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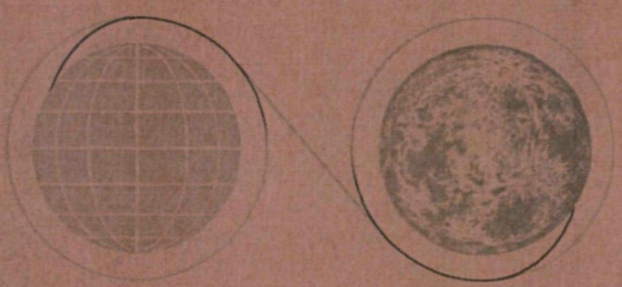

Apollo Extension Systems—Lunar Excursion Module
Phase B Final Report

Vol. XVI Prelaunch & Mission Operations (U)

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Apollo Extension Systems – Lunar Excursion Module
Phase B Final Report

to

National Aeronautics and Space Administration
Manned Spacecraft Center
Advanced Spacecraft Technology Division
Houston, Texas 77058

by

Grumman Aircraft Engineering Corporation
Bethpage, New York

Vol. XVI Prelaunch & Mission Operations

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Preface

This report presents the results of the Phase "B" Preliminary Definition Study (Contract NAS 9-4983) of the Lunar Excursion Module (LEM) and its modifications and additions, as necessary, for use in the Apollo Extension Systems (AES). This use includes a Laboratory for Earth and lunar orbital missions, and a Shelter, a Taxi and a Truck for extended-stay lunar surface missions. The overall objective of this study was to conduct sufficient analyses to provide a basis for selection by NASA of a single concept for each mission for final definition and development.

The study results are distributed in the volumes listed below in the following manner: Volume I contains a summary of the Preliminary Project Development Plan (PDP) with emphasis on estimates of the program costs and schedules. This volume was submitted on 30 October 1965, one month in advance of the remaining final documentation. Volume II is a brief summary of the overall study. Volumes III through XVI contain the design analyses, preliminary specifications, and operations analyses for each of the AES/LEM vehicle types. Volumes XVII through XXVI contain preliminary project planning data in the areas of management, manufacturing, development testing, and support.

It was necessary to base the preliminary project planning data, including estimated costs, on a single configuration for each of the AES/LEM vehicle types. Since these PDP data were required by the end of October, the configurations had to be selected at the mid-point of the study, before the configuration studies had been completed. These configurations have been called "baseline" configurations. The continuing design analyses in the second half of the study have resulted in recommended changes to the baseline configurations. Volumes III through VI describe the "recommended" configurations, the baseline configurations, and some additional alternates which were studied. It is anticipated that NASA will make a selection from these configurations, and that these selections will then be the new baseline configurations for the next phase of AES definition studies.

The scope of this study included integration of the experimental payloads with the Shelter and Taxi, but did not include study of the integration on individual LEM Laboratory flights. At approximately the mid-point of the study, an addendum was written with the objective of providing support to the NASA Mission Planning Task Force for study of the Phase I Laboratory flights. The schedule for the addendum calls for completion of these mission planning studies in January, 1966. Therefore, the addendum efforts are not described in this report.

The volumes which comprise this report are as follows:

- I *Phase B Preliminary Definition Plan (30 Oct 1965)*
- II *Preliminary Definition Studies Summary*
- III *Phase I Laboratory Design Analysis Summary*
- IV *Phase II Laboratory Design Analysis Summary*
- V *Shelter Design Analysis Summary*
- VI *Taxi Design Analysis Summary*
- VII *Truck Design Analysis Summary*
- VIII *Phase I Laboratory Master End Item Specification*
- IX *Phase II Laboratory Master End Item Specification*
- X *Shelter Master End Item Specification*
- XI *Taxi Master End Item Specification*
- XII *Phase I Laboratory Experimental Payload Performance & Interface Specification*
- XIII *Phase II Laboratory Experimental Payload Performance & Interface Specification*
- XIV *Shelter Experimental Payload Performance & Interface Specification*
- XV *Taxi Experimental Payload Performance & Interface Specification*
- XVI *Prelaunch & Mission Operations*
- XVII *Manufacturing Plan*
- XVIII *AES Modifications to LEM Quality Control Program Plan*
- XIX *Ground Development Test Plan*
- XX *Support Equipment Specification*
- XXI *Facilities Plan*
- XXII *Support Plan*
- XXIII *Transportation Plan*
- XXIV *Training Equipment Requirements*
- XXV *Support Equipment Requirements*
- XXVI *Management Plan*

CONTENTS

CONTENTS

Tables

Illustrations

1. INTRODUCTION

1.1 BACKGROUND

The Prelaunch and Mission Operation Report presents the results of a preliminary analysis of the operations requirements for the AES LEM Program. The study has been carried out in response to the Statement of Work for Contract NAS 9-4983. The task has been divided into two concurrent study efforts: one concerned with mission and mission related operations such as tracking requirements; and the other with prelaunch and launch operations.

1.2 STUDY OBJECTIVES

The Grumman study objective for operations planning was to conduct sufficient analysis to provide NASA a basis for making a sound judgment on follow-on operations activities. The purpose of this study was not to concentrate on the optimization of one particular solution, but rather to explore a number of possible approaches and select the most promising. The primary effort has been directed toward establishing realistic criteria, identifying problem areas and constraints, and carrying the planning to the point where solutions appear to be practical. AES-LEM spacecraft operational requirements will be a foundation for developing detailed operational requirements as spacecraft and experiment configurations are made more definitive.

1.3 STUDY APPROACH

During the 5-month Phase B study, the Baseline Spacecraft Configurations and the Recommended Spacecraft Configurations were considered in operations planning. These configurations are identified in the "Vehicle Design Analysis Summaries" (Phase I Lab, Vol. III; Phase II Lab, Vol. IV; Shelter, Vol. V; Taxi, Vol. VI). Volume I, "Phase B Preliminary Definition Plan" dated 29 October 1965, reflects the operations planning for the Baseline Configurations. Subsequently, all planning efforts were reviewed and updated in accordance with the Recommended Configurations. All prelaunch and mission operations planning presented in this volume reflects the Recommended Configurations.

The ground rules, guidelines, and assumptions pertinent to prelaunch and mission operations are included in proper context within the appropriate sections of this volume.

Section 2 of this report presents the preliminary flight mission planning information. First, the flight operations logic including flight test requirements and prerequisite ground tests are summarized. Next, the Phase I Lab, Phase II Lab, Shelter, and Taxi missions are categorized and described. Emphasis is given to spacecraft test objectives and rationale. After each mission category is presented, the mission related tracking, operational data handling and instrumentation requirements are discussed.

Section 3 of the report presents the preliminary prelaunch operations planning. The checkout rationale pertinent to the development of prelaunch checkout plans, sequences, and vehicle flows for the AES-LEM spacecraft is summarized. After describing the checkout approach for each AES-LEM subsystem, the checkout flow for each AES-LEM spacecraft-launch vehicle combination is developed. These individual Phase I Lab, Phase II Lab, Shelter, and Taxi checkout flows are then integrated into an overall KSC launch operations schedule. The checkout operations are analyzed to assess the KSC requirements for the AES-LEM Program with respect to those of the Apollo Program. The checkout requirements for the overall AES-LEM Program are identified for KSC facilities, ACE, and ground support equipment. The Phase I Lab operations planning and scheduling, presented in Section 3, emphasizes the AES-LEM spacecraft requirements and assumes a nominal experiment complement. During the course of the Addendum study, the effects of Lab experiments defined by NASA for each Phase I Lab will be investigated.

2. MISSION OPERATIONS

2.1 FLIGHT OPERATIONS LOGIC

2.1.1 General

This section presents the operational aspects of mission planning. The flight test requirements summarized herein together with the scientific mission objectives will describe the total mission requirements for the AES-LEM Program. Mission planning studies emphasizing mission related requirements on spacecraft design and performance capabilities are presented in Vol. III through VII.

2.1.2 Test Requirements

The prime purposes of the AES missions are to conduct extensive experiments for basic scientific research, develop and qualify new systems and subsystems, show spacecraft and crew capability to withstand long-duration missions, and develop space operating procedures and techniques. In lieu of performing special flight development missions, the AES Program will utilize the prerequiste Apollo Program flight development, in conjunction with a comprehensive AES Ground Development Test Program, to relieve AES test constraints. However, flight test objectives will be integrated within the flight operations of the initial flight of each AES-LEM/mission combination. The chief requirements for this are:

- To demonstrate system performance for environmental conditions not attainable to a satisfactory degree on the ground.
- To assure subsequent mission success of each similar AES-LEM.
- To assure maintaining the high density launch schedule.

Table 2.1-1 indicates the flight test requirements associated with each of the AES-LEM. These requirements are further defined in terms of test objectives for each type of AES-LEM/mission combination in Paragraphs 2.2 through 2.5. As the scientific mission objectives are defined in detail, the flight test requirements will be reviewed and considered in the light of total flight mission requirements.

Since each type of AES-LEM is scheduled for a number of flight missions, it is desirable to satisfy the spacecraft test objectives as early in the flight program as practical, e.g. on the first flight of each vehicle type. The planned number of AES flight missions are:

AES-LEM	LAUNCH VEHICLE	
	Saturn IB	Saturn V
Phase I Lab	2	3
Phase II Lab	4	7
Shelter	-	3
Taxi	-	3

2.1.3 Test Logic

The AES flight mission and constraint logic is presented in Fig. 2.1-1, which shows the dependence on Apollo flights and the AES Ground Development Test Programs. The AES mission prerequisite testing is a combination of the AES ground development tests which are detailed in Vol XIX and summarized in Tables 2.1-2 and 2.1-3, and the basic Apollo Program test prerequisites listed in Table 2.1-4.

2.2 PHASE I LAB MISSIONS

2.2.1 Earth Orbit, Saturn V Launch

2.2.1.1 Mission Description

The generalized Phase I Lab flight profile is an earth orbital mission at an altitude of 200 n.mi, and orbital inclination of 28.5 or 50 deg, and a flight duration of 14 days. A Saturn V launch vehicle is used to boost the spacecraft into the 200-n.mi circular orbit for experiment operations. A three-man crew is required for these missions.

The prime purpose of the Phase I Lab missions is to conduct extensive experiments for basic scientific research, develop and qualify new systems and subsystems, and qualify equipment for subsequent missions. These missions are also intended to show spacecraft and crew capability to withstand long-duration space flights, and develop space operating procedures and techniques.

2.2.1.2 Spacecraft Test Objectives

The following spacecraft test objectives have been derived from the logic of Paragraph 2.1 and are a general group that pertain to all Phase I Lab missions.

OBJECTIVE	RATIONALE
1. Demonstrate the performance of the modified LEM structure and insulation over a 14-day Earth orbital Lab mission.	1. Previous Apollo LEM test flights will have shown that the basic LEM structure and insulation are capable of withstanding the boost environment plus short duration stays in a thermal vacuum environment. Modifications to the structure caused by equipment additions and deletions plus additions of thermal insulation require demonstration of the new configuration's ability to support a 14-day mission in the near space environment.
2. Demonstrate the pointing capability of Lab Flight Control System (FCS).	2. The Apollo FCS will have been tested over the complete range of LEM inertias. However, the LEM will not have been required to maintain the stability that various Earth oriented applications require. The ability of the modified RGA and ATCA to maintain a 0.1-deg, one-pulse, limit cycle must be demonstrated. In addition, the

OBJECTIVE	RATIONALE
2. (Cont'd)	modified Lab systems, plus the requirement of the Lab to maintain Lab/CSM stability, require the system to be completely checked out in flight.
3. Demonstrate operation of the modified LEM subsystems after being subjected to boost environment.	3. The basic Apollo LEM Subsystem configuration will have been flown on both Saturn IB and Saturn V boosters. Structure and support modifications require that the loads and vibrations imparted to the Lab by the Launch Vehicle and by the Lab to the various equipment areas be investigated. ECS and EPS Subsystem additions, plus deletion of the Propulsion Subsystems, require that the boost environment effects on these modified subsystems be demonstrated.
4. Demonstrate the capability of the modified LEM ECS and crew provisions to support life over a 14-day Earth orbital Lab mission.	4. The Lab ECS subsystem is a modified version of the LEM ECS. The modifications are chiefly in the form of added comsumables and tankage. The ECS must be shown to have the capability of life support for a 14-day mission, and consumable usage for a 14-day mission must be established. It must also be shown that the ECS can provide atmosphere circulation for the Lab/CSM combination. The ability of the ECS to provide equipment and vehicle thermal control during long-duration flights in conjunction with maintaining the crew must be investigated.
5. Evaluate the Lab data management systems including instrumentation, communications, and MSFN/MCC performance in handling experimental data.	5. Although the Instrumentation and Communications Subsystems will have been checked out previously during Apollo Earth orbital and lunar missions, the mass of experiment data that must be handled will not have been approached. Methods of storing, transmitting, and ascertaining proper ground acquisition of large quantities of data must be established for periods of minimum ground coverage.
6. Evaluate extravehicular crew operations.	The ability of the crew to perform useful extravehicular activities will not have been evaluated previously to the extent required in the AES missions. The ability to transfer equipment from and to the Lab, perform repairs, and carry out experiments and potential rescue operations must be

OBJECTIVE	RATIONALE
6. (Cont'd)	confirmed as early as practical in the AES Program. Changes in the internal and external Lab configuration require demonstration of crew ingress, egress, and extravehicular operations.

2.2.1.3 Earth Orbit, Saturn V Launch, Mission Profile (200 N. Mi)

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
1. Saturn V Ascent to Orbit a) S-IC firing b) S-II Firing c) LES Jettison d) S-IVB firing	00:12:00	None
2. S-IVB Stabilization a) CSM C/O	03:00:00	None
3. Transposition & Docking a) CSM-S-IVB separation b) Transposition c) CSM-LEM Lab docking d) LEM-Lab extraction from S-IVB	00:30:00	None
4. LEM Lab C/O a) Crew transfer to Lab b) Lab C/O	01:30:00	Demonstrate operation of modified LEM subsystems after being subjected to boost environment.
5. Earth Orbit Lab Experiment Operations	336:00:00 (14 days)	Demonstrate the: • Pointing capability of FCS. • Modified LEM ECS and Crew Provisions capability to support life for 14-day mission. • Performance of modified LEM structure and insulation over 14-day mission. Evaluate the: • Lab data management system. • Extravehicular crew operations.

MISSION PHASE	NOMINAL PHASE TIME (hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
6. Lab Shutdown & Equipment and Data Transfer to CSM	01:30:00	
7. Preparation for CM Entry a) Lab jettison b) SPS deorbit maneuver c) SM jettison	00:10:00	
8. Entry	00:11:00	
9. Parachute descent	00:07:00	
10. Post landing through S/C retrieval	Variable	

2.2.2 Earth Orbit Rendezvous, Saturn IB Launch

2.2.2.1 Mission Description

Saturn IB launched Labs will be part of dual launch Earth orbital rendezvous missions. The Lab will be launched into a 200-n.mi Earth orbit at an inclination of 28.5 deg. The launch vehicle configuration will be that of the Apollo 206A/LEM-1 mission, (Ref. 4.1), and consists of Lab, boilerplate CSM, SLA, and LES. The CSM will be launched with the crew and will rendezvous and dock to the LAB. Manned mission duration is 14 days and a three-man crew is required. The primary purpose of this type mission is to extend the capability of the CSM and provide a greater orbital payload than that available with a single Saturn IB launch.

2.2.2.2 Spacecraft Test Objectives

In addition to the basic objectives in Paragraph 2.2.1, the following spacecraft test objectives are associated with an Earth orbital rendezvous mission profile.

OBJECTIVE	RATIONALE
1. Demonstrate integrated mission control from countdown through dual launching, equal period orbit capability, rendezvous, and docking.	1. The dual launch concept requires coordinated efforts during the prelaunch checkout to assure proper timing relationships between the Lab and CSM launches. The two pad (34 & 37B) launch operations, as well as the coordinated tracking operations for two separate vehicles, will have not been demonstrated during the basic Apollo Program.

OBJECTIVE	RATIONALE
2. Demonstrate the ability of the Lab ECS, EPS, Instrumentation and Communications equipment to perform as required during unmanned orbital storage period.	2. The ability of the Lab ECS to maintain thermal control during the unmanned storage period, and of the EPS to supply sufficient power for the storage period must be shown. The Instrumentation and Communication Subsystems' ability to operate after prolonged exposure to a thermal vacuum environment must be shown. Ground tests can give an indication of the subsystem requirements for prolonged storage; however, only during space operations can the effects of storage in a thermal vacuum environment be demonstrated.
3. Demonstrate unmanned Lab FCS ability to operate after orbital storage and effect a docking with the CSM.	3. Long-duration orbital storage may have a detrimental effect on the Lab FCS, especially if the RCS is pressurized and is used for extracting the Lab from the S-IVB/SLA prior to storage. The effects of any prolonged Earth orbital environment must be determined prior to manned operation of the Lab. The FCS must be capable of stabilizing the Lab for docking with the CSM.

2.2.2.3 Earth Orbit Rendezous, Saturn IB Launch, Mission Profile (200 N.Mi, 200 deg. Incl.)

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
1. Saturn IB Ascent to Orbit (Lab) a) S-IB firing b) S-IVB firing c) LES boilerplate CSM jettison	00:12:00	Demonstrate integrated mission control. (Note: Applicable during all phases through CSM-Lab docking.)
2. Earth Orbit Coast, S-IVB Stabilization a) Subsystems status check	03:00:00	Demonstrate operation of modified LEM subsystems after being subjected to boost environment.
3. S-IVB-Lab Separation a) SLA petal deploy b) LMP initiated sep c) LMP shuts down S/S	00:20:00	None
4. Earth Orbit Storage (Lab unstabilized) a) LMP activates S/S for status checks	Variable (From several hr up to 30 days.)	Demonstrate ability of Lab ECS, EPS, and Inst & Comm equipment to perform during unmanned orbital storage.

	MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
5.	Saturn IB Ascent to Orbit (CSM & Crew) a) Same as 1a & b, above b) LES jettison	00:12:00	None
6.	Earth Orbit CSM C/O	00:30:00	None
7.	CSM-SIVB Separation	00:05:00	None
8.	CSM Rendezvous with Lab	Variable	None
9.	CSM Active Docking a) LMP stabilizes Lab b) CSM docks	00:15:00	Demonstrate unmanned Lab FCS ability to operate after orbital storage, and effect docking with a manned CSM.
10.	Lab C/O a) Crew transfer b) Lab C/O	01:30:00	None
11.	Earth Orbit Lab Experiment Operations: a) Biomedical & behavioral studies b) EVA studies c) Radiation monitoring	336:00:00 (14 days)	Evaluate the: • EVA crew operations. • Lab data management system. • Capability of modified LEM ECS & crew provisions to support life. • Performance of modified LEM structure and insulation over a 14-day mission. • Pointing capability of the Lab FCS.
12.	Lab Shutdown and Equipment and Data Transfer to CSM	01:30:00	
13.	Preparation for CM Entry a) Lab jettison b) SPS deorbit maneuver c) SM jettison	00:10:00	
14.	Entry	00:11:00	
15.	Parachute Descent	00:07:00	
16.	Post Landing Through S/C Retrieval	Variable	

2.2.3 Earth Polar Orbit, Saturn V Launch

2.2.3.1 Mission Description

The launch configuration for all Saturn V launched AES missions will be the same as the basic Apollo missions, and consists of S-IC, S-II and S-IVB booster stages, CSM and Lab, SLA, and LES. For the polar mission trajectory, the booster will be launched from KSC in a south easterly direction (144 deg azimuth), with the spacecraft inserted directly into a 200-n.mi, 90-deg inclination orbit, using a yaw steering maneuver prior to orbital insertion. Experiment operations will be carried on by a three-man crew for 14 days. The CM will return the crew for a water landing and recovery in the Pacific recovery area.

2.2.3.2 Spacecraft Test Objectives

A polar mission profile adds the following spacecraft test objectives to the basic objectives listed in Paragraph 2.2.1.

OBJECTIVE	RATIONALE
1. Demonstrate Lab structural integrity after Saturn V yaw steering maneuver to effect a polar orbit.	1. Based on the current launch schedule, this is the first Lab launched using the Saturn V booster. Although the Saturn V environment will be known, the added effect of the booster yaw steering maneuver must be demonstrated.
2. Demonstrate compatibility of Lab with the MSFN for polar orbit mission operations.	2. The present MSFN stations are designed for low-inclination Earth orbit trajectory coverage. The capability of the present and new MSFN stations to monitor and track the spacecraft must be determined.
3. Evaluate radiation levels throughout mission duration.	This is the first manned Earth polar mission. Cosmic ray intensity is greatest near the poles and the resulting effects on equipment and crew must be studied.

2.2.3.3 Earth Polar Orbit, Saturn V Launch, Mission Profile (200-N.Mi, 90-Deg Inclination)

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec:)	OPERATIONAL TEST OBJECTIVE
1. Saturn V Ascent to Polar Orbit a) S-IC firing b) S-II firing (yaw steering) c) LES jettison d) S-IVB firing (yaw steering)	00:16:30	Demonstrate Lab structural integrity after Saturn V yaw steering maneuvering to effect a polar orbit.

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec:)	OPERATIONAL TEST OBJECTIVE
2. Orbit Coast, S-IVB Stabilized a) CSM C/O b) CSM transposition c) CSM-LEM Lab docking d) Lab S-IVB separation	03:00:00	None
3. Lab C/O a) Crew enters Lab b) Activation & C/O of Lab subsystems	02:00:00	Demonstrate performance of modified LEM subsystems after being subjected to boost environment.
4. Earth Polar Orbital Lab Experiment Operations: a) Biomedical & behavioral studies b) Lunar survey equipment c/o (Earth mapping)	336:00:00 (14 days)	Demonstrate the: • Pointing capability of Lab FCS. • Performance of the modified LEM structure & insulation over a 14-day Earth orbital mission. • Capability of the modified LEM ECS and crew provisions to support life over a 14-day Earth orbital mission. • Compatibility of Lab with MSFN for polar orbital operations. Evaluate the: • EVA crew operations. • Radiation levels throughout mission duration. • Lab data management system.
5. Lab shutdown & equipment and data transfer to CSM.	00:30:00	None
6. Preparation for CM reentry a) Lab jettison b) Service propulsion deorbit maneuver c) SM jettison	00:10:00	
7. Entry	00:11:00	
8. Parachute descent	00:07:00	
9. Post landing through S/C retrieval	Variable	

2.2.4 Earth Synchronous Orbit, Saturn V Launch

2.2.4.1 Mission Description

The Saturn V launch vehicle is used for manned synchronous earth orbital missions. The spacecraft including the S-IVB stage is first inserted into a 100-n.mi, 28.5-deg inclination Earth orbit. The S-IVB is restarted at the fourth descending nodal crossing for a partial plane change and a simultaneous transfer to synchronous orbit altitude of 19,350 n.mi. The SPS and S-IVB circularize and complete the plane changes necessary to maintain a stationary 14-day orbit. Ground station coverage is continuous for this mission and all experiments may be ground monitored and/or recorded in real time. Experiments and orbital operations will be carried out by a three-man crew. Radiation monitoring will be of primary importance on this type mission because of prolonged operations within the Earth radiation belts.

2.2.4.2 Spacecraft Test Objectives

The Earth synchronous orbit mission profile adds the following spacecraft objectives to the basic objectives listed in Paragraph 2.2.1.

OBJECTIVES	RATIONALE
1. Demonstrate Lab thermal control during synchronous orbit mission profile.	1. The synchronous mission profile, in conjunction with a 14-day mission duration has not been demonstrated during the basic Apollo missions. The thermal environment differs from the low Earth orbit in that the Earth re-radiation is reduced, and the spacecraft remains in direct sunlight for longer periods of time. In addition, several experiments place attitude constraints on the Lab which preclude maintaining a thermal balance by rotating the spacecraft as is done in the Apollo missions. The efficiency of the Lab thermal control system should therefore be demonstrated on this type mission prior to a lunar orbiting mission which has similar attitude constraints imposed by the experiments.
2. Demonstrate compatibility of Lab with the MSFN for synchronous orbit mission operations.	2. Since only two synchronous missions are planned, the first manned flight must confirm ground communications capability. The MSFN must have the capability of providing continuous coverage for operations required to obtain synchronous altitude, and for operations while in orbit. Ground station coverage must also be available for the return portion of the mission.

OBJECTIVE	RATIONALE
3. Evaluate radiation levels throughout mission duration.	3. This is the first manned synchronous orbit mission. The effect of prolonged exposure to both cosmic and outer Van Allen belt radiation on crew and electronic components must be determined. The effectiveness of crew and equipment shielding must be demonstrated.

2.2.4.3 Earth Synchronous Orbit, Saturn V Launch, Mission Profile (19350 N.Mi, 0^{o} Incl.)

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
1. Saturn V Ascent to 100-N.Mi Parking Orbit 28.5-Deg Inclin a) Launch azimuth 90 deg b) S-IC firing c) S-II firing d) LES jettison e) S-IVB firing f) Parking orbit insertion	00:12:00	None
2. Earth Parking Orbit ($3\frac{1}{4}$ Orbits) a) CSM systems check b) Preparation for transfer orbit insertion	05:00:00	None
3. Transfer Orbit Insertion a) S-IVB restart b) Orbit transfer & partial plane change	00:06:00	None
4. Transfer Orbit Coast to 19,350 n.mi	05:15:00	None
5. S-IVB Restart to do Partial Plane Change and Orbit Change at Apogee	00:02:00	None
6. Elliptical Orbit Coast a) CSM S-IVB separation b) CSM transposition & docking with Lab c) Lab S-IVB separation d) Orbit coast to apogee	13:41:00	None

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
7. CSM Firing to Complete Plane Change and Circularization	00:01:30	None
8. Lab C/O a) Crew transfer to Lab b) Activation and C/O of Lab S/S	01:30:00	Demonstrate operation of modified LEM S/S after being subjected to boost environments.
9. Earth Synch Orbit Lab Experiment Operations operations a) Biomedical & behavioral studies b) Astronomical studies and observations c) Small maneuverable satellite studies	336:00:00 (14 days)	Demonstrate the: • Lab thermal control. • Compatibility of Lab with MSFN for synch orbit mission. • Capability of the modified LEM ECS and crew provisions for 14-day mission. • Pointing capability of Lab FCS. Evaluate the: • Radiation levels • EVA crew operations. • Lab data management systems.
10. Lab shutdown & equipment and data transfer to CSM.	01:30:00	Demonstrate performance of modified LEM structure and insulation.
11. Preparation for CM re-entry a) Lab jettison b) Service propulsion deorbit maneuver c) SM jettison	05:30:00	
12. Entry	00:11:00	
13. Parachute Descent	00:07:00	
14. Post Landing through S/C retrieval	Variable	

2.2.5 Lunar Orbit, Saturn V Launch

2.2.5.1 Mission Description

The launch, parking orbit insertion, trans-lunar insertion, trans-lunar coast, and lunar orbit insertion will be identical to the Apollo lunar mission. The trans-earth insertion, trans-earth coast, re-entry, and recovery will also be the same. The vehicle will orbit the moon in an 80-n.mi. altitude orbit with a 10-deg inclination. Earth ground station coverage is continous during line-of-sight operation. This mission is designed to obtain detailed lunar mapping data in the visual, IR, and radar frequency ranges. Visual observations will be made on the light-side of the Moon, while radar and IR surveys will be made of both sides. This mission will utilize the lunar survey equipment developed on an earlier AES earth orbital mission.

2.2.5.2 Spacecraft Test Objectives

The following spacecraft test objectives are applicable to lunar orbital missions. The basic Phase I Lab test objectives of Paragraph 2.2.1 are accomplished during earlier Phase I flights.

OBJECTIVE	RATIONALE
1. Evaluate radiation and micrometeorite levels in low-inclination lunar orbital environment.	1. This is the first Lab long-duration lunar orbital mission. The radiation levels that can be expected on a lunar landing mission and their resulting effects on spacecraft electronics and crew should be determined for a long-duration lunar mission.
2. Demonstrate CSM/LEM Lab I mission compatibility for lunar orbital thermal vacuum environment over mission duration.	2. This is the first lunar orbital mission with the modified LEM configuration. Although the configuration will have been flown in long-duration Earth orbital missions, the effects of thermal vacuum in the lunar orbital environment must be confirmed. The spacecraft will be required to point at the lunar surface for long periods of time to accomplish mapping and survey tasks. This will limit attitude changes for thermal control. The ability of the modified LEM ECS to maintain crew comfort and supply adequate vehicle cooling during these phases must be shown. The ability of the modified LEM structure and insulation to survive boost environments and to maintain integrity in a lunar thermal vacuum environment must be demonstrated.

2.2.5.3 Lunar Orbit, Saturn V Launch, Mission Profile

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
1. Saturn V Ascent to Parking Orbit (100 n.mi.) a) S-IC firing b) S-II firing c) LES jettison d) S-IVB firing e) Parking orbit insertion	00:12:00	None
2. Earth Parking Orbit a) CSM C/O b) Preparation for trans-lunar insertion	02:49:00	None
3. Translunar Insertion a) S-IVB restart	00:05:00	None
4. Translunar Coast a) CSM-S-IVB separation b) Transposition & docking c) CSM/Lab-S-IVB separation d) 1st mid-course correction e) 2nd mid-course correction f) 3rd mid-course correction	61:10:00	None
5. Lunar Orbit Insertion a) SPS firing	00:05:00	None
6. Lab C/O in Lunar Orbit a) Crew transfer to Lab b) Activate & C/O of Lab systems	01:30:00	Demonstrate operation of modified LEM systems after boost environments.
7. Lunar Orbit Lab Experiment Operations a) Biomedical & behavioral studies b) Lunar photographic studies c) Lunar oriented experiments	168:00:00 (7 days)	Evaluate radiation and micrometeorite levels in low-inclination lunar orbit. Demonstrate CSM-LEM Lab I mission compatability for lunar mission thermal vacuum environment.

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
8. Lab shutdown and equipment and data transfer to CSM.	01:30:00	None
9. Transearth Injection a) Lab jettison b) SPS firing	00:05:00	None
10. Transearth Coast a) 1st mid-course correction b) 2nd mid-course correction c) 3rd mid-course correction	89:00:00	None
11. SPS Deorbit a) SPS firing b) SM jettison	00:05:00	
12. Entry	00:11:00	
13. Parachute descent	00:07:00	
14. Post-landing through S/C retrieval	Variable	

TABLE 2.1-1

AES SPACECRAFT FLIGHT TEST REQUIREMENTS SUMMARY

REQUIREMENT	AES VEHICLE			
	Ph I Lab	Ph II Lab	Shelter	Taxi
• Capability of the extended LEM spacecraft ECS to support the crew over the mission duration shall be demonstrated prior to extended missions. As flight mission durations build up from Phase I through Phase II, the flight data shall be monitored and considered in the detailed ground test planning for subsequent missions.	X	X	X	X
• Integrated flight control of the AES LEM and AES CSM shall be confirmed for all flight regimes, specifically:				
- Transposition and docking maneuvers	X	X	X	X
- Docked maneuvering throughout each mission's inertial range	X	X	X	X
• AES fluid systems, particularly fuel cell EPS shall be demonstrated under long term earth orbital space conditions prior to extended lunar mission commitment, specifically:				
- Radiator thermal control system performance		X	X	
- Fuel cell power generator performance		X	X	
• Polar orbital tracking and MSFN/MCC capability shall be demonstrated by ground simulation and verified on the first polar orbital AES mission.	X			
• Functional mechanical operations perfected during the basic Apollo program should be reconfirmed. Typical of these operations are:				
- Spacecraft compatability with Saturn 1B, Saturn V and Service Module vibration environments.	X	X	X	X
- LEM stage separation				X

TABLE 2.1-1 (Cont'd)

REQUIREMENT	AES VEHICLE			
	Ph I Lab	Ph II Lab	Shelter	Taxi
- Spacecraft separation from the S-1VB.	X	X	X	X
- LEM/CSM docking and separations	X	X		X
- Landing gear deployment and landing stability			X	X
• AES experiment and functions which cannot be demonstrated satisfactorily in ground test conditions (e.i. simulated space flight environment) and which could compromise flight safety in the event of failure will be demonstrated in early near Earth orbital conditions, rather than during lunar, Phase II Earth orbital missions or resupply missions.	X			

TABLE 2.1-2

AES GROUND DEVELOPMENT TESTING

	ASSOCIATED AES TEST ARTICLE/FACILITY			
	Ph I Lab	Ph II Lab	Shelter	Taxi
• Structural-mechanical integrity shall be certified; particularly, vibratory response of the experiment-spacecraft combination shall be proven to be within limits acceptable for satisfactory experiment performance.	LLTA-1	LLTA-3	SLTA-1	TTE-1
• Electrical integration and compatibility between the spacecraft and experiments shall be demonstrated to maximize mission success, and to uncover and correct system or electrical degradation problems prior to flight mission commitment.	LLTA-1	LLTA-3	SLTA-1	TLTA-1
• Integrated Flight Control System capability shall be confirmed for experiment-spacecraft combinations when the nature of the experiment demands pointing, stabilization limit cycle or other dynamic and/or long term flight control requirements. Ground testing should include verification of the LEM guidance computer programming and operation for each mission that utilizes an LGC.	FCI	FCI	FCI	FCI
• Fluid subsystem performance and expendable scheduling to accommodate subsystem and experiment time-line requirements shall be demonstrated during system level ground testing, notably:				
- Environmental Control System	(ECS, subsys devel)	(ECS, subsys devel)	(ECS, subsys devel)	(ECS, subsys devel)
- Fuel Cells		PGS	PGS	

TABLE 2.1-2 (Cont'd)

	ASSOCIATED AES TEST ARTICLE/FACILITY			
	Ph 1 Lab	Ph 11 Lab	Shelter	Taxi
- Propulsion System - Reaction Control System		HR-2 HR-3 PA-1	PD-1 HD-1 HR-2 HR-3 PA-1	HD-1 PD-1
• Thermal-vacum environmental suitability of the experiment when integrated into the manned spacecraft shall be confirmed during system test. Thermal control of experiments (particularly those which interface with the spacecraft ECS) must be demonstrated prior to mission commitment. Manned operations under simulated altitude conditions must be confirmed prior to flight.	LTE-1 LLTA-2 IES	LTM-1 LLTA-3 IES	STM-2 SLTA-1 IES	TTM-1 TLTA-1
• Experiments which interface directly with spacecraft subsystems will be developed and certified flight-ready by ground system testing with prototype experiment-spacecraft hardware prior to completion of prelaunch operations of the first spacecraft utilizing subject experiment.	LM-1 LLTA-2	LM-2 LTM-1 LLTA-3 LLTA-4	SM-1 SM-2 SLTA-1	

TABLE 2.1-3

GROUND TEST ARTICLE/FACILITY

DESIGNATION	IDENTIFICATION	TEST AREA: STRUCTURAL - MECHANICAL	THERMAL VACUUM	ELECTRICAL-ELECTRONIC INTEGRATION	FLIGHT CONTROL	FLUID SYSTEM/PROP.	EXPERIMENT INTERFACE
TTE-1	Battery/RTG Bay Test Element - Taxi	X					
LLTA-1	House Spacecraft - Phase I Lab	X		X			X
LLTA-2	Thermal - Vacuum Phase I Lab		X				
LLTA-3	Thermal Vacuum (and Environmental Test) Phase II Lab	X	X	X			X
LLTA-4	Phase II Lab Test Article						X
SLTA-1	Electronic/Environmental Verification - Shelter	X	X	X			
LTE-1	Battery Bay Test Element - Phase 1 Lab		X				
LTM-1	Test Model - Phase II Lab		X				X
STM-1	Test Model - Shelter		X				
TTM-1	Test Model - Taxi		X				
TLTA-1	Taxi Test Article		X	X			
TLTA-2	Taxi Test Article		X				
IES	Internal Environmental Simulator		X				
FCI	Flight Control Integration Laboratory				X		
PGS	Power Generation Section Lab					X	
LM-1	Exterior-Mockup - Phase II Lab						X

TABLE 2.1-3 (Cont'd)

		TEST AREA					
DESIGNATION	IDENTIFICATION	STRUCTURAL - MECHANICAL	THERMAL VACUUM	ELECTRICAL-ELECTRONIC INTEGRATION	FLIGHT CONTROL	FLUID SYSTEM/PROP.	EXPERIMENT INTERFACE
LM-2	Interior Mockup - Phase II Lab						X
SM-1	Mockup - Shelter						X
HR-2	Cold Flow Test Rig (RCS)					X	
HR-3	Hot Firing Test Rig (RCS)					X	
PA-1	Hot Firing Test Rig (RCS)					X	
HD-1	Decent Propulsion Test Rig					X	
PD-1	Decent Propulsion Test Rig					X	

TABLE 2.1-4

AES FLIGHT MISSION TEST PREREQUISITES

For Earth-Orbital AES Missions
The Apollo spacecraft shall have completed all Earth orbital flight development required for demonstrating lunar landing mission capability before engaging in AES Earth orbital missions. Specifically,: • Block 11 CSM capability, including transposition, docking, 14-day mission capability, CSM life support, entry, Earth landing, rescue, and abort of LEM crew shall have been demonstrated. • LEM capability, including full duration, manned operation, propulsion and flight control operations, and subsystem performance in Earth orbit shall have been demonstrated. • MSFN/MCC operational support for all phases of Earth-orbit missions and recovery shall have been demonstrated. • A representative amount of flight data using both Saturn 1B and Saturn V launch vehicles shall have been acquired, analyzed, and compared with subsystem specification and performance data to assure Apollo capability for AES.
For Lunar AES Missions
The Apollo spacecraft shall have demonstrated lunar mission capability before engaging in AES lunar missions. Specifically,: • Apollo expendable utilization and lunar mission time-line verification for both subsystem performance and flight operational tasks shall have been demonstrated. • Lunar surface characteristics, lunar landing and lunar take-off shall have been confirmed by a vehicle exhibiting LEM characteristics; notably, mass, inertia, center of gravity, gear tread, and crew support. • MSFN/MCC operational support of lunar landing missions and recovery shall have been demonstrated.

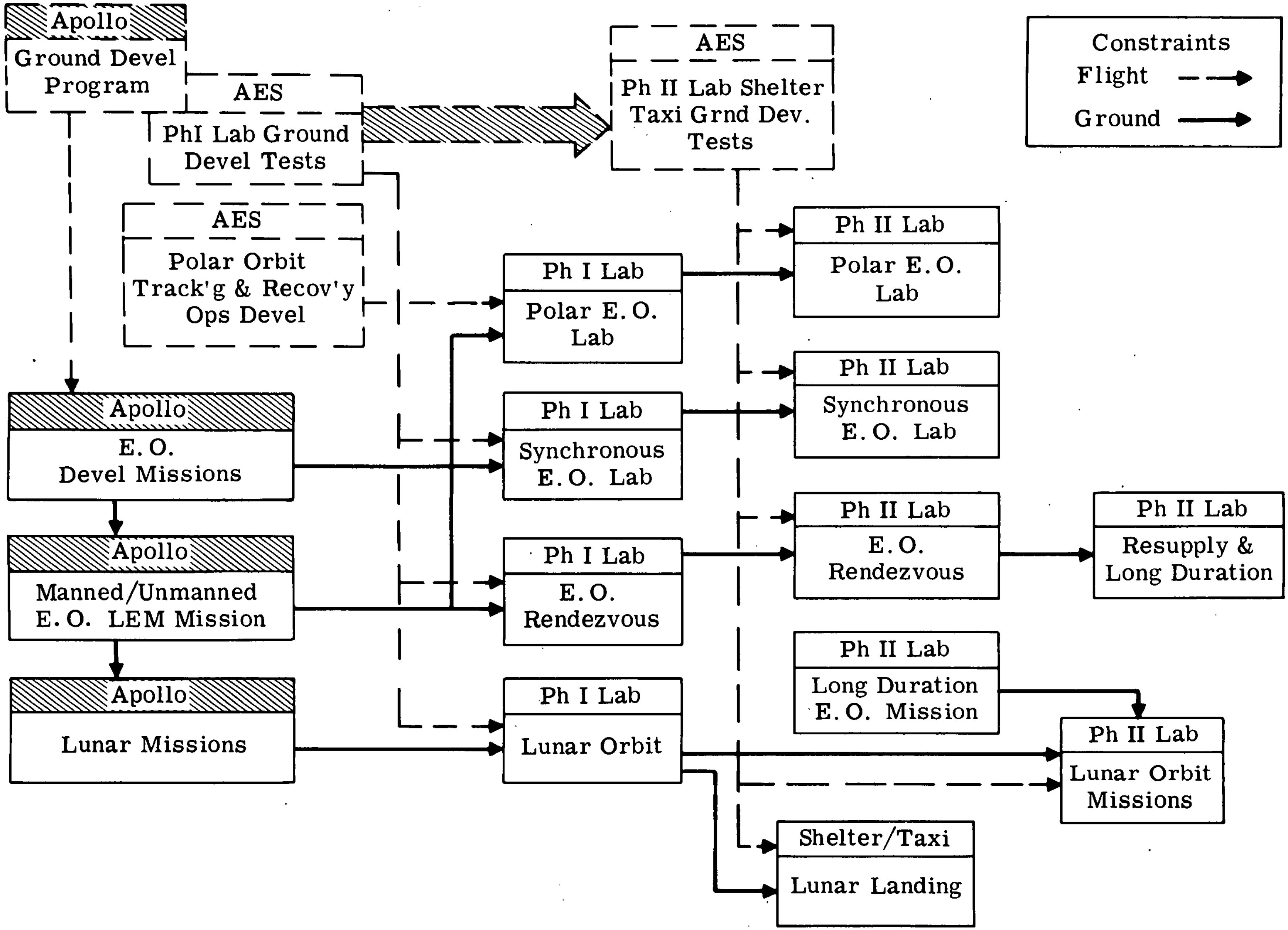


Fig. 2.1-1 AES Flight Mission and Constraint Logic

2.3 PHASE II LAB MISSIONS

2.3.1 Earth Orbit, Low-Inclination, Saturn V

2.3.1.1 Mission Description

The Phase II Lab Saturn V launched Earth orbital mission description is identical to that of the Phase I Saturn V launched Earth orbital mission (Paragraph 2.2.1.1). However, the mission duration is 45 days. The Saturn V is capable of placing a larger payload in low Earth orbit than the Saturn IB. The prime purpose of this mission is to conduct extensive experiments throughout the increased mission duration consistent with the Phase II Lab capability. The prime test goal of this mission is to confirm the capability of the modified LEM subsystems to perform satisfactorily over a long-duration Earth orbital mission.

2.3.1.2 Spacecraft Test Objectives

The following spacecraft test objectives are applicable to all Phase II Lab missions.

OBJECTIVE	RATIONALE
1. Demonstrate performance of the modified LEM structure and insulation over a 45-day Earth orbital Lab mission.	1. The basic Apollo LEM is designed for a 4-day active lifetime. The modifications to the structure caused by equipment changes and experiment payload plus the modified insulation must be evaluated in a long-duration thermal vacuum environment. Long-duration exposure to thermal vacuum environment could cause structural or material degradation. Micrometeorite penetration could cause compromise of thermal shielding and/or load bearing structures.
2. Demonstrate operation of modified LEM subsystems after being subjected to boost environments.	2. The Phase II Lab flights represent the first time that the modified equipment and installation will be subjected to the boost environment, and to the frequency variations and amplifications caused by the attachment of the new vehicle primary and secondary structure. The flight results will verify that the modified subsystem equipment will operate after exposure to the launch environment for the successful completion of this and all subsequent Phase II Lab missions.
3. Demonstrate the capability of the redesigned LEM ECS to maintain thermal control over 45-day earth orbital mission.	3. The earlier Phase I Labs will have used a modified LEM ECS for shorter duration missions. To accomplish a 45-day mission, the ECS will be further modified and a performance demonstration on the first long duration mission is necessary. In addition, information on the functioning of the ECS

OBJECTIVE	RATIONALE
3. (Cont'd)	equipment cooling loop (radiator, H_2O boiler) is necessary to differentiate between electronic subsystem and ECS cooling loop malfunctions in the event of thermal control problems.
4. Demonstrate the capability of the two-gas ARS to support the crew over a 45-day Earth orbital mission.	4. The two-gas ARS (70% O_2, 30% N_2) will not have been flight tested previously. The ability of the ARS to maintain proper mixture ratios and proper pressure must be shown. The only way to confirm the redesigned ARS is to investigate it after exposure to launch accelerations and the space environment over the 45-day mission period.
5. Demonstrate the performance of Lab airlock and airlock compatibility with vehicle design and the two-gas ARS.	5. The Phase II Lab flights will be the first time that an airlock is used for egress and ingress. The ability to egress and ingress without depressurizing and pressurizing the entire cabin will mean a savings in consumable usage. The compatibility of the airlock with the Lab design, so that pressure and gas leakage rates are minimized, must be demonstrated. The ease with which the airlock can be used must also be demonstrated.
6. Demonstrate cryogenic storage, distribution, and pressure regulation throughout the 45-day mission duration.	6. The ability of the cryogenic tank heaters to maintain the O_2 and H_2 in the supercritical region must be shown. The zero-g effects on heater cycling and consequent pressure regulation must be shown. The fuel cell reactant supply system operation for a long-duration space mission must be shown.
7. Evaluate the operational characteristics of the Lab RCS in the space environment over the 45 day mission.	7. The ability to start, restart, and cycle the RCS quads in the vacuum and the cold of space will be evaluated. Potential problems, such as freezing or sluggish propellants, can be evaluated over a 45-day space mission. The effect on engine life of long-duration usage and outgassing of the thermal coating of the thrust chambers under vacuum, high temperature (due to usage) shock, and vibration will be evaluated.
8. Demonstrate satisfactory operation of the fuel cell EPS configuration in the space environment over the 45-day mission.	8. Although fuel cells will have been flown previously, the overall Lab power generation section including the fuel cells will not have been exposed to a 45-day space operational environment. The susceptibility of failure of the fuel cells and the cryogenic supply system under prolonged zero-g effects

OBJECTIVE	RATIONALE
8. (Cont'd)	will not be known because these types of failures are design dependent. Fuel cell cooling and electrolyte stratification are also affected by the zero-g environment. This could cause the loss of all fuel cells because of a common fault. The effectiveness of the fuel cell radiators to maintain temperature must be evaluated.
9. Demonstrate operation of the modified instrumentation and data management systems.	9. The effectiveness of the modified PCM and the modified CSM recorders in handling large amounts of spacecraft and experimental data must be demonstrated. The ability to dump large amounts of data in the limited ground station coverage time available must be demonstrated (409.6-kb/s dump rate).

2.3.1.3 Earth Orbit, Saturn V Launch, Mission Profile (200 N. Mi)

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
1. Saturn V Ascent to Orbit a) S-IC firing b) S-II firing c) LES jettison d) S-IVB firing	00:12:00	None
2. S-IVB Stabilization a) CSM C/O	03:00:00	None
3. Transposition & Docking a) CSM-S-IVB separation b) Transposition c) CSM-LEM Lab docking d) Lab extraction from S-IVB	00:30:00	None
4. Lab C/O a) Crew transfer to Lab b) Lab C/O	01:30:00	Demonstrate the: • Operation of modified LEM subsystems after being subjected to boost environment.
5. Earth Orbit Lab Experiment Operations a) Earth oriented applications	1080:00:00 (45 days)	• Capability of the redesigned ECS to maintain thermal control over a 45-day Earth orbital mission.

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
		• Satisfactory operation of fuel cells in space environment over 45-day mission. • Cryogenic storage, distribution and pressure regulation throughout 45-day mission. • Performance of modified LEM structure and insulation over 45-day Earth orbital mission. • Capability of the two-gas ARS to support the crew over a 45-day Earth orbital mission. • Performance of Lab airlock and airlock compatibility with vehicle design and the two-gas ARS. • Operation of the modified instrumentation and data management systems. Evaluate operational characteristics of the Lab RCS in space environment over 45-day mission.
6. Lab shutdown and equipment and data transfer to CSM	01:30:00	
7. Preparation for CM entry a) Lab jettison b) SPS deorbit maneuver c) SM jettison	00:10:00	
8. Entry	00:11:00	
9. Parachute descent	00:07:00	
10. Post landing through S/C retrieval	Variable	

2.3.2 Earth Orbit Rendezvous, Saturn IB Launch

2.3.2.1 Mission Description

The Phase II Lab Saturn IB launched missions are the same as those of Phase I, i.e., they are part of dual launch rendezvous and/or resupply missions. The Phase II Lab mission duration is 45 days.

2.3.2.2 Spacecraft Test Objectives

All Spacecraft Test Objectives for Phase I Earth orbit rendezvous, Saturn IB launch (Paragraph 2.2.2.2.), as well as the Phase II Lab Spacecraft Test Objectives (Paragraph 2.3.1.2) are applicable.

