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Phase B Final Report

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Vol. XI Taxi Master End Item Specification (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

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Vol. XI Taxi Master End Item Specification

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Contract No. NAS 9-4983
ASR 378B

8 December 1965

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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*

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

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SPECIFICATION

Page 1 of 215

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MASTER END ITEM SPECIFICATION

TAXI

APOLLO EXTENSION SYSTEMS - LUNAR EXUCRSION MODULE (U)

Approved by: T A Barnes
Project Engineer

Approved by:
(NASA Office)

Date: 12/1/65

Approval Date

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Exhibit A;para. 6.1.7 Document Type Preliminary Line Item Primary No.

SPECIFICATION NO. ESP 14-0100

TABLE OF CONTENTS

SPECIFICATION NO. ESP 14-0100

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

ILLUSTRATIONS

ILLUSTRATIONS (Continued)

TABLES

MASTER END ITEM SPECIFICATION

TAXI

APOLLO EXTENSION SYSTEMS-LUNAR EXCURSION MODULE (U)

1 SCOPE

1.1 Scope. - This specification establishes the requirements for the Baseline Taxi of the Apollo Extension Systems-Lunar Excursion Module, hereinafter identified as Taxi. The Taxi shall provide the life support necessary for the crew to survive in a free space and lunar environment while performing their assigned tasks. The Taxi shall be capable of landing two crewmen in the vicinity of the Shelter. The crew shall transfer to the Shelter after placing the Taxi in a quiescent mode until completion of the Shelter mission. After completion of the Shelter mission the crew shall enter the Taxi for ascent and rendezvous with the CSM. Specific deviations from the basic Taxi configuration which are imposed by different mission requirements shall be defined by individual End Item Specifications, prepared as addenda to this Master End Item Specification.

2 APPLICABLE DOCUMENTS

2.1 Document Precedence. - The following documents, of exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced here and other detail content of Sections 3, 4, 5, and 10, the detail requirements of Sections 3, 4, 5, and 10 shall be considered a superseding requirement.

2.1.1 Specifications. -

NASA

Number	Title	Date
MSFC-PROC-158A	Soldering of Electrical Connections (High Reliability), Procedure for	4-12-62

2.1.1 (Continued)

Name	Title	Date
MSC-ASPO-S-5B	Manned Spacecraft Center (MSC) Apollo Spacecraft Project Office (ASPO) Soldering Specification; and Supplement dated 5-18-65	2-10-64
Military		
MIL-E-6051C	Electrical-Electronic System Compatibility and Interference Control Requirements for Aeronautical Weapon Systems, Associated Subsystems and Aircraft	6-17-60
MIL-P-7788A	Plate, Plastic, Lighting	2-15-61
MIL-P-26539	Propellant, Nitrogen Tetroxide	4-5-63
MIL-P-27402	Propellant, Hydrazine and Unsymmetrical Dimethylhydrazine (50% N_2H_4 + 50% UDMH)	8-25-51
Grumman		
ESP 14-9110	Experimental Payload Performance and Interface Specification, Taxi, Apollo Extension Systems - Lunar Excursion Module	12-1-65

SPECIFICATION NO. ESP 14-0100

2.1.1 (Continued)

Name	Title	Date
LSP-14-001	Identification Markings, General Specification for	12-1-63
LSP-14-009 with Amendments 1 through 4	Preservation, Packaging and Packing, General Specification for	4-22-65
LSP-370-2A	Navigation and Guidance Subsystem, Rendezvous Radar/Transponder and Landing Radar Sections, Design Control Specification for	11-4-63
LSP-390-001	Bonding, Electrical, General Specification for	4-22-65
LSP-390-002	Wiring and Wiring Devices, Installation of, General Specification for	2-24-66
LSP-470-1A	Contract Technical Specification (U) Lunar Excursion Module System	6-7-65
LSP-530-001 with Amendment 1	Electromagnetic Interference Control Requirements, General Specification for	9-16-63

North American Aviation

Name	Title	Date
TBD	AES-CSM/Taxi Performance and Interface Specification - Block II	

2.1.2 Standards. -

Number	Title	Date
MIL-STD-704	Electrical Power, Aircraft, Characteristics and Utilization of	10-5-59
MIL-STD-810	Environmental Test Methods for Aerospace and Ground Equipment	6-14-62
IRIG		
IRIG-106-60	Inter-Range Instrumentation Group (IRIG) Standards	8-62

2.1.3 Drawings. -

NASA

MSFC-10M01071	Manned Space Flight Center Drawing	

Grumman

TBD	Level I Functional Diagram	

2.1.4 Bulletins. -

NASA

AFMTCP-80-2 Vol. 1	General Spacecraft Center (MSC) Engineering Criteria Bulletin	11-8-63

2.1.4 (Continued)

Name	Title	Date
EC-1	Manned Spacecraft Center (MSC) Engineering Criteria Bulletin	11-8-63

2.1.5 Other Publications. -

NASA

Name	Title	Date
NPC-200-2	Quality Program Provisions for Space Systems Contractors	4-20-62
NPC-250-1	Reliability Program Provisions for Space Systems Contractors	7-63

2.2 Availability of Documents. -

2.2.1 NASA and Government Documents. - Copies of NASA and Government documents may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D.C., 20402.

2.2.2 Grumman Documents. - Copies of this specification and other applicable Grumman documents may be obtained from AES Program Data Management, Grumman Engineering Corporation, Bethpage, Long Island, New York, 11714.

2.2.3 North American Aviation Corporation, Space and Information Systems Division Documents. - Copies of North American Aviation Corporation, Space and Information Systems documents may be obtained from NAA, SID, Downey, California, Attention: Mr. R. Berry, Mgr. Assoc. Contr. Admin.

3. REQUIREMENTS

3.1 Performance Requirements. -

3.1.1 Operational Requirements. -

3.1.1.1 Mission Related Requirements. - The Taxi shall be capable of landing two crewmen on the lunar surface and returning them to an orbiting CSM for subsequent return to earth. The Taxi shall be capable of being stored in a quiescent state for periods up to 14 days between the time of landing and return flight. The Taxi shall operate in conjunction with an AES-LEM Shelter and shall include features which allow effective crew participation in the operation of the vehicle. The flight crew shall have the capability to direct the control of the spacecraft throughout all flight modes. The flight crew shall participate in navigation, control, monitoring, computing, and observation when such participation enhances mission reliability or crew safety. The Taxi shall contain all subsystems necessary to complete its mission. Status of subsystems shall be displayed for crew monitoring such as failure detection, mode of operation, mode selected, subsystems status, staging, sequences, touchdown and docking control. Normal operation of any subsystem shall not require continuous monitoring by the crew. Such requirements shall be met through use of automatic features of the subsystems. Crew monitoring of these subsystems with provisions for executing command control on board is required. This includes the capability for crew initiation and determination of all abort paths independent of the CSM or ground based information. This requirement shall not preclude the use of CSM or ground based information to increase reliability, accuracy and performance. The Taxi shall be designed so that any single crewman will be able to perform all tasks essential to return to the CSM. Automatic systems shall be employed in the stabilization and control (S/C) only when required to obtain necessary precision or response speed, or to relieve the crew of excessively tedious tasks. A manual override capability will be provided for all automatic flight control modes. The crew of the Taxi will wear unpressurized space suits during normal operation. However, Taxi onboard subsystem arrangements, hatch operations, etc., shall be designed for use and operation be crew members in pressurized space suits. The Taxi shall provide sufficient storage for

3.1.1.1 (Continued)

return experimental payloads to satisfy mission objectives. A hatch shall be provided to allow ingress to and egress from the Taxi during earth countdown and into space while in the docked position and onto the lunar surface. The Taxi shall be capable of performing the lunar landing maneuver with or without the aid of an active beacon on the lunar surface at the Shelter site. The Taxi shall be capable of using the Descent Propulsion Subsystem (DPS) and the Reaction Control Subsystem (RCS) supplied by the Ascent Propulsion Subsystem (APS) propellants as backup to the CSM Service Propulsion System (SPS) within the limits of the existing Reaction Control Thruster life.

3.1.1.1.1 Mission. - The lunar orbit rendezvous technique will be used to perform the lunar landing mission. Employing this technique, the spacecraft consisting of the Command Module and the Service Module, (CSM), and Taxi is injected into a translunar trajectory. Upon reaching the moon the spacecraft is inserted into a lunar orbit by the CSM. In lunar orbit the Taxi with two crewmen aboard separates from the CSM and descends to the lunar surface on the Shelter site. The separated lifetime shall be no greater than TBD hours. The third crew member remains in the CSM and in lunar orbit. After Taxi landing and checkout of the Shelter, the Taxi is shut down for the lunar stay. The crew shall perform their lunar tasks using the Shelter as a base. At the conclusion of the lunar stay the crew shall return to the Taxi taking with them scientific records and specimens. The Taxi is then activated to return the crew to lunar orbit. The rendezous and docking maneuvers are then performed. The crew and payload are transferred to the CSM and the CSM, without the Taxi is injected into a trans-earth trajactory. The Taxi Descent Propulsion Subsystem (DPS) and the ascent propulsion propellants as utilized by the Taxi RCS shall be available as a backup to the SPS subsequent to the transposition and docking phase and through the separation phase. The use of the Taxi as a backup to the SPS shall be constrained by the Taxi ΔV capability and shall impose minimum penalties on the Taxi design.

3.1.1.1.1.1 Prelaunch. - The space vehicle will be moved to the launching pad approximately TBD days before the scheduled launch date. The Taxi shall be designed for a maximum time period of TBD days between roll out and launch. Prelaunch positioning and checkout will continue until approximately 72 hours prior to launch, at which time launch countdown begins.

3.1.1.1.1.2 Launch. - All lunar missions shall be launched from Cape Kennedy, Florida. The launch azimuth shall be within limitations set by range safety and tracking considerations. The launch phase for lunar missions begins with S-IC ignition and ends with S-IVB cutoff in earth parking orbit. Lunar mission flight plans shall include provisions for a 4.0 hour launch delay period. The Taxi shall be designed for operation on internal stores a maximum of 10 hours prior to launch.

3.1.1.1.1.3 Earth Parking Orbit. - The earth parking orbit phase shall begin with S-IVB cutoff in orbit and end with S-IVB ignition for translunar injection. The parking orbit altitudes for lunar missions shall be limited to altitudes from 90 to 120 nautical miles. The duration of this phase shall not exceed 4.5 hours.

3.1.1.1.1.4 Translunar Injection. - The translunar injection phase shall begin with S-IVB ignition in earth parking orbit and end with S-IVB cutoff.

3.1.1.1.1.5 Translunar Coast. - The translunar coast phase shall begin with S-IVB cutoff and end with SPS ignition for lunar orbit insertion. The translunar trajectory shall have a duration of 60 to 110 hours. The translunar trajectories for lunar missions shall have a nominal pericynthion altitude of 80 nautical miles. Transposition will begin with CSM/adapter separation and the folding of the adapter panels. The CSM will separate, transpose, close and dock using the SM RCS jets. After a hard dock has been accomplished, the Taxi will be separated from the adapter and the spacecraft will be separated from the S-IVB by firing the SM RCS nozzles. The SLA shall remain attached to the S-IVB. The transposition, docking, and separation from the S-IVB shall be completed with 70 minutes after translunar injection. An addition 50 minutes shall be available for contingencies.

3.1.1.1.1.6 Lunar Orbit Insertion. - Lunar orbit insertion shall begin with Service Propulsion Subsystem (SPS) ignition and end with SPS cutoff in lunar orbit.

3.1.1.1.1.7 Lunar Orbit. - The lunar orbit phase shall begin with SPS cutoff in lunar orbit and end with SPS ignition for trans-earth injection. The nominal lunar orbit altitude shall be 80 n.m. The Taxi shall be designed

3.1.1.1.1.7 (Continued)

to permit alignment of inertial reference subsystems and systems checkout in lunar orbit prior to separation from the CSM. Two hatches shall be provided in the Taxi through which crew members can transfer between the Taxi and CSM in a pressurized suit. When hard docked transfer between the vehicles may be made in an unpressurized suit.

3.1.1.1.1.8 <u>Separation and Descent</u>. - This phase begins with Taxi separation from the CSM and ends with touchdown on the lunar surface at the Shelter site. Separation from the CSM will be performed manually by the Taxi crew using the Taxi RCS. All disconnect mechanisms shall avoid release of parts which may pierce or inflict damage to vital components or the crew. The Taxi will separate from the CSM and transfer from the circular lunar orbit to a direct transfer orbit which does not intersect the moon's surface. The direct transfer orbit shall have a nominal pericynthion altitude of 50,000 feet and 80 nmi, respectively. The descent propulsion system will provide the velocity impulse required to attain the desired transfer orbit. This impulse will be applied while in lunar orbit on the far side of the moon. The initiation of powered descent shall occur at the pericynthion of the direct transfer orbit. The DPS shall provide the thrust requirements for this phase. At the termination of powered descent, the Taxi shall land within a one-half nautical mile circular error probability (CEP) of the Shelter site without a beacon and 100 feet with the aid of an active beacon. The final phase of the powered descent trajectory prior to final approach shall be such that the crew can see the landing area. The Taxi shall have the capability to perform the hovering and final touchdown with either automatic or manual control.

3.1.1.1.1.9 <u>Lunar Landing</u>. - The Taxi shall be designed to provide the capability to operate satisfactorily within the following lunar landing conditions:

(a) Vertical Velocity: $\leq$10 feet/second

(b) Horizontal Velocity: $\leq$4 feet/second

(c) Pitch and Roll Attitude: $\leq$3 degrees

(d) Yaw Attitude - Random

(e) Vehicle rates about all three axes: $\leq$3 degrees/second

3.1.1.1.1.9 (Continued)

The Taxi shall include a sensing device which will provide an indication for descent engine thrust termination prior to landing gear impact. The post landing attitude of the Taxi will not exceed 30 degrees with respect to the local gravity vector.

3.1.1.1.1.10 Lunar Stay. - The lunar stay begins with touchdown and ends with Taxi ascent stage ignition. The Taxi crew shall transfer to the Shelter for the lunar stay after placing the Taxi in quiescent state (low power drain) for storage up to 14 days. A hatch shall be provided to allow ingress and egress to the lunar surface. The Taxi is not required to have lunar surface mobility. Repositioning of the Taxi prior to launch is not required.

3.1.1.1.1.11 Ascent. - The Taxi shall be capable of performing powered ascent with the ascent propulsion subsystem. The descent propulsion subsystem and other subsystems not required for continuation of the Taxi mission or contingencies shall remain on the lunar surface. Provision shall be made for launch and rendezvous of the Taxi out-of-plane ± TBD degrees from the CSM. Normally, the Taxi shall transfer to the CSM orbit without an intermediate parking orbit. The Taxi shall have the capability to perform midcourse corrections during the coasting portion of the transfer orbit. The Taxi shall have the capability of performing the rendezvous with the CSM. The Taxi shall be designed to permit the docking maneuver to be performed with the Taxi as either the active or the passive vehicle.

3.1.1.1.1.12 Post Docking. - This phase begins with hard docking of the Taxi to CSM and ends with jettison of the Taxi in lunar orbit. The Taxi shall be designed to permit transfer of crew, equipment and specimens to the CSM.

3.1.1.1.1.13 Taxi Abort. - The Taxi shall have an abort capability consistent with the overall crew safety reliability requirements.

3.1.1.1.2 Taxi ΔV Budget. - The ΔV Budget signifies the minimum velocity increment (integral of thrust acceleration) capability of the Taxi for purposes of performing the maneuvers associated with a given mission and a given initial thrust to weight ratio. Contingency allowances are included in the budget for flight mechanics effects only. All other contingencies

3.1.1.1.2 (Continued)

(i.e., RCS tank failure modes) must be handled with additional propellant. If additional fuel is required to solve subsystem contingenices, Δ V increases to the budget will not be recognized. (Contingency fuel for subsystem performance are not covered by ΔV budget). The amount of additional propellant will reflect itself in the weight reporting. The minimum Δ V for the descent phase is 7430 feet/second. This velocity increment is based on an initial thrust to weight ratio of 0.326 and the following mission:

(a) A CSM orbit altitude of 80 n, mi.

(b) A Taxi Hohmann Descent transfer to a 50,000 feet pericynthion altitude.

The minimum ΔV for the ascent phase is 6664 feet/second. This velocity increment is based on an initial thrust-to-weight ratio of 0.323 and the following mission:

(c) At launch, the Taxi is TBD degree out-of plane from the CSM orbital plane.

(d) Nominal powered ascent burnout altitude is 50,000 feet.

3.1.1.2 Mission Technique. - The relationship between the mission phases delineated in 3.1.2.8 and the detail mission profile shall be defined in the individual end item specifications written as addenda to this specification for each flight.

3.1.2 Operability Requirements. -

3.1.2.1 Reliability. - The mission success reliability objectives for the Taxi shall be based on the operating times and environmental conditions incurred during each Taxi flight.

3.1.2.1.1 Reliability Objectives. - The reliability objectives for the Taxi shall be:

(a) Mission Success - TBD

(b) Crew Safety - TBD

3.1.2.1.1 (Continued)

The reliability objectives shall be exclusive of radiation and meteoroid impact consideration.

3.1.2.1.2 Crew Safety Reliability Objective. - The crew safety reliability objective shall be to minimize the probability of injury or loss of a crew member, due to a failure, or combination of failures, of Taxi equipment.

3.1.2.2 Maintainability. - Where feasible, the Taxi shall be designed to provide accessibility, replaceability and serviceability consistent with efficient servicing, checkout and maintenance operations. As a design consideration Taxi equipment shall be designed for rapid repair or replacement of malfunctioned equipment consistent with launch window requirements. Where practical, maintenance of Taxi equipment shall not require the use of special tools.

3.1.2.2.1 Vehicle Maintenance Concept. - There shall be no in-flight maintenance requirement for subsystems except for certain items which will be identified by Grumman and approved by NASA. The Taxi subsystems shall be designed for field maintenance as follows:

(a) For electrical or electronic equipment or both (either installed or on the bench), checkout and replacement shall be at the integral package (black box) level. A "balck box" is defined as a combination of factory replaceable units which are contained within a physical package, and which is removable from the Taxi as an integral unit.

(b) For non-electrical or non-electronic equipment or both (either installed or on the bench) checkout and replacement shall be at the lowest replaceable serialized unit level, which includes only those parts which are removable as integral units from the Taxi.

3.1.2.2.1.1 Test Points. - Test points and test ports shall be provided and identified to permit rapid fault isolation to the replaceable assembly or component, as applicable.

3.1.2.3 Useful Life. - The Taxi subsystems equipment shall be designed for an operating life and shelf life consistent with the operational and reliability requirements. Storage of explosive materials is a special case covered in the explosive device subsystem.

3.1.2.4 Natural Environment. - The Taxi shall be designed to meet its operational requirements during and after exposure to the following natural environments:

3.1.2.4.1 Transportation, Ground Handling and Storage of Non-Operating Taxi Equipment. - The following environments will be encountered by non-operating Taxi equipment during transportation, ground handling and storage. Taxi equipment shall be protected by suitable packaging for transportation and storage if these environmental extremes exceed the equipment design requirements.

3.1.2.4.1.1 Temperature. -

(a) Ground Transportation:

(1) Packaged: -65 to +160 degrees F for two weeks

(2) Unpackaged: -20 to 110 degrees F air temperature plus 360 BTU/sq ft/hr up to six hours per day.

(b) Air Transportation: -45 to +140 degrees F for eight hours

3.1.2.4.1.2 Sand and Dust. - As simulated by MIL-STD-810, Method 510, Procedure I. Modify exposure temperature to +90 $\pm$20 degrees F instead of +160 degrees F.

3.1.2.4.1.3 Fungi. - Exposure as defined in MIL-STD-810, Method 508, Procedure I.

3.1.2.4.1.4 Ozone. - Three years exposre at 0.05 PPM concentration.

3.1.2.4.1.5 Salt Spray. - As simulated by Method 509 of MIL-STD-810, Procedure I.

3.1.2.4.1.6 Humidity. - Exposure as defined in MIL-STD-810, Method 507, Procedure I. Modify maximum temperature portion of cycle from +160 degrees F to +110 degrees F.

3.1.2.4.1.7 Rain. - Exposure as defined in MIL-STD-810, Method 506. (No direct impingement on flight hardware).

3.1.2.4.1.8 Pressure. -

(a) Air Transporation - Minimum of 3.45 psia for 8 hours (35,000 feet altitude).

(b) Ground Transporation and Storage - Minimum of 11.78 pounds per square inch absolute (psia).

3.1.2.4.2 Earth Ascent, Earth Parking Orbit, Translunar Injection, Translunar Coast, Lunar Orbit Insertion, Lunar Orbit, Lunar Descent, and Lunar Ascent. -

3.1.2.4.2.1 Pressure. - Atmospheric pressure at sea level to less than 10^{-13} mm Hg.

3.1.2.4.2.2 Thermal Radiation. - The source of radiation presented below impinges on the exterior of the Taxi in logical combination:

(a)	Solar Flux:	442 BTU/ft^2/hr
(b)	Earth Emission:	73 BTU/ft^2/hr
(c)	Lunar Emission (sub-solar point):	419 BTU/ft^2/hr
(d)	Lunar Emission (dark side)	2.2 BTU/ft^2/hr
(e)	Earth Albedo (over entire solar spectrum):	0.35
(f)	Earth Albedo (over visible spectrum):	0.40

3.1.2.4.2.2 (Continued)

(g) Lunar Normal Albedo (over entire solar spectrum): 0.047

(h) Lunar Normal Albedo (over visible spectrum): 0.098

(i) Lunar Spherical Albedo (over visible spectrum): 0.073

(j) Space Sink Temperature: 4 degrees K

NOTES: 1. Thermal emitted energy distribution to be interpreted according to cosine law.

2. Electromagnetic radiation from the sun is shown in Figure 1.

3.1.2.4.2.3 Meteoroid Environment. - The meteoroid environment is defined in MSC Engineering Criteria Bulletin, EC-1, for sporadic and shower meteoroids.

3.1.2.4.2.4 Nuclear Radiation. - The nuclear radiation environments for near-earth, cislunar and near-lunar space will be as presented below:

(a) Trapped Radiation - Radiation levels due to the Van Allen and artificial belts will use protons and electrons fluxes obtained from the Goddard Orbital Flux Code.

(b) Galactic Cosmic Rays - Galactic cosmic ray doses range from 0.1 radiation absorbed dosage (RAD) per week for solar activity maximum to 0.3 RAD per week for solar activity minimum.

(c) Solar Particle Events - The solar particle events described below are for rigidities above the cut-off rigidity for solar particle events in the earth's magnetic field. The cut-off rigidity is defined by:

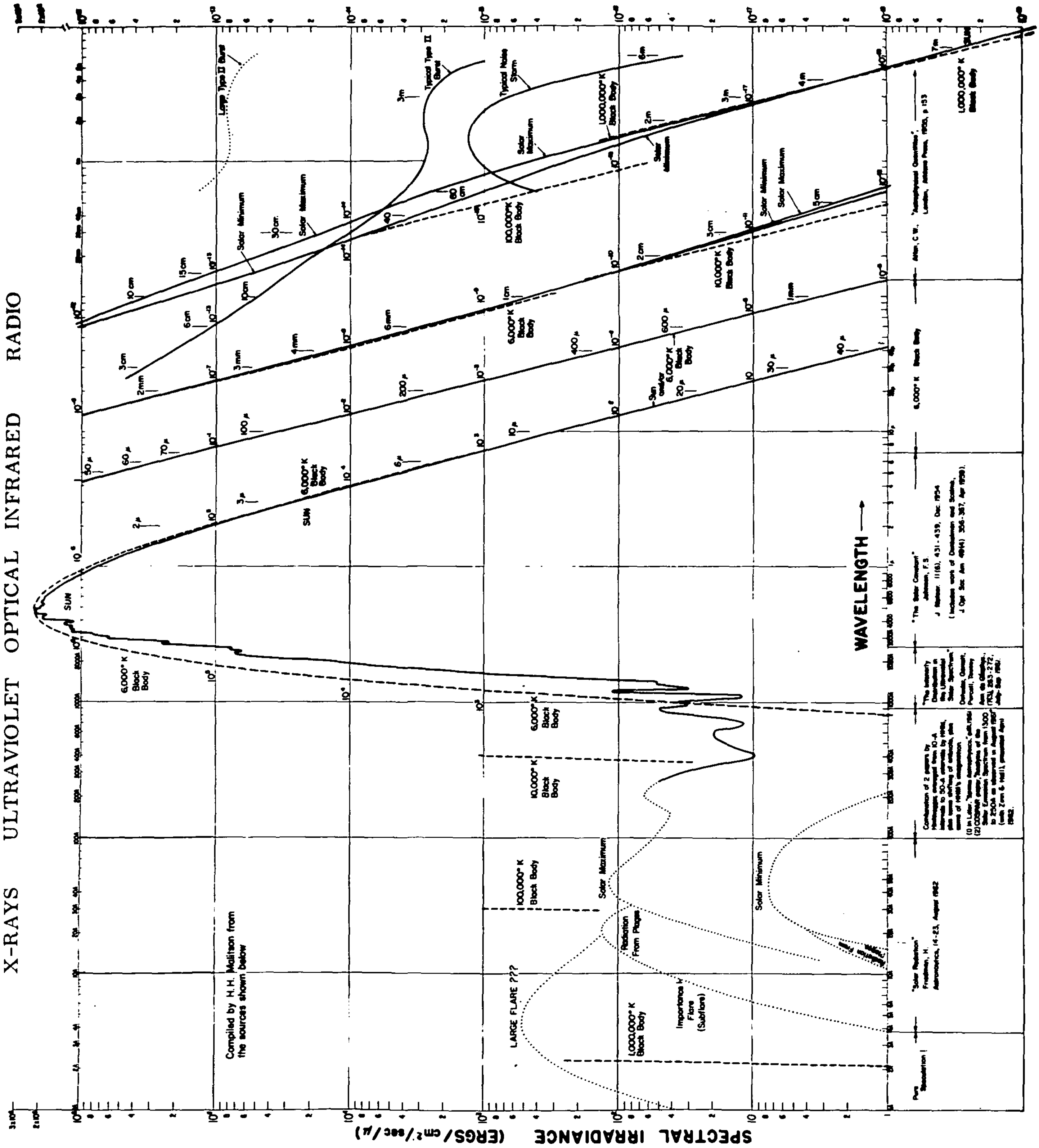


Fig. 1 The Solar Spectrum

3.1.2.4.2.4 (Continued)

(c) (Continued)

$$N = \left[\frac{2.49 \times 10^9}{(6371 + h)^2}\right] \left[\frac{2 + \cos^3 \lambda - 2 (1 + 3 \cos^3 \lambda)^{1/2}}{\cos^2 \lambda}\right]$$

where:

N = Particle's cut-off rigidity, BV.

h = Altitude, KM.

λ = Geomagnetic latitude.

<u>NOTE</u>: Solar particle events will be considered to contain solar produced alphas and protons with equal rigidity spectra.

(1) <u>Time-Integrated Spectra</u> - The time-integrated spectrum for alphas and protons with rigidities greater than 137 MV (10 Mev) will be considered to be of the form:

$$N(>P) = N_o \ \text{EXP} \left[-P/P_o \right] \quad \text{where } P = 137 \text{ MV}$$

where:

$N(>P)$ = time integrated flux with rigidities greater than P, particles/cm^2/

N_o = total intensity of event, particles/cm^2/

P = particle rigidity, million volts.

P_o = characteristics rigidity, million volts.

The rigidity of a partcle is given by:

$$P = \frac{-1}{Z_e} (T^2 + 2 \ TM_oC^2)^{1/2}$$

3.1.2.4.2.4 (Continued)

(c) (1) (continued)

where:

Z_e = particle's charge in units of electron charge, i.e.,

$Z_e = -1$ (for protons) and $Z_e = -2$ (for alphas).

T = particle kinetic energy, Mev.

M_oC^2 = particle's rest mass energy, Mev

$M_oC^2 = 938.2$ Mev for protons:

$M_oC^2 = 3727.1$ for alphas.

P_o is evaluated in the energy ranges:

$10 \text{ Mev} \leq T \leq 30 \text{ Mev}$ and $30 \text{ Mev} \leq T \leq 100 \text{ Mev}$.

Below 10 Mev the spectrum is defined by:

$$N(>T) = N_oT^{-n}$$

A model spectrum is described by the following expressions:

$$T < 10 \text{ Mev:} \quad N(>T) = 22.3\ N(>239\text{MV})\ T^{-1.2}$$

$$137 \text{ MV} \leq P \quad 239 \text{ MV:} \quad N(>P) = 35.5\ N(>239\text{MV})\ e^{-P/67}$$

$$P \geq 239 \text{ MV:} \quad N(>P) = 10.9\ N(>239\text{MV})\ e^{-P/100}$$

where: $N(>239 \text{ MV})$ is the number of particles/CM^2 with rigidities greater than 239 MV (30 Mev) encountered during the mission. Figure 2 shows the probability of encountering greater than $N(>239 \text{ MV})$. Particles/cm^2 during the mission plotted against $N(>239 \text{ MV})$. The values obtained for N_o shall be considered to hold for both alphas and protons.

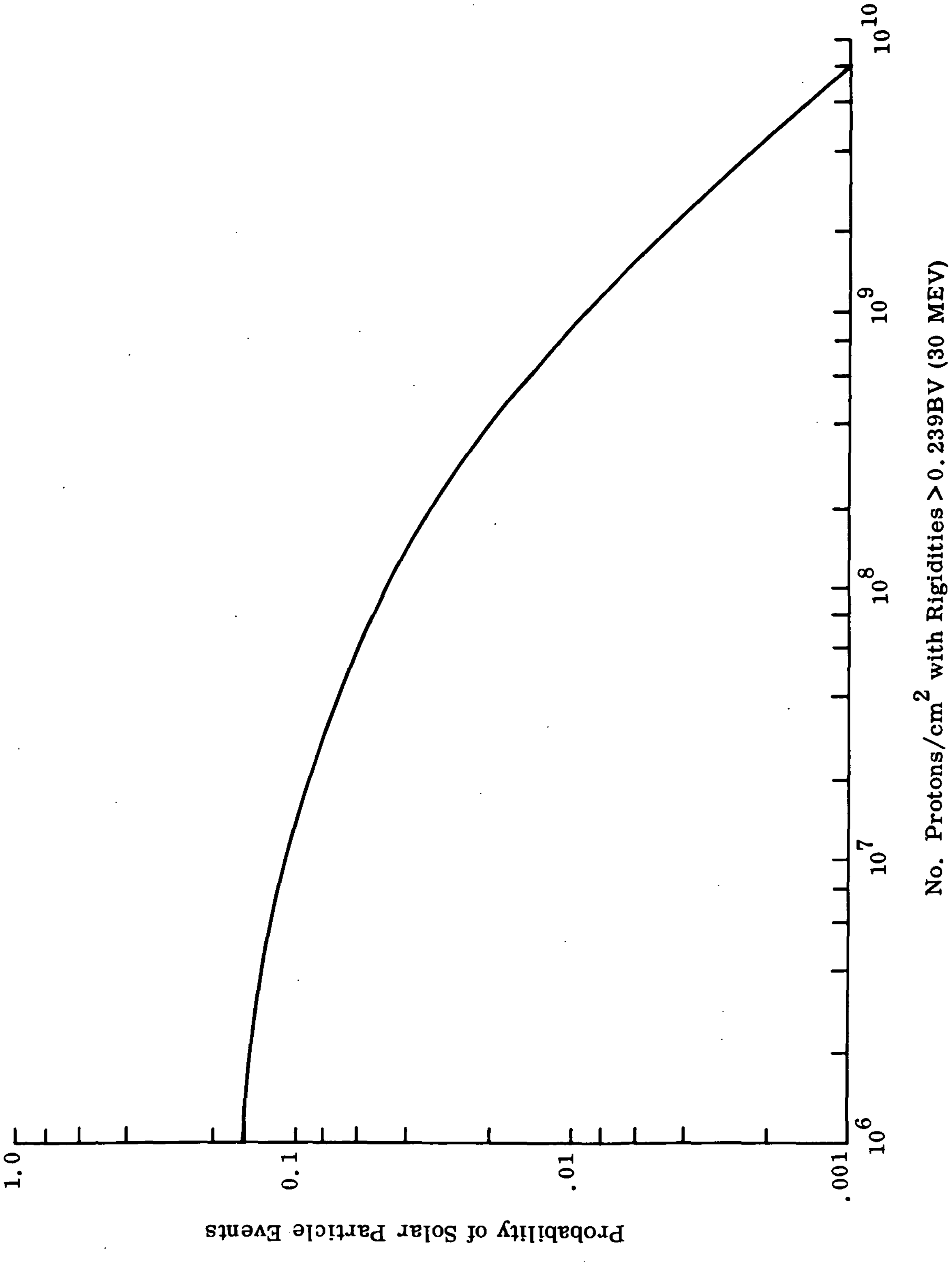


Fig. 2 Probability - Solar Particle Events

3.1.2.4.4 (Continued)

(c) (Continued)

(2) Time Dependent Spectrum - The model time dependent integral spectrum is shown in Figure 3 for several rigidities. The spectrum will be considered to hold for both alphas and protons. Note that the spectrum is normalized to one particle/cm^2 with rigidities greater than 0.239 B_V for the entire event.

3.1.2.4.3 Lunar Surface Environment. -

3.1.2.4.3.1 Meteoroid Environment. - The meteoroid environment is defined in MSC Engineering Criteria Bulletin, EC-1 for sporadic, shower and secondary meteoroids. The density for secondary meteoroids will be 2.5 g/cc instead of 3.5 g/cc as delineated in MSC Engineering Criteria Bulletin, EC-1.

3.1.2.4.3.2 Radiation Environment. - The radiation environment is the same as that contained in 3.1.2.4.2.4 with an appropriate shielding factor for the moon.

3.1.2.4.3.3 Lunar Thermal Model. -

3.1.2.4.3.3.1 Surface Temperatures. - The variation of the surface temperature of a point on the lunar equator during a complete lunation (29.53 days) is shown by a solid line in Figure 4. During the lunar day, the temperatures of local surface areas may be up to 30 degrees centigrade higher than the averaged temperatures shown on this plot. This effect is due to local variations in albedo and topography, which cannot be taken into consideration on such a plot. For a point at some higher latitude, the temperature decreases approximately as the cosine of the latitude to the 1/4 power, as compared to the temperature of an equatorial point at the same brightness longitude. The characteristics of a normal terrestrial rock is shown in Figure 4 by a dash line, ($\gamma = 30$).

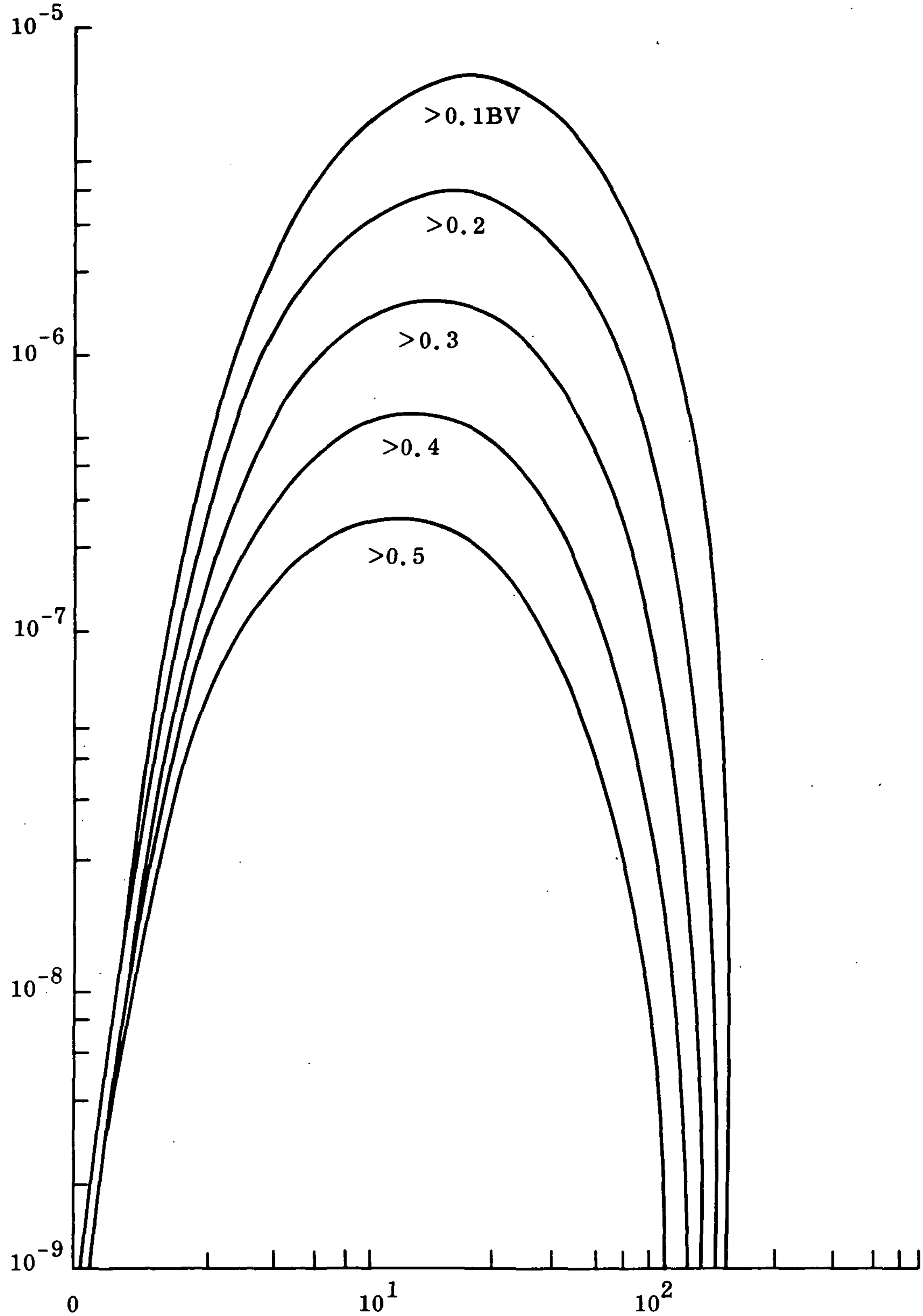


Fig. 3 Normalized Model-Time Dependent Integral Spectrum

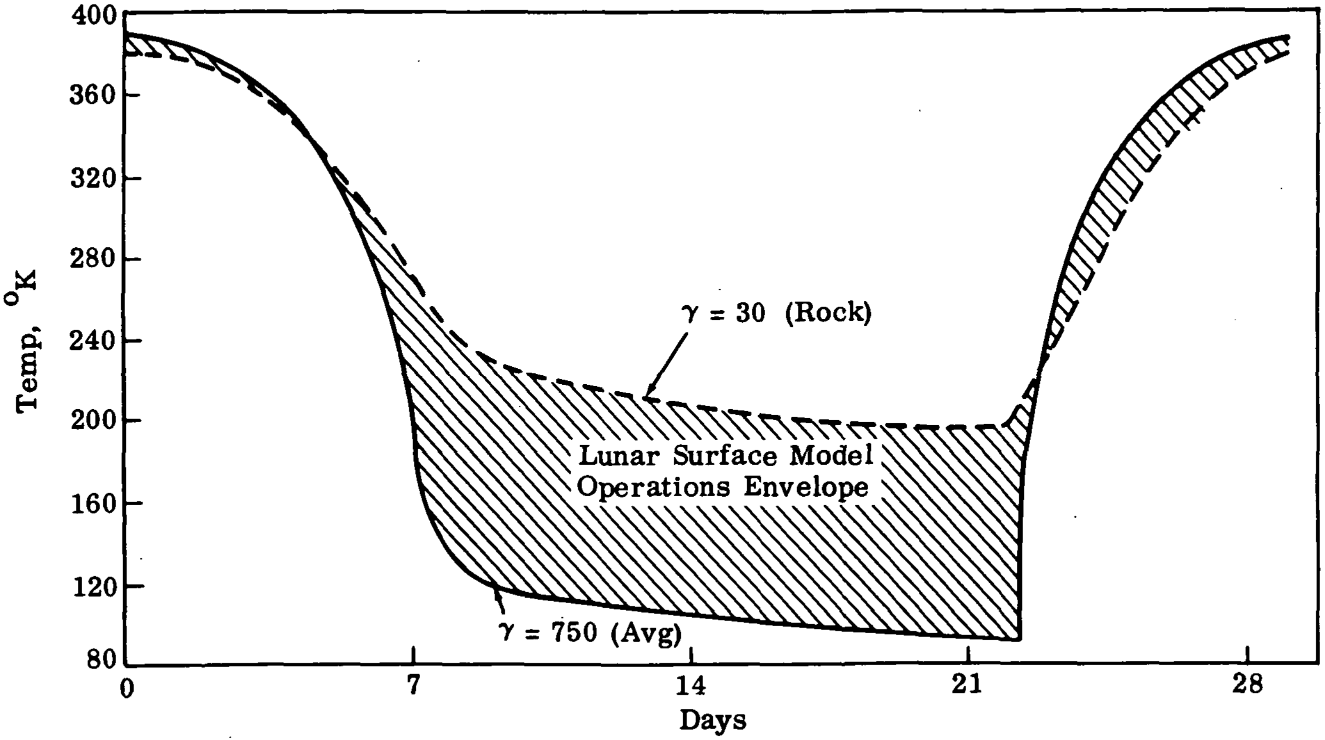


Fig. 4 Variation of Lunar Surface Temperature During a Complete Lunation

3.1.2.4.3.3.2 Thermal Properties. -

3.1.2.4.3.3.2.1 Average Model. - The variation of the lunar surface temperature during a lunar day is shown in Figure 4. The measured surface temperatures are best fit by a theoretical survey of temperature versus time based on a lunar surface thermal inertia γ = 750 (cgs units). The thermal inertia $\gamma = (k\rho c)^{-1/2}$.

where:

(a) K (thermal conductivity) $\approx 1.0 \times 10^{-5}$ cal/cm/sec/degree centigrade.

(b) ρ (density) $\approx$ 0.9 gm/cm^3.

(c) c (specific heat) $\approx$ 0.2 cal/gm/degrees centigrade.

3.1.2.4.3.3.2.2 Model for Local Variation. - Although most, if not all, of the lunar surface is covered with material having the above properties, there may be local patches of material whose thermal properties approach those of normal terrestrial rocks (Figure 4). Such material would have approximately the following characteristics:

(a) k $\approx 2.2 \times 10^{-3}$ cal/cm/sec/degrees centigrade.

(b) $\rho \approx$ 2.5 gm/cm^3.

(c) c $\approx$ 0.2 cal/gm/degrees centigrade.

(d) $\gamma = (k\rho c)^{-1/2} \sim 30$ cgs units.

3.1.2.4.3.4 Lunar Model at Touchdown Point. - The following is a description of a lunar touchdown point solely for the purposes of Taxi design:

(a) The touchdown point at the landing site is considered to be a circle having a radius of 10 meters. The landing site is considered to be an area of about 10 square kilometers.

3.1.2.4.3.4 (Continued)

(b) The surface consists both of high porosity material (either a cohesive or noncohesive aggregate) of variable thickness and a structurally competent material. A combination of these materials, whose essential properties are described in (c) and (d), may produce a heterogeneous surface which does not exceed the requirements listed in (a) through (g).

(c) The minimum bearing strength of the high porosity material is such that a static load of 7×10^4 dynes/cm^2 (1 lb/in^2) will penetrate no more than 10 cm (4 in) and a dynamic load of 8.3×10^5 dynes/cm^2 (12 lb/in^2) will penetrate no more than 60 cm (24 in) below the surface.

(d) The effective rigidity and strength of the structurally competent material is infinite.

(e) Shallow depressions and low protuberances will be sufficiently numerous so that one or more of the landing pads of the Taxi will be horizontally constrained after moving along the surface a variable distance. The coefficient of friction that may be expected during horizontal sliding will vary between 0.4 and 1.0. Topography in the touchdown area will produce both forms of surface resistance.

(f) The "effective protuberances" at the touchdown point will be less than 60 cm (24 in.). Effective protubrances may result from single protuberances such as blocks, or from various combinations of heights, depressions, and surface sinkage within a horizontal distance of approximately 10 meters (11 yards).

(g) The "effective slopes" at the touchdown point will not exceed 12 degrees. The effective slope consists of the general surface slope of the touchdown area plus or minus the combined effects of protuberances, depressions and surface sinkage. The increment of the "effective slope" due to protuberances and depressions (after accounting for erosion and soils mechanics effects) may be calaulated from the formula:

3.1.2.4.3.4 (Continued)

(g) (Continued)

$$\text{Arc sin} \left[\frac{\text{Height of protuberance + depth of depression}}{\text{2 (overturn radius of the landing gear)}}\right]$$

3.1.2.5 Transportability and Ground Handling. - Full design recognition shall be given to the durability requirements of Taxi equipment during transportation preparation. Wherever possible, equipment shall be designed to be transported by a common carrier. The use of protective materials and devices to insure no damage to the equipment shall be minimized. Special packaging and transportation methods shall be employed as required to prevent damage to the equipment.

3.1.2.6 Human Performance. - The vehicle design shall utilize the capability of the crew to perform efficiently throughout the mission. The design shall reflect human engineering principles. Provisions for preferred presentation arrangements, ease of maintenance, environmental and personnel safety shall be considered for ground and flight personnel.

