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# OPERATIONAL SPACECRAFT ATTITUDE SEQUENCE FOR MISSION F

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LUNAR MISSION ANALYSIS BRANCH
MISSION PLANNING AND ANALYSIS DIVISION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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# PROJECT APOLLO

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# OPERATIONAL SPACECRAFT ATTITUDE SEQUENCE FOR MISSION F

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## 1. SUMMARY AND INTRODUCTION

### 1.1 General

This document contains the operational spacecraft attitude sequence for mission F. The purpose of the document is to provide a source of spacecraft (command and service module (CSM) and lunar module (LM)) attitude data for the nominal cislunar and lunar orbit mission operations. Changes and revisions to the preliminary F mission attitude sequence, Reference 1, have been incorporated in order to present the latest possible mission planning inputs. These updates include the May 18 launch date with the extended lunar orbit stay time, the approach azimuth change to duplicate the lunar landing mission (mission G) ground track, and the recommended landmark tracking procedures.

Cislunar and lunar orbit data for the spacecraft operational attitude sequence are presented in the following format:

1. Discussion of the major attitude events occurring in the mission

2. Figures illustrating the spacecraft attitude events and activities

3. An attitude timeline listing the chronological sequence of events (Table I). Mission event times were obtained from the Apollo 10 Final Flight Plan, Reference 2.

4. Tabular data summarizing the pertinent spacecraft attitude and orbital parameters (TableII)

### 1.2 Trajectory Profile

The CSM and LM state vector and ephemeris data for generating the CSM solo, LM ascent propulsion system (APS) burn to depletion, and

docked CSM/LM attitude data were obtained from the Lunar Mission Analysis Branch of MPAD-MSC. The lunar orbit rendezvous trajectory parameters were furnished by the Orbital Mission Analysis Branch of MPAD-MSC. The mission trajectory profile from earth parking orbit insertion to entry at 400,000 feet altitude was precision integrated by the Apollo Reference Mission Program, Version ARM06. Launch date for the mission is May 18, 1968 at 11:48:35.3 Eastern Standard Time with a 72-degree launch azimuth and a Pacific translunar injection (TLI) on the first opportunity.

Translunar and transearth flight times are approximately 73 hours and 53 hours, respectively. The lunar orbit phase consists of 31 revolutions (approximately 62 hours) in lunar orbit devoted primarily to LM testing in the lunar environment and lunar landmark tracking.

## 1.3 Attitude Data Generation

The ARM06 program was used in producing the CSM and LM attitude data required to define the nominal mission attitude timeline. For the program simulation, instantaneous maneuvers were assumed in reorienting the spacecraft from an existing attitude. Appropriate time intervals are provided for finite reorientations in the timeline. The maneuver times are representative only and are not intended to reflect actual rates.

In addition to the spacecraft attitude data supplied by this document, computer tapes of the mission trajectory and attitude profile are available. Requests for these tapes should be made through the Mission Planning Support Office of MPAD-MSC.

## 1.4 Spacecraft Attitude Constraints

The CSM and LM, both in the docked and undocked configurations, are subject to attitude restrictions throughout the mission. In general, these restrictions are imposed by subsystem requirements, mission requirements, or geometry limitations.

The major constraints considered in defining the F mission spacecraft attitude timeline are enumerated below. Unless noted otherwise, the constraints are relevant to specific events or operations. Violation of any constraint is noted in the attitude timeline discussion (Sections 3, 4, 5, and 6).

1. Earth Orbit and Cislunar Phases

a. The S-IVB/SLA/CSM/LM configuration in earth orbit coast should maintain a local horizontal attitude hold with the CSM plus X-axis forward along the direction of motion and the crew heads down (CSM minus

Z-axis towards the earth). This local attitude hold should be established following parking orbit insertion and maintained until just prior to the translunar injection burn.

b. CSM tracking, telemetry, and voice are required during transposition, docking, and ejection.

c. CSM tracking, command, telemetry, and voice are required for 1 hour following ejection.

d. CSM inertial measurement unit (IMU) gimbal lock must be avoided for all events and operations in the cislunar phase. For the F mission, IMU gimbal lock is assumed to occur when the angle between the outer and inner gimbal axes is less than 45 degrees.

e. During docking with no artificial lighting, the sun must lie between 90 and 150 degrees of the CSM positive X-axis.

f. Pitch and roll maneuvers required for transposition and docking are performed at 5 degrees per second.

g. CSM monitoring of the S-IVB is required for 1 hour following ejection.

h. During passive thermal control (PTC) the angle between the line of sight to the sun and the CSM Y-Z plane must be less than 20 degrees. A roll rate between one and two and a half revolutions per hour must also be maintained.

i. A ratio of a least 5 to 1 should be maintained between periods of PTC and attitude holds. The maximum length of a continuous attitude hold should not exceed 3 hours during translunar coast and 2 hours during transearth coast.

2. Lunar Orbit Phase

a. CSM and LM gimbal lock must be avoided for all events and operations in the lunar orbit phase. For the F mission, IMU gimbal lock is assumed to occur when the angle between the outer and inner gimbal axes is less than 45 degrees.

b. CSM and LM high-gain communications are highly desirable when earth line of sight exists and the attitude does not conflict with other mission objectives.

c. During the sleep period prior to LM undocking, the CSM/LM docked attitude must provide MSFN coverage through the CSM S-band steerable antenna when earth line of sight exists. A nominal thermal environment must also be provided for the CSM RCS quads by orienting the spacecraft with respect to the sun and lunar surface.

d. CSM and LM IMU alignments in lunar orbit must avoid sunlight interference. For the F mission, this is accomplished by scheduling these events to occur in darkness. During the alignment operation, the spacecraft attitude must provide the sextant (SXT) field of coverage with at least two reference stars from 20 to 90 degrees apart. The shaft drive axis (SDA) must be at least 20 degrees above the lunar horizon.

e. During undocked activities, CSM and LM attitudes should be favorable for VHF communications unless precluded by other requirements.

f. During CSM landmark tracking, the actual marking operation should be confined to the portion of the orbit above 35 degrees elevation angle with respect to the landmark. The CSM attitude and attitude rate should be established to allow maximum optics coverage during this time. Due to an optics system constraint, the CSM attitude rate while marking is limited to a rate less than 2/3 degree per second.

g. LM inspection by the CSM must be made in sunlight as soon as possible after undocking.

h. Tracking periods during undocked activities specify a line of sight be maintained between the vehicles which satisfies the respective tracking requirements of each. The initial tracking attitude for the CSM and LM should be heads down and heads up, respectively.

i. For the CSM-LM docking maneuver performed in sunlight, the angle between the minus X-axis of the active vehicle and the sun should not be greater than 90 degrees to avoid glare interference to the active vehicle.

j. During terminal rendezvous and docking, at ranges greater than 50 feet the LM attitude must provide CSM visibility through the LM forward (plus Z) windows. After pitchover to the docking orientation at a range of 50 feet, CSM visibility is required through the overhead (plus X) window.

k. From the LM jettison maneuver after docking to the LM APS burn to depletion, the CSM attitude should permit visual monitoring of the LM to confirm adequate separation.

l. The LM inertial APS burn to depletion attitude should provide MSFN coverage of the burn through the LM S-band steerable antenna.

m. At LM jettison, the burn for the CSM evasive maneuver must place the CSM above and behind the LM at APS ignition.

Further detail on lunar mission attitude constraints may be obtained from Reference 3. Information concerning CSM/LM docked high-gain communications is found in Reference 4.

## 2. SYMBOLS

| | |
|---|---|
| AGS | abort guidance system |
| ALT | altitude |
| AOT | alignment optical telescope |
| APS | ascent propulsion subsystem |
| ARM06 | Apollo Reference Mission Program, Version ARM06 |
| CDH | constant delta altitude |
| CM | command module |
| CMP | command module pilot |
| COAS | crew optical alignment sight |
| CP | control point |
| CPA | closest point of approach |
| CSI | coelliptic sequence initiation |
| CSM | command and service module |
| DOI | descent orbit insertion |
| DPS | descent propulsion subsystem |
| g. e. t. | ground elasped time (hr:min:sec) |
| G&N | guidance and navigation |
| HGA | high-gain antenna |
| IGA | inner gimbal angle |
| IMU | inertial measurement unit |
| IP | initial point |
| LAT | selenographic latitude |
| LM | lunar module |
| LOI-1 | first lunar orbit insertion burn |
| LOI-2 | lunar orbit circularization burn |

| | |
|---|---|
| LON | selenographic longitude |
| LR | landing radar |
| LS | landing site |
| MGA | middle gimbal angle |
| MI | mirror image |
| MPAD-MSC | Mission Planning and Analysis Division - Manned Spacecraft Center |
| MSFN | Manned Space Flight Network |
| OGA | outer gimbal angle |
| PDI | powered descent initiation |
| PTC | passive thermal control |
| RCS | reaction control subsystem |
| REFSMMAT | reference to stable member coordinate transformation matrix |
| RR | rendezvous radar |
| SCT | scanning telescope |
| SDA | shaft drive axis |
| SLA | spacecraft LM adapter |
| SM | service module |
| SPS | service propulsion system |
| SXT | sextant |
| S-IVB | third stage of Saturn V vehicle |
| TEI | transearth injection |
| TLI | translunar injection |
| TPF | terminal phase final |
| TPI | terminal phase initiation |
| VHF | very high frequency |
| $\Delta V$ | velocity increment |

## 3. EARTH ORBIT

The S-IVB/SLA/LM/CSM configuration is inserted into a 100-nautical mile altitude circular parking orbit by the Saturn V booster at 00:11:24 g.e.t. The booster/spacecraft attitude at insertion burn termination is inertially fixed for 20 seconds. Following this hold, the S-IVB attitude control system positions the S-IVB (and CSM) X-axis along the local horizontal in the direction of motion. The CSM plus Z-axis is directed along the current position vector. This alignment (which is heads down for the crew) is maintained by an S-IVB orbital pitch rate during the earth orbit phase of the mission. This attitude provides communication coverage during passes over MSFN stations. The local attitude hold is terminated prior to ignition of the TLI burn which occurs at 02:33:27 g.e.t. during the second earth parking orbit revolution. Attitude control for the burn is also through the S-IVB control system.

Spacecraft position and attitude data for the earth orbit phase of the mission are listed in Table II(a). The IMU gimbal angle data for this phase apply to the launch pad alignment of the spacecraft IMU. The transformation matrices (REFSMMAT) for this and other nominal IMU alignments pertaining to various mission phases are given in Table III. Alignment of the IMU to a new inertial reference is noted in both the discussion and the tabular IMU gimbal angle data.

# 4. TRANSLUNAR

Presented in this section are major translunar events for which specific attitude sequences have been determined. These events include the transposition, docking, ejection sequence, the spacecraft evasive maneuver, and the PTC periods. Table II(b) lists the spacecraft attitude data for the translunar coast phase which begins at TLI burn termination (02:38:49 g. e. t.) and ends at lunar orbit insertion (LOI-1) burn ignition (75:49:40 g. e. t.). Spacecraft look angles (theta, phi) are defined in Figure 1. Preflight attitudes for IMU alignments, midcourse corrections, and cislunar navigation cannot be predicted precisely; attitude data for these events are, therefore, not available. The nominal mission event times are indicated, however, as obtained from Reference 2. Figure 2 is a schematic representation of the major cislunar events.

## 4. 1 Post-TLI Sequence of Events

Termination of the TLI burn occurs at 02:38:49 g. e. t. The S-IVB attitude control system maintains the burnout attitude inertially fixed for 20 seconds following thrust termination. A local horizontal attitude hold is then established by the S-IVB with the CSM plus X-axis forward in the direction of motion and the CSM plus Z-axis up along the local vertical. At TLI cutoff plus 15 minutes, the S-IVB orients the spacecraft/booster configuration to the required inertial attitude for transposition and docking. This attitude, in terms of the local horizontal orientation at TLI cutoff plus 15 minutes, consists of a positive 120-degree pitch, a positive 40-degree yaw, and a roll of 180 degrees for the S-IVB. The CSM orientation is identical except for the roll orientation which is 0 degree for the CSM. With this orientation, the S-IVB and CSM are prepared for the transposition and docking maneuver sequence initiated at TLI cutoff plus 25 minutes with CSM/S-IVB separation. A CSM RCS plus X-axis translation burn of 1 foot per second provides the CSM-S-IVB separation rate. Approximately 2 minutes later, (TLI cutoff plus 27 minutes), the CSM nulls the separation rate and pitches 180 degrees to prepare for the CSM/LM docking maneuver. After aligning to the proper CSM/LM docking index (LM plus Z-axis in the CSM minus Z-plus Y quadrant 60 degrees (±10 degrees) from the CSM minus Z-axis), the CSM closes with the LM (and S-IVB) and completes the docking maneuver. LM withdrawal is accomplished at approximately TLI plus 90 minutes after which the CSM orients to the S-IVB evasive maneuver attitude. The evasive maneuver burn by the CSM service propulsion system (SPS) is scheduled to occur at TLI cutoff plus 110 minutes. The spacecraft attitude for this maneuver is designed to account for the required SPS thrusting direction, allow the command module pilot (CMP) in the left-hand seat to view the S-IVB through the side window, and also provide CSM high-gain communications. With these considerations, the CSM local horizontal attitude for the burn is pitched 75 degrees below the local horizontal in the direction of motion and rolled positively 60 degrees.

The CSM IMU realignment and cislunar navigation sightings are performed beginning at 05:00:00 g. e. t. The navigation sightings consist of 5 sets of star-earth horizon sightings.

The first midcourse burn is scheduled at 11:33:00 g. e. t. The primary purpose of this burn besides reducing the trajectory dispersions, is to alter the lunar orbit groundtrack to duplicate the G mission groundtrack. This maneuver completes the post-TLI activities. Information for this mission phase was obtained from the F mission flight plan, Reference 2, and References 5 and 6.

## 4.2 Passive Thermal Control

The translunar coast period following the post-TLI events and ending at the time for the last translunar midcourse correction consists, in terms of spacecraft attitude, primarily of maintaining an acceptable thermal environment for the various spacecraft subsystems. This nominal thermal environment is provided by the PTC mode which involves spinning the spacecraft about the body X-axis at approximately 1 revolution per hour. The spacecraft is aligned initially so that the X-axis is normal (within ±20 degrees) to the sun, thereby, equalizing the solar heat incidence when the spin is induced. Once the spin rate is established, all RCS control jets may be disabled (true PTC), or the pitch-yaw control may be maintained in wide deadband which is planned for mission F. Two PTC test periods with a 3-revolution per hour spin rate and without attitude control are scheduled for the mission. The first test is conducted with the CSM/LM docked during the translunar coast, and the second test occurs in the transearth coast involving the CSM. The times for these tests are noted in the attitude timeline, Table I. Simulation of PTC periods for this document assumed exact attitude control in all channels (pitch, yaw, and roll). The REFSMMAT used in establishing the spacecraft PTC orientation was defined in accordance with Reference 7. The IMU Y-axis pointing was determined so that the possibility of gimbal lock occurring for transearth midcourse burns is minimized. The PTC attitude is also designed to optimize spacecraft-MSFN communications by orienting the spacecraft X-axis as near normal to the earth line of sight as possible while satisfying the other attitude constraints noted previously.

## 4.3 S-band High-Gain Antenna Reflectivity Test

At 27:00:00 g. e. t. the spacecraft is oriented to the attitude required to conduct the S-band high-gain antenna (HGA) reflectivity test. The purpose of this test is to provide in-flight data on high-gain signal interference of the docked CSM/LM with the S-band HGA tracking in the CSM plus X-axis direction. The spacecraft attitude at test initiation with respect to the local horizontal orientation is a pitch of minus 80 degrees and a yaw of 20 degrees. Maneuvers subsequent to this initial orientation were not simulated.

## 4.4 Pre-LOI Events

The pre-LOI sequence of events is assumed to begin at approximately 70:00:00 g. e. t. when the CSM IMU is aligned to the landing site REFSMMAT. This inertial IMU alignment corresponds to a local horizontal attitude of 90. 0, 0. 0, 0. 0 degrees (pitch, yaw, roll) with the nominal (assumed) time of LM touchdown and descent orbit approach azimuth. The IMU realignment is followed at approximately 70:45:00 g. e. t. by a midcourse correction, if required.

At 72:00:00 g. e. t. the spacecraft is maneuvered to an inertial attitude that provides TV coverage of the lunar surface from the center (hatch) window. This orientation consists of a 45-degree pitch and a 180-degree roll maneuver with respect to the lunar local horizontal. In addition to providing the desired TV coverage, the attitude also places the CSM S-band HGA within MSFN line of sight.

The lunar TV coverage is scheduled to end at 72:35:00 g. e. t. Since the spacecraft enters lunar umbra at 72:47:00 g. e. t, a reorientation to the PTC attitude would be impractical, and the inertial attitude used for TV is maintained until approximately 74:45:00 g. e. t. At this time, the spacecraft is oriented to the LOI-1 burn attitude that is maintained inertially fixed until LOI-1 ignition at 75:45:43 g. e. t.

# 5. LUNAR ORBIT PHASE

This section contains a detailed description of the lunar orbit attitude profile. The events are discussed in chronological order with only those mission events which affect the attitude profile being mentioned.

The mission F lunar orbit profile may be divided into three major segments

1. LOI-1 burn cutoff to CSM/LM undocking
2. CSM/LM undocking to LM jettison
3. LM jettison to TEI burn ignition

The discussion will be divided into these segments with the first and third segments being discussed primarily revolution by revolution, while the second segment is discussed according to major events. For the purpose of this document, a vehicle revolution will be referenced to the lunar surface. The first vehicle revolution is assumed to start at LOI-1 burn cutoff and end at 180 degrees selenographic longitude. All other revolutions start and end at 180 degrees selenographic longitude except the thirty-second revolution which ends at TEI burn ignition.

Detailed trajectory and attitude data for the lunar orbit phase of the mission is presented in Table II(c). Part 1 of Table II(c) presents LOI-1 burn cutoff to CSM/LM undocking. Part 2 of Table II(c) presents all of the two-vehicle data for the lunar orbit phase from CSM/LM undocking to the LM unmanned APS burn to depletion cutoff. Part 3 of Table II(c) presents the portion of the lunar orbit phase from the LM unmanned APS burn to depletion cutoff to TEI burn ignition. It should be noted that the IMU gimbal angle data presented in Table II(c) are based on the landing site REFSMMAT. The CSM and LM IMU's are aligned to the landing site REFSMMAT throughout the lunar orbit phase of the mission.

## 5.1 LOI-1 Burn Cutoff to CSM/LM Undocking

5.1.1 First revolution (Figure 3). - The LOI-1 burn is designed to deboost the CSM/LM from the cislunar trajectory and place it into a 60- by 170-nautical elliptical lunar parking orbit. The burn is performed with the CSM SPS engine. The CSM is in a retrograde attitude, and the crew is heads down to afford visual reference with the lunar surface. The LOI-1 burn cutoff attitude is maintained following the burn until approximately 12 minutes prior to acquisition of MSFN line of sight. The CSM is then rolled 180 degrees (right) to provide CSM S-band HGA communications. This attitude is maintained inertially fixed until communications with MSFN have been established. The vehicle is then maneuvered to a lunar observation attitude. The CSM attitude, with respect to the local horizontal orientation, is a pitch of -45 degrees and a roll of 180 degrees.

This lunar observation attitude allows observation of the CSM/LM groundtrack through the CSM hatch window and oblique views of the lunar surface through each of the CSM side windows. This lunar observation attitude is held locally fixed until the vehicle enters darkness. At this time the local attitude hold is terminated, and the existing vehicle attitude is maintained inertially fixed to allow a CSM IMU realignment. The IMU realignment occurs approximately 5 minutes after the vehicle enters darkness and is a realignment to the lunar landing site REFSMMAT. Approximately 17 minutes prior to the loss of MSFN line of sight, the CSM/LM is maneuvered to the lunar orbit sleep attitude for an evaluation of the CSM HGA communications mode to be used during lunar orbit sleep. The lunar orbit sleep attitude will be more fully discussed in one of the following sections, but the attitude is an inertial attitude such that the CSM local horizontal angles at the subsolar point would be a pitch of -140 and a roll of 135 degrees. To fully evaluate the communications mode, the CSM/LM must remain in an inertially fixed attitude from loss of MSFN line of sight to acquisition of MSFN line of sight. Thus, the vehicle attitude is maintained inertially fixed through the completion of the first revolution. CSM S-band HGA communications will be available from acquisition of MSFN line of sight to loss of MSFN line of sight.

5.1.2 Second revolution (Figure 4). - At the completion of the first vehicle revolution, the spacecraft is in the inertially fixed lunar orbit sleep attitude for an evaluation of the lunar orbit sleep communications reacquisition mode. This attitude is held inertially fixed until completion of the communications test. Approximately 10 minutes after acquisition of MSFN line of sight, the CSM is rolled 45 degrees (right) to improve lunar observation near the lunar morning terminator. The resulting attitude is maintained inertially fixed until the time to maneuver to the LOI-2 burn attitude. The inertial attitude satisfies the attitude requirements for an IMU realignment to the landing site REFSMMAT that occurs immediately after the CSM/LM enters darkness. Approximately 25 minutes before loss of MSFN line of sight, the CSM/LM is maneuvered to the LOI-2 burn attitude. This attitude is maintained through the completion of the second revolution. CSM S-band HGA communications will be available from acquisition of MSFN line of sight until the maneuver to the LOI-2 burn attitude.

5.1.3 Third revolution (Figure 5). - Following the start of the third revolution, the LOI-2 burn is performed. This burn is the circularization burn that transforms the initial elliptical parking orbit into a 60-nautical mile circular lunar orbit. The burn is performed with the CSM SPS engine with the CSM in a retrograde attitude. The CSM roll attitude allows the crew to be heads down during the burn to allow visual reference with the lunar surface. Following burn cutoff the LOI-2 burn attitude is maintained. Approximately 10 minutes prior to acquisition of MSFN line of sight, the CSM is rolled 180 degrees (right) to provide CSM S-band HGA communications. The resulting attitude is maintained inertially fixed until communications with MSFN have been established. The vehicle is then maneuvered to the lunar observation attitude. The same attitude which

was used in the first revolution is utilized. The CSM attitude, with respect to the local horizontal orientation is a pitch of -45 degrees and a roll of 180 degrees. This attitude allows observation of the vehicle groundtrack through the CSM hatch window and oblique views of the lunar surface through each of the CSM side windows. This attitude is held locally fixed until just prior to the vehicle entering into darkness. This attitude should allow through-the-window observation of the landmarks to be tracked during the next vehicle revolution. In addition, a possible 10-minute TV transmission is scheduled at mission time 80:45:00. This attitude will provide S-band HGA communications and will allow a view of the lunar surface. Prior to the vehicle entering darkness, the local attitude hold is terminated, and the existing vehicle attitude is held inertially fixed until the CSM/LM enters into sunlight. This inertial attitude will allow a CSM IMU realignment to the landing site REFSMMAT that occurs approximately 7 minutes after the CSM/LM enters darkness. As the vehicle enters into sunlight, the CSM/LM is maneuvered to the initial landmark tracking attitude for the landmark tracking on F-1 (a lunar landmark to be tracked in the fourth vehicle revolution). The initial landmark tracking attitude is a pitch 2.1 degrees below the local horizontal orientation 90 seconds before the CPA to F-1 (approximately 35 degrees elevation). This initial landmark tracking attitude is maintained through the completion of the third vehicle revolution. It should be noted that approximately 3 minutes after the loss of MSFN line of sight the LM is occupied, and LM attitude requirements must be taken into account. CSM S-band HGA communications will be available from acquisition of MSFN line of sight to loss of MSFN line of sight.

5.1.4 Docked lunar landmark tracking. - A complete list of the lunar landmarks which will be tracked during the lunar orbit phase is presented in Table IV. This list was obtained from Reference 8. An IP is a prominent initial point which aids the astronaut by leading him into the landmark to be tracked. The geometry for lunar landmark tracking is defined by Figures 6 and 7. The acceptable marking region is defined as the area from 35 degrees elevation to 35 degrees elevation. The period of time the spacecraft remains in the acceptable marking region is on the order of 3 minutes. Marks taken within this region must be equally spaced and at least 25 seconds apart. Five marks are required on each landmark, with a minimum time of 100 seconds required between the first and the last mark. The primary consideration is that the marks be taken over a wide spread of elevation geometry. The SCT will be used to acquire the landmark, and the SXT will be used to track the landmark.

The landmark tracking attitude mode to be used for docked lunar landmark tracking is a mode I type. A complete discussion of the lunar landmark tracking attitude modes available for landmark tracking is presented in Reference 9. Mode I tracking consists of an inertial attitude hold with the CSM X-Z plane approximately in the lunar orbit plane. As the spacecraft approaches the landmark, a pitch rate is added to allow the landmark to remain in the optical fields of coverage while the spacecraft

is in the acceptable marking region. The geometry for the particular mode I tracking used is presented in Figure 8. The initial inertial attitude is such that the CSM is pitched 2.1 degrees below the local horizontal orientation at 90 seconds before the CPA. A -0.3 degree per second pitch rate is added at 35 degrees elevation and is maintained until the vehicle exits the acceptable marking region approximately 90 seconds after the CPA. At the termination of the pitch rate the CSM X-axis lies approximately 47 degrees below the local horizontal. The landmark enters the SCT field of coverage 148 seconds before the CPA (21 degrees elevation) and enters the SXT field of coverage 112 seconds before the CPA (28.2 degrees elevation). The landmark is still in both the SXT and SCT fields of coverage at the termination of the pitch rate.

To aid the astronaut in landmark tracking, two times, $T_1$ and $T_2$, will be updated to the astronaut in real time. $T_1$ is the g.e.t. when the spacecraft comes across the landmark topocentric horizon. This is primarily an astronaut alert time. $T_1$ occurs approximately 390 seconds before the CPA to the landmark. $T_2$ is the g.e.t. to start the pitch rate. $T_2$ occurs approximately 90 seconds before the CPA.

As a result of the maximum rate limits of the optics shaft and trunnion angles, there are certain zones in the optical coverage area where the optics line of sight cannot keep up with the coverage of the landmark. This occurs when the groundtrack of the optics shaft axis passes close to the landmark. In mission F, the optical blind zone will be avoided by rolling the spacecraft so that the minimum trunnion angle is at least 10 degrees. This maneuver will be added in real time, and is not simulated here. The required roll is small, and the times given above are not appreciably affected. The optics shaft and trunnion angles given in Table II(c) are the optics angles required to center the optics line of sight along the vehicle to landmark line of sight at 35 degrees elevation before the CPA. These angles do not reflect the roll maneuver required to avoid the optics blind zone. Detailed shaft and trunnion plots are available for each landmark but will not be presented in this document.

5.1.5 Fourth revolution (Figure 9). - At the beginning of the fourth revolution the spacecraft is in the initial inertial attitude for landmark tracking on F-1. A mode I type tracking sequence is performed on F-1, and at the conclusion of the tracking sequence the vehicle pitch rate is terminated and the spacecraft is maneuvered to the initial inertial attitude for landmark tracking on B1. Because of the pitch rate for the mode I tracking, only a small pitch maneuver is required. A mode I type tracking sequence is performed on B1, and at the completion of the sighting sequence the spacecraft pitch rate is terminated and the spacecraft is maneuvered to the lunar orbit sleep attitude. CSM S-band HGA communications will not be available during the landmark tracking sequences. The lunar orbit sleep attitude is the same used for the communication test in the first revolution. The CSM inertial attitude is such that the CSM is pitched -140 degrees and rolled 135 degrees from the local horizontal orientation at the subsolar point. Approximately 3 minutes after the spacecraft enters darkness, 25 minutes of LM communications tests start.

Before the start of these tests, the CSM RCS thrusters that might cause impingement on the LM S-band steerable antenna when unstowed are disabled. These thrusters are RCS jets B-3 and C-4. With these thrusters disabled, the LM steerable antenna may track outside of the preseparation pointing region. The lunar orbit sleep attitude will allow both CSM and LM S-band steerable communications with MSFN. This sleep attitude is held inertially fixed through the completion of the fourth revolution. Another test of the lunar orbit sleep reacquisition mode is provided before the crew starts its sleep period. The LM is vacated approximately 15 minutes after loss of MSFN line of sight.

5.1.6 Fifth revolution (Figure 10). - At the start of the fifth revolution, the spacecraft is in the inertially fixed lunar orbit sleep attitude. At acquisition of MSFN line of sight a test of the lunar orbit sleep communications reacquisition mode is provided. An 8-hour lunar sleep period is started approximately 20 minutes after the acquisition of MSFN line of sight. The lunar orbit sleep attitude is maintained inertially fixed through the completion of the fifth revolution. CSM S-band HGA communications are available from acquisition of MSFN line of sight to loss of MSFN line of sight.

5.1.7 First lunar orbit sleep period (Figures 11, 12, 13, and 14). - The inertial lunar orbit sleep geometry is shown in Figure 15. An inertial attitude hold is used to minimize RCS fuel usage and to provide continuous CSM S-band HGA communications when line of sight to earth exists. The attitude must be compatible with CSM S-band HGA communications. Also, RCS quad cold problems must be avoided. The thermal constraints may be avoided by placing the CSM X-axis normal to the sun plus or minus some bias. The allowable bias is approximately 40 degrees. The CSM must also be rolled so that direct sunlight "splits" two RCS quads. This insures that all the quads receive some heating. Two quads receive direct sunlight, and the other two quads receive reflected heat from the lunar surface. A flight crew constraint is that the CSM X-axis remain in-plane during the sleep period. All these constraints are satisfied by the inertial lunar orbit sleep attitude. The 40-degree bias and the roll to split the RCS quads is taken in such a way that communications are improved. The inertial attitude is such that the CSM is pitched -140 degrees and rolled 135 degrees from the local horizontal orientation at the subsolar point. The longitude of the subsolar point used in calculating the attitude is the longitude at the nominal time of starting the crew sleep period. The attitude is kept in a G&N attitude hold with a ±10-degree dead band throughout the lunar orbit sleep period. Two adjacent RCS quads are used for attitude control. Additional information on the lunar orbit sleep attitude may be obtained from Reference 10. The lunar orbit sleep period lasts approximately 8 hours, being terminated late in the ninth revolution. The inertial sleep attitude is maintained through the completion of the ninth revolution. CSM S-band HGA communications will be available from acquisition of MSFN line of sight to loss of MSFN line of sight in each vehicle revolution.

5.1.8 Tenth revolution (Figure 16). - At the beginning of the tenth revolution, the spacecraft is in the inertial lunar orbit sleep attitude and the crew is awake. This attitude is maintained inertially fixed until approximately 4 minutes prior to loss of MSFN line of sight. The LM is occupied approximately 8 minutes after acquisition of MSFN line of sight, and the sleep attitude provides LM steerable antenna communications for the LM communications checks. The sleep attitude also satisfies the attitude requirements for a CSM IMU realignment to the landing site REFSMMAT, which occurs approximately 2 minutes after the CSM/LM enters into darkness. Prior to loss of MSFN line of sight the spacecraft is maneuvered to the initial inertial attitude for a mode I landmark tracking to be performed on landmark 130 in the eleventh revolution. This attitude is held inertially fixed through the completion of the tenth revolution. CSM and LM S-band steerable communications will be available from acquisition of MSFN line of sight until the maneuver to the landmark tracking attitude.

5.1.9 Eleventh revolution (Figure 17). - At the beginning of the eleventh revolution the spacecraft is in the initial inertial attitude for a mode I landmark tracking on landmark 130. This attitude is held inertially fixed until 90 seconds before the CPA to landmark 130. After the completion of the mode I landmark tracking sequence on landmark 130, the spacecraft is maneuvered to an attitude that is rolled 180 degrees from the CSM/LM undocking attitude. CSM and LM S-band steerable communications were not available during the landmark tracking sequence, but this maneuver allows CSM and LM S-band steerable communications. This attitude is held inertially fixed until approximately 3 minutes after loss of MSFN line of sight. The spacecraft is then rolled 180 degrees (right) to the undocking attitude and held inertially fixed while LM checkout continues.

Approximately 25 minutes before undocking, the vehicle is yawed 14 degrees (right) for a LM AGS calibration. After completion of the AGS calibration, the spacecraft is yawed -14 degrees (left) to return to the undocking attitude. The undocking attitude is then held inertially fixed until CSM/LM undocking. This occurs early in the twelfth revolution. CSM and LM S-band steerable antenna communications are available from the completion of landmark tracking until loss of MSFN line of sight.

## 5.2 Undocking to LM Jettison

5.2.1 Undocking to DOI (Figure 18). - Undocking will occur at 98:10:00 g.e.t., which is approximately 25 minutes prior to the CSM-RCS separation burn. The orientation of the vehicles is such that the LM is ahead of the CSM. The CSM is in-plane, heads down and pitched 13.3 degrees above the local horizontal. This attitude is the CSM inertial separation burn attitude except for a 180-degree roll angle that shades the CSM windows during the LM inspection. Following undocking the LM will null the relative range rate after a separation distance of 40 to 50 feet is achieved. The CSM will then station keep at this distance while the LM performs a 120-degree negative roll (pilot yaw right) maneuver and a

90-degree positive pitch maneuver. This will place the LM heads down and at an attitude where the crews will be eye to eye. The CMP will then inspect and photograph the LM landing gear and descent engine bell while the LM does a rotation maneuver (pilot yaw right) of 2 degrees per second for 360 degrees. Immediately after completion of the inspection, the LM will begin station keeping and the CSM will manually roll 180 degrees to acquire the MSFN with the HGA. These attitudes are held inertially fixed until after the CSM-RCS separation burn cutoff.

Separation is accomplished by the CSM X-axis RCS thrusters applying a $\Delta V$ of 2.5 feet per second radially downward. This maneuver is performed at approximately 180 degrees central angle prior to DOI. At separation burn ignition the CSM is in-plane and pitched 90 degrees above the local horizontal (positive X-axis is coincident with the radius vector). An attitude maneuver should not be required at this time since the CSM undocking attitude was the inertial separation burn attitude. The LM will have performed small translation maneuvers during the LM station keeping phase so that it will be above and slightly ahead of the CSM at separation. This will allow the LM to visually monitor the CSM-RCS separation burn while maintaining an attitude that is favorable for establishing the RR tracking attitude which follows separation. Each spacecraft will be in an attitude favorable for HGA communications during the separation burn.

Following the CSM separation burn, the CSM and LM will be maneuvered (pitched) automatically to the required attitudes for CSM SXT tracking - VHF ranging and LM RR tracking. The necessary tracking attitude results in the center of the common coverage of the CSM SXT and RR transponder to be pointing at the LM (35 degrees from the positive X-axis toward the positive Z-axis measured in the X-Z plane). Likewise, the center of coverage of the LM tracking light should be pointing at the CSM (along the positive Z-axis). This attitude is also the preferred attitude for LM RR coverage. For this tracking period, and for all subsequent CSM/LM tracking, the CSM is oriented in a heads down attitude and the LM in a heads up attitude. The initial attitudes of the vehicles allow for CSM SXT/RR transponder and LM RR/tracking light line-of-sight maintenance. The amount each vehicle is pitched in order to obtain the preferred track axis (vehicle-to-vehicle look angles discussed above) is dependent upon the relative positions of the vehicles at the time of separation. Assuming that the LM is 50 feet above and 5 feet ahead of the CSM at separation, the CSM will be pitched approximately 35 degrees and the LM will be pitched approximately 0.5 degree following the CSM separation burn cutoff in order to obtain the preferred track axis.

The CSM and LM will perform an IMU realignment beginning about 5 minutes after sunset. Both vehicles will be in inertial attitude hold during the IMU realignments and will continue in this mode until 6 minutes prior to LM DOI burn ignition. At this time the CSM will begin an automatic maneuver to the preferred track axis discussed previously in order to monitor the LM burn and to provide radar transponder coverage. The LM will begin an automatic maneuver to the inertial DOI burn attitude which is a retrograde, in-plane orientation. The LM DPS DOI burn ignition occurs at 99:33:59 g.e.t.

The attitude of the CSM from the time it performs a 180-degree roll maneuver subsequent to the LM inspection to LOS is favorable for HGA communications. The attitude of the LM from the time the LM begins station keeping until LOS is favorable for HGA communications.

A relative motion plot of the two spacecraft from separation to DOI is illustrated in Figure 19. It was assumed that the LM was approximately 50 feet above the CSM at separation. The attitude sequences from undocking to DOI were developed by utilizing the crew procedures information presented in References 11 and 12.

5. 2. 2 DOI burn cutoff to phasing burn ignition (Figure 20). - The CSM-LM relative motion for the lunar orbit phase from DOI to docking is shown in Figure 21.

Following cutoff of the DPS DOI burn at 99:34:27 g. e. t., the LM orients to the RR tracking attitude described in the preceding section. This tracking interval lasts for approximately 15 minutes after which the LM orients to the inertial powered descent initiation (PDI) attitude. The PDI attitude is defined at pericynthion of the descent orbit by a LM retrograde, local horizontal, and face down orientation. The CSM continues to track the LM for an onboard determination of the LM descent orbit state vector. Following DOI cutoff, the CSM continues SXT tracking - VHF ranging operations until termination of the LM phasing burn (assuming both of these burns are nominal). Reference 11 contains the CSM contingency procedures for the CSM-LM rendezvous. This CSM tracking period is interrupted shortly before MSFN line-of-sight acquisition for the CSM to perform a 180-degree roll maneuver. This maneuver places the CSM plus Z-axis forward, in the direction of motion, providing S-band HGA communications at MSFN acquisition. Following the roll maneuver, the CSM is reoriented to the tracking attitude, and SXT tracking - VHF ranging is resumed. The CSM tracking profile from MSFN acquisition to nominal phasing burn cutoff permits MSFN coverage through the HGA. CSM and LM tracking periods were obtained from Reference 13 with two exceptions. First, the prephasing tracking for the CSM was obtained from Reference 11 and the post-DOI LM tracking was agreed upon in an F mission data priority meeting on March 10, 1969. The second exception is the inclusion of a LM-IMU realignment lasting 15 minutes during the post-phasing tracking period. The termination of this tracking period for the LM was also changed to 5 minutes prior to LM loss of MSFN line of sight. This change was obtained informally from the Math-Physics Branch - MSC. It is emphasized that CSM and LM preinsertion tracking periods are subject to change and the times shown in this report for these periods should not be regarded as final.

The LM acquires earth line of sight in the PDI attitude. A negative roll (pilot yaw right) of 180 degrees and a negative pitch maneuver is executed in preparation for the landing radar (LR) test. The direction of the roll (pilot yaw) is required to verify the ability to maintain S-band high-gain communications during this maneuver, and the pitch maneuver orients the LM to the local vertical (LM plus X-axis up). A pitch rate of approximately -0. 055 degree per second is induced with the LM X-axis pitched back 10 degrees from the local vertical. The LR test is initiated

400 seconds prior to pericynthion of the descent orbit trajectory and ends 600 seconds later. The landing site is visible through the LM window for approximately 1 minute during the test. The spacecraft attitude sequence for the LR test is shown in Figure 22. Note from the figure that the LM could be reoriented, following LR test completion, to increase the landing site observation time.

Upon completion of the LR test, the LM prepares for the DPS phasing burn. The inertial burn attitude (plus X-axis 29 degrees above the local horizontal in the direction of motion and face down at ignition) is established 8 minutes prior to ignition which occurs at 100:46:21 g. e. t. The LM attitude profile from MSFN acquisition to ignition provides HGA-MSFN line of sight.

5. 2. 3 Phasing burn cutoff to insertion burn ignition (Figure 23). - The DPS phasing burn cutoff is at 100:47:03 g. e. t. with the LM holding the burn attitude inertially until executing a pitch and roll (pilot yaw) maneuver for RR tracking of the CSM starting 5 minutes after burn termination. The CSM, upon confirming the burn is nominal, continues the line-of-sight maintenance tracking attitude rate and resumes tracking beginning 5 minutes after the burn. The LM tracking attitude at the end of the 10-minute tracking period is held inertially fixed for the LM IMU realignment mentioned previously. The CSM also tracks for 10 minutes and maintains the final tracking attitude inertially fixed.

The CSM and LM initiate tracking again at 101:17:03 g. e. t. At 101:20:47 g. e. t. (5 minutes prior to loss of MSFN line of sight by the LM) the LM terminates tracking. The LM orientation at the end of tracking is maintained inertially until resumption of LM RR tracking at 101:59:18 g. e. t. The CSM terminates tracking at 101:27:03 g. e. t. holding the final tracking attitude inertially fixed until the next tracking period beginning at 101:48:18 g. e. t. LM and CSM attitudes for the period from phasing burn cutoff to loss of MSFN provide HGA communication for both vehicles.

After the CSM ceases tracking at 102:18:18 g. e. t., the vehicle maneuvers to the inertial mirror image (MI) insertion burn attitude. The MI burn attitude is a means of providing CSM backup capability for the LM rendezvous burns from insertion to the final braking maneuvers (the CSM nominally performs the docking maneuver). The MI burn attitude consists of aligning the CSM propulsion system (SPS or RCS) in a thrusting direction opposite the LM burn orientation. Ignition for the MI burn is scheduled at 3 minutes after the nominal time of ignition for the LM burn.

The CSM MI insertion burn attitude, at the time of LM insertion burn ignition, has the plus X-axis 26. 8 degrees above the local horizontal in the direction of motion with the crew heads down. The MI burn attitude is maintained until the LM burn is performed and verified. The CSM acquires MSFN in the MI burn attitude with the S-band HGA oriented nominally for MSFN coverage.

The LM terminates tracking at 102:19:18 g. e. t. and prepares for jettison of the descent stage. The jettison maneuver sequence begins at 102:33:18 g. e. t. with the LM orienting to a retrograde, face down local horizontal attitude. An RCS minus X-axis burn of 2 feet per second is then executed. Shortly after this burn, the LM RCS plus X-axis thrusters are fired to provide a 2-foot per second retrograde $\Delta V$ increment. During this burn, the descent stage is jettisoned. The object of these maneuvers is to place the descent stage in a higher orbit and return the LM ascent stage to essentially the original (phasing) orbit. This results in the descent stage being behind and above the LM ascent stage at insertion burn ignition, thereby, minimizing the probability of recontact between the ascent stage and descent stage during the burn.

Following descent stage jettison, the LM prepares for the ascent propulsion subsystem (APS) insertion burn. The LM insertion burn attitude at ignition (102:43:18 g. e. t. ) is with the LM plus X-axis 24. 4 degrees above the local horizontal opposite the direction of motion and the plus Z-axis towards the moon. The LM attitude from MSFN acquisition to burn ignition provides high-gain coverage with the MSFN.

5. 2. 4 Insertion burn cutoff to CDH burn ignition (Figure 24). - Burn termination for the APS insertion burn occurs at 102:43:33 g. e. t. The LM holds the burnout attitude inertially until time to orient for a RR tracking period beginning 18 minutes after burn cutoff. The reorientation maneuver to the initial tracking attitude involves a 180-degree roll (pilot yaw) and pitch of 120 degrees to point the plus Z-axis approximately along the local horizontal in the direction of motion.

The CSM, upon confirmation of a nominal APS insertion burn, orients from the MI insertion burn attitude to a retrograde, heads down inertial attitude. The purpose of this orientation is to establish a suitable attitude for performing an IMU realignment and provide S-band HGA-MSFN line of sight. This attitude also prepares the CSM for the SXT tracking - VHF ranging period starting 23 minutes after insertion burn termination.

The CSM and LM track until approximately 16 minutes and 11 minutes, respectively, prior to the CSI burn. At these times the vehicles maneuver to their inertial CSI burn attitudes (LM posigrade local horizontal and face down, CSM retrograde local horizontal and heads up at RCS burn ignition). Both CSM and LM high-gain communications are satisfactory throughout the time from insertion burn cutoff to loss of MSFN.

The LM performs the CSI burn with the plus X-axis RCS thrusters beginning at 103:33:46 g. e. t. The burn attitude is maintained inertially and the LM prepares for another period of RR tracking starting 6 minutes after the CSI burn. This maneuver consists of pitching the Z-axis up to the local horizontal in the direction of motion.

The CSM, after verifying the LM CSI burn was nominal, also orients to the SXT tracking - VHF ranging attitude. The maneuver is essentially a roll of 180 degrees to establish the initial heads-down tracking attitude.

The roll maneuver is required because the MI CSI burn attitude is heads up to allow MSFN coverage until loss of signal. The CSM tracking period also starts 6 minutes after the burn.

After this period of tracking (20 minutes for the CSM and 17 minutes for the LM), another tracking interval is started 9 minutes later for the LM and 5 minutes later for the CSM. The LM plane change maneuver occurs in this break but is not simulated in this document. After resuming tracking, both vehicles maintain the respective tracking attitude for the duration of the period which ends at 104:20:18 g. e. t. In this second period, MSFN line of sight is acquired. The LM tracking attitude provides S-band high-gain lock but the CSM attitude violates high-gain antenna pointing constraints. High-gain communications requirements are satisfied, however, when the CSM orients to the inertial MI CDH burn attitude (retrograde local horizontal and heads down at LM RCS ignition). The LM inertial CDH burn attitude (plus Z-axis forward along the local horizontal and heads up at ignition) also provides MSFN coverage with the LM steerable antenna. The LM orients to the CDH burn attitude following the RR tracking ending at 104:20:18 g. e. t. CDH burn ignition is at 104:31:42 g. e. t. The four RCS minus X-axis thrusters perform the burn with the thrust direction radially downward.

