W70-10,054

MSC-01296 -70-2809570,

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## **MSC INTERNAL NOTE**

U70-10,054

MAR 3 2070

**JANUARY 7, 1970** 

## APOLLO MISSION TECHNIQUES MISSION H-2 AND SUBSEQUENT

# ABORT FROM LUNAR POWERED DESCENT AND SUBSEQUENT RENDEZVOUS

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TECHNIQUES DESCRIPTION FINAL ISSUE

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MSC-01296 11176-H427-R0-00

## MSC INTERNAL NOTE

## APOLLO MISSION TECHNIQUES MISSION H-2 AND SUBSEQUENT

### ABORT FROM LUNAR POWERED DESCENT AND SUBSEQUENT RENDEZVOUS

JANUARY 7, 1970

#### APOLLO SPACECRAFT PROGRAM OFFICE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION MANNED SPACECRAFT CENTER HOUSTON, TEXAS

und **M**1 Approved by

Howard W. Tindall, Jr., Chief Apollo Data Priority Coordination

#### FOREWORD

This Abort from Lunar Powered Descent and Subsequent Rendezvous Techniques Document is one of several documents describing the H-2 (Apollo 13) mission. The others are as follows:

• Launch Aborts

- Earth Parking Orbit and Translunar Injection
- Translunar Midcourse Corrections and Lunar Orbit Insertion
- Lunar Orbit Activities
- Lunar Descent
- Lunar Surface Activities
- Manual Ascent
- Powered Ascent
- Transearth Injection, Midcourse Corrections, and Entry
- Tracking Data Selection Controllers Procedures
- Contingency Procedures

These documents contain the officially approved guiddance and control sequence of events, the data flow, and real-time decision logic for the H-2 mission. The purpose of these documents is to ensure compatibility of all related MSC and supporting contractor activities.

For each mission phase, a Data Priority Working Group has been established under the direction of Chief, Apollo Data Priority Coordination, ASPO. These groups, which are comprised of representatives of MSC and support contractors

#### FOREWORD (Continued)

hold frequent meetings to coordinate their various associated activities and develop agreed upon mission techniques. TRW assists in the development of the techniques and documents them for ASPO. After formal review by ASPO, E&DD, FCOD, FOD, GAEC, MDC, MIT, NR, and TRW, a document such as this one is issued.

This is the final issue of the Abort from Lunar Powered Descent and Subsequent Rendezvous Techniques Document. The mission dependent data limits and trajectory parameter values given herein are applicable to the H-2 mission; the sequence of events, data flow, and decision logic are applicable to the H-2 and subsequent Apollo missions.

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## NOMENCLATURE

1. A. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.	
AGS	abort guidance system
APS	ascent propulsion system
ATT	attitude
AUTO	automatic
CDR	commander
CIRC	circularization burn
СМС	command module computer
CMP	command module pilot
CONT	control
CSM	command service module
CSI	coelliptic sequence initiation
CDH	concentric delta height
DAP	digital autopilot
DEDA	data entry and display assembly
DPS and	descent propulsion system
DOI	descent orbit insertion
DSKY	display and keyboard
g.e.t.	ground elapsed time
GDA	gimbal drive actuator
G&N	guidance and navigation
GNCS	CSM primary guidance navigation and control system
Н	altitude
Ĥ	altitude rate
HAM	height adjust maneuver

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### NOMENCLATURE (Continued)

- <sup>H</sup>PD predicted perilune altitude (measured above the landing site)
- HT height adjust
- IMU inertial measurement unit
- INS insertion
- LGC lunar module guidance computer
- LM lunar module
- LMP lunar module pilot
- LS landing site
- MCC-H Mission Control Center-Houston
- MCC-1, MCC-2 midcourse corrections 1 and 2
  - N number of apsidal crossing
  - PDI powered descent initiation
  - PFP powered flight processor
    - PH phasing
  - PGNCS (PGNS) LM primary guidance navigation and control system
    - RCS reaction control system
    - RDZ rendezvous
    - RR rendezvous radar
    - SPS service propulsion system
    - TEI transearth insertion
    - TIG time of ignition
    - TPI terminal phase initiation
    - TPF terminal phase final
    - T<sub>1</sub>, T<sub>2</sub> first and second lunar stay/no stay lift-off times
      - TM telemetry
      - VHF very high frequency (CSM radar)

## NOMENCLATURE (Continued)

VG	velocity to be gained
VGX	X component of VG
VI	velocity magnitude
VIT	variable insertion targeting
$\Delta \mathrm{H}$	difference in height of LM and CSM
$\Delta V$	delta velocity
ΔVX	X component of maneuver $\Delta V$
$\Delta$ VGX	X component of velocity to be trimmed
$\Delta$ VGZ	Z component of velocity to be trimmed
$\Delta W_p$	predicted wedge angle
P12	Powered Ascent Guidance Program
P20	Rendezvous Navigation Program
P30	External $\Delta V$ Program
P32	CSI Targeting Program
P33	CDH Targeting Program
P34	TPI Program
P40	DPS or SPS Thrust Program
P41	RCS Thrust Program
P42	APS Thrust Program
P47	Thrust Monitor Program
P52	IMU Realign Program
P63	Braking Phase Program
P64	Approach Phase Program
P65	Landing Phase (Auto) Program
P66	Landing Phase (Rate of Descent) Program

P67 Landing Phase (Manual) Program

## NOMENCLATURE (Continued)

- P70 DPS Abort Program
- P71 APS Abort Program
- P76 Target  $\Delta V$  Program
- R11 Abort Discretes Monitor Routine

R36 Rendezvous Out-of-Plane Display Routine

#### 1. INTRODUCTION

The guidance and navigation sequence of events, the flow of data, and the real-time decisions which must be made for aborts prior to or during the powered-descent and early lunar surface phases of the H-2 lunar landing mission (Apollo 13) are presented in this document. The recommended procedures are presented in flow charts (Section 4) which are preceded by a description of the techniques. These charts document the standard, approved procedures to be used in the event of a primary guidance, navigation, and control system (PGNCS) failure, a descent propulsion system (DPS) failure, or some other critical system failure.

Routine procedures are included in the flow charts, as required, to verify the continued operation of unfailed PGNCS or DPS during an abort so that the proper alternative action will be taken in the event of subsequent malfunction.

