96:00

PREP FOR UNDOCKING
USE ACTIVATION & C.O.
C/L TO 10 MIN BEFORE UNDOCK
CHECK ATT (0, 284, 060)
V48 22012
LM WT _____ (36,693)
PRO, V34
V06N20 COPY LM AND CSM ANGLES AND TIME
P47

UNDOCK & SEPARATION ____:____:____ (96:14)
V77E
P00, V60 TRIM TO .1 FPS
YAW LT 60°
PITCH UP 90°
*SEQUENCE CAMERA - ON (1 MIN) *
FDAI (0, 013, 0)
*VHF ANT - FWD *
*SEQUENCE CAMERA - OFF *
HELMETS & GLOVES - OFF (OPT)

*SUIT GAS DIVERTER - EGRESS *
*CABIN GAS RETURN - EGRESS *

*S-BD ANT - AFT, VERIFY COMM *
*√S-BD P_____(+63) *
* Y_____(-32) *
*S-BD ANT - SLEW (>3.0) *
*TRACK MODE - AUTO *
*VHF B XMTR - OFF *
*BIOMED - LEFT, PCM - HI *
*
*UPLINK SQUELCH - OFF *
VOICE N20 ANGLES AND TIME TO MSFN
CAMERA SETTINGS FOR CABIN PHOTOS
LM/DAC/10/CEX (T/1.8, 1/60, 2ft)
* 6 FPS, .125 MAG N, (2 MIN) *
*LM/DC/60/HCEX (f5.6, 1/2 - 1/8, *
* FOCUS) 5 FR, MAG-A *

AOS
96
+16

96:20

96:20

DPS THROTTLE CHECK
*CB(16) STAB/CONT: ENG ARM - CLOSE *
THROT CONT - MAN/CDR
TTCA (BOTH) - THROTTLE (MIN)
*VERIFY MSFN CONTACT *
ENG STOP - PUSH
ENG ARM - DES (DES REG LT - ON)
TTCA MIN (6.6% - 13.4%)
THEN SOFT STOP (46.2% - 59.2%)
THEN MAX (93.6% - 100+%)
THEN MIN
ADJUST FRICTION
MAN THROT - LMP
*REPEAT TEST FOR LMP TTCA *
ENG ARM - OFF
*CYCLE CWEA (DES REG LT - OFF) *
ENG STOP - RESET
THROT CONT - AUTO/CDR
TTCA (BOTH) - JETS

DPS PRESS & C.O.

PRPLNT TEMP/PRESS MON - DES 1 & 2
FUEL 50°-75°F 50-130 PSI
OXID 50°-75°F 30-80 PSI
HELIUM MON: SUPCRIT PRESS 1070-1570
: AMB PRESS 1495-1750
DES He REG 1 tb - GRAY, REG 2 tb - bp
MASTER ARM - ON
DES PRPLNT ISOL VLV - FIRE
He PRESS/DES START - FIRE
MASTER ARM - OFF
PRPLNT TEMP/PRESS MON: DES 1 & 2
FUEL & OXID 50°-90°F 200-250 PSI
HELIUM MON: AMB PRESS 200-1110
: SUPCRIT PRESS 1070-1570

95:25

96:25

AGS ACTIVATION

*AGS STATUS - STBY (MASTER ALARM, & AGS WARNING LT - ON) *
*CB(16) STAB/CONT: AEA - CLOSE *
* (AGS WARNING LT - OFF) *

CB(11) AC BUS B: AGS - CLOSE
*RECORD TIME _____:_____:_____ *
*AGS STATUS - OPERATE (MASTER ALARM, & AGS WARNING LT - ON) *
*02/H2O QTY MON - C/W RESET *
*ATT MON (LMP) - AGS *
*V16 N65E *
*SET AGS TIME USING 90 HR BIAS *
* 377 _____ (+03850) *
*616+0 *
*224 _____ (+60514) *
*225 _____ (+29419) *
*226 _____ (+60384) *
*305 _____ (+00563) *
*662 _____ (-33024) *
*673 _____ (-54517) *
*412R+1 SELF TEST SATISFACTORY *
* +3 LOGIC TEST FAILURE *
* +4 MEMORY TEST FAILURE *
* +7 LOGIC & MEMORY TEST FAILURE *
*574R DESCENT STAGE (+ NOT STAGED) *
*604R LUNAR SURFACE FLAG *
* (+ NOT ON LUNAR SURFACE) *
*612R STAGING COUNTER (+0 NOM) *

96:30

96:30

*232R +00600 *
*233R +00250 *
*464R +00500 *
*465R +00195 *
*623R +00000 *
*514R +00000 *
*515R +40000 *
*516R +00000 *
*000 +888888 (OPR ERR LT - ON) *
*123 -45679 (DO NOT ENTR) *

MSFN UPDATE

*COPY AGS K FACTOR _____:_____:_____ *
*V47E *
*V25E LOAD AGS K FACTOR UPDATE *
*414+1 *
*400+3 (AFTER 50 16) *
*V83, 317R, 440R, SET ORDEAL *

LANDING RADAR CHECKOUT

CB(11) PGNS: LDG RDR - CLOSE
CK TEMP (60° - 95°)
X-PNTRS - HI MULT

MODE SEL - LR
TM SW - H/Ḣ
LDG ANT - AUTO
RDR TEST - LDG
POWER SIGNAL LIGHT OUT
TEST MON - ALT/VEL XMTR (2.1 - 5.0), AGC
X-PNTRS PEGGED UP, LT
TM - H (8000 ± 100), Ḣ (-480 ± 2)
V63 N12 OPT 2, PRO
N66 8286 ± 10, ANT POS 1 (00001), PRO
N67 V_x (-00495 ± 2), V_y (+01862 ± 2), V_z (+01331 ± 2)
V34, RDR TEST OFF (ALT - 0, POWER SIGNAL LIGHT ON, X-PNTRS - CENTERED)
CB(11) PGNS: LDG RDR - OPEN

96:35

LB-92

96:35

AGS CONT CHECK

MODE CONT (AGS) - ATT HOLD
GUID CONT - AGS
MNVR TO FDAI (0, 330, 0)
*CAMERA SETTINGS FOR REV 12 TCA *
*LM3/DAC/10/CEX (T/2.8, 1/250, ∞) *
* 1 FPS, .05 MAG N, (5 MIN) *
*LM/DC/60/HCEX (f5.6, 1/125, ∞) *
* 5 FR, MAG A *
*SEQUENCE CAMERA - ON (96:41) *
REV 12 LS TCA ___:___:___ (96:46)
*SEQUENCE CAMERA - OFF *

RENDEZVOUS RADAR CHECKOUT

GUID CONT - PGNS
CB(11) AC BUS A: RNDZ RDR - CLOSE

CB(11) PGNS: RNDZ RDR - CLOSE
*VHF A XMTR - VOICE/RNG *
✓ TEMP (10° - 75°)
RT/ERR MON - RR
RR SLEW, MANUAL LOCK-ON, RR LGC
TM - RNG/RNG RT
V63, PRO, NO TRACK LIGHT OUT, PRO, N78

	R	Ṙ
MAX	27 NM	7 FPS
N78		
VHF		
TM		

COMPARE N78, VHF, TM
V34
*VHF A XMTR - VOICE *
V41N72E (+00000 TRUN, +28300 SHFT)
CB(11) PGNS: RNDZ RDR - OPEN
CB(11) AC BUS A: RNDZ RDR - OPEN
V44, RR - SLEW
RT/ERR MON - LDG RDR/CMPTR
TM - H/Ḣ

96:50

96:50

MSFN UPDATE

*COPY CSM CIRC P76 *
*SET DET TO COUNT DN TO CSM CIRC *
*COPY PADS FOR *
* NO PDI + 12 ABORT *
* PDI *
* PDI EARLY ABORT *
* PDI LATE ABORT *
* T2 ABORT *
* T3 TIG *

SS
96
+52

IMU FINE ALIGN

V76
P52 OPT 3
CB(11) AC BUS B: AOT LAMP - CLOSE
AOT - DETENT F/0.0°
PGNS MODE CONT - AUTO
1ST STAR SPICA (226)
PRO
2ND STAR ANTARES (233)
NO5 ANGLE DIFF _____
PRO
N93 TORQUING ANG
X_____
Y_____
Z_____
PRO, RCD GET ___:___:___
N25, ENTR
P00
DETENT CL
CB AOT LAMP - OPEN

MSFN UPLINK

*UPDATA LINK - DATA *
*UPLINK CSM/LM S.V., E-MEMORY, DESCENT TARGETING *
*UPDATA LINK - OFF *
*V47, 414+1, 400+3 *
*V83, 317R, 440R, SET ORDEAL *

97:05

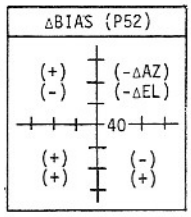
LB-93

97:05

COAS CALIBRATION
P52
PGNS MODE CONT - AUTO
N70, ENTR 026 (SPICA), PRO
N87, (+00000, +00000) PRO, PRO

BIAS AZ_____
EL_____

LPD CALIBRATION
ENTR
N70, ENTR 026 (SPICA), PRO
N87, (+00000, +32046) PRO, PRO
P00



MSFN UPDATE
COPY AND LOAD GYRO DRIFT COMP, PIPA BIAS
(REF. P2 DATA CARD BOOK)

CONFIGURE COMM FOR LOS

*MATCH INDICATED ANGLES *
*TRACK MODE - SLEW *
*S-BD ANT - FWD *
*SET P____(- 2) *
* Y____(+41) *
*VHF B XMTR - DATA, PCM - LO *
*UPLINK SQUELCH - ENABLE *

MNVR TO AGS CAL ATT
V49, +02250 OGA ROLL 24
+11250 IGA PITCH 122 } FDAI
+02250 MGA YAW 339

LOS 97 +22

97:25

97:25

AGS CALIBRATION
*READ AND RECORD INITIAL CAL.NOS. *
PGNS MODE CONT - ATT HOLD
*VERIFY 25 MIN SINCE TURN-ON *
V60, V76, V16N20E
RATES < 0.075°/SEC
*400+6, START WATCH *
*400R *
MONITOR ICDU LIMITS
{OGA +00000 / +04500
IGA +09000 / +13500} LIMITS
MGA +00000 / +04500}

BEFORE LIMITS ARE EXCEEDED, 400+0.
IF TIME IS LESS THAN 5 MINUTES
REPEAT AGS CALIBRATION.

*CHECK ECS, RCS, EPS, APS *
*CYCLE CWEA CB *
*400R+0 *
*READ AND RECORD CAL VALUES *

	INIT	CAL	Δ LIM
540	+2	-3	± .039
541	-1	+3	± .039
542	-2	+3	± .039
544	+6	-3	±2.00
545	-30	-6	±2.00
546	-47	+0	±2.00

CSM CIRCULARIZATION ____:____:____(97:42)
P76 (UPDATE CSM S.V.), PRO
V82, N12-00002, PRO
✓CSM HA/HP
*PCM - HI *
*V47, 414+1 *
*V83, 317R, 440R *
*PCM - LO *

SR 97 +41

97:45

LGB94

97:45

P63 IGNITION ALGORITHM TEST
P63
*RESET DET TO CONT DN TO PDI *
PGNS MODE CONT - AUTO
N18 R, P, Y (0, 111, XXX) PRO
YAW TO 340°
P00
V48, 22112, 00011, PRO, V34

*CAMERA SETTING (PDI) *
LM3/DAC/10/CEX-WDG (T/2.8, 1/500, ∞)
* 12 FPS, .75 MAG N, (6 MIN) *
*CAMERA SETTING (EARTH RISE) *
*LM/DC/60/HCEX (f16, 1/250, ∞) *
* 5 FR, MAG A *

COAS TO OVERHEAD WINDOW
VERIFY LOOSE GEAR STOWED
RESTRAINTS ATTACHED
VERIFY FDAI'S INERTIAL

PRE-PDI ECS CHECKOUT

HELMETS AND GLOVES ON
*CABIN REPRESS - CLOSE *
*SUIT GAS DIVERTER - EGRESS *
*CABIN GAS RETURN - EGRESS *
*PRESS REGS A&B - EGRESS *

PRE-PDI SWITCH SETTING CHECK
*VHF ANT - FWD *
CB(11)EPS: INV 1 - CLOSE *
*SELECT INV 1 *

98:00

98:00

CB(11) STAB/CONT: AELD - CLOSE
CB(11) STAB/CONT: ABORT STAGE - CLOSE
RESET ENG STOP PB
SET WINDOW BARS

*CB(16) STAB/CONT: AELD - CLOSE *
CB(16) STAB/CONT: ABORT STAGE - CLOSE

*CYCLE CWEA CB *
-30 *BATS 5 & 6 NORM FEED - ON *
*RECORD GET ____:____:____ *
THROT CONT - AUTO
CDR TTCA - THROTTLE - MIN
*LMP TTCA - THROTTLE - SOFT STOP
RATE SCALE - 25°/SEC
ATT/TRANSL - 4 JET
CHECK DPS, APS, RCS, ECS, EPS
CHECK SWITCH GUARDS
PRPLNT QTY MON - DES 1
*S-BD ANT - FWD, VERIFY COMM *
-25 *✓S-BD P ____(-2) *
* Y____(+41) *
*S-BD ANT - SLEW (>3.0) *
*TRACK MODE - AUTO *
*VHF B XMTR - OFF *
*BIOMED - LEFT, PCM - HI *
*UPLINK SQUELCH - OFF *
*VOICE AGS CAL. NOS. TO MSFN *
*CHECK ED BATTS AND REPORT *
*VOICE ASC BATT ON TIME TO MSFN *

MSFN UPLINK, UPDATE
*UPDATA LINK - DATA *
UPLINK LM S.V., RLS
*UPDATA LINK - VOICE BU *
*COPY, LOAD AGS RLS (231)_____ *
*COPY, LOAD LPD BIAS *

✓BURN ABORT RULES

AOS 98 +10

98:20

LGB95

98:20

AGS INITIALIZE

-15
- *V47, 414+1 *
- *V83, 317R, 440R *
- *240 + (231 RLS PAD) *
- *254+05390 *
- *262-00150 *

MODE SEL - AGS

POWERED DESCENT INITIATION

-10
- V25 N69E (IF NO UPLINK)
- PGNS MODE CONT - AUTO
- AGS MODE CONT - AUTO
- P63
- AUDIO MODE (BOTH) - VOX

✓DPS CONFIG CARD

-8
- *RESET DET *
- N18, R, P, Y (0, 111, 340)
- VERIFY FDAI
- *V40N20E, 400+3, 410+0 *
- *400+1, 433R VI *

-5
- CB(11) PGNS: LDG RDR - CLOSE
- ✓ALT XMTR

-4
- PRO - FINAL TRIM
- ENTR, ✓DET
- GO/NO-GO FOR PDI
- COMM CHECK WITH CSM
- RESET WATCH

-2:00
- MASTER ARM - ON
- MODE SEL - PGNS
- *367R *

-0:30 ENG ARM - DES

-0:07.5 ULLAGE

-0:05 PRO

0:00 PDI ___:___:___ (98:34:41)

+0:02 (NO IGN) - START PB - PUSH

+0:05 DES ENG CMD OVRD - ON
MASTER ARM - OFF

GO-AROUND

SECURE SYSTEMS
- ENG ARM - OFF
- MASTER ARM - OFF
- POO
- LR - OFF
- ASC BATTS - OFF
- PRLPNT QTY MON - OFF
- AUDIO - PTT
- ECS - CABIN MODE
- HELMETS & GLOVES - OFF (OPTIONAL)
- AGS - ATT HOLD

ALIGN IMU
- P52 (SAME STARS)

MSFN UPDATE
- COPY PADS FOR:
  - NO PDI + 12
  - PDI
  - PDI EARLY ABORT
  - PDI LATE ABORT
  - T2 ABORT
  - T3 TIG
  - AGS ABORT CONSTANTS
    224,225,226,305,662,673
  - AGS T2 UPDATE - 254

MSFN UPLINK
- DESCENT TARGETING, ABORT CONSTANTS, LM & CSM S.V.

CONFIGURE COMM FOR LOS

PICK UP WITH P63 IGNITION ALGORITHM TEST, P.5

LAP 96

-2:00 MASTER ARM-ON
MODE SEL-PGNS
367R

- :30 ENG ARM-DES

- :07.5 ULLAGE

- :05 PRO

+ :00 PDI

+ :02 (NO IGN) ---
START PB-PUSH

+ :05 DES ENG OVRD-ON
MASTER ARM-OFF

+ :26 THROTTLE UP
✓T/W > 1.6

+2 V21 N69E (DN RNG)

+3 YAW FACE UP

+4 ✓ ED BATTS
V57E TO PERMIT
LR DATA

+5 V24 N69E (DN RNG, X-RNG)

N68

EVAL MAN CONT

+8 V23 N69E (ALT)

223+00140 (E @ 14K)
360-0XXX0E
SEQ CAMERA - ON

TFI	θ	ΔHMAX	(-ḢMAX) -HDOT	H	DPS	SBD
0:00	111		5.0	52700	95	-2/41
0:30	111		7.0	52600	95	
1:00	103		25.0	52100	95	5/36
1:30	97		36.0	51100	92	
2:00	93		45.0	49900	87	13/29
2:30	89		51.0	48500	82	
3:00	85		57.0	46800	77	19/23
3:30	82		62.0	45100	71	
4:00	79		67.0	43100	66	8/5
4:30	77		73.0	40400	61	
5:00	75	+17000	78.0	39000	56	11/2
5:30	74	+17000	89.0	36600	50	
6:00	72	+16000	99.0	32800	45	13/0
6:30	71	+14000	(511.0) 107.0	30000	40	
7:00	67	+12400	(481.0) 104.0	26900	35	17/-3
7:30	62	+10000	(447.0) 103.0	23500	30	
8:00	59	+ 8200	(410.0) 130.0	20000	27	23/-8
8:30	59	+ 6900	(368.0) 155.0	16400	24	
9:00	55	+ 4500	(298.0) 172.0	11300	21	26/-11

P64

P64 + 15 SEC:
NO THROTTLE DN
- ABORT

MODE CONT (PGNS)-ATT HOLD

P66

X-PNTR - LO MULT

BINGO FUEL
DES QTY LT+1+31

TOUCHDOWN

ENG STOP - PUSH
ENG ARM - OFF
PRO
DES ENG CMD OVRD - OFF
MODE CONT (PGNS)-ATT HLD
MODE CONT (AGS)-AUTO
413+1
RECYCLE PARKER VALVES

H	(-ḢMAX) -HDOT	DPS	VH (362)
7000	(226.0) 176.0	18	254
6000	(207.0) 159.0	18	234
5000	(185.0) 137.0	17	219
4000	(162.0) 115.0	16	200
3000	(135.0) 92.0	15	176
2000	(104.0) 66.0	14	144
1000	(63.0) 36.0	13	96
500	(35.0) 17.0	11	53
400	(28.0) 12.0	11	39
300	(21.0) 8.0	10	19
200	(12.0) 5.0	9	-6

ABORT STAGE - PUSH
ENG ARM - ASC
ENG STOP - RESET
ENG START - PUSH
V22 N46 E,E
MODE CONT (BOTH) - AUTO

LAP 97

TD +3 THRU T2 ABORT

N76 5510.6 V HORZ
19.5 V VERT
CROSS RNG (<8.1)
N74 TFI, YAW, PITCH

*IF AGS ALIGNMENT NO GO *
*V47E, 414+1 *
*V40N20E, 400+3 *

*410+0 *

*RECYCLE PARKER VALVES *
PRPLNT TEMP PRESS MON - ASC, THEN DES
ASC He MON - CYCLE
*02/H2O QTY MON - ASC 1, 2, THEN DES 2, 1 *
*SEQUENCE CAMERA - OFF *
CB(11) PGNS: LDG RDR - OPEN