3.1.2.6.1 Visibility. - The required external visibility will be achieved with a minimum amount of glass. Parallax, distortions, and unwanted reflection from glass (both window and instrument cover) and similar surfaces shall be kept to a minimum. Anti-reflection coatings on glass surfaces shall be used in order to reduce reflection. Consideration shall be given to the use of variable density optical filters for windows in order to reduce light from sun shafting and earth and lunar reflections. When not in use, these filters shall be retractable from the window area. Internal lighting shall provide for control and display panel illumination. It shall be adjustable in intensity to compensate for varying ambient light conditions and also to insure retention of crew visual adaptation.

3.1.2.6.2 Atmospheric Environments. - The crew shall be provided a cabin atmosphere with the following characteristics for nominal operations;

(a) Pressure: 5.0 ± 0.2 psia

(b) Oxygen Partial Pressure: 233 mm Hg

3.1.2.6.2 (Continued)

(c) Carbon Dioxide Partial Pressure: 7.6 mm Hg

(d) Temperature: 75 ± 5 degrees Fahrenheit

(e) Relative Humdity: 40 percent to 70 percent

For emergency conditions, the following limits apply:

(f) Pressure: 3.7 ± 0.2 psia

(g) Oxygen Partial Pressure: 160 mm Hg absolute

(h) Carbon Dioxide Partial Pressure: See Figure 5

(i) Temperature: 129 degrees Fahrenheit for four hours maximum

Nominal limits are defined as the limits within which the crew's environment shall be maintained during extended and normal operations. Emergency limits are defined as the environmental limits beyond which there is an increased probability of degraded performance or irreversible injury.

3.1.2.6.3 Noise Limits. - The noise non-stressed limits to the crew's ear canals shall not be greater than that shown in Figure 6, including an average at 55 db in the 600 CPS to 4800 CPS range to a reference level of 0.002 dynes/cm^2. The stressed limit is that noise level where combinations of white noise duration and decible level measured at the entrance of the crewman's ear canal shall not be greater than that defined by Figure 7. A limiting constraint shall be that the maximum noise level permisslbe is that which will permit communications with the ground and between crew members at all times and

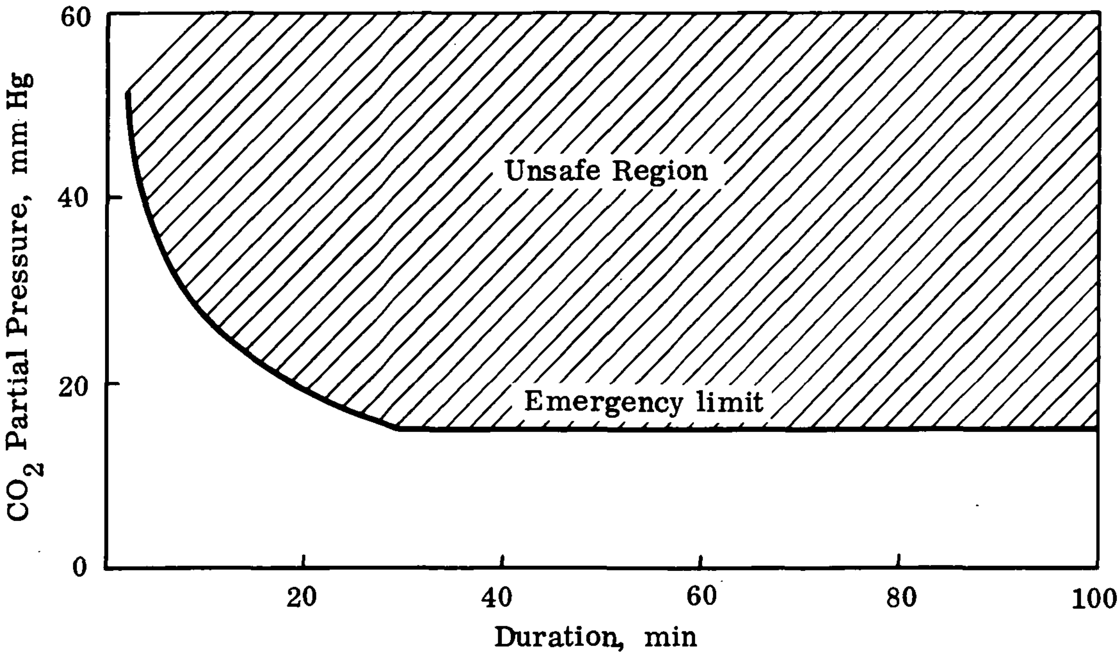


Fig. 5 Emergency Carbon Dioxide Limit

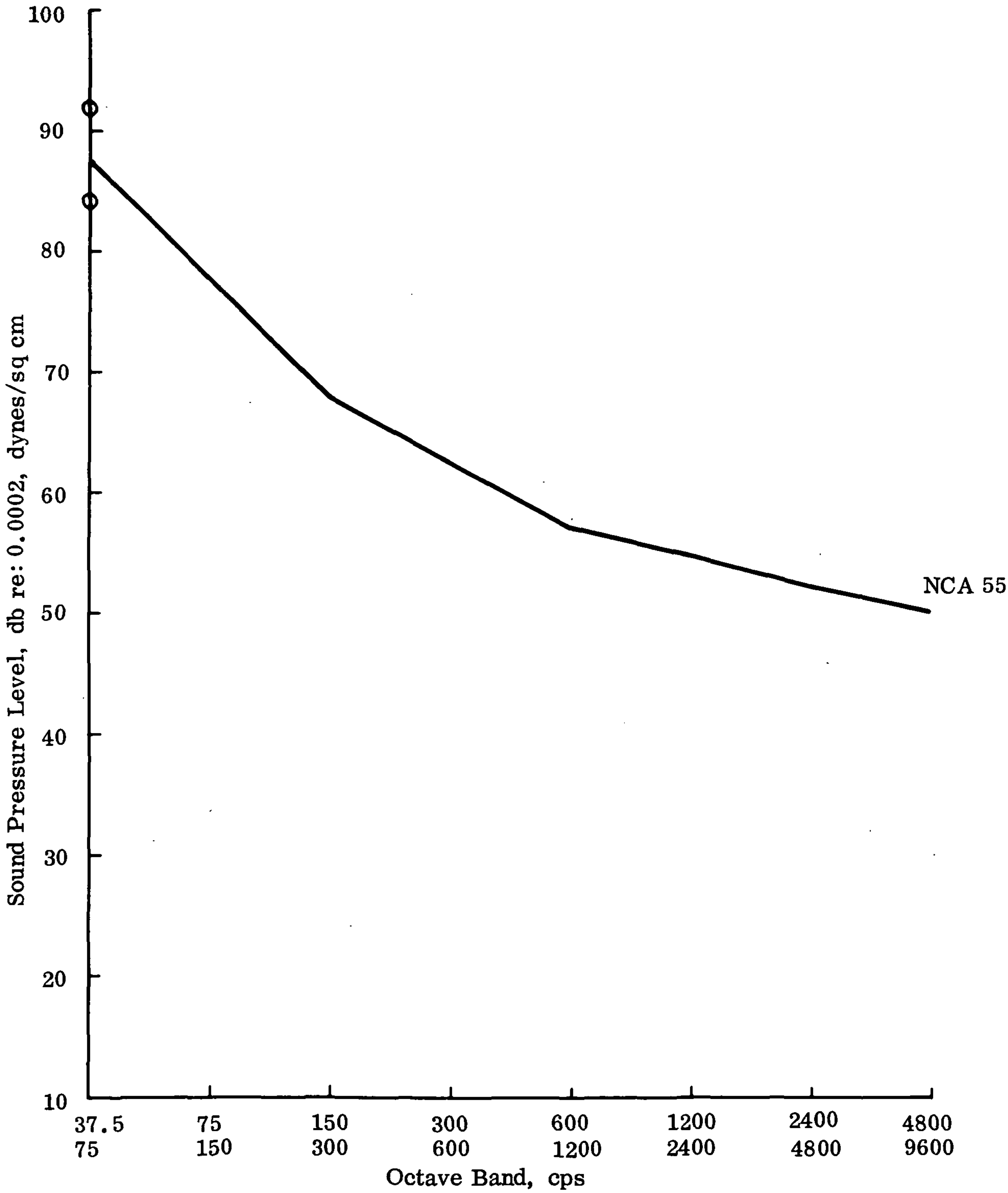


Fig. 6 Noise Limits

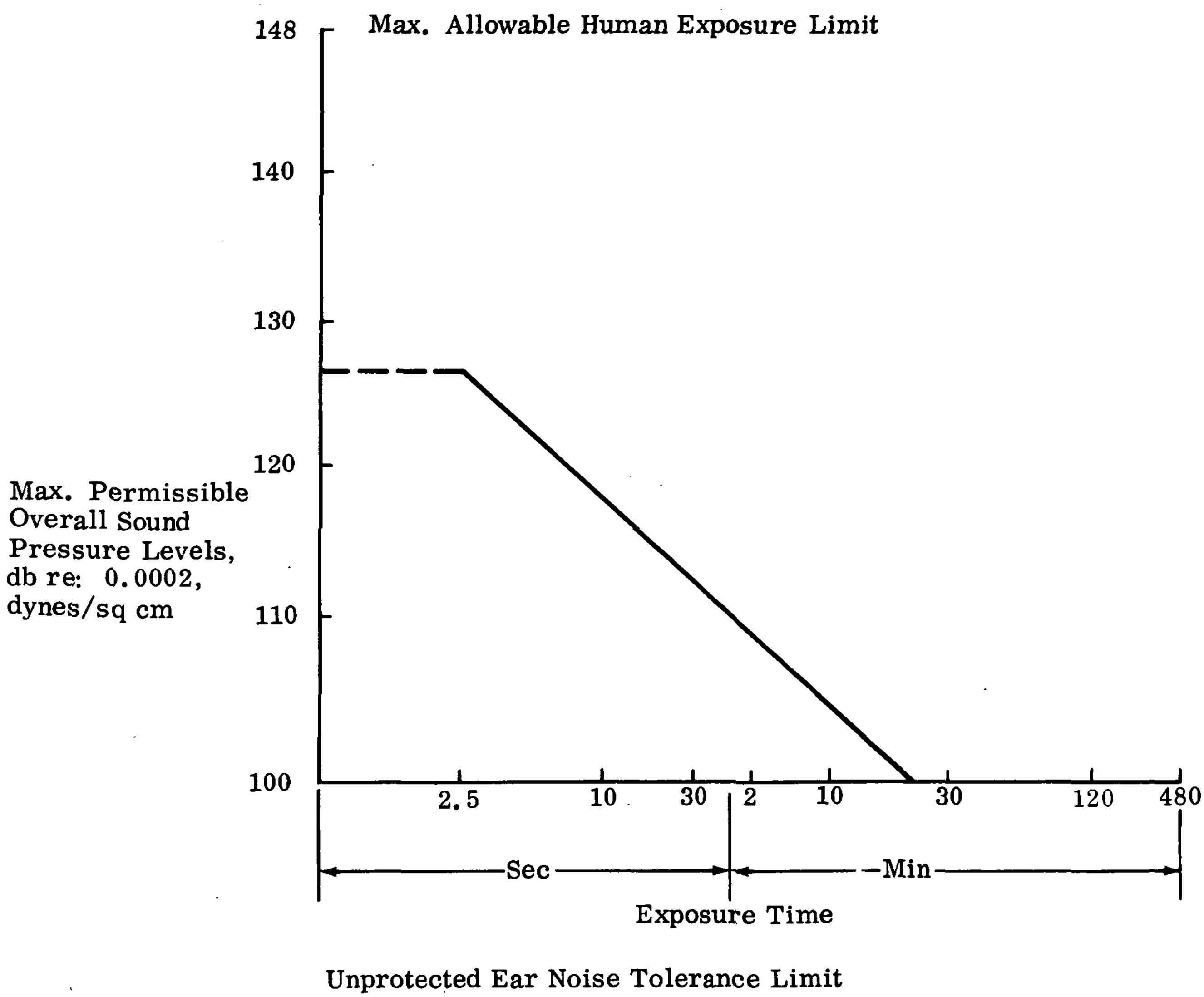


Fig. 7 Unprotected Ear Noise Tolerance Limit

3.1.2.6.3 (Continued)

which will not induce physiological disturbances. The emergency limit shall be considered that limit at which the crew finds the noise painful or tissue damage can occur. For design and test purposes, 127 db or higher peak value sustained for a period of no more than 2.5 seconds, in a pattern of equal periods of rest or low noise relief, is defined as the emergency limit. Pure tones generated in the cabin by operating equipment will be kept to a minimum intensity level.

3.1.2.6.4 Crew Vibration Limits. - The stress limits are those vibration loads which are uncomfortable to the crew but tolerable below the painful threshold, and shall not be greater than defined in Figure 8. The emergency limit shall be considered that limit at which the crew finds the vibration painful or where tissue damage can occur. The emergency limit shall not be greater than depicted in Figure 8 for less than one minute; one minute; and three minutes. For continuous exposure the continuous maximum tolerable curve shall be used. Crew performance degradation will occur immediately during emergency stress. Exposure to nominal stressed limits will result in performance degradation if sufficient recovery time is not provided between vibratory pulses. Minimum recovery time is equal to twice the exposure time period.

3.1.2.6.5 Metabolic Requirements. - Metabolic requirements and rates for various mission phase activities shall be as shown in Tabe I.

3.1.2.7 Safety. -

3.1.2.7.1 Hazard Proofing. - The design of the Taxi shall minimize the hazard of fire, explosion and toxicity to crew. Launch area personnel and facilities shall also be considered in designing for hazard proofing. Toxic, combustible and corrosive materials accumulated from leakages, and discharges from equipment sources or static potentials capable of ignition shall not occur.

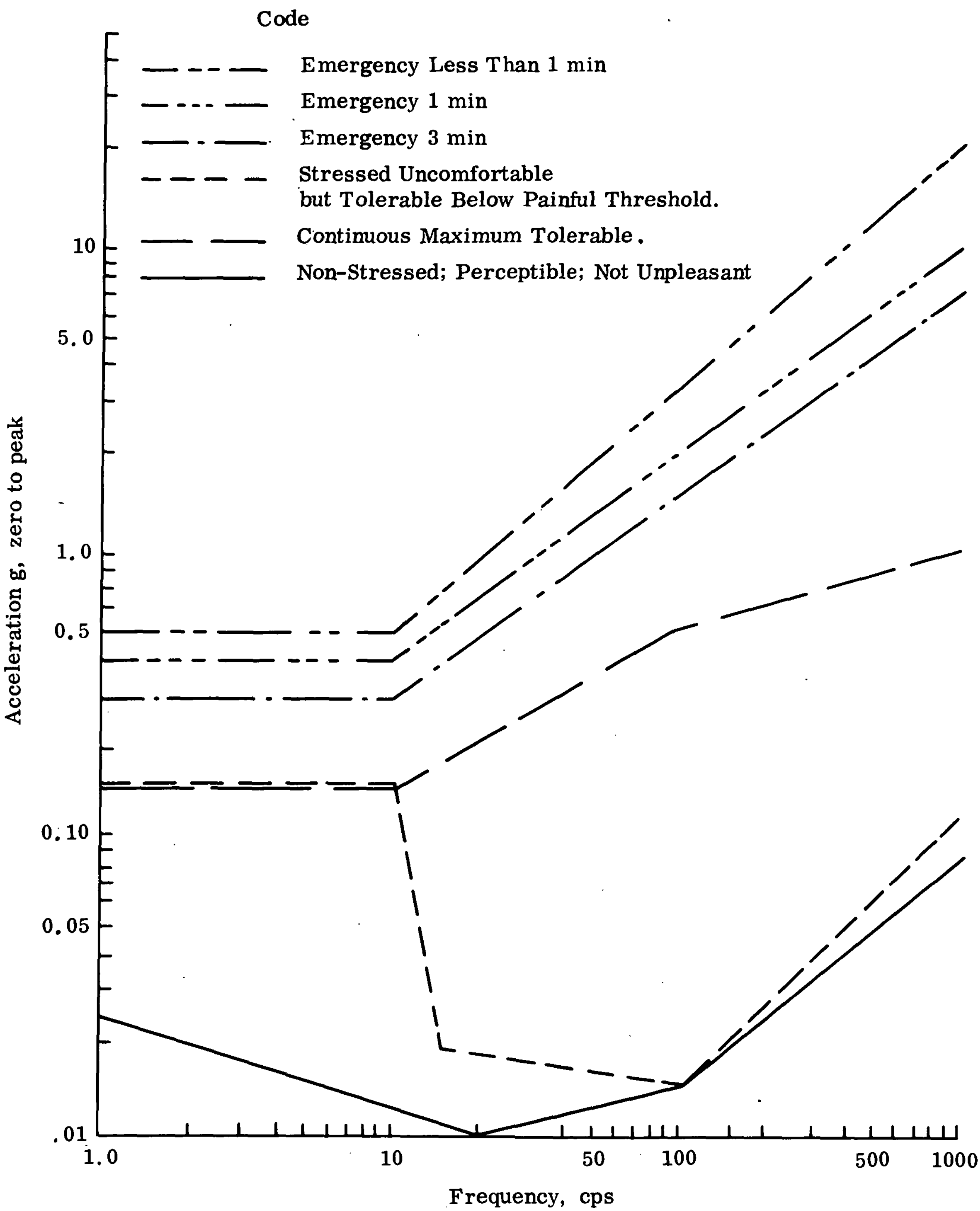


Fig. 8 Vibration Curve (Human Sensitivity to Vertical Vibrations)

TABLE I

ESTIMATES OF METABOLIC RATE, THERMAL BALANCE AND WATER REQUIREMENTS FOR CREW MEMBERS

	PER MAN	UNIT OF MEASURE	ROUTINE FLIGHT PER HOUR	ROUTINE FLIGHT PER DAY	EMERGENCY DECOMPRESSION PER HOUR	LUNAR SURFACE EXTRAVEHICULAR OPERATIONS PER HOUR
(a)	Heat Output	BTU				
(b)	Oxygen	lbs				
(c)	Carbon Dioxide	lbs				
(d)	Latent Heat (lungs)	BTU				
(e)	Latent Heat (sweat)	BTU				
(f)	Sensible Heat	BTU		TBD		
(g)	Urinary Loss	g				
(h)	Sweat Loss	g				
(i)	Lung Loss	g				
(j)	Total Water Requirement	g				
(k)	Total Water Requirement	lbs				
(l)	Food Consumption	K cal				

3.1.2.7.2 Explosion Proofing. - Taxi components shall be either hermetically sealed or of explosion proof construction.

3.1.2.7.3 Fail Safe. - A failure in a subsystem or component shall not cause a failure in any other subsystem or component; that is, the design shall be "fail safe".

3.1.2.7.4 Taxi and Personnel Safety Requirements. - The design shall consider the following Taxi and personnel safety requirements:

(a) Toxicological control of outgas in Taxi atmosphere.

(b) Cabin control of aerosols, dust (such as LiOH from LiOH cartridges) and condensates.

(c) The Taxi interior and exterior shall be free of sharp objects, metal burrs or any abrasive surface which may puncture or otherwise damage the space suit or harm the crew.

(d) The cabin shall have adequate hand holds to facilitate controlled movement under zero "g" and interior design from of "traps" whereby a crewman wearing a pressurized suit may become jammed or wedged and be incapable of escape.

(e) Adequate restraint for landing and lift off "g" forces.

(f) Eye protection from direct (unfiltered) sunlight.

(g) Bacteriological and fungus control

(h) Provisions for securing items stowed or transferred into the Taxi cabin, to prevent their becoming a cabin hazard during vehicle operation.

(i) Safe egress/ingress from vehicle (ladder, hand holds, etc.)

(j) Protection from electrical shock hazard.

(k) Protection from cryogenic lines (freezing).

3.1.2.7.4 (Continued)

(l) Protection from static electrical hazard.

(m) Shielding from space thermal radiation hazard.

(n) Protection from excessive radiative heat loss.

(o) Protection from microwave and other RF radiation

(p) Prevention of excessive load lifting (strain) and excessive fatigue.

(q) Protection for a suited crewman from damaging the suit by proper design and use of scientific instruments, stowage, packaging, and specimen containers.

(r) "Non Slip" Taxi walking surfaces.

(s) Fail safe and "jam proof" umbilical connections.

(t) Connectors keyed to preclude mismating.

3.1.2.7.4.1 Crew Safety Design Criteria. - The Taxi shall be designed such that no single failure shall cause the loss of all methods of implementing a function critical to crew safety. In those instances where redundant control and information paths are provided for crew safety, the redundant mechanical and electrical elements of these paths shall be separated from each other where practicable.

3.1.2.8 Induced Environment. - The Taxi shall be designed to meet its operational requirements during and after exposure to the induced environments listed in the following paragraphs.

3.1.2.8.1 Prelaunch. -

3.1.2.8.1.1 Prelaunch - Packaged. - Transportation and handling in the shipping container shall not produce critical design loads on the

SPECIFICATION NO. ESP 14-0100

3.1.2.8.1.1 (Continued)

Taxi equipment and shall not increase the flight weight of the equipment. The equipment shall be protected by a suitable shipping container if the following externally induced environments caused by transportation and handling exceed the equipment design requirements.

(a) Acceleration - 2.67g vertical with 0.4g laterial applied simultaneously to the package. This condition also applies to the complete Taxi.

(b) Shock - In accordance with MIL-STD-810, Method 516, Procedure III.

(c) Vibration - Sinusoidal vibration shall be applied to the test package along the three mutually perpendicular axes (X, Y, and Z). The frequency shall be cycled three times between 5 cps and maximum cps and back to 5 cps at an applied double amplitude or accelerations as detailed by weights in (1), (2) or (3). The rate or change of frequency shall be logarithmic at 1/2 octave per minute.

(1) For 100 pounds or less:

cps	g or D.A.
5-7.2	0.5 in D.A.
7.2-26	± 1.3g
26-52	.036 in D.A.
52-500	± 5.06g

(2) For 100 pounds to 300 pounds: Use Figure 514.8, Method 514 of MIL-STD-810 for maximum frequency.

3.1.2.8.1.1 (Continued)

(c) (Continued)

(3) For 300 pounds or more:

cps	g or D.A.
5-7.2	0.5 in D.A.
7.2-26	± 1.3g
26-52	.036 in D.A.

(d) Electromagnetic Interference. - In accordance with 3.3.9.

3.1.2.8.1.2 Prelaunch - Unpackaged. - Ground handling equipment shall not produce critical design loads on the Taxi equipment and shall not increase its flight weight. The unpackaged equipment shall meet its operational requirements after exposure to the following ground handling externally induced environments.

(a) Acceleration - 2.67g vertical with 0.4g lateral applied simultaneously. This condition also applies to the complete Taxi.

(b) Shock - In accordance with MIL-STD-810, Method 516, Procedure I except, modify shock pulse to a sawtooth 15g peak, having a 10 to 12 millisecond rise and a 0-2 millisecond decay.

(c) Pressure (Ambient Ground Level) - Hermetically sealed units installed in the crew compartment will be subjected to a maximum pressure of 20.5 psi absolute during preflight checkout.

(d) Hazardous Gases - As simulated by MIL-STD-810, Method 511 and in accordance with MSFC Drawing 10M01071. This condition also applies to the complete Taxi.

(e) Electromagnetic Interference - Same as prelaunch - packaged.

3.1.2.8.2 Launch and Boost. - (See NOTE 7)

(a) Acceleration (See NOTE 5):

	X		Y		Z	
	G	RAD/SEC^2	G	RAD/SEC^2	G	RAD/SEC^2
Lift Off Condition	+1.60	--	$\pm$ .65	--	$\pm$ .65	--
Max Q Condition	+2.07	--	$\pm$ .30	--	$\pm$ .30	--
End Boost Condition	+4.90	--	$\pm$ .10	--	$\pm$ .10	--
Engine Hardover	-1.70	--	$\pm$ .10	--	$\pm$ .10	--
Engine Hardover	+2.15	--	$\pm$ .40	--	0	--
Earth Orbit	+2.15	--	0	--	$\pm$ .40	--
	0	0	0	0	0	0

(b) Acoustics - As specified in North American Specification TBD.

(c) Vibration (See NOTE 6) - The mission vibration environment is represented by the following random and sinusoidal envelopes considered separately:

(1) Exterior Primary Structure -

a. Random -

10 to 23 cps	12 db/octave rise to
23 to 80 cps	0.0148g^2/cps
80 to 105 cps	12 db/octave rise to
105 to 950 cps	0.044g^2/ cps
950 to 1250 cps	12 db/octave decrease to
1250 to 2000 cps	0.0148g^2/cps

3.1.2.8.2 (Continued)

(c) (1) (Continued)

b. Sinusoidal -

5 to 18.5 cps	0.154 inches double amplitude
18.5 to 100 cps	2.69g peak

(2) Interior Primary Structure -

a. Random -

10 to 23 cps	12 db/octave rise to
23 to 80 cps	$0.0148g^2$/cps
80 to 100 cps	12 db/octave rise to
100 to 1000 cps	$0.0355g^2$/cps
1000 to 1200 cps	12 db/octave decrease to
1200 to 2000 cps	$0.0148g^2$/cps

b. Sinusoidal -

5 to 16 cps	0.154 inch double amplitude
16 to 100 cps	1.92g peak

During the launch and boost phase of flight the Taxi is exposed to random vibration of varied levels and spectra for 17 minutes. During all but approximately 2.5 minutes of this period, the intensity of the random vibration is of such a low level that it is considered to be of negligible design significance. In addition, the launch and boost environment is considered to include peak vibration levels which are represented by the above sinusoidal vibration envelopes.

3.1.2.8.2 (Continued)

(c) (2) b. (Continued)

The number of sinusoidal peaks for design can be considered to be one percent of the natural frequency of the equipment being designed times the number of seconds of exposure. For design purposes, the random spectrum applied for 5 minutes along each of the three mutually perpendicular axes, X, Y and Z, when applied in addition to the sinusoidal vibration for 300 seconds exposure time will adequately represent the vibration environment. Vibration levels may be lower at specific equipment locations due to the reaction of the equipment on primary structure. Therefore, a rationally demonstrated reduction in these levels may be used for Taxi equipment design and test.

(d) Pressure - Atmospheric pressure at sea level to 1 x 10^{-8} mm Hg (N_2) as specified in North American Specification TBD.

(1) Controlled Cabin - 20.5 psia to 5.4 psia (O_2) with decay time of approximately 2 minutes.

(2) Uncontrolled Cabin - Decay to 1 x 10^{-4} mm Hg is approximately 17 minutes.

(e) Temperature - As specified in North American Specification TBD.

(f) Hazardous Gases - Same as prelaunch unpackaged.

(g) Electromagnetic Interference - Same as prelaunch unpackaged.

3.1.2.8.3 Space Flight-Translunar. -

(a) Acceleration - (See NOTE 5)

	X		Y		Z	
	g	Rad/Sec^2	g	Rad/Sec^2	g	Rad/Sec^2
SPS operating:	-.36	--	±.062	±1.99	±.062	±1.99
SPS not operating:	0	0	0	0	0	0
(b) Shock - (See NOTE 5):						
Condition transposition	-.052	--	±.065	±.10	±.065	±.10

3.1.2.8.3 (Continued)

(c) Vibration Service Propulsion System (SPS) Operating. - Present information indicates that the levels are of negligible design significance and need not be considered for design or test.

(d) Plume Effects - As specified in North American Specification TBD.

(e) Electromagnetic Interference - Same as prelaunch unpackaged.

3.1.2.8.4 Space Flight-Earth Orbiting. - TBD.

NOTES:

1. Factors of safety are not included in the levels specified in 3.1.2.8.1.1 through 3.1.2.8.3.
2. All accelerations are "earth g's".
3. Vibration spectra shown give straight lines on a log-log plot.
4. Packaged and unpackaged - The word "packaged" refer to containers used for transportation, handling and storage.
5. Acceleration and shock levels are at the Taxi center of gravity.
6. For launch and boost vibration, the primary structure which is directly excited by the acoustics transmitted through the Spacecraft LEM Adapter (SLA) is designated exterior primary structure. The primary structure which either does not face the adapter or is shielded from it by another piece of structure is designated interior primary structure.
7. The environments specified in 3.1.2.8.2 represent preliminary figures and will be modified after mass properties of the equipment installed on the Taxi are determined.

3.2 Interface Requirements. - The Taxi shall be compatible with and shall satisfy the requirements of the following interfaces:

(a) Command Service Module, (CSM).

(b) Spacecraft Lem Adapter, (SLA).

(c) Acceptance Checkout Equipment, (ACE)

(d) Manned Space Flight Net, (MSFN)

(e) NASA Crew Equipment

(f) Experimental Payload, (EP)

(g) Guidance, Navigation and Control, (GFE - GN & C)

(h) Mobile Launcher Tower, (MLT)

(i) Mobile Service Structure (MSS)

3.2.1 CSM Interface. - The Taxi shall be compatible with the CSM interface requirements as specified in North American Aviation Performance and Interface Specification TBD.

3.2.2 SLA Interface. - The Taxi shall be compatible with the SLA interface requirements as specified in North American Aviation Performance and Interface Specification TBD.

3.2.3 ACE Interface. - The Taxi shall be compatible with the ACE interface requirements which will be determined.

3.2.4 MSFN Interface. - The Taxi shall be compatible with the MSFN interface requirements as specified in Grumman Specification TBD.

3.2.5 NASA Crew Equipment Interface. - The Taxi shall be compatible with the NASA Crew Equipment Interface requirements as specified in Grumman Specification TBD.

3.2.6 EP Interface. - The Taxi shall be compatible with the EP interface requirements as specified in ESP 14-9110.

3.2.7 GN and C Interface. - The Taxi shall be compatible with the GFE section of the GN & C as defined by Grumman Specification TBD.

3.2.8 Launch Facility Interface. -

3.2.8.1 MLT Interface. - The Taxi shall be compatible with the MLT interface requirements as defined by Grumman Specification TBD.

3.2.8.2 MSS Interface. - The Taxi shall be compatible with the MSS interface requirements as defined by Grumman Specification TBD.

3.3 Design and Construction. -

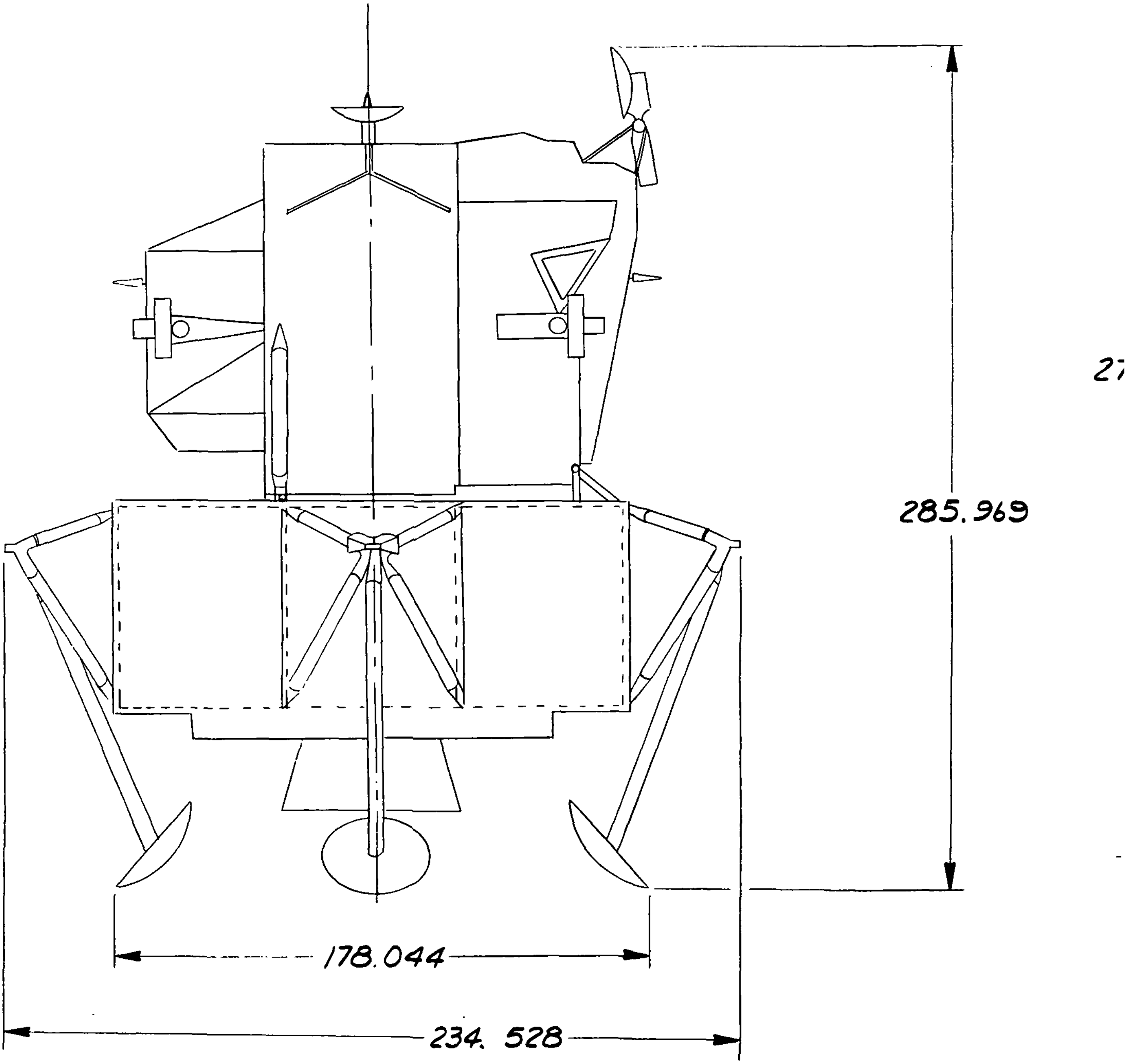
3.3.1 General Design Features. -

3.3.1.1 Configuration. - The overall features and dimensions of the baseline vehicle are shown in Figure 9. The detailed configuration of each vehicle will be defined in the individual vehicle end-item specifications.

3.3.1.2 Weight. - The total weight of the vehicle including payload and expendables will be defined in the individual vehicle end-item specifications.

3.3.2 Selection of Specifications and Standards. - Specifications and standards shall be selected from released lists of NASA, Federal, Military, Industry (trade associations) and Grumman Specifications and standards in that order of preference. Requirements of specifications and standards selected shall not be less stringent than those imposed by the application and the reliability goal specified for the parts, material, or processes covered.

3.3.3 Materials, Parts and Processes. - Materials, parts and processes shall be selected to meet the requirements of the specifications and standards chosen in accordance with 3.3.2. Compliance with requirements of applicable specifications or standards shall be demonstrated by test data or analysis.



SIDE ELEVATION

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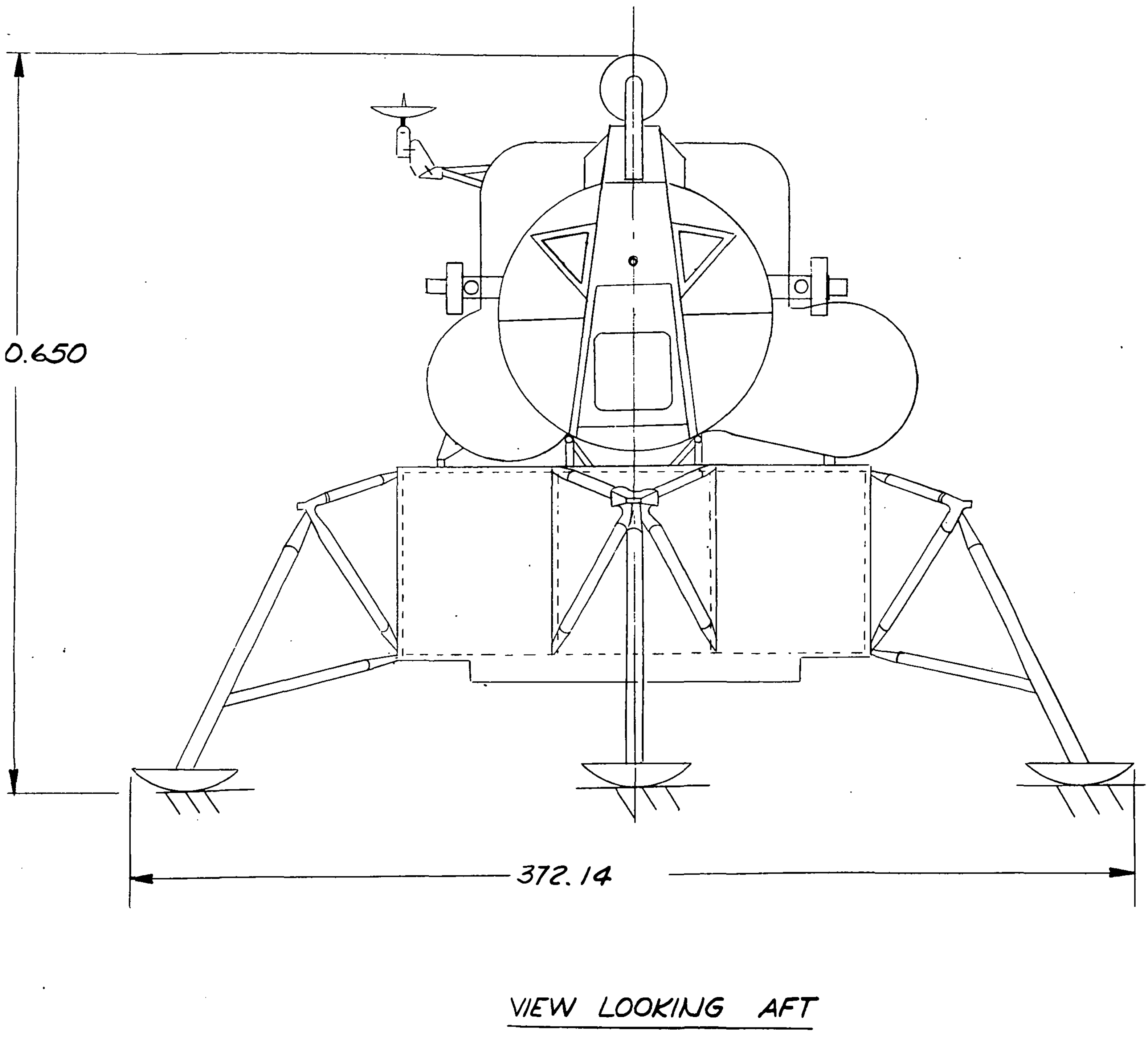


Fig. 9 Vehicle Design

3.3.3.1 Soldering. - Soldering requirements shall conform to MSFC-PROC-158 as amended by MSC-ASPO-S-5B.

3.3.3.2 Wiring. - The fabrication and installation of the vehicle cabling and wiring for the interconnection of electrical and electronic equipment shall be in accordance with Grumman Specification LSP-390-002 as modified for the AES.

3.3.4 Standard and Commercial Parts. - Parts shall be selected on the basis of adequate data history with demonstrated reliability and knowledge that they are qualified for a given application selected from sources practicing proven reliability and quality control procedures in their manufacture. Parts qualified to the applicable MIL Specifications shall be selected when a need for such parts exists. IDEP files and other similar sources of information relating to the selection of parts and their application will be used wherever possible.

3.3.5 Moisture and Fungus Resistance - Materials which are nutrient to fungus shall only be permitted in hermetically sealed assemblies. In other applications, non-nutrient materials shall be used. However, if it is necessary to use nutrient material in an assembly which is not hermetically sealed, the material shall be treated such that it will be capable of satisfactorily passing the fungus test specified in MIL-STD-810.

3.3.6 Corrosion of Metal Parts. - Metal parts shall be of corrosion resistant materials, or shall be processed to resist corrosion. Such corrosion resistant processes shall not prevent compliance with Grumman Specification LSP-390-001.

3.3.7 Interchangeability and Replaceability. - Mechanical and electrical interchangeability shall exist between like items having the same manufacturer's part number. Substitution of like assemblies and replaceable parts shall be easily effected without physical or electrical modification of any part of the equipment, including cabling and wiring.

3.3.8 Workmanship. - Workmanship shall be performed in a high grade manner in accordance with the applicable drawings, specifications, and standards. Processes and manufacturing methods, not covered by specifications, shall be suitable for the article, and workmanship shall be

3.3.8 (Continued)

in accordance with high grade spacecraft practice. The quality of workmanship shall not degrade the reliability, performance, or life inherent in the design of the article. All surfaces shall be smooth and free from porosity, burrs, chips, dents, and other irregularities.

3.3.9 Electromagnetic Interference. -

3.3.9.1 Vehicle Interference Control. - The vehicle shall satisfy the requirements of MIL-E-6051C with the following exceptions:

(a) Delete "MIL-I-26600" and substitute Grumman Specification "LSP-530-001 as modified for AES" in all places.

(b) Delete "MIL-B-5087" and substitute Grumman Specification "LSP-390-001" in all places.

(c) Delete paragraph 3.1.1.

(d) Paragraph 4.3.1: Delete reference to "first electrical-electronic weapon system" and "weapon system" and substitute: "appropriate AES Test Article" in two places.

(e) Paragraph 4.3.2: Delete second sentence and substitute: "The specification compliance test shall be performed on the appropriate AES Test Article."

(f) Paragraph 4.3.5, add the following: "The 6 db level shall be a requirement where it has meaningful application as determined by Grumman and delineated in the approved test procedure.

3.3.9.2 Vehicle Equipment Interference Control. - AES vehicle equipment shall satisfy the requirements of Grumman Specification LSP-530-001, as modified for the AES. The modifications to this specification are to be determined.

3.3.10 Identification and Marking. - Identification and marking shall be as specified in Grumman Specification LSP-14-001.

3.3.11 Storage. - The vehicle and its equipment shall be capable of withstanding a storage period of five years. The storage environments shall be as specified in 3.1.2.4.1 and 3.1.2.8.1.1 for the five year period except where shorter periods of time are specified for certain environments.

3.3.12 Structural Design Criteria. -

3.3.12.1 Margins of Safety. - The vehicle and its equipment shall possess a zero or positive margin of safety.

3.3.12.2 Limit Conditions. - The design limit load envelope shall be established by superposition of the rationally deduced critical loads which occur throughout the mission. The load envelopes shall recognize the cumulative effects of additive type loads. The vehicle shall be capable of performing as required at limit load conditions.

3.3.12.3 Primary Structure Design. - Primary structures shall not require pressure stabilization.

3.3.12.4 Pressure Vessel Design. - Pressure vessels shall be designed to withstand the design internal pressure continuously for a period equivalent to twice the mission duty cycle without permanent deformation.

3.3.12.4.1 Pressure Vessel Design Limit Load. - The pressure vessel design limit loads shall be derived from the combination of the critical loads imposed on it, and the applicable limit pressure. If the internal pressure of a vessel tends to reduce the effects of the critical loads, the resulting reduction in the pressure vessel design limit loads shall not be considered.

NOTE: Limit pressure is defined as the relief valve nominal pressure plus its tolerances, plus the hydrostatic head. For equipment which does not include a relief valve, the limit pressure is the maximum pressure which results from the highest temperature experienced after pressurization.

3.3.12.5 Effects of Transportation, Handling and Storage. -

(a) Provision which are incorporated to withstand the effects of transportation, handling and storage shall not cause an increase in the weight of the vehicle or its equipment.

(b) Structural design shall be such that the environments of transportation, handling and storage shall not cause critical loads on the vehicle.

3.3.12.6 Vibration Design Requirements. - The vehicle and its equipment shall be designed to withstand the vibration levels specified in 3.1.2.8 multiplied by the appropriate factors presented in 3.3.12.7. The vibration levels shown in 3.1.2.8 are considered to be the maximum vibration response of the vehicle primary structure to the input excitation occuring during the mission. For the design of the equipment these vibration levels are the inputs from the vehicle primary structure. The modifying effects of the secondary or supporting structure shall be considered in determining vibration levels for both design analysis and test.

3.3.12.6.1 Vibration Amplification Factor. - The vibration motion amplification factor on any portion of the equipment shall be limited to 10, except in special cases which shall be identified by Grumman and approved by NASA.

3.3.12.7 Factors of Safety. - The factors of safety specified below will be applied to the limit loads to attain the proof, yield and ultimate loads.

3.3.12.7.1 Ultimate Factor of Safety. - The ultimate factor of safety for structural design shall be 1.5 except the vehicle landing gear which shall use a factor of 1.35 on all mechanical moving parts. This factor of 1.5 may be reduced to 1.35 for special cases subject to rational analysis and approval by NASA, MSC.

3.3.12.7.2 Proof Pressure Factor. - The proof pressure factor shall be 1.33 when pressure is applied as a singular load.

3.3.12.7.3 Vibration Factors. - For structural loads the following factors of safety shall be applied to the vibration amplitudes specified in 3.1.2.8.

3.3.12.7.3.1 Factors for Fatigue-Critical Structure. -

NOTE: These factors are used to determine the vibration qualification test levels for "equipment operating" modes.

(a) Prelaunch-Packaged and Unpackaged - Sinusoidal Levels: 1.0 applied to acceleration or double amplitude.

(b) All Mission Phases after Launch -

(1) Sinusoidal levels: 1.3 applied to acceleration or double amplitude.

(2) Random levels: $(1.3)^2$ applied to acceleration spectral density (g^2/cps).

3.3.12.7.3.2 Factors for Strength-Critical Structure. -

NOTE: These factors are included in structural ultimate qualification test levels.

(a) Prelaunch - Packaged and Unpackaged - Sinusoidal Levels: 1.5 applied to acceleration or double amplitude.

(b) All Mission Phases after Launch -

(1) Sinusoidal levels: 1.5 applied to acceleration or double amplitude.

(2) Random levels: $(1.5)^2$ applied to acceleration spectral density (g^2/cps).

