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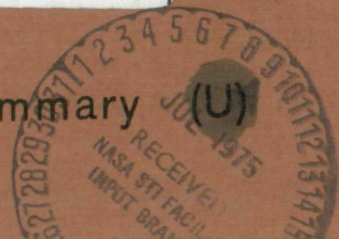
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Apollo Extension Systems—Lunar Excursion Module Phase B Final Report

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Vol. VI Taxi Design Analysis Summary



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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. VI Taxi Design Analysis Summary

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Contract No NAS 9-4983
ASR 378B

8 December 1965

Preface

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

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

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

The scope of this study included integration of the experimental payloads with the Shelter and Taxi, but did not include study of the inte-

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

The volumes which comprise this report are as follows:

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

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Note: Tables and Figures are grouped at the rear of each major subsection.

1. INTRODUCTION

This volume presents the results of the Taxi design analysis. The Taxi is a modified LEM which has the capability to land a crew of two on the lunar surface from a lunar orbit, survive the lunar environment for up to 14 days while the crewmen are supported by the LEM Shelter, and then allow the crew to ascend to lunar orbit and rendezvous with a Command and Service Module. The preliminary design data which are provided are intended to permit NASA to select a Taxi configuration.

The following vehicle-level ground rules were observed during this study. Additional subsystem-level ground rules and assumptions are included in this report where applicable.

- Minimum spacecraft modifications
- Maximum utilization of Apollo hardware
- Utilization of other qualified spacecraft hardware (Mercury, Gemini)
- Maximum utilization of and coordination with existing development studies
- Minimum modifications to Ground Support Equipment (GSE), Automatic Check-out Equipment (ACE), and Manned Spaceflight Network (MSFN)
- Where possible, qualification of modifications without flight testing
- Modifications and development to be compatible with spacecraft launch vehicle availability and launch schedules as defined in AES Reference Flight Schedule ML 65-1
- Mission time of up to 14 days lunar surface manned operations
- Consistency in design requirements and commonality of design approaches for the selected configurations for the Lab, Shelter and Taxi.

Because of the short performance period of this contract, it was necessary to select a single configuration at the mid-study point to form the basis for the preliminary Project Definition Plan (PDP). This configuration was described in the mid-study report and was called the "baseline" configuration. In the latter half of the study, this baseline configuration was modified as a result of NASA direction and/or continuing vehicle design studies. For this report, this more current configuration is called the "recommended" configuration.

The technical discussions in this volume are based upon the recommended configuration; however, any differences between the two configurations are described with appropriate explanations in the individual subsystem discussions. Also included, where applicable, are discussions of the "alternate" configurations considered and the potential modifications per flight.

2. CONFIGURATION SUMMARY

2.1 INTRODUCTION

This section summarizes the recommended and baseline Taxi configurations, as well as the subsystem alternates which were studied during the contract period. The definition of these configurations is based on the following:

- NASA/MSC ground rules as defined in the Work Statement and Blue Book
- Analysis of NASA/MSFC mission descriptions
- Results of Phase A studies, Contract NAS 9-3681
- Subsystem and system studies
- Vehicle design and integration analyses.

The vehicle level ground rules that were observed during the study are defined in Section 1. The mission analysis and supporting studies are described in detail in Sections 3 through 6.

2.2 ASSUMPTIONS

Gross vehicle design assumptions used during the study are summarized by subsystem in Table 2.2-1. These assumptions are based upon the established ground rules and the following mission related requirements:

- Operate in conjunction with the Shelter
- Perform a day or night mission

2.3 RECOMMENDED CONFIGURATION

The recommended Taxi (Fig. 6.1-7) is a LEM with modifications needed to meet the extended staytime on the lunar surface. The specific subsystems requiring modification are environmental control, electrical power, and the structural changes associated with these modifications. Minor modifications have also been made to the micrometeoroid shielding, crew provisions and communications. All modifications, or changes, with reference to the present LEM configuration are listed in Table 2.3-1, and are described in detail in Sections 5 and 6. Summary descriptions are presented in the following paragraphs. A Level 1 functional block diagram of the recommended Taxi subsystem interfaces is shown in Fig. 2.3-1.

2.3.1 Environmental Control

During the 14-day quiescent storage period, the temperature variations of the various components and subsystems within the vehicle will be controlled by the heat transport section, using both passive and active techniques capable of meeting the demands of either a day or night mission. The allowable ascent stage structural temperature limits, imposed by propellant considerations, are +40 to +90°F. The internal structure is thermally coupled to the propellant tanks and the life support expendables to help stabilize the interior temperatures. The ascent stage is thermally decoupled from the environment by insulation and the use of exterior surfaces having the proper radiation properties.

Passive thermal control of the Taxi is the same as LEM with the addition of a blanket of insulation to cover the top docking tunnel and insulated reflectors applied to the interior of the windows. These will be positioned by the crew prior to the quiescent storage.

The active thermal control system consists of the LEM water boiler, plus additional water for day missions, and a RTG waste heat transfer system for night missions. The heat pipe, required for transferring the RTG waste heat to the cabin, is a part of the Taxi recommended configuration. The RTG, however, is carried on the Shelter for use during the 3-month storage period, and later is transported to the Taxi by the crew and connected into the heat pipe system.

2.3.2 Electrical Power

The night mission represents the critical requirement for the Taxi. The recommended design approach is to use three modified descent batteries each having a 12-kw-hr capacity and high rate capability, and a 50-w RTG for the quiescent lunar stay phase. Two ascent batteries are used for the ascent phase of the mission as in the present LEM configuration.

2.4 BASELINE CONFIGURATION

The baseline configuration is summarized in Table 2.3-1 and listed as changes to the LEM configuration. It is essentially identical to the recommended configuration.

2.5 ALTERNATE CONFIGURATIONS

In arriving at the recommended Taxi configuration, alternate methods of achieving the mission requirements were studied. The candidate systems studied are summarized by subsystem in Table 2.5-1.

2.5.1 Electrical Power

As a means to reduce weight, zinc-oxygen (ZOX) batteries were considered as an alternate to the silver-zinc batteries of the recommended configuration. The ZOX batteries have the capability of delivering 50% higher energy per unit weight than the best silver-zinc batteries. By use of this new type of battery, a potential weight savings of 160 lb may be achieved. Although the ZOX batteries are in the early state of development, it appears that the Taxi schedule would be compatible with the time required for their development and qualification. Thus, it is felt that their use should be further investigated during the Phase C effort, when a decision could be made on whether to develop them as a significant weight saving alternate.

2.5.2 Environmental Control

As an alternate to the system of transferring the RTG waste heat to the cabin by an intermediate fluid heat transfer loop (heat pipe), a direct radiation system was studied. With this system, the RTG is mounted on top of the descent stage in an insulated enclosure, one side of which is the ascent stage pressure vessel. The amount of heat transferred to the cabin is controlled by a hinged panel.

The RTG heat pipe system of transferring waste heat to the cabin was recommended, because of the physical consideration involved in transferring the RTG from the Shelter to the Taxi. With the direct radiation system, the RTG must be installed at the top of the descent stage and will require an elaborate lifting mechanism. The heat pipe system requires the astronaut, standing on the lunar surface, to install the RTG into a side bay on the descent stage.

2.5.3 Guidance, Navigation and Control

The recommended method of initiating status transmissions during storage is with a time sequencer. Two alternates are suggested: use of LGC standard frequency output to time the transmissions, or use of an Earth uplink. The time sequencer was selected because of simplicity, light weight, low-power consumption, and no dependence upon any system other than power.

2.5.4 Reaction Control System

The RCS performance and propellant requirements for the Taxi are essentially the same as the present LEM. However, because of the extended quiescent stay period, the electrical energy required to maintain the cluster temperature by the present electrical heaters is excessive. The recommended configuration is to allow the thrusters to cool down; then during the pre-launch lunar checkout, large electrical heaters are turned on to thaw the propellant feed-lines and bring the thrusters up to operating temperature. This requires the addition of larger heaters as indicated in Table 2.3-1.

As an alternate to this system, cluster covers were investigated as a possible approach to maintaining the thruster temperature by reducing the amount of heat lost by radiation. These were not selected, because of the inaccessibility of the clusters for manual emplacement and the complexity of automatic devices. In addition, the weight of the covers is high when compared to the additional battery weight required for the recommended cluster heaters.

2.5.5 Communications

The recommended communication configuration includes a modification to change the operating frequency of the Taxi S-band transceiver, power amplifier, and diplexer. This is required to prevent interference between the Earth, Taxi, CSM, and Shelter. As an alternate to this concept, two approaches have been considered:

- Time sharing transmission
- Right and left circular polarization of Taxi and Shelter antennas.

The modification to change the operating frequency of the Taxi was recommended, because this allows for the most versatile operation of each spacecraft communication system and assures no mutual interference of transmission to the Earth.

2.6 POTENTIAL MODIFICATIONS PER FLIGHT

Two potential per-flight modifications exist which are dependent upon the time phasing of the mission; lunar day or night. For an all-day mission, it is possible

Table 2.2-1

TAXI SUBSYSTEM ASSUMPTIONS

Subsystem	Assumptions
1.0 Structure	<ul style="list-style-type: none"> ● LEM hardware components to be retained in their original locations. ● No change to LEM adapter (SLA). ● LEM/SLA pick-up structure to be preserved.
2.0/3.0 Stabilization & Control/Navigation & Guidance	<ul style="list-style-type: none"> ● Taxi will be able to land within 1,000 ft of Shelter. ● IMU must be maintained at $135 \pm 5^\circ\text{F}$ during quiescent phase. ● ASA must be maintained between 105 & 120°F during quiescent phase. ● Status data transmissions controlled by a time sequencer.
4.0 Crew Provisions	<ul style="list-style-type: none"> ● Food required for three meals, 5.21 lb, from separation to rendezvous, based on 3,000 K-cal/man/day. ● No food consumed on lunar surface. ● Soft suits, liquid-cooled garments, and backpacks for each astronaut worn during lunar landing are used to support crew until they enter Shelter; and, where applicable, during Shelter mission.
5.0 Environmental Control	<ul style="list-style-type: none"> ● RTG waste heat transferred to Taxi cabin during night quiescent phase. ● Window and hatch covers required to reduce heat leak. ● Exterior surface will have a coating with radiation properties of 0.20 absorptance and 0.25 emittance. ● Life support Taxi provides 43 man-hr (incl. 9-hr orbital contingency & approx. 4 hr of EVA).
6.0 Landing Gear	<ul style="list-style-type: none"> ● Landing velocity envelope identical to LEM.
7.0 Instrumentation	<ul style="list-style-type: none"> ● Status data are periodically transmitted to Earth on S-Band; abort warning relayed to Shelter. ● Taxi checkout in lunar orbit & post-landing will be similar to LEM.
8.0 Electrical Power	<ul style="list-style-type: none"> ● Shelter 50-watt RTG is available for use on Taxi during the 330-hr quiescent period.
9.0 Propulsion	<ul style="list-style-type: none"> ● Descent stage propellant tanks are to be depressurized after landing. ● Descent trajectory identical to LEM.
10.0 Reaction Control	<ul style="list-style-type: none"> ● RCS requirements same as LEM except for extended stay time storage. ● Propellant lines can be allowed to freeze during quiescent storage.

to off-load one descent stage battery because of the reduced energy requirements. However, this is not recommended, because of reliability considerations. For other mission times, approaching the all-night mission, the water quantity which has been sized for the most severe mission (all-day) can be off-loaded. The payload capability made available by this off-loading could be used for items such as film for the Shelter scientific missions.

Table 2.2-1 (cont.)

Subsystem	Assumptions
11.0 Communications	<ul style="list-style-type: none">● Transmit vehicle status data only (no experiment information).● No TV requirement.● Taxi landing site within 1,000 ft of Shelter; therefore, EVA communications will use in-flight VHF antenna.
12.0 Controls & Displays	<ul style="list-style-type: none">● Pre-separation, post-landing & prelaunch checkout are assumed not to require any additional controls & displays.

Table 2.3-1

TAXI RECOMMENDED/BASELINE CONFIGURATIONS

Vehicle Change w/re- spect to LEM Subsystem	Recommended			PDP Baseline Configuration		
	Removed	Modified	Added	Removed	Modified	Added
1.0 Structure		oIncrease Micro- teorite Shielding oWater Tank Mount- ing Supports (con- ductivity change)	oWindow Covers oTop Hatch Cover oBattery Supports		oIncrease Micro- meteorite Shielding oWater Tank Mounting Supports (conductivity change)	oWindow Covers oTop Hatch Cover oBattery Supports
2.0 Stab Cont			oTime Programmer for Status Data Transmission			oTime Programmer for Status Data transmission
3.0 Nav Guid						
4.0 Crew Prov	oTwo PLSS Batteries o4 lb Food oThree PLSS LiOH Cartridges				oPLSS Calibration Unit oTwo PLSS Batteries o4 lb Food oThree PLSS LiOH Cartridges	
5.0 Environ Cont	oOne LiOH Cartridge o24 lb O2 from Descent Tank		oWater Added for Day Mission oHeat Pipe for use with RTG oBattery Cooling/IMU- ASA Bypass. oWater tank heaters		oOne LiOH Cartridge o24 lb O2 from Descent Tank	o20 lb Water Added for Day Mission oHeat Pipe for Use with RTG oBattery Cooling/IMU- ASA Bypass. oWater tank heaters
6.0 Ldg Gear						
7.0 Instrum	oLEM Scientific Equipment				oData Storage oLEM Scientific Equipment	
8.0 Elec Pwr	oDescent Batteries		oProvisions for RTG oThree Modified Desc Batteries (12.0 kw-hr)		oDescent Batteries oThree Descent Electri- cal Control Assys	oProvisions for RTG oThree Modified Desc Batteries
9.0 Propulsion			oThree Vent Valves to Descent Plumbing			oThree Vent Valves to Descent Plumbing
10.0 Reaction Cont			o250 W Heater to each RCS Cluster			o250 W Heater to each RCS Cluster

Table 2.3-1 (cont.)

Vehicle Change w/re- spect to LEM Subsystem	Recommended			PDP Baseline		
	Removed	Modified	Added	Removed	Modified	Added
11.0 Comm	oEVA Antenna oTelevision			oEVA Antenna oTelevision		
12.0 Cont & Disp	oOne Battery Display		oRTG displays		oSlight Modifi- cation	

Table 2.5-1

TAXI SUBSYSTEM ALTERNATIVES

Subsystem		Candidates
1.0	Structure	<ul style="list-style-type: none"> Structural provisions to accommodate alternates.
2.0	Stab & Control	<ul style="list-style-type: none"> Status transmissions initiated by Time Sequencer vs. LGC time sequencing or Earth up-link.
3.0	Nav & Guid	
4.0	Crew Prov	
5.0	Environ Cont	<ul style="list-style-type: none"> Transfer RTG excess heat to cabin via heat pipe vs. direct radiation.
6.0	Ldg Gear	
7.0	Instrum	
8.0	Elec Pwr	<ul style="list-style-type: none"> Modified LEM descent batteries & RTG vs. ZnO₂ batteries & RTG. Transfer RTG from Shelter vs. carry own RTG.
9.0	Propul	
10.0	Reaction Cont	<ul style="list-style-type: none"> Thermal control of RCS clusters with 250-watt heaters vs. adding thermal cluster covers.
11.0	Comm	<ul style="list-style-type: none"> Non-interference of transmission by changing frequency of S-band equipt vs. right & left circular polarization of S-band antennas on Taxi & Shelter.
12.0	Cont & Disp	

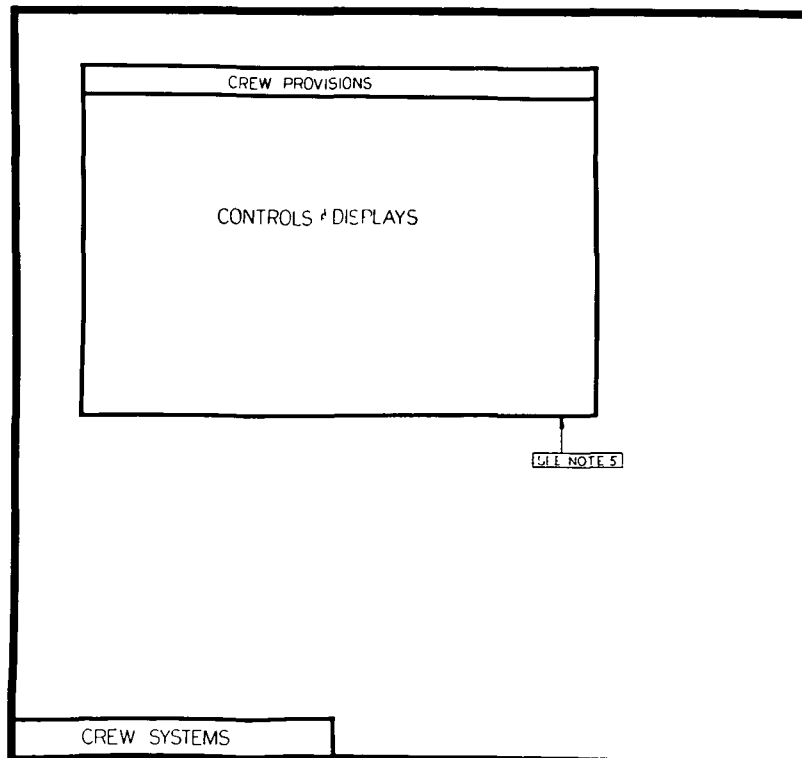
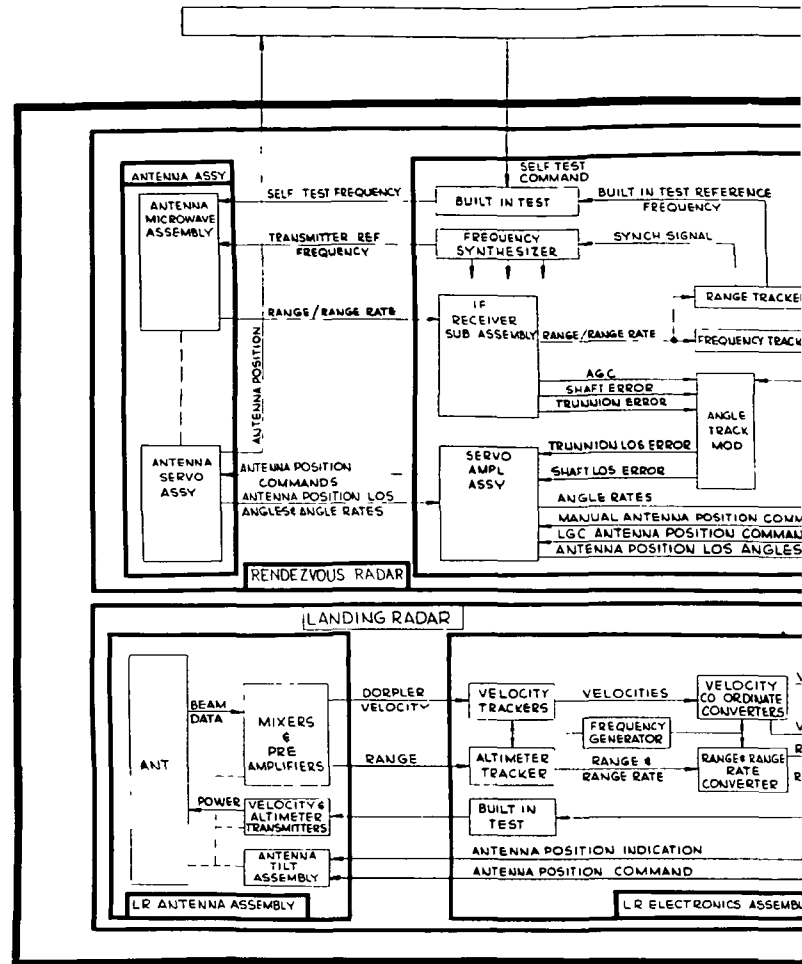
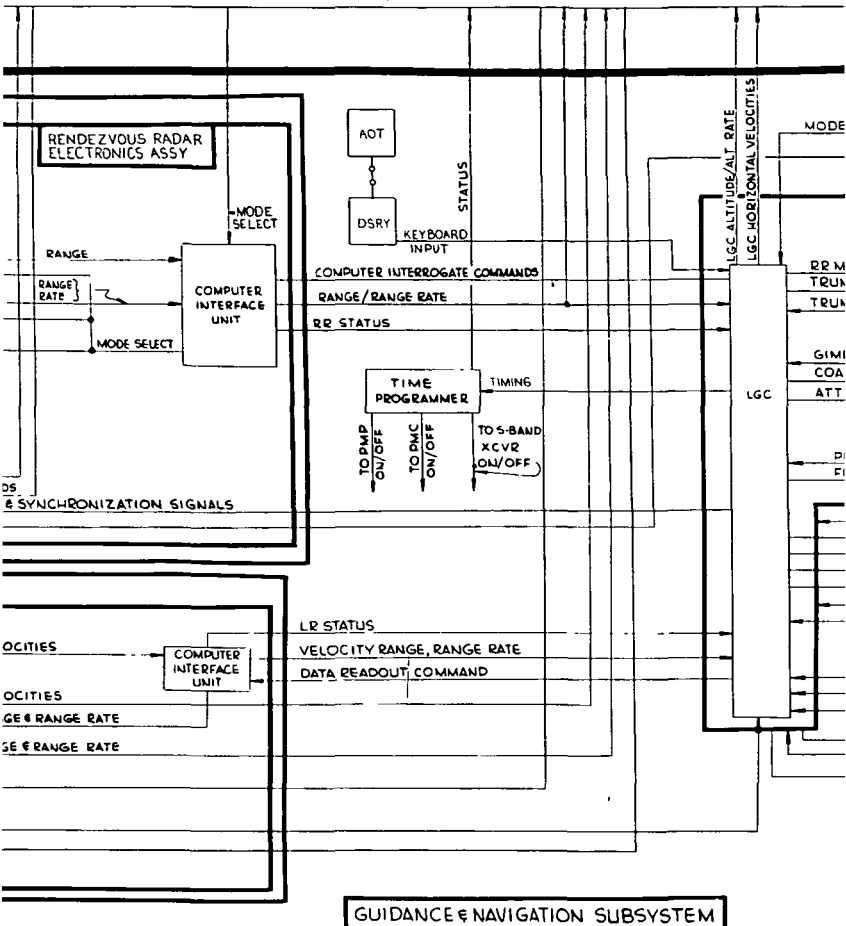
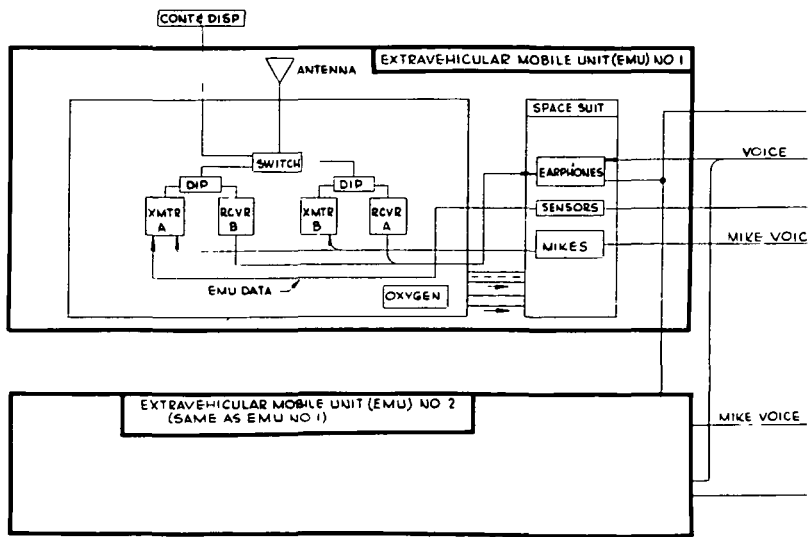


Fig 2.3-1A
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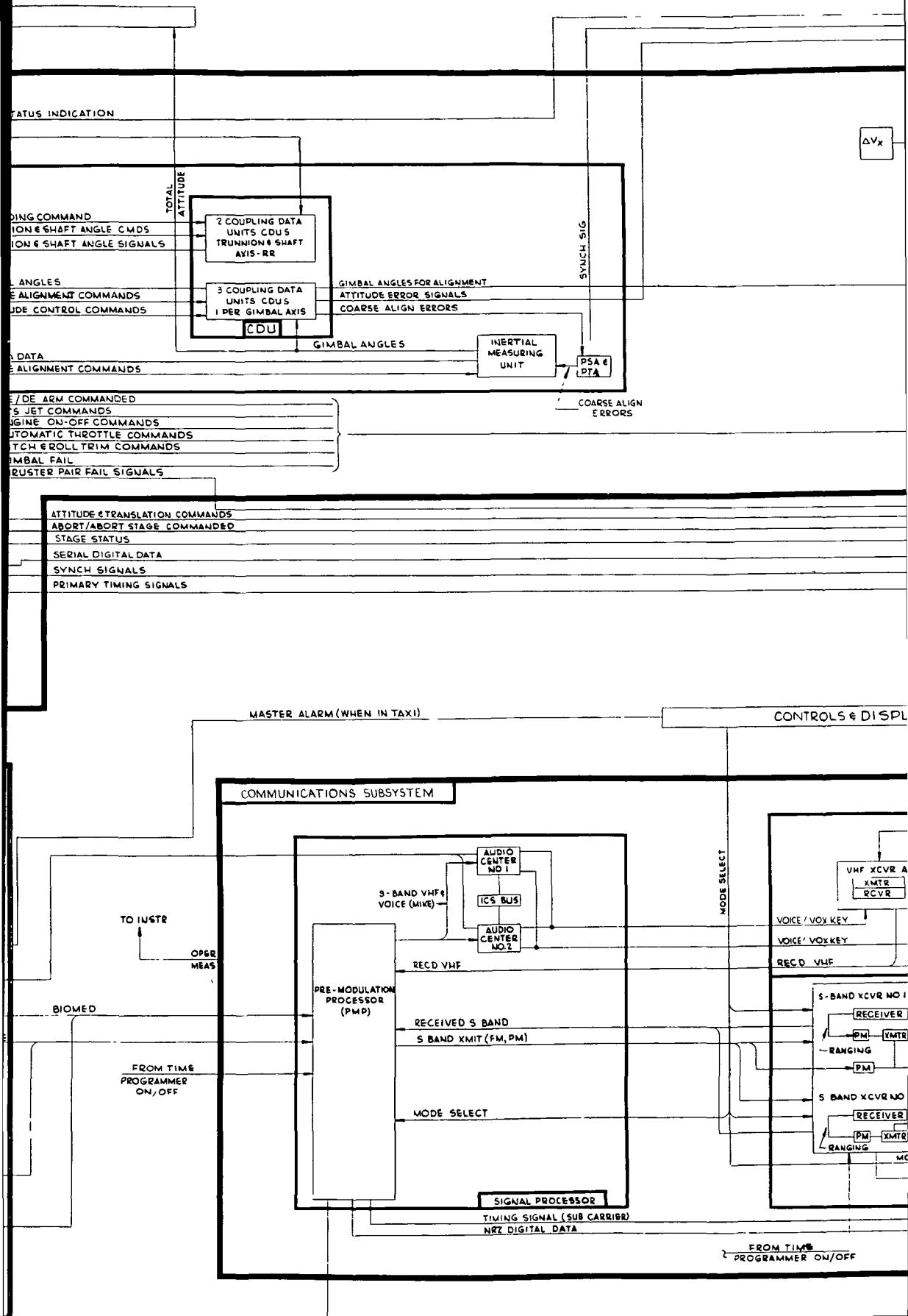
CONTROLS & DISPLAYS



GUIDANCE & NAVIGATION SUBSYSTEM

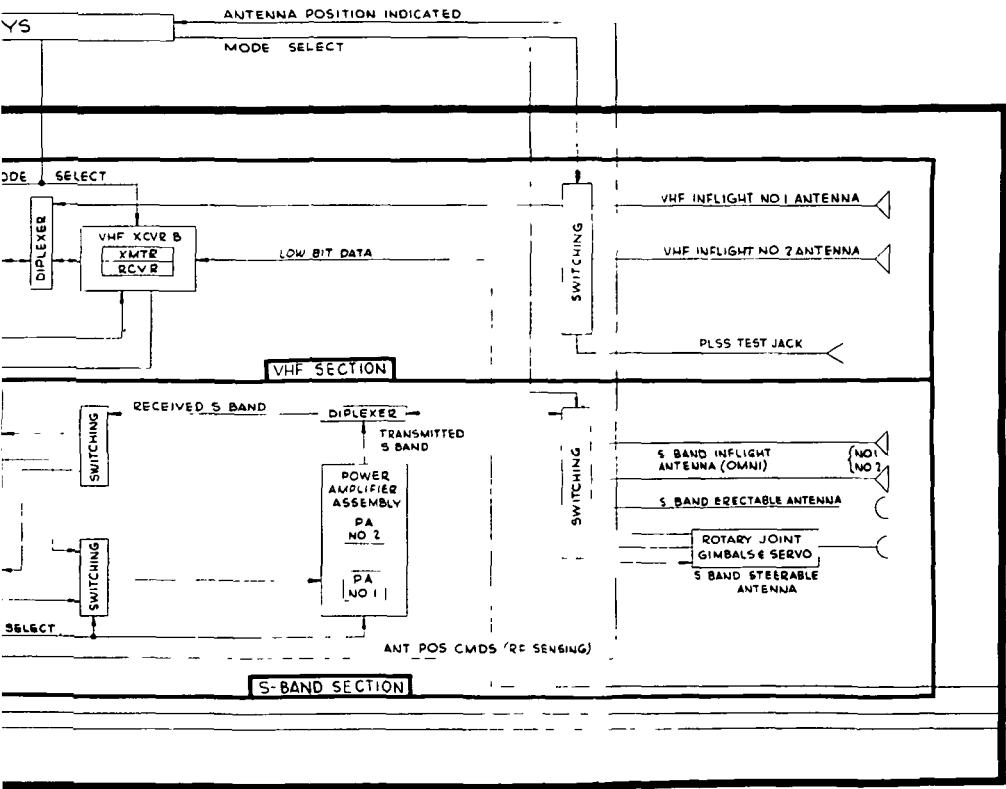
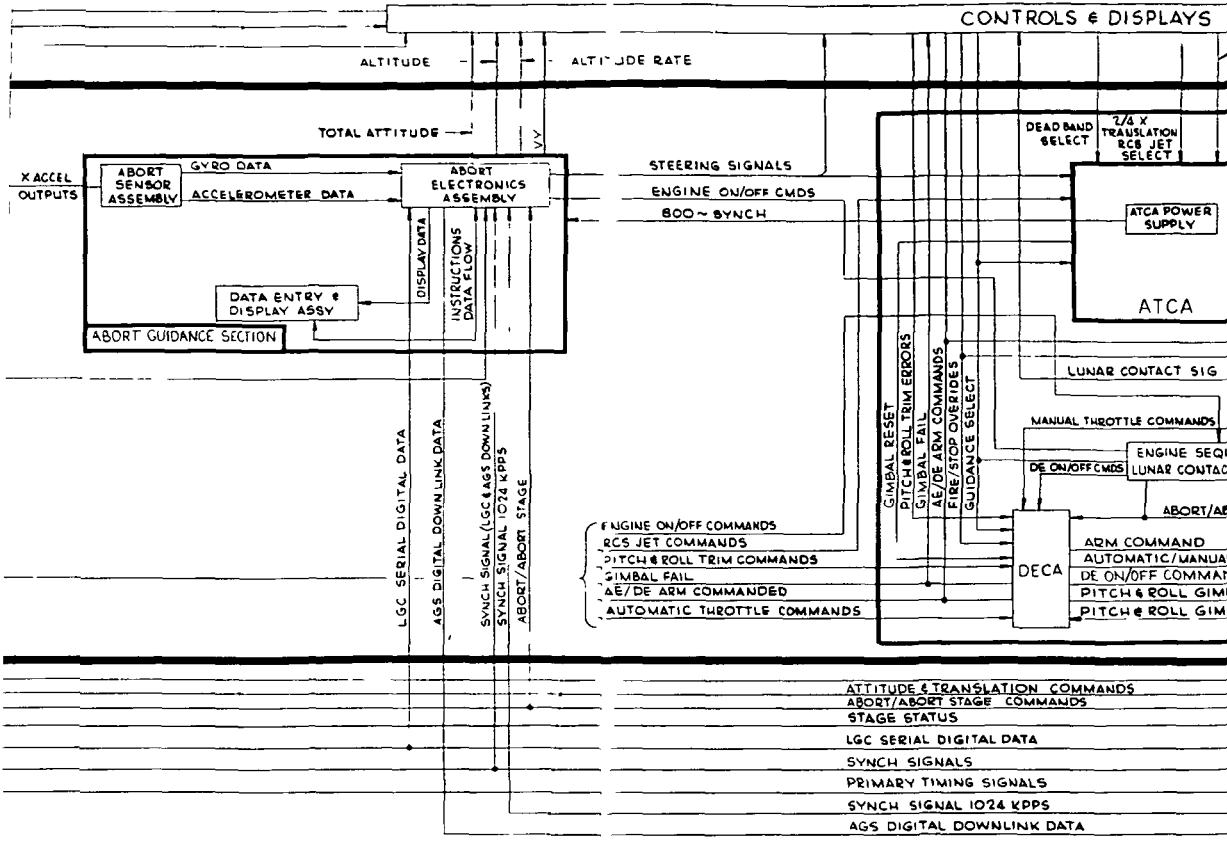


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2-3-1 A
 (3)

CONTROLS & DISPLAYS



2.3 - 1 A
 (4)

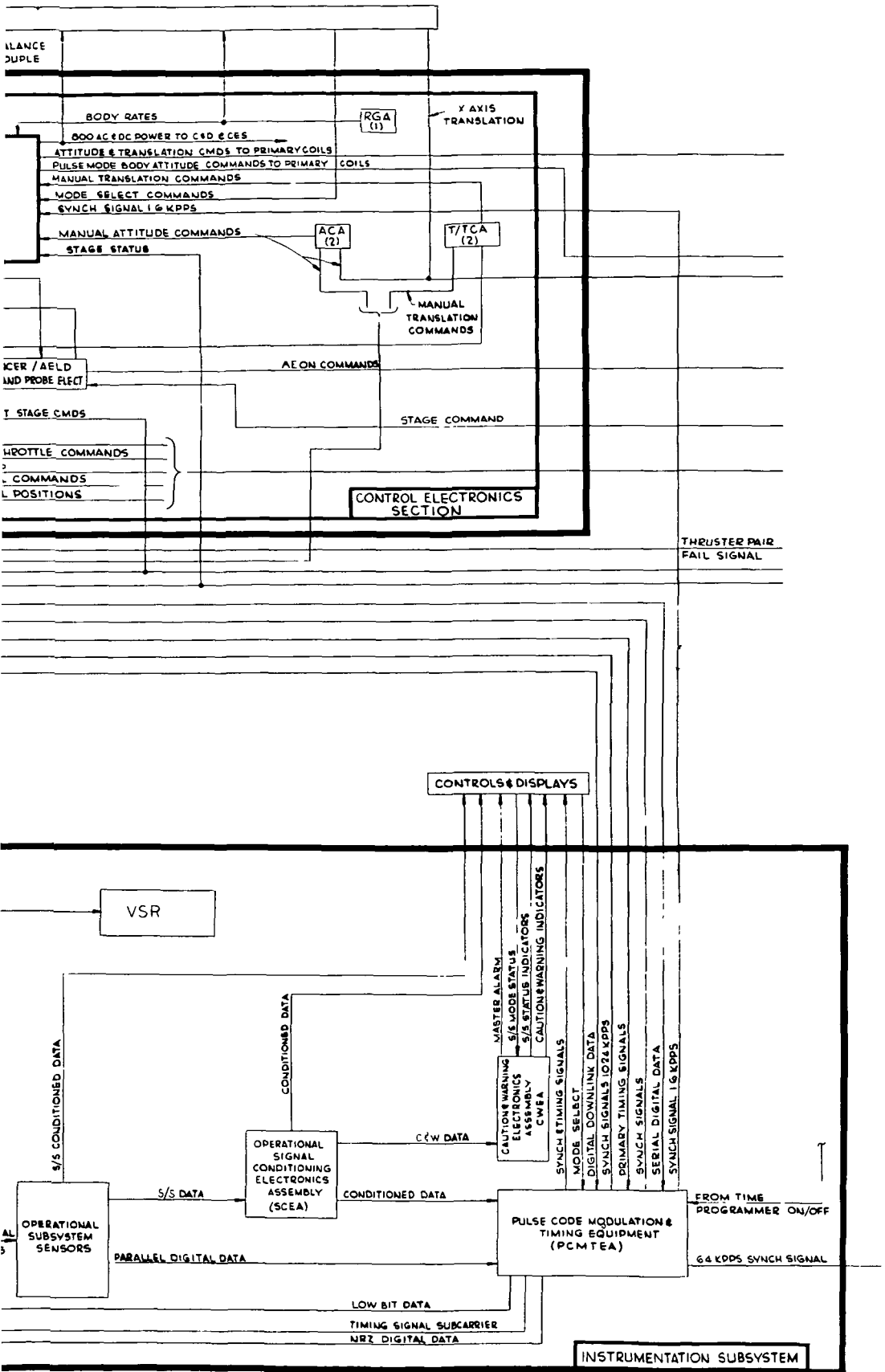
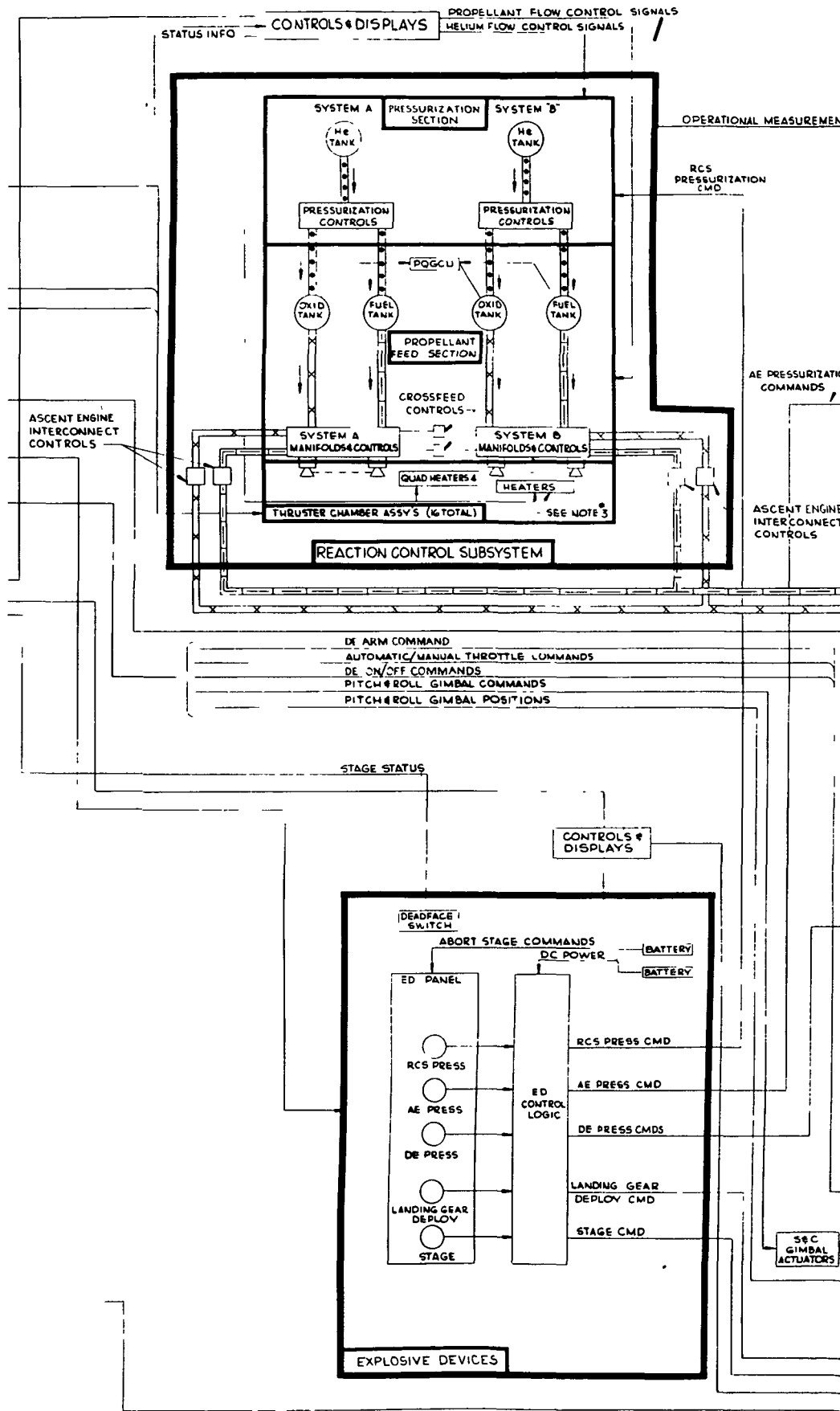


Fig. 2.3-1 Taxi Level I Functional Block Diagram (Sheet 1 of 2)

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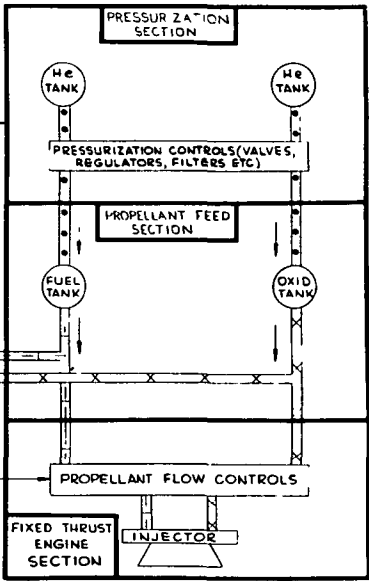


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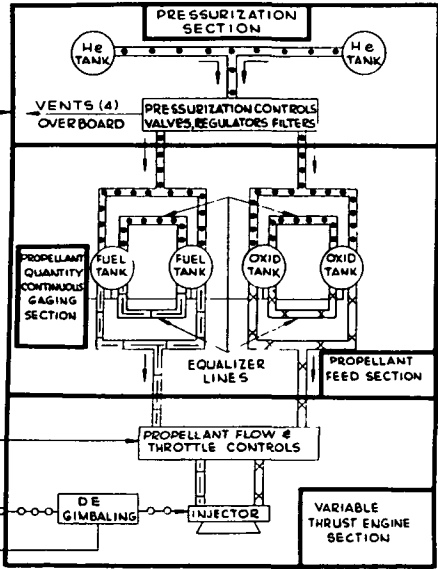
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OPER MEAS

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ASCENT



DESCENT

He FLOW CONTROL SIGNALS

STATUS INFORMATION

CONTROLS & DISPLAYS

He FLOW CONTROL SIGNALS

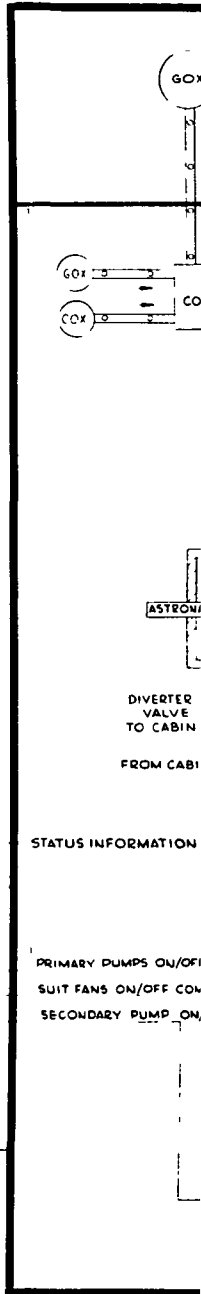
STATUS INFORMATION

CONTROLS & DISPLAYS

CONTROLS & DISPLAYS

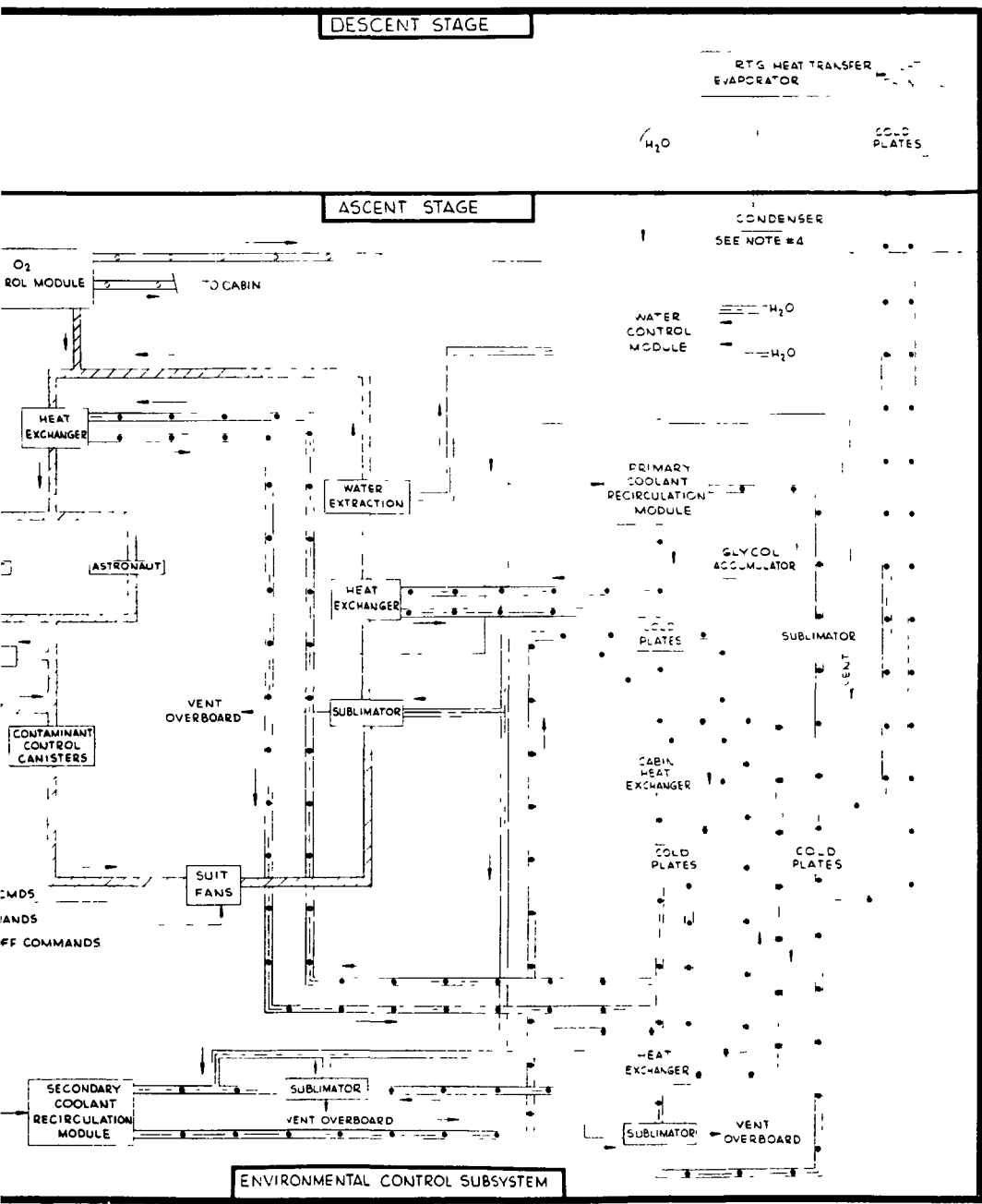
TO INSTR

OPER MEAS



- LANDING GEAR DEPLOY COMMAND
- STAGE COMMAND
- LANDING GEAR LOCKED & DEPLOYED
- G 4 KPPS SYNCH SIGNAL

23.1.B
 (2)

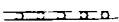

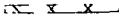


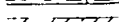




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SYMBOLS

-  OXYGEN LINE
-  WATER
-  OXIDIZER
-  COOLANT
-  HELIUM
-  FUEL
-  CONDITIONED OXYGEN LINE
-  MECHANICAL LINKAGE

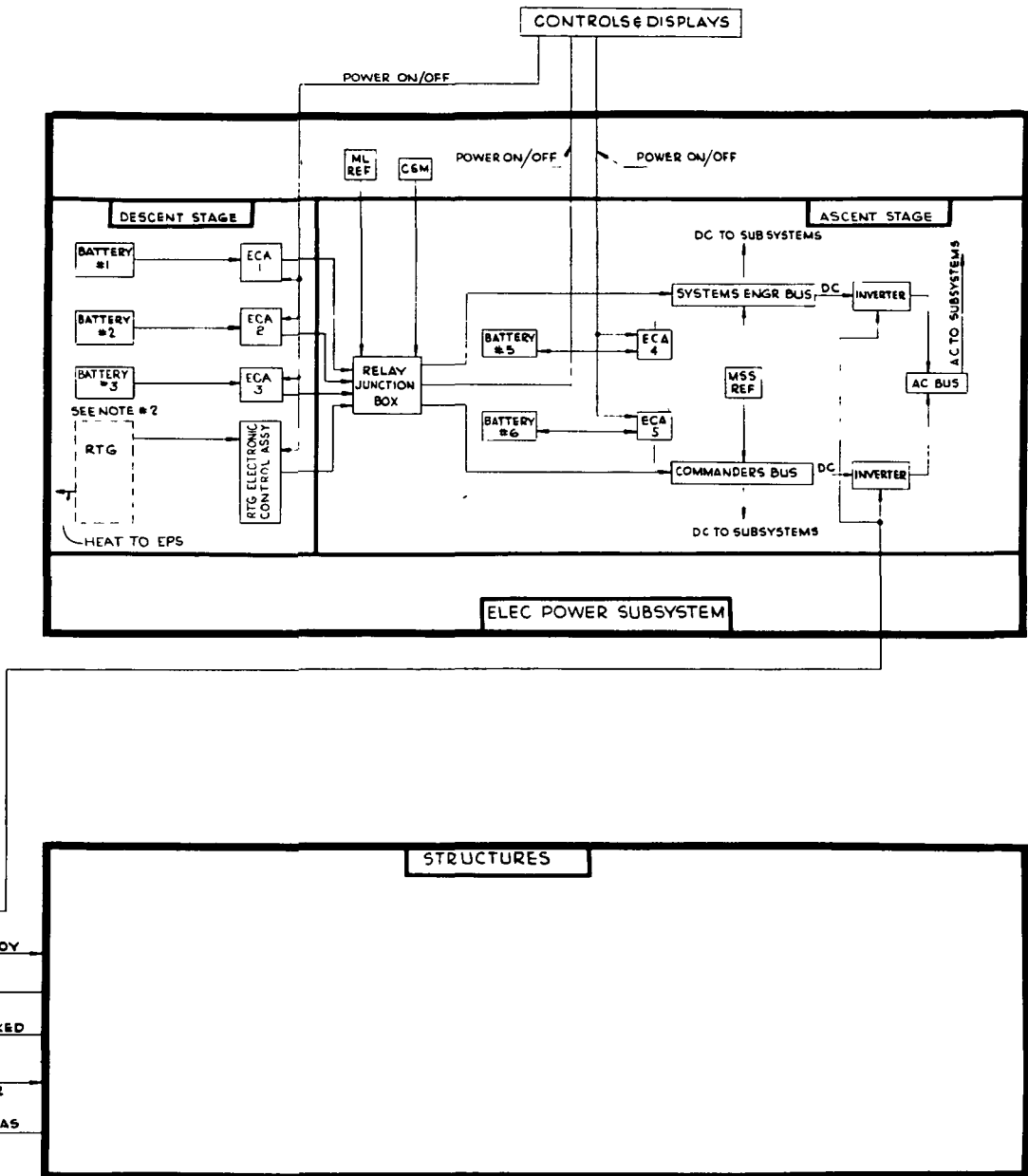


Fig. 2.3-1 Taxi Level I Functional Block Diagram (Sheet 2 of 2)

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3. MISSION ANALYSIS

3.1 GROUND RULES

The following NASA ground rules are unique to the mission analysis:

- Characteristics of the Shelter and Taxi missions shall be assembled and summarized in coordination with NASA/Marshall Space Center
- NASA will define the experiments which shall be integrated with the Shelter/Taxi
- Taxi return payload design goal is 250 lb.

3.2 ASSUMPTIONS AND BACKGROUND DATA

The mission related assumptions used in the Taxi mission analysis are as follows:

- Shelter is landed and stored on the lunar surface for a period of up to 3 months before the Taxi is launched
- Shelter capability to support the lunar mission will be verified by Earth command before the Taxi is committed to a lunar landing
- Taxi will land within 1000 ft of the Shelter, aided by a transponder
- All Extra Vehicular Activity (EVA) is supported by the Apollo Portable Life Support System (PLSS)
- Only one crewman will be permitted on the lunar surface at a time, except for emergency situations
- All EVA will be monitored by the crewman remaining in the spacecraft (Taxi or Shelter)
- All critical Taxi subsystems will be monitored by MSFN during the quiescent storage
- Taxi mission profile from Earth countdown to lunar touchdown is the same as LEM.

The Taxi mission profile is similar to that of the LEM except for the requirement to remain up to 14 days on the lunar surface. During this 14-day period, the Taxi will be in a quiescent storage mode for approximately 330 hr and in an operational mode for about 6 hr.

The Taxi/Shelter mission can be divided into five phases:

- Shelter prelaunch to lunar touchdown
- Shelter storage
- Taxi prelaunch to lunar touchdown
- Lunar exploration
- Taxi ascent to CSM rendezvous and Taxi jettison.

The Taxi is involved in the last three phases, i.e., starting with Taxi prelaunch up to jettison of the Taxi ascent stage in lunar orbit at the end of the mission. The sequence of events from Taxi prelaunch to lunar touchdown (Table 3.2-1) have been assumed to be the same as the LEM mission. Forty-eight hours prior to Taxi left-off, the Shelter is remotely activated to full operational status. A check

of all subsystems is made to arrive at some specified confidence level that the Shelter is operational before committing the Taxi to the mission.

The lunar exploration phase is assumed to start after Taxi touchdown. The sequence of events for the Commander and Systems Engineer is shown in Table 3.2-2 for Day 1 of the exploration phase. Following the post-landing checkout and status check, a 20-min rest period is provided during which the crew eats and performs personal hygiene. Preparation for Shelter inspection largely involves the checkout of the suits and PLSS units. The Systems Engineer leaves the Taxi and performs a walk-around inspection and erects the S-band antenna. He then walks to the Shelter in an estimated 20 min. This traverse is monitored visually by the Commander who remains in the repressurized Taxi. Therefore, the preferred landing orientation of the Taxi is with the windows facing the direction of the landed Shelter. After the Systems Engineer arrives at the Shelter, he completes activation of the ECS and connects his suit to the cabin suit circuit assembly. A 1.25-hr interval has been allocated for a go/no-go decision by the Systems Engineer who performs the Shelter inspection.

Upon receipt of a go decision, the Commander secures the Taxi for quiescent storage and activates the time sequencing system for status monitoring. After egressing the Taxi, his walk to the Shelter is monitored by the Systems Engineer. The Commander then unloads, activates, and checks out the Local Scientific Survey Module (LSSM) with assistance from the Systems Engineer, if needed. The RTG unit, requiring special handling and stowage provisions, is removed from the Shelter descent stage compartment and transported via LSSM to the Taxi, where it is installed. The RTG unit provides heat and electrical power required for the Taxi quiescent storage phase. After re-entering the Taxi to verify satisfactory RTG operation, the Commander drives the LSSM back to the Shelter where preparation is made for commencing the scientific program.

On the 14th day of the exploration phase (Table 3.2-3), the Systems Engineer drives the LSSM and experiment return payload to the Taxi. After performing a visual walk-around inspection, he enters the Taxi and activates the ECS. The Systems Engineer monitors the Commander's return to the Taxi; they together transfer the return payload to the Taxi for stowage. One hr is allotted for systems activation and 1 hr for prelaunch checkout. Taxi lift-off occurs at the completion of the 14th day. The last phase of the mission, Taxi ascent to Taxi jettison (Table 3.2-4), is the same as the LEM.

3.3 RECOMMENDED CONFIGURATION MISSION REQUIREMENTS

3.3.1 Life Support Requirements

The ECS expendable requirements for the recommended configuration are reduced appreciably from the LEM because of the reduced life support time needed for the two crew men. Table 3.3.1 lists the cabin support time intervals, and Table 3.3-2 lists the portable life support time intervals for the entire mission as computed from the mission timeline. The total man hours of life support is arrived at as follows:

	Life Support (man-hr)
Cabin:	20.8
PLSS:	4.3
Orbital Contingency:	<u>18.0*</u>
	43.1

3.3.2 Repressurization Requirements

Although only one repressurization of the Taxi cabin is essential (this on the 14th day for the return mission), the time interval of 2 hr 28 min between egresses requires a second cabin repressurization of the 1st day. This permits a shirt-sleeve environment for the Commander and reduces his energy expenditures. This reduction is important in view of the activities required of him upon leaving the Taxi. Two repressurizations are therefore recommended at this time.

3.4 BASELINE CONFIGURATION MISSION REQUIREMENTS

The mission requirements for the baseline configuration are the same as for the recommended configuration.

3.5 ENVIRONMENTAL PROTECTION REQUIREMENTS

3.5.1 Meteoroid Hazard Evaluation

The meteoroid environment used is that defined by LEM Specification LSP-470-1. The sporadic flux is presented as an average isotropic flux that is constant throughout the regions of space applicable to the AES missions. It is modified only by the planetary shielding factor determined by each mission trajectory. Shower meteoroids are not included.

The secondary meteoroid flux ejected from the lunar surface by the sporadic meteoroids is defined only for vehicles resting on the surface. Vehicles in descent or ascent or in low lunar orbits do not encounter secondary meteoroids.

3.5.1.1 Approach

LEM Specification LSP-470-1 presents criteria for defining the meteoroid protection provided by single- and double-skin areas against both primary (sporadic) and secondary meteoroids. It does not contain criteria for handling multi-skinned configurations and double skins with small separation distances. Such situations were conservatively analyzed by omitting the thinnest skins until the configurations fit the LEM specification. The analysis was performed for the recommended Taxi configuration with no meteoroid shielding assumed in addition to that provided by LEM.

* Ref: Contract Technical Specification for LEM System, LSP-470-1A, 7 June 1965.

Approximations were made to estimate the meteoroid protection provided by the Taxi structure that is composed of spherical and cylindrical shapes enclosed by flat surfaces. Since the penetration mechanics are very sensitive to the distance between the bumper skins, the critical areas exposed to meteoroids by spherical and cylindrical tanks were divided into two sections: the cap area which is an area of the tank closest to the bumper; and the doughnut area which is a section of the tank area adjoining the cap (Fig. 3.5-1). The distance from the bumper to the point of closest approach in each area was used to ensure conservative calculations. The critical areas were also sized by their cone of exposure to the isotropic flux. A very conservative 2π solid angle was applied in most cases. A nominal critical area was added to include the effect of such miscellaneous items as black boxes, wiring, and tubing. Though the ascent and descent stages were utilized for reciprocal shielding, the SM was not included in the calculations because of the long durations in the mission profile where the Taxi and CSM are separated.

3.5.1.2 Computer Program

The Taxi basic design was described in terms of critical areas, exposure periods, skin thicknesses, and skin separation distances, and the information fed into a computer program which contained the LEM protection criteria. When a particular combination of skin thickness and separation distance for a specified critical area resulted in a bumper skin too thin to melt the meteoroid, the size of the meteoroid was reduced to the melting point and the probability of such a particle impacting during the mission was determined.

The program evaluated both an existing vehicle structure for the probability that it will not be damaged by meteoroids during its mission, and determines those locations where shielding would be most profitably applied.

3.5.1.3 Micrometeoroid Hazard Results

The Taxi configuration was evaluated for a 14-day stay on the lunar surface. The results are listed below:

	Primaries	Secondaries	Total
Crew Safety	0.999388	0.995512	0.994900
Mission Success	0.999327	0.994620	0.993947

Crew safety was defined as the probability that no fatality would occur among the crew, and mission success was defined as the probability that the mission will not be aborted by a micrometeoroid penetration. Events that are specified as causes of a crew fatality are:

- Puncture of a manned, pressurized cabin
- Penetration of more than 25% of a high-pressure tank wall thickness.

It was assumed that the descent stage propellant tanks would be vented after the landing is accomplished, and therefore they would not constitute an explosion hazard. The cabin was considered to be a crew safety item during the half day it is manned.

Events that are specified as cause for aborting the mission are:

- Puncture of the cabin while manned, whether pressurized or not
- Penetration of more than 25% of a pressure tank wall thickness.

A puncture of the Taxi cabin while the men are in the Shelter will not cause an abort, because the men will not be aware of the penetration. Therefore, the cabin is exposed for only a half day in the mission success considerations. Because the secondaries are the major cause of the low probability of mission success, considerable gains can be obtained for minimum shielding weight. The reason for this is the prescribed lack of any bumper effect for low-velocity particles. As a result, the penetrating capability of a secondary meteoroid is mainly dependent upon the thickness of the back-up material.

About 20% of the probability of penetration by secondaries was contributed by the three water containers, because one-quarter of the tank thicknesses was used. If the full tank thickness can be used for this low-pressure container, the total reliability for mission success will reach 0.995. If patches of additional shielding are placed on the small cap areas of the RCS fuel and oxidizer tanks, the mission success will reach 0.997. The effects of the water tank thickness change on the primaries will be small, because of the large distance of the descent stage water tank from the bumper skin. By adding additional shielding of the patch type to the cap areas of the ascent stage propulsion tanks, the crew safety reliability could be raised to 0.996.

3.5.2 Radiation Hazard Evaluation

The major radiation hazard for lunar missions comes from the high-intensity solar flare events that are encountered near solar maximum. The statistical model and spectrum used for AES analyses is the Apollo environmental model documented in LPS 470-1A.

The two potential radiation problems that have to be considered are:

- A biological dose to the crew in excess of the allowable emergency skin dose of 500 rad
- Degradation in equipment performance because of prolonged exposure to space radiation.

The Taxi mission was analyzed with respect to the potential radiation hazard. It is presently concluded that there is no requirement for additional radiation protection for the Taxi. It may be necessary to raise the Taxi requirement, if it were decided to thicken the Shelter cabin structure to provide additional radiation protection for the Shelter crew on the lunar surface. The Taxi requirement then changes, because the Shelter crew could now survive more intense solar flares without aborting, thus possibly necessitating additional protection for the Taxi electronic systems. In that event, a detailed analysis of possible equipment degradation in the Taxi during 14 days of lunar storage would have to be performed.

A situation that would result in crew exposure to excessive radiation arises from the following two concurrent events:

- Onset of a large solar flare
- A failure necessitating an abort which causes a significant delay in rendezvous.

Since this is a highly improbable situation depicting two independent events, it does not impose a design requirement.

3.6 FUNCTIONAL FLOW DIAGRAMS

This paragraph presents functional flow diagrams for the Taxi mission (Figs. 3.6-1 through 3.6-22). These diagrams define the operations and functions to be mechanized to achieve the mission objectives. They also serve as a ready reference, identifying all the operations and functions associated with a success oriented flight mission; future work will consider contingencies.

The functional flow diagrams for the Taxi mission have been structured in four levels. The top level has been structured on an overall program basis and calls out the hardware, facilities, ground support, and manufacturing requirements to fulfill the program activities. The numbering system essentially corresponds to the LEM Design Reference Mission phase numbering system. The Taxi portion of the entire AES Program has been numbered from 4.0 through 18.0 in the Top Level functional diagram.

The first-level diagram describes the Taxi mission phases starting with Earth launch and ending with Taxi-CSM docking and subsequent Taxi jettison. These phases are represented in the first-level diagram by the operational functions 4.0 through 4.11. It is to be noted that operational functions 4.0 through 4.11 cover the total lunar landing mission. Since the Taxi is active only during operational functions 4.7, 4.9, 4.10, and 4.11, only these functions are expanded into Second- and third-level diagrams.

For each box identified in the first-level diagrams, second-level diagrams are provided for the necessary operations and functions. For most of the operations and functions listed on the second-level diagrams, third-level diagrams are provided which generally detail the operations and functions required of the Taxi major subsystems to accomplish the mission objectives. Specific hardware is not called out, but rather vehicle functional requirements such as "Provide Taxi - CSM Telecommunication Functions," "Provide Required Thrust Duration and Levels," etc.

Functions and operations identified on the diagrams at each level are numbered in a manner which preserves the continuity of functions and provides information with respect to function origin throughout the system. Functions which further subdivide these top functions, contain the same parent identifier and are coded at the next decimal level for each indenture. For example, the first subdivision function of function 4.0 is 4.1, the second 4.1.1, the third 4.1.1.1, etc. Each diagram contains a reference block. For example, function 4.7 is shown as a reference block in the case where the functions 4.7.1, 4.7.2, and 4.7.n, are used to expand function 4.7. Reference blocks are also used to indicate interfacing functions as appropriate.

Each separate function is presented in a single box enclosed by a solid line. Blocks used for reference to other flows are indicated as dotted boxes labeled "Ref."

The level of detail of each function corresponds to the level of functional Diagram on which it appears. Lines connecting functions indicate the order in which the functions must be performed. In indicating the flow with vertical and horizontal lines between blocks, all functions so interrelated are performed in either a parallel or series sequence as indicated.

The functional diagrams are laid out so that the functions are performed from left to right. Primary input lines enter the function block from the left side; the primary output or "go" line exists from the right. In some cases of special interest, a "no go" line from the bottom of the box is shown.

A circle is used to depict a logic gate. The logic gate is used to indicate the convergence of parallel or alternate functional paths and is annotated with the terms "AND" or "OR", respectively. The term "AND" is used to indicate that all parallel functions leading into the gate must be accomplished before proceeding into the next function. The term "OR" is used to indicate that any one of several alternate paths may initiate a succeeding function.

Table 3.2-1

TAXI PRE-LAUNCH TO LUNAR TD TIMELINE

<u>Time</u>	
<u>hr</u> : <u>min</u>	
-48 : 00	Remote Activation of Shelter
-10 : 00	Prelaunch Checkout of Taxi
00 : 00	Taxi Lift-off SIC Thrusting
00 : 025	Commence S-II Thrusting
00 : 03	Jettison Launch Escape System
00 : 09	Commence S-IVB Thrusting
00 : 12	Earth Orbit Injection
03 : 01	Commence Translunar Injection on Second Orbit
03 : 06	Commence Initial Coast to Transposition and Docking
03 : 21	Commence Transposition and Docking
03 : 48	CSM Docked - Begin Coast Through S-IVB Jettison
03 : 51	Jettison S-IVB - Begin Coast to Lunar Orbit Insertion
05 : 6	Perform First Midcourse Correction
55 : 30	Perform Second Midcourse Correction
63 : 15	Perform Third Midcourse Correction
64 : 15	Commence Lunar Orbit Injection
64 : 21	Commence Lunar Orbit Coast
65 : 49	Begin Crew Transfer into Taxi, Commence Preseparation Checkout
68 : 4	Taxi Separates from CSM
68 : 24	Commence Transfer Orbit Insertion
68 : 25	Commence Coast
69 : 23	Commence Powered Descent
69 : 31	Commence Hover to Touchdown
69 : 32	Touchdown

Table 3.2-2

LUNAR EXPLORATION - DAY 1

Time, hr:min From To	Systems Engineer	Commander
00:00 - 00:15	Taxi Touchdown	Taxi Touchdown
00:15 - 00:35	Post Landing Checkout	Status Check
00:35 - 01:15	Eat and Hygiene	Eat and Hygiene
00:15 - 01:28	Prepare for Shelter Inspection	Assist Systems Engineer
01:28 - 01:33	Egress Taxi	Monitor Systems Engineer
01:33 - 01:53	Perform Walk-Around Inspection	Monitor Systems Engineer
01:53 - 02:13	Erect & Align, S-band Dish Antenna	Checkout of S-band Comm.
02:13 - 03:33	Walk to Shelter	Monitor Systems Engineer
03:33 - 03:43	Checkout and Inspection, Deploy Airlock - Make go/no go decision	Monitor Systems Engineer
03:43 - 03:56	Monitor Commander	Secure Taxi for Quiescent Storage; Activate Status Communication Link*
03:56 - 04:16	Monitor Commander	Egress Taxi
04:16 - 05:16	Monitor Commander	Walk to Shelter
05:16 - 05:31	Replace PLSS & Recharge	Unload LSSM, Activate and Checkout
05:31 - 05:36	Monitor Commander	Remove RTG and Place On LSSM
05:36 - 05:56	Monitor Commander	Drive LSSM to Taxi
05:56 - 06:06	Monitor Commander	Install RTG Unit in Taxi
06:06 - 06:16	Monitor Commander	Ingress Taxi & Switch Power to RTG. Check
06:16 - 06:21	Monitor Commander	Egress Taxi
06:21 - 06:31	Monitor Commander	Drive LSSM to Shelter
06:31 - 07:01	Monitor Commander	Ingress Shelter
07:01 - 07:30	Establish Earth Communications	Recharge PLSS
07:30 - 10:00	Eat and Hygiene	Eat and Hygiene
10:00 - 12:00	General Familiarization Position Fix and Internal Checkout	Same, Photograph Surrounding Terrain from Shelter
12:00 - 13:00	Mission Planning for 2nd Day	Mission Planning for 2nd Day
13:00 - 24:00	Eat and Hygiene	Eat and Hygiene
	Rest	Rest

*Transmission to MSFN every 2 hr for 7-min, interval until Taxi activation on the 14th day.

Table 3.2-3

LUNAR EXPLORATION - DAY 14

Time, hr:min	Systems Engineer	Commander
From To		
0 - 01:00	Eat and Hygiene	Eat and Hygiene
01:00 - 02:00	Report and Preparation	Report and Preparation
02:00 - 06:00	Final Reporting and Sample Preparation	Final Reporting and Sample Preparation
06:00 - 07:00	Eat and Hygiene	Eat and Hygiene
07:00 - 09:00	Sample Preparation	Sample Preparation
09:00 - 16:00	Rest	Rest
16:00 - 17:00	Eat and Hygiene	Eat and Hygiene
17:00 - 17:30	Monitor Commander	Egress
17:30 - 19:30	Final Preparation of Shelter Interior	Final Surface Examination and Equipment Storage
19:30 - 20:00	Egress	Ingress
20:00 - 20:48	Load Return Payload into LSSM	Monitor Systems Engineer
20:48 - 20:53	Return to Taxi	Prepare to Depart Shelter
20:53 - 20:54	Walk around Taxi for Visual Inspection	
20:54 - 20:58	Ingress Taxi and Activate ECS	Monitor Systems Engineer
20:58 - 21:08	Monitor Commander	Egress Shelter & Secure
21:08 - 21:28	Monitor Commander	Walk to Taxi
21:28 - 21:57	Assist Commander	Load Experiment Payload into Taxi and Stow
21:57 - 22:00	Monitor Commander	Ingress Taxi
22:00 - 23:00	Activate Taxi	Activate Taxi
23:00 - 24:00	Prelaunch Checkout	Prelaunch Checkout
24:00	Ascent Ignition	Ascent Ignition

Table 3.2-4

TAXI ASCENT TO JETTISON TIMELINE

<u>Time</u> <u>hr:min</u>	
00 : 00	Taxi Ascent - Thrusting
00 : 07	Commence Coast
00 : 16	Perform First Midcourse Correction
00 : 30	Perform Second Midcourse Correction
00 : 40	Perform Third Midcourse Correction - Coast to Terminal Rendezvous
00 : 54	Perform First Rendezvous Thrusting
00 : 58	Perform Second Rendezvous Thrusting
01 : 2	Perform Third Rendezvous Thrusting
01 : 6	Commence Manual Docking Maneuver
01 : 17	Hard Dock with CSM
01 : 27	Coast
01 : 35	Begin Transfer of Payload and Crew to CSM
02 : 07	Jettison Taxi

Table 3.3-1

CABIN LIFE SUPPORT REQUIREMENTS

Phase	hr:min	
	Sys Engr	Cmdr
Taxi prelaunch to lunar TD	03:41	03:16
Lunar exploration (Day 1)	01:15	03:43
Lunar exploration (Day 14)	03:02	02:00
Taxi ascent to jettison	02:02	01:37
Subtotal	10:00	10:46
Total	20.8 man-hr	

Table 3.3-2

PORTABLE LIFE SUPPORT REQUIREMENTS

Lunar Explorat'n Phase	hr:min	
	Sys Engr	Cmdr
Day 1	01:28	02:48
Day 14	00:58*	00:52*
Subtotal	01:28	02:48
Total	4.3 man-hr	

*Chargeable to Shelter Requirements

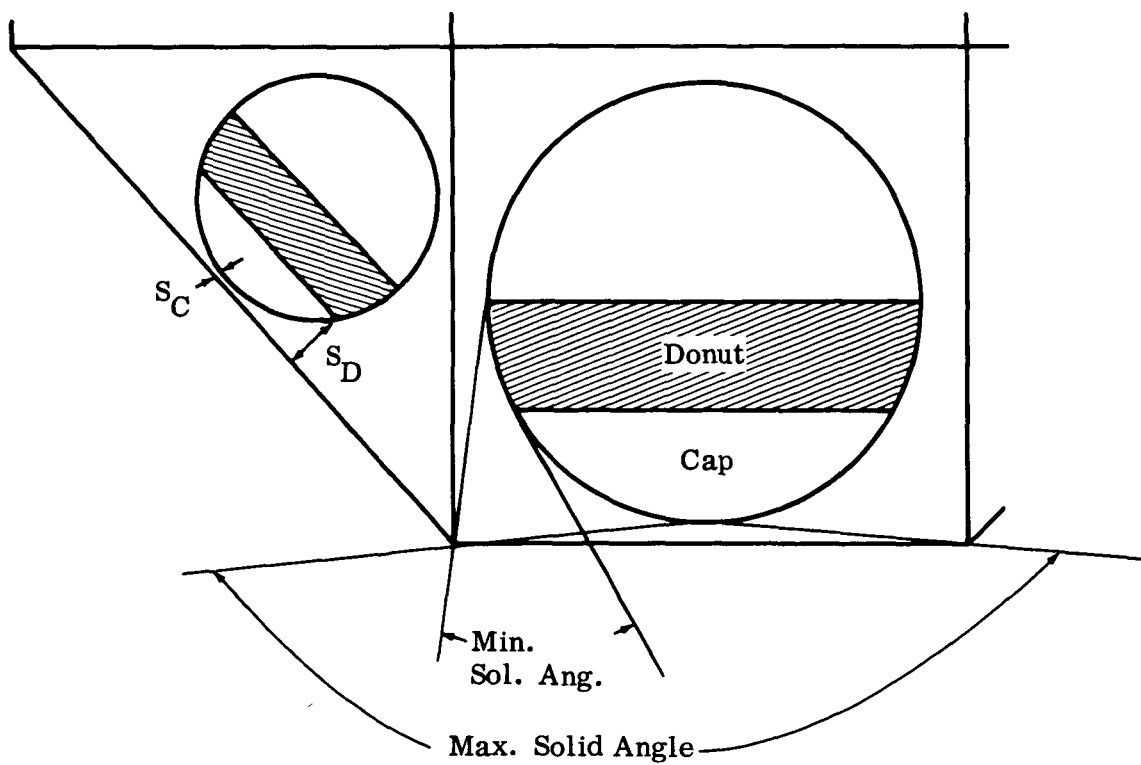


Fig. 3.5-1 Micrometeoroid Hazard - Critical Tank Area

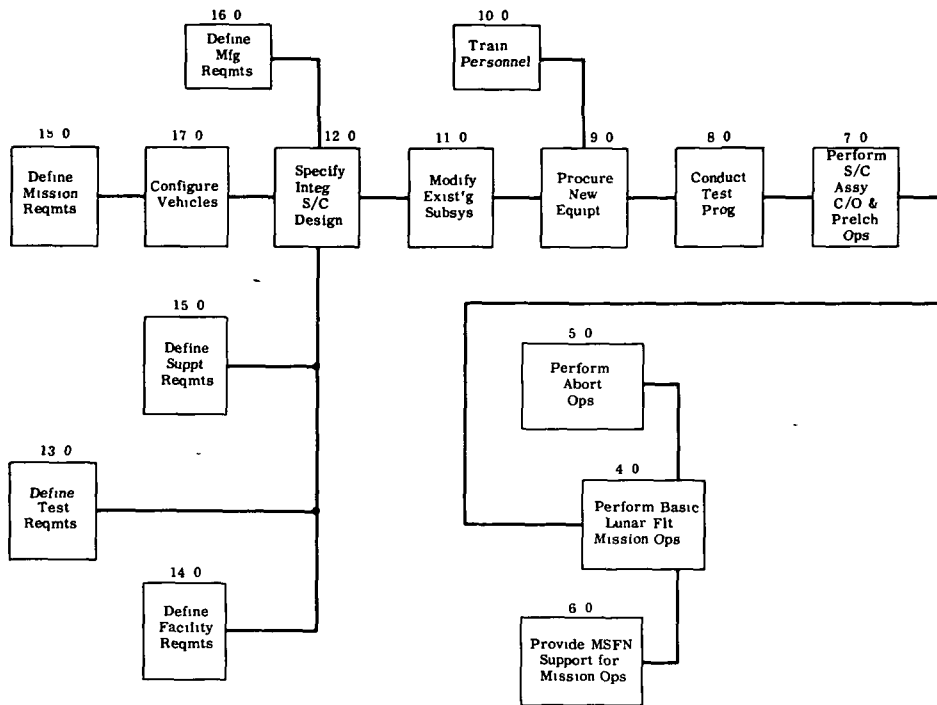


Fig. 3.6-1 Top Level Functional Flow Diagram

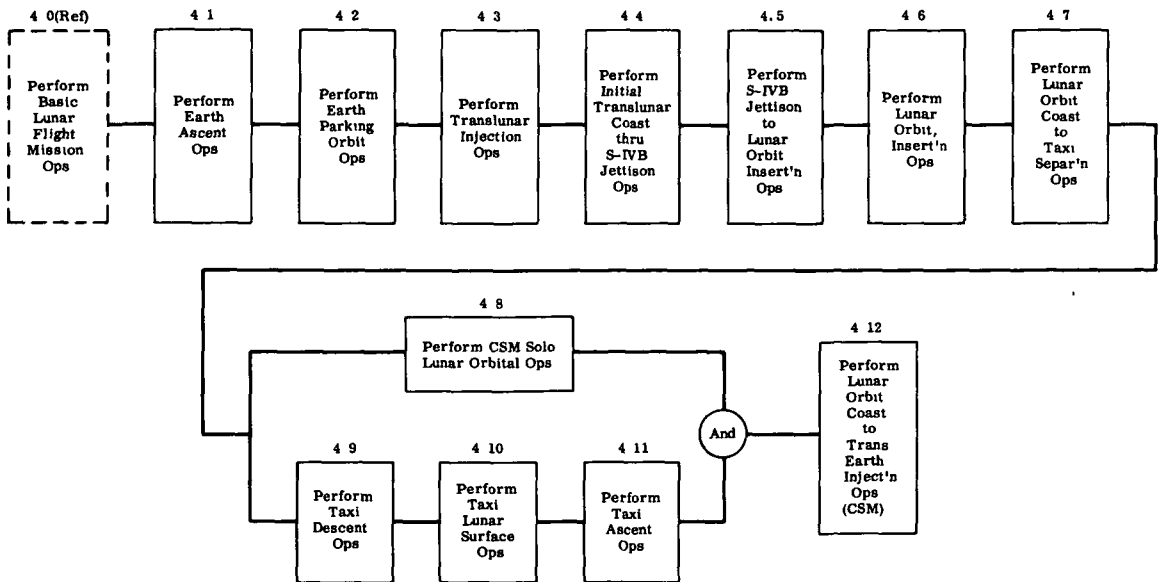


Fig. 3.6-2 First Level Functional Flow Diagram-Perform Basic Lunar Flight Mission Operations

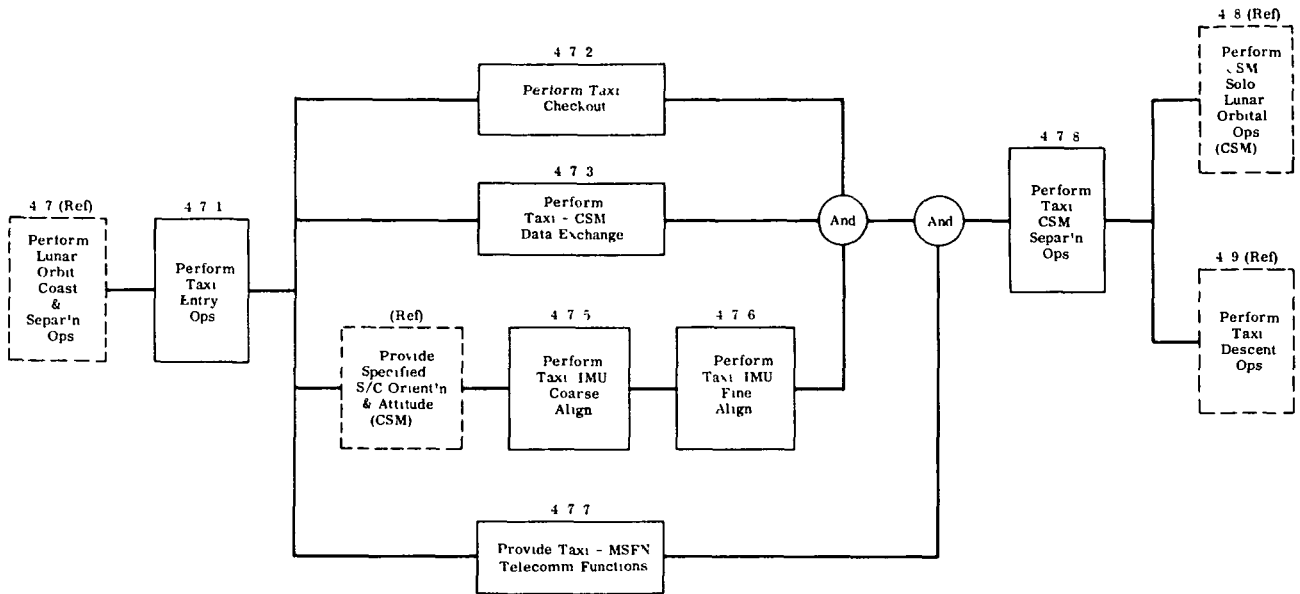


Fig. 3.6-3 Second Level Functional Flow Diagram-Perform Lunar Orbit Coast & Separation Operations

