R. LARSON

"C"

RNDZ

Addressees:
CA/D. K. Slayton
CB/A. B. Shepard
W. M. Schirra
D. F. Eisele
R. W. Cunningham
T. P. Stafford
J. W. Young
E. A. Cernan
CF/W. J. North
CF2/J. W. Bilodeau
CF3/C. H. Woodling
CF131/M. K. Lake
CF33/C. C. Thomas
CF33/S. Faber
C. D. Nelson
CF34/J. W. O'Neill
W. M. Anderson
EG/D. C. Cheatham
W. J. Kliner
EG27/H. E. Smith
FC/G. S. Lunney
C. B. Parker
P. C. Shafter
FM/H. W. Tindall
FM4/R. T. Savely
FM6/E. C. Lineberry
K. A. Young
FM5/J. R. Garman
T. F. Gibson
G. R. Kimball
PA2/G. W. Abbey
PD12/M. H. Von Ehrenfried
McDonnell-Douglas/J. C. Callihan
W. W. Hauffler
MIT/J. Nevins (3)
TRW/R. Boudreau

CF/R. Kramer:esp 4-29-68

UNITED STATES GOVERNMENT

Memorandum

TO : See attached list

DATE: April 29, 1968

In reply refer to:
CF241-8M-51

FROM : CF24/Chief, Crew Safety and Procedures Branch

SUBJECT: "C" Mission Rendezvous Procedures

Enclosed is a review copy of the "C" Mission Rendezvous Procedures. These procedures are consistent with the 205/101 trajectory as of mid-April. The work-around for P35 is included as an enclosure to this memorandum which replaces Pages 2-12, 2-13, and 2-14 of the subject document.

It is planned to hold a Rendezvous Procedures Review at 9 a.m., May 9 in Building 4, Room 276, to receive comments and corrections. Following the review, the document will be updated and presented for approval to the Crew Procedures Control Board on May 27, 1968.

For further information, contact Duane K. Mosel, extension 5340.

Paul C. Kramer

Paul C. Kramer

```
     N  KEY V83E
         F 06 54(R,R,E)
     L  BORESIGHT ON TGT(CSAS)  9
     R  COPY E(TFI=BMIN)        8
     N  KEY N20E
         F 06 20(R,P,Y)
     R  COPY YAW
     N  KEY RLSE
         F 06 54(R,R,E)                P20

29+10L  BORESIGHT ON TGT(CSAS)  6
     P  COPY R,P,E(TFI=5MIN)    5
     N  KEY N20E
         F 06 20(R,P,Y)
     R  COPY YAW/CALC BACKUPS
     N  KEY RLSE
         F 06 54(R,R,E)
     R  PRO
         F 50 25   00203

     L BMAG MODE(3)-RATE 2
       SC CONT-CMC
       CMC MODE-ALTO
       MAN ATT(3)-RATE CMD
     N KEY ENTER                   4
         06 22(R,P,Y)
     L MONITOR MANEUVER
         F 50 19(R,P,Y)

     R COMPARE TPI SOLUTIONS       3

29+15N PRO BEFORE TFI=3OSEC       1
         F 06 85(VG-BODY)
       L EMS MODE-ALTO(AT 3OSEC)

TPI  L NULL VG'S AT TFI=O          0
     N PRO
         F 06 44(HA,HP,TPF)
     N PRO
         F 06 32(TIME TO PER)
```

```
     N PRO
         F 50 07
     L EMS FUNCTION-OFF
       EMS MODE-STBY
       BMAG MODE(3)-RATE 2
       SC-CONT-CMC
       CMC MODE-AUTO
     N KEY V37E20E

         F 04 06(SV-OPTION)

     L KEY V48E(LOAD 0.5 DB)  59
         F 04 06   11102DAP
                   11111CON-
                     B  FIG
     L PRO
         F 06 47(IX,IYIZ,WT)
     L PRO
         F 06 48(P,Y TRIM,TLX)
     L PRO

         F 04 06    00001 SV
                   00001OPTION
                      B
     N G/N PWR,OPTICS-ON
       ZERO OPTICS-15 SEC
       OPTICS MODE-CMC
     L MAN ATT(P)-ACC CMD
     N PRO
     L MAN S/C TO NAV TRACK    58
       ATT(SXT)
```

```
       MAN ATT(3)-RATE CMD
     N KEY V58E


     N KEY V37E35E                 57
P35
         F 16 35(TIME FROM INT)
     N PRO
         F 16 45(N,TF-INT,B)

     N KEY V57E
         F 51 BB
     N OPTICS MODE-MAN
29+20  MAKE 1 PHONEY SIXE MARK
     N OPTICS MODE-CMC             56
     N KEY ENTER
         F 06 49(DEL R,DEL V,B)
     N KEY V32E(REJECT UPDATE)
     N RESET ALARM LIGHTS

     N KEY V81E

     N KEY V57E
         F 51 BB
     N OPTICS MODE-MAN
     N MAKE 4 CSM MARKS-1/MIN 55
       (OPTICS MODE-CMC/CHK SV)
     N KEY ENTER(ET=52MIN)         52
         F 16 45(N,TF-INT,B)

     N AFTER LAST MARK PRO-
       CESSED-KEY V85E
         F 06 53(R,R,Q)
       N  BORESIGHT ON TGT(SXT)
29+25R  COPY Q(ET=51MIN)           51
       N  PRO
         F 16 45(N,TF-INT,B)

     N KEY V57E
         F 51 BB
```

```
N MAKE 2 CSM MARKS                50
N OPTICS MODE-CMC
N KEY ENTER(ET=49MIN)             49
    F 16 45(N,TF-INT,B)

N AFTER LAST MARK PROC-
   CESSED-KEY V85E
    F 06 53(R,R,@)
N  BORESIGHT ON TGT(SXT)
R  COPY R,R,@(ET=48MIN)           48
   CALCULATE BACKUPS
N  PRO
    F 16 45(N,TF-INT,B)

N PRO(ET=47+30MIN)
    F 16 45(N,TFI,MGA)
N PRO
    F 16 50(DVMD,TFI,DVTPF)
N PRO
    F 50 07


N KEY V37E41E                     47
P41
    F 04 06(AXIS CODE)
N PRO
    F 06 85(VG-BODY)
N PRO
    F 06 22(R,P,Y)
N PRO
    F 06 85(VG-LV)
N PRO
    F 50 25   00203
N PRO
    ~~F 06 22(R,P,Y)~~
    F 50 19(R,P,Y)

N PRO BEFORE ET=46+30MIN
    F 06 85(VG-BODY)
```

```
R COMPARE SOLUTIONS
MCC1 L NULL VG'S(ET=46MIN)        46
SUNUPN PRO
29+30   F 06 44(HA,HP,TFF)
    N PRO
      F 06 32(TIME TO PER)
    N PRO
      F 50 07
    N KEY V37E35E
P35
      F 16 35(TIME FROM INT)
    N PRO
      F 16 45(N,TF-INT,B)

                  46
L KEY V48E(LOAL C.S DP)
    F 04 06   11102DAP
              1111CON-
                B FIG
L PRO
    F 06 47(IX,IYIZ,WT)
L PRO
    F 06 48(P,Y TRIM,TLX)
L PRO
    F 16 45(N,TF-INT,B)


N KEY V58E

N KEY V85E                        45
    F 06 53(R,R,@)
N  BORESIGHT ON TGT(SXT)
R  COPY @(ET=44MIN)               44
N  PRO                            P41
    F 16 45(N,TF-INT,B)

N KEY V57E
```

```
    F 51 BB
  N OPTICS MODE-MAN
  N MAKE 2 CSM MARKS              43
  N KEY ENTER(ET=42MIN)           42
    F 16 45(N,TF-INT,B)

  N AFTER LAST MARK PROC-
   CESSED-KEY V85E
    F 06 53(R,R,@)
  N  BORESIGHT ON TGT(SXT)
29+35R  COPY R,R,@(ET=41MIN)      41
   CALCULATE BACKUPS
  N  PRO
    F 16 45(N,TF-INT,B)

  N OPTICS MODE-CMC
   G/N PWR,OPTICS-OFF
  N KEY V56E

  N PRO(ET=40+30MIN)
    F 16 45(N,TFI,MGA)

  L BMAG MODE(3)-ATT1/RATE2
   SC CONT-SCS
   MAN ATT(P)-ACC CMD
   BORESIGHT ON TGT(CDAS)
   MAN ATT(3)-RATE CMD

  N PRO
    F 16 59(DVMD,TFI,DVTPF)
  N PRO
    F 50 07


  N KEY V37E41E                   40
    F 04 06(AXIS CODE)
  N PRO
    F 06 85(VG-BODY)
  N PRO
```

```
        F 06 22(R,P,Y)
    N PRO
        F 06 86(VG-LV)
    N PRO
        F 50 25    CO2C3
    N PRO
        C6 22(R,P,Y)
        F 50 19(R,P,Y)

    L FORESIGHT ON TGT(C9AS)

    N PRO BEFORE ET=39+30MIN
        F 06 85(VG-BODY)

    P COMPARE SOLUTIONS

MCC2 L NULL VG'S(ET=39MIN)      39
    N PRO
        F 06 44(PA,-P,1FF)
    N PRO
        F 06 32(TIME TO PER)
    N PRO
        F 50 07
    N KEY V37E00E
PCO
        50 07




    L EMS FUNCTION-OV
      LOCK THC


    N KEY V37E47E
P47
      F 16 83(DV-BODY)
    L COMP LT-OFF/THC ARMED
      ATT DB-MIN IF NORMAL
```

```
        LOS RATES ARE LOW
    N KEY V60E AS REQUIRED

    N KEY V83E
29+40    F 06 54(R,P,0)          36
    L EMS MODE-AUTO
    L REMOVE NORMAL LOS
       RATES AS PER CHARTS

    L BRAKING GATES-
       R=1.0 NM/RDOT TO 25FPS
       R=0.5 NM/RDOT TO 15FPS
       R=0.25NM/RDOT TO 10FPS
29+55  R=1000FT/RDOT TO  5FPS

30+COL STATION KEEPING
```

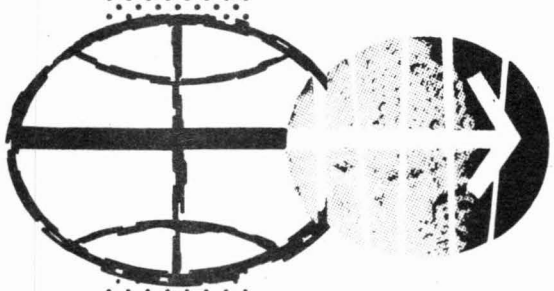
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RENDEZVOUS PROCEDURES

C MISSION

REVIEW COPY

APRIL 29, 1968



MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

RENDEZVOUS PROCEDURES

C MISSION

AS-205/101

April 29, 1968

Prepared by Duane K. Mosel

Duane K. Mosel
Flight Procedures Section

Approved by Paul C Kramer

Paul C. Kramer
Chief, Crew Safety and
Procedures Branch

Warren J. North
Chief, Flight Crew Support
Division

Donald K. Slayton
Chairman, Procedures CCB

TABLE OF CONTENTS

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 SPD8-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 5348.

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 NCC1 and 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 38 most significant nominal mission events are shown in the S-IVB centered relative motion plot. The CSM attitude angles are summarized in a similar manner on Figure 2-2.

2.1 NCC1 Maneuver

At 22:00 hrs. after liftoff, the CMC, IMU, and SCS will be 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, NCC1 burn information and the time that an integral number of orbits prior to TPI is reached will be uplinked at 22:30 over BDA. Sunset on this orbit will occur at about 22:40 at which time the IMU orientation determination program P51 will be performed by the CSM pilot in the LEB. If time permits, a fine align (P52, nominal mode) to the next time corresponding to the TPI position 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 a fine align check.

At 24:05 a perigee will be reached and the ORDEAL will be initialized to the local vertical by slewing the left FDAI to the angle Θ 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). The next sunset will occur at 24:27. Another fine alignment to REFSMMAT will be accomplished, followed by a fine align check on a third star.

During the next daylight period which begins at about 25:00 hrs., the rendezvous navigation program will be called up, the CSM maneuvered manually to the track attitude, V86E performed to initialize the W matrix, and the S-IVB vector updated by sextant marks for a period of about 30 minutes. This will provide the first data for post-flight analysis of the optical navigation.

At 25:35 hrs. over BDA, an MSFN update of both state vectors and the NCC1 maneuver parameters will occur. Following this, the CSM pilot will call the external ΔV program (P30), the Commander will perform the EMS ΔV test, and load the NCC1 ΔV magnitude into the EMS. At about 25:45, the CSM event timers will be synchronized to the NCC1 ignition time to go (V16 N35) and the SPS thrusting program (P40) will be called. The vehicle will be maneuvered automatically to the approximate burn attitude and a fine align to REFSMMAT and fine align check will be performed during the darkness period prior to the NCC1 burn.

At approximately 26:08, the CSM pilot will call the SPS thrust program (P40) and automatically orient to the final burn attitude. The last task to be performed in the LEB prior to NCC1 will be a SXT/Star check after the maneuver to the final burn attitude. At about 26:15, the CSM pilot will leave the LEB and occupy the center seat while the Commander prepares the SPS for ignition.

The 11.7 second NCC1 maneuver will be performed at 26:25. In the interest of conserving RCS propellant it is planned to record but not trim the ΔV residuals, since an SPS NCC2 maneuver will almost certainly be required in any case. Following the NCC1 burn, P00 will be called to terminate average g.

2.2 NCC2 Maneuver

Shortly after the NCC1 maneuver the CSM pilot will enter the LEB and, at sunrise, call the rendezvous navigation program P20. The Commander will maneuver the spacecraft to the track orientation in the acceleration command mode and the CSM pilot will initialize the W matrix and update the S-IVB vector from 26:35 until 27:00. At 27:05 over MLS the MSFN will send up NCC2 and NSR maneuver data, as well as updated state vectors for both vehicles. This will be followed by P30, the EMS ΔV test and loading the NCC2 ΔV into the EMS counter. An automatic maneuver to the burn attitude and a SXT/Star check will be performed. The CSM pilot will leave the LEB at about 27:20.

NCC2 is a phase correction maneuver to place NSR at the desired trailing displacement and altitude. It will be performed with the SPS engine if larger than ~~15 fps~~ .5 sec SPS BURN TIME.

The NCC2 burn will occur at 27:30. If the SPS is used, the Commander will trim the residual velocities to minimize errors at NSR. At the completion of the thrust program, the CMC idling program (P00) 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 CSM pilot will enter the LEB and call P30 while the Commander loads the DAP for narrow deadband and .5 degrees per second rate.