3.3.12.7.4 Environmental Factors. - The ultimate factor of safety shall be 1.0 for the following natural environments specified in 3.1.2.4:

(a) Rain

(b) Salt Spray and Fog

(c) Sand and Dust

(d) Fungus

(e) Temperature

3.3.13 Thermal Design Criteria. - TBD

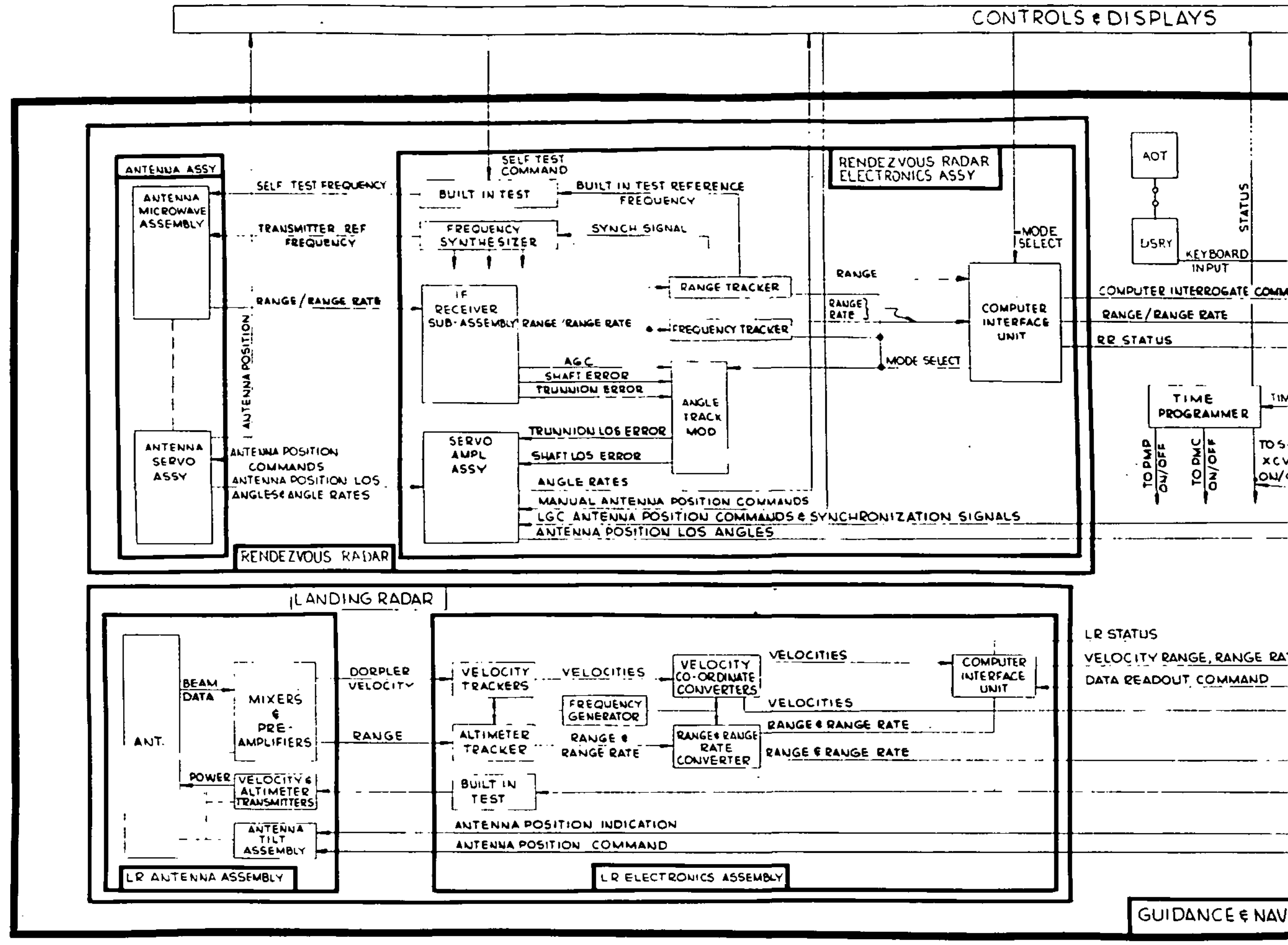
3.3.14 Radiation Protection. - The level of radiation protection provided shall be that which is inherent in the vehicle structure.

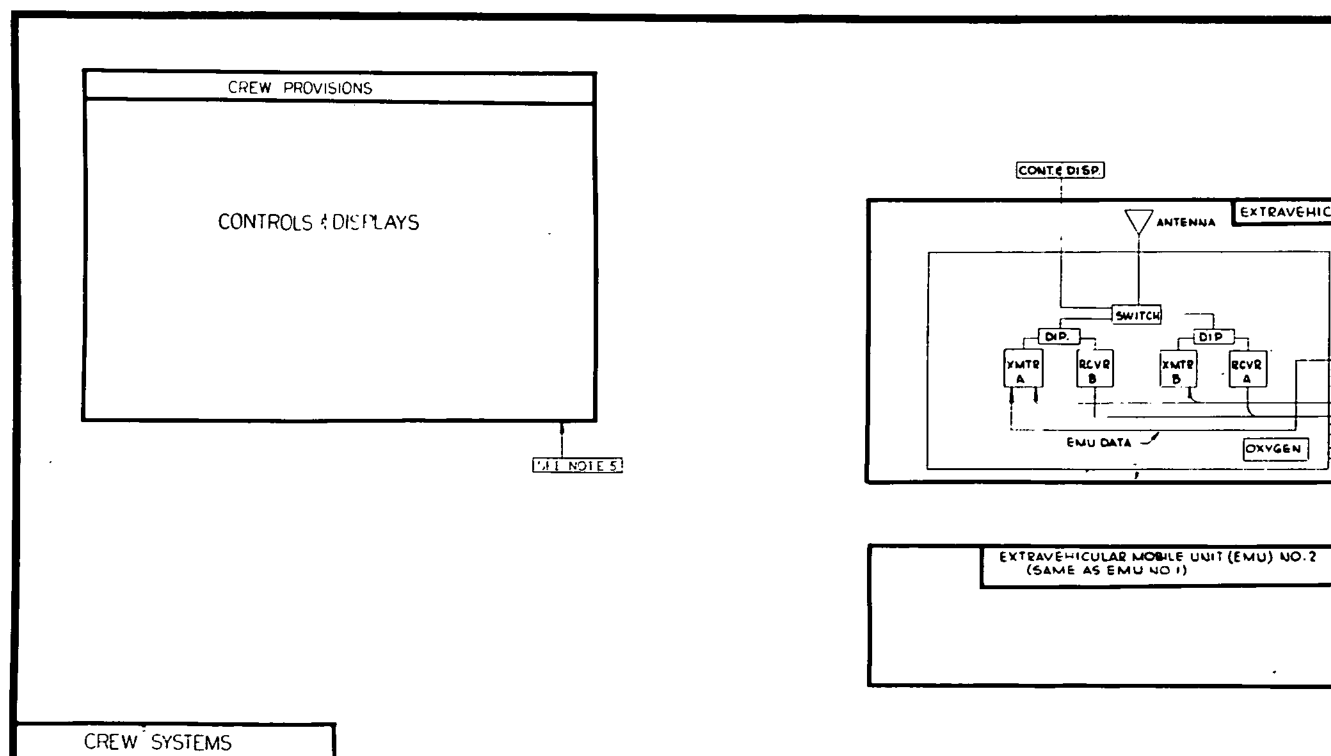
3.3.15 Micrometeoroid Protection. - TBD

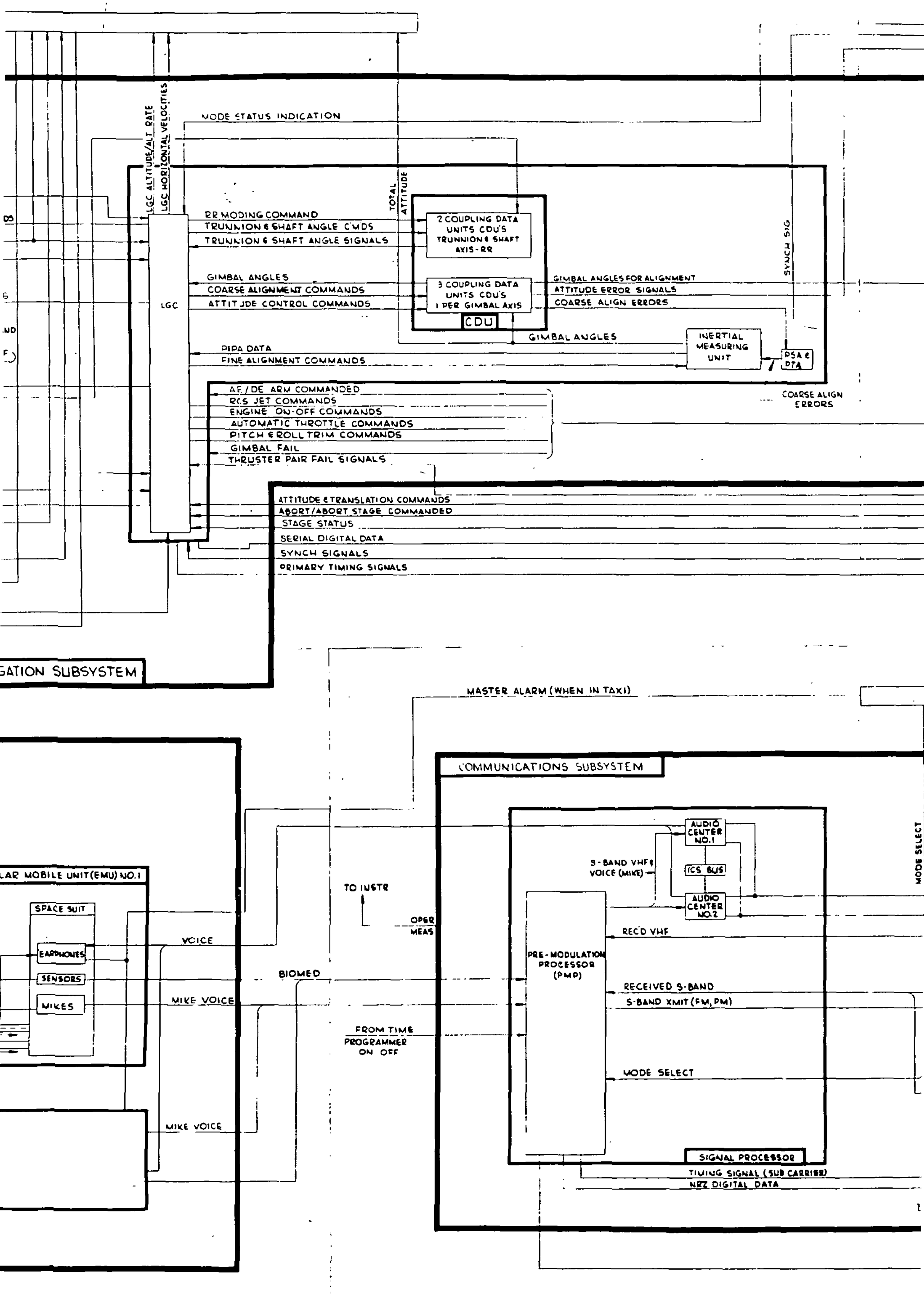
3.3.15.1 Penetration Mechanics. - TBD

3.3.16 Modification Criteria. - The design of the vehicle shall be such that modifications to the vehicle will not cause a perturbation of the interfaces with other modules of the AES Spacecraft.

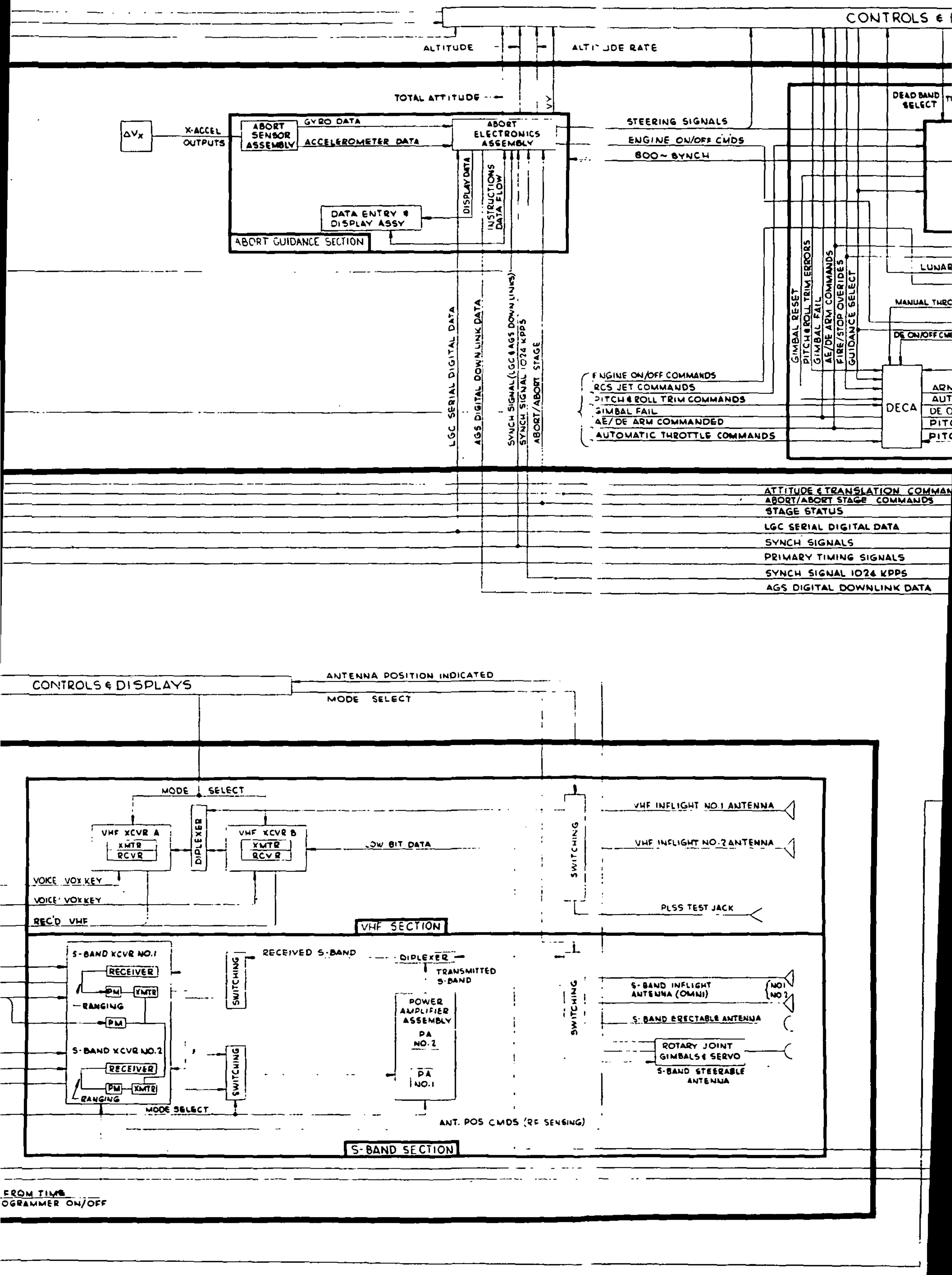
3.4 Requirements of Sub-Areas. - The functional interrelationship between the subsystem of the Taxi and between major assemblies within subsystems shall be as shown in the Level I Functional Diagram (Fig. 10).


CONTROLS & DISPLAYS
ANTENNA ASSY
ANTENNA MICROWAVE ASSEMBLY
ANTENNA SERVO ASSY
SELF TEST FREQUENCY
TRANSMITTER REF FREQUENCY
RANGE / RANGE RATE
ANTENNA POSITION
ANTENNA POSITION COMMANDS
ANTENNA POSITION LOS ANGLES & ANGLE RATES
RENDEZVOUS RADAR
SELF TEST COMMAND
BUILT IN TEST
BUILT IN TEST REFERENCE FREQUENCY
FREQUENCY SYNTHESIZER
SYNCH SIGNAL
RENDEZVOUS RADAR ELECTRONICS ASSY
IF RECEIVER SUB-ASSEMBLY
RANGE TRACKER
FREQUENCY TRACKER
AGC
SHAFT ERROR
TRUNNION ERROR
ANGLE TRACK MOD
SERVO AMPL ASSY
TRUNNION LOS ERROR
SHAFT LOS ERROR
ANGLE RATES
MANUAL ANTENNA POSITION COMMANDS
LGC ANTENNA POSITION COMMANDS & SYNCHRONIZATION SIGNALS
ANTENNA POSITION LOS ANGLES
RANGE
RANGE RATE
MODE SELECT
COMPUTER INTERFACE UNIT
AOT
DSKY
STATUS
KEYBOARD INPUT
COMPUTER INTERROGATE COMM
RANGE / RANGE RATE
RR STATUS
TIME PROGRAMMER
TO PMP ON/OFF
TO DMC ON/OFF
LANDING RADAR
ANT.
BEAM DATA
MIXERS & PRE-AMPLIFIERS
POWER
VELOCITY & ALTIMETER TRANSMITTERS
ANTENNA TILT ASSEMBLY
LR ANTENNA ASSEMBLY
DOPPLER VELOCITY
RANGE
VELOCITY TRACKERS
VELOCITIES
VELOCITY CO-ORDINATE CONVERTERS
FREQUENCY GENERATOR
ALTIMETER TRACKER
RANGE & RANGE RATE
RANGE & RANGE RATE CONVERTER
BUILT IN TEST
ANTENNA POSITION INDICATION
ANTENNA POSITION COMMAND
LR ELECTRONICS ASSEMBLY
LR STATUS
VELOCITY RANGE, RANGE RA
DATA READOUT COMMAND
GUIDANCE & NAV


CREW PROVISIONS
CONTROLS & DISPLAYS
SEE NOTE 5
CONT & DISP.
ANTENNA
EXTRAVEHIC
SWITCH
DIP.
DIP
XMTR A
RCVR B
XMTR B
RCVR A
EMU DATA
OXYGEN
EXTRAVEHICULAR MOBILE UNIT (EMU) NO. 2 (SAME AS EMU NO. 1)
CREW SYSTEMS



LGC ALTITUDE/ALT RATE
LGC HORIZONTAL VELOCITIES
MODE STATUS INDICATION
TOTAL ATTITUDE
RR MODING COMMAND
TRUNNION & SHAFT ANGLE CMDS
TRUNNION & SHAFT ANGLE SIGNALS
2 COUPLING DATA UNITS CDU'S TRUNNION & SHAFT AXIS - RR
SYNCH SIG
GIMBAL ANGLES
COARSE ALIGNMENT COMMANDS
ATTITUDE CONTROL COMMANDS
LGC
3 COUPLING DATA UNITS CDU'S 1 PER GIMBAL AXIS
CDU
GIMBAL ANGLES FOR ALIGNMENT
ATTITUDE ERROR SIGNALS
COARSE ALIGN ERRORS
GIMBAL ANGLES
INERTIAL MEASURING UNIT
PIPA DATA
FINE ALIGNMENT COMMANDS
PSA & PTA
COARSE ALIGN ERRORS
AE/DE ARM COMMANDED
RCS JET COMMANDS
ENGINE ON-OFF COMMANDS
AUTOMATIC THROTTLE COMMANDS
PITCH & ROLL TRIM COMMANDS
GIMBAL FAIL
THRUSTER PAIR FAIL SIGNALS
ATTITUDE & TRANSLATION COMMANDS
ABORT/ABORT STAGE COMMANDED
STAGE STATUS
SERIAL DIGITAL DATA
SYNCH SIGNALS
PRIMARY TIMING SIGNALS
GATION SUBSYSTEM
MASTER ALARM (WHEN IN TAXI)
COMMUNICATIONS SUBSYSTEM
AUDIO CENTER NO.1
ICS BUS
AUDIO CENTER NO.2
S-BAND VHF & VOICE (MIKE)
LAR MOBILE UNIT (EMU) NO.1
SPACE SUIT
EARPHONES
SENSORS
MIKES
VOICE
MIKE VOICE
BIOMED
TO INSTR
OPER MEAS
FROM TIME PROGRAMMER ON OFF
MIKE VOICE
PRE-MODULATION PROCESSOR (PMP)
REC'D VHF
RECEIVED S-BAND
S-BAND XMIT (FM, PM)
MODE SELECT
MODE SELECT
SIGNAL PROCESSOR
TIMING SIGNAL (SUB CARRIER)
NRZ DIGITAL DATA



CONTROLS &
ALTITUDE
ALTI JDE RATE
TOTAL ATTITUDE
ΔVx
X-ACCEL OUTPUTS
ABORT SENSOR ASSEMBLY
GYRO DATA
ACCELEROMETER DATA
ABORT ELECTRONICS ASSEMBLY
DISPLAY DATA
INSTRUCTIONS DATA FLOW
DATA ENTRY & DISPLAY ASSY
ABORT GUIDANCE SECTION
STEERING SIGNALS
ENGINE ON/OFF CMDS
800~ SYNCH
DEAD BAND SELECT
LGC SERIAL DIGITAL DATA
AGS DIGITAL DOWNLINK DATA
SYNCH SIGNAL (LGC & AGS DOWN LINKS)
SYNCH SIGNAL 1024 KPPS
ABORT/ABORT STAGE
GIMBAL RESET
PITCH & ROLL TRIM ERRORS
GIMBAL FAIL
AE/DE ARM COMMANDS
FIRE/STOP OVERIDES
GUIDANCE SELECT
LUNAR
MANUAL THRO
DE ON/OFF CM
ENGINE ON/OFF COMMANDS
RCS JET COMMANDS
PITCH & ROLL TRIM COMMANDS
GIMBAL FAIL
AE/DE ARM COMMANDED
AUTOMATIC THROTTLE COMMANDS
DECA
ARM
AUT
DE O
PITC
PITC
ATTITUDE & TRANSLATION COMMAN
ABORT/ABORT STAGE COMMANDS
STAGE STATUS
LGC SERIAL DIGITAL DATA
SYNCH SIGNALS
PRIMARY TIMING SIGNALS
SYNCH SIGNAL 1024 KPPS
AGS DIGITAL DOWNLINK DATA
CONTROLS & DISPLAYS
ANTENNA POSITION INDICATED
MODE SELECT
MODE SELECT
VHF XCVR A
XMTR
RCVR
DIPLEXER
VHF XCVR B
XMTR
RCVR
LOW BIT DATA
SWITCHING
VHF INFLIGHT NO.1 ANTENNA
VHF INFLIGHT NO.2 ANTENNA
PLSS TEST JACK
VOICE VOX KEY
VOICE VOX KEY
REC'D VHF
VHF SECTION
S-BAND XCVR NO.1
RECEIVER
PM
XMTR
RANGING
PM
SWITCHING
RECEIVED S-BAND
DIPLEXER
TRANSMITTED S-BAND
POWER AMPLIFIER ASSEMBLY
PA NO.2
PA NO.1
SWITCHING
S-BAND INFLIGHT ANTENNA (OMNI)
NO1
NO2
S-BAND ERECTABLE ANTENNA
ROTARY JOINT GIMBALS & SERVO
S-BAND STEERABLE ANTENNA
S-BAND XCVR NO.2
RECEIVER
PM
XMTR
RANGING
SWITCHING
MODE SELECT
ANT. POS CMDS (RF SENSING)
S-BAND SECTION
FROM TIME
OGRAMMER ON/OFF

51 (3)

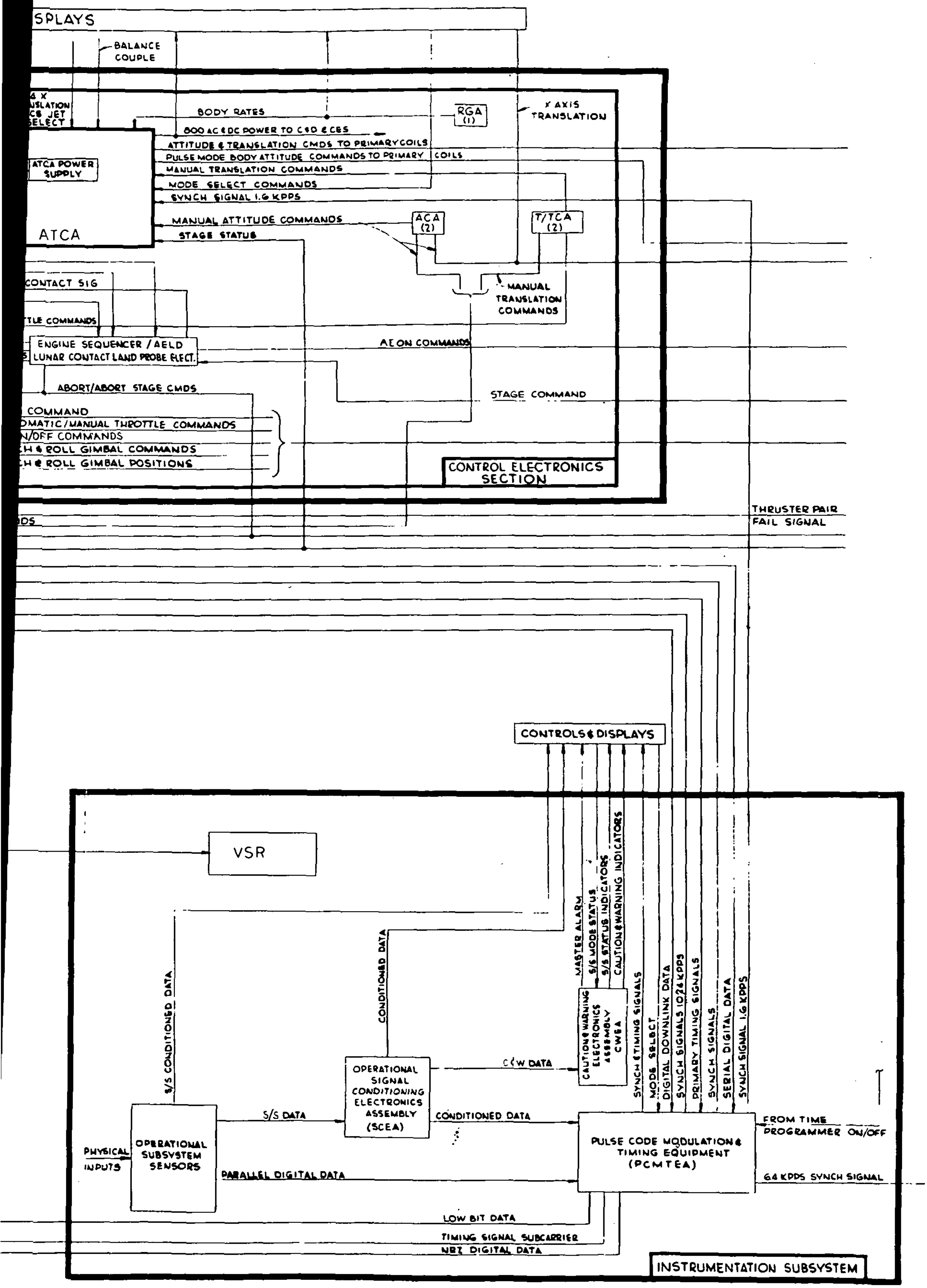
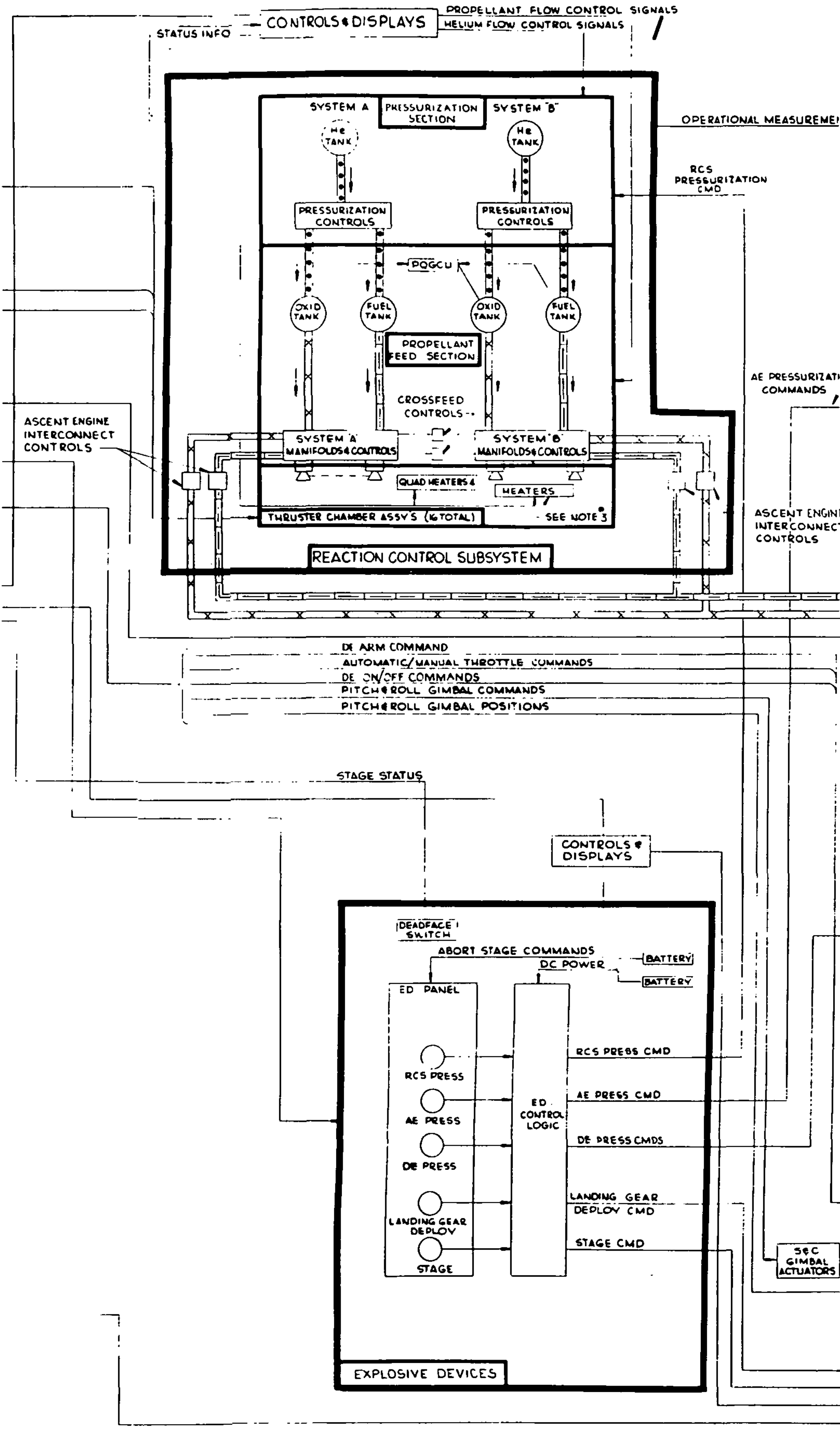
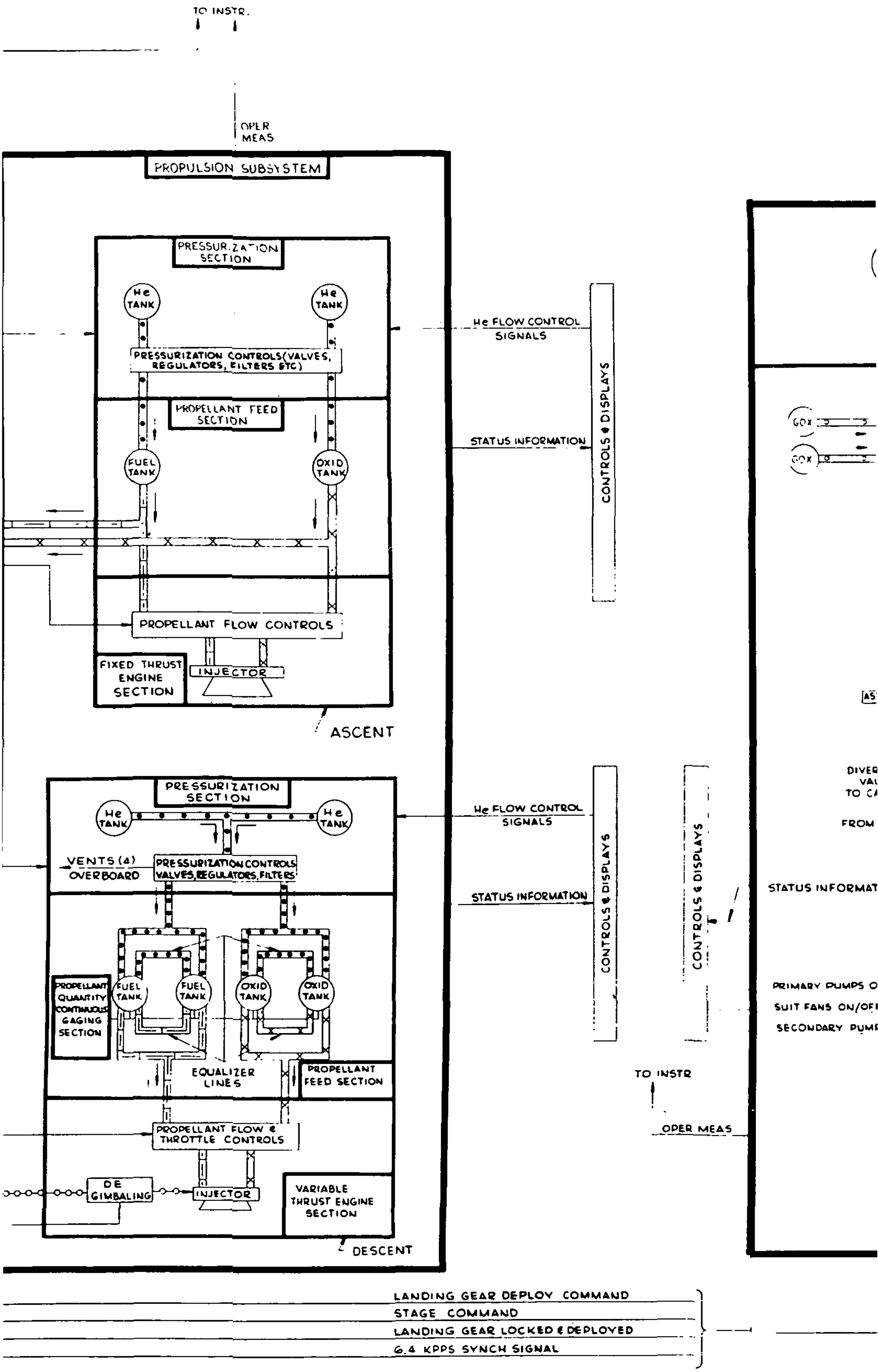


Fig. 10 Level I Functional Diagram For Taxi (Sheet 1 of 2)

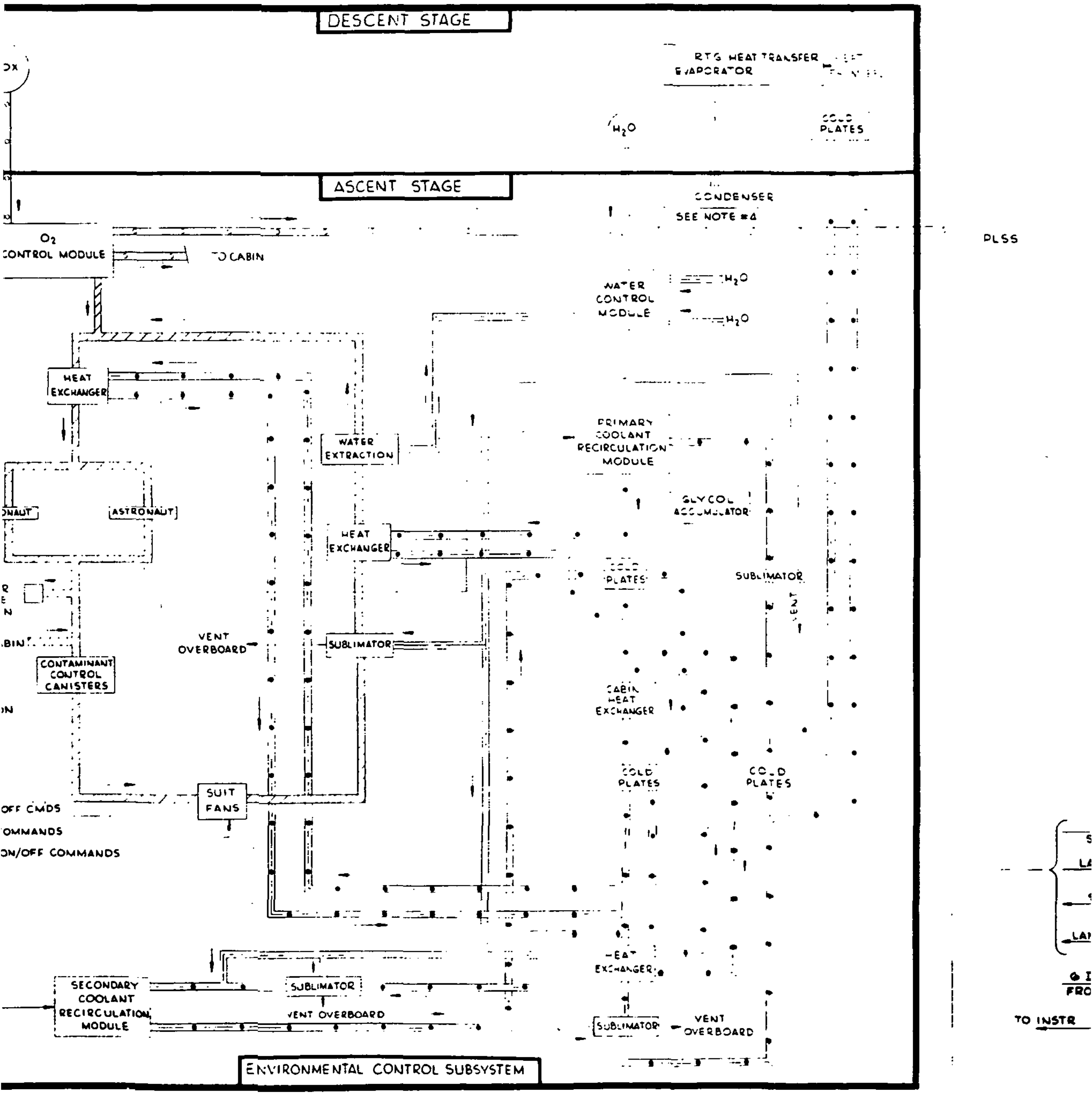
Grumman


CONTROLS & DISPLAYS
PROPELLANT FLOW CONTROL SIGNALS
HELIUM FLOW CONTROL SIGNALS
STATUS INFO
SYSTEM A
PRESSURIZATION SECTION
SYSTEM "B"
He TANK
He TANK
OPERATIONAL MEASUREMEN
RCS PRESSURIZATION CMD
PRESSURIZATION CONTROLS
PRESSURIZATION CONTROLS
PQGCU
OXID TANK
FUEL TANK
OXID TANK
FUEL TANK
PROPELLANT FEED SECTION
AE PRESSURIZATI
COMMANDS
CROSSFEED CONTROLS
ASCENT ENGINE INTERCONNECT CONTROLS
SYSTEM 'A' MANIFOLDS & CONTROLS
SYSTEM 'B' MANIFOLDS & CONTROLS
QUAD HEATERS &
HEATERS
THRUSTER CHAMBER ASSY'S (16 TOTAL)
SEE NOTE 3
ASCENT ENGIN
INTERCONNEC
CONTROLS
REACTION CONTROL SUBSYSTEM
DE ARM COMMAND
AUTOMATIC/MANUAL THROTTLE COMMANDS
DE ON/OFF COMMANDS
PITCH & ROLL GIMBAL COMMANDS
PITCH & ROLL GIMBAL POSITIONS
STAGE STATUS
CONTROLS & DISPLAYS
DEADFACE SWITCH
ABORT STAGE COMMANDS
DC POWER
BATTERY
BATTERY
ED PANEL
RCS PRESS
AE PRESS
DE PRESS
LANDING GEAR DEPLOY
STAGE
ED CONTROL LOGIC
RCS PRESS CMD
AE PRESS CMD
DE PRESS CMDS
LANDING GEAR DEPLOY CMD
STAGE CMD
S&C GIMBAL ACTUATORS
EXPLOSIVE DEVICES



TO INSTR.
OPER MEAS
PROPULSION SUBSYSTEM
PRESSURIZATION SECTION
He TANK
He TANK
PRESSURIZATION CONTROLS(VALVES, REGULATORS, FILTERS ETC)
PROPELLANT FEED SECTION
FUEL TANK
OXID TANK
PROPELLANT FLOW CONTROLS
FIXED THRUST ENGINE SECTION
INJECTOR
ASCENT
He FLOW CONTROL SIGNALS
STATUS INFORMATION
CONTROLS & DISPLAYS
PRESSURIZATION SECTION
He TANK
He TANK
VENTS (4) OVERBOARD
PRESSURIZATION CONTROLS VALVES, REGULATORS, FILTERS
PROPELLANT QUANTITY CONTINUOUS GAGING SECTION
FUEL TANK
FUEL TANK
OXID TANK
OXID TANK
EQUALIZER LINES
PROPELLANT FEED SECTION
PROPELLANT FLOW & THROTTLE CONTROLS
DE GIMBALING
INJECTOR
VARIABLE THRUST ENGINE SECTION
DESCENT
He FLOW CONTROL SIGNALS
STATUS INFORMATION
CONTROLS & DISPLAYS
CONTROLS & DISPLAYS
TO INSTR
OPER MEAS
GOX
GOX
STATUS INFORMAT
PRIMARY PUMPS O
SUIT FANS ON/OF
SECONDARY PUMP
LANDING GEAR DEPLOY COMMAND
STAGE COMMAND
LANDING GEAR LOCKED & DEPLOYED
6.4 KPPS SYNCH SIGNAL

52 (2)


DESCENT STAGE
RTG HEAT TRANSFER
EVAPORATOR
H_2O
COLD PLATES
ASCENT STAGE
CONDENSER
SEE NOTE #4
PLSS
O_2
CONTROL MODULE
TO CABIN
WATER CONTROL MODULE
H_2O
H_2O
HEAT EXCHANGER
WATER EXTRACTION
PRIMARY COOLANT RECIRCULATION MODULE
GLYCOL ACCUMULATOR
ASTRONAUT
ASTRONAUT
HEAT EXCHANGER
COLD PLATES
SUBLIMATOR
VENT
VENT OVERBOARD
SUBLIMATOR
CONTAMINANT CONTROL CANISTERS
CABIN HEAT EXCHANGER
COLD PLATES
COLD PLATES
SUIT FANS
OFF CMDS
OMMANDS
ON/OFF COMMANDS
HEAT EXCHANGER
SECONDARY COOLANT RECIRCULATION MODULE
SUBLIMATOR
VENT OVERBOARD
SUBLIMATOR
VENT OVERBOARD
ENVIRONMENTAL CONTROL SUBSYSTEM
TO INSTR

52 3

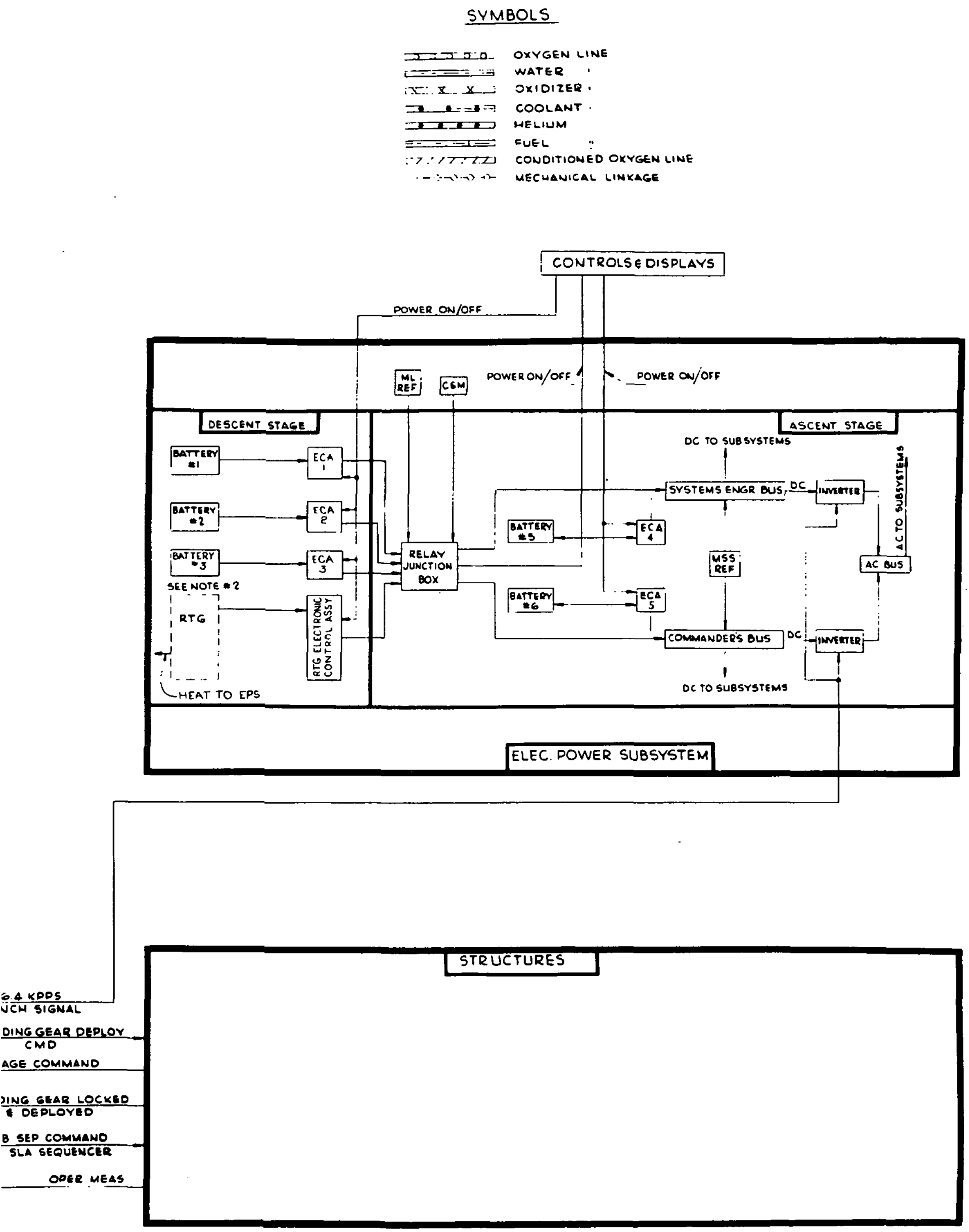


Fig. 10 Level I Functional Diagram For Taxi (Sheet 2 of 2)

3.4.1 Structural Design Subsystem (SDS). - The Structural Design Subsystem shall consist of the following major sections:

(a) Ascent Stage Section Structure, consisting of the Forward Cabin Structure, Aft Cabin Structure, External Equipment Bay Structure, Thermal and Micrometeoroid Shield, and Subsystems Support Structure.

