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MAY 7, 1969

APOLLO MISSION TECHNIQUES
MISSIONS F AND G
LUNAR ORBIT ACTIVITIES
REVISION A

VOLUME 1
TECHNIQUES DESCRIPTION

APOLLO SPACECRAFT PROGRAM OFFICE
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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MISSIONS F AND G LUNAR ORBIT ACTIVITIES
REVISION A - VOLUME I
TECHNIQUES DESCRIPTION

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HOUSTON, TEXAS

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

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FOREWORD

This document presents the officially approved guidance and control sequence of events, the data flow, and real-time decision logic for the mission F and G lunar orbit activities. The purpose of this document 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, comprised of representatives of MSC and support contractors, 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.

NOMENCLATURE

AOS	acquisition of signal
APS	ascent propulsion system
ASCP	attitude set control panel
ATT	attitude
AZ	azimuth angle
BMAG	body-mounted attitude gyros
BSS	boresight star
BT	burn time (time from engine on to engine off)
BT F/A	burn time for/aft
BT L/R	burn time left/right
BT U/D	burn time up/down
CDH	concentric delta height
CDR	commander
CES	Control Electronics Section
CFP	concentric flight plan
CM	command module
CMC	command module computer
CMP	command module pilot
COAS	crewman optical alignment sight (boresight)
CSI	concentric sequence initiation
CSM	command and service module
DAP	digital autopilot
DECA	descent engine control assembly
DSKY	display and keyboard (CMC)
ECI	earth-centered inertial (reference frame)

NOMENCLATURE (Continued)

EDA	electronic display assembly (SCS)
EL, E	elevation angle
FDAI	flight director attitude indicator
FOV	field of view
g.e.t.	ground elapsed time
GETI	ground elapsed time of ignition (MCC-H nomenclature)
GETMID	desired g.e.t. of TPI (midpoint of darkness)
H	altitude
HA	height of apogee
HP	height of perigee
IAVG	moment of inertia (average of body Y- and Z-axes)
IMU	inertial measurement unit
IXX	moment of inertia about body X-axis
LDS	landing site
LEB	lower equipment bay
LMP	lunar module pilot
LOS	line of sight or loss of sight
MCC-H	Mission Control Center - Houston
MSFN	Manned Space Flight Network
N	number of apsidal crossing
OI	orbit insertion
ORDEAL	orbital rate display - earth and lunar
OUA	optical unit assembly (SXT, SCT)
P	pitch gimbal angle at burn attitude
P05	PGNCS Power-up Program
P20	RDZ Navigation Program

P27	LGC (CMC) Update Program
P30	External ΔV Program
P32	CSI Targeting Program
P33	CDH Targeting Program
P34	TPI Targeting Program
P35	TPM Targeting Program
P40	DPS (or SPS) Thrust Program
P41	RCS Thrust Program
P42	APS Thrust Program
P47	Thrust Monitor Program
P51	IMU Orientation Determination Program
P52	IMU Realign Program
PAD	data voiced to crew from ground
PC	plane change
PGNCS	primary guidance navigation and control system
PIPA	pulse integrating pendulous accelerometer
R	range
R	roll gimbal angle at burn attitude
$\dot{R}$	range rate
RCS	reaction control system
RDZ	rendezvous
REFSMMAT	transformation matrix from ECI reference frame to IMU inertial coordinates
RHC	rotational hand controller
RJ/EC	reaction jet and engine on/off control assembly
$\underline{R}_{LS}$	landing site position vector

RSS	root sum square
SC	spacecraft
SCS	stabilization and control system
SCT	scanning telescope
SPS	service propulsion system
SXT	sextant
SXTS	sextant star
TBD	to be determined
TD	desired g.e.t. of TPI (same as GETMID)
TFI	time from ignition
TGO	time to go to event
TGT	target
THC	translational hand controller
TIG	time of ignition (CMC nomenclature)
TPF	terminal phase final
TPI	terminal phase initiation
TPM	terminal phase midcourse
TRN	trunnion angle of SXT
Vgx	X-component of velocity to be gained in body axes
Vgy	Y-component of velocity to be gained in body axes
Vgz	Z-component of velocity to be gained in body axes
Vgx (LV)	X-component of velocity to be gained in local vertical axes
Vgy (LV)	Y-component of velocity to be gained in local vertical axes
Vgz (LV)	Z-component of velocity to be gained in local vertical axes

NOMENCLATURE (Continued)

Vgm	total velocity to be gained
V_m	accumulated delta velocity
Y	yaw gimbal angle at burn attitude
$\dot{Y}$	out-of-plane velocity
ΔH	difference in height of LM and CSM
ΔTT	transfer duration from TPI to intercept
ΔV	delta velocity
ΔV F/A	ΔV forward/aft required for TPI (in LOS coordinates)
ΔV L/R	ΔV left/right required for TPI (in LOS coordinates)
ΔV U/D	ΔV up/down required for TPI (in LOS coordinates)

1. INTRODUCTION

This document presents the guidance and navigation sequence of events, data flow, and real-time decisions for the missions F and G lunar orbit activities. A functional description of activities is presented in Section 2. Section 3 presents a general discussion of techniques for both spacecraft. Section 4 presents a discussion of the sequence of events in chronological order. Contingency procedures required for the various phases are contained in Section 5.

The flow charts (Section 6) document the approved mission techniques for verification and usage of G&N data and identify the backup procedures to be used if the G&N fails. The charts do not attempt to delineate all routine procedures except as they differ from standard practice or provide additional information. System comparison limits for each decision point were obtained from various analysis reports which are referenced in the notes.

It is to be emphasized that the F mission has been basically designed to develop, test, and evaluate all lunar orbit operations to be used on a lunar landing flight except powered descent, lunar surface activities, and powered ascent. Additional test objectives have been included whenever it was possible to do so without jeopardizing that basic mission design objective. As a result, with minor exceptions, the mission techniques defined in this document have been designed to apply directly to the G mission as well as the F. These exceptions are noted specifically in this document.

2. FUNCTIONAL DESCRIPTION OF THE LUNAR ORBIT ACTIVITIES

This section presents a brief description of the nominal sequence of events while in lunar orbit. The lunar orbit activities start when the lunar parking orbit circularization maneuver (LOI-2) is completed and terminate when preparations for the transearth injection (TEI) burn are initiated. Prior to this time, LOI-1 and LOI-2 have been performed in such a manner that the docked CSM/LM spacecraft is in a near-circular retrograde orbit of approximately 60 nautical miles. An abbreviated timeline for the activities during this period is given in Figure 2-1 and consists of the following sequence of events:

1) Prerest period LM partial activation
2) Postrest period LM activation and systems checkout
3) Undocking of the CSM from the LM
4) Station keeping by the CSM to inspect the LM landing gear and structure
5) CSM separation maneuver
6) LM descent orbit insertion (DOI) maneuver to reduce perigee to 50,000 feet
7) LM phasing maneuver and coast for 117 minutes
8) LM descent stage jettison
9) LM insertion maneuver
10) LM active rendezvous (CSI/CDH/TPI/TPF)
11) LM/CSM docking
12) Unmanned APS burn to depletion
13) Landmark tracking and strip photography.

Following the LOI-2 maneuver and prior to the first lunar orbit sleep period, the lunar module pilot (LMP) and the commander (CDR) enter the LM and perform the initial LM activation. The command module pilot (CMP) performs pseudo landing-site observations to provide real-time training and familiarization with the terrain. Following the sleep

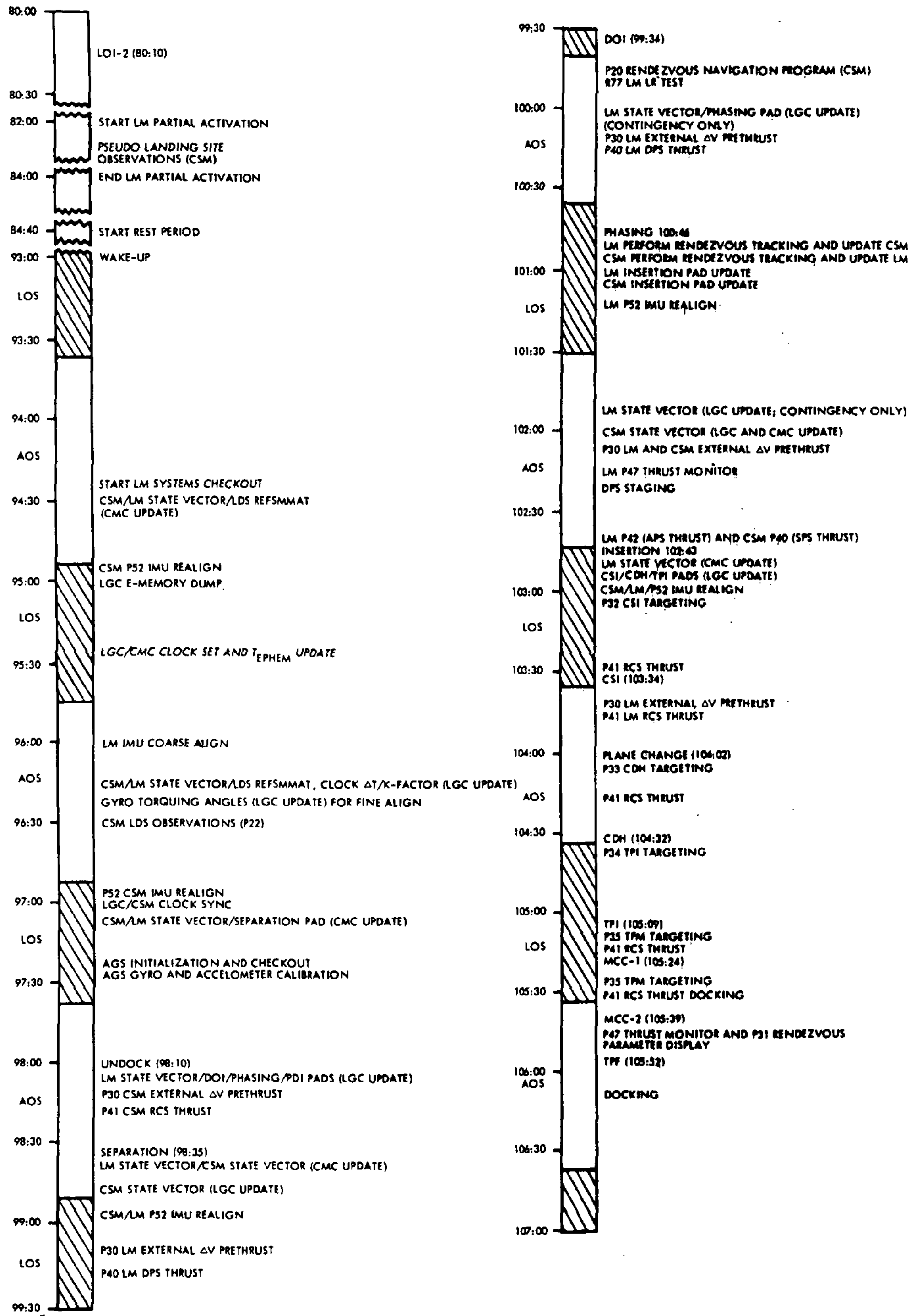

Figure 2-1. F Mission Lunar Activities Timeline

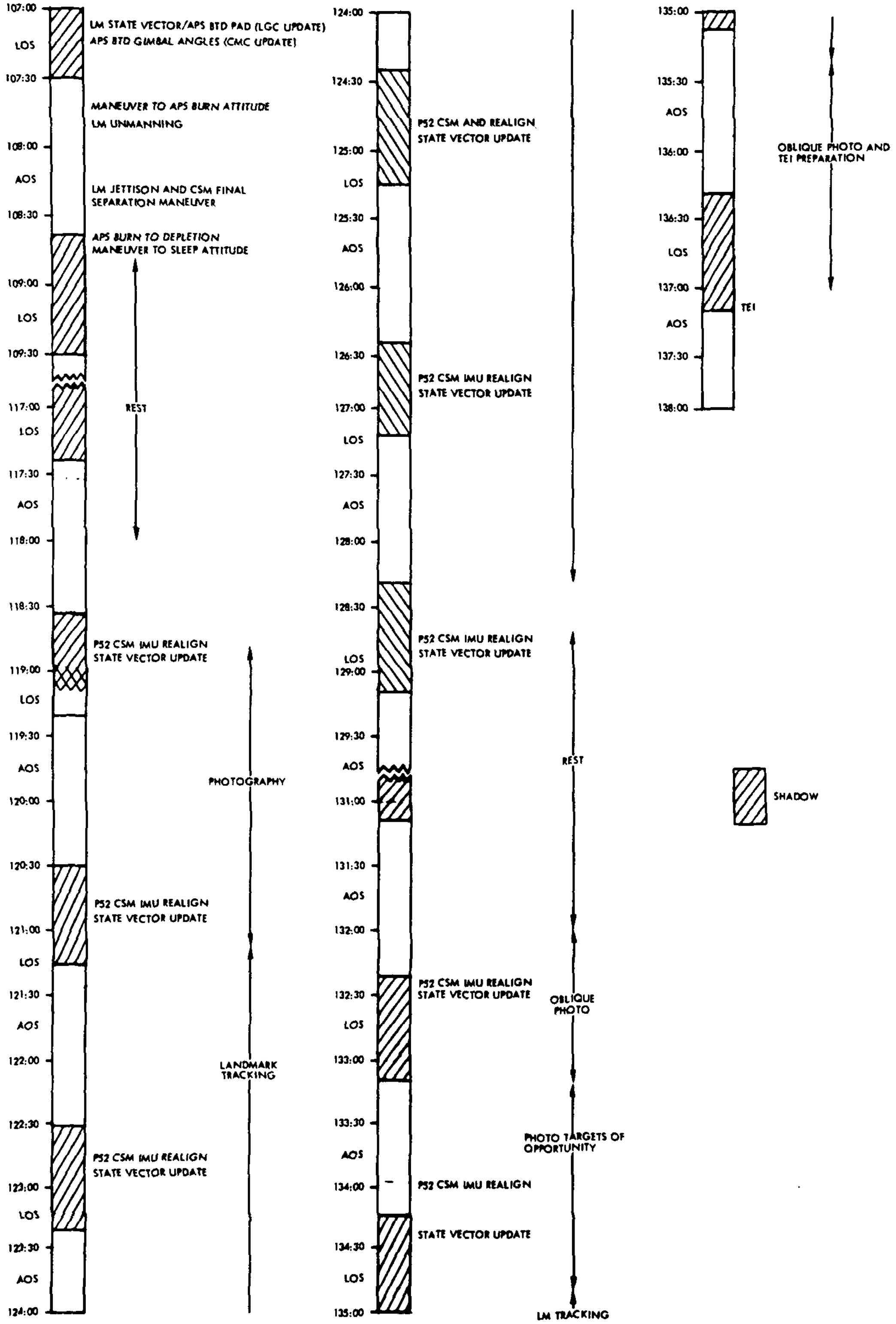

Figure 2-1. F Mission Lunar Activities Timelines (Continued)

period for all crew members, the LMP and the CDR reenter the LM and complete the LM activation and systems checkout. Landing-site observations are again performed by the CMP one revolution prior to separation and the data are processed by the RTCC. These sightings are used to improve the accuracy of the descent targeting for the G mission lunar landing.

Undocking will take place approximately 25 minutes prior to the RCS separation burn. After the CSM undocks from the LM, the CSM will station keep to inspect the LM landing gear and structure while the LM does a rotation maneuver (yaw) at 1 degree per second for 360 degrees. When the inspection is complete, the LM will station keep while the CMP prepares for the RCS separation. The separation burn is a 2.5-foot per second radial inward maneuver which results in the CSM leading the LM by 11,400 feet at descent orbit insertion (DOI) one-half revolution later. Also, if DOI is not performed, this maneuver places the CSM in a position for manual braking and rendezvous approximately one revolution later.

The DOI maneuver is performed 195 degrees prior to the targeted landing site and is a PGNCS controlled retrograde burn of about 71 feet per second using the descent propulsion system (DPS). This Hohmann descent transfer maneuver serves to reduce perilune to 50,000 feet at 15 degrees prior to the targeted landing site, the position at which powered descent will be initiated for a G-mission lunar landing. Following DOI, approximately 72 minutes of coasting flight during the Hohmann descent will allow close observation of the planned landing sites. Figure 2-2 shows the relative position of the LM with respect to the CSM from DOI through the terminal phase of the LM active rendezvous.

Approximately 16 minutes (50 degrees) past perilune or approximately 11 minutes (35 degrees) past the landing site, a LM phasing maneuver of 195 feet per second is performed using the DPS. This posigrade maneuver is designed to establish (at insertion) a CSM lead angle equivalent to that which occurs at nominal powered ascent cutoff in the lunar landing mission. The LM apolune altitude resulting from the phasing maneuver is 195 nautical miles which affords

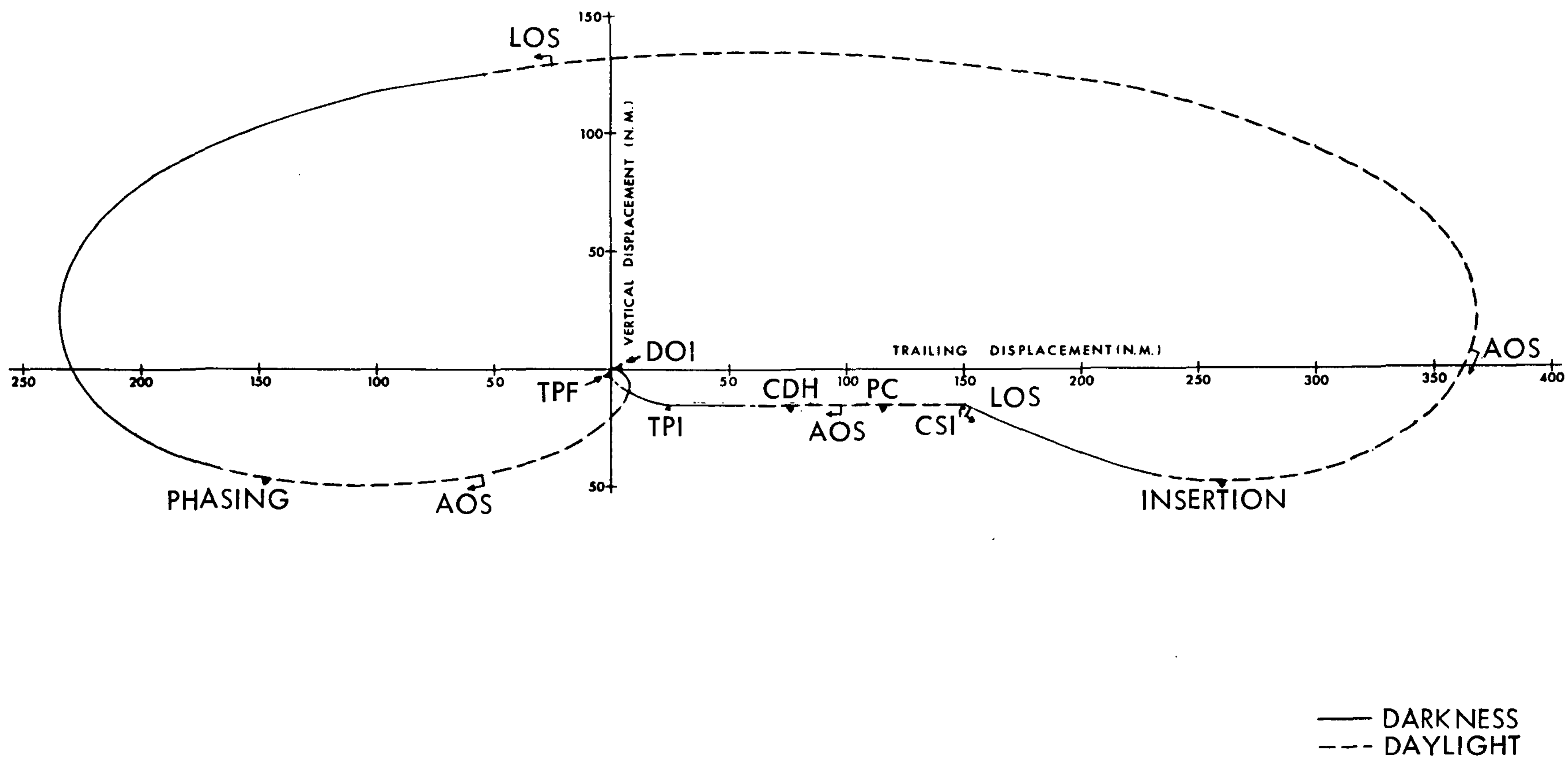

Figure 2-2. F Mission Lunar Activities Relative Motion (CSM Centered Curvilinear Coordinates) (For Reference Only)

the required CSM catch-up time between phasing and insertion. The CSM lead angle is approximately -9 degrees at phasing and +16 degrees at insertion. The resulting perilune altitude following phasing is approximately 60,000 feet.

Approximately 2 hours following phasing, the LM descent stage is jettisoned and the insertion maneuver of 207 feet per second with a 30-foot per second radial component is performed. This maneuver using the ascent propulsion system (APS) is designed to establish the equivalent of the LM insertion orbit (9 by 45 nautical miles) of the lunar landing mission. At the completion of the insertion maneuver, the conditions are equivalent to those at powered ascent cutoff for the lunar landing mission, and the LM active rendezvous is initiated.

Approximately 51 minutes after LM insertion, the CSI maneuver is performed using the LM RCS. This 50-foot per second maneuver results in a near-circular LM orbit of approximately 45 nautical miles. The CDH maneuver of about 4 feet per second is executed one-half of the LM orbital period (approximately 58 minutes) after CSI and is designed to circularize the LM orbit at a constant delta height of 15 nautical miles below the CSM orbit. When the elevation angle from the LM to the CSM reaches 26.6 degrees (approximately 37 minutes after CDH), the LM terminal phase initiation (TPI) maneuver is executed. This nominal 25-foot per second maneuver is designed to place the LM on a trajectory that will intercept the CSM orbit after 130 degrees of CSM travel. Two midcourse correction maneuvers are scheduled between TPI and braking: the first, 15 minutes after TPI, and the second, 30 minutes after TPI. Terminal phase final (TPF) braking is initiated 43 minutes after TPI which circularizes the LM orbit at 60 nautical miles altitude. Docking is accomplished after completion of the braking maneuvers in which relative range and range rate are reduced to zero.

Following the lunar rendezvous and docking, the LM crew configures the LM for jettison and an APS burn to propellant depletion, then transfers to the CSM. The LM is jettisoned shortly after AOS, approximately 2 hours after docking. The APS burn to propellant depletion is initiated at 0 degree longitude about 30 minutes after LM jettison. This maneuver is targeted to place the LM in solar orbit. The remainder of the lunar orbit activities are devoted to landmark tracking, strip photography, and TEI preparations.

3. GENERAL TECHNIQUES DISCUSSION

3.1 GO/NO-GO DECISIONS

Go/no-go decisions are made by the crew at three points in the mission based on the equipment required in Tables 3-1 and 3-2. The basic requirement before initiating DOI is that the LM should be able to perform the navigation, targeting, and burns required for a LM active RDZ, and the CSM should be able to perform the navigation, targeting, and burns required for a LM rescue. Secondly, before committing to the next phase of the lunar orbit activities and risking the crew with a failed system, completion of that phase should satisfy a primary mission objective. Table 3-1 assumes single failures only; i.e., when a system is not required, it is assumed that all other systems are available (exceptions are called out in the notes).

3.2 LM RDZ NAVIGATION

RDZ navigation is conducted in the LM using the RDZ Navigation Program (P20) and RR data to update the LM state vector in the LGC and in some cases to update the CSM state vector in the LGC. RR tracking is conducted per the tracking schedule shown in Table 3-3. The W-matrix is manually reinitialized at specific points as shown in the tracking schedule to reduce navigation errors. The W-matrix values are 2,000 feet in each position component, 2 feet per second in each velocity component, and 5 milliradians for each angle for all reinitializations except following the phasing and insertion maneuvers. The W-matrix values manually entered for the reinitialization following phasing and the first reinitialization following insertion are 10,000 feet, 10 feet per second, and 15 milliradians.

Throughout the RDZ sequence from insertion + 20 minutes to TPF, the LM will be held at the RDZ tracking attitude to maintain RR lock with the exception of CSI, TPI, and possibly, CDH. This means that the PC maneuver will be accomplished with the Z-axis boresighted (or nearly so) on the CSM. On mission G, the TPI maneuver will also be accomplished with the Z-axis boresighted on the CSM to maintain RR lock.

Table 3-1. Mission F Mandatory Spacecraft Systems

LM Systems	Undocking and Separation[1]	DOI
PGNCS LGC	R[2]	R
IMU	R[2]	R
DSKY	R[2]	R
AGS (ASA, AEA, DEDA)	NR	NR
CES	R[2]	R
DPS/DECA	NR	R
RR	NR	R
Tape Meter	NR	NR
FDAI	NR	R[3]
AOT or COAS	NR	R[4]
Hand Controllers[5]	R	R
Crosspointers	NR	NR
Flashing Light on LM	NR	NR
CSM Systems		
GNCS CMC	NR	NR
IMU	NR	NR
DSKY	NR	NR
Optics SXT	NR	NR
SCT	NR	NR
COAS	NR	NR
SCS BMAGS	NR	R[6]
GDC	NR	R
FDAI	NR	R[3]
SPS[7]	R	R
Hand Controllers	R	R
EMS ΔV Counter	NR	NR
VHF Ranging	NR	NR
RR Transponder	NR	R
Flashing Light on CSM	NR	NR

(1)The separation maneuver and mini-football activities will be performed for all conditions allowing undocking.

(2)Either PGNCS or CES required. (Direct mode provides redundant capability).

(3)Only one unit is required.

(4)Assumes either unit can be used to align IMU.

(5)Translation and at least one RHC.

(6)One set of BMAGS required.

(7)If SPS has failed, TEI will be performed at the next opportunity.

Table 3-2. Mission G Mandatory Spacecraft Systems

LM Systems	Undocking and Separation[1]	DOI	PDI
PGNCS LGC	R	R	R
IMU	R	R	R
DSKY	R	R	R
AGS (ASA, AEA, DEDA)	R	R	R
CES	R	R	R
DPS/DECA	R	R	R
RR	NR	R	R
Tape Meter	NR	NR	R
FDAI	R[2]	R[2]	R[2]
AOT	NR	R	R
Hand Controllers[3]	R	R	R
Crosspointers	NR	NR	R
Flashing Light on LM	NR	R	R
CSM Systems			
GNCS CMC	R	R	TBD
IMU	R	R	TBD
DSKY	R	R	TBD
Optics SXT	NR	R	TBD
SCT	NR	R	TBD
COAS	NR	R	TBD
SCS BMAGS[4]	R	R	TBD
GDC	R	R	TBD
FDAI	R	R	TBD
SPS[5]	R	R	TBD
Hand Controllers	R	R	TBD
EMS ΔV Counter	NR	NR	TBD
VHF Ranging	NR	NR	TBD
RR Transponder	NR	R	TBD
Flashing Light on CSM	NR	R	TBD

(1) The separation maneuver and mini-football activities will be performed for all conditions allowing undocking.

(2) Only one unit is required.

(3) Translation and at least one RHC.

(4) One set of BMAGS required.

(5) If SPS has failed, TEI will be performed at the next opportunity.

Table 3-3. Onboard Tracking Schedule for Mission F (Reference 1)

LM Events	Time (Min)	CSM Events	Time (Min)
DOI	-189	DOI	-189
		IT	-136
		CT	-126
Phasing	-117	Phasing	-117
		IT[1]	-112
IT[2]	-111		
CT	-106		
IT[2,3]	- 87		
		CT	- 79
CT	- 72		
		IT[1]	- 54
IT[2]	- 35		
		CT	- 34
CT	- 22		
Insertion	0	Insertion	0
IT[4]	18		
		IT[5]	19
		CT (SXT)[6]	24
CT	39	CT (VHF)[6]	39
CSI	51	CSI	51
IT[7]	56		
		IT[8]	58
CT	74		
		CT	79
PC	80	PC	80
IT[7]	82		
		IT[8]	85
CT	97	CT	97

Table 3-3. Onboard Tracking Schedule for Mission F (Reference 1) (Continued)

LM Events	Time (Min)	CSM Events	Time (Min)
CDH Maneuver	109	CDH Maneuver	109
IT[7]	111		
		IT[8]	115
		CT	133
CT	134		
TPI Maneuver	146	TPI Maneuver	146
IT[9]	149	IT[10]	151
CT	158	CT	158
MCC-1	161	MCC-1	161
IT[9]	163	IT[10]	164
CT	173	CT	173
MCC-2	176	MCC-2	176

(1) Reinitialize W-matrix after third mark to 10,000 feet, 10 feet per second.

(2) Update the CSM state vector only during this interval.

(3) Reinitialize W-matrix after fourth mark to 10,000 feet, 10 feet per second, 0.015 radian.

(4) Reinitialize W-matrix before first mark to 10,000 feet, 10 feet per second, 0.015 radian.

(5) Reinitialize W-matrix before first mark to 10,000 feet, 10 feet per second.

(6) Sextant tracking will cease at 24 minutes following insertion unless the range exceeds 327 nautical miles, in which case VHF will be inhibited (V88) and SXT tracking continued until insertion + 39 minutes.

(7) Reinitialize W-matrix after fourth mark to 2,000 feet, 2 feet per second, 0.005 radian.

(8) Reinitialize W-matrix after third mark to 2,000 feet, 2 feet per second.

(9) Reinitialize W-matrix before first mark to 2,000 feet, 2 feet per second, 0.005 radian.

(10) Reinitialize W-matrix before first mark to 2,000 feet, 2 feet per second.

(11) IT = Initiate Track, CT = Cease Track

On mission F, TPI will be performed using X-axis RCS through the APS interconnect and, therefore, will break RR lock to perform TPI. The difference in procedures reflects the different propellant loading between mission F and G.

Because of the crowded crew timeline, the AGS will not be updated with RR data on either mission F or G unless the PGNCS fails. The AGS state vectors will be initialized from the PGNCS and the AGS aligned to the PGNCS following verification of each PGNCS rendezvous maneuver solution.

In the RDZ tracking period preceding CSI, CDH, and TPI, the CDR will read RR range and range rate from the tape meter and transmit them to the CMP for comparison with range and range rate read out of the CMC. The readouts are manually synchronized by voice communication to allow comparisons of the data for an evaluation of the CMC navigation accuracy.

3.3 CSM RDZ NAVIGATION AND EVALUATION

RDZ navigation is conducted in the CSM using the RDZ Navigation Program (P20) and SXT tracking and VHF ranging data to update the LM state vector. SXT and VHF ranging data are incorporated according to the tracking schedule (Table 3-3).

If valid VHF range data are available at ranges less than 327 nautical miles, the P20 program should accept and allow the range data to correct the state vector. Since a range ambiguity exists at ranges greater than 327 nautical miles, the VHF data should be inhibited using V88 beyond this range. The W-matrix is manually reinitialized as shown in the tracking schedule to reduce navigation errors. The W-matrix values are 2,000 feet in each position component and 2 feet per second in each velocity component except the reinitializations after phasing and the first reinitialization immediately following the insertion maneuver. The values manually entered after phasing and for the first reinitialization following insertion are 10,000 feet and 10 feet per second.

In the RDZ tracking periods preceding CSI, CDH, and TPI, the CMC's navigation capability is verified by evaluating the CMC input data. The CMP determines if the SXT data have been good (crew judgement) and compares navigated range and range rate from the CMC with RR data from the LM. If the CMC range and range rate agree with RR range and range rate and the SXT data has been good, the CMC solutions for CSI, CDH, and TPI will be used to verify the LGC solution.

3.4 LM AND CSM STATE VECTOR CORRECTION LIMITS DURING RDZ NAVIGATION

The LM and CSM differential state vector correction limits (RMAX and VMAX) in the LGC and CSM will be set to 2,000 feet and 2 feet per second. However, the RMAX and VMAX are expected to be exceeded for the first mark after a maneuver or after a long time period of no navigation. Between DOI and CSI, the crew will accept the state vector corrections if RMAX is less than 12,000 feet and VMAX is less than 12 feet per second but will verify a downward trend in the magnitude of the corrections as the relative state is continually improved. If the state vector corrections do not decrease, the crew will investigate the tracking data source to verify that the system is operating correctly before continuing to accept the corrections. If the corrections exceed 12,000 feet or 12 feet per second, the crew will reject the mark and take action to determine if the data source is valid. After CSI, the differential correction acceptability limit will be reduced from 12,000 feet and 12 feet per second to 5,000 feet and 5 feet per second since the expected relative errors between the onboard state vector are larger before CSI than following CSI.

