RENDZVOUS PROCEDURES

APOLLO 7

FINAL

REVISION A

SEPTEMBER 27, 1968

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
RENAZVOUS PROCEDURES

APOLLO 7

AS-205/101

September 27, 1968

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1.0 **Purpose**

This document contains the primary and backup crew procedures for the CSM 101 spacecraft rendezvous with the AS-205 S-IVB stage, in accordance with Detailed Test Objective P20.13 defined in the February 14, 1968, Mission Requirements SPF8-R-001.

The purpose of the Rendezvous Procedures Document is to provide a single source of procedures information for use in flight planning, crew training, and preparation of onboard data.

This is a control document, subject to review by all elements of the Apollo Program, and approval by the Procedures Configuration Control Board. Comments should be directed to Mr. Duane K. Mosel, Crew Safety and Procedures Branch, Flight Crew Support Division, Extension 5340.
2.0 Major Events

The AS-205/101 rendezvous exercise will begin on the second day at about 22:00 hr. with preparation for the phasing maneuver NCCI 3:1 end with the CSM in formation flight with the S-IVB at about 30:00 hr. This time period is divided into the six segments of Section 2.0, and each is treated separately in the following paragraphs. On Figure 2-1 the locations of the most significant nominal mission events are shown in the S-IVB centered relative motion plot. The CSM attitude angles are also indicated in this figure.
2.1 **NCC1 Maneuver**

At 22:00 hrs. after liftoff, the CMC, IMU, and SCS will be powered up (if not already powered up) and the DAP initialized in preparation for IMU alignment and subsequent rendezvous navigation. This occurs about three revolutions prior to the NCC1 maneuver to allow sufficient time for state vector uplink and two complete night passes for coarse and fine align. State vectors for both vehicles, NCCI burn information and the time, $T_{(\text{Align})}$, that an integral number of orbits prior to TPI is reached, will be transmitted to the spacecraft by voice at 22:30 over BDA. Sunset on this orbit will occur at about 23:06 at which time the IMU orientation determination program P51 will be performed (only if the IMU had been powered down) by the CSM pilot in the LEB. If more than 10 minutes of darkness remains, a fine align (P52, nominal mode) to $T_{(\text{Align})}$ will be performed. The automatic star selection and optics pointing will be used for the fine align. Sighting on a third star is planned as part of a fine align check.

At 24:00 a perigee will be reached and the ORDEAL will be initialized to the local vertical by slewing the left FDAI to the angle $\theta$ from V83 and setting the orbital rate for the altitude $\frac{H_A + H_P}{2}$, where $H_A$ and $H_P$ will be obtained from V82.
Throughout the mission the ORDEAL will be initialized as near to apsidal crossings as possible, to minimize effect of orbit eccentricity on FDAI error (See Reference 6.4). If the IMU had been powered down prior to the rendezvous, a PIPA bias measurement will be performed at approximately 24:12. The next sunset will occur at 24:36, at which time another fine alignment to REFSMMAT will be accomplished (assuming P52, nominal mode, completed), followed by a fine align check on a third star.

Prior to the next daylight period which begins at about 25:12 hrs., the rendezvous navigation program will be called up, the CSM maneuvered automatically to the track attitude, and, if time permits, a few SXT marks may be taken. The purpose of this exercise will be to verify that the DAP and auto-optics are tracking the target properly, and not to obtain any navigation data for post-flight analysis.

At 25:35 hrs. over BDA, an MSFN update of both state vectors and the NCCL maneuver parameters will occur. Following this, the CMP will call the external ΔV program (P30) and the CDR will perform the EMS ΔV test and load the NCCL ΔV magnitude into the EMS. At about 25:45, the CSM event timers will be synchronized to the NCCL ignition time to go (V16 N35) and
the SPS thrusting program (P40) will be called. The vehicle will be maneuvered automatically to the burn attitude for a SXT/star check. A fine align to REFNUMAT and fine align check will then be performed during the darkness period prior to the NCCL burn. The gyro-torque angles, used in this alignment, will be voiced to the MSFN for future uplink of the IMU drift compensation.

At 26:10, the CMP will leave the LEB and occupy the center seat. He will then call the SPS thrust program (P40) and automatically orient to the final burn attitude. At about 26:15 the CDR will begin preparation for SPS ignition.

The 10.1 second NCCL maneuver will be performed at 26:25. After the ΔV's have been trimmed with the RCS to an acceptable level, the residuals will be recorded. Following the NCCL burn, POO will be called to terminate average g.
2.2 NCC2 Maneuver

Shortly after the NCC1 maneuver, if time is available, the CMP will enter the LEB and call the rendezvous navigation program P20. The spacecraft will be maneuvered automatically to the track orientation. Upon completion of the track exercise the CMP will again move back to the center seat. At 27:05 over MIL, the MSFN will uplink NCC2 burn data and state vectors for both vehicles, as well as voice the NSR burn data. This will be followed by P30, the EMS ΔV test (if NCC2 is an SPS maneuver) and loading the NCC2 ΔV into the EMS counter. At 27:15, P40 or P41 will be called and an automatic maneuver made to the burn attitude.

NCC2 is a phase correction maneuver to place NSR at the desired trailing displacement and altitude. If possible, it is desirable to eliminate the NCC2 maneuver. This can be done by varying the time of NSR to obtain the desired TPI TIG. If the resulting ΔH is not acceptable, the ΔH at the closest bound will be used to compute a TPI TIG. If this time falls outside the lighting constraints then the NCC2 burn is inevitable and will be calculated for a nominal ΔH and desired TPI TIG (midpoint of darkness). It will be performed with the SPS engine if larger than 0.5 sec SPS burn time.
The MCC2 burn will occur at 27:30. If the SPS is used, the CDR will trim the residual velocities to minimize errors at NSR. Residuals after trimming will be recorded. At the completion of the thrust program, the CMC idling program (POO) will again be called to terminate average g.
2.3 NSR Maneuver

The purpose of the NSR maneuver is to make the spacecraft and S-IVB orbits coelliptical. At about 27:32, after completion of NCC2, the CMP will enter the LEB, load the DAF for narrow deadband, and call P30.

The NSR ignition time and burn components will be loaded into P30 followed by the EMS test and initialization for monitoring and backup. The event timers will be set counting down to ignition time, and approximately 25 minutes before NSR the spacecraft will be manually maneuvered to the burn attitude. A fine align to REF55MATT (P52) and an align check will be performed prior to calling the SPS thrust program (P4C), 15 minutes prior to NSR, at 27:45. If time allows, a SXT/Star check will be done at this point. Ten minutes before NSR, at 27:50, the CMP will leave the LEB in preparation for the burn. NSR ignition will be approximately 28:00. Duration of the SPS burn will be nominally 8.8 seconds.

The velocity residuals will be trimmed carefully to minimize errors in the coelliptical orbit. Residuals will be recorded after trimming.
2.4 TPI Maneuver

Following the NSR maneuver, the CMP will enter the LEB and call the rendezvous navigation program (P20) and the TPI prethrust program (P34). The CSM will be automatically oriented to the track attitude. The elevation option for TPI will be selected by entering a value of 27.45 degrees. The nominal TPI time will be entered to minimize CMC interactions in determining actual time of TPI. The time between TPI and TPF will be 35:00 minutes corresponding to approximately 140 degrees orbit travel. On the initial pass through P34, the event timers will be synchronized counting down to TPI. At TPI-64 minutes, 10 S-IVB sightings will be made and P34 recycled to observe the change in TPI time and total ΔV. (The threshold parameters, RMAX and VMAX, will be pad loaded to -1. Consequently, no state vector updates will be incorporated automatically. The crew must always proceed from the ΔR, ΔV display before mark incorporation.) This computed TPI TIG is then compared with the MCC-H TIG as a preliminary check of the CMC's navigation.

At TPI -48 minutes, ORDEAL will be updated to provide the best possible attitude reference for terminal phase backup.
If time permits, 5-10 S-IVB marks will be made, starting at TPI -38 minutes. The MSFN recommendation for the TPI maneuver will be transmitted to the spacecraft over ANT at 28:47. Should it be necessary, the state vectors for both the CSM and SIVB will be available, via uplink, at this time. At approximately TPI-30 minutes, the two CMC parameters; "WRENDPOS" and "WRENDVEL", will be loaded to 1000 feet and 1 fps. respectively (if they have not previously been loaded to these values). An additional 10 S-IVB marks will then be taken starting at TPI-25 minutes. After the first three marks, the W matrix will be rediagonalized to the values given above.