(b) Descent Stage Section Structure, consisting of Descent Stage Primary Structure, Subsystems Support Structure, and Thermal and Micrometeoroid Shields.

(c) Landing Gear Section

3.4.1.1 Performance Requirements. -

3.4.1.1.1 Ascent Stage (AS) Section. - The AS Section shall perform the following:

(a) Provide environmental protection for a two man crew during the lunar landing, lunar stay, ascent, rendezvous, and docking phases of the mission.

(b) Provide passive thermal control of the AS subsystem environment.

(c) Provide passive protection of the AS subsystem from the meteoroid environment.

(d) Provide adequate visibility to the crew for the lunar landing, ascent, rendezvous, and docking maneuvers.

(e) Provide support and environmental protection for all AS equipment.

3.4.1.1.2 Descent Stage (DS) Section. - The DS Section shall perform the following:

(a) Serve as the support for the vehicle in the Spacecraft LEM Adapter (SLA) and provide support for all DS equipment.

3.4.1.1.2 (Continued)

(b) Provide support for the thermal and micrometeoroid shields.

(c) Provide passive thermal control of DS subsystem equipment except the Electrical Power Subsystem (battery installation) which shall be actively controlled.

(d) Provide protective shielding for critical DS subsystems from the meteoroid environment.

(e) Provisions shall be made to separate these connections explosively for abort or lunar launch.

3.4.1.1.3 Landing Gear Section. - The Landing Gear Section shall perform the following:

(a) Provide the impact attenuation required to land the vehicle on the lunar surface, prevent tip-over and support the vehicle during the lunar stay. Impact attenuation shall be accomplished to the load levels required to preserve the structural integrity of the vehicle.

(b) Mounting provisions for an altitude sensing device.

(c) The forward landing gear primary strut shall provide support points for a ladder in a position beneath the ascent stage forward hatch.

(d) The landing gear shall be deployed by manual actuation of the gear deployment switch which shall actuate the explosive uplock release device. Preloaded spring driveout mechanisms shall then extend the gear, and latch mechanisms shall secure the gear in the fully deployed position. The landing gear shall be capable of being manually deployed by an extra-vehicular crewman.

3.4.1.2 Design Requirements. -

3.4.1.2.1 Ascent Stage (AS) Section Description. - The Ascent Stage Section shall consist of a pressurized forward cabin, a pressurized aft cabin, and an external equipment bay. The AS Section shall be structurally joined to the Descent Stage at four points. Functional continuity between Descent Stage and Ascent Stage subsystems shall be provided. The Ascent Stage Section shall withstand the environmental conditions encountered during all phases of the Taxi mission. The

3.4.1.2.1 (Continued)

Ascent Stage structural design limit-load envelopes shall be established from the critical loads determined by the induced and natural environmental and load conditions.

3.4.1.2.1.1 Forward Cabin Structure. - The Forward Cabin structural shell shall be cylindrical in shape and of semimonocoque construction. It shall be a welded and mechanically fastened assembly of 2219 aluminum alloy sheet, chemilled to appropriate structural thickness, and machined longerons. The shell shall be supported by formed sheet metal rings of channel cross-section riveted to the structural skin. All mechanically fastened joints shall be sealed.

(a) The front face bulkhead shall be an assembly of integrally stiffened machined parts of 2219 aluminum alloy plate. Two near vertical beams shall support the bulkhead pressure loads and carry forward interstage loads. The front face bulkhead shall contain the forward hatch and the two crew windows.

(b) The forward windows shall be of dual pane construction. The inner pane shall be structural glass and is designed to carry the cabin pressure loads imposed on it. The window shall be sealed with dual Roco seals, and bolted to the structural window frame through an edge member bonded to the glass using sealing fasteners. Coatings shall be applied to reduce glare and reflections, and defogging provisions incorporated. The outer pane shall be glass, coated to limit thermal transmissions. The forward windows shall provide the visibility range from the design eye position.

(c) To provide visibility for the docking maneuver a third window is located above the commander's flight station. This window is rectangular and consists of two panes of glass, the inner pane is load carrying. Anti-reflective coatings are used on the inner pane. Coatings to limit thermal transmission are applied to the outer pane. Visibility through this window shall be based upon the design eye position.

3.4.1.2.1.2 Aft Cabin Structure. - The structure of the aft cabin shall consist of a ring stiffened semimonocoque shell constructed similarly to the forward cabin. Integrally stiffened machined decks of 2219 aluminum alloy shall be employed to close off the aft cabin assembly. The aft cabin shell shall be mechanically fastened to flanges on major structural bulkheads. These bulkheads shall be integrally stiffened machined bulkheads of 2219 aluminum alloy plate. The forward cabin shell shall be mechanically fastened to the outboard flange of one bulkhead to complete the assembly of the pressurized portion of the AS structure. The upper deck shall provide structural support for the upper docking tunnel and shall contain the upper hatch. The one major bulkhead shall contain provisions for the attachment of the tubular aft interstage structure. The propellant storage tanks shall be mounted between the major bulkheads.

3.4.1.2.1.3 The External Equipment Bay. - The external equipment shall be unpressurized and shall consist of the Electronic Replaceable Assembly Rack and its support structure. The rack shall consist of vertically oriented cold plates mounted in a structural frame. The frame shall be supported at its lower and upper edge by an arrangement of truss members supported on the bulkhead.

3.4.1.2.1.4 Thermal and Micrometeoroid Shield. - The thermal and micrometeoroid shield shall be a composite of an outer sheet of aluminum and multiple layers of aluminized mylar mounted on low thermal conductance supports. The sheet of aluminum shall act as a micrometeoroid bumper and will differ in thickness over the surface to meet shielding requirements.

3.4.1.2.1.5 Subsystem Support Structure. -

(a) The ascent stage propellant tanks shall be located midway between the major bulkheads. The fuel tank shall be aft and the oxidizer tank shall be at the forward bulkhead.

(b) The RCS propellant and helium pressurization tanks shall be modularized and mounted on each side of the aft cabin.

(c) The Rendezvous Radar (RR), Alignment Optical Telescope (AOT), Navigation Base (NVB) and Inertial Measuring Unit (IMU) shall be located on the top center line of the cabin, outside of the pressure shell.

3.4.1.2.1.5 (Continued)

(d) The External Equipment Bay, shall contain the cold plates for the mounting of the Electronic Replaceable Assemblies (ERA's), batteries and control assemblies, supports for the two ambient helium propellant pressurization tanks, and supports for the two ECS gasious oxygen tanks.

(e) The four RCS thruster clusters are supported from the ascent stage primary structure.

(f) The ascent engine is supported on a fixed mount on the X axis of the spacecraft.

3.4.1.2.1.6 Ascent Stage Hatch Mechanism. - The forward and upper hatches shall be hinged to the forward face bulkhead and upper aft cabin deck, respectively. Latches shall be provided to dog the hatches sufficiently to provide an initial seal. The final sealing force shall be supplied by the cabin pressure. The latches shall be operable from either side for depressurization of the cabin.

3.4.1.2.2 Descent Stage Section Description. - The Descent Stage Section shall withstand the environmental conditions encountered during all phases of the Taxi mission. The Descent Stage structural design limit-load envelopes shall be established from the critical loads determined by the induced and natural environmental and load conditions.

3.4.1.2.2.1 Descent Primary Stage Structure. - The DS structure shall be of aluminum alloy and steel construction and shall consist of two pairs of parallel beams arranged in a cruciform shape with structural decks on upper and lower surfaces. At the ends of each pair of beams shall be a four legged truss to serve as support for the Taxi in the SLA and as the attachment point for the main strut of the landing gear. This truss shall be of aluminum alloy tubular construction. Aluminum alloy fittings shall be provided to serve as the aft attachment points for the Ascent Stage.

3.4.1.2.2.2 Thermal and Micrometeoroid Shield. - The thermal shielding for the descent stage shall be composed of an outer micrometeoroid shield, thermal coatings, and multiple layers of aluminized mylar mounted on low thermal conductance supports. The base heat shield, in addition to the normal environmental requirements, shall protect the descent stage structure and equipment from descent engine thermal radiation and plume impingement.

3.4.1.2.2.3 Subsystem Support Structure. - The compartments formed by the Descent Stage structural arrangement shall house the equipment required by the subsystems. The equipment, as a minimum shall include:

(a) Descent Propellant Tanks

(b) Oxidizer Tanks

(c) Fuel Tanks

(d) Helium Tanks

(e) S-Band Erectable Antenna

(f) Landing Radar Antenna Components

(g) PLSS Water Tank

(h) Descent Engine Control Assembly

(i) ECS Gaseous Oxygen Tank

(j) Supercritical Helium Tank

(k) Batteries

(l) Control Assemblies

3.4.1.2.3 Landing Gear Subsystem Requirements. - The landing gear shall be designed to withstand limit loads determined from the induced and natural environmental and load conditions without deformations which might compromise the performance of the gear. Ground handling loading environment shall not exceed landing environment. The landing gear stability performance shall include the effects of a 1500 pound

3.4.1.2.3 (Continued)

average descent engine nozzle crushing load. The design requirements shall include, as a minimum, the following:

(a) Requirements for crushing load and availabile stroke will be of correct values to satisfy stability and energy absorbing criteria of the cartridges that are contained in the energy absorbing struts. The variation of cartridge properties with velocity and termperature possibilities and other effects will be included.

(b) Loads sustained by gear structural components are basically limited by the crush loads of the individual energy absorbing struts. For design of all the gear structural components, the most critical combinations of struts, loads, and geometry will be used.

(c) The effects of velocity will be accounted for insofar as cartridge load and structural response are affected.

(d) The landing gear shall have the capability of manual retraction with a clearance-fit in the stowed position with the uplock mechanism. There shall be sufficient clearance within the spacecraft LEM adapter and the S-IVB instrument unit during and throughout the entire LEM/S-IVB separation event.

(e) The landing gear shall be configured such that no portion of the Descent Stage will contact any lunar surface protuberance as specified in 3.1.2.4.3.4. Criteria used for determining ground clearance shall be based on gear deflection derived from landing dynamics and not from geometrically possible gear deflections.

3.4.1.2.3.1 Landing Gear Structure Design. - The landing gear structure shall consist of four gear assemblies attached to the descent stage at the vehicle support outrigger positions. In the initially deployed configuration the radius of the circle through the pad attachment points shall be 167.57 inches. Each gear assembly shall be a cantilevered gear of tubular (Al Alloy) construction capable of being retracted and shall consist of the following:

(a) The primary strut shall consist of a piston-cylinder device which shall produce suitable load-stroke characteristics when stroked in compression. The primary strut upper end shall attach to the descent stage outrigger fitting and the lower end shall provide a ball joint support for the foot pad.

(b) Each secondary strut shall consist of a piston cylinder device which shall produce suitable load-stroke characteristics when stroked in both tension and compression. The outboard end of each secondary strut shall attach to the primary strut outer cylinder and the inboard end of each secondary strut shall attach to the deployment truss.

(c) Shock absorbers shall be of a crushable material capable of providing the necessary load-stroke requirements and shall be installed in each primary and secondary strut.

(d) The footpad shall provide for vehicle flotation on a 12 psi bearing strength surface under the maximum gear reaction force. Each footpad shall support a lunar surface sensing probe. (See (e) (4).

(e) The landing gear mechanisms shall consist of the following:

(1) There shall be one "uplock" device provided for each landing gear assembly and it shall be installed between the descent stage and the primary strut. The "uplock"

3.4.1.2.3.1 (Continued)

(e) (1) (Continued)

device (explosively actuated) shall be installed with sufficient pre-load tension to adequately restrain the landing gear in the stowed position under all vibratory and shock conditions. A manually operated switch in the crew station shall electrically actuate initiators on all "uplocks" allowing the unlocked gear assemblies to be deployed with the deployment mechanism.

(2) The deployment mechanism on each landing gear assembly consists of a deployment truss, deployment spring devices and connecting linkages. The deployment mechanism spring devices and connecting linkage shall deploy the landing gear from the stowed position to the fully deployed (gear locked down) position, by continuously driving through this entire travel. The mechanisms shall be so arranged that either of the two spring devices shall deploy the gear to the gear locked down configuration from any standstill position. The impact of the landing gear extension due to the stored spring energy of two springs per assembly shall be absorbed by the structure.

(3) The landing gear deployer (gear locked down) mechanism consists of tw spring loaded locks per landing gear assembly, capable of sustaining balancing loads imposed on the deployment frame during landing. The landing gear down locks shall secure the deployment truss in the deployed configuration. "Down" lock springs (one for each lock) shall retain the lock in the secured position under all vibratory and shock loads. Each lock shall contain provisions for two independent electric switches that are actuated when the lock is in the landing gear locked down position. The landing gear deployed indicator in the crew station shall indicate a safe condition (all landing gear assemblies locked down) when at least one switch on each of eight down locks has been actuated.

3.4.2 Electrical Power Subsystem (EPS). -

3.4.2.1 EPS Performance. - The Electrical Power Subsystem shall provide, distribute and control the total allowable electrical energy for the mission. The total allowable electrical energy shall be 62.6 kilowatt hours.

3.4.2.1.1 Electrical Power Characteristics. - Power characteristics sensed at the load shall be as follows:

(a) DC Power - The DC power system shall be a nominal 28 vdc 2-wire negative ground system with the following characteristics:

(1) Steady-State Voltage Limits - 22 to 33 volts

(2) Transient Voltage Limits -

a. Positive: 50 volts for 10 microseconds at 10 pps repetition rate for a period of 5 minutes.

b. Negative: 100 volts for 10 microseconds at 10 pps repetition rate for a period of 5 minutes.

c. Ripple Voltage Limits: Per MIL-STD-704 except that the maximum sum of the peak a-c ripple and d-c voltage shall be 33.0 volts.

(b) AC Power -

(1) Phases: Single phase.

(2) Nominal Steady State Voltage: 115 plus or minus two volts rms.

(3) AC Transient Voltage Limit: The a-c voltage shall recover to a minimum voltage of 144 volts peak or to a maximum voltage of 188 volts peak within 2.5 milliseconds, and return to steady-state conditions within 50 milliseconds,

3.4.2.1.1 (Continued)

(a) (3) (Continued)

after experiencing an input line or load step change within the limits specified for line and load. Voltage spikes superimposed at any point of the sinusoidal wave shape shall not exceed 10 volts peak. The maximum transient voltage at the output shall not exceed 225 volts peak.

(4) Modulation: 2.5 volts single amplitude.

(5) Nominal Frequency Tolerance:

a. Normal: 400 plus or minus 4 cps (synchronized to master timing)

b. Free Running: 400 plus or minus 10 cps (loss of master timing

(6) Waveshape:

a. Sine wave

b. Maximum total distortion: 5 percent

c. Highest harmonic: 4 percent

d. Crest Factor: 1.414 plus or minus 10 percent

3.4.2.2 Design Requirements. - The EPS shall include the following major assemblies:

(a) Electrical Control Assembly (ECA)

(b) Batteries

(c) Static inverters

(d) Radioisotope thermoelectric generator control assembly

3.4.2.2.1 Electrical Control Assembly (ECA). - One ECA shall be provided for control of each ascent and descent battery. Each ECA shall include the necessary electrical and electronic equipment for manual or automatic control of battery power output to the Taxi power distribution section. The ECA shall control battery "turn-on" or battery "turn-off". The ECA shall provide overcurrent and reverse current sensing and protection.

3.4.2.2.2 Batteries. - The primary source of electrical power shall be provided by three descent stage and two ascent stage batteries. The descent stage batteries shall supply 30.8 kilowatt hours, and the ascent stage batteries shall supply 15.3 kilowatt hours.

3.4.2.2.2.1 Battery Performance. - The battery voltage shall be as follows:

(a) Maximum voltage during all discharge: 32.5 volts

(b) Nominal voltage: 30.0 volts

(c) Minimum voltage during all discharge 28.0 volts - A low voltage tap will be used, if required, to enable the battery to achieve the above specified voltage requirements.

3.4.2.2.2.2 Capacity. -

(a) The ascent battery shall have a capacity of not less than 295 ampere-hours when discharged at 25 amperes at 80 degrees Fahrenheit. These requirements are based upon a minimum voltage of 28.0 volts.

(b) The descent battery shall have a capacity of not less than TBD ampere-hours when discharged at 10 amperes at 80 degrees Fahrenheit. These requirements are based upon a voltage of 28.0 volts.

3.4.2.2.2.3 Load Sharing. - The batteries shall be sufficiently uniform to allow parallel operation without detrimental effect upon performance or load sharing characteristics.

3.4.2.2.2.4 Parallel Operation. - The voltage requirements of 3.4.2.2.2.1 and capacity requirements of 3.4.2.2.2.2 shall be satisfied when the ascent and descent batteries are operated in parallel.

3.4.2.2.3 Static Inverters. - The static inverters shall be solid state devices that convert 28 volts dc (nominal) electrical power to 115 volts ac, single phase, 400 cps (nominal). Either inverter shall have the capability of supplying ac power to its assigned loads with the other serving as a redundant standby unit.

3.4.2.2.3.1 Mounting. - The inverters shall be rigidly mounted on the equipment rack.

3.4.2.2.3.2 Input Power. - Rated input voltage shall be 28 ± 4 volts dc. The inverter shall operate but need not meet performance requirements when the input voltage falls below 20 volts dc for five seconds or longer.

3.4.2.2.3.3 AC Power Output Characteristics. -

(a) Voltage output: 117 volts rms single phase, 400 cps.

(b) Steady-state voltage regulation: ± 1 percent at the a-c terminals of the mating connectors.

(c) Normal load requirements: 0 to 350 volt amperes at power factors ranging from 0.65 lagging to 0.80 leading.

(d) Low power factor load requirements: Leading power factors to 120 volt amperes at power factors ranging from 0.8 to 0.10 leading.

(e) AC voltage transients: The a-c voltage shall recover to a minimum voltage of 144 volts peak or to a maximum voltage of 188 volts peak or to a maximum voltage of 188 volts peak within 2.5 milliseconds, and return to steady-state conditions within 50 milliseconds, after experiencing an input line or load step change within the limits specified for line and load. Voltage spikes superimposed at any point of the sinusoidal wave shape shall not exceed 10 volts peak. The maximum transient voltage at the output shall not exceed 225 volts peak.

3.4.2.2.3.3 (Continued)

(f) Frequency - 2 modes of operation shall be provided:

(1) Externally Synchronized Mode - The frequency of the inverter shall be 400 $\pm$ 4 cps with an externally supplied synchronizing signal.

(2) Free-running Mode - In the absence of the external synchronizing signal the inverter shall maintain a free-running frequency of 400 $\pm$ 10 cps.

(g) Isolation - The a-c output shall be electrically isolated from the d-c input and from the case, except for the RFI feed-through capacitors which may be grounded to the case.

3.4.2.2.3.4 Overload. - The inverter shall provide up to 150 $\pm$ 5 percent of the maximum load requirements specified in 3.4.2.2.3.3 for a period of ten minutes. During the overload condition the inverter shall satisfy its performance requirements and shall incur no damage. The inverter shall automatically limit the output current to a maximum of 330 $\pm$ 10 percent of the maximum load requirements specified in 3.4.2.2.3.3 and shall be capable of withstanding this overcurrent condition for 20 seconds without damage and resuming normal operation when the overload is removed.

3.4.2.2.4 Distribution Equipment. - Power distribution shall be accomplished by a two wire grounded system for d-c loads and a single phase system for a-c loads. Wire and busses shall be employed as the return path for electrical currents, rather than the spacecraft structure. The system negative and neutral shall be grounded at one point only.

3.4.2.2.4.1 Load Grouping. - D-C electrical oads shall be connected to a common two-section, electrically connected d-c bus. Provisions shall be made for disconnecting one section of the bus from the other in the event of a failure. Loads shall be grouped into two sections and in the event of a failure and subsequent disconnection of the busses, electrical power will continue to be supplied to the operating bus. A-C loads shall be supplied from a single a-c bus. The bus configuration shall be as shown in Figure 11.

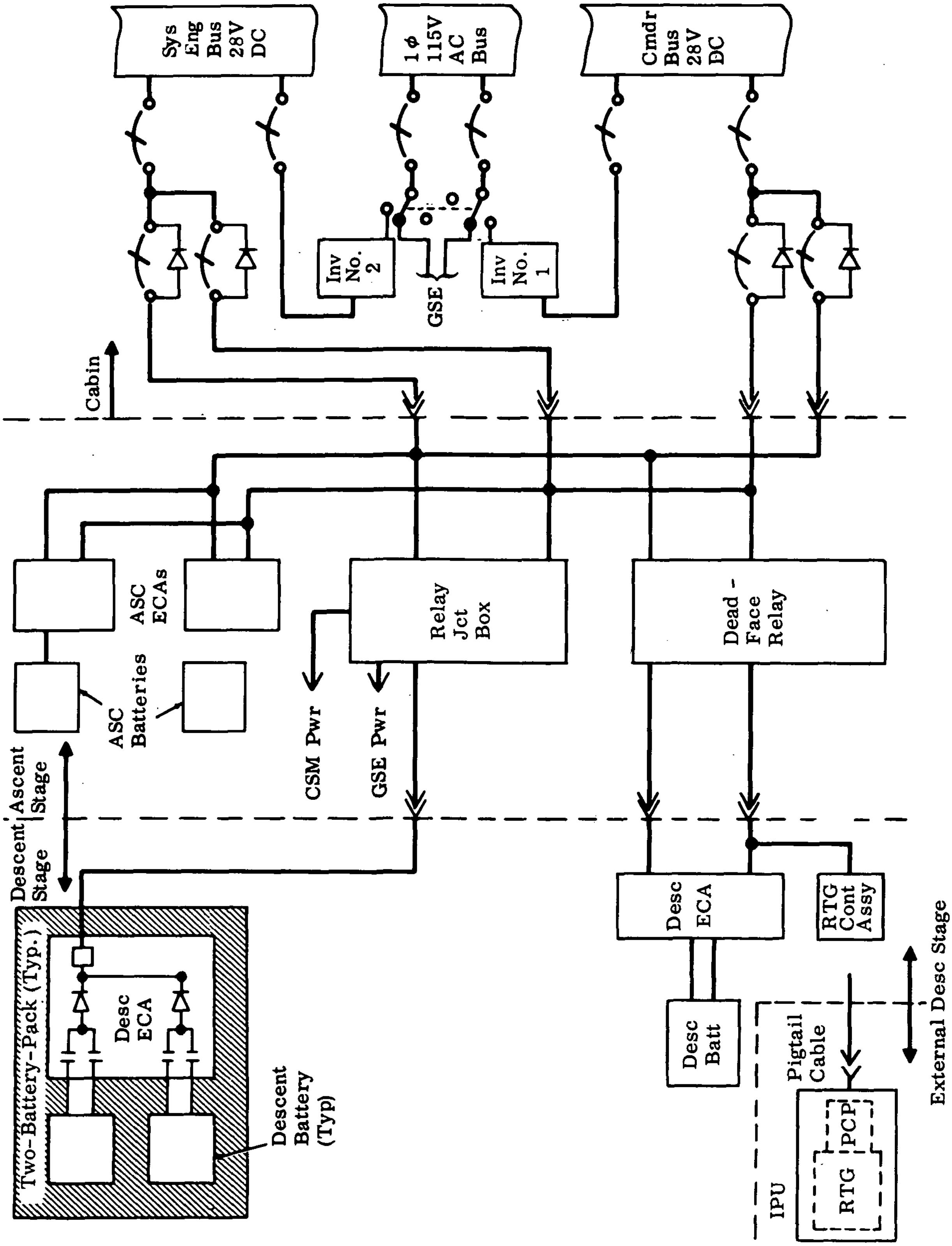


Fig. 11 Electrical Distribution System Block Diagram

3.4.2.2.4.2 Electrical Distribution Panels. - The distribution panels shall be adequately enclosed or otherwise protected to minimize hazards to the crew and provide maximum mechanical protection for the electrical system and components. Switching and control shall be accomplished by manually operated circuit breakers or switches, except where use of a remotely controlled device will reduce weight or increase reliability.

3.4.2.2.4.3 Power Interruption Protection. - Busses and electrical loads shall be selectively protected such that individual load faults will not cause an interruption of power on the bus to which the load is connected. The bus shall be protected from a fault in a battery or its power feeder by the Electrical Control Assembly (ECA) and the tie-in control circuit. The bus ties connecting the divided busses shall be protected on either end by a circuit protective device. In the event of an interruption of power on the a-c bus, the loads shall be transferred to the standby inverter.

3.4.2.2.4.4 Power Distribution Equipment. - The power distribution equipment shall be capable of being energized by the following external power:

(a) D-C: 27.5 V - 32.5 V

(b) A-C: 115 V nom.

3.4.3 Guidance, Navigation and Control Subsystem. -

3.4.3.1 Primary Guidance, Navigation and Control Subsystem (PGNCS). -

3.4.3.1.1 General Description. - The PGNCS shall be an aided inertial subsystem utilizing radar and optical sensor data to provide vehicle guidance, navigation, control, and status reporting. The subsystem shall have the capability for fully automatic and manual operations.

3.4.3.1.2 Subsystem Sections. - The PGNCS shall consist of the following sections:

(a) Government Furnished Equipment (GFE) Section

(b) Rendezvous Radar Section (RR)

(c) Transponder Section (TP)

(d) Landing Radar Section (LR)

(e) LEM Tracking Light Section (LTL)

(f) Landing Point Designator Section (LPD)

The transponder sections of the Taxi PGNCS are mounted on the CSM and Shelter.

3.4.3.1.2.1 GFE Section. - The GFE Section consists of the following:

(a) Inertial Measurement Unit (IMU) - The IMU shall include inertial sensing gyros mounted on a three gimbaled platform which is maintained fixed in inertial space. The IMU shall also include acceleration sensors used to measure vehicle acceleration along the platform axes.

SPECIFICATION NO. ESP 14-0100

3.4.3.1.2.1 (Continued)

(b) Power and Servo Assembly/Signal Conditioning Assembly (PSA/SCA) -

(1) The PSA, in conjunction with the PTA, shall provide the power supplies, amplifiers, demodulators and calibration circuitry required for the IMU, LGC, CDU's and DSKY.

(2) The SCA, in conjunction with the PTA, shall provide the required conditioning circuitry for telemetry and display signals, and interfaces with other subsystems.

(c) Pulse Torquing Assembly (PTA) - The PTA shall contain the circuitry required to support the IMU sensor torquing requirements. The PTA shall be located close to the IMU to reduce the effects of cable loading.

(d) Coupling Data Unit (CDU) - The CDU shall transfer angular data between the IMU, LORS, LGC and the Stabilization and Control Subsystem (SCS). Functions of the CDU shall include analog-to-digital and digital-to-analog conversion.

(e) LEM Guidance Computer (LGC) - The LGC is the central data processing equipment and is a binary, fixed point digital computer with a fixed rope core memory and an erasable ferrite core memory. Primary inputs to the LGC are received from the inertial equipment, LORS, radar equipment, and from the crew via DSKY and hand-controllers. The LGC processes this information and furnishes primary outputs in the form of attitude and thrusting command signals to the Control Electronics Section and data signals to the DSKY and Displays and Controls Subsystem.

3.4.3.1.2.1 (Continued)

(f) Computer Display and Keyboard (DSKY) and additional displays and controls -

(1) The DSKY enables the crewman to manually enter data into the LGC.

(2) Controls and displays required for operation of the LORS.

(3) Displays and controls required for other GFE equipment are an integral part of the Taxi Displays and Controls Subsystem.

(g) Alignment Optical Telescope (AOT) - The AOT shall be an articulating, unity-power wide-field telescope with an adjustable reticle. It can be positioned in three distinct viewing positions with a fourth position provided for storage when not in use. The AOT has a manually rotated reticle with visual read-out. This reticle consists of a radial orientation line with a superimposed spiral. The AOT shall provide sensor data relative to the stars in the form of angular information in Taxi body coordinates.

(h) Navigation Base (NVB)

(i) Cable Harness

3.4.3.1.2.2 Rendezvous Radar Section (RR). - The RR shall consist of an X-Band system capable of three tone Phase Modulated Continuous Wave (PMCW) ranging to a transponder and obtaining range rate and angle tracking to a transponder by utilizing an amplitude comparison, monopulse scheme. The RR shall also be capable of surface tracking by utilizing a Frequency Switch Keying (FSK) scheme. This system shall incorporate solid-state circuitry and furnish the following outputs:

(a) Range

(b) Range Rate

3.4.3.1.2.2 (Continued)

(c) Line-of-sight (LOS) angles with respect to RR antenna reference axes

(d) Line-of-sight (LOS) inertial angle rate with respect to RR antenna axes

The RR shall consist of an electronic assembly, antenna assembly, and control assembly.

3.4.3.1.2.3 Transponder Section (TP). - The transponder shall consist of an electronic assembly, and an antenna assembly, which operates in the X-Band frequency region. The Taxi RR shall coherently track the transponder section of either the CSM or the Shelter.

3.4.3.1.2.4 Landing Radar Section (LR). - The LR shall be an X-Band doppler velocity sensor and altimeter and shall consist of an electronics assembly, antenna assembly and control assembly. The antenna shall be capable of being positioned with respect to the Taxi body axes to maximize LR accuracy. The LR outputs shall be range, along the altitude beam; and velocity data, in antenna coordinates.

3.4.3.1.2.5 LEM Tracking Light Section (LTL). - To be determined.

3.4.3.1.2.6 Landing Point Designator Section (LPD). - The Landing Point Designator shall consist of a grid type display, which, when used in conjunction with the GFE section, provides a means of determining the landing site to which the vehicle is being guided and of selecting an alternate landing site.

3.4.3.1.3 PGNCS General Functional Requirements. - The PGNCS shall provide automatically, with manual override capability, the functions necessary for performance of the navigation, guidance and control tasks for a manned lunar landing mission and for aborts from such a mission. The detailed mission and abort related functional requirements are outlined below.

3.4.3.1.3.1 PGNCS Navigation Functional Requirements. - The navigation function of the PGNCS shall be to provide (to suitable accuracy), the Taxi position, velocity, acceleration, attitude, and timing information necessary for guidance of the Taxi and the monitoring of this guidance. The PGNCS shall provide this navigational information by using the LGC for determination of guidance commands and the DSKY for display of PGNCS performance. The PGNCS shall be capable of aligning to a common inertial attitude reference system with that of the PGNCS on the CSM. The PGNCS shall be capable of producing signals for initializing and aligning the AGS. The PGNCS shall provide the flight crew with the capability of determining the location of the computed landing site during the powered descent.

The navigation functions of the internal sections of the PGNCS are as follows:

(a) IMU Assembly - The IMU is an inertial sensing assembly which establishes spacecraft attitude in inertial space and determines accelerations along the inertial axes to be used in computing the navigation parameters.

(b) AOT Assembly - The AOT shall provide sensor data relative to the stars in the form of angular information in Taxi body coordinates to be used by the crewman for insertion into the PGNCS or AGS.

(c) LPD Section - The Landing Point Designator shall provide a means of determining the landing site to which the vehicle is being guided and of selecting an alternate landing site by means of measurement of LOS angle with respect to body axes.

(d) RR Section - The Rendezvous Radar, in conjunction with a transponder, shall provide data from which the relative vehicle state vectors can be determined for navigation as follows:

   (1) Tracking of a transponder on the CSM during coasting flight, powered ascent and descent flight, and lunar surface phases of the mission.

3.4.3.1.3.1 (Continued)

(d) (Continued)

(2) Tracking of a transponder on the Shelter during the powered descent maneuver

(3) Tracking the lunar surface to provide range and range rate during the powered landing maneuver

(e) LR Section - The LR shall provide sensor data relative to the lunar surface in the form of range, along the altitude beam; and velocity, in antenna coordinates. This data is provided to the LGC, and to the DSKY for display.

(f) LGC Assembly - The LGC shall process the sensor information to obtain Taxi position, velocity, acceleration, attitude, and timing information for:

(1) Guidance and control command computation

(2) Display

(3) Initializing and aligning the AGS

(4) Telemetering to earth

(g) DSKY Assembly - The DSKY shall accept navigational data inserted by the crewman and shall display sensor data and navigational information obtained by processing sensor data in the LGC.

(h) LTL Assembly - TBD

3.4.3.1.3.2 PGNCS Guidance Functional Requirements. -

3.4.3.1.3.2.1 Mission Related Requirement. - The GFE PGNCS shall provide guidance functions to accomplish the following mission related requirements:

(a) Separation from the CSM in lunar orbit and orientation for subsequent phases.

(b) Insertion into the required coasting descent transfer orbit that will cause the Taxi to arrive at a predetermined pericynthion altitude and lunar central angle from the Shelter's landing site.

(c) Powered descent maneuver to a specified landing site while providing the capability for manual inputs and override.

(d) Determine the nominal launch window for direct ascent trajectories and latest launch time for insertion into a parking orbit having a clear pericynthion altitude, while on the lunar surface.

(e) Powered ascent guidance with ΔV budget constraints to achieve the following:

(1) Burnout conditions resulting in a Taxi trajectory that nominally intercepts the CSM at the predetermined aimpoint.

(2) Burnout conditions resulting in a parking orbit with a specified clear pericynthion altitude.

(f) Midcourse corrections within ΔV constraints to reduce dispersions about the nominal aimpoint.

(g) Terminal rendezvous guidance with manual override to allow manual takeover for docking.

3.4.3.1.3.2.2 Abort Related Requirements. - The PGNCS shall provide guidance functions to accomplish the following abort related requirements:

3.4.3.1.3.2.2 (Continued)

(a) Achieve burnout conditions to insert the Taxi into a nominal intercept trajectory with the CSM for a short time of flight within the ΔV, propulsion, vehicle dynamics and crew limitations.

(b) Achieve burnout conditions to insert the Taxi into a nominal intercept trajectory with the CSM for minimum ΔV within the pericynthion and operating time constraints.

(c) Inject the Taxi into a parking orbit with a specified clear pericynthion altitude and within ΔV budget constraints.

(d) Midcourse corrections within ΔV budget constraints to reduce dispersions about the nominal aimpoint.

(e) Terminal rendezvous guidance within the mission constraints including manual takeover for docking.

(f) Inject the space vehicle (CSM with Taxi attached) into a transearth trajectory that will achieve a safe atmospheric entry corridor in event of a Service Module Propulsion Subsystem failure.

(g) The powered ascent portion of the above aborts shall be accomplished with either ascent or descent engine alone, or in combination, as determined by the fuel remaining in the descent stage. The midcourse and terminal rendezvous portions of the above aborts shall be accomplished with the following:

(1) RCS thrusters

(2) Ascent engine

(3) Descent engine

(4) Appropriate combinations of (1), (2) and (3)

3.4.3.1.3.3 PGNCS Control Functional Requirements. - To execute the necessary guidance of the Taxi, the PGNCS shall provide for vehicle stabilization and control when operating in conjunction with the SCS in both automatic and attitude hold modes. The characteristics of the control signals provided to the SCS shall be such as to permit vehicle attitude control with adequate performance characteristics during either coasting or powered flight under either automatic or manual control modes. In the attitude hold mode, the PGNCS shall accept and execute manual rotation and translation command signals from the crewman. Attitude control shall be provided by individual RCS thruster commands and descent engine trim commands. In addition, the PGNCS shall provide descent engine throttling, and engine commands. Detailed functional requirements for the Automatic and Attitude Hold modes are given below.

(a) Automatic Mode -

(1) Attitude Control - During thrusting phases, the PGNCS shall provide automatic command signals to the SCS to control thrust vector direction by commanding vehicle attitude changes. These control signals shall be in the form of RCS thruster commands and Descent Engine trim gimbal commands.

(2) RCS Translation Control - Automatic translation command capability shall be provided by the LGC along all three axes. Translation along the X axis shall be performed utilizing all four available thrusters.

(3) Unbalanced Couples - The thruster logic shall allow firing of only those thrusters which provide forces parallel to the X axis in a +X direction during powered ascent, and during powered abort using the ascent engine through selection of the proper jets. Automatic inhibit of the unbalanced couple restriction shall be provided when desired control torque exceeds the torque capability in the unbalanced couple mode.

(4) X axis Override - This mode of yaw control shall override automatic attitude control about the X axis during the powered descent maneuver. Proportioned yaw commands generated by manual inputs to the Attitude Controller X axis shall generate yaw rate commands similar to the attitude hold mode. The attitude control for Y and Z axes shall remain in the automatic mode.

3.4.3.1.3.3 (Continued)

(a) (Continued)

(5) Descent Engine Throttling - The LGC shall provide the SCS with automatic throttling signals representing positive and negative incremental changes in thrust. The incremental commands are summed and converted in the SCS to a form representing an automatic component of total thrust command. The automatic component is then summed with a manual component coming from the throttle controller. The throttle controller normally stays at a ten percent thrust position but may be used to override the automatic thrust command in the positive direction.

(6) Engine ON-OFF Commands - The LGC shall provide engine ON-OFF commands at the beginning and end of all powered phases except lunar touchdown. At lunar touchdown, the Descent Engine is shut-off as a function of external touchdown sensors. The engine ON-OFF signals are directed to the SCS where they are processed and sent to the descent or ascent engines. In providing the thruster ON and OFF signals, the LGC shall provide for the ullage required for inflight thrusting and account for the effects of tailoff at shutdown.

(b) Attitude Hold Mode -

(1) Attitude Control - Capability shall be provided to accept crew commands of vehicle attitude rates proportional to attitude controller displacement. When the controller is returned to the detent position, the vehicle attitude shall be maintained at the attitude existing at the time the attitude rate goes below a specified threshold. When large attitude changes are required, four jet couples shall be automatically commanded about the affected axis. The PGNCS shall provide the command signals to the SCS to perform the maneuvers and maintain the changed attitude. These command signals shall be the same as those specified in 3.4.3.1.3.3(a). The PGNCS shall provide for manual selection of fine deadband attitude hold.

3.4.3.1.3.3 (Continued)

(b) (Continued)

(2) Translation Control - Capability shall be provided to accept crew commands for linear translational acceleration of the vehicle through ON-OFF firing of the RCS thrusters via the LGC by means of the Translation Controller. This mode shall produce a two-jet response along all three axes.

(3) Rate of Descent Control - Upon swtiching to the Attitude Hold mode the vehicle rate of descent along the nominal landing site local vertical shall be maintained by means of incremental thrust commands issued from the LGC to the SCS. Upon receipt of momentary discretes from a control switch at the crew station, the LGC shall command incremental changes in rate of descent in the positive and negative direction.

3.4.3.1.3.4 Other Functional Requirements. -

(a) Displays - The GFE Section of the PGNCS shall provide:

(1) Signals to permit the time-sharing of displays between the Radar Sections of the PGNCS and the AGS. These signals shall include components of altitude, altitude rate and horizontal velocity. Total attitude and attitude error signals shall be supplied by the GFE Section.

(2) Displays of the status, navigation and guidance data via the DSKY. The navigation and guidance data shall be displayed automatically or at the command of a crewman via the keyboard.

(3) The DSKY shall permit a crewman to initiate the LGC programs for all mission phases, perform in-flight checkout and insert updated navigation data.

3.4.3.1.3.4 (Continued)

(b) Controls - The GFE Section shall permit a crewman to transfer star position information from the AOT to the LGC and the AGS. The GFE Section shall provide the required temperature control for the IMU for ground testing and all mission phases.

(c) GFE/Radar Functional Requirements - The GFE Section shall provide the signals required to command and control the transfer of radar output information from the RR and LR to the LGC as follows:

(1) The LGC shall provide the signals required to automatically designate the RR Antenna to the required target, within an angle that guarantees the target to be within the radar beamwidth, and automatically search over a prescribed volume using LGC generated commands.

(2) The LGC shall provide electrical limiting of the RR antenna for each antenna zone (two zones) to assure that the antenna positions are restricted such that the radar accuracy requirements are met and that servo drives are disengaged before mechanical stops are reached.

(3) The LGC shall automatically position the LR antenna at those points in the mission phase when LR data accuracy is optimized by changing antenna position with respect to the vehicle.

(4) The Rendezvous Radar and Landing Radar will be used simultaneously during powered descent while landing the Taxi to the Shelter transponder.

(d) Communciation Subsystem Functional Requirements - Upon command of a crewman, the LGC shall compute and display, via the DSKY, the required angles for the Communications Subsystem's steerable antenna to aid in earth acquisition for the S-Band Section.

3.4.3.1.3.4 (Continued)

(e) Vehicle Staging Requirement - The PGNCS shall provide signals for staging the Taxi automatically via the ascent engine on command for inflight and surface aborts.

(f) Functional Requirement of LEM Tracking Light - The Taxi Tracking Light shall provide a light source for visual acquisition by a crewman using the CSM optics for navigational measurements during ascent transfer and rendezvous.

3.4.3.1.3.5 Rendezvous Radar Functional Requirements. - The RR shall have the capability of providing the necessary data after manual or automatic slew and acquisition for obtaining range, range rate, angle and angle rate data under the following conditions:

(a) Tracking a transponder mounted on the Shelter while the Taxi is in powered descent to the lunar surface.

(b) Tracking a transponder mounted on the CSM while the Taxi is on the lunar surface and during powered and coast phases of ascent and rendezvous.

(c) Providing range and range rate to the LGC by tracking the lunar surface when the antenna is pointed by the GFE PGNCS along a nominal local vertical. The data obtained will be provided to the PGNCS or displays as required.

3.4.3.1.3.6 Transponder Functional Requirements. - The transponder shall receive the signal from the Rendezvous Radar, and re-transmit a coherent signal at a frequency offset from the RR transmitted frequency. A beaçon mode of operation shall be provided to assist in acquiring the transponder signal.

3.4.3.1.3.7 Landing Radar Functional Requirements. - The landing radar shall furnish the following:

(a) Primary Function (PGNCS)

(1) Range along the altitude beam

(2) Doppler velocity in an antenna referenced orthogonal coordinate system

3.4.3.1.3.7 (Continued)

(b) Secondary Function (Crewman via Displays and Controls Subsystem) -

(1) Range along the altitude beam

(2) Velocity components in an orthogonal coordinate system referenced to the range beam.

3.4.3.1.4 PGNCS Operating Modes. -

3.4.3.1.4.1 GFE Section Operating Modes. - The GFE Section of the PGNCS will have two primary operating modes (Automatic and Manual) and three secondary operating modes (Alignment, IMU Temperature Control and LGC Control).

3.4.3.1.4.1.1 Automatic Mode. - In the automatic mode, the PGNCS will generate and issue all required commands to effect thrust vector control and vehicle stabilization and control as defined in 3.4.3.1.3.3.

3.4.3.1.4.1.2 Manual Mode. - In the manual mode the PGNCS shall execute vehicle rotation and translation commands as directed by a crewman via the hand controllers. These crew commands will establish one of the control modes described in 3.4.3.1.3.3.

3.4.3.1.4.1.3 Alignment Mode. - In the alignment mode the GFE section will align the stable member of the IMU using crewman inputs to DSKY to initiate the following phases of this mode:

(a) Zero Mode - The zero mode shall set the gimbal angle registers in the CDU and the LGC to zero. These gimbal angle registers shall accept gimbal angle information in the incremental format. The Signal initiating this mode shall also be sent to the AGS.

(b) Coarse Align - The coarse align mode shall be used for the initial coarse alignment of the IMU. The stable member of the IMU shall be coarse aligned by torquing the gimbal torquers with CDU error signals derived from LGC specified gimbal angles.

(c) Fine Align - The IMU stable member shall be positioned in the fine align mode to the required inertial orientation. The LGC transforms star line of sight information into the required inertial reference frame. The difference between the required and the existing coarse aligned reference frame shall be used to compute the necessary gyro torquing signals to position the stable member to the desired orientation.

3.4.3.1.4.1.4 IMU Temperature Control Mode. - There will be one temperature control mode for the IMU which will be completely automatic and remain in operation once power is applied through an IMU standby switch closure. The temperature control system will consist of three integrated circuits as follows:

(a) Temperature Control Circuit

(b) Temperature Alarm Circuit

(c) Blower Control Circuit

Provision will also be made for external ground support eouipment temperature control of the IMU during shipping, transportation and storage.