3.5 CSM ACTIVITIES DURING LM MANEUVERS

As a nominal procedure, the CSM will be mirror-image targeted to back up the CSI, CDH, and TPI maneuvers. The ΔV components will be approximately the same as those for the LM with the sign changed, and the CSM TIG will be the same as the LM TIG. A one-foot per second bias is added to the LM CSI solution for use in the CSM if the LM fails to perform the CSI maneuver. However, the LM and CSM solutions for CDH and TPI can be compared directly (with a sign reversal) without biasing.

Since the CSM will be targeted with the same TIG as the LM for CSI, CDH, and TPI, the maneuver will necessarily be executed slightly late by the CSM for a LM failure at (or very near) nominal TIG. However, this situation is considered very unlikely due to the fact that these maneuvers are RCS burns. Obviously, if it is known beforehand that the LM will be unable to execute the maneuver, the CSM will perform the burn at the nominal TIG.

The CSM will not be mirror-image targeted to back up the phasing maneuver but instead will be targeted by the MCC-H to perform a rescue maneuver if the LM is unable to perform phasing. The maneuver (denoted Rescue No. 2) is a near horizontal, retrograde burn of approximately 50 feet per second with TIG being about DOI TIG + 119 minutes.

The CSM will be targeted (not mirror image) by the MCC-H to back-up the insertion maneuver in the event the LM fails to complete the burn. The CSM will use a TIG three minutes later than the LM TIG to allow time for the LM crew to check the failure and contact the CSM. A delay of three minutes also prevents turning on the SPS gimbal motors until it is known that a CSM maneuver is required.

The CMP will always use the SPS engine for the phasing, insertion, CSI, CDH, and TPI backup maneuvers to conserve RCS propellant. The type of maneuver to be used in backing up a LM maneuver is further described in the nominal sequence of events in Section 4 and in the contingency procedures in Section 5.

After each LM maneuver except insertion, the CMP will update the LM state vector in the CSM using the Target ΔV Program (P76) inserting the P30 $\bar{V}g$ and TIG which is biased by one-half the nominal burn time. Following insertion, the LM state vector in the CMC will be updated by MCC-H using the LM telemetry state vector.

4. DETAILED TECHNIQUES DISCUSSION

This section presents in chronological order the G&N activities as related to the data requirements, real-time decisions, and techniques during the nominal lunar orbit activities.

4.1 DOCKED ACTIVITIES

This phase includes the lunar orbit activities from LOI-2 to initiation of undocking. These activities are

- Prerest period LM partial activation
- Pseudo landing site observations
- Postrest period LM activation and systems checkout
- Landing site observations

4.1.1 Prerest Period LM Partial Activation and Pseudo Landing Site Observations

Following the lunar parking orbit circularization maneuver (LOI-2) and prior to the first lunar orbit sleep period, the LMP and CDR enter the LM and perform general housekeeping chores and the initial LM activation. The LM guidance, navigation, and control systems will not be powered at this time. This two-hour period of activity primarily provides the crew an opportunity to get equipment stowed and other housekeeping chores done before DOI day. It also provides the flexibility to add any additional activities which may be discovered to be necessary at a later date.

During this period, the CMP performs a CSM IMU Realign (P52) to the landing site REFSMMAT uplinked earlier. In addition, the CMP performs pseudo landing site observations to provide real-time training and familiarization with the terrain. The observations will be performed on sites F-1 and B-1, using the Orbital Navigation Program (P22) in a manner similar to that discussed in Section 4. 1. 3.

4.1.2 Postrest Period LM Activation and Systems Checkout

Following the lunar orbit sleep period, the LMP and the CDR reenter the LM and start the LM activation and systems checkout. Detailed activities during this time period are discussed individually in subsequent paragraphs.

4.1.2.1 State Vector and REFSMMAT Updates

On the revolution prior to the landing-site observations, the MCC-H will uplink to the CMC using P27 the LM/CSM state vector which is time tagged near the landmark sighting time and the landing site REFSMMAT which is computed for the nominal time of landing.

On the revolution during the landing-site observations, the MCC-H will uplink to the LGC using P27 the LM/CSM state vector which is time tagged near undocking and the landing site REFSMMAT which is computed for the nominal time of landing.

The LGC and CMC landing-site REFSMMAT's are identical and are computed from the a priori knowledge of the landing-site location. They will not be changed later to agree with an updated landing-site location based on optical observations. The use of a REFSMMAT which is not based upon the updated landing-site location substantially simplifies procedures, but it will cause the gimbal angles to be non-zero at touchdown for the lunar landing mission. However, this difference is expected to be less than the resolution of the FDAI.

4.1.2.2 Docked IMU Alignments and Drift Checks

After the CMC landing-site REFSMMAT update from MCC-H, the CSM IMU is realigned to REFSMMAT using the IMU Realign Program (P52). When P52 is completed, a third star check using the auto optics routine will be performed. Adequate alignment of the IMU is assured if the third star is centered in the sextant field of view. If the alignment is not satisfactory, the procedure will be repeated. Once a satisfactory IMU alignment has been obtained, the GDC will be aligned to the IMU.

When the landing-site observations are complete and the spacecraft enters the lunar umbra, the CSM IMU is again realigned to REFSMMAT using the IMU Realign Program (P52), and a third star check using the auto optics routine is performed. Once a satisfactory IMU alignment has been obtained, the gyro torquing angles will be used to assess the gyro drift from the previous alignment. If at any time the gyro torquing angles indicate a change in gyro drift greater than 1.5 degrees per hour (Reference 2), the GNCS IMU has failed.

Prior to undocking, a LM PGNCS alignment is performed which enables an IMU drift check prior to DOI which will detect a failed IMU. The LM IMU is coarse aligned to the CSM IMU using the docked alignment procedure (Reference 3) which is based on the docking ring angle (DKAN), known CSM/LM geometry, and the CSM inertial attitude. The CMP will read the IMU gimbal angles from the DSKY and pass them to the LM. The LMP will compute the LM gimbal angles using the following equations:

$$OGA_{LM} = DKAN - 60 - OGA_{CM}$$

$$IGA_{LM} = IGA_{CM} + 180$$

$$MGA_{LM} = -MGA_{CM}$$

The LMP will then coarse align the LM IMU using V41N20 with the computed angles, and allow the LM IMU to go inertial. The CMP and LMP will then key V16N20 and stand by to enter in "verb." The CMP will give a mark and both the CMP and LMP will enter in "verb" to freeze the displayed gimbal angles. The IMU gimbal angles are voiced to MCC-H for calculation of fine align gyro torquing angles. These angles, voiced to the LM crew, are loaded into the LGC using fine align extended verb (V42) to torque the LM gyros to the desired angles.

While the spacecraft are docked, a gross LM IMU drift check will be performed by MCC-H noting changes in the difference between CSM and LM gimbal angles. If any gyro drift exceeds 1.5 degrees per hour, either the PGNCS or GNCS has failed. Because the GNCS has been powered up since launch, with approximately 10 realignments and drift checks, it is much more probable that the PGNCS has failed if the change in the difference between LM and CSM gimbal angles becomes excessive.

4.1.2.3 AGS Initialization and Calibration

Following the PGNCS alignment, the AGS state vectors are initialized from the PGNCS, AGS is aligned to the PGNCS, and the AGS accelerometers and gyros are calibrated. For the AGS alignment and calibration, the CSM is used to orient the LM to an AGS calibration attitude by displacing all three LM axes at least 11.5 degrees from zero or multiples of 45 degrees from the IMU principle axes. This technique will permit the AGS alignment and calibration to be performed without CDU transients.

The AGS calibration is performed after the navigation initialization. Gyro and accelerometer checks are made by the crew to determine if any of the accelerometer biases or gyro drift have exceeded the allowable limits. If the change in accelerometer bias exceeds 0.04 foot per second,* the AGS is considered failed. If the total gyro drift exceeds 2.5 degrees per hour, the AGS or PGNCS may have failed since the PGNCS is used as a reference for the AGS gyro drift test. If the total gyro drift is less than 2.5 degrees per hour,* the AGS is considered acceptable. If the total gyro drift is less than 1.5 degrees per hour, both PGNCS and AGS are considered verified.

4.1.2.4 CMC, LGC, and AEA Clock Synchronization

The MCC-H and crew will update the LGC clock and CMC clock as accurately as possible using ground elapsed time from lift-off as the time reference. The CMC clock will be updated by the ground, after which the LM crew will synchronize the LGC clock to the CMC clock. The ground will then compute the difference between ground time and LGC time (ΔT) and voice it to the LM crew. Fine synchronization of the LGC clock will be accomplished by the ground or manually by the crew using the ΔT.

The AEA clock is initialized relative to the LGC clock by the crew using the AGS initialization routine in the LGC (R47). The AGS time bias used is an integral number of hours (nominally 90:00:00 (hr:min:sec, g.e.t.)) to facilitate monitoring by the LM crew.

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*Supplied by TRW

4.1.3 Landing-Site Observations

Landing-site observations will be performed by the CMP one revolution prior to separation, and the data will be processed by the RTCC. The optical sightings will be performed in the pitch mode using the Orbital Navigation Program (P22). A predetermined inertial attitude will be held until the spacecraft is at a 35-degree elevation angle as viewed from the landmark. At this time, a pitch rate of at least 0.3 degree per second is initiated. The local vertical attitude at the time of starting the pitch rate is 0, -2.1, 0 degrees roll, pitch, and yaw, respectively. MCC-H will supply the following data to the crew in real time:

a) Time at which the identification point is at an elevation angle of 35 degrees

b) Time to start the pitch rate

c) Inertial attitude to be held until the pitch rate is started

d) Shaft and trunnion angles at the initiation of the pitch rate

e) Whether the landmark will be north or south of ground track.

The crew will decide whether or not to slightly roll the spacecraft to avoid excessively high sextant shaft rates if the landmark is too close to the ground track. The constraint is that the sextant trunnion angle should never get less than 10 degrees.

The landing site observation data will be relayed to the ground using low bit-rate telemetry communication and the omni antennas. The DSKY display of the state vector position correction (ΔR) and the state vector velocity correction (ΔV) will be maintained by the crew until MCC-H verifies receipt of the sighting data.

These sightings should eliminate part of the relative uncertainty between the landing site and the CSM orbit and, therefore, significantly improve the accuracy of the descent targeting for mission G. The sightings also provide a complete, independent check on the overall targeting scheme. The method whereby the landing site observation data is used to improve the relative accuracy of the landing site with respect to the orbit is outlined in Section 4.3.

4.1.4 Separation Pad Data

When the landing site observations are complete, MCC-H will voice to the CMP PAD data for the separation maneuver (Table 4-1).

4.2 UNDOCKING, STATION KEEPING, AND LM INSPECTION

Undocking will take place approximately 25 minutes prior to the RCS separation burn, with the spacecraft oriented in the inertial separation attitude. Average g will not be on in either vehicle during the undocking or station-keeping phase. This will preserve the desired relative state vector accuracy until average g comes on in the CSM for the RCS separation maneuver.

After the CSM undocks from the LM, the LM will yaw right 120 degrees and pitch up 90 degrees. This will place both spacecraft at an attitude where the crews will be eye-to-eye. The CSM will station keep at a distance of 30 to 40 feet from the LM to inspect the LM landing gear and structure while the LM does a rotation maneuver (yaw) of 1 degree per second for 360 degrees. When the inspection is complete, the LM will station keep while the CMP prepares for the RCS separation.

4.3 DESCENT TARGETING

The PAD data that the ground provides for DOI, phasing, and PDI are transmitted to the crew between undocking and separation (Tables 4-1, 4-2, and 4-3). The DOI maneuver targeting data and the LM state vector will be uplinked to the LGC using the LGC Update Program (P27) immediately prior to separation. The CSM state vector for the LGC and the LM and CSM state vectors for the CMC will be updated after separation prior to LOS. The time tags for these vectors are as follows for Missions F and G:

	F Mission	G Mission
LM state vector (LGC and CMC)	DOI - 10 min	DOI - 10 min
CSM state vector (LGC and CMC)	Phasing + 5 min	PDI + 25 min

Table 4-1. CSM External ΔV (P30) PAD

P30 MANEUVER							
							PURPOSE
SET STARS				/			PROP/GUID
	+						WT N47
R ALIGN ___ ___ ___		0	0				P_{TRIM} N48
P ALIGN ___ ___ ___		0	0				Y_{TRIM}
Y ALIGN ___ ___ ___	+	0	0				HRS GETI
	+	0	0	0			MIN N33
	+	0					SEC
ULLAGE ___							ΔV_X N81
___							ΔV_Y
___							ΔV_Z
___	X	X	X				R
	X	X	X				P
	X	X	X				Y
	+						H_A N44
							H_P
	+						ΔVT
HORIZON/WINDOW ___	X	X	X				BT
___	X						ΔVC
___	X	X	X	X			SXTS
___	+					0	SFT
	+				0	0	TRN
	X	X	X				BSS
	X	X					SPA
	X	X	X				SXP
OTHER ___		0					LAT N61
___							LONG
___	+						RTGO EMS
	+						V10
							GET 0.05G

Table 4-2. LM External ΔV (P30) PAD

P30 LM MANEUVER

												PURPOSE
+	0	0				+	0	0				HR N33
+	0	0	0			+	0	0	0			MIN TIG
+	0					+	0					SEC
												ΔVX N81
												ΔVY LOCAL
												ΔVZ VERT
+						+						ΔVR
X	X	X				X	X	X				BT
X	X	X				X	X	X				R FDAI
X	X	X				X	X	X				P INER
												ΔVX AGS N86
												ΔVY AGS
												ΔVZ AGS
X	X	X				X	X	X				COAS
X	X					X	X					AZ
X	X					X	X					EL

REMARKS: GETI (CSI)
GETI (TPI)
N

Table 4-3. CSM Target ΔV (P76) PAD

P76 UPDATE PAD

												PURPOSE	
+	0	0				+	0	0				HR	N33
+	0	0	0			+	0	0	0			MIN	TIG
+	0					+	0					SEC	
												ΔVX	N84
												ΔVY	
												ΔVZ	
												PURPOSE	
+	0	0				+	0	0				HR	N33
+	0	0	0			+	0	0	0			MIN	TIG
+	0					+	0					SEC	
												ΔVX	N84
												ΔVY	TIG
												ΔVZ	
												PURPOSE	
+	0	0				+	0	0				HR	N33
+	0	0	0			+	0	0	0			MIN	TIG
+	0					+	0					SEC	
												ΔVX	N84
												ΔVY	
												ΔVZ	

REMARKS: GETI (CSI)
GETI (TPI)
N

The landing site position vector ($\underline{R}_{LS}$) will also be updated in the LGC during this time period. Both $\underline{R}_{LS}$ and the state vector time tags will be biased to adjust for expected propagation errors of the R-2 lunar potential model and to obtain a better relative position of the landing site with respect to the orbit using sextant data. $\underline{R}_{LS}$ is biased for propagation errors in the radial component only. Expected downrange propagation errors are corrected by adjusting the LM and CSM state vector time tags. $\underline{R}_{LS}$ is also biased in all three components using sextant data to improve the relative accuracy of the orbit with respect to the landing site. The method whereby the biases are determined in real time is outlined in subsequent paragraphs.

4.3.1 MSFN Consistency Check and Propagation Error Determination

A 2 orbit state vector solution is obtained using MSFN tracking from orbits 3 and 4 with the orbital plane fixed pre-LOI and the solution propagated forward to orbit 6. This solution is differenced with the orbit 6 unconstrained plane single pass solution and the differences recorded at five discrete times as shown below:

Time	ΔU	ΔV	ΔW
t	-	-	-
t + 20 min	-	-	-
t + 40 min	-	-	-
t + 60 min	-	-	-
t + 80 min	-	-	-

The above procedure is repeated for MSFN tracking data on orbits 4 and 5 being propagated to orbit 7 and MSFN tracking data on orbits 5 and 6 being propagated to orbit 8. This provides three sets of differences, with five data points per set per state vector position component.

The radial (ΔU) and downrange (ΔV) differences are plotted for each of the three sets of data and compared for agreement. If all three sets agree within some limit, MSFN consistency is verified, and biases can be computed to compensate for expected propagation errors over the two orbits before landing.

The radial (ΔU) difference which is predicted to exist at the nominal landing time is determined from the ΔU plot and added to the premission value of $\underline{R}_{LS}$. An equivalent time shift corresponding to the downrange (ΔV) difference at landing is also determined and used to adjust the time tags of the CSM and LM state vectors in the CMC, LGC, and RTCC. By shifting the state vector time tag instead of $\underline{R}_{LS}$, insertion flight-path angle errors are avoided for aborts from descent.

The out-of-plane (ΔW) difference is only used as a plane consistency check and not used to update $\underline{R}_{LS}$ or state vectors. Inclination residuals are also examined on each pass to verify the pre-LOI plane, which is fixed for use during all lunar orbit operations.

4.3.2 Bias Confirmation Using Landing Site Observation Data

The biases determined in Section 4.3.1 are confirmed using the landing site observation sextant data obtained on orbit 11. A two orbit solution (with the plane fixed) using MSFN tracking data from orbits 8 and 9 is obtained. This solution is propagated to orbit 11, and using the sextant data obtained on orbit 11, the landing site position ($\underline{R}_{LS}$) is determined. In addition, $\underline{R}_{LS}$ is determined with a single pass solution with the plane constrained using orbit 11 MSFN data and the sextant data. The difference between the two $\underline{R}_{LS}$ solutions is compared with the biases determined previously using MSFN data only from orbits 3 through 8. If the biases agree within some limit, the sextant data has confirmed the propagation growth error.

4.3.3 Adjustments to $\underline{R}_{LS}$ Using Sextant Data

The landing site position determined using the orbit 11 single pass solution and sextant data from orbit 11 is used to bias all components of $\underline{R}_{LS}$ to improve the relative accuracy of the orbit with respect to the landing site. This biasing is performed only if the $\underline{R}_{LS}$ as determined from orbit 11 MSFN and sextant data and the premission value of $\underline{R}_{LS}$ agrees within the following limits:

$\Delta\lambda$ (downrange) - 6,000 feet

$\Delta\phi$ (crossrange) - 12,000 feet

Δr (radius) - 6,000 feet

If the $\underline{R}_{LS}$ differences are not within the above limits, the mission may be continued without adjusting $\underline{R}_{LS}$ with sextant data or the landing (G mission) will be delayed one orbit to obtain more data.* If the differences are within limits and the MSFN propagation errors are determined and confirmed, the $\underline{R}_{LS}$ with all adjustments uplinked to the LGC prior to DOI is as follows:

Downrange: $\lambda = \lambda_{MAP} + \Delta\lambda_{SXT} + (\Delta V)^{**}$

Crossrange: $\phi = \phi_{MAP} + \Delta\phi_{SXT}$

Radius: $R = R_{MAP} + \Delta r_{SXT} + \Delta U$

The methods outlined whereby $\underline{R}_{LS}$ and state vector time tags are biased will be exercised by the ground crew on mission F. However, $\underline{R}_{LS}$ will not be uplinked to the LGC after the landing site observations on mission F as a result of the RTCC limitations which will not exist for mission G. Tentatively, the state vector time tags will not be adjusted on mission F.

4.3.4 DOI Maneuver Targeting

The DOI targeting for mission F will be computed by MCC-H based on the LM state vector with unbiased time tag and the premission $\underline{R}_{LS}$. However, on mission G the targeting will include state vector time-tag biases and biases to $\underline{R}_{LS}$. These targeting data are uplinked to the LGC (Table 4-2) prior to separation.

*Open item as to which will be done.

**ΔV will be added to $\underline{R}_{LS}$ only if the state vector time tag offset is not performed.

4.4 SEPARATION ACTIVITIES

This phase includes the activities from separation to the preparation for DOI. These activities are:

- Separation maneuver
- CSM and LM IMU alignment and drift check
- CSM and LM PIPA bias calibration
- AGS initialization and alignment
- RR and VHF verification

4.4.1 Separation Maneuver

The 2.5-foot per second radial inward separation maneuver is performed by the CSM approximately 180 degrees central angle (1 hour) prior to DOI. Preparations for the burn are accomplished using the External ΔV Program (P30) and the RCS Thrusting Program (P41). The P30 $\overline{V}_g$ and TIG are obtained from the CSM separation PAD (Table 4-1). This maneuver, using the X-axis RCS thrusters, places the CSM and LM in equiperiod orbits and provides for a rendezvous one revolution later if the DOI maneuver is not performed. It also provides separation distance for RR and VHF checkout and eliminates the need for vehicle station keeping, thus conserving RCS fuel. The maximum LM-CSM separation occurs at the time of DOI when the CSM leads the LM by about 11,400 feet. Performing the separation maneuver with the CSM will not change the LM state vector from that which was used by the RTCC for the targeting of DOI. After separation, the CSM state vector in the LGC will be updated by MCC-H via the LGC Update Program (P27).

4.4.2 IMU Alignments and Drift Checks

After separation, the CSM and LM IMU are realigned to REFSMMAT (P52), and a third star check using the auto optics routine is performed. The gyro torquing angles are used to assess the gyro drift from the previous alignment. If the gyro torquing angles in the LM indicate a PGNCS gyro drift change greater than 1.5 degrees per hour (Reference 1), DOI will not be initiated. The DOI will be performed if the GNCS has failed on mission F, but not on mission G.

4.4.3 PIPA Bias Calibration

The CSM and LM PIPA bias is calibrated before or after separation, depending on where the calibration can be accomplished conveniently in the timeline. The calibration can be performed completely by MCC-H from the PIPA outputs that are on the downlink during coasting navigation. If the uncompensated PIPA bias is greater than 0.003 foot per second per second, the bias compensation will be updated. The mission is discontinued if the change in PIPA bias is greater than 0.166 foot per second per second, the impending failure limit (compensation limit is 0.1025 foot per second per second) (Reference 2).

4.4.4 AGS Initialization and Alignment

Following the PGNCS alignment and prior to DOI, the AGS state vectors are initialized from the PGNCS, and the AGS is aligned to the PGNCS. The AGS gyros and accelerometers are not calibrated at this time since the calibration was performed during the LM activation and systems checkout. No precautions will be taken to avoid the CDU transient problem for the AGS alignment since small AGS misalignments during DOI do not affect burn monitoring or subsequent procedures.

4.4.5 RR and VHF Verification

The rendezvous radar (RR) is evaluated to ensure that it is operating properly before the LM is committed to DOI since this system is required for accurate rendezvous navigation and for immediate verification of the DOI maneuver if PGNCS and AGS were to disagree. The VHF is evaluated at this time although the mission would be continued whether or not this system is operating properly. (It is assumed that a CSM rescue of the LM could be accomplished without using the VHF.) The CDR and CMP call the Rendezvous Parameter Display Routine (R31) for the display of range and range rate which are then compared with the RR and VHF measurements. The range at the time of the check is approximately 5000 feet and range rate is less than 5.6 feet per second. The allowable limits which have been determined are 1600 feet for the range measurements and 7 feet per second for range rate (Reference 4).

4.5 DOI MANEUVER AND VERIFICATION

Prior to DOI, the PGNCS External ΔV Program (P30) is selected, and the displayed $\overline{V}_g$ and the TIG are verified from the DOI PAD (Table 4-2). The DPS Thrusting Program (P40) is selected to execute the maneuver, and the LM is maneuvered to the ignition attitude (retrograde, face up). The ignition attitude is verified by observing the PAD star in the COAS which has been aligned in the overhead window position. The AGS External ΔV Routine is selected for burn monitoring, and an AGS attitude check is performed by comparing the PGNCS and AGS attitude errors on the two FDAI's.

The DPS engine firing for DOI is monitored by the CDR and the LMP. The crew determines if the DPS engine has ignited. If it has failed to ignite, the ignition auto recycle is initiated. If the DPS engine does not ignite after the auto recycle, the LM crew will back out the ullage, wait one complete revolution, and attempt the DOI sequence initiation again. If the DPS engine ignition again fails, the crew will proceed on an alternate mission.

The DOI burn is performed using manual throttle with the control initially at 10 percent. At 15 seconds after TIG, the throttle setting is increased to 40 percent where it is held for the remainder of the burn.* If the DPS engine has ignited properly, the crew monitors the thrust meter to see that the actual thrust follows the commanded thrust during the throttle change. If the DPS engine fails to respond to the throttle command, the LM crew will disarm the DPS and abort (Section 5.1).

During the DOI burn, the absence of physiological cues such as high rotational rates will be the indication that the PGNCS has not incurred a catastrophic failure. Proper functioning of the PGNCS will otherwise be

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*For the F mission, LUMINARY I Program is used and the throttle must be at 40 percent or greater to obtain DPS engine gimbal trimming. For the G mission, LUMINARY IA Program is used and engine gimbal trimming is activated with the throttle at the 10 percent setting or above.

established by onboard observations that the LM is operating within the following limits:

FDAI attitude < ± 10 degrees
Attitude errors < ± 5 degrees
Attitude rates < ± 5 degrees per second

If PGNCS is malfunctioning, LM control will be switched to AGS and a direct abort will be performed (Section 5. 1).

Low thrust or LGC failure to send an engine shutdown command can result in exceeding the estimated engine burn time. The current procedure is to shut down the engine manually if the burn duration exceeds the estimated DOI burn time by more than two seconds and AGS Vgx indicates an overburn of more than two feet per second.

After thrust termination, the DOI maneuver is verified by comparing PGNCS-AGS readings of Vgx. If these readings agree within ± 2 feet per second, RCS trimming of the DSKY displayed Vgx is performed in accordance with the policy presented in Table 4-4. If the PGNCS-AGS readings of Vgx differ by more than two feet per second, the RR is used to determine whether PGNCS or AGS is failed. If either the PGNCS has failed on mission F or if the PGNCS or AGS has failed on mission G, abort action is then taken in accordance with the velocity state at engine shutdown (Table 4-4), using the procedures presented in Section 5. 1.

The radial (Vgz) and out-of-plane (Vgy) velocities to be gained are not nulled because they have little effect on the descent trajectory, and their effects can be removed more efficiently in later maneuvers.

Table 4-4. DOI, Phasing, and Insertion Partial Burn Summary (F Mission Only)

Maneuver	State at Engine Shutdown[1]	Procedure
DOI	$V_M < 12$ ($Vg > 61$)	Remove V_M with - X RCS
(DPS Burn)	$5 < Vg \leq 61$	Perform PDI Abort[2]
	$3 < Vg \leq 5$	Add $V_M = 3$ with + X RCS
	$-12 \leq Vg \leq 3$	Null Vgx with RCS
	$Vg < -12$[3]	Perform Direct Return[2]
Phasing	$Vg > 25$	Stage DPS, Complete with APS[2]
(DPS Burn)	$5 < Vg \leq 25$	Stage DPS, Null Vgx with RCS[2]
	$3 < Vg \leq 5$	Add $\Delta_M = 3$ with +X RCS
	$-12 \leq Vg \leq 3$	Null Vgx with RCS
	$Vg < -12$	Retarget Insertion[2]
Insertion	$V_M < 45$ ($Vg > 162$)	Remove V_M with - X RCS, CSM Rescue[2]
(APS Burn)	$0 < Vg \leq 162$	Null Vgx with RCS or Burn 55 Seconds Whichever Occurs First[2]
	$-45 \leq Vg \leq 0$	Null Vgx with RCS
	$Vg < -45$	Do 180 Degree Pitch, Trim APS and RCS[2]

(1) Velocities in feet per second

(2) See Section 5 for contingency procedures.

(3) The allowable overburn for safe orbit (perilune > 30,000 feet) is approximately 4.5 feet per second. The lunar impact overburn is approximately 12 feet per second.

4.6 PREPHASING MANEUVER ACTIVITIES (F MISSION)

The acceptability of the LM Hohmann descent orbit will be verified by the MCC-H as soon as sufficient tracking data becomes available after DOI. The ground uses the LM telemetry vector as an a priori state vector for orbit determination since it will include DOI guidance and control errors. It may be desirable to update the LM state vector in the LGC at this time (P27). An abort will be performed if the MSFN state vector indicates a perilune altitude less than 30,000 feet.

The PAD data required for the phasing maneuver were transmitted from MCC-H to the LM crew prior to separation and updated following DOI if required (Table 4-2). The PGNCS External ΔV Program (P30) is selected, and $\overline{V}g$ and TIG are inserted manually. The DPS Thrusting Program (P40) will be selected to execute the burn. The AGS External ΔV Routine will be initialized for backup guidance and verification of the maneuver.

A landing radar system check will be performed as the LM approaches perilune (approximately one hour after DOI). The LR Spurious Test Routine (R77) will be selected for this test to provide the range and velocity data on the downlink. R77 will be selected and the LM X-axis oriented near local vertical to provide an appropriate attitude for LR reflection from the lunar surface.

After completion of the landing radar check, the LM is reoriented to the phasing burn attitude (posigrade, face down). The proper ignition attitude is verified by observing the PAD star in the COAS which has been aligned to the overhead window position.

During the period between DOI and phasing, the CMP performs RDZ navigation (P20) and updates the LM state vector in the CMC, provided the state vector corrections do not exceed 12,000 feet and 12 feet per second. The PAD data (Table 4-3) for updating the LM state vector in the CMC following the phasing burn are also voiced to the CMP during this time.

4.7 PHASING MANEUVER VERIFICATION (F MISSION)

The DPS engine burn for phasing is similar to the DOI burn and is monitored by the LM crew and MCC-H. The crew verifies engine ignition. If the engine has failed to ignite, the ignition auto recycle is initiated. If the DPS engine does not ignite after the auto recycle, the crew will manually stage and complete the burn with the APS under AGS control. *

If the DPS engine has ignited properly, the crew will monitor engine performance in the same maneuver as they did for DOI (Section 4.5). If DPS engine throttle-up fails to occur after the trim phase, the crew will disarm the DPS and manually stage and complete the burn with APS under AGS control.

During the phasing burn the absence of physiological cues such as high rotational rates will be the indication that the PGNCS has not incurred a catastrophic failure. Malfunctioning of PGNCS will otherwise be established by MCC-H using TM information from the LM. If PGNCS fails, the ground will advise the crew and LM control will be switched to AGS.

Low thrust or LGC failure to send an engine shutdown command can result in exceeding the estimated engine burn time. The current procedure is to shut down the engine manually if the phasing burn duration exceeds the estimated burn time by more than two seconds, and AGS Vgx indicates an overburn of more than two feet per second.

After thrust termination, the phasing maneuver is verified in a manner similar to the DOI maneuver verification (Section 4.5). The RCS trimming is performed in accordance with the policy presented in Table 4-4. Contingency procedures are discussed in Section 5-2.

Following the phasing maneuver, rendezvous navigation is performed in the CSM to update the LM state vector in the CMC. Rendezvous navigation is also performed in the LM to update the CSM state vector in the LGC. While the LM is behind the moon, MCC-H will determine if the LM state vector in the LGC is acceptable for execution of the insertion

*Switching to AGS will circumvent an immediate manual DAP reset as a result of the configuration change.

maneuver. If it is acceptable, MCC-H will not update the LM state vector in the LGC at AOS. If the state vector is not acceptable, the LM crew will terminate the Rendezvous Navigation Program (P20) and call the LGC Update Program (P27) so that MCC-H may transmit an acceptable LM state vector for the insertion maneuver. The CSM state vector will be updated in both the LGC and CMC prior to insertion but time tagged at approximately insertion plus 20 minutes.

4.8 INSERTION MANEUVER AND VERIFICATION (F MISSION)

The PAD data required for the insertion maneuver are voiced to the LM and CSM following the phasing maneuver (Tables 4-1 and 4-2). However, targeting for insertion is recalculated by the RTCC following the phasing burn. If required, new insertion PAD data will be voiced to the LM and CSM at AOS approximately 25 minutes prior to insertion. In addition, it may be desirable to update the LM state vector in the LGC at this time (P27).