5. 2. 5 CDH burn cutoff to docking (Figure 25). - After cutoff of the CDH burn at 104:31:45 g. e. t., the LM and CSM begin another period of tracking 4 and 5 minutes later, respectively. The CSM and LM tracking attitudes provide high-gain coverage during this period. Both vehicles hold the tracking attitude inertially at the end of the period (17 minutes and 19 minutes in length for the CSM and LM, respectively) until executing their TPI burn attitude orientation. The LM performs TPI with the plus X-axis jets in a heads up posigrade attitude. The CSM MI burn attitude is heads down and retrograde at the nominal time of ignition (105:08:57 g. e. t. ). Following TPI cutoff at 105:09:13 g. e. t., two short periods of tracking by the CSM and LM occur prior to the LM RCS braking burn at 105:50:14 g. e. t. (The CSM-LM separation at burn ignition is 3000 feet. The first braking burn at a separation distance of 5000 feet was not required in the rendezvous maneuver simulation. All braking burns are performed by the RCS minus Z-axis thrusters. ) The first of the two tracking periods is within sight of MSFN stations. The CSM and LM HGA positions are acceptable for MSFN acquisition until loss of signal.

The CSM maintains the required line-of-sight tracking attitude during the subsequent LM braking maneuvers. The LM also continues with the nominal RR tracking attitude (plus Z-axis pointed at the CSM) between the braking burns. This tracking profile is compatible with the line-of-sight thrust direction (along the LM minus Z-axis).

The final LM braking burn (at 100 feet CSM-LM separation distance) is performed at 105:56:36 g. e. t. The CSM-LM range at burn termination is approximately 85 feet with an approximate closing rate of 0. 2 foot per second. When the LM closes to within 50 feet of the CSM (the LM is ahead and slightly below the CSM at this point), both vehicles begin final docking preparations. The LM pitches negatively through 90 degrees to point the LM plus X-axis at the CSM. The vehicle-to-vehicle line of sight is then

approximately normal to the sun line of sight. As noted earlier, the CSM executes the closing translational maneuvers required for docking. Completion of the CSM/LM docking maneuver was assumed at 106:20:00 g. e. t.

5. 2. 6 Docking to LM jettison (Figure 26). - After post-docking checks, the spacecraft is maneuvered to the LM jettison attitude. The attitude is such that the LM is in the correct inertial burn attitude for the APS burn to depletion, which occurs approximately one revolution after docking. The attitude must also provide LM HGA communications for MSFN tracking of the burn. This attitude is held inertially fixed until time for LM jettison at 108:29:24 g. e. t.

## 5. 3 LM Jettison to TEI Burn Ignition

5. 3. 1 LM jettison to end of seventeenth revolution (Figure 27). - Since the LM APS burn to depletion is an unmanned burn, the LM must be jettisoned in the correct inertial attitude for the APS burn. The LM jettison attitude is such that the LM is in the local horizontal orientation at the LM APS burn ignition (108:38:57 g. e. t. ). The LM jettison occurs at 90 degrees east selenographic longitude with the CSM pitched 90 degrees and rolled -60 degrees from the local horizontal orientation. Immediately following jettison, the CSM is translated above the LM, using short RCS thrusts. After translating above the LM, a CSM $\Delta V$ of 2 feet per second is applied radially upward to effect final separation. This evasive maneuver puts the CSM above and behind the LM at the APS burn ignition. Following the evasive maneuver, the CSM is maneuvered to a LM observation attitude. This attitude is an inertially fixed attitude that allows the LM APS burn to be seen through the CSM hatch and rendezvous windows. This attitude also allows CSM S-band HGA communications.

The unmanned LM APS burn to fuel depletion is initiated with the LM at 0 degree selenographic longitude. The burn is an in-plane, posigrade, face-down burn with the LM aligned along the local horizontal orientation at burn ignition. The burn is targeted to place the LM ascent stage in solar orbit. The LM remains in continuous line of sight with MSFN with LM S-band steerable antenna coverage available for monitoring of the LM for several hours after the burn.

Following the LM burn and approximately 16 minutes before loss of MSFN line of sight, the CSM maneuvers to the lunar orbit sleep attitude. This attitude is held inertially fixed through the completion of the seventeenth revolution. Both CSM and LM S-band steerable antenna communications are available during the seventeenth CSM revolution whenever line of sight to MSFN exists.

5. 3. 2 Second lunar orbit sleep period (Figures 28, 29, 30, and 31). - The CSM attitude during the second lunar orbit sleep period will be the same attitude as that for the first lunar orbit sleep period. This sleep period, following the strenuous rendezvous day, will be approximately 9 hours long with sleep terminating early in the twenty-second revolution.

The inertial attitude hold during the sleep period will provide CSM S-band HGA communications from acquisition of MSFN line of sight to loss of MSFN line of sight during each revolution.

5.3.3 Twenty-second revolution (Figure 32). - Early in the twenty-second revolution, the second lunar orbit sleep period is terminated. Approximately 5 minutes after acquisition of MSFN line of sight, the CSM is maneuvered to the initial attitude for an oblique photography sequence of LS2. A schematic of an oblique photography sequence is shown in Figure 33. The camera used for the photography sequence will be placed in a bracket that is mounted in the CSM right-hand rendezvous window. The camera optical axis, using the bracket, will be pitched 12 degrees (up) from the CSM X-axis (Reference 14). The oblique photography attitude sequence will allow the LS line of sight to remain within a 15-degree half-angle cone about the camera optical axis. The initial attitude for the photography sequence will allow the LS to be seen as the spacecraft crosses the LS topocentric horizon. The CSM is pitched -8 degrees and rolled 180 degrees from the local horizontal orientation. This attitude is held locally fixed until approximately 20 degrees elevation from LS2. A 0.5 degree per second pitch rate is then initiated to keep LS2 in the camera field of view. The pitch rate is terminated at the LS zenith. The spacecraft attitude is changing faster than the LS line of sight during the period the spacecraft is at low elevation angles. The maximum backup occurs at approximately 47 degrees elevation, after which the LS line of sight changes faster than the spacecraft attitude. At the completion of the sequence the spacecraft has been pitched approximately 78 degrees below the local horizontal.

At the completion of the oblique photography sequence, the pitch rate is terminated and the existing attitude is held inertially fixed. This attitude satisfies the requirements for an IMU realignment to the landing site REFSMMAT, which occurs approximately 7 minutes prior to loss of MSFN line of sight. Prior to the CSM entering into sunlight, the spacecraft is maneuvered to an attitude that allows vertical strip photography of the spacecraft groundtrack. The spacecraft attitude is a pitch of -78 degrees and a roll of 180 degrees from the local horizontal orientation. This allows the camera optical axis to be pointed vertically down and allows the spacecraft windows to be shaded from the sun. This attitude is held locally fixed through the completion of the twenty-second revolution. CSM S-band HGA communications will be available from acquisition of MSFN line of sight to loss of MSFN line of sight.

5.3.4 Twenty-third revolution (Figure 34). - At the beginning of the twenty-third revolution, the CSM is in the locally fixed strip photography attitude. This attitude is maintained locally fixed until the spacecraft reaches the subsolar point. The CSM is then maneuvered to shade the spacecraft windows from the sun. The CSM attitude, with respect to the local horizontal orientation, is then a pitch of -102 degrees. This attitude allows the camera optical axis again to be pointed vertically down. This attitude is maintained locally fixed. As the spacecraft approaches LS1, the CSM is yawed 20 degrees (right) to include LS1 in the photography.

After passing LS1, the CSM is yawed -20 degrees (left) to place the camera axis back on the spacecraft groundtrack. The strip photography attitude is maintained locally fixed until the lunar morning terminator is reached. At the terminator, the spacecraft is maneuvered to an IMU realignment attitude. This inertial attitude satisfies the attitude requirements for the IMU realignment to the landing site REFSMMAT, which occurs approximately 2 minutes after the spacecraft enters darkness. The IMU realignment attitude also sets up the undocked landmark sighting attitude for the series of sightings starting early in the twenty-fourth revolution. The IMU realignment attitude is held inertially fixed until the CSM becomes pitched 22 degrees below the local horizontal orientation. The inertial attitude hold is then terminated, and a local attitude hold is initiated for the landmark sightings. This attitude is maintained locally fixed through the completion of the twenty-third revolution. CSM S-band HGA communications will be available from the maneuver to the IMU realignment attitude until loss of MSFN line of sight.

5.3.5 Undocked lunar landmark tracking. - During the undocked landmark tracking periods, several lunar landmarks are to be tracked in each vehicle revolution. Because of this, a relatively simple spacecraft attitude mode which does not require attitude reorientations between sightings should be used. In addition, LM blockage, which obscured part of the CSM optics during docked sightings, is no longer a problem for the undocked sightings. For these reasons, mode III type landmark tracking will be used for the undocked landmark sightings (Reference 9). The spacecraft attitude, with respect to the local horizontal orientation, during undocked sightings is a pitch of -22 degrees. The geometry of the mode III type landmark tracking is shown in Figure 35. The landmark enters the SCT field of coverage 100 seconds before the CPA (32 degrees elevation) and exits the SXT field of coverage 56 seconds past the CPA (49.7 degrees elevation). Although the tracking and acquisition times are significantly reduced over those of the mode I docked sightings, the landmark remains in the SXT field of coverage for 146 seconds within the acceptable mark region. This should be adequate time to obtain the required 5 marks. It should be pointed out, if trouble occurs in obtaining the marks, additional tracking time can be made available by adding a small pitch rate near the end of the tracking period. The optical blind zone constraint may be satisfied, as in the docked sightings, by rolling the spacecraft as the landmark is approached to assure a minimum trunnion angle of at least 10 degrees.

Two times, $T_1$ and $T_2$, are used during undocked landmark sightings to help in acquiring the correct landmark. $T_1$ occurs when the spacecraft is 35 degrees elevation from the IP for the landmark. $T_2$ occurs when the spacecraft is 35 degrees elevation from the landmark. The times listed in Table II(c) for the beginning of tracking of the landmarks are the $T_2$ times.

5.3.6 Landmark tracking revolutions (Figures 36, 37, 38, and 39). - Revolutions twenty-four, twenty-five, twenty-six, and twenty-seven are very similar. A series of four landmarks are tracked on each of these

four consecutive revolutions. The landmarks to be tracked on these revolutions are $CP_1$, $CP_2$, F-1, and landmark 130. Of these, it is not mandatory to track F-1, but it is included in the timeline to be tracked if sufficient time is available without endangering the tracking of the other three landmarks.

During each vehicle revolution, the mode III local horizontal attitude is maintained throughout the tracking of the four landmarks. On revolutions 24, 25, and 26, after the completion of landmark tracking on landmark 130, the CSM is maneuvered to an IMU realignment attitude. This attitude satisfies the requirements for the IMU realignment to the landing site REFSMMAT, which occurs immediately after darkness on each of these revolutions. The IMU realignment attitude also sets up the landmark sighting attitude for the next revolution. The IMU realignment attitude is maintained inertially fixed until the CSM becomes pitched 22 degrees below the local horizontal orientation. The inertial attitude hold is then terminated, and a local attitude hold is initiated for the landmark tracking.

In revolution 27, the last of the consecutive landmark tracking revolutions, the CSM is maneuvered to a lunar orbit rest attitude after the completion of landmark tracking on landmark 130. This rest attitude is held inertially fixed through the end of the twenty-seventh revolution. CSM S-band communications are available on each of these revolutions only from the end of landmark tracking on landmark 130 to the loss of MSFN line of sight.

5.3.7 Twenty-eight revolution (Figure 40). - After the completion of the landmark tracking in the twenty-seventh revolution, a 3-1/2 hour rest period is provided for the crew. During this time, no duties are scheduled and the spacecraft is left in an inertial attitude hold. The lunar orbit rest attitude provides CSM S-band HGA communications whenever line of sight to MSFN exists. In addition, the rest attitude allows observation of the lunar surface near the lunar morning terminator, if desired. The lunar orbit rest attitude is maintained inertially fixed throughout the twenty-eighth revolution.

5.3.8 Twenty-ninth revolution (Figure 41). - At the beginning of the twenty-ninth revolution, the CSM is in the inertially fixed lunar orbit rest attitude. Early in the twenty-ninth revolution, the rest period is terminated, and the CSM is maneuvered to the initial attitude for an oblique photography sequence of LS3. The attitude sequence for the oblique photography is the same as that discussed earlier for the oblique photography sequence of LS2 in the twenty-second revolution. At the completion of the oblique photography sequence of LS3, the pitch rate is terminated and the spacecraft is maneuvered to an IMU realignment attitude. This inertially fixed attitude satisfies the requirement for an IMU realignment to the landing site REFSMMAT, which occurs approximately 5 minutes after the CSM enters darkness. This attitude is held inertially fixed until approximately 5 minutes after the loss of MSFN line of sight. The CSM is then maneuvered to the lunar observation attitude for targets of opportunity photography. The CSM attitude, with respect to the local horizontal orientation,

is a pitch of -45 degrees and a roll of 180 degrees. This attitude is maintained locally fixed through the completion of the twenty-ninth revolution. The lunar observation attitude allows photography of the spacecraft groundtrack through the CSM hatch and rendezvous windows and oblique photography through the CSM side windows. CSM S-band HGA communications will be available from the acquisition of MSFN line of sight until loss of MSFN line of sight.

5.3.9 Thirtieth revolution (Figure 42). - At the beginning of the thirtieth revolution, the CSM is in the locally fixed lunar observation attitude. This attitude is maintained locally fixed until approximately 9 minutes after acquisition of MSFN line of sight. The CSM is then maneuvered to the undocked lunar landmark tracking attitude for landmark tracking on B1 and landmark 150. The CSM attitude, with respect to the local horizontal orientation, is a pitch of -22 degrees. This attitude is held locally fixed throughout the two landmark tracking periods. Upon completion of the landmark tracking on landmark 150, the CSM is rolled 180 degrees for communication, and the resulting attitude is held inertially fixed through the completion of the thirtieth revolution. CSM S-band HGA communications will be available from the maneuver after the landmark sighting on landmark 130 to the loss of MSFN line of sight.

5.3.10 Thirty-first revolution (Figure 43). - At the beginning of the thirty-first revolution, the CSM is in an inertially fixed communications attitude. This attitude is maintained until approximately 10 minutes prior to acquisition of MSFN line of sight. The CSM is then maneuvered to the vertical strip photography attitude for descent strip photography. The CSM attitude, with respect to the local horizontal orientation, is a pitch of -102 degrees. This allows the camera optical axis to be pointed vertically down, and the CSM windows to be shaded from the sun during the actual photography. This attitude is held locally fixed during the photography. At 85 degrees east selenographic longitude, the spacecraft is yawed -20 degrees (left) to include a highland site (Censorinus) in the photography. At 30 degrees selenographic longitude, the CSM is yawed 20 degrees (right) to place the camera axis back on the spacecraft groundtrack. The strip photography attitude is maintained locally fixed until after the spacecraft crosses the lunar morning terminator. The CSM is then maneuvered to an attitude that is rolled 180 degrees from the TEI burn attitude. This attitude is held inertially fixed. This attitude satisfies the attitude requirements for the IMU realignment to the landing site REFSMMAT, which occurs approximately 14 minutes after the CSM enters into darkness. After the completion of the IMU realignment, the CSM is rolled 180 degrees into the TEI burn attitude. This attitude is held inertially fixed through the completion of the thirty-first revolution. CSM S-band HGA communications will be available from the completion of the strip photography until the maneuver to the TEI burn attitude.

5.3.11 Start of thirty-second revolution (Figure 44). - Shortly after the CSM enters the thirty-second revolution, the TEI burn occurs. The TEI burn is an SPS burn which boosts the CSM from the approximately 60-nautical mile circular lunar orbit into the transearth trajectory. The burn is performed with the CSM in a posigrade attitude, and the crew is heads down to afford visual reference with the lunar surface. The TEI burn ignition occurs at 137:20:22 g. e. t.

# 6. TRANSEARTH

The transearth phase of the mission begins at TEI burn termination and ends at earth atmospheric entry of the CM. Most of the major events occurring in this phase (midcourse corrections, PTC, IMU realignments, and cislunar navigation) are similar in nature to the translunar coast. Those events unique to the transearth phase, which will be discussed in this section, are the attitude sequences following TEI and prior to entry. The spacecraft attitude data for the transearth coast phase are presented in Table II(d).

## 6.1 Post-TEI Sequence of Events

Following TEI cutoff at 137:23:11 g. e. t. the CSM maneuvers to an inertial attitude that provides the crew with visual observation of the lunar surface. This orientation consists of the CSM plus X-axis pointing radially inward and the plus Z-axis forward in the trajectory plane. MSFN communications through the HGA at acquisition of signal is also provided with this attitude. Earth line of sight is acquired at 137:29:15 g. e. t. An IMU realignment begins at approximately 138:00:00 g. e. t. during which the IMU reference system is realigned to the PTC REFSMMAT defined in Section 4. The completion of the realignment marks the termination of post-TEI activities.

## 6.2 Preentry Sequence of Events

The start of the preentry attitude sequence is assumed at 187:30:00 g. e. t. when the spacecraft IMU is aligned to the entry REFSMMAT. This inertial reference system corresponds to the nominal CM entry attitude of 156 degrees positive pitch from the local horizontal at the nominal time of entry with the body X-Z axes in-plane. A midcourse correction is scheduled at 188:50:00 g. e. t., if required. One hour later, at 189:50:00 g. e. t., the CSM orients to the entry attitude and performs a star check to verify the attitude. An IMU realignment is performed at 190:15:00 g. e. t. Upon completion of the realignment, the spacecraft prepares for the CM/SM separation maneuver which occurs at 191:35:00 g. e. t. The CM/SM separation attitude is shown in Figure 45. The spacecraft is yawed 45 degrees for separation to minimize CM-SM recontact probability during entry. After completing the separation maneuver, the CM reorients to the nominal entry attitude in preparation for entry which occurs at 191:50:32 g. e. t. The CM entry attitude is presented in Figure 46.

Table I. Mission F Event Timeline
(a) Translunar

| Mission Time (hr:min:sec) | Event |
|---|---|
| 02:38:49 | TLI cutoff, inertial attitude hold |
| 02:39:09 | S-IVB maneuver to local horizontal attitude, local attitude hold |
| 02:53:49 | S-IVB maneuver to CSM/S-IVB separation attitude, inertial attitude hold |
| 03:03:49 | CSM/S-IVB separation |
| 03:05:49 | CSM null separation rate, pitch 180 deg for docking |
| 04:08:49 | LM withdrawal |
| 04:28:47 | SPS evasive maneuver burn ignition |
| 04:28:50 | Evasive maneuver burn cutoff |
| 05:00:00 | Begin IMU realignment, change to PTC REFSMMAT |
| 05:30:00 | Begin star-earth horizon navigation sightings |
| 11:33:00 | SPS midcourse burn ignition for G mission groundtrack |
| 11:40:00 | Begin IMU realignment |
| 12:00:00 | Begin PTC |
| 24:40:00 | Terminate PTC, begin IMU realignment |
| 25:00:00 | Begin star-earth horizon navigation sightings |
| 26:30:00 | Midcourse correction |
| 27:00:00 | Maneuver to S-band reflectivity attitude |
| 28:00:00 | Begin PTC |
| 45:00:00 | Terminate PTC, begin IMU realignment |
| 45:30:00 | Begin PTC at 3 revolutions per hour roll rate without pitch-yaw axis control |

Table I. Mission F Event Timeline
(a) Translunar (Continued)

| Mission Time (hr:min:sec) | Event |
|---|---|
| 49:30:00 | Terminate PTC test, resume normal PTC |
| 53:00:00 | Terminate PTC, begin IMU realignment |
| 53:45:00 | Midcourse correction |
| 54:30:00 | Begin PTC |
| 70:00:00 | Terminate PTC, begin IMU realignment, change to landing site REFSMMAT |
| 70:45:00 | Midcourse correction |
| 72:00:00 | Maneuver to lunar TV attitude, inertial attitude hold |
| 72:35:00 | Terminate TV, continue inertial attitude hold |
| 72:47:00 | Enter lunar umbra |
| 74:38:00 | Enter sunlight |
| 74:45:00 | Maneuver to LOI-1 burn attitude, inertial attitude hold |
| 75:38:00 | Lose MSFN line of sight |
| 75:45:43 | LOI-1 burn ignition |

Table I. Mission F Event Timeline
(b) Lunar Orbit

| Mission Time (hr:min:sec) | Event |
|---|---|
| 75:51:45 | LOI-1 cutoff, inertial attitude hold |
| 76:00:00 | Roll 180 deg for communications, inertial attitude hold |
| 76:12:05 | Acquire MSFN line of sight |
| 76:17:00 | Maneuver to lunar observation attitude, local attitude hold |
| 76:55:00 | Terminate orbital rate, inertial attitude hold |
| 76:55:06 | Enter lunar umbra |
| 77:00:00 | Begin IMU realignment |
| 77:20:00 | Maneuver to sleep attitude for communications reacquisition test, inertial attitude hold |
| 77:37:18 | Lose MSFN line of sight |
| 77:41:42 | Enter sunlight |
| 78:20:22 | Acquire MSFN line of sight |
| 78:30:00 | Roll 45 deg to improve lunar observation near morning terminator, inertial attitude hold |
| 79:03:35 | Enter lunar umbra |
| 79:05:00 | Begin IMU realignment |
| 79:20:00 | Maneuver to LOI-2 burn attitude, inertial attitude hold |
| 79:45:20 | Lose MSFN line of sight |
| 79:50:10 | Enter sunlight |
| 80:10:46 | LOI-2 ignition |
| 80:11:00 | LOI-2 cutoff, inertial attitude hold |
| 80:20:00 | Roll 180 deg for communications, inertial attitude hold |
| 80:29:54 | Acquire MSFN line of sight |
| 80:35:00 | Maneuver to lunar observation attitude, local attitude hold |
| 81:00:00 | Terminate local hold, inertial attitude hold |

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

| Mission Time (hr:min:sec) | Event |
|---|---|
| 81:03:30 | Enter lunar umbra |
| 81:10:00 | Begin IMU realignment |
| 81:41:52 | Lose MSFN line of sight |
| 81:45:00 | LM occupied |
| 81:49:52 | Enter sunlight |
| 81:50:00 | Maneuver to landmark tracking attitude for F-1, inertial attitude hold |
| 82:27:45 | Time $T_1$ for F-1 |
| 82:27:56 | Acquire MSFN line of sight |
| 82:32:45 | Time $T_2$ for F-1, start -0.3 deg/sec pitch rate for landmark tracking on F-1 |
| 82:35:45 | Terminate pitch rate, inertial attitude hold |
| 82:38:45 | Maneuver to landmark tracking attitude for B1, inertial attitude hold |
| 82:44:46 | Time $T_1$ for B1 |
| 82:49:46 | Time $T_2$ for B1, start -0.3 deg/sec pitch rate for landmark tracking on B1 |
| 82:52:46 | Terminate pitch rate, inertial attitude hold |
| 82:55:46 | Maneuver to sleep attitude, inertial attitude hold |
| 83:00:00 | Deactivate CSM RCS jets B-3, C-4 prior to LM S-band steerable activation |
| 83:02:00 | Enter lunar umbra |
| 83:05:00 | Start LM communications tests |
| 83:30:00 | Terminate LM communications tests |
| 83:40:09 | Lose MSFN line of sight |
| 83:48:22 | Enter sunlight |
| 83:55:00 | LM unoccupied |

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

| Mission Time (hr:min:sec) | Event |
|---|---|
| 84:26:14 | Acquire MSFN line of sight |
| 84:45:00 | Start crew sleep period |
| 85:00:30 | Enter lunar umbra |
| 85:38:20 | Lose MSFN line of sight |
| 85:46:52 | Enter sunlight |
| 86:24:36 | Acquire MSFN line of sight |
| 86:59:01 | Enter lunar umbra |
| 87:36:32 | Lose MSFN line of sight |
| 87:45:22 | Enter sunlight |
| 88:22:55 | Acquire MSFN line of sight |
| 88:57:30 | Enter lunar umbra |
| 89:34:49 | Lose MSFN line of sight |
| 89:43:51 | Enter sunlight |
| 90:20:36 | Acquire MSFN line of sight |
| 90:56:01 | Enter lunar umbra |
| 91:32:31 | Lose MSFN line of sight |
| 91:42:22 | Enter sunlight |
| 92:18:51 | Acquire MSFN line of sight |
| 92:54:29 | Enter lunar umbra |
| 93:00:00 | Crew wake-up |
| 93:30:46 | Lose MSFN line of sight |
| 93:40:51 | Enter sunlight |
| 94:17:07 | Acquire MSFN line of sight |
| 94:25:00 | LM occupied |
| 94:53:00 | Enter lunar umbra |
| 94:55:00 | Begin IMU realignment |
| 95:25:00 | Maneuver to landmark tracking attitude for 130, inertial attitude hold |

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

| Mission Time (hr:min:sec) | Event |
|---|---|
| 95:29:05 | Lose MSFN line of sight |
| 95:39:21 | Enter sunlight |
| 96:15:28 | Acquire MSFN line of sight |
| 96:35:39 | Time $T_1$ for 130 |
| 96:40:39 | Time $T_2$ for 130, start -0.3 deg/sec pitch rate for landmark tracking on 130 |
| 96:43:39 | Terminate pitch rate, inertial attitude hold |
| 96:46:39 | Maneuver to undocking attitude rolled 180 deg, inertial attitude hold |
| 96:51:30 | Enter lunar umbra |
| 97:27:23 | Lose MSFN line of sight |
| 97:30:00 | Roll 180 deg to undocking attitude, inertial attitude hold |
| 97:37:51 | Enter sunlight |
| 97:45:00 | AGS calibration maneuvers |
| 97:55:00 | LM deploy landing gear |
| 98:10:00 | Undocking, inertial attitude hold |
| 98:12:39 | LM maneuver to inspection attitude, inertial attitude hold except for 360-deg roll (pilot yaw) maneuver |
| 98:13:24 | CSM, LM acquire MSFN line of sight |
| 98:15:39 | LM begin station keeping, inertial attitude hold |
| 98:17:09 | CSM roll 180 deg for S-band high-gain communications, inertial attitude hold |
| 98:35:16 | CSM separation burn ignition, inertial attitude hold |
| 98:35:30 | CSM separation burn cutoff |
| 98:39:00 | CSM maneuver to SXT tracking - VHF ranging attitude; LM maneuver to RR tracking attitude, line-of-sight maintenance |

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

| Mission Time (hr:min:sec) | Event |
|---|---|
| 98:49:58 | CSM enter lunar umbra |
| 98:50:00 | LM enter lunar umbra |
| 98:55:00 | CSM, LM begin IMU realignment, inertial attitude hold |
| 99:25:38 | CSM lose MSFN line of sight |
| 99:25:39 | LM lose MSFN line of sight |
| 99:29:00 | LM maneuver to DOI burn attitude, inertial attitude hold |
| 99:33:59 | LM DOI burn ignition, inertial attitude hold; CSM maneuver to SXT tracking - VHF ranging attitude, line-of-sight maintenance |
| 99:34:27 | DOI burn cutoff, LM maneuver to RR tracking attitude |
| 99:36:18 | CSM enter sunlight |
| 99:36:23 | LM enter sunlight |
| 99:49:27 | LM terminate tracking, maneuver to PDI attitude, inertial attitude hold |
| 100:04:27 | CSM roll 180 deg, maneuver to SXT tracking - VHF ranging attitude |
| 100:11:43 | CSM acquire MSFN line of sight |
| 100:14:17 | LM acquire MSFN line of sight |
| 100:24:37 | LM maneuver to LR test attitude, begin -0.055 deg/sec pitch rate (approximate) |
| 100:31:17 | Pericynthion of LM descent orbit |
| | LM at 0-deg landing site elevation angle |
| 100:41:31 | LM enter lunar umbra |
| 100:46:21 | DPS phasing burn ignition, CSM monitor burn in SXT tracking - VHF ranging attitude |
| 100:47:03 | Phasing burn cutoff, inertial attitude hold |
| 100:48:27 | CSM enter lunar umbra |

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

| Mission Time (hr:min:sec) | Event |
|---|---|
| 100:52:03 | CSM and LM maneuver to SXT tracking and RR tracking attitude, respectively |
| 101:02:03 | CSM and LM terminate tracking, CSM inertial attitude hold, LM maneuver to IMU realignment attitude, inertial attitude hold |
| 101:17:03 | CSM and LM maneuver to SXT tracking and RR tracking attitude, respectively |
| 101:20:47 | LM terminate tracking, inertial attitude hold |
| 101:23:52 | CSM lose MSFN line of sight |
| 101:25:52 | LM lose MSFN line of sight |
| 101:27:03 | CSM terminate tracking, inertial attitude hold |
| 101:28:57 | LM enter sunlight |
| 101:34:49 | CSM enter sunlight |
| 101:48:18 | CSM maneuver to SXT tracking attitude |
| 101:59:18 | LM maneuver to RR tracking attitude |
| 102:08:18 | CSM terminate tracking, maneuver to MI insertion burn attitude, inertial attitude hold |
| 102:09:57 | CSM acquire MSFN line of sight |
| 102:14:19 | LM acquire MSFN line of sight |
| 102:19:18 | LM terminate tracking, maneuver to descent stage jettison attitude, inertial attitude hold |
| 102:33:18 | Begin descent stage jettison |
| 102:36:18 | Complete descent stage jettison, maneuver to insertion burn attitude, inertial attitude hold |
| 102:43:18 | APS insertion burn ignition |
| 102:43:33 | Insertion burn cutoff, inertial attitude hold |
| 102:46:58 | CSM enter lunar umbra |
| 102:47:58 | LM enter lunar umbra |
| 103:01:33 | LM maneuver to RR tracking attitude |
| 103:06:33 | CSM maneuver to SXT tracking - VHF ranging attitude |

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

| Mission Time (hr:min:sec) | Event |
|---|---|
| 103:18:33 | CSM terminate tracking, maneuver to MI CSI burn attitude, inertial attitude hold |
| 103:22:03 | CSM lose MSFN line of sight |
| 103:24:01 | LM lose MSFN line of sight |
| 103:24:33 | LM terminate tracking, maneuver to CSI burn attitude, inertial attitude hold |
| 103:33:17 | CSM enter sunlight |
| 103:33:46 | CSI burn ignition (RCS plus X-axis 4 jets) |
| 103:34:18 | CSI burn cutoff, inertial attitude hold |
| 103:36:52 | LM enter sunlight |
| 103:40:18 | CSM and LM maneuver to SXT tracking - VHF ranging/RR tracking attitude, respectively |
| 104:08:12 | CSM acquire MSFN line of sight |
| 104:11:03 | LM acquire MSFN line of sight |
| 104:20:18 | CSM and LM terminate tracking, CSM maneuver to MI CDH burn attitude, inertial attitude hold; LM maneuver to CDH burn attitude, inertial attitude hold |
| 104:31:42 | CDH burn ignition (RCS minus X-axis 4 jets) |
| 104:31:45 | CDH burn cutoff, inertial attitude hold |
| 104:35:45 | CSM and LM maneuver to SXT tracking - VHF ranging/RR tracking attitude, respectively |
| 104:45:29 | CSM enter lunar umbra |
| 104:45:44 | LM enter lunar umbra |
| 104:52:34 | CSM and LM terminate tracking, CSM maneuver to MI TPI burn attitude, inertial attitude hold; LM maneuver to TPI burn attitude, inertial attitude hold |

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

| Mission Time (hr:min:sec) | Event |
|---|---|
| 105:08:57 | TPI burn ignition (RCS plus X-axis 4 jets) |
| 105:09:13 | TPI burn cutoff, CSM and LM maneuver to SXT tracking - VHF ranging/RR tracking attitude, respectively |
| 105:19:32 | LM lose MSFN line of sight |
| 105:20:07 | CSM lose MSFN line of sight |
| 105:31:49 | CSM enter sunlight |
| 105:32:13 | LM enter sunlight |
| 105:50:14 | LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 3000 ft |
| 105:50:30 | Braking burn cutoff, CSM and LM continue tracking |
| 105:51:27 | LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 1500 ft |
| 105:51:39 | Braking burn cutoff, CSM and LM continue tracking |
| 105:53:04 | LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 500 ft |
| 105:53:10 | Braking burn cutoff, CSM and LM continue tracking |
| 105:54:24 | LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 100 ft |
| 105:54:30 | Braking burn cutoff, CSM-LM range = 85 ft, CSM-LM range rate = -0.22 ft/sec |
| 105:57:10 | CSM and LM maneuver to docking attitude, CSM-LM range = 50 ft |
| 106:06:33 | CSM and LM acquire MSFN line of sight |
| 106:20:00 | CSM/LM docking, inertial attitude hold |
| 106:43:56 | Enter lunar umbra |
| 106:50:45 | Maneuver to LM jettison attitude, inertial attitude hold |
| 107:18:17 | Lose MSFN line of sight |

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

| Mission Time (hr:min:sec) | Event |
|---|---|
| 107:30:17 | Enter sunlight |
| 108:04:34 | Acquire MSFN line of sight |
| 108:09:24 | Complete LM jettison, LM inertial hold in APS burn attitude; CSM evasive maneuver ignition |
| 108:09:29 | CSM evasive maneuver cutoff, CSM maneuver to LM observation attitude, inertial attitude hold |
| 108:38:57 | LM unmanned APS burn to depletion ignition |
| 108:42:30 | Enter lunar umbra |
| 109:00:00 | Maneuver to sleep attitude, inertial attitude hold, start crew sleep period |
| 109:16:43 | Lose MSFN line of sight |
| 109:28:50 | Enter sunlight |
| 110:02:53 | Acquire MSFN line of sight |
| 110:40:59 | Enter lunar umbra |
| 111:14:55 | Lose MSFN line of sight |
| 111:27:19 | Enter sunlight |
| 112:01:11 | Acquire MSFN line of sight |
| 112:39:30 | Enter lunar umbra |
| 113:13:10 | Lose MSFN line of sight |
| 113:25:50 | Enter sunlight |
| 113:59:30 | Acquire MSFN line of sight |
| 114:37:59 | Enter lunar umbra |
| 115:11:26 | Lose MSFN line of sight |
| 115:24:20 | Enter sunlight |
| 115:57:11 | Acquire MSFN line of sight |
| 116:36:29 | Enter lunar umbra |

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

| Mission Time (hr:min:sec) | Event |
|---|---|
| 117:09:02 | Lose MSFN line of sight |
| 117:22:50 | Enter sunlight |
| 117:55:25 | Acquire MSFN line of sight |
| 118:00:00 | Crew wake-up, maneuver to initial attitude for oblique photography of LS2, local attitude hold |
| 118:19:29 | Start 0.5 deg/sec pitch rate for photography of LS2 |
| 118:22:04 | Terminate pitch rate, inertial attitude hold |
| 118:34:59 | Enter lunar umbra |
| 118:55:00 | Begin IMU realignment |
| 119:07:21 | Lose MSFN line of sight |
| 119:10:00 | Maneuver to strip photography attitude, local attitude hold |
| 119:21:19 | Enter sunlight |
| 119:53:43 | Acquire MSFN line of sight |
| 119:55:00 | Maneuver at subsolar point to turn windows away from sun, continue strip photography, local attitude hold |
| 120:06:00 | Yaw 20 deg to include LS1, local attitude hold |
| 120:17:00 | Yaw -20 deg, adjust attitude, continue strip photography, local attitude hold |
| 120:27:00 | Terminate strip photography, maneuver to IMU realignment attitude, inertial attitude hold |
| 120:33:29 | Enter lunar umbra |
| 120:35:00 | Begin IMU realignment |
| 121:05:40 | Lose MSFN line of sight |
| 121:14:00 | Maneuver to landmark sighting attitude, local attitude hold |

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

| Mission Time (hr:min:sec) | Event |
|---|---|
| 121:19:49 | Enter sunlight |
| 121:26:06 | Time $T_1$ for $CP_1$ |
| 121:28:51 | Time $T_2$ for $CP_1$ |
| 121:41:09 | Time $T_1$ for $CP_2$ |
| 121:42:50 | Time $T_2$ for $CP_2$ |
| 121:52:03 | Acquire MSFN line of sight |
| 121:53:49 | Time $T_1$ for F-1 |
| 121:56:06 | Time $T_2$ for F-1 |
| 122:15:14 | Time $T_1$ for 130 |
| 122:16:51 | Time $T_2$ for 130 |
| 122:19:51 | Maneuver to IMU realignment attitude, inertial attitude hold |
| 122:31:59 | Enter lunar umbra |
| 122:35:00 | Begin IMU realignment |
| 123:03:56 | Lose MSFN line of sight |
| 123:13:22 | Start local attitude hold for landmark tracking |
| 123:18:19 | Enter sunlight |
| 123:24:15 | Time $T_1$ for $CP_1$ |
| 123:27:00 | Time $T_2$ for $CP_1$ |
| 123:39:19 | Time $T_1$ for $CP_2$ |
| 123:41:00 | Time $T_2$ for $CP_2$ |
| 123:49:57 | Acquire MSFN line of sight |
| 123:52:00 | Time $T_1$ for F-1 |
| 123:54:17 | Time $T_2$ for F-1 |
| 124:13:24 | Time $T_1$ for 130 |
| 124:15:02 | Time $T_2$ for 130 |
| 124:18:02 | Maneuver to IMU realignment attitude, inertial attitude hold |

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

| Mission Time (hr:min:sec) | Event |
|---|---|
| 124:30:28 | Enter lunar umbra |
| 124:33:00 | Begin IMU realignment |
| 125:02:12 | Lose MSFN line of sight |
| 125:11:33 | Start local attitude hold for landmark tracking |
| 125:16:49 | Enter sunlight |
| 125:22:25 | Time $T_1$ for $CP_1$ |
| 125:25:10 | Time $T_2$ for $CP_1$ |
| 125:37:29 | Time $T_1$ for $CP_2$ |
| 125:39:10 | Time $T_2$ for $CP_2$ |
| 125:48:14 | Acquire MSFN line of sight |
| 125:50:10 | Time $T_1$ for F-1 |
| 125:52:27 | Time $T_2$ for F-1 |
| 126:11:34 | Time $T_1$ for 130 |
| 126:13:12 | Time $T_2$ for 130 |
| 126:16:12 | Maneuver to IMU realignment attitude, inertial attitude hold |
| 126:28:59 | Enter lunar umbra |
| 126:30:00 | Begin IMU realignment |
| 127:00:27 | Lose MSFN line of sight |
| 127:09:43 | Start local attitude hold for landmark tracking |
| 127:15:19 | Enter sunlight |
| 127:20:35 | Time $T_1$ for $CP_1$ |
| 127:23:21 | Time $T_2$ for $CP_1$ |
| 127:35:39 | Time $T_1$ for $CP_2$ |
| 127:37:20 | Time $T_2$ for $CP_2$ |
| 127:46:32 | Acquire MSFN line of sight |
| 127:48:20 | Time $T_1$ for F-1 |

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

| Mission Time (hr:min:sec) | Event |
|---|---|
| 127:50:37 | Time $T_2$ for F-1 |
| 128:09:44 | Time $T_1$ for 130 |
| 128:11:22 | Time $T_2$ for 130 |
| 128:14:20 | Maneuver to rest attitude, inertial attitude hold |
| 128:27:28 | Enter lunar umbra |
| 128:58:27 | Lose MSFN line of sight |
| 129:13:49 | Enter sunlight |
| 129:44:51 | Acquire MSFN line of sight |
| 130:25:58 | Enter lunar umbra |
| 130:56:44 | Lose MSFN line of sight |
| 131:12:18 | Enter sunlight |
| 131:42:54 | Acquire MSFN line of sight |
| 131:55:00 | End crew rest period, maneuver to initial attitude for oblique photography of LS3, local attitude hold |
| 132:14:53 | Start 0.5 deg/sec pitch rate for photography of LS3 |
| 132:17:28 | Terminate pitch rate, inertial attitude hold |
| 132:20:28 | Maneuver to IMU realignment attitude, inertial atttiude hold |
| 132:24:28 | Enter lunar umbra |
| 132:30:00 | Begin IMU realignment |
| 132:55:01 | Lose MSFN line of sight |
| 133:00:00 | Maneuver to attitude for photo targets of opportunity, local attitude hold |
| 133:10:49 | Enter sunlight |
| 133:41:11 | Acquire MSFN line of sight |
| 133:50:00 | Maneuver to landmark sighting attitude, local attitude hold |

Table I. Mission F Event Timeline
(b) Lunar Orbit (Continued)

| Mission Time (hr:min:sec) | Event |
|---|---|
| 134:00:27 | Time $T_1$ for B1 |
| 134:02:15 | Time $T_2$ for B1 |
| 134:12:38 | Time $T_1$ for 150 |
| 134:14:08 | Time $T_2$ for 150 |
| 134:17:08 | Roll 180 deg for communications, inertial attitude hold |
| 134:22:57 | Enter lunar umbra |
| 134:53:13 | Lose MSFN line of sight |
| 135:09:18 | Enter sunlight |
| 135:30:00 | Maneuver to strip photography attitude, local attitude hold |
| 135:39:29 | Acquisition of MSFN line of sight |
| 135:45:23 | Yaw -20 deg to include highland site, local attitude hold |
| 136:03:30 | Yaw 20 deg, adjust attitude, continue strip photography, local attitude hold |
| 136:20:00 | Maneuver to TEI attitude, rolled 180 deg, inertial attitude hold |
| 136:21:28 | Enter lunar umbra |
| 136:35:00 | Begin IMU realignment |
| 136:45:00 | Roll 180 deg to TEI burn attitude, inertial attitude hold |
| 136:51:28 | Lose MSFN line of sight |
| 137:07:48 | Enter sunlight |
| 137:20:22 | TEI burn ignition |

Table I. Mission F Event Timeline
(c) Transearth

| Mission Time (hr:min:sec) | Event |
|---|---|
| 137:23:11 | TEI cutoff, maneuver to lunar surface observation attitude (CSM plus X-axis down and plus Z-axis forward), inertial attitude hold |
| 137:29:15 | Acquire MSFN |
| 138:00:00 | Begin IMU realignment, change to PTC REFSMMAT |
| 138:30:00 | Begin PTC |
| 150:30:00 | Terminate PTC, begin IMU realignment |
| 151:00:00 | Begin star-lunar landmark navigation sightings |
| 152:20:00 | Midcourse correction |
| 152:45:00 | Begin PTC |
| 165:00:00 | Terminate PTC, begin IMU realignment |
| 165:20:00 | Begin star-earth horizon navigation sightings |
| 165:45:00 | Begin PTC at 3 revolutions per hour roll rate without pitch-yaw axis control |
| 169:45:00 | Terminate PTC test, resume normal PTC |
| 171:00:00 | Terminate PTC, begin star-earth horizon navigation sightings |
| 171:30:00 | Begin PTC |
| 174:30:00 | Terminate PTC, begin star-earth horizon navigation sightings |
| 175:30:00 | Begin IMU realignment |
| 176:50:00 | Midcourse correction |
| 177:15:00 | Begin PTC |
| 187:30:00 | Terminate PTC, begin IMU realignment, change to entry REFSMMAT |
| 188:50:00 | Midcourse correction |
| 189:50:00 | Maneuver to entry attitude, inertial attitude hold |
| 190:15:00 | Begin IMU realignment |
| 191:35:00 | CM/SM separation |
| 191:50:32 | Entry interface |

## Table II. Mission F Spacecraft Attitude Data
### (a) Earth Orbit

| Mission Time (hr:min:sec) | Event | Geographic Position | | | Local Horizontal Attitude | | | IMU Gimbal Angles | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Altitude* (n mi) | Latitude* (deg) | Longitude* (deg) | Pitch (deg) | Yaw (deg) | Roll (deg) | IGA (deg) | MGA (deg) | OGA (deg) |
| 00:11:24 | Earth orbit insertion, begin inertial attitude hold | 103.4 | 32.8 | -54.2 | 0.0 | 0.0 | 180.0 | -25.4 | 0.6 | -179.4 |
| 00:11:44 | Begin local attitude hold | 103.4 | 32.8 | -54.7 | 0.0 | 0.0 | 180.0 | -25.9 | 0.6 | -179.4 |
| 02:33:27 | Initiate TLI burn | 99.2 | -25.4 | 136.0 | 0.0 | 0.0 | 180.0 | 114.1 | -0.3 | 178.9 |

*Altitude is measured with respect to the Fischer reference ellipsoid; latitude and longitude are measured positive north of the equator and east from the Greenwich meridian, respectively.