Throughout the coelliptical phase, whenever time permits, range and angle data from V83 or V85 will be recorded on the crew's polar plot. This will provide additional information on the status of the trajectory at TPI.

Following the end of the second set of S-IVB marks at TPI-15 minutes, the final comp-cycle in P34 will be selected. The magnitude of the resulting TPI solution will then be set into the EMS and the event timers will be resynchronized counting down to TPI. At TPI-11 minutes, the RCS thrusting program will be called and the spacecraft rotated manually in SCS, pulse mode to boresight on the S-IVB using the COAS.
At TPI-8 and 5 minutes, range, range rate, and angle data will be recorded while boresighted on the target. These data will be used to enter the flight charts for determining the backup solution for TPI as explained in Section 4.1.

By approximately TPI-4 minutes the decision will be made in accordance with mission rules as to whether the FNGS TPI maneuver is usable. If the FNGS solution is used, the CSM will be auto maneuvered to the burn attitude. If the MSFN or backup chart solution is to be used, the spacecraft X-axis will be boresighted on the target and F47 will be used for thrust monitoring. In this case the solution is impulsive; the EMS would be turned on at TPI-1 minute and the CIB would begin the burn at TPI-30 seconds.
2.5 **Midcourse Maneuvers**

Following the TPI burn, P35 will be called, the CSM will automatically maneuver back to the track attitude, and the DAP will be configured for 0.5 degree deadband in preparation for SXT marks on the S-IVB. At approximately TPI+4 minutes, a "phoney" S-IVB mark will be made in order to bring the W matrix into synchronization with the state vectors. The update option will then be changed and 4 CSM marks made. The CMP will key ENTER at TPI+8 minutes to permit taking backup data at +9 minutes using V85 with the SXT bore-sighted on the S-IVB. Two more CSM updates will then be made before obtaining final backup data at 12 minutes. At 12 minutes, 30 seconds, the PROCEED from V16 N45 will be keyed which will fix the time of the midcourse maneuver at TPI+14 minutes. (The parameter "ATIGINC" will be padloaded to a value of 90 seconds.) The RCS thrust program will be utilized but the spacecraft will not be maneuvered from the track attitude.

After the first midcourse maneuver Program P35 will again be called at about TPI+15 minutes, and backup data will be recorded at 16 and 19 minutes with 2 SXT marks in between backup measurements. At 19 minutes 30 seconds, the PROCEED will be
keyed which sets the second and final midcourse at 21 minutes. Prior to the burn the spacecraft will be maneuvered to boresight on the SIVB. Program 41 will be used for the second midcourse exactly as the first.
2.6 Line of Sight Control and Braking Maneuvers

After the midcourse maneuver at TPI+21 minutes, the SIVB will be tracked using the COAS. No more SXT marks will be made after TPI+18 minutes.

When the S-IVB is boresighted in the COAS, SCS narrow deadband attitude hold will be selected, and with hands off the attitude controller, the drift of the S-IVB in the COAS reticle will be observed. By timing the drift, corrections normal to the line of sight will be obtained from flight charts and executed to maintain a collision course along an inertially fixed line.

The selection of P4\textsubscript{y} will be delayed as long as possible to minimize average g on-time, but early enough to insure all of the thrust acceleration is measured. That is, the CDR must anticipate line-of-sight thrusting by at least one minute due to the time lag in P4\textsubscript{y}.

At the braking gates, range rate will be reduced to the maximum allowable values defined in the following table:

<table>
<thead>
<tr>
<th>R_{\text{MAX}}</th>
<th>1.00</th>
<th>0.50</th>
<th>0.25</th>
<th>0.15</th>
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<tr>
<td>R_{\text{MAX}}</td>
<td>25</td>
<td>15</td>
<td>10</td>
<td>5</td>
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FPS
MSFN targeting of NCC2/NSR will attempt to assure sunrise by the time 1 N MI range is reached. Therefore, the COAS will be useful for estimating range and closing rate inside the braking gates. Thus a transition can be made from the DSKY display of ranging information to the visual scene. The final braking and initial formation flying will occur about 30:10 after liftoff for TPI at the nominal time.
## Apollo VII Mission Rendezvous Procedures

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<table>
<thead>
<tr>
<th>GPC</th>
<th>ERR</th>
<th>TOE</th>
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<th>ERR</th>
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<th>GPC</th>
<th>ERR</th>
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<td>DISPLAYS/PROCEDURES</td>
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<td><strong>RECEIVE GO FOR RENDEZVOUS</strong></td>
<td><strong>TVS GMBL DRIVE(2)=AUTO</strong></td>
<td><strong>LEB PRO (UNTIL STBY LIGHT=OFF)</strong></td>
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<td><strong>FCSM(A,B)=RESET/OVERRIDE</strong></td>
<td><strong>22±00 RSET</strong></td>
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<td><strong>EMS FUNCTION=OFF</strong></td>
<td><strong>CDR MANEUVER S/C-SELF/MDM=UP</strong></td>
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<td><strong>EMS MODE=STBY</strong></td>
<td><strong>LEB KEY V37E05E (IF IMU=OFF)</strong></td>
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<td><strong>UP TLM (MDM)=BLOCK</strong></td>
<td><strong>P05</strong></td>
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<td></td>
<td><strong>RCS TRN/FR=SM</strong></td>
<td><strong>F 50 25 00060</strong></td>
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<td><strong>PANEL 8 CB=CLOSED EXCEPT</strong></td>
<td><strong>LEB G/N PWR, IMU=ON</strong></td>
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<td><strong>ELS BAT A AND B (2)</strong></td>
<td><strong>(MONITOR N9 ATT LT)</strong></td>
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<td><strong>SECS ARM (2)</strong></td>
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<td><strong>PL VENT FLT/PL</strong></td>
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<td><strong>FLAT BAT BAG (3)</strong></td>
<td><strong>LEB KEY V37E00E</strong></td>
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<td><strong>SPS GMBL (4)</strong></td>
<td><strong>SUNUP</strong></td>
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<td><strong>LEB SERVO PWR (BOTH)=OFF</strong></td>
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<td><strong>LEB GPI PWR=OFF</strong></td>
<td><strong>F 50±25</strong></td>
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<td><strong>HAND CONT PWR=OFF</strong></td>
<td><strong>MONITOR GND UPLINK (BDA)</strong></td>
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<td><strong>SCS ELECT PWR=CDM/CEC</strong></td>
<td><strong>P27</strong></td>
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<td><strong>BMAG PWR (BOTH)=ON</strong></td>
<td><strong>LMP RECORD VOICE DATA</strong></td>
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<td><strong>LEMP RECORD VOICE DATA</strong></td>
<td><strong>CDR UP TLM (MDM)=BLOCK</strong></td>
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<td><strong>CMP ENTER NAV BAY</strong></td>
<td><strong>LEB KEY V48E (DAP LOAD)</strong></td>
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<td><strong>21±50 PERFORM INITIAL SWITCH CHECKLIST</strong></td>
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<td><strong>FDIA SEL=1/2</strong></td>
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<td><strong>+0060 YTRIM</strong></td>
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<td><strong>DV THRUST DIRECT=OFF</strong></td>
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<td><strong>SCS TVC (2)=RATE CMD</strong></td>
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<td><strong>GMBL MOTORS (4)=OFF</strong></td>
<td><strong>LEB PRO</strong></td>
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<td><strong>SCS LOGIC BUS 3=ON</strong></td>
<td><strong>LEB PRO</strong></td>
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<td><strong>LV GUIDANCE IU</strong></td>
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<td><strong>IMU CAGE=OFF</strong></td>
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<td><strong>EMS QUL (6)=OFF</strong></td>
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<td><strong>LV/SPS IND SII/SIVB=OFF</strong></td>
<td><strong>LEB PRO</strong></td>
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</table>
CDR ATT DB-MIN
SCS CHAN (4)-A
BMAG MODE (3)-ATT1/HATC2
SC CONT-SCS
LEB G/N, PWR, OPTICS-ON
ZER0 OPTICS-15 SEC
OPTICS MODE-MAN
LEB KEY V37E51E (IF IMU OFF)
P51
23+05 F 50 25 00015
CDR MAN ATT (P, Y)=ACC CMD
SUNDN MONITOR FDAI
23+06
LEB ACC STARS IN SCT
(AVAILABLE STARS=NUNKI, ALTAIR+DABIH)
CDR MAN ATT (3)-RATE CMD
LEB KEY ENTER
F 51 70 STAR CODE
LEB MARK ON STAR 1
F 50 25 00016
LEB KEY ENTER
23+10 F 01 70 000XX
LEB PRO
F 51 70 STAR CODE
LEB MARK ON STAR 2
F 50 25 00016
LEB KEY ENTER
23+15 F 01 70 000XX
LEB PRO
06 05 (ANGLE DIFF)
(PROBE IF REQUIRED)
F 50 07
LEB PRO
F 01 70 STAR CODE 2
LEB ZER0 OPTICS-15 SEC
CHECK STAR CODE 2
OPTICS MODE-CMC