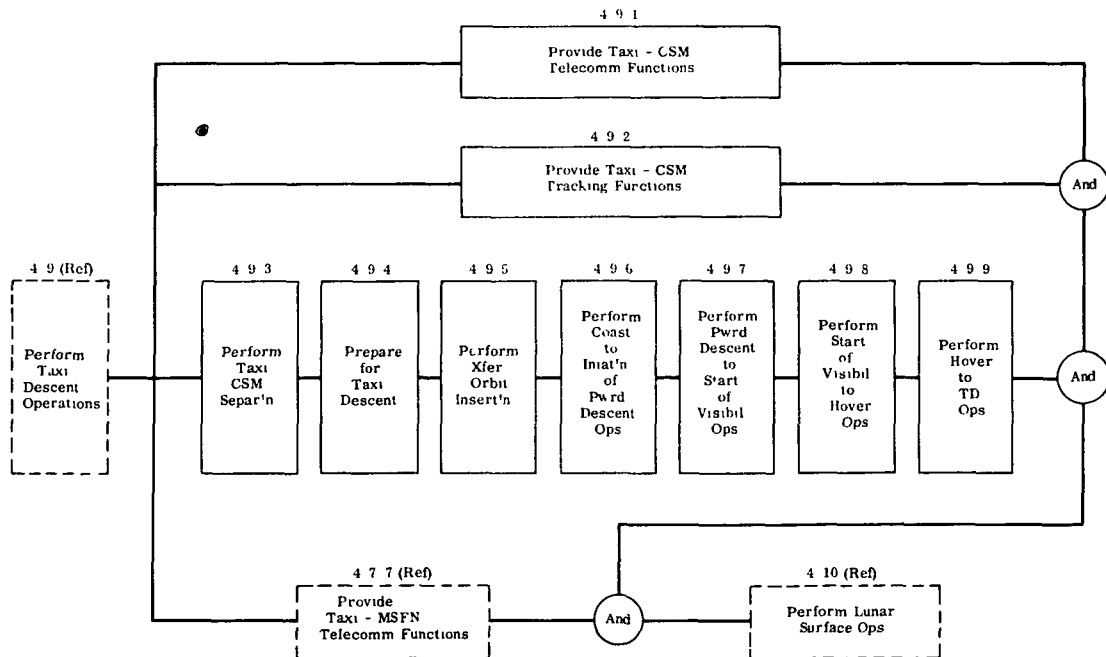


Fig. 3.6-4 Second Level Functional Flow Diagram-Perform Taxi Descent Operations

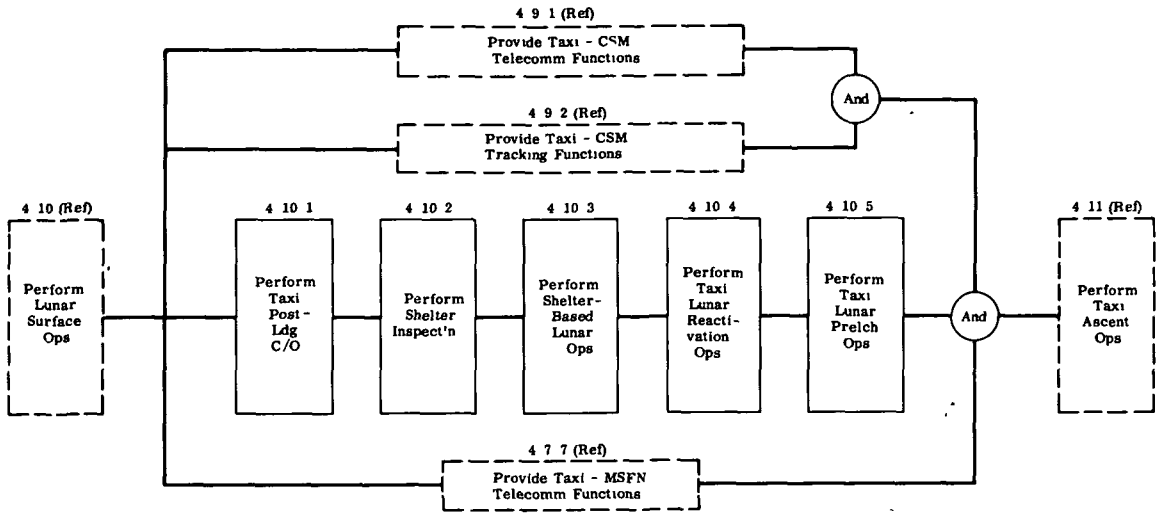


Fig. 3.6-5 Second Level Functional Flow Diagram-Perform Lunar Surface Operations

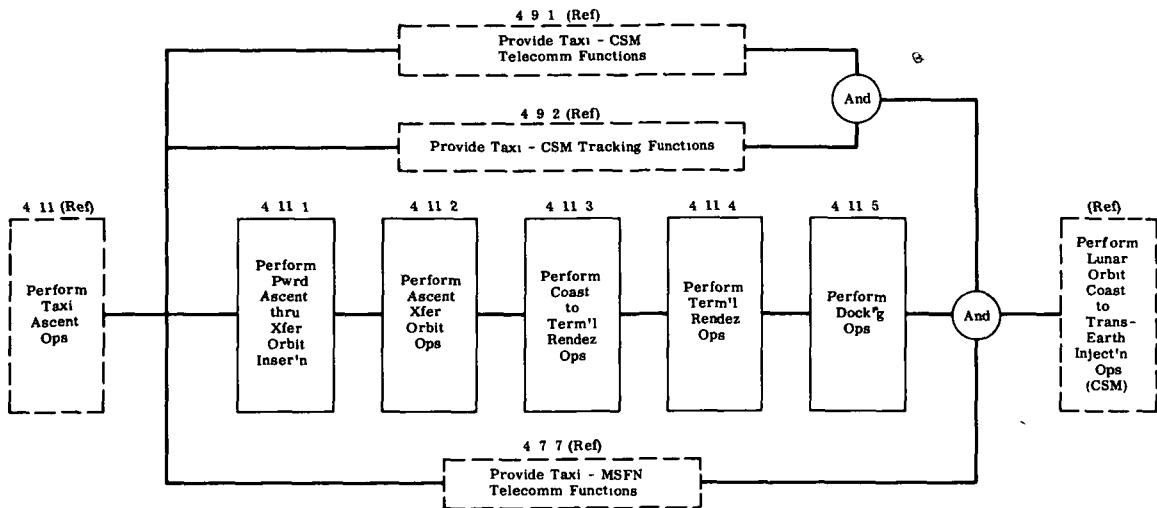


Fig. 3.6-6 Second Level Functional Flow Diagram-Perform Taxi Ascent Operations

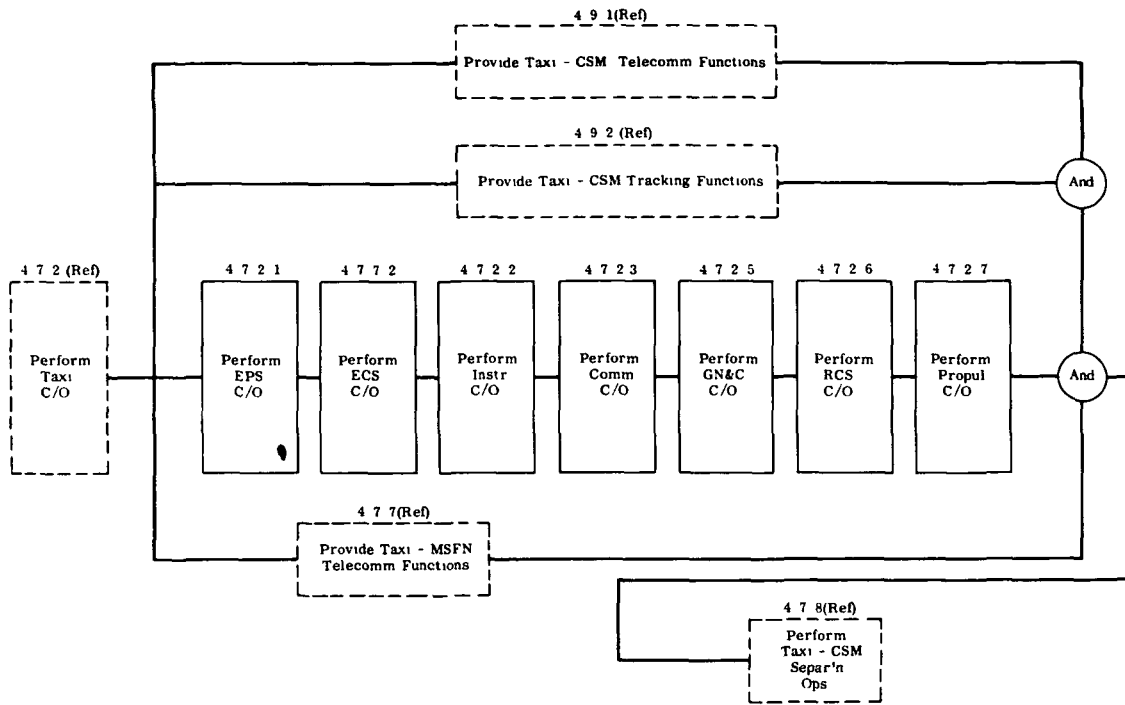


Fig. 3.6-7 Third Level Functional Flow Diagram-Perform Taxi Checkout

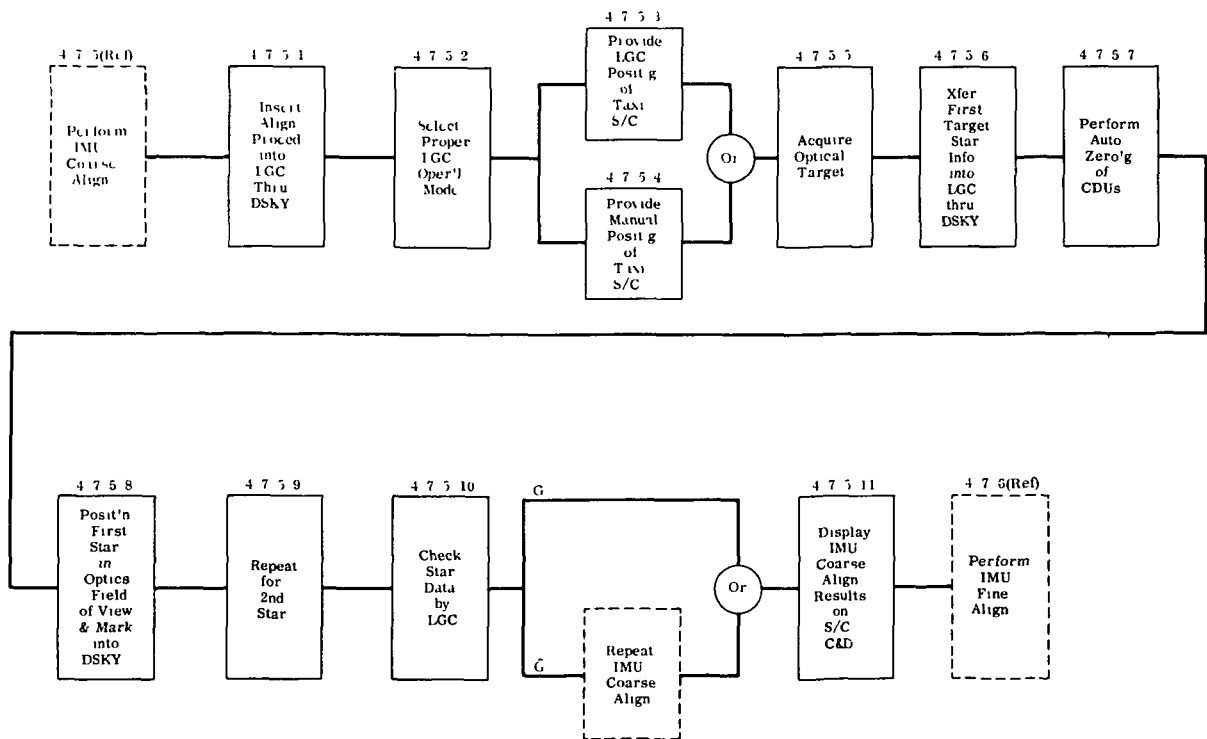


Fig. 3.6-8 Third Level Functional Flow Diagram-Perform IMU Coarse Alignment

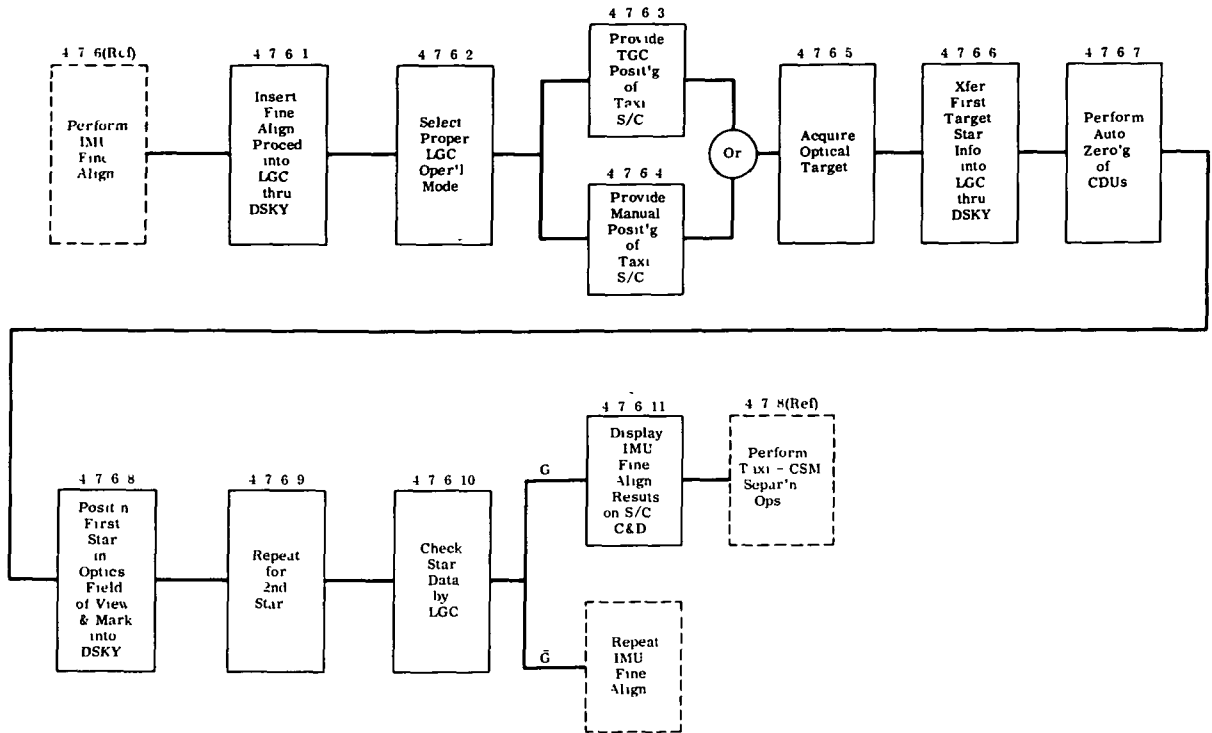


Fig. 3.6-9 Third Level Functional Flow Diagram-Perform IMU Fine Alignment

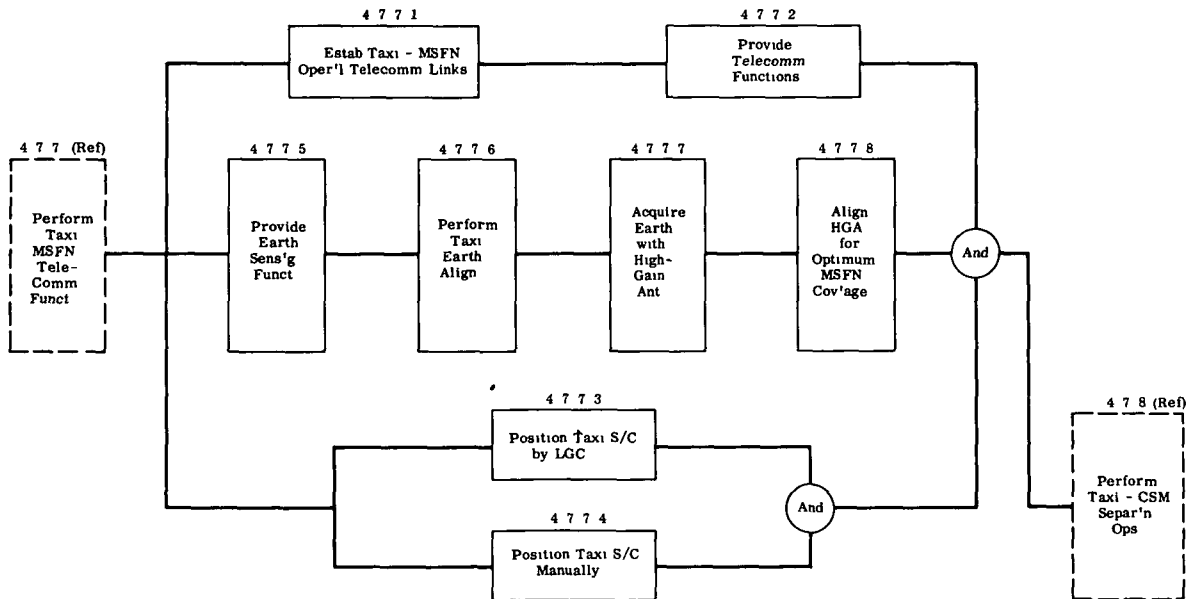


Fig. 3.6-10 Third Level Functional Flow Diagram-Perform Taxi/MSFN Telecommunication Functions

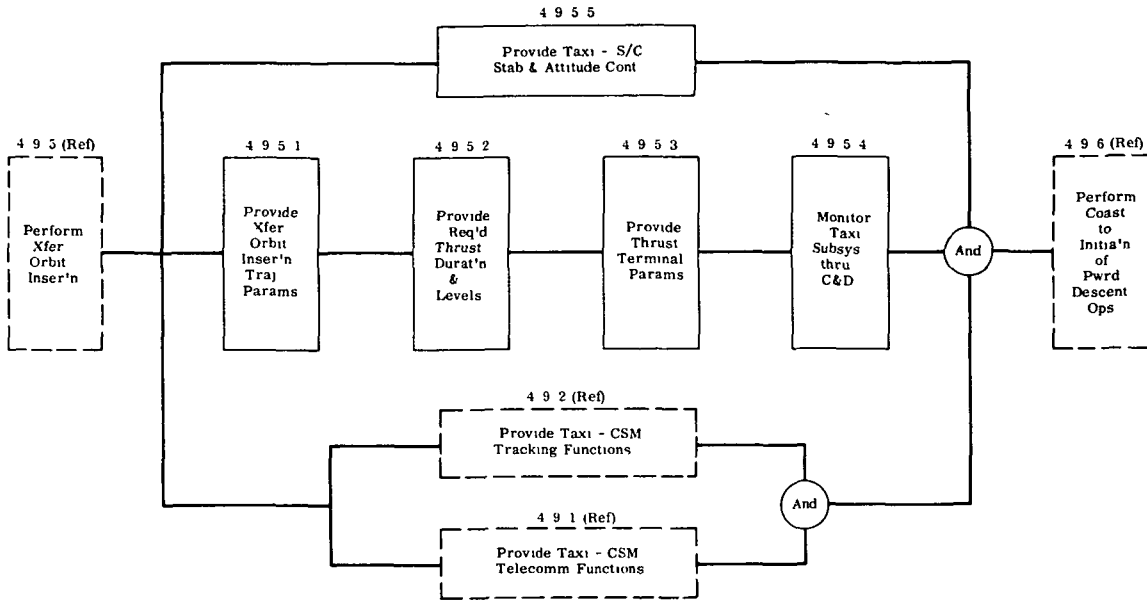


Fig. 3.6-11 Third Level Functional Flow Diagram-Perform Transfer Orbit Insertion

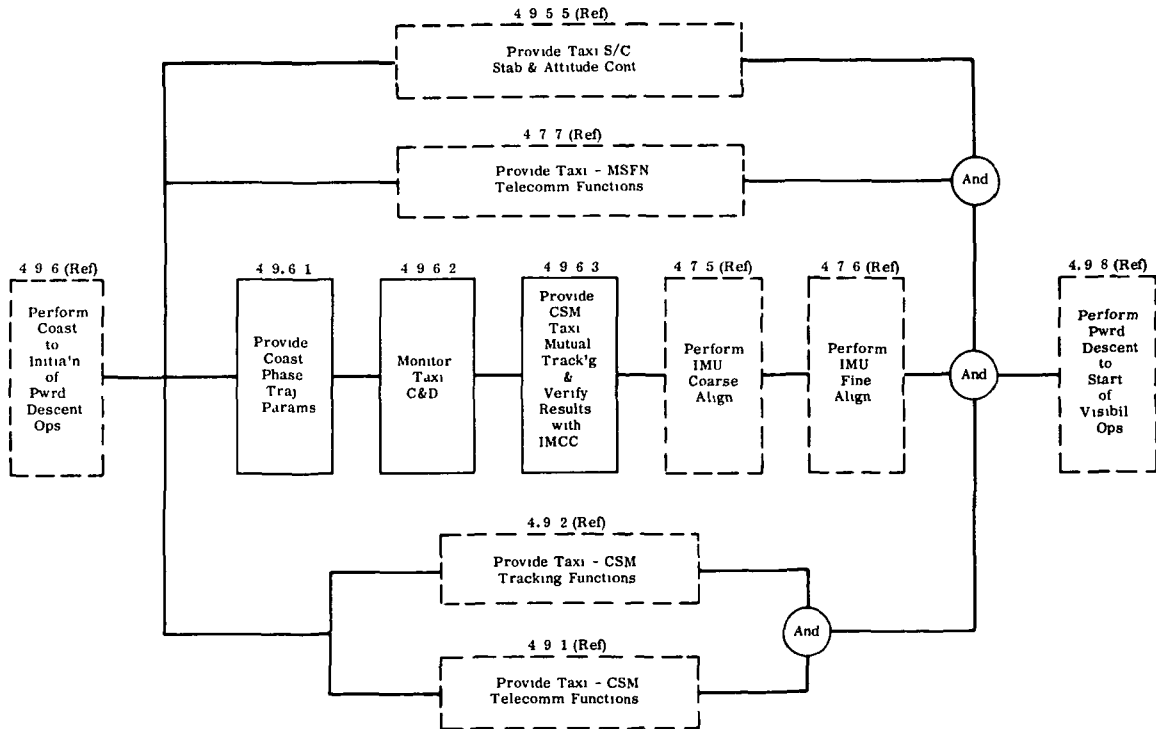


Fig. 3.6-12 Third Level Functional Flow Diagram-Perform Coast to Initiation of Powered Descent Operations

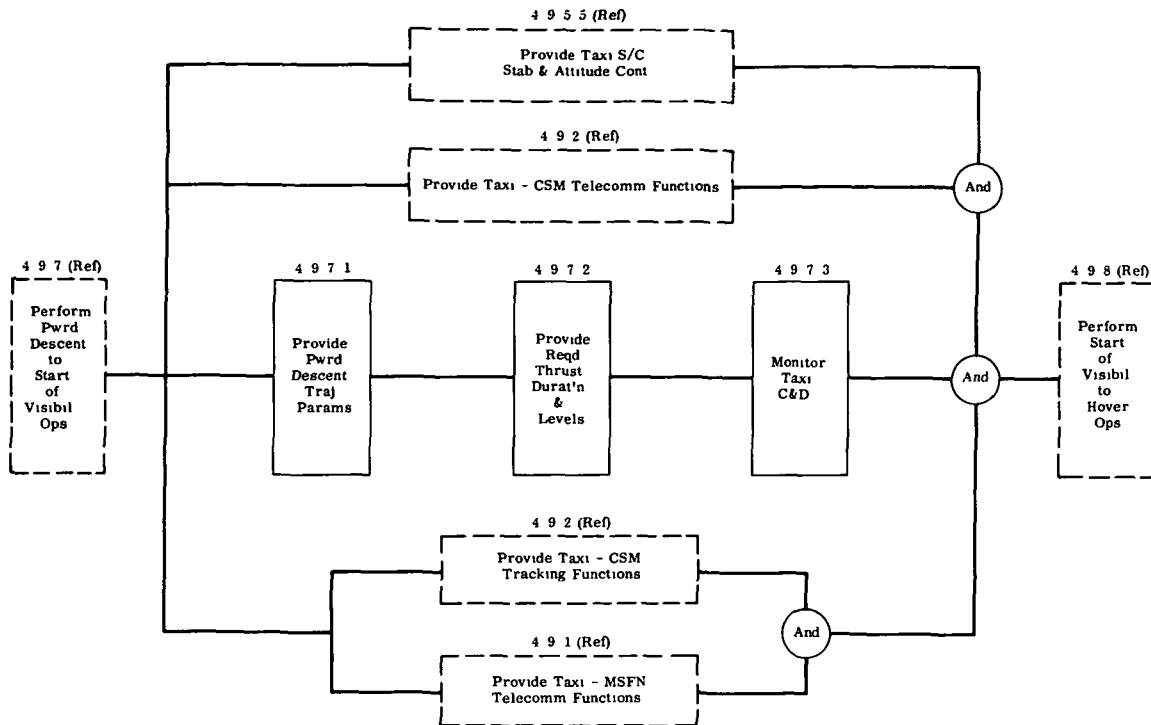


Fig. 3.6-13 Third Level Functional Flow Diagram-Perform Powered Descent to Start of Visibility Operations

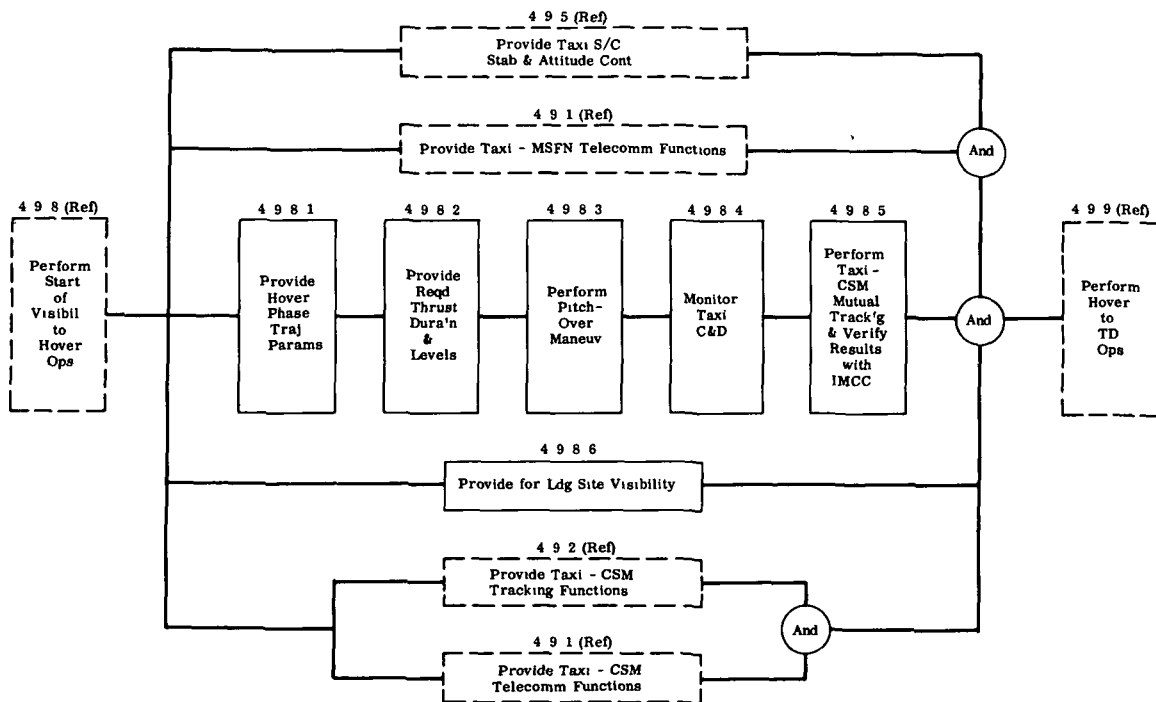


Fig. 3.6-14 Third Level Functional Flow Diagram-Perform Start of Visibility to Hover Operations

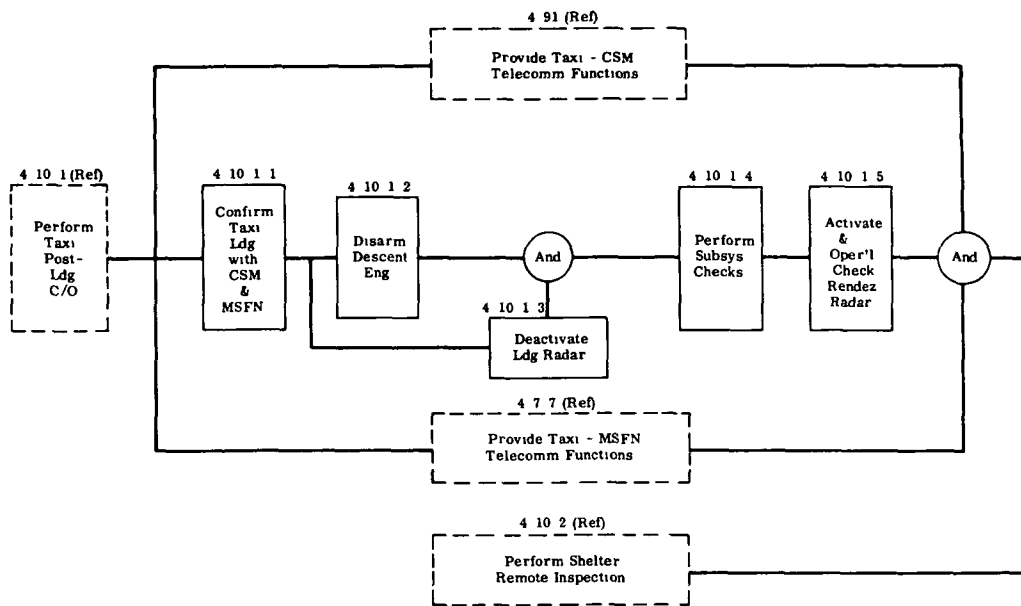


Fig. 3.6-15 Third Level Functional Flow Diagram-Perform Taxi Post Landing Checkout

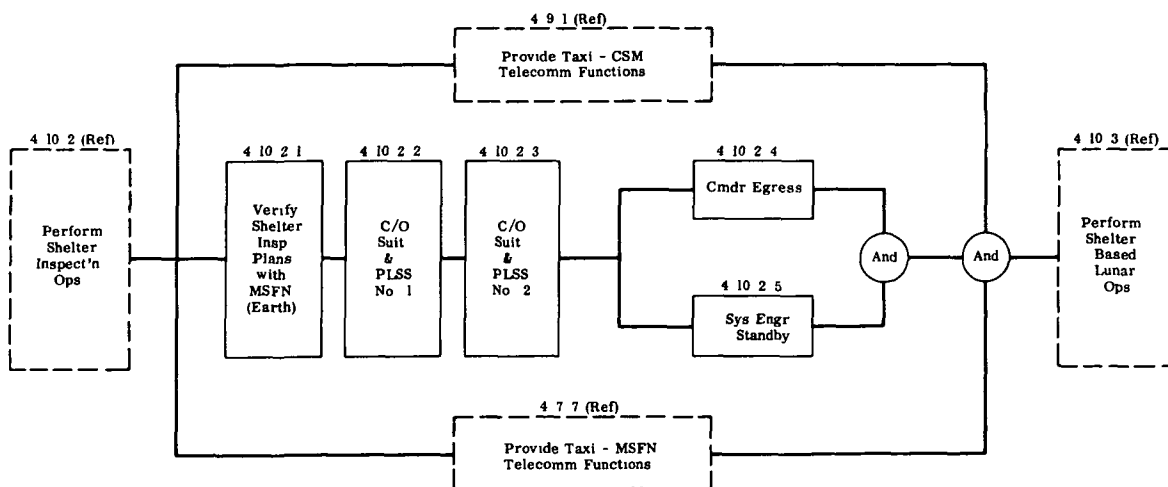


Fig. 3.6-16 Third Level Functional Flow Diagram-Perform Shelter Inspection Operations

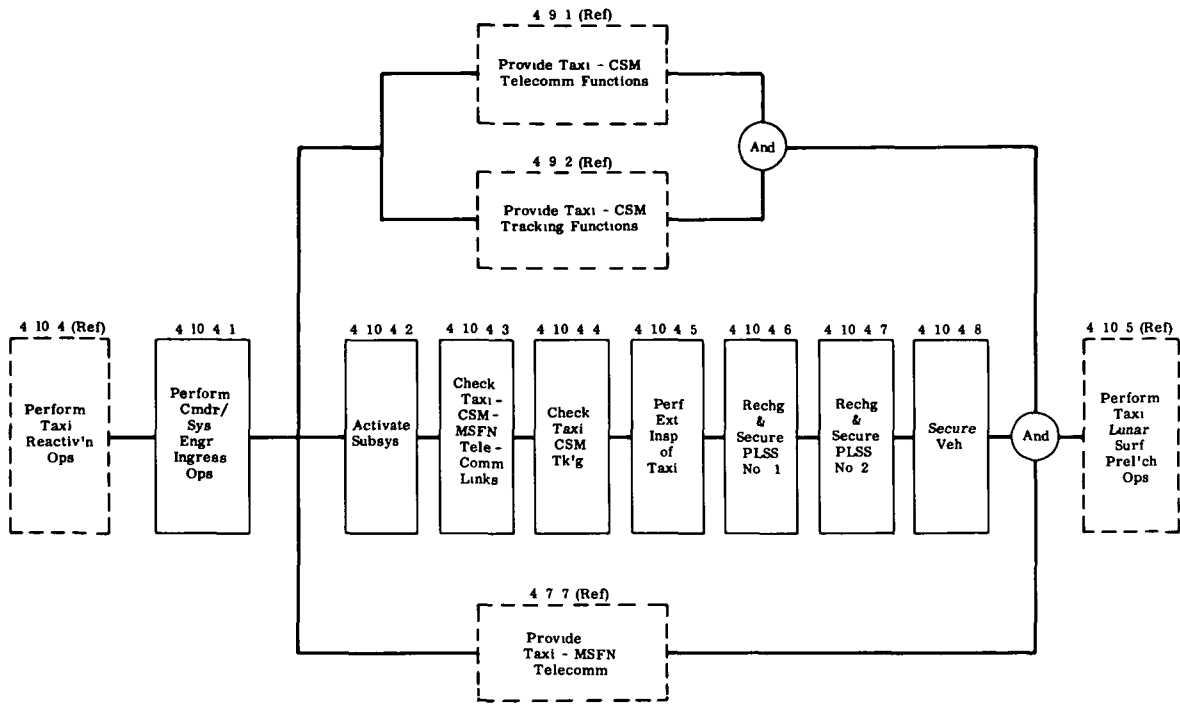


Fig. 3.6-17 Third Level Functional Flow Diagram-Perform Taxi Reactivation Operations

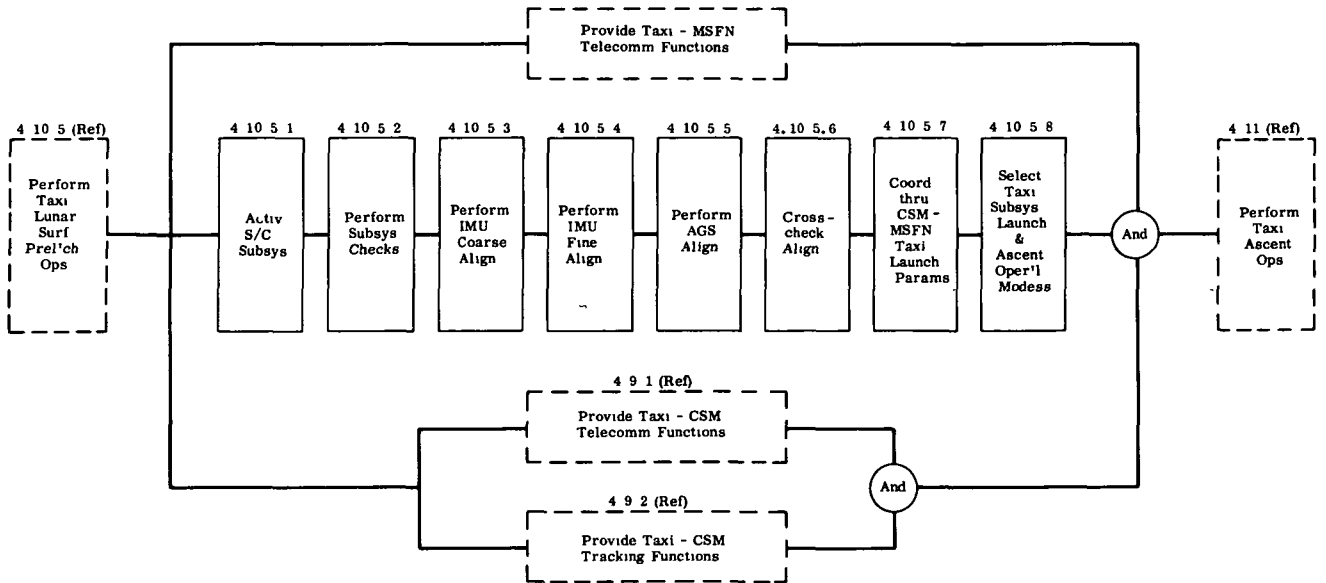


Fig. 3.6-18 Third Level Functional Flow Diagram-Perform Taxi Lunar Surface Prelaunch Operation

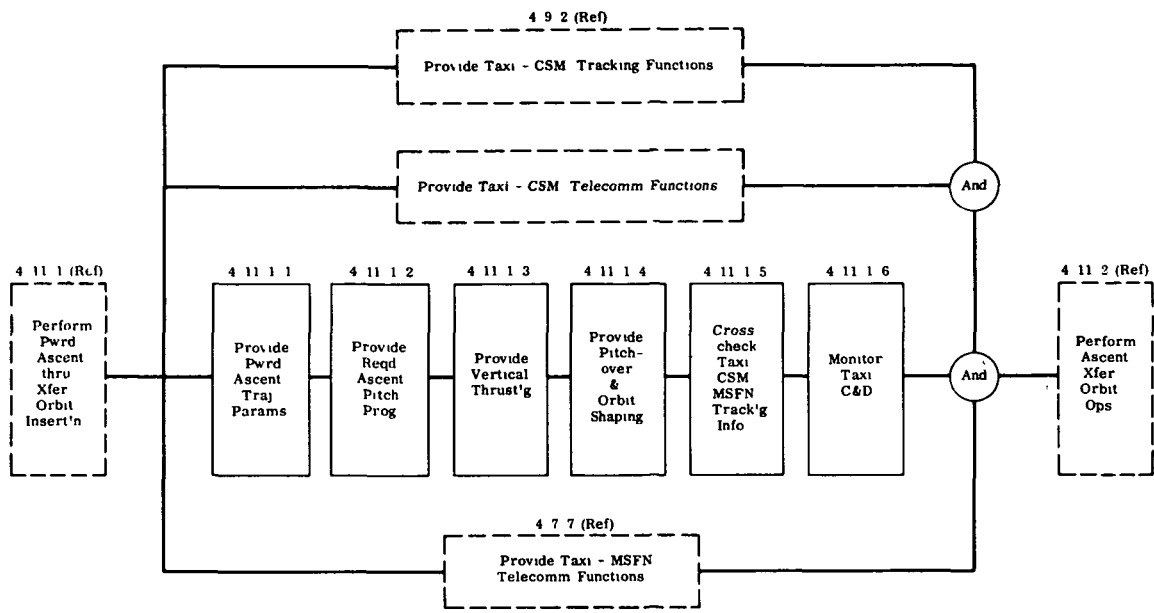


Fig. 3.6-19 Third Level Functional Flow Diagram-Perform Powered Ascent Thru Transfer Orbit Insertion

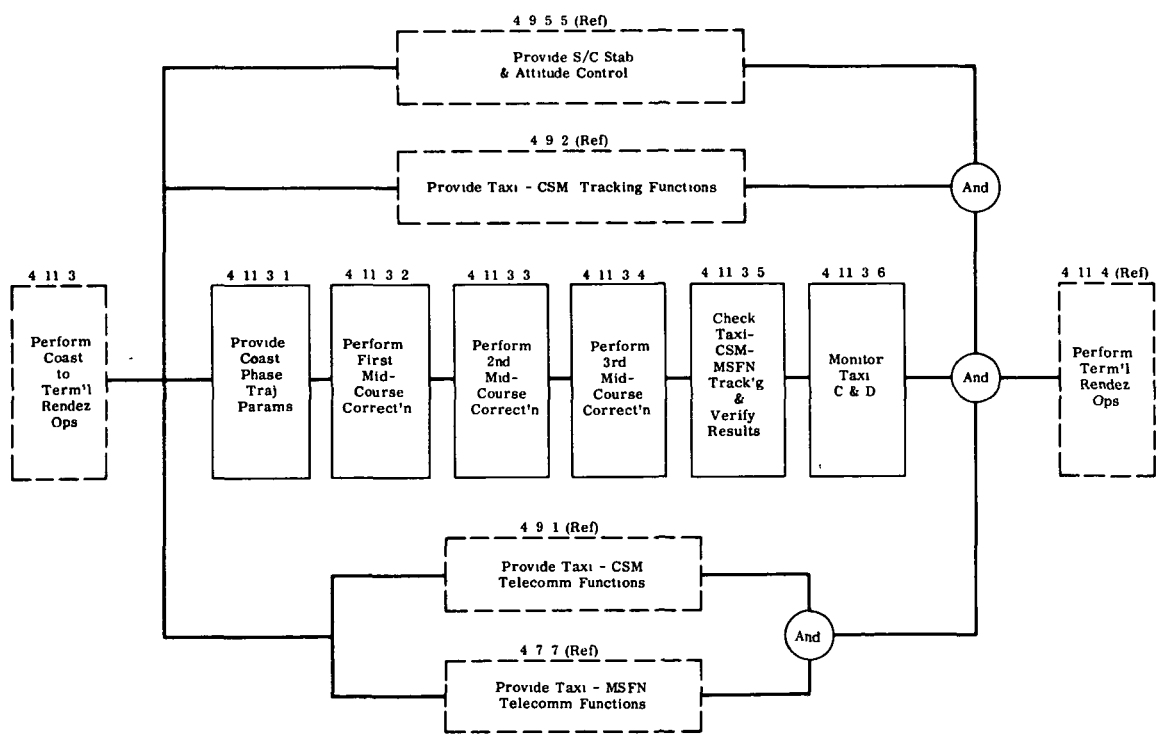


Fig. 3.6-20 Third Level Functional Flow Diagram-Perform Coast to Terminal Rendezvous Operations

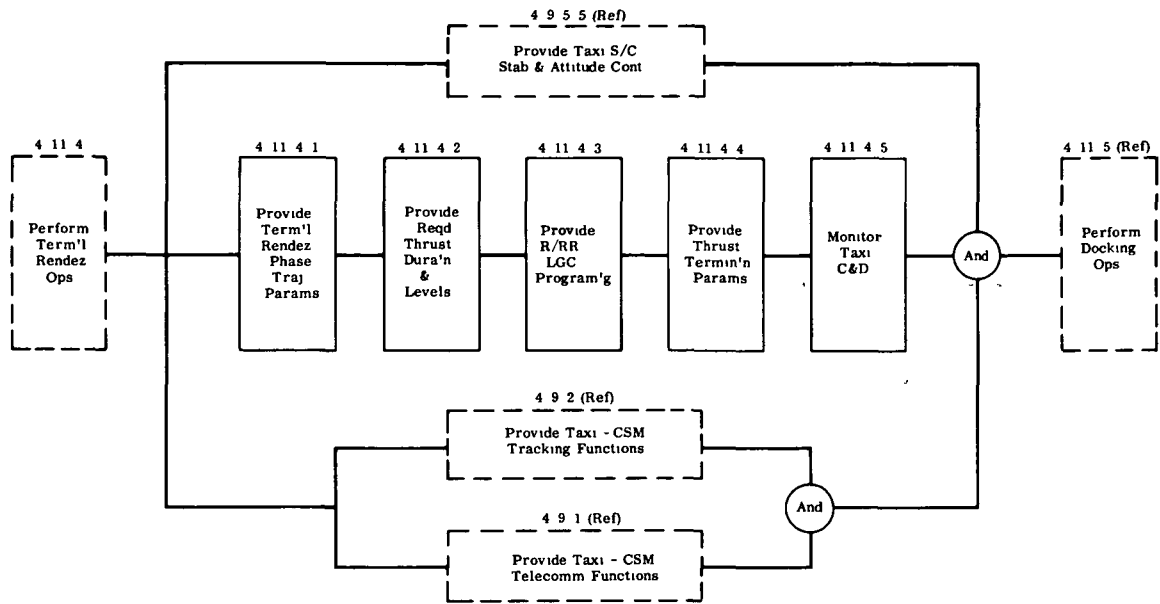


Fig. 3.6-21 Third Level Functional Flow Diagram-Perform Terminal Rendezvous Operations

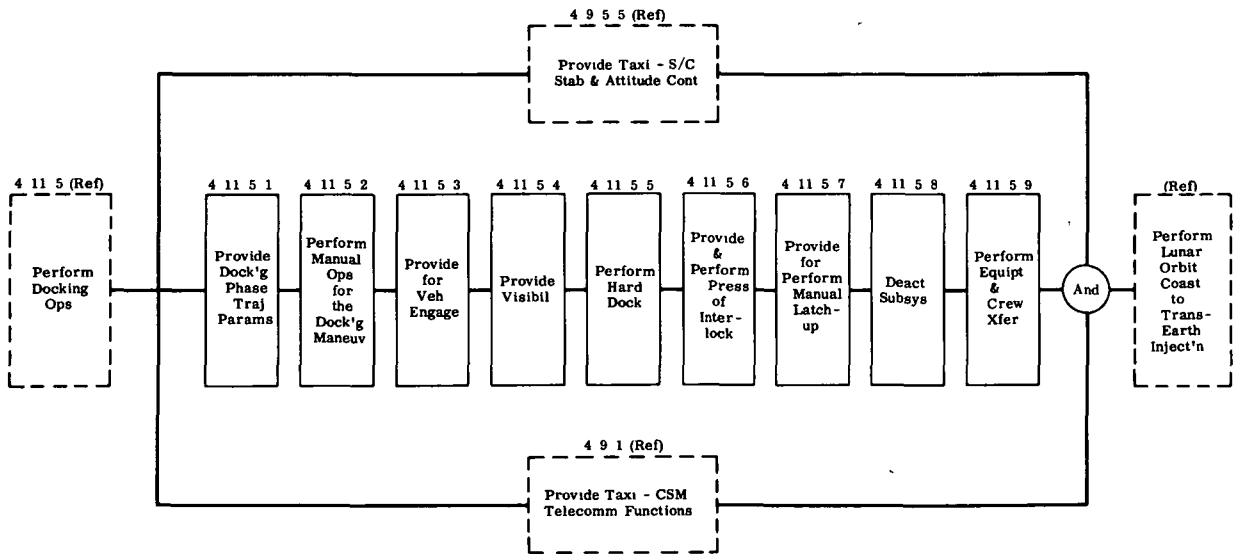


Fig. 3.6-22 Third Level Functional Flow Diagram-Perform Docking Operations

4. SYSTEM ENGINEERING

4.1 THERMODYNAMICS

4.1.1 Ground Rules

There were no NASA ground rules unique to this portion of the study

4.1.2 Assumptions and Background Data

It is assumed that the Taxi thermal control requirements for all mission phases, exclusive of the lunar surface mission, are identical with the requirements of the LEM. Therefore, all differences between the LEM and the Taxi are a direct result of the different lunar surface missions for the two vehicles. The passive thermal design includes the following features:

- External Surface Radiation Properties
 - Ascent Stage: α_s/ϵ = 0.20/0.25
 - Descent Stage: α_s/ϵ = 0.25/0.25
- External Surface Insulation Thickness
 - Ascent Stage: 25 layers
 - Descent Stage: 25 layers

The active thermal control system is designed to supplement the passive control system to maintain the desired thermal environment within the vehicle. During unmanned portions of the mission, the minimum cabin temperature is 40°F and the maximum temperature is 90°F. The cabin temperature during manned phases of the mission will be between 70 and 80°F. The general objectives of the Taxi thermal control are to provide all vehicle components with a suitable thermal environment for all mission phases with minimum weight penalty and with minimum design changes from the LEM.

The allowable temperature for the various subsystem components are as follows:

<u>Item</u>	<u>Temperature (°F)</u>	
	<u>Minimum</u>	<u>Maximum</u>
Ascent Propellant	40	90
RCS Propellant	40	100
Ascent Engine (Casing)	-65	165
Ascent Engine (Ablative Liner)	To be determined	

<u>Item</u>	<u>Temperature(°F)</u>	
	<u>Minimum</u>	<u>Maximum</u>
RCS Engine (Propellant Valves)	35	175
Battery Surface (Operating)	40	80
Battery Surface (Storage)	-30	40
Water Tanks	40	165
Abort Sensor Assembly (Operating)	115	125
Abort Sensor Assembly (Storage)	105	120
Inertial Measuring Unit (Operating)	135	135
Inertial Measuring Unit (Storage)	130	140
Antennas	-65	160

These allowable temperature limits show that specific thermal control attention must be given to such items as the IMU, ASA, batteries, and descent stage water tanks.

The results of the Phase A analysis concluded that a close thermal coupling between the propellant tanks, ascent stage water tanks, and cabin structure, while keeping the cabin temperature between 40 and 90°F, was the preferred approach. The major thermal control objective is then reduced to controlling the cabin temperature within these allowable limits with a minimum weight thermal control system.

4.1.3 Recommended Configuration

During the 14-day quiescent storage period, the temperature variation of the various components and subsystems within the vehicle are controlled by both passive and active techniques, and are capable of meeting the demands of either a day or night mission. The allowable ascent stage structural temperature limits, imposed by propellant and equipment considerations, are 40 to 90°F. The ascent stage structure is well coupled to the propellant tanks and life support expendables to help stabilize the interior temperatures. The ascent stage is thermally decoupled from the environment by insulation and the use of exterior surfaces having the proper radiation properties.

4.1.3.1 Passive Thermal Control

Passive thermal control of the Taxi is the same as LEM with the addition of a blanket of insulation to cover the top docking tunnel and insulated reflectors applied to the interior of the windows. These are placed in position by the astronaut prior to the quiescent stay.

Figure 4.1-1 shows the passive heat loss or gain from the ascent stage cabin during the lunar surface mission. The heat transfer rate is a function of solar angle and is shown for various cabin structural temperatures ranging from 40 to 130°F. The Taxi is located on the lunar equator and the adjacent lunar terrain is assumed to be a flat, black body radiator which is in equilibrium with the Sun during the day and at a constant temperature of -250°F at night.

The heat transfer rate shown in Fig. 4.1-1 is the steady state rate at which heat is passively transferred between the cabin and the lunar environment. An active thermal control system, which adds or removes heat from the interior of the cabin at the same rate as the passive loss or gain, is required to maintain a particular cabin temperature whenever there is a net exchange of heat with the environment. Maintaining the cabin at 70°F at sub-solar (0-deg solar angle) requires the removal of 840 BTU/hr from the cabin. During the night mission phase, heat addition at the rate of 740 BTU/hr is required to keep the cabin at 70°F.

The important heat transfer paths thermally coupling the recommended Taxi configuration with the external environment include: exterior insulated surfaces, top docking tunnel (with its insulated cover deployed), and RCS clusters. Thermal coupling, assumed equivalent to an additional 10%, occurs through the ascent engine, forward hatch, and antenna.

4.1.3.2 Active Thermal Control

During the lunar surface phase of the Taxi mission, an active heat rejection system is required to maintain the desired vehicle thermal balance. This thermal balance is influenced by:

- o Electrical equipment heat dissipation
- o Structural heat transfer
- o Crew metabolic heat (manned mission phases only).

During a day mission, all loads must be dissipated by the active thermal control system. During a night mission, the negative structural load (heat loss) is partially reduced by the electrical equipment load.

Figure 4.1-1 is used to determine the quantity of boiloff water required for cooling the vehicle during a daylight mission lasting 14 days. The maximum allowable cabin temperature during quiescent storage is 90°F; therefore, the positive area between the 90°F temperature line and the zero ordinate is proportional to the quantity of water required to dissipate the structural load. This area is calculated by numerical integration to be 150,000 BTU, which corresponds to 150 lb of water. The night heating energy required for a 14-day mission with the minimum cabin temperature at 40°F is 205,000 BTU. This corresponds to an electrical energy expenditure of 60 kw-hr.

4.1.3.2.1 Day Mission Cooling. The active thermal control system for a day mission uses a slightly modified version of the LEM glycol loop and water boiler. The glycol loop modification consists of bypassing the IMU during storage to eliminate the need for simultaneous heating and cooling. Additional water is carried in the descent stage water tanks, because of the greater cooling requirement of the Taxi during its lunar surface mission.

The maximum cabin temperature of 90°F is maintained during the day storage mission by circulating glycol through the electronic equipment cold plates. It is assumed that the structural heat leakage into the cabin and the power dissipation from the electrical equipment can be effectively rejected to the water boiler by operating the glycol coolant loop on a 25% duty cycle.

4.1.3.2.2 Night Mission Heating. Active thermal control of the Taxi cabin during a night storage mission is accomplished using the thermal energy rejected by a RTG as a heat source and using a heat pipe distribution system. The RTG is carried to the lunar surface by the Shelter; an astronaut transfers the RTG from the Shelter to the Taxi. A discussion of the heat pipe distribution system is given in Paragraph 5.2. In this system, heat is transferred by radiation from the RTG to a heat exchanger containing a volatile liquid. The heat vaporizes the liquid which rises in a pipe to a condensing section in the ascent stage. The vapor then condenses on the cold surface giving up its latent heat to the ascent stage and returning by gravity to the descent stage boiler. The cold condensing surface could consist of tubes having good thermal contact with the cabin pressure vessel. This system requires the presence of the lunar gravity field to insure proper circulation of the fluid.

Preliminary calculations have been made on the use of water as the fluid in the heat pipe system. Typical operating pressures and temperatures for the system are: 30 psi and 250°F throughout the system when there is a demand for heat from the ascent stage, and 300 psi and 600°F in the boiler and descent stage piping when no heat is required. The maximum operating temperature is determined by the surface temperature of the RTG, and the maximum pressure is a function of the total quantity of water and the volume of the system.

A parametric study has been conducted to determine the suitability of maintaining the temperature of the entire ascent stage pressure vessel by heating a relatively small area of the pressure shell. The ability of this small heated surface to then transfer heat to a larger enclosure depends primarily on the temperature of the enclosure and the area and emittance of the small heated surface. Figure 4.1-2 shows the mean radiant temperature of a surface transferring a net rate of 500, 750 and 1,000 BTU/hr to a 40°F enclosure, as a function of the radiating surface area. The analysis of the ascent stage pressure vessel was performed using a numerical relaxation procedure that accounted for both radiation and two-dimensional conductive effects. The effect of thermal conduction is to increase the effective radiating area, thereby reducing the mean radiant temperature required to transfer a given rate of heat from a fixed area to its enclosing surfaces. The analysis used a conductive coupling based only on the 0.03 in pressure vessel thickness, and neglected any advantage afforded by the conductive coupling of the structural reinforcing members. The actual conduction tends to lower the required mean radiating temperature. The small radiating surface area of the cabin is assumed to have a 0.9 emittance and can be considered as the area to which the condenser tubes of the heat pipe system are attached.

4.1.3.3 Special Thermal Control System

Various subsystem components cannot be kept within their desired temperature range only by passive means; therefore, special active thermal control systems are required. These components are either located outside the ascent stage insulating blanket, or have limited allowable temperature variations. A tabulation of the components requiring special active heating systems and their heat or power requirements are presented in Table 4.1-1.

4.1.3.3.1 RCS Cluster Heaters. The RCS cluster assembly must be kept above a minimum temperature during the translunar mission phase to prevent the propellant lines from freezing. Part of this heat is passively transferred from the cabin structure, and the remainder must be supplied by electric heaters at each cluster. The amount of RCS heater energy required for the Taxi night mission is excessive; therefore, the recommended procedure is to allow the propellant lines to freeze during night storage and to supply sufficient electrical power to heaters, during the prelaunch phase, to thaw the frozen propellant lines in approximately 1 hr. The energy required for thawing the clusters is 1 kw-hr.

4.1.3.3.2 Rendezvous Radar Antenna. The rendezvous radar antenna is located externally on the top of the ascent stage and requires heater power to survive a night storage mission. Many electronic components, such as resistors, capacitors, and transistors, have limited temperature ranges. Beyond these limits, their performance may alter significantly and preclude proper system operation. Therefore, heaters are provided by the vendor to keep the components above their survival temperatures. The total heater power needed to maintain allowable temperatures during the night mission storage phase is 25 w, assuming that the antenna is thermally isolated from the cabin structure.

4.1.3.3.3 S-Band Steerable Antenna. The S-band Antenna requires a heater power of 6 w, not in use, to maintain the antenna steering components above their low-temperature survival limits. Components such as servo-motors, electronic equipment, and gimbal mechanisms must be maintained above -65°F .

4.1.3.3.4 Navigational Equipment. The IMU and the ASA navigational equipment are both located in the navigation bay above the cabin. Although they are not exposed to space, they require precise thermal control ($\pm 0.1^{\circ}\text{F}$) when in use and must be maintained at 130 to 140 $^{\circ}\text{F}$ (IMU) and 105 to 120 $^{\circ}\text{F}$ (ASA) during the storage period. At present, temperature control of the IMU and ASA (non operative) is achieved in the LEM by utilizing a cooling loop and heaters. This mode of operation requires an excess of heater power, since the proportional heater has to over-drive the cooling loop. The Taxi incorporates a by-pass valve in the cooling loop to by-pass the IMU and ASA coolant when the units are not operating. The heater power required by the IMU and ASA to maintain temperature during the night storage mission is 13 and 7 w, respectively.

4.1.3.3.5 Descent Stage Water Tanks. Transient analysis has established that the water in the descent stage tanks will freeze unless adequate protection is provided. Based on the tank support system and the insulation level recommended in the Phase A Report, 5 w of continuous heating is required. It is assumed that waste heat rejected by the RTG heat source can be put to this use.

4.1.3.3.6 Descent Stage Batteries. Special thermal control for the descent stage batteries is required to prevent excess degradation while in storage. The internal inefficiency of the battery is assumed adequate to compensate for the heat loss during a night mission; however, it is necessary to supply glycol coolant to the battery during a day storage mission. It is estimated that 4 lb of boil-off water is required during a day storage mission with the structure at 135°F and the battery at 80°F.

4.1.4 Baseline Configuration

There are no differences between the Taxi baseline configuration and the recommended configuration with respect to the thermal control system.

4.1.5 Alternate Configurations

The alternate configurations considered for the Taxi thermal control system include both passive and active modifications. In general, passive control modifications will reduce the passive rate of heat transfer between the vehicle and its thermal environment, while active thermal control modifications influence the manner in which heat is added, removed from, or distributed within the vehicle.

4.1.5.1 Passive Thermal Control

The alternate passive control devices under consideration include the following:

- Manually deployed insulation covers on the RCS clusters
- Additional 75 layers of insulation on the ascent stage.

A further discussion of these passive design changes is presented in Paragraph 4.1.6.

4.1.5.2 Active Thermal Control

The alternate active control system under consideration consists of an RTG waste heat system using direct-radiation heat transfer for cabin heating. In this configuration, the RTG is mounted on top of the descent stage in an insulated enclosure which has one side open to space and another side formed by an exposed portion of the ascent stage pressure vessel. An insulated hinged panel is placed in the enclosure between the RTG and the pressure vessel, and the amount of heat transferred to the cabin is controlled by varying the position of this panel.

The analysis in Paragraph 4.1.3.2 on the use of the pressure vessel for transferring heat from the RTG to the ascent stage cabin using the recommended heat pipe system is also valid for the alternate direct-radiation system. In the performance curves presented in Fig. 4.1-2, the cabin surface area can be considered to be the exposed pressure vessel area viewing the RTG.

4.1.6 Discussion of Configuration Choices

4.1.6.1 Passive Design Tradeoff

Studies conducted during Phase A established that quiescent storage during lunar night represented the most severe of all the Taxi missions considered. This results because the electrical equipment power dissipated within the cabin during the storage mission is not enough to replace the passive heat loss from the structure.

The two approaches to solving the night heating problem of the Taxi during storage are to either add insulation to the structure thereby reducing the heat leak, or to have larger power supplies to replace the passive heat loss. Therefore, a basic tradeoff exists between the addition of insulation to the Taxi structure and the addition of thermal energy sources for night mission heating.

The following changes to the insulation level of the LEM are considered for the Taxi:

- Change 1: LEM insulation level plus an automatically deployed insulation cover over the top docking tunnel. Weight estimate of tunnel cover is 10 lb.
- Change 2: Change 1 plus manually deployed insulation covers on the cabin side of the windows. Weight estimate for window covers is 10 lb.
- Change 3: Change 2 plus manually deployed insulation covers for each RCS cluster. Weight estimate of RCS covers is 40 lb.
- Change 4: Change 3 plus the addition of 75 layers of NRC-2 insulation to the existing 25 layers on the ascent stage external skins. Weight estimate of 75 layers of insulation is 87 lb.

Three sources of thermal energy are considered for heating the Taxi during the night mission. These sources and an estimate of their power/weight ratio for the 14-day storage phase are:

- Batteries: 0.24 w/lb
- RTG - electrical energy: 1.0 w/lb
- RTG - thermal energy (waste heat): 5.0 w/lb.

It is recognized that the power output of the thermal energy sources does not increase linearly with weight, but rather in stepwise manner; however, for this analysis the linear relation will be used.

Figure 4.1.3 shows the weight of added insulation and also the total weight of added insulation and power supply for the three power systems considered, as a function of required heater power. This figure shows that using waste heat from the RTG for night mission heating results in the lightest total weight. Moreover, for a particular power supply, the optimum weight of added insulation increases as the weight of the power supply increases.

Since the recommended configuration Taxi uses RTG thermal energy for night heating, a unique optimum insulation level is not determined. This is shown in Fig. 4.1-3 where it can be seen that the total weight of added insulation and power supply is the same for the LEM insulation level as it is for the recommended Taxi insulation levels with added docking tunnel cover and with added window covers.

There are other factors which influence the tradeoff between extra insulation and additional active heat sources, which have not been included in the analysis to date. These are the staging penalties applied to the weight of insulation added to the ascent stage, and the reduction in the weight of boiloff water required for cabin cooling during a day mission resulting from the addition of insulation.

Based on the evaluation to date of the factors influencing the insulation level weight tradeoff, it is recommended that the top tunnel insulation and the window shades be used for the recommended Taxi configuration. As better estimates of the weight of both the insulation covers and the power supply become available, these considerations will be reviewed, and if necessary, changes recommended.

4.1.6.2 Active Heating Source Selection

The advantages of the direct radiation RTG system over the heat pipe system are that the former adds no weight to the ascent stage and also requires no gravity field. The disadvantage is primarily a human factors consideration. Since the astronaut must transfer the RTG from the Shelter to the Taxi, placing the RTG on top of the descent stage would probably require the addition of a mechanical lifting system. For the heat pipe system, a lesser effort is required in placing the RTG in a side bay of the descent stage. Based on this consideration, the heat pipe system was selected as the recommended configuration.

4.1.6.3 Transient Analysis

The estimated heating and cooling loads for the ascent stage given in Paragraph 4.1.3 are based on steady state conditions which are valid only if the vehicle has no appreciable heat capacity, and only if the entire vehicle structure located within the insulation blanket is at a uniform temperature. No allowance is made for the stabilizing effect of the vehicle mass absorbing, or releasing, appreciable quantities of heat as the cabin temperature varies within its acceptable limits. The vehicle heat capacity prevents rapid temperature changes of the cabin, and thereby constitutes an element of conservatism in the estimated heating and cooling loads.

The transient response of a simplified model of the Taxi ascent and descent stages has been determined using a digital computer program. The model reduces the descent stage to 21 constant temperature elements, and the ascent stage to 17 elements. The elements chosen for the computer model are those vehicle components having the most significant influence on the vehicle transient response. Among the vehicle elements included in the simple model are: the exterior surfaces, cabin structure, propellant tanks, water tanks, and propulsion engines. The cabin structure was divided into three elements; these are: the cabin pressure vessel forward of the +Z27 bulkhead, the pressure vessel and structure located between the +Z27 and -Z27 bulkheads, and the structure and equipment located in the aft equipment bay.

The thermal model accounts for heat transfer between the ascent and descent stages, and between the vehicle external skins and the lunar environment. The influence of both the RCS clusters and the docking tunnel on the ascent stage balance is also included in the computer program. For this analysis, the ascent engine radiation coupling with its external environment was reduced by an order of magnitude. This can be achieved by the application of one layer of NRC-2 insulation (0.0002-in. thick) to the exposed portions of the engine. The insulation layer is perforated to vent any leaking gas. The engine was insulated because initial computer runs indicated excessive heat loss from the cabin via the ascent stage engine.

The range of thermal environments the Taxi could encounter during a 14-day lunar surface mission is sufficient to vary component temperatures beyond allowable limits. Therefore, active internal heating and cooling of the ascent stage cabin is required.

It has been assumed that limiting the allowable range of cabin structural temperature between 40 and 90°F will keep the temperature variations of most of the Taxi subsystems and components within allowable limits. Separate active temperature control systems will be provided for the vehicle components and subsystems which the cabin temperature control system cannot stabilize. These special thermal control systems were discussed in Paragraph 4.1.3.3.

Figures 4.1-4 and 4.1-5 show the transient thermal response of the cabin and propellant during the two most severe lunar surface missions. Figure 4.1-4 represents a 336-hr night mission and Fig. 4.1-5 represents a 336-hr day mission. Both missions begin at a terminator with the vehicle at a uniform temperature of 70°F. During the quiescent storage of both missions, no attempt is made to control the temperature of the cabin structure until it reaches its allowable limit. For the night mission analyzed, no heat is internally generated until the temperature of the mid-cabin structure drops to 40°F. At this temperature, sufficient heat is supplied to the cabin to stabilize its temperature. This mission is shown by the solid lines in Fig. 4.1-4. The dashed lines in Fig. 4.1-4 are the continuations of the initial cooling rate curves which predict the vehicle temperature history for the remainder of the night mission, if no heat is supplied to the cabin.

The vehicle temperature history during a day mission, with a constant internal heat load of 45w, is shown in Fig. 4.1-5. For this case, no heat is removed from the cabin until the mid-cabin structure reaches 90°F, at which time the ECS becomes operative and stabilizes the cabin at this temperature. The dashed continuation of the day mission heating curves predict the vehicle temperature history for the remainder of the day mission, if no cooling were provided.

A summary of the pertinent results of the computer analysis for these two missions is presented in Table 4.1-2. Maximum and minimum temperatures of selected elements of the Taxi are included in this table.

The results of the computer analysis for the night storage mission in which the cabin temperature is maintained at 40°F shows that the following elements are below their allowable temperatures:

<u>Element</u>	<u>Night Mission Minimum Temperature (°F)</u>	
	<u>Allowable</u>	<u>Computer Prediction</u>
Ascent Stage Oxidizer Tank	40	37
Ascent Stage Water Tank	40	33
Ascent Stage RCS Propellants	40	31
Descent Stage Water Tank	40	-41
Descent Stage Batteries	40	-39

The difference between the allowable and the computer predicted minimum temperatures of the ascent stage oxidizer, water, and RCS propellant tanks is not sufficiently large to require special active thermal controls, such as heaters. This tends to confirm the belief that by actively controlling the temperature of the cabin structure, the temperature of the fuel and water tanks located in the side bays of the ascent stage will be passively stabilized. The problem remains to investigate methods of limiting the minimum temperature of these liquids to 40°F during a night mission. This can be accomplished either by raising the minimum cabin temperature above 40°F, by further decoupling these tanks from the environment by addition of

insulation, or by some combination of these two approaches. The difference between the allowable minimum and the computer predicted descent stage battery and water tank temperatures are sufficiently large to conclude that these items require special thermal control. This was discussed in Paragraph 4.1.3.

The results of the day mission transient with 45-w internal heat load shows (Fig. 4.1-5 and Table 4.1-2) that day storage is a much less severe surface mission than the night storage mission. With a uniform temperature distribution of 70°F at the start of a daytime storage mission, little cabin cooling is required for propellant survival. Therefore, additional computer investigation was undertaken to investigate the influence of initial vehicle temperature on stay time cooling water requirement. The initial temperature distribution for the storage mission depends primarily on the vehicle orientation and active thermal control operation during the translunar mission.

Since the IEM can land on the Moon with its allowable propellant temperatures anywhere between 50 and 90°F, the worst possible case for the Taxi is an initial temperature of 90°F. The cooling water requirements for both the structural and 45-w equipment loads, as determined by both steady state and transient analysis for different initial temperatures, are as follows:

<u>Analysis</u>	<u>Initial Temperature (°F)</u>	<u>Cooling Water Required (lb)</u>
Steady State	any	200
Transient	70	12
Transient	90	64

The recommended Taxi design is based on thermal control water requirements determined by the steady state analysis. The transient analysis results indicate a weight reduction of at least 100 lb, and a possible elimination of any water requirement during the storage mission.

Table 4.1-1

SPECIAL HEATER REQUIREMENTS DURING A NIGHT MISSION

Quiescent Storage Mode - Cabin Temperature 40°F

Component	Heater Requirement, watts
RCS Clusters*	1,000
Rendezvous Radar Antenna	25
S-Band Steerable Antenna	6
IMU	13
ASA	7
Descent Stage Water Tank**	5
Descent Stage Batteries	0

*Required for 1 hr during prelaunch checkout to thaw frozen propellant lines.

**Provided by waste heat from RTG.

Table 4.1-2

TEMPERATURE EXTREMES DURING STORAGE PHASE

<u>Element</u>		<u>Night Storage Mission</u> <u>Minimum Temperature, °F</u>		<u>Day Storage Mission</u> <u>Maximum Temperature, °F</u>	
		<u>Cabin Heated</u> <u>at 40°F</u>	<u>Cabin</u> <u>Unheated</u>	<u>Cabin Cooled</u> <u>at 90°F</u>	<u>No Cooling</u> <u>Provided</u>
Ascent Stage	Fwd	38	0	92	96
	Cabin Mid*	40	0	90	95
	Aft	34	-3	95	99
	Fuel Tank	41	26	85	87
	Oxidizer Tank	37	12	79	81
	Water Tank	33	0	93	96
RCS Propellant Tanks	31	2	85	87	
Descent Stage	Water Tank**	-41	-44	93	93
	Batteries**	-39	-41	91	91

*Active thermal control is achieved by adding or removing heat from this element of cabin structure.

**Special thermal control required which was not included in computer analysis.

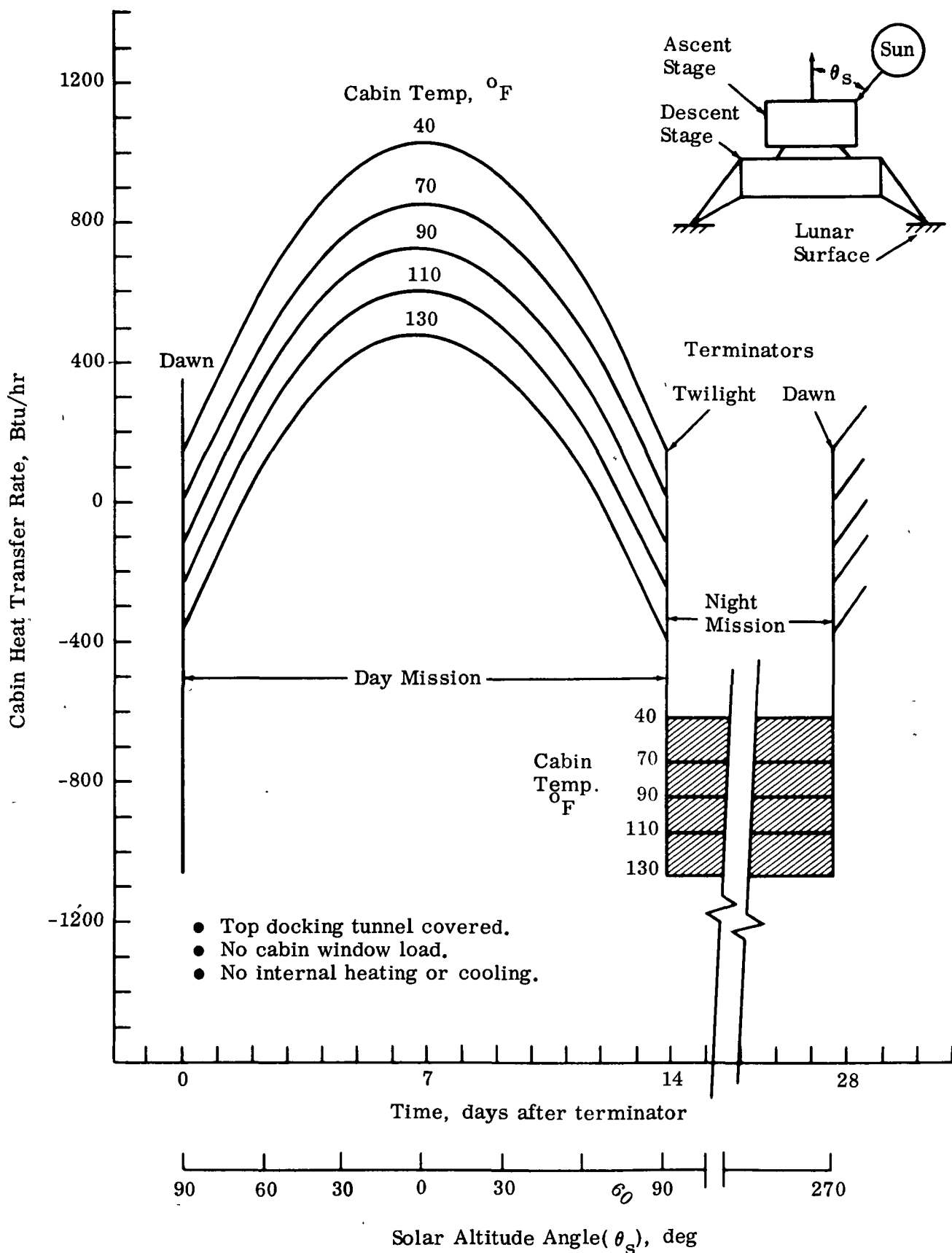


Fig. 4.1-1 Ascent Stage Steady State Thermal Characteristics

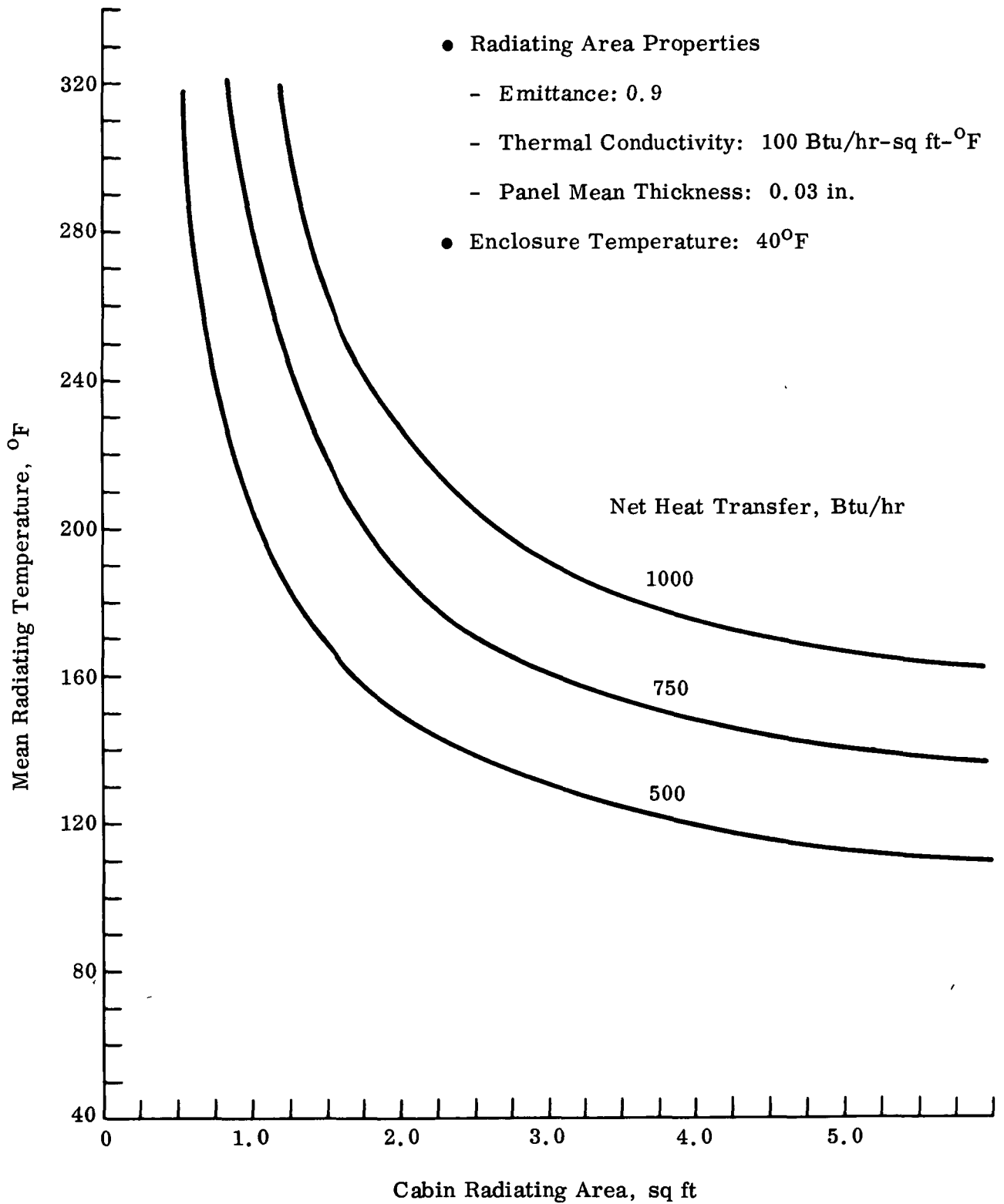


Fig. 4.1-2 Performance of Cabin Pressure Vessel for Night Heating Mission

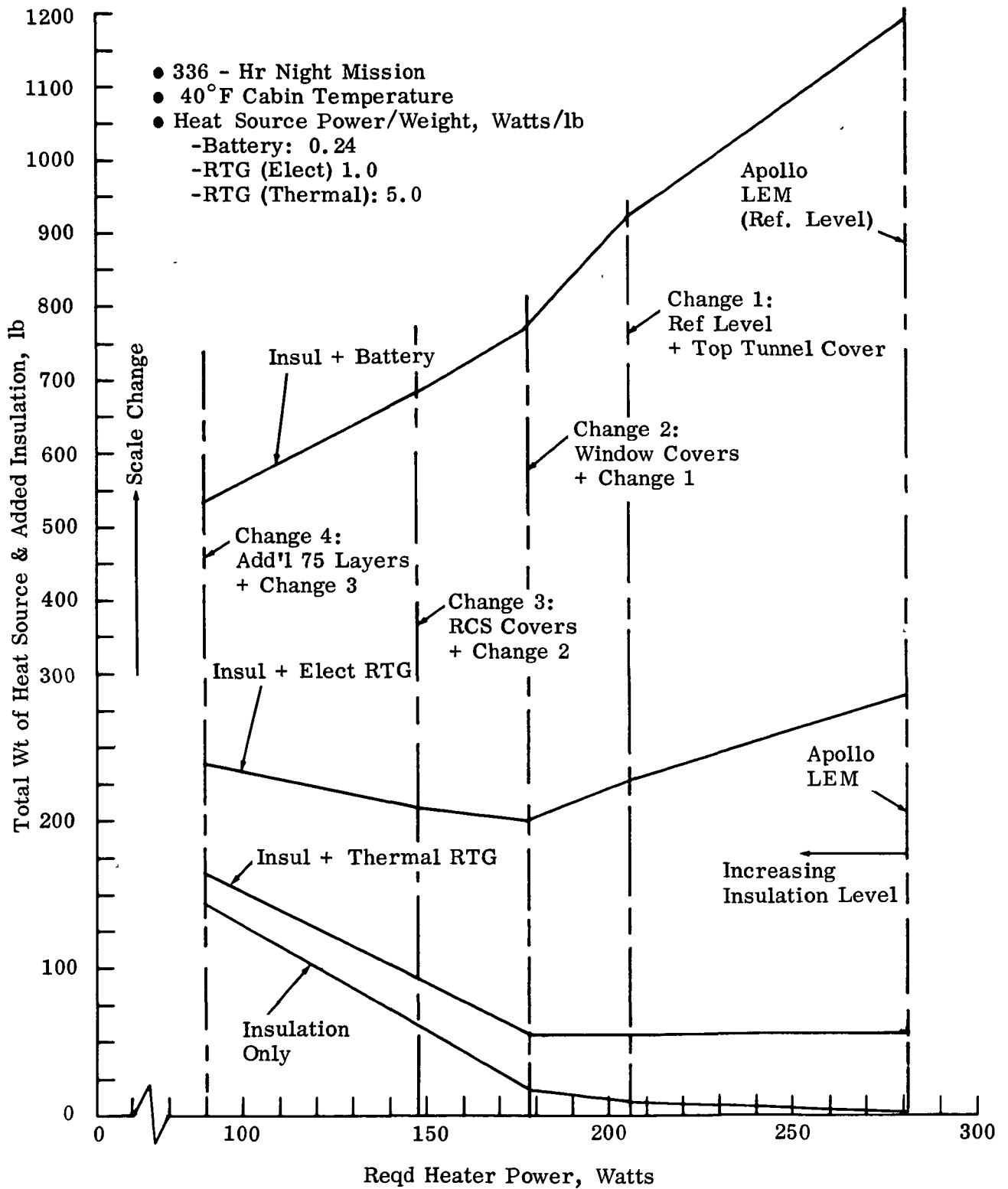


Fig. 4.1-3 Insulation/Heat Source Relationship

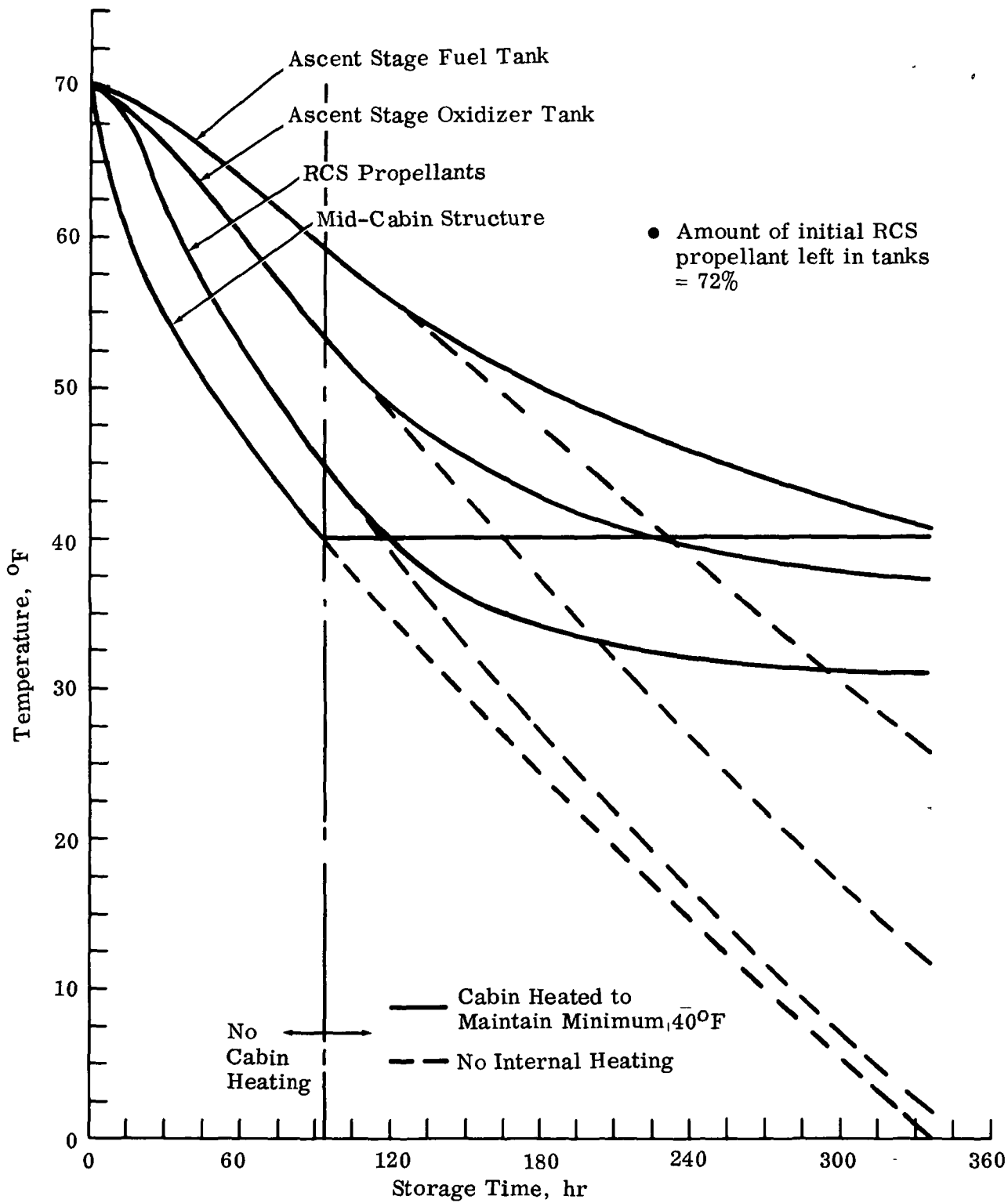


Fig. 4.1-4 Temperature History of Cabin & Propellants During Night Mission

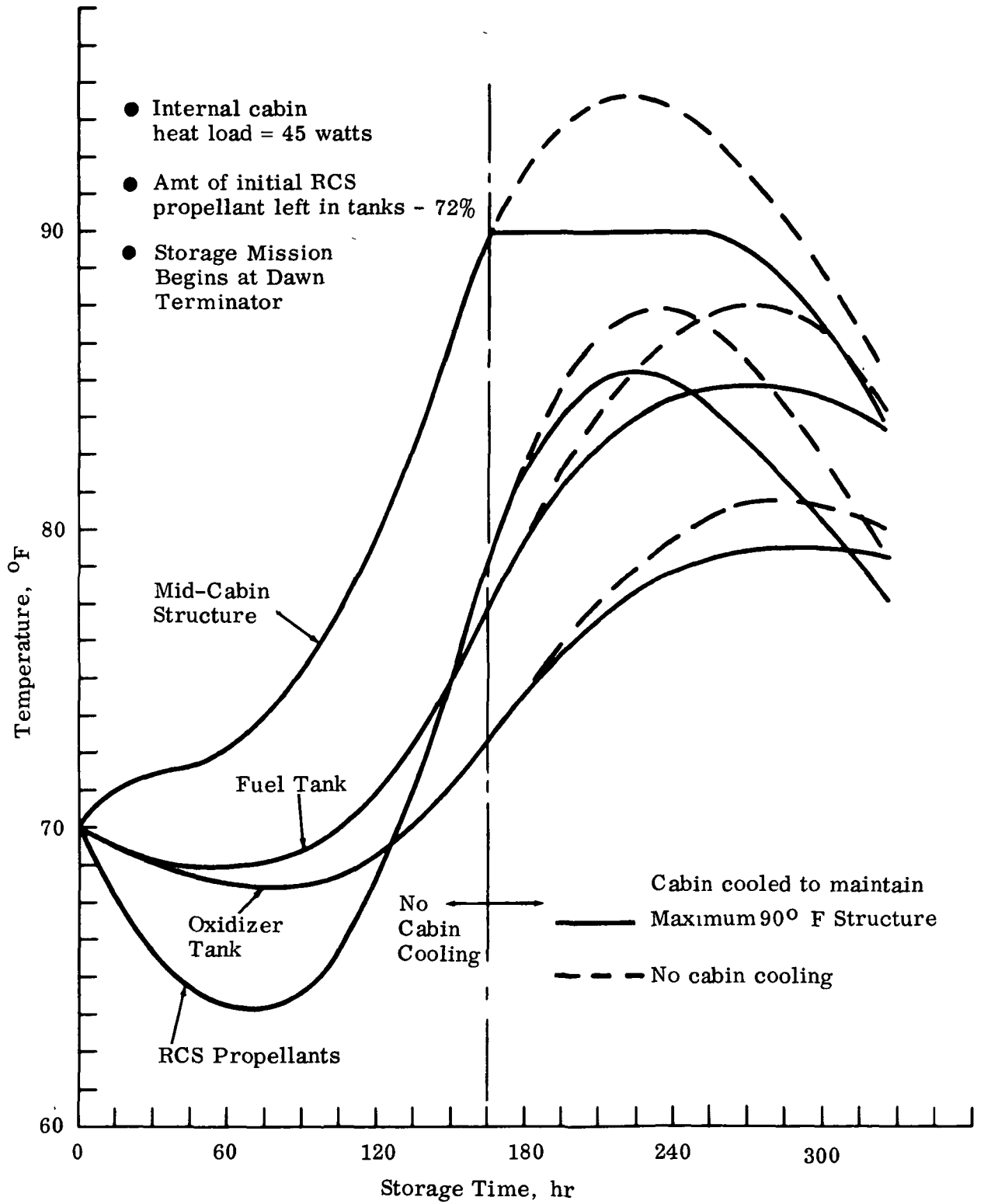


Fig. 4.1-5 Temperature History of Cabin & Propellants During Day Mission

4.2 INTEGRATED GUIDANCE & CONTROL

4.2.1 Ground Rules

The following ground rules were applicable to this area:

- Taxi shall have the ability to make a transponder aided landing;
- Anytime abort shall be retained when possible.

4.2.2 Assumptions and Background Data

It is assumed that relationships between the lunar orbit characteristics and the Earth injection parameters will be established by NASA.

Abort from the lunar surface may be conveniently divided into the following categories: anytime, conditional, and partial.

The condition implied by anytime abort is that abort capability is provided during a 12.8-min launch window at least once during each pass of the CSM for the duration of the lunar stay. In addition, the CSM must have the capability to rescue the Taxi from a 50,000-ft orbit. This requires that out-of-plane ΔV requirements be drawn within the limits of the Taxi propulsion system.

For a conditional abort, the CSM rescue requirement is relaxed, and all the CSM rescue ΔV is assumed to be available for plane change. Conditional abort precludes the possibility of certain types of ascent propulsion system failure, i.e., it assumes that likelihood of such failure is low enough to be negligible. When this assumption is not feasible, the rescue procedure must revert to anytime abort.

Partial abort requires that the capability for conditional abort be provided for some percentage of the lunar stay. If the likelihood of failure of Taxi systems during quiescent storage on the surface is found to be minimal, the inability to abort for a limited time will not seriously degrade the probability of crew safety.

4.2.3 Recommended Configuration

The LEM and Taxi requirements differ in terms of location of nominal landing sites, increased stay time, and increased return payload requirements. In addition, the Taxi has the requirement to land within walking distance of the Shelter.

4.2.3.1 Transponder Aided Landing

The Taxi descent profile is identical to LEM down to the powered descent phase. During the powered descent phase (Fig. 4.2.1), the Taxi differs from the LEM in that a transponder aided landing is assumed to be the primary landing mode. Since a rendezvous radar search mode for transponder acquisition is not provided in the LEM, the typical non-transponder descent must be modified. Phase II of the transponder descent is initiated at a greater surface range (20 vs 7 n.mi) and at a higher altitude (36,000 vs 10,600 ft), with a resulting fuel expenditure penalty (i.e., ΔV penalty) of 238 fps.

The design objective of a rendezvous radar/transponder aided system is to land within 200 ft of the transponder. This objective was met on all computer runs performed at Grumman under assumed rendezvous and landing radar error models.

4.2.3.2 Effects of Anytime Abort on Surface Stay-time and Return Payload Capability

The abort criteria were varied from a requirement for Taxi abort at anytime with maximum payload to a requirement in which limited abort capability is specified and interaction with lunar stay and payload capability was investigated. The resulting effects can be summarized for a landing at Alphorsus as follow:

- If the mission objective requires the capability for a Taxi abort at anytime, with the added safety of the capability for CSM rescue, and, if provisions must be made for a 250-lb payload return at anytime throughout the lunar stay, then a maximum stay time of 7.15 days can be achieved.
- If the mission objective is merely to return a 250-lb payload at the nominal time specified for ascent, a lunar stay of up to 10.2 days can be achieved while retaining Taxi anytime abort capability.
- If the ΔV allocated to the CSM for Taxi rescue can be used to increase the plane-change capability of the combined CSM/Taxi system, a lunar stay of up to 13.2 days can be achieved.
- If the mission objective is to retain abort capability only for a short period (critical time) after landing and prior to ascent, lunar stays in excess of 14 days can be achieved.

4.2.3.2.1 General Abort Procedure. The ascent used in the normal abort requires three thrusting maneuvers. The first impulse provides ascent to a 50,000-ft parking orbit, at a heading angle determined by the out-of-plane displacement at launch. The second impulse occurs at the node (i.e., the intersection of the parking orbit with the plane of the CSM orbit). This simultaneously performs the plane-change and initiates a Hohmann transfer to 80 n.mi. Note that performing both maneuvers concurrently requires an on-time launch (i.e., an instantaneous launch window), since there is no provision made for phasing with the CSM. The third burn circularizes the Taxi orbit at 80 n.mi to prepare for the docking maneuver. This type of ascent has many advantages compared with the "direct ascent" which does not utilize a parking orbit. Some advantages are the following:

- The Nominal boost pitch profile will be independent of both the out-of-plane displacement and the deviation between nominal and actual launch time
- As noted above, the heading angle (launch azimuth) depends only on the out-of-plane displacement, whereas in a direct ascent, the exact position of the CSM in its orbit must be considered
- Given equal ΔV and payload requirements, greater out-of-plane displacements can be tolerated in a parking orbit ascent. Similarly, greater launch windows are available for equal out-of-plane displacements
- The taxi must traverse a downrange central angle of approximately 270 deg to be in position to rendezvous. This enables Earth ground-tracking with MSFN to monitor the rendezvous maneuver.

The ΔV requirements associated with the parking orbit technique discussed above, and used in Table 4.2-1 for propellant calculations, were based on the following:

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Curves in which δ_3 is fixed, and δ_1 and δ_2 vary simultaneously show increases of about:

- 0.6 day/deg for anytime abort
- 0.4 day/deg for conditional abort.

It is possible to further increase the stay time by having the CSM perform a plane change maneuver shortly before point B (Fig. 4.2-2) is reached; that is allowing the CSM to expend some of its ΔV to change its orbit and reducing δ_3 accordingly (Fig. 4.2-5).

It appears at first glance that the time gained by this maneuver is quite substantial. However, it must be remembered that α , (Fig. 4.2-5) like δ_3 , has an upper limit of 7.38 deg. Performing the maximum plane change at the optimum position (the zenith of trace I) still leaves trace II well west of point C, rather than between C and D. Nonetheless, increases in stay time of more than a day result in many cases, as is shown in Fig. 4.2-6 and 4.2-7.

Figure 4.2-6 illustrates stay time vs landing site latitude for $\alpha = 1.5, 4.5,$ and 7.5 deg. It will be noted that a stay time of 12.8 days is possible at Alphonsus (13 deg S, 2 Deg W). When $\alpha = 7.5^\circ$ Figure 4.2-7 shows explicitly what is gained as a direct result of the plane change as a function of latitude. A further possibility to be looked into is that of a number of smaller plane changes α_i , such that $\sum \alpha_i = \alpha$

4.2.3.2.4 Effect of Partial Abort on Stay Time. Figure 4.2-5, with one modification, may also be used to represent the partial abort criteria. The modification is that the requirement $i = \theta + \delta_3$ is now relaxed; that is, the inclination of the CSM orbit is increased so that for a limited time, the Taxi is too far out of plane for a conditional abort, and δ_3 in Fig. 4.2-5 would now lie on either side of the Zenith of I. The question as to how large a percentage of the mission can be tolerated in the "no abort" region remains to be explored. However, some representative cases are displayed in Fig. 4.2-8.

In general, the partial abort configuration has a much larger effect on stay time at high latitudes than at low latitudes. Within a few degrees of the equator, in fact, the stay time decreases as the CSM orbit inclination increases. This will also be reflected in the next paragraph in Fig. 4.2-12 and -13, in which the stay time does not seem to increase appreciably in the partial abort case as compared with the conditional abort.

4.2.3.2.5 Correlation of Payload and Stay Time. A knowledge of the plane change required of the Taxi to abort at anytime during the mission is sufficient, using Fig. 4.3-1, to generate curves showing payload capability as a function of stay time. Assume that the target is to provide the capability to launch a payload of 250 lb throughout the lunar stay. As mentioned earlier, preliminary results indicate that the Taxi can do this and still perform a plane change of 1.8 deg. Imposing the restriction that the Taxi always shall be within 1.8 deg of the CSM plane, the maximum stay time for a landing at Alphonsus (13 deg S, 2 deg W) is 7.15 days. Stay time is displayed as a function of latitude for this case in Fig. 4.2-9. If it is sufficient merely to return a 250-lb payload at the nominal ascent, it is only necessary to specify $\delta_1 = 1.8$ deg. The rest of the lunar stay can proceed according to the normal abort modes as previously defined. The stay times are then: anytime abort, abort, 11.7 days with no CSM plane change, and 13.2 days with a CSM plane

change of 7.5 deg; and partial abort, perhaps up to 15 days. Fig. 4.2-10, -11, and -12 show payload vs stay time for an Alphonsus mission assuming, respectively, each of the abort criteria. In each case, some payload capability is provided for significant portions of the stay, and 250 lb is provided at nominal lift-off. For each case a 2-deg out-of-plane descent and a maximum plane change ascent stage (i.e., a vehicle weighing 10,465 lb) is assumed.

At first glance, it appears that payload capability can be increased by allowing the CSM to perform the ascent plane change wherever possible. However, because of transearth trajectory requirements, the CSM must keep its ΔV in reserve, and thus, Fig. 4.2-10, -11, and -12 were generated by assuming that the Taxi performs the plane change wherever possible.