22:16 T2 STAY/NO STAY AND GO/NO-GO FOR DPS VENT

NO STAY

-2:00 ASC He SEL - BOTH
MASTER ARM - ON
ASC He PRESS - FIRE
ASC He REGS 1, 2 - OPEN
A ASC FEED 2-OPEN (UNLESS CDR)
A MAIN SOV -CLOSE (BUSS LOSS)
B ASC FEED 2-OPEN (UNLESS LMP)
B MAIN SOV -CLOSE (BUSS LOSS)
*CRSFD - CLOSED *
*BAT 1,3 - OFF *
*BAT 2,4 - OFF *
*CB(16) EPS:ASC ECA CONT-CLOSE *
*DES BAT - DEADFACE *
*SELECT ASC H2O TANK *
*DES O2 - CLOSE *
*ASC 1 O2 - OPEN *
*DES H2O - CLOSE *
*ASC H2O - OPEN *
*400+1, 367R *
- :10 ABORT STAGE - PUSH (AT T=0 FOR AGS)
ENG ARM - ASC
- :05 PRO
:00 *DET - RESET, RELEASE *
T2 ____:____:____ (98:58:57)
+ :01 ENG START - PUSH (IF AUTO IGN)

STAY *TAPE RECORDER - OFF *
AUDIO MODE - ICS/PTT
P00

17:50 T1 STAY/NO STAY

NO STAY

V22 N46 E,E
MODE CONT (BOTH) - AUTO
ABORT STAGE - PUSH
ENG ARM - ASC
ENG STOP - RESET
ENG START - PUSH

STAY *414+2 *
*400+4 *

P68
ENG STOP-RESET

PRO
P12
MODE CONT (PGNS) - AUTO
N33 T-2 (98:58:57)

L8-98

FDAI AND OVERHEAD WINDOW ANGLES FOR MANUAL DESCENT ABORT

DPS/APS

1:00	250/0	4:30	0/LV	8:00	0/LV
2:26	SD(FDAI)	4:44	300/36	8:14	300/36
2:36	SD(OHW)	6:26	270/5	10:16	270/15
		7:32	250/0	14:30	250/0
		8:19	SD	14:43	SD
1:30	0/0	5:00	0/LV	8:30	0/LV
1:44	300/0	5:14	300/36	8:44	300/36
2:30	250/0	6:58	270/5	11:12	270/15
3:20	SD	8:20	250/0	15:18	250/0
		9:03	SD	15:31	SD
2:00	0/LV	5:30	0/LV	9:00	0/LV
2:14	300/36	5:44	300/36	9:14	300/36
3:00	300/0	7:34	270/10	12:10	270/16
3:18	250/0	9:04	250/0	16:04	250/0
4:16	SD	9:46	SD	16:18	SD
2:30	0/LV	6:00	0/LV	9:30	0/LV
2:44	300/36	6:14	300/36	9:44	300/36
3:46	300/0	8:04	270/11	12:56	270/16
4:02	250/0	9:50	250/0	16:44	250/0
5:12	SD	10:39	SD	16:58	SD
3:00	0/LV	6:30	0/LV	10:00	0/LV
3:14	300/36	6:44	300/36	10:14	300/36
4:34	270/0	8:34	270/11	13:16	270/16
5:10	250/0	11:04	250/0	17:32	SD
5:57	SD(FDAI)	11:47	SD		
6:06	SD(OHW)				
3:30	0/LV	7:00	0/LV	10:30	0/LV
3:44	300/36	7:14	300/36	10:44	300/36
5:24	270/0	9:06	270/14	13:48	270/16
5:54	250/0	12:26	250/0	18:05	SD
6:50	SD(FDAI)	12:53	SD		
7:02	SD(OHW)				
4:00	0/LV	7:30	0/LV	11:00	*
4:14	300/36	7:44	300/36		USE
5:56	270/0	9:38	270/14		MANUAL
6:38	250/0	13:38	250/0		ASCENT
7:34	SD(FDAI)	13:53	SD		ANGLES
7:40	SD(OHW)				

ALL PITCH RATES
5°/SEC

* ESTABLISH POSITIVE HDOT, THEN ABORT STAGE TO USE MANUAL ASCENT ANGLES

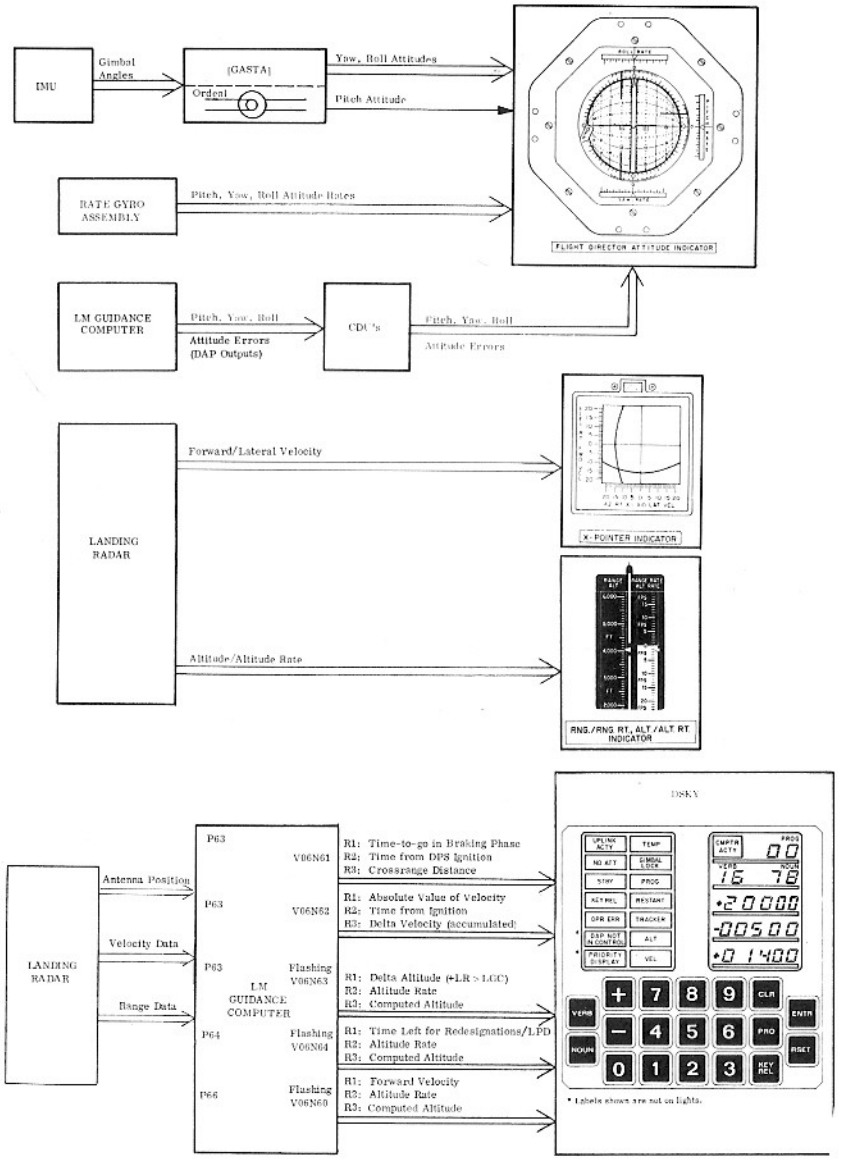
APS

1:00	250/0	4:30	0/LV	8:00	0/LV
2:24	SD/(FDAI)	5:10	300/36	8:40	300/36
2:36	SD(OHW)	6:22	270/10	12:06	270/14
		8:26	250/0	14:26	250/0
		8:51	SD	15:05	SD
1:30	0/LV	5:00	0/LV	8:30	0/LV
2:10	250/0	5:40	300/36	9:10	300/36
3:32	SD(FDAI)	7:08	270/10	13:00	270/14
3:52	SD(OHW)	9:20	250/0	15:02	250/0
		9:46	SD	15:50	SD
2:00	0/LV	5:30	0/LV	9:00	0/LV
2:40	300/0	6:10	300/36	9:40	300/36
3:10	250/0	7:54	270/12	13:54	270/14
4:24	SD(FDAI)	10:14	250/0	15:34	250/0
4:34	SD(OHW)	10:42	SD	16:31	SD
2:30	0/LV	6:00	0/LV	9:30	0/LV
3:10	300/0	6:40	300/36	10:10	300/36
4:00	250/0	8:44	270/14	14:30	270/14
5:18	SD	11:08	250/0	16:12	250/0
		11:37	SD	17:07	SD
3:00	0/LV	6:30	0/LV	10:00	0/LV
3:40	300/36	7:10	300/36	10:40	300/36
4:22	270/0	9:34	270/14	14:30	270/14
5:28	250/0	12:02	250/0	17:00	250/0
6:09	SD	12:33	SD	17:37	SD
3:30	0/LV	7:00	0/LV	10:30	0/LV
4:10	300/36	7:40	300/36	11:10	300/36
5:00	270/5	10:24	270/14	14:48	270/14
6:30	250/0	12:56	250/0	17:50	250/0
7:02	SD	13:28	SD	18:09	SD
4:00	0/LV	7:30	0/LV	11:00	*
4:40	300/36	8:10	300/36		USE
5:40	270/5	11:12	270/14		MANUAL
7:28	250/0	13:48	250/0		ASCENT
7:56	SD	14:19	SD		ANGLES

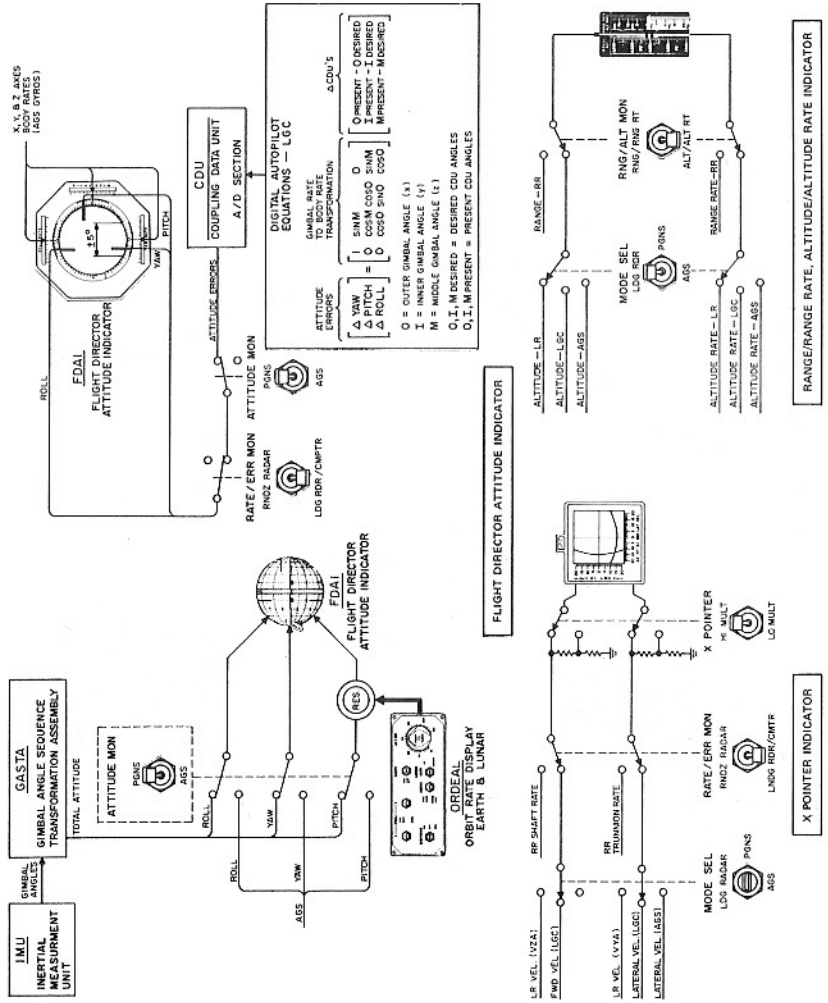
L8-99

LM LANDING DISPLAYS

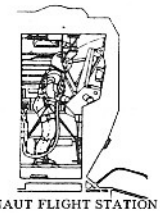
P63, P64, P66



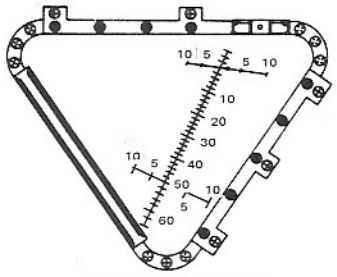
DESCENT DISPLAYS



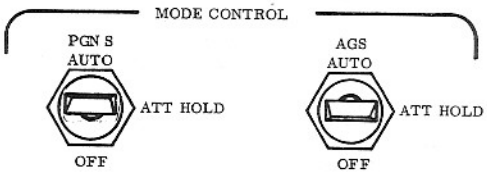
LANDING SITE REDESIGNATION (P64 ONLY)

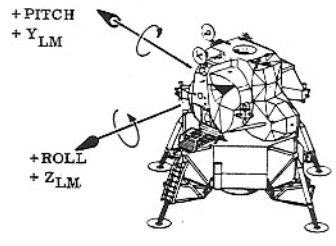


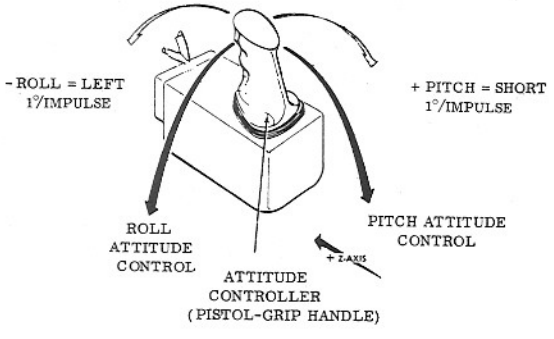
ASTRONAUT FLIGHT STATION



COMMANDER'S WINDOW
(LANDING POINT DESIGNATOR ON
COMMANDER'S WINDOW ONLY)