23+20 F 04 06 00005.14
LEB PRO
F 04 06 00005.14
CDR PRO
F 06 39
LEB PRO
F 06 22 (R, P, Y)
LEB PRO
CDR ZERO OPTICS-15 SEC
CDR MAN ATT (P, Y)=ACC CMD
CDR ACC STARS IN SCT
CDR MAN ATT (3)-RATE CMD
CDR KEY ENTER
(AVAILABLE STARS=FOH AND
HUTUP+DIPIHDAU+ACHERNAR)
F 01 70 STAR CODE 1
LEB CHECK STAR CODE 1
OPTICS MODE-CMC
LEB PRO
06 92 (SHAFT, TRUN)
LEB IDENTIFY STAR 2
OPTICS MODE-MAN
F 51 70 STAR CODE 2
LEB MARK ON STAR 2
F 50 25 00016
LEB KEY ENTER
F 01 70 STAR CODE 2

LEB PRO
06 05 (ANGLE DIFF)
F 06 93 (GYR0 T9RC ANG)
LEB PRO
23+30 F 50 25 00014
LEB (FOR FINE ALIGN CHECK*,
KEY ENTER, RETURN TO *,
ZERO OPTICS AND USE
THIRD STAR)
LEB PRO
SUNDN F 50 07
23+42
LEB G/N, PWR, OPTICS-OFF
CDR ATT DB-MAX
LEB KEY V37E00E

P52

CDR SET ORDEAL ON FDAI 2
24+00
LEB KEY V82E
F 06 44 (NA, HP, TFF)
CDR SET ALT TO HAJHP AVG
LEB PRO
F 06 32 (TIME TO P4R)
LEB PRO
LEB KEY V83E
F 06 54 (R, E)
CDR SLEW FDAI TO B
LEB PRO
LEB MEASURE PIPA BIAS (CYL 24+12) (IF IMU HAS BEEN POWERED DOWN)
LEB KEY V25N21E F 21 21 (X,Y,Z PIPAS)
LEB SET ET=1ZER0
LEB KEY ENTER/ENTER
ENTER AND YO6
LEB KEY ENTER/START ET
LMP RECORD INITIAL VALUES
LEB KEY ENTER (A: 4+16 MIN)
LMP RECORD FINAL VALUES CALCULATE X,Y,Z PIPA BIAS AND V0ICE TO GND

CDR ATT DB-MIN BMAG MODE(3)=ATT1/RATE2 SC CON T=SCS
LEB G/N PWR,OPTICS=ON
LEB KEY V37E02E
P52
24+35 F 04 06 00025 IMU 00003 ORIENT B SEL
(IF P52 COMPLETED ON PREVIOUS NIGHT PASS)
LEB PRO
F 50 25 00015
LEB ZERO OPTICS=15 SEC CDR MAN ATT (P,Y)=ACC CMD SUNDN 24+36
LEB ACQ STARS IN SCT CDR MAN ATT(3)=RATE CMD LEB KEY ENTER (AVAILABLE STARS=NUNKI)
 seeming to be a page from a technical manual or guide, with various entries and instructions. The content appears to be related to spacecraft operations, with commands and settings for different modes and operations. Specific entries include:

- **LEB KEY V57E(IF DESIRED)**
  - 25+00 F 51 88
  - LEB OPTICS MODE=MAN
  - MARK(IF DESIRED)
  - LEB OPTICS MODE CMC
  - G/N PWR,OPTICS=OFF
  - LEB KEY ENTER

- **LEB KEY V37E00E**
  - P88
  - SUNUP
  - 25+12

- **CDR UP TLM(MDC)=ACCEPT**
  - 25+35 MONITOR GND UPLINK(BDA)
  - P27
  - LMP RECORD VOICE DATA
  - CDR UP TLM(MDC)=BLOCK

- **LEB KEY V37E30E**
  - P30
  - 25+40 F 06 33
  - LMP COMPARE WITH PAD DATA

- **LEB PR8**
  - F 06 82
  - 00026=TVG
  - 00024=OBF
  - 0055=00NCC1

- **LEB PR8**
  - F 06 42(MA,HP,DV)
  - LMP COPY DV

- **CDR PERFORM EMS DV TEST**
  - EMS FUNCTION=OFF
  - CB EMS(2)=CLOSED
  - EMS MODE=STBY
  - EMS FUNCTION=DV SET

- **LOAD 1586.8**
  - EMS FUNCTION=DV TEST
  - (SPS LT OFF AT DV=0.1)
  - EMS MODE=STBY

- **CDR EMS FUNCTION=DV SET**
  - LOAD VC
  - EMS FUNCTION=DV

- **LEB PR8**
  - F 16 35(TFI)
  - CDR SET MDC DET
  - 38
  - LEB SET LEB DET
  - LEB PR8
  - F 16 45(N,TFI,MGA)
  - LEB PR8
  - F 50 07

- **LEB KEY V37E40E**
  - 40
  - 25+45 F 06 86(VG=LV)

- **LEB PR8**
  - F 06 22(R,P,Y)
  - LMP COMPARE WITH PAD DATA

- **LEB PR8**
  - F 50 25 00203
  - CDR ALIGN S/C IN ROLL
  - CDR BMAG MODE(3)=ROLL
  - SC CONT=CMC
  - CMC MODE=AUTO
  - LEB KEY ENTER
  - 06 22(R,P,Y)
  - CDR NAVIGATOR MANEUVER
  - F 50 19(R,P,Y)

- **LEB PR8**
  - F 50 25 00204
  - LEB G/N PWR,OPTICS=ON

- **LEB PERFORM SXT/STAR CHECK**
  - 25+50 ZERO OPTICS=15 SEC
  - 35
  - OPTICS MODE=CMC
  - KEY V41NS1E
  - F 21 92
  - SHAFT
  - TRUNR
  - KEY ENTER AND OBSERVE
  - OPTICS DRIVE TO STAR
  - KEY RLSE
  - F 50 25 00204

- **CDR ATX DB MIN**
  - BMAG MODE(3)=ATT1 RATE2 S/C CONT=SCS

- **LEB KEY V37E52E**
  - P52
  - 25+55 F 04 06 00005 IMU 30
  - 00000 ORIENT
  - B SEL

- **LEB PR8**
  - F 50 25 00015
  - LEB ZERO OPTICS=15 SEC
  - CDR MAN ATT(R,P,Y)=ACC CMD
  - LEB ACQ STARS IN SCT
  - CDR MAN ATT(3)=RATE CMD
  - LEB KEY ENTER
  - (AVAILABLE STARS=SPICA, ALKAID, ARCTURUS)
  - F 01 70
  - STAR CODE 1