The abort procedures described herein begin at the command and service module (CSM) circularization burn  $(CIRC)^*$  and are categorized as follows:

- Powered descent initiation (PDI) no go aborts which are initiated at either one-half revolution after CSM CIRC or at the nominal PDI TIG + 12 minutes
- Powered descent or early lunar surface aborts initiated at any time during powered descent through the first lunar stay/no stay lift-off time (T<sub>1</sub>\*\*)
- Lunar surface abort at the second stay/no stay lift-off time (T2\*\*\*)

In contrast to previous missions, the CSM, rather than the LM, performs an early descent orbit insertion (DOI) burn, while the LM and CSM are still docked, in order to conserve LM propellants and to provide additional tracking data for descent orbit determination. After undocking and 1-1/2 revolutions before PDI, CSM CIRC places the CSM in a circular orbit, leaving the LM in the elliptical descent orbit.

 $<sup>{}^{**}</sup>T_1$  is the latest time on the lunar surface that the PGNCS abort program P71 can be used.

 $T_2$  is the first discrete lift-off time that utilizes the nominal PGNCS ascent program Pl2.

PDI no go aborts are planned abort maneuvers which simply initiate rendezvous sequences as discussed in Section 3.6. The PDI no-go rendezvous maneuver computation and execution are not included in the flow charts because they are basically the same as corresponding maneuvers following descent and early lunar surface aborts. Any descent or early lunar surface abort (through  $T_1$ ) and subsequent rendezvous will follow the procedures presented in this document. Procedures for lift-off from the lunar surface at  $T_2$  are presented in Reference 1. The subsequent rendezvous procedures are basically identical to those for lunar surface aborts initiated prior to  $T_1$ . Aborts from the lunar surface after  $T_2$  are executed at preferred lift-off times and so employ nominal ascent targeting and rendezvous techniques (References 2 and 3).

Timelines of the powered descent functions and corresponding lunar module (LM) abort capability are presented in Figure 1.

1 - 2



Figure 1. Powered Descent Timelines

#### 2. GENERAL DESCENT ABORTS DESCRIPTION

Control of aborts from the powered descent phase of the lunar landing mission will be accomplished by either the PGNCS or the LM abort guidance system (AGS).

Two PGNCS programs, Luminary Programs P70 and P71, are available for control of descent aborts. These programs are essentially executive logic routines which order the computations necessary to control the LM along an ascent trajectory targeted to orbit insertion. P70 is the DPS Abort Program designed to accomodate descent engine thrusting, and P71 is the Ascent Propulsion System (APS) Abort Program designed for ascent engine thrusting.

The AGS uses virtually the same computational procedures as PGNCS. However, there are no unique DPS or APS abort programs, and AGS does not exercise control over DPS throttle variations.

Proper phasing for the subsequent rendezvous following a descent abort is achieved by variable insertion targeting which is identical for both PGNCS and AGS controlled aborts. For the first PDI opportunity (PDI<sub>1</sub>), target apolune will vary from approximately 140 to 127 nautical miles between TIG and TIG + 6 minutes, and from approximately 150 to 30 nautical miles between TIG + 6 minutes and  $(T_1)$ . For the second PDI opportunity (PDI<sub>2</sub>), target apolune will vary from approximately 163 to 127 nautical miles \*\* between TIG and TIG + 9 minutes, and from 150 to 78 nautical miles between TIG + 9 minutes and  $T_1$ .

<sup>\*</sup>The  $T_1$  time for PDI<sub>1</sub> and PDI<sub>2</sub> is PDI + 15:00 (minutes:seconds).

<sup>\*\*</sup> The PDI<sub>2</sub> targeting in the LGC is uplinked after the decision to delay PDI has been made.

#### 3. DISCUSSION

The following paragraphs describe the techniques and rationale used in developing the sequence of events, the data flow, and the real-time decision logic for aborts from the lunar powered descent phase of the Apollo H-2 mission.

#### 3.1 GROUND RULES

The following ground rules were used in the development of all abort techniques and procedures presented in this report:

- a) The abort procedures should be as simple and straight forward as possible without compromising the success of the abort.
- b) It is acceptable to burn the DPS and the APS to propellant depletion.
- c) The DPS should be used in abort situations whenever possible, even if there is only a few seconds burn available, to aid in establishing a positive radial rate and to improve propellant margins.
- d) A "working" engine should not be shut down until a safe orbit is achieved.
- e) Short APS burns (less than 3 seconds) are to be avoided.

A highly desirable feature during an abort is uninterrupted communications with the ground so that MCC-H can continue to monitor and verify the state of the LM and its subsystems. Maintaining S-band communications requires that the high-gain antenna always view the earth.<sup>\*</sup> This implies that LM attitude changes and attitude rates must be compatible with antenna orientation capability and drive rates. To avoid blocking the S-band antenna, the crew will yaw the LM right, 30 degrees immediately after initiating a descent abort.

 $<sup>^*</sup>$ S-band communication can also be maintained with the onmi antennas if the 210-foot earth antenna coverage is available; this coverage is planned for the H-2 mission.

In performing aborts from lunar powered descent, the following major functions must be accomplished:

- a) Establish abort mode
- b) Monitor engine performance during abort
- c) Monitor G&N performance during abort
- d) Monitor engine cutoff conditions
- e) Stage DPS when necessary
- f) Perform tweak burn or null velocity to be gained (VGX) residual
- g) Complete rendezvous

The significant elements in these functions are described below.

#### 3.2 ABORT MODES

Aborts will proceed under the control of the PGNCS, if operating, otherwise under the control of the AGS. A manual guidance scheme is available as a back-up procedure in the event of a combined PGNCS and AGS failure. This scheme is presented in a separate Mission Techniques Document (Reference 4). Propulsion will be provided by the DPS, if operating, otherwise by the APS. When a decision to abort on DPS is made after the descent has been in progress for approximately 300 seconds, orbit insertion will require an APS burn after DPS propellant depletion.

#### 3.2.1 PGNCS Control

An abort situation in which the DPS and PGNCS are both operational implies that some other subsystem is at fault. For this case the recommended procedure is to push the ABORT button. This action provides a discrete signal to the lunar module guidance computer (LGC) and AGS. At DPS ignition the Abort Discretes Monitor Routine (R11) is activated. This routine detects the presence of the ABORT discrete and calls the DPS Abort Program (P70) for use by the LGC.