The NSR ignition time and burn complnents will be loaded into P30 and EMS test and initialization for monitoring and backup. The event timers will be set counting down to ignition time, and approximately 23 minutes before NSR an auto maneuver to the burn attitude will be performed. A fine align to REFSMMATT (P52) and an align check will be performed prior to calling the SPS thrust program (P40) 13 minutes prior to NSR, at 27:47. Ten minutes before NSR, at 27:50, the CSM pilot will leave the LEB in preparation for the burn. NSR ignition will be at 28:00. Duration of the SPS burn will be nominally 10.8 seconds.

The velocity residuals will be trimmed carefully to minimize errors in the coelliptical orbit.

2.4 TPI Maneuver

Following the NSR maneuver, the CSM pilot will enter the LEB and call the rendezvous navigation program (P20) and the TPI prethrust program (P34). The CSM will be manually oriented to the track attitude using acceleration command. 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 iterations 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, and at 28:24 the W matrix will be initialized. Then 10 minutes of S-IVB sightings will be made and P34 recycled to observe the change in TPI time and total ΔV. If the updated TPI time is more than ~~10~~ 12 minutes early or ~~20~~ 18 minutes late, ~~P34 will be recalled and the time option will be selected, using the time limit closest to the time predicted by P34~~ STET after the tracking period.

At 28:40 ORDEAL will be initialized to provide the best possible attitude reference for terminal phase backup. The MSFN recommendation for the TPI maneuver will be transmitted to the spacecraft over ANT at 28:47. An additional 10 minutes of S-IVB marks will then be taken starting at 28:51.

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, the event timers will be resynchronized counting down to TPI. The magnitude of the TPI solution will then be set into the EMS. At TPI-10 minutes, the RCS thrusting program will be called and the spacecraft rotated manually in PNGS 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 PNGS TPI maneuver is usable. If the PNGS solution is used, the CSM will be auto maneuvered to the burn attitude. At TPI-30 seconds, the EMS will be turned on and when the event timer reaches zero the DSKY V_G's will be driven to zero by the Commander using the translation controller.

2.5 Midcourse Maneuvers

Following the TPI burn, the DAP will be configured for .5 deg/sec maneuver rate, P20 will be called and the CSM will be maneuvered in acceleration command to the track attitude in preparation for SXT marks on the S-IVB. The midcourse program P35 will be called and 5 SXT marks made by TPI+8 minutes. The CSM Pilot will key ENTER at TPI+8 minutes to permit taking backup data at +9 minutes uisng V85 with the SXT boresighted on the S-IVB. Two more S-IVB 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 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, backup data will be recorded at 16 and 19 minutes with 2 S-IVB 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, Program 47 will be called, the SIVB will be tracked using the COAS. No more S-IVB marks will be made after TPI+18 minutes.

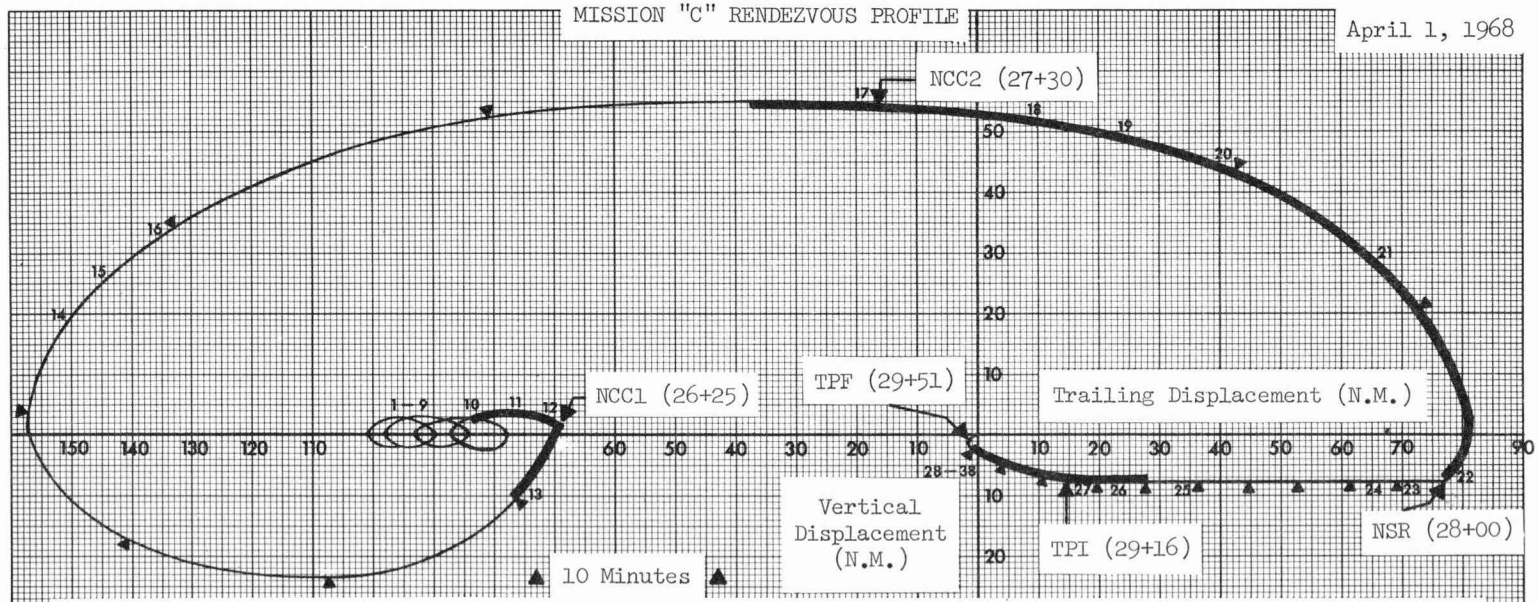
When the S-IVB is boresighted in the COAS, SCS narrow deadband attitude hold will be selected, and with hands off the attitude controller, the drift of the S-IVB in the COAS reticle will be observed. By timing the drift, corrections normal to the line of sight will be obtained from flight charts and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

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

R_{NM}	1.00	0.50	0.25	0.15
R_{MAX} FPS	25	15	10	5

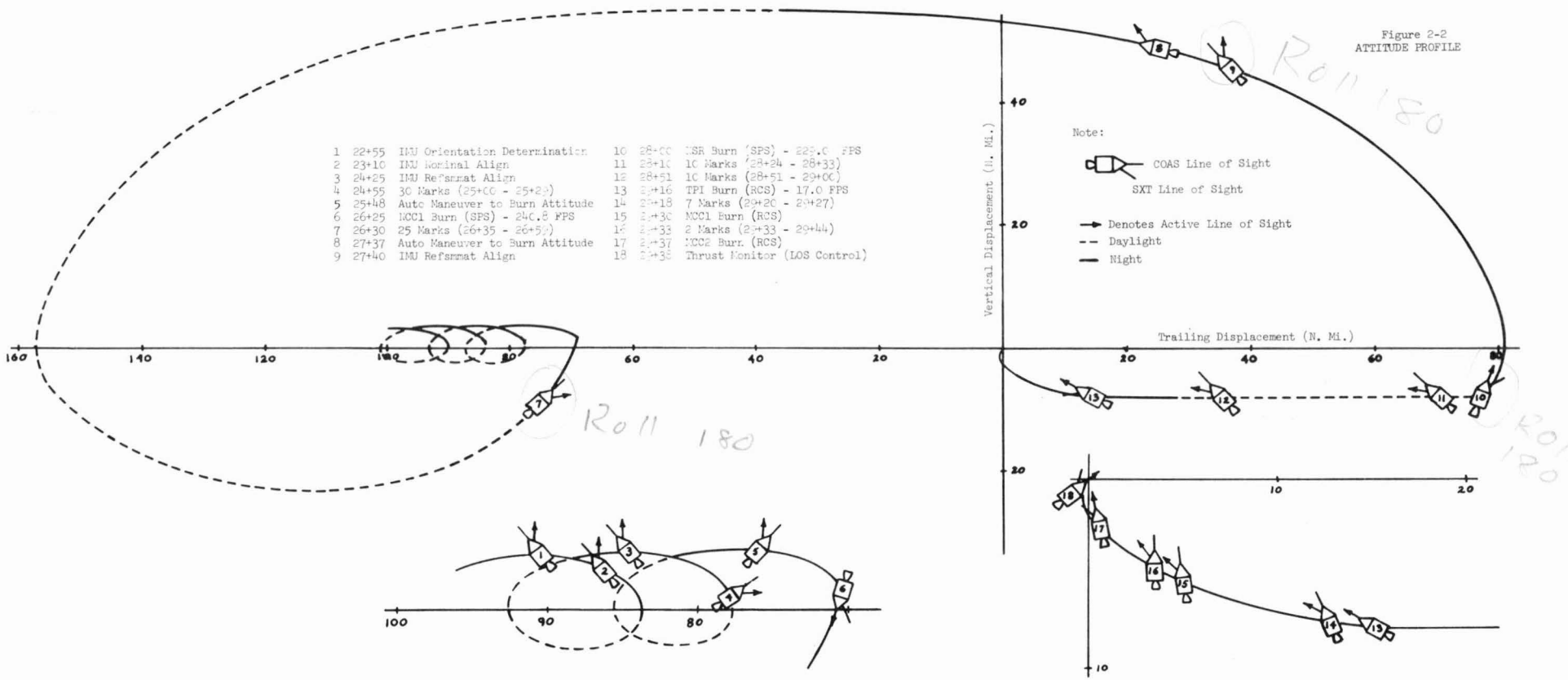
Since limits on TPI time will assure sunrise by the time 1 N MI range is reached, the COAS will be useful for estimating range and closing rate inside the braking gates. Thus a transition can be made from the DSKY display of ranging information to the visual scene. The final braking and initial formation flying will occur about 30:00 hours after liftoff for TPI at the nominal time.

Figure 2-1



1	22+00	P05	GNCS Startup	20	27+40	P52	IMU Refsmmat Align
2	22+25	P00	Ground Uplink (BDA)	21	27+47	P40	NSR Thrust Program
3	22+55	P51	IMU Orientation Determination	22	28+00		NSR Burn (SPS) - 229.0 FPS
4	23+10	P52	IMU Nominal Align	23	28+10	P20	10 Marks (28+24 - 28+33)
5	24+25	P52	IMU Refsmmat Align	24	28+15	P34	TPI Prethrust Program
6	24+55	P20	30 Marks (25+00 - 25+29)	25	28+51		10 Marks (28+51 - 29+00)
7	25+35	P00	Ground Uplink (BDA)	26	29+06	P41	TPI Thrust Program
8	25+40	P30	NCC1 External ΔV	27	29+16		TPI Burn (RCS) - 17.0 FPS
9	25+48	P40	Auto Maneuver to Burn Attitude	28	29+18	P20	7 Marks (29+20 - 29+27)
10	25+55	P52	IMU Refsmmat Align	29	29+19	P35	MCC1 Prethrust Program
11	26+08	P40	NCC1 Thrust Program	30	29+29	P41	MCC1 Burn Program
12	26+25		NCC1 Burn (SPS) - 240.8 FPS	31	29+30		MCC1 Burn (RCS)
13	26+30	P20	25 Marks (26+35 - 26+59)	32	29+31	P35	MCC2 Prethrust Program
14	27+05	P00	Ground Uplink (MLA)	33	29+33		2 Marks (29+33 - 29+44)
15	27+07	P30	NCC2 External ΔV	34	29+36	P41	MCC2 Thrust Program
16	27+10	P40/P41	NCC2 Thrust Program	35	29+37		MCC2 Burn (RCS)
17	27+30		NCC2 Burn (SPS/RCS)	36	29+38	P47	Thrust Monitor (LOS Control)
18	27+33	P30	NSR External ΔV	37	29+51		TPF (RCS) - 17.5 FPS
19	27+37	P40	Auto Maneuver to Burn Attitude	38	30+00		Station Keeping