- **LEB CHECK STAR CODE 1**
  - OPTICS MODE=CMC

- **LEB PR8**
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<tr>
<td>LEA IDENTIFY STAR 1</td>
<td>PITCH 1 = START ON</td>
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<td>OPTICS MODE-MAN</td>
<td>YAW 1 = START ON</td>
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<td>51 70</td>
<td>THC = CW</td>
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<td>LEA MARK ON STAR 1</td>
<td>RNC = VERIFY NO MTVC</td>
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<td>50 25</td>
<td>GMBL MOTORS</td>
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<td>F 0016</td>
<td>PITCH 2 = START ON</td>
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<td>LEA KEY ENTER</td>
<td>YAW 2 = START ON</td>
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<td>01 70</td>
<td>CONFIRM GPI TRIM CONT</td>
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<td>STAR CODE 1</td>
<td>SET GPI-TRIM (+1.06)</td>
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<td>LEA ZERO OPTICS-15 SEC</td>
<td>HAND CONT PWR-BOTH</td>
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<td>CDR ALIGN ROLL (HDS = UP)</td>
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<td>LMP RECORD/VOICE TO GND</td>
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<td>LEA (FOR FINE ALIGN CHECK-</td>
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<td>KEY ENTER, RETURN TO *,</td>
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<td>LEA G/N PWR,OPTICS=OFF</td>
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<td>LEA LEAVE NAV BAY</td>
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<td>LMP IGNITION PREPARATION</td>
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<td>MA BUS TIE(2)=ON(UP)</td>
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<td>S=BAND ANT=C</td>
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<td>SPS HE VLV TB(2)=BP</td>
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<td>CDR CB SPS GMBL(*)=CLOSED</td>
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<td>SCS TVC(2)=RATE CMD</td>
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<td>TVC GMBL DRIVE(2)=AUTO</td>
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<td>CDR GMBL DRIVE AND TRIM CHK</td>
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<td>TVC SERV PWR 1=AC1/MNA</td>
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</table>
CDR DV THRUST(2)=NORM(1 MIN)
THC-ARMED
RMC(2)=ARMED
CDR EMS "MODE-AUTO"(AT 30SEC)
CMP MONITOR DVM
CDR PERFORM ULLAGE(AT 15SEC)
F 50 991(TFG, VFG, DVM)
CDR VERIFY ENGINE TRIM
CMP KEY ENTER (AT 15SEC)
NC121 20.25 06 40(TFG, VFG, DVM)
CDR STOP ULLAGE
MONITOR FDI, PC GAUGE
LMP MONITOR VALVES OPEN
CMP MONITOR DSKY
CDR DV THRUST(2)=OFF(TGB=0)
F 16 40(TFG, VFG, DVM)
LMP MONITOR VALVES CLOSED
CDR GMBL MOTORS
PITCH 2=OFF
YAN 2=OFF
PITCH 1=OFF
YAN 1=OFF
TVG SERVO PW(2)=OFF
TVG SERVO PW(1)=OFF
EMS MODE=STBY
LMP PRO
F 16 85(VG=BODY)
CDR NULL VG
TMC-LOCKED
LMP RECORD RESIDUALS
CMP PRO
F 06 44(HA, HP, TFF)
CMP PRO
F 06 32(TIME TO PER)
CMP PRO
F 50 07

CMP KEY V37E00E
P00

CMP KEY V74E

CMP ENTER "NAV BAY"(IF TRACKING EXERCISE TO BE D0,F)

CDR CB SPS GMBL(4)=OFF
EMS FUNCTION=OFF
FDI SCALE=5/1
RATE=LOW
DIRECT RCS=OFF
LMP MN BUS TIE(2)=OFF

LEN KEY V37E20E (IF DESIRED)
LEN KEY V57E (IF DESIRED)
LEN KEY ENTER

LEB PRO
F 06 47 00182.1X
+00575.4Y1Z
+31838.0NT

LEB PRO
F 06 48 0015028TRIM
+000738TRIM
+02010.7TLX

LEB PRO
F 04 46 1110212AP
111128 - F IG

LEB LEAVE "NAV BAY"

27+00

CDR SET ORDEAL(FDI 1)
CMP KEY V82E
F 06 44(HA, HP, TFF)

CDR SET ALT TO HA, HP AVG
CMP PRO
F 06 32(TIME TO PER)

CMP PRO
F 06 54(HA, HP, 8)

CDR SLEW FDI TO A
CMP PRO
CDR UP TLM (MDC) = ACCEPT
27+05 MONITOR GND UPLINK (MIL) P27
LMP RECORD VOICE DATA (DECISION = CC2 = RCS/SPS)
CDR UP TLM (MDC) = BLOCK

27+10
CMP KEY V37E30E
P30
F 06 33 0000027 TIG
+0000000 BF
+00000000 CC2

CMP PR0
F 06 82
- - - - - - - - - - - - DVLX
- - - - - - - - - - - - DVLX

CMP PR0
F 06 42 (HA, HP, DV)
LMP COPY DV

CDR PERFORM EMS DV TEST
EMS FUNCTION = OFF
CB EMS(2) = CLOSED
EMS MODE = STBY
EMS FUNCTION = DV SET
LOAD + 1586.8

CDR PERFORM EMS DV TEST (SPS)
(SPS LT O FF AT DV = 0:01)
EMS MODE = STBY

CDR EMS FUNCTION = DV SET
LOAD VC
EMS FUNCTION = DV

CMP PR0
F 16 35 (TFI)
CDR SET MDC DET

19

CMP PR0
F 16 45 (NTFI, MGA)

CMP PR0
F 50 07

27+15
CMP KEY V37E40E (IF SPS BURN)
P40
F 06 86 (VG = LV)
LMP COMPARE WITH PAD DATA

CMP PR0
F 06 22 (R, P, Y)
LMP COMPARE WITH PAD DATA

CMP PR0
F 50 25 00203
CDR ALIGN S/C IN ROLL
CDR CMAG MO DE (3) = RATE 2
SC CONT = CMC
CMC MODE = AUTO

CDR KEY ENTER
06 22 (R, P, Y)

LMP MIRROR MANEUVER
F 50 19 (R, P, Y)

27+20
LMP IGNITION PREP (RAT ION)
MN BUS TIE(2) = ON (UP)
SPS HE VLV TB(2) = OFF
SPS HE VLV TB(2) = AUTO

CDR CB SPS GMBL(4) = CLOSED
DIRECT RCS = OFF
SICS/TVC(2) = RATE CM C
TVC GMBL DRIVE(2) = AUTO

27+25
CDR ALIGN GDC TO IMU

37

CDR PR0
F 50 25 00204

CDR KEY ENTER

CDR MONITOR GMBL DRIVE TEST
VERIFY GPI TRIM
06 40 (TFI, VG, DVM)

CDR VERIFY MDC DET

TVC SER V PWR 1 = AC1/MNA
TVC SER V PWR 2 = AC2/MNB
HAND CONT PWR = 1
RHC 2 = ARMED
GMBL MOTORS
PITCH 1 = START = ON
YAW 1 = START = ON
THC = CW
RHC = VERIFY NO MTVC
GMBL MOTORS
PITCH 2 = START = ON
YAW 2 = START = ON
CONFIRM GPI TRIM CONT
SET GPI = PTRIM = 1 C9
YTRIM = 0.73
RHC = VERIFY MTVC
THC NEUTRAL
HAND CONT PWR = BOTH

CDR ALIGN S/C IN ROLL
CDR MONITOR MANEUVER
F 50 19 (R, P, Y)
CDR MANAT (3) = RATE CMD
RATE = HIGH
DIRECT RCS = ON
CMAG MO DE (3) = ATT1 = RATE 2
CDR ATT OBI=1
SMAG MODE(3)=ATT1/RATE2
SC CONT=SCS
MAN ATT(P)=ACC CMD
MANEUVER TO BURN ATT
MAN ATT(3)=RATE CMD
LEB G/N PWR,OPTICS=5N

27+35
LEB KEY V37E52E
P52
F 04 06 00005 IMU
MOD U3 ORIENT
B SEL

LEB PRO
F 50 25 00C15
LEB ZERO OPTICS=15 SEC
CDR MAN ATT(P,Y)=ACC CMD
SUNDN 27+36
LEB ACQ STARS IN SCT
CDR MAN ATT(3)=RATE CMD
LEB KEY ENTER
(AVAILABLE STARS:
Fomalhaut,Diphda,Achernar)