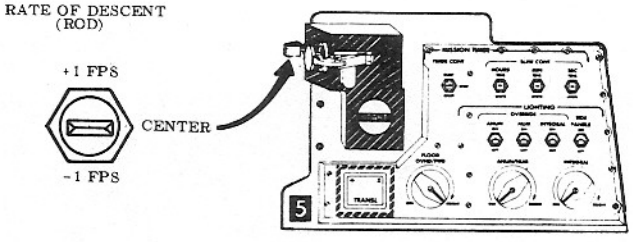


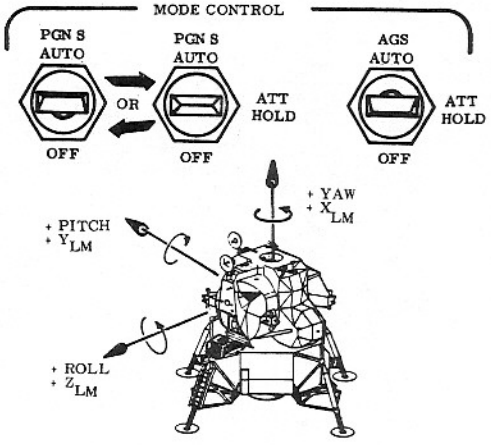


LB-102

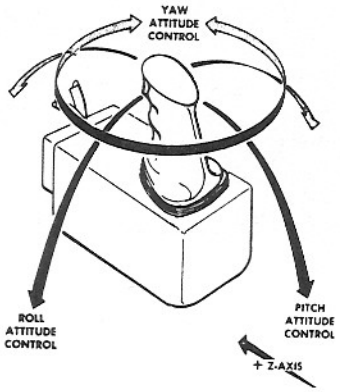
LANDING PHASE MODE CONTROL
P66

ASTRONAUT FLIGHT STATION

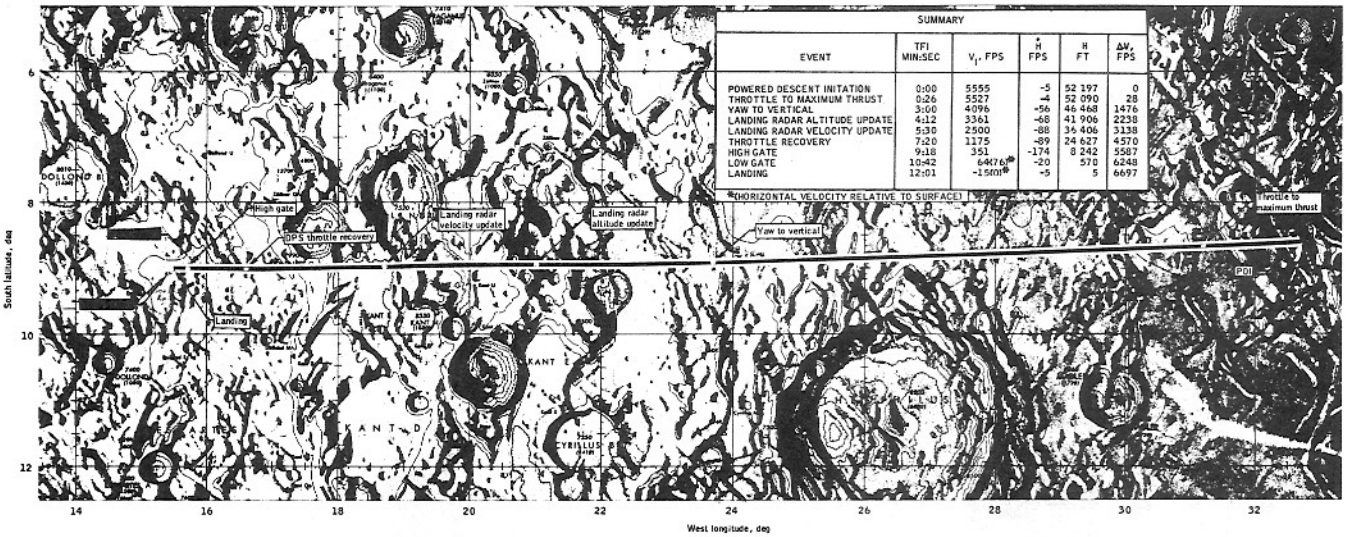




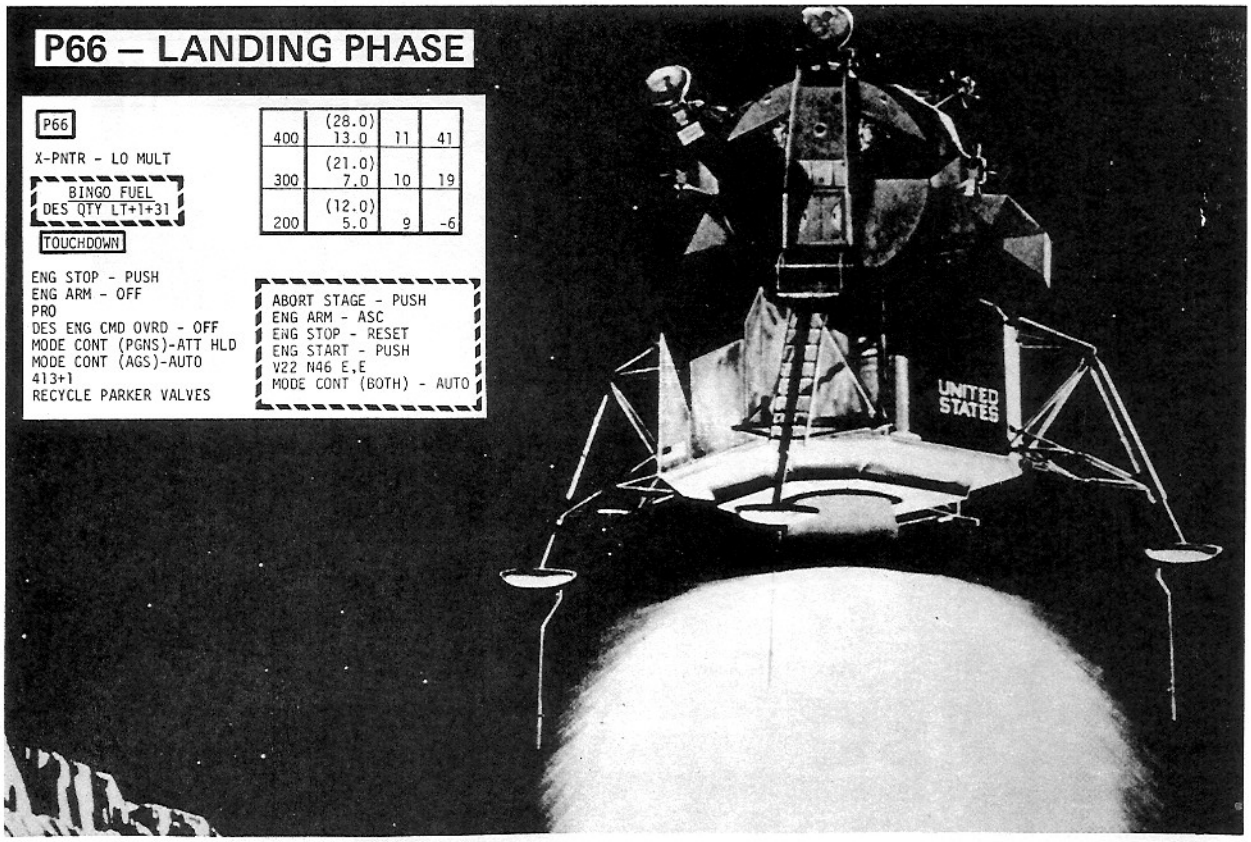
MANUAL LM ATTITUDE CONTROLLER



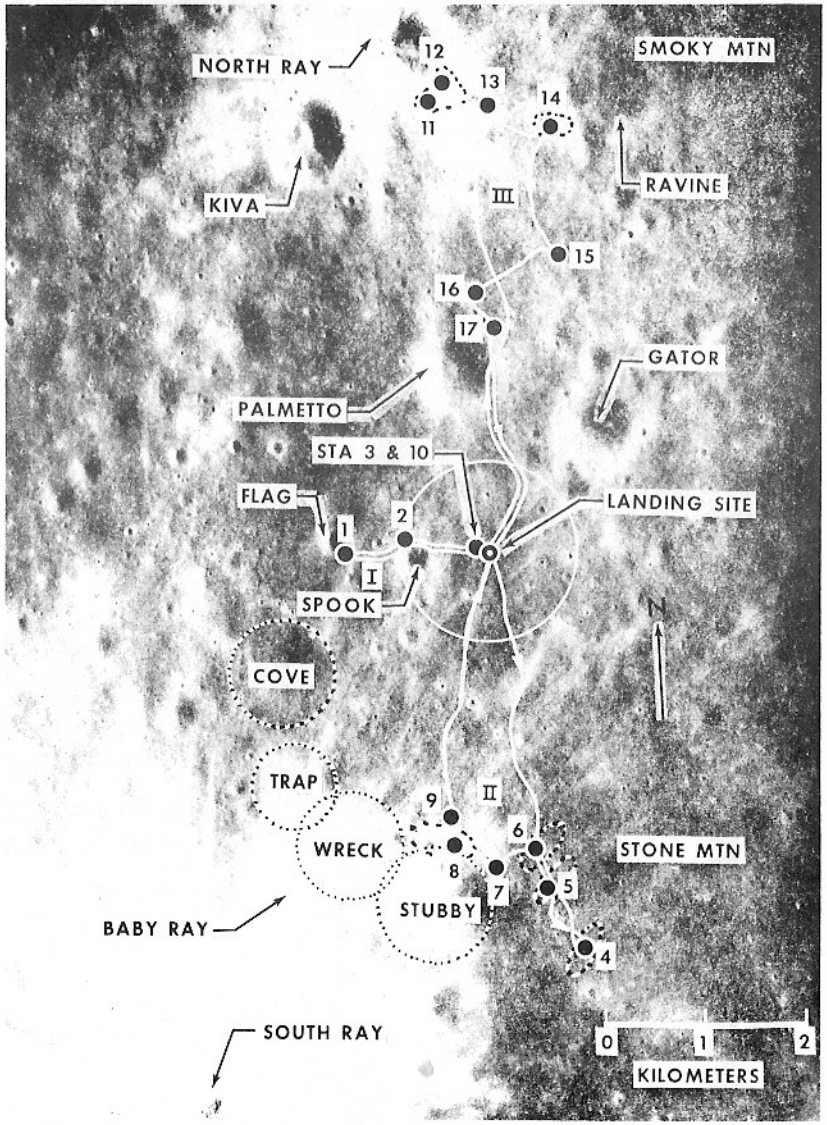
LB-103

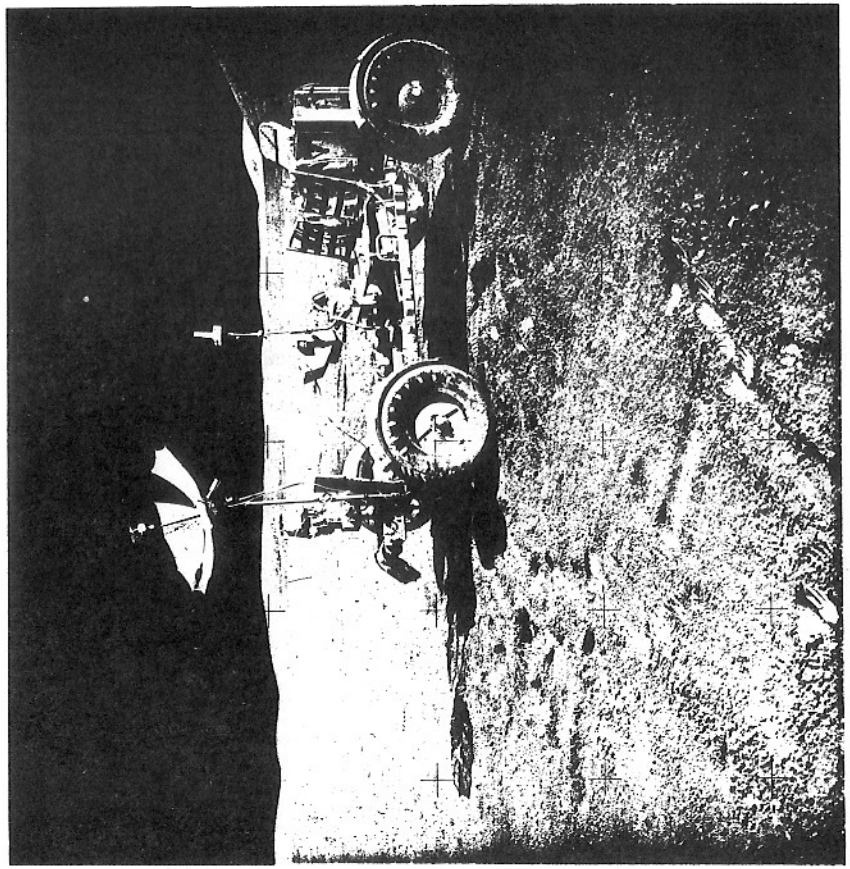


APOLLO 16 LM POWERED DESCENT GROUNDTRACK



DESCARTES LRV TRAVERSES





1st P57

P57E, R2 00003
N06 00010
00003
00110
PRO
(No Att light-On/Off, Twice)
N04 + _____ Navigation Error (0.01°)
V32E
(No Att light-On/Off, Twice)
N04 _____ Gravity Error (0.01°)
PRO
N22 ICDU Angles
PRO
(No Att light-On/Off)
N70 100 (Rigil Kent) 54
PRO
N88 –0.37780 X
–0.31056 Y
–0.87225 Z
PRO
N71 Star, 4 Marks
N88 Verify Vector
PRO
N05 _____ Angle Difference (0.01°)
PRO
N93 _____ X Torquing Angles (0.01°)
_____ Y
_____ Z
PRO
N25 00014, Enter, 00E

2nd P57

P57, Set R2 00004
N34 Load LO Time, PRO
N06 00010
00003
00010
PRO
(No Att light - On/Off, Twice)
N04 +_____ Gravity Error (0.01°)
V32E (Recycle)
N04 +_____ Gravity Error (0.01°)
PRO
N22 ICDU Angles
PRO (No Att light - On/Off)
N70/71 _____ STAR ID
N79
Cursor _____ (0.01°)
Spiral _____
PRO
N79
Cursor _____
Spiral _____
PRO
N79
Cursor _____
Spiral _____
PRO, PRO
N05 _____ Star Angle Difference (0.01°)
PRO
N93 _____ X Torquing Angles (0.001°)
_____ Y
_____ Z
PRO (Gyro Torquing), GET ___:___:___
N25 00014, ENTR (TERM)
OOE

3rd P57

P57E, R2 00004
N34 Load TIG, PRO
N06 00010
00003
00110
PRO
(No Att light - On/Off, Twice)
N04 +_____ Gravity Error (0.01°)
V32E
N04 +_____ Gravity Error
PRO
N22 ICDU Angles
PRO (No Att light - On/Off)
N70/71 _____ STAR ID
N79
Cursor _____ (0.01°)
Spiral _____
PRO
N79
Cursor _____
Spiral _____
PRO
N79
Cursor _____
Spiral _____
PRO, PRO
N05 _____ Star Angle Difference (0.01°)
PRO
N93 _____ X Torquing Angles (0.001°)
_____ Y
_____ Z
PRO (Gyro Torquing), GET ___:___:___
N25 00014, ENTR (TERM)
OOE

APOLLO 16 P 57's

The first P-57 subsequent to touchdown is a realignment to the landing site REFSMMAT. This is accomplished via selection of Option 3. The second and third P-57's are performed in preparation for ascent after power up. These are both performed to Option 4, which specifies the IMU Orientation to the liftoff REFSMMAT at TIG.

All P-57's are performed via Technique 3 which specifies alignment using data from gravity and one star sighting.

$$\begin{bmatrix} X_{SM} \\ Y_{SM} \\ Z_{SM} \end{bmatrix} = \begin{bmatrix} \text{Landing Site} \\ \text{REFSMMAT} \end{bmatrix} \qquad \bar{1}_{ECI} = \begin{bmatrix} \text{Unit } (\bar{r}_{LS_{TIG}}) \\ \text{Unit } (\bar{Z}_{SM} \times \bar{X}_{SM}) \\ \text{Unit } [(\bar{r}_{CSM} \times \bar{V}_{CSM})_{TIG} \times \bar{X}_{SM})] \end{bmatrix} \begin{bmatrix} X_{ECI} \\ Y_{ECI} \\ Z_{ECI} \end{bmatrix}$$

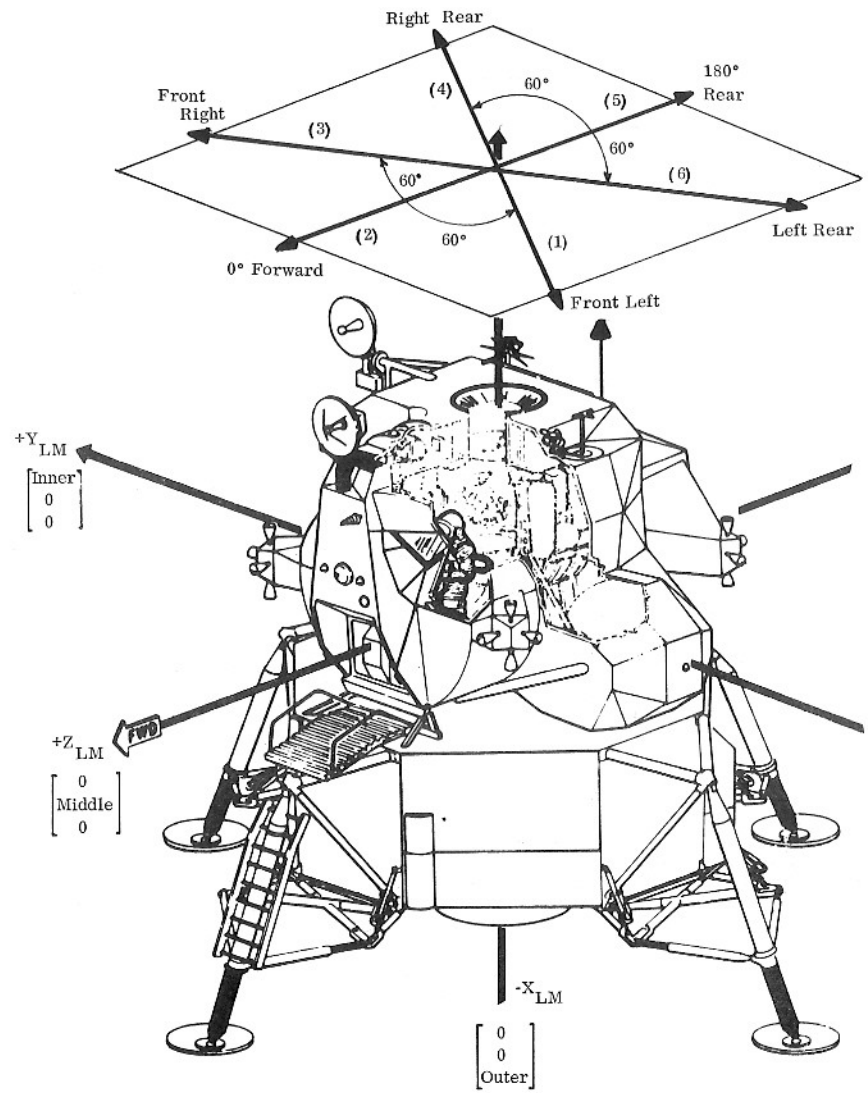
$$[\bar{S}_A] = \underset{\text{(specified)}}{\begin{bmatrix} \text{Unit } (\bar{r}_{LS_{TIG}}) \\ \text{Unit } (\bar{r}_{LS_{TIG}} \times \bar{S}_2) \times \bar{r}_{LS_{TIG}} \\ \text{Unit } (\bar{r}_{LS_{TIG}} \times \bar{S}_2) \end{bmatrix}} \begin{bmatrix} X_{SMD} \\ Y_{SMD} \\ Z_{SMD} \end{bmatrix} \qquad \bar{S}_B = \underset{\text{(measured)}}{\begin{bmatrix} \text{Unit } \bar{g}_{LS} \\ \text{Unit } (\bar{g}_{LS} \times \bar{S}_2') \times \bar{g}_{LS} \\ \text{Unit } (\bar{g}_{LS} \times \bar{S}_2') \end{bmatrix}} \begin{bmatrix} X_{SM} \\ Y_{SM} \\ Z_{SM} \end{bmatrix}$$

$$[\bar{S}_A] = [A][\bar{1}_{SMD}] \qquad [\bar{S}_B] = [B][\bar{1}_{SM}]$$

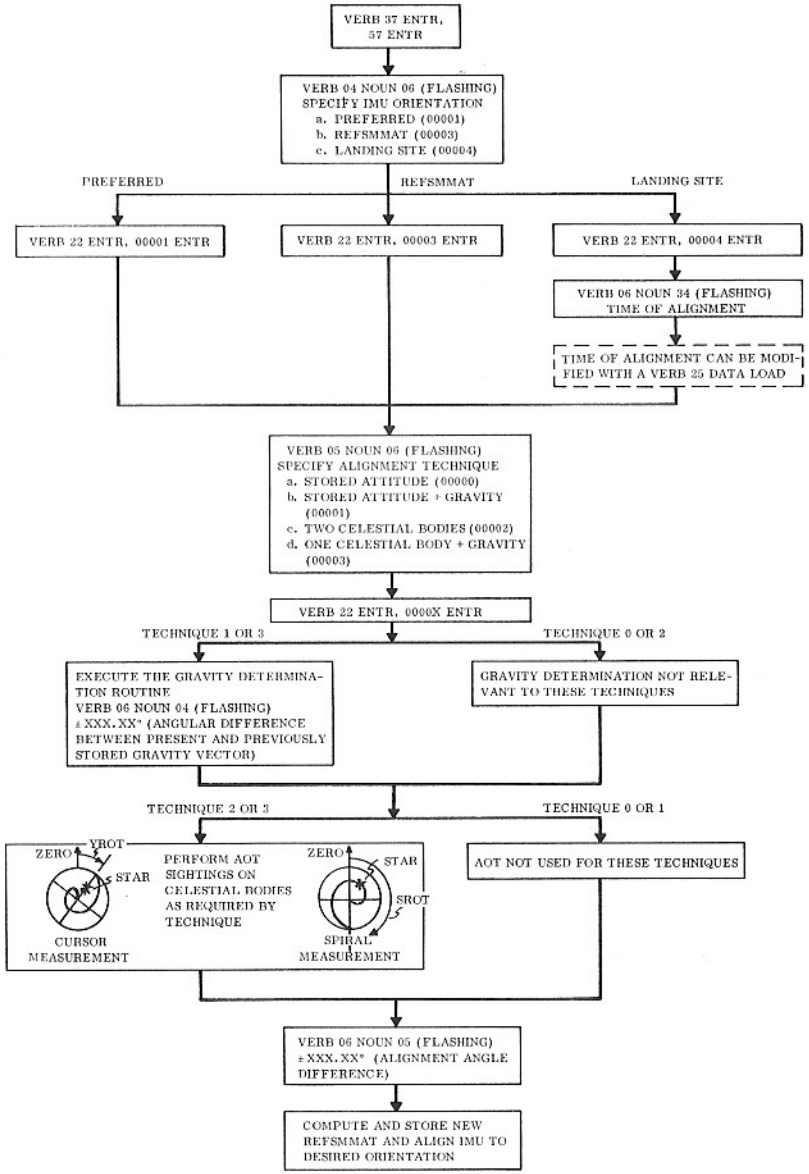
$$[\bar{1}_{SMD}] = [B]^T[A][\bar{1}_{SM}]$$

$[\bar{1}_{SMD}] \rightarrow$ CALGTA $\rightarrow$ GTA's

LUNAR SURFACE ALIGNMENT
AOT DETENT POSITIONS



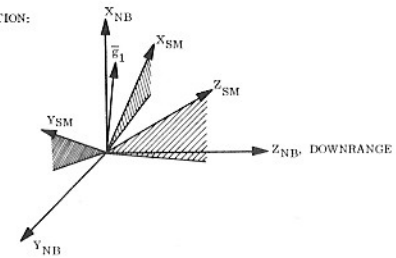
LUNAR SURFACE ALIGNMENT - P57



LUNAR SURFACE ALIGNMENT
GRAVITY DETERMINATION ROUTINE

1. COARSE ALIGN THE IMU TO THE FIRST ORIENTATION:

   OGA ≃ +42°
   MGA ≃ +35.25°
   IGA ≃ −42°



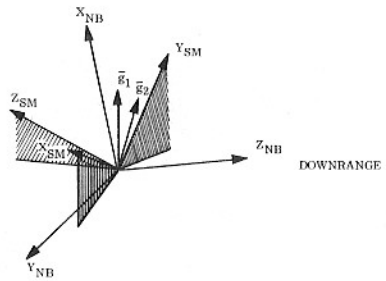
2. PLACE THE IMU IN AN INERTIAL MODE AND SAMPLE THE OUTPUT OF THE PIPA's OVER A PERIOD OF 40 SECONDS. ($PIPA_X$, $PIPA_Y$, $PIPA_Z$). FORM A UNIT VECTOR $\vec{g}_1$

$$\vec{g}_1 = \frac{PIPA_X\,\hat{X}_{SM} + PIPA_Y\,\hat{Y}_{SM} + PIPA_Z\,\hat{Z}_{SM}}{\sqrt{PIPA_X^{\,2} + PIPA_Y^{\,2} + PIPA_Z^{\,2}}}$$

WHERE $\vec{g}_1$ INDICATES THE DIRECTION OF THE FIRST ESTIMATE OF THE LUNAR GRAVITY VECTOR IN SM COORDINATES.