3-2

When the DPS is not operational, the procedure is to press the ABORT STAGE button. Pressing the ABORT STAGE button closes switch contacts that activate relays to:

- a) Dearm the descent engine
- b) Switch to ascent electrical power
- c) Signal the LGC and AGS that ABORT STAGE was selected
- d) Close the "auto start" circuit for the APS
- e) Pressurize the APS system
- f) Activate pyrotechnic devices to separate descent stage from ascent stage

The Abort Discretes Monitor routine (R11) detects the presence of the ABORT STAGE discrete and calls APS Abort Program P71 for use in the LGC.

The LM may be under the control of any one of the PGNCS landing programs (P63, P64, or P66) at the time either the ABORT or ABORT STAGE button is pushed. In P63 and P64, the nominal procedures call for LGC control of the LM attitude and DPS throttle. In P66, the crew controls LM attitude since the MODE CONT switch is in the ATT HOLD position. In any landing program, the crew may control both the DPS throttle and the LM attitude by placing the THR CONT switch in the MAN position and the MODE CONT switch in the ATT HOLD posi-

In order for the LM to respond to PGNCS Abort Program P70, the attitude MODE CONT switch must be set to the AUTO position, and either

<sup>&</sup>quot;Not nominally employed on Mission H-2.

In previous missions, the selection of manual throttle control caused an irreversible entry to program P67 which did not permit a subsequent return to automatic throttle control. To eliminate this situation, P67 was eliminated and manual throttle control was provided as a crew option in any landing program. Program P65 previously provided automatic attitude control and nulling of horizontal velocity during the final landing phase. P65, however, has been deleted and its capabilities have been made available in P66 when the MODE CONT is in the AUTO position.

the engine thrust control switch, THR CONT, must be in the AUTO position or the crew must manually advance the throttle to its maximum thrust position. A manual throttle advance is preferred over the thrust control switch action. These actions should follow the ABORT event as soon as possible.

Similarly, for proper LM response to PGNCS Abort Program P71, the attitude MODE CONT switch must be set to the AUTO position. Since the APS engine is not throttleable, the program will not respond to prior engine control constraints; therefore, switching to AUTO throttle is unnecessary. Again, the required action should follow the ABORT STAGE event as soon as possible.

#### 3.2.2 AGS Control

In the event of a PGNCS failure, aborts will be performed under AGS control. The readiness state for AGS was achieved prior to PDI. The AGS MODE CONT switch will be in the AUTO position. The commander (CDR) will place the LM under AGS control by setting the GUID CONT switch to AGS position. When this is done, the subsequent action depends on the operational status of the DPS. Assuming the DPS is operating satisfactorily, the CDR will manually advance the throttle to its maximum position to ensure commanded maximum thrust since AGS does not provide thrust control. The CDR will next press the ABORT button to enable engine off at target conditions. In the event the DPS is not operating properly or propellant depletion is imminent before cutoff conditions are achieved, the CDR will ensure APS ullage; then the CDR will press the ABORT STAGE button. The AGS will control the LM under APS thrusting until guided cutoff.

#### 3.3 MONITORING AFTER DESCENT ABORT

#### 3.3.1 Monitor Engine Performance

Onboard indications and ground monitoring, if available, will be used to establish the operational status of the DPS engine. Continued monitoring of engine performance during aborts will help to ensure achievement of target conditions for subsequent LM-active rendezvous.

3-4

For aborts initiated on DPS, thrust level, throttle response, and uniformity of burn are items that should be watched. If the DPS is operating in the throttleable region and an abort on DPS is commanded, the crew will manually advance the throttle to maximum; the thrust level should rise to the full thrust point. If this action does not produce the desired result, the subsequent step is to abort stage and continue on the APS.

Onboard instrumentation available for monitoring DPS engine performance are the thrust level gage, thrust to weight (T/W) gage and the DPS engine trim gimbal light. \* If the T/W is less than 1.6 g's and the thrust level gage indicates that the thrust level is less than 80 percent with the X-axis velocity to be gained (VGX) still greater than 30 feet per second, control is switched from the CDR throttle to the LMP throttle. If the thrust does not recover within 100 seconds of the first indication of low thrust and VGX is still greater than 30 feet per second, the LM is abort staged. If VGX becomes less than 30 feet per second, the DPS is shut down manually and the crew stands by for an RCS tweak burn. If only one of the gages indicates low thrust, a second cue is required to verify low thrust. If no second cue is present and MCC-H does not confirm the low thrust, no action is taken. Other DPS monitoring cues are the DPS engine trim gimbal light on, attitude errors indicating an offset of greater than 3 degrees, or an unexpected increase in RCS activity. If any one of these cues is present, the gimbal drive actuators (GDA's) are switched to the OFF position and insertion is continued.

3.3.2 Monitor Guidance and Control Performance

Physiological cues, onboard instrumentation, and ground monitoring, if available, will furnish the crew data for assessing the status of LM guidance and control. The primary indications are attitude rates greater than 5 degrees per second for the DPS and 10 degrees per second for the APS. Use of the AGS and PGNCS error needles provide another indication of a PGNCS failure. If these error needles indicate greater than a 5-degree error for DPS or a 10-degree error for APS, a second cue such

 $<sup>\</sup>overline{}^{*}$  A detailed discussion of DPS engine monitoring is contained in Reference 8.

as the horizon angle would be grounds for a switch to AGS. If no second cue is present and the error needles do not agree, the AGS has failed and switchover will be inhibited. Ground monitoring of descent aborts is based on the abort predictor plotboard display of predicted perilune altitude ( $H_{PD}$ ) versus predicted wedge angle ( $\Delta W_p$ )<sup>\*</sup>. If the PGNCS  $H_{PD}$ is less than 40,000 feet <sup>\*\*</sup> or  $\Delta W_p$  is greater than 1 degree, and if the AGS is performing better than PGNCS, MCC-H will advise a switch to AGS. Strip chart velocity and range rate residual displays, along with a comparison of the PGNCS predictor values with those for AGS and the PFP, are used to determine whether or not to switch from PGNCS to AGS.

#### 3.3.3 Monitor Engine Shutdown

When a DPS abort is initiated after TIG plus 300 seconds, DPS propellant depletion will nominally occur prior to guided cutoff. At DPS engine shutdown it is necessary to know the velocity to be gained (VG) for achieving the target condition, since the crew decision regarding subsequent action to stage the DPS is a function of VG. Two problem areas enter into the decision: first, an overburn possibility and second, a minimum APS burn-time constraint.

An analysis of the Luminary Program presented in Reference 5 indicates that, when the VG exceeds approximately 33 feet per second, the crew can abort stage and expect a proper guided cutoff of the APS engine. As VG decreases toward zero large overburns can occur if abort stage action is taken. Figure 2 shows overburn velocity as a function of VG at staging. The 2-second guidance cycle causes these conditions.