* F 01 70 1 STAR CODE 1
LEB CHECK STAR CODE 1
OPTICS MODE=CMC
LEB PRO
06 92(shaft,run)
LEB IDENTIFY STAR 1
OPTICS MODE=MAN
F 51 70 1 STAR CODE 1
LEB MARK ON STAR 1 22
F 50 25 00C16
LEB KEY ENTER
F 01 70 1 STAR CODE 1

LEB PRO
F 01 70 1 STAR CODE 2
LEB ZERO OPTICS=15 SEC
CHECK STAR CODE 2
OPTICS MODE=CMC
LEB PRO
06 92(shaft,run)
LEB IDENTIFY STAR 2
OPTICS MODE=MAN
F 51 70 1 STAR CODE 2
LEB MARK ON STAR 2 22+40
F 50 25 00016 20
LEB KEY ENTER
F 01 70 1 STAR CODE 2

LEB PRO
06 05(ANGLE DIFF)
F 06 93(GYR9 TARIQ ANG)
LEB PRO
F 50 25 00014 16
LEB (FOR FINE ALIGN CHECK=
KEY ENTER,RETURN TO *,
ZERO OPTICS AND USE
THIRD STAR)
LEB PRO
F 50 07

LEB PRO
F 01 70 1 STAR CODE 1
LEB KEY V37E40E
P40
F 06 86(VG+LV)
LEB COMPARE WITH PAD DATA
LEB PRO
F 06 22(R,P,Y)
LEB COMPARE WITH PAD DATA
LEB PRO
F 50 25 CO2C3
CDR ALIGN S/C IN PALL
CDR SMAG MODE(3)=RATE 2
SC CONT=SCS
CMC MODE=ALT0
LEB KEY ENTER
06 22(R,P,Y)
CDR MONITOR MANEUVER
F 50 19(R,P,Y)

LEB PERFORM SXT/STAR CHECK
ZERO OPTICS=15 SEC 13
OPTICS MODE=CMC
KEY V41N91E
F 21 92 SHAFT
--- TRUN
8
KEY ENTER AND OBSERVE
OPTICS DRIVE TO STAR
KEY RELSE
F 50 19(R,P,Y)

LEB G/N PWR,OPTICS=OFF
27+50
LEB LEAVE NAV BAY

LMP IGNITION PREPARATION
MN BUS TIE(2)=ON(UP)
S=BAND ANT+D
SPS ME VLV TB(2)=BP
SPS ME VLV(2)=AUTO
CDR CB SPS GMAL(4)=CLOSED
DIRECT RCS=OFF
SCS TWC(2)=RATE CMD
TWC GMAL DRIVE(2)=AUTO

CDR GMAL DRIVE AND TRIM CHK 9
TWC SERV PWR 1=AC1/MNA
TWC SERV PWR 2=AC2/MAB
HAND CONT PWR+1
RHC 2-ARMED
GMBL MOTORS
PITCH 1 = START-ON
YAW 1 = START-ON
THC=0
RHC=VERIFY V0 TVC
GMBL MOTORS
PITCH 2 = START-ON
YAW 2 = START-ON
CONFIRM GPI TRIM CONT
SET GPI-TRIM(=1.09)
YTRIM(=0.73)
RHC=VERIFY TVC
THC=NEUTRAL
HAND CONT PWR-BOTH

CDR ALIGN ROLL (HDS=DOWN)  7

CMP KEY ENTER
06 22(R, P, Y)

CDR MONITOR MANEUVER
F 50 19(R, P, Y)

CDR MAN ATT(3)=RATE CMD
RANGE=HIGH
DIRECT RCS=ON
BMAE MODE(3)=ATT1/RATE2

27+55

CDR ALIGN GOC TO IMU  5

CMP PRO
F 50 25 00204

CMP KEY ENTER  4

CDR MONITOR GMBL DRIVE TEST
VERIFY GPI TRIM
06 40(TFI, VG, DVM)

CDR VERIFY MDC DET
CMP VERIFY VG
CHECK C/W LAMPS
CDR FDAI SCALE=5/5

VERIFY S/C ATTITUDE
LEB KEY V74E

CDR DV THRUST(2)=NORM(1 MIN)
THC ARMED
RHC=ARMED
RHC(2)=ARMED
CDR EMG MODE=AUTH/AT 30 SEC
CMP MONITOR DVM
CDR PERFORM ULLAGE AT 15 SEC
F 50 99(TFI, VG, DVM)
CDR VERIFY ENGINE TRIM
CMP KEY ENTER(1 SEC)

28+00

CDR STOP ULLAGE
MONITOR FDAI, PC GAUGE
LMP MONITOR VALVES OPEN
CMP MONITOR DSKY
CDR DV THRUST(2)=OFF(TGE=0)
F 16 40(TG0, VG, DVM)
LMP MONITOR VALVES CLOSED

CDR GMBL MOTORS
PITCH 2=OFF
YAW 2=OFF
THC=OFF
TV SERV PWR(2)=OFF
TV SERV PWR(1)=OFF
EMS MODE=STBY

CMP PRO
F 16 85(VG, BBDY)

CDR NULL VG/S
THC LOCKED
LMP RECORD RESIDUALS

CMP PRO
F 06 44(HA, HP, TFF)

CMP PRO
F 06 32(TIME T0 PER)

F 06 50 07 00 00

F 06 32(TIME T0 PER)

F 06 50 07

F 06 32(TIME T0 PER)

F 06 50 07 00 00

F 06 32(TIME T0 PER)

F 06 50 07

F 06 32(TIME T0 PER)

F 06 50 07 00 00

F 06 32(TIME T0 PER)

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F 06 32(TIME T0 PER)

F 06 50 07 00 00

F 06 32(TIME T0 PER)

F 06 50 07

F 06 32(TIME T0 PER)
LEB KEY ENTER
F 16 45(N,TF1,0)

LEB KEY V74E

LEB IF W41,000/1 =
LOAD W41,000/1
KEY V24:\01E
KEY 2000E
KEY 47E
KEY 20E
0007
0002C
0002V
KEY RLSE
F 16 45(N,TF1,0)

CDR ALIGN GDC TO IMU
LMP S=BAND ANT=B

LEB KEY V57E
28-55 F 51 BB
LEB OPTICS MODE=MAN
28-58
LEB MAKE 3 SIVB MARKS=1/MIN
(OPTICS MODE=CMC/CHK SV)
LEB KEY ENTER
F 16 45(N,TF1,0)

29+01
LEB KEY V86E

LEB KEY V57E
F 51 BB
LEB MAKE 7 SIVB MARKS=1/MIN
SUNDN (OPTICS MODE=CMC/CHK SV)
29+05
LEB OPTICS MODE=CMC
LEB G/N PWR,OPTICS=OFF

29+08
LEB KEY ENTER
F 16 45(N,TF1,0)

LEB KEY V85E
F 06 53(R,R,\Q)
LMP COPY R,R,\Q(POLAR PLOT)
LEB PRO

329+10
F 16 45(N,TF1,0)

LEB PRO
F 06 37(TIG OF TPI)
LEB PRO
F 06 58(DVTP,HP,DVTPF)

CDR EMS MODE=STBY
EMS FUNCTION=DV SET
LOAD DV
EMS FUNCTION=DV

29+15
LEB PRO
F 16 35(TFI)
CDR CHECK MDC DET
LEB CHECK LEB SET
LEB PRO
F 16 45(N,TF1,HGA)
LEB PRO
F 50 07

LEB KEY V37E*1E
11

22+41
F 04 06 0000\% AXIS 0000\% CODE

CDR BMAG MODE(3)=ATT1/RATE2
SC CONT=CMC
MAC ATT(P)=ACC CMD
BMRESIGHT ON TGT(COAS) 10
MAC ATT(3)=RATE CMN

LEB PRO
F 50 25 00203

LEB PRO
F 06 22(R,P,Y)
LEB PRO
F 06 06(VG=BBY)
LMP COMPARE TPI SOLUTIONS

PAGE 12
LEB KEY RLSE
F 50 07
LEB KEY V37E00E
P00
LEB KEY V74E
294+5

CDR EMS FUNCTION=DV
LOCK THC
LEB KEY V37E07E/WHEN REQUIRED

PA7
F 16 83(DV=BODY)
CDR COMP LT-8FF/THC ARMED
ATT DB-MIN IF NORMAL
LOS RATES ARE LOW
LEB KEY V60E AS REQUIRED

LEB KEY V83E
F 06 54(R,R,R)

CDR EMS MODE=AUTO
LMP TLM INPUTS=41/L9
BEFORE/AFTER TRANSLATION
CDR REMOVE NORMAL LOS
RATES AS PER CHARTS
LMP RECORD N40 DVM

CDR BRAKING GATES=
R=1.0 NM/RDST TO 25FPS
R=2.5 NM/RDST TO 15FPS
R=0.25NM/RDST TO 10FPS
30+00 R=1000FT/RDST TO 5FPS

30+10
CDR STATION KEEPING
4.0 Backup Techniques

The purpose of this section is to describe the methods by which the rendezvous maneuvers will be monitored onboard and define techniques for completing the mission in the event of PNMS malfunction. It is not an objective of this document to specify the circumstances under which the rendezvous will be terminated or the systems performance limits that will require alternate maneuver solutions to be used. These factors will be controlled through the Apollo Data Priority Coordination Meetings, and the Mission Rules Documents.