4.2.3.2.6 Correlation with Transearth Trajectory Requirements. All the results above were generated independent of the requirements of the transearth phase of the mission. The minimum ΔV required for a transearth injection is a rather complicated function of the stay time. For an Alphonsus mission using the abort techniques described in this report, the ΔV margin is very small until about 3 days into the mission, since the injection window lies in the northeast quadrant, and the CSM ground trace begins in the southeast and northwest quadrants. The situation again becomes serious about 12 days later. A preliminary study was made of the conditional abort from Alphonsus, with respect to transearth injection. Fig. 4.2-13 shows the ΔV available for injection and the ΔV necessary for injection as a function of stay time. The dip in the ΔV available curve represents the CSM role in Taxi rescue, and the sudden drop is a result of the CSM plane change at 10.5 days. From Fig. 4.2-13, it can be seen that for significant parts of the mission, substantial margins for injection ΔV exist. Thus, trade-offs between these margins and both the rescue and payload capability are possible and must be studied. These trade-offs may yield considerable increases in stay time and/or maximum launch payload.

4.2.3.2.7 Extended Waiting Time in Parking Orbit. Additional ΔV may be obtained for Taxi rescue if the ΔV used during the deboost into lunar parking orbit can be minimized. In some cases a more favorable translunar trajectory may be chosen. However, for an Alphonsus landing, most such trajectories would leave the CSM orbit too far out of the plane of the landing site for a Taxi descent. Waiting in orbit for some additional time, until the landing site is within range, or waiting after ascent for a favorable trans-earth trajectory to become accessible may offer a solution. In the case of an Alphonsus landing, the latter appears to be more promising and will be studied further.

4.2.4 Baseline Configuration

The baseline configuration used for the Taxi is the same as the recommended configuration described in Paragraph 4.2.3.

4.2.5 Discussion of Configuration Choices

Performance capabilities of the Taxi are strongly dependent on operational flight plans and decisions. There is a particularly significant relationship between the lunar orbit characteristics and Earth injection parameters.

All the NASA objectives for lunar stay time and payload return capability at the designated landing sites can be met. However, some compromise of stated abort criteria and redistribution of the ΔV budget for both the Taxi and the CSM must be made (from that for the nominal Apollo/LEM mission). The necessary changes appear reasonable, and appropriate direction from NASA is anticipated during the early portion of the Phase C.

- Using a digital simulation of the equations of motion and the PNGCS, a ΔV of 6014 fps was computed for the powered ascent from lift-off to a 50,000-ft circular parking orbit. The trajectory was computed for a 10,850-lb ascent stage and included a 12-sec vertical rise prior to initiation of the pitch maneuver.
- Plane change and transfer ΔV 's at the CSM-Taxi orbit node were computed impulsively, assuming a Hohmann transfer.
- 75-fps ΔV for mid-course was based on the figures quoted in Apollo Spacecraft ΔV Budget, MSC Internal Note No. 65-FM-56.
- 97-fps ΔV required for circularization and rendezvous at 80 n.mi was computed impulsively and assumes a Hohmann transfer.
- 25-fps ΔV required for docking was based on figures quoted in the Apollo Spacecraft ΔV Budget, MSC Internal Note No. 65-FM-56.

4.2.3.2.2 Plane Change Capability. Paragraph 4.3 presents an analysis of the Taxi return payload capability as a function of ascent stage weight, propellant quantity and plane change during the second burn of the parking orbit ascent (Fig. 4.3-1). Based on this analysis, the Taxi is capable of maximum plane change of 4.45 deg with a minimum lunar launch gross weight of 10,464 lb and zero payload. A nominal launch with a 250-lb payload can be accomplished with a 1.8-deg plane change and a Taxi gross weight of 10.710 lb.

In addition, the CSM has enough ΔV allotted for an additional 7.38-deg plane change per Apollo Spacecraft ΔV Budget, MSC Internal Note No. 65-FM-56. Thus, the maximum plane change for anytime abort is 4.45 deg, and for conditional abort is 11.83 deg.

4.2.3.2.3 Effects of Anytime and Conditional Abort on Stay Time. The problem of maximizing the stay time, as is illustrated in Fig. 4.2-2, is the problem of making optimum use of the three out-of-plane capabilities: during ascent (δ_1), during descent (δ_2), and for emergency abort (δ_3). The small circle arc AB, lying on the parallel of latitude = θ deg, is the path of the landing site relative to the CSM orbit trace as it precesses. In the configuration shown in Fig. 4.2-2, an emergency abort would require the maximum plane change (δ_3) at only one point during the entire stay. Similarly the maximum descent and ascent plane changes (δ_2 and δ_1) are only required at points A and B.

The CSM remains in a fixed 80-n.mi circular parking orbit of inclination $i = \theta + \delta_3$, which precesses from east to west (in selenographic coordinates). The larger part of this precession is due to the Moon's rotation of 13.177 deg/day and is east to west. The lesser part, due to the tri-axiality of the Moon, equals $1.243 \cos i$, and is west to east (e.g., an equatorial orbit precesses at 11,937 deg/day). Without the triaxiality term, stay time vs landing site latitude displays a marked symmetry around $\theta = (90 - \delta_3)/2$, for which stay time is a minimum. The regression distorts this symmetry somewhat.

Figures 4.2-3 and 4.2-4 demonstrate the effect on stay time of varying δ_3 while δ_1 and δ_2 are fixed at zero for anytime and conditional aborts, respectively. As was already apparent by virtue of the symmetry exhibited by Fig. 4.2-2, the effect on the stay time of changing δ_1 is exactly equivalent to the effect of changing δ_2 by the same amount. Curves in which δ_3 is fixed at its maximum value while either δ_1 or δ_2 is varied (and the other is fixed) shows an increase in stay time of about:

- 0.3 day/deg for anytime abort
- 0.2 day/deg for conditional abort.

Phase C efforts should be directed to achieving early definition of the operational philosophy which will allow the performance of error analyses and agreement between NASA and the associate contractors upon a "nominal" ΔV budget.

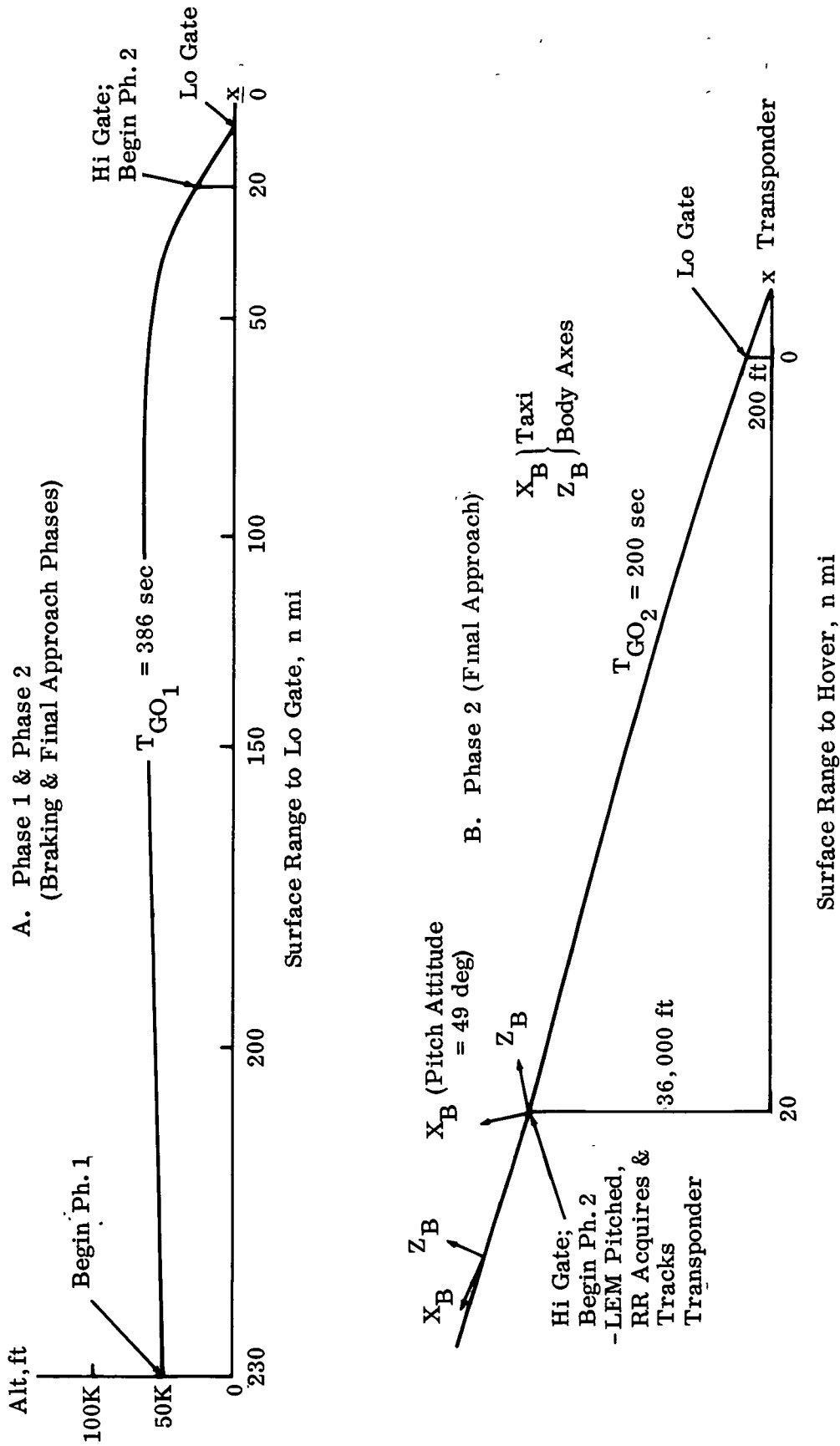


Fig. 4.2-1 Beacon-Aided Descent Trajectory Profile

Table 4.2-1

TAXI ΔV REQUIREMENTS ($W_0 = 10,820$ lb)

Plane Change, deg \ Mission Phase	0	1	2	3	4	4.8
Powered Ascent to 50,000-ft Circ. Orbit	6014	6014	6014	6014	6014	6014
Plane Change & Transfer*	99	138	217	306	399	473
Midcourse	75	75	75	75	75	75
Rendezvous	97	97	97	97	97	97
Docking	25	25	25	25	25	25
TOTAL	6310	6349	6428	6517	6610	6684

*Plane change & transfer performed with one impulse.

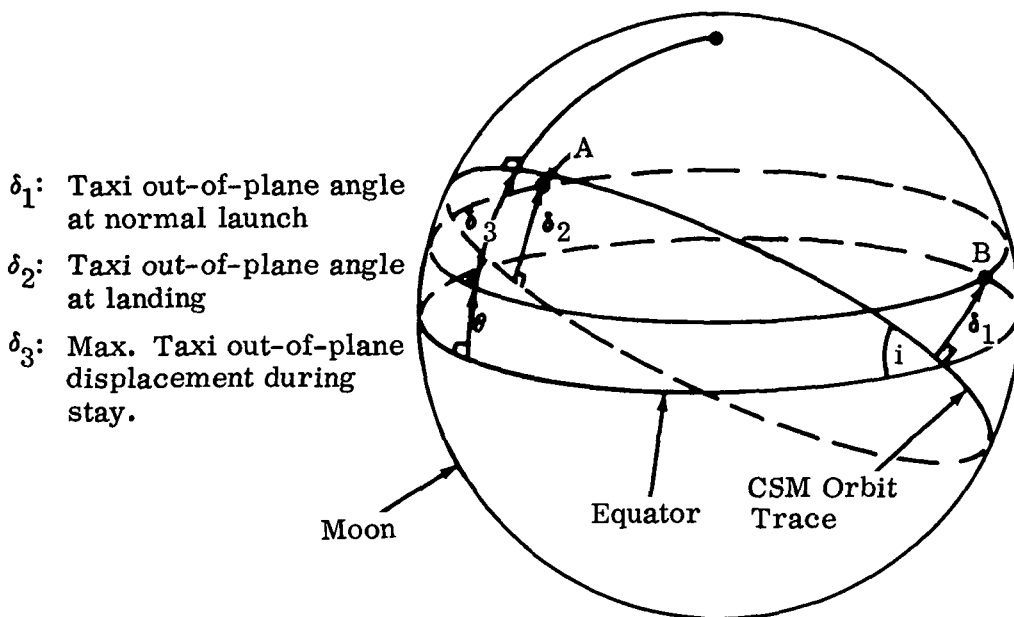


Fig. 4.2-2 Geometric Representation of Typical Taxi Mission

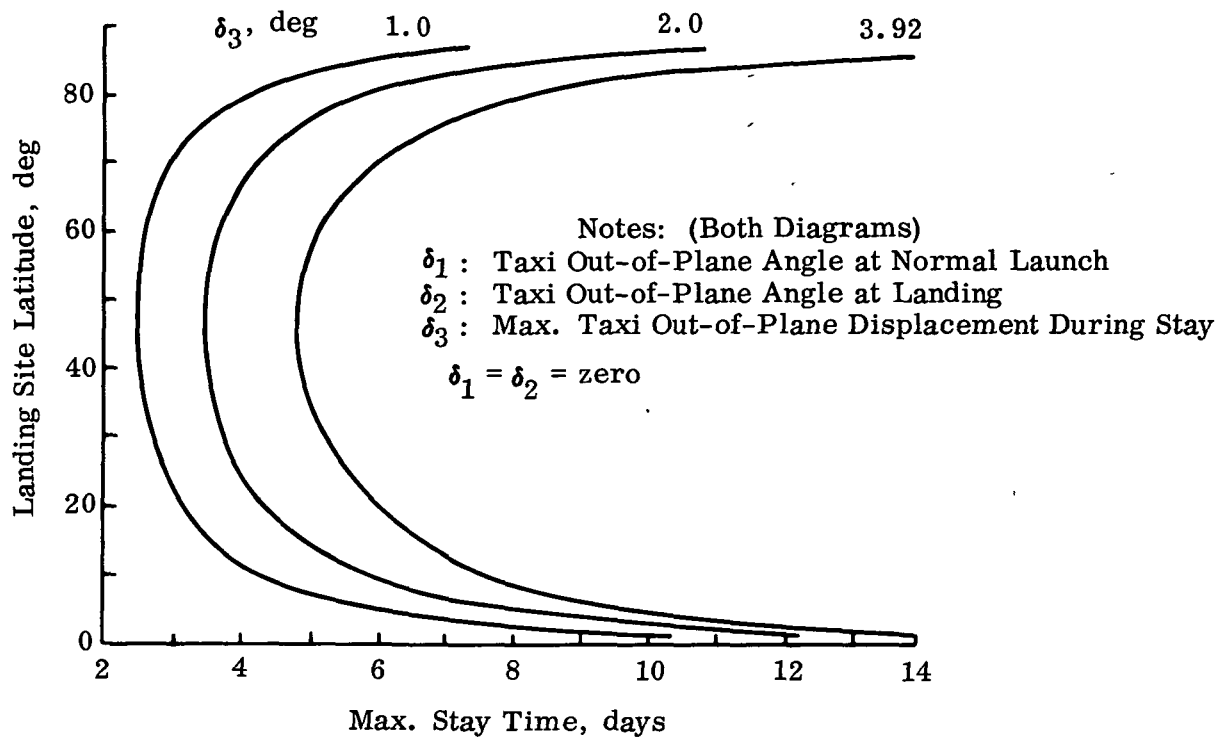


Fig. 4.2-3 Maximum Stay Time-Anytime Abort

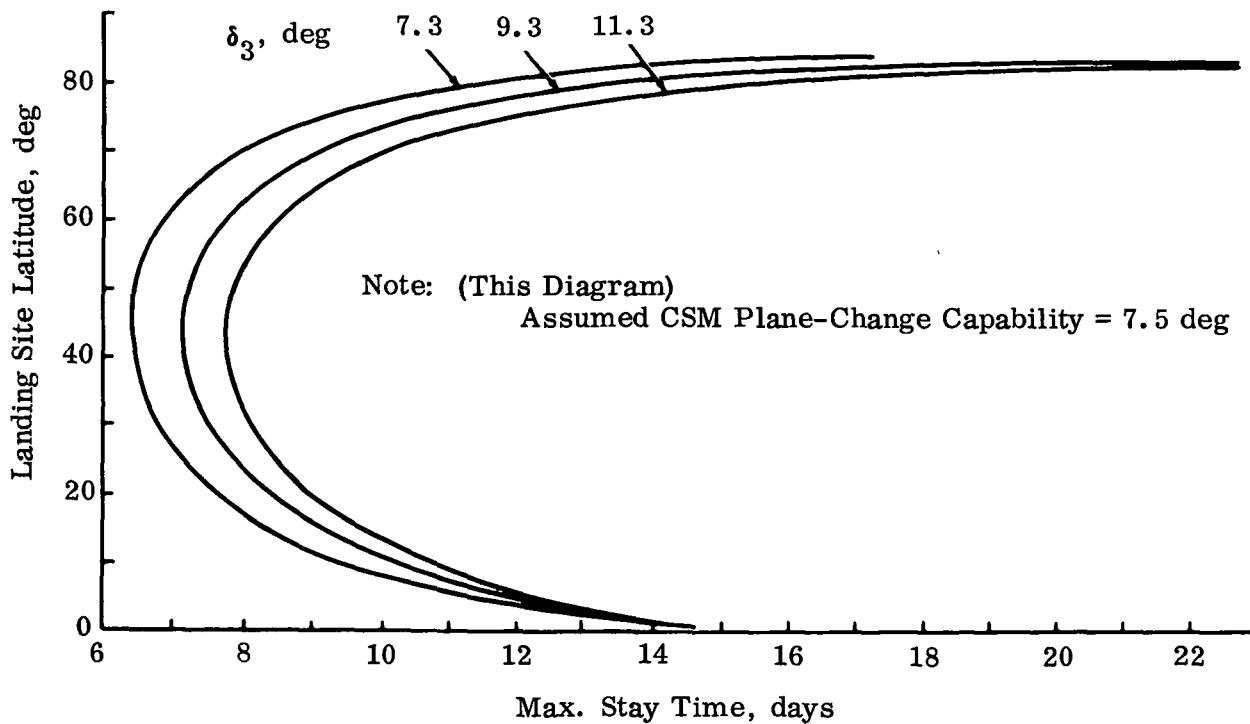


Fig. 4.2-4 Maximum Stay Time-Conditional Abort

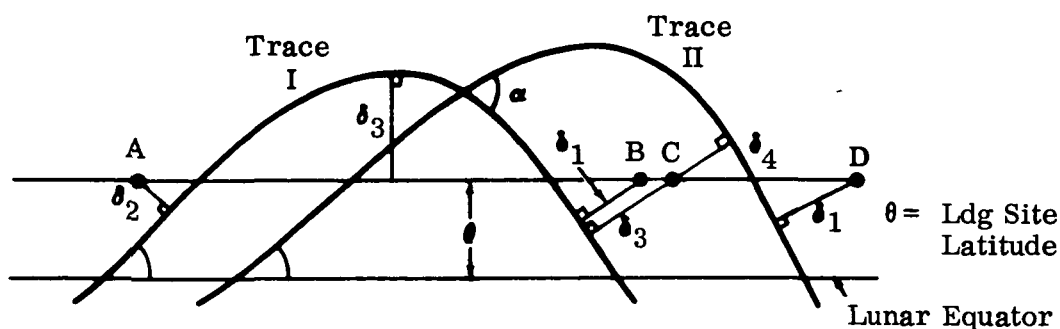


Fig. 4.2-5 Mercator Projection of Taxi Conditional Abort Geometry

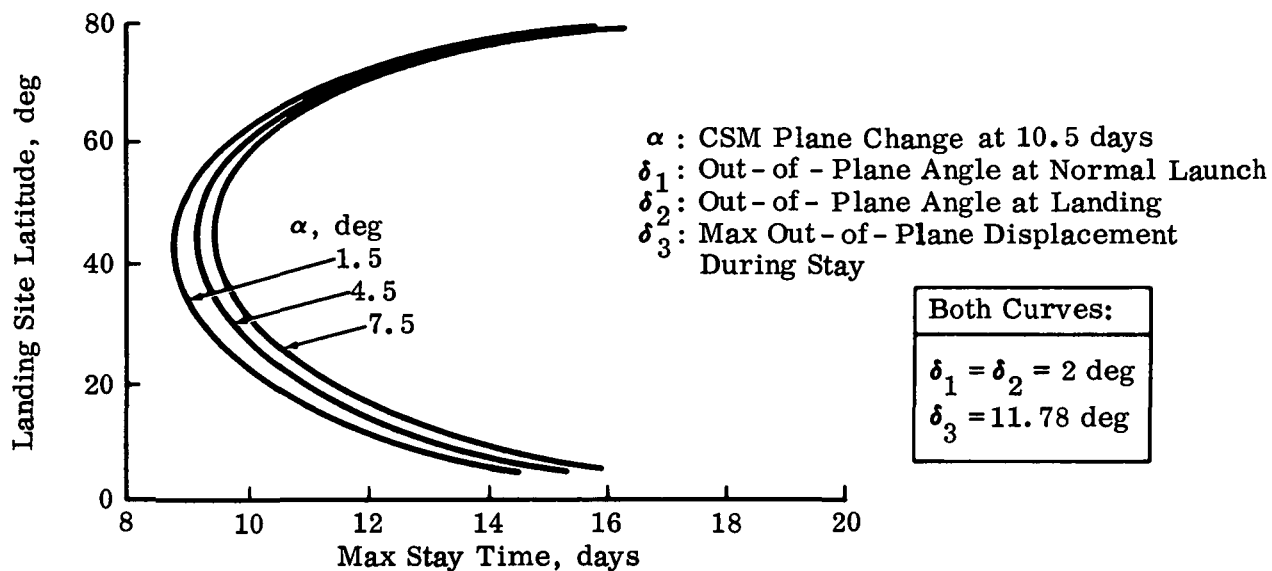


Fig. 4.2-6 Maximum Stay Time-Conditional Abort with CSM Plane Change

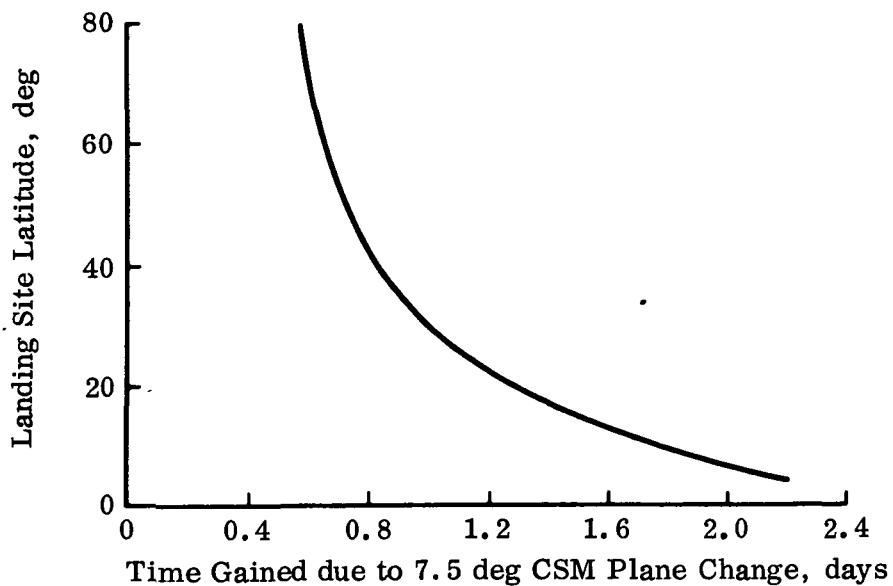


Fig. 4.2-7 Effect of CSM Plane Change on Stay Time (Conditional Abort)

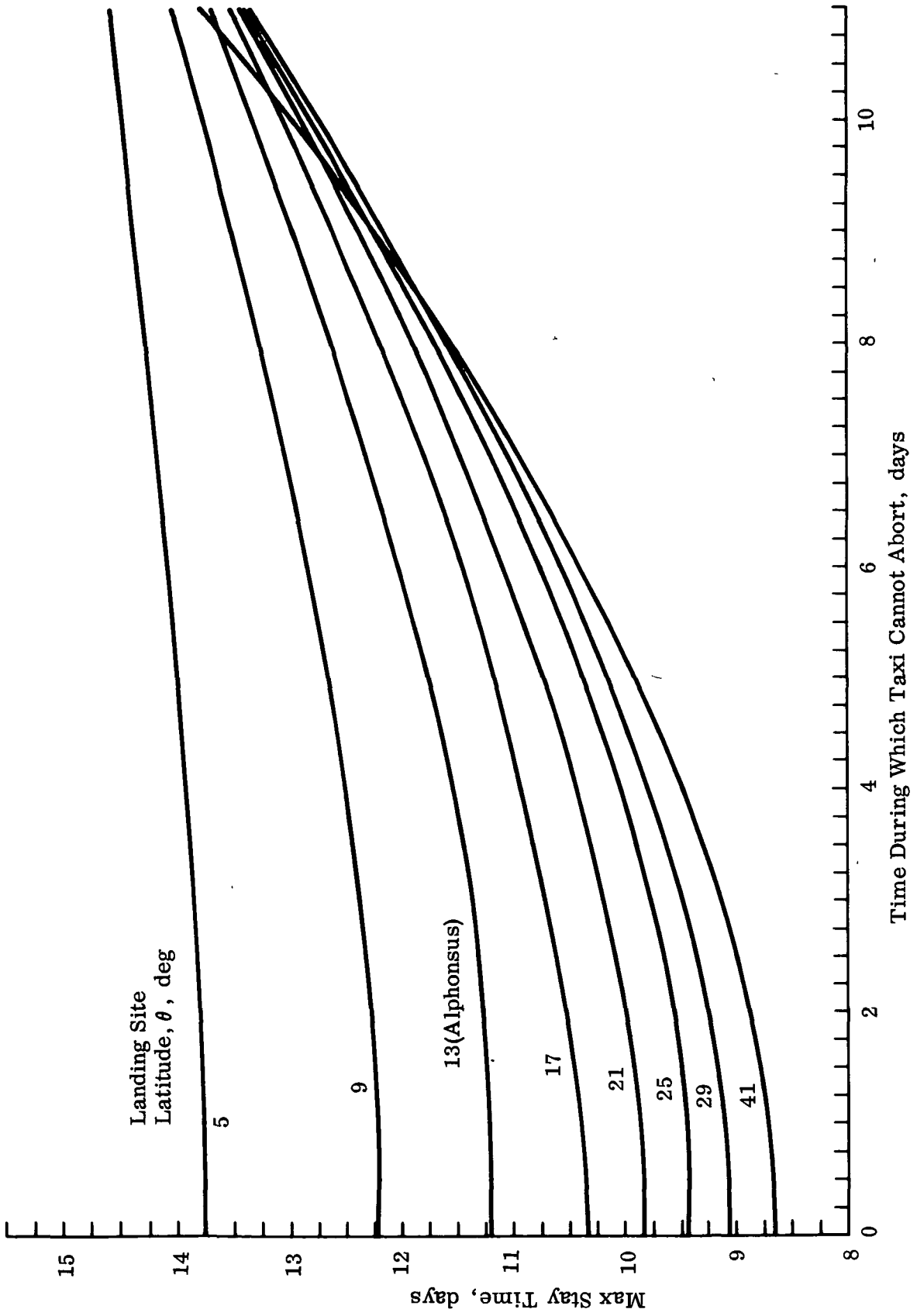
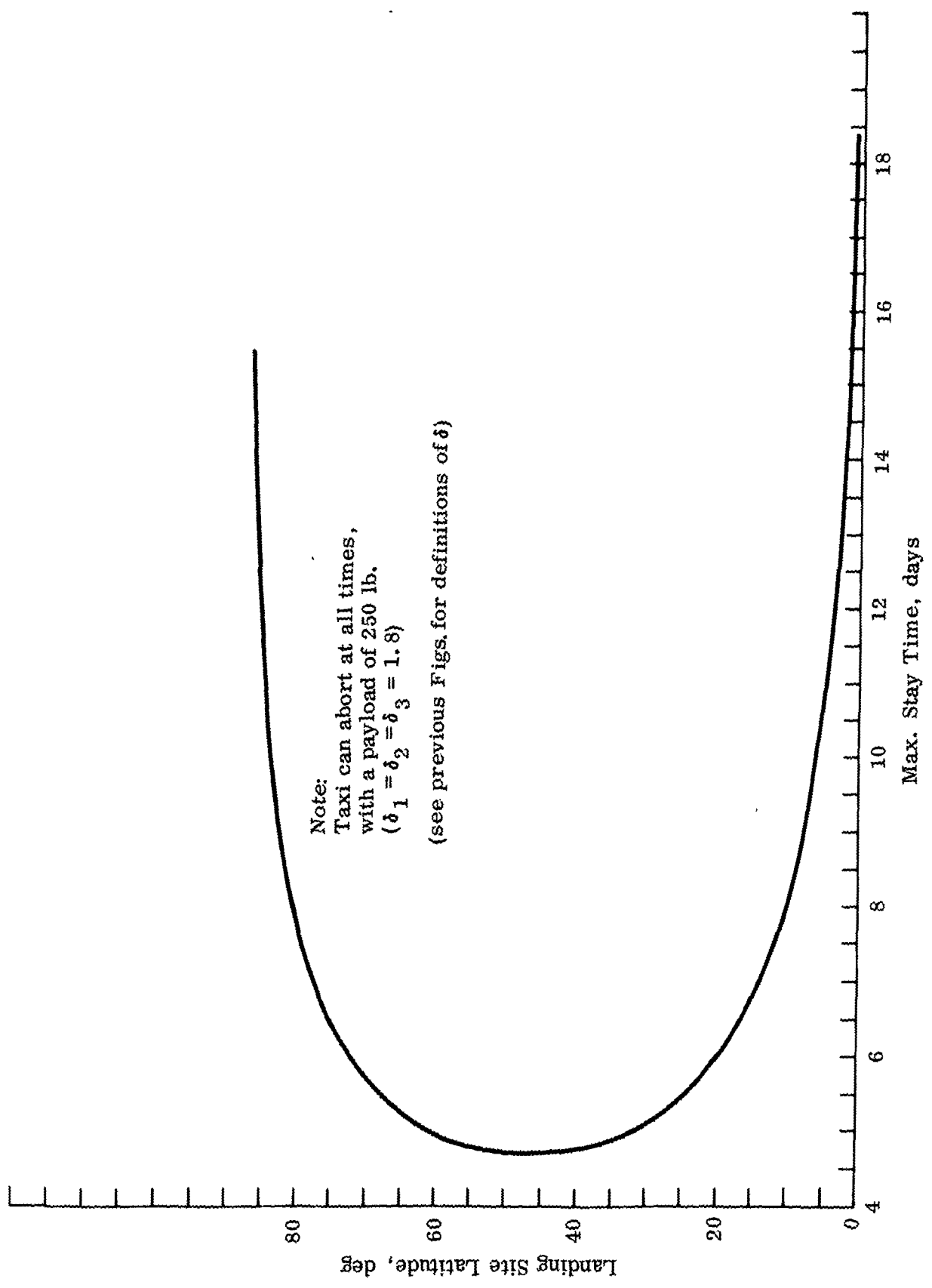


Fig. 4.2-8 Maximum Stay Time-Partial Abort



Note:
 Taxi can abort at all times,
 with a payload of 250 lb.
 ($\delta_1 = \delta_2 = \delta_3 = 1.8$)
 (see previous Figs. for definitions of δ)

Fig. 4.2-9 Maximum Stay Time-Anytime Abort with 250 lb Payload

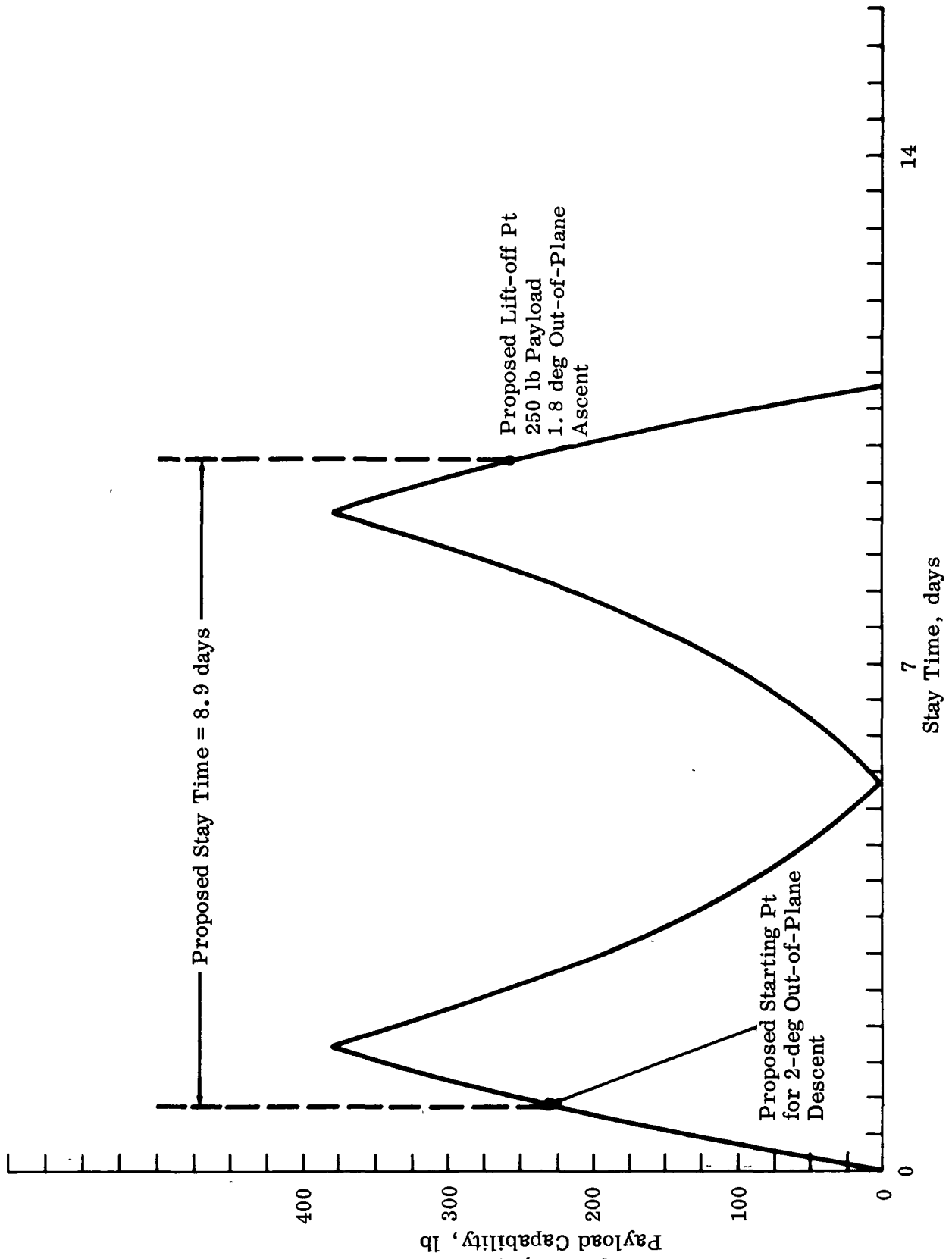


Fig. 4.2-10 Payload Capability (Alphonsus Mission)-Anytime Abort

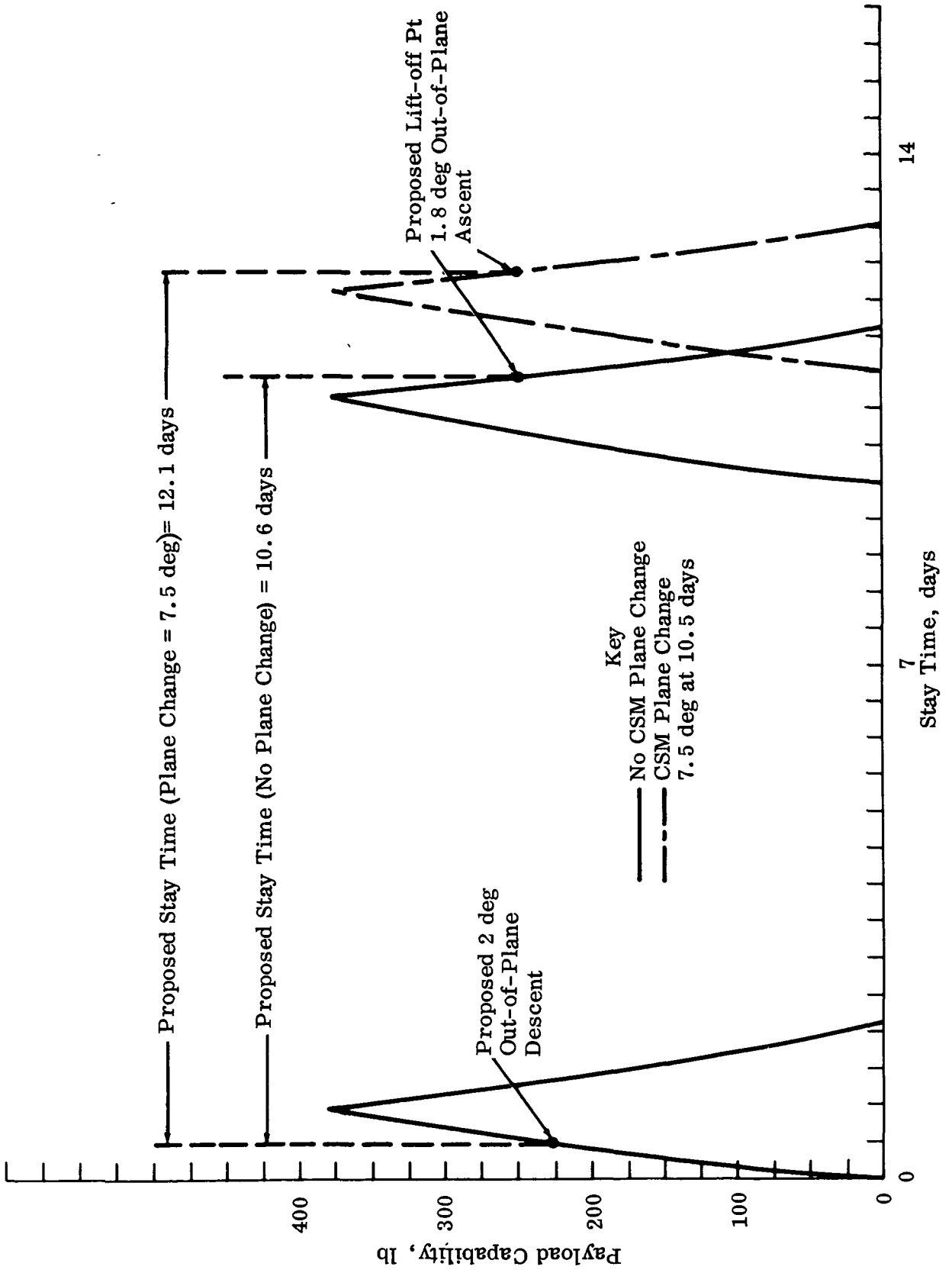


Fig. 4.2-11 Payload Capability (Alphonsus Mission) - Conditional Abort



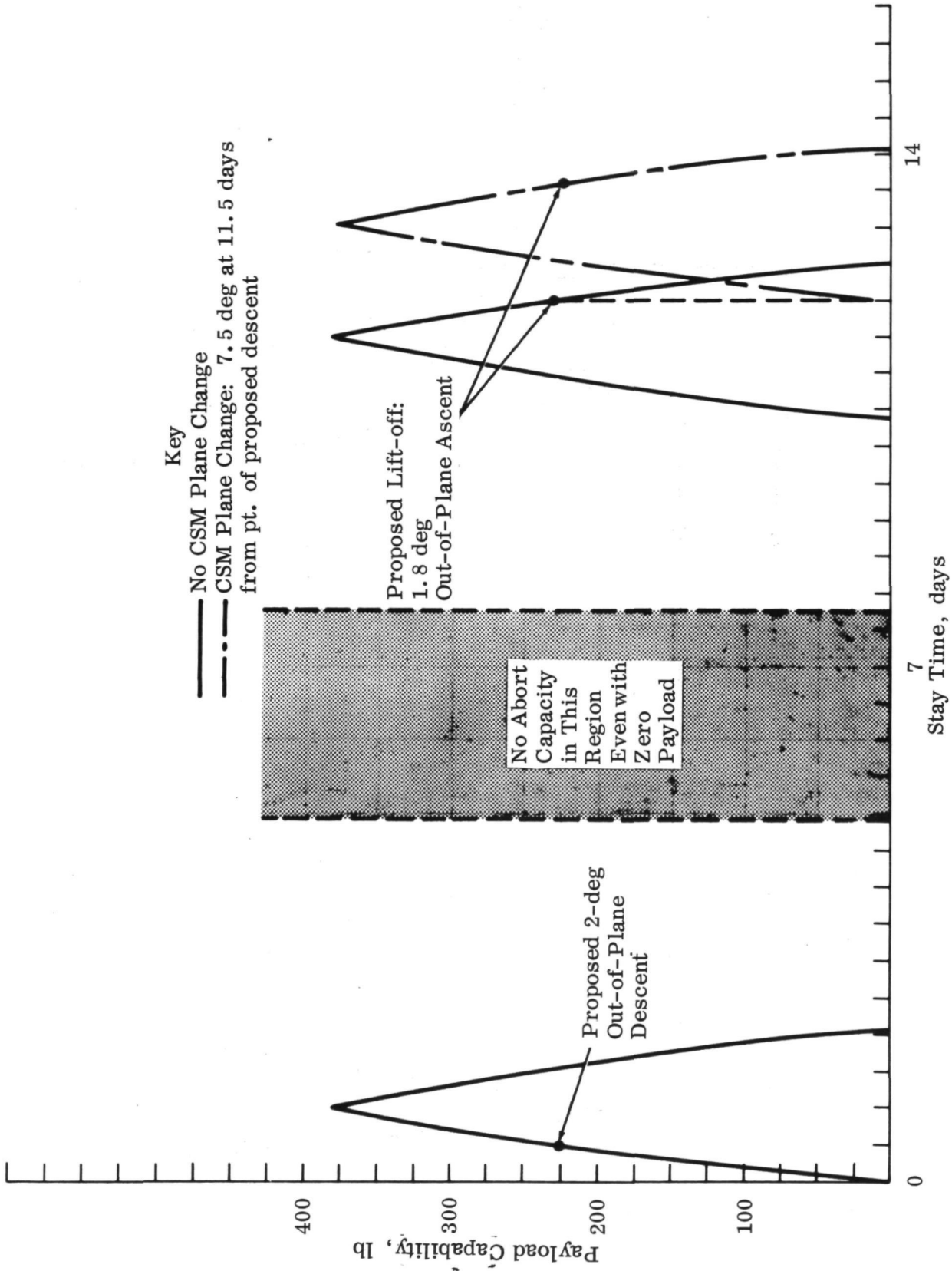


Fig. 4.2-12 Payload Capability (Alphonsus Mission) - Partial Abort

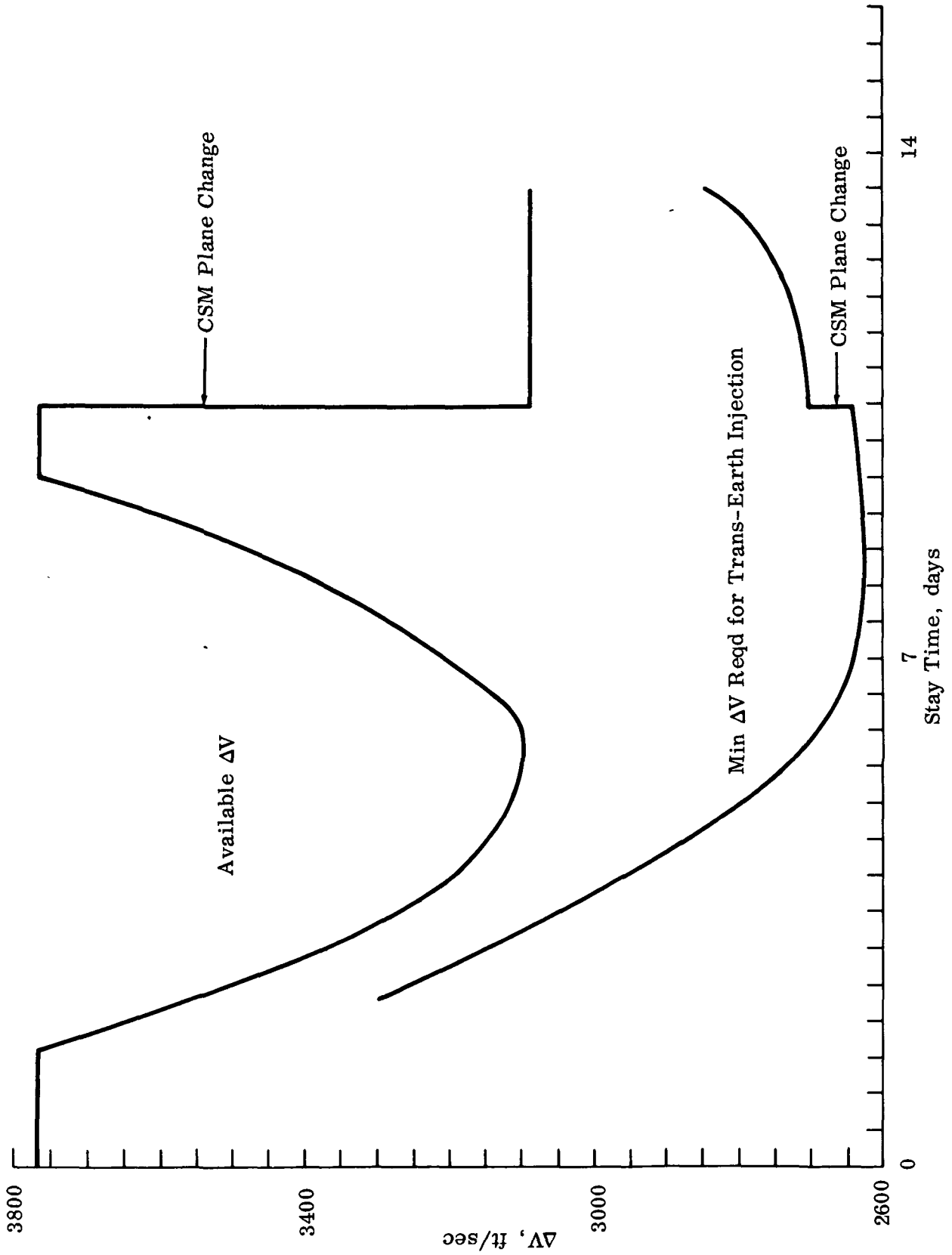


Fig. 4.2-13 CSM Trans-Earth Injection ΔV Profile (Alphonsus Mission)

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4.3 REACTION CONTROL AND PROPULSION

4.3.1 Ground Rules

The following ground rules were applicable to this area:

- The propulsion capability of either the ascent or descent stage is not to be exceeded
- The Taxi shall have the ability to make a transponder aided landing
- Anytime abort shall be retained when possible
- Taxi payload design goal of 250 lb.

4.3.2 Assumptions and Background Data

The Taxi mission is identical to LEM to the powered descent phase. During the powered descent phase, a transponder aided landing is assumed to be the primary landing mode, with a resulting fuel expenditure ΔV penalty of 238 fps (see Section 4.2.3).

For the analysis of the RCS and propulsion requirements during the ascent phase of the mission, the following assumptions were used:

- Mission phase ΔV requirements are as shown in Table 4.2-1
- Main engine specific impulse = 306 sec
- RCS engine specific impulse = 230 sec for all RCS ΔV thrusting periods
- $\frac{\partial (\Delta V)}{\partial (T/W_0)} = \frac{-2350 \text{ ft./sec}}{1 \text{ lbf/lbm}}$
- During powered ascent, the maximum moment unbalance = 500 ft-lb
- ΔV required for propellant ullage settling is 17 fps.
- Taxi inert weight immediately after docking is 5040 lb; this includes both main and RCS residuals as well as 2 lb of GOX.

The approach taken to propellant loading to compute payload capability is extremely important since one can be traded for the other on almost a one-for-one basis (i.e., 1 lb of propellant is required for each pound of payload). The philosophy of loading taken here was as follows:

Main propulsion was assumed to provide the total ΔV necessary for powered ascent, Hohmann transfer, and plane change requirements with no cg moment unbalance. To this was added sufficient reaction control propellants to allow for a maximum cg moment unbalance of 500 ft-lb during powered ascent, plus propellant for non- ΔV attitude maneuvers.

Assuming that ullage settling, midcourse corrections, rendezvous, and docking are all accomplished by the RCS, sufficient propellant was loaded to provide a total ΔV of 214 fps plus 17 fps for ullage settling. RCS propellant for non- ΔV maneuvers and contingency requirements was also included to complete the RCS tank loading. This philosophy of main engine and RCS propellant loading for Taxi ascent compares very nearly to the LEM. The use of this philosophy for the Taxi has two advantages; first, it insures that sufficient propellant is provided to take care of the two extreme cases of cg moment unbalance, i.e., no unbalance and 500 ft-lb unbalance; and secondly, it provides sufficient main and RCS propellants to meet the LEM ΔV budget which includes all flexibility and 3 σ ΔV allowances.

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4.3.3 Recommended Configuration

The Taxi payload capability is shown in Fig. 4.3-1 as a function of plane change requirements and gross lift-off weight. Two conclusions can be drawn from this figure:

- A Taxi payload capability of 250 lb can be achieved with a 1.8 deg plane change capability by completely filling the main ascent propellant tanks (5017 lb usable propellant). This corresponds to a Taxi lunar lift-off weight of 10,720 lb.
- The maximum plane change capability of the Taxi is 4.45 deg and corresponds to zero payload capability with full propellant tanks. Taxi lift-off weight is 10,464 lb.

An estimate of RCS and main propellant requirements for a Taxi ascent has been calculated and is shown in Tables 4.3-1 and 4.3-2. The assumption and philosophy of propellant loading used in this analysis are as described in Section 4.3.2. In addition, the loadings shown correspond to a 250 lb return payload and a Taxi plane change capability of approximately 1.8 deg.

4.3.4 Baseline Configuration

The baseline configuration used for the Taxi is the same as the recommended configuration described above.

4.3.5 Alternate Configuration

No alternates were considered during this study.

4.3.6 Potential Modifications Per Flight

No per flight modifications were considered.

Table 4.3-1

MAIN PROPULSION-PROPELLANT LOADING FOR TAXI ASCENT

Mission Event	ΔV , ft/sec	Isp, Sec	Main Propellant, lb
Lunar Launch to 50,000 ft	6007	306	4898
Hohmann Transfer & Plane Change 1.8 deg	200	306	118
Trapped and Residuals	--	--	126
Total Propellants			5142

Table 4.3-2

REACTION CONTROL-PROPELLANT LOADING FOR TAXI ASCENT

Mission Phase	Propellant Which does Not Contribute ΔV , lb	Propellant Which Contributes ΔV , lb	Total Propellant Req'd. for Mission Phase, lb
Ascent			
Lunar Launch to End of Insertion to Hohmann	(27.7)	(181.3)	(209.0)
Ullage Settling (ΔV)		8.1	8.1
cg Compensation (ΔV)		173.2	173.2
Attitude Control-Maneuvers	4.0		4.0
For Contingency Orbit	23.7		23.7
Coast Mid-course Corrections			
Rendezvous Docking	(21.3)	(162.2)	(183.5)
Translation (ΔV)		162.2	162.2
Attitude Control-Maneuvers	21.3		21.3
Contingency for Single Tank Failure at Rendezvous	(21.0)		(21.0)
Total RCS Propellants			413.5

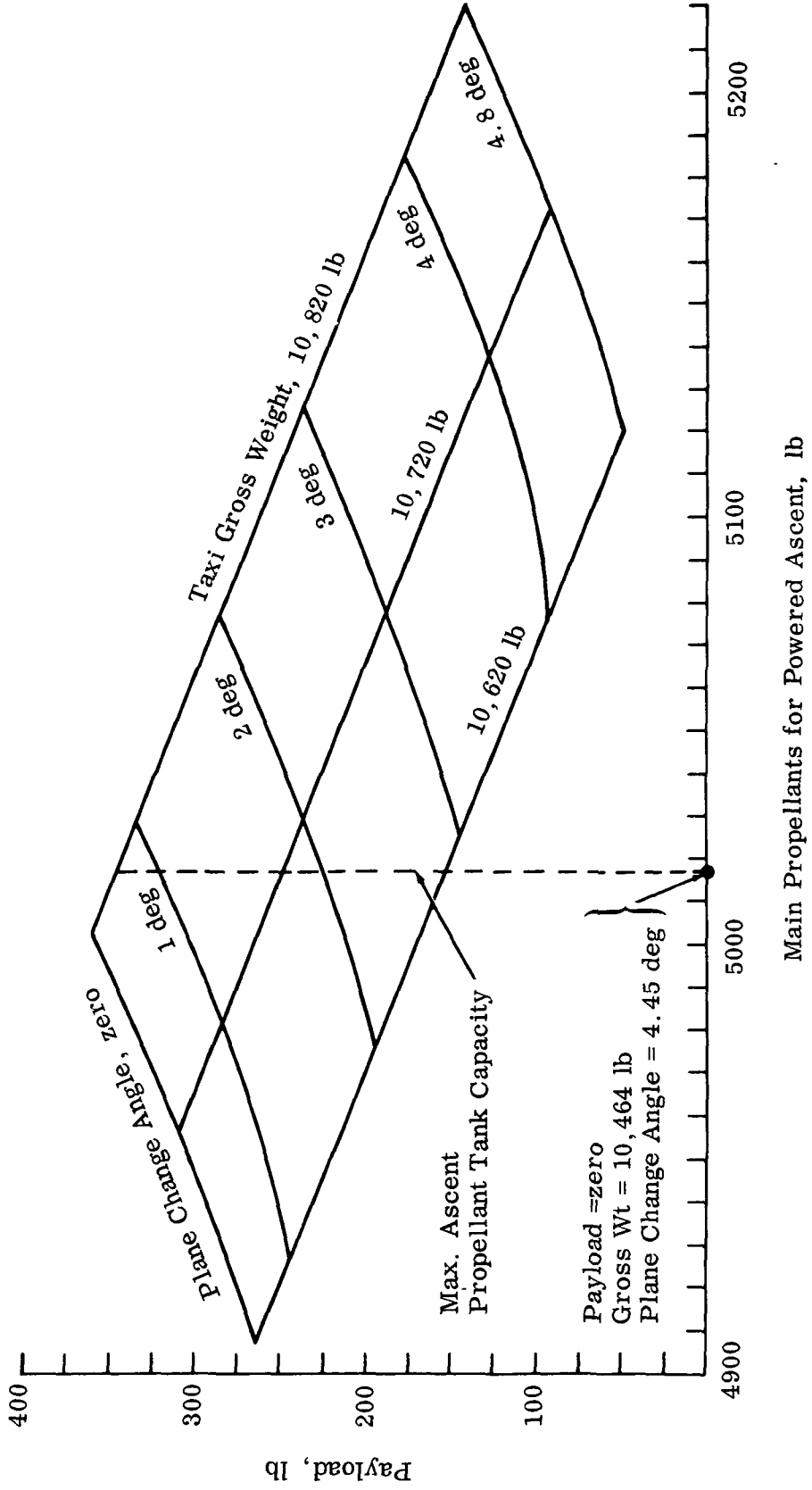


Fig. 4.3-1 Taxi Return Payload Capability

4.4 CREW SYSTEMS

4.4.1 Ground Rules

There were no NASA ground rules unique to the Crew Systems Analysis.

4.4.2 Assumptions and Background Data

It was assumed that the crew life-support and human-engineering requirements for the Taxi are the same as for the LEM.

4.4.3 Crew Functions

The mission profile, or sequence of events, from Earth launch to lunar surface touch-down, in the vicinity of the Shelter, is assumed to be identical to the LEM. However, after touchdown the sequence of events are as described in Section 3, Mission Analysis.

During the first day, the Commander and Systems Engineer will coordinate their efforts to:

- Inspect, checkout, and deactivate the Taxi
- Inspect and checkout the Shelter
- Transfer RTG from Shelter to Taxi
- Prepare Shelter for habitability
- Plan mission EVA exploration procedures

During the 14th or final day of the mission, the crew will:

- Deactivate Shelter
- Transport payload to Taxi
- Inspect, checkout, and reactivate the Taxi
- Lift-off, rendezvous, and docking with CSM

Subsequent to the post-landing Taxi checkout by the crew, the Systems Engineer dons a PLSS, leaves the Taxi, walks to and inspects the Shelter. Following the inspection period of approximately 1 hr and 20 min, a go/no-go decision is made. Assuming a go condition, the commander then secures the Taxi for quiescent storage (Table 4.4-1.). He then dons a PLSS, leaves the Taxi, and walks to the Shelter.

With the assistance of the Systems Engineer, the Local Scientific Survey Module (LSSM) is deployed, checked out, and activated. The RTG is disconnected, removed from the Shelter and loaded onto the LSSM. The LSSM is then driven back to the Taxi where the RTG is unloaded, installed in the Taxi, and checked-out. The Commander again boards the LSSM and returns to the Shelter (Table 4.4-2).

Following completion of the lunar exploration phase, the crew departs the Shelter and traverses to the Taxi, possibly on the LSSM. The Systems Engineer boards the Taxi while the Commander conducts a walk-around inspection. He then boards the Taxi after which both crew members reactivate the Taxi systems (Table 4.4-3). Prelaunch preparation and checkout is then performed prior to ignition of the ascent engine for lift-off.

The one unique task directly associated with the Taxi mission is the transfer of the RTG from the Shelter to the Taxi; therefore, a more detailed discussion of this task is presented in the succeeding paragraph.

4.4.3.1 RTG Transfer

In transferring the RTG from the Shelter to the Taxi, the major human factors items of concern are:

- Thermal radiation (heat emission)
- Thermal conductivity (contact burns)
- Nuclear radiation (health physics)
- Mechanical assembly, detachment connections, etc.
- Physical transport of the unit from the Shelter to the Taxi.

The RTG generates more thermal energy (heat) than can be effectively used. To avoid self-destruction and to provide the required Δt at the thermoelectric N-P junctions, the unit must radiate considerable excess heat to its surroundings. The astronaut's space suit and backpack cooling system has been sized to dissipate metabolic heat plus solar thermal loads. Excess heat loading to the astronaut, by exposure to the RTG thermal radiation, could overload the thermal balance of the suit. Under ordinary circumstances, however, this can be easily avoided by the astronaut moving away from the unit (1 meter) or moving into the heat shadow. The efficiency of proposed thermal radiation garments may also obviate this problem.

Direct contact burns offer the greatest threat to the space suited astronaut. The surface temperature of the RTG exceeds the melting point of the space suit. A direct brief physical contact of the suit against the RTG radiation surface or against a wire-type guard, would melt and/or degrade the fabric to the point where its integrity as a pressure vessel could not be maintained. Prevention of direct contact burns is the prime human factors safety consideration.

The radioactivity of the unit will add to the overall dosage of crew radiation and may require slight upward revision of the NASA allowable Apollo mission dosage. The dosage is not heavy, and, under the most adverse conditions, the astronaut could carry a cold fin assembly unit in his hands for over 30 min before receiving a 1 rad dose. The ground handling of the unit would have to be under strict administrative control. The greatest crew and ground nuclear hazards are not associated with normal operations but with accidents, such as a capsule explosion. The SNAP program has proven RTG units to be apparently safe, dependable, and easily handled. An indirect radiation problem is that of heavy irradiation of the drinking water tank which is located only a few centimeters from the RTG capsule. Minute impurities in the water could become radioactive and cause excessive irradiation of the GI tract and enter the metabolic processes of the cells. Preliminary analyses show that the radiation problem is minimal for the assumed mission profile parameters. However, it is recommended that a more thorough study be made, especially of stored purity of water and shielding interface.

Accurate estimation of the problems and techniques of transporting the RTG from the Shelter to the Taxi is impeded by the lack of knowledge of the exact nature of the lunar surface. At present, the only mode of transport considered is on the LSSM.

In summary, there are no serious human factor obstacles to transporting the RTG and attaching it to the Taxi. Contact burn, melting, and failure of the space suit is

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the greatest hazard, and the major effort should be devoted to minimizing this hazard. The nuclear radiation doses exceed presently specified limits, but are within a tolerable range.

Table 4.4-1

CREW TASKS REQUIRED TO PREPARE TAXI FOR QUIESCENT STORAGE

Time, hr:min	Commander	Systems Engineer
(After lunar surface touchdown)	<ul style="list-style-type: none"> Review checklist for preparation of Taxi for quiescent storage 	(In Shelter during this mission phase.)
73:05	<ul style="list-style-type: none"> Cover top hatch and windows Initiate IMU-ASA coolant bypass; check indicator lights. Secure VHF link. Activate status monitoring communication link. Shut down Atmosphere Revitalization Section; activate PLSS, close faceplate, open cabin dump valve 	
73:15	<ul style="list-style-type: none"> Descend to lunar surface and walk to Shelter. 	

Table 4.4-2

SEQUENCE OF OPERATIONS FOR RTG TRANSFER

Operation No.	Commander	Systems Engineer
1		Walk to Shelter.
2		Make Shelter go/no-go decision.
3	Place Taxi in quiescent storage.	
4	Walk to Shelter.	
5	Unload LSSM from Shelter.	Assist with unloading from inside Shelter.
6	Detach RTG from Shelter with mechanical aid.	
7	Load RTG on LSSM.	
8	Drive LSSM to Taxi.	
9	Unload RTG from LSSM with mechanical aid.	
10	Attach RTG to Taxi with mechanical aid.	
11	Enter Taxi and check out RTG installation.	
12	Drive LSSM to Shelter.	
13	Enter Shelter.	

Table 4.4-3

CREW TASKS REQUIRED TO REACTIVATE TAXI FOR ASCENT AND RENDEZVOUS

Time hr:min	Commander	System Engineer
402:32	<ul style="list-style-type: none"> ● Activate ECS & Communication System ● Connect suit to suit loop system ● Uncover windows 	<ul style="list-style-type: none"> ● Monitor Cmdr
403:00	<ul style="list-style-type: none"> ● Assist S.E. & stow return payload ● Uncover top hatch ● Dispose of jettisonable material 	<ul style="list-style-type: none"> ● Load return payload in Taxi ● Dispose of all jettisonable material
403:32	<ul style="list-style-type: none"> ● Activate Rendezvous Radar ● Establish radar contact with CSM ● Establish voice comm with CSM 	<ul style="list-style-type: none"> ● Connect suit-to-suit loop system ● Reestablish IMU-ASA active thermal control
403:52	<ul style="list-style-type: none"> ● Lose voice comm. with CSM ● Reactivate VHF ● Reactivate Rendezvous Radar ● Remove & stow PLSS ● Remove thermal & meteoroid protective garments 	<ul style="list-style-type: none"> ● Secure fwd hatch ● Pressurize cabin to 5.0 psia ● Remove & stow PLSS ● Remove thermal & meteoroid protective garments.
404:32	Prelaunch Prep (Same as LEM)	

4.5 RELIABILITY

4.5.1 Assumptions and Background Data

A time line summary for a design reference LEM Taxi Mission (DRM) is presented in Table 4.5-1. This profile is not intended to represent any particular flight. It has been selected to provide a basis for reliability estimation, configuration analysis, trade-off studies, and mission success predictions. The mission times are divided into boost and non-boost periods. Applicable environmental stress factors (K factors) are shown for each period depending on operation or non-operation of the equipment during boost and non-boost periods. These factors are used to modify equipment inherent failure rates. In accordance with the mission time-lines, K factors, subsystem equipment failure rates, math models, and operating usage times shown in this report, the probability of mission success can be calculated on a subsystem basis.

Mission success is defined as the probability of not aborting the DRM because of a failure of the defined configuration. Although failures of either the booster, CSM, or experiment packages would cancel the scientific and engineering experiments, they could not be judged failures against the Taxi. A mission shall be aborted if the future occurrence of a single functional failure may endanger the general well-being of any crew member, or if the projected probability of catastrophe would be greater than a maximum acceptable level.

Wherever possible, failure rate data were extracted from LEM Report No. LED-550-58, "Failure Rates Used for LEM Reliability Estimate." Data used from other sources are specifically denoted.

4.5.2 Recommended Configuration - Reliability Estimates

Subsystem reliability math models, functional block diagrams (Fig. 4.5-1), and equipment utilization times (Table 4.5-2) were developed to determine recommended system reliability estimates.

4.5.2.1 Subsystem Reliability Estimates

4.5.2.1.1 Navigation, Guidance and Control. The PGNS and AGS are assumed to be in series, i.e., failure of either system would be cause for abort, during the launch through descent and touchdown phases of the mission. During the lunar stay through rendezvous phases of the mission, they are assumed to be in parallel, i.e., ascent and rendezvous can be accomplished with either system. The rendezvous radar is used in the descent phase, both for tracking the CSM and for locking on the transponder which radiates from the Shelter on the lunar surface. The transponder reliability is considered under the Shelter configuration.

4.5.2.1.2 Descent Propulsion Subsystem. The reliability analysis of the descent propulsion subsystem (DPS) involved investigation into the storage, regulation, and thrust capabilities of the main propulsion subsystem. Evaluation of the subsystem was accomplished through the utilization of the existing LEM DPS reliability analysis with some slight modification (two vent valves and a pressure relief valve added on the Taxi subsystem). The mathematical reliability model for the DPS is:

$$R_{DPS} = R_1 \times R_2 \times R_3^5 \times R_4^2 \times R_5 \times R_6 \times R_7^3 \times R_8^{60} \times R_9 \times R_{10} (2 - R_{10}) \times R_{11} \times \left[2 - R_9 \times R_{10} (2 - R_{10}) R_{11}^2 \right] \times R_{12} \times \left[R_{13}^4 + 4R_{13}^3 (1 - R_{13}) + 2R_{13}^2 (1 - R_{13})^2 \right] \times \left[R_{14}^4 + 4R_{14}^3 (1 - R_{14}) + 2R_{14}^2 (1 - R_{14})^2 \right] \times \left[R_{15}^4 + 4R_{15}^3 (1 - R_{15}) + 4R_{15}^2 (1 - R_{15})^2 \right] \times \left[R_{16}^4 + 4R_{16}^3 (1 - R_{16}) + 4R_{16}^2 (1 - R_{16})^2 \right] \times R_{19}^5 \times \left[R_{17} \times R_{18} + R_{19} - R_{17}R_{18}R_{19} \right]^5 \times R_{20}^5 \times R_{21}^2 \times R_{22}^2 \times R_{23}^2 \times R_{24}^4 \times R_{25}^2 \times R_{26} \times R_{27} \times R_{28}^4 \times \left[R_{29} + R_{30} - R_{29}R_{30} \right]^2$$

When the combined reliability degrading factor time (t), mechanical stress factor (K), and failure rate (λ) are introduced into the mathematical model above according to the exponential relationship $R = \exp(-K\lambda t)$, the product yields a descent propulsion subsystem reliability equal to 0.997986. This value is slightly lower than the LEM DPS reliability estimate and is caused by the modifications over the LEM subsystem.

4.5.2.1.3 Ascent Propulsion Subsystem. The reliability analysis of the ascent propulsion subsystem (APS) involved investigation into the storage, regulation, and thrust capabilities of the main propulsion subsystem. Evaluation of the subsystem was accomplished through the utilization of the existing LEM APS reliability analysis. The mathematical reliability model for the entire APS reliability appears below:

$$R_{APS} = R_1^2 \times R_2^4 \times R_3^3 \times R_4^2 \times R_5^4 \times R_6^{60} \times R_7 \times R_8 (2 - R_8) \times R_9^2 \left[2 - R_7 \times R_8 (2 - R_8) \times R_9^2 \right] \times R_{10} \times R_{11} \times R_{12} \times R_{13} \times R_{14} \times \left[R_{15} \times R_{16} + R_{17} - R_{15}R_{16}R_{17} \right]^2 \times R_{18}^2 \times R_{19} \times R_{20} \times R_{21}^2 \times R_{22}^2 \times R_{23} \times R_{24} \times \left[R_{25} + R_{26} - R_{25}R_{26} \right]^7$$

The product yields an APS reliability equal to 0.995178. The result obtained is lower than the LEM subsystem reliability estimate, because the Taxi subsystem has a greater time degradation factor than the LEM subsystem.

4.5.2.1.4 Reaction Control Subsystem. Reliability analysis of the reaction control system (RCS) involved investigation into the attitude and translation capabilities of the vehicle, including helium, oxidizer, and propellant storage, regulation, and

thrust capability. The mathematical modeling for the RCS appears below:

$$R_{RCS} = \left\{ R_1 \times R_2^4 \times R_3 \times R_4^5 \times R_5(2 - R_5) \times R_6 \times R_7 \times R_8(2 - R_8) \times R_9^2 \right. \\ \times \left[2 - R_7 \times R_8(2 - R_8) \times R_9^2 \right] \times \left[R_{10}^4 + 4R_{10}^3(1 - R_{10}) + 2R_{10}^2(1 - R_{10})^2 \right] \\ \times \left[R_{11}^4 + 4R_{11}^3(1 - R_{11}) + 2R_{11}^2(1 - R_{11})^2 \right] \times \left[R_{12}^4 + 4R_{12}^3(1 - R_{12}) + \right. \\ \left. 4R_{12}^2(1 - R_{12})^2 \right] \times \left[R_{13}^4 + 4R_{13}^3(1 - R_{13}) + 4R_{13}^2(1 - R_{13})^2 \right] \times R_{14}^2 \\ \times \left[R_{15} \times R_{16} + R_{17} - R_{15} \times R_{16} \times R_{17} \right]^2 \times R_{18} \times R_{19} \times R_{20}^2 \times \left[(R_{21} \right. \\ \left. + R_{22} - R_{21} \times R_{22})^2 \right] \times \left[(2 - (R_{21} + R_{22} - R_{21} \times R_{22}))^2 \right] \times \left[R_{23} + R_{24} \right. \\ \left. - R_{23} \times R_{24} \right]^3 \times R_{25}^4 \times R_{26}^4 \times R_{27}^{16} \times R_{28}^{16} \times R_{29}^{80} \times R_{30}^{16} \times R_{31}^{16} \times R_{32}^4 \times R_{33}^4 \\ \left. \times R_{34}^2 \times R_{35} \times R_{36} \times R_{37}^4 \times R_{37}^2 \right.$$

When the combined factors are introduced for each reliability block established above, the product yields a reliability of the RCS equal to 0.917422.

The propellant tank bladders are the major contributing factors to the mission unreliability, because of their high failure rate, and because the loss of any one bladder during the post separation period will require CSM rescue. No additional problem areas are pointed out. The reliability of the Taxi RCS is slightly lower than the value available from the LEM mission.

4.5.2.1.5 Electrical Power Subsystem. The EPS consists of three modified LEM descent stage batteries with associated LEM ECA, two LEM ascent batteries with associated ECA, and an RTG (utilized during the quiescent storage period). The failure rates for the reliability assessment were based on LEM ascent battery/ECA failure rates, and vendor estimates for the RTG and 10-Kw-hr modified descent battery. The EPS critical design reference mission (with contingencies), used for the analysis, is presented below:

<u>Mission Phase</u>	<u>Phase Time (hr)</u>
Countdown, launch, transposition	6.80
Translunar	111.60
Preseparation c/o, descent and post-landing c/o	4.45
Go/no-go decision and secure for quiescent storage	2.90
Quiescent storage	330.00
Pre-launch activation	2.60
Powered ascent through crew transfer	11.73
Total Mission Time	470.08

For the purpose of this analysis, all batteries are considered operational when they are charged and activated, and the ECA's are considered operational during battery discharge time only. The RTG is considered operational during the Taxi

quiescent storage period (the total utilization time includes time accrued on the RTG during the Shelter quiescent storage period). The reliability of the EPS configuration, based on the math model (Fig. 4.5-1) with all equipments required to complete the full mission, is 0.909220.

4.5.2.1.6 Environmental Control Subsystem. The ECS consists of four integrated sections: atmosphere revitalization, heat transport, oxygen supply and pressure control, and water management. The following ground rules and assumptions were incorporated into the ECS model for reliability assessment. Because of CSM backup potential prior to Taxi separation, the model was analyzed for the preseparation and postseparation independently with the reliability of the mission equal to $R_{Presep} \times R_{Postsep}$.

- Heat transport system was considered pressurized (operating) for the extent of the mission
- Atmosphere revitalization, oxygen supply, and rate management systems, exclusive of the water and oxygen tanks, are considered depressurized during the quiescent storage phase
- Ascent and descent water tanks are assumed to undergo one operating cycle each during the full mission
- Component failure rates presented in LED-550-58, 18 June 1965, and source data supplied by Hamilton Standard are the basis of the reliability estimates
- Heat pipe has been excluded from this estimate because of insufficient failure rate information.

The ECS reliability assessment based on the above ground rules yields a success probability of 0.992390.

4.5.2.1.7 Communications Subsystem. The reliability analysis of the Taxi communications subsystem consists of an investigation into the S-band transmission and receiving capabilities for communications between the crew and Earth, including status data, and the VHF communications mode for EVA.

Several additional assumptions have been made to expedite the reliability modeling analysis. The first involves the failure rate apportionment to the signal processor assembly. Since this part of the system has multiple operational modes, sometimes acting independently of one another and at other times operating in a completely dependent arrangement, it was assumed that for the majority of the mission time the entire failure rate of the unit ($\lambda = 64,549 \times 10^{-6}$) shall be applied to the mathematical model during any period of mission time where any one section of the signal processor is used.

Another assumption is the VHF channel B transmitter has the capability to be used as a backup mode for voice communications with the CM (assuming CM capability to receive voice communications on this channel). Consequently, the VHF transmitters A and B are considered as active redundancies in the reliability analysis (as are VHF receivers A and B). Also configured as redundant items in the modeling analysis are the astronaut's headset receiver and microphone assemblies - under the assumption that headset receiver 1 and microphone 1 operate together in series.

The mathematical representation of the reliability mode for each mission phase appears below:

- Preseparation phase:

$$R = \left[1 - (1 - R_1)(1 - R_2)(1 - R_3)^2 \right] \times R_4 \times R_5(2 - R_5) \times R_6 \times \\ \left[1 - (1 - R_7)(1 - R_8)^2 \right] \times R_9 \times R_{10} \times R_{11} \times R_{12} (2 - R_{11}R_{12}) \times \\ R_{13}(2 - R_{13}) \times R_{14} \times R_{15A}(2 - R_{15B}) \times R_{16A}(2 - R_{16B}).$$

- Post separation to lunar lift-off phase:

$$R = \left[1 - (1 - R_1)(1 - R_2)(1 - R_3)^2 \right] \times R_4 \times R_5^2 \times R_6^2 \times \\ \left[1 - (1 - R_7)(1 - R_8)^2 \right] \times R_9 \times R_{10} \times R_{11}^2 \times R_{12}^2 \times R_{13}(2 - R_{13}) \\ \times R_{14} \times R_{15A} \times R_{15B} \times R_{16A} \times R_{16B}.$$

When the combined factors are introduced for each of the reliability blocks established above (for each phase depicted), the product yields a reliability for the Taxi communications subsystem equal to 0.983273. Problem areas arise largely from the fact that the reliability network equations, during the postseparation to lift-off phase, are based upon non-redundant communications equipment. The prime degrading component for this analysis was the signal processor assembly as was mentioned before. The S-band transmit-receive electronic replaceable assembly, S-band power supply-power amplifier, and the timer, are mentioned in order of downgraded effect on the subsystem.

4.5.2.1.8 Instrumentation. The instrumentation configuration is divided in two parts: one for the manned phases of the mission, another for the un-manned phase. In the manned phases, the C&WEA, status displays, and voice recorder are required. The PCM is considered in parallel with the C&WEA and displays.

In the unmanned phase, the C&WEA, status displays, and voice recorder are not operated. During this phase, a time sequencer is required to turn on the equipment at intervals. The sequencer itself operates on a 5.83% duty cycle; the PCMTEA on a 1.67% duty cycle; the transducers on a 5.83% duty cycle, and the SCEA on a 5.83% duty cycle. Based on these duty cycles the reliability for the instrumentation is 0.994947.

4.5.2.1.9 Controls and Displays Subsystem. The reliability analysis of the C&D subsystem consisted of an examination of all of the individual displays and controls required by the other subsystems in the Taxi.

The overall C&D subsystem reliability was obtained from the following mathematical model:

$$R_{CD} = R_1 \times R_2 \times R_3 \times R_6 \times R_7 \times R_8(2 - R_8) \times R_9(2 - R_9) \times \\ R_{10} \times R_{11}(2 - R_{11}) \times R_{12}(2 - R_{12}) \times R_{13}(2 - R_{13}) \times R_{14} \times \\ R_{15}(2 - R_{15}) \times R_{16}(2 - R_{16}) \times R_{17} \times R_{18} \times R_{19}(R_{20} + R_{21} - R_{20}R_{21}) \\ \times R_{22} \times R_{23}(2 - R_{23}) \times \left[1 - (1 - R_{24})^2(1 - R_{25})^2 \right] \times R_{26}(2 - R_{26}) \times$$

$$R_{27}(2 - R_{27}) \times R_{28}(2 - R_{28}) \times R_{29}(2 - R_{29}) \times R_{30}(2 - R_{30}) \times R_{31} \times R_{32} \times \\ (R_{33} + R_{34}R_{35} - R_{33}R_{34}R_{35}) \times (R_{36} + R_{37} - R_{36}R_{37}) \times R_{38} \times R_{39}.$$

Applying t , K , and λ data to this equation and solving yields a reliability equal to 0.993328.

4.5.2.2 System Reliability Analysis

A summary of subsystem reliability estimates for the Taxi, together with pertinent LEM data are shown in Table 4.5-3. Approximation of structure, explosive, controls and displays, and instrumentation subsystem reliabilities were obtained by utilizing LEM estimates with exponential degradation allowed for the extended duration.

In general, $R = e^{-k \lambda t}$ and $Q = 1.0 - R$. For small values of $k \lambda t$, $Q \approx k \lambda t$ and $k \lambda \approx Q/t$

Then

$$Q_2 \approx \frac{Q_1 \times t_2}{t_1}$$

where subscript 1 represents LEM and subscript 2 represents AES

$$Q_2 \approx \frac{Q_1}{115.567} \times 418.074 \approx 3.618 Q_1$$

<u>Subsystem</u>	<u>Q₁</u>	<u>Q₂</u>	<u>R₂</u>
Controls & Displays			
Instrumentation	0.000622	0.002250	0.997750
Structure	0.000022	0.000080	0.999920
Explosives	0.000076	0.000275	0.999725

Figure 4.5-2 represents vehicle reliabilities for various mission durations. The Taxi reliability curve shown is based on an exponential degradation of reliability with mission duration, and therefore represents a close approximation to the actual estimate. Also included in Fig. 4.5-2 are a series of curves representing experiment package reliabilities plotted against a scale which indicates the product of vehicle and experiment package reliabilities.

Although the Taxi reliability curve indicates values equal to the LEM estimate, both fall below the LEM specification goal. The Taxi is dependent on LEM subsystems design, and improvement of the reliability can only be achieved by upgrading the inherent reliability of each component therein.

Table 4.5-1

RELIABILITY - DESIGN REFERENCE MISSION

Nom Phase	Description	Boost	Non-Boost	Total Time
		Time $K_O = 10.0$ $K_{NO} = 0.01$	Time $K_O = 1.0$ $K_{NO} = 0.001$	
1	Total Preseparation (Includes 10 hr of Pre-Earth Launch Checkout)	0.39	75.83	76.22
2	AES Checkout to Insertion (Total Checkout 1.85)		2.18	2.18
3	Insertion and Hohmann Transfer Orbit	0.01	0.968	0.978
4	Powered Descent from Pericyynthion to Hover	0.14		0.14
5	Hover to Touchdown & Post-Landing Checkout	0.019	0.25	0.034
6	Lunar Stay		336.00	336.00
7	Prelunar Launch Checkout, Powered Ascent and Injection	0.118	1.00	1.118
8	Transfer Coast		0.781	0.781
9	Rendezvous (5 n. mi. to 500 ft)		0.138	0.138
10	Docking (500 ft to contact)		0.25	0.25
	TOTAL	0.677	417.397	418.074

Table 4.5-2

EQUIPMENT UTILIZATION TIMES

Ident No.	Name (& Quantity if More Than One)	Fail Rate $f/10^6$ hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boost	Boost	Non-Boost
A. Navigation, Guidance & Control ($R=R_D \cdot R_A$) = .983345						
1. Launch through Descent & TD ($R_D = .984743$)						
1	IMU-Inertial Measuring Unit	137	.169	3.068	.39	76.16
2	IGC-LEM Guidance Computer	352	.169	3.068	.39	76.16
3	CDU-Coupling Data Unit	675	.169	3.068	.39	76.16
4	PSA-Power Servo Ass'y	126	.169	3.068	.39	76.16
5	PTA-Pulse Torquer Ass'y	62	.169	3.068	.39	76.16
6	IR-Landing Radar	186	.159	.500	.40	78.73
7	ATCA-Attitude & Transl. Cntrl Ass'y	117.2	.169	3.068	.39	76.16
8	ACA-Attitude Controller Ass'y	33.4	.169	3.068	.39	76.16
9	TCA-Translation Controller Ass'y	30.5	.169	3.068	.39	76.16
10	RGA-Rate Gyro Ass'y	99.1	.169	3.068	.39	76.16
11	DECA-Desc. Engine Cntrl Ass'y	56.5	.159	.100	.40	79.13
12	GDA-Gimbal Drive Actuator	83.9	.159	.100	.40	79.13
13	ESA-Engine Sequencer Ass'y	12.6	.159	.100	.40	79.13
14	AEID-Ascent Engine Latching Device	4.3			.559	79.23
15	ASA-Abort Sensor Ass'y	370.3	.169	3.068	.39	76.16
16	AEA-Abort Electronics Ass'y	1016.0	.169	3.068	.39	76.16
17	AOT-Alignment Optical Telescope	43.0		.300	.559	78.83
18	CES P/S-Cntrl Elect. Syst. Pwr. Supply	24.8	.169	3.148	.39	76.08
19	RR-Rendezvous Radar	278.9		.300	.559	78.83
20	TL-Tracking Light	70.0		.100	.559	79.13
2. Lunar Stay Through Rendezvous ($R_A = .9985803$)						
1	IMU-Inertial Measuring Unit	137	.118	2.169		333.71
2	IGC-LEM Guidance Computer	352	.118	2.169		333.71
3	CDU-Coupling Data Unit	675	.118	2.169		333.71

Table 4.5-2 (cont)

Ident No.	Name (& Quantity if More Than One)	Fail Rate f/10 ⁶ hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boost	Boost	Non-Boost
A. Lunar Stay Through Rendezvous (R _A = .9985803) (cont)						
4	PSA-Power Servo Assy	126	.118	2.169		333.71
5	PTA-Pulse Torque Ass'y	62	.118	2.169		333.71
6	ASA-Abort Servo Assy	370	.118	2.169		333.71
7	AEA-Abort Electronics Ass'y	1016	.118	2.169		333.71
8	ATCA-Att. & Trans. Cntrl Ass'y	117.2	.118	2.169		333.71
9	RGA-Rate Gyro Ass'y	99.1	.118	2.169		333.71
10	ACA-Attitude Controller Ass'y	33.4	.118	2.169		333.71
11	TCA-Translation Controller Ass'y	30.5	.118	2.169		333.71
12	AETD-Ascent Engine Latching Device	4.3	.118	.100		335.78
13	CES P/S-Cntrl Elect. Pwr. Supply	24.8	.118	2.169		333.71
14	RR-Rendezvous Radar	278.9	.118	2.169		333.71
15	TL-Tracking Light	70.0		1.169	.118	334.71
B. Descent Propulsion (R = .9979863)						
1	He Pressure Vessel	.04	.559	78.01	0	0
2	Liquid Level Transducer	.05	.559	78.01	0	0
3	Temperature Transducer (5)	.05	.559	78.01	0	0
4	Pressure Transducer (2)	.05	.559	78.01	0	0
5	Helium Initiate Valve-Squib	.06	.559	78.01	0	0
6	Heat Exchanger	.60	.559	78.01	0	0
7	Filter (3)	.31	.559	78.01	0	0
8	Lines, Joints, Fittings (60)*	.05	.559	78.01	0	0
9	Shutoff Valve	14.2	.559	78.01	0	0
10	Pressure Regulator - Fail Open	13.67	.559	0	0	0
11	Press Regulator - Fail Closed	13.67	.559	0	0	0
12	Manifold	.04	.559	78.01	0	0
13	Quad Check Valve - Oxidizer - Fail Closed	8.7	.159	0	0	0
14	Quad Check Valve - Fuel - Fail Closed	8.7	.159	0	0	0
15	Quad Check Valve - Oxidizer - Fail Open	8.7	.40	78.01	0	0
16	Quad Check Valve - Fuel - Fail Open	8.7	.40	78.01	0	0

Table 4.5-2 (cont)

Ident No.	Name (& Quantity if More Than One)	Fail Rate f/10 ⁶ hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boost	Boost	Non-Boost
B. Descent Propulsion (R=.9979863) (cont)						
17	Pressure Relief Valve	5.7		78.01	0	0
18	Test Point	12.5		78.01	0	0
19	Burst Disc	.11		78.01	0	0
20	Burst Disc (5)	.11		78.01	0	0
21	Oxidizer Storage Tank (2)	.04		78.01	0	0
22	Fuel Storage Tank (2)	.04		78.01	0	0
23	Vent Valve (2)	12.5		.1	0	78.01
24	Low Level Sensor (4)	.05		78.01	0	0
25	Trim Orifice (2)	.5		78.01	0	0
26	Descent Engine Assembly - Fire	226.005		0	0	0
27	Descent Engine Assembly - No-Fire	226.005		0	.40	78.01
28	Diffuser (4)	.05		78.01	0	0
29	Fill Valve	3.66		78.01	0	0
30	Cap	80.0		78.01	0	0
* Assumed vendor estimate.						
C. Ascent Propulsion (R=.9951784)						
1	Helium Pressure Vessel (2)	.04		417.257	0	0
2	Temperature Transducer (4)	.05		417.257	0	0
3	Pressure Transducer (3)	.05		417.257	0	0
4	Helium Initiate Valve-Squib (2)	.06		417.257	0	0
5	Filter (4)	.31		417.257	0	0
6	Lines, Joints, Fittings (60) *	.05		417.257	0	0
7	Shutoff Valve	14.2		0	0	0
8	Pressure Regulator - Fail Open	13.67		0	0	0
9	Pressure Regulator - Fail Closed	13.67		0	0	0
10	Quad Check Valve - Oxidizer - Fail Closed	8.7 *		0	0	0
11	Quad Check Valve - Fuel - Fail Closed	8.7 *		0	0	0
12	Quad Check Valve - Oxidizer - Fail Open	8.7 *		417.257	.559	0
13	Quad Check Valve - Fuel - Fail Open	8.7 *		417.257	.559	0

Table 4.5-2 (cont)

Ident No.	Name (& Quantity if More Than One)	Fail Rate f/10 ⁶ hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boost	Boost	Non-Boost
C. Ascent Propulsion (R=.9951784)						
14	Manifold	.04 *	.677	417.257	0	0
15	Pressure Relief Valve	5.7	.677	417.257	0	0
16	Test Point	12.5	.677	417.257	0	0
17	Burst Disc	.11	.677	417.257	0	0
18	Burst Disc (2)	.11	.677	417.257	0	0
19	Oxidizer Storage Tank	.04	.677	417.257	0	0
20	Fuel Storage Tank	.04	.677	417.257	0	0
21	Low Level Sensor (2)	.05	.677	417.257	0	0
22	Trim Orifice (2)	.5	.677	417.257	0	0
23	Ascent Engine Assembly - Fire	254.930	.118	0	0	0
24	Ascent Engine Assembly - No-Fire	254.930	0	0	.559	417.257
25	Fill Valve	3.66	.677	417.257	0	0
26	Cap	80.0	.677	417.257	0	0
* Assumed vendor estimate.						
D. Reaction Control Subsystem (R=.9174221)						
1	Helium Pressure Vessel	.04	.677	417.257	0	0
2	Pressure Transducer (4)	.05	.677	417.257	0	0
3	Manifold	.04 *	.677	417.257	0	0
4	Temperature Transducer (5)	.05	.677	417.257	0	0
5	Helium Initiate Squib Valve	.06	.677	417.257	0	0
6	Helium Filter	.31	.677	417.257	0	0
7	Shutoff Valve - Solenoid	14.20	.277	0	0	0
8	Pressure Regulator - Fail Open	13.67	.277	0	0	0
9	Pressure Regulator - Fail Closed	13.67	.277	0	0	0
10	Quad Check Valve - Oxidizer - Fail Closed	8.7 *	.277	0	0	0
11	Quad Check Valve - Fuel - Fail Closed	8.7 *	.277	0	0	0
12	Quad Check Valve - Oxidizer - Fail Open	8.7 *	.40	417.257	0	0
13	Quad Check Valve - Fuel - Fail Open	8.7 *	.40	417.257	0	0
14	Burst Disc (2)	.11	.677	417.257	0	0

Table 4.5-2 (cont)

Ident No.	Name (& Quantity if More Than One)	Fail Rate f/10 ⁶ hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boost	Boost	Non-Boost
D. Reaction Control Subsystem (R=.9174221)						
15	Pressure Relief Valve	5.7	.677	417.257	0	0
16	Test Point	12.5	.677	417.257	0	0
17	Burst Disc	.11	.677	417.257	0	0
18	Oxidizer Tank (Bladder)	8400.0	0	1	0	0
19	Fuel Tank (Bladder)	8400.0	0	1	0	0
20	Main Shutoff Valve	3.09	.677	417.257	0	0
21	Fill Valve	3.66	.677	417.257	0	0
22	Cap	80.0	.677	417.257	0	0
23	Fill Valve	3.66	.677	417.257	0	0
24	Cap	80.0	.677	417.257	0	0
25	Thrust Chamber Assembly - Fire (4)	1057.9	.277	0	0	0
26	Thrust Chamber Assembly - No-Fire (4)	1057.9	0	0	.40	417.257
27	Isolation Valve (16)	3.09	.277	338.279	.40	78.978
28	Propellant Inlet Filter (16)	.31	0	0	.677	417.257
29	Lines, Joints, Fittings (80)	.05	.677	417.257	0	0
30	Thrust Chamber Assembly Injector Valve - Fire (1b)	34.40	.277	0	0	0
31	Thrust Chamber Assembly Injector Valve - No Fire (1b)	34.40	0	0	.40	417.257
32	Heater - 250 Watt (4)	30.0 *	.10	.90	.40	417.257
33	Ascent Interconnect Valve (4)	3.09	.677	417.257	0	0
34	Crossfeed Valve (2)	3.09	.677	417.257	0	0
35	Oxidizer Filter	.05	.677	417.257	0	0
36	Fuel Filter	.05	.677	417.257	0	0
37	Vent Valve (2)	3.66	.177	.10	.40	417.257

* Assumed vendor estimate.