In the LM, the External ΔV Program (P30) and the APS Thrust Program (P42) are used to accomplish the insertion burn. Since the maneuver is performed in sunlight, the proper ignition attitude cannot be verified by observing a check star in the COAS or AOT.

At approximately TIG - 10 minutes, the LM descent stage is jettisoned, using X-axis RCS, AGS attitude-hold submode, and the PGNCS Thrust Monitor Program (P47). Immediately prior to staging, a ΔV of two feet per second posigrade using - X RCS is applied (LM is in a retrograde attitude), and at staging a ΔV of two feet per second retrograde using + X RCS is applied. This maneuver places the ascent stage behind the descent stage for the retrograde insertion maneuver. After staging, the PGNCS DAP constants are updated using the DAP Data Load Routine (R03).

The CSM is targeted (not mirror image) to back up the insertion maneuver in the event the LM is unable to execute the burn. The $\overline{V}_g$ and TIG obtained from PAD data (Table 4-1) are inserted into the External ΔV Program (P30). The CSM TIG is LM TIG plus 3 minutes. The SPS Thrust Program (P40) is selected to perform the maneuver.

The APS engine firing for insertion is monitored by the crew and MCC-H. The crew verifies engine ignition. If the engine has failed to ignite the ignition auto recycle is initiated. If the APS engine does not start, the recommended procedure is a CSM rescue described in Section 5. 3.

As in the case of other engine burns, the absence of physiological cues such as high rotational rates will be the indication that the PGNCS has not incurred a catastrophic failure. Malfunctioning of PGNCS will otherwise be established by MCC-H using TM information from the LM. If PGNCS fails, the ground will advise the crew and LM control will be switched to AGS.

Low thrust or LGC failure to send an engine shutdown command can result in exceeding the estimated engine burn time. The current procedure is to shut down the engine manually if the insertion burn duration exceeds the estimated burn time by more than two seconds and AGS Vgx indicates an overburn of more than two feet per second. After thrust termination, the insertion maneuver is verified in a manner similar to the DOI maneuver verification (Section 4. 5). RCS trimming is performed in accordance with the policy presented in Table 4-4. Contingency procedures are discussed in Section 5. 3.

The radial (Vgz) and out-of-plane (Vgy) velocities to be gained are not nulled because they have very little effect on the trajectory, and their effects can be removed more efficiently in later maneuvers.

After verification of the insertion maneuver, the MCC-H will update the LM and CSM state vectors in the CMC (P27) using the LM TM state vector.

4. 9 PRE-CSI ACTIVITIES

Following the insertion maneuver, the MCC-H will voice to the LM crew PAD data for the CSI, CDH, and TPI maneuvers (Tables 4-5, 4-6, and 4-7). This data is essentially based on preseparation data, assuming nominal maneuvers. Both the LM and CSM perform an IMU realign to

Table 4-5. LM CSI (P32) PAD

P32 CSI UPDATE

+	0	0				+	0	0				HR TIG
+	0	0	0			+	0	0	0			MIN CSI
+	0					+	0					SEC
+	0	0				+	0	0				HR N37
+	0	0	0			+	0	0	0			MIN TIG
+	0					+	0					SEC TPI
	0						0					ΔVY LOCAL N81
	0	0					0	0				ΔVY VERT
X	X	X				X	X	X				PLM FDAI
	0	0					0	0				ΔVX AGS N86
	0	0					0	0				ΔVY AGS
	0	0					0	0				ΔVZ AGS
	0	0					0	0				ΔVX N81
	0	0					0	0				ΔVY PGNCS LOCAL
	0	0					0	0				ΔVZ VERT
	0	0					0	0				ΔVX N81
X	X	X	X	X	X	X	X	X	X	X	X	ΔVY CHARTS LOCAL
X	X	X	X	X	X	X	X	X	X	X	X	ΔVZ VERT

REMARKS:

Table 4-6. LM CDH (P33) PAD

P33 CDH UPDATE

+	0	0				+	0	0				HR	TIG CDH	
+	0	0	0			+	0	0	0			MIN		
+	0					+	0					SEC		
	0						0					ΔVX	LOCAL VERT	N81
	0	0					0	0				ΔVY		
	0	0					0	0				ΔVZ		
X	X	X				X	X	X				PLM	FDAI	
	0						0					ΔVX	AGS	N86
	0	0					0	0				ΔVY	AGS	
	0	0					0	0				ΔVZ	AGS	
	0	0					0	0				ΔVX	PGNCS LOCAL VERT	N81
	0	0					0	0				ΔVY		
	0	0					0	0				ΔVZ		
	0	0					0	0				ΔVX	CHARTS LOCAL VERT	N81
X	X	X	X	X	X	X	X	X	X	X	X			
	0	0					0	0				ΔVZ		

REMARKS:

Table 4-7. LM TPI (P34) PAD

P34 TPI UPDATE												
+	0	0				+	0	0				HR TIG
+	0	0	0			+	0	0	0			MIN TPI
+	0					+	0					SEC
												ΔVX N81
												ΔVY LOCAL
												ΔVZ VERT
+	0	0				+	0	0				ΔVR
X	X	X				X	X	X				RLM FDAI N42
X	X	X				X	X	X				PLM INER
+	0					+	0					R TPI N54
	0						0					R TPI TIG-5
	0	0					0	0				F/A(+/-) N59
	0	0					0	0				L/R(-/+) ΔV
	0	0					0	0				V/D(-/+) LOS
												BT
	0	0					0	0				F/A PGNCS N59
	0	0					0	0				L/R ΔV
	0	0					0	0				V/D LOS
	0	0					0	0				F/A CHARTS N59
X	X	X	X	X	X	X	X	X	X	X	X	L/R ΔV
	0	0					0	0				U/D LOS

REMARKS:

REFSMMAT (P52) to remove any drift accumulated since the last alignment and to check gyro drift rates which may affect rendezvous navigation. Following the alignment, the AGS state vectors are initialized from the PGNCS and the AGS is aligned to the PGNCS.

The RDZ navigation is performed in both spacecraft (LM update option in both the LGC and CMC), and an evaluation is made of the CMC's navigation capability (See Section 3.3 for procedures). If the CMC is acceptable, the CMP reads out the LM out-of-plane velocity for TM TIG (CSI) using the LM Rendezvous Out-of-Plane Display Routine (R36). The CMC estimate of $\dot{y}$ is used instead of the LGC estimate because rendezvous navigation analysis (Reference 5) shows that prior to TPI the CMC estimate of $\dot{y}$ based on SXT tracking is much more accurate than the LGC estimate as a result of RR angular errors. The $\dot{y}$ is voiced to the LM if it exceeds two feet per second for incorporation into the LM CSI Targeting Program (P32). Plane corrections should not be required for the F mission, but probably will be required for mission G.

4.10 CSI MANEUVER

The LM CSI targeting is performed in the LM using P32 in the LGC and using RR data with the RR backup charts. The P32 requires inputs of TIG (CSI), TIG (TPI), the elevation angle (E) at TPI, N (the number of the apsidal crossing at which CDH occurs). The TIG (CSI), TIG (TPI), and N were included in the PAD data which were voiced to the LM and CSM prior to DOI (Tables 4-2 and 4-3) and updated if required following insertion. For the nominal rendezvous, E = 26.6 degrees, TIG (TPI) is about the midpoint of darkness for the CSM orbit (23 minutes prior to CSM sunrise), TIG (CSI) is insertion + 51 minutes, and N = 1.

The LM crew will compare CSI $\overline{V}g$ solutions from the PGNCS, onboard chart, MCC-H, and the GNCS. (The MCC-H solution is the pre-separation nominal CSI $\overline{V}g$.) The largest solution of the three most reasonable solutions will be burned in the LM provided it is no greater than the next largest solution plus one foot per second in which case the next largest solution plus one foot per second will be burned. In either case the nominal LM TIG (CSI) will be used. It should be noted that burning

CSI too large will result in TPI occurring later than nominal which is much more desirable from a crew timeline viewpoint than an early TPI. If the LGC solution is verified, the AGS state vectors are initialized from the PGNCS, and the AGS is aligned to the PGNCS.

The CSM also targets for CSI using P32 of the CMC. The CMC P32 requires inputs of TIG(CSI), TIG(TPI), E, and N. For the CSM, TIG(CSI), E is 208.3 degrees, and N is the LM N. Since the CSM P32 solution is calculated for a CSM maneuver, the solution cannot be used directly. A fixed bias of one foot per second must be subtracted from the magnitude of the CMC solution to obtain a value for LM use. Also the sign of the CSM solution must be reversed.

If the LM RR fails, the LM crew will compare the CMC P32 $\overline{V}g$ solution (after subtracting the one foot per second bias) with the MCC-H CSI solution. If the CMC $\overline{V}g$ (minus one foot per second) is greater than the MCC-H solution plus one foot per second, the MCC-H solution plus one foot per second is burned in the LM. Otherwise, the larger solution is burned in the LM. In either case, the nominal LM TIG (CSI) is used.

If the plane correction required at CSI is greater than two feet per second, the CMC R36 $\dot{y}$ is inserted into the LGC CSI Targeting Program and accomplished in conjunction with the CSI maneuver. The LM uses the RCS Thrust Program (P41) to accomplish CSI with the + X RCS jets (four). The APS interconnect will be used on mission F.

4.11 PLANE CHANGE MANEUVER

After CSI, rendezvous navigation is performed in both spacecraft. The CMP obtains the LM out-of-plane velocity, $\dot{y}$, for LM CSI time + 29 minutes from the CMC using the out-of-plane RDZ Display Routine (R36). The $\dot{y}$ is voiced to the LM for the plane change maneuver. If $\dot{y}$ is less than two feet per second, the maneuver will not be performed. If $\dot{y}$ exceeds two feet per second, the plane change is accomplished using the External ΔV Program (P30) and RCS Thrust Program (P41). This maneuver is performed using Y RCS thrusters to avoid gimbal lock and with the + Z-axis boresighted on the CSM to prevent loss of RR lock. The CSM will not be targeted to backup the plane change maneuver on mission F. If the LM is known to be inactive on mission G, the CSM will perform the plane change with the SPS and pulse torquing the platform.

4.12 CDH MANEUVER

After the plane change maneuver, rendezvous navigation is performed in both spacecraft, and another evaluation is made of the CMC's navigation capability. If the CMC is acceptable, the CMP obtains the LM out-of-plane velocity for LM TIG (CDH) using R36 and voices it to the LM for incorporation into the CDH Targeting Program (P33).

Lunar module CDH targeting is performed in the LM using P33 of the LGC and RR data with the RR backup charts. Inputs to P33 are TIG(TPI) inserted before CSI, and TIG(CDH) which is computed by the LGC in the CSI Targeting Program (P32).

The CSM also targets for CDH using P33 of the CMC. Inputs to this program are the same as for the LGC. P33 is used in preference to P73 since it is possible to make solution comparisons with the LM P33 while at the same time simplify the number of operations required by the CMP in preparing to back up the CDH maneuver. The CSM solution for CDH is voiced to the LM for comparison with the LGC solution. The sign of the $\overline{V}g$ must be reversed for comparison.

The LM crew will compare the LGC P33 $\overline{V}g$ solution with both the CMC P33 solution and the onboard chart solution. If the LGC agrees with either the CMC or the chart ($\Delta Vgx < 2$ feet per second and $\Delta Vgz < 6$ feet per second), the LGC solution will be burned in the LM. If the LGC does not agree with either the CMC or the chart, the chart solution will be burned in the LM if it agrees with the CMC ($\Delta Vgx < 2$ feet per second and $\Delta Vgz < 6$ feet per second). If all three solutions disagree, the CMC solution will be burned in the LM by inserting the $\overline{V}g$ into the LGC Targeting Program (P33). If the LGC solution is verified, the AGS state vectors are initialized from the PGNCS, and the AGS is aligned to the PGNCS.

If a plane correction is required at CDH ($\dot{y}$ > 2 feet per second), the CMC R36 $\dot{y}$ is inserted into the LGC CDH Targeting Program and accomplished in conjunction with the CDH maneuver. The LM uses the RCS Thrust Program (P41) to accomplish CDH so that the + Z-axis remains boresighted on the CSM to maintain RR lock.

4.13 TPI MANEUVER

Following the CDH maneuver, rendezvous navigation is performed in both the LM and CSM. In the CSM, another evaluation is made of the CMC navigation capability as described in Section 3.3. Lunar module TPI targeting is performed in the LM using P34 of the LGC and the RR backup charts. In P34, the elevation angle option (E = 26.6 degrees) is used to calculate a Vg and TIG (TPI). If the P34 solution for TIG (TPI) is less than nominal TIG (TPI) - 8 minutes. The TPI will not be executed earlier than nominal TIG (TPI) - 8 minutes in order to maintain adequate time between CDH and TPI for rendezvous navigation. Since there is no TPF lighting constraint, TPI can occur late by any amount.

Lunar module TPI targeting is also performed in the CSM using P34 of the CMC. The elevation angle option (E = 208.3 degrees) is used to calculate a $\overline{V}g$ and TIG(TPI) which is voiced to the LM for comparison with the LGC computed $\overline{V}g$ and TIG(TPI). The sign of the $\overline{V}g$ must be reversed for comparison.

The LM crew will compare the LGC P34 $\overline{V}g$ solution with the CMC P34 solution (local vertical coordinates) and the onboard chart solution (line-of-sight coordinates). If the LGC agrees with either the CMC or the chart ($\Delta V gx < 2$ feet per second, $\Delta Vgy < 5$ feet per second, and $\Delta V gz <$ 6 feet per second), the LGC solution will be burned in the LM. If the LGC does not agree with either the CMC or the chart, the chart solution will be burned in the LM if it agrees with the CMC ($\Delta Vgx < 2$ feet per second, $\Delta Vgz < 6$ feet per second). If all three solutions disagree, the

CMC solution will be burned in the LM by inserting the $\overline{V}g$ into the LGC Targeting Program (P34). If the LGC solution is verified, the AGS state vectors are initialized from the PGNCS, and the AGS is aligned to the PGNCS.

On mission F, the LM X-axis RCS thrusters through the APS interconnect will be used to execute TPI, and therefore, RR lock will be lost. However, on mission G, the Z-axis thrusters will be used to maintain RR lock throughout TPI and the remainder of the rendezvous. The difference in procedures reflect the different propellant loading between missions F and G.

4.14 TERMINAL PHASE MIDCOURSE MANEUVERS

Following TPI, rendezvous navigation and TPM targeting is performed in both spacecraft. Terminal phase midcourse targeting is performed in the LM using P35 of the LGC. The CSM is targeted for TPM using P35 of the CMC. The CSM does not compute a LM TPM solution for comparison with the LGC solution. It is assumed that, if the LGC has successfully navigated through TPI, it is capable of calculating a TPM solution. If an obvious failure occurs in the LM, the CSM will execute TPM.

4.15 TPF

The TPF braking is performed in the LM according to the planned braking gates. Rendezvous radar range and range-rate data are used to determine the required ΔV, and the Thrust Monitor Program (P47) is used to measure the applied $\overline{V}g$. Line-of-sight rates are controlled using RCS X- and Y-translation.

In the CSM, the CMP monitors Rendezvous Parameter Display Routine (R31) range and range-rate and VHF range. If the LM fails to acquire the CSM visually (and the CSM acquires the LM), or if the DPS has not been staged, the CMP calls the Thrust Monitor Program (P47) and performs the LOS control. The LM performs the braking if possible.

4.16 LM JETTISON AND APS BURN TO DEPLETION

After docking has been completed, the CDR and LMP configure the LM for jettison and the APS burn to depletion. The PGNCS External ΔV Program (P30) will be called and the targeting parameters input via the uplink. The AGS External ΔV Routine will be targeted from PAD data which were voiced to the LM crew earlier (Table 4-2).

As many LM communications special tests as possible will be performed between docking and LM jettison. These tests primarily evaluate the LM steerable antenna and omni-antenna communication modes at lunar distance. In addition, automatic tracking will be demonstrated with the CSM high-gain antenna using wide, medium, and narrow beam widths.

Once the LM has been properly configured, the CDR and LMP will transfer to the CSM. The APS burn-gimbal angles will be voiced to the CMP, and the CSM maneuvered to the final burn attitude. The docking ring is blown to jettison the LM, and the CSM executes a two feet per second radial outward burn using - X RCS and the Thrust Monitor Program (P47). This maneuver will place the CSM above and behind the LM to observe the APS burn to depletion.

For the APS burn, MCC-H will command ullage under PGNCS control and send the ascent engine ARM command. As soon as ullage is determined, MCC-H will command a PGNCS-to-AGS guidance switchover. The AGS will then automatically start the ascent engine and provide guidance steering commands.

4.17 ORBITAL ACTIVITIES PRIOR TO TEI PREPARATION (F MISSION)

Following the APS depletion burn, the crew will rest for approximately nine hours. At the conclusion of the rest period, about 20 hours (10 orbits) remain prior to TEI for the following activities:

- one revolution, strip photography
- four revolutions, landmark tracking
- two revolutions, rest
- one revolution, targets of opportunity photography

- one revolution, landmark tracking
- one revolution, strip photography

During each pass, the MCC-H will update the CSM state vector (P27) and each night the IMU will be realigned to REFSMMAT (P52). The landmark tracking will be performed using the Orbital Navigation Program (P22) and MCC-H will supply the necessary tracking data to the crew in real time as outlined in Section 4.1.3.

The primary targets for the first revolution of strip photography are landing site 1 (longitude 34°E.) and landing site 2 (longitude 23°E.). The four revolutions of landmark tracking will be performed on sites CP-1 (longitude 170°E.), CP-2 (longitude 127°E.) and F-1 (longitude 87°E.) and landmark 130 (longitude 23°E.).

On the first revolution following the 3.5 hour rest period, the crew will photograph landing site 3 (longitude 1.4°W.), selected areas of interest on the lunar surface, and targets of opportunity. One additional revolution of landmark tracking (P22) will be performed on site B-1 (longitude 35°E.) and landmark 150 (longitude 1.4°W.). During the last revolution prior to TEI, strip photography will be performed, beginning at longitude 90°E. and continuing to the terminator. The spacecraft will be maneuvered to include CENSORINUS and landing site 3 in the strip.

5. CONTINGENCY PROCEDURES

Contingency procedures consist of those techniques required during the lunar operations phase of mission F (and mission G where applicable) in the event of a critical LM (or possible CSM) systems malfunction which precludes completion of the nominal rendezvous. The mission F systems malfunction regions considered in this section begin with separation and end at CSI initiation. The contingency procedures involve the use of backup guidance and propulsion systems and LM abort and CSM rescue sequences. Abort and rescue sequences are generally employed either when it is not feasible to perform the nominal maneuver or in time critical situations which require an earlier than nominal rendezvous. All abort or alternate maneuver sequences after CSI initiation are the same as the nominal sequence.

The possible abort and rescue sequences for different periods of applicability are summarized in Table 5-1. These maneuver sequences generally attempt to provide the necessary height (raising or lowering apogee or perigee) and phasing maneuvers (orbital speedup or slowdown with respect to target vehicle) necessary to achieve a CSI/CDH coelliptic sequence with a ΔH of 15 nautical miles. In two instances the 15 nautical miles ΔH is not possible; these are:

- zero phasing rescue after a partial or completed DOI maneuver
- zero or partial phasing CSM rescues when a partial phasing burn of $0 < \Delta V_M < 40$ feet per second has been executed by the LM.

Both these cases involve an extra revolution in the overall sequence and are targeted for a ΔH of 10 nautical miles. Detailed descriptions of all the sequences are presented in Reference 6.

The systems malfunction techniques are based on the time of occurrence of the malfunction, the nature of the malfunction (i.e., G&N or propulsion system failure, etc.), and the LM orbit. Malfunctions which occur during a coast phase are most straightforward in that subsequent

Table 5-1. Abort and Rescue Sequences

Abort and/or Rescue Period	LM Active Abort	CSM Active - LM Nonpropulsive (Rescue)	Mission Applicability (F Only)	Mission Applicability (F and G)
No/go for DOI (Mini-football)	Manual Braking (Closing ΔV is required)	Manual braking (Closing ΔV is required)		X
DOI until DOI + 10 min	a) Direct abort: • LM executes closing ΔV = 10 x (R n mi) ft/sec along X-body axis at a burn attitude of 10 degrees above line of sight to CSM ASAP • Manual braking and docking b) Same as PDI abort (Described below)*	Zero phasing rescue (height/five impulse): • CSM (or LM after HT maneuver if it becomes active) executes HT/CSI/ CSI_2 (nominally zero)/ CSI_3 (nominally zero)/ CDH/TPI/TPF burn sequence initiated one revolution after DOI • MCC-H provides HT ΔV and TIG, and CSI, TIG • ΔH = 10 n mi • TPI revolution occurs one revolution later than nominal for mission F		X
DOI + 10 min until: • DOI + 58 min for mission F • PDI + 10 min for mission G (Assuming no/ go for PDI)	PDI abort (phasing/ five impulse): • LM (or CSM after PH burn if LM becomes inactive) executes PH/CSI/ CDH/TPI/TPF burn sequence initiated 1/2 revolution after DOI • MCC-H provides phasing Vgx and TIG to backup onboard chart and CSI and TPI TIG's • TPI revolution occurs one revolution earlier than nominal for mission F	Zero phasing rescue described above)		X
DOI + 58 until phasing	a) 100-foot per second phasing abort: • LM executes 100-foot per second ΔV (manual cutoff) at nominal phasing	Zero phasing rescue (described above)	X	

*Mission F only

Table 5-1. Abort and Rescue Sequences (Continued)

Abort and/or Rescue Period	LM Active Abort	CSM Active - LM Nonpropulsive (Rescue)	Mission Applicability (F Only)	Mission Applicability (F and G)
DOI + 58 until phasing (continued)	TIG and attitude followed by a CSI/CDH TPI/ TPF sequence initiated one revolution from DOI • MCC-H provides CSI and TPI TIG's • TPI revolution occurs one revolution earlier than nominal for mission F b) MCC-H targeted two impulse maneuver abort: • TPI revolution occurs one revolution earlier than nominal for mission F			
Phasing until insertion	a) Zero phasing abort (height/five impulse): • Same as zero phasing rescue described above except that LM executes all burns after HT burn b) Partial phasing abort (height/five impulse): • Same as partial phasing rescue described in adjacent column except that LM executes all burns after HT burn	a) Zero phasing rescue (Described above) b) Partial phasing rescue (height/five impulse rescue): • CSM (or LM after HT maneuver if it becomes active) executes HT/ CSI_1/CSI_2 (nominally zero)/CDH/TPI/TPF initiated one revolution after DOI • MCC-H provides HT ΔV and TIG, and CSI_1 and TPI TIG's • For $0 < V_M < 40$, h = 10 n mi and TPI revolution occurs one revolution later than nominal for mission F • For $V_M > 40$ $\Delta H = 15$ n mi and TPI revolution occurs the same as nominal for mission F	X	

Table 5-1. Abort and Rescue Sequences (Continued)

Abort and/or Rescue Period	LM Active Abort	CSM Active - LM Nonpropulsive (Rescue)	Mission Applicability (F Only)	Mission Applicability (F and G)
Insertion until CSI	a) Zero insertion abort (CSM insertion/five impulse): • Same as zero insertion rescue described in adjacent column except that LM executes all burns after CSM insertion. b) Partial insertion abort (HT/five impulse): • Same as partial insertion rescue described in adjacent column except that LM executes all burns after HT	a) Zero insertion rescue (CSM Insertion/five impulse): • CSM (or LM after INS burn if it becomes active) executes INS/CSI/CDH/TPI/TPF burn sequence initiated 3 minutes after nulling partial insertion burn to zero • MCC-H provides INS ΔV and TIG, and CSI and TPI TIG's • TPI revolution occurs the same as nominal for mission F b) Partial insertion rescue (height/five impulse): • CSM (or LM after HT burn if it becomes inactive) executes HT/CSI_1/CSI_2 (nominally zero)/CDH/TPI/TPF burn sequence initiated two revolutions after DOI. • MCC-H provides HT ΔV and TIG, and CSI_1 and TPI TIG's • TPI revolution occurs one revolution later than nominal for mission F	X	

maneuvers are based on a known LM orbit. The required action after partial completion of the DOI, phasing, or insertion burns depends on the degree of completion of the maneuver. In general, the LM will attempt to remain active in abort situations with backup G&N (AGS) or backup propulsion systems as required. In the event the LM becomes nonpropulsive, the CSM will execute a rescue maneuver sequence. Detailed techniques for the nominal mission F DOI, phasing, and insertion maneuvers are defined in the next three sections.

5.1 DOI CONTINGENCY PROCEDURES

In the event of a PGNCS failure between DOI initiation and DOI + 10 minutes, a direct return abort will be executed prior to DOI + 10 minutes. For a subsequent PGNCS failure, the nominal maneuver sequence will be executed under AGS control. Underburn and overburn failures not involving the PGNCS are broken down as follows (Figure 5-1):

a) Underburns

- DPS cutoff within 5 feet per second of nominal cutoff ΔV (approximately 72 feet per second). Trim X-residual ΔV to zero or 3 feet per second maximum with + X RCS (four-jet) and continue with nominal maneuver sequence using available LM propulsion systems.
- DPS cutoff in the range 61 feet per second > $\bar{V}g$ > 5 feet per second. Execute PDI abort sequence using available LM propulsion system one-half revolution later.
- DPS cutoff in the range $\bar{V}g$ > 61 feet per second. Null ΔV_M to zero and execute manual braking and rendezvous from mini-football.

b) Overburns

- DPS cutoff within 12 feet per second of nominal cutoff ΔV. Trim X-residual ΔV to zero using -X RCS (four-jet) and continue with nominal maneuver sequence using available LM propulsion systems.

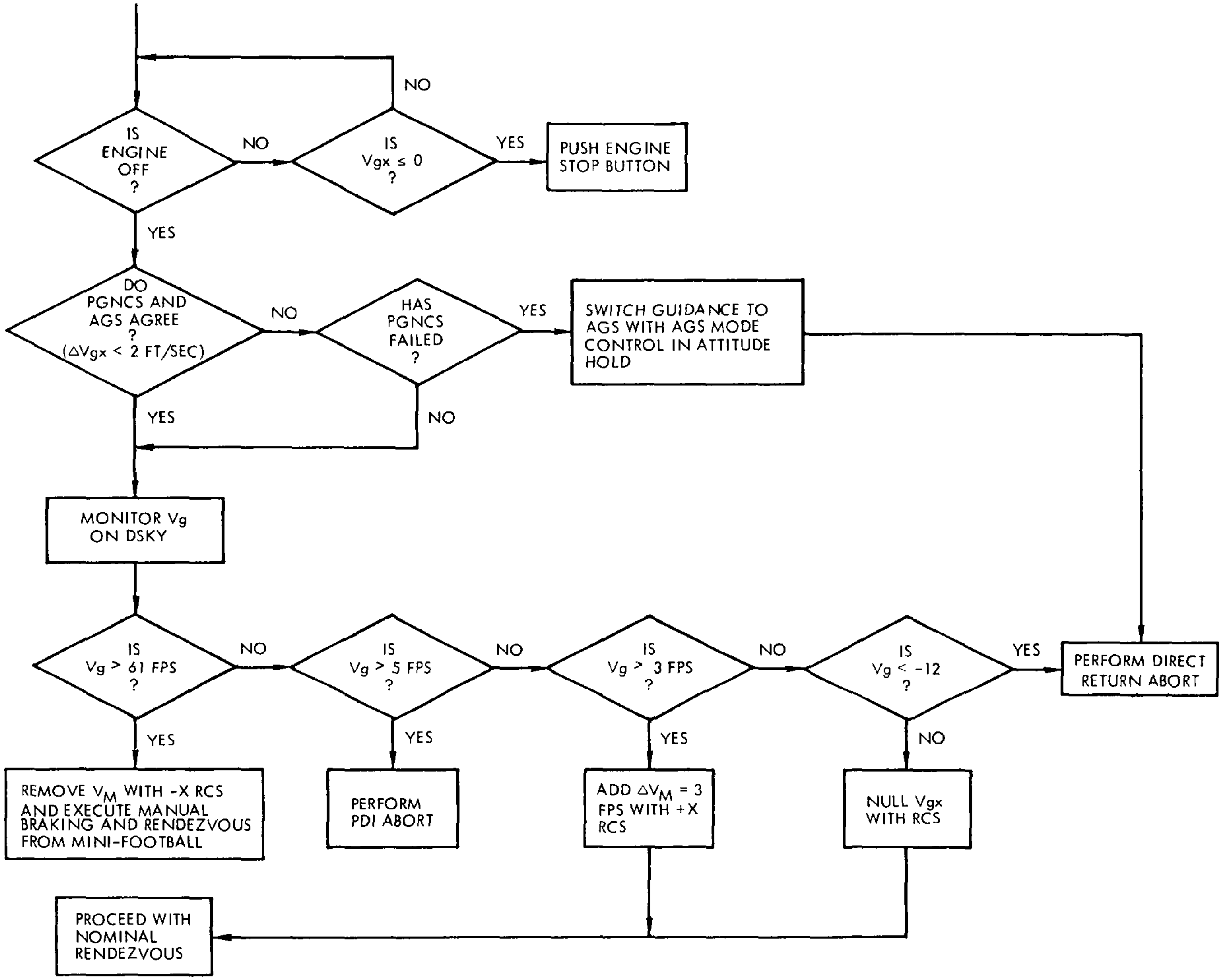


Figure 5-1. DOI Maneuver Contingency Procedures

- Overburn greater than 12 feet per second. Execute direct return abort as soon as possible (no later than DOI + 10 minutes).

Time-critical failures (e.g., ECS, power supply systems, etc.) in the coast phase from DOI + 10 minutes until DOI + 58 minutes (nominal PDI abort execution time) which require an earlier than nominal rendezvous result in a PDI abort one-half revolution after DOI. In the event of such a failure between DOI + 58 minutes and DOI + 72 minutes (nominal mission F phasing TIG), the 100-foot per second phasing abort is executed. Both these abort sequences result in rendezvous one revolution earlier than nominal.

5.2 PHASING MANEUVER CONTINGENCY PROCEDURES

The phasing maneuver underburn and overburn malfunctions are handled in a similar manner as those for the DOI maneuver. These procedures (Figure 5-2) are:

a) Underburn

- DPS (or possible APS) cutoff within 5 feet per second of the nominal cutoff ΔV (approximately 193 feet per second. Trim X-residual ΔV to zero or by 3 feet per second with + X RCS (four-jet), and continue with nominal maneuver sequence.

- DPS (or possible APS) cutoff in the range 25 feet per second > Vg > 5 feet per second. Stage DPS, complete burn with + X RCS (four-jet), and continue with nominal maneuver sequence.

- DPS (or possibly APS) cutoff in the range $\bar{V}g$ > 25 feet per second. Stage DPS, complete burn with APS under AGS control*, and continue with nominal maneuver sequence. If APS cutoff after staging, burn ΔV_M to 40 feet per second (if required) with + RCS (four-jet), and continue with partial phasing abort or CSM rescue sequence.

*The APS is burned under AGS control as a result of a time delay needed to set the DAP constants to undocked configuration values for PGNCS control.

