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PRELIMINARY CONTINGENCY  
PROCEDURES FOR THE LUNAR ORBIT  
INSERTION, LUNAR ORBIT, AND  
TRANSEARTH INJECTION PHASES  
OF THE LUNAR MISSION



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MISSION PLANNING AND ANALYSIS DIVISION



MANNED SPACECRAFT CENTER  
HOUSTON, TEXAS

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1.0 SUMMARY

The preliminary contingency ground rules and procedures are presented for the lunar orbit insertion, lunar orbit, and transearth injection phases of the lunar mission. A flow chart of the CM, LM, and related MCC-H activities is included and identifies the command module computer and LM guidance computer programs required during these contingencies. In order to provide a more complete discussion of the abort techniques, the abort procedures following a complete communications failure (CM and LM) is presented.

2.0 INTRODUCTION

This preliminary procedures document is based on the abort data presented in reference 1. This reference contains an extensive discussion of the abort techniques and presents a substantial amount of parametric data on all phases of the lunar mission.

The discussion is broken down into the abort activity related to the LOI burn, lunar orbit, and the TEI burn. The LOI portion of the document contains a very complete description of the LOI burn monitoring philosophy and associated shutdown criteria. The abort procedures are then presented for the normal RTCC targeted maneuvers and also the onboard backup (no communications) technique. The lunar orbit abort procedures are identical to the normal transearth injection procedures and therefore are not included in this document. However, the onboard backup (no communications) abort technique is discussed. The TEI situation is discussed in less detail due to similarities to the LOI case. However, a discussion of the TEI monitoring philosophy is included.

## 3.0 SYMBOLS AND NOMENCLATURE

AOT	alignment optical telescope
APO ALT	apogee altitude, n. mi.
BMAGS	body mounted altitude gyro system
CDU	coupling display units
CM	command module
CMC	command module computer
CSM	command and service modules
DELTA VM, DVM	$\Delta V$ magnitude, fps
DPS	descent propulsion system
DSKY	display and keyboard
EMS	entry monitoring system
FDAI	flight director attitude indicator
G&N	guidance and navigation
GDC	gyro display coupler
IG	inner gimbal angle, deg
IMU	inertial measuring unit
LGC	LM guidance computer
LM	lunar module
LOI	lunar orbit insertion
MCC-H	mission control center - Houston
MG	middle gimbal angle, deg
MSI	moon's sphere of influence
OG	outer gimbal angle, deg

PER ALT	perigee altitude, n. mi.
PGNCS	primary guidance navigation control system
RCS	reaction control system
REFSMMAT	transformation matrix from the basic reference system to the stable member system
RTCC	real time computer complex
SCS	stabilization and control system
SPS	service module propulsion system
TFC	time from cut off, min:sec
TEI	transearth injection, min:sec
TF	time to pericyynthion
TFF	time of free fall
TFI	time from ignition, min:sec
TIG	time of ignition
TLI	translunar injection
VG	velocity-to-be-gained vector, fps
VGX, VGY, VGZ	components of VG in the local vertical coordinate system, fps

#### 4.0 LUNAR ORBIT INSERTION BURN

The lunar orbit insertion (LOI) burn transfers the spacecraft from a free-return circumlunar trajectory to the lunar parking orbit. Premature termination of this maneuver places the vehicle on a non-nominal lunar orbit from which either an alternate mission or abort situation may result. An early shutdown of the SPS engine may occur as a result of two situations:

1. A systems failure which would cause inadvertent shutdown of the SPS from which a restart may not be possible.



## 2. Manual shutdown by the crew.

Investigation has indicated that the only spacecraft failure that can be identified during the brief period of the LOI burn which would warrant manual thrust termination by the crew is an SPS control system failure. For this case as for the case of a non-restartable inadvertent shutdown of the SPS, aborts must be performed from possibly undesirable lunar orbits. For all other failure situations in which the option of continuing the burn is present, LOI burn completion, even manually controlled, has been shown to be desirable from an abort operations standpoint.

### 4.1 Trajectory Classes

The lunar orbits which result from premature LOI thrust termination range from lunar escape hyperbolas to stable lunar ellipses and fall into three general categories.

Class I - resulting from shutdowns during the first 130 seconds of the LOI burn. These trajectories are hyperbolic and will escape the moon's sphere of influence.

Class II - resulting from shutdowns 130 to 160 seconds into the LOI burn. These trajectories are unstable orbits with lunar impact or extremely long orbital periods for both.

Class III - resulting from shutdowns 160 seconds to nominal SPS thrust termination (approximately 380 seconds). These are relatively stable lunar ellipses that will not result in lunar impacts at the end of one revolution.

Figure 1 is a graphical representation of typical trajectories resulting from premature SPS shutdown during the lunar orbit insertion burn.

### 4.2 Abort Modes

Following premature LOI shutdown, if an abort is required it can take one of three forms which generally are determined by the class of the preabort trajectory. These forms are:

1. Mode I - a one-impulse maneuver which will return the spacecraft directly to earth. The abort burn is always initiated as soon as possible on the preabort trajectory. The range of LOI burn times that the abort is available is a function of the abort  $\Delta V$  available and the delay time to abort initiation.

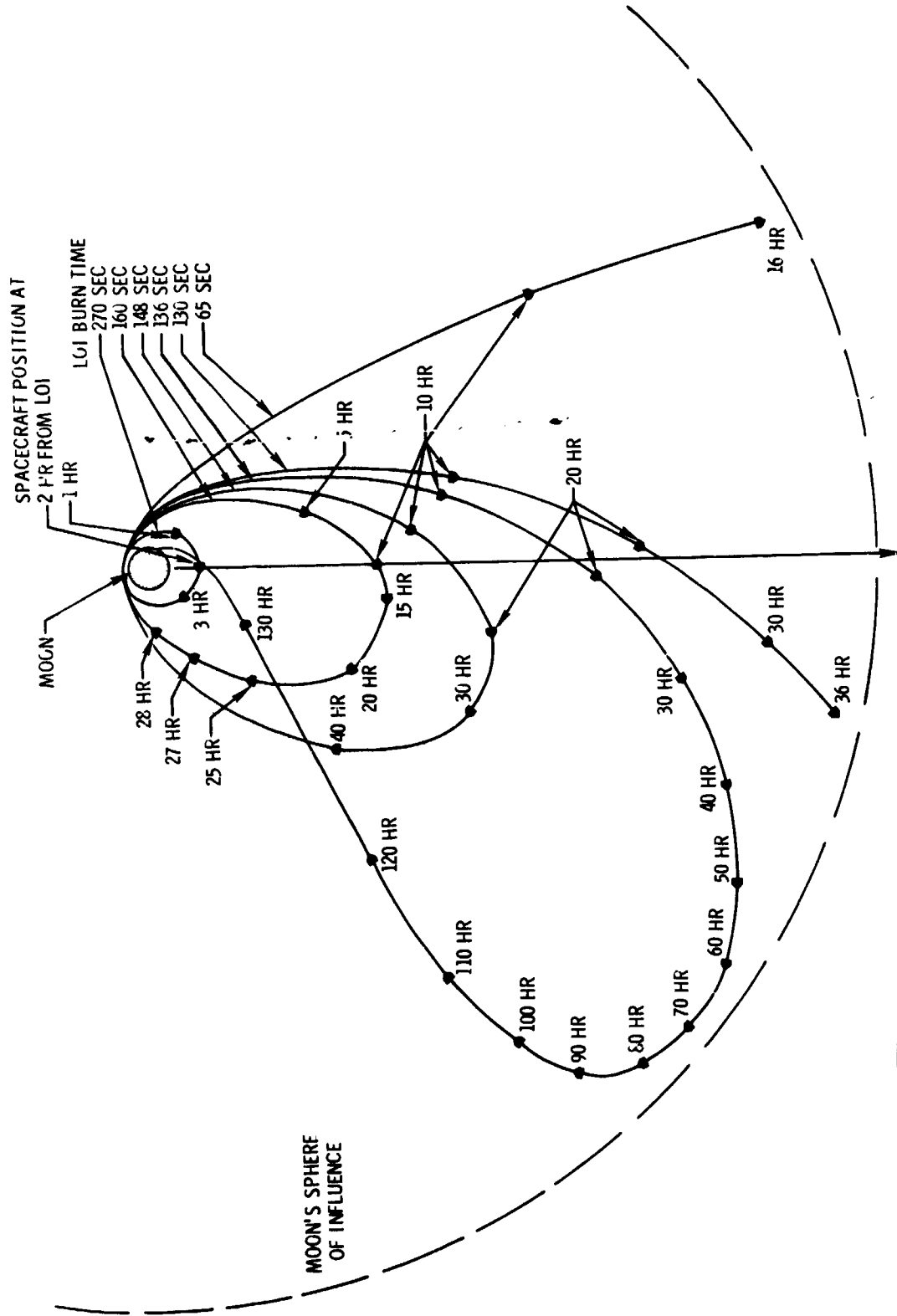


Figure 1.- Graphical representation of typical trajectories resulting from premature SPS shutdown during the lunar orbit insertion burn.

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2. Mode II - a two-impulse maneuver which will involve one lunar orbit prior to earth return. The first impulse adjusts the preabort orbit so that impacts do not occur and orbital periods are within system constraints. This first corrective maneuver is applied down the radius vector and is initiated as soon as possible. The second impulse occurs slightly before pericyynthion and returns the spacecraft directly to earth. The range of LOI burn times that the abort is available is a function of the abort  $\Delta V$ , the delay time to the corrective maneuver, and the allowable time between maneuvers.

3. Mode III - a one-impulse maneuver which occurs slightly before pericynthion following one lunar orbit (except for very late shutdowns in which the orbital period is so low that two revolutions are required for system preparation). The abort is essentially a mode II except that the corrective maneuver is not required since a stable ellipse with acceptable period has been achieved.

Figure 2 is a summary of the three lunar orbit insertion abort modes.

#### 4.3 Abort Ground Rules

The abort ground rules are as follows:

1. In the event that an inadvertent or manual SPS shutdown occurs (except for rough combustion, see rule 4), the LM DPS is considered the prime propulsion system. This recommendation is based on the belief that if the SPS has failed and caused inadvertent thrust termination or forced manual shutdown by the crew, it would probably be unreliable for future use.
2. If CSM system problems occur during LOI and they are non-trajectory related, complete the G&N burn. The following considerations have been included in this recommendation:
  - a. The abort procedure would approximate the normal TEI situation.
  - b. The total return-to-earth trip time would not be increased.
  - c. Shutdowns during the burn resulting in undesirable or impacting trajectories are avoided.
  - d. Multiple abort opportunities are provided.
  - e. The  $\Delta V$  penalties are heavily outweighed by the other considerations. (The  $\Delta V$  is still within the DPS capability.)