Table 4.5-2 (cont)

Ident No.	Name (& Quantity if More Than One)	Fail Rate f/10 ⁶ hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boost	Boost	Non-Boost
E. Electrical Power Subsystem (R=.909220)						
1	Descent Battery (3) **	20				
2	Ascent Battery (2)	40			*470.58	
3	RTG ***	5.1			*420.58	
4	Descent ECA (3)	20			*2322	
5	Ascent ECA (2)	20			*346.75	
					*12.73	
* Based on electrical power profile time-line. ** Eagle-Picher estimate on 10kw-hr batteries (descent) *** GE estimate on RTG						
F. Environmental Control Subsystem						
1. Preseparation (R=.99694)						
1	GOX Tank (3)	.04			.390	
2	O ₂ Filter (3)	.05			.390	
3	O ₂ Shutoff Valve (3)	2.43			.390	
4	Cabin Repress Emergency Valve	0.0			.390	
5	Flow Limiter	.05			.390	
6	O ₂ Demand Valve	6.48			.390	
7	Descent/Ascent H ₂ O Tanks (3)	29610/c		.25 cycle/ea.		
8	Fill Valve	3.66			.390	
9	Cap	80.0			.390	
10	Check Valve (3)	.67			.390	
11	Water Tank Select Valve	.90			.390	
12	Water Pressure Regulator (3)	1.46			.390	
13	Shutoff Valve	.30				
14	Select Valve	.81				
15	Check Valve (3)	.67				
16	H ₂ O Separator	1.01				
17	Suit Circuit Regen Heat Exch	2.0				



Table 4.5-2 (cont)

Ident No.	Name (& Quantity if More Than One)	Fail Rate f/10 ⁶ hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boost	Boost	Non-Boost
F. Environmental Control Subsystem						
1. Preseparation (R=.99694)						
18	Suit Circuit Assy	2.95	.390		77.68	
19	Suit Circuit Relief Valve	2.54				
20	LIOH Cannister	.14				
21	Selector Valve	.09				
22	Suit CKT Fan	15.50				
23	Fan Check Valve	.44				
24	Pressure Control	22.17				
25	Pressure Sensor	2.0				
26	Suit CKT Heat Exchanger	2.0				
27	Water Evaporator	2.0				
28	Pri H ₂ O Boiler	2.0				
29	Glycol Accumulator	1.34				
30	Pump	16.1				
31	Check Valve	2.0				
32	Bypass Relief Valve	1.12				
33	Glycol Filter	0.0				
34	Temp. Cnt. Valve	.05				
35	Cabin Heat Exchanger	2.0				
36	Regen Heat Exchanger	2.0				
37	Water Boiler	2.0				
38	Cabin Fans	8.58				
39	Temp Control Valve	.05				
40	Cabin Dump Valve	3.41				
41	H ₂ O Hose	.10				
42	H ₂ O Disconnect	1.33				
43	H ₂ O Assy	.05				
44	O ₂ Relief Valve	3.37				
45	O ₂ Shutoff Valve	2.43				
46	O ₂ Filter	.05				
47	O ₂ Hose	.05				

Table 4.5-2 (cont)

Ident No.	Name (& Quantity if More Than One)	Fail Rate f/10 ⁶ hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boost	Boost	Non-Boost
F. Environmental Control Subsystem						
1. Preseparation (R=.99694)						
48	O2 Disconnect	.24	.390	77.68		
49	O2 Hose Assembly	.05	.390	77.68		
2. Post-Separation (R=.99544)						
1	GOX Tank (3)	.04	.287	338.467		
2	O2 Filter (3)	.05	.287	338.467		
3	Shutoff Valve (3)	2.43	.287	338.467		
4	Cabin Repress Emergency Valve	0.0	.287	2.467		336.00
5	Flow Limiter	.05	.287	2.467		336.00
6	O2 Demand Valve	6.48	.287	2.467		336.00
7	Descent/Ascent H ₂ O Tanks (3)	296.0/c	.75c/e			
8	Fill Valve	3.66	.287	338.467		
9	Cap	80.0	.287	338.467		
10	Check Valve (3)	.67	.287	338.467		
11	Water Tank Select Valve	.90	.287	338.467		
12	Water Pressure Regulator (3)	1.46	.287	338.467		
13	Shutoff Valve (3)	.30	.287	2.467		336.00
14	Select Valve	.81		2.467		336.00
15	Check Valve	.67		2.467		336.00
16	H ₂ O Separator	1.01		2.467		336.00
17	Suit Circuit Regen Heat Exch	2.0		2.467		336.00
18	Suit Circuit Assy	2.95		2.467		336.00
19	Suit Circuit Relief Valve	2.54		2.467		336.00
20	LIOH Cannister	.14		2.467		336.00
21	Selector Valve	.09		2.467		336.00
22	Suit Circuit Fan	15.50		2.467		336.00
23	Fan Check Valve	.44		2.467		336.00
24	Pressure Control	22.17		2.467		336.00
25	Pressure Sensor	2.0		2.467		336.00



Table 4.5-2 (cont)

Ident No.	Name (& Quantity if More Than One)	Fail Rate f/10 ⁶ hr	Equipment Usage Time, hr			
			Boost	Operate		Non-Boost
				Non-Boost	Boost	
F. Environmental Control Subsystem						
2. Post-Separation (R=.99544)						
26	Suit CKT Heat Exchanger	2.0	.287	2.467	336.00	
27	Water Evaporator	2.0				
28	Pri H ₂ O Boiler	2.0				
29	Glycol Accumulator	1.34	338.467	338.467		
30	Pump	16.1				
31	Check Valve	2.0				
32	Bypass Relief Valve	1.12				
33	Glycol Filter	0.0				
34	Temperature Control Valve	.05				
35	Cabin Heat Exchanger	2.0				
36	Reg. Heat Exch.	2.0				
37	Water Boiler	2.0				
38	Cabin Fans	8.58				
39	Temperature Control Valve	.05			336.00	
40	Cabin Dump Valve	3.41			336.00	
41	H ₂ O Hose	.10			336.00	
42	H ₂ O Disconnect	1.33			336.00	
43	Hose Assy	.05			336.00	
44	O ₂ Relief Valve	3.37				
45	O ₂ Shutoff Valve	2.40				
46	O ₂ Filter	.05				
47	O ₂ Hose	.05				
48	O ₂ Disconnect	.24				
49	O ₂ Hose Assy	.05				

Table 4.5-2 (cont)

Ident No.	Name (&Quantity if More Than One)	Fail Rate f/10 ⁶ hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boost	Boost	Non-Boost
G. Communications Subsystem (R=.983273)						
1. Preseparation						
1	S-Band Erectable Antenna	.025*	0	0	.40	78.978
2	S-Band Steerable Antenna	41.0	0	0	.40	78.978
3	S-Band Omnidirectional Antenna	.025	0	0	.40	78.978
4	S-Band Diplexer	1.7	0	0	.40	78.978
5	S-Band Power Supply - Power Amplifier	36.531	0	0	.40	78.978
6	S-Band Transmit-Receive Electronic Replaceable Assy	52.9	0	0	.40	78.978
7	F.M. Modulator	.162*	0	0	.40	78.978
8	P.M. Modulator	.757*	0	0	.40	78.978
9	Signal Processor Assembly	64.549	0	0	.40	78.978
10	Timer	35.0*	0	0	.40	78.978
11	Headset Audio Receiver	.30	0	0	.40	78.978
12	Headset Microphone	.120	0	0	.40	78.978
13	VHF Omnidirectional Antenna	.025	0	0	.40	78.978
14	VHF Diplexer	1.7	0	0	.40	78.978
15A	VHF Transmitter A	12.067*	0	0	.40	78.978
15B	VHF Transmitter B	12.067*	0	0	.40	78.978
16A	VHF Receiver A	13.252*	0	0	.40	78.978
16B	VHF Receiver B	13.252*	0	0	.40	78.978
2. Post-Separation to Lift-Off						
1	S-Band Erectable Antenna	.025	.159	19.60	0	317.65
2	S-Band Steerable Antenna	41.0	.159	0	0	337.25
3	S-Band Omnidirectional Antenna	.025	0	0	.159	337.25
4	S-Band Diplexer	1.7	.159	19.60	0	317.65
5	S-Band Power Supply - Power Amplifier	36.531	.159	19.60	0	317.65
6	S-Band Transmit-Receive Electronic Replaceable Assy	52.9	.159	19.60	0	317.65
7	F.M. Modulator	.162*	.159	19.60	0	317.65
8	P.M. Modulator	.757*	.159	19.60	0	317.65

Table 4.5-2 (cont)

Ident No.	Name (& Quantity if More Than One)	Fail Rate f/10 ⁶ hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boost	Boost	Non-Boost
G. Communications Subsystem (R=983273)						
2. Post-Separation to Lift-Off						
9	Signal Processor Assembly	64.549	.159	19.60	0	317.65
10	Timer	35.0*	.159	337.25	0	0
11	Headset Audio Receiver	.30	0	0	.40	78.978
12	Headset Microphone	.120	0	0	.40	78.978
13	VHF omnidirectional antenna	.025	0	0	.40	78.978
14	VHF diplexer	1.7	0	0	.40	78.978
15A	VHF Transmitter A	12.067*	0	0	.40	78.978
15B	VHF Transmitter B	12.067*	0	0	.40	78.978
16A	VHF Receiver A	13.252*	0	0	.40	78.978
16B	VHF Receiver B	13.252*	0	0	.40	78.978
2. Post-Separation to Lift-Off						
1	S-band erectable antenna	.025*	.159	19.60	0	317.65
2	S-band steerable antenna	41.0	.159	0	0	337.65
3	S-band omnidirectional antenna	.025	0	0	.159	337.25
4	S-band diplexer	1.7	.159	19.60	0	317.65
5	S-band powersupply-power amplifier	36.531	.159	19.60	0	317.65
6	S-band transmit-receive electronic replaceable assembly	52.9	.159	19.60	0	317.65
7	F.M. modulator	.162*	.159	19.60	0	317.65
8	PM modulator	.757*	.159	19.60	0	317.65
9	Signal processor assembly	64.549	.159	19.60	0	317.65
10	Timer	35.0 *	.159	337.25	0	0
11	Headset Audio Receiver	.30	.159	19.60	0	317.65
12	Headset microphone	.120	.159	19.60	0	317.65
13	VHF omnidirectional antenna	.025*	0	1.0	0	336.409

Table 4.5-2 (cont)

Ident No.	Name (& Quantity if More Than One)	Fail Rate $f/10^6$ hr	Equipment Usage Time, hr					
			Operate		Non-Operate		Boost	
			Non-Boost	Boost	Non-Boost	Boost	Non-Boost	Boost
14	VHF Diplexer	1.7	0	1.0	0	0	0	336.409
15A	Transmitter A	12.067*	0	1.0	0	0	0	336.409
15B	Transmitter B	12.067*	0	1.0	0	0	0	336.409
16A	Receiver A	13.252*	0	1.0	0	0	0	336.409
16B	Receiver B	13.252*	0	1.0	0	0	0	336.409
* Assumed vendor experience valve.								
1	TRANSDUCERS	49.1	.287	4.148	.39	4.148	.39	75.83
2	SCEA-Signal Conditioning Elec. Ass'y.	122.7	.287	4.148	.39	4.148	.39	75.83
3	C & WEA - Caution + Warning Electrnc Ass'y.	59.5	.287	4.148	.39	4.148	.39	75.83
4	Status Displays	121.0	.287	4.148	.39	4.148	.39	75.83
5	PCM - Pulse Code Modulator	20.0	.287	4.148	.39	4.148	.39	75.83
6	TEA - Timing Electronics Ass'y.	8.2	.287	4.148	.39	4.148	.39	75.83
7	Voice Recorder	12.9	.287	4.148	.39	4.148	.39	75.83
8	Sequencer Ass'y.	4.0	.287	4.148	.39	4.148	.39	75.83
2. Unmanned Phase ($R_u = .996365$)								
1	TRANSDUCERS	49.1		19.59		19.59		315.41
2	SCEA-Signal Conditioning Elec. Ass'y.	122.7		19.59		19.59		328.55
3	Sequencer Ass'y.	4.0		19.59		19.59		315.41
4	PCM - Pulse Code Modulator	20.0		5.61		5.61		329.39
5	TEA - Timing Electronics Ass'y.	8.2		5.61		5.61		329.39

Table 4.5-2 (cont)

Ident No.	Name (& Quantity if More Than One)	Fial Rate f/10 ⁶ hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boose	Boost	Non-Boost
1	Engine/Thrust Controls	5.40	0.230	7.045	0.390	283.765
2	Explosive Devices	5.80	0.096	5.672	0.390	263.730
3	Electrical Power System	31.20	0.236	8.125	0.360	407.421
4	Caution & Warning	*65.80	0.287	9.737	0.390	406.080
5	C&W -Master Alarm	* 1.20	0.287	9.737	0.390	406.080
6	Environmental Control System	38.70	0.287	9.737	0.390	406.080
7	Realtion Control Syste	51.00	0.287	9.737	0.390	406.080
8	RCS - System A Regulators	1.00	0.287	9.737	0.390	406.080
9	RCS - System B Regulators	1.00	0.287	9.737	0.390	406.080
10	Flight Control	206.69	0.287	9.737	0.390	406.080
11	Flight Control - FDA 1	30.30	0.287	9.737	0.390	406.080
12	Flight Control - Rate/RT Err. Monitor	0.30	0.287	9.737	0.390	406.080
13	Flight Control - X Pointer Indicator	3.20	0.287	9.737	0.390	406.080
14	Main Propulsion	13.70	0.287	9.737	0.390	406.080
15	Main Propulsion - ASC Regulator	1.00	0.287	9.737	0.390	406.080
16	Main Propulsion - DES Regulator	1.00	0.169	2.818	0.390	75.830
17	Stabilization & Control	14.70	0.287	9.737	0.390	406.080
18	Navigation & Guidance	158.60	0.287	5.565	0.390	409.825
19	Communications	9.70	0.287	9.737	0.390	406.080
20	Communications - VHF A	1.11	0.287	9.737	0.390	406.080
21	Communications - VHF B	1.12	0.287	9.737	0.390	406.080
22	Communication Antennas	14.10	0.287	9.737	0.390	406.080
23	Audio - S-Band	0.91	0.287	9.737	0.390	406.080
24	Audio - VHF A	0.91	0.287	9.737	0.390	406.080
25	Audio - VHF B	0.91	0.287	9.737	0.390	406.080
26	Audio - ICS	0.91	0.287	9.737	0.390	406.080
27	Audio VOX	0.91	0.287	9.737	0.390	406.080
28	Audio - Audio Select	0.40	0.287	9.737	0.390	406.080
29	Audio - MASTER Control	.51	0.287	9.737	0.390	406.080

Table 4.5-2 (cont)

Ident No.	Name (& Quantity if More Than One)	Fial Rate f/10 ⁶ hr	Equipment Usage Time, hr					
			Operate		Non-Operate		Boost	
			Boost	Non-Boost	Boost	Non-Boost	Boost	Non-Boost
30	Audio - Relay Select	0.30	0.287	9,737	0.390	406.080		
31	Audio - Circuit Breakers	6.00	0.287	9,737	0.390	406.080		
32	Lighting Controls	9.00	0.287	9,737	0.390	406.080		
33	Lighting - Anun/Num Control	0.20	0.287	9,737	0.390	406.080		
34	Lighting - Anun Override	0.30	0.287	9,737	0.390	406.080		
35	Lighting - Num Override	0.30	0.287	9,737	0.390	406.080		
36	Lighting - Integral Control	0.20	0.287	9,737	0.390	406.080		
37	Lighting - Integral Override	0.30	0.287	9,373	0.390	406.080		
38	Radar Controls	5.70	0.279	9,251	0.390	382.904		
39	Heater Controls	17.60	0.276	9,069	0.390	374.181		

* Calculations included in Instrumentation.

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Table 4.5-3
RELIABILITY SUBSYSTEM SUMMARY

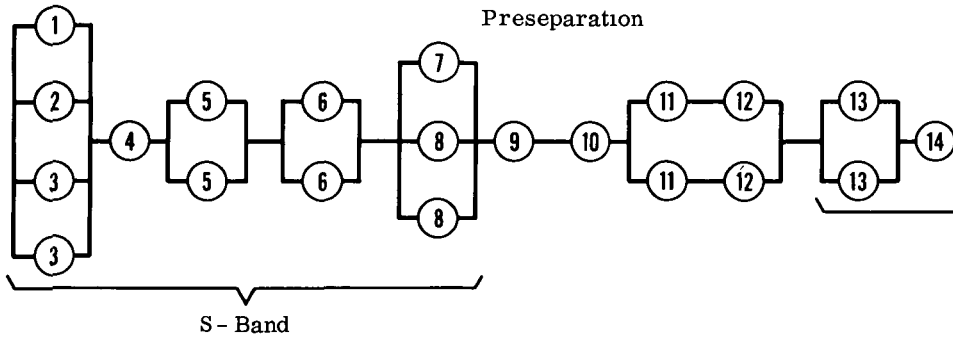
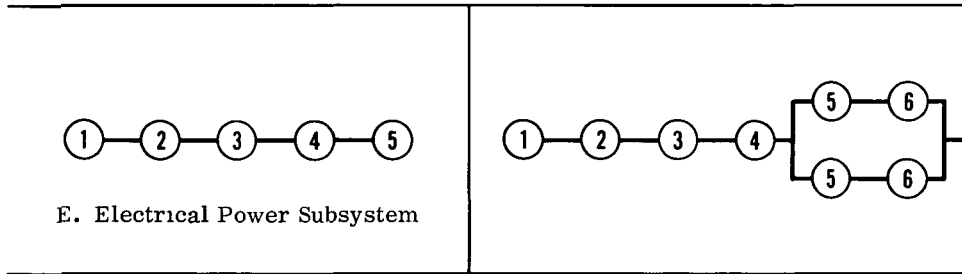
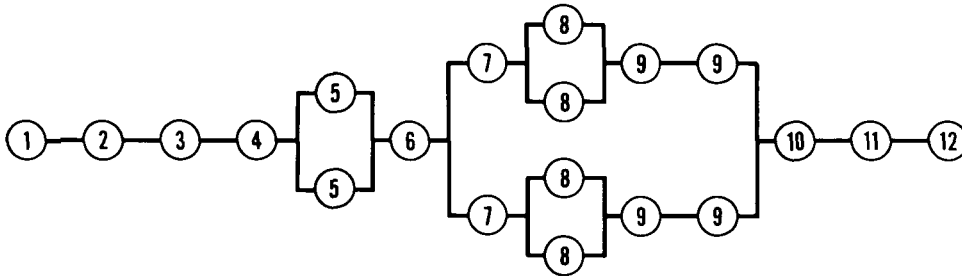
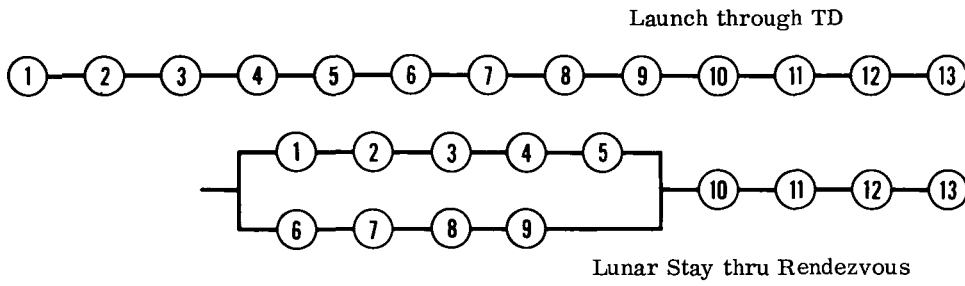
Subsystem	LEM (See Note)			AES Taxi		
	Crew Safety	Apportion	Estimate	Equivalent LEM DRM	300-hr Lunar Stay Time	Taxi DRM
Nav/Guidance	.999651	.990700	.988205	.983375	.999969	.983345
Descent Propul	.999899	.999075	.998764	.997986	-	.997986
Ascent Propul	.999899	.999961	.998300	.996741	.998432	.995178
RCS	.997807	.999804	.919600	.927369	.989274	.917422
EPS	.999993	.998600	.963896	.957200	.949870	.909220
ECS	.999994	.999446	.994760	.995746	.996630	.992390
Communications		.999910	.997680	.998533	.984718	.983273
Instrumentation		.999500	.999378*	.999378**	.998371**	.997750**
Controls & Displays		.999950	.999978	.999978**	.999942**	.999920**
Structure	.999999	.999980	.999924	.999924**	.999801**	.999725**
Explosives	.999954	.999990	Not Avail	Not Avail	Not Avail	Not Avail
Crew Provisions						
System		.987	.866	.863	.919	.793

* Does not include sensors

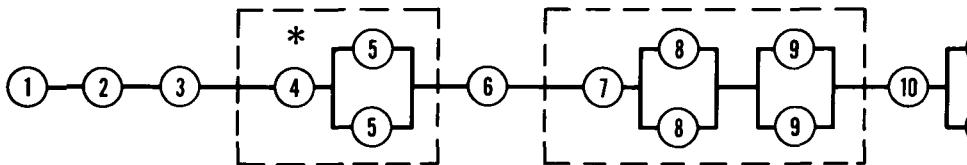
** Utilizes LEM estimate with exponential degradation for extended duration

Note: Values obtained from LPR-550-9, Quarterly Reliability Status Report, 1 Aug. 1965

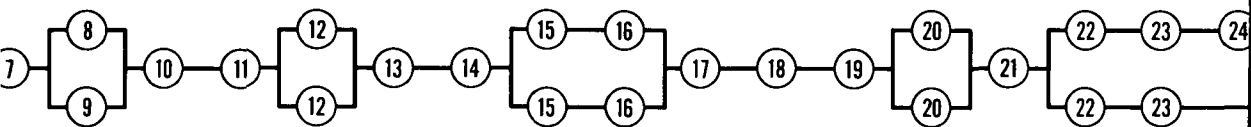
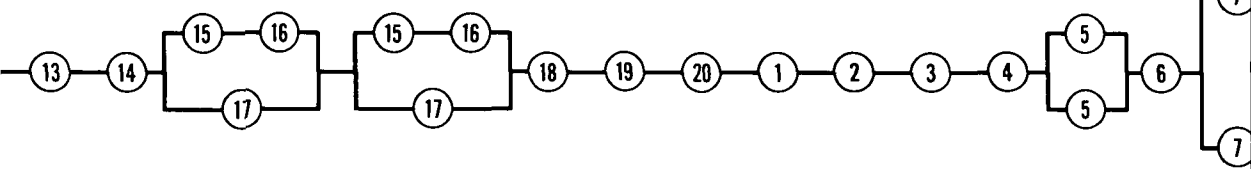
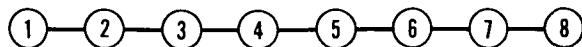
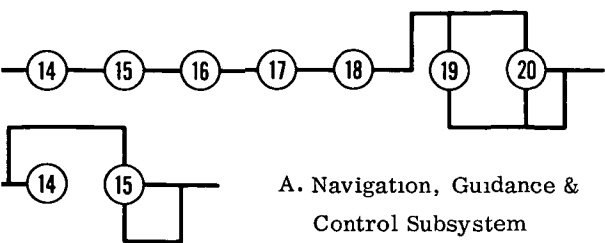
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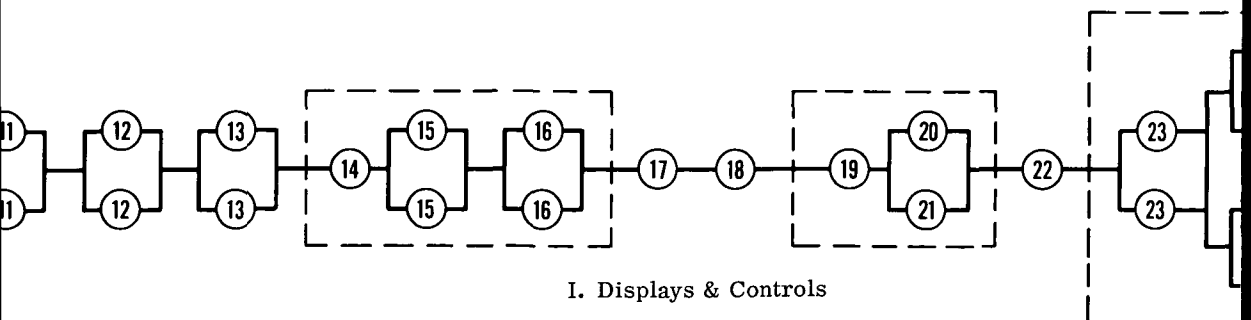
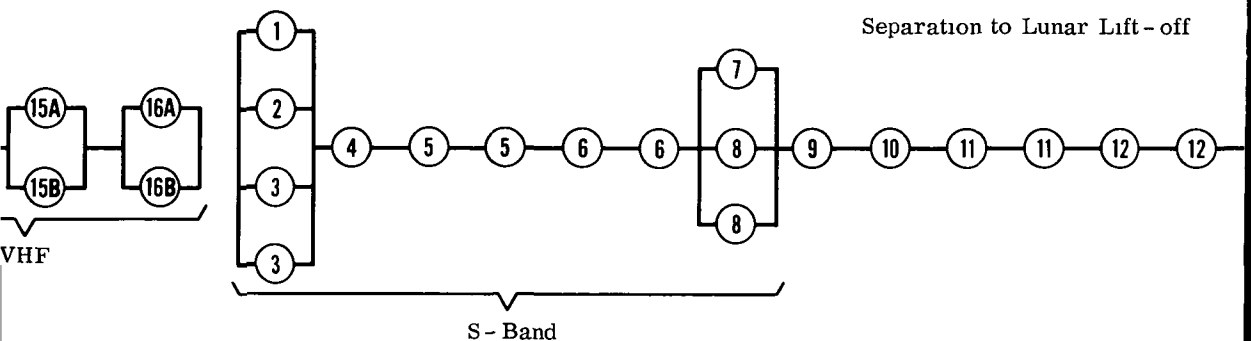
* Calculations included in Instrumentation



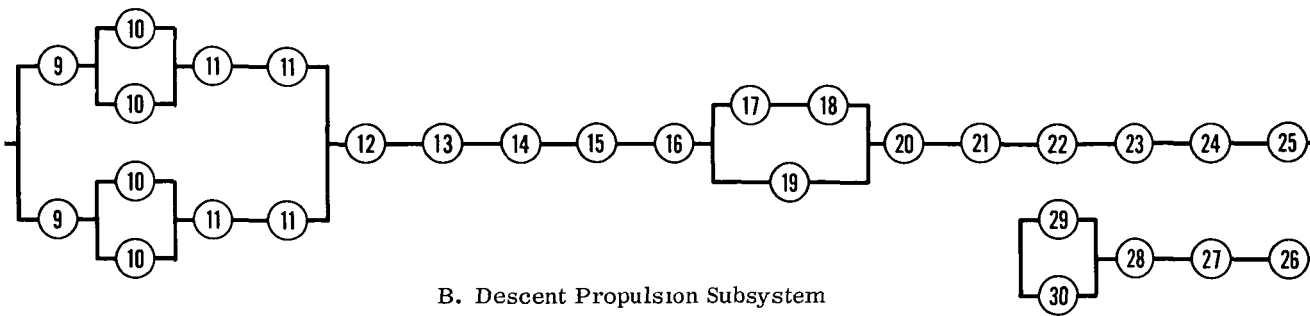
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4.5-1
①



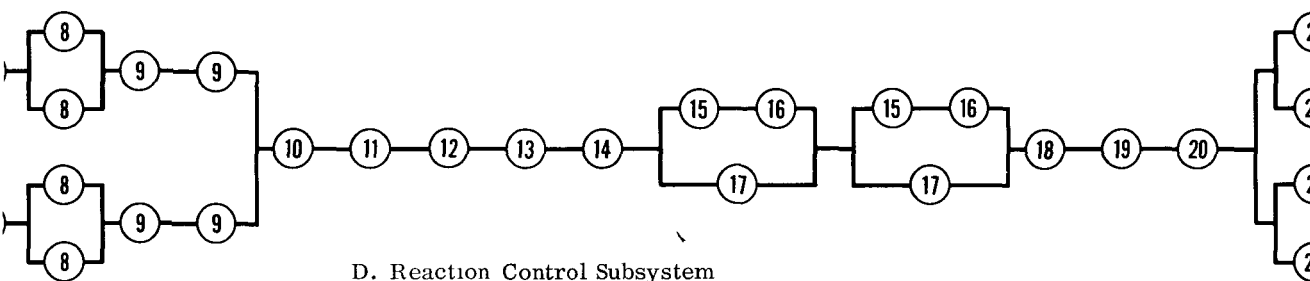
F. Environmental Cont



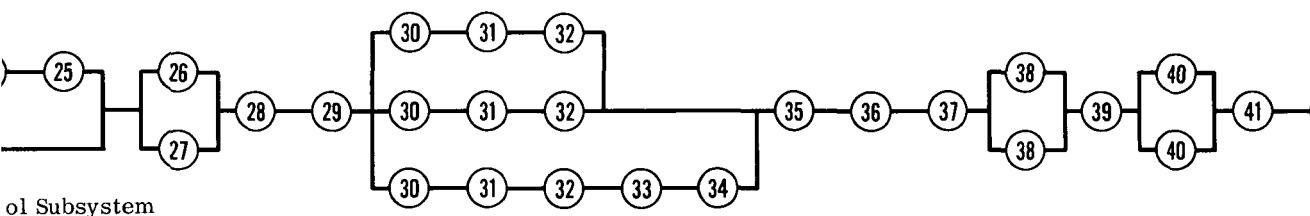
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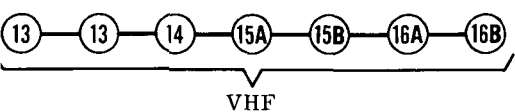
B. Descent Propulsion Subsystem



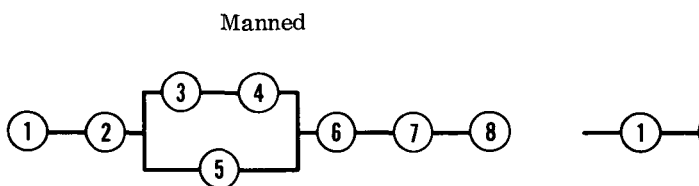
D. Reaction Control Subsystem



ol Subsystem

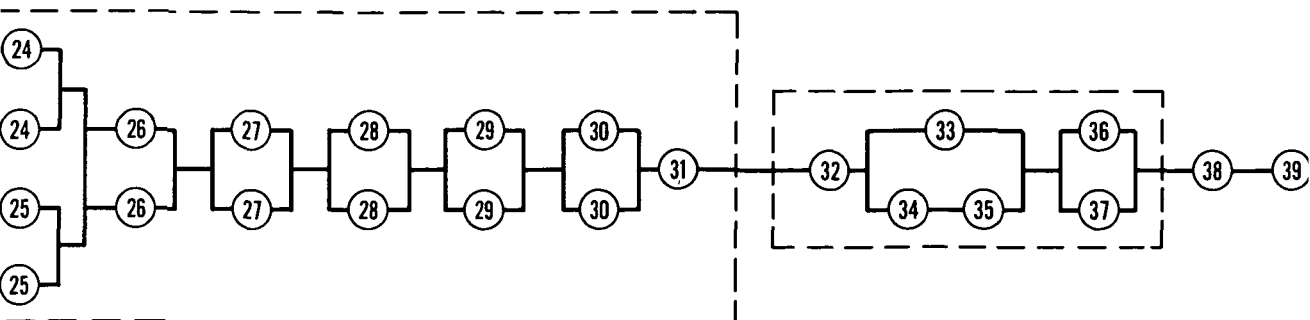


G. Communications Subsystem

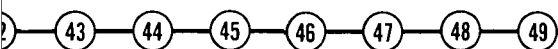
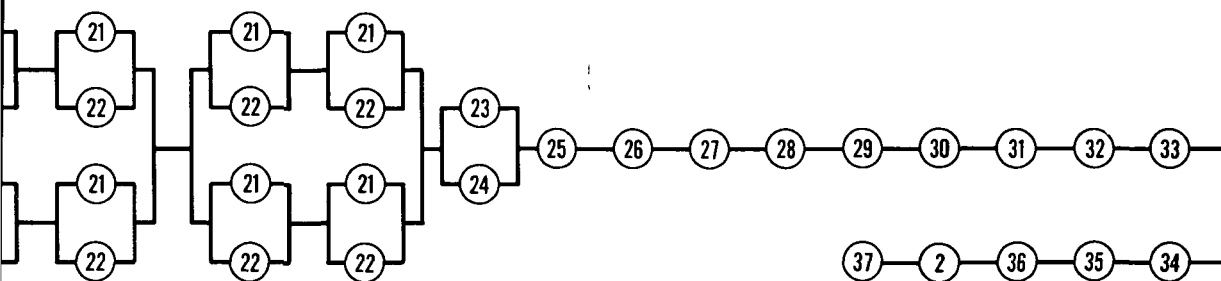
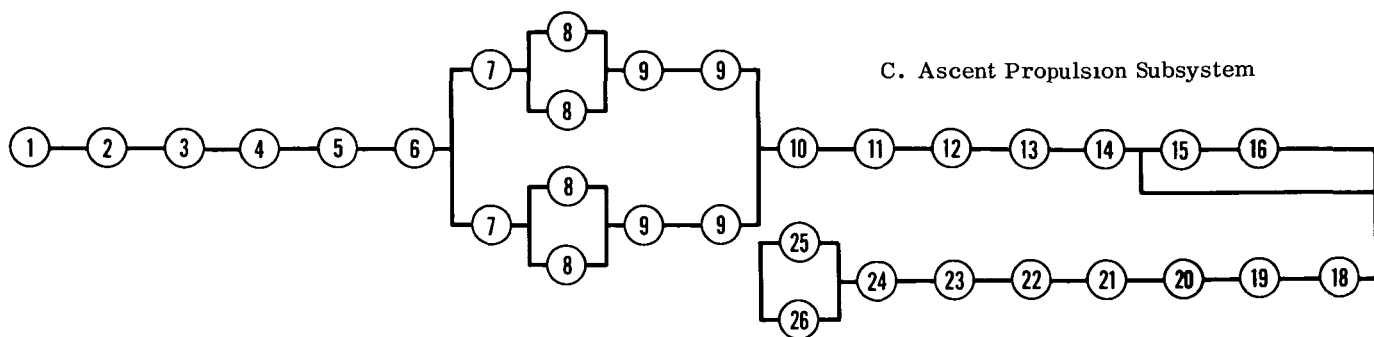


Manned

H. Instrumentation



4.5-1
3



Unmanned

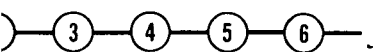


Fig. 4.5-1 Reliability Block Diagram



Grumman

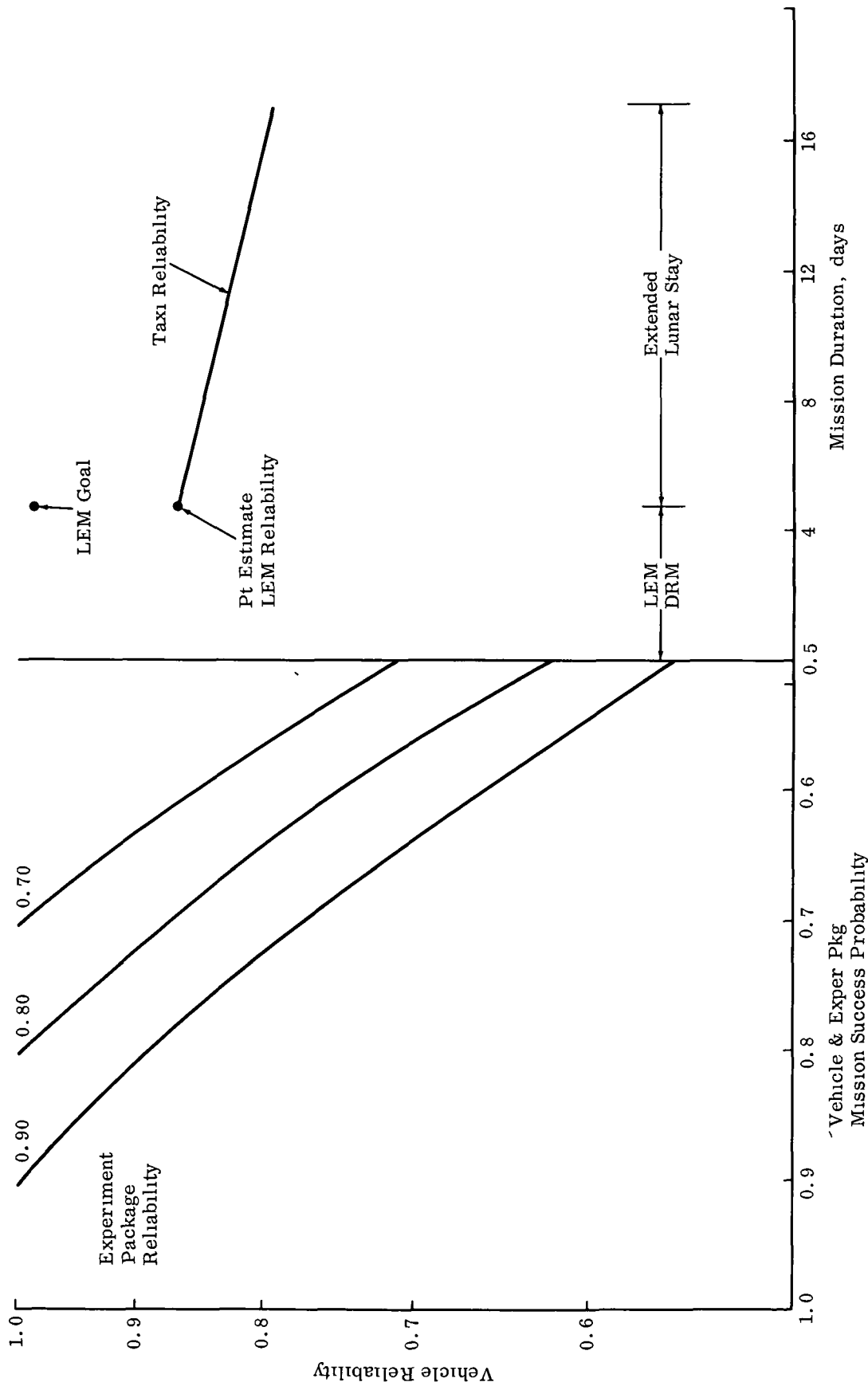


Fig. 4.5-2 Taxi Mission Success Probability

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4.6 MASS PROPERTIES

4.6.1 Ground Rules

The basic ground rule affecting the mass properties analysis of the Taxi configuration is to stay within the propulsion capability of the ascent and descent stages. In areas where limits have yet to be defined, as with centers of gravity and moments of inertia, the configurations presented maintain present LEM values wherever possible.

4.6.2 Assumptions and Background Data

The basis for all reported mass properties is the 1 August 1965 LEM weight statement, modified by the addition of 77 lb of descent propulsion and 18 lb of ascent stage structure to attain the LEM design separation weight.

Only the more critical day mission is presented in this mass properties report. A night mission would be lighter, since the Taxi does not require 180 lb of water for thermal control during the lunar stay. For an "all-night" mission, the Taxi could land a similar weight in payload.

Specific assumptions affecting the mass properties of the Taxi are:

- No scientific payload carried to the Moon
- Capability to return 250 lb of payload is based on the Propulsion Analysis (Section 4.3) for approximately 1 deg plane change capability and 4962 lb of ascent propellant
- An allowance of 34 lb for additional micrometeorite shielding is provided.
- RTG provisions only; RTG unit will be provided from the Shelter.
- Three 12 kw-hr descent batteries used for both day and night missions
- ECS expendables reflect approximately 50% less cabin occupancy than LEM and only two EVAs.

4.6.3 Recommended Configuration

The recommended configuration mass properties summary by mission phase and by subsystem are presented in tables 4.6-1 and 4.6-2, respectively. These tables describe for each of the mission phases or subsystem the weight and moments of inertia for the ascent and descent stages, separately, and as a total, where applicable.

A detailed weight statement for the recommended configuration is presented in Table 4.6-4. In most cases, the initial weight in each subsystem is a one line entry taken directly from LEM. The subsequent items indicate additions or deletions from the basic LEM subsystem. Where only one or two items from the LEM are used, a "build up" technique is used.

Changes from the baseline configuration to the recommended configuration are detailed in Table 4.6-6.

4.6.4 Baseline Configuration

The mass properties of the baseline configuration are defined in the following tables:

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- Mass Properties Summary by Mission Phase (Table 4.6-1)
- Mass Properties Summary by Subsystem (Table 4.6-3)
- Detailed Weight Statement (Table 4.6-5)
- Changes to the Baseline Configuration (Table 4.6-7)

4.6.5 Alternate Configuration

Weight estimates have been made of the various alternates considered. The delta effects of these alternates on the mass properties of the recommended configuration at lunar orbit separation are summarized in Table 4.6-8 and detailed in Table 4.6-9.

The ascent propellant tanks in the recommended configuration are not full. An additional 55 lb of propellant could be added. If the inert weight of the Taxi was decreased proportionately, an approximate increase of 55 lb return payload capability could be provided.

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Table 4.6-1
MASS PROPERTIES SUMMARY-BASELINE & RECOMMENDED
CONFIGURATIONS - BY MISSION PHASE

Vehicle	Mass Property		Dry	Burnout	Lunar Launch	Lunar Landing	Separation	Earth Launch
Baseline	Weight	(lb)	4239	5311	10685	15182	32705	32203
		{ Ascent	3966	4489				
		{ Descent						
	CG Inches From Reference Datum	{ X	257	256	243	214	186	185
		{ Y	10	9	1	2	1	1
		{ Z	-3	2	1	1	0	0
		{ Descent						
	Moments of Inertia Slug ft ²	{ I _{xx} - CG	2417	2905	6117	11560	23045	22743
		{ I _{yy} - CG	4859	5191	3353	12691	25913	25165
		{ I _{zz} - CG	3097	3284	5330	14811	25080	24532
Recommended	Weight	(lb)	4242	5293	10703	15227	32750	32248
		{ Ascent	3891	4414				
		{ Descent						
	CG-Inches From Reference Datum	{ X	257	256	243	215	86	85
		{ Y	7	6	1	1	1	1
		{ Z	-3	2	1	1	0	0
		{ Descent						
	Moments of Inertia Slug ft ²	{ I _{xx} - CG	2418	2866	6058	11491	22968	22666
		{ I _{yy} - CG	4793	5120	3364	12779	26097	25354
		{ I _{zz} - CG	2980	3169	5323	14565	24963	24420

Note: cg given in inches from the reference datum
xcg in LEM stations (Ascent/Descent separation
plane is LEM sta. 2.00.0) Y & Z cg measured from
the vertical ξ moments of Inertia are slug ft²
about vehicle cg.

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Table 4.6-2

**MASS PROPERTIES SUMMARY-RECOMMENDED
CONFIGURATION-BY SUBSYSTEM**

Code	Subsystem	Weight, lb		cg, in. from Ref Datum			Moments of Inertia, slug-ft ²		
		Ascent	Descent	x	y	z	I _{xx} (roll)	I _{yy} (pitch)	I _{zz} (yaw)
1.0	Structure	1369	1517	259	-1	9	712	724	448
2.0	Stabilization & Control	87	15	157	1	-1	1505	1002	969
3.0	Navigation & Guidance	294	15	273	16	-31	58	64	10
4.0	Crew Provisions	103	37	158	32	12	6	2	5
5.0	Environmental Control	246	37	275	-3	10	153	201	63
6.0	Landing Gear			132	-60	-45	2	5	5
7.0	Instrumentation	202	93	246	9	31	33	23	20
8.0	Electrical Power Supply	767	531	265	14	2	50	54	39
9.0	Propulsion	556	529	176	5	-45	49	15	53
10.0	Reaction Control	305	1150	121	0	4	2043	1128	1071
11.0	Communications	100	14	249	-11	-48	39	38	11
12.0	Controls & Displays	213	5	153	8	-15	1	1	0
		4242	3891	255	1	-28	244	249	49
	Total Dry Weight			180	45	42	102	79	52
				230	-4	-10	215	82	185
				154	4	-5	597	388	380
				265	0	-3	277	132	165
				267	37	-35	43	41	27
				138	-40	46	1	0	1
				267	-1	58	54	38	29
				257	1	-3	2418	2264	1234
				154	7	3	4793	3100	2980
	<u>Trapped & Residual</u>								
4.0	Crew Provisions	527	-	249	-1	47	66	49	108
5.0	Environmental Control	54	18	261	10	-10	8	7	6
9.0	Propulsion	139	505	143	-39	-48	3	1	4
10.0	Reaction Control Payload	81	250	209	3	1	89	5	89
		5293	4414	132	1	-2	300	196	124
				264	0	0	38	4	35
				274	23	0	1	8	8
	Total Weight at Burnout			256	2	2	2866	2683	1597
				151	6	2	5120	3358	3169

Table 4.6-2 (Cont.)

Code	Subsystem	Weight, lb		cg, in. from Ref Datum			Moments of Inertia, slug-ft ²		
		Ascent	Descent	x	y	z	I _{xx} (roll)	I _{yy} (pitch)	I _{zz} (yaw)
5.0	Consumed on Ascent	77		300	0	-1	18	6	12
9.0	Environmental Control	4962		227	0	0	3030	60	2985
10.0	Propulsion	371		274	0	0	176	17	160
	Reaction Control								
	Total Weight @ Lunar Launch	10703		243	1	1	6058	3364	5323
	Expended on Moon								
1.0	Structure	15		301	0	8	2	2	1
4.0	Crew Provisions	68		266	18	18	13	4	12
			10	155	-70	35	0	0	0
5.0	Environmental Control		261	137	-46	-47	42	11	52
10.0	Reaction Control	5		281	0	1	2	1	2
	Payload	-250		274	23	0	-1	-8	-8
	Total Weight @ Lunar Landing	10542	4685	243	1	1	6058	3336	5277
				151	3	0	5428	3508	3350
	Consumed on Descent	15227		215	1	1	11491	12779	14565
5.0	Environmental Controls		24	140	-49	-49	1	1	1
9.0	Propulsion		17357	160	0	0	11383	7309	4788
10.0	Reaction Controls	142		285	0	0	68	46	59
	Total Weight @ Separation	10684	22066	244	1	1	6124	3395	5390
				158	1	0	16841	11353	8226
			32750	186	1	0	22968	26097	24963
	Consumed on Trans-Lunar Flight								
4.0	Crew Provisions	-527		249	-1	47	-67	-51	-108
5.0	Environmental Controls		20	144	-40	-48	3	1	4
10.0	Reaction Controls	5		264	0	0	3	3	2
	Total Weight @ Earth Launch	10162	22086	243	1	-1	5803	3086	5280
				158	1	0	16862	11364	8238
			32248	185	1	0	22666	25354	24420

Table 4.6-3

MASS PROPERTIES SUMMARY-BASELINE
CONFIGURATION-BY SUBSYSTEM

Code	Subsystem	Weight, lb		cg, in.*			Moments of Inertia,		
		Ascent	Descent	x	y	z	I_{x-x} (roll)	I_{y-y} (pitch)	I_{z-z} (yaw)
1.0	Structure	1,369	1,514	259 156	-1 2	9 0	712 1,490	724 979	448 973
2.0	Stab & Cont	87	15	273 158	16 32	-31 12	58 6	64 2	10 5
3.0	Nav & Guid	294	37	275 132	-3 -60	10 -45	153 2	201 5	63 5
4.0	Crew Provisions	103		246	9	31	33	23	20
5.0	Environ Cont	246	93	265 176	14 5	2 -45	50 49	54 15	39 53
6.0	Landing Gear		531	121	0	4	2,043	1,128	1,071
7.0	Instrumentation	199	5	248 153	-11 8	-48 -15	38 1	37 1	9 0
8.0	Elect Power	767	607	255 162	1 57	-28 32	244 97	249 70	49 87
9.0	Propulsion	556	1,150	230 154	-4 4	-10 -5	215 597	82 388	185 380
10.0	Reaction Control	305		265	0	-3	277	132	165
11.0	Communications	100	14	267 138	37 -40	-35 46	43 1	41 0	27 1
12.0	Cont & Displ	213		267	-1	58	54	38	29
	TOTAL DRY WT	4,239	3,966	257 152	1 10	-3 2	2,417 4,859	2,263 2,931	1,234 3,097
	<u>TRAPPED & RESIDUAL</u>								
4.0	Crew Provisions	527		249	-1	47	66	49	108
5.0	Environ Cont	54	18	261 143	10 -39	-10 -48	8 3	7 1	6 4
9.0	Propulsion	139	505	209 132	3 1	1 -2	89 300	5 196	89 124
10.0	Reaction Control	81		264	0	0	38	4	35
	Payload	271		274	23	0	1	8	8
	TOT WT AT BURN-OUT	5,311	4,489	256 150	2 9	2 1	2,905 5,191	2,686 3,178	1,600 3,284
	<u>CONSUMED ON ASCENT</u>								
5.0	Environ Cont	77		300	0	-1	18	6	12
9.0	Propulsion	4,990		277	0	0	3,043	60	3,000
10.0	Reaction Control	307		273	0	0	146	14	132
	TOT WT AT LUNAR LCH	10,685		243	1	1	6,117	3,353	5,330

Table 4.6-3 (Cont)

Code	Subsystem	Wt, lb		cg, in.*			Moments of Inertia, slug-ft ²		
		Asc	Desc	x	y	z	I _{x-x} (roll)	I _{y-y} (pitch)	I _{z-z} (yaw)
	<u>EXPENDED ON MOON</u>								
1.0	Structure	15		301	0	8	2	2	1
4.0	Crew Provisions	68		266	18	18	13	4	12
			10	155	-70	35	0	0	0
5.0	Environ Control		181	143	-40	-48	29	8	36
10.0	Reaction Control	5		281	0	1	2	1	2
	Payload	-271		274	23	0	1	1	1
	TOT WT AT LUNAR LANDING	10,502		243	1	1	6,114	3,320	5,276
			4,680	149	7	0	5,419	3,284	3,425
			15,182	214	2	1	11,560	12,691	14,811
	<u>CONSUMED ON DESCENT</u>								
5.0	Environ Control		24	140	-49	-49	1	1	1
9.0	Propulsion		17,357	160	0	0	11,383	7,309	4,788
10.0	Reaction Control	142		285	0	0	68	46	59
	TOTAL WEIGHT & SEPARATION	10,644		243	1	1	6,182	3,420	5,389
			22,061	158	1	0	16,860	11,152	8,351
			32,705	186	1	0	23,045	25,913	25,080
	<u>CONSUMED ON TRANS- LUNAR FLIGHT</u>								
4.0	Crew Provisions	-527		249	-1	47	-67	-51	-108
5.0	Environ Control		20	144	-40	-48	3	1	4
10.0	Reaction Control	5		264	0	0	3	3	2
	TOTAL WEIGHT @ EARTH LAUNCH	10,122		243	1	-1	5,861	3,112	5,280
			22,081	158	1	0	16,880	11,164	8,363
			32,203	185	1	0	22,743	25,164	24,532

* From Ref. Datum

AES TAXI RECOMMENDED CONFIGURATION						
ASCENT DRY WEIGHT						
CODE	TITLE	WEIGHT POUNDS	C.G.			
			X	Y	Z	
1.0001	AST STRUCT	1326	259	- 1	9	
1.0	MM SHIELD	25	270	0	0	
1.	CON WT INC	18	259	- 1	9	
1.0	STRUCTURE	1369	259	- 1	9	
2.0	STAB+CONTROL	87	273	16	-31	
3.0	N+G ASCENT	289	275	- 3	10	
3.0	TME PRGMR	5	265	0	0	
3.0	NAV+GUIDANCE	294	275	- 3	10	
4.0	CREW PROVISN	103	246	9	31	
5.0	ENVIRN ASC	347	269	12	0	
5.8	ECS EXPND-	61	293	2-	3	
5.43	H2O TK HTR	1	223	0	0	
5.	BTY BYPASS	1	260	0	0	
5.7	GLYCOL	- 37	255	10-	10	
5.811	LICH	- 8	261	19	5	
5.0	HEAT PIPE	3	250	0	0	
5.0	ENVIRON CONT	246	265	14	2	
7.0	INSTN ASC	202	249	-11	-48	
7.13	DATA STORG	- 3	285	0	-35	
7.13	VOICE RECD	3	285	0	-35	
7.0	INSTRUMENTN	202	249	-11	-48	
8.0	ELECTRIC PWR	767	255	1	-28	
9.0	PROPULSION	695	226	- 3	- 8	
9.33	HELIUM	- 13	232	-11	-10	
9.12	TRAPD PROP	-126	207	4	2	
9.0	PROPULSION	556	230	- 4	-10	
10.0	RCS	386	265	0	- 2	
10.1	RCS RESIDL	-81	264	0	0	
10.0	RCS	305	265	0	- 3	
11.0	COMMUNICATN	100	267	37	-35	

12.0 CONTS+D	
TOTAL ASCENT	
*****	**
DESCENT DRY W	
CODE	TITLE
1.0002	DST STR
1.0	MM SHIE
1.	H2O TK
1.1111	BAT+ECA
1.11	BAT+ECA
1.1511	RTG SUP
1.1510	RTG INS
1.0	STRUCTURE
2.0	STAB+CONT
3.3	LANDG P
3.0	NAV+GUIDA
5.0	ENVIRN
5.8	ECS EX
5.0	HEAT PI
5.0	ENVIRON C
6.0	LANDING C
7.4	SENSORS
7.0	INSTRUMEN
8.0	EPS DE
8.112	BATTRYS
8.112	BATTERI
8.12	BAT CON
8.1	BAT CON
8.1	RTG ECA
8.0	ELECTRIC
9.0	PROPULS
9.34	HELIUM
9.12	TRAPD F
9.36	VENT VA
9.0	PROPULSIC

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PL	213	267	- 1	58
RY	4242	257	1 - 3	
***	*****	*****	*****	
WEIGHT	C.G.			
POUNDS	X	Y	Z	
CT	1499	156	2	0
D	9	160	0	0
TG	6	145	-49	-49
SU	- 50	164	57	36
SU	40	176	50	50
S	7	188	-50	-70
L	6	188	-50	-70
	1517	157	1 - 1	
QL	15	158	32	12
DR	37	132	-60	-45
CE	37	132	-60	-45
ES	302	156	19	46
ND	213	148	30	47
E	4	190	-50	-65
NT	93	176	5	-45
AR	531	121	0	4
	5	153	8	-15
N	5	153	8	-15
	656	162	58	33
DS	-556	159	63	36
S	429	180	50	50
LS	- 38	171	44	36
LS	28	171	44	36
	10	185	-50	-70
WR	529	180	45	42
ON	1640	147	3 - 4	
	- 50	156	8 - 8	
OP	- 455	129	0 - 1	
VE	15	180	17 - 35	
	1150	154	4 - 5	

11.0	COMMUNCTN	16	138	-44	44
11.0	TV	- 2	128	-71	30
11.0	COMMUNICATN	14	138	-40	46
TOTAL DESCNT DRY		3891	154	7	3
*****	*****	*****	*****	*****	*****
ASCENT STAGE TRAPPED + RESIDUAL					
CODE	TITLE	WEIGHT	C.G.		
		POUNDS	X	Y	Z
4.0	CREW PROVISH	527	249	- 1	47
5.7	GLYCOL	37	255	10 - 10	
5.811	LIGH	8	261	19	5
5.821	O2 T+R	4	266	0 - 53	
5.83	H2O ASC	5	300	0	0
5.0	ENVIRON CONT	54	261	10 - 10	
9.12	TRAPD PROP	126	207	4	2
9.33	HELIUM	13	232	-11	-10
9.0	PROPULSION	139	209	3	1
10.0	RCS	81	264	0	0
PAYLOAD		250	274	23	0
TOTAL ASCENT T+R		1051	251	6	23
*****	*****	*****	*****	*****	*****
DESCENT STAGE TRAPPED + RESIDUAL					
CODE	TITLE	WEIGHT	C.G.		
		POUNDS	X	Y	Z
5.83	H2O	16	138	-49	-49
5.822	GOX DESC	2	184	40	-40
5.0	ENVIRON CONT	18	143	-39	-48
9.34	HELIUM	50	156	8 - 8	
9.12	TRAPD PROP	455	129	0 - 1	
9.0	PROPULSION	505	132	1 - 2	

TOTAL DESCNT T+R	523	132		
*****	*****	*****	*****	*****
CONSUMED ON ASCENT				
CODE	TITLE	WEIGHT		
		POUNDS	X	
5.83	H2O	76	300	
5.8	O2	1	266	
5.0	ENVIRON CONT	77	300	
9.111	PROPELLANT	4962	227	
9.0	PROPULSION	4962	227	
10.1	RCS PROP	169	277	
10.11	RCS PROP	138	269	
10.1	RCS PROP	64	278	
10.0	RCS	371	274	
CONSUMED ON ASC	5410	231		
*****	*****	*****	*****	*****
EXPEND OR JETTISON ON MOON A				
CODE	TITLE	WEIGHT		
		POUNDS	X	
1.	WINDOW CVR	2	275	
1.0	TUNNEL CVR	13	305	
1.0	STRUCTURE	15	301	
4.0	CREW PROV	87	261	
4.54	LIGH	- 14	242	
4.52	FOOD	- 4	252	
4.0	CREW PROVISH	68	266	
10.1	RCS PROP	5	281	
10.0	RCS	5	281	
PAYLOAD		-250	274	
EXPEND MOON ASC	-161	275		

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Table 4.6-4

DETAILED WEIGHT STATEMENT - RECOMMENDED CONFIGURATION

1 - 3		EXPEND OR JETTISON ON MOON DESCENT				10.1 RCS PROP		5 264 0 0	
*****		CODE	TITLE	WEIGHT POUNDS	C.G. X Y Z	10.0 RCS		5 264 0 0	
		4.113	PLSS BATTS	10	155 -70 35	CREW TRANSFER		- 527 249 - 1 47	
		4.0	CREW PROVISION	10	155 -70 35	CONSUMD XL FLT AS		- 522 249 - 1 48	
C.G.		5.82	GOX	18	184 40 -40	*****		*****	
Y Z		5.83	H2O	243	139 -49 -49	*****		*****	
0 0		5.0	ENVIRON CONT	261	137 -46 -47	CONSUMED ON XLUNAR FLT DESCENT			
0 -54						CODE		TITLE WEIGHT C.G.	
0 - 1						POUNDS		X Y Z	
0 0						5.82 GOX		2 184 40 -40	
0 0						5.83 H2O		18 140 -49 -49	
0 0						5.0 ENVIRON CONT		20 144 -40 -48	
0 0						CONSUMD XL FLT D		20 144 -40 -48	
0 0						*****		*****	
0 0						CONSUMED ON DESCENT -ASCENT			
0 0						CODE		TITLE WEIGHT C.G.	
0 0						POUNDS		X Y Z	
0 0		10.1	RCS PROP	22	282 0 0	10.1 RCS PROP		54 284 0 0	
0 0		10.1	RCS PROP	54	284 0 0	10.1 RCS PROP		66 287 0 0	
0 0		10.1	RCS PROP	66	287 0 0	10.0 RCS		142 280 0 0	
0 0						CONSUMD DSC -ASC		142 285 0 0	
0 0						*****		*****	
0 0						CONSUMED ON DESCENT -DESCENT			
0 0						CODE		TITLE WEIGHT C.G.	
0 0						POUNDS		X Y Z	
0 62		5.83	H2O	24	140 -49 -49	9.0 EXPND PROP		17357 160 0 0	
0 0		5.0	ENVIRON CONT	24	140 -49 -49	9.0 PROPULSION		17357 160 0 0	
0 8						CONSUMD DSC -DSC		17381 160 0 0	
13 19						*****		*****	
-15 17						CONSUMED ON XLUNAR FLT ASCENT			
17 31						CODE		TITLE WEIGHT C.G.	
18 18						POUNDS		X Y Z	
0 1						*****		*****	
0 1						*****		*****	
23 0						*****		*****	
28 - 9						*****		*****	



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Table 4.6-5 Detailed Weight

AES TAXI BASELINE				
ASCENT DRY WEIGHT				
CODE	TITLE	WEIGHT POUNDS	C.G. X Y Z	
1.0001	AST STRUCT	1326	259	- 1 9
1.0	MM SHIELD	25	270	0 0
1.	CON WT INC	18	259	- 1 9
1.0	STRUCTURE	1369	259	- 1 9
2.0	STAB+CONTROL	87	273	16 -31
3.0	N+G ASCENT	283	275	- 3 10
3.0	TME PRGMFR	5	265	0 0
3.0	NAV+GUIDANCE	234	275	- 3 10
4.0	CREW PROVISN	103	246	9 31
5.0	ENVIRN ASC	347	269	12 0
5.8	ECS EXPND-	61	293	2- 3
5.43	H2O TK HTR	1	223	0 0
5.	BTY BYPASS	1	260	0 0
5.7	GLYCOL	- 37	255	10- 10
5.811	LICH	- 8	261	19 5
5.0	HEAT PIPE	3	250	0 0
5.0	ENVIRON CONT	246	265	14 -2
7.0	INSTN ASC	202	249	-11 -48
7.13	DATA STORP	- 3	285	0 -35
7.0	INSTRUMENTN	199	248	-11 -48
8.0	ELECTRIC PWR	767	255	1 -28
9.0	PROPULSION	695	226	- 3 - 8
9.33	HELIUM	- 13	232	-11 -10
9.12	TRAPD PROP	-126	207	4 2
9.0	PROPULSION	556	230	- 4 -10
10.0	RCS	386	265	0 - 2
10.1	RCS RES IDL	-81	264	0 0
10.0	RCS	305	265	0 - 3
11.0	COMMUNICATN	100	267	37 -35

12.0	CONTS+DISPL	213	267	- 1 58
TOTAL	ASCENT DRY	4239	257	1 - 3
DESCENT DRY WEIGHT				
CODE	TITLE	WEIGHT POUNDS	C.G. X Y Z	
1.0002	DST STRUCT	1499	156	2 0
1.0	MM SHIELD	9	160	0 0
1.	H2O TK MTG	5	145	-49 -49
1.0	STRUCTURE	1514	156	2 0
2.0	STAB+CONTROL	15	158	32 12
3.3	LANDG PADR	37	132	-60 -45
3.0	NAV+GUIDANCE	37	132	-60 -45
5.0	ENVIRN DES	302	156	- 19- 46
5.8	ECS EXPND-	213	148	- 30- 47
5.0	HEAT PIPE	4	190	-50 -65
5.0	ENVIRON CONT	93	176	5 -45
6.0	LANDING GEAR	531	121	0 4
7.4	SENSORS	5	153	8 -15
7.0	INSTRUMENTN	5	153	8 -15
8.0	FPS DES	656	162	58 33
8.112	BATTPYS DS	-556	159	63 36
8.1	BATTPYS DS	510	159	63 36
8.12	BAT CNTLS	- 38	171	44 36
8.1	BAT CNTLS	28	171	44 36
8.1	RTG PROV	7	188	-50 -70
8.0	ELECTRIC PWR	607	162	57 32
9.0	PROPULSION	1640	147	3 - 4
9.34	HELIUM	- 50	156	8 - 8
9.12	TRAPD PROP	- 455	129	0 - 1
9.36	VENT VALVE	15	180	- 17- 35
9.0	PROPULSION	1150	154	4 - 5
11.0	COMMUNCTN	16	138	-44 44
11.0	TV	- 2	138	-71 30
11.0	COMMUNICATN	14	138	-40 46

TOTAL DESC	
ASCENT TRAI	
CODE	TIT
4.0	CREW PR
5.7	GLYCO
5.811	LICH
5.821	O2 T
5.83	H2O
5.0	ENVIRON
9.12	TRAPD
9.33	HELIU
9.0	PROPULS
10.0	RCS
	PAYLO
TOTAL ASCEN	
DESCENT TRAI	
CODE	TIT
5.83	H2O
5.822	GOX
5.0	ENVIRON
9.34	HELIU
9.12	TRAPD
9.0	PROPULS
TOTAL DESC	
CONSUMED ON	
CODE	TIT
5.83	H2O
5.8	O2
5.0	ENVIRON

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Statement Baseline Configuration

DRY 3966 152 10 2

+RFSD

F WEIGHT POUNDS X C.G. Y Z

VISN 527 249 - 1 47

37 255 10- 10

8 261 19 5

4 266 0 -53

ASC 5 300 0 0

CONT 54 261 10 -10

PROP 126 207 4 2

13 232 -11 -10

ON 139 209 3 1

81 264 0 0

D 271 274 23 0

T+R 1072 252 6 23

D+RFSD

F WEIGHT POUNDS X C.G. Y Z

16 138 -49 -49

DFSC 2 184 40 -40

CONT 18 143 -39 -48

PROP 50 156 8 - 8

455 129 0 - 1

ON 505 132 1 - 2

T+P 523 132 - 1 - 3

ASCENT

F WEIGHT POUNDS X C.G. Y Z

76 300 0 0

1 266 0 -54

CONT 77 300 0 - 1

9.111 PROPELLANT 4990 227 0 0

9.0 PROPULSION 4990 227 0 - 0

10.1 RCS PROP 169 277 0 0

10.111 RCS PROP 138 269 0 0

10.0 RCS 307 273 0 0

CONSUMED ON ASC 5374 231 0 0

EXPEND OR JETTISON ON MOON - ASCENT

CODE TITLE WEIGHT POUNDS X C.G. Y Z

1. WINDOW CVR 2 275 0 62

1. TUNNEL CVR 13 305 0 0

1.0 STRUCTURE 15 301 0 8

4.0 CREW PROV 87 261 13 19

4.54 LIQH - 14 242 -15 17

4.52 FOOD - 4 252 17 31

4.110 PLSS CALIB - 1 238 37 49

4.0 CREW PROVISN 68 266 18 18

10.1 RCS PROP 5 281 0 1

10.0 RCS 5 281 0 1

PAYLOAD - 271 274 23 0

EXPEND MOON ASC -183 275 27 - 7

EXPEND OR JETTISON ON MOON DESCENT

CODE TITLE WEIGHT POUNDS X C.G. Y Z

4.113 PLSS BATTS 10 155 -70 35

4.0 CREW PROVISN 10 155 -70 35

5.82 GOX 18 184 40 -40

5.83 H2O 163 138 -49 -49

5.0 ENVIRON CONT 181 143 -40 -48

EXPEND MOON DESC 191 143 -42 -44

CONSUMED ON DESCENT -ASCENT

CODE TITLE WEIGHT POUNDS X C.G. Y Z

10.1 RCS PROP 22 282 0 0

10.1 RCS PROP 54 284 0 0

10.1 RCS PROP 66 287 0 0

10.0 RCS 142 280 0 0

CONSUMED ON DESCENT -DESCENT

CODE TITLE WEIGHT POUNDS X C.G. Y Z

5.83 H2O 24 140 -49 -49

5.0 ENVIRON CONT 24 140 -49 -49

9.0 EXPND PROP 17357 160 0 0

9.0 PROPULSION 17357 160 0 0

CONSUMED ON DESCENT -DESCENT

CODE TITLE WEIGHT POUNDS X C.G. Y Z

CONSUMED DSC -DSC 17381 160 0 0

CONSUMED ON XLUNAR FLT ASCENT

CODE TITLE WEIGHT POUNDS X C.G. Y Z

10.1 RCS PROP 5 264 0 0

10.0 RCS 5 264 0 0

CREW TRANSFER - 527 249 - 1 47

CONSUMED ON XLUNAR FLT ASCENT

CONSUMED XL FLT AS - 522 249 - 1 48

CONSUMED ON XLUNAR FLT DESCENT

CODE TITLE WEIGHT POUNDS X C.G. Y Z

5.82 GOX 2 184 40 -40

5.83 H2O 18 140 -49 -49

5.0 ENVIRON CONT 20 144 -40 -48

CONSUMED ON XLUNAR FLT DESCENT

CONSUMED XL FLT D 20 144 -40 -48

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Table 4.6-6

ΔWT CHANGES FROM BASELINE TO RECOMMENDED CONFIGURATION

Code	Subsystem	Item	Weight Change	Description of Change
7.0	Instrumentation	Voice Recorder	+ 3	Required for Mission
		Ascent Dry Weight	+ 3	
1.0	Structure	RTG Insulation	6	} Better Information available After Baseline Configuration was Defined
		RTG Supports	7	
		Battery & ECA Supports	-10	
8.0	Electric Power	Descent Batteries	-78	Change in Power Profile
		Descent Dry Weight	-75	
	Payload		-21	Ascent Propellant Offloaded
		Ascent Trapped & Residual	-21	
9.0	Propulsion	Ascent Propellant	-28	Offloaded to Maintain 32750# Separation Weight
10.0	Reaction Control	Propellant	+64	Additional Contingency Requirements
		Consumed on Ascent	+36	
4.0	Crew Provisions	PLSS Calib Unit	+ 1	Omitted in Error
	Payload		+21	Payload Reduced from 271 to 250 pounds
		Expended on Moon - Ascent	+22	
5.0	Environmental Control	Water	+80	Reestimated Water Requirement for Thermal Control
		Expended on Moon Descent	+80	
		Total Changes	+45	

Table 4.6-7

 Δ WT CHANGES FROM MID-TERM BASELINE TO PRESENT BASELINE

Code	Subsystem	Item	Δ Wt	Reason for Change
1.0	Structure	Control Weight Δ	+18	Transferred from descent to ascent stage.
3.0	Nav & Guid	Time Programmer	+5	Omitted by error from Mid-Term Report.
5.0	Environ Control	Heat Pipe	-7	Better information
		H ₂ O Tank Heater	+1	Omitted by error from Mid-Term Report.
		Battery Bypass	+1	
		ASCENT DRY WT Δ s	+18	
1.0	Structure	Window Cover	-10	Transferred to "Expended on Moon - Ascent"
		Tunnel Cover	-10	
		Control Weight Δ	-18	Transferred to ascent stage.
5.0	Environ Control	Heat Pipe	-11	Better information.
8.0	Elect Power	RTG Provisions	-25	
		DESCENT DRY WT Δ s	-74	
1.0	Structure	Window Cover	+2	Transferred from "Descent Dry Wt" & reduced by 5 lb.
		Tunnel Cover	+13	
11.0	Communications	EVA Antenna & RF Cable	-4	Omitted by error from Mid-Term Report.
		EXPENDED ON MOON-ASCENT	+11	
		TOTAL WT CHANGES	-45	

Table 4.6-8

MASS PROPERTIES SUMMARY-SUBSYSTEM ALTERNATES

Alternates	Wt,lb	cg, in. from Ref Datum			Moments of Inertia, slug-ft ²		
		x	y	z	I _{xx} (roll)	I _{yy} (pitch)	I _{zz} (yaw)
Add RCS Cluster Covers	100	254	0	0	210	105	105
Replace Descent Batteries With Zox Batteries	-156	179	52	64	43	36	- 6
Direct R.T.G. Radiation	10	237	-63	-19	0	- 4	- 1
Carry Own RTG	50	140	-50	-70	0	0	0
Right & Left Polarization of S Band Antenna.	0	0	0	0	0	0	0
More Elaborate Prelaunch Check Out	0	0	0	0	0	0	0

NOTE: All inertias are about the Alternate Delta change C.G.

TABLE 4.6-9

Detailed Weight Statement-Subsystem Alternates

ALTERNATES TO RECOMMENDED TAXI						
CODE	TITLE	WEIGHT POUNDS	C.G. X Y Z			
ADD RCS CLUSTER COVERS						
1.0	RCS CL CVP	25	254	65	65	
1.0	RCS CL CVP	25	254	65	-65	
1.0	RCS CL CVP	25	254	-65	-65	
1.0	RCS CL CVP	25	254	-65	65	
DELTA WEIGHT		100	254	0	0	0
*****	*****	*****	*****	*****	*****	*****
REPLACE DESCENT BATTERIES WITH ZOX BATTERIES						
CODE	TITLE	WEIGHT POUNDS	C.G. X Y Z			
5.5	02 REGS	6	185	40	40	
5.5	02 PLUMBNG	5	185	40	0	
5.82	02	18	184	40	-40	
8.11	ZOX BATRY5	210	180	50	50	
8.1	CONT UNITS	30	180	50	50	
8.1	MISC	4	185	50	0	
8.112	BATTERIES	-429	180	50	50	
DELTA WEIGHT		-156	179	52	64	
*****	*****	*****	*****	*****	*****	*****
DIRECT RTG RADIATION						
NO WEIGHT CHANGE						

CODE TITLE WEIGHT C.G.						
POUNDS X Y Z						
1.0	INSUL INST	15	215	-53	-43	
1.	SUPT BEAM	10	202	-50	-50	
1.0	DOOR INST	3	215	-36	-43	
1.0	MISC	2	215	-40	-43	
1.151	RTG INSUL	-6	188	-50	-70	
1.151	RTG SUPTS	-7	188	-50	-70	
5.0	HEAT PIPE	-4	190	-50	-65	
5.0	HEAT PIPE	-3	250	0	0	
DELTA WEIGHT		10	237	-63	-19	
*****	*****	*****	*****	*****	*****	*****
CARRY OWN RTG						
CODE	TITLE	WEIGHT POUNDS	C.G. X Y Z			
	RTG	50	140	-50	-70	
DELTA WEIGHT		50	140	-50	-70	
*****	*****	*****	*****	*****	*****	*****
P+L CIRCULAR POLARIZATION						
NO WEIGHT CHANGE						
*****	*****	*****	*****	*****	*****	*****
MOPE ELABORATE PRELAUNCH CHECK OUT						
NO WEIGHT CHANGE						

5. SUBSYSTEM ENGINEERING

5.1 ELECTRICAL POWER

5.1.1. Ground Rules

There were no NASA ground rules unique to the Taxi Electrical Power Subsystem (EPS).

5.1.2 Assumptions and Background Data

It was assumed for this study that the Taxi EPS must supply power for the same basic mission as the LEM with the following differences:

- Lunar stay is increased to 336 hr (LEM mission is 35 hr)
- No experiment power is furnished by the Taxi.

5.1.2.1. Power and Energy Requirements

The design power profile, based on the EPS critical time line (109-hr translunar flight and 336-hr night surface mission), is presented in Fig. 5.1-1a through c and Tables 5.1-1a through g.

The specific equipment power levels are based on LEM current status and/or the latest information available from vendor and test data. A factor of 20% has been added for growth to account for unforeseen changes. Essentially, the Taxi power and energy requirements are the same as the LEM from Earth launch through lunar touch-down, and from pre-lunar launch checkout through rendezvous. The main difference between the LEM and Taxi occurs during the lunar stay period. The LEM is used to directly support 35 hr of lunar experiments.

After touch-down and checkout has insured that the Taxi is in good condition, and it has been established that the Shelter can support its intended mission (go/no go decision), the Taxi will be shut down. Only those loads which are required to maintain the Taxi so that it will not be damaged or degraded, along with those required to transmit a status report every 2 hr, will be left on. Loading during secure-for-storage and reactivation has been assumed to change linearly between the quiescent level and the nominal lunar mission level in 12 and 9 min, respectively.

A detailed summary sheet, showing the specific load requirements and assumed duty cycles, has been included for the Taxi quiescent phase. Loading has been broken down between night and day missions, with and without a Radioisotope Thermoelectric Generator (RTG).

5.1.2.2. Power Sources Background Data

The following power sources were considered for use on the Taxi: silver-zinc batteries, zinc-oxygen batteries, and radioisotope thermoelectric generator.

5.1.2.2.1 Silver-Zinc Batteries. The LEM ascent and descent batteries differ, each has been designed and optimized for its specific missions and profiles. Although both are high merit factor, silver-zinc, primary-type batteries, there are differences in their design. The ascent battery has been designed to be used with a pre-discharge and discharged at high rates of up to 3000 to 4000 w. The descent battery is designed for cell taps and discharge rates approximately 1/3 of the ascent battery. The significant characteristics of both of these batteries are shown in Table 5.1-2.

The two major differences in design considerations between the Taxi and LEM battery power supplies are: the Taxi has a 13-day longer mission time, and the descent energy requirement is approximately 75% of the LEM.

Activated wet life of silver-zinc, primary-type, batteries is always a primary design consideration. Batteries initially designed for a 30-day wet stand plus a 150-hr mission (LEM) cannot be extended for use on a 450-hr mission (Taxi) without changing some of the other design requirements and/or the probability for mission success.

The primary design problem of activated wet life rests with the separator design. Time, temperature, and state of charge (potential gradient) are the major factors contributing to separator degradation. By operating at low temperatures and discharge rates, the rate of separator degradation will be appreciably reduced. Since the Taxi battery discharge rates and temperatures for its 330-hr quiescent storage period is low, it was estimated that the LEM batteries could perform over the extended Taxi time line with some slight reduction in reliability.

Figure 5.1-2 shows the estimated loss of capacity as a function of lunar stay temperature, and an estimate of the reliability to be expected with the assigned derating. These curves are based on the normal LEM discharge prior to the quiescent period. The portion of the curves from 96 to 336 hr is conservative, since there is insufficient supporting data to provide confidence that better reliability could be achieved. Little support data is available for this particular cell at temperatures above 125°F; however, short periods of operation at temperatures up to 160°F may be encountered without expectation of failures. To realize full rated capacity, with lunar stay time extended to 336 hr, the cell temperatures must be kept below 88°F. At the low discharge rates obtained during quiescent operation, little heat is dissipated in the battery, and the cell temperature will be at about the same temperature as the battery case temperature. The descent battery cases must be maintained below an upper temperature limit of 88°F.

During long-term storage, temperatures below 88°F will result in improved reliability and high capacity retention. At temperatures of 40°F and lower, storage up to 3 months would have little effect on capacity or reliability. In the case of the ascent batteries, which must be capable of supplying immediate power in the event of an abort, the storage temperature must not be less than 40°F.

5.1.2.2.2 Zinc-Oxygen Batteries. Zinc-oxygen (ZOX) batteries are a hybrid utilizing a consumable metallic zinc anode (similar to that of a silver-zinc battery) and gaseous oxygen. The oxygen is fed to a non-consumable cathode (sintered electrode made of teflon impregnated with platinum black and silver as activation agents). It operates as a primary battery and has some characteristics of a low-temperature fuel

cell, without the degradation problems. The electrolyte is 40% potassium hydroxide, similar to that of silver-zinc batteries. The oxygen pressure requirement is 15 psi for the Leeson Moos design, and 150 psi for the Eagle-Pitcher design. Oxygen is stored externally and could be supplied from the LEM oxygen tank supply with a pressure regulating valve in the feed line. Approximately 0.5 lb. of oxygen is required per kw-hr of energy produced.

The electrical characteristics closely follow those obtained with a medium to low-rate silver-zinc battery, except for the specific voltages and the peroxide/monoxide voltage effect. A comparison of the weights of ZOX batteries and silver-zinc batteries as a function of capacity and discharge rate is shown in Fig. 5.1-3.

The reaction product is a zinc compound, which remains within the pores of the fuel electrode so that no problem of disposal exists. Cell voltage as a function of current density and discharge time is plotted in Fig. 5.1-4. Output voltage increases with increasing operating pressure as shown in Fig. 5.1-5. In the Eagle-Picher system, power falls off rapidly below 40 psi, and at pressures above 150 psi, the container package weight becomes excessive for the optimum cylindrical configuration. Pressures between 100 and 150 psi appear to result in minimum weight.

Operation at temperatures down to 20°F is likely to result in a loss of 20% of capacity. The upper operating temperature limit of 120°F is possible for a short time, but side reactions of zinc with potassium hydroxide result in the production of hydrogen, and continuous operation should be limited to temperatures below 100°F.

The Leeson Moos ZOX battery is designed to operate at atmospheric pressure. This battery is in an early development stage with primary effort being directed to single-cell performance. Leeson Moos does not feel that any difficult problems remain to be solved in developing qualified units for the Taxi; however, they have not engineered a complete battery system nor established a program for its development and qualification.

Eagle-Picher is under contract to Lockheed to develop a 20 kw-hr, low-rate, ZOX battery. At present, they are in the initial stages of assembly and testing of a preproduction unit with about 6 months to a year before qualification testing.

5.1.2.2.3 Radioisotope Thermoelectric Generator. The radioisotope thermoelectric generator (RTG) produces 1300 w of thermal energy and 50 w of electrical energy at 14 v DC. The RTG works with a power conditioning package (PCP) that is used to boost and regulate the RTG voltage to 29 v \pm 1% so that it will be compatible with spacecraft equipment

The RTG consists of a fuel component (radioisotope heat source) and a thermoelectric generator. The fuel used is Pu-238. Initially, enough heat is produced to generate 66 w of electrical energy. At the end of 1 yr, the amount of heat produced generates 56 w. The SNAP 27 design characteristics are shown in Table 5.1-3.

Full load efficiency of the PCP is 90%. Output from the PCP is 59 w at 29 v \pm 1% at initial conditions and 50 w at 29 v \pm 1% after 1 yr. It may be necessary to modify the PCP regulating point from 29 to 32 v so that the RTG may be paralleled with the Taxi silver-zinc batteries and properly share its load requirements. Performance curves for the RTG are shown in Fig. 5.1-6.

5.1.3 Recommended Configuration

The recommended EPS configuration (Fig. 5.1-7) consists of three modified descent batteries, two LEM ascent batteries, provisions for interconnecting a RTG power source to support the 14-day quiescent period, and the controls and modifications required to integrate the difference in logic and operational requirements between the Taxi and LEM. The two LEM 350-VA inverters and the present LEM Electrical Control Assemblies are retained with no change.

5.1.3.1 System Description

The primary power for the Taxi is DC, except for the prelaunch phase when both the AC and DC power requirements are provided by the GSE power source.

The recommended configuration uses batteries for all manned phases of the mission, CSM-supplied power for the translunar phase, and a RTG and batteries for the quiescent phase. The AC power requirements are supplied by an inverter for all phases except for that portion of the prelaunch phase supplied by GSE AC power.

Three descent stage batteries provide 36 kw-hr of stored energy during mission phases up to lunar prelaunch. During the lunar quiescent phase, these batteries provide the power in excess of the RTG capability. Two ascent stage batteries provide 18 kw-hr of stored energy for the lunar launch, beginning with the pre-launch preparation through docking and crew transfer. The two LEM 350-VA inverters, one on each DC bus, can individually supply the complete AC power requirements. The second inverter is a back-up unit, and is only used when the first inverter fails.

The RTG provides quiescent power, supplemented by the three descent stage batteries, as described above. It will be removed from the Shelter and connected into the Taxi electrical distribution section and thermal loop for the cabin night heat requirements.

5.1.3.1.1 Feeder Configuration. Except for the additional feeder interconnection in the descent stage necessitated by the RTG, the feeder configuration is the same as for the LEM.

5.1.3.1.2 Bus Configuration. The bus configuration is the same as used in the LEM. The two DC busses are paralleled through either or both sets of redundant feeders which can be energized from any of the primary DC power sources. The AC bus may be powered from either of two inverters or from GSE AC power when available.

5.1.3.1.3 Protection and Control Equipment. The protection requirements are the same as for the LEM and the same equipment is proposed. Associated with each battery is an Electrical Control Assembly (ECA) which monitors the battery for overcurrent, reverse current, and magnitude of current. A relay contact within the ECA can be opened to disconnect the battery from its feeder. The contact opens automatically in the event of an overcurrent condition; it may be remotely positioned from the control panel in the cabin. An RTG control assembly carried in the Taxi will provide the means for electrically connecting the RTG into the Taxi distribution section.

A relay junction box (RJB) and dead face relay (DFR) provides the means for dead-facing and isolating the power interconnections of the GSE, CSM, descent stage feeders, batteries, and RTG. In addition, the RJB provides relays and control logic for automatic transfer from descent to ascent batteries either on receipt of an abort signal, or on sensing the failure of two or more descent batteries to supply power.

To isolate faults between bus and load, circuit breakers are provided at the bus. The LEM configuration of circuit breakers and power diodes is used for isolating feeder faults from the DC busses.

5.1.3.1.4 Silver-Zinc Batteries. The recommended ascent battery configuration is the same as the LEM. The descent battery configuration recommended is based on using the same battery as used in the Shelter. While the present LEM descent battery could be used for the Taxi, it is preferable to use a modified battery for the following reasons.

- By modifying the battery with extra plate area, two batteries could support a descent mission within voltage regulation. This allows one descent battery to be removed from the LEM complement of four descent batteries and still allow for the completion of the descent mission with a descent battery failure.
- Taxi mission is 13 days longer than the LEM mission, which increases the battery stand life by that length of time. The separator degradation can be minimized by maintaining battery temperature between 40 and 60°F. Even so, the reliability is lowered slightly. Since the Shelter battery has to be designed for a long standlife (90-day mission) and must perform essentially the same descent mission, it would be suitable for the Taxi and would provide increased probability for Taxi mission success.
- A common battery design for Shelter and Taxi would provide interchangeability between the two vehicles.
- Development time for the battery modification is no problem for the time period in which they are required. Development cost for the Taxi battery is not affected since the Shelter battery requires a modification for its long standlife.

The descent batteries are slightly longer and heavier than the LEM batteries, because of the increase in separator thickness and increased plate area required for the higher two-battery profile.

5.1.3.1.5 RTG Power Supply. Provision is made in the Taxi to connect the RTG into the DC distribution section and the cabin thermal loop. A pigtail cable and connector from the Taxi is connected to the RTG once it is mounted to the Taxi. An RTG control assembly (Taxi component) provides the means for connecting and controlling the electrical output of the RTG to the Taxi EPS.

A heat-pipe assembly installed in the Taxi is used to transfer the required amount of radiated waste heat from the RTG to the cabin thermal loop.

5.1.3.2 Performance

The EPS performance will be the same as the LEM with respect to the electrical characteristics of AC and DC voltage and AC frequency. The electric power and total

energy requirements will differ from LEM because of mission changes. To accommodate these changes, the batteries are sized according to the mission power profile and the power available from the RTG.

The steady-state voltage limits for the battery are 28 to 32.5 v DC. The minimum operating voltage for the subsystem DC load equipment are specified lower than 28 v DC to allow for voltage drops in circuit breakers, wire, connectors, contacts, and current sensors.

The steady-state voltage limits for the inverter are 117 \pm 1.17 v. The subsystem AC load equipment voltage operating range will be 115 \pm 2.5 v to allow for miscellaneous voltage drops. The energy requirements and capacities are summarized below:

DC POWER	AVAILABLE ENERGY (kw-hr)	MAX. ENERGY USED* (kw-hr)
3-descent batteries (12 kw-hr, ea)	36	35.6
2-ascent batteries (9 kw-hr, ea)	18	15.7
1-RTG (50-w output)	16.6	16.5
CSM (translunar only)	---	11.0

AC POWER	POWER RATING (VA)	MAX. POWER USED (VA)
2-AC inverters (115 v, 400 cps, ea)	350	145.8

(one inverter used only as backup)

5.1.4 Baseline Configuration

The only significant difference between the baseline and recommended configurations are the descent batteries. The three modified descent batteries used for the baseline configuration were rated at 13 kw-hr, 170 lb, with one redundant battery. Therefore, with the baseline configuration (Fig. 5.1-7), the total mission could be completed with the loss of one battery. The energy requirements are increased from 26 kw-hr.

5.1.5 Alternate Configuration - Zinc-Oxygen Batteries

As a means to reduce weight, zinc-oxygen (ZOX) batteries were considered as an alternate to the silver-zinc descent batteries of the recommended configuration. The ZOX batteries have the capabilities of delivering 50% higher energy per unit weight than the best silver-zinc batteries. By use of this new type of battery, a potential weight savings of 160 lb may be achieved. Although the ZOX batteries are in the early state of development, it appears that the Taxi schedule would be

- - - - -
* based on a 14-day "all-night" mission

compatible with the time required for their development and qualification. Thus, it is felt that their use should be further investigated during the Phase C effort, when a decision could be made on whether to develop them as a significant weight saving alternate.

An oxygen-supply/pressure-regulating system and an electrical control assembly would have to be developed for this configuration. All other basic controls, logic power and energy requirements would remain essentially the same as the recommended configuration. A schematic, including the electrical and reactant control systems, is shown in Fig. 5.1-8.

The ZOX battery requires oxygen as a consumable at the approximate rate of 0.5 lb per kw-hr of electrical output power. Eagle-Picher proposes the use of oxygen at pressure of a 100 to 150 psi, whereas Leeson Moos Labs proposes to operate at atmospheric pressures. For this alternate configuration, it was felt that the higher pressure system might result in a more optimum weight. The oxygen is obtained from the 3000 psi descent GOX tanks; a pressure regulator is required to drop and regulate the pressure within the limit for the batteries. There is no tank penalty associated with this oxygen requirement, since 24 lb of capacity are available in excess of the metabolic oxygen requirement.

Since the electrical output characteristics of the ZOX battery closely parallels that of the present LEM batteries, it was felt that similar control and monitoring requirements would exist with the exception of the battery tap control. Also, control of the input oxygen supply is required. The power consumption for this control assembly was estimated at 7.5 w, 2.5 w higher than the battery ECA. The weight was estimated at 10 lb, the same as battery ECA. Because of the higher estimated power consumption of the ECA, control power energy requirements for the design mission was 0.8 kw-hr per battery higher than that estimated for the recommended batteries.

Besides the oxygen supply and electrical control requirements described above, these batteries will have to be temperature controlled within a range similar to the silver-zinc batteries. To maintain some interchangeability with the descent batteries and to utilize the LEM system for waste heat removal, a cylindrical shape has been assumed for the battery with longitudinal flanges for heat removal and structural attachment to the cold rail. The battery would be located between the cold rails in the same manner as the LEM descent batteries. It was estimated that excess heat generated would be about 20% greater than the silver-zinc batteries, requiring about 10 extra lb of ECS water.

5.1.6 Potential Modification Per Flight

The quiescent energy requirement for the day mission is 20.5 kw-hr. This is 17 kw-hr less than that required for the night mission. Therefore, it is possible to remove one of the three descent batteries. However, this would result in reduced reliability and probability of mission success, since a single battery failure would preclude completion of a descent mission and thus require an abort. Therefore, it is preferable to use three batteries which allows a trade-off of partial day-night missions with increased reliability.

