NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NO

CSM RENDEZVOUS PROCEDURES D MISSION

FINAL REVISION

FEBRUARY 1, 1969

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

RENDEZVOUS PROCEDURES

D MISSION

REVISION A

AS-504/CSM-104/LM-3

February 1, 1969

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List of Acronyms and Abbreviations

ADJ	Adjust
AOH	Apollo Operations Handbook
ATT	Attitude
AWY	Away
B/U	Backup
CALIB	Calibration
CDH	Constant Differential Height
CMC	Command Module Computer
CMD	Command Module Commander's Position
CMP	Command Module Pilot
COAS	Crew Optical Alignment Sight
CSI	Concentric Sequence Initiation
CSM	Command and Service Modules
CT	Cease Track
DAP	Digital Autopilot
DH	Delta Height
DPS	Descent Propulsion System
DSKY	Display and Keyboard
DV	Delta Velocity
DWN	Down
EMS	Entry Monitoring System
ET	Event Timer
FPS	Feet Per Second
FWD	Forward
GDC	Gyro Display Coupler
GET	Ground Elapsed Time
GND	Ground (Mission Control)

HORIZ	Horizontal
IMU	Inertial Measurement Unit
INS	Insertion
IT	Initiate Track
LEB	Lower Equipment Bay
LGC	Lunar Guidance Computer
LM	Lunar Module
MANV	Maneuver
MCC	Midcourse Correction
MTCS	Move to Command Seat
MTLEB	Move to Lower Equipment Bay
NAV	Navigation
PAD	Data Voiced to Crew from Ground
PHS	Phasing
PIPA	Pulse Integrating Pendulous Accelerometer
PLM	LM Pitch Angle
PRO	Proceed
PROG	Program
PROP	Propellant
RCS	Reaction Control System
REFSMMAT	Reference Stable Member Matrix
RR	Rendezvous Radar
S	Shaft
SC	System Checks
SCS	Stabilization and Control System
SEF	Small End Forward
SEP	Separation
SM	Service Module
SPS	Service Propulsion System
SXT	Sextant
SYNC	Synchronize

T	Trunnion
TIGN	Time of Ignition
TPF	Terminal Phase Final
TPI	Terminal Phase Initiation
(XX+XX)	Indicated GET From Liftoff in Hours:Minutes
(XX+XX+XX)	Indicates GET From Liftoff in Hours:Minutes:Seconds

Tracking Stations

ANG	Antigua Near Space Support Station
BDA	Bermuda Near Space Support Station
CRO	Carnarvon Near Space Support Station
CYI	Canary Near Space Support Station
GYM	Guaymas Near Space Support Station
HSK	Honeysuckle Deep Space Support Station
HTV	Huntsville Near Space Support Ship
MAD	Madrid Deep Space Support Station
MER	Mercury Near Space Support Ship
MIL	MILA Near Space Support Station
RED	Redstone Near Space Support Ship
TEX	Corpus Christi Near Space Support Station
VAN	Vanguard Near Space Support Ship

1.0 Purpose

This document contains the primary crew procedures for the CSM-104 spacecraft which will be the target vehicle for the LM-3 active rendezvous. The procedures were developed in accordance with the Detailed Test Objective P20.33 defined in Reference 8.1.

The purpose of the Rendezvous procedures document is to provide a single source of procedures information for use in flight planning, in crew training, and in preparing onboard data.

This is a control document, subject to review by all elements of the Apollo Program and to approval by the Procedures Configuration Control Board. Comments should be directed to Mr. Don W. Lewis, Crew Safety and Procedures Branch, Flight Crew Support Division, Extension 3291, or to Mr. R. W. Puschinsky, Apollo Flight Crew Support Group, Houston Operations, McDonnell Douglas Astronautics Company, Extension 6101.

2.0 Narrative

The AS-504/CSM-104/LM-3 rendezvous exercise will occur during the "Fifth Period of Activities". The CSM procedures during this period are divided into 11 segments of major activities which are discussed separately in the paragraphs of Section 2.0. A relative motion profile is presented in Section 3.0. It shows locations in time and position of the most significant nominal mission events. The nominal AS-504/CSM-104/LM-3 mission profile used in the procedures was obtained from Reference 8.4.

2.1 CSM Power Up and Crew Transfer

The CSM power up procedures begin with a Guidance and Control basic switch checklist and include CMC and IMU turn on. The CDR and LMP will transfer into the LM, leaving the CMP in the LEB. A ground uplink of state vectors, CMC clock sync, and a REFSMMAT, which provides a nominal CSM IMU orientation (0, 0, 0 with respect to a local vertical) at TPI, will occur at 89:02 over MER.