Two general requirements exist for Guidance and Control backup techniques. The first requirement is for assessment of system performance during apparently normal operation. This monitoring function is carried out during translation by observing critical parameters such as attitude errors, vehicle rates and \( V_g \), and during determination of maneuvers by independent calculations of the \( V_g \)'s. The second requirement for backup is for taking over either attitude or translation control using alternate systems and/or targeting when an obvious failure occurs. The techniques for monitoring are treated in section 4.1.

For purpose of failure procedures development the G & N system is considered to be comprised of three major subsystems:

(a) Optics
(b) IMU
(c) CMC

Techniques for completing the mission for each of the above failures are presented in sections 4.2, 4.3, and 4.4. It is assumed that since no onboard targeting capability exists for maneuvers prior to TPI,
backup for any PNGS failure prior to NSR will be to use the SCS and EMS to complete the maneuvers through NSR, or to terminate the maneuver sequence, which ever is specified in the mission rules.

Because of the number of possible failure modes, procedures will be developed only for total failure of the subsystems listed above. Partial failures wherein some performance can be realized from the failed system will be handled by the crew utilizing whatever data can be salvaged by combining the primary and backup techniques.
4.1 PNGS Monitoring

The NCC1, NCC2, and NSR maneuvers will be targeted by the MSFN and cannot be determined onboard. Monitoring for these maneuvers therefore consists of observing the SPS start sequence attitude errors, attitude rates, and other parameters and manual backup of engine shutdown using the EMS AV counter. If PNGS fails to start the SPS, the SCS will be used. Subsequent to NSR, range and target elevation data will be called as time permits by the CS: pilot in the LEB calling V85 with the SXT boresighted on the SIVB. The data will be plotted by the LM Pilot on the SIVB centered relative motion graph shown in Figure 4.1. This information will be valuable to determine qualitatively the ellipticity of the CSM orbit, TPI arrival time, magnitude of TPI maneuver, and approach angle. PNGS targeting of the TPI and midcourse maneuvers will be monitored by the use of the flight charts shown as Figures 4-2, 4-3, and 4-5. These charts will be used to determine maneuver components along the line of sight to the SIVB, normal to the line of sight inplane, and out of plane. The TPI chart will be used in the monitoring mode as follows:

(a) After the last SIVB mark prior to TPI, the Event Timers will be set counting down to TPI ignition.

(b) At TPI-8 minutes, with the COAS boresighted on the SIVB, elevation angle from V83 will be recorded. This angle will be recorded by the LM pilot on Figure 4-3 in the block labeled "MONITOR COMP" in the space next to \( \theta_8 \).

(c) At TPI-5 minutes, \( \theta_5 \) is recorded in the space above \( \theta_8 \) and range and range rate from V83 are recorded in the spaces provided within the same block.
(d) With $\theta_5$ and $R_5$ as inputs the lower left graph in Figure 4-2 will be used to read $\hat{R}_{REQ}$ which will be logged in the space provided below $R_5$.

(e) The difference between $\dot{R}_5$ and $\hat{R}_{REQ}$ then represents the component of TPI $\Delta V$ along the line of sight to the SIVB.

(f) Subtracting $\theta_8$ from $\theta_5$ will define $\Delta \theta$. Entering the lower right graph with $\theta_5$, progressing horizontally to the value of $\Delta \theta$, and moving vertically to $R_5$ in the upper right graph will determine the inplane component of the TPI $\Delta V$ normal to the line of sight.

(g) The two components of TPI will be recorded in the maneuver block under the label "CHART" for comparison with the MSFN and PNGS solutions labeled "GND" and "DSKY" respectively.

By the above process the monitoring solution for the midcourse maneuvers will be determined utilizing Figures 4-3 and 4-5.*

A summary of the monitoring data required and time of acquisition relative to TPI follows:

**MONITORING DATA**

<table>
<thead>
<tr>
<th>DATA</th>
<th>UNITS</th>
<th>SOURCE</th>
<th>TIME-MIN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>TPI</td>
</tr>
<tr>
<td>Range</td>
<td>.01 NMI</td>
<td>V 83</td>
<td>-5</td>
</tr>
<tr>
<td>Range Rate</td>
<td>.1 FPS</td>
<td>V 83</td>
<td>-5</td>
</tr>
<tr>
<td>Elevation Angle</td>
<td>.01 DEG</td>
<td>V 83</td>
<td>-8</td>
</tr>
</tbody>
</table>
Since MCC1 is to be performed the navigation tracking attitude, an additional chart (Figure 4-4) must be utilized. Knowing the yaw angle, one can use this chart to convert the X-axis line-of-sight velocity components, calculated by the MCC1 flight chart (Figure 4-3), into the appropriate components at the navigation tracking attitude.
4.2 Optics Failure

Failure of the Optics subsystem degrades performance of the G & N system by preventing SXT alignment of the IMU and state vector updates by SIVB marks. Thus all translation maneuvers would be degraded by attitude errors and PNGS targeting for TPI and midcourse corrections would be based on MSFN uplink vectors. The technique for IMU alignment in case of optics failure will be to utilize the backup alignment programs (P53 and P54) using the COAS for star sightings. The alignment accuracy will be enhanced if the COAS bias errors can be determined on the first mission day prior to G & N power down. Therefore, it is planned during the first 9 hours of the mission to do the Inflight COAS calibration as defined in section 4.11.7 of reference 6.4.

The method for determining the TPI maneuver will be as follows:

After NSR the SCS pulse mode will be selected and the commander will control attitude to maintain wings level and boresight the COAS on the SIVB. The event timer will be set to 52 minutes and holding, awaiting the start of the TPI backup sequence. The CSM pilot will monitor elevation angle from V83 and when 20.0 degrees is reached, the event timer will be started counting up. This will establish the time of TPI and the measurements 5 and 8 minutes prior to the burn. Use of the TPI chart (Figure 4-2) will be similar to that for monitoring as defined in section 4.1, except that range data will not be used. Rather the value of $\Delta V_{\text{FWD}}$ will be obtained from the right edge scale on the upper right graph of Figure 4-2.

Midcourse maneuver data will be obtained in the same manner as for TPI. Midcourse charts and maneuver times will be the same as for PNGS monitoring; however, simulations have shown that an additional midcourse
after TPI is required to control arrival time for large trajectory errors. The chart for this additional correction is shown as Figure 4-9.

A summary of the backup data required for optics failure and time of acquisition relative to TPI follows:

<table>
<thead>
<tr>
<th>DATA</th>
<th>UNITS</th>
<th>SOURCE</th>
<th>TIME FROM TPI - MIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation Angle</td>
<td>.01 DEG</td>
<td>V 83</td>
<td>TPI: -8, B/U MC: -5, MCC1: 3, 6, 9, 12, MCC2: 16, 19</td>
</tr>
</tbody>
</table>
4.3 CMC Failure

The effect of a failed CMC would be to remove all PNGS attitude and translation control capability as well as targeting for the terminal phase maneuvers. For CMC failure prior to NSR the SPS under SCS control will be used through NSR if the mission is continued. The TPI maneuver will be accomplished by the following method:

(a) After NSR the ORDEAL will be initialized by slewing the FDAI to -15 degrees while the COAF is boresighted on the horizon.