The predictor display propagates a given state vector through the remainder of powered ascent and computes predicted values of perilune altitude and wedge angle. This display can be driven by the powered flight processor (PFP) or PGNCS or AGS state vectors. The PFP is an RTCC processor that uses doppler observations from several tracking stations to obtain by triangulation the state vector change since the last set of observations. The processor uses Kalman filter equations to compute the state vector corrections at the time of a set of doppler observations. After the update, the state and weighting matrices are propagated to the next set of doppler observations and another state correction is computed.

<sup>&</sup>lt;sup>\*\*</sup>The Hpp less than 40,000 feet constraint is used to ensure that the actual Hpp never becomes less than 30,000 feet.



Figure 2. Luminary Control of APS Burns at Staging

For short APS burns, the propellant will freeze in the engine injector. A considerable delay is then required before another burn may be made. Although it is not anticipated that a postinsertion APS burn will ever be desired, it is considered worthwhile to leave this avenue open. The minimum allowable burn to avoid the freezing problem is approximately 3 seconds. The average acceleration near orbit insertion for a fully loaded ascent stage is approximately 11 feet per second per second. The velocity gained in a 3-second burn is about 33 feet per second, which correlates with the overburn bound.

Components of VG with respect to LM body axes are available for display on the DSKY. These values have signs associated with their magnitudes, and in the overburn case, a sign change of the X-component would be immediately noticed. Observation of the LM body X-component of VG appears to be the desirable way of monitoring engine cutoff. It appears that for practical operations, the crew should abort stage when VGX is greater than or equal to 30 feet per second. If DPS engine shutdown occurs at VGX less than 30 feet per second, the velocity residual will be nulled by RCS thrusting (tweak burn or residual trimming).

When the LM is under control of PGNCS P70 or P71, the automatic DSKY display prior to guided engine cutoff is verb-noun V16 N63, which displays VI, H, and H. To obtain the display of VG components the crew will key V16 N85 and ENTER on the DSKY. The original display may be recalled by pressing the KEY REL button.

The AGS computed VG components can be displayed only individually on the DEDA. The lunar module pilot (LMP) will press the CLR button to initialize the system, then key address 500 for VGX, and finally press the READOUT button to display VGX. This should be done sometime after abort initiation to aid in engine shutdown monitoring.

There is a 2- to 4-second delay from the time PGNCS VG components are computed until they can be displayed on the DSKY. This delay complicates the decision/action process, since the crew has difficulty in establishing present values for the VG components.

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If a DPS engine shutdown occurs when the present display shows VGX greater than 100 feet per second, the crew can abort stage immediately knowing that the actual VGX will be in the region where abort stage action should be taken. When DPS engine shutdown occurs with VGX less than 100 feet per second displayed, the crew can safely wait for the display to stabilize before making a decision as to the subsequent action necessary. A delay of 6 seconds should be adequate for display stabilization.

If the DPS continues to thrust as VGX goes negative, the engine should be stopped immediately by manual action. The resulting overburn will be included in a subsequent MCC-H computed tweak burn.

As in the case of the DPS, if the APS continues thrusting as VGX goes negative, the engine should be stopped immediately by manual action. An overburn will occur and the residual will be accounted for during the tweak burn. In the event of a significant APS underburn, VGX greater than 200 feet per second which corresponds to an APS thrust failure 10 seconds before insertion, the crew will attempt to restart the engine before continuing on RCS thrusting. If the underburn is less than or equal to 200 feet per second, VGX will be driven to zero using the RCS. Any residuals will be trimmed out during the tweak burn.

3.4 STAGE DPS

As indicated in the preceding discussion, the DPS will be staged when a DPS malfunction is detected. Staging is also performed at DPS propellant depletion or engine cutoff when VGX is greater than 30 feet per second. If VGX is less than or equal to 30 feet per second, staging is optional. The DPS can be retained throughout rendezvous if it is desirable to do so.

#### 3.5 POSTINSERTION ACTIVITY

#### 3.5.1 VGX Residual Trimming

The nominal postinsertion technique following a descent or lunar surface abort is to trim the VGX residual to zero on the MCC-H recommended G&N system (i.e., PGNCS or AGS). This is done to ensure a near nominal rendezvous coelliptic delta height ( $\Delta H = 15$  nautical miles). (A 10-foot per second VGX overburn or underburn changes  $\Delta H$  by about 5 nautical miles.) Crossrange and radial residuals have little effect on  $\Delta H$  and can be more accurately removed during later rendezvous maneuvers which incorporate rendezvous navigation data.

In the event that communications are lost, VGX will be trimmed on PGNCS (assuming a PGNCS insertion). The PGNCS and AGS residuals are then compared and if they agree within 10 feet per second no further action is taken. In the event they disagree, both systems are compared with the RR. If the AGS/RR difference is less than the PGNCS/RR difference, then VGX will be trimmed on AGS.

#### 3.5.2 Tweak Burn

In the event of an abort insertion on a degraded PGNCS or AGS, a premature APS shutdown or a premature DPS shutdown with VGX < 30 feet per second, the ground will compute an RCS tweak burn consisting of a  $\Delta$ VX and TIG. If required, the tweak burn will be voiced to the crew within 30 seconds after insertion; the specified TIG will always be within 4 minutes after insertion. In "no comm" situations involving excessive insertion residuals (i. e., residuals greater than about 10 feet per second) or significant discrepancy between PGNCS and AGS residuals, the LM crew will attempt to receive relayed advice from MCC-H via the CSM. In the unlikely event that the tweak burn  $\Delta$ V exceeds approximately 360 feet per second, the AGS will be used for the maneuver. This is desirable because the AGS continues to cycle through the guidance equations after receiving the initial engine shutdown discrete.

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If a tweak burn is required and the LM becomes inactive and/or it is undesirable to stage the DPS, MCC-H will voice the tweak burn  $\Delta VX$ , TIG, and pitch angle to the CSM for execution at insertion plus 12 minutes. The CSM will execute the burn on RCS provided  $\Delta VX$  does not exceed 12 feet per second. In the event  $\Delta VX$  does exceed 12 feet per second, the SPS will be used.

