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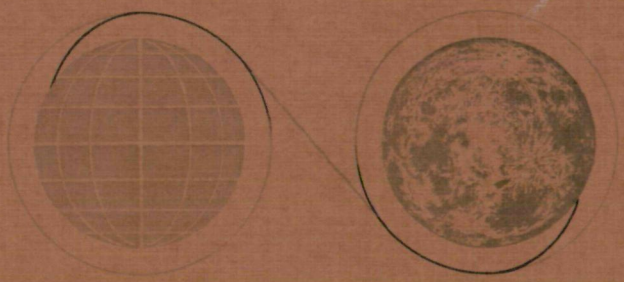
Grumman Design 378B



Apollo Extension Systems—Lunar Excursion Module
Phase B Final Report

Vol. II Preliminary Definition Studies Summary (U)

CONFIDENTIAL

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. II Preliminary Definition Studies Summary

Contract No. NAS 9-4983
ASR 378B

8 December 1965

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*

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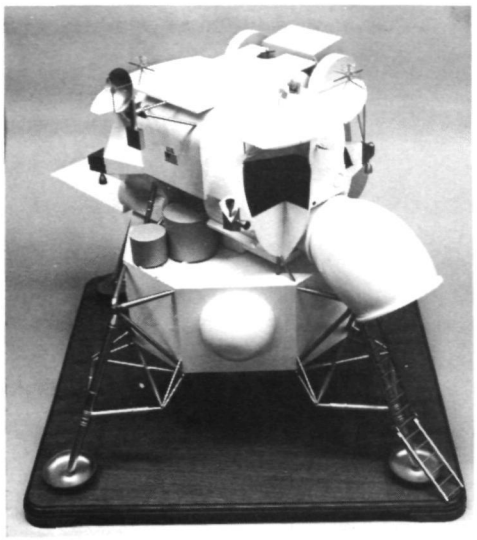
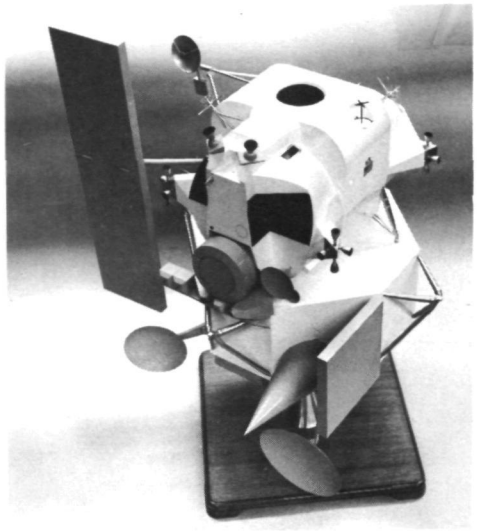
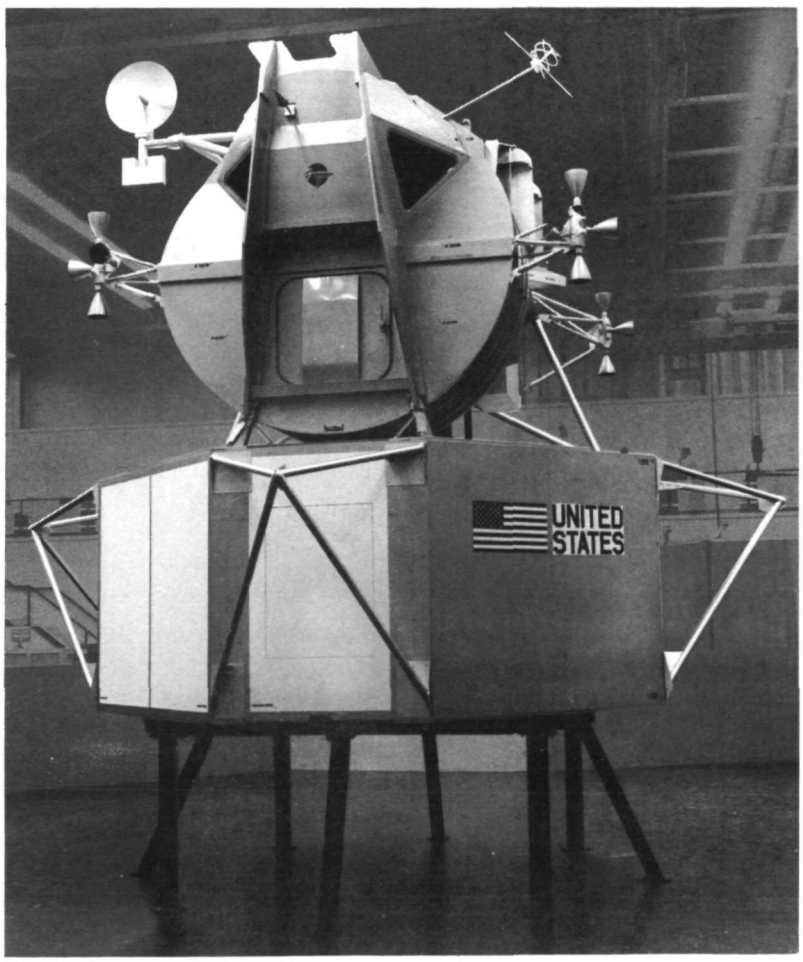


One-tenth Scale Model of Shelter with Representative Surface Exploration Payload.



One-tenth Scale Model of Phase II Laboratory and Experiments for Remote Sensing of Earth's Surface and Atmosphere.



Mockup of Phase II Laboratory.

1. INTRODUCTION

The Phase "B" Preliminary Definition Study of LEM utilization for the Apollo Extension System Program has yielded analyses, recommended designs, and plans for the various vehicles that may be selected for the AES Program. In accordance with NASA's phased planning policy, the Definition Phase and the Development/Operations Phase will follow this study.

Grumman management has a deep-rooted interest in the national space goals of the United States. This is evidenced by the Corporation's participation in a variety of space programs including in-house studies on the manned space stations, LEM Truck and associated payload modes, and NASA directed and financed studies on the AES Program, as well as participation in the OAO, the Echo II and the Apollo Programs.

The underlying philosophy in planning the AES Program is based on Grumman's experience that prime contractors must be accountable for design, fabrication, procurement, test, and support of the entire system under their jurisdiction. This systems responsibility demands an extensive array of facilities and manpower skills which have been developed at Grumman on OAO, LEM and major defense programs.

Making use of this valuable experience, Grumman has conducted the study of LEM utilization for the AES Program according to requirements and constraints set by NASA and some additional guidelines outlined below. Highlights of this 26-volume report are presented in this summary volume. Further, final definition of the various designs, parameters and constraints forms the basis of continuing study at both NASA and Grumman.

The basic requirements and constraints set by NASA for this study are:

- No interference with the LEM Lunar Landing Program will occur
- Minimum spacecraft modifications
- Maximum utilization of Apollo hardware
- Utilization of other qualified spacecraft hardware (Mercury, Gemini)
- Maximum utilization of, and coordination with, existing development studies
- Minimum modifications to Ground Support Equipment (GSE), Acceptance Checkout Equipment (ACE), and Manned Spaceflight Network (MSFN)
- Where possible, qualification of modifications without flight testing
- Modifications and development to be compatible with spacecraft launch vehicle availability and launch schedules as defined in the Flight Mission Assignment Plan for AES Planning, ML-65-1 dated 7 August 1965, and the LEM Program Schedule III Revision 1, dated 7 September 1965
- Mission time: Up to three months storage time on lunar surface for Shelter; up to 14 days lunar surface manned operations; up to 45 days Earth orbital operations; and up to 28 days lunar orbital operations

- Consistency in design requirements and commonality of design approaches for the selected configurations for the Lab, Shelter, and the Taxi
- Integration of experimental payloads with the Taxi and Shelter is included in the basic study, but integration on individual LEM Laboratory flights is not. (The addendum for study of the Phase I Laboratory flights, currently underway, is due for completion in January 1966.)

Additional guidelines used during the AES/LEM Study were:

1. General:

   - Phase I Labs will be manufactured as LEM Spacecraft and modified at KSC
   - All other vehicles will be manufactured to final configuration at the Contractor's plant
   - Each flight shall be supported by an AES/LEM of the same configuration, available for test in the environmental chamber at MSC, and a similarly configured house spacecraft at Grumman prior to, during, and after the flight
   - Mission Support for the Phase I and II Labs is a Payload Integration task

2. Design:

   - No additional penetrations of the cabin pressure shell
   - Use of ascent and descent structures with added reinforcements
   - Retention of existing piping and wiring where possible
   - Possible use of modules for housekeeping or experiment extras.

3. Plans and Schedules:

   - All demonstrations and verifications existing as constraints on a flight mission should be satisfactorily relieved six weeks prior to launch
   - Launch complex (LC) assignments are:

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

   - All vehicle/experiment comprehensive prelaunch checkout will be accomplished in the Manned Spaceflight Operations Building (MSOB). (However, it is recognized that, since all experiments have not yet been defined, specific exceptions may require other facilities such as the Hypergolic Test Building (HTB), and the RF Systems Test Facility (RFSTF).)
   - All experiments are installed before integrated testing.

2. VEHICLES & MISSIONS

2.1 BASELINE AND RECOMMENDED CONFIGURATIONS

To provide NASA with a preliminary definition of the complete program required for the AES/LEM schedules, one configuration was selected for each of the Phase I and Phase II Labs, the Shelter, and the Taxi at the mid-study point. These configurations were identified as "baseline configurations" and described in the Mid-Term Report dated 20 September 1965, and the Preliminary Project Development Plan (PDP), Volume I of this report, submitted on 30 October 1965. In the latter half of the study, these baseline configurations were modified as a result of NASA direction and continuing vehicle design studies. These more current configurations are identified as "recommended configurations" and are described in this final report of the Preliminary Definition Study. In addition, for each of the four vehicles, various "alternates" in certain subsystem areas have been identified and are presented as possible candidates for NASA selection. Finally, vehicle changes required only for specific flights have been identified as "per-flight modifications" and are also presented.

The recommended configurations, described briefly in this section, are capable of performing most of the AES missions as they are presently understood. The mission-related requirements for these configurations were derived from:

- Table II (Revision L) of the Blue Book (included in Appendix A for reference)
- Experiment Payload requirements studied in Phase A
- NASA/MSFC mission descriptions
- Preliminary results of the Phase B Addendum study of Experiment Payload Integration.

The recommended vehicle designs keep the present LEM intact to the maximum extent possible. Increases in subsystem capability are made by additions where possible, rather than modifications.

The LEM-Phase I Lab modification flow is represented pictorially in Fig. 2-1. General equipment arrangements for the Phase I Lab, Phase II Lab, Shelter and Taxi are shown in Figs. 2-2 through 2-5, respectively. Further descriptions of these vehicles follow. In addition, itemized configuration comparisons to the present LEM vehicle are included in Appendix B. A summary of AES hardware requirements itemizing degree of modification by subsystem, by vehicle, is included in Appendix C.

The LEM Truck design study effort has been limited to maintaining the Truck consistent in concept with the other vehicles, particularly the Shelter.

2.2 PHASE I LAB

2.2.1 Mission

The Phase I Lab is a minimum-modification LEM used as an Earth and lunar orbital laboratory to provide experiment support for mission durations of up to 14 days.

This vehicle operates in conjunction with the Apollo Command and Service Module. Its launch vehicle is a Saturn IB or Saturn V.

The orbital characteristics of the Phase I Lab missions are described in Appendix A. These include low-altitude Earth orbits of varying inclination, synchronous Earth orbits, and low-inclination lunar orbits. Experiment-imposed mission requirements were selected from a broad survey of the Phase A studies and from data available from the early portion of the Addendum I (Experiment Payload Integration Study) to this Phase B study. Experiments identified by NASA for the Phase I Lab flights, and which are being studied in the Addendum, are listed in Appendix D.

The accomplishment of rendezvous and/or dual launch were not included as mission imposed requirements.

2.2.2 Vehicle

2.2.2.1 Nature of Modifications to LEM Sybsystems

The recommended Phase I Lab configuration is a LEM with specific modifications to the environmental control, electrical power, stabilization and control, and instrumentation subsystems. Specific deletions and/or minor modifications are required to the guidance and navigation, landing gear, propulsion, communications and crew provisions subsystems. Deletions and modifications associated with these subsystem changes are required for the structure and the displays and controls subsystem.

All modifications or changes, with reference to the present LEM configuration are listed in Table B-1 of Appendix B. In addition, Table C-1 of Appendix C summarizes the hardware changes in terms of the degree of modification and commonality of changes between the Phase I Lab, Phase II Lab, Shelter, and Taxi.

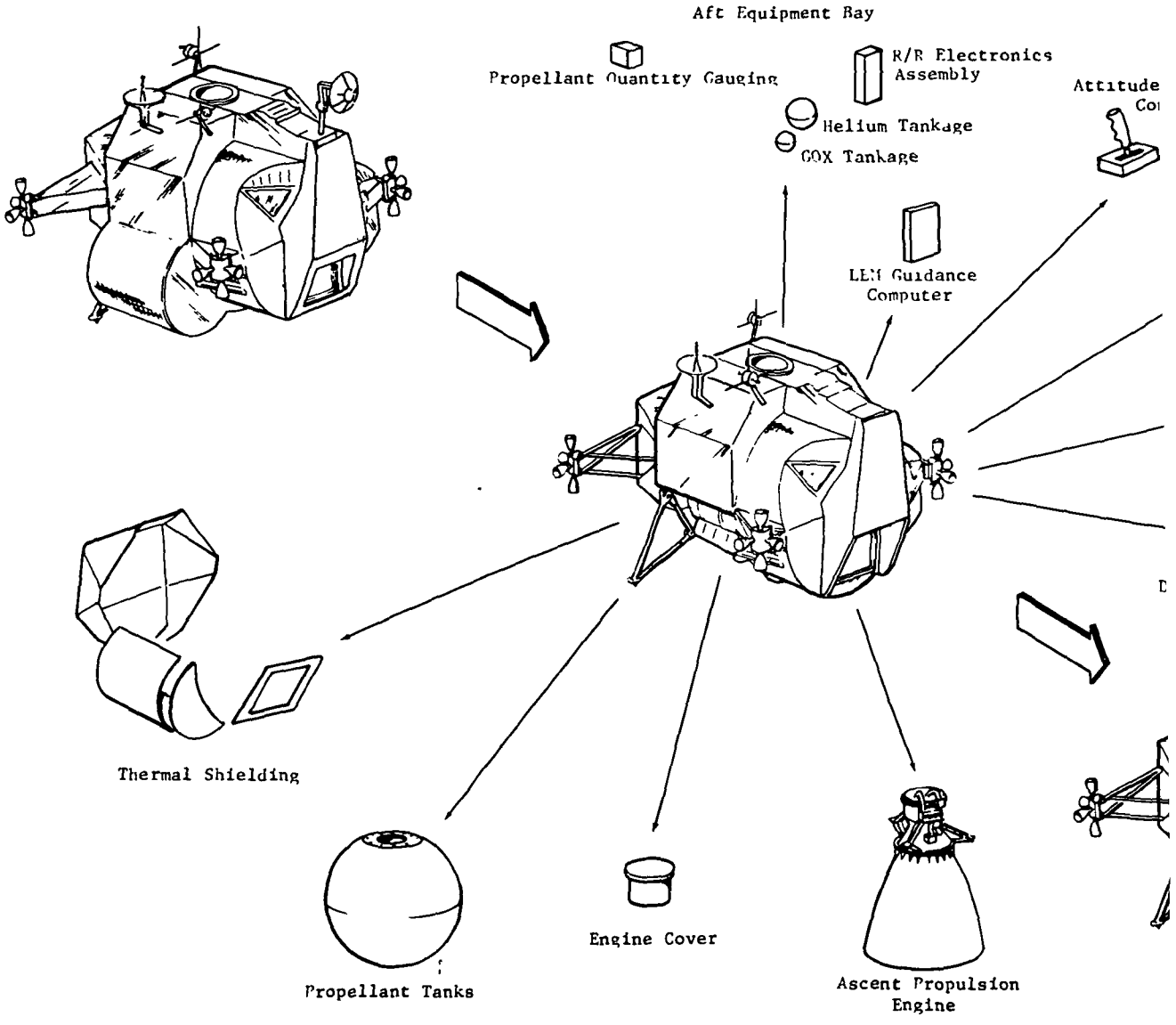
Significant modifications required for the Phase I Lab are:

2.2.2.2 Environmental Control

- Addition of two descent water tanks to the LEM active thermal control system capacity for the 14-day mission
- Provision of Environmental Control Subsystem (ECS) capacity to reject the heat loads associated with the available 91.1 kw-hr of experiment energy plus all housekeeping energy
- Cold plate area within the cabin to cool 500 watts of experiment load
- Addition of five descent stage type gaseous oxygen (GOX) tanks to enable 18 Lab repressurizations and 18 backpack charges.

2.2.2.3 Electrical Power

- Addition of 16 LEM descent batteries
- Batteries actively cooled using cold rails, identical to LEM
- Increased capacity of LEM Electrical Power Subsystem (EPS) from 68 kw-hr to 274 kw-hr to provide 91.1 kw-hr for experiment use and 182.9 kw-hr for housekeeping.



Ascent Stage Disassembly

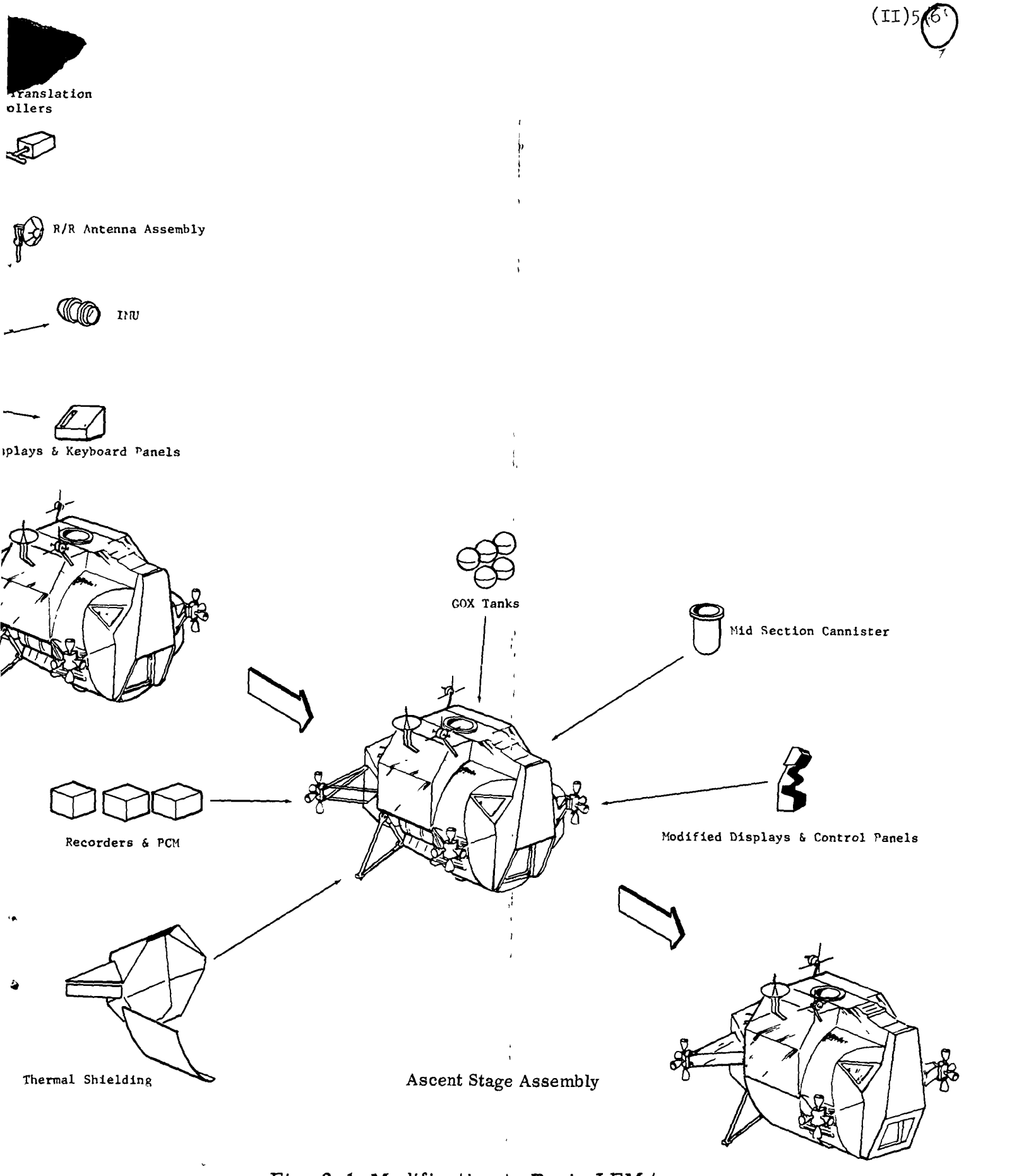


Fig. 2-1 Modification to Basic LEM to Produce Phase I Laboratory (Sheet 1 of 2)

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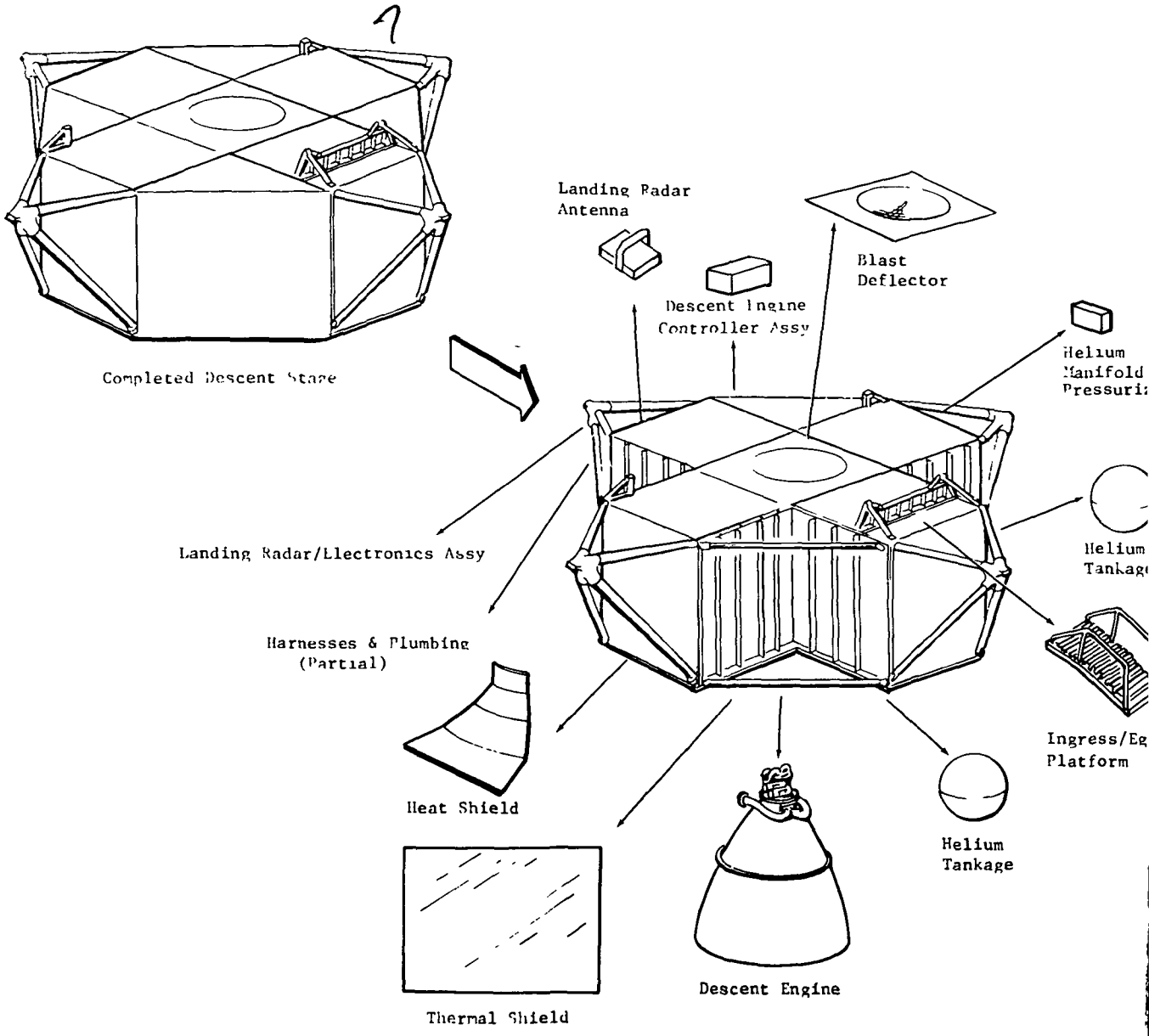