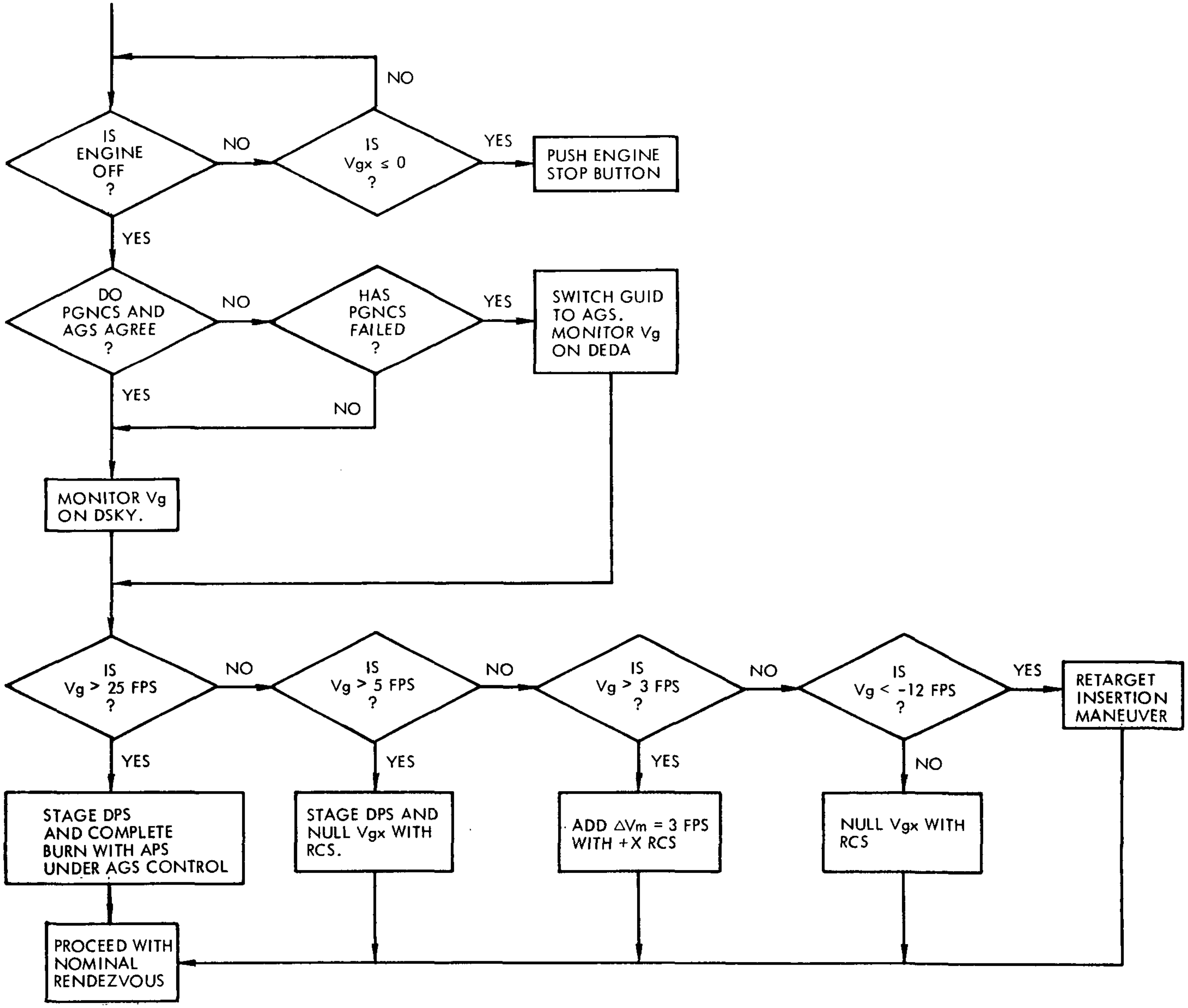


Figure 5-2. Mission F Phasing Maneuver Contingency Procedures

b) Overburn

- DPS (or possibly APS) cutoff within 12 feet per second of nominal cutoff ΔV. Trim X-residual ΔV to zero using - X RCS (four-jet), and continue with nominal maneuver sequence.

- DPS (or possibly APS) overburn $\Delta V > 12$ feet per second MCC-H will retarget the insertion maneuver and the nominal maneuver sequence continued.

5.3 INSERTION MANEUVER CONTINGENCY PROCEDURES

The insertion maneuver underburn and overburn contingency logic (Figure 5-3) is: :

a) Underburn

- APS cutoff at $V_g < 162$ feet per second. Trim X-residual ΔV to zero or burn 55 seconds maximum with + X RCS (continuous RCS burn constraint), whichever occurs first, and continue with partial insertion abort or rescue sequence if $\bar{V}_g > 5$ feet per second*. If $\bar{V}_g \leq 5$ feet per second, the nominal CSI/CDH sequence will be used.

- APS cutoff at $V_g > 162$ feet per second. Trim V_m to zero with RCS and continue with zero insertion abort or rescue sequence.

b) Overburn

- If APS cutoff ΔV within 45 feet per second of nominal cutoff ΔV (approximately 207 feet per second, trim X-residual ΔV to zero using - X RCS (four-jet), and continue with the nominal rendezvous.

- If APS cutoff ΔV exceeds nominal cutoff ΔV by more than 45 feet per second, pitch over and trim X-residual to zero with APS and X-axis RCS (four-jet) and continue with the nominal rendezvous.

---

*The crossover between retargeting the nominal CSI/CDH sequence and executing the partial insertion abort or rescue sequence is a real-time decision which depends on the retargeted ΔH; $\bar{V}_g = 5$ feet per second is the approximate crossover value.

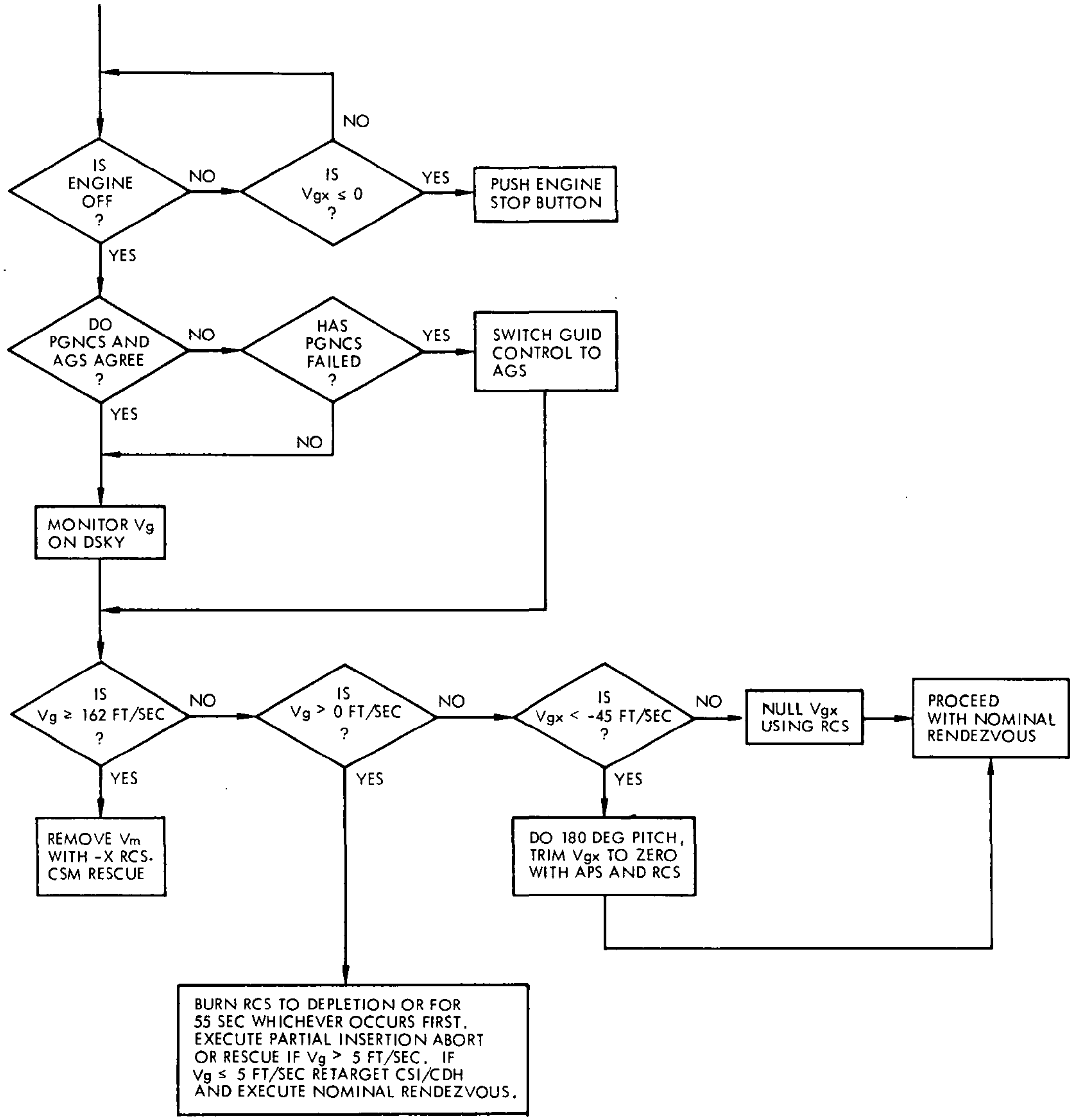
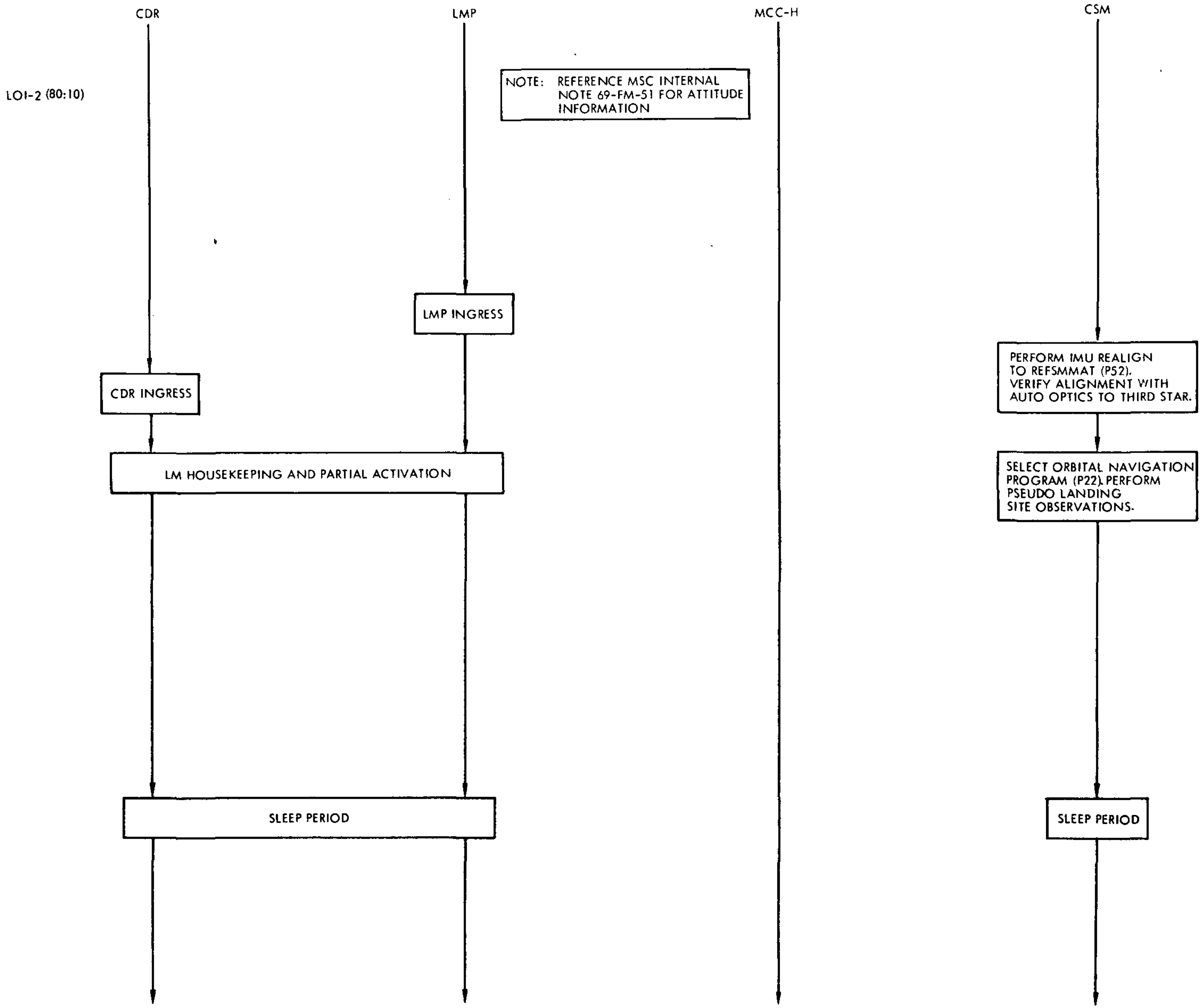
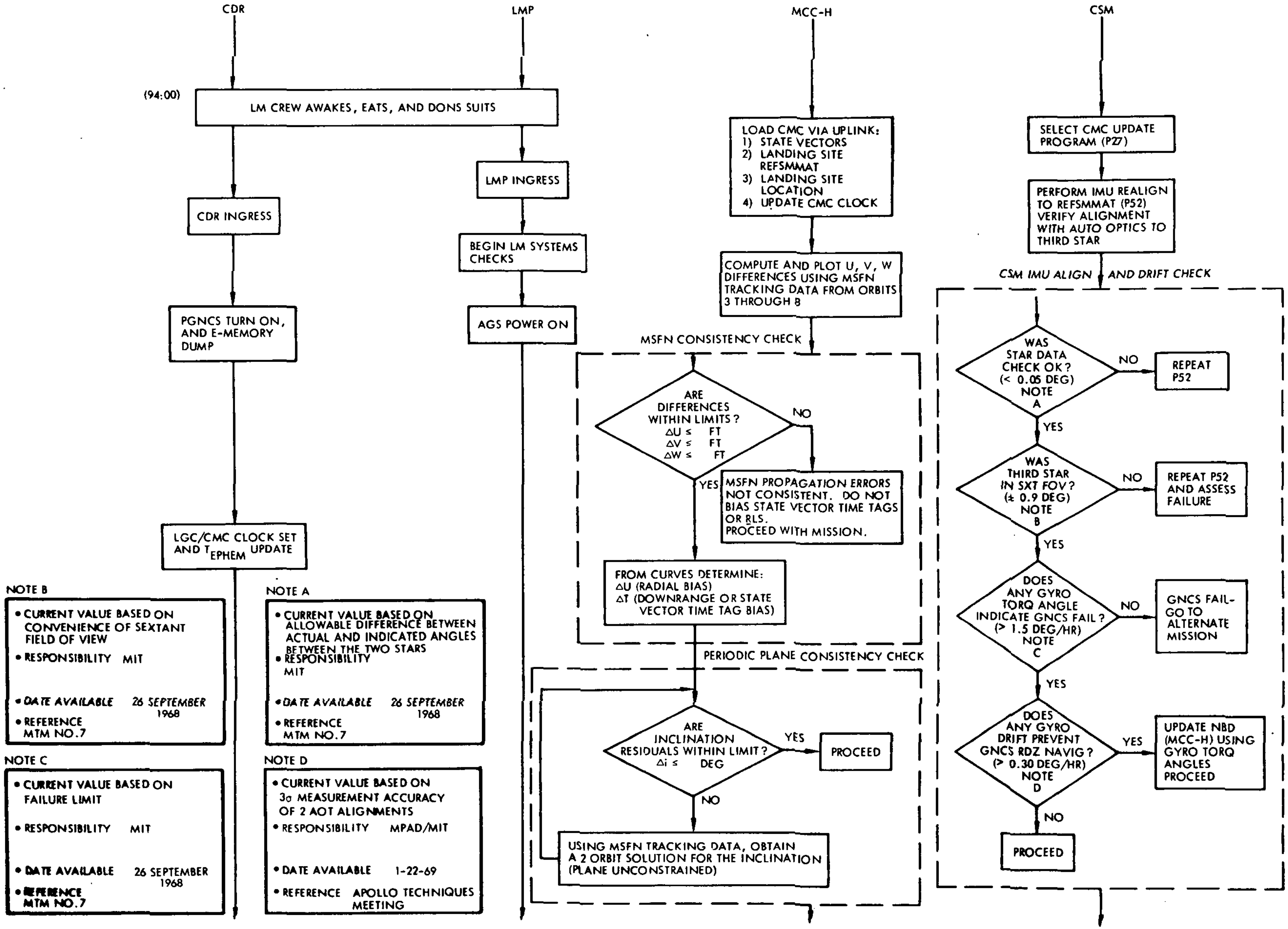


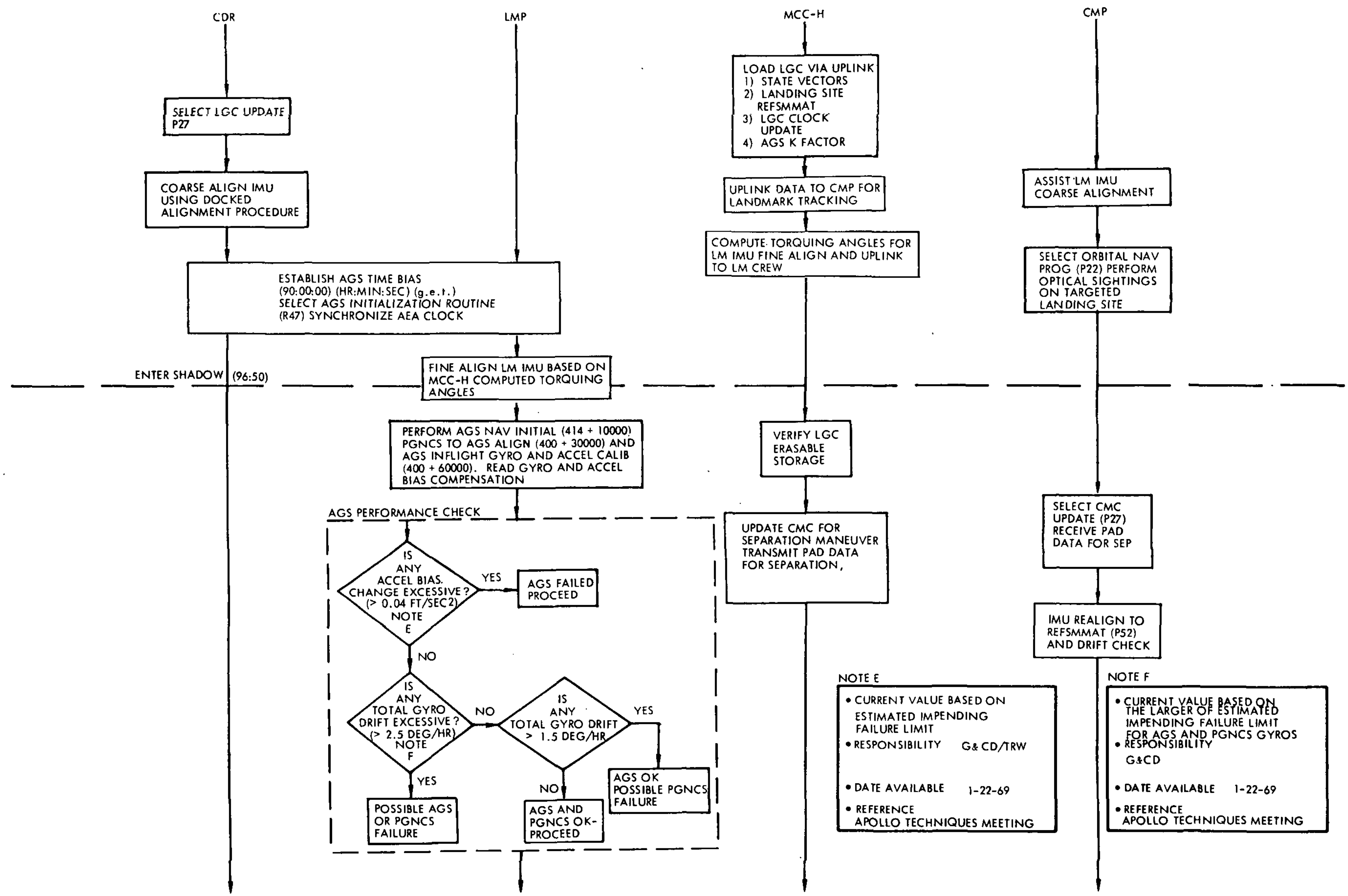
Figure 5-3. Mission F Insertion Maneuver Contingency Procedures

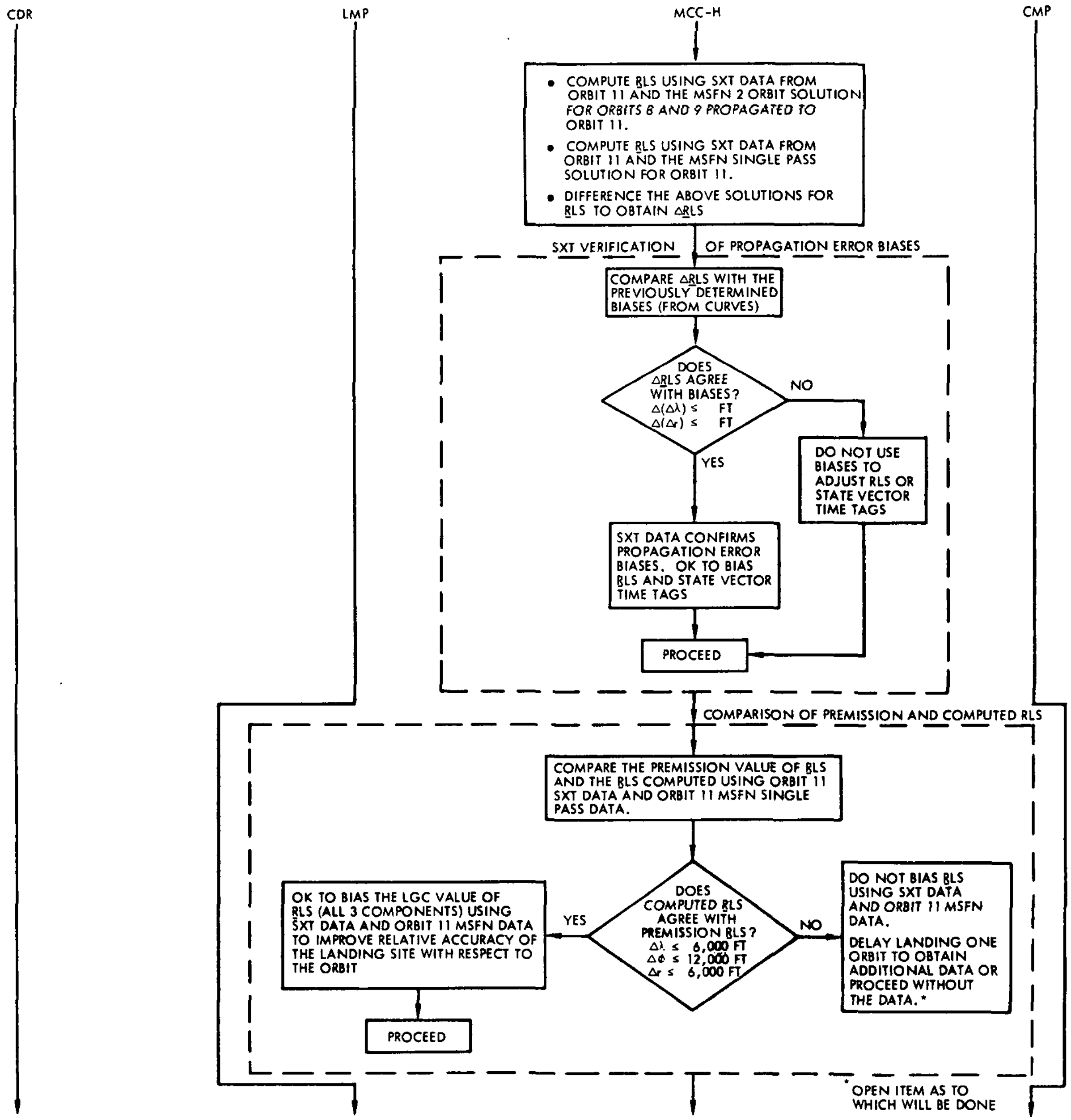
6. LUNAR ORBIT ACTIVITIES FLOW CHARTS

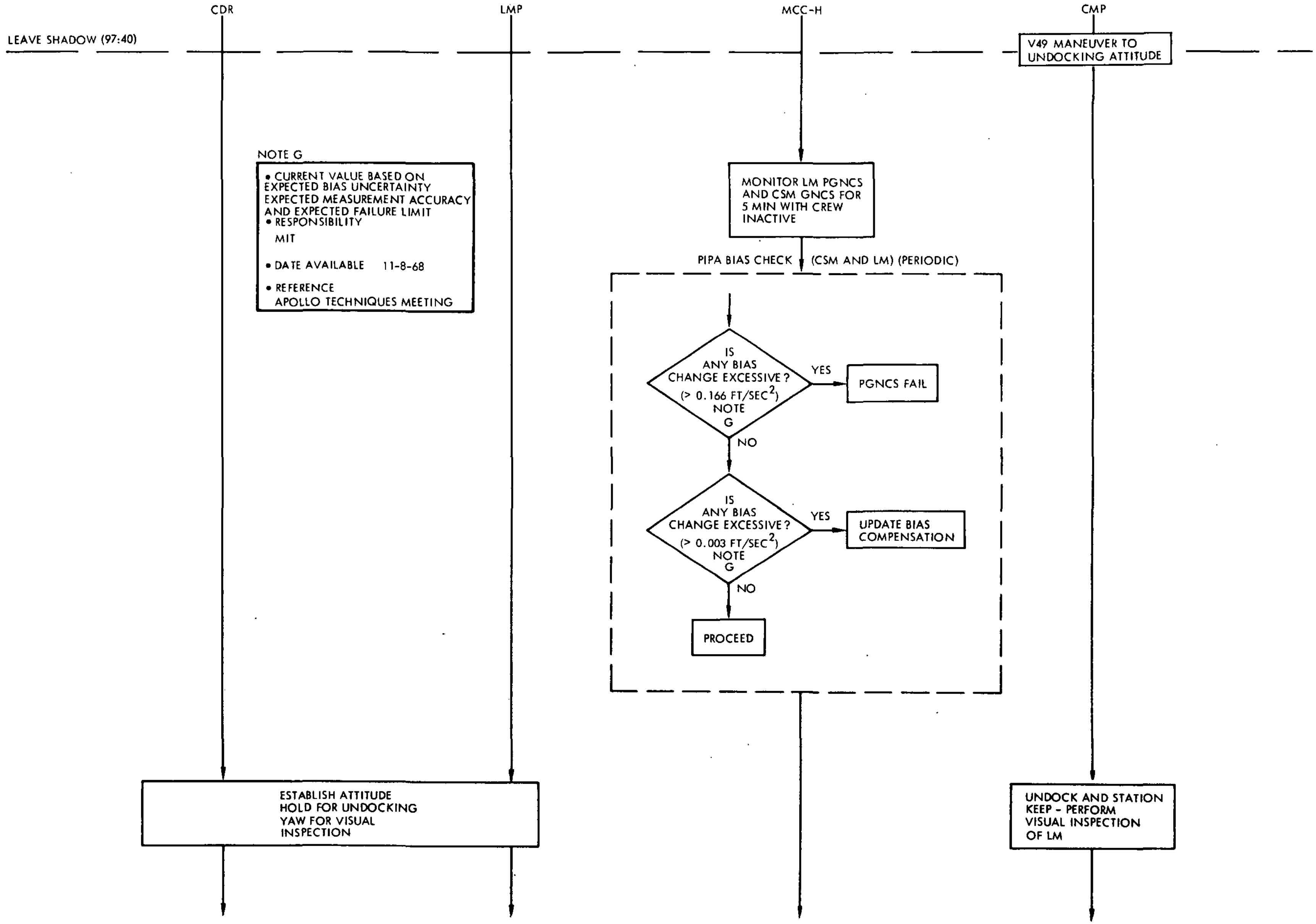
The following flow charts present the approved procedures to be followed for the guidance and control sequence of events for the Missions F and G Lunar Orbit Activities.


CDR
LMP
MCC-H
CSM
LOI-2 (80:10)
NOTE: REFERENCE MSC INTERNAL NOTE 69-FM-51 FOR ATTITUDE INFORMATION
LMP INGRESS
CDR INGRESS
PERFORM IMU REALIGN TO REFSMMAT (P52). VERIFY ALIGNMENT WITH AUTO OPTICS TO THIRD STAR.
LM HOUSEKEEPING AND PARTIAL ACTIVATION
SELECT ORBITAL NAVIGATION PROGRAM (P22). PERFORM PSEUDO LANDING SITE OBSERVATIONS.
SLEEP PERIOD
SLEEP PERIOD

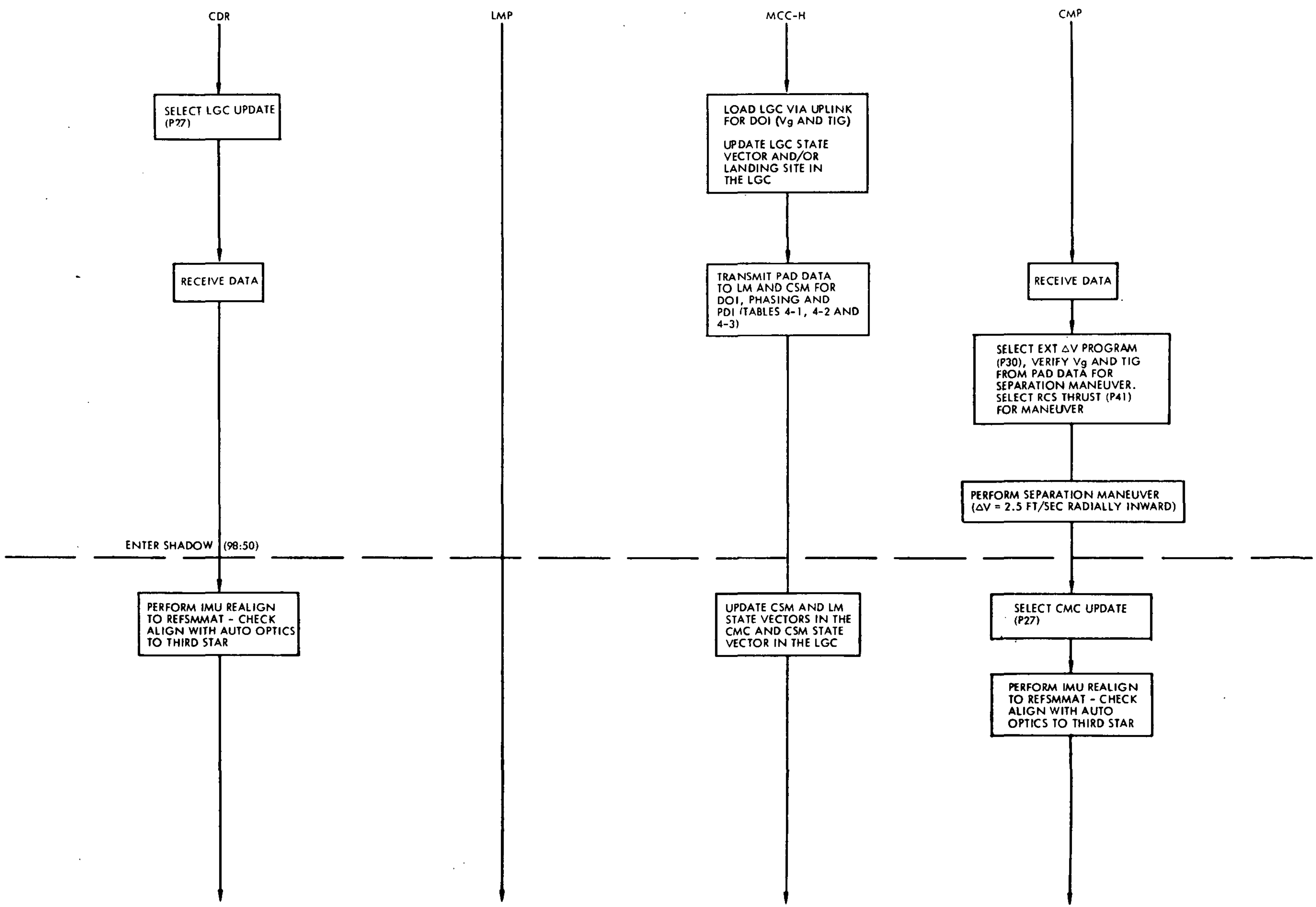

CDR
LMP
MCC-H
CSM
(94:00)
LM CREW AWAKES, EATS, AND DONS SUITS
CDR INGRESS
PGNCS TURN ON, AND E-MEMORY DUMP
LGC/CMC CLOCK SET AND T_{EPHEM} UPDATE
LMP INGRESS
BEGIN LM SYSTEMS CHECKS
AGS POWER ON
LOAD CMC VIA UPLINK: 1) STATE VECTORS 2) LANDING SITE REFSMMAT 3) LANDING SITE LOCATION 4) UPDATE CMC CLOCK
COMPUTE AND PLOT U, V, W DIFFERENCES USING MSFN TRACKING DATA FROM ORBITS 3 THROUGH 8
MSFN CONSISTENCY CHECK
ARE DIFFERENCES WITHIN LIMITS? ΔU ≤ FT ΔV ≤ FT ΔW ≤ FT
NO
YES
MSFN PROPAGATION ERRORS NOT CONSISTENT. DO NOT BIAS STATE VECTOR TIME TAGS OR RLS. PROCEED WITH MISSION.
FROM CURVES DETERMINE: ΔU (RADIAL BIAS) ΔT (DOWNRANGE OR STATE VECTOR TIME TAG BIAS)
PERIODIC PLANE CONSISTENCY CHECK
ARE INCLINATION RESIDUALS WITHIN LIMIT? Δi ≤ DEG
YES
PROCEED
NO
USING MSFN TRACKING DATA, OBTAIN A 2 ORBIT SOLUTION FOR THE INCLINATION (PLANE UNCONSTRAINED)
SELECT CMC UPDATE PROGRAM (P27)
PERFORM IMU REALIGN TO REFSMMAT (P52) VERIFY ALIGNMENT WITH AUTO OPTICS TO THIRD STAR
CSM IMU ALIGN AND DRIFT CHECK
WAS STAR DATA CHECK OK? (< 0.05 DEG) NOTE A
NO
REPEAT P52
YES
WAS THIRD STAR IN SXT FOV? (± 0.9 DEG) NOTE B
NO
REPEAT P52 AND ASSESS FAILURE
YES
DOES ANY GYRO TORQ ANGLE INDICATE GNCS FAIL? (> 1.5 DEG/HR) NOTE C
NO
GNCS FAIL-GO TO ALTERNATE MISSION
YES
DOES ANY GYRO DRIFT PREVENT GNCS RDZ NAVIG? (> 0.30 DEG/HR) NOTE D
YES
UPDATE NBD (MCC-H) USING GYRO TORQ ANGLES PROCEED
NO
PROCEED
NOTE B
• CURRENT VALUE BASED ON CONVENIENCE OF SEXTANT FIELD OF VIEW
• RESPONSIBILITY MIT
• DATE AVAILABLE 26 SEPTEMBER 1968
• REFERENCE MTM NO.7
NOTE A
• CURRENT VALUE BASED ON ALLOWABLE DIFFERENCE BETWEEN ACTUAL AND INDICATED ANGLES BETWEEN THE TWO STARS
• RESPONSIBILITY MIT
• DATE AVAILABLE 26 SEPTEMBER 1968
• REFERENCE MTM NO.7
NOTE C
• CURRENT VALUE BASED ON FAILURE LIMIT
• RESPONSIBILITY MIT
• DATE AVAILABLE 26 SEPTEMBER 1968
• REFERENCE MTM NO.7
NOTE D
• CURRENT VALUE BASED ON 3σ MEASUREMENT ACCURACY OF 2 AOT ALIGNMENTS
• RESPONSIBILITY MPAD/MIT
• DATE AVAILABLE 1-22-69
• REFERENCE APOLLO TECHNIQUES MEETING