3.4.3.1.4.1.5 LEM Guidance Computer Control Modes. - The LGC will have the following operating modes:

(a) Power off

(b) Standby (LGC clock on)

(c) Power on

Once the LGC is initialized, the power is not turned off, but the standby mode is used for retention of stored data.

3.4.3.1.4.2 Rendezvous Radar Section Operating Modes. - The RR shall have the following operating modes:

(a) Designate Mode - The RR antenna shall be designated to acquire the required target on LGC command.

(b) Search Mode - The RR shall sweep out a prescribed search volume until the required target is acquired. This mode shall be initiated either manually or by the LGC.

3.4.3.1.4.2 (Continued)

(c) Cooperative Track Mode - The RR automatically tracks its transponder located on the lunar surface.

(d) Surface Track Mode - The RR shall track either a passive beacon on the lunar surface, or the lunar surface itself.

3.4.3.1.4.3 Transponder Operating Modes. - The transponder shall operate in the following two modes:

(a) Beacon - The transponder shall provide a signal to assist acquisition of the RR signal.

(b) Transponder - The transponder shall receive the signal from the RR and retransmit a coherent signal that is frequency offset from the RR transmitted frequency.

3.4.3.1.4.4 Landing Radar Operating Mode. - The Landing Radar shall have a single automatic mode of operation.

3.4.3.1.5 PGNCS Performance Requirements. - The PGNCS performance shall be such that when operating with all interfacing subsystems, the functional requirements of the PGNCS are satisfied. In all phases of the mission, the PGNCS shall provide no commands which result in transients beyond the tolerance of the crew, structure or subsystems equipment.

3.4.3.1.5.1 LTL Section Performance Requirements. - TBD

3.4.3.1.5.2 LPD Section Performance Requirements. - TBD

3.4.3.1.5.3 GFE Section Performance Requirements. - The contribution of GFE PGNCS guidance mechanization and execution errors to differences in ΔV from the idealized minimum value, shall be so limited that the overall Taxi system accuracy in performing the DRM is achieved within the total ΔV budget will be specified at a later date, however, Grumman Specification LSP-470-1A essentially represents this requirement and should be used as a reference.

3.4.3.1.5.3.1 GFE Section Stabilization and Control Performance Requirements. - Performance requirements are defined in the LEM GFE PGNCS Performance and Interface Specification.

3.4.3.1.5.4 Radar Section Performance Requirements. - The performance requirements of the RR, T and LR Sections will be specified at a later date, however Grumman Specification LSP-370-2A Section 3.0 and all approved MSC amendments and revisions essentially represents these requirements and should be used as a reference.

3.4.3.1.6 PGNCS Interfaces. - The PGNCS shall interface with the following:

(a) Stabilization and Control Subsystem (SCS) - The PGNCS shall interface with the SCS to perform the following functions:

(1) Out of Detent - Signals from the Attitude Controller Stick to tell the LGC that the Attitude Controller is not in the neutral position.

(2) Translation Command (X Axis) - Command translation by ON-OFF firing of the RCS jets by means of the LGC

(3) Translation Command (Y Axis) - Command translation by ON-OFF firing of the RCS jets by means of the LGC

(4) Translation Command (Z Axis) - Command translation by ON-OFF firing of the RCS jets by means of the LGC

(5) Engine On Command - Initiate engine start sequence

(6) Engine Off Command - Initiate engine stop sequence

(7) Increase Throttle - Signal from the LGC to command the thrust to increase

(8) Decrease Throttle - Signal from the LGC to command the thrust to decrease

(9) ± Pitch Gimbal Trim Commands - Signal from LGC to CES to position DE Pitch Gimbal

3.4.3.1.6 (Continued)

(a) (Continued)

(10) ± Roll Gimbal Trim Commands - Signal from LGC to CES to position DE Roll Gimbal

(11) RCS Jet On Commands (16) - Command signals from LGC to the jet driver preamps

(12) Thruster Pair Fail Discretes (8) - Signals to inform the LGC of thruster pair failure

(13) Proportional Rate Commands (Pitch, Roll, Yaw) - Attitude signals from Attitude Controller

(14) Pitch and Roll - Gimbal Off - Signals to inform LGC of descent engine pitch or roll gimbal failure

(15) ± Δ Aig (Increment of Inner Gimbal Angle) - Increments of gimbal angles used in transfer of alignment to the AGS

(16) ± Δ Amg (Increment of Middle Gimbal Angle) - Increments of gimbal angles used in transfer of alignment to the AGS

(17) ± Δ Aog (Increment of Outer Gimbal Angle) - Increments of gimbal angles used in transfer of alignment to the AGS

(18) CDU Zero (Initial Clear) - Signal to inform AGS that PGNCS is zeroing the CDU's

(b) Instrumentation Subsystem (IS) - The PGNCS interface with the IS is as follows:

(1) Synch. (1024 KPPS) - Synchronize Taxi master timing equipment with LGC

3.4.3.1.6 (Continued)

(b) (Continued)

(2) Serial Digital Data - Digital data from LGC for downlink

(3) Stop Pulse - Signal to indicate end of LGC downlink word transmission

(4) Start Pulse - Signal to indicate start of LGC downlink word transmission

(5) Bit Synch. Pulses - Synchronized serial bits transmitted through downlink between start and end pulses

(6) Discretes PGNCS Subsystem Status Data - PGNCS Caution and Warning signals to Instrumentation for Control Panel Display and Telemetry

(7) Analog PGNCS Subsystem Status Data - Analog data to the IS for telemetry

(c) Explosive Devices Subsystem (EDS) - The PGNCS shall interface with the EDS to receive staging information and abort command signals

(d) Staged Status - Removes stage status signal to LGC at stage operation. Used in LGC software to inform LGC that staging has occurred

(e) Ascent Stage Structure - The PGNCS shall interface with the ascent structure to provide the required physical bonding and alignment for the RR antenna, AOT, IMU, PTA and LTL

(f) Descent Stage Structure - The PGNCS shall interface with the descent stage structure to provide the physical bonding and alignment for the LR antenna

3.4.3.1.6 (Continued)

(g) Electrical Power Subsystem (EPS) - The PGNCS shall interface with the EPS to accept the required electrical power for the particular loads incorporated in the PGNCS

(h) Ground Support Equipment (GSE) - The PGNCS shall interface with the GSE to exchange intelligence required for ground (prelaunch) testing

(i) Command/Service Module (CSM) - The Taxi RR shall interface with the CSM transponder to permit tracking of the CSM by the Taxi

(j) Shelter - The Taxi RR shall interface with the Shelter transponder to permit tracking of the Shelter by the Taxi

(k) Crew Provisions Subsystem (CPS) - The PGNCS shall interface with the Crew Provisions Subsystem to accomplish the following:

(1) Installation of the Power Servo Assembly/Signal Conditioning Assembly (PSA/SCA)

(2) Installation of the LEM Guidance Computer (LGC)

(3) Installation of landing point designator (LPD)

(4) Installation of display and keyboard (DSKY) for LGC

(5) Provide "design eye" visibility position

3.4.3.2 Stabilization and Control Subsystem (SCS). - The SCS shall consist of the Control Electronics Section (CES) and the Abort Guidance Section (AGS). The SCS shall be operational in both the primary guidance and control path, and the abort guidance and control path.

3.4.3.2.1 The Control Electronics Section (CES). - The CES shall consist of the following:

(a) ATCA - Attitude Translation Control Assembly

(b) DECA - Descent Engine Control Assembly

(c) RGA - Rate Gyro Assembly

(d) GDA - Gimbal Drive Assembly

(e) ACA - Attitude Controller Assembly

(f) T/TCA - Thrust/Translation on Controller Assembly

(g) SA - Sequencer Assembly

3.4.3.2.1.1 CES Functional Requirements. - The CES shall provide categories of stabilization and control functions as follows:

(a) Signal processing, generation and switching as required to complete the primary control path in conjunction with PGNCS.

(b) Signal processing, generation and switching as required to provide the abort guidance stabilization and control path. This path shall function in conjunction with the AGS, but shall also provide a manual stabilization and control capability independent of the AGS.

(c) Override functions that are independent of the primary and abort control paths in varying degrees. These functional requirements are as follows.

(d) Initiates the status bus for lunar surface checkout.

3.4.3.2.1.1.1 CES Functions for Primary Control Path. - When operating as part of the primary control path in conjunction with the PGNCS, the CES shall provide the implementation of the control signals originating from the LGC to accomplish attitude and translation control of the vehicle. The necessary display and control signals as specified below:

(a) Reaction Jet Firing - The CES will accept from the LGC discrete (ON-OFF) thrust command signals for each of the 16 reaction control jets and convert them to the required electrical power signals to operate the RCS jet solenoid valves.

(b) Descent Engine Gimbaling - The CES will accept from the LGS discrete (ON-OFF) rotation command signals and will provide the implementation necessary to effect angular rotation of the descent engine about its two orthogonal gimbal axes. Upon receipt of the ON command signal, the descent engine will rotate at a constant angular rate, in the direction and axis commanded, within a limited angular deflection region until receipt of the OFF signal.

(c) Throttle and ON-OFF Control - The CES shall accept the descent engine ON-OFF commands from the LGC via the engine sequencer portion of the Displays and Controls Subsystem, and provide them to propulsion to fire or stop the descent engine.

(d) Thrust Control Mode - During operation of the descent engine, both manual and automatic thrust control signals will be used to throttle the engine within 10 to 100 percent normalized range of operation. Both manual and automatic throttle signals will generate engine throttle commands.

   (1) Automatic Control - Automatic throttle signals from the PGNCS will be processed in the CES and directed to the descent engine. Manual interruption of this path by means of controls and display switching will permit either crew member to fly displayed automatic throttle signals by actuation of the translation controllers. Manual control override of the automatic signal in the positive direction only shall be provided when the T/TCA is advanced to a thrust position exceeding the automatic thrust level.

3.4.3.2.1.1.1 (Continued)

(d) (Continued)

(2) Manual Control - Throttle control signals proportional to to the displacement of the X axis Translation Controller shall generate descent engine throttling commands. Selection of the controller providing descent engine thrust commands shall be a crew function via Displays and Controls Subsystem switching.

(e) Displays and Controls - The CES shall provide the rate signals to energize the rate needles of the Flight Director Attitude Indicator (FDAI). The CES shall provide to the LGC the ON-OFF translation control signals from the Translation Controller Assembly.

The CES shall provide to the detent and attitude control signals from the Attitude Controller Assembly.

3.4.3.2.1.1.2 CES Functions for Abort Control Path. - When the abort guidance and control path is in operation, the CES provides stabilization and control utilizing the following basic modes:

(a) Automatic Mode - In the operation of this control mode, attitude steering errors shall be directed from the AGS to the CES where the appropriate RCS jet and descent engine gimbal commands are generated to achieve stable vehicle control response to the commanded maneuver. The steering signals shall also be directed to error needles on the control panel for monitoring by the crew. A wide and narrow dead zone capability shall be provided that is manually selectable from the Displays and Controls Subsystem during coasting phases. An override of the automatic attitude control function shall be available in each of the three axes by moving the attitude controller to the hardover position. When thus activated, it commands four jet couples directly via the secondary coils of the RCS thrusters. In addition, a two jet direct mode shall be available which is enabled on a per axis basis at the crew station. When in the two jet direct mode, automatic attitude control about the affected axis is

3.4.3.2.1.1.2 (Continued)

(a) (Continued)

disabled and the two jet couples are activated by switches in the attitude controller directly engergizing the RCS thruster secondary coil. The switches are activated when the controller is displaced by 2 1/2 degrees.

A pulse mode shall be available which is activated on a per axis basis by a switch at the crew station. When the pulse mode is activated, automatic attitude control is disabled about the affected axis and a fixed train of torque impulses shall be commended by means of the attitude controller when displaced 2 1/2 degrees.

The normal operation of the RCS jets for attitude control during operation of the ascent engine shall be such that jets providing force in the negative X axis direction will not be fired.

Engine ON-OFF signals from the AGS shall be directed to sequencer logic circuitry of the S & C control panel where they shall be combined with status signals regarding engine arm, engine firing and abort conditions. OUtput signals shall be directed to latching relay devices for operating either the ascent or descent engine (depending on the phase of the mission) to start or stop the engine.

Pitch and roll gimbal trim signals shall be generated within the CES to assure that the descent engine thrust vector operates through the vehicle center of gravity and to trim out steady state attitude errors.

(b) Attitude Hold Mode - The CES shall operate as a closed loop rate command servo for vehicle attitude maneuvering and shall have attitude hold capability in conjunction with the AGS during non-maneuvering periods.

3.4.2.1.1.2 (Continued)

(b) (Continued)

Attitude error signals from the AGS computer shall be used to maintain present vehicle attitude within limit cycle regions, when the attitude controller is in the neutral or detent position. When the controller is moved out of detent, the AGS shall be placed in follow-up about all vehicle axes and an attitude angular rate shall be commanded which is proportional to the controller displacement. Upon return of the attitude controller to the neutral position, the attitude error signals shall be re-established from the AGS to control the vehicle to the attitude existing at the time of controller return to the detent position. Capability for wide and narrow dead band operation shall be provided in a manner identical to the automatic mode.

Four-jet direct, two-jet direct, and pulse modes shall be available for override of the Attitude Hold mode in a manner identical to the Automatic mode. An open loop acceleration command system shall be available for translation by means of the reaction jets.

During thrusting periods of the descent engine, translations of the vehicle in the Y and Z directions shall be commended by displacement of the translation controller in the appropriate directions, while throttling of the descent engine shall be accomplished by controller displacements in the X direction. During all other periods, translation controller displacements shall command positive or negative translation in the X, Y, and Z vehicle directions. Crew selection of either two or four jet translation along the X axis shall be provided by switches in the Displays and Controls Subsystem.

The translation signals shall be directed to jet select logic circuitry of the CES and shall be capable of commanding independent and simultaneous translation along the vehicle X, Y, and Z control axes in either a positive or negative direction by means of ON-OFF operation of the RCS jet engines. A manual plus X axis translation capability shall be provided by means of a switch in the Displays and Controls Subsystem that activates four-jet operation via the RCS secondary coils.

3.4.3.2.1.1.2 (Continued)

(c) Rate Command Mode - This mode shall be functionally the same as the Attitude Hold mode except that the attitude hold capability is not provided when the attitude controller is in the neutral position.

3.4.3.2.1.2 CES Performance Requirements For The Abort Control Path. -

3.4.3.2.1.2.1 Automatic Mode. - Commanded attitude rates shall be limited to a maximum of ten degrees per second in the pitch axis and five degrees per second in the roll and yaw axes.

RCS thruster commands shall be such that the number of jet operations is minimized and the frequency of jet operations is less than seven pulses per second.

3.4.3.2.1.2.2 Attitude Hold Mode. -

(a) The vehicle response to crew commanded rates, from the attitude controller when the CES is in the attitude hole control mode, shall be within the times given in Table II; i.e., the elapsed time from the initiation of controller displacement until the vehicle reaches within 0.15 per second of its steady-state vehicle rate shall not exceed the values given in the table. The final vehicle rate attained shall be within one degree per second of the commanded rate during ascent, and 0.4 degree per second during descent. The attitude control system shall also be capable of commanding and responding to vehicle rates of 20 degrees per second.

The vehicle attitude response when the attitude controller is dropped into detent and the CES is in the attitude hold control mode shall not exceed the values listed in Table III. The attitude control system shall be capable of maintaining, in this mode, at the completion of the initial attitude transient, a minimum impulse limit cycle. A minimum impulse limit cycle shall also be maintained during all periods of undisturbed operation, (i.e., ascent or descent engine non-operative, no large c.g. shifts, absence of external disturbances). A minimum impulse limit cycle is one

3.4.3.2.1.2.2 (Continued)

(a) (Continued)

in which a single torque impulse (about each axis) is imparted to the vehicle at each end of the deadband in order to maintain vehicle attitude within the deadband in order to maintain vehicle attitude within the deadband limits. A minimum torque impulse shall be less than ten ft-lb-sec about any one vehicle axis.

The deadband limit during thrusting phases in the attitude hold modes shall not exceed 0.5 degree.

RCS thruster commands shall be such that the number of jet operations is minimized and the frequency of jet operations is less than seven pulses per second.

(b) RCS Propellant Consumption - The performance of the CES in conjunction with its related subsystems shall be such that the RCS propellant consumption does not exceed the RCS propellant tank capacity. The performance shall be such that it can perform the typical control tasks described within the propellant allotment listed in Table IV.

TABLE II

FLIGHT CONTROL SYSTEM

DYNAMIC PERFORMANCE

ATTITUDE HOLD MODE

RATE COMMAND RESPONSE

	Commanded Vehicle Rate (Rad/Sec)	Rigid Body Moment of Inertia ($Slug-ft^2$)	Response* Time (Sec)
Ascent	.050	1500	0.3
	.100	1500	0.35
	.200	1500	0.45
	.050	6000	2.0
	.100	6000	2.5
	.200	6000	2.7
Descent	.050	10000	0.65
	.100	10000	1.2
	.200	10000	2.2
	.050	20000	1.1
	.100	20000	2.2
	.200	20000	4.0

*Time for error to converge within 0.15 deg/sec of rate deadzone
(Two Jet Response - 1100 lb-ft. torque)
(Times apply to all axes)

TABLE III

FLIGHT CONTROL SYSTEM

DYNAMIC PERFORMANCE

ATTITUDE HOLD MODE

VEHICLE ATTITUDE RESPONSE

(INITIAL RATE, ZERO INITIAL ATTITUDE)

	Vehicle Initial Rate (Rad/sec)	Rigid Body Moment of Inertia ($Slug-ft^2$)	Maximum Angle Overshoot (Deg)	Response* Time (Sec)
Ascent	.050	1500	0.55	0.4
	.100	1500	1.2	0.7
	.200	1500	3.1	1.2
	.050	6000	0.8	3.5
	.100	6000	2.5	3.5
	.200	6000	8.0	5.75
Descent	.050	10000	1.1	1.8
	.100	10000	3.5	3.5
	.200	10000	8.6	6.6
	.050	20000	1.8	3.2
	.100	20000	6.3	5.7
	.200	20000	23.0	9.25

*Time for attitude error to converge to 0.5 deg. (which includes 0.3 deg. control deadband.) (Two Jet Response - 1100 lb-ft torque)

TABLE IV

RCS PROPELLANT REQUIREMENT FOR CONTROL TASKS

(a) Powered Descent Control

(1) Control Task - Maintain vehicle attitude during main engine thrusting periods within the tight RCS deadband limits using both the RCS and main engine. Control of the main engine will be maintained through the gimbal drive actuator.

Mass Properties:

Weight	Vehicle Inertia (slug-ft^2)		
(earth lbs)	Ixx	Iyy	Izz
18900-16947	14600-12350	17900-14500	18900-16500

Propellant Consumption RAte (Average) 4.2 lbs/min all axes

(2) Control Task - Produce a constant displacement of the attitude controller in any one axis until the commanded rate is reached within the allowed tolerance*. Drop the attitude controller into detent to maintain the vehicle attitude.

* Rate to converge within 0.15 deg/sec of rate deadzone as in Table II.

Mass Properties:

Weight (earth lbs)	Rigid Body Inertia (slug-ft^2)
15000	10000

Propellant Consumption:

Commanded Rate (rad/sec)	Propellant Consumption** (lbs)
.05	0.80
.10	2.10
.20	4.50

** NOTE: The propellant consumption covers the time from the initiation of the controller displacement until the attitude error converges to 0.4 deg. (control deadband = 0.3 deg)

TABLE IV (Continued)

(b) Powered Ascent Control

Control Task - Pitch the vehicle over until the commanded rate (10°/sec) is reached within the allowed tolerance. Hold this rate until the vehicle attitude reaches 57° and hold this angle within the tight RCS deadband through the remainder of the ascent phase. Maintain attitude control about the other two axes within the tight deadband.

Elapsed Time in this Phase: 422 sec.

Mass Properties:

Mission Event	(earth lbs) Vehicle Weight	y(in) c.g. Offset	z(in)	Ixx Inertia ($slug\text{-}ft^2$)	Iyy	Izz
Lunar Launch	10820	0.6	0.8	6500	3300	5650
End Insertion to Hohmann	5516	1.2	1.8	2900	2700	1650

Propellant Consumption: 130 lbs all axes for the mass properties and elapsed time as specified above.

(c) Rendezvous Control

Mass Properties: (Tasks 1 & 2)

Weight (earth lbs)	Inertia ($slug\text{-}ft^2$) Ixx	Iyy	Izz
Start of Rendexvous 5516	2900	2700	1650

(1) Control Task - Translate the vehicle using the RCS thrusters to meet the required terminal conditions and maintain attitude control about all axes within the tight deadband.

Propellant Consumption Rate (Average) 0.7 lbs/ft/sec. for each axis

TABLE IV (Continued)

(c) (Continued)

(2) Control Task - Maintain limit cycle attitude motion under undisturbed conditions (i.e., ascent engine non-operative, no c.g. offset, absence of external disturbances)

Propellant Consumption Rate (Average): 0.7 lb/min all axes

(3) Control Task - Produce a constant displacement of the attitude controller in any one axis until the commanded rate is reached within the allowed tolerance.* Drop the attitude controller into detent to maintain the vehicle attitude.

Mass Properties -

Rigid Body Inertia (Slug-ft^2)

1500

Propellant Consumption -

Commanded Rate (rad/sec)	Propellant Consumption** (lbs)
.05	.20
.10	.35
.20	.75

* Rate to converge within 0.15 deg/sec of rate deadzone as in Table VI.

3.4.3.2.1.2 CES Assemblies Description. - The individual CES assemblies shall have the following characteristics and performance capabilities:

3.4.3.2.1.3.1 Rate Gyro Assembly (RGA). - The RGA consisting of three sub-miniature, single-degree-of-freedom rate gyros, shall sense the vehicle pitch, roll and yaw rates and shall supply 800 cps rate signals to the appropriate channels of the ATCA. The 800 cps rate signals shall be used to rate damp the attitude control loop and shall have a maximum range of 25 degrees per second in the positive and negative direction.

3.4.3.2.1.3.2 Attitude and Translation Control Assembly (ATCA). - The ATCA shall consist of the electronics necessary to perform the following functions in addition to those in 3.4.3.2.1:

(a) Generate power supply voltages required by the DECA, RGA, and Controllers.

(b) Accept rate signals from the RGA for rate damping of the attitude control function provided by the ATCA.

3.4.3.2.1.3.3 Descent Engine Control Assembly (DECA). - The DECA shall consist of the electronics necessary to perform the following functions:

(a) Process LGC throttle commands to the throttle control electronics of the Descent Engine

(b) Process manual throttle commands to the throttle control electronics of the Descent Engine

(c) Process Gimbal Trim Commands from LGC and ATCA to the GDA's

(d) Process engine ON-OFF commands

(e) Provide GDA failure detecting circuitry

(f) Provide power control circuitry for the GDA's

3.4.3.2.1.3.4 Gimbal Drive Actuator (GDA). - The GDA shall be a slow speed electromechanical device, containing a 400 cps brushless A-C motor driving a screw jack. The screw jack shall be irreversible under full load and shall require an electrical signal to rotate the gimbal in either direction. On command from DECA the GDA's shall trim the Descent Engine so that the thrust vector rotates about the pitch and roll axes. Two GDA's shall be provided, one for each of the pitch and roll gimbals.

3.4.3.2.1.3.5 Attitude Controller Assembly (ACA). - The attitude controller shall contain a position transducer, detent switches, direct mode switches and limit switches in each of the three axes and shall provide:

(a) Proportional rate commands in the attitude hold mode or rate command mode to either the LGC or the ATCA

(b) Pulse and two jet direct commands

(c) Four jet direct commands

(d) Out of detent signals to command the LGC or the AGS to go into an attitude follow-up mode

3.4.3.2.1.3.6 Translation Controller Assembly (TCA). - The translation controller, containing a transducer in one axis and detent switches, shall provide:

(a) Throttle control commands to DECA

(b) Translation ON-OFF commands to the LGC when in the PGNCS primary mode and to the ATCA when in the Abort Guidance and Control mode

3.4.3.2.1.3.7 Sequencer Assembly. - The Sequencer Assembly contains a timer that initiates the status bus checkout procedure while on the lunar surface.

3.4.3.2.1.4 External Interfaces. - The CES shall interface with the following subsystems or equipment:

(a) Electrical Power Subsystem (EPS) - The CES shall accept the electrical power required for operation from the EPS.

3.4.3.2.1.4 (Continued)

(b) Primary Guidance and Navigation Subsystem (PGNCS) - The CES shall accept input signals from the PGNCS to provide the following:

(1) ON-OFF commands for each of the 16 Reaction Control Jets

(2) ON-OFF commands to the Ascent or Descent engine

(3) Descent engine trim gimbal commands

(4) Thrust mangitude commands to the descent engine

(5) 800 Cycle power to excite the controller

The CES shall feed signals to the LGC to provide the following in the PGNCS primary mode:

a. Proportional attitude rate commands

b. Gimbal Fail signals

c. Translation ON-OFF commands

d. Attitude controller out of detent

(c) Reaction Control Subsystem (RCS) - The CES shall provide the signals to actuate the RCS jet solenoids.

(d) Descent Engine (DE) - The CES shall provide the command signals to the (DE) to accomplish the following:

(1) Ignition and shut-down of the Descent engine

(2) Automatic and manual throttling of the Descent engine

3.4.3.2.1.4 (Continued)

(e) Ascent Engine (AE) - The CES shall provide command signals to the AE for ignition and shut-down of the ascent engine.

(f) Displays and Controls Subsystem (D&C) - The CES shall provide inputs to the appropriate controls and displays to enable control and monitoring of the SCS.

(g) Instrumentation Subsystem (IS) - The CES shall provide output signals to the IS for in-flight monitoring.

(h) Environmental Control Subsystem (ECS) - The ECS shall provide mounting surfaces and thermal protection for the CES equipment.

(i) Structure Subsystem, Ascent Stage and Descent Stage - The Structure Subsystem shall provide the area and mounting accommodations to house the CES equipment within the structure.

(j) Explosive Devices Subsystem (EDS) - The CES shall interface with the EDS for stage status information.

3.4.3.2.2 Abort Guidance Section (AGS). - The AGS shall consist of the following:

(a) Abort Electronics Assemblies (AEA)

(b) Abort Sensor Assembly (ASA)

(c) Data Entry and Display Assembly (DEDA)

3.4.3.2.2.1 Functional Requirements. - The AGS shall be capable of performing the following:

(a) The AGS shall perform guidance computation and steering required to place the Taxi in a direct intercept trajectory to a nominal CSM intercept point, or in an elliptical lunar parking orbit with a minimum pericynthion altitude of 30,000 ft. upon abort from coasting and powered descent, powered ascent, or from the lunar surface. The abort trajectories shall be such that rendezvous with the CM can be accomplished within the Taxi fuel budget. During coasting phases of flight, the AGS shall supply an inertial attitude reference and measure transfer and midcourse ΔV. The AGS midcourse correction ΔV and the rendezvous maneuver(s) shall be manually controlled. The capability of AGS controlled midcourse correction terminal rendezvous including its associated braking maneuver, and abort from coasting descent is to be provided when such provision does not exceed 4096 words of memory after all other requirements of this specification have been met.

(b) The AGS shall provide an all-attitude inertial reference which can be used as an attitude reference for vehicle stabilization during the coasting phases of the Taxi mission and for stabilization and control during the powered phases of the Taxi mission.

(c) The AGS shall provide the Displays and Controls Subsystem with the necessary signals for the flight crew to perform the decision making and control functions required by the nominal and abort mission paths.

3.4.3.2.2.1 (Continued)

(c) (Continued)

The necessary signals are: inertially computed Taxi altitude, altitude rate, Y axis velocity, total velocity, attitude errors and ΔV. For abort monitoring, attitude with respect to the PGNCS reference system shall be used.

(d) The AGS shall provide a general purpose input/output device for crew communications with the AGS.

(e) The AGS shall be capable of aligning to the inertial reference frame as determined by the PGNCS incremental alignment information. It shall also be capable of self aligning to the Taxi body axis at any time and to the local vertical and to a manually inserted azimuth angle (ϕ) on the lunar surface.

(f) The AGS shall be capable of receiving position and velocity information from the PGNCS as initial conditions for AGS guidance computations, via the LGC downlink interface or via manual imputs through the DEDA.

(g) The AGS shall be capable of providing data via a telemetry data output channel in order to verify AGS performance.

(h) The AGS shall provide the capability of performing upon command, self-check of the AEA equipment.

(i) The AGS shall have the ascent and descent engine ON-OFF control necessary to provide the capability of using the descent engine for the initiation of aborts which occur prior to touchdown. The ascent engine shall be used to complete the burn to attain a parking orbit or direct transfer orbit if the fuel remaining in the descent stage is insufficient to achieve this goal.

3.4.3.2.2.2 Performance Requirements. -

3.4.3.2.2.2.1 AGS Modes of Operation. - AGS mode and submode commands, with the exception of the inertial reference sub-mode commands, shall be performed via the DEDA. The AGS modes of operation are:

3.4.3.2.2.2.1 (Continued)

(a) Warm-Up Mode - During the warm-up mode the only function performed by the AGS will be to apply excitation for the fast warm-up heaters of the ASA.

(b) Standby Mode - During the Standby mode the AGS shall:

(1) Provide excitation and power for all subassemblies within the ASA.

(2) Provide degraded operation after a ten minute period. All of the period may be spent in the standby mode, or five minutes of it may be spent in the warm-up mode.

(3) Provide the capability of entering the AGS alignment mode after a 35 minute period. If 25 minutes or more are spent in the warm-up mode, and additional 20 minutes shall be spent in the standby mode before the AGS alignment sub-mode can be initiated.

(4) Provide the capability of accepting PGNCS alignment information 20 seconds after entering the standby mode.

(c) Alignment Mode - During this mode of operation the AGS shall be capable of aligning to any inertial reference frame within a three minute period as determined by the alignment sub-mode scheme selected via the DEDA. The alignment sub-modes are:

(1) IMU Alignment - When AGS alignment is to be accomplished via the PGNCS the IMU alignment sub-mode will be utilized. In this sub-mode, the AGS shall align to the inertial reference frame as determined by the PGNCS incremental alignment information.

(2) Lunar Alignment - When AGS alignment is to be accomplished on the lunar surface and the PGNCS is inoperative the lunar alignment sub-mode shall be utilized. In this sub-mode the AGS shall use the local vertical and the

3.4.3.2.2.2.1 (Continued)

(2) (Continued)

CSM orbital plane as the inertial reference. The alignment shall be accomplished as follows:

a. The ASA accelerometers shall be used to sense local vertical.

b. The value of the outer gimbal angle or equivalent angle will be determined at lunar touchdown from the PNGCS or AGS, and will be updated prior to lunar alignment for launch by voice link information defining CSM orbital inclination and Taxi landing site lunar latitude.

c. Orbital Alignment - When AGS alignment is to be accomplished in orbit and no external information is available the orbital alignment sub-mode will be utilized. In this sub-mode the AGS shall align itself to the Navigation Base reference axes. The Navigation Base reference axes are nominally coincident with the Taxi body axes.

(d) Inertial Reference Mode - When the AGS is in the Inertial Reference Mode, it shall provide attitude error information which will be used for vehicle stabilization and for directing vehicle abort. The inertial reference mode shall be composed of the following sub-modes:

(1) Follow-Up Sub-mode - While in the Follow-up Sub-Mode, the AGS shall cause the attitude error information signals to be reduced to zero during any change in vehicle attitude.

(2) Automatic Sub-mode - In this sub-mode the AGS shall output attitude error information signals which are necessary to guide the vehicle to a safe parking orbit or to a direct rendezvous with the CSM.

(3) Attitude Hold Sub-mode - In this sub-mode, the AGS shall output attitude error information signals which shall maintain the vehicle attitude which existed upon entering this sub-mode.

3.4.3.2.2.2.2 AGS Inputs/Outputs. -

(a) The AGS shall be capable of accepting inputs from the following:

(1) Instrumentation Subsystem -

a. Basic AEA clock signal

b. Telemetry control signals for extracting information from the AEA

(2) Control Electronics Section -

a. Abort Stage

b. Ascent Engine ON

c. Descent Engine ON

d. Automatic

e. Followup

f. 800 cps reference

(3) PGNCS -

a. Simultaneous IMU gimbal angle increments (plus or minus) for each of the three gimbal angles upon removal of the CDU Zero signal.

b. CDU Zero

The PGNCS incremental gimbal angles shall be accumlated in the AGS following the receipt of the CDU Zero signal. These signals shall be accumulated during all modes of operation except warmup.

c. Downlink Information - The AEA shall decode PGNCS downlink information and extract position and velocity data for updating.

(4) Electrical Power Subsystem -

(5) Explosive Devices Subsystem - The abort button provides the closure to inform the AGS of an abort condition.

3.4.3.2.2.2.2 (Continued)

(b) The AGS shall supply the following outputs:

(1) Instrumentation Subsystem - The AGS shall supply a digital telemetry output signal and required outputs for test instrumentation.

(2) CES - The AGS shall provide the CES with steering signals and engine commands during abort.

(3) Displays - The AEA shall continusouly provide the Displays and Controls Subsystem with:

a. Total attitude in all modes except standby and warmup

b. Attitude error in all modes except standby and warmup

c. Lateral body velocity (V_y) (Inertial Reference Mode only)

d. Altitude (h) (Inertial Reference Mode only)

e. Altitude rate ($\dot{h}$) (Inertial Reference Mode only)

f. Δ V increments along the X axis (Inertial Reference Mode only)

3.4.3.2.2.2.3 Detailed Requirements. -

(a) The AGS shall be designed for a minimum operating life of 5000 hours with scheduled maintenance and a minimum shelf of five years. During its operating life, the AGS shall meet specified requirements without scheduled maintenance in 1000 hour increments.

(b) The AGS shall provide the capability for gyro null bias drift compensation during ground and in-flight operations.

(c) AGS performance parameters which cannot be adjusted without hardware modification or removal of the AGS from the Taxi must maintain specified values after calibration for a minimum of 120 days. During the 120 day period no more than 1000 hours operating time capacity may be accumualted.

3.4.3.2.2.2.3 (Continued)

(d) The AGS memory capacity shall be 4096 words.

(e) AGS Attitude Drift Rate - The AGS attitude drift rate shall be within the values indicated over a 30 day period without restriction on duty cycle while in a one g force field or an equivalent 0.165 g force field without rebiasing. (3.4.3.2.2.2.3(c) takes precedence where applicable).

(1) Static Environment - The AGS while in a desirable orientation (with the ASA X axis parallel to the specific force vector) shall have a maximum drift rate of less than one degree per hour per axis.

(2) Degraded Operation Drift Rate - In the degraded mode of operation, the AGS shall have a total drift rate equal to or less than six degrees per hour per axis.

(f) Reference Loss Due to Rotation - The AGS shall not cause the accumulation of a permanent loss of reference greater than 0.0005 degree per net degree of vehicle rotation about any axis for vehicle rates up to and including 22 degrees per second.

(g) Combined Rates - The AGS shall be capable of following rotational rates up to and including 25 degrees per second consecutively or concurrently about all vehicle axis.

(h) Acceleration Range - The AGS shall be capable of sensing acceleration along any vehicle axis within the range from +100 feet per $second^2$ to -100 feet per $second^2$.

(i) Velocity Increment - The AGS shall be capable of detecting velocity changes of 0.05 feet per second along each vehicle axis.

(j) IMU Alignment Accuracy - The AGS shall be aligned to within five arc minutes per axis maximum of the accumulated incremental IMU angles at the completion of the IMU alignment sub-mode.

(k) Lunar Alignment Accuracy - The AGS shall be aligned to within ten arc minutes maximum per axis at the completion of the lunar align sub-mode.

3.4.3.2.2.2.3 (Continued)

(l) Orbital Alignment Accuracy - The AGS shall be aligned to within five arc minutes maximum per axis to the Navigation Base at the completion of the orbital alignment sub-mode.

(m) Total Attitude - The total attitude signal for display shall be accurate to plus or minus 0.5 degree maximum per axis at any attitude.

(n) Guidance Law - An explicit guidance law shall be used provided the computer capacity of 4096 words is not exceeded. If the specified computer capacity cannot be retained using explicity guidance, a guidance law will be proposed which meets the memory capacity requirements.

(o) AEA Memory Requirements - TBD

(p) Trajectory Performance - TBD

3.4.3.2.2.3 AGS Assemblies. - The AGS shall consist of the following assemblies:

(a) Abort Sensor Assembly (ASA) - The abort sensor assembly shall consist of three strapped down pulse rebalanced rate integrated gyros and three strapped down pulse rebalanced accelerometers. The ASA shall be capable of sensing accelerations along the vehicle axis and angular rates about the vehicle axis.

(b) Abort Electronics Assembly (AEA) - The abort electronics assembly shall consist of a general purpose digital computer. The AEA shall be capable of fulfilling all the computational requirements of the AGS within the limitations of a 4096 word memory.

(c) Data Entry and Display Assebmly (DEDA) - The Data Entry and Display Assembly (DEDA) of the AGS shall be capable of the following:

(1) Manual control of the AGS modes of operation

(2) Manual insertion of data into the AEA and display of these data

(3) Manual command of the contents of a desired AEA memory word location to be displayed on the DEDA

3.4.4 Reaction Control and Propulsion Subsystems. - The Reaction Control and Propulsion Subsystem shall consist of the following:

(a) Reaction Control Subsystem (RCS) consisting of:

(1) Two independent helium pressurization sections

(2) Two independent positive expulsion propellant supply and distribution sections with crossfeed capability

(3) Sixteen reaction control rocket engines

(4) A propellant quantity gaging section

(5) Heaters

(b) Propulsion Subsystems consisting of:

(1) Descent Propulsion Subsystem consisting of:

a. Engine section

b. Propellant feed section

c. Pressurization section

d. A pressure venting system for depressurizing the pressurization and propellant tanks after lunar landing

(2) Ascent Propulsion Subsystem consisting of:

a. Engine section

b. Propellant feed section

c. Pressurization section

d. Propellant quantity gaging section

e. RCS interconnect

3.4.4.1 Performance. -

3.4.4.1.1 Reaction Control Subsystem. - The Reaction Control Subsystem (RCS) shall provide the impulse for either three axis rotational or translational control of the Taxi during all flight mission phases and shall operate in a zero gravity environment. The attitude and translational control functions shall include but not be limited to:

(a) Translation for separation from the Command Service Module (CSM), mid-course velocity corrections, rendezvous, docking, and landing site surveillance.

(b) Ullage settling of the propulsion subsystem propellants

(c) Complete thrust vector control during power ascent mission phase

3.4.4.1.1.1 The RCS rocket engine shall have the following performance characteristics:

(a) Thrust - The rocket engine shall develop a continuous operation vacuum thrust of 100 ± 5 lbs.

(b) Thrust Transient Rate - The rocket engine shall demonstrate a thrust buildup and thrust decay as shown in Figure 12

(c) Specific Impulse - When operating engines for periods in excess of one second the specific impulse shall be 294 seconds nominal. Specific impulse for pulse mode operation shall be as shown in Figure 13

(d) Minimum Impulse - The engine shall be capable of providing a minimum impulse of 0.4 plus or minus 0.2 pound seconds during vacuum operation when an electrical signal (pulse width) of 12.5 milliseconds is provided.

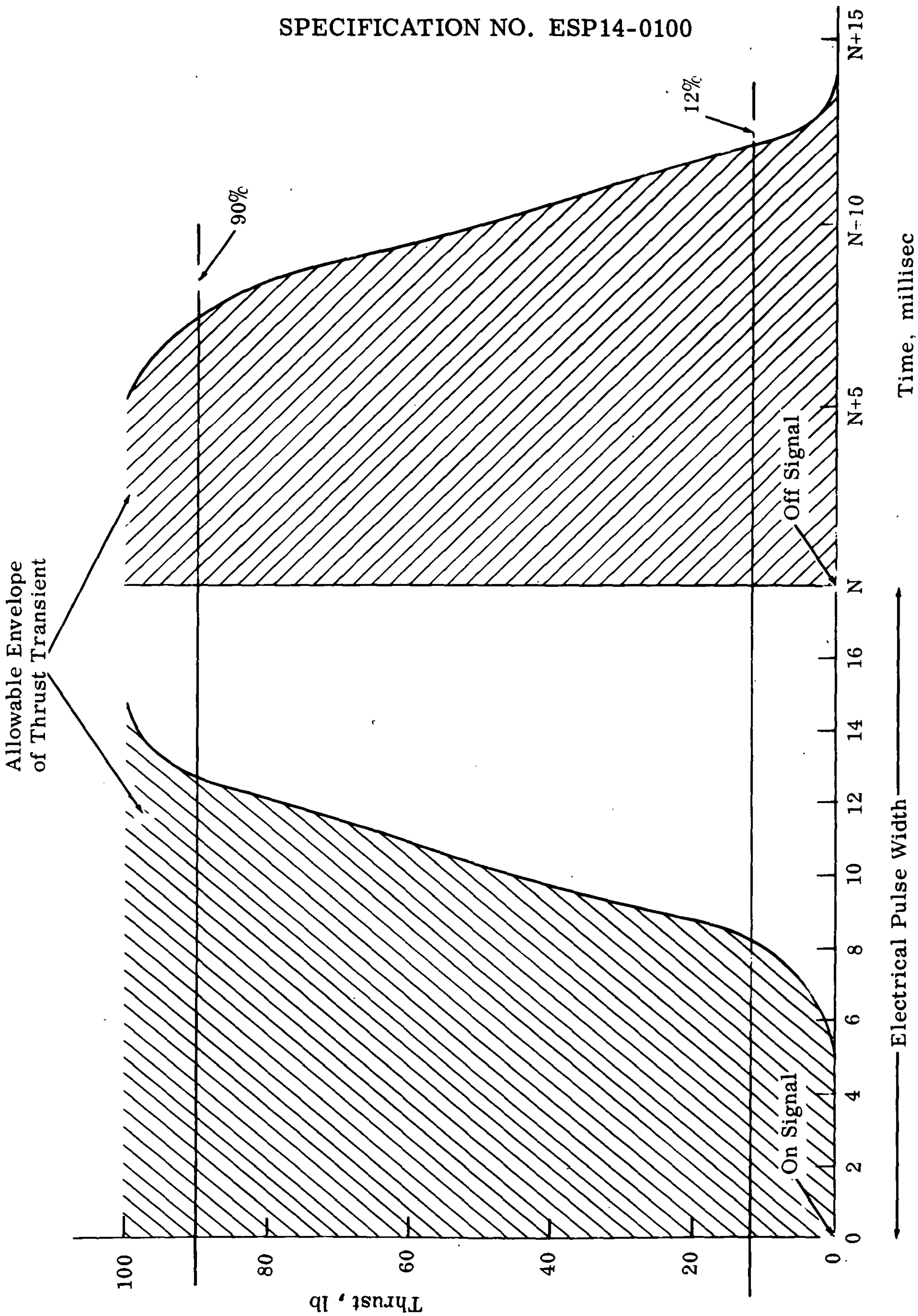


Fig. 12 Thrust vs Time

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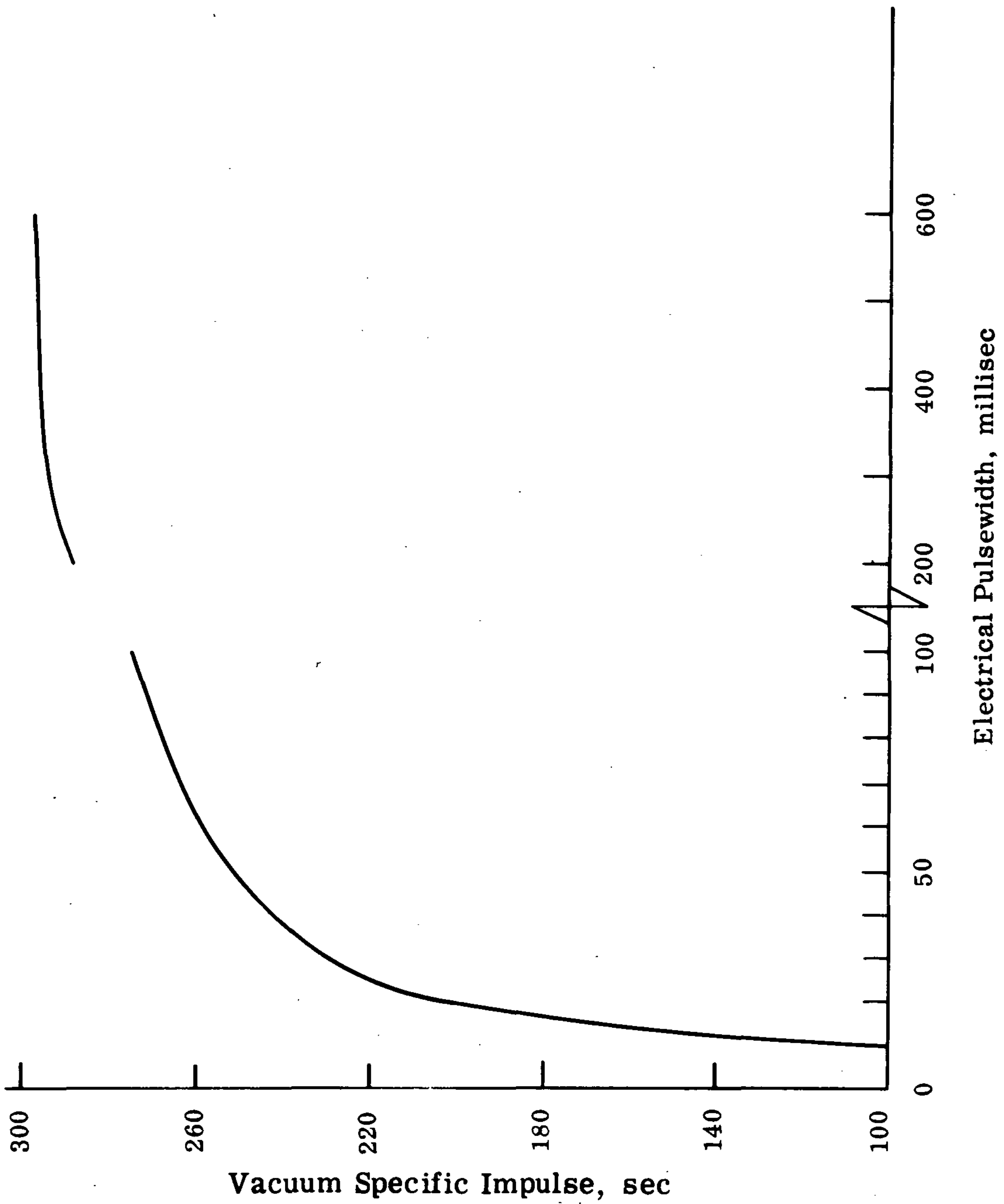


Fig. 13 Vacuum Specific Impulse vs Electrical Pulse Width

3.4.4.1.1.1 (Continued)

(e) Reliable Operating Life - Following acceptance tests, the engine shall have a minimum reliable life of 1000 seconds. The engine shall withstand a minimum of 10,000 operational cycles during the 1000 second operating life without deterioration. The engine shall be capable of continuous operation for a period of 500 seconds.

