Automatic rate damping

V77 - Used to provide a manual rate command. Commanded rotational rate is proportional to hand controller (ACA) deflection. Maximum commanded rotational rate is either 4 deg/s or 20 deg/s as chosen in DAP Data Load routine.

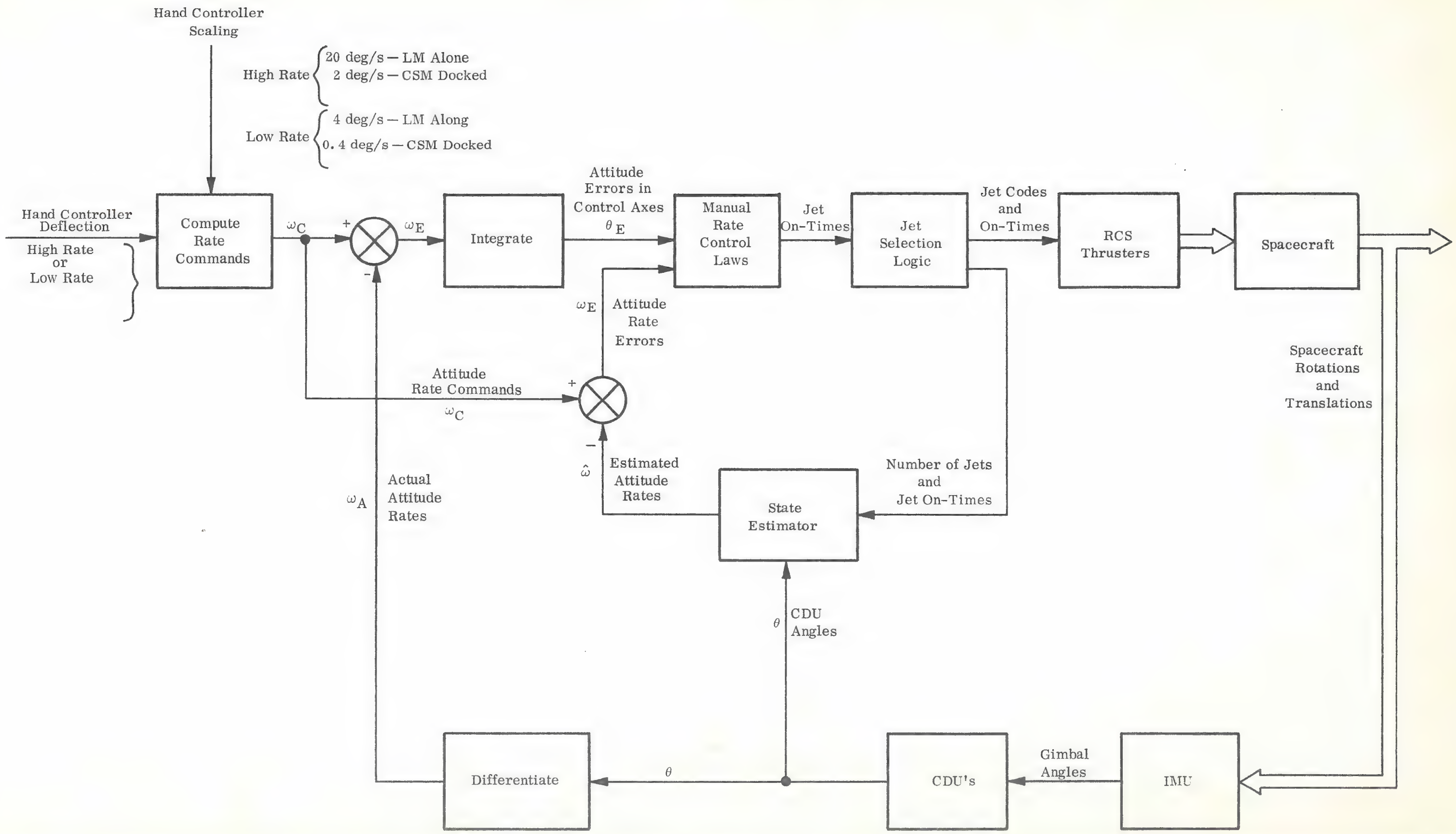
V76 - Used to provide a minimum impulse command. Releases Attitude Hold mode and allows vehicle to drift freely. One impulse is produced for each hand controller (ACA) deflection greater than 2.5 degrees.