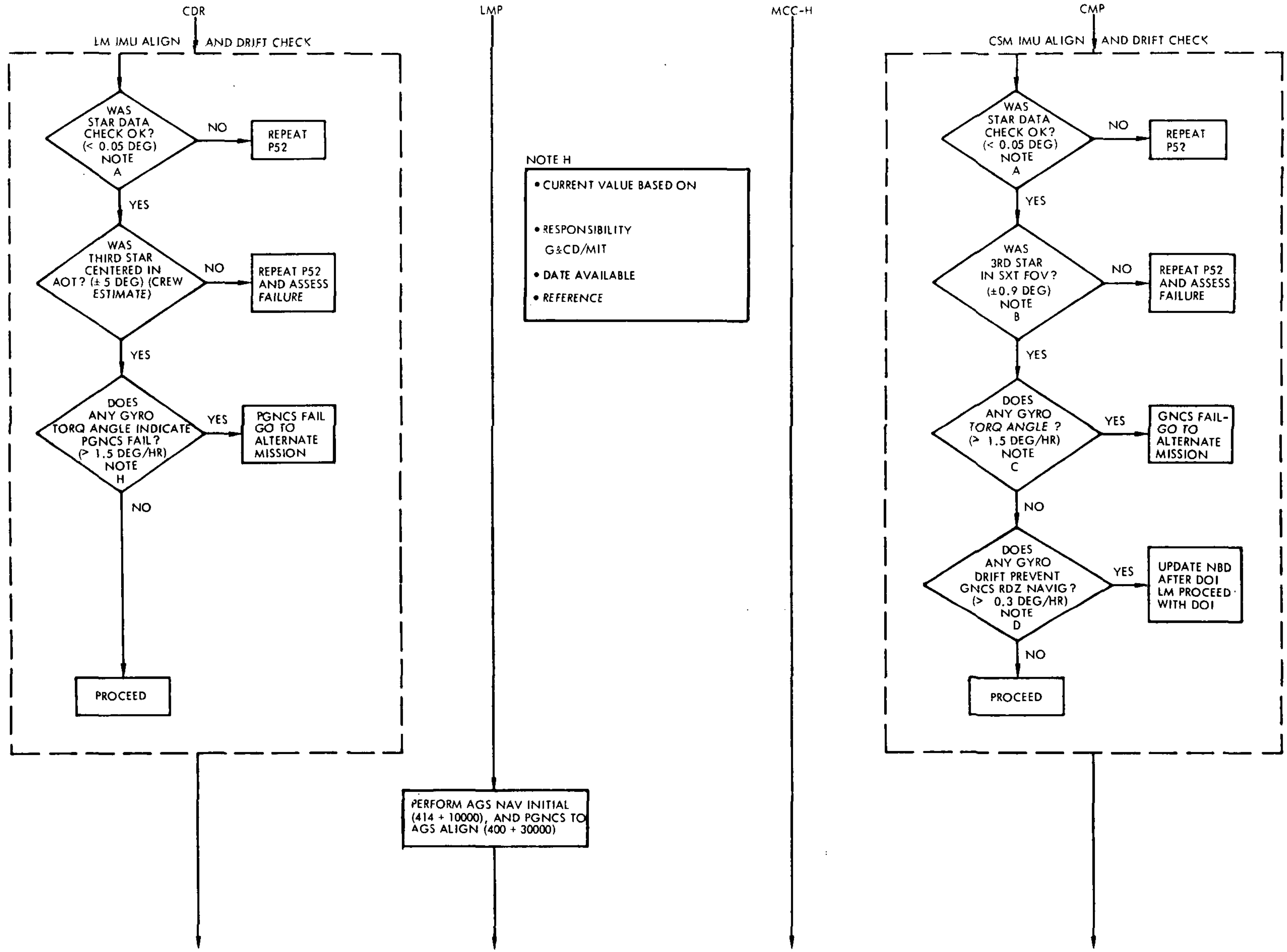

CDR
LMP
MCC-H
CMP
SELECT LGC UPDATE P27
COARSE ALIGN IMU USING DOCKED ALIGNMENT PROCEDURE
ESTABLISH AGS TIME BIAS (90:00:00) (HR:MIN:SEC) (g.e.t.) SELECT AGS INITIALIZATION ROUTINE (R47) SYNCHRONIZE AEA CLOCK
ENTER SHADOW (96:50)
FINE ALIGN LM IMU BASED ON MCC-H COMPUTED TORQUING ANGLES
PERFORM AGS NAV INITIAL (414 + 10000) PGNCS TO AGS ALIGN (400 + 30000) AND AGS INFLIGHT GYRO AND ACCEL CALIB (400 + 60000). READ GYRO AND ACCEL BIAS COMPENSATION
AGS PERFORMANCE CHECK
IS ANY ACCEL BIAS CHANGE EXCESSIVE? (> 0.04 FT/SEC2) NOTE E
YES
AGS FAILED PROCEED
NO
IS ANY TOTAL GYRO DRIFT EXCESSIVE? (> 2.5 DEG/HR) NOTE F
YES
POSSIBLE AGS OR PGNCS FAILURE
NO
IS ANY TOTAL GYRO DRIFT > 1.5 DEG/HR
YES
AGS OK POSSIBLE PGNCS FAILURE
NO
AGS AND PGNCS OK-PROCEED
LOAD LGC VIA UPLINK
1) STATE VECTORS
2) LANDING SITE REFSMMAT
3) LGC CLOCK UPDATE
4) AGS K FACTOR
UPLINK DATA TO CMP FOR LANDMARK TRACKING
COMPUTE TORQUING ANGLES FOR LM IMU FINE ALIGN AND UPLINK TO LM CREW
VERIFY LGC ERASABLE STORAGE
UPDATE CMC FOR SEPARATION MANEUVER TRANSMIT PAD DATA FOR SEPARATION,
ASSIST LM IMU COARSE ALIGNMENT
SELECT ORBITAL NAV PROG (P22) PERFORM OPTICAL SIGHTINGS ON TARGETED LANDING SITE
SELECT CMC UPDATE (P27) RECEIVE PAD DATA FOR SEP
IMU REALIGN TO REFSMMAT (P52) AND DRIFT CHECK
NOTE E
• CURRENT VALUE BASED ON ESTIMATED IMPENDING FAILURE LIMIT
• RESPONSIBILITY G& CD/TRW
• DATE AVAILABLE 1-22-69
• REFERENCE APOLLO TECHNIQUES MEETING
NOTE F
• CURRENT VALUE BASED ON THE LARGER OF ESTIMATED IMPENDING FAILURE LIMIT FOR AGS AND PGNCS GYROS
• RESPONSIBILITY G&CD
• DATE AVAILABLE 1-22-69
• REFERENCE APOLLO TECHNIQUES MEETING

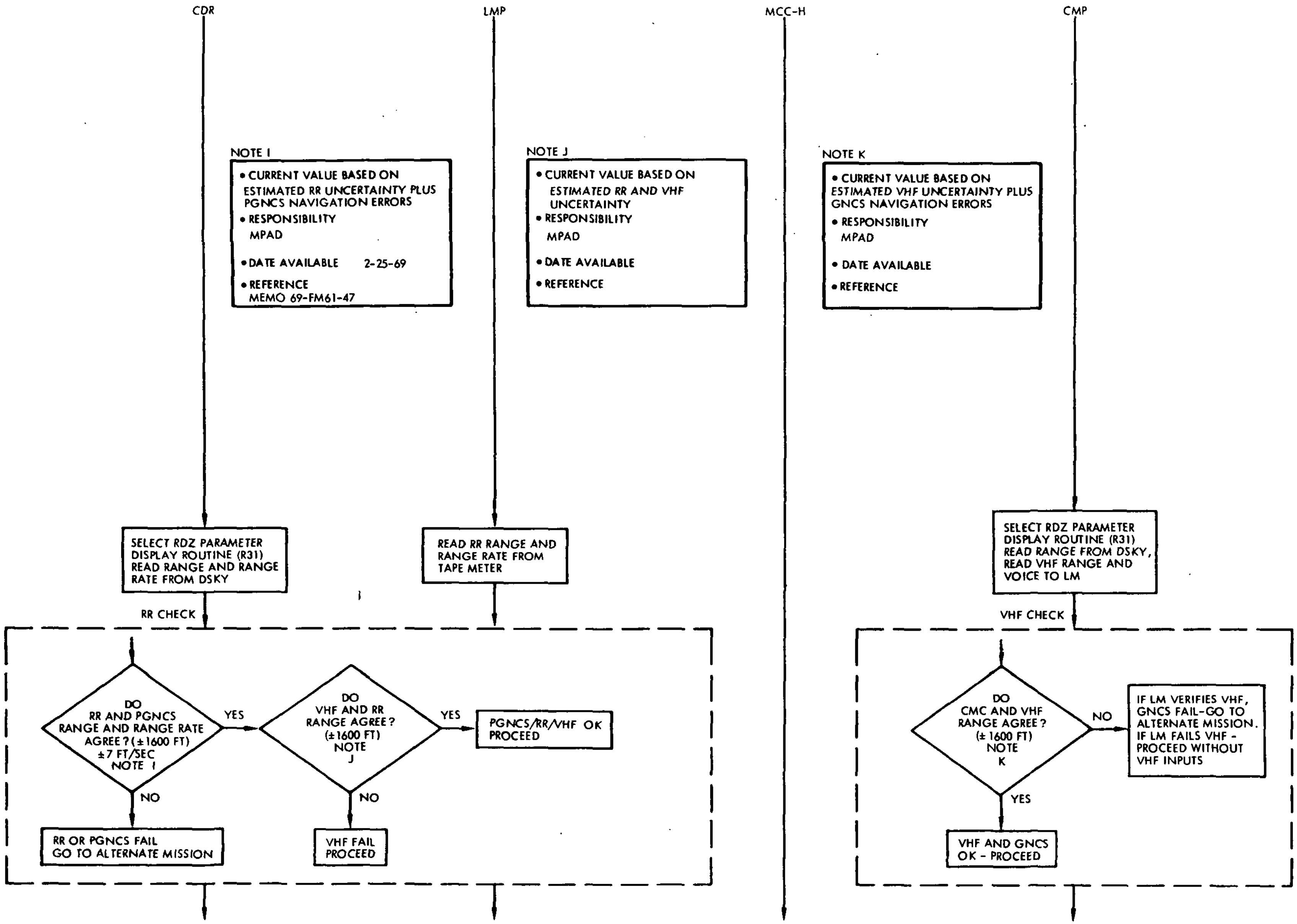

CDR
LMP
MCC-H
CMP
• COMPUTE RLS USING SXT DATA FROM ORBIT 11 AND THE MSFN 2 ORBIT SOLUTION FOR ORBITS 8 AND 9 PROPAGATED TO ORBIT 11.
• COMPUTE RLS USING SXT DATA FROM ORBIT 11 AND THE MSFN SINGLE PASS SOLUTION FOR ORBIT 11.
• DIFFERENCE THE ABOVE SOLUTIONS FOR RLS TO OBTAIN ΔRLS
SXT VERIFICATION OF PROPAGATION ERROR BIASES
COMPARE ΔRLS WITH THE PREVIOUSLY DETERMINED BIASES (FROM CURVES)
DOES ΔRLS AGREE WITH BIASES? Δ(Δλ) ≤ FT Δ(Δr) ≤ FT
NO
DO NOT USE BIASES TO ADJUST RLS OR STATE VECTOR TIME TAGS
YES
SXT DATA CONFIRMS PROPAGATION ERROR BIASES. OK TO BIAS RLS AND STATE VECTOR TIME TAGS
PROCEED
COMPARISON OF PREMISSION AND COMPUTED RLS
COMPARE THE PREMISSION VALUE OF RLS AND THE RLS COMPUTED USING ORBIT 11 SXT DATA AND ORBIT 11 MSFN SINGLE PASS DATA.
DOES COMPUTED RLS AGREE WITH PREMISSION RLS? Δλ ≤ 6,000 FT Δφ ≤ 12,000 FT Δr ≤ 6,000 FT
YES
OK TO BIAS THE LGC VALUE OF RLS (ALL 3 COMPONENTS) USING SXT DATA AND ORBIT 11 MSFN DATA TO IMPROVE RELATIVE ACCURACY OF THE LANDING SITE WITH RESPECT TO THE ORBIT
PROCEED
NO
DO NOT BIAS RLS USING SXT DATA AND ORBIT 11 MSFN DATA.
DELAY LANDING ONE ORBIT TO OBTAIN ADDITIONAL DATA OR PROCEED WITHOUT THE DATA.*
*OPEN ITEM AS TO WHICH WILL BE DONE



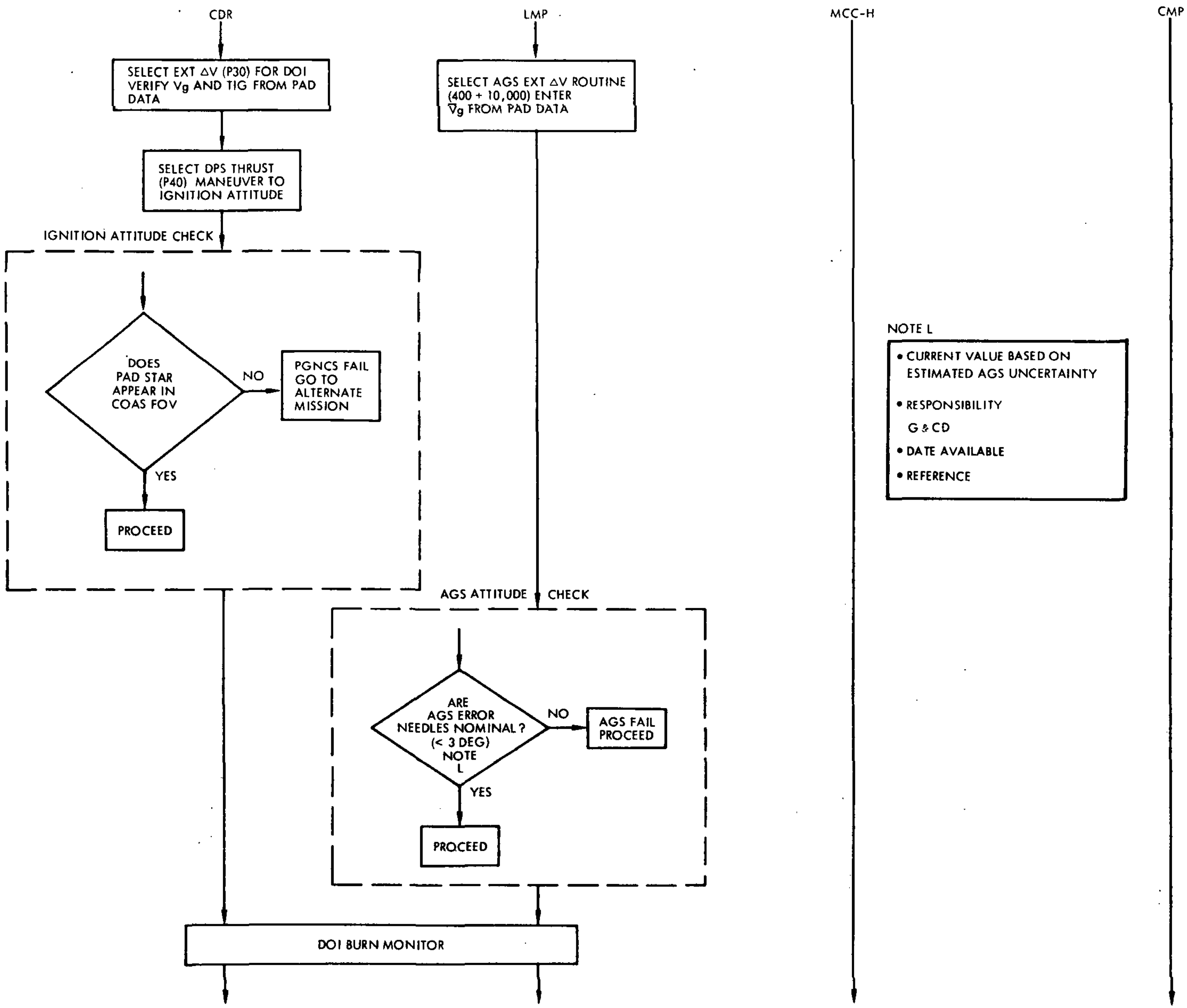
CDR
LMP
MCC-H
CMP
LEAVE SHADOW (97:40)
V49 MANEUVER TO UNDOCKING ATTITUDE
NOTE G
• CURRENT VALUE BASED ON EXPECTED BIAS UNCERTAINTY EXPECTED MEASUREMENT ACCURACY AND EXPECTED FAILURE LIMIT
• RESPONSIBILITY
MIT
• DATE AVAILABLE 11-8-68
• REFERENCE
APOLLO TECHNIQUES MEETING
MONITOR LM PGNCS AND CSM GNCS FOR 5 MIN WITH CREW INACTIVE
PIPA BIAS CHECK (CSM AND LM) (PERIODIC)
IS ANY BIAS CHANGE EXCESSIVE? (> 0.166 FT/SEC²) NOTE G
YES
PGNCS FAIL
NO
IS ANY BIAS CHANGE EXCESSIVE? (> 0.003 FT/SEC²) NOTE G
YES
UPDATE BIAS COMPENSATION
NO
PROCEED
ESTABLISH ATTITUDE HOLD FOR UNDOCKING YAW FOR VISUAL INSPECTION
UNDOCK AND STATION KEEP - PERFORM VISUAL INSPECTION OF LM

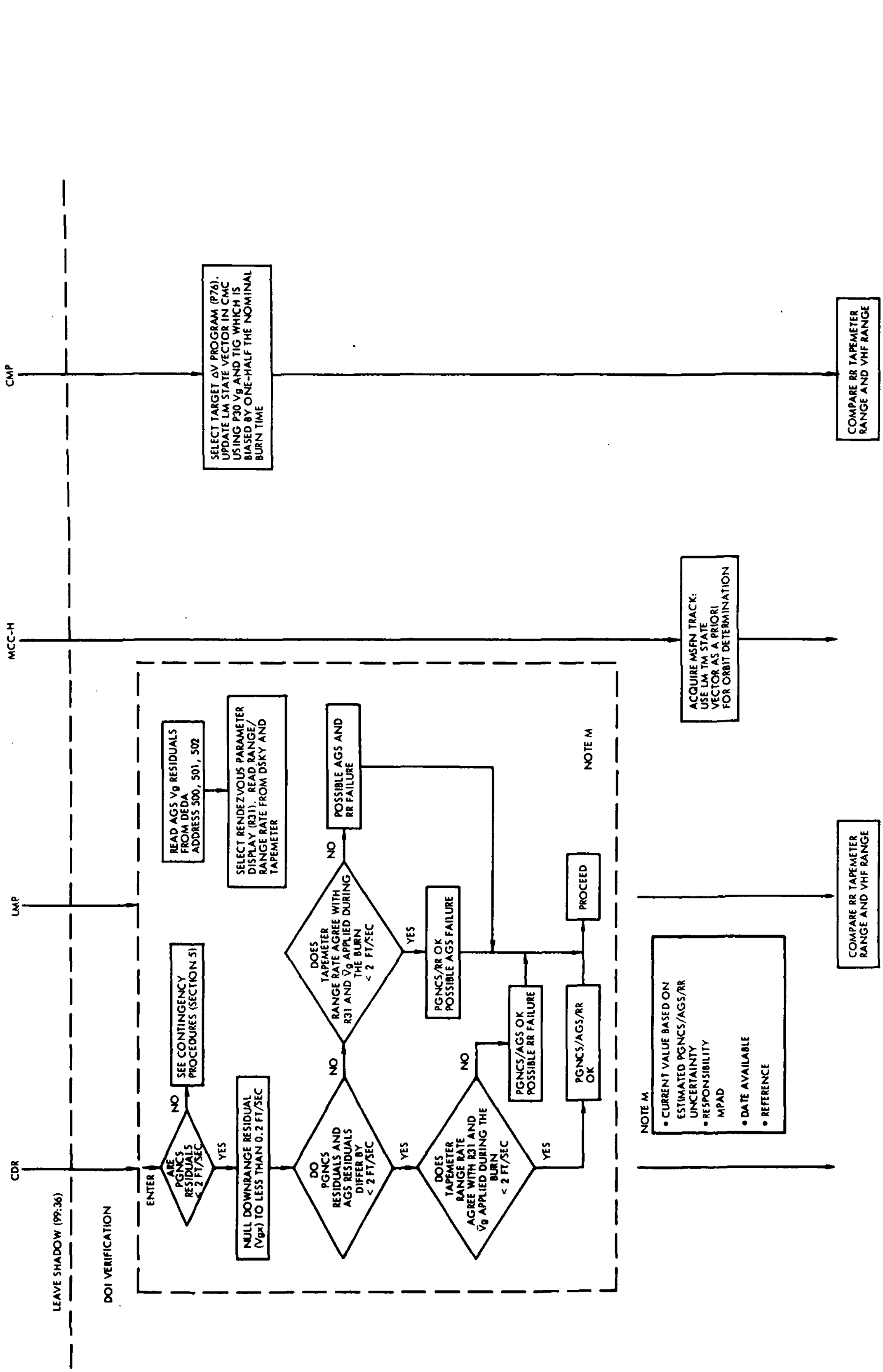

CDR
LMP
MCC-H
CMP
SELECT LGC UPDATE (P27)
LOAD LGC VIA UPLINK FOR DOI (Vg AND TIG)
UPDATE LGC STATE VECTOR AND/OR LANDING SITE IN THE LGC
RECEIVE DATA
TRANSMIT PAD DATA TO LM AND CSM FOR DOI, PHASING AND PDI (TABLES 4-1, 4-2 AND 4-3)
RECEIVE DATA
SELECT EXT ΔV PROGRAM (P30), VERIFY Vg AND TIG FROM PAD DATA FOR SEPARATION MANEUVER. SELECT RCS THRUST (P41) FOR MANEUVER
PERFORM SEPARATION MANEUVER (ΔV = 2.5 FT/SEC RADIALLY INWARD)
ENTER SHADOW (98:50)
PERFORM IMU REALIGN TO REFSMMAT - CHECK ALIGN WITH AUTO OPTICS TO THIRD STAR
UPDATE CSM AND LM STATE VECTORS IN THE CMC AND CSM STATE VECTOR IN THE LGC
SELECT CMC UPDATE (P27)
PERFORM IMU REALIGN TO REFSMMAT - CHECK ALIGN WITH AUTO OPTICS TO THIRD STAR


CDR
LM IMU ALIGN AND DRIFT CHECK
WAS STAR DATA CHECK OK? (< 0.05 DEG) NOTE A
NO
REPEAT P52
YES
WAS THIRD STAR CENTERED IN AOT? (± 5 DEG) (CREW ESTIMATE)
NO
REPEAT P52 AND ASSESS FAILURE
YES
DOES ANY GYRO TORQ ANGLE INDICATE PGNCS FAIL? (> 1.5 DEG/HR) NOTE H
YES
PGNCS FAIL GO TO ALTERNATE MISSION
NO
PROCEED
LMP
NOTE H
• CURRENT VALUE BASED ON
• RESPONSIBILITY G&CD/MIT
• DATE AVAILABLE
• REFERENCE
PERFORM AGS NAV INITIAL (414 + 10000), AND PGNCS TO AGS ALIGN (400 + 30000)
MCC-H
CMP
CSM IMU ALIGN AND DRIFT CHECK
WAS STAR DATA CHECK OK? (< 0.05 DEG) NOTE A
NO
REPEAT P52
YES
WAS 3RD STAR IN SXT FOV? (±0.9 DEG) NOTE B
NO
REPEAT P52 AND ASSESS FAILURE
YES
DOES ANY GYRO TORQ ANGLE ? (> 1.5 DEG/HR) NOTE C
YES
GNCS FAIL-GO TO ALTERNATE MISSION
NO
DOES ANY GYRO DRIFT PREVENT GNCS RDZ NAVIG? (> 0.3 DEG/HR) NOTE D
YES
UPDATE NBD AFTER DOI LM PROCEED WITH DOI
NO
PROCEED

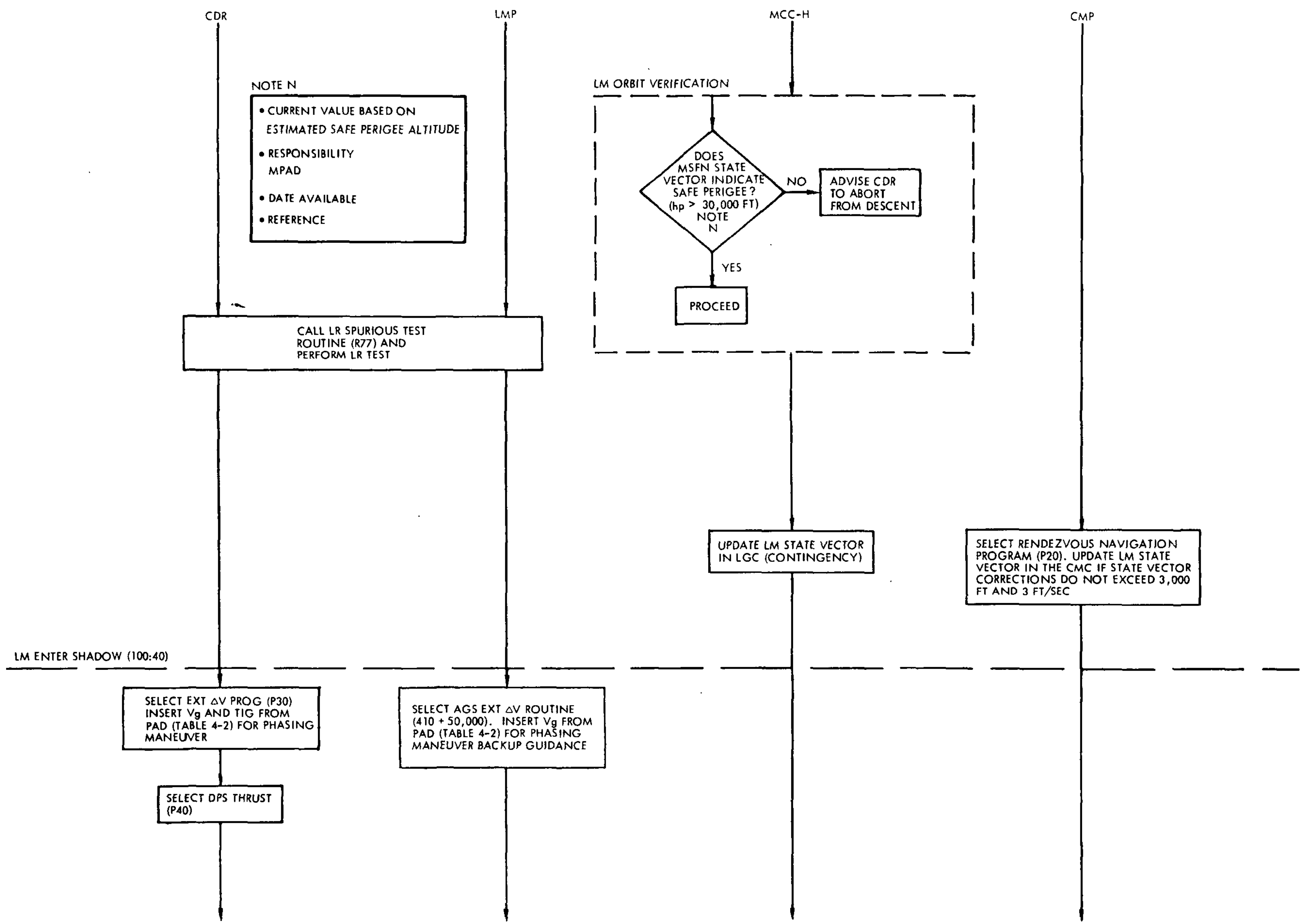


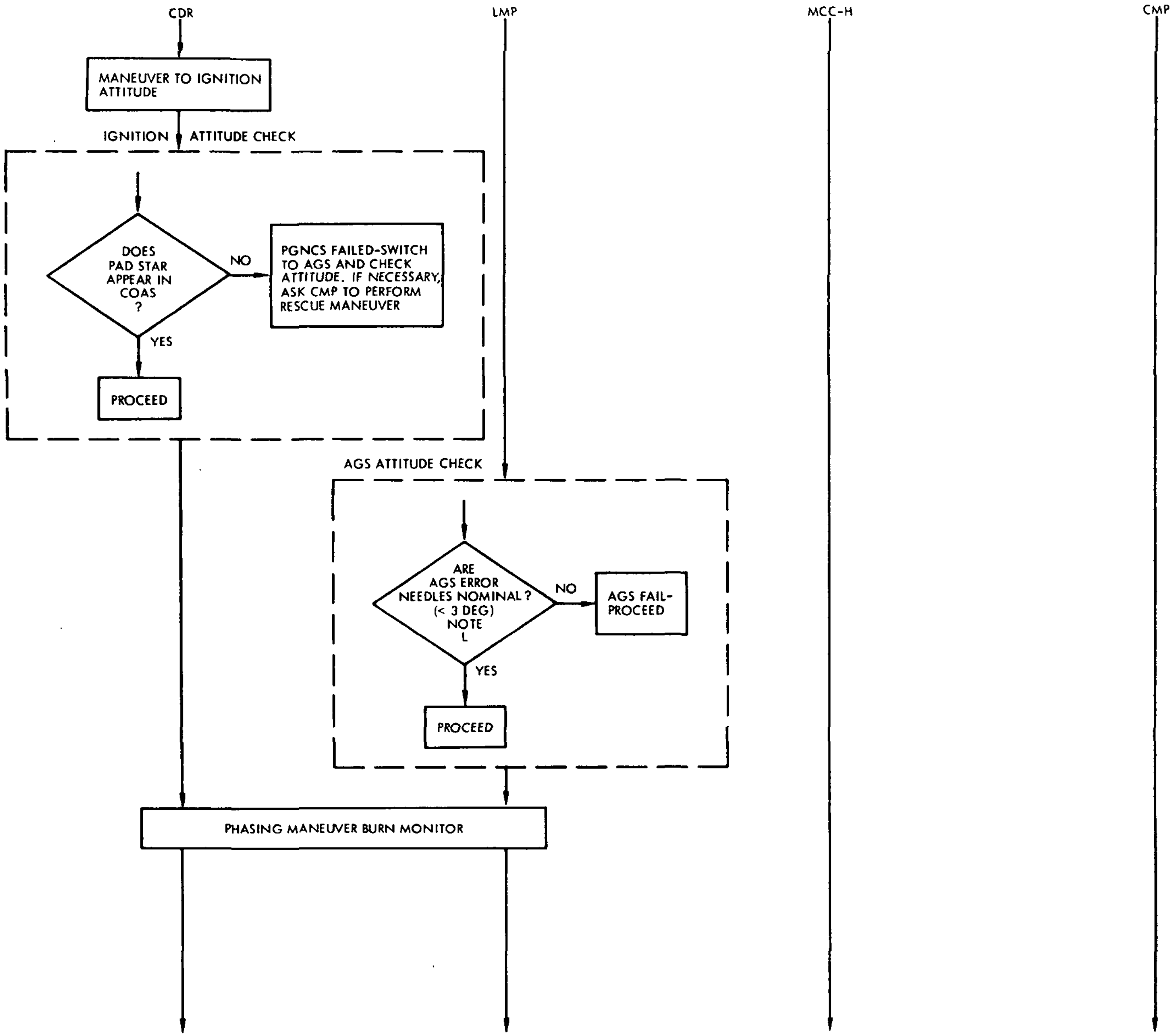
CDR
LMP
MCC-H
CMP
NOTE I
• CURRENT VALUE BASED ON ESTIMATED RR UNCERTAINTY PLUS PGNCS NAVIGATION ERRORS
• RESPONSIBILITY MPAD
• DATE AVAILABLE 2-25-69
• REFERENCE MEMO 69-FM61-47
NOTE J
• CURRENT VALUE BASED ON ESTIMATED RR AND VHF UNCERTAINTY
• RESPONSIBILITY MPAD
• DATE AVAILABLE
• REFERENCE
NOTE K
• CURRENT VALUE BASED ON ESTIMATED VHF UNCERTAINTY PLUS GNCS NAVIGATION ERRORS
• RESPONSIBILITY MPAD
• DATE AVAILABLE
• REFERENCE
SELECT RDZ PARAMETER DISPLAY ROUTINE (R31) READ RANGE AND RANGE RATE FROM DSKY
READ RR RANGE AND RANGE RATE FROM TAPE METER
SELECT RDZ PARAMETER DISPLAY ROUTINE (R31) READ RANGE FROM DSKY, READ VHF RANGE AND VOICE TO LM
RR CHECK
VHF CHECK
DO RR AND PGNCS RANGE AND RANGE RATE AGREE? (±1600 FT) ±7 FT/SEC NOTE I
YES
NO
RR OR PGNCS FAIL GO TO ALTERNATE MISSION
DO VHF AND RR RANGE AGREE? (±1600 FT) NOTE J
YES
NO
PGNCS/RR/VHF OK PROCEED
VHF FAIL PROCEED
DO CMC AND VHF RANGE AGREE? (±1600 FT) NOTE K
NO
YES
IF LM VERIFIES VHF, GNCS FAIL-GO TO ALTERNATE MISSION. IF LM FAILS VHF - PROCEED WITHOUT VHF INPUTS
VHF AND GNCS OK - PROCEED