3.4.4.1.1.2 Propellant Section Performance. - Each independent Propellant Section shall provide storage and supply for the oxidizer and fuel. The oxidizer and fuel equipment are identical except for the volume of the supply tanks. The propellant shall be furnished to the engine for steady state operation at a dynamic pressure of 170 $\pm$ 10 psia.

3.4.4.1.1.3 Propellant Quantity Gaging Section. - The Propellant Quantity Gaging Section shall determine the quantity of propellant in the positive expulsion tanks and provide propellant "quantity remaining" data to the crew. The Propellant Quantity Gaging equipment shall perform even while the vehicle is exposed to a zero gravity environment.

3.4.4.1.1.4 Pressurization Section. - Each independent Pressurization Section shall distribute helium at regulated pressure to the propellant tanks for positive expulsion of propellant through the assembly components and tubing. Pressure regulation shall be accomplished by a parallel series regulator arrangement. The helium supply pressure shall be reduced to the normal dynamic operating pressure of approximately 181 psia.

3.4.4.1.1.5 Heaters. - The Heaters shall thaw the propellant feed lines and RCS thrusters prior to ascent from the lunar surface.

3.4.4.1.2 Propulsion Subsystems Performance. -

3.4.4.1.2.1 Descent Propulsion Subsystem (DPS). -

(a) The Descent Propulsion Subsystem shall supply the impulse for the following modes:

(1) Normal - All major velocity increments required for insertion into descent transfer orbit and powered descent including initial deboost, landing approach, hover and touchdown.

(2) Abort - Backup of SPS within the limits of the propulsion subsystem Δ V capability.

(b) Thermal control of subsystem components shall be by passive means.

3.4.4.1.2.1.1 Descent Engine. - The Descent Engine shall have the following characteristics:

(a) Thrust - Throtteable over a 10:1 range from 10,500 pounds to 1,050 pounds, nominal in a vacuum.

(b) Specific Impulse - I_{sp} = 305 minimum 3-sigma value at maximum thrust following 857 seconds of operation for the nominal duty cycle shown in Figure 14. I_{sp} = 285 minimum 3-sigma value at minimum thrust following 857 seconds of operation for the nominal duty cycle shown in Figure 14

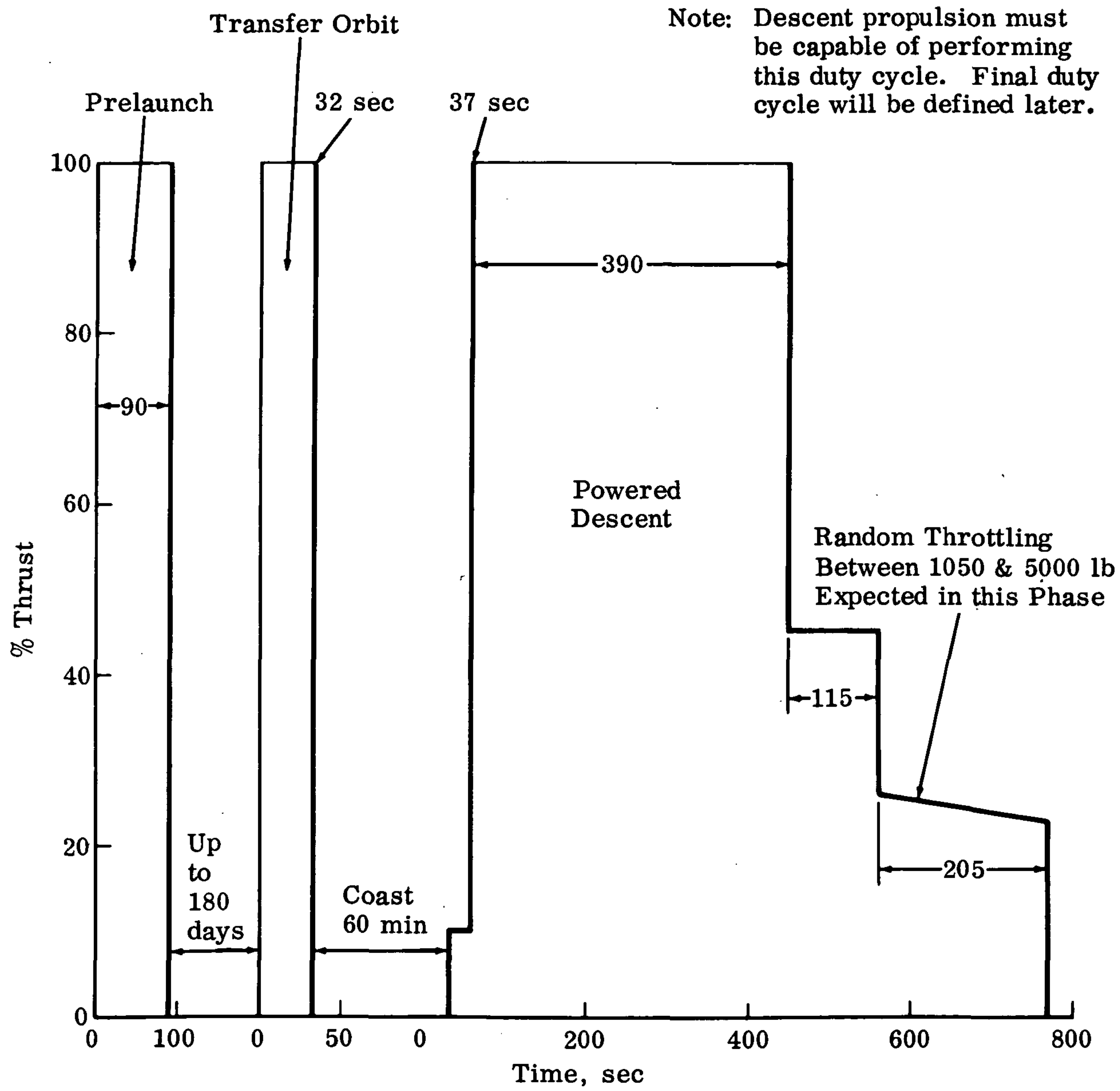


Fig. 14 Descent Propulsion Nominal Mission

3.4.4.1.2.1.1 (Continued)

(c) Operating Life: 857 seconds for the nominal duty cycle shown in Figure 14. The engine shall be designed to comsume the remainder of 17931 lbs. of propellant following completion of the duty cycle with the throttle set at 25 percent thrust position.

(d) Gimbal Angle - In both Y and Z axes, plus or minus six degrees

3.4.4.1.2.1.2 Propellant Section Performance. - The propellant section shall provide storage and supply for the oxidizer and fuel. The oxidizer and fuel equipment are identical with parallel feedout and a propellant distribution assembly. Crossover lines are provided between like tanks for passive propellant management. The propellant shall be furnished to the engine for steady state operation at a dynamic pressure of 210 $\pm$ 4 psia.

3.4.4.1.2.1.3 Propellant Quantity Gaging. - There shall be provisions for continuous quantity gaging. There shall be sensors provided to warn of imminent propellant depletion.

3.4.4.1.2.1.4 Pressurization Section. - The Pressurization Section shall distribute supercritical helium at regulated pressure to the propellant tanks for positive expulsion of propellants through the assembly components and tubing. Pressure regulations shall be accomplished by a parallel series regulator arrangement. The supercritical helium supply pressure shall be reduced to the normal dynamic operating pressure of approximately 230 psia. High pressure helium shall be considered as an alternate. The Taxi shall use the same pressurization system as the LEM.

3.4.4.1.2.1.5 Pressure Venting Section. - The pressure shall be vented from the pressurization and propellant tanks after lunar landing.

3.4.4.1.2.2 Ascent Propulsion Subsystem (APS). -

(a) The Ascent Propulsion Subsystem shall supply the impulse for the following modes:

(1) Normal - All major velocity increments required for powered ascent from the lunar surface, transfer orbital insertion, midcourse correction, and rendezvous.

(2) Abort - Abort capability throughout all phases of the Taxi mission.

(b) Thermal control of subsystem components shall be by passive means.

3.4.4.1.2.2.1 Ascent Engine. - The Ascent Engine shall have the following characteristics:

(a) Thrust - Fixed 3,500 pounds, nominal in a vacuum

(b) Specific Impulse - I_{sp} = 306.3 seconds, minimum 3-sigma value following 525 seconds of operations for the duty cycle shown in Figure 15

(c) Operating Life - Minimum life shall be 525 seconds for the duty cycle shown in Figure 15

3.4.4.1.2.2.2 Propellant Section Performance. - The propellant section shall provide storage and supply for the oxidizer and fuel. The oxidizer and fuel equipment are identical with parallel feedout and a propellant distribution assembly. Crossover lines are provided between like tanks for passive propellant management. The propellant shall be furnished to the engine for steady state operation at a dynamic pressure of 165 ± 4 psia.

3.4.4.1.2.2.3 Propellant Quantity Gaging. - There shall be no provisions for continuous quantity gaging. There shall be provisions for leak detection prior to APS utilization and sensors to warn of imminent propellant depletion.

Note: Ascent Propulsion must be capable of performing this duty cycle. Final duty cycle will be defined later.

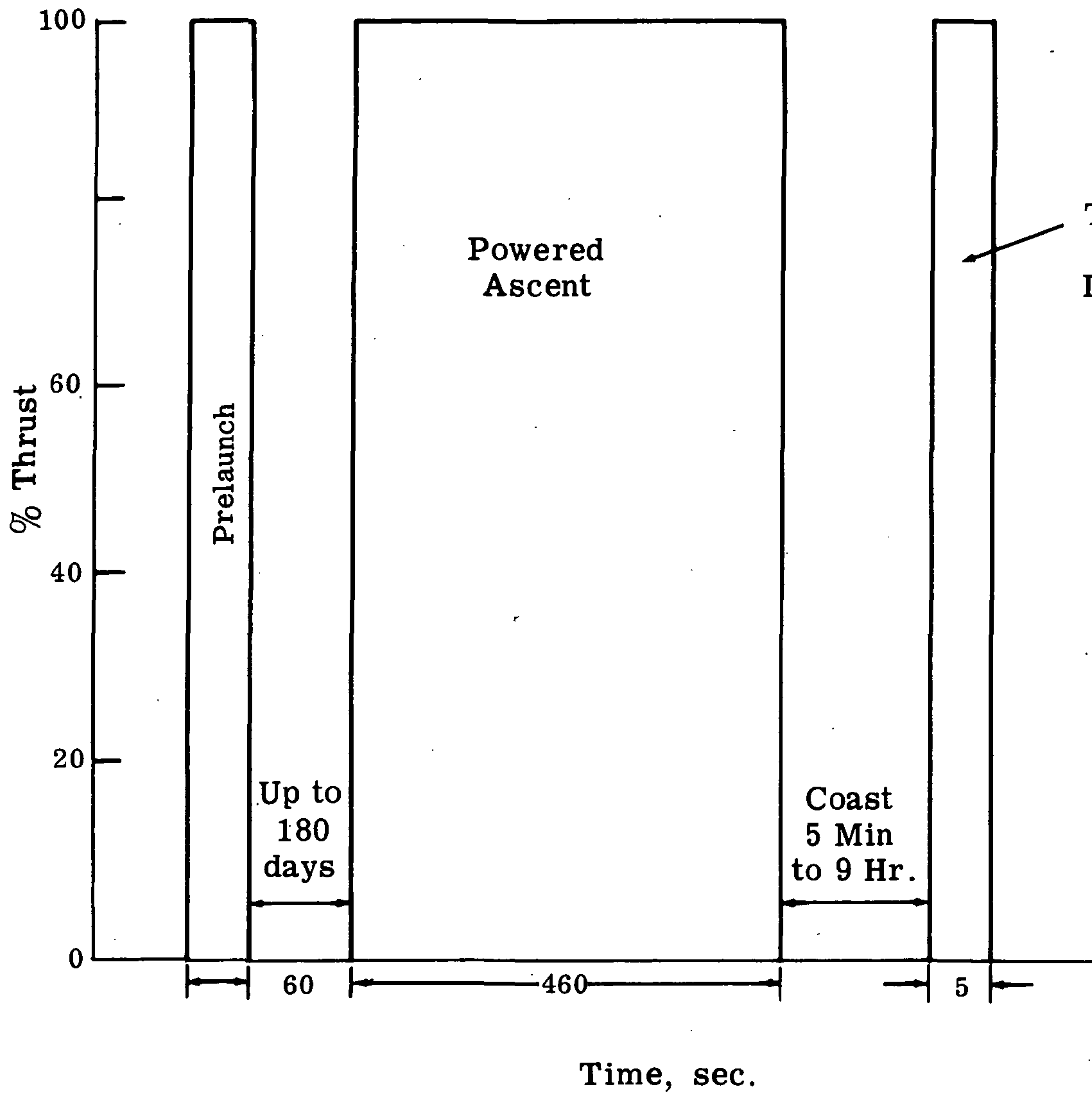


Fig. 15 Ascent Propulsion Nominal Mission

3.4.4.1.2.2.4 Pressurization Section. - The Pressurization Section shall distribute supercritical helium at regulated pressure to the propellant tanks for positive expulsion of propellants through the assembly components and tubing. Pressure regulations shall be accomplished by a parallel series regulator arrangement. The supercritical helium supply pressure shall be reduced to the normal dynamic operating pressure of approximately 194 psia. High pressure helium shall be considered as an alternate. The Taxi shall use the same pressurization system as the LEM.

3.4.4.1.2.2.5 RCS Interconnect. - The APS Propellant Section shall interconnect with the RCS feed system so that ascent propellant may be used by RCS during certain mission phases.

3.4.4.2 Design Requirements. -

3.4.4.2.1 RCS Design Requirements. -

3.4.4.2.1.1 Rocket Engine. - The rocket engines are mounted in clusters of four as shown in Figure 16. The rocket engine shall be pulse-modulated, pressure-fed, radiation cooled, and shall utilize earth-storable hypergolic propellants.

3.4.4.2.1.2 Propellant Section. - The propellant supply shall consist of nitrogen tetroxide (N_2O_4) oxidizer (per specification MIL-P-26539) and a mixture of 50 percent hydrazine (N_2H_4) and 50 percent unsymmetrical dimethylhydrazine (UDMH) (per specification MIL-P-27402) as fuel. The oxidizer and fuel shall be stored in separate tanks. The tanks shall be cylindrical with hemispherical ends, of titanium alloy. A teflon bladder shall be incorporated between the pressurant and propellant for expulsion. The maximum tank working pressure shall be 248 psia, proof pressure 331 psia, and burst pressure 372 psia.

3.4.4.2.1.3 Propellant Quantity Gaging Section. - The propellant quantity gaging equipment shall be a nucleonic type using cobalt 60 radioisotope source. A signal shall be provided to the master auction-warning panel from the ratio section if the ratio exceeds a preset range. The accuracy of the propellant mass ratio circuit shall be within two percent of total tank capacity of the tankage module. The difference between the actual propellant quantity and the quantity measured shall not exceed one percent of the total tank capacity except tank quantities less than 10 percent and more than 90 percent when one-half percent accuracy is required. Means shall be provided to conduct a complete system ground checkout including failure identification of a replaceable assembly.

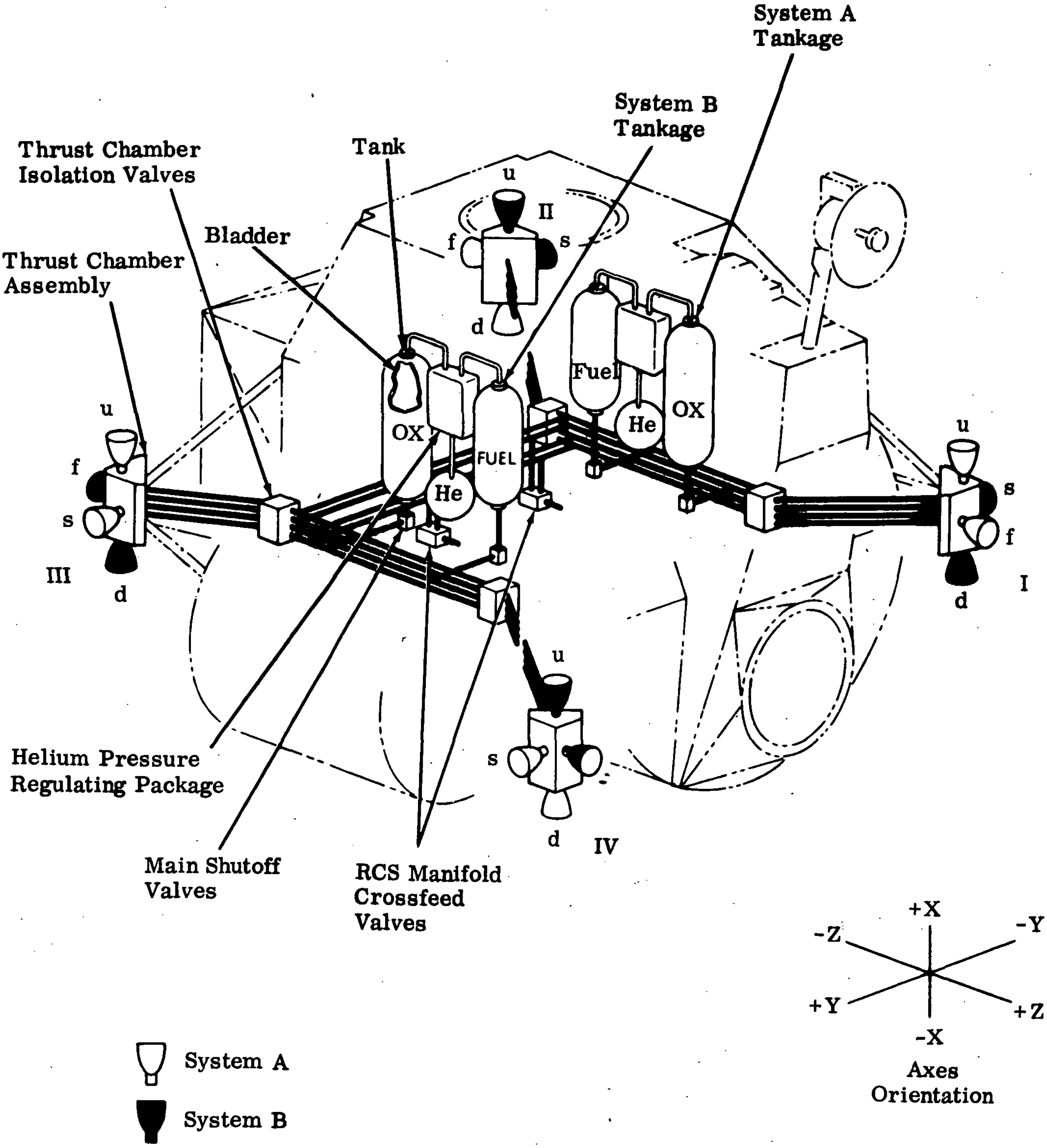


Fig. 16 RCS General Arrangement

3.4.4.2.1.4 Pressurization Section. - The pressurization section shall consist of a high pressure helium supply contained in one spherical, titanium tank and associated pressure regulation and distribution assembly. The tank shall accommodate 1.03 lbs of helium at an initial pressure of 3050 ± 50 psia. The maximum working pressure shall be 3500 psia to accommodate pressure transients. Proof pressure shall be 4650 psia and burst pressure 7000 psia.

3.4.4.2.1.5 Pressure Venting System. - TBD

3.4.4.2.1.6 Heaters. - TBD

3.4.4.2.2 Propulsion Subsystems Design. -

3.4.4.2.1 DPS Design Requirements. -

3.4.4.2.1.1 Engine Section. - The descent engine shall consist of a single unit, pressure-fed variable area injector, throttleable, gimballed, ablation-cooled, bipropellant, hypergolic liquid-fueled rocket engine with a crushable radiation-cooled nozzle skirt. The engine shall have multiple restart capability and be gimbal mounted to permit thrust vector control.

3.4.4.2.2.1.2 Propellant Section. - The propellant section shall consist of an oxidizer and fuel supply using nitrogen tetroxide (N_2O_4) as the oxidizer (per Specification MIL-P-26539) as a mixture of 50 percent hydrazine (N_2H_4) and 50 percent unsymmetrical dimethylhydrazine (UDMH) (per Specification MIL-P-27402) as the fuel, each shall have two cylindrical skirt mounted titanium tanks with parallel feedout and a propellant distribution assembly. Crossover lines are provided between like tanks for passive propellant management. Propellant utilization shall be accomplished with fixed orifices.

3.4.4.2.2.1.3 Propellant Quantity Gaging. - Continuous quantity gaging shall be provided. Low level sensors shall be furnished in each tank to provide warning of imminent propellant depletion.

3.4.4.2.2.1.4 Pressurization Section. - The pressurization section shall consist of a supercritically stored helium supply contained in a single, spherical, vacuum-jacketed tank equipped with internal heat exchanger valves, associated external heat exchanger, pressure regulation and distribution assembly. High pressure helium shall be considered as an alternate pressurization system. The Taxi shall use the same pressurization system as the LEM.

3.4.4.2.2.1.5 Pressure Venting Section. - Upon command, pressure shall be vented from the pressurization and propellant tanks after lunar landing.

3.4.4.2.2.2 APS Design Requirements. -

3.4.4.2.2.2.1 Engine Section. - The Ascent Engine shall consist of a single unit, pressure-fed, fixed thrust, fixed mounted, ablation-cooled, bipropellant, hypergolic liquid-fueled rocket engine. The engine shall have multiple restart capability.

3.4.4.2.2.2.2 Propellant Section. - The propellant section shall consist of an oxidizer and fuel supply using nitrogen tetroxide (N_2O_4) as the oxidizer (per specification MIL-P-26539) and a mixture of 50 percent hydrazine (N_2H_4) and 50 percent unsymmetrical dimethylhydrazine (UDMH) (per specification MIL-P-27402) as the fuel. Each shall have two cylindrical skirt mounted titanium tanks with parallel feedout and a propellant distribution assembly. Crossover lines are provided between like tanks for passive propellant management. Propellant utilization shall be accomplished with fixed orifices.

3.4.4.2.2.2.3 Propellant Quantity Gaging. - Continuous quantity gaging shall not be provided. Low level sensors shall be furnished in each tank to provide warning of imminent propellant depletion.

3.4.4.2.2.2.4 Pressurization Section. - The pressurization section shall consist of a supercritically stored helium supply contained in a single, spherical, vacuum-jacketed tank equipped with internal heat exchanger valves, associated external heat exchanger, pressure regulation and distribution assembly. High pressure helium shall be considered as an alternate pressurization system. The Taxi shall use the same pressurization system as the LEM.

3.4.5 Communication Subsystem (CS). - The CS shall consist of the following sections:

(a) S-band section

(b) VHF section

(c) Signal processing assembly

(d) Television section

3.4.5.1 Performance Requirements. - Communications capability shall be provided between the Taxi and the Manned Space Flight Net (MSFN), Command Service Module (CSM) and Extra Vehicular Astronaut (EVA). The communications equipment shall be compatible with the equipments with which it interfaces, as shown in Figure 17.

3.4.5.1.1 Types of Communications. - The following types of communications shall be provided:

(a) Two way voice and voice conference

(b) Tracking and ranging aids

(c) Telemetry transmission

(d) Television transmission

(e) Key transmission

(f) Biomedical data transmission

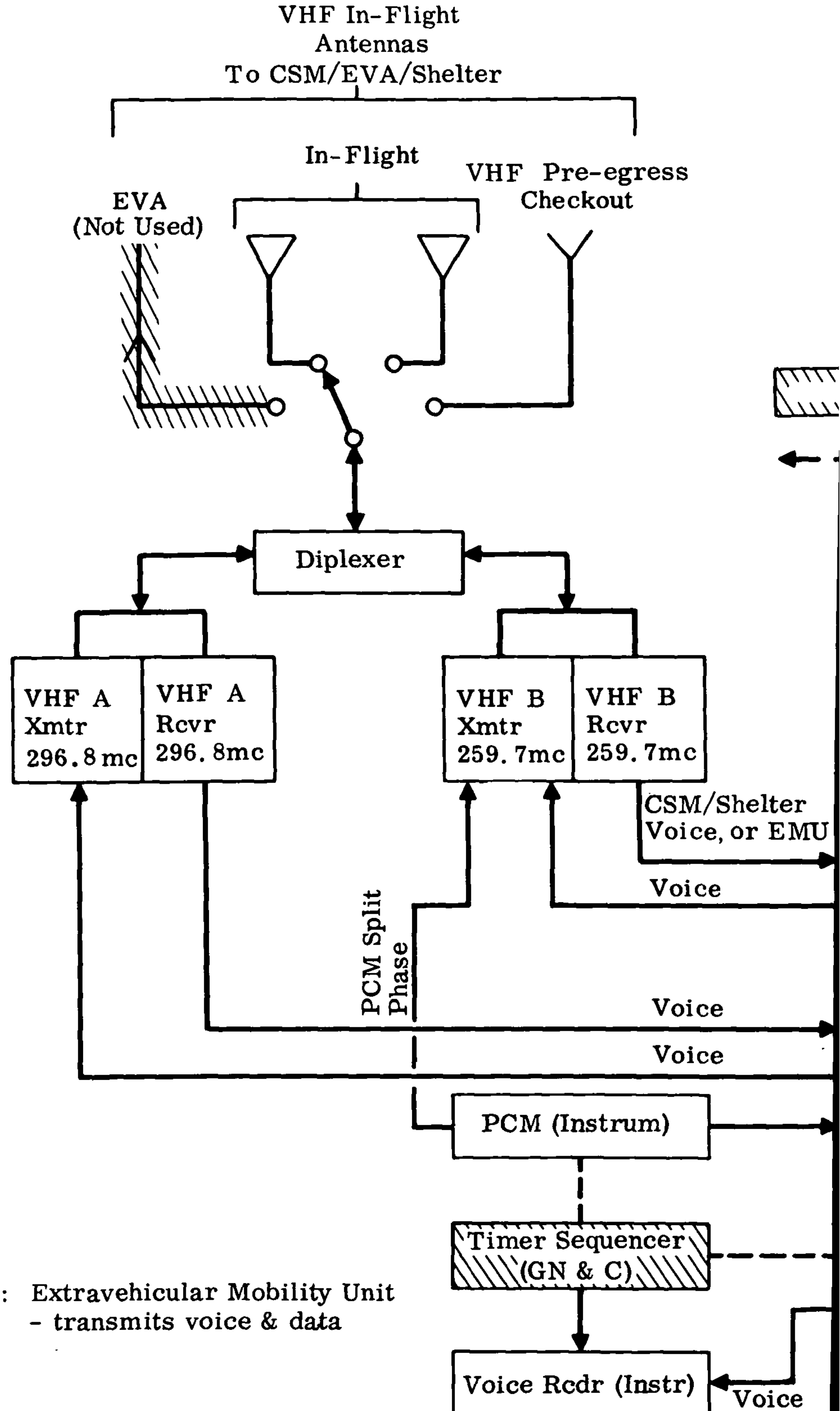
Radio frequency utilization shall be as shown in Figure 18.

3.4.5.1.2 Two Way Voice Conference. - Two way voice and voice conference shall be available between the following:

(a) Taxi/MSFN - Duplex voice communications capability between the Taxi and the MSFN to a minimum slant range of 220,000 nautical miles shall be provided by an S-Band communications link. The voice channel shall be so designed as to provide two-way voice capability using the Taxi inflight omni antennas.

(b) Intercommunications. - An intercommunications capability between the crew members inside the Taxi shall be provided.

(c) Taxi/EVA - Duplex voice communications capability between the crew member inside the Taxi and an EVA within a three nautical mile radius of the Taxi shall be provided by a VHF/AM communications link. Duplex voice communications capability shall exist between the Taxi and an EVA as a backup.



Note: EMU: Extravehicular Mobility Unit
- transmits voice & data

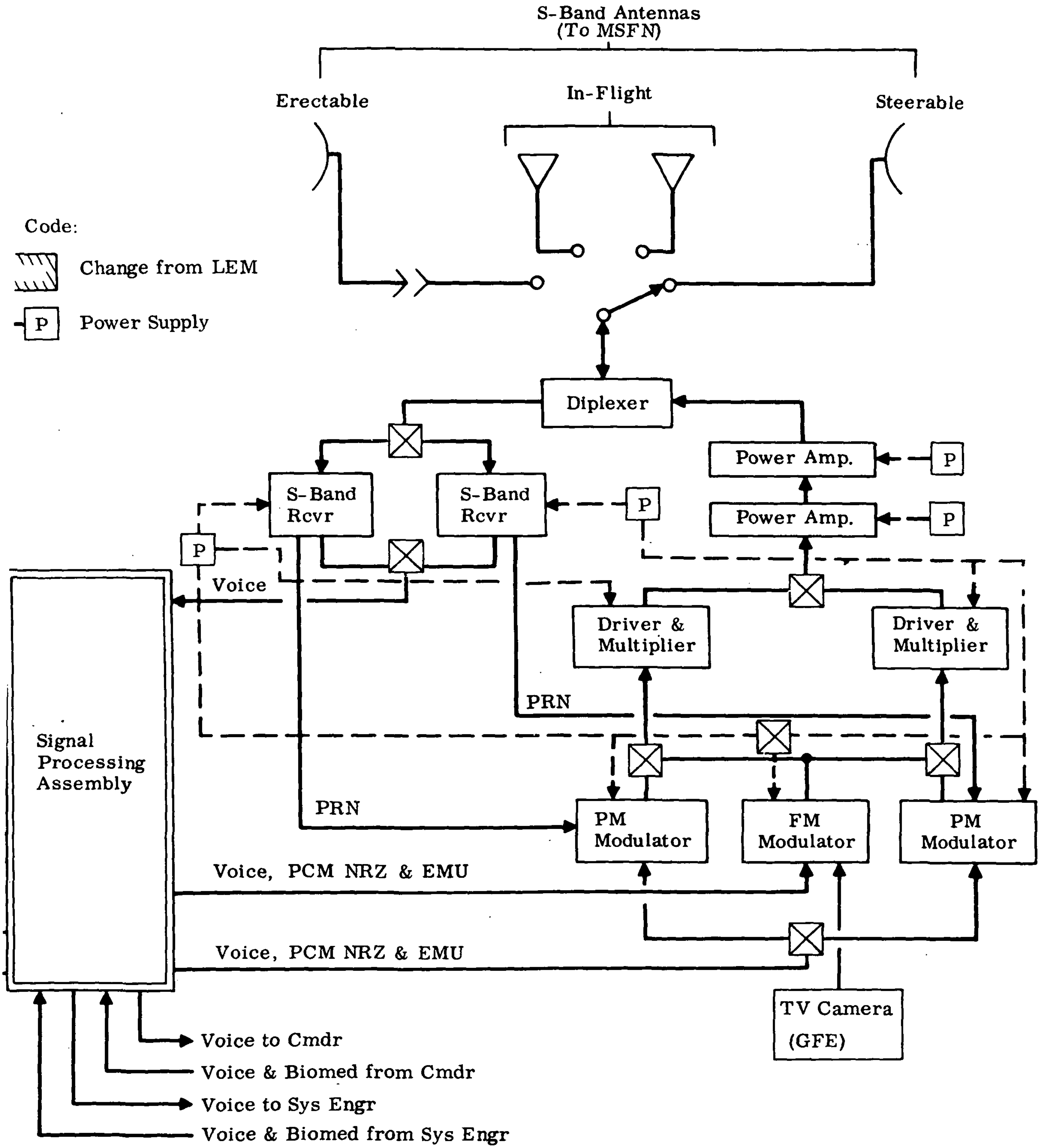
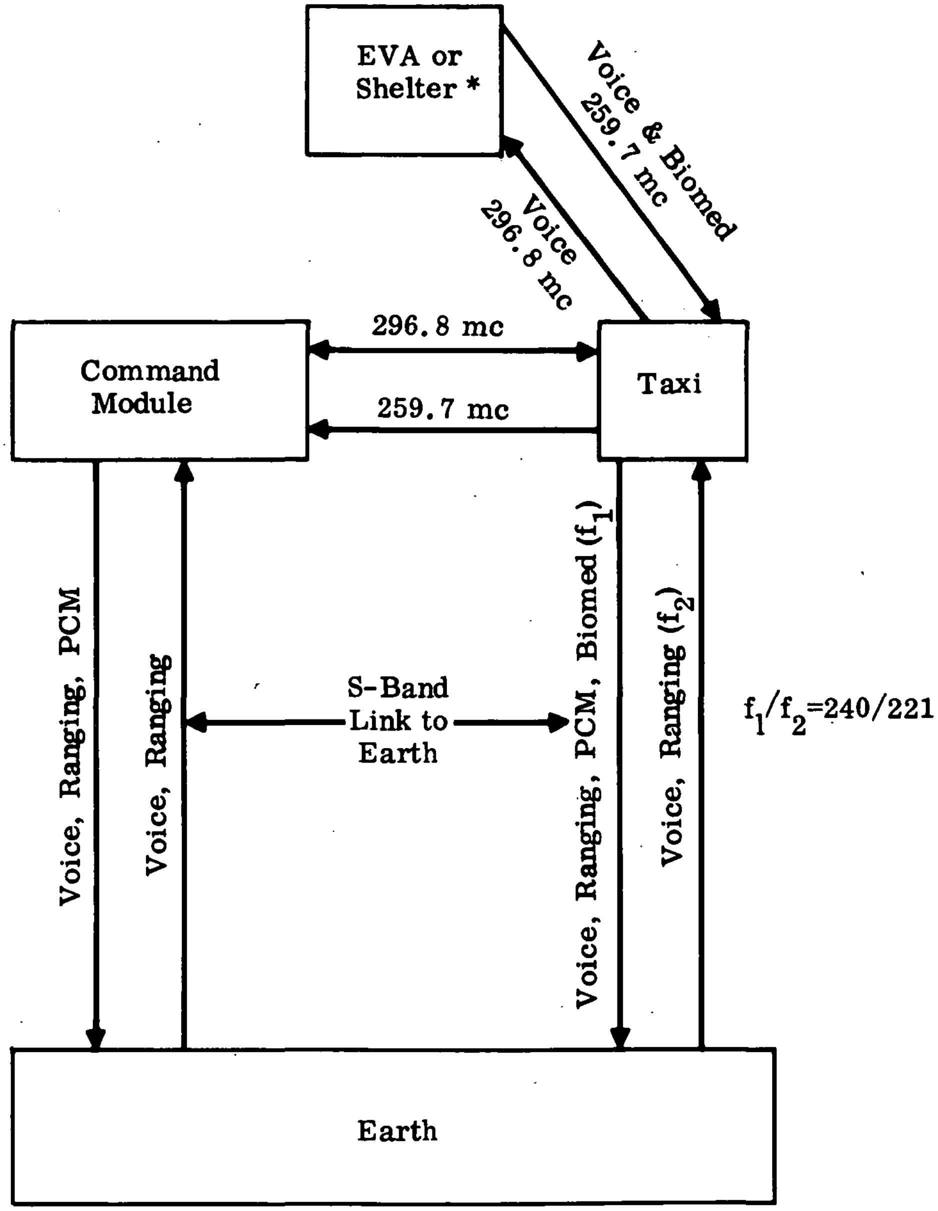


Fig. 17 Communication Subsystem Block Diagram

(2)

Grumman



* Only when Taxi is manned.

Fig. 18 Taxi Communications Links

3.4.5.1.2 (Continued)

(d) Taxi/CSM - Simplex voice communications capability between the Taxi and the CSM shall be provided during all inflight line of sight phases of the lunar mission. Range capability inflight shall be 550 nautical miles, minimum.

(e) (MSFN/Taxi/CSM) and (MSFN/Taxi/EVA) Voice Conferences - Voice conference capability between the MSFN, Taxi and CSM or EVA shall be provided by use of the Taxi to relay voice from the CSM or EVA to the MSFN via the (Taxi/MSFN) Duplex S-Band voice link, and to relay voice from the MSFN to the CSM or EVA via the (CSM/Taxi) simplex VHF or (Taxi/EVA) Duplex VHF voice links, respectively. Simultaneous capability for these two modes is not required.

3.4.5.1.3 S-Band Tracking and Ranging. - The Taxi shall be equipped to permit the MSFN to track the Taxi at any time, to a minimum slant range of 220,000 nautical miles, during which the Taxi is in line of sight of a MSFN station. The S-Band communications equipment shall aid the MSFN in determining spacecraft velocity by receiving a phase modulated carrier from the MSFN, and re-transmitting a carrier coherently related to a 240/221 ratio to the frequency of the received carrier. The Taxi shall aid the MSFN in determining accurately the spacecraft range through the reception, demodulation and re-transmission of a Pseudo-Random-Noise Ranging (PRN) Signal generated by the MSFN. This ranging capability shall be possible at any time when the MSFN and Taxi are communicating via the S-Band link when in the Phase Modulation Mode.

3.4.5.1.4 Telemetry Transmission. - The Taxi shall be capable of transmitting telemetry as follows:

(a) Taxi to MSFN PCM Telemetry Transmission - The Taxi shall have the capability of providing Taxi data to the MSFN via a PCM telemeter and the S-Band link to a minimum slant range of 220,000 nautical miles. Two modes of telemetry capability shall be provided, low bit rate output of 1600 bits/second and a high bit rate output of 51,200 bits/second.

(b) Taxi to CSM PCM Telemetry Transmission - The inflight capability shall exist to transmit 1600 bits/second PCM data from the Taxi to the CSM via a VHF communications link to a minimum slant range of 300 nautical miles for recording onboard the CSM for subsequent playback to the MSFN.

3.4.5.1.4 (Continued)

(c) EVA Data Relay - During extravehicular operations, the capability shall exist for the Taxi to relay transmissions from the EVA to the MSFN via the S-Band communications link. The capability shall also exist to check out the EMU data system prior to the egressing of the crewman from the Taxi, by relaying the EMU Data System composite waveform to the MSFN for analysis via the S-Band Link.

3.4.5.1.5 Television Transmission. - The Taxi shall provide the capability of transmitting to the MSFN via the S-Band link television signals obtained from the GFE TV camera. TV signals shall be transmitted using the lunar surface erectable antenna. The TV camera shall be operable inside the Taxi cabin through the top hatch and on the lunar surface.

3.4.5.1.6 Key Transmission. - An S-Band Transmission Mode shall exist that enables the transmission of manually encoded Morse code.

3.4.5.1.7 Biomedical Data Transmission. - Biomedical information shall be hardlined from each crewman within the Taxi and processed for transmission via the S-Band transmitter. Biomedical data shall be processed and transmitted for only one crewman at a time.

3.4.5.2 Design Requirements. -

3.4.5.2.1 S-Band Section. - The S-Band section shall consist of the following equipment:

(a) Transceiver Assembly

(b) Power Amplifier Assembly

(c) Diplexer

(d) RF Switch

(e) In-flight Antenna

(f) Steerable Antenna

(g) Erectable Antenna

(h) RF Cable Assemblies

3.4.5.2.1.1 Transceiver Assembly. - The transceiver assembly shall consist of the following:

(a) Two coherent transponders

(b) One FM modulator capable of using either transponder multiplier chain.

(c) Fail-Safe Switching

3.4.5.2.1.1.1 Coherent Transponders. - Each transponder shall consist of one phase locked receiver, one coherent phase modulator, a multiplier chain and power supply. The transponder shall permit ranging to the Taxi by the ground station as well as transmission of voice, telemetry, biomedical and EMU information from Taxi to the ground station. Simultaneous operation of transponders shall be precluded. The receiver shall be capable of detecting a carrier at TBD mc, a voice modulated subcarrier, a data modulated sub-carrier and pseudo-random noise which is angle modulated by the ground transmitter. It shall also be capable of coherently translating and routing pseudo-random noise to the phase modulator (PM) in a coherent ranging mode. The transmitters shall be miniaturized, solid state devices capable of an RF output of 0.75 watts.

3.4.5.2.1.1.2 FM Modulator. - The FM modulator shall be provided for modes not requiring coherency. Simultaneous transmission of FM and PM shall be precluded.

3.4.5.2.1.1.3 Fail-Safe Switching. - Fail-Safe Switching shall be provided in the receiver section to automatically detect failure and switch to the secondary receiving section.

3.4.5.2.1.2 Power Amplifier Assembly. - The power amplifier assembly shall consist of two amplifier tubes, one input isolator, one output isolator, and two power supplies mounted in a common enclosure. The power amplifier assembly shall be capable of operation with either multiplier chain. Simultaneous operation of the two amplifiers shall be precluded. The power amplifier equipment shall provide a 20 watt RF signal to the S-Band diplexer. The equipment shall provide power amplification at TBD mc.

3.4.5.2.1.3 Diplexer. - The diplexer shall permit the transmitter and receiver to utilize one antenna at a time and shall be physically attached to the power amplifier assembly.

3.4.5.2.1.4 RF Switch. - The RF switch shall enable the crewman to select the desired S-Band antenna.

3.4.5.2.1.5 In-Flight Antenna. - The in-flight antenna assembly shall consist of radiating elements and matching devices.

3.4.5.2.1.6 S-Band Steerable Antenna. - The S-Band steerable antenna shall be used for communications between Taxi and earth. During most phases of the lunar mission, the RF sensor shall track an earth transmitting station and direct the steering components of the antenna in such a manner as to obtain continuous Taxi earth communications. An automatic search mode shall be provided. Controls and displays shall be provided for antenna acquisition of an earth transmitting station from lunar distances, and for any required manual antenna steering.

3.4.5.2.1.7 Erectable Antenna. - The Erectable Antenna shall be used for communications between Taxi and earth, when Taxi is on the lunar surface. After the Taxi lands on the lunar surface, a crewman shall remove the antenna from storage on the Taxi Descent stage and erect the antenna some distance from the Taxi. The antenna shall be directional and be capable of manual adjustment to the shape of the terrain and the position of the earth in the sky.

3.4.5.2.1.8 RF Cable Assemblies. - The RF cable assemblies shall provide a means of interconnecting RF signals between the S-Band equipments.

3.4.5.2.2 VHF Section. - The VHF section shall consist of the following equipment:

(a) Two Transceiver (A and B)

(b) Diplexer

(c) RF Switch

(d) In-Flight Antenna

(e) RF Cable Assemblies

3.4.5.2.2.1 Transceivers. - Transceiver A shall be capable of simplex operation between Taxi and CM. The transmitter shall be a solid-state unit, modulated by infinitely clipped speech. The receiver shall contain automatic volume control (AVC) and squelch capabilities. Transceiver A shall operate at 296.8 mc. Transceiver B shall consist of a solid-state unit capable of transmitting PCM data at 1.6 KB rate or, as in Transceiver A, infinitely clipped speech; it shall receive EMU information from the EVA or voice from the CM. The receiver shall also contain AVC and squelch capabilities. Transceiver B shall operate at 259.7 mc.

3.4.5.2.2.2 Taxi/EVA Communications. - The primary duplex link for Taxi EVA Communications shall utilize the Taxi 259.7 mc receiver for EVA voice data reception and the Taxi 296.8 mc transmitter would be used in conjunction with the Taxi 296.8 mc receiver for duplex, voice only, communications.

3.4.5.2.2.3 Diplexer. - The diplexer shall permit the VHF transceiver units to utilize the same antenna.

3.4.5.2.2.4 RF Switch. - The RF switch shall allow the crewman to select the desired antenna.

3.4.5.2.2.5 In-flight Antennas. - There shall be two circularly polarized antennas with matching devices.

3.4.5.2.2.6 RF Cable Assemblies. - The RF cable assemblies shall provide a means of interconnecting RF signals between the VHF equipments.

3.4.5.2.3 Television Section. - This section shall consist of a government furnished portable television camera and optics and a contractor furnished 80 feet long television cable. The portable television camera shall be transferred from the CM to the Taxi and be stored within the Taxi crew compartment. The video information shall be hardlined back to the Taxi from the lunar surface and transmitted to earth via the S-Band transmitter. A connector shall be provided external to the cabin to allow use of the TV camera on the lunar surface. The TV camera shall be returned to the Taxi for subsequent transfer to the CM.

3.4.5.2.4 Signal Processing Assembly. - The signal processing assembly (SPA) shall provide the following functions:

(a) Voice, EMU and Biomedical Signals -

(1) Voice information shall be hardlined to the SPA from each crewman. The SPA shall process the voice information for input to the Taxi ICS, S-Band modulator and VHF modulator as determined by mode selection.