Figure 2-2
ATTITUDE PROFILE



GET	PRO G	CRE W	DISPLAYS/PROCEDURES	ET
			RECEIVE GO FOR RENDEZVOUS	
		M	ENTER NAV BAY	
21+50			(PERFORM INITIAL SWITCH CHECKLIST)	
		L	CMC ATT=IMU	
			FDAI SCALE=5/1	
			FDAI SEL=1/2	
			FDAI SOURCE=ATT SET	
			ATT SET=GDC	
			MAN ATT(3)=RATE CMD	
			LIMIT CYCLE=OFF	
			ATT DB=MAX	
			RATE=LOW	
			DIRECT RCS=OFF	
			SCS CHAN(4)=OFF	
			SC CONT=CMC	
			CMC MODE=FREE	
			BMAG MODE(3)=RATE 2	
			DV THRUST DIRECT=OFF	
			DV THRUST(A,B)=OFF	
			SCS TVC(2)=RATE CMD	
			GMBL MOTORS(4)=OFF	
			SCS LOGIC BUS 3=ON	
			ELS LOGIC=OFF	
			ELS AUTO/MAN=AUTO	
			IMU CAGE=OFF	
			EMS ROLL=OFF	
			.05G=OFF	
			∝/PC=PC	
			SII/SIVB/GPI=GPI	
			TVC GMBL DRIVE(2)=AUTO	
			FCSM(A,B)=RESET/OVERRIDE	
			LV GUIDANCE=IU	
			EMS FUNCTION=OFF	
			EMS MODE=STBY	
			UP TLM(MDC)=BLOCK	
			FLT RCDR=OFF	
			PANEL 8 CB=CLOSED	
			TVC SERVO PWR(BOTH)=OFF	
			FDAI PWR=BOTH	
			HAND CONT PWR=BOTH	
			SCS ELECT PWR=GDC/ECA	
			BMAG PWR(BOTH)=ON	
		R	G/N PWR=AC1	
			PANEL 5 G/N CB=CLOSED	
		N	G/N PWR,OPTICS=OFF	
			G/N PWR,IMU=OFF	
			OPTICS MODE=ZERO	
			CONT SPEED=HI	
			CONT COUPLING=DIRECT	
			SCT TRUN=SLAVE TO SXT	
			CONDITION LAMPS=ON	
			UP TLM(LEB)=ACCEPT	
		N	PRO(STBY LIGHT=OFF)	
22+00			RSET	
		N	KEY V37E05E	
P05				
			F 50 25 00060	
		N	G/N PWR,IMU=ON	
			(MONITOR NO ATT LT)	
		N	KEY ENTER	
			F 50 07	
		N	KEY V37E00E	
P00				
			50 07	
		L	UP TLM(MDC)=ACCEPT	
22+25			MONITOR GND UPLINK(BDA)	
P27		R	RECORD VOICE DATA	
		L	UP TLM(MDC)=BLOCK	
		L	KEY V48E(DAP LOAD)	
22+35			F 04 06 11102 DAP	
			11111 CON=	
			B FIG	
		L	PRO	
			F 06 47 +00187 .IX	
			+00584 .IYIZ	
			+32607 .WT	
		L	PRO	
			F 06 48 -001.06 PTRIM	
			-000.60 YTRIM	
			+01980 .TLX	
		L	PRO	
			06 48(P,Y TRIM,TLX)	
		N	KEY V46E	
		N	KEY V62E	

```
     L ATT DB=MIN
       SCS CHAN(4)=A
       BMAG MODE(3)=ATT1/RATE2
       SC CONT=SCS
     N G/N PWR,OPTICS=ON
       ZERO OPTICS=15 SEC
       OPTICS MODE=MAN

     N KEY V37E51E
P51
22+55     F 50 25    00015
     L MAN ATT(P,Y)=ACC CMD
SUNDN  MONITOR FDAI
22+57N ACQ ARCTURUS AND VEGA
        IN SCT
     L MAN ATT(3)=RATE CMD

     N KEY ENTER
         F 51 70    STAR CODE
     N MARK ON ARCTURUS
         F 50 25    00016
     N KEY ENTER
23+00    F 01 70    00031

     N PRO
         F 51 70    STAR CODE
     N MARK ON VEGA
         F 50 25    00016
     N KEY ENTER
23+05    F 01 70    00036
     N PRO
           06 05(ANGLE DIFF)
         F 50 07



     N KEY V37E52E
P52
23+10    F 04 06    00005 IMU
                    00002ORIENT
                      B    SEL
```

```
     N PRO
         F 06 34  +000__.TIME
                  +000__. OF
                  +0__.__ALIGN
     L MAN S/C TO SEP,HEADS-UP
     N PRO
         F 06 22(R,P,Y)
     N PRO
     L MONITOR FDAI AND
       NO ATT LIGHT
         F 50 25    00015
     N ZERO OPTICS=15 SEC
     L MAN ATT(P,Y)=ACC CMD
     N ACQ STARS IN SCT
     L MAN ATT(3)=RATE CMD
     N KEY ENTER
       (AVAILABLE STARS=VEGA,
        DENEB,ALTAIR)

      *  F 01 70    STAR CODE 1
     N CHECK STAR CODE 1
       OPTICS MODE=CMC
     N PRO
           06 92(SHAFT,TRUN)
     N IDENTIFY STAR 1
       OPTICS MODE=MAN
         F 51 70    STAR CODE 1
     N MARK ON STAR 1
23+15    F 50 25    00016
     N KEY ENTER
         F 01 70    STAR CODE 1

     N PRO
         F 01 70    STAR CODE 2
     N ZERO OPTICS=15 SEC
       CHECK STAR CODE 2
       OPTICS MODE=CMC
     N PRO
           06 92(SHAFT,TRUN)
     N IDENTIFY STAR 2
```

```
       OPTICS MODE=MAN
         F 51 70    STAR CODE 2
     N MARK ON STAR 2
         F 50 25    00016
     N KEY ENTER
         F 01 70    STAR CODE 2
     N PRO
           06 05(ANGLE DIFF)
         F 06 93(GYRO TORQ ANG)
     N PRO
23+20    F 50 25    00014
     N (FOR FINE ALIGN CHECK=
        KEY ENTER,RETURN TO *,
        ZERO OPTICS AND USE
        THIRD STAR)
     N PRO
SUNUP    F 50 07
23+30N G/N PWR,OPTICS=OFF
     L ATT DB=MAX


     N KEY V37E00E
POO
           50 07


     L SET ORDEAL
24+05N  KEY V82E
         F 06 44(HA,HP,TFF)
     L  SET ALT TO HA,HP AVG
     N  PRO
         F 06 32(TIME TO PER)
     N  PRO
           06 32(TIME TO PER)
     N  KEY V83E
         F 06 54(R,Ṙ,θ)
     L  SLEW ORDEAL FDAI TO θ
     N  PRO
           06 54(R,Ṙ,θ)
```

```
     L ATT DB=MIN
       BMAG MODE(3)=ATT1/RATE2
       SC CONT=SCS
     N G/N PWR,OPTICS=ON

     N KEY V37E52E
P52
24+25     F 04 06    00005 IMU
                     00003ORIENT
                        B    SEL
       (IF P52 COMPLETED ON
        PREVIOUS NIGHT PASS)
     N PRO
         F 50 25    00015
     N ZERO OPTICS=15 SEC
     L MAN ATT(P,Y)=ACC CMD
SUNDN
24+27N ACQ STARS IN SCT
     L MAN ATT(3)=RATE CMD
     N KEY ENTER
       (AVAILABLE STARS=
        ARCTURUS,VEGA,DENEB)

      *  F 01 70    STAR CODE 1
     N CHECK STAR CODE 1
       OPTICS MODE=CMC
     N PRO
           06 92(SHAFT,TRUN)
     N IDENTIFY STAR 1
       OPTICS MODE=MAN
         F 51 70    STAR CODE 1
     N MARK ON STAR 1
24+35     F 50 25    00016
     N KEY ENTER
         F 01 70    STAR CODE 1

     N PRO
         F 01 70    STAR CODE 2
     N ZERO OPTICS=15 SEC
       CHECK STAR CODE 2

       OPTICS MODE=CMC
     N PRO
           06 92(SHAFT,TRUN)
     N IDENTIFY STAR 2
       OPTICS MODE=MAN
         F 51 70    STAR CODE 2
     N MARK ON STAR 2
         F 50 25    00016
     N KEY ENTER
         F 01 70    STAR CODE 2
     N PRO
           06 05(ANGLE DIFF)
         F 06 93(GYRO TORQ ANG)
     N PRO
24+40     F 50 25    00014
     N (FOR FINE ALIGN CHECK=
        KEY ENTER,RETURN TO *,
        ZERO OPTICS AND USE
        THIRD STAR)
     N PRO
24+45     F 50 07
     N G/N PWR,OPTICS=OFF


     N KEY V37E00E
P00
           50 07

     L ALIGN GDC TO IMU
       ATT DB=MAX

     L VERIFY ORDEAL
24+50N  KEY V82E
         F 06 44(HA,HP,TFF)
     L  SET ALT TO HA,HP AVG
     N  PRO
         F 06 32(TIME TO PER)
     N  PRO
           06 32(TIME TO PER)
     N  KEY V83E

         F 06 54(R,Ṙ,θ)
     L  SLEW ORDEAL FDAI TO θ
     N  PRO
           06 54(R,Ṙ,θ)


     L BMAG MODE(3)=RATE 2
       SC CONT=CMC
       CMC MODE=AUTO
     N KEY V37E20E
P20
24+55     F 04 06    00001 SV
                     00001OPTION
                        B
     N G/N PWR,OPTICS=ON
       ZERO OPTICS=15 SEC
       OPTICS MODE=CMC
     L MAN ATT(P)=ACC CMD
     N PRO
     L MAN S/C TO NAV TRACK
        ATT(SXT)
       MAN ATT(3)=RATE CMD
     N KEY V58E

     N KEY V86E
SUNUPN KEY V57E
25+00     F 51 BB
     N OPTICS MODE=MAN
     N MAKE 30 SIVB MARKS=1/MIN
       (OPTICS MODE=CMC/CHK SV)
     N OPTICS MODE=CMC
       G/N PWR,OPTICS=OFF
     N KEY ENTER
           51 BB
     N AFTER LAST MARK PRO=
        CESSED=KEY V56E


     N KEY V37E00E
P00
```

```
          51 BB
     L UP TLM(MDC)=ACCEPT
25+35  MONITOR GND UPLINK(BDA)
P27  R RECORD VOICE DATA
     L UP TLM(MDC)=BLOCK


     N KEY V37E30E
P30
25+40     F 06 33 +00026.TIG
                  +00025.0F
                  +024.10NCC1
     N PRO
          F 06 82 +0051.3DVXL
                  -0001.3DVYL
                  +0235.3DVZL
     N PRO
          F 06 42(HA,HP,DV)
     R COPY DV

     L 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

     L EMS FUNCTION=DV SET
25+45  LOAD DV=12
       EMS FUNCTION=DV

     N PRO
          F 16 35(TFI)
     L SET MDC DET                38
     N SET LEB DET
     N PRO
          F 16 45(N,TFI,MGA)
```

```
     N PRO
          F 50 07



     N KEY V37E40E                37
P40
          F 06 86(VG=LV)
     N PRO
          F 06 22(R,P,Y)
     N PRO
          F 50 25   00203
     L BMAG MODE(3)=RATE 2
       SC CONT=CMC
       CMC MODE=AUTO
     N KEY ENTER
25+50     F 06 22(R,P,Y)           35
     L MONITOR MANEUVER
          F 50 19(R,P,Y)