2.3.2.3 Earth Orbit Rendezous, Saturn IB Launch, Mission Profile (200 N.Mi, 28.5 Deg Incl.)

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVES
1. Saturn IB Ascent to Orbit (Lab) a) S-IB firing b) S-IVB firing c) LES-Boilerplate CSM Jettison	00:12:00	Demonstrate integrated mission control. (Note: Applicable during all phases through CSM-Lab docking.)
2. Earth Orbit Coast S-IVB Stabilization a) Subsystems status check	03:00:00	Demonstrate operation of modified LEM subsystems after being subjected to boost environment.
3. S-IVB - Lab Separation a) SLA petal deploy b) LMP initiates sep c) LMP shuts down S/S	00:20:00	None
4. Earth Orbit Storage (Lab Unstabilized) a) LMP activates S/S for status C/O	Variable up to 30 days	Demonstrate ability of Lab ECS, EPS, Instr. & Comm. equipment to perform during unmanned orbital storage.
5. Saturn IB Ascent to Orbit (CSM & Crew) a) Same as 1, above	00:12:00	
6. Earth Orbit CSM C/O	00:30:00	
7. CSM - S-IVB Separation	00:05:00	
8. CSM Rendezvous with Lab	Variable	

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
9. CSM Active Docking a) LMP stabilizes Lab b) CSM docks	00:15:00	Demonstrate unmanned Lab FCS ability to operate after orbital storage and effect docking with a manned CSM.
10. Lab C/O a) Crew transfer b) Lab C/O	01:30:00	None
11. Earth Orbit Lab Experiment Operations a) Biomedical & behavioral studies b) EVA studies c) Radiation monitoring	1080:00:00 (45 days)	Demonstrate the: • Satisfactory operation of the fuel cell EPS configuration over a 45-day mission. • Capability of the redesigned ECS to maintain thermal control over a 45-day mission. • Performance of modified LEM structure & insulation over 45-day mission. • Cryogenic storage, distribution, and pressure regulation throughout a 45-day mission. • Capability of the two-gas ARS. • Performance of the airlock. • Operation of the modified instrumentation and data management systems. Evaluate operational characteristics of the Lab RCS over a 45-day mission.
12. Lab Shutdown and Equipment and Data Transfer to CSM	01:30:00	None
13. Preparation for CM Entry a) Lab jettison b) SPS deorbit maneuver c) SM jettison	00:10:00	
14. Entry	00:11:00	
15. Parachute Descent	00:07:00	
16. Post Landing through S/C Retrieval.	Variable	

2.3.3 Earth Polar Orbit, Saturn V Launch

2.3.3.1 Mission Description

The Phase II polar Earth orbit mission descriptions are the same as those of Phase I Labs missions. However, the mission duration is 45 days.

2.3.3.2 Spacecraft Test Objectives

All Spacecraft Test Objectives for Phase I polar Earth orbit mission (Paragraph 2.2.3.2), as well as the Phase II Lab Spacecraft Test Objectives (Paragraph 2.3.1.2) are applicable.

2.3.3.3 Earth Polar Orbit, Saturn V Launch, Mission Profile (200 N.Mi, 90-Deg Inclination)

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
1. Saturn V Ascent to Polar Orbit a) S-IC firing b) S-II firing (yaw steering) c) LES jettison d) S-IVB firing (yaw steering)	00:16:30	Demonstrate Lab structural integrity after Saturn V yaw steering maneuvering to effect a polar orbit.
2. Orbit Coast - S-IVB Stabilized a) CSM C/O	03:00:00	
3. CSM Transposition and Docking a) CSM - SIVB separation b) CSM transposition c) CSM-LEM Lab/Docking d) LAB-S-IVB separation	00:30:00	
4. Lab C/O a) Crew enters Lab b) Activation & C/O of Lab subsystems	02:00:00	Demonstrate performance of modified LEM subsystems after being subjected to boost environment.
5. Earth Polar Orbital Lab Operations a) Biomedical & behavioral studies	1080:00:00 (45 days)	Demonstrate the: • Satisfactory operation of the fuel cell EPS configuration over a 45-day mission.

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
b) Weather studies c) Geophysical observations		• Cryogenic storage, distribution, and pressure regulation throughout a 45-day mission. • Performance of the modified LEM structure and insulation over a 45-day mission. • Capability of the redesigned ECS to maintain thermal control over a 45-day mission. • Compatibility of Lab with MSFN for polar orbit operations. • Capability of the two-gas ARS. • Performance of the Lab airlock. • Operation of the modified instrumentation and data management systems. Evaluate the: • Radiations levels throughout mission duration. • Operational characteristics of the Lab RCS over a 45-day mission.
6. Lab Shutdown and Equipment and Data Transfer to CSM	01:30:00	None
7. Preparation for CM Reentry a) Lab jettison b) Service propulsion deorbit maneuver c) SM jettison	00:10:00	
8. Entry	00:11:00	
9. Parachute Descent	00:07:00	
10. Post Landing through S/C Retrieval	Variable	

2.3.4 Earth Synchronous Orbit, Saturn V Launch

2.3.4.1 Mission Description

The Phase II synchronous Earth orbit mission descriptions are the same as those of Phase I Lab missions. The mission duration is 45 days.

2.3.4.2 Spacecraft Test Objectives

All Spacecraft Test Objectives for Phase I synchronous Earth orbit mission (Paragraph 2.2.4.1), as well as the Phase II Spacecraft Test Objectives (Paragraph 2.3.1.2) are applicable.

2.3.4.3 Earth Synchronous Orbit, Saturn V Launch, Mission Profile (19,350 N.Mi, 0-Deg Inclination)

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
1. Saturn V Ascent to 100-N.Mi Parking Orbit, 28.5-deg inclin. a) Launch azimuth 90 deg b) S-IC firing c) S-II firing d) LES jettison e) S-IVB firing f) Parking orbit insertion	00:12:00	None
2. Earth Parking Orbit (3-1/4 orbits) a) CSM systems check b) Preparation for transfer orbit insertion	05:00:00	None
3. Transfer Orbit Insertion a) S-IVB restart b) Orbit transfer & partial plane change	00:06:00	None
4. Transfer Orbit Coast to 19,350 N.Mi	05:15:00	None
5. S-IVB Restart to do Partial Plane Change & Orbit Change at Apogee.	00:02:00	None

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
6. Elliptical Orbit Coast a) CSM - S-IVB separation b) CSM transposition & docking with Lab c) Lab - S-IVB separation d) orbit coast	13:41:00	None
7. CSM firing to complete plane change and circularization	00:01:30	None
8. Lab C/O a) Crew Transfer to Lab b) Activation and C/O of Lab S/S	01:30:00	• Demonstrate operation of modified LEM subsystems after being subjected to boost environments
9. Earth Synch. Orbit Lab Experiment Operations a) Biomedical & behavioral studies b) Astronomical studies and observations	1080:00:00 (45 days)	Demonstrate the: • Lab thermal control throughout mission. • Capability of Lab with MSFN for synch. orbit mission. • Performance of the modified LEM structure and insulation over a 45-day mission. • Satisfactory operation of the fuel cell EPS configuration over a 45-day mission. • Cryogenic storage, distribution and pressure regulation through a 45-day mission. • Capability of the redesigned ECS to maintain thermal control over a 45-day mission. • Capability of the two-gas ARS. • Performance of the Lab airlock. • Operation of the modified instrumentation and data management systems. Evaluate the: • Radiation levels. • Operational characteristics of the Lab RCS over a 45-day mission.

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVE
10. LEM Lab Shutdown & Equipment and Data Transfer to CSM	01:30:00	None
11. Preparation for CM Re-entry a) Lab jettison b) Service propulsion deorbit maneuver c) SM jettison	05:30:00	
12. Entry	00:11:00	
13. Parachute descent	00:07:00	
14. Post-Landing through Spacecraft Retrieval	Variable	

2.3.5 High-Inclination Lunar Orbit, Saturn V Launch

2.3.5.1 Mission Description

These missions are similar to the Phase I lunar orbit mission; however, the mission duration is 35 days, and are lunar polar orbital. The orbit is inclined 90 deg at an altitude of 80 n.mi. During lunar orbit insertion extra Δ V is applied by the service module propulsion system (SPS), to give polar inclination.

2.3.5.2 Spacecraft Test Objectives

The following spacecraft test objectives are applicable to lunar orbit missions. The Phase II Test Objectives (Paragraph 2.3.1.2) are considered accomplished during earlier Earth orbital flights.

OBJECTIVE	RATIONALE
1. Evaluate radiation and micrometeorite levels in high-inclination lunar orbital environment.	1. Previous lunar orbital missions have evaluated radiation levels and micrometeorite activity in low-inclination orbits. These phenomena must be investigated during a long-duration, 35-day, Phase II mission to show the effectiveness of the modified micrometeorite shielding, as well as the radiation effects on electronics and crew.

OBJECTIVE	RATIONALE
2. Demonstrate CSM-LEM Lab II mission compatibility for lunar orbital thermal vacuum environment over mission duration 35 days.	2. This is the first long-duration lunar orbital mission in a high-inclination orbit. The thermal vacuum effects on vehicle structure and subsystem electronic components must be demonstrated. The ability of the Phase II Lab ECS to maintain crew comfort and perform equipment thermal control must be demonstrated.
3. Demonstrate Lab II structural and system integrity after lunar polar orbit insertion SPS firing.	3. The effect of long-duration SPS firing on modified subsystems after translunar coast in a thermal vacuum environment must be demonstrated. The negative-g effects on modified structure and subsystems must be demonstrated.
4. Demonstrate Lab II expendable utilization during extended lunar mission time line.	4. Expendable usage for long-duration lunar missions will not have been demonstrated previously. Although long-duration, earth orbital mission, consumable usage for Phase II Labs will be known; the different environmental and mission conditions require expendable usage to be demonstrated in lunar orbit.

2.3.5.3 Lunar Orbit, Saturn V Launch, Mission Profile

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVES
1. Saturn V Ascent to Parking Orbit (100 n.mi) a) S-IC firing b) S-II firing c) LES jettison d) S-IVB firing e) Parking orbit insertion	00:12:00	None
2. Earth Parking Orbit a) CSM C/O b) Preparation for translunar insertion	02:49:00	None
3. Translunar Insertion a) S-IVB restart	00:05:00	None
4. Translunar Coast a) CSM-SIVB separation b) Transposition & docking c) CSM/Lab-SIVB separation	61:10:00	None

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVES
d) 1st mid-course correction e) 2nd mid-course correction f) 3rd mid-course correction		
5. Lunar Orbit Insertion a) SPS firing for orbit insertion. b) SPS firing plane change.	00:05:00	Demonstrate Lab Structural and system integrity after lunar polar orbit insertion SPS firing.
6. Lab C/O in Lunar Orbit a) Crew transfer to Lab b) Activate & C/O of Lab systems	01:30:00	Demonstrate operation of modified subsystems after boost environments.
7. Lunar Orbit Lab Experiment Operations a) Biomedical & behavioral studies b) Lunar photographic studies c) Lunar oriented experiments	672:00:00 (28 days)	Evaluate radiation and micrometeorite levels in high-inclination lunar orbit. Demonstrate the: o CSM-LEM Lab II mission compatibility for lunar mission thermal vacuum environment, 35 days. o Lab II expendable usage during extended lunar mission stay time.
8. LEM Lab Shutdown and Equipment and Data Transfer to CSM	01:30:00	None
9. Transearth Injection a) Lab jettison b) SPS firing	00:05:00	
10. Transearth Coast a) 1st mid-course correction b) 2nd mid-course correction c) 3rd mid-course correction	89:00:00	
11. SPS Deorbit a) SPS firing b) SM jettison	00:05:00	

2.4 SHELTER MISSIONS

2.4.1 Mission Description

The Shelter launch, earth parking orbit, translunar insertion, transluar coast, and lunar orbit insertion mission phases are the same as an Apollo lunar mission. The Shelter is dormant before separation from the CSM in lunar orbit. After lunar orbit checkout, the Shelter separates unmanned and performs a pre-programmed descent to a preselected site. Two methods of lunar descent are being considered. Method A is a direct descent method from an initial orbit of 20 n.mi. Method B is an Apollo lunar mission Hohmann transfer descent from 80 n.mi. The non-essential Shelter subsystems are shut down after touch-down and the CSM returns to earth. The Shelter has the capability of a 90-day stay time on the lunar surface. Ground station coverage is continuous for line-of-sight portions of the mission. The prime purpose of the Shelter is to provide a base for lunar surface exploration and experiments. All three planned Shelter missions are basically identical. Mission variations will depend on the Shelter payload.

2.4.2 Spacecraft Test Objectives

The following spacecraft test objectives are applicable to the Shelter missions. The Shelter spacecraft test objectives will complement the spacecraft tests and investigation performed during the Phase I and early Phase II Lab missions.

OBJECTIVE	RATIONALS
1. Demonstrate Earth-Shelter communication capability during lunar orbit and descent to the lunar surface.	1. The ability of the Comm Subsystem to transmit data to the Earth during lunar orbit operations and line-of-sight descent must be demonstrated. The subsystem capability to transmit via VHF to the CSM during non-line-of-sight operations and to switch to direct communications with the Earth must be demonstrated.
2. Demonstrate unmanned pre-programmed inertial landing system.	2. This is the first time that an unmanned lunar landing will have been attempted. The ability of the Shelter GN&C to maintain spacecraft control during descent engine thrusting and to automatically follow a pre-programmed descent profile to a pre-selected sight must be demonstrated. The ability of the 8-jet RCS to maintain vehicle control must be demonstrated.
3. Demonstrate landing stability and structural integrity of the Shelter/payload combination.	3. Although Apollo lunar landings will have been performed, the effects of the modified structure and subsystems plus a large payload on landing stability must be shown. The effects

OBJECTIVE	RATIONALE
3.	3. of landing loads during an unmanned landing on vehicle structural integrity must be demonstrated.
4. Demonstrate the performance of the Shelter thermal control design during quiescent stay time.	4. The capability of the Shelter ECS to maintain thermal control during the unmanned lunar storage period must be demonstrated. Phase I and II Lab's ability to maintain thermal control during extended and unmanned Earth orbital storage periods will have been demonstrated. However, this capability in a lunar environment has not been shown before. Addition of the RTG affects the thermal control. The effectiveness of the modified thermal insulation and of additional equipment heaters must be demonstrated. The heat rejection ability of the thermal radiators must be demonstrated.
5. Demonstrate fuel cell section operational capability from cold storage through warmup and earth command activation.	5. The ability to maintain fuel cell reactant tank pressures within acceptable limits during lunar storage must be demonstrated. The capability of the fuel cells to warm up and then be activated by ground command must be shown. Fuel cell startup after thermal vacuum storage will not have been demonstrated previously.
6. Demonstrate operation of modified subsystems after being subjected to boost environment.	6. The LEM subsystems will have been flown on both the Saturn IB and Saturn V boosters. Modifications to the structure and supports require that loads and vibrations imparted to the spacecraft by the launch vehicle and by the Shelter to the various equipments and equipment areas be confirmed. Major additions to the ECS and EPS (RTG, fuel cells and associated tankage) plus deletion of the ascent propulsion subsystem and 50% of the RCS cluster hardware require that the boost environment effects on the overall Shelter be confirmed.

7. Demonstrate the performance of the Shelter airlock during multiple lunar surface egress and ingress cycles.	7. The ability of the astronaut to effectively use the airlock wearing a hardsuit and handling equipment must be demonstrated. The ability to maintain a shirtsleeve cabin atmosphere during egress and ingress cycles must be shown. The pressure and atmosphere leakage rates of the cabin to the airlock must be determined.

2.4.3 Shelter, Saturn V Launch, Mission Profile

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec:)	OPERATIONAL TEST OBJECTIVE
1. Saturn V Ascent to Parking Orbit (100 n.mi) a) S-IC firing b) S-II firing c) LES jettison d) S-IVB firing e) Parking orbit insertion	00:12:00	None
2. Earth Parking Orbit a) CSM C/O b) Preparation for trans-lunar insertion	02:49:00	None
3. Translunar Insertion a) S-IVB restart	00:05:00	None
4. Translunar Coast a) CSM-SIVB separation b) Transposition & docking c) CSM/Shelter - S-IVB separation d) 1st mid-course correction e) 2nd mid-course correction f) 3rd mid-course correction	61:10:00	None
5. Lunar Orbit Insertion a) SPS firing (Note: 20-n. mi circular for direct descent, 80-n. mi circular for Apollo descent.)	00:05:00	None

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec:)	OPERATIONAL TEST OBJECTIVE
6. Shelter C/O and Lunar Orbit a) Crew transfer to Shelter b) Activate & C/O Shelter systems	03:43:00 (80-n.mi orbit) 02:49:00 (20-n.mi orbit)	Demonstrate the: • Earth-Shelter communications capability during lunar orbit. • Operation of modified subsystems after being subjected to boost environment.
7. Shelter-CSM Separation a) Preparation for separation b) Remove inhibit from descent programmer c) Crew return to CSM d) Shelter separation	00:20:00	None
8. Lunar Descent & Landing Method A - Direct Descent from 20 n.mi a) Initiate powered descent b) Braking phase c) Final approach phase d) Landing phase	00:15:00	Demonstrate the: • Unmanned preprogrammed inertial landing system • Earth-Shelter communication capability during descent to the moon.
Method B - Hohmann transfer from 80 n.mi a) Transfer orbit insertion b) Initiate powered descent at 50,000 ft c) Braking phase d) Final approach phase e) Landing phase	01:10:00	Demonstrate landing stability and structural integrity of the Shelter/payload combination.
9. Lunar Storage Period a) Post landing S/S C/O b) S/S shutdown c) Periodic status checks	(up to 90 days)	Demonstrate performance of the Shelter thermal control during quiescent stay time.
10. Lunar Shelter Manned Experiment Operations a) Topographical studies b) Geological studies c) Photography & radiometry d) Gravity and magnetic studies e) Extra vehicular activities	336:00:00 (14 days)	Demonstrate the: • Fuel cell section operational capability from cold storage through warm-up and Earth command activation. • Performance of the Shelter airlock during multiple lunar surface egress and ingress cycles.
11. Shelter Shutdown & Equipment Transfer to Taxi	01:30:00	None

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec)	OPERATIONAL TEST OBJECTIVES
12. Entry	00:11:00	
13. Parachute Descent	00:07:00	
14. Post-Landing through S/C Retrieval	Variable	

2.5 TAXI MISSIONS

2.5.1 Mission Description

The Taxi launch, earth parking orbit, translunar injection, translunar coast, lunar orbit insertion, lunar orbit checkout, transfer orbit insertion, and lunar descent and landing are the same as that of an Apollo lunar landing mission. The manned Taxi lands at the selected location and the crew transfers to the Shelter. At the completion of the lunar liftoff, CSM docking and transearth injection sequences follow the basic Apollo mission. Taxi launch occurs prior to CSM passage overhead. Directly over launch site, at an altitude of 50,000 ft, burnout occurs followed by a 3/4 orbit rendezvous coast. The Taxi rendezvous and docks with the CSM and data transfer. Approximately 1-3/4 orbits after Taxi/CSM docking, transearth injection is initiated. The CSM initiates a multi-impulse or single-impulse transearth trajectory maneuver. The return to Earth is the same as an Apollo lunar mission. The CSM-Taxi mission duration is 23 days, of which 14 are on the lunar surface. Ground station coverage is continuous for all line-of-sight operations. The prime purpose of the Taxi is to provide a means for crew arrival and departure from the lunar surface. All three planned Taxi mission are the same as the basic Taxi mission described.

2.5.2 Spacecraft Test Objectives

The following spacecraft test objectives are applicable to all Taxi missions. The Taxi spacecraft test objectives will implement the spacecraft tests and investigations performed on the Phase I and early Phase II Lab missions.

OBJECTIVE	RATIONALE
1. Demonstrate the performance of the Taxi thermal control design for a 14-day lunar stay mission.	1. The additions and modifications to subsystem equipment, plus the addition of thermal insulation, window covers, and top docking tunnel cover require that the ECS's ability to maintain thermal control of cabin and equipment be demonstrated. The effectiveness of such heat transfer equipment as the RTG "heat pipe" must be shown during the lunar stay quiescent period.
2. Demonstrate Taxi landing with the aid of a transponder	2. This is the first time a lunar landing using a beacon (on Shelter) for homing purposes has been planned. The ability of the rendezvous radar to acquire the beacon and use it for lunar descent and landing in vicinity of the Shelter must be demonstrated.
3. Demonstrate the capability of the Taxi ECS and crew provisions to support crew in accordance with the Taxi mission profile.	3. The ability of the Taxi ECS to maintain thermal control of cabin and equipment and to maintain cabin pressure and O_2 supply must be shown. The ability of the ECS to perform repeated pressurization/depressurization/pressurization cycles must be shown.

2.5.3 Taxi, Saturn V Launch, Mission Profile

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec:)	OPERATIONAL TEST OBJECTIVE
1. Saturn V Ascent to Parking orbit (100 n.mi a) S-IC firing b) S-II firing c) LES jettison d) S-IVB firing e) Parking orbit insertion	00:12:00	None
2. Earth Parking Orbit a) CSM C/O b) Preparation for trans-lunar insertion	2:49:00	None
3. Translunar Insertion a) S-IVB restart	00:05:00	None
4. Translunar Coast a) CSM-S-IVB separation b) Transposition & docking c) CSM/Shelter-S-IVB separation d) 1st mid-course correction e) 2nd mid-course correction f) 3rd mid-course correction	61:10:00	None
5. Lunar Orbit Insertion (80 n.mi) a) SPS firing	00:05:00	None
6. Taxi C/O and Lunar Orbit a) Crew transfer to Taxi b) Activate and C/O Taxi systems	03:43:00	None
7. Taxi-CSM Separation a) Preparation for separation b) Taxi active separation	00:20:00	None
8. Lunar Descent and Landing a) Transfer orbit insertion b) Initiate powered descent at pericynthian c) Braking phase	01:10:00	Demonstrate the: • Taxi landing with aid of a transponder. • Capability of the Taxi ECS and crew provisions to support crew in

MISSION PHASE	NOMINAL PHASE TIME (Hr: Min: Sec:)	OPERATIONAL TEST OBJECTIVE
d) Final approach phase e) Landing phase f) Post landing C/O		accordance with the Taxi mission profile.
9. Taxi Storage Period a) Shutdown of Taxi b) Crew transfer to Shelter c) Shelter operations	336:00:00 (14 days)	Demonstrate the: • Performance of Taxi thermal control design during 14-day mission.
10. Taxi Ascent a) Systems activation and Prelaunch C/O b) Ascent	01:40:00	• Capability of the taxi ECS and crew provisions to support crew in accordance with the Taxi mission profile.
11. Taxi-CSM Rendezvous a) Taxi active rendezvous b) Taxi active docking	00:45:00	• Capability of the Taxi ECS and crew provisions to support crew in accordance with the Taxi mission profile.
12. Taxi Shutdown & Equipment and Data Transfer to CSM	01:30:00	
13. Transearth Injection a) Taxi jettison b) SPS firing	00:05:00	
14. Transearth Coast a) 1st mid-course correction b) 2nd mid-course correction c) 3rd mid-course correction	89:00:00	
15. SPS Deorbit a) SPS firing b) SM jettison	00:05:00	
16. Entry	00:11:00	
17. Parachute Descent	00:07:00	
18. Post-Landing through S/C Retrieval	Variable	

2.6 TRACKING REQUIREMENTS

This section presents the operational ground tracking coverage and communications requirements for AES missions. A brief summary of the MSFN capabilities is given. Subsequently, the results of an analysis of the ground station coverage times, applicable to the Earth orbital and lunar missions, are summarized. Finally, the Lab, Shelter, and Taxi operational communications requirements are described and compared with MSFN capabilities.

2.6.1 Ground Rules

The tracking requirements are based on the following:

- The projected Apollo Manned Spaceflight Network (MSFN) of 11 near-space and three deep-space stations will be utilized for AES missions.

2.6.2 Assumptions

The tracking requirements are based on the following assumptions:

- For comparison between spacecraft communication requirements and MSFN capabilities, it is assumed that given four distinct S-Band frequencies, two may be processed and recorded in real-time and the remaining two signals are recorded.
- S-Band ground antenna line-of-sight is limited to 5 deg above the horizon.
- For lunar missions coverage, time begins upon lunar insertion.
- Parking-orbit insertion is taken as mission initiation.
- Thrusting maneuvers, involving Hohmann transfer from parking-orbit to a higher operational altitude, are not considered. Parking-orbit altitude is assumed for the duration of transfer resulting in less coverage time.
- All orbits are considered circular.
- Tracking ships provide continuous coverage for earth-orbital missions up to point of insertion.

2.6.3 Summary of MSFN Capabilities

The projected Apollo Unified S-Band (USB) system will consist of 11 near-space locations (30-ft antenna), deployed for Earth-orbital and lunar-injection phase communications, along with three deep-space sites (85-ft antenna) providing coverage at translunar and lunar distances. For ranges greater than 10,000 n. mi (a nominal boundary differentiating near-space and deep-space active tracking), deep-space stations perform as active transmitting and receiving stations, while near-space sites passively track. This technique enables a multi-station "fix" on the spacecraft's position. Table 2.6-1 designates locations, operational date and near-space or deep-space mode of operation. Also tabulated is site "dual" or "single" capability as described below.

2.6.3.1 Dual Stations

Eight stations, including the deep-space locations, will have "dual" capabilities permitting concurrent tracking of two space vehicles within the antenna main beam width (85-ft antenna: 0.35 ± 0.05 deg, 30-ft antenna: 1.05 ± 0.25 deg). During the dual track mode at lunar distances (ground antenna pointing is performed on one spacecraft), a minimum beamwidth of 0.30 deg limits the separation between spacecraft, in a plane perpendicular to an earth station, to approximately 500 n. mi (Fig. 2.6-1). Cognizance of such an existing constraint, although not expected to be exceeded during any phase of the lunar missions, should, nonetheless, be taken.

The deep-space stations will have facilities necessary for real-time processing of two S-Band signals. In addition, two other frequencies may be received; however, this information will be recorded. According to References 4-2 and 4-3, three S-Band frequencies are the maximum number of signals which would be received at translunar and lunar distances; two telemetry signals could be processed in real-time and the third recorded. Further inquiry into ground station facilities implies that four S-Band frequencies could be received, hence it has been assumed that this additional signal could only be recorded. Coverage afforded by the deep-space stations at translunar and lunar distances is continuous in that at least one site will always be in "view" of the spacecraft (24-hour coverage, clearly presupposes no lunar eclipsing of the spacecraft). Furthermore, there are certain periods when two locations can maintain communications with the spacecraft.

2.6.3.2 Single Station

The remaining five stations will possess "single" capabilities for communications and tracking support of one spacecraft. These stations will be able to receive and process two distinct S-Band frequencies.

2.6.4 Ground Tracking Analysis for Earth-Orbital Missions

The Phase I Lab missions discussed in Paragraph 2.2 may be categorized into five groups, according to earth or lunar orbital altitude and inclination. This paragraph presents a summary of ground station tracking coverage time available for the 14 Unified S-Band locations. Eleven near-space MSFN stations are primarily considered for low-inclination earth-orbital missions. In addition to these locations, the effects of introducing the Fairbanks, Alaska site for polar orbits has been examined. The three deep-space MSFN locations provide coverage for lunar orbital missions, with the near-space sites as back-up.

2.6.4.1 Low-inclination Earth-Orbit

The mission profile is 200-n. mi altitude and 28.5-deg inclination. The average coverage per orbit is 19.73 min.

A graphical representation of the first four orbits is shown in Fig. 2.6-2. Figure 2.6-3 gives a ground coverage analysis for the initial 36 orbits. Individual station coverage time is shown along with the total time available for tracking per orbit (station overlap included). Orbits 11 through 13 are indicative of an orbital grouping where minimum coverage is afforded. Also arising is the possibility of no ground tracking, typified by orbit 27. It is possible that by planning non-critical mission events, during the orbits where no coverage is afforded this situation, may be tolerable. Thirty-six orbits are shown in Fig. 2.6-3, however, approximate repetition was found to occur after 47 orbits. This periodicity is typical of all 200 n.mi altitude missions.

2.6.4.2 Polar Earth-Orbit

The mission profile is 200-n.mi altitude and 90-deg inclination. The average coverage per orbit is 8.43 min for USB sites, and 11.14 min when FBKS is added.

The ground track of the initial 4 1/4 orbits of a polar mission is shown in Fig. 2.6-4. The apparent discontinuity arises from the characteristics of the Mercator projection in that the polar ground track exhibits the same disjointedness as the Meridians. Table 2.6-2 indicates coverage available for the first thirty-six orbits. Total coverage per orbit is given first for the projected USB stations alone and then for the case where the Fairbanks, Alaska location is included.

In conclusion, implementing USB at the Fairbanks location would be highly desirable as indicated by the increased coverage time. This analysis indicates that utilization of this site extends the average orbital coverage by 32%. An additional important result is the elimination of orbits without ground contact.

2.6.4.3 Polar Retrograde-Orbit

The mission profile is 200-n.mi altitude and -83 deg (retrograde-orbit) inclination. The average coverage per orbit is 8.45 min for USB sites, and 11.30 min when FBKS is added.

Shown in Fig. 2.6-5 is the ground track of the initial 5 1/4 orbits, and Table 2.6-2 indicates coverage available for the first 36 orbits. Total coverage per orbit is given for USB stations alone and for the case when Fairbanks, Alaska location is included.

In conclusion, implementing USB at the Fairbanks location would result in similar benefits as in the previously cited Polar Earth-Orbit mission.

2.6.4.4 Synchronous Earth-Orbit

The mission profile is 19,350-n.mi altitude and 0-deg inclination. The coverage is continuous. Continuous coverage is possible in synchronous orbit since the orbital period coincides with Earth rotation, hence the spacecraft appears virtually stationary.

Figure 2.6-6 illustrates the entire ground track sequence until synchronous orbital insertion. Figure 2.6-7 shows the ground station coverage from parking orbit insertion, through the Hohmann transfer to synchronous altitude.

In conclusion, the ground station visibility chart, Fig. 2.6-7, shows that the spacecraft is continously tracked from a point 1 hr after transfer orbit insertion to synchronous altitude. At the synchronous point (0° lat., 168° W long.) the spacecraft is visible to seven ground stations, simultaneously.

2.6.5 Ground Tracking Analysis for Lunar Missions

2.6.5.1 Low-Inclination Lunar Orbit (80-n.mi Altitude)

Figure 2.6-8 graphically represents the coverage times afforded by the three active (transmitting and receiving) ground stations for lunar orbits. The solid bars indicate the spacecraft is ground-tracked, whereas the cross-hatching signifies lunar eclipsing of the vehicle. The upper time scale designates hours elapsed subsequent to lunar insertion, while the lower scale identifies the day. Nearly 13-2/3 days were taken before repition due to the lunar cycle occurred. 13-2/3 days constitutes one-half of the complete lunar cycle. The next half-cycle represents the mirror image. And every 13-2/3-day interval will have a similar pattern. However, due to the Earth rotation, the ground station tracking sequence may be different. This periodicity is typical of all lunar-orbital and lunar-stay missions.

Table 2.6-3 summarizes the ground station coverage times for the following three periods: (1) Total 13-2/3-Day Interval, (2) Continuous Coverage, (3) Lunar Occultation. Period 1 is the entire ground track time shown in Fig. 2.6-8. This period is further subdivided into three tracking modes. Column one indicates the total time available for tracking by one station. The second column gives the total coverage time afforded by two stations simultaneously. Summation of the first and second yields the total effective coverage and is shown in third column. Period 2 is the time interval providing continuous spacecraft coverage. The second period is subdivided into three tracking modes as follows: Average Coverage - One Station; Average Coverage - Two Stations; Total Average Coverage. The third period accounts for all the time intervals characterized by lunar eclipsing of the spacecraft. Subdivision of this period coincides with the continuous period cited above.

Table 2.6-3 indicates no continuous coverage periods for the low-inclination type missions. The spacecraft is in ground station "view" approximately 1 hr and 17 min per orbit, while the average occultation period lasts 46 min.

On an average, the lunar orbiting vehicle is ground-tracked 65% of the time. The spacecraft will spend approximately 2/3 of the total coverage time in "view" of one ground station. The remaining time will be available for simultaneous ground-tracking by two stations.

2.6.5.2 Lunar Polar-Orbit

Figure 2.6-9 charts the ground coverage time for the point of lunar insertion until the lunar cycle repeats 13-2/3 days later. A summary of the results appears in Table 2.6-3. (The description of the figures and the tabulation is the same as Paragraph 2.6.5.1.)

In Fig. 2.6-9, hours 37-125 illustrate a continuous coverage period exhibiting no lunar interposition. Hours 0-37 and 125-328 represent time intervals marked by lunar occultations. Such a pattern, characterized by alternate intervals of continuous and intermittent coverage periods, is unique for the high-inclination, lunar-orbital missions. Figure 2.6-10 depicts the effects of lunar position on earth coverage. Position 1 illustrates partial lunar eclipsing while position 2 shows no lunar interference.

The results shown in Table 2.6-3 indicate that coverage (by either one or two deep-space stations) is available 76% of the time. Furthermore, spacecraft "viewing" time is approximately doubled in the single tracking station mode as compared to the double station mode. The second column of Table 2.6-3 (Continuous Coverage Period) suggests a contradiction; however this is due to an averaging over a short-time interval when the most favorable double station coverage exists.

2.6.5.3 Shelter or Taxi Lunar Stay

A satisfactory approximation of the ground tracking capability for the Shelter/Taxi lunar stay coverage times may be taken from the low-inclination, lunar-orbital, mission tracking analysis. Therefore, Fig. 2.6-8 is applicable if the cross-hatched lunar occultation periods are assumed to be solid bars, signifying ground coverage. (For a description of the ground coverage figures and the tabulated summary refer to the discussion on the Low-Inclination Lunar Orbit, Paragraph 2.6.5.1.)

As shown in Table 2.6-3, the tracking time spent in line-of-sight of one ground station exceeds that of the two-station mode by two-fold. Ground coverage will be continuous with the possible exceptionoof two small gaps (Fig. 2.6-9, hours 264 and 288). The maximum time interval between coverage periods is nominally 14 min. The gaps are neglected at the present time since this duration is small and their occurrence infrequent.

2.6.6 <u>Lunar Mission Communications Operations</u>

2.6.6.1 Phase I - Earth-Orbit

Station coverage for launch, Earth-orbital, and translunar injection phases are similar for all Apollo lunar missions. Information concerning ground-tracking time for parking orbit may be found in Paragraph 2.6.4.1, noting that the 100-n.mi initial earth-orbit, typical for lunar missions, results in less coverage time than indicated for 200-n.mi earth-orbital flights. Ground Station tracking will be provided by the MSFN near-space stations for this phase.

Communications between Shelter, Taxi, or Lab (depending upon mission) and Earth during the earth-orbital phase are not required; however, CSM data acquisition and monitoring will be necessary during this period. A single phase modulated rf signal, transmitted by the CSM, provides the data link. CSM FM transmission is possible on a second rf carrier; therefore, all USB stations may receive and process both signals in real-time, simultaneously.

2.6.6.2 Phase II - Translunar

During the translunar phase, continuous telemetry and tracking coverage is afforded by the three deep-space stations for all AES missions. Spacecraft communication requirements are identical to Phase I (Paragraph 2.6.6.1). Ground capability increases to the extent that all active locations possess "dual" capability.

2.6.6.3 Phase III - Lunar

2.6.6.3.1 <u>Lab (Lunar Orbit)</u>. While 24-hour coverage is available throughout the translunar flight, lunar orbiting introduces occultation periods, where the spacecraft, shielded by lunar interposition, is not within line-of-sight. This periodic loss of communication will necessitate planning of real-time scientific experiments to take place directly after and prior to lunar interference. Experiments capable of being recorded may be performed at any time and "dumped" once earth-spacecraft acquisition is established.

The CSM-Lab combination will not separate during the lunar-orbital phase of the mission, thus excluding the requirement of tracking two spacecraft for the lunar-orbital Lab missions. Communication requirements, as far as the number of carrier frequencies needed, are similar to Phases I and II herein. Digital information telemetered to Earth, however, increases in conjunction with the scientific experiment being performed and has a maximum rate of 409.6 kbps.

2.6.6.3.2 Shelter - Direct Descent. Presently, there are two methods of Shelter descent under discussion. One suggests a direct lunar landing while the other method coincides with the basic Apollo descent. This paragraph describes the direct landing, while the Hohmann transfer method is summarized in a following paragraph which discusses the Taxi (or Shelter) coast and descent.

Since abort capabilities are not necessary for the unmanned Shelter, a direct lunar descent method is possible. The mission description may be summarized as: Lunar insertion begins while the Shelter-CSM combination is eclipsed by the moon, followed by a circular orbital coast at an altitude of 20 n.mi, nearly 0-deg inclination. Approximately 1-1/2 orbits later, Shelter separation and direct descent is initiated. Separation and subsequent powered landing from the coasting orbit could possibly be performed while in line-of-sight of the CSM and Earth, for landing sites in the western longitudes. The two proposed lunar landing locations are Alphonsus exploration site (13° 13'S, 1° 20'W) and Hyginus Crater (7° 45'N, 6° 18'E). Figure 2.6-11 illustrates the preceding mission sequences.

Visual monitoring of the unmanned Shelter during descent is performed by the astronauts in the CSM. Full Shelter status data will be transmitted (51.2 kbps) directly to Earth until successful landing and storage is verified. Continuous Earth-tracking coverage of both the CSM and Shelter vehicles is provided by the deep-space stations.

During this period there exists the possibility of three different S-Band frequencies being transmitted simultaneously. Two frequencies originating from the CSM, one carrying communications and another TV, while a third gives Shelter tracking and status data. Present deep-space station capabilities, when in view of one station, allow for concurrent real-time processing of two signals while the third signal, if necessary, may be recorded. If complete real-time processing of all three frequencies is required, then this phase must be carried out in view of two deep-space stations.

2.6.6.3.3 Shelter - Lunar Stay. During the Shelter storage mode, prior to Taxi launch, status data will be transmitted periodically to Earth in real-time, low- or high-bit rate upon uplink command. Forty-eight hrs preceding the Taxi launch, full Shelter status data will be telemetered and shall continue until Taxi arrival. Earth stations shall be able to provide 24-hour, real-time coverage.

2.6.6.3.4 Taxi - Lunar Insertion, Coast and Descent (Alternate Shelter Method). In lunar vicinity, the mission description coincides with the basic Apollo flight and is summarized as follows: Lunar orbital insertion will begin out of line-of-sight of Earth, followed by an 80-n.mi, low-inclination coast of one orbit. Separation of the Taxi-CSM occurs on the second orbit. The Hohmann descent transfer to 50,000 ft is initiated approximately 20 min later. One-quarter of an orbit later, the CSM-Taxi spacecraft emerges from the backside of the moon into line-of-sight of earth stations. Figure 2.6-11 shows lunar insertion along with the Hohmann descent transfer.

The Taxi-CSM separation and the initial phase of the Hohmann descent transfer both occur during lunar occultation resulting in loss of communication with Earth stations. The Taxi status, during this period, will be transmitted to the CSM (VHF, 1.6 kbps) and recorded. Upon acquisition of the earth stations, the CSM will transmit the recorded data to earth. Data transmission at 51.2 kbps when Earth-Taxi acquisition and lock-on is established. At this time, Taxi-CSM communications cease and a direct Earth-Taxi link is maintained. Deep-space station capabilities permit full tracking of both CSM and Taxi when in line-of-sight of the Earth antenna.

Utilization of all S-Band carriers implies that a total of four frequencies will be necessary during Taxi descent phase. Frequency allocation proceeds as follows: CSM, requiring two carriers for communications and TV; Shelter, telemetering full status data; Taxi communications. Considering singular deep-space station coverage, two S-Band frequencies may be processed in real-time. The remaining two signals can be recorded. For complete real-time processing support, the descent phase must occur during a period where two deep-space station coverage is available. If the two-station coverage method is not feasible, then station augmentation is required.

2.6.6.3.5 Taxi - Lunar Landing. The Taxi-powered landing from 50,000 ft to touch-down occurs while in line-of-sight of the CSM, Earth, and the Shelter. A Shelter-Taxi transponder link provides a guide for the Taxi landing.

Earth-spacecraft communication requirements are identical to those of the Lunar Insertion, Coast and Descent (Paragraph 2.6.6.3.4).

2.6.6.3.6 Taxi - Lunar Stay. In addition to the aforementioned S-Band frequencies required, the mobile payloads, i.e., the LSSM and MFS, operating independently of the Shelter-Taxi, will utilize one S-Band frequency each, thus increasing the total number of signals received by Earth to six. Although continuous coverage will be afforded, the possibility of six simultaneous S-Band frequencies must be considered.

Assuming deep-space station support is not augmented, then it would be necessary to implement such procedures as: time-sharing of signals; scheduling communications when two-station coverage is available. The following suggests a possible Earth-Moon communications method. During the lunar stay, the Shelter will accommodate both astronauts while the Taxi, in the storage mode, provides status transmission upon earth command via an onboard timer sequencer. Periodic monitoring of the Taxi can be performed while the CSM, in lunar orbit, is eclipsed by the moon. Upon LSSM or MFS deployment, astronaut A, located in the Shelter, will monitor astronaut B, conducting exploration. This precludes the possibility of simultaneous operation of both LSSM and MFS. Some communications possibilities for ground support are given in Table 2.6-4.

This table is divided into two major columns indicating whether the CSM is shielded by the Moon or is in line-of-sight of the Earth. Only one operational mode is shown in the first major column, whereby real-time support is extended to the manned vehicles (Shelter and MFS/LSSM). The CSM transmission frequencies (f_2, f_3) are not represented in the first major column (CSM Eclipsed by Moon) since no Earth-CSM communication link exists.

The second major column of Table 2.6-4 (CSM in LOS of Earth) is further subdivided into two modes of communications. In both modes the LSSM or MFS is assumed to be operational; however, only in Mode 1 is there real-time support. Real-time communication with Earth is maintained between manned Shelter and Earth for both modes. Note that the Taxi transmission frequency (f_1) is not shown in either mode.

In the preceding discussion it was assumed that ideal communications existed between ground stations and vehicles located on the lunar surface. The crater-marked lunar surface suggests that such a terrain would reduce coverage afforded by ground stations. That this is the case for the LSSM/MFS and not for the Shelter/Taxi will be described below.

Study of the two lunar landing sites (Alphonsus and Hyginus Crater) indicates that there are no immediate obstructions to limit communications for the Shelter/Taxi. The lunar terrain does introduce an approximate 6-deg mask angle above the horizon in certain directions; however, this will not reduce Earth-tracking coverage. A problem arises in the case of MFS or LSSM communication. In this case the mobile vehicles may at times be in such a position where higher terrain may directly block Earth from view, resulting in a loss of communication. (See Vol. V, Sec 5.5.3)

TABLE 2.6-1

Unified S-Band Station Capabilities

Station	Near Space Site	Deep Space Site	Dual or Single	Proposed Operational Date
Carnarvon	X		D	Dec '66
Bermuda	X		S	Jan '67
Hawaii	X		D	Feb '67
Cape Kennedy	X		D	Mar '67
Texas (Corpus Christi)	X		S	May '67
Guaymas	X		S	Apr '67
Guam	X		D	Jan '67
Ascension	X		D	Jun '67
Antigua	X		S	Oct '67
Grand Canary Is.	X		S	Sep '67
Grand Bahama Is.	X		S	Jul '67
Goldstone		X	D	Apr '67
Canberra		X	D	Jul '67
Madrid		X	D	Oct '67

Ref: SID 64-1866

A. 83-deg Inclination

Rev	Site Coverage Time, min*
1	TEX/7.49, GYM/5.79
2	GYM/5.48
3	FBKS/6.96, HAW/4.65
4	FBKS/7.59, HAW/5.88
5	FBKS/5.42, ASC/5.56 CYI/7.31
6	ASC/4.09, GAM/7.42
7	ANT/6.79, BDA/7.08
8	CRO/7.51, GBI/7.53, CKEN/7.57, BDA/2.79
9	TEX/7.13, GYM/6.80, FBKS/5.28
10	GYM/3.16, FBKS/7.56
11	HAW/5.24, FBKS/7.04
12	HAW/5.45
13	ASC/1.63, CYI/7.56
14	ASC/6.34, GAM/7.52
15	CRO/2.50, BDA/7.38, ANT/7.47, GBI/1.00
16	CRO/6.78, CKEN/7.38, GBI/7.01, TEX/5.00
17	GYM/7.43, TEX/6.11
18	FBKS/3.89
19	FBKS/7.54, HAW/7.18
20	FBKS/7.15
21	CYI/7.42, FBKS/3.95, GAM/4.32
22	ASC/7.42, GAM/5.62
23	CRO/4.54, ANT/7.52, BDA/7.56, GBI/4.52, CKEN/3.5
24	CRO/6.20, GBI/6.33, CKEN/6.81, TEX/6.33, FBKS/1.
25	GYM/7.56, TEX/4.58, FBKS/6.37
26	FBKS/7.73
27	HAW/7.30, FBKS/6.00
28	CYI/3.38
29	GAM/1.72, CYI/6.74
30	GAM/6.48, ANT/4.09, ASC/6.67
31	CRO/6.69, BDA/7.42, CKEN/5.62, GBI/6.47
32	CRO/6.69, BDA/7.42, TEX/7.24, GBI/4.22
33	GYM/7.29
35	FBKS/7.73, HAW/7.41
36	CYI/5.53, FBKS/6.41

*Station sequence in chronological order

ABLE 2.6-2 Site Coverage Times

	Total Cov'ge/rev, min		B. 90-deg Inclination	Total Cov'ge/rev, min	
	USB Sites	USB & FBKS	Site Coverage Time, min*	USB Sites	USB & FBKS
	7.49	7.49	TEX/6.94, GYM/6.97	7.05	7.05
	5.48	5.48	FBKS/5.97, GYM/1.78	1.78	7.75
	4.65	11.61	FBKS/7.73, HAW/6.21	6.21	13.94
	5.88	12.47	FBKS/6.01, HAW/3.71	3.71	9.72
	12.87	18.29	ASC/6.24, CYI/6.84	13.08	13.08
	11.51	11.51	ASC/1.29, CYI/2.54, GAM/7.07	10.90	10.90
	10.80	10.80	ANT/6.46, BDA/6.3	10.30	10.30
	15.66	15.66	CRO/7.55, GBI/7.55, ANT/1.77, CKEN/7.45, BDA/5.07	15.35	15.35
	7.63	12.91	TEX/7.43, GYM/6.06	7.43	7.43
	3.16	10.72	GYM/4.87, FBKS/6.20	4.87	11.07
	5.24	12.31	HAW/4.17, FBKS/7.72	4.17	11.89
	5.45	5.45	HAW/6.00, FBKS/5.76	6.00	11.76
	9.19	9.19	ASC/1.90, CYI/7.21	9.11	9.11
	13.86	13.86	ASC/6.15, GAM/7.52	13.67	13.67
	13.50	13.50	CRO/5.69 BDA/7.54, GBI/5.47, CKEN/4.40, ANT/7.00	16.70	16.70
	14.33	14.33	CRO/5.04, CKEN/6.35, TEX/6.78, GBI/5.47	12.00	12.00
	7.43	7.43	GYM/7.50, TEX/2.91	7.50	7.50
		3.89	FBKS/7.10		7.10
	7.18	14.72	FBKS/7.49, HAW/7.53	7.53	15.02
		7.15	FBKS/4.02		4.02
	11.76	15.71	ASC/7.51, CYI/7.53, GAM/6.08	21.12	21.12
	13.02	13.02	GAM/2.93	2.93	2.93
	15.98	15.98	CRO/3.36, ANT/7.52, BDA/7.57, GBI/3.12	8.86	8.86
9	13.62	14.71	CRO/6.52, GBI/6.68, CKEN/7.12, TEX/5.72	13.92	13.92
	7.56	13.93	GYM/7.54, TEX/5.31, FBKS/2.28	7.54	9.82
		7.73	FBKS/7.21		7.21
	7.30	13.30	HAW/7.22, FBKS/7.42	7.22	14.64
	3.38	3.38	FBKS/3.46, CYI/6.38	6.38	9.84
	8.46	8.46	ASC/6.97, GAM/2.47, CYI/4.26	13.50	13.50
	14.85	14.85	GAM/6.20, BDA/5.44 ANT/6.31	17.95	17.95
	16.93	16.93	CRO/7.50, BDA/6.05, CKEN/7.24, GBI/7.46, ANT/2.64	16.00	16.00
	9.70	9.70	TEX/7.54, GYM/5.31	7.54	7.54
	7.29	7.29	FBKS/4.87, GYM/5.74	5.74	10.61
		5.92	FBKS/7.64, HAW/3.16	3.16	9.80
	7.41	15.14	FBKS/6.75, HAW/6.37	6.37	13.12
	5.53	11.94	ASC/2.92, CYI/5.02	8.00	8.00

TABLE 2.6-3

Summary of Ground Coverage

Period → / Mission ↓	13-2/3 days			Continuous Coverage			Lunar Occultation		
	Coverage Time, days		Total Effective Coverage days	Avg Coverage, hr/day		Total Avg Coverage, hr/day	Avg Coverage hr/day		Total Avg Coverage, hr/day
	One Sta	Two Sta		One Sta	Two Sta		One Sta	Two Sta	
Low-Inclin. Lunar Orbit	5.76	2.94	8.70	None			10.1	5.16	15.26
Lunar Polar Orbit	6.86	3.47	10.33	13.0	11.0	24.0	11.0	4.2	15.2
Shelter or Taxi Lunar Stay	9.23	4.44	13.67	16.25	7.75	24.0	None		

TABLE 2.6-4

Possible Ground Support Communication Modes for Shelter/Taxi Lunar Stay

Vehicle	CSM Eclipsed by Moon		CSM in LOS of Earth			
			Mode 1		Mode 2	
	Ground Station Real-Time Support	Ground Station Record	Ground Station Real-Time Support	Ground Station Record	Ground Station Real-Time Support	Ground Station Record
Taxi (f_1) or CSM* (f_2,f_3)		f_1	f_2	f_3		f_2, f_3
Shelter (f_4)	f_4		f_4		f_4	
LSSM (f_5) or MFS (f_6)	f_5 or f_6			f_5 or f_6	f_5 or f_6	

* CSM is capable of transmitting two S-Band frequencies:

- f_2, tracking and communications
- f_3, TV and communications

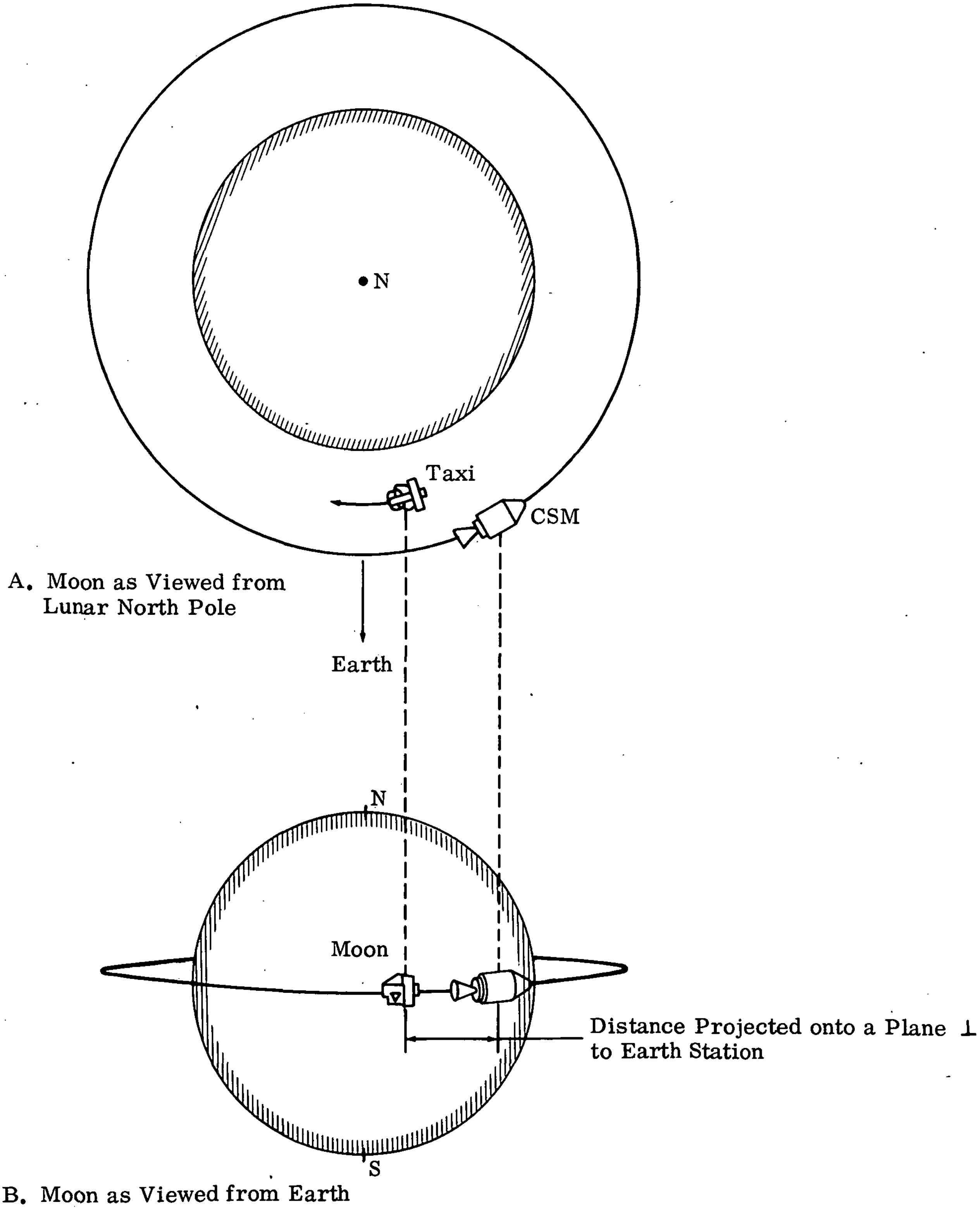
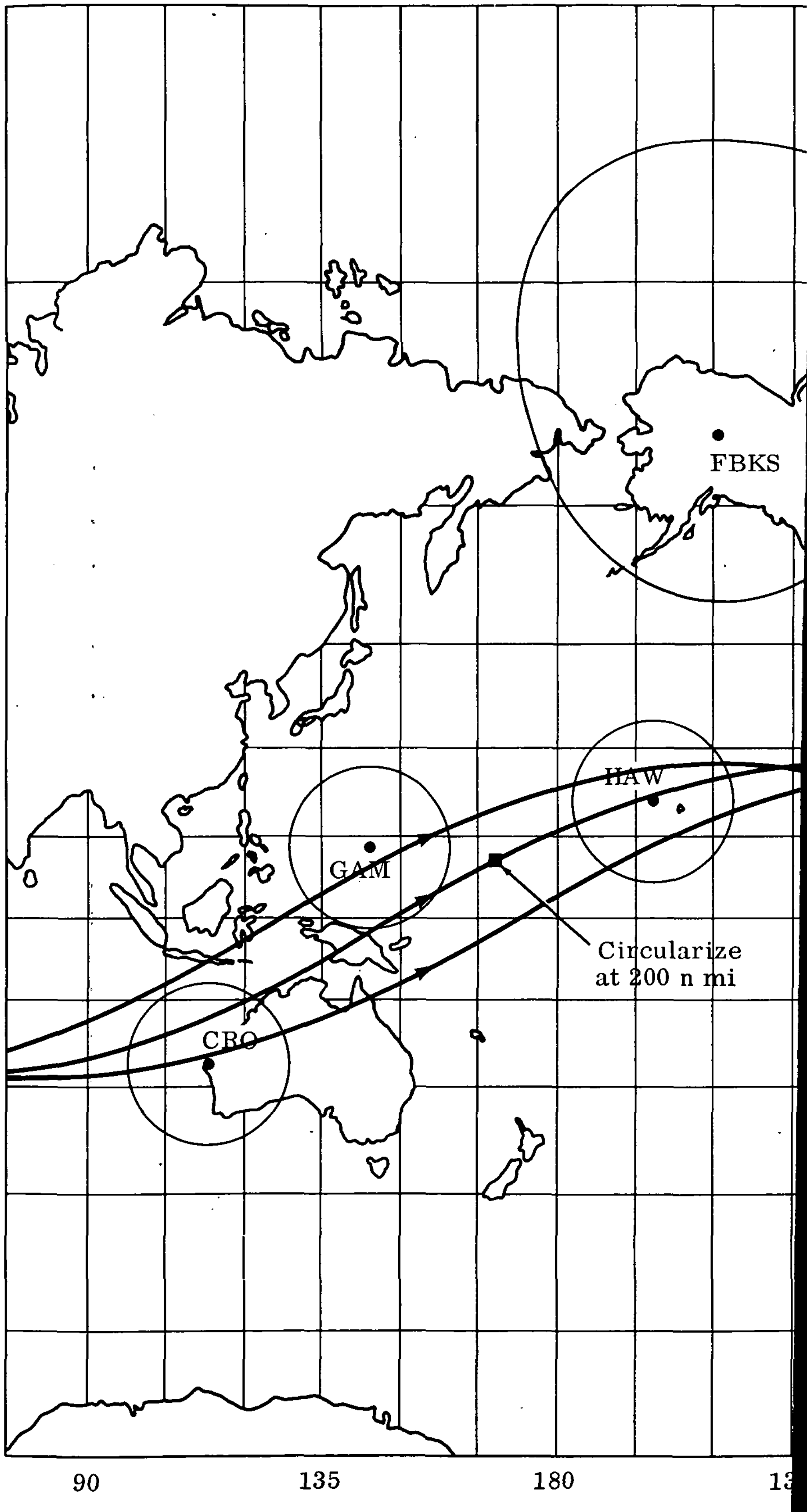


Fig. 2.6-1 Lunar Projected Planar Distance

(2-61)

ANT Antiqua
ASC Ascension
BDA Bermuda
CKEN Cape Kennedy
CRO Carnarvon
CYI Grand Canary Island
FBKS Fairbanks (Alaska)
GAM Guam
GBI Grand Bahama Island
GYM Guaymas
HAW Hawaii
TEX Texas (Corpus Christi)

Note: Station Coverage Shown for 200 n mi



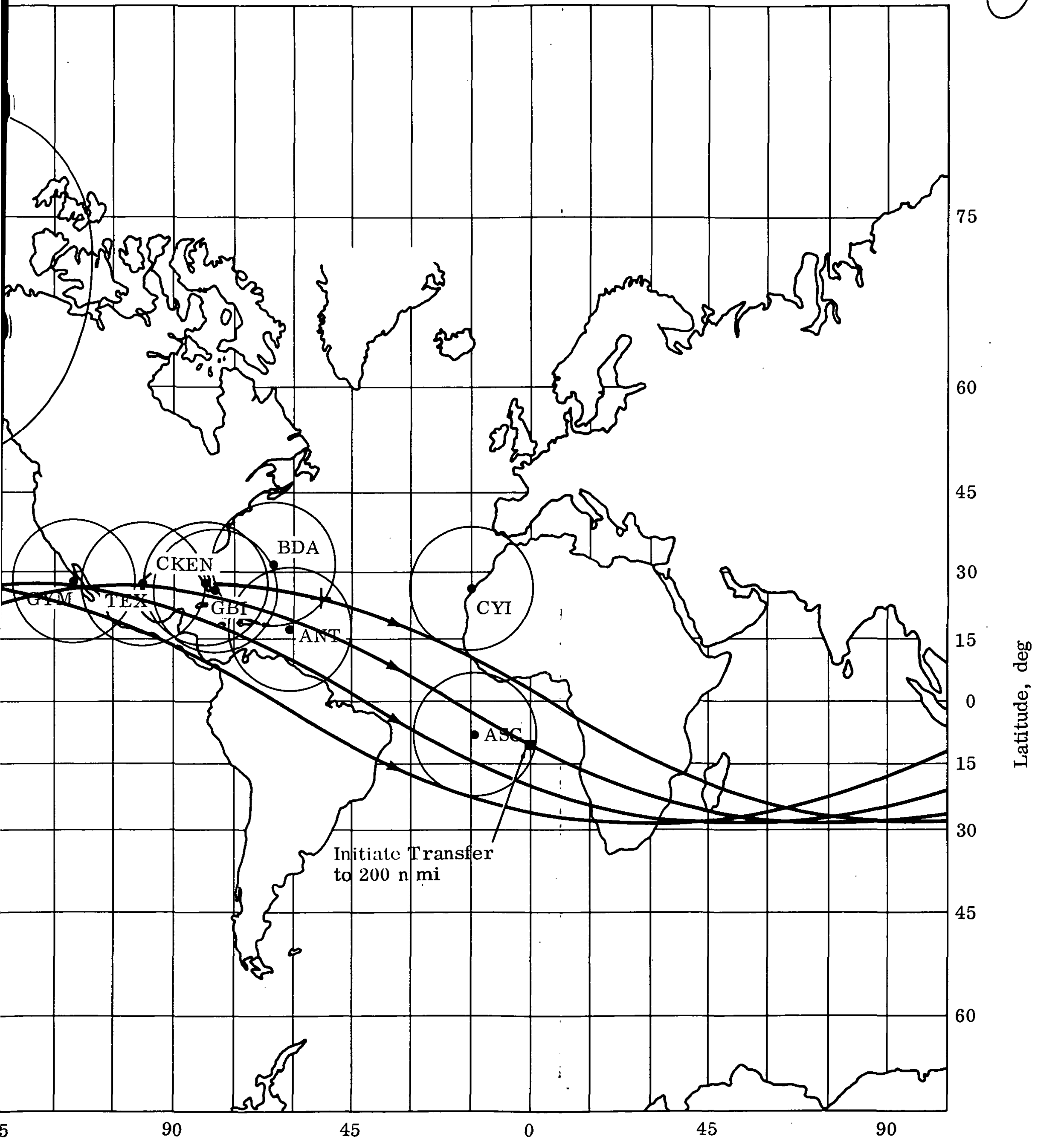


Fig. 2.6-2 Ground Track - 28.5 Deg Inclination Orbit

Fig 2.6-3 A

(1)

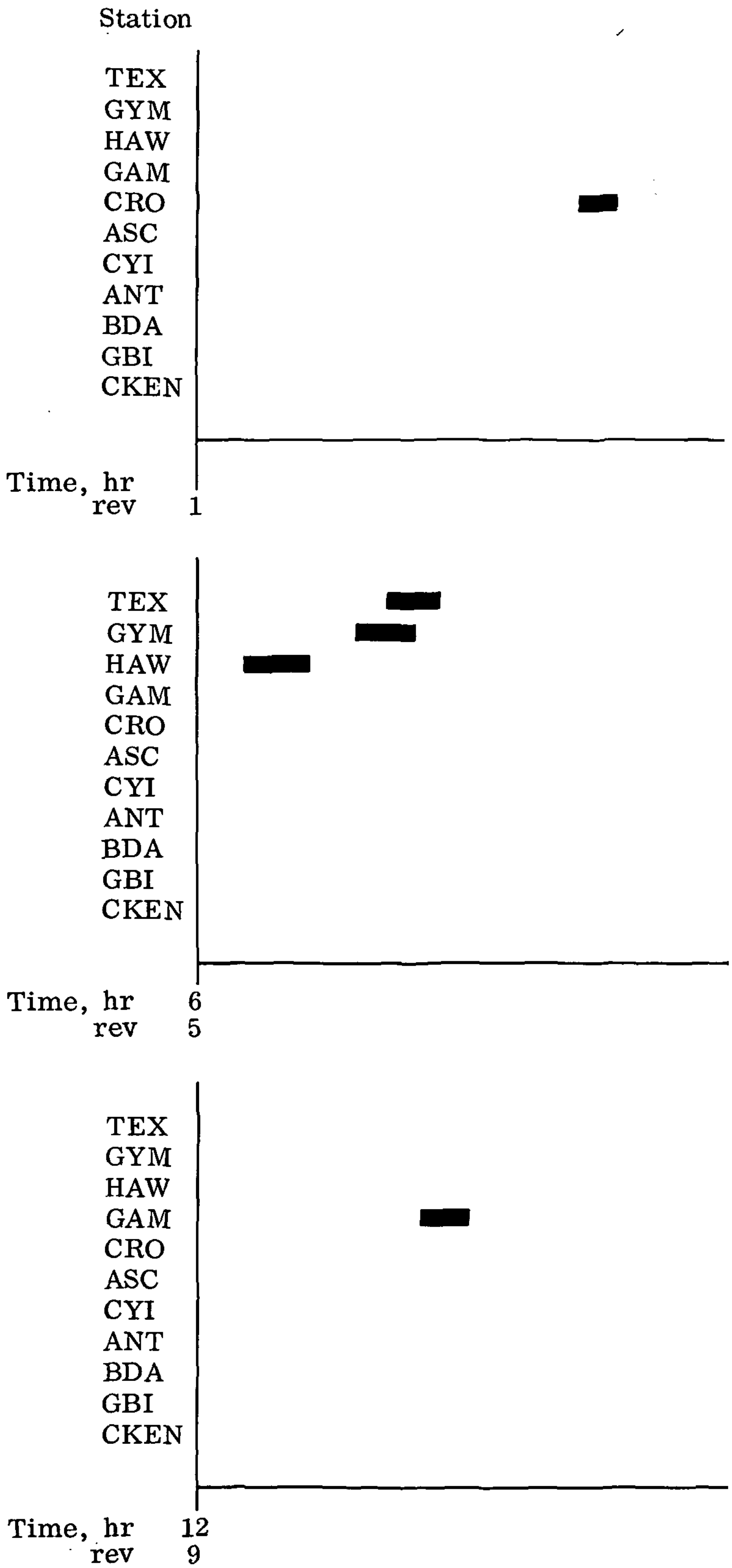
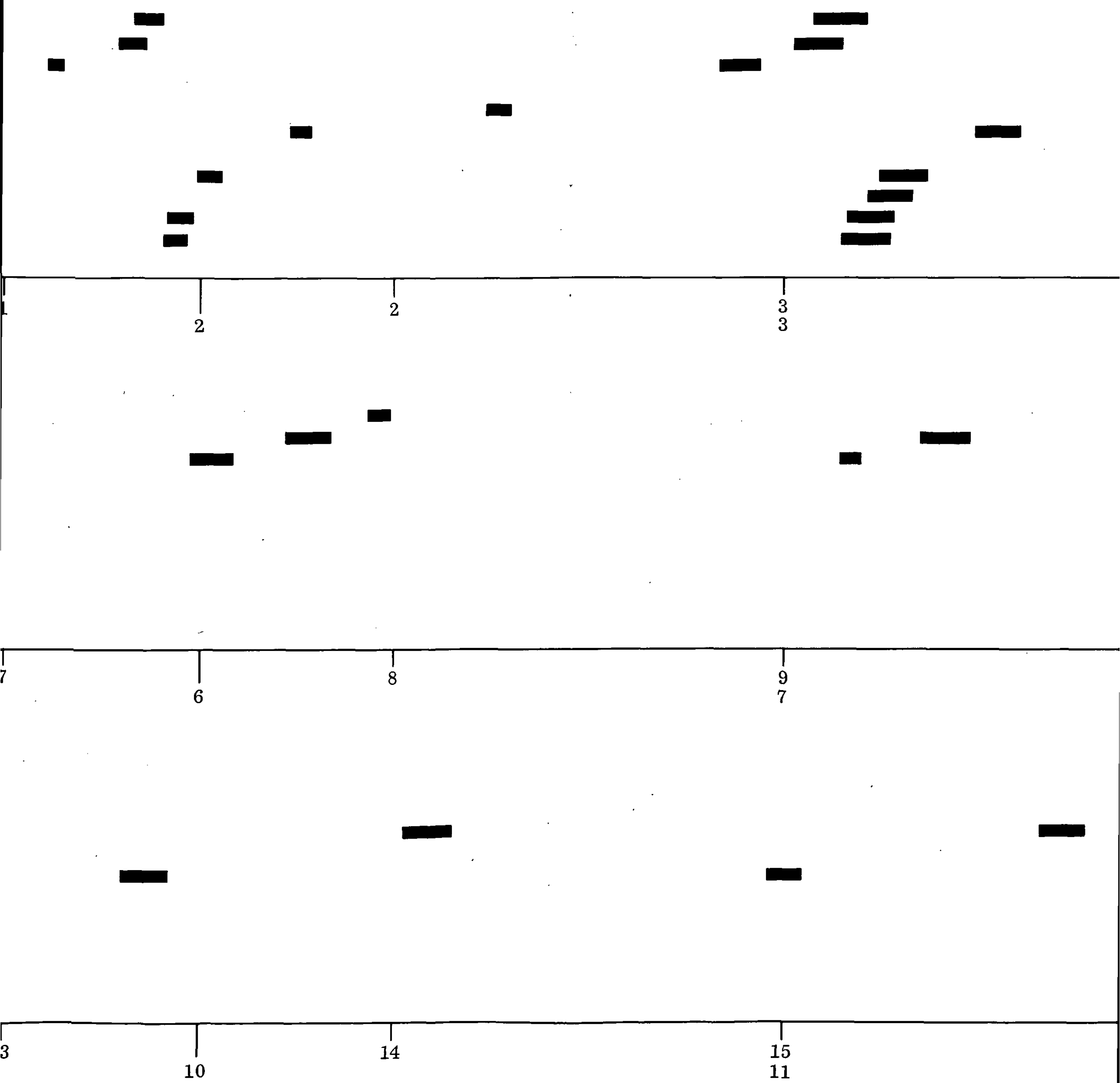
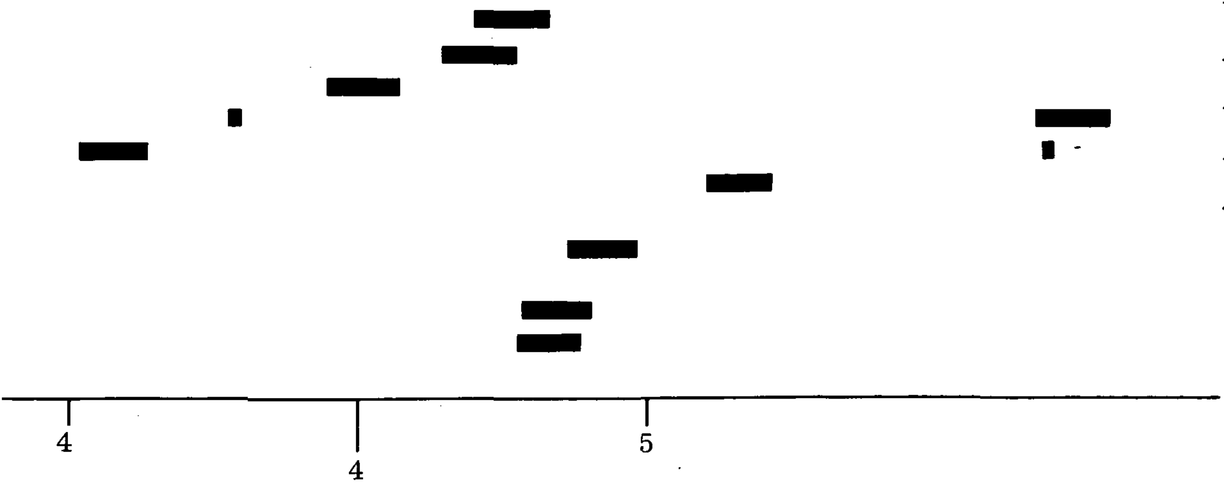
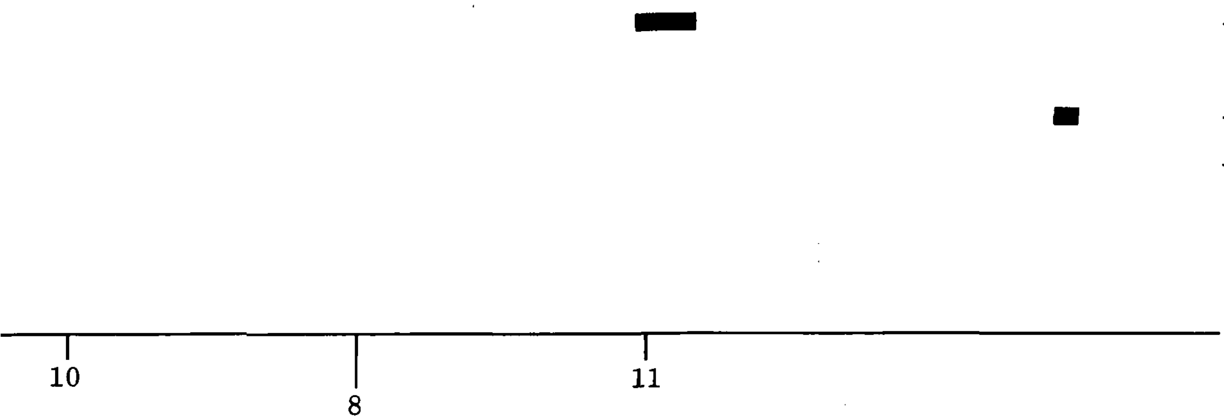
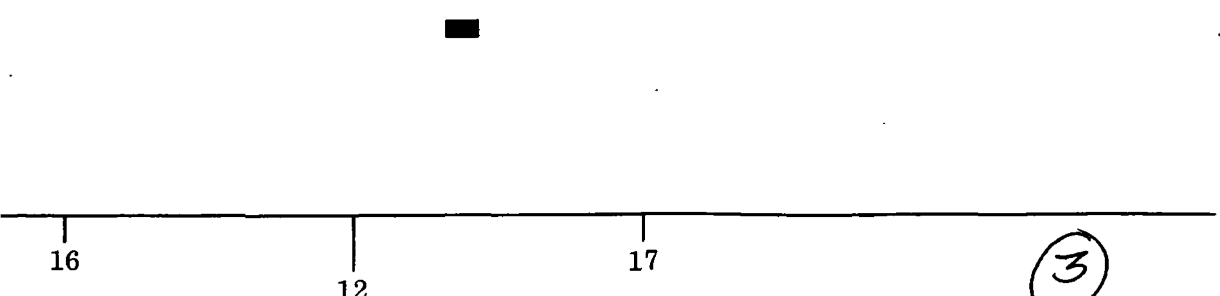

Station
TEX
GYM
HAW
GAM
CRO
ASC
CYI
ANT
BDA
GBI
CKEN
Time, hr
rev 1
TEX
GYM
HAW
GAM
CRO
ASC
CYI
ANT
BDA
GBI
CKEN
Time, hr 6
rev 5
TEX
GYM
HAW
GAM
CRO
ASC
CYI
ANT
BDA
GBI
CKEN
Time, hr 12
rev 9

Fig 2.6-3 (2) A



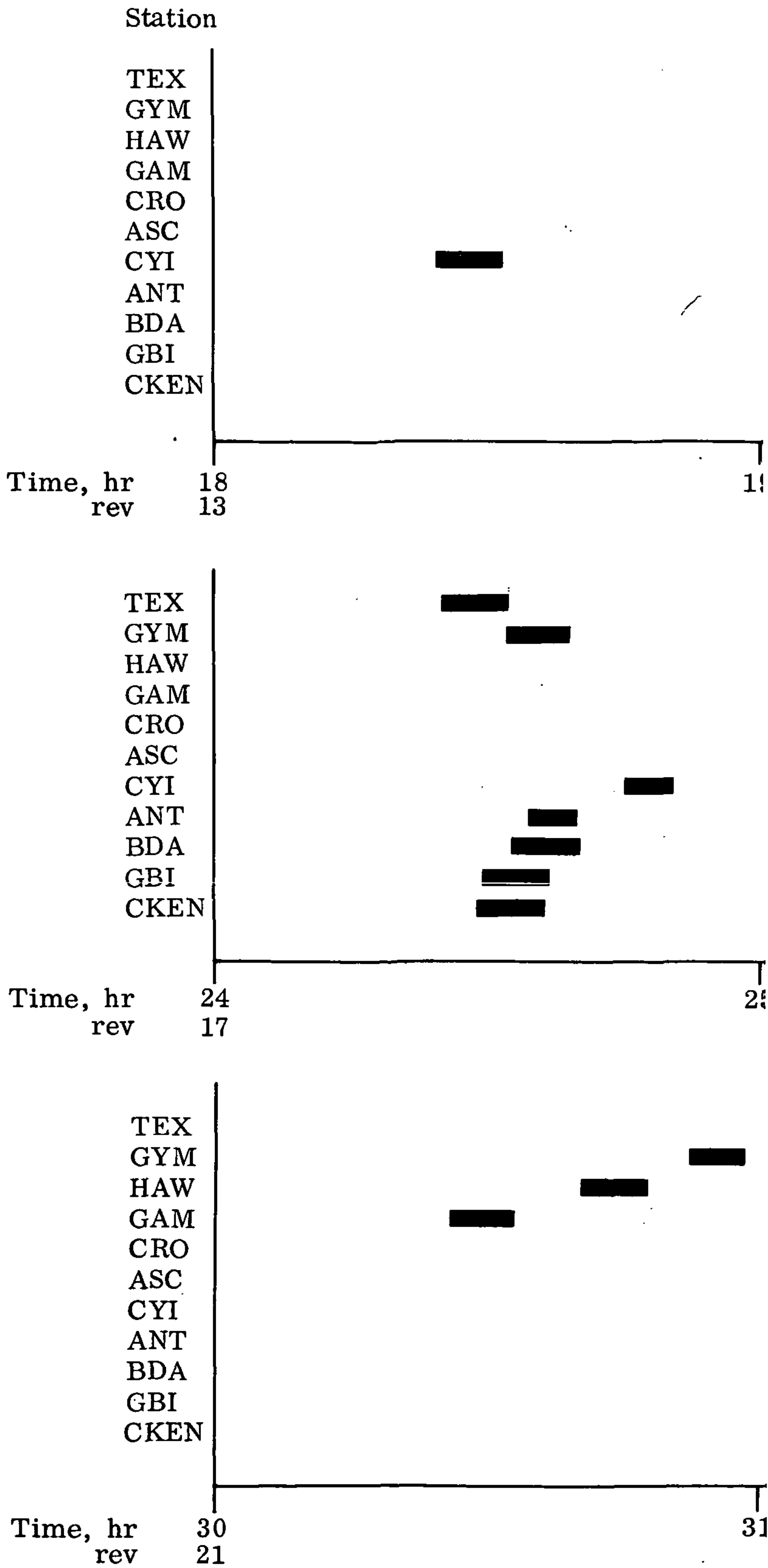




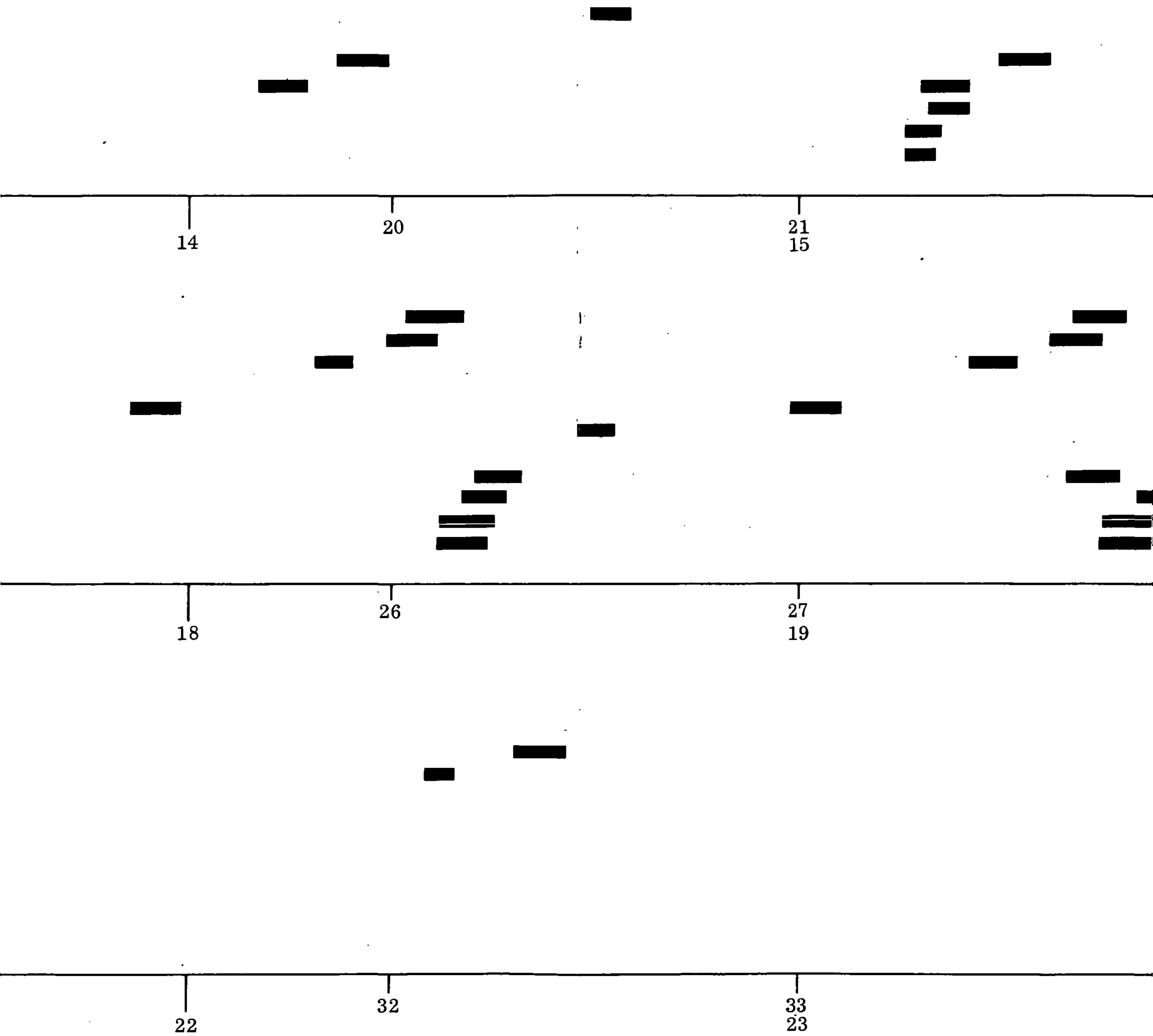


Rev	Total Coverage/Rev
1	17.43
2	16.38
3	39.23
4	38.62
5	17.90
6	13.52
7	10.79
8	8.33
9	11.75
10	11.79
11	6.7
12	2.92

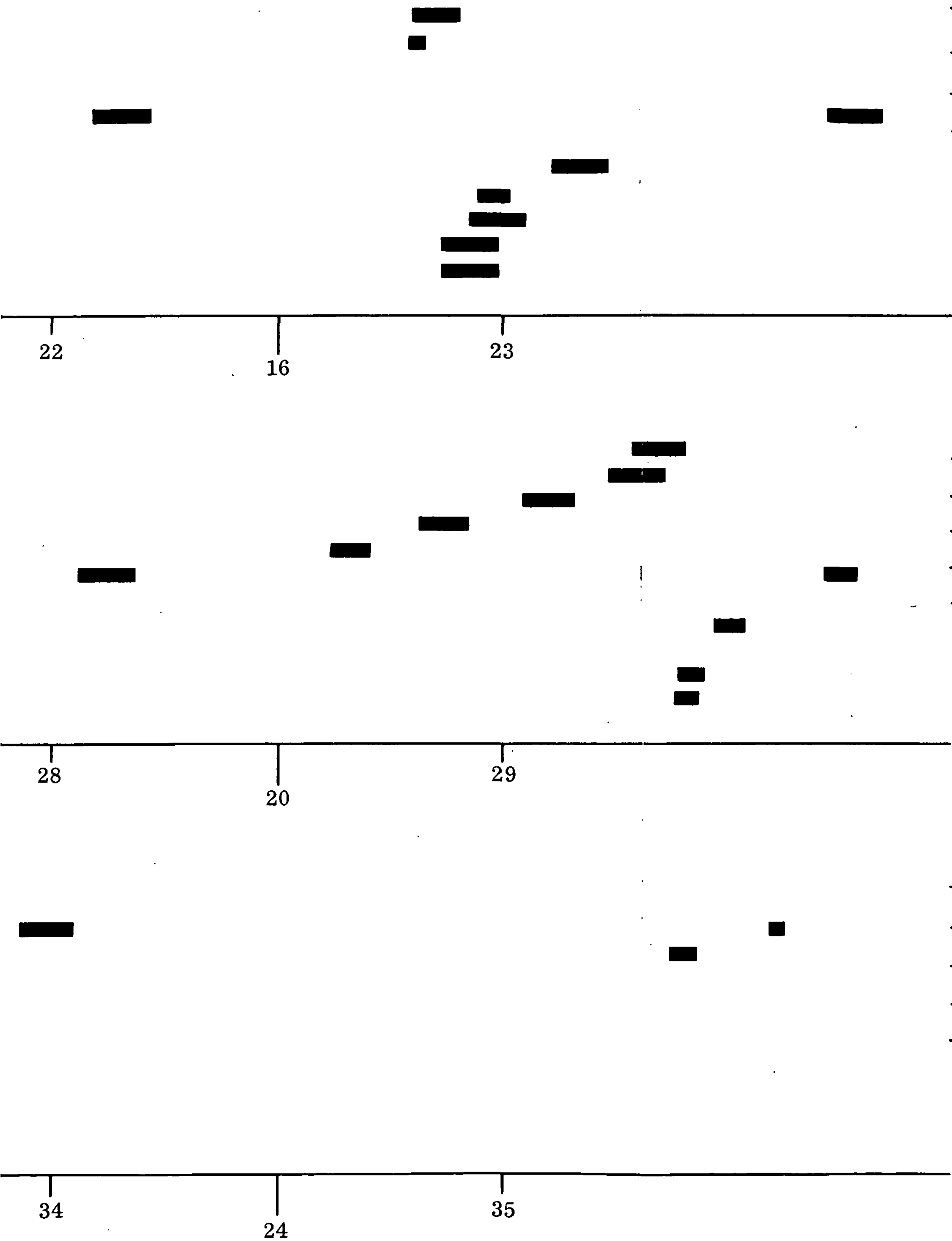
Fig. 2.6-3 (3) ~~(Sheet 1 of 3)~~ Ground Station A Visibility, 28.5 deg Inclination Orbit; Alt: 200 n mi


Station
TEX
GYM
HAW
GAM
CRO
ASC
CYI
ANT
BDA
GBI
CKEN
Time, hr
rev
18
13
TEX
GYM
HAW
GAM
CRO
ASC
CYI
ANT
BDA
GBI
CKEN
Time, hr
rev
24
17
TEX
GYM
HAW
GAM
CRO
ASC
CYI
ANT
BDA
GBI
CKEN
Time, hr
rev
30
21
31

2.6-3B (1)



2-6-3B (2)



Rev	Total Coverage/Rev
13	7.10
14	21.23
15	24.44
16	29.85
17	27.89
18	33.31
19	36.22
20	36.76
21	19.45
22	11.96
23	7.19
24	4.22

Fig. 2.6-3 (Sheet 2 of 3)

3 B

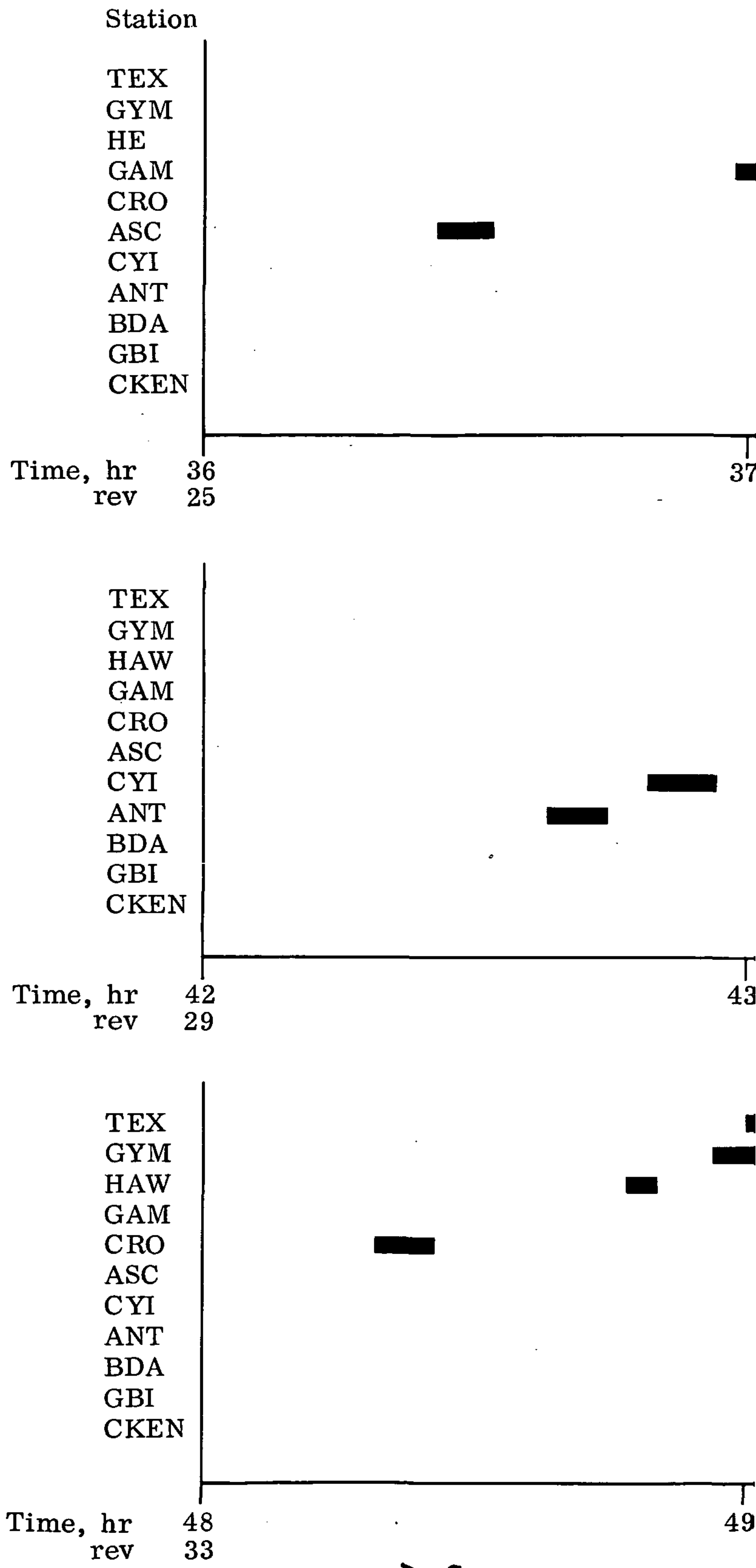
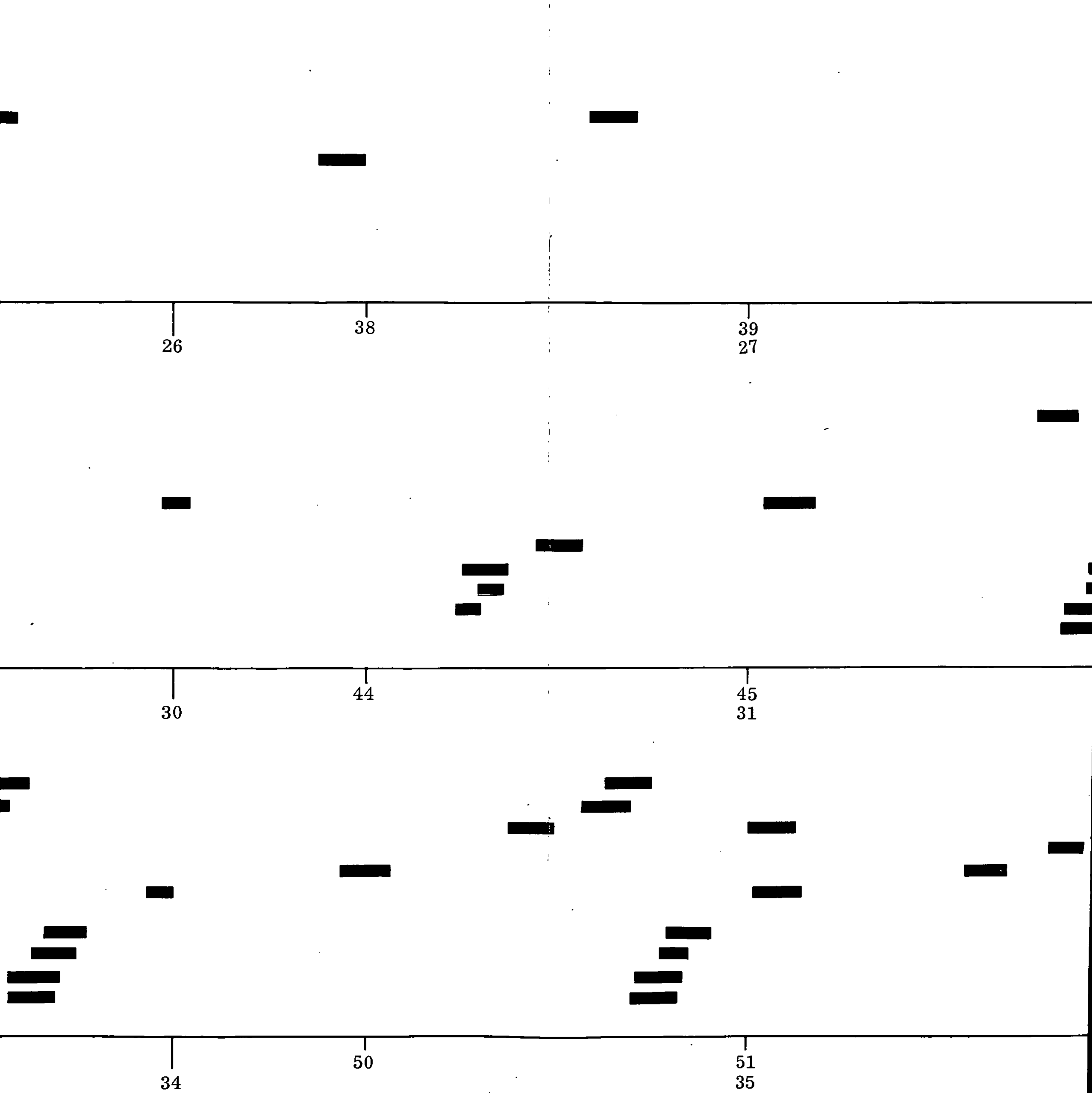
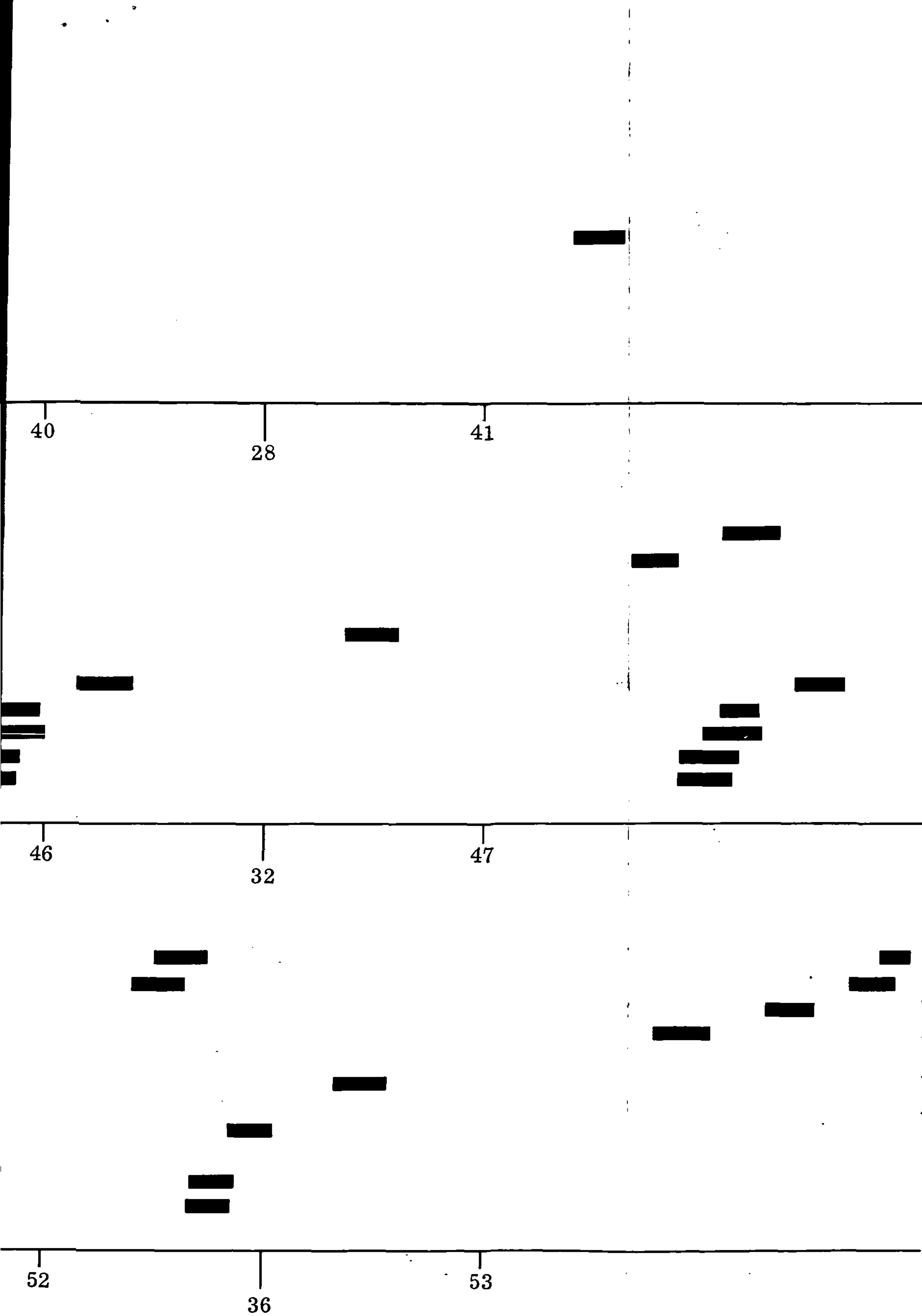

Station
TEX
GYM
HE
GAM
CRO
ASC
CYI
ANT
BDA
GBI
CKEN
Time, hr 36
rev 25
37
TEX
GYM
HAW
GAM
CRO
ASC
CYI
ANT
BDA
GBI
CKEN
Time, hr 42
rev 29
43
TEX
GYM
HAW
GAM
CRO
ASC
CYI
ANT
BDA
GBI
CKEN
Time, hr 48
rev 33
49

Fig 2.6-3 C

(1)



2.6-3 c
②



Rev	Total Coverage/Rev
25	13.00
26	14.72
27	
28	6.54
29	16.89
30	24.29
31	25.66
32	26.41
33	33.35
34	34.87
35	38.25
36	29.40

Fig. 2.6-3 (Sheet 3 of 3)

