BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

SUBJECT: Review of Apollo Test Objectives Remaining After Mission D - Case 310

DATE: February 19, 1969

FROM: A. C. Merritt

ABSTRACT

The addition of Mission C-Prime resulted in a revision to the old (C, D, E, F/G) test mission sequence and subsequent redistribution of test objectives among the missions of the new (C, C-Prime, D, F, G-1) sequence.

This memorandum reviews the Detailed Test Objectives which will remain after a successful Mission D. In addition to the new mission sequence, both (C, C-Prime, D, G-1) and (C, C-Prime, D, D-Prime, G-1) sequences are discussed, noting the test objectives which could be accomplished and those which would remain.

The new (C, C-Prime, D, F, G-1) sequence will accomplish all but four of the test objectives associated with the old (C, D, E, F/G) sequence. Two of these four objectives are of a more important nature, requiring a long duration Descent Propulsion System burn simulating the lunar landing mission descent burn, and a LM rendezvous with burns controlled by the Abort Guidance System. A (C, C-Prime, D, D-Prime, G-1) sequence might provide additional freedom for development should there be some problems on Mission D, but even in the best case nine test objectives (all associated with LM performance in the lunar environment) would remain after this sequence. A (C, C-Prime, D, G-1) sequence would require a major departure from existing flight test requirements, and would result in at least 20 objectives unsatisfied prior to Mission G-1.

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MEMORANDUM FOR FILE

INTRODUCTION

The Apollo test mission sequence has been revised and test objectives have been redistributed among the missions of the new sequence. Some of the possible implications of this redistribution of objectives are: loss of in-flight development, the addition of non-essential test objectives, and the creation of new opportunities for in-flight development. In order to discuss these possible implications, an analysis is presented in which several variations to the current mission sequence are compared by noting differences in the accomplishment of the previous "fixed" set of test objectives.

There are several points to mention in defining the scope of this memorandum. First, the memorandum is not primarily concerned with the redistribution of Detailed Test Objectives (DTOs) that was caused by the addition of Mission C-Prime. Rather, the emphasis here is on the change in the DTOs remaining after Mission D. In the mission sequence of August 1968, prior to the decision to fly Mission C-Prime, the Mission E and F DTOs defined the flight test requirements remaining after the successful completion of Missions C and D. In this memorandum, objectives accomplished on Mission C-Prime are subtracted from the "old" Mission E and F objectives, and the resulting set of objectives is used to define the flight test requirements which will remain after Mission D. Using the "old" objectives is in keeping with the intention to examine a set of "fixed" flight test requirements which are as independent of the mission profiles as possible.

The DTOs that were officially assigned to Mission C-Prime are similar, but not identical to, the "old" Mission E and F objectives that were accomplished on Mission C-Prime. These differences are noted in Appendix A, which contains a tabulation of the redistribution of the "old" Mission E and F DTOs.

1.0 DETAILED TEST OBJECTIVES

Detailed Test Objectives specified in References (1) and (2) were assigned by the Apollo Spacecraft Program Office to Missions E and F, and these were the current E and F mission requirements just prior to the decision to fly Mission C-Prime. In Table (1), the old Mission E and F DTOs have been listed according to the related lunar landing mission phase, and divided into two groups: those items essentially resolved by the addition of the lunar orbit C-Prime Mission, and those which will remain after Mission D. The DTO numbering scheme and DTO category definitions (i.e., "M", "P", or "S") used in Table (1) are explained in Appendix B.

There is a certain degree of duplication among the 55 DTOs that were assigned to Missions E and F. For example, objectives P20.75 Passive Thermal Control Procedures and P20.79 Passive Thermal Control Mode both required a simulation of passive thermal cycling, in order to determine the long-term stability of the spacecraft's low-roll-rate dynamics. Duplicate objectives and objectives concerned with the same type of system evaluation have therefore been grouped together (bracketed) in Table (1). The major flight tests issues resolved on Mission C-Prime have been asterisked in Table (1) and listed in Figure (1), to emphasize the accomplishments of this mission.

2.0 PARTIALLY COMPLETED OBJECTIVES

Three of the flight test issues listed in Figure (1) were only partially resolved on Mission C-Prime, namely Passive Thermal Control, Cislunar Navigation, and Lunar Orbit Navigation. Translunar thermal cycling, although at heavy inertia on Mission C-Prime, did not entirely resolve questions concerning the long-term roll stability of the docked CSM and LM. Typical spacecraft docked and undocked inertia properties are listed in Table (2). The moments of inertia in pitch and yaw are approximately 10 times the rolling inertia for the docked configuration, but only about 2.6 times the rolling inertia for the fully loaded undocked configuration. Non-zero products on inertia, residual attitude rates within the deadbands, propellant sloshing, and other disturbance torques can cause the spacecraft to slowly diverge from the intended thermal control attitude. However, because of the large difference between either pitch or yaw and roll inertias, one can expect that, in the docked configuration, pitch and yaw coupling of the thermal control roll rate will be less pronounced than for the undocked configuration.

The Mission C-Prime (undocked) passive thermal cycling test evidently indicated adequate roll stability for the translunar phase, so there should be little concern for the stability of translunar thermal cycling in the docked configuration. Figure (2) shows how the CSM high gain antenna (HGA) boresight reference angles can vary during one typical passive thermal cycling rotation. With the LM attached, the shadow zone does not change so as to affect communications during thermal cycling. The data from Mission C-Prime should be adequate for the assessment of communications during docked passive thermal cycling.

Transearth thermal control, performed at low fuel loading, is considered the worst-stability case, because the low roll momentum and large ullage volume aggrevate disturbance effects. The transearth case was flight-tested on Mission C, but atmospheric drag, as expected, caused an attitude divergence rate of approximately 1°/minute, much higher than should be expected during cislunar flight. Mission C-Prime permitted an improved exercise in which: (a) the spacecraft was entirely free from atmospheric drag, and in inertial drift for many hours, (b) the high gain antenna was operating and communication constraints could be assessed, and (c) the crew timeline was constrained only by actual cislunar activities.

In summary, lack of the LM on Mission C-Prime does not have severe implications for the thermal cycling issue. It should be noted that the passive thermal control objectives (P20.75 and P20.79 in Table 1) relate to the dynamics of thermal control, and do not require determination of the resulting thermal balance. Objective P7.26 (CSM and LM) Space Environment Thermal Control requires an assessment of the CSM and LM thermal balance in cislunar space and, as indicated in Table (1), this objective was not accomplished on Mission C-Prime, because the Mission C-Prime configuration did not include the LM.

The other flight test issues listed in Figure (1) that were only partially resolved on Mission C-Prime are CSM Cislunar Navigation and CSM Lunar Orbit Navigation. As indicated in Figure (3), the field of view of both the sextant and the scanning telescope is more constrained with the LM attached, and onboard navigation was performed on the C-Prime Mission without this LM interference. Sunlight reflected into the optics from LM surfaces is also a problem unique to the docked configuration. The larger inertias of the docked configuration will make the spacecraft less maneuverable while doing navigation sightings, so that in the manual mode, sightings might be more difficult on the lunar landing mission. While the importance of constraints such as these should not be discounted a priori, it is expected that knowledge of the related effects will at most cause refinements (rather than major revisions) to the navigation sighting and landmark tracking procedures.

In addition to the major issues listed in Figure (1), there are also several more or less secondary test objectives which were only partially completed on Mission C-Prime. P20.44 Simulated LOI Maneuver is among the DTOs listed on the left of Table (1), but was only partially completed on Mission C-Prime. The Lunar Orbit Insertion (LOI) burn duration was approximately 246 seconds on the C-Prime Mission (versus approximately 380 seconds on the lunar landing mission), and the dynamics and control of the burn were different without the LM. Similarly, translunar midcourse corrections (re S20.76 and S20.95) were performed in the undocked configuration on Mission C-Prime, and are performed in the docked configuration on the lunar landing mission. Flight test of differences such as these should at most result in refinements to procedures, rather than any major revisions.

3.0 REMAINING DTOs

After the successful completion of Mission D, there will be 31 DTOs remaining, out of the 55 DTOs assigned to Missions E and F in References (1) and (2), treated here as a "fixed set" of requirements. These 31 "Remaining DTOs" are listed on the right of Table (1). DTOs requiring the same type of system evaluation have been grouped together (bracketed) as 26 separate test objectives, in order to avoid duplication. The majority of these 26 objectives pertain to rendezvous and LM activity, and this is a dominant consideration in the assessment of the mission assignment for SA-505/CSM-106/LM-4.

A detailed discussion of the 31 (26 separate) DTOs remaining after a (C, C-Prime, D) sequence is included with the discussion of mission sequences in the next section.

4.0 TEST MISSION SEQUENCE POSSIBILITIES

Accompanying the addition of Mission C-Prime to the flight test program, the test mission sequence was changed from (C, D, E, F/G) to (C, C-Prime, D, F, G-1). In order to evaluate this change, this section considers the mission sequence possibilities that were available at the time the change was made, noting differences in the accomplishment of the 31 "Remaining DTOs".