     N PRO
          F 50 25   00204



     L ATT DB=MIN
       BMAG MODE(3)=ATT1/RATE2
       SC CONT=SCS
     N G/N PWR,OPTICS=ON

     N KEY V37E52E
P52
25+55     F 04 06   00005 IMU  30
                    00003ORIENT
                      B   SEL
     N PRO
          F 50 25   00015
     N ZERO OPTICS=15 SEC
     L MAN ATT(P,Y)=ACC CMD
38SUNDN
25+57N ACQ STARS IN SCT           28
     L MAN ATT(3)=RATE CMD
     N KEY ENTER
```

```
       (AVAILABLE STARS=SPICA,
        ALKAID,ARCTURUS)

      *  F 01 70   STAR CODE 1
     N CHECK STAR CODE 1
       OPTICS MODE=CMC
     N PRO
          06 92(SHAFT,TRUN)
     N IDENTIFY STAR 1
       OPTICS MODE=MAN
          F 51 70   STAR CODE 1
     N MARK ON STAR 1
26+00     F 50 25   00016       25
     N KEY ENTER
          F 01 70   STAR CODE 1

     N PRO
          F 01 70   STAR CODE 2
     N ZERO OPTICS=15 SEC
       CHECK STAR CODE 2
       OPTICS MODE=CMC
     N PRO
          06 92(SHAFT,TRUN)
     N IDENTIFY STAR 2
       OPTICS MODE=MAN
          F 51 70   STAR CODE 2
     N MARK ON STAR 2
26+05     F 50 25   00016       20
     N KEY ENTER
          F 01 70   STAR CODE 2
     N PRO
          06 05(ANGLE DIFF)
          F 06 93(GYRO TORQ ANG)
     N PRO
          F 50 25   00014       18
     N (FOR FINE ALIGN CHECK=
       KEY ENTER,RETURN TO *,
       ZERO OPTICS AND USE
       THIRD STAR)
     N PRO
```

```
      F 50 07
    N G/N PWR,OPTICS=OFF


    N KEY V37E00E
P00
      50 07


    N KEY V37E40E              17
P40
      F 06 86(VG=LV)
    N PRO
      F 06 22(R,P,Y)
    N PRO
      F 50 25   00203
    L BMAG MODE(3)=RATE 2
      SC CONT=CMC
      CMC MODE=AUTO
    N KEY ENTER
      F 06 22(R,P,Y)
    L MONITOR MANEUVER
      F 50 19(R,P,Y)

    N PERFORM SXT/STAR CHECK
26+10  ZERO OPTICS=15 SEC     15
       OPTICS MODE=CMC
       KEY V41N91E
        F 21 92 [___.__]SHAFT
                [__.___]TRUN
                   B
       KEY ENTER AND OBSERVE
        OPTICS DRIVE TO STAR
       KEY RLSE
        F 50 19(R,P,Y)

26+15N LEAVE NAV BAY           10

    R IGNITION PREPARATION
      MN BUS TIE(2)=ON
```

```
      SPS HE VLV TB(2)=BP
      SPS HE VLV(2)=AUTO
   L  FCSM SPSA=ON

   L GMBL DRIVE AND TRIM CHK 9
      TVC SERV PWR 1=AC1/MNA
      TVC SERV 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              8
       PITCH 2 = START=ON
       YAW 2 = START=ON
      CONFIRM GPI TRIM CONT
      SET GPI=PTRIM(=1.06)
              YTRIM(=0.60)
      RHC=VERIFY MTVC
      THC=NEUTRAL
      HAND CONT PWR=BOTH

   L ALIGN S/C IN ROLL        7

   M KEY ENTER
      F 06 22(R,P,Y)
   L MONITOR MANEUVER
      F 50 19(R,P,Y)
   L MAN ATT(3)=RATE CMD
     RATE=HIGH
     DIRECT RCS=ON
     BMAG MODE(3)=ATT1/RATE2

26+20L ALIGN GDC TO IMU        5

   M KEY PRO
      F 50 25   00204
   M KEY ENTER                 4
```

```
   L MONITOR GMBL DRIVE TEST
     VERIFY GPI TRIM
        06 40(TFI,VG,DVM)
   L VERIFY MDC DET
   M VERIFY VG
     CHECK C/W LAMPS
   L FDAI SCALE=5/5            3
     VERIFY S/C ATTITUDE

   L DV THRUST A=NORMAL(1MIN)
     THC=ARMED
     RHC(2)=ARMED
   M FLT RCDR=RECORD
26+25L EMS MODE=AUTO(AT 30SEC)
   M MONITOR DVM               8
   L PERFORM ULLAGE(AT 15SEC)
       F 50 99(TFI,VG,DVM)
   L VERIFY ENGINE TRIM
NCC1 M KEY ENTER BEFORE TFI=0  0
        06 40(TGO,VG,DVM)
   L STOP ULLAGE
     MONITOR FDAI,PC GAUGE
   R MONITOR VALVES OPEN
   M MONITOR DSKY
   L DV THRUST A=OFF(TGO=0)    7
       F 16 40(TGO,VG,DVM)
   R MONITOR VALVES CLOSED

   L GMBL MOTORS
      PITCH 2=OFF
      YAW 2=OFF
      PITCH 1=OFF
      YAW 1=OFF
     TVC SERVO PWR(BOTH)=OFF
     EMS MODE=STBY
   M FLT RCDR=OFF              5
   M PRO
       F 06 85(VG=BODY)
   L THC=LOCKED
   M PRO                       4
```

```
     F 06 44(HA,HP,TFF)
M PR0
     F 06 32(TIME T0 PER)
M PR0
     F 50 07
M KEY V37E00E
P00
       50 07

M ENTER NAV BAY

L EMS FUNCTI0N=0FF
  FDAI SCALE=5/1
  RATE=L0W
  DIRECT RCS=0FF
  FCSM A=RESET/0VERRIDE
R MN BUS TIE(2)=0FF

L KEY V48E(DAP L0AD)
     F 04 06    11102DAP
                11111C0N=
                  B  FIG
L PR0
     F 06 47  +00182.IX
              +00573.IYIZ
              +31838.WT
L PR0
     F 06 48  -001.09PTRIM
              -000.73YTRIM
              +02010.TLX
L PR0
```

```
       06 48(P,Y TRIM,TLX)


SUNUPL BMAG M0DE(3)=RATE 2
26+30  SC C0NT=CMC
       CMC M0DE=AUT0
     N KEY V37E20E
P20
         F 04 06   00001 SV
                   00001 0PTI0N
                     B
     N G/N PWR,0PTICS=0N
       ZER0 0PTICS=15 SEC
       0PTICS M0DE=CMC
     L MAN ATT(P)=ACC CMD
     N PR0
     L MAN S/C T0 NAV TRACK
       ATT(SXT)
       MAN ATT(3)=RATE CMD
     N KEY V58E

     N KEY V86E
     N KEY V57E
       F 51 BB
26+35N 0PTICS M0DE=MAN
     N MAKE 25 SIVB MARKS=1/MIN
       (0PTICS M0DE=CMC/CHK SV)
     N 0PTICS M0DE=CMC
       G/N PWR,0PTICS=0FF
     N KEY ENTER
27+00      51 BB
     N AFTER LAST MARK PR0=
       CESSED=KEY 56E


     N KEY V37E00E
P00
           51 BB

     L SET 0RDEAL
```

```
     N  KEY V82E
         F 06 44(HA,HP,TFF)
     L  SET ALT T0 HA,HP AVG
     N  PR0
         F 06 32(TIME T0 PER)
     N  PR0
           06 32(TIME T0 PER)
     N  KEY V83E
         F 06 54(R,Ṙ,0)
     L  SLEW 0RDEAL FDAI T0 0
     N  PR0
           06 54(R,Ṙ,0)

     L UP TLM(MDC)=ACCEPT
27+05  M0NIT0R GND UPLINK(MLA)
P27  R REC0RD V0ICE DATA
       (DECISI0N=NCC2=RCS/SPS)
     L UP TLM(MDC)=BL0CK


     N KEY V37E30E
P30
         F 06 33 +00027.TIG
                 +00030.0F
                 +000.00NCC2
     N PR0
         F 06 82 +____._DVXL
                 +____._DVYL
                 +____._DVZL
     N PR0
         F 06 42(HA,HP,DV)
     R C0PY DV

     L PERF0RM EMS DV TEST
       EMS FUNCTI0N=0FF
       CB EMS(2)=CL0SED
       EMS M0DE=STBY
       EMS FUNCTI0N=DV SET
       L0AD +1586.8
       EMS FUNCTI0N=DV TEST
```

```
      (SPS LT 0FF AT DV=-0.1)
      EMS M0DE-STBY

    L EMS FUNCTI0N-DV SET
      L0AD DV-12
      EMS FUNCTI0N-DV

    N PR0
        F 16 35(TFI)
    L SET MDC DET                21
    N SET LEB DET
    N PR0
        F 16 45(N,TFI,MGA)
    N PR0
        F 50 07


27+10N KEY V37E40E               20
P40
        F 06 86(VG-LV)
    N PR0
        F 06 22(R,P,Y)
    N PR0
        F 50 25   00203
    L BMAG M0DE(3)-RATE 2
      SC C0NT-CMC
      CMC M0DE-AUT0
    N KEY ENTER
        F 06 22(R,P,Y)
    L M0NITOR MANEUVER
        F 50 19(R,P,Y)

    N PERF0RM SXT/STAR CHECK
27+15   ZER0 0PTICS-15 SEC       15
        0PTICS M0DE-CMC
        KEY V41N91E
         F 21 92  ---•--SHAFT
                  ---•---TRUN
                     B
        KEY ENTER AND 0BSERVE

         0PTICS DRIVE T0 STAR
        KEY RLSE
         F 50 19(R,P,Y)

27+20N LEAVE NAV BAY             10

      R IGNITI0N PREPARATI0N
        MN BUS TIE(2)-0N
        SPS HE VLV TB(2)-BP
        SPS HE VLV(2)-AUT0
      L  FCSM SPSA-0N

      L GMBL DRIVE AND TRIM CHK  9
        TVC SERV PWR 1-AC1/MNA
        TVC SERV PWR 2-AC2/MNB
        HAND C0NT PWR-1
        RHC 2-ARMED
        GMBL M0T0RS              8
         PITCH 2 - START-0N
         YAW 2 - START-0N
        C0NFIRM GPI TRIM C0NT
        SET GPI-PTRIM(-1.09)
                YTRIM(-0.73)
        RHC-VERIFY MTVC
        THC NEUTRAL
        HAND C0NT PWR-B0TH

      L ALIGN S/C IN R0LL        7

      M KEY ENTER
          F 06 22(R,P,Y)
      L M0NITOR MANEUVER
          F 50 19(R,P,Y)
      L MAN ATT(3)-RATE CMD
        RATE-HIGH
        DIRECT RCS-0N
        BMAG M0DE(3)-ATT1/RATE2

27+25L ALIGN GDC T0 IMU          5

      M KEY PR0
          F 50 25   00204
      M KEY ENTER                4
      L M0NITOR GMBL DRIVE TEST
        VERIFY GPI TRIM
            06 40(TFI,VG,DVM)