(b) The SIVB will be tracked at the top of the COAS reticle using SCS pulse mode and the event timer will be started counting up from 52:00 minutes when the FDAI reaches 15 degrees. At this time the control will be switched to SCS attitude hold.

(c) At 55:00 minutes the SIVB elevation angle on the COAS will be called out by the commander and recorded by the LM pilot in the space labeled \( \alpha \) in the "FAILURES" block.

(d) The LMP then determines \( \Delta \theta \) by adding 7 degrees to \( \alpha \) and \( \theta_5 \) by adding 27 degrees to \( \alpha \).

(e) The graphs on the right side of Figure 4-2 will be used as described in section 4.2 to determine the TPI maneuver components along and normal to the line of sight. Since no \( \Delta V \) can be measured in the body \( Z \) axes for this failure mode, the up/down component will be converted to burn time using the scale at the top of Figure 4-2. The forward component
will be loaded into the EMS and all components executed at 30 seconds on the event timer.

The above process will be repeated for each of the three midcourse maneuvers, except that the burns will be executed at the impulsive burn times. The data required are as follows:

### CMC/IMU FAIL BACKUP DATA

<table>
<thead>
<tr>
<th>DATA</th>
<th>UNITS</th>
<th>SOURCE</th>
<th>TIME FROM TPI - MIN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>TPI</td>
</tr>
<tr>
<td>Elevation Angle</td>
<td>DEG</td>
<td>ORDEAL</td>
<td>-8</td>
</tr>
<tr>
<td>(\Delta) Elevation Angle</td>
<td>.1 DEG</td>
<td>COAS</td>
<td>-5</td>
</tr>
</tbody>
</table>
4.4 IMU Failure

Loss of the IMU results in loss of FNGS attitude and translation as for CMC failure. However, if the failure is close to TPI or a mid-course, a valid solution for the upcoming maneuver might be available. Otherwise the techniques will be identical to those of section 4.3.
### TPI Chart - LOS Components

<table>
<thead>
<tr>
<th>Monitor Comp</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_5$</td>
<td>21.1</td>
<td>$R_5$</td>
</tr>
<tr>
<td>GND DSKY Chart</td>
<td>$\Delta T$</td>
<td>$-\theta_8$</td>
</tr>
<tr>
<td>F/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D/U</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \theta$</td>
<td>23</td>
<td></td>
</tr>
</tbody>
</table>

| Failures | 7.0 | 27.0 |

(5:00) $\rightarrow + \alpha$ 4.7 $\rightarrow + \alpha$ 4.7 $\Delta \theta$ 23 $\theta_5$ |
LINE-OF-SIGHT

ΔV_{P-A} __________

ΔV_{U-D} __________

ΔV_{total} __________

57.0

Δ_{trunnion} __________

Δ_{rotation} __________

Δ_{total \ ΔV} __________

Δ_{rotation} __________

Δ_{track \ ΔV} __________

TRACK

ΔV_{P-A} __________

ΔV_{U-D} __________
OUT OF PLANE - LINE OF SIGHT RATE CHART

- Y AT TPI + 22 MIN ~ DEG
- RANGE AT TPI + 22 MIN ~ N.M.
- TIME PAST TPI ~ MIN.

- At 2:
- F1= 2.0
- F2= 1.5
- F3= 1.0
- F4= 0.5
- F5= 0.25
RENDEZVOUS FAILURE PROCEDURES

OPTICS FAILURE

CDR S/C Control SW - SCS
THC - Neutral
Man ATT SW - Roll - R/C
Pitch - R/C
Yaw - R/C
Limit Cycle SW - OFF
ATT Deadband SW - Min
Rate SW - Low
SCS Channel SW - Roll A/C - OFF
Roll B/C - ON
Pitch - ON
Yaw - ON
BMAG Mode SW - Roll, Pitch,
Yaw - Att 1 Rate 2

FDAI Scale SW - 5/1
FDAI Select SW - 1
FDAI Source SW - ATT SET
ATT SET SW - IMU
CNC ATT SW - IMU

CMP Proceed through P34
Key V37EOOE

PLATFORM FAILURE

CDR S/C Control SW - SCS
THC - Neutral
Man ATT SW - Roll - R/C
Pitch - Min Imp
Yaw - R/C
Limit Cycle SW - OFF
ATT Deadband SW - Min
Rate SW - Low
SCS Channel SW - Roll A/C - OFF
Roll B/D - ON
Pitch - ON
Yaw - ON
BMAG Mode SW - Roll, Pitch,
Yaw - Att 1 Rate 2
Set Attitude Set Wheels
0° - Roll
0° - Pitch
0° - Yaw

FDAI Scale SW - 5/1
FDAI Select SW - 1
FDAI Source SW - ATT SET
ATT SET SW - GDC
CNC ATT SW - IMU

CMP Proceed through P34
CDR Pitch S/C Down - Boresight on horizon.
Establish Roll Reference
Pitch S/C UP - Verify yaw references with target
Press GDC Align
Pitch S/C Down - Boresight on horizon.
CMP Key V37EOOE

COMPUTER FAILURE

CDR S/C Control SW - SCS
THC - Neutral
Man ATT SW - Roll - R/C
Pitch - Min Imp
Yaw - R/C
Limit Cycle SW - OFF
ATT Deadband SW - Min
Rate SW - Low
SCS Channel SW - Roll A/C - OFF
Roll B/D - ON
Pitch - ON
Yaw - ON
BMAG Mode SW - Roll, Pitch,
Yaw - Att 1 Rate 2

FDAI Scale SW - 5/1
FDAI Select SW - 1
FDAI Source SW - ATT SET
ATT SET SW - IMU
CNC ATT SW - IMU

Pitch S/C Down - Boresight on horizon.
OPTICS FAILURE

(28:35) CDR Set ORDEAL
Key V83E
Set Alt to Gnd HA, HP Avg
PWR SW - Earth
FDAl 1 SW - Orb Rate
FDAl 2 SW - Orb Rate
Slew Up/Down to DSKY R3

CMP PRO
CDR Zero FDAl-1 Error Needles
with ATT SET
FDAl Select SW - ½
ATT SET SW - GDC
GDC Align - Press until
FDAl 2 ALIGNS
Man Att SW - Roll, Pitch,
Yaw - Min Imp
Boresight on Target

CMP Key V83E
CDR Set ET to 8:00 Down

(8:00) CDR,CMP When $\theta = 20.0^\circ$ Start ET

CDR Pitch S/C Dow to 1.5° on ball
PRO
Call P41

(6:30) Proceed to body $\Delta V$
components
LMP Copy $\Delta V$

PLATFORM FAILURE

(28:35) CDR Set ORDEAL
Set Alt to Gnd HA, HP Avg
PWR SW - Earth
FDAl 1 SW - Orb Rate
Slew Up/Down to $\theta_{\text{BALL}} = 345.7^\circ$

(8:00) When $\theta_{\text{BALL}} \text{ is } 15.0^\circ$, Start ET,
Pitch and Yaw Man Att SW - R/C

COMPUTER FAILURE

(28:35) CDR Set ORDEAL
Set Alt to Gnd HA, HP Avg
PWR SW - Earth
FDAl 1 SW - Orb Rate
FDAl 2 SW - Orb Rate
Slew Up/Down to $\theta_{\text{BALL}} = 345.7^\circ$

Zero FDAl-1 Error Needles
with ATT SET
FDAl Select SW - ½
ATT SET SW - GDC
GDC Align - Press until
FDAl 2 ALIGNS
Yaw Man Att SW - Min Imp
Pitch S/C Up - Place Target
at Top of Reticle

Set ET to 8:00 Down

(8:00) When $\theta_{\text{BALL}} \text{ is } 15.0^\circ$, Start ET,
Pitch and Yaw Man Att SW - R/C
OPTICS FAILURE

CDR Boresight on Target
CMP Key V37E00E, V83E
(5:00)
LMP C, y R, R, θ
Calculate Up/Down, Fwd/Aft
ΔV (Use Computer or Nominal R)