## Table II. Spacecraft Attitude and Trajectory Data
## (b) Translunar

| Mission Time (hr:min:sec) | Event | IMU Gimbal Angles | | | Look Angles to Earth | | Look Angles to Moon | | Look Angles to Sun | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | IGA (deg) | MGA (deg) | OGA (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) |
| 02:38:49 | TLI cutoff (inertial attitude hold not simulated) | 88.0 | 1.5 | 179.0 | 90.0 | 180.0 | 30.7 | -6.2 | 9.4 | -75.3 |
| 02:39:09 | S-IVB maneuver to local horizontal, local attitude hold | 87.0 | 1.5 | 179.0 | 90.0 | 180.0 | 30.7 | -6.2 | 9.4 | -75.3 |
| 02:53:49 | S-IVB maneuver to CSM/S-IVB separation attitude, inertial attitude hold | 150.7 | 39.8 | -2.3 | 131.6 | 48.1 | 89.7 | 176.4 | 64.0 | -169.6 |
| 03:03:49 | CSM/S-IVB separation | 150.7 | 39.8 | -2.3 | 120.6 | 29.8 | 89.7 | 176.0 | 64.0 | -169.6 |
| 03:05:49 | CSM null separation rate, pitch 180 deg and roll 60 deg left for docking | -29.3 | -39.8 | -57.6 | 60.5 | -149.8 | 90.2 | 64.0 | 115.9 | 50.4 |
| 04:08:49 | LM withdrawal | -29.3 | -39.8 | -57.6 | 86.8 | 27.7 | 90.5 | 64.0 | 115.9 | 50.3 |
| 04:28:47 | SPS evasive maneuver burn ignition | -108.7 | -1.6 | 60.7 | 15.0 | 120.0 | 161.1 | -49.4 | 166.6 | 77.1 |
| 04:28:50 | Evasive maneuver burn cutoff | -108.7 | -1.6 | 60.7 | 15.0 | 120.0 | 161.1 | -49.4 | 166.6 | 77.1 |
| 05:00:00 | Begin IMU realignment, change to PTC REFSMMAT | Maneuver spacecraft as required | | | | | | | | |
| 05:30:00 | Begin star-earth horizon navigation sightings | Maneuver spacecraft as required | | | | | | | | |
| 11:33:00 | SPS midcourse burn for G mission groundtrack | Maneuver spacecraft as required | | | | | | | | |
| 11:40:00 | Begin IMU realignment | Maneuver spacecraft as required | | | | | | | | |
| 12:00:00 | Begin PTC | -90.0 | 0.0 | 0.0 | 83.5 | -44.5 | 94.5 | 156.2 | 90.0 | 180.0 |
| 24:40:00 | Terminate PTC, begin IMU realignment | Maneuver spacecraft as required | | | | | | | | |
| 25:00:00 | Begin star-earth horizon navigation sightings | Maneuver spacecraft as required | | | | | | | | |

## Table II. Spacecraft Attitude and Trajectory Data
## (b) Translunar (Continued)

| Mission Time (hr:min:sec) | Event | IMU Gimbal Angles | | | Look Angles to Earth | | Look Angles to Moon | | Look Angles to Sun | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | IGA (deg) | MGA (deg) | OGA (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) |
| 26:30:00 | Midcourse correction | Maneuver spacecraft as required | | | | | | | | |
| 27:00:00 | Maneuver to S-band reflectivity test attitude | -36.2 | -41.5 | 71.5 | 22.3 | -117.3 | 145.0 | 138.5 | 126.0 | 151.5 |
| 28:00:00 | Begin PTC | -90.0 | 0.0 | 0.0 | 84.8 | -55.2 | 94.3 | 160.9 | 90.0 | -178.6 |
| 45:00:00 | Terminate PTC, begin IMU realignment | Maneuver spacecraft as required | | | | | | | | |
| 45:30:00 | Begin PTC at 3 revolutions per hour roll rate without pitch-yaw axis control | -90.0 | 0.0 | 0.0 | 85.3 | -59.0 | 94.3 | 164.0 | 90.0 | -179.2 |
| 49:30:00 | Terminate PTC tests, resume normal PTC | -90.0 | 0.0 | -90.0 | 85.5 | 30.2 | 94.3 | -105.1 | 90.0 | -89.5 |
| 53:00:00 | Terminate PTC, begin IMU realignment | Maneuver spacecraft as required | | | | | | | | |
| 53:45:00 | Midcourse correction | Maneuver spacecraft as required | | | | | | | | |
| 54:30:00 | Begin PTC | -90.0 | 0.0 | 90.0 | 85.5 | -150.2 | 94.3 | 75.4 | 90.0 | 90.4 |
| 70:00:00 | Terminate PTC, begin IMU realignment, change to landing site REFSMMAT | Maneuver spacecraft as required | | | | | | | | |
| 70:45:00 | Midcourse correction | Maneuver spacecraft as required | | | | | | | | |
| 72:00:00 | Maneuver to lunar TV attitude, inertial attitude hold | 128.2 | 2.1 | 173.7 | 167.9 | 24.1 | 45.0 | 0.0 | 49.8 | 7.0 |
| 72:35:00 | Terminate TV, continue inertial attitude hold | 128.2 | 2.1 | 173.7 | 167.9 | 24.1 | 46.3 | 0.0 | 49.8 | 7.0 |
| 72:47:00 | Enter lunar umbra | 128.2 | 2.1 | 173.7 | 167.9 | 24.1 | 47.2 | 0.0 | No line of sight | |
| 74:38:00 | Enter sunlight | 128.2 | 2.1 | 173.7 | 168.0 | 24.1 | 62.0 | 0.0 | 49.7 | 7.0 |
| 74:45:00 | Maneuver to LOI-1 burn attitude, inertial attitude hold | -128.5 | -19.9 | -4.1 | 86.4 | -0.7 | 161.8 | -130.3 | 147.4 | -143.3 |
| 75:38:00 | Lose MSFN line of sight | -128.5 | -19.9 | -4.1 | No line of sight | | 129.0 | -1.5 | 147.3 | -143.3 |
| 75:45:43 | LOI-1 burn ignition | -128.5 | -19.9 | -4.1 | No line of sight | | 107.0 | -0.7 | 147.3 | -143.3 |

# Table II. Spacecraft Attitude and Trajectory Data
## (c) Lunar Orbit
## Part 1: LOI-1 Cutoff to CSM/LM Undocking

| Mission Time (hr:min:sec) | Event | Selenographic Position | | | Local Horizontal Attitude | | | IMU Gimbal Angles | | | Look Angles to Earth | | Look Angles to Sun | | Optics Angles to Landmark | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Altitude (n mi) | Latitude (deg) | Longitude (deg) | Pitch (deg) | Yaw (deg) | Roll (deg) | IGA (deg) | MGA (deg) | OGA (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) | Shaft (deg) | Trunnion (deg) |
| 75:51:45 | LOI-1 cutoff, inertial attitude hold | 58.2 | 0.2 | 172.6 | -173.4 | -20.1 | -3.6 | -128.1 | -20.1 | -3.6 | No line of sight | | 147.3 | -142.3 | | |
| 76:00:00 | Roll 180 deg for communications, inertial attitude hold | 60.7 | 0.7 | 146.9 | -147.7 | -20.1 | 176.4 | -128.1 | -20.1 | 176.4 | No line of sight | | 147.3 | 37.7 | | |
| 76:12:05 | Acquire MSFN line of sight | 80.4 | 1.2 | 109.9 | -111.1 | -20.1 | 176.4 | -128.1 | -20.1 | 176.4 | 85.6 | 179.4 | 147.3 | 37.7 | | |
| 76:17:00 | Maneuver to lunar observation attitude, local attitude hold | 92.2 | 1.2 | 95.4 | -45.0 | 0.0 | 180.0 | -76.7 | 0.0 | 180.0 | 36.2 | 170.7 | 155.2 | -179.4 | | |
| 76:55:00 | Terminate orbital rate, inertial attitude hold | 167.6 | -0.1 | -6.6 | -45.0 | 0.0 | 180.0 | -178.4 | 0.0 | 180.0 | 137.9 | 171.8 | 103.1 | -0.3 | | |
| 76:55:06 | Enter lunar umbra | 167.6 | -0.1 | -6.9 | -44.7 | 0.0 | 180.0 | -178.4 | 0.0 | 180.0 | 137.9 | 171.8 | No line of sight | | | |
| 77:00:00 | Begin IMU realignment | 167.9 | -0.4 | -19.3 | -33.3 | 0.0 | 180.0 | -178.4 | 0.0 | 180.0 | 137.9 | 171.8 | No line of sight | | | |
| 77:20:00 | Maneuver to sleep attitude for communications reacquisition test, inertial attitude hold | 141.4 | -1.2 | -70.9 | 45.5 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 112.1 | -140.9 | No line of sight | | | |
| 77:37:18 | Lose MSFN line of sight | 96.8 | -1.1 | -119.0 | 93.2 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | No line of sight | | No line of sight | | | |
| 77:41:42 | Enter sunlight | 85.7 | -0.9 | -131.8 | 106.0 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | No line of sight | | 129.4 | 44.7 | | |
| 78:20:22 | Acquire MSFN line of sight | 79.9 | 1.2 | 109.4 | -135.5 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 112.1 | -140.8 | 129.4 | 44.7 | | |
| 78:30:00 | Roll 45 deg to improve lunar observation near morning terminator, inertial attitude hold | 103.9 | 1.2 | 81.3 | -107.4 | 0.0 | 180.0 | -152.0 | 0.0 | 180.0 | 112.1 | 174.2 | 129.4 | -0.3 | | |
| 79:03:35 | Enter lunar umbra | 167.6 | -0.1 | -8.0 | -18.4 | 0.0 | 180.0 | -152.0 | 0.0 | 180.0 | 112.7 | 174.1 | No line of sight | | | |
| 79:05:00 | Begin IMU realignment | 167.9 | -0.3 | -11.4 | -14.8 | 0.0 | 180.0 | -152.0 | 0.0 | 180.0 | 112.8 | 174.1 | No line of sight | | | |
| 79:20:00 | Maneuver to LOI-2 burn attitude, inertial attitude hold | 157.7 | -0.9 | -49.8 | 36.7 | -2.4 | 0.1 | -138.5 | -2.4 | 0.1 | 99.4 | -6.0 | No line of sight | | | |
| 79:45:20 | Lose MSFN line of sight | 98.2 | -1.1 | -118.7 | 104.5 | -2.4 | 0.1 | -138.5 | -2.4 | 0.1 | No line of sight | | No line of sight | | | |
| 79:50:10 | Enter sunlight | 86.3 | -0.9 | -132.9 | 119.4 | -2.4 | 0.1 | -138.5 | -2.4 | 0.1 | No line of sight | | 142.7 | -177.4 | | |
| 80:10:46 | LOI-2 ignition | 57.9 | 0.3 | 164.0 | -177.6 | -2.4 | 0.1 | -138.5 | -2.4 | 0.1 | No line of sight | | 142.7 | -177.4 | | |
| 80:11:00 | LOI-2 cutoff, inertial attitude hold | 57.9 | 0.3 | 163.3 | -176.9 | -2.4 | 0.1 | -138.5 | -2.4 | 0.1 | No line of sight | | 142.7 | -177.4 | | |
| 80:20:00 | Roll 180 deg for communications, inertial attitude hold | 57.9 | 0.8 | 135.9 | -149.5 | -2.4 | -179.9 | -138.5 | -2.4 | -179.9 | No line of sight | | 142.7 | 2.6 | | |
| 80:29:54 | Acquire MSFN line of sight | 57.9 | 1.2 | 105.7 | -119.5 | -2.4 | -179.9 | -138.5 | -2.4 | -179.9 | 99.5 | 174.0 | 142.7 | 2.6 | | |
| 80:35:00 | Maneuver to lunar observation attitude, local attitude hold | 57.9 | 1.2 | 90.2 | -45.0 | 0.0 | 180.0 | -79.5 | 0.0 | 180.0 | 41.1 | 171.8 | 158.2 | -179.3 | | |
| 81:00:00 | Terminate local hold, inertial attitude hold | 57.8 | 0.4 | 14.0 | -45.0 | 0.0 | 180.0 | -155.4 | 0.0 | 180.0 | 117.0 | 174.0 | 125.8 | -0.3 | | |
| 81:03:30 | Enter lunar umbra | 57.8 | 0.1 | 3.4 | -34.4 | 0.0 | 180.0 | -155.4 | 0.0 | 180.0 | 117.2 | 174.0 | No line of sight | | | |
| 81:10:00 | Begin IMU realignment | 57.8 | -0.1 | -7.2 | -14.1 | 0.0 | 180.0 | -155.4 | 0.0 | 180.0 | 117.3 | 174.0 | No line of sight | | | |
| 81:41:52 | Lose MSFN line of sight | 57.8 | -1.2 | -113.5 | 82.5 | 0.0 | 180.0 | -155.4 | 0.0 | 180.0 | No line of sight | | No line of sight | | | |
| 81:45:00 | LM occupied | 57.8 | -1.1 | -123.1 | 91.7 | 0.0 | 180.0 | -155.4 | 0.0 | 180.0 | No line of sight | | No line of sight | | | |
| 81:49:52 | Enter sunlight | 57.8 | -0.9 | -137.9 | 106.9 | 0.0 | 180.0 | -155.4 | 0.0 | 180.0 | No line of sight | | 125.8 | -0.3 | | |
| 81:50:00 | Maneuver to landmark tracking attitude for F-1, inertial attitude hold | 57.8 | -0.9 | -138.3 | -131.9 | 0.0 | 0.0 | -34.2 | 0.0 | 0.0 | No line of sight | | 113.0 | 0.3 | | |
| 82:27:56 | Acquire MSFN line of sight | 57.9 | 1.2 | 106.1 | -16.6 | 0.0 | 0.0 | -34.2 | 0.0 | 0.0 | 6.4 | -123.2 | 113.0 | 0.3 | | |

# Table II. Spacecraft Attitude and Trajectory Data
## (c) Lunar Orbit (Continued)
## Part 1: LOI-1 Cutoff to CSM/LM Undocking

| Mission Time (hr:min:sec) | Event | Selenographic Position | | | Local Horizontal Attitude | | | IMU Gimbal Angles | | | Look Angles to Earth | | Look Angles to Sun | | Optics Angles to Landmark | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Altitude (n mi) | Latitude (deg) | Longitude (deg) | Pitch (deg) | Yaw (deg) | Roll (deg) | IGA (deg) | MGA (deg) | OGA (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) | Shaft (deg) | Trunnion (deg) |
| 82:32:45 | Start -0.3 deg/sec pitch rate for landmark tracking on F-1 | 57.9 | 1.2 | 91.5 | -2.1 | 0.0 | 0.0 | -34.2 | 0.0 | 0.0 | 6.3 | -123.0 | 113.0 | 0.3 | 10.1 | 20.3 |
| 82:35:45 | Terminate pitch rate, inertial attitude hold | 57.9 | 1.2 | 82.3 | -47.0 | 0.0 | 0.0 | -88.3 | 0.0 | 0.0 | 50.8 | -6.9 | 167.1 | 1.2 | 174.2 | 36.9 |
| 82:38:45 | Maneuver to landmark tracking attitude for B1, inertial attitude hold | 57.9 | 1.2 | 73.2 | -35.5 | 0.0 | 0.0 | -85.9 | 0.0 | 0.0 | 48.5 | -7.1 | 164.7 | 1.0 | | |
| 82:49:46 | Start -0.3 deg/sec pitch rate for landmark tracking on B1 | 57.8 | 0.8 | 39.6 | -2.1 | 0.0 | 0.0 | -85.9 | 0.0 | 0.0 | 48.6 | -7.1 | 164.7 | 1.0 | 42.1 | 24.9 |
| 82:52:46 | Terminate pitch rate, inertial attitude hold | 57.8 | 0.7 | 30.5 | -47.0 | 0.0 | 0.0 | -139.9 | 0.0 | 0.0 | 102.5 | -5.5 | 141.3 | 179.6 | 153.5 | 39.2 |
| 82:55:46 | Maneuver to sleep attitude, inertial attitude hold | 57.8 | 0.5 | 21.3 | -49.9 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 114.5 | -140.9 | 129.2 | 44.7 | | |
| 83:02:00 | Enter lunar umbra | 57.8 | 0.1 | 2.3 | -29.5 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 114.6 | -140.9 | No line of sight | | | |
| 83:05:00 | Start LM communications tests | 57.8 | 0.1 | -6.8 | -21.8 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 114.7 | -140.9 | No line of sight | | | |
| 83:30:00 | Terminate LM communications tests | 57.7 | -1.2 | -83.0 | 54.1 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 115.2 | -140.9 | No line of sight | | | |
| 83:40:09 | Lose MSFN line of sight | 57.8 | -1.2 | -113.9 | 94.4 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | No line of sight | | No line of sight | | | |
| 83:48:22 | Enter sunlight | 57.8 | -0.9 | -138.9 | 109.7 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | No line of sight | | 129.2 | 44.7 | | |
| 83:55:00 | LM unoccupied | 57.8 | -0.5 | -159.1 | 130.0 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | No line of sight | | 129.2 | 44.7 | | |
| 84:26:14 | Acquire MSFN line of sight | 57.9 | 1.2 | 105.7 | -135.1 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 115.1 | -140.8 | 129.2 | 44.7 | | |
| 84:45:00 | Start crew sleep period | 57.8 | 1.0 | 48.6 | -78.1 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 115.3 | -140.8 | 129.2 | 44.7 | | |
| 85:00:30 | Enter lunar umbra | 57.8 | 0.1 | 1.3 | -31.1 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 115.6 | -140.9 | No line of sight | | | |
| 85:38:20 | Lose MSFN line of sight | 57.8 | -1.2 | -114.0 | 83.0 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | No line of sight | | No line of sight | | | |
| 85:46:52 | Enter sunlight | 57.8 | -0.9 | -139.9 | 109.8 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | No line of sight | | 129.1 | 44.7 | | |
| 86:24:36 | Acquire MSFN line of sight | 57.9 | 1.2 | 105.1 | -135.6 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 116.1 | -140.8 | 129.1 | 44.7 | | |
| 86:59:01 | Enter lunar umbra | 57.8 | 0.1 | 0.3 | -31.1 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 116.6 | -140.9 | No line of sight | | | |
| 87:36:32 | Lose MSFN line of sight | 57.7 | -1.2 | -114.1 | 82.9 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | No line of sight | | No line of sight | | | |
| 87:45:22 | Enter sunlight | 57.8 | -0.9 | -141.0 | 109.7 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | No line of sight | | 129.0 | 44.7 | | |
| 88:22:55 | Acquire MSFN line of sight | 57.9 | 1.2 | 104.7 | -136.2 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 117.1 | -140.8 | 129.0 | 44.7 | | |
| 88:57:30 | Enter lunar umbra | 57.8 | 0.1 | -0.7 | -31.2 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 117.6 | -140.8 | No line of sight | | | |
| 89:34:49 | Lose MSFN line of sight | 57.7 | -1.2 | -114.4 | 81.9 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | No line of sight | | No line of sight | | | |
| 89:43:51 | Enter sunlight | 57.8 | -0.9 | -141.9 | 109.8 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | No line of sight | | 129.0 | 44.6 | | |
| 90:20:36 | Acquire MSFN line of sight | 57.9 | 1.1 | 106.1 | -138.7 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 118.0 | -140.8 | 128.9 | 44.6 | | |
| 90:56:01 | Enter lunar umbra | 57.8 | 0.1 | -1.7 | -31.2 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 118.6 | -140.8 | No line of sight | | | |
| 91:33:31 | Lose MSFN line of sight | 57.7 | -1.2 | -112.9 | 79.6 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | No line of sight | | No line of sight | | | |
| 91:42:22 | Enter sunlight | 57.8 | -0.9 | -143.0 | 109.5 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | No line of sight | | 128.9 | 44.6 | | |
| 92:18:51 | Acquire MSFN line of sight | 57.9 | 1.1 | 105.9 | -134.6 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 119.0 | -140.8 | 128.8 | 44.6 | | |
| 92:54:20 | Enter lunar umbra | 57.8 | 0.1 | -2.7 | -33.3 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 119.6 | -140.8 | No line of sight | | | |
| 93:00:06 | Crew wake-up | 57.8 | -0.2 | -19.5 | -14.6 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 119.7 | -140.8 | No line of sight | | | |
| 93:30:46 | Lose MSFN line of sight | 57.7 | -1.2 | -113.2 | 78.7 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | No line of sight | | No line of sight | | | |
| 93:40:51 | Enter Sunlight | 57.8 | -0.9 | -143.9 | 109.7 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | No line of sight | | 128.9 | 44.6 | | |
| 94:17:07 | Acquire MSFN line of sight | 57.9 | 1.1 | 105.6 | -141.0 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 120.0 | -140.8 | 128.8 | 44.6 | | |
| [illegible] | LM occupied | 57.9 | 1.2 | 81.5 | -116.5 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 120.0 | -140.8 | 128.8 | 44.6 | | |

# Table II. Spacecraft Attitude and Trajectory Data
## (c) Lunar Orbit (Continued)
## Part 1: LOI-1 Cutoff to CSM/LM Undocking

| Mission Time (hr:min:sec) | Event | Selenographic Position | | | Local Horizontal Attitude | | | IMU Gimbal Angles | | | Look Angles to Earth | | Look Angles to Sun | | Optics Angles to Landmark | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Altitude (n mi) | Latitude (deg) | Longitude (deg) | Pitch (deg) | Yaw (deg) | Roll (deg) | IGA (deg) | MGA (deg) | OGA (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) | Shaft (deg) | Trunnion (deg) |
| 94:53:00 | Enter lunar umbra | 57.8 | 0.1 | -3.8 | -31.4 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 120.6 | -140.8 | No line of sight | | | |
| 94:55:00 | Begin IMU realignment | 57.9 | 0.1 | -9.8 | -25.4 | 0.0 | 135.0 | -152.0 | 0.0 | 135.0 | 120.6 | -140.8 | No line of sight | | | |
| 95:25:00 | Maneuver to landmark tracking attitude for 130, inertial attitude hold | 57.7 | -1.2 | -101.2 | 128.1 | 0.0 | 0.0 | -89.7 | 0.0 | 0.0 | 59.0 | -5.8 | No line of sight | | | |
| 95:29:05 | Lose MSFN line of sight | 57.7 | -1.2 | -113.7 | 140.5 | 0.0 | 0.0 | -89.7 | 0.0 | 0.0 | No line of sight | | No line of sight | | | |
| 95:39:21 | Enter sunlight | 57.8 | -0.9 | -145.0 | 171.7 | 0.0 | 0.0 | -89.7 | 0.0 | 0.0 | No line of sight | | 169.0 | 140.1 | | |
| 96:15:28 | Acquire MSFN line of sight | 57.9 | 1.1 | 105.0 | -79.6 | 0.0 | 0.0 | -89.7 | 0.0 | 0.0 | 59.0 | -5.8 | 169.0 | 140.7 | | |
| 96:40:39 | Start -0.3 deg/sec pitch rate for landmark tracking on 130 | 57.8 | 0.8 | 28.3 | -2.1 | 0.0 | 0.0 | -89.7 | 0.0 | 0.0 | 59.2 | -5.8 | 169.0 | 140.1 | 15.5 | 21.0 |
| 96:43:39 | Terminate pitch rate, inertial attitude hold | 57.8 | 0.6 | 19.2 | -47.0 | 0.0 | 0.0 | -143.6 | 0.0 | 0.0 | 113.1 | -5.4 | 137.0 | 179.6 | 170.6 | 36.9 |
| 96:46:39 | Maneuver to undocking attitude rolled 180 deg, inertial attitude hold | 57.8 | 0.4 | 10.0 | 120.1 | 0.0 | 0.0 | 14.3 | 0.0 | 0.0 | 45.0 | -173.0 | 65.0 | 0.3 | | |
| 96:51:30 | Enter lunar umbra | 57.8 | 0.1 | -4.7 | 135.0 | 0.0 | 0.0 | 14.3 | 0.0 | 0.0 | 45.0 | -173.0 | No line of sight | | | |
| 97:27:23 | Lose MSFN line of sight | 57.7 | -1.2 | -114.1 | -116.1 | 0.0 | 0.0 | 14.3 | 0.0 | 0.0 | No line of sight | | No line of sight | | | |
| 97:30:00 | Roll 180 deg to undocking attitude, inertial attitude hold | 57.8 | -1.2 | -122.0 | -108.2 | 0.0 | 180.0 | 14.3 | 0.0 | 180.0 | No line of sight | | No line of sight | | | |
| 97:37:51 | Enter sunlight | 57.8 | -0.9 | -146.0 | -84.1 | 0.0 | 180.0 | 14.3 | 0.0 | 180.0 | No line of sight | | 65.0 | -179.7 | | |
| 97:45:00 | AGS calibration maneuvers | 57.8 | -0.5 | -167.7 | -62.6 | 0.0 | 180.0 | 14.3 | 0.0 | 180.0 | No line of sight | | 65.0 | -179.7 | | |
| 97:55:00 | LM deploy landing gear | 57.9 | 0.2 | 161.8 | -32.3 | 0.0 | 180.0 | 14.3 | 0.0 | 180.0 | No line of sight | | 65.0 | -179.7 | | |
| 98:10:00 | CSM/LM undocking | 57.9 | 1.0 | 116.1 | 13.3 | 0.0 | 180.0 | 14.3 | 0.0 | 180.0 | No line of sight | | 65.1 | -179.7 | | |

# Table II. Spacecraft Attitude and Trajectory Data
## (c) Lunar Orbit
## Part 2: CSM/LM Undocking to LM APS Burn to Depletion

| Mission Time (hr:min:sec) | Event | Vehicle | Selenographic Position | | | Local Horizontal Attitude | | | IMU Gimbal Angles | | | Look Angles to Earth | | Look Angles to Sun | | Look Angles to Other Vehicle | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Altitude (n mi) | Latitude (deg) | Longitude (deg) | Pitch (deg) | Yaw (deg) | Roll (deg) | IGA (deg) | MGA (deg) | OGA (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) |
| 98:10:00 | Undocking, inertial attitude hold | CSM | 57.9 | 1.0 | 116.1 | 13.3 | 0.0 | 180.0 | 14.3 | 0.0 | 180.0 | No line of sight | | 65.1 | -179.7 | 0.0 | 0.0 |
| | | LM | 57.9 | 1.0 | 116.1 | -166.7 | 0.0 | 120.0 | -165.7 | 0.0 | 120.0 | No line of sight | | 114.9 | 59.7 | 0.0 | 0.0 |
| 98:12:39 | LM maneuver to inspection attitude, continue inertial attitude hold except for 360 deg roll (pilot yaw) maneuver | CSM | 57.9 | 1.1 | 108.0 | 21.3 | 0.0 | 180.0 | 14.3 | 0.0 | 180.0 | No line of sight | | 65.1 | -179.7 | 4.1 | -0.3 |
| | | LM | 57.9 | 1.1 | 108.0 | -68.7 | 0.0 | 0.0 | -75.7 | 0.0 | 0.0 | No line of sight | | 155.1 | 0.6 | 94.0 | 180.0 |
| 98:13:24 | CSM, LM acquire MSFN line of sight | CSM | 57.9 | 1.1 | 105.7 | 23.6 | 0.0 | 180.0 | 14.3 | 0.0 | 180.0 | 44.4 | 7.0 | 65.1 | -179.7 | 5.6 | 0.0 |
| | | LM | 57.9 | 1.1 | 105.7 | -66.4 | 0.0 | 90.0 | -75.7 | 0.0 | 90.0 | 46.0 | -96.8 | 155.1 | -89.4 | 95.6 | 90.0 |
| 98:15:39 | LM begin station keeping, continue inertial attitude hold | CSM | 57.9 | 1.2 | 98.9 | 30.5 | 0.0 | 180.0 | 14.3 | 0.0 | 180.0 | 44.4 | 7.0 | 65.1 | -179.7 | 9.9 | 0.1 |
| | | LM | 57.9 | 1.2 | 98.9 | -59.6 | 0.0 | 0.0 | -75.7 | 0.0 | 0.0 | 46.0 | -6.8 | 155.1 | 0.6 | 99.9 | 180.0 |
| 98:17:04 | CSM roll 180 deg for HGA communications, inertial attitude hold | CSM | 57.9 | 1.2 | 94.3 | 35.0 | 0.0 | 0.0 | 14.3 | 0.0 | 0.0 | 44.4 | -173.0 | 65.1 | 0.3 | 12.3 | -179.9 |
| | | LM | 57.9 | 1.2 | 94.3 | -55.0 | 0.0 | 0.0 | -75.7 | 0.0 | 0.0 | 46.0 | -6.8 | 155.1 | 0.6 | 102.3 | 180.0 |
| 98:35:16 | CMS separation burn ignition, inertial attitude hold | CSM | 57.9 | 1.0 | 39.2 | 90.0 | 0.0 | 0.0 | 14.3 | 0.0 | 0.0 | 44.2 | -173.0 | 65.1 | 0.3 | 7.2 | -179.9 |
| | | LM | 57.9 | 1.0 | 39.2 | 0.0 | 0.0 | 0.0 | -75.7 | 0.0 | 0.0 | 46.2 | -6.8 | 155.1 | 0.6 | 97.2 | 180.0 |
| 98:35:30 | CSM separation burn cutoff | CSM | 57.9 | 0.9 | 38.4 | 90.7 | 0.0 | 0.0 | 14.3 | 0.0 | 0.0 | 44.2 | -173.0 | 65.1 | 0.3 | 4.9 | -179.9 |
| | | LM | 57.9 | 0.9 | 38.4 | 0.7 | 0.0 | 0.0 | -75.7 | 0.0 | 0.0 | 46.2 | -6.8 | 155.1 | 0.6 | 94.9 | 180.0 |
| 98:39:00 | CMS maneuver to SXT tracking - VHF ranging attitude; LM maneuver to RR tracking attitude, line-of-sight maintenance | CSM | 57.8 | 0.8 | 27.8 | 136.1 | 0.0 | 0.0 | 49.1 | 0.0 | 0.0 | 78.7 | -175.0 | 30.3 | 0.6 | 35.0 | 180.0 |
| | | LM | 57.9 | 0.8 | 27.8 | 11.1 | 0.0 | 0.0 | -75.9 | 0.0 | 0.0 | 46.5 | -6.8 | 155.3 | 0.7 | 90.0 | 180.0 |
| 98:44:58 | CSM enter lunar umbra | CSM | 57.5 | 0.1 | -5.7 | 164.4 | 0.0 | 0.0 | 44.1 | 0.0 | 0.0 | 73.5 | -174.9 | No line of sight | | 35.0 | 180.0 |
| | | LM | 57.8 | 0.1 | -5.7 | 39.4 | 0.0 | 0.0 | -80.9 | 0.0 | 0.0 | 51.8 | -6.2 | 160.4 | 0.8 | 90.0 | 180.0 |
| 98:50:00 | LM enter lunar umbra | CSM | 57.5 | 0.1 | -5.7 | 164.5 | 0.0 | 0.0 | 44.0 | 0.0 | 0.0 | 73.4 | -174.9 | No line of sight | | 35.0 | 180.0 |
| | | LM | 57.8 | 0.1 | -5.7 | 39.5 | 0.0 | 0.0 | -81.0 | 0.0 | 0.0 | 51.8 | -6.2 | No line of sight | | 90.0 | 180.0 |
| 98:55:00 | CSM, LM begin IMU realignment, inertial attitude hold | CSM | 57.4 | -0.2 | -21.0 | 174.3 | 0.0 | 0.0 | 38.6 | 0.0 | 0.0 | 67.9 | -174.7 | No line of sight | | 35.0 | 180.0 |
| | | LM | 57.8 | -0.2 | -21.0 | 49.3 | 0.0 | 0.0 | -86.4 | 0.0 | 0.0 | 57.3 | -5.8 | No line of sight | | 90.0 | 180.0 |
| 99:25:36 | CSM lose MSFN line of sight | CSM | 57.5 | -1.2 | -114.4 | -92.6 | 0.0 | 0.0 | 38.6 | 0.0 | 0.0 | No line of sight | | No line of sight | | 94.1 | 180.0 |
| | | LM | 57.8 | -1.2 | -114.4 | 142.3 | 0.0 | 0.0 | -86.4 | 0.0 | 0.0 | 57.7 | -5.7 | No line of sight | | 149.1 | 180.0 |
| 99:25:37 | LM lose MSFN line of sight | CSM | 57.5 | -1.2 | -114.4 | -92.6 | 0.0 | 0.0 | 38.6 | 0.0 | 0.0 | No line of sight | | No line of sight | | 94.2 | 180.0 |
| | | LM | 57.8 | -1.2 | -114.4 | 142.4 | 0.0 | 0.0 | -86.4 | 0.0 | 0.0 | No line of sight | | No line of sight | | 149.2 | 180.0 |
| 99:29:00 | LM maneuver to DOI burn attitude, inertial attitude hold | CSM | 57.6 | -1.1 | -124.7 | -112.8 | 0.0 | 0.0 | 8.1 | 0.0 | 0.0 | No line of sight | | No line of sight | | 71.2 | 180.0 |
| | | LM | 57.8 | -1.1 | -124.6 | 164.9 | 0.0 | 0.0 | -74.0 | 0.0 | 0.0 | No line of sight | | No line of sight | | 169.1 | 180.0 |
| 99:33:59 | LM DOI burn ignition, inertial attitude hold; CSM maneuver to SXT tracking - VHF ranging attitude, line-of-sight maintenance | CSM | 57.6 | -1.0 | -134.1 | -145.0 | 0.0 | 0.0 | -39.2 | 0.0 | 0.0 | No line of sight | | No line of sight | | 35.3 | 180.0 |
| | | LM | 57.8 | -1.0 | -134.8 | 180.6 | 0.0 | 0.0 | -74.0 | 0.0 | 0.0 | No line of sight | | No line of sight | | 179.6 | 0.0 |
| 99:34:27 | DOI burn cutoff, LM maneuver to RR tracking attitude | CSM | 57.8 | -1.0 | -141.3 | -145.0 | 0.0 | 0.0 | -40.5 | 0.0 | 0.0 | No line of sight | | No line of sight | | 35.0 | 180.0 |
| | | LM | 57.8 | -1.0 | -141.2 | 89.9 | 0.0 | 0.0 | -165.5 | 0.0 | 0.0 | No line of sight | | No line of sight | | 90.0 | 180.0 |
| 99:36:18 | CSM enter sunlight | CSM | 57.8 | -0.9 | -147.4 | -141.0 | 0.0 | 0.0 | -42.6 | 0.0 | 0.0 | No line of sight | | 122.1 | 0.3 | 35.0 | 180.0 |
| 99:36:23 | LM enter sunlight | LM | 57.8 | -0.9 | -147.2 | 93.8 | 0.0 | 0.0 | -167.6 | 0.0 | 0.0 | No line of sight | | 112.9 | 179.7 | 90.0 | 180.0 |
| 99:49:27 | LM terminate tracking, maneuver to PDI attitude, inertial attitude hold | CSM | 58.2 | -0.1 | 173.6 | -97.3 | 0.0 | 0.0 | -38.4 | 0.0 | 0.0 | No line of sight | | 117.9 | 0.3 | 35.0 | 180.0 |
| | | LM | 49.7 | -0.1 | 173.5 | 45.6 | 0.0 | 180.0 | 105.0 | 0.0 | 180.0 | No line of sight | | 25.5 | -0.6 | 1.6 | 179.8 |
| 100:04:27 | CSM roll 180 deg, maneuver to SXT tracking - VHF ranging attitude | CSM | 58.4 | 0.8 | 127.4 | -165.4 | 0.0 | 180.0 | -32.0 | 0.0 | 180.0 | No line of sight | | 171.5 | -178.2 | 35.0 | 180.0 |
| | | LM | 30.6 | 0.8 | 126.8 | 92.2 | 0.0 | 180.0 | 105.0 | 0.0 | 180.0 | No line of sight | | 2.6 | -0.6 | 18.0 | 180.0 |
| 100:11:43 | CSM acquire MSFN line of sight | CSM | 58.3 | 1.1 | 105.3 | -85.2 | 0.0 | 180.0 | -96.1 | 0.0 | 180.0 | 67.3 | 174.2 | 175.6 | -176.6 | 35.0 | 180.0 |
| 100:14:17 | LM acquire MSFN line of sight | LM | 17.4 | 1.2 | 95.1 | 124.9 | 0.0 | 180.0 | 105.0 | 0.0 | 180.0 | 133.5 | 6.6 | 25.5 | -0.6 | 11.5 | 180.0 |
| 100:24:37 | LM maneuver to LR test attitude, begin -0.055 deg/sec pitch rate (approximate) | CSM | 58.1 | 1.2 | -66.4 | -66.4 | 0.0 | 180.0 | -115.8 | 0.0 | 180.0 | 87.0 | 175.2 | 104.7 | -1.0 | 35.0 | 180.0 |
| | | LM | 9.4 | 1.2 | 93.0 | 180.0 | 0.0 | 0.0 | 47.2 | 0.0 | 0.0 | 76.0 | -175.0 | 32.3 | 0.5 | 52.0 | 0.0 |

# Table II. Spacecraft Attitude and Trajectory Data
## (c) Lunar Orbit (Continued)
## Part 2: CSM/LM Undocking to LM APS Burn to Depletion

| Mission Time (hr:min:sec) | Event | Vehicle | Selenographic Position | | | Local Horizontal Attitude | | | IMU Gimbal Angles | | | Look Angles to Earth | | Look Angles to Sun | | Look Angles to Other Vehicle | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Altitude (n mi) | Latitude (deg) | Longitude (deg) | Pitch (deg) | Yaw (deg) | Roll (deg) | IGA (deg) | MGA (deg) | OGA (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) |
| 100:31:17 | Pericynthion of LM descent orbit | CSM | 57.9 | 1.0 | 45.7 | -62.1 | 0.0 | 180.0 | -130.2 | 0.0 | 180.0 | 101.4 | 175.1 | 150.3 | -0.5 | 35.0 | 180.0 |
| | | LM | 6.5 | 1.0 | 38.8 | 90.0 | 0.0 | 0.0 | 15.0 | 0.0 | 0.0 | 43.8 | -174.0 | 64.5 | 0.3 | 69.8 | 0.0 |
| 100:33:45 | LM at 0 deg landing site elevation angle, begin landing site observation | CSM | 57.8 | 1.0 | 38.1 | -60.3 | 0.0 | 180.0 | -135.9 | 0.0 | 180.0 | 107.1 | 174.9 | 144.6 | -0.4 | 35.0 | 180.0 |
| | | LM | 6.8 | 0.8 | 30.4 | 90.0 | 0.0 | 0.0 | 6.7 | 0.0 | 0.0 | 35.7 | -171.7 | 72.7 | 0.3 | 72.4 | 0.0 |
| 100:34:37 | LM terminate LR test, inertial attitude hold | CSM | 57.8 | 0.9 | 35.5 | -59.7 | 0.0 | 180.0 | -137.9 | 0.0 | 180.0 | 109.2 | 174.9 | 142.6 | -0.4 | 35.0 | 180.0 |
| | | LM | 7.0 | 0.8 | 27.6 | 90.0 | 0.0 | 0.0 | 3.9 | 0.0 | 0.0 | 32.8 | -171.0 | 75.6 | 0.3 | 73.2 | 0.0 |
| 100:38:21 | LM maneuver to phasing burn attitude, inertial attitude hold | CSM | 57.8 | 0.8 | 24.3 | -57.5 | 0.0 | 180.0 | -146.4 | 0.0 | 180.0 | 117.6 | 174.5 | 134.1 | -0.4 | 35.0 | 180.0 |
| | | LM | 8.5 | 0.6 | 15.7 | 2.2 | 0.0 | 0.0 | -96.1 | 0.0 | 0.0 | 67.7 | -5.2 | 175.6 | 3.6 | 167.6 | 0.0 |
| 100:41:31 | LM enter lunar umbra | LM | 10.7 | 0.4 | 4.2 | 121.1 | 0.0 | 0.0 | -96.1 | 0.0 | 0.0 | 67.7 | -5.2 | No line of sight | | 156.9 | 0.0 |
| 100:46:21 | DPS phasing burn ignition, CSM monitor burn in SXT tracking - VHF ranging attitude | CSM | 57.5 | 0.3 | -0.2 | -53.2 | 0.0 | 180.0 | -147.0 | 0.0 | 180.0 | 138.4 | 172.7 | 113.5 | -0.3 | 35.0 | 180.0 |
| | | LM | 15.2 | 0.0 | -11.2 | 28.8 | 0.0 | 0.0 | -96.1 | 0.0 | 0.0 | 67.8 | -5.2 | No line of sight | | 144.1 | 0.0 |
| 100:47:03 | Phasing burn cutoff, inertial attitude hold | CSM | 57.5 | 0.2 | -2.4 | -52.8 | 0.0 | 180.0 | -168.8 | 0.0 | 180.0 | 140.1 | 172.4 | 111.7 | -0.3 | 35.0 | 180.0 |
| | | LM | 16.2 | 0.0 | -13.6 | 31.1 | 0.0 | 0.0 | -96.1 | 0.0 | 0.0 | 67.9 | -5.2 | No line of sight | | 142.3 | 0.0 |
| 100:48:27 | CSM enter lunar umbra | CSM | 57.4 | 0.1 | -6.7 | -52.0 | 0.0 | 180.0 | -168.8 | 0.0 | 180.0 | 140.1 | 172.4 | No line of sight | | 35.0 | 180.0 |
| 100:52:03 | CSM and LM maneuver to SXT tracking and RR tracking attitude, respectively | CSM | 57.4 | -0.1 | -17.6 | -48.6 | 0.0 | 180.0 | -179.8 | 0.0 | 180.0 | 151.1 | 169.9 | No line of sight | | 35.0 | 180.0 |
| | | LM | 29.6 | -0.3 | -30.2 | 89.0 | 0.0 | 180.0 | -54.8 | 0.0 | 180.0 | 27.0 | 169.3 | No line of sight | | 90.0 | 180.0 |
| 101:02:03 | CSM and LM terminate tracking, inertial attitude hold, LM maneuver to IMU realignment attitude, inertial attitude hold | CSM | 57.3 | -0.7 | -48.1 | -39.0 | 0.0 | 180.0 | 159.4 | 0.0 | 180.0 | 171.1 | 146.9 | No line of sight | | 35.0 | 180.0 |
| | | LM | 69.2 | -0.9 | -61.8 | 99.7 | 0.0 | 180.0 | -75.6 | 0.0 | 180.0 | 47.8 | 173.5 | No line of sight | | 90.0 | 180.0 |
| 101:17:03 | CSM and LM maneuver to SXT tracking and RR tracking attitude, respectively | CSM | 57.4 | -1.2 | -93.8 | -17.7 | 0.0 | 180.0 | 135.1 | 0.0 | 180.0 | 162.3 | 16.0 | No line of sight | | 35.0 | 180.0 |
| | | LM | 136.5 | -1.2 | -104.3 | 117.8 | 0.0 | 180.0 | -99.9 | 0.0 | 180.0 | 72.1 | 175.0 | No line of sight | | 90.0 | 180.0 |
| 101:20:47 | LM terminate tracking, inertial attitude hold | CSM | 57.4 | -1.2 | -105.2 | -9.6 | 0.0 | 180.0 | 131.9 | 0.0 | 180.0 | 159.2 | 13.6 | No line of sight | | 35.0 | 180.0 |
| | | LM | 151.0 | -1.2 | -114.2 | 124.3 | 0.0 | 180.0 | -103.1 | 0.0 | 180.0 | 75.4 | 175.0 | No line of sight | | 90.0 | 180.0 |
| 101:23:52 | CSM lose MSFN line of sight | CSM | 57.5 | -1.2 | -114.7 | 2.1 | 0.0 | 180.0 | 131.9 | 0.0 | 180.0 | No line of sight | | No line of sight | | 35.0 | 180.0 |
| 101:25:52 | LM lose MSFN line of sight | LM | 167.8 | -1.2 | -127.1 | 137.0 | 0.0 | 180.0 | -103.1 | 0.0 | 180.0 | No line of sight | | No line of sight | | 90.0 | 180.0 |
| 101:27:03 | CSM terminate tracking, inertial attitude hold | CSM | 57.6 | -1.1 | -124.3 | 9.1 | 0.0 | 180.0 | 131.5 | 0.0 | 180.0 | No line of sight | | No line of sight | | 35.0 | 180.0 |
| | | LM | 171.2 | -1.1 | -130.1 | 140.2 | 0.0 | 180.0 | -103.1 | 0.0 | 180.0 | No line of sight | | No line of sight | | 89.7 | 180.0 |
| 101:28:57 | LM enter sunlight | LM | 176.2 | -1.0 | -134.8 | 144.5 | 0.0 | 180.0 | -103.1 | 0.0 | 180.0 | No line of sight | | 177.3 | -5.8 | 91.4 | 180.0 |
| 101:34:48 | CSM enter sunlight | CSM | 57.8 | -0.8 | -147.9 | 33.4 | 0.0 | 180.0 | 131.5 | 0.0 | 180.0 | No line of sight | | 52.3 | -0.3 | 47.6 | 180.0 |
| 101:48:18 | CSM maneuver to SXT tracking attitude | CSM | 58.2 | -0.1 | 170.9 | 174.9 | 0.0 | 0.0 | -127.2 | 0.0 | 0.0 | No line of sight | | 153.2 | 179.4 | 35.0 | 180 0 |
| | | LM | 188.9 | -0.2 | 178.3 | -168.3 | 0.0 | 180.0 | -103.1 | 0.0 | 180.0 | No line of sight | | 177.3 | -5.8 | 120.9 | 180.0 |
| 101:59:18 | LM maneuver to RR tracking attitude | CSM | 58.3 | 0.6 | 137.0 | -161.0 | 0.0 | 0.0 | -136.6 | 0.0 | 0.0 | No line of sight | | 143.9 | 179.5 | 35.0 | 180.0 |
| | | LM | 165.0 | 0.3 | 151.2 | 60.2 | 0.0 | 0.0 | 98.4 | 0.0 | 0.0 | No line of sight | | 18.9 | 179.2 | 90.0 | 180.0 |
| 102:08:18 | CSM terminate tracking, maneuver to MI insertion burn attitude, inertial attitude hold | CSM | 58.4 | 1.0 | 110.0 | -79.5 | 0.0 | 180.0 | -82.2 | 0.0 | 180.0 | No line of sight | | 161.8 | -179.1 | 104.6 | 0.0 |
| | | LM | 131.8 | 0.8 | 127.8 | 68.3 | 0.0 | 0.0 | 83.2 | 0.0 | 0.0 | No line of sight | | 3.6 | 175.7 | 90.0 | 180.0 |
| 102:09:57 | CSM acquire MSFN line of sight | CSM | 58.3 | 1.1 | 103.0 | -72.5 | 0.0 | 180.0 | -82.2 | 0.0 | 180.0 | 55.0 | 174.1 | 161.8 | -179.1 | 107.5 | 0.0 |
| 102:14:19 | LM acquire MSFN line of sight | LM | 105.3 | 1.0 | 111.2 | 72.6 | 0.0 | 0.0 | 71.0 | 0.0 | 0.0 | 98.9 | -175.2 | 8.5 | 1.8 | 90 0 | 180.0 |
| 102:19:18 | LM terminate tracking, maneuver to descent stage jettison attitude, inertial attitude hold | CSM | 58.2 | 1.2 | 76.6 | -46.1 | 0.0 | 180.0 | -82.2 | 0.0 | 180.0 | 54.5 | 174.1 | 161.8 | -179.1 | 127 6 | 0.0 |
| | | LM | 82.2 | 1.2 | 96.8 | 76.1 | 0.0 | 0.0 | 60.1 | 0.0 | 0.0 | 88.0 | -172.5 | 19.5 | 0.8 | 90.0 | 180.0 |
| 102:33:18 | Begin descent stage jettison | CSM | 57.8 | 0.9 | 33.9 | -3.5 | 0.0 | 180.0 | -82.2 | 0.0 | 180.0 | 54.8 | 174.1 | 161.8 | -179.1 | 161.4 | 0.0 |
| | | LM | 26.1 | 1.1 | 52.9 | 180.0 | 0.0 | 180.0 | 127.1 | 0.0 | 180.0 | 147.9 | -8.9 | 40.7 | 0.4 | 176.2 | 180.0 |
| 102:36:18 | Complete descent stage jettison, maneuver to insertion burn attitude, inertial attitude hold | CSM | 57.7 | 0.8 | 24.2 | 6.2 | 0.0 | 180.0 | -82.2 | 0.0 | 180.0 | 54.8 | 174.1 | 161.8 | -179.1 | 161.4 | 0.0 |
| | | LM | 17.7 | 1.1 | 42.2 | -170.0 | 0.0 | 180.0 | 119.6 | 0.0 | 180.0 | 147.0 | 8.8 | 40.0 | -0.4 | 168.4 | 180.0 |
| 102:43:18 | APS insertion burn ignition | CSM | 57.6 | 0.4 | 3.5 | 26.8 | 0.0 | 180.0 | -82.2 | 0.0 | 180.0 | 55.0 | 175.0 | 161.8 | -0.4 | 171.5 | 180.0 |
| | | LM | 8.0 | 0.7 | 19.1 | 155.6 | 0.0 | 180.0 | 62.2 | 0.0 | 180.0 | 89.7 | 4.8 | 17.4 | -179.2 | 152.9 | 0.0 |