CDR
LMP
MCC-H
CMP
SELECT EXT ΔV (P30) FOR DOI VERIFY Vg AND TIG FROM PAD DATA
SELECT AGS EXT ΔV ROUTINE (400 + 10,000) ENTER V̄g FROM PAD DATA
SELECT DPS THRUST (P40) MANEUVER TO IGNITION ATTITUDE
IGNITION ATTITUDE CHECK
DOES PAD STAR APPEAR IN COAS FOV
NO
PGNCS FAIL GO TO ALTERNATE MISSION
YES
PROCEED
NOTE L
• CURRENT VALUE BASED ON ESTIMATED AGS UNCERTAINTY
• RESPONSIBILITY
G & CD
• DATE AVAILABLE
• REFERENCE
AGS ATTITUDE CHECK
ARE AGS ERROR NEEDLES NOMINAL? (< 3 DEG) NOTE L
NO
AGS FAIL PROCEED
YES
PROCEED
DOI BURN MONITOR

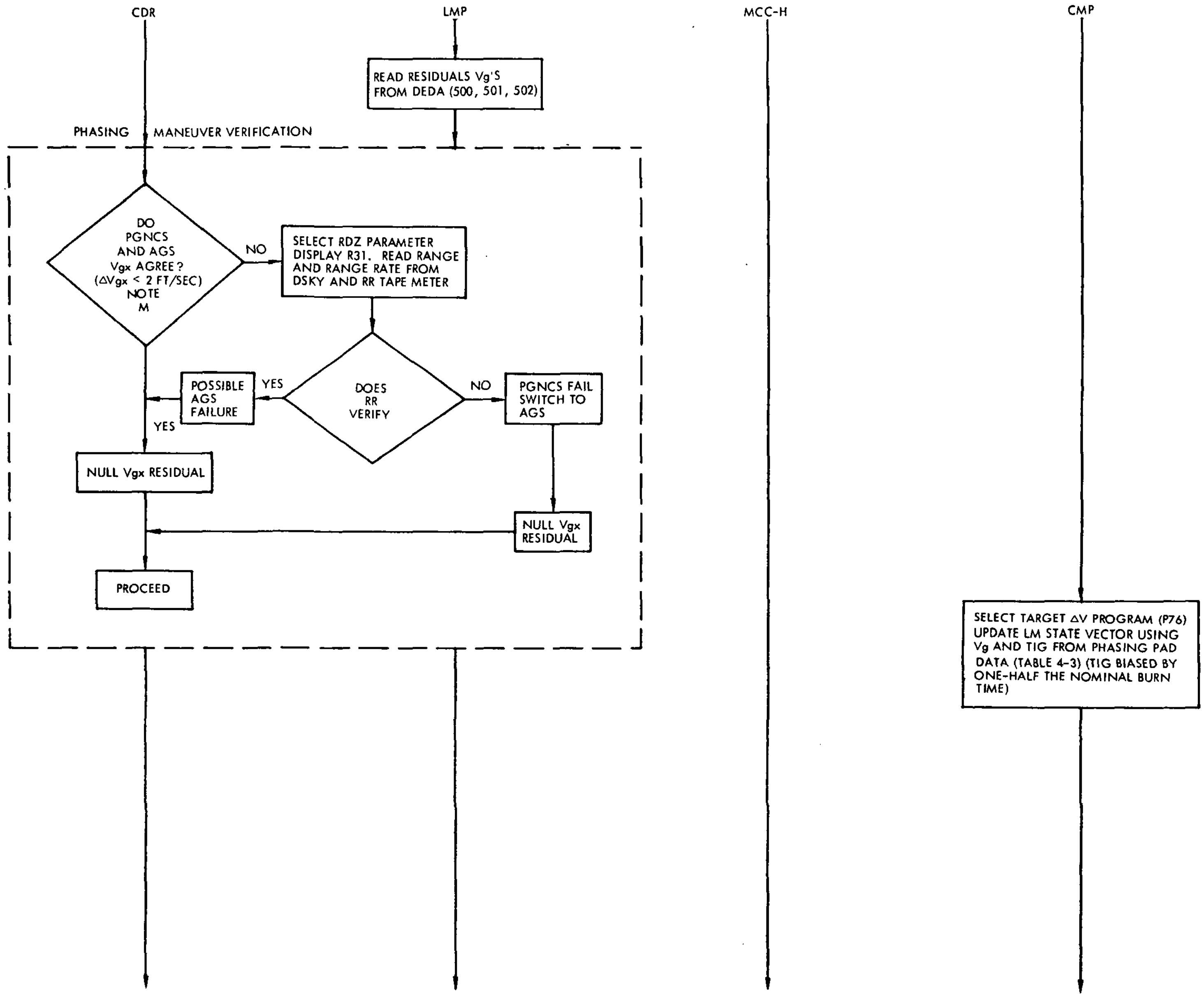


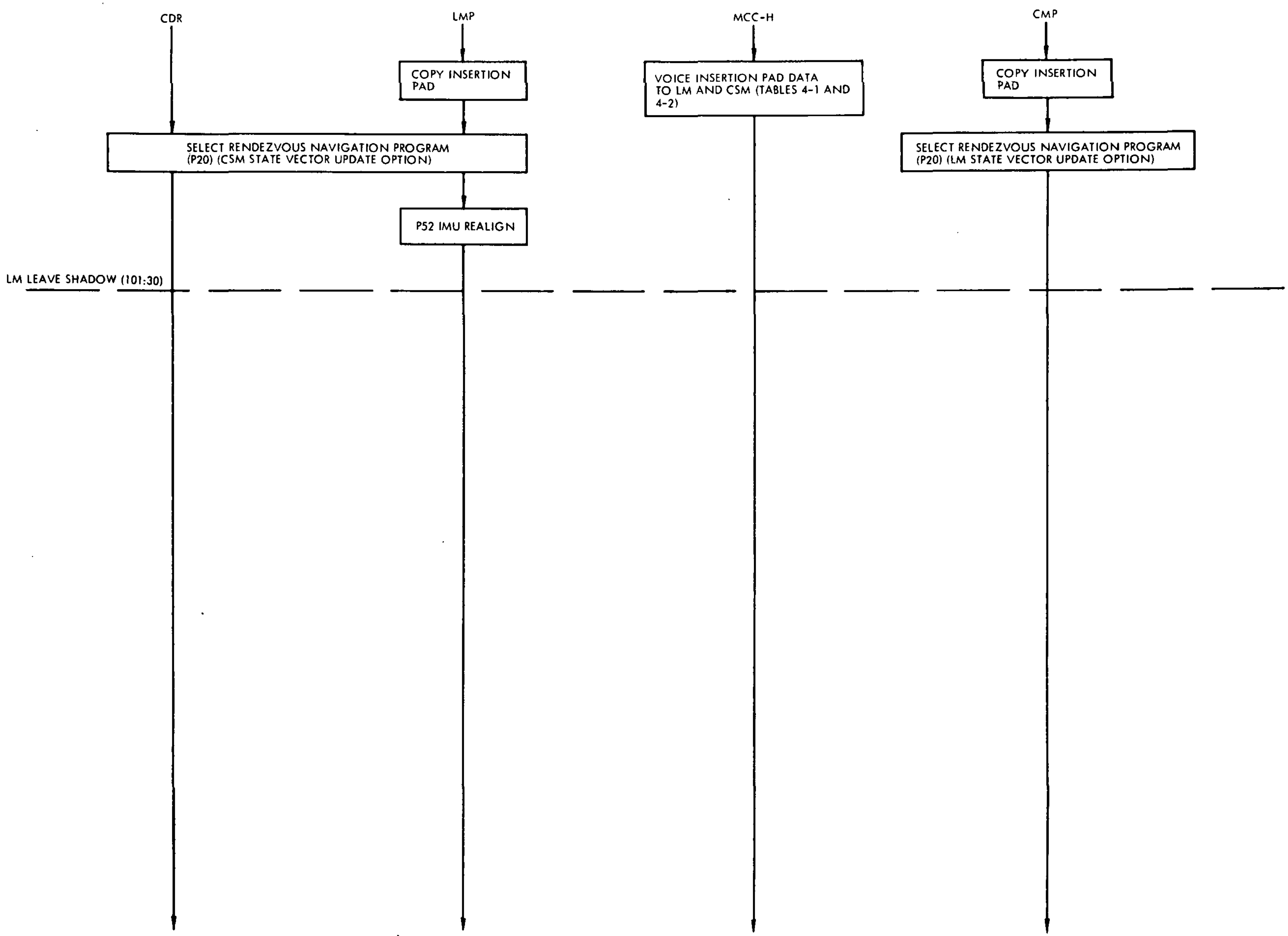
CMP
MCC-H
LMP
CDR
LEAVE SHADOW (99:36)
DOI VERIFICATION
ENTER
ARE PGNCS RESIDUALS < 2 FT/SEC
NO
SEE CONTINGENCY PROCEDURES (SECTION 5)
YES
NULL DOWNRANGE RESIDUAL (V_{gx}) TO LESS THAN 0.2 FT/SEC
DO PGNCS RESIDUALS AND AGS RESIDUALS DIFFER BY < 2 FT/SEC
NO
YES
READ AGS V_g RESIDUALS FROM DEDA ADDRESS 500, 501, 502
SELECT RENDEZVOUS PARAMETER DISPLAY (R31). READ RANGE/RANGE RATE FROM DSKY AND TAPEMETER
DOES TAPEMETER RANGE RATE AGREE WITH R31 AND $\bar{V}_g$ APPLIED DURING THE BURN < 2 FT/SEC
NO
POSSIBLE AGS AND RR FAILURE
YES
PGNCS/RR OK POSSIBLE AGS FAILURE
DOES TAPEMETER RANGE RATE AGREE WITH R31 AND $\bar{V}_g$ APPLIED DURING THE BURN < 2 FT/SEC
NO
PGNCS/AGS OK POSSIBLE RR FAILURE
YES
PGNCS/AGS/RR OK
PROCEED
NOTE M
SELECT TARGET ΔV PROGRAM (P76). UPDATE LM STATE VECTOR IN CMC USING P30 V_g AND TIG WHICH IS BIASED BY ONE-HALF THE NOMINAL BURN TIME
ACQUIRE MSFN TRACK: USE LM TM STATE VECTOR AS A PRIORI FOR ORBIT DETERMINATION
NOTE M
• CURRENT VALUE BASED ON ESTIMATED PGNCS/AGS/RR UNCERTAINTY
• RESPONSIBILITY MPAD
• DATE AVAILABLE
• REFERENCE
COMPARE RR TAPEMETER RANGE AND VHF RANGE
COMPARE RR TAPEMETER RANGE AND VHF RANGE

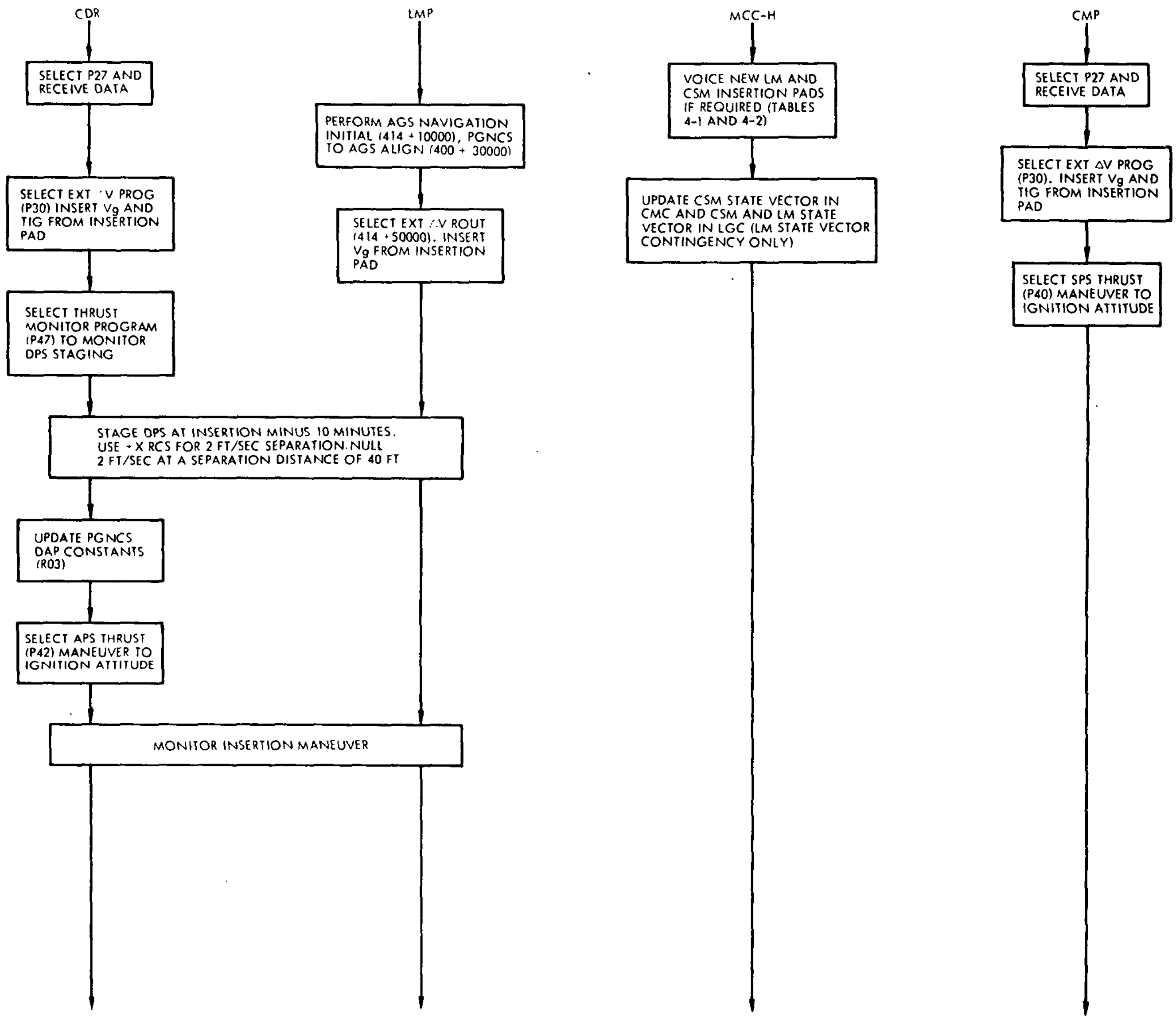

CDR
LMP
MCC-H
CMP
NOTE N
• CURRENT VALUE BASED ON ESTIMATED SAFE PERIGEE ALTITUDE
• RESPONSIBILITY MPAD
• DATE AVAILABLE
• REFERENCE
LM ORBIT VERIFICATION
DOES MSFN STATE VECTOR INDICATE SAFE PERIGEE? (hp > 30,000 FT) NOTE N
NO
ADVISE CDR TO ABORT FROM DESCENT
YES
PROCEED
CALL LR SPURIOUS TEST ROUTINE (R77) AND PERFORM LR TEST
UPDATE LM STATE VECTOR IN LGC (CONTINGENCY)
SELECT RENDEZVOUS NAVIGATION PROGRAM (P20). UPDATE LM STATE VECTOR IN THE CMC IF STATE VECTOR CORRECTIONS DO NOT EXCEED 3,000 FT AND 3 FT/SEC
LM ENTER SHADOW (100:40)
SELECT EXT ΔV PROG (P30) INSERT Vg AND TIG FROM PAD (TABLE 4-2) FOR PHASING MANEUVER
SELECT AGS EXT ΔV ROUTINE (410 + 50,000). INSERT Vg FROM PAD (TABLE 4-2) FOR PHASING MANEUVER BACKUP GUIDANCE
SELECT DPS THRUST (P40)

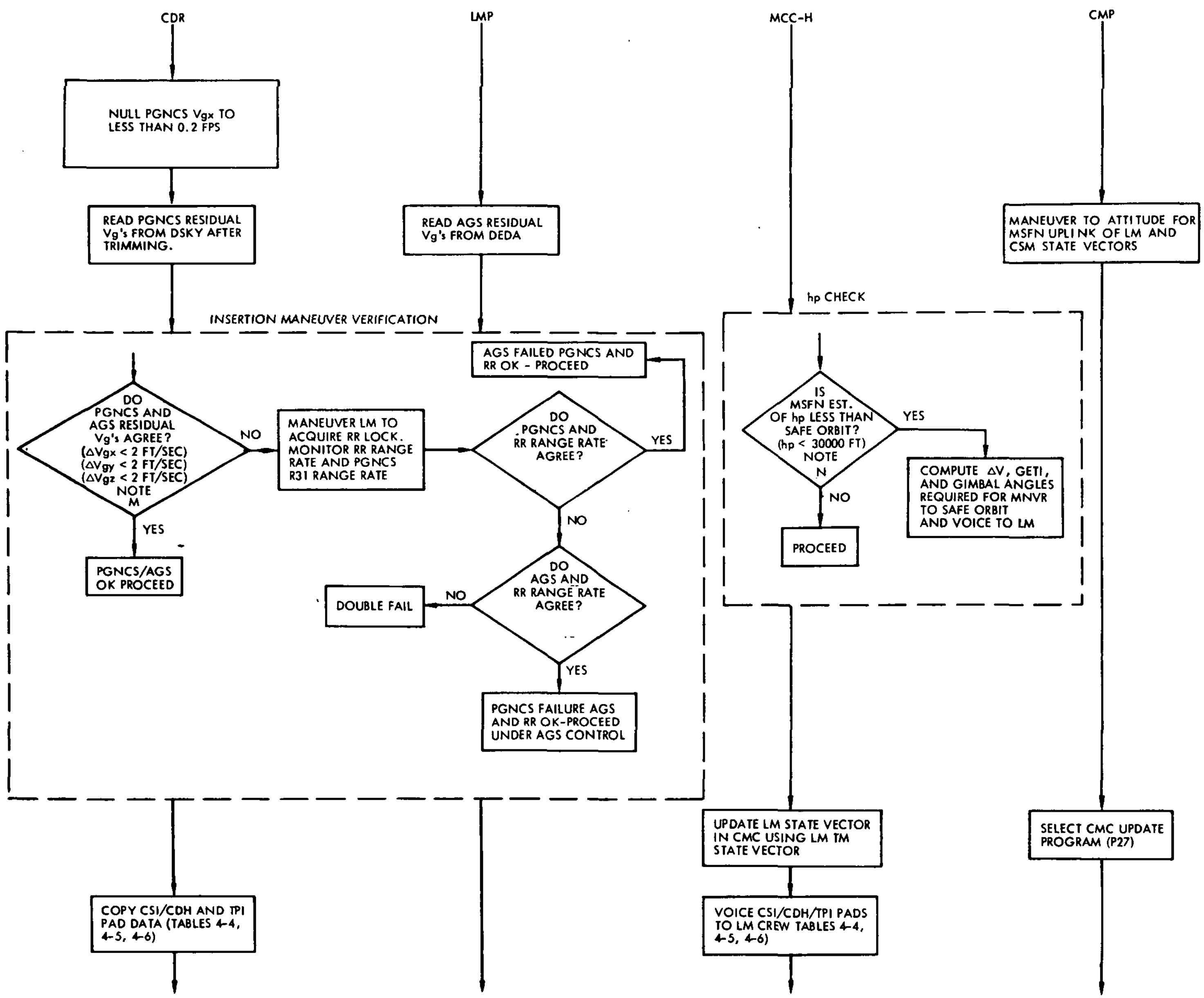


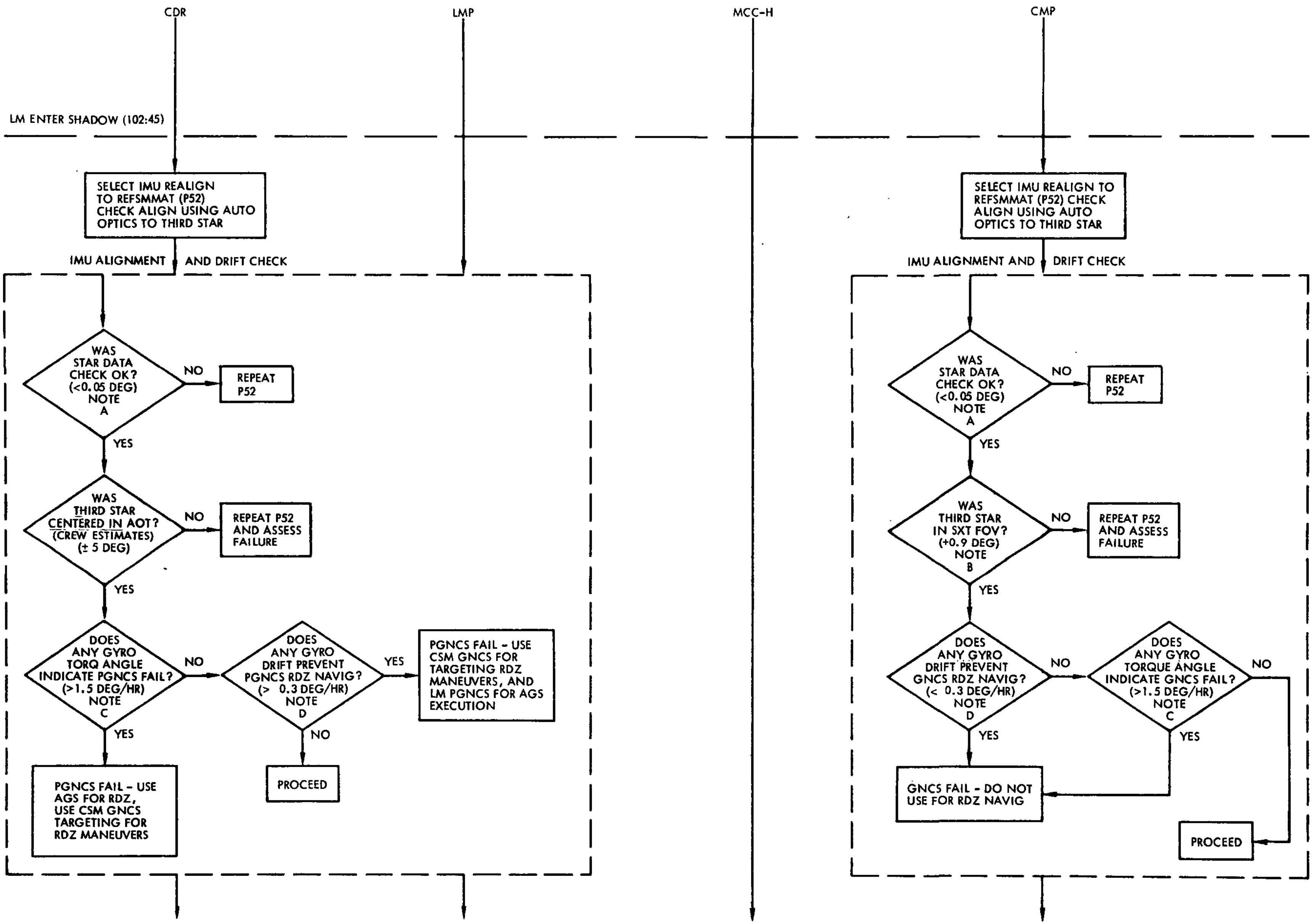
CDR
LMP
MCC-H
CMP
MANEUVER TO IGNITION ATTITUDE
IGNITION ATTITUDE CHECK
DOES PAD STAR APPEAR IN COAS ?
NO
PGNCS FAILED-SWITCH TO AGS AND CHECK ATTITUDE. IF NECESSARY, ASK CMP TO PERFORM RESCUE MANEUVER
YES
PROCEED
AGS ATTITUDE CHECK
ARE AGS ERROR NEEDLES NOMINAL ? (< 3 DEG) NOTE L
NO
AGS FAIL-PROCEED
YES
PROCEED
PHASING MANEUVER BURN MONITOR


CDR
LMP
MCC-H
CMP
READ RESIDUALS Vg'S FROM DEDA (500, 501, 502)
PHASING MANEUVER VERIFICATION
DO PGNCS AND AGS Vgx AGREE? (ΔVgx < 2 FT/SEC) NOTE M
NO
SELECT RDZ PARAMETER DISPLAY R31. READ RANGE AND RANGE RATE FROM DSKY AND RR TAPE METER
DOES RR VERIFY
YES
POSSIBLE AGS FAILURE
NO
PGNCS FAIL SWITCH TO AGS
YES
NULL Vgx RESIDUAL
NULL Vgx RESIDUAL
PROCEED
SELECT TARGET ΔV PROGRAM (P76) UPDATE LM STATE VECTOR USING Vg AND TIG FROM PHASING PAD DATA (TABLE 4-3) (TIG BIASED BY ONE-HALF THE NOMINAL BURN TIME)


CDR
LMP
MCC-H
CMP
COPY INSERTION PAD
VOICE INSERTION PAD DATA TO LM AND CSM (TABLES 4-1 AND 4-2)
COPY INSERTION PAD
SELECT RENDEZVOUS NAVIGATION PROGRAM (P20) (CSM STATE VECTOR UPDATE OPTION)
SELECT RENDEZVOUS NAVIGATION PROGRAM (P20) (LM STATE VECTOR UPDATE OPTION)
P52 IMU REALIGN
LM LEAVE SHADOW (101:30)


CDR
SELECT P27 AND RECEIVE DATA
SELECT EXT ΔV PROG (P30) INSERT Vg AND TIG FROM INSERTION PAD
SELECT THRUST MONITOR PROGRAM (P47) TO MONITOR DPS STAGING
STAGE DPS AT INSERTION MINUS 10 MINUTES. USE + X RCS FOR 2 FT/SEC SEPARATION. NULL 2 FT/SEC AT A SEPARATION DISTANCE OF 40 FT
UPDATE PGNCS DAP CONSTANTS (R03)
SELECT APS THRUST (P42) MANEUVER TO IGNITION ATTITUDE
MONITOR INSERTION MANEUVER
LMP
PERFORM AGS NAVIGATION INITIAL (414 + 10000), PGNCS TO AGS ALIGN (400 + 30000)
SELECT EXT ΔV ROUT (414 + 50000). INSERT Vg FROM INSERTION PAD
MCC-H
VOICE NEW LM AND CSM INSERTION PADS IF REQUIRED (TABLES 4-1 AND 4-2)
UPDATE CSM STATE VECTOR IN CMC AND CSM AND LM STATE VECTOR IN LGC (LM STATE VECTOR CONTINGENCY ONLY)
CMP
SELECT P27 AND RECEIVE DATA
SELECT EXT ΔV PROG (P30). INSERT Vg AND TIG FROM INSERTION PAD
SELECT SPS THRUST (P40) MANEUVER TO IGNITION ATTITUDE


CDR
LMP
MCC-H
CMP
NULL PGNCS Vgx TO LESS THAN 0.2 FPS
READ PGNCS RESIDUAL Vg's FROM DSKY AFTER TRIMMING.
READ AGS RESIDUAL Vg's FROM DEDA
MANEUVER TO ATTITUDE FOR MSFN UPLINK OF LM AND CSM STATE VECTORS
INSERTION MANEUVER VERIFICATION
DO PGNCS AND AGS RESIDUAL Vg's AGREE? (ΔVgx < 2 FT/SEC) (ΔVgy < 2 FT/SEC) (ΔVgz < 2 FT/SEC) NOTE M
NO
YES
PGNCS/AGS OK PROCEED
MANEUVER LM TO ACQUIRE RR LOCK. MONITOR RR RANGE RATE AND PGNCS R31 RANGE RATE
AGS FAILED PGNCS AND RR OK - PROCEED
DO PGNCS AND RR RANGE RATE AGREE?
YES
NO
DO AGS AND RR RANGE RATE AGREE?
NO
DOUBLE FAIL
YES
PGNCS FAILURE AGS AND RR OK-PROCEED UNDER AGS CONTROL
hp CHECK
IS MSFN EST. OF hp LESS THAN SAFE ORBIT? (hp < 30000 FT) NOTE N
YES
COMPUTE ΔV, GETI, AND GIMBAL ANGLES REQUIRED FOR MNVR TO SAFE ORBIT AND VOICE TO LM
NO
PROCEED
UPDATE LM STATE VECTOR IN CMC USING LM TM STATE VECTOR
VOICE CSI/CDH/TPI PADS TO LM CREW TABLES 4-4, 4-5, 4-6)
SELECT CMC UPDATE PROGRAM (P27)
COPY CSI/CDH AND TPI PAD DATA (TABLES 4-4, 4-5, 4-6)