Descent Stage Disassembly

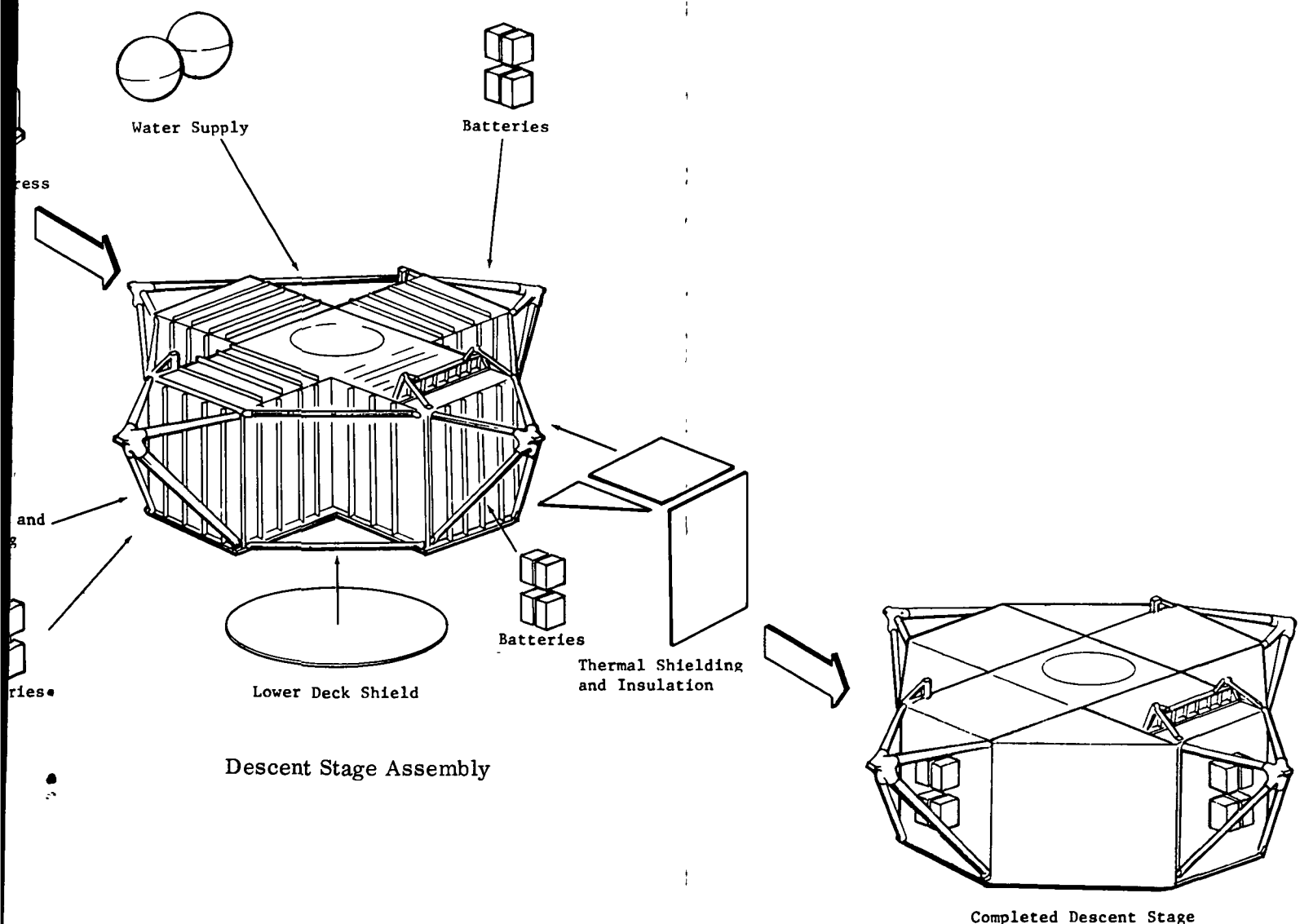

Fig 2-1 Modification to Basic LEM to Produce Phase I Laboratory (Sheet 2 of 2)

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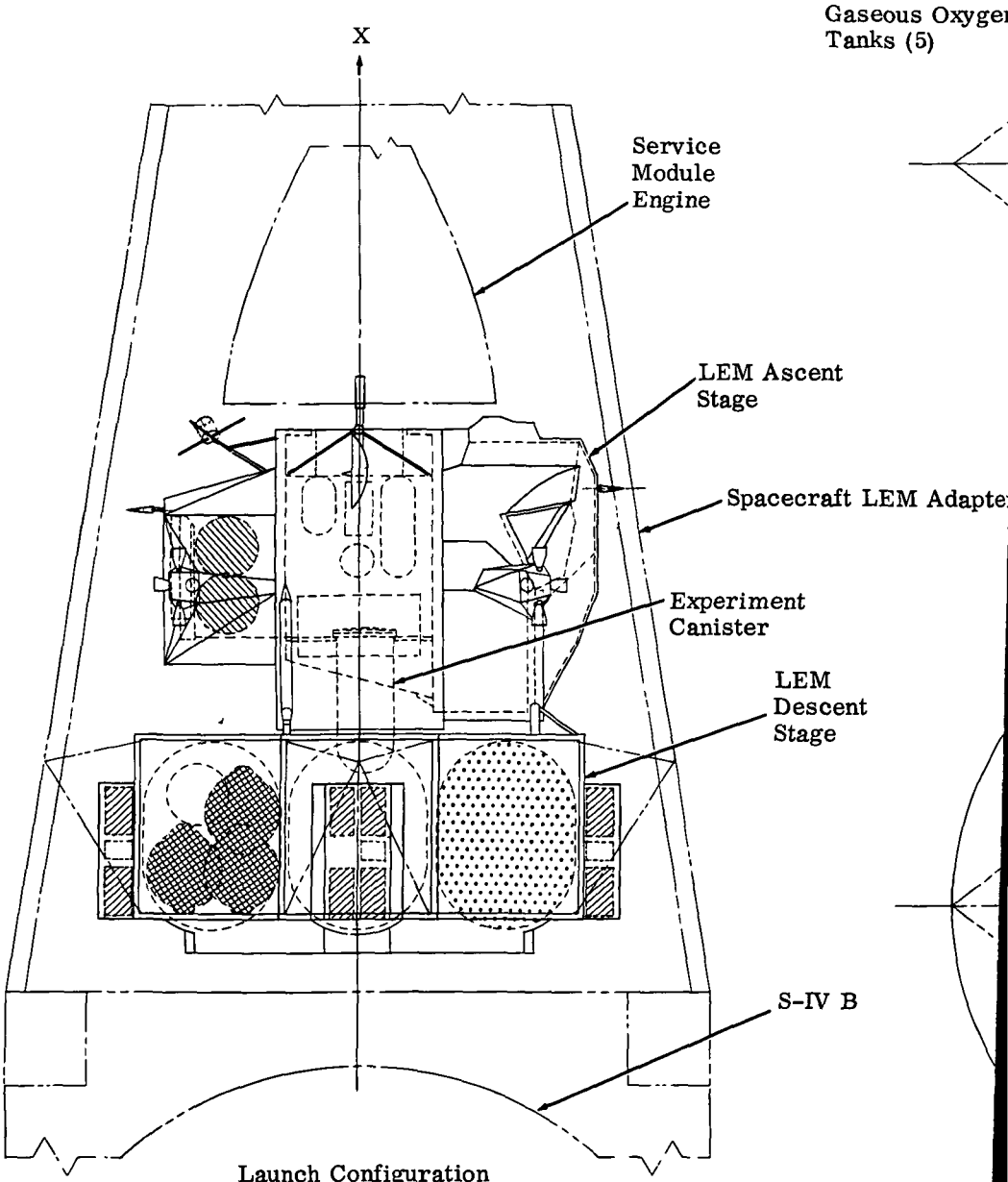
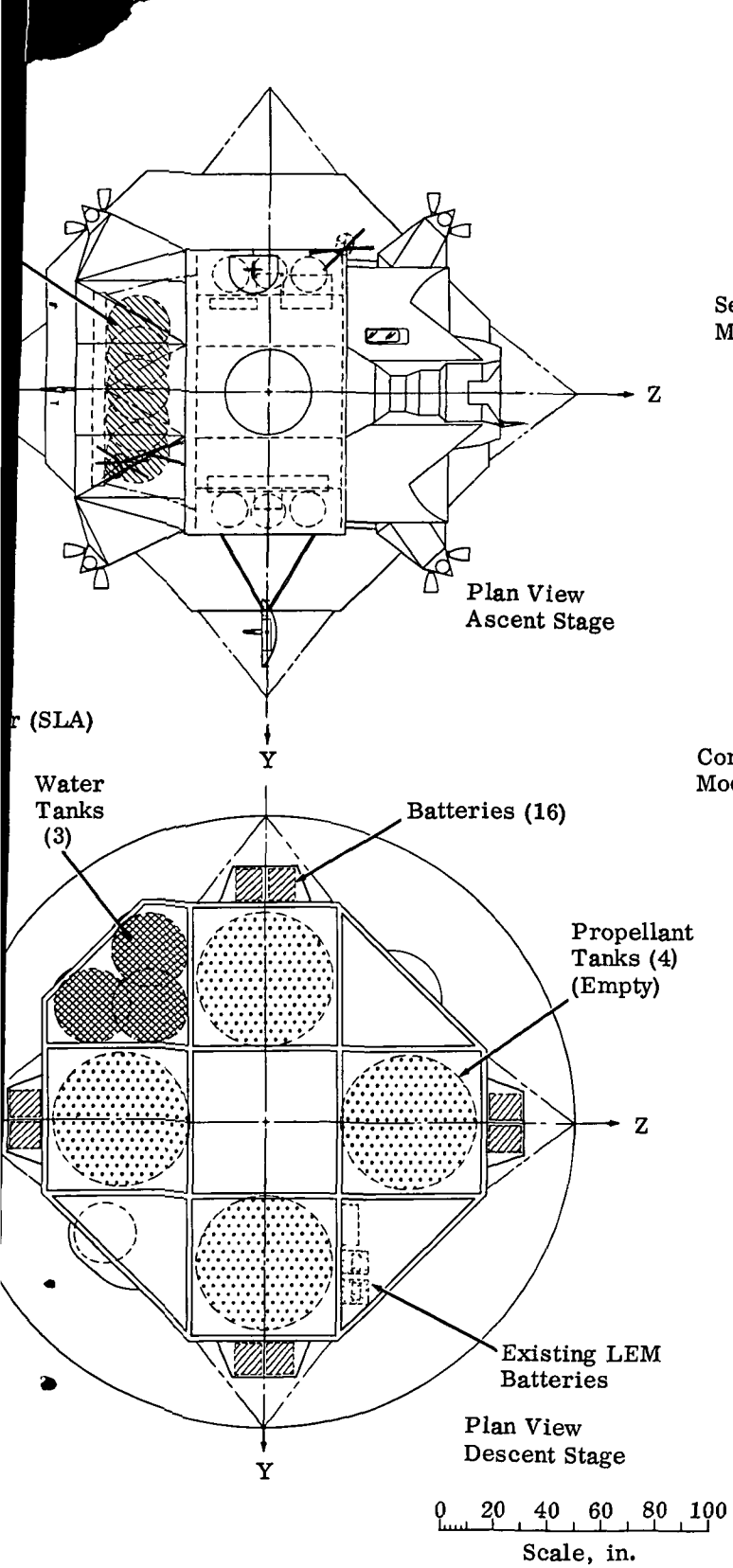


Launch Configuration



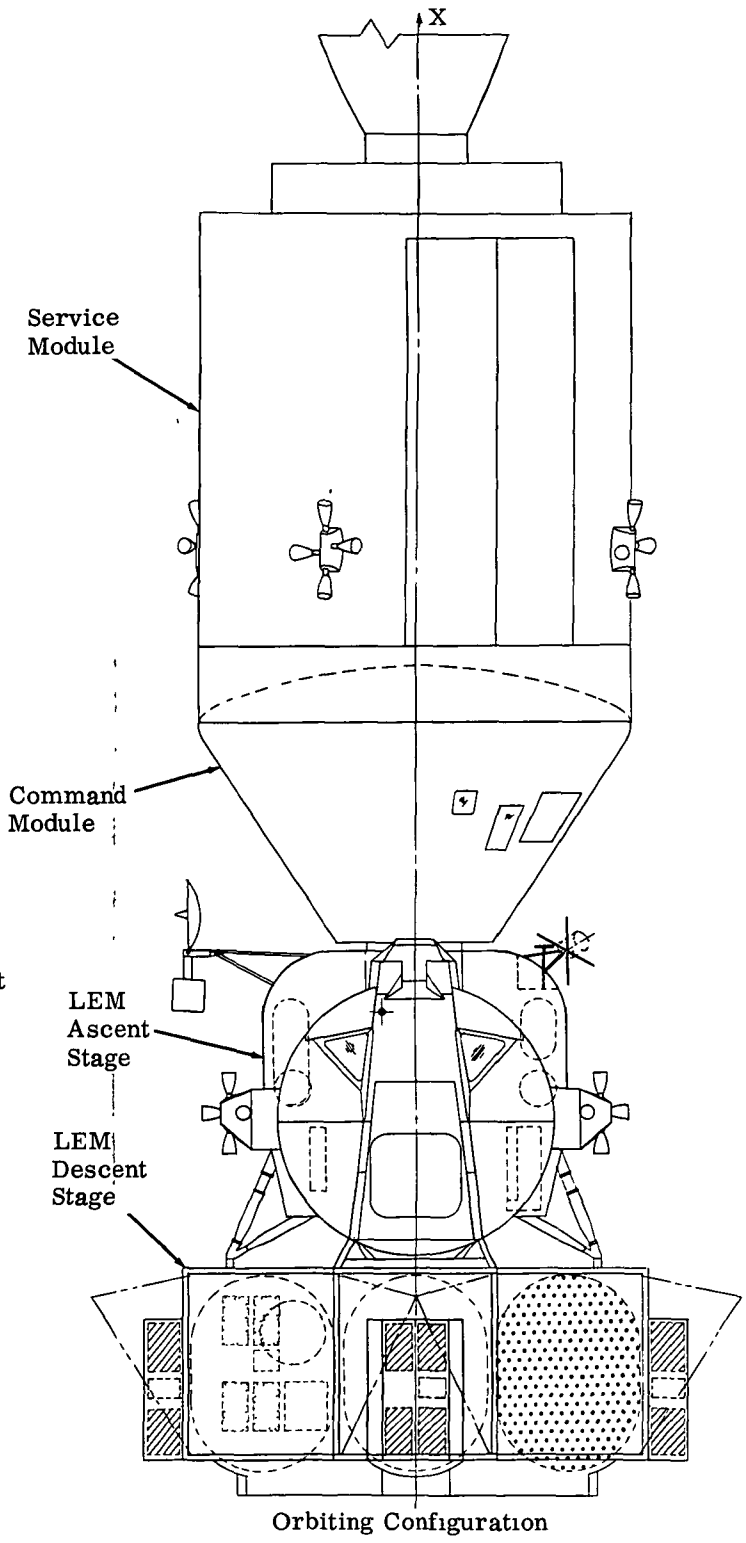


Fig. 2-2 Phase I Lab Recommended General Arrangement

2.2.2.4 Stabilization & Control

- Deletion of current LEM Primary Guidance, Navigation & Control Section
- Modification of current LEM Abort Guidance & Control Section, Rate Gyro Assembly and Attitude and Translation Control Assembly for reduced propellant consumption during limit cycling
- Modification of Abort Electronics Assembly programming to enable interfacing with Alignment Optical Telescope for attitude reference updating.

2.2.2.5 Instrumentation

- Addition of a data handling section to LEM instrumentation to provide recording, storage, and transmission of experiment data.

2.2.2.6 Propulsion

- Deletion of ascent propulsion system
- Deletion of descent propulsion engine and Helium tanks.

2.2.2.7 Alternates

Significant subsystem alternate configurations are also presented in Volume III for the Phase I Lab environmental control, electrical power and stabilization and control subsystems.

Per-flight modifications for the Phase I Lab are also presented in Volume III and include considerations of experiment cooling, experiment storage volume within the vehicle, stabilization and control and propulsion.

2.3 PHASE II LAB

2.3.1 Mission

The Phase II Lab, a conversion from the LEM design, is used as an Earth and lunar orbital laboratory to provide experiment support for mission durations of up to 45 days. This vehicle also operates in conjunction with an AES Command and Service Module. Its launch vehicle is a Saturn IB or Saturn V.

The orbital characteristics of the Phase II Lab missions, described in Appendix A, are similar to those for the Phase I Lab, except they also include polar lunar orbits. Experiment-imposed mission requirements were selected from a broad survey of the proposed missions and from data available from the first phase of this study (Phase A).

The accomplishment of rendezvous and/or dual launch were not included as mission imposed requirements.

2.3.2 Vehicle

2.3.2.1 Nature of Modifications to LEM Subsystems

The recommended Phase II Lab configuration is a LEM with specific modifications to the environmental control, electrical power, stabilization and control,

instrumentation, and reaction control subsystems. Specific deletions and/or minor modifications are required to the guidance and navigation, landing gear, propulsion, reaction controls, communications and crew provisions subsystems. Deletions and modifications associated with these subsystem changes are required for the structure and the displays and controls subsystem. The structure is also modified by the incorporation of an airlock.

All modifications or changes, with reference to the present LEM configuration are listed in Table B-2 of Appendix B. In addition, Table C-I of Appendix C summarizes the hardware changes in terms of the degree of modification and commonality of changes between the Phase I Lab, Phase II Lab, Shelter, and Taxi.

A summary of the significant modifications required for the Phase II Lab follows:

2.3.2.2 Environmental Control

- Addition of 60 sq ft of radiator area and supplemental LEM type water boiling for the 45-day mission
- Provision of ECS capacity capable of rejecting the heat loads associated with 834 kw-hr of experiment energy plus all housekeeping energy
- Cold plate area within the cabin to cool 500 watts of experiment load
- A LEM ascent gaseous oxygen (GOX) tank functioning as an accumulator to supply oxygen from the Electrical Power Subsystem (EPS) cryogenic tanks and gaseous nitrogen stored in the LEM descent GOX tank, provide capacity to pressurize the airlock 44 times and recharge the backpack 44 times.

2.3.2.3 Electrical Power

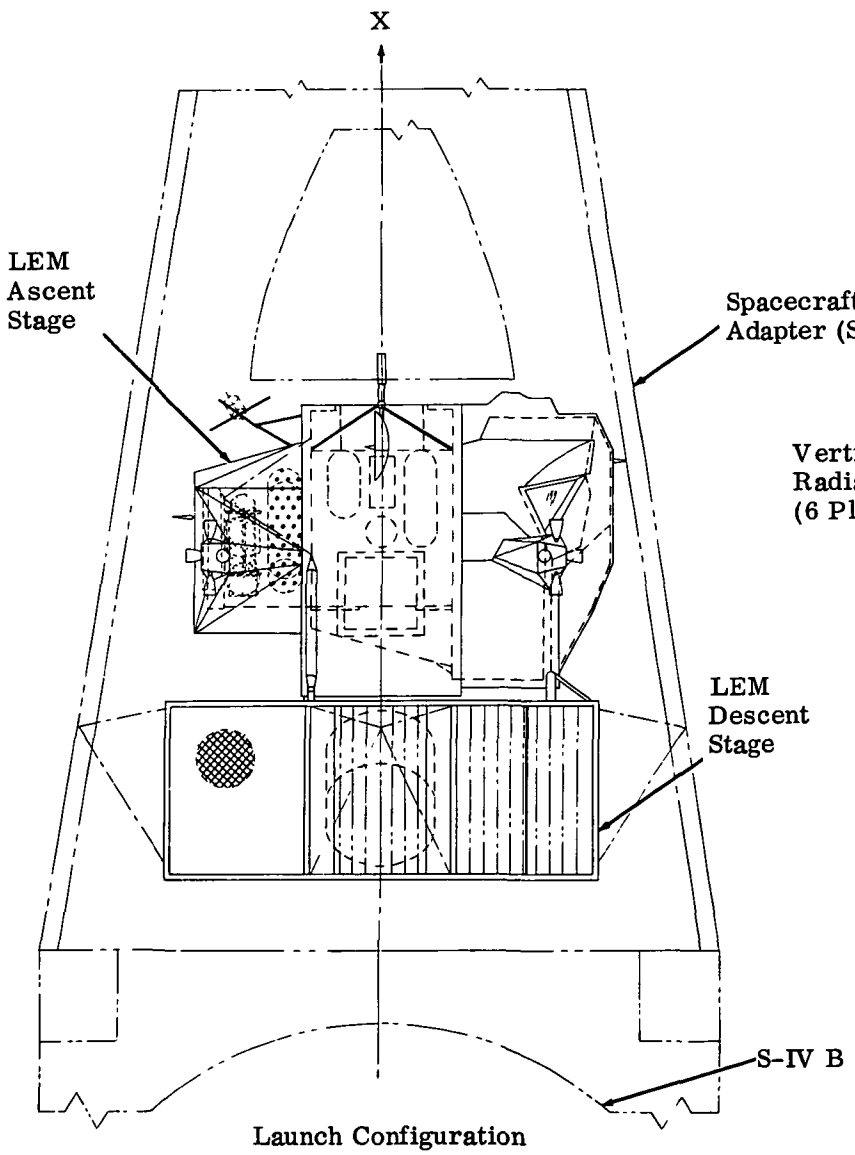
- Replacement of LEM batteries by two Allis Chalmers 2-kw nominal design fuel cells
- Addition of cryogenic tanks (presently being developed for the AES-CSM) for fuel cell reactants providing capacity of 1680 kw-hr for a typical mission
- Provision of Phase II Lab EPS capacity of 676 kw-hr for experiments and 1004 kw-hr for housekeeping
- Addition of 60 sq ft of radiator area for fuel cell cooling.