# Table II. Spacecraft Attitude and Trajectory Data
## (c) Lunar Orbit (Continued)
## Part 2: CSM/LM Undocking to LM APS Burn to Depletion

| Mission Time (hr:min:sec) | Event | Vehicle | Selenographic Position | | | Local Horizontal Attitude | | | IMU Gimbal Angles | | | Look Angles to Earth | | Look Angles to Sun | | Look Angles to Other Vehicle | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Altitude (n mi) | Latitude (deg) | Longitude (deg) | Pitch (deg) | Yaw (deg) | Roll (deg) | IGA (deg) | MGA (deg) | OGA (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) |
| 102:43:33 | Insertion burn cutoff, inertial attitude hold | CSM | 57.5 | 0.3 | 2.7 | 27.6 | 0.0 | 180.0 | -82.2 | 0.0 | 0.0 | 55.0 | 174.1 | 161.8 | -179.1 | 170.8 | 180.0 |
| | | LM | 8.0 | 0.6 | 18.2 | 156.5 | 0.0 | 180.0 | 62.2 | 0.0 | 180.0 | 89.7 | 4.8 | 17.4 | -179.2 | 153.7 | 0.0 |
| 102:46:58 | CSM enter lunar umbra | CSM | 57.5 | 0.1 | -7.7 | 166.1 | 0.0 | 0.0 | -82.2 | 0.0 | 0.0 | 55.0 | 174.1 | No line of sight | | 169.9 | 180.0 |
| 102:47:58 | LM enter lunar umbra | LM | 10.1 | 0.4 | 3.5 | 169.7 | 0.0 | 180.0 | 62.2 | 0.0 | 180.0 | 89.7 | 4.8 | No line of sight | | 166.0 | 0.0 |
| 103:01:33 | LM maneuver to RR tracking attitude | CSM | 57.2 | -0.8 | -52.1 | 82.4 | 0.0 | 0.0 | -82.2 | 0.0 | 0.0 | 55.0 | 174.1 | No line of sight | | 150.8 | 180.0 |
| | | LM | 21.3 | -0.6 | -40.8 | 94.8 | 0.0 | 0.0 | -58.4 | 0.0 | 0.0 | 31.6 | -9.1 | No line of sight | | 90.0 | 180.0 |
| 103:06:33 | CSM maneuver to SXT tracking - VHF ranging attitude | CSM | 57.3 | -1.0 | -67.4 | -130.0 | 0.0 | 0.0 | 50.2 | 0.0 | 0.0 | 77.2 | -175.1 | No line of sight | | 35.0 | 180.0 |
| | | LM | 26.3 | -0.8 | -56.8 | 94.4 | 0.0 | 0.0 | -74.8 | 0.0 | 0.0 | 48.0 | -6.4 | No line of sight | | 90.0 | 180.0 |
| 103:18:33 | CSM terminate tracking, maneuver to MI CSI burn attitude, inertial attitude hold | CSM | 57.4 | -1.2 | -104.0 | -133.2 | 0.0 | 0.0 | 10.6 | 0.0 | 0.0 | 37.7 | -172.2 | No line of sight | | 35.0 | 180.0 |
| | | LM | 37.2 | -1.2 | -94.7 | 92.5 | 0.0 | 0.0 | -114.4 | 0.0 | 0.0 | 87.6 | -4.7 | No line of sight | | 90.0 | 180.0 |
| 103:22:03 | CSM lose MSFN line of sight | CSM | 57.5 | -1.2 | -114.7 | -121.0 | 0.0 | 0.0 | 10.6 | 0.0 | 0.0 | No line of sight | | No line of sight | | 48.0 | 180.0 |
| 103:24:01 | LM lose MSFN line of sight | LM | 40.7 | -1.2 | -111.7 | 91.7 | 0.0 | 0.0 | -133.9 | 0.0 | 0.0 | No line of sight | | No line of sight | | 90.0 | 180.0 |
| 103:24:33 | LM terminate tracking, maneuver to CSI burn attitude, inertial attitude hold | CSM | 57.6 | -1.2 | -122.3 | 152.0 | 0.0 | 180.0 | -82.5 | 0.0 | 180.0 | No line of sight | | No line of sight | | 38.6 | 180.0 |
| | | LM | 41.0 | -1.2 | -113.4 | -28.4 | 0.0 | 0.0 | 106.1 | 0.0 | 0.0 | No line of sight | | No line of sight | | 30.1 | 0.0 |
| 103:33:17 | CSM enter sunlight | CSM | 57.8 | -0.9 | -148.9 | 178.5 | 0.0 | 180.0 | -82.5 | 0.0 | 180.0 | No line of sight | | 162.1 | -179.1 | 9.9 | 180.0 |
| 103:33:46 | CSI burn ignition (RCS plus X-axis 4 jets) | CSM | 57.8 | -0.8 | -150.4 | 180.0 | 0.0 | 180.0 | -82.5 | 0.0 | 180.0 | No line of sight | | 162.1 | -179.1 | 9.9 | 180.0 |
| | | LM | 43.3 | -1.0 | -141.8 | 0.0 | 0.0 | 0.0 | 106.1 | 0.0 | 0.0 | No line of sight | | No line of sight | | 1.4 | 0.1 |
| 103:34:18 | CSI burn cutoff, inertial attitude hold | CSM | 57.9 | -0.8 | -152.0 | -178.4 | 0.0 | 180.0 | -82.5 | 0.0 | 180.0 | No line of sight | | 162.1 | -179.1 | 8.3 | 180.0 |
| | | LM | 43.3 | -1.0 | -143.5 | 1.6 | 0.0 | 0.0 | 106.0 | 0.0 | 0.0 | No line of sight | | No line of sight | | 0.2 | -177.3 |
| 103:36:52 | LM enter sunlight | LM | 43.3 | -0.8 | -151.5 | 7.8 | 0.0 | 0.0 | 106.0 | 0.0 | 0.0 | No line of sight | | 26.4 | 179.4 | 6.2 | -177.3 |
| 103:40:18 | CSM and LM maneuver to SXT tracking - VHF ranging and RR tracking attitude, respectively | CSM | 58.0 | -0.5 | -170.3 | -134.9 | 0.0 | 0.0 | -57.3 | 0.0 | 0.0 | No line of sight | | 136.9 | 0.4 | 35.0 | 180.0 |
| | | LM | 43.3 | -0.6 | -162.2 | 92.0 | 0.0 | 0.0 | 177.7 | 0.0 | 0.0 | No line of sight | | 98.1 | 179.7 | 90.0 | 180.0 |
| 104:08:12 | CSM acquire MSFN line of sight | CSM | 58.3 | 1.1 | 104.8 | -133.7 | 0.0 | 0.0 | -141.0 | 0.0 | 0.0 | 114.0 | -5.1 | 139.6 | 179.6 | 35.0 | 180.0 |
| 104:11:03 | LM acquire MSFN line of sight | LM | 43.0 | 1.1 | 102.0 | 95.5 | 0.0 | 0.0 | 88.1 | 0.0 | 0.0 | 114.9 | -174.8 | 8.4 | 178.2 | 90.0 | 180.0 |
| 104:20:18 | CSM and LM terminate tracking, CSM maneuver to MI CDH burn attitude, inertial attitude hold; LM maneuver to CDH burn attitude, inertial attitude hold | CSM | 58.1 | 1.2 | 68.0 | -124.6 | 0.0 | 0.0 | -168.3 | 0.0 | 0.0 | 141.2 | -172.5 | 112.0 | 0.3 | 43.2 | 0.0 |
| | | LM | 42.9 | 1.2 | 73.2 | 54.5 | 0.0 | 0.0 | 16.1 | 0.0 | 0.0 | 43.1 | 173.1 | 63.6 | 0.2 | 47.6 | 180.0 |
| 104:31:42 | CDH burn ignition (RCS minus X-axis 4 jets) | CSM | 57.8 | 0.9 | 33.2 | -90.0 | 0.0 | 180.0 | -168.3 | 0.0 | 180.0 | 141.2 | -172.4 | 112.0 | 0.3 | 13.2 | 0.0 |
| | | LM | 42.9 | 1.0 | 37.7 | 90.0 | 0.0 | 0.0 | 16.1 | 0.0 | 0.0 | 43.0 | -173.0 | 63.5 | 0.3 | 81.2 | 180.0 |
| 104:31:45 | CDH burn cutoff, inertial attitude hold | CSM | 57.8 | 0.9 | 33.1 | -90.0 | 0.0 | 180.0 | -168.3 | 0.0 | 180.0 | 141.2 | -172.4 | 112.0 | 0.3 | 13.2 | 0.0 |
| | | LM | 42.9 | 1.0 | 37.5 | 90.0 | 0.0 | 0.0 | 16.1 | 0.0 | 0.0 | 43.0 | -173.0 | 63.5 | 0.3 | 81.2 | 180.0 |
| 104:35:45 | CSM and LM maneuver to SXT tracking - VHF ranging/RR tracking attitude, respectively | CSM | 57.7 | 0.7 | 20.9 | -131.1 | 0.0 | 0.0 | 138.2 | 0.0 | 0.0 | 164.1 | -162.5 | 58.6 | 179.7 | 35.0 | 180.0 |
| | | LM | 42.8 | 0.8 | 25.1 | 99.7 | 0.0 | 0.0 | 13.2 | 0.0 | 0.0 | 40.0 | -172.7 | 66.4 | 0.3 | 90.0 | 180.0 |
| 104:45:29 | CSM enter lunar umbra | CSM | 57.5 | 0.1 | -8.7 | -129.2 | 0.0 | 0.0 | 109.8 | 0.0 | 0.0 | 136.0 | -173.2 | 30.2 | 179.5 | 35.0 | 180.0 |
| 104:45:44 | LM enter lunar umbra | LM | 42.4 | 0.2 | -6.1 | 102.4 | 0.0 | 0.0 | -151.1 | 0.0 | 0.0 | 121.4 | -157.0 | 94.8 | 0.3 | 90.0 | 180.0 |
| 104:52:34 | CSM and LM terminate tracking, CSM maneuver to MI TPI burn attitude, inertial attitude hold; LM maneuver to TPI burn attitude, inertial attitude hold | CSM | 57.3 | -0.5 | -37.0 | -126.4 | 0.0 | 0.0 | 85.2 | 0.0 | 0.0 | 113.3 | -174.9 | No line of sight | | 35.0 | 180.0 |
| | | LM | 42.3 | -0.4 | -34.2 | 105.7 | 0.0 | 0.0 | -39.8 | 0.0 | 0.0 | 14.4 | -19.2 | No line of sight | | 90.0 | 180.0 |
| 105:08:57 | TPI burn ignition (RCS plus Z-axis 4 jets) | CSM | 57.3 | -1.2 | -80.3 | -110.7 | 0.0 | 0.0 | 45.4 | 0.0 | 0.0 | 71.4 | -175.0 | No line of sight | | 35.0 | 180.0 |
| | | LM | 42.2 | -1.2 | -78.7 | 26.9 | 0.2 | -0.1 | -163.0 | 0.2 | -0.1 | 136.9 | -6.5 | No line of sight | | 0.3 | -137.4 |

# Table II. Spacecraft Attitude and Trajectory Data
## (c) Lunar Orbit (Continued)
## Part 2: CSM/LM Undocking to LM APS Burn to Depletion

| Mission Time (hr:min:sec) | Event | Vehicle | Selenographic Position | | | Local Horizontal Attitude | | | IMU Gimbal Angles | | | Look Angles to Earth | | Look Angles to Sun | | Look Angles to Other Vehicle | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Altitude (n mi) | Latitude (deg) | Longitude (deg) | Pitch (deg) | Yaw (deg) | Roll (deg) | IGA (deg) | MGA (deg) | OGA (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) |
| 105:09:13 | TPI burn cutoff, CSM and LM maneuver to SXT tracking - VHF ranging and RR tracking attitude, respectively | CSM | 57.3 | -1.2 | -81.1 | -116.5 | 0.0 | 0.0 | 51.2 | 0.0 | 0.0 | 77.1 | -175.2 | No line of sight | | 35.0 | 180.0 |
| | | LM | 42.4 | -1.2 | -79.5 | 116.9 | 0.0 | 0.0 | -73.8 | 0.0 | 0.0 | 48.1 | -6.3 | No line of sight | | 90.0 | 180.0 |
| 105:19:32 | LM lose MSFN line of sight | LM | 44.2 | -1.2 | -111.7 | 127.8 | 0.0 | 0.0 | -91.0 | 0.0 | 0.0 | No line of sight | | No line of sight | | 90.0 | 180.0 |
| 105:20:07 | CSM lose MSFN line of sight | CSM | 57.5 | -1.2 | -114.3 | -101.9 | 0.0 | 0.0 | 29.3 | 0.0 | 0.0 | No line of sight | | No line of sight | | 35.0 | 180.0 |
| 105:31:49 | CSM enter sunlight | CSM | 57.8 | -0.9 | -150.0 | -84.7 | 0.0 | 0.0 | 19.1 | 0.0 | 0.0 | No line of sight | | 60.6 | 0.3 | 35.0 | 180.0 |
| 105:32:13 | LM enter sunlight | LM | 49.4 | -0.8 | -151.4 | 157.5 | 0.0 | 0.0 | -107.6 | 0.0 | 0.0 | No line of sight | | 172.7 | 177.9 | 90.0 | 180.0 |
| 105:50:14 | LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 3000 ft | CSM | 58.3 | 0.2 | 153.8 | -93.3 | 0.0 | 180.0 | -50.2 | 0.0 | -179.4 | No line of sight | | 130.0 | 179.7 | 0.0 | 0.0 |
| | | LM | 57.9 | 0.2 | 153.8 | 30.0 | 0.4 | 179.8 | 73.1 | 0.4 | 179.8 | No line of sight | | 6.6 | 179.1 | 90.0 | 180.0 |
| 105:50:30 | Braking burn cutoff, CSM and LM continue tracking | CSM | 58.3 | 0.2 | 153.1 | -92.5 | 0.0 | 180.0 | -49.4 | 0.0 | -179.4 | No line of sight | | 129.2 | 179.7 | 0.2 | 0.0 |
| | | LM | 57.9 | 0.2 | 153.1 | 30.8 | 0.4 | 179.8 | 73.9 | 0.4 | 179.2 | No line of sight | | 7.4 | -179.2 | 90.0 | 180.0 |
| 105:51:27 | LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 1500 ft | CSM | 58.3 | 0.3 | 150.2 | -53.5 | 0.3 | -179.6 | -14.1 | 0.3 | -179.6 | No line of sight | | 94.0 | 179.8 | 0.2 | 0.0 |
| | | LM | 58.1 | 0.3 | 150.2 | 33.2 | 0.3 | 179.7 | 73.9 | 0.4 | 179.7 | No line of sight | | 5.8 | 179.2 | 90.0 | 180.0 |
| 105:51:39 | Braking burn cutoff, CSM and LM continue tracking | CSM | 58.3 | 0.3 | 149.6 | -52.9 | 0.3 | -179.6 | -14.1 | 0.3 | -179.6 | No line of sight | | 93.9 | 179.8 | 0.2 | 0.0 |
| | | LM | 58.1 | 0.3 | 149.6 | 34.0 | 0.3 | 179.7 | 74.8 | 0.4 | 179.7 | No line of sight | | 6.7 | 179.2 | 90.0 | 180.0 |
| 105:53:04 | LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 500 ft | CSM | 58.3 | 0.4 | 145.2 | -48.4 | 0.3 | -179.6 | -13.9 | 0.3 | -179.6 | No line of sight | | 93.6 | 179.9 | 0.4 | 0.0 |
| | | LM | 58.3 | 0.4 | 145.2 | 42.6 | 0.3 | 179.7 | 75.9 | 0.3 | 179.7 | No line of sight | | 6.1 | 179.5 | 90.0 | 180.0 |
| 105:53:10 | Braking burn cutoff, CSM and LM continue tracking | CSM | 58.3 | 0.4 | 144.9 | -48.0 | 0.3 | -179.6 | -13.9 | 0.3 | -179.6 | No line of sight | | 93.6 | 179.9 | 0.4 | 0.0 |
| | | LM | 58.3 | 0.4 | 144.9 | 42.1 | 0.3 | 179.7 | 75.4 | 0.3 | 179.6 | No line of sight | | 5.7 | 179.5 | 90.0 | 180.0 |
| 105:54:24 | LM braking burn ignition (RCS minus Z-axis 2 jets), CSM-LM range = 100 ft | CSM | 58.3 | 0.5 | 141.2 | -43.9 | 0.3 | -179.7 | -13.5 | 0.3 | -179.6 | No line of sight | | 93.2 | 180.0 | 0.6 | 0.0 |
| | | LM | 58.3 | 0.5 | 141.2 | 46.2 | 0.3 | 179.7 | 76.6 | 0.3 | 179.6 | No line of sight | | 3.1 | 179.6 | 90.0 | 180.0 |
| 105:54:30 | Braking burn cutoff, CSM-LM range = 85 ft, CSM-LM range | CSM | 58.3 | 0.5 | 140.9 | -43.6 | 0.3 | -179.7 | -13.5 | 0.3 | -179.6 | No line of sight | | 93.2 | 180.0 | 0.7 | 0.0 |
| | | LM | 58.3 | 0.5 | 140.9 | 46.6 | 0.3 | 179.7 | 76.7 | 0.3 | 179.6 | No line of sight | | 3.0 | 179.7 | 90.0 | 180.0 |
| 105:57:10 | CSM and LM maneuver to docking attitude, CSM-LM range = 50 ft | CSM | 58.4 | 0.7 | 128.0 | -30.8 | 0.3 | 120.0 | -14.5 | 0.3 | 120.0 | No line of sight | | 94.2 | -120.0 | 0.0 | 0.0 |
| | | LM | 58.4 | 0.7 | 128.0 | 148.2 | -0.3 | 180.0 | 165.5 | -0.3 | 180.0 | No line of sight | | 85.8 | 0.0 | 0.0 | 0.0 |
| 106:06:33 | Acquire MSFN line of sight | CSM | 58.3 | 1.1 | 104.2 | 3.1 | 0.3 | 120.0 | -14.5 | 0.3 | 120.0 | 12.0 | -45.7 | 94.2 | -120.0 | 0.0 | 0.0 |
| | | LM | 58.3 | 1.1 | 104.2 | 148.2 | -0.3 | 180.0 | 165.5 | -0.3 | 180.0 | 168.0 | -75.3 | 85.8 | 0.0 | 0.0 | 0.0 |
| 106:20:00 | CSM/LM docking, inertial attitude hold | CSM | 58.1 | 1.2 | 64.0 | 10.0 | 0.3 | 120.0 | -14.5 | 0.3 | 120.0 | 12.0 | -45.7 | 94.2 | -120.0 | 0.0 | 0.0 |
| | | LM | 58.1 | 1.2 | 64.0 | -140.0 | -0.3 | 180.0 | 165.5 | -0.3 | 180.0 | 168.0 | -75.3 | 85.8 | 0.0 | 0.0 | 0.0 |
| 106:43:56 | Enter lunar umbra | CSM | 57.5 | 0.1 | -9.7 | 109.9 | 0.3 | 120.0 | -14.5 | 0.3 | 120.0 | 12.0 | -45.7 | No line of sight | | | |
| 106:50:45 | Maneuver to LM jettison attitude, inertial attitude hold | CSM | 57.4 | -0.2 | -30.0 | -150.0 | 0.0 | -60.0 | 70.3 | 0.0 | -60.0 | 95.1 | -115.4 | No line of sight | | | |
| 107:18:21 | Lose MSFN line of sight | CSM | 57.5 | -1.2 | -114.6 | 65.4 | 0.0 | -60.0 | 70.3 | 0.0 | -60.0 | No line of sight | | No line of sight | | | |
| 107:30:17 | Enter sunlight | CSM | 57.8 | -0.8 | -151.2 | -28.9 | 0.8 | -60.0 | 70.3 | 0.0 | -60.0 | No line of sight | | No line of sight | | | |
| 108:04:34 | Acquire MSFN line of sight | CSM | 58.3 | 1.1 | 104.3 | 75.7 | 0.8 | -60.0 | 70.3 | 0.0 | -60.0 | 95.1 | -115.4 | No line of sight | | | |
| 108:09:24 | Complete LM jettison, start CSM evasive maneuver | CSM | 58.3 | 1.2 | 90.0 | 89.9 | 0.0 | -60.0 | 70.3 | 0.0 | -60.0 | 95.2 | -115.4 | 9.5 | 61.5 | 0.0 | 0.0 |
| | | LM | 58.3 | 1.2 | 90.0 | -90.0 | 0.0 | 0.0 | -109.6 | 0.0 | 0.0 | 84.7 | -4.6 | 170.6 | 178.3 | 0.0 | 0.0 |
| 108:09:29 | CSM complete evasive maneuver, maneuver to LM observation attitude, inertial attitude hold | CSM | 58.3 | 1.2 | 89.7 | -75.0 | 0.0 | 180.0 | -94.8 | 0.0 | 180.0 | 70.0 | 175.1 | 174.6 | -177.1 | 15.2 | 0.0 |
| | | LM | 58.3 | 1.2 | 89.7 | -89.7 | 0.0 | 0.0 | -109.6 | 0.0 | 0.0 | 84.7 | -4.6 | 170.6 | 178.3 | 179.5 | 0.0 |
| 108:38:57 | LM unmanned APS burn to depletion ignition | CSM | 57.9 | 0.4 | 0.0 | 14.4 | 0.0 | 180.0 | -94.8 | 0.0 | 180.0 | 70.5 | 175.1 | 174.7 | -177.1 | 41.2 | 0.0 |
| | | LM | 57.6 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | -109.6 | 0.0 | 0.0 | 85.2 | -4.6 | 170.6 | 178.3 | 153.5 | 0.0 |
| 108:42:30 | CSM and LM enter umbra | CSM | 57.8 | 0.1 | -10.8 | 25.3 | 0.0 | 180.0 | -94.8 | 0.0 | 180.0 | 70.6 | 175.2 | 174.7 | -177.1 | 15.1 | 0.0 |
| | | LM | 71.1 | 0.0 | -14.4 | 14.1 | 0.0 | 0.0 | -109.6 | 0.0 | 0.0 | 85.2 | -4.6 | 170.6 | 178.3 | 179.6 | 0.0 |

# Table II. Spacecraft Attitude and Trajectory Data
## (c) Lunar Orbit
## Part 3: LM APS Burn to Depletion Cutoff to TEI Burn Ignition

| Mission Time (hr:min:sec) | Event | Selenographic Position | | | Local Horizontal Attitude | | | IMU Gimbal Angles | | | Look Angles to Earth | | Look Angles to Sun | | Look Angles to Landmark | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Altitude (n mi) | Latitude (deg) | Longitude (deg) | Pitch (deg) | Yaw (deg) | Roll (deg) | IGA (deg) | MGA (deg) | OGA (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) | Shaft (deg) | Trunnion (deg) |
| 108:42:41 | LM unmanned APS burn to depletion cut off | 57.8 | 0.1 | -10.8 | 25.3 | 0.0 | 180.0 | -94.8 | 0.0 | 180.0 | 70.6 | 175.2 | No line of sight | | | |
| 109:00:00 | Maneuver to sleep attitude, inertial attitude hold | 57.4 | -0.9 | -64.1 | 23.5 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | 125.6 | -140.6 | No line of sight | | | |
| 109:16:43 | Lose MSFN line of sight | 57.3 | -1.2 | -115.0 | 73.2 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | No line of sight | | No line of sight | | | |
| 109:28:50 | Enter sunlight | 57.5 | -0.9 | -152.0 | 111.1 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | No line of sight | | 130.4 | 44.6 | | |
| 110:02:53 | Acquire MSFN line of sight | 58.2 | 1.0 | 104.2 | -149.4 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | 125.6 | -140.5 | 130.4 | 44.6 | | |
| 110:40:59 | Enter lunar umbra | 57.8 | 0.1 | -11.8 | -35.9 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | 126.2 | -140.6 | No line of sight | | | |
| 111:14:55 | Lose MSFN line of sight | 57.3 | -1.2 | -115.2 | 73.5 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | No line of sight | | No line of sight | | | |
| 111:27:19 | Enter sunlight | 57.5 | -0.9 | -153.1 | 111.1 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | No line of sight | | 130.3 | 44.6 | | |
| 112:01:11 | Acquire MSFN line of sight | 58.2 | 1.0 | 103.8 | -149.1 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | 126.6 | -140.5 | 130.3 | 44.6 | | |
| 112:39:30 | Enter lunar umbra | 57.8 | 0.2 | -12.9 | -29.7 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | 127.2 | -140.6 | No line of sight | | | |
| 113:13:10 | Lose MSFN line of sight | 57.3 | -1.2 | -115.4 | 72.5 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | No line of sight | | No line of sight | | | |
| 113:25:50 | Enter sunlight | 57.5 | -0.8 | -154.1 | 111.1 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | No line of sight | | 130.3 | 44.6 | | |
| 113:59:30 | Acquire MSFN line of sight | 58.2 | 1.0 | 103.4 | -149.7 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | 127.6 | -140.5 | 130.2 | 44.6 | | |
| 114:37:59 | Enter lunar umbra | 57.8 | 0.1 | -13.8 | -29.9 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | 128.2 | -140.6 | No line of sight | | | |
| 115:11:26 | Lose MSFN line of sight | 57.3 | -1.2 | -115.6 | 71.6 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | No line of sight | | No line of sight | | | |
| 115:24:20 | Enter sunlight | 57.5 | -0.8 | -155.1 | 111.1 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | No line of sight | | 130.2 | 44.6 | | |
| 115:57:11 | Acquire MSFN line of sight | 58.2 | 1.0 | 104.9 | -149.3 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | 128.6 | -140.5 | 130.2 | 44.6 | | |
| 116:36:29 | Enter lunar umbra | 57.8 | 0.1 | -14.8 | -30.1 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | 129.2 | -140.5 | No line of sight | | | |
| 117:09:02 | Lose MSFN line of sight | 57.3 | -1.2 | -114.2 | 69.1 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | No line of sight | | No line of sight | | | |
| 117:22:50 | Enter sunlight | 57.5 | -0.9 | -156.1 | 110.9 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | No line of sight | | 130.1 | 44.6 | | |
| 117:55:25 | Acquire MSFN line of sight | 58.2 | 1.0 | 104.6 | -149.9 | 0.0 | 135.0 | -149.7 | 0.0 | 135.0 | 129.6 | -140.5 | 130.1 | 44.6 | | |
| 118:00:00 | Maneuver to initial attitude for oblique photography of LS2, local attitude hold | 58.3 | 1.1 | 92.7 | -8.6 | 0.0 | 180.0 | -21.4 | 0.0 | 180.0 | 4.5 | 169.4 | 161.6 | -179.7 | | |
| 118:19:29 | Start 0.5 deg/sec pitch rate for photography of LS2 | 58.2 | 1.0 | 81.4 | -8.0 | 0.0 | 180.0 | -80.4 | 0.0 | 180.0 | -1.0 | 175.2 | 156.8 | -179.2 | | |
| 118:22:04 | Terminate pitch rate, inertial attitude hold | 58.1 | 0.9 | 24.5 | -77.7 | 0.0 | 180.0 | -155.1 | 0.0 | 180.0 | 138.2 | 171.6 | 121.7 | -0.3 | | |
| 118:36:59 | Enter lunar umbra | 57.8 | 0.1 | -14.4 | -35.8 | 0.0 | 180.0 | -144.3 | 0.0 | 180.0 | 148.5 | 171.6 | No line of sight | | | |
| 118:55:00 | Begin IMU realignment | 57.4 | -1.1 | -66.1 | 61.7 | 0.0 | 180.0 | -155.1 | 0.0 | 180.0 | 135.9 | 175.6 | No line of sight | | | |
| 119:07:21 | Lose MSFN line of sight | 57.3 | -1.2 | -114.4 | 90.4 | 0.0 | 180.0 | -155.1 | 0.0 | 180.0 | No line of sight | | No line of sight | | | |
| 119:10:00 | Maneuver to strip photography attitude, local attitude hold | 57.3 | -1.2 | -122.7 | -76.0 | 0.0 | 180.0 | 75.9 | 0.0 | 180.0 | No line of sight | | No line of sight | | | |
| 119:21:19 | Enter sunlight | 57.5 | -0.9 | -157.1 | -76.9 | 0.0 | 180.0 | -21.4 | 0.0 | -180.0 | No line of sight | | 56.8 | -179.7 | | |
| 119:53:43 | Acquire MSFN line of sight | 58.2 | 1.0 | 104.2 | -78.0 | 0.0 | 180.0 | -77.0 | 0.0 | 180.0 | 57.9 | 175.1 | 157.3 | -178.1 | | |
| 119:55:00 | Maneuver at subsolar point to turn windows away from sun, continue strip photography, local attitude hold | 58.2 | 1.0 | 100.4 | -102.0 | 0.0 | 0.0 | -104.8 | 0.0 | 0.0 | 86.8 | -4.1 | 175.0 | 176.9 | | |

# Table II. Spacecraft Attitude and Trajectory Data
## (c) Lunar Orbit (Continued)
## Part 3: LM APS Burn to Depletion Cutoff to TEI Burn Ignition

| Mission Time (hr:min:sec) | Event | Selenographic Position | | | Local Horizontal Attitude | | | IMU Gimbal Angles | | | Look Angles to Earth | | Look Angles to Sun | | Look Angles to Landmark | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Altitude (n mi) | Latitude (deg) | Longitude (deg) | Pitch (deg) | Yaw (deg) | Roll (deg) | IGA (deg) | MGA (deg) | OGA (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) | Shaft (deg) | Trunnion (deg) |
| 120:06:00 | Yaw 20 deg to include LS1, local attitude hold | 58.3 | 1.2 | 66.9 | -102.0 | 20.0 | 0.0 | -138.1 | 20.0 | 0.0 | 118.8 | 6.5 | 137.3 | 156.3 | | |
| 120:17:00 | Yaw -20 deg, adjust attitude, continue strip photography, local attitude hold | 58.2 | 1.0 | 33.4 | -102.0 | 0.0 | 0.0 | -171.5 | 0.0 | 0.0 | 152.5 | -9.0 | 108.2 | 179.7 | | |
| 120:27:00 | Terminate strip photography, maneuver to IMU realignment attitude, inertial attitude hold | 58.0 | 0.5 | 2.9 | -164.3 | 0.0 | 0.0 | 95.3 | 0.0 | 0.0 | 113.7 | 174.9 | 15.0 | 179.4 | | |
| 120:33:29 | Enter lunar umbra | 57.8 | 0.1 | -16.8 | -144.6 | 0.0 | 0.0 | 95.3 | 0.0 | 0.0 | 113.6 | -175.9 | No line of sight | | | |
| 120:35:00 | Begin IMU realignment | 57.8 | -0.2 | -21.5 | -140.5 | 0.0 | 0.0 | 95.3 | 0.0 | 0.0 | 113.6 | -174.9 | No line of sight | | | |
| 121:05:40 | Lose MSFN line of sight | 57.3 | -1.2 | -114.9 | -47.1 | 0.0 | 0.0 | 95.3 | 0.0 | 0.0 | No line of sight | | No line of sight | | | |
| 121:14:00 | Start local attitude hold for landmark tracking | 57.4 | -1.1 | -140.3 | -22.0 | 0.0 | 0.0 | 95.3 | 0.0 | 0.0 | No line of sight | | No line of sight | | | |
| 121:19:49 | Enter sunlight | 57.5 | -0.9 | -158.1 | -22.0 | 0.0 | 0.0 | 77.5 | 0.0 | 0.0 | No line of sight | | 3.3 | 4.8 | | |
| 121:28:51 | Begin landmark tracking on $CP_1$ | 57.7 | -0.4 | 174.5 | -22.0 | 0.0 | 0.0 | 50.2 | 0.0 | 0.0 | No line of sight | | 30.2 | 0.5 | 18.3 | 39.8 |
| 121:42:50 | Begin landmark tracking on $CP_2$ | 58.0 | 0.5 | 131.8 | -22.0 | 0.0 | 0.0 | 7.7 | 0.0 | 0.0 | No line of sight | | 72.6 | 0.3 | 6.2 | 39.2 |
| 121:52:03 | Acquire MSFN line of sight | 58.2 | 1.0 | 103.7 | -22.0 | 0.0 | 0.0 | -20.1 | 0.0 | 0.0 | 8.7 | -27.9 | 106.0 | 0.3 | | |
| 121:56:06 | Begin landmark tracking on F-1 | 58.3 | 1.1 | 91.5 | -22.0 | 0.0 | 0.0 | -34.0 | 0.0 | 0.0 | 16.6 | -15.2 | 114.3 | 0.3 | 6.0 | 39.6 |
| 122:16:51 | Begin landmark tracking on 130 | 58.2 | 1.0 | 28.2 | -22.0 | 0.0 | 0.0 | -95.4 | 0.0 | 0.0 | 77.9 | -4.2 | 175.9 | 3.8 | 5.4 | 40.0 |
| 122:19:51 | Maneuver to IMU realignment attitude, inertial attitude hold | 58.1 | 0.8 | 19.1 | 175.0 | 0.0 | 0.0 | 92.4 | 0.0 | 0.0 | 109.9 | -175.7 | 12.0 | 178.7 | | |
| 122:31:59 | Enter lunar umbra | 57.8 | 0.1 | -17.4 | -148.2 | 0.0 | 0.0 | 92.4 | 0.0 | 0.0 | 109.6 | -175.7 | No line of sight | | | |
| 122:35:00 | Begin IMU realignment | 57.7 | 0.0 | -26.9 | -139.0 | 0.0 | 0.0 | 92.4 | 0.0 | 0.0 | 109.6 | -175.7 | No line of sight | | | |
| 123:03:56 | Lose MSFN line of sight | 57.3 | -1.2 | -115.3 | -51.0 | 0.0 | 0.0 | 92.4 | 0.0 | 0.0 | No line of sight | | No line of sight | | | |
| 123:13:22 | Start local attitude hold for landmark tracking | 57.4 | -1.1 | -144.0 | -22.0 | 0.0 | 0.0 | 92.4 | 0.0 | 0.0 | No line of sight | | No line of sight | | | |
| 123:18:19 | Enter sunlight | 57.5 | -0.9 | -159.1 | -22.0 | 0.0 | 0.0 | 77.6 | 0.0 | 0.0 | No line of sight | | 1.8 | 8.9 | | |
| 123:27:00 | Begin landmark tracking on $CP_1$ | 57.7 | -0.4 | 174.5 | -22.0 | 0.0 | 0.0 | 51.3 | 0.0 | 0.0 | No line of sight | | 29.1 | 0.6 | 18.4 | 40.1 |
| 123:41:00 | Begin landmark tracking on $CP_2$ | 58.0 | 0.5 | 131.8 | -22.0 | 0.0 | 0.0 | 8.8 | 0.0 | 0.0 | No line of sight | | 71.6 | 0.3 | 6.5 | 39.2 |
| 123:49:57 | Acquire MSFN line of sight | 58.2 | 1.0 | 104.6 | -22.0 | 0.0 | 0.0 | -18.5 | 0.0 | 0.0 | 4.3 | -68.8 | 99.0 | 0.3 | | |
| 123:54:17 | Begin landmark tracking on F-1 | 58.3 | 1.1 | 91.5 | -22.0 | 0.0 | 0.0 | -30.7 | 0.0 | 0.0 | 14.3 | -16.4 | 111.1 | 0.3 | 6.2 | 39.6 |
| 124:15:02 | Begin landmark tracking on 130 | 58.2 | 1.0 | 28.2 | -22.0 | 0.0 | 0.0 | -94.5 | 0.0 | 0.0 | 77.8 | -4.1 | 174.9 | 3.1 | 5.3 | 40.0 |
| 124:18:02 | Maneuver to IMU realignment attitude, inertial attitude hold | 58.1 | 0.8 | 19.1 | 175.0 | 0.0 | 0.0 | 93.4 | 0.0 | 0.0 | 110.0 | -175.8 | 12.9 | 178.8 | | |
| 124:30:28 | Enter lunar umbra | 57.8 | 0.1 | -18.8 | -147.1 | 0.0 | 0.0 | 93.4 | 0.0 | 0.0 | 109.7 | -175.8 | No line of sight | | | |
| 124:33:00 | Begin IMU realignment | 57.8 | 0.0 | -26.6 | -139.5 | 0.0 | 0.0 | 93.4 | 0.0 | 0.0 | 109.6 | -175.8 | No line of sight | | | |
| 125:02:12 | Lose MSFN line of sight | 57.3 | -1.2 | -115.6 | -50.7 | 0.0 | 0.0 | 93.4 | 0.0 | 0.0 | No line of sight | | No line of sight | | | |
| 125:11:33 | Start local attitude hold for landmark tracking | 57.4 | -1.1 | -144.0 | -22.0 | 0.0 | 0.0 | 93.4 | 0.0 | 0.0 | No line of sight | | No line of sight | | | |
| 125:16:49 | Enter sunlight | 57.5 | -0.9 | -160.1 | -22.0 | 0.0 | 0.0 | 77.7 | 0.0 | 0.0 | No line of sight | | 2.8 | 3.2 | | |
| 125:25:10 | Begin landmark tracking on $CP_1$ | 57.7 | -0.4 | 174.5 | -22.0 | 0.0 | 0.0 | 52.4 | 0.0 | 0.0 | No line of sight | | 28.1 | 0.6 | 18.7 | 40.2 |
| 125:39:10 | Begin landmark tracking on $CP_2$ | 58.4 | 0.5 | 131.8 | -22.0 | 0.0 | 0.0 | 9.9 | 0.0 | 0.0 | No line of sight | | 70.6 | 0.3 | 6.8 | 39.3 |

# Table II. Spacecraft Attitude and Trajectory Data
## (c) Lunar Orbit (Continued)
## Part 3: LM APS Burn to Depletion Cutoff to TEI Burn Ignition

| Mission Time (hr:min:sec) | Event | Selenographic Position | | | Local Horizontal Attitude | | | IMU Gimbal Angles | | | Look Angles to Earth | | Look Angles to Sun | | Look Angles to Landmark | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Altitude (n mi) | Latitude (deg) | Longitude (deg) | Pitch (deg) | Yaw (deg) | Roll (deg) | IGA (deg) | MGA (deg) | OGA (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) | Shaft (deg) | Trunnion (deg) |
| 125:48:14 | Acquire MSFN line of sight | 58.2 | 0.9 | 104.2 | -22.0 | 0.0 | 0.0 | -17.5 | 0.0 | 0.0 | 4.2 | -69.5 | 98.0 | 0.3 | | |
| 125:52:27 | Begin landmark tracking on F-1 | 58.3 | 1.1 | 91.5 | -22.0 | 0.0 | 0.0 | -29.6 | 0.0 | 0.0 | 14.2 | -16.2 | 110.1 | 0.3 | 6.2 | 39.6 |
| 125:13:12 | Begin landmark tracking on 130 | 58.2 | 1.0 | 28.2 | -22.0 | 0.0 | 0.0 | -93.4 | 0.0 | 0.0 | 77.8 | -4.0 | 173.9 | 2.6 | 5.0 | 39.7 |
| 126:[illegible]:12 | Maneuver to IMU realignment attitude, inertial attitude hold | 58.2 | 0.9 | 19.1 | 175.0 | 0.0 | 0.0 | 94.5 | 0.0 | 0.0 | 110.0 | -175.8 | 13.9 | 178.9 | | |
| 126:28:59 | Enter lunar umbra | 57.8 | 0.1 | -19.8 | -146.3 | 0.0 | 0.0 | 94.5 | 0.0 | 0.0 | 109.7 | -175.9 | No line of sight | | | |
| 126:30:00 | Begin IMU realignment | 57.8 | 0.0 | -22.9 | -148.1 | 0.0 | 0.0 | 94.5 | 0.0 | 0.0 | 109.7 | -175.9 | No line of sight | | | |
| 127:09:27 | Lose MSFN line of sight | 57.4 | -1.2 | -115.7 | -51.3 | 0.0 | 0.0 | 94.5 | 0.0 | 0.0 | No line of sight | | No line of sight | | | |
| 127:09:43 | Start local attitude hold for landmark tracking | 57.4 | -1.1 | -144.0 | -22.0 | 0.0 | 0.0 | 94.5 | 0.0 | 0.0 | No line of sight | | No line of sight | | | |
| 127:15:19 | Enter sunlight | 57.5 | -0.9 | -161.1 | -22.0 | 0.0 | 0.0 | 77.6 | 0.0 | 0.0 | No line of sight | | 4.8 | 3.3 | | |
| 127:23:21 | Begin landmark tracking on $CP_1$ | 57.7 | -0.4 | 174.5 | -22.0 | 0.0 | 0.0 | 53.4 | 0.0 | 0.0 | No line of sight | | 27.2 | 0.6 | 19.2 | 40.0 |
| 127:37:20 | Begin landmark tracking on $CP_2$ | 58.0 | 0.5 | 131.8 | -22.0 | 0.0 | 0.0 | 10.9 | 0.0 | 0.0 | No line of sight | | 69.6 | 0.3 | 7.1 | 39.3 |
| 127:46:32 | Acquire MSFN line of sight | 58.2 | 0.9 | 103.8 | -22.0 | 0.0 | 0.0 | -16.4 | 0.0 | 0.0 | 4.1 | -70.2 | 97.0 | 0.3 | | |
| 127:50:37 | Begin landmark tracking on F-1 | 58.3 | 1.1 | 91.5 | -22.0 | 0.0 | 0.0 | -28.5 | 0.0 | 0.0 | 14.1 | -15.9 | 109.1 | 0.3 | 6.2 | 39.6 |
| 128:11:22 | Begin landmark tracking on 130 | 58.2 | 1.0 | 28.2 | -22.0 | 0.0 | 0.0 | -92.2 | 0.0 | 0.0 | 77.6 | -3.9 | 172.8 | 2.2 | 5.0 | 39.7 |
| 128:14:20 | Maneuver to rest attitude, inertial attitude hold | 58.2 | 0.9 | 19.2 | -55.0 | 0.0 | 180.0 | -134.3 | 0.0 | 180.0 | 119.7 | 175.6 | 145.0 | -0.5 | | |
| 128:27:24 | Enter lunar umbra | 57.8 | 0.1 | -20.8 | -15.5 | 0.0 | 180.0 | -134.3 | 0.0 | 180.0 | 120.0 | 175.6 | No line of sight | | | |
| 128:58:27 | Lose MSFN line of sight | 57.3 | -1.2 | -115.2 | 78.6 | 0.0 | 180.0 | -134.3 | 0.0 | 180.0 | No line of sight | | No line of sight | | | |
| 129:13:44 | Enter sunlight | 57.5 | -0.9 | -162.1 | 126.5 | 0.0 | 180.0 | -134.3 | 0.0 | 180.0 | No line of sight | | 145.0 | -0.5 | | |
| 129:44:51 | Acquire MSFN line of sight | 58.2 | 0.9 | 103.4 | -140.1 | 0.0 | 180.0 | -134.3 | 0.0 | 180.0 | 120.3 | 175.7 | 145.0 | -0.5 | | |
| 130:25:58 | Enter lunar umbra | 57.9 | 0.1 | -21.8 | -15.2 | 0.0 | 180.0 | -134.3 | 0.0 | 180.0 | 121.0 | 175.6 | No line of sight | | | |
| 130:56:44 | Lose MSFN line of sight | 57.3 | -1.2 | -115.4 | 78.4 | 0.0 | 180.0 | -134.3 | 0.0 | 180.0 | No line of sight | | No line of sight | | | |
| 131:13:18 | Enter sunlight | 57.5 | -0.9 | -162.1 | 126.7 | 0.0 | 180.0 | -134.3 | 0.0 | 180.0 | No line of sight | | 144.9 | -0.5 | | |
| 131:42:54 | Acquire MSFN line of sight | 58.2 | 0.9 | 103.8 | -141.7 | 0.0 | 180.0 | -134.3 | 0.0 | 180.0 | 121.3 | 175.7 | 144.9 | -0.5 | | |
| 131:55:00 | End rest period, maneuver to initial attitude for oblique photography of LS, local attitude hold | 58.3 | 1.2 | 90.4 | -58.0 | 0.0 | 180.0 | -17.4 | 0.0 | 180.0 | 25.0 | 171.3 | 118.4 | -179.7 | | |
| 132:14:51 | Start 0.5 deg/sec pitch rate for photography of LS | 58.1 | 0.7 | 74.4 | -58 | 0.0 | 180.0 | -98.0 | 0.0 | 180.0 | 85.5 | 174.3 | 178.7 | -167.5 | | |
| 132:17:25 | Terminate pitch rate, inertial attitude hold | 58.0 | 0.6 | -1.5 | -77.7 | 0.0 | 180.0 | -175.5 | 0.0 | 180.0 | 162.6 | 167.7 | 103.8 | -9.3 | | |
| 132:20:25 | Maneuver to IMU realignment attitude, inertial attitude hold | 58.0 | 0.4 | -19.6 | -56.0 | 0.0 | 180.0 | -156.9 | 0.0 | 180.0 | 144.4 | 173.7 | 122.3 | -0.3 | | |
| 132:24:25 | Enter lunar umbra | 57.9 | 0.1 | -22.4 | -37.6 | 0.0 | 180.0 | -156.9 | 0.0 | 180.0 | 144.4 | 173.7 | No line of sight | | | |
| 132:30:00 | Begin IMU realignment | 57.7 | -0.4 | -24.7 | -21.1 | 0.0 | 180.0 | -156.9 | 0.0 | 180.0 | 144.6 | 173.7 | No line of sight | | | |
| 132 55:01 | Lose MSFN line of sight | 57.3 | -1.2 | -116.0 | 55.1 | 0.0 | 180.0 | -156.9 | 0.0 | 180.0 | No line of sight | | No line of sight | | | |
| 133:09:00 | Maneuver to attitude for photo targets of opportunity, local attitude hold | 57.3 | -1.2 | -161.1 | -45.0 | 0.0 | 180.0 | 87.9 | 0.0 | 180.0 | No line of sight | | No line of sight | | | |