A potential modification for an all-day mission would be the elimination of the use of the RTG and the removal of control and other equipment installed to support the

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RTG use on the Taxi. The day mission, without the use of a RTG, requires 35.5 kw-hr of energy from the descent power supply. Since the recommended configuration descent power supply produces 36 kw-hr of energy, it is capable of supporting an all-day mission without the use of the RTG.

5.1.7 Discussion of Configuration Choices

In considering the different EPS configurations to support the Taxi missions, the following approach was taken:

- Only the descent power supply would be considered for revision, since the ascent mission requirements are assumed to be the same as LEM
- Subsystem design optimization is centered about the quiescent phase, where both electrical and thermal energy requirements have to be satisfied.

Table 5.1-4 is an energy and weight trade-off summary of the candidate configurations evaluated.

5.1.7.1 RTG

The use of an RTG power source is always attractive where it can be continuously loaded near its full load rating for long periods of time. The quiescent phase time line of 330 hours, and the continuous load requirements of over 50 w for the night missions and 43 w for the day mission, give this type of supply a significant weight advantage over the best silver-zinc batteries.

An additional significant weight advantage of the RTG, is the use of a portion of the excess generated heat to help maintain the cabin above 40°F during the lunar night mission. (See Fig. 5.1-9 for the quiescent phase energy requirements.) It is estimated that a total of 148 w of the thermal energy is required to make up the cabin thermal losses. A "heat pipe" (boiler) concept has been investigated which would be designed to convert enough of the RTG excess radiated heat to supply the cabin thermal loop with 110 thermal w. The other 38 w required is obtained from the electrical equipments in the cabin thermal loop. Without the RTG heat, an additional 36 kw-hr of electrical energy would be required which would double the electrical requirements for this mission phase. It has been assumed that the RTG will be installed on the Shelter and will be available for use on the Taxi after it lands on the lunar surface. Thus, only the weight required to connect it to the Taxi thermal and electrical systems are charged against the Taxi. (Refer to Table 5.1-5 for battery and RTG vs all-battery energy and weight trade-offs).

Because of its significant weight advantages, the RTG has been included in the baseline, recommended, and alternate configurations.

5.1.7.2 Zinc-Oxygen Batteries

In comparison to silver-zinc batteries, ZOX batteries begin to show significant weight advantages when energy requirements exceed the range of 7 to 10 kw-hr. From its estimated performance, it appears that ZOX batteries could deliver upwards of 50% more energy per unit weight than the best performing silver-zinc batteries. It was estimated that a ZOX battery configuration would be 160 lb lighter than the recommended configuration (Table 5.1-4). For this reason, the ZOX batteries have been proposed as an alternate configuration for the descent stage batteries.

5.1.7.3 Baseline vs. Recommended Configurations

The main difference between the baseline and recommended configurations is the concept of three 50% descent batteries for the baseline, three 33-1/3% (long-life) descent batteries for the recommended configuration. All three descent batteries are required for an all-night 330-hr quiescent phase, and for this critical design mission they are considered non-redundant.

However, an all-day 330-hr mission can be supported by two descent batteries, and in this case, the batteries can be considered as three 50% batteries, i.e., one battery is redundant for the quiescent phase.

Also shown in Fig. 5.1-10 is: the maximum mix of a night-day mission that can be completed with two batteries -- 70 hr of night and 260 hr of day; and the maximum all-night mission (6 days) that can be completed with two batteries.

Table 5.1-1a

TAXI ELECTRICAL POWER SUMMARY, TRANSLUNAR PHASE (111.6 hr)
(Includes 2.6 hrs for Lunar Insertion & Coast)

Subsystem	Power, watts	Duty Cycle	Avg. Power watts
<u>Communications</u>			
S-Band Steerable Antenna Heater	6.0	Cont.	6.0
<u>G N & C</u>			
Landing Radar Htr.	10.0	Cont.	10.0
Rendez Radar Htr.	25.0	16.5%	4.2
IMU (Standby)	45.5	Cont.	45.5
ASA (Standby)	10.0	Cont.	10.0
Sub-Total			75.7
Distrib. Losses (7.5%)			5.7
Current Status Avg. Pwr.			81.4
Growth Allow (20%)			16.3
Design Avg. Power			97.7
Design Energy (111.6 hr x 97.7w) = 10.9 kw-hr			

Table 5.1-1b

ELECTRICAL POWER SUMMARY - GO/NO DECISION PHASE

It has been assumed that the following power will be required while awaiting a go-no/go decision from the results of the Shelter check-out.

Subsystem		Power, watts	Duty Cycle	Avg. Power, watts
COMM	S-Band Transceiver	36.0	Cont.	36.0
	S-Band Pwr. Ampl.	62.0	Cont.	62.0
	S-Band Steer. Ant. Elect.	1.7	Cont.	1.7
	S-Band Steer. Ant. Elect. (AC)	3.2	Cont.	3.2
	S-Band Steer. Ant. Htr.	6.0	Cont.	6.0
	Signal Processor Assy.	15.5	Cont.	15.5
	VHF	31.0	Cont.	31.0
CREW PROV	EL Lighting (AC)	6.2	Cont.	6.2
	Master Alarm & Comp. Caut/ANN. Lts	1.6	Cont.	1.6
	Flood Light	30.0	50%	15.0
	Exterior Lights (2)*	150.0	Cont.	150.0
DISP	Indicator Flags	9.6	Cont.	9.6
	S.S. Meters	19.2	10%	1.9
EPS	ECA's	15.0	Cont.	15.0
	Spacesuit 16.8V Pwr. Supply	3.9	Cont.	3.9
	Inverter Losses (assume 65% eff.)	5.6	Cont.	5.6
ECS	Cabin Fan (1)	39.0	Cont.	39.0
	Suit Fan	152.2	Cont.	152.2
	Glycol Pump	28.0	Cont.	28.0
	CO ₂ Sensor	1.0	Cont.	1.0
	ECS Relay Box	7.4	10%	0.7
INSTR	PCMTEA	12.9	Cont.	12.9
	Signal Cond. Elect. Assy.	44.4	Cont.	44.4
	Caution & Warn. Assy.	22.0	Cont.	22.0
	Sensors	15.8	Cont.	15.8
	Voice Storage Rec. (AC)	2.5	24%	0.6
GN&C	Rend. Radar Htr.	25.0	Cont.	25.0
	IMU (Standby)	45.5	Cont.	45.5
	LGC (Standby)	10.0	Cont.	10.0
	ASA	73.0	Cont.	73.0
	AOT Htr.	5.0	Cont.	5.0
	Rend. Radar Elect.	162.0	2%	3.2
	Rend. Radar Elect. (AC)	14.0	2%	0.3
RCS	Cluster Heaters	80.0 (Avg.)	Cont.	80.0
*Potential alternate addition to recommended configuration.		Sub-Total		922.8
		Distrib Losses (7.5%)		69.2
		Current Status Avg. Pwr.		922.0
		Growth Allow. (20%)		198.4
		Design Avg. Pwr.		1190.4
Design Energy = (2.7 hr. x 1190.2w) = 3.21 kw-hr				

Table 5.1-1c

TAXI ELECTRICAL POWER SUMMARY, SECURE FOR QUIESCENT PHASE (0.2 hr)

It has been assumed that the following equipments will be on while the Taxi is being secured for quiescent:

Subsystem	Power, watts	Duty Cycle	Avg. Power, watts
<u>Communications</u>			
S-Band Steerable Ant. Htr.	6.0	Cont.	6.0
<u>Crew Provisions</u>			
Exterior Lights (2)**	150.0	Cont.	150.0
<u>EPS</u>			
ECAs	15.0	Cont.	15.0
<u>ECS</u>			
Glycol Pump	28.0	Cont.	28.0
Cabin Fan *	39.0	Cont.	39.0
Suit Fan *	152.2	Cont.	152.2
<u>G N & C</u>			
IMU (Standby)	45.5	Cont.	45.5
LGC (Standby)*	10.0	Cont.	10.0
ASA (Standby)	10.0	Cont.	10.0
Taxi Sequencer Assy	0.5	Cont.	0.5
Rend. Radar Htr.	25.0	Cont.	25.0
Sub-Total			481.2
Dist. Losses (7.5%)			36.1
Current Status Avg. Power			517.3
Growth Allow. (20%)			103.5
Design Avg. Power			620.8
Design-Energy = (0.2 hr x 620.8w) = 0.12 kw-hr			
* Shut-down at the end of 12-min. period.			
** Potential Alternate Addition			

Table 5.1-1d

TAXI ELECTRICAL POWER DATA SHEET, QUIESCENT PHASE (330 hr)

Subsystem	NIGHT MISSION				DAY MISSION			
	WITH RTGs		WITHOUT RTGs		WITH RTGs		WITHOUT RTGs	
	Power, watts	Duty Cycle	Avg Pwr, watts	Duty Cycle	Power, watts	Duty Cycle	Avg Pwr, watts	Duty Cycle
Communications								
S-Band Tranceiver	36.0	5.83%	2.10	5.83%	36.00	5.83%	2.10	5.83%
S-Band Steer. Ant. Htr.	6.0	Cont.	6.00	Cont.	6.00	Cont.	6.00	Cont.
PMP P/O Signal Proc. Assy	4.3	5.83%	0.25	5.83%	4.3	5.83%	0.25	5.83%
S-Band Power Ampl.	62.0	5.83%	3.61	5.83%	62.0	5.83%	3.61	5.83%
<u>EGS</u>								
Glycol Pump	28.0	25%	7.00	25%	28.0	25%	7.00	25%
Water Tank Htr.	-	-	-	-	-	-	-	-
<u>Crew Provisions</u>								
Exterior Lights (2)	150.0	1.21%	1.82	1.21%	150.0	1.21%	1.82	1.21%
<u>Instrumentation</u>								
FCMTEA	12.9	1.67%	0.22	1.67%	12.9	1.67%	0.22	1.67%
Signal Cond. Units	21.5	5.83%	1.25	5.83%	21.5	5.83%	1.25	5.83%
Sensors	3.9	5.83%	0.23	5.83%	3.9	5.83%	0.23	5.83%
<u>CN & C</u>								
T.M.U. (Standby)	13.0	Cont.	13.00	Cont.	13.0	Cont.	13.00	Cont.
ASA (Standby)	7.0	Cont.	7.00	Cont.	7.0	Cont.	7.00	Cont.
Taxi Sequencer Ass'y.	0.5	Cont.	0.50	Cont.	0.5	Cont.	0.50	Cont.
Rend. Radar Ant. Htr.	25.0	Cont.	25.00	Cont.	25.0	Cont.	25.00	Cont.
<u>EFES</u>								
ECAs - (Desc. Batt.)	15.0	Cont.	15.00	Cont.	*15.00	Cont.	15.00	Cont.
ECAs - (RTG)	5.0	Cont.	5.00	Cont.	-	-	5.00	-
Sub-Total			87.98				48.16	
Dust. Losses (Assumed 7.5%)			6.60				3.61	
Current Status Avg. Power			94.58				51.77	
Growth Allowance (Assumed 20%)			18.92				10.35	
Design Avg Power			113.50				62.12	
Design Energy = (330 hr x Avg. Pwr.) kw-hr		37.5	71.3				20.5	20.5

NOTE: 5.83% Duty-Cycle: 5-min Warmup & 2-min Status Transmission every 2 hr; 1.67% Duty-Cycle: 2-min Status Transmission every 2 hr.

*Two ZnO₂ ECAs

**Equipment counted in cabin balance: Total heat required for cabin is 148w for night mission. Equip in cabin heat balance contributes 37.8w without RTG heat, 110.2w are required from electrical cabin heaters.

***110.2w - Electrical heaters required to maintain cabin temp. (See **). This power may be considered as growth allowance for equipment in cabin heat balance (**), and has been based on the use of RCS cluster covers.

****Potential alternate addition to recommended configuration.



Table 5.1-1e

TAXI ELECTRICAL POWER SUMMARY, PRELAUNCH ACTIVATION PHASE (FIRST 9 MIN)

It is assumed that the following power will be required when reactivating the Taxi from the quiescent phase:

Subsystem	Power, watts	Duty Cycle	Avg. Power, watts
<u>Communications</u>			
S-Band Steer. Ant. Htr.	6.0	Cont.	6.0
<u>Crew Provisions</u>			
Floodlighting	30.0	Cont.	30.0
<u>EPS - ECA's</u>	15.0	Cont.	15.0
<u>ECS</u>			
Cabin Fan	78.0	Cont.	78.0
Suit Fan	152.2	Cont.	152.2
Glycol Pump	28.0	Cont.	28.0
CO ₂ -Sensor	1.0	Cont.	1.0
Relay Box	7.4	10%	0.7
<u>Instrumentation</u>			
PCMTEA	12.9	Cont.	12.9
Caution & Warn. Assy	22.0	Cont.	22.0
Signal Cond. Elect. Assy	44.4	Cont.	44.4
Sensors	15.8	Cont.	15.8
<u>G N & C</u>			
Rend. Radar Htr.	25.0	Cont.	25.0
IMU (Standby)	45.5	Cont.	45.5
ASA (Standby)	10.0	Cont.	10.0
Taxi Sequencer Assy	0.5	Cont.	0.5
<u>RCS Cluster Htrs.</u>	1000.0	Cont.	1000.0
	Sub-Total		1487.0
	Dist. Losses (7.5%)		<u>111.5</u>
	Current Status Avg. Power		1598.5
	Growth Allow. (20%)		<u>319.7</u>
	Design Average Power		1918.2
Design Energy = (0.15 hr x 1918.2 w) = 0.29 kw-hr			

Table 5.1-1f

TAXI ELECTRICAL POWER - PRE-LAUNCH ACTIVATION PHASE (REMAINING 49 MIN.)

It is assumed that the following power will be required after the first 9 min. of Taxi re-activation

Subsystem	Power, watts	Duty Cycle	Avg. Power, watts
<u>Communications</u>			
S-Band Transceiver	36.0	Cont.	36.0
S-Band Pwr. Ampl.	62.0	Cont.	62.0
S-Band Steer. Ant. Htr. & Elect.	10.9	Cont.	10.9
Signal Processor Assy.	15.5	Cont.	15.5
<u>Crew Provisions</u>			
Floodlighting	30.0	Cont.	30.0
EL Lighting (A.C.)	6.2	Cont.	6.2
Master Alarm Comp. Caut./Ann. Lts.	1.5	Cont.	1.5
<u>EPS</u>			
ECA's	15.0	Cont.	15.0
Inverter Losses (assume 65% eff.)	5.1	Cont.	5.1
ECS (same as "First 9 min")	259.9	Cont.	259.9
<u>Instrumentation</u> - (same as "First 9 min")			
	95.1	Cont.	95.1
<u>G N & C</u>			
IMU (Standby)	45.5	Cont.	45.5
LGC (Standby)	10.0	Cont.	10.0
ASA (Standby)	10.0	Cont.	10.0
Taxi Sequencer Assy	0.5	Cont.	0.5
Rend. Radar Htr.	50.0/25.0	20%/80%	30.0
Rend. Radar Elect.	162.0	10%	16.2
Rend. Radar Elect. (A.C.)	14.0	10%	1.4
RCS Cluster Htrs.	1000.0	Cont.	1000.0
Sub-Total			1650.8
Dist. Losses (7.5%)			<u>123.8</u>
Current Status Avg. Pwr.			1774.6
Growth Allow. (20%)			<u>354.9</u>
Design Avg. Power			2129.5

$$\text{Design Energy} = (0.82 \text{ hr} \times 2129.5) = 1.75 \text{ kw-hr}$$

Table 5.1-1g

TAXI-ENERGY SUMMARY

<u>MISSION PHASE</u>	<u>PHASE TIME, hr</u>	<u>ENERGY, kw-hr</u>	<u>POWER SOURCE</u>
Countdown, Launch Through Transposition	6.80	0.80	Descent Batt.
Translunar	111.60	10.97	CSM (FCAS)
Preseparation c/o	1.25	2.00	Descent Batt.
Preseparation c/o	.25	0.40	Ascent Batt.
Descent	1.70	3.39	Descent Batt.
Post Landing c/o	1.00	1.34	Descent Batt.
Post Landing c/o	.25	0.34	Ascent Batt.
Go-No/Go Decision & Secure for Quiescent	2.90	3.33	Descent Batt.
Quiescent (Night Mission)	330.00	16.5	RTG
		21.0	Descent Batt.
Quiescent (Day Mission)	330.00	14.0	RTG
		6.50	Descent Batt.
Prelaunch Activation	0.97	2.04	Descent Batt.
Prelaunch Preparation	1.17	1.73	Descent Batt.
Prelaunch Preparation	0.50	0.74	Ascent Batt.
Powered ascent, orbit-contingency, coast, rendezvous dock & crew transfer	11.73	14.2	Ascent Batt.

	Power Source	ENERGY, kw-hr	
		Night Mission	Day Mission
Summary	CSM	11.0	11.0
	Descent Batt.	35.6	21.1
	Ascent Batt.	15.7	15.7
	RTG	16.5	14.0

Table 5.1-2

BATTERY CHARACTERISTICS

Characteristics	Ascent (LEM/Taxi)	Descent (LEM)	Mod Desc (Estim.) Taxi/Shelter Recomd Config
Designation	Asc-1C	Desc II-B	Desc. (Mod)
No. Cells	20	20	20
Weight, lb	130.5	139	147
Volume, cu in.	1545	1500	1630
Dimensions in. (h x w x l)	8.0 x 5.125 x 37.0	10.0 x 8.813 x 17.5	10.0 x 8.813 x 19.0
Capacity amp-hr	340/300*	400	400
Energy, kw-hr	10.2/9.0*	12.0	12.0
watt-hr/lb	78/69*	91	82
watt-hr/cu in.	6.6/5.8*	8.2	7.35
Mission watt-hr/lb	62 ^{LEM} 60	82	81
watt-hr/cu in.	5.2 ^{LEM} 5.0 ^{Taxi}	7.5	7.3
Wt of Terminals & Other Hdwe, lb	Zero	0.4	0.4
Canister Weight, lb	10.5	10.0	10.2
Canister Material	Mg	Mg	Mg
Reliability Estimate	0.995 (LEM Mission)	0.995 (LEM Mission)	0.998 (Taxi Mission)
Cycling Capability	3	3 (Test only)	3 (Test only)
Cell Weight, lb	6.0	6.28	6.63
Silver Weight/Cell, gm	952	956	975
Zinc Weight/Cell, gm	746	850	865
Cell Dimensions, in. (w x th x h)			
with Terminal	4.9 x 1.82 x 7.5	4.3 x 1.68 x 9.25	4.3 x 1.76 x 9.25
without Terminal	4.9 x 1.82 x 7.0	4.3 x 1.68 x 8.75	4.3 x 1.76 x 8.75
No. Cells, Positive/Negative	12/13	9/10	11/12
Total Effective Cell Area, sq in.	620	494	604
Separator System			
Electrolyte Qty, cc, wt, gm, Conc, %	320/432/35	300/420/40	330/460/40
Voltage at 10 amp, Initial/Plateau/Final	31.4/30.9/29.5	36.9/30.5/29.2	36.9/30.5/29.2
Voltage at 40 amp, Initial/Plateau/Final	30.2/30.1/27.4	36.3/29.4/27.1	36.3/29.4/27.1
Min. Voltage (40 amp) at 30°/80°/160°F	-	26.2/27.0/29.2	26.2/27.0/29.2
Max. Voltage (40 amp) at 30°/80°/160°F	-	32.2/33.5/35.8	32.2/33.5/35.8
Capacity after 30 days charged			
Stand at 32°/80°/100°F	1.1C/1.1C/1.025C	1.0C/1.0C/0.9C	1.0C 1.0C 0.9C
Heat Generated Btu	7,200/3,800**	16,600/9,800**	
Specific Heat	0.19	0.19	0.19
Short Circuit Current into 0.01 Ω Load, amp	750	600	
Mounting Structure Weight, lb	5	5	5
ECA Weight, lb	10	10	10

* After Predischarge

** Normal LEM Mission/Abort (1 Battery)

*** 4 Battery/3 Battery LEM Mission

Table 5.1-3
SNAP 27 (RTG) CHARACTERISTICS

Fuel	Pu 233
Mission Life, yr	1
Reliability	0.9
Net Power Output	50 watts 29 DVC \pm 1%
RTG Output	56 watts minimum 14V
Thermal Power Input, watts	1400
Overall Efficiency, %	3.6
Thermoelectric Efficiency, %	5.5
Converter/Regulator Efficiency, %	90
Radiator Efficiency, %	-
RTG Configuration	Finned Cylinder
Overall Weight, lb	50 (nominal)
Converter/Regulator Weight, lb	4
RTG Weight, lb	30.4
RTG Dimensions, in.	18.1 long x 16.5 dia.
Thermoelectric Materials	Pb Te (N) PB Sn Te (p)
No. Couples	392
Hot Junction Temp.	1100 $^{\circ}$ F
Cold Junction Temp.	525 $^{\circ}$ F
Radiator	Beryllium Fins

Power Source	Config No.	Desc Batt Energy Reqmt, kw-hr	Main Batteries			
			No.	Type	Rat'g kw-hr	Wt, lb/batt
One RTG & AgZn Batts	A-1	35.6 ¹⁰	3	Mod Desc	12.0	147
	A-2	37.3 ¹⁰	4	AgZn	9.4	121
	A-3	26.0 ⁹	3		13.0	170
One RTG & ZnO ₂ Batts	B-1	38.1 ¹⁰	3	ZnO ₂	12.7	87
	B-2	40.6	4		10.2	71
Two RTGs & AgZn Batts	C-1	22.5	3	Mod Desc AgZn	7.5	104
	C-2	21.0	4		5.25	78
Two RTGs & ZnO ₂ Batts	D-1	22.5	3	ZnO ₂	7.5	56
	D-2	24.1	4		6.0	47 55
AgZn No RTG	E-1	98.5	6	Mod Desc AgZn	16.4	183

5.1.4 ①

Table 5.1-4

(2)

AND WEIGHT TRADE-OFF SUMMARY

Att	Acc Wt, lb	Total Batt Wt, lb	RTG			ECA		Total Wt, lb	Major Advantage	Disadv	Rema No./Cap
			No.	Wt, lb	Energy, kw-hr	No.	Wt, lb				
		441	1	13	16.5	4	34	488	Note 3	Weight	3/33 Reco
		484				5	44	541	Note 4		4/25
		510				4	34	557	Note 11		3/50 Base
	9	261 ^⑧				4	34	317	Note 6 & 12	Sched & Cost to Devel & Reliab of ZnO _z Batts	3/33 Batt Alte
	10.5	284 ^⑧				5	44	351.5	Note 13		4/25 Batt
		312	2	76	31.3	5	38	426	Note 5	RTG Cost & Taxi Mod	3/33
		312			32.8	6	48	436	Note 14		4/25
	9	168 ^⑧			33.0	5	38	291	Notes 5 & 6	Same +Sched & Costs to Devel & Reliab.	3/33
	10.5	188 ^⑧			33.0	6	48	323	Notes 6 & 15		4/25
		1100				6	60	1160	Note 7	Weight	

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NOTES:

1. RTG Supplies All Loads To Full Load Rating, The Batt Top Off RTG.
2. First RTG On Shelter; Taxi Penalty Is For Mount. & Inst.
3. Complete Day Mission Or 6.3 Days Of Night Mission With One Batt Failure At Begin Of Mission.
4. Complete Day Mission Or 9 Days Of Night Mission With One Batt Failure At Begin Of Mission.
5. Complete Day Mission With One Batt Fail At Begin Of Mission.
6. Light Weight.
7. No RTG Or Prob In Moving To Taxi.
8. Zn-O₂ Batt And O₂ React Wts Without Fluid Syst Hardware (Acc. Wt).
9. Baseline Was Based On The Prelim Energy Reqmts Of 26 Kw-H; Latest Reqmts Are 35.6 Kw-H.
10. B-1 And A-1 Differ By 2.5 Kw-Hr Because Of Extra Control Power Reqmts For 2 ZnO₂ Batt.
11. Complete Day Mission Or 7.6 Days Of Night Mission With One Batt Failure At Begin Of Mission.
12. Complete Day Mission Or 7.2 Days Of Night Mission With One Batt Failure At Begin Of Mission.
13. Complete Day Mission Or 10.6 Days Of Night Mission With One Batt Failure At Begin Of Mission.
14. Complete Day Mission With One Batt Failure At Begin Of Mission.
15. Complete Day Mission Or 2.25 Days Of Night Mission With One Batt Failure At Begin Of Mission.

ECA-TYPE	Assumed Reqmts.	
	wt, lb	watts
AgZn Battery	10	5
ZnO ₂ Battery	10	7.5
RTG	4	5

5. 1-4 (3)

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Table 5.1-5

ALL BATTERY vs BATTERY/RTG-NIGHT/DAY TRADE-OFF

A. ENERGY, kw-hr

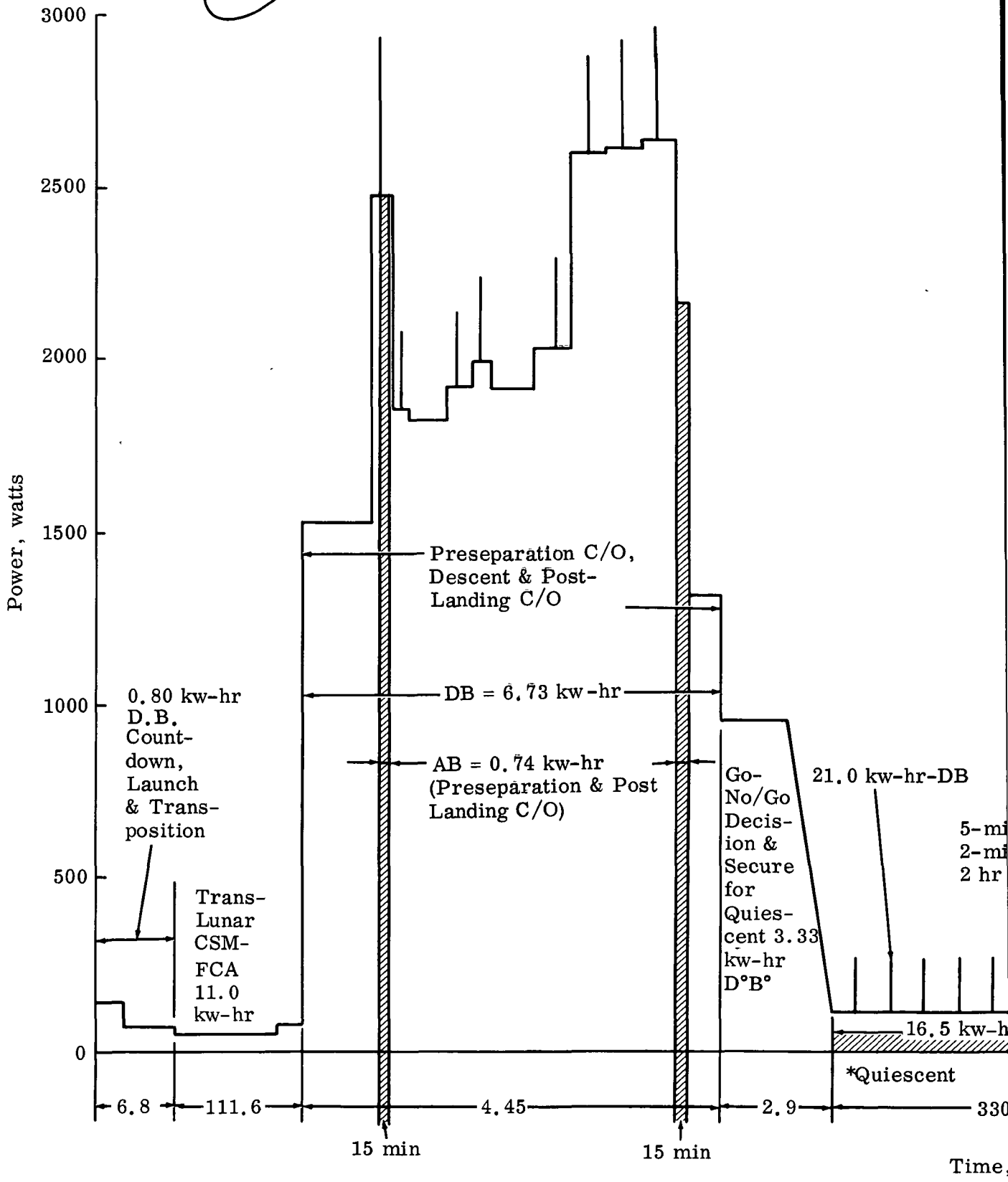
NIGHT MISSION	All Battery		Battery & RTG			
	Avg. Pwr, watts	Energy, Kw-hr	RTG		Battery	
			Avg Pwr, watts	Energy, Kw-hr	Avg Pwr, watts	Energy, Kw-hr
Quiesc Phase (330 hr)	68.14	22.3	50	16.5	63.5	21.0
Thermal (Elect)	148.0	49.0	(110)	36.3	-	-
Subtotal	216.14	71.3	160	52.8	63.5	21.0
Energy, Other Phases		14.6				14.6
Total (Note 1)		85.9				88.4
DAY MISSION						
Quiesc Phase (330 hr)	62.12	20.5	43.2	14.0	18.9	6.5
Thermal/Elect	-	-	-	-	-	-
Subtotal	62.12	20.5	43.2	14.0	18.9	6.5
Energy, Other Phases		14.6				14.6
Total		35.1				35.1

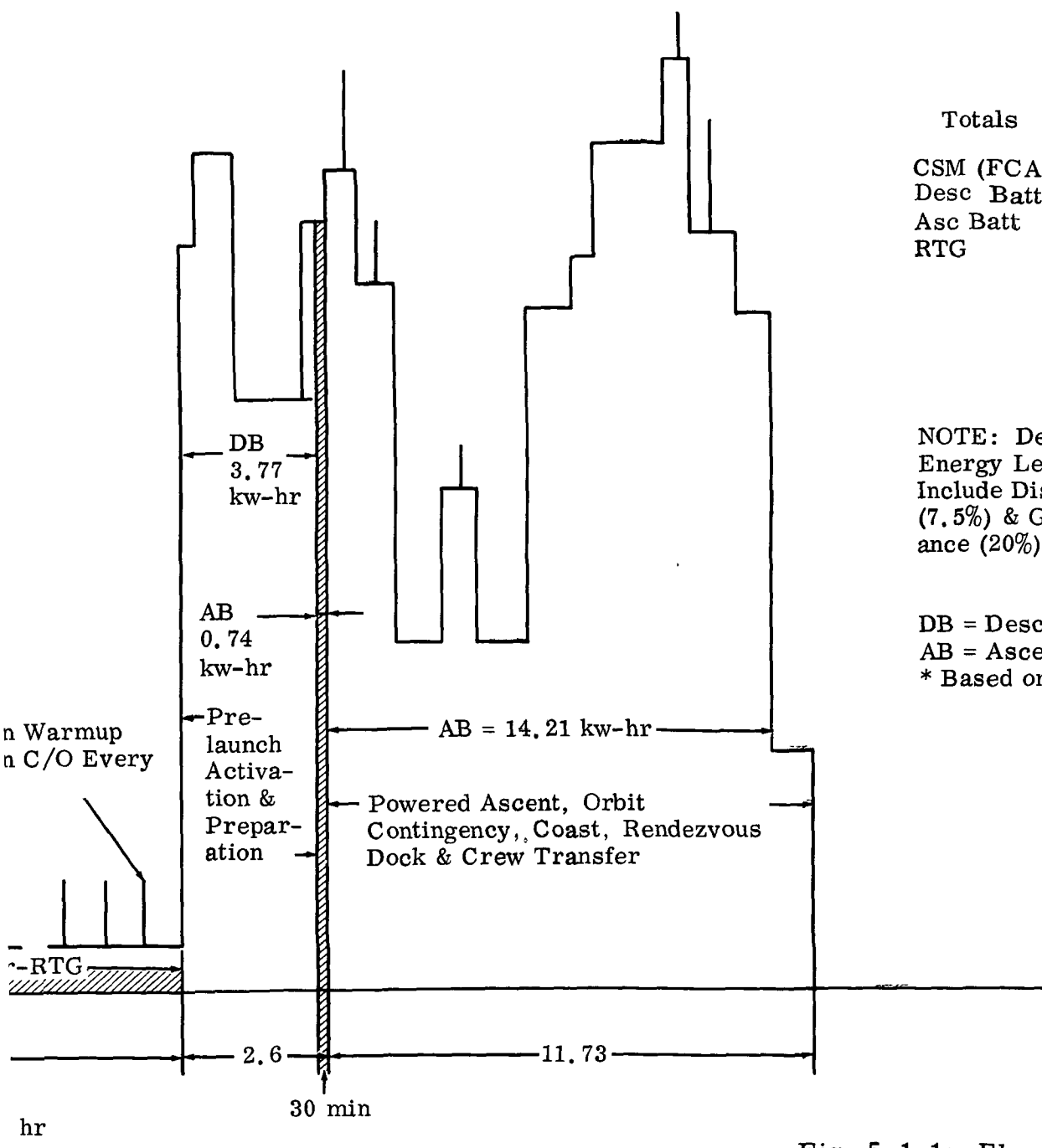
B. WEIGHT, lb

	Night Mission		Day Mission	
	All-Battery	Battery & RTG	All Battery	Battery & RTG
Batteries	(6) 954	441	441	270
Battery ECAs	(6) 60	30	30	20
RTG Instl	-	13	-	13
RTG-ECA	-	4	-	4
Total Wt	1014	498	471	307

Notes: 1. Difference of 2.5 kw-hr lies in growth allowance for the 37.8-watt load in cabin thermal balance. The RTG configuration contributes 20% growth whereas the all-battery configuration already includes its growth in the electrical heater.

23





Totals	Energy, kw-hr
CSM (FCA)	11.0
Desc Batt	35.6
Asc Batt	15.7
RTG	16.5

NOTE: Design Power & Energy Levels Shown Include Dist. Losses (7.5%) & Growth Allowance (20%).

DB = Descent Batteries
 AB = Ascent Batteries
 * Based on Night Mission

Fig. 5.1-1a Electric Power Profile Complete Mission

- NOTES:
- Typical Duty Cycle Continuous For 330 hr
 - Design Power Levels Shown Include Distribution Losses (7.5%) & Growth Allowance (20%)

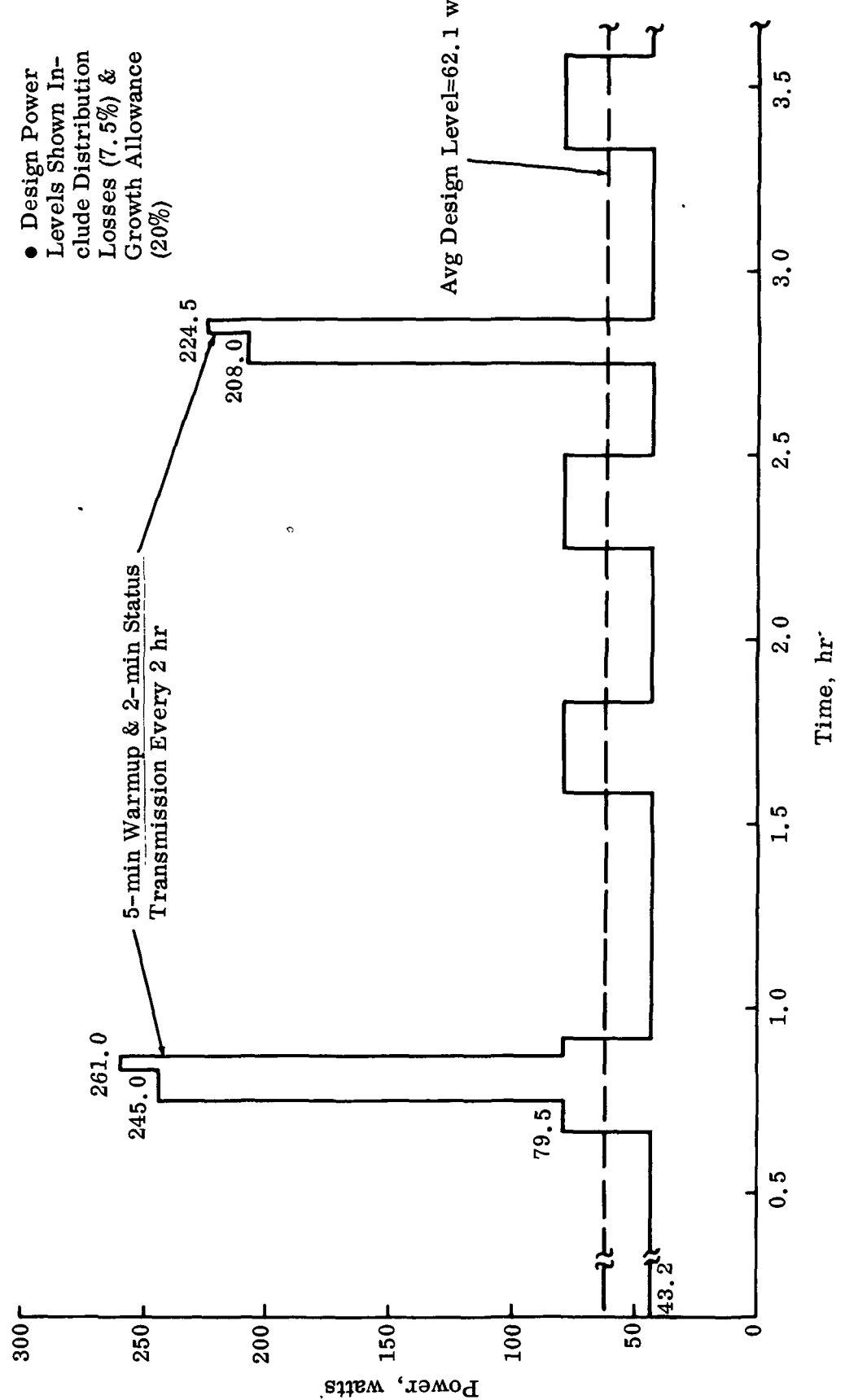


Fig. 5. 1-1b Electric Power Profile-Quiescent Storage (Day)



- NOTES:
- Typical Duty Cycle Continuous For 330 Hours
 - Design Power Levels Shown Include Distrib. Losses (7.5%) & Growth Allowance (20%)
 - *Potential Alternate Addition to Recommended Configuration

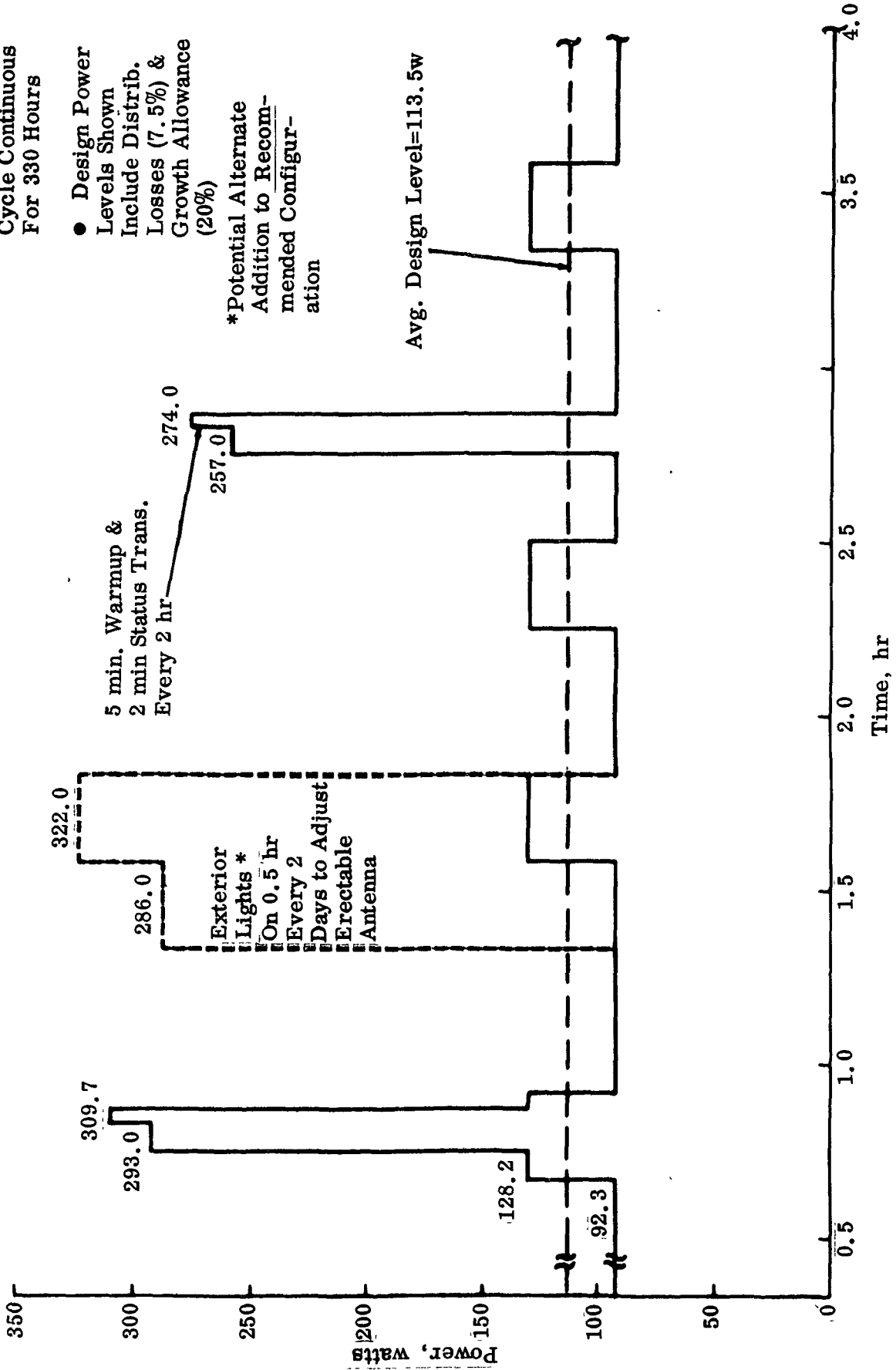


Fig. 5.1-1c Electric Power Profile-Quiescent Storage (Night)

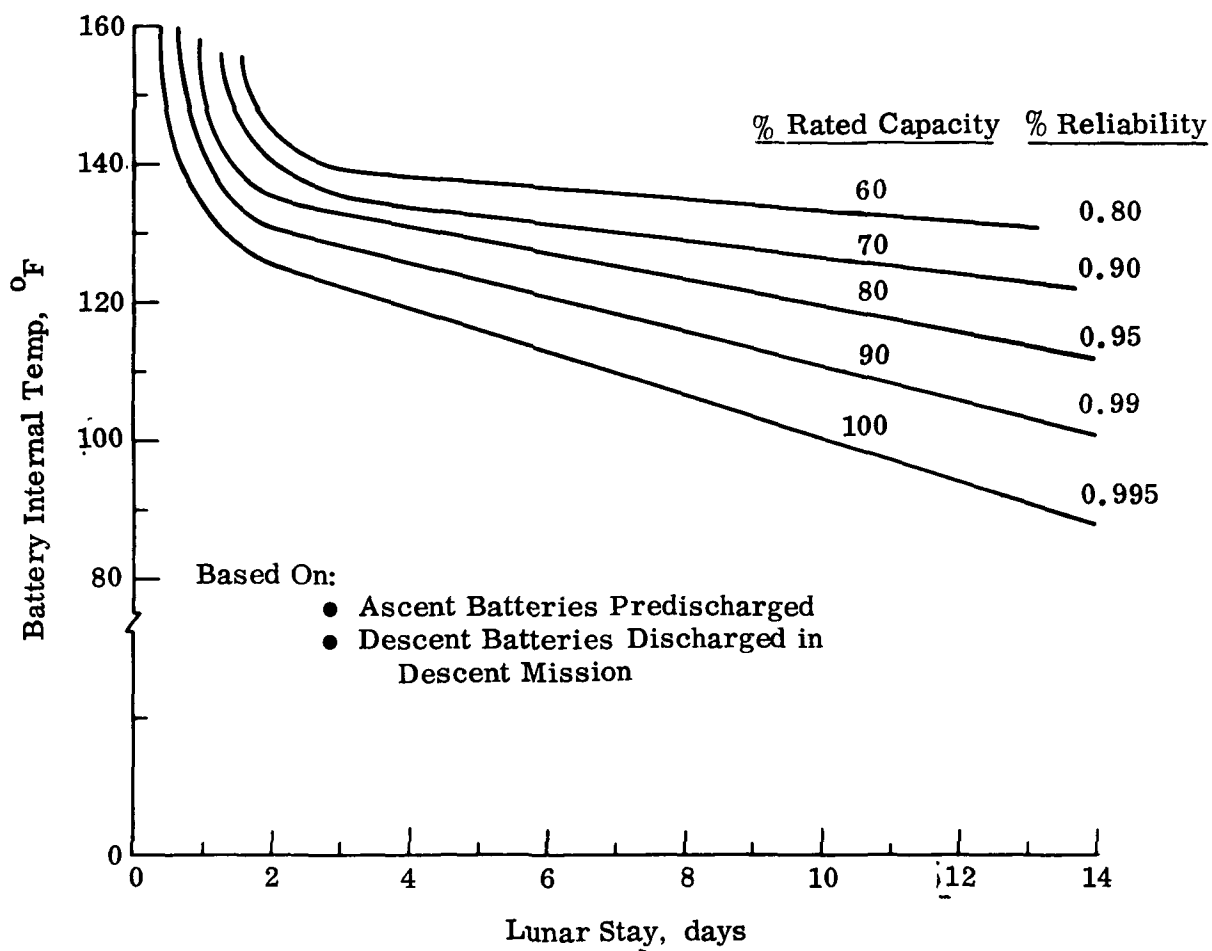


Fig. 5.1-2 Estimate Ascent/Descent Battery Capacity Retention

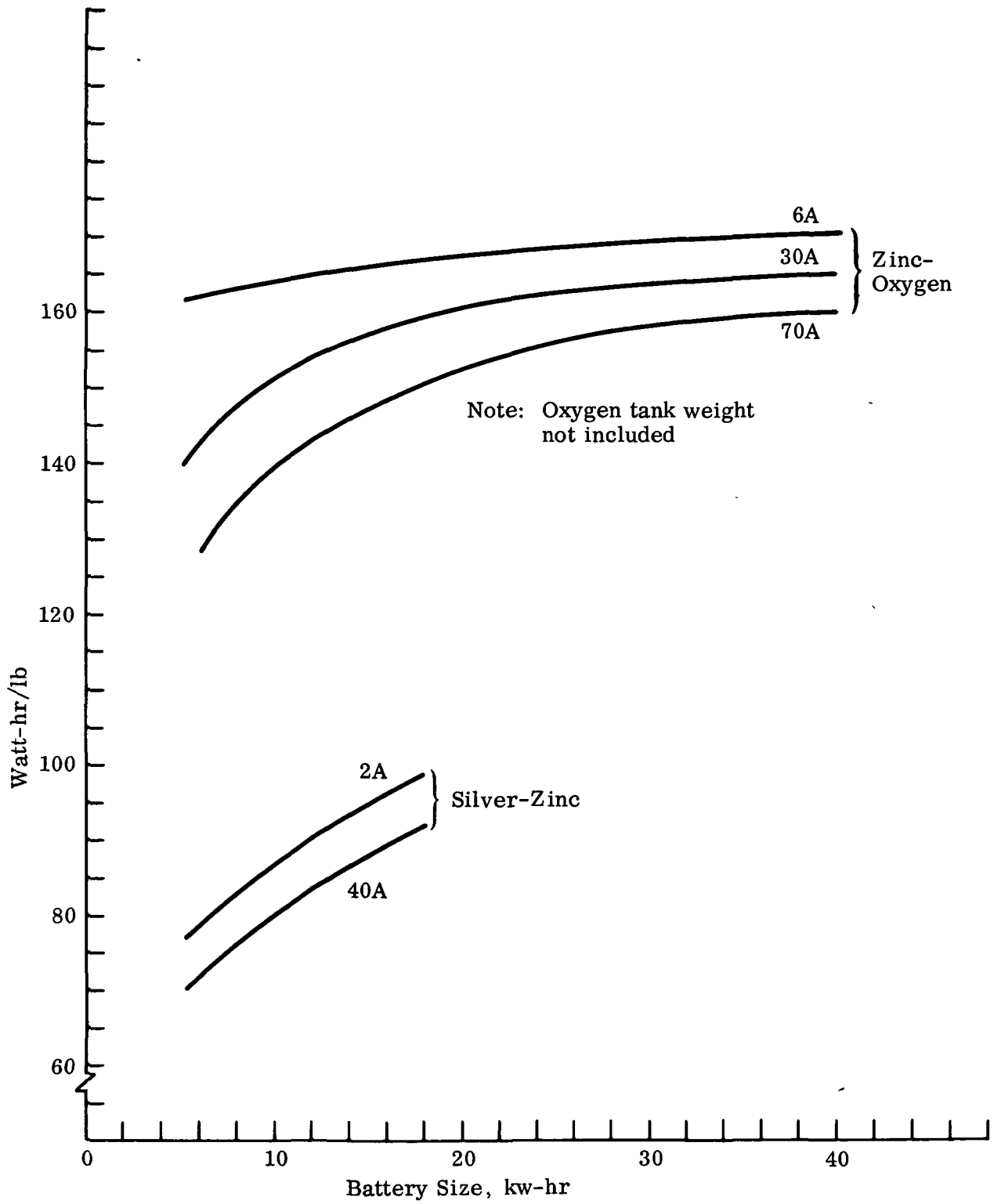


Fig. 5.1-3 Estimated Merit Factors For Silver Zinc & Zinc-Oxygen Batteries

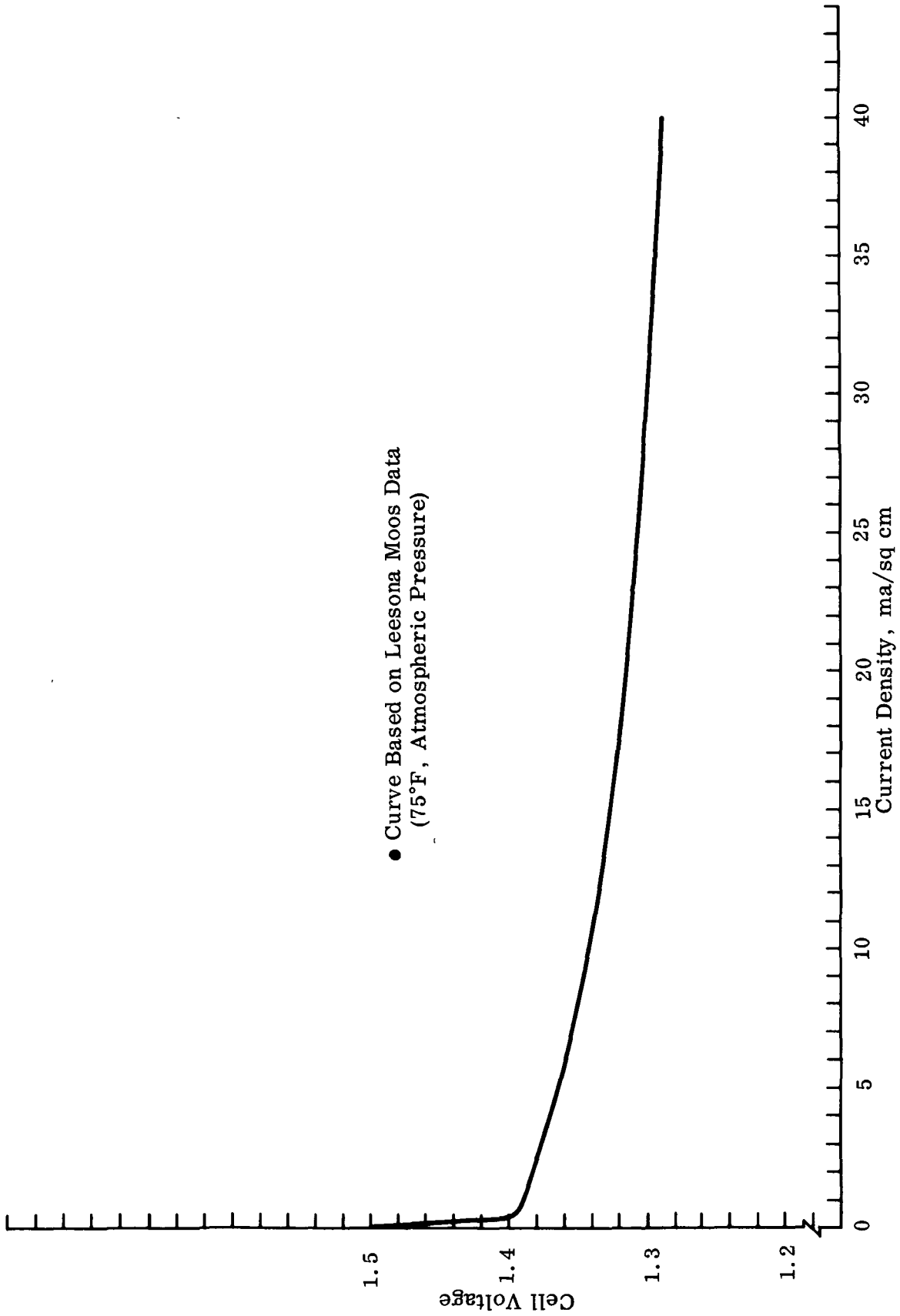


Fig. 5.1-4 Zox Battery-Cell Volts vs Current Density

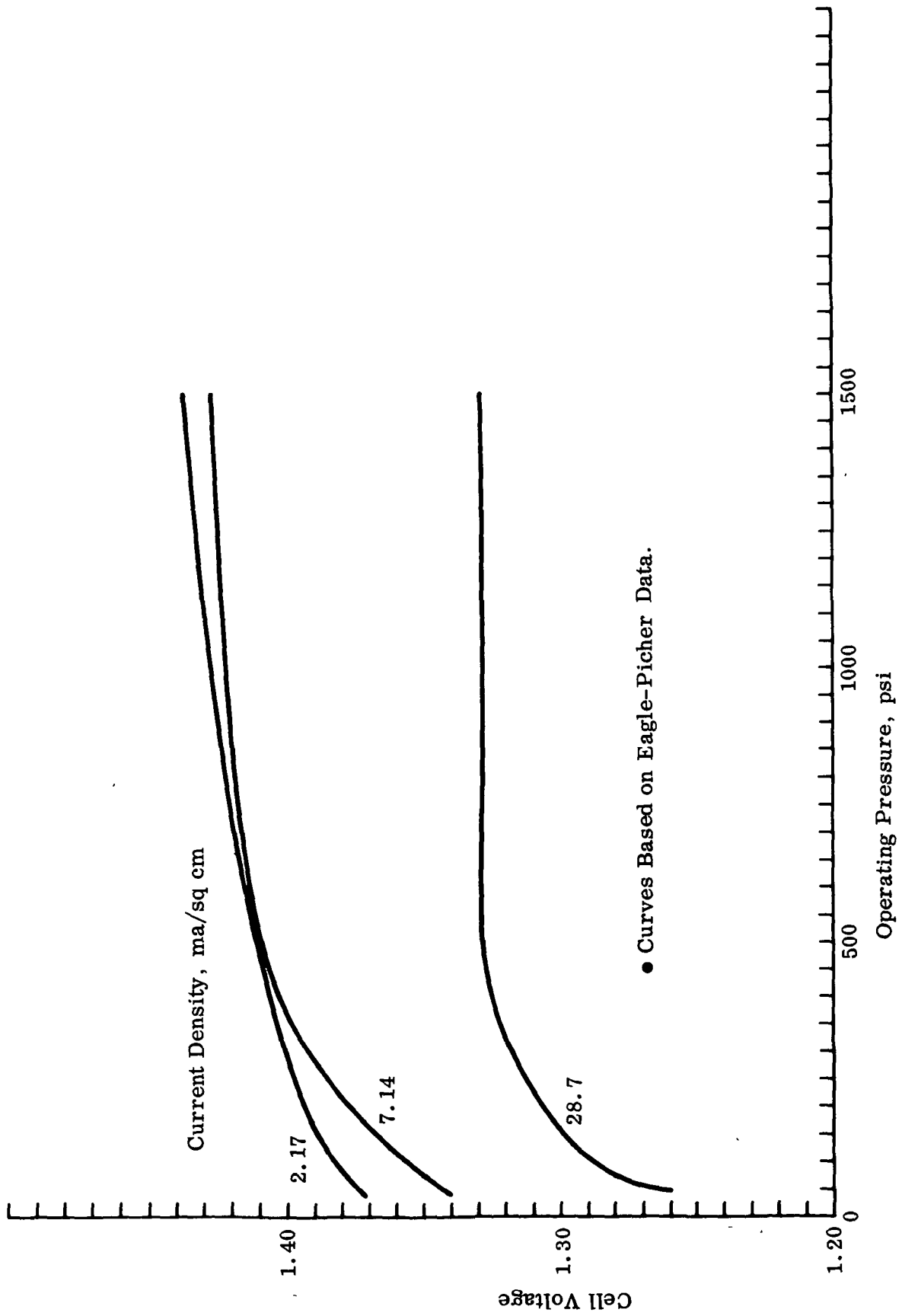


Fig. 5.1-5 Zox Battery-Cell Volts vs Pressure

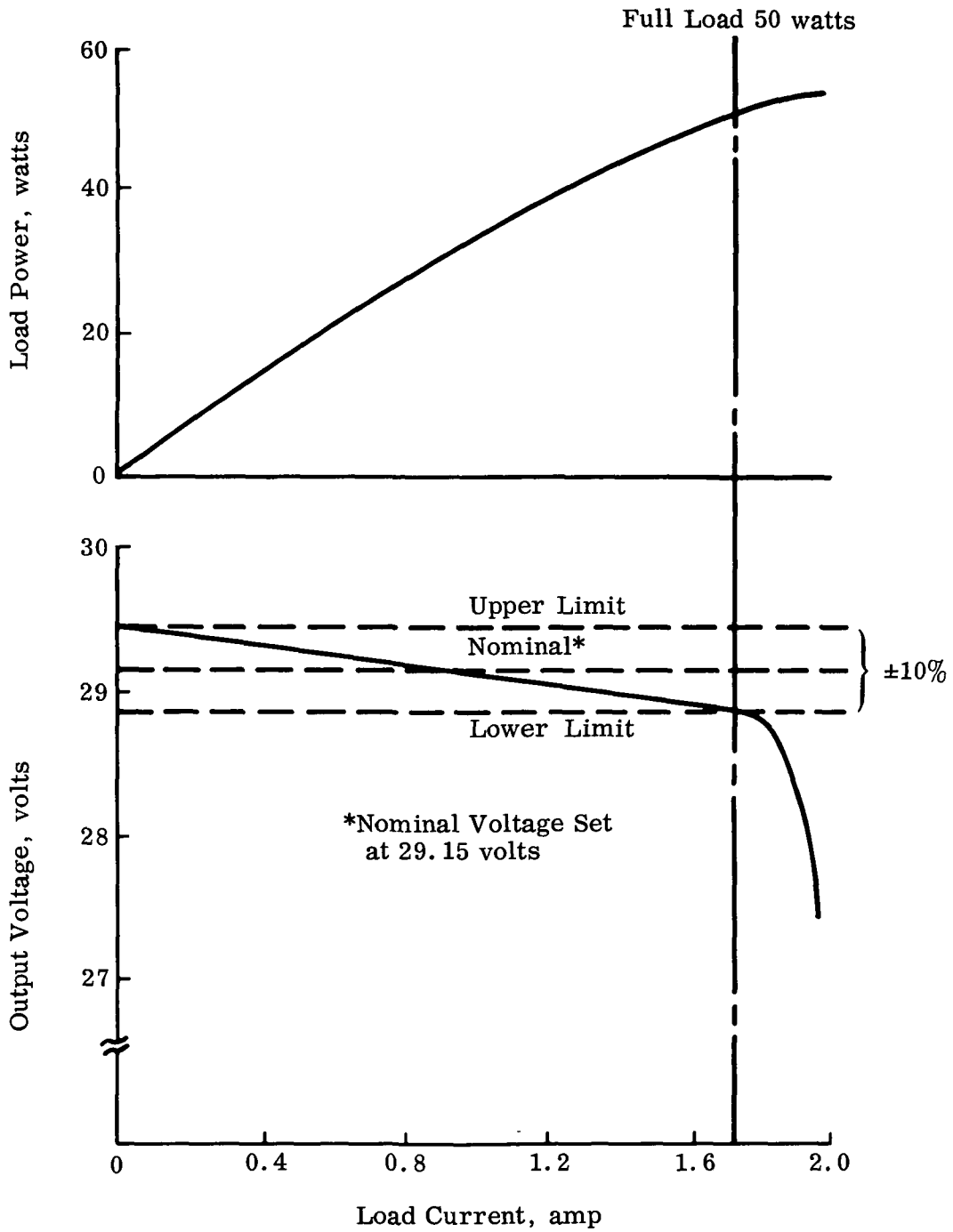


Fig. 5.1-6 SNAP 27 (RTG) Performance

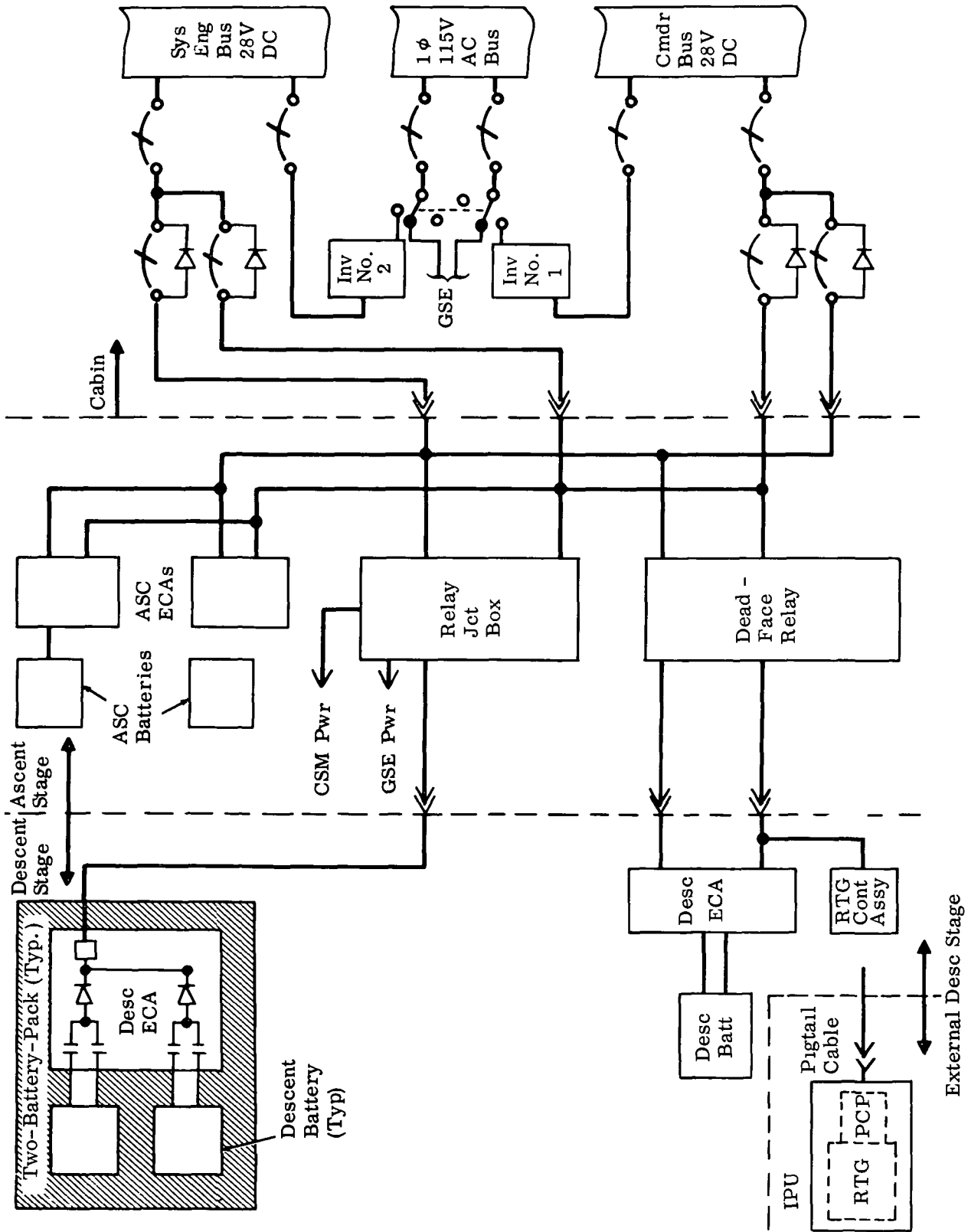


Fig. 5. 1-7 Electrical Distribution Section-Recommended & Baseline Configurations

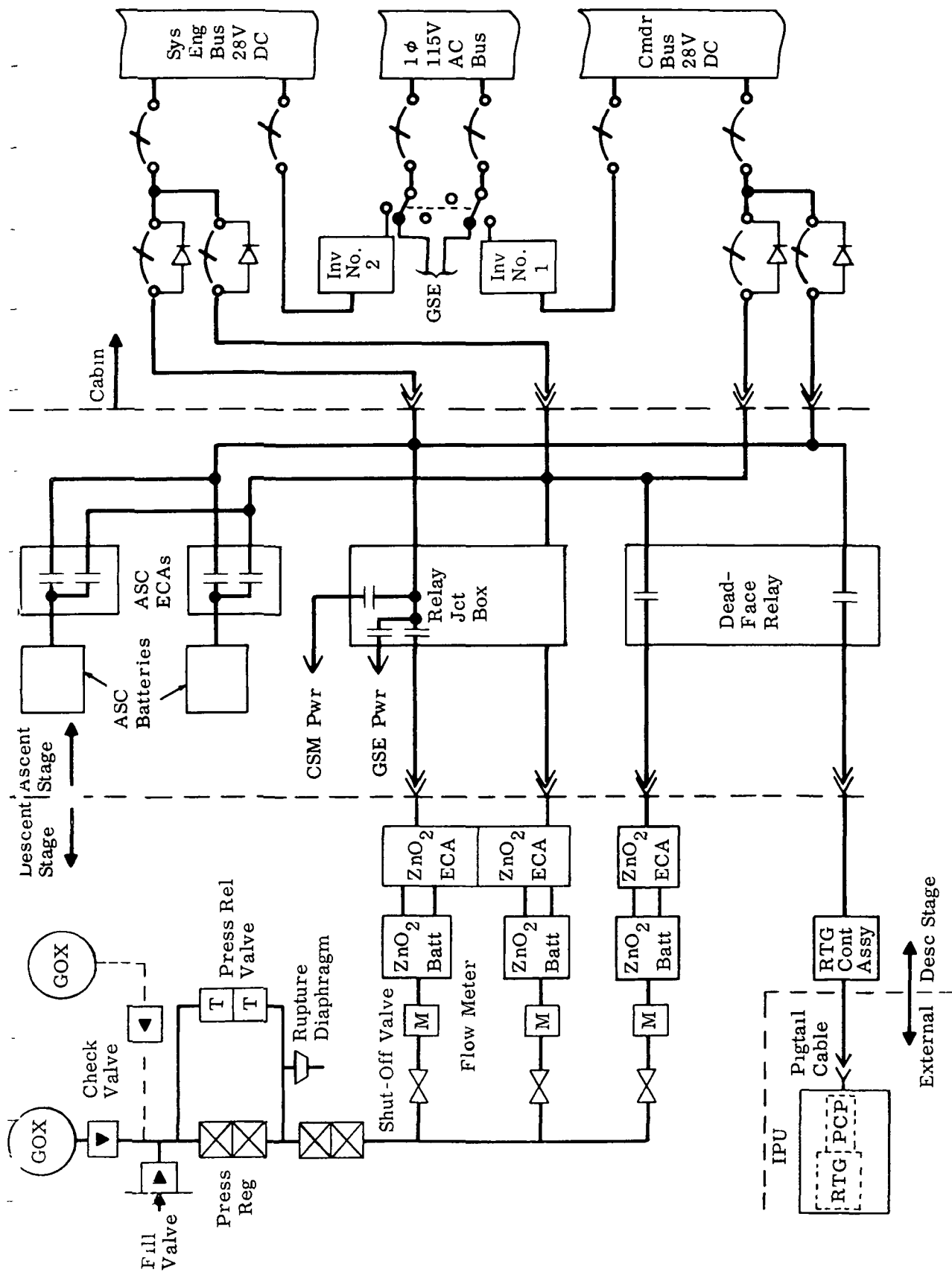


Fig. 5.1-8 Electrical Distribution Section-Zox Battery Alternate Configuration

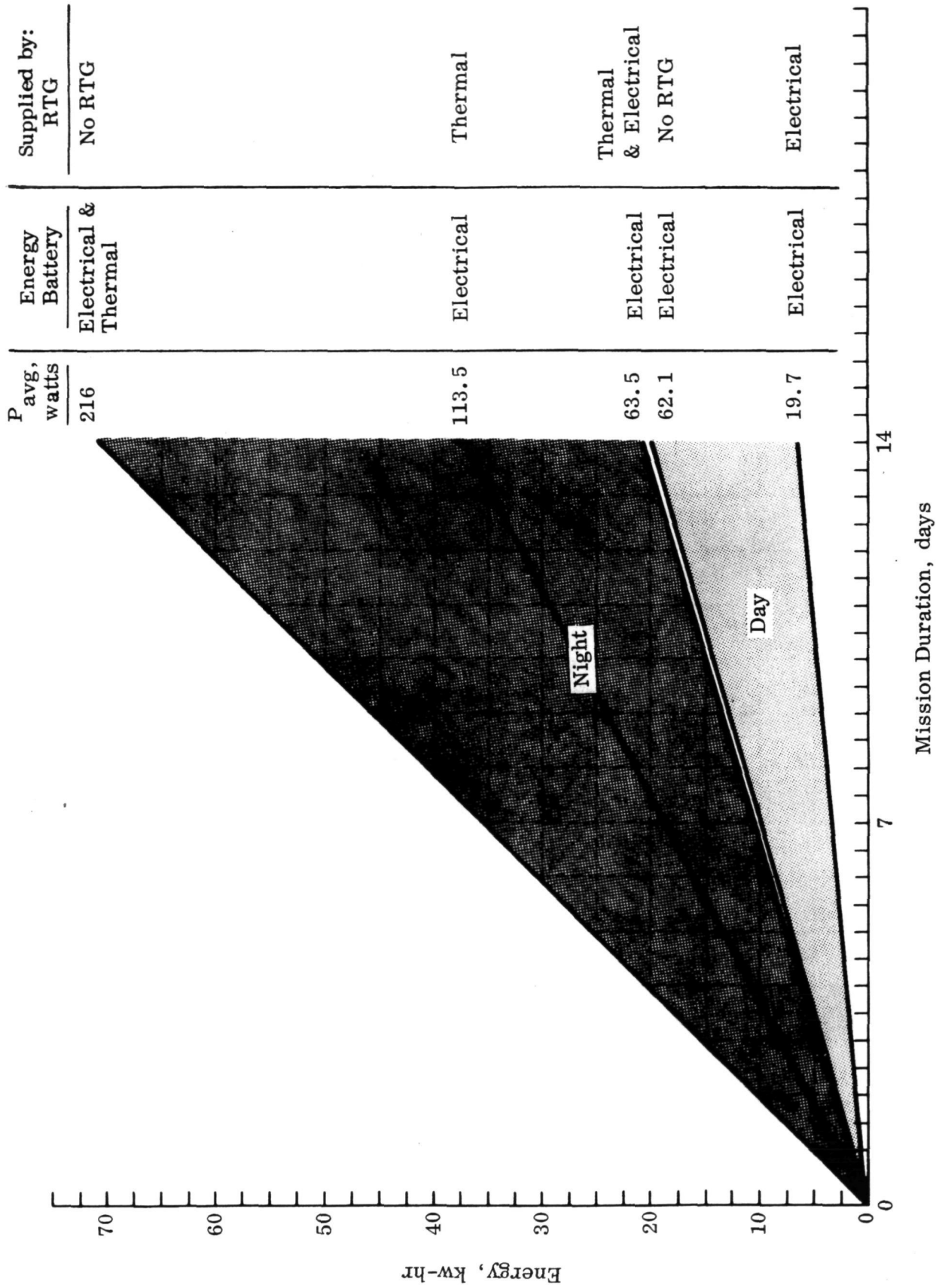


Fig. 5.1-9 Energy Requirements-Quiescent Phase.

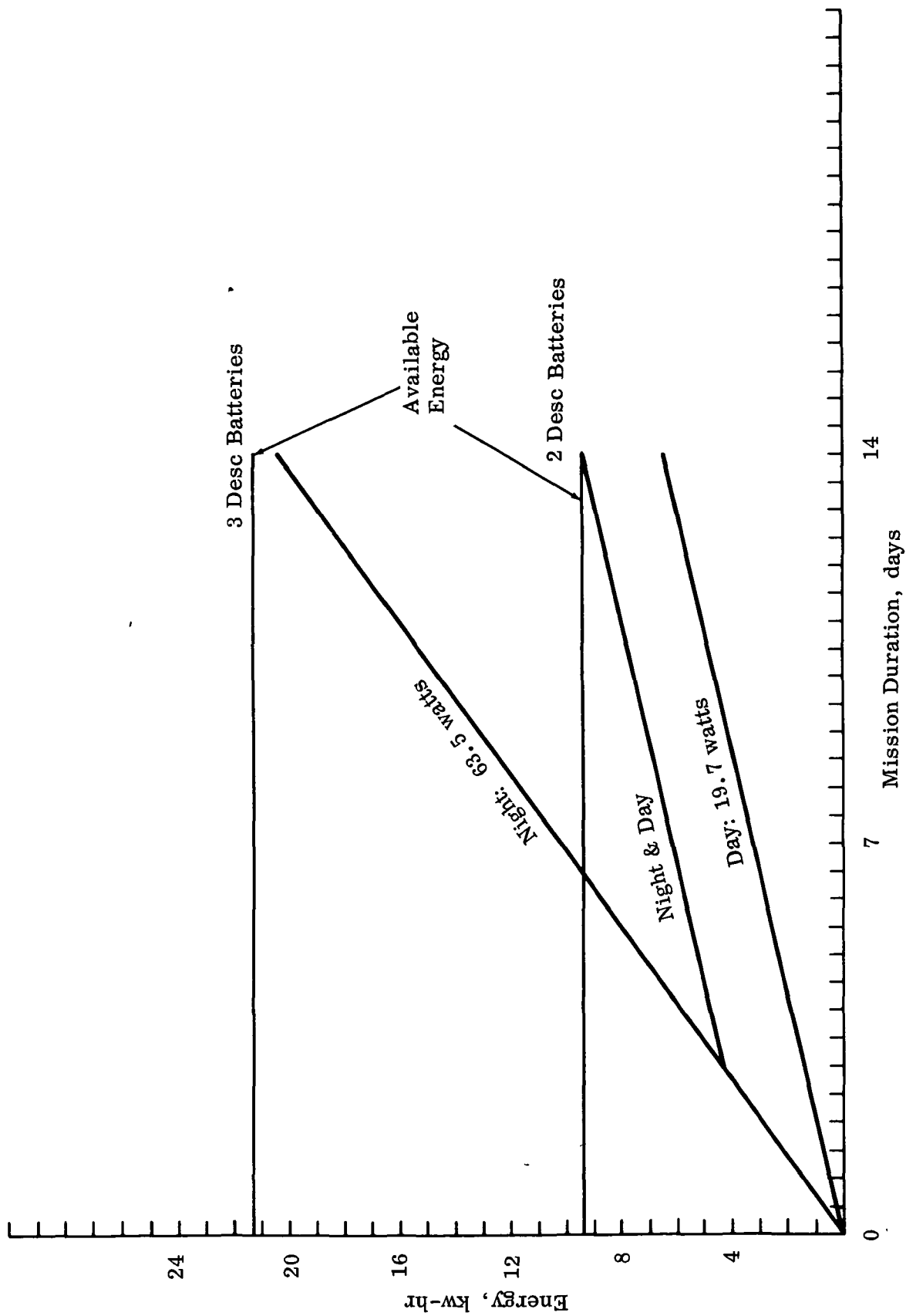


Fig. 5.1-10 Day/Night Battery Energy Requirements

5.2 ENVIRONMENTAL CONTROL

5.2.1 Ground Rules

The following ground rule was applicable to this subsystem:

- For manned operations the cabin atmosphere shall be maintained at $75 \pm 5^{\circ}\text{F}$ and 40 to 70 percent relative humidity.

5.2.2 Assumption and Background Data

In establishing the functional requirements of the Taxi Environmental Control Subsystem (ECS) configurations, the following assumptions were used:

- Taxi flight phases prior to lunar touchdown and subsequent to lift-off are identical to LEM
- Surface phases of the Taxi mission conform to the generalized timeline in Table 5.2-1
- Electrical heat loads are those associated with the power profiles defined in Paragraph 5.1
- Heat loads imposed on the ECS by the external thermal environment are as described in Paragraph 4.1
- The Taxi ECS must be capable of completely automatic operation during quiescence
- The ECS must be capable of supporting 14-day quiescence in either a lunar day or night external thermal environment.

5.2.3 Recommended Configuration

The recommended ECS configuration is capable of meeting the demands of Taxi missions in either a day or night external lunar surface thermal environment. Minor modifications are necessary to the LEM ECS to provide this capability.

Since the functional and operational requirements of the atmosphere revitalization, and oxygen supply and pressurization control sections of the LEM ECS remain unchanged for Taxi missions, no changes to existing LEM hardware or to the manner in which it is configured are contemplated. Modifications and additions are, however, necessary in the heat transport and water management sections to:

- Minimize electrical heating requirements for night missions
- Minimize water requirements for heat rejection during lunar day
- Provide for thermal requirements of batteries and thermally sensitive electronic equipments during the quiescent mission phase.

The following paragraphs describe the recommended Taxi ECS sections with emphasis on the manner in which they differ from their LEM counterparts.

5.2.3.1 Atmosphere Revitalization Section

The functional and operational requirements of the Taxi Atmosphere Revitalization Section (ACS) are identical to those of the LEM (Fig. 5.2-1). No configuration

or hardware changes are contemplated. However, since the Taxi mission is less demanding with regard to crew support durations, a reduction in the quantities of LiOH required for the removal of metabolic carbon dioxide in the ARS and PLSS can be realized. The LEM cabin is occupied for 75 man-hrs (ARS Support) while the cumulative EVA duration is 24 man-hr (PLSS Support). For the Taxi mission, the corresponding cabin occupancy is 39 man-hr, while the cumulative Taxi supported EVA duration is 4.3 man-hr. Table 5.2-2 compares the LiOH requirements for the LEM and Taxi missions.

5.2.3.2 Heat Transport Section

The requirement for a 14-day quiescent lunar surface storage capability requires that modifications be made to the LEM Heat Transport Section (HTS). The modified HTS configuration is shown schematically in Fig. 5.2-2. A manual diverter valve has been added upstream of the IMU and ASA coldplates, such that during nighttime quiescent storage, coolant may bypass these components to reduce their electrical heating requirements from 118.5 to 18 w average.

Since heat must be provided to maintain the Taxi ascent stage within acceptable temperature limits during nighttime quiescence, Radioisotope Thermoelectric Generator (RTG) waste heat utilization equipment has been added (Fig. 5.2-3). It is capable of transporting 500 to the ascent stage structure of the Taxi. The system is designed such that the vehicle will reach and maintain thermal equilibrium (at approximately 60°F) with the external environment. Distilled water is used as the heat transport fluid and operates at a temperature and pressure of 250°F and 30 psi, respectively.

The RTG heat utilization sub-section operates in the following manner. Prior to system activation, water is stored on the condenser side of the control valve. The control valve electrically opens when sensors mounted on the ascent stage signal that structural temperatures have reached a predetermined lower limit. Water is gravity fed to the boiler, where it evaporates and rises to condensers which provide a thermal path into the ascent stage pressure shell. The steam condenses and returns to the boiler by gravity feed, beginning another cycle. The vehicle temperature rises and eventually reaches equilibrium. If the external environment changes and the maximum temperature limit of the ascent stage structure is exceeded, the valve closes. When this occurs, condensate collects above the control valve, and the temperature and pressure of steam remaining in the boiler rises. The control valve, having relief capability, eventually cracks and equalizes overall system pressure and then closes again. The system remains in a non-operating state with residue steam at 400°F on the boiler side of the control valve and the remaining fluid in condensate form on the condenser side of the valve. In the non-operating mode, the heat leak across the control valve is 7.5 which has a negligible effect on ascent stage temperature.

The weight summary for the RTG heat utilization equipment is as follows:

<u>Component</u>	<u>Weight (lb)</u>
Condenser	1.30
Boiler	1.12
Control valve	1.25

<u>Component</u>	<u>Weight (lb)</u>
GSE connection	0.15
Interstage fitting	1.13
Sensors	0.50
Controller	1.50
Insulation	1.30
Water	0.15
TOTAL	8.70

Electrical power has been allocated to the HTS on a 25% duty cycle, to support distribution of the heat supplied to the ascent stage by the RTG heat utilization equipment. A thermal path is provided between the pressure shell and the coolant loop to transfer the RTG heat to the HTS. The pump will be energized by signals originating from thermal sensors mounted on temperature sensitive equipment when their temperature reaches pre-determined lower temperature limits and will be de-energized when a nominal temperature (60°F) is reached.

During the 330-hr day quiescence, the primary HTS will operate approximately 25% of the time. Sensors will monitor those equipments requiring periodic cooling and energize the coolant pump and the water evaporator water feed valve (Paragraph 5.2.3.3) when cooling is required. Approximately 200 lb of water must be stored on the Taxi for waste heat rejection by water evaporation for the 330-hr period. Thermal water requirements for a day quiescent storage mission are itemized in Table 5.2-3 for each Taxi mission phase.

An automatic pump control, recently deleted from the LEM ECS will be added to the Taxi HTS. It will receive differential pressure signals from the glycol pump differential pressure sensor presently incorporated on the LEM. If the glycol pump differential pressure drops below a preselected valve during the time the primary glycol pump is energized, the automatic pump control will de-energize the primary pump and energize the secondary pump.

5.2.3.3 Water Management Section

To meet the demands of the quiescent storage period, the Taxi Water Management Section (WMS) must provide for the following.

- Positive shutoff of water feed to HTS water evaporators during lunar night to prevent the continuous sublimation of water
- Automatic opening of water feed to HTS water evaporators to provide heat rejection during lunar day
- Addition of small quantities of heat to the descent stage water tank to prevent freezing
- Provision of a sufficient quantity of water to reject all HTS heat loads associated with day quiescence.

To control water feed to the HTS water evaporator, a solenoid actuated valve has been added to the WMS as shown schematically in Fig. 5.2-4. This valve will be closed during lunar night and during those portions of lunar day when active heat rejection is not required.

Since the descent stage water tank is located in the same quadrant as the RTG, tubing associated with waste heat utilization equipment will be routed such that a sufficient quantity of heat will be provided to prevent freezing.

Table 5.2-3 presents an itemized tabulation of Taxi water requirements for the critical all-day mission. The following were assumed for this analysis:

- Taxi flight per LEM ECS Critical Design Mission
- Electrical loads during flight per LEM EPS Sizing Load Analysis
- Surface mission per Taxi Timeline Analysis (Section 3)
- Surface electrical loads per Taxi Load Analysis (Paragraph 5.1)
- Maximum Ascent stage temperature 90°F
- Thermal protection as described in Paragraph 4.1.

Storage provisions for the required water are summarized in Table 5.2-4. The two LEM ascent stage tanks filled to capacity and the one LEM descent stage tank off-loaded approximately 40 lb are sufficient to satisfy these requirements.

5.2.3.4 Oxygen Supply and Pressurization Control Section

The storage, pressure regulating, and delivery equipment associated with the Oxygen Supply and Pressurization Control Section (OSPCS) are unmodified for the Taxi.

LEM ECS oxygen is stored at ambient temperatures and high pressure. It is contained in two small (2.2-lb capacity each) tanks located in the ascent stage aft equipment bay and one large tank (45.2-lb capacity) in the second quadrant of the descent stage. Characteristics of these tanks are summarized in Table 5.2-7. The ascent stage tanks are filled to capacity to satisfy the ascent ECS oxygen requirements for the Taxi flight phases subsequent to lift-off since these phases are assumed identical to LEM. Table 5.2-5 shows a detailed breakdown of ascent oxygen requirements.

The Taxi descent oxygen tank requirements were determined using the Taxi ECS surface mission profile and the flight plan of the LEM ECS Critical Design Mission. The Taxi mission profile is identical to the LEM Critical Design Mission from lunar orbit checkout to post-landing check. For these mission phases, the oxygen requirements are assumed identical. Taxi ECS Oxygen Requirements (Table 5.2-6) were developed based on the surface mission profile and the following oxygen consumption rates and vehicle parameters:

- | | |
|-------------------------------------|-----------------------|
| ● Cabin leakage at 5 psia: | 0.2 lb/hr |
| ● Oxygen supply system leakage: | |
| high-pressure components: | 0.005 lb/hr |
| low-pressure components:* | 0.005 lb/hr |
| ● Metabolic consumption rate | 0.081-0.130 lb/man-hr |
| ● Oxygen per cabin repressurization | 6.9 lb |
| ● Number of cabin repressurizations | 2 |

 * Since these components are in the Taxi cabin, this leakage is applied only when the cabin is unpressurized.

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PLSS oxygen tanks are charged prior to Earth launch and are not refilled prior to lunar liftoff. This is consistent with current LEM guidelines.

As may be observed in Table 5.2-7, Taxi oxygen requirements are approximately 23.4 lb less than the storage capability of the LEM descent stage tanks and will be off-loaded accordingly.

The OSPCS is illustrated schematically in Figure 5.2-5.

5.2.4 Baseline Configuration

The recommended Taxi ECS configuration differs from the baseline in the following areas:

- The LEM Heat Transport Section has been reconfigured because of battery cooling considerations.
- Refinement of vehicle thermal balance for quiescent storage increased the water requirements for day missions from 120 to 200.5 lb
- A solenoid water shutoff valve was added to the evaporator water feed line to prevent water sublimation during night quiescence.

The recommended configuration reflects the latest LEM HTS design which arranges the coolant network such that battery heat loads may be removed by the addition of a small (2800 Btu/hr) water evaporator.

The addition of a solenoid water shutoff valve for the primary HTS water evaporator (Paragraph 5.2.3.2) is required to prevent water sublimation during night quiescence. This valve is opened in response to cabin temperature sensors to provide heat rejection during lunar day and represents a refinement to the baseline configuration.

5.2.5 Alternate Configuration - Zinc-Oxygen Batteries

An alternate configuration, utilizing three Zinc-Oxygen (ZOX) batteries in place of the LEM descent stage batteries is discussed in Paragraph 5.1. These batteries would impose the following additional requirements on the Taxi ECS:

- 23 lb of additional oxygen in the descent stage tank
- 3.5 lb additional water for evaporative cooling (10 to 20% increase in heat dissipation from ZOX batteries).

The additional oxygen requirement can be met, since the recommended ECS offloads 23.4 lb of oxygen from the descent stage tank. Although 22 lb of useable oxygen are required for the ZOX batteries, a slightly larger quantity must be carried to meet the minimum (100 psi) oxygen supply pressure required throughout the ZOX battery operating life. During the mission phases requiring continuous coolant pump operation, the additional battery heat load can be accommodated by the coolant loop. The descent stage water tank can accommodate the additional 3.5 lb of water required to dissipate the added battery heat load.

5.2.6 Alternate Configuration - Passive Utilization of RTG Waste Heat

The RTG waste heat utilization equipment described in paragraph 5.2.3.2 may be eliminated by mounting the RTG on top of the Taxi descent stage and incorporating provisions for controlling the thermal coupling between the RTG heat source and the ascent stage pressure vessel. The thermodynamics of this alternate con-

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figurations are discussed in Paragraph 4.1. In this configuration, the RTG is installed in an insulated enclosure which exposes the generator to both space and a selected portion of the ascent stage structure. Radiation to the ascent stage is controlled by a hinged panel which is actuated in response to an ascent stage temperature sensor.

5.2.7 Potential Modifications Per Flight

Water requirements have been sized for the most severe mission, all day. Off-loading of water for other mission times, approaching the all-night mission case, may be considered a potential per flight modification. The payload capability made available by this off-loaded water could be used for items such as film for the Shelter scientific mission.

5.2.8 Discussion of Configuration Choices

Paragraph 5.1 discusses in more detail the possible use of ZOX batteries as an alternate to the recommended RTG-LEM battery configuration. The only requirement that would be imposed on the Taxi ESC by the selection of ZOX batteries would be the storage of an additional 23 lb of oxygen. Because of the reduced metabolic requirements for the Taxi mission, this quantity could be stored with no tankage penalty.

The alternate location for the RTG, on top of the descent stage, was not selected because of the potential difficulties in transferring the RTG from the Shelter to this position. The location selected in the descent stage scientific equipment bay is the same as for the LEM.

Table 5.2-1

TAXI SURFACE MISSION TIMELINE

Duration, hr	1.22	2.89	3.29	1.2	0.1	1.59	
Phase	Post-Landing Checkout	Taxi Shut-down	Quiescent Stay	Taxi Activation	Taxi Activation	Taxi Active Prelaunch c/o	
Cabin Pressure Status, psia	5	0	0	0	0	5	
Suit Pressure Status, psia	0	3.7	-	3.7	3.7	0	
No. Men on ECS	2	1	0	1	2	2	
	Touch Down	Cabin Dump	Secure for Storage	Reactivate	2nd Man Entry	Repress.	Lift Off

Table 5.2-2

L10H REQUIREMENTS

Parameter Cartridge Location	No. Cartridges	Capacity per Cartridge man-hr	Total Capacity, man-hr	Actual Reqmt, man-hr
LEM				
Cabin ARS	2	40	80	75
PLSS	8	4	32	24
Taxi				
Cabin ARS	1	40	40	39
PLSS	2	4	8	2

	Wt. lb	Dia. in.	Length in.
Cabin Cartridge	7.6 lb	7.9	12
PLSS Cartridge	4.4 lb	5.5	12

Table 5.2-3

WATER REQUIREMENTS

Phase Description	Time hr	Thermal Control, lb	PLSS, lb	Net Meta- bolic Make- up, lb	Produced in LiOH Reaction, lb	Net Stor- age, lb	Cumul Total, lb
Checkout	1.5	10.72	6.80	.33	.12	17.17	17.73
Separation	.002	.22	-	-	-	.22	17.95
Prepare for Descent	.478	4.64	-	.05	.02	4.67	22.62
Orbit Insertion	.010	.08	-	-	-	.08	22.75
Coast to Pericyc.	1.0	10.07	6.80	.22	.11	16.98	39.73
Initial Powered Descent	.10	1.04	-	.02	.01	1.05	40.78
Final Powered Descent	.003	.36	-	.01	-	.37	41.15
Hover to Touchdown	.05	.51	-	.01	-	.52	41.67
Post Landing Check	1.22	10.52	-	.28	.11	10.69	52.36
LEM Taxi Shutdown	2.89	13.75	-	.30	.13	13.92	66.28
Quiescent Stay	329.00	200.5	-	-	-	200.5	266.78
ECS Activation	1.2 .10	2.10	-	.10 .01	.05	2.16	268.94
Taxi Activation Pre-Launch Check	1.59	13.48	-	.36	.13	13.71	282.65
				Residual Water 16.40 lb			
				Descent Stage Total 299.05 lb			

TABLE 5.2-3 (Cont.)