3. COARSE ALIGN THE STABLE MEMBER 180° ABOUT THE MEASURED GRAVITY VECTOR.

   OGA ≃ −138°
   MGA ≃ +35.25°
   IGA ≃ −42°



4. PLACE THE IMU IN AN INERTIAL MODE AND SAMPLE THE OUTPUT OF THE PIPA's OVER A PERIOD OF 40 SECONDS ($PIPA_X$, $PIPA_Y$, $PIPA_Z$). FORM A UNIT VECTOR $\vec{g}_2$

$$\vec{g}_2 = \frac{PIPA_X\,\hat{X}_{SM} + PIPA_Y\,\hat{Y}_{SM} + PIPA_Z\,\hat{Z}_{SM}}{\sqrt{PIPA_X^{\,2} + PIPA_Y^{\,2} + PIPA_Z^{\,2}}}$$

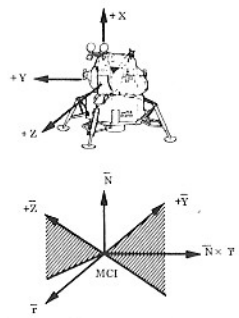
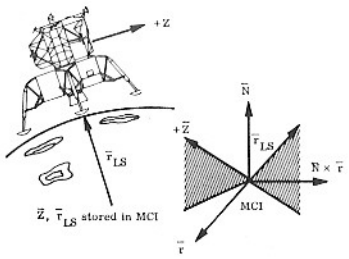
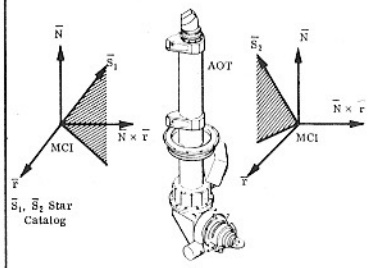
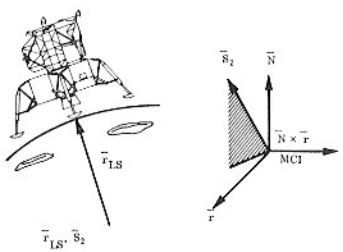
where $\vec{g}_2$ INDICATES THE DIRECTION OF THE SECOND ESTIMATE OF THE LUNAR GRAVITY VECTOR IN SM COORDINATES.

5. DEFINE A UNIT VECTOR $\vec{U}_G$ OUT OF $\vec{g}_1$ AND $\vec{g}_2$ WHICH REPRESENTS THE DIRECTION OF THE LUNAR GRAVITY VECTOR.

$$\vec{U}_G = \text{UNIT}\,(\vec{g}_1 + \vec{g}_2)$$

NOTE: THE $\vec{R}_{LS}$ VECTOR IS CONSIDERED TO BE COLINEAR WITH THE GRAVITY VECTOR.

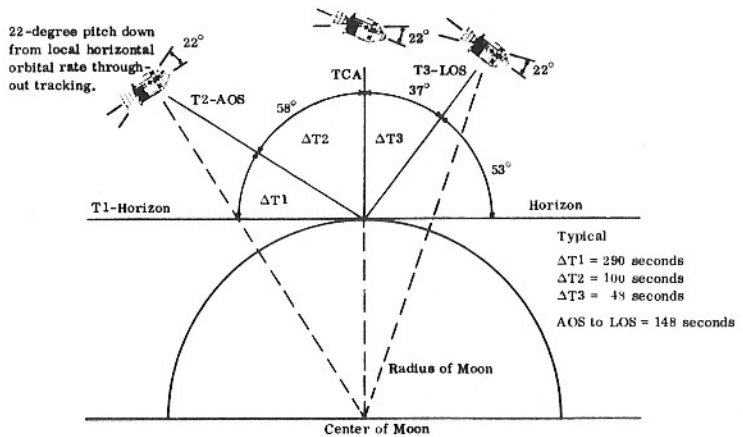
LUNAR SURFACE ALIGNMENT – P57

TECHNIQUE	LOS DIRECTION IN BASIC REF. COORDINATES	ABSOLUTE INERTIAL REFERENCE
0	 LM +$\bar{Y}$ and +$\bar{Z}$ stored from previous alignment (P57, P68)	$\bar{S}_A$ = (specified) $\begin{bmatrix} \bar{Y} \\ (\bar{Y} \times \bar{Z}) \times \bar{Y} \\ \bar{Y} \times \bar{Z} \end{bmatrix} \bar{i}_{MCI} \triangleq [A]\ \bar{i}_{MCI}$ $\bar{S}_B$ = (measured) $\begin{bmatrix} \bar{Y}_M \\ (\bar{Y}_M \times \bar{Z}_M) \times \bar{Y}_M \\ \bar{Y}_M \times \bar{Z}_M \end{bmatrix} \bar{i}_{SMCS} \triangleq [B]\ \bar{i}_{SMCS}$ $\bar{S}_A = [A]\ \bar{i}_{MCI} = \bar{S}_B = [B]\ \bar{i}_{SMCS}$ $\bar{i}_{SMCS} = [REFSMMAT]\ \bar{i}_{MCI} = [B]^{-1}[A]\ \bar{i}_{MCI}$
1		$\bar{S}_A$ = (specified) $\begin{bmatrix} \bar{r}_{LS} \\ (\bar{r}_{LS} \times \bar{Z}) \times \bar{r}_{LS} \\ \bar{r}_{LS} \times \bar{Z} \end{bmatrix} \bar{i}_{MCI} \triangleq [A]\ \bar{i}_{MCI}$ $\bar{S}_B$ = (measured) $\begin{bmatrix} \bar{e}_{LS} \\ (\bar{e}_{LS} \times \bar{Z}_M) \times \bar{e}_{LS} \\ \bar{e}_{LS} \times \bar{Z}_M \end{bmatrix} \bar{i}_{SMCS} \triangleq [B]\ \bar{i}_{SMCS}$ $\bar{i}_{SMCS} = [REFSMMAT]\ \bar{i}_{MCI} = [B]^{-1}\ [A]\ \bar{i}_{MCI}$
2		$\bar{S}_A$ = (specified) $\begin{bmatrix} \bar{S}_1 \\ (\bar{S}_1 \times \bar{S}_2) \times \bar{S}_1 \\ \bar{S}_1 \times \bar{S}_2 \end{bmatrix} \bar{i}_{MCI} = [A]\ \bar{i}_{MCI}$ $\bar{S}_B$ = (measured) $\begin{bmatrix} \bar{S}_{1M} \\ (\bar{S}_{1M} \times \bar{S}_{2M}) \times \bar{S}_{1M} \\ \bar{S}_{1M} \times \bar{S}_{2M} \end{bmatrix} \bar{i}_{SMCS} = [B]\ \bar{i}_{SMCS}$ $\bar{i}_{SMCS} = [REFSMMAT]\ \bar{i}_{MCI} = [B]^{-1}\ [A]\ \bar{i}_{MCI}$
3		$\bar{S}_A$ = (specified) $\begin{bmatrix} \bar{r}_{LS} \\ (\bar{r}_{LS} \times \bar{S}_2) \times \bar{r}_{LS} \\ \bar{r}_{LS} \times \bar{S}_2 \end{bmatrix} \bar{i}_{MCI} = [A]\ \bar{i}_{MCI}$ $\bar{S}_B$ = (measured) $\begin{bmatrix} \bar{e}_{LS} \\ (\bar{e}_{LS} \times \bar{S}_{2M}) \times \bar{e}_{LS} \\ \bar{e}_{LS} \times \bar{S}_{2M} \end{bmatrix} \bar{i}_{SMCS} = [B]\ \bar{i}_{SMCS}$ $\bar{i}_{SMCS} = [REFSMMAT]\ \bar{i}_{MCI} = [B]^{-1}\ [A]\ \bar{i}_{MCI}$

MCI = Moon Centered Inertial; SMCS = Stable Member Coordinate System

P24 — LANDMARK TRACKING

CSM Landmark Tracking Profile



TGT: ( )

T_1 __ __ __ : __ __ : __ __

T_2 __ __ __ : __ __ : __ __

TCA __ __ __ : __ __ : __ __

T_3 __ __ __ : __ __ : __ __

R __ __ __ ° P __ __ __ ° Y __ __ __ ° (T2 ACQ)

N or S nmi __ __ / SA __ __ TA __ __ (T2 ACQ)

N89 LAT __ __ . __ __

LONG/2 __ __ . __ __

ALT __ __ __ . __

TGT: ( )

T_1 __ __ __ : __ __ : __ __

T_2 __ __ __ : __ __ : __ __

TCA __ __ __ : __ __ : __ __

T_3 __ __ __ : __ __ : __ __

R __ __ __ ° P __ __ __ ° Y __ __ __ ° (T2 ACQ)

N or S nmi __ __ / SA __ __ TA __ __ (T2 ACQ)

N89 LAT __ __ . __ __

LONG/2 __ __ . __ __

ALT __ __ __ . __

P24 RATE-AIDED OPTICS TRACKING

CMC – on (req)
ISS – on and aligned
SCS – on
BMAG MODE (3) – RATE 2
G&N PWR OPTICS – on
OPT ZERO – ZERO (verify)
OPT MODE – CMC

V37E 24E

F 06 89 — LAT, LONG/2, ALT (0.001°, 0.001°, 0.01 nmi)
LOAD LMK COORDS
OPT ZERO – OFF
PRO

06 92 — AUTO OPT SHF/TRUN (0.01°, 0.001°)
- F 05 09 00404 (TRUN > 90°)
- MNVR to acquire
- PRO
- or V34E, F 37

OPTICS MODE – MAN

F 51 — MARK REQUEST
MARK (as often as desired)
To terminate:
PRO

F 37 — XXE
OPT ZERO – ZERO

P24 – LANDMARK TRACKING
MARK DATA

+	0	0				Hours	+	0	0			
+	0	0	0			Minutes GET	+	0	0	0		
+	0					Seconds	+	0				
+						P IMU Gimbal Angles (degree)	+					
+						Y	+					
+						R	+					
+						Shaft SXT Angles (degree)	+					
+						Trunnion	+					

+	0	0				Hours	+	0	0			
+	0	0	0			Minutes GET	+	0	0	0		
+	0					Seconds	+	0				
+						P IMU Gimbal Angles (degree)	+					
+						Y	+					
+						R	+					
+						Shaft SXT Angles (degree)	+					
+						Trunnion	+					

+	0	0				Hours	+	0	0			
+	0	0	0			Minutes GET	+	0	0	0		
+	0					Seconds	+	0				
+						P IMU Gimbal Angles (degree)	+					
+						Y	+					
+						R	+					
+						Shaft SXT Angles (degree)	+					
+						Trunnion	+					

NOTES:

P30–EXTERNAL ΔV
TEI 26 & TEI 32

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} N44	+					
						$H_{Perigee}$ 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:

P30–EXTERNAL ΔV

TEI 42

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} N44	+							
						$H_{Perigee}$ 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 (degrees)		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:

P30–EXTERNAL ΔV

Plane Change 1 & TEI 53

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} N44	+							
						$H_{Perigee}$ 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 (degrees)		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

Plane Change 1

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 N85 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

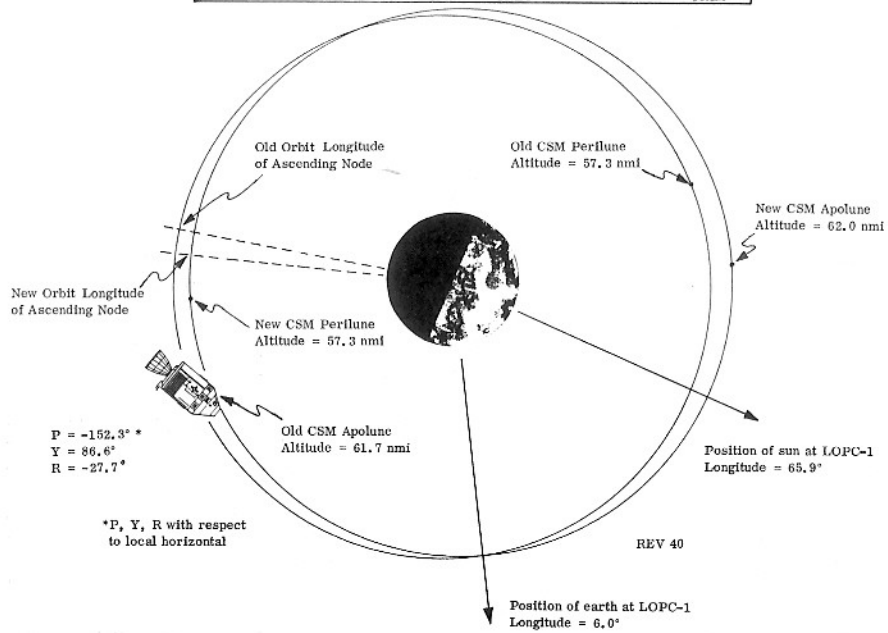
V16 N44 Flashing, Apogee Altitude, Perigee Altitude, Time to Freefall to 35 K ft Moon Orbit, 300 K ft Earth Orbit

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)

LUNAR ORBIT PLANE CHANGE NO. 1

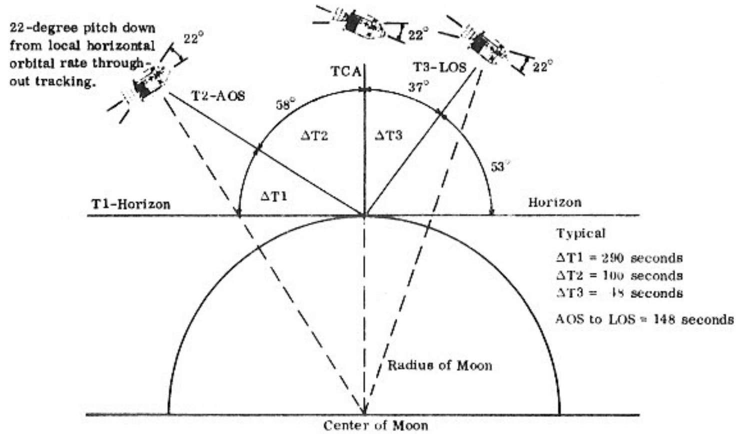
EVENT	BT/ΔV	G.E.T.	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
LOPC-1 (OUT-OF-PLANE)	9.1/158.7	152:28:48.1	SPS/G&N EXT Δ V (P-40)	P-30
	ΔV_x N85		+ x x	h
	ΔV_y RESIDUALS (ft/s)		+ x x x	min GET
	ΔV_z (BODY AXIS)		+ x	s

$V_{x_{TRIM}}$ $V_{y_{TRIM}}$ $V_{z_{TRIM}}$ (ft/s)



P24 – LANDMARK TRACKING

CSM Landmark Tracking Profile



TGT: ( )

T_1 _ _ _:_ _:_ _

T_2 _ _ _:_ _:_ _

TCA _ _ _:_ _:_ _

T_3 _ _ _:_ _:_ _

R _ _ _° P _ _ _° Y _ _ _° (T2 ACQ)

N or S nmi _ _ / SA _ _ TA _ _ (T2 ACQ)

N89 LAT _ _._ _ _

LONG/2 _ _._ _ _

ALT _ _ _._ _

TGT: ( )

T_1 _ _ _:_ _:_ _

T_2 _ _ _:_ _:_ _

TCA _ _ _:_ _:_ _

T_3 _ _ _:_ _:_ _

R _ _ _° P _ _ _° Y _ _ _° (T2 ACQ)

N or S nmi _ _ / SA _ _ TA _ _ (T2 ACQ)

N89 LAT _ _._ _ _

LONG/2 _ _._ _ _

ALT _ _ _._ _

P24 RATE-AIDED OPTICS TRACKING

CMC - on (req)
ISS - on and aligned
SCS - on
BMAG MODE (3) - RATE 2
G&N PWR OPTICS - on
OPT ZERO - ZERO (verify)
OPT MODE - CMC

V37E 24E

F 06 89 LAT, LONG/2, ALT (0.001°, 0.001°, 0.01 nmi)
LOAD LMK COORDS
OPT ZERO - OFF
PRO

06 92 AUTO OPT SHF/TRUN (0.01°, 0.001°)
- F 05 09 00404 (TRUN >90°)
- MNVR to acquire
- PRO
- or V34E, F 37

OPTICS MODE - MAN

F 51 MARK REQUEST
MARK (as often as desired)
To terminate:
PRO

F 37 XXE
OPT ZERO - ZERO

P24 – LANDMARK TRACKING

MARK DATA

+	0	0				Hours		+	0	0			
+	0	0	0			Minutes	GET	+	0	0	0		
+	0					Seconds		+	0				
+						P		+					
+						Y	IMU Gimbal Angles (degree)	+					
+						R		+					
+						Shaft	SXT Angles (degree)	+					
+						Trunnion		+					

+	0	0				Hours		+	0	0			
+	0	0	0			Minutes	GET	+	0	0	0		
+	0					Seconds		+	0				
+						P		+					
+						Y	IMU Gimbal Angles (degree)	+					
+						R		+					
+						Shaft	SXT Angles (degree)	+					
+						Trunnion		+					

+	0	0				Hours		+	0	0			
+	0	0	0			Minutes	GET	+	0	0	0		
+	0					Seconds		+	0				
+						P		+					
+						Y	IMU Gimbal Angles (degree)	+					
+						R		+					
+						Shaft	SXT Angles (degree)	+					
+						Trunnion		+					

NOTES:

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				

NOTES:

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)
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 N94 Flashing
  VGX, 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
  V16 N44 Flashing
    Apocenter altitude, pericenter altitude, TFF (0.1 nmi, 0.1 nmi, min/s)

+	0	0			Hours	N33	+	0	0			
+	0	0	0		Minutes — TIG of Ascent		+	0	0	0		
+	0				Seconds		+	0				
+					Desired Downrange Velocity (ft/s)	N76	+					
+					Desired Radial Velocity (ft/s)		+					
	0				*Crossrange Distance (nmi)			0				
					047 Sine of Azimuth Angle (Octal) (AGS)							
					053 Cosine of Azimuth Angle (Octal (AGS)							
					224/226 Semimajor Axis at Insertion (k ft) (AGS)							
					231 Landing Site Radius (k ft) (AGS)							
					465 Target Radial Rate at Insertion (ft/s) (AGS)							
					373 TIG of TPI (min) (AGS)							
+	0	0			Hours	N37	+	0	0			
+	0	0	0		Minutes — TIG of TPI		+	0	0	0		
+	0				Seconds		+	0				
+					LM Weight (lb)		+					
+					H_{Apogee} CSM (nmi)		+					
+					$H_{Perigee}$ CSM (nmi)		+					

*Load 8 nmi if crossrange is greater than 8 nmi.

NOTES:

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	N11	+	0	0			
+	0	0	0			Minutes TIG for CSI		+	0	0	0		
+	0					Seconds (LGC)		+	0				

N55 (+00001) No. of Apsidal Crossings (+026.60) Elevation Angle (+130.00) Central Angle

+	0	0				Hours	N37	+	0	0			
+	0	0	0			Minutes TIG for TPI		+	0	0	0		
+	0					Seconds (LGC)		+	0				
+	0					ΔV_X Components of ΔV in local	N81	+	0				
	0					ΔV_Y vertical coordinates (ft/s)			0				
+						373 TIG for CSI (AGS) (minutes)		+					
+						275 TIG for TPI (AGS) (minutes)		+					

410 +1(AGS-CSI), 605 + 00777 (desired cotan of LOS angle between LM and CSM at desired TPI in octal),
416 + 1(compute CSI with CDH at ½ orbit after CSI), 623 + 0 (orient Z body-axis parallel to CSM orbit plane.)