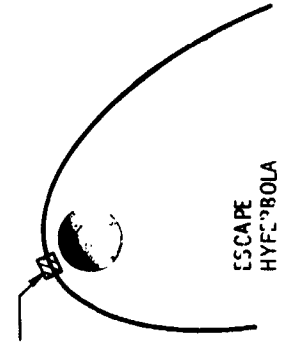
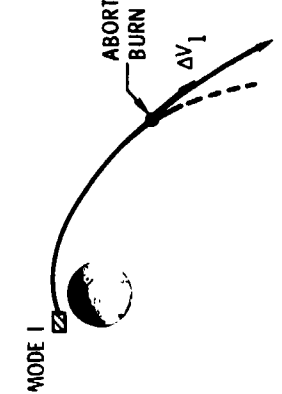
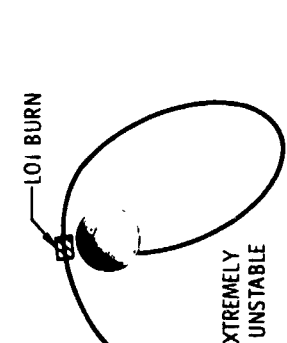
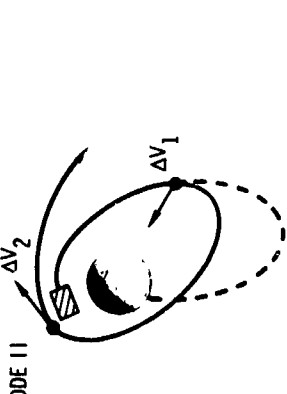
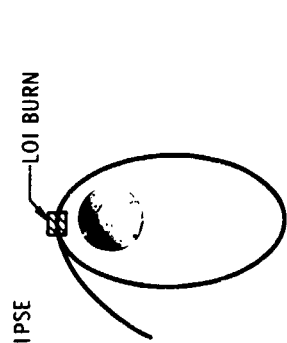
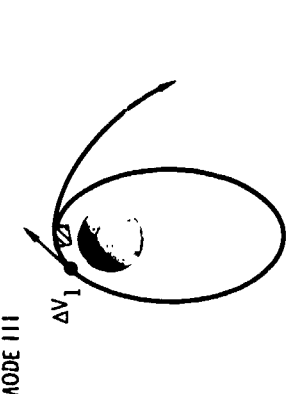
LOI SHUTDOWN RANGE	PREABORT TRAJECTORY	ABORT MODE
0-120 SEC		
120-180 SEC		
180-NOMINAL CUTOFF		

Figure 2.- Summary of lunar orbit insertion abort modes.

f. A more complete CSM systems check can be made in lunar orbit.

g. There is only a single impulse required to abort.

3. If attitude and attitude rate limits are exceeded due to G&N problems, initiate an SCS takeover. Recent studies (ref. 2) have shown that such a manual takeover will result in acceptable lunar orbits. A stable lunar ellipse would be achieved with its inherent alternate mission possibilities. Also, if a subsequent abort decision is made, the advantages of a stable lunar orbit (listed under ground rule 2) are obtained.

4. If an SPS shutdown occurs due to rough combustion, attempt an immediate restart and complete the LOI burn. Test data have shown that a restart can be performed simply if initiated within 10 seconds of cutoff. Any longer delays result in the need for a rather lengthy restart procedure which may preclude completion of the LOI maneuver.

5. The abort procedures must satisfy the known CSM/LM systems and trajectory constraints:

a. The maximum time between LM DPS burns is 50 hours.

b. The maximum delay time from SPS shutdown to abort is 70 hours.

c. All intermediate ellipses must have pericyynthion altitudes exceeding 30 000 ft.

d. The minimum delay time to allow for LM preparation is 2 hours.

#### 4.4 Abort Timeline and Procedures

The timeline for the LOI burn and abort is enclosed as flow chart 1. The timeline begins with the LOI preparations and is broken down into the functions of the CM crew, LM crew, and MCC-h. The related CMC ~~on~~ ~~LM~~ programs are noted when applicable. The timeline consists of the following major events:

1. LOI preparation
2. LOI burn ignition and monitoring
3. Mission evaluation
4. Immediate LM activation decision

5. Primary abort procedures
6. Onboard backup abort procedures

In the following paragraphs, each of the major events is discussed in detail and related to the abort ground rules in the previous section.

4.4.1 LOI Preparation.- The majority of procedures in this portion were obtained from reference 3. Summarizing briefly, the events in LOI preparation are as follows:

1. Assure proper operation and orientation of the IMU by calling the IMU orientation determination program (P51).
2. Provide burn targeting parameters and state vector update (P27).
3. Call for the prethrusting program which provides an onboard calculation of the  $\Delta V$  components in inertial components at the ignition time, TIG, (P31).
4. Call for the thrusting program (P40).
5. Insure the proper alignment of the IMU for the burn to avoid gimbal lock (P52).
6. Insure the proper orientation of the spacecraft to the burn direction.
7. To facilitate the burn monitoring and manual takeover procedures the IMU and BMAGS are aligned. Also the  $\Delta V$  counter on the EMS is set with the proper value of the LOI  $\Delta V$ . The FDAI sources are selected so that the CMC drives one FDAI while the GDC drives the other.

4.4.2 LOI Burn Ignition and Monitoring.- Reiterating the abort ground rules, the primary consideration during the LOI burn is attaining a stable lunar orbit. If non-trajectory related systems failures occur, the nominal burn will be completed. If attitude/attitude rate limits are exceeded due to G&N problems, an SCS takeover will be initiated. However, if the problem involves control of the SPS itself and a manual takeover cannot be achieved, the LOI burn will be terminated.

Reference 4 suggested spacecraft display limits which will require crew action if exceeded during either TLI, LOI, or TEI maneuvers. The following information is included from this document. The displays listed below may be used by the crew for monitoring the LOI burn:

1. IMU FDAI - total attitude, attitude rates, steering errors

2. CMC DSKY - time to go, velocity to be gained, delta V magnitude
3. BMAG FDAI - SCS total attitude, BMAG rates, attitude error
4. ΔV counter - ΔV accumulated
5. Clock
6. SPS tank pressures
7. SPS engine attitude indicator

The BMAG FDAI attitude is monitored during the burn so that if attitude limits are exceeded, the SCS takeover can be initiated. If the IMU is drifting, it will provide FDAI and DSKY displays which appear normal. Because the IMU is in control, the BMAG FDAI, on the other hand, will deviate in total attitude regardless of whether the IMU or the BMAGS are in error. Therefore, when the BMAG FDAI indicates an attitude deviation, a determination of the system in error (IMU or BMAGS) must be made.

Reference 5 recommends a method for making this determination. Under a nominal G&N configuration, gyro assembly no. 1 provides an attitude error which is effectively a third attitude reference source. Therefore, for an observed total attitude deviation on the BMAG FDAI, the attitude error needles on this ball will also show an error (other than normal c.g. motion) if the IMU is drifting. However, if no attitude error is shown, gyro assembly no. 2 must be drifting. Since the prime objective is to complete the LOI maneuver, the crew should complete the burn under SCS control if the IMU is drifting or continue under G&N control if gyro assembly no. 2 is drifting.

Based on the above information and the fact that LOI is now almost a constant attitude (Lambert) maneuver, reference 5 suggests the following procedures to provide a reasonable LOI maneuver.

1. If both gyro assemblies indicate less than 5° at 100 seconds (BMAG FDAI total attitude and attitude errors), assume manual control when they do show 5°, and complete LOI at the initial BMAG attitude (0°, 0°, 0°).
2. If both gyro assemblies show 5° or more at 100 seconds, assume manual control and finish LOI at the initial BMAG attitude.
3. For higher drift rates which are still too small to see on the rate needles (1 deg/sec), assume manual control at an attitude deviation of 15° on both gyro assemblies and complete LOI at the initial BMAG attitude.