2.2 Alignments

Prior to undocking the IMU Orientation Determination Program, P51, will be performed. A fine alignment to the preferred orientation using the IMU Realign Program, P52, will be performed on a later night pass. A second fine alignment will be performed during a subsequent darkness period as a backup or trim alignment before the docked LM IMU alignment. The Automatic Star Selection and Optics Positioning Routines will be used for each fine alignment. A fine align check using a third star will be made if sufficient time in darkness remains. Following the initial IMU alignment, the CMP will move to the command seat, align the GDC to the IMU, initialize ORDEAL to the local vertical using altitude information from Extended Verb 82 and angle information from Extended Verb 83, determine CSM PIPA bias, perform the EMS accelerometer check, perform the EMS test, and perform the SM RCS and SPS propulsion checks. The CSM will maneuver to the inertial undocking attitude at 92:22. Subsequent to undocking and the separation maneuver, an IMU realignment to REFSMMAT using P52 is scheduled at 93:14 during daylight. If the realignment during daylight is successful a COAS calibration will be accomplished at 93:26 which is after sunset. Should the daylight realignment not be successful, it will be accomplished during the time period allotted for the COAS calibration and the COAS calibration will not occur. Another realignment to REFSMMAT is scheduled subsequent to phasing at 94:54 during darkness.

2.3 Undocking and Separation

The CSM will maneuver to the undocking attitude at 92:22 and will be accomplished by targeting the RCS thrust program (P41) for a +1.0 FPS "X" axis burn using the separation burn ignition time. The remainder of P41 after the maneuver will be bypassed.

The CSM will undock and separate to a distance of 30 feet using two RCS jets. The CSM will maintain the undocking attitude and will perform the required station keeping maneuvers during an inspection of the LM landing gear and structure.

The CSM RCS separation maneuver targeting using the External Delta V Program, P30, will be performed at 92:38. The maneuver will be loaded into the program as a five foot per second CSM burn radically up. The burn will actually be accomplished along the body minus "X" axis to minimize further maneuver requirements.

At 93:00 the CMP will call the RCS thrust program (P41) via the DSKY and will monitor the automatic attitude maneuver. The burn will be made using four RCS jets in the CSM minus "X" direction by increasing the DSKY "X" direction component from five feet per second to 10 feet per second. The separation burn will occur at 93:05:45.

2.4 LM Phasing Maneuver Monitor

Following the RCS separation burn, the Crew Defined Maneuver Routine, R62, will be called and an automatic maneuver will be initiated for close range LM radar checks.

Automatic "X" axis tracking will be initiated at 93:20 and the CSM will be manually rolled 180 degrees at 93:22.

The elapsed time from separation will be recorded at 15 degrees (V83, θ - 165 degrees) before the horizontal crossing for use in the mini football horizontal adjust chart presented in paragraph 5.4. Nominally the 15-degree point should occur at separation plus 30 minutes 45 seconds.

The CSM will be maneuvered at 93:40 to an inertial attitude that will result in a BEF and wings level attitude with the "X" axis on the local horizontal at the nominal time of phasing. The maneuver will be accomplished by targeting P41 with a -1.0 FPS "X" axis burn delta velocity using the time of phasing.

The LM DPS phasing burn will occur at 93:50:03.6. In the event of a total LM phasing burn failure, the mini football horizontal adjust chart solution will be applied to the CSM using the RCS Thrusting Program, P41.

Subsequent to the LM phasing burn the burn parameters will be confirmed and loaded into the CMC via the Target Delta V Program (P76). A computer restart (V69) will be called after the completion of P76 to reconfigure the optics positioning logic. The optics positioning logic is normally reconfigured by continuing through the burn program (P41) which was used to obtain automatic maneuver to the CSM attitude for phasing.

2.5 TPI_0 Targeting

2.5.1 TPI_0 First Opportunity

Following the LM phasing maneuver, P20 will be called to initiate automatic preferred attitude tracking. At 94:01 eight SXT navigation marks will be taken in five minutes (8/5). All CSM navigation marks are used to update the LM state vector in the CMC as long as the LM is the active spacecraft. The TPI Prethrust Program, P34, will be called at 94:06 and the nominal TPI_0 time will be loaded along with a TPI_0 elevation angle of 0 degrees. The program will be recycled for a solution and a comparison of the CSM and LM TPI_0 solutions will be made for use in the ground Go/No-Go decision to continue the mission. Navigation SXT marks (5/3.5) will be taken at 94:16 and the two TPI_0 pads are scheduled thereafter. At 94:31, navigation SXT marks will be taken with reinitialization of the W matrix (3/1.5*5/3.5) and Program P34 will be recycled for the last solution based upon the nominal TPI_0 time. Navigation SXT marks (5/3.5) are scheduled for 94:39 and will be followed by a final pass through Program P34 based upon the LM TPI_0 ignition time. The onboard Go/No-Go decision to continue the mission will occur at 94:53.