The discussion here is limited to sequences formed from the following six mission types:

1. Mission C: CSM Operations

2. Mission C-Prime: CSM Operations

3. Mission D: CSM/LM Operations

4. Mission D-Prime

5. Mission F: Lunar Mission Development

6. Mission G-1: First Lunar Landing

With the exception of Mission D-Prime, the basic mission profile for each of these mission types is specified in Reference (5). Mission D-Prime is a variation of Mission D which would provide an earth orbital resolution of the maximum number of "Remaining DTOs" from Table (1). There has been no formal definition of a Mission D-Prime profile. The first lunar landing mission (G-1) has been categorized in the above list of mission types as a test mission. This reflects the fact that a number of test objectives which require an actual lunar landing have been assigned to Mission G-1.

Mission E is not included among the above mission types because there did not appear to be sufficient justification for a high-earth-orbit mission, after a (C, C-Prime, D) sequence. All of the DTOs that require a high-earth-orbit E-Type Mission, with the exception of P20.46 Transposition/Docking/LM Ejection, are listed on the left of Table (1), among the DTOs that were accomplished on Mission C-Prime. Objective P20.46 is listed on the right side of Table (1), among the DTOs that will remain after Mission D. All other "Remaining DTOs" either require a lunar orbital mission, or can be performed in low earth orbit. Transposition, docking and LM ejection during the high earth orbit on Mission E would have simulated the related lighting and trajectory conditions for a translunar trajectory. Redesign of the SLA (Spacecraft LM Adapter) panel deployment system has relieved lighting constraints for T&D (transposition and docking), and CSM, S-IVB/ground communications are now the major T&D attitude constraint. Objective P20.46 has been downgraded to Secondary and is currently assigned to Mission F.

It is assumed in this memorandum that test mission sequences formed from the above mission types must satisfy the following constraints:

1. The last mission in the sequence must be G-1.

2. The first three missions must be C, C-Prime and D, respectively.

3. Repetition of a mission type must not be pre-planned.

4. Mission D-Prime should not be preceded by Mission F.

Constraint (1) is in keeping with the goal of the Apollo Program. Constraint (2) specifies that Missions C and C-Prime must be the first missions in any sequence discussed, since these missions have already been successfully completed. Constraint (2) also assumes that current planning for Mission D has progressed to the point where rescheduling would be detrimental to overall development and scheduling. Constraint (3) is imposed to be consistent with the implicit assumption of mission success. Constraint (4) specifies that a progressive inflight development be maintained.

Mission sequences which satisfy these constraints are listed in Table (3), with each sequence compared in brief to the current baseline schedule. The four mission sequences listed in Table (3) are the only sequences, formed from the six mission types, which satisfy constraints (1) through (4). In the comparisons of Table (3), it is assumed that, relative to the current baseline sequence, increased risk in achieving a lunar landing is incurred whenever: (a) a mission (or mission activities) is added prior to G-1, or (b) less in-flight development is provided prior to G-1. Note that assumption (a) is not entirely valid if the increased development associated with an added flight (or added flight tests) can be shown to decrease the risk of flying the subsequent mission(s), such that the overall risk in achieving a lunar landing is decreased. Assumption (b) is valid if the areas of decreased development are actually correlated with a decreased probability of lunar landing success.

The overall relative advantages and disadvantages noted in Table (3) relate to three areas: development, scheduling and risk. The six mission sequence, (C, C-Prime, D, D-Prime, F, G-1), would provide more in-flight development than the current schedule, but with a corresponding delay in lunar landing and an increase in overall program risk, per assumption (a). The five mission sequence (C, C-Prime, D, D-Prime, G-1), would probably incur less overall risk than the current sequence, but would provide less in-flight fidelity testing. The four mission sequence (C, C-Prime, D, G-1), would have the advantage of an earlier lunar landing opportunity but would provide less in-flight development, and therefore additional risk, in accord with assumption (b).

The column to the right of Table (3) lists the number of test objectives, from the "fixed set" of old Mission E and F DTOs, which would remain prior to Mission G-1, for each of the four mission sequences. The exact number of DTOs remaining after a (C, C-Prime, D, D-Prime) mission sequence is somewhat in doubt because several objectives that would be assigned to Mission

D-Prime would require conflicting demands on the spacecraft consumables and subsystem operating constraints. The number in parenthesis represents the most optimistic case, in which apparently conflicting requirements are all satisfied. These conflicts will be discussed subsequently in Section (7.0).

5.0 (C, C-Prime, D, D-Prime, F, G-1) MISSION SEQUENCE

The second mission sequence of Table (3), viz. (C, C-Prime, D, D-Prime, F, G-1), will not be discussed in detail in this memorandum. This sequence can accommodate all of the current test objectives. Acceptance of this sequence would have required a clear trade-off of scheduling, in favor of spacecraft development. With the (C, C-Prime, D, F, G-1) sequence as a baseline, however, the (C, C-Prime, D, D-Prime, F, G-1) sequence must be rated as assuming increased risk in achieving a lunar landing. The inherent risk of performing operations such as launch-to-orbit and entry must be considered for every flight, and these risks must be justified by the added development which would further insure a successful lunar landing mission. Although there is a shortage of LM flight test data (no manned LMs have been flown), it appears that flying two missions between D and G-1 would only be justified if some rather severe LM development problems were to arise. Since the ability to react to currently unacticipated schedule and development delays will depend upon the alternatives available, this sequence should be retained as an "inactive" option until Mission D is flown.

6.0 (C, C-Prime, D, G-1) MISSION SEQUENCE

Flight test requirements for the Apollo program have evolved over a period of several years, and have been allocated to a sequence of flight test missions involving either two or three manned CSM/LM missions prior to the first lunar landing attempt, (viz. C, D, E, F/G), or currently, (C, C-Prime, D, F, G-1). A (C, C-Prime, D, G-1) sequence would therefore be a major change to the flight test program philosophy. However, examination of this sequence provides a constructive analysis of flight test requirements remaining after successful completion of (C, C-Prime, D).

Of the 26 separate DTOs that will remain after Mission D, 6 could possibly be assigned to Mission G-1 in a (C, C-Prime, D, G-1) mission sequence. These are listed in Table (4). These 6 DTOs would have to be accomplished prior to a point in the mission where an irreversible decision was made to commit to a situation which required dependence upon the system being tested. A mission phase which would allow this "pre-commitment" testing is denoted here as an "evaluation plateau". It should be noted that the concept of assigning DTOs to an evaluation plateau on G-1 is used here in a distinctly limited sense. The purpose of the flight test program is to provide data which will verify analysis and ground testing. Obtaining this data prior to the first lunar landing mission provides the opportunity for improving redlines, procedures, and possibly hardware. Obtaining flight test data during G-1 would provide a check on subsystem operations, but would probably not permit real-time improvement of procedures and redlines.

With the exception of some details, all of the objectives listed in Table (4) are presently included in the nominal lunar landing mission timeline (References 6, 7 and 8). Although the time that could be devoted to each of these DTOs would be limited on the G-1 mission, there would be no doubt as to the fidelity of the testing conditions, as there might be on a D-Prime Mission, for example. One of the risks incurred in testing these systems during the G-1 Mission is that lunar landing might be aborted simply because a "work-around" could not be devised in real time. For example, if acquisition with the LM high gain antenna proved difficult and lock-on could not be achieved, powered descent would not be attempted (Reference 8). Post-flight analysis might then reveal a procedure to overcome this (postulated) problem. Discovery of a problem like this on a test mission would not have such severe consequences.

The 20 test objectives which could not be accomplished during an "evaluation plateau" on the G-1 Mission, in a (C, C-Prime, D, G-1) mission sequence, are listed in Table (5). The 13 asterisked test objectives pertain to the nominal lunar landing mission operations, and would be resolved by a successful G-1 mission. The 7 other DTOs would remain unresolved as long as strictly nominal lunar landing missions were flown subsequent to Mission G-1.

There are 15 Principal (P) DTOs and 5 Secondary (S) DTOs listed in Table (5). By the established definition, which is given in Appendix B, a Principal test objective is one which must be accomplished prior to the first lunar landing mission. A Secondary test objective need not be accomplished prior to the first lunar landing mission but, if satisfied, would provide additional useful flight test data. Because of the importance of Principal test objectives, all 15 of the Principal objectives from Table (5) will be discussed in more detail in the following sections. The "Constraining Factors" listed on the right of Table (5) will be explained for each of the 15 Principal objectives.

P2.9 GNCS/MTVC Takeover (E)

This flight test requires manual thrust vector control takeover of a GNCS (CSM Guidance, Navigation, and Control System) initiated SPS (Service Propulsion System) burn. At least 15 seconds of manual control is required, and the test is to continue until EMS (backup) ΔV counter shutdown. The CSM is to be stabilized in attitude prior to takeover and average attitude errors during manual control are expected to be less than 2 degrees (Reference 1). The more serious case of manual control takeover during attitude transients will not be flight tested, and will evidently be analyzed via simulators. This objective has been assigned to Mission D, and therefore can be removed from the list of DTOs remaining after a (C, C-Prime, D) mission sequence.

P7.26 (CSM/LM) SPACE ENVIRONMENT THERMAL CONTROL (F)

The purpose of this test objective is to determine if the CSM and LM thermal shielding provides adequate control of structural and component temperatures during a lunar orbit mission. This objective was partially satisfied by the collection of CSM data on Mission C-Prime, so that the remaining issue is LM thermal control. Areas of particular interest include thermal control of the LM landing gear, Landing Radar and Rendezvous Radar antennas, helium supply, fuel and oxidizer tanks, and the RCS quads. While Mission D will provide data on many of the LM thermal control problems (e.g., RCS thruster impingement), the earth orbital environment will differ from the lunar mission environment. Cycling between sunlight and darkness on an earth orbital mission, as well as earth albedo, will present an entirely different thermal radiation time history than a circumlunar/lunar orbit trajectory.