# Table II. Spacecraft Attitude and Trajectory Data
## (c) Lunar Orbit (Continued)
## Part 3: LM APS Burn to Depletion Cutoff to TEI Burn Ignition

| Mission Time (hr:min:sec) | Event | Selenographic Position | | | Local Horizontal Attitude | | | IMU Gimbal Angles | | | Look Angles to Earth | | Look Angles to Sun | | Look Angles to Landmark | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Altitude (n mi) | Latitude (deg) | Longitude (deg) | Pitch (deg) | Yaw (deg) | Roll (deg) | IGA (deg) | MGA (deg) | OGA (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) | Shaft (deg) | Trunnion (deg) |
| 133:10:49 | Enter sunlight | 57.5 | -0.9 | -164.1 | -45.0 | 0.0 | 180.0 | 55.1 | 0.0 | 180.0 | No line of sight | | 29.4 | -179.4 | | |
| 133:41:11 | Acquire MSFN line of sight | 58.2 | 0.9 | 103.3 | -45.0 | 0.0 | 180.0 | -37.3 | 0.0 | 180.0 | 25.5 | 171.4 | 118.0 | -179.7 | | |
| 133:50:00 | Maneuver to landmark sighting attitude, local attitude hold | 58.3 | 1.1 | 76.5 | -22.0 | 0.0 | 0.0 | -40.9 | 0.0 | 0.0 | 29.2 | -5.1 | 121.7 | 0.4 | | |
| 134:02:15 | Begin landmark tracking on B1 | 58.3 | 1.2 | 39.2 | -22.0 | 0.0 | 0.0 | -78.1 | 0.0 | 0.0 | 66.4 | -3.9 | 159.0 | 0.8 | 22.5 | 39.5 |
| 134:14:08 | Begin landmark tracking on 150 | 58.1 | 0.7 | 3.1 | -22.0 | 0.0 | 0.0 | -114.2 | 0.0 | 0.0 | 102.7 | -3.7 | 165.0 | 178.9 | -4.7 | 39.5 |
| 134:17:08 | Roll 180 deg for communications, inertial attitude hold | 58.0 | 0.5 | -6.1 | -22.0 | 0.0 | 180.0 | -123.3 | 0.0 | 180.0 | 111.8 | 176.2 | 155.9 | -0.7 | | |
| 134:22:57 | Enter lunar umbra | 57.8 | 0.1 | -23.8 | -4.4 | 0.0 | 180.0 | -123.3 | 0.0 | 180.0 | 111.9 | 176.2 | No line of sight | | | |
| 134:53:13 | Lose MSFN line of sight | 57.3 | -1.2 | -116.1 | 87.6 | 0.0 | 180.0 | -123.3 | 0.0 | 180.0 | No line of sight | | No line of sight | | | |
| 135:09:18 | Enter sunlight | 57.5 | -0.9 | -165.1 | 136.5 | 0.0 | 180.0 | -123.3 | 0.0 | 180.0 | No line of sight | | 155.8 | -0.7 | | |
| 135:30:00 | Maneuver to strip photography attitude, local attitude hold | 58.0 | 0.4 | 131.8 | -102.0 | 0.0 | 0.0 | -64.7 | 0.0 | 0.0 | No line of sight | | 145.6 | 0.5 | | |
| 135:39:29 | Acquisition of MSFN line of sight | 58.2 | 0.9 | 103.0 | -102.0 | 0.0 | 0.0 | -93.5 | 0.0 | 0.0 | 82.6 | -3.5 | 174.4 | 2.3 | | |
| 135:45:23 | Yaw -20 deg to include highland site, local attitude hold | 58.3 | 1.1 | 85.0 | -102.0 | -20.0 | 0.0 | -111.4 | -20.0 | 0.0 | 98.6 | -6.9 | 156.9 | -122.9 | | |
| 136:03:30 | Yaw 20 deg, adjust attitude, continue strip photography, local attitude hold | 58.2 | 1.1 | 29.9 | -102.0 | 0.0 | 0.0 | -166.4 | 0.0 | 0.0 | 155.5 | -8.4 | 112.7 | 179.7 | | |
| 136:20:00 | Maneuver to TEI attitude, rolled 180 deg, inertial attitude hold | 58.0 | 0.2 | -20.4 | 166.9 | -0.2 | 0.0 | 52.4 | -0.2 | 0.0 | 62.8 | -176.1 | 28.5 | 1.0 | | |
| 136:21:28 | Enter lunar umbra | 57.9 | 0.1 | -24.8 | 171.3 | -0.2 | 0.0 | 52.4 | -0.2 | 0.0 | 62.7 | -176.1 | No line of sight | | | |
| 136:35:00 | Begin IMU realignment | 57.5 | -0.7 | -66.1 | -147.5 | -0.2 | 0.0 | 52.4 | -0.2 | 0.0 | 62.6 | -176.1 | No line of sight | | | |
| 136:45:00 | Roll 180 deg to TEI burn attitude, inertial attitude hold | 57.4 | -1.1 | -96.6 | -117.1 | -0.2 | 180.0 | 52.4 | -0.2 | 180.0 | 62.3 | 3.9 | No line of sight | | | |
| 136:51:28 | Lose MSFN line of sight | 57.3 | -1.2 | -116.2 | -97.5 | -0.2 | 180.0 | 52.4 | -0.2 | 180.0 | No line of sight | | No line of sight | | | |
| 137:07:48 | Enter sunlight | 57.5 | -0.9 | -166.1 | -47.8 | -0.2 | 180.0 | 52.4 | -0.2 | 180.0 | No line of sight | | 28.6 | -179.0 | | |
| 137:20:22 | TEI burn ignition | 58.8 | -0.1 | 155.6 | -9.6 | -0.2 | 180.0 | 52.4 | -0.2 | 180.0 | No line of sight | | 28.6 | -179.0 | | |

## Table II. Spacecraft Attitude and Trajectory Data
## (d) Transearth

| Mission Time (hr:min:sec) | Event | IMU Gimbal Angles | | | Look Angles to Earth | | Look Angles to Moon | | Look Angles to Sun | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | IGA (deg) | MGA (deg) | OGA (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) |
| 137:23:11 | TEI cutoff, maneuver to lunar surface observation attitude, inertial attitude hold | -39.2 | -0.4 | -179.7 | No line of sight | | 0.0 | 0.0 | 120.2 | -179.4 |
| 137:29:15 | Acquire MSFN | -39.2 | -0.4 | -179.7 | 29.4 | 173.2 | 29.3 | 0.0 | 120.2 | -179.4 |
| 138:00:00 | Begin IMU realignment, change to PTC REFSMMAT | Maneuver spacecraft as required | | | | | | | | |
| 138:30:00 | Begin PTC | -90.0 | 0.0 | 40.8 | 87.8 | -132.6 | 89.7 | -6.7 | 90.0 | 136.2 |
| 150:30:00 | Terminate PTC, begin IMU realignment | Maneuver spacecraft as required | | | | | | | | |
| 151:00:00 | Begin star-lunar landmark navigation sightings | Maneuver spacecraft as required | | | | | | | | |
| 152:20:00 | Midcourse correction | Maneuver spacecraft as required | | | | | | | | |
| 152:45:00 | Begin PTC | -90.0 | 0.0 | 130.9 | 87.9 | 136.0 | 89.3 | -76.6 | 90.0 | 45.6 |
| 165:00:00 | Terminate PTC, begin IMU realignment | Maneuver spacecraft as required | | | | | | | | |
| 165:20:00 | Begin star-earth horizon navigation sightings | Maneuver spacecraft as required | | | | | | | | |
| 165:45:00 | Begin PTC at 3 revolutions per hour roll rate without attitude control | -90.0 | 0.0 | 130.9 | 88.0 | 133.6 | 89.4 | -74.6 | 90.0 | 45.0 |
| 169:45:00 | Terminate PTC test, resume normal PTC | -90.0 | 0.0 | 130.9 | 88.1 | 132.5 | 89.4 | -74.2 | 90.0 | 44.8 |
| 171:00:00 | Terminate PTC, begin star-earth horizon navigation sightings | Maneuver spacecraft as required | | | | | | | | |
| 171:30:00 | Begin PTC | -90.0 | 0.0 | 40.9 | 88.1 | -138.1 | 89.5 | 16.0 | 90.0 | 134.8 |
| 174:30:00 | Terminate PTC, begin star-earth horizon navigation sightings | Maneuver spacecraft as required | | | | | | | | |
| 175:30:00 | Begin IMU realignment | Maneuver spacecraft as required | | | | | | | | |
| 176:50:00 | Midcourse correction | Maneuver spacecraft as required | | | | | | | | |

## Table II. Spacecraft Attitude and Trajectory Data
## (d) Transearth (Continued)

| Mission Time (hr:min:sec) | Event | IMU Gimbal Angles | | | Look Angles to Earth | | Look Angles to Moon | | Look Angles to Sun | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | IGA (deg) | MGA (deg) | OGA (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) | Theta (deg) | Phi (deg) |
| 177:15:00 | Begin PTC | -90.0 | 0.0 | -49.1 | 88.3 | -50.6 | 89.5 | 107.0 | 90.0 | -135.5 |
| 187:30:00 | Terminate PTC, begin IMU realignment, change to entry REFSMMAT | Maneuver spacecraft as required | | | | | | | | |
| 188:50:00 | Midcourse correction | Maneuver spacecraft as required | | | | | | | | |
| 189:50:00 | Maneuver to entry attitude, inertial attitude hold | 156.0 | 0.0 | 0.0 | 125.8 | 180.0 | 59.1 | 0.6 | 172.4 | 28.2 |
| 190:15:00 | Begin IMU realignment | Maneuver spacecraft as required | | | | | | | | |
| 191:33:00 | CM/SM separation | -92.7 | -45.0 | 0.0 | 74.8 | 19.2 | 64.8 | 151.0 | 73.2 | 23.1 |
| 191:50:32 | Entry interface | 156.0 | 0.0 | 0.0 | 114.0 | 0.0 | 58.3 | 0.5 | 172.3 | 27.9 |

Table III. F Mission IMU Matrices; Launch Date May 18, 1969; 72-Degree Launch Azimuth

Launch Pad

$$\begin{bmatrix}\bar{X}\\ \bar{Y}\\ \bar{Z}\end{bmatrix} = \begin{bmatrix} -0.80333901 & 0.07758623 & -0.59044622\\ 0.53013973 & 0.54483762 & -0.64969514\\ 0.27128991 & -0.83494449 & -0.4788209\end{bmatrix}$$

PTC

$$\begin{bmatrix}\bar{X}\\ \bar{Y}\\ \bar{Z}\end{bmatrix} = \begin{bmatrix} -0.5 & -0.8660254 & 0.0\\ -0.79453912 & 0.45872741 & 0.39784005\\ -0.34453959 & 0.19892003 & -0.91745479\end{bmatrix}$$

Landing Site

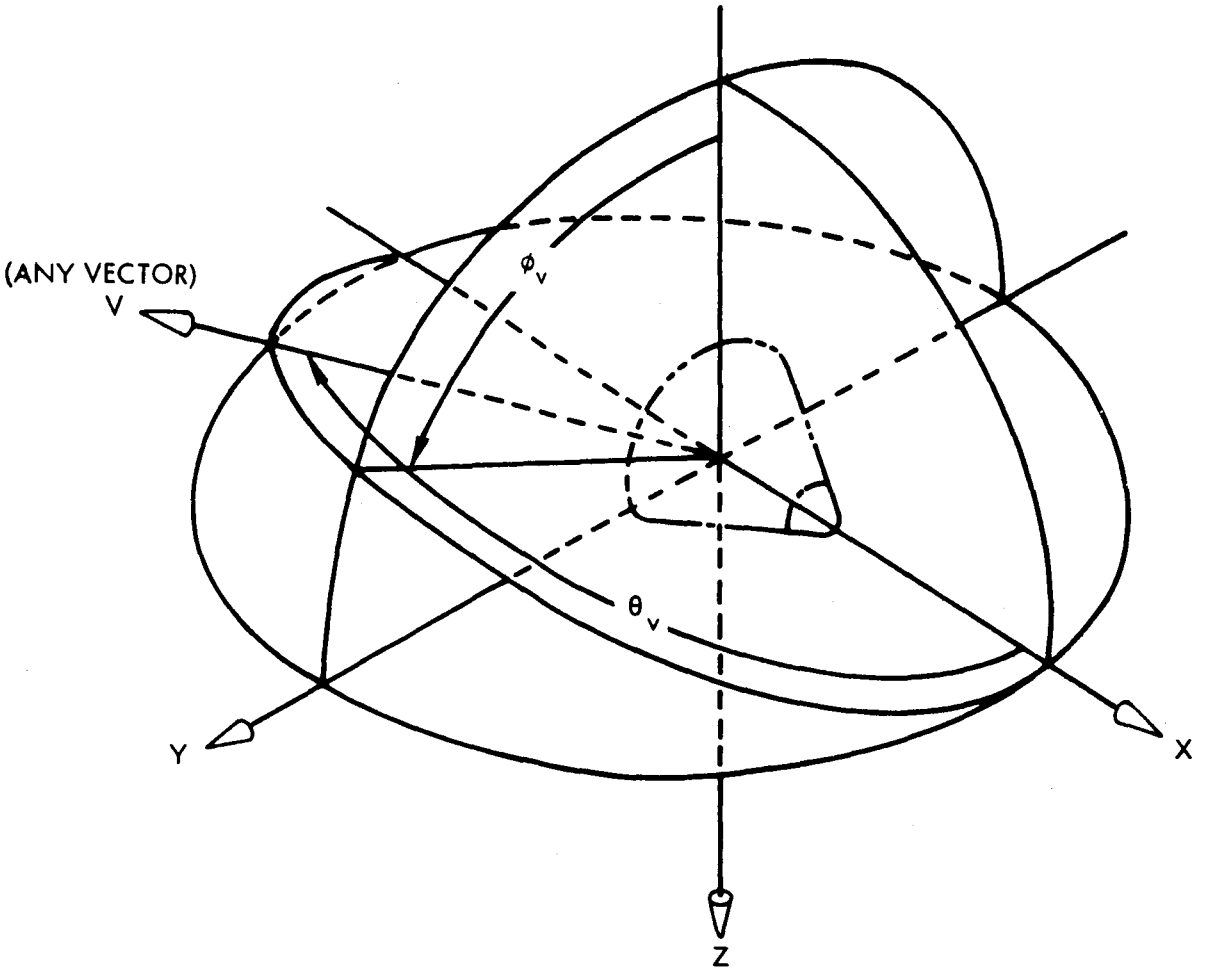
$$\begin{bmatrix}\bar{X}\\ \bar{Y}\\ \bar{Z}\end{bmatrix} = \begin{bmatrix} 0.95054742 & 0.01675490 & -0.31012723\\ -0.29246011 & -0.38436486 & -0.87563163\\ -0.10453089 & 0.92302923 & -0.37025716\end{bmatrix}$$

Entry

$$\begin{bmatrix}\bar{X}\\ \bar{Y}\\ \bar{Z}\end{bmatrix} = \begin{bmatrix} 0.82559319 & -0.00450212 & -0.56424786\\ 0.50208567 & 0.46219075 & 0.73095123\\ 0.25749931 & -0.88676912 & 0.38384198\end{bmatrix}$$

Table IV. Prime Landmark Tracking Targets for May 18, 1969 Launch

| Landmark Nomenclature | Latitude | Longitude | Altitude (n mi) |
|---|---|---|---|
| IP for CP1 | 0.000 | 178.438E | 0.00 |
| CP1 | 0.875N | 170.146E | 0.00 |
| IP for CP2 | 0.800N | 132.480E | 0.00 |
| CP2 | 1.000N | 127.400E | 0.00 |
| IP for F-1 | 1.280N | 93.840E | 0.00 |
| F-1 | 1.600N | 86.880E | 0.00 |
| IP for B1 | 1.505N | 40.105E | -0.97 |
| B1 (LS1 landmark) | 2.522N | 35.036E | -1.49 |
| IP for 130 | 1.885N | 28.726E | -1.03 |
| 130 (LS2 landmark) | 1.266N | 23.679E | -1.68 |
| IP for 150 | 0.300N | 3.383E | 0.30 |
| 150 (LS3 landmark) | 0.283N | 1.429W | -1.00 |