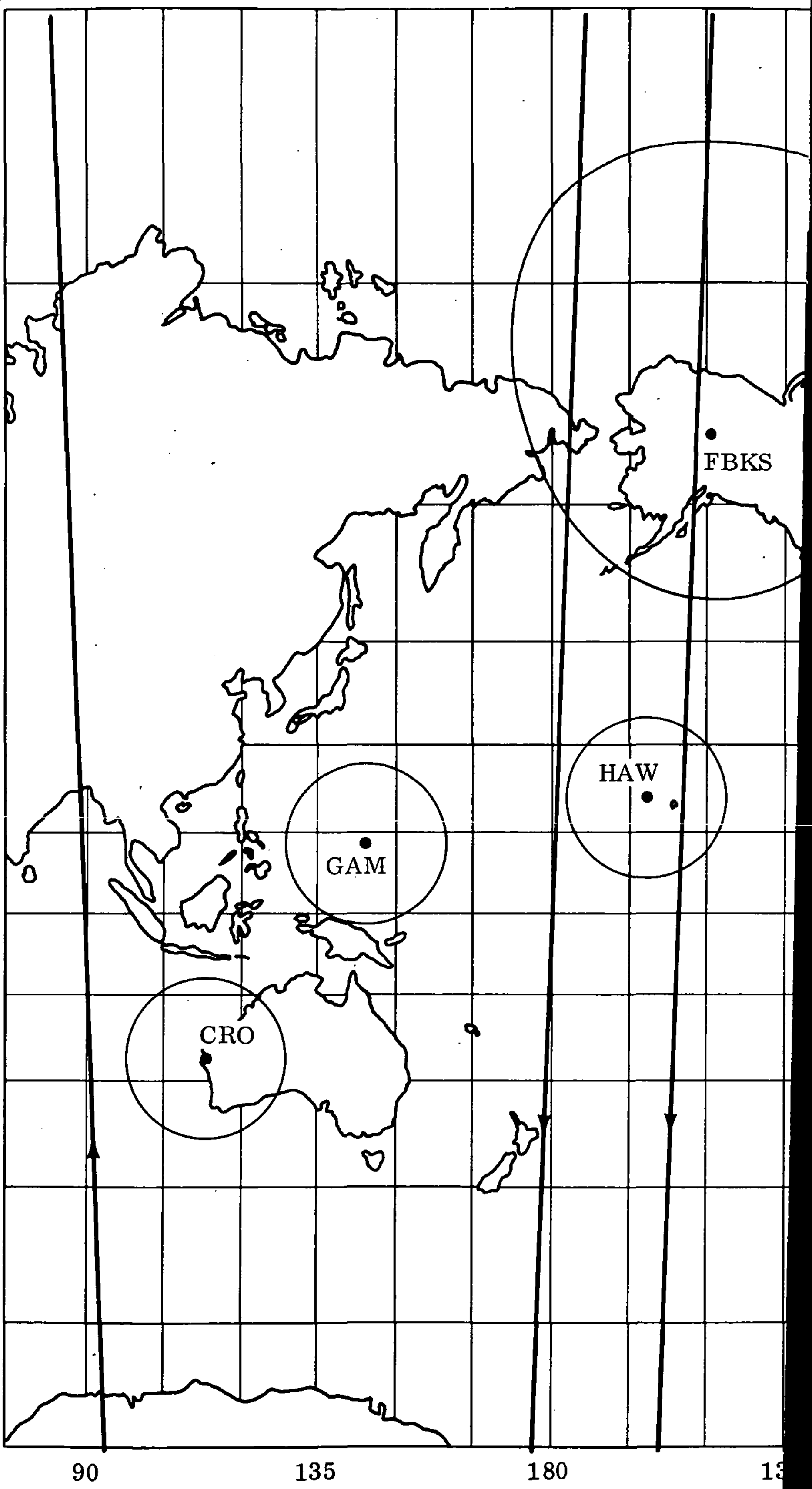
C (3)

Grumman

2-69

ANT	Antiqua
ASC	Ascension
BDA	Bermuda
CKEN	Cape Kennedy
CRO	Carnarvon
CYI	Grand Canary Island
FBKS	Fairbanks (Alaska)
GAM	Guam
GBI	Grand Bahama Island
GYM	Guaymas
HAW	Hawaii
TEX	Texas (Corpus Christi)

Note: Station Coverage Shown for 200 n mi



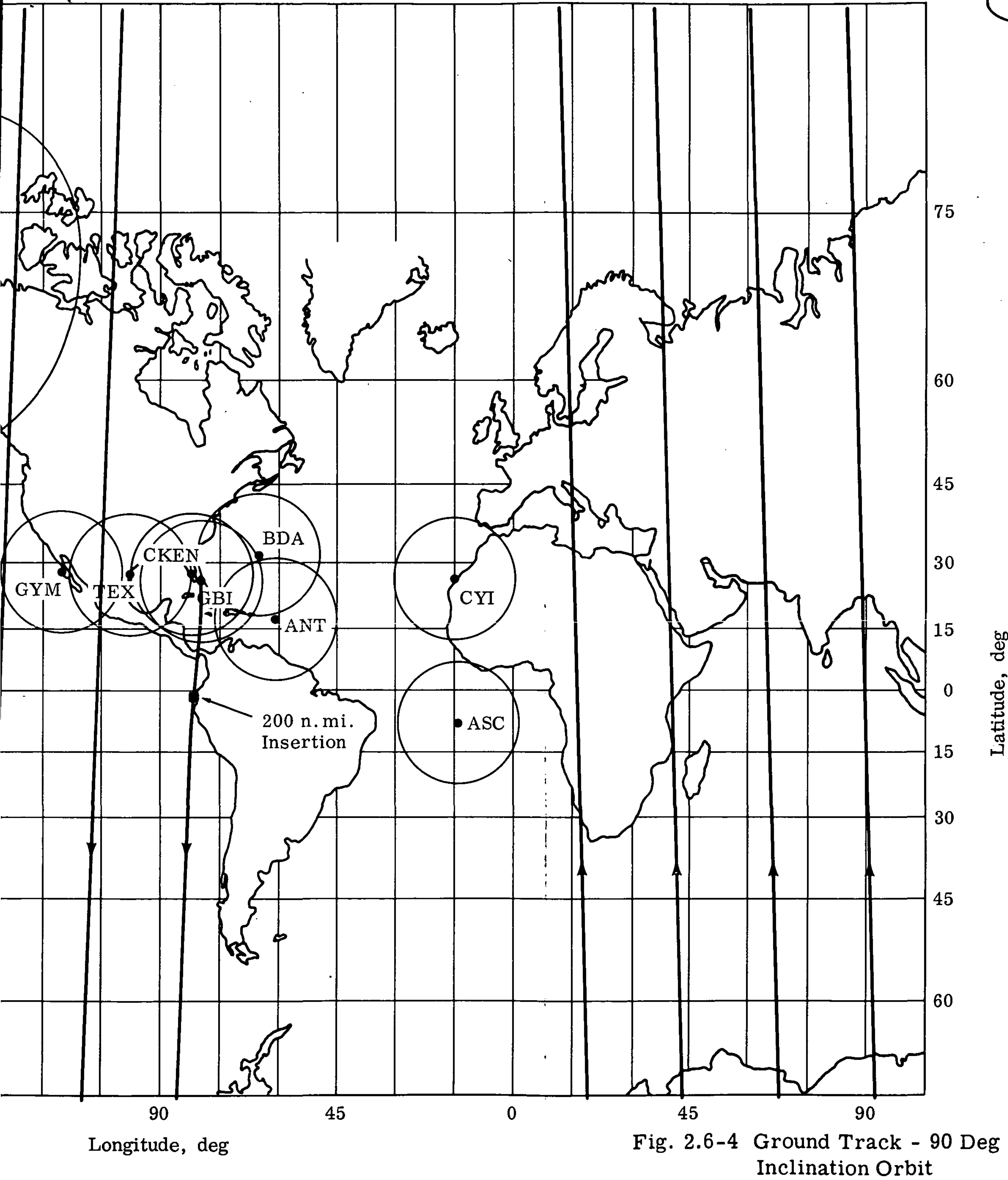
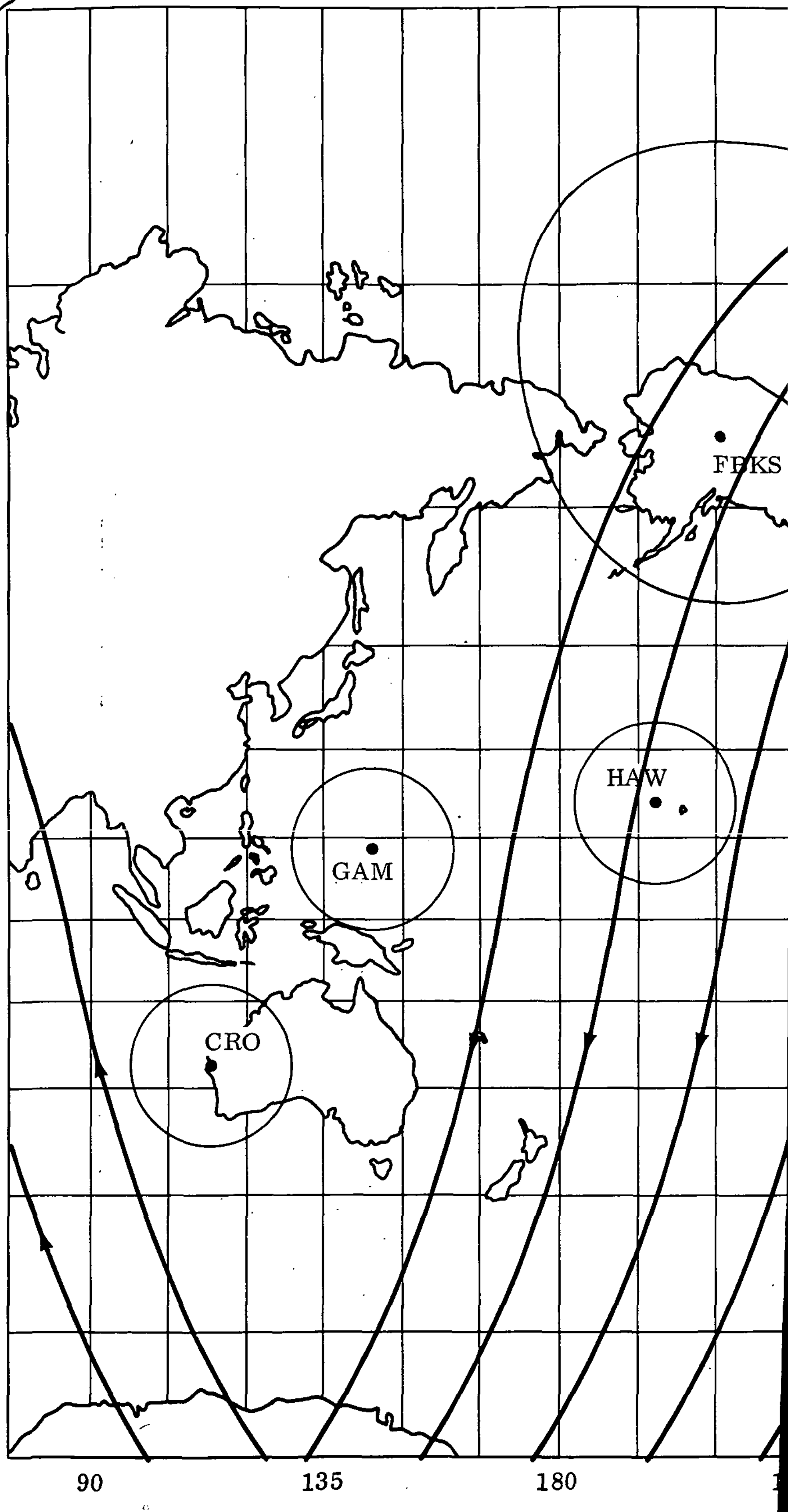


Fig. 2.6-4 Ground Track - 90 Deg Inclination Orbit

2-71

ANT	Antiqua
ASC	Ascension
BDA	Bermuda
CKEN	Cape Kennedy
CRO	Carnarvon
CYI	Grand Canary Island
FBKS	Fairbanks (Alaska)
GAM	Guam
GBI	Grand Bahama Island
GYM	Guaymas
HAW	Hawaii
TEX	Texas (Corpus Christi)

Note: Station Coverage Shown for 200 n mi



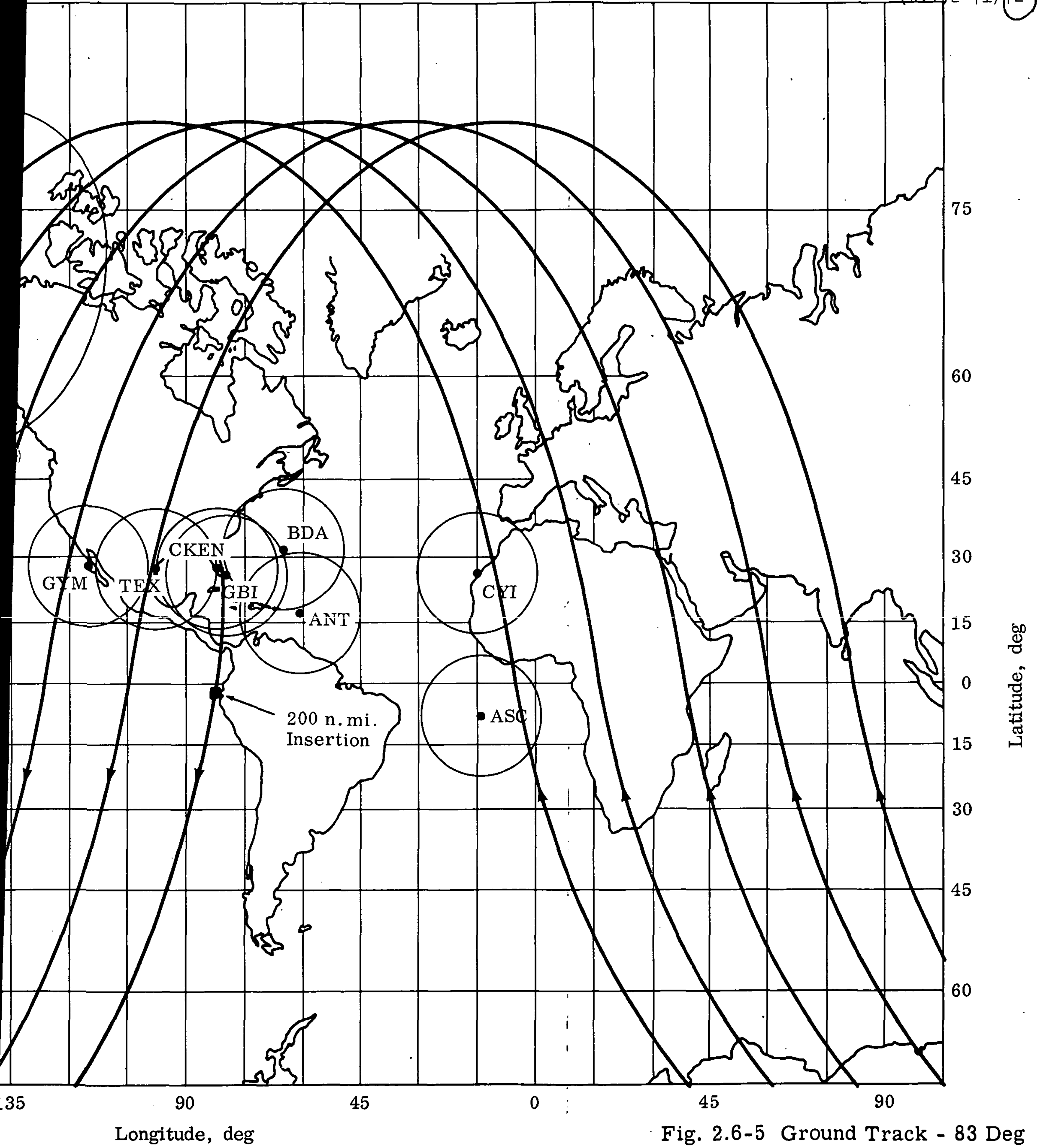


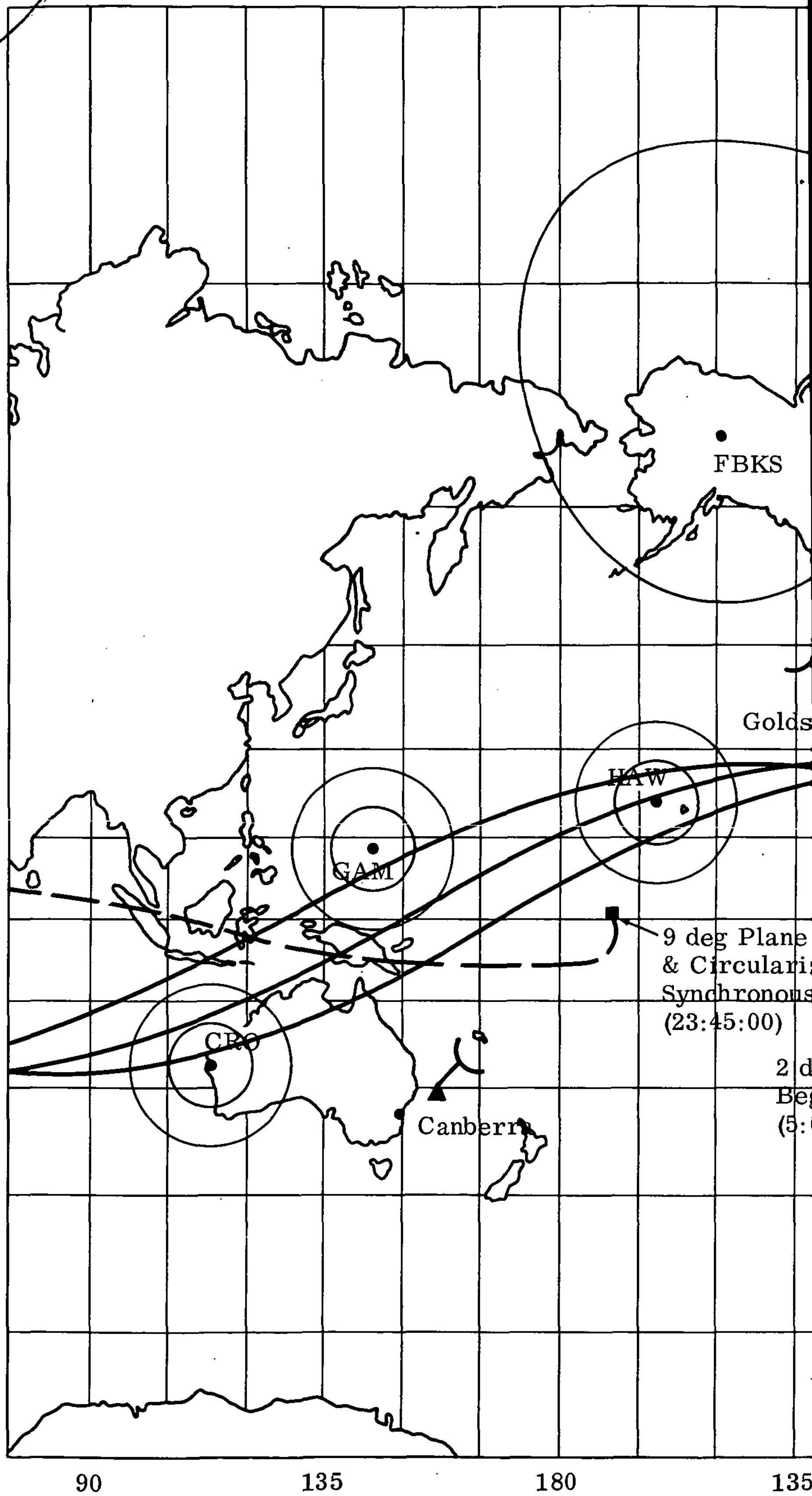
Fig. 2.6-5 Ground Track - 83 Deg Inclination Orbit

2-73

ANT	Antiqua
ASC	Ascension
BDA	Bermuda
CKEN	Cape Kennedy
CRO	Carnarvon
CYI	Grand Canary Island
FBKS	Fairbanks (Alaska)
GAM	Guam
GBI	Grand Bahama Island
GYM	Guaymas
HAW	Hawaii
TEX	Texas (Corpus Christi)

Deep Space Tracking Stations

Note: Station Coverage Shown for 200 n mi



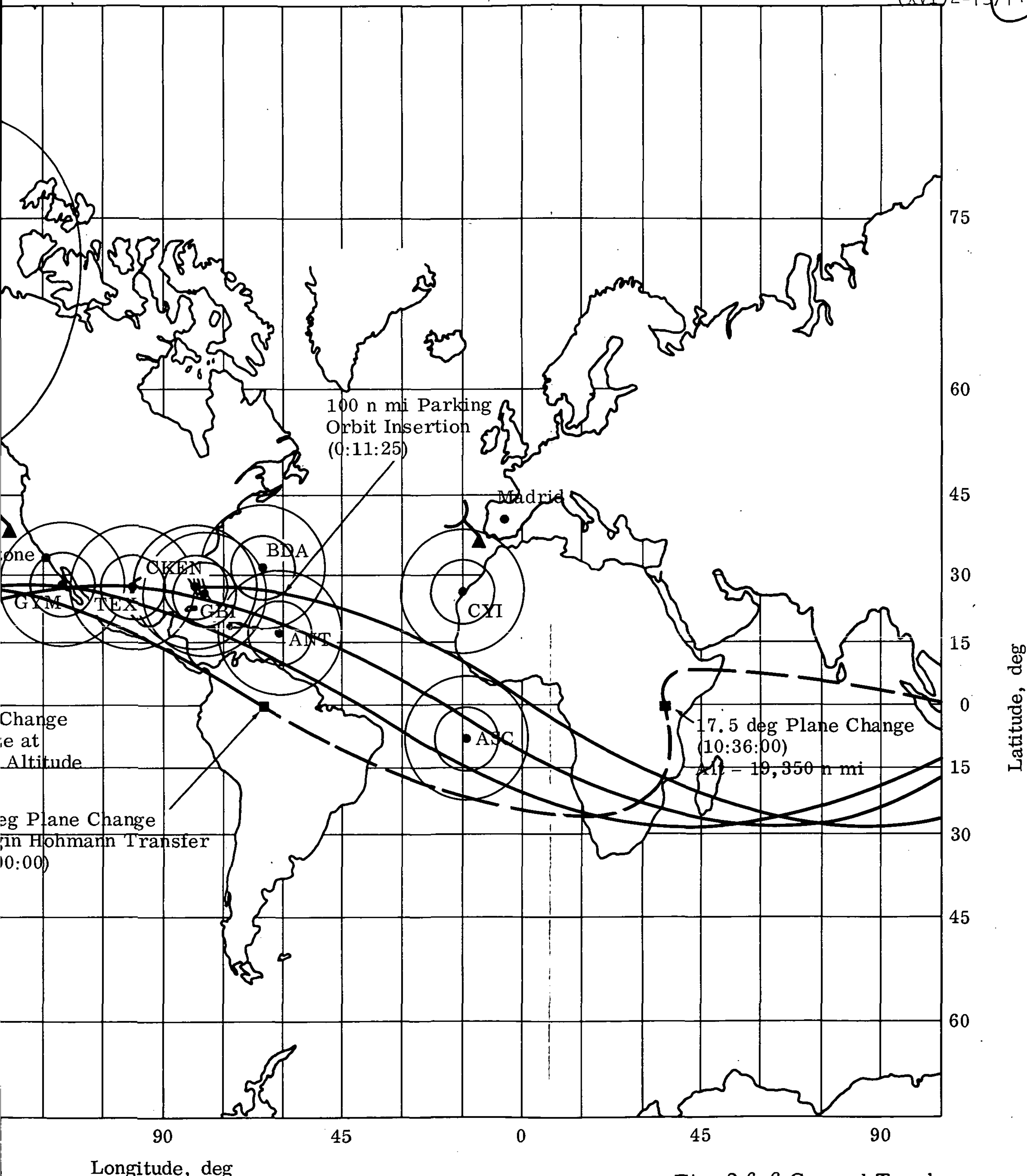
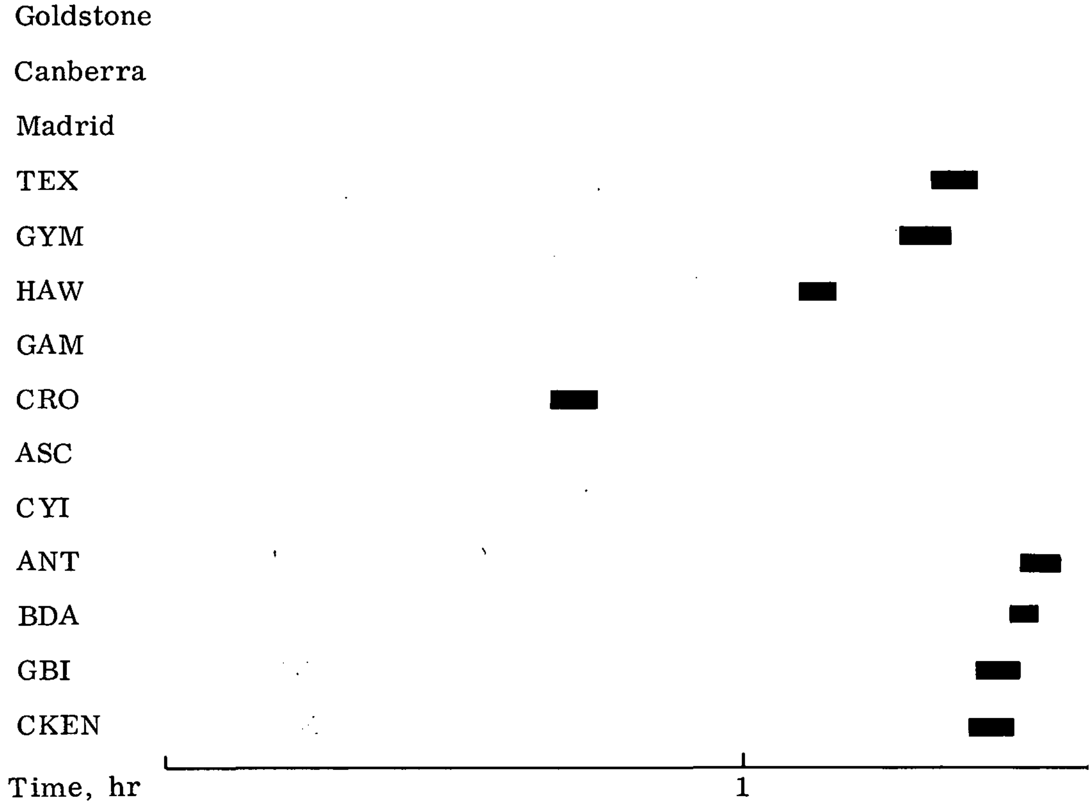
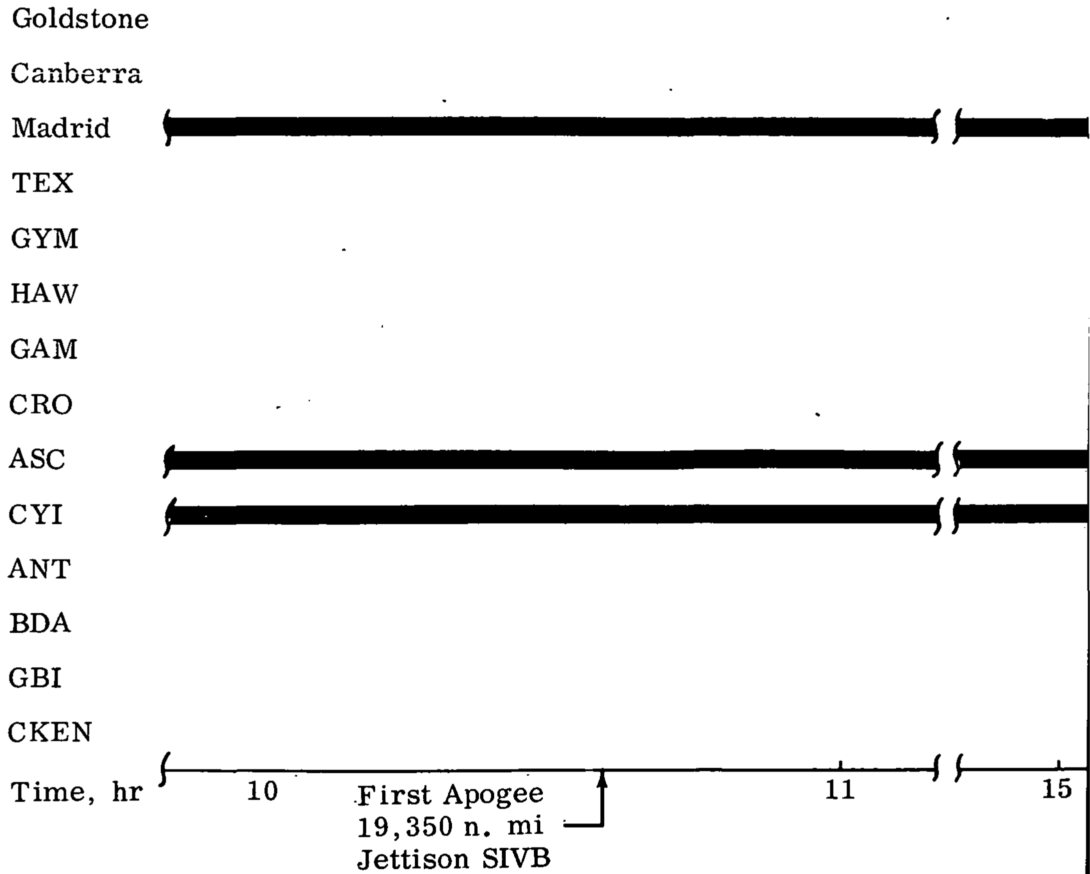
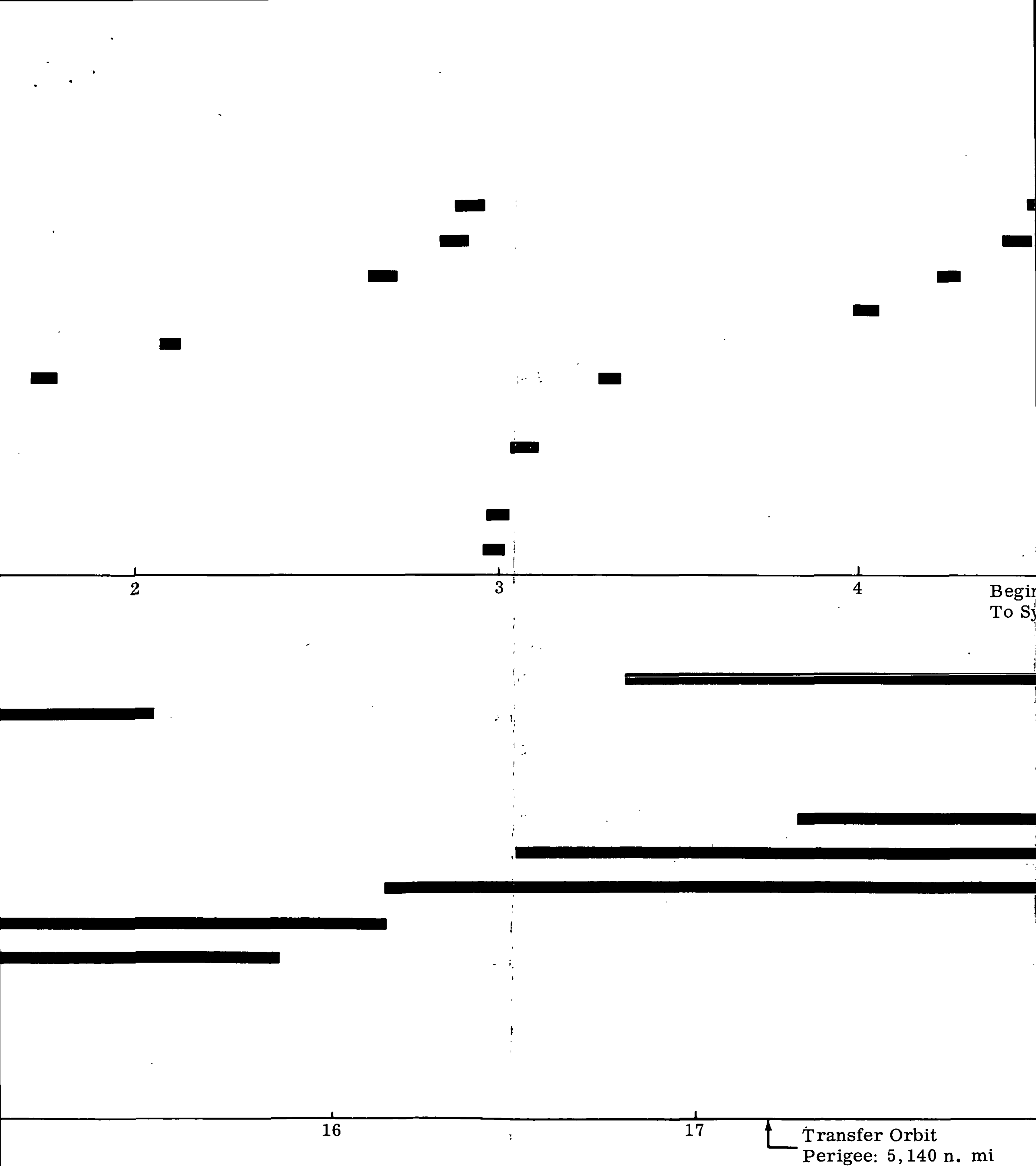


Fig. 2.6-6 Ground Track -
Synchronous Orbit

Grumman


Goldstone
Canberra
Madrid
TEX
GYM
HAW
GAM
CRO
ASC
CYI
ANT
BDA
GBI
CKEN
Time, hr
1


Goldstone
Canberra
Madrid
TEX
GYM
HAW
GAM
CRO
ASC
CYI
ANT
BDA
GBI
CKEN
Time, hr
10
11
15
First Apogee
19,350 n. mi
Jettison SIVB


2
3
4
16
17
Transfer Orbit
Perigee: 5,140 n. mi

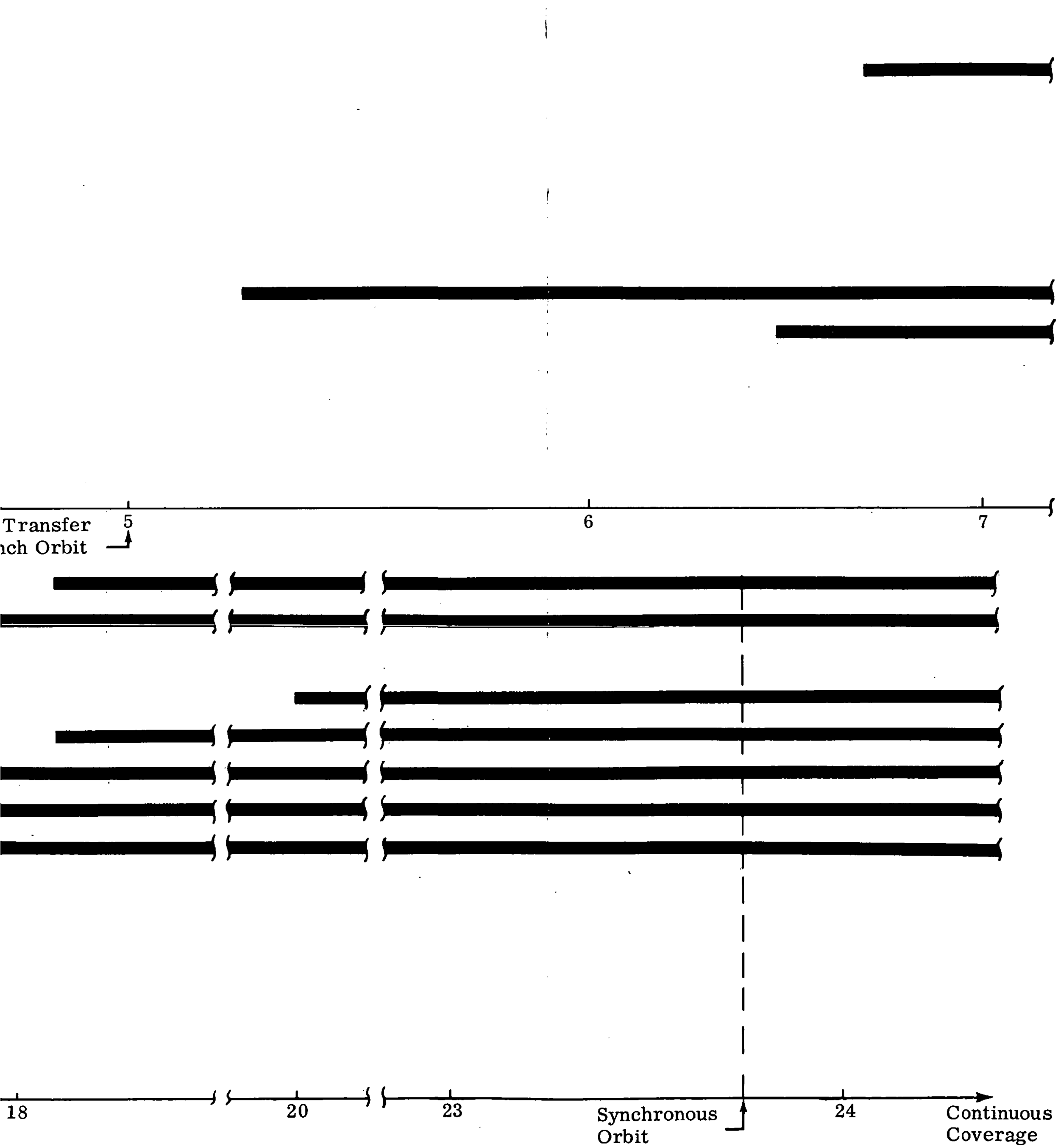
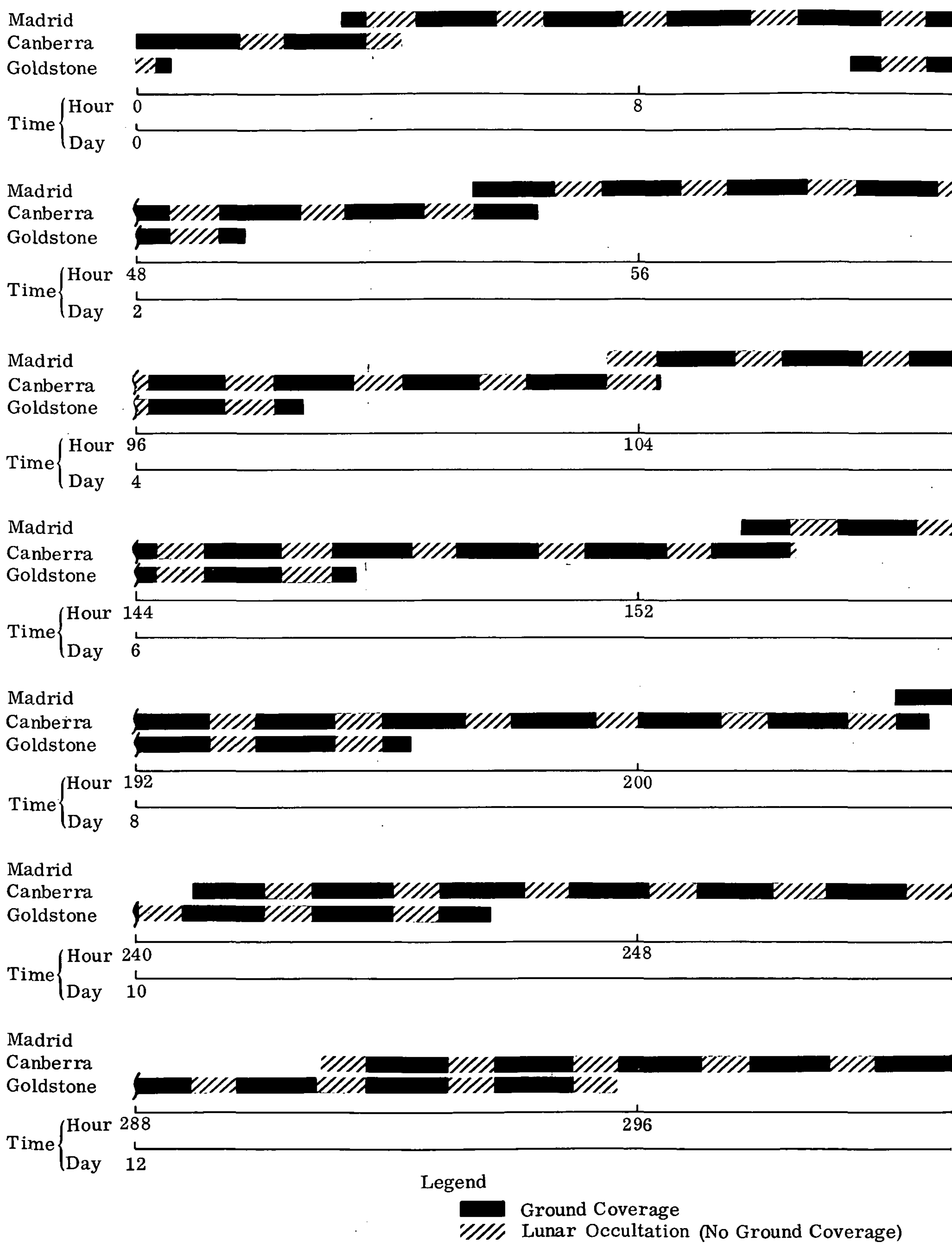


Fig. 2.6-7 Ground Station Visibility - Synchronous Orbit

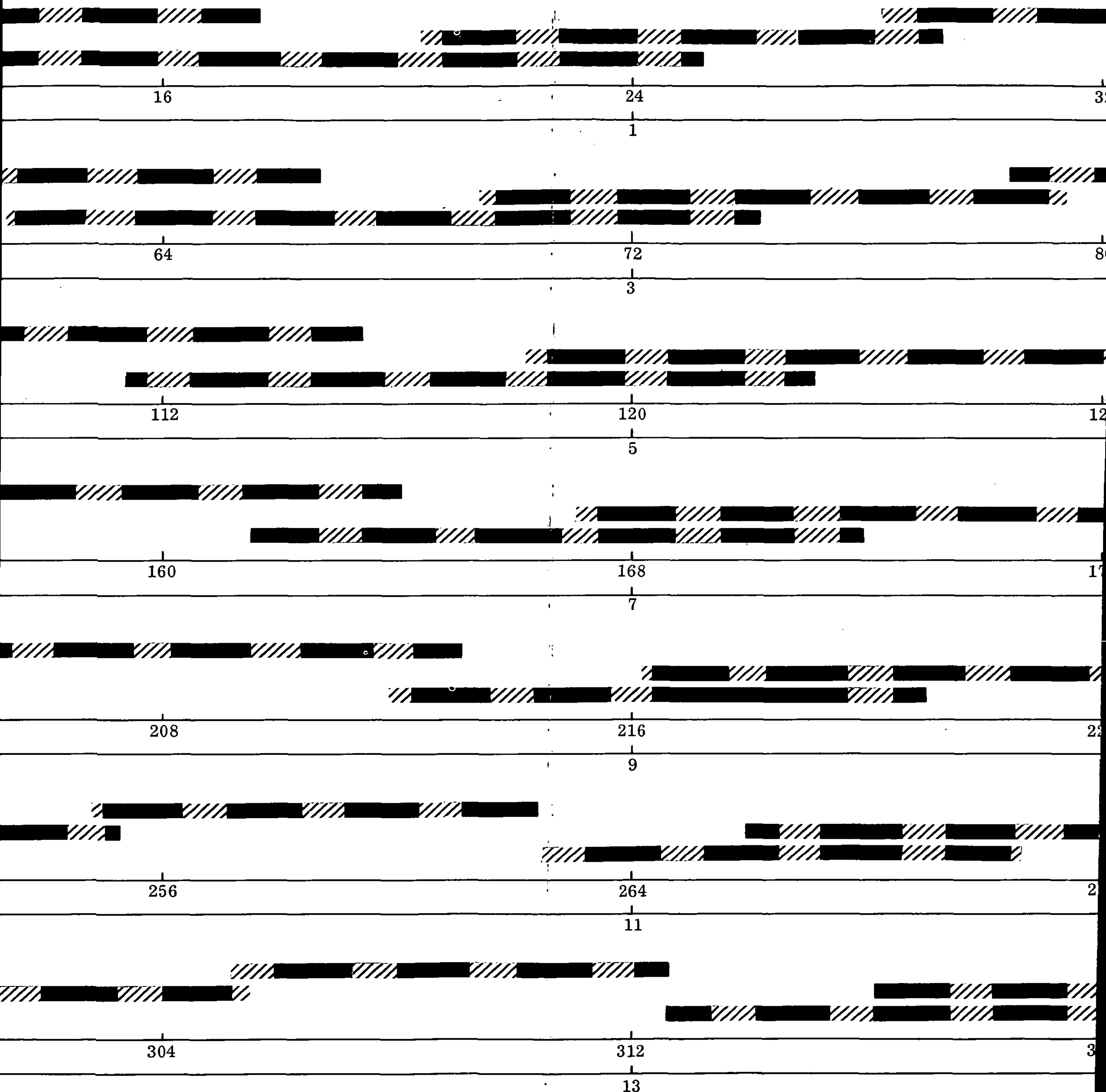
8

Grumman



Madrid
Canberra
Goldstone
Time
Hour 0
8
Day 0
Madrid
Canberra
Goldstone
Time
Hour 48
56
Day 2
Madrid
Canberra
Goldstone
Time
Hour 96
104
Day 4
Madrid
Canberra
Goldstone
Time
Hour 144
152
Day 6
Madrid
Canberra
Goldstone
Time
Hour 192
200
Day 8
Madrid
Canberra
Goldstone
Time
Hour 240
248
Day 10
Madrid
Canberra
Goldstone
Time
Hour 288
296
Day 12
Legend
Ground Coverage
Lunar Occultation (No Ground Coverage)

2-6-8
(1)