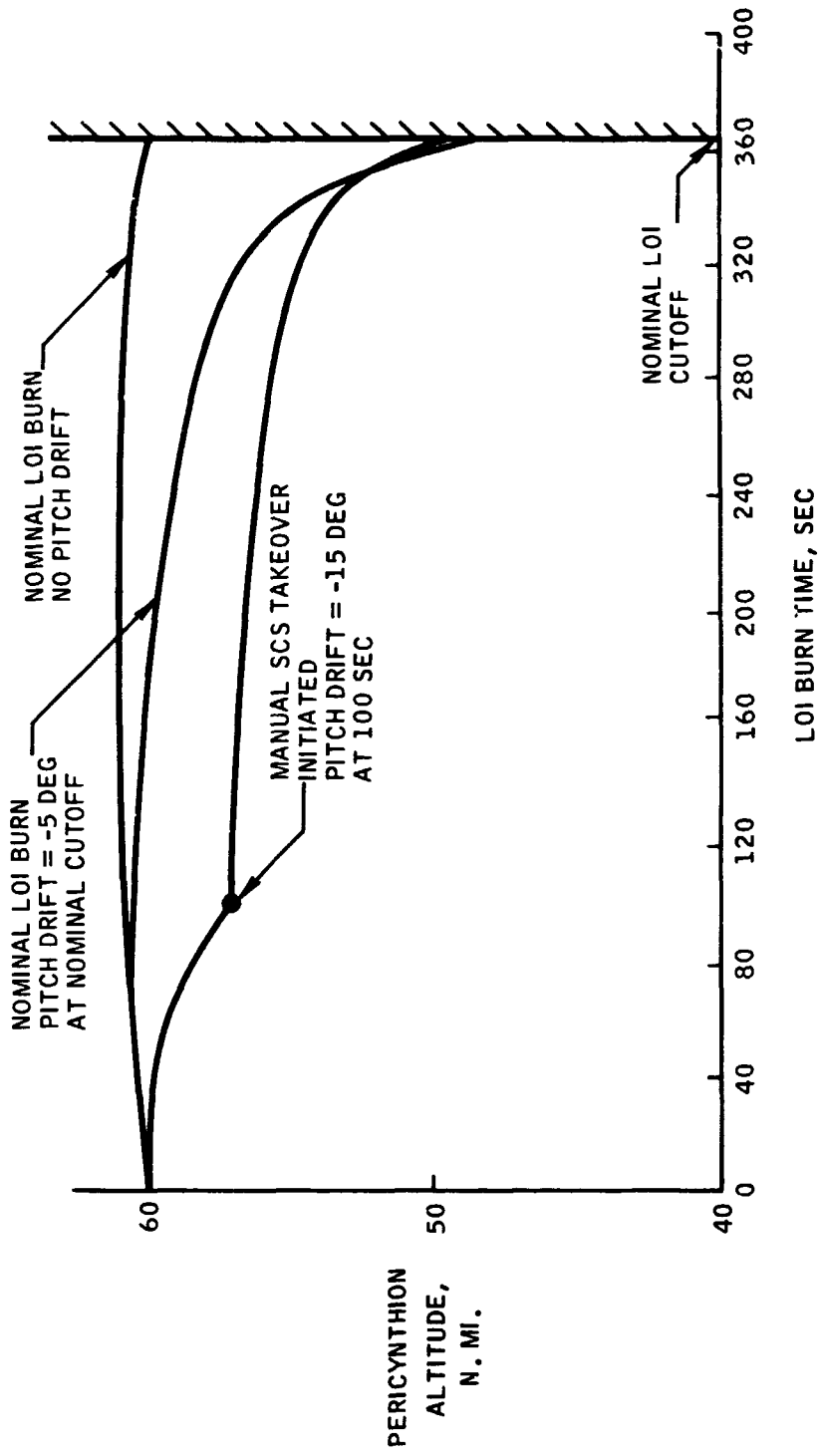


Figure 3.- Instantaneous pericynthion altitude for nominal and drifting lunar orbit insertion burns.



A current study (ref. 2) is investigating the feasibility of an SCS takeover using the above attitude limits. Figure 3 shows the instantaneous pericyynthion altitude for nominal and drifted LOI burns to a 60- by 170-n. mi. lunar parking orbit. Included on the figure is  $-15^\circ$  drift in pitch at 100-second LOI burn time followed by an SCS takeover to nominal burn completion. At SPS shutdown the pericynthion is approximately 50 n. mi. In addition a drift of  $-5^\circ$  at nominal SPS shutdown results in a final pericynthion of 50 n. mi. Therefore, the current study has shown that the attitude limits for LOI monitoring of reference 5 will result in satisfactory lunar orbits.

The previous discussion has been limited to the spacecraft attitude during the LOI burn. However, for both the nominal G&N burn and the SCS takeover situation, the  $\Delta V$  counter and clock will be monitored to insure that an acceptable lunar orbit is achieved. The procedure used to insure a near nominal lunar orbit is beyond the scope of this document, however, it suffices to say that if during the G&N burn, cutoff occurs early, an SPS restart using SCS EMS control to complete the burn will be initiated until the necessary  $\Delta V$  has been applied. Also if no cutoff command is given by some maximum allowable burn time manual cutoff will be effected. Finally the shutdown criteria following manual takeover will be a result of the aforementioned studies in progress.

4.4.3 Mission Evaluation.- This portion of the flow chart contains the evaluation of the LOI burn primarily with regard to the lunar orbit following thrust termination. This is accomplished by monitoring from routine 30 the time to pericynthion display. If the period is greater than 15 hours the orbit would require a mode I or mode II abort and an alternate mission would not be available. However, if the period is less than 15 hours a stable lunar orbit has been achieved and either a mode III abort or alternate mission could result. The spacecraft systems are evaluated to determine the desirability of an alternate mission.

4.4.4 Immediate LM Activation Decision.- Once the decision has been made to abort, then it must be determined whether or not the LM must be activated immediately. If a stable lunar ellipse has not been achieved, then a mode I or mode II abort will be required using the LM DPS. This requires immediate activation of the LM. However, if a stable lunar ellipse has been achieved, then LM activation is not time critical and a mode III abort may be performed. If communications with the MCC-H in the CM are established, the crew will coordinate systems evaluation and abort targeting with MCC-H. However, if a CM communications failure has occurred, an immediate LM activation is performed to the extent required to confirm LM communications availability. If communications with MCC-H are reestablished with LM systems the primary abort procedures are continued. However, if neither CM or LM communications

are available, the onboard backup abort procedures are initiated.

4.4.5 Primary Abort Procedures.- The crew will coordinate with the MCC-H to determine which abort mode will be initiated. Once the abort mode has been selected, the following events will follow:

1. Assure proper operation and orientation of the IMU by calling the IMU orientation determination program (P51), LGC
2. Provide burn targeting parameters and state vector update (P27), LGC
3. Call for external  $\Delta V$  program (P30), LGC
4. Call for DPS thrusting program (P40), LGC
5. Maneuver to desired attitude determined and stored by P40 (R60), LGC
6. Monitor the DPS ignition and burn

Displays available during burn are the FDAI (attitude errors and attitude rates) and thrust indicator, percent max chamber pressure, and LGC throttle command percent full thrust.

The mode I abort maneuver and mode II second impulse will occur at 2 hours following LOI shutdown (the current minimum LM activation time). After the first mode II burn the orbital parameter display from routine 30 is used to monitor the apocynthion altitude, pericynthion altitude, and time to pericynthion. The mode II second impulse and mode III abort maneuver will occur after one revolution in the lunar orbit. Following the abort maneuvers, the spacecraft will coast in the docked configuration to the vicinity of the lunar sphere of influence where the first midcourse correction will occur.

4.4.6 Onboard Backup Abort Procedures.- The onboard backup abort procedures are designed to enable the flight crew to determine a return-to-earth solution and effect an abort, if communications with MCC-H should be lost during docked CSM LM lunar phase operations. The onboard technique consists of using crew charts which will specify the time of ignition and the  $\Delta V$  magnitude as a function of the lunar orbital state. A single inertial attitude is specified for each abort mode. The inertial attitude is either (1) referenced to a known star pair or (2) determined by a set of gimbal angles relative to the pre-LOI IMU orientation. These data, in conjunction with information available from the DSKY, (VG or  $\Delta V$  magnitude) will be used to select the correct abort mode and determine the return-to-earth abort solution. The abort maneuver will be performed using the LM DPS engine in the attitude hold mode.

Onboard orbit determination will be required for state vector updates. An accurate state vector is required, in the event of preabort trajectory dispersions, to determine the time of ignition for the second mode II maneuver and the mode III maneuver. In addition, an accurate state vector will be required for the return-to-earth targeting program (p37) that will be used to determine if a midcourse correction is required. The midcourse maneuver will be performed in a guided mode.

Because all of the functions normally performed by MCC-H must now be performed onboard, it is necessary that certain trajectory related systems be available.

The following systems are required:

1. The CMC since it contains the return-to-earth targeting program (P37) necessary to compute the midcourse maneuvers.
2. The LGC to effect the docked DPS burns.
3. Either the IMU or BMAG system for attitude reference.
4. Optics necessary to perform onboard orbit determination using CMC program P22 or P23.

To simplify the abort procedures the techniques for each mode are very similar to the ground supported procedures discussed in section 4.4.5. The theory of the mode I, II, and III abort maneuvers is basically unchanged. However, an alternate method of performing the mode II first impulse is presented. This method consists of a single, fixed-inertial attitude burn with a variable  $\Delta V$  magnitude depending on the preabort orbit.

Since all contingencies consist of the same basic functions, this discussion is intended to simplify the explanation of all contingencies by outlining these basic recurring operations:

1. Acquisition of preferred attitude
2. Execution of thrusting maneuvers
3. Orbit determination and IMU alignment
4. Midcourse correction targeting

The following paragraphs discuss the basic operations and their various possible alterations.

4.4.6.1 Acquisition of preferred attitude: Without ground support, all abort maneuvers in the lunar sphere of influence will be made at some fixed inertial attitude which is dependent on the abort mode. This fixed attitude, once selected by the crew from onboard charts, becomes the preferred attitude to which the spacecraft should be reoriented. The preferred attitude is either (1) referenced to a known star pair or (2) determined by a set of gimbal angles relative to the pre-LOI IMU orientation.

The procedure using the known star pair consists of maneuvering to the inertial direction of the stars and then locating the preferred attitude described as a set of error angles with respect to the reference stars. If the IMU and optics are available, the procedure uses the IMU realignment program (P52) to help reorient the spacecraft so each reference star is in the optics field of view. If the IMU was inoperable or not aligned the BMAGS could be used to locate the reference stars. This could be accomplished by a set of Euler angles relative to the pre-LOI orientation that the FDAI should be displaying if the spacecraft were pointing in the correct direction. By monitoring the gimbal angles on the FDAI the crew could manually adjust the attitude to the general location of the reference stars. The crew would then maneuver to the preferred attitude described as a set of error angles with respect to these reference stars.

4.4.6.2 Execution of thrusting maneuvers: The onboard backup abort thrusting maneuvers are generally fixed-attitude burns using the attitude hold mode in the LM PGNCs. However, the mode II first impulse and the midcourse correction could be performed in the external  $\Delta V$  mode, using the thrusting program (P40).

The velocity increase must be monitored to terminate the abort maneuver when the magnitude accumulated equals that determined from the crew charts. In the attitude-hold mode, velocity accrued can be monitored along the spacecraft X-axis with either program P47 (requiring an IMU) or the EMS  $\Delta V$  counter. The DSKY (if the IMU is operable) and the FDAI are available to monitor attitude deviations.

4.4.6.3 Orbit determination and IMU alignment: The mode II second impulse and mode III aborts require calculation of ignition time as a function of longitude, which requires an accurate state vector. All midcourse calculations must be done onboard with the return-to-earth targeting program (P37) in the CMC. This program also requires accurate state vector data. In addition, the accuracy of the Encke state vector propagation is an indirect function of the time propagated prior to state vector update. Therefore, a requirement for some form of onboard state vector update exists.

The standard procedure for state vector determination is to make optical sightings on landmarks with the orbital navigation program (P22) or star/moon sightings using the Cis-lunar midcourse navigation program (P23). Both programs require some initial guess at the state vector and use several sightings of known landmarks or stars to obtain an accurate state vector.