The importance of this objective must be considered in view of several factors. The LM-4 and LM-5 descent stage thermal shield and blanket configurations are different (Reference 9), and this will reduce somewhat the importance of LM-4 flight test data. In addition, the effect of lunar surface infrared and reflected solar radiation is an important factor, and this cannot be completely determined until an actual lunar landing mission is performed. The "constraining factor" that prevents this objective from being assigned to Mission G-1 is that it requires a total evaluation of CSM/LM thermal balance from launch through final LM jettison. The thermal response of the Rendezvous Radar, for example, cannot be determined until actual rendezvous lighting and thrusting conditions are experienced.

P11.15 PGNCS Undocked Performance (F)

This objective was P11.2 on the Apollo 5 (LM-1) flight, and was not completed due to premature DPS (Descent Propulsion System) shutdown (Reference 10). As per Reference (2), P11.15 requires at least 24 seconds of PGNCS (Primary Guidance, Navigation, and Control System) controlled DPS firing at fixed throttle point (92.5% thrust). Ignition attitude transients, response to DPS throttling, response to c.g. change, etc. were to have been evaluated on LM-1. Following a premature DPS shutdown on the LM-1 Mission, all burns were sequenced by the Mission Programmer and controlled by the Stabilization and Control System (i.e., backup system). These maneuvers were performed without closed-loop guidance and with no attitude control except for rate damping. While there is an undocked PGNCS DPS burn on Mission D, it is at only 10% throttle, and will not satisfy the 24 second fixed-throttle-point requirement of the new objective (P11.15). This objective cannot be transferred to the G-1 Mission because 24 seconds of fixed throttle point thrusting prior to actual descent would, among other things, result in a negative DPS propellant margin.

P11.16 PGNCS (Unstaged) Attitude/Translation Control (E)

This objective was partially accomplished on the LM-1 Mission, but the digital autopilots for LM-3 and subsequent are different, and some corrections resulting from the LM-1 flight have been introduced. As per Reference (1), this objective requires attitude-hold and maneuver exercises, with minimum and maximum deadband, for an unstaged LM (heavy ascent stage, light descent stage). This objective was not assigned to Mission D because of the large number of objectives already on that mission. There is, however, a similar exercise on Mission D for the staged configuration. This objective does not appear among the new Mission F requirements, and appears to have been dropped from the flight test program when Mission E was dropped. This objective cannot be performed prior to descent on either Mission F or Mission G-1 because it requires a light descent stage, and neither of these missions provides for LM coasting flight with low DPS loading.

P12.5 AGS Inflight Alignment/AOT (E)

In the event of a PGNCS failure, the AGS (Abort Guidance System) cannot be aligned to the PGNCS reference (normal mode), but must be aligned to a stellar reference. This requires ground processing of the onboard sighting information, and update of the reference. The AOT (Alignment Optical Telescope) is specified for this objective, but the COAS (Crew Optical Alignment Subsystem) can also be used. This objective probably could not be done prior to descent on Mission G-1 because of the impact on the crew timeline. This objective is currently transferred to the "new" list of Mission F DTOs.

P12.7 AGS Controlled APS Burn (F)

As per Reference (2), this objective requires at least 15 seconds of APS (Ascent Propulsion System)/AGS control. Start transients and RCS propellant consumption are to be determined. This objective is similar to P12.9 Unmanned AGS Controlled APS Burn (E), and is treated as the same objective in Table (5). An unmanned APS burn is scheduled for Mission D, but this will be controlled by the PGNCS. The purpose of this objective is to verify predicted AGS/APS ΔV errors and RCS fuel consumption for both heavy and light ascent stage inertias. This objective has been given the Mission E number, P12.9, and is now assigned to Mission F. It cannot be assigned to G-1 because there is obviously no evaluation plateau available.

P12.8 AGS/CES Attitude and Translation Control (Staged) (E)

This objective requires attitude-hold and maneuvering for a heavy ascent stage, with AGS/CES (Control Electronics Section) control. A similar exercise is planned for Mission D, but in the unstaged configuration. This objective has been assigned to the new list of Mission F objectives and was to have been satisfied by an AGS-controlled CDH (Constant Delta Height Maneuver) burn during the LM active rendezvous on Mission F. However, the APS will be off-loaded on Mission F, and CDH will be nominally zero in the current revised LM rendezvous. Therefore, both the inertia conditions and extent of testing specified by this objective will be compromised. This objective cannot be done on Mission G-1 because there is no nominal situation in which the ascent stage is at heavy inertia and in coasting flight.

P20.45 Simulated DOI/Descent Burns (E)

This objective was included in M13.7 on Apollo 5, and was not completed due to premature DPS shutdown (Reference 10). The major purpose of this objective is to verify specific impulse, thrust, and mixture ratio characteristics for the lunar landing descent throttling profile. As an example of DPS performance variations, the predicted lunar mission duty cycle DPS specific impulse varies between 290.4 and 294.8 seconds (1-sigma) at 10% throttle and 300.0 to 304.2

seconds at full throttle. According to Reference (1), the DPS throat-erosion vs. time profile contains three distinct rates of erosion. The third erosion rate is predicted to start at 600 seconds total burn time, and it will be necessary to burn at least 30 seconds after this time to confirm the ground test prediction of erosion. The docked DPS burn on Mission D will be about 364 seconds, too short to verify the throat-erosion profile. With a low DPS propellant margin for the lunar landing mission (Reference 12), DPS performance is an important item for flight test verification. This objective is not included in the current Mission F objectives because of the difficulty in performing a docked DPS burn in lunar orbit. This objective appears to have been dropped from the flight test program.

M20.48 LM Abort Rendezvous (E)

This objective requires a Concentric Flight Plan rendezvous in which all burns are controlled by the AGS (Abort Guidance System), and Rendezvous Radar updating of the AGS is performed. The PGNCS solution can be used for executing maneuvers (it is more accurate), but AGS solutions must be calculated. The intent of this exercise is to evaluate AGS navigation and control performance, especially the effect on propellant consumption. This objective was rated mandatory (M) because a PGNCS failure during LM descent, surface-stay, or LM ascent will require an AGS rendezvous as a first backup. The major intent of this objective was to have been satisfied on Mission F by performing the terminal phase on AGS control, and this would have been more consistent with the testing of other backup systems, e.g., the CSM SCS control system. However, this objective does not appear among the current Mission D or F requirements, and has been dropped from the flight test program.

P20.66 (CSM and LM) Lunar Distance Crew Activities (F)

This objective requires a simulation of lunar landing mission activities (other than actual landing and ascent) which have not been previously simulated on Missions C, C-Prime, and D. It specifically requires a simulation of activities that only Mission F can provide, such as the timeline of events during a lunar orbit rendezvous. It is among the current Mission F objectives.

P20.77 VHF Ranging/CSM Active Rendezvous

This objective requires a CSM active rendezvous from TPI (Terminal Phase Initiation) to TPF (Terminal Phase Finalization), with sextant navigation complemented by VHF ranging data. The resulting flight test data would confirm the SM-RCS LM rescue allowance, and provide increased confidence that CSM rescue of the LM could be performed on a lunar landing mission. The predicted SM-RCS propellant margin, including an allowance for LM rescue, is 18% (Reference 12), so that the terminal phase of a CSM rescue should not be of great concern at present. Preparation for CSM rescue of the LM will be performed on Mission D prior to each LM rendezvous burn (Reference 13), and this should confirm the capability for one-man targeting of CSM maneuvers. The success of the Apollo 7 rendezvous and the results of VHF ranging tests at White Sands indicate that CSM rescue of the LM is not a major flight test problem.

This objective, along with S20.47 CSM Active Rendezvous (E), has been dropped from the flight test program because of the preference given to the AGS/APS burn on Mission F. Both CSM rendezvous and the AGS/APS burn could not be accommodated within LM consumables constraints on Mission F. Similarly, CSM rendezvous cannot be performed on Mission G-1 subsequent to the nominal rendezvous, and in any case, would not be a test of CSM rescue capability prior to a commitment point.

P20.78 LM Active Rendezvous (F)

The purpose of this test is to verify ground simulations of the nominal lunar landing mission rendezvous and therefore reduce the risk of performing the rendezvous on Mission G-1. The only other LM active rendezvous in the flight test program is the Mission D rendezvous, which has been reduced to a series of evaluation orbits, followed by a simulation of the nominal lunar landing mission rendezvous from CDH (Constant Delta Height) to TPF (Terminal Phase Finalization) (Reference 14). The relative motion geometry, burn durations, delta-h, etc., on Mission D are different from the current lunar landing mission rendezvous of Reference (15). Since rendezvous is largely a flight mechanics and navigation problem, there is some argument for requiring a rendezvous flight test in lunar orbit, in the presence of the lunar gravitational field, and with the proper lighting conditions. This objective is among the current Mission F requirements.