2.3.2.4 Stabilization and Control - Same as Phase I Lab

2.3.2.5 Instrumentation - Same as Phase I Lab with a minor additional modification.

2.3.2.6 Reaction Control

- Addition of two sets of Reaction Control Subsystem (RCS) tanks to the present LEM capacity
- Reversal of fuel and oxidizer tank sizing due to lower oxidizer-fuel ratio of the RCS engine during minimum impulse bit firing, to produce a usable tank capacity of 1048 lb.



Launch Configuration

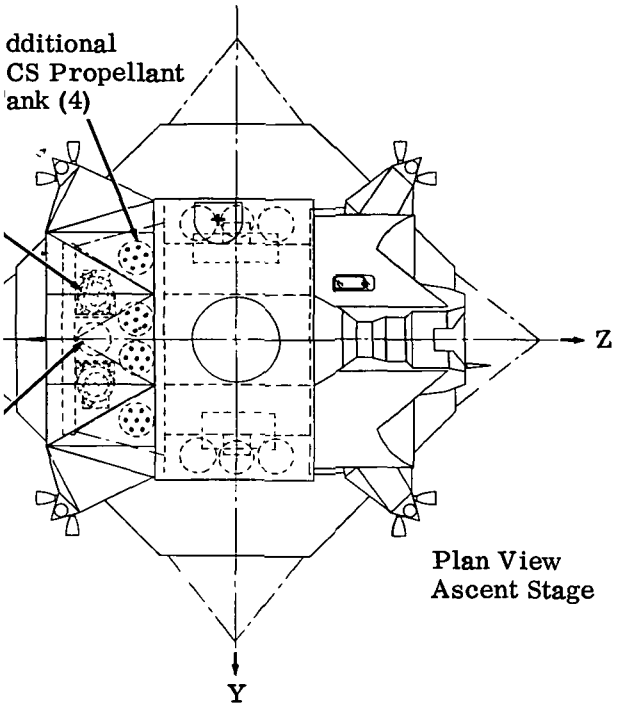
Allis - Chalmers
Fuel Cells (2)

Gaseous Oxygen
& Water Tanks

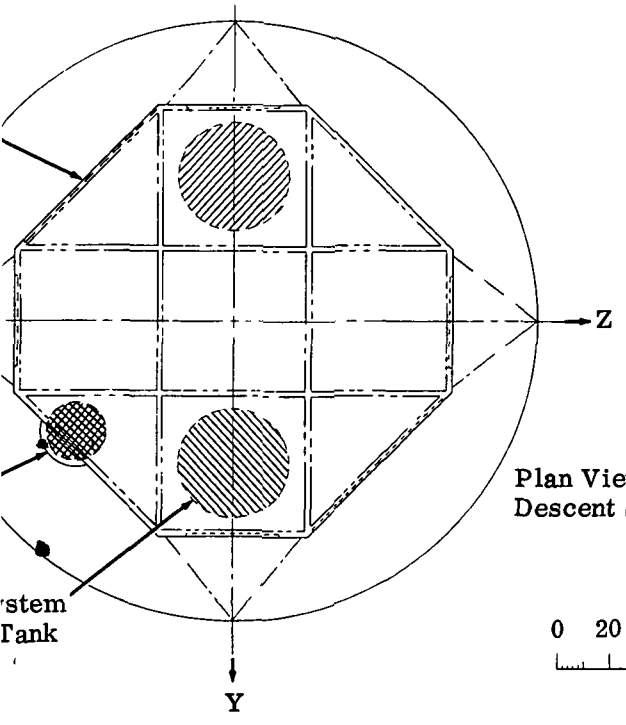
Vertical
Radiators
(6 Places, 120 sq ft Total)

Nitrogen Tank

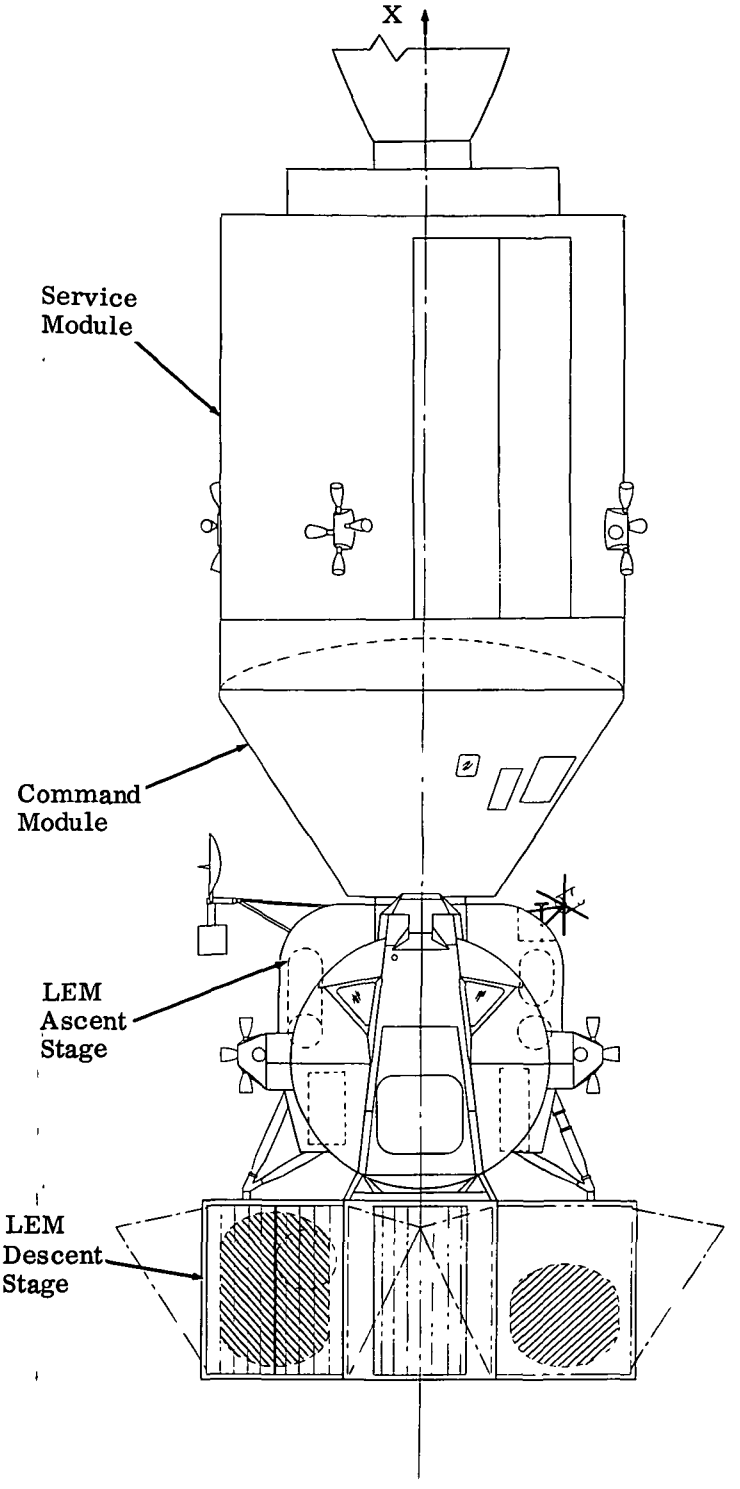
Electric Power Subs
Cryogenic Hydrogen



Plan View
Ascent Stage



Plan View
Descent Stage



Orbiting Configuration

0 20 40 60 80 100

Scale, in.

Fig. 2-3 Phase II Lab Recommended General Arrangement

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2.3.2.7 Alternates

Significant alternate subsystem configurations are also presented in Volume IV for the Phase II Lab environmental control, electrical power and stabilization and control subsystems. In addition, several alternate airlock designs are presented.

Per-flight modifications for the Phase II Lab are also presented and include considerations of additional RCS tankage, use of the "low profile" descent stage, the descent propulsion, and additional storage boxes, as well as incorporation of a viewfinder.

2.4 SHELTER

2.4.1 Mission

Significant mission characteristics of the Shelter are summarized as follows:

- Descent trajectory is Hohmann transfer from a CSM 80-n.mi parking orbit
- Systems are activated, aligned and checked out by the astronaut prior to separation from the CSM in parking orbit
- Shelter operates in conjunction with LEM Taxi and provides capability for a day or night manned mission on the lunar surface
- Shelter is capable of unmanned lunar landing, surviving the lunar environment in a quiescent state for periods up to three months, and then providing life support and scientific mission capability for the two LEM Taxi crewmen for periods up to 14 days
- There shall be a capability of providing status data to Earth on command from the Earth during the quiescent state period of three months
- Ascent capability is not required.

2.4.2 Vehicle

2.4.2.1 Nature of Modifications to LEM Subsystems

The recommended Shelter configuration is a LEM with specific modifications to the environmental control, electrical power, navigation and guidance, and crew provisions subsystems. Specific deletions and/or minor modifications are required to the stabilization and control, communications, instrumentation, propulsion, and reaction control subsystems. Because of these subsystem changes, deletions and modifications are also required for the structure and the controls and displays subsystem. The structure is also modified by the incorporation of an airlock.

All modifications and changes to the present LEM configuration, are listed in Table B-3 of Appendix B. In addition, a summary of the hardware modifications in terms of degree of modification and commonality with the Phase I Lab, Phase II Lab, Shelter, and Taxi is presented in Table 6-1 of Appendix C.

A summary of significant, required Shelter modifications follows:

2.4.2.2 Environmental Control

- Addition of 75 sq ft of radiator assemblies with supplemental water boiling for heat rejection during manned mission phases
- Addition of 3/4 in. of insulation to the cabin, a passive thermal insulation blanket covering the top docking tunnel, and insulating reflectors to the interiors of the windows
- Addition of a Radioisotope Thermoelectric Generator (RTG) waste heat transfer system for the three-month storage period
- Addition of life support provisions for extended cabin occupancy and surface exploration.

2.4.2.3 Electrical Power

- Modification of LEM descent batteries due to increased mission operating time and changed power utilization time profile
- Addition of a 50-watt Space Nuclear Auxiliary Power (SNAP) 27, RTG for primary power during the 90-day storage, with peak loads carried by energy remaining in the descent batteries
- Deletion of ascent batteries and addition of two fuel cells (remotely started prior to the Taxi launch) for the 14-day manned phase
- Addition of fuel cell reactant ambient storage tanks (the oxygen tank also includes the metabolic crew provisions).

2.4.2.4 Guidance, Navigation & Control

- Addition of LEM Optical Rendezvous System (LORS) for automatic updating of Inertial Measurement Unit (IMU) during descent
- Deletion of Abort Guidance Section, Rate Gyro Assembly, and Alignment Optical Telescope.

2.4.2.5 Propulsion

- Deletion of ascent propulsion system.

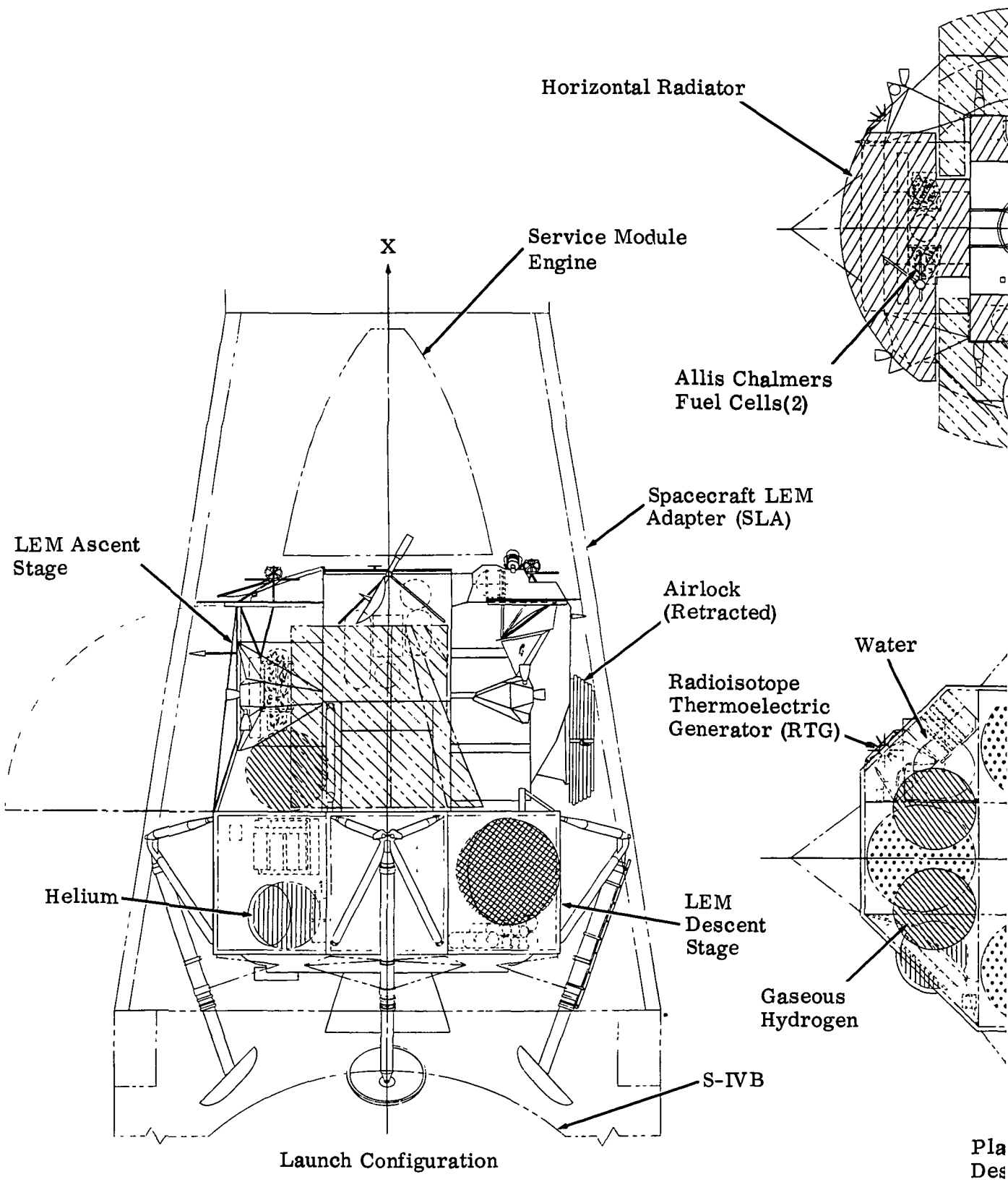
2.4.2.6 Reaction Control

- Deletion of eight of the 16 LEM thrusters and associated cluster plumbing/hardware to reduce jet impingement and heat loss, and increase external payload volume. In addition, deletion of half of the propellant tankage since ascent is not required.

2.4.2.7 Alternates

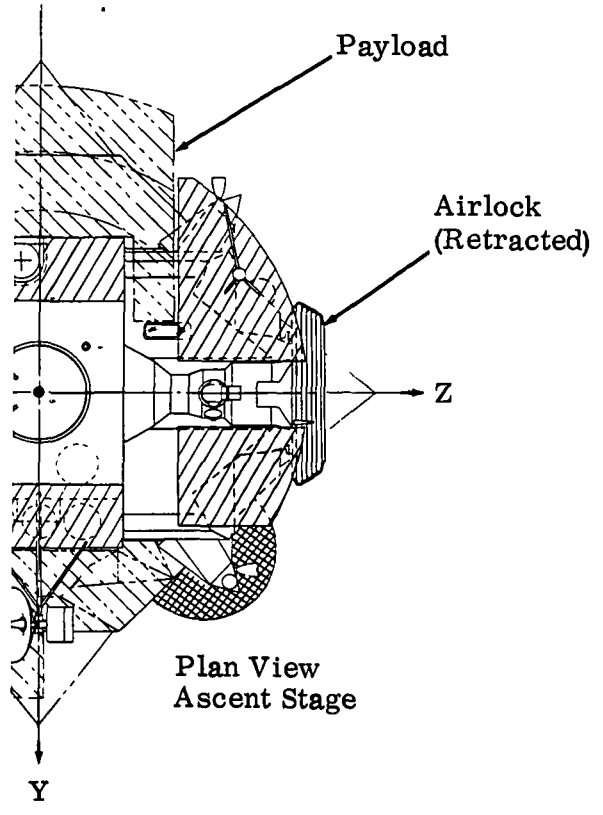
Significant subsystem alternate configurations, presented in Volume V for the Shelter, include environmental control, electrical power, guidance, navigation and control, reaction control, and communications subsystems.

Per-flight modifications for the Shelter are also presented in Volume V and include considerations of antenna locations as a function of experiment payload integration; in particular, the two Lunar Scientific Survey Modules which would require relocating the S-band steerable antenna.

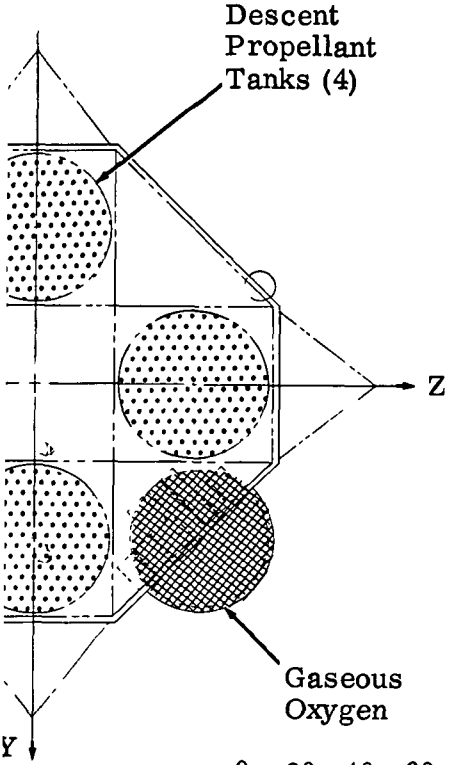


Launch Configuration

Pla
Des

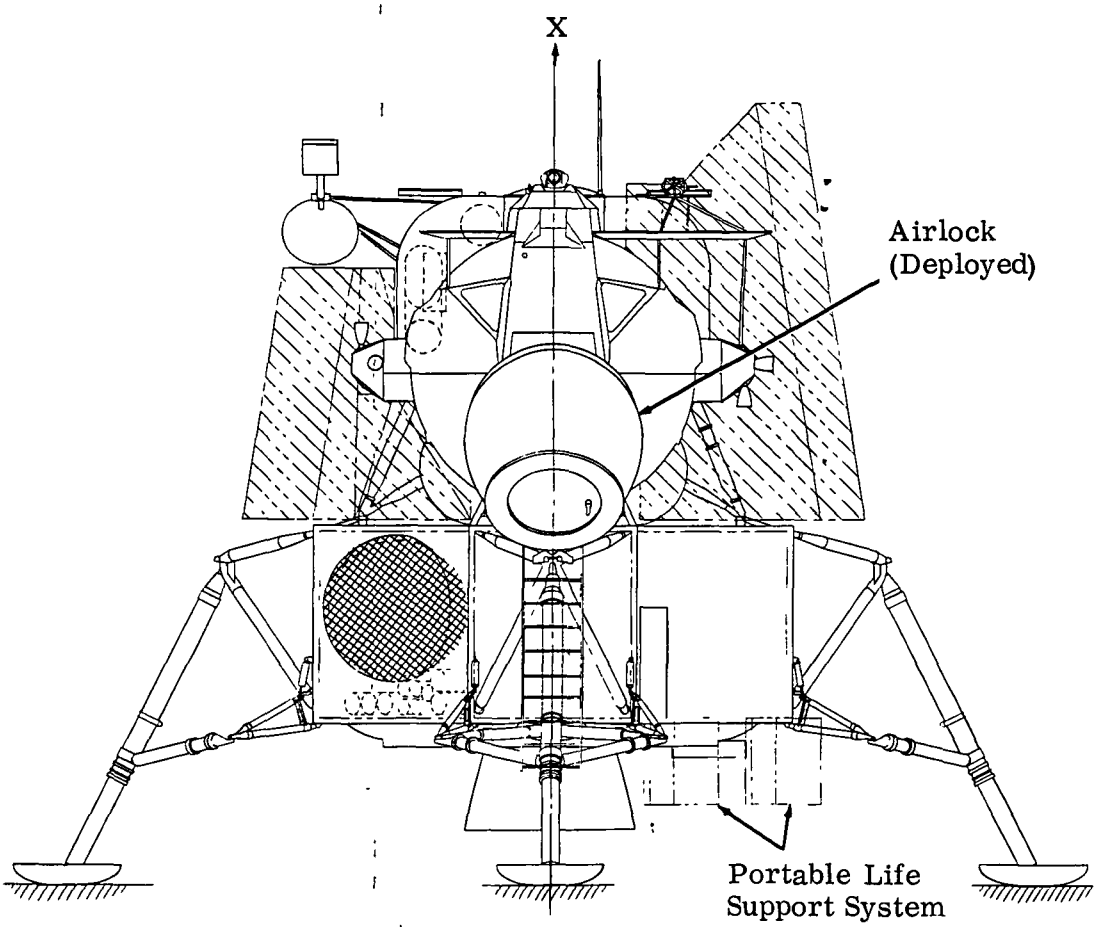


Plan View
Ascent Stage



Y
ı View
cent Stage

0 20 40 60 80 100
Scale, in.



Landed Configuration

Fig. 2-4 Shelter Recommended General Arrangement

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2.5 TAXI

2.5.1 Mission

The LEM Taxi mission differs from the basic LEM mission in that, subsequent to the manned lunar landing in close proximity to the LEM Shelter, the Taxi must survive the lunar environment up to 14 days unmanned, and then execute a normal LEM rendezvous with the CSM.

2.5.2 Vehicle

2.5.2.1 Nature of Modifications to LEM Subsystems

The recommended Taxi configuration is a LEM with specific modifications to the environmental control and electrical power subsystems and structural changes associated with these modifications. Minor modifications are also required to the crew provisions and communications subsystems and to the micrometeoroid shielding. All modifications or changes, with reference to the present LEM configuration are listed in Table B-4 of Appendix B. A summary of the significant Taxi modifications follows (Refer also to Table C-1, Appendix C):

2.5.2.2 Environmental Control

- Addition of an insulating blanket to cover the top docking tunnel and insulated reflectors to the interior of the windows during quiescent storage
- Additional water for the LEM active thermal control system water boiler for day missions
- Addition of an RTG waste heat transfer system for night missions.

2.5.2.3 Electrical Power

- Utilization of three modified LEM descent batteries and a 50 watt RTG for the quiescent storage night mission
- The RTG is the Shelter RTG used during the Shelter three month quiescent storage and transported to the Taxi by the crew after Taxi landing.