Phase Description	Time hr	Thermal Control, lb	PLSS, lb	Net Meta- bolic up, lb	Produced in LiOH Reaction, lb	Net Stor- age, lb	Cumul Total, lb
ASCENT STAGE STORAGE							
Final Pre-Launch Prep	.50	4.68		.11	.04	4.75	4.75
Powered Ascent	.125	1.17		.03	.01	1.19	5.94
Orbital Contingency	.50	4.86		.11	.04	4.93	10.87
Orbital Contingency	7.0	30.90		1.54	.55	31.90	42.77
Orbital Contingency	1.5	13.42		.33	.12	13.63	56.40
Insert into Trans. Orbit	.002	.02		-	-	.02	56.42
Coast in Trans. Orbit	1.5	16.50		.33	.13	16.70	73.12
Rendezvous	0.4	4.38		.09	.04	4.43	77.55
Docking	.25	2.42		.06	.02	2.46	80.01
Crew Transfer	.33	1.14		.07	.04	1.17	81.18
				Residual Water 5.05 lb			
				Ascent Stage Total 86.23 lb			

Table 5.2-4

WATER STORAGE TANK CHARACTERISTICS

Parameter	Ascent Stage	Descent Stage
No. Tanks	2	1
Storage Pressure, psia		
Initial (80°F)	43	44.5
Final (35°F)	10	21.7
Tank Diameter, in.	14.7	28.3
Tank Volume, (usable, internal) cu ft	0.915	7.1
Tank Weight, lb	5.7	23.7
Usable Fluid, lb	40.6	282.65
Total Fluid, lb	43.1	299.05

Table 5.2-5

OXYGEN REQUIREMENTS-ASCENT STAGE STORAGE

Phase Description	Time hr	Metabolic, lb/hr	Met + Leak, lb/hr	Met + Leak, lb	Cabin Re- press, lb	Cumul Total lb
Final Pre-Launch Prep.	.50	.164	.364	.182	-	.182
Powered Ascent	.125	.234	.434	.054	-	.236
Orbital Contingency	.50	.162	.362	3.258	-	3.494
Orbital Contingency	7.0					
Orbital Contingency	1.5					
Insert into Trans. Orbit	-	.234	.434	.001	-	3.495
Coast in Trans. Orbit	1.5	.182	.382	.573	-	4.068
Rendezvous	0.4	.202	.402	.161	-	4.229
Docking	.25	.202	.402	.100	-	4.329
Crew Transfer	.33	-	-	-	-	4.329
				Residual Oxygen		.480 lb
				Total Oxygen		4.809 lb

Table 5.2-6

OXYGEN REQUIREMENTS-DESCENT STAGE STORAGE

Phase Description	Time, hr	Metabolic, lb/hr	Met + Leak, lb/hr	Met + Leak, lb	Cabin Re- press, lb	Cumul Total, lb
GOX Fill to check- out	143.73	-	.010	1.437	-	1.437
Checkout	.167	.164	.369	.062	-	1.499
Separation	.022	.226	.431	.009	-	1.508
Prepare for Descent	.478	.226	.431	.206	-	1.714
Orbit Insertion	.010	.226	.431	.004	-	1.718
Coast to Pericyn.	1.0	.226	.431	.431	-	2.149
Initial Powered Descent	.10	.226	.431	.043	-	2.192
Final Powered Descent	.033	.248	.453	.015	-	2.207
Hover to Touch- Down	.050	.248	.453	.023	-	2.230
Post Landing Check	1.22	.164	.369	.450	6.90	9.580
Taxi Shutdown	2.89	.130	.135	.390	-	9.970
Quiescent Stay	329.00	-	.010	3.29	-	13.26
ECS Activation	1.20	.130	.135	1.62	-	14.88
	.10	.260	.265	.032	6.90	21.812
Taxi Activation Pre-Launch Check	1.59	.164	.369	.587	-	22.399
				Residual Oxygen		1.680 lb
				Descent Stage Total		24.079 lb

Table 5.2-7

OXYGEN STORAGE TANK CHARACTERISTICS

Parameter	Ascent Stage	Descent Stage	
	LEM & Taxi	LEM	Taxi
No. Tanks	2	1	1
Storage Pressure PSIA (Filled, 95°F A/S, 160°F D/S)	1000	2740	1320
Tank Diameter, in.	11.76	21.67	21.67
Tank Volume-cu ft/tank	0.494	3.089	3.089
Tank Weight, lb/tank	2.97	46.5	46.5
Usable Fluid, lb/tank	2.17	45.175	21.812
Total Fluid, lb/tank	2.41	46.675	24.079

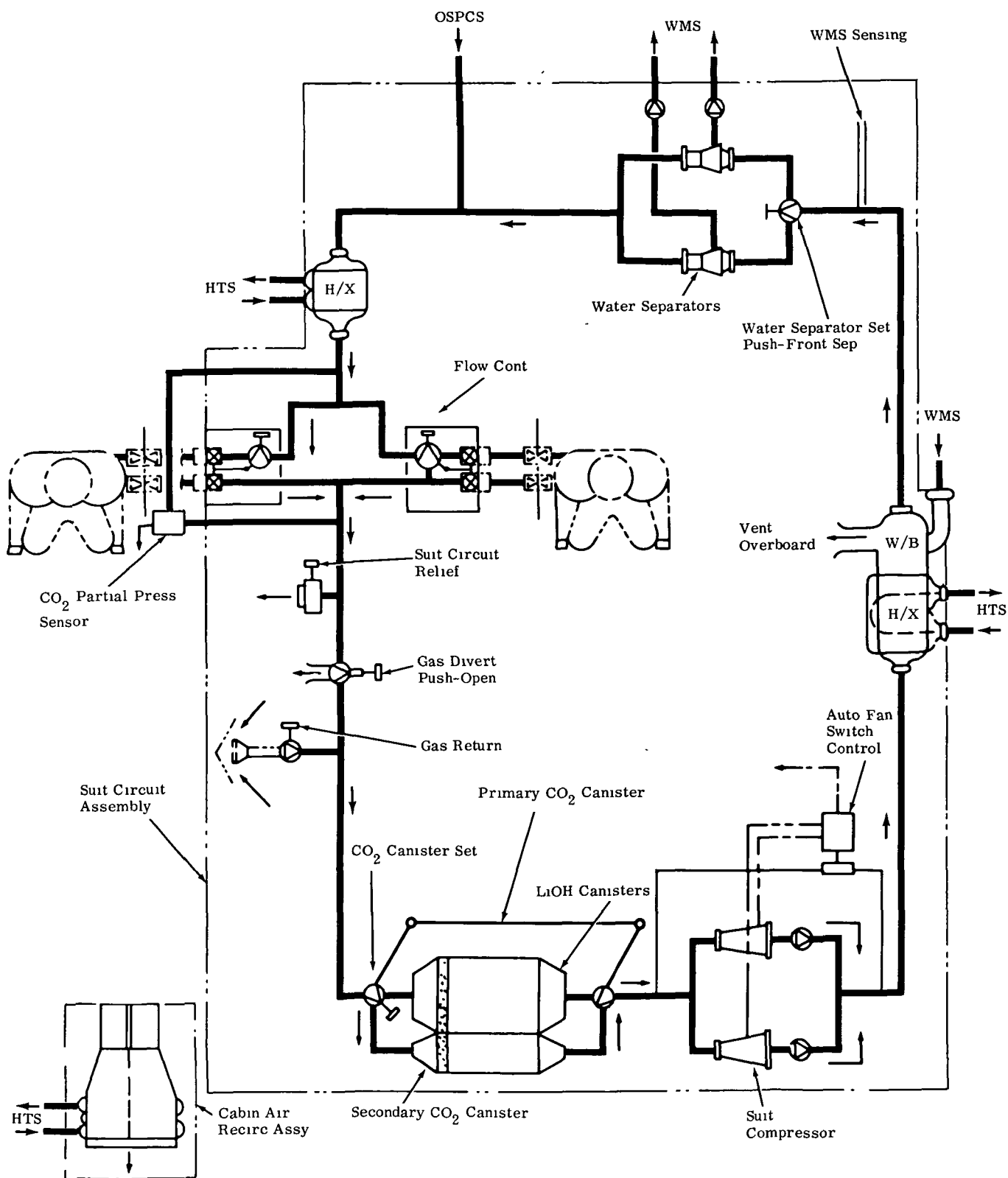
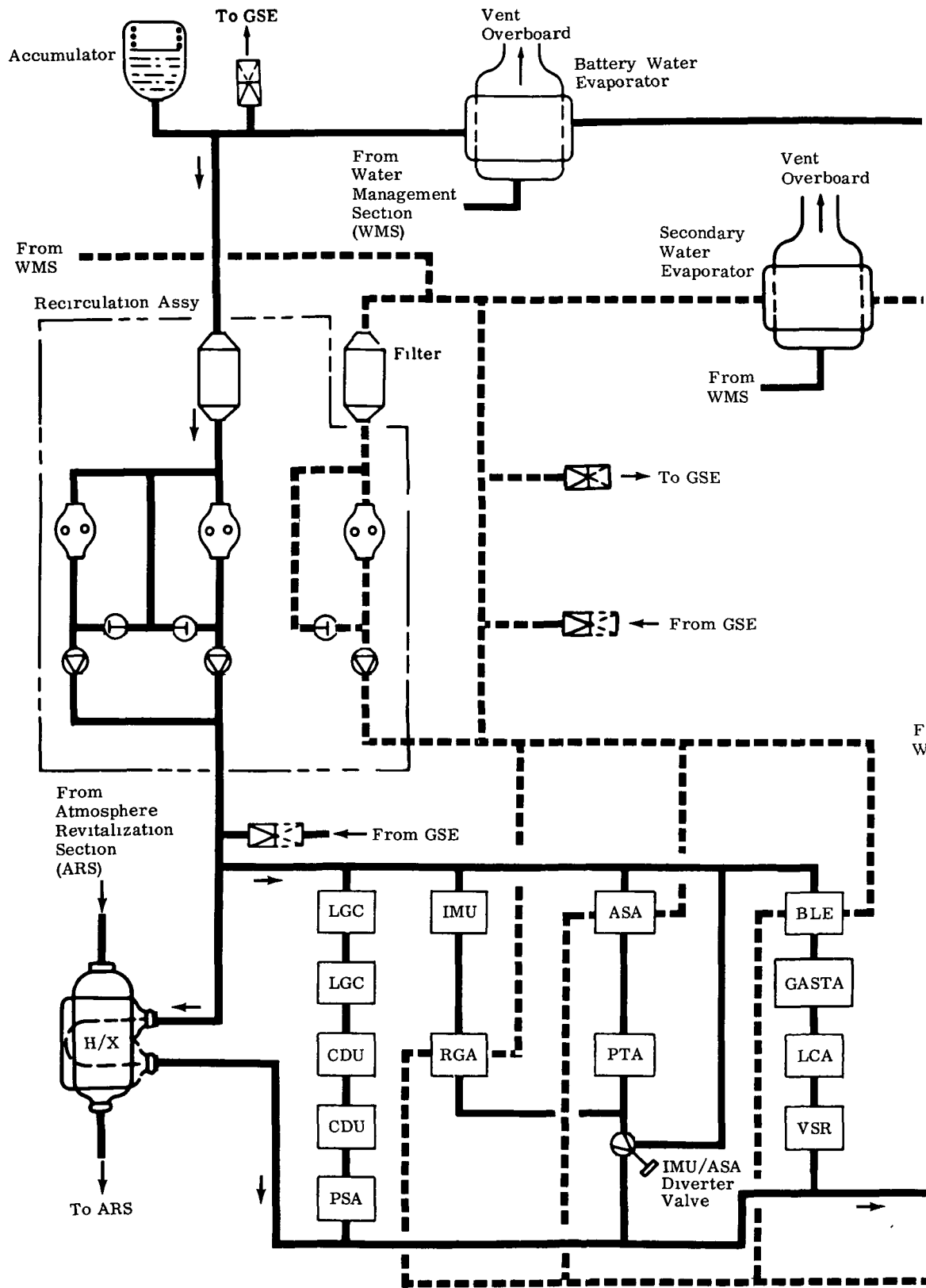
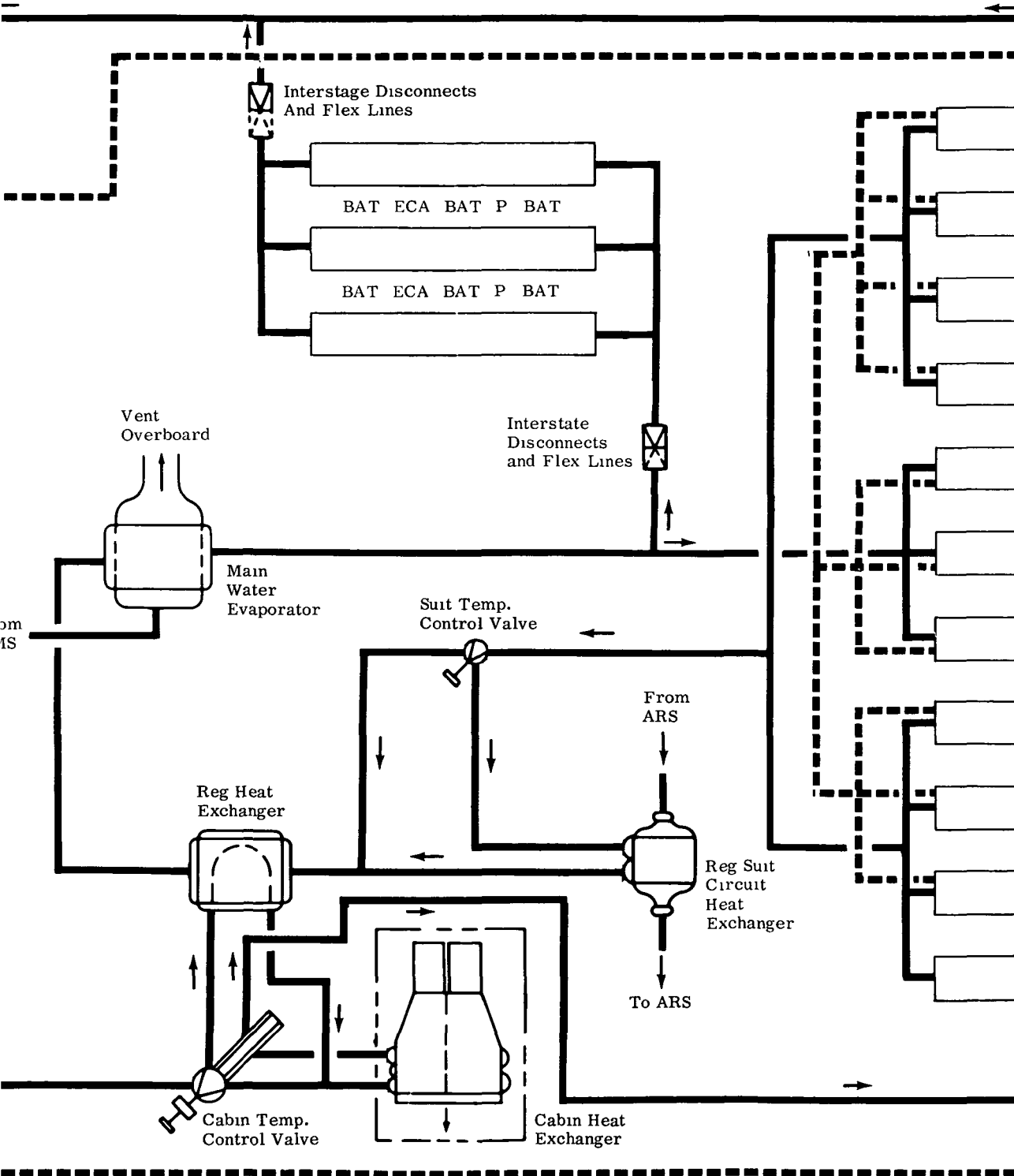


Fig. 5.2-1 Atmosphere Revitalization Section



5.2-2
①



5.9-2
 (2)

Abbreviations Used on Heat Transport Diagram

BAT	Battery
BLE	Beacon Light Assembly
GASTA	Gimbal Angle Sequence Transformer Assy
VSR	Voice Storage Equipment
ECA	Electronic Control Assy
SP	Signal Processor
S-BX	S-Band Transponder
S-BP	S-Band Power Amplifier
VHF	Very High Frequency Communications
INV	Inverter
ATCA	Attitude & Translation Control Assy
CWE	Caution & Warning Assy
SCEA	Signal Conditioning Electronic Assy
PCMTE	Pulse Code Modulation & Tuning Equipt
PQGS	Propellant Quantity Gaging System
RRE	Rendezvous Radar Electronics
LCA	Lighting Control Assy
ASA	Abort Sensor Assy
AEA	Abort Electronics Assy
LGC	LEM Guidance Computer
CDU	Coupling and Display Unit
PSA	Power Servo Assembly
IMU	Inertial Measuring Unit
RGA	Rate Gyro Assy
P. BAT	Pyrotechnic Battery
PTA	Pulse Talk Assy

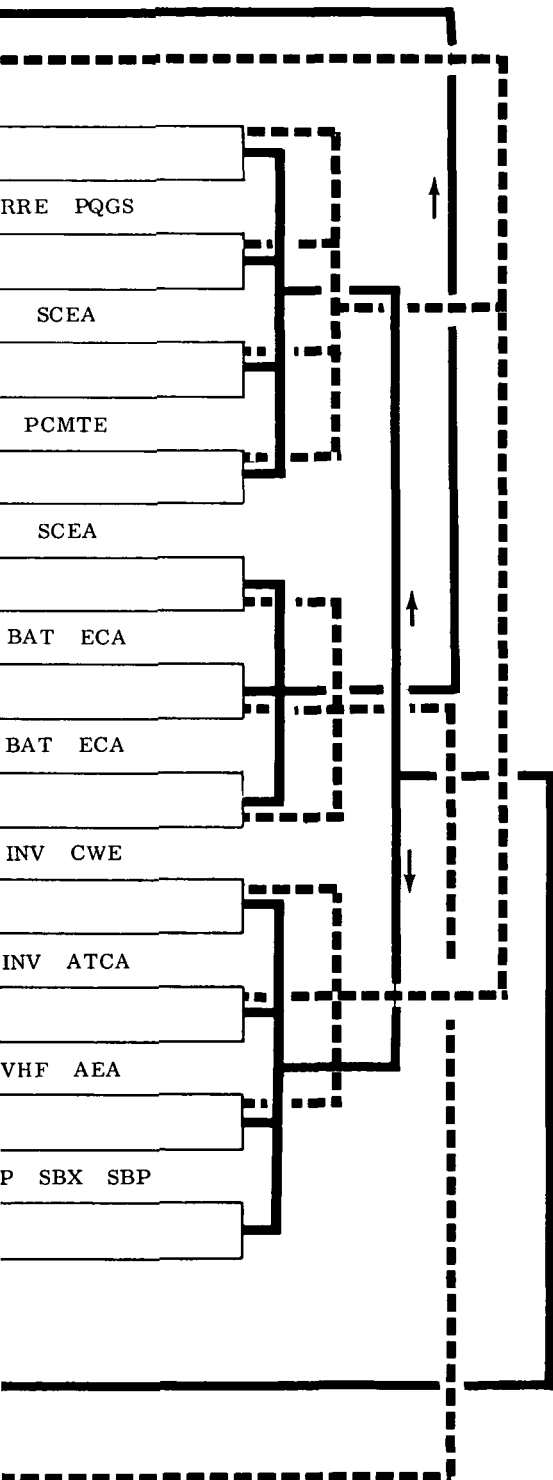


Fig. 5.2-2 Heat Transport Section

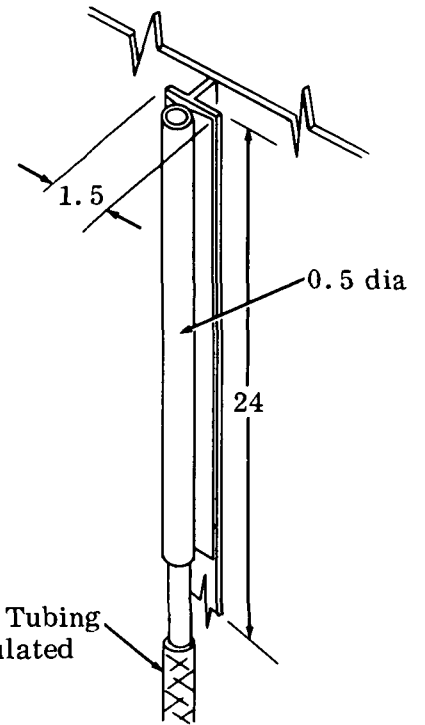
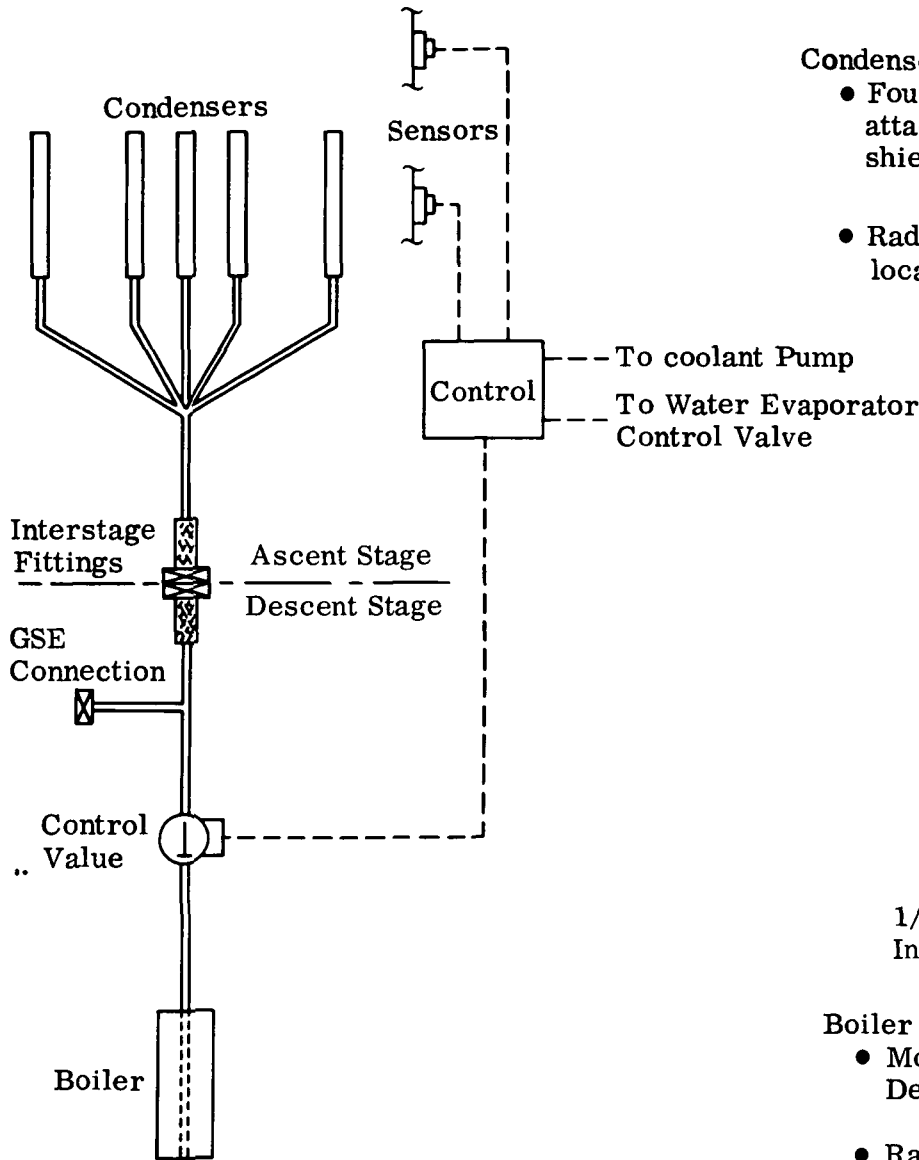
3

Grumman

Component Design

Condensers

- Four condensers mechanically attached inboard of thermal shield to pressure shell webs.
- Radiation heat transfer from localized area to remaining cabin.



Boiler

- Mounted inboard of RTG in Descent stage
- Radiation heat transfer between RTG & Boiler

All dimensions in inches.

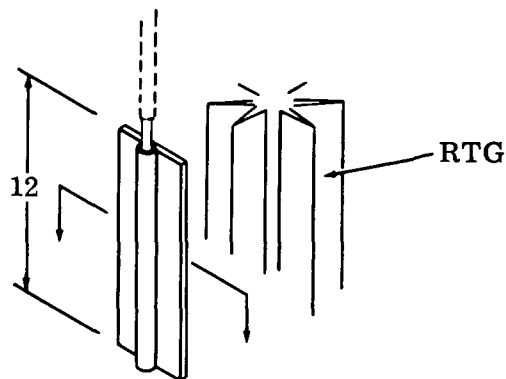
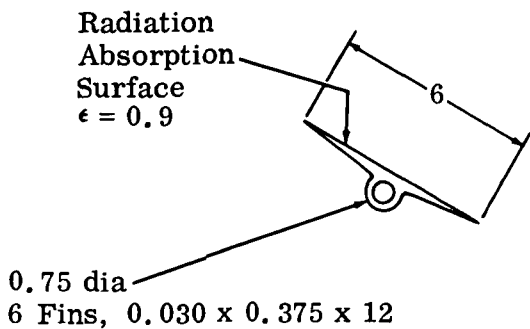


Fig. 5.2-3 RTG Heat Pipe

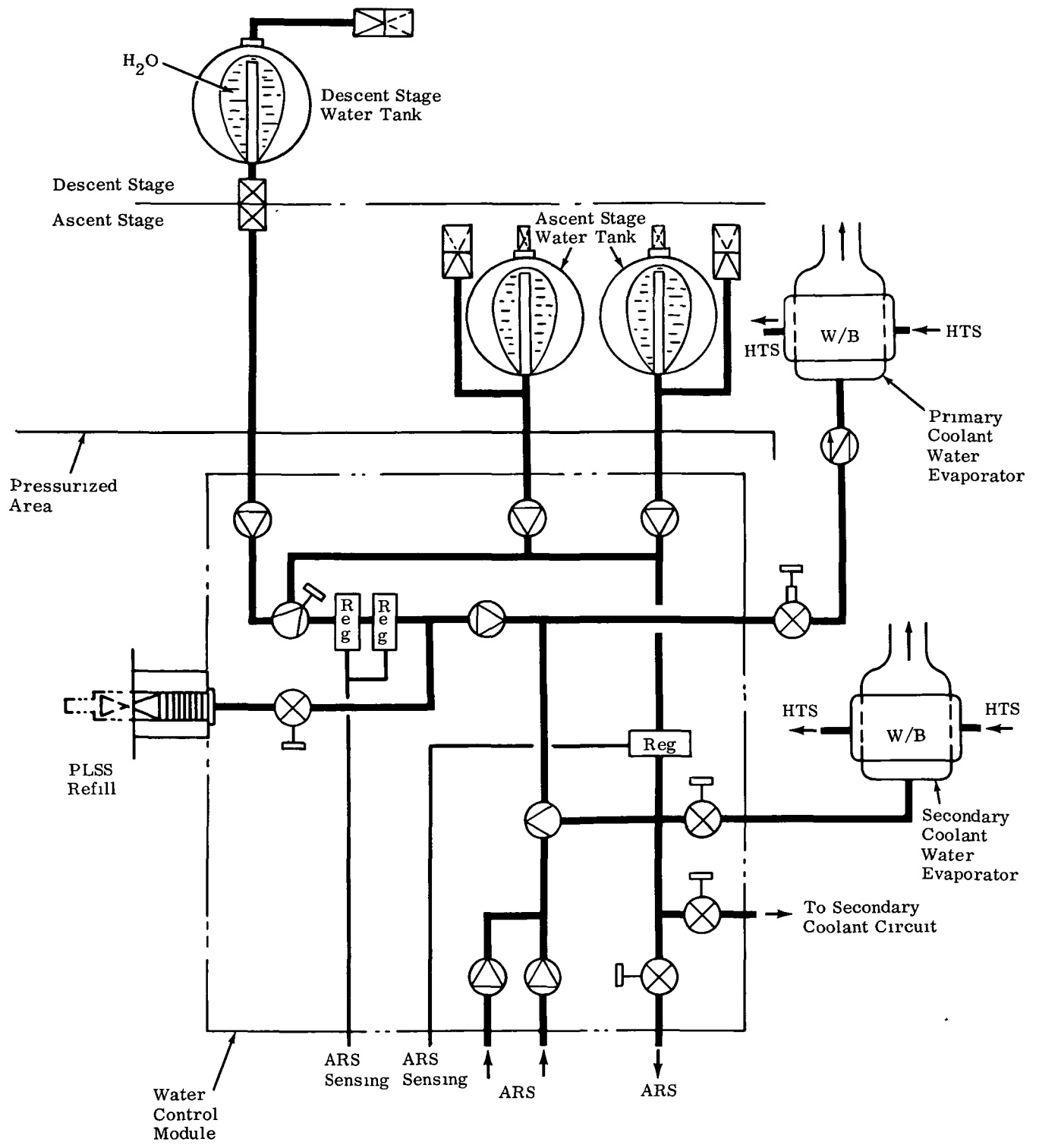


Fig. 5.2-4 Water Management Section

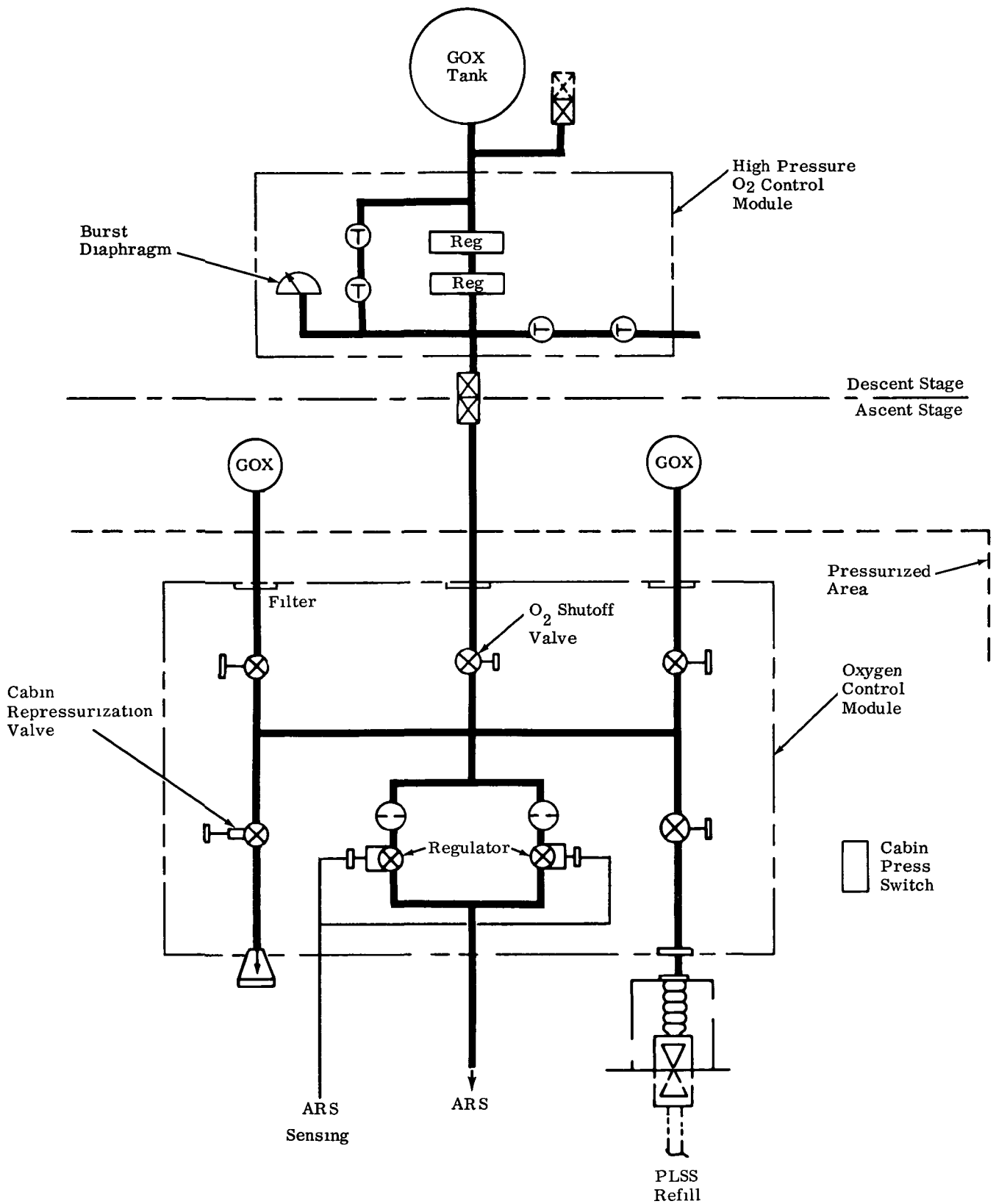


Fig. 5.2-5 Oxygen Supply & Pressurization Control Section

5.3 GUIDANCE, NAVIGATION & CONTROL

5.3.1 Ground Rules

The Taxi shall have the ability to land with the aid of a transponder.

5.3.2 Assumptions and Background Data

In addition to the NASA ground rules, the Taxi Guidance, Navigation and Control (GN&C) Subsystem was configured based on the following assumptions:

- Astronauts will accomplish post-landing checkout and place Taxi into storage mode
- Thermal limits of $135 \pm 5^{\circ}\text{F}$ and $105\text{-to-}120^{\circ}\text{F}$ will be maintained on the Inertial Measuring Unit (IMU) and Abort Sensor Assembly (ASA), respectively
- Periodic status checks of critical systems, including IMU and ASA gyro temperatures, will be performed during the quiescent phase and results telemetered back to Earth via S-band communications
- Astronauts will perform pre-launch checkout and warm-up of all systems
- Taxi will land within walking distance of the Shelter.

5.3.3 Recommended Configuration

The recommended Taxi GN&C Subsystem (Fig. 5.3-1) is the same as the LEM except for the addition of a time sequencer to periodically activate the equipment necessary to perform status checks during quiescent storage. The recommended configuration is to use a self-contained timer to initiate the checkout procedure, with sequencing performed by either the timer or by time-delay relays. The timer can be either electrically operated, spring driven with an electric rewind, or completely spring driven for 14 days.

To land the Taxi within walking distance (approximately 1000 ft) of the Shelter, the CSM transponder electronic and antenna assemblies are incorporated into the Shelter for use in conjunction with the Taxi rendezvous radar. The LEM Primary GN&C Subsystem has an overall design objective of achieving a lunar landing circular error probability (CEP) of 3000 ft for landing sites not marked by a surface transponder. The use of the rendezvous radar/transponder as a landing aid will reduce the CEP to 200 ft.

The angular coverage provided by the CSM transponder, at angles close to the horizon, varies in radiation level between -1 and -15 db. The proposed mission trajectories will be incident to a landing site within these angles. Because of the holes in the coverage pattern, the rendezvous radar transponder maximum range will be reduced from 400 to 70 n.mi. Horizon coverage may be improved by minor modifications to the present system, such as coupling the transponders on opposite sides of the Shelter, or a new antenna configuration.

5.3.4 Baseline Configuration

There is no difference between the recommended and baseline configurations.

5.3.5 Alternate Configuration - LGC for Initiation of Status Check

One of the alternate configurations for a programmer for status data transmission would use the LGC standard frequency outputs. The times between checkouts would be limited to specific time segments, such as 1.5, 2.9, and 5.8 hr. However, there are a variety of frequencies available, such that many combinations of times between checkouts and sequencing times are possible. A disadvantage to this approach is that the computer must be on standby for these outputs to be available.

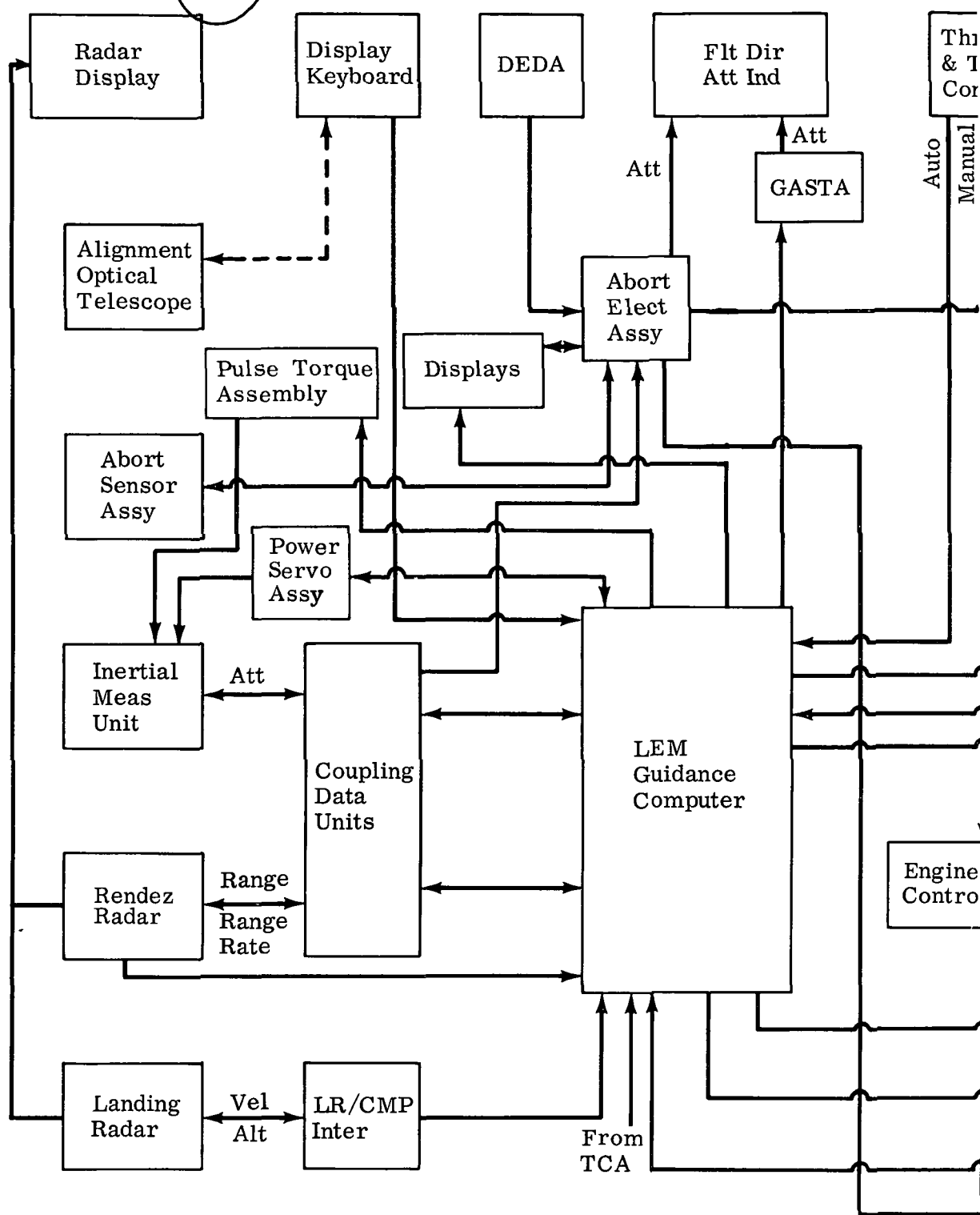
5.3.6 Alternate Configuration - Earth Uplink for Initiation of Status Check

Use of an Earth uplink to initiate the status checks during storage was also considered as an alternate configuration. This approach would require the addition of a decoder, relay drivers, and a modified Program Coupler Assembly similar to that used on the Shelter. This approach could be interchangeable with the Shelter, since this equipment would not be needed on the Shelter once the Taxi has landed.

5.3.7 Discussion of Configuration Choices

The selection was made of a time sequencer to initiate the periodic status checks during quiescent storage, since this approach has the advantage of simplicity, light weight, and low-power consumption. It also does not depend upon any other system other than electrical power for its operation.

59



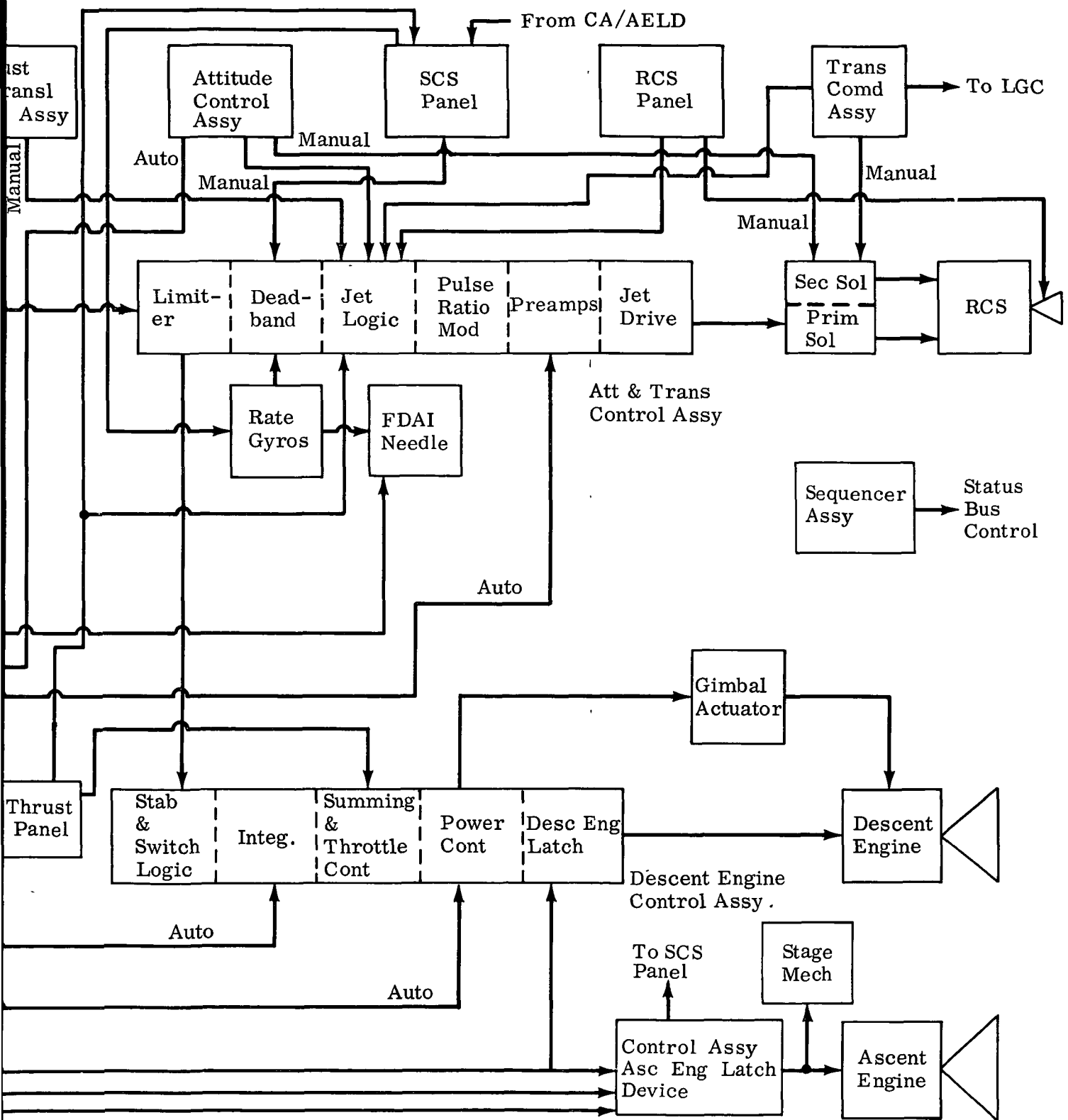


Fig. 5.3-1 Guidance, Navigation & Control Subsystem

5.4 RCS & PROPULSION

5.4.1 Ground Rules

There were no NASA ground rules unique to the Reaction Control and Propulsion Subsystems.

5.4.2 Assumptions and Background Data

The recommended RCS and Propulsion Subsystems configuration were developed based on the vehicle-level ground rules and the following assumptions:

- Performance and propellant requirements for the Taxi are assumed to be essentially the same as the present LEM with the exception of the extended lunar surface stay time.
- The ascent and descent engines are assumed to be capable of meeting the Taxi mission duty cycle without major modification.
- The descent helium pressurant will warm up to the level of the relief valve pressure setting within 24 hours after landing. Concern over the resultant uncontrolled venting has led to study of alternate methods of venting as discussed in Paragraphs 5.4.3.3 and 5.4.6.

5.4.3 Recommended Configuration

5.4.3.1 RCS

The recommended configuration is the basic LEM RCS utilizing sixteen thrusters and a dual helium and propellant feed system with the addition of cluster heaters (250 watts per cluster) to be turned on during pre-launch checkout. The system schematic is shown in Fig. 5.4-1.

During the quiescent lunar stay period, it is not practical to maintain controlled cluster temperature by means of the LEM cluster heaters because of the large energy requirement. Therefore, the present LEM cluster heaters will be turned off after landing and the thrusters will be allowed to cool down to equilibrium temperature (approximately 0 to -20°F). During pre-launch checkout, the larger 250 watt heaters will be turned on at each cluster to thaw propellant feed lines and bring the thrusters up to operational temperatures (approximately one hour will be required for this operation). Freezing of the fuel is expected during this period and some separation will occur. Discussions with the engine manufacturer (Marquardt) have indicated that the thrusters should operate satisfactorily under these conditions. This will be further verified during the Phase C study.

The Taxi will stay on the lunar surface for 14 days, and thus the RCS components will be exposed to pressure, propellants and propellant vapors longer than in the LEM mission. It is believed that components which satisfactorily meet the present LEM compatibility requirement of 30 days will be adequate for the Taxi mission. Continuous monitoring of the LEM development program will be necessary to insure that potential trouble areas are recognized if they should arise.

5.4.3.2 Ascent Propulsion

The Taxi ascent propulsion subsystem (Fig. 5.4-2) will be exactly the same as the LEM. The performance requirements are the same with the exception of the extended lunar stay time.

The ability of the propellants, especially N_2O_4 , to diffuse throughout the ascent propulsion helium section has generated a stringent propellant compatibility requirement for the LEM. This is of greater concern on the Taxi because of the extended mission duration. At present, two methods of meeting this requirement are under consideration. These are the use of squib actuated valves to isolate the helium section from the propellant vapors (see Fig. 5.4-2), or the use of components which are constructed of materials which are capable of withstanding the attack of the propellant for the mission duration. If the final LEM subsystem incorporates the isolation valves, it will be used on the Taxi "as is". However, if components with revised materials are used, it is expected that the capability of these components to meet the Taxi extended mission will require verification testing.

The LEM 45-day propellant loaded condition also imposes a stringent compatibility requirement on the ascent engine valves. A 45-day test with pressurized propellants is planned for these valves by the LEM Project. The result of this test will be reviewed for applicability to the Taxi. The post-test disassembly and inspection will determine the course of action. If little or no deterioration is found, it is expected that further testing will be unnecessary. Evidence of more serious problems will require testing to verify the valves capability to meet the Taxi requirements. The same philosophy will be applied to the helium components discussed above.

The extended mission increases the requirement of the ascent engine ablative liner to resist the thermal-vacuum environment on the lunar surface. At present, it is expected that the engine will be capable of meeting this requirement. It is assumed that a test beyond that planned for LEM to verify this capability is required. However, further study of this in Phase "C" is planned and the verification test may be deleted.

5.4.3.3 Descent Propulsion

The Taxi descent propulsion will be the same as the LEM except for the three added vent valves which will be used to depressurize the helium and propellant tanks following lunar landing (see Fig. 5.4-3). As shown, two low pressure relief valves will be used in series with the propellant tank vent valves to limit the quantity of propellant vapors which are vented to the lunar atmosphere.

The use of vent valves to depressurize the descent helium and propellant tanks is dictated by safety considerations. The use of three vent valves is necessitated by the low temperatures of the supercritical helium. Venting the supercritical helium through the propellant tank vent valves would freeze the propellant vapors and eventually would clog the vent line. The sequence of operations for the recommended configuration will be venting of the supercritical helium tanks, followed by venting of one set of propellant tanks and then the other.

The primary safety consideration is a catastrophic failure of the helium or propellant tanks. Tank failures can occur at least two ways. The first is an increase in tank pressure combined with a failed-closed relief valve. It is estimated that the tank pressure will increase to the level of the relief valve pressure setting within 24 hours. The increase in pressure is the result of the rise in temperature

of the cold pressurizing helium gas. The second means of catastrophic failure is micrometeoroid penetration of a tank with an internal pressure greater than 40 psi. Based on the tank geometries and material, 40 psi was established as a conservative estimate of the pressure level at which no crack propagation will occur if the tank is punctured.

The secondary safety consideration is the possible contamination of the astronaut's garments with propellants as a result of uncontrolled (random) venting of pressure when the astronaut is on the lunar surface and in close proximity to the vehicle. During the lunar day, the oxidizer vapors will react with the garment material possibly causing injury, while the fuel vapors may cling to the material subsequently contaminating the breathing oxygen with toxic fumes when the astronaut re-enters the vehicle. The conditions associated with the lunar night are discussed below.

This latter consideration, combined with the desire to prevent catastrophic failure of a tank which is punctured, generated the need for a low pressure relief valve in series with each of the propellant tank vent valves. As originally conceived, the tank pressure was to be reduced to lunar atmospheric (vacuum). The reduction in pressure causes propellant boiling and a corresponding reduction in temperature. Eventually, the propellant bulk will freeze. Heat flow from the vehicle structure will then slowly vaporize the frozen propellant, with the vapors flowing overboard through the vent valves, thus presenting the same contamination problem discussed above. As a result, a low pressure relief valve has been added to limit the quantity of propellant vapors which are vented to the atmosphere. The relief valves will be set at 40 psia (maximum), the estimated "safe" pressure level for the tanks. The nominal relief valve reseal pressure will be 30 psia.

The phenomenon of liquid/vapor forming "snow" when vented into a vacuum (Ref. 1) has led to the final design consideration for the vent system. This phenomenon presents a contamination problem similar to that discussed above. The low lunar night temperature prevents the "snow" from vaporizing and dispersing. Thus, the lunar surface can be covered with a layer of propellant "snow" which can be tracked into the vehicle on the astronaut's shoes. It is therefore desirable to vent the propellant into a confined area or at least into an area which the astronaut will not traverse. The area directly below the descent stage is under consideration. Further studies are required to be certain that the vented propellants will not disperse beyond the perimeter of the descent stage. If it is found that they will disperse beyond the perimeter, a means of preventing this will be determined. The possibility of venting the propellants into their respective tank bays is also being explored. The available volume in the bays is sufficient to hold the vented propellant. Problems of sealing adjacent oxidizer and fuel tank bays and compatibility of materials within the bays have not been explored to date. Investigations into these problem areas will be conducted during Phase "C". In addition, trade-off studies of the two solutions will be conducted to determine the best course of action.

5.4.4 Baseline Configuration

There is no difference between the recommended and baseline configurations.

5.4.5 Alternate Configuration-RCS Cluster Covers

The use of cluster covers during the lunar stay period was studied as an alternate to cluster heaters to prevent the freezing of propellants. Details of these studies are discussed in Section 6. Deployment of the covers by hand was considered as well as remote actuation.

5.4.6 Alternate Configuration - Methods of Venting Descent Propellant Tanks

Alternate methods of preventing the contamination problems discussed above were investigated.

- The possibility of decomposing the propellant into non-toxic, low freezing-point gases was explored. Other than burning with a fuel, no means of decomposing the oxidizer was found. The use of Shell Catalyst No. 405 to decompose the fuel was investigated. The manufacturer provided information that the 50-50 fuel combination has been satisfactorily decomposed using the catalyst. However, no attempt to analyze the decomposition products has been made. Investigation into this possibility will be continued in Phase "C".
- A brief investigation into the possible use of a fused quartz helium diffusion cell to separate the helium and propellant vapors was made. The fused quartz, being permeable to helium, will allow it to vent overboard while retaining the propellant vapors. These brief investigations indicate possible problems in regard to the size and weight of the diffusion cells. Further investigations into the size, weight, flow capacity and material compatibility of the diffusion cell are required.

5.4.7 Potential Modifications Per Flight

No per flight modifications were considered for the Taxi.

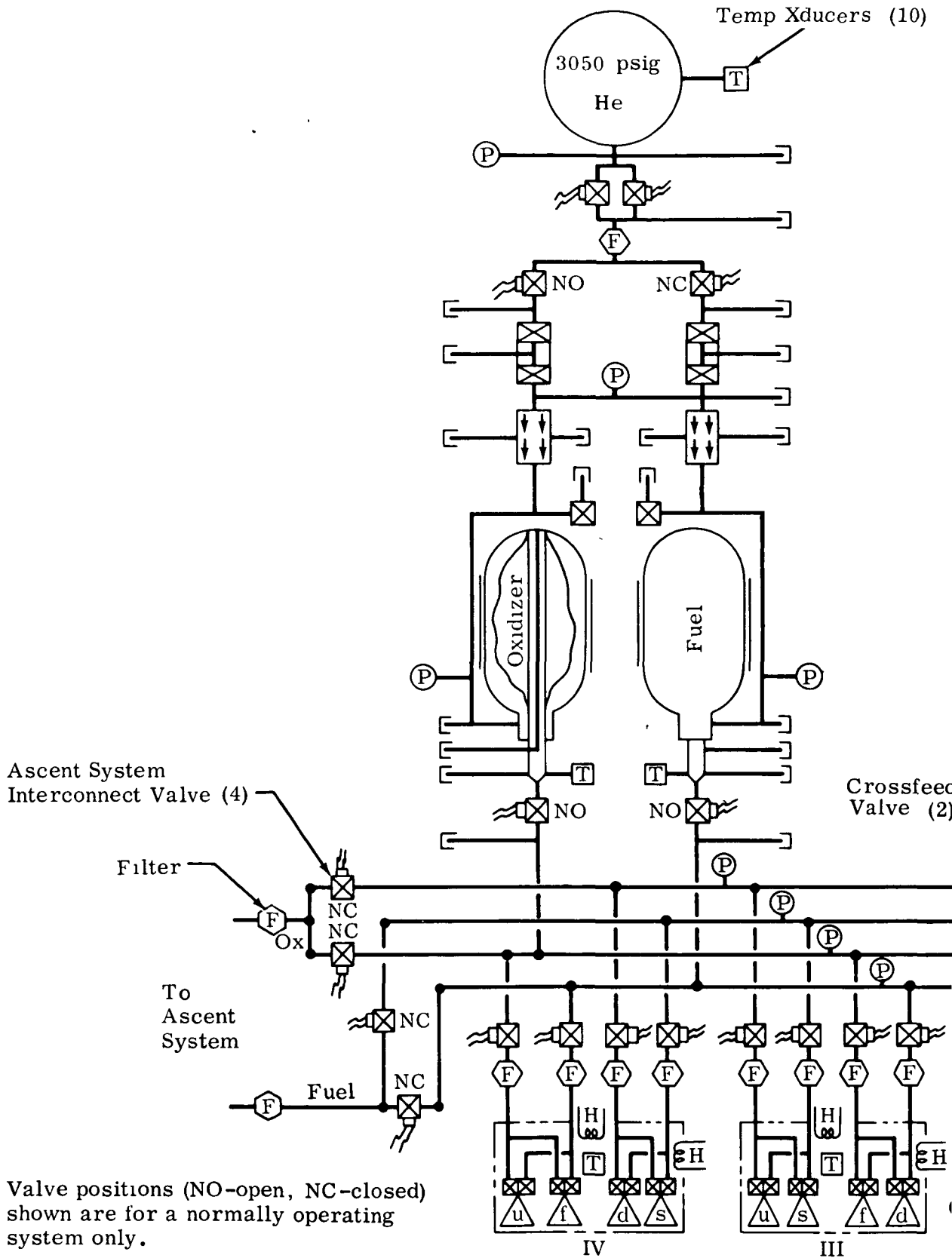
5.4.8 Discussion of Configuration Choices

The RCS cluster covers were not selected, since in the manned mode, inaccessibility of the clusters raised serious questions as to whether the astronaut could successfully place the covers properly. Also, if the astronaut were incapacitated, removal of the covers might be impossible and prevent a successful abort. In the remote actuation case, adequate thermal sealing of the covers appears to be a major problem. Also, storage space is marginal and the weight is high when compared to the additional battery weight for the recommended cluster heaters (120 lb vs 13 lb).

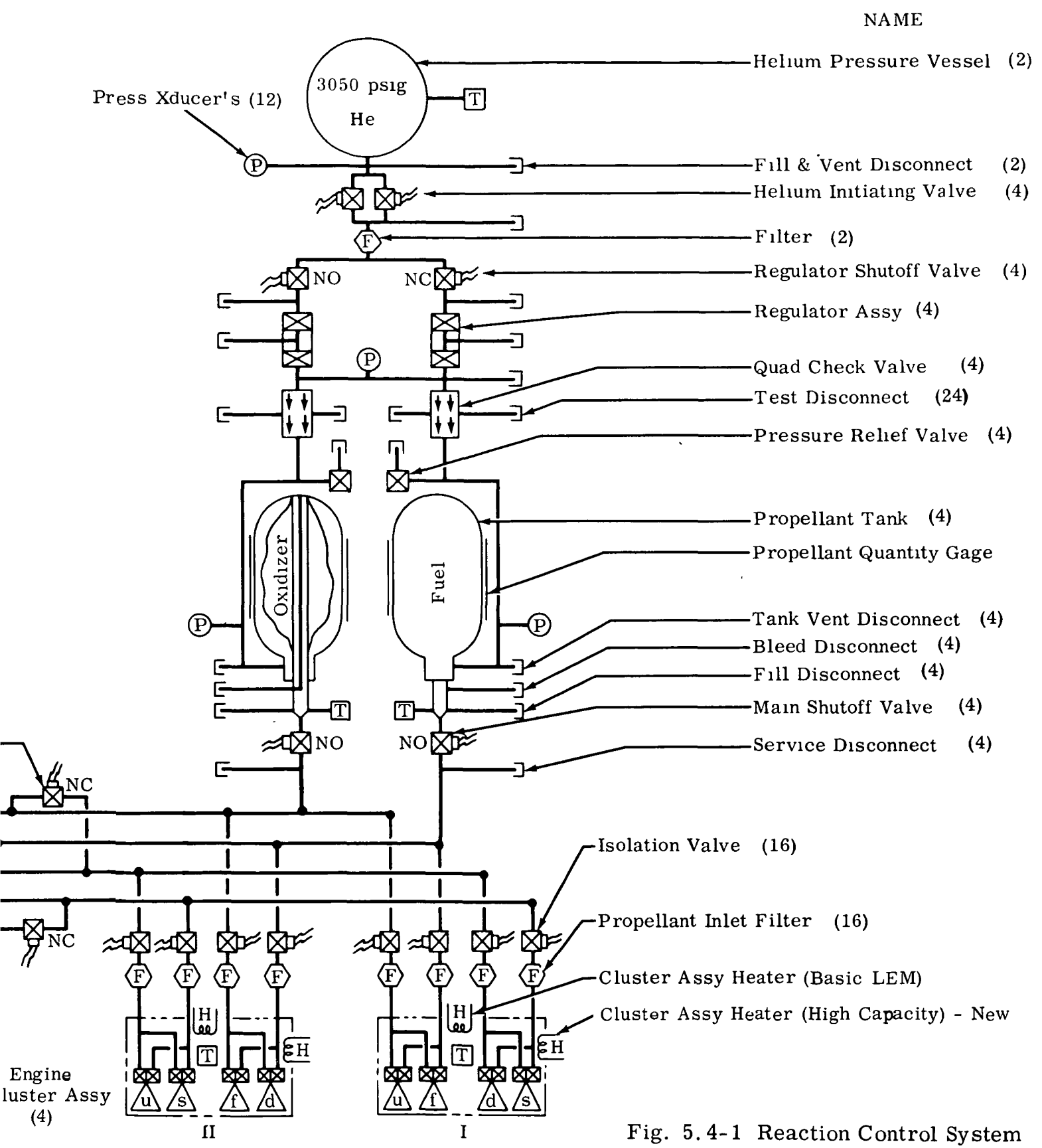
The combination of vent and low pressure relief valves was chosen to depressurize the descent helium and propellant tanks, because of the lack of adequate information on the alternates. Further investigations during Phase "C" may show the catalyst bed or helium diffusion cells to be more desirable.

- Reference: 1) Simmons, J.A. and Gift, R.D., "Phenomena Associated with the Exposure, Leakage and Discharge of Propellants in a Vacuum". Paper presented at 56th Air Force-Industry Conference, February 1965. This paper was based on Contract No. NAS 8-11044, Report No. X65-12159, dated 12/18/64.

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NOTE: Valve positions (NO-open, NC-closed) shown are for a normally operating system only.



NAME

Helium Pressure Vessel (2)

Press Xducer's (12)

3050 psig
He

Fill & Vent Disconnect (2)

Helium Initiating Valve (4)

Filter (2)

Regulator Shutoff Valve (4)

Regulator Assy (4)

Quad Check Valve (4)

Test Disconnect (24)

Pressure Relief Valve (4)

Propellant Tank (4)

Propellant Quantity Gage

Tank Vent Disconnect (4)

Bleed Disconnect (4)

Fill Disconnect (4)

Main Shutoff Valve (4)

Service Disconnect (4)

Isolation Valve (16)

Propellant Inlet Filter (16)

Cluster Assy Heater (Basic LEM)

Cluster Assy Heater (High Capacity) - New

Engine Cluster Assy (4)

II

I

Fig. 5.4-1 Reaction Control System



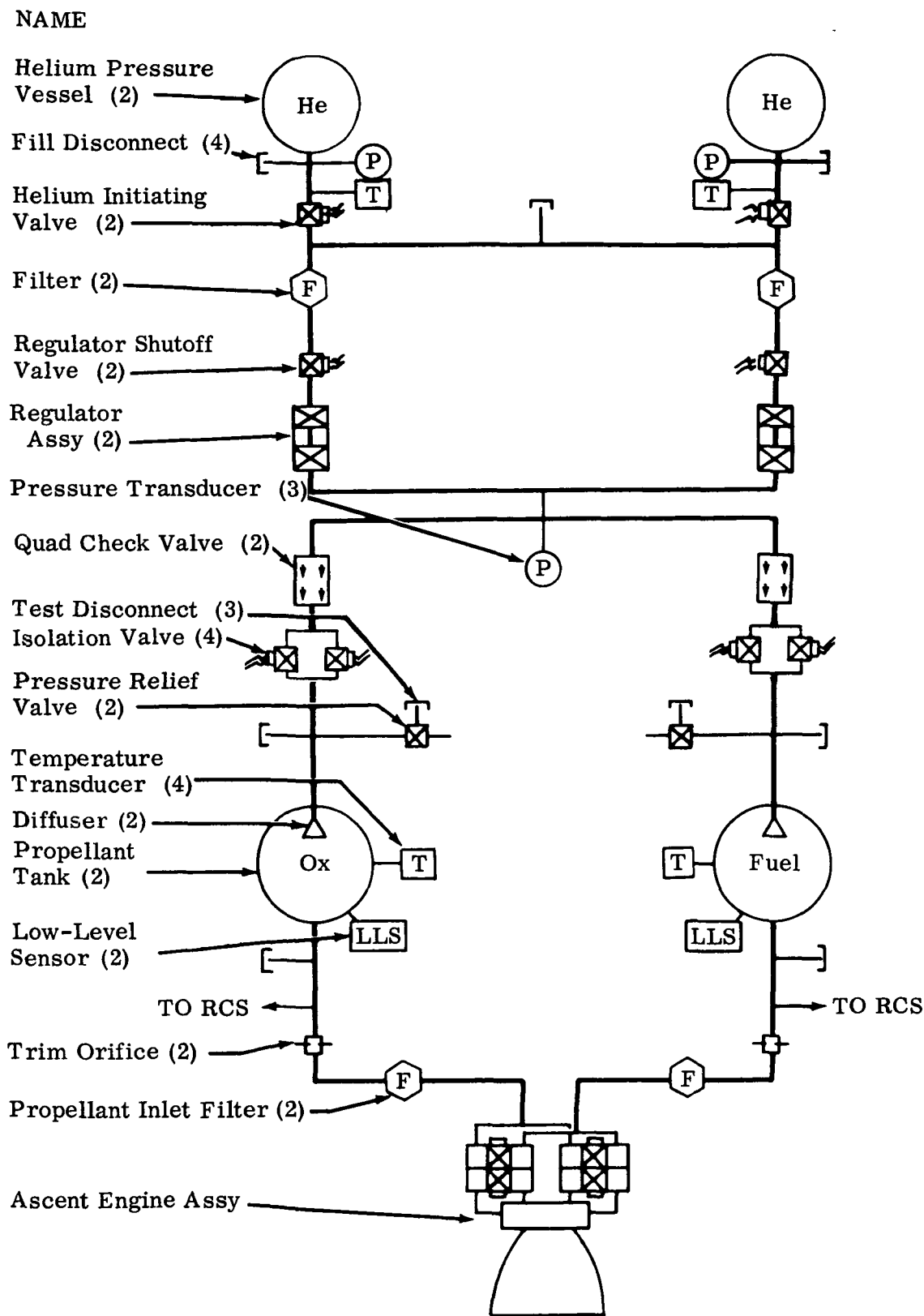


Fig. 5.4-2 Ascent Propulsion System

Legend

- | | | |
|-----------------------------|--------------------------------|----------------------------------|
| 1 Pressure Relief Valve (3) | 8 Heat Exchanger | 15 Diffuser (4) |
| 2 Fill Disconnect (3) | 9 Filter | 16 Propellant Tank (4) |
| 3 Pressure Transducer (2) | 10 Regulator Shutoff Valve (2) | 17 Temp Transducer (5) |
| 4 He Initiating Valve | 11 Regulator Assy (2) | 18 Low Level Sensor (4) |
| 5 Liquid Level Transducer | 12 Test Disconnect (9) | 19 Trim Orifice (2) |
| 6 Vent Disconnect (3) | 13 Quad Check Valve (2) | 20 Propellant Inlet Filter (2) |
| 7 He Pressure Vessel | 14 Vent Valve (3) | 21 Descent Engine Assy |
| | | 22 Low Pressure Relief Valve (2) |
| | | 23 Isolation Valve (4) |

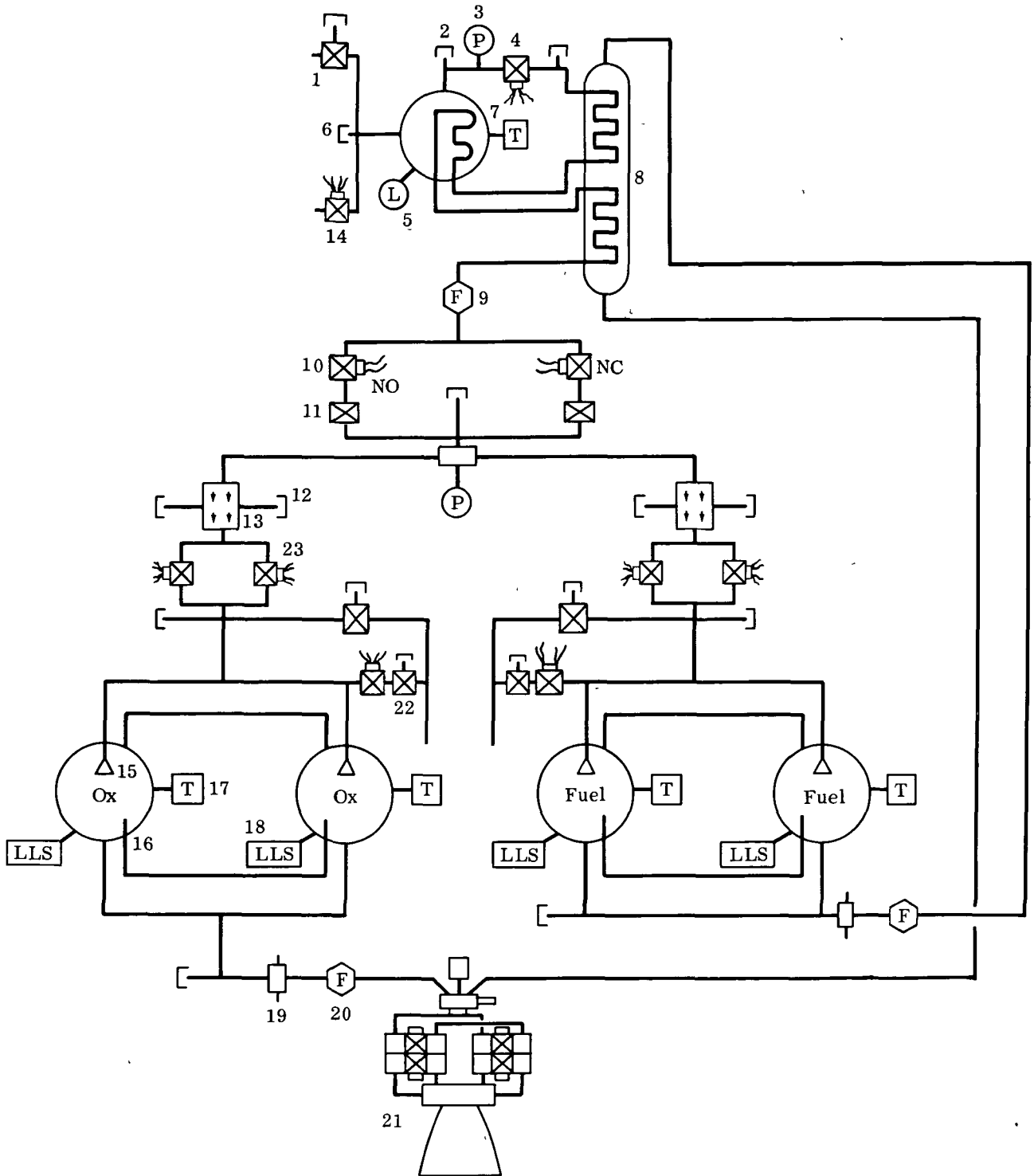


Fig. 5.4-3 Descent Propulsion System

5.5 COMMUNICATIONS

5.5.1 Ground Rules

There were no NASA ground rules unique to the Taxi Communications Subsystem.

5.5.2 Assumptions and Background Data

The Taxi Communication Subsystem requirements are the same as the present Apollo LEM except for the mission period between lunar touchdown and powered ascent from the lunar surface. The communication requirements during the surface mission are based on the following assumptions and background data:

- During the quiescent storage, Taxi status and warning data will be transmitted to Earth for relay to the Shelter
- There is to be no interference in S-band Earth transmissions between the Taxi, Shelter, CSM and experiment payloads
- There are no experiments carried on the Taxi; therefore, there will be no requirement for television or experiment data transmissions
- EVA communications will use the in-flight VHF antenna
- Taxi will land within 1,000 ft of the Shelter.

In addition, it has been assumed that the ground stations will provide real time voice communication with the three astronauts in the interval during which one astronaut is in each of the spacecrafts, ie., Taxi, Shelter and CSM. This voice link is independent of any relay capability between the spacecrafts. Ground capabilities will exist for the simultaneous reception, real time processing and/or recording of data transmitted from the CSM, Shelter, experiment payloads, and Taxi.

5.5.3 Recommended Configuration

The Taxi will use the present LEM Communications Subsystem with minor modifications as indicated in the subsystem block diagram, Fig. 5.5-1. The modifications are as follows:

- The erectable EVA sleeve dipole antenna is deleted. Communications between the EVA astronaut and the Taxi will be through the Taxi VHF in-flight antennas. The circuit performance margins will be equal to or greater than LEM because of the reduced range of operation (1,000 ft as compared to 3 n mi on LEM)
- A time sequencer has been added to the Taxi to control transmission of status data during the unmanned quiescent storage period. A transmission will be made every two hours for a period of seven minutes.
- The Taxi communication links are shown in Fig. 5.5.-2. The Taxi and Shelter will have different S-band frequencies allocated to prevent interference.

The S-band communication operational modes for the Taxi mission are shown in Figure 5.5-3. Circuit performance margins were determined for the Taxi during lunar storage. The analysis employed is that presently used on the LEM (LIS 380-15006). Bit rate is not yet finalized for status data and therefore margins for both high and low rates are presented. These margins are for the PM operational mode (Fig. 5.5-3). Transmission is via the S-band erectable antenna on the lunar surface and reception via the 210 ft diameter dish at the ground station.

The Circuit performance margins are listed in Table 5.5-1, as db above the signal-to-noise system requirements.

5.5.4 Baseline Configuration

The baseline configuration is essentially identical to the recommended configuration.

5.5.5 Alternate Configuration

Since the Taxi Communication Subsystem (including antennas) is identical to the LEM, the only alternate studied is directed towards removing the requirement for new S-band frequencies. Two alternate configurations were considered:

- Time sharing transmissions on the same frequency
- Right and left circular polarization of Taxi and Shelter antennas.

Time sharing transmissions is not an attractive selection, since the possibility of interference exists because of the automatic operation of status transmissions from the Taxi, and the operation is not as versatile as independent frequency allocations for each spacecraft.

The technique of utilizing right and left circular polarization of the Taxi and Shelter S-band antennas is based on the fundamental electromagnetic wave property that no radiation interference (pattern distortion) or crosstalk occurs when two perfectly circular polarized space waves, with opposite rotation senses, interact. The waves are essentially invisible to each other. The approach intended is to assign different polarization senses to the Shelter and Taxi which already utilize circularly polarized antennas.

A preliminary analysis of available data and research along with some basic calculations indicated that the polarization allocation technique is definitely feasible. Further study, and possibly experimentation, is required in areas, such as described below:

- Ground Station Receiving Antenna - The feed for this antenna must be capable of receiving both circularly polarized waves of opposite rotation sense simultaneously with a minimum of cross talk. The development of the required antenna feed is well within the state of the art. Actually, such a feed has already been developed (Ref. 1) and is assumed to be in operation at the present time. This feed was developed for JPL and intended for use on their 85 foot diameter dish antenna for certain radio-astronomy applications. This feed receives both polarized waves and separates them into two outputs. The feed exhibited -50 db coupling between the output parts and -40db ellipticity.
- Shelter/Taxi Transmitting Antennas - These must have good circularity on, and a little about, their axes (Earth subtends an angle of 1.7° deg at lunar distance). Ellipticity will contribute to crosstalk. The S-band erectable antenna intended for use on the lunar surface, and the S-band steerable antennas appear to satisfy this on-axis requirement (actual data is not available at this time).

- Faraday Rotation - Circularity of the Earth incident wave may be affected by Faraday rotation which occurs because of the inhomogeneity of the Earth's atmosphere and the wave interaction with the Earth's magnetic field. This problem is difficult to define because available data based on lunar reflected signals is sparse. For frequencies above 100 mc, a magnetic-ionic theory (Ref. 2) has shown that polarization shift is inversely proportional to frequency and consequently at S-band is expected to be small. Other earlier work (Refs. 3,4,5) tends to verify that the Faraday rotation effect would be negligible at S-band.

5.5.6 Potential Modifications per Flight

There were no per flight modifications considered for the Taxi communications subsystem.

REFERENCES:

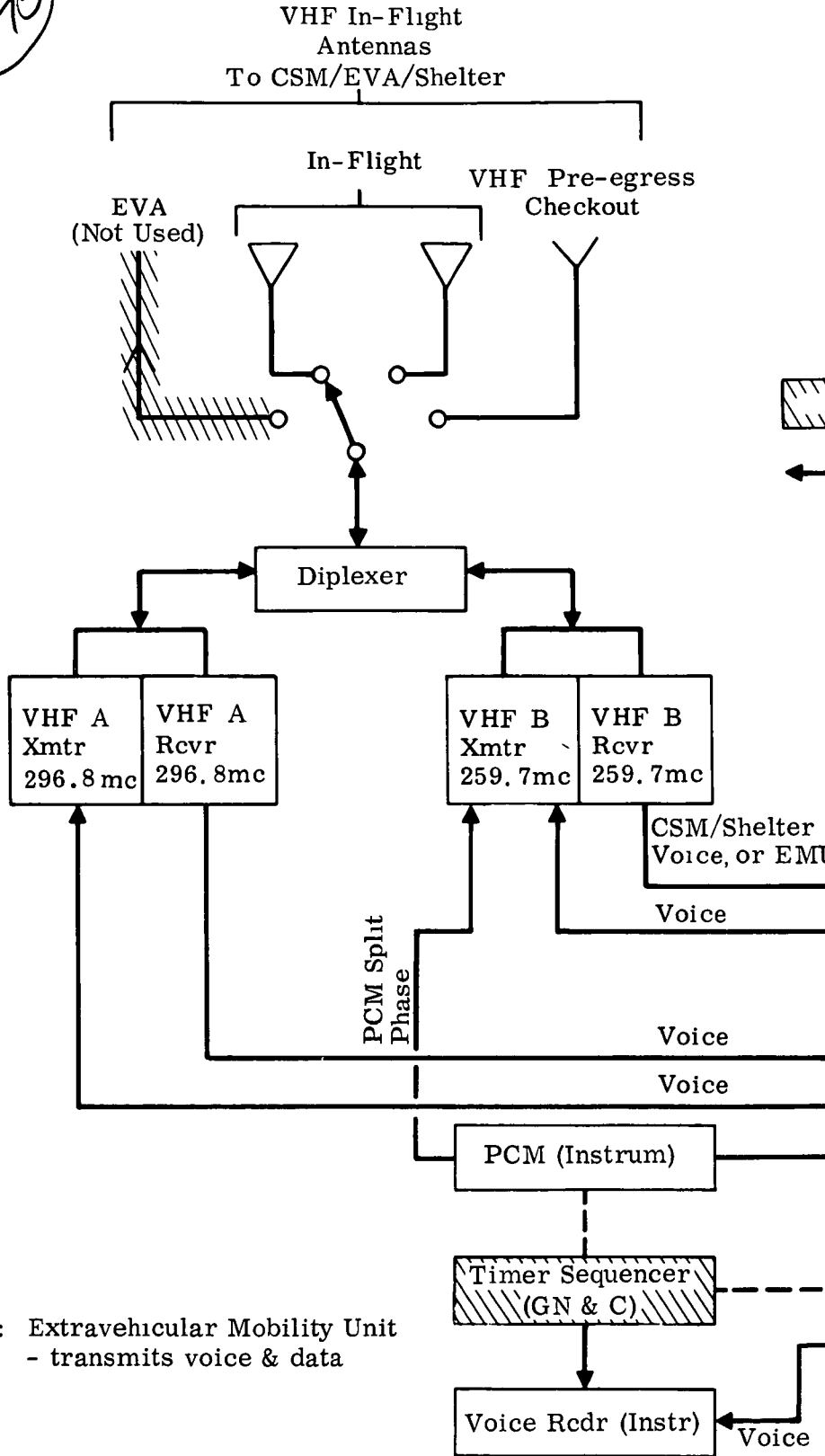
- 1) "Feed System for Clockwise and Counter-clockwise Circular Polarization" PGAP Communication Section, November 1961.
- 2) "Lunar Radio Echoes and the Faraday Effect in the Ionosphere" Nature, May 15, 1954.
- 3) "Scattering Behavior of the Moon at Wavelength of 3.6, 68, and 784 Centimeters" Journal of Geophysical Research, January 1963
- 4) "Radio Measurements of the Lunar Surface", The Man, IAG Symposium 14, 1962
- 5) "Propagation and Communication Problems in Space" Proceedings of the IRE, April 1960.

Table 5.5-1

PCM S-BAND CIRCUIT PERFORMANCE MARGINS

Data Rate, k-bits/sec	Power Output			
	20 watts		0.75 watt	
	C/N, db	Margin, db	C/N, db	Margin, db
51.2	+49	+28	+32	+11
1600	+52	+41	+35	+24

13



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

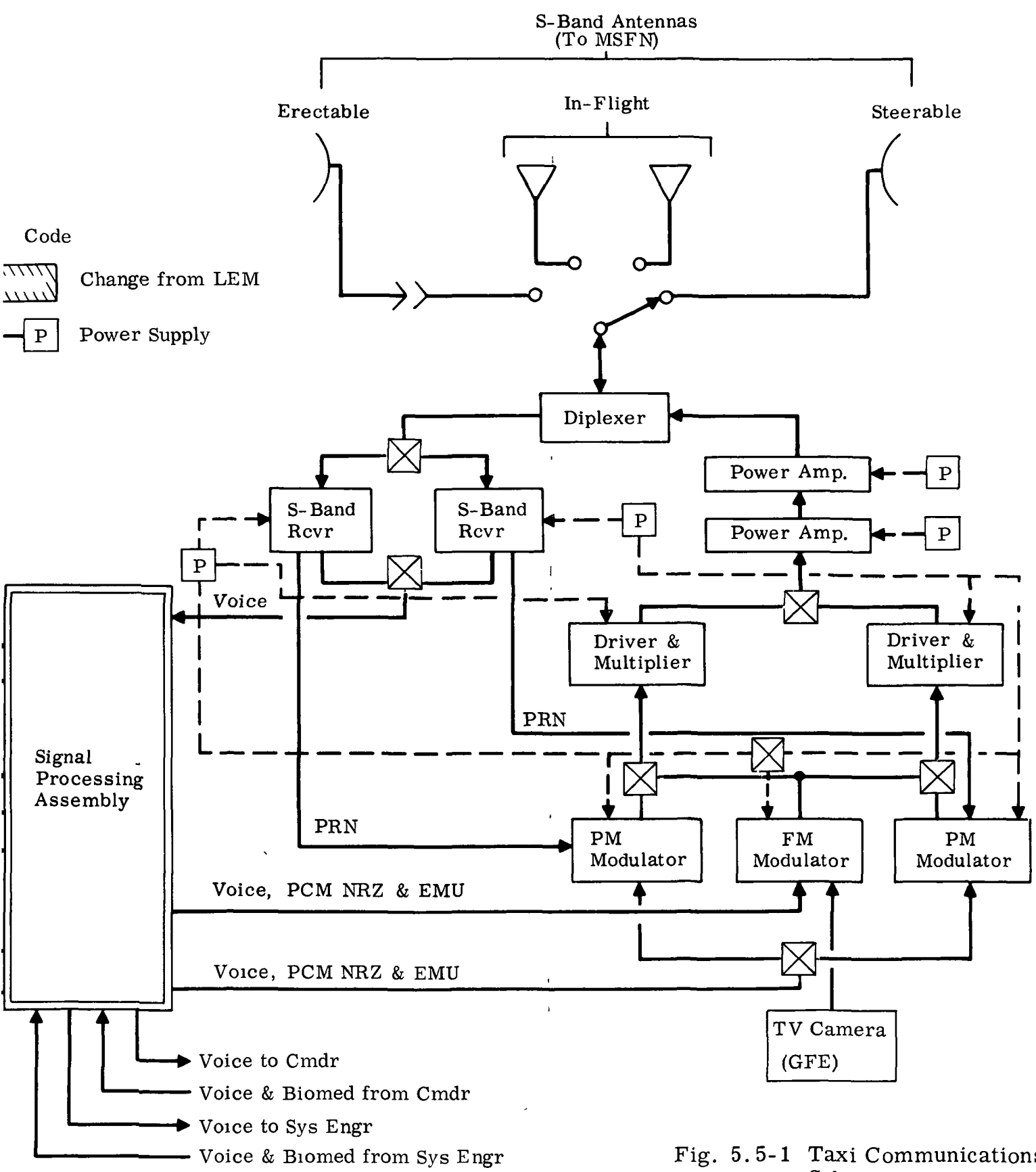
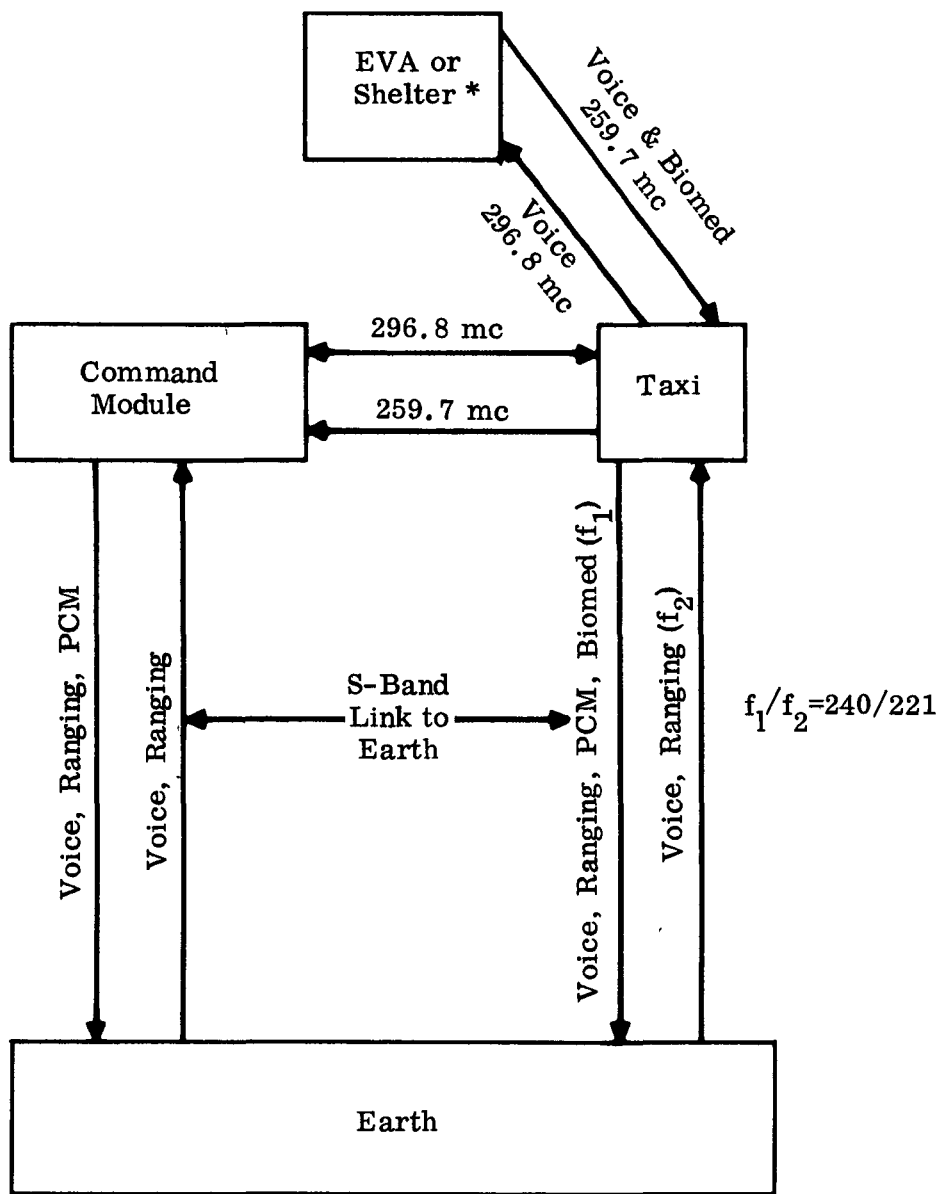
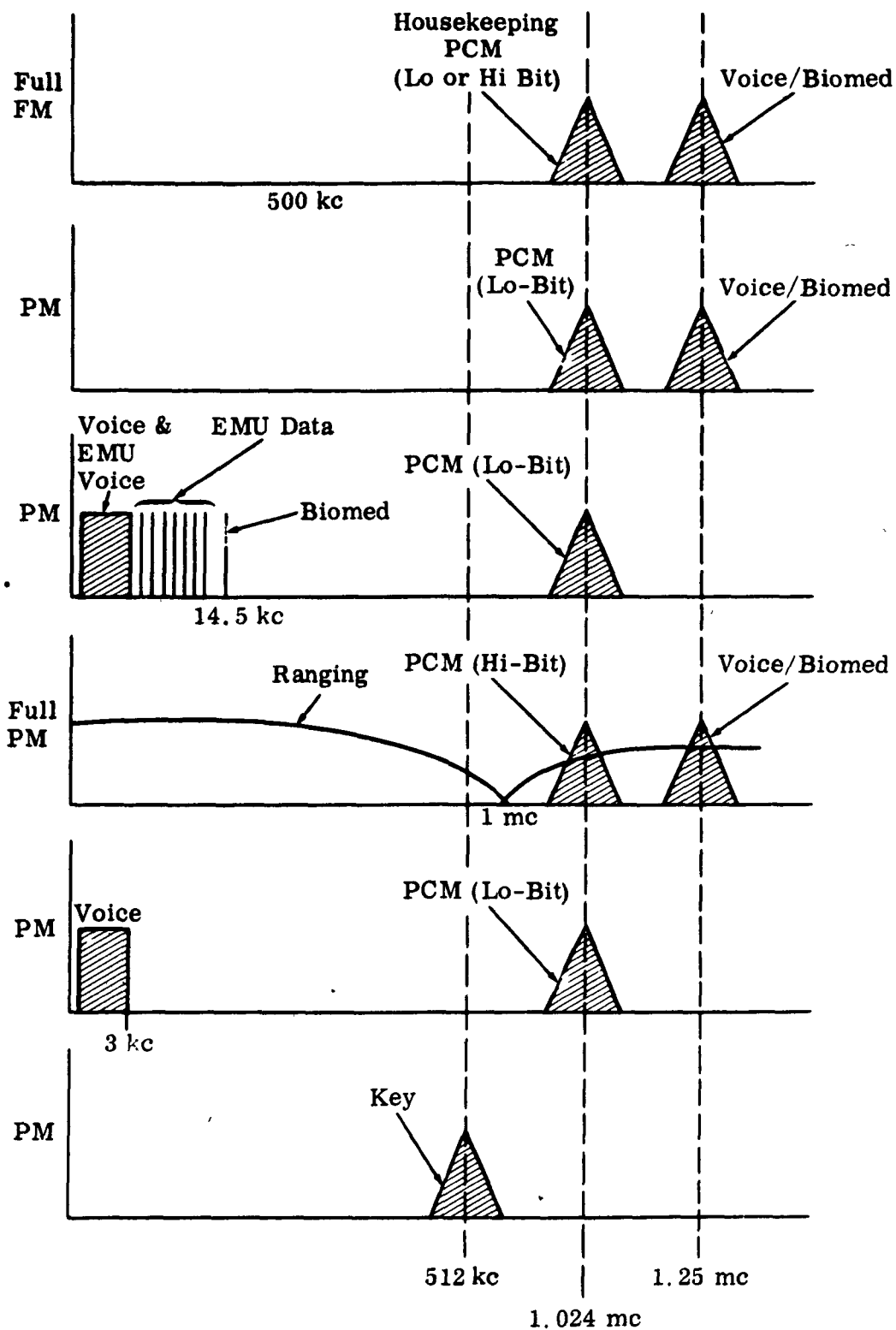


Fig. 5.5-1 Taxi Communications Subsystem



* Only when Taxi is manned.