P20.80 (CSM & LM) Lunar Distance Ground Support (F)

The purpose of this objective is to assess the adequacy of operational ground support for a lunar orbit mission. This objective includes assessment of the equipment and operation of the Mission Control Center, the Real-Time Computer Center, and the Manned Space Flight Network. A number of lunar distance ground support items were verified on Mission C-Prime, and the remaining issue is support of rendezvous and LM activity at lunar distance. The objective is currently assigned to Mission F. It could not be assigned to Mission G-1 because it requires post-flight evaluation.

P20.82 PGNCS/AGS Monitor-Lunar Orbit (F)

Ground and crew identification of a PGNCS or AGS failure is critical to the formulation of an abort decision during the lunar landing mission. This objective was established to verify that the Mission Control Center can obtain a valid indication of PGNCS and AGS performance during the lunar landing mission, for example, during powered descent. This objective is among the current Mission F requirements. It cannot be performed on Mission G-1 because it requires post-mission assessment.

P20.83 LM Consumables - Lunar Orbit (F)

Recent and contemplated changes to LM checkout and operations for the lunar landing mission have increased the importance of pre-mission and real-time consumables assessment capability. Descent and ascent stage batteries, water, oxygen, main propellants, and RCS propellants are among the items which must be predicted to show an adequate margin for the lunar landing mission. Post-mission analysis of Mission F data will further verify Mission G-1 consumables margins. This objective has been downgraded to Secondary, and is currently among the Mission F Secondary mission requirements.

Secondary Test Objectives

Returning to Table (5), all Principal objectives which would remain after a (C, C-Prime, D) mission sequence have been discussed. Of the 5 separate Secondary objectives listed in Table (5), only S16.14 Landing Radar Test (F) is a distinctly "new" test, but is of Secondary importance because it will be performed at high altitude (50,000 ft.) and the data return will be marginal.

In summary, the discussion of this section indicates that a (C, C-Prime, D, G-1) mission sequence would require a major departure from the previously established flight test requirements of References (1) and (2) because of the large number of tests which would have to be deleted. As noted, several Principal test objectives have already been dropped from the flight test program, viz. P11.16 PGNCS (Unstaged) Attitude/Translation Control (E), P20.45 Simulated DOI/Descent Burns (E), M20.48 LM Abort Rendezvous (E), and P20.77 VHF

Ranging/CSM Active Rendezvous (F). The philosophy of reducing the risk of the lunar landing mission by selective flight testing has been a basis for mission planning for several years. Acceptance of a (C, C-Prime, D, G-1) mission sequence would be a departure from this philosophy.

7.0 (C, C-Prime, D, D-Prime, G-1) Mission Sequence

The mission profile for a D-Prime Mission was never officially established prior to the decision to fly Mission F after Mission D. For the purpose of this discussion, however, Mission D-Prime can be defined as an earth orbital CSM/LM mission which is synthesized from portions of Missions D and E, and which maximizes the accomplishment of the "Remaining DTOs" of Table (1).

Table (6) contains a list of 16 DTOs which could be assigned to a D-Prime type mission, and Table (7) lists 12 DTOs which would remain after a (C, C-Prime, D, D-Prime) mission sequence. Table (6) contains six test objectives which would be in conflict on a D-Prime mission. Only these conflicting requirements will be discussed further.

Beginning at the top of Table (6), P11.15 PGNCS Undocked Performance (F) and P20.45 Simulated DOI/Descent Burns (E) might not be compatible requirements. Satisfaction of both these requirements is constrained by three major factors. First, there must be sufficient propellant for both a long duration performance-verification burn and a shorter undocked control-verification burn. Second, any sequence of DPS burns must be compatible with propellant pressurization system constraints and the thermal/structural limits of the DPS propellant tanks. Third, heat soakback between burns results in thrust chamber charring, and this charring must not result in an unsafe condition, such as chamber burn-through.

The DPS burn that was assigned to Mission E, in support of P20.45, would have resulted in a 1031 lb (6%) usable propellant margin (Reference 16). In order to maintain an equivalent margin, and to satisfy the P11.15 requirement for a 24 second undocked burn at fixed throttle point, the docked-burn duty cycle would have to be shortened somewhat. It would be preferable to give priority to the undocked DPS burn requirement, since the long docked DPS burn on Mission D will supply DPS performance data, whereas if P11.15 is not satisfied, there will be <u>no</u> fixed throttle point (92.5% thrust) PGNCS/DPS undocked burns prior to the actual descent maneuver on the lunar landing mission. If the constraints mentioned could not be satisfied, the short undocked DPS burn at 92.5% thrust might have to be limited to a somewhat longer burn at 40% thrust. The particular DPS duty cycle for a D-Prime mission would evidently have to be verified by ground testing at the White Sands Testing Facility.

The rendezvous requirements of M20.48 LM Abort Rendezvous (E) and P20.78 LM Active Rendezvous (F) are also in conflict. Only one terminal phase, either on AGS or PGNCS, could be performed. A compromise between these objectives would be a long-range (200 n.mi. max. range) lunar landing mission type rendezvous, with targeting, navigation, and control functions divided between the AGS and PGNCS for the various burns.

Objectives P20.77 VHF Ranging/CSM Active Rendezvous (F) and S13.13 Long Duration APS Burn (E) would both be possible only if the LM ascent stage electrical power were sufficient to permit several hours of LM attitude-hold for the CSM active rendezvous prior to a long duration APS burn.

The flight test requirements that would remain <u>after</u> a (C, C-Prime, D, D-Prime) mission sequence, listed in Table (7), are largely associated with lunar vicinity flight. The four asterisked DTOs of Table (7) could be assigned to the G-1 Mission, as per the evaluation plateau philosophy discussed earlier. If the conflicting DPS, LM rendezvous, CSM rendezvous, and APS requirements could be accommodated, then only 5 of the DTOs in Table (7) would remain. They are: P7.26 (CSM & LM) Space Environment Thermal Control, P20.66 (CSM & LM) Lunar Distance Crew Activities, P20.80 (CSM & LM) Lunar Distance Ground Support, P20.82 PGNCS/AGS Monitor-Lunar Orbit, and S16.14 Landing Radar Test. P7.26 was discussed earlier in connection with the (C, C-Prime, D, G-1) mission sequence and, as noted, this objective would definitely require a lunar orbit mission. P20.66, P20.80 and P20.82 are not quite as "environment dependent" as P7.26, and were partially satisfied on Mission C-Prime.

If successful, S16.14, on Mission F, would yield a small sample of data on the lunar surface radar reflectivity for one landing area. It is expected that performance would be marginal at the 50,000 ft. altitude at which this test would be performed.

In summary, a (C, C-Prime, D, D-Prime, G-1) mission sequence would be acceptable if: (a) the D-Prime mission accommodated a number of conflicting requirements, (b) several objectives were deferred to Mission G-1, (c) the mission planning and training could be accomplished in the required time, and (d) several more or less secondary DTOs were "dropped" as requirements.

8.0 (C, C-Prime, D, F, G) Mission Sequence

This sequence is the current test mission sequence, and was used as the basis for the relative comparison of Table (3). The specific question in this section is how the old Mission E and F objectives have been allocated to the current (C, C-Prime, D, F, G-1) mission sequence. Of the 16 Mission E DTOs listed on the right of Table (1) as remaining after Mission D, 10 have been assigned to Mission F; these are listed in Table (8). Three of the 10 listed in Table (8), viz. P16.9 LM S-Band Updata Link (E), S16.18 LM Steerable Antenna (E), and S20.54 LM Consumables (E), have been combined with similar Mission F DTOs, and will be accomplished implicitly. Objective P20.46 Transposition/Docking/LM Ejection (E) is now Secondary on Mission F. (A tabulation of these reassignments is given in Appendix A.)

Table (9, A and B) lists the 7 Mission E and old Mission F DTOs which remain after the current mission sequence. Six of these are from Mission E and one was among the old list of Mission F requirements. P2.9 GNCS/MTVC Takeover has been assigned to Mission D, and a DTO similar to S20.52 Single Crewman CSM Operations (E) is assigned to Mission D. These two DTOs are listed accordingly in Table (9A). There are then really only four DTOs which have been completely "dropped" from the flight test program because of the conflicts discussed in Section (5.0). These are listed in Table (9B). P20.45 Simulated DOI/Descent Burns (E) cannot be satisfied on Mission F, but some data will be obtained by the 364 second DPS burn on Mission D. M20.48 LM Abort Rendezvous (E) has been dropped in preference to a nominal PGNCS rendezvous on Mission F, and all rendezvous burns on Mission D, with the exception of a DPS/AGS phasing burn, will be under PGNCS control, including terminal phase RCS burns. P20.77 VHF Ranging/CSM Active Rendezvous (F) has been dropped from Mission F in favor of an APS/AGS burn-to-depletion. The VHF ranging system will be flown for the first time on Mission F, and some data will be obtained on performance. This data, along with the success of the Apollo 7 rendezvous, reduces the importance of P20.77. P11.16 PGNCS Attitude/Translation Control (Unstaged) (E) is of a more secondary nature and will be partially accomplished on Mission D along with nominal activities involving a light descent stage and a heavy ascent stage.

Summary

This memorandum has assumed the mission requirements assigned to Missions E and F, as per August 1968, to be a valid indication of the flight test requirements remaining after the old (C, D) mission sequence. Objectives accomplished on Mission C-Prime were subtracted from the old Mission E and F objectives to obtain a "fixed set" of flight test requirements remaining after a (C, C-Prime, D) mission sequence. Mission sequence possibilities, including the current baseline sequence, were discussed as offering the possibility of assigning either Mission D-Prime, F, or G-1 to the SA-505/CSM-106/LM-4 configuration.