2.5.2.4 Alternates

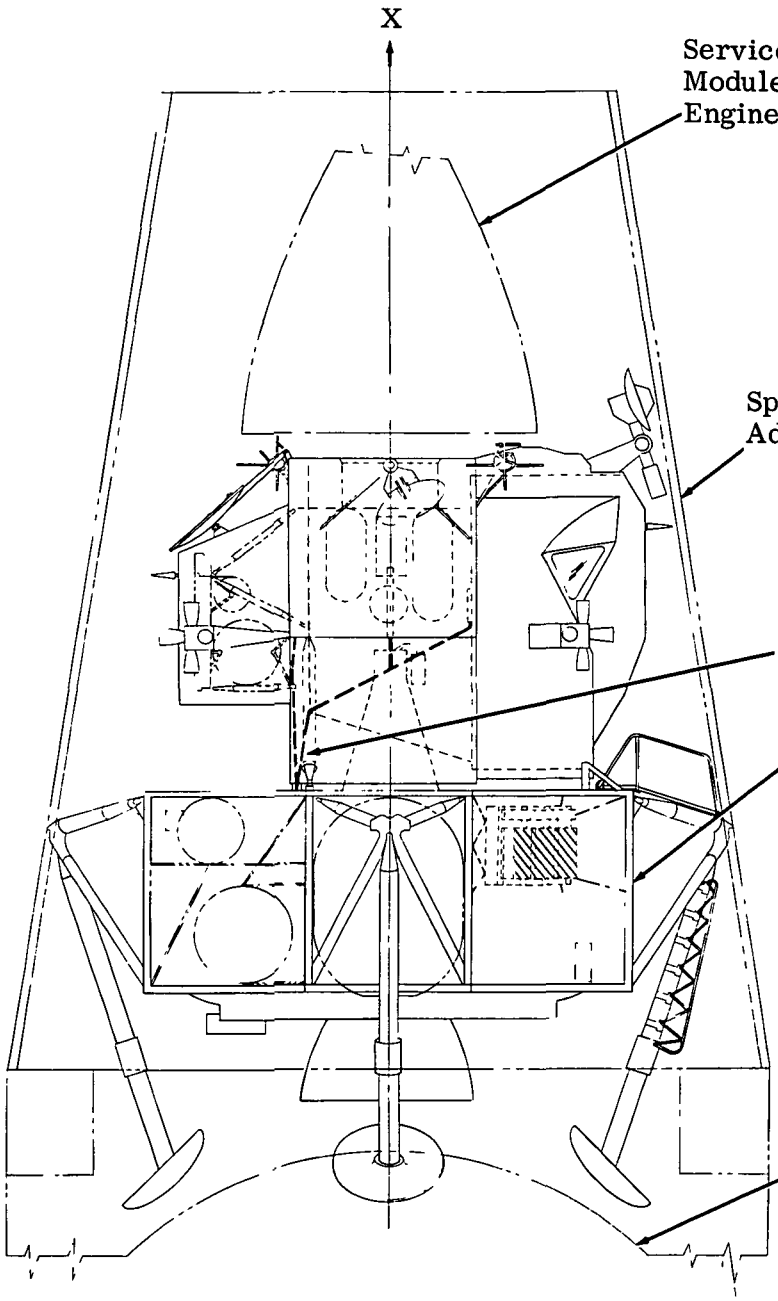
Significant subsystem alternate configurations are presented in Volume VI of this report for the Taxi environmental control, electrical power, guidance, navigation and control, reaction control, and communications subsystems.

Per-flight modifications for the Taxi are also presented and include consideration of off-loading one descent stage battery or some quantity of water as a function of mission time and phasing, i.e. day or night.

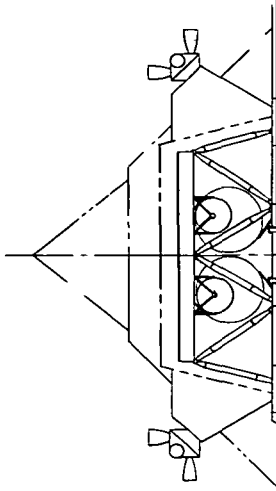
2.6 TRUCK

Although specific recommendations for Truck subsystems were beyond the scope of the "minimum design study effort", a "Reference" configuration is presented which makes use of the "Recommended" Shelter wherever feasible. This occurs in the areas of

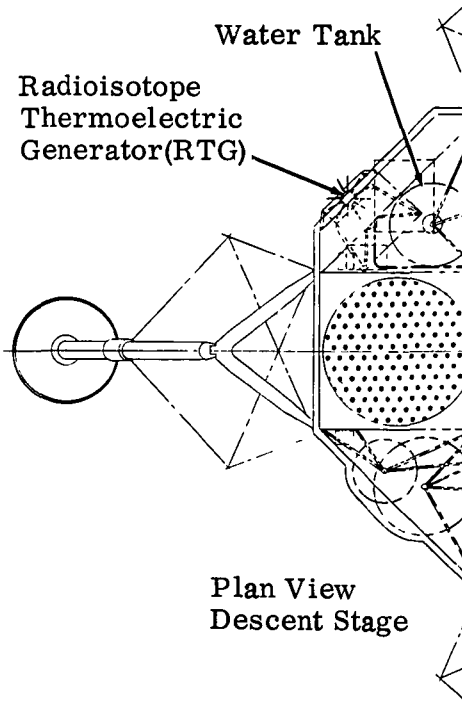
guidance, navigation and control, instrumentation, propulsion, communications and structure (descent stage only). Conversely, the Environmental Control and Electrical Power Subsystem reflect the differences between the Truck and Shelter missions. All modifications or changes with reference to the present LEM configuration are listed in Table B-5 of Appendix B.



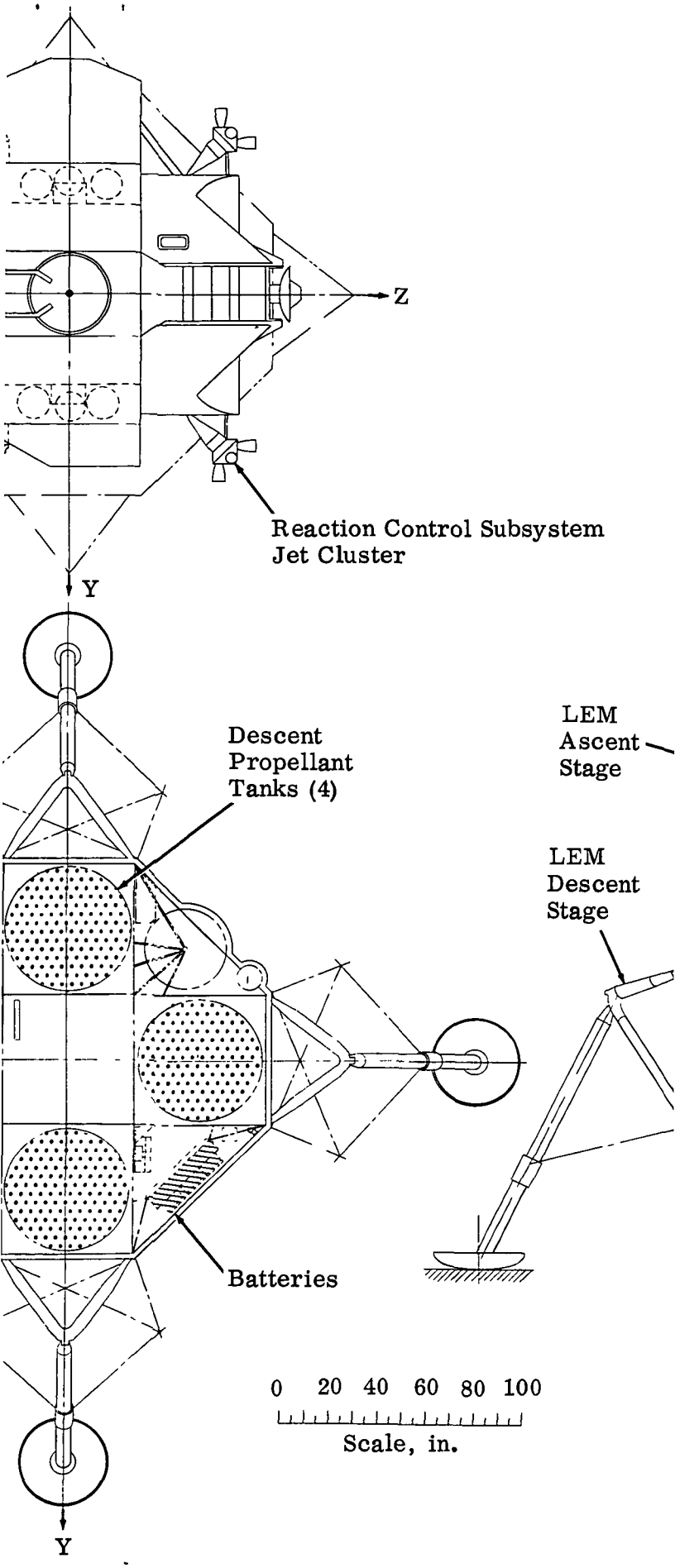
Launch Configuration



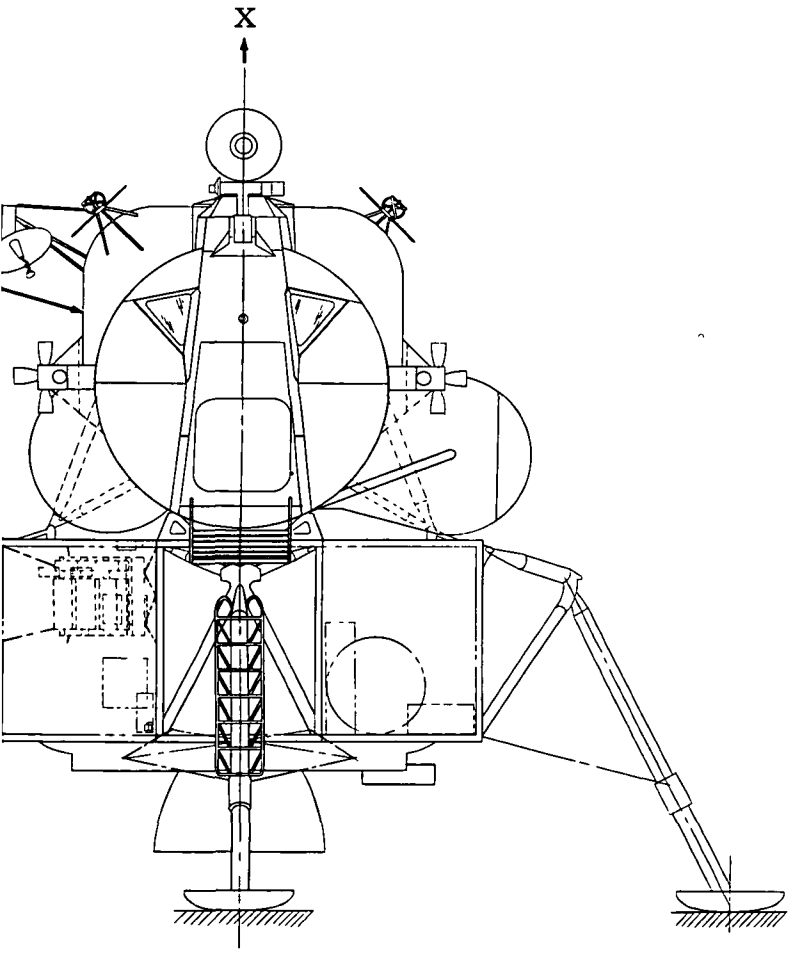
Plan View
Ascent Stage



Plan View
Descent Stage


Z
Reaction Control Subsystem
Jet Cluster
Y
Descent
Propellant
Tanks (4)
LEM
Ascent
Stage
LEM
Descent
Stage
Batteries
0 20 40 60 80 100
Scale, in.
Y

E 2



Landed Configuration

Fig. 2-5 Taxi Recommended General Arrangement

3. MANAGEMENT PLAN

3.1 ORGANIZATION

The AES/LEM Program will be managed by an organization designed specifically to meet the special requirements of this program. (See Fig. 3-1). Dr. R. H. Tripp will head the organization as Program Director. He will report to Grumman President E. Clinton Towl, from whom he derives the authority to command all resources required for the program.

The organization consists of key managers who will be accountable for planning and meeting the costs, schedules, and performance goals which will collectively assure the meeting of overall AES Program objectives. The functions they will manage have been carefully defined to prevent duplication of effort and to promote clear understanding of accountability. For example, each subsystem will be handled both within the Grumman Company and at the subcontractor's plant by a Subsystem Manager who will be accountable for all aspects of the management of his subsystem until it is installed in a vehicle. There will be a vehicle manager for each vehicle from inception to launch. Continuing top management guidance and participation will be accomplished through the Executive and Technical Review Board.

Studies of the proposed organization will continue during the Definition Phase. As a result of these studies and discussions with NASA, the organization for the Development/Operations Phase will be finalized.

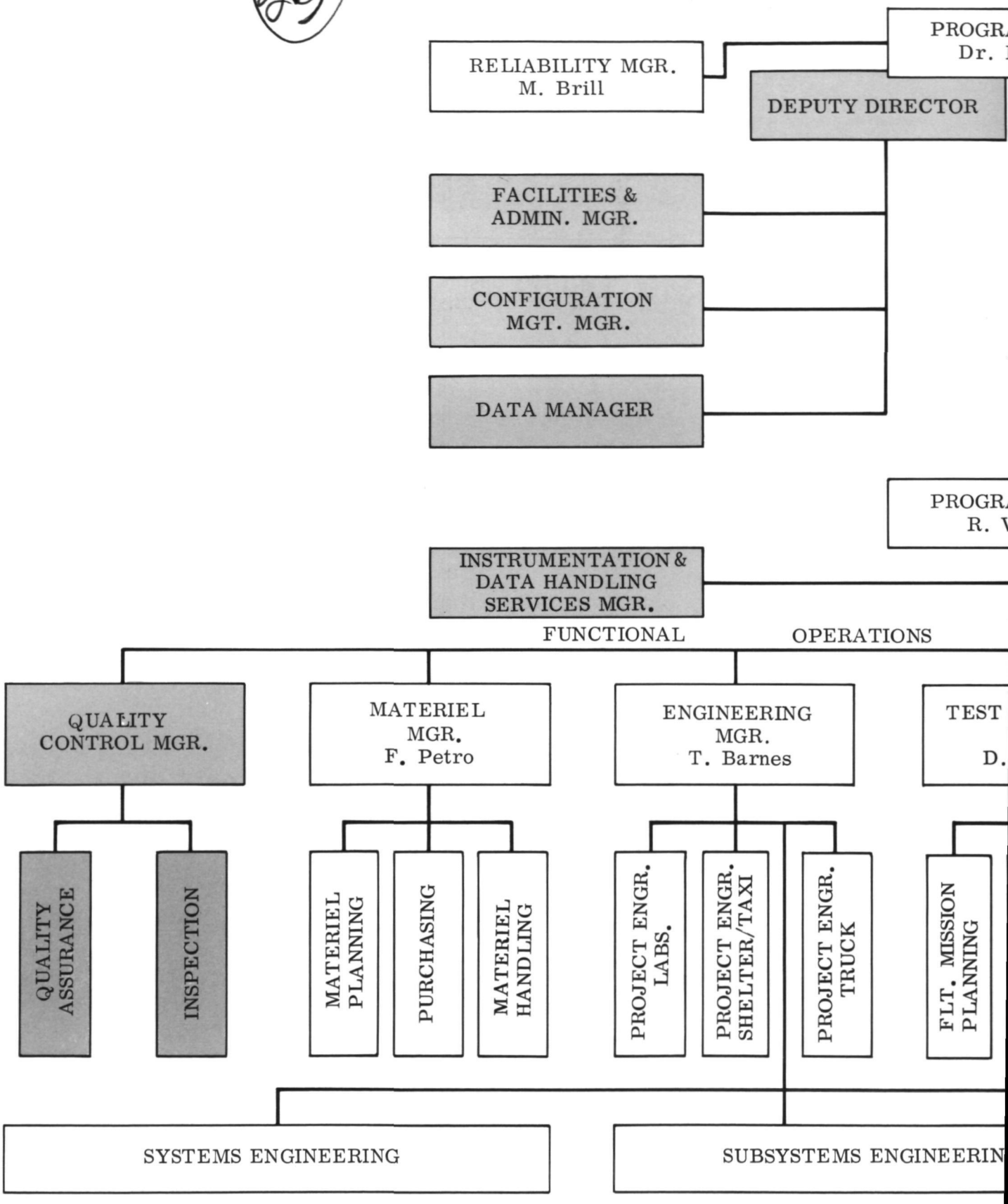
The work task requirements for the AES Program dictate the need for people with high technical competence and space technology experience. Grumman can meet this need with people who will become available from the LEM, OAO and other Company programs. This will be done without interference to these programs and will provide people who have experience in design, development, fabrication and test of space hardware and vehicles.

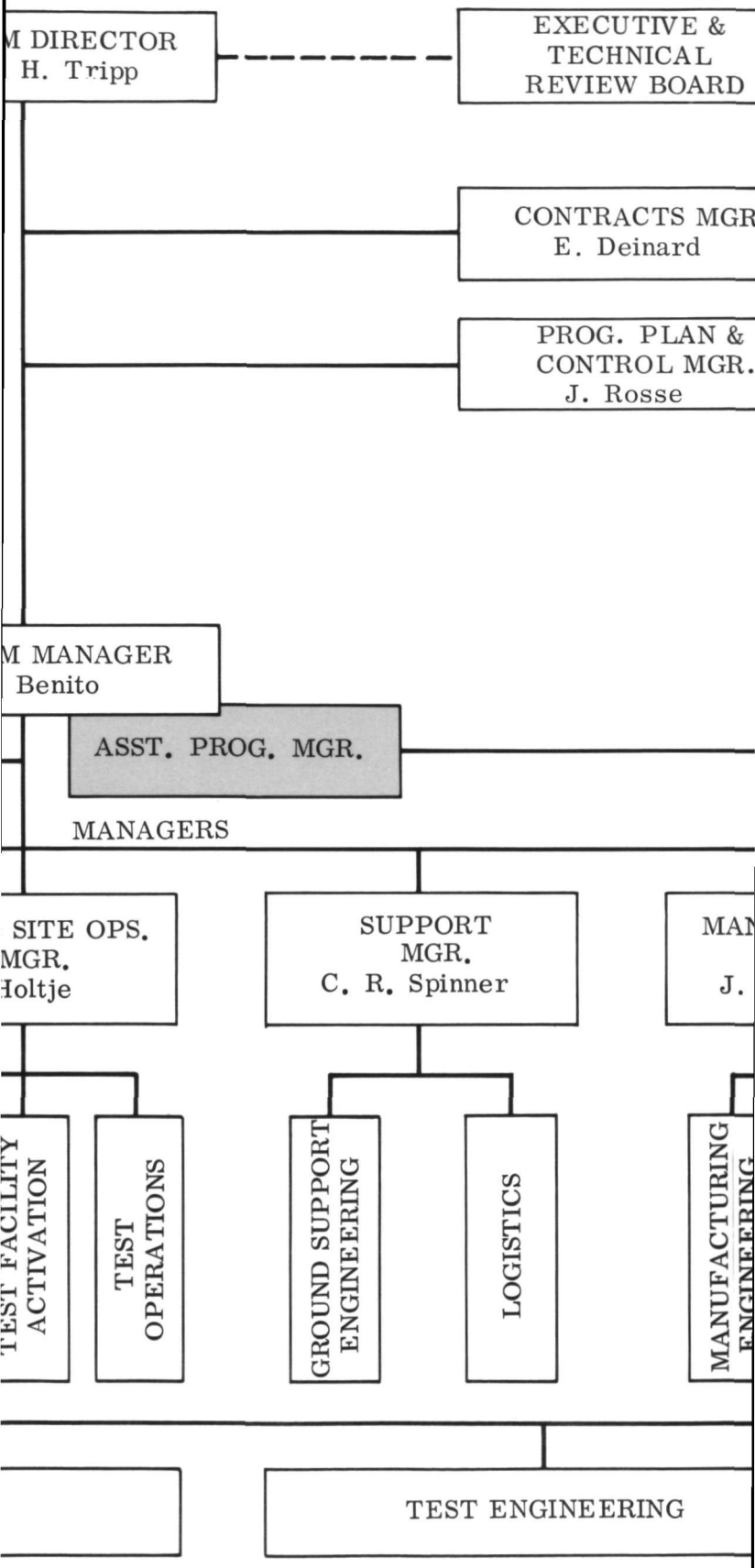
3.2 PLANS & CONTROLS

Plans required for the Definition and Development/Operations Phases are presented and discussed in the various volumes of this report. They include the following areas:

- Design and Development
- Procurement
- Test and Site Operations
- Manufacturing
- PERT Integration
- Manpower
- Facilities
- Configuration Management
- Quality
- Reliability
- Maintenance
- Support
- Training
- Transportation

These plans to be defined in detail throughout the Definition Phase, will be the basis of controlling all program parameters.


PROGR
Dr.
RELIABILITY MGR.
M. Brill
DEPUTY DIRECTOR
FACILITIES &
ADMIN. MGR.
CONFIGURATION
MGT. MGR.
DATA MANAGER
PROGR
R. V
INSTRUMENTATION &
DATA HANDLING
SERVICES MGR.
FUNCTIONAL
OPERATIONS
QUALITY
CONTROL MGR.
MATERIEL
MGR.
F. Petro
ENGINEERING
MGR.
T. Barnes
TEST
D.
QUALITY
ASSURANCE
INSPECTION
MATERIEL
PLANNING
PURCHASING
MATERIEL
HANDLING
PROJECT ENGR.
LABS.
PROJECT ENGR.
SHELTER/TAXI
PROJECT ENGR.
TRUCK
FLT. MISSION
PLANNING
SYSTEMS ENGINEERING
SUBSYSTEMS ENGINEERIN


M DIRECTOR
H. Tripp
EXECUTIVE &
TECHNICAL
REVIEW BOARD
CONTRACTS MGR
E. Deinard
PROG. PLAN &
CONTROL MGR.
J. Rosse
M MANAGER
Benito
ASST. PROG. MGR.
MANAGERS
SITE OPS.
MGR.
Holtje
SUPPORT
MGR.
C. R. Spinner
MAN
J.
TEST FACILITY
ACTIVATION
TEST
OPERATIONS
GROUND SUPPORT
ENGINEERING
LOGISTICS
MANUFACTURING
ENGINEERING
TEST ENGINEERING

Note: Shaded Boxes Designate Activities Which Will Be Staffed & Phased-in During the Definition Phase

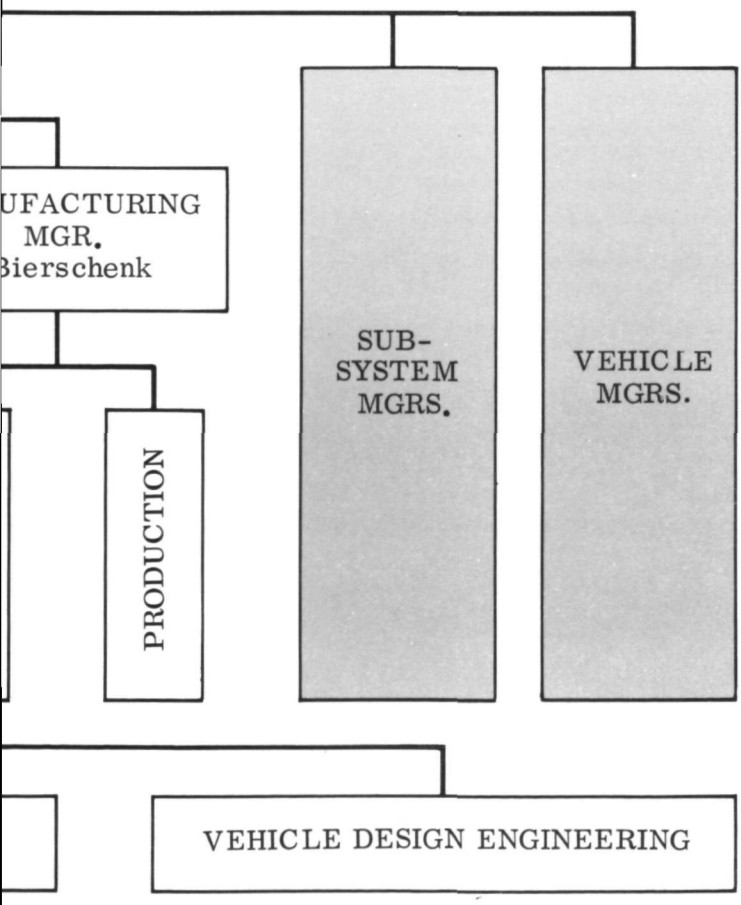


Fig. 3-1 Grumman AES/LEM Program Organization

4. SCHEDULES

4.1 AES/LEM SUMMARY SCHEDULE

The AES/LEM Summary Schedule shown in Fig. 4-1 presents the basic program for each of the four vehicles in relation to the LEM launch schedule. (The schedules are based upon the Flight Mission Assignment Plan for AES Planning, ML-65-1 dated 7 August 1965, and the LEM Program Schedule III Revision 1, dated 7 September 1965.)