In the event that it is decided to accomplish TPI_0 First Opportunity, a manual maneuver (approximately 180 degrees) followed by an auto trim maneuver to the TPI_0 burn attitude will be accomplished in 1.5 minutes. The TPI_0 burn attitude is generally along the CSM/LM line-of-sight away from the LM. Another manual maneuver to the navigation track attitude is required after the LM or CSM TPI_0 burn. Other than the manual maneuvers, the timeline for midcourse maneuvers is identical to TPI which is discussed in paragraph 2.10 and 2.11.

2.5.2 TPI_0 Second Opportunity

In the event that it is decided to accomplish TPI_0 Second Opportunity, an IMU realignment to REFSMMAT, P52, will be performed at 94:54. The CSM will be mirror image targeted for the second phasing burn attempt to provide backup in the event the LM fails to provide the large football geometry from which TPI_0 can be executed. The External DV Targeting Program, P30, is called at 95:10. The SPS Thrust Program, P40, will be called at 95:12 and an automatic maneuver to the burn attitude will be made. The LM second phasing burn will nominally be made at 95:20:04. If the burn is normal, P40 will be terminated by calling P76, the Target Delta V Program, to update the navigated LM state vector with the second Phasing burn data. Again a computer restart (V69) will be called after P76 to reconfigure the optics positioning logic. P20 will be called following the phasing burn, to initiate automatic preferred attitude tracking. At 95:30, navigation SXT marks will be taken with reinitialization of the W matrix (3/1.5*5/3.5) and Program P34 will be called and loaded with the nominal TPI_0 time along with an elevation angle of zero degrees. The program will be recycled for a solution and a comparison of the CSM and LM TPI_0 solutions will be made. Navigation SXT marks (5/3.5) will be taken at 95:46 and the two TPI_0 pads are scheduled thereafter. At 96:01, navigation SXT marks will be taken (5/3.5) and Program P34 will be recycled for the last solution based upon the nominal TPI_0 time. Navigation SXT marks (5/3.5) are scheduled for 96:09 and will be followed by a final pass through Program P34 based upon the LM TPI_0 ignition time. The SPS Thrust Program, P40, will be called at 96:23. A manual maneuver (approximately 180 degrees) followed by an auto trim maneuver to the TPI_0 burn attitude will be accomplished in three minutes.

Another manual maneuver to the navigation track attitude is required after the LM or CSM TPI_0 burn. Other than the manual maneuvers, the timeline for midcourse maneuvers is identical to TPI which is discussed in paragraph 2.10 and 2.11.

2.6 LM Insertion Maneuver Monitor and Backup

If the Go decision is reached for Insertion, the IMU will be realigned to REFSMMAT and the CSM maneuvered for CSM +X axis tracking of the LM to monitor the flyby. Ground pads for Insertion will be transmitted prior to the ground Go/No-Go for Insertion. The PAD will be loaded into the External DV Targeting Program (P30) at 95:29. The targeted CSM Insertion burn backup is equal in direction and magnitude to the LM burn and is therefore actually an anti-insertion backup. The CSM burn is targeted to occur one minute after the LM burn time. The entire CSM anti-insertion burn could be made in the event of a partial LM primary system burn. It is assumed that the LM will complete the originally targeted LM burn by backup means. Therefore, in the event of a partial LM primary system insertion burn, insertion could be cancelled by the CSM. The maneuver to the CSM anti-insertion burn attitude is approximately 150 degrees and will be initiated 10 minutes before the LM ignition time when the SPS Thrust Program, P40, is called. The LM insertion burn is scheduled at 95:41:48. If the LM burn is nominal, P40 will be terminated by loading the Target Delta V Program, P76. A computer restart (V69) will be called after the completion of P76 to reconfigure the optics positioning logic. The optics positioning logic is normally reconfigured by continuing through the burn program (P40). However, the crew desires to terminate the burn program as early as possible and continue through the timeline.

