D. Hoffman / Bellcomm

IQ

SD68-723

SD 68-723

MISSION EVALUATION PRESIMULATION REPORT

Part 1: CSM 104 (Mission D) Operations Plan

August 1968

Contract NAS9-150, SA 300, Exhibit I, Paragraph 5.1.1.2

SPACE DIVISION
NORTH AMERICAN ROCKWELL CORPORATION

SD 68-723

MISSION EVALUATION PRESIMULATION REPORT

Part 1: CSM 104 (Mission D) Operations Plan

August 1968

Contract NAS9-150, SA 300, Exhibit I, Paragraph 5.1.1.2

SPACE DIVISION
NORTH AMERICAN ROCKWELL CORPORATION

CONTENTS

ILLUSTRATIONS

TABLES

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of the Mission Evaluation 104 Simulation Study is to verify that the spacecraft guidance, navigation, and control subsystems are capable of performing the planned mission phases under nominal and certain off-nominal conditions. Crew procedures for selected failure mode conditions will be verified for Mission D. In addition, spacecraft guidance, navigation, and control subsystems performance characteristics will be evaluated for backup and failure conditions. As a result, a data base will be generated for postflight analysis.

The purpose of this report is to define the studies to be accomplished during the ME 104 simulation. The flight phases and test objectives of Mission D are identified with simulation study phases. The objectives of each simulation study phase are presented as are the detailed run schedules. The performance results of the ME 101 study, Reference 1, strongly influenced the distribution of emphasis on this study.

1.2 MISSION D G&C OBJECTIVES

The Mission D objectives (Reference 2), which are related to the guidance, navigation, and control functions are listed in succeeding paragraphs:

P1.23 CSM Autopilot Stability Margin (Cannot be satisfied by ME 104)

a. Validate control system stability during short- and long-duration thrusting.

b. Provide a measure of structural dynamic response to a known forcing function.

P1.24 CSM IMU Alignment Accuracy

a. Evaluate man-machine interfaces during the alignment process.

b. Establish the uncertainties in the alignment process.

c. Evaluate the overall alignment accuracy in a docked configuration

Pl. 25 IMU Orientation Determination (Cannot be satisfied in ME 104)

a. Determine if star patterns are visible in daylight.

b. Obtain data for prediction of star visibility in the lunar landing mission.

c. Determine if LM surface reflections or mass expulsion are detrimental to the performance of the IMU orientation determination function or midcourse navigation sighting.

Pl. 28 GNCS Automatic Entry

a. Verify ability of DAP to control an automatic entry and to maintain attitude and attitude rates within required deadbands.

b. Evaluate GNCS accuracy in guiding the CM to a desired target point without exceeding the allowable g loads.

P20. 33 CSM Single Crewman Rendezvous Capability

a. Obtain data on the single crewman accomplishment of procedures and on the operational timeline used in preparing the CSM for an active rendezvous and update the simulation if required.

b. Prepare the CSM for a LM rescue while the LM executes the phases of the LM concentric flight plan (CFP) rendezvous.

Sl. 26 Orbital Navigation/Landmark Tracking

a. Establish error uncertainties in the landmark navigation sightings.

b. Evaluate the procedural aspects of landmark tracking in a flight environment using the SCT.

1. 3 SIMULATION CONFIGURATION

The simulation configuration consists of the following six major areas:

Analog computers
Partial SCS hardware

Partial GNCS hardware
CM evaluator
RTSS/interface
Visual displays

A total simulation configuration flow diagram is shown in Figure 1-1. A detailed description of each area can be found in Part II of this Pre-simulation Report. This simulation configuration resembles that of ME 101; however, it has the additional capability of providing a visual cue for terminal rendezvous braking employing a LM model.

1.4 SIMULATION SCHEDULE

The ME 104 simulation will be conducted in seven study phases described in detail in Section 3.0. The preliminary schedule for conducting these study phases is presented in Figure 1-2 and is based on an estimated start date of 2 September 1968. The schedule is for planning purposes only. Past experience has shown that a detailed schedule changes frequently because of unpredictable situations and events.

Page Intentionally Left Blank

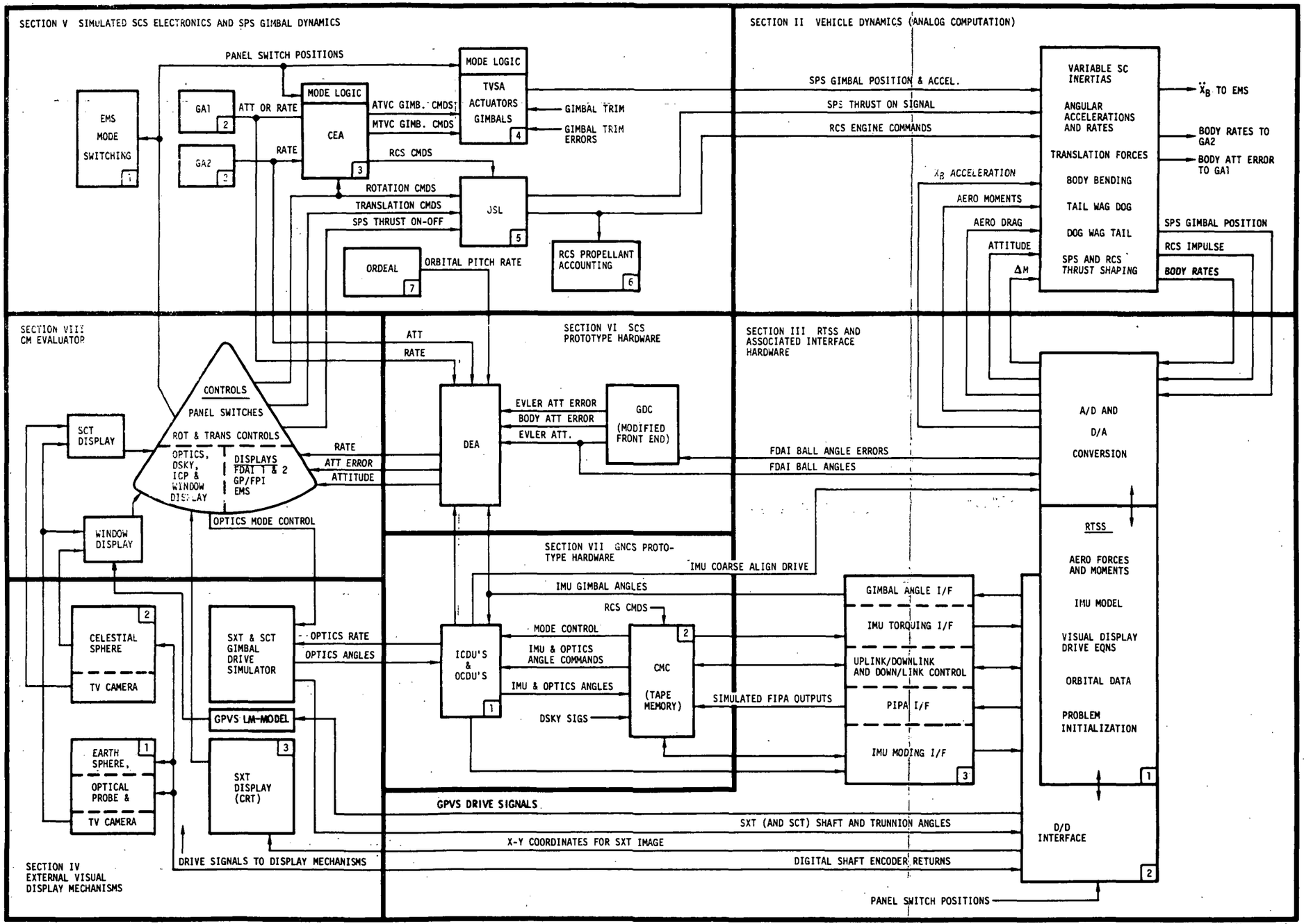

Figure 1-1. Simulation Configuration Flow Diagram

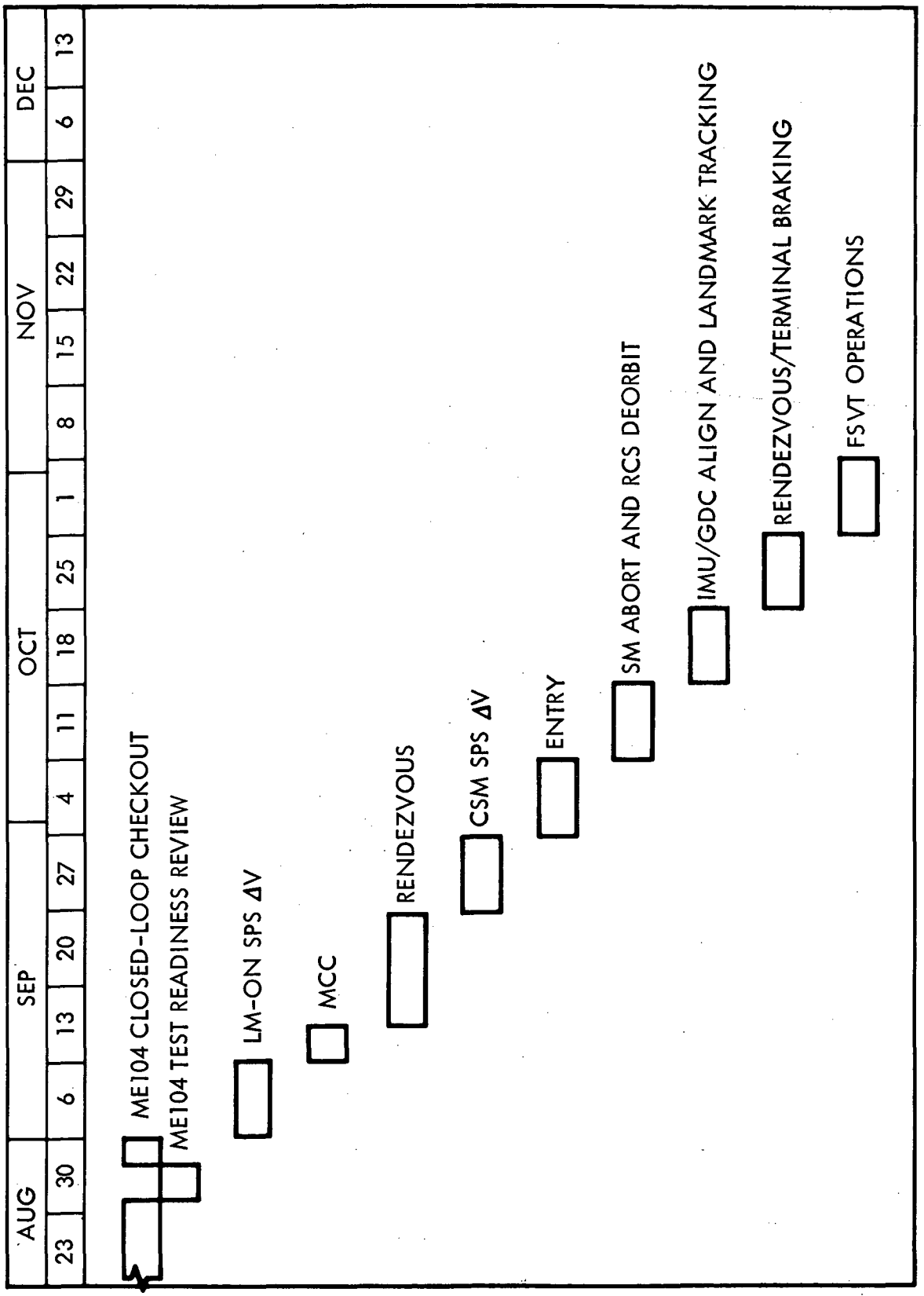

Figure 1-2. ME 104 Operations Schedule

2.0 MISSION DESCRIPTION

2.1 NOMINAL MISSION PHASES

The Apollo Mission D is divided into six major periods of activities which are described in detail in Reference 3. The events in each of these six periods that will be simulated are discussed in some detail below. The SPS burn schedule is summarized in Table 2-1. Contingency phases will be discussed in the next section.

2.1.1 First Period of Activities

Prelaunch and launch phases are not simulated.

2.1.1.1 Earth Parking Orbit

Earth parking orbit includes the CSM transposition, docking, and withdrawal of the LM, which will not be evaluated.

2.1.1.2 First Docked SPS Burn

Upon entering darkness, the CSM IMU is realigned, and preparation is made for the first docked SPS ignition. The 63 fps GNCS controlled, external ΔV targeted burn raises the apogee to 140 nautical miles to ensure an adequate orbital lifetime. This burn also establishes a safe operating distance from the S-IVB. A partial demonstration of the CSM digital automatic pilot (DAP) attitude control capability is accomplished with this burn.

2.1.2 Second Period of Activities

2.1.2.1 Second Docked SPS Burn

This docked SPS burn is the first of two out-of-plane, long-duration burns. The resultant ΔV of 1200 fps reduces the orbital inclination and rotates the line of nodes to the west. About 20,600 pounds of propellant are consumed during the 220 seconds of burn, reducing the CSM mass in order to increase the effectiveness of the CM RCS to perform LM rescue. This burn also partially demonstrates the CSM DAP attitude control capability during the one-half amplitude stroking test accomplished during the burn.

Table 2-1. Mission D SPS Burn Summary

Burn No.	GET of Initiation (day:hr:min:sec)	Duration (sec)	ΔV (fps)	Control Mode	Configuration	Total Ullage Time (sec)	Resulting h_a/h_p (NM)	Purpose
1	0:04:26:13	8.88	62.86	GNCS/Ext ΔV	Docked	0	140/104	Provides orbital lifetime and safe separation from S-IVB before first S-IVB restart. Partially demonstrates CSM autopilot stability margin.
2	0:22:08:33	220.22	1699.15	GNCS/Ext ΔV	Docked	0	140/104	Reduces CSM weight for LM rescue or RCS deorbit. Partially demonstrates CSM autopilot stability margin. One half amplitude stroking test.
3	0:23:39:10	185.93	1699.04	GNCS/Ext ΔV	Docked	0	140/104	Cancels trajectory effects of burn 2. Reduces CSM weight. Completes the demonstration of CSM auto-pilot stability margin. Full amplitude stroking test.
4	1:03:36:19	9.97	103.4	GNCS/Ext ΔV	Docked	18	134/134	Circularizes orbit for rendezvous. Lessens orbital drag.
5	5:00:18:22	6.11	132.36	GNCS/Ext ΔV	CSM solo	16	207/131	Raises apogee to lessen RCS deorbit requirements.
6	5:01:13:40	4.16	93.21	GNCS/Ext ΔV	CSM solo	16	210/95	Lower apogee to lessen RCS deorbit requirements. Positions perigee to set up deorbit conditions.
7	9:20:35:31	12.24	266.13	GNCS/Ext ΔV	CSM solo	16	202/-11	Deorbits CM. Nominal touchdown at ·60° longitude.

2.1.2.2 Third Docked SPS Burn

Approximately one revolution after the second SPS burn, a 1700 fps GNCS controlled external ΔV burn is performed to cancel out the trajectory effects of the second burn. About 12,000 pounds of propellant are consumed during the 186 seconds of burn, further enhancing the CSM's capability for LM rescue and SM RCS deorbit. A full-amplitude stroking test is accomplished during this burn.

2.1.2.3 Fourth Docked SPS Burn

The final docked SPS burn circularizes the orbit at 134 nautical miles. This burn is also GNCS-controlled, and external V targeted to burn 9 seconds, providing a 100-fps ΔV. The resultant circular orbit is the base orbit from which the LM active rendezvous will be initiated in the fifth period.

2.1.3 Third Period of Activities

Not simulated.

2.1.3.1 LM Power-Up and Systems Check

The two LM crew members transfer intravehicle to the LM, where they proceed to power up the LM and conduct systems check and evaluation.

2.1.3.2 Docked Descent Propulsion System (DPS) Burn

A 283-second DPS burn is accomplished to verify the GNCS DAP capability to control rates and attitude during a thrusting maneuver in the docked configuration and to demonstrate manual throttling of the DPS engine.

2.1.4 Fourth Period of Activities

Not simulated.

2.1.4.1 EVA

The primary event is the extra-vehicular transfer of a crew member from the LM to the CSM.

2.1.5 Fifth Period of Activities

Only CSM activities are simulated. The primary activities within this period are the LM-active "double bubble" rendezvous and an unmanned, long-duration ascent propulsion system (APS) burn. The rendezvous profile begins

with the LM burning radially up into a small "football" from which the two co-elliptic sequence initiation/constant delta height (CSI/CDH) sequences are set up. The first sequence results in a terminal phase initiation (TPI) from above, which is not performed, and the second results in a TPI from below, which is performed.

The CSM may be required to back up the LM on the above CSI/CDH burns and perform a LM rescue. This will be discussed later in Section 2.2.1.

2.1.6 Sixth Period of Activities

In order to reduce the SM RCS propellant required to deorbit the CM into the nominal recovery area, two orbit-shaping burns are introduced to lower the perigee and raise the apogee.

2.1.6.1 Fifth SPS Burn (Apogee Adjust)

The fifth SPS burn is a posigrade, CSM-only burn. The 132-fps, 6-second, GNCS-controlled burn raises the apogee from 133 nautical miles to 207 nautical miles.

2.1.6.2 Sixth SPS Burn (Perigee Adjust)

The 93-fps, retrograde, GNCS-controlled burn lowers the perigee from 131 to 95 nautical miles and adjusts the apogee to 210 nautical miles.

2.1.6.3 Predeorbit Activities

The remainder of the sixth period before deorbit is devoted to accomplishing navigational sighting objectives, gaining new experience with IMU alignments, and conducting experiments. Only a landmark tracking exercise will be simulated.

2.1.6.4 Seventh SPS Burn (Deorbit)

The deorbit burn is performed over Hawaii with the CSM pitched down 47 degrees in a retrograde position. The external ΔV, GNCS-controlled burn lasts for 12 seconds to provide a 266 fps ΔV.

2.1.6.5 Entry

During the 15 minutes of free fall between the deorbit burn and the 400,000-feet entry interface, the CM is separated from the SM and is

maneuvered to the entry attitude. About 11 minutes later, the CM arrives at the drogue deployment point, where the simulation is terminated. The GNCS-controlled CM will attain a maximum g peak of 3.3 before achieving the required target site.

2.2 MISSION CONTINGENCY PHASES

2.2.1 LM Rescue

During the fifth period of activities described above, the CSM must be prepared to back up the LM during the CSI/CDH sequences and perform a subsequent rendezvous. The relative motion of the CSM in the LM-centered local vertical system is shown in Figure 2-1.

In backing up the CSI/CDH burns, the CSM will be targeted (external ΔV) to burn 1 minute after the scheduled LM burn. The SPS burn will be opposite in direction to LM burn and about equal in magnitude.

The actual LM rescue could be initiated at three different positions in the trajectory: TPI_0, TPI_1, or TPI_2. Prior to TPI, SXT marks will be taken of the LM to update the LM state vector in the GNCS. The TPI burns are SM RCS +X translations or SPS burns depending on the required burn duration. Subsequent to TPI, two midcourse burns may be required, MCC1 and MCC2. Normally the LM will perform the braking maneuvers to conserve SM RCS propellant. The CSM will perform the docking maneuver.

2.2.2 SM Abort

The SM boost abort phase covers the portion of launch from LES jettison to orbit insertion. Present philosophy for SM boost aborts includes three abort modes. Mode II is in effect from LES jettison to approximately 630 seconds GET and results in impact in the continuous recovery area (CRA). The Mode III abort region begins at Mode II termination and ends at insertion. Depending on abort conditions, impact occurs in the discrete recovery area (DRA) 3350 nautical miles down-range of the pad or in the Indian Ocean recovery area (IORA). Throughout the Mode III region, capability exists for contingency orbit insertion, which is Mode IV. Therefore, Mode III is least likely to be used, because contingency orbit insertion is primary when possible. It should be noted that the ME 104 mechanization does not include a simulation of the booster flight phase.

2.2.3 RCS Deorbit

An RCS deorbit capability should be provided from at least one point in each orbit as a backup in the event of an SPS failure. The RCS deorbit

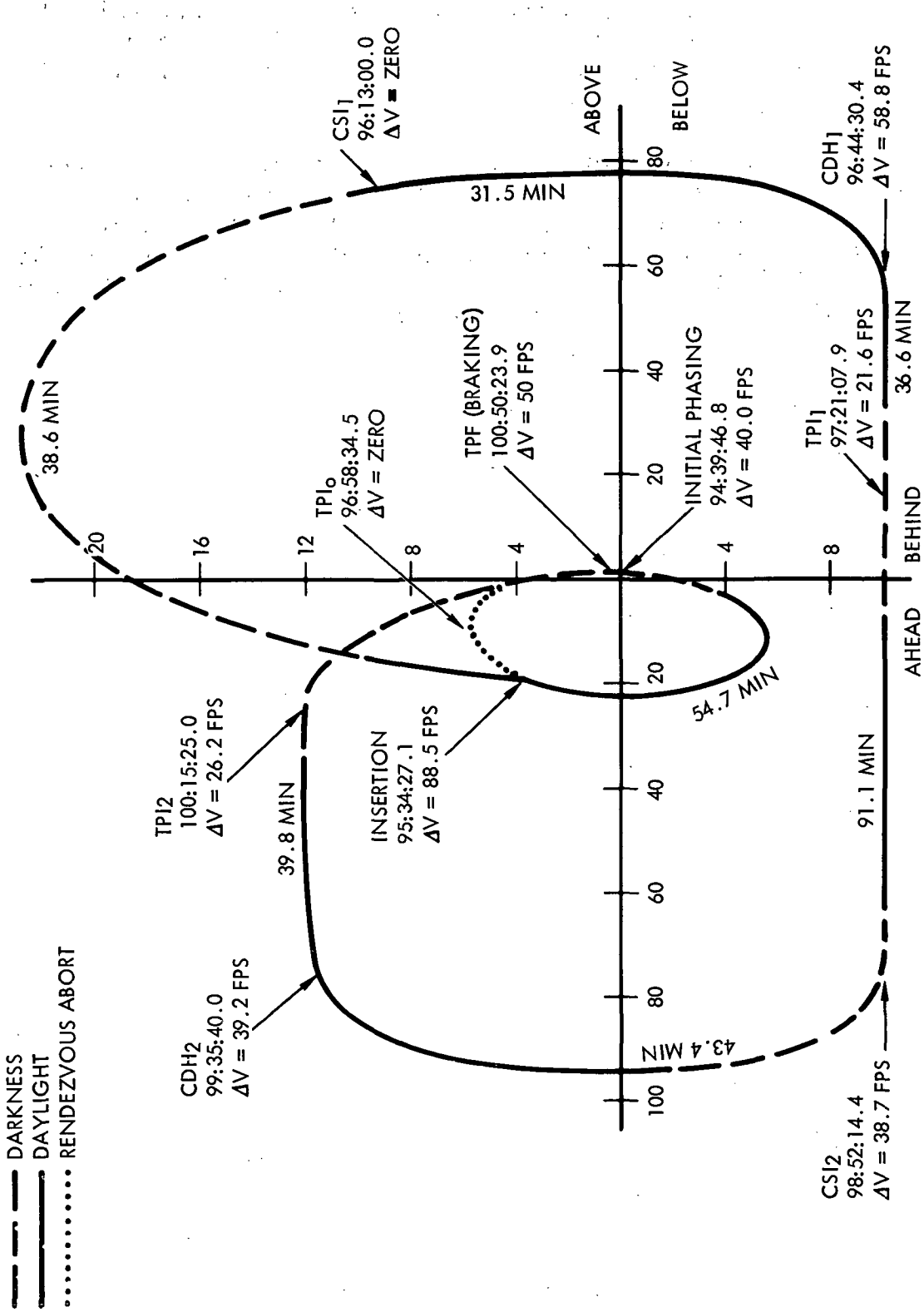

Figure 2-1. Relative Motion of CSM in LM Curvilinear System During LM-Active Rendezvous

maneuver is performed by applying the steady-state thrust generated by the RCS thrusters opposite to the inertial velocity vector, V_I, at apogee so as to maximize the reduction in perigee altitude per pound of RCS propellant expended.