In accordance with NASA guidelines, the Phase I Laboratory vehicles will be fabricated and assembled to the LEM configuration at Grumman; subsequently, they will be modified to each particular laboratory flight configuration at KSC. The Phase I Lab missions currently planned include Earth orbit rendezvous, Earth polar orbit, Earth synchronous orbit, and lunar orbit flights. Saturn IB and Saturn V launch vehicles will be used. As shown on the schedule, these launches will occur during the time span of the last four LEM launches.

The Phase II Laboratories will be fabricated and assembled at Grumman using a modified LEM manufacturing cycle. Their missions will be similar to those of the Phase I Laboratories except that mission durations will be up to 45 days instead of 14, and the experiments conducted will be progressively more comprehensive. All Laboratory missions will be manned. Some of the missions will be launched by the Saturn IB, the others will use the Saturn V launch vehicle.

The Shelter and Taxi vehicles, also fabricated and assembled at Grumman, will be used for extended-stay lunar exploration missions. These missions, along with the Phase II Lab missions, will take place in the two-year time period following the basic LEM and Phase I Lab missions. The Shelter will be landed unmanned on the lunar surface and be capable of 90-day storage prior to use as the base of operations for the two-man team during their 14-day stay. The Taxi, which will separate from the CSM in lunar orbit, will land the two-man team on the Moon and, after a 14-day quiescent storage period during the operations from the Shelter, the Taxi's ascent stage will return them to the CSM, and thence to Earth. Shelters and Taxis will be launched by the Saturn V.

4.2 AES AND BASIC LEM VEHICLE SCHEDULE

A composite manufacturing, prelaunch, mission operations schedule for all LEM and AES vehicles is shown in Fig. 4-2. It indicates the phasing required to integrate the AES spacecraft into the presently planned Manned Lunar Landing Program without impairing the LEM schedule. It should be noted that the start of manufacturing after LEM 4 is advanced to accommodate the Phase I Lab modifications and the test article development, within the launch-date and final-assembly facility availability constraints. This is additionally advantageous in that it permits a constant delivery rate for efficient manpower/facility utilization.

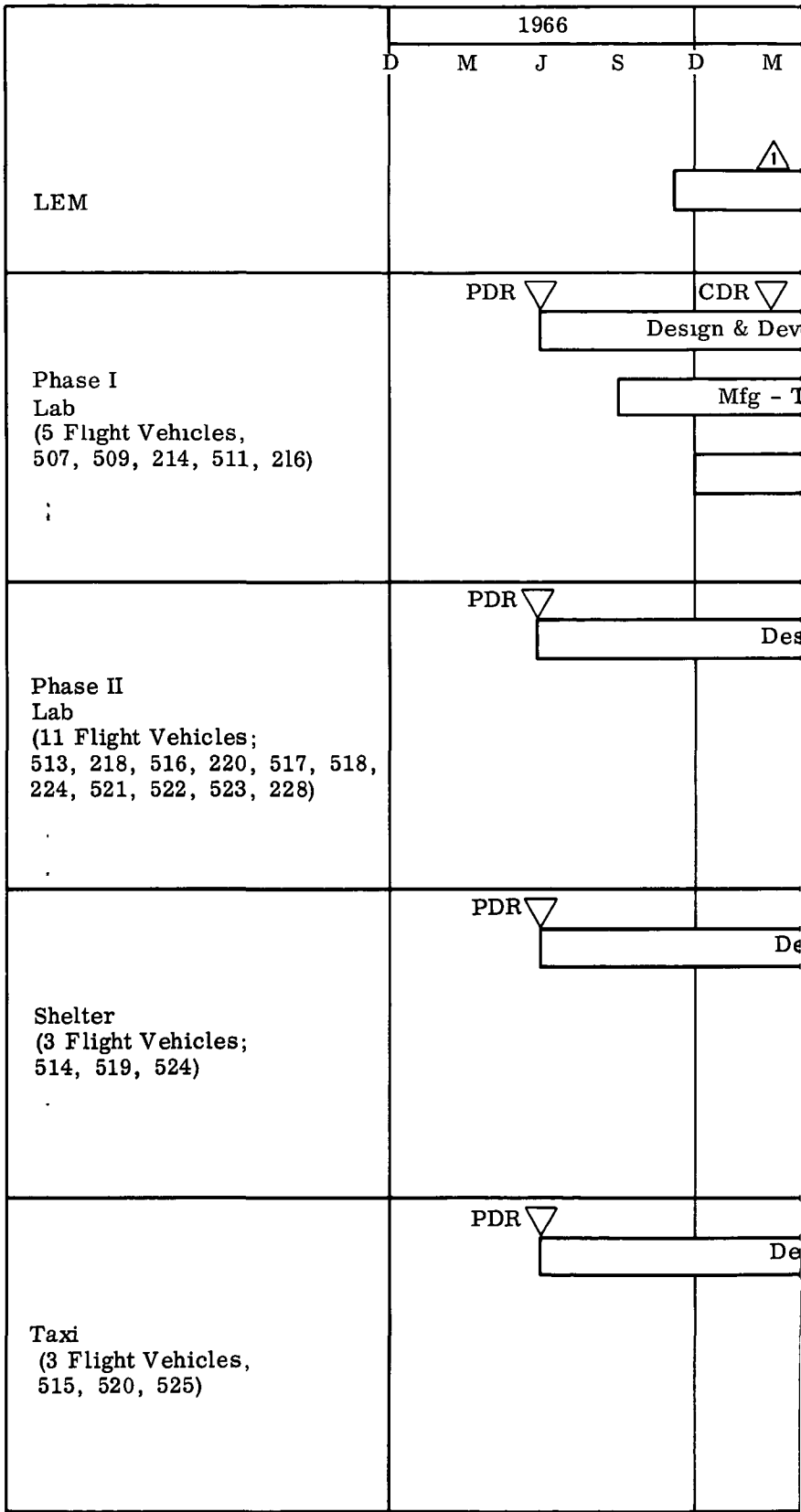
Phase II Laboratory experiments are assumed to be installed on the assembly line in parallel with installation of the Lab primary systems and subsystems. This procedure will reduce the number of stations in the operational flow, preclude

repetition of test cycles, and permit simultaneous checkout of the experiments with the basic Lab.

Spacecraft-launch vehicle combination checkout flows are based upon currently approved Apollo prelaunch operations and make maximum use of existing KSC facilities and equipment. Based on a two-shift, five-day week, the checkout flows require the following nominal calendar time spans (weeks):

- Phase I Lab 16
- Phase II Lab 18
- Shelter 17 1/2
- Taxi 16

29


1966
D
M
J
S
D
M
LEM
1
PDR
CDR
Design & Dev
Phase I
Lab
(5 Flight Vehicles,
507, 509, 214, 511, 216)
Mfg - T
PDR
Des
Phase II
Lab
(11 Flight Vehicles;
513, 218, 516, 220, 517, 518,
224, 521, 522, 523, 228)
PDR
De
Shelter
(3 Flight Vehicles;
514, 519, 524)
PDR
De
Taxi
(3 Flight Vehicles,
515, 520, 525)

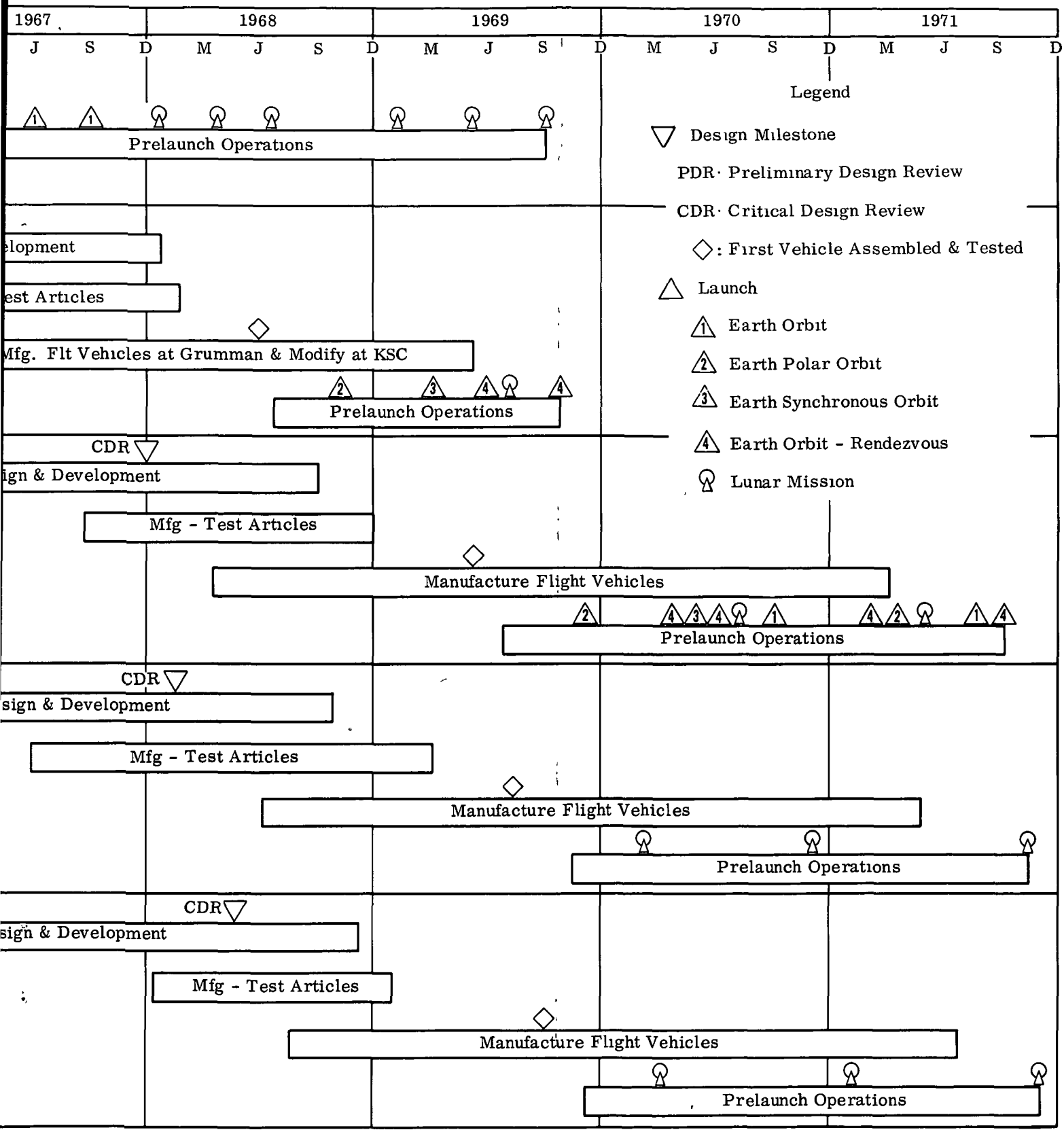


Fig. 4-1. AES/LEM Schedule Summary

Fig 4-2

Vehicle	Booster No.	1965 J	A	S	O	N	D	J	F	M	A	M
LEM-1	206	LEM-1										
LEM-2	207					LEM-2						
LEM-3	503							LEM-3				
LEM-4	504										LEM-4	
LEM-5	505										LE	
LEM-6	506											
LEM-7	508											
Lab I-1	507											
LEM-8	510											
Lab I/LLTA-1												
Lab I-2	509											
Lab I-3	214											
Lab I-4	511											
LEM-9	512											
Lab I-5	216											
Lab II/LLTA-4												
Sh/SLTA-1												
Lab II/LLTA-3												
Lab II-1	513											
Shelter- 1	514											
Taxi-1	515											
Lab II-2	218											
Lab II-3	516											
Lab II-4	220											
Lab II-5	517											
Lab II-6	518											
Shelter-2	519											
Taxi-2	520											
Lab II-7	224											
Lab II-8	521											
Lab II-9	522											
Lab II-10	523											
Lab II-11	228											
Shelter-3	524											
Taxi-3	525											

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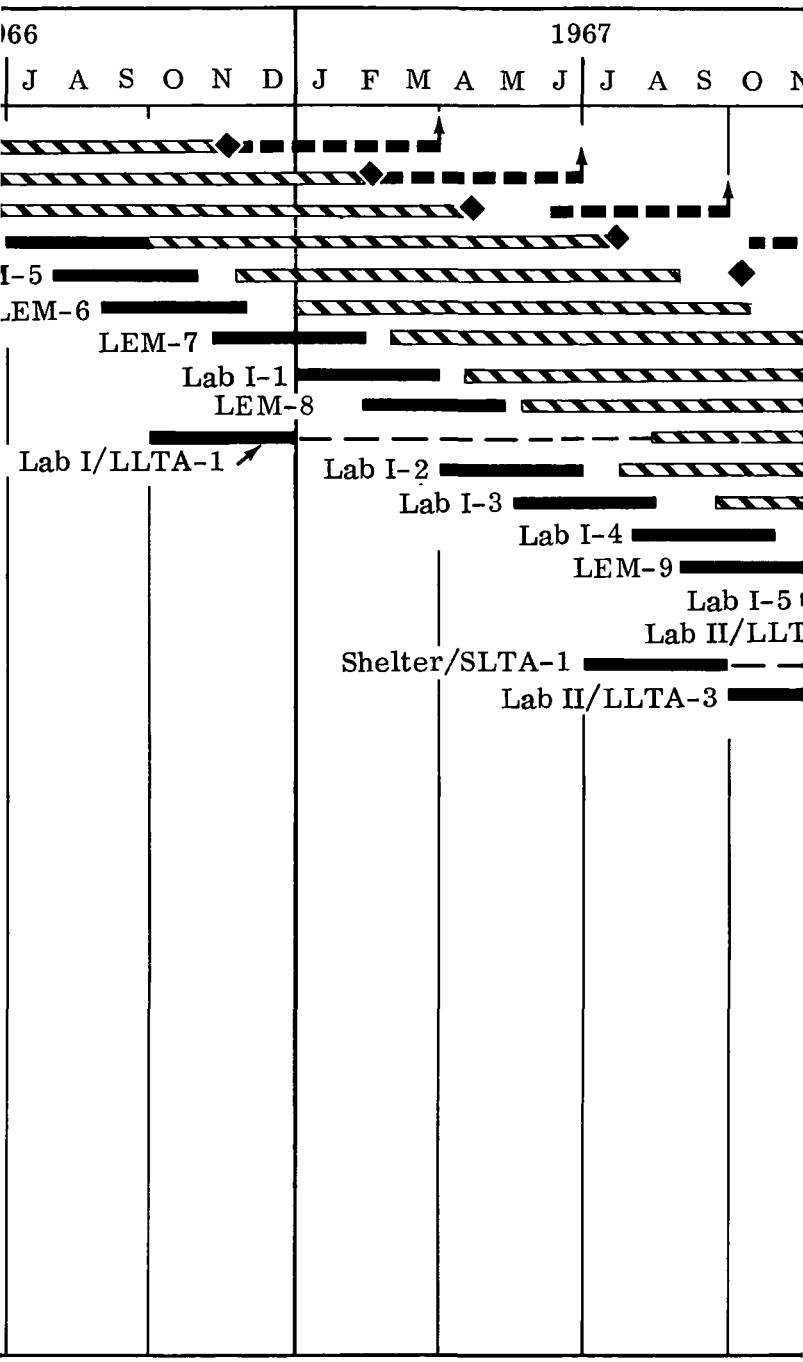

Fig 4.2

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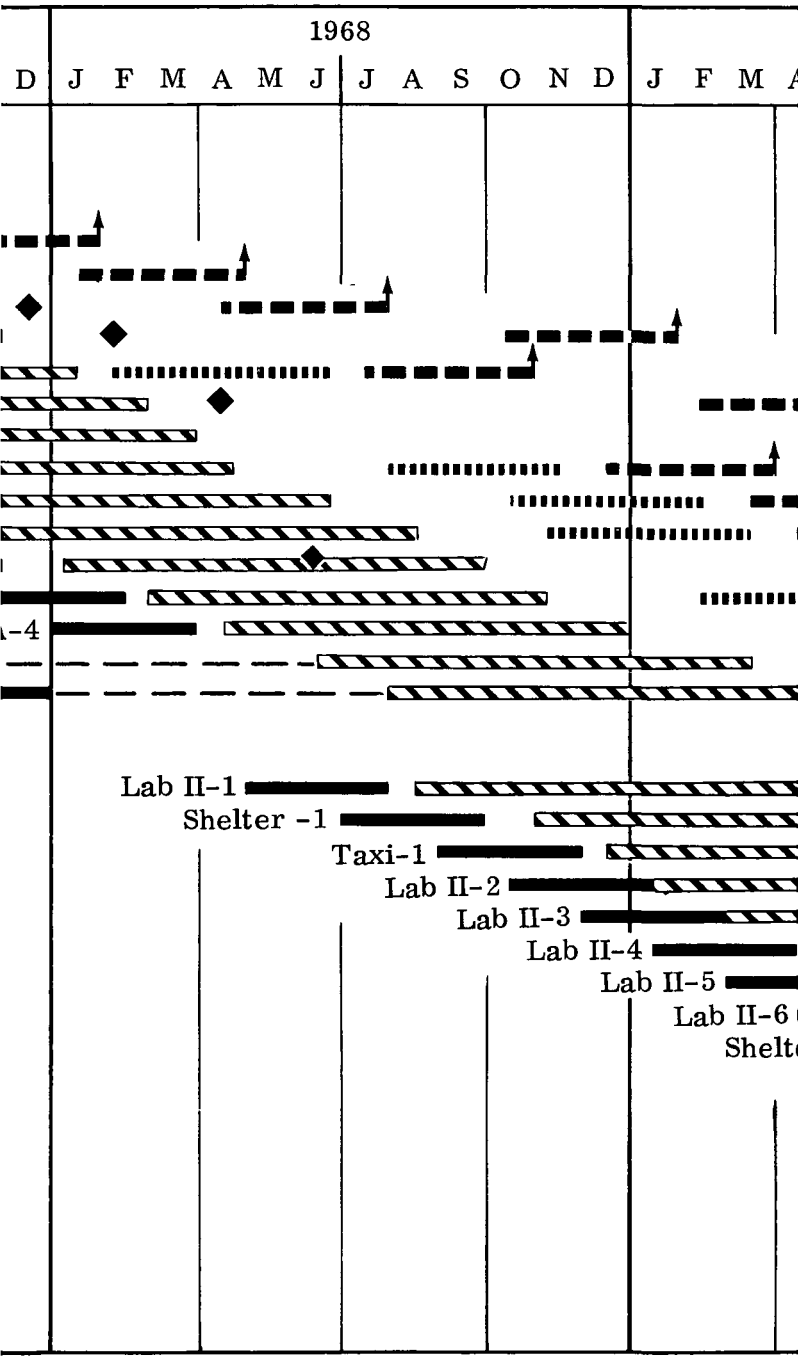

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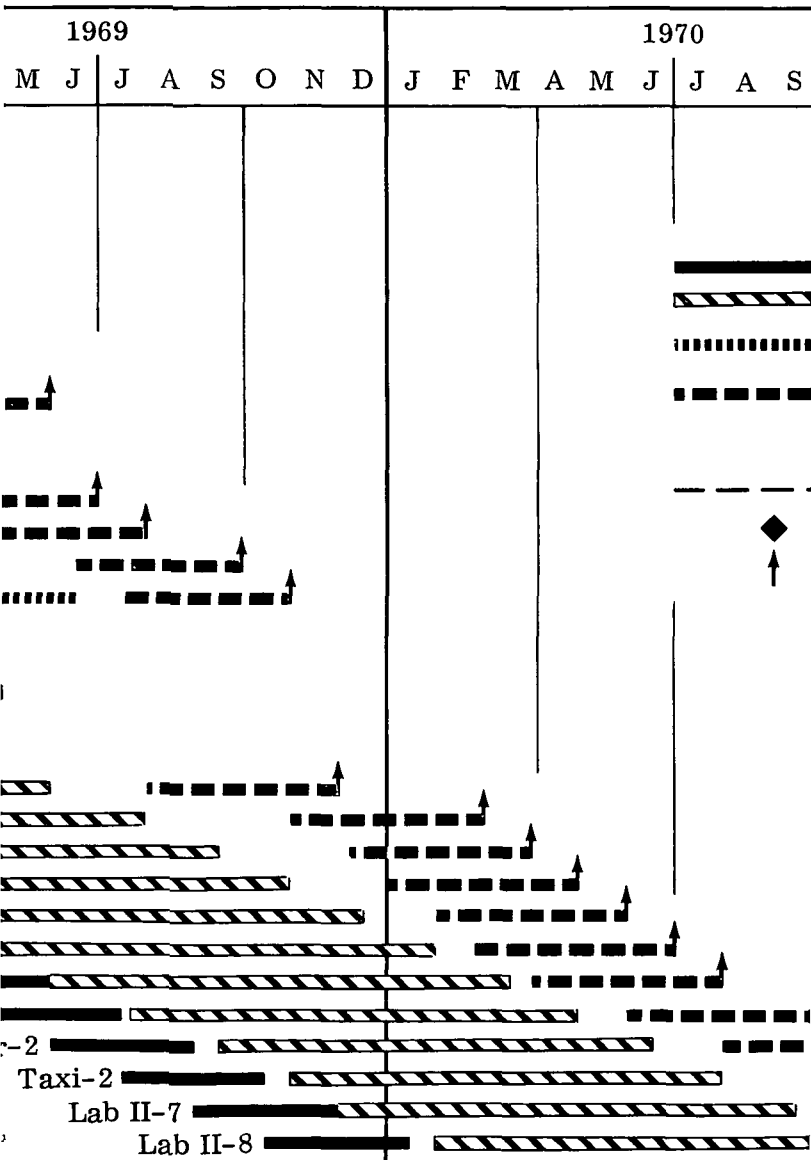