CMP, LMP Proceed to LOCAL VERTICAL
DISPLAY OF ΔV - Copy
CDR Boresight on Target & Roll
S/C + 7° (Right)
EMS Function SW - DV Set
EMS Mode SW - STBY
Load ΔV FWD on counter
EMS Function SW - DV
CMP Key V37E00E

PLATFORM FAILURE

(5:00)
CDR Read α in Reticle and θ BALL
LMP Compute Up/Down Thrust
Time and Forward ΔV
(Use Computer or Nominal R)
CMP Key V37E01E

CDR EMS Mode SW - Auto
SCS Channel SW - Roll A/C - ON
Man Att SW - Roll, Pitch
Yaw - R/C
(00:30)
Thrust to obtain desired ΔV
on DSKY Display

CMP PRO, Key V37E00E
CDR SCS Channel SW - Roll A/C - OFF

COMPUTER FAILURE

(5:00)
CDR Read α in Reticle and θ BALL
LMP Compute Up/Down Thrust
Time and Forward ΔV
(Use Nominal R)

CDR Boresight on Target & Roll
S/C + 7° (Right)
EMS Function SW - DV Set
EMS Mode SW - STBY
Load ΔV FWD on counter
EMS Function SW - OFF, DV

EMS Mode SW - Auto
SCS Channel SW - Roll A/C - ON
(00:30)
Thrust Forward to Zero EMS
counter and Up/Down for
computed time
SCS Channel SW - Roll A/C - OFF
OPTICS FAILURE

CDR Bore sight on Target
Man Att SW - Pitch, Yaw -
Min Imp

CMP Key V33E

(L5:00)

LMP Copy O

CDR EMS Mode SW - STBY
EMS Function SW - OFF, DV

CMP PRO

(V5:00)

Key V37EYIF, VE3E

(V5:00)

LMP Copy R, ð, ø

Compute Up/Down
Forward/Aft ∆V
(Use Nominal or Computer R)

CMP PRO

EMS Mode SW - Auto
CDR SCS Channel SW - Roll A/C -
ON
Man Att SW - Pitch, Yaw - R/C
Thrust to obtain desired ∆V
on 3SKY display ASAP

CMP PRO, Key V37EOCE

SCS Channel SW - Roll A/C - OFF

PLATFORM FAILURE

CDR Roll S/C to 0° Att

Man Att SW - Pitch, Yaw -
Min Imp

Place TGT at Top of Reticle

(57:00)

Man Att SW - Pitch, Yaw - R/C
EMS Mode SW - STBY
EMS Function SW - OFF, DV

COMPUTER FAILURE

CDR Roll S/C to 0° Att

Man Att SW - Pitch, Yaw -
Min Imp

Place TGT at Top of Reticle

(57:00)

Man Att SW - Pitch, Yaw - R/C
EMS Mode SW - STBY
EMS Function SW - OFF, DV

(54:00)

CDR Read α and θ BALL

Compute Up/Down
Thrust Time and Fwd/Aft
∆V (Use Nominal R)

CDR SCS Channel SW - Roll A/C -
ON
Roll S/C + 7° (Right)
EMS Mode SW - AUTO
Thrust Up/Down for computed
times and Fwd/Aft to obtain
desired ∆V on EMS ASAP

SCS Channel SW - Roll A/C -
OFF

(54:00)

CDR Read α and θ BALL

Compute Up/Down and Fwd/Aft
∆V (Use Nominal R)

SCS Channel SW - Roll A/C -
ON
Roll S/C + 7° (Right)
EMS Mode SW - AUTO
Thrust Up/Down for computed
times and Fwd/Aft to obtain
desired ∆V on EMS ASAP

SCS Channel SW - Roll A/C -
OFF
OPTICS FAILURE

CDR Boresight on Target
Man Att SW - Pitch, Yaw - Min Imp.

CMP Key V3E

51:00
IMP Copy O

EMS Mode SW - STBY
EMS Function SW - OFF, DV

CMP PRO

49:00 (49:00)
Key V37E, V3E

48:00
IMP Copy R, ., O

Compute Up/Down, FWD/AFPT
$\Delta V$ (Use Nominal or Compute R)

CMP Press Key Release

PRO
EMS Mode SW - Auto
CDR SCS Channel SW - Roll A/C - ON
Min Att SW - Pitch, Yaw - R/C
Thrust to obtain desired $\Delta V$
on DSKY Display ASAP

51:00 (51:00)
CDR Man Att SW - Pitch, Yaw - R/C

PLATFORM FAILURE

CDR Roll S/C to $0^\circ$ Att
Place TGT at Top of Reticle
Man Att SW - Pitch, Yaw - Min Imp

(51:00)
CDR Man Att SW - Pitch, Yaw - R/C

EMS Mode SW - STBY
EMS Function SW - OFF, DV

COMPUTER FAILURE

CDR Roll S/C to $0^\circ$ Att
Place TGT at Top of Reticle
Man Att SW - Pitch, Yaw - Min Imp

(51:00)
CDR Man Att SW - Pitch, Yaw - R/C

EMS Mode SW - STBY
EMS Function SW - OFF, DV

(48:00)
CDR Read $\alpha$ and $\phi_{B A L L}$

LMP Compute Up/Down Thrust
Time and FWD/AFPT $\Delta V$
(Use Nominal R)

CDR SCS Channel SW - Roll A/C - OFF

50:00
CDR SCS Channel SW - Roll A/C - ON
Roll S/C + $\gamma^\circ$ (Right)
EMS Mode SW - Auto
Thrusted Up/Down for
Computed Time and
FWD/AFPT to obtain
desired $\Delta V$ on EMS ASAP

SCS Channel SW - Roll A/C - OFF

(48:00)
CDR Read $\alpha$ and $\phi_{B A L L}$

LMP Compute Up/Down Thrust
Time and FWD/AFPT $\Delta V$
(Use Nominal R)

CDR SCS Channel SW - Roll A/C - ON
Roll S/C + $\gamma^\circ$ (Right)
EMS Mode SW - Auto
Thrusted Up/Down for
Computed Time and
FWD/AFPT to obtain
desired $\Delta V$ on EMS ASAP

SCS Channel SW - Roll A/C - OFF
**OPTICS FAILURE**

CDR Bore sight on Target
Man Att SW - Pitch, Yaw - Min Imp

CMP Key V63E
LMP Copy Q

(44:00)

**PLATFORM FAILURE**

CDR Roll S/C to 0° Att
Bore sight on Target
Man Att SW - Pitch, Yaw - Min Imp

(44:00)

CDR Man Att SW - Pitch, Yaw - R/C
EMS Mode SW - STBY
EMS Function SW - OFF, DV

**COMPUTER FAILURE**

CDR roll S/C to 0° Att
Bore sight on Target
Man Att SW - Pitch, Yaw - Min Imp

(44:00)

CDR Man Att SW - Pitch, Yaw - R/C
EMS Mode SW - STBY
EMS Function SW - OFF, DV

(41:00)

Read $\alpha$ and $\phi_{\text{BALL}}$
LMP Compute Up/Down Thrust
Time and FWD/AFT $\Delta V$
(Use Nominal R)

(41:00)

LMP Compute Up/Down Thrust
Time and FWD/AFT $\Delta V$
(Use Nominal R)

CDR EMS Mode SW - Auto
SCS Channel SW - Roll A/C - ON
Roll S/C + 7° (Right)
Thrust Up/Down for
Computed Time and FWD/AFT to obtain desired $\Delta V$
on EMS ASAP

CDR EMS Mode SW - Auto
SCS Channel SW - Roll A/C - ON
Roll S/C + 7° (Right)
Thrust Up/Down for
Computed Time and FWD/AFT to obtain desired $\Delta V$
on EMS ASAP

Read $\alpha$ and $\phi_{\text{BALL}}$

CDR EMS Mode SW - Auto
SCS Channel SW - Roll A/C - ON
Roll S/C + 7° (Right)
Thrust Up/Down for
Computed Time and FWD/AFT to obtain desired $\Delta V$
on EMS ASAP
6.0 References

6.1 SPD-8-001, Mission Requirements, "C" Type Mission, CSM Operations, Revision 1, dated February 14, 1968