The prime method of specifying the inertial attitude of the abort maneuver is by using gimbal angles relative to the pre-LOI CM IMU orientation. For the mode I abort and mode II first impulse the delay time from LOI shutdown to the abort maneuver will be 2 hours (the current minimum LM activation time). For these maneuvers the CM IMU or BMAG system as a backup will be used as the inertial reference. However, the mode II second impulse and mode III abort maneuver is initiated following one revolution in the intermediate lunar orbit. The periods of these orbits will vary from 2 hours to approximately 50 hours for an extreme mode II situation. In this case the LM IMU will be used as the reference. This technique will conserve SM RCS propellant needed for midcourse corrections since IMU alignments and attitude maneuvers will use the LM RCS.

The procedure to align the LM IMU to the CM IMU pre-LOI orientation involves voicing over to the LM the CMC REFSMMAT and performing optical sightings using the LM AOT. The inertial thrust directions for each of the abort maneuvers are known premission and once the CM IMU orientation for the LOI burn is known the gimbal angles can be calculated on the ground. The gimbal angles will then be transmitted to the crew prior to the LOI burn to be used to reorient the spacecraft to the desired inertial attitude in the event a communications failure occurs.

As a backup to the gimbal angles which require data transmitted prior to LOI, onboard data will include star data and associated error angles to determine the desired thrust direction independent of the IMU orientation. Therefore, premission data will be available to specify the thrust direction if no updates had occurred.

4.4.6.4 Midcourse correction targeting: All midcourse corrections will be targeted using the return-to-earth program (P37) in the CMC. This program will compute a trajectory providing the CSM is outside the lunar sphere of influence at time of ignition. The program assumes that contact with the ground is not available and is completely self contained.

4.4.6.5 Onboard backup abort objectives and detailed procedures: Following premature SPS shutdown, the orbital state vector is evaluated using crew charts and data from the DSKY to determine the correct abort mode. Studies are in progress to determine the most optimum way to determine the abort solution. At this time it appears the velocity-

to-be-gained or SPS  $\Delta V$  magnitude will provide the most accurate variable for use on crew charts. As a backup, the SPS burn time could be used.

The inertial attitude for the abort maneuver is determined from the abort mode and the crew charts will then provide the abort  $\Delta V$  magnitude and selenocentric longitude at time of ignition for the mode II and mode III aborts. This longitude of ignition is then converted to the time of ignition by use of the ground track determination program (P21).

The following paragraphs are intended to outline the sequence of events to be accomplished for each abort mode. Also included is a discussion of any special considerations as well as any system priorities that should be observed.

1. Mode I - lunar aborts - Following a premature LOI shutdown in the mode I region the crew will maneuver the spacecraft to the desired thrust direction using the CSM systems with the CM IMU (or BMAG system) as the attitude reference. The thrust direction is the same for all mode I aborts. In addition, the time of ignition of the LM DPS burn is always 2 hours following IOI thrust termination (the current minimum LM activation time). During the LM activation process, the crew will also determine the abort  $\Delta V$  magnitude from the crew charts. The LM DPS burn is then initiated in the PGNC attitude hold mode and the burn is monitored using LGC thrust monitor program (P47). Following the coast to exit of the MSI the midcourse correction will be determined using the CMC return-to-earth program (P37).

2. Mode II - lunar aborts - The abort procedure for shutdowns in the mode II region will involve two maneuvers. The first maneuver is very similar to that of the mode I except that the inertial thrust direction is down the radius vector. The time of ignition is again at 2 hours after LOI shutdown with the required  $\Delta V$  magnitude determined from crew charts. Also similar to the mode I procedure, the crew attains the thrust attitude using CSM systems and gimbal angles referenced to the CM IMU orientation.

The second abort burn occurs slightly prior to pericyynthion in the intermediate orbit. The abort  $\Delta V$  magnitude is determined from crew charts and the thrust attitude gimbal angles are constant for all lunar orbits. However, since the abort burn occurs from 15 to 50 hours after the first corrective maneuver the LM systems will be used to achieve the correct inertial attitude. The LM IMU is aligned to the CM IMU pre-LOI orientation and the crew then maneuvers the spacecraft to the correct gimbal angles. Use of the LM RCS for this maneuver will conserve CSM RCS propellant needed for the midcourse corrections.

The time of ignition of the second abort burn is determined from the crew charts in conjunction with the ground track determination program (P21) in the CMC or LGC. The charts will provide the selenographic longitude of ignition as a function of the LOI shutdown. Using P21 in an iterative process the time of ignition can be found.

3. Mode III - lunar aborts - The mode III abort procedure is identical to the mode II second impulse. The gimbal angles are referenced to the CM IMU pre-LOI orientation and the LM IMU is again used for the attitude reference. The mode III thrust direction is again constant for all mode III burns. The abort  $\Delta V$  magnitude and selenographic longitude are determined from the mode III crew charts.

4. Midcourse correction - Following exit of the MSI the midcourse correction necessary to enter the allowable entry corridor will be evaluated using the onboard return-to-earth program. The CSM RCS will be used to perform the midcourse correction. The decision will be made to jettison the LM after considering the system backups required and the magnitude of the midcourse requirements since the LM DPS could provide an additional  $\Delta V$  source.

## 5.0 LUNAR ORBIT

The abort procedures during lunar orbit are identical to the normal transearth injection procedures and therefore are not included in this document. However, the availability of the LM DPS engine prior to LM operations permits use of the LM DPS as a backup to the SPS engine for the abort maneuver. The LM DPS engine has the required  $\Delta V$  to place the spacecraft on a satisfactory transearth trajectory, however, the SPS engine in the docked configuration does not have the necessary  $\Delta V$ . Therefore, depending on the system backups required by the CSM, and the requirement of a backup to the SPS engine, either the DPS or SPS engine is available for the abort maneuver.

In the event that a total communications failure has occurred in lunar orbit, the normal TEI procedures could not be followed. To alleviate this problem, a block data technique is employed. Specifically, prior to LOI, an abort solution for the nominal lunar orbit will be transmitted to the crew. Following the LOI burn if ground communications exist this solution will be updated to account for dispersion during the burn. This abort solution will be good for several revolutions in lunar orbit. At later points in lunar orbit this solution will be updated. Consequently, a return-to-earth solution will be available if communications are subsequently lost in lunar orbit. A significant point is that although this abort solution will require midcourse corrections, these

corrections will be within the  $\Delta V$  capability of the spacecraft. Also, once outside the moon's sphere of influence, the CMC return-to-earth program (P37) is available.

#### 6.0 TRANSEARTH INJECTION BURN

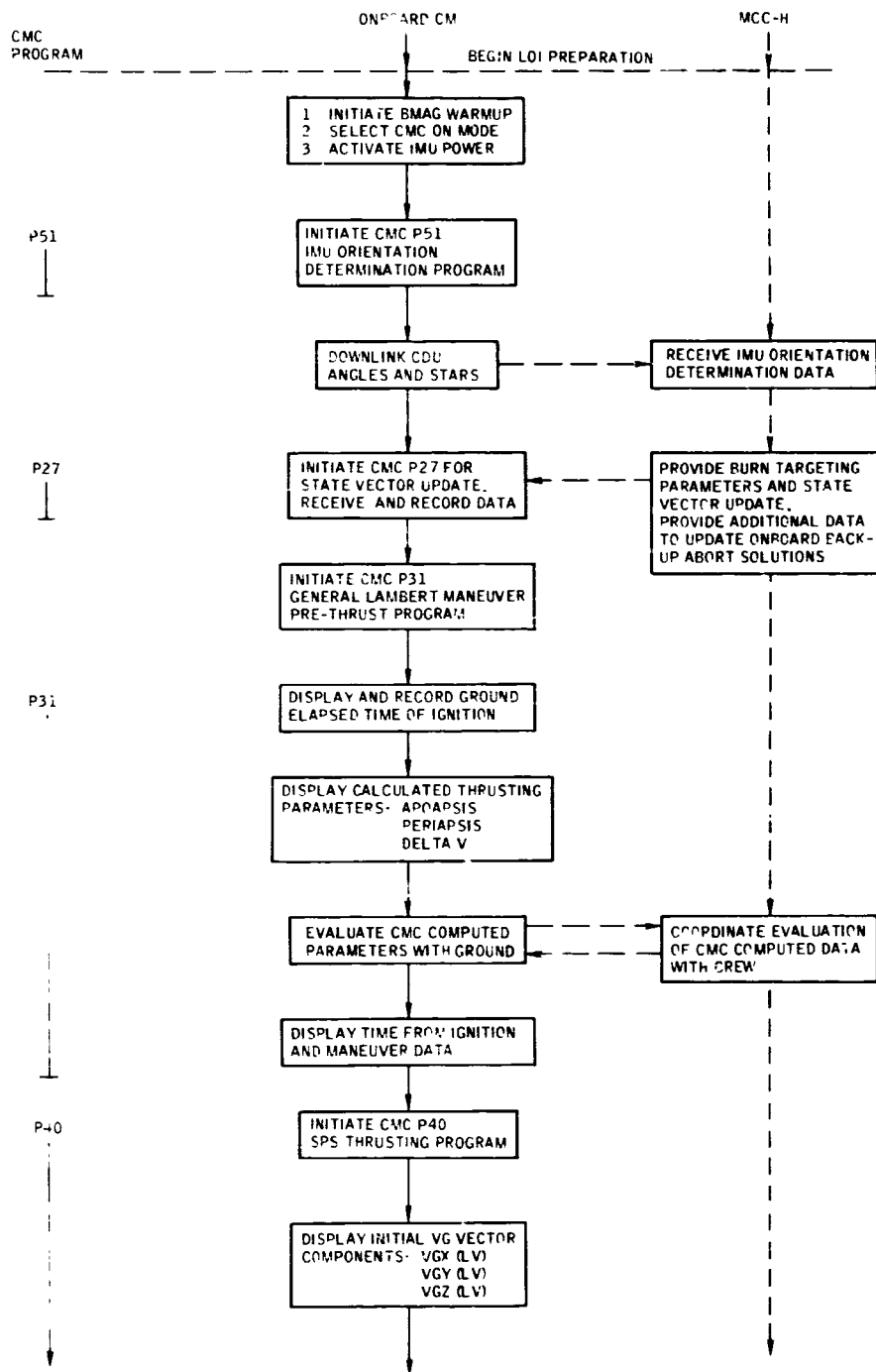
The transearth injection burn transfers the spacecraft from the lunar orbit to a trajectory that will result in CM entry into the earth's atmosphere. Premature termination of the SPS burn will result in lunar orbits very similar to those of the LOI case (section 4.1). Consequently, the abort modes are identical to those in section 4.2.