A four-quad SM RCS deorbit is considered to be the nominal backup deorbit. However, in the event the mission is extended past the SM RCS four-quad deorbit propellant redline, or a portion of the SM RCS four-quad capability is lost, a hybrid RCS deorbit using both the SM RCS and CM RCS can be performed. A CM-RCS-only deorbit is not feasible for the "D" mission because the delta V required is not available.

3.0 STUDY DEFINITION

3.1 STUDY PHASES

The mission evaluation study will be divided into the following phases:

SPS ΔV
Rendezvous
Entry
IMU/GDC alignment
Landmark tracking
SM abort
RCS deorbit

In addition, periods of time are allotted for MCC/ME 104 joint simulation and final software verification tests (FSVT). The S-IVB/CSM separation and the subsequent transposition and docking will not be simulated. The study objectives and scope and a run schedule synopsis for each study phase are defined in the following paragraphs.

3.2 SPS ΔV

3.2.1 Study Objectives

Study objectives are as follows:

1. Evaluate the ΔV performance, and dynamic characteristics of the CSM/LM-on for the following TVC modes:

   CMC
   MTVC-acceleration

2. Determine the impact of the stroking test on the ΔV performance.

3. Verify the related CMC programs (P30, P40).

4. Evaluate the ΔV performance and dynamic characteristics for the CSM solo in the following TVC modes:

   CMC
   Automatic SCS
   MTVC-Rate

5. Evaluate the ΔV performance for the backup ΔV's during LM rescue.

6. Evaluate the related G&C procedures under nominal and failure take-over conditions.

7. Determine the pointing accuracy capability of the previously mentioned TVC modes with and without system errors.

8. Verify that attitude control is maintained or recovered during an MTVC failure take-over.

9. Determine if a preventive deorbit potential exists for hard-over failures.

10. Determine the SM RCS propellant required for orientation maneuvers, propellant settling maneuvers, and damping the SPS shutdown transient.

11. Provide data base for postflight analysis.

3.2.2 Study Scope

The SPS ΔV study phase will be divided into two subphases: (1) LM-on SPS burns and (2) CSM-only SPS burns.

3.2.2.1 LM-ON SPS Burns

In this subphase, the ΔV performance and dynamic characteristics with the LM-on will be evaluated under nominal, system errors, and failure take-over conditions. Burns 1 through 4 are included in this category. The stroking test will be accomplished in Burns 2 and 3. All burns will be GNCS-controlled unless a failure is inserted at which time MTVC Acceleration command is initiated. The use of SCS automatic TVC does not seem warranted with the LM-on and will not be studied.

3.2.2.2 CSM-Only SPS Burns

In this subphase, the ΔV performance and dynamic characteristics will be evaluated under nominal, system error, and failure takeover conditions. Burns 5 through 7 are included in this category. These burns will be GNCS-controlled unless a failure is inserted, at which time the MTVC rate command is initiated. In addition, the deorbit burn, Burn 7, will be evaluated in the SCS automatic TVC mode. Of the scheduled SPS burns, the deorbit burn will receive the most attention.

In addition, potential CSM-only SPS burns exist during the rendezvous phase. SPS burns may be required to back up the LM at CDH_1, CSI_1, and/or CDH_2 (Figure 2-1). At this time, only GNCS-controlled burns will be evaluated, including the effects of system error. Furthermore, no backup to partial LM burns will be considered. The resultant rendezvous after CDH_1 and CDH_2 will then be accomplished in real time. A detailed discussion of rendezvous is covered in section 3.3.

3.2.3 Run Description

Although in the actual mission each SPS burn is preceded by an IMU alignment, during this study phase all runs will be initiated with a prealigned IMU (ideal REFSMMAT). This reduces run duration; moreover, IMU alignments are covered in another phase. Based on ME 101 experience, the alignments and subsequent SPS burns will be accomplished during MCC/ME 104 joint simulation and Final Software Verification Test (FSVT).

The detailed sequence of events is taken from the SC 103 AOH (Reference 4). The step-by-step test procedures for CMC and SCS ATVC,

are presented in Tables 3-1 and 3-2, respectively. The test procedure for the backup SPS burns is presented in Table 3-3. It includes both the nonburn option and required LM update as well as the burn-required option.

3.2.4 Run Schedule Synopsis

The run schedule synopsis is divided into the two areas described under Scope: LM-on SPS burns (Table 3-4) and CSM-only SPS burns (Table 3-5). The proposed runs include the various error sources and/or failures. The error sources being considered are thrust misalignment angle (ϵ_T), center-of-gravity uncertainty (ϵ c.g.,), and actuator torque load bias (T_L). A combined system error (RSS/3σ) value will be obtained using a $\sqrt{3}\sigma$ value from each error source. The failure being considered is the SPS gimbal servo-amplifier hard over in either pitch or yaw. The run schedule synopsis includes the initial conditions, run description, presence of failures, error sources, and the estimated run lengths.

Table 3-1. ME 104 - GNCS SPS Burn

Time	Step	Procedure		Results
		Panel 8		
		All Circuit Breakers	IN	
		B/D Roll (4)	OFF	
		A/C Roll (4)	MNA	
		Pitch (4)	MNA	
		Yaw (4)	MNA	
		Panel 7		
		EDS Pwr	ON	
		TVC Servo Pwr 1	AC1/MNA	
		TVC Servo Pwr 2	AC2/MNB	
		FDAI/GPI Pwr	BOTH	
		LOGIC Pwr 2/3	ON	
		BMAG Power 1 & 2	ON	
		SCS Electronics Pwr	GDC/ECA	
		Panel 1		
		CMC Att	IMU	
		FDAI Scale	5/1	
		FDAI Select	1/2	
		FDAI Source	CMC	
		Att Set	GDC	
		Man Att (3)	RATE CMD	
		Limit Cycle	OFF	
		Att Deadband	MAX	
		Rate	LOW	
		Trans Contr Pwr	ON	
		Rot. Contr Pwr Norm (2)	AC/DC	
		Rot. Contr Pwr Direct (2)	OFF	
		SC Cont	CMC	

Table 3-1. ME 104 - GNCS SPS Burn (Cont)

Time	Step	Procedure		Results
		CMC Mode	AUTO	
		BMAG Mode (3)	RATE 2	
		SPS Thrust Direct	NORMAL	
		ΔV Thrust A&B	OFF	
		SCS TVC (2)	RATE CMD if LM-OFF, ACCEL CMD if LM-ON	
		SPS Gmbl Motors (4)	OFF	
		ΔVCG	LM/CSM or CSM	
		IMU Cage	OFF	
		Entry EMS Roll	OFF	
		Entry .05G	OFF	
		LV/SPS Ind	α/P_c - P_c	
		LV/SPS Ind	SII/SIVB/GPI	
		TVC Gmbl Drive (2)	AUTO	
		FCSM (2)	RESET/OVERRIDE	
		Panel 2		
		Up TLM CM	ACCEPT	
		Up TLM IU	BLOCK	
		RCS CMD	ON	
		RCS Trnpr	SM	
		Prim Prplnt (4)	GRAY	
		CM/SM Sep (2)	OFF (DN)	
		RHC (2)	ARMED	
		THC	ARMED	
		EMS Mode	STBY	
		EMS Func	ΔV SET	
		ORDEAL FDAI Orbit Rate/Inrt (2)	INRT	

Table 3-1. ME 104 - GNCS SPS Burn (Cont)

Time	Step	Procedure	Results
		CMC-ON (required) ISS-ON, orientation known and aligned SCS-ON (required) Orbit change vehicle preparation (desired) CMC ATT-IMU .05G SW-OFF Test C/W Lamps EMS Mode - STBY EMS Func - ΔV SET Set ΔV IND to _ _ _ _ . _ fps EMS Func - ΔV <u>RCS DAP - LOAD AND ACTIVATE (R03)</u> Key V48E (load DAP) FL V04 N46 (DAP config) R1 _ _ _ _ _ R2 _ _ _ _ _ V24E, load desired data PRO FL V06 N47 CSM WT _ _ _ _ _. lbs LM WT _ _ _ _ _. lbs V24E, load desired data PRO	

Table 3-1. ME 104 - GNCS SPS Burn (Cont)

Time	Step	Procedure	Results
		FL V06 N48 PITCH TRIM _ _ _ _ . _ _ deg YAW TRIM _ _ _ _ . _ _ deg V24E, load desired data PRO (exit R03) Key V46E (activate DAP) <u>EXT ΔV PRE-THRUST (P30)</u> Key V37E 30E FL V06 N33 GETI, stored 00 _ _ _ _. hrs 000 _ _ _ _. min 0 _ _._ _ sec V25E, load desired data PRO FL V06 N81 (ΔV LCL VRT components) ΔVX _ _ _ _ _._ fps ΔVY _ _ _ _ _._ fps ΔVZ _ _ _ _ _._ fps V25E, load desired data PRO	

Table 3-1. ME 104 - GNCS SPS Burn (Cont)

Time	Step	Procedure	Results
		FL V06 N42 (calculated thrust parameters) HA _ _ _ _ . _ nm HP _ _ _ _ . _ nm ΔV (required) _ _ _ _ . _ PRO FL V16 N45 Marks (VHF optics) _ _ B _ _ TF GETI (next burn) _ _ B _ _ min-sec MGA (next burn) _ _ _ . _ _ deg Set event timer to DSKY value PRO (exit P30) FL V37 ESTROKER LOAD (IF REQUIRED) Key V06 N02E Key 03012E Check R1 _ _ _ _ _ Accept, PRO Reject Key V21 N01E Key 03012E Key 0 0 0 0 _ E PRO	

Table 3-1. ME 104 - GNCS SPS Burn (Cont)

Time	Step	Procedure	Results
		PRESENT ORBITAL PARAMETERS- OPTIONAL Key V82E (R30) FL V04 N06 Option Code 0 0 0 0 2 CMC assumed option 0 0 0 0 1 (1=CSM, 2=LM) V22E, load desired data in R2 PRO FL V16 N44 HA _ _ _ _._ nm HP _ _ _ _._ nm TFF - 5 9 B 5 9 min-sec PRO (exit R30) ALIGN GDC TO IMU Key V16 N20E FL V16 N20 R _ _ _._ _ deg P _ _ _._ _ deg Y _ _ _._ _ deg ATT SET tw - Adjust to IMU Gimbal angles on DSKY ATT SET - GDC GDC align pb - Push, Hold	

Table 3-1. ME 104 - GNCS SPS Burn (Cont)

Time	Step	Procedure	Results
		KEY REL FL V37 G&N THRUSTING (P40) Key 00E Key V37E 40E Key V06 N81E FL V06 N81 VGX _ _ _ _._ fps VGY _ _ _ _._ fps VGZ _ _ _ _._ fps KEY REL FL V50 N18 (desired final gimbal angles) R _ _ _._ _ deg P _ _ _._ _ deg Y _ _ _._ _ deg Call for SM RCS fuel readout CMC Mode - Auto FDAI/GPI PWR - Both Logic 2/3 PWR - ON (Up) CMC ATT-IMU FDAI SEL - 1/2 SCS ELEC PWR - GDC/ECA BMAG MODE (3) - Rate 2 SC CONT - CMC MAN ATT (3) - Rate CMD	

Table 3-1. ME 104 - GNCS SPS Burn (Cont)

Time	Step	Procedure	Results
		AUTOMATIC MANEUVER TO THRUSTING ATTITUDE PRO FL V06 N18 (until maneuver completed) Go to Step A MANUAL MANEUVER TO THRUSTING ATTITUDE Select desired attitude control mode ENTR Maneuver to thrusting attitude	
	A	FL V50 N18 (ATT trim enable) Final ATT trim maneuver performed after gimbal drive and trim check Call for SM RCS fuel readout IGNITION PREPARATION MN BUS TIE (2) - ON (Up) SPS He VLV tb (both) - bp SPS He VLV (both) - Auto RHC PWR Direct (both) - Off SC CONT - CMC CMC Mode-Auto SCS TVC (2) - Rate CMD or Accel CMD LV/SPS IND SII/SIVB - GPI TVC GMBL Drive (2) - Auto FCSM SPS A - On (Up)	

Table 3-1. ME 104 - GNCS SPS Burn (Cont)

Time	Step	Procedure	Results
05:00		GIMBAL DRIVE AND TRIM CHECK TVC Servo PWR 1 - AC1/MNA TVC Servo PWR 2 - AC2/MNB TRANS CONTR PWR - ON (Up) RHC PWR NORM 2 - AC RHC 2 - ARMED IF Rate 1 ΔV planned BMAG MODE PITCH - RATE 1 BMAG MODE YAW - RATE 1 SPS GMBL MOT PITCH 1 - START SPS GMBL MOT YAW 1 - START AUTO SWITCHOVER CHECK THC - CW RHC - Verify no MTVC control SECONDARY TVC CHECK SPS GMBL MOT PITCH 2 - START SPS GMBL MOT YAW 2 - START Confirm and set trim control SPS GMBL tw (2) - + and - Set to CG trim values PITCH _._ _ deg YAW _._ _ deg RHC 2 - Verify MTVC THC - Neutral RHC PWR NORM 2 - AC/DC	

Table 3-1. ME 104 - GNCS SPS Burn (Cont)

Time	Step	Procedure	Results
		COMPLETE AUTO ATT TRIM ACCEPT (maneuver) BMAG Mode (3) - RATE - 2 Align SC in Roll (ACCEL CMD) SC Cont - CMC PRO FL V06 N18 (until maneuver completion) R _ _ _._ _ deg P _ _ _._ _ deg Y _ _ _._ _ deg FL V50 N18 R _ _ _._ _ deg P _ _ _._ _ deg Y _ _ _._ _ deg REJECT (no maneuver) SC CONT - CMC ENTR (exit R60) RHC PWR Direct (both) - MNA/MNB MAN ATT (3) - RATE CMD RATE - HIGH BMAG MODE (3) - ATT 1 RATE 2 Call for SM RCS fuel readout	

Table 3-1. ME 104 - GNCS SPS Burn (Cont)

Time	Step	Procedure	Results
		CMC GMBL DRIVE TEST	
		FL V50 N25 R1 00204	
		ACCEPT - PRO (trim at 16 sec)	
		REJECT - ENTR (trim at 4 sec)	
		V06 N40	
		TF GETI _ _ B _ _ min-sec	
		VG _ _ _ _._ fps	
		ΔV (ACCUM) _ _ _ _._ fps	
02:00		2 MIN COUNTDOWN	
		Report TTI = 2 min FDAI SCALE - 5/5 ΔV THRUST A - NORMAL THC - ARMED RHC (both) - ARMED	
00:35		DSKY clears	
00:30		V06 N40 (Avg G On) EMS MODE - AUTO	
00:15		Perform ullage (if required)	
00:05		FL V99 N40 (engine enable)	

Table 3-1. ME 104 - GNCS SPS Burn (Cont)

Time	Step	Procedure	Results
		TF GETI _ _ B _ _ min-sec	
		VG _ _ B _._ fps	
		ΔV (ACCUM)_ _ _ _._ fps	
		PRO (ENTR inhibits ENG IGN)	
00:00		IGNITION	
		SPS THRUST lt - ON V06 N40	
		TFC _ _ B _ _ min-sec	
		VG (DECR) _ _ _ _._ fps	
		ΔV ACCUM (INCR) _ _ _ _._ fps	
		ΔV IND - DECREASING	
IGN +1 SEC		Monitor FDAI AND GPI	
		Discontinue ullage	
		INITIATE STROKER TEST (IF REQUIRED)	
		AT TFC = ___ MIN ___ SEC Key V68E (initiates stroker test)	
		Auto termination of stroker test	
		ENGINE OFF AND SHUTDOWN	
		SPS THRUST lt - Off	

Table 3-1. ME 104 - GNCS SPS Burn (Cont)

Time	Step	Procedure	Results
		FL V16 N40 (Engine Cutoff) TFC _ _ B _ _ min-sec VG _ _ _ _._ fps ΔV (ACCUM) _ _ _ _._ fps ΔV THRUST A - OFF Report engine OFF SPS ENG INJ VLV A IND (2) - CLOSE SPS He VLV tb (both) - bp SPS GMBL MOT PITCH 2 - OFF SPS GMBL MOT YAW 2 - OFF SPS GMBL MOT PITCH 1 - OFF SPS GMBL MOT YAW 1 - OFF SCS TVC SERVO PWR 2 - OFF SCS TVC SERVO PWR 1 - OFF EMS MODE - STBY Record ΔV IND _ _ _ _._ fps PRO FL V16 N85 (VG vector components) VGX _ _ _ _._ fps VGY _ _ _ _._ fps VGZ _ _ _ _._ fps Key V82E	

Table 3-1. ME 104 - GNCS SPS Burn (Cont)

Time	Step	Procedure	Results
		FL V16 N44 (orbital parameters) HA_ _ _ _._ nm HP_ _ _ _._ nm TFF_ _B_ _ _min-sec PRO FL V16 N85 VGX, Y, Z . fps PRO FL V37 Key 00E MN BUS TIE (2) - OFF EMS FUNC - OFF TRANS CONTR PWR - OFF FCSM SPS A - RESET/OVERRIDE	

Table 3-2. ME 104 - SCS ATVC BURN

TIME	STEP	PROCEDURE	RESULTS
		CMC-ON (Req'd) ISS-ON, Orientation Known & Aligned SCS-ON (Req'd) Orbit Change Vehicle Preparation (Desired) CMC ATT-IMU .05G SW-OFF Test C/W Lamps EMS Mode - STBY EMS Func - ΔV SET Set ΔV IND to ____._ EMS Func - ΔV BMAG Mode (3) - ATT 1 RATE 2 SC CONT-SCS, SCS TVC (2) - AUTO ATT DB - MAX., LIMIT CYCLE - ON EXT ΔV PRE-THRUST (P30) Key V37E 30E FL V06 N33 GETI, Stored + 00 ____. HRS + 000 __. MIN +0__.__ SEC V25E, Load Desired Data PRO FL V06 N81 (ΔV LCL VRT Components) ΔVX _____._ FPS ΔVY _____._ FPS ΔVZ _____._ FPS	__MIN__SEC FR INIT TO IGN __MIN__SEC BURN DUR.

Table 3-2. ME 104 - SCS ATVC BURN (Cont)

TIME	STEP	PROCEDURE	RESULTS
		V25E, Load Desired Data PRO FL V06 N42 (Calc'd Thrust Parameters) HA _ _ _ _._ NM HP _ _ _ _._ NM ΔV (Req'd) _ _ _ _._ FPS PRO FL V16 N45 Marks (VHF Optics) _ _B_ _ TF GETI (Next Burn) _ _B_ _ MIN-SEC MGA (Next Burn) _ _ _._ _ DEG Set Event Timer to DSKY Value PRO (Exit P30) FL V37 PRESENT ORBITAL PARAMETERS-OPTIONAL Key V82E (R30) FL V04 N06 Option Code 0 0 0 0 2	

Table 3-2. ME 104 - SCS ATVC BURN (Cont)

TIME	STEP	PROCEDURE	RESULTS
		CMC Assumed Option 0 0 0 0 1 (1=CSM, 2=LM) V22E, Load Desired Data in R2 PRO FL V16 N44 HA ___.__ } AT INIT HP ___.__ } TFF __ B __ MIN-SEC PRO (Exit R30) ALIGN GDC TO IMU Key V16 N20E FL V16 N20 R ___.__ DEG P ___.__ DEG Y ___.__ DEG ATT SET tw - Adjust to IMU Gimbal Angles on DSKY ATT SET - GDC GDC Align pb - Push, Hold KEY REL FL V37	

Table 3-2. ME 104 - SCS ATVC BURN (Cont)

TIME	STEP	PROCEDURE	RESULTS
		G&N THRUSTING (P40) Key 00E Key V37E 40E Key V06 N81E FL V06 N81 VGX _ _ _ _._ FPS VGY _ _ _ _._ FPS VGZ _ _ _ _._ FPS KEY REL FL V50 N18 (Desired Final Gimbal Angles) R _ _ _._ _ DEG P _ _ _._ _ DEG Y _ _ _._ _ DEG Call for SM RCS Fuel Readout CMC Mode - AUTO FDAI/GPI PWR - BOTH Logic 2/3 PWR - ON (Up) CMC ATT-IMU FDAI SEL - 1/2 SCS ELEC PWR - GDC/ECA SC CONT - SCS MANUAL MANEUVER TO THRUSTING ATTITUDE BMAG Mode (3) - RATE 2, MAN ATT(3) - ACCEL CMD, LIMIT CYCLE-OFF PRO Maneuver to Thrusting Attitude FL V50 N18 (ATT Trim Enable)	

Table 3-2. ME 104 - SCS ATVC BURN (Cont)

TIME	STEP	PROCEDURE	RESULTS
		Final ATT Trim Maneuver Performed After Gimbal Drive & Trim Check	
		Call for SM RCS Fuel Readout BMAG Mode (3) - ATT 1, RATE 2 MAN ATT (3) - RATE CMD, LIMIT CYCLE-ON	
		IGNITION PREPARATION	
		MN BUS TIE (2) - ON (Up) SPS He VLV tb (Both) - bp SPS He VLV (Both) - AUTO RHC PWR Direct (Both) - CH SC CONT - SCS CMC Mode- AUTO SCS TVC (2) - AUTO LV/SPS IND SII/SIVB - GPI TVC GMBL Drive (2) - AUTO FCSM SPS (2) - ON (UP)	
05:00		GIMBAL DRIVE AND TRIM CHECK	
		TVC Servo PWR 1 - AC1/MNA TVC Servo PWR 2 - AC2/MNB TRANS CONTR PWR - ON (Up) RHC PWR NORM 2 - AC RHC 2 - ARMED	
		IF Rate 1 ΔV Planned BMAG MODE PITCH - RATE 1 BMAG MODE YAW - RATE 1	
		SPS GMBL MOT PITCH 1 - START SPS GMBL MOT YAW 1 - START	
		AUTO SWITCHOVER CHECK	
		THC - CW RHC - Verify no MTVC Control	

Table 3-2. ME 104 - SCS ATVC BURN (Cont)

TIME	STEP	PROCEDURE	RESULTS
		SECONDARY TVC CHECK SPS GMBL MOT PITCH 2 - START SPS GMBL MOT YAW 2 - START Confirm & Set Trim Control SPS GMBL tw (2) - + and - Set to CG Trim Values PITCH - _._ _ DEG YAW - _._ _ DEG RHC 2 - Verify MTVC THC - Neutral RHC PWR NORM 2 - AC/DC COMPLETE ATT TRIM LIMIT CYCLE-OFF BMAG Mode (3) - RATE 2, MAN ATT (3) - MIN IMP RHC 2—NULL ATT ERRORS ATT DB-MIN ENTR RHC PWR Direct (Both) - MNA/MNB MAN ATT (3) - RATE CMD, LIMIT CYCLE-ON RATE - LO BMAG MODE (3) - ATT 1 RATE 2 Call for SM RCS Fuel Readout CMC GMBL DRIVE TEST FL V50 N25 R1 00204 ACCEPT - PRO (Trim at 16 SEC)	

Table 3-2. ME 104 - SCS ATVC BURN (Cont)