      L VERIFY MDC DET
      M VERIFY VG
SUNDN CHECK C/W LAMPS
27+27L FDAI SCALE-5/5            3
        VERIFY S/C ATTITUDE

      L DV THRUST A-N0RMAL(1MIN)
        THC-ARMED                1
        RHC(2)-ARMED
      M FLT RCDR-REC0RD
      L EMS M0DE-AUT0(AT 30 SEC)
      M M0NITOR DVM
      L PERF0RM ULLAGE(AT 15SEC)
          F 50 99(TFI,VG,DVM)
      L VERIFY ENGINE TRIM
NCC2  M KEY ENTER BEF0RE TFI-0   0
27+30     06 40(TGO,VG,DVM)
      L ST0P ULLAGE
        M0NITOR FDAI,PC GAUGE
      R M0NITOR VALVES 0PEN
      M M0NITOR DSKY
      L DV THRUST A-0FF(TG0-0)
          F 16 40(TGO,VG,DVM)
      R M0NITOR VALVES CL0SED

      L GMBL M0T0RS
         PITCH 2-0FF
         YAW 2-0FF
         PITCH 1-0FF
         YAW 1-0FF
        TVC SERV0 PWR(B0TH)-0FF
        EMS M0DE-STBY
      M FLT RCDR-0FF
      M PR0
```

```
      F 06 85(VG=B0DY)
   L NULL VG!S
     THC=L0CKED
   M PR0
      F 06 44(HA,HP,TFF)
   M PR0
      F 06 32(TIME T0 PER)
   M PR0
      F 50 07
   M KEY V37E00E
P00
      50 07

   M ENTER NAV BAY

   L EMS FUNCTI0N 0FF
     FDAI SCALE=5/1
     RATE=L0W
     DIRECT RCS=0FF
     FCSM A=RESET/0VERRIDE
   R MN BUS TIE(2)=0FF

   L KEY V48E(DAP L0AD)
      F 04 06   11102DAP
                11111C0N=
                  B  FIG
   L PR0
      F 06 47 +00182.IX
              +00573.IYIZ
              +31838.WT
   L PR0
```

```
      F 06 48 =001.09PTRIM
              =000.73YTRIM
              +02010.TLX
   L PR0
      06 48(P,Y TRIM,TLX)

   N KEY V37E30E
P30
      F 06 33 +00027.TIG
              +00059.0F
              +054.50NSR
   N PR0
      F 06 82 =0083.8DVXL
              +0002.0DVYL
              =0213.1DVZL
   N PR0
      F 06 42(HA,HP,DV)
   R C0PY DV

   L PERF0RM EMS DV TEST
27+35  EMS FUNCTI0N=0FF
       CB EMS(2)=CL0SED
       EMS M0DE=STBY
       EMS FUNCTI0N=DV SET
       L0AD +1586.8
       EMS FUNCTI0N=DV TEST
       (SPS LT 0FF AT DV=-0.1)
       EMS M0DE=STBY

   L EMS FUNCTI0N=DV SET
     L0AD DV=12
     EMS FUNCTI0N=DV

   N PR0
      F 16 35(TFI)
   L SET MDC DET          24
   N SET LEB DET
   N PR0
      F 16 45(N,TFI,MGA)
```

```
   N PR0
      F 50 07

   N KEY V37E40E
P40                                23
      F 06 86(VG=LV)
   N PR0
      F 06 22(R,P,Y)
   N PR0
      F 50 25   00203
   L BMAG M0DE(3)=RATE 2
     SC C0NT=CMC
     CMC M0DE=AUT0
   N KEY ENTER
      F 06 22(R,P,Y)
   L M0NIT0R MANEUVER
      F 50 19(R,P,Y)
   N PR0
      F 50 25   00204

   L ATT DB=MIN
     BMAG M0DE(3)=ATT1/RATE2
     SC C0NT=SCS
   N G/N PWR,0PTICS=0N

27+40N KEY V37E52E             20
P52
      F 04 06   00005 IMU
                00003 0RIENT
                  B   SEL
   N PR0
      F 50 25   00015
   N ZER0 0PTICS=15 SEC
   L MAN ATT(P,Y)=ACC CMD
   N ACQ STARS IN SCT
   L MAN ATT(3)=RATE CMD
   N KEY ENTER
     (AVAILABLE STARS=
```

```
     ALPHERATZ,FORMALHAUT,
     DIPHDA)

   *  F 01 70   STAR CODE 1
   N CHECK STAR CODE 1
     OPTICS MODE=CMC          P00
   N PRO
       06 92(SHAFT,TRUN)
   N IDENTIFY STAR 1
     OPTICS MODE=MAN
       F 51 70   STAR CODE 1  P40
   N MARK ON STAR 1          18
       F 50 25   00016
   N KEY ENTER
       F 01 70   [STAR CODE 1]

   N PRO
       F 01 70   STAR CODE 2
   N ZERO OPTICS=15 SEC
     CHECK STAR CODE 2
     OPTICS MODE=CMC
   N PRO
       06 92(SHAFT,TRUN)
   N IDENTIFY STAR 2
     OPTICS MODE MAN
       F 51 70   STAR CODE 2
   N MARK ON STAR 2          16
       F 50 25   00016
   N KEY ENTER
       F 01 70   [STAR CODE 2]
   N PRO
       06 05(ANGLE DIFF)
       F 06 93(GYRO TORQ ANG)
   N PRO
27+45  F 50 25   00014        15
   N (FOR FINE ALIGN CHECK=
      KEY ENTER,RETURN TO *,
      ZERO OPTICS AND USE
      THIRD STAR)
   N PRO
       F 50 07
   N G/N PWR,OPTICS=OFF


   N KEY V37E00E

        50 07


   N KEY V37E40E             13
       F 06 86(VG=LV)
   N PRO
       F 06 22(R,P,Y)
   N PRO
       F 50 25   00203
   L BMAG MODE(3)=RATE 2
     SC CONT=CMC
     CMC MODE=AUTO
   N KEY ENTER
       F 06 22(R,P,Y)
   L MONITOR MANEUVER
       F 50 19(R,P,Y)

   N PERFORM SXT/STAR CHECK
      ZERO OPTICS=15 SEC     12
      OPTICS MODE=CMC
      KEY V41N91E
       F 21 92  [___•__]SHAFT
                [__•___]TRUN
                    B
      KEY ENTER AND OBSERVE
       OPTICS DRIVE TO STAR
      KEY RLSE
       F 50 19(R,P,Y)


27+50N LEAVE NAV BAY          10

   R IGNITION PREPARATION
      MN BUS TIE(2)=ON
      SPS HE VLV TB(2)=OP
      SPS HE VLV(2)=AUTO
   L  FCSM SPSA=ON

   L GMBL DRIVE AND TRIM CHK 9
      TVC SERV PWR 1=AC1/MNA
      TVC SERV PWR 2=AC2/MNB
      HAND CONT PWR=1
      RHC 2=ARMED
      GMBL MOTORS              8
       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(=1.09)
              YTRIM(=0.73)
      RHC=VERIFY MTVC
      THC=NEUTRAL
      HAND CONT PWR=BOTH       7

   L ALIGN S/C IN ROLL

   M KEY ENTER
       F 06 22(R,P,Y)
   L MONITOR MANEUVER
       F 50 19(R,P,Y)
   L MAN ATT(3)=RATE CMD
     RATE=HIGH
     DIRECT RCS=ON
     BMAG MODE(3)=ATT1/RATE2

27+55L ALIGN GDC TO IMU          5

   M KEY PRO
       F 50 25   00204
   M KEY ENTER                   4
```

```
     L MONITOR GMBL DRIVE TEST
       VERIFY GPI TRIM
            06 40(TFI,VG,DVM)
     L VERIFY MDC DET
     M VERIFY VG
       CHECK C/W LAMPS
     L FDAI SCALE=5/5                3
       VERIFY S/C ATTITUDE           P00

     L DV THRUST A=NORMAL(1MIN)
       THC=ARMED                     1
       RHC(2)=ARMED
     M FLT RCDR=RECORD
     L EMS MODE=AUTO(AT 30SEC)
     M MONITOR DVM
     L PERFORM ULLAGE(AT 15SEC)
         F 50 99(TFI,VG,DVM)
     L VERIFY ENGINE TRIM
NSR  M KEY ENTER BEFORE TFI=0        0
SUNUP     06 40(TGO,VG,DVM)
28+00L STOP ULLAGE
       MONITOR FDAI,PC GAUGE
     R MONITOR VALVES OPEN
     M MONITOR DSKY
     L DV THRUST A=OFF(TGO=0)
         F 16 40(TGO,VG,DVM)
     R MONITOR VALVES CLOSED

     L GMBL MOTORS
        PITCH 2=OFF
        YAW 2=OFF
        PITCH 1=OFF
        YAW 1=OFF
       TVC SERVO PWR(BOTH)=OFF
       EMS MODE=STBY
     M FLT RCDR=OFF
     M PRO
         F 06 85(VG=BODY)
     L NULL VG'S
       THC=LOCKED
```

```
     M PRO
         F 06 44(HA,HP,TFF)
     M PRO
         F 06 32(TIME TO PER)
     M PRO
         F 50 07
     M KEY V37E00E
P00
           50 07

     M ENTER NAV BAY

     L EMS FUNCTION=OFF
       FDAI SCALE=5/1
       RATE=LOW
       DIRECT RCS=OFF
       FCSM A=RESET/OVERRIDE
     R MN BUS TIE(2)=OFF

     L KEY V48E(DAP LOAD)
28+05    F 04 06    11102 DAP
                    11111 CON-
                        B  FIG
     L PRO
         F 06 47  +00177. IX
                  +00563. IYIZ
                  +31124. WT
     L PRO
         F 06 48(P,Y TRIM,TLX)
     L PRO
           06 48(P,Y TRIM,TLX)
```

```
     L BMAG MODE(3)=RATE 2
       SC CONT=CMC
       CMC MODE=AUTO
28+10N KEY V37E20E
P20
         F 04 06    00001 SV
                    00001 OPTION
                        B
     N G/N PWR,OPTICS=ON
       ZERO OPTICS=15 SEC
       OPTICS MODE=CMC
     L MAN ATT(3)=ACC CMD
     N PRO
     L MAN S/C  TO NAV TRACK
        ATT(SXT)
       MAN ATT(3)=RATE CMD
     N KEY V58E


28+15N KEY V37E34E
P34
         F 04 06    00003 TPI
                    00002 DATA
                        B   OPT
     N KEY V06N37E
         F 06 37  +00029. TIG
                  +00016. OF
                  +025.90 TPI
     N KEY RLSE
         F 04 06(TPI DATA OPT)
     N PRO
         F 06 55       B  ELEV
                  +027.45 ANG
                        B
     N PRO
         F 06 39  +00000. DT
                  +00035. TRANS
                  +000.00
```

```
     N PR0
       F 06 37(TIG 0F TPI)
     N PR0
       F 06 58(DVTPI,HP,DVTPF)
     N PR0
       F 16 35(TFI)
     L SET MDC DET                58