2-6-8

2

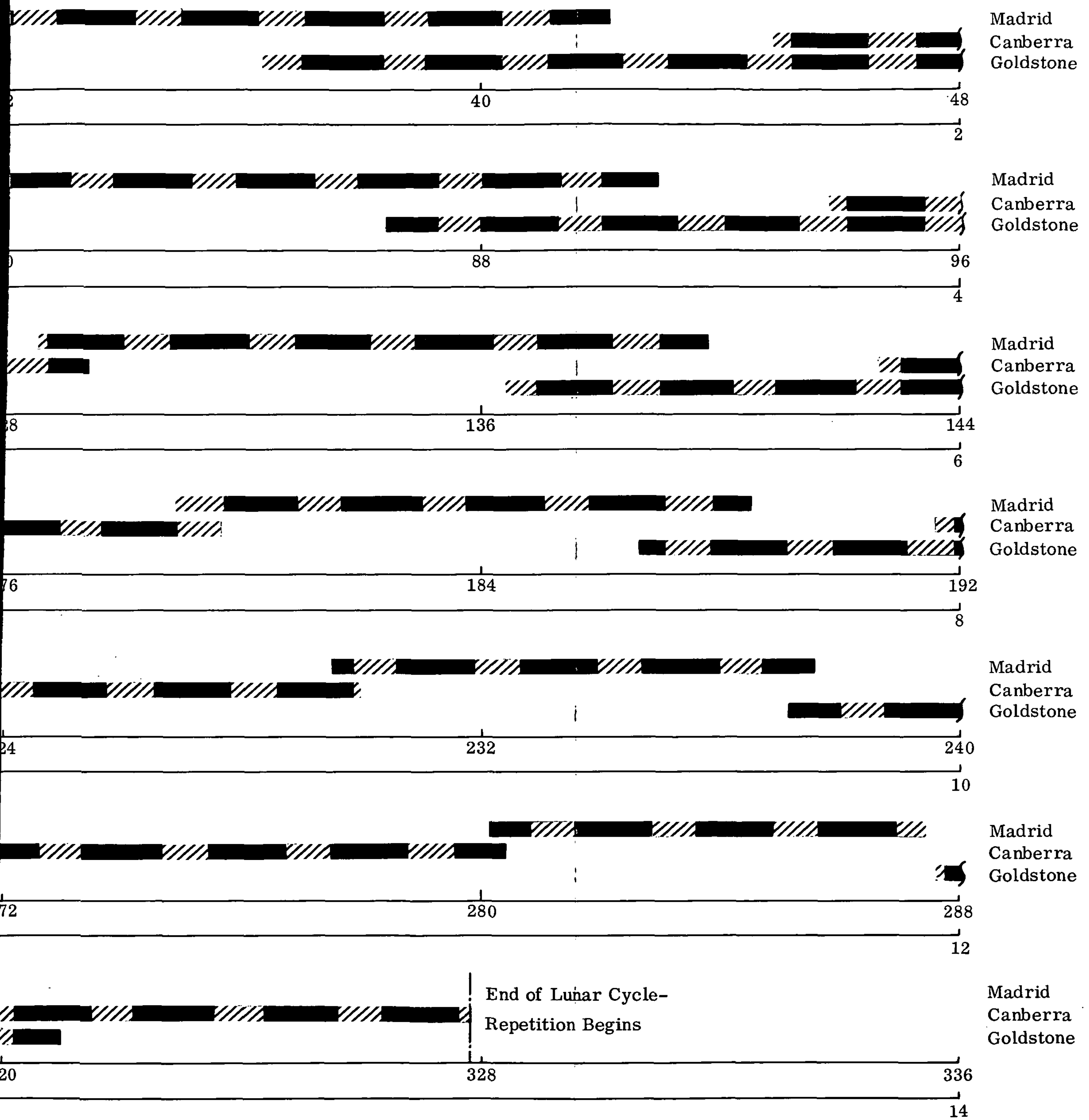
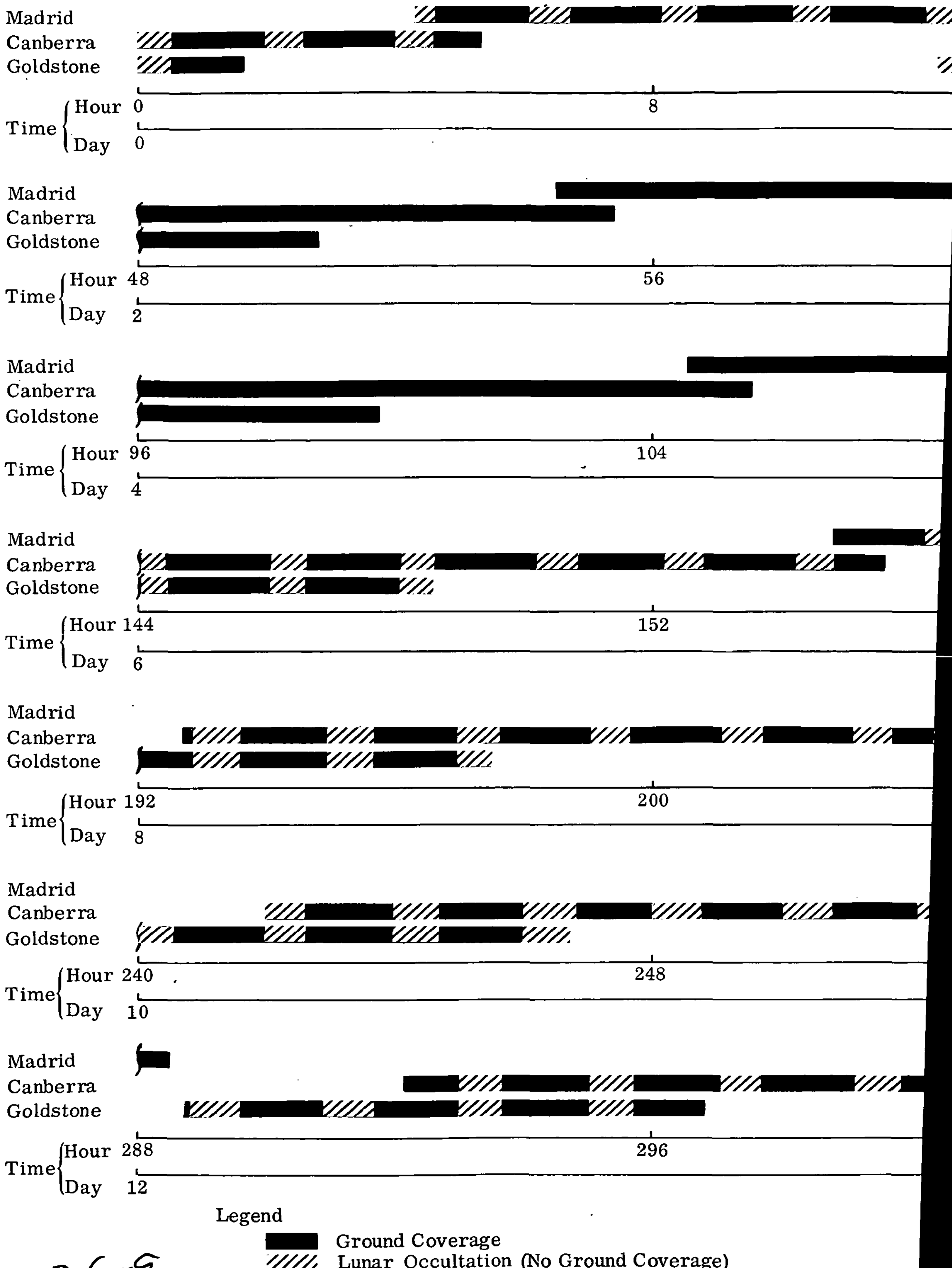
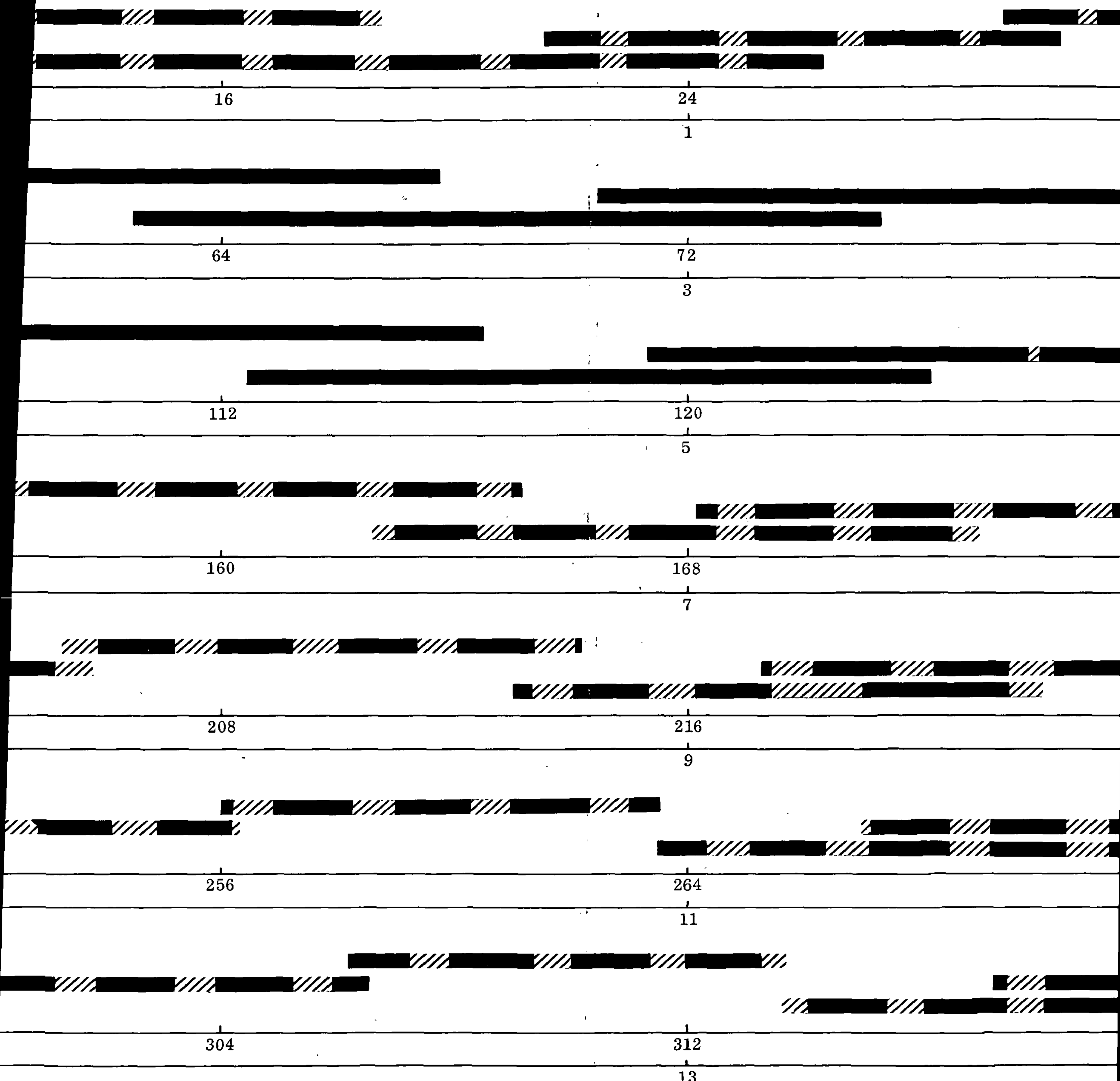


Fig. 2.6-8 Low-Inclination Lunar Orbit Ground Station Visibility


Madrid
Canberra
Goldstone
Time
Hour 0
8
Day 0
Madrid
Canberra
Goldstone
Time
Hour 48
56
Day 2
Madrid
Canberra
Goldstone
Time
Hour 96
104
Day 4
Madrid
Canberra
Goldstone
Time
Hour 144
152
Day 6
Madrid
Canberra
Goldstone
Time
Hour 192
200
Day 8
Madrid
Canberra
Goldstone
Time
Hour 240
248
Day 10
Madrid
Canberra
Goldstone
Time
Hour 288
296
Day 12
Legend
Ground Coverage
Lunar Occultation (No Ground Coverage)

2.6-9

(1)



2.69
(2)

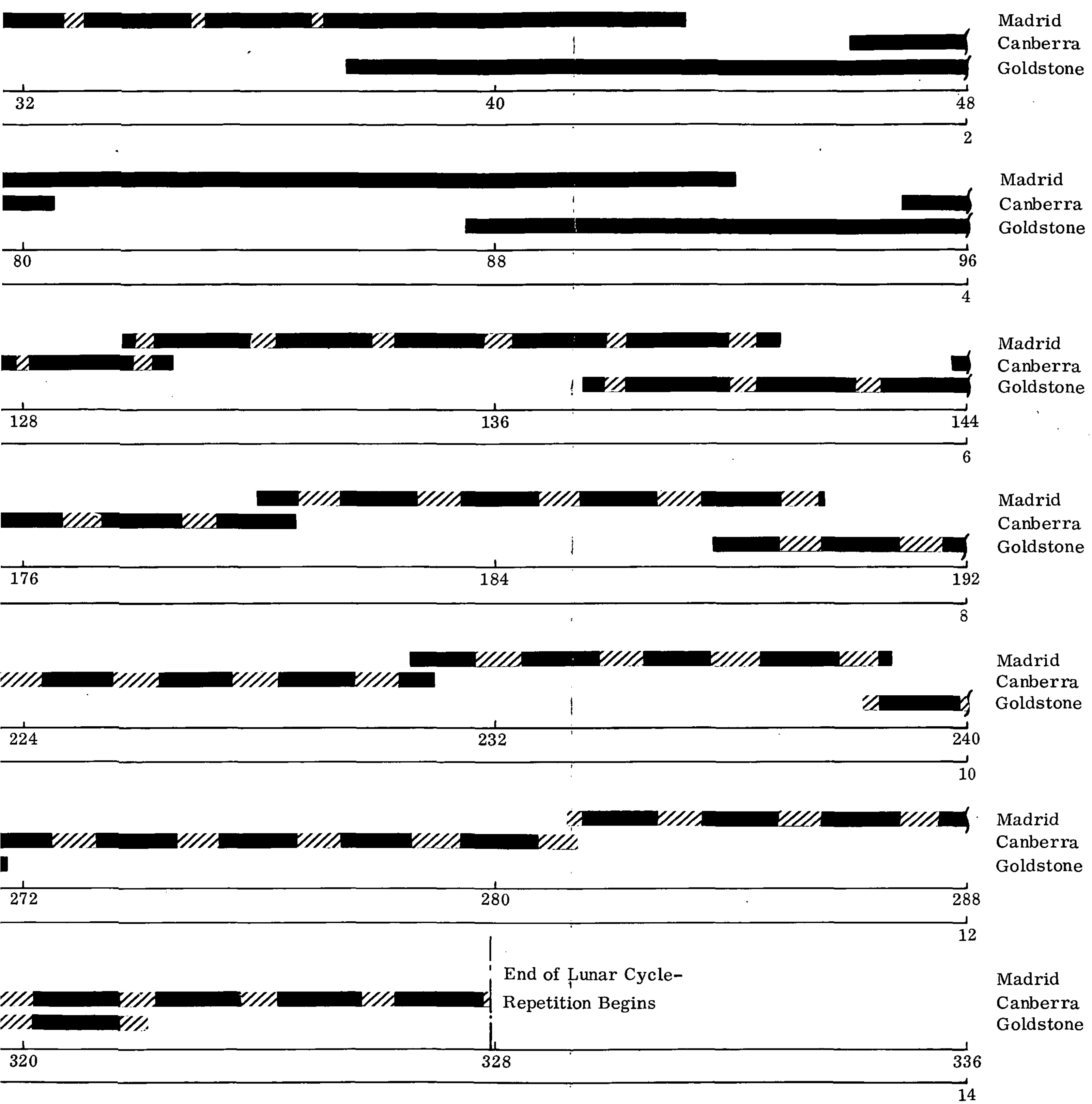


Fig. 2.6-9 Lunar Polar Orbit Ground Station Visibility

(3)

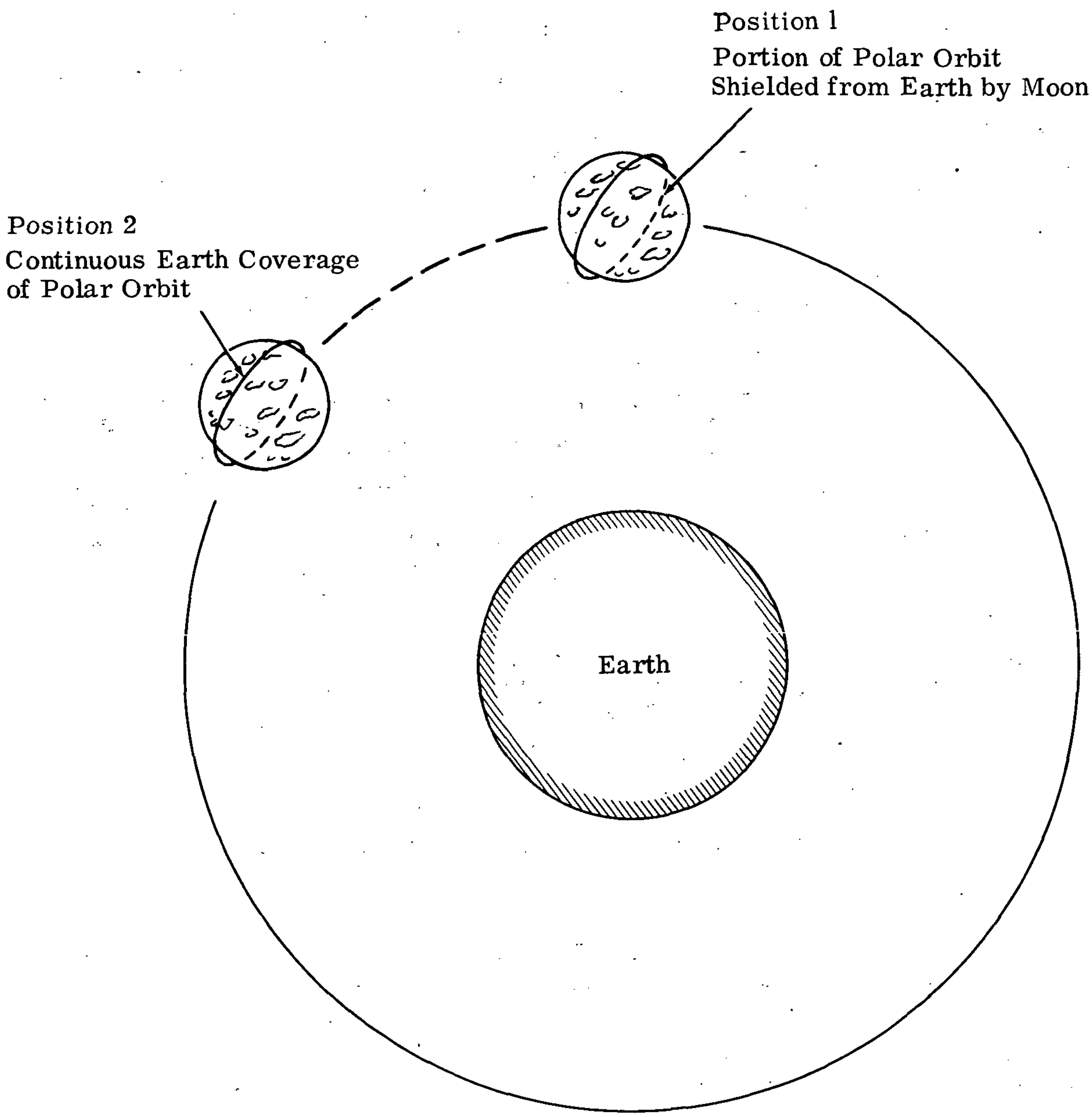
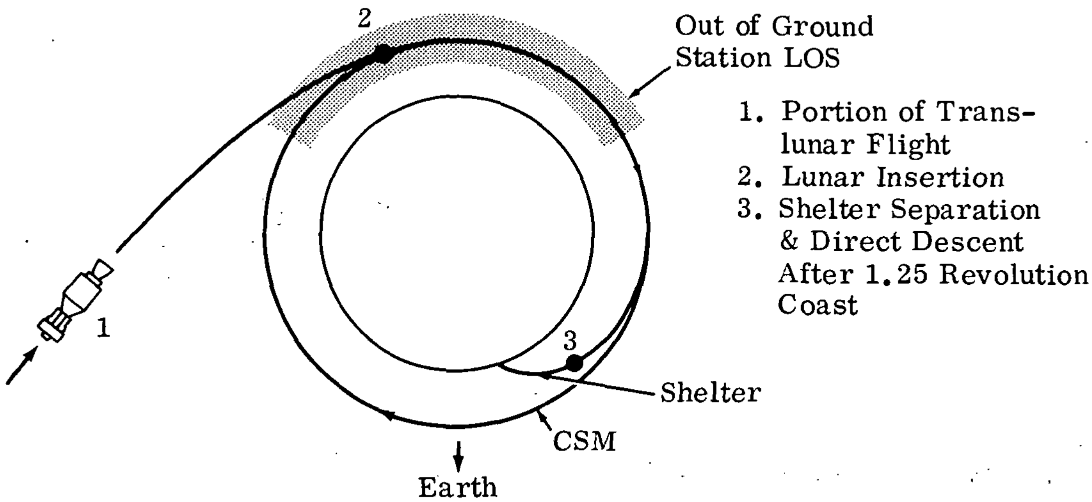
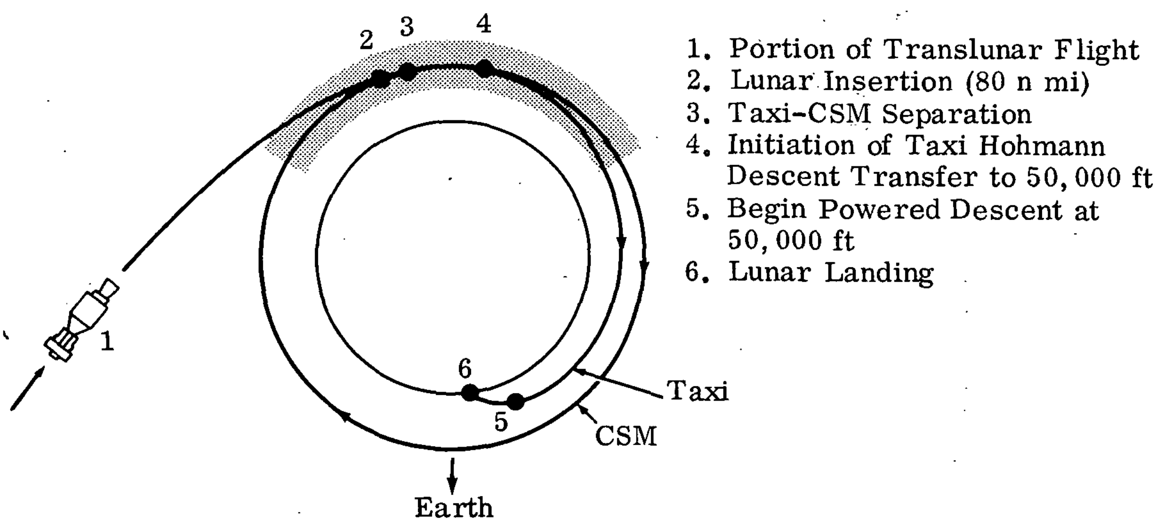


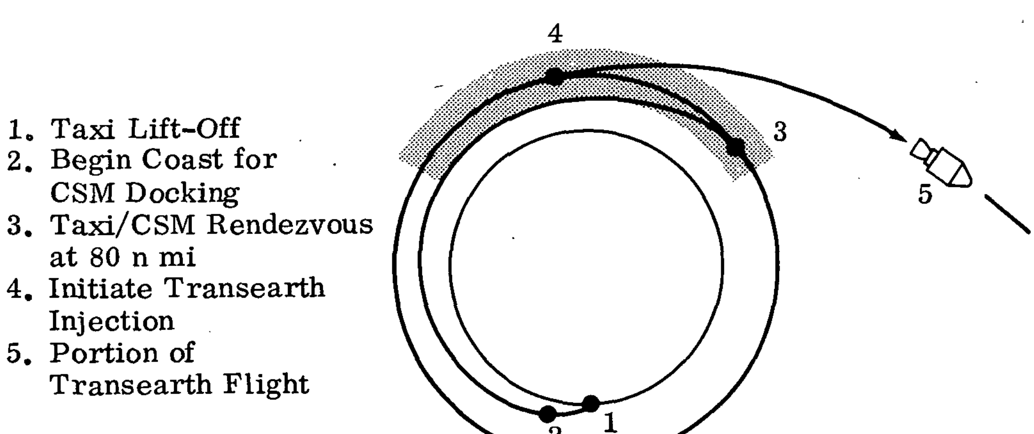
Fig. 2.6-10 Effect of Lunar Position on Earth Coverage



A. Shelter Coast and Landing, Direct Descent Method



B. Taxi Coast and Landing (Alternate Shelter Method)



C. Taxi Ascent and Transearth Injection

Fig. 2.6-11. Shelter/Taxi Operations in Lunar Orbit

2.7 OPERATIONAL DATA HANDLING

2.7.1 Assumptions

The operational data handling analysis is based on the following assumptions:

- The Apollo Mission Control Center (MCC) will be used as a base for AES mission control and data handling.
- All MSFN remote sites supporting AES flight operations will be remoted to the MCC-Houston.
- Sufficient data will be routed to the MCC in real-time to conduct the flight control and experimental program.
- Ground control will retain the capability of acquiring and analyzing sufficient significant data so that specific contingencies or malfunctions can be isolated and the crew advised that a potential need to modify or abort the flight may exist.

2.7.2 Basic Spacecraft Data Requirement

The mission control philosophy on which this analysis is based is that the AES missions follow the basic Apollo LEM missions, except that more responsibility is placed upon the crew for spacecraft subsystem monitoring. The objective of the MCC real-time data monitoring is to provide assistance to the crew in achieving mission objectives and recommend action in emergency situations. Table 2.7-1 presents a preliminary definition of operational subsystem and aeromedical parameters for real-time MCC display and compares these parameters to the onboard spacecraft displays. The parameter listing is based upon the recommended Phase I and II Labs, Shelter, and Taxi configurations (Vol III - VI). As subsystem design and aeromedical requirements become more detailed, and as the basic configurations reflect particular experiment requirements, the data handling requirements will be modified and expanded accordingly.

2.7.3 Experiment Data Interface

Experiment data in the case of the Labs will not be transmitted to the ground in real-time. Two on-board tape recorders will be used enabling continuous recording capability during lengthy experiments, and subsequent transmission to the ground followed by tape erasure. The magnitude of experiment data per mission, the minimal ground station coverage during near-earth and polar trajectory flights, and experiment packing per flight impose a requirement for quick tape verification by the acquiring ground station. This capability is requisite in deciding to erase the tape (required for continuous data acquisition during lengthy experiments and for proceeding to the next experiment), re-dumping when adequate ground station coverage is available, or repeat the experiment (if deemed necessary because on-board acquisition was not accomplished, etc.). Because of the need for expeditious confirmation of tape verification, the read-after-write method is proposed. The use of read-after-write techniques would allow signal strength and quality to be determined concurrently with the stripping out, buffering, and processing of significant parameters for display. These parameters would constitute a cross sample representation of data tape content for tape verification. After satisfactory acquisition of the experiment data, the data should be expedited to MSC, Houston for disposition.

2.7.4 Operational Data Flow

The operational data flow should follow, as closely as possible, the currently planned Apollo/LEM data flow. The operational telemetry data will be acquired by the remoted MSFN site and formatted to the existing ground communications equipment. Near real-time processed data and summary messages will be selected for transmission to MCC. MCC will retain and store the data that has been received and will be able to selectively recall, reduce, and/or display it on the display consoles or make available hard copy of particular data. When practicable or when requested, MSFN will ship all of the operational data it has acquired (magnetic tapes, strip chart records, etc.) to MSC for logging into the Control Metric Data File. All reduceable data will then be processed, copied, and reduced per existing or special data processing request. The processed data will aid mission analysis during and after the flight. The GAEC copies of the operational data will be expedited to Grumman's facility. There it will be logged in, processed, reduced, and analyzed for detailed subsystems performance evaluation. Operational data that is required for correlation with experiment data will be recorded such that groups of related operational and experimental data can be stripped-out with minimum complexity.

2.7.5 Instrumentation Subsystem

2.7.5.1 Onboard Instrumentation Subsystem Description

The Instrumentation Subsystem consists of operational equipment, caution and warning equipment, and experiment support equipment. The major sections within the subsystem are as follows:

- Operational Equipment Section: This section will detect, measure, and provide to the on-board displays certain data for monitoring and evaluating subsystem performance. It will also provide data and "real-time" reference for transmission to earth, to facilitate ground assessment of vehicle performance and failure analysis. The operational instrumentation section will consist of sensor equipment, signal conditioning equipment and pulse code modulation and timing equipment (PCMTE).

- Caution and Warning Section: This section provides constant monitoring of certain critical subsystem areas and supplies displays and telemetry data when malfunctions occur.

- Experiment Support Equipment: This equipment consists of a LEM pulse code modulation (PCM) unit and two modified Apollo tape recorders. Input signals to the equipment are pre-conditioned, and all experiments will provide separate display outputs.

2.7.5.2 Measurements Lists

A preliminary measurements analysis has been made for the four basic types of spacecraft, and the complete parameter tabulations are presented in the Vehicle Design Analysis Reports, Vol III through VI. These lists indicate how the measurements are made and monitored. Tables 2.7-2 through 2.7-5 summarize the total number and type of measurements available, per subsystem, that may be used to satisfy both ground control and flight test objectives for the AES spacecraft. Experiment instrumentation measurement listing is beyond the scope of this report.

Table 2.7-1

REAL-TIME STATUS DATA HANDLING REQUIREMENTS

	On Board Displays				MCC Display Consoles			
	Taxi	Shelter	Ph II Lab	Ph I Lab	Taxi	Shelter	Ph II Lab	Ph I Lab
BIOMEDICAL								
Heart Rate	D	D	D	D	R	R	R	R
Cardiac Output	A	A	A	A	R	R	R	R
Blood Pressure - Systolic	A	A	A	A	R	R	R	R
- Diastolic	A	A	A	A	R	R	R	R
Respiration - Rate	D	D	D	D	R	R	R	R
- Depth	A	A	A	A	R	R	R	R
Ear Oximeter Output	A	A	A	A	R	R	R	R
Body Temperature	D	D	D	D	R	R	R	R
STRUCTURE								
Landing Legs Deployed	F	F			R	R		
ELECTRICAL POWER SUBSYSTEM								
Batteries High Voltage Tap	F	F		F	R	R		R
Batteries Low Voltage Tap	F	F		F	R	R		R
Batteries Voltage	A	A		A				
Batteries Reverse/Overcurrent	C	C		C	R	R		R
Batteries Current	A	A		A				
Batteries Temperature	A	A		A				
Peaking Battery No. 1 Voltage		A				R		
Peaking Battery No. 1 Current		A				R		
Commander's Bus Voltage	P	P	P	P	R	R	R	R
Batteries 21/22 On Commander's Bus				F				R
Descent Batteries On Commander's Bus	F							
Ascent Batteries On Commander's Bus	F							
System Engineer's Bus Voltage	P	P	P	P	R	R	R	R
Batteries 21/22 On System Engineer's Bus				F				R
Descent Batteries On System Engineer's Bus	F							
Ascent Batteries On System Engineer's Bus	F							
Inverter Bus Voltage	P	P	P	P	R	R	R	R
Inverter Bus Frequency	C	C	C	C	R	R	R	R
N_2 Regulator Outlet No. 1 Pressure		A	A			R	R	
FCA No. 1 H_2 Purge Closed		L	L			R	R	
FCA No. 1 O_2 Purge Closed		L	L			R	R	
H_2 Tank No. 1 Pressure		A	A			R	R	
H_2 Tank No. 1 Temperature		A	A			R	R	
O_2 Tank No. 1 Pressure		A	A			R	R	
O_2 Tank No. 1 Temperature		A	A			R	R	
FCA No. 1 H_2 Closed		L	L					
FCA No. 1 O_2 Closed		L	L					
H_2 Regulator No. 1 Outlet Pressure		A	A			R	R	
O_2 Regulator No. 1 Outlet Pressure		A	A			R	R	
FCA No. 1 O_2 Flow Rate						R	R	
FCA No. 1 H_2 Flow Rate						R	R	
N_2 Regulator Outlet No. 2 Pressure		A	A			R	R	
FCA No. 2 H_2 Purge Closed		L	L			R	R	
FCA No. 2 O_2 Purge Closed		L	L			R	R	
H_2 Tank No. 2 Pressure		A	A			R	R	
H_2 Tank No. 2 Temperature		A	A			R	R	
O_2 Tank No. 2 Pressure		A	A			R	R	

Key

A Analog Display
C Caution Light
D Digital Display
F Flag Indicator
K Items D + W
L Light

P Items C + A
R Required
Q Items A + W
X Items C + L + A
Y Items C + L
W Warning Light
* Undefined At This Time

Table 2.7-1 (Cont'd)

On Board Displays				MCC Display Consoles				
Taxi	Shelter	Ph II Lab	Ph I Lab	Taxi	Shelter	Ph II Lab	Ph I Lab	
	A	A			R	R		O_2 Tank No. 2 Temperature
	L	L						FCA No. 2 H_2 Closed
	L	L						FCA No. 2 O_2 Closed
	A	A			R	R		H_2 Regulator No. 2 Outlet Pressure
	A	A			R	R		O_2 Regulator No. 2 Outlet Pressure
					R	R		FCA No. 2 O_2 Flow Rate
					R	R		FCA No. 2 H_2 Flow Rate
	A	A			R	R		H_2 Heat Exchanger Outlet Temperature
	A	A			R	R		O_2 Heat Exchanger Outlet Temperature
	A	A						FCA No. 1 Condenser Exit Temperature
	A	A						FCA No. 1 Skin Temperature
	A	A			R	R		FCA No. 1 Radiator Outlet Temperature
	A	A			R	R		FCA No. 1 Output Current
	A	A			R	R		FCA No. 1 Output Voltage
	A	A			R	R		FCA No. 1 Neutral Voltage
	A	A						FCA No. 1 Phase A Voltage
	A	A						FCA No. 1 Phase B Voltage
	A	A						FCA No. 1 Phase C Voltage
	A	A			R	R		FCA No. 1 H_2O pH Factor
	A	A						H_2O No. 1 Quantity
	A	A						FCA No. 2 Condenser Exit Temperature
	A	A						FCA No. 2 Skin Temperature
	A	A			R	R		FCA No. 2 Output Current
	A	A			R	R		FCA No. 2 Output Voltage
	A	A			R	R		FCA No. 2 Neutral Voltage
	A	A						FCA No. 2 Phase A Voltage
	A	A						FCA No. 2 Phase B Voltage
	A	A						FCA No. 2 Phase C Voltage
	A	A			R	R		FCA No. 2 H_2O pH-Factor
	A	A						Coolant Radiator Inlet Temperature
*	*			R	R			RTG Temperature
*	*			R	R			RTG Voltage
*	*			R	R			RTG Current
								ENVIRONMENTAL CONTROL SUBSYS
A	A	A	A	R	R	R	R	Cabin Temperature
A	A	A	A	R	R	R	R	Cabin Pressure
	A	A						Airlock Pressure
A	A	A	A	R	R	R	R	Suit Inlet Temperature
Q	Q	Q	Q	R	R	R	R	Suit Outlet Pressure
	A	A			R	R		FCA H_2O Tank Quantity
A	A			R	R			Heat Pipe Condenser Temperature
A	A			R	R			Heat Pipe Evaporator Temperature
A	A			R	R			Radiator Outlet Glycol Temperature
		A						Coolant Radiator Temperature
P	P		C	R	R		R	Descent H_2O Tank No. 1 Quantity
							R	Descent H_2O Tank No. 2 Quantity
P			C	R			R	Ascent H_2O Tank No. 1 Quantity
P			C	R				Ascent H_2O Tank No. 2 Quantity
				R	R	R	R	Coolant Pumps Δ Pressure
C	C	C	C	R	R	R	R	Coolant Accumulator Fluid Low Level
L	L	L	L					LiOH SEL/HI CO_2
	A							PLSS Supplement Tank Pressure
				R	R	R	R	Suit Diverter VPI Closed
Y	Y	L	Y	R	R		R	Select H_2O Separator Rate
				R	R		R	H_2O Separator No. 2 Select
L	L	L	L					CO_2 Cartridge in Secondary Position
X	X	X	X	R	R	R	R	CO_2 Partial Pressure
W	W	W	W	R	R	R	R	Emergency O_2 VPI Open
W	W	W	W	R	R	R	R	Emergency O_2 Valve Elect Open
C	C	C	C	R	R	R	R	Primary Suit Compressor Failure

Table 2.7-1 (Cont'd)

On Board Displays				MCC Display Consoles				
Taxi	Shelter	Ph II Lab	Ph I Lab	Taxi	Shelter	Ph II Lab	Ph I Lab	
W		W	W	R	R	R	R	Spare Suit Compressor Failure
L	L	L	L					Select Suit Compressor Failure
Y	Y	Y	Y	R	R	R	R	Coolant Pump No. 1 Failure
Y	Y			R	R			Coolant Pump No. 2 Failure
A	A	A	A					Primary Pump Discharge Pressure
A			A					Redundant Pump Discharge Pressure
A								Selected Pump Outlet Pressure
P	P	P	P					Main Water Boiler Coolant Outlet Temp
P			P					Redundant Water Boiler Coolant Outlet Temp
P				R				Selected Water Boiler Coolant Outlet Temp
Y	Y		Y					H_2O Separator No. 1 Rate
Y	Y		Y					H_2O Separator No. 2 Rate
								GUIDANCE, NAVIGATION & CONTROL
				R	R			Computer Digital Data
				R	R			IMU Standby/Off
				R		R	R	ACA Out Of Detent
				R	R	R	R	Deadband Select
				R	R	R	R	SCS Mode Select (Auto)
				R	R	R	R	SCS Mode Select (Att Hold)
C	C			R	R			Pitch Trim Failure
C	C			R	R			Roll Trim Failure
W	W							LGC Warning
W	W							Inertial Reference Warning
C	C							PGNS Caution
W		W	W					AEA Test Mode Failure
W		W	W					AGS Power Supply Failure
				R				Guidance Select Switch - AGS
				R		R	R	AGS Mode (Stand-By)
				R		R	R	AGS Mode (Warm-Up)
				R				Abort Stage Commanded
				R		R	R	ASA Temperature
				R				PIPA Temperature
W		W	W					+ 32 VDC Abort Sensing Assembly
W		W	W					+ 12 VDC Abort Sensing Assembly
W		W	W					- 12 VDC Abort Sensing Assembly
W		W	W					+ 6 VDC Abort Sensing Assembly
W		W	W					+ 4 VDC Abort Sensing Assembly
W		W	W					- 2 VDC Abort Sensing Assembly
W	W	W	W					+ 15 VDC Supply Voltage
W	W	W	W					- 15 VDC Supply Voltage
W	W	W	W					+ 4 VDC Supply Voltage
W	W	W	W					- 4 VDC Supply Voltage
W	W	W	W					+ 6 VDC Supply Voltage
W	W	W	W					- 6 VDC Supply Voltage
A		A	A	R	R	R	R	Pitch RGA Signal (0.8kc) Voltage
A		A	A	R	R	R	R	Yaw RGA Signal (0.8kc) Voltage
A		A	A	R	R	R	R	Roll RGA Signal (0.8kc) Voltage
W	W		W					RGA Pick-Off Exct 0.8kc Voltage
W	W		W					RGA Spin Motor A Ph 0.8kc Voltage
W	W		W					RGA Spin Motor B Ph 0.8kc Voltage
W	W		W					RGA Spin Motor C Ph 0.8kc Voltage
				R	R			Yaw Attitude Error Voltage (0.8kc)
				R	R			Pitch Attitude Error Voltage (0.8kc)
				R	R			Roll Attitude Error Voltage (0.8kc)
				R				Descent Engine Arm Command (Pnl)
				R				Ascent Engine Arm Command (Pnl)
				R	R	R	R	Roll Attitude Cont Select (Pulsed)
				R	R	R	R	Pitch Attitude Cont Select (Pulsed)
				R	R	R	R	Yaw Attitude Cont Select (Pulsed)
				R		R	R	Roll Attitude Cont Select (Direct)

Table 2.7-1 (Cont'd)

On Board Displays				MCC Display Consoles				
Taxi	Shelter	Ph II Lab	Ph I Lab	Taxi	Shelter	Ph II Lab	Ph I Lab	
				R		R	R	Pitch Attitude Cont Select (Direct)
				R		R	R	Yaw Attitude Cont Select (Direct)
				R				Manual Thrust Command Voltage
				R	R			Auto Thrust Command Voltage
				R	R			Descent Engine On/Off To Prop
				R				Ascent Engine On/Off To Prop
				R	R	R	R	X-Translation Command Voltage
				R	R	R	R	Y-Translation Command Voltage
				R	R	R	R	Z-Translation Command Voltage
				R				X-Translation Override
W	W	W	W	R	R	R	R	Jet Drivers Out 28V Voltage
A	A							Auto/Manual Thrust Voltage
				R	R			Pitch Gimbal Drive Actuator Position (0.4kc)
				R	R			Roll Gimbal Drive Actuator Position (0.4kc)
A	A			R	R			Sin IG 1x Res Out Voltage
A	A			R	R			Cos IG 1x Res Out Voltage
A	A			R	R			Sin MG 1x Res Out Voltage
A	A			R	R			Cos MG 1x Res Out Voltage
A	A			R	R			Sin OG 1x Res Out Voltage
A	A			R	R			Cos OG 1x Res Out Voltage
A		A	A					Yaw Attitude Error To CES
A		A	A					Pitch Attitude Error To CES
A		A	A					Roll Attitude Error To CES
				R				± Delta Gamma From PGNS
				R				± Delta Theta From PGNS
				R				± Delta Phi From PGNS
				R				CDU Zero
A	A							PGNS Pitch Attitude Error Voltage
A	A							PGNS Yaw Attitude Error Voltage
A	A							PGNS Roll Attitude Error Voltage
D	D							LGC Altitude Position
D	D							LGC Altitude Velocity Rate
A	A							LGC Forward Velocity
A	A							LGC Lateral Velocity
A		A	A					Display Total, Sin Alpha (0.8kc) Voltage
A		A	A					Display Total, Cos Alpha (0.8kc) Voltage
A		A	A					Display Total, Sin Beta (0.8kc) Voltage
A		A	A					Display Total, Cos Beta (0.8kc) Voltage
A		A	A					Display Total, Sin Gamma (0.8kc) Voltage
A		A	A					Display Total, Cos Gamma (0.8kc) Voltage
A		A	A					Altitude To Display Voltage
A		A	A					Altitude Rate To Display Voltage
A		A	A					Latitude Velocity To Display Voltage
D		D	D					+ ΔV To Display Voltage
D		D	D					- ΔV To Display Voltage
								INSTRUMENTATION SUBSYS
				R	R	R	R	Frame Synch ID's
				R	R	R	R	Format ID
				R	R	R	R	Calibration 85% High Level
				R	R	R	R	Calibration 15% High Level
				R	R	R	R	Calibration 85% Low Level
				R	R	R	R	Calibration 15% Low Level
				R	R	R	R	Greenwich Mean Time
L	L	L	L					C & WE Master Alarm ID
F	F		F					TCA's Failure
								RADARS
W	W			R	R			Ldg Radar Range Data No Good
W	W			R	R			Ldg Radar Velocity Data No Good
C	C							Ldg Radar Heater Caution
A	A							Ldg Radar Velocity Xmtr RF Pwr Out Pwr

Table 2.7-1 (Cont'd)

On Board Displays				MCC Display Consoles				
Taxi	Shelter	Ph II Lab	Ph I Lab	Taxi	Shelter	Ph II Lab	Ph I Lab	
A	A							Ldg Radar Altitude Xmtr RF Pwr Out Pwr
D	D							Ldg Radar V'XA Velocity (Alt Rate)
A	A							Ldg Radar V'YA Velocity
A	A							Ldg Radar V'ZA Velocity
D	D							Ldg Radar Range Data Posit (Display)
W				R				Rend Radar Data No Good
C								Rend Radar Heater Caution
A								Rend Radar RF Pwr Output Power
A								Rend Radar ATM Output (Trun) Voltage
A								Rend Radar ATM Output (Shaft) Voltage
A								Rend Radar ATM Output (AGC) Voltage
A								Rend Radar Shaft Angle 1x Posit
A								Rend Radar Shaft Angle Rate
A								Rend Radar Trun Angle 1x Posit
A								Rend Radar Trun Angle Rate
D								Rend Radar Range (Trans Mode) Posit
D								Rend Radar Range Rate (PRF) Velocity
D								Rend Radar Range (PRF) Surf Mode Posit
				R				Rend Radar Range Rate Strobe Voltage
								PROPULSION SUBSYS - ASC STAGE
K				R				He Supply Tank No. 1 Pressure
D				R				He Supply Tank No. 1 Temperature
K				R				He Supply Tank No. 2 Pressure
D				R				He Supply Tank No. 2 Temperature
F				R				He Primary Line Sol Valve Closed
F				R				He Secondary Line Sol Valve Closed
C				R				Fuel Tank Level Low
A				R				Fuel Tank Fuel Bulk Temperature
Q				R				Fuel Isol Valve Inlet Pressure
C				R				Oxid Tank Level Low
A				R				Oxid Tank Oxid Bulk Temperature
Q				R				Oxid Isol Valve Inlet Pressure
C				R				Regulator Outlet Manifold Pressure
				R				P_c
								PROPULSION SUBSYS - DESC STAGE
D	D			R	R			He Supply Tank Pressure
				R	R			He Supply Tank Temperature
F	F			R	R			He Primary Sol Valve CLOSED
F	F			R	R			He Secondary Sol Valve CLOSED
W	W			R	R			He Regulator Outlet Manifold Pressure
					R			He Burst Disc Rupture
W	W			R	R			Fuel Tank No. 1 Liquid Low Level
W	W			R	R			Fuel Tank No. 2 Liquid Low Level
A	A			R	R			Fuel Tank No. 1 Bulk Temperature
A	A			R	R			Fuel Tank No. 2 Bulk Temperature
A	A			R	R			Fuel Control Valve Inlet Pressure

Table 2.7-1 (Cont'd)

On Board Displays				MCC Display Consoles				
Taxi	Shelter	Ph II Lab	Ph I Lab	Taxi	Shelter	Ph II Lab	Ph I Lab	
W	W			R	R			Oxid Tank No. 1 Liquid Low Level
W	W			R	R			Oxid Tank No. 2 Liquid Low Level
A	A			R	R			Oxid Tank No. 1 Bulk Temperature
A	A			R	R			Oxid Tank No. 2 Bulk Temperature
				R	R			Oxid Control Valve Inlet Pressure
				R	R			Shut-Off Valves A/B Mid Posit
				R	R			Shut-Off Valves C/D Mid Posit
				R	R			Variable Injector Actuator Posit
A	A			R	R			P_c
								REACTION CONTROL SUBSYS
P		P	P	R		R	R	He Tank A Pressure
P	P	P	P	R	R	R	R	He Tank B Pressure
		P				R		He Tank C Pressure
		P				R		He Tank D Pressure
A		A	A	R		R	R	He Tank A Temperature
A	A	A	A	R	R	R	R	He Tank B Temperature
		A				R		He Tank C Temperature
		A				R		He Tank D Temperature
W		W	W	R		R	R	He Regulator A Outlet Pressure
W	W	W	W	R	R	R	R	He Regulator B Outlet Pressure
		W				R		He Regulator C Outlet Pressure
		W				R		He Regulator D Outlet Pressure
F		F	F	R		R	R	He Shut-Off A-1 Closed
F	F	F	F	R	R	R	R	He Shut-Off B-1 Closed
		F				R		He Shut-Off C-1 Closed
		F				R		He Shut-Off D-1 Closed
F		F	F	R		R	R	He Shut-Off A-2 Not Closed
F	F	F	F	R	R	R	R	He Shut-Off B-2 Not Closed
		F				R		He Shut-Off C-2 Not Closed
		F				R		He Shut-Off D-2 Not Closed
A		A	A	R		R	R	Fuel Tank A Pressure
A	A	A	A	R	R	R	R	Fuel Tank B Pressure
		A				R		Fuel Tank C Pressure
		A				R		Fuel Tank D Pressure
A		A	A	R		R	R	Fuel Tank A Temperature
A	A	A	A	R	R	R	R	Fuel Tank B Temperature
		A				R		Fuel Tank C Temperature
		A				R		Fuel Tank D Temperature
D		D	D	R		R	R	Fuel Tank A Quantity
D	D	D	D	R	R	R	R	Fuel Tank B Quantity
		D				R		Fuel Tank C Quantity
		D				R		Fuel Tank D Quantity
A		A	A	R		R	R	Oxid Tank A Pressure
A	A	A	A	R	R	R	R	Oxid Tank B Pressure
		A				R		Oxid Tank C Pressure
		A				R		Oxid Tank D Pressure
A		A	A	R		R	R	Oxid Tank A Temperature
A	A	A	A	R	R	R	R	Oxid Tank B Temperature
		A				R		Oxid Tank C Temperature
		A				R		Oxid Tank D Temperature
D		D	D	R		R	R	Oxid Tank A Quantity
D	D	D	D	R	R	R	R	Oxid Tank B Quantity
		D				R		Oxid Tank C Quantity
		D				R		Oxid Tank D Quantity
A		A	A	R		R	R	Fuel Manifold A Pressure
A	A	A	A	R	R	R	R	Fuel Manifold B Pressure
		A				R		Fuel Manifold C Pressure
		A				R		Fuel Manifold D Pressure
A		A	A	R		R	R	Oxid Manifold A Pressure

Table 2.7-1 (Cont'd)

On Board Displays				MCC Display Consoles				
Taxi	Shelter	Ph II Lab	Ph I Lab	Taxi	Shelter	Ph II Lab	Ph I Lab	
A	A	A	A	R	R	R	R	Oxid Manifold B Pressure
		A				R		Oxid Manifold C Pressure
		A				R		Oxid Manifold D Pressure
F		F	F					Fuel Main Feed S/O A Closed
F	F	F	F					Fuel Main Feed S/O B Closed
		F						Fuel Main Feed S/O C Closed
		F						Fuel Main Feed S/O D Closed
F		F	F					Fuel Manifold X-Feed Valve Not Closed
F		F	F					Oxid Main Feed S/O A Closed
F	F	F	F					Oxid Main Feed S/O B Closed
		F						Oxid Main Feed S/O C Closed
		F						Oxid Main Feed S/O D Closed
F		F	F					Oxid Manifold X-Feed Valve Not Closed
				R		R	R	Manifold X-Feed Valves Not Closed
F		F	F					TCA Isolation Fuel Valves A 1-4 Closed
F	F	F	F					TCA Isolation Fuel Valves B 1-4 Closed
		F						TCA Isolation Fuel Valves C 1-4 Closed
		F						TCA Isolation Fuel Valves D 1-4 Closed
F		F	F					TCA Isolation Oxid Valves A 1-4 Closed
F	F	F	F					TCA Isolation Oxid Valves B 1-4 Closed
		F						TCA Isolation Oxid Valves C 1-4 Closed
		F						TCA Isolation Oxid Valves D 1-4 Closed
				R		R	R	TCA Isolation Valves A 1-4 Closed
				R	R	R	R	TCA Isolation Valves B 1-4 Closed
						R		TCA Isolation Valves C 1-4 Closed
						R		TCA Isolation Valves D 1-4 Closed
				R				RCS/Ascent Intcon A Not Closed
				R				RCS/Ascent Intcon B Not Closed
				R		R	R	Main Propellant Valve A Closed
				R	R	R	R	Main Propellant Valve B Closed
						R		Main Propellant Valve C Closed
						R		Main Propellant Valve D Closed
F		F	F					TCA Fuel Inlets A 1-4 Pressure
F	F	F	F					TCA Fuel Inlets B 1-4 Pressure
		F						TCA Fuel Inlets C 1-4 Pressure
		F						TCA Fuel Inlets D 1-4 Pressure
F		F	F					TCA Oxid Inlets A 1-4 Pressure
F	F	F	F					TCA Oxid Inlets B 1-4 Pressure
		F						TCA Oxid Inlets C 1-4 Pressure
		F						TCA Oxid Inlets D 1-4 Pressure
				R	R	R	R	Quad Clusters 1-4 Temperature
C		C	C	R		R	R	O/F Ratio A Out, Toler
C	C	C	C	R	R	R	R	O/F Ratio B Out, Toler
		C				R		O/F Ratio C Out, Toler
		C				R		O/F Ratio D Out, Toler
								COMMUNICATIONS SUBSYS
L	L							S-Band Steerable Antenna No Track
A	A							Gimbal Pick-Off Output Y Posit
A	A							Gimbal Pick-Off Output X Posit
				R	R	R	R	Selected S-Band Rcvr AGC Voltage
A	A	A	A					S-Band Rcvr AGC Voltage
				R	R	R	R	Selected S-Band Xmtr RF Power
				R	R	R	R	S-Band PA RF Power Output Power
				R	R	R	R	ST, PM, ER, Selected S-Band Xpond Phase

PHAS

Parameter / Subsystem	Acceleration	Phase	Current	Vibration	Power	Frequency	Force	Position	Biomedical
Structures									
Thermodynamic									
Electrical Power			22			1			
Environmental Cont.									
Navigation & Guid.									
Radars									
S & C - CES									
S & C - AGS									
Instrumentation						2			
Propulsion - Ascent									
Propulsion - Descent									
Reaction Control									
Communications		1			4				2
Pyrotechnics									
Totals		1	22		4	3			2

Table 2.7-2

E I LAB OPERATIONAL MEASUREMENT SUMMARY

																		Measurements Usage		
Radiation	Velocity	Mass	Res./Cont.	Pressure	Quantity	Rate	Strain	Temperature	Combination	Voltage	Time	Descrete	Acoustic	Ph-Acidity	Undefined	Stimuli	Total S/S (Measurements)	Telemetry	C&W, Disp	Prelaunch C/O
								22		27		66					138	137	138	136
				22	5	2		9	2	9		26					75	40	27	58
								1		55		14			23		93	40	51	55
									8	5	2	33			8		58	16	40	21
				32	8			10	11	16		28					105	43	67	59
										5					9		21	5	1	18
				54	13	2		42	21	117	2	167			40		490	281	324	347

PHAS

Subsystem \ Parameter	Acceleration	Phase	Current	Vibration	Power	Frequency	Force	Position
Structures								
Thermodynamics								
Electrical Power			2			1		
Environmental Cont.								
Navigation & Guid.								
Radars								
S & C - CES								
S & C - AGS								
Instrumentation						2		
Propulsion - Ascent								
Propulsion - Descent								
Reaction Control								
Communications		1			4			
Pyrotechnics								
Totals		1	2		4	3		

Table 2.7-3

II LAB OPERATIONAL MEASUREMENTS SUMMARY

Biomedical	Radiation	Velocity	Mass	Res./Cont.	Pressure	Quantity	Rate	Strain	Temperature	Combination	Voltage	Time	Descrete	Acoustic	Ph-Acidity	Undefined	Stimuli	Total S/S Measurements	Meas. Usage		
																			TM Total	C&W and DISP	Prelaunch C/O
					10	1	4		12		15		8		2			55	53	51	5
					15	1	2		7	2	8		25					60	33	21	48
											38		12					50	30	29	36
									1		24		2			14		41	3	22	18
											5	2	33			8		50	16	32	21
					64	16			16	21	16		54					187	79	133	97
2											5					9		21	5	1	18
2					89	18	6		36	23	111	2	134		2	31		464	219	289	243

SHELTER OPERAT

Subsystem \ Parameter	Acceleration	Phase	Current	Vibration	Power	Frequency	Force	Position	Biomedical	Radiation	Velocity
Structures											
Thermodynamics											
Electrical Power			6			1					
Environmental Cont.											
Navigation & Guid.		1	2					1			3
Radars					4	4		1			3
S & C - CES											
S & C - AGS											
Instrumentation						2					
Propulsion - Ascent											
Propulsion - Descent								2			
Reaction Control											
Communications		1	2		4			2	2		
Pyrotechnics											
Totals		2	10		8	7		6	2		6

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ONAL MEASUREMENT SUMMARY

Mass	Res./Cont.	Pressure	Quantity	Rate	Strain	Temperature	Combination	Voltage	Time	Descrete	Acoustic	Ph-Acidity	Undefined	Stimuli	Total S/S Measurements	Meas. Usage		
																TM Total	C & W and DISP	Prelaunch C/O
						3	1			8					12	4	1	1
		10	1	4		15		19		14		2			72	70	65	16
		13	3	2		10	2	16		28					74	43	30	57
						5		65		15					92	41	16	76
								26		7			11		56	3	9	39
								58		18			4		80	46	25	73
							8	5	2	40			8		65	14	48	19
		8				5	4			15					34	20	14	22
		16	4			7	6	8		15					56	24	34	32
								9		3			11		34	5	4	24
		47	8	6		45	21	206	2	163		2	34		575	270	246	359

Ta

TAXI OPERATIONA

Subsystem \ Parameter	Acceleration	Phase	Current	Vibration	Power	Frequency	Force	Position	Biomedical	Radiation	Velocity	Mass	Res./Cont.	Pressure
Structures														
Thermodynamics														
Electrical Power			6			1								
Environmental Cont.														17
Navigation & Guid.		1	2					1			3			
Radars					6	9		6			4			
S & C - CES														
S & C - AGS														
Instrumentation						2								
Propulsion - Ascent														14
Propulsion - Descent								2						8
Reaction Control														32
Communications		1	2		4			2	2					
Pyrotechnics													2	
Totals		2	10		10	12		11	2		7		2	71

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MEASUREMENT SUMMARY

Quantity	Rate	Strain	Temperature	Combination	Voltage	Time	Descrete	Acoustic	Ph-Acidity	Undefined	Stimuli	Total S/S Measurements	Meas. Usage: TM Total	Meas. Usage: C & W and DISP	Meas. Usage: Prelaunch C/O
			3	1			8					12	4	1	1
			2									2	2		
			6		11		25					49	37	46	37
6	2		16	5	16		28					90	55	38	64
			5		73		15					100	45	16	84
	4				54		15			11		109	11	22	81
					67		27			4		98	56	32	83
			1		23		2			23		49	6	22	25
				8	5	2	41			8		66	15	49	20
			4	2			8					28	15	16	20
			5	4			14					33	19	14	21
8			10	13	16		32					111	45	71	61
					9		3			11		34	5	4	24
					10		7					19	5		9
14	6		52	33	284	2	225			57		800	320	331	530

3. PRELAUNCH OPERATIONS

3.1 CHECKOUT RATIONALE

The prelaunch checkout rationale for AES-LEM vehicles will be consistent with the present "Apollo Criteria" (Refs. 4-4 and 4-5) and presently planned Apollo LEM prelaunch operations (Ref. 4-6). The checkout of the AES-LEM vehicles will begin in the factory during subsystems installation and continue through in-house vehicle acceptance testing. At KSC, checkout will consist of subsystem, combined subsystem, and integrated system verification.