TIME	STEP	PROCEDURE	RESULTS
		REJECT - ENTR (Trim at 4 SEC)	
		V06 N40	
		TF GETI __ B __ MIN-SEC	
		VG + _ _ _ _ . _ FPS	
		ΔV (ACCUM) + 0 0 0 0 0 FPS	
02:00		2 MIN COUNTDOWN	
		Report TTI = 2 Min FDAI SCALE - 5/5 ΔV THRUST (2) - NORMAL THC - ARMED RHC (Both) - ARMED LIMIT CYCLE - OFF	
00:35		DSKY Clears	
00:30		V06 N40 (Avg. G On) EMS MODE - AUTO	
		Perform Ullage	
00:05		FL V99 N40 (Engine Enable)	
		TF GETI __ B __ MIN-SEC	
		VG _ _ _ _ . _ FPS	
		ΔV (ACCUM) _ _ _ _ . _ FPS	
		PRO (ENTR Inhibits ENG IGN)	
00:00		IGNITION	
		THRUST ON pb PUSH SPS THRUST lt - ON	

Table 3-2. ME 104 - SCS ATVC BURN (Cont)

TIME	STEP	PROCEDURE	RESULTS
IGN+1 SEC		V06 N40 RATE - HIGH TFC __ B __ MIN-SEC VG (DECR) _ _ _ _._ FPS ΔV ACCUM (INCR) _ _ _ _._ FPS ΔV IND - DECREASING Monitor FDAI & GPI Discontinue Ullage ENGINE OFF & SHUTDOWN SPS THRUST 1t - Off FL V16 N40 (Engine Cutoff) TFC __ B __ MIN-SEC VG +0 0 0 0.0 FPS ΔV (ACCUM) _ _ _ _._ FPS ΔV THRUST (2) - OFF Report Engine OFF SPS ENG INJ VLV A IND (2) - CLOSE SPS He VLV tb (Both) - bp SPS GMBL MOT PITCH 2 - OFF SPS GMBL MOT YAW 2 - OFF SPS GMBL MOT PITCH 1 - OFF SPS GMBL MOT YAW 1 - OFF	

TABLE 3-2. ME 104 - SCS ATVC BURN (Cont)

TIME	STEP	PROCEDURE	RESULTS
		SCS TVC SERVO PWR 2 - OFF SCS TVC SERVO PWR 1 - OFF EMS MODE - STBY Record ΔV IND _ _ _ _._ FPS PRO FL V16 N85 (VG Vector Components) VGX _ _ _ _._ FPS VGY _ _ _ _._ FPS VGZ _ _ _ _._ FPS Key V82E FL V16 N44 (Orbital Parameters) HA _ _ _ _._ NM HP _ _ _ _._ NM TFF _ _ B _ _ MIN-SEC PRO FL V16 N85 VGX, Y, Z _ _ _ _._ FPS PRO FL V37 FCSM SPS (2) - RESET/OVERRIDE KEY 61E GO TO G&N CM/SM SEPARATION	

Table 3-2. ME 104 - SCS ATVC BURN (Cont)

TIME	STEP	PROCEDURE	RESULTS
		ENTRY PARAMETERS (IF RUN ENDS AT CM/SM SEPARATION) FL V06 N61 IMPACT LAT (+NORTH) ___.__ DEG IMPACT LONG (+EAST) ___.__ DEG HDS UP/DN (+UP) _____. __._____ V25E, LOAD DESIRED DATA PRO FL V06 N60 (ENTRY DATA) GMAX ___.__ G V PRED _____. FPS GAMMA EI ___.__ DEG PRO FL V06N63 RTOGO (.05G TO SPLASH) ____._ NM VIO (AT .05G) ____. FPS TFE (TIME FROM ENTRY) __B__ MIN-SEC PRO (EXIT P61) TERMINATE RUN	

Table 3-3. ME 104 Rendezvous SPS CSI/CDH ΔV Procedures
a. CSM Backup ΔV with LM Ignition and Burn
b. CSM Backup ΔV with No LM Lignition - CSM Performs SPS ΔV

GET	TF TIG	PROCEDURE
		Initial Switch Positions
		Panel 8
		All Circuit Breakers - IN
		B/D Roll Jets (4) - OFF
		A/C Roll Jets (4) - MNA
		Pitch Jets (4) - MNA
		Yaw Jets (4) - MNA
		Panel 7
		EDS Pwr - ON
		TVC Servo Pwr 1 - AC1/MNA
		TVC Servo Pwr 2 - AC2/MNB
		FDAI/GPI Pwr - Both
		Logic Pwr 2/3 - ON (up)
		BMAG Pwr (both) - ON
		SCS Elec Pwr - GDC/ECA
		Panel 2
		UPTLM CM - Accept
		UPTLM IU - Block
		RCS CMD - ON
		RCS Transfer - SM
		PRIM PRPLNT (4) - Gray
		Panel 1
		CMC Att - IMU
		FDAI Scale - 5/1
		FDAI Select - 1/2
		FDAI Source - CMC
		Att Set - GDC
		Man Att (3) - Rate CMD
		Limit Cycle - OFF
		Att DB - Max
		Rate - Low

Table 3-3. ME 104 Rendezvous SPS CSI/CDH ΔV Procedures (Cont)

GET	TF TIG	PROCEDURE	
		Panel 1	
		Trans Contr Pwr	- ON
		RHC Pwr - Norm (2)	- AC/DC
		RHC Pwr - Direct (2)	- OFF
		SC Control	- CMC
		CMC Mode	- Auto
		BMAG Mode (3)	- Rate 2
		SPS Thrust Direct	- Normal
		ΔV Thrust A & B	- OFF
		SCS TVC (2)	- Rate CMD
		SPS Gimbal Motrs (4)	- OFF
		ΔV CG	- CSM
		IMU Cage	- OFF
		Entry EMS Roll	- OFF
		Entry .05G	- OFF
		LV/SPS IND - α/Pc	- Pc
		LV/SPS IN DSB/SIVB/GPI	- GPI
		TVC GMBL Drive (2)	- Auto
		FCSM (2)	- Reset/Override
		CM/SM Sep (2)	- OFF
		Preliminary EMS Set	
		EMS Mode	- STBY
		EMS Func	- ΔV Set
		Set ΔV Ind to	_ _ _. _ fps
		EMS Func	- ΔV
		Set ET to	_ _:_ _
		Initial Attitude of CSM	
		(, ,)	
		Heads UP/DOWN	
		Nose (DOWN/UP) Range	
		Key V37E 00E	P00
		*Key V48E	(Load DAP)
		F V04 N46	11103 11111
		Key V24E to Load	

Table 3-3. ME 104 Rendezvous SPS CSI/CDH ΔV Procedures (Cont)

GET	TF TIG	PROCEDURE
		PRO F V06 N47 {+_ _ _ _ _ lbs +0 0 0 0 0 lbs Key V24E to Load
		PRO F V06 N48 {-_ _ _._ _ deg -_ _ _._ _ deg Key V24E to Load
		PRO Key V46E (activate DAP)
		Key V37E 30E P30
		F V06 N33 (CSM TIG) Key V25E Load {+0 0 0 _ _ +0 0 0 _ _ +0 _ _._ _
		PRO F V06 N81 (ΔV_{LV}) Key V25E Load {-_ _ _ _ _ fps -_ _ _ _ _ fps -_ _ _ _ _ fps
		PRO F V06 N42 (HA, HP, ΔV_{CDH}) DSKY {_ _ _ _._ n. mi _ _ _ _._ n. mi _ _ _ _._ fps
		Copy Values
		PRO F V16 N45 (N, TFI, MGA)
		Set ET to R2 (count down)

Table 3-3. ME 104 Rendezvous SPS CSI/CDH ΔV Procedures (Cont)

GET	TF TIG	PROCEDURE	
		PRO	
		F V37	
		Key 00E	P00
		CB EMS (2)	- Closed
		EMS Mode	- STBY
		EMS Func.	- ΔV Set
		EMS Mode	- Auto
		Load ΔV	= 1586.8 fps
		EMS Func	- ΔV Test
		Monitor SPS lt.	- ON
		Monitor ΔV	Countdown
		Monitor SPS lt.	- OFF
		Confirm ΔV	= -20.8 ± 20.7
		EMS Mode	- STBY
		EMS Func	- ΔV Set
		Load ΔV	- _ _ _ _._
		EMS Func	- ΔV
		Key V82E	(ORB. PARAM.)
		F V04 N06 (code, option)	
		00002	
		0000x	
		(1 = CSM, 2 = LM)	
		Accept or Load	00001
		PRO	
		F V16 N44 (HA, HP, TFF)	
		DSKY	_ _ _ _._ n. mi _ _ _ _._ n. mi _ _ B _ _ m/s
		PRO	
		Align GDC to IMU	
		Key V16 N20 E	
		F V16 N20 (R, P, Y)	

Table 3-3. ME 104 Rendezvous SPS CSI/CDH ΔV Procedures (Cont)

GET	TF TIG	PROCEDURE
		Att. Set TW - R1, R2, R3 Att. Set - GDC GDC Align PB - Press/Hold Key RLSE Key V37E 40E P40 F V50 N18 (R, P, Y) Key V06 N81E F V06 N81 (ΔV_{LV} at TIG) DSKY {____._ fps; ____._ fps; ____._ fps} Copy Values Key RLSE F V50 N18 (R, P, Y) Call for RCS Fuel Printout (1) CMC Mode - Auto SC Control - CMC CMC Att - IMU BMAG Mode (3) - Rate 2 Man Att. (3) - Rate CMD FDAI Select - 1/2 FDAI/GPI Pwr - Both Logic 2/3 Pwr - ON (up) SCS Elec Pwr - GDC/ECA a. Automatic Maneuver F V50 N18 (R, P, Y) PRO F V06 N18 (R, P, Y) F V50 N18 (R, P, Y)

Table 3-3. ME 104 Rendezvous SPS CSI/CDH ΔV Procedures (Cont)

GET	TF TIG	PROCEDURE	
		PRO	(to trim)
		F V06 N18	
		F V50 N18	
		b. Manual Maneuver	
		F V50 N18 (R, P, Y)	
		SC Control	- SCS
		Man. Att.	- Accel. CMD
		PRO	
		RHC	- maneuver to Att.
		Man Att.	- Rate CMD
		c. Trim Maneuver	
		F V50 N18 (R, P, Y)	
		SC Control	- CMC
		CMC Mode	- Auto
		PRO	
		F V06 N18	
		F V50 N18	
		Final Trim After Tests	
		Call for Fuel Printout (2)	
		Ignition Preparation	
		MN Bus Tie (2)	- ON (up)
		SPS He VLV tb (Both)	- Bp
		SPS He VLV (Both)	- Auto
		RHC Pwr Direct (Both)	- OFF
		SC Control	- CMC
		CMC Mode	- Auto
		SCS TVC (2)	- Rate CMD
		LV/SPS IND SII/SIVB	- GPI

Table 3-3. ME 104 Rendezvous SPS CSI/CDH ΔV Procedures (Cont)

GET	TF TIG	PROCEDURE	
		TVC GMBL Drive (2)	- Auto
		FCSM SPS A	- ON (up)
	04:00	Gimbal Drive and Trim Check	
		TVC Servo Pwr 1	- AC1/MNA
		TVC Servo Pwr 2	- AC2/MNB
		Trans. Contr. Pwr	- ON (up)
		RHC Pwr Normal (2)	- AC
		RHC (2)	- Armed
		If Rate 1 ΔV Planned	
		BMAG Mode (P, Y)	- Rate 1
		SPS GMBL Motr (P1)	- Start
		SPS GMBL Motr (Y1)	- Start
		Auto Switchover Check	
		THC	- CW
		RHC	- Verify No MTVC CONTR
		Monitor SPS GMBL Display	
		F V50 N18 (R, P, Y)	
		Secondary TVC Check	
		SPS GMBL Motr (P2)	- Start
		SPS GMBL Motr (Y2)	- Start
		Confirm and Set Trim Control	
		SPS GMBL TW (2) (+ and -)	
		Pitch	_._ _ deg
		Yaw	_._ _ deg
		RHC (2)	- Verify MTVC
		THC	- Neutral
		RHC Pwr. Normal (2)	- AC/DC

Table 3-3. ME 104 Rendezvous SPS CSI/CDH ΔV Procedures (Cont)

GET	TF TIG	PROCEDURE	
		Final Maneuver Trim	
		BMAG Mode (3)	- Rate 2
		Align SC in Roll	(0 or 180)
		SC Control	- SCS
		Man. Att. (R)	- Accel CMD
		RHC	- maneuver
		Man. Att. (3)	- Rate CMD
		SC Control	- CMC
		CMC Mode	- Auto
		PRO	
		F V06 N18	
		F V50 N18	
		Key ENTR	(accept)
		RHC Pwr Direct (Both)	- MNA/MNB
		Man. Att. (3)	- *Rate CMD*
		Rate	- High
		BMAG Mode (3)	- Att. 1/Rate 2
		Attitude DB	- Min
		Enable B/D Roll Jets	- MNA
		F V50 N25	
		R1 00204	(Ignore)
		Call for Fuel Printout (3)	
		Realign GDC to IMU	
		Key V16 N20E	
		F V16 N20	(R, P, Y)
		Att. Set TW	- R1, R2, R3
		Att. Set	- GDC
		GDC Align PB	- Press/Hold
		Key RLSE	
		F V50 N25	(00204)

Table 3-3. ME 104 Rendezvous SPS CSI/CDH ΔV Procedures (Cont)

GET	TF TIG	PROCEDURE
		Gimbal Drive Test (CMC) To Monitor Drive Key PRO GMBL's trim in 16 sec To Bypass Test Sequence Key ENTR, then PRO GMBL's trim in 4 sec F V06 N40 (TFI, V_G, ΔV_{acc}) DSKY { __ B __ m/s ; _____ fps ; _____ fps
	01:00	Report: 1 min to LM IGN. FDAI Scale - 5/5 Verify SPS Thrust lt - OFF ΔV Thrust A - Normal
	00:00	LM Ignition Set ET Counting UP
	00:05	LM Ignition Confirmed
	00:10	If NO LM IGNITION GO TO PAGE
	00:15	LM Thrusting Confirmed Monitor LM Burn
	00:20	Key V34E (Exit P40) F V37 Key 00E P00

Table 3-3. ME 104 Rendezvous SPS CSI/CDH ΔV Procedures (Cont)

GET	TF TIG	PROCEDURE	
		ΔV Thrust A	- OFF
		SPS GMBL Motr P, Y2	- OFF
		SPS GMBL Motr P, Y1	- OFF
		SPS Eng. Inj VLV A Ind	- Close
		SPS He VLV tb (Both)	- Bp
		SPS TVC Servo Pwr 2	- OFF
		SPS TVC Servo Pwr 1	- OFF
		RHC Pwr Direct (Both)	- OFF
		FCSM SPSA (Both)	- Reset/OVRD
	00:40	LM Burn Completed	
		EMS Func	- OFF
		EMS Mode	- STBY
		MN Bus Tie (Both)	- OFF
		THC Pwr	- OFF
		Key V82E	
		Load LM Code	
		PRO	
		F V06 N44 (Hp, Ha, TFF)	
		PRO	
		Receive LM ΔV's and TIG	
		Key V37E 76E	P76
		F V06 N84	(LM $\Delta V_{x, y, z,}$)
		Key V25E	-_ _ _ _._ fps
		Load	-_ _ _ _._ fps
			-_ _ _ _._ fps
		PRO	
		F V06 N33	(LM TIG)
		Key V25E	+0 0 _ _ _ hr
		Load	+0 0 0 _ _ min
			+0 _ _._ _ _ sec

Table 3-3. ME 104 Rendezvous SPS CSI/CDH ΔV Procedures (Cont)

GET	TF TIG	PROCEDURE
		PRO F V37 Key 00E — P00 Key V82E Load LM code PRO F V06 N44 (Hp, Ha, TFF) PRO
Step A		a. If TPI to be completed Key V37E 20E — P20 Continue: Use Rendezvous Procedures
		b. If TPI Computations Only Key V37E 34E — P34 F V06 N37 (TIG TPI) Key V25E Load — +0 0 _ _ _ hr; +0 0 0 _ _ min; +0 _ _ . _ _ sec PRO F V06 N55 — (-, E, σ) Key V22E Load E — = _ _ _ . _ _ deg Key V23 E Load σ — = _ _ _ . _ _ deg PRO F V16 N45 (N, TFI, MGA)

Table 3-3. ME 104 Rendezvous SPS CSI/CDH ΔV Procedures (Cont)

GET	TF TIG	PROCEDURE
		DO NOT PROCEED Key V32E (Recycle) F V06 N37 (TIG/TPI) (DSKY) { +0 0 _ _ _ hr +0 0 0 _ _ min +0 _ _._ _ sec Copy Values PRO F V06 N58 (H_P, ΔV_{TPI}, ΔV_{TPF}) DSKY { _ _ _ _._ n. mi _ _ _ _._ fps _ _ _ _._ fps Copy Values PRO F V06 N59 (ΔV_{LOS} comp.) DSKY { _ _ _ _._ fps _ _ _ _._ fps _ _ _ _._ fps Copy Values PRO F V16 N45 (N, TFI, MGA) Key V34E (terminate prog.) F V37 Key 00E P00 TERMINATE RUN

Table 3-3. ME 104 Rendezvous SPS CSI/CDH ΔV Procedures (Cont)

GET	TF TIG	PROCEDURE
		CSM Performs SPS ΔV
		F V06 N40 (T_{FI}, V_G, ΔV_{acc}) DSKY { - _ _ B _ _ m/s _ _ _ _ _._ fps _ _ _ _._ fps
	0020	If PROG Alarm TIG slipped DSKY Returns at new TIG - 35 sec
	00:25	DSKY Blanks
		THC - Armed RHC - Armed
	00:30	V06 N40 (Ave G ON)
		EMS Mode - Auto Check ΔV_{acc} for PIPA Bias
	00:35	R3 ≤ 001.0 fps
	00:45	Perform Ullage +X Translation - THC
	00:55	F V99 N40 (Engin enable) DSKY { - _ _ B _ _ m/s _ _ _ _ _._ fps _ _ _ _._ fps
		PRO (to request ignition) (ENTR to inhibit)
	01:00	CSM Ignition SPS Thrust lt. - ON
		V06 N40 (T_{FC}, V_G, ΔV_{acc}) TFC (Time from C/O -)

Table 3-3. ME 104 Rendezvous SPS CSI/CDH ΔV Procedures (Cont)

GET	TF TIG	PROCEDURE	
	01:01	Discontinue Ullage	
		Monitor Burn	
		EMS ΔV Ind.	- decrease
		N40: V_G and TFC	
		SPS Pc Ind.	
		SPS Engine Cutoff	
		SPS Thrust lt.	- OFF
		F V16 N40	(Eng C/O)
		TFC	(time from C/O +)
	C/O + 00:01	ΔV Thrust A	- OFF
		Report: Engine Off	
		SPS ENG. INJ. VLV A IND (2)	- Close
		SPS He VLV tb (Both)	- Bp
		SPS GMBL MOTR P, Y-2	- OFF
		SPS GMBL MOTR P, Y-1	- OFF
		SCS TVC SERVO Pwr 2	- OFF
		SCS TVC SERVO Pwr 1	- OFF
		EMS Mode	- STBY
		Record ΔV Ind.	
		PRO	
		F V16 N85 (V_G Body)	
		Null V_G (x, y, z) if necessary	
		THC	- Locked
		Key V82E	(ORB Param.)
		F V16 N44 (H_A, H_P, TFF)	

Table 3-3. ME 104 Rendezvous SPS CSI/CDH ΔV Procedures (Cont)

GET	TF TIG	PROCEDURE
		PRO F V16 N85 (V_G-Body) PRO (exit P40) F V37 MN Bus Tie (2) - OFF EMS Func. - OFF Trans Contr. Pwr - OFF FCSM SPS A - RESET/OVRD Return to Step A

Table 3-4. LM On SPS ΔV Run Schedule

Burn No.	TVC Mode	Burn Duration (sec)	ΔV (fps)	Error Sources ϵ_T	Error Sources ϵ_{CG}	Error Sources T_L	Total No. of Runs	Est Time per Run (min) ①	Total Est Time (min)	Comments
NOMINAL										
*1	GNCS/ext ΔV	8.88	62.86	0	0	0	1	32	32	
				±.346°	±1.154"	±260 lbs	2	32	64	
2	GNCS/ext ΔV	220.22	1699.15	0	0	0	3	36	108	Includes nom, late, and early stroking tests
				±.346°	±1.154"	±260 lbs	6	36	216	
3	GNCS/ext ΔV	185.93	1699.04	0	0	0	3	37	111	Includes nom, late, and early stroking tests
				±.346°	±1.154"	±260 lbs	6	37	219	
4	GNCS/ext ΔV	9.97	103.4	0	0	0	1	40	40	
				±.346°	±1.154"	±260 lbs	2	40	80	
							18		870 (14 hr, 30 min)	

*Priority of runs in order listed.

① Includes 15 min set-up time, 8 min uplink, 3 min after burn, and run time.

Table 3-4. LM On SPS ΔV Run Schedule (Cont)

Burn No.	TVC Mode	Burn Duration (sec)	ΔV (fps)	Error Sources ϵ_T	Error Sources ϵ_{CG}	Error Sources T_L	No. of Pilots	No. Runs per Pilot	Total No. of Runs	Est Time per Run (min) ①	Total Est Time (min)	Comments
BACKUP AND FAILURE												
1	GNCS/MTVC	8.88	62.86	Worst case			3	1	3	32	96	All failures consist of TVC servo amp hardover in axis with least authority in direction to maximize vehicle rotational acceleration. Failures in all runs listed.
2	GNCS/MTVC	220.22	1699.15	Worst case			3	2	6	36	216	Includes failures during and before early stroking test.
2	GNCS/MTVC	220.22	1699.15	Premature engine shut down			1	1	1	30	30	Verity R40
3	GNCS/MTVC	185.93	1699.04	Worst case			3	2	6	37	222	Includes failures before earliest and during latest stroking tests.
4	GNCS/MTVC	9.97	103.4	Worst case			3	1	3	40	120	
									18		684 (11 hr, 24 min)	① Includes 15 min set-up time, 8 min uplink, 3 min after burn, and actual run time. All failure takeovers in MTVC ACCEL CMD.

Table 3-5. LM Off SPS ΔV Run Schedule

Burn No.	TVC Mode	Burn Duration (sec)	ΔV (fps)	Error Sources ϵ_T	Error Sources ϵ_{CG}	Error Sources T_L	Total No. of Runs	Est Time per Run (min) ①	Total Est Time (min)	Comments
NOMINAL										
5	GNCS/ext ΔV	6.11	132.36	0	0	0	1	40	40	① Includes 15 min set-up time, 8 min uplink, 3 min after burn, and run time.
				±.346°	±1.154"	±260 lbs	2	40	80	
6	GNCS/ext ΔV	4.16	93.21	0	0	0	1	42	42	
				±.346°	±1.154"	±260 lbs	2	42	84	
7	GNCS/ext ΔV	12.24	266.13	0	0	0	1	65	65	
				±.346°	±1.154"	±260 lbs	2	65	130	
CDH 1	GNCS/ext ΔV	≈3	58.75	0	0	0	1	41	41	Backup CSMΔV
				±.346°	±1.154"	±260 lbs	2	41	82	
CSI 2	GNCS/ext ΔV	≈2	38.69	0	0	0	1	41	41	Backup CSMΔV
				±.346°	±1.154"	±260 lbs	2	41	82	
CDH 2	GNCS/ext ΔV	≈2	39.19	0	0	0	1	45	45	Backup CSMΔV
				±.346°	±1.154"	±260 lbs	2	45	90	
							18		822 (13 hr, 42 min)	

*Priority of runs in order listed.