LM DIGITAL AUTOPILOT
COASTING FLIGHT

ATTITUDE-HOLD CONTROL MODE

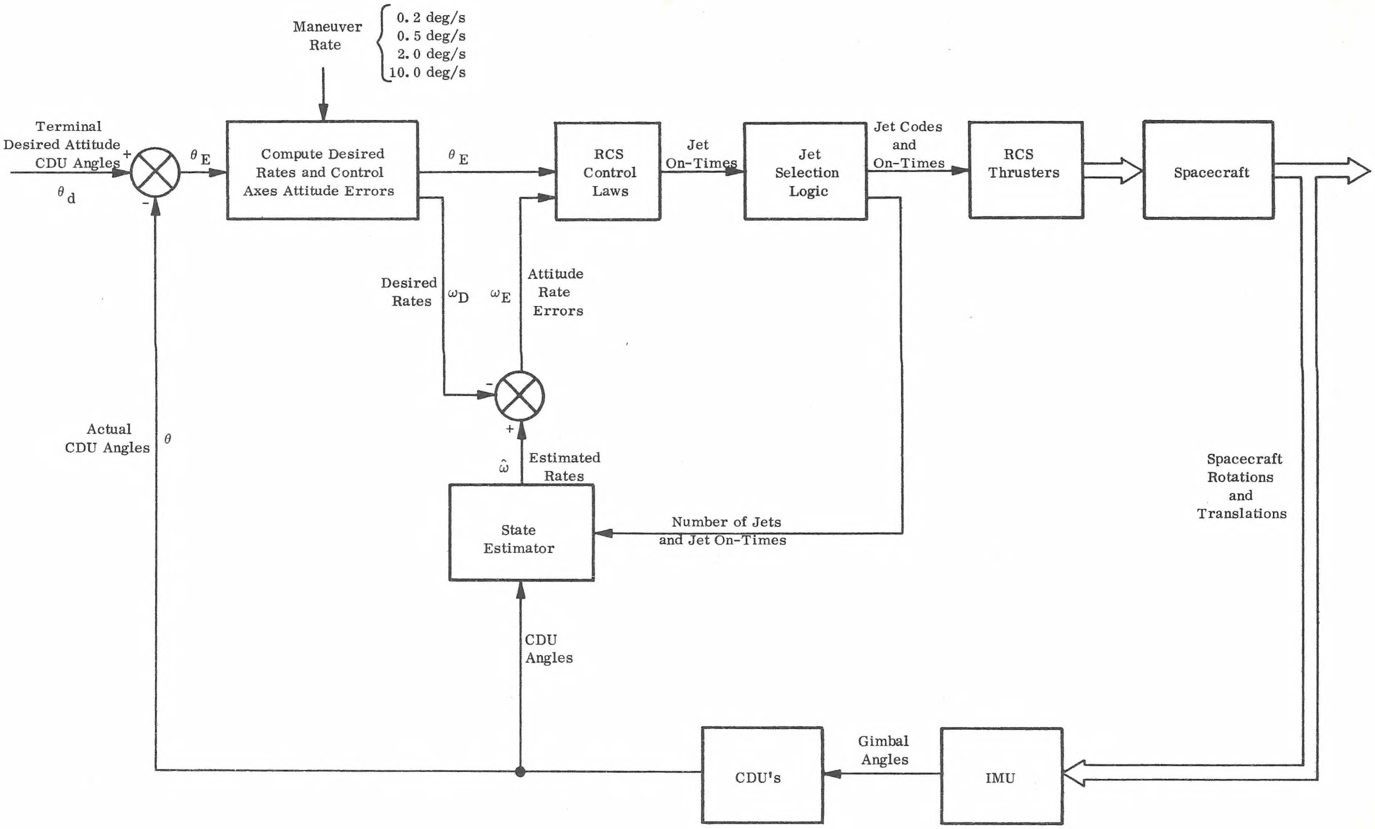


LM DIGITAL AUTOPILOT
COASTING FLIGHT
MANUAL ATTITUDE RATE MODE



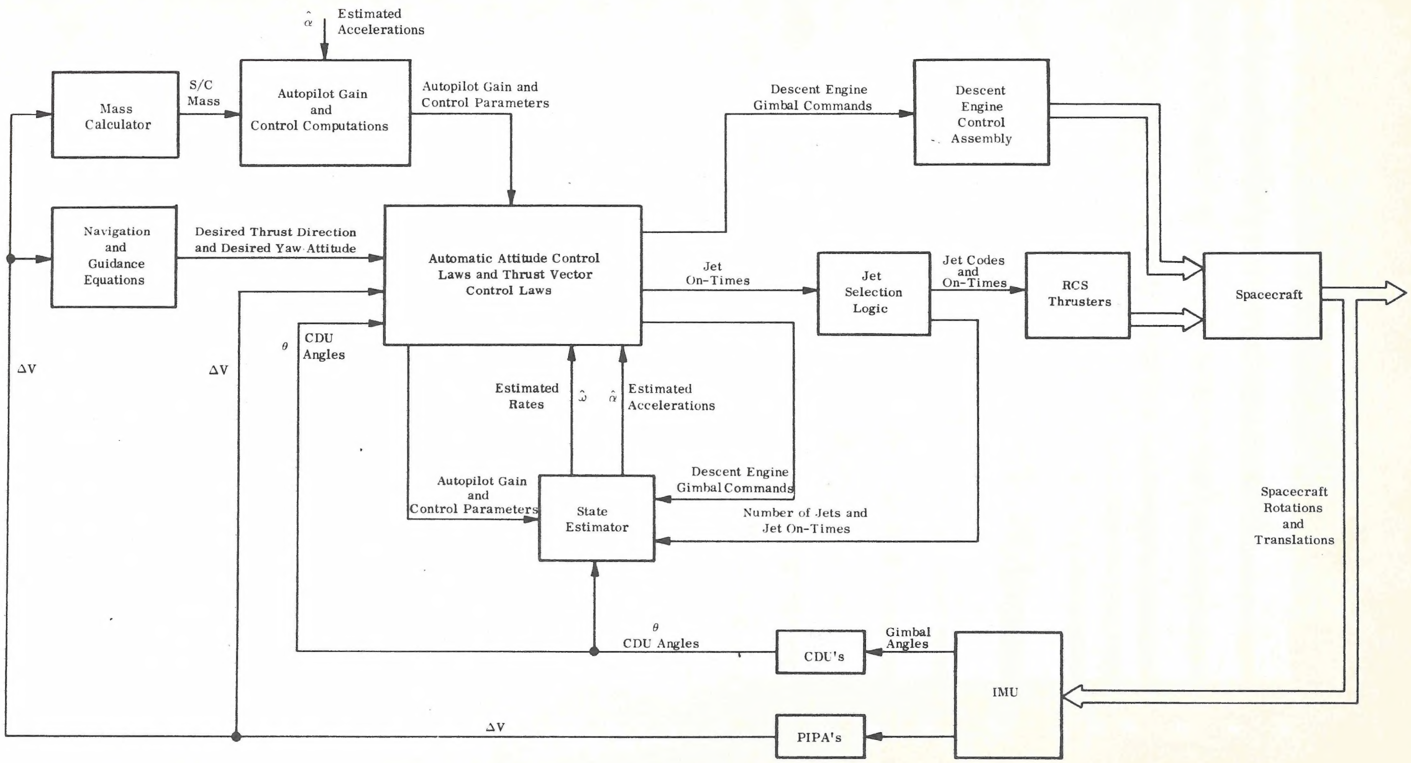
LM DIGITAL AUTOPILOT
COASTING FLIGHT

AUTOMATIC ATTITUDE POSITIONING MODE



LM DIGITAL AUTOPILOT
POWERED FLIGHT

AUTOMATIC ATTITUDE AND STEERING CONTROL MODE



REFERENCES

1. Guidance System Operations Plan for Manned LM Earth Orbital and Lunar Landing Missions Using Program Luminary, MIT Instrumentation Laboratory, Report No. R-567, Section 5, April 1969.

2. Spacecraft Operational Trajectory for Mission G, Volume I, Operational Mission Profile, Launched July 16, 1969, MSC Internal Note No. 69-FM-98, May 16, 1969.

3. Spacecraft Operational Trajectory for Mission G, Volume II, Operational Mission Profile Trajectory Parameters, Launched July 16, 1969, MSC Internal Note No. 69-FM-99, May 8, 1969.

4. Preliminary Apollo 11 Flight Plan, NASA, April 15, 1969.

5. LM Rendezvous Procedures, G Mission, MSC Internal Note No. CF-R-69-23, May 16, 1969.

6. Guidance System Operations Plan for Manned LM Earth Orbital and Lunar Landing Missions Using Program Luminary IA, MIT Instrumentation Laboratory, Report No. R-567, Section 4, April 1969.

7. Guidance System Operations Plan for Manned CM Earth Orbital and Lunar Missions Using Program Colossus 1 and Program Colossus 1A, MIT Instrumentation Laboratory, Report No. R-577, Section 4, December 1968.

8. Guidance System Operations Plan for Manned CM Earth Orbital and Lunar Missions Using Program Colossus 2A, MIT Instrumentation Laboratory, Report No. R-577, Section 5, April 1969.