The major objectives of prelaunch checkout are to:

1. Verify system performance to assure accomplishment of mission objectives.
2. Establish compatibility of installed subsystems.
3. Demonstrate flight readiness.
4. Minimize the risk of:
   a. Launching with a system which has degraded performance
   b. "Holding" a flight-ready vehicle
   c. Missing the launch window.

The basic Manned Lunar Landing Program (Apollo-LEM) overlaps the Earth orbit and Lunar AES flights so that the LEM prelaunch and mission operations are interspersed with all the Phase I Labs; therefore the prelaunch checkout concepts and criteria will follow from the already approved plans for Apollo prelaunch operations. The resulting AES prelaunch operations will minimize expenditures for facilities and GSE beyond those planned for the basic Apollo Program.

3.1.1 Concepts and Criteria

The prelaunch operations are based upon the following concepts and criteria:

a. End-to-end testing will be employed as the basic testing approach to prelaunch checkout. End-to-end testing is defined as applying an input stimulus (or set of stimuli) to an identifiable functional flow path or paths, within the system under test, and measuring the system response at the end of that flow path or paths.

b. While end-to-end testing is the best approach for an overall prelaunch checkout, it will be necessary, in order to achieve all of the prelaunch checkout objectives, to deviate from the basic approach in certain cases. These cases will be justified on an individual basis.

c. Handling and transportation at all checkout sites will be minimized.

d. Prelaunch checkout will be performed at as high an assembly level as possible with the objective of maximum probability of malfunction detection.

e. The capability will exist to isolate a fault to a replaceable unit when a malfunction is detected. Exceptions must be justified on the basis of significant reduction in weight or complexity of flight equipment.

f. Supporting subsystems will be tested to verify their supporting function. These supporting subsystems will be exercised over the required range necessary to meet the checkout objectives during the course of other subsystem testing where these subsystems supply a supporting function.

g. In formulating checkout procedures and in the design of GSE, changing the flight configuration for the purpose of checkout shall be minimized, i.e., GSE complexity is allowed for the sake of vehicle and flight hardware simplification.

h. Electrical, mechanical, and fluid connections of flight equipment shall not be disconnected for equipment checkout after the vehicle has been assembled and mated.

i. Spacecraft operation and performance of redundant elements within replaceable units will be verified.

j. Each branch of parallel functional processes will be verified independently.

k. All interfaces, both internal and external, will be verified.

l. All external equipment and ground complexes that interface with the spacecraft will be verified prior to mating with the AES spacecraft or experiment.

m. Mission-essential GSE will be subjected to failure effects analysis to insure a vehicle-GSE fail-safe system.

n. Spacecraft telemetry (flight PCM) will be utilized during prelaunch checkout to the extent possible with no ACE carry-on duplication, except for those checkout measurements that require an accuracy beyond the capability of the flight PCM Subsystem.

o. Measurements required for prelaunch checkout will be available in real-time to ACE.

p. Maximum utilization, consistent with safety, will be made of astronauts or equivalents and onboard controls and displays during checkout.

q. Maximum utilization will be made in the prelaunch checkout program of all information and knowledge gained during the ground development program.

r. Common checkout logic will be provided at all checkout locations for equivalent levels of test.

s. System performance data obtained before and during prelaunch checkout will be maintained to develop a basis for trend analysis.

t. Data obtained during the factory checkout period will be applicable to KSC checkout.

u. Monitoring of critical parameters will be provided up to time of launch, so that malfunctions can be detected and remedial action taken.

3.2 SUBSYSTEM CHECKOUT APPROACH

The development of a sound overall KSC prelaunch operations plan which effectively utilizes facilities and ground support equipment, must consider the four basic AES-LEM spacecraft requirements individually and collectively. Since the foundation for facility and equipment requirements is dependent upon the AES-LEM subsystem configurations, this discussion considers a preliminary approach to the prelaunch checkout of the AES-LEM subsystems. These approaches are based upon the Recommended Configurations of the Phase I Lab, Phase II Lab, Shelter, and Taxi which are presented in the respective Design Analysis Reports, Vol III through VI.

The approaches are later reflected in the development of individual AES-LEM spacecraft flows (Paragraph 3.3), overall checkout operations (Paragraph 3.4), and finally KSC facility and support equipment requirements (Paragraph 3.5).

3.2.1 Propulsion/RCS Subsystems

3.2.1.1 Assumptions

Table 3.2-1 summarizes the vehicle/subsystem configurations assumed for checkout of the Propulsion/RCS Subsystems. Additional assumptions are:

a. Propulsion engine orifice sizing will be accomplished, and oxidizer to fuel (O/F) ratio checked, during cold-flow tests with substitute propellants at the factory. This capability, although not required during "normal" KSC checkout, will exist at KSC for contingencies (e.g., engine change).

b. The cryogenic system for helium storage (descent engine) does not require a full mission heat leak check at KSC.

c. No static firing of the AES RCS or Propulsion Subsystems will be accomplished at KSC.

3.2.1.2 Objectives

a. To verify pressure integrity of the RCS and Propulsion Subsystems (pressurization sections, propellant feed sections, and engine or thruster chamber assemblies).

b. To verify the functional capability of each component within each section.

c. To verify the operational capability of the engine or each thruster.

d. To verify supercritical helium tank insulation integrity.

3.2.1.3 Approach

a. Internal and external leakage will be determined on each component, line, tank, and disconnect. Leaks will be determined by volumetric-displacement, mass-spectrometer, and/or pressure-decay methods.

b. Operation of each regulator, solenoid valve, relief valve, and check valve will be verified by flowing inert, conditioned gas through each of these components. Solenoid valve cycling, however, will be kept to a minimum.

c. End-to-end inert gas flow checks, bypassing squib valves, will be made through the propulsion pressurization, propellant feed, sections and engine (i.e., from upstream of regulator shut-off valves through the engine) to determine that no blockages exist in the system.

d. End-to-end checks of Guidance Navigation and Control Subsystem (GNCS) functions will include evaluation of command-signal response from propulsion and RCS.

e. Because of the existence of positive expulsion bladders in the RCS propellant tanks, end-to-end gas flow checks of the system are not feasible. Therefore, the RCS propellant feed section/thruster assemblies will be flow checked independently. Inert gas flow checks will be made individually through each RCS thruster to verify injector valve response and ascertain that no blockages exist in the propellant flow path.

f. Cryogenic-tank insulation integrity will be verified by performing a heat leak check in a compressed time schedule.

g. Servicing of the propellant tanks will be accomplished at KSC for the first and only time (assuming no launch abort) on the launch pad.

h. Checkout of squib actuated vent, isolation, and initiator valves will be accomplished during the checkout routine of other electro-explosive devices (Paragraph 3.2.7).

3.2.2 Environmental Control Subsystems

3.2.2.1 Assumptions

Table 3.2-2 summarizes the vehicle/subsystem configurations assumed for checkout of the Environmental Control Subsystem (ECS).

3.2.2.2 Objectives

a. To verify the internal and external pressure integrity of each ECS section (ARS, OSCP, WMS, and HTS) and each interface.

b. To verify the support capability of those ECS sections which are used in conjunction with checkout tests of other subsystems.

c. To demonstrate the functional performance of each section independently and interdependently.

3.2.2.3 Approach

3.2.2.3.1 Atmosphere Revitalization Section (ARS).

a. Pressure distribution and circulation functional flow paths, components, and parts will be leak-checked and exercised to demonstrate pressure and functional integrity.

b. Temperature control, and carbon dioxide and water removal functions will be verified by simulating astronaut (or animal) metabolic inputs and outputs and establishing the ARS capability.

c. Operation of fans and pressure sensing circuitry will be checked simulating the range of differential and total pressures anticipated for the mission.

d. CM/LEM interfaces (or interdependencies) will be functionally verified and leak checked during docking tests.

3.2.2.3.2 Oxygen Supply & Cabin Pressurization (OSCP).

a. The cabin, airlock, oxygen storage tanks and distribution lines will be leak-checked to establish pressure integrity of hatch seals, relief valves, check valves, dump valves, and quick disconnects.

b. Functional operation of over-pressure relief valves and dump valves will be verified by determining cracking, open, and reseat pressures and determining dump and repressurization times.

c. The OSCP will be exercised to demonstrate its ability to control the pressure and supply of oxygen to the ARS, PLSS, cabin, airlock, CM, and water tanks.

3.2.2.3.3 Water Management Section (WMS).

a. The pressure and functional integrity of the water functional flow paths will be verified by circulating gas through the system to ascertain that no blockages or leaks exist in the lines, water boilers, and associated components and WMS/HTS interfaces, and WMS/Fuel Cell interface.

b. The ability of the water control module to achieve water regulation and process waste water will be verified.

3.2.2.3.4 Heat Transport Section (HTS).

a. Before ECS provides cooling support for testing of other subsystems, the internal and external pressure and leakage integrity of the HTS will be established.

b. The ability of the HTS to supply coolant to other sections of ECS, EPS, radar, radiators and cold plates will be established by circulating fluid through the system to ascertain that no blockages exist.

c. Proper operation of backflow prevention, over-pressure relief valves, and coolant pump operation and control will be demonstrated.

3.2.3 Guidance Navigation & Control Subsystem (GNCS)

3.2.3.1 Assumptions

Table 3.2-3 summarizes the vehicle/subsystem configurations assumed for checkout of the GNCS. Additional assumptions are:

a. The Control Electronics Section (CES) and Command Control Section (CCS) will not require a section level checkout.

b. A complete checkout and verification of the CES and CCS will be performed during the integrated GNCS checkout where the required CES and CCS inputs will be available from other GNCS subsystems and sections.

c. The Abort Sensor Assembly (ASA) will undergo a complete laboratory bench check at KSC and will be re-installed in the vehicle prior to vehicle testing involving the Abort Guidance Section (AGS).

3.2.3.2 Objectives

3.2.3.2.1 Radar Section.

a. To verify radar transmitter and receiver operation in all modes.

b. To verify Landing Radar (LR) boresight accuracy.

c. To verify Rendezvous Radar (RR) pointing accuracy.

d. To verify Beacon Transponder operation.

3.2.3.2.2 Primary Guidance Navigation & Control Section (PGNCS) - GFE.

a. To functionally verify guidance, navigation and control operation.

b. To verify inertial parameters.

c. To verify computer operational parameters.

d. To verify overall alignment between Inertial Measurement Unit (IMU), the Alignment Optical Telescope (AOT) or Optical Tracker System (OTS).

3.2.3.2.3 Abort Guidance Section.

a. To verify the functional operation of the Abort Guidance Section (AGS) in all of its modes of operation.

b. To verify the various computer operational functions.

c. To determine Abort Sensor Assembly (ASA) drift coefficients.

d. To verify the AGS operation under dynamic conditions.

3.2.3.2.4 Integrated GNCS.

a. To insure correct polarity of attitude references, control systems, and displays.

b. To verify the mechanical and electrical alignment throughout the GNCS.

c. To verify integrated GNCS operation.

d. To exercise the GNCS so that all RCS and propulsion electrical interfaces and control circuits are verified.

e. To verify Shelter Mission Programmer operation.

3.2.3.3 Approach

3.2.3.3.1 Radar Section.

a. The RR tracking circuitry will be verified with IF target generator signal inputs.

b. The boresight alignment of the LR transmitting and receiving antenna arrays will be checked to verify the electrical alignment of the beams relative to each other and to a tilt mechanism.

c. RR pointing accuracy tests will be performed to verify the stringent bias and bias drift error limits of the RR.

d. Boresight shifts and tracking accuracies will be determined.

e. Compatibility between the RR and the CSM transponder will be verified.

f. The Shelter Beacon Transponder frequency, power output, sensitivity and delay time will be verified.

g. Antenna hats will be employed in the verification of the RR and LR Receiver and Transmitter sections.

3.2.3.3.2 PGNCS (GFE).

a. LEM Guidance Computer (LGC) special test programs will be used in the verification of the individual functions and operations within the PGNCS.

b. LGC special test programs and optical tracker self-test will be used in the verification of all modes of operation of the tracker.

c. Dynamic tracking tests will be performed to demonstrate the OTS stability and tracking.

d. Inertial parameters and computer operational parameters will be determined to obtain a measure of performance and trend data.

e. IMU and AOT or OTS alignment will be determined.

f. The PGNCS will be operated as a subsystem to verify all interfaces.

3.2.3.3.3 AGS.

a. An AGS functional test will be performed to verify proper operation in each mode. In the Inertial Reference Mode a special test program in the Abort Electronics Assembly (AEA) memory will verify all AES output interfaces and proper mode operation.

b. The AEA self-test programs will be used to verify AEA operation, whenever the computer is required in any test sequence.

c. ASA drift coefficients will be verified and determined, with the ASA in the AES-LEM, so that these coefficients can be loaded into the AEA for drift compensation.

d. The AES-LEM will be positioned by a three-axis positioner so that the ASA accelerometer outputs can be checked and accelerometer error sources determined.

e. While in the positioner, significant changes in ASA gyro scale factor, bias and misalignment coefficients will be determined. Gyro scale factor, per se, can not be determined while the ASA is installed in the AES-LEM vehicle.

3.2.3.3.4 Integrated GNCS.

a. GNCS polarity, descent engine gimbaling, PGNCS automatic translation commands and displays will be verified with vehicle inputs from the polarity test fixture.

b. Alignment of the RR to the navigation base, LR antenna and descent engine will be verified.

c. End-to-end checkout of the GNCS will be accomplished in all modes of operation through radar inputs into the LGC, special computer test programs and the resulting LGC and AEA inputs to the CES.

d. The Program Coupler Assembly operation will be verified by monitoring GNCS responses to uplink commands to the command receiver of the Shelter.

e. The X-Y Scanner operation will be verified as described in 3.2.5.3d

f. The Sequencer Assembly operation will be verified by "initializing" the scanner and monitoring the taxi status bus.

3.2.4 Electrical Power Subsystems

3.2.4.1 Assumptions

Table 3.2-4 summarizes the vehicle/subsystem configurations assumed for checkout of the Electrical Power Subsystems (EPS). Additional assumptions are:

a. The Power Distribution Section (PDS) serves a supporting function and after initial verification, will be checked in conjunction with other vehicle checks.

b. Development of the cryogenic storage system for fuel-cell reactants does not require a full mission heat leak check at KSC.

3.2.4.2 Objectives

a. To monitor and verify PDS operation while functioning under subsystem loads.

b. To verify the compatibility of the PDS and Power Generation Section (PGS) under load and no-load conditions.

c. To verify the continuity and isolation of the wiring harness and all external interfaces.

d. To verify the activation of the flight batteries.

e. To verify the internal and external pressure integrity of the PGS, i.e., the fuel-cell and reactant storage subsections.

f. To verify the functional operation of the electrical and fluid control and monitoring devices of the fuel cells.

g. To verify cryogenic storage tank insulation integrity.

h. To verify operating performance of the fuel-cells.

3.2.4.3 Approach

a. The malfunction detection and correction, and switch-over functions of Electrical Control Assemblies (ECA) will be verified.

b. Inverter operations will be checked and monitored.

c. Continuity and isolation of wiring harnesses and external interfaces will be established.

d. After activation, batteries will be partially discharged to verify proper activation.

e. Battery charger operation will be functionally verified.

f. Internal and external leak checks (with inert gas) will be made on the fuel-cell and reactant storage tanks, components, distribution networks and interfaces to establish pressure integrity.

g. Components (flow control valves and regulators, purge valves, pressure switches, etc.) throughout functional flow paths will be exercised to establish functional integrity of each fuel-cell and storage subsection individually.

h. Servicing functions and cryogenic-tank insulation integrity will be verified by performing a heat leak test in a compressed time schedule.

i. The operation of the fuel cells will be verified by generating electrical power to subsystems loads, simulating critical power distribution, redundant, and emergency modes of electrical control logic.

3.2.5 Communications Subsystem

3.2.5.1 Assumptions

Table 3.2-5 summarizes the vehicle/subsystem configurations assumed for checkout of the communications subsystem.

It is assumed that the S-Band steerable antenna and its related equipment is on all Phase I and Phase II Labs; however, the inclusion of the S-Band equipment is dependent on the communications circuit margin requirements for different missions of the Phase I and Phase II Labs.

3.2.5.2 Objectives

a. To verify that the Communication Subsystem is functioning properly in all modes of operation.

b. To verify S-Band steerable antenna operation.

c. To verify command receiver and up-data link operation.

d. To demonstrate communications compatibility with Manned Space Flight Network (MSFN).

e. To verify the Electro-Magnetic Compatibility (EMC) of the AES-LEM vehicle.

3.2.5.3 Approach

a. The proper functioning of the Communication Subsystem will be verified end-to-end by operating the subsystem in all its modes. Antenna adapters will be placed over the S-Band steerable antenna, the two S-Band inflight and the two VHF inflight antennae. The LEM erectable antenna bulkhead connector and the S-Band antenna adapters will be coupled via transmission lines to an RF switch and then to the communications console. The operation functions will be performed utilizing a selected S-Band and VHF antenna.

b. A complete end-to-end test will be performed with the ground station to demonstrate compatibility between the vehicle Communication System and the MSFN.

c. The S-Band steerable antenna's dynamic tracking characteristics will be tested with the use of an S-Band source located at a distance from the vehicle and by moving the vehicle within the antenna's tracking limits.

d. The Shelter's X-Y Scanner will be functionally verified. With the S-Band steerable antenna locked on to an S-Band source the vehicle will be moved so that "lock on" is broken. An up-link command will then be sent initiating the X-Y Scanner operation.

e. Vehicle EMC will be verified by operating all equipment including radiating devices and monitoring system performance.

3.2.6 Instrumentation Subsystems

3.2.6.1 Assumptions

Table 3.2-6 summarizes the Vehicle/Subsystem configurations assumed for checkout of the Instrumentation Subsystem. Additional assumptions are:

a. The Instrumentation Subsystem serves a supporting function and, after initial verification, will be checked in conjunction with other vehicle checks.

b. The instrumentation for the Phase I Labs will be recalibrated at KSC after the manufacturing modification.

3.2.6.2 Objectives

a. To verify that the Operational Instrumentation is ready to support specific vehicle checkout.

b. To verify that all instrumentation inputs, outputs and all redundant paths are functioning.

c. To verify the proper functioning of the Caution and Warning Section, Pulse Code Modulation & Timing Electronics Assembly (PCMTEA), and Voice Storage Recorder (VSR).

d. To verify Experiment-Instrumentation section.

3.2.6.3 Approach

a. All Caution and Warning (C&W) alarms will be verified by applying an "alarm enable" to each C&W channel while inhibiting all other channels.

b. The PCMTEA will be verified by monitoring its downlink and GSE data.

c. The Experiment Instrumentation for the Phase I and Phase II Labs will be verified by the application of stimuli and monitoring the down-link.

d. The VSR will be checked by monitoring read-head output after applying a time limited test signal to the recording head.

3.2.7 Structural/Mechanical and Electro-Explosive Devices Subsystems

3.2.7.1 Assumptions

Table 3.2-7 summarizes the vehicle/subsystem configurations assumed for checkout of the Structural/Mechanical and Electro-Explosive Devices Subsystem.

3.2.7.2 Objectives

a. To verify the mechanical connections between AES-LEM stages and between the vehicle and the Spacecraft-LEM Adapter (SLA).

b. To establish leakage integrity across soft and hard dock seals, hatches, tunnels, and airlocks.

c. To verify the mechanical and electrical docking interfaces and hatch operations.

d. To verify the proper functioning of the thermal covers for hatches, windows, and RCS clusters.

e. To verify mechanical functioning of airlocks.

f. To demonstrate landing gear deployment.

g. To demonstrate performance of each type of electro-explosive device.

h. To verify the firing circuits for each electro-explosive device.

3.2.7.3 Approach

a. Electrical and mechanical interfaces between AES-LEM and CSM will be verified and leakage integrity established during hard docking between the vehicles or stages involved.

b. Fit checks between SLA and descent stage will be made to establish mechanical compatibility before stacking the AES-LEM and CSM within the SLA.

c. Performance of electro-explosive devices (EED) will be demonstrated in "destructive tests" using statistical sampling methods prior to EED installation in the vehicle.

3.2.8 Crew Provisions Subsystems

3.2.8.1 Assumptions

Table 3.2-8 summarizes the vehicle/subsystem configurations assumed for checkout of the Crew Provisions Subsystem. It is assumed that all GFE items will be checked out as components before delivery to GAEC or at field installations.

3.2.8.2 Objectives

a. To verify the functional capability of the pressurized compartments including installation of equipment and station arrangement; instrument panels and consoles; lighting fixtures, illumination and color; and interstage circuitry.

b. To verify the functional interfaces between the Portable Life Support System (PLSS) and AES LEM.

c. To verify the compatibility and functional interfaces between the AES LEM and soft and hard suits.

d. To verify the component and installation integrity of harnesses, belts, slings, seats, hand/foot holds, and other Crew Provision equipment.

e. To verify the leakage integrity and functional operation of the Waste Management Section.

f. To verify the functional operation of Special Devices (e.g., water probe).

g. To assure completeness of quantities of equipment and mechanical interface provisions.

3.2.8.3 Approach

a. All lighting will be inspected to verify lamp function, intensity of illumination, color, and coordination of dimming control.

b. Pressure checks at operating and higher pressures will be made at the liquid and gas interfaces between the PLSS and vehicle, and PLSS and suit.

c. Pull tests will be performed on all crew harnesses, belts, slings, and foldable bunk components.

d. Components and plumbing of the Waste Management Section will be leak checked with an inert gas and functionally checked with test fluids.

e. Water probe operation in the preparation of food, drinking, and PLSS recharge will be checked.

f. Space suit and PLSS stowage provisions and vehicle interfaces will be checked.

3.2.9 Experiment Interfaces

As related to checkout functions, the AES-LEM experiment categories are defined as follows:

a. Independent experiments are those which depend on the AES-LEM vehicle solely for storage and/or mounting. An instrumentation interface with the vehicle may or may not exist.

b. Dependent experiments are those which depend on the vehicle for power, environmental control, orientation, and/or other supporting functions in addition to storage, mounting, and instrumentation.

c. Integrated experiments are those which are essentially interrelated (either in functional flow path or structurally) within the AES-LEM vehicle subsystems, such that the experiment cannot be conducted without vehicle function.

3.2.9.1 Assumptions

Table 3.2-9a summarizes the experiment interface checkout assumptions as applicable to each category of experiments.

3.2.9.2 Objectives

Table 3.2-9b summarizes the experiment interface checkout objectives as applicable to each category of experiments.

3.2.9.3 Approach

Table 3.2-9c summarizes the vehicle/experiment checkout approach as applicable to each category of experiments.

TABLE 3.2-1

PROPULSION/RCS CHECKOUT CONFIGURATIONS

	Phase I Lab	Phase II Lab	Shelter	Taxi
LEM Ascent Stage Propulsion				X
LEM RCS	X			X
LEM RCS (1/2 Propellant Capacity and Thrusters)			X	
LEM RCS (Double Propellant Capacity)		X		
RCS Vent Valves			X	
LEM Descent Stage Propulsion with Vent Valves			X	X
NOTE: Based on Vehicle Recommended Configuration; See Vols. III, IV, V & VI.				

TABLE 3.2-2

ECS CHECKOUT CONFIGURATIONS

	Phase I Lab	Phase II Lab	Shelter	Taxi
ATMOSPHERE REVITALIZATION SECTION				
Suit Circuit Assy	X	X	X	X
Cabin Recirculation Assy	X	X	X	X
CSM/LEM Recirculation Duct	X	X		
O_2 SUPPLY & CABIN PRESSURIZATION SECTION				
LEM System				X
Additional LEM GOX Tanks	X			
Airlock		X	X	
Two-Gas System		X		
GOX from Fuel Cell Storage		X	X	
WATER MANAGEMENT SYSTEM				
LEM System				X
Additional Potable Water Tanks	X			
Modified CSM System		X	X	
HEAT TRANSPORT SECTION				
ASA Bypass	X	X		X
Radiators		X	X	
Separate Fuel Cell Cooling Loop		X	X	
RTG Heat Pipe			X	X
Additional Cold Plates	X			

NOTE: Based on Vehicle Recommended Configuration; See Vols. III, IV, V & VI.

TABLE 3.2-3

GN&C CHECKOUT CONFIGURATIONS

	Phase I Lab	Phase II Lab	Shelter	Taxi
• RADAR SECTION Rendezvous Radar				X
Landing Radar			X	X
Beacon Transponder			X	
• PRIMARY GN&C (GFE) Inertial Measurement Unit			X	X
LEM Guidance Computer			X	X
Power and Servo Assembly			X	X
Pulse Torque Assembly			X	X
Display and Keyboard			X	X
Alignment Optical Telescope	X	X		X
Optical Tracker			X	
Navigation Base	X	X	X	X
• ABORT GUIDANCE SECTION Abort Sensor Assembly	X	X		X
Abort Electronics Assembly	X	X		X
Data Entry and Display Assy	X	X		X
• CONTROL ELECTRONICS SECTION Attitude and Translation Control Assembly	X	X	X	X
Rate Gyro Assembly	X	X		X
Ascent Engine Latching Device				X
Descent Engine Control Assy			X	X
Gimbal Drive Actuator			X	X
Attitude Control Assembly	X	X	X	X
Thrust Translation Control Assy	X	X		X
• COMMAND CONTROL SECTION Program Coupler Assy			X	
X-Y Scanner Assy			X	
Sequencer Assy				X

NOTE: Based on Vehicle Recommended Configuration; See Vols. III, IV, V & VI.

TABLE 3.2-4

EPS CHECKOUT CONFIGURATIONS

	Phase I Lab	Phase II Lab	Shelter	Taxi
All-Battery PGS	X			X
Fuel Cells with Cryogenic Storage of Reactants		X		
Fuel Cells with Ambient Storage of Reactants			X	
Radioisotope Thermal Generator (RTG)			X	X
NOTE: Based on Vehicle Recommended Configuration; See Vols. III, IV, V & VI.				

TABLE 3.2-5

COMMUNICATIONS CHECKOUT CONFIGURATIONS

	Phase I Lab	Phase II Lab	Shelter	Taxi
S-Band	X	X	X	X
VHF	X	X	X	X
Signal Processor Assy	X	X	X	X
TV Camera				X
X-Y Scanner *			X	
Command Receiver			X	
Up-Data Link			X	
AES-LEM/CSM Intercom	X	X		
S-Band Erectable Antenna			X	X

NOTE: Based on Vehicle Recommended Configuration; See Vols. III, IV, V & VI.

* Listed for reference only; part of GNCS.

TABLE 3.2-6

INSTRUMENTATION CHECKOUT CONFIGURATIONS

	Phase I Lab	Phase II Lab	Shelter	Taxi
Pulse Code Modulation & Timing Electronic Assy	X	X	X	X
Signal Conditioning Electronics Assy	X	X	X	X
Caution & Warning Electronics Assy	X	X	X	X
Voice Storage Recorder	X	X	X	X
Experiment Pulse Code Modulation & Timing Electronic Assy	X	X		
Experiment Data Storage Equipment	X	X		
NOTE: Based on Vehicle Recommended Configuration; See Vols. III, IV, V & VI.				

TABLE 3.2-7

STRUCTURAL/MECHANICAL AND EED CONFIGURATIONS

	Phase I Lab	Phase II Lab	Shelter	Taxi
STRUCTURAL Window Covers			X	X
Hatch Covers			X	X
MECHANICAL Interstage Exp. Bolts				X
Guillotine Cable Cutter				X
Landing Gear			X	X
Propulsion Pyro Components	X	X	X	X

NOTE: Based on Vehicle Recommended Configuration; See Vols. III, IV, V & VI.

TABLE 3.2-8

CREW PROVISIONS CHECKOUT CONFIGURATIONS

	Phase I Lab	Phase II Lab	Shelter	Taxi
Modified Ext & Int Lighting	X	X	X	
Waste Management System			X	
Flexible, Stowable Bunks			X	
Hard Suit (GFE)			X	
Extra PLSS (GFE)*			X	
PLSS LiOH Cartridges (GFE)*	X	X	X	X
PLSS Batteries	X	X	X	X
Crew Support & Restraint	X	X		X
Work Tops	X	X	X	
Pressurized Compartments - Equipt Instls	X	X	X	X
Medical Facilities (GFE)**			X	
Mod Instr Panel & Consoles ***	X	X	X	X
Ingress/Egress Provisions (Airlock, etc)		X	X	
Food (GFE)*	X	X	X	X
Extra Constant-Wear Garments (CWG; GFE)	X	X	X	

* Equipt presently in LEM, but different quantities.

** Anticipated variation from LEM.

*** Result of Control & Display changes.

NOTE: Based on Vehicle Recommended Configurations; See Vols. III, IV, V & VI.

TABLE 3.2-9a

EXPERIMENT INTERFACE ASSUMPTIONS & CATEGORIES

ASSUMPTIONS	EXPERIMENT CATEGORY		
	Independent	Dependent	Integrated
• If electrical power is provided to an experiment only for instrumentation control or stimuli, it is considered to be an instrumentation interface for the purpose of experiment categorization.	X		
• The experimenter will checkout his own experiment package, using bench test equipment, to the degree possible in an earth environment, prior to installation in the vehicle.	X	X	
• EMI testing will be accomplished for each mission-vehicle/experiment package at the system test level.	X	X	X
• Experiments requiring active thermal control will be supported by the ECS thermal control loop.		X	X
• When total experiment checkout cannot be accomplished, component checkout within the experiment package will be conducted prior to installation and an integrated checkout will be performed after installation.			X

TABLE 3.2-9b

EXPERIMENT INTERFACE CHECKOUT OBJECTIVES & CATEGORIES

OBJECTIVES	EXPERIMENT CATEGORY		
	Independent	Dependent	Integrated
• To demonstrate that experiment can be stored, set up and operated in the AES vehicle.	X	X	X
• To verify the data functional flow paths when an instrumentation interface with the vehicle data recording and transmission equipment exists.	X	X	X
• To verify that no EMI problems exist after installation of experiments in the AES flight article.	X	X	X
• To verify that the mechanical interface points required for storage and operation of the experiment are compatible with the delivered experiment package.	X	X	X
• To verify the operational compatibility between supporting subsystem(s) and experiment(s).		X	X
• To verify the integrity of the fluid flow paths when a direct fluids interface exists between experiment(s) and subsystem(s).		X	X
• To functionally demonstrate experiment(s) deployment mechanism.		X	X
• To verify the capability of the vehicle to provide support to the experiment.			X
• To verify that the crew/experiment/vehicle combination operates properly in all modes of operation, to the extent possible in Earth environment.			X

TABLE 3.2-9c

EXPERIMENT INTERFACE APPROACH & CATEGORIES

APPROACH	EXPERIMENT CATEGORY		
	Independent	Dependent	Integrated
• Storage of an experiment in the AES-LEM vehicle will be verified by actual installation. Since a prior check will have been made using an experiment mock-up or prototype, the final fit check demonstrates that the delivered experiment package is compatible with the flight article.	X	X	X
• To verify the capability of the Lab to accept an experiment configured for operation, the experiment will be set up and operated, if possible, in earth environment.	X	X	X
• After experiment installation, a screen room test will be performed with all subsystems and experiments operating to verify that no EMI problems exist.	X	X	X
• Instrumentation data flow paths will be end-to-end checked during experiment operation. If the experiment is incapable of Earth environment operation, artificial stimuli will be used, if possible, to accomplish the end-to-end check.	X	X	X
• If special fluid systems or loops exist to support a particular experiment, these loops will also be checked out independently. A comparison of system output parameters versus experiment input requirements will be made. In addition, leak checks and component functional tests will be performed.		X	X

TABLE 3.2-9c

(Cont'd)

APPROACH	EXPERIMENT CATEGORY		
	Independent	Dependent	Integrated
• The supporting subsystems shall be operated in conjunction with the experiment to demonstrate that the subsystem/experiment combination can function normally in the flight vehicle.		X	X
• Mechanical deployment devices will be exercised, if possible, to demonstrate their proper operation.		X	X
• When the nature of the experiment precludes its complete operation outside of the vehicle, an integrated mission-oriented test after installation will be performed, within the constraints of Earth environment, exercising the particular vehicle/experiment combination.			X

3.3 CHECKOUT OPERATIONS

The checkout flow through the KSC facilities for each of the basic AES-LEM spacecraft/launch vehicle configurations is shown in Fig. 3.3-1 and discussed in the paragraph to follow.

3.3.1 Assumptions

The checkout flow for each type of AES-LEM through the KSC facilities is based on the checkout approach for the individual subsystems (Sec. 3.2) and reflects maximum utilization of currently planned KSC facilities and equipment. The following assumptions are made relative to the operations in each of the facilities:

3.3.1.1 General

a. The Phase I Labs have not been cycled through any part of the KSC prelaunch checkout flow before the modification period.

b. As a goal, all vehicle/experiment comprehensive testing will be accomplished in the MSOB. However, it is recognized that specific exceptions may require other facilities (e.g. HTB, RFTF).

c. All experiments are installed before integrated testing.

d. Storage of the descent stage will not require a facility normally used for checkout purposes.

3.3.1.2 Hypergolic Test Building (HTB)

a. The checkout of the Phase II Lab RCS requires two more days than the Phase I Lab because of the multiple tank configuration of the propellant feed section in the former.

b. The duration of concurrent checkout for the Shelter RCS and descent propulsion is established by the descent stage checkout.

c. The duration of checkout for the propulsion subsystems of the Taxi is established by the sequential checkout of the ascent engine and RCS.

3.3.1.3 Manned Spacecraft Operations Building (MSOB)

a. Modification of the Phase I Labs at KSC necessitates a Phase I Lab integrated subsystems compatibility verification. As a result, the total Phase I Lab MSOB checkout will be 7 days longer than the Phase II Lab MSOB checkout.

b. Phase II Labs and Shelters require two additional days in the Altitude Chamber for fuel cell checkout.

c. Top deck buildup for the spacecraft launched on Saturn V will be accomplished in the MSOB.

3.3.1.4 Fuel Cell Systems Test Facility (FCSTF)

a. Fuel cell, reactant storage, and ECS configuration of the Phase II Lab and Shelter requires that the ascent and descent stages be mated prior to checkout in the FCSTF.

b. The cryogenic storage configuration of the Phase II Labs requires four more days of checkout time than the ambient storage configuration of the Shelter because of the insulation integrity checks required of the former.

3.3.1.5 RF Systems Test Facility (RFSTF)

The additional time required by the Taxi at the RFSTF is for checkout of the Rendez-Radar.

3.3.1.6 Launch Complex

a. The checkout times shown for the VAB, Launch Pads 39 and 37 are governed by Saturn launch vehicle checkout requirements. The spacecraft checkout (CSM/LEM) is done concurrently with booster operations.

b. The difference in times between Launch Complex 37 and 39 operations is attributed to launch vehicle activities.

3.3.2 <u>Phase I Lab</u> (Fig. 3.3-1A)

3.3.2.1 Ascent Stage

3.3.2.1.1 <u>Hypergolic Test Building (West Cell)</u>. Upon completion of the KSC modification, the ascent stage will be transported to the West Cell of the HTB. Checkout and servicing of the ECS Heat Transport Section will be performed to provide coolant capability during subsequent tests. Leak and functional checks will be performed on the RCS, Oxygen Supply and Cabin Pressurization Section and Water Management Section plumbing. The ascent stage will then be transported to the MSOB.

3.3.2.1.2 <u>Manned Spacecraft Operations Building</u>. After the ascent stage is transported to the MSOB it will be installed in the cleaning fixture, inverted and then moved to the docking fixture, for the Lab-CSM docking test. Upon completion of the docking test the ascent stage will be moved to the cleaning fixture for reinversion and Water Management, Heat Transport and Oxygen Supply and Cabin Pressurization Sections checkout. The ascent stage will then be prepared for mating with the descent stage.

3.3.2.2 Descent Stage

3.3.2.2.1 <u>Storage Area</u>. After completion of the KSC modification period the Lab descent stage will be stored until required for SLA fit check in the MSOB. No specific area has been designated for storage.

3.3.2.2.2 Manned Spacecraft Operations Building. Upon arrival of the descent stage at the MSOB it will be transported to the SLA stand for a descent stage/SLA fit check. The stage will then be moved to the proper work stand for mating with the ascent stage. The Heat Transport and Water Management Sections of the ECS will be checked prior to mating the descent and ascent stages.

3.3.2.3 Mated Lab

3.3.2.3.1 Manned Spacecraft Operations Building. After mating, the Heat Transport Section will be leak checked and serviced. The Power Distribution Section and Instrumentation Subsystem capability to support vehicle testing will be verified. Checks will be made to verify Alignment Optical Telescope calibration and the alignment of the S-Band antenna and experiment equipment. Electrical and electronic subsystem tests, GNCS polarity, and experiment verification will be performed.

The Phase I Labs will undergo a complete vehicle system integrated checkout. All vehicle electronic subsystems will be operated in an integrated fashion so that all possible system modes are verified. A "plugs out" vehicle EMC test will be performed in a shielded chamber. To demonstrate the ability of the electrical and electronic subsystems to work together as a system, a mission-oriented "plugs out" test will be performed. The AES Lab will then be installed in the altitude chamber.

After installation in the altitude chamber, ECS, cabin leak, and hatch operation tests will be performed prior to evacuating the chamber. The chamber will be evacuated with the Lab unmanned, and ECS functional tests will be performed to demonstrate the capability of the ECS to support manned altitude tests. The structural integrity of the Lab, during emergency re-pressurization of the chamber, will be demonstrated in the unmanned altitude run. The manned altitude tests will demonstrate ECS and Crew Provisions capabilities with a man in the loop. After the manned altitude tests the vehicle will be deserviced and transported to the RFSTF.

3.3.2.3.2 RF System Test Facility. The vehicle will be mounted on the RFSTF three-axis positioner. A communication test with the MSFN will be performed to verify the compatibility between the Lab Communication Subsystem and MSFN. The S-band steerable antenna will be functionally tested, utilizing an S-band source located at some distance from the vehicle, and motion inputs to the positioner. An AGS dynamic test will be performed with the use of the three-axis positioner. The vehicle will be oriented to various positions so that a gross determination of ASA scale factors can be made. Lab EMC and Lab/CSM EMC tests will be performed at the RFSTF. Upon completion of testing at the RFSTF, the vehicle will be transported to the MSOB.

3.3.2.3.3 Manned Spacecraft Operations Building. The Lab will be installed on a workstand in the MSOB. Pyrotechnic circuitry will be verified and the explosive devices (minus initiatrrs) mechanically installed. After thermal shield installation and exterior refurbishment, the Lab will be mated with the CSM/SLA in the SLA stand. For Saturn IB missions, the mated spacecraft (Lab/SLA/Boilerplate CSM) will be transported to LC-37. For Saturn V missions the spacecraft (Lab/SLA/CSM) will be transported to the VAB.

3.3.2.3.4 Vehicle Assembly Building (Saturn V). The Spacecraft (S/C) will be stacked on the Launch Vehicle (LV) which will be in place on the Mobile Launcher (ML) in a high-bay area of the VAB. While integrated tests of the CSM and LV are being performed, checks will be made on the Lab electronic subsystems, and a pressure decay test made on the RCS. EMC checks will be performed on the Lab during the CSM/LV "plugs out" test. The Launch Escape System (LES) will be installed and ML swing arm tests will be performed. The space vehicle will then be moved to the launch pad.

3.3.2.3.5 Launch Pad 39 (Saturn V). The space vehicle will be transported to the launch pad on the ML and placed in position. Range/Space Vehicle RFI tests will be performed before the Mobile Service Structure (MSS) is moved into position. After the MSS is positioned, a checkout of the Lab subsystems will be performed. Lab RF subsystem checks will be performed, using antenna hats and SLA reradiating antennas. Following subsystems verification, the Lab will participate in a flight readiness test and then hypergolic servicing will be accomplished. A countdown demonstration will be performed to verify the capability of accomplishing terminal countdown procedures in the allotted time. EPS flight batteries will be installed. After a final subsystems checkout, all ACE carry-on equipment will be removed from the SLA. Lab pyrotechnic initiators and pyrotechnic batteries will then be installed. Final fluid servicing will be accomplished, and the Lab cabin will be closed out and pressurized. All GSE work platforms will be removed from the SLA and the SLA will be closed out.

3.3.2.3.6 Launch Pad 37B (Saturn IB). The Spacecraft (S/C) will be stacked on the Launch Vehicle (LV) at Launch Pad 37B. The Launch Escape System (LES) will be installed and launch tower swing arm tests will be performed. While integrated tests of the CSM and the LV are being performed, the Lab subsystems will be checked. The service structure will be removed and Range/Spacecraft RFI tests and "plugs out" tests performed. The service structure will be repositioned and pressure decay tests made on the Lab RCS. A countdown demonstration will be performed to verify the capability of accomplishing terminal countdown procedures in the allotted time. The Lab will then participate in the Space Vehicle Simulated Flight. All hypergolic servicing will then be accomplished and EPS flight batteries installed. After a final subsystems checkout, all ACE carry-on equipment will be removed from the SLA. Pyrotechnic initiators and batteries will then be installed. Final fluid servicing will be accomplished, and the Lab cabin will be closed-out and pressurized. All GSE and work platforms will be removed from the SLA and the SLA will be closed-out.

3.3.3. Phase II Lab (Fig. 3.3-1B)

3.3.3.1 Ascent Stage

3.3.3.1.1 Hypergolic Test Building (West Cell). Upon arrival at KSC, the ascent stage will be transported to the West Cell of the HTB where the receiving inspection of the stage will be performed. Checkout and servicing of the ECS Heat Transport Section will be performed to provide coolant capability during subsequent tests. Leak and functional checks will be performed on the RCS, Oxygen Supply and Cabin Pressurization Section, and Water Management Section plumbing. The ascent stage will then be transported to the MSOB.

3.3.3.1.2 Manned Spacecraft Operations Building. After the ascent stage is transported to the MSOB it will be installed in the cleaning fixture, inverted and then moved to the docking fixture for the Lab-CSM docking test. Upon completion of the docking test, the ascent stage will be moved to the cleaning fixture for inversion and Water Management, Heat Transport, and Oxygen Supply and Cabin Pressurization Sections checkout. The ascent stage will then be prepared for mating with the descent stage.

3.3.3.2 Descent Stage

3.3.3.2.1 Storage Area. Upon arrival at KSC, the Lab descent stage will be transported to a storage area where the receiving inspection of the stage will be performed. The Lab descent stage will be stored until required for SLA fit check in the MSOB. No specific area has been designated for storage.

3.3.3.2.2 Manned Spacecraft Operations Building. Upon arrival of the descent stage at the MSOB it will be transported to the SLA stand for a descent stage/SLA fit check. The stage will then be moved to the proper workstand for mating with the ascent stage. The Heat Transport and Water Management Sections of the ECS will be checked prior to mating the descent and ascent stages.

3.3.3.3 Mated Lab

3.3.3.3.1 Manned Spacecraft Operations Building. The ascent stage and descent stage will be mated and transported to the FCSTF.

3.3.3.3.2 Fuel Cell System Test Facility. The Lab will be installed on a checkout stand. Electrical functional checks will be performed on the reactant storage section, including the associated controls and displays. After leakage and mechanical functional checks are performed, the storage section will be serviced with cryogenic fluids and heat leak test performed to establish insulation integrity. Flow checks will be performed without start up of the fuel cells. The vehicle will then be deserviced and transported to the MSOB.

3.3.3.3.3 Manned Spacecraft Operations Building. Upon arrival at the MSOB the Lab will be installed on a checkout stand, and the Heat Transport Section will be leak checked and serviced. The Power Distribution Section and Instrumentation Subsystem capability to support vehicle testing will be verified. Checks will be made to verify Alignment Optical Telescope calibration, and S-Band antenna and experiment alignments. Electrical and Electronic Subsystem tests, GNCS polarity, and experiment verification will be performed.

An integrated GNCS test will be performed wherein all functional flow paths and modes of operation are verified. To demonstrate the ability of the electrical and electronic subsystems to work together as a system, a mission oriented "plugs out" test will be performed. The Lab will then be installed in the altitude chamber.

After installation in the altitude chamber, ECS, cabin, airlock, and hatch leakage and functional tests will be performed prior to evacuating the chamber. The chamber will be evacuated with the Lab unmanned, and ECS functional tests will be performed to demonstrate the capability of the ECS to support manned altitude tests. The structural integrity of the Lab, during emergency re-pressurization of the chamber, will be demonstrated in the unmanned altitude run. The manned altitude tests will demonstrate ECS and Crew Provisions capabilities with a man in the loop. The fuel cells will be operated (with no cryogenic servicing involved) in the altitude chamber concurrently with ECS checkout. Electrical power will be generated to other subsystems simulating critical power distribution requirements, redundant and emergency modes of electrical and control logic. After the manned altitude tests, the vehicle will be deserviced and transported to the RFSTF.

3.3.3.3.4 RF Systems Test Facility. The vehicle will be mounted on the RFSTF three-axis positioner. A communication test with the MSFN will be performed to verify the compatibility between the Lab Communication Subsystem and MSFN. The S-band steerable antenna will be functionally tested, utilizing an S-band source located at some distance from the vehicle and motion inputs to the positioner. An AGS dynamic test will be performed with the use of the three-axis positioner. The vehicle will be oriented to various positions so that a gross determination of ASA scale factors can be made. Lab EMC and Lab/CSM EMC tests will be performed at the RFSTF. Upon completion of testing at the RFSTF, the vehicle will be transported to the MSOB.

3.3.3.3.5 Manned Spacecraft Operations Building. The Lab will be installed on a work stand in the MSOB. The pyrotechnic circuitry will be verified and the explosive devices (minus initiators) mechanically installed. After thermal shield installation, radiator servicing, and exterior refurbishment, the Lab will be mated with the CSM/SLA in the SLA stand. For Saturn IB missions, the mated spacecraft (Lab/SLA/Boilerplate CSM) will be transported to LC-37. For Saturn V missions the spacecraft (Lab/SLA/CSM) will be transported to the VAB.

3.3.3.3.6 Vehicle Assembly Building (Saturn V). The Spacecraft (S/C) will be stacked on the Launch Vehicle (LV) which will be in place on the Mobile Launcher (ML) in a high-bay area of the VAB. While integrated tests of the CSM and LV are being performed, checks will be made on the Lab electronic subsystems, and a pressure decay test made on the RCS. EMC checks will be performed on the Lab during the CSM/LV "plugs out" test. The Launch Escape System (LES) will be installed and ML swing arm tests will be performed. The space vehicle will then be moved to the launch pad.