Table 3-5. LM Off SPS ΔV Run Schedule (Cont)

Burn No.	TVC Mode	Burn Duration (sec)	ΔV (fps)	Error Sources ϵ_T	Error Sources ϵ_{CG}	Error Sources T_L	No. of Pilots	No. Runs per Pilot	Total No. of Runs	Est Time per Run (min) ①	Total Est Time (min)	Failure	Comments
BACKUP AND FAILURE													
5	GNCS/MTVC	6.11	132.36	Worst case			3	1	3	40	120	Yes	① Includes 15 min set up, 8 min uplink, 3 min after run, and run time.
6	GNCS/MTVC	4.16	93.32	Worst case			3	1	3	42	126	Yes	All failure takeovers in MTVC rate cmd.
②†	GNCS/MTVC/ GNCS entry	12.24	266.13	Worst case			3	1	3	65	195	Yes	All failures consist of TVC servo amp hardover in axis with least authority in direction to maximize vehicle rotational acceleration. Failures in all runs listed.
	GNCS (over burn)/ GNCS entry			0	0	0	1	1	1	65	65	No	
	GNCS (under burn)/ GNCS entry			0	0	0	1	1	1	65	65	No	
②†	SCS auto TVC/ SCS entry	12.24	266.13	0	0	0	3	1	3	65	195	No	② Also listed in entry run schedule
	SCS auto TVC/ SCS entry	12.24	266.13	±.346	±1.154	±260	3	2	6	65	390	No	
	SCS auto TVC/ MTVC/SCS entry	12.24	266.13	Worst case			3	1	3	65	195	Yes	
	GNCS/GNCS manual entry	12.24	266.13	0	0	0	3	1	3	65	195	No	
									23		1546	Total = 25 hrs 46 min	

3.3 RENDEZVOUS

3.3.1 Study Objectives

Although the SC 104 mission plan does not include an actual inflight confirmation of CSM-active rendezvous capability by a single crew member, in the event LM-active rendezvous is not completed, the capability for a CSM rescue of the LM is mandatory. This capability, then, must be demonstrated through simulation. The objectives for this simulation study are:

1. Verify the software (COLOSSUS) rendezvous programs: P00, P17, P20, P34, P35, P40, P41, P47, and P76.
2. Verify the adequacy of G&C procedures for both passive and active rendezvous.
3. Develop alternate procedures as required.
4. Evaluate the effects of trajectory deviations.
5. Evaluate the effect of navigation on MSFN errors.
6. Evaluate the effects of system error sources.
7. Determine the effect of a GNCS failure on the capability to complete a rendezvous.
8. Determine the effect of RCS jet or quad failure on the capability to complete a rendezvous.
9. Establish SM RCS propellant values for both active and passive rendezvous.
10. Provide a data base for postflight analysis.

3.3.2 Study Scope

The rendezvous study phase will be divided into three areas of investigation: CSM-passive rendezvous performance, CSM-active rendezvous performance, and failure effects on rendezvous success and performance.

3.3.2.1 CSM-Passive Rendezvous

The CSM-passive rendezvous study will evaluate the nominal operations and procedures onboard the CSM while the LM-active rendezvous is in progress. Nominal operation will include:

1. Acquiring the necessary observation data
2. Accepting and incorporating uplinked and voice-linked data
3. Monitoring LM actions and status both visually and in the CSM computer
4. Performing backup computations
5. Performing the required procedures for ΔV preparations and count downs.

In addition, backup charts for LM-active operations will be utilized, if available, where CSM activities must respond to voice-link from the LM.

3.3.2.2 CSM-Active Rendezvous

The CSM-active rendezvous study will evaluate the rendezvous performance under both nominal and off-nominal conditions for each of the seven event times (except CSI_1, which is nominally zero) at which CSM-active rendezvous may be initiated. This will include external ΔV activities and on-board computed ΔV operations, both with and without error sources.

3.3.2.3 Failure Effects on Rendezvous Success and Performance

This portion of the study will evaluate both the dynamics and operational effects resulting from various failures during the CSM-active rendezvous. The ability of a single crew member to detect a failure and make a successful rendezvous will be evaluated. Failure conditions may include CMC, IMU, or optics failure and RCS jet or quad failure. Suggestions for modifications to the procedures will be made and/or evaluated.

3.3.3 Run Description

The majority of the runs will begin immediately following the scheduled LM burn. Normally the CMC will be initiated with a different state vector than is the RTSS in order to simulate MSFN errors. Each run requires the use of the external visual displays, normally the SXT and always the docking window. During prebraking, the docking window scene will just contain a moving, blinking light representative of the LM beacon. At braking distances,

the scene will change to a view of an LM model using the GPVS. The test procedures were derived from the Mission D Rendezvous procedures Document (Reference 5) and the CSM 103 AOH, but they include certain simulation-determined and data requirement procedures. The detailed test procedures are listed in Table 3-6.

3.3.4 Run Schedule Synopsis

The rendezvous study includes both LM-active and CSM-active rendezvous. Run schedule synopses for both are presented in Tables 3-7 and 3-8.

Table 3-6. ME104 Post CDH to Rendezvous Termination

Step	Procedure
	COAS Calibration for Post CDH Operations
1	Switch Positions
	FDAI/GPI Pwr (both) - ON SCS Elect Pwr - GDC/ECA Logic 2/3 Pwr - ON
	CMC Att - IMU FDAI Select - 1/2 BMAG Mode - ATT1/Rate 2 SC CONT - SCS SCS Sig Cond/DR Bias - AC1 or AC2 RHC Pwr Norm (both) - AC/DC Auto RCS Sel (16) - MNA
	Optics Mode - Man Zero Optics - Zero (15 sec) Zero Optics - OFF COAS - against the stops, pitch down
2	Operate (start trajectory) Optics in Window Mode Docking Position
3	Key V37E 52E
	F V04 N06

Step	Procedure
	R1 00001 Code R2 0000X Option
	Key V22E Load 3E (REFSMMAT)
4	PRO
	F V50 N25 R1 00015 (Tgt Acquisition)
5	Attitude Control Boresight/Maneuver
	Man Att - Min. Imp SC Control - SCS BMAG Mode - Att 1/Rate 2
	or Maneuver
	Man Att - Accel CMD SC Control - SCS
6	Maneuver to Acquire Star in COAS
7	PRO
	F V01 N70 R1 000 __ Target Code
	Key V21 Load 000XXE Optics Mode - CMC

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

Step	Procedure	Step	Procedure
8	PRO (attempts auto acquisition) F V16 N92 R1 XXX.XX SA R2 XX.XXX TA Boresight Tgt - when Tgt centered in COAS &SA and TA are relatively constant		
9	Key VERB (freeze display) Accept: Record SA & TA Reject: Key RLSE - Recenter Tgt.		
10	Terminate Calibration Zero Optics - Zero Key V37E XXE (new prog)		

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
		CDH Burn Completed Switch Settings FDAI/GPI Pwr - Both SCS Elec Pwr - GDC/ECA Trans Cont Pwr - ON Rot Cont Pwr Direct (Both) - OFF Auto RCS Sel (B/D Roll-4) - OFF FDAI Scale - 5/1 Rate - Low Att DB - Max FDAI Select - Both CMC Att - IMU EMS Mode - STBY EMS Func - OFF BMAG Mode (3) - Rate 2 Man Att (3) - Rate CMD Optics Mode - Man Optics Zero - Zero Optics Drive - RSLV Optics in Telescope Mode (Blinking Target) *Zero in the SXT - adjust Remove Zero in SXT Optics Zero - OFF SC Control - CMC CMC Mode - Free Countdown to Operate Operate (-) ET

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
		Key V37E 00E P00 Key V48E (Load DAP) F V04 N46 (11102) (11111) PRO F V06 N47 (+_____) (+00000) PRO F V06 N48 (+00_._) (+00__._) PRO Key V46E (Activate DAP) Mnvr to Zero R, Y on FDAI 1 <u>GDC Align</u> Key V06 N20 E Set Att Set TW (O, P, O) GDC Align PB - Press <u>ORDEAL Set</u> Key V82 E F V06 N44 (Hp, Ha, TFF) Ave R1 & R2 Set Alt on Dial PRO Key V83E F V16 N54 (R, $\dot{R}$, θ) Slew FDAI to θ PRO

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
		Call for Fuel Printout ① P00 Key V37 E 20E P20 F V50 N18 (please mnvr) (R, P, Y) a. Auto Maneuver SC Control - CMC CMC Mode - Auto PRO V06 N18 (R, P, Y) Monitor on FDAI F V50 N18 b. Manual Maneuver SC Control - SCS CMC Mode - Auto Man Att - Accel CMD PRO RHC maneuver F V50 N18 Man Att - Rate CMD c. Trim Maneuver F V50 N18 SC Control - CMC CMC Mode - Auto PRO V06N18 Monitor on FDAI FV50 N18 Key ENTR (when satisfied) RHC - Locked Call for Fuel Printout ② Enable Roll Jets B/D Move to LEB Optics Zero - OFF Optics Zero - Zero (15 sec)

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
		Key V37E 34E P34 F V50 N18 Key ENTR F V06 N37 (TIG/TPI) Key V25E Load {+00 _ _ _ . / +000 _ _ . / +0 _ _ . _ _} PRO Optics Zero - OFF Optics Mode - CMC F V06 N55 (-, E, σ) [To Compute E / Key V22E / Load (+00000E)] To Load E Key V22E Load (+207.45E) To Load σ Key V23E Load (+XXX.XXE) PRO F V16 N45 (N, TFI, MGA DO NOT PROCEED Key V32E (Recycle) F V06 N55 (-, E, σ) or F V06 N37 (TIG/TPI). Copy E or TIG

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
		PRO P34 F V06 N58 (H_P, ΔV_{TPI}, ΔV_{TPF}) Copy ΔV's *EMS Func -ΔV Set Set ΔV Indicator to R2 EMS Func -ΔV PRO F V06 N59 (ΔV_{LOS}comp) Copy Data PRO F V16 N45 (N, TFI, MGA) Set ET - countdown Compare Solutions *Key V06 N52E F V06 N52 (σ CSM) Key RLSE F V16 N45 (N, TFI, MGA) Key V57E F V51 (please mark) Optics Mode - Man Make__Marks (one/min) F V06 N49 (ΔR, ΔV, +1) Accept : PRO Reject : Key V32E

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
		Optics Mode - CMC P34 PRO (process last mark) F V16 N45 (N, TFI, -1) Key V93E (reinitialize) *Key V85E (if time) F V06 N53 (R, $\dot{R}$, ϕ) Copy (R, ϕ) PRO Key V57E F V51 please mark Make___marks (one/min) F V06 N49 (ΔR, ΔV, +1) Accept : PRO Reject : Key V32E [Alternate W/V85E if time Record Data - PRO] PRO (process last mark) F V16 N45 (N, TEI, MGA) Optics Mode - Man Optics Zero - Zero Move to Couch Receive TIG from LM F V16 N45 (N, TFI, MGA)

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
		PRO (final recycle) P34 F V06 N55 (-, E, σ) or F V06 N37 (TIG/TPI) Record E or TIG PRO F V06 N58 (H_P, ΔV_{TPI}, ΔV_{TPF}) Record ΔV's *EMS Func - ΔV Set Set ΔV Indicator to R2 EMS Func - ΔV PRO F V06 N81 (V_G LV) Copy ΔV components PRO F V06 N59 (V_G LOS) Copy V_GLOS PRO F V16 N45 (N, TFI, MGA) Reset ET Call for Fuel Printout ③ Key V77E (+X axis track)

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
		Optics in Window Mode P34 (blinking Tgt) Docking Position F V50 N18 (please mnvr) PRO (accept mnvr) V06 N18 Monitor Mnvr. to COAS Track F V50 N18 (please trim) Key ENTR (accept trim) F V16 N45 (N, TFI, MGA) PRO (exit P34) F V37
	09:00	Key 41E P41 F V50 N18 (please mnvr) Backup Data Procedure Att DB - Min Rate - Low SC Control - SCS BMAG Mode (3) - Att 1/Rate 2 Man Att (P, Y) - Min Imp RHC - Armed Disable Roll Jets B/D Boresight on LM (COAS)
	08:30	Key V83E F V06 N54 (R, $\dot{R}$, θ) Maintain Boresight (COAS)

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
	08:00	Key NOUN (freeze display) P41 Copy R, $\dot{R}$, θ Key 20E F V06 N20 (R, P, Y) Att Set tw-R1, R2, R3 Align GDC to IMU GDC Align PB - Press Key RLSE F V06 N54 (R, $\dot{R}$, θ) Boresight on LM (COAS)
	06:00	Verify ORDEAL (θ) Maintain Boresight (COAS)
	05:00	Key NOUN (freeze display) Copy R, $\dot{R}$, θ Key RLSE PRO F V50 N18 (please mnvr) Call for Fuel Printout ④ Auto Maneuver BMAG Mode (3) - Rate 2 Man Att (P, Y) - Rate CMD Enable Roll Jets - B/D (4) SC Control - CMC CMC Mode - Auto

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
	04:00	PRO P41
		V06 N18
		Monitor Mnvr to TPI Thrust Att
		F V50 N18
	01:20	PRO (last trim)
		V06 N18 F V50 N18
	01:00	Key ENTR (accept trim)
		F V06 N85 (V_G Body)
		Calculate Backups Compare Solutions
		EMS Mode - STBY EMS Func - ΔV Set Load ΔV TPI EMS Func - ΔV EMS Mode - Auto Lim Cycle - OFF BMAG Mode (3) - Att 1/Rate 2
	00:40	If PROG Alarm
		TIG slipped DSKY clears at new TIG - 35 sec COMP ACTY light off (exit R41)
	00:35	DSKY Blanks
		THC - Armed RHC - Armed
	00:30	V16 N85 (V_G Body)

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure	
	00:15	Call for Fuel Printout ⑤	P41
	00:00	F V16 N85 (V_G Body) Null V_G's w/THC Start ET countup	
		V_G Zero	
		PRO (exit P41)	
		THC - Locked Att DB - Max EMS Mode - STBY EMS Func - OFF BMAG Mode (3) - Rate 2	
		Call for Fuel Printout ⑥	
		F V37	
	01:00	Key 35E	P35
		F V50 N18 (auto mnvr)	
		PRO	
		V06 N18 (mnvr)	
		Monitor mnvr to COAS	
		F V50 N18 (please trim)	
		PRO (for trim)	
		Key ENTR (to accept)	
		Call for Fuel Printout ⑦	
		F V16 N45 (N, TFI, MGA)	

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
		Key V54E P35 F V06 N94 (S, T, -) Key V24E Load + _ _ _ . _ _ E + _ _ . _ _ _ E PRO F V53 (please mark) Att DB - min SC Control - SCS BMAG Mode (3) - Att 1/Rate 2 Man Att (P, Y) - Min Imp Boresight on LM (COAS)
	03:00	Make__Marks (one/min) by keying ENTR Reject with V86E F V06 N49 (ΔR, ΔV, +1) Accept : PRO Reject : Key V32E PRO (process last mark) F V16 N45 (N, TFI, MGA)
	06:30	Key V83E F V06 N54 (R, $\dot{R}$, θ) Boresight on LM (COAS)
	07:00	Key NOUN (freeze display) Copy θ Key RLSE PRO F V16 N45 (N, TFI, MGA)

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
		Key V54E P35
		F V06 N94 (S, T, -)
		PRO
		F V53 (please mark)
		Boresight on LM (COAS)
	08:00	Make__marks (one/min) by keying ENTR Reject with V86E
		F V06 N49 (ΔR, ΔV, +1)
		(Remove V50 N18 with ENTR)
		Accept: PRO Reject: Key V32E
		PRO (process last mark)
		F V16 N45 (N, TFI, -1)
Exactly	09:30	PRO (final Cycle)
		F V06 N81 (V_G LV)
		Copy V_G's
		Key V83E
		F V06 N54 (R, $\dot{R}$, θ)
		Boresight on LM (COAS)
	10:00	Key NOUN (freeze display)
		Copy R, $\dot{R}$, θ
		Key RLSE
		PRO

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
		Calculate Backups P35
		F V06 N81 (V_G LV)
		Key V22E Load (+00000) in R2
		PRO
		F V06 N59 (V_G LOS)
		Copy data/Compare Solns
		PRO
		F V16 N45 (N, TFI, MGA)
		PRO
		F V37
	11:00	Key 41E P41
		F V50 N18
		Key ENTR (Bypass mnvr)
		F V06 N85 (V_G Body)
		Man Att (3) - Rate CMD
	11:20	If PROG Alarm, TIG Slipped DSKY Returns at new TIG - 35 sec
	11:25	DSKY Blanks
	11:30	V16 N85 (V_G Body)
		THC - Armed
	11:45	Call for Fuel Printout ⑧

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
	12:00	F V16 N85 (V_G Body) P41
		Null V_G's with THC
		PRO (exit P41)
		Call for Fuel Printout ⑨
		THC - Locked
		F V37
		Key 35E P35
		F V50 N18 (auto mnvr)
		Key ENTR (bypass mnvr)
		F V16 N45 (N, TFI, -1)
		Key V54E
		F V06 N94 (S, T, -1)
		Key V24E Load +___.___E +__.____E
		PRO
		F V53 please mark
		Man Att (P, Y) - Min Imp
		Boresight on LM (COAS)
	14:00	Make___LM Marks (one/min) by keying ENTR Reject with V86E F V06 N49 (ΔR, ΔV, +1) Accept : PRO Reject : Key V32E

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
		PRO (process last mark) P35 F V16 N45 (N, TFI, MGA)
	16:30	Key V83E F V06 N54 (R, $\dot{R}$, θ) Boresight on LM (COAS)
	17:00	Key NOUN Copy θ Key RLSE PRO F V16 N45 (N, TFI, MGA) Key V54E F V06 N94 (S, T, -) PRO F V53 (please mark) Boresight on LM (COAS)
	18:00	Make__LM Marks (one/min) by keying ENTR Reject with V86E F V06 N49 (ΔR, ΔV, +1) Accept : PRO Reject : Key V32E PRO (process last mark) F V16 N45 (N, TFI, MGA)

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
Exactly	19:30	PRO (final cycle) P35 F V06 N81 (V_G LV) Copy V_G Key V83E F V06 N54 (R, $\dot{R}$, θ) Boresight on LM (COAS)
	20:00	Key NOUN (freeze display) Copy R, $\dot{R}$, θ Key RLSE F V06 N54 (R, $\dot{R}$, θ) PRO Calculate Backups F V06 N81 (V_G LV) PRO F V06 N59 (V_G LOS) Copy/Compare Solns PRO F V16 N45 (N, TFI, MGA) PRO (Exit P35) F V37
	21:00	Key 41E P41 F V50 N18 (R, P, Y)

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure	
		Key ENTR (bypass mnvr)	P41
		V06 N85 (V_G Body)	
		Man Att (3) - Rate CMD	
	21:20	If PROG Alarm, TIG slipped DSKY Returns at new TIG - 35 sec	
	21:25	DSKY Blanks	
	21:30	V06 N85 (V_G Body)	
		THC - Armed	
	21:45	Call for Fuel Printout (10)	
	22:00	F V16 N85 (V_G Body) Null V_G's with THC	
		PRO (Exit P41)	
		Call for Fuel Printout (11)	
		THC - Locked	
		*Call for R, $\dot{R}$ data (RTSS)	
		F V37	
		Key 00E	P00
		SC Control - SCS	
		Key V83E	
		F V06 N54 (R, $\dot{R}$, θ)	

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
		SC Control - SCS P00 Att DB - Min BMAG Mode (3) - Att 1/Rate 2 Check LOS Rates *Call for R $\dot{R}$ data Compare R, $\dot{R}$, LOS Rate with LM Radar Data Man Att (P, Y) - Min Imp Boresight on LM - COAS Man Att (3) - Rate CMD Key V83 if LM not burned F V16 N54 (R, $\dot{R}$, θ) *Call for R, $\dot{R}$ data F V16 N54 (R, $\dot{R}$, θ) Compare R & $\dot{R}$ w/RRdata PRO Check LOS Rate/Compare w/RR data *Call for R, $\dot{R}$ data <u>LOS Control & Braking</u> Auto RCS Sel B/D Roll - MNA EMS Func - ΔV EMS Mode - Auto Key V37E 47E P47 F V16 N83 (ΔV Body) THC - Armed Key V83E if LM not burned F V16 N54 (R, $\dot{R}$, θ)

Table 3-6. ME104 Post CDH to Rendezvous Termination (Cont)

GET	TF TPI	Procedure
		Perform Braking P47 Perform LOS Control (Key V60 as Required) Call for Fuel Printout for Braking Before and After Call for frequent R, $\dot{R}$ data Braking Gates

R	$\dot{R}$
1.0 nmi	25 fps
0.5	15
0.25	10
1000 ft	5 fps

Table 3-7. LM Active Rendezvous Run Schedule

Run No.	Trajectory Deviation	Navigation Marks	MSFN Errors	System Errors	Failures	Run Duration (min)	Remarks
1	—	Yes	—	—	—	120	Initial phasing burn to intercept — TPI_o but no insertion burn
2	—	Yes	—	—	—	60	Initial phasing burn through insertion burn
3	—	Yes	—	—	—	45	Pre-CSI1 through CDH1
4	—	Yes	—	—	—	45	Pre-TPI1 through intercept
5	—	Yes	—	—	—	90	TPI1 through CSI2, includes IMU align
6	—	Yes	—	—	—	45	Post-CSI2 through CDH2
7	—	Yes	—	—	—	45	Pre-TPI2 through intercept

Table 3-8. CSM Active Rendezvous Run Schedule

Run No.	Trajectory Deviation	Navigation Marks	MSFN Errors	System Errors	Failures	Run Duration (min)	Remarks
8	—	—	—	—	—	120	TPI0
9	—	Yes	Yes	—	—	120	
10	—	Yes	Yes	Yes	—	120	Run begins at post initial phasing maneuvers, no LM insertion, ends at intercept
11	+Δh	Yes	Yes	—	—	120	
12	+Δh	Yes	Yes	Yes	—	120	
13	-Δh	Yes	Yes	—	—	120	
14	-Δh	Yes	Yes	Yes	—	120	
15	*	Yes	Yes	Yes	RCS jet or quad CMC, IMU, or optics	120	*Select worst-case trajectory deviations
16	*	Yes	Yes	Yes		120	
17	—	—	—	—	—	75	TPI1
18	—	Yes	Yes	—	—	75	
19	—	Yes	Yes	Yes	—	75	Run begins post-CDH1 and ends at intercept
20	+Δh	Yes	Yes	—	—	75	
21	+Δh	Yes	Yes	Yes	—	75	
22	-Δh	Yes	Yes	—	—	75	
23	-Δh	Yes	Yes	Yes	—	75	

Table 3-8. CSM Active Rendezvous Run Schedule (Cont)

Run No.	Trajectory Deviation	Navigation Marks	MSFN Errors	System Errors	Failures	Run Duration (min)	Remarks
24	*	Yes	Yes	Yes	RCS jet or quad, CMC, IMU, or optics	75	*Select worst case trajectory deviations
25	*	Yes	Yes	Yes		75	
26	—	—	—	—	—	90	TPI2
27	—	Yes	Yes	—	—	90	
28	—	Yes	Yes	Yes	—	90	Run begins post-CDH2 and ends at intercept
29	+Δh	Yes	Yes	—	—	90	
30	+Δh	Yes	Yes	Yes	—	90	
31	-Δh	Yes	Yes	—	—	90	
32	-Δh	Yes	Yes	Yes	—	90	
33	*	Yes	Yes	Yes	RCS jet or quad CMC, IMU, or optics	90	*Select worst case trajectory deviations
34	*	Yes	Yes	Yes		90	
35	—	—	—	—	—	90	CDH1 { External ΔV's. Runs start 15 min before burn-CDH runs end at intercept
36	—	—	—	—	—	90	CDH2
Total run duration: 53.25 hours							

3.4 ENTRY

3.4.1 Study Objectives

Study objectives are as follows:

1. Substantiate the capability of the integrated subsystem to perform an automatically steered trajectory under nominal and off-nominal entry state vector, spacecraft, and landing site conditions.
2. Substantiate the capability to perform a manually steered GNCS entry for nominal and off-nominal landing site conditions.
3. Demonstrate capability to perform an entry with the GNCS inoperative.
4. Substantiate EMS as a backup display and verify adequacy of the scroll pattern.
5. Establish propellant budgets for entry.
6. Establish contingency procedures dictated by new panel configuration.
7. Verify nominal and backup G&C procedures.
8. Substantiate EMS, constant bank, and rolling entries.
9. Provide a data base for postflight analysis.
10. Verify the related COLOSSUS programs. (P61, P62, P63, P64, P67)

3.4.2 Study Scope

During the entry study phase, the G&C events that occur between the end of the deorbit burn and jettison of the apex cover prior to drogue chute deployment will be evaluated. For particular cases, SPS deorbit and RCS deorbit phases will be included to provide continuity. The three basic entry modes will be substantiated for ME 104, the major portion of the evaluation having been accomplished during ME 101. Particular emphasis will be given to the verification of the COLOSSUS entry programs. The three entry modes

are the automatic GNCS, the manual GNCS, and the SCS. The modes are described below, and a simplified block diagram of each is shown in Figure 3-1.