Fig. 5.5-2 Taxi Communications Links.



Hi bit = 51.2 kilo bits per second
Lo bit = 1.6 kilo bits per second

Note:
Where Lo-Bit Rate is
Indicated, the Hi-Bit
Rate May be Substituted.

Fig. 5.5-3 S-Band Operational Modes

5.6 INSTRUMENTATION

5.6.1 Ground Rules

There were no NASA ground rules unique to the Taxi Instrumentation Subsystem.

5.6.2 Assumptions and Background Data

The primary function of the operational spacecraft instrumentation section is to acquire and present spacecraft housekeeping data to the astronauts and ground monitoring personnel. In reviewing the measurement requirements of the Taxi, it was concluded that the existing LEM equipment would continue to fulfill this task. The following assumptions were used in standardizing an approach for the operational spacecraft data acquisition section of the Taxi:

- The Taxi will continue to utilize the existing LEM PCM for operational data.
- The Taxi will adapt the existing LEM vehicle measurements for operational data and any additions due to changes in configuration.
- Any changes in the operational measurements will not exceed the present LEM measurements for the lunar landing mission.
- Maximum utilization of the crew for redundancy monitoring and failure mode corrections/operations will be used.
- Safety data will also be carried as vehicle operational data.

5.6.3 Recommended Configuration

The recommended operational instrumentation section for the Taxi (Fig. 5.6-1) consists mainly of existing LEM assemblies or components. The existing LEM assemblies have certain built-in flexibility which allows for some minor configuration changes. This flexibility lies primarily with the plug-in modular concept of the Signal Conditioning Electronics Assemblies (SCEA) and the input channel interchangeability to the Pulse Code Modulation (PCM) and the Caution and Warning Electronics Assembly (C&WEA). The measurement list prepared for the Taxi (Table 5.6-5) was reviewed and analyzed to assure that the changed support requirements would still be adequately covered using the existing LEM system. A power and weight summary of the recommended configuration appears in Table 5.6-1.

5.6.3.1 Transducers

The transducers convert the physical and electrical phenomena of interest into a usable form for presentation to the astronauts or ground station personnel. These measurements from the various subsystems provide the majority of the input sources to the operational acquisition system.

If new spacecraft subsystem measurement requirements demand additional transducers, consideration will be given first to LEM proven units. To date, it is felt that the transducers available from the LEM program are capable of making the new measurements identified for the Taxi. These are associated with the RTG heat pipe and the time sequencer used during the quiescent storage.

A summary of the parameters to be measured on the Text appears in Table 5.6-2. Allocated transducer weight and power consumption is listed on the enclosed measurements list (Table 5.6-5).

5.6.3.2 Signal Conditioning Equipment

The Signal Conditioning Electronics Assembly (SCEA), as presently designed for LEM, is a unit which conditions the signals from transducers and numerous signal monitoring points throughout the spacecraft and properly routes them to the Pulse Code Modulation and Timing Electronics Assembly (PCMTEA), Caution and Warning System (C&WEA), or on-board displays. The SCEAs fulfill the following basic functions:

- Act as a junction and routing assembly for all analog measurements and signals being monitored.
- Structurally supports the signal conditioning sub-assemblies which condition the measurement input signals.

The SCEA consists of two separate chassis assemblies. Each assembly can accommodate up to twenty-four separate sub-assembly modules. The Taxi measurements list (Table 5.6-5) reflects the existing LEM measurements and the addition of new measurements required for the Taxi. A review of this listing indicates that the changing measurement requirements can still be accommodated within the existing SCEA using adaption techniques presently employed by LEM. Based on the measurements summarized in Table 5.6-2, it is anticipated that there will be no modification to the assembly, as now used by LEM, or its sub-assemblies. The units, however, will require rewiring of the input-output routings and a new configuration of sub-assemblies to place the quiescent storage status measurements on the same SCEA.

5.6.3.3 Caution and Warning Equipment

This assembly advises the astronauts of the spacecraft subsystem status by continually monitoring critical parameters. During the mission, the C&WEA performs two basic functions:

- The caution function advises the astronaut of a malfunction requiring his corrective action
- The warning function advises the astronaut of crew safety items requiring immediate action.

The C&WEA accepts inputs from the SCEA or pre-conditioned signal sources from the subsystems. These inputs are compared to preset reference signals within the C&WEA to detect out-of-tolerance conditions. When an out-of-tolerance condition exists, an appropriate indication is initiated. The C&WEA, as now used for the lunar landing LEM, operates on discrete voltage changes or switch closures. The analog input channels have preset limits. This unit will continue to support the Taxi requirements in its present configuration.

5.6.3.4 Pulse Code Modulation and Timing Equipment

The PCMTEA consists of an unmodified lunar landing LEM assembly. The data acquisition capability of this unit includes the multiplexing, encoding, and timing of high-level analog, parallel digital, and serial digital data. The number of channels, sampling rates, and word length for each of the three data forms are presented in Table 5.6.4. The unit operates at a normal data rate of 51,200 bits per

second and a reduced data rate, commanded remotely, of 1,600 bits per second. The PCMTEA will operate as it does in the lunar landing LEM, including accepting a time reference from the LEM Guidance Computer and providing various timing signals to interfacing subsystems. The NRZ(C) data output is routed to the communications system for real time transmission.

5.6.3.5 Voice Storage Recorder

This magnetic tape recorder, originally referred to as the "Data Storage Equipment Assembly", provides a time correlated voice recording of comments and conversation between the astronauts during EVAs. This assembly employs automatic sequential record head switching with four tracks to provide up to a total of ten hours of recording time. The compact recorder is generally used with voice actuation circuits to run only for a required recording time. The recorder is used to:

- Support egress from CM to Taxi
- Support EVA's
- Record comments of vehicle status when off station coverage
- Record proprietary information.

5.6.3.6 Status Bus

During the quiescent storage period of the Taxi, limited data will be transmitted to monitor critical spacecraft data and to advise ground personnel of active readiness of the vehicle. During this period, the ground personnel will monitor the Taxi and advise the astronauts (now in the Shelter) of the status of their return vehicle. The "status system" uses reduced power and gathers only chosen information as indicated on the measurements list (Table 5.6-5). The limited portion of the operational system which will be activated is as follows:

- Transducers associated with the status monitoring requirements will receive their power through a separate feed.
- Only one signal conditioning electronics assembly will receive power for status monitoring.
- Pulse Code Modulation and Timing Electronics Assembly will be used during the transmission periods only.

A configuration of the status bus power distribution is shown in Fig. 5.6-2, and an electrical power usage summary is shown in Table 5.6-1. It should be noted that the caution and warning system, the voice storage recorder and approximately half the transducers and signal conditioners are off during the storage period.

5.6.3.7 Sequencer Commanded Items

During the lunar quiescent storage period, there will be a manually selected sequence started by the astronauts. This sequence will allow for periodic power-on cycles to energize the instrumentation status bus described above. The sequencer assembly will be energized prior to egress along with the de-activation of the Caution and Warning System and the voice recorder. The sequencer controlled items appear in Fig. 5.6-3, and the reduced power status system is described in Fig. 5.6-2. Upon the return of the astronauts to the Taxi, this sequencer will be deactivated, the C&WEA and voice recorder activated, and normal Taxi functions resumed.

5.6.3.8 Operational Measurements

The measurement requirements for the Taxi are shown in Table 5.6-5. A summary of these measurements is found in Table 5.6-2, which reflects the various types of instrumentation required and the quantities requested for each of the Taxi subsystems. These measurements support the Taxi performance and management plus provide sufficient information to:

- Enable normal spacecraft operations to be performed
- Provide the capability for decision making by the astronaut
- Monitor crew safety functions
- Provide status of expendable items
- Provide status of operational events.

An Apollo biomedical system supports EVAs by monitoring such items as electrocardiograms and impedance pneumograms (respiration) with associated power converters, vest, harness and electrodes. This information is transmitted via the VHF link to the CM or Taxi for re-transmission to Earth. During the on-board stay, however, only the electrocardiogram is monitored for transmission to Earth (hard-wired).

5.6.4 Baseline Configuration

The baseline configuration used for the Taxi is the same as the recommended configuration as described above.

5.6.5 Alternate Configuration

There were no alternate configurations studied, because the existing LEM system can satisfactorily perform all the described tasks.

5.6.6 Potential Modifications Per Flight

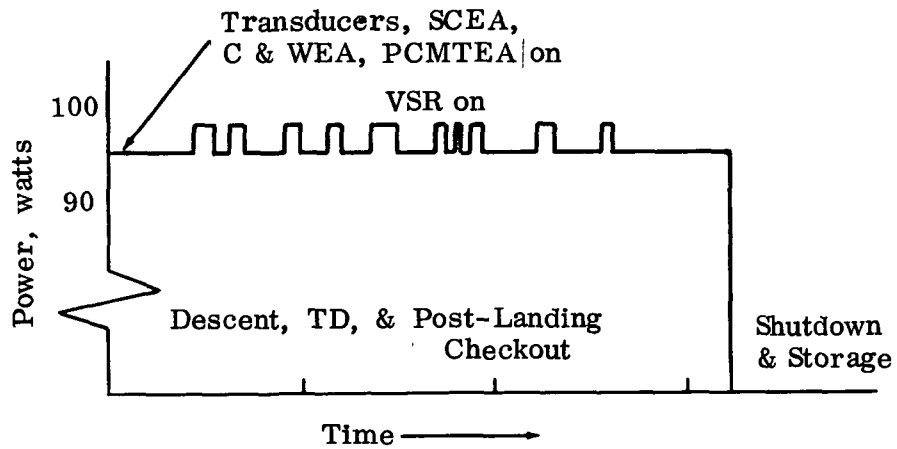
No per flight modifications are envisioned for the Taxi based on a review of existing measurement requirements and the capabilities of the existing system.

Table 5.6-1

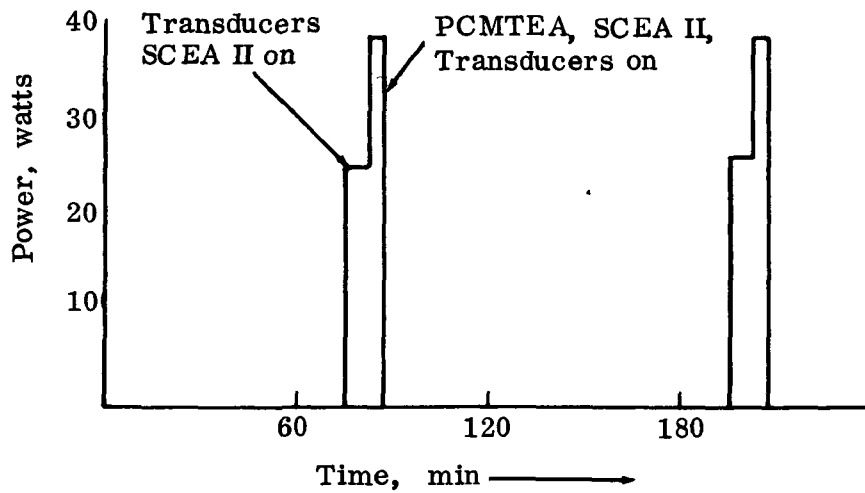
INSTRUMENTATION WEIGHT & POWER SUMMARY

Assembly	Transducers	SCEA-I	SCEA II	C& WEA	PCMTEA	VSR	Total
Operat'l Pwr, watts	15.8	22.9	21.5	22.0	12.9	2.3	97.4
Status Pwr, watts	3.9	N/A	21.5	N/A	12.9	N/A	38.3
Weight, lb	19.0	42.6	43.1	25.0	37.0	2.5	179.2

Operational Mode



Status Mode During Quiescent Storage



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OPERATION

Parameter Subsystem	Acceleration	Phase	Current	Vibration	Power	Frequency	Force	Position	Biomedical	Radiation	Velocity	Mass
Structures												
Thermodynamics												
Electrical Power			6			1						
Environ Control												
Nav & Guid		1	2					1			3	
Radars					6	9		6			4	
S & C - CES												
S & C - AGS												
Instrumentation						2						
Propulsion - Ascent												
Propulsion - Descent								2				
Reaction Control												
Communications		1	2		4			2	2			
Pyrotechnics												
Totals		2	10		10	12'		11	2		7	

ole 5.6-2
AL MEASUREMENT SUMMARY

Res./Cont.	Pressure	Quantity	Rate	Strain	Temperature	Combination	Voltage	Time	Discrete	Acoustic	Ph-Acidity	Undefined	Stimuli	Total S/S	Measurements	Measurements Usage		
																TM Total	C&W & DISP	Prelaunch C/O
					3	1			8						12	4	1	1
					2										2	2		
					6		11		25						49	37	46	37
	17	6	2		16	5	16		28						90	55	38	64
					5		73		15						100	45	16	84
			4				54		15			11			109	11	22	81
							67		27			4			98	56	32	83
					1		23		2			23			49	6	22	25
					8	5	2	41				8			66	15	49	20
	14				4	2			8						28	15	16	20
	8				5	4			14						33	19	14	21
	32	8			10	13	16		32						111	45	71	61
							9		3			11			34	5	4	24
2							10		7						19	5		9
2	71	14	6		52	33	284	2	225			57			800	320	331	530

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	SCEA Subassembly					
	502-2	502-3	503-2	503-3	504-1	504-2
Total Measurement Circuits	23	2	4	1	26	2
Circuits/Subassy	4	4	3	3	4	1
Quantity of Subassys Req'd	7	1	2	1	7	
No. of Spare Circuits	5	2	2	2	2	
ERA No. 1	5	1	2	-	5	
ERA No. 2	2	-	-	1	2	

Table 5.6-3
CEA SUMMARY

Type LSP-360-								
504-2	504-3	504-4	504-5	505-1	506-2	507-1	509-1	TOTAL
20	30	51	43	1	41	8	4	254
0	12	12	12	3	4	4	4	N/A
2	3	5	4	1	11	2	1	47
-	6	9	5	2	3	-	-	38
2	-	-	-	-	5	2	1	23
-	3	5	4	1	6	-	-	24

Table 5.6-4

PCMTEA INPUT DATA CAPABILITY

Data Format: 51,200 bits/sec Output Rate				
Data Form	No. Channels	samples/sec	bits/word	words/sec
Analog - High Level	5	200	8	1000
	17	100	8	1700
	6	50	8	300
	35	10	8	350
	137	1	8	137
Digital - Parallel	1	200	16	400
	3	100	8	300
	4	50	8	200
	1	10	8	10
	37	1	8	37
Digital - Serial	1	50	40	250
	1	50	24	150
Total	248			4834
Partial Format: 1,600 bits/sec Output Rate				
Analog - High Level	59	1	8	59
Digital Parallel	15	1	8	15
<p>Note: The low bit rate format of the LEM PCMTEA is presently undergoing design changes. The input capability presented here is incomplete and will be expanded when the design is finalized.</p> <p>* Normalized to 8 bit words.</p>				

Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 2					
BASELINE TAXI		NOVEMBER 8, 1965					
ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES		FREQUENCY A DSY	XDCR RANGES	OR C NTP XDCR XDCR	REFERENCES OR NOTES
		LOW	HIGH				
E0021-B							
E-MODULE CODE							
	A-ADAPTER	H-LEM SHELTER		P-LUNAR ORBIT LAB.			
	B-BOOSTER	J-STIMULI		S-SERVICE EQUIPMENT			
	C-COMMAND MODULE L-LAUNCH ESCAPE SYS. T-LEM TAXI						
	E-EARTH ORBIT LAB	M-LEM TRUCK		Y-GROUND TEST ARTICLE			
	G-LEM	N-GSE EQUIPMENT					
L-FUNCTIONAL SUBSYSTEM CODE							
	A-STRUCTURES	I-STAB/CONTROL-AGS		R-REACTION CONTROL			
	B-THERMODYNAMICS	L-INSTRUMENTATION		T-COMMUNICATIONS			
	C-ELECTRICAL POWER	M-MECHANICAL DESIGN		Y-PYROTECHNICS			
	F-ENVIRON CONTROL	N-RADARS		X-EXPERIMENTS			
	G-NAV. AND GUIDANCE	P-PROPULSION A/S					
	H-STAB/CONTROL-CES	Q-PROPULSION D/S					
0021-IDENTIFICATION NUMBER (BY SUBSYSTEM)							
B-MEASUREMENT CLASSIFICATION CODE							
	A-ACCELERATION	J-BIOMEDICAL		S-STRAIN			
	B-PHASE	K-RADIATION		T-TEMPERATURE			
	C-CURRENT	L-VELOCITY		U-COMBINATION MEAS.			
	D-VIBRATION	M-MASS		V-VOLTAGE			



Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 3				
BASELINE TAXI		NOVEMBER 8, 1965				
ID	MEASUREMENT	FREQ A S S B G O M H C F A X	XOCR	FREQ A O S Y	REFERENCES	
CODE	NAME AND LOCATION	LOW NORM HIGH UNIT	RATE	C R S G T D S C S L W L D X	OR C NTP XOCR XOCR	OR NOTES
	E-POWER	N-RESIST/CONTINUITY W-TIME				
	F-FREQUENCY	P-PRESSURE	X-DISCRETE EVENT			
	G-FORCE/MECH.IMPED.	Q-QUANTITY	Y-ACOUSTICAL			
	H-POSITION	R-RATE	Z-PH-ACIDITY			
	MEASUREMENT					
	NAME AND LOCATION					
	DESCRIBES THE MEASUREMENT TO BE OBTAINED AND ITS LOCATION, STATED BRIEFLY.					
	INTEREST					
	RANGES					
	LOW NORM HIGH UNIT					
	MINIMUM, NORMAL AND MAXIMUM MEASURAND RANGE EXPECTED AND ITS ASSOCIATED UNITS.					
	FREQ					
	OR					
	RATE					
	REALISTIC RECOVERABLE RESPONSE RATE REQUIRED (IN CPS)					
	ACC					
	REALISTIC RECOVERABLE END-TO-END SYSTEM ACCURACY IN PERCENT FULL SCALE.					

Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 4	
BASELINE TAXI		NOVEMBER 8, 1965	
ID	MEASUREMENT	FREQ A S S B G D M H C F A X	XDCR
CODE	NAME AND LOCATION	OP C C / I I R P C S / / / X	RANGES OR C NIP XDCR
		LOW NORM HIGH UNIT RATE C R S G T D S C S L W L D X	LOW HIGH RATE C DGE -PWR WT.
SCR	INTEREST	C T	REFERENCES H
	RANGES	FREQ A DSY	OR N
	LOW NORM HIGH UNIT RATE C R S G T D S C S L W L D X		NOTES G
	TRANSUCER PROCUREMENT SOURCE CODE.		
	S-SUBCONTRACTOR		
	I-INSTRUMENTATION		
	G-GROUND SUPPORT EQUIPMENT		
	N-NASA(GFE) GOVERNMENT FURNISHED EQUIPMENT.		
S/S	NUMBER OF SAMPLES PER SECOND.		
SIG	FORM AND LEVEL OF SIGNAL TO THE PCM EQUIPMENT.		
	L-LOW LEVEL ANALOG (0-40MV) P-PARALLEL DIGITAL (0 OR 5V)		
	H-HIGH LEVEL ANALOG (0-5V) E-DISCRETE EVENT (0 OR 5V)		
	S-SERIAL DIGITAL (0 OR 5V)		
BIT	NUMBER OF BITS PER SAMPLE.		
GRD	INDICATES THOSE MEASUREMENTS REQUIRED FOR FACTORY TEST OR CHECKOUT.		
	A-FACTORY C/D, NON-ACE MONITERED.		
	B-FACTORY C/D, ACE MONITERED.		



Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 5	
BASELINE TAXI		NOVEMBER 8, 1965	
INTEREST		FREQ A S S B G O M H C F A X XDCR FREQ A O S Y	
RANGES		OR C C T I R P C S / / / X RANGES OR C N I P XDCR XDCR	
LOW NORM HIGH UNIT RATE C R S G T D S C S L W L D X LOW HIGH RATE C DGE -PMR WT.		OR	
ID	MEASUREMENT	REFERENCES	M
CODE	NAME AND LOCATION	NOTES	G
DPS			
INDICATES THOSE MEASUREMENTS REQUIRED FOR PRELAUNCH CHECKOUT			
1--PRELAUNCH C/O, NON-ACE MONITERED.			
2--PRELAUNCH C/O, ACE MONITERED.			
INDICATES THAT THE TELEMETED MEASUREMENT IS REQUIRED BY THE			
MANNED SPACE FLIGHT NETWORK FOR REAL TIME DISPLAY(R).			
MCC			
INDICATES THOSE MEASUREMENTS REQUIRED DURING STORAGE PERIOD.(S)			
MSS			
ASSIGNMENT OF MEASUREMENT			
H--HIGH BIT RATE (51.2K BITS/SEC) TELEMETED SIGNAL.			
L--LOW BIT RATE (1.6K BITS/SEC) TELEMETED SIGNAL.			
X--INDICATES ON-BOARD RECORDING.			
*--NOT TELEMETED DIRECTLY, USED TO FORMULATE THE MEASUREMENT			
LISTED IN THE ADJACENT NOTES COLUMN.			
C/W			
INDICATES AN INPUT TO A CAUTION(IC) OR WARNING(W) LAMP.			

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Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 6	
BASELINE TAXI		NOVEMBER 8, 1965	
ID	MEASUREMENT	FREQ A	OSY
CODE	NAME AND LOCATION	OR C	NIP
	LOW NORM HIGH UNIT RATE	XDCR	XDCR
		RANGES	XDCR
		LOW HIGH	WT.
			NOTES
F/L	INTEREST RANGES		
	INDICATES AN ADVISORY FLAG(F)OR LIGHT(L).		
A/D	INDICATES AN INPUT TO AN ANALOG(A)OR DIGITAL(D)DISPLAY.		
XXX	TIME SHARED SWITCHING CODE 1-9		
XDCR			
RANGES			
LOW HIGH			
	SELECTED OR ALLOCATED TRANSDUCER RANGE.		
FREQ			
OR			
RATE	ALLOCATED EQUIPMENT RESPONSE CAPABILITY.		
ACC	END-TO-END SYSTEM ACCURACY EXPRESSED IN PERCENT FULL SCALE OF		
	ALLOCATED RANGE.		



Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983 BASELINE TAXI		PAGE NUMBER 7 NOVEMBER 8, 1965		C T										
ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	LOW NORM HIGH UNIT RATE	FREQ A OR C	S S B G O M H C F A X	XDCR RANGES	OR C NIP	OR C NIP	XDCR XDCR	XDCR XDCR	DGE	WT.	REFERENCES OR NOTES	
C T														
USY														
NIP														
DGE														
SIGNAL CONDITIONING TYPE OF UNITS REQUIRED.														
1-1 REFERS TO SIGNAL CONDITIONER LSP-360-501-1														
1-2 REFERS TO SIGNAL CONDITIONER LSP-360-501-2														
XDCR														
-PWR														
POWER REQUIREMENT FOR TRANSDUCER (IN WATTS)														
XDCR														
WT.														
WEIGHT OF TRANSDUCER ONLY.														
-WEIGHT IN POUNDS (UNMARKED)														
Z-WEIGHT IN OUNCES														
REFERENCES														
OR														
NOTES														
AVAILABLE SPACE FOR REFERENCES OR NOTES.														
CHNG														
REFLECTS LATEST MODIFICATION CODE.														

Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW NORM HIGH UNIT	CONTACT CLOSURE	S S I	*	STRUCTURES											REFERENCES OR NOTES					
						FREQ A	S S B	G D M	C F A X	XDCR	FREQ A	DSY	OR C	NIP	XDCR	XDCR		OR C	DGE	WT.		
TA0041-X	LAND GEAR -Y,LS DEPLOY LK	CONTACT CLOSURE	SS	I																	TA5000	
TA0042-X	LAND GEAR -Y,RS DEPLOY LK	CONTACT CLOSURE	SS	I	*																	TA5000
TA0043-X	LAND GEAR -Z,LS DEPLOY LK	CONTACT CLOSURE	SS	I	*																	TA5000
TA0044-X	LAND GEAR -Z,RS DEPLOY LK	CONTACT CLOSURE	SS	I	*																	TA5000
TA0045-X	LAND GEAR +Z,LS DEPLOY LK	CONTACT CLOSURE	SS	I	*																	TA5000
TA0046-X	LAND GEAR +Z,RS DEPLOY LK	CONTACT CLOSURE	SS	I	*																	TA5000
TA0047-X	LAND GFAR +Y,LS DEPLOY LK	CONTACT CLOSURE	SS	I	*																	TA5000
TA0048-X	LAND GEAR +Y,RS DEPLOY LK	CONTACT CLOSURE	SS	I	*																	TA5000
TA0064-T	TEMP 1,+Z LEG PRI STRUT	32 500 DEGF	SS	II	I	H										0	500	SS	6-2	0	.13	
TA2001-T	TEMP 1,HEAT SHIELD D/S	0 2000 DEGF	SS	III	I	H										0	2500	SS	9-1	0	.16	
TA2002-T	TEMP 2,HEAT SHIELD D/S	0 2000 DEGF	SS	III	I	H										0	2500	SS	9-1	0	.16	
TA5000-U	LAND LEGS DEPLOYED	CONTACT CLOSURE	SS	I	III	BB	2	RR	HH	FF								SS	4-4	0	1.00	



Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	LOW	NORM	HIGH	UNIT	THERMODYNAMICS		FREQ A S S R G O M M H C F A X OR C / I I R P C S / / X	XDCR RANGFS	FREQ A O S Y OR C N I P XDCR XDCP	C T	PAGE NUMBER NOVEMBER 8, 1965	9	REFERENCES PR NOTES
						INTEREST RANGES	DR C P S G T D S C S L W L D X LOW HIGH RATE C DGF -PWP WT.							
T83712-T	TEMP,RR RADAR ANTENNA	-250		+500	DEGF	SS	2 I I H 8		-250+500	SS	9-1	0	.25	
T83716-T	TEMP,LAND RADAR ANTENNA	-250		+500	DEGF	SS	2 I I H 8		-250+500	SS	9-1	0	.25	

Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	LOW NORM	UNIT	HIGH	ELECTRICAL POWER										XOCR RANGES	XOCR HIGH	XOCR -PWR	WT.	REFERENCES OR NOTES
						FREQ A	S S	B G	M C	F A	X C	F A	X C	FREQ A	OSY					
TC0071-V	VOLTAGE, INVERTER BUS	105 115	125	VRMS	SS	5 S	I H	B B	2 R	SL	C A	0	130	SS	3-3	---	---	TL4046		
TC0155-F	FREQ, INVERTER BUS	390 400	410	CPS	SS	5 S	I H	B B	2 P	SL	C	380	420	SS	5-1	---	---	TL4046		
TC0201-V	VOLT, BATT. DESCENT NO.1	20 28	40	VDC	SS	5 S	I H	B B	2	SL	A	0	40	SS	2-2	---	---			
TC0202-V	VOLT, BATT. DESCENT NO.2	20 28	40	VDC	SS	5 S	I H	B B	2	SL	A	0	40	SS	2-2	---	---			
TC0203-V	VOLT, BATT. DESCENT NO.3	20 28	40	VDC	SS	5 S	I H	B B	2	SL	A	0	40	SS	2-2	---	---			
TC0204-V	VOLT, BATT. ASCENT NO.1	20 28	40	VDC	SS	5 S	I H	B B	2	SL	A	0	40	SS	2-2	---	---			
TC0205-V	VOLT, BATT. ASCENT NO.2	20 28	40	VDC	SS	5 S	I H	B B	2	SL	A	0	40	SS	2-2	---	---			
TC0301-V	VOLT COMMANDER'S BUS	20	40	VDC	SS	4 S	I H	B B	2 R	L	A	0	40	SS	2-3	---	---			
TC0301-V	VOLT COMMANDER'S BUS	26.5		VDC	SS						C			SS	---	---	---	TL4047		
TC0302-V	VOLT SYSTEM ENGR'S BUS	20	40	VDC	SS	4 S	I H	B B	2 P	L	A	0	40	SS	2-3	---	---			
TC0302-V	VOLT SYSTEM ENGR'S BUS	26.5		VDC	SS						C			SS	---	---	---	TL4047		
TC1201-C	CURRENT, BATT DESCENT NO1	0	60	AMPS	SS	5 S	I H	B B	2	SL	A			SS	---	---	---			
TC1202-C	CURRENT, BATT DESCENT NO2	0	60	AMPS	SS	5 S	I H	B B	2	SL	A			SS	---	---	---			
TC1203-C	CURRENT, BATT DESCENT NO3	0	60	AMPS	SS	5 S	I H	B B	2	SL	A			SS	---	---	---			
TC1204-C	CURRENT, BATT ASCENT NO.1	0	60	AMPS	SS	5 S	I H	B B	2	SL	A			SS	---	---	---			
TC1205-C	CURRENT, BATT ASCENT NO.2	0	60	AMPS	SS	5 S	I H	B B	2	SL	A			SS	---	---	---			
TC3501-T	TEMP. BATT. DESCENT NO.1	0	200	DEGF	SS	5 S	I H	B B	2	SL	A	20	200	SS	6-2	0	0			
TC3502-T	TEMP. BATT. DESCENT NO.2	0	200	DEGF	SS	5 S	I H	B B	2	SL	A	20	200	SS	6-2	0	0			
TC3503-T	TEMP. BATT. DESCENT NO.3	0	200	DEGF	SS	5 S	I H	B B	2	SL	A	20	200	SS	6-2	0	0			
TC3504-T	TEMP. BATT. ASCENT NO.1	0	200	DEGF	SS	5 S	I H	B B	2	SL	A	20	200	SS	6-2	0	0			
TC3505-T	TEMP. BATT. ASCENT NO.2	0	200	DEGF	SS	5 S	I H	B B	2	SL	A	20	200	SS	6-2	0	0			
TC4361-X	HI VOLT TAP BATT DES NO1			CONTACT CLOSURE	SS	S I E I	B 2 R	H	F		CC			SS	4-4	0	0			
TC4362-X	LO VOLT TAP BATT DES NO1			CONTACT CLOSURE	SS	S I E I	B 2 R	H	F		CC			SS	4-4	0	0			
TC4363-X	HI VOLT TAP BATT DES NO2			CONTACT CLOSURE	SS	S I E I	B 2 R	H	F		CC			SS	4-4	0	0			
TC4364-X	LO VOLT TAP BATT DES NO2			CONTACT CLOSURE	SS	S I E I	B 2 R	H	F		CC			SS	4-4	0	0			



Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	ELECTRICAL POWER	UNIT	C	T	PAGE NUMBER	11	NOVEMBER 8, 1965		REFERENCES OR NOTES		
									NOVEMBER 8, 1965	NOVEMBER 8, 1965			
TC4365-X	HI VOLT TAP BATT DES NO3	CONTACT CLOSURE	SS S I E I H 2 R H F						SS	4-4	0	0	
TC4366-X	LO VOLT TAP BATT DES NO3	CONTACT CLOSURE	SS S I E I H 2 R H F						SS	4-4	0	0	
TC4367-X	HI VOLT TAP BATT ASC NO1	CONTACT CLOSURE	SS S I F I B 2 R H F						SS	4-4	0	0	
TC4368-X	LO VOLT TAP BATT ASC NO1	CONTACT CLOSURE	SS S I E I B 2 R H F						SS	4-4	0	0	
TC4369-X	HI VOLT TAP BATT ASC NO2	CONTACT CLOSURE	SS S I F I B 2 R H F						SS	4-4	0	0	
TC4370-X	LO VOLT TAP BATT ASC NO2	CONTACT CLOSURE	SS S I E I B 2 R H F						SS	4-4	0	0	
TC4371-X	BATT DES NO1 BY COM1 BUS	CONTACT CLOSURE	SS						SS	4-4	0	0	
TC4372-X	BATT DES NO2 BY COM1 BUS	CONTACT CLOSURE	SS						SS	4-4	0	0	
TC4373-X	BATT DES NO3 BY COM1 BUS	CONTACT CLOSURE	SS						SS	4-4	0	0	
TC4374-X	BATT ASC NO1 BY COM1 BUS	CONTACT CLOSURE	SS						SS	4-4	0	0	
TC4375-X	BATT ASC NO2 BY COM1 BUS	CONTACT CLOSURE	SS						SS	4-4	0	0	
TC6311-X	REVERSE POWER CUR 1 S NO1	CONTACT CLOSURE	SS S I I I H 2 R H C						SS	4-3	0	0	TL4047
TC6312-X	REVERSE POWER CUR 1 S NO2	CONTACT CLOSURE	SS S I F I S 2 F H C						SS	4-3	0	0	TL4047
TC6313-X	REVERSE POWER CUR 1 S NO3	CONTACT CLOSURE	SS S I F I H 2 F H C						SS	4-3	0	0	TL4047
TC6314-X	REVERSE POWER CUR ASC NO1	CONTACT CLOSURE	SS S I F I B 2 R H C						SS	4-3	0	0	TL4047
TC6315-X	REVERSE POWER CUR ASC NO2	CONTACT CLOSURE	SS S I F I B 2 F H C						SS	4-3	0	0	TL4047
TC6371-X	BATT DES NO1 BY SYS ENG BUS	CONTACT CLOSURE	SS						SS	4-4	0	0	
TC6372-X	BATT DES NO2 BY SYS ENG BUS	CONTACT CLOSURE	SS						SS	4-4	0	0	
TC6373-X	BATT DES NO3 BY SYS ENG BUS	CONTACT CLOSURE	SS						SS	4-4	0	0	
TC6374-X	BATT ASC NO1 BY SYS ENG BUS	CONTACT CLOSURE	SS						SS	4-4	0	0	
TC6375-X	BATT ASC NO2 BY SYS ENG BUS	CONTACT CLOSURE	SS						SS	4-4	0	0	
TC8073-T	TRIP POINTS		SS 5 2 3 6 0 0 1 5 6 F						SS	6-2	0	0	
TC8074-V	VOLTAGE LIMITS		SS 2 9 3 7 0 0 0 0 F						SS	2-2	0	0	
TC8075-C	CURRENT LIMITS		SS 0 2 3 4 1 5 5 5 F						SS	3	SS	--	

Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	ENVIRONMENTAL CONTROL	C T										REFERENCES OR NOTES									
				FREQ A S S B G O M H C F A X XDCP																			
				LOW	NORM	HIGH	UNIT	RATE	C	R	S	L	O		X	LOW	HIGH	RATE	C	DGE	-PWR	WT.	
TF1081-X	PRIME SUIT COMP. SELECT	CONTACT CLOSURE	SS	S	I	E	I	B	Z	H						CC	SS	4-5	0	0			
TF1082-X	SPARE SUIT COMP. SELECT	CONTACT CLOSURE	SS	S	I	E	I	B	Z	H						CC	SS	4-5	0	0			
TF1083-X	PRIME SUIT COMPRESS.+FAIL	CONTACT CLOSURE	SS	S	I	F	I	B	Z	R	H	C				CC	SS	4-3	0	0			
TF1084-X	SPARE SUIT COMPRESS.+FAIL	CONTACT CLOSURE	SS	S	I	E	I	B	Z	R	H	W				CC	SS	4-3	0	0			
TF1087-X	SELECT SUIT COMPRESS FAIL	CONTACT CLOSURE	SS							L						CC	SS	4-4	0	0			
TF1111-R	RATE.+H2O SEPARATOR NO 1	600	3500	RPM	SS	S				C	L					500	3600	SS			.25	.23	TF9999
TF1112-R	RATE.+H2O SEPARATOR NO 2	600	3500	RPM	SS	S				C	L					500	3600	SS			.25	.23	TF9999
TF1201-X	SUIT INLET VPI NO1 CLOSE	CONTACT CLOSURE	SS	S	I	E	I	B	Z	H						CC	SS	4-5	0	.13			
TF1202-X	SUIT INLET VPI NO2 CLOSE	CONTACT CLOSURE	SS	S	I	F	I	B	Z	H						CC	SS	4-5	0	.13			
TF1211-X	SUIT PRESS.+L/F VPI CLOSE	CONTACT CLOSURE	SS	S	I	F	I	B	Z	H						CC	SS	4-5	0	.13			
TF1212-X	SUIT PRESS.+R/L VPI UPEN	CONTACT CLOSURE	SS	S	I	E	I	B	Z	H						CC	SS	4-5	0	.13			
TF1221-X	SUIT DIVERTER VPI CLOSED	CONTACT CLOSURE	SS	S	I	E	I	B	Z	R	H					CC	SS	4-5	0	.13			
TF1231-X	CABIN GAS RETURN VPI CLD	CONTACT CLOSURE	SS	S	I	E	I	B	Z	S	L					CC	SS	4-5	0	.13			
TF1232-X	CABIN GAS RETURN VPI UPEN	CONTACT CLOSURE	SS	S	I	E	I	B	Z	H						CC	SS	4-5	0	.13			
TF1241-X	CO2 CARTRIDGE IN SEC POS	CONTACT CLOSURE	SS	S	I	E	I	B	Z	H						CC	SS	4-5	0	.13			
TF1242-X	CO2 CARTRIDGE IN SEC POS	CONTACT CLOSURE	SS							L						CC	SS	4-4	0	.13			TF9997
TF1251-X	H2O SEPARATOR NO2 SELECT	CONTACT CLOSURE	SS	S	I	E	I	B	Z	R	L					CC	SS	4-5	0	0			
TF1281-T	TEMP,SUIT INFLT	30	60	100	DEGF	SS	S	I	H	B	Z	P	L	A	30	110	SS	6-2	0	.12			
TF1291-T	TEMP,SUIT NO.1 OUTLET	30	80	100	DEGF	SS	S	I	H	B	Z	H				30	110	SS	6-2	0	.12		
TF1292-T	TEMP,SUIT NO.2 OUTLET	30	80	100	DEGF	SS	S	I	H	B	Z	H				30	110	SS	6-2	0	.12		
TF1301-P	PRESS.+SUIT OUTLET	0	5	10	PSIA	SS	S	S	I	H	B	Z	R	L		0	10	SS	4-1	.28	.31		
TF1301-P	PRESS.+SUIT OUTLET	0	10	PSIA	SS					A						0	10	SS					
TF1301-P	PRESS.+SUIT OUTLET	3.2			PSIA	SS				W						3.2		SS					
TF1521-P	PRESS.+CO2 PARTIAL	0	2	30	MMHG	SS	S	S	I	H	B	Z	R	L	C	L	0	30	SS	4-1	1.00	2.70	TF9993
TF1522-P	PRESS.+CO2 PARTIAL	0	30	MMHG	SS					A						0	30	SS	4-1	1.00	2.70		



Table 5.6-5 (cont'd)

ID	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	ENVIRONMENTAL CONTROL										REFERENCES											
			FREQ A	SS	B	G	O	M	H	C	F	A		X	XDCR	FREQ A	OSY	DR	NOTES					
CODE		LOW	NORM	HIGH	UNIT	C	R	S	G	T	D	S	L	W	L	D	X	LOW	HIGH	RATE	C	OGE	-PMR	WT.
TF1651-T	TEMP,CABIN	50	80	110	DEGF	SS	5	I	H	B	R	2	R	S	L	A	30	110	SS	6-2	0	.12		
TF2021-P	DEL P, PRIM COOLANT PUMP	0	45	50	PSID	SS	5	S	I	H	B	R	2	R	L		0	50	SS		.28	.31		
TF2041-X	COOLANT ACC. FLUID LO LVL	CONTACT CLOSURE	SS	S	I	E	I	B	2	R	S	L	C			CC			SS	4-3	0	0		
TF2071-X	COOLANT PUMP NO.1 SELECT	CONTACT CLOSURE	SS	S	I	E	I	B	2	L						CC			SS	4-5	0	0		
TF2072-X	COOLANT PUMP NO.2 SELECT	CONTACT CLOSURE	SS	S	I	E	I	B	2	L						CC			SS	4-5	0	0		
TF2571-T	TEMP, REDUNDANT W/B COOL OUT30	60	160	DEGF	SS	I										C	A	0	160	SS		0	.12	TF9998
TF2581-T	TEMP, MAIN W/B COOL, OUT	30	40	160	DEGF	SS	I									C	A	0	160	SS		0	.12	TF9998
TF2741-P	PRESS, PRIM PUMP DISCHRG	0	50	60	PSIA	SS	I									A	0	60	SS		.28	.28		TF9997
TF2921-P	PRESS, REDUND. PMP DISCHRG	0	50	60	PSIA	SS	I									A	0	60	SS		.28	.28		TF9997
TF2931-X	COOLANT PUMP NO.1 FAIL	CONTACT CLOSURE	SS	S	I	E	I	B	2	R	S	L	C			CC			SS	4-3	0	0		
TF2932-X	COOLANT PUMP NO.2 FAIL	CONTACT CLOSURE	SS	S	I	E	I	B	2	R	S	L	C			CC			SS	4-3	0	0		
TF2933-X	COOLANT PUMP NO1 FAIL	CONTACT CLOSURE	SS	S												L			CC	SS	4-4	0	0	
TF2934-X	COOLANT PUMP NO2 FAIL	CONTACT CLOSURE	SS	S												L			CC	SS	4-4	0	0	
TF3071-X	OX. REG VLV 306A CLOSED	CONTACT CLOSURE	SS	S	I	E	I	B	2	H						CC			SS	4-5	0	.13		
TF3072-X	OX. REG VLV 306A OPEN	CONTACT CLOSURE	SS	S	I	E	I	B	2	S	L					CC			SS	4-5	0	.13		
TF3073-X	OX. REG. VLV 306B CLOSED	CONTACT CLOSURE	SS	S	I	E	I	B	2	H						CC			SS	4-5	0	.13		
TF3074-X	OX. REG VLV 306B UPEN	CONTACT CLOSURE	SS	S	I	E	I	B	2	S	L					CC			SS	4-5	0	.13		
TF3081-X	EMERGENCY O2 VPI OPEN	CONTACT CLOSURE	SS	S	I	E	I	B	2	R	H	W				CC			SS	4-3	0	.13		
TF3571-P	PRESS, CABIN	0	5	10	PSIA	SS	5	I	H	B	R	2	R	S	L		0	10	SS		.28	.28		
TF3571-P	PRESS CABIN	0	10	PSIA	SS	I										A	0	6	SS					
TF3572-X	EMER. O2 VLV ELECT OPEN	CONTACT CLOSURE	SS	S	I	E	I	B	2	R	L	W				CC			SS	4-3	0	.13		
TF3582-P	PRESS ASCENT O2 TANK NO1	TBA	SS	I	H	B	R	2	H							SS			SS		.28	.28		
TF3583-P	PRESS ASCENT O2 TANK NO2	TBA	SS	I	H	B	R	2	H							SS			SS		.28	.28		
TF3584-P	PRESS DESCENT O2 TANK	TBA	SS	I	H	B	R	2	H							SS			SS		.28	.28		
TF3591-P	PRESS, SAFETY VLV 1 SERVO	0	25	PSIA	SS	5	I	H	B	R	2	H				0	25	SS			.28	.28		

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HASPLINE TAXI

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Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 14																			
BASELINE TAXI		NOVEMBER 8, 1965																			
ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	ENVIRONMENTAL CONTROL				XOCR RANGES	FREQ A OSY	REFERENCES OR NOTES												
			LOW NORM	HIGH UNIT	C R S G T D S C S L M L D X	F A X				C F A X	M H C										
TF3592-P	PRESS, SAFETY VLV 2 SERVO	0	25	PSIA	SS	5	I	H	B	B	2	H	0	25	SS	-	.28	.28	C		
TF4101-P	DEL P SUIT/WATER MAIN	0	1	2	PSIA	SS	I	I	H	B	B	2	H	0	2	SS	-	.28	.31	H	
TF4102-P	DEL P SUIT/WATER REDUND	0	1	2	PSIA	SS	I	I	H	B	B	2	H	0	2	SS	-	.28	.31	H	
TF4511-I	TEMP, MAIN W/B IN WATER	30	70	160	DEGF	SS	5	I	I	H	B	SL	0	160	SS	6-2	0	.16		C	
TF4541-I	TEMP, SUIT W/B IN WATER	30	70	160	DEGF	SS	5	I	I	H	B	H	0	160	SS	6-2	0	.16		N	
TF4561-I	TEMP DESC, TANK OUT H2O	0	160	DEGF	SS	I	H	B	H	0	160	SS	6-2	0	.16					G	
TF4562-I	TEMP ASC, TANK NO1 OUT H2O	0	160	DEGF	SS	I	H	B	H	0	160	SS	6-2	0	.16					C	
TF4563-I	TEMP ASC, TANK NO2 OUT H2O	0	160	DEGF	SS	I	H	B	H	0	160	SS	6-2	0	.16					C	
TF4564-I	TEMP RTG HEAT PIPE COND	40	600	DEGF	SS	I	H	B	H	0	600	SS	6-2	0	.13					C	
TF4565-I	TEMP RTG HEAT PIPE BOIL	40	600	DEGF	SS	I	H	B	H	0	600	SS	6-2	0	.13					C	
TF4581-Q	QUANTITY, DESC, TANK WATER	0	100	PCT	SS	4	I	I	H	B	B	2	R	L	A	0	100	SS	4-1	.50	.75
TF4581-Q	QUANTITY, DESC, TANK WATER	10		PCT	SS											10					
TF4582-Q	QUANTITY, ASC, TANK 1 WATER	0	100	PCT	SS	4	I	I	H	B	B	2	R	L	A	0	100	SS	4-1	.50	.75
TF4582-Q	QUANTITY, ASC, TANK 1 WATER	5		PCT	SS											5					
TF4583-Q	QUANTITY, ASC, TANK 2 WATER	0	100	PCT	SS	4	I	I	H	B	B	2	R	L	A	0	100	SS	4-1	.50	.75
TF4583-Q	QUANTITY, ASC, TANK 2 WATER	5		PCT	SS											5					
TF8019-V	VOLT COOL PUMP SW DK9PO A	0	28	VDC	SS											0	28	SS			
TF8020-V	VOLT COOL PU SW DK 10PO A	0	28	VDC	SS											0	28	SS			
TF8024-V	VOLT PUMP DP SW DK 1 LO	0	28	VDC	SS											0	28	SS			
TF8025-V	VOLT PUMP DP SW DK 2 HI	0	28	VDC	SS											0	28	SS			
TF8026-V	VOLT PUMP DP SW DK 2 LO	0	28	VDC	SS											0	28	SS			
TF8027-V	VOLT PUMP DP SW DK 3 HI	0	28	VDC	SS											0	28	SS			
TF8028-V	VOLT PUMP DP SW DK 3 LO	0	28	VDC	SS											0	28	SS			
TF8507-V	VOLT SUIT DIVERT VLV POS	0	28	VDC	SS											0	28	SS			
TF8509-V	VOLT 02 REG ULV A/B TEST	0	28	VDC	SS											0	28	SS			



Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 15					
BASELINE TAXI		NOVEMBER 8, 1965					
ID	MEASUREMENT	ENVIRONMENTAL CONTROL				C	REFERENCES
		INTEREST RANGES	FREQ A S S B G O M H C F A X	XOCR	FREQ A OSY		
CODE	NAME AND LOCATION	LOW NORM HIGH UNIT	C R S G T D S C S L W L D X	RANGES OR C NIP XDCR	OR C NIP XDCR	WT.	NOTES
TF8521-V	VOLT CABIN FAN NO1	0	15 VDC SS	B 2	0	15 SS	
TF8522-V	VOLT CABIN FAN NO1	0	15 VDC SS	B 2	0	15 SS	
TF8523-V	VOLT CABIN FAN NO2	0	15 VDC SS	B 2	0	15 SS	
TF8524-V	VOLT CABIN FAN NO2	0	15 VDC SS	B 2	0	15 SS	
TF8525-V	VOLT H2O SOLENOID VALVE	0	28 VDC SS	B 2	0	28 SS	
TF8535-V	VOLT SUIT FAN NO2	0	28 VDC SS	B 2	0	28 SS	
TF8536-V	VOLT SUIT FAN NO2	0	28 VDC SS	B 2	0	28 SS	
TF8601-T	TEMP HEAT PIPE CONDENSER	30	160 DEGF SS	I I H B B 2 R H	A	0 160 SS	6-2 0 .31
TF8602-T	TEMP HEAT PIPE EVAPORATER	30	160 DEGF SS	I I H B B 2 R H	A	0 160 SS	6-2 0 .31
TF8603-T	TEMP RADIATOR OUT GLYCOL	30	160 DEGF SS	I I H B B 2 P H	A	0 160 SS	6-2 0 .31
TF9993-U	L10H SEL/HI CO2 70S6 ADV	CONTACT CLOSURE	SS		L	CC	SS 4-4 0 0
TF9997-U	PRESS,SELECTED PUMP OUT	0	60 PSIA SS	5 I H B B 2 SL	A	0 60 SS	
TF9998-U	TEMP,SELECT W/B COOL,OUT	30	160 DEGF SS	5 I H B B 2 P SL C		0 160 SS	6-2
TF9998-U	TEMP,SELECT W/B COOL OUT	45	160 DEGF SS		A	45 100 SS	
TF9999-U	RATE,SELECT H2O SEPARATOR	600	3500 RPM SS	1 H B B 2 R L C L		500 3600 SS	4-1

Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	NAVIGATION AND GUIDANCE										REFERENCES OR NOTIS												
			LOW	NORM	HIGH	UNIT	C	R	S	G	T	D		S	L	W	L	D	X	LOW	HIGH	RATE	C	DGE	-PWR
TG0001-X	COMPUTER DIGITAL DATA																								
TG0117-H	POS, ALTITUDE (LGC)																								
TG0118-L	VEL, ALTITUDE RATE (LGC)																								
TG0119-L	VEL, FORWARD (LGC)																								
TG0120-L	VEL, LATERAL (LGC)																								
TG1000-V	VOLT 120 VDC PULSE TOR, REF 0																								
TG1020-V	VOLT LGC +14 VDC SUP LEV																								
TG1021-V	VOLT LGC +14VDC SUP NOISE																								
TG1022-X	LGC +14VDC SUP NOISE PEAK																								
TG1030-V	VOLT LGC +4VDC SUP LEVEL																								
TG1031-V	VOLT LGC +4VDC SUP NOISE																								
TG1032-X	LGC +4VDC SUP NOISE PEAK																								
TG1040-V	VOLT CDU +4VDC SUP LEVEL																								
TG1041-V	VOLT CDU +4VDC SUP NOISE																								
TG1042-X	CDU +4VDC SUP NOISE PEAK																								
TG1050-V	VOLT SCA +20VDC SUPPLY																								
TG1100-V	VOLT -27.5 VDC SUPPLY																								
TG1110-V	VOLT, 2.5 VDC TM BIAS PCM																								
TG1201-V	VOLT IMU 28V 800CPS 1P-0D 0																								
TG1202-V	VOLT IMU 28V 800CPS 5P90D 0																								
TG1203-V	VOLT IMU 28V 800CPS 5P-0D 0																								
TG1306-B	PHASE 3.2KC 1-P/LGC SYNC																								
TG1307-V	VOLT 3.2KC BUTTERFLY REF																								
TG1307-V	VOLT 3.2KC BUTTERFLY REF																								
TG1341-V	VOLT SELECT PIPA SCOP SIG 0																								



Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 17																					
BASELINE TAXI		NOVEMBER 8, 1965																					
ID CODE	MEASUREMENT NAME AND LOCATION	NAVIGATION AND GUIDANCE										REFERENCES OR NOTES											
		INTEREST RANGES	LOW	NORM	HIGH	UNIT	C	R	S	G	T		D	S	L	H	L	D	X	XDCR RANGES	FREQ A	OSY	
TG1342-V	VOLT SELECT HIGH RATE	SIG	0	5	VDC	80C	400	8	B	2									0	5	80C		
TG1500-V	VOLT IMU OPER +28VDC LEV				VDC	SS	1	H	B	2	SL										SS		
TG1501-V	VOLT IMU OPER 28VDC NOISE				VRMS	SS	1	B	A	2											SS		
TG1502-X	IMU OPER 28VDC NOISE PFAK				GLT	10	10	1	B	2											10		
TG1510-V	VOLT IMU STBY 28VDC LEVEL				VDC	SS	1	B	B	2											SS		
TG1511-V	VOLT IMU STBY 28VDC NOISE				VRMS	SS	1	B	B	2											SS		
TG1512-X	IMU STBY 28VDC NOISE				GLT	10	10	1	B	2											10		
TG1513-X	IMU STANDBY/OFF				SS	N	1	E	1	R	H										SS		
TG1520-V	VOLT LGC OPER 28VDC LEVEL				VDC	SS	1	H	B	2	SL										SS		
TG1521-V	VOLT LGC OPER 28VDC NOISE				VRMS	SS	1	H	B	2	SL										SS		
TG1522-X	LGC OPER 28VDC NOISE PEAK				GLT	10	10	1	B	2											10		
TG1523-X	LGC OPERATF				SS	N	1	E	1	H											SS		
TG2000-V	VOLT X PIPA MODE CHECK		0	7	VRMS	4KC	10	A	1										0	7	4KC		
TG2001-V	VOLT X PIPA SG OPUT INPH		0	7	VRMS	10C	N50	H	B	2	H								0	7	10		
TG2002-V	VOLT X PIPA SG OPUT QUAD				VRMS	SS	N	1	H	B	2	H									SS		
TG2003-V	VOLT X PIPA +28VDC PVR				VDC	SS	N	1	H	B	2	SL									SS		
TG2020-V	VOLT Y PIPA MODE CHECK		0	7	VRMS	4KC	10	A	1										0	7	4KC		
TG2021-V	VOLT Y PIPA SG OPUT INPH		0	7	VRMS	10C	N50	H	B	2	H								0	7	10		
TG2022-V	VOLT Y PIPA SG OPUT QUAD				VRMS	SS	N	1	H	B	2	H									SS		
TG2023-V	VOLT Y PIPA +28VDC PVA				VDC	SS	N	1	H	B	2	SL									SS		
TG2040-V	VOLT Z PIPA MODE CHECK		0	7	VRMS	4KC	10	A	1										0	7	4KC		
TG2041-V	VOLT Z PIPA SG OPUT INPH		0	7	VRMS	10C	N50	H	B	2	H								0	7	10		
TG2042-V	VOLT Z PIPA SG OPUT QUAD				VRMS	SS	N	1	H	B	2	H									SS		
TG2043-V	VOLT Z PIPA +28VDC PVR				VDC	SS	N	1	H	B	2	SL									SS		
TG2107-V	VOLT IG SERVO ERROR INPH		0	20	VRMS	20C	5	N	100H	B	2	H							0	20	20C		

Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	NAVIGATION AND GUIDANCE											C T	REFERENCES OR NOTES														
			LOW	NDRM	HIGH	UNIT	FRQ	A	S	S	B	G	M			H	C	F	A	X	XDCR	FRQ	A	D	OSY				
TG2108-V	VOLI IG SERVO ERROR TOTAL	0	20 VRMS	2C	5	10	8 B 2																						
TG2112-V	VOLT IG 1X RES OUT,SIN	0	28 VRMS	2C		N 10H	8 B 2 R H																						
TG2113-V	VOLT IGA 1X RES OUT,COS	0	28 VRMS	2C		N 10H	8 B 2 R H																						
TG2122-V	VOLT IG 1X RES OUT,SIN	0	28 VRMS					A																					
TG2123-V	VOLT IG 1X RES OUT,COS	0	28 VRMS					A																					
TG2137-V	VOLT MG SERVO ERROR INPH	0	20 VRMS	20C	5	N100H	8																						
TG2138-V	VOLI MG SERVO ERROR TOTAL	0	20 VRMS	2C		10	8 B 2																						
TG2140-C	CURR,MG TORQUE MOTOR INP		AMP	SS	10	1	8 B 2																						
TG2142-V	VOLT,MG 1X RES OUT,SIN	0	28 VRMS	2C		N 10H	8 B 2 R H																						
TG2143-V	VOLT,MG 1X RES OUT,COS	0	28 VRMS	2C		N 10H	8 B 2 R H																						
TG2152-V	VOLT,MG 1X RES OUT,SIN	0	28 VRMS					A																					
TG2153-V	VOLT,MG 1X RES OUT,COS	0	28 VRMS					A																					
TG2167-V	VOLT OG SERVO ERROR INPH	0	20 VRMS	20C	5	N100H	8 B 2																						
TG2168-V	VOLT OG SERVO ERROR TOTAL	0	20 VRMS	2C		10	8 B 2																						
TG2170-C	CURR OG TOR MOTOR INPUT		AMP	SS	10	1	8 B 2																						
TG2172-V	VOLT,OG 1X RES OUT,SIN	0	28 VRMS	2C		N 10H	8 B 2 R H																						
TG2173-V	VOLT,OG 1X RES OUT,COS	0	28 VRMS	2C		N 10H	8 B 2 R H																						
TG2182-V	VOLT,OG 1X RES OUT,SIN	0	28 VRMS					A																					
TG2183-V	VOLI,OG 1X RES OUT,COS	0	28 VRMS					A																					
TG2205-V	VOLT IG CDU FINE ERROR		VRMS	SS		1	8 B 2																						
TG2207-V	VOLT IG CDU COARSE ERROR		VRMS	SS		1	8 B 2																						
TG2214-V	VOLT PITCH CDU DAC OUT		VRMS	2C		N 10H	8 B 2																						
TG2217-V	VOLT,PITCH ATT ERROR-PGNS	0	10 VRMS					A																					
TG2235-V	VOLT,MG CDU FINE ERROR		VRMS	SS		1	8 B 2																						
TG2237-V	VOLT,MG CDU COARSE ERROR		VRMS	SS		1	8 B 2																						



Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	NAVIGATION AND GUIDANCE										REFERENCES, OR NOTES		
			VRMS	2C	N	10H	8	B	2	H	A	0		10	SS
TG2244-V	VOLT,ROLL CDU DAC OUT	0	10	VRMS	SS	1	8	B	2	H	A	0	10	SS	---
TG2247-V	VOLT,ROLL ATT ERROR-PGNS	0	10	VRMS	SS	1	8	B	2	H	A	0	10	SS	---
TG2265-V	VOLT,OG CDU FINE ERROR			VRMS	SS	1	8	B	2	H	A	0	10	SS	---
TG2267-V	VOLT,OG CDU COARSE ERROR			VRMS	SS	1	8	B	2	H	A	0	10	SS	---
TG2274-V	VOLT,YAW CDU DAC OUT			VRMS	2C	N	10H	8	B	2	H	A	0	10	SS
TG2277-V	VOLT,YAW ATT ERROR-PGNS	0	10	VRMS	SS	1	8	B	2	H	A	0	10	SS	---
TG2300-T	TEMP,PIPA	0	140	DEGF	SS	2	N	1	H	8	B	2	R	L	0 140 SS
TG2301-T	TEMP,IRIG			DEGF	SS	1	8	B	2	H	A	0	10	SS	---
TG2302-X	IMU HEATER ON			SS	SS	1	1	B	2	H	A	0	10	SS	---
TG2303-X	IMU BLOWER ON			SS	SS	1	1	B	2	H	A	0	10	SS	---
TG3011-V	VOLT RDR SHFT ECDU F ERR			VRMS	SS	1	8	B	2	H	A	0	10	SS	---
TG3012-V	VOLT RDR SHFT ECDU C ERR			VRMS	SS	1	8	B	2	H	A	0	10	SS	---
TG3021-V	VOLT RDR TRUN ECDU F ERR			VRMS	SS	1	8	B	2	H	A	0	10	SS	---
TG3022-V	VOLT RDR TRUN ECDU C ERR			VRMS	SS	1	8	B	2	H	A	0	10	SS	---
TG3104-V	VOLT,RDR SHFT 1X RES,SIN	0	28	VRMS	2C	2	N	10H	8	B	2	H	A	0 28 2C	---
TG3105-V	VOLT,RDR SHFT 1X RES,COS	0	28	VRMS	2C	2	N	10H	8	B	2	H	A	0 28 2C	---
TG3124-V	VOLT,RDR TRUN 1X RES,SIN	0	28	VRMS	2C	2	N	10H	8	B	2	H	A	0 28 2C	---
TG3125-V	VOLT,RDR TRUN 1X RES,COS	0	28	VRMS	2C	2	N	10H	8	B	2	H	A	0 28 2C	---
TG4300-T	TEMP,LGC			DEGF	SS	N	1	8	B	2	H	A	0	10	SS
TG6020-T	TEMP,PIPA CAL MOD			DEGF	SS	1	8	B	2	H	A	0	10	SS	---
TG6022-T	TEMP,PSA			DEGF	SS	1	8	B	2	H	A	0	10	SS	---
TG9000-X	IMU CAGE	CONTACT CLOSURE		SS	SS	1	E	1	B	2	H	A	0	10	SS 4-5 0 0
TG9001-X	LGC (WARNING)	CONTACT CLOSURE		SS	SS	1	E	1	B	2	L	W	A	0	SS 4-3 0 0
TG9002-X	INRTL_REF (WARNING)	CONTACT CLOSURE		SS	SS	1	E	1	B	2	L	W	A	0	SS 4-3 0 0
TG9003-X	PGNS (CAUTION)	CONTACT CLOSURE		SS	SS	1	E	1	B	2	L	C	A	0	SS 4-3 0 0

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Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 20		
BASELINE TAXI		NOVEMBER 8, 1965		
ID CODE	MEASUREMENT NAME AND LOCATION	STABILITY AND CONTROL-CES		REFERENCES
		INTEREST RANGES	FREQ A S S S B G O M H C F A X XOCR RANGES OR C I R P C S / / X RANGES OR C NIP XOCR XDCR	
	LOW NORM HIGH UNIT RATE C R S G T D S C S L W L D X LOW HIGH RATE C DGE -PMR WT.			
TH1204-X	ACA OUT OF SETENT	SS	I E 1 R H CC	SS 4-5 0 0
TH1211-V	VOLT AUTO TH INCR 3,2KPPS	0	2-5 VDC SS B 2	0 5 SS - - - -
TH1212-V	VOLT AUTO TH DECR 3,2KPPS	0	2-5 VDC SS B 2	0 5 SS - - - -
TH1214-X	AUTO ENG ON COMMAND	0	OR 15 VDC SS I E 1 B 2 L	0 / 15 SS 4-2 0 0
TH1217-X	AUTO ENG OFF COMMAND	0	OR 15 VDC SS I E 1 B 2 L	0 / 15 SS 4-2 0 0
TH1229-X	DESC ENG ARM CMD (PNL)		SS I E 1 B 2 R H	SS 4-2 0 0
TH1230-X	ASC.ENG ARM (FROM PNL)		SS I E 1 B 2 R H	SS 2-2 0 0
TH1240-V	VOLT, 'X', TRANS.CMD	-10	OR +10 VDC 2C 10H 8 B 2 P H	-10 / +10 2C 2-2 0 0
TH1241-V	VOLT, 'Y', TRANS.CMD	-10	OR +10 VDC 2C 10H 8 B 2 R H	-10 / +10 2C 2-2 0 0
TH1242-V	VOLT, 'Z', TRANS.CMD	-10	OR +10 VDC 2C 10H 8 B 2 R H	-10 / +10 2C 2-2 0 0
TH1247-V	VOLT,PULSE YAW CMD	-13	+5 +13 VDC 2C 2 10H 8 B 2 H	-13 +13 2C 2-2 0 0
TH1248-V	VOLT,PULSE PITCH CMD	-13	+5 +13 VDC 2C 2 10H 8 B 2 H	-13 +13 2C 2-2 0 0
TH1249-V	VOLT,PULSE ROLL CMD	-13	+5 +13 VDC 2C 2 10H 8 B 2 H	-13 +13 2C 2-2 0 0
TH1260-X	A.E. ON/OFF TO PROP	0	28 VDC SS I E 1 B 2 R H	0 28 SS - - - -
TH1283-X	ABORT STAGE COMMANDED		SS I E 1 B 2 R L	SS 4-5 0 0
TH1286-X	ENG FIRE OVERRIDE		SS I E 1 B 2 H	SS 4-5 0 0
TH1301-X	DESC ENG -ON/OFF- TO PROP	0	28 VDC SS I E 1 B 2 R SL	0 28 SS - - - -
TH1311-V	VOLT,MANUAL THRUST CMD	2.6	15 VDC SS 2 I H 8 B 2 R H	0 15 SS 2-2 0 0
TH1313-V	VOLT,PITCH GDA POS (.4KC)	-15	+05 +15 VRMS IC 2 10H 8 B 2 R H	-15 +15 IC 7-1 0 0
TH1314-V	VOLT,ROLL GDA POS (.4KC)	-15	+05 +15 VRMS IC 2 10H 8 B 2 R H	-15 +15 IC 7-1 0 0
TH1318-	PITCH GDA EXTEND FROM LGC TBA		B 2	- - - -
TH1319-	PITCH GDA RETRAC FROM LGC TBA		B 2	- - - -
TH1320-X	PITCH GDA EXT/RET(.4KC)	0	OR 90 DEG SS B 2	SS - - - -
TH1323-X	PITCH TRIM FAIL	TBA	SS I E 1 B 2 F L C	SS 4-3 0 0
TH1330-X	ROLL TRIM FAIL	TBA	SS I E 1 B 2 R L C	SS 4-3 0 0



Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	STABILITY AND CONTROL-SES	FREQ A S S B G O M H C F A X	XOCR	RANGES	OR C NIP	XOCR	XOCR	W T.	PAGE NUMBER 21	NOVEMBER 8, 1965	REFERENCES OR NOTES	
														LOW
TH1331-V	VOLT, AUTO THRUST CMD	0, .015	12 VDC	IC 2	10H B B 2 R H	0	15	IC	2-2	0	0			
TH1332-V	VOLT, AUTO/MAN THRUST	0	5 VDC	SS	A	0	5	SS						
TH1343-	ROLL GDA EXTEND FROM LGC	TBA			B 2									
TH1344-	ROLL GDA RETRACT FROM LGC	TBA			B 2									
TH1345-X	ROLL GDA EXT/RET (.4KC)	0	OR 90 DEG	SS	B 2			SS						
TH1348-X	DESC ENG ARM (DECA OUT)	0	OR 28 VDC	SS	B 2			SS						
TH1401-V	VOLT RGA SPN MTR A PH, 8KC	-26	+26 VRMS											
TH1402-V	VOLT RGA SPN MTR B PH, 8KC	-26	+26 VRMS											
TH1403-V	VOLT RGA SPN MTR C PH, 8KC	-26	+26 VRMS											
TH1405-V	VOLT RGA PICKOFF EXCT, 8KC	-28	+28 VRMS											
TH1406-V	VOLT +15V DC SUPPLY		+15 VDC											
TH1407-V	VOLT -15V DC SUPPLY		-15 VDC											
TH1408-V	VOLT +4V DC SUPPLY		+4 VDC											
TH1418-V	VOLT, JET 1 DRIVER OUT, 28V 6PPS	MAX, 10-400 MS			200E 1 B 2 R H W			0 / 28	4-2	0				
TH1419-V	VOLT, JET 2 DRIVER OUT, 28V 6PPS	MAX, 10-400 MS			200E 1 B 2 R H W			0 / 28	4-2	0				
TH1420-V	VOLT, JET 3 DRIVER OUT, 28V 6PPS	MAX, 10-400 MS			200E 1 B 2 R H W			0 / 28	4-2	0				
TH1421-V	VOLT, JET 4 DRIVER OUT, 28V 6PPS	MAX, 10-400 MS			200E 1 B 2 R H W			0 / 28	4-2	0				
TH1422-V	VOLT, JET 5 DRIVER OUT, 28V 6PPS	MAX, 10-400 MS			200E 1 B 2 R H W			0 / 28	4-2	0				
TH1423-V	VOLT, JET 6 DRIVER OUT, 28V 6PPS	MAX, 10-400 MS			200E 1 B 2 R H W			0 / 28	4-2	0				
TH1424-V	VOLT, JET 7 DRIVER OUT, 28V 6PPS	MAX, 10-400 MS			200E 1 B 2 R H W			0 / 28	4-2	0				
TH1425-V	VOLT, JET 8 DRIVER OUT, 28V 6PPS	MAX, 10-400 MS			200E 1 B 2 R H W			0 / 28	4-2	0				
TH1426-V	VOLT, JET 9 DRIVER OUT, 28V 6PPS	MAX, 10-400 MS			200E 1 B 2 R H W			0 / 28	4-2	0				
TH1427-V	VOLT, JET 10 DRIVER OUT, 28V 6PPS	MAX, 10-400 MS			200E 1 B 2 R H W			0 / 28	4-2	0				
TH1428-V	VOLT, JET 11 DRIVER OUT, 28V 6PPS	MAX, 10-400 MS			200E 1 B 2 R H W			0 / 28	4-2	0				
TH1429-V	VOLT, JET 12 DRIVER OUT, 28V 6PPS	MAX, 10-400 MS			200E 1 B 2 R H W			0 / 28	4-2	0				

Table 5.6-5 (cont'd)

ID	MEASUREMENT	INTEREST	STABILITY AND CONTROL-CES										C	REFERENCES											
			FREQ A	S S	B	G	D	M	M	H	C	F			A	X	XDCR	FREQ A	OSY						
CODE	NAME AND LOCATION	LOW NORM HIGH UNIT RATE	C	R	S	G	T	D	S	C	S	L	W	L	D	X	LOW	HIGH	RATE	C	DGE	-PWR	WT.	DR	NOTES
TH1430-V	VOLI, JET 13DRIVER OUT, 28V 6PPS	MAX, 10-400 MS	200E	1	B	2	R	H	W	0	/	28	0	/	28	4-2	0	0	0						
TH1431-V	VOLI, JET 14DRIVER OUT, 28V 6PPS	MAX, 10-400 MS	200E	1	B	2	R	H	W	0	/	28	4-2	0	0	0	0	0							
TH1432-V	VOLI, JET 15DRIVER OUT, 28V 6PPS	MAX, 10-400 MS	200E	1	B	2	R	H	W	0	/	28	4-2	0	0	0	0	0							
TH1433-V	VOLI, JET 16DRIVER OUT, 28V 6PPS	MAX, 10-400 MS	200E	1	B	2	R	H	W	0	/	28	4-2	0	0	0	0	0							
TH1434-V	VOLT LGC JET CMD NO 1	TBA								B	2														
TH1435-V	VOLI, LGC, JET CMD NO 2	TBA								B	2														
TH1436-V	VOLI, LGC, JET CMD NO 3	TBA								B	2														
TH1437-V	VOLI, LGC, JET CMD NO 4	TBA								B	2														
TH1438-V	VOLI, LGC, JET CMD NO 5	TBA								B	2														
TH1439-V	VOLI, LGC, JET CMD NO 6	TBA								B	2														
TH1440-V	VOLI, LGC, JET CMD NO 7	TBA								B	2														
TH1441-V	VOLI, LGC, JET CMD NO 8	TBA								B	2														
TH1442-V	VOLI, LGC, JET CMD NO 9	TBA								B	2														
TH1443-V	VOLI, LGC, JET CMD NO 10	TBA								B	2														
TH1444-V	VOLI, LGC, JET CMD NO 11	TBA								B	2														
TH1445-V	VOLI, LGC, JET CMD NO 12	TBA								B	2														
TH1446-V	VOLI, LGC, JET CMD NO 13	TBA								B	2														
TH1447-V	VOLI, LGC, JET CMD NO 14	TBA								B	2														
TH1448-V	VOLI, LGC, JET CMD NO 15	TBA								B	2														
TH1449-V	VOLI, LGC, JET CMD NO 16	TBA								B	2														
TH1450-V	VOLT PITCH TRIM ERROR	-14 +14 VDC								B	2														
TH1452-V	VOLT ROLL TRIM ERROR	-14 +14 VDC								B	2														
TH1455-V	VOLI, YAW ATT ERROR (.8KC)	TBA	2C	10H	8	B	2	R	H				2C	7-1	0	0	0	0							
TH1456-V	VOLI, PITCH ATT ERROR (.8KC)	TBA	2C	10H	8	B	2	R	H				2C	7-1	0	0	0	0							
TH1457-V	VOLI, ROLL ATT ERROR (.8KC)	TBA	2C	10H	8	B	2	R	H				2C	7-1	0	0	0	0							



Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 23					
BASELINE TAXI		NOVEMBER 8, 1965					
ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	STABILITY AND CONTROL-CES				REFERENCES
			LOW	NORM	HIGH	UNIT	
TH1461-V	VOLT, YAW RG SIG (.8KC)	+3.5	VRMS	2C	2	10H 8 B 2 R L	-3.5 +3.5 2C 7-1 0 0
TH1462-V	VOLT, PITCH RG SIG (.8KC)	-3.5	VRMS	2C		10H 8 B 2 R L	-3.5 +3.5 2C 7-1 0 0
TH1463-V	VOLT, ROLL RG SIG (.8KC)	-3.5	VRMS	2C	2	10H 8 B 2 R L	-3.5 +3.5 2C 7-1 0 0
TH1492-V	VOLT -4VDC SUPPLY	-4	VDC	SS		W	SS 4-1 0 0
TH1493-V	VOLT +6VDC SUPPLY	+6	VDC	SS		W	SS 2-2 0 0
TH1494-V	VOLT -6VDC SUPPLY	-6	VDC	SS		W	SS 2-2 0 0
TH1497-V	VOLT YAW RGA SIG (.8KC)	-3.5	VRMS	2C		A	-3.5 +3.5 2C -- -- --
TH1498-V	VOLT PITCH RGA SIG (.8KC)	-3.5	VRMS	2C		A	-3.5 +3.5 2C -- -- --
TH1499-V	VOLT ROLL RGA SIG (.8KC)	-3.5	VRMS	2C		A	-3.5 +3.5 2C -- -- --
TH1567-X	ENG STOP OVERRIDE	0	28 VDC	SS		1 E 1 B 2 H	0 28 SS 4-2 0 0
TH1603-X	DEADBAND SELECT	TBA		SS		1 E 1 B 2 R H	SS 4-5 0 0
TH1608-X	SCS MODE SELECT (AUTO)	TBA		SS		1 E 1 B 2 R H	SS 4-5 0 0
TH1609-X	SCS MUDE SELECT (ATT HOLD)	TBA		SS		1 E 1 B 2 R H	SS 4-5 0 0
TH1615-X	ROLL ATT CONT SEL (PULSED)	TBA		SS		1 E 1 B 2 R H	SS 4-5 0 0
TH1616-X	PIITCH ATT CONT SEL (PULSED)	TBA		SS		1 E 1 B 2 R H	SS 4-5 0 0
TH1617-X	YAW ATT CONT SEL (PULSED)	TBA		SS		1 E 1 B 2 R H	SS 4-5 0 0
TH1618-X	ROLL ATT CONT SEL (DIRECT)	TBA		SS		1 E 1 B 2 R H	SS 4-5 0 0
TH1619-X	PIITCH ATT CON SEL (DIRECT)	TBA		SS		1 E 1 B 2 R H	SS 4-5 0 0
TH1620-X	YAW ATT CONT SEL (DIRECT)	TBA		SS		1 E 1 B 2 R H	SS 4-5 0 0
TH1621-X	GUIDANCE SELECT SW.-AGS	TBA		SS		1 E 1 B 2 R L	SS 4-5 0 0
TH1852-V	VOLT MAN THROTTLE CMD. 8KC	3	17 VRMS	SS		B 2	3 20 SS -- -- --
TH1893-X	*X TRANS OVERRIDE	TBA		SS		1 E 1 B 2 R H	SS 4-5 0 0
TH1896-X	UNBALANCED COUPLES	TBA		SS		1 E 1 B 2 H	SS 4-5 0 0

Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	LOW	NORM	HIGH	UNIT	STABILITY AND CONTROL-AGS										REFERENCES OR NOTES	
						FREQ A	S S	B G	O M	M H	C F	A X	XDCR	FREQ A	OSY		
						OR C	T I	R P	C S	7 7	X RANGES	OP C	NIP	XDCR	XDCR		
						LOW	D S	SL	W L	D X	LOW	HIGH	RATE	C DGE	-PMR	WT.	
T10001	DIGITAL WORD					TBA											
							50S			B 2							
T13137-V	VOLT +/-Y DELTA VELOCITY																
										B 2							
T13138-V	VOLT +/-Z DELTA VELOCITY																
										B 2							
T13151-V	VOLT DISP TOT,SIN ALP.8KC	-26									A	-26	+26				
T13152-V	VOLT DISP TOT,COS ALP.8KC	-26									A	-26	+26				
T13153-V	VOLT DISP TOT,SIN BET.8KC	-26									A	-26	+26				
T13154-V	VOLT DISP TOT,COS RET.8KC	-26									A	-26	+26				
T13155-V	VOLT DISP TOT,SIN GAM.8KC	-26									A	-26	+26				
T13156-V	VOLT DISP TOT,COS GAM.8KC	-26									A	-26	+26				
T13166-V	VOLT YAW ATT ERR TO DIS										A						
T13167-V	VOLT PITCH ATT ERR TO DIS										A						
T13168-V	VOLT ROLL ATT ERR TO DIS										A						
T13171	YAW INCREMENTAL ANGLE																
											B 2						
T13172	ROLL INCREMENTAL ANGLE																
											B 2						
T13173	PITCH INCREMENTAL ANGLE																
											B 2						
T13175	ASA CLOCK																
											B 2						
T13176	BLOCK TEMP REFERENCE																
											B 2						
T13177	CDU ZERO																
											B 2						
T13178	+DELTA THETA FROM PNGS																
											B 2						
T13179	-DELTA THETA FROM PNGS																
											B 2						
T13180	+DELTA GAMMA FROM PNGS																
											B 2						
T13181	-DELTA GAMMA FROM PNGS																
											H B 2 R H						
T13182	+DELTA PHI FROM PNGS																
											H B 2 R H						
T13183	-DELTA PHI FROM PNGS																
											H B 2 R H						
T13184	PNGS T/M ONLINK DATA PUL																
											B 2						



Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 25	
BASELINE TAXI		NOVEMBER 8, 1965	
ID CODE	MEASUREMENT NAME AND LOCATION	STABILITY AND CONTROL-AGS	
		INTEREST RANGES	C T
	LOW NORM HIGH UNIT RATE C R S G T D S C S L W L D X LOW HIGH RATE C DGE -PMR WT.	FREQ A S S B G O M M H C F A X XDCR OR C NIP XDCR XDCR	REFERENCES
	TBA TBA	OR C / T R P C S / / X RANGES OR C NIP XDCR XDCR	OP NOTES
TI3185	1024 CLOCK	TBA B 2	
TI3201-V	VOLT +DELTA V TO DISPLAY	D	
TI3202-V	VOLT -DELTA V TO DISPLAY	D	
TI3203-V	VOLT ALT TO DISPLAY	A	
TI3204-V	VOLT ALT RATE TO DISPLAY	A	
TI3205-V	VOLT LAT VEL TO DISPLAY	A	
TI3214-V	+32 VDC ASA	W VDC 32	2-2 0 0
TI3215-V	+12 VDC ASA	W VDC 12	2-2 0 0
TI3216-V	-12 VDC ASA	W VDC -12	2-2 0 0
TI3217-V	+6 VDC ASA	W VDC 6	2-2 0 0
TI3218-V	+4 VDC ASA	W VDC 4	4-1 0 0
TI3219-V	-2 VDC ASA	W VDC -2	4-1 0 0
TI3221-V	AGS POWER SUPPLY FAIL	W	4-1 0 0
TI3232	AEA TEST MODE FAIL	W	4-1 0 0
TI3301-T	TEMP,ASA	TBA	6-2 0 .13
TI3305-X	AGS MODE (WARMUP).	SS S L E I R H	SS
TI3306-X	AGS MODE (STANDBY).	SS S L E I R H	SS
TI3311-V	VOLT +/-X DELTA VELOCITY	B 2	
TI3340	YAW ATTITUDE ERROR NULL	B 2	
TI3341	PITCH ATT ERROR NULL	B 2	
TI3342	ROLL ATTITUDE ERROR NULL	B 2	
TI3343	ASA X AXIS SMRD	B 2	
TI3344	ASA Y AXIS SMRD	B 2	
TI3345	ASA Z AXIS SMRD	R 2	

Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 26				
BASELINE TAXI		NOVEMBER 8, 1965				
ID	MEASUREMENT	INSTRUMENTATION		C Y	REFERENCES	
		INTEREST RANGES	FREQ A S S B G D M H C F A X			XDCR FREQ A OSY
CODE	NAME AND LOCATION	LOW NORM HIGH UNIT	RATE C R S G T D S C S L W L D X LOW HIGH RATE C DGE -PWR WT.	OR C NIP XDCR XDCR	OR	NOTES
TL0300	FRAME SYNCH + ID		I P 328 2 R SL			
TL0300-	FRAME SYNCH + ID		50P 328 2 R H			
TL0302	FORMAT ID		I P 8 B 2 R SL			
TL0401	CALIB 85 PCT HL	4.24 4.25 4.26	VDC SS	0 5 SS		
TL0401-	CALIB 85 PCT HL	4.24 4.25 4.26	VDC SS	0 5 SS		
TL0402	CALIB 15 PCT HL	.741 .75 .759	VDC SS	0 1 SS		
TL0402-	CALIB 15 PCT HL	.741 .75 .759	VDC SS	0 1 SS		
TL0411	OUTPUT REG ALL ZERO CK		I P 8 B 2 SL			
TL0501-W	TIME, GREENWICH MEAN		10P 328 2 R H			
TL0501-W	TIME, GREENWICH MEAN		I P 328 2 R SL			
TL0801-V	VOLT PCMT 1024KC TIM SIG		8 2		SS	
TL4021-X	(6DS1) TBA				SS	
TL4022-X	(6DS2) ASCENT LOW PRESS W				CC	
TL4023-X	6DS3 PRES HE REG OUT MFL W				CC	
TL4024-X	6DS4 LOW DESC PROP QUANT W				CC	
TL4025-X	6DS5 TBA				CC	
TL4026-X	CES AC PWR SUP FAIL(6DS6)W				SS	4-4 0 0
TL4027-X	CES DC PWR SUP FAIL(6DS7)W				CC	4-4 0 0
TL4028-X	AGS PWR SUPP FAIL (6DS8) W				CC	4-4 0 0
TL4029-X	6DS9 N+G LGC WARNING W				SS	
TL4030-X	6DS10 N+G INTERNAL REF W				CC	
TL4031-X	6DS11 RCS TCA JET FAIL W				CC	
TL4032-X	6DS12 PR RCS HE REG ADUT W				SS	
TL4033-X	6DS13 PR RCS HE REG BOUT W				CC	
TL4034-X	6DS14 TBA W				CC	



Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	INSTRUMENTATION FREQ A S S B G O M H C F A X OP C C / I I P C S / / X RATE C R S G T D S C SL W L D X	XDCR RANGES LOW HIGH	FRFQ A OSY OR C NIP XDCR RATE C DGE -PWR	REFERENCES OR NOTES	C T	PAGE NUMBER 77	
								NOVEMBER 8, 1965	
TL4035-X	6DS15 TBA W	CONTACT CLOSURE	SS	L CC	SS				
TL4036-X	6DS16 CABIN WARNING W	CONTACT CLOSURE	SS	L CC	SS				
TL4037-X	6DS17 SUIT/FAN WARNING W	CONTACT CLOSURE	SS	L CC	SS				
TL4038-X	6DS18 RNDZ RADAR DATA NG W	CONTACT CLOSURE	SS	L CC	SS				
TL4039-X	6DS19 LDG RADAR W	CONTACT CLOSURE	SS	L CC	SS				
TL4040-X	6DS20 TBA W	CONTACT CLOSURE	SS	L CC	SS				
TL4041-X	6DS21 ASC HI P UUT MFLD C	CONTACT CLOSURE	SS	L CC	SS				
TL4042-X	6DS22 ASC LOW PPOP QUAN C	CONTACT CLOSURE	SS	L CC	SS				
TL4043-X	6DS23 TBA C	CONTACT CLOSURE	SS	L CC	SS				
TL4044-X	6DS24 TBA C	CONTACT CLOSURE	SS	L CC	SS				
TL4045-X	6DS25 PGNS CAUTION C	CONTACT CLOSURE	SS	L CC	SS				
TL4046-X	6DS26 TRA C	CONTACT CLOSURE	SS	L CC	SS				
TL4047-X	6DS27 TBA C	CONTACT CLOSURE	SS	L CC	SS				
TL4048-X	6DS28 TBA C	CONTACT CLOSURE	SS	L CC	SS				
TL4049-X	6DS29 TBA C	CONTACT CLOSURE	SS	L CC	SS				
TL4050-X	6DS30 TBA C	CONTACT CLOSURE	SS	L CC	SS				
TL4051-X	6DS31 TRA C	CONTACT CLOSURE	SS	L CC	SS				
TL4052-X	6DS32 RCS CAUTION C	CONTACT CLOSURE	SS	L CC	SS				
TL4053-X	6DS33 HEATER CAUTION C	CONTACT CLOSURE	SS	L CC	SS				
TL4054-X	6DS34 TBA C	CONTACT CLOSURE	SS	L I F I B 2 L L	SS				
TL4055-X	6DS35 TBA C	CONTACT CLOSURE	SS	L CC	SS				
TL4056-X	6DS36 ECS CAUTION C	CONTACT CLOSURE	SS	L CC	SS				
TL4057-X	6DS37 FCS 02 ACCUM PRES C	CONTACT CLOSURE	SS	L CC	SS				
TL4058-X	6DS38 GLYCOL CAUTION C	CONTACT CLOSURE	SS	L CC	SS				
TL4059-X	6DS39 DES-ASC H2O QUAN C	CONTACT CLOSURE	SS	L CC	SS				

Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	INSTRUMENTATION	CONTACT CLOSURE	C T	REFERENCES OR NOTES	PAGE NUMBER 28	
							CONTRACT CLOSURE	NOVEMBER 8, 1965
CONTRACT NUMBER NAS9-4983	BASELINE TAXI	FRQ A S S R G O M M H C F A X	DR C C / I R P C S / / X RANGES	DR C NIP XDCR XDCR	DR C DGF -PWR	WT.		
		LOW NORM HIGH UNIT RATE C R S G T D S C SL W L D X LOW HIGH RATE C DGF -PWR						
TL4060-X	6DS40 THA C		L L CC	SS				
TL4069-X	C+WE MASTER ALARM ID		1 F 1 B 2 L	SS				
TL4111-V	VOLT C+WE WRN IN REF V 1	-4.995 -5 -5.005 V	B 2	0 -5 SS				
TL4112-V	VOLT C+WE WRN IN REF V 2	-4.995 -5 -5.005 V	B 2	0 -5 SS				
TL4113-V	VOLT C+WE WRN IN REF V 3	-4.995 -5 -5.005 V	B 2	0 -5 SS				
TL4114-V	VOLT C+WE CAUT IN REF V	-4.995 -5 -5.005 V	B 2	0 -5 SS				
TL4201-F	FREQ DSEA MONI HD OUTPUT	.3	3K CPS 3KC A I	3KC				
TL4202-F	FREQ DSEA BIAS OSC OUTPUT	36	36K CPS TBA A I					
TL9501-U	TCA FAILURE PR 4A		F	SS				
TL9502-U	TCA FAILURE PR 4B		F	SS				
TL9503-U	TCA FAILURE PR 3A		F	SS				
TL9504-U	TCA FAILURE PR 3B		F	SS				
TL9505-U	TCA FAILURE PR 2A		F	SS				
TL9506-U	TCA FAILURE PR 2B		F	SS				
TL9507-U	TCA FAILURE PR 1A		F	SS				
TL9508-U	TCA FAILURE PR 1B		F	SS				



Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 29							
BASELINE TAXI		NOVEMBER 8, 1965							
ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	RADARS				REFERENCES		
			LOW NORM HIGH UNIT RATE	C R S G T D S C S L W L D X LOW HIGH RATE	C NIP XDCR XDCR	C DGE -PMP WT.		OR	
			SS	HW	CC	SS	4-3	0	0
TN7521-X	LR RANGE DATA NO GOOD	CONTACT CLOSURE	SS	HW	CC	SS	4-3	0	0
TN7523-L	VEL LR VXA VEL(ALT RATE)	TBA	FT/S	D					
TN7524-L	VEL LR VYA VEL	TBA	FT/S	A					
TN7525-L	VEL LR VZA VEL	TBA	FT/S	A					
TN7527-H	POS LR RANGE DATA (DISP)		FEFT	D					
TN7529-V	VOLT LR RANGE GATE STROBE	4	7 10 VDC 3.2K	A 1	0	10			
TN7530-V	VOLT LR VXA GATE STROBE	4	7 10 VDC 3.2K	A 1	0	10			
TN7531-V	VOLT LR VYA GATE STROBE	4	7 10 VDC 3.2K	A 1	0	10			
TN7532-V	VOLT LR VZA GATE STROBE	4	7 10 VDC 3.2K	A 1					
TN7533-V	VOLT LR LGC ANT POS CMD	TBA		A 1					
TN7534-V	VOLT LR RESET STROBE	4	7 10 VDC 3.2K	A 1	0	10			
TN7535-V	VOLT LR COUNT READOUT CMD	4	7 10 VDC 3.2K	A 1	0	10			
TN7536-V	VOLT LR COUNTER OUTPUT 0	4	7 10 VDC 3.2K	A 1	0	10			
TN7537-V	VOLT LR COUNTER OUTPUT 1	4	7 10 VDC 3.2K	A 1	0	10			
TN7540-X	VOLT LR LOW SCALE FACTOR	17	TBA 39 VDC SS	B 2	0	40	SS		
TN7545-E	PWR LR VEL XMTR RF PWR OUT		MW	A					
TN7546-F	PWR LR ALT XMTR RF PWR OUT		MW	A					
TN7557-X	LR VEL, DATA NO GOOD	CONTACT CLOSURE	SS	S I F I B 2 R H W	CC	SS	4-3		
TN7562-X	LR HEATER CAUTION	CONTACT CLOSURE	SS	S I E I B 2 H C	CC	SS	4-3		
TN7567-V	VOLT LR GAIN STATE D1	-1	+6 VDC SS	R 2	-1	+6	SS		
TN7568-V	VOLT LR GAIN STATE D2	-1	+6 VDC SS	B 2	-1	+6	SS		
TN7569-V	VOLT LR GAIN STATE D3	-1	+6 VDC SS	B 2	-1	+6	SS		
TN7570-V	VOLT LR GAIN STATE D4	-1	+6 VDC SS	R 2	-1	+6	SS		
TN7571-V	VOLT LR -25 VDC	-27	-25 0 VDC SS	R 2	-28	0	SS		
TN7572-V	VOLT LR +25 VDC	0	25 27 VDC SS	B 2	0	28	SS		