It is concluded that a (C, C-Prime, D, D-Prime, F, G-1) sequence would accommodate all current test objectives, but would result in delayed lunar landing and possibly more overall program risk than necessary. A (C, C-Prime, D, G-1) sequence was found to require a major deviation from existing flight test requirements, even if several objectives were reassigned to Mission G-1, as per an "evaluation plateau" concept. A (C, C-Prime, D, D-Prime, G-1) sequence might provide additional freedom for development should there be some currently unanticipated problems on Mission D. The baseline sequence, (C, C-Prime, D, F, G-1), accomplishes all but four of the old test objectives, but these objectives, relating to a long DPS burn, LM abort rendezvous, CSM active rendezvous, and PGNCS/RCS control were all rated as Principal, requiring completion prior to the first lunar landing mission.

2013-ACM-srb

A. C. Merritt

Attachments:
- References
- Appendix A
- Appendix B
- Tables 1 through A-2
- Figures 1, 2, 3

REFERENCES

1. "Mission Requirements, E-Type Mission: Lunar Mission Development", ASPO/MSC, July 1, 1968 and subsequent revisions.

2. "Mission Requirements, SA-505/CSM-106/LM-5, F-Type Mission: Lunar Orbit", August 16, 1968.

3. "CSM/LM Spacecraft Operational Data Book","Vol. III - Mass Properties", MSC/ASPO, SNA-8-D-027, March 1968 and subsequent amendments.

4. "CSM/LM Spacecraft Operational Data Book", "Vol. I - CSM Data Book, Part I - Constraints and Performance", MSC SNA-8-D-027(1), May 1, 1968 and subsequent revisions.

5. "Apollo Flight Mission Assignments" (U), M-D MA-500-11, December 1968.

6. "Apollo Operations Handbook, Lunar Module 5, Vol. II - Operational Procedures", GAEC LMA 790-3-LM5, September 12, 1968.

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8. "Apollo Mission Techniques, Mission G, Lunar Descent", Vol. I - Techniques Description, MSC IN. S-PA-8N-021, August 23, 1968.

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18. "F-Mission Requirements, SA-505/CSM-106/LM-4", MSC/ASPO Review, November 22, 1968.

19. "Mission Requirements, D-Type Mission, LM Evaluation and Combined Operations, Revision 1", MSC/ASPO, SPD 8-R-005, November 6, 1968.

20. "Apollo Spacecraft Flight Test Plan", (Draft), TRW, Rep. No. 05952-H481-RO-000; April 15, 1968.

APPENDIX A: RE-DISTRIBUTION OF MISSION E AND F DTO'S

Tables (A-1) and (A-2) list all of the old Mission E and F DTOs of References (1) and (2), and note the current disposition of these DTOs. The Mission C-Prime objectives referenced are from Reference (17), and the current Mission F and Mission D objectives are from References (18) and (19), respectively.

APPENDIX B: DETAILED TEST OBJECTIVE NOTATION

DTO Numbering System (Reference 20)

1.0	CSM GUIDANCE & NAVIGATION
2.0	CSM STABILIZATION & CONTROL
3.0	CSM PROPULSION
4.0	CSM ENVIRONMENTAL CONTROL
5.0	CSM ELECTRICAL POWER
6.0	CSM COMMUNICATIONS/RADAR/INSTRUMENTATION
7.0	CSM THERMAL/STRUCTURAL/MECHANICAL
8.0	CSM SEQUENCING
9.0-10.0	(UNASSIGNED)
11.0	LM GUIDANCE & NAVIGATION
12.0	LM STABILIZATION & CONTROL
13.0	LM PROPULSION
14.0	LM ENVIRONMENTAL CONTROL
15.0	LM ELECTRICAL POWER
16.0	LM COMMUNICATIONS/RADAR/INSTRUMENTATION
17.0	LM THERMAL/STRUCTURAL/MECHANICAL
18.0	LM SEQUENCING
19.0	(UNASSIGNED)
20.0	OPERATIONAL/SYSTEMS

The following definitions of DTO categories are used in References (1) and (2):

MANDATORY (M) DTO

A principal detailed test objective which must be satisfactorily completed on the assigned mission. Failure to do so would unduly compromise subsequent flight schedules and/or require subsequent space vehicle configuration.

PRINCIPAL (P) DTO

A detailed test objective which must be accomplished in order to demonstrate a lunar landing capability. Any principal detailed test objective can be attempted on a subsequent mission without major impact.

SECONDARY (S) DTO

A detailed test objective which will provide significant data or experience, but which is not a prerequisite to the lunar landing mission.

TABLE (1) - DISPOSITON OF MISSION E AND F DTOs

RELATED LUNAR LANDING MISSION PHASE	E & F DTOs ACCOMPLISHED ON MISSION C-PRIME	E & F DTOs REMAINING AFTER MISSION D
LAUNCH THRU TLI	S20.39 PRE-PROGRAMMED LAUNCH WINDOW (E) S20.92 SIMULATED TLI BURN (E)	(NONE)
CISLUNAR & LUNAR ORBIT	{ P6.9 CSM/MSFN LUNAR DISTANCE COMM (H. GAIN) (F) * P20.57 CSM/MSFN HIGH ALTITUDE COMM. (E) P20.94 (CSM) COMM. PROCEDURES & PERFORMANCE (F) } P6.10 CSM OMNI ANTENNAS - LUNAR DISTANCE (F) P20.44 SIMULATED LOI MANEUVER (E) { P20.58 STAR/LANDMARK NAVIGATION (E) * P20.59 STAR/EARTH HORIZON NAVIGATION (E) S1.22 CSM GNCS SPACE NAVIGATION (F) } * { P20.79 PASSIVE THERMAL CONTROL MODE (F) S20.75 PASSIVE THERMAL CONTROL PROCEDURES (E) } * { P20.91 LUNAR LANDMARK TRACKING (F) S20.60 LUNAR LANDING SITE DETERMINATION (E) } P20.100 LUNAR PHOTOGRAPHS FROM CSM (F) S3.19 SPS EVALUATION (E) S20.49 SIMULATED TEI MANEUVER (E) { S20.76 SPS/RCS MIDCOURSE CORRECTION MANEUVERS (E) S20.95 MIDCOURSE CORRECTION CAPABILITY (F) }	P2.9 GNCS/MTVC TAKEOVER (E) (assigned to D) P16.17 LM/CSM/MSFN VOICE & TM (F) P20.46 TRANSPOSITION/DOCKING/LM EJECTION (E) P20.66 (CSM & LM) LUNAR DISTANCE CREW ACTIVITIES (F) P20.80 (CSM & LM) LUNAR DISTANCE GROUND SUPPORT (F) P20.86 (CSM/LM) LUNAR ORBIT VISBILITY (F) S20.52 SINGLE CREWMAN CSM OPERATIONS (E) (assigned to D)
RENDEZVOUS & LM ACTIVITY	(NONE)	P11.15 PGNCS UNDOCKED PERFORMANCE (F) P11.16 PGNCS (UNSTAGED) ATTITUDE/TRANSLATION CONTROL (E) P12.5 AGS INFLIGHT ALIGNMENT/AOT (E) { P12.7 AGS CONTROLLED APS BURN (F) P12.9 UNMANNED AGS CONTROLLED APS BURN (E) } P12.8 AGS/CES ATTITUDE & TRANSLATION CONTROL (STAGED) (E) { P16.9 LM S-BAND UPDATA LINK (E) P16.10 LM/MSFN LUNAR DISTANCE COMM. (H. GAIN) (F) ~~S16.18 LM STEERABLE ANTENNA (E)~~ } P16.12 LM OMNI ANTENNAS - LUNAR DISTANCE (F) P20.45 SIMULATED DOI/DESCENT BURNS (E) M20.48 LM ABORT RENDEZVOUS (E) { P20.77 VHF RANGING/CSM ACTIVE RENDEZVOUS (F) S20.47 CSM ACTIVE RENDEZVOUS (E) } P20.78 LM ACTIVE RENDEZVOUS (F) P20.82 PGNCS/AGS MONITOR - LUNAR ORBIT (F) { P20.83 LM CONSUMABLES - LUNAR ORBIT (F) S20.54 LM CONSUMABLES (E) } S12.6 AGS INFLIGHT CALIBRATION & PERFORMANCE (E) S13.13 LONG DURATION APS BURN (E) S16.14 LANDING RADAR TEST (F) S16.15 RENDEZVOUS RADAR PERFORMANCE (F)
ENTRY	* P1.21 GNCS LUNAR RETURN ENTRY (F) P4.5 ECS - LUNAR RETURN ENTRY (F) S7.14 HEAT SHIELD, LUNAR RETURN (F)	(NONE)
OVERALL MISSION	* { P20.68 CSM CONSUMABLES - LUNAR MISSION (F) S20.55 CSM CONSUMABLES - LUNAR TIMELINE (E) }	S1.19 CSM & LM IMU PERFORMANCE (E) P7.26 (CSM & LM) SPACE ENVIRONMENT THERMAL CONTROL (F)

*MAJOR ISSUES RESOLVED ON C-PRIME

TABLE (2) - SPACECRAFT DOCKED & UNDOCKED INERTIA PROPERTIES
(REFERENCE 3)