## 3.5.3 IMU Alignment and Drift Check

Following the residual trimming or tweak burn activity, MCC-H will uplink the LM telemetry state vector to the CMC. Both the LM and CSM perform an IMU realign to REFSMMAT (P52) after entering darkness to remove any alignment errors that may offset subsequent rendezvous navigation. Following the PGNCS alignment, the AGS state vectors are initialized from the PGNCS, and the AGS is aligned to the PGNCS. The detailed alignment and drift check rationale is discussed in Reference 3. The logic and limits are presented in the flow chart (page 4-8).

## 3.6 RENDEZVOUS TECHNIQUES FOR PDI NO GO AND DESCENT AND LUNAR SURFACE ABORTS

The PDI maneuver is nominally executed near perilune of the Hohman descent transfer orbit 1-1/2 revolutions after CSM CIRC. However, PDI can either be slipped one revolution or declared no go depending on the status of the LM (and CSM) onboard systems. The particular PDI no go and postabort sequences for the LM-active (nominal) and CSM-active (rescue) situations are summarized in Tables 1 and 2, respectively. These sequences include the height and phasing maneuvers required to enable the active vehicle to complete the rendezvous using the nominal CSI/CDH/TPI \*\*\* procedures presented in Reference 3.

<sup>\*</sup> Height adjust maneuvers (HAM) raise or lower the apolune or perilune of the active vehicle's orbit.

<sup>\*\*</sup> Phasing maneuvers adjust the central angle between the active and target vehicles. (The "abort maneuvers" mentioned in the tables are essentially phasing maneuvers.)

<sup>\*\*\*</sup> The nominal TPI is executed 23 minutes prior to daylight; however, following descent aborts, TPI will be executed 16 minutes prior to daylight.

SEQUENCE	APPLICABILITY	REQUIRED BURNS (TARGETING)	BURN EXECUTION TIMES	GENERAL TYPE OF RENDEZVOUS
NO PDI <sub>o</sub>	FIRST 1/2 REV AFTER CSM CIRC	•ABORT MANEUVER (MCC-H, P3D) •CSI (P32) •CDH (P33) •TPI (P34)	• 1/2 REV AFTER CSM CIRC • NOMINAL PDI TIG + -60 MIN • RESULT OF P32 COMPUTATIONS • 16 MIN PRIOR TO SUNRISE	1-REV
NO PDI1+12	PRIOR TO PDI <sub>]</sub>	•ABORT MANEUVER (MCC-H, P30) •BOOST - 10 FPS (P30) •HAM - NOMIPALY 0 FPS (MCC-H, P30) •CSI (P32) •CDH (P33) •TPI (P34)	•NOMINAL PDI TIG+12 MIN •NOMINAL PDI TIG+67 MIN •60 MIN AFTER BOOST •60 MIN AFTER HAM •ESULT OF P32 COMPUTATIONS •16 MIN PRIOR TO SUNRISE	2-REV
PDI <sub>1</sub> First region	PDI <sub>1</sub> to PDI <sub>1</sub> +5 min 40 sec	•INSERTION (P70/71) •BOOST = 10 FPS (P30) •HAM/CSI/COH/TPI SAME AS NO PDI <sub>1</sub> +12 SEQUENCE	•IMMEDIATE •60 MIN AFTER INSERTION •SAME AS NO PDI <sub>1</sub> +12 SEQUENCE	2-REV
PDI <sub>1</sub> SECOND REGION	PDI <sub>1</sub> +5 MIN 40 SEC To PDI <sub>1</sub> +15 MIN (T <sub>1</sub> )	•INSERTION (P70/71) •CSI (P32) •CDH (P33) •TPI (P34)	•IMMEDIATE •55 MIN AFYER INSERTION •RESULT OF P32 COMPUTATIONS •16 MIN PRIOR TO SUNRISE	ו -REV
T <sub>21</sub> PREFERRED LIFTOFF	PDI <sub>1</sub> +20 MIN 45 SEC (T <sub>2</sub> )	•INSERTION (P12) •BOOST - 10 FPS (P30) •HAM/CSI/CDH/TPI SAME AS NO PDI <sub>1</sub> +12 SEQUENCE	•T2 •50 MIN AFTER INSERTION •SAME TIMING EXCEPT CSI IS 50 MIN AFTER HAM	2-REV
NO POI2+12	PRIOR TO PDI2	•ABORT MANEUVER (MCC-H, P3O) •BOOST - 10 FPS (P3O) •HAM/CSI/CDH/TPI SAME AS NO PDI <sub>1</sub> +12 SEQUENCE	•SECOND NOMINAL PDI TIG+12 MIN •72 MIN AFTER NOMINAL PDI TIG •SAME AS NO PDI <sub>1</sub> +12 SEQUENCE	2-REV
PDI <sub>2</sub> FIRST REGION	PDI <sub>2</sub> TO PDI <sub>2</sub> +8 MIN 30 SEC	•INS/BOOST/HAM/CSI/CDH/TPI SAME AS PDI <sub>1</sub> FIRST REGION SEQUENCE	•SAME AS PDI <sub>1</sub> FIRST REGION SEQUENCE	2-REV
PDI <sub>2</sub> Second Region	PDI <sub>2</sub> +8 MIN 30 SEC TO PDI <sub>2</sub> +15 MIN (T <sub>1</sub> )	•INS/CSI/CDH/TPI SAME AS PDI <sub>1</sub> SECOND REGION SEQUENCE	•SAME AS PDI <sub>1</sub> Second region sequence	)-REV
T22 PREFERRED LIFTOFF	PDI <sub>2</sub> +18 MIN 56 SEC (T <sub>2</sub> )	•INSERTION (P12) •CSI (P32) •CDH/TPI SAME AS •PDI <sub>1</sub> SECOND REGION SEQUENCE	•T2 •50 MIN AFTER INSERTION	1-REV