$\phi_v$ MEASURED FROM MINUS Z-BODY AXIS POSITIVELY ABOUT X-BODY AXIS TO VECTOR PROJECTION IN Y-Z PLANE

$\theta_v$ SMALLEST ANGLE FROM X-BODY AXIS TO VECTOR

Figure 1. Spacecraft Body Aspect Angles

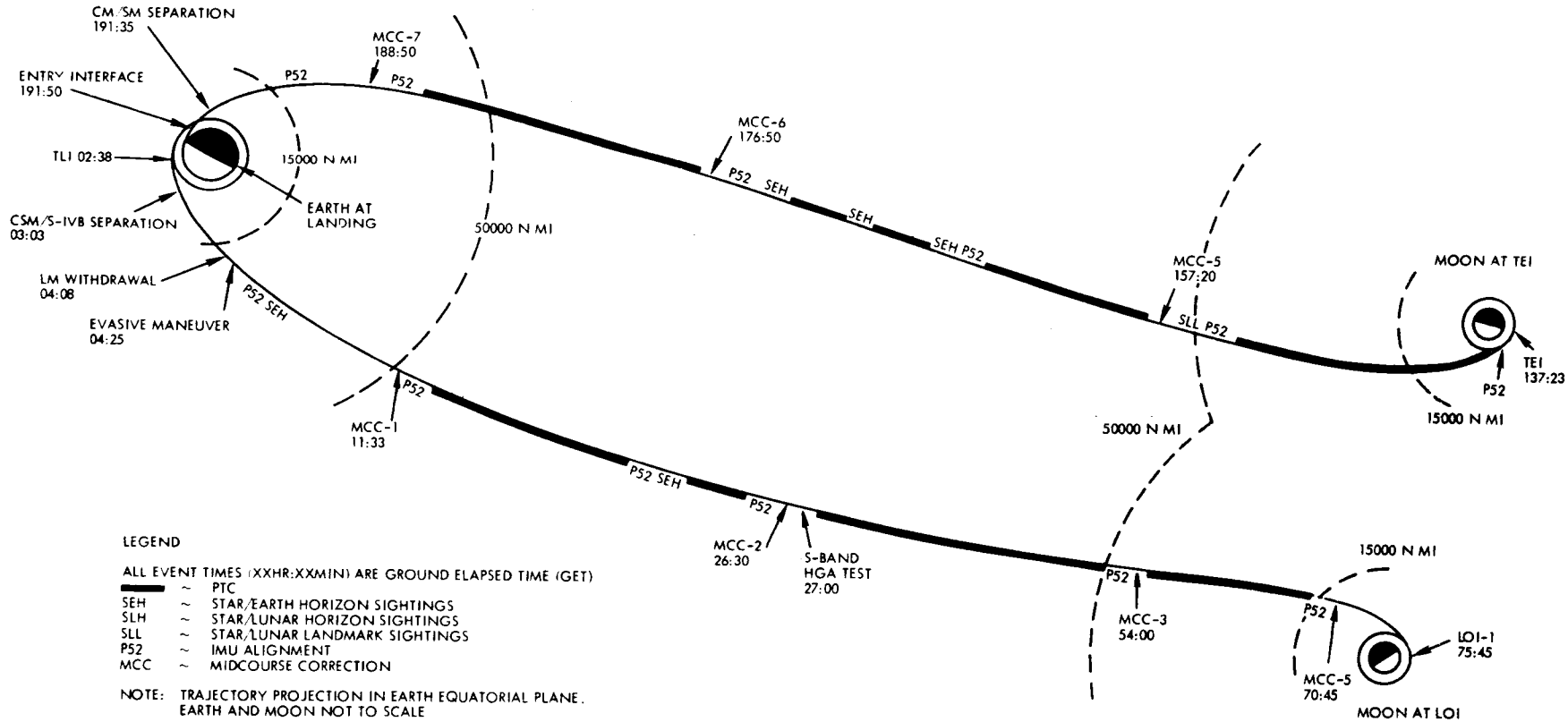



Figure 2. Cislunar Trajectory and Event Profile

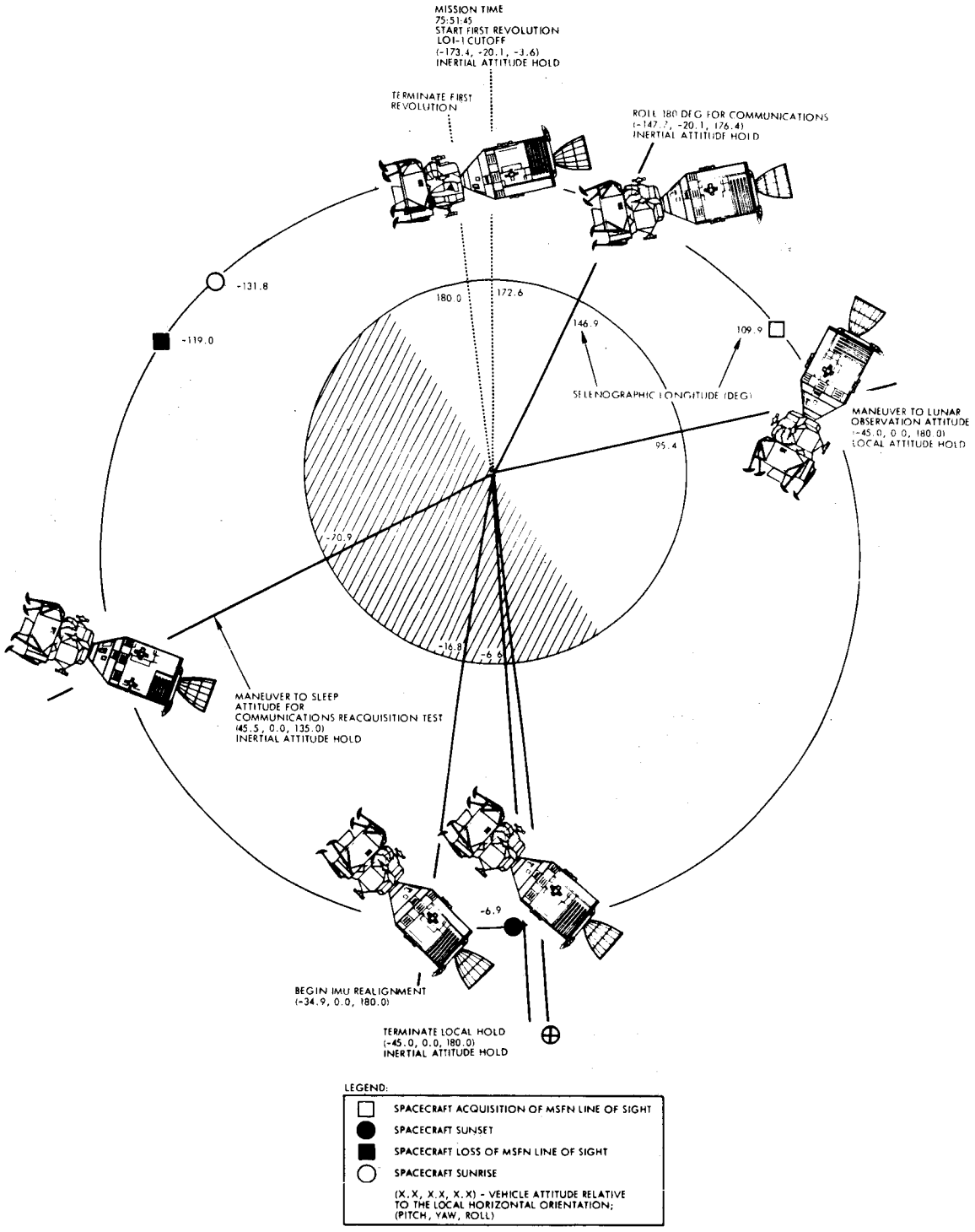



Figure 3. First Revolution Major Events and Attitudes

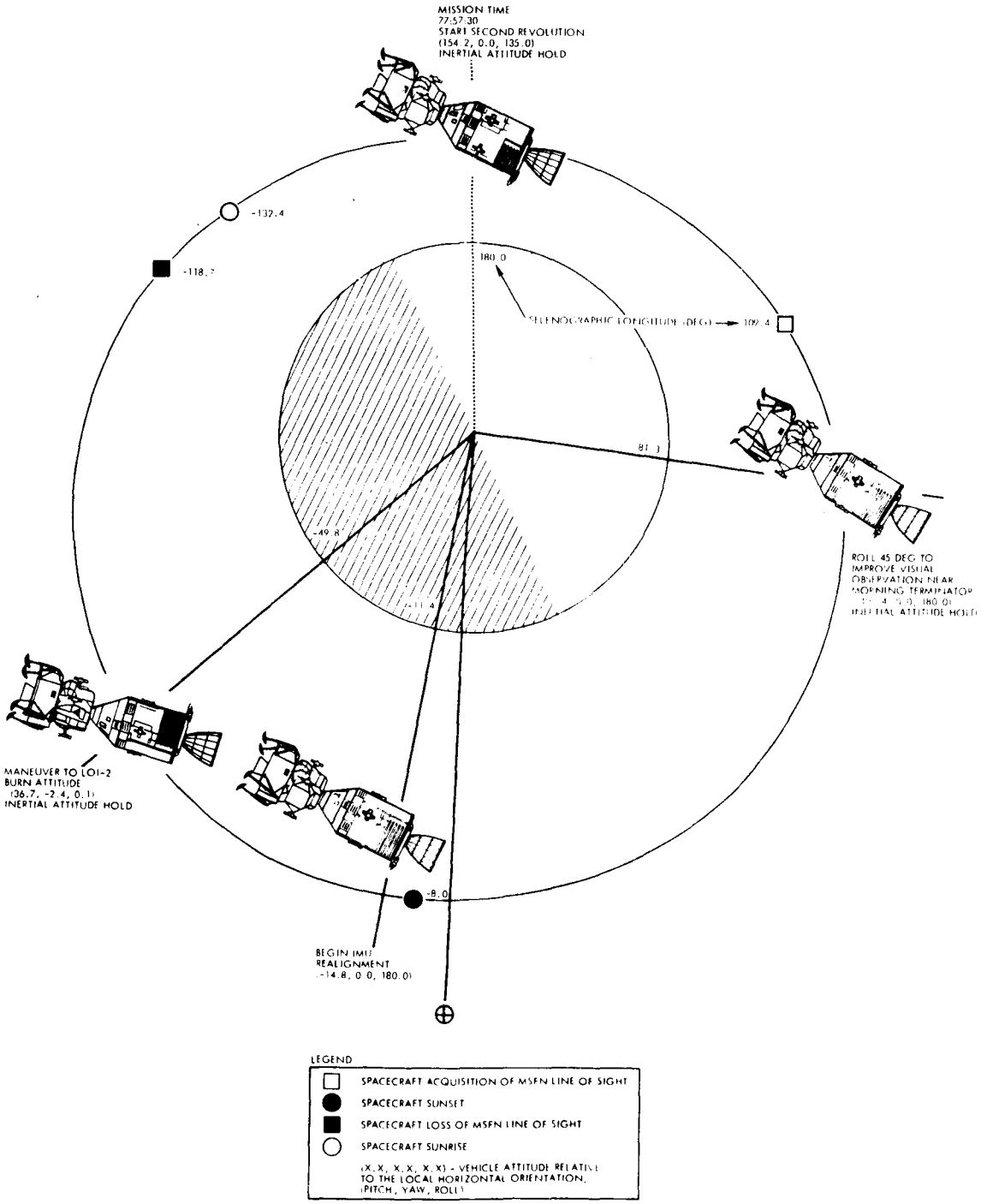



Figure 4. Second Revolution Major Events and Attitudes

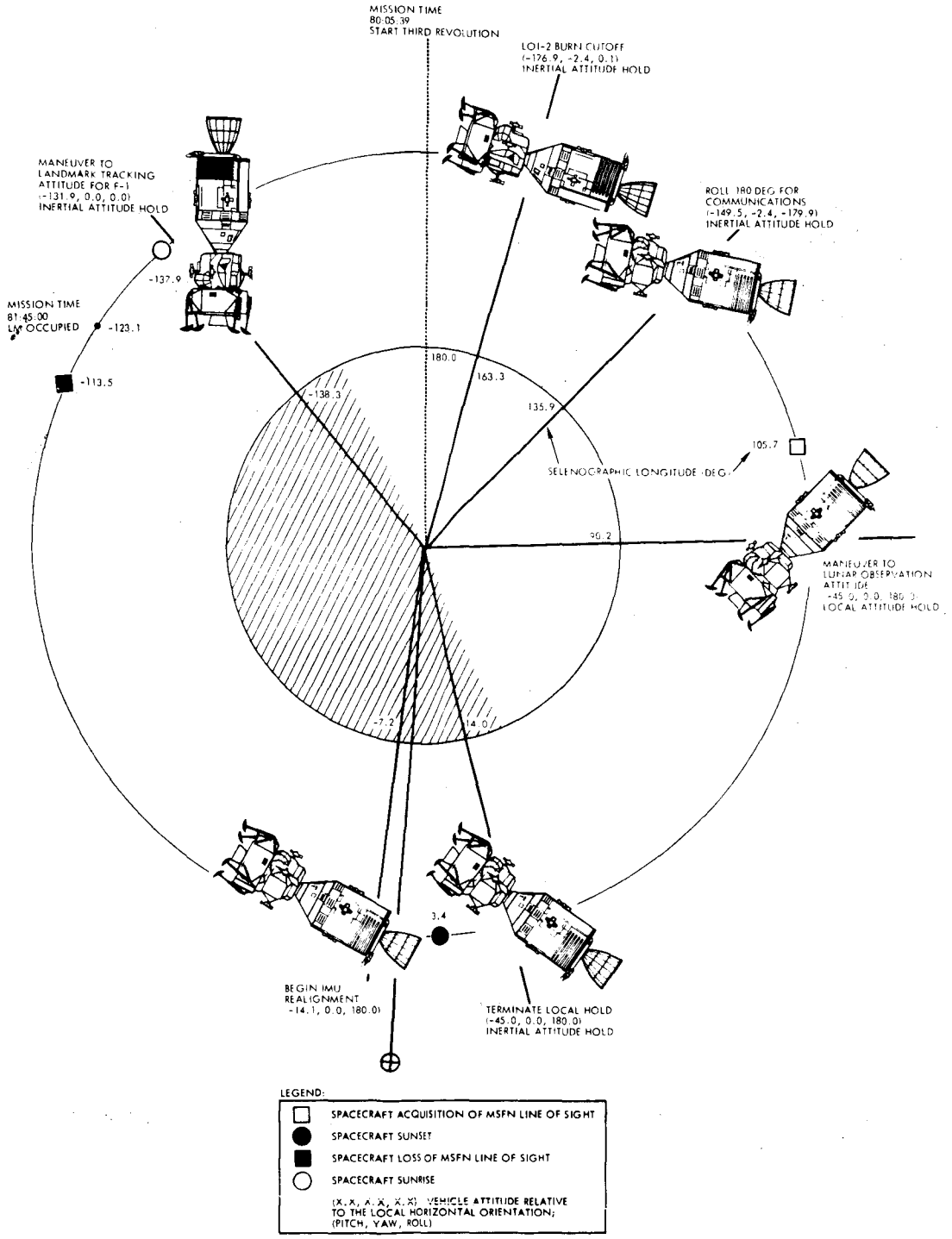



Figure 5. Third Revolution Major Events and Attitudes

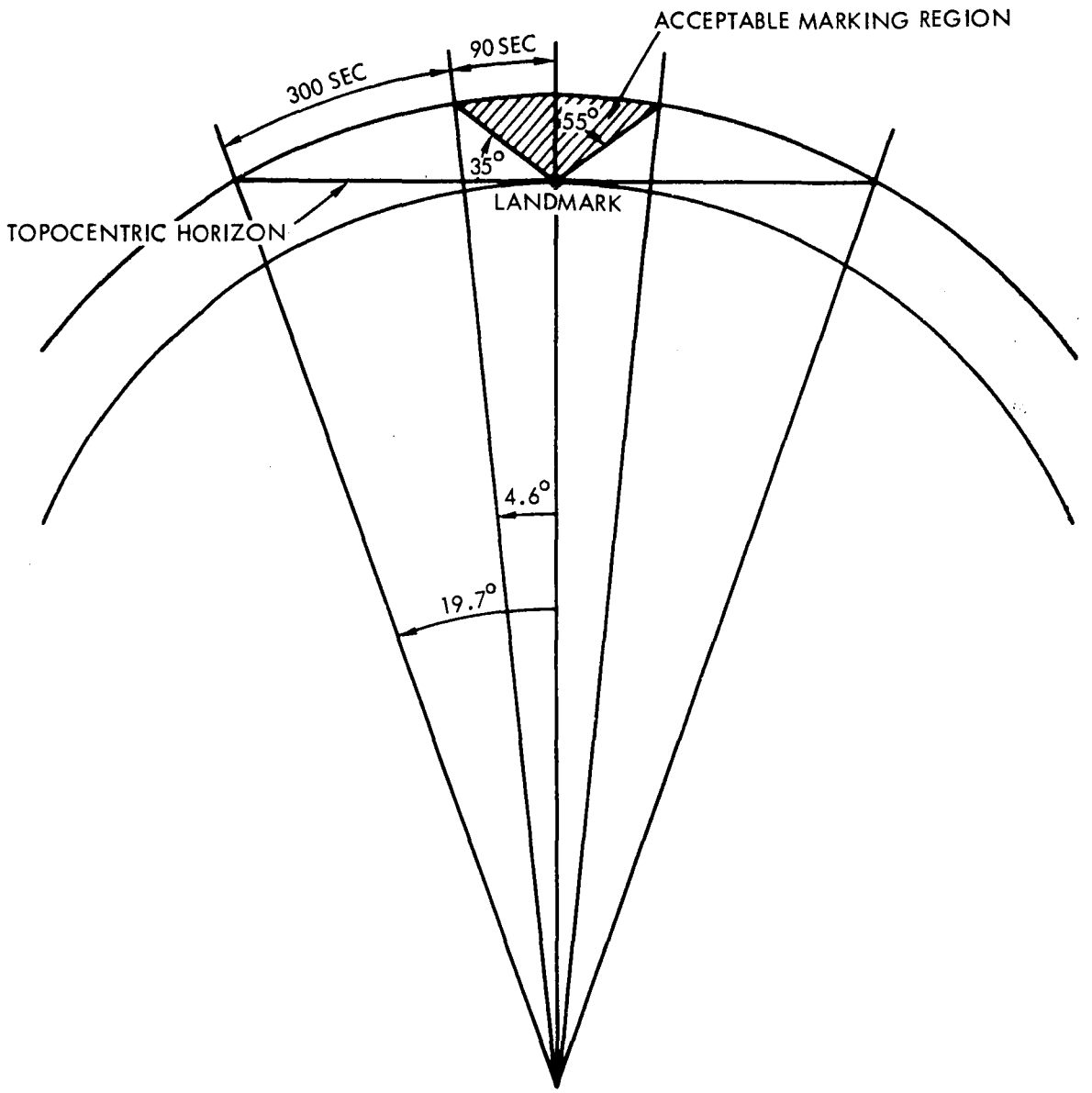



Figure 6. Landmark Tracking Geometry for a 60-Nautical Mile Circular Lunar Orbit

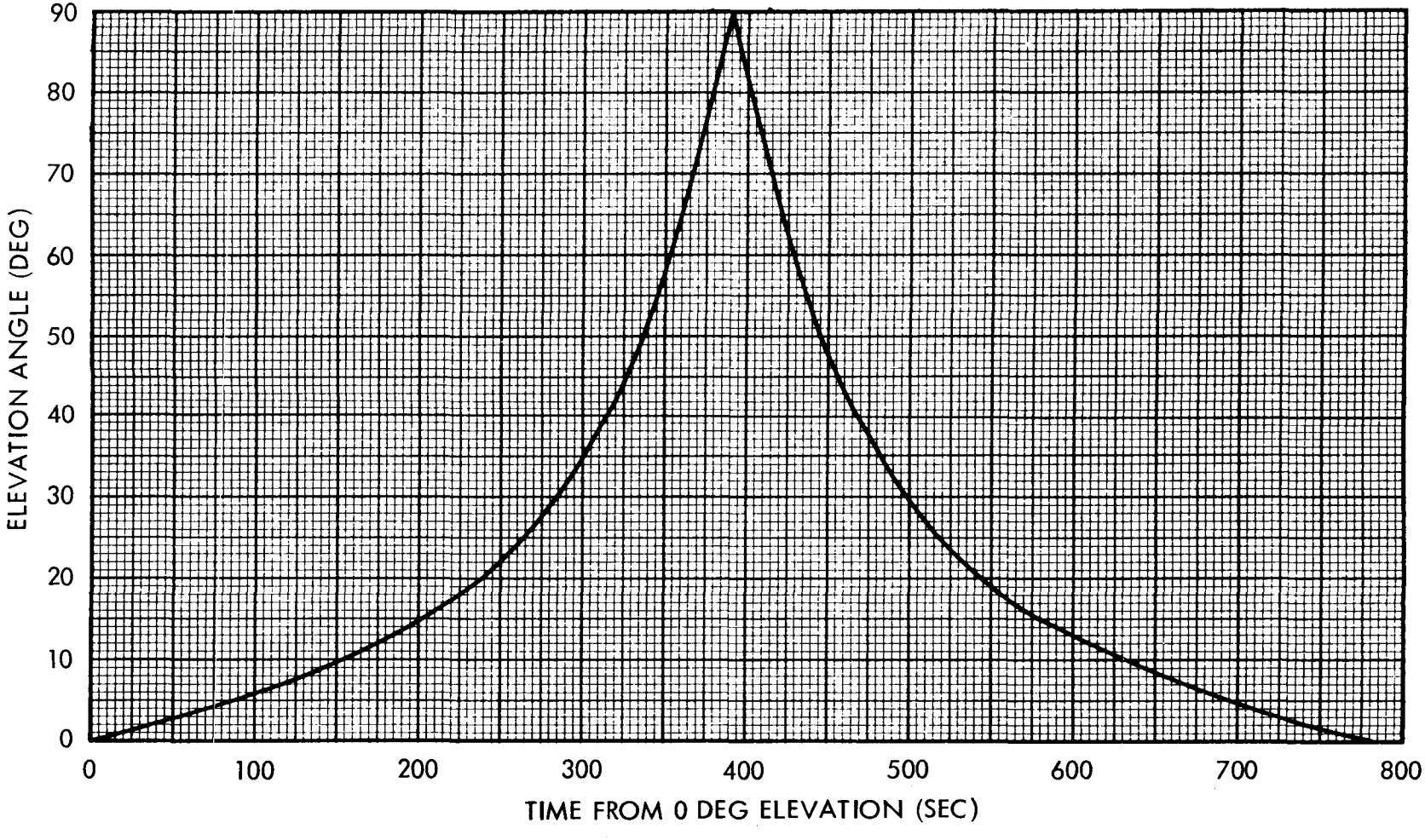



Figure 7. Elevation Angle versus Time Curve for In-plane Landmark

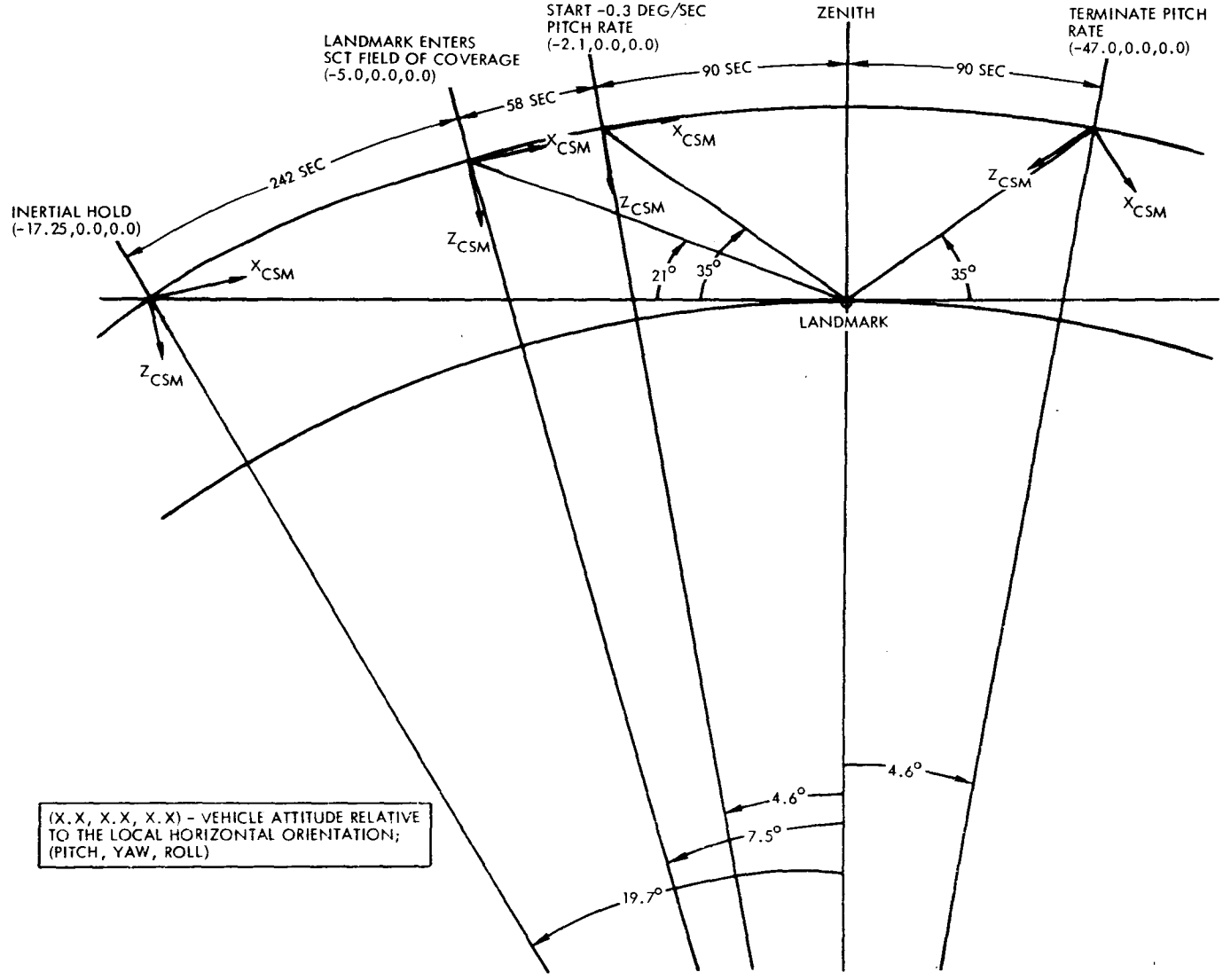



Figure 8. Tracking Geometry for Mode I Landmark Tracking

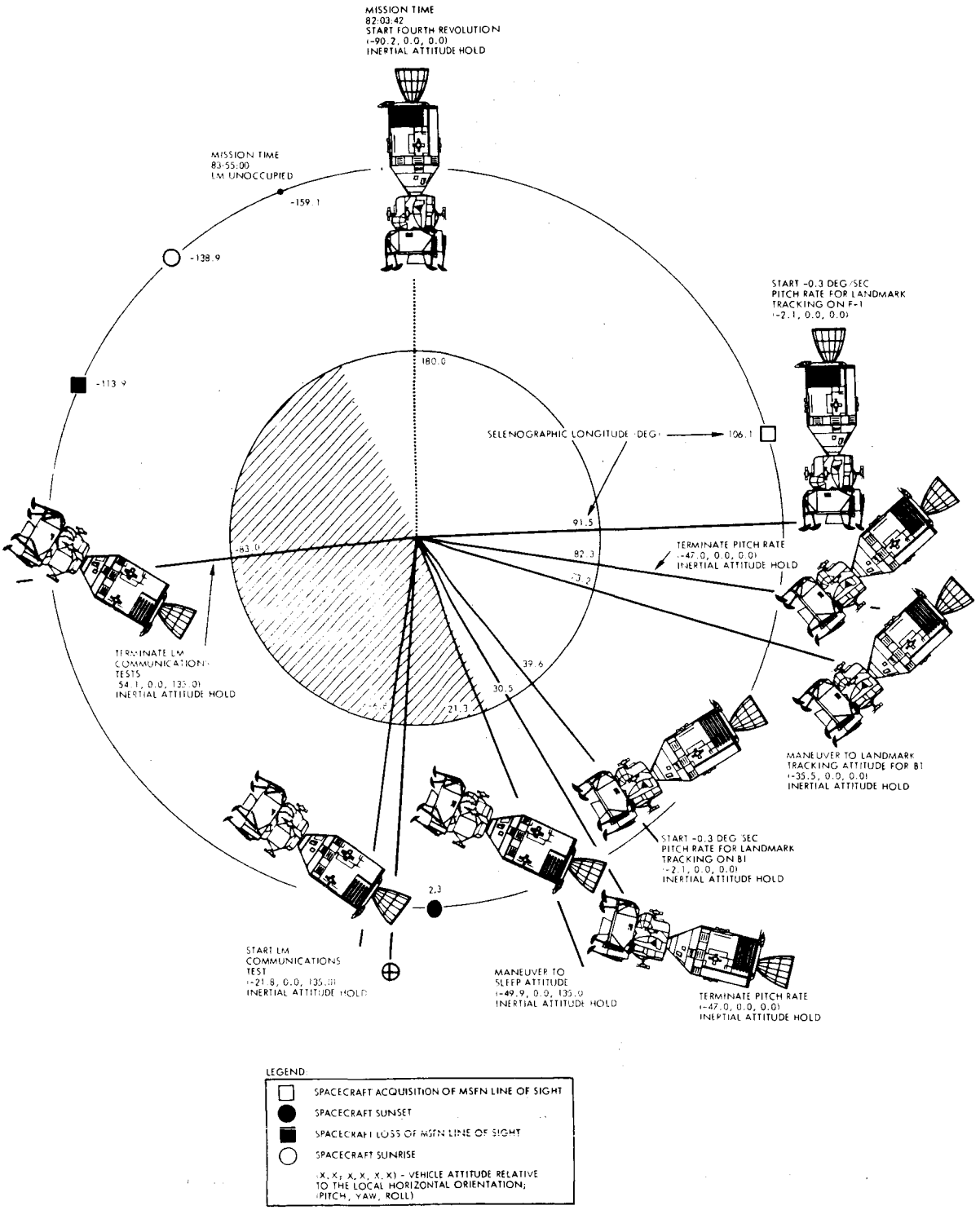



Figure 9. Fourth Revolution Major Events and Attitudes

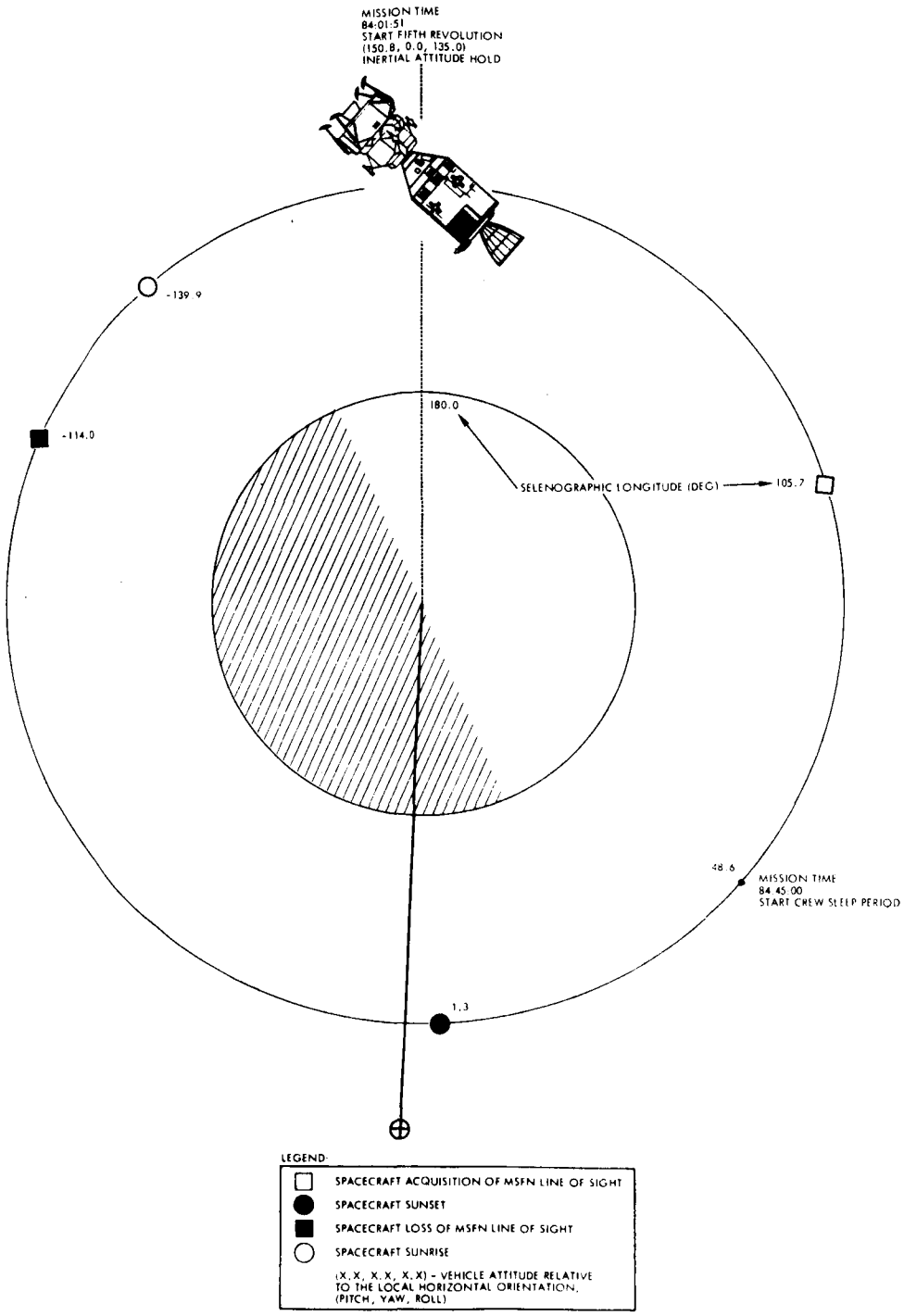



Figure 10. Fifth Revolution Major Events and Attitudes

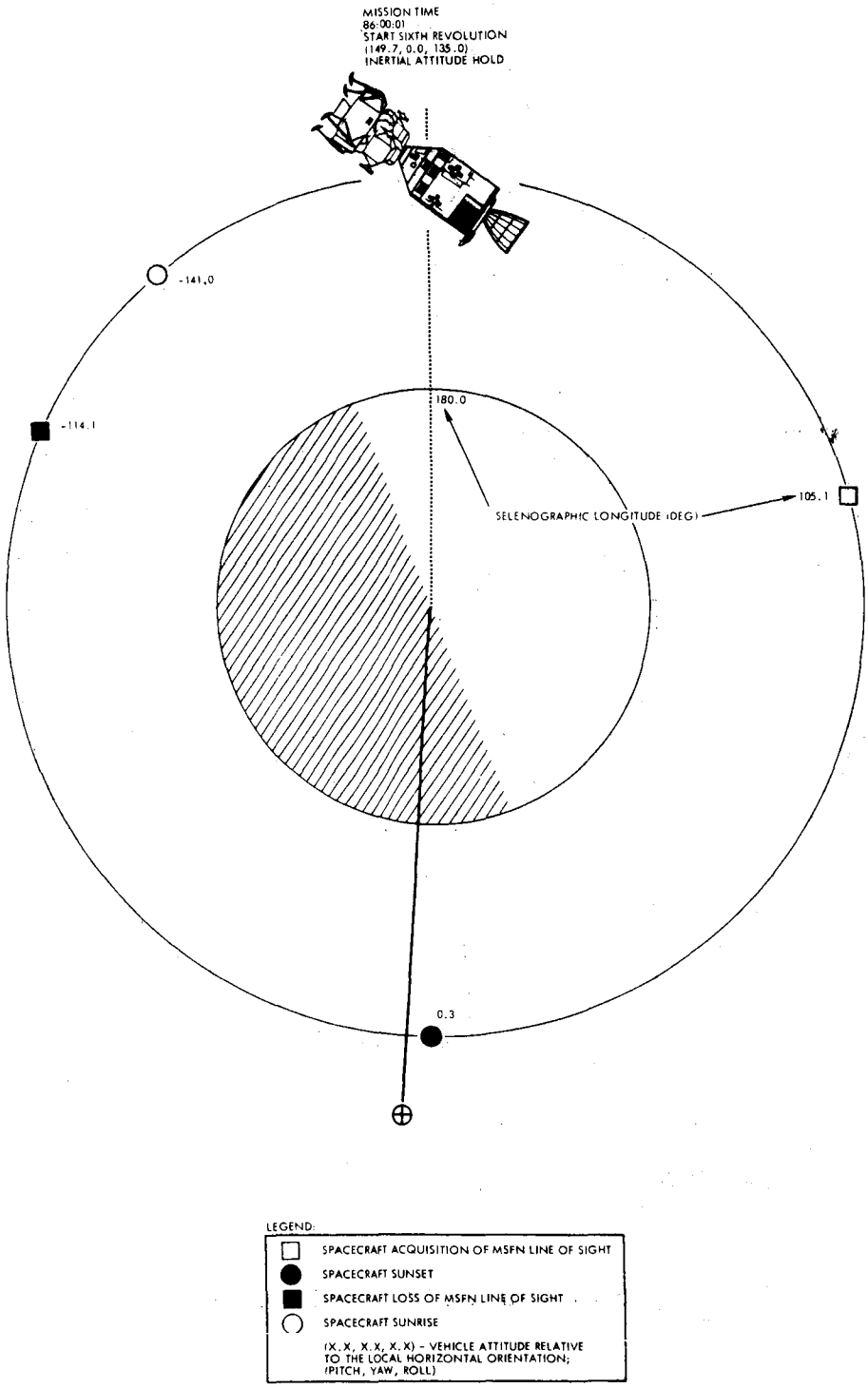



Figure 11. Sixth Revolution Major Events and Attitudes

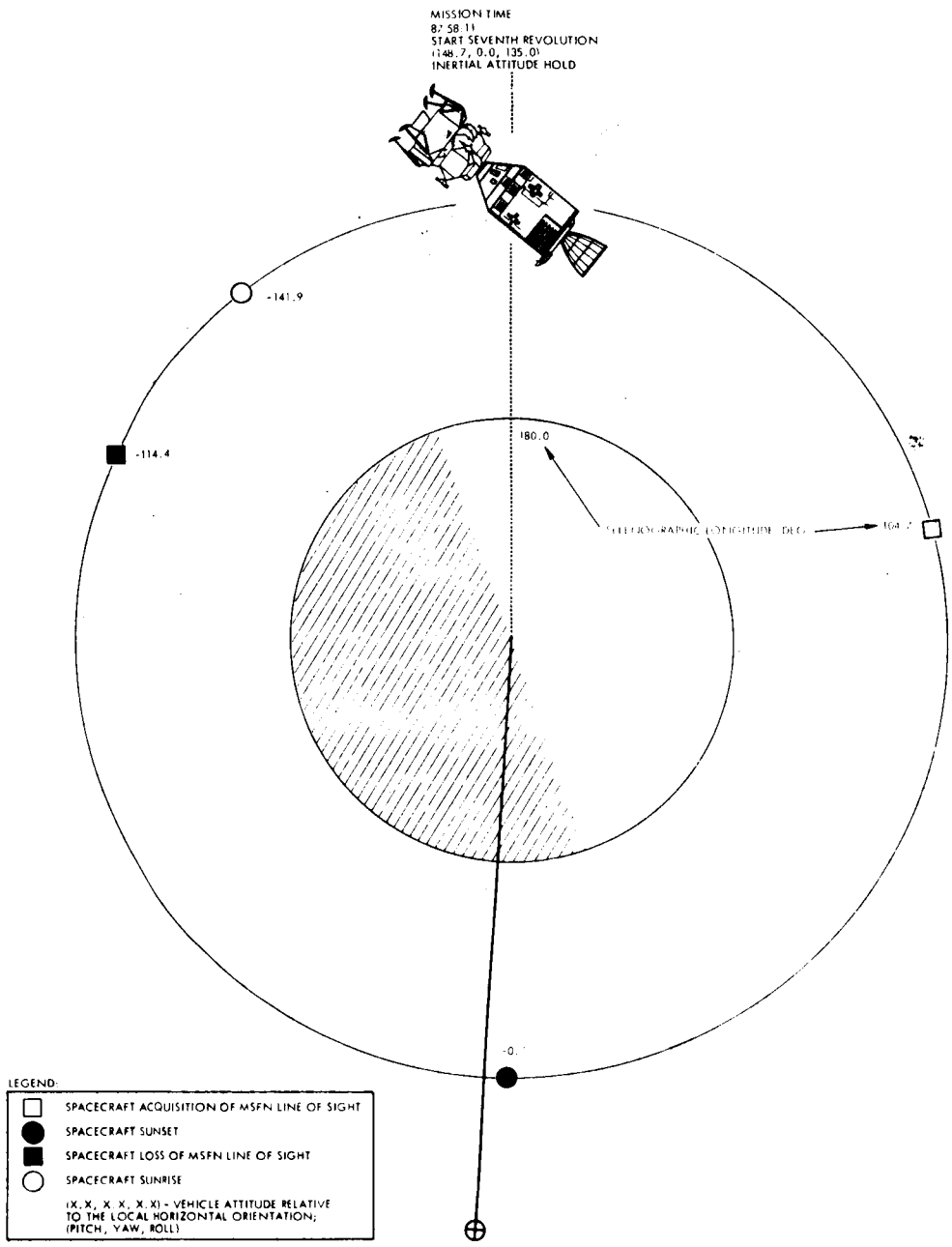



Figure 12. Seventh Revolution Major Events and Attitudes

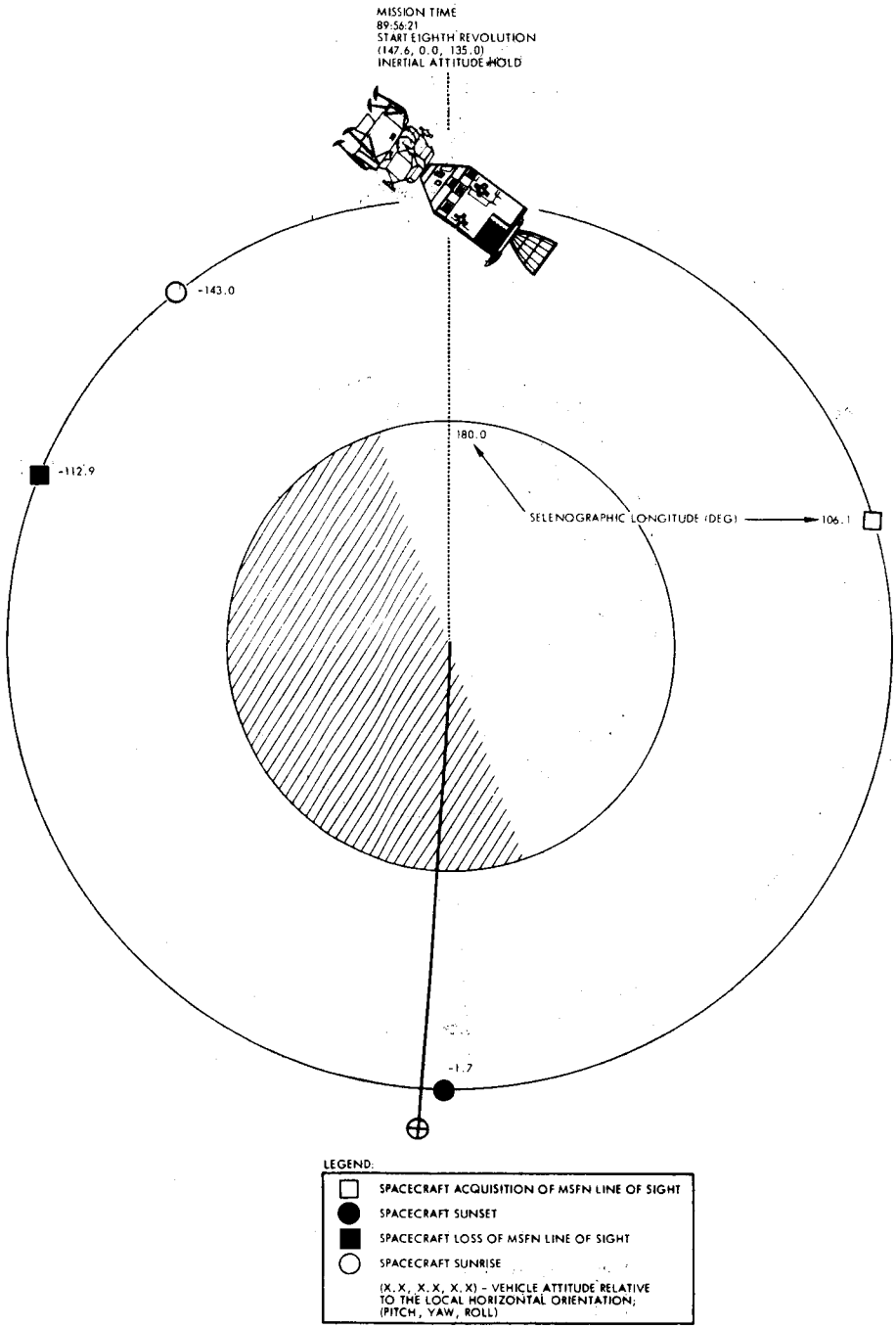



Figure 13. Eighth Revolution Major Events and Attitudes

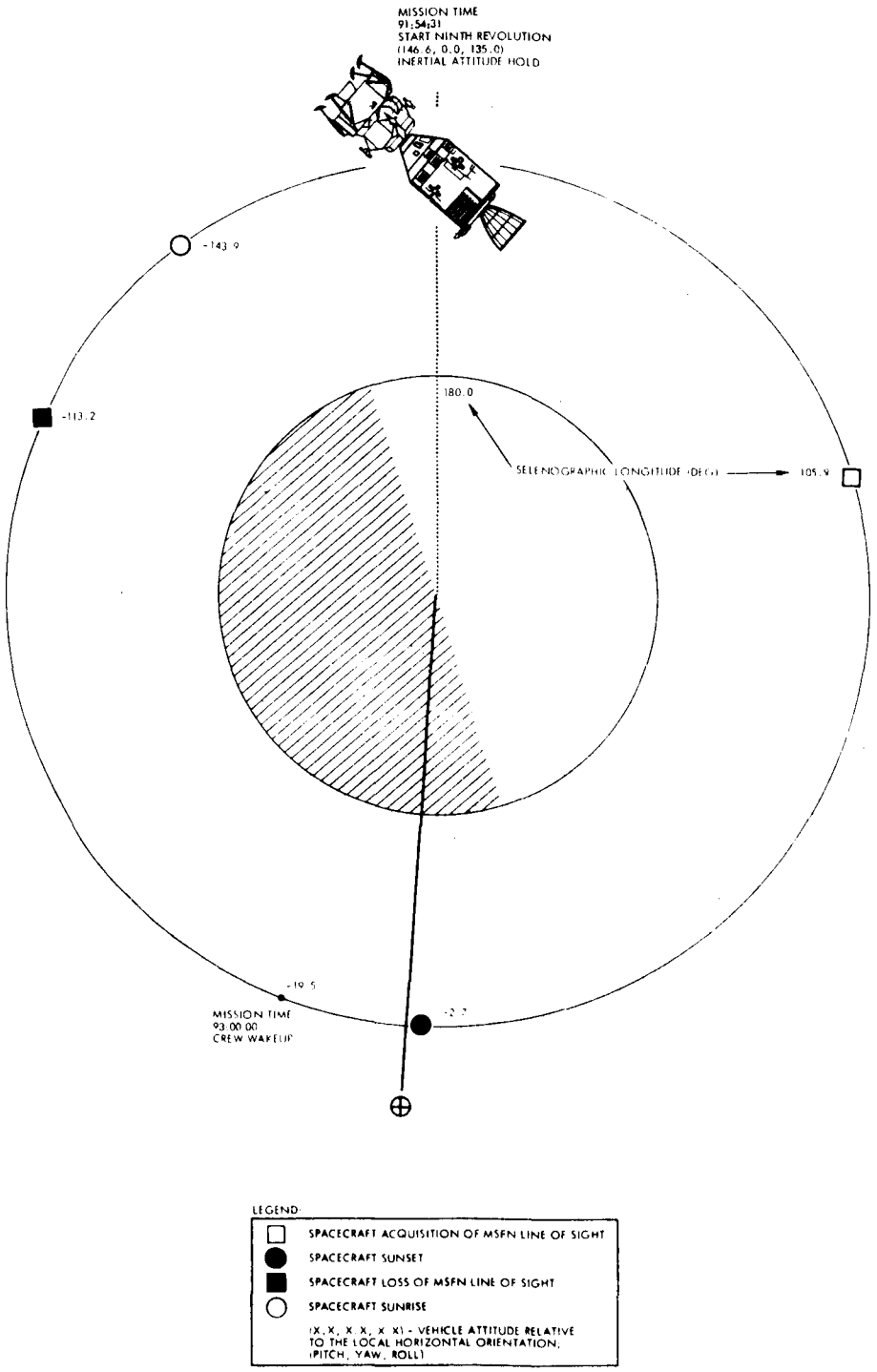



Figure 14. Ninth Revolution Major Events and Attitudes

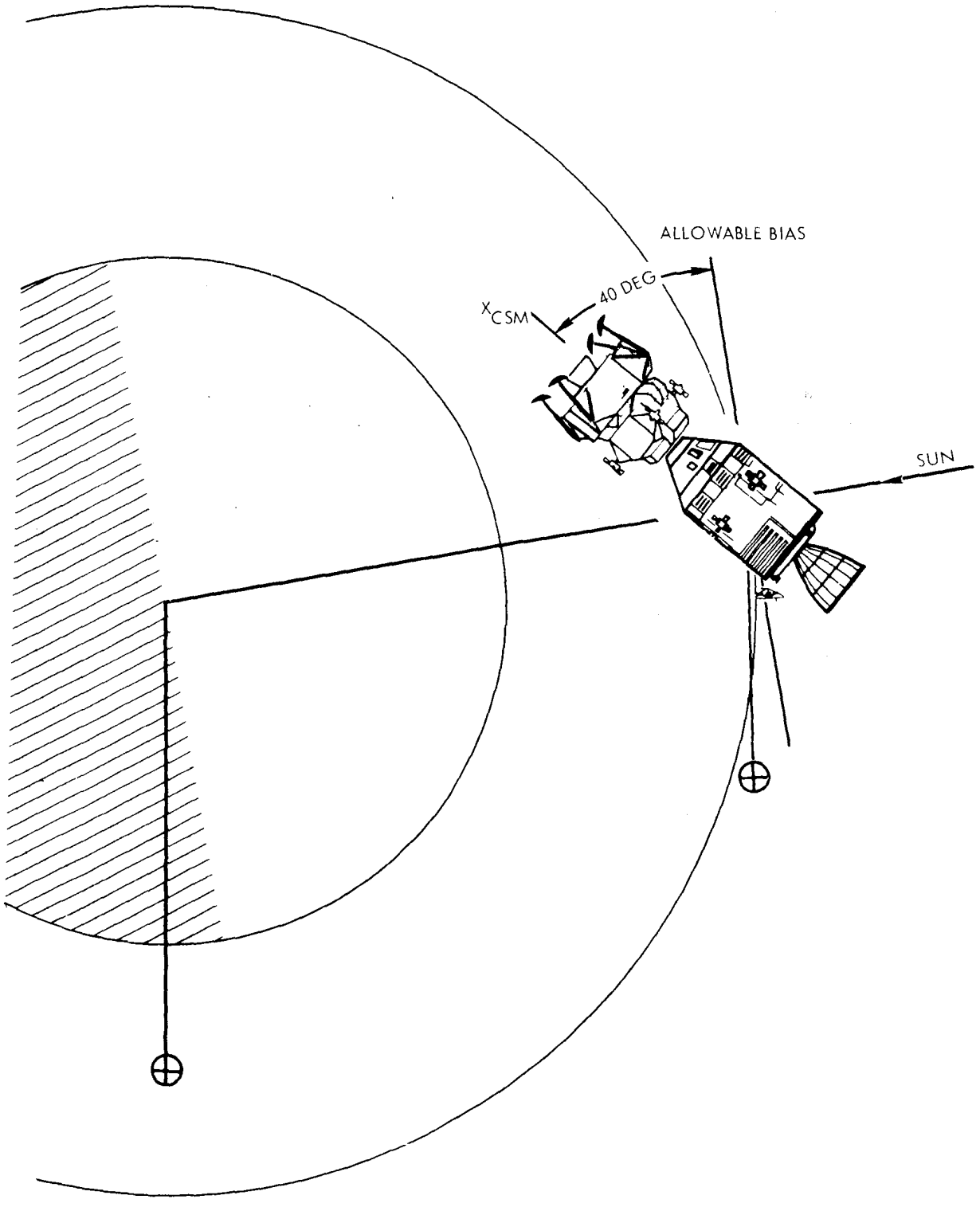



Figure 15. Lunar Orbit Sleep Geometry

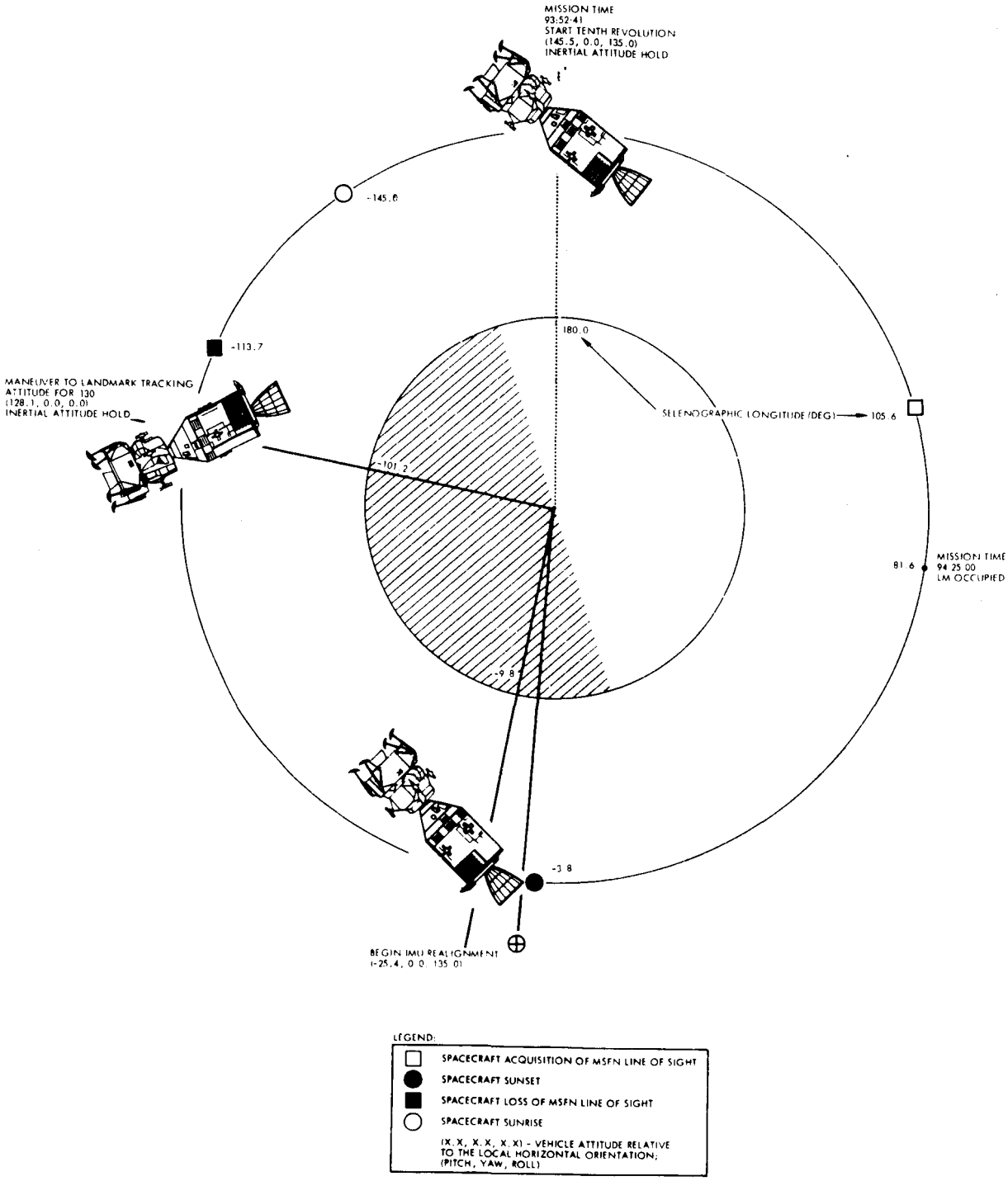



Figure 16. Tenth Revolution Major Events and Attitudes

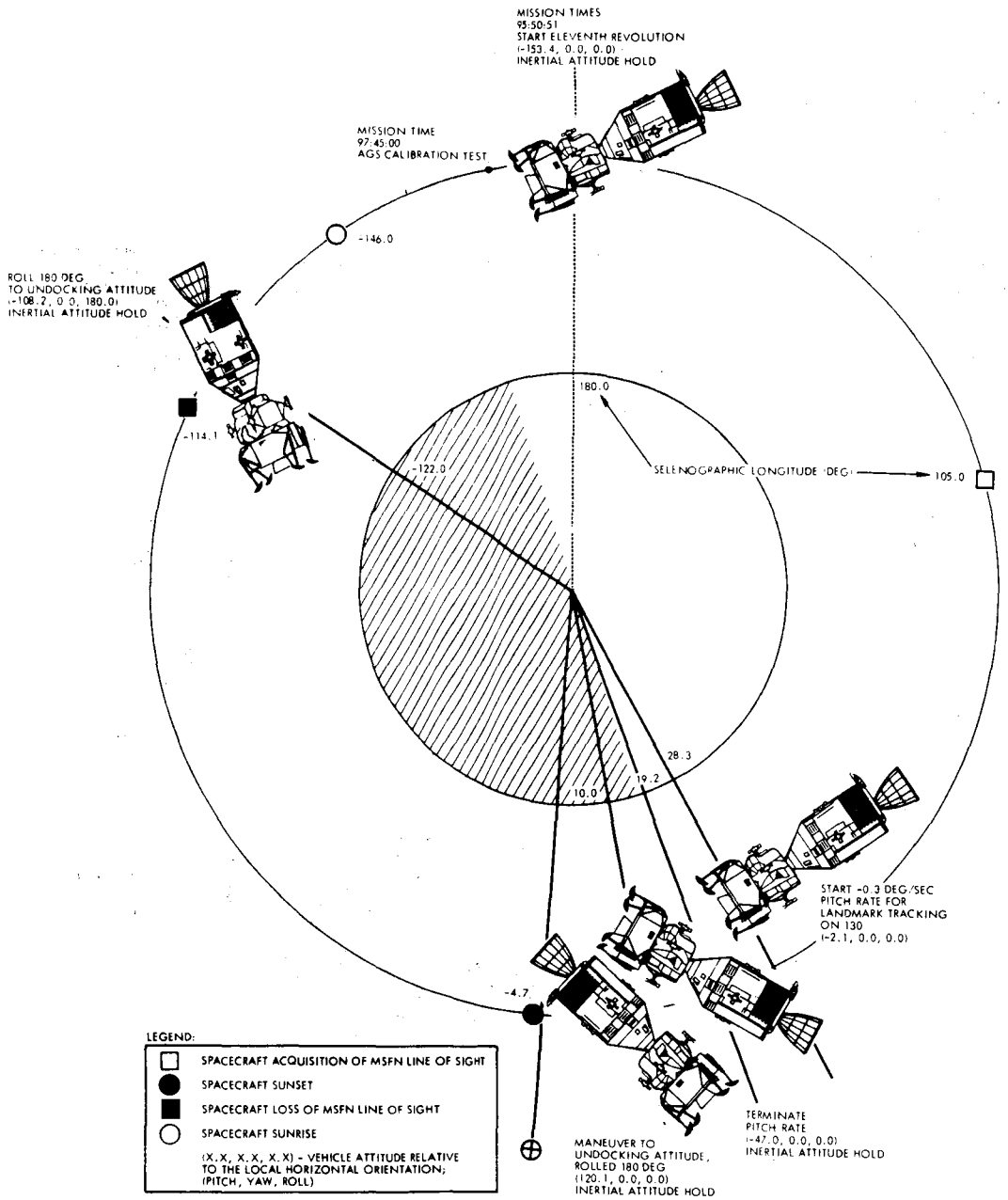



Figure 17. Eleventh Revolution Major Events and Attitudes

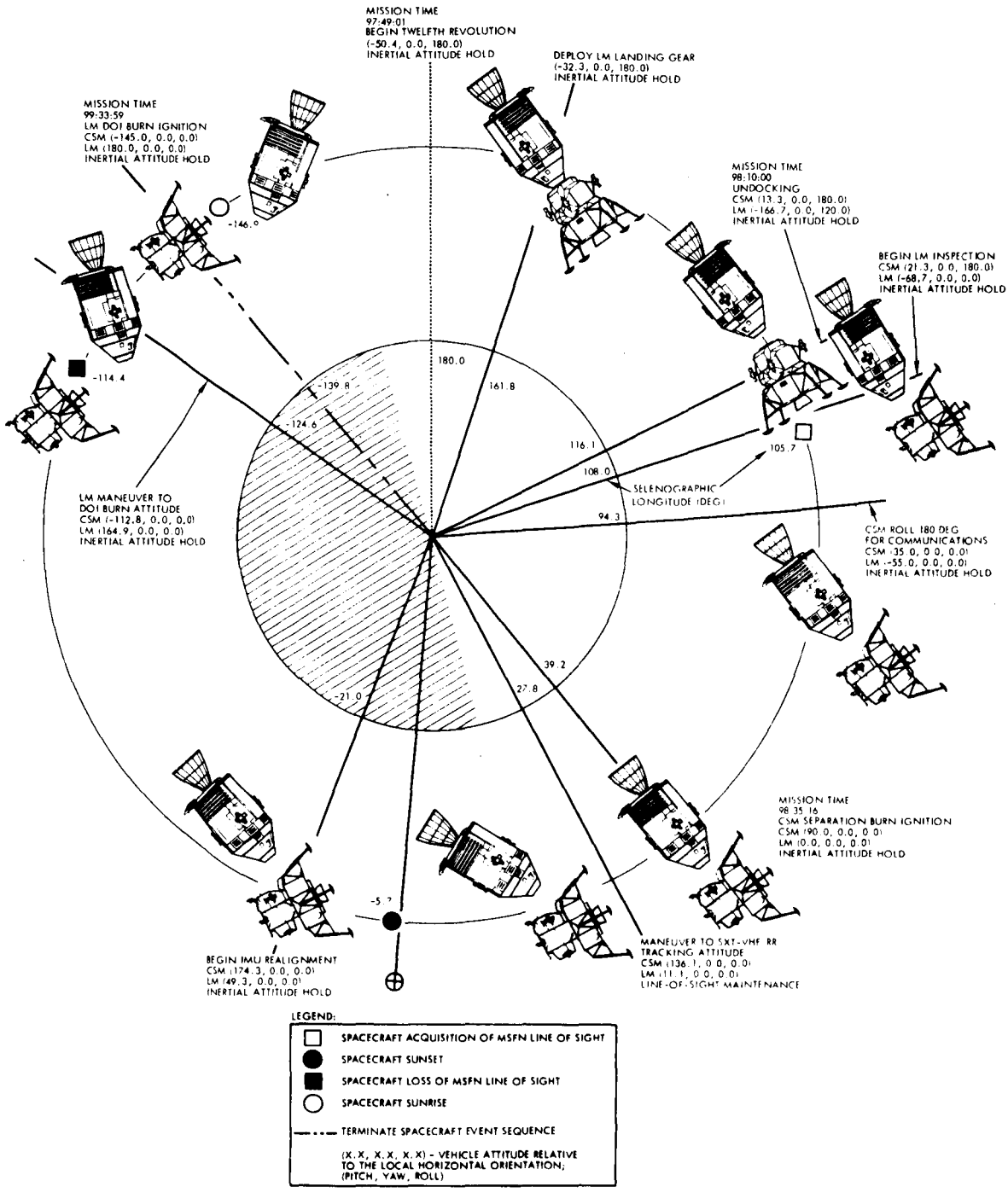



Figure 18. Begin Twelfth Revolution to DOI Burn Ignition

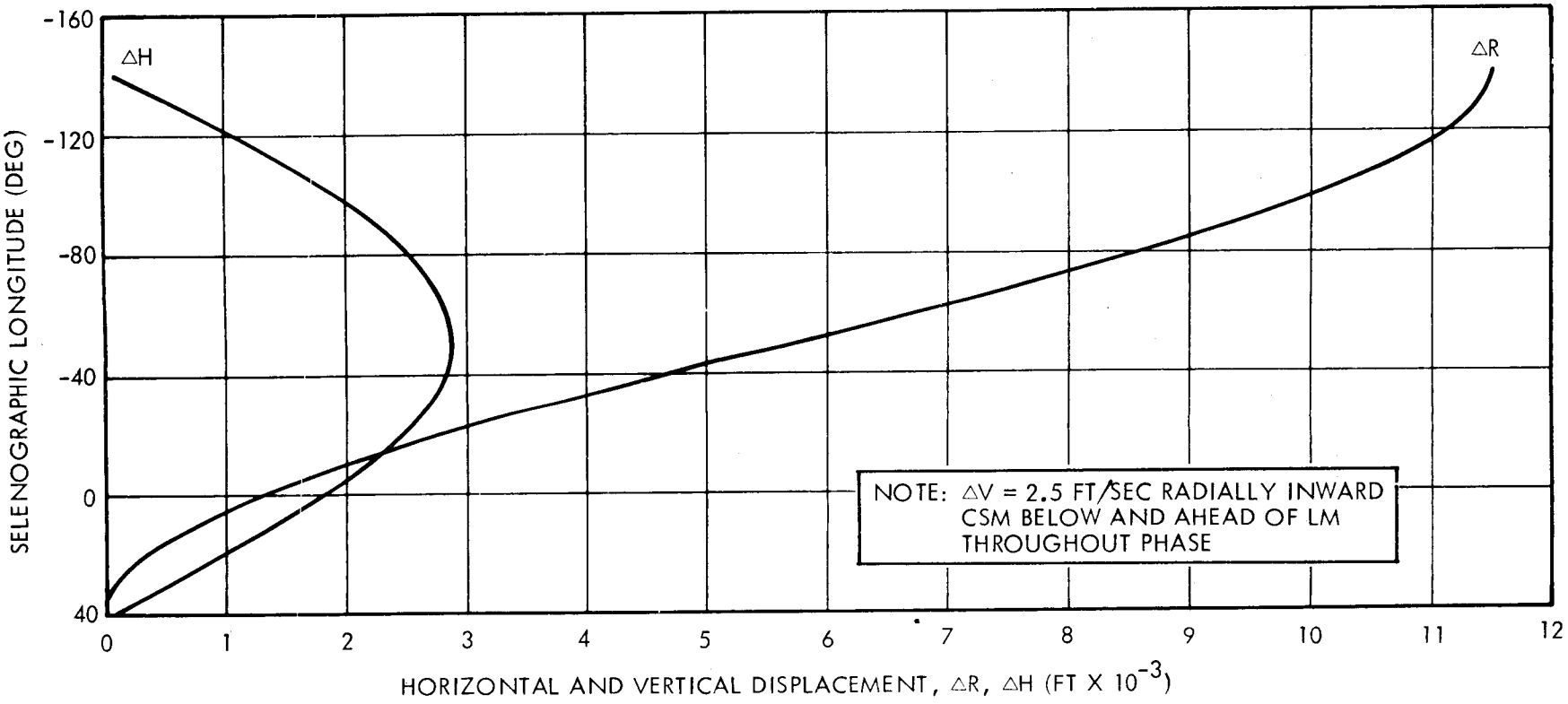



Figure 19. CSM/LM Relative Motion from Separation to DOI (LM Fixed)