The primary difference in the abort situation is the absence of a backup to the SPS engine. The SPS monitoring philosophy is therefore reduced to mandatory completion of the TEI burn. Studies are in progress to define the attitude limits for the TEI burn for initiation of an SCS takeover and completion of the burn. The only CSM system problem that will require shutdown of the burn is an SPS-related problem that can be corrected and the engine reignited. In the event this situation occurs, the primary (RTCC assist) and backup (no communications) abort procedures will be identical to those of section 4.4.

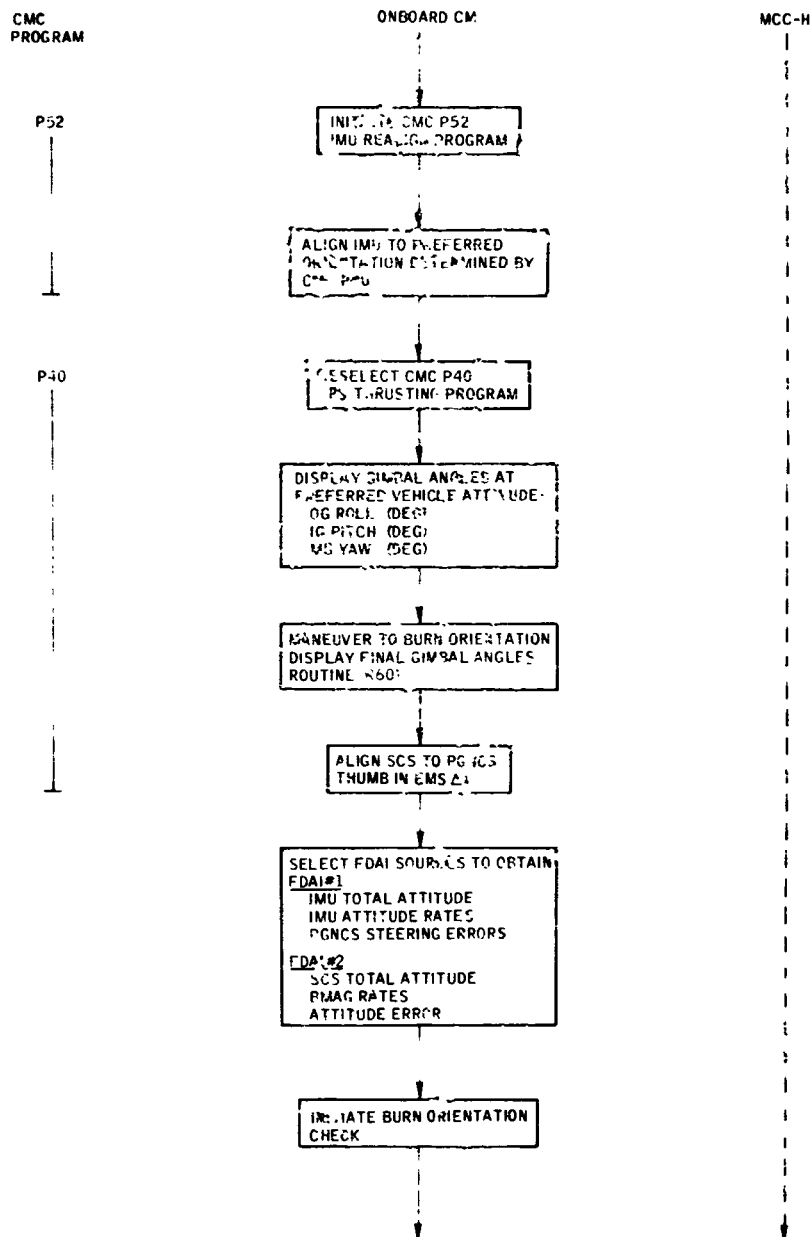
#### 7.0 CONCLUDING REMARKS

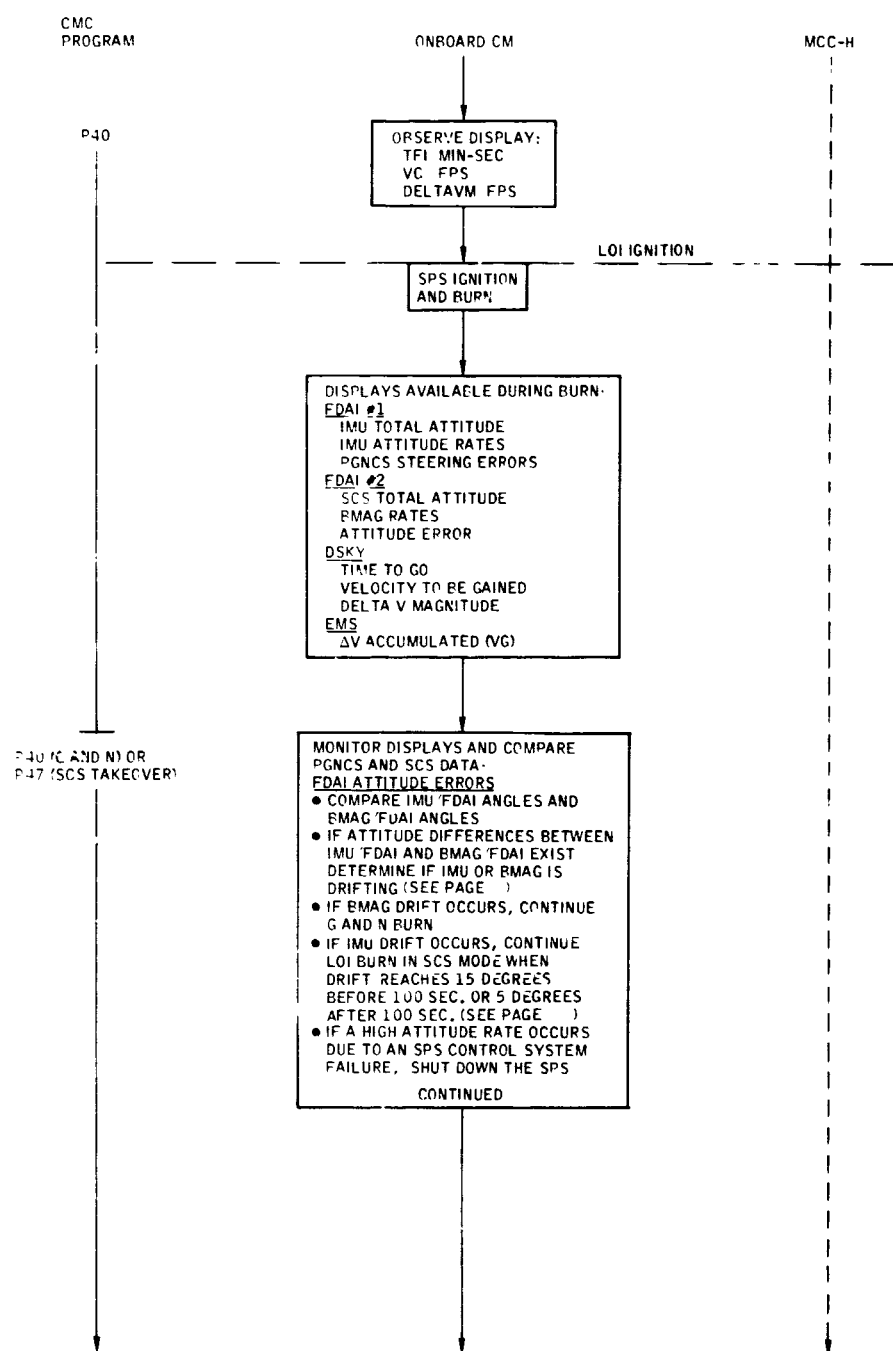
The preliminary contingency ground rules and procedures for the lunar orbit insertion, lunar orbit, and transearth injection phases of the lunar mission are presented in this document. A flow chart of the CM, LM, and related MCC-H activities during such contingencies is included. The flow chart indicates the CMC and LGC programs required. A discussion of the abort techniques and procedures following a complete communications failure is also presented. A complete description of the onboard CMC and LGC programs can be found in references 6 and 7, respectively.