3.3.3.3.7 Launch Pad 39 (Saturn V). The space vehicle will be transported to the launch pad on the ML and placed in position. Range/Space vehicle RFI tests will be performed before the Mobile Service Structure (MSS) is moved into position. After the MSS is positioned a checkout of the Lab subsystems will be performed. Lab RF Subsystem checks will be performed using antenna hats and SLA reradiating antennas. Following subsystems verification, the Lab will participate in a flight readiness test and then hypergolic servicing will be accomplished. A countdown demonstration will be performed to verify the capability of accomplishing terminal countdown procedures in the allotted time. EPS flight batteries will be installed. After a final subsystems checkout, all ACE carry-on equipment will be removed from the SLA. Servicing of the fuel cell reactant cryogenic storage section and start up of the fuel cells will be accomplished during the final countdown. Lab pyrotechnic initiators and pyrotechnic batteries will then be installed. Final fluid servicing will be accomplished, and the Lab cabin will be closed out and pressurized. All GSE work platforms will be removed from the SLA, and the SLA will be closed out.

3.3.3.3.8 Launch Pad 37B (Saturn IB). The spacecraft will be stacked on the Launch Vehicle (LV) at Launch Pad 37B. The Launch Escape System (LES) will be installed and launch tower swing arm tests will be performed. While integrated tests of the CSM and the LV are being performed, the Lab subsystems will be checked. The service structure will be removed and Range/Spacecraft RFI tests and "plugs out" tests performed. The service structure will be repositioned and pressure decay tests made on the Lab RCS. Fuel cells will be started and operationally checked using ambient reactants, shut down (if required), and then prepared for launch. A countdown demonstration will be performed to verify the capability of accomplishing terminal countdown procedures in the allotted time. The Lab will then participate in the Space Vehicle Simulated Flight. All hypergolic servicing will then be accomplished and EPS flight batteries will be installed. After a final subsystems checkout, all ACE carry-on equipment will be removed from the SLA. Final fluid servicing including fuel cell reactant loading will be accomplished and the Lab cabin will be closed-out and pressurized. Pyrotechnic initiators and batteries will then be installed. All GSE and work platforms will be removed from the SLA and the SLA will be closed out.

3.3.4 Shelter (Fig. 3.3-1C)

3.3.4.1 Ascent Stage

3.3.4.1.1 Hypergolic Test Building (West Cell). Upon arrival at KSC, the ascent stage will be transported to the West Cell of the HTB where the receiving inspection of the stage will be performed. Checkout and servicing of the ECS Heat Transport Section will be performed to provide coolant capability during subsequent tests. Leak and functional checks will be performed on the RCS, Oxygen Supply and Cabin Pressurization Section, and Water Management Section plumbing. The ascent stage will then be transported to the MSOB.

3.3.4.1.2 Manned Spacecraft Operations Building. After the ascent stage is transported to the MSOB, it will be installed in the cleaning fixture, inverted and then moved to the docking fixture, for the Shelter-CSM docking test. Upon completion of the docking test, the ascent stage will be moved to the cleaning fixture for re-inversion and Water Management, Heat Transport, and Oxygen Supply and Cabin Pressurization Sections checkout. The ascent stage will then be prepared for mating with the descent stage.

3.3.4.2 Descent Stage

3.3.4.2.1 Hypergolic Test Building (East Cell). The descent stage will be transported to the East Cell of the HTB where a receiving inspection will be performed. Leak and functional checks will be performed on the propulsion sections. The supercritical helium section will be serviced, and a heat leak check performed to establish insulation integrity. The descent stage will then be transported to the RFSTF.

3.3.4.2.2. RF Systems Test Facility. Upon arrival of the descent stage at the RFSTF, non-flight landing gear will be installed and the stage mounted on the three-axis positioner. The landing radar will be boresighted by comparing electrical beam position with the optical normal. The descent stage will then be removed from the three-axis positioner, the landing gear removed, and the stage transported to the MSOB.

3.3.4.2.3 Manned Spacecraft Operations Building. The descent stage will be transported to the SLA stand for a descent stage/SLA fit check. The stage will then be moved to the proper work stand for mating with the ascent stage. The Heat Transport and Water Management Sections of the ECS will be checked prior to mating the descent and ascent stages.

3.3.4.3 Mated Shelter

3.3.4.3.1 Manned Spacecraft Operations Building. The ascent stage and descent stage will be mated and permanent interstage plumbing connections leak checked. The Shelter will then be transported to the FCSTF.

3.3.4.3.2 Fuel Cell System Test Facility. The Shelter will be installed on a checkout stand. Electrical functional checks will be performed on the reactant storage section, including the associated controls and displays. After leakage and mechanical functional checks are performed, the storage section will be serviced with high-pressure gaseous reactants. Flow checks will be performed without start-up of the fuel cells. The vehicle will then be deserviced and transported to the MSOB.

3.3.4.3.3 Manned Spacecraft Operations Building. Upon arrival at the MSOB the Shelter will be installed on a checkout stand and the Heat Transport Section will be leak checked and serviced. The Power Distribution Section and Instrumentation Subsystem capability to support vehicle testing will be verified. Checks will be made to verify Optical Tracker calibration and Landing Radar (LR) antenna and S-band antenna alignments. Electrical and electronic subsystem tests and GNCS polarity verification will be performed. The up-data link will be functionally checked.

An integrated GNCS test will be performed, wherein all functional flow paths and modes of operation are verified. To demonstrate the ability of the electrical and electronic subsystems to work together as a system, a mission oriented "plugs out" test will be performed. The Shelter will then be installed in the altitude chamber.

After installation in the altitude chamber, ECS, cabin, airlock, and hatch leakage and functional tests will be performed prior to evacuating the chamber. The chamber will be evacuated with the Shelter unmanned, and ECS functional tests will be performed to demonstrate the capability of the ECS to support manned altitude tests. The structural integrity of the Shelter, during emergency re-pressurization of the chamber, will be demonstrated in the unmanned altitude run. The manned altitude tests will demonstrate ECS and Crew Provisions capabilities with a man in the loop. The fuel cells will be operated in the altitude chamber concurrently with ECS checkout. Electrical power will be generated to other subsystems, simulating critical power distribution requirements, and redundant and emergency modes of electrical control logic. In addition, the RTG and associated heat pipe operation will be functionally checked. After the manned altitude tests, the vehicle will be deserviced and transported to the RFSTF.

3.3.4.3.4 Radio Frequency Systems Test Facility. The vehicle will be mounted on the RFSTF three-axis positioner. A communications test with the MSFN will be performed to verify the compatibility between the Shelter Communications Subsystem and MSFN. The S-band steerable antenna will be functionally tested, utilizing an S-band source located at some distance from the vehicle and motion inputs to the positioner. Shelter EMC and Shelter/CSM EMC tests will be performed at the RFSTF. Upon completion of testing at the RFSTF, the vehicle will be transported to the MSOB.

3.3.4.3.5 Manned Spacecraft Operations Building. The Shelter will be installed on a landing gear installation fixture in the MSOB. Flight landing gear will be installed and functionally checked. Pyrotechnic circuitry will be verified and the explosive devices (minus initiators) mechanically installed. After thermal shield installation, radiator servicing, and exterior refurbishment, the Shelter will be mated with the CSM/SLA in the SLA stand. The spacecraft (Shelter/CSM/SLA) will be transported to the VAB after SLA work platform installation and top deck buildup.

3.3.4.3.6 Vehicle Assembly Building. The Spacecraft (S/C) will be stacked on the Launch Vehicle (LV) which will be in place on the Mobile Launcher (ML) in a high-bay area of the VAB. While integrated tests of the CSM and LV are being performed, checks will be made on the Shelter electronic subsystems, and pressure decay tests made on the RCS and Descent Propulsion Subsystem. EMC checks will be performed on the Shelter during the CSM/LV "plugs out" test. The Launch Escape System (LES) will be installed and ML swing arm tests will be performed. The space vehicle will then be moved to the launch pad.

3.3.4.3.7 Launch Pad 39 (Saturn V). The space vehicle will be transported to the launch pad on the ML and placed in position. Range/Space Vehicle RFI tests will be performed before the Mobile Service Structure (MSS) is moved into position. After the MSS is positioned, a checkout of the Shelter subsystems will be performed. Shelter RF subsystem checks will be performed, using antenna hats and SLA re-radiating antennas. Fuel cells will be started and operationally checked using ambient reactants, shut down, and then prepared for launch. Following subsystems verification, the Shelter will participate in a flight readiness test and then hypergolic servicing will be accomplished. A countdown demonstration will be performed to verify the capability of accomplishing terminal countdown procedures in the allotted time. EPS flight batteries will be installed. After a final subsystems checkout, all ACE carry-on equipment will be removed from the SLA. Shelter pyrotechnic initiators and pyrotechnic batteries will then be installed. Final fluid servicing including fuel cell reactants will be accomplished, and the Shelter cabin will be closed out and pressurized. The RTG will be fueled, all GSE work platforms removed from the SLA, and the SLA will be closed out.

3.3.5 Taxi (Fig. 3.3-1D)

3.3.5.1 Ascent Stage

3.3.5.1.1. Hypergolic Test Building (West Cell). Upon arrival at KSC the ascent stage will be transported to the West Cell of the HTB where the receiving inspection of the stage will be performed. Checkout and servicing of the ECS Heat Transport Section will be performed to provide coolant capability during subsequent tests. Leak and functional checks will be performed on the RCS, Ascent Propulsion, Oxygen Supply and Cabin Pressurization Section, and Water Management Section plumbing. The ascent stage will then be transported to the MSOB.

3.3.5.1.2 Manned Spacecraft Operations Building. After the ascent stage is transported to the MSOB it will be installed in the cleaning fixture, inverted and then moved to the docking fixture, for the Taxi-CSM docking test. Upon completion of the docking test, the ascent stage will be moved to the cleaning fixture for inversion and Water Management, Heat Transport, and Oxygen Supply and Cabin Pressurization Sections checkout. The ascent stage will then be prepared for mating with the descent stage.

3.3.5.2 Descent Stage

3.3.5.2.1 Hypergolic Test Building (East Cell). The descent stage will be transported to the East Cell of the HTB where a receiving inspection will be performed. Leak and functional checks will be performed on the Propulsion Sections. The supercritical helium section will be serviced, and a heat leak check performed to establish insulation integrity. The descent stage will then be transported to the RFSTF.

3.3.5.2.2 RF Systems Test Facility. Upon arrival of the descent stage at the RFSTF, non-flight landing gear will be installed and the stage mounted on a three-axis positioner. The landing radar will be boresighted by comparing electrical beam position with the optical normal. The descent stage will then be removed from the three-axis positioner, the landing gear removed, and the stage transported to the MSOB.

3.3.5.2.3 Manned Spacecraft Operations Building. The descent stage will be transported to the SLA stand for a descent stage/SLA fit check. The stage will then be moved to the proper work stand for mating with the ascent stage. The Heat Transport and Water Management Sections of the ECS will be checked prior to mating the descent and ascent stages.

3.3.5.3 Mated Taxi

3.3.5.3.1 Manned Spacecraft Operations Building. After mating, the Heat Transport Section will be leak checked and serviced. The Power Distribution Section and Instrumentation Subsystem capability to support vehicle testing will be verified. Checks will be made to verify Alignment Optical Telescope calibration and Rendezvous Radar (RR) antenna, Landing Radar (LR) antenna, and S-band antenna alignments. Electrical and electronic subsystem tests and GNCS polarity verification will be performed.

An integrated GNCS test will be performed wherein all the functional flow paths and modes of operation are verified. To demonstrate the ability of the electrical and electronic subsystems to work together as a system, a mission oriented "plugs out" test will be performed. The Taxi will then be installed in the altitude chamber.

After installation in the altitude chamber, ECS, cabin, and hatch functional and leakage tests will be performed prior to evacuating the chamber. The chamber will be evacuated with the Taxi unmanned, and ECS functional tests will be performed to demonstrate the capability of the ECS to support manned altitude tests. The structural integrity of the Taxi, during emergency re-pressurization of the chamber, will be demonstrated in the unmanned altitude run. The manned altitude tests will demonstrate ECS and Crew Provisions capabilities with a man in the loop. In addition, the RTG and associated heat pipe operation will be functionally checked. After the manned altitude tests, the vehicle will be deserviced and transported to the RFSTF.

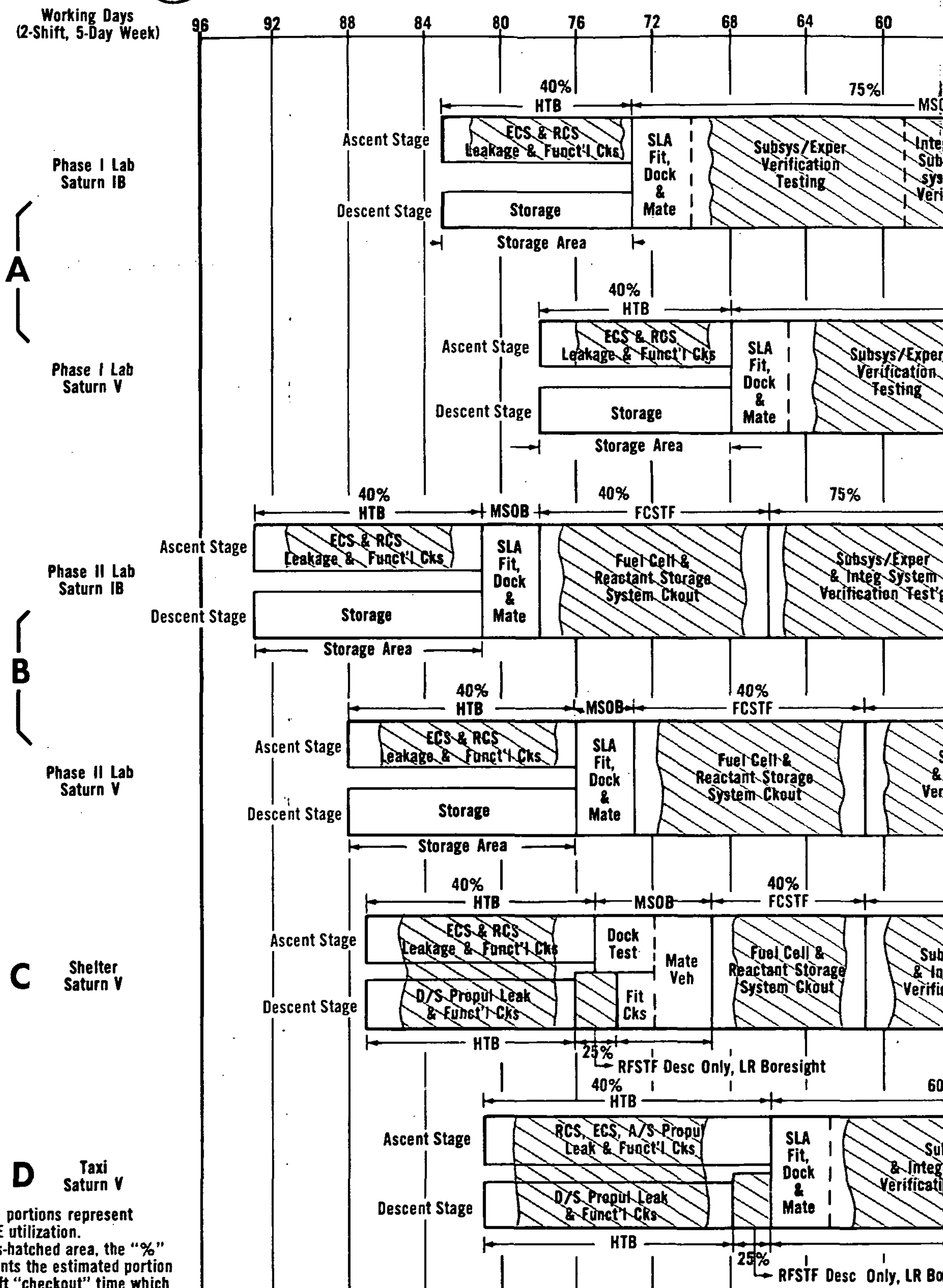
3.3.5.3.2 RF Systems Test Facility. The vehicle will be mounted on the RFSTF three-axis positioner. A communications test with the MSFN will be performed to verify the compatibility between the Taxi Communications Subsystem and MSFN. The S-band steerable antenna will be functionally tested, utilizing an S-band source located at some distance from the vehicle and motion inputs to the positioner. An AGS dynamic test will be performed with the use of the three-axis positioner. The vehicle will be oriented to various positions so that a gross determination of ASA scale factors can be made. The Taxi will be optically aligned to the signal source at the far end of the range and Rendezvous Radar pointing accuracy and tracking tests performed. At the completion of testing at the RFSTF, the vehicle will be transported to the MSOB.

3.3.5.3.3 Manned Spacecraft Operations Building. The Taxi will be installed on a landing gear installation fixture in the MSOB. Flight landing gear will be installed and functionally checked. Pyrotechnic circuitry will be verified and the explosive devices (minus initiators) mechanically installed. After thermal shield installation and exterior refurbishment, the Taxi will be mated with the CSM/SLA in the SLA stand. The spacecraft (Taxi/CSM/SLA) will be transported to the VAB after SLA work platform installation and top deck buildup.

3.3.5.3.4 Vehicle Assembly Building. The Spacecraft (S/O) will be stacked on the Launch Vehicle (LV) which will be in place on the Mobile Launcher (ML) in a high-bay area of the VAB. While integrated tests of the CSM and LV are being performed, checks will be made on the Taxi electronic subsystems, and pressure decay tests made on the RCS and Propulsion subsystems. EMC checks will be performed on the Taxi during the CSM/LV "plugs out" test. The Launch Escape System (LES) will be installed and ML swing arm tests will be performed. The space vehicle will then be moved to the launch pad.

3.3.5.3.5 Launch Pad 39 (Saturn V). The space vehicle will be transported to the launch pad on the ML and placed in position. Range/Space Vehicle RFI tests will be performed before the Mobile Service Structure (MSS) is moved into position. After the MSS is positioned, a checkout of the Taxi subsystems will be performed. Taxi RF subsystem checks will be performed using antenna hats and SLA reradiating antennas. Following subsystems verification, the Taxi will participate in a flight readiness test and then hypergolic servicing will be accomplished. A countdown demonstration will be performed to verify the capability of accomplishing terminal countdown procedures in the allotted time. EPS flight batteries will be installed. After a final subsystems checkout, all ACE carry-on equipment will be removed from the SLA. Taxi pyrotechnic initiators and pyrotechnic batteries will then be installed. Final fluid servicing will then be accomplished, and the Taxi cabin will be closed out and pressurized. All GSE work platforms will be removed from the SLA, and the SLA closed out.

39



Notes: 1. Cross-hatched portions represent periods of ACE utilization.
2. For each cross-hatched area, the "%" figure represents the estimated portion of the two-shift "checkout" time which will require ACE.

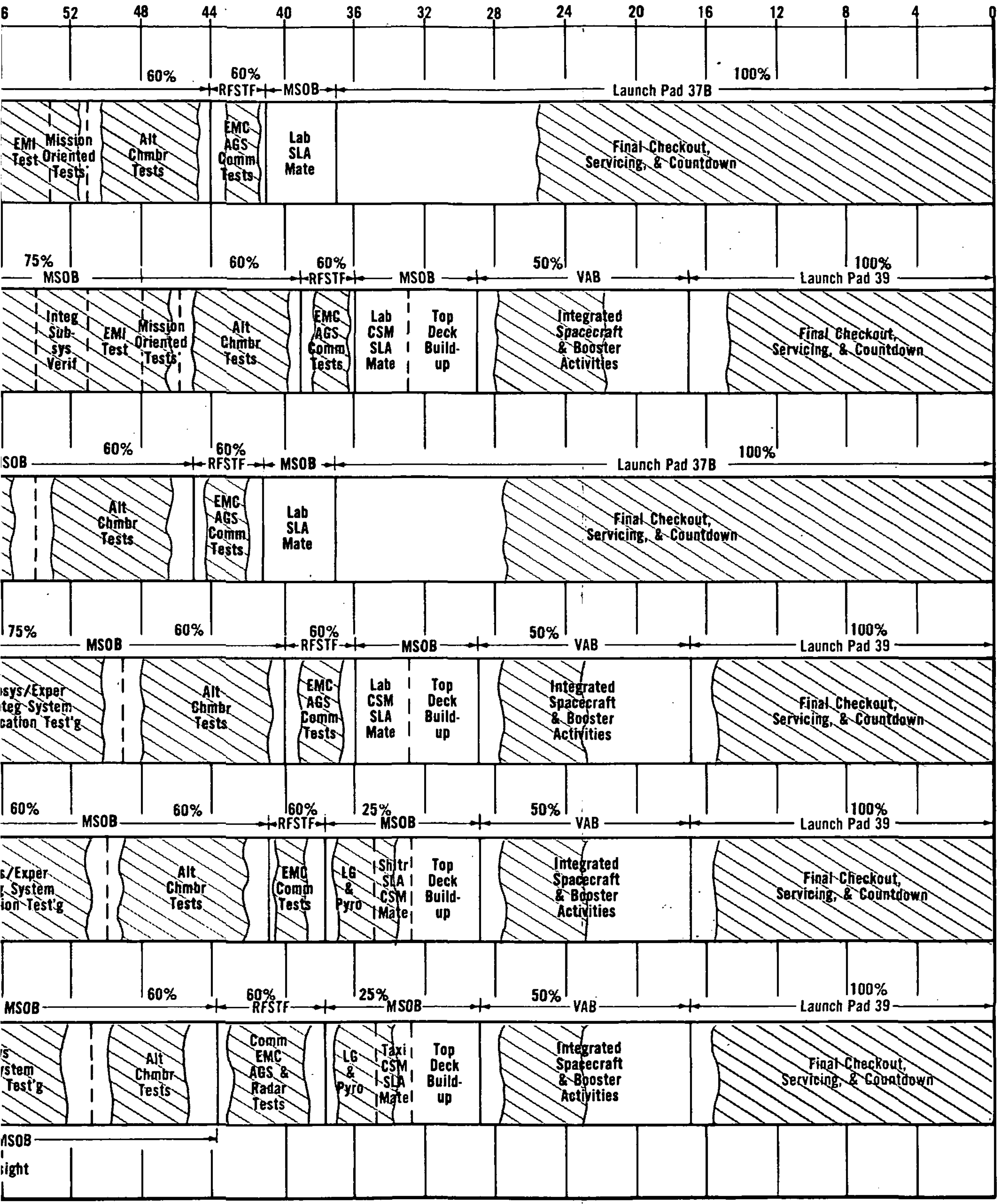


Fig. 3.3-1 KSC Facility/AES Vehicle Flows

3.4 PRELAUNCH OPERATIONS SCHEDULE

The integrated schedule of AES-LEM prelaunch operations at KSC is presented in Fig. 3.4-1. The schedule is made up of the operations flows of each of the four basic AES-LEM vehicles shown in Fig. 3.3-1 and discussed in Paragraphs 3.3.2 (Phase I Lab), 3.3.3 (Phase II Lab), 3.3.4 (Shelter), and 3.3.5 (Taxi). The overall flow is based on the launch schedule of Ref. 4-7 and maximum use of existing and currently planned Apollo facilities and GSE. The KSC modification time for the Phase I Labs is shown for reference only. Discussion of manufacturing and modification time is found in the Manufacturing Plan, Vol XVII. The Apollo LEM checkout spans are shown for reference purpose only, and are based on Ref. 4-6.

3.4.1 Assumptions

The preliminary prelaunch schedule and planning analysis reflects a number of basic assumptions. The major assumptions affecting vehicle and checkout facility scheduling are as follows:

a. For planning purposes the Launch Complex (LC) assignments are:

Saturn V Flights:	LC 39
Saturn IB LEM Lab Flights:	LC 37B
Saturn IB CSM Flights:	LC 34

b. The checkout times shown for LC 37B and 39 are based on Launch Vehicle (LV) checkout requirements. The spacecraft checkout (CSM/AES LEM) is performed concurrently with LV operations.

c. Checkout scheduling is based on a two-shift work-day, 5-day work week, and 22-work-day month.

d. To avoid simultaneous checkout operations (100% overlap) between two AES-LEM spacecraft, and to avoid simultaneous launches of two manned spacecraft, the dual launch rendezvous missions are scheduled so that the Lab is launched at the end of the month and the respective CSM is launched at the beginning of the next month as follows:

214 LEM Lab I	End of June 1969
215 CSM	Beginning of July 1969
216 LEM Lab I	End of October 1969
217 CSM	Beginning of November 1969
218 LEM Lab II	End of April 1970
219 CSM	Beginning of May 1970
220 LEM Lab II	End of June 1970
221 CSM	Beginning of July 1970
224 LEM LAB II	End of February 1971
225 CSM	Beginning of March 1971

For the same reasons, the triple launch mission is scheduled as follows:

523 CSM/LEM Lab II	Mid August 1971
228 LEM Lab II	End of September 1971
229 CSM	Beginning of October 1971

Saturn V launches (with the exception of 523) are assumed at the beginning of the month.

e. As a goal, all vehicle/experiment comprehensive testing will be accomplished in the Manned Spaceflight Operations Building (MSOB). However, it is recognized that specific exceptions may require other facilities such as the Hypergolic Test Building (HTB), and the RF Systems Test Facility (RFSTF).

f. All experiments are installed before integrated testing.

g. It is assumed that the Phase I Labs have not been cycled through any part of the prelaunch checkout flow before the start of KSC modification.

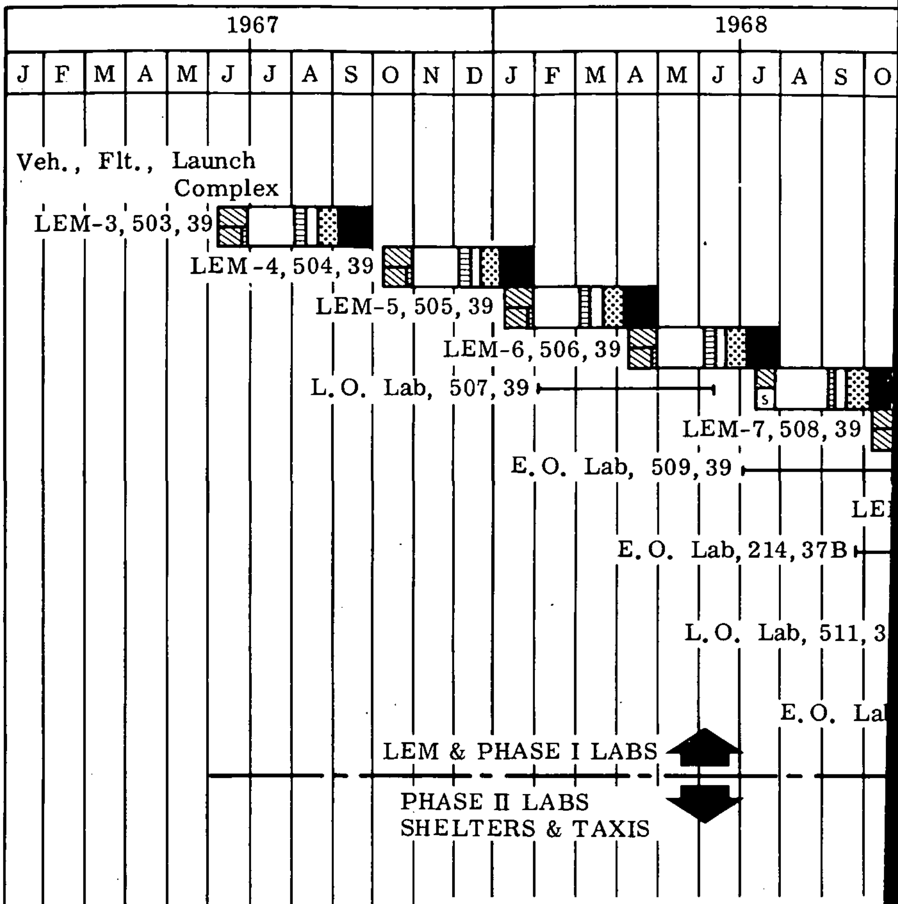
h. The requirement for modification of the Phase I Labs at KSC necessitates the demonstration of vehicle subsystem compatibility while operating as a system. This will be accomplished in the MSOB in three parts:

Integrated Subsystem Verification
Electro-Magnetic Interference (EMI) Verification
Mission Oriented Tests

The total Phase I Lab MSOB checkout will be longer than the Phase II Lab MSOB checkout as a result of this integrated subsystems compatibility verification. (For the Phase II Lab, this will have been accomplished before the Lab leaves Bethpage).

i. Stage mating can only be performed in the MSOB.

j. Weight and cg of the Phase I Labs will be determined during the manufacturing modification period at KSC. Weight and cg of the Phase II Labs will be determined at Bethpage.



Prelaunch Checkout Time Spans		
AES S/C	Saturn Launch Vehicle	Worki Days
Phase I Lab	IB V	83 78
Phase II Lab	IB V	93 88
Shelter	V	87
Taxi	V	81

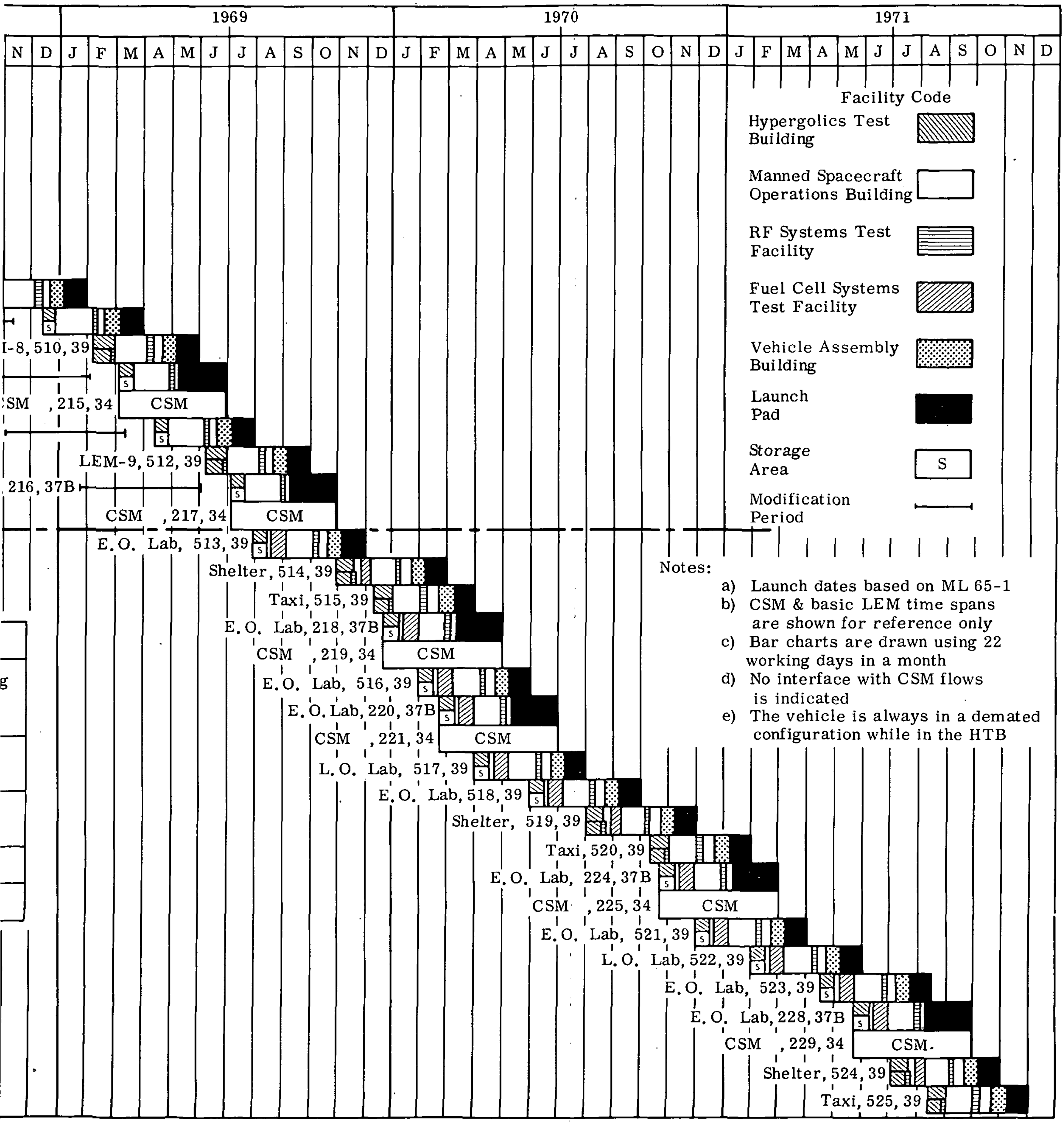


Fig. 3.4-1 Prelaunch Operations Schedule

3.5 CHECKOUT REQUIREMENTS AT KSC

The checkout operations for the AES-LEM vehicles (Paragraph 3.3) will use the existing Saturn/Apollo checkout facilities, Acceptance Checkout Equipment (ACE) and Ground Support Equipment (GSE). Additional requirements for checkout are the result of the high launch rates (Paragraph 3.4) and the AES-LEM modifications to the basic LEM configuration.

This paragraph describes the existing checkout facilities and discusses the facility, ACE, and GSE requirements resulting from the AES-LEM configurations and launch schedule.

3.5.1 Facility Description

The AES-LEM checkout functions are performed in the facilities of the KSC Industrial area and Saturn Launch complexes, specifically:

a. Manned Spacecraft Operations Building (MSOB)
b. Hypergolics Test Building (HTB)
c. RF Systems Test Facility (RFSTF)
d. Fuel Cell Systems Test Facility (FCSTF)
e. Launch Complex 39 (Vehicle Assembly Building and Launch Pads) or Launch Complex 37 (Launch Pad 37B).

3.5.1.1 Manned Spacecraft Operations Building (MSOB)

The MSOB, with the LEM addition, will be the central area for Apollo LEM checkout and maintenance, and will provide space for engineering and administration personnel. The major areas within the building are:

a. ACE and Data Facility - Data Processing (off-line) and ACE Stations (Computer Rooms, Control Rooms, and Terminal Facility Rooms)
b. Altitude Chamber - Simulates altitude conditions for spacecraft systems checkout. The chamber is capable of achieving an altitude of 250,000 ft within 1 hour, returning to sea level in 150 sec. in an emergency, and returning to sea level from 250,000 ft in 16 min. normal operation.
c. Assembly and Test (A&T) Area - Polarity fixture, A/S & D/S work stands, and checkout equipment for LEM system checkout
d. Instrumentation Calibration Laboratory - Calibration of flight and test instrumentation
e. Integrated-Test Area (ITA) - (SLA stand and landing gear installation fixture) fit checks, stacking, and landing gear installation
f. Maintenance Areas - Laboratories and bench maintenance equipment for scheduled and unscheduled maintenance:
   - Battery Laboratory
   - Communications/Radar Laboratory
   - ECS Laboratory
   - EPS Laboratory
   - Modification Shop
   - S&C Laboratory
g. Photography Laboratory - Photographic processing support
h. Propellant Gaging Laboratory - Calibration & maintenance of propellant quantity gaging systems (PQGS)

i. S-Band and UHF Electronics Laboratory - Support of scheduled open-loop (RF link) and closed-loop (hardline) checkout tests of LEM communications.
j. Spare Part and Tool Room - Hand tools required for LEM checkout and shelf-type spare parts.

3.5.1.2 Hypergolics Test Building (HTB)

The facility has two test cells (East Cell and West Cell) for conducting LEM Ascent Propulsion, Descent Propulsion, and RCS functional and leakage checks, and gas cold-flow operation. The facility has the capability for supporting substitute-propellant cold-flow operations. The control room in the HTB affords a centralized control station for directing tests in the East and West Test Cells, provides continuous data recording equipment and ACE interleaving equipment for Propulsion, RCS, and supporting subsystems under test.

3.5.1.3 RF Systems Test Facility (RFSTF)

The RFSTF will provide the facilities required to perform test and alignment checks of AES-LEM radiative equipment. The facility consists of a two-story control building and a 50-ft wooden tower, 1000 ft away from the control building, with a specially prepared strip between the two. The Control Building houses most of the GSE required to perform the RF subsystem tests. A three-axis positioner for the LEM vehicle will permit orientation of the AES-LEM antennae toward the tower at the opposite end of the range, while a control console in the building will permit remote control of antenna position at the down-range tower.

The strip between the Control Building and tower is a wide grass strip, graded level to control ground reflections. The strip and surrounding area will be free of any signal reflecting discontinuities.

The Range Tower is a rigid, wooden structure, used to support receiving and transmitting antennae. Optical targets used for sighting and calibration of AES-LEM antennae and GNCS components will also be located here. Signal sources for the radars will be housed at the tower and feed horns will be mounted on a movable carriage, the position of which is servo controlled from the Control Building.

3.5.1.4 Fuel Cell Systems Test Facility

This facility is not used in the basic LEM prelaunch checkout. However, for the Phase II Lab and Shelter configurations using fuel cells for electrical power generation, an existing FCSTF will provide the area for checkout of the fuel cell and reactant storage systems.

An LO_2 pad and LH_2 pad for reactant servicing equipment are located at a safe distance from the test cell and from each other. The facility incorporates a fuel-cell pre-installation acceptance laboratory to provide the capability for fuel cell replacement and unscheduled maintenance. An equipment room will be provided for protection of GSE and ACE items which are not designed to operate in a hydrogen-hazardous environment.

3.5.1.5 Launch Complex 39 (VAB and Pad)

3.5.1.5.1 Vehicle Assembly Building (VAB). The VAB will permit simultaneous stacking of four Apollo spacecraft to Saturn V launch vehicles in a vertical position. Buildings within the main structure will provide individual office and work area for each space vehicle assembly. Enclosed, air conditioned, work platforms that move vertically along the inside walls of the VAB telescope in and out to permit working on any point of the space vehicle. Heavy duty cranes and hoists within the VAB will facilitate stacking operations. The fully assembled Space Vehicle (S/V) and Mobile Launcher (ML) will be moved intact in a vertical position to the launch pad on a tractor-crawler.

3.5.1.5.2 Launch Pads 39A and 39B. The S/V will be transported to the Launch Pad on the ML and placed in position on the pedestal. A work platform will be provided on the Mobile Service Structure (MSS) at the LEM level. This work platform will be used to gain access through the SLA to the LEM, and it will also be used to support GSE that must be near the spacecraft. Prior to launch, the MSS is moved away from the space vehicle and ML by the tractor-crawler. The ML is designed to withstand the launch environment.

3.5.1.6 Launch Complex 37B

As part of the basic Apollo Program, Complex 37B will be configured to support a Saturn IB launch of a LEM and CSM. Pad 37B is equipped with a pedestal, Mobile Service Structure umbilical tower and ground control station. This facility will be utilized for the Phase I and II Lab-CSM Boilerplate flights. (Pad 34, as in the Apollo Program, will be in the configuration to support the manned CSM launches which rendezvous with the unmanned Saturn IB-launched Labs.)

3.5.2 Facility Requirements

The preliminary facility requirements are based on the prelaunch checkout operations discussed in Paragraph 3.3 and the schedule presented in Paragraph 3.4. The requirements for the facilities described in Paragraph 3.5.1 are discussed in the following paragraphs.

3.5.2.1 Assumptions

a. The overlap in KSC prelaunch checkout operations for the different AES-LEM vehicles is based upon the following nominal checkout time spans (Paragraph 3.3) and KSC modification time spans (Vol. XVII):

	Time (months)
- Basic LEM C/O	3-2/3
- Phase I Lab Modification at KSC	4-1/4
- Phase I Lab C/O (Sat. IB)	3-3/4
- Phase I Lab C/O (Sat. V)	3-1/2
- Phase II Lab C/O (Sat. IB)	4-1/4
- Phase II Lab C/O (Sat. V)	4
- Shelter C/O	4
- Taxi C/O	3-2/3

b. Storage facility is not identified as a particular building.

c. The requirements for the Phase I Lab modification are assumed to be satisfied:

- At a facility other than one which is presently planned for checkout, or
- By modification (or expansion) of one of the existing or currently planned KSC facilities.

d. As part of the basic Apollo Program, Launch Pad 37B will be configured to support a Saturn IB launch of a LEM/CSM Boilerplate (Ref. 4-1.) and Launch Pad 34 will be configured to support a Saturn IB launch of a manned CSM without LEM.
e. The facility "turnaround" time relative to spacecraft operations is estimated to be 1 month for Launch Pad 37B and 15 days for Launch Pad 39.
f. All LEM and AES-LEM vehicles will be checked for EMC in the Bethpage shielded chamber before shipment to KSC.
g. Background EMI noise levels in the unshielded KSC facilities will be sufficiently high and variable to mask potential EMC problems.

3.5.2.2 General Requirements

LEM/AES-LEM vehicle loading through the KSC facilities is shown in Fig. 3.5-1. When only one stage (ascent or descent) is in a given facility, the figure indicates a half vehicle. The KSC facilities presently planned for the Apollo Program (Paragraph 3.5.1) will be used to satisfy the requirements of the AES-LEM checkout with the additions noted below.

3.5.2.2.1 Hypergolic Test Building (HTB). The HTB presently configured to support an Apollo LEM ascent stage in one cell and a descent stage in the other cell will meet the requirements of AES-LEM vehicle Propulsion and RCS checkout. The HTB loading shown in Fig. 3.5-1 indicates overlap of the Taxi ascent and descent stages and Phase II Lab descent stage in December 1969 and October 1970. Since the overlap is approximately 1 week, the problem may be amenable to schedule adjustments.

3.5.2.2.2 RF Systems Test Facility (RFSTF). The requirements for a RFSTF at KSC, as described in Paragraph 3.5.1 are based on the prelaunch checkout operations discussed in Paragraph 3.2. The checkout operations that must be performed at such a facility because of subsystem requirements are:

a. RR pointing accuracy
b. RR tracking accuracy and antenna stabilization
c. LR boresighting
d. AGS dynamic testing
e. S-band antenna functional testing
f. X-Y scanner functional checkout
g. AES-LEM/CSM EMC checkout
h. Required experiment checkout

3.5.2.2.3 Fuel Cell Systems Test Facility (FCSTF). This existing facility is not presently required by the Apollo Program LEM. The Phase II Labs and Shelters will require the facility as described in Paragraph 3.5.1 for checkout of the fuel cells and reactant storage systems. The checkout operations, as discussed in Paragraph 3.3, require that the facility be capable of supporting:

a. Leakage and functional checks of fuel cell and reactant storage systems.
b. Liquid hydrogen and liquid oxygen servicing of Phase II Lab reactant storage.
c. High-pressure gaseous hydrogen and oxygen servicing of Shelter reactant storage.
d. Functional flow checks of the fuel cells systems.

As presently planned, the fuel cells will not be started in the FCSTF as part of the fuel cell checkout operation in this facility. The fuel cells will be operated in the Altitude Chamber (MSOB) and Launch Pad.

3.5.2.2.4 Manned Spacecraft Operations Building (MSOB). The MSOB, as described in Paragraph 3.5.1, requires an addition of an EMC shielded chamber and modification of the altitude chamber. The shielded chamber is necessary to demonstrate the EMC characteristics of each Phase I Lab after KSC modification and integration of experiments. This recommendation is based on:

a. The relatively high and variable ambient EMI levels at the KSC testing facilities.
b. Low Lab communication circuit margins under operating conditions.
c. Detection and correction of EMC anomalies not determined in the development program due to manufacturing differences.
d. Verification of the absence of all EMC anomalies that were detected during development testing.

Ambient EMC testing is unacceptable due to the high and variable EMI levels that will be found at the KSC test facilities. This background EMI will mask some of the EMC problems while inducing others. The result of EMC testing in an uncontrolled environment will be an increase in testing time and the consequent possibility of schedule impact without any further assurance of having a compatible vehicle. The Phase I Lab EMC testing is in line with the present LEM test approach and the AES test philosophy for Phase II Labs, Taxi, and Shelter since these three vehicles will undergo EMC testing in a shielded chamber at Bethpage.

The altitude chamber requires modification so that the fuel cells of the Phase II Lab and Shelter can be started and operated using facility supplied gaseous reactants.

Fig. 3.5-1 indicates that, for short periods of time (1 week or less), three vehicles are in the MSOB at one time; and that, for periods of 1 to 2 weeks, two vehicles are in the MSOB at one time. In all of these instances, no two vehicles require the same checkout area at the same time except during AES-LEM/SLA fit check and AES-LEM/CSM mating functions which are normally accomplished in the SLA stand located in the CSM checkout area. This potential problem may be solved by the eventual elimination of the requirement for the fit check or by relocating equipment, necessary for the fit check, from the SLA stand to another available stand.

3.5.2.2.5 Launch Complex. Since no more than one AES-LEM vehicle is in the VAB at one time, no changes to the facility, as presently planned for the Apollo Program, are required. The time span between LC 39 single-pad operations is greater than 30 days with two exceptions: between the launch of 524 Shelter and pad arrival of 515 Taxi, and between the launch of 524 Shelter and pad arrival of 525 Taxi. The time spans involved are less than 15 days; however, the two Saturn V launch pads at Complex 39 can satisfy the launch schedule. The time span between the launch of 218 Lab and arrival at the pad of 220 Lab is less than 1 month and, therefore, an area to be further studied. Since significant overlap in operations exists between the launch pad of Complex 37 and the launch pad(s) of Complex 39, sharing of GSE between these complexes will be limited.

3.5.3 Acceptance Checkout Equipment (ACE) Requirements

A requirement for four ACE stations to support the AES-LEM vehicles is indicated by the density of vehicles at KSC; i.e., by combination of pre-launch checkout time, launch schedule, and different vehicle/mission combinations of the Apollo LEM, Phase I Lab, Phase II Lab, Shelter, and Taxi.

3.5.3.1 Assumptions

a. No variations in the planned launch rates nor vehicle flows are considered.
b. No contingencies are considered.
c. Validation of KSC ACE programming is performed at the KSC ACE facilities.
d. A nominal ACE turnaround time of 3 weeks is assumed for station reconfiguration and internal checkout, software verification, and checkout of ACE peripheral equipment.
e. One ACE station is capable of supporting only one vehicle at one facility (or test station) at one time.
f. When a facility-vehicle requirement is within the program and configuration of an ACE station, switching time between facilities or between vehicles is negligible.
g. While an ACE station is supporting launch pad operation, it will not be used for any other operations.
h. No consideration is given to concurrent sharing of an ACE station between "LEM" and "CSM" function.
i. Each vehicle will have its own set of ACE carry-on equipment.

3.5.3.2 Requirements

Two different viewpoints were considered in the determination of requirements:

a. Orienting the ACE station(s) to satisfy the general requirements established by facility (or group of facilities) usage and,
b. Orienting the ACE station(s) to satisfy the general requirements established by a vehicle/mission combination.

The ACE loading presented, one of many possible combinations of a and b, illustrates the nature of the problems that may arise in optimizing ACE utilization. The indication, nevertheless, of a total of four ACE stations for Grumman use, is apparent throughout the loading study.

Fig. 3.5-2 presents an estimated percentage of ACE utilization in each facility during the KSC checkout cycle for each of the AES vehicles. The estimates were based on the present LEM Ground Operations Requirements Plan (Ref. 4-6) and the vehicle flows presented in Paragraph 3.3. The cross-hatched portions of each flow in Fig. 3.5-2 represent periods of ACE utilization, whereas the "open" areas indicate no ACE utilization. The "percentage figures" for each cross-hatched area represent the estimated portion of the two-shift day "checkout" time which will require ACE. This figure does not assume ACE setup time nor does it assume the distribution of ACE utilization within the open area. Third-shift operation is reserved for ACE maintenance.

Fig. 3.5-3 presents the ACE station utilization in relation to the KSC prelaunch operations and manufacturing schedule of the LEM and AES-LEM vehicles. The ACE utilization (approximately 1 month) during the KSC manufacturing cycle of Phase I Labs, based on the Manufacturing Plan, is assumed for subsystem build-up verification. Each ACE station is identified by a letter, and the utilization time is represented by the length of the arrows. The extension of the arrow to the left of the checkout cycle indicates the 3-week period for station "turnaround". Several times in the flow, ACE sharing between vehicle/facility combinations is assumed (and noted in the figure) rather than requiring an additional ACE station.

Fig. 3.5-4 summarizes the ACE loading by relating it to the vehicle and facility loading discussed in Paragraph 3.5.2. Utilization of four ACE stations is indicated from early 1969 through early 1971. Continuous four-station utilization is indicated from January to June of 1970. This ACE station loading is generated predominantly by the density of vehicles and the different configurations of these vehicles. The modification cycle for Phase I Labs requires that the additional ACE station(s) are necessary sooner in the AES schedule time span than would be necessary if no modification at KSC were accomplished.

3.5.4 Ground Support Equipment (GSE) Requirements

The GSE requirements to implement the prelaunch checkout are based on the checkout functions, AES vehicle configurations, and KSC facilities.

3.5.4.1 Assumptions

a. The following activities are prerequisite to any given checkout function:

  - Power distribution verification
  - Instrumentation turn on and verification
  - Cabin entry (and closeout)
  - Heat transport (HTS) servicing

b. One set of ACE carry-on equipment is with each vehicle throughout the checkout cycle.
c. Power supplies (ac and dc) are a function of facility.
d. The pressure maintenance unit (all AES-LEM vehicles), IMU portable temperature controller (Shelter and Taxi), and ASA portable temperature controller (Phase I Lab, Phase II Lab, and Taxi) are always with a given vehicle.
e. The Instrumentation Subsystem of the Phase I Labs will be calibrated in the LEM instrumentation lab area located in the MSOB.
f. Requirements generated by unscheduled maintenance, Phase I Lab manufacturing at KSC, and ACE utilization are not shown in Fig. 3.5-5.
g. The figure also does not indicate the order or sequence of checkout functions within a given facility nor the order in which the facilities will be used.