1. Automatic GNCS Entry. In this entry mode, the crew primarily monitors trajectory parameters and vehicular dynamics.

2. Manual GNCS Entry. In this entry mode, the crewman will satisfy CMC steering commands displayed on the FDAI with rotation control inputs into the SCS for roll attitude control.

3. SCS Entry. In this entry mode, the crewman manually controls the CM attitude by monitoring the FDAI and utilizing the rotation control. The crewmen must control the lift vector such that no violations of tangency rays on the EMS scroll occur. For some cases, transition to an SCS entry from a GNCS entry, simulating a CMC malfunction, will be accomplished.

3.4.3 Run Description

The entry study phase will cover the G&C events from CM/SM separation to drogue chute deployment. This includes the preentry phase prior to 0.05 g and the atmospheric entry phase after 0.05 g. During the preentry phase, the CM is oriented to the inertial attitude required for a heat shield-forward aerodynamic trim condition at 0.05 g and maintains this inertial attitude until 0.05 g. During the atmospheric entry phase, the CM is "steered" to a preselected target by rotating the CM about the wind axis (roll) with rate damping in the pitch and yaw axes. The CMC and crew functions after CM/SM separation are described below for each of the three basic entry modes.

1. Automatic GNCS Entry. The detailed test procedures and the initial switch positions for the display panels are presented in Table 3-9.

2. Manual GNCS Entry. The only difference between a manual GNCS entry and an automatic GNCS entry is that the CM attitude is controlled by the astronaut using the rotation control rather than the entry DAP. The astronaut uses the CMC steering commands that appear on the FDAI attitude error needles for attitude control information. Manual maneuver control is selected by a clockwise rotation of the translation control.

3. SCS Entry. When in the SCS entry mode, the astronaut manually controls the vehicle attitude using the rotation control and

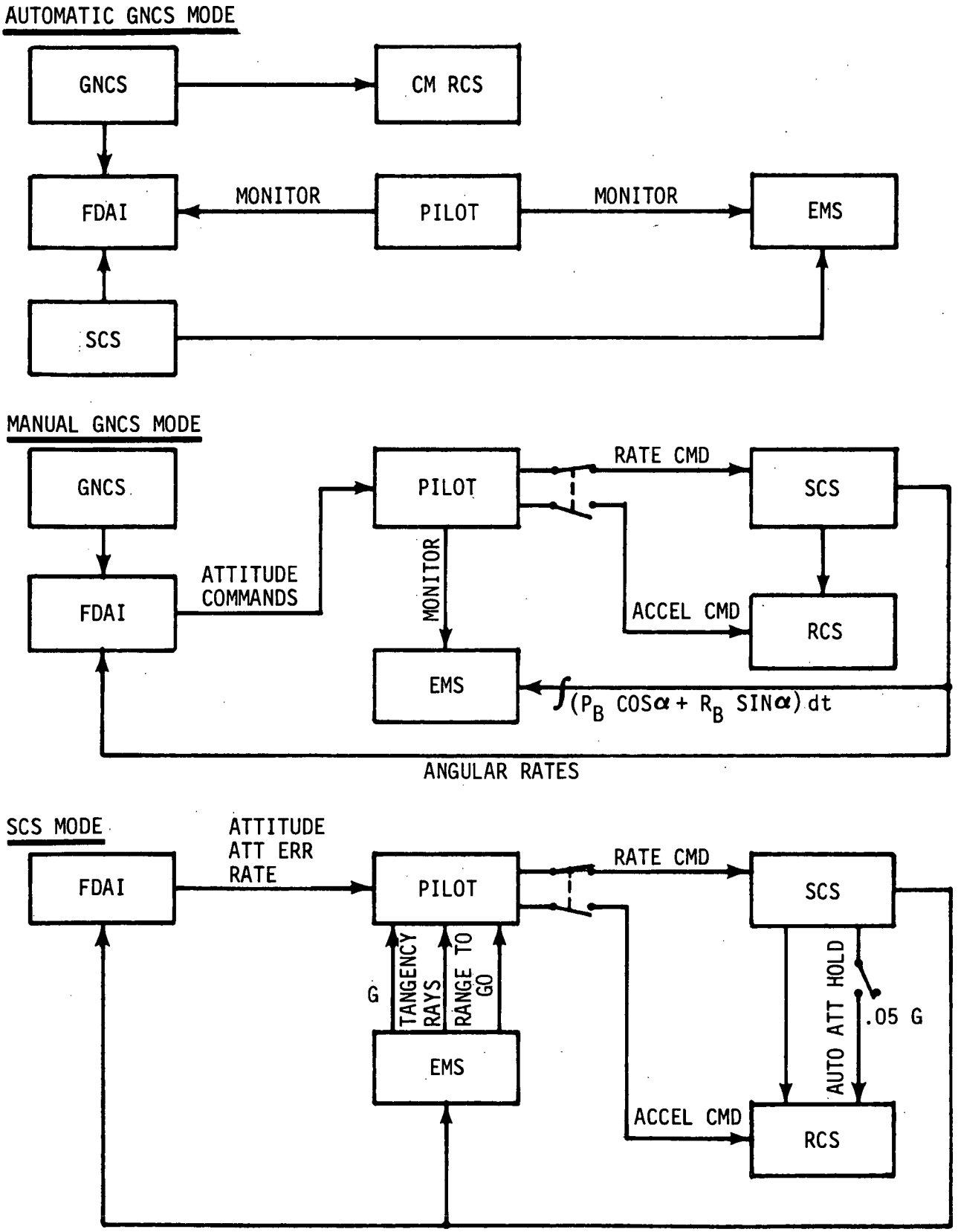

Figure 3-1. Basic Entry Control Modes

monitoring the FDAI ball and EMS displays. Several control techniques can be used, including a rolling entry and constant-bank profiles.

3.4.4 Run Schedule Synopsis

The run schedule synopsis is presented in Table 3-10. Included in the schedule is the flight mode utilized, the type of initial condition state vector, the target, CM L/D, control mode, estimated time per run, and a comment as to objective.

Table 3-9. Display Panel Switch Position Prior to Entry Run

Panel No.	Switch Name	Switch Position	Panel No.	Switch Name	Switch Position
1	CMC attitude	IMU	1	ΔV/SPS ind	Pc
1	FDAI scale	50/15 50/10	1	ΔV/SPS ind	GPI
1	FDAI select	1/2	1	ΔV CG	CSM
1	FDAI source	GDC	1	ELS logic	OFF
1	Attitude set	GDC	1	ELS logic	MAN
			1	CM RCS logic	OFF
1	Limit cycle	OFF	1	CM propellent dump	OFF
1	Attitude dead band	MAX	1	CM propellent purge	OFF
1	Rate	HIGH	1		
1	Trans control power	ON	8	Auto RCS select (16)	MNA
1	Rotary control power normal (2)	AC/DC			
1	Rotary control power direct (2)	MNA/MNB	7	EDS power	ON
1	SC control	SCS	7	TVC servo power (2)	OFF
1	CMC mode	AUTO	7	Logic power 2/3	ON
1	BMAG mode (3)	RATE 2			
			7	FDAI/GPI	BOTH
1	SPS thrust	NORMAL	7	SCS electronic power	GDC/ECA
1	ΔV thrust (2)	OFF	7	BMAG power (2)	ON
1	SCS TVC (2)	RATE CMD			
1	SPS gimbal motor (4)	OFF	2	UT TLM CM	ACCEPT
1	IMU cage	OFF (GUARDED)	2	CM RCS propellent	GRAY
			2	RCS trnfr*	SM
1	EMS roll	OFF	2	RCS command	ON
1	0.05 G	OFF			

*SCS entry-set RCS trnfr switch to 'CM' position.

Table 3-9A. ME 104 Automatic GNCS Entry

Step	Procedure	Expected
	REQUIRED CMC - ON ISS - ON SCS - ON Set display panel switches Set event timer	
1	Count up event timer at start of program Key V37E 00E Align FDAI 2 Man Att — Accel CMD Maneuver to separation attitude Roll = 1 8 0 . 0 DEG Pitch = 1 8 0 . 0 DEG Yaw = 4 5 . 0 DEG	
2	CM/SM sep (both) —on (up) RCS TRNFR —CM RCS CMD — ON	
3	Maneuver to entry attitude Roll 0.0 DEG Pitch 55.0 DEG Yaw 0.0 DEG	
4	Auto RCS SEL A/C ROLL(4) —OFF Auto RCS SEL CM2(6) — OFF (D1, D2, A3, C4, D3, B4)	
5	Key V37E 61E FL V06 N61 Impact lat _ _ _ . _ _ DEG Impact long _ _ _ . _ _ DEG Hds up/dn _ _ _ _ _ IF reject V25E load data Accept PRO	
6	FL V06 N60 (Entry Data) G max _ _ _ . _ _ G V pred _ _ _ _ _ . FPS Gamma EI _ _ _ . _ _ DEG Record PRO	

Table 3-9A. ME 104 Automatic GNCS Entry (Cont)

Step	Procedure	Expected
7	FL V06 N63 RTOGO (0.05g to spl) _ _ _ _ _ . _ NM VIO (at 0.05g) _ _ _ _ _ _ . FPS TFE _ _B_ _ MIN SEC EMS mode — STBY EMS func — Test 5 Set scroll patt. to 37K EMS func — RNG set Set RNG ind for RTOGO EMS func — Vo set Align scroll to display ind EMS func — Entry PRO	
8	P62 (auto select by P61) IF FL V37 Key 62E	
9	FL V51 N25 0 0 0 4 1 (Request CM/SM sep) PRO	
10	FL V06 N61 Impact lat _ _ _ . _ _ DEG Impact long _ _ _ . _ _ DEG Hds up/dn _ _ _ . _ _ PRO (If rej V25E load new data)	
11	DSKY P63 EMS mode — Auto Align FDAI 2 BMAG MODE (3) — rate 2	
12	V06 N64 (monitor) G _ _ _ . _ _ G VI _ _ _ _ _ . FPS RTOGO _ _ _ _ . _ NM Check RTOGO agrees with EMS MAN ATT(3) — Rate CMD SC CONT — CMC	

Table 3-9A. ME 104 Automatic GNCS Entry (Cont)

Step	Procedure	Expected
13	DSKY — P64 (0.5g) 0.05g sw—On (up) EMS roll—On (up)	
14	V06 N68 (MONITOR) BETA ___.__ DEG VI ____.__ FPS H DOT ____.__ FPS	
	DSKY — P67 (0.2g)	
15	V06 N66 (MONITOR) BETA ___.__ DEG CRSRNG ERR ____.__ NM DWNRNG ERR ____.__ NM	
16	V16 N67 (MONITOR) RTOGO ____.__ NM LAT ___.__ DEG LONG ___.__ DEG MONITOR ALTIMETER	

3.5 IMU ALIGNMENT

3.5.1 Study Objectives

Study objectives are as follows:

1. Determine the accuracy of the IMU orientation as performed by the crew using the sextant (SXT) for both the CSM and LM/CSM configurations.

2. Determine the accuracy of the IMU orientation as performed by the crew using the crewman's optical alignment sight (COAS) for the LM-off configuration.

3. Determine the accuracy of alignment of the IMU using the SXT for both LM-on and LM-off configurations.

4. Determine the accuracy of alignment of the IMU using the COAS for the LM-off configuration.

5. Verify the operational integrity of the IMU orientation program (P51) and IMU realignment program (P52).

6. Verify the operational integrity of the backup IMU orientation program (P53) and backup IMU realignment program (P54).

7. Determine the time and RCS propellant required to perform each IMU alignment and realignment.

8. Evaluate the related G&C procedures.

9. Provide a data base for postflight analysis.

3.5.2 Study Scope

This portion of the study will evaluate the capability to perform the IMU orientation, the accuracy of the determination, and the RCS propellant required for the alignment tasks. The IMU alignment that occurs before each of the seven SPS burns, except Burn 6, will be simulated. IMU orientation determination will be simulated, in addition to alignment, for SPS Burns 1, 2, and 5. IMU alignment prior to the rendezvous operations, prephasing and

Table 3-10. Entry Run Schedule

Deorbit Flight Mode	Entry Flight Mode	Run Initiation	Entry State Vector	Target Lat/Long	L/D	Att Control	Est No. of Runs	Est Time per Run	Total Est Time	Comments
G&N/extΔV	G&N auto	Prior to deorbit burn	Nominal	Nominal	Nominal	DAP	1	*	*	Monitor CMC, and EMS. Verify DAP control
G&N/3σextΔV							2	*	*	
G&N/MTVC							3	*	*	
G&N (over burn)			Over burn	80 center			1	*	*	
G&N (under burn)			Under burn	30 center			1	*	*	
SCS auto TVC	SCS-EMS		Nominal	Nominal		Rate or ACCEL CMD	3	*	*	Verify backup control procedures
3σ SCS auto TVC							6	*	*	
SCS auto TVC/ MTVC							3	*	*	
G&N/extΔV	G&N manual						3	*	*	Pilot flies CMC attitude error needles
										*Time for above 23 schedule runs are listed in SPS ΔV LM-off run schedule
Reentries only										
NA	G&N auto	End of deorbit burn	Nominal	Nominal	High	DAP	1	35	35	Monitor CMC and observe CMC trends for different target locations
				Nominal	Low		1	35	35	
				30 off center	Nominal		1	35	35	
				60 off center			1	35	35	
	G&N manual			80 center		Rate CMD	1	35	35	Evaluate crew capability in following CMC commands for different target locations
				80 center		ACCEL CMD	1	35	35	
				30 off center		Rate CMD	1	35	35	
				30 off center		ACCEL CMD	1	35	35	
				60 off center		Rate CMD	1	35	35	
				60 off center		ACCEL CMD	1	35	35	
	SCS-EMS	400 k		Nominal		Rate CMD	1	25	25	Evaluate the backup entry technique
				30 off center			1	25	25	
				60 off center			1	25	25	
				Nominal	Low		1	25	25	
				Nominal	Nominal	ACCEL CMD	1	25	25	
				30 off center			1	25	25	
				60 off center			1	25	25	
				Nominal	Low		1	25	25	
	Constant bank				Nominal	Rate CMD	1	25	25	
	GNCS man/SCS	End of deorbit burn					2	35	70	CMC fails during reentry and EMS takeover is required
				30 off center			2	35	70	
				60 off center			2	35	70	
	Rolling	400 k		TBD from run		ACCEL CMD	1	25	25	

Table 3-10. Entry Run Schedule (Cont)

Failure Mode	Entry Flight Mode	Run Initiation	Entry State Vector	Target Lat/Long	L/D	Att Control	Est No. of Runs	Est Time per Run (min)	Total Est Time (min)	Comments
Roll jet drvr hrd over	G&N auto/ man	End of deorbit burn	Nominal	Nominal	Nominal	Rate CMD	1	35	35	Failure at $g < 0.05$
Pitch jet drvr hrd over							1	35	35	Failure at $g > 0.05$
Yaw jet drvr hrd over							1	35	35	Failure at $g < 0.05$
Roll direct coil hot short							1	35	35	Failure at $g > 0.05$
Pitch direct coil hot short							1	35	35	Failure at $g > 0.05$
Yaw direct coil hot short							1	35	35	Failure at $g < 0.05$
Yaw BMAG 2 open	G&N man						1	35	35	Failure at $g > 0.05$
Roll sw amp hrd over with no opp jet	G&N man						1	35	35	Failure at $g > 0.05$
			Total runs for reentry only = 34 runs						1065	
			Total estimated time includes only run time and uplinking time							

post-TPI_1, will be simulated. The alignment of the IMU to one of three orientations will be investigated: the "preferred" orientation, which is the optimum platform alignment for a specific burn; the "nominal" orientation, which is the local geocentric orientation; and the "REFSMMAT" orientation. The "landing site" orientation will not be investigated. For those SPS burns or rendezvous operations performed in the LM-off configuration, the IMU orientation and alignment using the crewman's optical alignment sight (COAS) will be simulated.

3.5.3 Run Description

Prior to each of the seven SPS burns (except Burn 6) and the rendezvous operations, post-TPI_1, and prephasing, the IMU is fine-aligned to one of the three orientations. If the IMU has been turned off or has been allowed to drift for an extended period of time, the existing alignment must first be determined. The IMU orientation determination is accomplished using program P51. The IMU alignment is then performed using program P52 and, time permitting, occurs on the succeeding nightside portion of the orbit. In the contingency of an optics failure, the IMU orientation determination and alignment may be performed using the COAS. COAS utilization requires a modified program procedure; the IMU orientation is accomplished using the backup IMU orientation program (P53), and the alignment is performed using the backup IMU realignment program (P54). The detailed procedures for each of these programs are presented in Tables 3-11, 3-12, 3-13, and 3-14, respectively.

3.5.4 Run Schedule Synopsis

Table 3-15 presents the schedule of runs that will be used to verify the IMU and backup IMU orientation determination and alignment programs. The runs are categorized as to SPS or rendezvous burn, number and type of run, IMU orientation utilized, vehicle configuration, programs verified, error sources, control modes, and simulator run times. The total number of runs scheduled is 31, of which 17 use the sextant and programs (P51 and P52), 9 are scheduled for backup alignments employing COAS and programs P53 and P54, and the remaining 5 are for backup IMU-GDC alignments. SPS burns 1 through 5 will be preferred orientation alignments. REFSMMAT alignments will be used for both rendezvous operations. The nominal alignment option of P52 is scheduled for verification on the post-TPI_1 rendezvous operation. The deorbit burn will be aligned to a simulated ground uplink orientation. All runs except a duplication of Burn 4 will be made with IMU error coefficients. The duplicated SPS Burn 4 run will be initiated with data simulating the effects of long-term gyro drift.

Table 3-11. P51 IMU Orientation Procedures

Step	Crew Operation	Step	Crew Operation
	CMC - on ISS - on SCS - on CMC ATT-IMU logic 2/3 power-on		V42 N22 (coarse align) R,P,Y 000.00 deg No attitude light on - then off and recycle to Step 4
1	Optics power - up G/N opt pwr - on G/N pwr - AC1 or AC2 Opt mode - manual Opt zero - zero 15 sec	5	FL V51 (please mark)
2	Select total attitude display	6	FL V50 N25 00016 (terminate marks) ACCEPT - PRO REJECT - mark reject button
3	Key 37E 51E	7	FL V01 N71 000XX (target code) ACCEPT - PRO REJECT - V21E - load data, recycle to Step 5 for Target 2
4	FL V50 N25 00015 (acquire target) a. Select desired attitude control mode and maneuver May key V16 N20 to monitor for impending gimbal lock) PRO or b. To coarse align IMU to SC axis ENTR (when attitude is acceptable)	8	Planet only FL V06 N88
		9	FL V06 N05 XXX.XX DEG (star angle difference) ACCEPT - PRO REJECT - V32E return to Step 4
		10	FL V37 KEY XXE

Table 3-12. P52 IMU Realignment

Step	Crew Operation	Step	Crew Operation
1	CMC - on IMU - powered - up and aligned SCS - powered - up G/N pwr optics - on BMAG mode (3 ea) - Rate 2 SCS channels (4 ea) - on SC cont - CMC Optics - man, opt zero - 15 sec		ACCEPT - PRO (REFS - Step 9) (pref - Step 7) Reject - KEY V22E and load option Possible FL V05 N09 00215 - orientation not specified KEY V32E and go to Step 4 PROG and PGNS lt - on
2	KEY V37E 52E		a. nominal or REFSMAT acceptable. (V32E) repeat selection RSET
3	Perform IMU status check routine (R02)		b. Preferred desired - select new program to define orientation V37E__E RSET
4	FL V04 N06 Option code ID 00001 Option 0000X Blank R1 - option code R2 - option assumed by CMC 00001 preferred 00002 nominal 00003 REFSMMAT 00004 landing site	5	FL V06 N34 GET (ALIGN) XXXXX. hrs 000XX. min 0XX.XX sec ACCEPT - PRO (If nominal go to Step 7) REJECT - Load GET (KEY V25E) (ALIGN)

Table 3-12. P52 IMU Realignment (Cont)

Step	Crew Operation
6	FL V06 N89 XX.XXX deg lat XX.XXX deg long/2 XXX.XX nm alt *stored landing site coordinates *alt should be zero ACCEPT - PRO REJECT - Load data V25E
7	FL V06 N22 XXX.XX deg OG roll XXX.XX deg IG pitch XXX.XX deg MG yaw a. If MGA is acceptable, select mode to ensure CSM stability PRO b. If MGA not acceptable, either (1) Maneuver vehicle to obtain acceptable MGA, KEY V32E or (2) Select new program V37E__E
8	Perform coarse alignment routine (R50) NO ATT light on FDAI ball follows IMU gimbal movement-- NO ATT light off *If all angular changes are less than 5 deg, coarse align will not be performed.
9	FL V50 N25 00015 } please acquire Blank } celestial Blank } body a. Maneuver to acquire suitable body - PRO or b. Bypass star selection routine ENTER - go to Step 10 Possible FL V05 N09 00405 - 2 stars not in FOV PROG lt - on PGNS lt - on a. Maneuver to acquire suitable star PRO RSET or b. KEY V32E Repeat Step 9 RSET
10	FL V01 N70 000XX celest body code Blank Blank 00 → Planet 01-45 → Star 46 → Sun 47 → Earth 50 → Moon ACCEPT - optics - CMC PRO (if planet go to 12) REJECT - load data V21E

Table 3-12. P52 IMU Realignment (Cont)

Step	Crew Operation	Step	Crew Operation
11	FL V06 N88 For planet load only ACCEPT - PRO, REJECT - KEY V25E and load	16	Planet only FL V06 N88 ACCEPT - PRO
12	Perform auto optics positioning (R52) *If OCDU angles not displayed - V16 N92E *Possible FL V05 N09 404 ~ TA > 90 deg a. Select control mode and maneuver to reduce TA b. or key V34E *Possible FL V05 N09 407 ~ TA > 50 deg KEY RELEASE and maneuver to reduce TA *When marks are desired, optic mode - manual	17	FL V06 N05 XXX.XX deg { sighting angle difference ACCEPT - PRO REJECT - V32E (go to Step 19)
		18	FL V06 N93 (Δgyro angles) X, Y, Z, XX.XXX deg ACCEPT - PRO REJECT - V32E
13	FL V51 (please mark) Mark (on target)	19	FL V50 N25 00014 { fine align check ACCEPT - PRO return to Step 9 REJECT - ENTR
14	FL V50 N25 00016 (term. marks) ACCEPT - PRO REJECT - mark reject	20	FL V37 00E
15	FL V01 N71 000XX target code ACCEPT - PRO REJECT - V21E and load desired code	21	Optics Zero - Zero
*	Repeat steps 10 through 15 for Target 2		