     N SET LEB DET
     N PR0
28+20  F 16 45(N,TFI,B)

     N KEY V86E                   53
     N KEY V57E
       F 51 BB
     N 0PTICS M0DE=MAN            52
28+24N MAKE 10 SIVB MARKS=1/MIN
       (0PTICS M0DE=CMC/CHK SV)
     N 0PTICS M0DE=CMC
28+34N KEY ENTER                  42
       F 16 45(N,TFI,B)

28+35N KEY V32E=RECYCLE
       F 06 37(TIG 0F TPI)
       (MAKE DECISI0N 0N TPI      38
        TIG WIND0W)

     N PR0
       F 06 58(DVTPI,HP,DVTPF)
     N PR0
       F 16 35(TFI)
     L SET MDC DET                37
     N SET LEB DET
     N PR0
       F 16 45(N,TFI,B)

     L SET 0RDEAL
28+40N  KEY V82E                  36
       F 06 44(HA,HP,TFF)
     L  SET ALT T0 HA,HP AVG
     N  PR0
       F 06 32(TIME T0 PER)
     N  PR0
       F 16 45(N,TFI,B)
     N  KEY V83E
       F 06 54(R,R.,0)
     L  SLEW  0RDEAL FDAI T0 0
     N  PR0
       F 16 45(N,TFI,B)

     N  KEY V85E                  34
       F 06 53(R,R.,Q)
     R  C0PY R,R.,Q(P0LAR PL0T)
     N  PR0
       F 16 45(N,TFI,B)

28+45L ALIGN GDC T0 IMU           31

28+47R REC0RD V0ICE TPI           29
       DATA(ANT)

     N KEY V57E
28+50  F 51 BB                    26
     N 0PTICS M0DE=MAN            25
28+51N MAKE 10 SIVB MARKS=1/MIN
SUNDN  (0PTICS M0DE=CMC/CHK SV
28+57N 0PTICS M0DE=CMC
     N G/N PWR,0PTICS=0FF
29+01N KEY ENTER                  15
       F 16 45(N,TFI,B)
     N AFTER LAST MARK PR0=
       CESSED=KEY V56E

     N  KEY V85E                  14
       F 06 53(R,R.,Q)
     R  C0PY R,R.,Q(P0LAR PL0T)
     N  PR0
       F 16 45(N,TFI,B)

     L BMAG M0DE(3)=ATT1/RATE2
       SC C0NT=SCS
       MAN ATT(P)=ACC CMD
       B0RESIGHT 0N TGT(C0AS)
       MAN ATT(3)=RATE CMD
       MAN ATT(P,Y)=MIN IMP

     N PR0                        12
       F 06 37(TIG 0F TPI)
     N PR0
       F 06 58(DVTPI,HP,DVTPF)

     L EMS M0DE=STBY
       EMS FUNCTI0N
       L0AD DV
       EMS FUNCTI0N=DV

     N PR0
       F 16 35(TFI)
29+05L CHECK MDC DET              11
     N CHECK LEB DET
     N PR0
       F 16 45(N,TFI,MGA)
     N PR0
       F 50 07


     N KEY V37E41E                10
P41
       F 04 06   00004 AXIS
                 00001 C0DE
                   B
     N PR0
       F 06 85(VG=B0DY)
     N PR0
       F 06 22(R,P,Y)
     N PR0
       F 06 86(VG=LV)
     R C0PY/C0MPARE WITH GND
     N PR0
       F 50 25   00203
```

```
     N  KEY V83E
          F 06 54(R,R,0)
     L  BORESIGHT ON TGT(COAS) 9
     R  COPY 0(TFI=8MIN)       8P00
     N  KEY N20E
          F 06 20(R,P,Y)
     R  COPY YAW
     N  KEY RLSE
          F 06 54(R,R,0)

29+10L  BORESIGHT ON TGT(COAS) 6
     R  COPY R,R,0(TFI=5MIN)   5
     N  KEY N20E
          F 06 20(R,P,Y)
     R  COPY YAW/CALC BACKUPS
     N  KEY RLSE
          F 06 54(R,R,0)
     N  PRO
          F 50 25   00203

     L BMAG MODE(3)=RATE 2
       SC CONT=CMC
       CMC MODE=AUTO
       MAN ATT(3)=RATE CMD
     N KEY ENTER               4
          06 22(R,P,Y)
     L MONITOR MANEUVER
          F 50 19(R,P,Y)

     R COMPARE TPI SOLUTIONS   3

29+15N PRO BEFORE TFI=30SEC    1
          F 06 85(VG=BODY)
     L EMS MODE=AUTO(AT 30SEC)  P20
     L SET ET COUNTING UP/
TPI    NULL VG'S AT TFI=0      0
     N PRO
          F 06 44(HA,HP,TFF)
     N PRO
          F 06 32(TIME TO PER)
```

```
     N PRO
          F 50 07
     N KEY V37E00E

          50 07
     L EMS FUNCTION=OFF
       EMS MODE=STBY

     L KEY V48E(LOAD 0.5 DB)
          F 04 06   11102DAP
                    11111CON=
                      B  FIG
     L PRO
          F 06 47(IX,IYIZ,WT)
     L PRO
          F 06 48(P,Y TRIM,TLX)
     L PRO
          06 48(P,Y TRIM,TLX)

     L BMAG MODE(3)=RATE 2
       SC=CONT=CMC
       CMC MODE=AUTO
     N KEY V37E20E             2

          F 04 06   00001 SV
                    00001OPTION
                       B
     N G/N PWR,OPTICS=ON
       ZERO OPTICS=15 SEC
       OPTICS MODE=CMC
```

```
     L MAN ATT(P)=ACC CMD
     N PRO
     L MAN S/C TO NAV TRACK
       ATT(SXT)
       MAN ATT(3)=RATE CMD
     N KEY V58E


     N KEY V37E35E                3
P35
          F 16 35(TIME FROM INT)
     N PRO
          F 16 45(N,TF=INT,B)

     N KEY V57E
          F 51 BB
     N OPTICS MODE=MAN
129+20N MAKE 5 SIVB MARKS=1/MIN 4
       (OPTICS MODE=CMC/CHK SV)
     N KEY ENTER(ET=8MIN)         8
          F 16 45(N,TF=INT,B)

     N AFTER LAST MARK PRO=
       CESSED=KEY V85E
          F 06 53(R,R,Q)
     N  BORESIGHT ON TGT(SXT)
29+25R  COPY Q(ET=9MIN)          9
     N  PRO
          F 16 45(N,TF=INT,B)

     N KEY V57E
          F 51 BB
     N MAKE 2 SIVB MARKS         10
     N OPTICS MODE=CMC
     N KEY ENTER(ET=11MIN)       11
          F 16 45(N,TF=INT,B)

     N AFTER LAST MARK PRO=
       CESSED=KEY V85E
          F 06 53(R,R,Q)
```

```
     N  BØRESIGHT ØN TGT(SXT)
     R  CØPY R,Ṙ,Q(ET=12MIN)   12
        CALCULATE BACKUPS
     N  PRØ
         F 16 45(N,TF=INT,B)      P00

     N ØPTICS MØDE=CMC

     N PRØ(ET=12+30MIN)
         F 16 45(N,TFI,MGA)
     N PRØ
         F 16 59(DVMD,TFI,DVTPF)
     N PRØ
         F 50 07



     N KEY V37E41E              13
P41
         F 04 06(AXIS CØDE)
     N PRØ
         F 06 85(VG=BØDY)
     N PRØ
         F 06 22(R,P,Y)
     N PRØ
         F 06 86(VG=LV)
     N PRØ
         F 50 25   00203        P35
     N PRØ
           06 22(R,P,Y)
         F 50 19(R,P,Y)

     N PRØ BEFØRE ET=13+30MIN
         F 06 85(VG=BØDY)

     R CØMPARE SØLUTIØNS

MCC1 L NULL VG!S(ET=14MIN)     14
SUNUPN PRØ
29+30    F 06 44(HA,HP,TFF)
     N PRØ
         F 06 32(TIME TØ PER)
     N PRØ
         F 50 07
     N KEY V37E00E

           50 07



     L KEY V48E(LØAD 0.5 DB)
         F 04 06   11102DAP
                   11111CØN=
                     B  FIG
     L PRØ
         F 06 47(IX,IYIZ,WT)
     L PRØ
         F 06 48(P,Y TRIM,TLX)
     L PRØ
           06 48(P,Y TRIM,TLX)

     N KEY V58E



     N KEY V37E35E              15
         F 16 35(TIME FRØM INT)
     N PRØ
         F 16 45(N,TF=INT,B)

     N KEY V85E
         F 06 53(R,Ṙ,Q)
     N  BØRESIGHT ØN TGT(SXT)
     R  CØPY Q(ET=16MIN)        16P41
     N  PRØ
         F 16 45(N,TF=INT,B)

     N KEY V57E
         F 51 BB
     N ØPTICS MØDE=MAN
     N MAKE 2 SIVB MARKS        17
     N KEY ENTER(ET=18MIN)      18
         F 16 45(N,TF=INT,B)

     N AFTER LAST MARK PRØ=
       CESSED=KEY V85E
         F 06 53(R,Ṙ,Q)
     N  BØRESIGHT ØN TGT(SXT)
29+35R CØPY R,Ṙ,Q(ET=19MIN)   19
       CALCULATE BACKUPS
     N  PRØ
         F 16 45(N,TF=INT,B)

     N ØPTICS MØDE=CMC
       G/N PWR,ØPTICS=ØFF
     N KEY V56E

     N PRØ(ET=19+30MIN)
         F 16 45(N,TFI,MGA)

     L BMAG MØDE(3)=ATT1/RATE2
       SC CØNT=SCS
       MAN ATT(P)=ACC CMD
       BØRESIGHT ØN TGT(CØAS)
       MAN ATT(3)=RATE CMD

     N PRØ
         F 16 59(DVMD,TFI,DVTPF)
     N PRØ
         F 50 07



     N KEY V37E41E              20
         F 04 06(AXIS CØDE)
     N PRØ
         F 06 85(VG=BØDY)
     N PRØ
         F 06 22(R,P,Y)
```

```
     N PR0
       F 06 86(VG-LV)
     N PR0
       F 50 25   00203
     N PR0
         06 22(R,P,Y)
     L B0RESIGHT 0N TGT(C0AS)
       F 50 19(R,P,Y)

     N PR0 BEF0RE ET=20+30MIN
       F 06 85(VG-B0DY)

     R C0MPARE S0LUTI0NS

MCC2 L NULL VG'S(ET=21MIN)     21
     N PR0
       F 06 44(HA,HP,TFF)
     N PR0
       F 06 32(TIME T0 PER)
     N PR0
       F 50 07
     N KEY V37E00E
P00
         50 07




     L EMS FUNCTI0N-DV
       L0CK THC


     N KEY V37E47E
P47
       F 16 83(DV-B0DY)
     L C0MP LT-0FF/THC ARMED
       ATT DB-MIN IF N0RMAL
        L0S RATES ARE L0W
     N KEY V60E AS REQUIRED
```

```
     N KEY V83E
29+40   F 06 54(R,Ṙ,θ)          24
     L EMS M0DE-AUT0
     L REM0VE N0RMAL L0S
       RATES AS PER CHARTS