3.4.5.2.4 (Continued)

(a) (Continued)

(2) Biomedical information shall be hardlined to the SPA from each crewman within the Taxi and processed for transmission via the S-Band transmitter. Biomedical data will be processed and transmitted for only one crewman at a time.

(3) The SPA shall be capable of processing received VHF signals and of routing them to the ICS and the S-Band transmitter as determined by mode selection. The SPA shall also be capable of processing the EMU information received from the EVA for subsequent transmission to earth. EMU data shall be processed from only one EVA at a time.

(4) The SPA shall be capable of processing the S-Band received voice subcarrier and routing the audio to either crewman's headset or the VHF transmitters or both.

(5) The SPA shall provide side tone for all VHF, S-Band and ICS voice paths.

(6) The SPA shall provide control of associated equipment with both push-to-talk and voice-operated relay methods.

(b) Other Signals - The SPA shall provide the interface between the pulse code modulation and timing equipment, voice recorder equipment, TV camera, and the RF electronics, as related to the various modes of information transferral.

(c) The SPA shall accommodate the voice hardline intercom between the CSM and Taxi. The SPA provides complete conference capability between Earth/CSM/EVA/Taxi.

3.4.5.2.5 Hardline Intercom. - The hardline intercom shall interface between the CSM audio center and the Taxi SPA.

3.4.5.2.6 Associated Equipment. - The CS shall be capable of operation with the following associated equipments which are not a part of this subsystem:

(a) Pulse Code Modulation and Timing Electronics Assembly (PCMTEA)

(b) Data Storage Electronics Assembly (DSEA)

(c) Displays and Controls Subsystem

(d) Ascent and Descent Stage Structure

(e) EMU Communications System (GFE)

(f) Electrical Power Subsystem

(g) Command and Service Modules

(h) Ground Support Equipment

(i) Manned Space Flight Net (MSFN)

(j) Environmental Control Subsystem

(k) Television Camera (GFE)

3.4.6 Instrumentation Subsystem. - The instrumentation subsystem shall detect, measure, process, distribute and analyze various parameters encountered during the mission to:

(a) Acquire data to determine Taxi status

(b) Generate a "real-time" reference

3.4.6.1 Performance Requirements. - The Instrumentation Subsystem shall display data required by the crew for monitoring and evaluating the integrity and environment of the Taxi subsystems. The subsystem shall also provide data and "real-time" reference for transmission to earth, for evaluation of either the performance or failure of any Taxi system.

3.4.6.1.1 Data Acquisition. - The instrumentation subsystem shall, with the aid of controls and displays, acquire and present the status of the Taxi subsystems to crew and ground stations for:

(a) Aiding pre-flight assessment of Taxi readiness for launch

(b) In-flight management of the Taxi housekeeping functions

(c) Post-flight evaluation of performance

(d) Maintaining a periodic status presentation capability with earth during the quiescent state on the lunar surface

3.4.6.1.2 "Real-Time" Reference. - The Instrumentation subsystem shall generate a "real-time" reference and provide synchronizing signals to other equipment as required for all phases of the mission.

3.4.6.2 Instrumentation Subsystem Design Requirements. - The Instrumentation Subsystem shall consist of:

(a) Pulse Code Modulation and Timing Electronics Assembly (PCMTEA)

(b) Signal Conditioning Electronics Assembly (SCEA)

3.4.6.2 (Continued)

(c) Transducers

(d) Caution and Warning Electronics Assembly (CWEA)

3.4.6.2.1 Pulse Code Modulation and Timing Electronics Assembly (PCMTEA). -

3.4.6.2.1.1 Data Distribution. - The PCMTEA shall convert analog data, parallel-digital data, and serial-digital data into serial non-return-to-zero (NRZ), Type C, binary-coded signals for the signal processing assembly. It shall also provide serial return-to-zero (RZ), Type C, binary-coded signals for prelaunch checkout equipment. The PCMTEA shall supply output data at a high bit rate of 51.2 kilobits per second. The primary operational mode for the PCMTEA shall be at the high bit rate. The lowest bit rate shall be used when power conservation is necessary during a mission. In general, design of the PCMTEA shall be based upon requirements of Inter-Range Instrumentation Group (IRIG) Standard, IRIG-106-60.

3.4.6.2.1.2 Timing Data. - The PCMTEA shall supply timing frequencies to synchronize Taxi equipment, and binary-coded, decimal Greenwich Mean Time for telemetering. The timing equipment shall accept 1.024 mcs input as its master timing signal. As a secondary mode of operation the unit shall generate an internal, highly stable 1.024 mcs signal for operation of the PCMTEA when the external input is absent.

3.4.6.2.2 Signal Conditioning Electronics Assembly (SCEA). - The SCEA shall act as a junction box for all analog signals pertaining to status and housekeeping functions of the Taxi subsystems. The SCEA shall accept raw analog signals from transducers, signal pickoff points and contact closures from the Taxi subsystems and shall condition these signals to the proper voltage and impedance levels. Those signals

3.4.6.2.2 (Continued)

not requiring conditioning will be routed through the data distribution subassembly of the SCEA. All conditioned analog signals shall be made available for routing to any combination of PCMTEA, CWEA and Displays.

3.4.6.2.3 Transducers. - The transducers shall sense and convert physical phenomena from all the vehicle subsystems into a form compatible with the SCEA. The transducers shall be capable of accepting excitation power from either the SCEA or the onboard power supply.

3.4.6.2.4 Caution and Warning Electronics Assembly (CWEA). - The CWEA shall provide two basic functions:

(a) Caution function to advise the crew of an out-of-tolerance condition in a Taxi subsystem which does not require immediate attention, but could ultimately affect crew safety.

(b) Warning function to advise the crew of a malfunction which affects crew safety and requires immediate attention.

3.4.6.2.4.1 Caution Function. - The CWEA shall remain ON during all manned phases of the Taxi mission. The CWEA shall accept signals from both the SCEA and the subsystems, and shall analyze these signals for out-of-tolerance conditions. The CWEA shall have reset capability. The caution function shall activate a master alarm and onboard display whenever an out-of-tolerance condition exists.

3.4.6.2.4.2 Warning Function. - Inhibit gates contained in the CWEA shall be controlled by the subsystems to prevent false malfunction indications when a subsystem is intentionally made inoperative. The warning function in the CWEA shall activate a master warning alarm and display onboard the Taxi and shall advise the ground station of a malfunction by telemetry.

3.4.7 Environmental Control Subsystem (ECS). - The ECS shall consist of the following:

(a) Oxygen Supply and Cabin Pressure Control Section

(b) Atmosphere Revitalization Section

3.4.7 (Continued)

(c) Heat Transport Section

(d) Water Management Section

(e) Radioisotope Thermoelectric Generator (RTG) Heat Utilization Section

The ECS is shown schematically in Figure 19.

3.4.7.1 Performance Requirements. - The ECS shall provide pressurization, atmospheric conditioning, ventilation, active thermal control, water management, PLSS refilling and heat utilization of the RTG.

3.4.7.1.1 Oxygen Supply and Cabin Pressurization Performance. - This section shall store in a gaseous form all oxygen required by the ECS and shall maintain cabin or suit pressurization by supplying oxygen in sufficient quantities to replenish losses due to crew metabolic consumption and cabin or suit leakage. This section shall also protect the cabin pressure shell against overpressurization and enable the crew to intentionally depressurize and repressurize the cabin. Capability shall be provided for 2 repressurizations of the cabin. The design of the Oxygen and Cabin Pressurization Section shall be based on the following:

3.4.7.1.1 Cabin Criteria. -

(a) Free volume = 235 ft^3

(b) Total leakage at 5.0 psia and 75 degrees Fahrenheit = 0.2 lbs/hours (inclusive of leakage of both cabin pressure relief and dump valves

(c) Repressurization time to a cabin pressure of 4.7 psia = TBD seconds maximum

3.4.7.1.1.2 Cabin Pressure Relief and Dump Valve Criteria. -

(a) Maximum leakage at 5.0 psia and 75 degrees Fahrenheit (both valves) = 0.01 lbs/hour

TBD

ENVIRONMENTAL CONTROL SUBSYSTEM (SCHEMATIC)

FIGURE 19

3.4.7.1.1.2 (Continued)

(b) Depressurization time: (5.0 psia to 0.08 psia with no inflow)

(1) One cabin pressure relief and dump valves open = 200 seconds maximum

(2) Two cabin pressure relief and dump valves open = 100 seconds maximum

(c) Maximum cabin to ambient differential = 5.8 psi

3.4.7.1.1.3 Oxygen Criteria. -

(a) PLSS refill = 0.91 lbs/refill at 850 psia

(b) Descent oxygen tank capacity = 45.17 lb

3.4.7.1.1.4 Space Suit Criteria. -

(a) Maximum leakage: 0.04 lbs/hour/suit at 3.7 psia and 70 degrees Fahrenheit

(b) Minimum purge flow: TBD

(c) Suit pressure increase rate: TBD

(d) Ascent Oxygen tank capacity: TBD

3.4.7.1.2 Atmosphere Revitalization Section Performance. - This section shall provide ventilation and atmospheric conditioning for the cabin and suits. Atmospheric conditioning shall consist of the removal of carbon dioxide, odors, particular matter, and excess water vapor. The design of the Atmosphere Revitalization Section shall be based on the following:

3.4.7.1.2.1 Suit Pressure Drop. - The pressure drop of each suit, including both halves of the suit umbilical hose disconnect shall be 5.0 inches of water at suit inlet conditions of 12 cfm at 3.5 psia and 50 degrees Fahrenheit.

3.4.7.1.2.2 Suit Inlet Temperature. - The range of suit inlet temperatures, for the conditions listed in Table V, shall be as follows:

Suit Inlet Temperature	Conditions	
	Min. Heat Load	Max. Heat Load
Minimum	45°F	60°F
Maximum	60°F	80°F

3.4.7.1.2.3 Suit Ventilation Flow. - The minimum suit ventilation flow rate shall be as follows:

(a) Unpressurized Cabin = 13.9 lb/hr

(b) Pressurized Cabin = 18.0 lb/hr

3.4.7.1.2.4 Cabin Ventilation Flow. - The nominal cabin ventilation flow rates of the cabin recirculation assembly shall be 5 lbs/min with one cabin fan operating and 10 lbs/min with both cabin fans operating.

3.4.7.1.3 Heat Transport Section. - This section shall provide active thermal control of electrical and electronic equipment, cabin and suit ventilating gases. Redundant active thermal control shall be provided for those electrical and electronic equipments required to effect a successful return to the CM. The design of the heat transport section shall be based on the following:

3.4.7.1.3.1 Coolant. - The coolant shall be a corrosion inhibited ethylene glycol (37.5 percent by weight) and water solution.

3.4.7.1.3.2 Coolant Temperature. - Coolant temperature limits during steady state operation shall be as follows:

(a) Minimum = 32 degrees Fahrenheit

(b) Maximum = 120 degrees Fahrenheit

TABLE V

ECS THERMAL DESIGN CRITERIA

TBD

3.4.7.1.3.3 Coolant Flow Rate. - The nominal coolant flow rate shall be as follows:

(a) Primary coolant loop flow rate = 222 lbs/hr

(b) Redundant coolant loop flow rate = 100 lbs/hr

3.4.7.1.3.4 Coolant Pressure Drop. - The maximum total pressure drop of each of the coolant loops shall be 30 psi.

3.4.7.1.3.5 Thermal Loads. - The structural, electrical and electronic heat loads imposed upon the section shall be as shown in Table VI. The cold plate thermal load characteristics shall be as shown in Table VI.

3.4.7.1.4 Water Management Section. - This section shall provide for storage and distribution of water used in the Taxi for PLSS refilling, metabolic consumption by the crew, and evaporative cooling. In addition, this section shall provide for the utilization of the condensed water vapor removed by the Atmosphere Revitalization Section. The design of the Water Management Section shall be based on the following:

(a) PLSS Water Refill -

(1) Water quantity per refill: 6.8 lbs

(2) Minimum refill pressure: 0.5 psi above cabin pressure

(b) Water Storage - Usable water quantity

(1) Descent tank: 322.0 lbs

(2) Ascent tanks: 40.0 lbs each

3.4.7.1.5 Radioisotope Thermoelectric Generator (RTG) Section. - The RGT heat utilization section shall distribute heat from the RTG to the structure of the vehicle, when structure temperatures drop below acceptable limits.

3.4.7.2 Design Requirements. -

3.4.7.2.1 Oxygen Supply and Cabin Pressurization Section. - The Oxygen Supply and Cabin Pressurization Section shall consist of:

TABLE VI

ELECTRONIC EQUIPMENT COLD

PLATE CHARACTERISTICS

TBD

3.4.7.2.1 (Continued)

(a) Oxygen Supply Control Module

(b) High Pressure Oxygen Control Assembly

(c) Oxygen Hose Assembly

(d) Descent Stage GOX Tank

(e) Ascent Stage GOX Tanks (2)

(f) Cabin Pressure Switch

(g) Cabin Pressure Relief and Dump Valve

(h) GOX Interstage Disconnect

3.4.7.2.1.1 Oxygen Supply Control Module. - The Oxygen Supply Control Module shall sense the suit loop pressure and replenish the suit loop oxygen from the GOX tanks to maintain the selected suit loop pressure. The module shall also contain a cabin repressurization emergency O_2 valve to dump oxygen into the cabin upon an electrical signal from the cabin pressure switch, or by manual control. The module shall contain provisions for manually selecting one of the three GOX tanks to be used, provisions for filtering oxygen before it enters the suit loop or the cabin, and a manual control valve for recharging the PLSS.

3.4.7.2.1.2 High Pressure Oxygen Control Assembly. - The High Pressure Oxygen Control Assembly shall reduce the descent stage GOX tank pressure, provide overpressure relief protection, and incorporate a quick disconnect for purging and refilling the GOX tanks.

3.4.7.2.1.3 Oxygen Hose Assembly. - An Oxygen Hose Assembly shall be provided for refilling the PLSS.

3.4.7.2.1.4 Descent Stage GOX Tanks. - The Descent Stage GOX Tanks shall provide adequate oxygen supply for the Taxi for use during the manned phases of the Taxi mission.

3.4.7.2.1.5 Ascent Stage GOX Tanks. - The Ascent Stage GOX Tanks shall provide adequate oxygen supply for the Taxi mission from the prelaunch lunar surface checkout to the completion of the Taxi mission. Two redundant ascent GOX tanks shall be provided, each of which shall contain an adequate oxygen supply to return the flight crew to the CSM.

3.4.7.2.1.6 Cabin Pressure Switch. - The cabin pressure switch shall sense the absolute pressure in the cabin. The switch shall provide a signal to activate or deactivate the cabin repressurization emergency O_2 valve. This valve shall maintain the cabin pressure at 4.7 psia. When the cabin repressurization emergency O_2 valve is activated, the cabin pressure switch shall provide a signal to close the suit diverter valve. When the cabin pressure is below 3.0 psia, the cabin pressure switch shall also provide another switch closure to energize the cabin fan control relay.

3.4.7.2.1.7 Cabin Pressure Relief and Dump Valve. - The cabin pressure relief and dump valve shall be a three position servo valve with manual overrides on the automatic actuation. When the valve handle is in "automatic" position the valve shall open to the ambient whenever the cabin pressure exceeds 5.3 psia. With the valve handle in "manual closed" position the valve shall remain closed irrespective of the cabin pressure. With the handle in the "manual open" position the valve shall open to the ambient and allow a rapid reduction of cabin pressure. There shall be one cabin pressure relief and dump valve on each Taxi hatch.

3.4.7.2.1.8 GOX Interstage Disconnect. - The GOX interstage disconnect shall be provided to carry the descent GOX lines across the descent/ascent stage interface. Both the descent and ascent stage valves of the disconnect shall be self sealing upon separation. Both valves of the disconnect shall be designed for gimbal mounting to accommodate stage misalignment during mating and separation.

3.4.7.2.2 Atmosphere Revitalization Section Design Requirements. - The Atmosphere Revitalization Section shall consist of:

(a) Suit circuit

(b) Cabin recirculation assembly

(c) Steam flex duct

3.4.7.2.2.1 Suit Circuit. - The suit circuit shall consist of two suit umbilical hose assemblies, the suit circuit assembly, and the carbon dioxide partial pressure sensor.

3.4.7.2.2.1.1 Suit Umbilical Hose Assembly. - Two suit umbilical hose assemblies shall be provided to carry ventilating gas to and from the crewman's space suit and the suit circuit assembly. The suit umbilical hose assembly shall be sufficiently flexible to provide required crew mobility in both the pressurized and unpressurized modes of suit operation.

3.4.7.2.2.1.2 Suit Circuit Assembly. - The suit circuit assembly shall provide heat exchangers for rejection of all waste heat to the Heat Transport Section for cooling and for transfer of heat from the Heat Transport Section to the suit circuit gas stream for warming. A water evaporator shall reject waste heat when the heat exchanger is inoperative. Excess moisture condensed in the suit circuit shall be delivered by water separators to the Water Management Section. The carbon dioxide level in the suit circuit shall be maintained within limits by adsorption in lithium hydroxide, and odors shall be adsorbed in activated charcoal. Recirculation of gas through the suit circuit shall be provided by fans. The fans shall be capable of maintaining the pressure vessel integrity of the suit circuit in the event of any internal fan failure.

3.4.7.2.2.1.3 Carbon Dioxide Partial Pressure Sensor. - The carbon dioxide partial pressure sensor shall measure the partial pressure of carbon dioxide in the ventilating gas entering the suits. The sensor shall provide output signals to displays and telemetry which represent the value of the partial pressure of carbon dioxide.

3.4.7.2.2.2 Cabin Recirculation Assembly. - The cabin recirculation assembly shall provide for transfer of heat between the cabin gas and the Heat Transport Section, by means of the Cabin Heat Exchanger. The heat exchanger shall provide for storage of condensed moisture and for evaporation of water when the heat exchanger discharge gas is not saturated. Two cabin fans shall recirculate cabin gas through the heat exchanger to maintain cabin gas temperature within limits and to provide ventilation. The cabin fans shall be designed to permit operation at sea level for checkout purposes.

3.4.7.2.2.3 Steam Flex Duct. - A flexible duct shall be provided to carry the steam discharged from the suit circuit water evaporator.

3.4.7.2.3 Heat Transport Section Design Requirements. - The heat transport section shall consist of the following:

(a) Coolant Recirculation Assembly

(b) Automatic Pump Switch Control

(c) Coolant Regenerative Heat Exchanger

(d) Cabin Temperature Control Valve

(e) Suit Temperature Control Valve

(f) Coolant Water Evaporator

(g) Battery Coolant Water Evaporator

(h) Redundant Coolant Water Evaporator

(i) Interstage Disconnect

(j) Coolant Accumulator

(k) Cold Plate Assemblies

(l) GSE Quick-Disconnects

(m) Redundant Coolant Filter

(n) Flex Lines

(o) Cabin Structure Temperature Sensors

3.4.7.2.3.1 Coolant Recirculation Assembly. - The coolant recirculation assembly shall be divided internally into two separate portions. The primary coolant loop portion shall recirculate coolant through the primary coolant loop of the heat transport section. The redundant coolant loop section shall recirculate coolant through the redundant coolant loop of the heat transport section.

3.4.7.2.3.2 Automatic Pump Switch Control. - The automatic pump switch control shall activate a primary coolant pump whenever a signal is received from the cabin structure temperature sensor. In addition the automatic pump switch control shall shut off the operating pump in the primary coolant loop and actuate the other primary coolant loop pump whenever a signal is received from the pump differential pressure sensor indicating that pump differential pressure has fallen below allowable limits.

3.4.7.2.3.3 Coolant Regenerative Heat Exchanger. - The coolant regenerative heat exchanger shall provide for transfer of the heat rejected from the electronic equipment and suit circuit regenerative heat exchanger to the coolant entering the cabin heat exchanger for heating of the cabin gas.

3.4.7.2.3.4 Cabin Temperature Control Valve. - A cabin temperature control valve shall be provided to control the temperature of the coolant supplied to the cabin heat exchanger. The control valve shall sense the temperature of the coolant leaving the cabin heat exchanger. The valve shall respond mechanically to divert and modulate the flow of coolant through the coolant regenerative heat exchanger for temperature control of coolant entering the cabin heat exchanger. The valve shall include provisions for manual reset of the control temperature and provide for manual control in the event of sensor failure.

3.4.7.2.3.5 Suit Temperature Control Valve. - The suit temperature control valve shall permit the crew to manually control the temperature of the ventilating gas delivered to their space-suits. The valve shall effect this control by controlling the flow of warm coolant through the suit circuit regenerative heat exchanger.

3.4.7.2.3.6 Coolant Water Evaporator. - A coolant water evaporator of porous plate design shall provide for rejection of waste heat from the Heat Transport Section coolant by evaporating water. Water evaporated shall be discharged to the Taxi ambient atmosphere. The coolant water evaporator shall be designed to preclude overcooling of the coolant.

3.4.7.2.3.7 Battery Coolant Water Evaporator. - A coolant evaporator shall be provided for rejection of battery heat loads in the heat transport section primary loop. Water evaporated shall be discharged to the ambient atmosphere.

3.4.7.2.3.8 Redundant Coolant Water Evaporator. - A redundant coolant water evaporator of porous plate shall be provided for the rejection of waste heat from the heat transport section redundant loop coolant by evaporating water. Water evaporated shall be discharged to the external environment.

3.4.7.2.3.9 Interstage Disconnects. - A disconnect shall be provided to carry primary loop coolant across descent/ascent stage interface. Both the descent and ascent halves shall be self sealing upon separation. Both halves of this disconnect shall be designed for gimbal mounting to accommodate stage misalignment during mating and separation.

3.4.7.2.3.10 Coolant Accumulator. - The coolant accumulator shall maintain coolant pressure at all points in the coolant loop and absorb normal volumetric changes of the coolant mass. Coolant pressure shall be maintained mechanically and the accumulator shall provide an electrical signal in the event of excessive reduction of the coolant volume within the loop.

3.4.7.2.3.11 Cold Plate Assemblies. - The Cold Plate Section shall consist of the following:

(a) Structural ("strip") cold plates

(b) Non-structural ("flat") cold plates

All cold plates shall be designed to permit removal of the equipment for which they provide thermal control without disconnecting the cold plates from the Heat Transport Section plumbing.

3.4.7.2.3.11.1 Strip Cold Plates. - Strip cold plates shall provide both active thermal control and structural support for those electrical and electronic equipments which utilize the Electronic Replaceable Assembly (ERA) packaging concept. The strip cold plates shall contain a single flow passage through which the Heat Transport Section coolant shall be circulated. This passage shall contain fins as required to provide adequate heat transfer surface area. Strip cold plates shall be provided for the electrical and electronic equipment as shown in Table VI.

3.4.7.2.3.11.2 Flat Cold Plates. - Flat cold plates shall provide active thermal control for those electrical and electronic equipments which utilize packaging concepts other than the ERA concept. The flat cold plates shall contain a single flow passage through which Heat Transport Section coolant shall be circulated. Flat cold plates shall be provided for the electrical and electronic equipment as shown in Table VI.

3.4.7.2.3.12 GSE Quick Disconnects. - Self-sealing quick disconnects shall be provided for the recirculation of coolant through the loop by the GSE during ground operation of the Heat Transport Section.

3.4.7.2.3.13 Redundant Coolant Filter. - The redundant coolant filter shall be located upstream of the redundant coolant loop pump external to the coolant recirculation assembly.

3.4.7.2.3.14 Flex Lines. - Flex lines shall be provided to accommodate relative motion between the interstage disconnect halves and the adjacent hard line coolant plumbing.

3.4.7.2.3.15 Cabin Structure Temperature Sensor. - The cabin structure temperature sensor shall send a signal to the RTG condensate control valve controller.

3.4.7.2.4 Water Management Section Design Requirements. - The water management section shall consist of the following:

(a) Descent Stage Water Tanks (3)

(b) Ascent Stage Water Tanks

(c) GSE Connections

(d) Water Control Module

(e) Water Squib Valve

(f) Water Hose Assembly

3.4.7.2.4.1 Descent Water Tank. - The descent stage water tanks shall provide adequate usable storage for the water required for PLSS refill and evaporative cooling from earth launch through switchover to ascent stage water supplies. The tanks shall be spherical and shall provide positive expulsion of water by use of a bladder and standpipe design. The tanks shall be pressurized with nitrogen prior to earth launch.

3.4.7.2.4.2 Ascent Water Tank. - Two ascent stage water tanks shall provide adquate usable water storage for the water required for PLSS refill and evaporative cooling subsequent to switchover from descent stage water supplies. The tanks shall be spherical and shall provide positive expulsion of water by use of a bladder and standpipe design. The tanks shall be pressurized with nitrogen prior to earth launch.

3.4.7.2.4.3 GSE Quick Disconnect. - Self-sealing quick disconnects shall be provided for the GSE to evacuate, fill and pressurize the water tanks.

3.4.7.2.4.4 Water Control Module. - The water control module shall consist of components including all interconnecting plumbing and couplings. This assembly shall also include all brackets required to mount and support the foregoing components and to mount the assembly itself.

3.4.7.2.4.4.1 Water Check Valve. - The water check valves shall be provided for the following functions:

(a) Prevent water flow from the water control module to the water separators.

(b) Prevent water flow from the water control module to the water tanks.

(c) Prevent flow of water from the water separators to the water hose assembly.

3.4.7.2.4.4.2 Water Shut-Off Valves. - Manually operated water shut-off valves shall be provided for the following functions:

(a) Control the flow of water from the water control module to the water hose assembly.

(b) Control the flow of water from the water control module to the suit circuit water evaporator.

3.4.7.2.4.4.3 Water Evaporator Manual Feed Valve. - A manually operated, modulating valve shall be provided to control the flow of water from the water control module to the redundant coolant water evaporator.

3.4.7.2.4.4.4 Water/Coolant Isolation Valve. - A valve shall be provided to isolate the Water Management Section from the redundant coolant loop of the Heat Transport Section. The valve shall be a puncture-disc type. When punctured, the valve shall permit the Water Management Section to serve as an accumulator for the redundant coolant loop of the Heat Transport Section.

3.4.7.2.4.4.5 Water Tank Selector Valve. - A manually operated valve shall be provided for selection of the following modes of Water Management Section operation.

(a) In the "descent tank" position, the valve shall supply water from the descent water tanks.

(b) In the "ascent tank" position, the valve shall supply water from the ascent water tanks.

3.4.7.2.4.4.6 Water Pressure Regulators. - The water pressure regulators shall control the pressure of the water supplied from the water control module to a level which is compatible with the water pumping capability of the water separators. Two regulators in series shall control the pressure of water supplied to the water hose assembly and coolant water evaporator. A single regulator shall control the pressure of water supplied to the suit circuit water evaporator and the redundant coolant water evaporator.

3.4.7.2.4.5 Water Squib Valve. - An explosively actuated valve shall be provided to initiate water flow from the water control module to the coolant water evaporator. The valve shall be normally closed. Once opened, the valve shall not be capable of closing.

3.4.7.2.4.6 Water Hose Assembly. - The water hose assembly shall provide for the transfer of water from the water control module to the water storage tanks of the PLSS. The water hose assembly shall consist of the following:

3.4.7.2.4.6.1 Water Hose. - A flexible water hose shall be provided of sufficient length and flexibility to permit refill of the PLSS water tank in both the PLSS tunnel stowing and the PLSS donning positions.

3.4.7.2.4.6.2 Water Disconnect. - A quick disconnect shall be provided for coupling the water hose to the PLSS for refilling the water storage tank of the latter. The disconnect shall be self-sealing and shall require no tools for engaging or disengaging the PLSS.

3.4.7.2.5 Radioisotope Thermoelectric Generator (RTG) Utilization Section. - The RTG Utilization Section shall consist of the following:

(a) RTG Boiler

(b) Condensers (4)

(c) Condensate Control Valve

(d) Condensate Control Valve Controller

3.4.7.2.5.1 RTG Boiler. - The RTG boiler shall provide a thermal coupling between the RTG heat utilization section, RTG heat utilization section and the RTG. The boiler shall provide adequate heat transfer surface area in order to insure the sufficient radient heat transfer between the boiler and the RTG to provide the required amount of steam

3.4.7.2.5.2 Condensers. - The condensers shall provide a thermal couple between the RTG heat utilization section and the vehicle structure. Steam will be supplied to the condensers and condensate shall be returned to the boiler through the same fluid line.

3.4.7.2.5.3 Condensate Control Valve. - The condensate control valve shall be provided to allow the flow of condensate into the boiler by a signal from the condensate control valve controller. In addition, the condensate control valve shall provide pressure relief capability from the RTG boiler to the condensers to insure minimum pressure buildup in the boiler.

3.4.7.2.5.4 Condensate Control Valve Controller. - The condensate control valve controller shall open the condensate control valve when a signal is received from the cabin structure temperature sensor.

3.4.8 Crew Provisions Subsystem (CPS). - Crew Provisions Subsystem shall support the nominal and abort missions by providing the equipment or the volume for equipment (CFE and GFE) integrated into a cohesive pressurized cabin arrangement. Crew aids, lighting and marking on the exterior of the vehicle shall be provided to the extent required. The cabin arrangement shall provide for the crew in stations predicated on task requirements.

3.4.8.1 Crew Equipment Performance Requirement. -

3.4.8.1.1 Extravehicular Mobility Unity (EMU). - A self downable and doffable EMU (GFE) shall be provided for environmental protection and life support of the crew in or outside the cabin as required. The EMU, in conjunction with the vehicle ECS, shall provide a secondary environmental and life support protection necessary in the event of a pressure failure of the vehicle. The EMU in a pressurized mode shall not reduce the capability of the crew to adequately perform the tasks essential to crew safety and mission success.

3.4.8.1.2 Crewman Umbilicals. - Umbilicals shall be provided to support crew environment and life support requirements. The length of the umbilicals shall be routed in accordance with cabin arrangement to provide necessary mobility for crew tasks with the minimum of incumberances. The required ECS umbilicals plus the communication, electrical and instrumentation cables shall be assembled into one primary umbilical assembly for each crewman's connection for intravehicular operation.

3.4.8.1.3 Ingress and Egress. - Crew ingress and egress routes from free space for extravehicular crew and equipment transfer between the CM and the vehicle shall be free of protuberances or unprotected areas which would act as a snare or otherwise hamper crew transfer. Hand grips and foot holes so provided shall be in accordance with human factors and cabin arrangement. The arrangement shall also provide for crew egress-ingress to the lunar surface via an alighting ladder from the hatch to the platform located on the exterior structure. Hand and fool holds to assist in descending and ascending from the vehicle shall be provided.

3.4.8.1.4 Equipment - Additional GFE which is installed, stowed or otherwise interfaced with the CPS as specified, or referenced with appropriate P&I Specifications shall include, but not limited to, the following:

(a) Portable Life Support System (PLSS)

(b) PLSS Calibration Unit

(c) PLSS Spare Parts

(d) Pressure Garment Assembly

(e) Thermal Meteoroid Garment

3.4.8.1.4 (Continued)

(f) Extravehicular Boots

(g) Extravehicular/Intravehicular Gloves

(h) Extravehicular Mittens

(i) Suit Repair Kit

(j) External Visor Assembly

(k) Auxiliary PLSS Battery

(l) Radiation Survey Meter

(m) LiOH Cartridges

(n) Medications

(o) Water Dispenser

(p) Food packages (including disinfectant)

(q) Emergency Oxygen System

(r) Umbilical Stowage Fitting

(s) Coupling Display Units

(t) Eye Register and Reticule

(u) Two Digit Readout for Reticule

(v) Inflight Data Management Kit

(w) EMU - Radiation Dosimeter

(x) EMU - Bioinstrumentation

(y) Constant Wear Garment

(z) Liquid Cooled Garment

3.4.8.1.4 (Continued)

(aa) Battery Charger (PLSS)

(bb) EMU Spare Parts

(cc) LEM Guidance Computer

3.4.8.1.5 Waste Management. - The waste management system shall provide for the transfer of urine from the EMU. The liquid shall be stored in containers which may be off-loaded, without rupture, from the EMU. The containers shall accommodate the physiological needs of the crew, the storage areas available and the environmental requirements. Manual and automatic shut off provisions shall be incorporated.

3.4.8.2 Cabin Arrangement Design Requirements. - The cabin arrangement shall provide for effective performance of the crew tasks by efficient storage of associated equipment and expendables, and the establishment of appropriate crew primary and secondary stations. The cabin shall consist of a 92 inch inside diameter cylindrical forward cabin and a 54 inch long cylindrical equipment tunnel with a total volume of approximately 250 cubic feet. The forward cabin, which accounts for about two-thirds of the total volume, shall contain the primary stations and most of the controls and displays. The cabin arrangement and crew station geometry shall accommodate the required ranges of crew sizes (10-90 percentile men) with respect to reach, body clearance, visibility, mobility, "cubical" size and body position or attitude.

3.4.8.2.1 Primary Stations. - Two side by side flight stations shall be provided for standing crewmen. A design reference point (design eye) shall be established to orient flight station geometry for the required balance between external visibility, visual and physical access to controls and displays. Instrument panels, windows, glare shields, controllers, arm rests and landing aids shall be oriented with respect to this design reference point. The flight station shall be provided with the necessary floor to overhead height, body clearance and arm rest adjustment to accept all crewmen in the 10-90 percentile anthropomorphic body size. It is not mandatory that the crewmen be indexed at the "design eye" in order to effectively perform the assigned tasks, therefore, no adjustment with respect to the floor will be operationally employed for this purpose. A docking "design eye" shall be establshed to orient the overhead docking window in the primary station with respect to location and viewing angles.

3.4.8.2.2 Secondary Station. - The secondary station is located in the center aisle between the individual flight stations for use of the alignment optical telescope (AOT). The crewman shall have a single step up adjustment for height in order to accommodate the range of percentile men to the eye-piece and the AOT controls. The donning station shall also be in the center aisle but slightly aft of the optical alignment station. A removable height adjusting PLSS support harness shall permit donning and doffing of the PLSS backpack. A recharge station shall be provided on the side of the tunnel for recharging the PLSS, water and oxygen. This station will be completely accessible from the forward cabin. An observation station shall be provided, while on the lunar surface. at the opened upper hatch for surveillance of the lunar surface and of the activities of the extravehicular crewman.

3.4.8.2.3 Lighting. -

3.4.8.2.3.1 Internal Lighting. - A primary and secondary means of control and display panel illumination shall be provided. These shall include, as required, integral and flood-lighting of electroluminscent, incandescent or self luminous methods. Lighting shall also be provided for crew use in illuminating remote or shadowed areas of crew cabin.

3.4.8.2.3.2 External Lighting. - External lighting shall be provided as visual aids for crewmembers of associated vehicles to locate, track and dock with the vehicle.

3.4.8.2.4 Displays and Controls. - The displays and controls shall be mounted in associated panels and consoles consistent with the crew station and conforming to the human factor and geometry capability of the crewmen. The panel arrangement shall consist of tiered side panels sloping to provide greater surface area, recessed protection of controls and displays, and to approximate normal inclination to the line of sight. A main panel shall be located between the forward windows which will permit visual and physical access by both crewmen in the primary station. Exposed areas of the panels or the displays shall not exceed a gloss level of 5 units as measured by ASTM Method D523 of Specification, MIL-P-7788A. The panels and consoles shall be designed for efficient ground service maintainability.

3.4.8.2.5 Support and Restraint. - A system which will load the human body during zero or reduced "G" conditions in a manner simulating the earth gravitational load shall be used. The harness provides for the loading of the human body through the center of mass in a manner similar to the normal earth gravitational loading. This is accomplished with a spring and cable which is attached to the velcro covered floor by means of a universal joint. The system shall provide for the following:

(a) Fixation for the crewman at a work station.

(b) Allowing for limited mobility to perform such tasks as the operation of controls, monitoring of instruments and maintenance activities.

(c) External loading to the human body to help prevent:

(1) Muscular atrophy

(2) Bone decalcification

(d) Possible alleviation of associated cardiovascular problems.

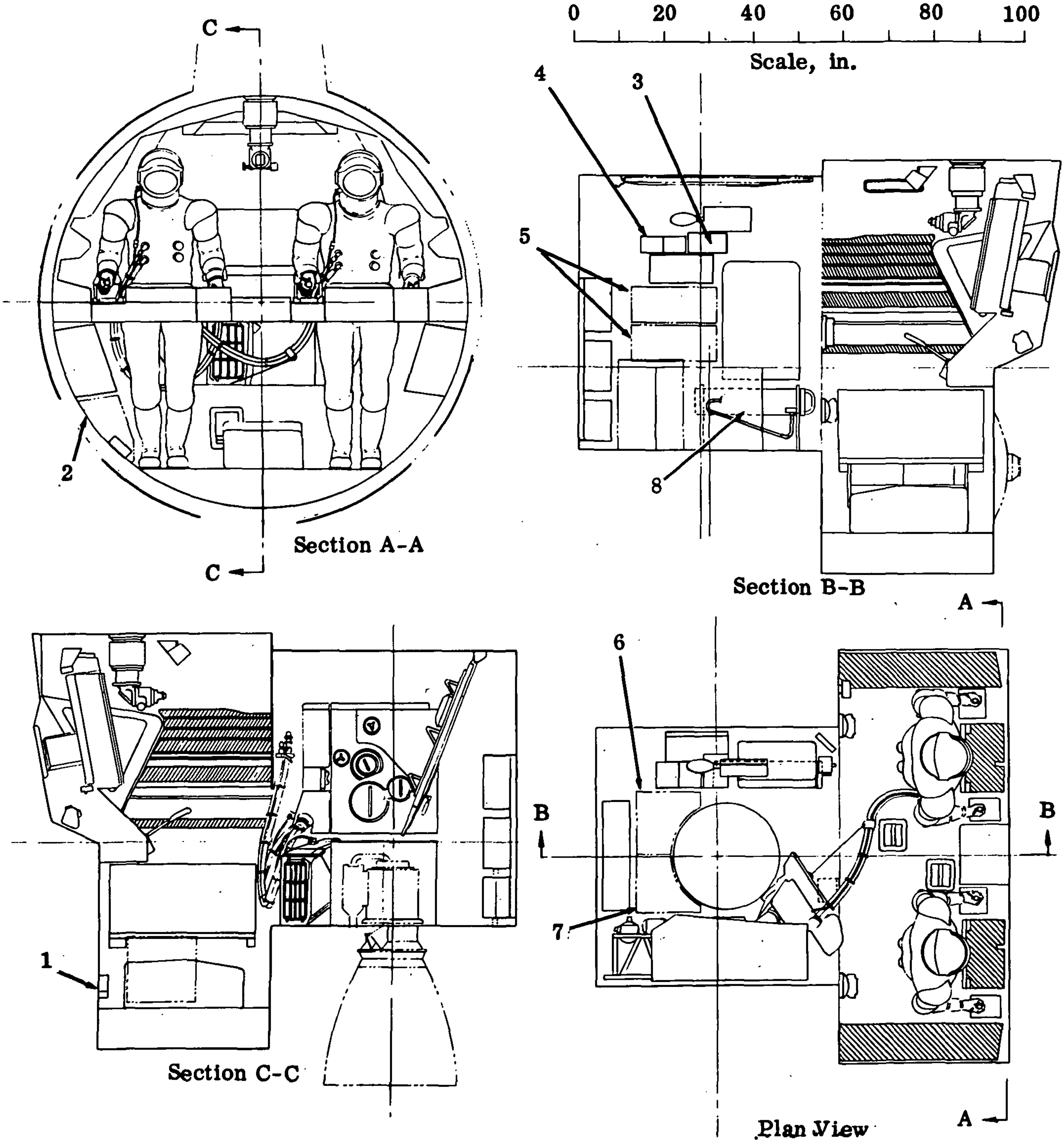
3.4.8.2.6 Crew Aids. - Provisions or aids shall be included to permit safe transfer of crewmen and equipment in and out of the vehicle. Provisions shall also be provided for resting during the performance of mission tasks.

(a) Interior and exterior aids shall be provided, as required, to promote and facilitate crew mobility. Hand holds, foot holes, alighting ladders, platforms and tether line attachments, may be used for this purpose.

(b) An arm rest shall be provided for the crewman operating the left hand controller at the primary station.

3.4.8.2.7 Marking and Identification. - Markings for interior and exterior areas, coloring and identification, including nomenclature shall be provided as required to support the performance of tasks by flight and ground servicing personnel.

3.4.8.2.8 Inboard Profile Drawing. - The inboard profile drawing in Figure 20 depicts the arrangement of the equipment to support the crew in the performance of their duties.



Key

1 Sequence Assy
2 Specimen Return Container Space (1400 cu in.)
3 Food Container (358 cu in.)
4 PLSS Batteries
5 Same as 2, Except 1750 cu in. each
6 Same as 2, Except 2500 cu in.
7 Same as 2, Except 2500 cu in.
8 PLSS LiOH Cartridges

Fig. 20 Inboard Profile

3.4.9 Displays and Controls Subsystem (D&C). - The D&C equipment shall present information to, and accommodate control action inputs from, the Taxi crew for the following purposes:

(a) Initiation, monitor and control of spacecraft maneuvers, maneuver sequences, and event sequences.

(b) Operation of Taxi subsystems and management of subsystem conditions.

(c) Management of Taxi stored propellants and energy sources.

(d) Alarm for hazardous conditions and Taxi subsystem malfunctions affecting the mission.

3.4.9.1 Performance Requirements. -

3.4.9.1.1 Engine/Thrust Control. -

Control/Indicator	Function
Engine Arm Switch	The switch (ascent) position shall provide an arming signal enabling firing of the ascent engine while simultaneously signalling the LGC that the engine is armed.
Engine Start Switch (Guarded Pushbutton) (CDR)	This switch shall provide a manual override capability for immediate firing of either the ascent or descent engine.
Engine Stop Switch (CDR) Engine Stop Switch (SE) (Guarded Pushbuttons Main)	This switch shall provide discrete stop signals to the ascent and descent engines.
Rate of Descent Switch	This switch provides PGNS control of the vehicle rate of descent.

3.4.9.1.1 (Continued)

Control/Indicator	Function
X-Translation-Switch	This switch shall select the number of jets to be used in X-axis translation maneuvers.
Balanced Couples Switch	This switch shall select either balanced pairs of RCS jets in a couple or unbalanced X-axis RCS jets for use in maintaining pitch and roll attitudes.
Manual Throttle Switch	This switch shall select the controller to be used for manual descent engine thrust level adjustment.
Thrust Control Switch	This switch shall provide the capability of switching from automatic control (LGC) to manual throttle control.
X-Axis Translation Control (Guarded Pushbutton)	This pushbutton shall provide a continuous 4 jet translation in the +X direction when in the depressed condition.
Descent Abort Switch (Guarded Pushbutton)	This switch shall initiate an abort using the descent engine.
Ascent Abort Switch (Guarded Pushbutton)	This switch shall initiate an abort using the ascent engine.
Attitude Controller (CDR) (SE)	The 3-axis Attitude Controllers shall provide attitude command signals to the vehicle.
Thrust/Translation Controller (CDR) (SE)	These controllers shall provide translation capability along the Y and Z axis. The controllers shall also provide X axis translation capability when the select lever is positioned to JETS.

3.4.9.1.1 (Continued)

Control/Indicator	Function
Throttle/Jets Control Select Switch (CDR) (SE)	The THROTTLE position shall provide manual descent engine throttling capability. The JET position shall provide RCS X-axis translation capability.
Lunar Contact Light (CDR) (SE)	These lights shall illuminate red when the probe on the vehicle landing gear touches the lunar surface.
Circuit Breakers (CDR Panel) (SE Panel)	The circuit breakers within the vehicle shall provide electrical protection. Some circuit breakers shall serve as ON-OFF controls.

3.4.9.1.2 Explosive Devices. -

Control/Indicator	Function
Descent Engine Pressurization Switch	This switch shall activate all squib valves necessary to pressurize the descent propulsion subsystem.
RCS Pressurization Switch	This switch shall activate all squib valves necessary to pressurize the Reaction Control Subsystem.
Ascent Helium Select Switch	This switch shall actuate ascent helium tank squib valves
Ascent Helium Pressure Switch	This switch shall actuate the squib valves necessary to pressurize the ascent propulsion subsystem.

3.4.9.1.2 (Continued)

Control/Indicator	Function
Master Arm Switch	This switch shall arm all explosive devices.
Abort Switch	This switch shall initiate the abort program using the descent engine.
Stage Switch	This switch shall actuate the explosive devices which separate the descent stage from the Taxi.
Landing Gear Deploy Switch	This switch shall actuate the explosive devices which extend the landing gear.
Landing Gear Status Indicator Flag	This indicator flag shall indicate the stowed or deployed status of the landing gear.

3.4.9.1.3 Reaction Control Subsystem. -

Control/Indicator	Function
Propellant Quantity Monitor Select Switch	This switch shall select the mode for monitoring the fuel and oxidizer tank quantities.
Ascent Feed Switches System A System B	Each switch shall actuate latch-type solenoid valves which control the flow of propellant from the ascent propulsion tanks.
Thruster Pair Switches System A System B	Each of eight switches shall actuate a TCA isolation valve controlling the fuel and oxidizer flow to the TCA.