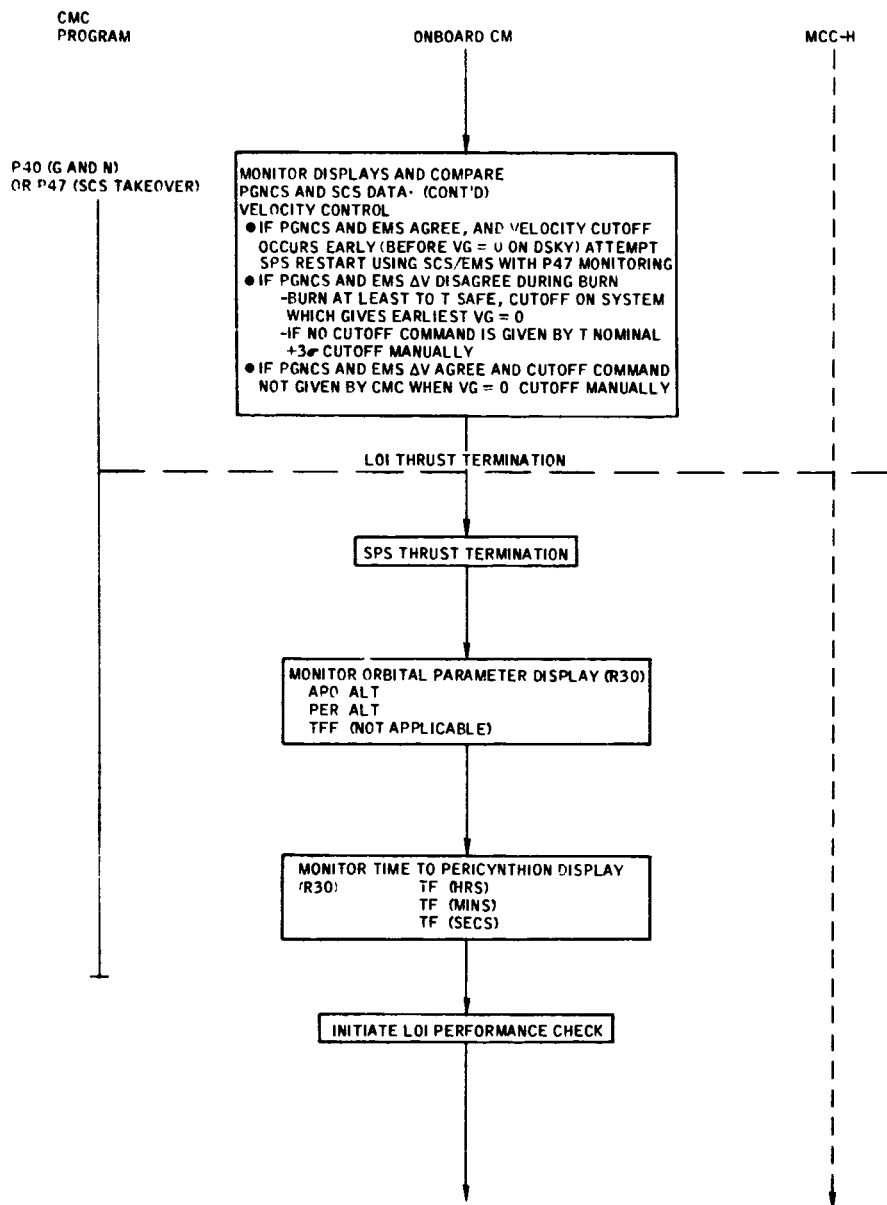


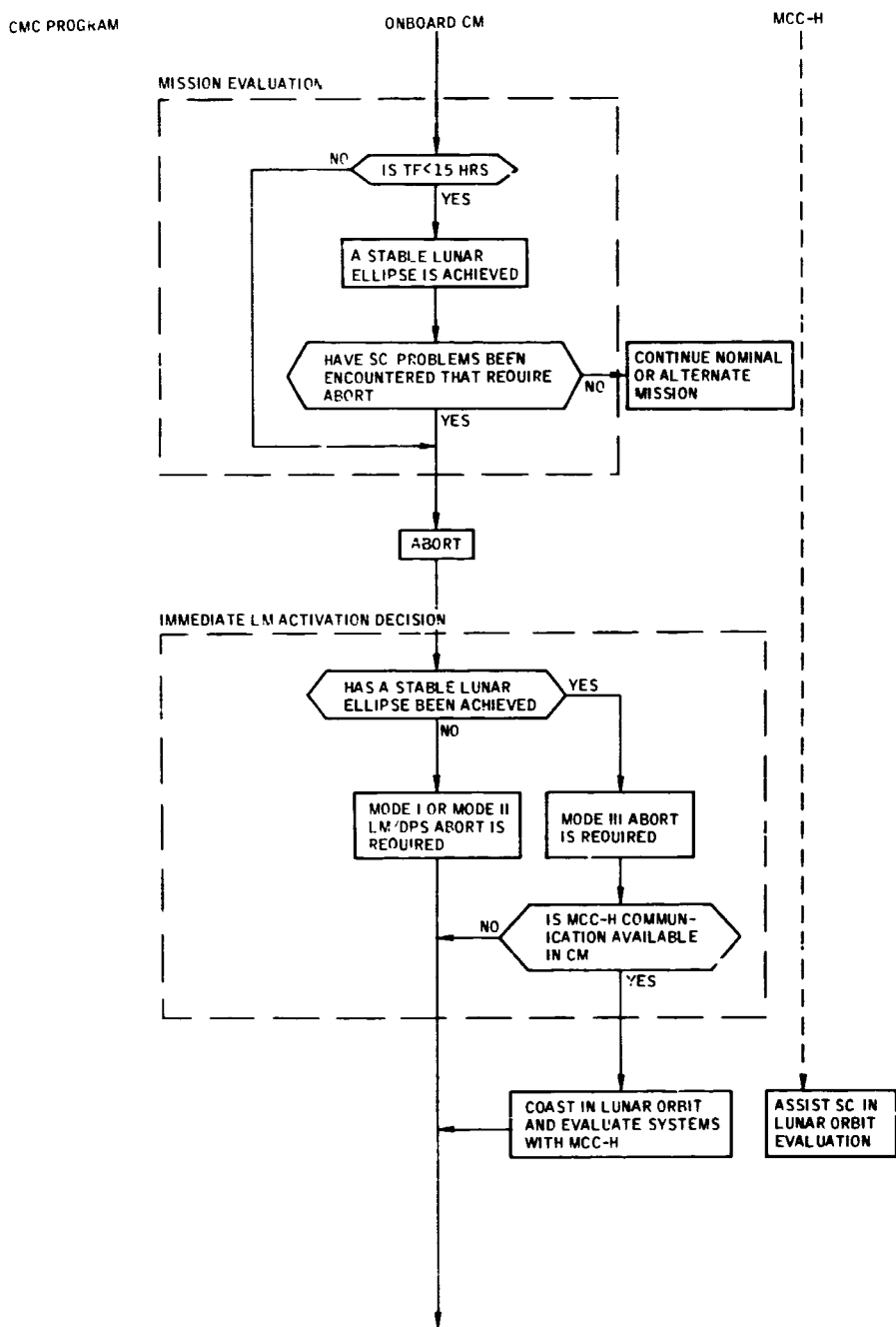


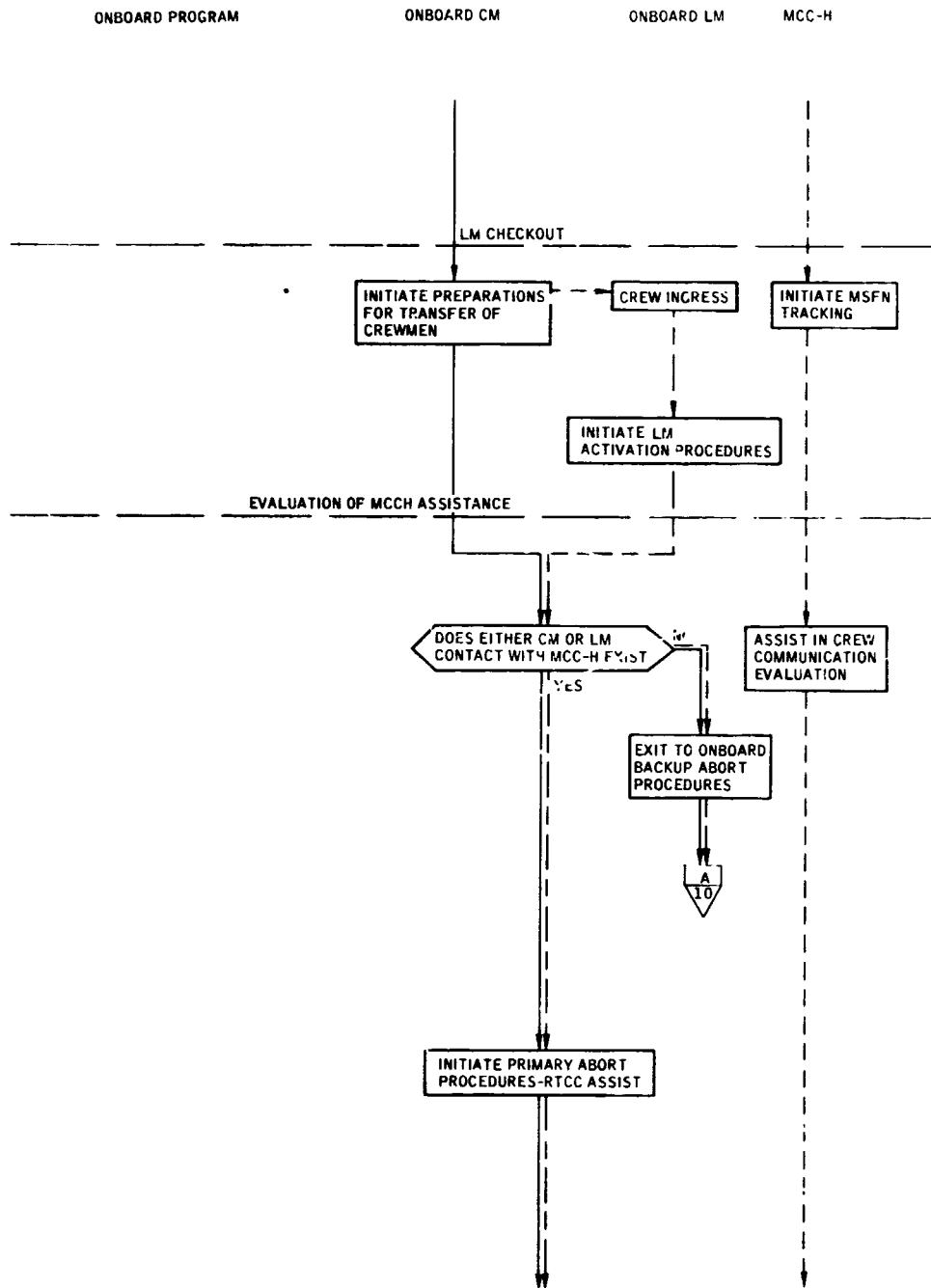
Flow chart 1.- Contingency procedures for the Lunar Orbit Insertion burn.