Table 1. Summary of LM Active Rendezvous Sequences

Table 2. Summary of CSM Active (Rescue) Rendezvous Sequences

SEQUENCE	APPLICABILITY	REQUIRED BURNS (TARGETING)	BURN EXECUTION TIMES
RESCUE 2	PARTIAL LM NO-PDJ ABORT MANEUVERS UNDERSPEEDS FOLLOWING DESCENT ABORTS (LM HIGH ENOUGH FOR CSM TO COME DOWN)	• RESCUE-2 MANEUVER • CSI <sub>1</sub> (P32: N = EVEN INTEGER DEPENDENT ON LM ABORT $\Delta V$ . SEE TABLE 3) • CSI <sub>1</sub> - NOM. O FPS (P32: N <sub>1</sub> =N <sub>1-1</sub> -2, N <sub>1</sub> $\geq$ 2) • CSI - NOM. O FPS (P32 NOMINAL CASE: N=1) • CDH (P33) • TPI (P34)	•AT LONGITUDE OF CSM CIRC •AT ORBIT PERILUNE •EACH REV AFTER CSI 1/2 TIME BETWEEN CSI (N=2) AND CDH •RESULT OF P32 COMPUTATIONS # 16 MIN BEFORE SUNRISE
MIRROR IMAGE	ABORTS FROM DESCENT - (SUCCESSFUL INSERTION) NO-PDI ABORTS - (SUCCESSFUL ABORT MANEUVER) T2 ABORTS - (SUCCESSFUL INSERTION) CERTAIN ANYTIME LIFTOFFS	<ul> <li>A. RESCUE FROM 2-REV SEQUENCE HAM/CSI/CDH/TPI</li> <li>B. RESCUE FROM 1-REV SEQUENCE CSI/CDH/TP1</li> </ul>	• MANEUVERS AT LM-ACTIVE TIMES • MANEUVERS AT LM-ACTIVE TIMES
CONTINGENCY DWELL	UNDERSPEEDS FOLLOWING DESCENT ABORTS (CSM CANNOT COME DOWN)	• PHASING (NCC-H, P30) • PHASING; - NOMINALLY D FPS (MCC-H, P30) • CSI (P32) • CDH (P33) • TPI (P34)	• PDI+67 MIN     •ONE REVOLUTION AFTER PREVIOUS PHASING     •AT SAME LONGITUDE AS PHASING BURNS     • RESULT OF P32 COMPUTATIONS     • ~ 16 MIN PRIOR. TO SUMRISE
ANYTIME DWELL	ANYTIME LIFTOFF	• DWELL INITIATE (MCC-H, P30) • DWELL TERMINATE - CSM CIRC. (MCC-H, P30) • CSI (P32) • CDH (P33) • TPI (P34)	• 92 DEG WEST OF LANDING SITE • 92 DEG WEST OF LANDING SITE AFTER SUFFICIENT WEVS FOR PROPER PHASING • NOMINAL RENDEZYOUS TIMES • BASED ON CIRCULAR CSM ORBIT
MANUAL ASCENT	FOLLOWING LM MANUAL ASCENT	• PHASING (MCC-H, P3O) • PHASING <sub>1</sub> -NOMINALLY O FPS (MCC-H, P3O) • CSI (P32) • CDH (P33) • TPI (P34)	• ONE REV AFTER INSERTION • ONE REVOLUTION AFTER PREVIOUS PHASING • 1/2, 1-1/2, or 2-1/2 REVS AFTER PHASING DEPENDING ON LM ORBIT • RESULT OF P32 COMPUTATIONS • BASED ON ORBIT AFTER CSI

In all abort situations, the subsequent rendezvous will employ the LM-active sequences whenever possible. This eliminates the need in certain cases for the CSM to maneuver into a lower orbit which would require additional SPS propellant for TEI and in some instances tend to jeopardize crew safety. CSM-active rescue sequences will be initiated only in the event of LM inability to maneuver safely.

#### 3. 6. 1 LM-Active Sequences

One of two basic rendezvous sequences will be utilized following an abort. The 1-REV sequence consists of the nominal CSI/CDH/TPI maneuvers following orbit insertion or the initial abort maneuver. The 2-REV sequence includes a canned, 10-foot-per-second boost maneuver and a height adjust maneuver (HAM) (nominally 0 foot per second) prior to the usual CSI/CDH/TPI maneuvers. The boost maneuver raises the nominal LM perilune from 10 nautical miles to about 17 nautical miles in order to insure a safe perilune passage, and the HAM is used to adjust for offnominal rendezvous conditions. The 2-REV sequence is used in abort situations which would place the spacecraft beyond the maximum VHF ranging distance during the tracking period prior to the nominal 1-REV CSI maneuver. Rendezvous maneuver schematics for the 1-REV and 2-REV sequences are shown in Figure 3.

#### 3. 6. 1. 1 PDI No Go Aborts

If it becomes apparent, during the first one-half revolution after CSM CIRC, that the LM will be unable to proceed with the powered descent, then a NO PDI<sub>0</sub> abort will be initiated at the pericynthion of the LM orbit. The target parameters for the abort (phasing) maneuver performed at that time will have been received on a PAD sent to the crew after acquisition of signal (AOS) following CSM CIRC on revolution 13.

Subsequent abort decisions prior to  $PDI_1$  or, if PDI has been slipped one revolution, prior to  $PDI_2$  will require a NO PDI + 12-minute abort initiated at the nominal PDI TIG + 12 minutes, followed by a 2-REV rendezvous sequence. The PAD for the initial abort and boost maneuvers will be

3-13



Figure 3. Rendezvous Schematics for LM Active (Nominal) Sequences

updated by MCC-H during revolution 13 (for the NO  $PDI_1 + 12$  abort) or 14 (for the NO  $PDI_2 + 12$  abort). \* MCC-H targeting for the HAM will be sent to the crew as soon as the state vectors of the spacecraft become available after AOS following the boost maneuver.

#### 3. 6. 1. 2 Descent and Lunar Surface Aborts

Powered descent aborts and early lunar surface aborts have been divided into three categories as follows:

PDI <sub>i</sub> FIRST REGION	- Aborts occurring early during powered descent which require a 2-REV rendezvous sequence.
PDI <sub>i</sub> SECOND REGION	- Aborts occurring late in powered descent, and early lunar surface aborts through $T_1$ , which require a 1-REV rendezvous sequence.
T <sub>2</sub> PREFERRED LIFT-OFF	- An abort occurring at a discrete lift- off time after the first lunar stay/no stay decision which uses P-12, the nominal LM ascent program. A 2-REV rendezvous sequence is required for i = 1; a 1-REV sequence for i = 2.

The mission times corresponding to each of these categories are delineated in Table 1.

Insertion and proper phasing for rendezvous are accomplished at the same time through the use of variable insertion targeting (VIT). Both PGNCS abort programs (P70 and P71) and the AGS provide VIT for FIRST and SECOND REGION descent aborts.

3. 6. 2 CSM-Active Sequences (Rescue)

3. 6. 2. 1 PDI No Go Abort Rescues

If the LM is able to perform the initial abort maneuver successfully, but is unable to continue the rendezvous, then the CSM will take over as the active vehicle and will perform the required 1-REV or 2-REV maneuvers in a mirror image fashion. The boost maneuver, however, will never

A sample NO PDI + 12 abort pad is shown in Figure 4.