     L BRAKING GATES-
       R=1.0 NM/RD0T T0 25FPS
       R=0.5 NM/RD0T T0 15FPS
       R=0.25NM/RD0T T0 10FPS
29+55  R=1000FT/RD0T T0  5FPS

30+00L STATI0N 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 PNGS 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 back-up 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

(G) 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 can not 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 ΔV 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 CSM 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 4-4. 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 and yaw gimbal angle from V85 and N90 respectively will be recorded. These angles will be recorded by the LM pilot, on Figure 4-1 in the block labeled "OPTICS FAIL" in the spaces next to θ_8 and ψ_8.

(c) At TPI-5 minutes, θ_5 and ψ_5 are recorded in the space above θ_8

and Ψ_8 and range and range rate from V83 are recorded in the spaces provided within the block labled "MONITOR COMP".

(d) With θ_5 and R_5 as inputs the lower left graph in Figure 4-2 will be used to read $\dot{R}_{REQ}$ which will be logged in the space provided below $\dot{R}_5$.

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

(f) Subtracting θ_8 from θ_5 will define $\Delta\theta$. Entering the upper right graph with $\Delta\theta$, progressing horizontally to the value of θ_5, and dropping vertically to R_5 in the lower right graph will determine the inplane component of the TPI ΔV normal to the line of sight.

(g) Differencing Ψ_8 and Ψ_5 results in $\Delta\Psi$ which will be recorded in the space below Ψ_8. From the table of Ψ_5 vs $\Delta\Psi_{nom}$ the value of $\Delta\Psi_{nom}$ will be obtained and recorded below $\Delta\Psi$. Adding $\Delta\Psi$ to $\Delta\Psi_{nom}$ will define $\delta\Delta\Psi$ which will be used as an input to the graph in place of $\Delta\theta$ to determine the right/left component of TPI.

(h) The three components of TPI will be recorded in the maneuver block under the lable "CHART" for comparison with the MSFN and PNGS solutions labeled "GND" and "BSKY" respectively.

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

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

MONITORING DATA

DATA	UNITS	SOURCE	TIME-MIN					
			TPI		MCC1		MCC2	
Range	.01 NMI	V 83		-5		12		19
Range Rate	.1 FPS	V 83		-5		12		19
Elevation Angle	.01 DEG	V 83	-8	-5	9	12	16	19
Azimuth Angle	.01 DEG	N 90	-8	-5	9	12	16	19

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 6.3.

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 ΔV_{FWD} will be obtained from the right edge scale on the lower 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 4-7.

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

OPTICS FAIL BACKUP DATA

DATA	UNITS	SOURCE	TIME FROM TPI - MIN							
			TPI		B/U MC		MCC1		MCC2	
Elevation Angle	.01 DEG	V 83	-8	-5	3	6	9	12	16	19
Azimuth Angle	.01 DEG	N 90								

4.3 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 COAS 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.

(c) At this time the control will be switched to SCS attitude hold, and FDAI yaw angle will be recorded on Figure 4-2 in the space labeled Ψ_8 which is located in the box labeled COMP/PLAT FAIL.

(d) At 55:00 minutes the SIVB azimuth and elevation angle on the COAS will be called out by the commander and recorded by the LM pilot in the spaces labeled Ψ_8 and α in the COMP/PLAT FAIL block along with θ_B.

(e) The LM pilot then determines $\Delta\theta$ by adding 7 degrees to α, θ_5 by adding 27 degrees to α, and Ψ_5 by adding $\Delta\Psi$ to Ψ_8

(f) 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 ΔV can be measured in the body Y and Z axes for this failure mode, the up/down and left/right components will be converted to burn time using the scales at the bottom of Figure 4-2. The forward component will be loaded into the

EMS and all components executed at 0.00 on the event timer.

The above process will be repeated for each of the three midcourse maneuvers. The data required are as follows:

CMC/IMU FAIL BACKUP DATA

DATA	UNITS	SOURCE	TIME FROM TPI - MIN							
			TPI		B/U MC		MCC1		MCC2	
Elevation Angle	DEG	ORDEAL	-8			6		12		19
Azimuth Angle	DEG	ORDEAL	-8		3		9		16	
Δ Elevation Angle	.1 DEG	COAS		-5		6		12		19
Δ Azimuth Angle	.1 DEG	COAS		-5		6		12		19

4.4 IMU Failure

Loss of the IMU results in loss of PNGS 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.

CSM RELATIVE REFERENCE TRAJECTORY

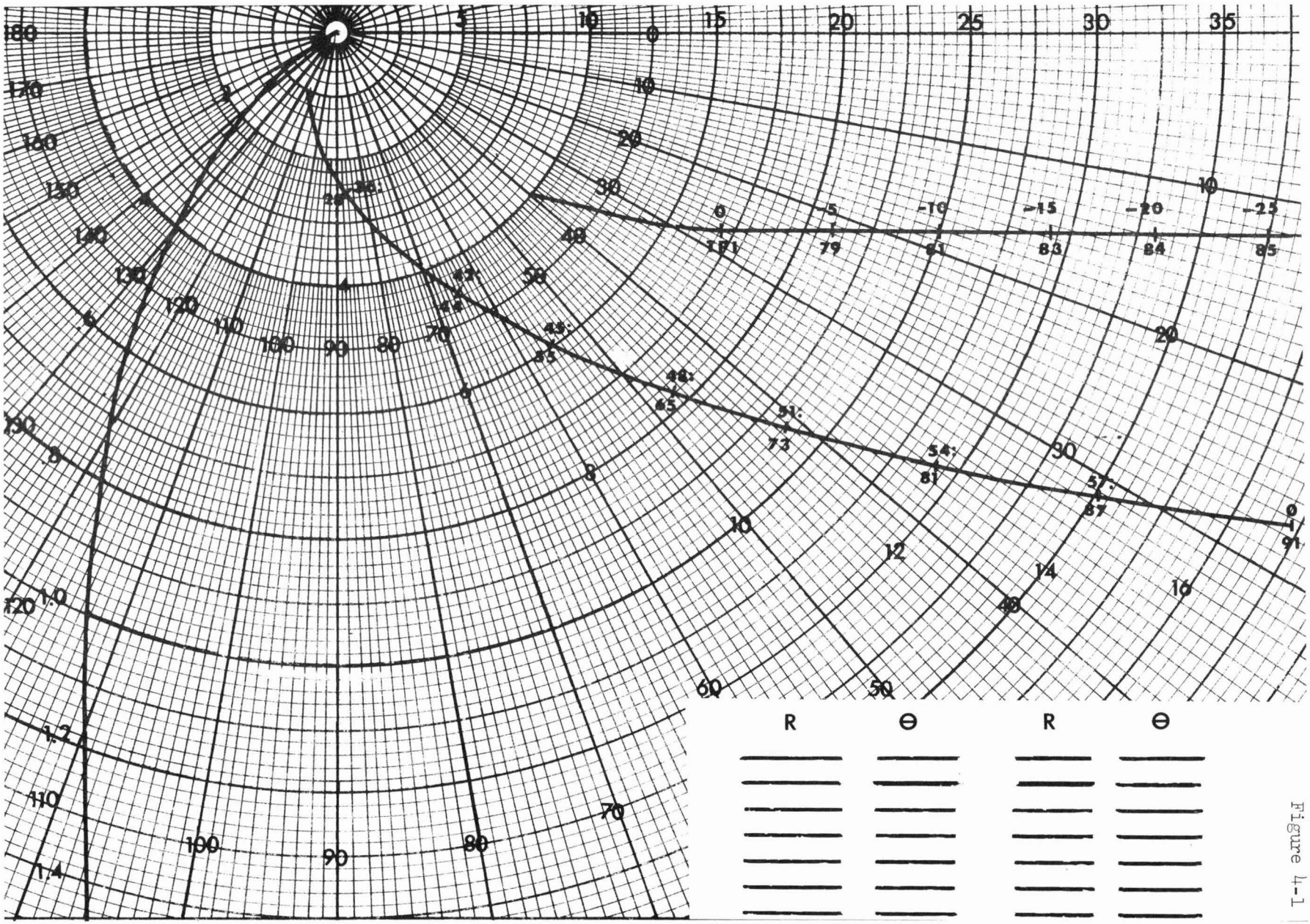


Figure 4-1

TPI CHART LOS. COMPONENTS

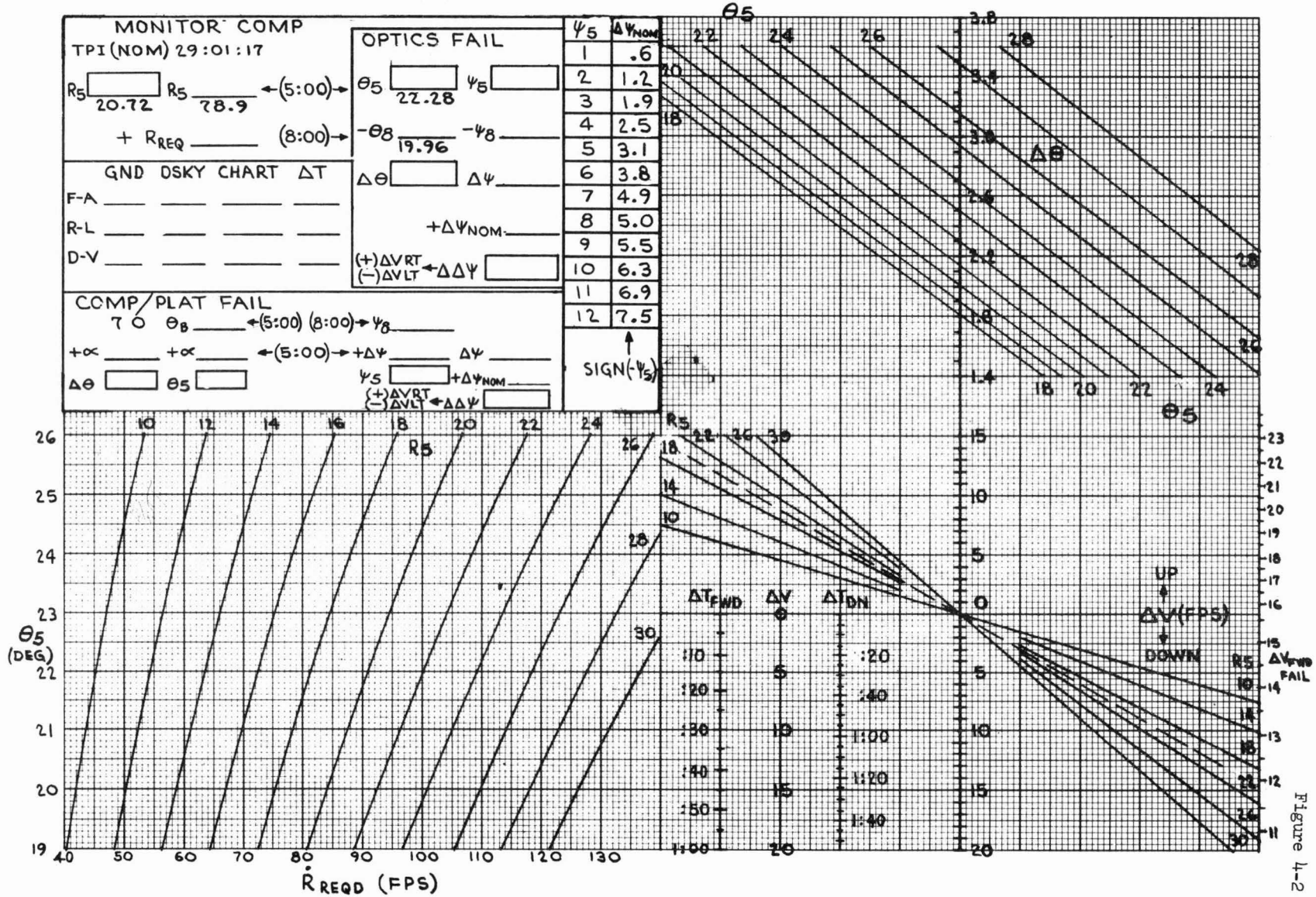


Figure 4-2

1ST MIDCOURSE CHART – LOS COMPONENTS

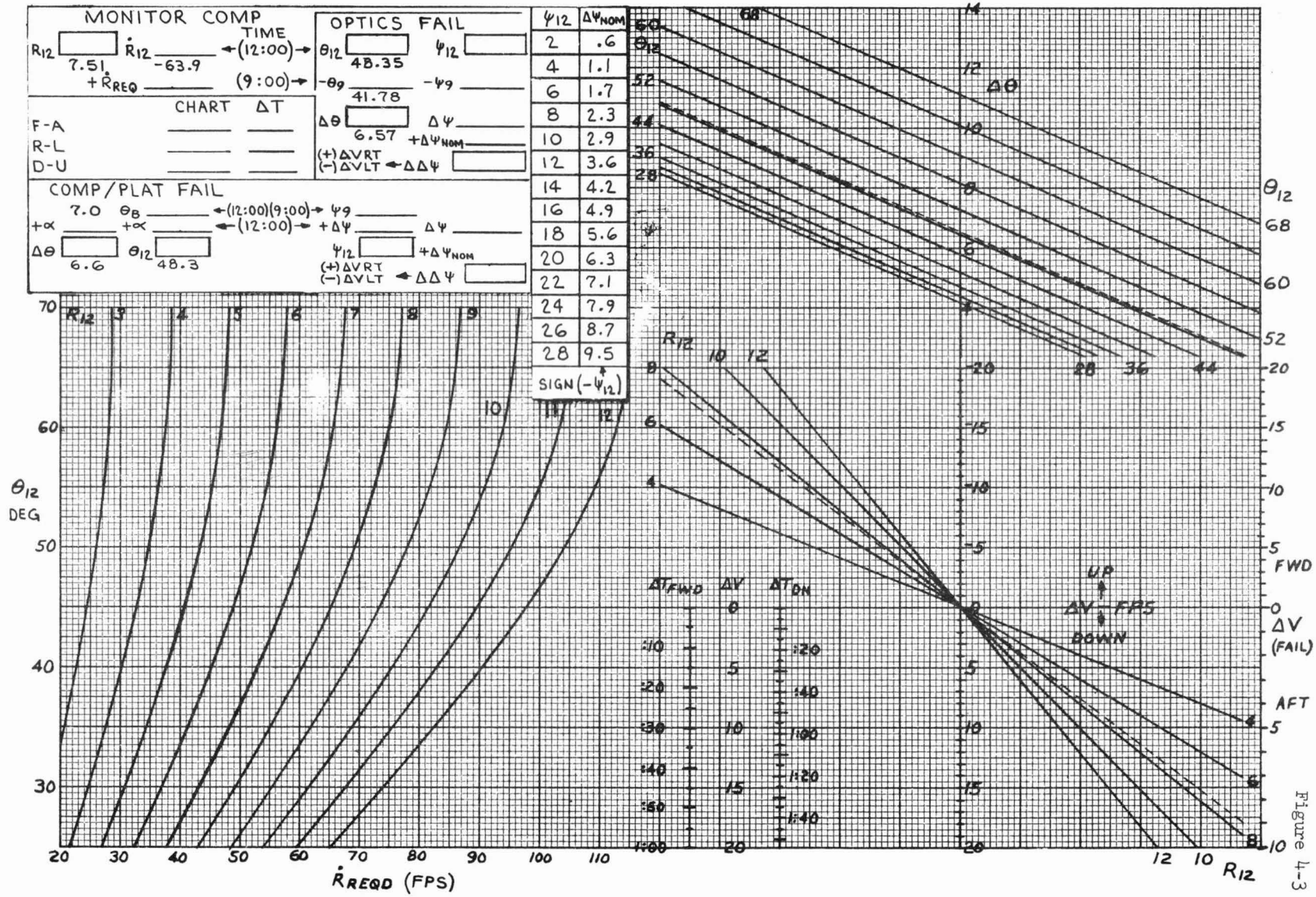


Figure 4-3

2ND MIDCOURSE CHART - LOS COMPONENTS

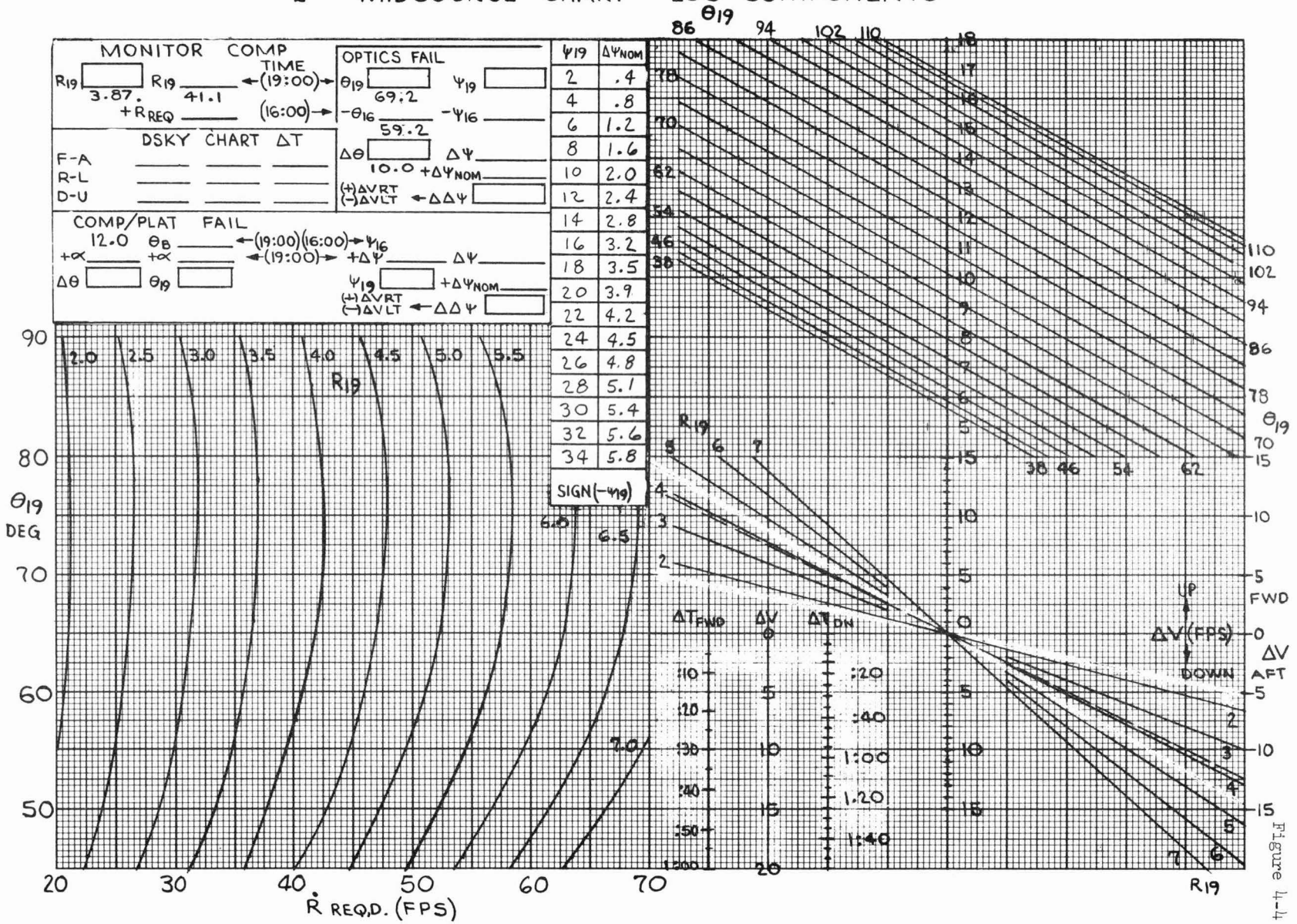


Figure 4-4

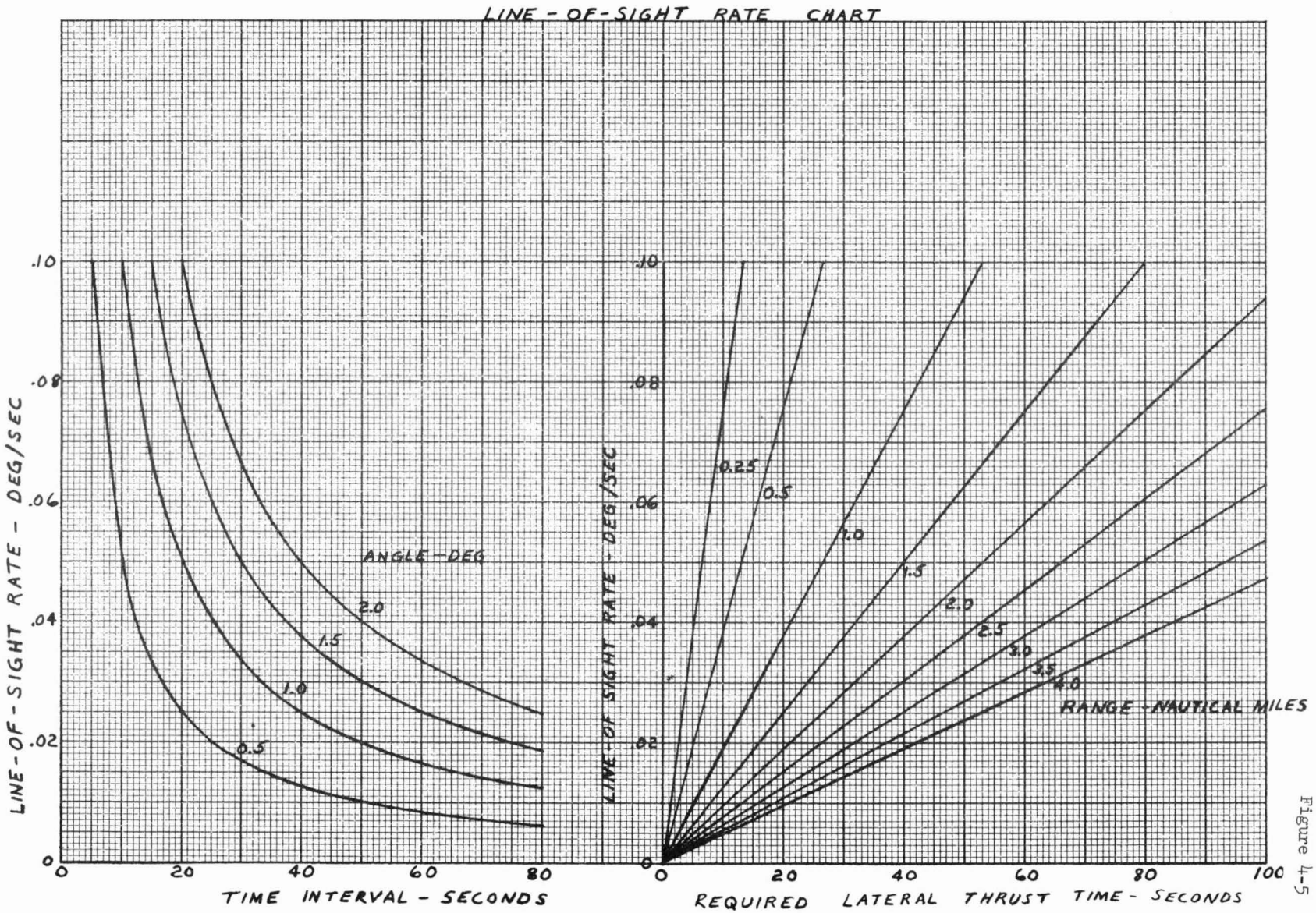

LINE - OF - SIGHT RATE CHART
LINE-OF-SIGHT RATE - DEG/SEC
.10
.08
.06
.04
.02
0
ANGLE - DEG
2.0
1.5
1.0
0.5
0
20
40
60
80
TIME INTERVAL - SECONDS
LINE-OF-SIGHT RATE - DEG/SEC
.10
.08
.06
.04
.02
0
0.25
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
RANGE - NAUTICAL MILES
0
20
40
60
80
100
REQUIRED LATERAL THRUST TIME - SECONDS

Figure 4-5

BRAKING

TIME$_N$	θ_N	R_N	$\dot{R}_N$	α	TIME	R
22:00	81.03	2.85	-33.0			
23:00	85.33	2.54	-30.3			
24:00	89.78	2.25	-28.0			
25:00	94.36	1.98	-25.8			
26:00	99.03	1.74	-24.0			
27:00	103.76	1.51	-22.4			
28:00	108.50	1.29	-21.2			
29:00	113.23	1.09	-20.2			
30:00	117.89	.89	-19.5			
31:00	122.48	.70	-19.0			
32:00	126.95	.52	-18.7			
33:00	131.29	.33	-14.7			

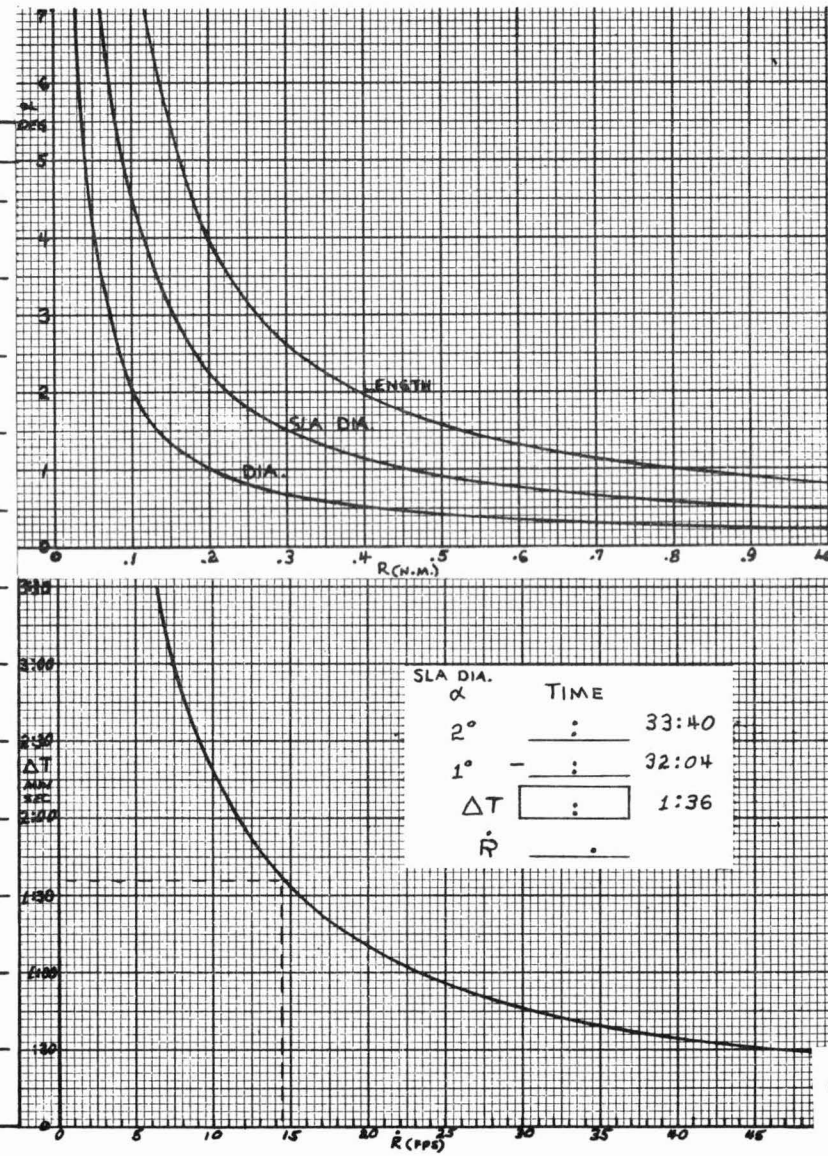


Figure 4-6

BACKUP MIDCOURSE CHART - LOS COMPONENTS

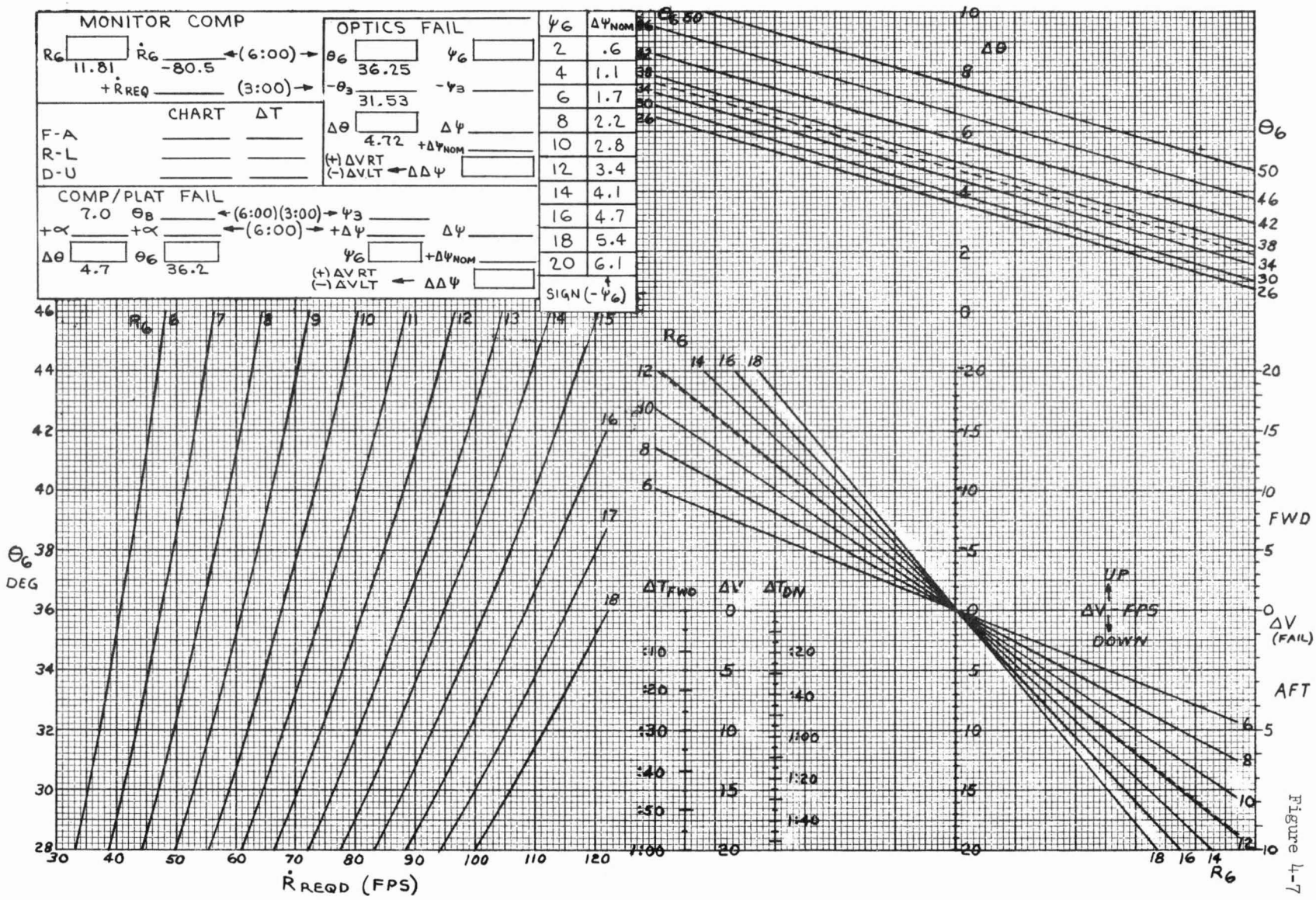


Figure 4-7

5.0 Backup Procedures

OPTICS FAILURE

L 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/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
CMC ATT SW - IMU

M Proceed through P34

(28:25) Set ORDEAL (28:25)
Key V83E

L Set Alt - 140 N.M.
PWR SW - Earth
FDAI 1 SW - Orb Rate
FDAI 2 SW - Orb Rate
Slew Up/Down to DSKY R3

M PRO

L Zero FDAI - 1 Error Needles with ATT SET
FDAI Select SW - 1/2
ATT SET SW - GDC
GDC Align - Press until FDAI-2 ALIGNS

PLATFORM FAILURE

L 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
CMC ATT SW - IMU

M Proceed through P34

L Pitch S/C Down - Boresight on Horizon
Establish Roll Reference
Pitch S/C UP - Verify yaw reference with target
Press GDC Align
Press S/C Down - Boresight on Horizon
Verify Roll Reference

Set ORDEAL (28:25)

Set Alt - 140 N.M.
PWR SW - Earth
FDAI 1 SW - Orb Rate

Slew Up/Down to $\Theta_{BALL} = 345.7^{\circ}$

COMPUTER FAILURE

L 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
345.7° - Pitch
0° - Yaw

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

Pitch S/C Down - Boresight on Horizon

Set ORDEAL

Set Alt - 140 N.M.
PWR SW - Earth
FDAI 1 SW - Orb Rate
FDAI 2 SW - Orb Rate
Slew Up/Down to $\Theta_{BALL} = 345.7^{\circ}$

Zero FDAI - 1 Error Needles with ATT Set
FDAI Select SW - 1/2
ATT SET SW - GDC
GDC Align - Press until FDAI 2 ALIGNS

		OPTICS FAILURE			PLATFORM FAILURE			COMPUTER FAILURE
	L	Man Att SW - Roll, Pitch, Yaw - Min Imp Boresight on Target		L	Yaw Man Att Sw - Min Imp Pitch S/C Up - Place Target at Top of Reticle		L	Yaw Man Att Sw - Min Imp Pitch S/C Up - Place Target at Top of Reticle
	M	Key V83E						
	L	Set ET to 52:00 UP			Set ET to 52:00 UP			Set ET to 52:00 UP
52:00	L,M	When θ = 20.0° Start ET and Key N20E	52:00		When θ_{BALL} is 15.0°, Start ET, Pitch and Yaw	52:00		When θ_{BALL} is 15.0°, Start ET, Pitch and Yaw
	R	Copy yaw angle			Man Att SW - R/C and Read ψ_{BALL}			Att SW - R/C and Read ψ_{BALL}
	L	Pitch S/C down to 1.5° on ball						