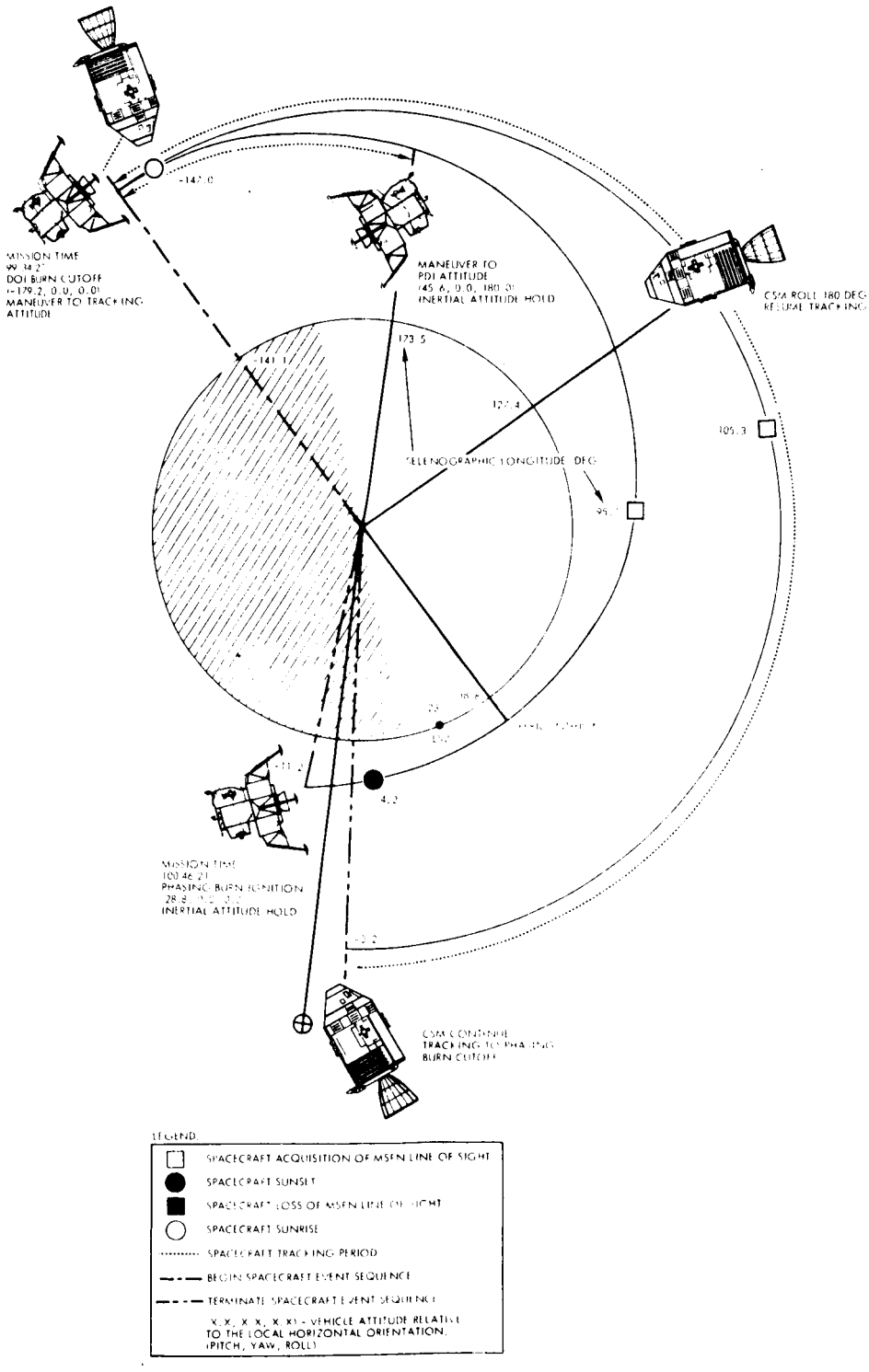



Figure 20. DOI Burn Cutoff to Phasing Burn Ignition

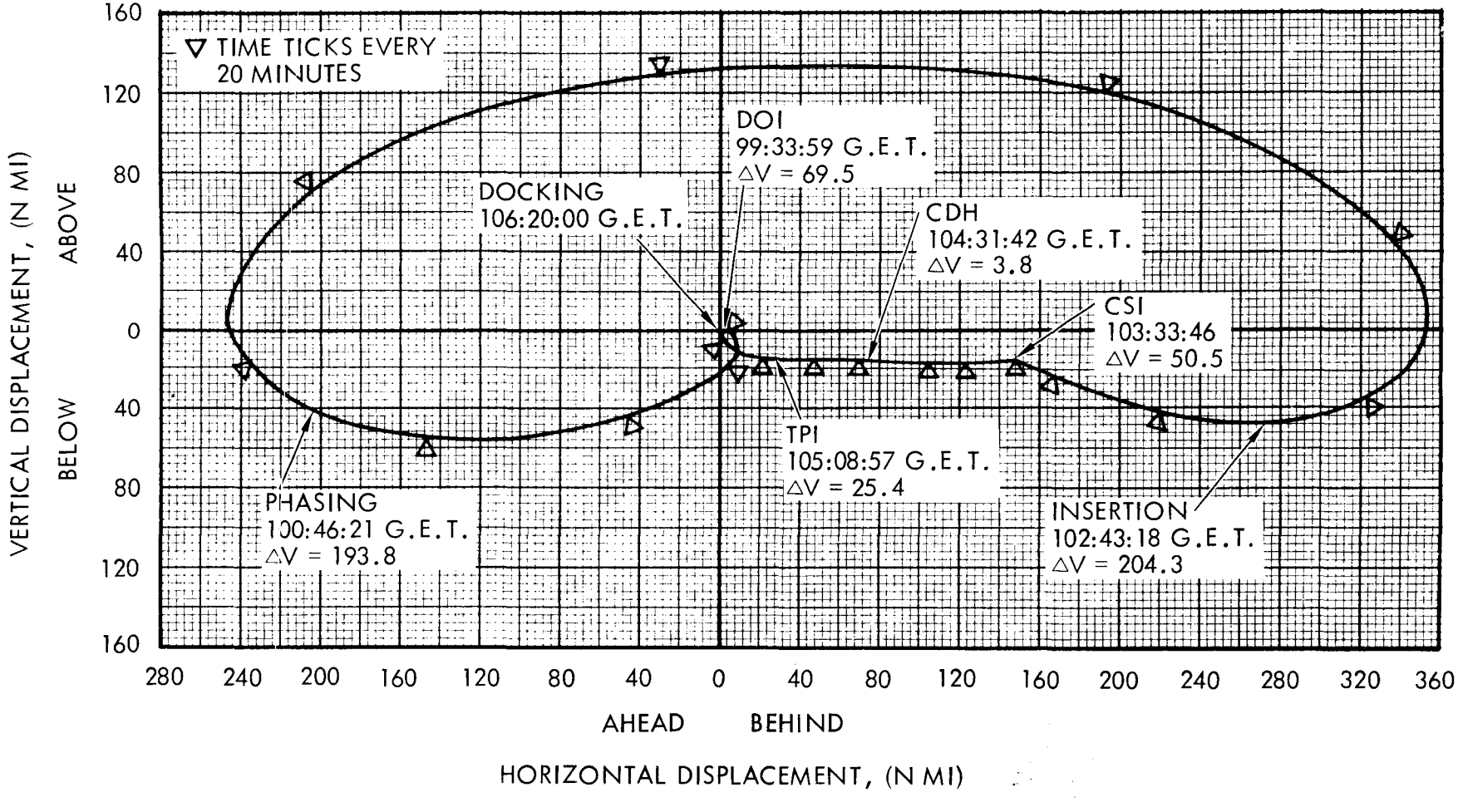



Figure 21. CSM-LM Relative Motion from DOI Cutoff to Docking

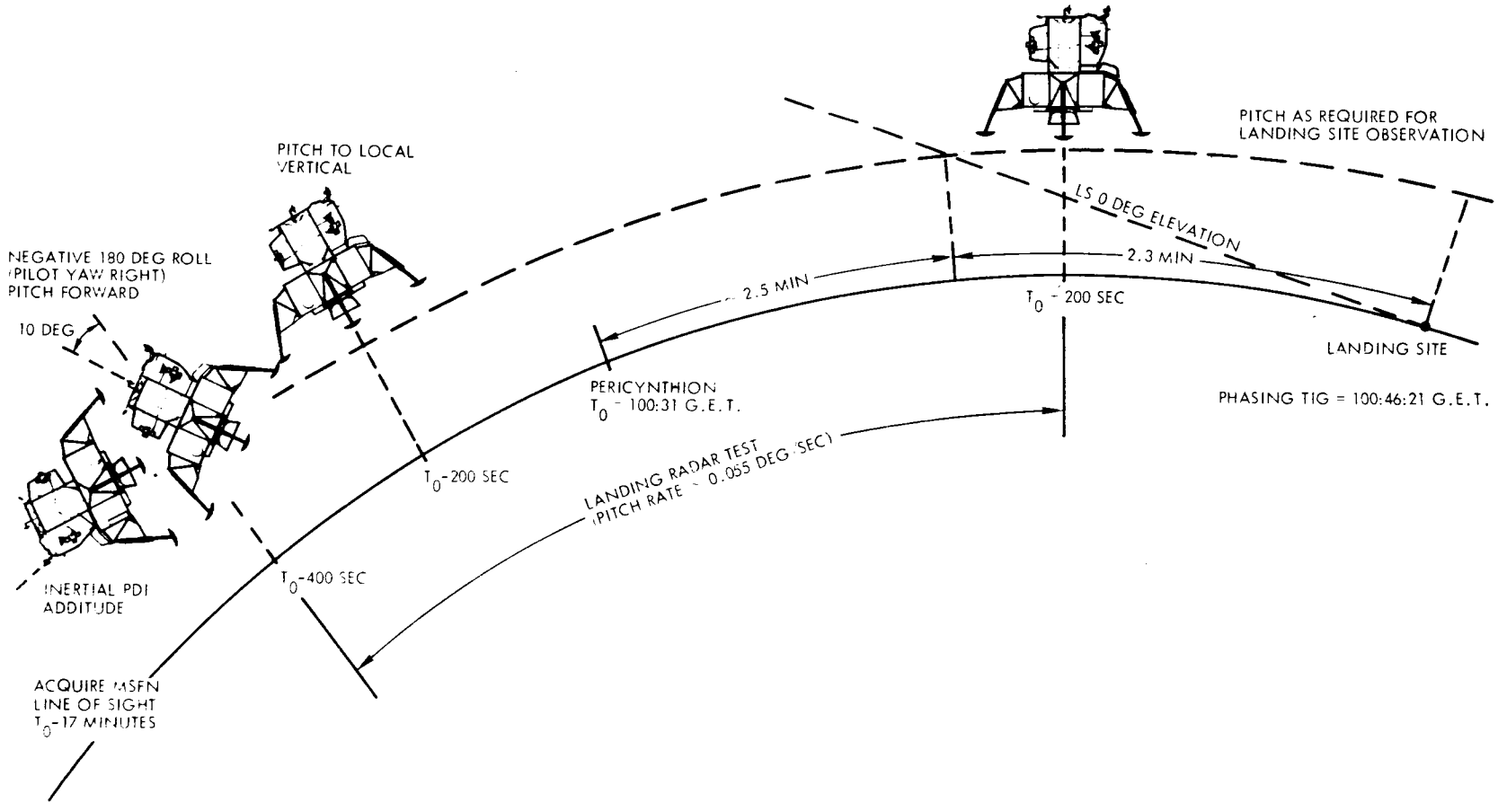



Figure 22. Landing Radar Test Attitude Sequence

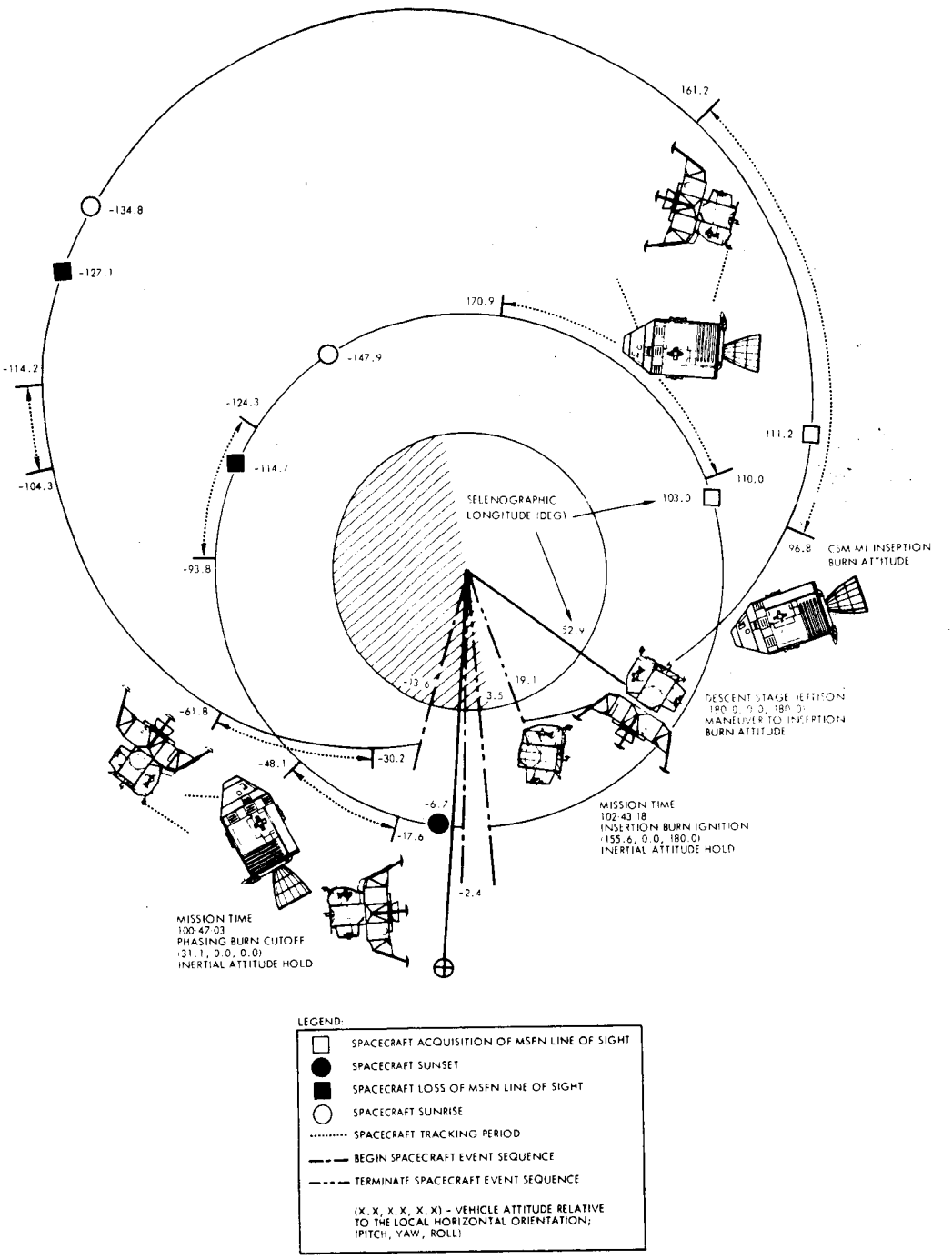



Figure 23. Phasing Burn Cutoff to Insertion Burn Ignition

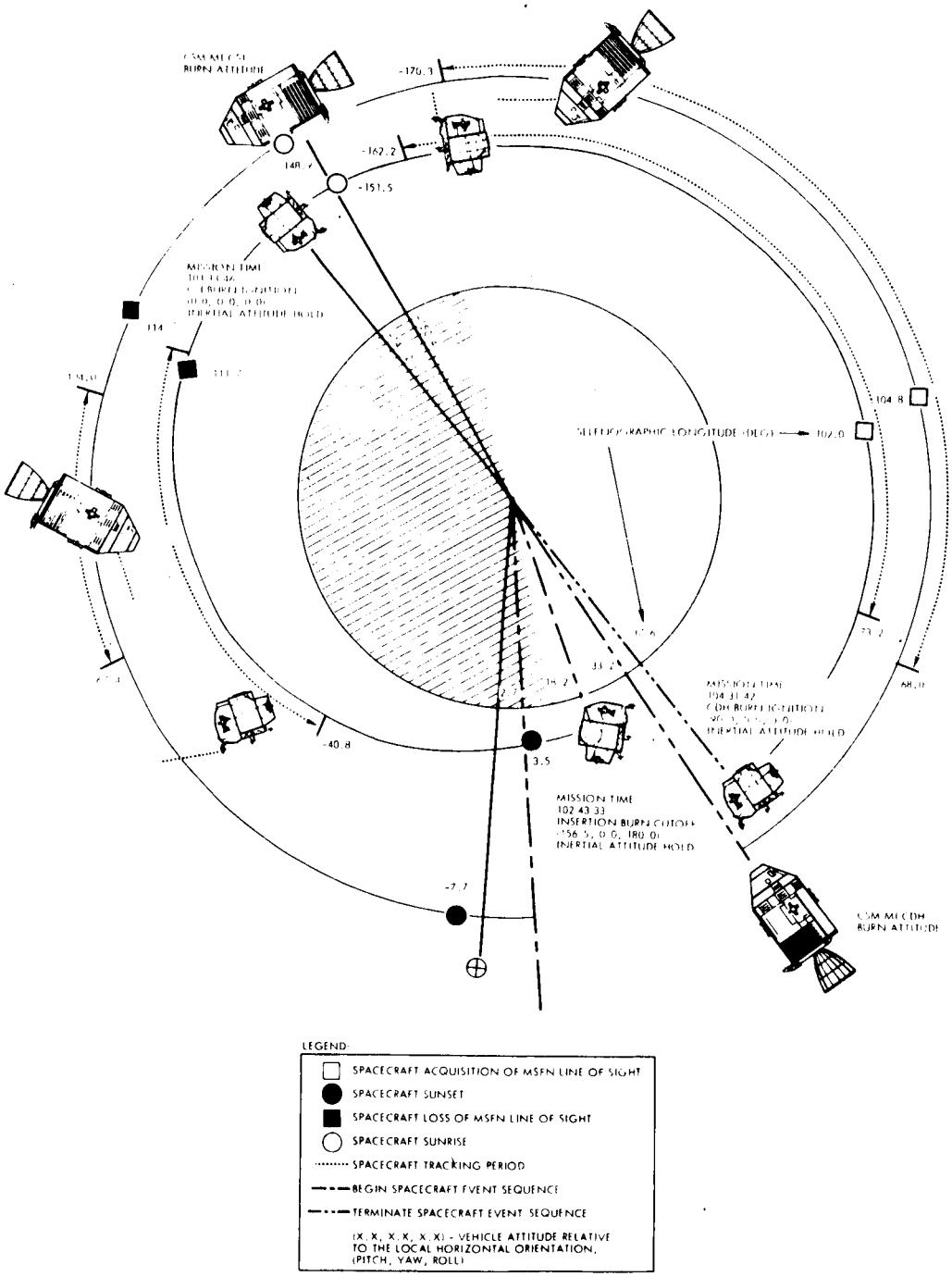



Figure 24. Insertion Burn Cutoff to CDH Burn Ignition

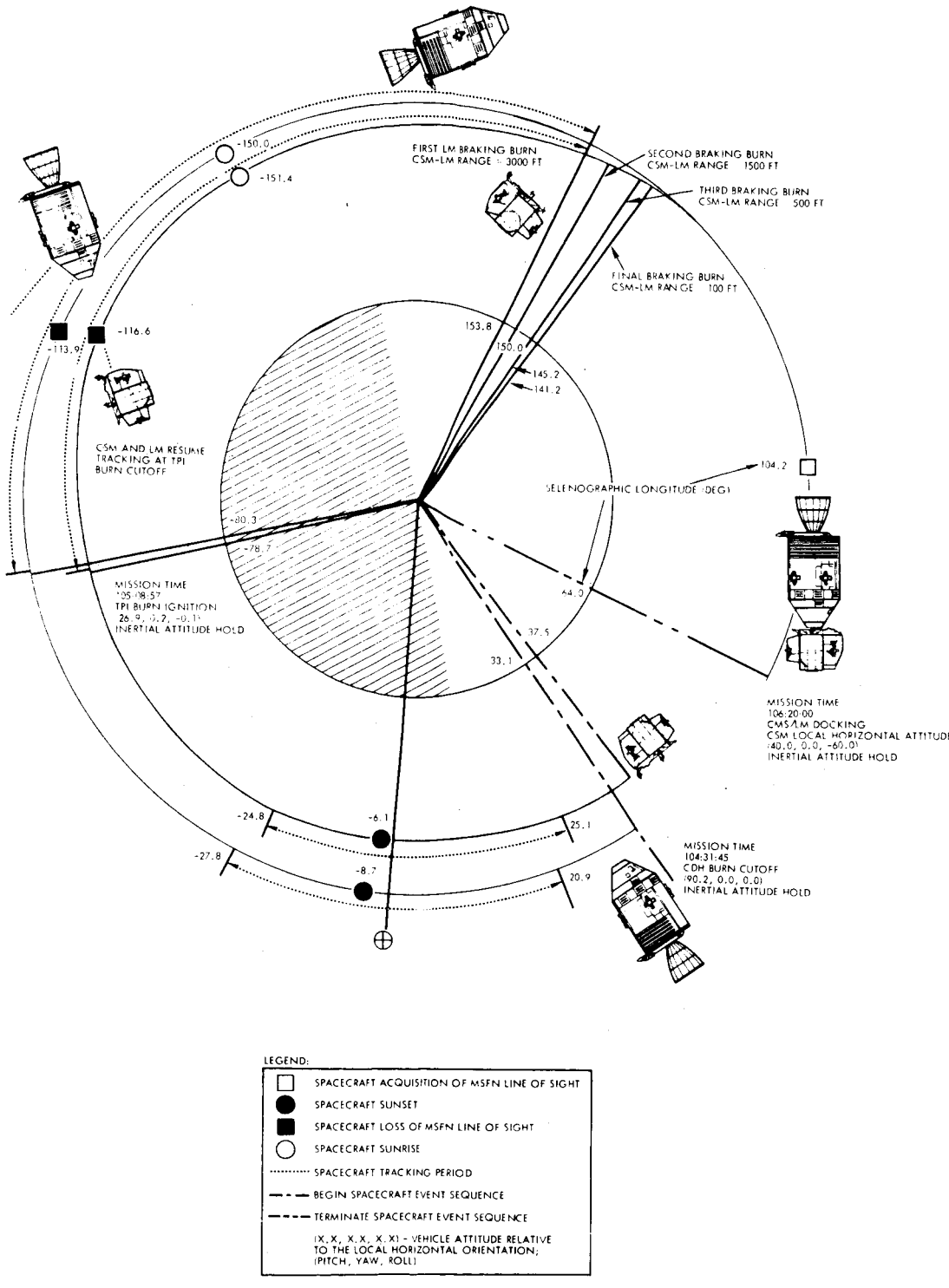



Figure 25. CDH Burn Cutoff to Docking

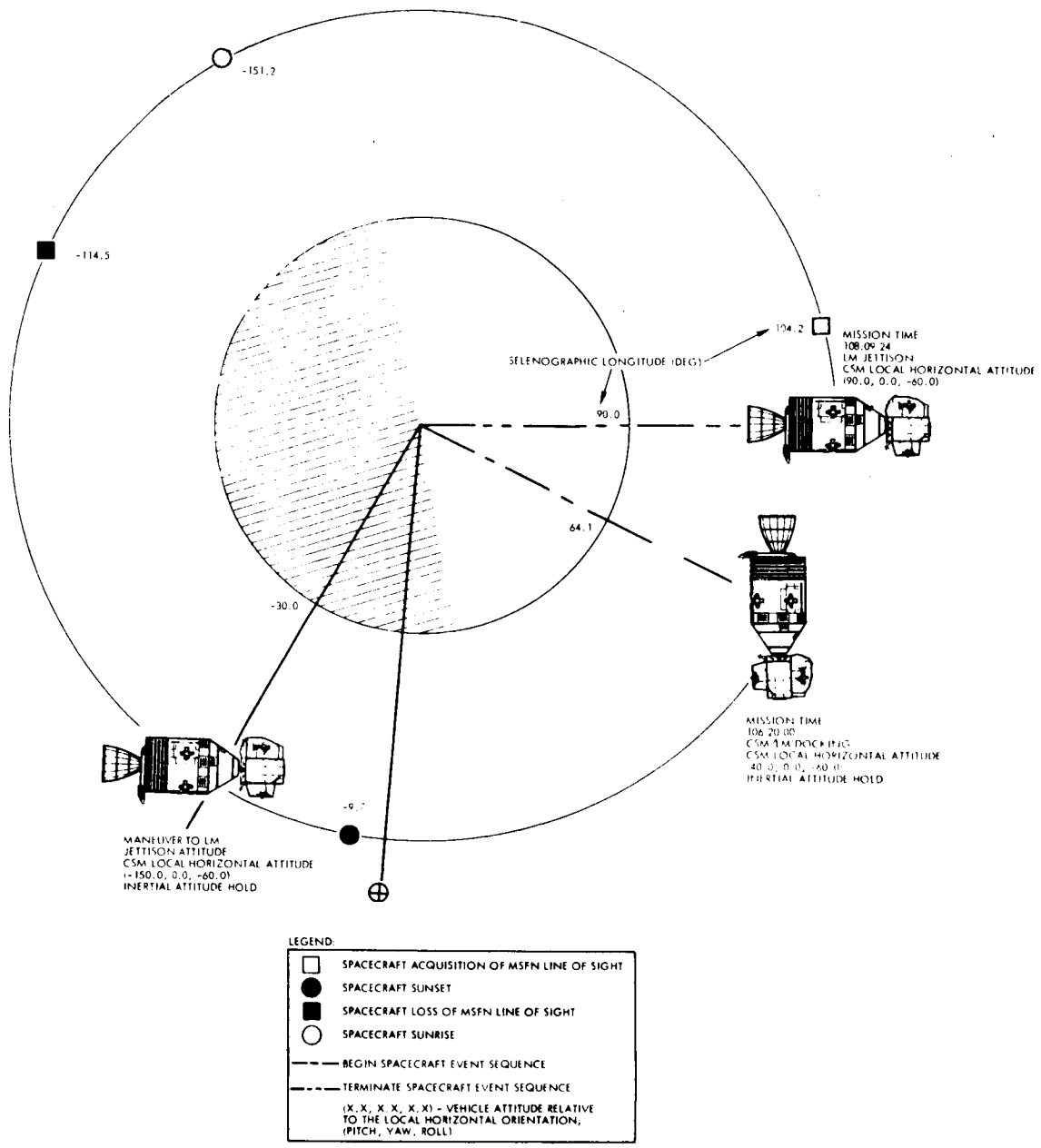



Figure 26. Docking to LM Jettison

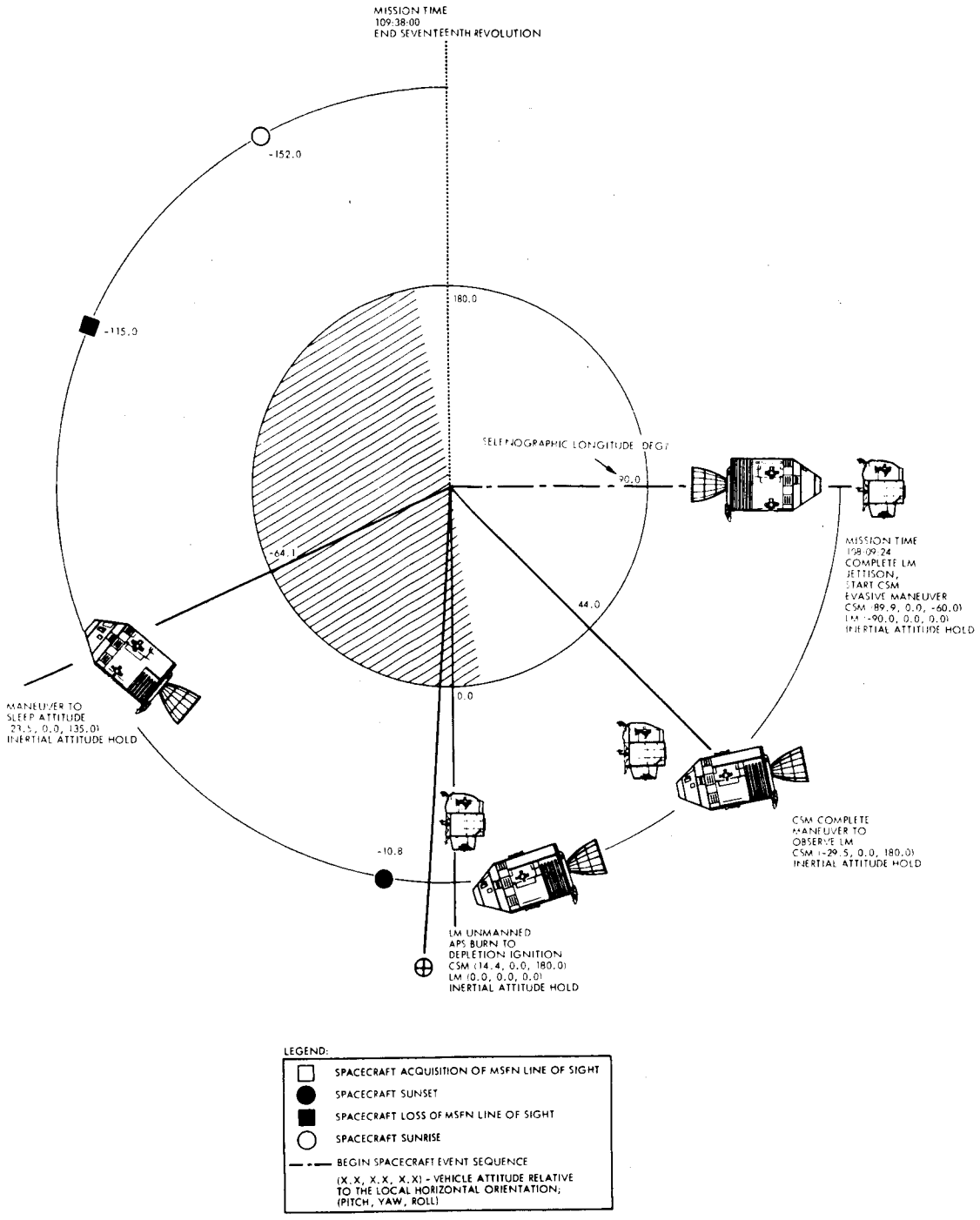



Figure 27. LM Jettison to End of Seventeenth Revolution

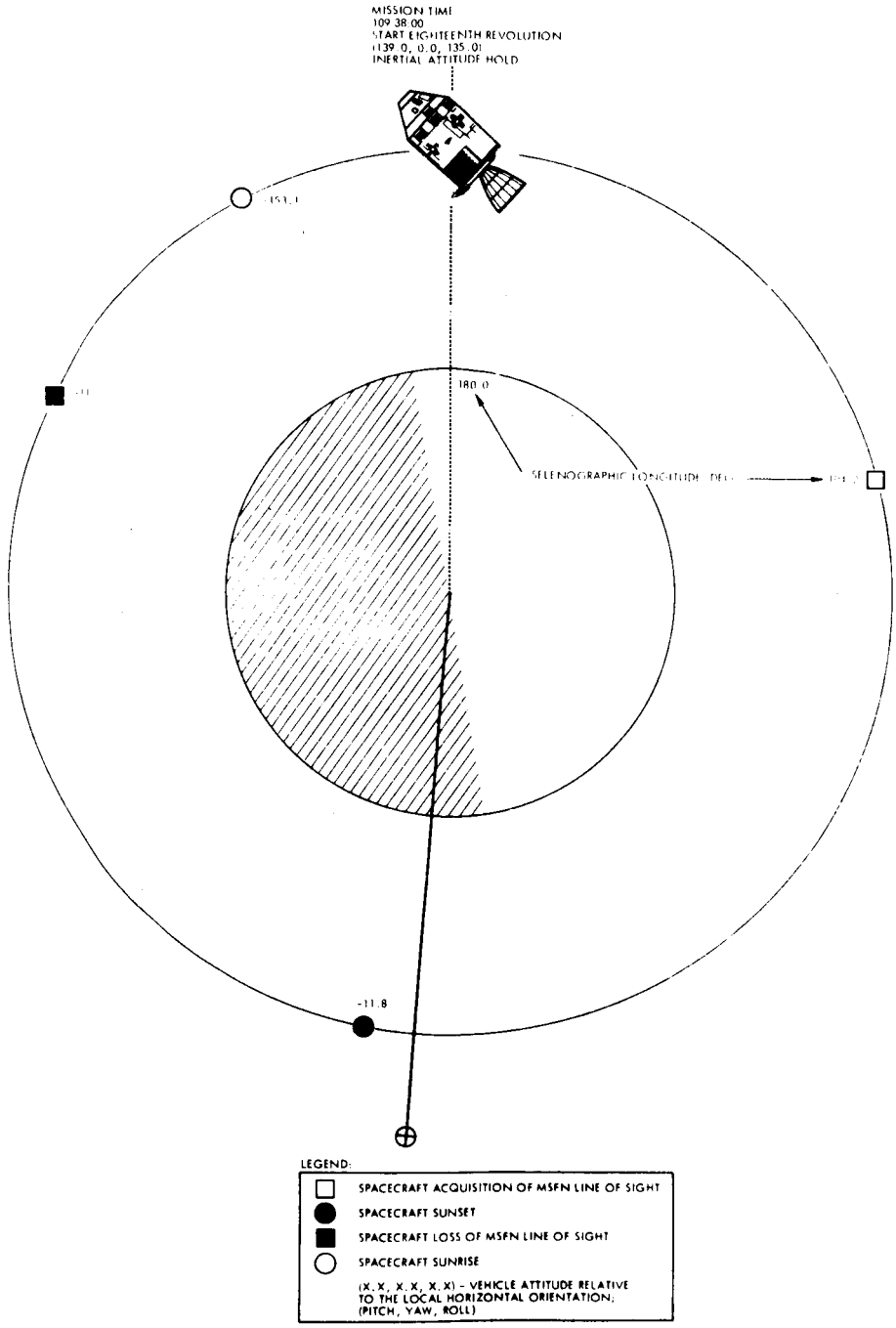



Figure 28. Eighteenth Revolution Major Events and Attitudes

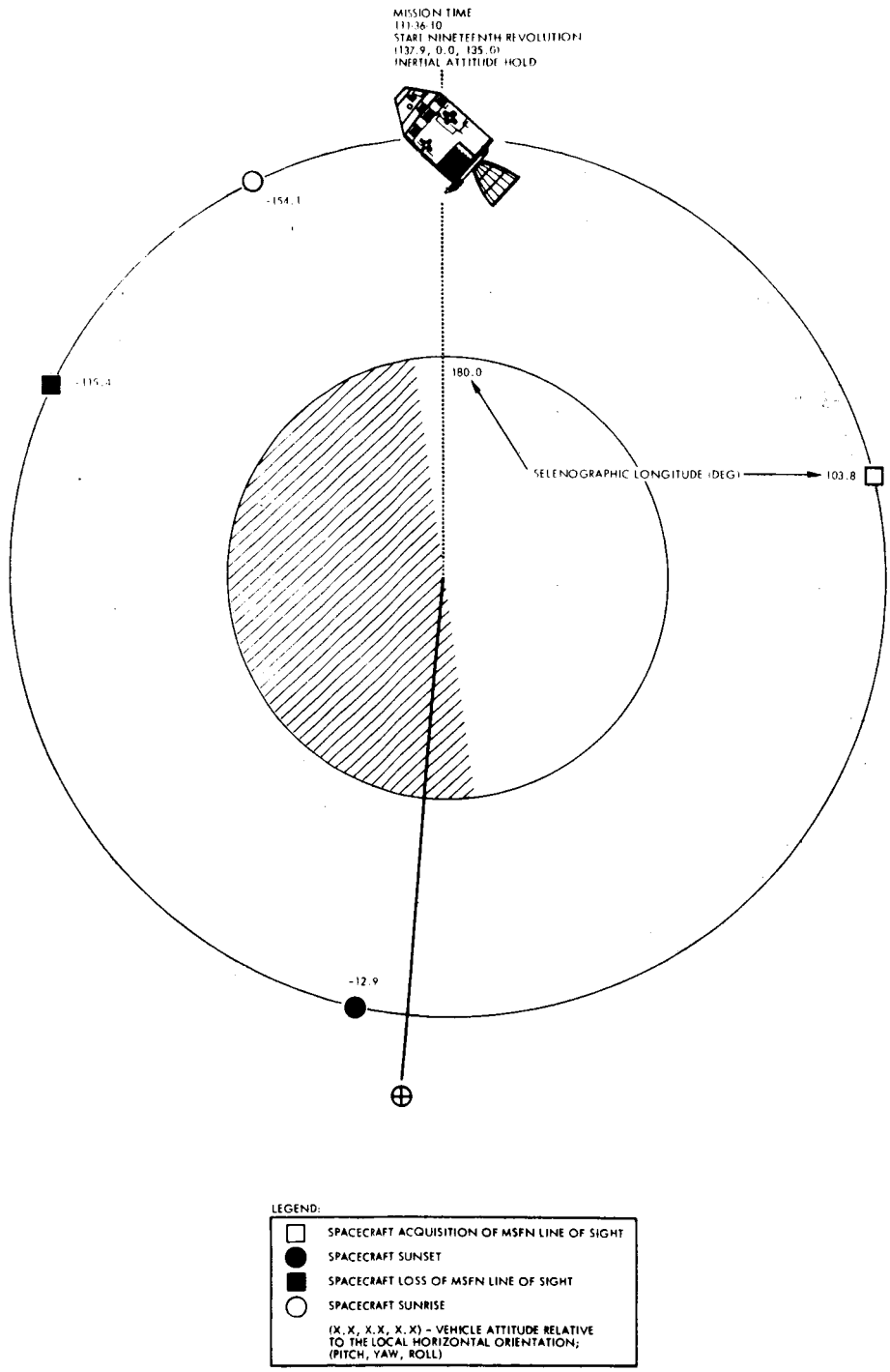



Figure 29. Nineteenth Revolution Major Events and Attitudes

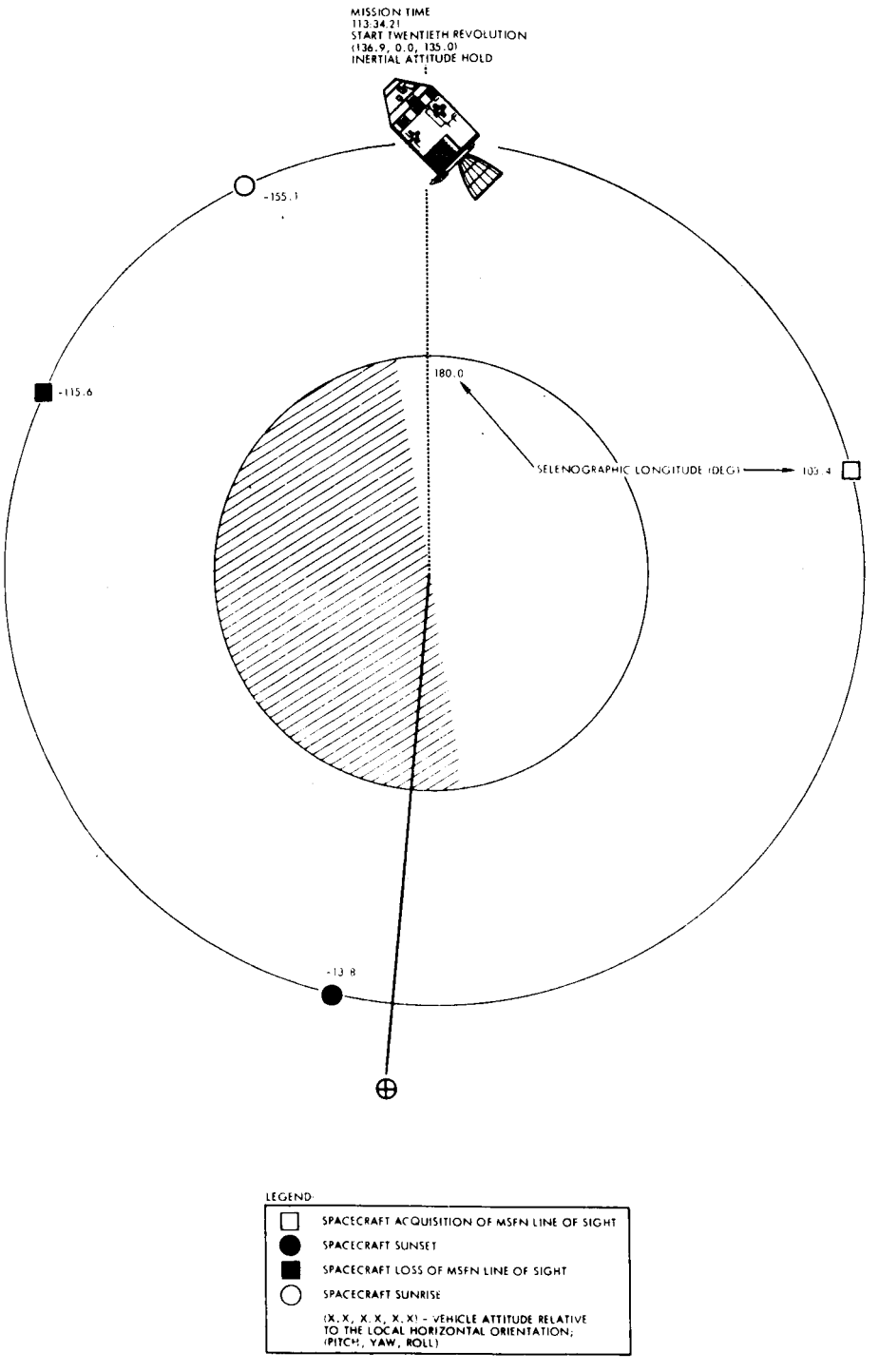



Figure 30. Twentieth Revolution Major Events and Attitudes

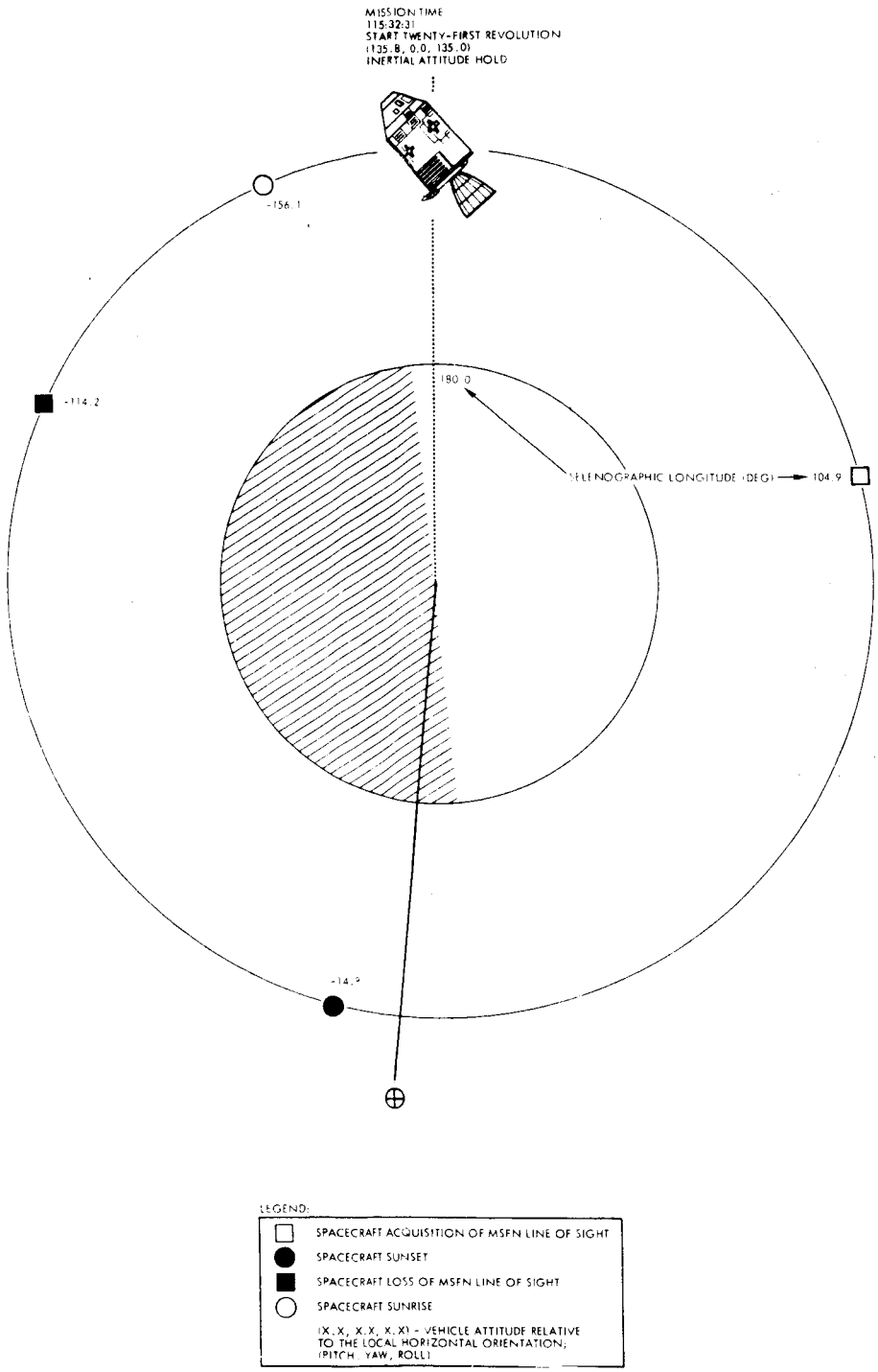



Figure 31. Twenty-first Revolution Major Events and Attitudes

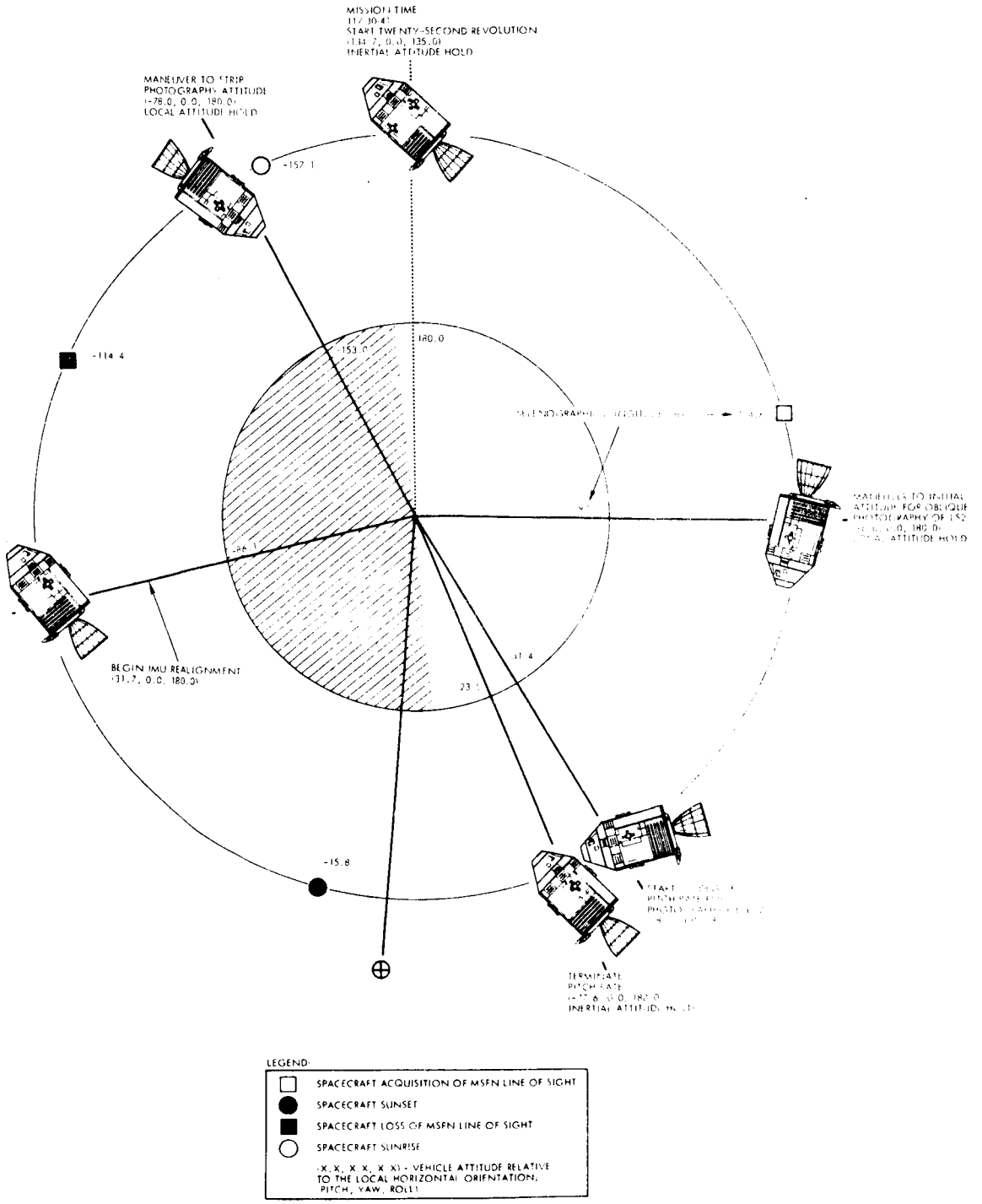



Figure 32. Twenty-second Revolution Major Events and Attitudes

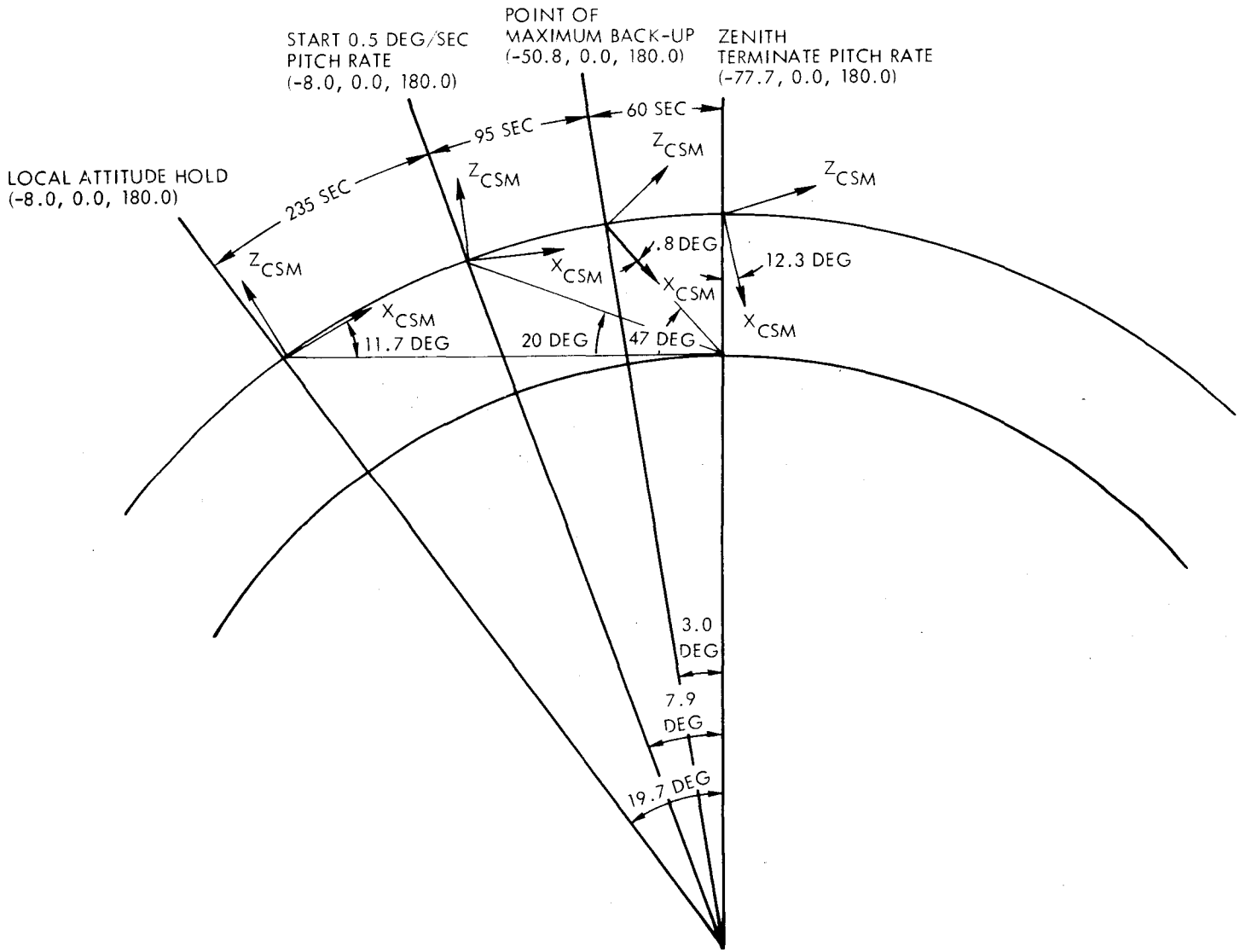



Figure 33. Oblique Photography Attitude Sequence

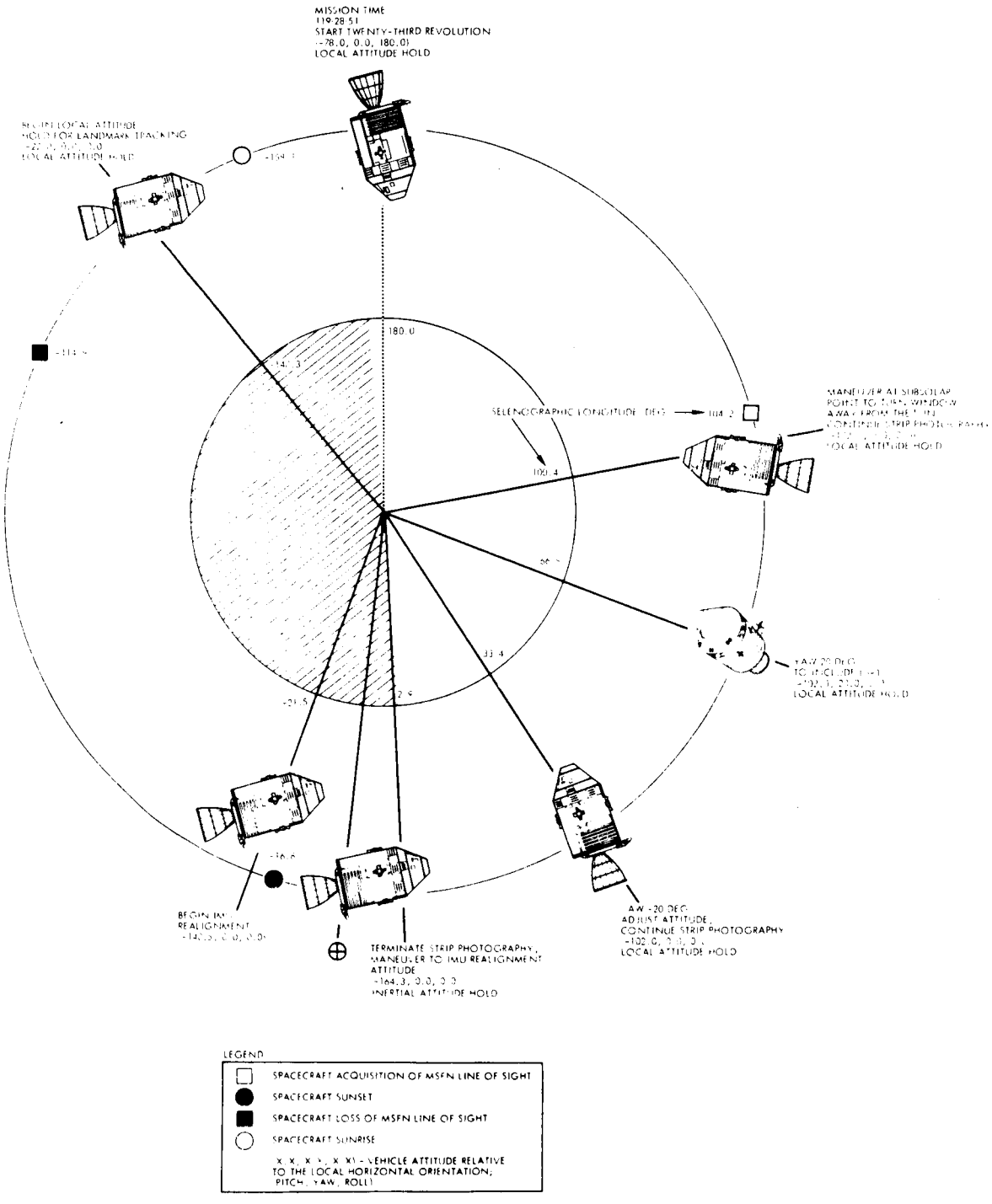