	NO PDI 1 + 12 ABORT PAD										
+	0	0		:	+	0	0	Í		HRS	N33
+	0	0	0			0	0	0	· · "• ·	MIN	TIG
+	0		•		+	0		•		SEC	
			<u>`</u> `_ <del>``</del>	•				<u></u> ,	•	∆۷Х	N81
				•	+	0	0	0	•	∆۷۷	LOCAL
			*	•					•	∆VZ	VERT
+				•	+				÷	H <sub>A</sub>	N42
+				•	+				ė	H H B	
+				•	+				•	ΔVR	
Х	X	χ			Х	Х	X	:		BT	
Х	X	X	•		Х	Х	Х			R	FDAI
Х	X	X			х	Х	X	_		Р	INER
				•					•	ΔVX	AGS
				٠					٠	∆۷۷	AGS
				٠					•	∆۷Z	AGS
+	0	0		-	+	0	0			HRS	N]]
+	0	0	0		+	0	0	0		MIN	CSI
+	0		•		+	0		•		SEC	
+	0	0			+	0	0			HRS	N37
+	0	0	0		+	0	0	0		MIN	TPI
+	0		•		+	0				SEC	···
	RESIDUALS										
PGNS					AG	S					
				•	5	00			•	∆VX	
N85				٠	5	01			٠	∆۷۷	
				•	5	02			•	ΔVZ	

Figure 4. No PDI Plus 12-Minute Abort Data Pad

be performed by the CSM, since it would serve no purpose to do so. All CSM-active maneuvers during a mirror image rendezvous will be performed at the corresponding LM-active times.

If the LM is unable (or just partially able) to execute the initial abort maneuver, the CSM will use the rescue-2 rendezvous maneuver sequence detailed in Table 2. The rescue-2 maneuver places the CSM in an orbit which will lead to a CDH maneuver at a differential altitude ( $\Delta$ H) of 10 nautical miles. The rescue-2 maneuver is targeted by MCC-H (an onboard chart is available for backup use), and the various CSI type maneuvers are computed onboard. The value of the rendezvous parameter N (the apsidal crossing after CSI at which the CDH maneuver should occur) is based upon the actual amount of  $\Delta$ V which the LM was able to achieve during the initial abort maneuver. The initial value of N as a function of LM  $\Delta$ V for the various types of PDI no go aborts is shown in Table 3.

#### 3. 6. 2. 2 Descent and Lunar Surface Abort Rescues

The CSM-active rendezvous sequences following descent or lunar surface aborts are similar to those following PDI no-go aborts. If the LM reaches its targeted insertion orbit, the CSM will perform a mirror image rescue. If the LM does not reach the correct insertion orbit but does attain sufficient altitude to allow the CSM to maneuver safely inside the LM orbit<sup>\*\*</sup>, the rescue-2 procedures will be utilized. If the LM is too low, the CSM will perform a contingency dwell sequence, consisting of several ground targeted phasing maneuvers followed by the usual CSI/CDH/TPI maneuvers.

To accomplish a rescue following an emergency "anytime lift-off" from the lunar surface, the ground will target the CSM for a single dwell orbit. After proper phasing is achieved, the CSM will recircularize

<sup>&</sup>lt;sup>\*</sup>For a LM-active rendezvous, the target  $\Delta$ H is 15 nautical miles.

<sup>\*\*</sup> To reduce the time required for rendezvous, the phasing orbit of the active vehicle usually has its pericynthion at a lower altitude than that of the target vehicle. This allows the active vehicle to physically "catch up" with the target vehicle, rather than vice versa.

<sup>\*\*\*</sup> Dwell-type sequences are generally undesirable because of the amount of time, up to 12 hours, required to achieve rendezvous.

PDI NO-GO ABORT TYPE	LM ABORT MANEUVER ∆V (IN FT/SEC)	INITIAL VALUE OF N
No PDI <sub>o</sub>	0 < ΔV < 30 30 < ΔV	4 2
No PDI <sub>1</sub> +12	$0 < \Delta V < 10$ 10 < $\Delta V < 30$ 30 < $\Delta V < 65$ 65 < $\Delta V$	8 6 4 2
No PDI <sub>2</sub> +12	$\begin{array}{rcrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$	10 8 6 4 2

Table 3. PDI No Go Rescue-2 Rendezvous: CSI Parameter Values

its orbit before proceeding with the CSI/CDH/TPI maneuvers. If the LM performs a manual ascent, the CSM-active rescue sequence may require several MCC-H targeted phasing maneuvers. Detailed procedures for this type of rescue are discussed in Reference 6.

### 3. 6. 3 <u>Rendezvous Maneuver Solution Determination</u>

#### 3. 6. 3. 1 Phasing and Height Adjust Maneuvers

All phasing maneuvers will be targeted by MCC-H. The ground is also prime for determining height adjust maneuvers. However, the crew (LM or CSM) can also determine HAM solutions by using the CSI program (P32) to compute the differential altitude ( $\Delta$ H) target for CDH, finding the required  $\Delta$ V from a chart of  $\Delta$ V versus  $\Delta$ H<sup>\*</sup>, and then entering this into the external  $\Delta$ V targeting program (P30). The boost maneuver is a canned, 10-foot-per-second, posigrade burn executed along the local horizontal. The execution time may be adjusted by MCC-H, if required.

#### 3.6.3.2 CSI, CDH, and TPI Maneuvers

The CSI, CDH, and TPI maneuver solutions are computed using onboard PGNCS (or GNCS) programs: P32 for CSI targeting, P33 for CDH targeting, and P34 for TPI targeting. The AGS also provides onboard software solutions via DEDA address 410; data word entry + 10000 for CSI, + 20000 for CDH, and + 40000 for TPI. In addition, the crew can manually target the maneuvers using charts based on rendezvous radar measurements of range and range rate. For comparison, the LM and CSM solutions must be biased in order to account for differences caused by relative orbital geometry. The crew will use onboard charts to determine the biases for the CSI maneuver. The ground will provide the biases for the CDH maneuver because the use of crew charts would be unduly tedious.