CDR
LMP
MCC-H
CMP
LM ENTER SHADOW (102:45)
SELECT IMU REALIGN TO REFSMMAT (P52) CHECK ALIGN USING AUTO OPTICS TO THIRD STAR
IMU ALIGNMENT AND DRIFT CHECK
WAS STAR DATA CHECK OK? (<0.05 DEG) NOTE A
NO
REPEAT P52
YES
WAS THIRD STAR CENTERED IN AOT? (CREW ESTIMATES) (± 5 DEG)
NO
REPEAT P52 AND ASSESS FAILURE
YES
DOES ANY GYRO TORQ ANGLE INDICATE PGNCS FAIL? (>1.5 DEG/HR) NOTE C
NO
DOES ANY GYRO DRIFT PREVENT PGNCS RDZ NAVIG? (> 0.3 DEG/HR) NOTE D
YES
PGNCS FAIL - USE CSM GNCS FOR TARGETING RDZ MANEUVERS, AND LM PGNCS FOR AGS EXECUTION
NO
PROCEED
YES
PGNCS FAIL - USE AGS FOR RDZ, USE CSM GNCS TARGETING FOR RDZ MANEUVERS
SELECT IMU REALIGN TO REFSMMAT (P52) CHECK ALIGN USING AUTO OPTICS TO THIRD STAR
IMU ALIGNMENT AND DRIFT CHECK
WAS STAR DATA CHECK OK? (<0.05 DEG) NOTE A
NO
REPEAT P52
YES
WAS THIRD STAR IN SXT FOV? (+0.9 DEG) NOTE B
NO
REPEAT P52 AND ASSESS FAILURE
YES
DOES ANY GYRO DRIFT PREVENT GNCS RDZ NAVIG? (< 0.3 DEG/HR) NOTE D
NO
DOES ANY GYRO TORQUE ANGLE INDICATE GNCS FAIL? (>1.5 DEG/HR) NOTE C
NO
PROCEED
YES
YES
GNCS FAIL - DO NOT USE FOR RDZ NAVIG

CDR

SELECT RENDEZVOUS NAV PROGRAM (P20) (LM STATE VECTOR UPDATE OPTION)

REINITIALIZE W-MATRIX TO (10,000, 10, 0.015) BEFORE FIRST MARK

PERFORM RDZ NAVIGATION TRACKING

AFTER 15 MINS OF TRACKING, READ RANGE AND RANGE RATE FROM TAPE METER SYNCHRONIZED WITH CMP'S DSKY READOUT OF CMC'S NAVIGATED RANGE AND RANGE RATE. TRANSMIT RR DATA TO CMP. RECEIVE LM $\dot{Y}$ FOR TIG (CSI) FROM CMP

LMP

MCC-H

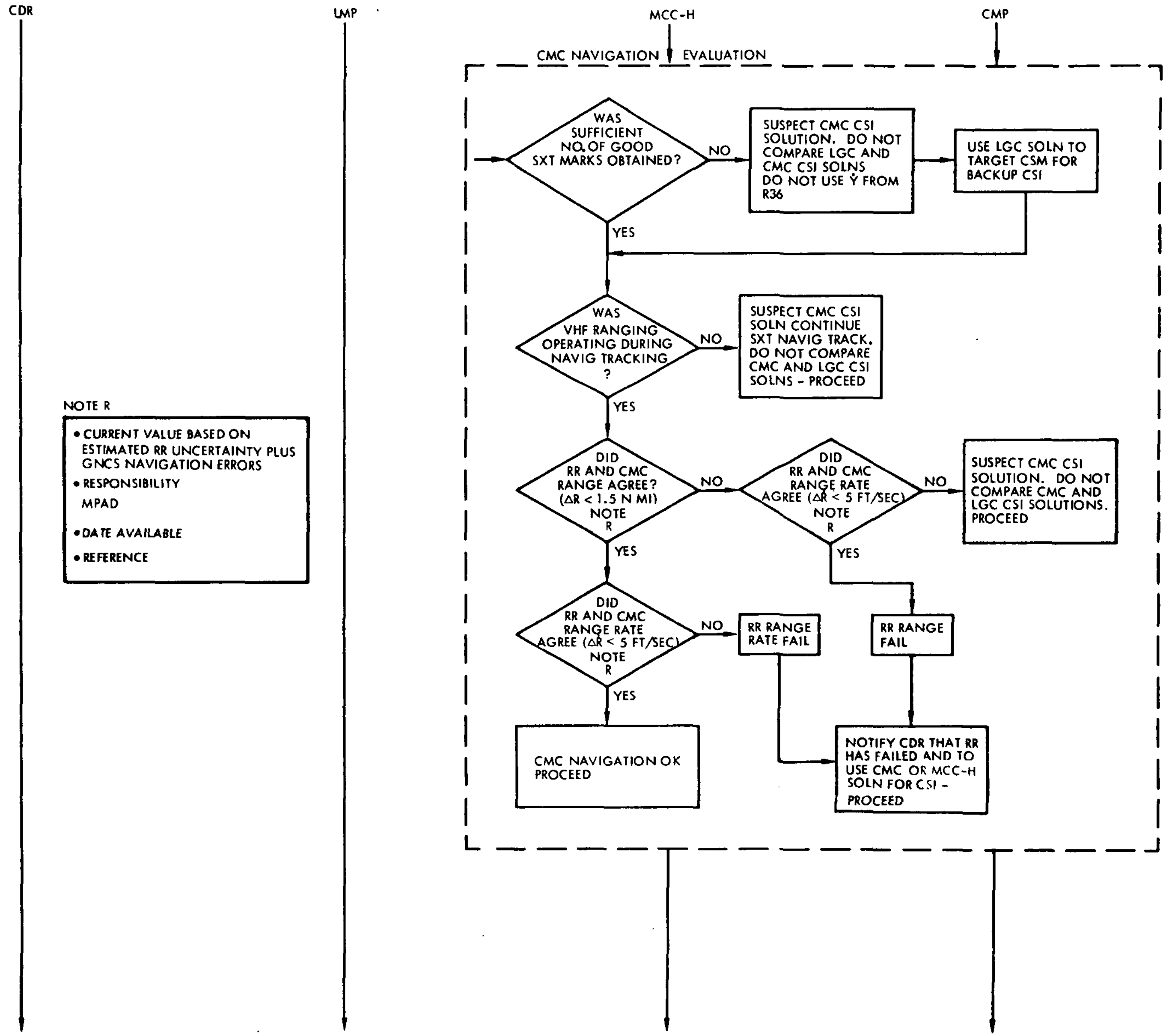
CMP

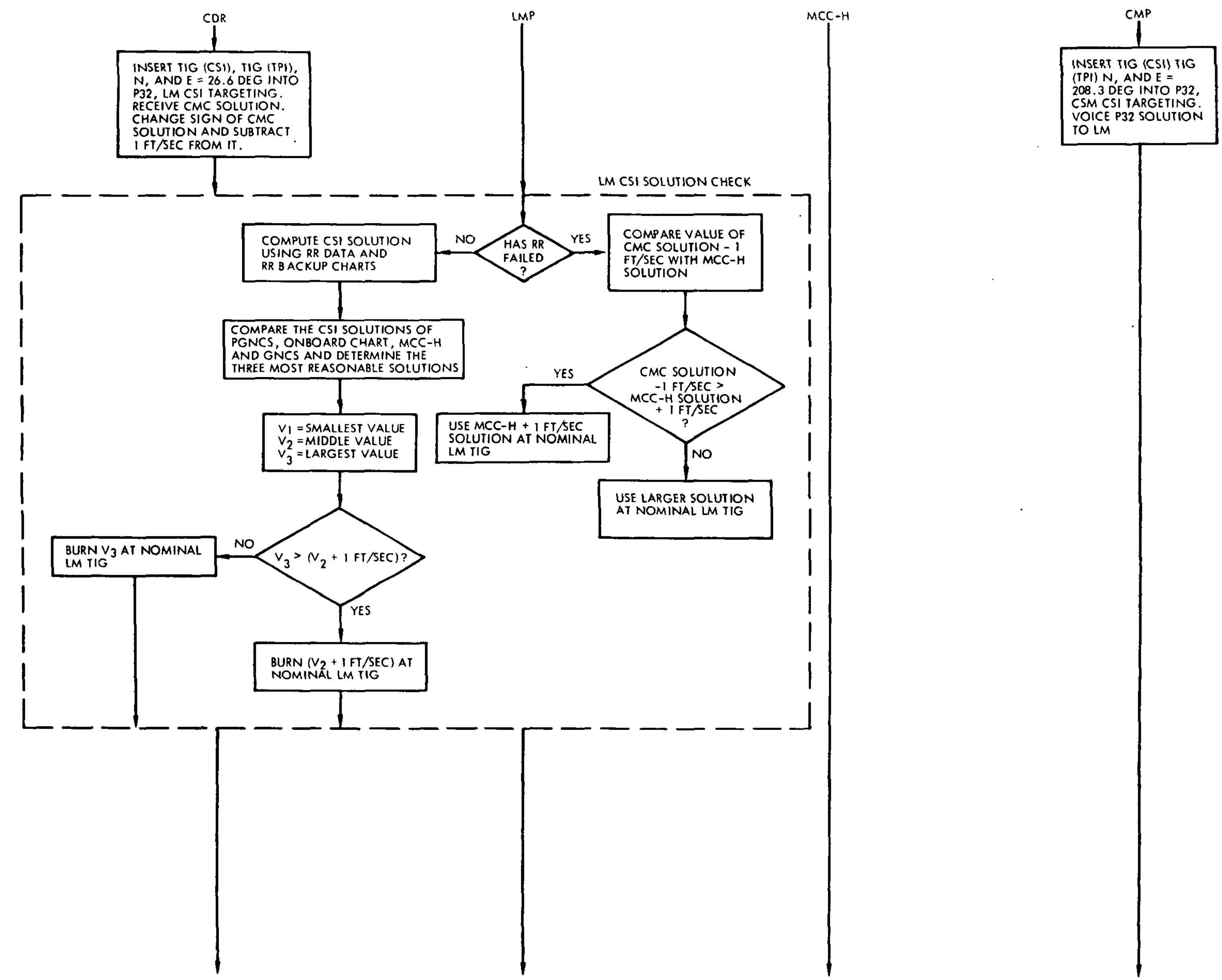
SELECT RENDEZVOUS NAV PROGRAM (P20) (LM STATE VECTOR UPDATE OPTION)

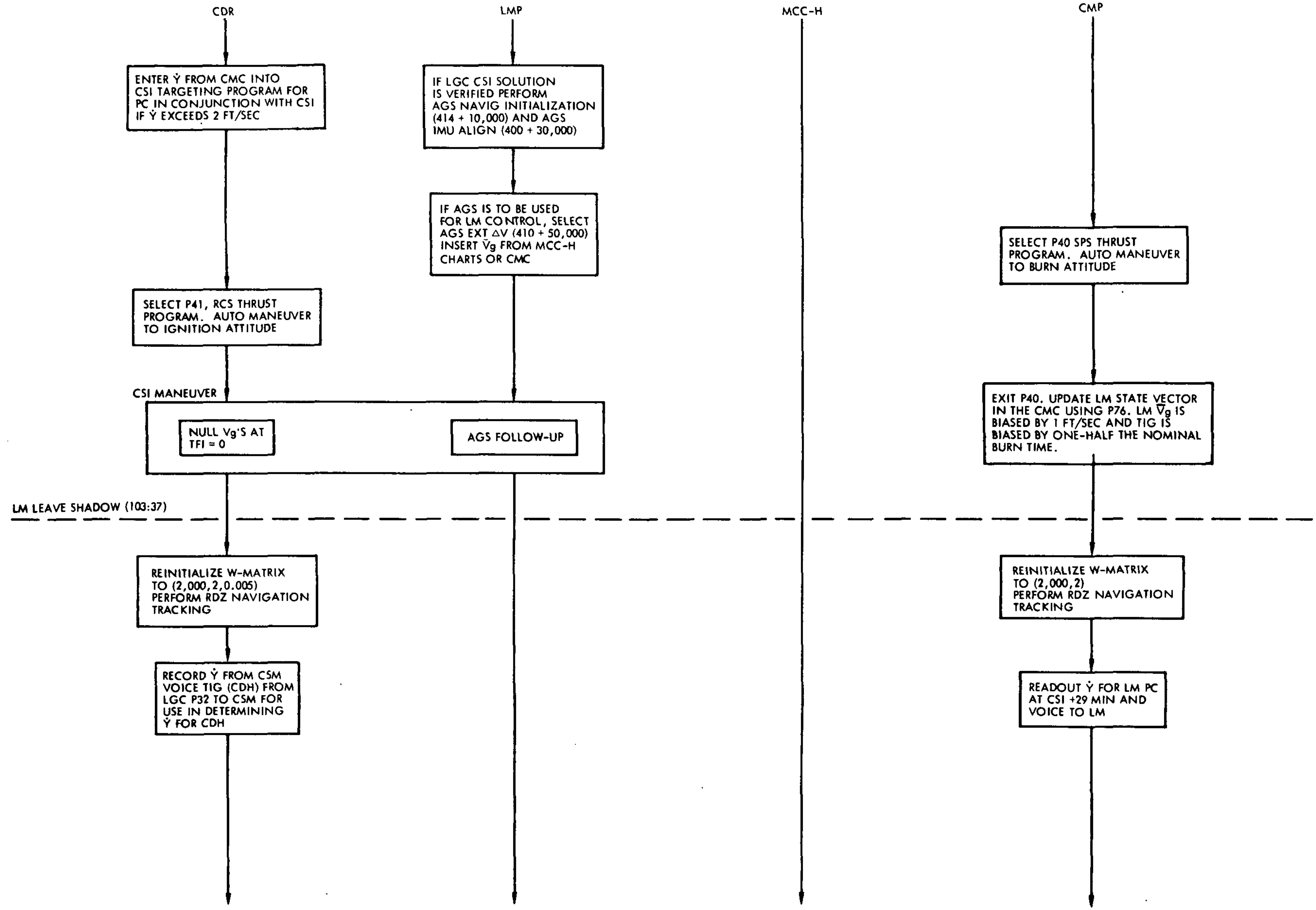
REINITIALIZE W-MATRIX TO (10,000, 10) BEFORE FIRST MARK

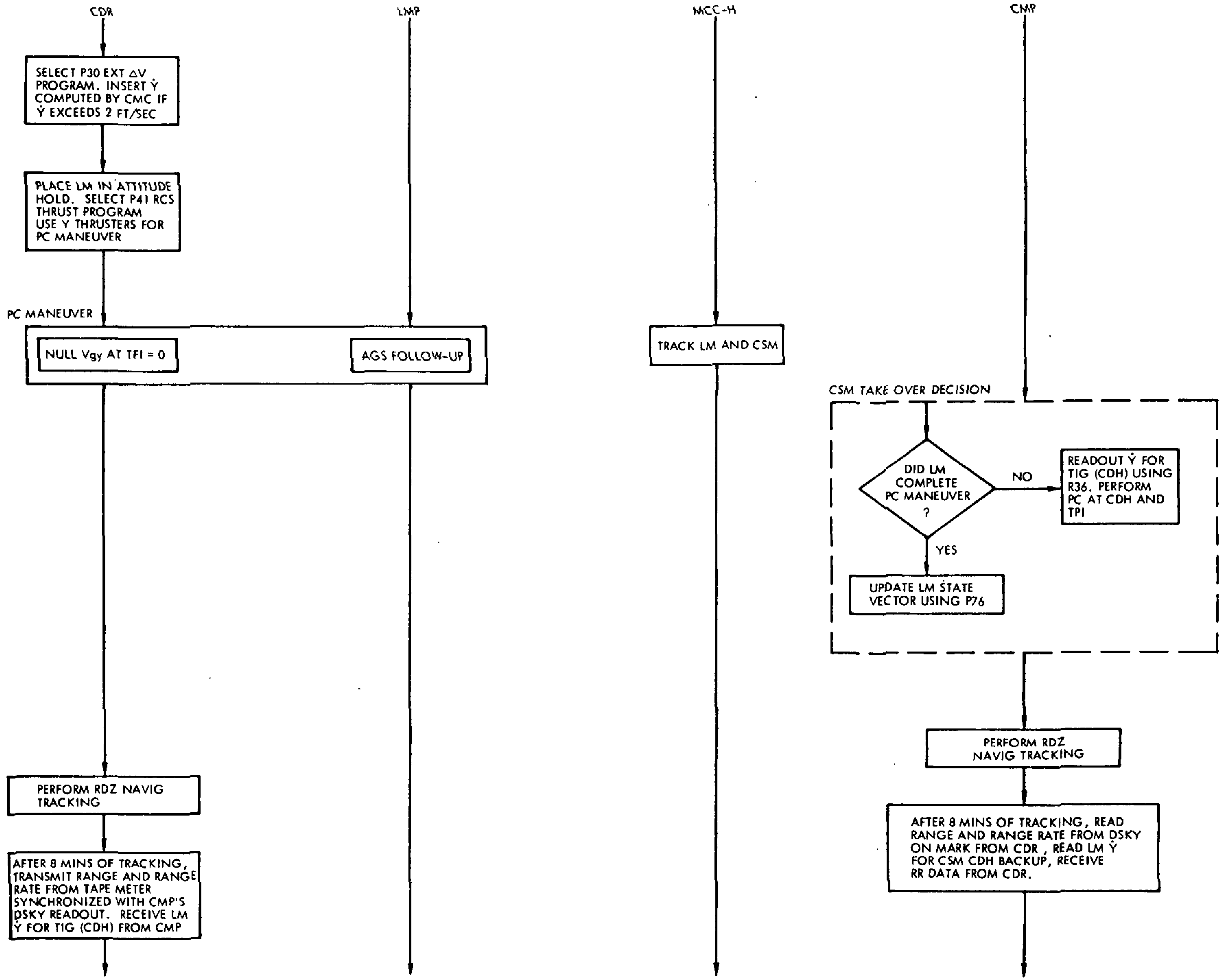
PERFORM RDZ NAVIGATION TRACKING USING SXT AND VHF RANGE DATA

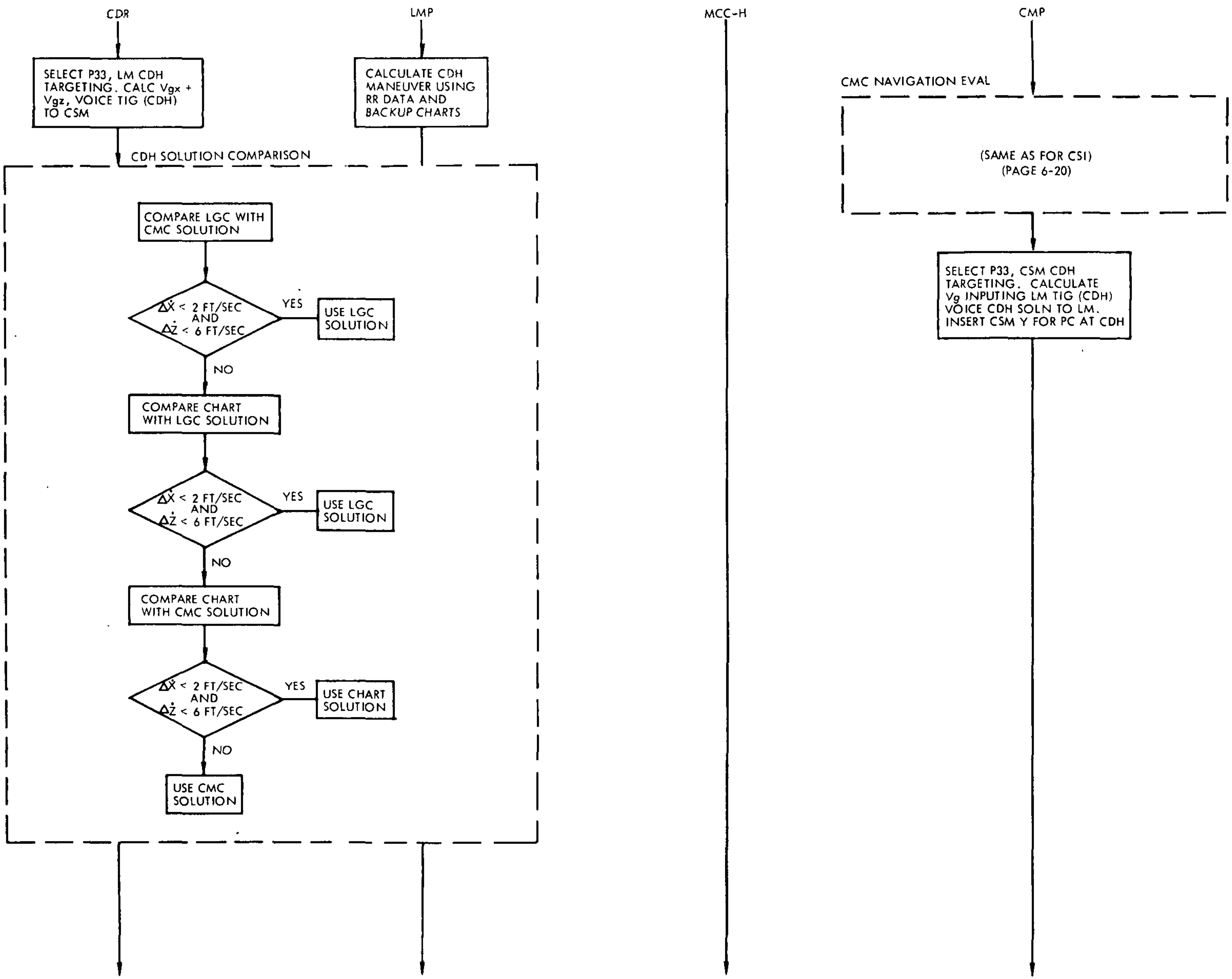
AFTER 15 MIN OF TRACKING, READ RANGE AND RANGE RATE FROM DSKY ON MARK FROM CDR, RECORD DATA. SELECT R36 AND RECORD LM $\dot{Y}$ FOR TIG (CSI) (FROM PAD (TABLE 6) SELECT R36 AND RECORD CSM $\dot{Y}$ FOR CSM TIG (CSI) (CSM BACKUP). TRANSMIT LM $\dot{Y}$ TO CDR. RECEIVE RR DATA FROM CDR

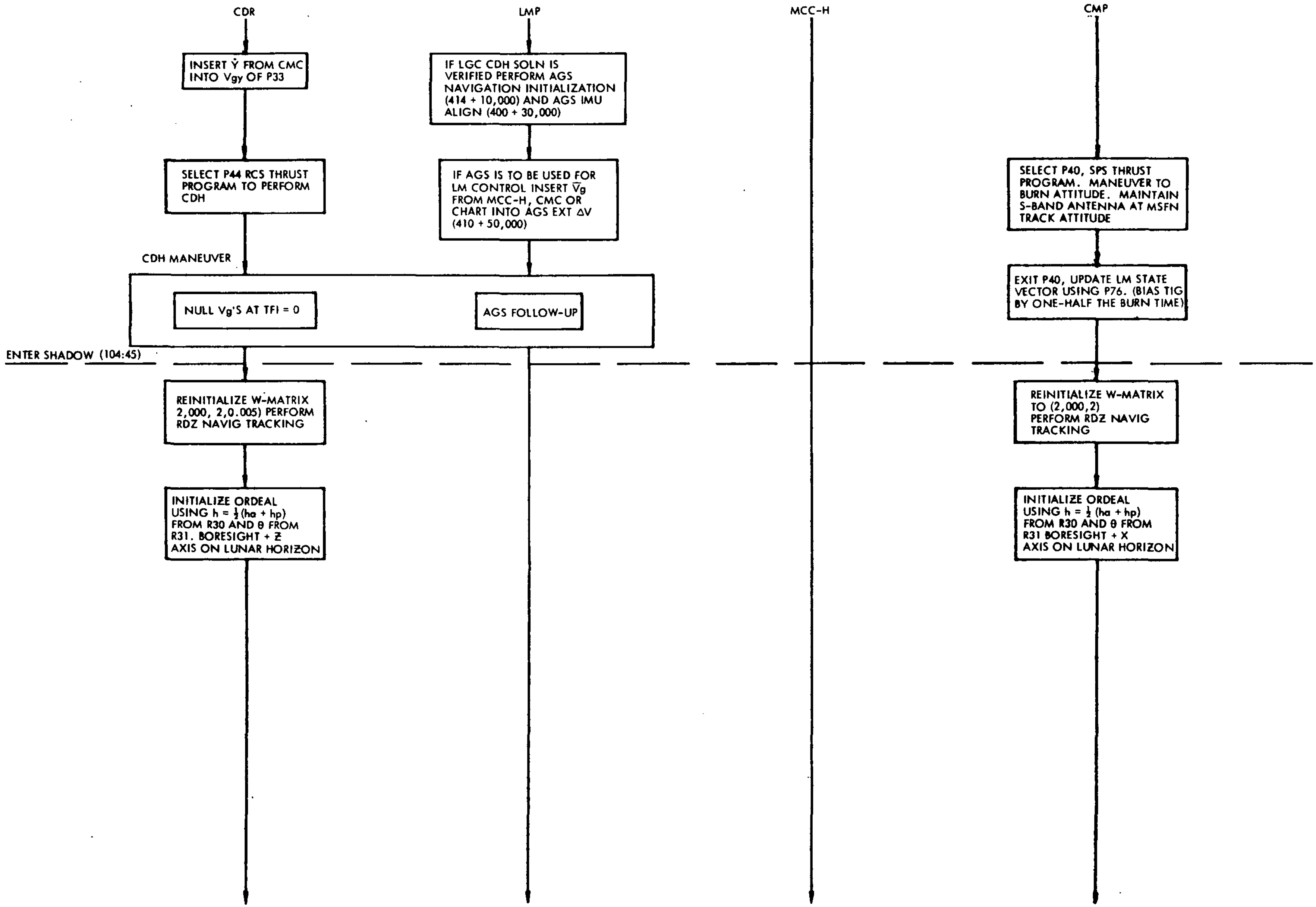

CDR
LMP
MCC-H
CMP
CMC NAVIGATION EVALUATION
WAS SUFFICIENT NO. OF GOOD SXT MARKS OBTAINED?
NO
SUSPECT CMC CSI SOLUTION. DO NOT COMPARE LGC AND CMC CSI SOLNS DO NOT USE Ẏ FROM R36
USE LGC SOLN TO TARGET CSM FOR BACKUP CSI
YES
WAS VHF RANGING OPERATING DURING NAVIG TRACKING ?
NO
SUSPECT CMC CSI SOLN CONTINUE SXT NAVIG TRACK. DO NOT COMPARE CMC AND LGC CSI SOLNS - PROCEED
YES
DID RR AND CMC RANGE AGREE? (ΔR < 1.5 N MI) NOTE R
NO
DID RR AND CMC RANGE RATE AGREE (ΔṘ < 5 FT/SEC) NOTE R
NO
SUSPECT CMC CSI SOLUTION. DO NOT COMPARE CMC AND LGC CSI SOLUTIONS. PROCEED
YES
RR RANGE FAIL
YES
DID RR AND CMC RANGE RATE AGREE (ΔṘ < 5 FT/SEC) NOTE R
NO
RR RANGE RATE FAIL
NOTIFY CDR THAT RR HAS FAILED AND TO USE CMC OR MCC-H SOLN FOR CSI - PROCEED
YES
CMC NAVIGATION OK PROCEED
NOTE R
• CURRENT VALUE BASED ON ESTIMATED RR UNCERTAINTY PLUS GNCS NAVIGATION ERRORS
• RESPONSIBILITY
MPAD
• DATE AVAILABLE
• REFERENCE

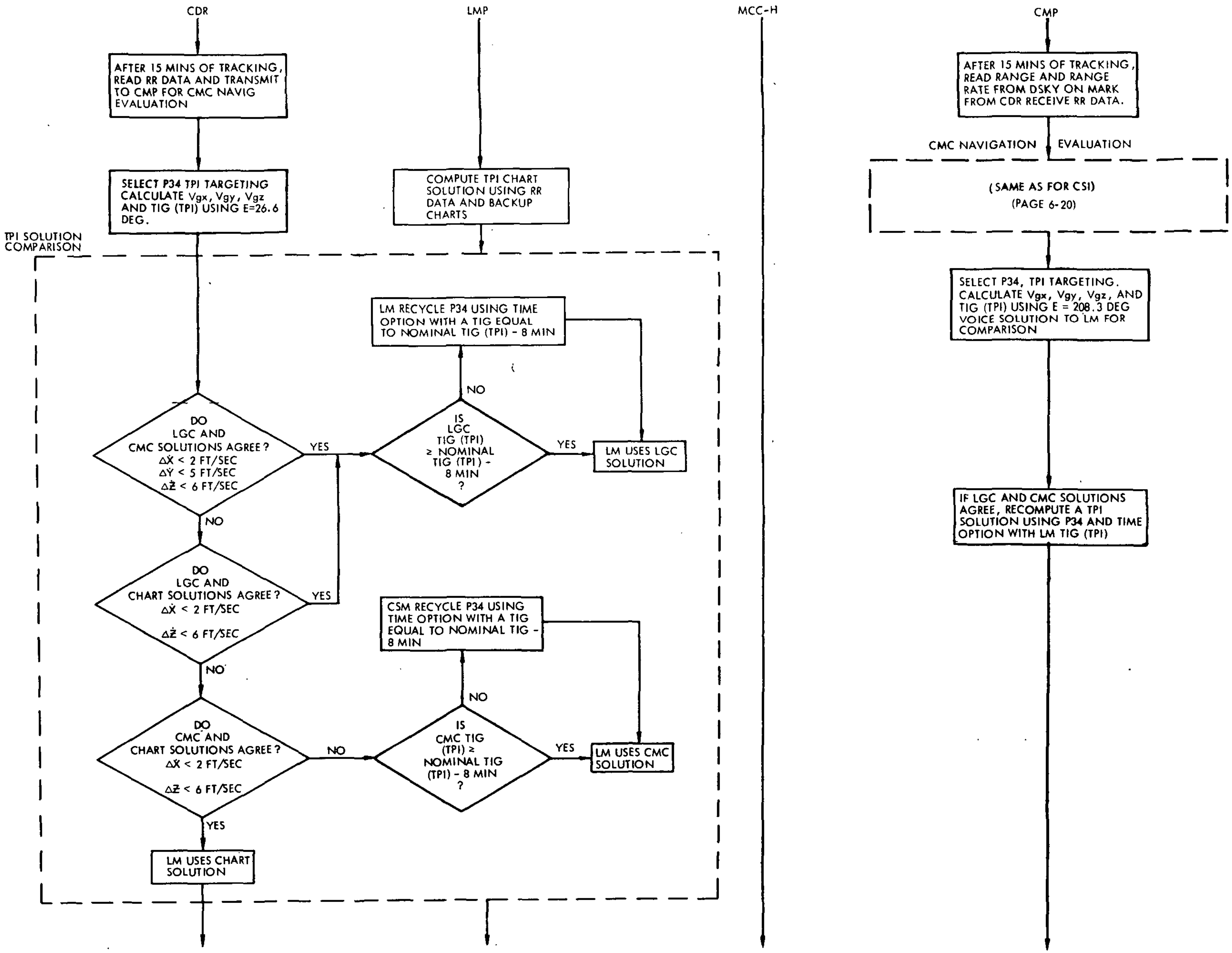

CDR
LMP
MCC-H
CMP
INSERT TIG (CSI), TIG (TPI), N, AND E = 26.6 DEG INTO P32, LM CSI TARGETING. RECEIVE CMC SOLUTION. CHANGE SIGN OF CMC SOLUTION AND SUBTRACT 1 FT/SEC FROM IT.
INSERT TIG (CSI) TIG (TPI) N, AND E = 208.3 DEG INTO P32, CSM CSI TARGETING. VOICE P32 SOLUTION TO LM
LM CSI SOLUTION CHECK
HAS RR FAILED ?
NO
YES
COMPUTE CSI SOLUTION USING RR DATA AND RR BACKUP CHARTS
COMPARE VALUE OF CMC SOLUTION - 1 FT/SEC WITH MCC-H SOLUTION
COMPARE THE CSI SOLUTIONS OF PGNCS, ONBOARD CHART, MCC-H AND GNCS AND DETERMINE THE THREE MOST REASONABLE SOLUTIONS
CMC SOLUTION -1 FT/SEC > MCC-H SOLUTION + 1 FT/SEC ?
YES
NO
USE MCC-H + 1 FT/SEC SOLUTION AT NOMINAL LM TIG
USE LARGER SOLUTION AT NOMINAL LM TIG
V_1 = SMALLEST VALUE
V_2 = MIDDLE VALUE
V_3 = LARGEST VALUE
$V_3 > (V_2 + 1$ FT/SEC)?
NO
YES
BURN V_3 AT NOMINAL LM TIG
BURN (V_2 + 1 FT/SEC) AT NOMINAL LM TIG