	0					ΔV_X Components of ΔV in local	N86		0				
	0					ΔV_Y vertical coordinates used in AGS (ft/s)			0				
	0					ΔV_Z			0				

NOTES:

ASCENT

MANUAL ASCENT (WILL NOMINALLY BE TARGETED 11.5 MIN LATE)
CONFIGURATION NOMINAL EXCEPT:
MODE CONT - ATT HOLD
PROFILE NOMINAL EXCEPT:
7-STEP FOR DIRECT MODE

TFI	FDAI	OHW
0:00		0
0:15	305	
2:00	295	31
3:00	290	28
4:00	285	24
5:00	275	18
6:00	265	11
7:00	260	8

PITCH RATES 5°/SEC

TFI	θ	OHW (0°YAW)	VGX	H DOT	H	SBD
0:00			1080.0	0.0	0	79/-30
0:10			880.0	53.0	300	
0:30	308	39	4810.0	91.0	1800	
1:00	305	38	4640.0	124.0	5100	137/-18
1:30	302	36	4460.0	151.0	9200	
2:00	299	34	4240.0	170.0	14000	142/-15
2:30	296	31	3980.0	183.0	19400	
3:00	293	29	3700.0	190.0	25000	147/-11
3:30	289	27	3380.0	190.0	30700	
4:00	285	24	3020.0	184.0	36300	152/-6
4:30	282	22	2640.0	173.0	41700	
5:00	278	19	2230.0	157.0	46600	158/-1
5:30	274	17	1790.0	135.0	51000	
6:00	269	14	1320.0	109.0	54700	164/4
6:30	265	11	810.0	80.0	57500	
7:00	260	8	270.0	49.0	59500	170/11
7:14	257	6	0.0	32.0	60100	172/13

TIG-2 MASTER ARM - ON
AUDIO MODE (BOTH) - VOX
400+1E GUID STEERING
RESET WATCH
(604+0 FOR AGS)
367R
START CAMERA
- :10 ABORT STAGE - PUSH (AT T=0
ENG ARM - ASC FOR AGS)
- :05 PRO
+ :00 [ASC] (171:45:09)
+ :01 ENG START-PUSH (IF AUTO IGN)
CHECK S-BD ANT

N76E (VH, Vv, ΔR)
V16 N77E (Tgo, VY, VI)
KEY RLSE

+4:00 STOP CAMERA
500R
500 FPS MAIN SOV (2) - OPEN↑
ASC FEED 2 (2) - CLOSE↓
200 FPS ENG ARM-OFF(IF IGN WAS AUTO)
0 FPS ABORT STAGE-RESET
ENG STOP - PUSH

PRO, NULL X < 2 FPS
PRO
STOP DET, RESET WATCH
COPY GET
ENG STOP - RESET
P00
AMCC FOR TWEAK

FOR NO VOICE (TRIM <2 FPS)
PGNS,AGS DIFFER <10 FPS,
TRIM ACTIVE SYSTEM
PGNS,AGS DIFFER >10 FPS,
TRIM SYSTEM THAT AGREES
WITH RR
(10° IN OHW) (0° YAW)

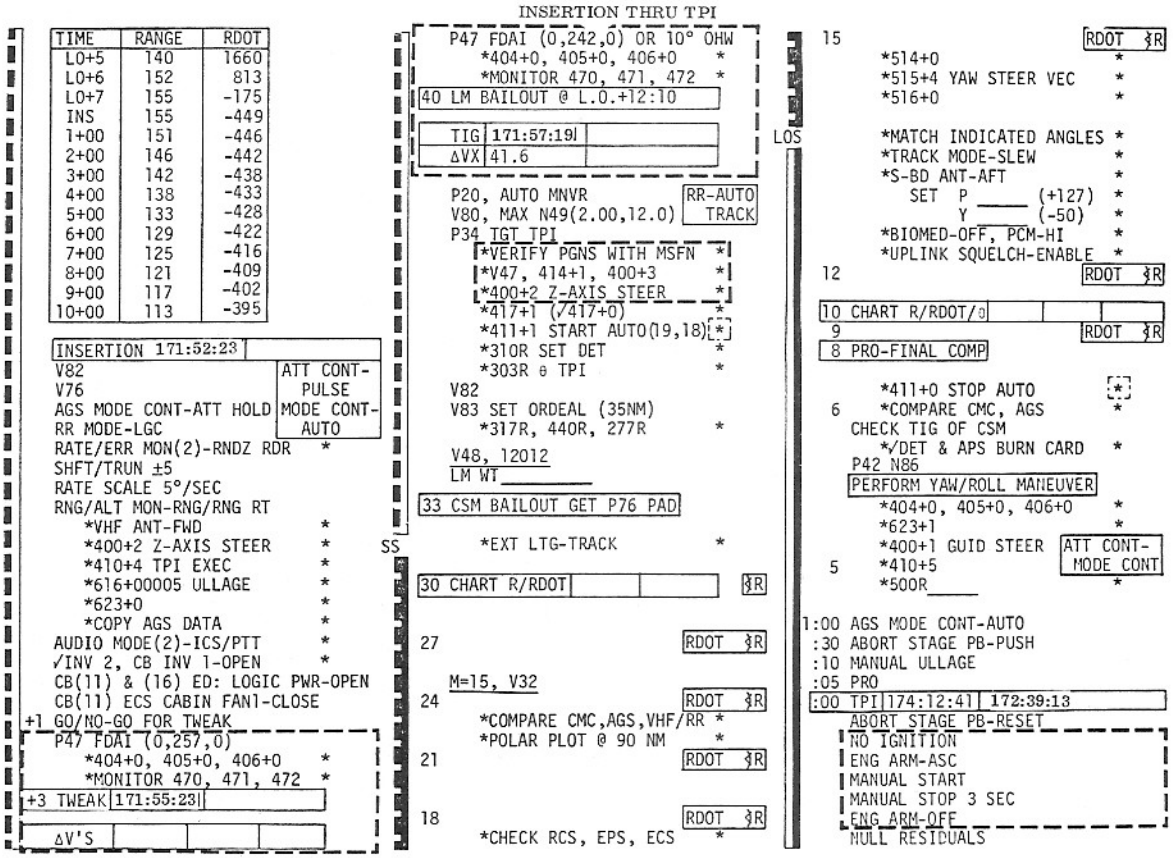
V82

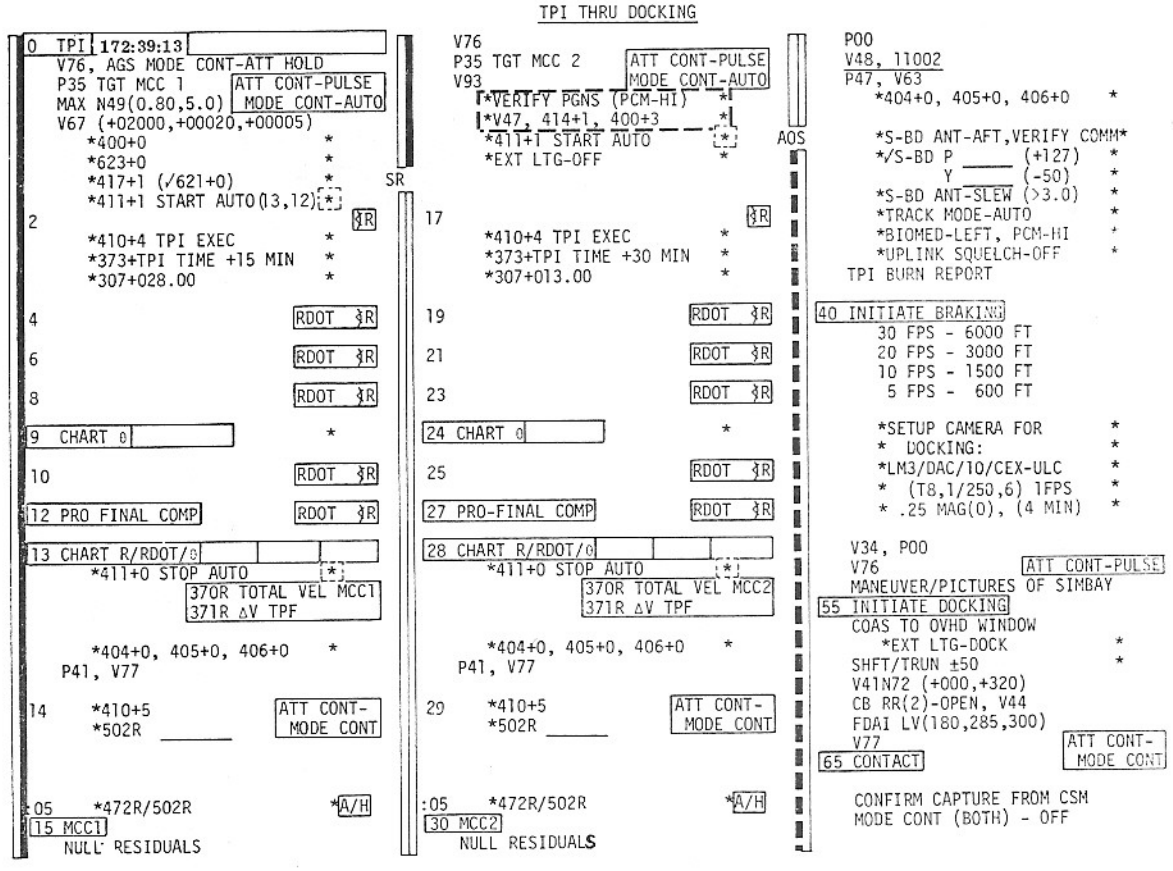
MSFN WILL CALL PITCH AND ROLL BIAS COMMANDS FROM GROUND TRACKING.

6+30 - MAIN SOV(2) - OPEN↑
ASC FEED 2 (2) - CLOSE↓

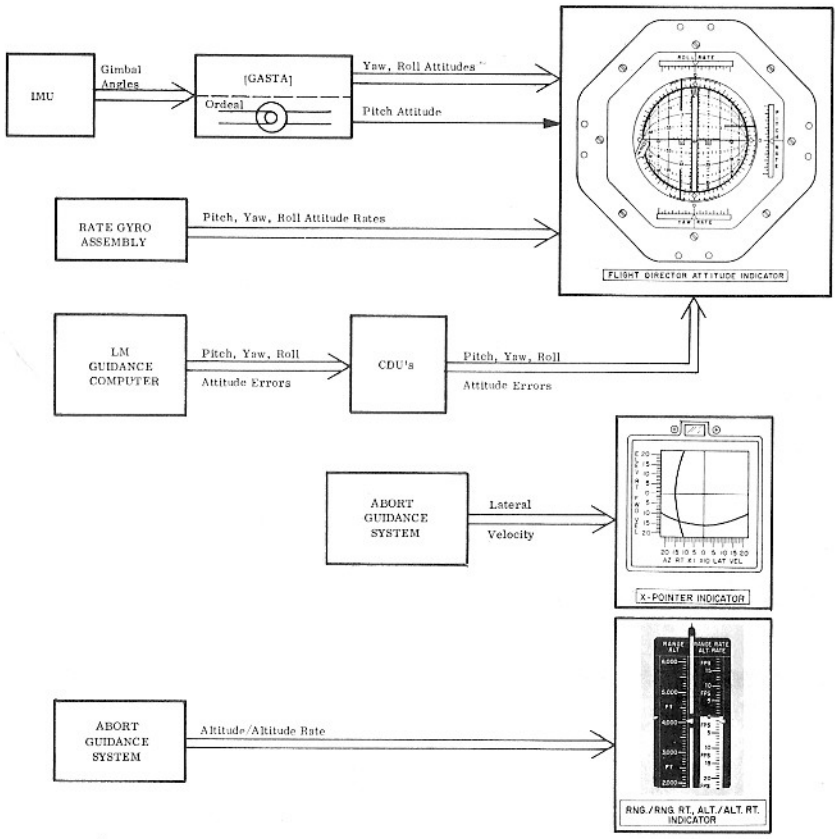
SHUTDOWN
ENGINE ARM OFF
STANDBY TO RESET ABORT STAGE
Pb AND DEPRESS ENGINE STOP
Pb ON CALL FROM MSFN

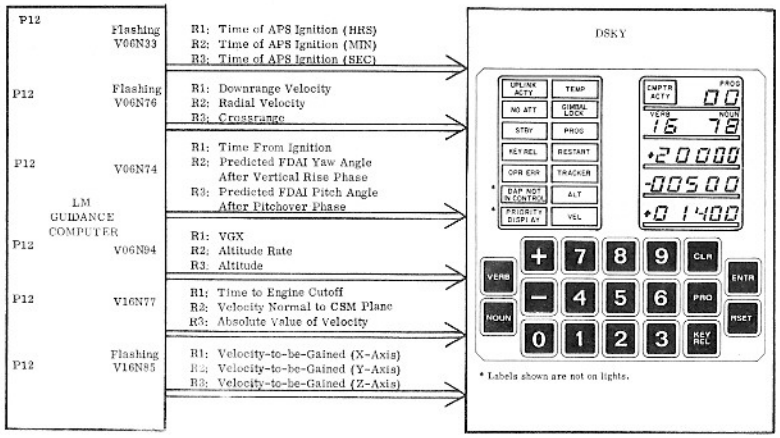
NO AUTO IGNITION
WITHIN 10 SEC:
1. GUID CONT-AGS
STILL NO IGNITION
1. GUID CONT-PGNS
2. ENG START-PUSH

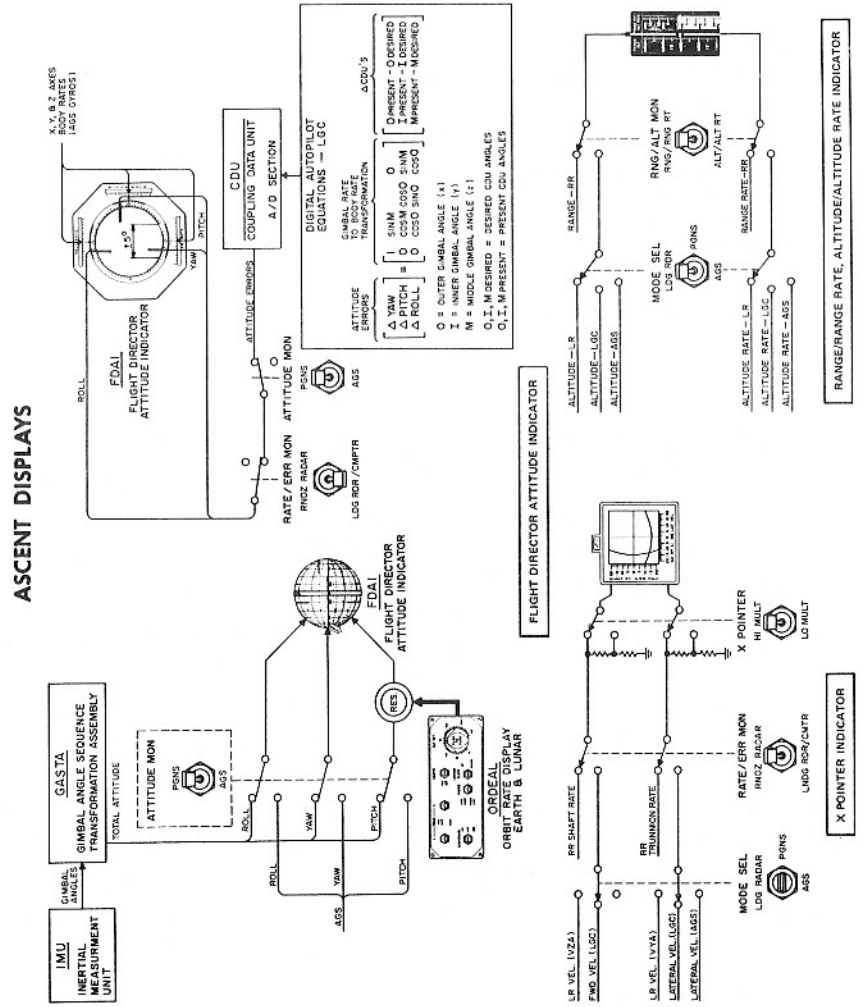

INSERTION THRU TPI
TIME | RANGE | RDOT
L0+5 | 140 | 1660
L0+6 | 152 | 813
L0+7 | 155 | -175
INS | 155 | -449
1+00 | 151 | -446
2+00 | 146 | -442
3+00 | 142 | -438
4+00 | 138 | -433
5+00 | 133 | -428
6+00 | 129 | -422
7+00 | 125 | -416
8+00 | 121 | -409
9+00 | 117 | -402
10+00 | 113 | -395
INSERTION 171:52:23
V82
V76
AGS MODE CONT-ATT HOLD
RR MODE-LGC
ATT CONT-PULSE
MODE CONT-AUTO
RATE/ERR MON(2)-RNDZ RDR
SHFT/TRUN ±5
RATE SCALE 5°/SEC
RNG/ALT MON-RNG/RNG RT
*VHF ANT-FWD
*400+2 Z-AXIS STEER
*410+4 TPI EXEC
*616+00005 ULLAGE
*623+0
*COPY AGS DATA
AUDIO MODE(2)-ICS/PTT
✓INV 2, CB INV 1-OPEN
CB(11) & (16) ED: LOGIC PWR-OPEN
CB(11) ECS CABIN FAN1-CLOSE
+1 GO/NO-GO FOR TWEAK
P47 FDAI (0,257,0)
*404+0, 405+0, 406+0
*MONITOR 470, 471, 472
+3 TWEAK 171:55:23
ΔV'S
SS
P47 FDAI (0,242,0) OR 10° OHW
*404+0, 405+0, 406+0
*MONITOR 470, 471, 472
40 LM BAILOUT @ L.O.+12:10
TIG 171:57:19
ΔVX 41.6
P20, AUTO MNVR
V80, MAX N49(2.00,12.0)
RR-AUTO TRACK
P34 TGT TPI
*VERIFY PGNS WITH MSFN
*V47, 414+1, 400+3
*400+2 Z-AXIS STEER
*417+1 (✓417+0)
*411+1 START AUTO(19,18)
*310R SET DET
*303R θ TPI
V82
V83 SET ORDEAL (35NM)
*317R, 440R, 277R
V48, 12012
LM WT
33 CSM BAILOUT GET P76 PAD
*EXT LTG-TRACK
30 CHART R/RDOT
27 RDOT
M=15, V32
24 RDOT
*COMPARE CMC,AGS,VHF/RR
*POLAR PLOT @ 90 NM
21 RDOT
18 RDOT
*CHECK RCS, EPS, ECS
LOS
15 RDOT
*514+0
*515+4 YAW STEER VEC
*516+0
*MATCH INDICATED ANGLES
*TRACK MODE-SLEW
*S-BD ANT-AFT
SET P _____ (+127)
Y _____ (-50)
*BIOMED-OFF, PCM-HI
*UPLINK SQUELCH-ENABLE
12 RDOT
10 CHART R/RDOT/θ
9 RDOT
8 PRO-FINAL COMP
*411+0 STOP AUTO
6 *COMPARE CMC, AGS
CHECK TIG OF CSM
*✓DET & APS BURN CARD
P42 N86
PERFORM YAW/ROLL MANEUVER
*404+0, 405+0, 406+0
*623+1
*400+1 GUID STEER
5 *410+5
*500R
ATT CONT-MODE CONT
1:00 AGS MODE CONT-AUTO
:30 ABORT STAGE PB-PUSH
:10 MANUAL ULLAGE
:05 PRO
:00 TPI 174:12:41 172:39:13
ABORT STAGE PB-RESET
NO IGNITION
ENG ARM-ASC
MANUAL START
MANUAL STOP 3 SEC
ENG ARM-OFF
NULL RESIDUALS
LB-128