	M	Press Key Release PRO Call P41						
53:30		Proceed to body ΔV components						
	R	Copy ΔV						
	L	Boresight on target						
	M	Key V34E						
55:00	M,R	Key V83E, Copy Key N20E, Copy yaw angle	55:00	L,M,R	Read α and $\Delta\psi$ in Reticle and θ_{BALL} V83E-Copy	55:00		Read α and $\Delta\psi$ in Reticle and θ_{BALL}
	R	Calculate Up/Down, Forward/Aft, Right/Left ΔV (Use Computer or Nominal R)		R	Compute Up/Down, Right/Left Thrust Times and Forward ΔV (Use Computer or Nominal R)		R	Compute Up/Down, Right/Left Thrust Times and Forward ΔV (Use Nominal R)
				M	Key V37E41E		L	Boresight on target
				M,R	Proceed to LOCAL VERTICAL DISPLAY of ΔV - Copy			
				L	Boresight on target			
	L	EMS Function SW - DV Set EMS Mode SW - STBY Load ΔV FWD on Counter EMS Function SW - DV			EMS Function SW - DV Set EMS Mode SW - STBY Load ΔV FWD on counter EMS Function SW - DV			EMS Function SW - DV Set EMS Mode SW - STBY Load ΔV FWD on Counter EMS Function SW - DV
	M	Press Key Release PRO		M	Key V34E			
58:00		Key V37E47E						
59:00	L	EMS Mode SW - Auto SCS Channel SW - Roll A/C - ON Man Att Sw - Roll, Pitch, Yaw - R/C		L	EMS Mode SW - Auto SCS Channel SW - Roll A/C - ON			EMS Mode SW - Auto SCS Channel SW - Roll A/C - ON
59:30		Thrust to obtain desired ΔV on DSKY Display	59:30		Thrust Forward to Zero EMS Counter	59:30		Thrust Forward to Zero EMS Counter
	M	PRO			Thrust Up/Down and Right/Left for Computed Times			Thrust Up/Down and Right/Left for Computed Times
	L	Man Att SW - Roll, Pitch, Yaw - Min Imp SCS Channel SW - Roll A/C - OFF			Man Att SW - Roll, Pitch, Yaw - Min Imp SCS Channel SW - Roll A/C - OFF			Man Att SW - Roll, Pitch, Yaw - Min Imp SCS Channel SW - Roll A/C - OFF

OPTICS FAILURE

	L	Boresight on Target
3:00	M,R	Key V83E, Copy
		Key N20E, Copy yaw angle
	L	EMS Function SW - DV Set
		EMS Mode SW - STBY
		Load 0 fps on Counter
		EMS Function SW - DV
	M	Press Key Release
		PRO
5:00		Key V37E47E
6:00	M,R	Key V83E, Copy
		Key N20E, Copy Yaw Angle
	R	Computer Up/Down, Forward/Aft, Right/Left ΔV
		(Use Nominal or Computer R)
	M	Press Key Release
		PRO
		EMS Mode SW - Auto
	L	SCS Channel SW - Roll A/C - ON
		Man ATT Sw - Roll, Pitch, Yaw - R/C
		Thrust to obtain desired ΔV on DSKY Display
	M	PRO ASAP
	L	Man ATT SW - Roll, Pitch, Yaw - Min. Imp
		SCS Channel SW - Roll A/C - OFF
		Boresight on Target
9:00	M,R	Key V83E, Copy
		Key N20E, Copy yaw angle
	L	EMS Function SW - DV Set
		EMS Mode SW - STBY
		Load 0 fps on Counter
		EMS Function SW - DV
	M	Press Key RElease
		PRO
11:00		Key V37E47E
12:00	M,R	Key V83E, Copy
		Key N20E, Copy Yaw Angle
	R	Compute Up/Down, FWD/AFT, Right/Left ΔV
		(Use Nominal or Computer R)
	M	Press Key Release
		PRO
		EMS Mode SW - AUTO
	L	SCS Channel SW - Roll A/C - ON
		Man ATT SW - Roll, Pitch, Yaw - R/C
		Thrust to obtain desired ΔV on DSKY Display ASAP
	M	PRO
	L	Man ATT SW - Roll, Pitch, Yaw - Min Imp
		SCS Channel SW - Roll A/C - OFF

PLATFORM FAILURE

	L	Place TGT at Top of Reticle
3:00		Man ATT Sw - Roll, Pitch, Yaw - R/C and Read Ψ_{BALL} 3:00
		EMS Mode SW - STBY
		EMS Function SW - DV Set
		Load 0 fps on Counter
		EMS Function SW - DV
6:00		Read α, $\Delta\Psi$ and θ_{BALL} 6:00
	R	Compute Up/Down, Fwd/Aft & Right/Left Thrust Times
		(Use Nominal R)
	L	SCS Channel SW - Roll A/C - ON
		EMS Mode SW - AUTO
		Thrust Up/Down, FWD/AFT and Right/Left for computed times ASAP
		Man ATT SW - Roll, Pitch, Yaw - Min Imp
		SCS Channel SW - Roll A/C - OFF
		Place TGT at Top of Reticle
9:00		Man ATT SW - Roll, Pitch, Yaw - R/C and Read Ψ_{BALL} 9:00
		EMS Mode SW - STBY
		EMS Function SW - DV Set
		Load 0 fps on Counter
		EMS Function SW - DV
12:00		Read α, $\Delta\Psi$ and θ_{BALL} 12:00
	R	Compute Up/Down, FWD/AFT and Right/Left Thrust times
		(Use Nominal R)
	L	SCS Channel SW - Roll A/C - ON
		EMS Mode SW - AUTO
		Thrust Up/Down, FWD/AFT and Right/Left for Computed Times ASAP
		Man ATT SW - Roll, Pitch, Yaw - Min Imp
		SCS Channel SW - Roll A/C - OFF

COMPUTER FAILURE

	L	Place TGT at Top of Reticle
3:00		Man ATT SW - Roll, Pitch, Yaw - R/C and read Ψ_{BALL}
		EMS Mode SW - STBY'
		EMS Function SW - DV Set
		Load 0 fps on counter
		EMS Function SW - DV
6:00		Read α, $\Delta\Psi$ and θ_{BALL}
	R	Compute Up/Down, FWD/AFT and Right/Left Thrust Times
		(Use Nominal R)
	L	SCS Channel SW - Roll A/C - ON
		EMS Mode SW - AUTO
		Thrust Up/Down, FWD/AFT and Right/Left for computed times ASAP
		Man ATT SW - Roll, Pitch, Yaw - Min Imp
		SCS Channel SW - Roll A/C - OFF
		Place TGT at Top of Reticle
9:00		Man ATT SW - Roll, Pitch, Yaw - R/C and read Ψ_{BALL}
		EMS Mode SW - STBY
		EMS Function SW - DV Set
		Load 0 fps on Counter
		EMS Function SW - DV
12:00		Read α, $\Delta\Psi$ and θ_{BALL}
	R	Compute Up/Down, FWD/AFT and Right/Left Thrust Times
		(Use Nominal R)
	L	SCS Channel SW - Roll A/C - ON
		EMS Mode SW - AUTO
		Thrust Up/Down, FWD/AFT and Right/Left for computed Times ASAP
		Man ATT Sw - Roll, Pitch, Yaw - Min Imp
		SCS Channel SW - Roll A/C - OFF

OPTICS FAILURE

	L	Boresight on Target
16:00	M,R	Key V83E, Copy
		Key N20E, Copy Yaw Angle
	L	EMS Function SW - DV Set
		EMS Mode SW - STBY
		Load 0 fps on Counter
		EMS Function SW - DV
	M	Press Key Release
		PRO
18:00		Key V37E47E
19:00		Key V83E, Copy
		Key N20E, Copy Yaw Angle
	R	Compute Up/Down, FWD/AFT, Right/Left ΔV (Use Nominal or Computer R)
	L	EMS Mode SW - AUTO
		SCS Channel SW - Roll A/C - ON
		Man ATT SW - Roll, Pitch, Yaw - R/C
		Thrust to Obtain Desired ΔV on DSKY Display ASAP
	M	Key V83E
	L,R	Control Line of Sight Rates
	L	EMS Function SW - DV Set
		Load 0 fps on Counter
		EMS Function SW - DV
		When SLA diameter is one degree, reduce RDOT by five fps
		When SLA diameter is two degrees, reduce estimated RDOT to five fps

PLATFORM FAILURE

	L	Boresight on Target
16:00		Man ATT SW - Roll, Pitch, Yaw - R/C
		EMS Function SW - DV Set
		EMS Mode SW - STBY
		Load 0 fps on Counter
		EMS Function SW - DV
19:00		Read α_C, $\Delta\Psi$ and Θ_{BALL}
	R	Compute Up/Down, FWD/AFT and Right Left Thrust Times (Use Nominal R)
	L	EMS Mode SW - AUTO
		SCS Channel SW - Roll A/C - ON
		Thrust Up/Down, FWD/AFT and Right/Left for Computed Times - ASAP
	L,R	Control Line of Sight Rates
	L	EMS Function SW - DV Set
		Load 0 fps on Counter
		EMS Function SW - DV
		When SLA diameter is one degree, reduce RDOT by five fps
		When SLA diameter is two degrees, reduce estimated RDOT to five fps

COMPUTER FAILURE

	L	Boresight on Target
16:00		Man ATT SW - Roll, Pitch, Yaw - R/C
		EMS Function SW - DV Set
		EMS Mode SW - STBY
		Load 0 fps on Counter
		EMS Function SW - DV
19:00		Read α_C, $\Delta\Psi$ and Θ_{BALL}
	R	Compute Up/Down, FWD/AFT and Right/Left Thrust Times (Use Nominal R)
	L	EMS Mode SW - AUTO
		SCS Channel SW - Roll A/C - ON
		Thrust Up/Down, FWD/AFT and Right/Left for Computed Times - ASAP
	L,R	Control Line of Sight Rates
	L	EMS Function SW - DV Set
		Load 0 fps on Counter
		EMS Function SW - DV
		When SLA diameter is one degree, reduce RDOT by five fps
		When SLA diameter is two degrees, reduce estimated RDOT to five fps

6.0 References

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

6.2 Young, Kenneth A., C Mission Trajectory Printout, dated March 26, 1968.

6.3 SM2A-03-SC101(2), Apollo Operations Handbook, Command and Service Modules, Volume 2, Operational Procedures, dated March 1, 1968.

6.4 Memorandum CF242-7M-122, Ordeal Error, David R. Blue, dated July 6, 1967.

6.5 Guidance System Operations Plan, Sundisk, Volume 1, MIT R-547, Revision 1, dated November 1967.

6.6 CSM/LM Spacecraft Operational Data Book, Volume III, Mass Properties, SNA-8-D-027, dated March 1968.

6.7 Apollo AS-205/101 Reference Flight Plan, Flight Crew Support Division, dated December 27, 1967.