INERTIA ELEMENT	DOCKED, FULL (CSM-103/LM-3)	CSM ONLY, FULL (CSM-103)	CSM ONLY, EMPTY (CSM-103)
I_{xx} (ROLL)	52,934	31,693	13,533
I_{yy} (PITCH)	516,824	78,721	38,199
I_{zz} (YAW)	521,880	83,106	37,194
I_{xy}	-7464.9	-1955.4	827.8
I_{xz}	-7518.4	-520.1	-899.1
I_{yz}	3131.9	2891.6	-208.6

(UNITS OF SLUG-FT^2)

TABLE (3) - MISSION SEQUENCE POSSIBILITIES

MISSION SEQUENCE						RELATIVE ADVANTAGE/DISADVANTAGE	NO. OF OLD DTOs REMAINING BEFORE G-1
C	C-PRIME	D	F	G-1		CURRENT BASELINE SCHEDULE	4
C	C-PRIME	D	D-PRIME	F	G-1	ADDED DEVELOPMENT/DELAYED LANDING & INCREASED RISK	0
C	C-PRIME	D	D-PRIME	G-1		LESS RISK/LESS FIDELITY TESTING	12 (9)
C	C-PRIME	D	G-1			EARLIER LANDING/LESS DEVELOPMENT & INCREASED RISK	20

TABLE (4) - DTOs WHICH COULD BE PERFORMED ON MISSION G-1
(C, C-PRIME, D, G-1 SEQUENCE)

TEST OBJECTIVE		EVALUATION PLATEAU
P16.9 P16.10 S16.18	LM S-BAND UPDATA LINK (E) LM/MSFN LUNAR DISTANCE COMM. (H. GAIN) (F) LM STEERABLE ANTENNA(E)	PRE-HOHMANN CHECKOUT
P16.12	LM OMNI ANTENNAS - LUNAR DISTANCE (F)	PRE-HOHMANN CHECKOUT
P16.17	LM/CSM/MSFN VOICE & TM (F)	PRE-HOHMANN CHECKOUT
P20.46	TRANSPOSITION/DOCKING/LM EJECTION (E)	TRANSLUNAR COAST
P20.86	(CSM/LM) LUNAR ORBIT VISIBILITY (F)	LM INSPECTION & HOHMANN DESCENT
S12.6	AGS INFLIGHT CALIBRATION & PERFORMANCE (E)	PRE-HOHMANN CHECKOUT

TABLE (5) - DTOs WHICH CANNOT BE PERFORMED DURING AN EVALUATION PLATEAU ON MISSION G-1
(C, C-PRIME, D, G-1 SEQUENCE)

TEST OBJECTIVE		CONSTRAINING FACTOR
P2.9	GNCS/MTVC TAKEOVER (E)	RISK (WILL BE DONE ON MISSION D)
*P7.26	(CSM & LM) SPACE ENVIRONMENT THERMAL CONTROL (F)	OVERALL MISSION EVALUATION REQUIRED
*P11.15	PGNCS UNDOCKED PERFORMANCE (F)	FULL THROTTLE REQUIRED; NO EVALUATION PLATEAU
*P11.16	PGNCS (UNSTAGED) ATTITUDE/TRANSLATION CONTROL (E)	REQUIRES LIGHT DESCENT STAGE
P12.5	AGS INFLIGHT ALIGNMENT/AOT (E)	TIMELINE IMPACT
P12.7 P12.9	AGS CONTROLLED APS BURN (F) UNMANNED AGS CONTROLLED APS BURN (E)	NO EVALUATION PLATEAU
P12.8	AGS/CES ATTITUDE & TRANSLATION CONTROL (STAGED) (E)	NO EVALUATION PLATEAU
*P20.45	SIMULATED DOI/DESCENT BURNS (E)	NO EVALUATION PLATEAU
M20.48	LM ABORT RENDEZVOUS (E)	NO EVALUATION PLATEAU
*P20.66	(CSM & LM) LUNAR DISTANCE CREW ACTIVITIES (F)	OVERALL MISSION EVALUATION REQUIRED
P20.77 S20.47	VHF RANGING/CSM ACTIVE RENDEZVOUS (F) CSM ACTIVE RENDEZVOUS (E)	NO EVALUATION PLATEAU
*P20.78	LM ACTIVE RENDEZVOUS (F)	NO EVALUATION PLATEAU
*P20.80	(CSM & LM) LUNAR DISTANCE GROUND SUPPORT (F)	OVERALL MISSION EVALUATION REQUIRED
*P20.82	PGNCS/AGS MONITOR - LUNAR ORBIT (F)	POST MISSION EVALUATION REQUIRED
*P20.83 S20.54	LM CONSUMABLES - LUNAR ORBIT (F) LM CONSUMABLES (E)	POST MISSION EVALUATION REQUIRED
*S1.19	CSM & LM IMU PERFORMANCE (E)	OVERALL MISSION EVALUATION REQUIRED
*S13.13	LONG DURATION APS BURN (E)	NO EVALUATION PLATEAU
*S16.14	LANDING RADAR TEST (F)	NO EVALUATION PLATEAU
*S16.15	RENDEZVOUS RADAR PERFORMANCE (F)	NO EVALUATION PLATEAU AT LONG RANGE
S20.52	SINGLE CREWMAN CSM OPERATIONS (E)	RENDEZVOUS REQ'D (WILL BE DONE ON MISSION D)

*INCLUDED IN NOMINAL G-1 MISSION

TABLE (6) - DTOs ALLOCATED TO MISSION D-PRIME

TEST OBJECTIVE		COMMENT
P2.9	GNCS/MTVC (DOCKED) TAKEOVER (E)	ASSIGNED TO MISSION D
P11.15 P20.45	PGNCS UNDOCKED PERFORMANCE (F) OR: SIMULATED DOI/DESCENT BURNS(E)	DPS CONSTRAINTS MIGHT PRECLUDE THE ACCOMPLISHMENT OF BOTH
P11.16	PGNCS (UNSTAGED) ATTITUDE/TRANSLATION CONTROL (E)	BEST DONE DURING AN "EVALUATION ORBIT"
P12.5	AGS INFLIGHT ALIGNMENT/AOT (E)	BEST DONE DURING AN "EVALUATION ORBIT"
P12.7 P12.9	AGS CONTROLLED APS BURN (F) UNMANNED AGS CONTROLLED APS BURN (E)	COULD BE PERFORMED DURING RENDEZVOUS; BURN > 15 SECONDS, LIGHT INERTIA
P12.8	AGS/CES ATTITUDE & TRANSLATION CONTROL (STAGED) (E)	BEST DONE DURING AN "EVALUATION ORBIT"
P16.9	LM S-BAND UPDATA LINK (E)	MIGHT REQUIRE OMNI ANTENNAS IN EARTH ORBIT
P20.46	TRANSPOSITION/DOCKING/LM EJECTION (E)	REQUIRES LIGHTING FIDELITY, POSSIBLY HIGH ORBIT
M20.48 P20.78	LM ABORT RENDEZVOUS (E) OR: LM ACTIVE RENDEZVOUS (F)	TERMINAL PHASE MUST BE EITHER FROM ABOVE OR BELOW; MUST DIVIDE BURNS BETWEEN AGS & PGNCS
P20.77 S20.47 S13.13	VHF RANGING/CSM ACTIVE RENDEZVOUS (F) CSM ACTIVE RENDEZVOUS (E) OR: LONG DURATION APS BURN (E)	ASCENT STAGE LIFETIME MIGHT PRECLUUDE THE ACCOMPLISHMENT OF BOTH
P20.83 S20.54	LM CONSUMABLES - LUNAR ORBIT (F) LM CONSUMABLES (E)	REQUIRES CLOSE ATTENTION TO LUNAR MISSION TIMELINE FIDELITY
S1.19	CSM & LM IMU PERFORMANCE (E)	SATISFIED BY BIAS TESTS & ALIGNMENTS
S12.6	AGS INFLIGHT CALIBRATION & PERFORMANCE (E)	BEST DONE DURING "EVALUATION ORBIT"
S16.15	RENDEZVOUS RADAR PERFORMANCE (F)	REQUIRES LONG RANGE RENDEZVOUS
S16.18	LM STEERABLE ANTENNA (E)	POSSIBLE EARTH ORBITAL TRACKING PROBLEMS
S20.52	SINGLE CREWMAN CSM OPERATIONS (E)	WILL BE SATISFIED ON MISSION D