TPI THRU DOCKING
0 TPI 172:39:13
V76, AGS MODE CONT-ATT HOLD
P35 TGT MCC 1
ATT CONT-PULSE
MODE CONT-AUTO
MAX N49(0.80,5.0)
V67 (+02000,+00020,+00005)
*400+0
*623+0
*417+1 (✓621+0)
*411+1 START AUTO(13,12)
2 R
*410+4 TPI EXEC
*373+TPI TIME +15 MIN
*307+028.00
4 RDOT R
6 RDOT R
8 RDOT R
9 CHART θ
10 RDOT R
12 PRO FINAL COMP RDOT R
13 CHART R/RDOT/θ
*411+0 STOP AUTO
370R TOTAL VEL MCC1
371R ΔV TPF
*404+0, 405+0, 406+0
P41, V77
14 *410+5
*502R
ATT CONT-MODE CONT
:05 *472R/502R *A/H
15 MCC1
NULL RESIDUALS
SR
V76
P35 TGT MCC 2
ATT CONT-PULSE
MODE CONT-AUTO
V93
*VERIFY PGNS (PCM-HI)
*V47, 414+1, 400+3
*411+1 START AUTO
*EXT LTG-OFF
17 R
*410+4 TPI EXEC
*373+TPI TIME +30 MIN
*307+013.00
19 RDOT R
21 RDOT R
23 RDOT R
24 CHART θ
25 RDOT R
27 PRO-FINAL COMP RDOT R
28 CHART R/RDOT/θ
*411+0 STOP AUTO
370R TOTAL VEL MCC2
371R ΔV TPF
*404+0, 405+0, 406+0
P41, V77
29 *410+5
*502R
ATT CONT-MODE CONT
:05 *472R/502R *A/H
30 MCC2
NULL RESIDUALS
AOS
P00
V48, 11002
P47, V63
*404+0, 405+0, 406+0
*S-BD ANT-AFT,VERIFY COMM
*✓S-BD P _____ (+127)
Y _____ (-50)
*S-BD ANT-SLEW (>3.0)
*TRACK MODE-AUTO
*BIOMED-LEFT, PCM-HI
*UPLINK SQUELCH-OFF
TPI BURN REPORT
40 INITIATE BRAKING
30 FPS - 6000 FT
20 FPS - 3000 FT
10 FPS - 1500 FT
5 FPS - 600 FT
*SETUP CAMERA FOR
* DOCKING:
*LM3/DAC/10/CEX-ULC
* (T8,1/250,6) 1FPS
* .25 MAG(0), (4 MIN)
V34, P00
V76
ATT CONT-PULSE
MANEUVER/PICTURES OF SIMBAY
55 INITIATE DOCKING
COAS TO OVHD WINDOW
*EXT LTG-DOCK
SHFT/TRUN ±50
V41N72 (+000,+320)
CB RR(2)-OPEN, V44
FDAI LV(180,285,300)
V77
ATT CONT-MODE CONT
65 CONTACT
CONFIRM CAPTURE FROM CSM
MODE CONT (BOTH) - OFF
LB-129

ASCENT DISPLAYS
(P12)







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)

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 N94 Flashing
  VGX, 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
  V16 N44 Flashing
    Apocenter altitude, pericenter altitude, TFF (0.1 nmi, 0.1 nmi, min/s)

+	0	0				Hours	N33	+	0	0			
+	0	0	0			Minutes TIG of Ascent		+	0	0	0		
+	0					Seconds		+	0				
+						Desired Downrange Velocity (ft/s)	N76	+					
+						Desired Radial Velocity (ft/s)		+					
	0					*Crossrange Distance (nmi)			0				
						047 Sine of Azimuth Angle (Octal) (AGS)							
						053 Cosine of Azimuth Angle (Octal (AGS)							
						224/226 Semimajor Axis at Insertion (k ft) (AGS)							
						231 Landing Site Radius (k ft) (AGS)							
						465 Target Radial Rate at Insertion (ft/s) (AGS)							
						373 TIG of TPI (min) (AGS)							
+	0	0				Hours	N37	+	0	0			
+	0	0	0			Minutes TIG of TPI		+	0	0	0		
+	0					Seconds		+	0				
+						LM Weight (lb)		+					
+						H_{Apogee} CSM (nmi)		+					
+						$H_{Perigee}$		+					

*Load 8 nmi if crossrange is greater than 8 nmi.

NOTES:

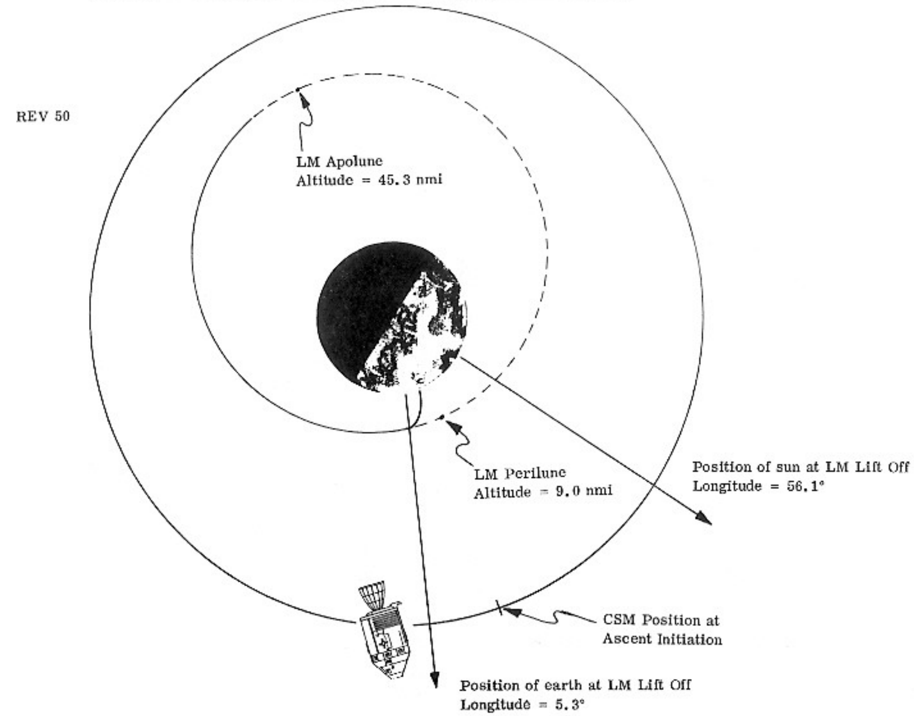
LM INSERTION

EVENT	BT/ΔV	G.E.T.	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
INSERTION	434.3/ 6047.9	171:45:08.6	LM-APS/PGNS	P-12

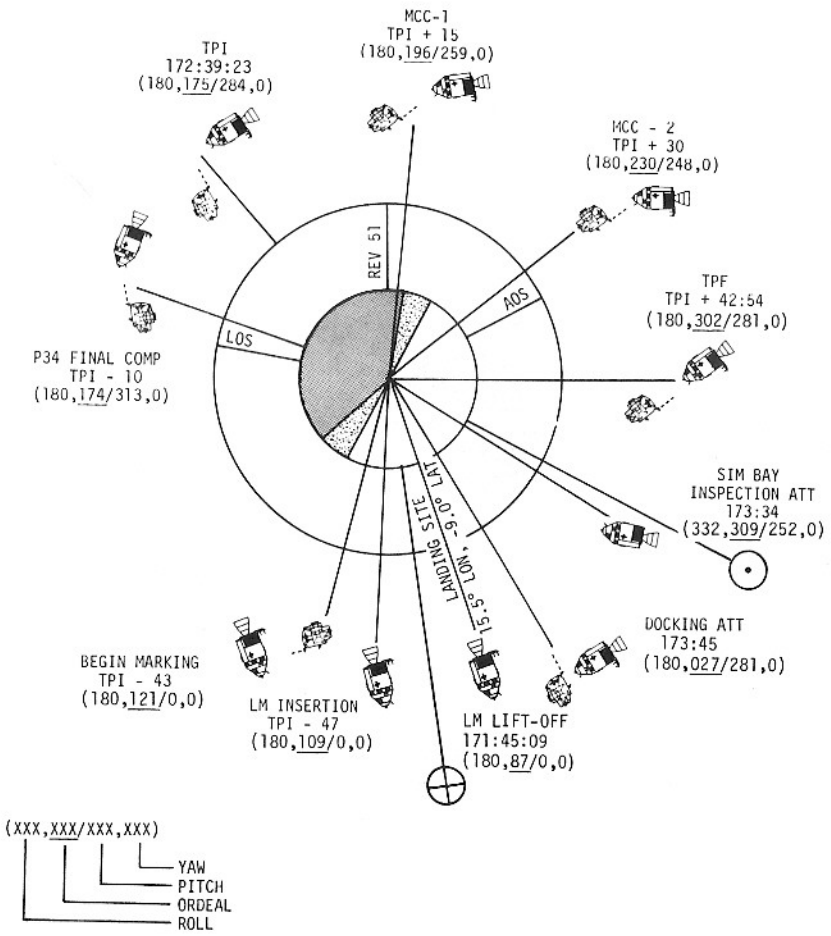
RESIDUALS (ft/s)					
ΔV_x	N85		AGS	500	
ΔV_y	PGNS			501	
ΔV_z				502	

+	x	x				h	
+	x	x	x			min	GET
+	x					s	

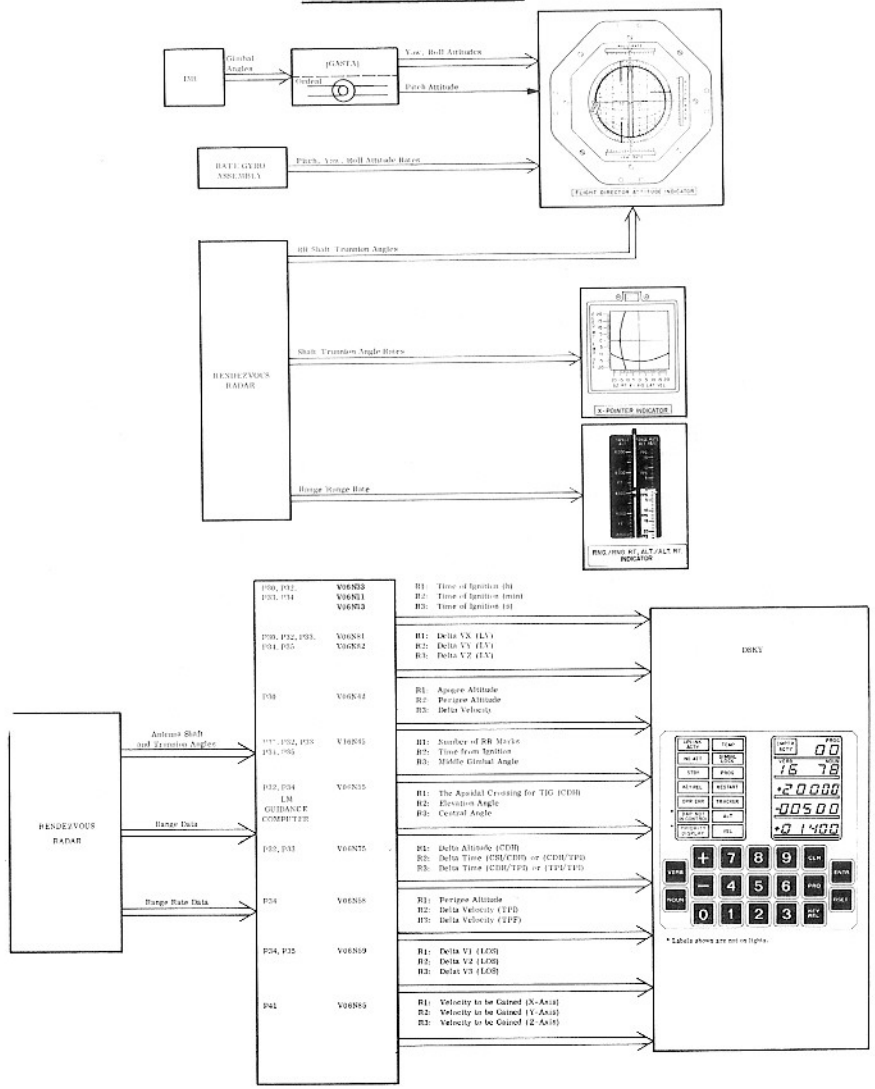
$V_{x_{TRIM}}$ $V_{y_{TRIM}}$ $V_{z_{TRIM}}$ (ft/s)



RENDEZVOUS



RENDEZVOUS DISPLAYS



P34—TRANSFER PHASE INITIATION (TPI)

V37 Enter, 34 Enter
V06 N37 Flashing
TIG of TPI (h, min, 0.01 s)
V06 N55 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)

+	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				
N55 (+00000) Conic Integration, (+00000)* Elevation Angle (+130.00) Central Angle													
	0					ΔV_X (LV) — Components of ΔV in local vertical coordinates (ft/s)	N81		0				
	0					ΔV_Y (LV)			0				
	0					ΔV_Z (LV)			0				
+	0					Range at TIG-5 min (nmi)	N54	+	0				
	0					Range rate at TIG-5 min (ft/s)			0				
X	X					Burn time (min/s)		X	X				

*P34 calculates Elevation Angle for given TIG of TPI

NOTES:

DIRECT TPI

PGNS				
: :	: :	: :	TIG TPI	N37
+ 0	+ 0	+ 0	HP (nmi)	N58
+ 0	+ 0	+ 0	ΔV TPI (ft/s)	
+ 0	+ 0	+ 0	ΔV TPF (ft/s)	
.	.	.	ΔVX LV (ft/s)	N81
.	.	.	ΔVY	
.	.	.	ΔVZ	
AGS				
0	0	0	θ LOS (deg)	303
0	0	0	ΔV TPI (ft/s)	370
0	0	0	ΔV TPF (ft/s)	371
.	.	.	ΔVX LV (ft/s)	450
.	.	.	ΔVY	451
.	.	.	ΔVZ	452
CSM				
: :	: :	: :	TIG TPI	N37
.	.	.	ΔVX LV (ft/s)	
.	.	.	ΔVY	
.	.	.	ΔVZ	
CHANGE SIGN; BIAS, ΔVX = -1.0, ΔVZ = +2.0				
			ELEV ≯	N55

BURN RULES

If two of three solutions agree, burn priority solution.

Priority of Solutions: PGNS, AGS, CMC, Charts

Guide Values: $\dot{X} = 3$ ft/s, $\dot{Y} = 7$ ft/s, $\dot{Z} = 9$ ft/s

RR agrees with VHF where
ΔR = 0.01R + 0.5 nmi, ΔR is always ≥1 nmi.

If RR does not agree with VHF, MSFN isolates failed system.

TRANSFER PHASE INITIATION

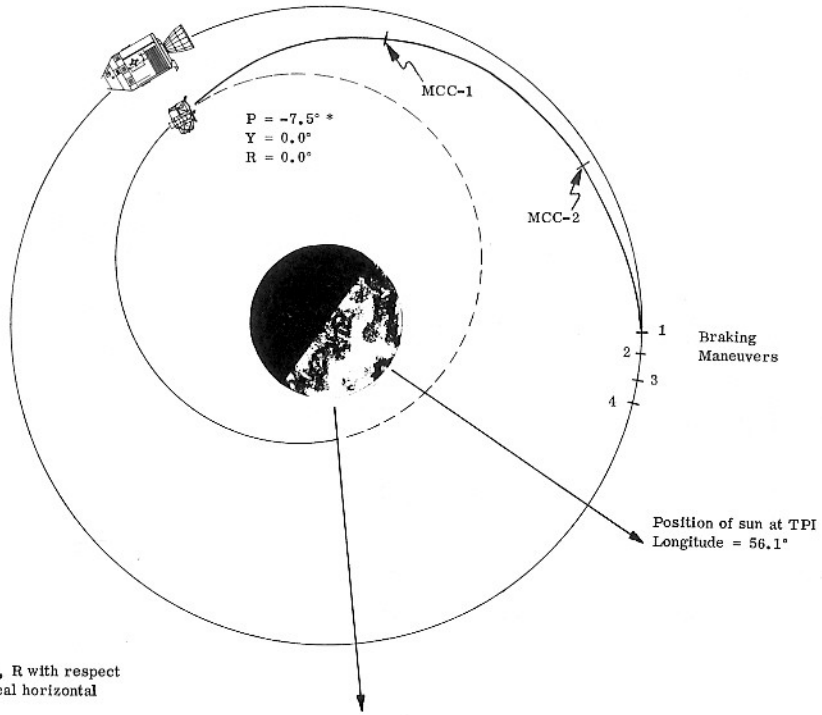
EVENT	BT/ΔV	G.E.T.	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
TPI	12.5/72.1	172:39:22.9	LM-APS/PGNS LAMBERT (P-42)	P-34

RESIDUALS (ft/s)

ΔV_x	N85	500	+ x x h
ΔV_y	PGNS	AGS 501	+ x x x min GET
ΔV_z		502	+ x s

$V_{x_{TRIM}}$ $V_{y_{TRIM}}$ $V_{z_{TRIM}}$ (ft/s)

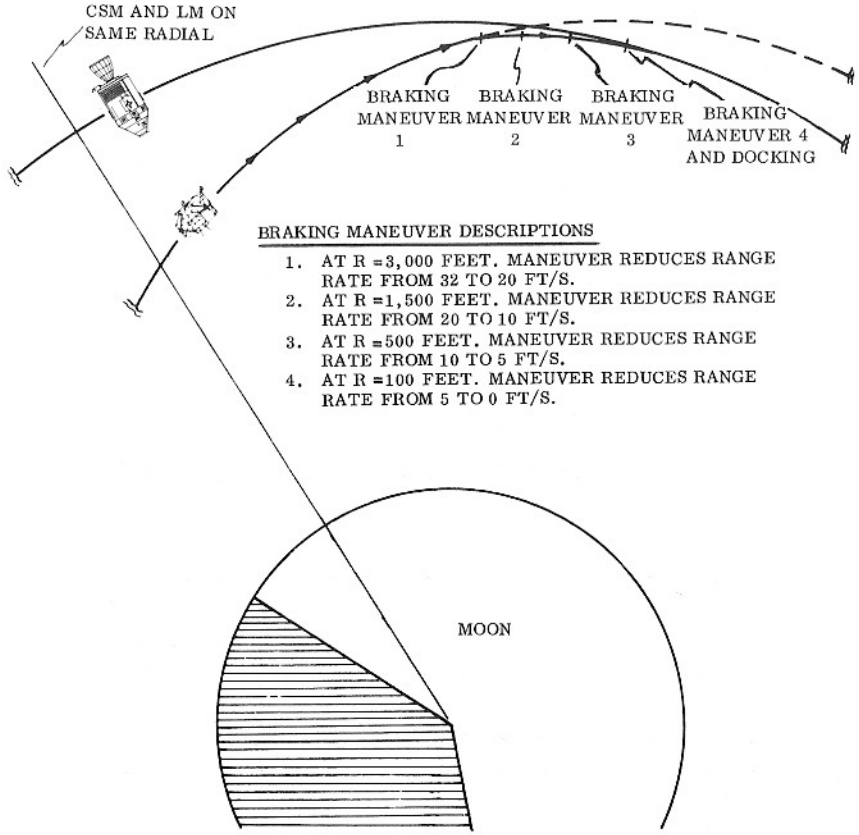
REVS 50/51



*P, Y, R with respect to local horizontal

Position of earth at TPI
Longitude = 5.3°

LM RENDEZVOUS FINAL PHASE



BRAKING MANEUVER DESCRIPTIONS

1. AT R = 3,000 FEET. MANEUVER REDUCES RANGE RATE FROM 32 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.

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		X	X	X			
X	X	X				P Angles (degrees)		X	X	X			
						ΔV_X	N86						
						ΔV_Y AGS Targeting (ft/s)							
						ΔV_Z							
+						H_{Apogee}	N42	+					
						$H_{Perigee}$ (nmi)							
+						ΔVT (ft/s)		+					

LM JETTISON PAD

+	0	0				Hours		+	0	0			
+	0	0	0			Minutes GETI JETT		+	0	0	0		
+	0					Seconds		+	0				
X	X	X				R	N22	X	X	X			
X	X	X				P IMU Gimbal Angles (deg)		X	X	X			
X	X	X				Y		X	X	X			