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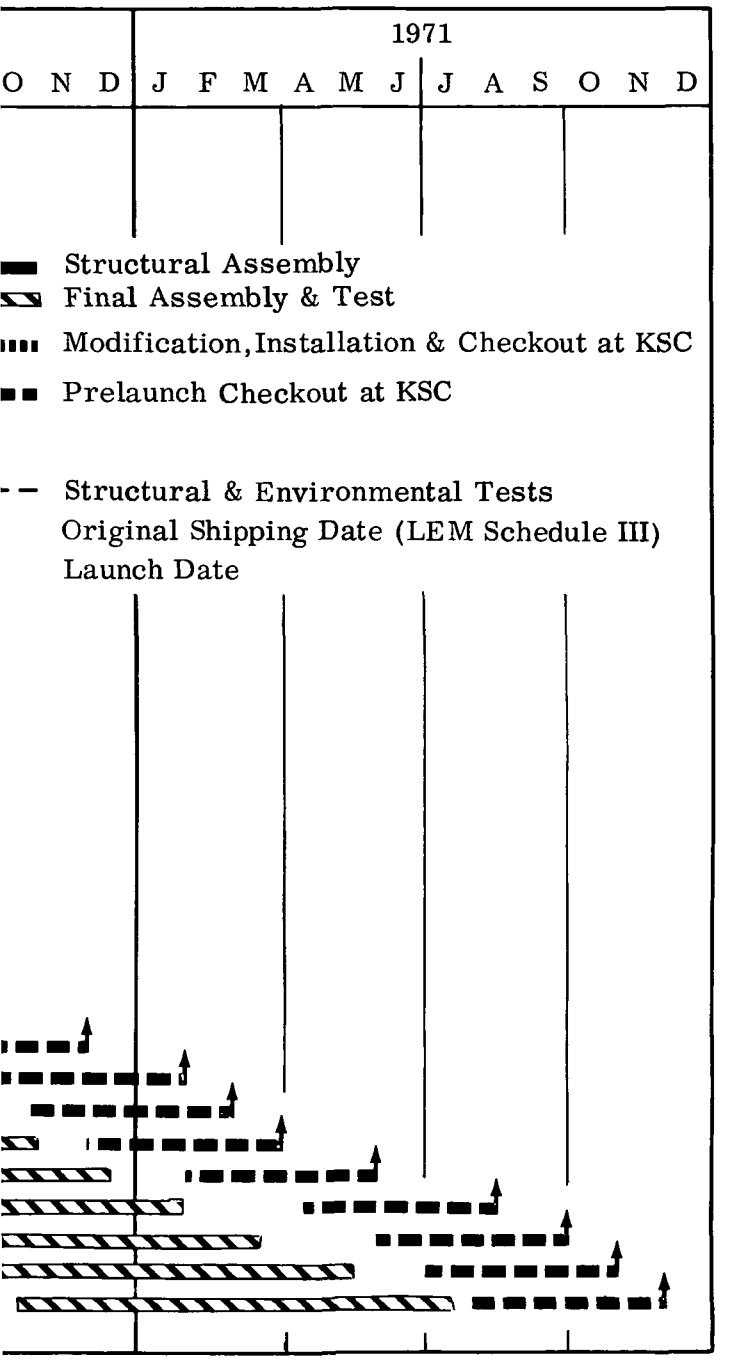

Fig. 4-2 Proposed LEM & AES Integrated Schedule

5. TEST REQUIREMENTS

5.1 GROUND DEVELOPMENT TESTING

5.1.1 Objectives

Ground development testing is concerned with events accomplished during design and development, system verification/demonstration, and flight spacecraft fabrication and acceptance. Design and development requires defining the structural, mechanical, thermal, electrical, and data management interfaces. System verification/demonstration is concerned with the structural dynamic response of the baseline vehicle and the verification or demonstration of experimental payload and spacecraft integration under ambient and induced environmental conditions. The flight spacecraft fabrication and acceptance identifies the procedures used for installation and acceptance testing of the integrated flight configuration.

Objectives of the AES/LEM development test articles are to verify:

- Subsystem and systems integration of the basic vehicle
- Functional integrity of the basic vehicle
- Basic vehicle subsystems under environmental conditions
- Design changes by testing
- Ground support equipment functional interface with the basic vehicle
- Operational checkout procedures generated to check out the basic vehicle
- Electromagnetic compatibility within the basic vehicles and between the basic vehicle subsystems and the external equipment
- Reliability analysis and predictions

5.1.2 Major Test Articles

The following is a summary of the required major test articles:

PHASE I LAB

LM-1	-	Wood-and-metal mockup fabricated in Phase "C" and further updated to reflect current configuration.
LLTA-1	-	Complete Ascent/Decent Stages structurally and thermally functional and representative of the Lab Configuration. Cabin leakage integrity must be maintained. Subsystems will be structurally and thermally representative of qualified equipment.
LLTA-2	-	LEM LTA-8 modified to the Phase I Lab Configuration for use at MSC.

PHASE II LAB

LM-2 - Wood-and-metal mockup of the Ascent/Descent Stages fabricated in Phase "B" and further updated to include airlock and current Phase II Lab Configuration.

LTM-1 - Full scale Ascent/Descent Stages with a CSM thermal simulator. Cabin to maintain leakage integrity, systems other than ECS to be thermally simulated.

Power Generation Simulator - Thermal model of structure supporting and surrounding fuel cell power generation system. Environmental Control System (ECS), Electrical Power System (EPS), and instrumentation as required for operation and temperature control. (Fuel cells, cryogenic tanks, etc.)

LLTA-3 - Complete Ascent/Descent Stages structurally and thermally functionally representative of Lab Configuration for use at MSC. Cabin leakage integrity must be maintained. Subsystems structurally and thermally representative of qualified equipment.

LLTA-4 - Identical to LLTA-3 for use as House Spacecraft.

SHELTER

SM-1 - Wood and metal mockup of the Ascent/Descent Stages fabricated in Phase "B" and further updated to include airlock and current Shelter Configuration.

STM-1 - LEM TM-2 modified from Taxi (TTM-1) to Shelter and configuration; systems other than ECS are thermally simulated.

SLTA-1 - Complete Ascent/Descent Stages with landing gear, structurally and thermally functionally representative of the Shelter. Leakage integrity must be maintained.

SLTA-2 - Modified Phase I Lab Test Article (LLTA-1) maintaining structural thermal and functional integrity.

TAXI

TTM-1 - LEM TM-2 modified to the Taxi configuration maintaining cabin structural and leakage integrity. Systems other than ECS are thermally simulated.

TTE-1 - Full-scale structural element representing the battery and Radioisotope Thermoelectric Generator (RTG) installation.

TLTA-1 - LLTA-2 (Phase I Lab from LEM LTA-8) modified to represent the Taxi, structurally and thermally.

TLTA-2 (HSC) - LTA-1 from LEM - functionally representative of Taxi flight article.

The development schedule presented in Fig. 5-1 indicates tasks necessary to verify the design and demonstrate the capability of the four basic spacecraft. It covers the utilization of the test articles listed above and highlights their use for more than one basic configuration.

5.2 FLIGHT TESTING

The prime purpose of the AES missions is 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. The planned number of AES-LEM flight missions can be categorized as follows:

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

Since each type of AES-LEM is scheduled for a number of flight missions, the spacecraft test objectives must be satisfied as early as practicable. Instead of performing special flight development missions, the AES program will utilize the prerequisite 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 baseline AES/LEM vehicle
- To assure maintaining the high-density launch schedule.

Table 5-1 summarizes the flight test requirements associated with each of the AES-LEM spacecraft. These requirements are further defined in terms of test objectives for each type of AES-LEM/mission combination in Vol. XVI, Prelaunch and Mission Operations. As the scientific mission objectives are further defined, the flight test requirements will be reviewed and considered in the light of the total flight mission requirements.

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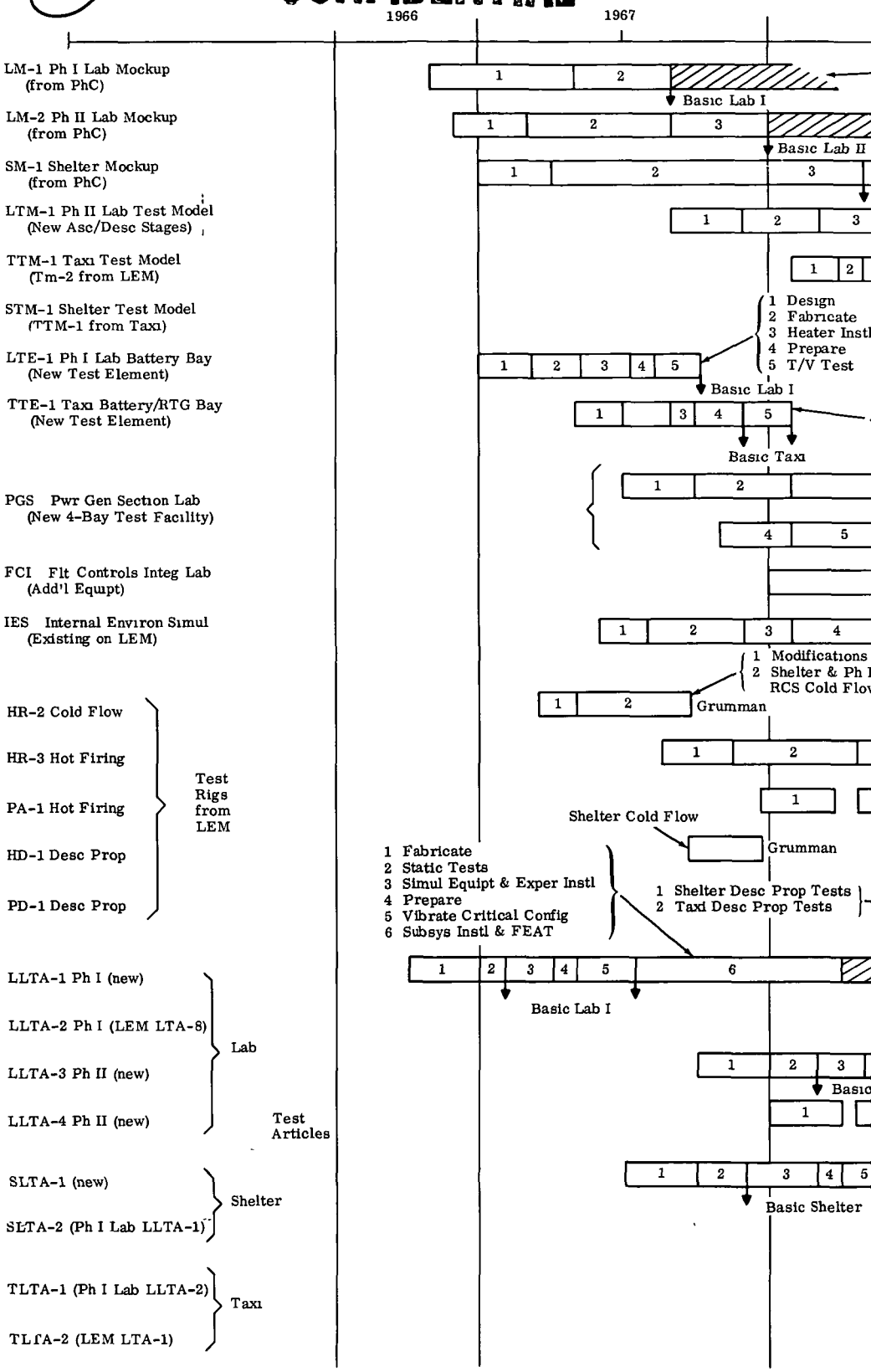

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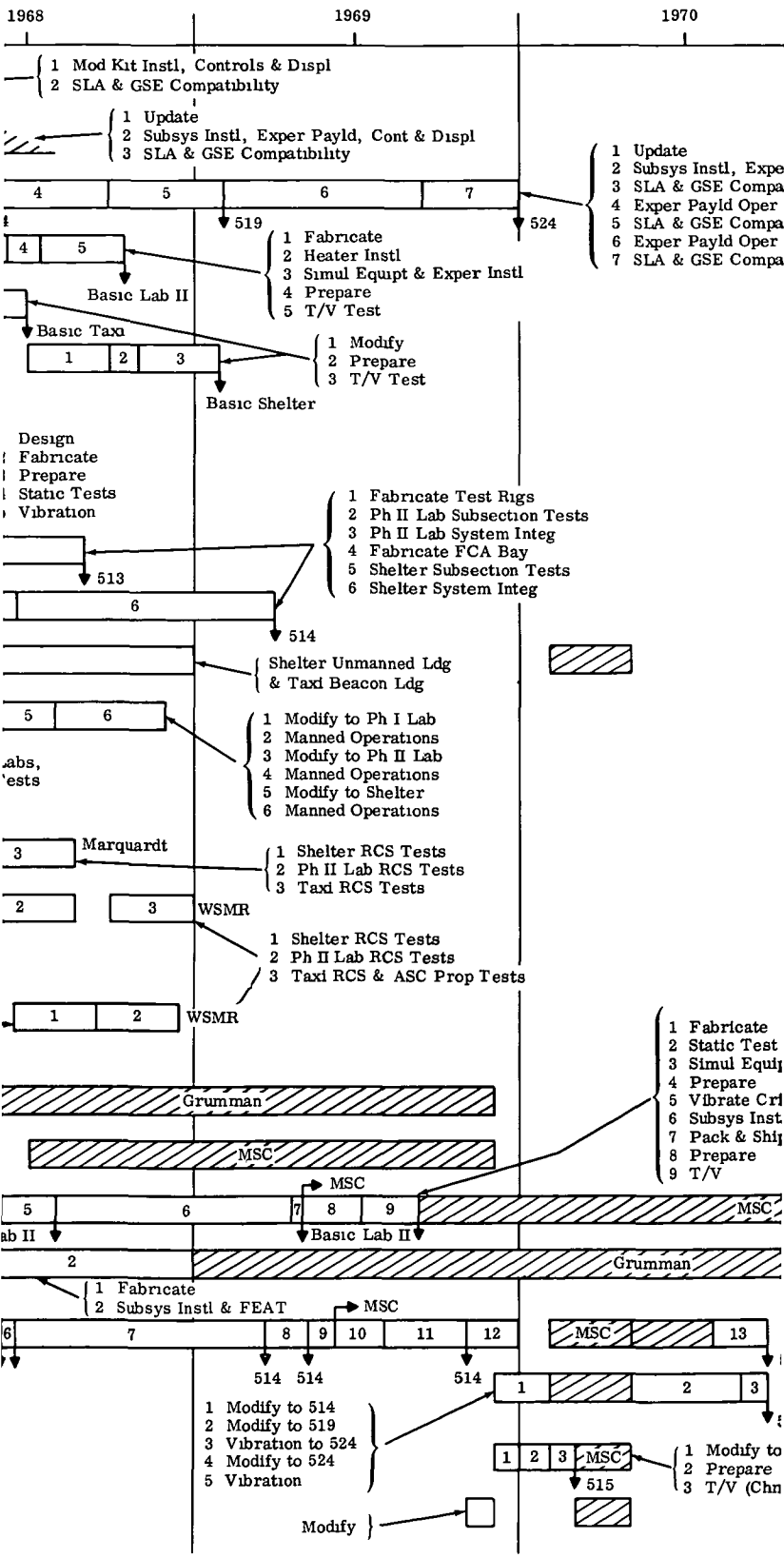

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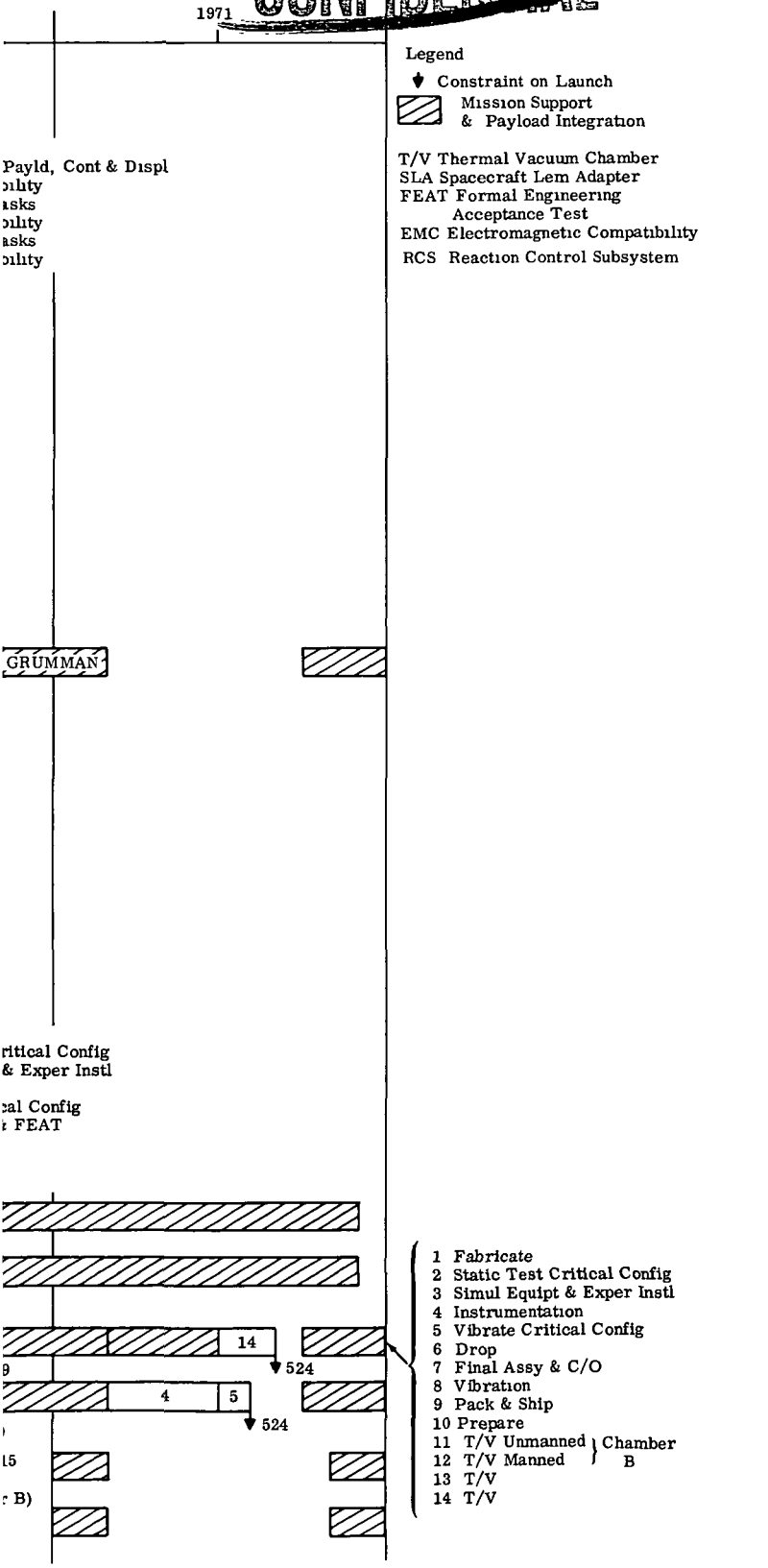

Fig. 5-1. Development Schedule

Table 5-1

AES SPACECRAFT FLIGHT TEST REQUIREMENTS SUMMARY

REQUIREMENTS	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 compatibility with Saturn 1B, Saturn V and Service Module vibration environments	X	X	X	X
- LEM stage separation				X
- 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 (i.e., 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			

6. FACILITIES

6.1 INTRODUCTION

The AES Program, as presently planned, takes fullest advantage of the current Apollo/LEM facilities on a non-interference basis. Because of the proposed vehicle modifications and increased production rate, some existing facilities will have to be modified and new ones added. These facilities include manufacturing and test facilities at Grumman and government facilities at Kennedy Spacecraft Center (KSC), Manned Spacecraft Center (MSC) and the White Sands Test Facility (WSTF). They do not include those for the Manned Spacecraft Flight Network (MSFN) or other operational facilities after vehicle launch.

6.2 GRUMMAN MANUFACTURING FACILITIES

The facilities planning performed during Phase B indicates that existing and planned LEM manufacturing facilities will satisfy the major needs for the manufacture and assembly of up to eight AES vehicles a year at Grumman. Fig. 6-1 is a recent photo of the LEM final assembly area, which will be similarly utilized for AES vehicles.

Additional facilities requirements are limited to accommodation space and a third Acceptance Checkout Equipment-Spacecraft (ACE-S/C) facility consisting of a computer and control room and assumed to be provided as Government Furnished Equipment (GFE). Fig. 6-2 shows a LEM Acceptance Checkout Facility.

6.3 GRUMMAN TEST FACILITIES

Existing or planned LEM test facilities at Grumman will be fully utilized for AES. New facilities or major modifications to existing facilities indicated by the Phase B study are:

- A Power Generation System (PGS) Test Facility to support fuel cell and reactant tankage development and integration testing
- An additional test room for concurrent Phase II Lab, Shelter and Taxi Electrical Power System (EPS) development, subsystems integration and power distribution (PDS) breadboarding.

6.4 GOVERNMENT FACILITIES

Government facilities utilization will be required at KSC, MSC, and WSTF. With few exceptions, existing facilities at these locations are capable of supporting the AES Program activities without major changes. Those additional facilities required are needed primarily to support the modification of LEM vehicles to the AES Phase I Lab configuration, and to accommodate the increased launch density planned for the AES vehicles. The required additional facilities are:

- Space at KSC for the modification activities associated with the Phase I Laboratories

- A vibration shaker system with sine and random capabilities to permit vibration testing at KSC after vehicle modifications
- Two additional ACE station installations to support the modification and prelaunch checkout operations of the AES/LEM vehicles
- Provisions for the support of mission training simulation and an Internal Environment Simulator for flight crew training.

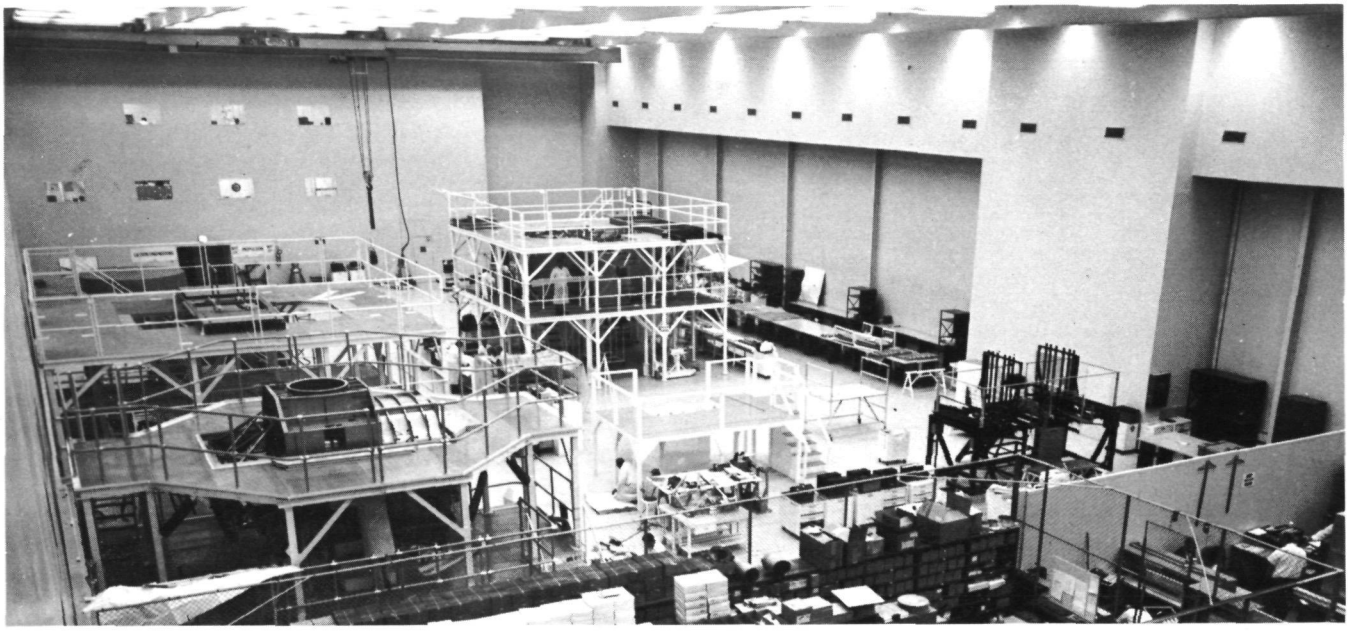

Fig. 6-1 LEM Final Assembly Area

Fig. 6-2 Acceptance Checkout Facility

7. SUPPORT

7.1 SCOPE

The AES Support Program will provide the definition, integration, and delivery of ground support equipment and publications during the development manufacturing, checkout, launch, and post-launch phases of the AES Lab I, Lab II, Shelter, and Taxi vehicles. The program is planned as a continuation of the LEM support effort along a parallel path with somewhat expanded objectives. Applicable LEM support elements and program plans will be continually monitored to ensure concurrent compatibility between the two programs relative to AES items which are dependent upon the LEM Program.