Table 3-13. P53 Backup IMU Orientation Determination

Step	Crew Operation	Step	Crew Operation
	CMC - on ISS - on SCS - on	4	FL V06 N92 SA XXX.XX deg TA XX.XXX deg
	CMC ATT - IMU COAS - calibrated		ACCEPT - PRO REJECT - V24E load desired SA and TA (nominal SA = 000.00, TA = 57.470)
1	Select total attitude display		
2	KEY V37E 53E	5	FL V53 (please mark)
			RHC - center target in COAS reticle (MIN IMP recommended) ENTR
3	FL V50 N25 00015 (acquire target) V16N20 in LEB to monitor for impending gimbal lock	6	FL V50 N25 00016 (terminate marks)
	*to avoid impending gimbal lock key ENTER and go to "b" below		ACCEPT - PRO REJECT - ENTR and return to 5
	a. Select desired attitude control mode, maneuver to acquire target if necessary PRO	7	FL V01 N71 000XX (target code)
			ACCEPT - PRO REJECT - V21E and load, return to Step 4 for target 2
	b. To coarse align IMU to SC axis ENTR (when attitude acceptable)	8	FL V06 N88 (planet only)
	V41 N22 (coarse align) R,P,Y - 000.00 deg NO ATT light - on, then off Return to Step 3		x,y,z PL .XXXXX ACCEPT - PRO REJECT - V25E and load
		9	FL V06 N05 XXX.XX deg star angle difference
			ACCEPT - PRO REJECT - V32E and return to Step 3
		10	FL V37 KEY XXE

Table 3-14. P54 Backup IMU Realignment Program

Step	Crew Operation	Step	Crew Operation
1	Setup CMC - on IMU - power up and aligned SCS - power up SC cont. - SCS Man att (3 ea) - minimum impulse SCS channels (4 ea) - on		*FL V05 N09 00215 PROG lt - on PGNS lt - on } preferred selected but not defined a. If nominal or REFSMMAT acceptable V32E and reselect RSET
2	Key V37E 54E		
3	Perform IMU status check routine (R02)		b. If preferred desired - select new program to define orientation V37__ E RSET
		5	FL V06 N34 00XXX. hrs GET (align) 000XX. min 0XX.XX sec GET (align) - time at which $\bar{R}$ and $\bar{V}$ are defined for nominal or landing site *Initial display is '0'. If accepted, GET (align) is present time. ACCEPT - PRO If nominal accepted: go to 7 REJECT - load GET (align)
4	FL V04 N06 00001 option code ID 0000X option Blank R1 - option code ID for IMU orientation selection R2 - option assumed by CMC 00001 preferred 00002 nominal 00003 REFSMMAT 00004 landing site ACCEPT - PRO If REFS selected go to 9 If pref selected go to 7 REJECT - load option (KEY V22E)	6	FL V06 N89 (landing site) XX.XXX lat (deg) XX.XXX long/2 (deg) XXX.XX alt (nm) ACCEPT - PRO REJECT - load correct data (KEY V25E)

Table 3-14. P54 Backup IMU Realignment Program (Cont)

Step	Crew Operation	Step	Crew Operation
7	FL V06 N22 (gimbal angles) XXX.XX roll (deg) XXX.XX pitch (deg) XXX.XX yaw (deg) a. If MGA is acceptable - select mode to ensure stability PRO b. If MGA not acceptable either (1) Maneuver to acceptable MGA, V32E or (2) Select new program V37E__E		*FL V05 N09 00405 } two stars Prog light - on } not available in PGNS light - on } field of view a. Maneuver to acquire PRO - then RSET b. V32E - repeat Step 9 RSET
		10	FL V01 N70 000XX } celestial Blank } body Blank } code 00 - Planet 01-45 - Star 46 - Sun 47 - Earth 50 - Moon ACCEPT - PRO If target not a planet, go to 12 REJECT - load desired code
8	Perform coarse alignment routine (R50) NO ATT light - on FDAI ball follows IMU gimbal movement NO ATT light - off *If angular changes are <5 deg coarse align will not be performed.		
9	FL V50 N25 00015 } acquire Blank } celestial Blank } body a. Maneuver to acquire body PRO b. Bypass star routine ENTR	11	If planet selected FL V06 N88 X, Y, Z PL .XXXXX ACCEPT - PRO REJECT - load data (KEY V25E)
		12	Perform alternate LOS mark routine (R56)
		13	Repeat Steps 10 through 12 for second body

Table 3-14. P54 Backup IMU Realignment Program (Cont)

Step	Crew Operation	Step	Crew Operation
14	Perform sighting display routine (R54) *If sighting results were rejected (V32E) - go to Step 16	16	FL V50 N25 00014 Blank Blank } Please perform fine align ACCEPT - PRO return to Step 9 REJECT - ENTR
15	Perform gyro torquing routine (R55)	17	Perform program termination routine (R00) FL V37 KEY XXE

Table 3-15. Alignment Run Schedule

Run Burn	Run Type and Number			Orientation	Configuration	Program		Errors	Control Modes	Time Run (No Setup) (min.)
	IMU	B/U IMU	B/U GDC			Nominal	B/U			
1	1	-	-	Preferred	LM/CSM	P51, 52	-	IMU error sources	SCS - man att, min impulse/ accel	30
2	1	-	-	Preferred	LM/CSM	P51, 52	-	IMU error sources	SCS - man att, min impulse/ accel	30
3	1	-	-	Preferred	LM/CSM	P52	-	IMU error sources	SCS - man att, min impulse/ accel	15
4	2	-	-	Preferred	LM/CSM	P52	-	Second run with long-term gyro drift	SCS - man att, min impulse/ accel	30
5	1	-	-	Preferred	CSM	P51, 52	P53,54	IMU error sources	SCS - man att, min impulse/ accel	30
Rendezvous Pre-phasing	2	2	-	REFSMMAT	CSM	P52	P54	IMU error sources	SCS - man att, min impulse/ accel	80
Post-TPI_1	3	2	-	REFSMMAT	CSM	P52	P54	IMU error sources	SCS - man att, min impulse/ accel	110
				Nominal	CSM	P52				
7	3	3	5	Uplink	CSM	P52	P54	IMU error sources	SCS - man att, min impulse/ accel	270
Totals	17	9	5							9 hr 45 min

3.6 LANDMARK TRACKING

3.6.1 Study Objectives

Study objectives are as follows:

1. Verify the operational integrity of the orbital navigation program (P22).
2. Verify the operational integrity of the ground track determination program (P21).
3. Determine ease in locating and identifying landmarks.
4. Determine the time and RCS propellant required to perform the navigation function.
5. Evaluate landmark tracking in the LM-on configuration.
6. Evaluate the orbit determination capability of the orbital navigation program (P22) for the tracking of known and unknown landmarks.
7. Provide a data base for postflight analysis.

3.6.2 Study Scope

This portion of the study will evaluate the automatic and manual tracking capability for known landmarks and the manual tracking capability for unknown landmarks. The tracking of landmarks with the CSM configuration will be performed in the "nominal" sighting a titude. LM-on landmark tracking will be performed using the broadside attitude with respect to the orbital ground track. Other sighting attitudes will be investigated to obtain a comparison with respect to ease of tracking and RCS propellant consumption. Tracking of a single landmark and sequential tracking of three or more landmarks will be simulated. The state vector updates resulting from processing tracking data will be used to evaluate the orbital determination capability of the tracking modes. The ground track determination program will be used during simulation runs to facilitate selection of landmarks.

3.6.3 Run Description

Orbital navigation is accomplished by scanning telescope tracking of a known landmark or by sextant tracking of an unknown landmark. The navigational measurements are used by the CMC to obtain an estimate of the vehicle's position and velocity. A known landmark is a landmark for which the longitude, latitude, and altitude are defined and may be stored in the CMC or entered by way of the DSKY by the astronaut. An unknown landmark is a landmark selected by the astronaut because of a recognizable terrain feature and ease of tracking, but whose coordinates are not defined. The tracking of a known landmark is further facilitated by the use of the automatic optics positioning routine, while unknown landmarks must be tracked manually. Prior to the tracking sequence, the orbital ground track program may be used to facilitate the selection of known landmarks by computing the longitude and latitude of the vehicle at selected times during the coming tracking sequence. The detailed procedures for the ground track determination program (P21) and the orbital navigation program (P22) are presented in Tables 3-16 and 3-17, respectively.

3.6.4 Run Schedule Synopsis

Table 3-19 presents the schedule of runs that will be used to verify the orbital navigation program (P22) and the ground track determination program (P21). The runs are classified as to landmark number, tracking option, control mode, error sources, error values, and simulator running time. The landmark numbers presented are symbolic in that two basic tracking sequences will be investigated. The landmark F type of sequence will occur near the highest latitude of the ground track, and the T-type landmark will be near-equatorial. Tracking will be performed on both a single landmark and a sequence of three or more landmarks for F and T types. Landmarks will be designated as known, unknown, or a combination of the two for sequential tracking. Runs 1 and 2 will be initiated as circular orbits, and state vector errors of various magnitude will be used to establish a data base and a region of convergence so as to evaluate the orbital determination capability of P22. The nominal, broadside and selected tracking attitudes will be employed for these runs. Runs 3 and 4 are designed for the same purpose as Runs 1 and 2 except that Type T landmarks will be employed. Runs 5 and 6 are scheduled to track, in sequence, three or more landmarks that are combinations of known and unknown. Run 7 is scheduled to show the effects of a drifting IMU on the orbit determination process. Program P21 may be utilized in any of the runs but will be scheduled for use in Runs 5 and 6.

Table 3-16. P21 Ground Track Determination

Step	Crew Operation	Step	Crew Operation
	CMC - on	4	FL V06 N43 Lat (+N) XXX.XX deg Long. (+E) XXX.XX deg Alt XXXX.X nm (alt above launch pad radius) *To increment time-lat-long. by 10 min key V32E and return to Step 3
1	Key V37E 21E		
2	FL V04 N06 00002 option code 0000X CMC assumed option (00001) = CSM (00002) = LM ACCEPT - PRO REJECT - V22E load option	5	PRO (terminates P21) FL V37 XXE
3	FL V06 N34 (GET lat-long.) 00XXX hr 000XX min 0XX.XX sec ACCEPT - PRO REJECT - V25E load time of lat-long		

Table 3-17. P22 Orbital Navigation

Step	Crew Operation	Step	Crew Operation
	Required		b. Maneuver to sighting attitude and establish orbit rate
	CMC - on ISS - on and orientation known Optics power - up Optics mode - CMC CMC Att - IMU 0.05 G switch - off SCS - on		RHC - position X_{SC} axis ≃20 deg below local horizontal, SEF heads up (COAS LOS on horizon or use ORDEAL FDAI)
1	Select total attitude display		RHC or ATT IMP - pitch to offset orbital rate, roll to avoid shaft axis ≃10 deg of landmark
2	Select attitude control mode desired		PRO
3	Key V37E 22E	5	FL V07 N70 (lunar orbit only)
	*Possible PROG alarm Key V05 N09E 00210 (ISS not on)		R2 - LMK code ABCDE
	or		A 1 (known LMK) g2 (unknown LMK) B Index of offset designator C Not used DE LMK ID
	00220 (IMU orientation not known) FL V37 KEY XXE		
4	FL V06 N45		ACCEPT - If A=2, OPT MODE-Manual PRO (Go to step 8)
	R3 XXX.XX deg } max MGA if x-axis in orbit plane		or
	a. If IMU alignment satisfactory, perform ORDEAL initialization		If A=1 & DE=00 PRO (Go to step 7)
			or

Table 3-17. P22 Orbital Navigation (Cont)

Step	Crew Operation	Step	Crew Operation
5 (cont)	If A=1 and DE=00 PRO *Possible PROG alarm (00404 and 00407) REJECT - Key V22E and load desired data	8	FL V51 (please mark) ACCEPT - repeat mark procedure or PRO REJECT - push mark reject and repeat mark procedure
6	FL V06 N89 (landmark data) Lat (+N) XX.XXX deg Long./2 (+E) XX.XXX deg Alt XXX.XX nm ACCEPT - PRO REJECT - V25E load data *Possible FL V05 N09 000404 (TA > 90 deg) maneuver until optics can acquire landmark or V34E (terminates program) (FL V37 XXE) *Possible PROG alarm (TA > 50 deg) Key V05 N09E 00407 Maneuver to reduce desired trunnion angle		{If 5 marks made FL V50 N25 00016 (terminate marks) ACCEPT - PRO REJECT - mark reject} Optics zero (15 sec) Optics mode - CMC
		9	FL V05 N71 (landmark data) R2 - ABCDE A = 1 (known), 2 (unknown) B = offset indicator C = unused DE = landmark ID ACCEPT - PRO, if A = 2 (or A = 1 and DE ≠ 0) go to Step 11 REJECT - V22E load data
7	V06 N92 (new OCDU angles SA XXX.XX deg TA XX.XXX deg If not displayed - V16 N92E to mark optics - MAN		

Table 3-17. P22 Orbital Navigation (Cont)

Step	Crew Operation	Step	Crew Operation
10	FL V06 N89 (landmark coordinates Lat XX.XXX deg Long./2 XX.XXX deg Alt XXX.XX nm ACCEPT - PRO REJECT - V25E load data	13	Key V34E (to terminate P22) FL V37 key XXE
11	FL V06 N49 ΔR XXXX.X nm ΔV XXXX.X fps ACCEPT - PRO REJECT - V32E and in EO - return to Step 6 or LO - return to Step 5		
12	FL V06 N89 Lat XX.XXX deg Long./2 XX.XXX deg Alt XXX.XX nm ACCEPT - PRO, EO - return to Step 6, LO - Step 5 REJECT - V32E, EO - return to Step 6, LO - Step 5		

Table 3-18. Orbital Navigation Run Schedule

Run Type No.	Run Description	Landmark No.	Landmark Tracking Option	Control Mode	Error Sources	Error Values	Run Time (min)	Remarks
1	Circular orbit, data base 2 repetitions	F	Auto-known	SCS minimum impulse & accel	None	-	15	Broadside track may be selected on any combination of the following runs. Program P21 to be evaluated for runs with and without IC errors.
1A	Establish region of state vector convergence for known and unknown tracking	F	Auto-known	SCS minimum impulse & accel	State vector	15,000 ft/axis 12 ft/sec	15	
1B		F	Auto-known	SCS minimum impulse & accel	State vector	10,000 and 8	15	
1C		F	Auto-known	SCS minimum impulse & accel	State vector	10,000 and 4	15	
2		F	Manual-unknown	SCS-minimum impulse & accel	None	-	15	
2A		F	Manual-unknown	SCS-minimum impulse & accel	State vector	15,000 ft/axis and 12 fps	15	
2B		F	Manual-unknown	SCS-minimum impulse & accel	State vector	10,000 and 8	15	
2C		F	Manual unknown	SCS-minimum impulse & accel	State vector	5,000 and 4	15	
3	Circular orbit, data base, 2 repetitions	T	Auto-known	SCS-minimum impulse & accel	None	-	10	
3A	Establish region of convergence	T	Auto-known	SCS-minimum impulse & accel	State vector	15,000 and 12	10	
3B		T	Auto-known	SCS-minimum impulse & accel	State vector	5,000 and 4	10	
4		T	Manual-unknown	SCS-minimum impulse & accel	None	-	10	
4A		T	Manual unknown	SCS-minimum impulse & accel	State vector	15,000 and 12	10	
4B		T	Manual unknown	SCS-minimum impulse & accel	State vector	5,000 and 4	10	

Table 3-18. Orbital Navigation Run Schedule (Cont)

Run Type No.	Run Description	Landmark No.	Landmark Tracking Option	Control Mode	Error Sources	Error Values	Run Time (min)	Remarks
5	Sequential land mark tracking exercise	F, F_1, F_2	Auto-known	SCS-minimum impulse & accel	None	-	35	Broadside track may be selected for any combination of these runs.
5A		F_1 unknown	Auto/manual known/ unknown	SCS-minimum impulse & accel	State vector	10,000 and 8	35	
5B		F, F_1, F_2	All unknown (manual)	SCS-minimum impulse & accel	State vector	10,000 and 8	35	
6		T, T_1, T_2	Auto-known	SCS-minimum impulse & accel	None	-	30	
6A		T_1 unknown	Auto/manual known/ unknown	SCS-minimum impulse & accel	State vector	10,000 and 8	30	
6B		T, T_1, T_2	Manual all unknown	SCS-minimum impulse & accel	State vector	10,000 and 8	30	
7	Circular orbit with IMU drifts present, assuming convergence of data on other runs	F	Auto-known	SCS-minimum impulse & accel	IMU drift	None	15	
7A		F	Manual-unknown	SCS-minimum impulse & accel	IMU drift	None	15	
26 runs							7 hr 25 min	

3.7 SM ABORT

3.7.1 Study Objectives

Study objectives are as follows:

1. Verify efficient and satisfactory crew operational procedures for each SM abort mode.
2. Evaluate the system rate damping capability for tumbling aborts.
3. Evaluate the adequacy of the time of free fall (t_{ff}) and maximum g (G_{max}) limit lines for Mode II aborts.
4. Evaluate the adequacy of the specified prethrust coast time for Mode III and IV aborts.
5. Determine SPS ΔV maneuver execution errors for tumbling aborts (Modes III and IV).
6. Evaluate abort criteria and mode selection logic.
7. Determine RCS and SPS propellant requirements for tumbling aborts.
8. Evaluate the effectiveness of the land avoidance criteria for Mode III aborts.
9. Evaluate the effectiveness of Mode III and IV ΔV maneuvers to achieve the desired terminal conditions.
10. Verify satisfactory operation of related CMC programs.

3.7.2 Study Scope

The SM abort study will evaluate the three abort modes (II, III and IV) that cover the phases of the launch from LES jettison to orbit insertion. The Mode II and III aborts for which orbit insertion is not achieved will be evaluated through the entry phase. This will be the first mission evaluation

of SM aborts off the Saturn V launch vehicle and with a fully loaded CSM. The basic SM abort philosophy is presented in the flow diagram in Figure 3-2.

3.7.3 Run Description

The major events of the three abort modes are described below.

3.7.3.1 Mode II

This mode results in a free fall into the continuous recovery area (Pad + 60 nm to 3350 nm downrange) with a maximum load factor during entry of 16 g and a minimum of 100 seconds' free fall to 300,000 feet. The nominal range of time from liftoff for this mode is approximately 185 to 630 seconds. The sequence of G&C events is as follows:

1. RCS +X translation and/or SPS rate damping burn
2. Maneuver to CM/SM separation attitude and separate
3. Maneuver to entry attitude
4. Full lifting entry

3.7.3.2 Mode III

This is the least probable abort mode and will be used only if immediate return of the spacecraft becomes necessary. This mode is used from approximately 630 seconds after liftoff to orbit insertion. It provides splashdown in the discrete recovery area 3350 nm downrange of the pad with the following sequence of events:

1. RCS +X translation and possibly an SPS rate damping burn
2. Maneuver to the retrograde thrusting attitude and performance of required ΔV
3. Maneuver to CM/SM separation attitude and separation
4. Maneuver to entry attitude
5. Entry into discrete landing area

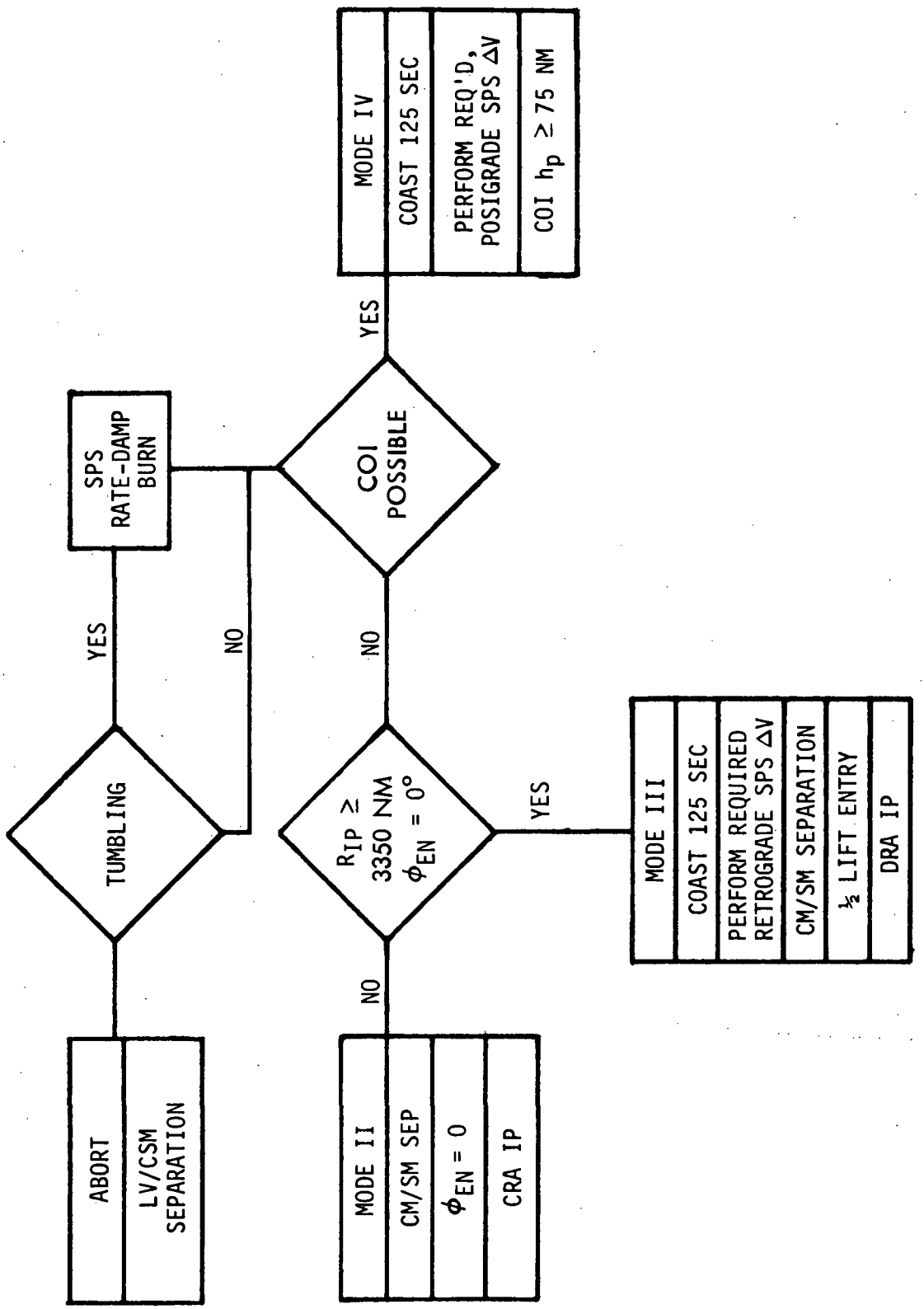

Figure 3-2. SM Abort Philosophy

3.7.3.3 Mode IV

From GET of 600 seconds to orbit insertion, the capability exists for contingency orbit insertion. The following sequence of events is planned.

1. RCS +$\dot{X}$ TRANSLATION and possibly an SPS rate damping burn

2. Maneuver to the posigrade thrusting attitude and performance of required ΔV to achieve an initial orbit with a minimum perigee altitude of 75 nm.

3. A burn at apogee to obtain the desired orbit

An example of a Mode IV abort is given in Table 3-19.

3.7.4 Run Schedule Synopsis

The SM abort study phase will evaluate the abort capability from various points throughout the launch phase from LES jettison to orbit insertion. Various failure conditions during the abort will be investigated; failures will include loss of internal attitude reference, loss of voice communications, and CMC failure. The run schedule synopsis is presented in Table 3-20.