P99–LM DEORBIT BURN

						Time from Ignition	N40						
						Velocity to be Gained							
						Velocity Accumulated							
						Time from Ignition	N40						
						Velocity to be Gained							
						Velocity Accumulated							
						X	N85						
						Y Residuals (ft/s)							
						Z							

P30–EXTERNAL ΔV
CSM Separation & TEI 62

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}	N44	+					
						$H_{Perigee}$ 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:

P41 — RCS THRUSTING

CSM Separation

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		

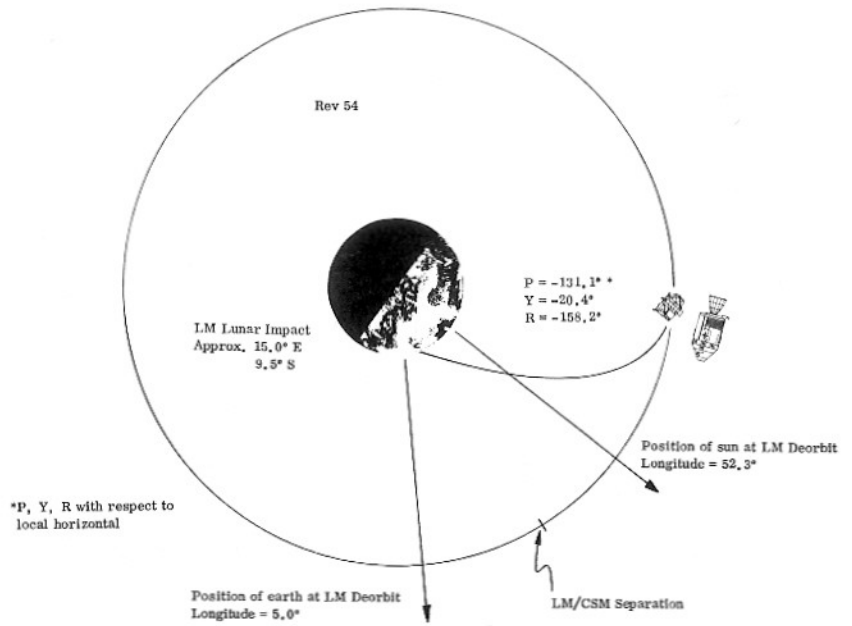
LM DEORBIT

EVENT	BT/ΔV	G.E.T.	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
LM DEORBIT (RETROGRADE)	95.5/229.6	179:16:29.2	LM-RCS/PGNS EXT ΔV (P-99)	P-30

RESIDUALS (ft/s)

ΔV_x	N85	AGS 500	+ x x	h
ΔV_y	PGNS	AGS 501	+ x x x	min GET
ΔV_z		AGS 502	+ x	s

$V_{x_{TRIM}}$ $V_{y_{TRIM}}$ $V_{z_{TRIM}}$ (ft/s)



*P, Y, R with respect to local horizontal

P30–EXTERNAL ΔV
TEI 65 & Plane Change 2

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}	N44	+						
							$H_{Perigee}$ 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
Plane Change 2

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

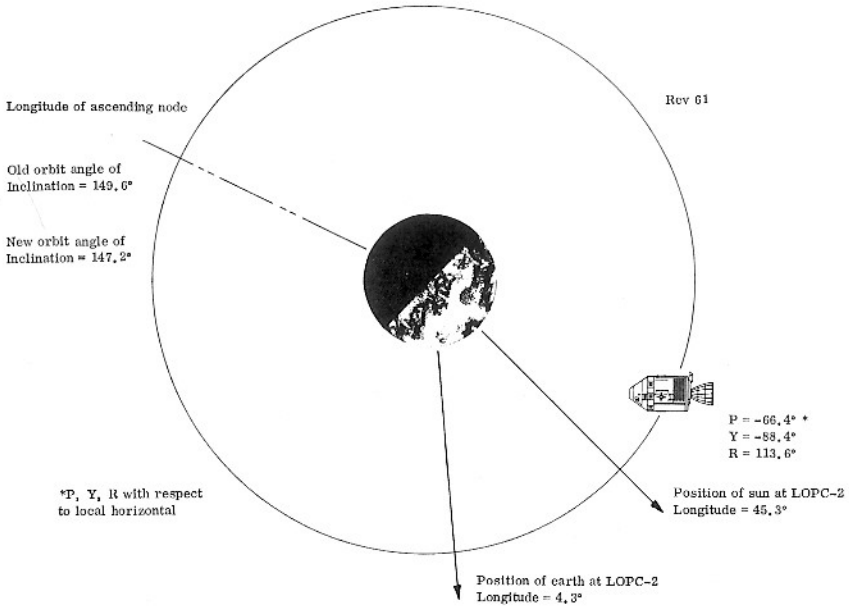
						50-18	Roll									
							Pitch (deg)									
							Yaw									
						06-18	Roll									
							Pitch (deg)									
							Yaw									
			X			06-40	TFI (min:s)							X		
							VG (ft/s)									
							ΔVM (ft/s)									
			X			06-40	TFC (min:s)							X		
							VG (ft/s)									
							ΔVM (ft/s)									
			X			16-40	TFC (min:s)							X		
							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)							X		

LUNAR ORBIT PLANE CHANGE NO. 2

EVENT	BT/ΔV	G.E.T.	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
LOPC-2 (OUT-OF-PLANE)	15.8/282.5	193:13:46.2	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)



P30–EXTERNAL ΔV

TEI 72 & TEI 74

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}	N44	+					
						$H_{Perigee}$ 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:

P30–EXTERNAL ΔV

Shape

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} N44	+						
						$H_{Perigee}$ 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

Shape

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

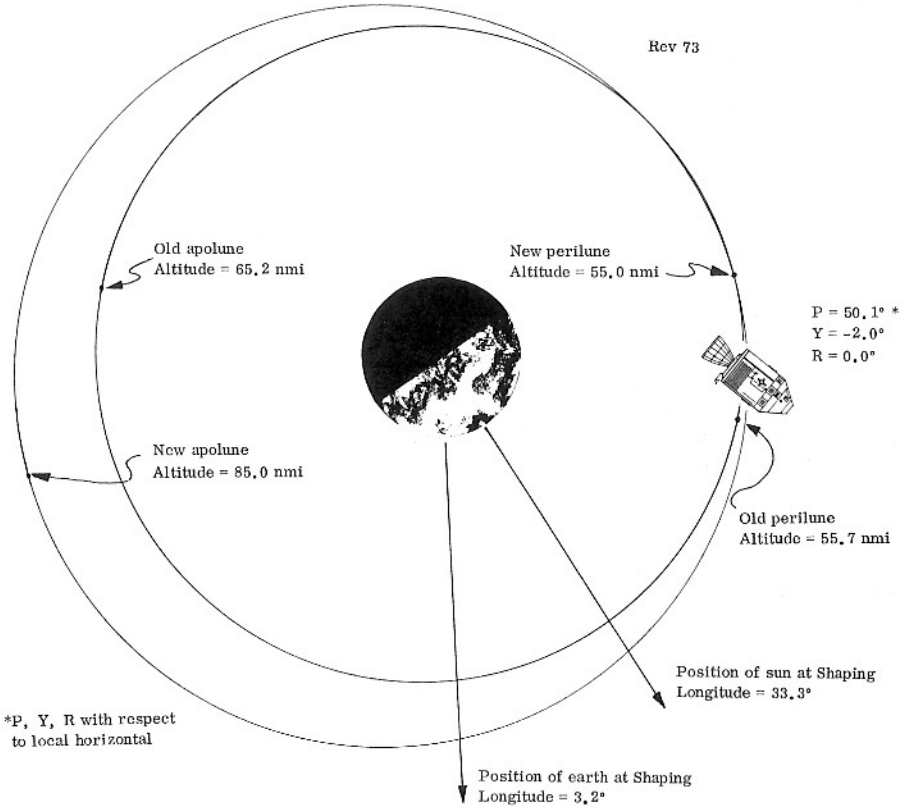
						50-18	Roll						
							Pitch (deg)						
							Yaw						
						06-18	Roll						
							Pitch (deg)						
							Yaw						
		X				06-40	TFI (min:s)				X		
							VG (ft/s)						
							ΔVM (ft/s)						
		X				06-40	TFC (min:s)				X		
							VG (ft/s)						
							ΔVM (ft/s)						
		X				16-40	TFC (min:s)				X		
							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)				X		

SHAPING

EVENT	BT/ΔV	G.E.T.	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
SHAPING	2.2/38.0	216:49:11.7	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)



P30—EXTERNAL ΔV

TEI 75 (Preliminary) & TEI 75

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}	N44	+					
						$H_{Perigee}$ 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:

P30—EXTERNAL ΔV

TEI 76

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} N44	+							
						$H_{Perigee}$ 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								

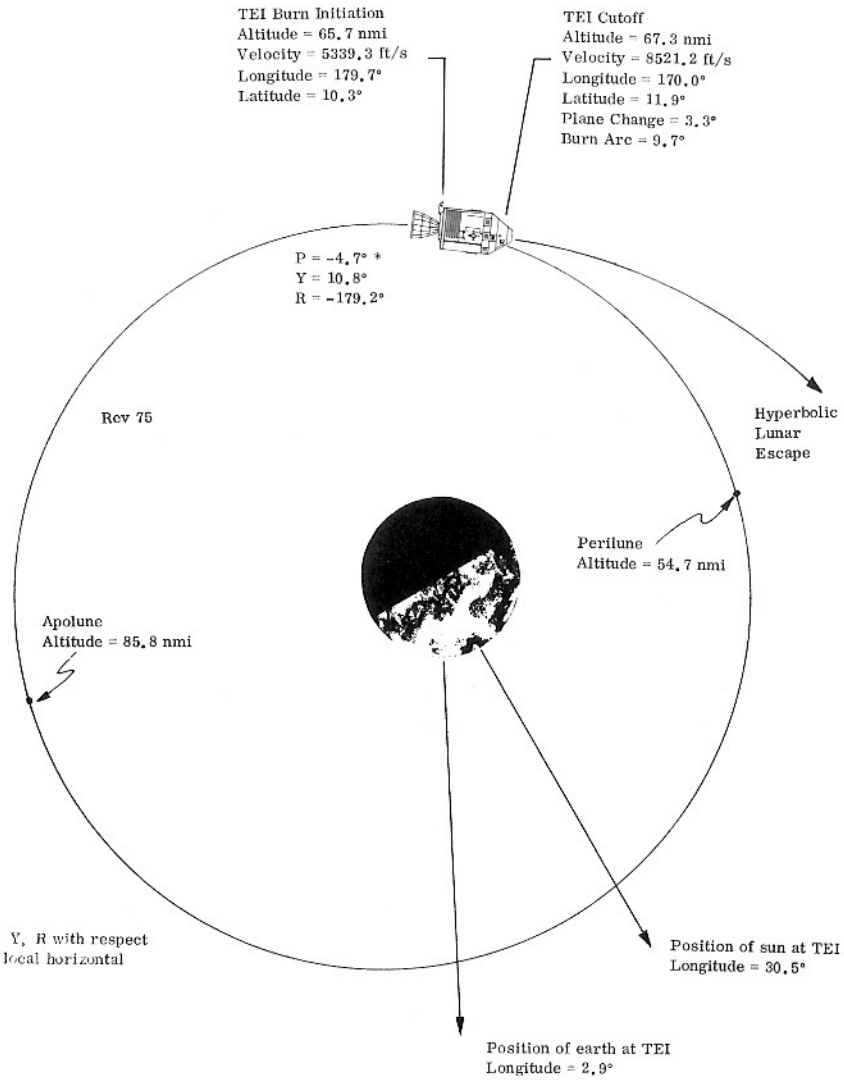
NOTES:

TRANSEARTH INJECTION

EVENT	BT/ΔV	G.E.T.	PROPULSION/ GUIDANCE	PRETHRUST TARGETING
TEI (POSIGRADE)	150.5/ 3212.2	222:20:32.8	SPS/G&N EXT Δ V (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)



P30–EXTERNAL ΔV
MCC 5

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} N44	+						
						$H_{Perigee}$ 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:

MCC 5

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						
		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)						

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						

P30–EXTERNAL ΔV

MCC 6

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} N44	+						
						$H_{Perigee}$ 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

MCC 6

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						
		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)						

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		↓	

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	X	X				R		X	X	X				
X	X	X				P	IMU Gimbal Angles (degrees)	X	X	X				
X	X	X				Y		X	X	X				
X	X	X		↓		BT	(min:s)	X	X	X		↓		
						VI	(ft/s)							
					↓	X	N83						↓	
					↓	Y	ΔV ft/s						↓	
					↓	Z							↓	
					↓	V	ft/s N62						↓	
					↓	HDOT	ft/s						↓	
					↓	H	nmi						↓	

NOTES:

P30—EXTERNAL ΔV

MCC 7

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}	N44	+						
						$H_{Perigee}$ 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

MCC 7

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 = 00204, 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	
		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)	

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

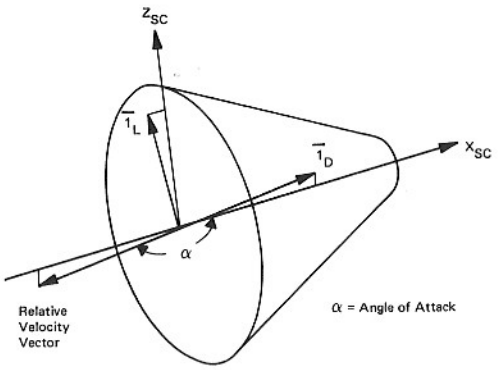
V16 N85 Flashing, Body Axes Residuals (to be Nulled)

						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	

APOLLO EARTH ENTRY

Aerodynamic Forces

The earth entry trajectory is shaped by the forces of gravity and atmospheric flow over the spacecraft surface. The latter force has two components, lift and drag.



Drag is a force directed opposite to the relative velocity vector and equal to:

$$\bar{D} = \tfrac{1}{2}\frac{SC_D}{M}\rho v^2 \bar{1}_D (ft/s^2)$$

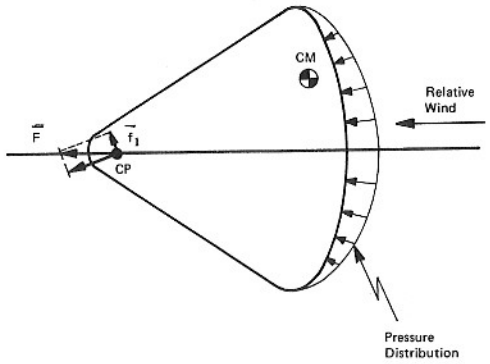
Lift is a force perpendicular to the relative velocity vector and equal to;

$$\bar{L} = \tfrac{1}{2}\frac{SC_L}{M}\rho v^2 \bar{1}_L (ft/s^2)$$

where,

ρ = Atmospheric density (slugs/ft^3)(1)
v = Relative velocity magnitude (ft/s)
C_D = Coefficient of drag (unitless)
C_L = Coefficient of lift (unitless)
M = Mass of spacecraft (slugs)
S = Surface area presented to atmospheric flow (ft^2)

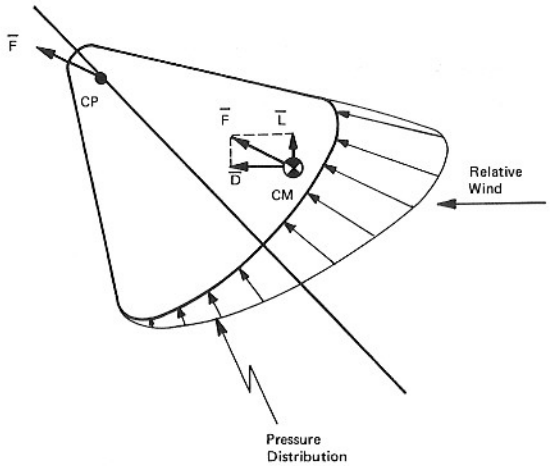
Aerodynamic lift (or C_L) is a consequence of the vehicle center-of-mass (CM)(2) being offset from its axis of symmetry. With the relative velocity vector along the axis of symmetry, the resulting symmetrical pressure distribution produces a resultant force ($\bar{F}$) through the center-of-pressure (CP)(3). The component of this force ($\bar{f}_1$) perpendicular to the line joining the CP and CM causes a torque about the CM. The spacecraft will rotate about the CM until a stable attitude is reached where the force $\bar{F}$ is fully along the line joining the CM and CP.



Notes:

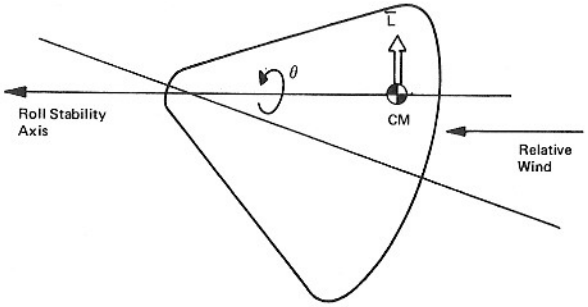
1. A slug is a constant, relating units in the equation
   F(pound-force) = M(slugs) x a(ft/s^2)
2. Center-of-mass: The point where the mass of a body may be regarded as being concentrated, insofar as motion of translation is concerned.
3. Center-of-pressure: The point where the resultant of all aerodynamic forces apparently operates.

In this stable attitude, the component of $\bar{F}$ perpendicular to the relative velocity vector produces lift. Because of the spherical shape of the heat shield, the stable attitude remains relatively unchanged throughout the entry phases.

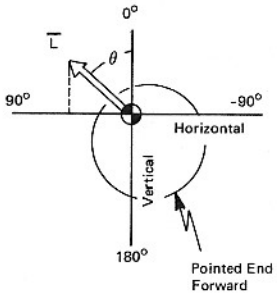


Lift Modulated Entry

During earth entry, steering is accomplished by orienting the lift vector ($\bar{L}$) so that the resulting specific forces satisfy the entry guidance objectives. The lift vector is rotated about the Roll Stability Axis according to roll commands issued by the AGC.

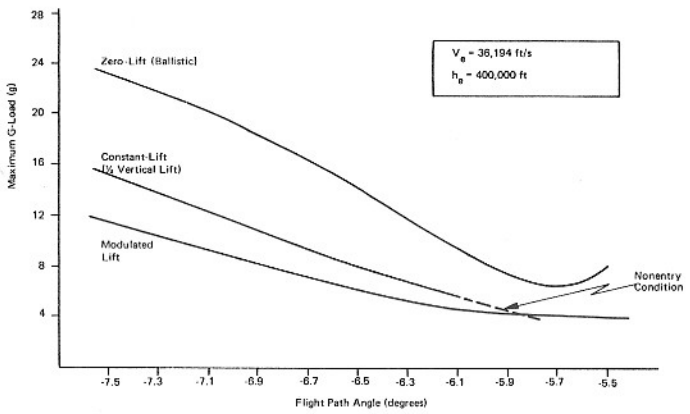


A roll angle (θ) of 0 degrees causes the lift vector to be up along the vertical and produces maximum downrange flight. A roll angle of ±90 degrees puts the lift vector in the local horizontal plane, producing maximum crossrange (or lateral) flight.