7.2 EQUIPMENT

Preliminary definition of the AES Support Equipment required for the AES Program during the development, manufacturing, and operational cycles, was accomplished during the Phase B Study. Areas included in this definition and covered more fully in the several Support volumes of this report are:

- Ground Support Equipment (GSE) and Special Test Equipment (STE) concepts
- GSE/STE end items required by the AES Program. The quantities of unique AES and existing Apollo equipment are summarized as follows:

	Equipment Designs	Total Quantity Required	Quantities Estimated To Be Available From Apollo	Additional Quantity To Be Obtained For AES	
				CFE	GFE
Apollo Equipment for AES/LEM	443	2101	1707	319	75
AES/LEM Unique Equipment	150	617	0	532	85
TOTALS	593	2718	1707	1011	

- Support Equipment Specification
- Training equipment concepts resulting in the following recommended items:

Phase I Lab Training Equipment

- Mission trainer using the LEM Mission Simulator (LMS) on a time-sharing basis, plus separate "trainee cabin"
(See Fig. 7-1)

- System Trainers
  - Integrated Flight Control System (IFCS)
  - Environmental Control System (ECS)
  - Electric Power System (EPS), Batteries
  - Sequential Flow System
- Familiarization Trainers

Phase II Lab Training Equipment

- Lab Mission Trainer
- Internal Environment Simulator (IES) Trainer
- System Trainers
  - IFCS (Phase I trainer modified)
  - ECS (Phase I trainer modified)
  - Electric Power System (EPS), Fuel Cells
  - Sequential Flow System (Phase I trainer modified)
- Familiarization trainers (Phase I trainers modified)

Shelter Training Equipment

- Operational Procedures Trainer (OPT)
- System trainers
  - Electric Power System (EPS), RTG
  - ECS(Phase II Lab trainer modified)
  - Sequential (Phase II Lab trainer modified)
- Familiarization Trainers (Phase II Lab trainers modified)

Taxi Training Equipment

- LEM Mission Simulator (Modified)

7.3 PLANNING

Preliminary analyses and studies were performed, and plans and schedules formulated for the AES Support Program, including:

- A Training Plan for identifying the general requirements, objectives, course data, training equipment, and facilities
- A Support Manual Program with the criteria and methods for its establishment, implementation, and maintenance
- The Maintenance Analysis effort, and the procedures and documentation involved in its application
- A Material Support Plan for insuring spare hardware availability in support of the development and operation of vehicles and Ground Support Equipment (Spare hardware includes two sets of "black box" spares plus the equivalent of one set in bit-and-piece parts.)
- The Basic Transportation Policy, which will be essentially the same as that developed for the LEM Program, will be to use air transportation as the basic mode for moving flight articles and major test articles to and from Grumman. Fig. 7-2 indicates a typical mode utilizing the B-377 P.G. Aircraft.

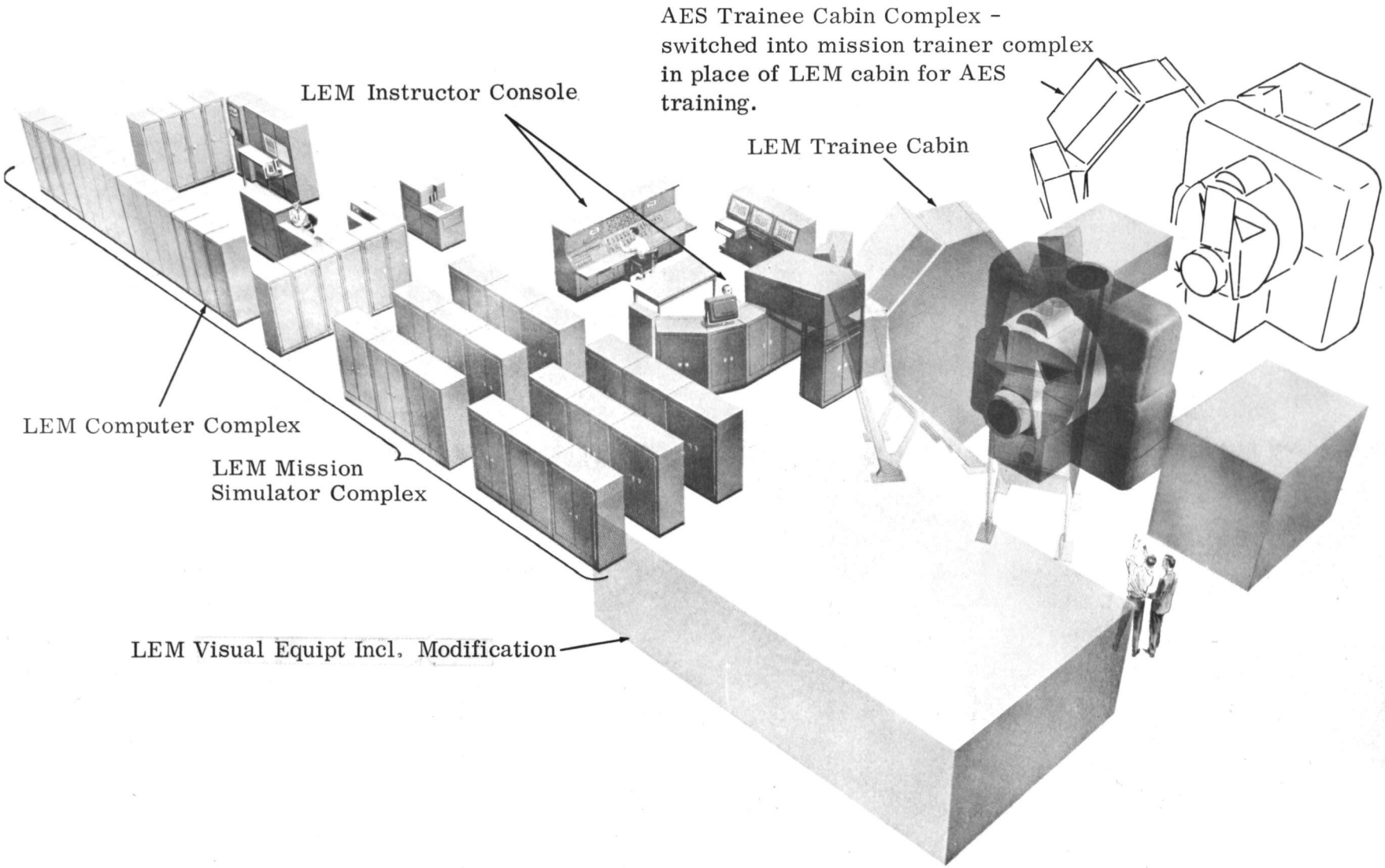

Fig. 7-1. Artist' s Conception of LEM Mission Simulator

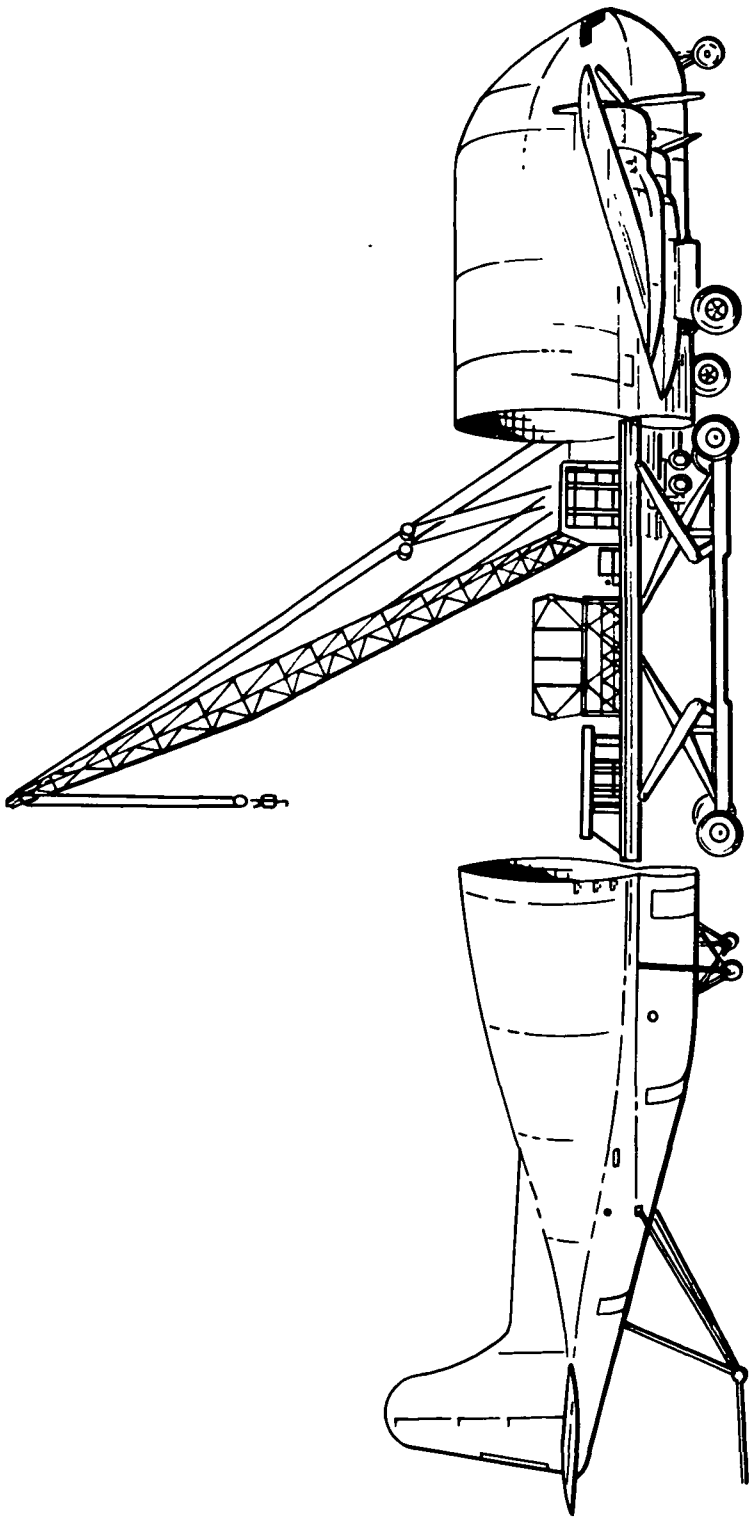

Fig. 7-2 Off-Loading B-377 P.G. Aircraft

APPENDIX A - TABLE II, REVISION L, AES BLUE BOOK

MISSION AND FLIGHT SUMMARY

Flt. No.	Config.	Orbit n.mi/ Alt/Incl deg	Duration, days	Prime Purpose	Payload Capability, lb, Less Adapter & LES	Remarks
211	CSM	200 E/90	14	Flt. Ops/Technology	-	SM Pallet, Biomedical
507	CSM/LEM	200 E/90	14	Earth Sensing/ Lunar Survey Sys Checkout	98,000	Lunar Survey System, Biomedical
509	CSM/LEM	19350 E/0	14	Astronomy	60,300	Pallet, Biomedical, Astronomy
214	LEM	200 E/28.5	--	--	*	Unamanned LEM Launch
215	CSM	200 E/28.5	14	--	31,800	Rendezvous between 214 & 215
511	CSM/LEM	80L/Low	14	Lunar Survey & Mapping	90,200	Lunar Survey System, Biomedical
216	LEM	200 E/28.5	--	--	*	Unmanned LEM Launch
217	CSM	200 E/28.5	14	--	31,800	Rendezvous between 216 & 217
513	CSM/LEM	200 E/83 R	45	Earth Oriented Applications	98,000	Biomed., Behavioral, Geophysical observations, Meteorology
514	CSM/LEM	80 L/O L.L.	10	LEM Shelter Delivery	90,200	Deliver Shelter for Flight 515
515	CSM/LEM	80 L/O L.L.	23	LEM Taxi Mission	90,200	Extended Lunar Surface Op. up to 14 Days - Surface Rendezvous with

						Flight 514
218	LEM	200 E/28.5	45	--	*	Unmanned LEM Launch
219	CSM	200 E/28.5	45	--	31,800	Rendezvous Between 218 & 219
516	CSM/LEM	19350 E/0	45	Astronomy	60,300	Prel. Astronomical Obs.
220	LEM	200 E/28.5	45	--	*	Unmanned LEM Launch
221	CSM	200 E/28.5	45	--	31,800	Rendezvous between 220 & 221
517	CSM/LEM	80 L/90	35	Lunar Orbital Survey	90,200	Lunar Survey, Probe Delivery
518	CSM/LEM	200 E/28.5	45	Earth Oriented Applications	98,000	Meteorology, Oceano-graphy
519	CSM/LEM	80 L/L.L.	10	LEM Shelter Delivery	90,200	Deliver LEM Shelter
520	CSM/LEM	80 L/L.L.	23	LEM Taxi Mission	90,200	Extended L.S. Op. up to 14 days Surface Rendez-vous with Flight 519
224	LEM	200 E/28.5	45	--	*	Unmanned LEM Launch
225	CSM	200 E/28.5	45	--	31,800	Rendezvous between 224 & 225
521	CSM/LEM	200 E/90	45	Earth Oriented Application	98,000	Meteorology, Oceano-graphy, Agricultural Obs.
522	CSM/LEM	80 L/90	35	Lunar Orbital Survey	90,200	Lunar Survey - Probe Delivery
523	CSM/LEM	200 E/28.5	45	Astronomy	98,000	Extra-Terrestial Obs.
228	LEM	200 E/28.5	45	--	*	Unmanned LEM Launch, Rendezvous with 523
229	CSM	200 E/28.5	45	--	31,800	229 Rendezvous with 228
524	CSM/LEM	80 L/L.L.	10	LEM Shelter Delivery	90,200	Deliver LEM Shelter for Flight 525
525	CSM/LEM	80 L/L.L.	23	LEM Taxi Mission	90,200	Extended Lunar Surface Obs. up to 14 Days, Surface Rendezvous with Flight 524

Abbreviations

L: Lunar
E: Earth
L.L.: Lunar Landing

*Maximum capability using 80-n.mi Parking Orbit is 31,800 lb. However, other modes to attain orbit without SM help will rapidly reduce payload capability.

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APPENDIX B
CONFIGURATION COMPARISONS
TO
PRESENT LEM VEHICLES

B-3

Vehicle Change / Item	Recommended Configuration: Removed	Modified	Added
1.0 Structure (Ascent)	• Ascent Engine Cover • Propellant Tank Supts. • Water Tank Supports • Ascent GOX Tank Supts. • Prop. Tank Shielding		• Mid-S • GOX T
(Descent)	• Base Heat Shield		• Lower • Water • Batte 16 Ba
2.0 Stabilization and Controls	• DECA • GDA	• AEA (Software change to accommodate star catalog) • Modify RGA to provide lower rate threshold • Change Rate gain in ATCA to insure one Pulse limit cycle	
3.0 Navigation and Guidance	• Landing Radar • Rendezvous Radar • IMU • LGC • PTA • PSA • CDU		
4.0 Crew Provisions	• Remove lunar specimen return containers • Remove EVA life line • Remove water probe and holster • Remove 1 LiOH (LEM/ ARS) conister	• Revise External Lighting	• 18 Li Back • Batte pack • Food • 26 CS • Add e • Provi ments • Add 2 light • Add 1 • Add 1 2)

Table B-1 Phase I Laboratory

	PDP Baseline Configuration		
	Removed	Modified	Added
Section Canister Tank Supports	• Ascent Engine Cover • Propellant Tank Supts. • Water Tank Supports • Ascent GOX Tank Supts. • Prop. Tank Shielding		• Mid-Section Canister • GOX Tank Supports
r Deck Insulation r Tank Supts. ery Supports (For atteries)	• Base Heat Shield*		• Lower Deck* Insulation • Water Tank Supts. • Battery Supports (For eight Batteries)
	• DECA*		
	• Landing Radar • Rendezvous Radar* • IMU* • LGC* • PTA* • PSA* • CDU* • DSKY*	• AEA	
LiOH Cartridges for Pack recharge eries for 18 back recharges for 13 days M LiOH cartridges xtra flood lights de 21 const. wear gar- work tops & work top s seat LEM voice recorder (total	* Vehicle must be capable of retaining all items marked with asterisk	• Revise External Lighting	

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Vehicle Change / Item	Recommended Configuration		
	Removed	Modified	Added
5.0 Environmental Control	• STD LEM Asent GOX Tanks • Secondary coolant loop Water evaporator • Accessible secondary coolant loop plumbing and valves	• Drain & Cap off secondary coolant loop • Cabin fans (to provide for duct losses)	• ASA Byp • CSM/Lab • 2 Desce • 5 Desce • Cold Pl 16 De 4 De
6.0 Landing Gear		o Remove Completely	
7.0 Instrumentation			• One PCM • Two mod recorde 409 KB/ single tion
8.0 Electrical Power	• 2 Descent ECA's		• 16 Desc • 5 Modif • 1 Circu • 1 Buss
9.0 Propulsion	• Ascent Engine • Ascent Prop Tank • Aseent He System • Descent Engine • Descent He Tank		

Table B-1 (Cont)

	PDP Baseline Configuration		
	Removed	Modified	Added
;s Recirc Duct , Water Tanks , GOX Tanks ;es for ;ent Batteries ;ent ECA's			• 21 PLSS LiOH Cartridges • CSM/Lab Recirc Fan Assy • 2 Descent Water Tanks • 5 Descent GOX Tanks • Cold Plates for 1 PCM 2 Recorders 8 Descent Batteries (1) 4 Descent ECA's
		• Remove Completely	
Fied CSM s providing dump rate and hase AC opera-			• One PCM (2) • Two CSM Type Recorder • One Selector Switch
nt Batteries ed Descent ECA's t BR Panel iring			• 8 Descent Batteries • 4 Descent ECA's • 1 Circuit BR Panel • 1 Buss Wiring
	• Ascent Engine • Ascent Prop Tank • Ascent He System • Ascent Controls & Control Electronics • Descent Engine* • Descent He Tanks*		
	* Vehicle must be capable of retaining all items marked with asterisk		(1) Batteries assume active cooling (2) Experiment data sensors, experiment signal conditioning and power to operate same are considered to be an experiment responsibility

Vehicle Change / Item	Recommended Configuration		
	Removed	Modified	Added
10.0 RCS	No Change From LEM		No Char
11.0 Communications	• S-Band Erect Antenna • VHF Erect Antenna	• SPA Mod - Provide for hardline intércom	• Hardl • Provi to FM (409
12.0 Displays & Controls	• ACA (1) • TCA (1) • FDAI (1) • DSKY • ASC Eng. conrols • Desc. eng. controls • Radar displays	• DEDA • S & C Panel • Audio Control • Explosive Devices	• Contr batte and h • Crew • Data and d

Table B-1 (Cont)

	PDP Baseline Configuration		
	Removed	Modified	Added
ge From LEM	No Change From LEM		No Change From LEM
ine Intercom le Data Channel Modulator B/s - Bypass SPA)	• S-Band Erect Antenna • VHF Erect Antenna	• SPA	• Hardline Intercom
ols for additional ies, water tanks ardline intercom afety displays andling controls splays	• ACA (1) • TCA (1) • FDA 1 (1)	• Revise EPS, COMM • Controls	• Controls for additional batteries, water tanks and hardline intercom.