TABLE (7) - DTOs REMAINING AFTER A (C, C-PRIME, D, D-PRIME) MISSION SEQUENCE

	TEST OBJECTIVE	COMMENT
P7.26	(CSM & LM) SPACE ENVIRONMENT THERMAL CONTROL (F)	REQUIRES ENVIRONMENTAL FIDELITY
P11.15 P20.45	PGNCS UNDOCKED PERFORMANCE (F) OR: SIMULATED DOI/DESCENT BURNS (E)	DPS CONSTRAINTS MIGHT PRECLUDE THE ACCOMPLISHMENT OF BOTH
* P16.10	LM/MSFN LUNAR DISTANCE COMM. (F)	REQUIRES 200,000 N.MI., RANGE
* P16.12	LM OMNI ANTENNAS - LUNAR DISTANCE (F)	REQUIRES 200,000 N.MI., RANGE
* P16.17	LM/CSM/MSFN VOICE & TM (F)	REQUIRES 200,000 N.MI., AND PROPER CONSTRAINTS
M20.48 P20.78	LM ABORT RENDEZVOUS (E) OR: LM ACTIVE RENDEZVOUS (F)	TERMINAL PHASE MUST BE EITHER FROM ABOVE OR BELOW; MUST DIVIDE BURNS BETWEEN PNGCS & AGS
P20.66	(CSM & LM) LUNAR DISTANCE CREW ACTIVITIES (F)	REQUIRES A LUNAR ORBIT RENDEZVOUS
{ P20.77 { S20.47 S13.13	VHF RANGING/CSM ACTIVE RENDEZVOUS (F) } CSM ACTIVE RENDEZVOUS (E) } OR: LONG DURATION APS BURN (E)	ASCENT STAGE LIFETIME MIGHT PRECLUDE THE ACCOMPLISHMENT OF BOTH
P20.80	(CSM & LM) LUNAR DISTANCE GROUND SUPPORT (F)	NOT NECESSARILY A FLIGHT TEST ITEM
P20.82	PGNCS/AGS MONITOR - LUNAR ORBIT (F)	REQUIRES EVALUATION OF NAVIGATION DIFFERENCES
* P20.86	(CSM/LM) LUNAR ORBIT VISIBILITY (F)	LUNAR BACKGROUND & LIGHTING REQUIRED
S16.14	LANDING RADAR TEST (F)	LOW ALTITUDE PASS REQUIRED

*COULD BE ACCOMPLISHED ON A MISSION G-1 "EVALUATION PLATEAU"

TABLE (8) - MISSION E DTOs ALLOCATED TO THE CURRENT F MISSION

TEST OBJECTIVE		MISSION PHASE
P12.5	AGS INFLIGHT ALIGNMENT/AOT (E)	LM - ACTIVE RENDEZVOUS
P12.8	AGS/CES ATTITUDE & TRANSLATION CONTROL (STAGED) (E)	LM - ACTIVE RENDEZVOUS, CDH BURN
P12.9	UNMANNED AGS CONTROLLED APS BURN (E)	AFTER LM RENDEZVOUS
P16.9 S16.18	LM S-BAND UPDATA LINK (E) LM STEERABLE ANTENNA (E)	PRE-HOHMANN CHECKOUT (INCLUDED IN P16.10 LM/MSFN COMM. (F)
P20.46	TRANSPOSITION/DOCKING/LM EJECTION (E)	TRANSLUNAR COAST (NOW SECONDARY)
S1.19	CSM & IMU PERFORMANCE (E)	OVERALL MISSION
S12.6	AGS INFLIGHT CALIBRATION & PERFORMANCE (E)	PRE-HOHMANN CHECKOUT
S13.13	LONG DURATION APS BURN (E)	AFTER LM RENDEZVOUS
S20.54	LM CONSUMABLES (E)	OVERALL MISSION (INCLUDED IN P20.83 LM CONSUMABLES (F)

TABLE (9-A) - MISSION E DTOs ASSIGNED TO MISSION D

TEST OBJECTIVE		COMMENT
P2.9	GNCS/MTVC TAKEOVER (E)	OFFICIALLY ASSIGNED TO MISSION D
S20.52	SINGLE CREWMAN CSM OPERATIONS (E)	WILL BE ACCOMPLISHED BY A SIMILAR MISSION D DTO

TABLE (9-B) - OLD DTOs REMAINING AFTER THE CURRENT MISSION SEQUENCE

TEST OBJECTIVE		COMMENT
P11.16	PGNCS ATTITUDE/TRANSLATION CONTROL (UNSTAGED) (E)	PARTIALLY ACCOMPLISHED BY MISSION D ACTIVITIES
P20.45	SIMULATED DOI/DESCENT BURNS (E)	SOME DATA FROM MISSION D
M20.48	LM ABORT RENDEZVOUS (E)	NOT AMONG CURRENT REQUIREMENTS
P20.77 S20.47	VHF RANGING/CSM ACTIVE RENDEZVOUS (F) CSM ACTIVE RENDEZVOUS (E)	NOT AMONG CURRENT REQUIREMENTS

TABLE (A-1) - DISPOSITION OF OLD MISSION E DTOs

TEST OBJECTIVE		DISPOSITION
M20.48	LM ABORT RENDEZVOUS	DROPPED FROM CURRENT MISSION REQUIREMENTS
P20.45	SIMULATED DOI/DESCENT BURNS	
P11.16	PNGCS ATTITUDE/TRANSLATION CONTROL	
S20.47	CSM ACTIVE RENDEZVOUS	
P2.9	GNCS/MTVC TAKEOVER	TRANSFERRED TO MISSION D WITH SAME NUMBER
S20.52	SINGLE CREWMAN CSM OPERATIONS	TRANSFERRED TO MISSION D UNDER S20.33
P20.44	SIMULATED LOI MANEUVER	ACCOMPLISHED BY P20.105 ON MISSION C-PRIME
P20.57	CSM/MSFN HIGH ALTITUDE COMMUNICATIONS	ACCOMPLISHED BY P6.11 ON MISSION C-PRIME
P20.59	STAR/EARTH HORIZON NAVIGATION	ACCOMPLISHED BY P1.34 ON MISSION C-PRIME
P20.58	STAR/EARTH LANDMARK NAVIGATION	ACCOMPLISHED BY S1.32 ON MISSION C-PRIME
S20.92	SIMULATED TLI BURN	ACCOMPLISHED BY P20.112 ON MISSION C-PRIME
S20.60	LUNAR LANDING SITE DETERMINATION	ACCOMPLISHED BY P20.111 ON MISSION C-PRIME
S3.19	SPS EVALUATION	ACCOMPLISHED BY S3.21 ON MISSION C-PRIME
S20.49	SIMULATED TEI MANEUVER	ACCOMPLISHED BY P20.106 ON MISSION C-PRIME
S20.55	CSM CONSUMABLES - LUNAR TIMELINE	ACCOMPLISHED BY S20.108 ON MISSION C-PRIME
S20.76	SPS/RCS MIDCOURSE CORRECTION MANEUVERS	ACCOMPLISHED BY P20.114 ON MISSION C-PRIME
S20.39	PRE-PROGRAMMED LAUNCH WINDOW	ACCOMPLISHED PRELAUNCH ON MISSION C-PRIME
P12.5	AGS INFLIGHT ALIGNMENT/AOT	TRANSFERRED TO MISSION F WITH SAME NUMBER
P12.8	AGS/CES ATTITUDE/TRANSLATION CONTROL	"
P12.9	UNMANNED AGS CONTROLLED APS BURN	"
S1.19	CSM AND LM IMU PERFORMANCE	"
S12.6	AGS INFLIGHT CALIBRATION AND PERFORMANCE	"
S13.13	LONG DURATION APS BURN	"
P20.46	TRANSPOSITION/DOCKING/LM EJECTION	TRANSFERRED TO MISSION F AND DOWNGRADED TO SECONDARY
P16.9	LM S-BAND UPDATA LINK	TRANSFERRED TO MISSION F UNDER P16.10
S20.75	PASSIVE THERMAL CONTROL PROCEDURES	TRANSFERRED TO MISSION F UNDER P20.79
S16.18	LM STEERABLE ANTENNA	TRANSFERRED TO MISSION F UNDER P16.10
S20.54	LM CONSUMABLES	TRANSFERRED TO MISSION F UNDER S20.83

TABLE (A-2) - DISPOSITION OF OLD MISSION F DTOs

TEST OBJECTIVE		DISPOSITION
P20.77	VHF RANGING/CSM ACTIVE RENDEZVOUS	DROPPED FROM CURRENT MISSION REQUIREMENTS
P7.26	SPACE ENVIRONMENT THERMAL CONTROL	CURRENTLY ASSIGNED TO MISSION F WITH SAME NUMBER
P11.15	PNGCS UNDOCKED PERFORMANCE	"
P16.10	LM/MSFN COMMUNICATIONS LUNAR DISTANCE	"
P16.12	LM OMNI ANTENNAS LUNAR DISTANCE	"
P16.17	LM/CSM/MSFN VOICE & TM	"
P20.66	CREW ACTIVITIES LUNAR DISTANCE	"
P20.78	LM ACTIVE RENDEZVOUS	"
P20.79	PASSIVE THERMAL CONTROL MODE	"
P20.80	GROUND SUPPORT LUNAR DISTANCE	"
P20.82	PNGCS/AGS MONITOR LUNAR ORBIT	"
P20.86	LUNAR ORBIT VISIBILITY	"
P20.91	LUNAR LANDMARK TRACKING	"
S16.14	LANDING RADAR TEST	"
S16.15	RENDEZVOUS RADAR PERFORMANCE	"
S20.95	MIDCOURSE CORRECTION CAPABILITY	"
P1.21	GNCS ENTRY LUNAR RETURN	ASSIGNED TO MISSION F AND DOWNGRADED TO SECONDARY
P6.9	CSM/MSFN COMMUNICATIONS LUNAR DISTANCE	"
P20.83	LM CONSUMABLES LUNAR ORBIT	"
P20.100	LUNAR PHOTOGRAPHY FROM CSM	"
S1.22	CSM GNCS SPACE NAVIGATION	ACCOMPLISHED BY P20.114, P1.33, & P1.34 ON C-PRIME AND SUPPORTED BY S1.36 AND S1.37 ON MISSION F
P4.5	ECS LUNAR RETURN ENTRY	ACCOMPLISHED BY S4.5 ON MISSION C-PRIME
P6.10	CSM OMNI ANTENNAS LUNAR DISTANCE	ACCOMPLISHED BY S6.10 ON MISSION C-PRIME
S7.14	HEAT SHIELD, LUNAR RETURN	ACCOMPLISHED BY S7.30 ON MISSION C-PRIME
P20.68	CSM CONSUMABLES LUNAR MISSION	ACCOMPLISHED BY S20.108 ON MISSION C-PRIME
P20.94	COMMUNICATION PROCEDURES & PERFORMANCE	ACCOMPLISHED BY P6.11 ON MISSION C-PRIME
P12.7	AGS CONTROLLED APS BURN	TRANSFERRED TO MISSION F UNDER P12.9