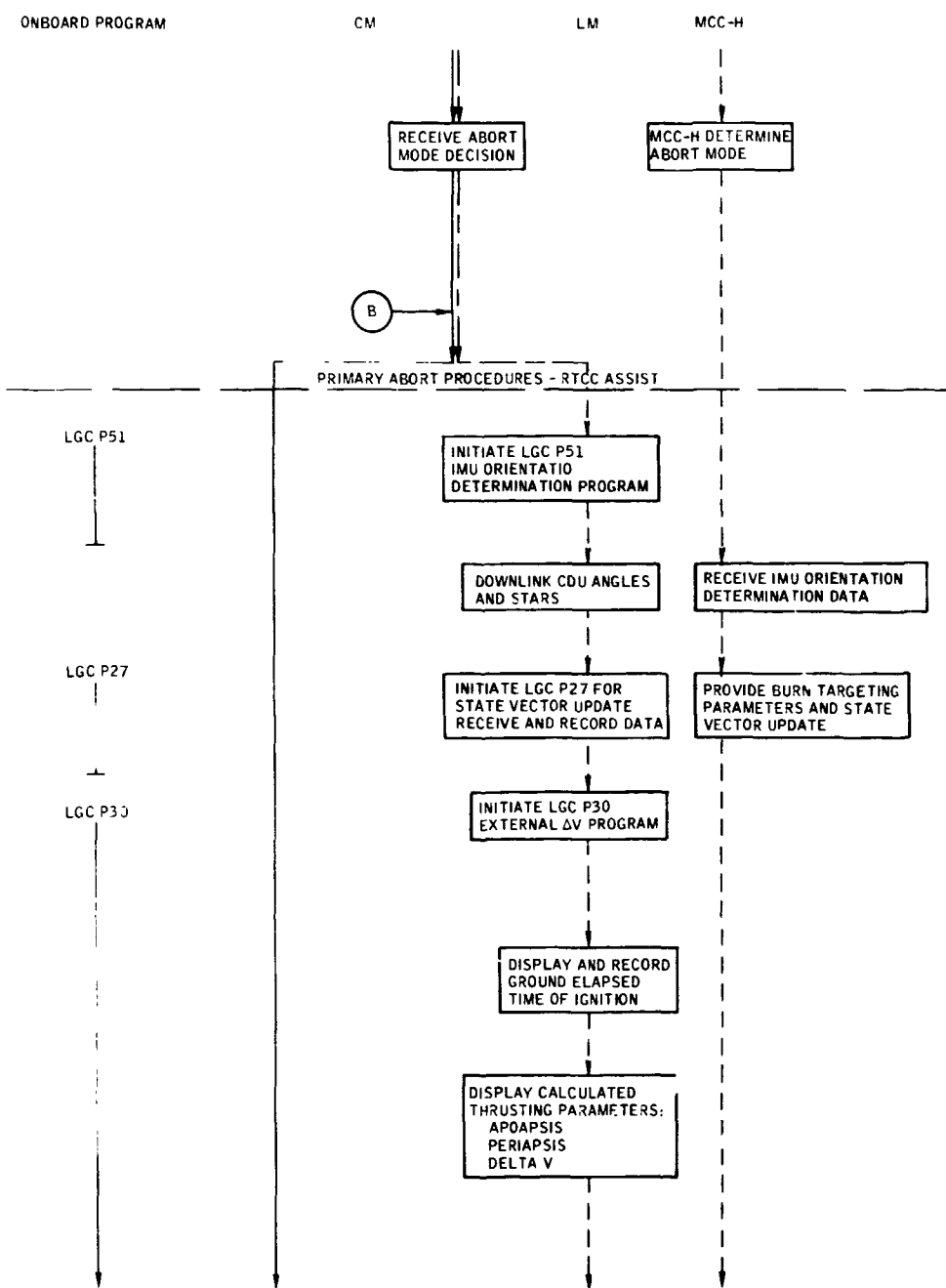


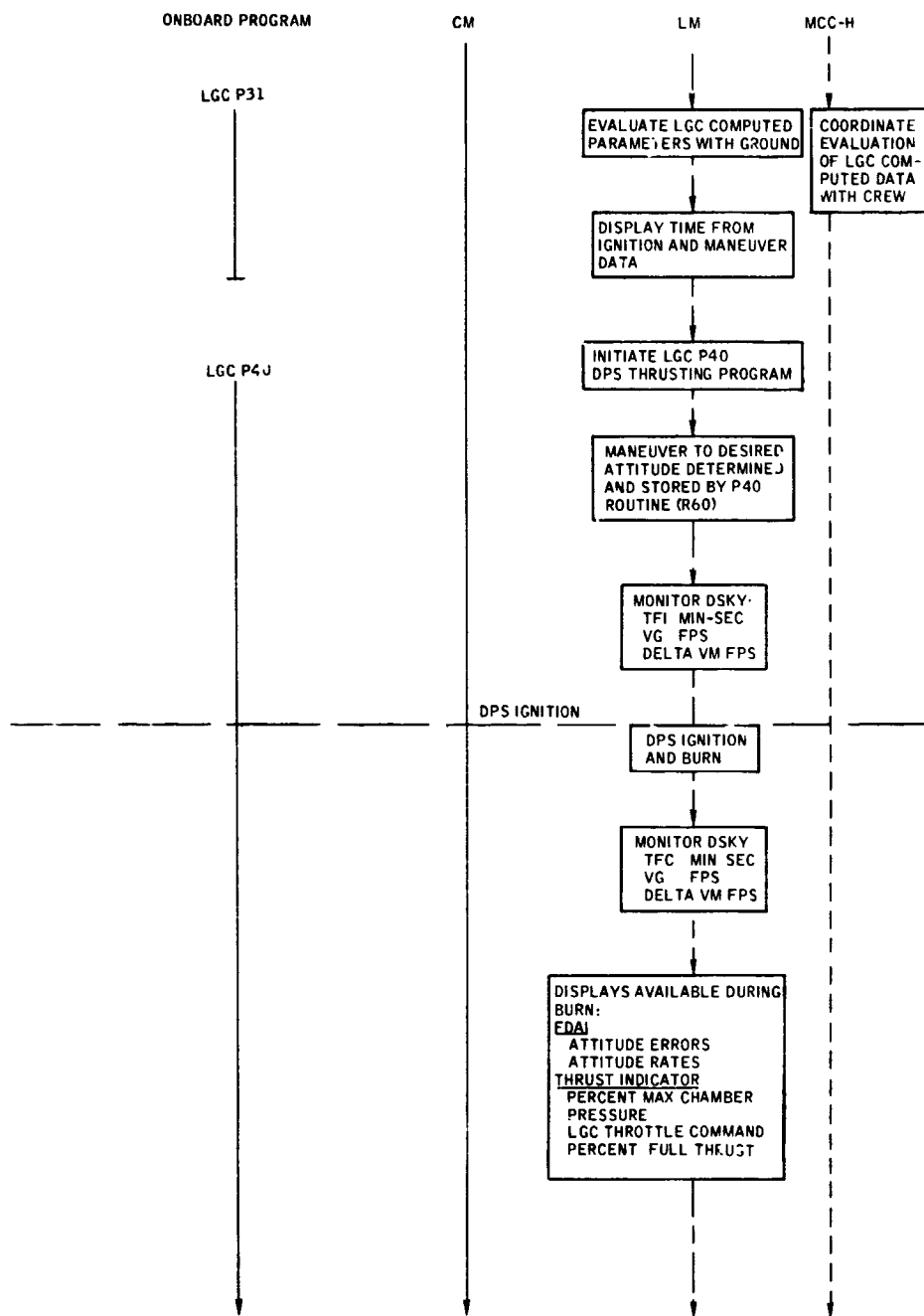




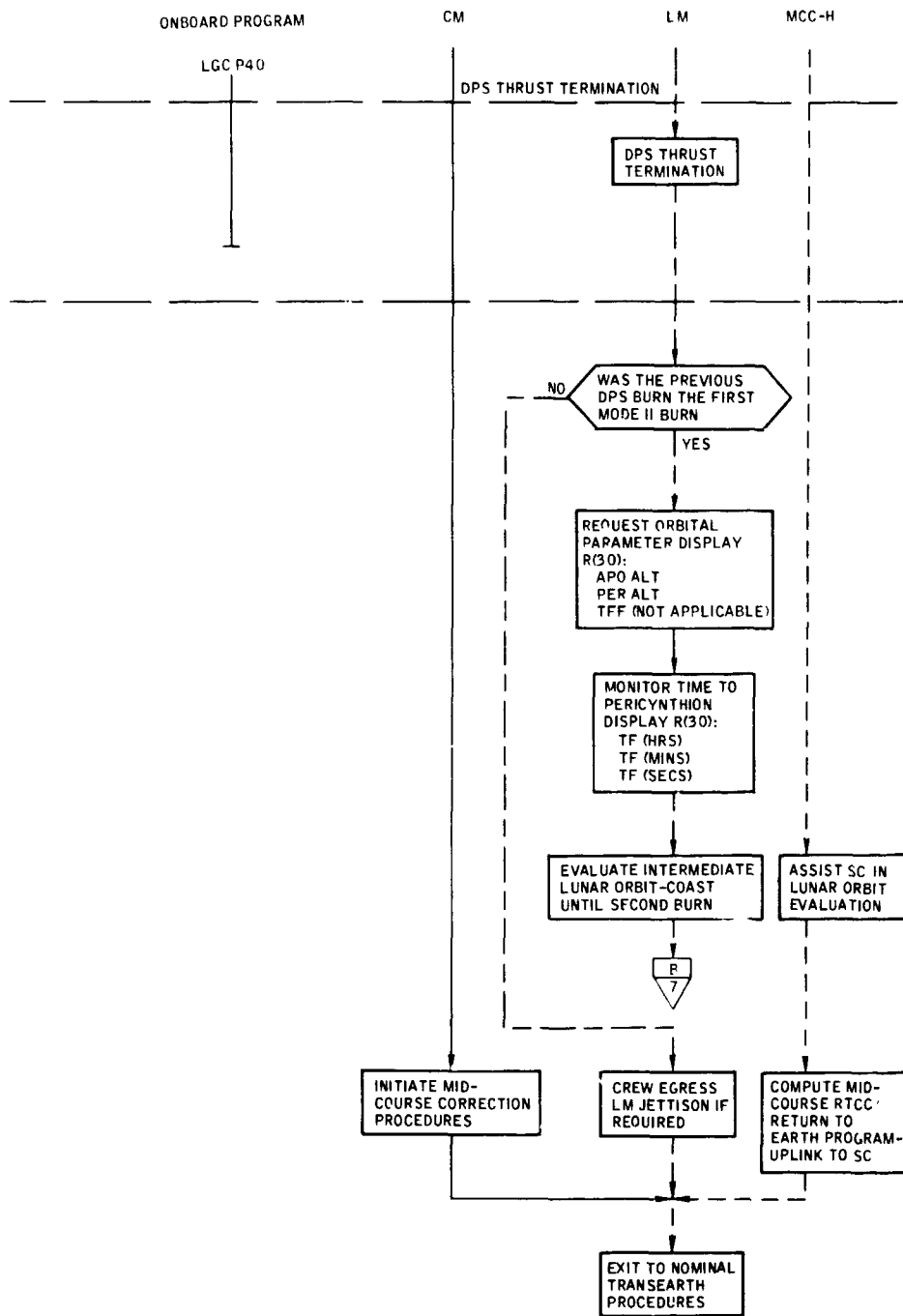


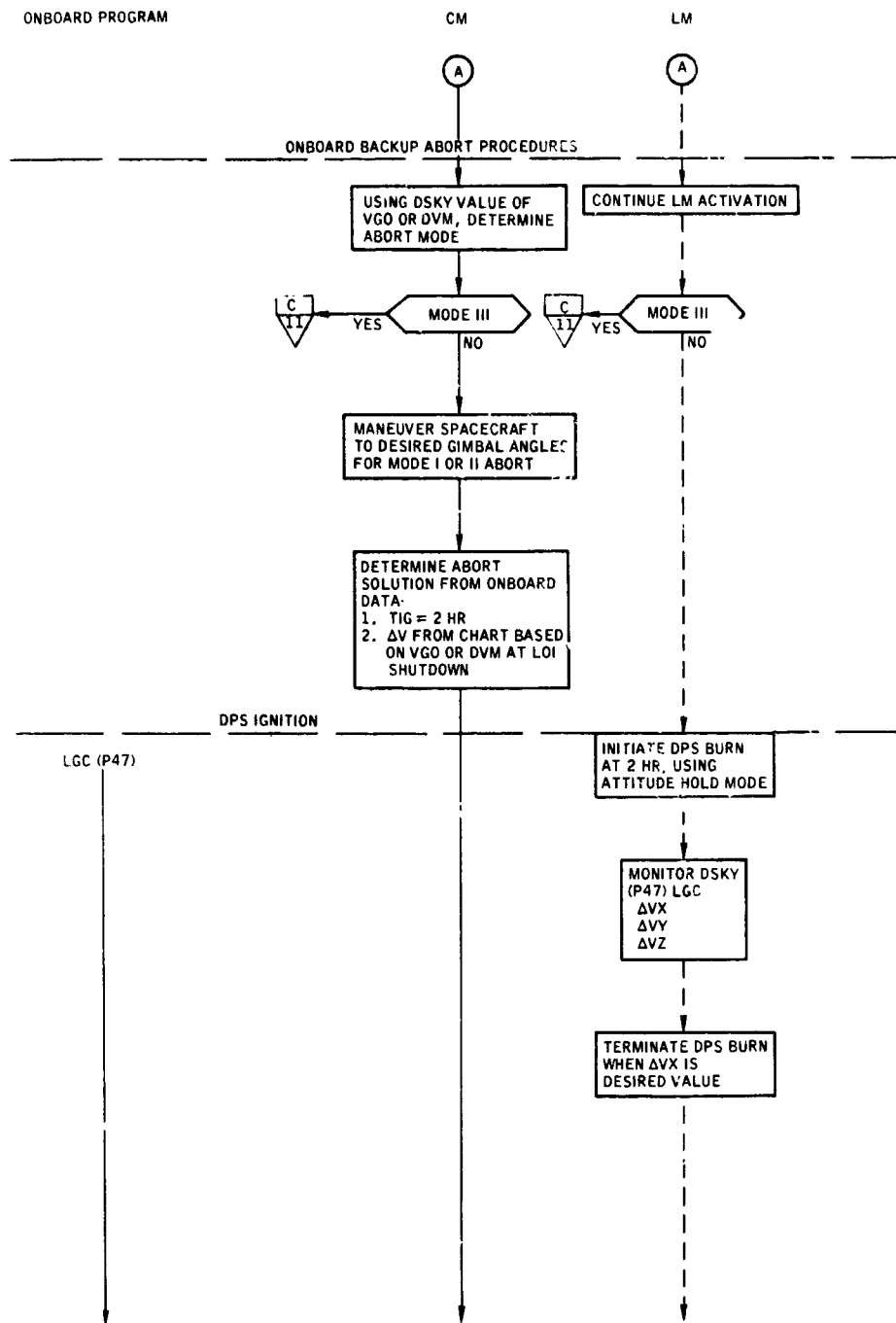




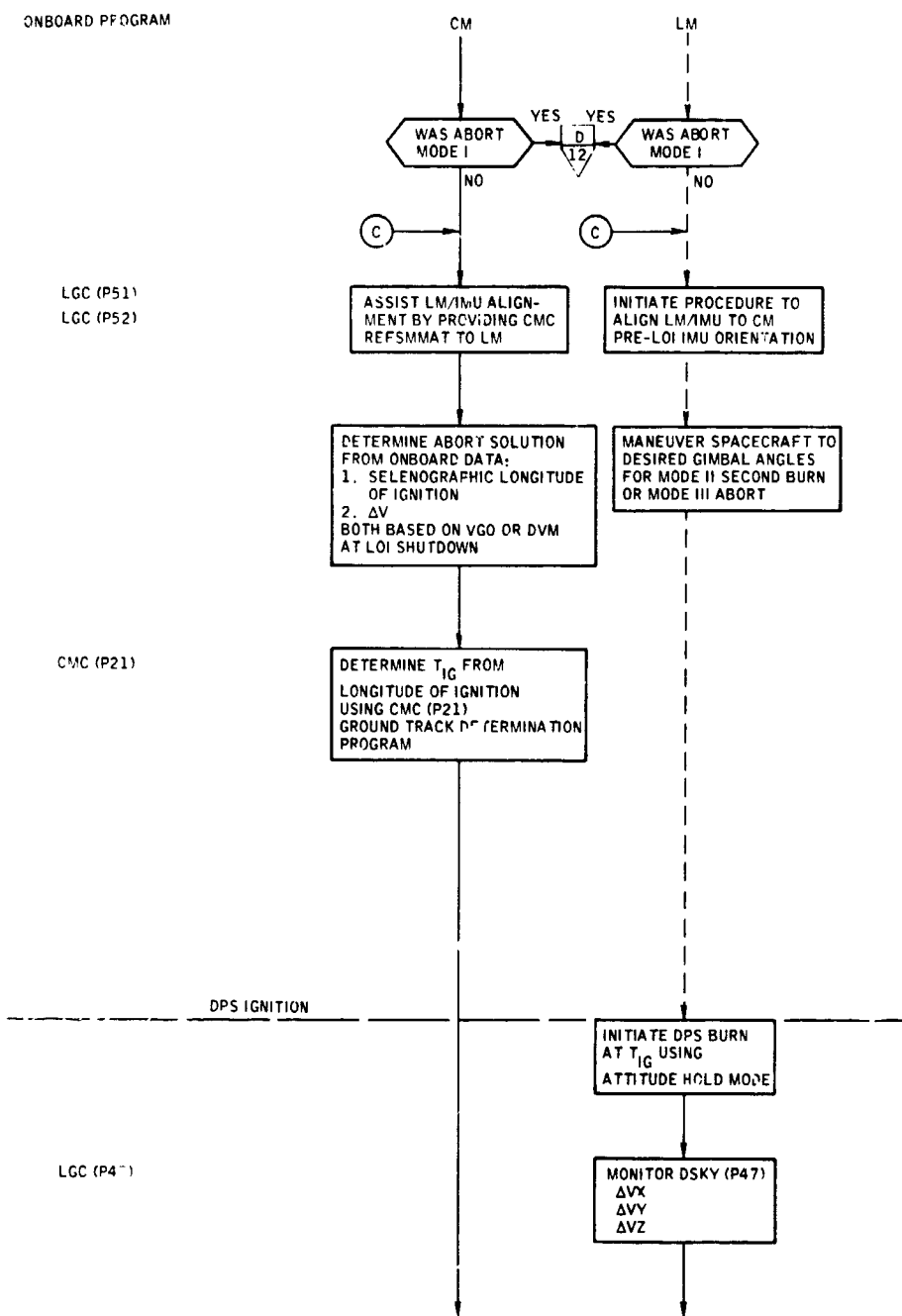