2.7 LM CSI Maneuver Monitor and Backup

Following the LM DPS insertion burn the CMP will call the Rendezvous Navigation Program, P20, at 95:43:30. A manual attitude maneuver of approximately 180 degrees at a rate of two degrees per second will be made followed by an auto trim maneuver to the preferred track axis. The SXT navigation process will be initiated with three marks in a minute and a half (3/1.5). These marks update the LM state vector in the CM C and cause the W matrix to shrink so that it must be reinitialized again to 1000 Ft. and 1 FPS. Five marks in 3.5 minutes are then taken. Two additional SXT mark periods (5/3.5) occur prior to the LM CSI burn. The mark periods are scheduled just prior to calling for range and range rate data. These data are used to compute the onboard CSI backup chart solution. Two ground computed CSI pad loads for a mirror image burn which would occur one minute after the LM burn are scheduled. The pad data will be loaded into P30 at 96:05 and the SPS Thrust Program, P40, will be called at 96:11. An automatic attitude maneuver to the burn attitude will be made. The LM CSI solution will be voiced over to the CSM at 96:14. The LM Descent Propulsion System will be jettisoned 30 seconds before the LM CSI burn ignition. If the LM cannot perform the burn the backup burn procedures of Section 6.3 will be followed. If the LM burn is nominal, P40 will be terminated by loading P76, the Target Delta V Program. Again a computer restart (V69) will be called after the completion of P76 to reconfigure the optics positioning logic.

2.8 LM CDH Maneuver Monitor and Backup

Following the LM RCS CSI burn at 96:24, the CMP will call the Rendezvous Navigation Program, P20, to provide preferred attitude tracking for SXT navigation. An automatic attitude maneuver of approximately 180 degrees will be made. Three SXT marks (3/1.5) will be made starting at 96:30. The W matrix is reinitialized and the five marks (5/3.5) are taken. Two additional marking periods of five marks (5/3.5) are taken prior to reading range rate data necessary for computing an onboard CSM backup CDH chart solution. Two backup external delta V pads for the CDH burn will be received, one over HSK and the other over HTV. The SPS Thrust Program, P40, will be called at 97:01:30 and an automatic maneuver to the burn attitude will be made. The LM CDH burn will nominally be made at 97:06:28. If the LM is unable to perform the burn, the CSM will backup the burn one minute later using the procedures in Section 6.3. If the burn is normal, P40 will be terminated by calling P76, the Target Delta V Program, to update the navigated LM state vector with the CDH burn data. Again a computer restart (V69) will be called after the completion of P76 to reconfigure the optics positioning logic.

2.9 TPI Targeting and LM Maneuver Backup

Following the LM APS CDH burn at 97:08, the CMP will call the Rendezvous Navigation Program, P20, to provide preferred attitude tracking for SXT navigation. An automatic attitude maneuver of approximately 180 degrees will be made. Three SXT marks (3/1.5) will be made starting at 97:15. The W matrix is reinitialized and five marks (5/3.5) are taken. The TPI Targeting Program, P34, is called after the marks and recycled for a solution based upon a TPI elevation angle of 207.5 degrees. Two additional marking periods of five marks (5/3.5) are accomplished. Two backup external delta V pads for the TPI burn will be received, one over MIL and the other over BDA. The LM will transmit its LM TPI burn ignition time at 97:48 and the CMP will proceed through P34 based upon the LM TPI ignition time. The SPS Thrust Program, P40, will be called nominally at 97:53 and an automatic maneuver (35 degrees) to the burn attitude will be made. The LM TPI burn will nominally be made at 97:59:20.6. If the LM is unable to perform the burn, the CSM will backup the burn using the procedures in Section 6.3. If the burn is normal, P40 will be terminated by calling P76, the Target Delta V Program, to update the navigated LM state vector with the TPI burn data. Again a computer restart (V69) will be called after the completion of P76 to reconfigure the optics positioning logic.

2.10 Midcourse Maneuver and Backup

Two midcourse maneuvers will be made by the LM following TPI, one at TPI + 10 minutes and another at TPI + 22 minutes. The CSM will backup both maneuvers with a CMC solution. Immediately following the TPI burn, the Midcourse Prethrust Program, P35, will be called and and automatic maneuver to the preferred track axis will be made. Four navigation SXT marks (4/3) will be made before Program P35 is proceeded through at TPI + 7 minutes. The RCS Thrust Program, P41, will be called at TPI + 9 minutes and the automatic maneuver will be bypassed. The LM burn will nominally be made at 98:09:20.6. If the LM is unable to perform the burn, the CSM will backup the burn using the procedures in Section 6.3. If the burn is normal, P41 will be terminated by calling P76, the Target Delta V Program, to update the navigated LM state vector with the MCC1 data. Two SXT marking periods (3/1.5*3/1.5 and 4/2.0) are taken prior to proceeding through Program P35 at TPI + 19 minutes. The RCS Thrust Program, P41, will be called at TPI + 20 minutes and the automatic maneuver will be bypassed. The LM burn will normally be made at 98:21:20.6. If the LM is unable to perform the burn, the CSM will backup the burn using the procedures in Section 6.3. If the burn is normal, P41 will be terminated by calling P76 to update the navigated LM state vector.