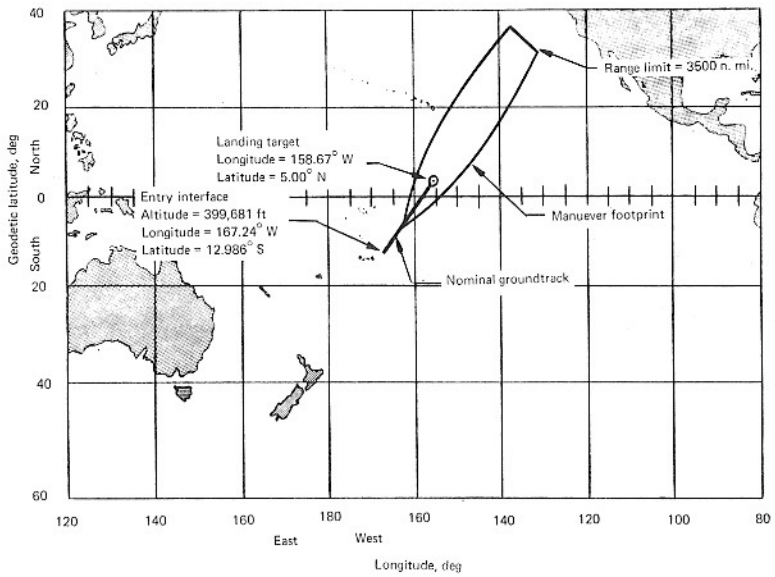


The entry control programs are designed to calculate the roll angle (θ) which will produce the vertical component of lift necessary to satisfy a guidance objective (constant drag flight, downrange target acquisition, and so forth). Crossrange control is maintained by choosing the proper sign of roll angle in order to reduce lateral errors.

Lift modulated flight can significantly reduce the peak accelerations experienced during entry, as shown below.



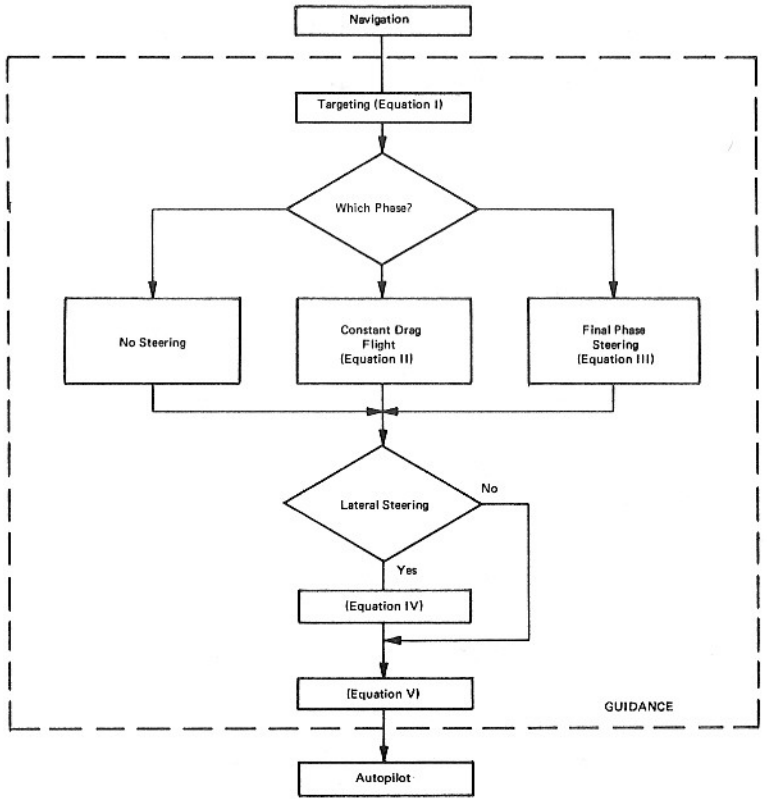
The maneuver footprint for a GNCS-controlled entry utilizing modulated lift is approximately 2,500 nautical miles in downrange and 250 nautical miles in crossrange. A typical entry footprint for a lunar return mission is shown below. A backup control procedure – the EMS ranging technique – defines the maximum range limit of 3,500 nautical miles.



Entry Control Equations

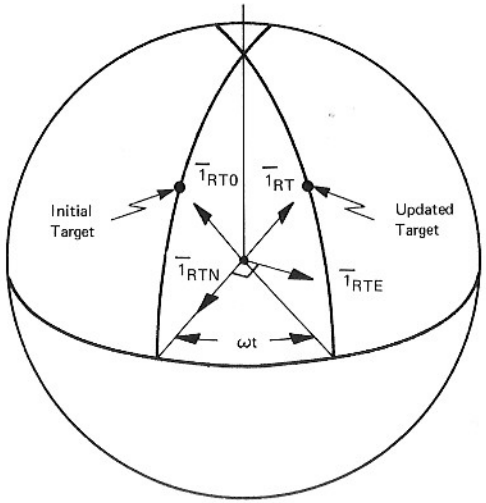
The entry guidance equations are solved every 2 seconds in the AGC. Navigation and autopilot functions are also performed during this computation cycle.

The guidance equations below are used during the entry phases associated with a nominal lunar return entry. Equation I (targeting) is executed every pass through the computation loop. Equations II and III are executed during their particular entry phases for downrange steering. Lateral steering is done by Equation IV dependent upon certain logic constraints in the AGC. The roll angle needed to meet the above equations is calculated using Equation V.



Equation I: Landing Point Targeting Equations

During the early entry phases, a unit vector is calculated which points from the earth's center to an estimated splash point. This initial target vector ($\overline{1}_{RTO}$), together with unit vectors in the equatorial plane directed easterly ($\overline{1}_{RTE}$) and in the target meridian ($\overline{1}_{RTN}$), is used as a reference from which a new target vector ($\overline{1}_{RT}$) is calculated based on an updated estimate of time-to-splash.



$$\bar{1}_{RT} = \bar{1}_{RT0} + \bar{1}_{RTN} [\cos(\omega t) - 1] + \bar{1}_{RTE} \sin(\omega t)$$

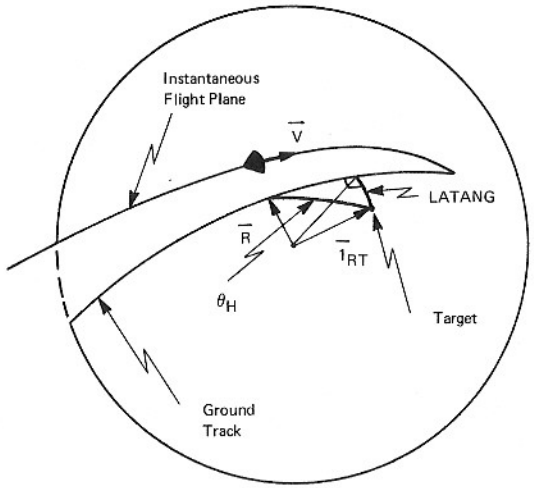
where (ωt) is the amount of earth's rotation for the difference between the old and new estimate of time-to-splash.

Based upon the new target vector $(\bar{1}_{RT})$, the downrange angle from the spacecraft to the splash point is computed using:

$$\theta_H = \arccos\left\{\bar{1}_{RT} \cdot \text{Unit } \bar{R}\right\} \text{(radians)}$$

The crossrange error from the present flight plane is calculated as follows:

$$\text{LATANG} = \bar{1}_{RT} \cdot \text{Unit } (\bar{V} \times \bar{R}) \quad \text{(radians)}$$



Equation II: Constant-Drag Flight Equation

Reduction of near-parabolic velocities (associated with the lunar return mission) to a point where capture in the earth's atmosphere is assured, is accomplished by flying a constant-drag trajectory.

Constant-drag guidance is achieved using an on-board computed reference trajectory and constant guidance factors for compensation of off-nominal conditions. The control refrence parameters are computed using the following constant drag relationships.

$$(L/D)_{Ref} = -\left(\frac{V^2}{R} - g\right) \frac{1}{D_0} \text{ (unitless)}$$

$$\dot{R}_{Ref} = \frac{2D_0}{\beta V} \text{ (ft/s)}$$

$$D_{Ref} = D_0 \text{ (ft/s}^2\text{)}$$

where

V = velocity (ft/s)

R = radial distance (ft)

g = gravity (ft/s^2)

D_0 = desired drag level (ft/s^2)

β = constant associated with atmosphere $(\frac{1}{\text{ft}})$

Gain factors were chosen which relate perturbations in drag and altitude rate to the reference L/D.

$$(L/D)_{control} = (L/D)_{Ref} + 0.01 (D - D_{Ref}) - 0.002 (\dot{R} - \dot{R}_{Ref})$$

Equation III: Final Phase Equation

Steering through the denser portions of atmosphere is accomplished using a terminal control method of guidance. A mean terminal glide trajectory is prestored into the AGC. Linear perturbation coefficients, used to adjust for deviations in flight parameters from nominal values, are also stored. Using velocity as the independent variable, the various quantities in storage are chosen which are used in the basic control equation:

$$(L/D)_{control} = (L/D)_{Ref} + K_1\left\{(R - R_{Ref}) + K_2 (D - D_{Ref}) + K_3 (\dot{R} - \dot{R}_{Ref})\right\}$$

where

$(L/D)_{Ref}$ = constant value (≈ 0.27)

R_{Ref} = reference range-to-go (radians)

D_{Ref} = reference drag (ft/s^2)

$\dot{R}_{Ref}$ = reference altitude rate (ft/s)

K_1 = sensitivity of L/D to deviations in range (unitless)

K_2 = sensitivity of range to deviations in drag level (radians/ft/s^2)

K_3 = sensitivity of range to deviations in altitude rate (radians/ft/s)

Equation IV: Crossrange (or Lateral) Control

Crossrange control is maintained only when the lateral error (LATANG) is in excess of a computed deadband limit. This limit (somewhat less than the crossrange capability of the spacecraft) is computed every 2 seconds as a function of spacecraft velocity.

When this limit is exceeded the sign of the commanded roll angle (K2ROLL) is changed so that the horizontal component of lift causes the spacecraft to steer laterally toward the target.

Equation V: Commanded Roll Angle Equation

Using previously determined quantities (K2ROLL and $L/D_{control}$) the commanded roll angle is calculated by

$$ROLLC = (K2ROLL)\ \text{arc-cos}\left[\frac{L/D_{control}}{L/D_{Ref}}\right] \quad \text{(degrees)}$$

where

$$L/D_{Ref} \simeq 0.3 \text{ (unitless)}$$

Entry Control Programs

The guidance function, which incorporates the entry control equations previously described together with certain logic decisions, can be considered as a basic set of AGC software programs (P60's). The programs are associated with various phases of the entry profile as described below.

P61 — Entry Preparation Program

a. Purpose: Start navigation, check IMU alignment, and provide EMS initialization data in case of communications failures.

b. Initiation: Astronaut keys DSKY — V37E 61E

c. Steering: None, lift vector is oriented full-up (0 degrees) or full-down (180 degrees), according to the astronaut specifications.

d. DSKY Displays:

V06N61

R1 — Impact latitude	Latitude of splash point
R2 — Impact longitude	Longitude of splash point
R3 — Heads up/down	±1

V06N60

R1 — G max	Maximum predicted g-load
R2 — V predicted	Predicted velocity at EI (400 K ft)
R3 — γ_{EI}	Predicted entry angle at EI

V06N63

R1 — RTOGO	Range-to-go from 290,626-foot altitude
R2 — V_{io}	Predicted velocity at 290,626-foot altitude
R3 — T_{fe}	Time to 290,626-foot altitude

P62 — CM/SM Separation and Preentry Maneuver Program

a. Purpose: Notifies crew when GNCS is prepared for CM/SM separation. Also orients the spacecraft to the entry attitude.

b. Initiation: P62 entered when P61 completed and the astronaut keys PROCEED after final P61 display.

c. Steering: None, lift vector orientation maintained.

d. DSKY Displays:

V50N25

R1 — 00041	Request to separate CM/SM
R2	Blank
R3	Blank

V06N61

R1 — Impact latitude
R2 — Impact longitude
R3 — Heads up/down

V06N22

R1 — AOG
R2 — AIG
R3 — AMG

} Desired final gimbal angles at EI

P63 — Entry Control Initialization Program

a. Purpose: Initializes the entry targeting and guidance equations.

b. Initiation: P63 entered automatically when P62 achieves the entry attitude.

c. Steering: None, lift vector orientation maintained.

d. DSKY Displays:

V06N64

R1 — G	Present g-load
R2 — V_i	Present velocity
R3 — RTOGO	Range to the target

P64 — Post 0.05 g Program

a. Purpose: Perform initial steering while awaiting subsequent phases.

b. Initiation: P64 is entered automatically when 0.05 g is sensed by the GNCS.

c. Steering:

When 0.05 g is sensed, a calculation is made to determine position of spacecraft in the entry corridor, and the lift vector is positioned full-up or full-down accordingly. The orientation is maintained until a precomputed drag level is exceeded (somewhat less than 1.5 g).

A constant drag trajectory is flown ($\approx$ 4 g) until the altitude rate becomes greater (more positive) than -700 ft/s.

Range-to-go checks are made to determine whether the available range will permit a controlled skip maneuver. Because the nominal range-to-target at EI is 1,250 nmi, this requirement is never satisfied and the constant-drag flight is continued.

A predicted exit velocity for the hypothetical skip maneuver will decrease below 18,000 ft/s and exit is made to the final phase.

d. DSKY Displays

V06N74

R1 – BETA	Commanded roll
R2 – V_i	Inertial velocity
R3 – G	Present g-load

P67 – Final Phase Program

a. Purpose: Steer through the dense portion of atmosphere and achieve the planned splash point.

b. Initiation: P67 is entered automatically from P64 for the nominal lunar return entry.

c. Steering: Steering is done using a terminal type controller based on a prestored nominal trajectory.

Guidance is terminated when velocity drops below 1,000 ft/s.

d. DSKY Displays:

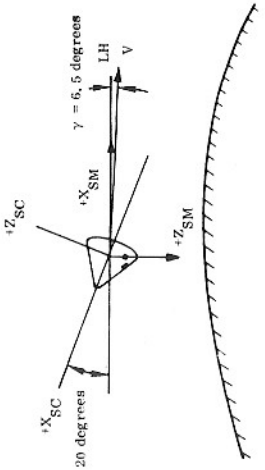
V06N66

R1 – BETA	Commanded roll angle
R2 – XRNGERR	Crossrange error
R3 – DWNRGER	Downrange error

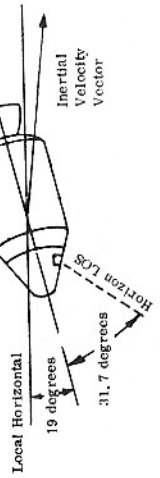
V16N67

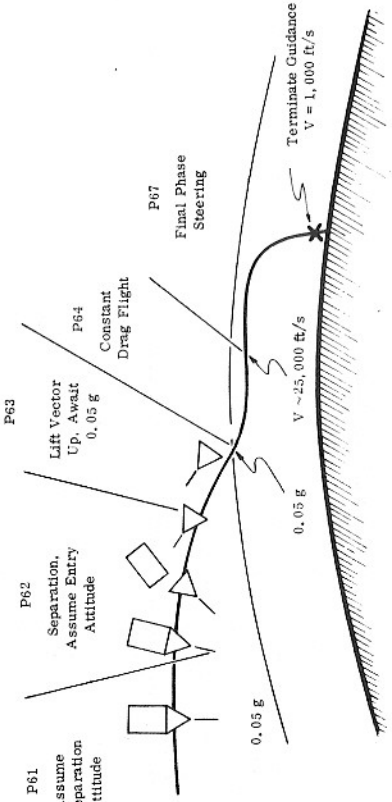
R1 – RTOGO	Range to target
R2 – LAT	Present latitude
R3 – LONG	Present longitude

TYPICAL ATTITUDE AT ALTITUDE OF 400,000 FEET



TYPICAL CM/SM SEPARATION ATTITUDE





TYPICAL ENTRY PROGRAM SEQUENCE OF EVENTS

APOLLO MISSION SPLASH POINT SUMMARY

Mission	Planned Target North Lat	Planned Target West Long	Final DSKY Reading North Lat	Final DSKY Reading West Long	Total DSKY Error Nmi Δ	Ship Splash Report North Lat	Ship Splash Report West Long	Total Recovery Ship Reported Error Nmi	Best-Estimate Trajectory (BET) Report North Lat	Best-Estimate Trajectory (BET) Report West Long	Total (official) Error Nmi	Remarks
Apollo 7	27.61	64.17	27.63	64.18	1.3	27.54	64.07	7.3	27.64	64.15	2.1	Earth Orbital
Apollo 8	8.13	165.03	8.10	165.01	2.1	8.12	165.02	0.9	8.1	165.01	2.3	Lunar Return
Apollo 9	23.25	68.00	23.26	68.01	0.8	23.21	67.94	4.3	23.22	67.98	2.1	Earth Orbital
Apollo 10	-15.07	164.67	-15.07	164.65	1.2	-15.03	164.65	2.7	-15.06	164.65	1.3	Lunar Return
Apollo 11	-13.25	169.15	-13.30	169.15	1.2	-13.25	169.15	4.2	*	*	1.0*	Lunar Return
Apollo 12	-15.81	165.17	-15.87	165.16	3.6	-15.78	165.15	2.2	-15.83	165.17	1.1	Lunar Return
Apollo 13	-21.66	165.37	-21.64	165.38	1.3	-21.64	165.36	3.9	-21.64	165.36	1.0	Lunar Return
Apollo 14	-27.02	172.65	-27.02	172.65	0	-27.00	172.659	1.3	-27.01	172.66	.62	Lunar Return
Apollo 15	-26.13	158.13	-26.13	158.13	0	-26.125	158.15	1.5**	-26.13	158.14	.63	Lunar Return

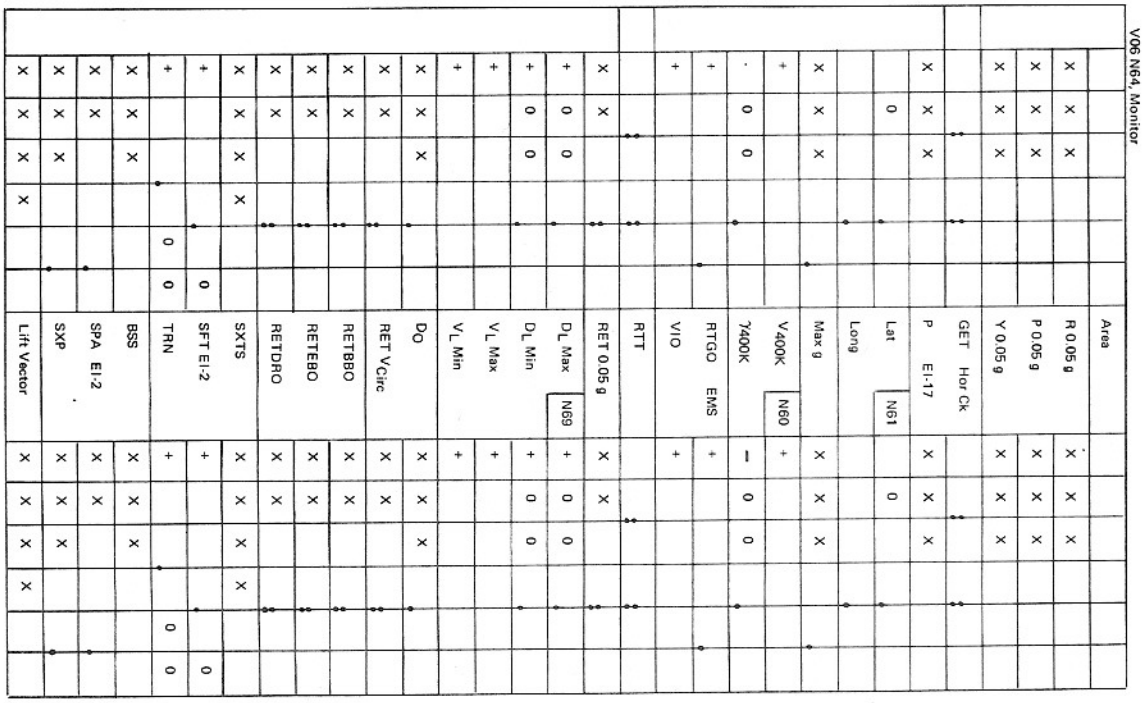
* Onboard data lost during entry - miss distance is best estimate
** Ship Report based on Nav Satellite Fix

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	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.