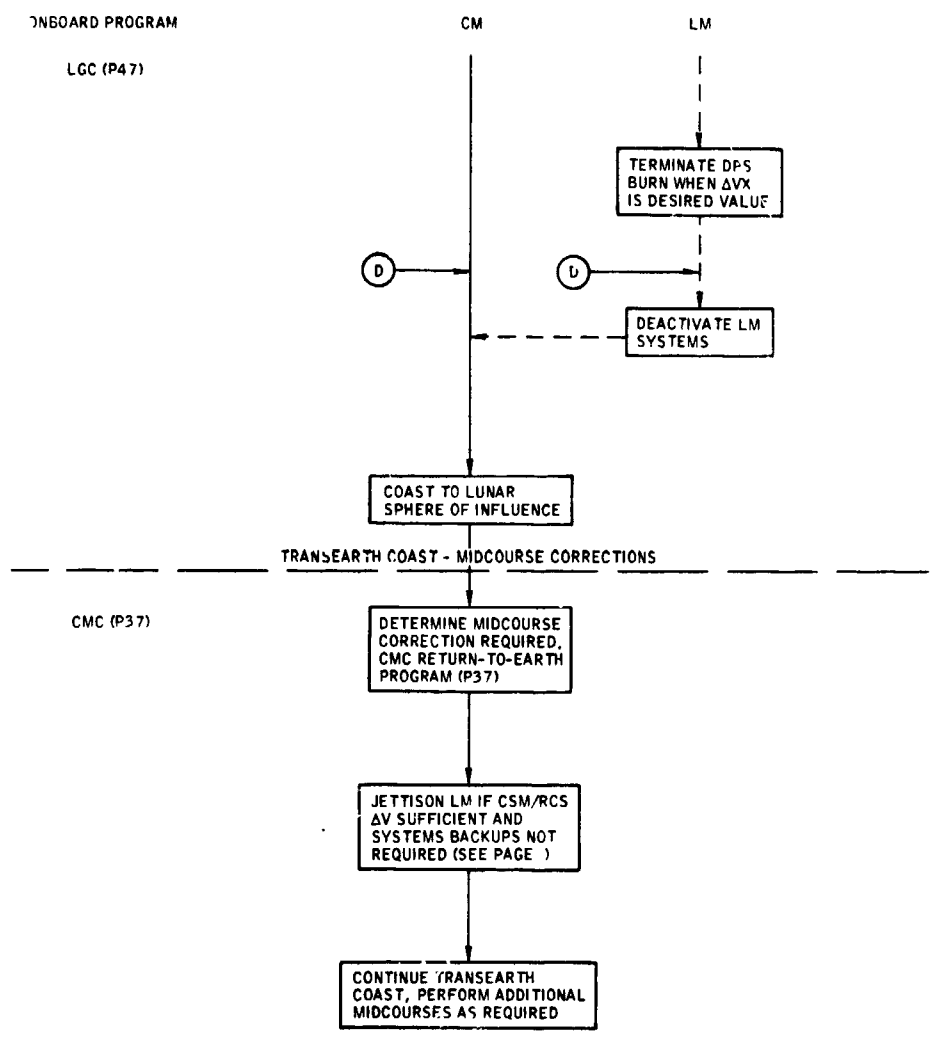






Flow chart 1.- Contingency procedures for the Lunar Orbit Insertion burn - Continued.





## 8.0 REFERENCES

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