3.5.4.2 Equipment Requirements

Fig. 3.5-5 summarizes the basic requirement for ground support equipment generated by the prelaunch operations at KSC for AES-LEM vehicles. These requirements, related to each facility and to the checkout functions within these facilities, are presented in a matrix format. Each major block, which is further subdivided into quadrants, relates the GSE requirements to the vehicle, facility, checkout function, and estimated extent of change from presently planned LEM GSE. The quadrants relate to the AES vehicles as follows:

a. Upper left-hand corner: Phase I Lab
b. Upper right-hand corner: Phase II Lab
c. Lower left-hand corner: Shelter
d. Lower right-hand corner: Taxi

a	b
c	d

The "extent of change" of the required GSE compared to the presently planned LEM equipment is identified as follows:

■ The checkout function is the same as presently planned for the current LEM, and the equipment which is planned to satisfy the LEM requirement will satisfy the AES-LEM requirement.

◧ The checkout function is basically the same as presently planned for the current LEM; however, the equipment which is planned to satisfy the LEM requirements may have to be modified to extend its capacity; e.g., greater capacity in fluid storage carts, greater load capacity for handling equipment and support stands, and/or greater heat sink capacity in cooling equip equipment.

□ The checkout function is unique to AES-LEM configurations, i.e., to subsystems which have major additions or modifications.

3.5.4.3 Scheduling Requirements

Review of Fig. 3.5-5 indicates that the majority of the AES-LEM requirements may be met by using the first two categories. New equipment (based on what is now available for LEM) is required for checkout and servicing of: fuel cell systems (Mid 1969), cryogenic systems (Mid 1969), RTG systems (Late 1969), CSM crew provisions (Late 1969). Radiator systems (Late 1969), beacon transponder (Early 1970).

The requirement for a shielded chamber at KSC for Phase I Lab EMC verification (Paragraph 3.5.2) necessitates the use of additional antenna for coupling RF energy into the chamber. Standard EMI test equipment (i.e., field strength meters, etc.) will also be required for the proper conduct of the EMC verification testing.

The quantity of equipment required will be dependent on the functional requirments as indicated in the chart and the vehicle/facility density (Fig.3.5.1). Two areas of particular concern, indicated by Paragraph 3.5.2, are the MSOB and Launch Complexes. The density of vehicles through these areas and turn-around time of the launch pads will limit the degree of sharing equipment between facilities, between vehicles and between launch complexes. The Mobile Launcher (ML) may be particularly affected in that another ML is required to be configured with duplicate sets of operational equipment to support the launches of the Shelter and Taxi missions scheduled for the early part of 1970 and latter part of 1970 and latter part of 1971 (Fig. 3.4-1).

Prelaunch operations analysis indicates that the following equipment is required in an operationally ready condition during the noted time periods:

a. Communications Checkout Stations to support three vehicles at one time (Mid 1969).
b. Radar checkout equipment to support Shelter-Taxi Scheduling (Early 1970).
c. Power Distribution Section checkout equipment to support three vehicles (Early 1969).

d. Ascent stage handling or mated-vehicle handling equipment to support three AES vehicles at one time (Mid 1969).
e. Descent stage handling and transportation equipment to handle two AES vehicles at one time (Early 1969).
f. Fuel cell system checkout and servicing equipment to support fuel cell checkout (Mid 1969).
g. Propulsion/RCS servicing and checkout equipment to support propulsion/RCS checkout in both cells of the HTB and to support propulsion servicing on LC 37B and LC 39 at one time (Mid 1969).
h. Fuel cell checkout and servicing equipment to support countdown on LP 37B concurrent with checkout operations in the altitude chamber and FCSTF (Early 1970).
i. Vehicle cooling equipment to support the vehicles in the MSOB, in the HTB, in the FCSTF and on LP 39 concurrently (Early 1970).
j. ECS servicing and checkout equipment for LP 37B, LP 39 and altitude chamber at the same time (Late 1969).
k. Pressure maintenance units to support each vehicle at all facilities.
l. The IMU and ASA Portable Temperature Controllers to maintain continuous thermal environment for the IMU and ASA at all times.
m. Calibration equipment for the Instrumentation Subsystem of the Phase I Labs at KCS will (Mid 1968).

55

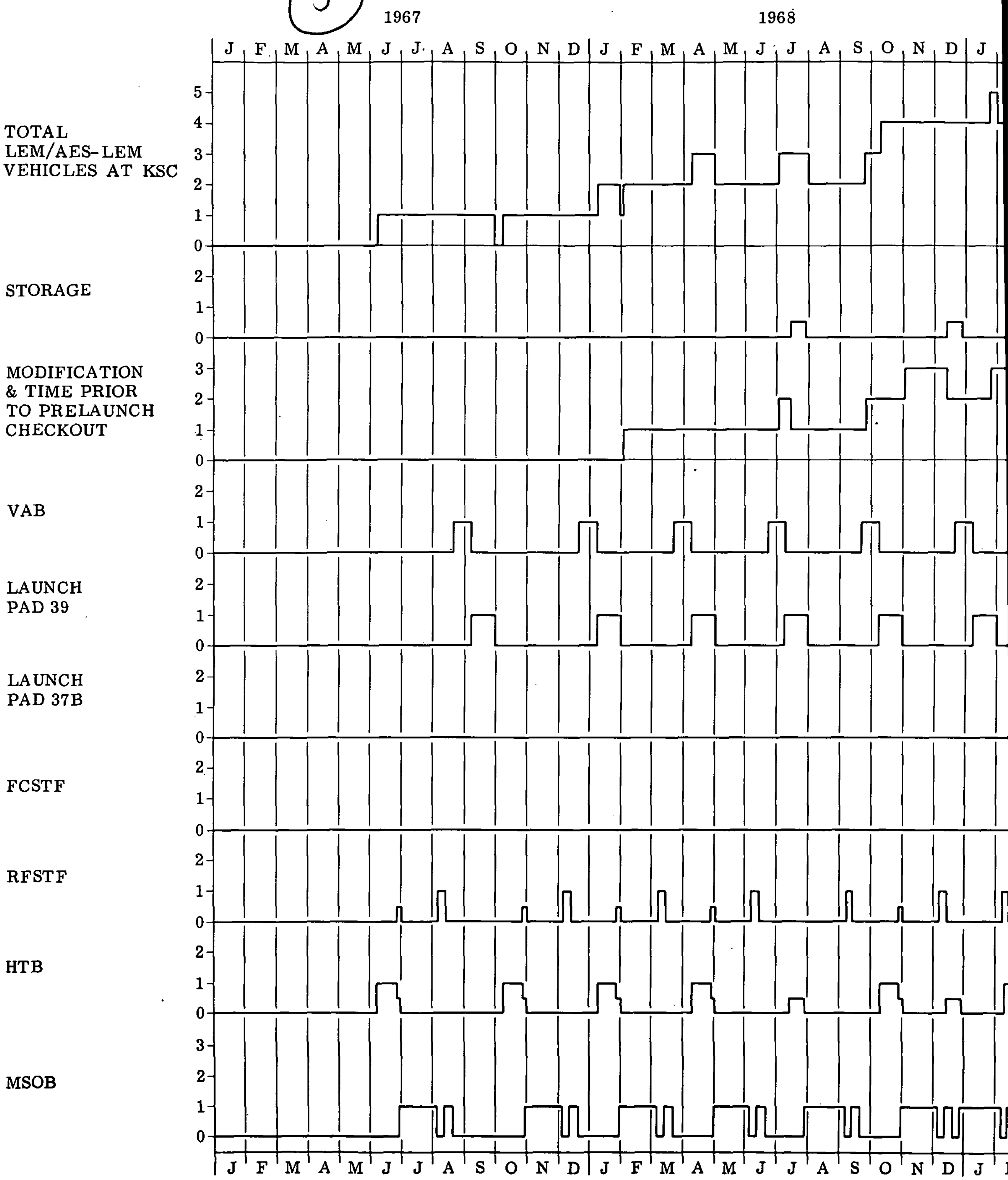
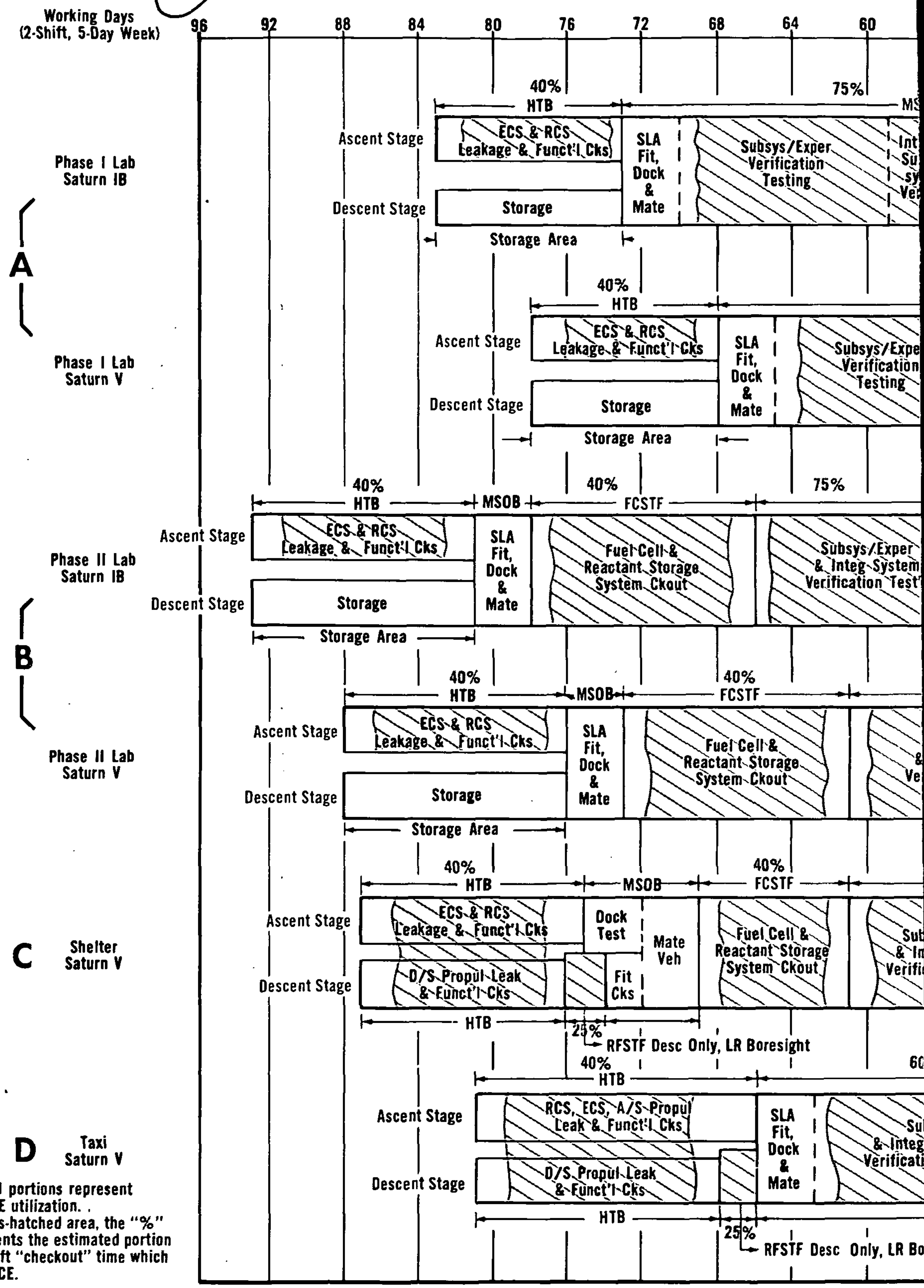

1967
1968
J F M A M J J A S O N D J F M A M J J A S O N D J
TOTAL LEM/AES-LEM VEHICLES AT KSC
STORAGE
MODIFICATION & TIME PRIOR TO PRELAUNCH CHECKOUT
VAB
LAUNCH PAD 39
LAUNCH PAD 37B
FCSTF
RFSTF
HTB
MSOB
0
1
2
3
4
5

Fig. 3.5-1 KSC Facility Loading Chart

57



Notes: 1. Cross-hatched portions represent periods of ACE utilization.

2. For each cross-hatched area, the "%" figure represents the estimated portion of the two-shift "checkout" time which will require ACE.

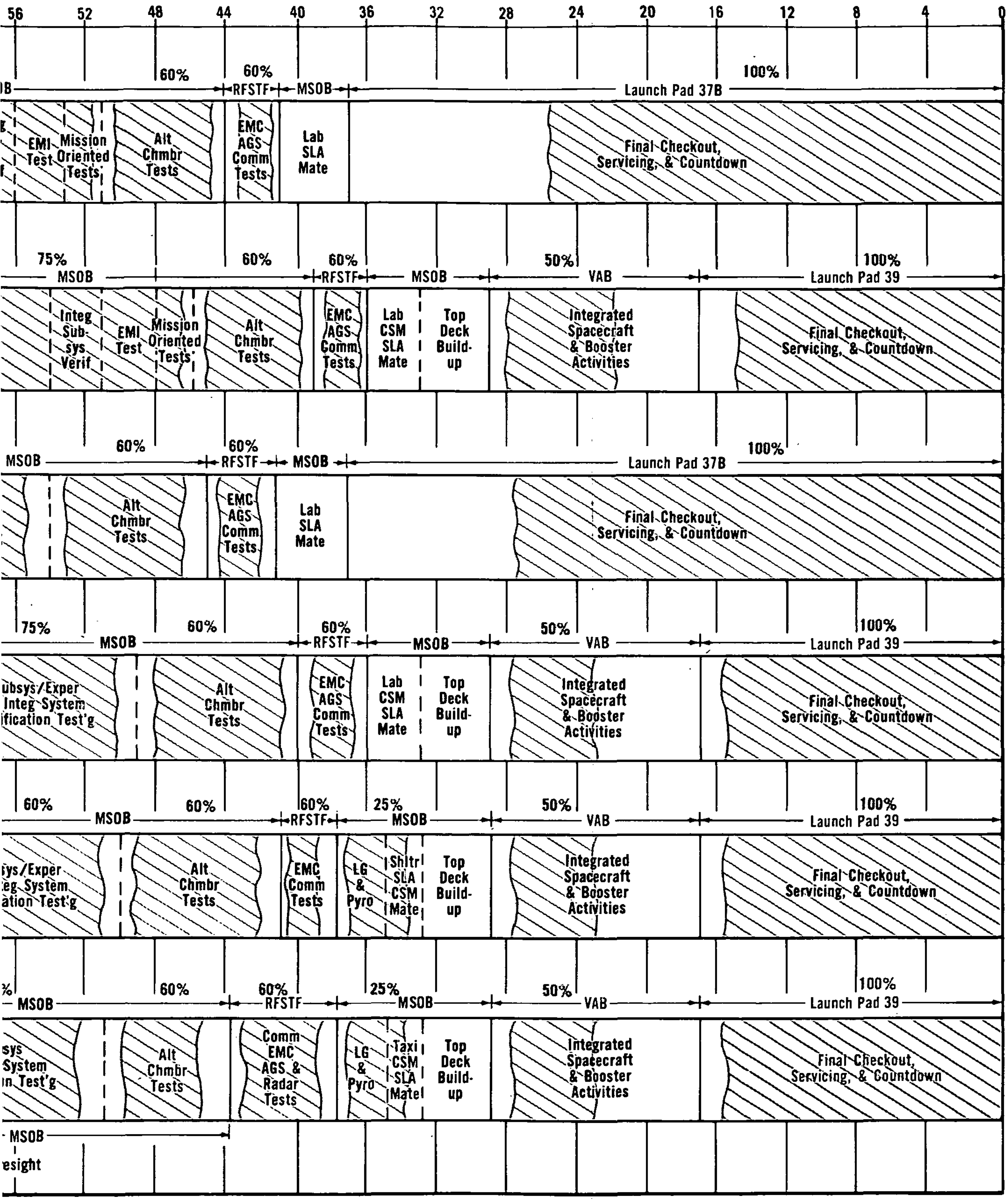


Fig. 3.5-2 Vehicle/Facility ACE Utilization

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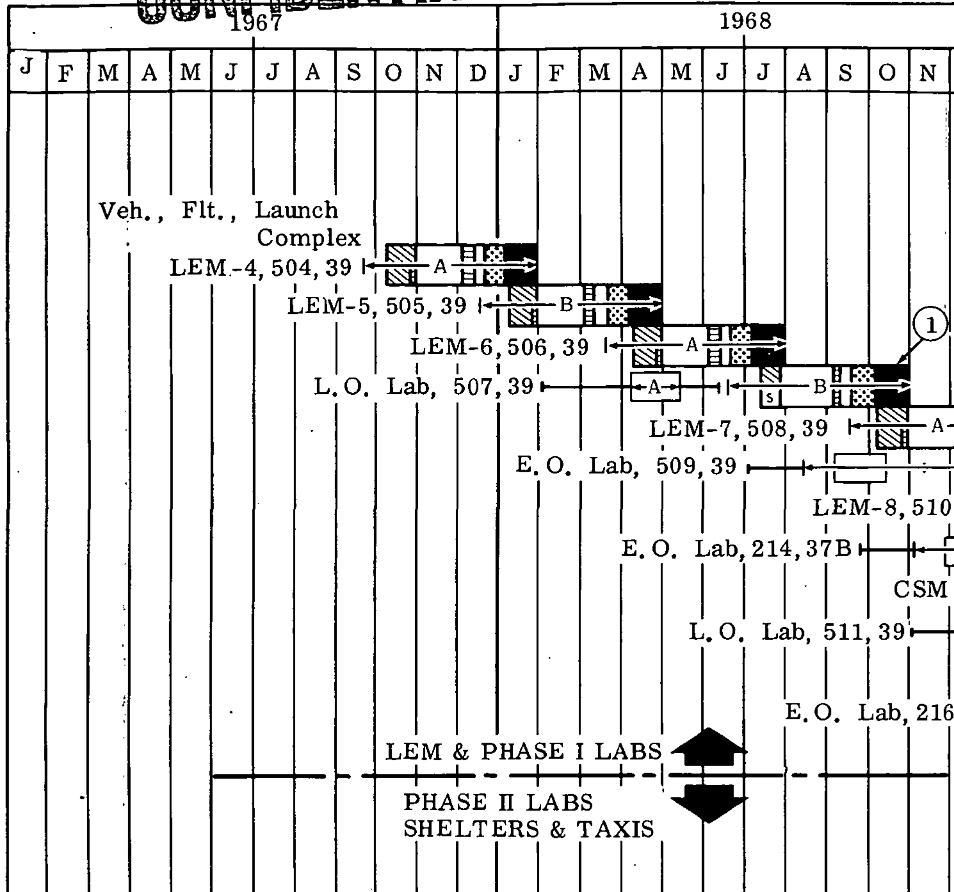

Note:
In lieu of an additional ACE station, the following station-sharing is assumed:

Note	Vehicle	Shares ACE With	While	is in
(1)	E.O. Lab 507	LEM 6	507 LEM 6	Mfg HTB & MSOB
(2)	L.O. Lab 511	E.O. Lab 214	511 214	Mfg Mfg
(3)	E.O. Lab 216	L.O. Lab 511	216 511	Mfg HTB & MSOB
(4)	E.O. Lab 220	E.O. Lab 516	220 516	HTB, MSOB & FCSTF MSOB & FCSTF
(5)	L.O. Lab 517	E.O. Lab 220	517 220	HTB & MSOB MSOB & RFSTF
(6)	Taxi 525	Shelter 524	525 524	HTB & MSOB MSOB & RFSTF

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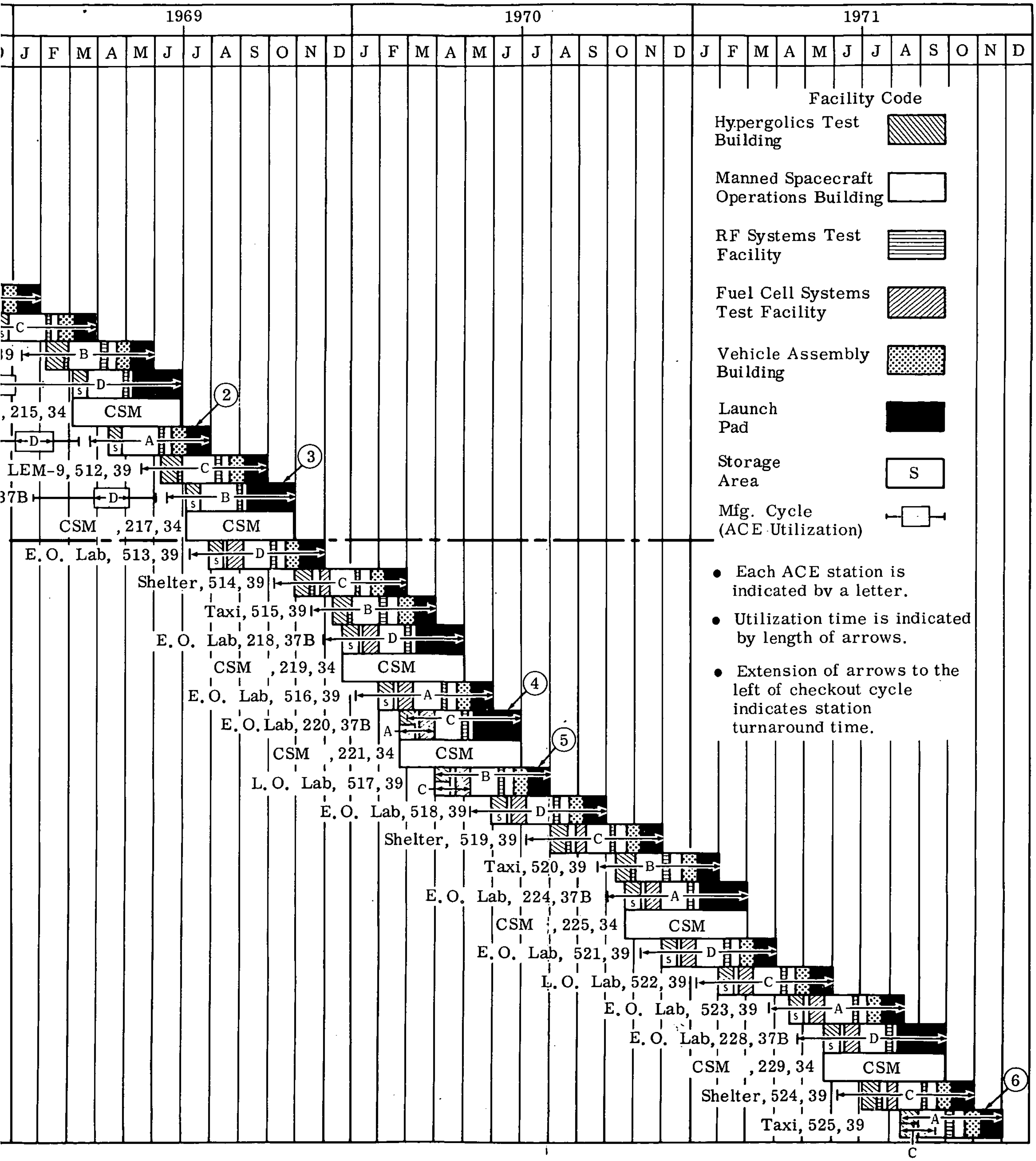
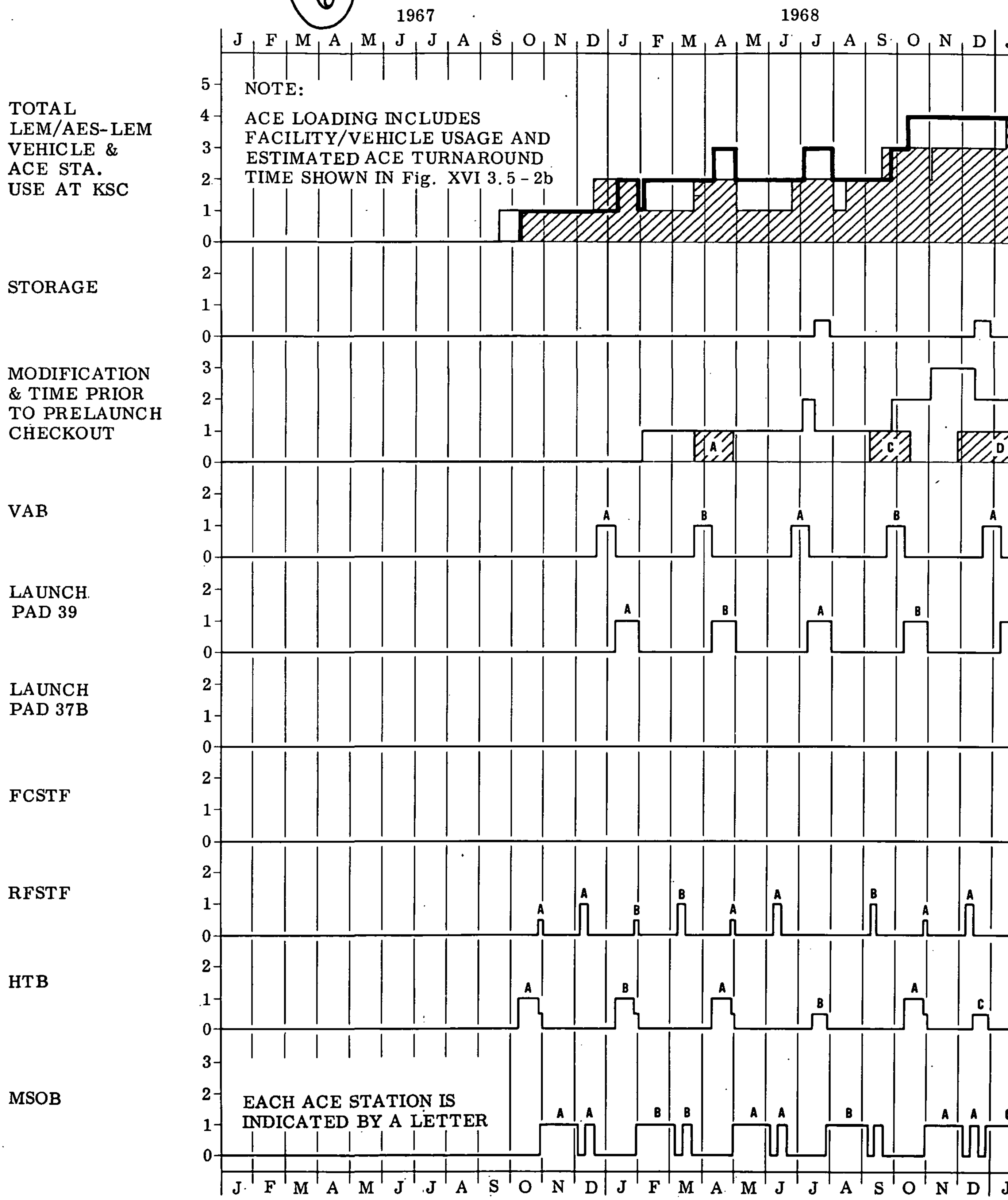


Fig. 3.5-3 KSC ACE Utilization and Prelaunch Operations

61


1967
1968
J F M A M J J A S O N D J F M A M J J A S O N D
TOTAL LEM/AES-LEM VEHICLE & ACE STA. USE AT KSC
NOTE:
ACE LOADING INCLUDES FACILITY/VEHICLE USAGE AND ESTIMATED ACE TURNAROUND TIME SHOWN IN Fig. XVI 3.5 - 2b
STORAGE
MODIFICATION & TIME PRIOR TO PRELAUNCH CHECKOUT
VAB
LAUNCH PAD 39
LAUNCH PAD 37B
FCSTF
RFSTF
HTB
MSOB
EACH ACE STATION IS INDICATED BY A LETTER

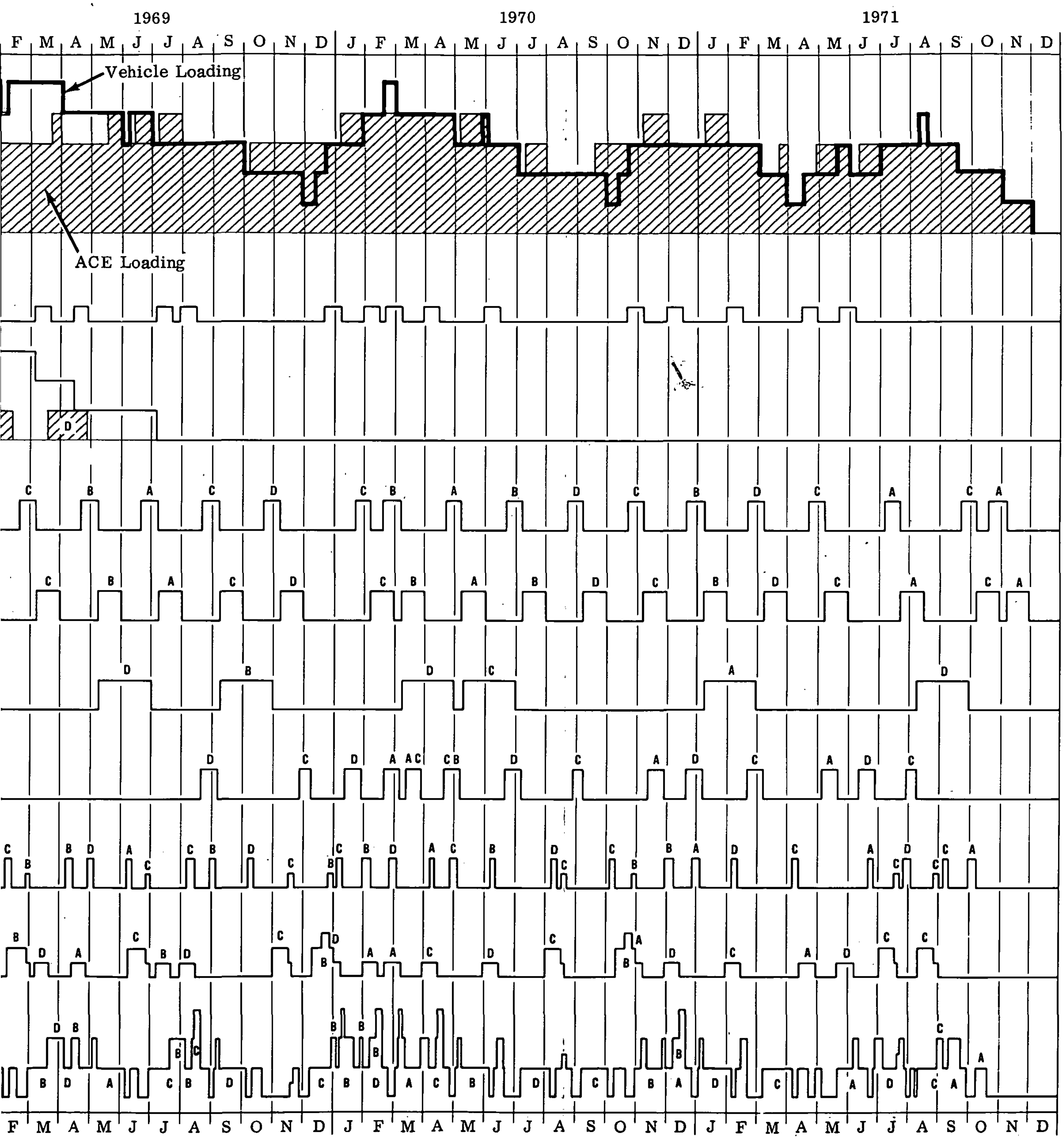


Fig. 3.5-4 Vehicle/Facility/ACE Loading Summary

63

Checkout Function \ Equipment Requirements		A/S Transport &/or Handl'g Equipt	D/S Transport &/or Handl'g Equipt	A/S Suppt Stand	D/S or Mated Veh Suppt Stand	Ldg Gear Handl'g Equipt & Instl Fixt	Polarity Fixture	Dock Test Handl'g Equipt & Fixture	Alt Chamber Suppt Stand	AES-LEM/SLA Handl'g Equipt & Fixt	3-Axis Positioner	Align Equipt & Mech'l/Optical Jigs	RTG Handl'g Equipt	Pyro Handl'g &/or C/O Equipt	Battery Handl'g Equipt	ECS Flush &
HTB	A/S or D/S Instl & Removal	◧◧ ◧■	◧■	◧◧ ■■	◧■											
	ECS C/O & Servicing			◧◧ ■■	◧■											■ ■
	D/S SHe Leak, Funct'l, Servicing & Heat Leak Cks				◧■											
	D/S Prop Leak & Funct'l Cks				◧■											
	A/S Prop Leak & Funct'l Cks			■												
	RCS Leak & Funct'l Cks			◧◧ ■■												
FCSTF	Mated Veh Instl & Removal	◧ ◧	◧ ◧		◧ ◧											
	ECS C/O & Servicing				◧ ◧											■
	Reactant Stor Leak, Funct'l, Servicing & Heat Leak Cks				◧ ◧											
	FCA Leakage & Funct'l Cks				◧ ◧											
MSOB	Instl & Removal of Stages or Mated Veh	◧◧ ◧■	◧◧ ◧■		◧◧ ◧■	■■	◧◧ ◧■	◧◧ ◧■	◧◧ ◧■							
	A/S or D/S Mating	◧◧ ◧■	◧◧ ◧■		◧◧ ◧■											
	SLA Fit Ck, Stacking & Pyro Instl	◧◧ ◧■	◧◧ ◧■							■■ ■■				■■ ■■		
	Ldg Gear Instl & Funct'l Cks	◧■				■■										
	Docking Tests	◧◧ ◧■						◧◧ ◧■								
	Alignment				◧◧ ◧■							■■ ■■				
	PDS C/O				◧◧ ◧■											
	Instrumentation C/O				◧◧ ◧■											
	Communications Functional C/O				◧◧ ◧■											
	Radar C/O				◧■											
	Beacon Xponder C/O				◧											
	AGS Funct'l C/O & Gyro Null Bias Compens				◧◧ ■							■■ ■				
	PGNCS Subsys C/O				◧■							■■				
	Mission – Oriented Systems C/O				◧◧ ◧■											
	GNCS Polarity Cks						◧◧ ◧■									
	Integrated GNCS C/O				◧◧ ◧■											
	Integrated Ph I Lab Subsystem C/O				◧											
	Ph I Lab EMC Cks				◧											
	ECS & Crew Prov C/O & Svcg (Alt Chmbr)								◧◧ ◧■							■ ■
	FCA Operational Cks (Alt Chmbr)								◧ ◧							
	RTG Funct'l Cks (Alt Chmbr)								◧■				□□			
	Radiator C/O & Servicing															

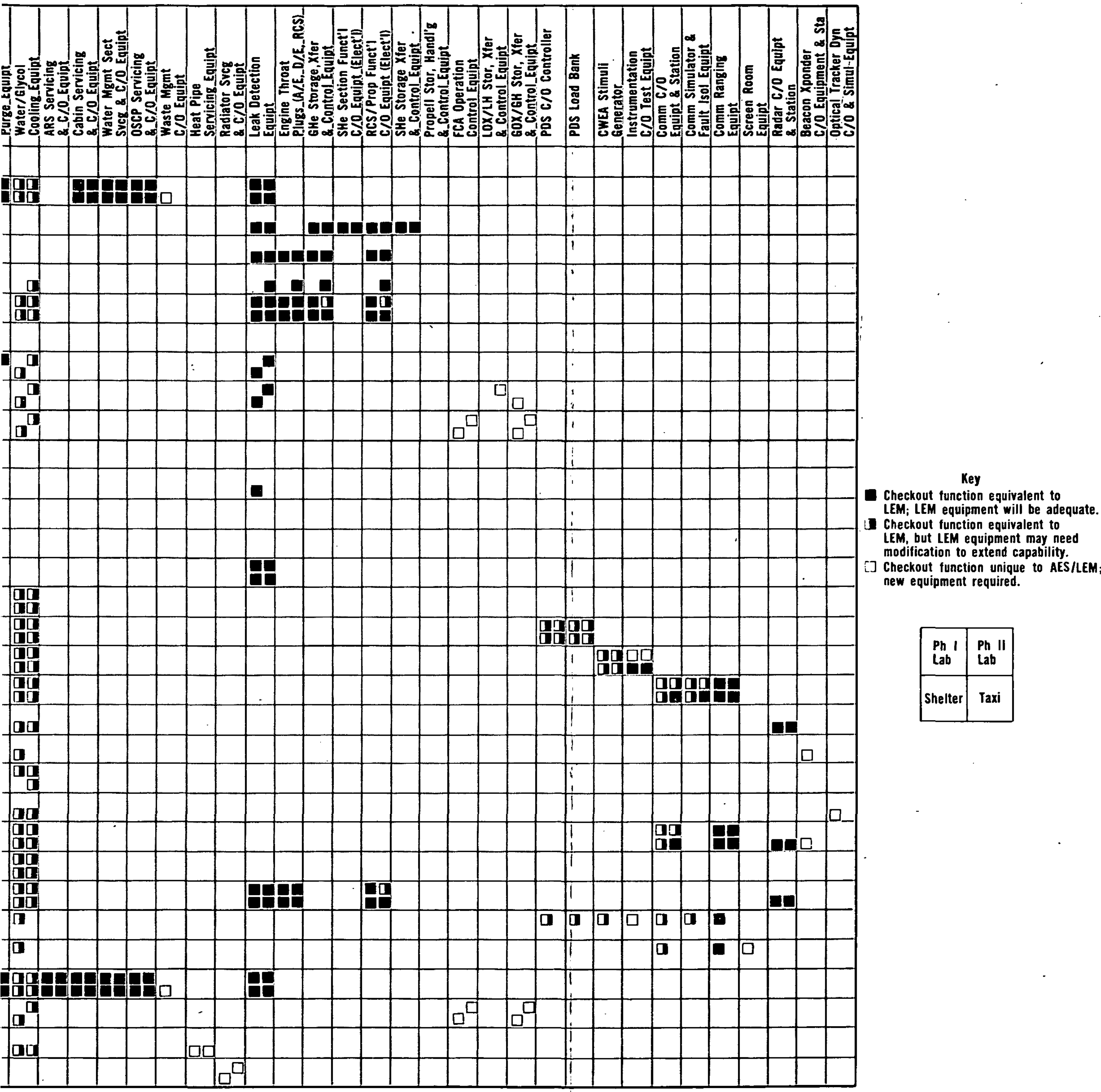


Fig. 3.5-5 AES-LEM Checkout Equipment Requirements (Sheet 1 of 2)

65

Checkout Function \ Equipment Requirements		A/S Transport &/or Handl'g Equipt	D/S Transport &/or Handl'g Equipt	A/S Suppt Stand	D/S or Mated Veh Suppt Stand	Ldg Gear Handl'g Equipt & Instl Fixt	Polarity Fixture	Dock Test Handl'g Equipt & Fixture	Alt Chamber Suppt Stand	AES-LEM/SLA Handl'g Equipt & Fixt	3-Axis Positioner	Align Equipt & Mech'l/Optical Jigs	RTG Handl'g Equipt	Pyro Handl'g &/or C/O Equipt	Battery Handl'g Equipt	ECS Flush & Purge Equipt
RFSTF	AGS Dynam Funct'l & Gyro Null Bias										■■ ■	■■ ■				
	Communications Verification				◧◧ ◧■											
	Rendez Radar B'sight & Tracking										■					
	Ldg Radar B'sight & C/O										■■					
	PGNCS Subsys C/O				◧■											
	AES — LEM/CSM EMC Cks				◧◧ ◧■											
VAB	Prop & RCS Press. Decay Tests															
	Communications Funct'l C/O															
	Radar C/O															
	Beacon Xponder C/O															
	AGS Funct'l & Gyro Null Bias Test											■■ ■				
	PGNCS Subsys C/O											■■				
	S/V EMC Cks															
	AES — LEM/CSM RR Xponder Compat															
LAUNCH PADS ▽ Pad 39 ▼ Pads 37B & 39	▼ PDS C/O															
	▼ Instrumentation C/O															
	▼ Communications Funct'l C/O															
	▼ Radar C/O															
	▼ Beacon Xponder C/O															
	▼ AGS Funct'l & Gyro Null Bias Test															
	▼ PGNCS Subsys C/O															
	▼ Integrated GNCS C/O															
	▽ AES — LEM/CSM RR Xponder Compat															
	▽ RFI Cks															
	▼ ECS & Crew Prov C/O & Servicing															■■ ■■
	▼ RCS C/O & Svcg															
	▽ A/S Prop C/O & Svcg															
	▽ D/S Prop C/O & Svcg															
	▽ SHe Servicing															
	▼ FCA Reactant Svcg															
	▼ FCA Operation															
	▼ EDS Funct'l Monitor'g & Pyro Instl													■■ ■■		
	▼ Flt Battery Instl														■■ ■■	
	▽ RTG Servicing												□			

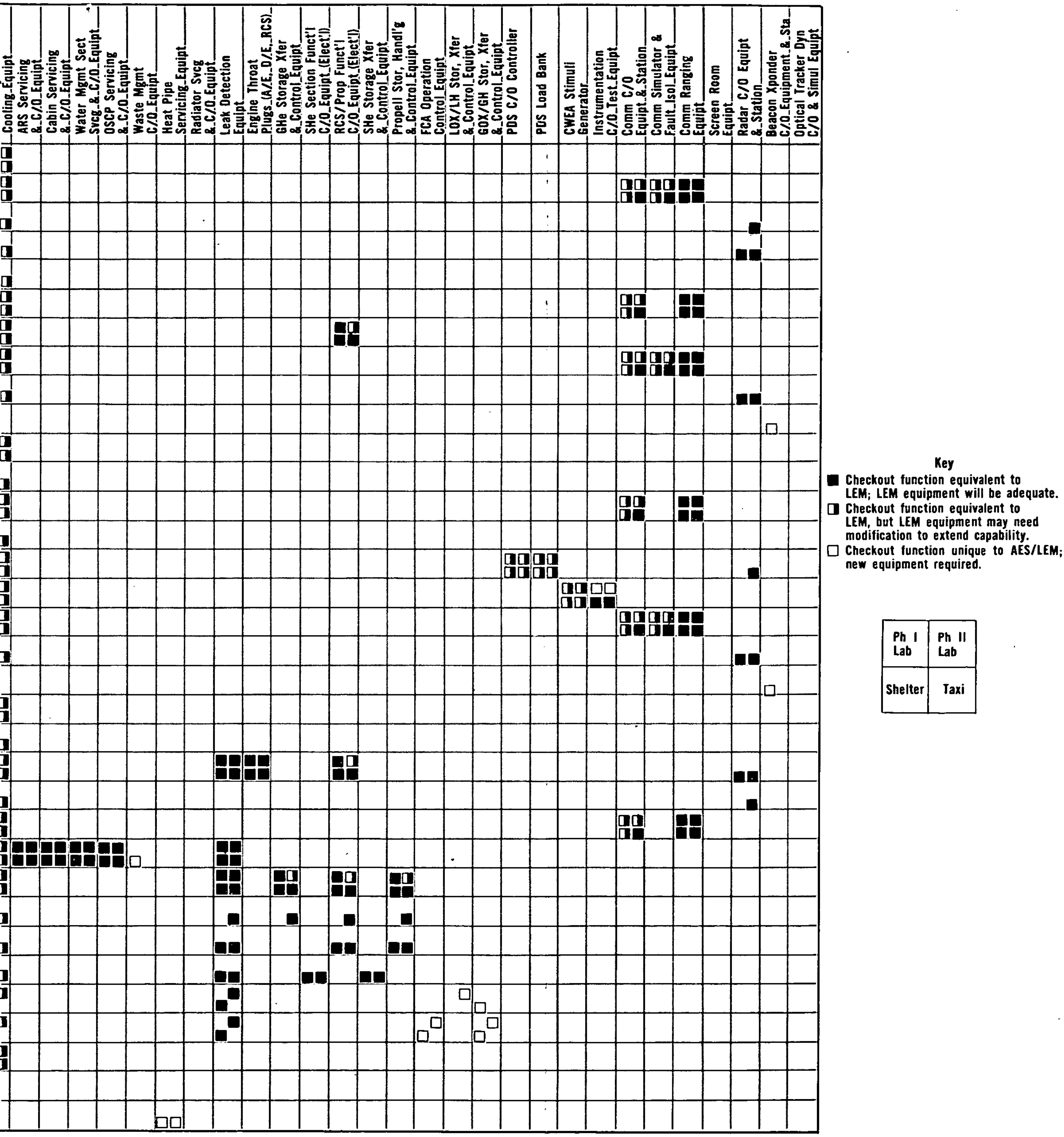


Fig. 3.5-5 AES-LEM Checkout Equipment Requirements (Sheet 2 of 2)

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5. ABBREVIATIONS & SYMBOLS

A	Analog Display
AC	Alternating Current
ACA	Attitude Controller Assembly
ACE	Acceptance Checkout Equipment
ADV	Advisory
A/E	Ascent Engine
AELD	Ascent Engine Latching Device
AES-LEM	Apollo Extension System - Lunar Excursion Module
AEA	Abort Electronic Assembly
AGC	Automatic Gain Control
AGS	Abort Guidance Section
ALT	Altitude
AOT	Alignment Optical Telescope
ARS	Atmosphere Revitalization Section
A/S	Ascent Stage
ASA	Abort Sensor Assembly
ATCA	Attitude and Translation Control Assembly
ATM	Angle Track Module
ATT	Attitude
AUTO	Automatic
C	Caution Light
CCS	Command Control Section
CES	Control Electronics Section
CG	Center of Gravity
C/O	Checkout
CO_2	Carbon Dioxide
CONT	Control
COS	Cosine
CSM	Command Service Module
C & W	Caution and Warning
CWEA	Caution & Warning Electronics Assembly
CWG	Constant Wear Garment

D	Digital Display
DC	Direct Current
D/E	Descent Engine
DECA	Descent Engine Control Assembly
D/S	Descent Stage
DSEA	Data Storage Electronics Assembly
ECA	Electrical Control Assembly
ECS	Environmental Control Subsystem
EDS	Electro-Explosive Devices Subsystem
EED	Electro-Explosive Devices
EMC	Electro Magnetic Compatibility
EMI	Electro Magnetic Interference
EMU	Extra-Vehicular Mobility Units
ENGR	Engineer
EPS	Electrical Power Subsystem
ER	Error
EXCT	Excitation
F	Flag Indicator
FCA	Fuel Cell Assembly
FCSTF	Fuel Cell System Test Facility
G & N	Guidance & Navigation
GFE	Government Furnished Equipment
GNCS	Guidance Navigation & Control Subsystem
GOX	Gaseous Oxygen
G H_e	Gaseous Helium
GO_2/GH_2	Gaseous Oxygen/Gaseous Hydrogen
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
H_2	Hydrogen
H_2O	Water
H_e	Helium
HI	High
HTB	Hypergolic Test Building
HTS	Heat Transport Section
ID	Identification
IF	Intermediate Frequency

IG	Inner Gimbal
IMU	Inertial Measurement Unit
INTCON	Interconnect
IR	Infra red
ISOL	Isolation
KSC	Kennedy Space Center
L	Light
LES	Launch Escape System
LC	Launch Complex
LG	Landing Gear
LGC	LEM Guidance Computer
LiOH	Lithium Hydroxide
LR	Landing Radar
LNDG	Landing
LN_2	Liquid Nitrogen
LO_2	Liquid Oxygen
LP	Launch Pad
LV	Launch Vehicle
MCC	Mission Control Center
MG	Middle Gimbal
MFLD	Manifold
MID	Middle
ML	Mobile Launcher
MSC	Manned Spacecraft Center
MSFN	Manned Space Flight Network
MSOB	Manned Spacecraft Operations Building
MSS	Mobile Service Structure
N_2	Nitrogen
NAV & GUID	Navigation & Guidance
O_2	Oxygen
O/F	Oxidizer to Fuel (Ratio)
OG	Outer Gimbal
OSCP	Oxygen Supply & Cabin Pressurization
OPS	Operations
OTS	Optical Tracking System
OUT	Outlet

OXID	Oxidizer
O/F	Oxidizer to Fuel
P	Pressure
PA	Power Amplifier
P_c	Thrust-Chamber Pressure
PCM	Pulse Code Modulation
PCMTEA	Pulse Code Modulation Timing Electronics Assembly
PDS	Power Distribution Section
PGNCS	Primary Guidance Navigation and Control Section
p^H	Hydrogen Potential
PH	Phase
PIPA	Pulsed Integrating Pendulous Accelerometer
PLSS	Portable Life Support System
POSIT	Position
PRESS	Pressure
PRF	Pulse Repetition Frequency
PROP	Propulsion
PWR	Power
R	Required
RCS	Reaction Control Subsystem
RCVR	Receiver
RES	Resistance
RF	Radio Frequency
RFI	Radio Frequency Interference
RFSTF	RF System Test Facility
RG	Rate Gyro
RGA	Rate Gyro Assembly
RNDZ	Rendezvous
RR	Rendezvous Radar
RSS	Root Sum Square
RTG	Radioisotope Thermal Generator
S/C	Spacecraft
SEL	Select
SH_e	Supercritical Helium
SIN	Sine
SLA	Spacecraft - LEM Adapter

S/O	Shut-off
SOL	Solenoid
S/S	Support Stand
ST	Steerable
SURF	Surface
SYNCH	Synchronization
S/V	Space Vehicle
TCA	Thrust Chamber Assembly
TOLER	Tolerance
TRUN	Trunnion
USB	Unified S-Band
VAB	Vehicle Assembly Building
VDC	Volts Direct Current
VLV	Valve
VPI	Valve Position Indicator
VSR	Voice Storage Recorder
W	Warning Light
WMS	Water Management Section
X	X-Axis (Vertical)
X Feed	Crossfeed
XMTR	Transmitter
X Pond	Transponder
Y	Y-Axis (Lateral)
Z	Z-Axis (Fore-aft)
Δ	Delta
ΔV	Change of Velocity

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