Figure 34. Twenty-third Revolution Major Events and Attitudes

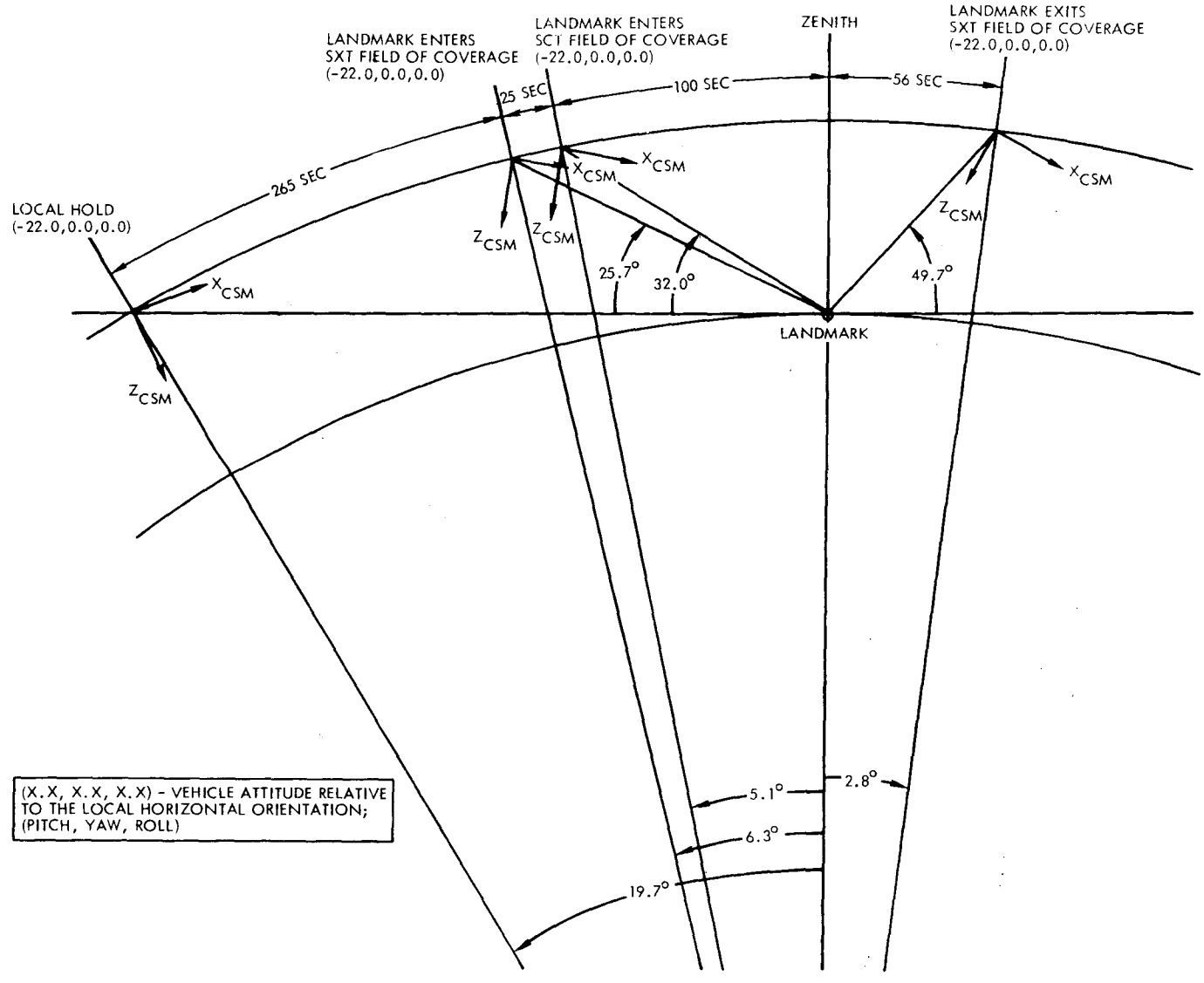



Figure 35. Tracking Geometry for Mode III Undocked Landmark Tracking

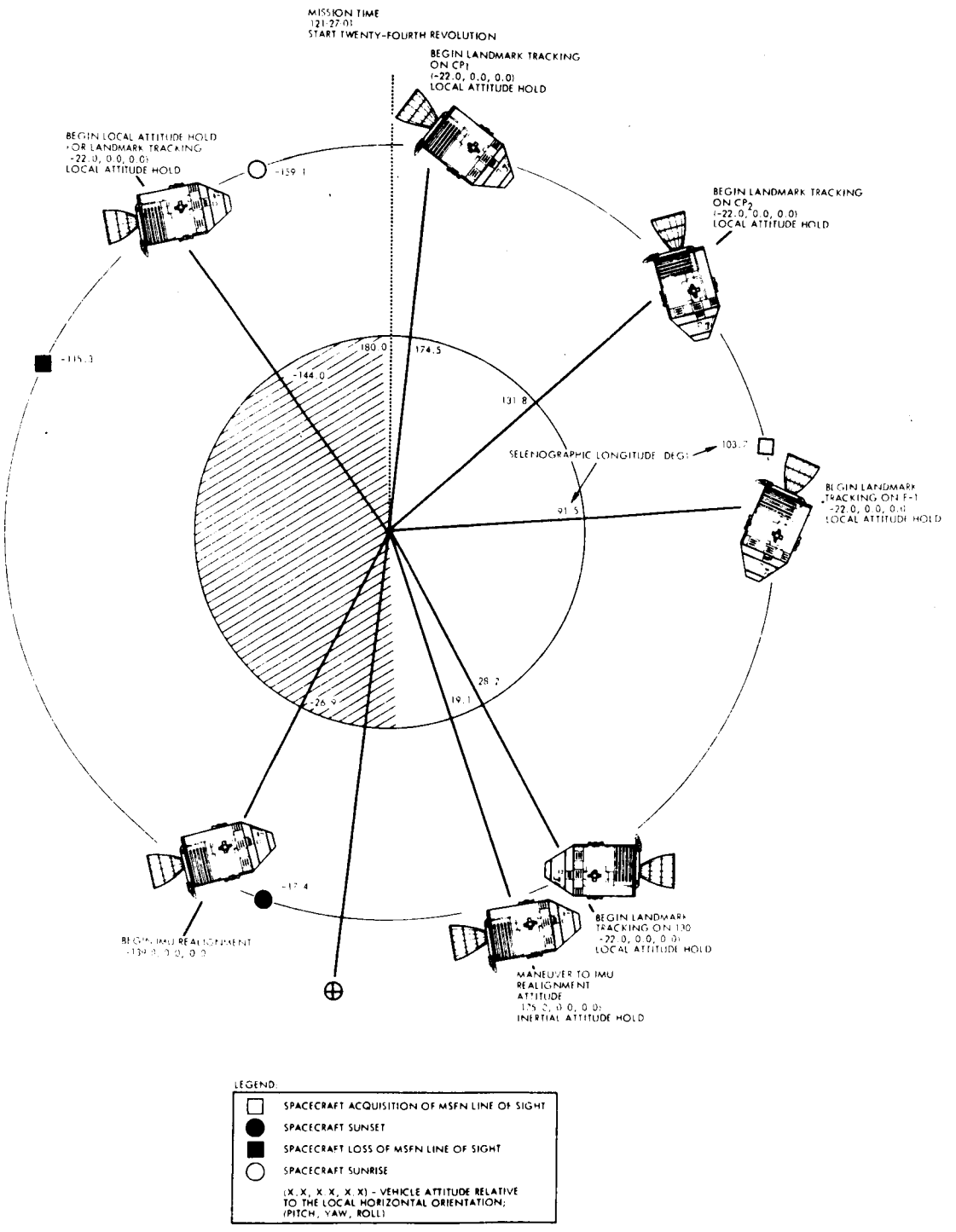



Figure 36. Twenty-fourth Revolution Major Events and Attitudes

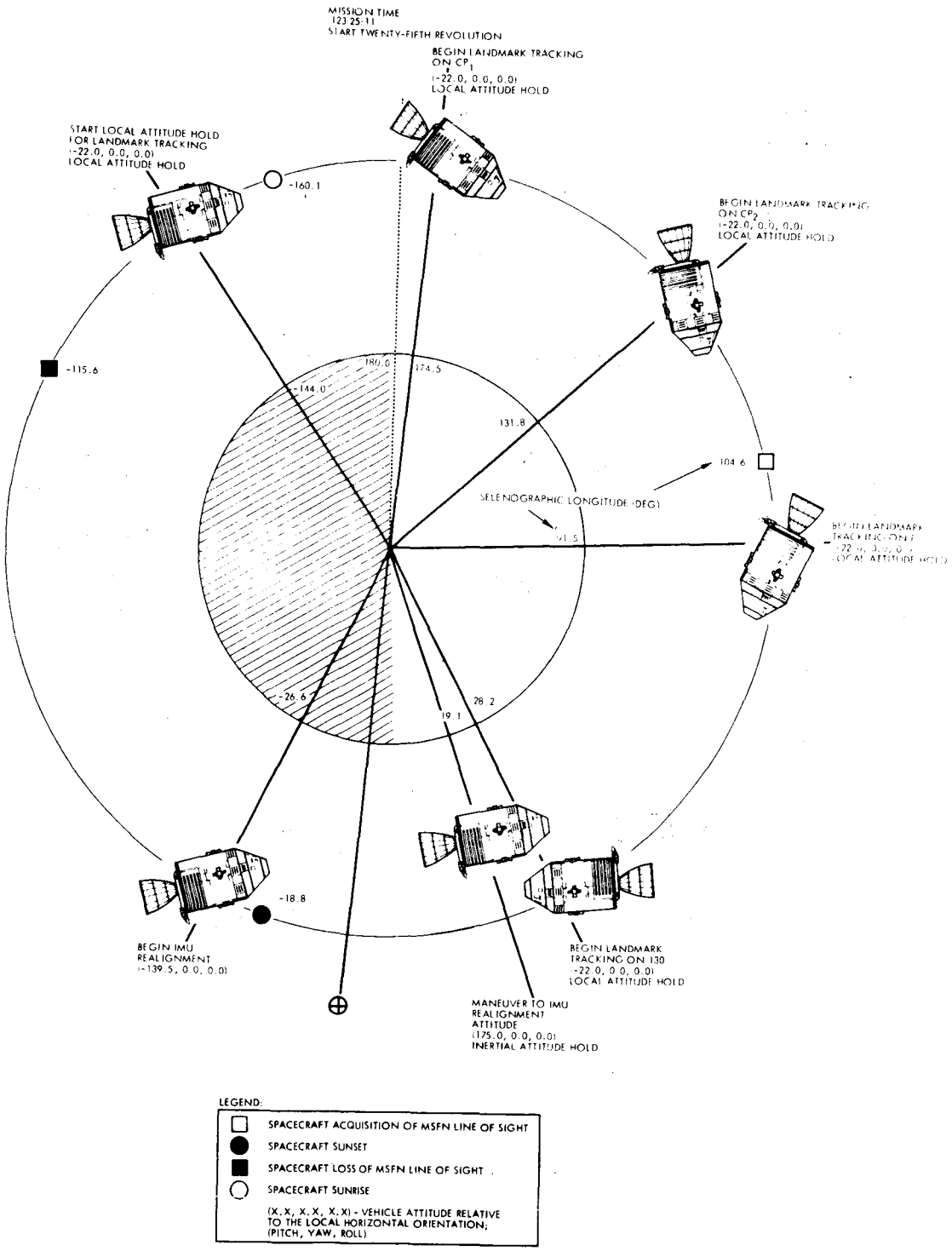



Figure 37. Twenty-fifth Revolution Major Events and Attitudes

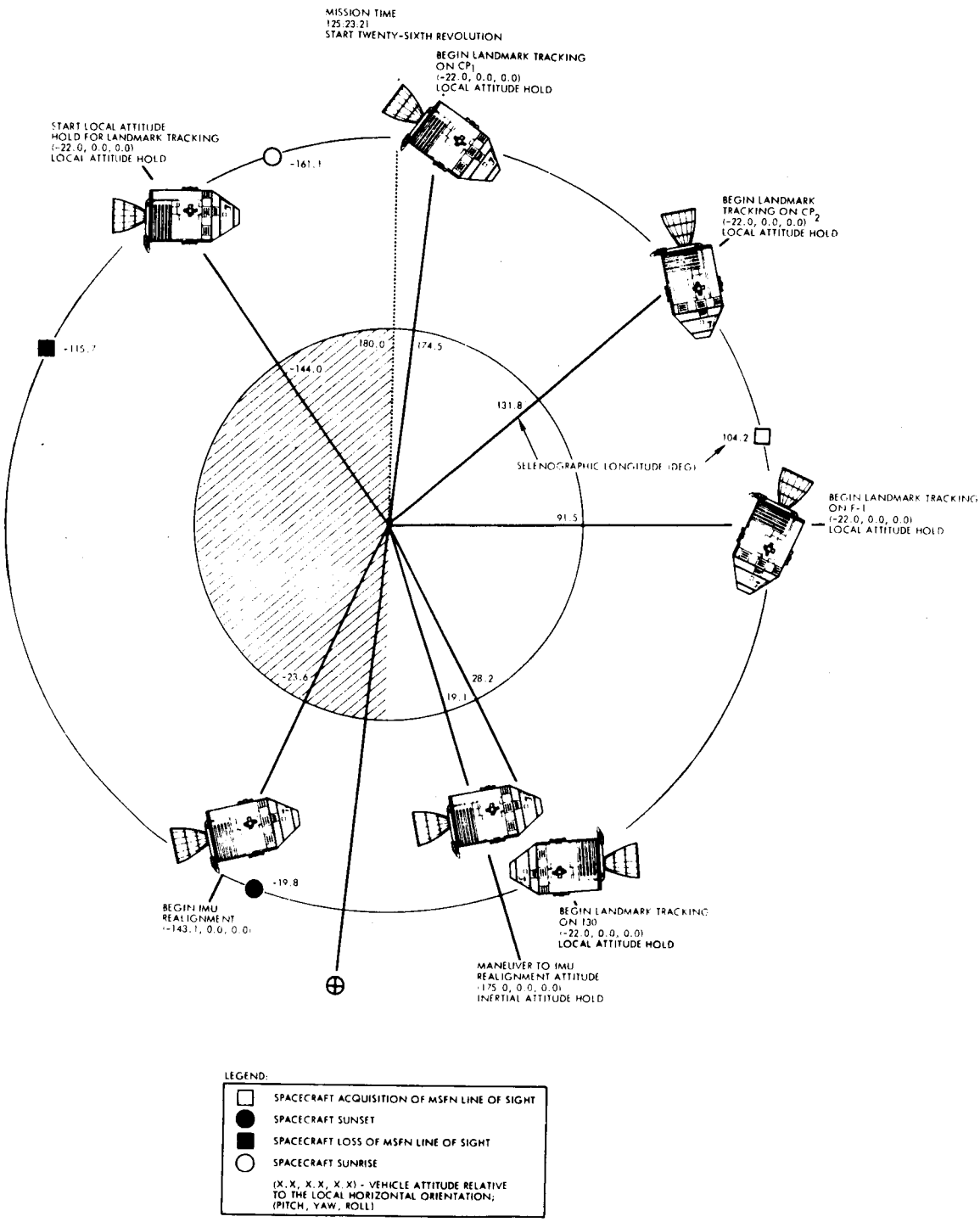



Figure 38. Twenty-sixth Revolution Major Events and Attitudes

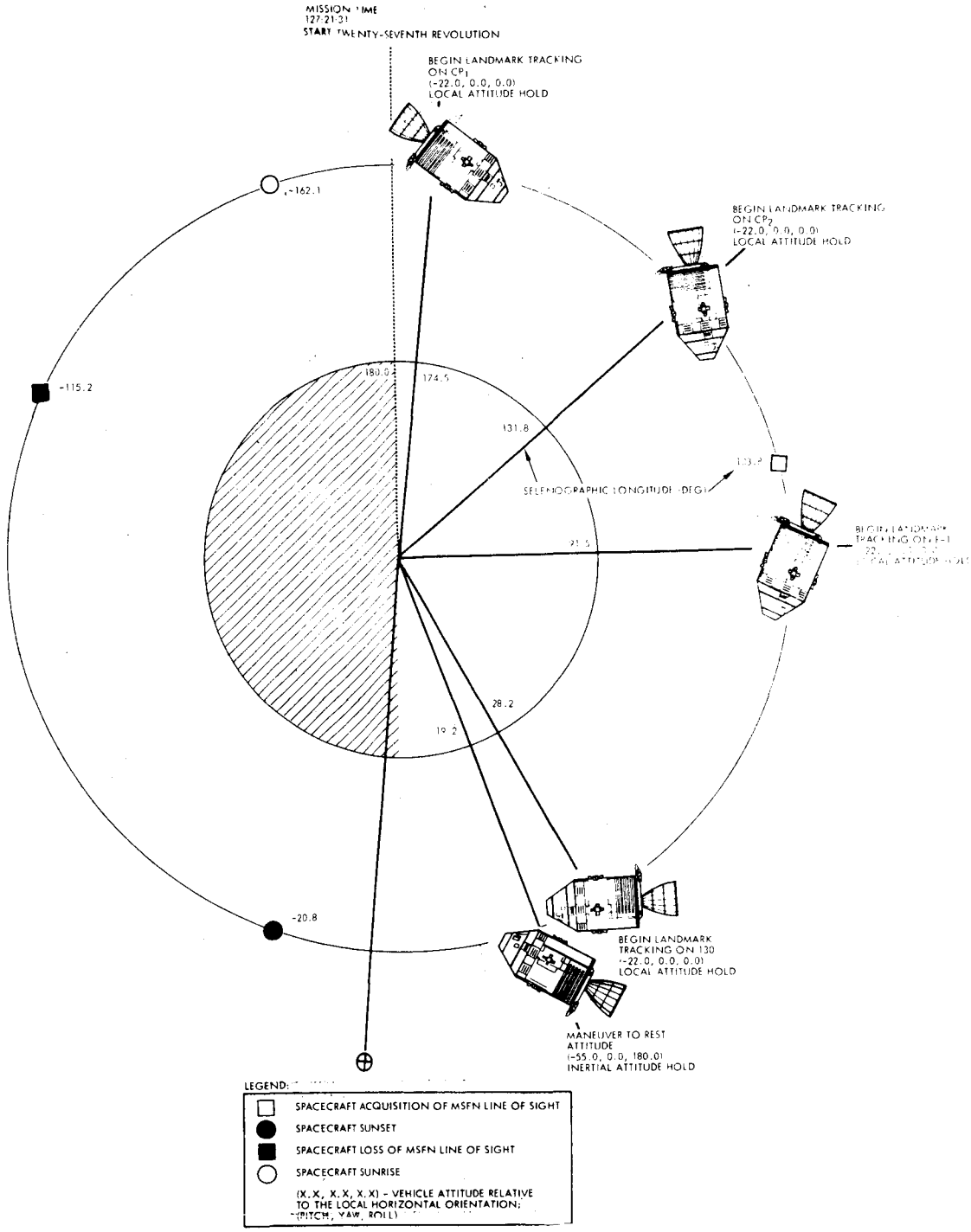



Figure 39. Twenty-seventh Revolution Major Events and Attitudes

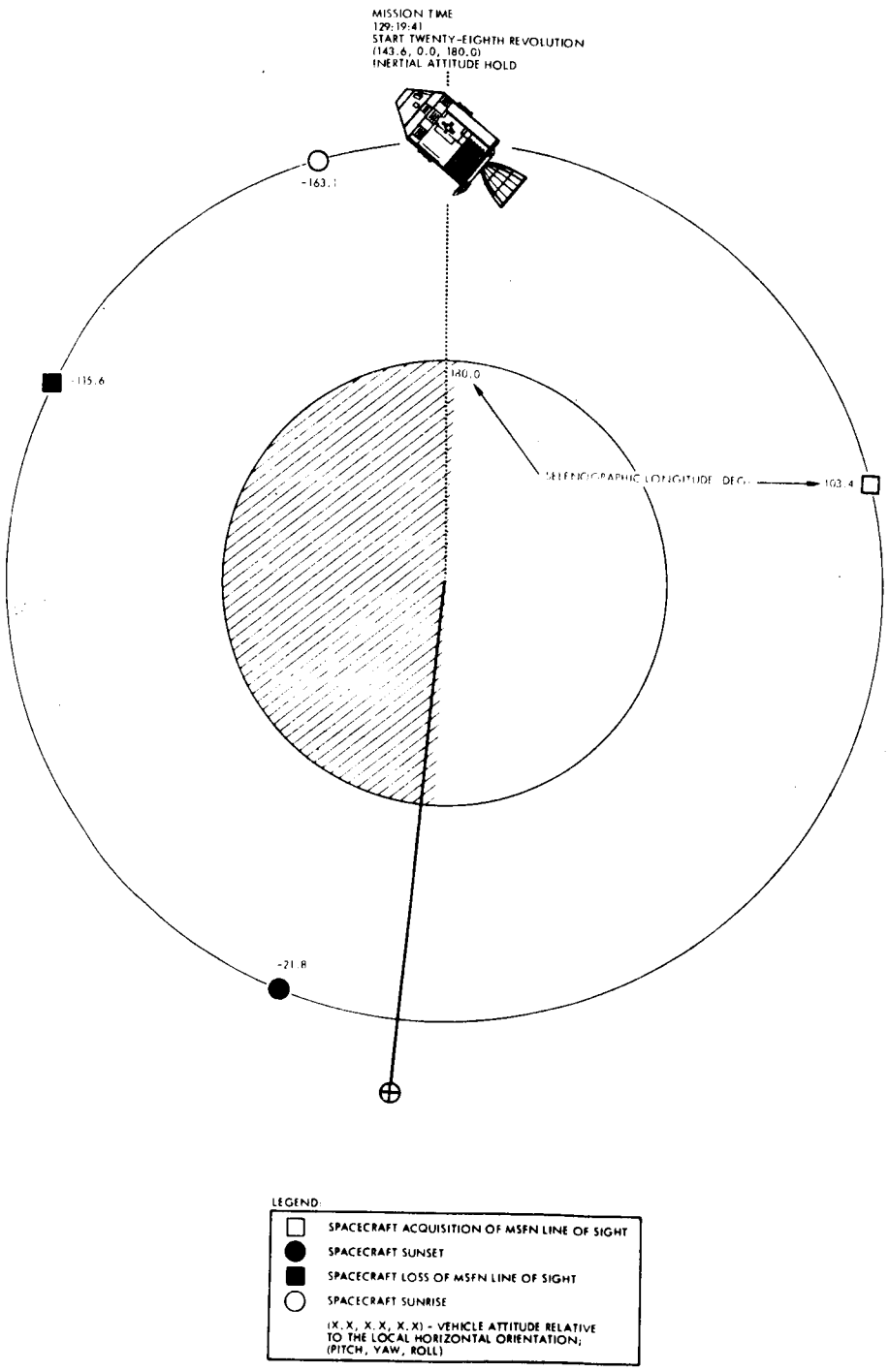



Figure 40. Twenty-eighth Revolution Major Events and Attitudes

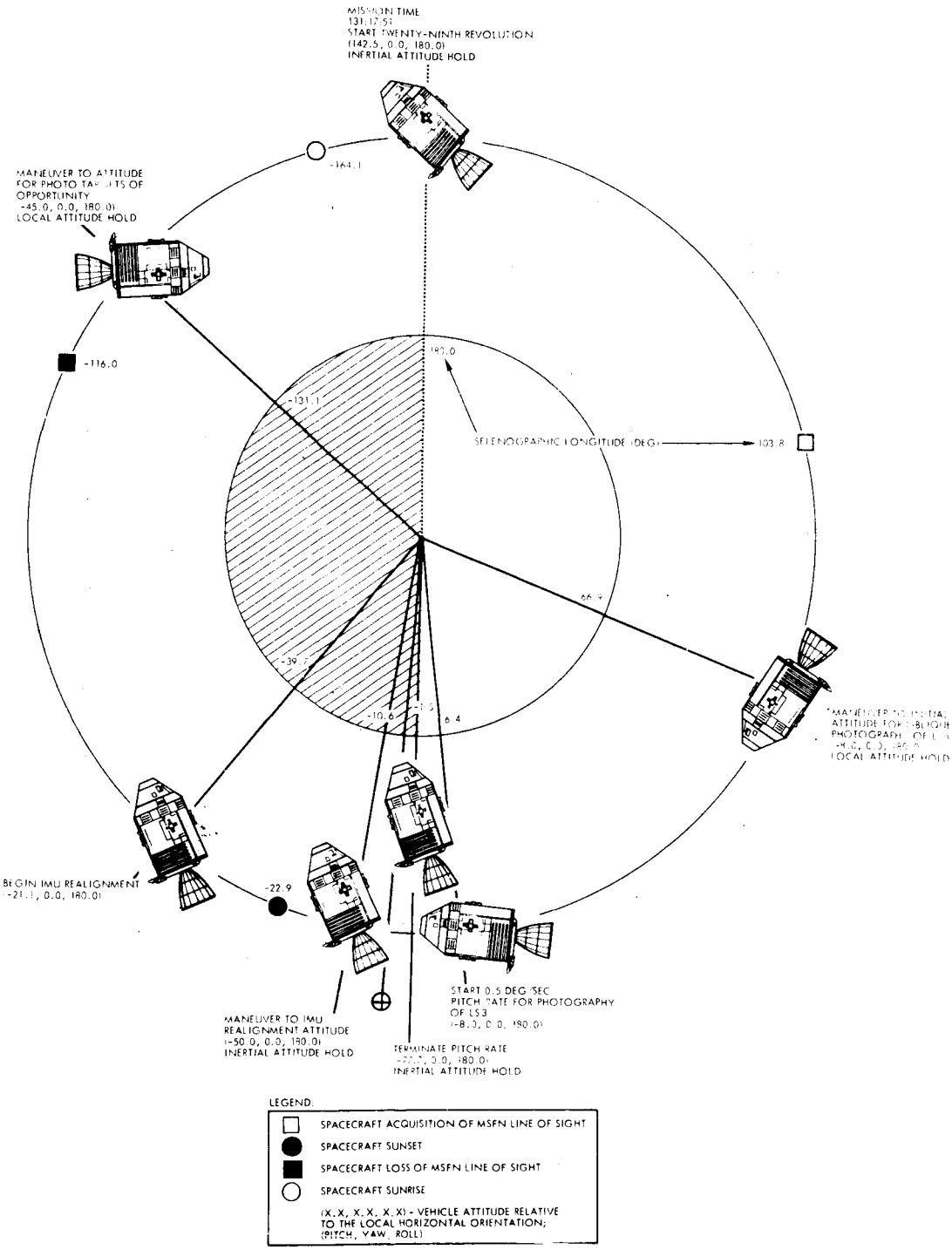



Figure 41. Twenty-ninth Revolution Major Events and Attitudes

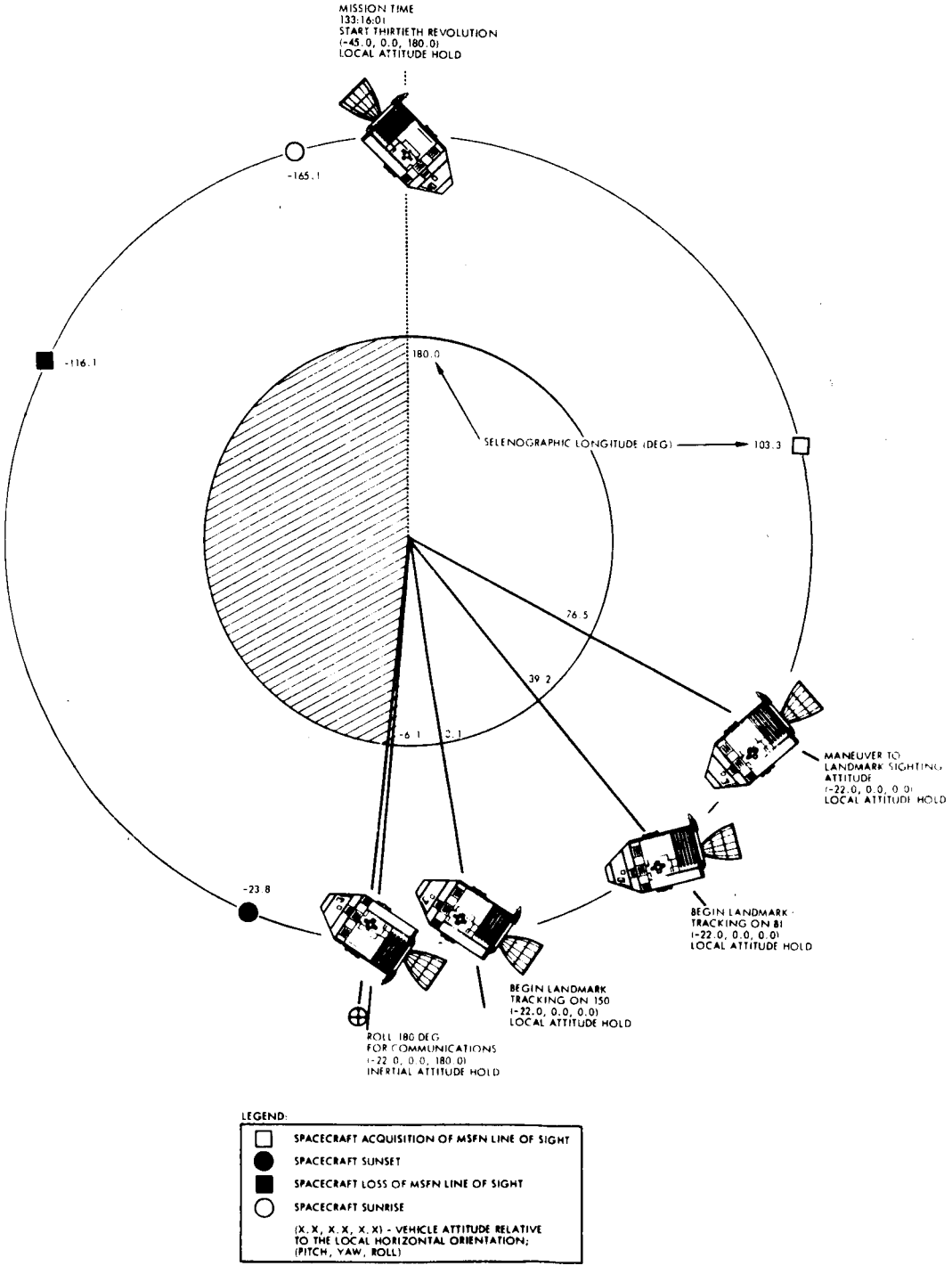



Figure 42. Thirtieth Revolution Major Events and Attitudes

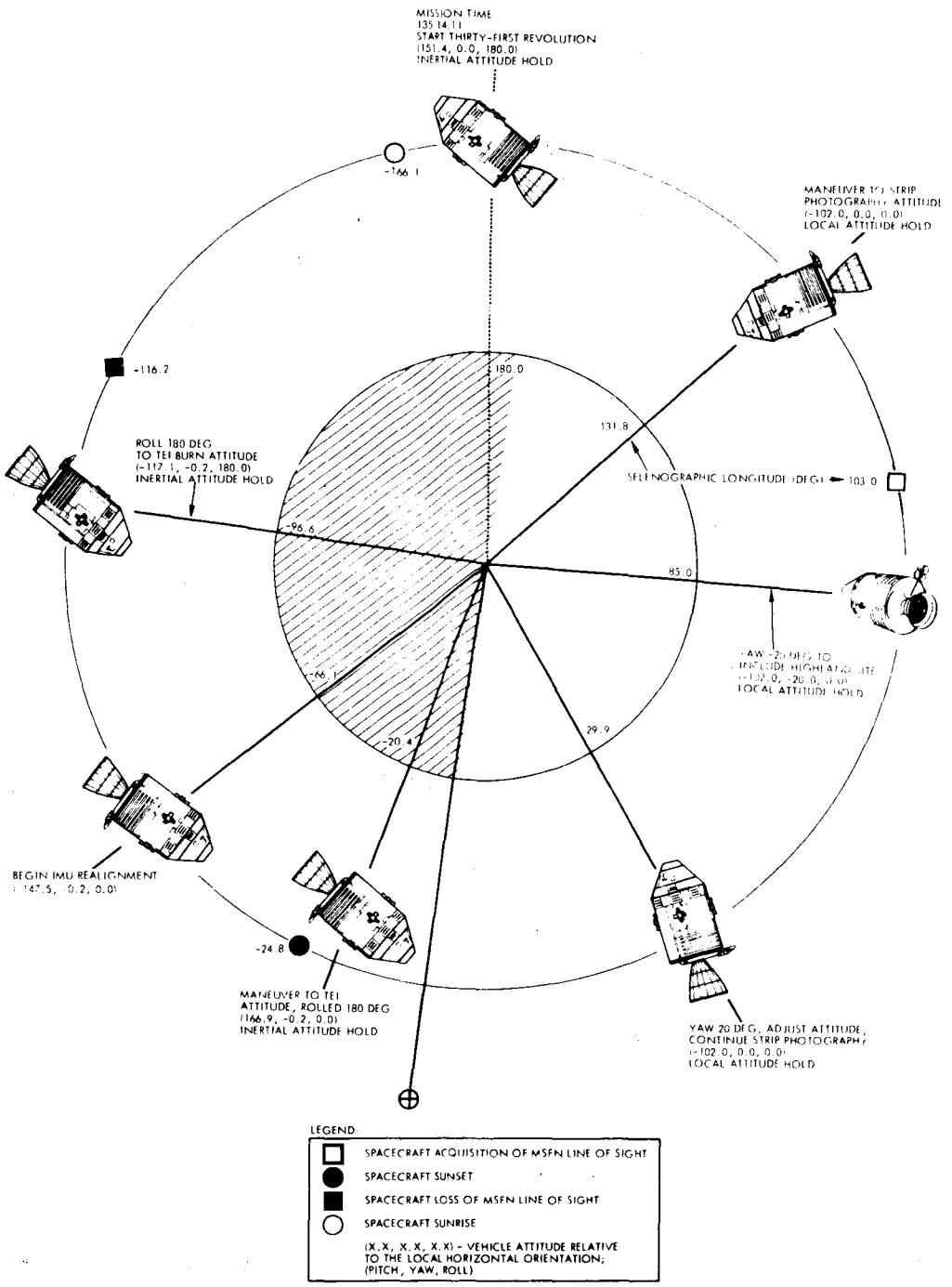
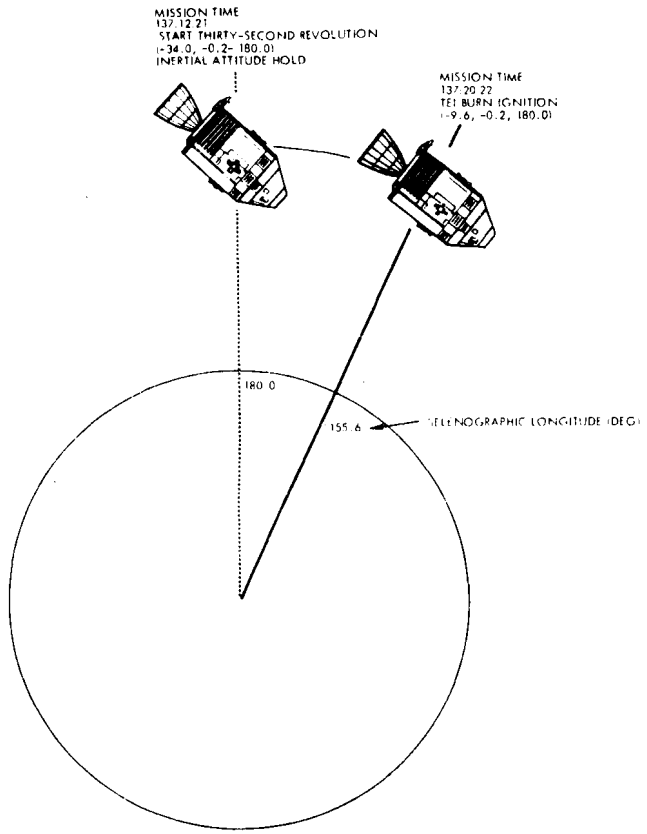



Figure 43. Thirty-first Revolution Major Events and Attitudes



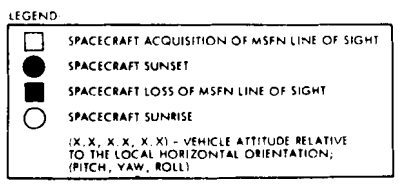




Figure 44. Start of Thirty-second Revolution to TEI Burn Ignition

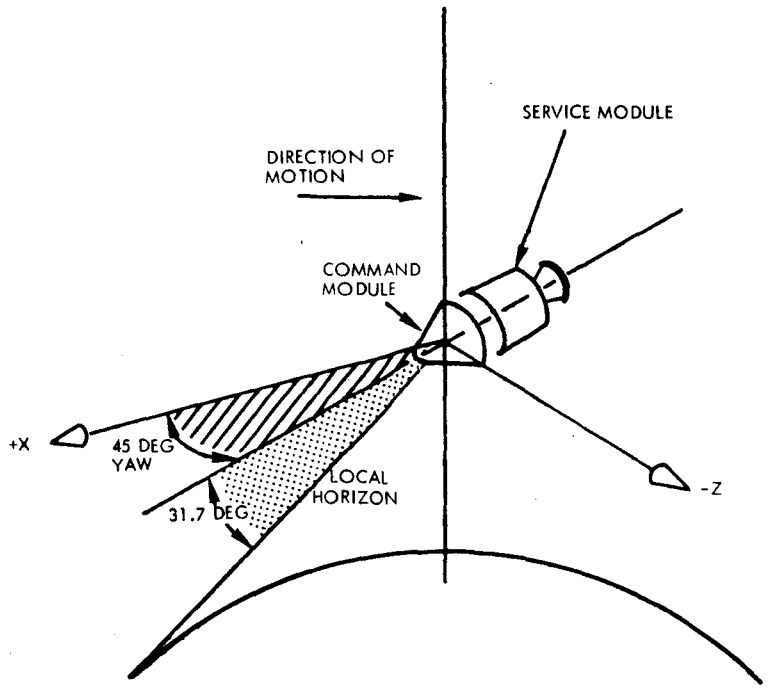



Figure 45. CM/SM Separation Attitude

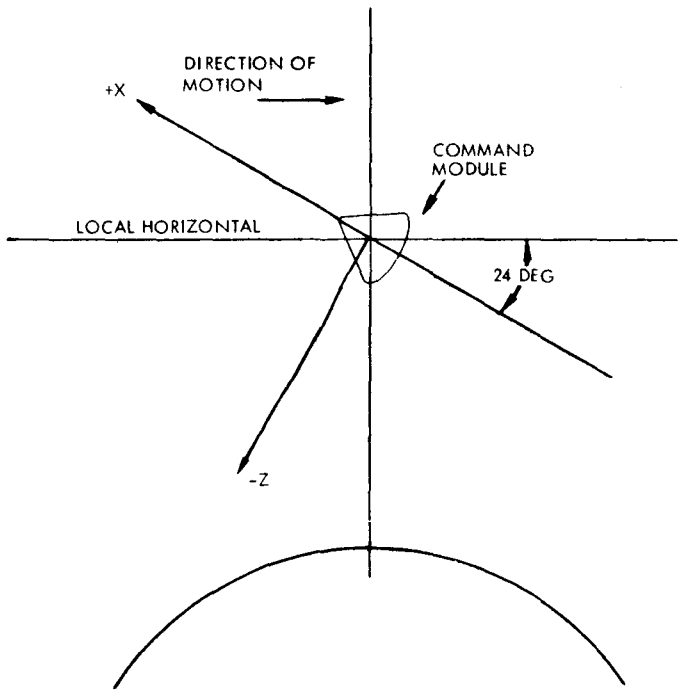



Figure 46. CM Entry Attitude

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