9. Guidance, Navigation, and Control, Lunar Module Functional Description and Operation Using Flight Program Luminary, MIT Instrumentation Laboratory, Report No. E-2260, March 1969.

10. Apollo Operations Handbook, Lunar Module LM5 and Subsequent, Volume I, Subsystems Data, LMA790-3-LM, Grumman Aircraft Engineering Corporation, December 15, 1968.

11. Universal Lunar Module Systems Handbook, LM4 and Subsequent Vehicles, FC027, NASA, January 17, 1969.

12. Apollo Mission Techniques, Missions F and G, Transearth Injection, Midcourse Corrections and Entry (Volume 1), MSC Internal Note No. S-PA-9T-040, February 24, 1969.

13. Apollo Operations Handbook, Lunar Module LM5 and Subsequent, Volume II, Operational Procedures, LMA790-3-LM, Grumman Aircraft Engineering Corporation, May 1, 1969.

14. Radar Section Study Guide Lunar Module LM-4, LSG 770-154-5-LM-4, Grumman Aircraft Engineering Corporation, January 1969.

15. Control Electronics Section Study Guide Lunar Module LM-4, LSG 770-154-7-LM-4, Grumman Aircraft Engineering Corporation, January 1969.

16. Declination, Radial Distance, and Phases of the Moon for the Years 1961 to 1971 for Use in Trajectory Considerations, NASA Technical Note D-911, August 1961.

17. Notes on the Block II ECDU, AP-M #17329, October 23, 1967.

18. Block II 25 IRIG Pulse Torquing Circuit, XDE 34-R-20, June 30, 1967.

19. Block II Stab-Amp, AP-M #15614, April 12, 1967.

20. Notes on G&N JDC's 12220 and 12619 - The Gimbal Response Test, AP-M #18834, May 1, 1968.

21. ECDU Computer Operate Optics, AP-M #18281, February 26, 1968.

22. Orbital Navigation Via Landmark Tracking, AP-M #21695, February 24, 1969.

23. Celestial Navigation, AP-M #21569, February 4, 1969.

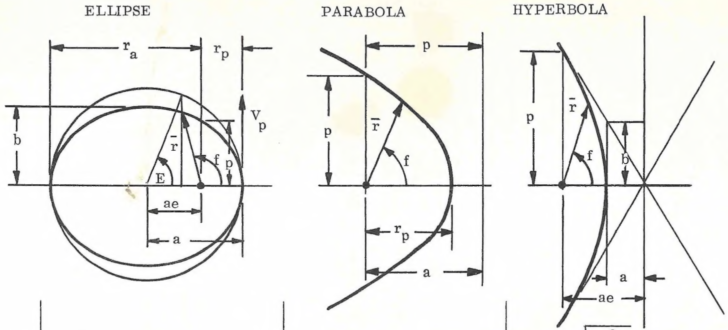
24. Notes on the Block II Coarse Align Loop, AP-M #16949, Rev. 1, November 17, 1967.

25. Block II Optical Subsystem Test Results, XDE 34-T-57, Rev. D, September 6, 1966.

26. Notes on the Block II and LEM PIPA, AP-M #17714, December 11, 1967.

27. AOT Usage During LM Operations on the Apollo 9 Mission, AP-M #21623, February 6, 1969.

ELLIPSE PARABOLA HYPERBOLA



		ELLIPSE	PARABOLA	HYPERBOLA
Semiminor Axis	b =	$\sqrt{r_a r_p}$		$r_p\sqrt{1+\frac{2a}{r_p}}$
Semimajor Axis	a =	$\frac{r_a + r_p}{2}$	$2 r_p$	$\frac{\mu}{V_\infty^2}$
Eccentricity	e =	$\sqrt{1-(\frac{b}{a})^2}$ <1	1	$\sqrt{1+(\frac{b}{a})^2}$ >1
Position	r =	$\frac{a(1-e^2)}{1+e\cos f} = a(1-e\cos E)$	$\frac{p}{1+\cos f}$	$\frac{a(e^2-1)}{1+e\cos f}$
Velocity	V =	$\left[\frac{\mu}{a}\left(\frac{1+2e\cos f+e^2}{1-e^2}\right)\right]^{1/2}$	$\left[\frac{2\mu(1+\cos f)}{p}\right]^{1/2}$	$\left[\mu\left(\frac{2}{r}+\frac{1}{a}\right)\right]^{1/2}$
Semilatus Rectum	p =	$a(1-e^2)$	$2 r_p$	$a(e^2-1)$
				$V_\infty^2 = \frac{\mu}{a}$