Prior to their respective TIG's, the CSI and CDH maneuver solutions (PGNCS, GNCS, and AGS) are compared. If the LGC agrees with either the CMC or chart (VGX less than 3 feet per second for CSI maneuvers; VGX less than 2 feet per second and VGZ less than 6 feet per second for CDH maneuvers), the LGC solution will be used. If the LGC does not

Since the desired  $\Delta H$  is 15 nautical miles, the onboard HAM chart indicates  $\Delta V = 0$  foot per second for  $\Delta H = 15$  nautical miles.

agree with either the CMC or AGS, the CMC solution will be used in the LGC if it agrees with the AGS (VGX less than 3 feet per second for CSI maneuvers; VGX less than 2 feet per second and VGZ less than 6 feet per second for CDH maneuvers). If all solutions disagree, the CMC solution will be used unless MCC-H specifies otherwise. The procedure is the same for both LM-active and CSM-active cases. Whenever the active vehicle uses the inactive vehicle solution, the biased value will be burned. In rendezvous situations where the tracking distance exceeds the onboard tracking capability, the LGC solutions for those CSI maneuvers will be prime because the PGNCS state vector is expected to be the best available. In the event of an AGS failure, the onboard chart solutions replace the AGS in the above comparison.

#### 3.6.4 Postabort Rendezvous Tracking Schedule

Postabort rendezvous tracking is complicated by the fact that many of the rendezvous maneuver sequences involve one or more height adjust and/or phasing maneuvers prior to initiation of the coelliptic sequence (i.e., CSI/CDH). The following tracking schedules are currently recommended (Reference 7):

- The nominal tracking schedule (Table 4) is generalized to postabort sequences by equating the maneuver which precedes the CSI/CDH sequence to "insertion" in the nominal tracking.
- The tracking schedule presented in Table 5 should be used for maneuvers which occur prior to the CSI/CDH sequence. This schedule provides about 25 minutes of tracking which is completed 12 minutes prior to the maneuver.

All 2-REV rendezvous sequences and certain rescue sequences involve tracking distances which initially exceed the RR and VHF ranging capability. For these cases the first tracking opportunity will employ W-matrix values of 10,000 feet, 10 feet per second, 15 mrad for the LM and 10,000 feet and 10 feet per second for the CSM. Thereafter the schedules presented in Tables 4 and 5 will apply.

LM Event	Time from Insertion (min)	CSM Event	Time from Insertion (min)
Insertion O		Insertion	0
V93 before first mark W = 10,000 ft, 10 ft/sec, 15 mrad		V93 before first mark ₩ = 10,000 ft, 10 ft/sec	
Initiate tracking	18	Initiate tracking (SXT + VHF)	19
Cease tracking	40	Cease tracking	38
CSI	50	CSI	50
V93 before first mark W = 2,000 ft, 2 ft/sec, 5 mrad		Y93 before first mark W = 2,000 ft, 2 ft/sec	
Initiate tracking	55	Initiate tracking (SXT + VHF)	56
Cease tracking	71	Cease tracking	78
Plane change	79	Plane change	79
V93 before first mark W = 2,000 ft, 2 ft/sec, 5 mrad		V93 before first mark W = 2,000 ft, 2 ft/sec	
Initiate tracking	81	Initiate tracking (SXT + VHF)	81
Cease tracking	98	Cease tracking	96
CDH	108	СОН	108
V93 before first mark W = 2,000 ft, 2 ft/sec, 5 mrad		V93 before first mark W = 2,000 ft, 2 ft/sec	
Initiate tracking	110	Initiate tracking	115
Cease tracking	137	Cease tracking	134
TPI	147	TPI	147
V93 before first mark W = 2,000 ft, 2 ft/sec, 5 mrad		V93 before first mark . W = 2,000 ft, 2 ft/sec	
Initiate tracking	149	Initiate tracking (SXT + VHF)	152
Cease tracking	160	Cease tracking	159
MCC-1	162	MCC-1	162
V93 before first mark W = 2,000 ft, 2 ft/sec, 5 mrad		V93 before first mark ** W = 2,000 ft, 2 ft/sec	
Initiate tracking	164	Initiate tracking	165
Cease tracking	175	Cease tracking	174
MCC-2 177		MCC-2 177	

## Table 4. Nominal Onboard Tracking Schedule for Mission H-2

\*If SXT or VHF only, no V93 between TPI and MCC-1 \*\*If SXT or VHF only, V93 after 3 marks following MCC-1

Table 5.	Onboard Tracking Schedule for Additional CSI Maneuvers
	in Multiple CSI Rendezvous Sequences

Time from CSI (min)	CSM Event	Tis: from CSI (min)
-37	V93, W = 10,000ft, 10 ft/sec initiate sextant and VHF track	-37
-10	Cease track	-12
0	CSI	0
	Time from CSI (min) -37 -10 0	Time from CSI (min)CSH Event-37V93, W = 10,000 ft, 10 ft/sec initiate sextant and VHF track-10Cease track0CSI

#### 3.6.5 Onboard Rendezvous Checklists

The various abort rendezvous sequences and associated procedures presented herein will be exposed to limited crew training and simulations. As a result, "cookbooks" of procedures for the LMP and CMP have been developed. These consist of relative motion plots for each of the abort cases shown in Tables 1 and 2 and a set of generalized timelines covering successive segments of time in the basic rendezvous sequence (i.e. insertion to boost, boost to HAM, etc). A typical example of a relative motion plot and a rendezvous timeline is presented in Figure 5.







## 4. LUNAR DESCENT ABORT TECHNIQUES

The following flow charts present the approved procedures to be followed for the guidance and control sequence of events, the data flow, and the real-time decision logic for aborts from the descent and early lunar surface phases of the Apollo 13 mission. These charts consist of an overall chart (pages 4-2 and 4-3) which summarizes the detailed activity and specific charts (pages 4-4 through 4-14) which present the detailed logic. The logic for events occurring after initiation of the coelliptic sequence (CSI/CDH/TPI) are presented in Reference 3 and so are not included herein. Although the rendezvous maneuvers shown in the flows represent descent and early lunar surface abort situations, the rendezvous techniques are also applicable for the PDI no go cases indicated in Tables 1 and 2. SUMMARY OF DETAILED LOGIC



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DETAILED LOGIC





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^40,000 FT IS EMPLOYED AS THE PGNCS TO AGS SWITCHOVER LIMIT IN ORDER TO ENSURE THAT THE ACTUAL  $\rm H_{PD}$  NEVER BECOMES LESS THAN 30,000 FT.

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IF THE CSM IS THE ACTIVE VEHICLE, THE SAME PROCEDURE APPLIES USING BIASED PONCS AND CHART SOLUTIONS FOR COMPARISON WITH THE GNCS.

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