3.4.9.1.3 (Continued)

Control/Indicator	Function
Temperature/Pressure Monitor Switch	This switch shall select: (a) helium, fuel and oxidizer tank pressure and temperature (b) fuel and oxidizer tank pressure and temperature (c) fuel and oxidizer manifold pressures on the pressure and temperature indicators.
RCS Crossfeed Switch	This switch shall control two valves which interconnect the propellant valves of Systems A and B.
Helium Regulator Switches System A System B	Each of four switches shall control the solenoid operated shutoff valve of Systems A and B, upstream of the pressure regulators in each helium leg.
Test Switch	This switch shall be used to isolate a leaking thrust chamber assembly, or to test the gaging assembly (in conjunction with the Quantity Monitor switch and the Propellant Quantity Indicators).
Main Shutoff Switch System A System B	Each of two switches actuates latch type solenoid valves which control the flow of propellant downstream of the propellant tanks.
Pressure Indicator System A System B	These indicators shall display the pressures in the helium, fuel or oxidizer tanks or manifolds as selected by the Monitor switch.
Temperature Indicator System A System B	This indicator shall display the temperatures in the helium, fuel or oxidizer tanks as selected by Monitor switch.

3.4.9.1.3 (Continued)

Control/Indicator	Function
Oxidizer Quantity Indicator, Fuel Quantity Indicator (two digital displays)	These digital indicators shall display oxidizer and fuel quantities left in System A or B.
Regulator #1 Status; System A Regulator #2 Status; System A Regulator #1 Status; System B Regulator #2 Status; System B (four 2-position flags)	Each of four 2-position flags shall indicate the open or closed status of its respective solenoid valve.
Main Shutoff Status System A System B	Each of two 2-position flags shall indicate the open or closed status of its respective solenoid valves.
Ascent Feed Status System A System B	Each of two 2-position flags shall indicate the open or closed status of its respective solenoid valves.
Thruster Pair Status Quad. #1, System A Quad. #2, System A Quad. #1, System B Quad. #2, System B Quad. #3, System A Quad. #4, System A Quad. #3, System B Quad. #4, System B	Each of two 2-position flags shall indicate the open or closed status of its respective solenoid valves.
Crossfeed Status	This 2-position flag shall indicate the open or closed status of the crossfeed solenoid valves.

3.4.9.1.4 Flight Controls. -

Control/Indicator	Function
Rate-Error Monitor Selector Switch (CDR) (SE)	This switch enables shaft and trunnion angles from the radar to be displayed on the pitch and yaw error needles of the FDAI and LOS azimuth and elevator rates to be displayed on the cross-pointer meter.
Attitude Monitor Selector Switch (CDR) (SE)	This switch enables monitoring on the FDAI vehicle attitude inputs and steering errors.
Altitude/Range Monitor Switch	This switch displays range and range rate or altitude and altitude rate data.
Mode Select Switch	This switch selects either radar attitude, altitude rate, forward and lateral velocity data or LGC computer altitude/altitude rate, forward and lateral velocity or AGS computed altitude, altitude rate and lateral velocity for display.
Δ V Reset to Zero-Restart Switch	This switch controls the inputs to the accumulated Δ V digital display.
Guidance Control Switch	This switch selects either the PGNCS or AGS for guidance control.
Shaft/Trunnion Scale Select Switch	This switch controls the range of display of the pitch and yaw error needles.
IMU Cage Switch	This switch provides an emergency function allowing recovery of the IMU to a zero position.
Up-Link Switch	(TBD)

3.4.9.1.4 (Continued)

Control/Indicator	Function
Forward Velocity and Lateral Velocity or LOS Azimuth Rate and LOS Elevation Rate (CDR) (SE)	Cross-Pointer - one meter.
Flight Director Attitude Indicator (CDR)	The Attitude Indicator consists of a gimballed, servo-driven sphere which is free to rotate through 360° in each of three mutually perpendicular axes. The yaw, pitch and roll attitude indications shall have a static accuracy of ± 0.5° at zero degrees. The yaw and pitch indicators have a static accuracy of ± 1.0° at other points on the sphere. Vehicle attitude inputs derived by either the AGS or PGNCS can be selected for display through the appropriate attitude monitor switch. Attitude rates shall be displayed from the rate gyros in the CES. The indicator lag in each axis shall not exceed 1.0 degree at an input rate of 10 degrees per second.
Thrust to Weight Indicator	This indicator shall display X-axis acceleration.
Δ V Accumulated Indicator	This indicator displays the time integral of X-axis acceleration.
Range and Range Indicator	When the Monitor switch is in the Range/Range Rate position, range and range rate data are displayed from the Rendezvous Radar.
Altitude and Altitude Rate Indicator	In the Altitude/Altitude Rate position, either Radar LGC or AGS altitude and altitude rate data are displayed.

3.4.9.1.4 (Continued)

Control/Indicator	Function
Elapsed Time Indicator	This indicator shall display AES mission elapsed time in hours, minutes and seconds.
Digital Event Timer	This indicator shall display time in minutes and seconds on a 4 digit display.
Elapsed Time Set Control	This control shall allow setting of the elapsed timer.
Timer Control Switch	This switch shall have momentary contacts for the start and stop positions.
Reset/Count Control Switch	This 3-position toggle switch shall determine the direction the digital event timer will count after it is manually started.
Slew Control Minutes Slew Switch	This momentary toggle switch shall slew the minutes' digits of the digital event timer.
Slew Control Seconds Switch	This momentary toggle switch shall slew the seconds' digits of the digital event timer.
Thrust Indicator	This indicator displays either LGC commanded thrust or manually commanded thrust.

3.4.9.1.5 Main Propulsion. -

Control/Indicator	Function
Propellant Temp/Press Monitor Select Switch	This switch selects the ascent or descent propellant temperatures and pressures for monitoring.

3.4.9.1.5 (Continued)

Control/Indicator	Function
Ascent Regulator Switches	Each of these two switches control a latch type solenoid valve located upstream of each helium pressure regulator. Valve position is indicated by flags.
Descent Regulator Switches (He)	Each of these switches control a latch type solenoid valve located upstream of each pressure regulator.
Helium Temp/Press Monitor Select Switch	This switch selects the ascent or descent propulsion helium tank temperature or pressure.
Helium Temp/Press Meter (4-place digital indicator)	This four digit electroluminescent indicator displays ascent or descent helium tank temperature or pressure.
Fuel Pressure and Oxidizer Pressure Meter	This dual scale meter displays fuel and oxidizer pressure for the ascent or descent subsystem.
Fuel Temperature and Oxidizer Temperature Meter	This dual scale meter displays fuel and oxidizer pressure for the ascent or descent subsystem.
Ascent Regulator Status No. 1 and No. 2	Each of the two regulators have two-position flags which indicate the open or closed status of its respective solenoid valve.
Descent Regulator Status No. 1 and No. 2	Each of the two regulators have two-regulators have two-position flags which indicate the open or closed status of its respective solenoid valve.

3.4.9.1.6 Guidance, Navigation and Control. -

Control/Indicator	Function
Gyro Test Select (Pitch, Roll, Yaw) Switch	This switch shall select a rate gyro for test.
Gyro Test Select (Positive Rate, Negative Rate) Switch	This switch shall torque the selected rate gyro positively.
Deadband Select Switch	This switch shall select either a large or narrow deadband amplitude limit cycle for vehicle attitude control.
Attitude Control Switch Pitch Attitude Control Switch Roll Attitude Control Switch Yaw	Each of these switches shall select direct or pulse operation. These switches shall provide individual selection in each attitude axis.
Attitude Control Mode Switch	This switch shall select the mode of operation of the vehicle's attitude axis.

3.4.9.1.7 Radar. -

Control/Indicator	Function
Rendezvous Manual Slew Switch	This switch is used to manually position the radar antenna along the shaft and trunnion axes.
Slew Rate Switch	This switch selects the rate of manual slew capability.

3.4.9.1.7 (Continued)

Control/Indicator	Function
Rendezvous Radar Mode Select Switch	This switch provides for computer driven antenna positioning and automatic tracking of the CSM. It also provides manual slewing of the rendezvous radar antenna and enables automatic track after manual acquisition of the CSM.
Landing Radar Antenna Switch	This switch, normally in the LGC position, enables LGC positioning of the landing radar antenna. The DES and HOVER position are used for testing the antenna.
Signal Strength Meter	This meter displays various signals depending on the setting of the Test/ Monitor switch.
No Track Light	This light illuminates to indicate "Data No Good". Range and frequency tracker lockups indicate "Data Good".
Self Test Select Switch	This switch tests subassemblies which in turn generate a test signal for checking the rendezvous and landing radar's operational status.
Test/Monitor Switch	This switch as six positions; Turn Shaft, XMTR PWR, AGC, VEL XMTR PWR and ALT RNG XMTR PWR position.
Track Select Switch	The transponder on the CSM is tracked by this switch being in the XPND position. The surface of the moon is tracked by this switch being in the surface position.

3.4.9.1.8 Communications. -

Control/Indicator	Function
Modulator Select Switch	This switch shall select phase modulated or frequency modulated transmission mode of the S-band transmitter.
Transmitter/Receiver Select Switch	This switch shall select either of two redundant transmitter/receiver sub-assemblies.
Power Amplifier Select Switch	This switch shall select either of two redundant S-band power amplifiers
Voice Function Select Switch	This switch shall select either normal voice or backup voice function of the S-band transmitter.
PCM/Key Function Select Switch	This switch shall select either the telemetry or Morse Code keying function for transmission via the S-band equipment.
Range/TV Function Select Switch	This switch shall select either the ranging or the television function for transmission via the S-band equipment.
Biomed Select Switch	This switch shall select biomedical data to be telemetered.
PCM Rate Select Switch	This shall select the high or low bit rate to be transmitted.
VHF Transmitter/Receiver Select Switch	This switch shall select various combinations of VHF A and B transmitters and receivers.
VHF A Squelch Control VHF B Squelch Control	These controls shall permit the adjustment of the threshold of the VHF A or B receiver squelch circuit.

3.4.9.1.9 Audio Control Panel (2 identical panels). -

Control/Indicator	Function
S-Band Switch	This switch shall tie the respective audio center into the S-band transmitter/receiver circuitry.
ICS Switch	This switch shall tie the audio into the intercom circuitry.
Relay Switch	This switch shall tie the VHF into the S-band transmitter/receiver circuit to provide voice communications between the Taxi, Earth, EVA or CM.
VHF A Switch VHF B Switch	These switches shall tie the respective audio center into the VHF A or B transmitter/receiver circuit.
VOX Switch	This switch shall provide either voice operated relay activation or push-to-talk keying of transmitters.
VOX Sensitivity	This control shall adjust the level of voice input required to activate the voice operated relay.
S-Band Volume Control	This control shall adjust the level of the S-band audio input to the headphone.
ICS Volume Control	This control shall adjust the level of the intercom audio input to the headphone.
VHF A Volume Control VHF B Volume Control	These controls shall adjust the level of the VHF A or B audio input to the headphone.
Master Volume Control	This control shall adjust simultaneously the level of all audio inputs to the headphone through the respective audio center.

3.4.9.1.10 Communications Antennas. -

Control/Indicator	Function
Pitch Antenna Control	This control shall drive the S-band antenna in the pitch axis.
Yaw Antenna Control	This control shall drive the S-band antenna in the yaw axis.
Track Mode Select	This switch shall select either the auto or manual mode of track of the S-band antenna.
VHF Antenna Select	This switch shall select the VHF antennas as well as a test position to check out ENU information exchange.
Signal Strength Meter	This meter shall monitor the S-band signals received from the earth.
Antenna Pitch Meter	This meter shall display the pitch angles of the S-band steerable antenna.
Antenna Yaw Meter	This meter shall display the yaw angle of the S-band steerable antenna.
No Track Light	The caution light indicates that the S-band steerable antenna has broken track with the RF signal transmitted from earth.

3.4.9.1.11 Electrical Power Supplies. -

Control/Indicator	Function
Battery #1 High Voltage Control Switch	Each 3-position toggle shall control the high voltage power output from one of 3 descent batteries

3.4.9.1.11 (Continued)

Control/Indicator	Function
Battery #2, High Voltage Control Switch Battery #3 High Voltage Control Switch	Each 3-position toggle shall control the high voltage power output from one of 3 descent batteries.
Battery #1 Low Voltage Control Switch Battery #2 Low Voltage Control Switch Battery #3 Low Voltage Control Switch	Each 3-position toggle shall control the low voltage power output from one of 3 descent batteries.
Descent Batteries Switch	This 3-position, center return toggle shall provide power interruption of the descent batteries' feed path to the ascent stage.
Battery #13 - Normal Feed Battery #14 - Normal Feed	These 3-position toggles shall control Ascent battery #13 and Ascent battery #14 feed paths to both busses, respectively.
Battery #13 - Alternate Feed	This 3-position toggle shall control Ascent battery #13 power feed path to both busses.
Battery #14 - Alternate Feed	This 3-position toggle shall control Ascent battery #14 power feed path to both busses.
AC Power Control Toggle	This 3-position toggle shall control AC power to the AC bus.
Power/Temperature Monitor Select Switch	This 10-position rotary shall provide power and temperature monitoring on meters of the electrical power subsystem.

3.4.9.1.11 (Continued)

Control/Indicator	Function
Ascent Power Auto Transfer Switch	This toggle shall control the automatic switch-over feature whereby the two ascent batteries energize the busses in the event of failure of two or more descent batteries.
Battery Temperature Indicator	This meter shall indicate battery temperature in Fahrenheit.
Voltmeter	This meter shall indicate the voltage of any battery or bus in the EPS.
Ammeter	This meter shall indicate the current of the batteries.
Over Temperature Light	This light shall warn of battery overheating.
Reverse Current Light	TBD
Descent Battery #1 Status Descent Battery #2 Status Descent Battery #3 Status	These flags shall indicate the battery is on the line when the gray position is in view. The battery is off the line when the "barber-pole" position is in view.
Ascent Battery #13 SE Bus Feed Status	This flag shall indicate that Battery #13 is powering the Systems Engineer's bus when the gray position is in view.
Ascent Battery #14 CDR Bus Feed Status	This flag shall indicate that Battery #14 is powering the Commander's bus when the gray position is in view.

3.4.9.1.11 (Continued)

Control/Indicator	Function
Ascent Battery #13 CDR Bus B.U. Feed Status	This flag shall indicate that Battery #13 is powering the Commander's bus when the gray position is in view.
Ascent Battery #14 SE Bus B.U. Feed Status	This flag shall indicate that Battery #14 is powering the Systems Engineer's bus when the gray position is in view.
Descent Deadface Status	This flag indicates whether the descent deadface has been accomplished.
RTG Switch	TBD

3.4.9.1.12 Environmental Control. -

Control/Indicator	Function
Suit Circuit Fan Select Switch	This switch shall select suit fans.
Coolant Pump Select Switch	This switch shall select pump #1, 2 or 3 and shall enable an automatic shutoff of a malfunctioning pump.
Water, O_2 Quantity Monitor Switch	This switch shall indicate the quantity of water or gaseous oxygen in percent.
CO_2 Partial Pressure Indicator	This indicator shall display carbon dioxide partial pressure of the Atmospheric Revitalization Section.
Cabin Pressure Indicator	This indicator shall display cabin interior pressure.

3.4.9.1.12 (Continued)

Control/Indicator	Function
Suit Pressure Indicator	This indicator shall display EMU suit pressure.
Cabin Pressure Indicator	This indicator shall display cabin temperature.
Suit Temperature Indicator	This indicator shall display EMU suit circuit temperature.
Gaseous Oxygen Pressure Indicator	This indicator shall display gaseous oxygen pressure.
Water, O_2 Quantity Meter	This meter shall display total water in ascent tanks #1 or #2 and descent tank.
Glycol Pressure Indicator	This indicator shall display the pressure of the glycol coolant in both the primary and secondary heat transport loops.
Glycol Temperature Indicator	This indicator shall display the temperature of the glycol coolant in both the primary and secondary heat transport loops.
CO_2 Component Caution Light	This light shall indicate the CO_2 status of the primary LiOH canister.
Water Separator Component Caution Light	This light shall indicate the failure status of the operating water separator.
Suit Circuit Fan Component Caution Light	This light shall indicate the failure status of the selected suit fan.

3.4.9.1.12 (Continued)

Control/Indicator	Function
Glycol Pump Component Caution Lights	Each of two lights shall indicate the failure status of its respective glycol pump.

3.4.9.1.13 Subsystem Lighting. -

Control/Indicator	Function
Annunciator Numeric Brightness Control	This control shall vary the brightness of all component caution lights, annunciator, and EL numeric displays.
Integral Lighting Control	This control shall vary the brightness of the low level integral lighting.
Flood Lighting Control	This control shall regulate the brightness of the floodlights.
Commander's Side Panel Control	This control shall make or break the circuits from the Integral Lighting Control and the Flood Lighting Control
System Eng. Side Panel	TBD
Dome Light Control	This control shall regulate the brightness of the dome light.
Docking Light Control	This control shall turn the docking light ON or OFF.
Exterior Lighting Control	This switch shall control the docking and tracking lights on the vehicle.
Override Toggle Switches (3)	Integral, Annunciate and Numerix
Lamp/Tone Test Switch	TBD

3.4.9.1.14 Abort Guidance Section. -

Control/Indicator	Function
2 Digit Address	Shall identify the program for communication with the computer.
5 Digit Data Readout and Algebraic Sign	Shall enable the crew to communicate with the computer.
Hold Button	Shall provide the capability of interrupting a continuously updated readout when activated.
Operator Error Light	This status light shall illuminate when an operator error occurs.
GASTA	Used to correct FDAI's.
DEDA	Data Entry Display Assembly.
DSKY	GFE Computer Display Keyboard.
DEDA	Data Entry Display Assembly.

3.4.9.1.15 Caution and Warning. -

Control/Indicator	Function
Caution and Warning Lights	The Caution and Warning lights shall provide the crew with a rapid check of the Taxi status by crew continuous monitor of critical subsystem parameters during the manned phases of the Taxi mission.
Caution and Warning Displays	These displays shall consist of two master alarm lights, an array of caution and warning indicators, and component caution lights.

3.4.9.1.15 (Continued)

Control/Indicator	Function
Master Alarm Lights	Two aviation red Master Alarm lights.
Master Alarm Tone	Shall be an audible tone heard through the headphones in conjunction with the Master Alarm lights.
Warning Array	Shall be an array of no more than 20 aviation red-lighted legends, located near the top of Panel I.
Caution Array	Shall be an array of no more than 20 aviation yellow-lighted legends, located near the top of Panel II.
Component Caution Lights	Shall be located on the control and display panels to aid in location of a particular malfunction. The face of these caution lights shall be circular and of the press-to-test type.
Caution & Warning Lights Test Switch	This switch shall provide a test for the bulbs in all the lights of Caution/Warning, Master Alarm, audible tone, and engine start and stop override pushbutton.

3.4.9.1.16 Heater Controls. -

Control/Indicator	Function
Battery Heaters	These heaters shall control heat of Ascent and Descent batteries.

3.4.9.1.16 (Continued)

Control/Indicator	Function
RCS Quad. #1 Heater Switch RCS Quad. #2 Heater Switch RCS Quad. #3 Heater Switch RCS Quad. #4 Heater Switch	These switches shall be used to control temperature of the four RCS quads.
Landing Radar Temperature and Rendezvous Radar Temperature Select Switches	These two toggle switches shall select the range of temperature control desired for the automatic heating of their respective radar antenna assemblies.
Landing Radar Heater and Rendezvous Radar Heater Switches	These two toggle switches control the heater assemblies of their respective radar systems.
Temperature Monitor Select Switch	This 6-position rotary switch shall provide monitoring of the RCS quad temperature.
Temperature Indicator	This indicator shall display the temperature, in degrees Fahrenheit, of the quad selected by switch 18-S-10.

3.4.9.1.17 Biomedical. -

Control/Indicator	Function
Body Temperature Meter	Shall display body temperature in degrees Fahrenheit.

3.4.9.1.17 (Continued)

Control/Indicator	Function
Respiration Rate Meter	Shall display respiration rate in breaths per minute.
Cardiotachometer/Rate Alarm	Shall display heart rate.

3.4.9.1.18 Radiation Protection. -

Control/Indicator	Function
Tissue Ionization Equiv. Chamber	Shall measure dangerous levels of radiation and display it on a rate meter.

3.4.9.2 Design Requirements. - The design of controls and displays shall conform to the following requirements:

(a) Display range and readout accuracy shall not exceed the needs of the flight crew to manage the vehicle. Scale markings shall not permit readout accuracies of a more precise nature than the accuracy of the input signal.

(b) All controls essential to crew safety shall permit satisfactory operation by a flight crew in pressurized space suits. Such considerations as appropriate location, spacing, size, and torque shall be included in this operation.

(c) Status indicators (flags or lights) shall be employed to indicate valve positions where such valves are actuated by inputs from momentary toggle switches.

(d) Time shared displays or parameters shall be employed when such parameters need not be monitored continuously or concurrently.

(e) Percentage readouts shall be employed where specific quantities are not required by the crew.

3.4.9.2 (Continued)

(f) Where feasible, dual meters of the fixed scale, moving pointer type shall utilize a single scale, appropriate for both parameters displayed, centered between two pointers.

(g) Scale graduations shall progress by 1, 5 or 2 units, in that order or preference, or decimal multiples.

(h) All scale markings shall be equally spaced. The use of non-linear scales shall be avoided.

(i) Heights, widths, and spacing of all nomenclature shall be as close as feasible to the preferred dimensions established by human engineering considerations. In no case shall these dimensions be smaller than the acceptable minimum established by these same considerations.

(j) Abstract symbols and abbreviations shall not be used unless they are easily understood by the crew. A minimum of two letters shall be required when any abbreviation is employed and shall be standard between modules.

(k) Interruption of power to any display shall be made immediately apparent to the crew.

(l) Maximum torque, which is required of the flight crew for small valve control handles, shall not exceed 10 inch-lbs. A small valve control handle will not exceed 2 1/4" in diameter. This valve control is of the faucet type.

(m) Where 20-30 inch-lbs. control torques are required, control handles shall not be less than 3 inches in length.

(n) Controls or displays shall be designed to avoid blind actuation by the flight crew.

3.4.10 Explosive Devices Subsystem (EDS). - The EDS shall consist of explosive devices and related components necessary to initiate and control the functions specified in 3.4.10.1

3.4.10.1 Performance Requirements. - The EDS shall initiate and control the following functions:

(a) Environmental Control Subsystem (ECS) water valve opening.

(b) Reaction Control Subsystem (RCS) pressurization.

(c) Landing Gear Deployment.

(d) Descent Propulsion Subsystem Pressurization.

(e) Ascent Propulsion Subsystem Pressurization.

(f) Stage Separation: structural, dead facing and interstage umbilical. The events will occur in the following sequence and each event will be completed prior to the initiation of a following event.

(1) Nut and Bolt and Ascent Stage dead facing shall occur simultaneously,

(2) Descent stage deadface fired,

(3) Umbilical severed.

(g) Desent Propulsion Vent Valve Opening.

(h) Top Hatch Cover Deployment.

3.4.10.2 Design Requirements. - Electrical wiring from the Taxi/CM interface to the Taxi/Spacecraft LEM Adapter (SLA) shall be provided through the Taxi to conduct the signal for SLA/Taxi separation.

3.4.10.2.1 Power Supplies. -

3.4.10.2.1.1 Logic Power. - Logic d-c power shall be supplied by the System Engineer buss and Commander buss in the ascent stage. Explosive device power shall be controlled by a manual switch.

3.4.10.2.1.2 Transient Power Characteristics. -

(a) The subsystem shall cause no transients under any condition as specified below:

(1) Signal duration or signal interruption of greater than 10 microseconds and voltage variation greater than plus or minus 2 volts.

(2) Signal duration sufficient to fire a standard pyrotechnic device.

(b) The subsystem shall operate satisfactorily when the logic bus voltage is maintained between 25 and 36.5 volts and with no logic bus voltage interruption greater than 500 microseconds during any 20 milliseconds period.

3.4.10.2.1.3 Explosive Devices Power. - The electrical power for the firing of explosive devices shall be supplied by two silver-oxide-zinc batteries in the descent stage.

(a) Battery Voltage - Open-circuit voltage shall be a maximum 37.8 volts. Nominal voltage shall be 23 volts while delivering 75 amperes. Final voltage shall be 20 volts when the battery is completely discharged after delivering 75 amperes.

(b) Battery Capacity - The battery shall be capable of delivering a current of 75 amperes for 36 seconds during the first six cycles of discharge down to a final voltage of 20 volts.

(c) Battery Service Life - The total number of complete cycles of discharge and recharge within the 60 to 100 degrees Fahrenheit temperature range shall be a minimum of six cycles.

3.4.10.2.2 Circuitry. -

(a) Circuit Protection. - Circuit protection for the EDS shall be provided by a system of high reliability circuit breakers and current limiting fuses.

(1) Circuit breakers shall be provided as follows:

a. To clear the logic busses of ground faults in the EDS.

b. To protect wiring from deterioration (including production of smoke or toxic fumes in the ascent stage cabin) caused by faults or overloads.

(2) Fused resistors shall be provided to limit current drain on the ED batteries due to vehicle wiring or ED firing circuit.

(b) Explosive Device Circuits - Explosive device circuits shall be the only electrical load to be connected to the explosive device power bus and shall not be powered from the logic bus.

(c) Isolation - Explosive device circuits and logic circuits shall be electrically and physically isolated from one another and their wiring shall be routed separately where possible.

(d) Grounds and Returns - The ED circuits shall not be grounded. The logic and instrumentation circuit ground returns shall be separate and shall in no way cause the ED circuits to become grounded.

(e) Shields - Firing circuit shields shall be electrically continuous with no physical discontinuities and grounding shall be consistent with the requirements of AFMTCP 80-2, General Range Safety Plan.

3.4.10.2.2 (Continued)

(f) Operational Assurance - To assure operation of all functions controlled by the EDS, the design shall be "fail safe" in all respects. The EDS shall consist of two independent circuits to provide redundancy. There shall be no electrical or mechanical crossovers except for the common mechanical actuation of control switches. A single failure shall not be cause for function failure or mission abort.

(g) Redundant Wiring - Redundant internal wiring shall be used where a loss of a single lead would cause premature initiation of a major function or loss of control of the function.

(h) Timing - Timing requirements shall be held within plus or minus 5 percent maximum under all conditions specified herein.

(i) Time Delays - Time delays shall be arranged to minimize the possibility of function initiation occurring before the termination of the specified time delay.

(j) Transients - See 3.4.10.2.1.2.

(k) Explosive Devices Shorting - The controller fire relay shall maintain a shunt across each explosive device circuit prior to firing. The firing circuit operation shall simultaneously remove this shunt and provide ED initiation. The shunt resistance shall be 2.5 ohms maximum.

(l) Manual Capability - Manual capability shall be provided for selected functions as specified herein.

3.4.10.2.3 Explosive Device Requirements. - The modular concept shall be used in the design of all explosive devices and assemblies. Explosive charge assemblies of all types shall be separate from higher assemblies and from structural elements. Devices containing an integral Apollo Standard Initiator (ASI) and which would by their own energy or by initiating a chain of events, cause injury to people or damage to property, shall be capable of installation on the launch pad. Explosive devices having unique applications shall be designed to preclude misinstallation. Threaded cartridges having different output characteristics shall have different thread sizes. All high explosive charges such as a mild detonating fuse (MDF), shall be mounted in suitable charge holders which are separable from structural elements. Charge holders shall be designed to protect the explosive trains, to minimize and direct backblast, and to permit ease of installation at the launch site. The explosive charge shall be sealed from exposure to atmospheric and mission environments. Explosive trains consisting of more than one integrally assembled component shall have booster interfaces.

3.4.10.2.4 Explosive Devices. - The following explosive devices separately or in various combinations shall accomplish the previously specified functions.

(a) Apollo Standard Initiator (ASI) - The ASI shall initiate all electrically actuated explosive functions required during the Taxi mission. This device is common usage with NAA.

(b) Apollo Standard Detonator (ASD) - The ASD shall be used to detonate all high explosive charges in the Taxi. This device is common usage with NAA.

(c) Mild Detonating Fuse (MDF) - The MDF shall be common usage with NAA.

(d) ECS Water Valve - The ECS water valve shall be actuated by one or both of the two ASI's installed.

(e) RCS Helium Pressurization - The RCS explosive valve shall be actuated by the single ASI installed.

3.4.10.2.4 (Continued)

(f) Ascent Propulsion Subsystem Pressurization Valve - The (APS) explosive valves shall be actuated by one or both of the two ASI's installed.

(g) Descent Propulsion Subsystem Pressurization Valve - The (DPS) explosive valve shall be actuated by one or both of the two ASI's installed.

(h) Landing Gear Uplock - Each landing gear leg shall be secured in the retracted position by a single restraining device. This device shall have turn buckle type tensioning capable of preloading. It shall have a dual initiation mode either of which is capable of actuating the device. The device shall separate into two parts to release the landing gear. No parts shall be unattached after release.

(i) Circuit Interrupter - Circuit interrupters shall be provided to terminate all signal and power leads running between the ascent and descent stages which are live at time of separation or which could subsequently become live due to activation of a circuit. These devices shall be initiated explosively approximately 10 milliseconds after stage command is received. They shall be actuated by either of the two ASI's.

(j) Explosive Nut and Bolt - The ascent and descent stages shall be structurally joined by four explosively actuated bolts and four explosively actuated nuts each with single initiation. Upon receiving the stage separation signal, they shall actuate within a total elapsed time of 0.1 second

(k) Guillotine. - A dual initiation mode MDF guillotine shall be used. Each mode shall be capable of severing an umbilical 35 percent greater than the actual umbilical within 0.5 second after receipt of the fire signal at the guillotine. A cross-over network shall be provided to fire both modes should a failure occur in the normal initiation mode of one.

3.4.10.2.4 (Continued)

(l) Descent Engine Helium/Propellant Venting - The venting explosive valve shall be actuated by one or both of the ASI's installed.

(m) Top Hatch Cover - The top hatch cover shall be secured in the retracted position by a single clamp. The clamp shall be fastened by two explosive bolts. The firing of either explosive bolt shall be capable of releasing the hatch cover.

3.4.10.2.5 Special Consideration. - The procedures below require special consideration.

(a) Abort - The abort of a mission shall be initiated by manual depression of the abort button. This button initiates abort programs in the PGNCS, SCS and Instrumentation Subsystems for use of the Descent Engine. It also provides a Descent Engine automatic arming command.

(b) Abort Stage - The abort stage button shall be used to abort the mission using the Ascent Engine. This button initiates the PGNCS, SCS and Instrumentation Subsystems for an abort using the Ascent Engine. It also provides Ascent Engine pressurization commands, Ascent Engine arm commands, Descent Engine OFF commands and interstage deadface commands. The depression of this button enables the vehicle to use computer outputs for operation with the Ascent stage.

(c) Stage - This switch shall provide the capability to stage the Taxi by means of explosive nut-bolt combinations without pressurizing the Ascent Engine.

4 QUALITY ASSURANCE PROVISIONS

4.1 Quality Program. - A Grumman quality program shall be established in accordance with NASA Publication NPC 200-2. The quality program shall provide the general requirements necessary to ensure that the vehicle meets the quality requirements of the contract. These requirements shall include the establishment and maintenance of an effective quality program from the design conception to the delivery of a vehicle.

4.1.1 Identification and Traceability. - The quality program shall provide for identification and traceability control.

4.2 Reliability Program. - A Grumman reliability program shall be established in accordance with NASA Reliability Publication NPC 250-1.

4.3 Tests. -

4.3.1 Development Tests. - The development tests shall be as specified in 4.3.1.1 and 4.3.1.2.

4.3.1.1 Design Feasibility Tests. - Design feasibility tests shall be conducted for all new equipment and to that LEM equipment that has been redesigned or modified to the extent that performance or safety strength margins under selected environments are now in doubt. The tests shall be conducted to:

(a) Achieve component and part selection.

(b) Investigate the performance of breadboard models, components and subassemblies unaer selected environmental conditions.

(c) Substantiate strength margins and analytical assumptions.

4.3.1.2 Design Verification Tests. - Design verification tests shall be conducted for all new equipment and to that LEM equipment that has been redesigned or modified in order to verify the optimum design characteristics prior to qualification testing. These tests shall include all those conducted to substantiate the correctness of the design for its intended mission under simulated ground and flight environments and off design conditions.

4.3.1.2.1 Required Tests. - As a culmination to design verification, the specified vehicle equipments shall be subjected to the critical environments of an operational cycle followed by an overstress test. These tests shall fulfill the following essentials:

(a) The tests shall be performed on production equipment.

(b) Successful completion of these tests except overstressed tests shall be a prerequisite to the start of qualification tests. Completion of overstress tests shall precede the completion of qualification tests.

(c) No failure, replacement of parts, maintenance or adjustments shall be permitted during the critical environments tests, except those adjustments which are included as part of the normal operations of the equipment under test.

4.3.1.2.1.1 Critical Environmental Tests. - The specified equipments shall be successfully subjected to the critical environments of an operational cycle. The critical environments shall be at mission levels. An operational cycle shall consist of all the environments and dynamic conditions to which the equipment will be exposed during the acceptance tests, handling, transportation and storage, prelaunch, launch, translunar, and lunar phases of the vehicle mission. Equipment subject to particular environments shall be subjected to applicable critical environmental tests.

4.3.1.2.1.2 Overstress Tests. - At the completion of the critical environmental tests, the equipment shall be tested to failure under systematically increasing dynamic and environmental stresses. Deviation of performance from the minimum acceptable operating mode shall constitute a failure. The equipment shall dwell long enough at each increment of overstress to stabilize conditions and complete an abbreviated operational test.

4.3.1.2.1.2.1 Selection of Stresses. - A failure mode predication analysis shall provide the basis for the selection of critical stresses to be employed in the overstress tests. Only conditions from the launch and post-launch phase of the mission shall be used for the overstress tests. If the critical mission stresses are due to a combination of dynamic and environmental conditions, the tests shall be performed under that combination of environments. If the critical stresses are due to several dynamic and

4.3.1.2.1.2.1 (Continued)

environmental conditions which are not in combination in the mission, the test increments shall be performed with each condition imposed separately. Each increment of the test conditions shall be increased in proportion to their values at mission levels.

4.3.1.2.1.3 Analysis of Results. - An engineering analysis of the data generated by the overstress tests, including a correlation with the failure mode predication analysis, shall be performed.

4.3.2 Qualification Tests. - Qualification tests shall be performed in compliance with the requirements of NASA Quality Publication NPC 200-2. Qualification tests of parts, components, subassemblies and higher levels of assembly shall be performed to demonstrate that the vehicle is capable of meeting the requirements specified in the individual End Item Specification. Qualification tests shall be performed on two production equipments. One equipment shall be used for design limit tests and the other equipment shall be used for endurance tests. A qualification endurance test shall be performed on a selective basis on only those equipments identified for endurance testing as the result of analysis.

4.3.2.1 Qualification Testing Requirements. -

4.3.2.1.1 Applicability. - The qualification tests shall start at the lower levels of assembly and proceed to levels of higher assembly. As a general rule, it is not economically practical or feasible to conduct qualification tests on complete subsystems. Accordingly, most of the qualification tests shall be conducted on lower levels of assemblies to the degree necessary to provide confidence on a subsystem basis. This will be done by conducting tests at hardware levels such that when the total qualification program on a subsystem is completed all items of hardware and all operational modes will, as a minimum, be tested to an amount equivalent to a subsystem qualification test.

4.3.2.1.2 Purpose. - Qualification tests shall be designed to:

(a) Locate significant failure modes.

(b) Determine the effects of varied stress levels.

(c) Determine the effects of combinations of tolerances and drift of design parameters.

4.3.2.1.2 (Continued)

(d) Determine the effects of applicable combinations and sequences of environments and stress levels.

4.3.2.1.3 Environments. - Qualification testing shall include both natural and induced environments. Combined environments shall be used when applicable.

4.3.2.1.3.1 Qualification Criteria for Environments. -

4.3.2.1.3.1.1 Criteria for Imposing Environment. - The criteria for imposing environments during qualification testing shall be based on the concept that all vehicle equipments shall demonstrate their capability to withstand the worst case of operational cycle environments, both natural and induced.

4.3.2.1.3.1.2 Natural Environments. - All natural environments shall be considered for inclusion such as: humidity, salt spray, rain, sand and dust, fungus, ozone, solar radiation, and pressure/vacuum.

4.3.2.1.3.1.3 Induced Environments. - All induced environments shall be considered for inclusion such as: acceleration, acoustics, shock, vibration, high temperature, low temperature, pressure/vacuum, oxygen, cabin contaminates (salt and humidity), and EMI/RFI.

4.3.2.1.3.1.4 Environmental Levels. - The environmental levels shall be derived from the most severe conditions that may be imposed during an operational cycle and shall be as defined in 3.1.2.4 and 3.1.2.8.

4.3.2.1.3.1.5 Testing. - Testing shall be performed on those equipments that have an inherent sensitivity to the particular environment. The sensitivity shall be based upon the item failure modes and the effects of the environment upon its endurance, strength, and operational characteristics.

4.3.2.1.3.1.6 Sensitivity. - If the sensitivity of the equipment to a particular environment cannot be positively determined, then the equipment shall be subjected to testing within that environment.

4.3.2.1.3.1.7 Particular Environment. - Testing to a particular environment may be waived when analysis demonstrates that the environmental level is reduced through reliable protective measures to a point where it is insignificant or where the inherent strength or design characteristic of the equipment renders it insensitive to the specified environmental level.

4.3.2.1.3.1.8 Sequence. - The sequence in which the environments shall be imposed during testing shall be as outlined below except that tests shall be planned to minimize the number of test set-ups, providing the test objectives are not severely compromised. Tests shall avoid facility and special test equipment overlap.

(a) For endurance qualification, environments shall be imposed in the same sequence that will be experienced during a normal operational cycle.

(b) For design limit qualification, the sequence shall be based upon its possibility of occurrence, the severity of the degradation effects and inter-reaction effects, where known. The most critical environments shall be imposed first.

4.3.2.1.4 Program Design. - In determining the number of equipments required for qualification, all prior development tests including integrated ground tests shall be considered. Portions of the development tests may be used to reduce the qualification tests required provided all qualification test requirements are met and prior NASA approval is obtained. Where redundancy in design exists, the qualification tests shall assure that each redundant component and mode will be included in the test program. Qualification test procedures and criteria shall be specified for each equipment which will undergo qualification testing, and the qualification tests will fully encompass the design requirements specified for that equipment.

4.3.2.1.5 Schedule. - Qualification tests supporting a particular flight vehicle shall be completed prior to that vehicle being delivered by the contractor.

4.3.2.1.6 Qualification Basis. - The minimum qualification shall include one set of equipment subjected to sequential, singly applied environments at design limit conditions (Design Limit Test), and another set subjected to one operational cycle and one subsequent mission cycle at nominal mission conditions (Endurance Test).

4.3.2.1.6.1 Qualification by Similarity. - Qualification by similarity may be accepted provided the following criteria are satisfied:

(a) The equipment was qualified to environmental test requirements that meet or exceed those specified for the Taxi.

(b) The equipment was fabricated by the same manufacturer with the same methods or processes and quality control.

(c) The equipment was designed to specifications that satisfy all the requirements set forth for that item in Taxi specifications.

4.3.2.1.6.2 Requalification. - Requalification shall be performed when:

(a) Design or manufacturing processes are changed to the extent that the original tests are invalidated.

(b) Inspection, test, or other data indicate that a more severe environment or operational condition exists than that to which the equipment was originally qualified.

(c) Manufacturing source is changed.

4.3.2.1.7 Procedures. -

(a) Acceptance test shall precede all qualification tests.

(b) Functional operation shall be required as applicable. During all qualification tests all interfaces shall be present or simulated.

(c) Adjustments shall be permitted during an operational cycle only if they are part of a normal procedure.

(d) Limited life items and single-shot devices may be replaced at the completion of satisfactory operation through their life requirement.

4.3.2.1.7 (Continued)

(e) Any failure shall be cause for positive corrective action. The degree of retest in event of a failure shall be agreed upon between the NASA and the contractor after evaluation of the failure. In the event of failure, the contractor shall immediately notify NASA.

4.3.2.1.8 Additional Testing. - Subsequent to the completion of the qualification tests further tests shall be conducted at conditions more severe that design limit. The purpose of these tests shall be to determine failure modes and actual design margins.

4.3.2.2 Design Limit Tests. - (To be determined)

4.3.2.3 Endurance Tests. - The second equipment shall be successfully subjected to the conditions of a complete operational cycle plus the conditions of the flight simulation phase of an operational cycle at mission levels.

4.3.2.4 Post-Qualification Tests. - At the completion of the qualification tests, the test units shall be subjected to the tests specified in 4.3.2.4.1 and 4.3.2.4.2 in order to increase confidence in equipment design life and strength. These tests shall be run on qualified equipment.

4.3.2.4.1 Overstress Tests. - The post-qualification testing of the design limit test unit shall consist of overstress tests in the same mode or condition as selected for the design verification overstress test (4.3.1.2.1.2), unless results of previous testing indicates otherwise.

4.3.2.4.2 Flight Simulation. - The post qualification testing of the endurance test unit shall consist of two additional flight simulations.

4.3.3 Test at Higher Levels. - Grumman uses the terms "flight ready" and "flight release" rather than "qualified" and "qualification" to describe subsystems test and higher level test to avoid confusion with the

4.3.3 (Continued)

generally accepted definition of qualification. Flight release does not connote demonstration of all taxi development requirements but only those associated with a specific flight. The ground test program proceeds through a series of logical steps to verify, within constraints, that the taxi will fulfill test requirements. These constraints are such that complete verification requires a test flight buildup before the mission is attempted. The successf 1 completion of each ground or flight test (except the last) releases a constraint on a subsequent test. At a point specified in the ground or flight plan, subsystems will be ranked as "flight ready" for a specific flight.

4.3.4 Acceptance Test. - Acceptance tests shall demonstrate that the equipment is representative of that equipment used in the qualification tests. Acceptance test conditions shall not be more severe than expected flight conditions and shall include factors of safety and margins of life. Contract end-item test is equivalent to an acceptance test.

4.3.4.1 Applicability. - Acceptance testing shall include all inspections and tests which are used as a basis for acceptance by the contractor. It may include tests on parts, components or subsystems. These requirements shall apply to the acceptance of hardware by the contractor from the subcontractors and to the acceptance of in-house produced hardware by the prime contractor.

4.3.4.2 Program Design. -

(a) Acceptance tests shall be performed on the equipment prior to delivery or upon completion of in-house manufacture.

(b) Acceptance tests of equipment are to be technically integrated with the manufacturing tests and the vehicle checkout so that the total program is designed to provide assurance that each contract end-item is capable of fulfilling its required end-use.

(c) Acceptance testing shall include functional tests, environmental exposures as required, and inspection techniques designed to:

(1) Locate manufacturing defects

(2) Locate handling damage

4.3.4.2 (Continued)

(c) (Continued)

(3) Provide assurance that no malfunction exists prior to shipping

(4) Provide assurance that equipments conform to their performance specification and other approved performance criteria

(d) Acceptance testing may include calibration or alignment or both

(e) The degree, duration, and number of tests and checks shall be sufficient to provide assurance that each equipment possesses the required quality and performance without degradation to the item

4.3.4.3 Procedure. -

(a) Selection of the acceptance test and checkout procedures shall be based upon the performance requirements of the item.

(b) Where possible, without degradation or destruction of the equipment, all normal, alternate, redundant, and emergency operational modes shall be demonstrated.

(c) The functional tests shall simulate end-use to the highest degree practicable without degradation of the operational or life characteristics of the item. Sampling plans may be employed when the tests are destructive or when the classification, characteristics, records, or non-critical application of the item indicates that less testing is required.

(d) If calibration of the equipment is necessary, then calibration and alignment shall be performed on the equipment in order to detect and adjust any variation in its accuracy prior to test. No adjustments shall be made during the performance of the test unless it represents a normal operating procedure.

4.3.4.3 (Continued)

(e) Final inspection techniques shall include visual examination, measurements, non-destructive tests, and special procedures such as x-ray, infrared, ultrasonics, and optical alignment where required.

4.3.4.4 Environments. -

(a) Each item shall be subjected to only those environmental tests necessary to reveal defects without overstressing or degradation.

(b) Selection of the environments and stress levels shall be based upon design specifications of end use requirements or both, and if available, the results of development and qualification tests may be used to modify these environments or stress levels.

(c) Environmental exposure shall be limited to the acceptance testing following manufacturing. Exposure to environments in excess of those specified for acceptance testing shall be cause for rejection.

4.3.4.5 Acceptance Basis. -

(a) The acceptance of each item shall be determined by a comparison between the acceptance test results and the applicable specification

(b) After completion of tests and inspections, execution of any repairs, modifications, or replacements shall necessitate a reinspection and retest to assure the acceptability of the change and its effects on related equipment. The extent of retest shall be determined jointly by the contractor and NASA or their delegated representatives.

4.3.4.6 Test Equipment. - The contractor shall provide for the selection, evaluation, approval, maintenance, and control of all inspection standards, gages, measuring and test equipment necessary to determine conformance with specification, drawing, and contract requirements.

4.3.5 Formal Engineering Acceptance Test (FEAT). - A formal engineering acceptance test will be performed on the vehicle prior to shipment, using ACE and other associated equipment, to verify compliance of operational and performance parameters with design requirements.

4.3.6 Electromagnetic Interference Test. - A test program to verify complicance to requirements imposed by paragraph 3.3.9 shall be conducted at all levels through the entire test program.

5 PREPARATION FOR DELIVERY

5.1 Preservation and Packaging. - Individual deliverable items shall be preserved and packaged for the maximum anticipated storage life. Preservation and packaging, in accordance with Grumman Specification LSP-41-009, shall maintain the cleanliness level established.

5.2 Packing. - Individual deliverable items shall be packed to withstand the selected mode of transporation and handling.

6 NOTES

10 APPENDIX (TBD)

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