- CSM/MSFN CISLUNAR & LUNAR ORBIT COMMUNICATIONS
- CSM PASSIVE THERMAL CONTROL
- CSM CISLUNAR NAVIGATION
- CSM LUNAR ORBIT NAVIGATION
- LUNAR RETURN ENTRY GUIDANCE
- CSM LUNAR MISSION CONSUMABLES

FIGURE (1) - MAJOR FLIGHT TEST ISSUES RESOLVED ON MISSION C-PRIME

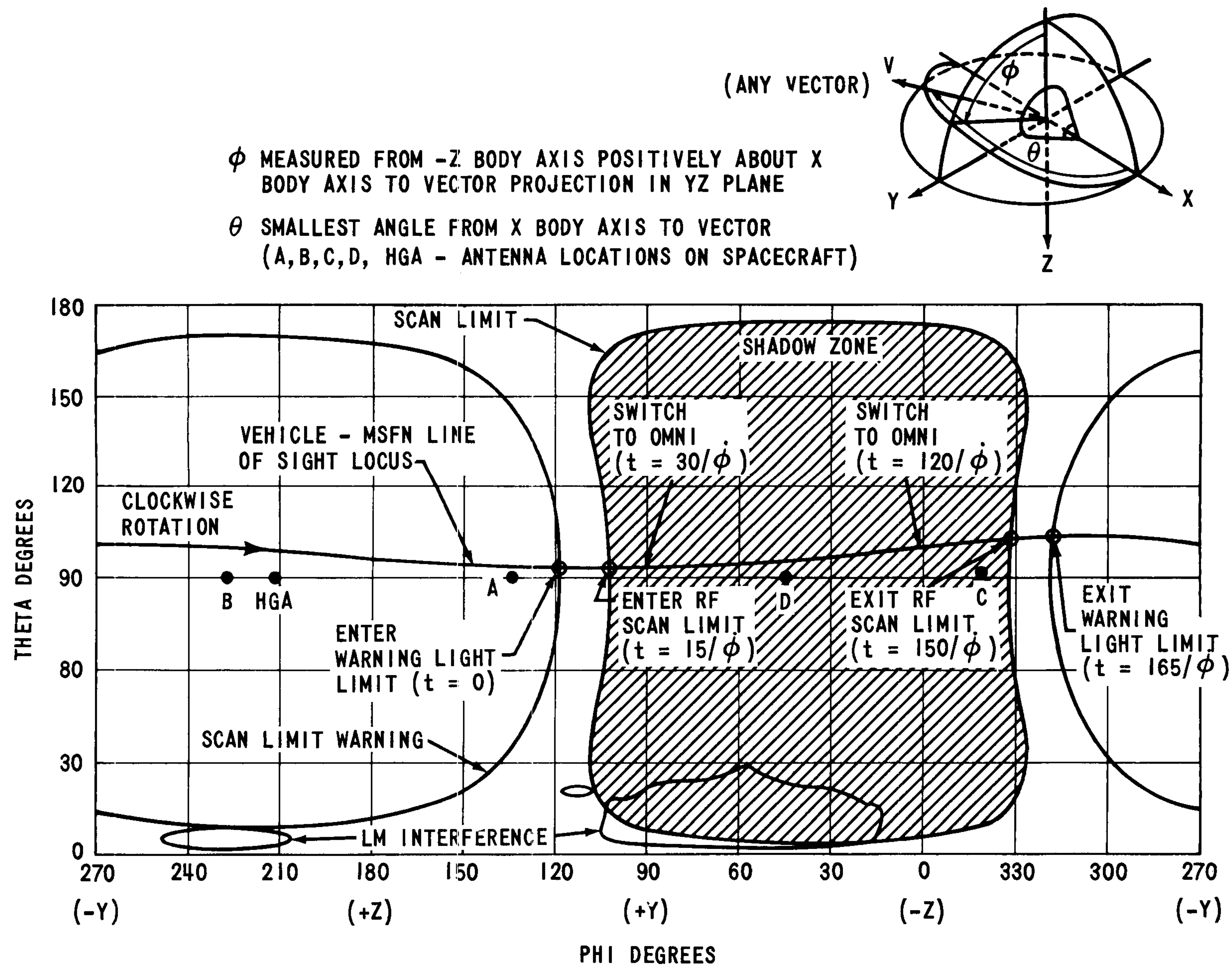

FIGURE (2) - CISLUNAR ANTENNA SWITCHING EVENTS DURING THERMAL CYCLING (FROM REF. 3)

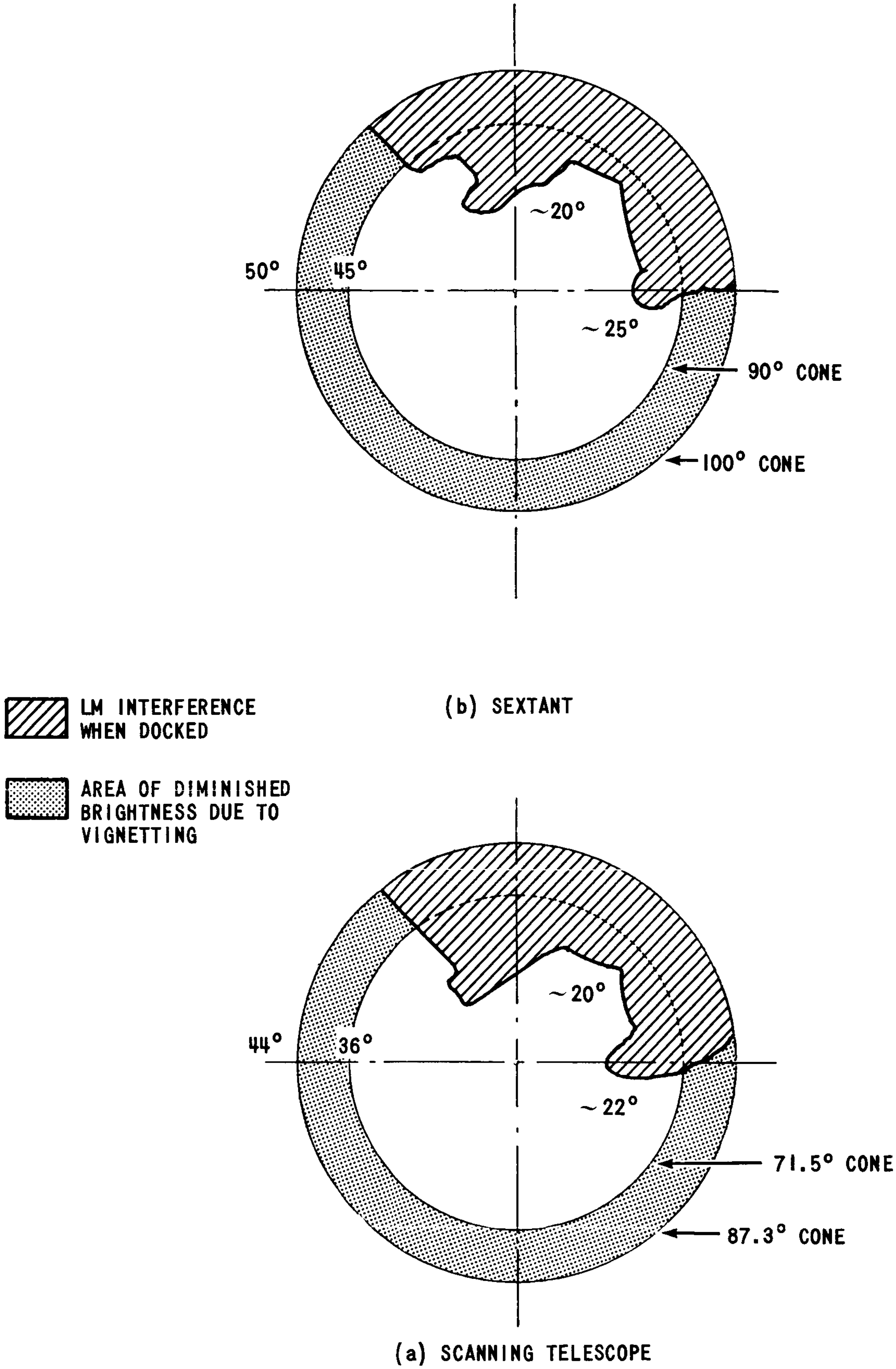

FIGURE (3) - CM OPTICS COVERAGE (FROM REFERENCE 4)

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Subject: Review of Apollo Test Objectives Remaining After Mission D - Case 310

From: A. C. Merritt

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