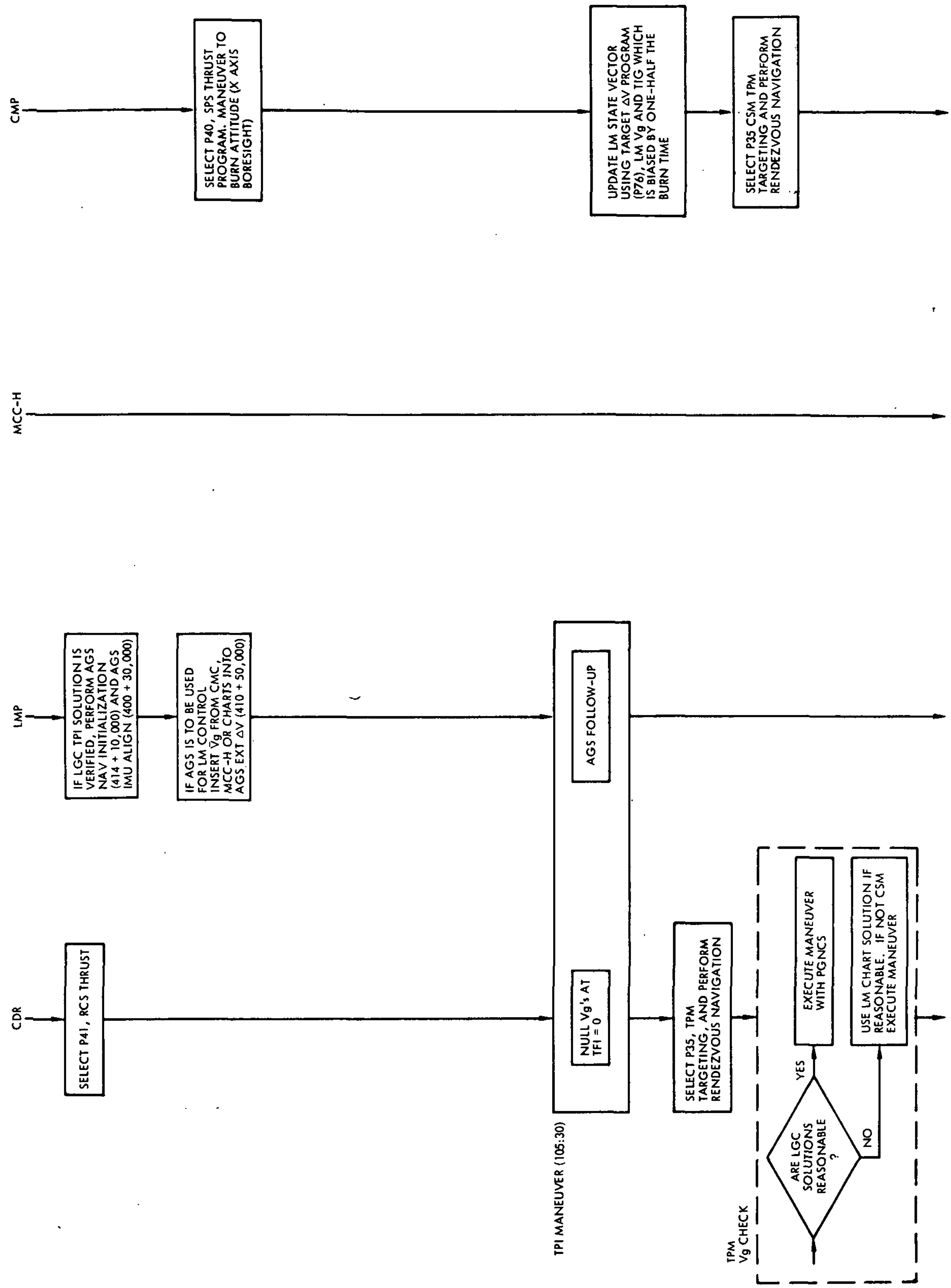

CDR
LMP
MCC-H
CMP
ENTER Ẏ FROM CMC INTO CSI TARGETING PROGRAM FOR PC IN CONJUNCTION WITH CSI IF Ẏ EXCEEDS 2 FT/SEC
IF LGC CSI SOLUTION IS VERIFIED PERFORM AGS NAVIG INITIALIZATION (414 + 10,000) AND AGS IMU ALIGN (400 + 30,000)
IF AGS IS TO BE USED FOR LM CONTROL, SELECT AGS EXT ΔV (410 + 50,000) INSERT $\vec{V}_g$ FROM MCC-H CHARTS OR CMC
SELECT P40 SPS THRUST PROGRAM. AUTO MANEUVER TO BURN ATTITUDE
SELECT P41, RCS THRUST PROGRAM. AUTO MANEUVER TO IGNITION ATTITUDE
EXIT P40. UPDATE LM STATE VECTOR IN THE CMC USING P76. LM $\vec{V}_g$ IS BIASED BY 1 FT/SEC AND TIG IS BIASED BY ONE-HALF THE NOMINAL BURN TIME.
CSI MANEUVER
NULL V_g'S AT TFI = 0
AGS FOLLOW-UP
LM LEAVE SHADOW (103:37)
REINITIALIZE W-MATRIX TO (2,000,2,0.005) PERFORM RDZ NAVIGATION TRACKING
REINITIALIZE W-MATRIX TO (2,000,2) PERFORM RDZ NAVIGATION TRACKING
RECORD Ẏ FROM CSM VOICE TIG (CDH) FROM LGC P32 TO CSM FOR USE IN DETERMINING Ẏ FOR CDH
READOUT Ẏ FOR LM PC AT CSI +29 MIN AND VOICE TO LM

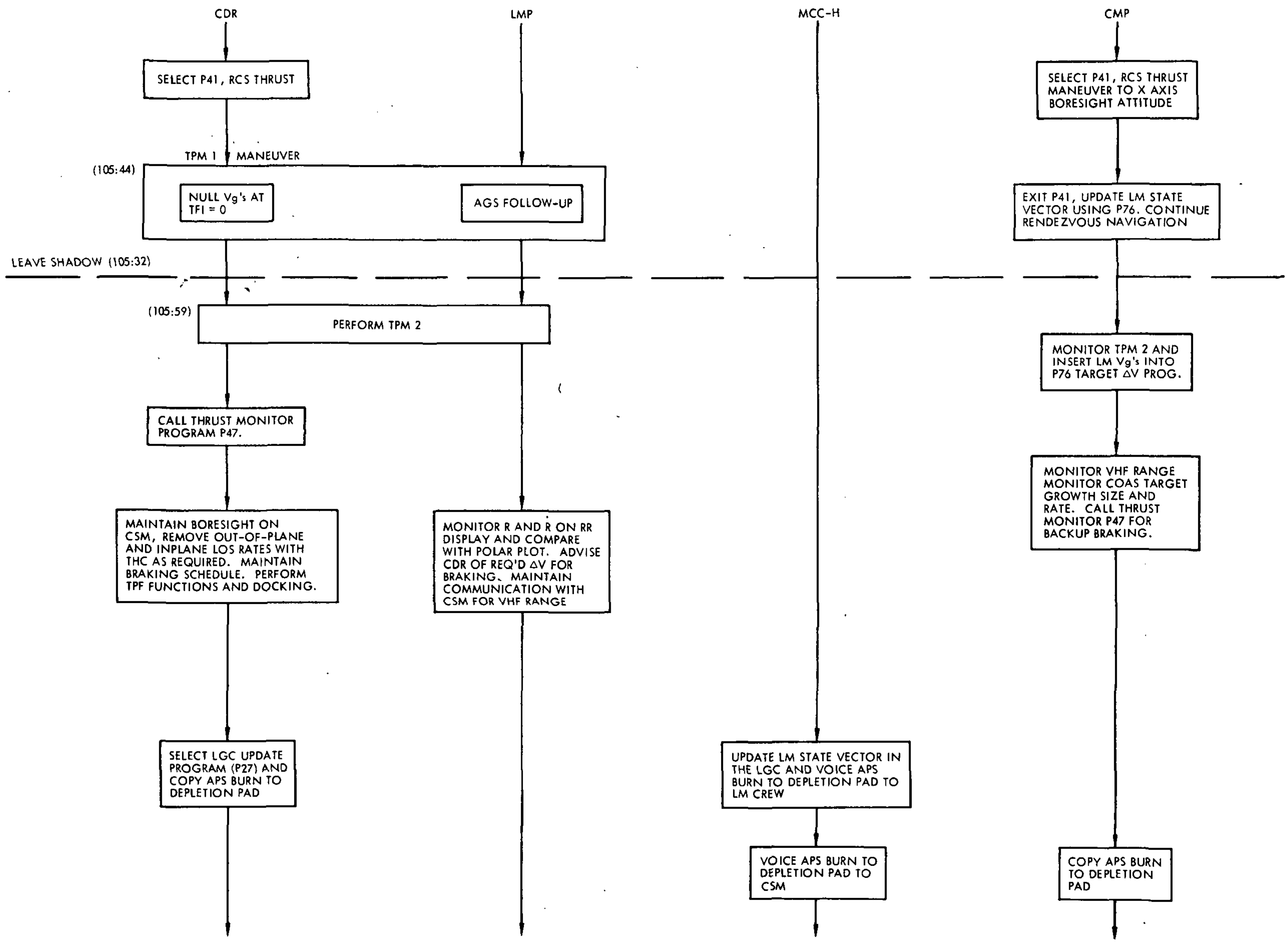

CDR
LMP
MCC-H
CMP
SELECT P30 EXT ΔV PROGRAM. INSERT Ẏ COMPUTED BY CMC IF Ẏ EXCEEDS 2 FT/SEC
PLACE LM IN ATTITUDE HOLD. SELECT P41 RCS THRUST PROGRAM USE Y THRUSTERS FOR PC MANEUVER
PC MANEUVER
NULL Vgy AT TFI = 0
AGS FOLLOW-UP
TRACK LM AND CSM
CSM TAKE OVER DECISION
DID LM COMPLETE PC MANEUVER ?
NO
YES
READOUT Ẏ FOR TIG (CDH) USING R36. PERFORM PC AT CDH AND TPI
UPDATE LM STATE VECTOR USING P76
PERFORM RDZ NAVIG TRACKING
PERFORM RDZ NAVIG TRACKING
AFTER 8 MINS OF TRACKING, TRANSMIT RANGE AND RANGE RATE FROM TAPE METER SYNCHRONIZED WITH CMP'S DSKY READOUT. RECEIVE LM Ẏ FOR TIG (CDH) FROM CMP
AFTER 8 MINS OF TRACKING, READ RANGE AND RANGE RATE FROM DSKY ON MARK FROM CDR, READ LM Ẏ FOR CSM CDH BACKUP, RECEIVE RR DATA FROM CDR.


CDR
LMP
MCC-H
CMP
SELECT P33, LM CDH TARGETING. CALC Vgx + Vgz, VOICE TIG (CDH) TO CSM
CALCULATE CDH MANEUVER USING RR DATA AND BACKUP CHARTS
CMC NAVIGATION EVAL
(SAME AS FOR CSI) (PAGE 6-20)
SELECT P33, CSM CDH TARGETING. CALCULATE Vg INPUTING LM TIG (CDH) VOICE CDH SOLN TO LM. INSERT CSM Y FOR PC AT CDH
CDH SOLUTION COMPARISON
COMPARE LGC WITH CMC SOLUTION
ΔẊ < 2 FT/SEC AND ΔŻ < 6 FT/SEC
YES
USE LGC SOLUTION
NO
COMPARE CHART WITH LGC SOLUTION
ΔẊ < 2 FT/SEC AND ΔŻ < 6 FT/SEC
YES
USE LGC SOLUTION
NO
COMPARE CHART WITH CMC SOLUTION
ΔẊ < 2 FT/SEC AND ΔŻ < 6 FT/SEC
YES
USE CHART SOLUTION
NO
USE CMC SOLUTION

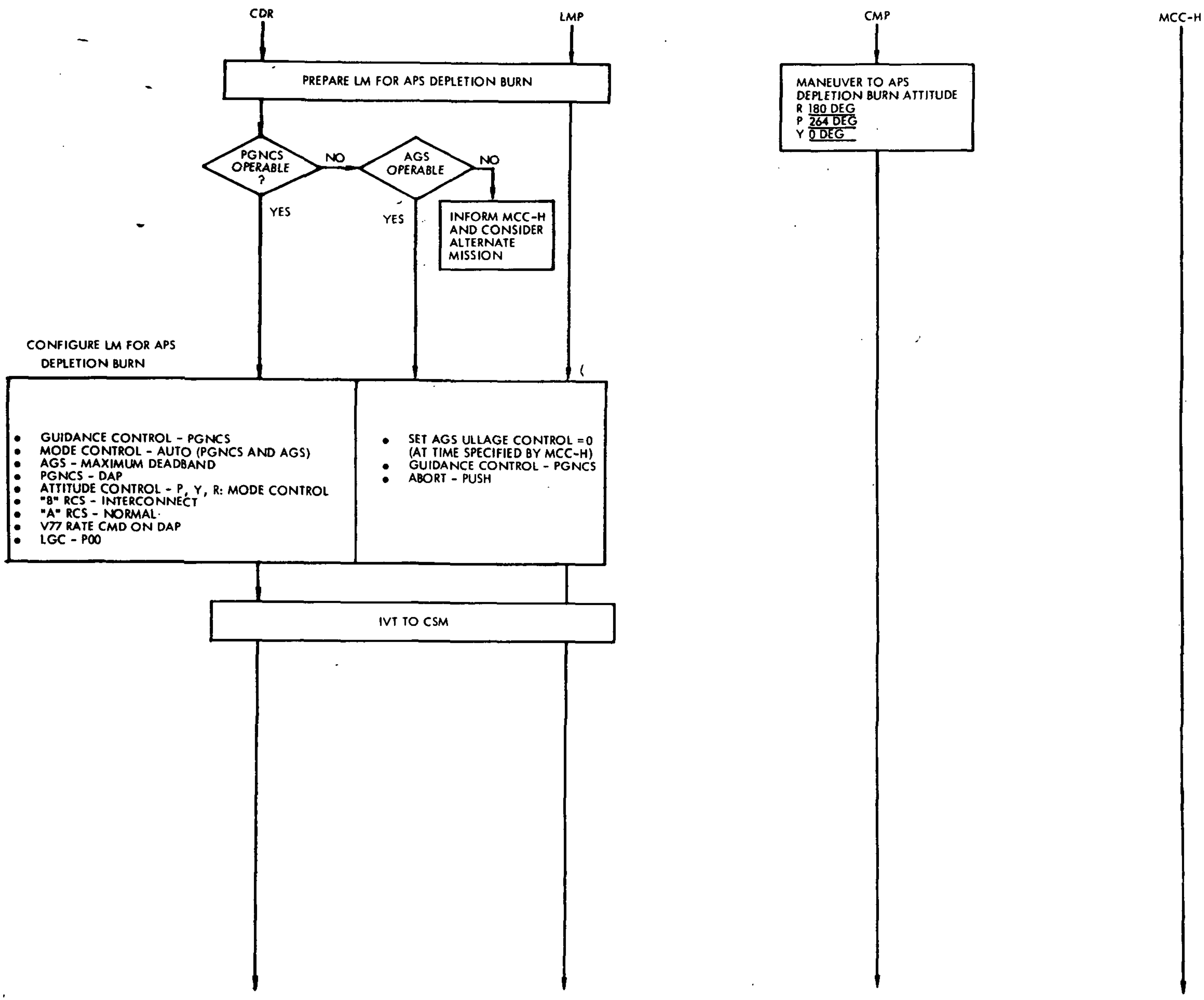

CDR
LMP
MCC-H
CMP
INSERT Ẏ FROM CMC INTO Vgy OF P33
IF LGC CDH SOLN IS VERIFIED PERFORM AGS NAVIGATION INITIALIZATION (414 + 10,000) AND AGS IMU ALIGN (400 + 30,000)
SELECT P44 RCS THRUST PROGRAM TO PERFORM CDH
IF AGS IS TO BE USED FOR LM CONTROL INSERT V̄g FROM MCC-H, CMC OR CHART INTO AGS EXT ΔV (410 + 50,000)
SELECT P40, SPS THRUST PROGRAM. MANEUVER TO BURN ATTITUDE. MAINTAIN S-BAND ANTENNA AT MSFN TRACK ATTITUDE
CDH MANEUVER
NULL Vg'S AT TFI = 0
AGS FOLLOW-UP
EXIT P40, UPDATE LM STATE VECTOR USING P76. (BIAS TIG BY ONE-HALF THE BURN TIME)
ENTER SHADOW (104:45)
REINITIALIZE W-MATRIX 2,000, 2,0.005) PERFORM RDZ NAVIG TRACKING
REINITIALIZE W-MATRIX TO (2,000,2) PERFORM RDZ NAVIG TRACKING
INITIALIZE ORDEAL USING h = ½ (ha + hp) FROM R30 AND θ FROM R31. BORESIGHT + Z AXIS ON LUNAR HORIZON
INITIALIZE ORDEAL USING h = ½ (ha + hp) FROM R30 AND θ FROM R31 BORESIGHT + X AXIS ON LUNAR HORIZON

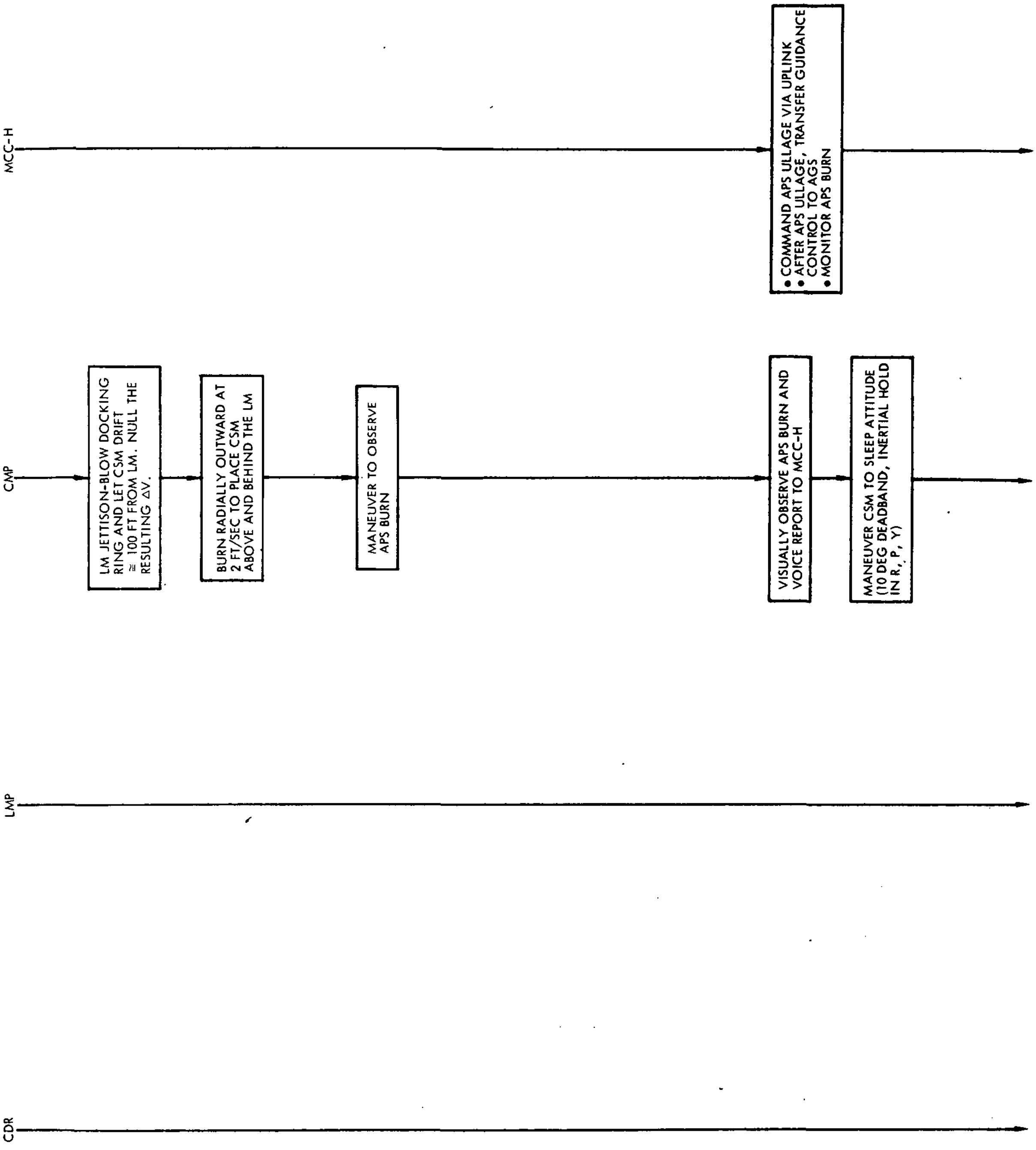

CDR
LMP
MCC-H
CMP
AFTER 15 MINS OF TRACKING, READ RR DATA AND TRANSMIT TO CMP FOR CMC NAVIG EVALUATION
SELECT P34 TPI TARGETING CALCULATE Vgx, Vgy, Vgz AND TIG (TPI) USING E=26.6 DEG.
TPI SOLUTION COMPARISON
DO LGC AND CMC SOLUTIONS AGREE? ΔẊ < 2 FT/SEC ΔẎ < 5 FT/SEC ΔŻ < 6 FT/SEC
YES
NO
DO LGC AND CHART SOLUTIONS AGREE? ΔẊ < 2 FT/SEC ΔŻ < 6 FT/SEC
YES
NO
DO CMC AND CHART SOLUTIONS AGREE? ΔẊ < 2 FT/SEC ΔŻ < 6 FT/SEC
YES
NO
LM USES CHART SOLUTION
COMPUTE TPI CHART SOLUTION USING RR DATA AND BACKUP CHARTS
LM RECYCLE P34 USING TIME OPTION WITH A TIG EQUAL TO NOMINAL TIG (TPI) - 8 MIN
NO
IS LGC TIG (TPI) ≥ NOMINAL TIG (TPI) - 8 MIN ?
YES
LM USES LGC SOLUTION
CSM RECYCLE P34 USING TIME OPTION WITH A TIG EQUAL TO NOMINAL TIG - 8 MIN
NO
IS CMC TIG (TPI) ≥ NOMINAL TIG (TPI) - 8 MIN ?
YES
LM USES CMC SOLUTION
AFTER 15 MINS OF TRACKING, READ RANGE AND RANGE RATE FROM DSKY ON MARK FROM CDR RECEIVE RR DATA.
CMC NAVIGATION
EVALUATION
(SAME AS FOR CSI)
(PAGE 6-20)
SELECT P34, TPI TARGETING. CALCULATE Vgx, Vgy, Vgz, AND TIG (TPI) USING E = 208.3 DEG VOICE SOLUTION TO LM FOR COMPARISON
IF LGC AND CMC SOLUTIONS AGREE, RECOMPUTE A TPI SOLUTION USING P34 AND TIME OPTION WITH LM TIG (TPI)

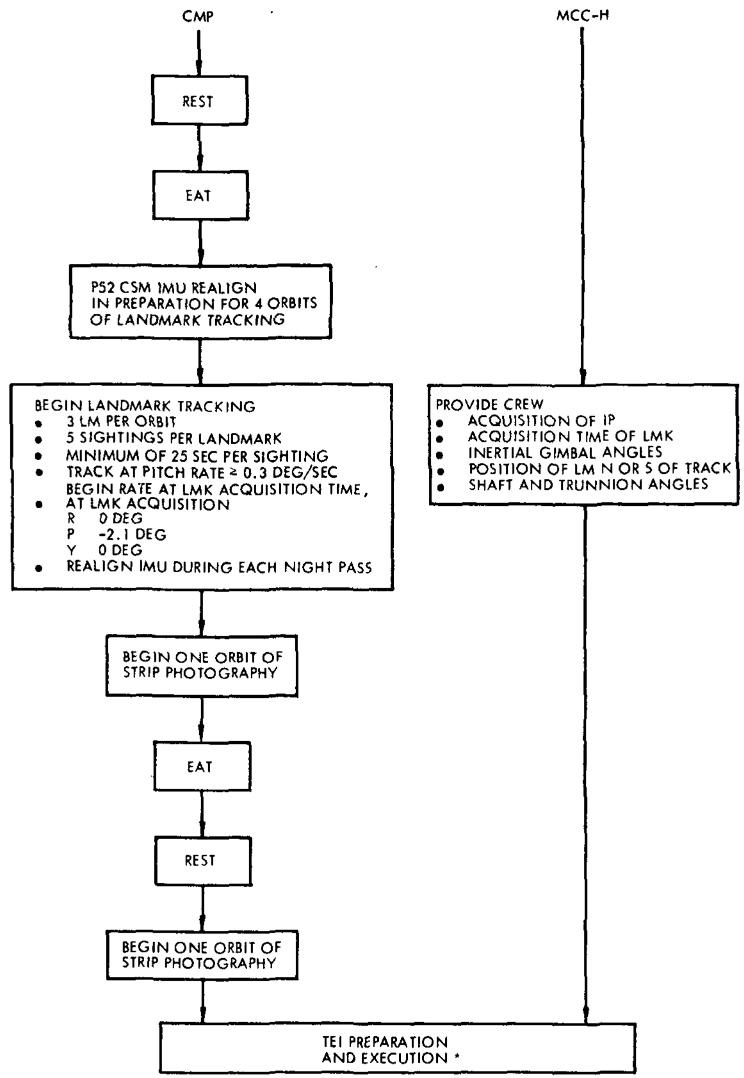

CMP
SELECT P40, SPS THRUST PROGRAM. MANEUVER TO BURN ATTITUDE (X AXIS BORESIGHT)
UPDATE LM STATE VECTOR USING TARGET ΔV PROGRAM (P76), LM Vg AND TIG WHICH IS BIASED BY ONE-HALF THE BURN TIME
SELECT P35 CSM TPM TARGETING AND PERFORM RENDEZVOUS NAVIGATION
MCC-H
LMP
IF LGC TPI SOLUTION IS VERIFIED, PERFORM AGS NAV INITIALIZATION (414 + 10,000) AND AGS IMU ALIGN (400 + 30,000)
IF AGS IS TO BE USED FOR LM CONTROL INSERT Vg FROM CMC, MCC-H OR CHARTS INTO AGS EXT ΔV (410 + 50,000)
AGS FOLLOW-UP
CDR
SELECT P41, RCS THRUST
NULL Vg's AT TFI = 0
TPI MANEUVER (105:30)
SELECT P35, TPM TARGETING, AND PERFORM RENDEZVOUS NAVIGATION
TPM Vg CHECK
ARE LGC SOLUTIONS REASONABLE ?
YES
NO
EXECUTE MANEUVER WITH PGNCS
USE LM CHART SOLUTION IF REASONABLE. IF NOT CSM EXECUTE MANEUVER



CDR
LMP
MCC-H
CMP
SELECT P41, RCS THRUST
SELECT P41, RCS THRUST MANEUVER TO X AXIS BORESIGHT ATTITUDE
TPM 1
MANEUVER
(105:44)
NULL Vg's AT TFI = 0
AGS FOLLOW-UP
EXIT P41, UPDATE LM STATE VECTOR USING P76. CONTINUE RENDEZVOUS NAVIGATION
LEAVE SHADOW (105:32)
(105:59)
PERFORM TPM 2
MONITOR TPM 2 AND INSERT LM Vg's INTO P76 TARGET ΔV PROG.
CALL THRUST MONITOR PROGRAM P47.
MONITOR VHF RANGE MONITOR COAS TARGET GROWTH SIZE AND RATE. CALL THRUST MONITOR P47 FOR BACKUP BRAKING.
MAINTAIN BORESIGHT ON CSM, REMOVE OUT-OF-PLANE AND INPLANE LOS RATES WITH THC AS REQUIRED. MAINTAIN BRAKING SCHEDULE. PERFORM TPF FUNCTIONS AND DOCKING.
MONITOR R AND $\dot{R}$ ON RR DISPLAY AND COMPARE WITH POLAR PLOT. ADVISE CDR OF REQ'D ΔV FOR BRAKING. MAINTAIN COMMUNICATION WITH CSM FOR VHF RANGE
SELECT LGC UPDATE PROGRAM (P27) AND COPY APS BURN TO DEPLETION PAD
UPDATE LM STATE VECTOR IN THE LGC AND VOICE APS BURN TO DEPLETION PAD TO LM CREW
VOICE APS BURN TO DEPLETION PAD TO CSM
COPY APS BURN TO DEPLETION PAD


CDR
LMP
CMP
MCC-H
PREPARE LM FOR APS DEPLETION BURN
PGNCS OPERABLE ?
NO
YES
AGS OPERABLE
NO
YES
INFORM MCC-H AND CONSIDER ALTERNATE MISSION
MANEUVER TO APS DEPLETION BURN ATTITUDE
R 180 DEG
P 264 DEG
Y 0 DEG
CONFIGURE LM FOR APS DEPLETION BURN
• GUIDANCE CONTROL - PGNCS
• MODE CONTROL - AUTO (PGNCS AND AGS)
• AGS - MAXIMUM DEADBAND
• PGNCS - DAP
• ATTITUDE CONTROL - P, Y, R: MODE CONTROL
• "B" RCS - INTERCONNECT
• "A" RCS - NORMAL
• V77 RATE CMD ON DAP
• LGC - P00
• SET AGS ULLAGE CONTROL =0 (AT TIME SPECIFIED BY MCC-H)
• GUIDANCE CONTROL - PGNCS
• ABORT - PUSH
IVT TO CSM


MCC-H
CMP
LMP
CDR
LM JETTISON-BLOW DOCKING RING AND LET CSM DRIFT ≅ 100 FT FROM LM. NULL THE RESULTING ΔV.
BURN RADIALLY OUTWARD AT 2 FT/SEC TO PLACE CSM ABOVE AND BEHIND THE LM
MANEUVER TO OBSERVE APS BURN
• COMMAND APS ULLAGE VIA UPLINK
• AFTER APS ULLAGE, TRANSFER GUIDANCE CONTROL TO AGS
• MONITOR APS BURN
VISUALLY OBSERVE APS BURN AND VOICE REPORT TO MCC-H
MANEUVER CSM TO SLEEP ATTITUDE (10 DEG DEADBAND, INERTIAL HOLD IN R, P, Y)



* REFERENCE LATEST ISSUE OF MSC INTERNAL NOTE S-PA-8T FOR TEI PROCEDURES

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2. M. W. Johnston, "C Prime EPO and TLI," Mission Techniques Memorandum No. 9 Revolution 1, 27 November 1968.

3. "Alignment Procedures for Mission D," FC5/Flight Dynamics Branch, NASA Memorandum (no number), 24 June 1968.

4. "Comparison Limits for Rendezvous Radar Test on Apollo 9," FM6/ Orbital Mission Analysis Branch, NASA Memorandum 69-FM61-47, 25 February 1969.

5. "Current State Vector Uncertainties for the G Mission Rendezvous," FM4/Mathematical Physics Branch, NASA Memorandum 68-FM46-402, 10 October 1968.

6. "Apollo 10 (Mission F) Spacecraft Operational Alternate Mission Plan, Volume 111 - Lunar Alternate Rendezvous," MSC Internal Note 69-FM-85, 9 April 1969.