Table 3-19. Mode IV SPS Abort

Step	Event Time (sec)	Crew Procedure
		CMC - on (required) ISS - on (required) SCS - on (required) CMC ATT - IMU LOGIC BUS 3 - on (up) .05 g - OFF BMAG MODE - RATE 1 FDAI SCALE - 50/15 FDAI SEL - 1/2 RATE - HIGH ATT DBD - MAX LIMIT CYCLE - OFF DIRECT RCS - on (up) RCS CHANNELS (4) - A SC CONT - SCS ΔV THRUST - OFF SPS THRUST - NORMAL LV/SPS IND - SII/SIVB RCS CMD - OFF SCS TVC - AUTO TVC GMBL DR - AUTO SPS GMBL MOT (4) - on EMS ΔV IND - 3000.0 fps GDC aligned to IMU MAN ATT - RATE CMD RSI align to 0 deg EMS FUNC - ΔV EMS MODE - STDBY RCS TRNFR - SM Event timer - 00:03 SPS GMBL ind settings $\delta\theta t$ = _____ deg. δ t = _____ deg.
	00:03	Computer run initiated following booster separation.

Table 3-19. Mode IV SPS Abort (Cont)

Step	Event Time (sec)	Crew Procedure
1		Event time reset and counting up EVNT TMR RSET - RESET EVNT TMR STRT - START DIRECT ULLAGE - push
	00:03.8	RCS CMD - on
2	00:04	LV/SPS IND SII/SIVB - GPI
3		THC - center and +X translation DIRECT ULL rel
4		Monitor spacecraft rates
5		Key V37E Key 47 ENTR (30 sec for display to appear)
6	00:24	Terminate +X translation Key V16 N50 E SPLASH ERROR _____._ n.mi. HP _____._ n.mi. TFF __B__ min - sec
7		Maneuver to insertion attitude R 180 deg P 350 deg Y 0 deg
8		Obtain insertion update

Table 3-19. Mode IV SPS Abort (Cont)

Step	Event Time (sec)	Crew Procedure
9		BMAG MODE (3) - ATT 1 RATE 2
10		Verify SPS GMBL ind (2) = SPS GMBL tw (2) settings $\delta_{\theta t}$ = _____ deg $\delta_{\psi t}$ = _____ deg
11		EMS MODE - AUTO
12	120	Start Ullage
13		ΔV THRUST (2) - NORMAL
14	135	SPS THRUST - DIRECT ON
15		Terminate ullage - IGN +1 sec
16		ΔV ind = 1950 fps (HP $\geq$ 75 nm)
17	173	ΔV THRUST (2) - OFF
18		EMS MODE - STBY EMS ΔV ind 1884 fps SECO +40 sec Status from ground

Table 3-20. SM Abort Run Schedule Synopsis

Run No.	Mode	Description of Run	Delta-V Reqm't (FPS)	Source of Crew Information	Number of Runs
1	II	Min. t_{ff} High LV/CSM Rates	0	Ground	1
2	II	Max. G, High LV/CSM Rates	0	Ground	1
3	II	End of Mode II High LV/CSM Rates	0	Ground	1
4	III	Early Mode III Nominal LV/CSM Rates	~ 400	Ground	1
5	III	Early Mode III Nominal LV/CSM Rates	~ 400	CMC	1
6	III	Late Mode III Nominal LV/CSM Rates	~1500	Ground	1
7	III	Late Mode III Nominal LV/CSM Rates	~1500	CMC	1
8	IV	Mode II/IV Crossover Nominal L/V CSM Rates	~2000	Ground	1
9	IV	Mode II/IV Crossover Nominal LV/CSM Rates	~2000	CMC	1
10	IV	Mode II/IV Crossover High LV/CSM Rates	~2000	Ground	1
11	IV	Mode II/IV Crossover High LV/CSM Rates	~2000	CMC	1
12	IV	Mid Mode IV Nominal LV/CSM Rates	~1000	Ground	1

Table 3-20. SM Abort Run Schedule Synopsis (Cont)

Run No.	Mode	Description of Run	Delta-V Reqm't (FPS)	Source of Crew Information	Number of Runs
13	IV	Mid Mode IV Nominal LV/CSM Rates	~1000	CMC	1
14	IV	Late Mode IV Nominal LV/CSM Rates	~100	Ground	1
15	IV	Late Mode IV Nominal LV/CSM Rates	~100	CMC	1
16	IV	Late Mode IV High LV/CSM Rates	~100	Ground	1
17	IV	Late Mode IV High LV/CSM Rates	~100	CMC	1
					17 Runs Total

3.8 RCS DEORBIT

3.8.1 Study Objectives

Study objectives are as follows:

1. To establish a data base for mission planning and postflight analysis
2. To verify RCS deorbit procedure compatibility with the COLOSSUS program and the SC 103 Main Control & Display Panel configuration
3. To verify RCS propellant requirements and maneuver efficiencies associated with various procedures and failure modes and to obtain data to define the RCS propellant/mission redlines beyond which successful RCS deorbits cannot be achieved.

4. To evaluate the CMC program used during RCS deorbit

5. To verify guidance and control capability of performing an RCS deorbit by achieving a specified entry state vector

3.8.2 Study Scope

The RCS deorbit study phase will evaluate RCS deorbit capability for three spacecraft loadings with orbit conditions corresponding to the following:

1. Insertion orbit

2. Rendezvous orbit

3. Final orbit (following failure of SPS deorbit)

Service module RCS deorbit will be evaluated at these orbit conditions in both the CMC and SCS modes with four-quad and two-quad configurations. Three-quad, spin-stabilized retro will be studied from the rendezvous orbit, during which the ΔV requirement (170 fps) will probably make two quad operation impractical.

Hybrid RCS deorbits that combine four-quad tx translation with single- and dual-system CM RCS ΔV will be evaluated from the rendezvous and final orbits.

3.8.3 Run Description

Simulation runs will start approximately 15 minutes prior to apogee, with the IMU prealigned and the CMC in the external ΔV program (P30). The G&C system will be properly configured for either the nominal or failure runs. An RCS deorbit simulation run is summarized in Table 3-21. A hybrid deorbit is given which utilizes both SM and CM RCS thrusting.

Table 3-21. Hybrid RCS Deorbit

Step	Crew Procedure
1	Configure MDP Key → Key Release Initialized in P30 V06 N33 _____. hr _____. min ___.__ sec

Table 3-21. Hybrid RCS Deorbit (Cont)

Step	Crew Procedure
2	Key V48E (load DAP) FL V04 N 46E 11103 01111 ACCEPT-PRO REJECT V24E - Load Desired Data
3	FL V06 N 47E + 00000 CSM Weight + 00000 LM Weight
4	FL V06 N 48E + _____ Gimbal Trim Pitch + _____ Gimbal Trim Yaw
5	FL V06 N 33 (GETI) + 00259. hr + 00055. min + 020.00 sec
6	FL V06 N 81 (Delta V Components) - 0090.2 fps along X + 00000 fps along Y - 0011.8 fps along Z
7	FL V16 N 45 _____ Marks + 06B 30 (SET THE DET) _____ Middle Gimbal Angle FL V37 Key 41E (Initiate P41)
8	FL V50 N 18 (Preferred Attitude) + 352.27 Roll + 228.19 Pitch + 000.74 Yaw
9	Perform Manual Attitude Maneuver To Roll = 0, Pitch = 228, Yaw = 0

Table 3-21. Hybrid RCS Deorbit (Cont)

Step	Crew Procedure
10	Key V16 N81E (Delta V Components) -00902 +00000 -0011.8
11	Key V48E (load DAP)
12	FL V04 N46 11103 01111
13	FL V06 N47 +25292 CM Weight 00000 LM Weight
14	FL V06 N47 _____ P trim _____ Y trim
15	Key V46E (activate DAP)
16	S/C Control to CMC CMC AUTO BMAGS ATT 1 Rate 2
17	Key Proceed (Auto attitude trim)
18	EMS Function - V set: set V 41.0 fps EMS Function V: ATT D.B. min: Rate-Low: RHC, THC armed: LIM cycle off: EMS Mode - AUTO
19	FL V50 N18 (preferred attitude) +00000 R +228.19 P +00000 Y
20	GETI minus 35 sec DSKY blanks

Table 3-21. Hybrid RCS Deorbit (Cont)

Step	Crew Procedure
21	GETI minus 30 sec FL V06 N85 +0 0 9 1 0 VGX +0 0 0 0 0 VGY +0 0 0 0 0 VGZ
22	When DET 00 B00 start SM RCS ΔV - Monitor EMS ΔV
23	V82 E FL V16 N44 + _ _ _ _ _ Apogee + _ _ _ _ _ Perigee + _ _ _ _ _ TFF
24	Burn complete; EMS ΔV = 0 HP = _ _ _ _ _
25	SC control - SCS; CM/SM Sep; RCS transfer - CM; Rate high
26	Manual maneuver to CM retro Desired ball R +0 0 0. 0 0 DEG P +3 3 5. 0 0 DEG Y +0 0 0 . 0 0 DEG
27	One minute after completion of SM ΔV, begin CM ΔV MAN ATT PITCH, ACCEL CMD
28	Begin CM ΔV RHC 1 - Initialize continuous neg pitch RHC 2 - Pulse plus pitch to maintain attitude in pitch axis Monitor Hp on DSKY
29	Discontinue CM ΔV when Hp = 37.0 N. M End of run

3.8.4 Run Schedule Synopsis

The RCS deorbit study, consisting of nominal and failure modes of SM RCS deorbit and hybrid deorbit, will be conducted at three points of the planned mission. The selection of initial conditions, grouping of runs, and related rationale are summarized in Table 3-22.

Table 3-22. RCS Deorbit Conditions and Rationale

Orbit	Type of Run	Rationale
Insertion	SM RCS deorbit, nominal and failure modes	Duty cycles for maximum SC loading
Rendezvous	SM RCS, hybrid nominal modes	Maximum retro velocity required, intermediate SC loading
Final	SM RCS, hybrid nominal and failure modes	Duty cycles for minimum SC loading; minimum retro velocity required

The run schedule synopsis for SM RCS deorbit and hybrid deorbit are presented in Tables 3-23 and 3-24.

3.9 MCC/ME 103 JOINT SIMULATION

The study objectives, scope, run definition, and run schedule are determined by the Flight Control Division of MSC. It is NR's understanding that the following maneuvers will be accomplished during the MCC/ME 103 joint simulation:

1. SPS Burn 1
2. SPS Burn's 1 and 2
3. SPS Burn 4
4. LM Rescue - CSM Active Rendezvous
5. SPS Burns 5 and 6
6. G&N SPS Deorbit

Table 3-23. SM RCS Deorbit Run Schedule

Run Type	Orbit ha/hp	Failure	Technique	Mode	Retro ΔV Required	End of Run	No. of Runs	Duration (min)
1	103/103	None	4-quad +x	CMC	120	25K	1	20
2		None	4-quad +x	SCS	120	End retro	1	20
3		Quad	2-quad +x	CMC	120	End retro	1	20
4		Quad	2-quad +x	SCS	120	End retro	1	20
5	130/130	None	4-quad +x	CMC	170	25K	1	50
6		None	4-quad +x	SCS	170	End retro	1	50
7	210/95	None	4-quad +x	CMC	108	25K	1	65
8		None	4-quad +x	SCS	108	End retro	1	65
9		Quad	2-quad +x	CMC	108	End retro	1	20
10		Quad	2-quad +x	SCS	108	End retro	1	20
11	130/130	Quad	3-quad +x (spin stabilized)	Direct	170	End retro	4	50
12	2/0/95	None	4-quad-x	CMC	108	End retro	1	
							15 runs Total	400 min. Total

Table 3-24. Hybrid RCS Deorbit Run Schedule Synopsis

Run Type	Orbit	Failure	Technique	Retro ΔV SM/CM	End of Run	No. of Runs	Duration (min)
1	130/130	None	Pitch	125/45	25 k	2	50
2	130/130	One CM RCS System	Pitch	125/45	End retro	2	20
3	210/95	None	Pitch	63/45	25 k	2	65
4	210/95	One CM RCS System	Pitch	63/45	End retro	2	20
5	130/130	DSKY	Pitch	125/45	End retro	2	50
						10	205

7. SCS SPS Deorbit

8. G&N SM RCS Deorbit

9. SCS SM RCS Deorbit

10. G&N Hybrid Deorbit

The initial conditions required and a daily run schedule covering a three day period will be provided by MSC at a later date.

The resultant data will be analyzed by NR personnel and reported on along with the results of the other study phases.

3.10 FINAL SOFTWARE VERIFICATION TESTS (FSVT)

The final software verification tests objective is to verify as many of the CMC software programs for flight as is practical. To achieve this end, the most recent trajectory data, usually the Operational Trajectory, AOH procedures, CMC Colossus Tape Revision, and flight plan information will be utilized in these tests. The exact procedures, and detailed runs schedule will be mutually determined by NR and MSC at a later date.

4.0 DATA OUTPUT REQUIREMENTS

The data output requirements for this simulation are divided into three categories: analog, environment, and downlink.

4.1 ANALOG

The analog data requirements consist of parameters that require continuous recording for transient response analysis as well as real-time monitoring. This list is composed of parameters computed on the analog computers and a few select parameters that are computed on the RTSS and D/A-converted. These analog requirements are defined in Table 4-1.

4.2 ENVIRONMENT

The environment data requirements consist primarily of trajectory-type parameters that are computed on the RTSS and discretes that represent the configuration of the CM panel switches. The environment recording requirements are defined in Table 4-2.

4.3 DOWNLINK

The downlink data consist of CMC stored information. Five downlink data lists exist: (1) powered, (2) coast and align, (3) rendezvous and pre-thrust, (4) entry and update, and (5) program 22 (landmark tracking). Each list has a 100-word capability. The downlink requirements for this study are defined in Table 4-3 for each of the five lists.

Table 4-1. Analog Recording Requirements

Channel	Term
RECORDER 1	
1	SPS pitch gimbal command
2	SPS pitch gimbal angle pickoff
3	SPS pitch gimbal rate
4	SPS yaw gimbal command
5	SPS yaw gimbal angle pickoff
6	SPS yaw gimbal rate
7	SPS thrust
8	LM on - LM off
RECORDER 2	
1	Roll rotational stick command
2	Roll RCS moment, SM/CM
3	Roll body acceleration
4	Roll body rate
5	Roll BMAG
6	IMU outer gimbal angle (roll)
7	Altitude
8	Dynamic pressure
RECORDER 3	
1	Pitch rotational stick command
2	Pitch RCS moment, SM/CM
3	Pitch body acceleration
4	Pitch body rate
5	Pitch BMAG
6	IMU inner gimbal angle (pitch)
7	α
RECORDER 4	
1	Yaw rotational stick command
2	Yaw RCS moment, SM/CM
3	Yaw body acceleration
4	Yaw body rate
5	Yaw BMAG

Table 4-1. Analog Recording Requirements (Cont)

Channel	Term
RECORDER 4 (Cont)	
6	IMU middle gimbal angle (yaw)
7	β
8	GA
RECORDER 5	
1	Displayed roll rate
2	Displayed roll attitude error
3	Displayed pitch rate
4	Displayed pitch attitude error
5	Displayed yaw rate
6	Displayed yaw attitude error
7	Scale rate discrete, 50/10
8	Scale rate discrete, 5
RECORDER 8	
1	Quad A/-roll SM/CM RCS propellant
2	Quad B/+roll
3	Quad C/pitch
4	Quad D/yaw
5	/system A
6	/system B
7	SM total/CM total
8	
RECORDER 9	
1	A4 - A2/ SM/CM RCS engines
2	C4 - C2/
3	B4 - B2/F9 - F12
4	D4 - D2/F11 - F10
5	C3 - A3/F1 - F2
6	A1 - C1/F3 - F4
7	B1 - D1/F5 - F8
8	D3 - B3/F7 - F6

Table 4-2. Environment Recording Requirements

Symbol	Definition	Units
ALTITUDE GREATER THAN 400,000 FEET		
T	Time from launch	sec
H	Geocentric altitude	ft
THTL	Geocentric latitude	deg
PSIL	Geocentric longitude	deg
X	Spacecraft position along X inertial axis	ft
Y	Spacecraft position along Y inertial axis	ft
Z	Spacecraft position along Z inertial axis	ft
XDI	Spacecraft velocity along X inertial axis	ft/sec
YDI	Spacecraft velocity along Y inertial axis	ft/sec
ZDI	Spacecraft velocity along Z inertial axis	ft/sec
V_I	Velocity relative to inertial axis	ft/sec
THTI	Inertial flight path angle	deg
PSIH	Inertial heading angle	deg
RG	Range measured from pad/target	nm
PHI	Local geocentric Euler angle	deg
THT	Local geocentric Euler angle	deg
PSI	Local geocentric Euler angle	deg
HD	Time rate of change of H	ft/sec
VG	Local geocentric velocity	ft/sec
GMA	Local geocentric flight path angle	deg
σ_{EF}	Local geocentric heading angle	deg
Alpha	Angle of attack	deg
Beta	Side slip angle	deg
GACCL	G's sensed along X body	g's
MASS	Total mass	slugs
V_{cx}	Characteristic velocity X reference axis	ft/sec
V_{cy}	Characteristic velocity Y reference axis	ft/sec
V_{cz}	Characteristic velocity Z reference axis	ft/sec
η_{man}	Maneuver efficiency	ND
F_X	Force sensed along X body axis	lb
F_Y	Force sensed along Y body axis	lb
F_Z	Force sensed along Z body axis	lb
RAD	Position along X_G axis from earth center	ft
AIG	IMU inner gimbal angle	deg
AMG	IMU middle gimbal angle	deg
AOG	IMU outer gimbal angle	deg
APX	Acceleration along X SM	ft/sec^2

Table 4-2. Environment Recording Requirements (Cont)

Symbol	Definition	Units
	ALTITUDE GREATER THAN 400,000 FEET (Cont)	
APY	Acceleration along Y SM	ft/sec^2
APZ	Acceleration along Z SM	ft/sec^2
THLGD	Geodetic latitude	deg
ϵ_θ	Pitch axis pointing errors	deg
ϵ_ψ	Yaw axis pointing errors	deg
T_{orb}	Orbital period	min
i	Orbital inclination angle	deg
e	Orbital eccentricity	ND
l	Angular momentum	ft^2/sec
XPAS	LM inertial X position relative to CSM	ft
YPAS	LM inertial Y position relative to CSM	ft
ZPAS	LM inertial Z position relative to CSM	ft
XDPS	LM inertial X velocity relative to CSM	ft/sec
YDPS	LM inertial Y velocity relative to CSM	ft/sec
ZDPS	LM inertial Z velocity relative to CSM	ft/sec
XCE	Difference between CMC and environment CSM inertial X position	ft
YCE	Difference between CMC and environment CSM inertial Y position	ft
ZCE	Difference between CMC and environment CSM inertial Z position	ft
XCDE	Difference between CMC and environment CSM inertial X velocity	ft/sec
YCDE	Difference between CMC and environment CSM inertial Y velocity	ft/sec
ZCDE	Difference between CMC and environment CSM inertial Z velocity	ft/sec
XLE	Difference between CMC and environment LM inertial X position	ft
YLE	Difference between CMC and environment LM inertial Y position	ft
ZLE	Difference between CMC and environment LM inertial Z position	ft
XLDE	Difference between CMC and environment LM inertial X velocity	ft/sec
YLDE	Difference between CMC and environment LM inertial Y velocity	ft/sec
ZLDE	Difference between CMC and environment LM inertial Z velocity	ft/sec

Table 4-2. Environmental Recording Requirements (Cont)

Symbol	Definition	Units
	ALTITUDE GREATER THAN 400,000 FEET (Cont)	
a	Semi-major axis	ft
p	Semi-latus rectum	ft
ϵ	Total energy	ft-lb
b	Semi-minor axis	ft
R_A	Apogee distance	ft
R_p	Perigee distance	ft
H_A	Apogee distance above earth surface	nm
H_p	Perigee distance above earth surface	nm
f	True anomaly	deg
E	Eccentric anomaly	deg
Ω	Longitude of ascending node	deg
C	Argument of latitude	deg
ω	Argument of perigee	deg
	*REFSMMAT (RTSS)	
AXI	Sensed acceleration along inertial X	ft/sec^2
AYI	Sensed acceleration along inertial Y	ft/sec^2
AZI	Sensed acceleration along inertial Z	ft/sec^2
RLOS	Range along the CSM to LM line-of-sight	ft
VLOS	Velocity along the CSM to LM line-of-sight	ft/sec
XPLV	CSM position in X of LM centered local vertical coordinate system	ft
YPLV	CSM position in Y of LM centered local vertical coordinate system	ft
ZPLV	CSM position in Z of LM centered local vertical coordinate system	ft
	*ALTITUDE LESS THAN 400,000 FEET	
QBAR	Dynamic pressure	lb/ft^2
MN	Mach number	ND
ALPHAT	Total angle of attack	deg
PHIA	Aerodynamic roll angle	deg
L/D	Aerodynamic lift-to-drag ratio	ND
V_A	Airspeed	ft/sec
U_l	Airspeed along SC X axis	ft/sec
V_l	Airspeed along SC Y axis	ft/sec
W_l	Airspeed along SC Z axis	ft/sec
G	Total g's	g's

*These parameters are recorded in addition to those listed under ALTITUDE GREATER THAN 400,000 FEET.