B-9

Vehicle Change / Item	Recommended Configurat	
	Removed	Modified
1.0 Structure (Ascent)	●Ascent Engine Cover ●Propellant Tank Supts ●Water Tank Supports ●Battery Supports ●GOX Tank Supports ●Prop. Tank Shielding	
(Descent)	●Base Heat Shield* ●Battery Supports	
2.0 Stabilization & Controls	●GDA ●DECA	●AEA (Softwa change to a date star catalogue) ●Modify RGA provide low rate ●Change rate in ATCA to one pulse cycle
3.0 Navigation & Guidance	●Landing Radar ●Rendezvous Radar ●IMU ●LGC ●PTA ●PSA ●CDU	
4.0 Crew Provisions		●Revise Ext lighting ●Add furni

*Vehicle Must Be Capable of Retaining All Items Mar

Table

ion		PDP Baseline Co
	Added	Removed
	•Airlock (No Specific Recommendation) •GOX Tank Supports •SOX & SH_2Tank Supts. •Fuel Cell Supts. •RCS Tank Supts. •Radiator Supts. •Lower Deck Insulation •Water Tank Supts.	•Ascent Engine Cover •Propellant Tank Sup •Water Tank Supports •Battery Supports •GOX Tank Supports •Prop. Tank Shieldin •Base Heat Shield* •Battery Supports
re ccomo- to er gain insure imit		•DECA*
		•Landing Radar •Rendezvous Radar* •IMU* •LGC* •PTA* •PSA* •CDU* •DSKY*
rnal ings	•Provide capability for .44 backpack recharges (assume rechargable batteries) •Airlock--suit loop in •Add battery charger	

d Witn Asterisk

3-2 Phase II Laboratory

'iguration	
Modified	Added
•M/M Shielding •M/M Shielding	•Mid Section Canister •GOX Accum. Supports •SOX & SH_2 Tank Supts. •Fuel Cell Supts. •RCS Tank Supts. •Radiator Supts. •Lower Deck* Insulation •Water Tank Supts.
•AEA	
•Revise External lighting •Add furnishings	

B-11

Vehicle Change / Item	Recommended Configuration	
	Removed	Modified
4.0 Crew Provision (cont'd)	•Lunar Speciman Return Containers •Still Camera •EVA Life Line •Water Probe and Holster	
5.0 Environmental Control	•LEM Water Tanks •Secondary Glycol Loop •One Water Boiler •Ascent Stage GOX Tank	•Glycol Pump •Cabin Fans (to provide for duct losses)
6.0 Landing Gear		•Remove Completely
7.0 Instrumentation		

Table B-2 (Cont)

	PDP Baseline Configuration		
Added	Removed	Modified	Added
•Change backpack battery capability to 44 (assume rechargeable) (°2 batts) •Provide 66 const. wear garments •Extra flood lights •2 work tops & work top lights •Dome Light •1 seat •1 LEM voice rec. (total--2)			
•ASA Bypass •Suit Circuit Interface to Airlock •CSM/Lab Recirc Duct •1 'Fuel Cell' Type Water Management Tanks •2 30 ft^2 Radiator Panels (A) •Fuel Cell Coolant Loop •Two Gas Airlock System	•LEM Water Tanks •Secondary Glycol Loop •One Water Boiler •2 A/S GOX Tanks	•Glycol Pump	•CSM/Lab Recirc Fan Assy •2 'Fuel Cell' Type Water Management Tanks •2 30 ft^2 Radiator Panels (A) •16 PLSS LiOH Cartridges
		•Remove Completely	
•1 Modified PCM (B) •2 CSM Type Recorders Modified to provide 409 kb/s dump digital track mod and Single Phase AC OP.		•PCM	•1 Modified PCM (B) •2 CSM Type Recorders

(A) 180° Apart
(B) Experiment Data Sensors, Experiment signal conditioning and power to operate same are considered to be an experimenter's responsibility

Vehicle Change / Item	Recommended Configuration	
	Removed	Modified
8.0 Electrical Power Supply	•LEM Batteries & ECA's	•Wiring
9.0 Propulsion	•Ascent Engine •Ascent Prop System •Ascent He System •Descent Engine •Descent He System •Descent Prop Tanks •Descent Prop Plumbing	
10.0 RCS		Interchange fuel and ox lines at tank outlets
11.0 Communications	•S-Band Erect Antenna •VHF Erect Antenna	•SPA mod-provide for hardline intercom
12.0 Displays & Controls	•ACA (1) •TCA (1) •FDA I (1) •GASTA •DSKY •Ascent Eng. Controls •Battery Controls •Descent Eng. Controls •Radar displays	•DEDA •Audio Control •Explosive Devices

*Vehicle Must Be Capable of Retaining all Items marked With As

Table B-2 (Cont)

	PDP Baseline Configuration		
dded	Removed	Modified	Added
Fuel Cell ECA's Peaking Battery ECA 2 AC Fuel Cells 2-30 ft^2 Radiators (A) 1 Peaking Battery 1 AES H_2 Tank 1 AES O_2 Tank	•LEM Batteries	•Wiring	•2 P&W Fuel Cells •2-25 ft^2 Radiators (A) •1-7 KW Hr Peaking Battery •2 CSM 'Housekeeping' H_2 Tanks •2 CSM 'Housekeeping' O_2 Tanks
	•Ascent Engine •Ascent Prop System •Ascent He System •Ascent Cont & Elect •Descent Engine* •Descent He System* •Descent Prop Tanks* •Descent Prop Plumbing*		
2 Oxidizer Tanks 2 Propellant Tanks 2 He Tanks All Associated Plumbing		Interchange fuel and ox lines at tank outlets	•2 Oxidizer Tanks (C) •2 Propellant Tanks •2 He Tanks •All Associated Plumbing (D)
Hardline Intercom Interface 409.6 Kb/s Data Channel Into FM Modulator	•S-Band Erect Antenna •VHF Erect Antenna		•Hardline Intercom
Controls for Fuel Cells, cryo tanks and hardline intercom. Crew Safety Displays Quantity Gage RCS Data Handling Controls and displays Control for peaking battery	•ACA (1) •TCA (1) •FDAI (1)	•Revise EPS, Comm •Controls	Controls for Fuel Cells, cryo tanks and hardline intercom.

(C) Double the LEM capacity
erisk (D) Reverse fuel and oxidizer line connections.

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B-15

Vehicle	Recommended		
Change with respect to LEM / Item	Removed	Modified	Ad
1.0 Structure	• Ascent Engine Cover • Engine Blast • Ascent Propellant Deflector & Helium Tanks	• Food Storage • Additional Insulation • Increase Micrometeorite Shielding • Water Tank Mounting Supports (conductivity change)	• • • • • •
2.0 Stabilization & Control	• Rate Gyro Assembly • Abort Guidance Sys		• •
3.0 Navigation & Guidance	• Rendezvous Radar • Alignment Optical Telescope (AOT)		• •
4.0 Crew Provisions	• Soft Suits • Radiation Dosimeters • Liquid Cooled Garments • Bio-Instrumentation • Thermal/Anti Meteoroid Protect. Garments • Suit Repair Kit • Crew • Crew Restraints • LEM Waste Management		• • • • • • • • • • • • • • • • •

Table B-3 Shelter

	PDP Baseline		
ded	Removed	Modified	Added
Window covers Top Hatch cover Battery Supports Canister for Waste Radiator Supports Supports for Crew Provisions	• Ascent Engine Cover Engine Blast Deflector • Ascent Propellant & Helium Tanks	• Food Storage • Additional Insulation • Increase Micrometeorite Shielding • Water Tank Mounting Supports (conductivity change)	• Window covers • Top Hatch cover • Battery Supports • Canister for Waste • Radiator Supports • Supports for Crew Provisions
S-band antenna X-Y Scanner Program Coupler Assembly	• Abort Guidance Sys.		
Transponder Auto. Star Tracker Assembly	• Rendezvous Radar		• Beacon • Mission Programmer (less paper tape reader)
Airlock One Hard Suit Additional PLSS Batteries Two Additional PLSS Additional PLSS Spare Parts 14 Constant Wear Garment Exercise, Recreation & Hygienic Equipment Two Bunks Work Stations Dome & Work Toplights Additional Food Additional PLSS LiOH Medical Equipment CSM Waste Management External flood lights (150W)	• Soft Suits • Radiation Dosimeters • Liquid Cooled Garments • Bio-Instrumentation • Thermal Garment • Meteoroid Protect Garments • Suit Repair Kit • Emergency O_2 System • Crew • Crew Restraints • LEM Waste Management		• One Hard Suit • Additional PLSS Batteries • Two Additional PLSS • Additional PLSS Spare Parts • 14 Constant Wear Garment • Exercise & Recreation Equipment • Two Bunks • Work Stations • Dome Light • Additional Food • Additional LiOH • Medical Equipment • CSM Waste Management

B-17

Vehicle	Recommended		
Change with respect to LEM / Item	Removed	Modified	
5.0 Environmental Control	• LEM GOX Tanks (3) • LEM GOX Plumbing • Ascent Water Tanks • Ascent Water Tank Plumbing • LEM GOX • Redundant Glycol Loop	• Glycol Pump • Cold Plates	
6.0 Landing Gear			
7.0 Instrumentation	• LEM Scientific Equip	• Sensors	
8.0 Electrical Power Supply	• Ascent Batteries • Descent Batteries • Control Assy-Ascent		

Table B-3 (Cont)

	PDP Baseline		
dded	Removed	Modified	Added
PLSS Supplementary GOX Tank Tanks for AC Fuel Cell Water Management Plumbing Assoc. with Fuel Cell Water Management* 12 Cabin LiOH Cartridges GOX for PLSS Supplement 75 ft^2 Radiator Heat Pipe for Use with RTG	• LEM GOX Tanks (3) • Ascent Water Tanks • Ascent Water Tank Plumbing • LEM GOX • Redundant Glycol Loop	• Glycol Pump • Cold Plates	• PLSS Supplementary GOX Tank • Tanks for Fuel Cell Water Management • Plumbing Assoc. with Fuel Cell Water Management • 12 Cabin LiOH Cartridges • GOX for PLSS Supplement • 75 ft^2 Radiator • Heat Pipe for Use with RTG
(1) Additional Voice Storage Recorder Cartridge	• Data Storage • LEM Scientific Equip	• Sensors	
Three Modified Descent Batteries (12.0 kwh) Battery Charger Two AC Fuel Cells FCA Radiator and glycol pump Oxygen Tank (47 in. D.) (1) Hydrogen Tanks (39 in. D) (2) Plumbing Oxygen (Ambient Storage) Hydrogen (Ambient Storage) RTG Unit	• Ascent Batteries • Descent Batteries • Control Assy-Ascent • Two Descent Control Assembly		• Two Modified Descent Batteries • Battery Charger • Storage Battery • Two P&W Fuel Cells • Oxygen Tanks • Hydrogen Tanks • Plumbing • Oxygen (Ambient Storage) • Hydrogen (Ambient Storage) • RTG Unit

B-19

Vehicle	Recommended		
Change with respect to LEM / Item	Removed	Modified	A
9.0 Propulsion System	• Ascent Prop-Usable • Ascent Prop-Trapped • Ascent Fuel Tanks • Ascent Oxid. Tanks • Ascent Prop Plumbing • Ascent Helium Tanks • Ascent Helium • Ascent Helium Plumbing • Ascent Engine		•
10.00 Reaction Control System	• Ascent Propellant • One Fuel Tank • One Oxidizer Tank • One Set Plumbing • One Helium Tank • 50% Helium • 50% Press. Plumbing • 8 Thrusters Assy. • 50% Cluster Hardware		•
11.0 Communications	• Television	• S-Band antenna Electronic Control Assembly. (to work with X-Y scanner) • S-Band Transceiver bandwidth (70 kc output)	• • •
12.0 Controls & Displays	• Flight Controls • Abort Guidance • Propulsion displays • ACA (1) TTCA (2) • RCS displays (1/2) • S & C displays (some)	• Waste Management • Environmental Control • Instrumentation	•

Table B-3 (Cont)

	PDP Baseline		
ded	Removed	Modified	Added
Vent Valves (3) to Descent Plumbing	• Ascent Prop-Usable • Ascent Prop-Trapped • Ascent Fuel Tanks • Ascent Oxid. Tanks • Ascent Prop Plumbing • Ascent Helium Tanks • Ascent Helium • Ascent Helium Plumbing • Ascent Engine		• Vent Valves (3) to Descent Plumbing
Vent Valves to Prop. tanks	• 336 lb. Propellant • One Fuel Tank • One Oxidizer Tank • One Set Plumbing • One Helium Tank • 50% Helium • 50% Press. Plumbing • 8 Thrusters Assy. • 50% Cluster Hardware		
Command Decoder & assoc. electronics Antenna switching matrix Command Receiver	• Television		• Command Decoder
Electric Power (FCA)	• Flight Controls • Abort Guidance • Controllers • Ascent Propulsion	• Waste Management • Environmental Control • Instrumentation	• Electric Power

B-21

Vehicle Change w/respect to LEM / Subsystem	Recommended		
	Removed	Modified	A
1.0 Structure		•Increase Micrometeorite Shielding •Water Tank Mounting Supports (conductivity change)	• • •
2.0 Stab Cont			•
3.0 Nav Guid			
4.0 Crew Prov	•Two PLSS Batteries •4 lb Food •Three PLSS LiOH Cartridges		
5.0 Environ Cont	•One LiOH Cartridge •24 lb O_2 from Descent Tank		• • • o
6.0 Ldg Gear			
7.0 Instrum	•LEM Scientific Equipment		
8.0 Elec Pwr	•Descent Batteries		• •
9.0 Propulsion			•
10.0 Reaction Cont			•
11.0 Comm	•EVA Antenna •Television		
12.0 Cont & Disp	•One Battery Display		•

Table B-4 Taxi

	PDP Baseline Configuration		
ided	Removed	Modified	Added
Window Covers Top Hatch Cover Battery Supports		•Increase Micro-meteorite Shielding •Water Tank Mounting Supports (conductivity change)	•Window Covers •Top Hatch Cover •Battery Supports
Time Programmer for Status Data Transmission			•Time Programmer for Status Data transmission
	•PLSS Calibration Unit •Two PLSS Batteries •4 lb Food •Three PLSS LiOH Cartridges		
Water Added for Day Mission Heat Pipe for use with RTG Battery Cooling/IMU-ASA Bypass. Water tank heaters	•One LiOH Cartridge •24 lb O_2 from Descent Tank		•20 lb Water Added for Day Mission oHeat Pipe for Use with RTG •Battery Cooling/IMU-ASA Bypass. •Water tank heaters
	•Data Storage •LEM Scientific Equipment		
Provisions for RTG Three Modified Desc Batteries (12.0 kw-hr)	•Descent Batteries •Three Descent Electrical Control Assys		•Provisions for RTG •Three Modified Desc Batteries
Three Vent Valves to Descent Plumbing			•Three Vent Valves to Descent Plumbing
250 W Heater to each RCS Cluster			•250 W Heater to each RCS Cluster
	•EVA Antenna •Television		
RTG displays		•Slight Modification	

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Table B-5 Truck

REFERENCE TRUCK SUMMARY

Item	Change	With Respect To LEM			Alternates (with respect to Reference Configuration)
		Removed	Modified	Added	
1.0	Structure	Ascent Stage Stage Separation System Egress Platform		RCS Thruster Supports Equipment Brackets Navigation Base	
2.0	Stabilization & Control	Rate Gyro Assembly Abort Guidance System			
3.0	Navigation & Guidance	Rendezvous Radar AOT		S-Band Ant X-Y Scanner Transponder Program Coupler Assy Auto Tracker Assy	Add Rendezvous Radar
4.0	Crew Provisions	All Crew Provisions Removed (Not Applicable to Truck)			
5.0	Environmental Control*	All Life Support	Glycol Pump Cold Plates		Semi-Active Cooling System
6.0	Landing Gear		No Change		
7.0	Instrumentation	Data Storage LEM Scientific Equipment	Sensors SCEA		
8.0	Electrical Power Supply**	Descent Batteries Inverters (except one)	ECA	Redundant Ascent Battery & ECA	Remove Redundant Battery and ECA New 5-kw-hr Battery Add Redundant 5kw-hr Battery & ECA

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Table B-5 (Cont)

With Respect to LEM				Alternates (with respect to Reference Configuration)
Item Change	Removed	Modified	Added	
9.0 Propulsion	Ascent Propulsion System		Vent Valves to Descent Propulsion Plumbing	
10.0 Reaction Control	336-lb Propellant One Fuel Tank One Oxidizer Tank One Set Plumbing One Helium Tank 50% Helium 50% Press. Plumbing 8 Thruster Assys 50% Cluster Hardware	Cant Angle of Two Nozzles	Vent Valves to Plumbing	8 Thruster Config-uncanted 16 Thruster Config-4 canted Extendible Clusters
11.0 Communications	Television		Command Decoder DCA Antenna Switching Matrix	Beacon Landing
12.0 Controls & Displays	All Controls and Displays		Automatic Controls	

* Items moved to Descent Stage: Water Tank, Glycol Accumulator, Water Boiler, Coolant Recirculation Assy.
** LEM ascent batteries relocated to Descent Stage.

C-1

APPENDIX C - AES HARDWARE REQUIREMENTS SUMMARY

SUB-SYSTEM	ITEM	PH I LAB				PH II LAB				SHELTER				TAXI				REMARKS
		NO MOD	MINOR MOD	MAJOR MOD	NEW OR REDES	NO MOD	MINOR MOD	MAJOR MOD	NEW OR REDES	NO MOD	MINOR MOD	MAJOR MOD	NEW OR REDES	NO MOD	MINOR MOD	MAJOR MOD	NEW OR REDES	
GN&C	ABORT GUIDANCE SECTION		●→				←●							●				●→ ←● IDENTICAL EQUIPT MODS
	RADAR SECTION																	
	RENDEZVOUS RADAR													●				
	LANDING RADAR									●				●				
	TRANSPONDER									●								
	CONTROL ELECTRONICS SECTION																	
	ATTITUDE CONTROLLER ASSY	●				●				●				●				
	THRUST TRANSLATION CONT ASSY	●				●								●				
	DESCENT ENGINE CONTROL ASSY									●				●				
	GIMBAL DRIVE ACTUATOR									●				●				
	ATTITUDE & TRANSL CONT ASSY		●→				←●			●				●				
	RATE GYRO ASSY		●→				←●							●				
	COMMAND CONTROL SECTION																	
	SEQUENCER ASSY																●	
	X-Y SCANNER												●					
	PROGRAM COUPLER ASSY										●							
RCS	HELIUM PRESSURIZATION SECTION	●					●A				●R			●				A ADD 2 HE, OX, & PROPELLANT TANKS PLUS PLUMBING
	PROPELLANT SECTION & THRUSTERS	●					●A				●R			●				R REMOVE 1 HE, OX, & PROPELLANT TANKS PLUS PLUMBING & 8 THRUSTERS
	250-W HEATER																●	
PROPUL	D/S PROPULSION SECTION									●				●				
	A/S PROPULSION SECTION													●				
	REVITALIZATION SECTION	●				●				●				●				
	CRYOGENIC LINES SECTION																	
	HYDROGEN CRYOGENIC HEAT EXCHANGER								●									
	OXYGEN CRYOGENIC HEAT EXCHANGER								●									
	HEAT TRANSPORT SECTION, PRESS AREA																	
	CABIN TEMP CONT VALVE	●				●				●				●				
	SUIT TEMP CONT VALVE	●				●				●				●				
	AUTO PUMP SWITCH CONTROL												●				●	
	COOLANT RECIRCULATION ASSY	●						→●				←●		●				
	COOLANT REGEN HEAT EXCHANGER	●				●●				●				●				
	HEAT TRANSPORT SECTION, NON PRESS AREA																	

ECS	COOLANT ACCUMULATOR	●				●				●				●			
	SECONDARY COOLANT WATER EVAP	●												●			
	15 SQ FT RADIATOR PANEL							●									
	75 SQ FT RADIATOR												●				
	RTG HEAT UTILIZATION ASSY												●↔				↔●
	WATER MANAGEMENT SECTION																
	WATER CONTROL MODULE	●						●		●				●			
	WATER HOSE ASSY	●						●		●				●			
	WATER TANK — A/S	●												●			
	GAS CHARGING VALVE — A/S	●												●			
	SQUIB VALVE	●												●			
	WATER MANAGEMENT TANK					●*				●*							*CSM HARDWARE
	WATER TANK — D/S	●								●				●			
	GAS CHARGING VALVE — D/S	●								●				●			
	OXYGEN & CABIN PRESSURE SECTION																
	OXYGEN CONTROL MODULE		↔				↔●				●			●			
	CABIN PRESS RELIEF & DUMP VALVE	●				●				●				●			
	CABIN PRESS SWITCH	●				●				●				●			
	D/S GOX TANK	●				●								●			
	PLSS SUPPL OXYGEN TANK												●				
	A/S GOX TANK					●								●			
EPS	POWER GENERATION SECTION																
	CRYO REACTANT STOR & SUPPLY SUBSECTION							●									
	AMBIENT REACTANT STOR & SUPPLY SUBSECTION												●				
	FUEL CELL ASSY							●↔					↔●				
	POWER DISTRIBUTION SECTION																
	D/S BATTERY CONT ASSY				●							●↔				↔●	
	D/S BATTERY	●										●↔				↔●	
	PEAKING BATTERY							●									
	A/S BATTERY	●												●			
	A/S BATTERY CONT ASSY	●												●			
COMM	SIGNAL PROC SECTION			●↔			↔●			●				●			
	ANTENNA ELECTRONICS SECTION	●				●						●	●	●			
	VHF SECTION	●				●				●				●			
	S-BAND SECTION																
	COMMAND DECODER												●				
	COMMAND RECEIVER												●				
	ANTENNA SW MATRIX												●				
	R F MANUAL SWITCH	●				●				●				●			
	POWER AMPLIFIER	●				●				●						●	
	TRANSCEIVER	●				●						●				●	
	STEERABLE ANTENNA	●				●				●				●			
	ERECTABLE ANTENNA									●				●			
	IN FLIGHT ANTENNA	●				●				●				●			
	AMPLIFIER — HARDLINE INTERCOM				●			●									
INST	PCM & TIMING ELEC ASSY	●				●					●			●			
	CAUTION/WARNING ELEC ASSY	●					●				●			●			
	SIGNAL CONDIT ELEC ASSY	●				●				●				●			
	DATA STORAGE ELEC ASSY (VSR)	●				●				●				●			
	PCM (E/PCMTEA) FOR EXPMTS	●						●									ADDITIONAL PCM FOR EXPERIMENTS
	RECORDER (E/DSE) CSM TYPE				*●		*●										*REDESIGNED CSM-TYPE RECORDER FOR PH I LAB, THEN MINOR MOD FOR PH II LAB
CREW PROV	WASTE MANAGEMENT SECTION											●		●			
	CREW SUPPORT & RESTRAINT SECTION				●↔				↔●								
	EXTERIOR LIGHTING SECTION				●↔				↔●				↔●				
	INTERIOR LIGHTING SECTION																
	DOME LIGHT				●↔				↔●				↔●				
	WORK TOP LIGHT				●↔				↔●				↔●				
	FLOODLIGHT		●↔				↔●				↔●						
C&D	COMPONENTS METERS, SWITCHES, ETC	●				●				●				●			

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APPENDIX D
PHASE I LAB EXPERIMENTS UNDER STUDY

AES FLIGHTS 507/511 - LABORATORY EXPERIMENTS

- Radiation Environment Monitoring (0501)*
- Photographic Investigations
  - Cartographic
  - Panoramic
  - Multispectral
- Infrared (IR) Surveying
- Remote Geochemical Sensing
- Ultraviolet Absorption and Luminescence
- X-Ray Fluorescence
- Gamma-Ray Mapping
- Detection of Alpha Emission
- Passive Microwave
- Radio Frequency (RF) Reflectivity Measurements
- Radar Imaging, Altimetry, and Surface State
- Micrometeorite Detection/Collection
- Lunar Gravity Measurement
- Lunar Surface Probes (6 on Flight 511, 2 on Flight 507)
- Viewfinder

AES FLIGHT 509 - LABORATORY EXPERIMENTS

- Radiation Environment Monitoring (0501)
- X-Ray Astronomy
- Martian Atmosphere
- Artificial Comets
- Far Ultraviolet (UV) Image Converter for UV Astronomy
- Radio Astronomy (0705B)
- Small Maneuvering Satellite
- Magnetometer
- Propellant Handling Techniques (1506) - Phase I - Water Transfer
- Extendable Rod Performance Test (1303) - Test No. 4 - Stem Rod

AES FLIGHT 214 - LABORATORY EXPERIMENTS

- Radiation Environment Monitoring (0501)
- Capillarity Studies (0601)
- Evaluation of Spacesuits (1501)
- Manned Locomotion and Maneuvering Capability (1502)
- Emergency Techniques for Rescue (1503)
- Development of Personnel and Cargo Transfer Operations (1504)
- Propellant Handling Techniques (1506) - Phase II - Astronaut Maneuvering Unit (AMU) Propellant Transfer (H_{202})
- Expendable Airlock
- Extendable Rod Performance Tests (1303)

AES FLIGHT 216 - LABORATORY EXPERIMENTS

- Radiation Environment Monitoring (0501)
- Control Moment Gyro
- Optical Guidance System for Rendezvous
- Deployment of RF Reflective Structure (1302)
- On-board Guidance and Navigation Systems (1407)
- Orbital Maneuvering and Docking (1601)
- Propellant Handling Techniques (1506)
  - Phase II - Remote Maneuvering Unit (RMU) Propellant Transfer (H_{202})
  - Phase III - Gryogenic Propellant Transfer

*Numbers in parentheses are experiment identification numbers assigned during the Addendum to the LEM Utilization Studies.

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