Table 4-2. Environmental Recording Requirements (Cont)

Switch Name	Switch Open (False or 0)	Switch Closed (True or 1)
DISCRETES		
FDAI SCALE		50/10
	1	5
FDAI SELECT		1
	1/2	2
FDAI SOURCE		GDC
	ATT SET	CMC
MAN ATT ROLL		MIN IMP
	ACCEL COMD	RATE
MAN ATT PITCH		MIN IMP
	ACCEL COMD	RATE
MAN ATT YAW		MIN IMP
	ACCEL COMD	RATE
ROTATION CONT POWER -NORMAL 1		AC
	OFF	AC/DC
ROTATION CONT POWER -NORMAL 2		AC
	OFF	AC/DC
ROT CONTROL POWER -DIRECT 1		MNA
	OFF	MNA/MNB
ROT CONT POWER -DIRECT 2		MNB
	OFF	MNA/MNB
BMAG MODE-ROLL		RATE 2
	ATT 1/RATE 2	RATE 1
BMAG MODE - PITCH		RATE 2
	ATT 1/RATE 2	RATE 1
BMAG MODE - YAW		RATE 2
	ATT 1/RATE 2	RATE 1
CMC MODE		AUTO
	HOLD	FREE
SCS TVC PITCH		AUTO
	RATE COMD	ACCEL COMD
SCS TVC YAW		AUTO
	RATE COMD	ACCEL COMD
TVC GIMBAL DRIVE - PITCH		1
	AUTO	2
TVC GIMBAL DRIVE - YAW		1
	AUTO	2
SCS ELEC POWER		GDC/ECA
	OFF	ECA

Table 4-2. Environmental Recording Requirements (Cont)

Switch Name	Switch Open (False or 0)	Switch Closed (True or 1)
DISCRETES		
SCS TVC SERVO PWR. 1	OFF	AC1/MNA AC2/MNA
SCS TVC SERVO PWR 2	OFF	AC1/MNA AC2/MNB
TELESCOPE TRUNNION	0°	SLAVE TO SXT 25°
SPEED	MED	HI LO
AUTO RCS SELECT A_1	OFF	MNA MNB
C_1	OFF	MNA MNB
A_2	OFF	MNA MNB
C_2	OFF	MNA MNB
B_1	OFF	MNA MNB
D_1	OFF	MNA MNB
B_2	OFF	MNA MNB
D_2	OFF	MNA MNB
A_3	OFF	MNA MNB
C_3	OFF	MNA MNB
A_4	OFF	MNA MNB
C_4	OFF	MNA MNB
B_3	OFF	MNA MNB
D_3	OFF	MNA MNB
B_4	OFF	MNA MNB

Table 4-2. Environmental Recording Requirements (Cont)

Switch Name	Switch Open (False or 0)	Switch Closed (True or 1)
DISCRETES		
AUTO RCS SELECT D_4	OFF	MNA
	OFF	MNB
LIMIT CYCLE	ON	OFF
ATTITUDE DEADBAND	MIN	MAX
RATE	LOW	HIGH
TRANS CONT POWER	OFF	ON
S/C CONTROL	SCS	CMC
SPS THRUST DIRECT	NORMAL	ON
DIRECT ULLAGE	OFF	ON
THRUST ON	OFF	ON
ΔV THRUST A	OFF	NORMAL
ΔV THRUST B	OFF	NORMAL
GDC ALIGN	OFF	ON
SPS GIMBAL MOTORS - PITCH 1	OFF	ON
SPS GIMBAL MOTORS - PITCH 2	OFF	ON
SPS GIMBAL MOTORS - YAW 1	OFF	ON
SPS GIMBAL MOTORS - YAW 2	OFF	ON
ΔV CG	LM/CSM	CSM
IMU CAGE	OFF	ON
ENTRY EMS ROLL	OFF	ON
ENTRY 0.05G	ON	OFF
LV/SPS IND	α	PC
LV/SPS IND	GPI	S II/SIVB
BMAG POWER 1	OFF	ON
BMAG POWER 2	OFF	ON
ATT SET	IMU	GDC
FDAI POWER	OFF	1
	2	2
		BOTH
OPTICS ZERO	OFF	ZERO
OPTICS COUPLING	DIRECT	RESOLVE
OPTICS MODE	CMC	MAN
UP TELEMETRY - MDC	BLOCK	ACCEPT
UP TELEMETRY - LEB	BLOCK	ACCEPT

Table 4-2. Environmental Recording Requirements (Cont)

Switch Name	Switch Open (False or 0)	Switch Closed (True or 1)
DISCRETES		
SM RCS PRI PROP A	OFF	ON
B	OFF	ON
C	OFF	ON
D	OFF	ON
SM RCS SEC PROP A	OFF	ON
B	OFF	ON
C	OFF	ON
D	OFF	ON
SM RCS H E 1 A	OFF	ON
B	OFF	ON
C	OFF	ON
D	OFF	ON
SM RCS HE 2 A	OFF	ON
B	OFF	ON
C	OFF	ON
D	OFF	ON
CM RCS PROP 1	OFF	ON
CM RCS PROP 2	OFF	ON
CM SM SEP	OFF	ON
RCS COMD	OFF	ON
RCS TRANSFER	SM	CM

Table 4-3. Downlink Data Requirements

Word Number	First Register	Second Register
	POWERED LIST	
1	I.D. (77774_8)	Synch bits (77340_8)
2	CSM state vector (R_X)	CSM state vector (R_X)
3	CSM state vector (R_Y)	CSM state vector (R_Y)
4	CSM state vector (R_Z)	CSM state vector (R_Z)
5	CSM state vector (V_X)	CSM state vector (V_X)
6	CSM state vector (V_Y)	CSM state vector (V_Y)
7	CSM state vector (V_Z)	CSM state vector (V_Z)
8	CSM state vector time	CSM state vector time
9	Actual X CDU angle	Actual Y CDU angle
10	Actual Z CDU angle	
11	ADOTS roll or OGARATE	ADOTS roll or OGARATE
12	ADOTS pitch or OMEGA B pitch	ADOTS pitch or OMEGA B pitch
13	ADOTS yaw or OMEGA B yaw	ADOTS yaw or OMEGA B yaw
14	X attitude error	Y attitude error
15	Z attitude error	RCS flags
16	THETADX	THETADY
17	THETADZ	
18	TIG	TIG
19	T_F Lambert	T_F Lambert
20	RTARGX	RTARGX
21	RTARGY	RTARGY
22	RTARGZ	RTARGZ
23	TGO	TGO

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
	POWERED LIST	
24	PIPTIME1	PIPTIME1
25	DELVX	DELVX
26	DELVY	DELVY
27	DELVZ	DELVZ
28	PACTOFF	YACTOFF
29	PCMD	YCMD
30	CSTEER	
31		
32		
33		
34	REFSMMAT (R_1C_1)	REFSMMAT (R_1C_1)
35	REFSMMAT (R_1C_2)	REFSMMAT (R_1C_2)
36	REFSMMAT (R_1C_3)	REFSMMAT (R_1C_3)
37	REFSMMAT (R_2C_1)	REFSMMAT (R_2C_1)
38	REFSMMAT (R_2C_2)	REFSMMAT (R_2C_2)
39	REFSMMAT (R_2C_3)	REFSMMAT (R_2C_3)
40	Flagword 0	Flagword 1
41	Flagword 2	Flagword 3
42	Flagword 4	Flagword 5
43	Flagword 6	Flagword 7
44	Flagword 8	Flagword 9
45	DSPTAB+0	DSPTAB+1
46	DSPTAB+2	DSPTAB+3
47	DSPTAB+4	DSPTAB+5
48	DSPTAB+6	DSPTAB+7

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
	POWERED LIST	
49	DSPTAB+8D	DSPTAB+9D
50	DSPTAB+10D	DSPTAB+11D
51	TIME 2	TIME 1
52	LM state vector (R_X)	LM state vector (R_X)
53	LM state vector (R_Y)	LM state vector (R_Y)
54	LM state vector (R_Z)	LM state vector (R_Z)
55	LM state vector (V_X)	LM state vector (V_X)
56	LM state vector (V_Y)	LM state vector (V_Y)
57	LM state vector (V_Z)	LM state vector (V_Z)
58	LM state vector time	LM state vector time
59	Actual X CDU angle	Actual Y CDU angle
60	Actual Z CDU angle	Optics CDU trunnion angle
61	ADOTS roll or OGARATE	ADOTS roll or OGARATE
62	ADOTS pitch or OMEGA B pitch	ADOTS pitch or OMEGA B pitch
63	ADOTS yaw or OMEGA B yaw	ADOTS yaw or OMEGA B yaw
64	X attitude error	Y attitude error
65	Z attitude error	RCS flags
66	THETADX	THETADY
67	THETADZ	
68		
69		
70		
71		

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
POWERED LIST		
72		PIPAX
73	PIPAY	PIPAZ
74	Elevation angle	Elevation angle
75	Central angle	Central angle
76	Offset point	Offset point
77	Flagword 10	Flagword 11
78	TEVENT	TEVENT
79	PCMD	YCMD
80		
81	LM MASS	CM MASS
82	DAPDATR1	DAPDATR2
83	ERROR X	ERROR Y
84	ERROR Z	
85	WBODY (roll) or OMEGA C (roll)	WBODY (roll) or OMEGA C (roll)
86	WBODY (pitch) or OMEGA C (pitch)	WBODY (pitch) or OMEGA C (pitch)
87	WBODY (yaw) or OMEGA C (yaw)	WBODY (yaw) or OMEGA C (yaw)
88		Desired FINAL CDUX
89	Desired FINAL CDUY	Desired FINAL CDUZ
90		
91	Channel 11	Channel 12
92	Channel 13	Channel 14
93	Channel 30	Channel 31
94	Channel 32	Channel 33

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
	POWERED LIST	
95	VGTIGX	VGTIGX
96	VGTIGY	VGTIGY
97	VGTIGZ	VGTIGZ
98		
99		
100		
	COAST AND ALIGN LIST	
1	I. D. (77777_8)	Synch bits (77340_8)
2	CSM state vector (R_X)	CSM state vector (R_X)
3	CSM state vector (R_Y)	CSM state vector (R_Y)
4	CSM state vector (R_Z)	CSM state vector (R_Z)
5	CSM state vector (V_X)	CSM state vector (V_X)
6	CSM state vector (V_Y)	CSM state vector (V_Y)
7	CSM state vector (V_Z)	CSM state vector (V_Z)
8	CSM state vector time	CSM state vector time
9	Actual X CDU angle	Actual Y CDU angle
10	Actual Z CDU angle	Optics CDU trunnion angle
11		
12		
13		
14		
15		
16	THETADX	THETADY
17	THETADZ	

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
	COAST AND ALIGN LIST	
18		
19	STARID1	STARID2
20	MARKTIME1	MARKTIME1
21	Y CDU angle	Optics shaft angle } for last
22	Z CDU angle	Optics trunnion angle } MARKTIME1
23	X CDU angle	
24	MARKTIME2	MARKTIME2
25	Y CDU angle	Optics shaft angle } for last
26	Z CDU angle	Optics trunnion angle } MARKTIME2
27	X CDU angle	
28		
29		
30		
31		
32		
33		
34	REFSMMAT (R_1C_1)	REFSMMAT (R_1C_1)
35	REFSMMAT (R_1C_2)	REFSMMAT (R_1C_2)
36	REFSMMAT (R_1C_3)	REFSMMAT (R_1C_3)
37	REFSMMAT (R_2C_1)	REFSMMAT (R_2C_1)
38	REFSMMAT (R_2C_2)	REFSMMAT (R_2C_2)
39	REFSMMAT (R_2C_3)	REFSMMAT (R_2C_3)
40	Flagword 0	Flagword 1
41	Flagword 2	Flagword 3
42	Flagword 4	Flagword 5

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
	COAST AND ALIGN LIST	
43	Flagword 6	Flagword 7
44	Flagword 8	Flagword 9
45	DSPTAB+0	DSPTAB+1
46	DSPTAB+2	DSPTAB+3
47	DSPTAB+4	DSPTAB+5
48	DSPTAB+6	DSPTAB+7
49	DSPTAB+8D	DSPTAB+9D
50	DSPTAB+10D	DSPTAB+11D
51		
52		
53		
54		
55		
56		
57		
58		
59	Actual X CDU angle	Actual Y CDU angle
60	Actual Z CDU angle	Optics CDU trunnion angle
61		
62		
63		
64		
65		RCS flags
66	THETADX	THETADY
67	THETADZ	

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
COAST AND ALIGN LIST		
68		
69		
70		
71		
72	Optics shaft	
73		
74		
75		
76		
77		
78		
79		
80		
81		
82		
83		
84		
85		
86		
87		
88		
89		
90	IMODES 30	IMODES 33
91	Channel 11	Channel 12
92	Channel 13	Channel 14

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
	COAST AND ALIGN LIST	
93	Channel 30	Channel 31
94	Channel 32	Channel 33
95	DSPTAB+0	DSPTAB+1
96	DSPTAB+2	DSPTAB+3
97	DSPTAB+4	DSPTAB+5
98	DSPTAB+6	DSPTAB+7
99	DSPTAB+8D	DSPTAB+9D
100	DSPTAB+10D	DSPTAB+11D
	RENDEZVOUS AND PRETHRUST LIST	
1	I. D. (77775_8)	Synch bits (77340_8)
2	CSM state vector (R_X)	CSM state vector (R_X)
3	CSM state vector (R_Y)	CSM state vector (R_Y)
4	CSM state vector (R_Z)	CSM state vector (R_Z)
5	CSM state vector (V_X)	CSM state vector (V_X)
6	CSM state vector (V_Y)	CSM state vector (V_Y)
7	CSM state vector (V_Z)	CSM state vector (V_Z)
8	CSM state vector time	CSM state vector time
9	Actual X CDU angle	Actual Y CDU angle
10	Actual Z CDU angle	Optics CDU trunnion angle
11	ADOTS roll or OGARATE	ADOTS roll or OGARATE
12	ADOTS pitch or OMEGA B pitch	ADOTS pitch or OMEGA B pitch
13	ADOTS yaw or OMEGA B yaw	ADOTS yaw or OMEGA B yaw

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
RENDEZVOUS AND PRETHRUST LIST		
14	X attitude error	Y attitude error
15	Z attitude error	RCS flags
16	THETADX	THETADY
17	THETADZ	
18	TIG	TIG
19	T_F Lambert	T_F Lambert
20	RTARGX	RTARGX
21	RTARGY	RTARGY
22	RTARGZ	RTARGZ
23		
24	MARK TIME	MARK TIME
25	Y CDU angle	Optics shaft angle
26	Z CDU angle	Optics trunnion angle
27	X CDU angle	
28		OPTIC MARKS
29	TPI TIME	TPI TIME
30	ECSTEER	
31	DELVTPF (magnitude)	DELVTPF (magnitude)
32		
33		
34	TPF time	TPF time
35	DELVSLV X	DELVSLV X
36	DELVSLV Y	DELVSLV Y
37	DELVSLV Z	DELVSLV Z
38	Range	Range

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
	RENDEZVOUS AND PRETHRUST LIST	
39	Range rate	Range rate
40	Flagword 0	Flagword 1
41	Flagword 2	Flagword 3
42	Flagword 4	Flagword 5
43	Flagword 6	Flagword 7
44	Flagword 8	Flagword 9
45	DSPTAB+0	DSPTAB+1
46	DSPTAB+2	DSPTAB+3
47	DSPTAB+4	DSPTAB+5
48	DSPTAB+6	DSPTAB+7
49	DSPTAB+8D	DSPTAB+9D
50	DSPTAB+10D	DSPTAB+11D
51	TIME 2	TIME 1
52	LM state vector (R_X)	LM state vector (R_X)
53	LM state vector (R_Y)	LM state vector (R_Y)
54	LM state vector (R_Z)	LM state vector (R_Z)
55	LM state vector (V_X)	LM state vector (V_X)
56	LM state vector (V_Y)	LM state vector (V_Y)
57	LM state vector (V_Z)	LM state vector (V_Z)
58	LM state vector time	LM state vector time
59	Actual X CDU angle	Actual Y CDU angle
60	Actual Z CDU angle	Optics CDU trunnion angle
61	ADOTS roll or OGARATE	ADOTS roll or OGARATE
62	ADOTS pitch or OMEGA B pitch	ADOTS pitch or OMEGA B pitch

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
	RENDEZVOUS AND PRETHRUST LIST	
63	ADOTS yaw or OMEGA B yaw	ADOTS yaw or OMEGA B yaw
64	X attitude error	Y attitude error
65	Z attitude error	RCS flags
66	THETADX	THETADY
67	THETADZ	
68		
69		
70		
71		
72	Optics shaft	
73		
74	Elevation angle	Elevation angle
75	Central angle	Central angle
76	Offset point	Offset point
77	DELVEET3 X	DELVEET3 X
78	DELVEET3 Y	DELVEET3 Y
79	DELVEET3 Z	DELVEET3 Z
80		
81	LM MASS	CM MASS
82	DAPDATR1	DAPDATR2
83	ERROR X	ERROR Y
84	ERROR Z	
85	WBODY (roll) or OMEGA C (roll)	WBODY (roll) or OMEGA C (roll)

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
	RENDEZVOUS AND PRETHRUST LIST	
86	WBODY (pitch) or OMEGA C (pitch)	WBODY (pitch) or OMEGA C (pitch)
87	WBODY (yaw) or OMEGA C (yaw)	WBODY (yaw) or OMEGA C (yaw)
88		Desired FINAL CDU X
89	Desired FINAL CDU Y	Desired FINAL CDU Z
90		
91	Channel 11	Channel 12
92	Channel 13	Channel 14
93	Channel 30	Channel 31
94	Channel 32	Channel 33
95	RTHETA	RTHETA
96	GEODETIC LAT	GEODETIC LAT
97	LONG	LONG
98	V PRED	V PRED
99	GAMMA(EI)	GAMMA(EI)
100		
	ENTRY AND UPDATE LIST	
1	I. D. (77776_8)	Synch bits (77340_8)
2	CSM state vector (R_X)	CSM state vector (R_X)
3	CSM state vector (R_Y)	CSM state vector (R_Y)
4	CSM state vector (R_Z)	CSM state vector (R_Z)
5	CSM state vector (V_X)	CSM state vector (V_X)
6	CSM state vector (V_Y)	CSM state vector (V_Y)

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
	ENTRY AND UPDATE LIST	
7	CSM state vector (V_Z)	CSM state vector (V_Z)
8	CSM state vector time	CSM state vector time
9	Actual X CDU angle	Actual Y CDU angle
10	Actual Z CDU angle	Optics CDU trunnion angle
11	ADOTS roll or OGARATE	ADOTS roll or OGARATE
12	ADOTS pitch or OMEGA B pitch	ADOTS pitch or OMEGA B pitch
13	ADOTS yaw or OMEGA B yaw	ADOTS yaw or OMEGA B yaw
14	X attitude error	Y attitude error
15	Z attitude error	RCS flags
16	THETADX	THETADY
17	THETADZ	
18	ENTRY DAP MODE	PREL (roll rate)
19	QREL (pitch rate)	RREL (yaw rate)
20	L/D1	L/D1
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
ENTRY AND UPDATE LIST		
31		
32		
33	Roll error	Roll angle
34	LATANG	LATANG
35	RDOT	RDOT
36	THETAH	THETAH
37	GEODETIC LAT (SPLSH)	GEODETIC LAT (SPLSH)
38	LONG (SPLSH)	LONG (SPLSH)
39	ALPHA	BETA
40	Flagword 0	Flagword 1
41	Flagword 2	Flagword 3
42	Flagword 4	Flagword 5
43	Flagword 6	Flagword 7
44	Flagword 8	Flagword 9
45	DSPTAB+0	DSPTAB+1
46	DSPTAB+2	DSPTAB+3
47	DSPTAB+4	DSPTAB+5
48	DSPTAB+6	DSPTAB+7
49	DSPTAB+8D	DSPTAB+9D
50	DSPTAB+10D	DSPTAB+11D
51	TIME 2	TIME 1
52	PIPTIME1	PIPTIME1
53	DELVX	DELVX
54	DELVY	DELVY

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
ENTRY AND UPDATE LIST		
55	DELVZ	DELVZ
56	TTE (EMS)	TTE (EMS)
57	VIO	VIO
58	VPRED (EI)	VPRED (EI)
59	Actual X CDU angle	Actual Y CDU angle
60	Actual Z CDU angle	Optics CDU trunnion angle
61	ADOTS roll or OGARATE	ADOTS roll or OGARATE
62	ADOTS pitch or OMEGA B pitch	ADOTS pitch or OMEGA B pitch
63	ADOTS yaw or OMEGA B yaw	ADOTS yaw or OMEGA B yaw
64	X attitude error	Y attitude error
65	Z attitude error	RCS flags
66	ERROR X	ERROR Y
67	ERROR Z	THETADX
68	THETADY	THETADZ
69	ENTRY DAP MODE	PREL (roll rate)
70	QREL (pitch rate)	RREL (yaw rate)
71		
72		
73		
74		
75		
76		
77		

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
ENTRY AND UPDATE LIST		
78		
79		
80		
81	LM MASS	CM MASS
82	DAPDATR1	DAPDATR2
83	Roll angle	Roll command
84		
85	WBODY (roll) or OMEGA C (roll)	WBODY (roll) or OMEGA C (roll)
86	WBODY (pitch) or OMEGA C (pitch)	WBODY (pitch) or OMEGA C (pitch)
87	WBODY (yaw) or OMEGA C (yaw)	WBODY (yaw) or OMEGA C (yaw)
88		Desired FINAL CDU X
89	Desired FINAL CDU Y	Desired FINAL CDU Z
90		
91	Channel 11	Channel 12
92	Channel 13	Channel 14
93	Channel 30	Channel 31
94	Channel 32	Channel 33
95		
96		
97		
98		
99		
100	GAMMA (EI)	Range for initialization

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
	PROGRAM 22 LIST	
1	I.D. (77773_8)	Synch bits (77340_8)
2	CSM state vector (R_X)	CSM state vector (R_X)
3	CSM state vector (R_Y)	CSM state vector (R_Y)
4	CSM state vector (R_Z)	CSM state vector (R_Z)
5	CSM state vector (V_X)	CSM state vector (V_X)
6	CSM state vector (V_Y)	CSM state vector (V_Y)
7	CSM state vector (V_Z)	CSM state vector (V_Z)
8	CSM state vector time	CSM state vector time
9	Actual X CDU angle	Actual Y CDU angle
10	Actual Z CDU angle	Optics CDU trunnion angle
11		
12		
13		
14	X attitude error	Y attitude error
15	Z attitude error	
16		
17		
18	MARKTIME for first mark	MARKTIME for first mark
19	INNER GIMBAL ANGLE	SHAFT ANGLE
20	MIDDLE GIMBAL ANGLE	TRUNNION ANGLE
21	OUTER GIMBAL ANGLE	Most significant part of MARKTIME for second mark

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
PROGRAM 22 LIST		
22	Least significant part of MARKTIME for second mark	INNER GIMBAL ANGLE
23	SHAFT ANGLE	MIDDLE GIMBAL ANGLE
24	TRUNNION ANGLE	OUTER GIMBAL ANGLE
25	MARKTIME for third mark	MARKTIME for third mark
26	INNER GIMBAL ANGLE	SHAFT ANGLE
27	MIDDLE GIMBAL ANGLE	TRUNNION ANGLE
28	OUTER GIMBAL ANGLE	Most significant part of MARKTIME for fourth mark
29	Least significant part of MARKTIME for fourth mark	INNER GIMBAL ANGLE
30	SHAFT ANGLE	MIDDLE GIMBAL ANGLE
31	TRUNNION ANGLE	OUTER GIMBAL ANGLE
32	MARKTIME for fifth mark	MARKTIME for fifth mark
33	INNER GIMBAL ANGLE	SHAFT ANGLE
34	MIDDLE GIMBAL ANGLE	TRUNNION ANGLE
35	OUTER GIMBAL ANGLE	
36	LANDMARK	
37		
38		

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
PROGRAM 22 LIST		
39		
40	Flagword 0	Flagword 1
41	Flagword 2	Flagword 3
42	Flagword 4	Flagword 5
43	Flagword 6	Flagword 7
44	Flagword 8	Flagword 9
45	DSPTAB+0	DSPTAB+1
46	DSPTAB+2	DSPTAB+3
47	DSPTAB+4	DSPTAB+5
48	DSPTAB+6	DSPTAB+7
49	DSPTAB+8D	DSPTAB+9D
50	DSPTAB+10D	DSPTAB+11D
51	TIME 2	TIME 1
52	LANDMARK LATITUDE	LANDMARK LATITUDE
53	LANDMARK LONGITUDE	LANDMARK LONGITUDE
54	LANDMARK ALTITUDE	LANDMARK ALTITUDE
55		
56		
57		
58		
59	Actual X CDU angle	Actual Y CDU angle
60	Actual Z CDU angle	Optics CDU trunnion angle
61		

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
PROGRAM 22 LIST		
62		
63		
64		
65		
66		
67		
68		
69		
70		
71		
72	Optics shaft	
73		
74	No. of marks	
75		
76	Landing site vector X comp.	Landing site vector X comp.
77	Landing site vector Y comp.	Landing site vector Y comp.
78	Landing site vector Z comp.	Landing site vector Z comp.
79		
80		
81		
82		
83		
84		

Table 4-3. Downlink Data Requirements (Cont)

Word Number	First Register	Second Register
PROGRAM 22 LIST		
85		
86		
87		
88		
89		
90		
91	Channel 11	Channel 12
92	Channel 12	Channel 14
93	Channel 30	Channel 31
94	Channel 32	Channel 33
95		
96		
97		
98		
99		
100		

APPENDIX

REFERENCES

1. Mission Evaluation 101 - Study Analysis Report. SD 68-452 (24 September 1968)

2. Mission Requirement - 'D' Type Mission - LM Evaluation and Combined Operations. NASA MSC SPD 8-R-005 (8 April 1968, revised 1 July 1968)

3. Apollo Mission D (AS-503/CSM-103/LM-3) - Spacecraft Reference Trajectory Volume 1 - Nominal Trajectory. MSC Internal Note No. 68-FM-93 (30 April 1968)

4. Apollo Operations Handbook - Command and Service Modules - Volume 2 - Operational Procedures. SD 67-778, SM2A-03-SC103-(2) (1 August 1968)

5. CSM Rendezvous Procedures - D Mission Preliminary Copy. NASA MSC, (19 July 1968).