Table 5.6-5 (cont'd)

IN CODE	MEASUREMENT NAME AND LOCATION	INTREST RANGES	LOW	HIGH	UNIT	FREQ OR RATE	PADARS											REFERENCES										
							A	S	S	B	G	M	H	C	F	A	X		XDCR	RANGES	OR	C	NIP	XDCR	XDCR			
					C	D	S	L	D	S	C	S	L	D	X	LOW	HIGH	RATE	C	DGE	-PWR	WT.						
TN7573-V	VOLT LK +25 VDC (SSC)	0 25 27	VDC	SS			R 2										0	28	SS									
TN7574-V	VOLT LR +4 VDC	0 4	VDC	SS			B 2										0	10	SS									
TN7575-V	VOLT LP -2 VDC	-4 -2	VDC	SS			R 2										-5	0	SS									
TN7576-X	LR ANTENNA POSIT 1 IND	TBA	VDC	SS			B 2												SS									
TN7577-X	LR ANTENNA POSIT 2 IND	TBA	VDC	SS			B 2												SS									
TN7582-E	PWR LR VEL XMTR RF PWRJUT		MW				B 2																					
TN7583-E	PWR LR ALT XMTR RF PWRJUT		MW				B 2																					
TN7584-X	LR MODE CONTROL	TBA					B 2																					
TN7585-F	FREQ LR SILF TEST	TBA					B 2																					
TN7586-F	FREQ LR RA TRAN BLANK SIG	TBA					B 2																					
TN7587-V	VOLT D1 AT ANGLE 0 DEG	TBA					B 2																					
TN7590-V	VOLT D2 AT ANGLE 0 DEG	TBA					B 2																					
TN7591-V	VOLT D3 AT ANGLE 0 DEG	TBA					B 2																					
TN7592-V	VOLT FR AT ANGLE 0 DEG	TBA					B 2																					
TN7593-V	VOLT D1 AT ANGLE 90 DEG	TBA					B 2																					
TN7594-V	VOLT D2 AT ANGLE 90 DEG	TBA					B 2																					
TN7595-V	VOLT D3 AT ANGLE 90 DEG	TBA					B 2																					
TN7596-V	VOLT FP AT ANGLE 90 DEG	TBA					B 2																					
TN7597-F	FREQ LR ALT TRAN TES CPLR	TBA					A 1																					
TN7598-F	FREQ LR VEL TRAN TES CPLR	TBA					A 1																					
TN7609-H	POS KR SHAFT ANGLE IX	-70																										
TN7610-R	RATE RR SHAFT ANGLE RATE	-10																										
TN7611-H	POS FR TRUNION ANGLE IX	-70																										
TN7612-P	RATI RR TRUN ANGLE RATE	-10																										
TN7613-H	POS RR RANGE (TRANS MOD) TBA																											



Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	CONTRACT NUMBER	NAS9-4983	BASELINE TAXI	INTLREST RANGES	FRFQ A S S B G O M H C F A X	OR C C / I I R P C S / / / X	UNIT RATE	C R S G T D S C S L W L D X	LOW HIGH	RANGES	XDCR	FREQ A DSY	OR C NIP	XDCR	DGE	PWR	WT.	REFERENCES	OR	NOTES	C T	C	
																								CONTRACT CLOSURE
TN7614-L	VEL RR RANGE RATE (PRF)	TBA			FT/S																			
TN7615-X	RR AUTO ANG TRACK ENABLE	TBA			VDC	B 2																		
TN7616-H	POS RR RANGE PRF SURF MOD				FEET																			
TN7618-V	VOLT RR +4 VDC	0	4	6	VDC	SS																		
TN7619-V	VOLT RR +6 VDC	0	6	8	VDC	SS																		
TN7620-V	VOLT RR -12 VDC	-14	-12	0	VDC	SS																		
TN7621-X	RR DATA NO GOOD				CONTACT CLOSURE	SS	1 E 1 B 2 R H M																	
TN7623-V	VOLT RR RANGE STROBE	4	7	10	VDC	3.2K	A 1					0	10											
TN7624-V	VOLT RR RANGE RATE STROBE	4	7	10	VDC	SS	1 H 8 A 1 R H					0	10											
TN7625-V	VOLT RR KESFT STROBE	4	7	10	VDC	3.2K	A 1					0	10											
TN7626-X	RR COUNTER READOUT CMD	4	7	10	VDC	3.2K	A 1					0	10											
TN7627-V	VOLT RR +0 DATA	4	7	10	VDC	3.2K	A 1					0	10											
TN7628-V	VOLT RR +1 DATA	4	7	10	VDC	3.2K	A 1					0	10											
TN7629-V	VOLT RR +12 VDC	0	12	14	VDC	SS	B 2					0	15	SS										
TN7630-V	VOLT RR +25 VDC	0	25	27	VDC	SS	B 2					0	28	SS										
TN7631-V	VOLT RR 25 VDC MULT CHAIN	0	25	27	VDC		B 2					0	28											
TN7632-R	RATE,RR SHAFT ANGLE RATE				DEG/S	IC	10H 8 B 2 H																	
TN7634-R	RATE,RR TRUNNION ANGLE				DEG/S	IC	10H 8 B 2 H																	
TN7636-X	RR RANGE LOW_SCALE FACTOR	TBA			VDC		B 2																	
TN7637-X	RR PWR ON,MODE SW IN LGC	TBA			VDC		B 2																	
TN7638-V	VOLT RR TRUN 16X RES SINE	0	28	VRMS			B 2					0	28											
TN7639-V	VOLT RR SHAFT 16X RES SIN	0	28	VRMS			B 2					0	28											
TN7642-E	PWR RR RF POWER OUTPUT				MW		A																	
TN7644-V	VOLT RR ATM OUTPUT(TRUN)	-150	0	+150	MVDC		A					-150+150												
TN7645-V	VOLT RR ATM OUTPUT(TRUN)	-150	0	+150	MVDC	SS	B 2					-150+150	SS											

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Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 32																									
BASELINE TAXI		NOVEMBER 8, 1965																									
ID CODE	MEASUREMENT NAME AND LOCATION	RADARS										REFERENCES OR NOTES															
		INTEREST RANGES	FREQ A OR RATE	S S S S	B G O M H C F A X	XDCR RANGES	OR C NIP	FREQ A OR RATE	OSY XDCR	C T																	
		LOW	NORM	HIGH	UNIT	C	R	S	G	T	D	S	C	S	L	W	L	D	X	LOW	HIGH	RATE	C	DGE	-PMR	WT.	
TN7646-V	VOLI RR ATM OUTPUT(SHAFT)	-3	0	+3	VDC															A	-3	+3					
TN7647-V	VOLI RR ATM OUTPUT(SHAFT)	-3	0	+3	VDC	SS				B 2											-3	+3	SS				
TN7648-V	VOLI RR ATM OUTPUT (AGC)	0		12	VDC															A	0	15					
TN7649-V	VOLI RR SHAFT MOTOR SIN	0		28	VRMS					B 2											0	28					
TN7650-V	VOLI RR TRUN MOTOR SINE	0		28	VRMS					B 2											0	28					
TN7652-V	VOLI RR SHAFT MOTOR COS	0		28	VRMS					B 2											0	28					
TN7653-V	VOLI RR TRUN MOTOR COS	0		28	VRMS					B 2											0	28					
TN7654-E	PMR RR RF PMR OUTPUT				MM					B 2																	
TN7655-V	VOLI RR 15 VRM AC PMR 1PH	0	15	17	VRMS					B 2											0	20					
TN7656-V	VOLI RR 15 VRM AC PWR 2PH	0	15	17	VRMS					B 2											0	20					
TN7681-F	FREQ RR TONE NO3		TBA							B 2																	
TN7682-F	FREQ RR TONE NO2		TBA							B 2																	
TN7683-F	FREQ RR TONE NO1		TBA							B 2																	
TN7684-V	VOLI,RP +2.5 VDC BIAS	0	2.5	5.0	VDC	SS	2			1	H	B	2								0	5	SS				
TN7685-F	FREQ RR VHF EXCITATION		TBA							B 2																	
TN7686-V	VOLI RR 800/400 CPS REF	0	28	30	VRMS					B 2											0	35					
TN7692-X	RR MODE SEL SW IN AUTO			CONTACT	CLOSURE	SS				S	L	E	1	B	2								SS	4-5	0	0	
TN7693-X	RR MODE SEL SW IN LGC			CONTACT	CLOSURE	SS				S	L	E	1	B	2									SS	4-5	0	0
TN7694-H	POS RR RANGE PRF		TBA							B 2																	
TN7696-F	FREQ RR REF, SYNTHESIZER		TBA							B 2																	
TN7697-X	RR HEATER CAUTION			CONTACT	CLOSURE	SS				S	L	E	1	B	2									SS	4-3	0	0
TN7698-V	VOLI RR TRUN 16X RES COS	0		28	VRMS					B 2											0	28					
TN7699-V	VOLI RR SHAFT 16X RES COS	0		28	VRMS					B 2											0	28					
JN9001	GYRO TEST INPUT SIG																										
JN9002	RCVR(SHAFT ERROR)INPT SIG																										



Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	RADARS												REFERENCES OR NOTES										
			LOW	NORM	HIGH	UNIT	FREQ	A	S	S	B	G	O	M		M	H	C	F	A	X	XDCR	FRFQ	A	USY
JN9003	RCVR(SUM) INPUT SIG																								
JN9004	RCVP (TRUN ERROR) INPUT SIG																								
JN9005	SHAFT CHANNEL INPUT SIG																								
JN9006	SUM CHANNEL INPUT SIG																								
JN9007	TUNNION CHANNEL INPT SIG																								
JN9008	VELOCITY RCVR N01 INPUT																								
JN9009	VFLUCITY RCVP N02 INPUT																								
JN9010	VELOCITY RCVR N03 INPUT																								
JN9011	ALTIMETER RCVP INPUT																								

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Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	LOW	NORM	HIGH	UNIT	PROPLUSTON-ASCENT										REFERENCES OR NOTES						
						FREQ OR RANGES	A OR RANGES	X OR RANGES	F OR RANGES	M OR RANGES	C OR RANGES	S OR RANGES	L OR RANGES	D OR RANGES	X OR RANGES		OSY OR RANGES					
TP0001-P	PRESS,HE SUPPLY TANK NO1	190	3250	3500	PSIA	SS	I	I	H	B	B	R	S	L	0	0	4000	SS	4-1	.28	.25	
TP0001-P	PRESS HE SUPPLY TANK NO1	0	3000	PSIA	SS										W	0	4000	SS				
TP0002-P	PRESS,HE SUPPLY TANK NO2	190	3250	3500	PSIA	SS	I	I	H	B	B	R	S	L	W	0	4000	SS				
TP0002-P	PRESS HE SUPPLY TANK NO2	0	3000	PSIA	SS										D	0	4000	SS	4-1	.28	.25	
TP0025-P	PRESS,REG OUT MANIFOLD	100	195	250	PSIA	SS	I	I	H	B	B	R	S	L		0	300	SS	4-1	.28	.25	
TP0025-P	PRESS REG OUT MANIFOLD	100	195	250	PSIA	100C									A	1	0	300	100C			
TP0025-P	PRESS REG OUT MANIFOLD	230	300	PSIA	SS										C	230	300	SS				
TP0201-T	TEMP,HE SUPPLY TANK NO1	40	70	100	DEGF	SS	I	I	H	B	B	R	S	L	0	-200	+200	SS	6-2	0	.16	
TP0202-T	TEMP,HE SUPPLY TANK NO2	40	70	100	DEGF	SS	I	I	H	B	B	R	S	L	0	-200	+200	SS	6-2	0	.16	
TP0318-X	HE PRI LINE SOL VLV CLOSE	CONTACT CLOSURE				SS	S	I	E	I	B	B	R	H	F	CC		SS	4-4	0	Z.03	
TP0320-X	HE SEC LINE SOL VLV CLOSE	CONTACT CLOSURE				SS	S	I	E	I	B	B	R	H	F	CC		SS	4-4	0	Z.03	
TP0718-T	TEMP,FUEL TANK FUEL BULK	40	70	100	DEGF	SS	I	I	H	B	B	R	S	L	A	40	100	SS	6-2	0	.16	
TP0908-X	FUEL TANK LEVEL LOW	CONTACT CLOSURE				SS	S	I	E	I	B	B	R	L	C	CC		SS	4-3	.75	.90	
TP1218-T	TEMP,OX TANK OX BULK	40	70	100	DEGF	SS	I	I	H	B	B	R	S	L	A	40	100	SS	6-2	0	.16	
TP1408-X	OX TANK LEVEL LOW	CONTACT CLOSURE				SS	S	I	E	I	B	B	R	L	C	CC		SS	4-3	.75	.90	
TP1501-P	PRESS,FUEL ISOL VALVE IN	50	165	250	PSIA	SS	S	I	H	B	B	R	S	L	0	250	SS	4-1	.28	.25		
TP1501-P	PRESS FUEL ISOL VLV INLET	50	165	250	PSIA	150C									A	1	0	300	150C			
TP1501-P	PRESS FUEL ISOL VLV INLET	0	50	PSIA	SS										W	0	50	SS				
TP1503-P	PRESS,OX ISOL VALVE IN	50	165	250	PSIA	SS	S	I	H	B	B	R	S	L	0	250	SS	4-1	.28	.25		
TP1503-P	PRESS OX ISOL VLV INLET	50	165	250	PSIA	150C									A	1	0	250	150C	4-1	.28	.25
TP1801-X	ISOL VLV A OPEN	CONTACT CLOSURE				SS									*	CC		SS		0	Z.03	TP2999
TP1802-X	ISOL VLV B OPEN	CONTACT CLOSURE				SS									*	CC		SS		0	Z.03	TP2999
TP1805-X	BIPROP VLV A OPEN	CONTACT CLOSURE				SS									*	CC		SS		0	Z.03	TP2999
TP1806-X	BIPROP VLV B OPEN	CONTACT CLOSURE				SS									*	CC		SS		0	Z.03	TP2999
TP2010-P	PRESS,THRUST CHAMBER	90	110	121	PSIA	SS	S	I	H	B	B	R	S	L	0	150	SS			.28	.25	



Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 35			
BASELINE TAXI		NOVEMBER 8, 1965			
ID CODE	MEASUREMENT NAME AND LOCATION	PROPLSION-ASCENT		REFERENCES OR NOTES	
		INTEREST RANGES	C T		
	LOW NORM HIGH UNIT	C R S G T D S C S L W L D X	XDCR RANGES	FREQ A OSY OR C NIP XDCR XDCR	
		RATE	LOW HIGH RATE	C DGE PWR WT.	
TP2010-P	PRESS THRUST CHAMBER	90 110 121 PSIA 600C	0 150 600C	-- --	
TP2999-U	ISOL/BIPROP VALVES ERROR	CONTACT CLOSURE SS	1 E 1 B 2 L CC	SS 4-5	
TP2999-U	ISOL/BIPROP VLV MISMATCH	CONTACT CLOSURE IMS	A 1 CC	IMS	

Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983
BASELINE TAXI

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	LOW	NORM	HIGH	UNIT	PROPLSION-DESCENT										REFERENCES DR	NOTES G											
							FREQ A	S	B	G	D	M	C	F	A	X			XDCR	FREQ A	USY								
							OR C	/ I	R	P	C	S	/ /	X	RANGES	DR	C	NIP	XDCR	XDCR									
							W	L	D	X	LOW	HIGH	RATE	C	DGE	-PWR	WT.												
TQ3001-P	PRESS, HE SUPPLY TANK	190	1398	PSIA	SS	I 1 H 8 B 2 R SL	D	0	1500	SS												.28	.25						
TQ3018-P	PRESS HE REG OUT MANIFOLD	210	235	270	PSIA	100C	A 1		0	300	100C																		
TQ3018-P	PRESS, HE REG OUT MANIFOLD	210	235	270	PSIA	SS	I 1 H 8 B 2 R HW		0	300	SS											4-1	.28	.25					
TQ3201-T	TEMP, HE SUPPLY TANK	-445	-335	DEGF	SS	I 1 H 8 B 2 R SL		-450	-300	SS													.25	.25					
TQ3309-X	HE PKI SOL VLV CLOSED	CONTACT CLOSURE	SS	S 1 E 1 B 2 R H F		F		CC	SS													4-4	*	SS WT./PWR.					
TQ3310-X	HE SEC SCL VLV CLOSED	CONTACT CLOSURE	SS	S 1 E 1 B 2 R H F		F		CC	SS														4-4	*	SS WT./PWR.				
TQ3718-T	TEMP, FUEL TANK 1, BULK	40	70	100	DEGF	SS	I 1 H 8 B 2 R SL	A	40	100	SS											6-2	0	.16					
TQ3719-T	TEMP, FUEL TANK 2, BULK	40	70	100	DEGF	SS	I 1 H 8 B 2 R SL	A	40	100	SS												6-2	0	.16				
TQ3909-X	FUEL TANK 1, LQD LFVEL LOW	CONTACT CLOSURE	SS	S 1 E 1 B 2 R HW				CC	SS														4-3	*	SS WT./PWR.				
TQ3910-X	FUEL TANK 2, LQD LEVEL LOW	CONTACT CLOSURE	SS	S 1 E 1 B 2 R HW				CC	SS														4-3	*	SS WT./PWR.				
TQ4218-T	TEMP, OX TANK 1, OX BULK	40	70	100	DEGF	SS	I 1 H 8 B 2 R SL	A	40	100	SS												6-2	0	.16				
TQ4219-T	TEMP, OX TANK 2, OX BULK	40	70	100	DEGF	SS	I 1 H 8 B 2 R SL	A	40	100	SS													6-2	0	.16			
TQ4409-X	OX TANK 1, LQD LEVEL LOW	CONTACT CLOSURE	SS	S 1 E 1 B 2 R HW				CC	SS															4-3	*	SS WT./PWR.			
TQ4410-X	OX TANK 2, LQD LEVEL LOW	CONTACT CLOSURE	SS	S 1 E 1 B 2 R HW				CC	SS															4-3	*	SS WT./PWR.			
TQ6001-P	PRESS, FUEL CONTROL VLV IN	50	210	270	PSIA	150C		0	300	150C																			
TQ6001-P	PRESS FUEL CONTROL VLV IN	50	210	270	PSIA	SS	I 1 H 8 B 2 R L	A	0	300	SS														.28	.25			
TQ6002-P	PRESS, OX CONTROL VLV IN	50	210	270	PSIA	SS	I 1 H 8 B 2 R L		0	300	SS														.28	.25			
TQ6301-H	POS MIXTURE FATIO ACTUAT	-15	+15	DEG	SS	S		-15	+15	SS																			
TQ6306-X	SHUTOFF VLV A NOT OPEN	CONTACT CLOSURE	SS	S		*		CC	SS																0	7.05	TQ7498		
TQ6307-X	SHUTOFF VLV A NOT CLOSED	CONTACT CLOSURE	SS	S		*		CC	SS																	0	7.05	TQ7498	
TQ6308-X	SHUTOFF VLV B NOT OPEN	CONTACT CLOSURE	SS	S		*		CC	SS																		0	7.05	TQ7498
TQ6309-X	SHUTOFF VLV B NOT CLOSED	CONTACT CLOSURE	SS	S		*		CC	SS																		0	7.05	TQ7498
TQ6314-X	SHUTOFF VLV C NOT OPEN	CONTACT CLOSURE	SS	S		*		CC	SS																		0	7.05	TQ7499
TQ6315-X	SHUTOFF VLV C NOT CLOSED	CONTACT CLOSURE	SS	S		*		CC	SS																		0	7.05	TQ7499
TQ6316-X	SHUTOFF VLV D NOT OPEN	CONTACT CLOSURE	SS	S		*		CC	SS																		0	7.05	TQ7499



Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	LOW NORM HIGH UNIT	CONTACT CLOSURE	PROLUSION-DESCENT												REFERENCES OR NOTES																
					C	F	A	X	X	D	C	R	S	G	T	D		S	C	S	L	W	L	D	X	LOW	HIGH	RATE	C	DGE	WT.		
TQ6317-X	SHUTOFF VLV D NOT CLOSED	11 110 121 PSIA	0	100 PCT	SS	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	0	2.05	TQ7499
TQ6510-P	PRESS. THRUST CHAMBER	11 110 121 PSIA	0	100 PCT	SS	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		
TQ6510-P	PRESS THRUST CHAMBER	11 110 121 PSIA	0	100 PCT	SS	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		
TQ6806-H	POS, VARIABLE INJ. ACTUATOR	10 100 PCT	10	100 PCT	SS	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		
TQ7498-U	SHUTOFF VLVS A/B MID POS.	CONTACT CLOSURE			SS	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		
TQ7498-U	SHUTOFF VLVS A/S MID POS.	CONTACT CLOSURE			IMS	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		
TQ7499-U	SHUTOFF VLVS C/D MID POS.	CONTACT CLOSURE			SS	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		
TQ7499-U	SHUTOFF VLVS C/D MID POS.	CONTACT CLOSURE			IMS	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		

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 BASELINE TAXI

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Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 38		NOVEMBER 8, 1965		C T		REFERENCES H	
BASELINE TAXI		INTEREST		REACTION CONTROL		FREQ A OSY		OR C NIP XDCR XDCR	
ID	MEASUREMENT	RANGES	OR C / I R P C S / / X RANGES	FREQ A OSY	OR C NIP XDCR XDCR	OR C NIP XDCR XDCR	OR C NIP XDCR XDCR	OR C NIP XDCR XDCR	OR C NIP XDCR XDCR
CODE	NAME AND LOCATION	LOW NORM. HIGH UNIT	C R S G T D S C S L W L D X LOW HIGH RATE C DGF -PWR. WT.	LOW NORM. HIGH UNIT	C R S G T D S C S L W L D X LOW HIGH RATE C DGF -PWR. WT.	LOW NORM. HIGH UNIT	C R S G T D S C S L W L D X LOW HIGH RATE C DGF -PWR. WT.	LOW NORM. HIGH UNIT	C R S G T D S C S L W L D X LOW HIGH RATE C DGF -PWR. WT.
TR1101-P	PRESSURE, HELIUM TANK A	3000 3050 3250	PSIA SS 3 I I H 8 B 2 R SL	A	0 3500 SS	4-1	.28	.25	
TR1101-P	PRESS HELIUM TANK A	0	1000 PSIA SS	C	0 1000 SS				
TR1102-P	PRESSURE, HELIUM TANK B	3000 3050 3250	PSIA SS 3 I I H 8 B 2 R SL	A	0 3500 SS	4-1	.28	.25	
TR1102-P	PRESS HELIUM TANK B	0	1000 PSIA SS	C	0 1000 SS				
TR1121-T	TEMP, HELIUM TANK A	40 70 100	DEGF SS 3 I I H 8 B 2 R SL	A	20 120 SS	6-2	0	.16	
TR1122-T	TEMP, HELIUM TANK B	40 70 100	DEGF SS 3 I I H 8 B 2 R SL	A	20 120 SS	6-2	0	.16	
TR1201-P	PRESS, HE REGULATOR A OUT	171 191 250	PSIA SS 3 I I H 8 B 2 R L	L	0 350 SS	4-1	.28	.25	
TR1201-P	PRESS HE REG A OUTPUT	0	175 SS	W	0 175 SS				
TR1202-P	PRESS, HE REGULATOR B OUT	171 191 250	PSIA SS 3 I I H 8 B 2 R L	L	0 350 SS	4-1	.28	.25	
TR1202-P	PRESS HE REG B OUTPUT	0	175 SS	W	0 175 SS				
TR1461-X	HE SHUTOFF VLV A-1, CLOSE	CONTACT CLOSURE	SS S I E I B 2 R H F	F	CC	SS	4-4	0	Z.05
TR1462-X	HE SHUTOFF A-2, NOT CLOSED	CONTACT CLOSURE	SS S I E I B 2 R SL F	F	CC	SS	4-4	0	Z.05
TR1463-X	HE SHUTOFF VLV B-1, CLOSE	CONTACT CLOSURE	SS S I E I B 2 R H F	F	CC	SS	4-4	0	Z.05
TR1464-X	HE SHUTOFF B-2, NOT CLOSED	CONTACT CLOSURE	SS S I E I B 2 R SL F	F	CC	SS	4-4	0	Z.05
TR2101-P	PRESSURE, FUEL TANK A	171 191 250	PSIA SS I I H 8 B 2 R SL	A	0 350 SS			.28	.25
TR2102-P	PRESSURE, FUEL TANK B	171 191 250	PSIA SS I I H 8 B 2 R SL	A	0 350 SS			.28	.25
TR2121-T	TEMPERATURE, FUEL TANK A	40 70 100	DEGF SS I I H 8 B 2 R SL	A	20 120 SS	6-2	0	.16	
TR2122-T	TEMPERATURE, FUEL TANK B	40 70 100	DEGF SS I I H 8 B 2 R SL	A	20 120 SS	6-2	0	.16	
TR2141-Q	QUANTITY, FUEL TANK A	0	99 PCT SS S I P 8 B 2 R L	L	0 99 SS				
TR2142-Q	QUANTITY, FUEL TANK B	0	99 PCT SS S I P 8 B 2 R L	L	0 99 SS				
TR2143-Q	QUANTITY, FUEL TANK A	0	99 PCT SS	D	0 99 SS				
TR2144-Q	QUANTITY, FUEL TANK B	0	99 PCT SS	D	0 99 SS				
TR2201-P	PRESS, A FUEL MANIFOLD	171 191 250	PSIA SS 3 I I H 8 B 2 R H	H	0 350 SS	4-1	.28	.25	
TR2202-P	PRESS, B FUEL MANIFOLD	171 191 250	PSIA SS 3 I I H 8 B 2 R H	H	0 350 SS	4-1	.28	.25	
TR2361-X	FUEL MNFL XFEED VLV NO CL	CONTACT CLOSURE	SS S	* F	CC	SS		Z.05	TR9613



Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	REACTION CONTROL										CT	PAGE NUMBER NOVEMBER 8, 1965	REFERENCES OR NOTES																	
			LOW	NORM	HIGH	UNIT	C	R	S	G	T	D				S	C	S	L	W	L	D	X	LOW	HIGH	RATE	C	DGE	XDCR	XDCR	WT.	
TR2362-X	OXID. MNFL. XFEED VLV NO. CL	CONTACT CLOSURE	SS	S																								0	Z.05	TR9613		
TR2461-X	FUEL MAIN FEED S/O A CL	CONTACT CLOSURE	SS	S																								0	Z.05	TR9609		
TR2462-X	FUEL MAIN FEED S/O B CL	CONTACT CLOSURE	SS	S																								0	Z.05	TR9610		
TR3101-P	PRESSURE,OXIDIZER TANK A	171 191 250 PSIA	SS	3	I	H	8	B	2	R	S	L	A	0	350	SS														.28	.25	
TR3102-P	PRESSURE,OXIDIZER TANK B	171 191 250 PSIA	SS	3	I	H	8	B	2	R	S	L	A	0	350	SS														.28	.25	
TR3121-T	TEMP,OXIDIZER TANK A	40 70 100 DEG F	SS	3	I	H	8	B	2	R	S	L	A	20	120	SS														6-2	0	.16
TR3122-T	TEMP,OXIDIZER TANK B	40 70 100 DEG F	SS	3	I	H	8	B	2	R	S	L	A	20	120	SS														6-2	0	.16
TR3141-Q	QUANTITY,OXID. TANK A	0 99 PCT	SS	3	S	I	P	8	B	2	R	L		0	99	SS															--	--
TR3142-Q	QUANTITY,OXID. TANK B	0 99 PCT	SS	3	S	I	P	8	B	2	R	L		0	99	SS															--	--
TR3143-Q	QUANTITY OXIDIZER TANK A	0 99 PCT	SS	3									D	X	0	99	SS													--	--	
TR3144-Q	QUANTITY OXIDIZER TANK B	0 99 PCT	SS	3									D	X	0	99	SS													--	--	
TR3201-P	PRESSURE,OXID. MNFLD A	171 191 250 PSIA	SS	3	I	H	8	B	2	R	H	A	0	350	SS															.28	.25	
TR3202-P	PRESSURE,OXID. MNFLD B	171 191 250 PSIA	SS	3	I	H	8	B	2	R	H	A	0	350	SS															.28	.25	
TR3461-X	OXID MAIN FEED S/O A CLSD	CONTACT CLOSURE	SS	S									* F			CC	SS												0	Z.05	TR9609	
TR3462-X	OXID MAIN FEED S/O B CLSD	CONTACT CLOSURE	SS	S									* F			CC	SS												0	Z.05	TR9610	
TR4261-X	TCA ISOL FUEL VLV 1A CLSD	CONTACT CLOSURE	SS	S									* F			CC	SS												0	Z.05	TR9661	
TR4262-X	TCA ISOL FUEL VLV 1B CLSD	CONTACT CLOSURE	SS	S									* F			CC	SS												0	Z.05	TR9662	
TR4263-X	TCA ISOL FUEL VLV 2A CLSD	CONTACT CLOSURE	SS	S									* F			CC	SS												0	Z.05	TR4663	
TR4264-X	TCA ISOL FUEL VLV 2B CLSD	CONTACT CLOSURE	SS	S									* F			CC	SS												0	Z.05	TR9664	
TR4265-X	TCA ISOL FUEL VLV 3A CLSD	CONTACT CLOSURE	SS	S									* F			CC	SS												0	Z.05	TR9665	
TR4266-X	TCA ISOL FUEL VLV 3B CLSD	CONTACT CLOSURE	SS	S									* F			CC	SS												0	Z.05	TR9666	
TR4267-X	TCA ISOL FUEL VLV 4A CLSD	CONTACT CLOSURE	SS	S									* F			CC	SS												0	Z.05	TR9667	
TR4268-X	TCA ISOL FUEL VLV 4B CLSD	CONTACT CLOSURE	SS	S									* F			CC	SS												0	Z.05	TR9668	
TR4269-X	TCA ISOL OXID VLV 1A CLSD	CONTACT CLOSURE	SS	S									* F			CC	SS												0	Z.05	TR9661	
TR4270-X	TCA ISOL OXID VLV 1B CLSD	CONTACT CLOSURE	SS	S									* F			CC	SS												0	Z.05	TR9662	

Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 40								
BASELINE TAXI		NOVEMBER 8, 1965								
ID CODE	MEASUREMENT NAME AND LOCATION	REACTION CONTROL				FREQ A DSY	XDCR RANGES	OR C NIP	XDCR WT.	REFERENCES OR NOTES
		INTEREST RANGES	LOW NORM HIGH UNIT	CONTACT CLOSURE	CONTACT CLOSURE					
TR4271-X	TCA ISOL OXID VLV 2A CLSD	191	250	PSIA	SS 3 S	SS	CC	0	Z.05	TR9663
TR4272-X	TCA ISOL OXID VLV 2B CLSD	191	250	PSIA	SS 3 S	SS	CC	0	Z.05	TR9664
TR4273-X	TCA ISOL OXID VLV 3A CLSD	191	250	PSIA	SS 3 S	SS	CC	0	Z.05	TR9665
TR4274-X	TCA ISOL OXID VLV 3B CLSD	191	250	PSIA	SS 3 S	SS	CC	0	Z.05	TR9666
TR4275-X	TCA ISOL OXID VLV 4A CLSD	191	250	PSIA	SS 3 S	SS	CC	0	Z.05	TR9667
TR4276-X	TCA ISOL OXID VLV 4B CLSD	191	250	PSIA	SS 3 S	SS	CC	0	Z.05	TR9668
TR5001-X	O/F RATIO A OUT, TOLER	S I E I B 2 R H C		CC	SS	4-3	0	Z.05		
TR5002-X	O/F RATIO B OUT, TOLER	S I E I B 2 R H C		CC	SS	4-3	0	Z.05		
TR5011-P	PRESS TCA FUEL INLT PR 1A 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR5012-P	PRESS TCA FUEL INLT PR 1B 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR5013-P	PRESS TCA FUEL INLT PR 2A 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR5014-P	PRESS TCA FUEL INLT PR 2B 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR5015-P	PRESS TCA FUEL INLT PR 3A 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR5016-P	PRESS TCA FUEL INLT PR 3B 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR5017-P	PRESS TCA FUEL INLT PR 4A 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR5018-P	PRESS TCA FUEL INLT PR 4B 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR5019-P	PRESS TCA OXID INLT PR 1A 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR5020-P	PRESS TCA OXID INLT PR 1B 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR5021-P	PRESS TCA OXID INLT PR 2A 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR5022-P	PRESS TCA OXID INLT PR 2B 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR5023-P	PRESS TCA OXID INLT PR 3A 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR5024-P	PRESS TCA OXID INLT PR 3B 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR5025-P	PRESS TCA OXID INLT PR 4A 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR5026-P	PRESS TCA OXID INLT PR 4B 171	191	250	PSIA	SS 3 S	F	0	175	SS	--
TR6001-T	TEMP, QUAD CLUSTER NO.1	0	200	DEGF	SS 3 I 1 H 8 R 2 R H	0	200	SS	6-2	0 .08



Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	LOW NORM HIGH UNIT RATE	REACTION CONTROL											REFERENCES OR NOTES									
				FREQ A	S	S	B	G	O	M	MH	C	F	A		X	XDCR	FREQ A	OSY					
				C	R	S	G	T	D	S	C	S	L	W	L	O	X	LOW	HIGH	RATE	C	DGE	-PWR	WT.
TR6002-T	TEMP, QUAD CLUSTER NO.2	0	200 DEG F	SS	3	I	1	H	8	B	2	R	H					0	200	SS	6-2	0	.08	
TR6003-T	TEMP, QUAD CLUSTER NO.3	0	200 DEG F	SS	3	I	1	H	8	B	2	R	H					0	200	SS	6-2	0	.08	
TR6004-T	TEMP, QUAD CLUSTER NO.4	0	200 DEG F	SS	3	I	1	H	8	B	2	R	H					0	200	SS	6-2	0	.08	
TR7001-X	ASC INTCON FU VLV A NO CL	CONTACT CLOSURE		SS	S															SS		0	Z.05	TR9611
TR7002-X	ASC INTCON FU VLV B NO CL	CONTACT CLOSURE		SS	S															SS		0	Z.05	TR9612
TR7003-X	ASC INTCON OX VLV A NO CL	CONTACT CLOSURE		SS	S															SS		0	Z.05	TR9611
TR7004-X	ASC INTCON OX VLV B NO CL	CONTACT CLOSURE		SS	S															SS		0	Z.05	TR9612
TR7121-V	VOLT SEC FUEL + OX INJT 1	0 28 32 VDC									B	2									0	35		
TR7122-V	VOLT SEC FUEL + OX INJT 2	0 28 32 VDC									B	2									0	35		
TR7123-V	VOLT SEC FUEL + OX INJT 3	0 28 32 VDC									B	2									0	35		
TR7124-V	VOLT SEC FUEL + OX INJT 4	0 28 32 VDC									B	2									0	35		
TR7125-V	VOLT SEC FUEL + OX INJT 5	0 28 32 VDC									B	2									0	35		
TR7126-V	VOLT SEC FUEL + OX INJT 6	0 28 32 VDC									B	2									0	35		
TR7127-V	VOLT SEC FUEL + OX INJT 7	0 28 32 VDC									B	2									0	35		
TR7128-V	VOLT SEC FUEL + OX INJT 8	0 28 32 VDC									B	2									0	35		
TR7129-V	VOLT SEC FUEL + OX INJT 9	0 28 32 VDC									B	2									0	35		
TR7130-V	VOLT SEC FUEL + OX INJT 10	0 28 32 VDC									B	2									0	35		
TR7131-V	VOLT SEC FUEL + OX INJT 11	0 28 32 VDC									B	2									0	35		
TR7132-V	VOLT SEC FUEL + OX INJT 12	0 28 32 VDC									B	2									0	35		
TR7133-V	VOLT SEC FUEL + OX INJT 13	0 28 32 VDC									B	2									0	35		
TR7134-V	VOLT SEC FUEL + OX INJT 14	0 28 32 VDC									B	2									0	35		
TR7135-V	VOLT SEC FUEL + OX INJT 15	0 28 32 VDC									B	2									0	35		
TR7136-V	VOLT SEC FUEL + OX INJT 16	0 28 32 VDC									B	2									0	35		
TR8609-U	MAIN PROP. VALVE A CLOSED	CONTACT CLOSURE		SS							I	E	B	2	R	H					CC		SS	4-4
TR8610-U	MAIN PROP. VALVE B CLOSED	CONTACT CLOSURE		SS							I	E	B	2	R	H					CC		SS	4-4

CONTRACT NUMBER NAS9-4983
BASELINE TAXI

PAGE NUMBER 41
NOVEMBER 8, 1965

Table 5.6-5 (cont'd)

CONTRACT NUMBFR BASELINE TAXI	NAS9-4983	ID CODE	MFASUREMENT NAME AND LOCATION	INNST A N/CLOSED	INNST B N/CLOSED	MNFELD XFFED VLVS N/CLOSED	TCA ISOL VLVS 1A CLOSED	TCA ISOL VLVS 1B CLOSED	TCA ISOL VLVS 2A CLOSED	TCA ISOL VLVS 2B CLOSED	TCA ISOL VLVS 3A CLOSED	TCA ISOL VLVS 3B CLOSED	TCA ISOL VLVS 4A CLOSED	TCA ISOL VLVS 4B CLOSED	PAGE NUMBER 42 NOVEMBER 8, 1965		C T		REFERENCES OR NOTES	
															INTEREST RANGES	LOW NORM HIGH UNIT RATE	CONTACT CLOSURE	SS		1 E 1 B 2 R SL
TR9611-U	RCS/ASC	INNCT A	N/CLOSED																	
TR9612-U	RCS/ASC	INNCT B	N/CLOSED																	
TR9613-U	MNFELD	XFFED VLVS	N/CLOSED																	
TR9661-U	TCA	ISOL VLVS 1A	CLOSED																	
TR9662-U	TCA	ISOL VLVS 1B	CLOSED																	
TR9663-U	TCA	ISOL VLVS 2A	CLOSED																	
TR9664-U	TCA	ISOL VLVS 2B	CLOSED																	
TR9665-U	TCA	ISOL VLVS 3A	CLOSED																	
TR9666-U	TCA	ISOL VLVS 3B	CLOSED																	
TR9667-U	TCA	ISOL VLVS 4A	CLOSED																	
TR9668-U	TCA	ISOL VLVS 4B	CLOSED																	



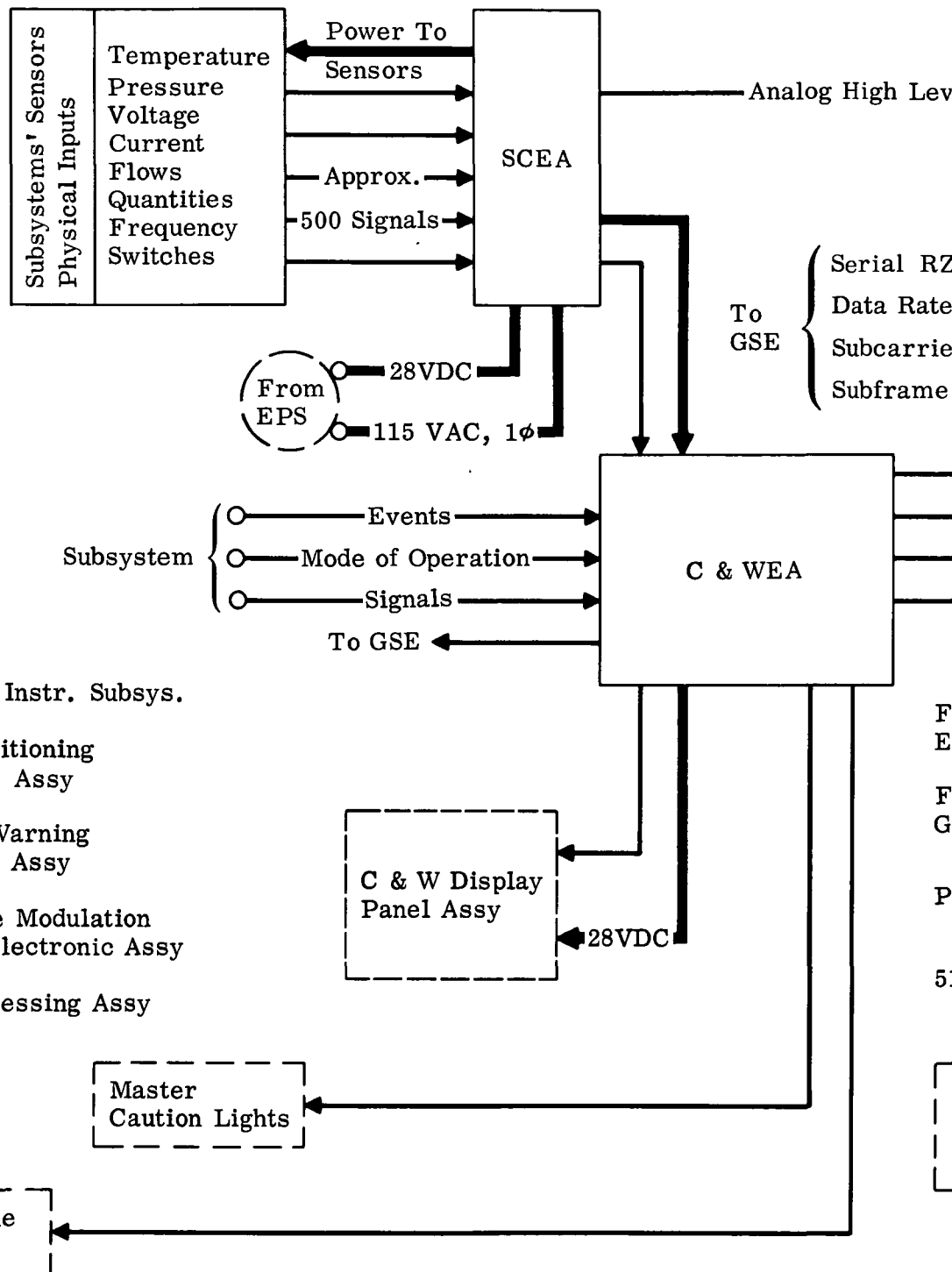
Table 5.6-5 (cont'd)

ID CODE	MEASUREMENT NAME AND LOCATION	LOW NORM HIGH UNIT	INTEREST RANGES	COMMUNICATIONS	FREQ A S S B G O M H C F A X OR C C / I I R P C S / / / X RANGES	XDCR OR C NIP XDCR XDCR RANGES	C T	REFERENCES OR NOTES
TT0105	PCM NRZ DATA INPUT	TBA	TBA	A 1				
TT0106	TE 512KC SYNC IN	TBA	TBA	A 1				
TT0107	PCM SPLIT PHASE IN	TBA	TBA	A 1				
TT0108	512KC SUBCARRIER REF IN	TBA	TBA	A 1				
TT0145-V	VOLT, SPS AVC RCVD VHF B	0	5 VDC SS	R 2		0	5 SS	
TT0161-V	VOLT, PMP FVG VOICE LINE	TBA	TBA	A 1				
TT0163	VHF RCVD VOICE IN A	TBA	TBA	A 1				
TT0164	VHF RCVD VOICE IN B	TBA	TBA	A 1				
TT0201-E	POWER, SBAND PA RF PWR OUT	0	18 25 WATTS SS	S I H B 2 R S L			SS	
TT0202-E	PWR, SBAND PA RF REFLECTED	0	.3 .5 WATTS SS	S I H B 2 H			SS	
TT0206-X	PA RECYCLING SIG NO 1			B 2				
TT0207-X	PA RECYCLING SIG NO 2			B 2				
TT0224-C	CURR, SBAND PWR AMP AN 1	20	25 30 MA SS	B 2		0	30 SS	
TT0225-C	CURR, SBAND PWR AMP AN 2	20	25 30 MA SS	B 2		0	30 SS	
TT0226-F	PWR VHF XMTR A+B RF OUT	TBA	TBA	B 2				
TT0451-H	POS GIMBAL PICOFF OPUT Y	-60	+240 DEG	A				
TT0452-H	PUS GIMBAL PICOFF OPUT X	-75	+75 DEG	A				
TT0453-X	SBAND STEER ANT NO TRACK	CLOSURE	SS	L	CC		SS	
TT0504-V	VOLT, SBAND RCVR AGC	0	4.2 VDC	A		0	5	
TT0511	SBAND XPNDR FM INPUT	TBA	TBA	A 1				
TT0513	SBAND XPNDR PM INPUT	TBA	TBA	A 1				
TT0555	S 8D RCVR SBAND WFORM OT	TBA	TBA	A 1				
TT0604-V	VOLT, VHF RCVR A AGC	0	4.2 VDC SS	B 2		0	5 SS	
TT0605-V	VOLT, VHF RCVR B AGC	0	4.2 VDC SS	B 2		0	5 SS	
TT0660-V	VOLT, ST ANT SERV ERR INP	TBA	TBA	A 1				

Table 5.6-5 (cont'd)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 44			
BASELINE TAXI		NOVEMBER 8, 1965			
ID	MEASUREMENT	COMMUNICATIONS		REFERENCES	
		OR C / I T R P C S / / X RANGES	FREQ A OSY		
CODE	NAME AND LOCATION	LOW NORM HIGH UNIT RATE C R S G T D S C S L W L D X LOW HIGH RATE C DGF -PWR WT.	XDCR	OR	
				NGTES	
TI0992-B	PHASE ST PH ER SLCTD S/B	-15 0 +15 DEG 2C	S 10H 8 B 2 R L	2C	
TI0993-F	PMR SLCTD SBAND XMTR RF	.5 .75 1 WATT SS	S I H 8 B 2 R SL	SS	
TI0994-V	VOLTI SLCTD SBAND RCVR AGC	0 4.2 VDC 2C	S 10H 8 B 2 R SL	0 5 2C	
TI8001	VHF XMTR A CW CONTROL				
TI8002	VHF XMTR B CW CONTROL				
TI8003-V	VOLTI PRIM PWR SUPP CONTR				
TI8005-V	VOLTI SEC PWR SUPP CONTR				
TI9991-J	7 SPACE SUIT/PLSS MPX OUT				SBAND
TI9999-J	ELECTROCARDIOGRAM NO.1/2				SBAND





Key

- Not Part of Instr. Subsys.
- SCEA: Signal Conditioning Electronics Assy
- C&WEA: Caution & Warning Electronics Assy
- PCMTEA: Pulse Code Modulation & Timing Electronic Assy
- SPA: Signal Processing Assy

F
E
F
G
P
5

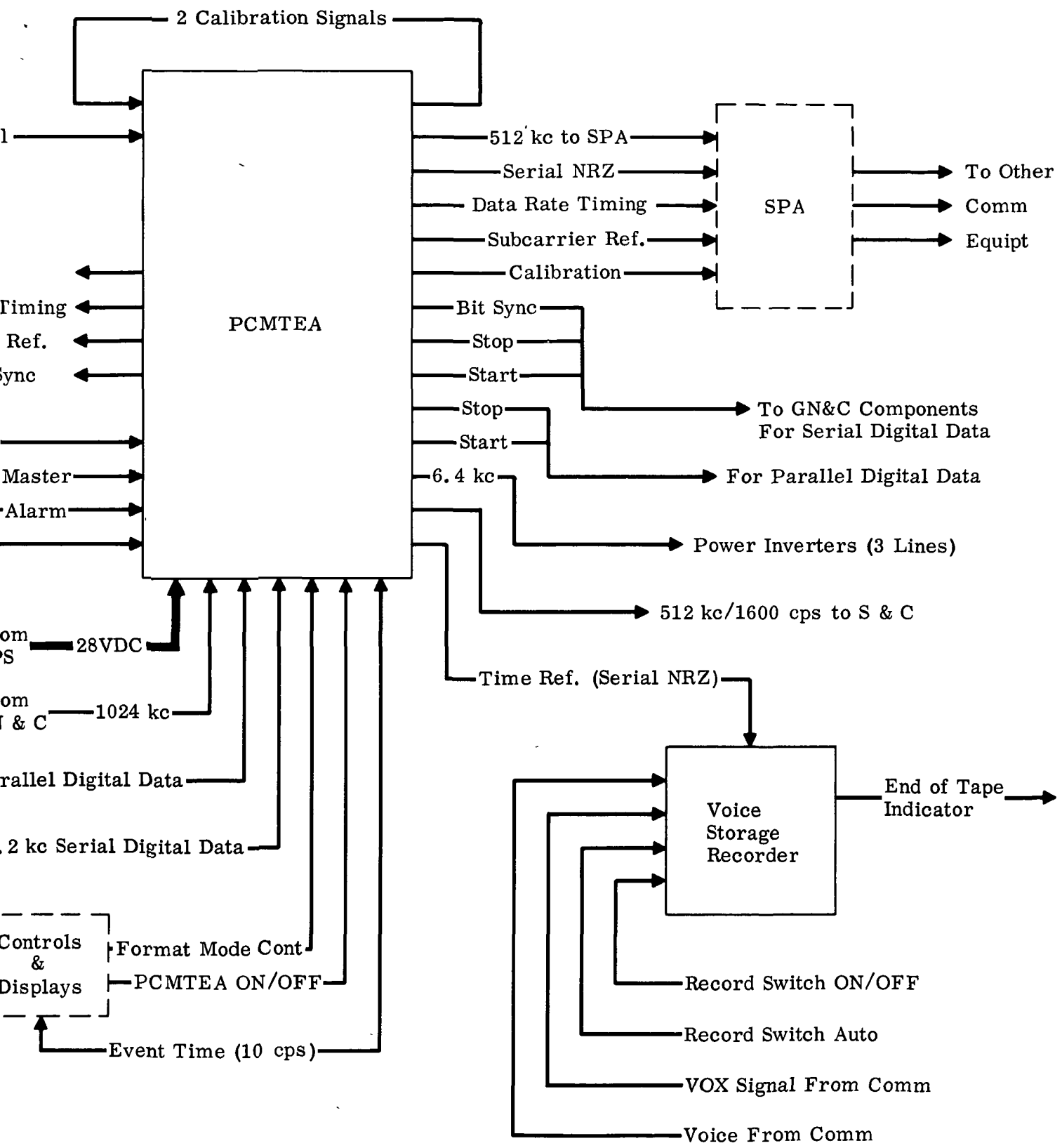


Fig. 5.6-1 Instrumentation Subsystem

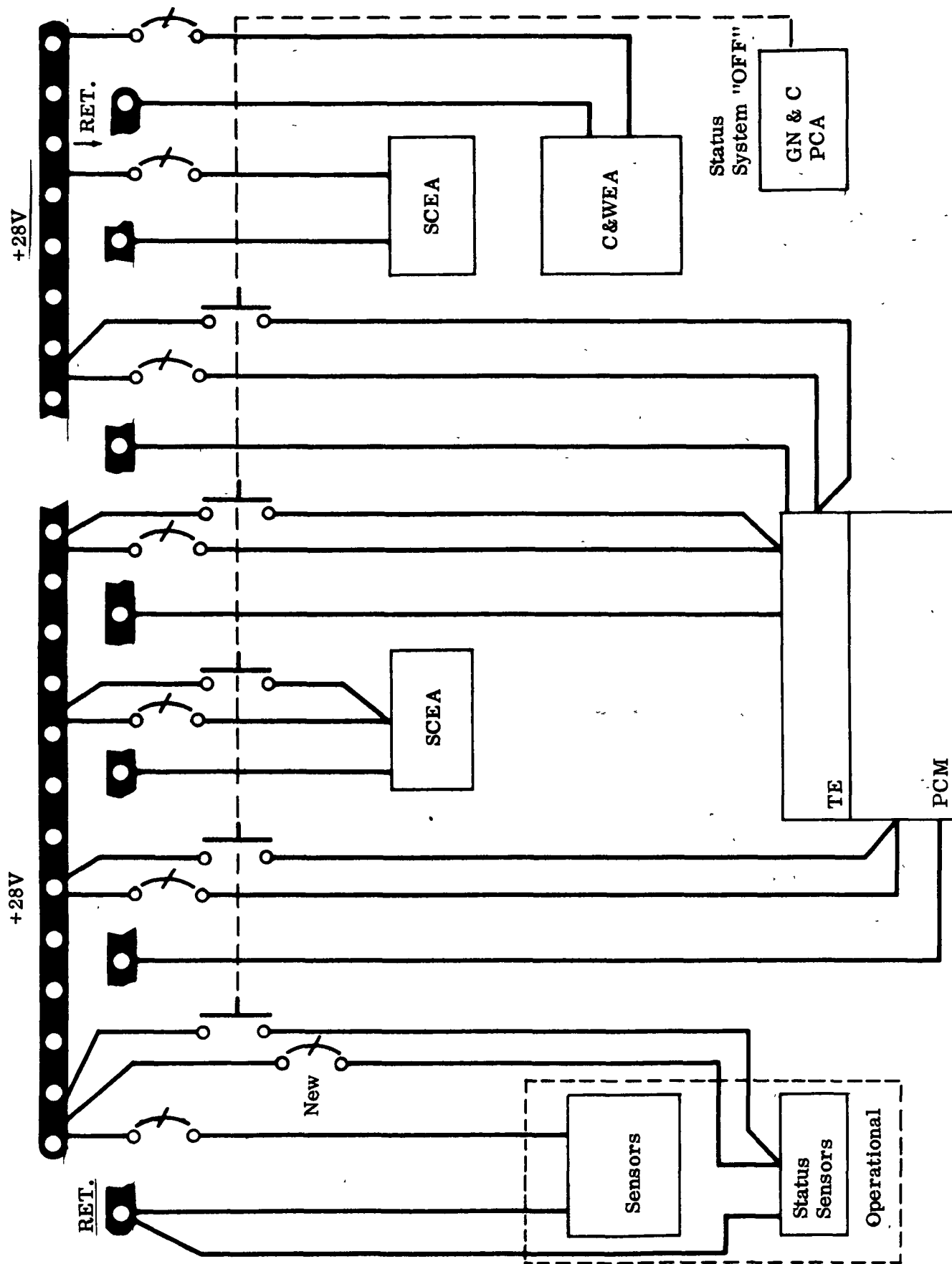
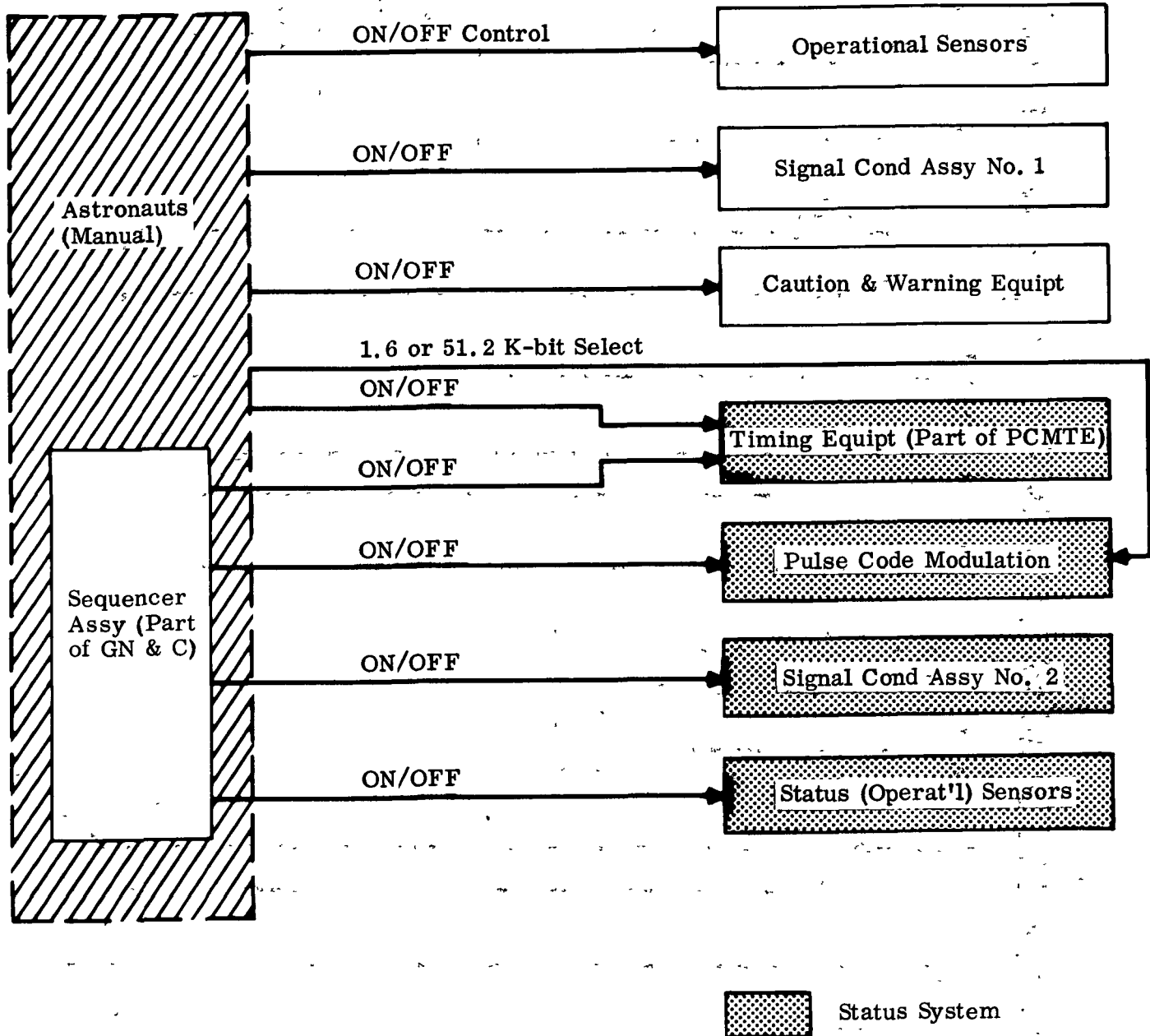


Fig. 5.6-2 Status Bus Power Distribution



Note: The astronauts will perform all functions normally, as in LEM. When the Taxi is placed into a storage mode, the Sequencer Assembly will control the limited status system.

Fig. 5.6-3 Status Data Time Sequencer Command Control

5.7 CONTROLS AND DISPLAYS

5.7.1 Ground Rules

There are no NASA ground rules unique to the Taxi Controls and Displays Subsystem.

5.7.2 Assumptions

It is assumed that the preseparation, post-landing, and prelaunch checkouts of the Taxi do not require any additional controls and displays.

5.7.3 Recommended Configuration

In general, the Taxi controls and displays are identical to those of the LEM. There are a few exceptions, such as the deletion or addition of a switch position on a rotary select switch. These modifications do not require deletion of the component, just the elimination of that position. Specifically, these changes are as follows:

- Four descent batteries have been deleted and replaced with three 12-kw-hr batteries; therefore, one set of high and low switches and status flag can be deleted.
- Since the EVA antenna functions are to be performed only by the VHF in-flight antenna, the erectable VHF antenna mode has been removed from the VHF Select Switch.
- TV camera has been deleted; therefore the TV Switch and connectors have been removed.
- Circuit breakers will have the appropriate additions and deletions of breakers to satisfy the subsystem and safety requirements.

The Taxi will make use of the Shelter Radioisotope Thermal Generator (RTG), and therefore it will be necessary to provide controls and displays for it. If the RTG is connected to the Taxi without proper checkout it could malfunction, and thus cause the descent batteries to supply power instead of the RTG. This would drain all the power from the descent batteries and cause a mission abort. Therefore, it is necessary for one of the astronauts to enter the vehicle after the RTG is in place and check the voltage, amperage, and temperature. This requires a slight modification to the EPS display to accommodate these functions.

Figures 5.7-1 through 5.7-9 illustrate the Taxi Control and Display Panels. The complete panel layout is shown in Section 6.2.

5.7.4 Baseline Configuration

The baseline configuration is the same as the recommended, except that it does not include the controls and displays required for checkout of the RTG.

5.7.5 Alternate Configuration

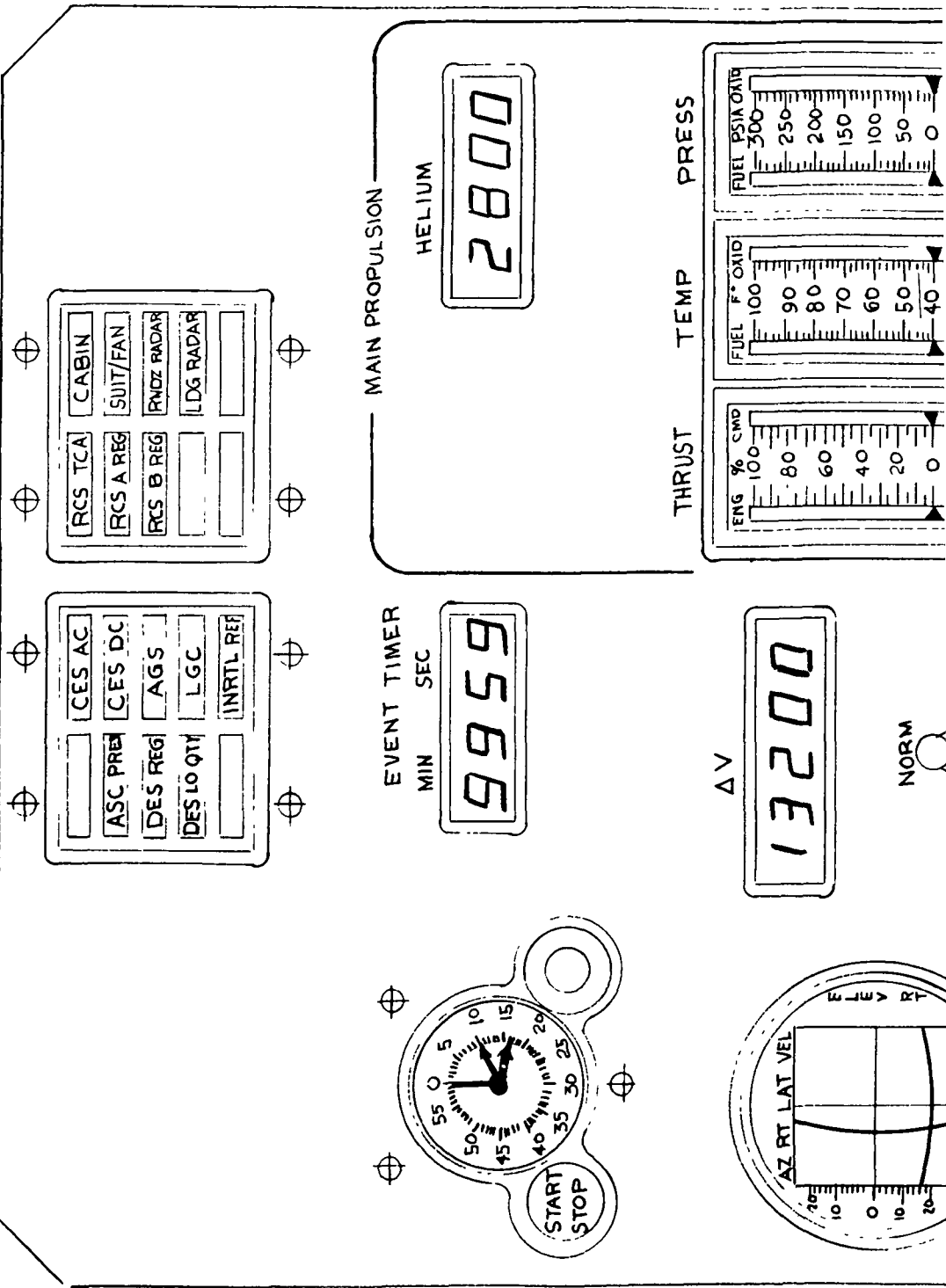
No alternate configurations were considered for the Taxi.

5.7.6 Potential Modification Per Flight

No per flight modifications were considered for the Taxi.

(3)

I



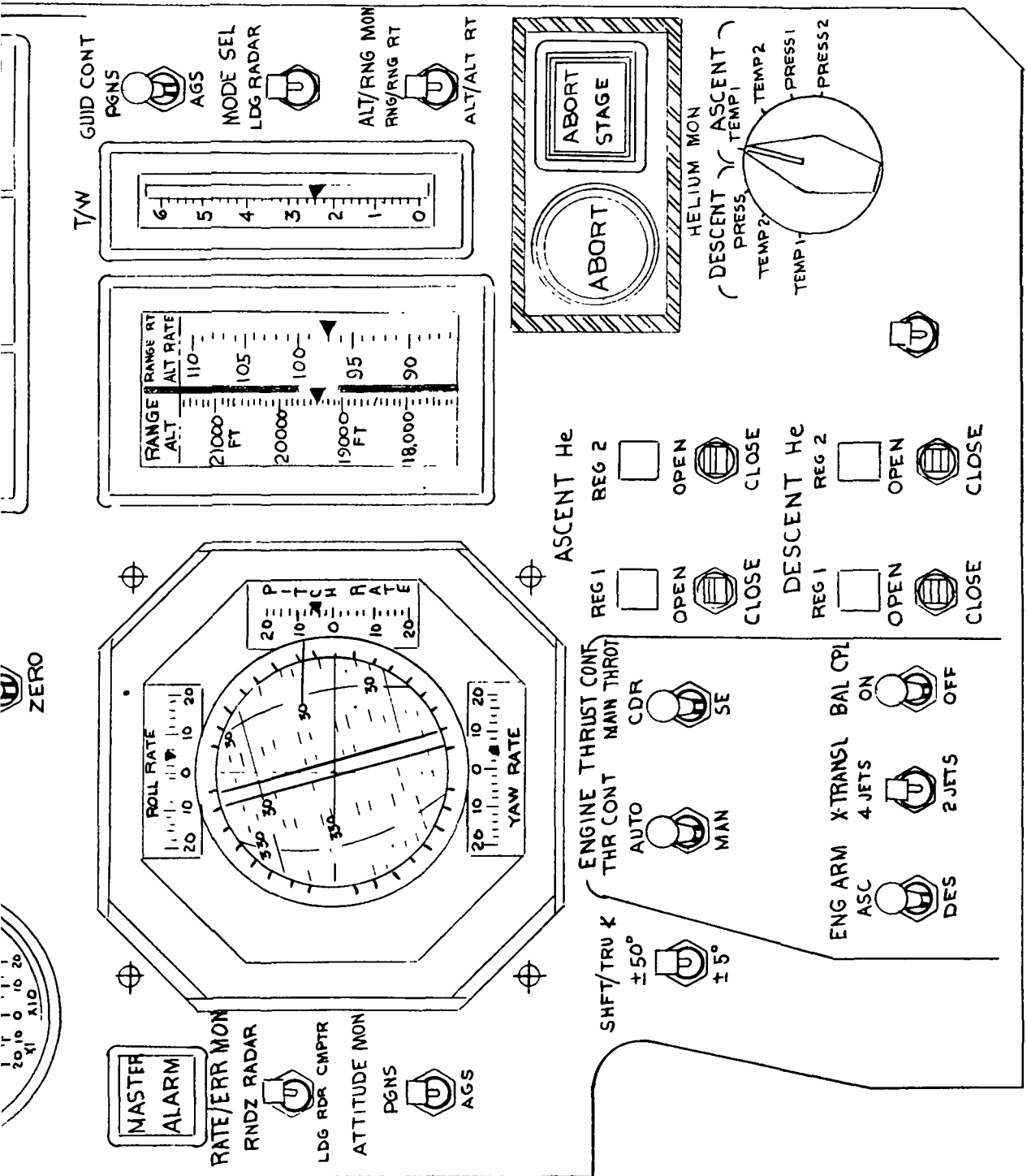
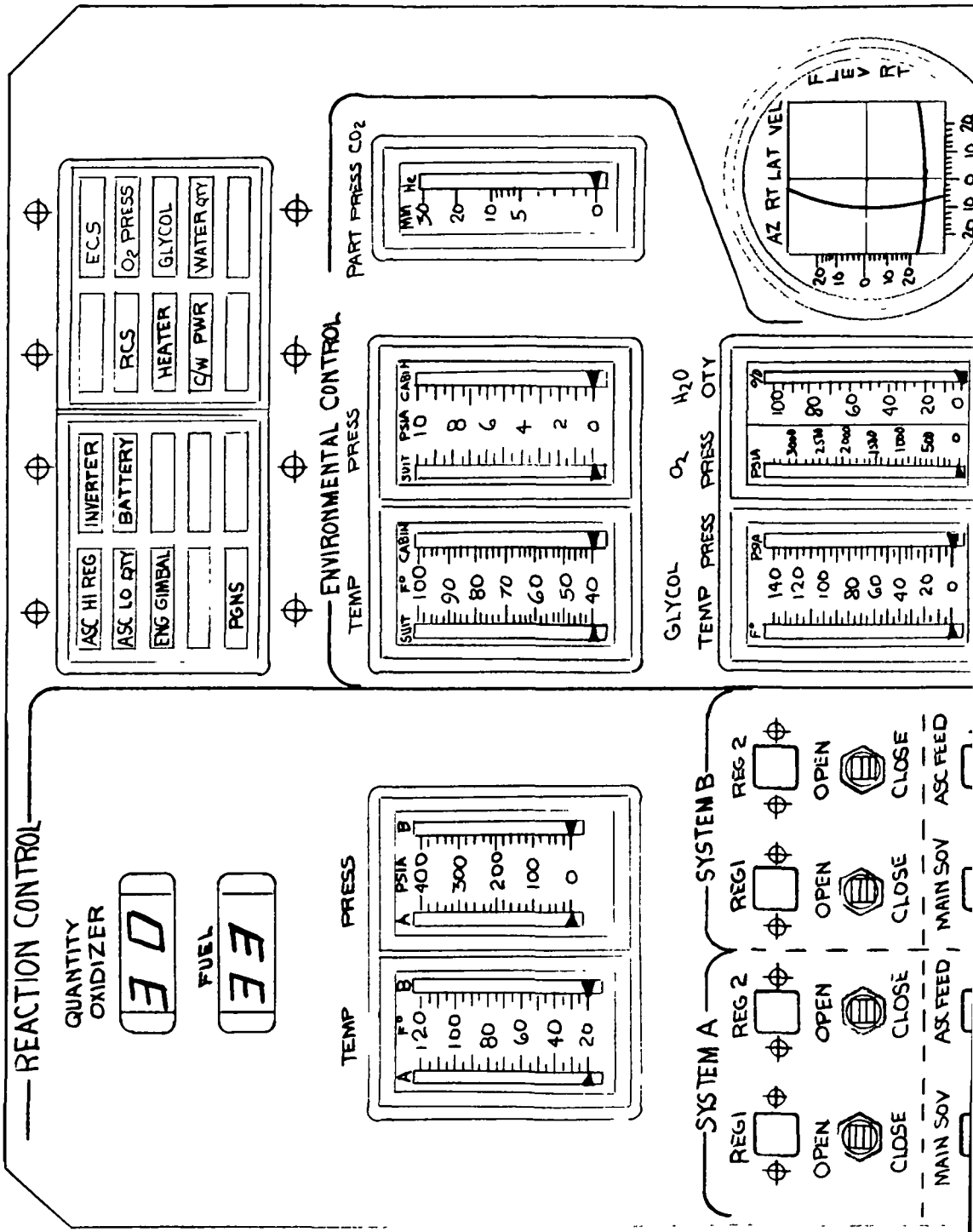


Fig. 5.7-1 Controls & Displays Panel I



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II



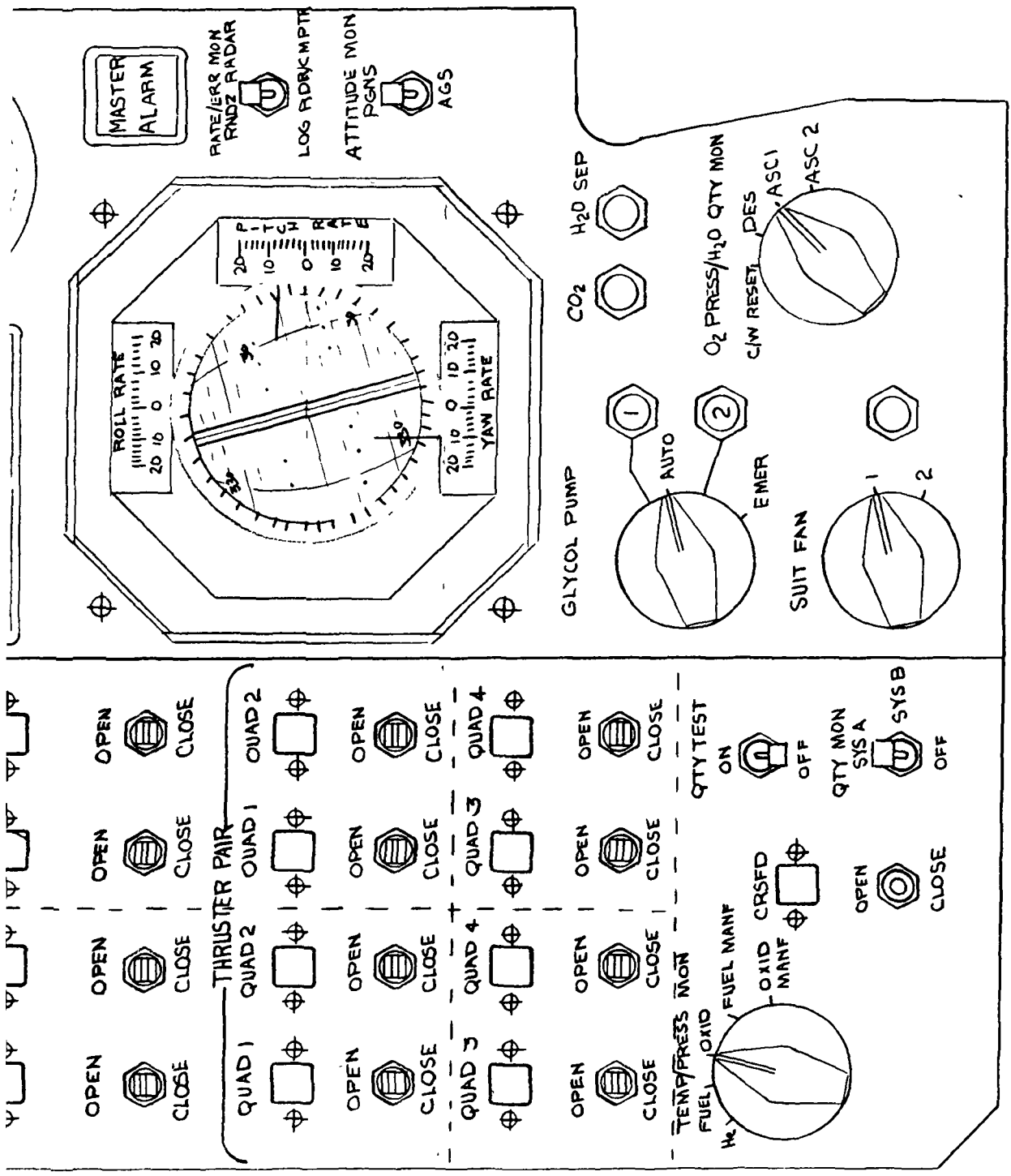
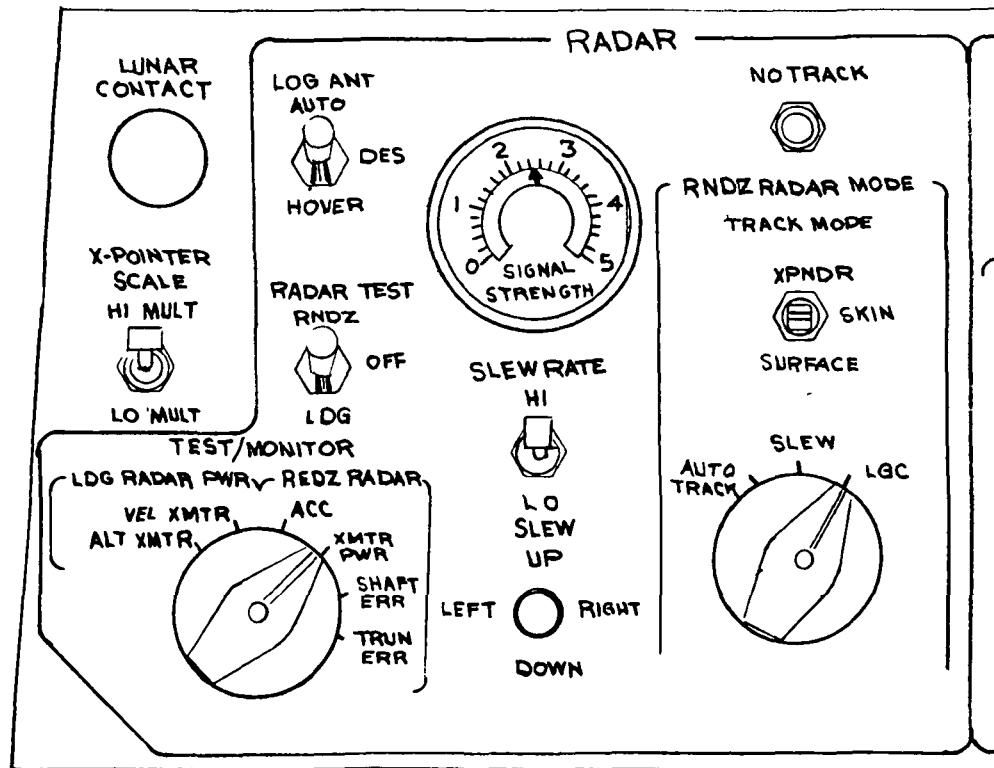


Fig. 5.7-2 Controls & Displays Panel II



5.7-3
①

STABILIZATION CONTROL

DEAD BAND



GYRO TEST



PITCH



POS RT



OFF

NEG RT

ATTITUDE CONTROL

ROLL MODE CONT



PULSE

DIR

PITCH MODE CONT



PULSE

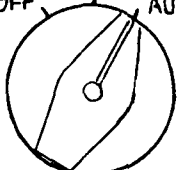
DIR

YAW



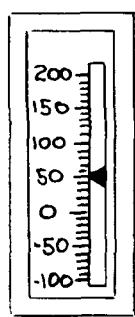
DIR

MODE CONTROL
ATT HOLD



HEATER CONTROL

TEMP



RNDZ RADAR

OPR TEMP



STBY TEMP

AUTO



MAN

QUAD 1

AUTO



MAN

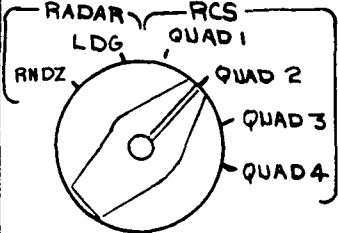
QUAD 2

AUTO



MAN

TEMP MONITOR



CDR

AUTO



MAN

5.7.3

2

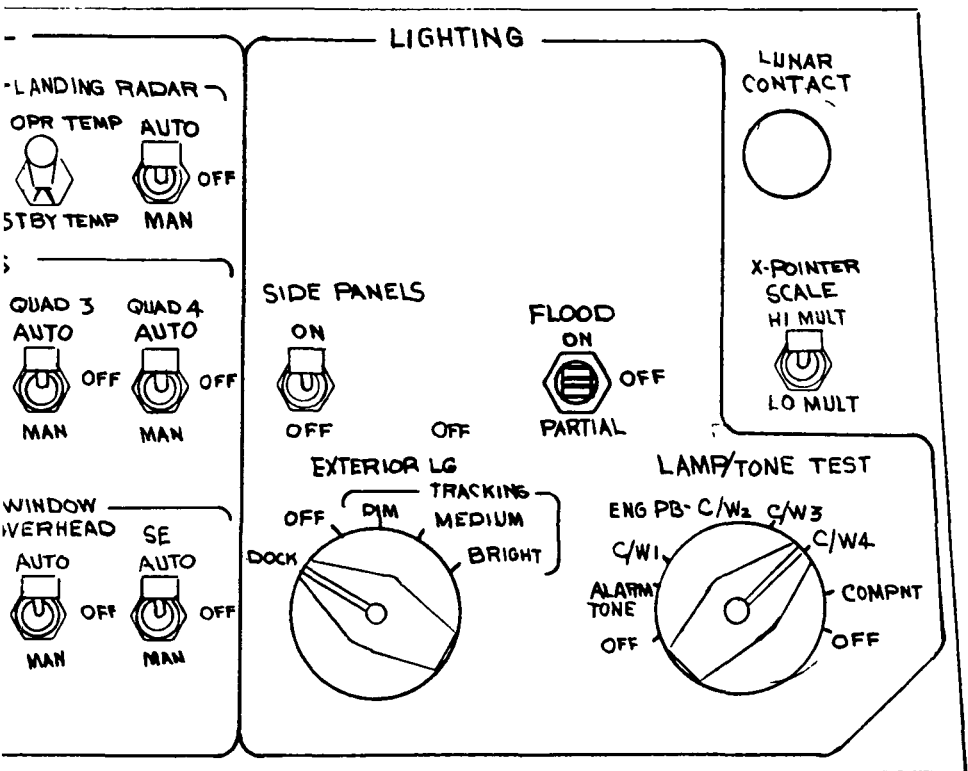
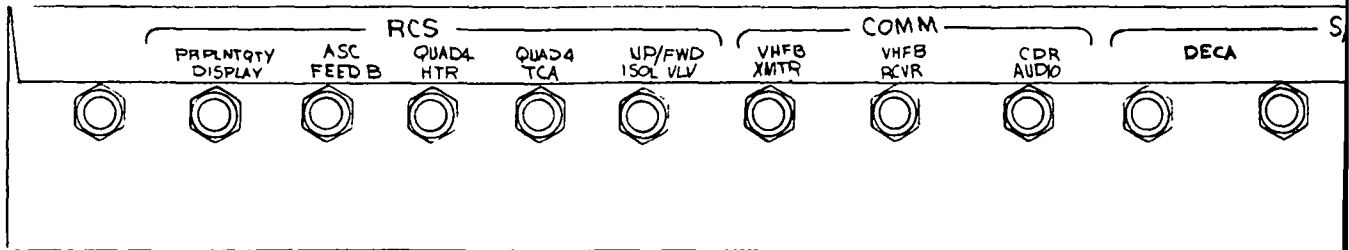
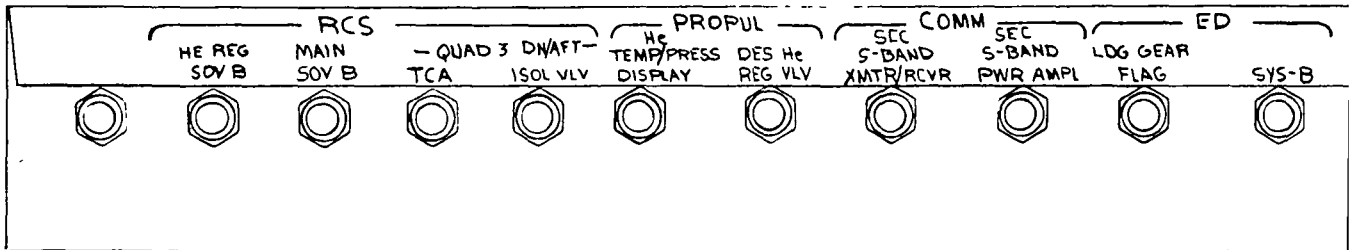
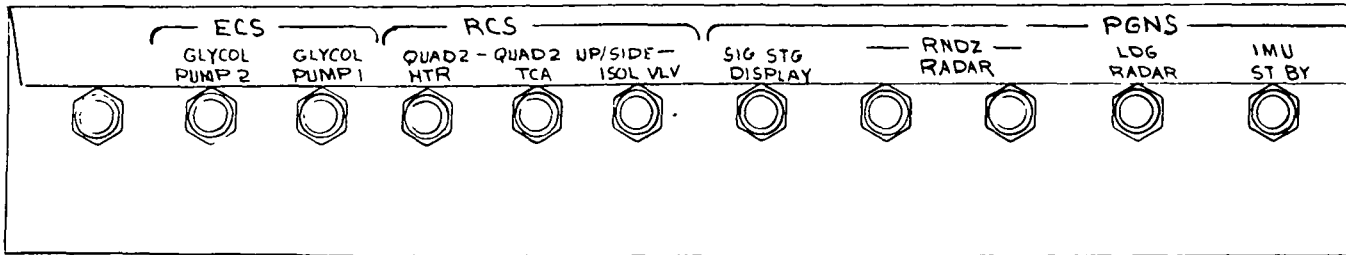
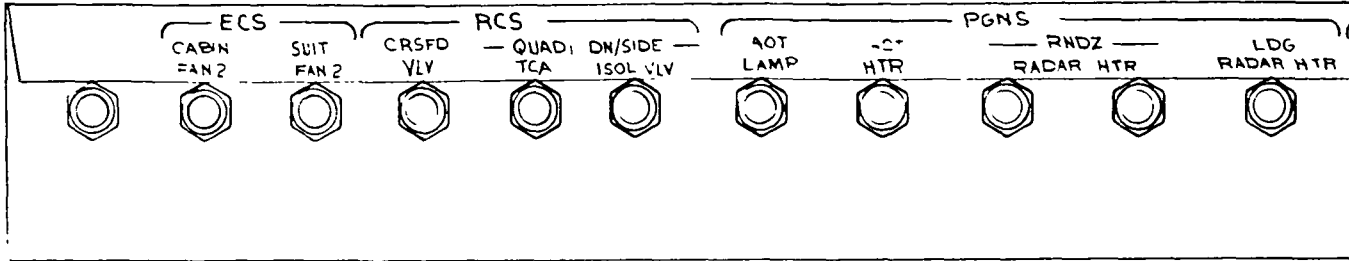


Fig. 5.7-3 Controls & Displays Panel III

3

143



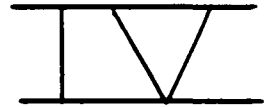
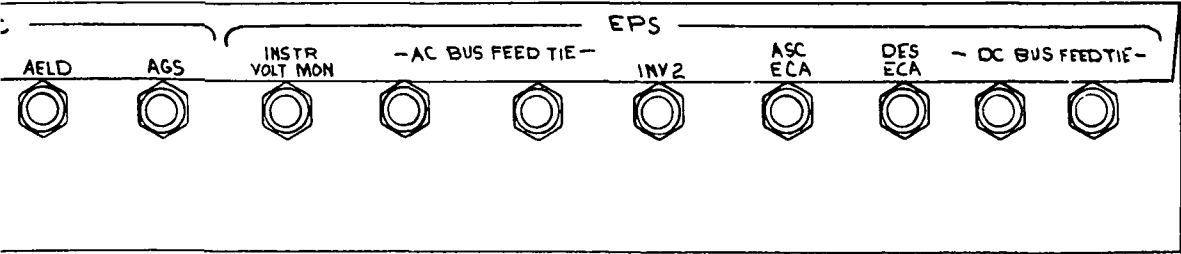
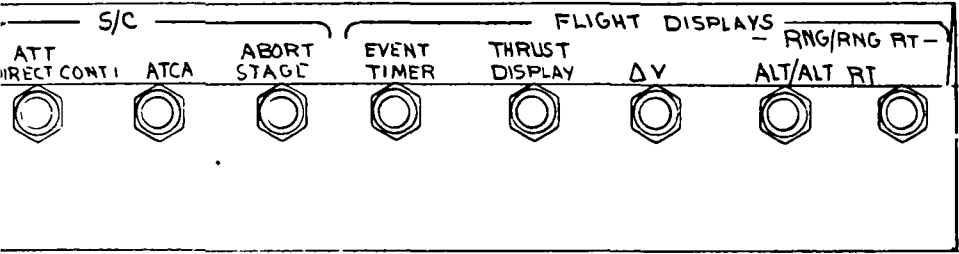
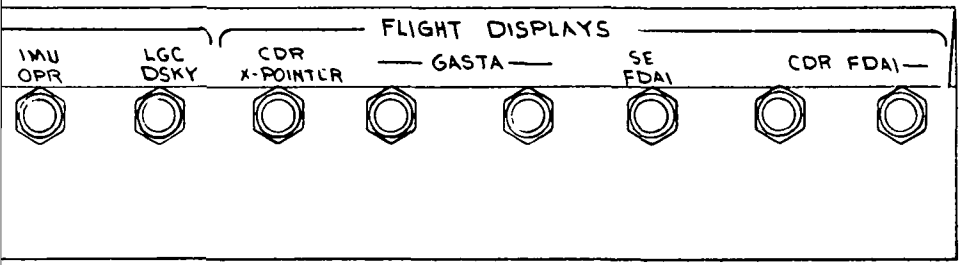
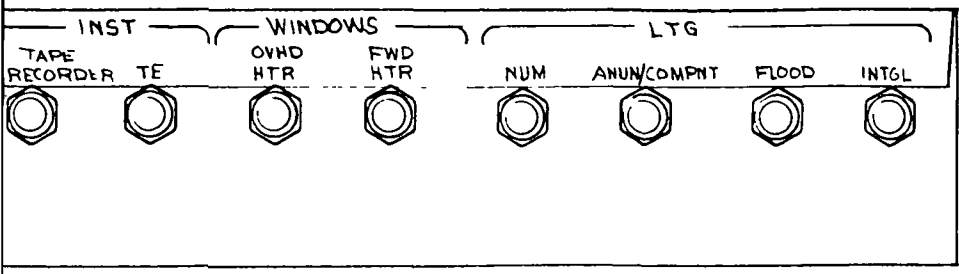
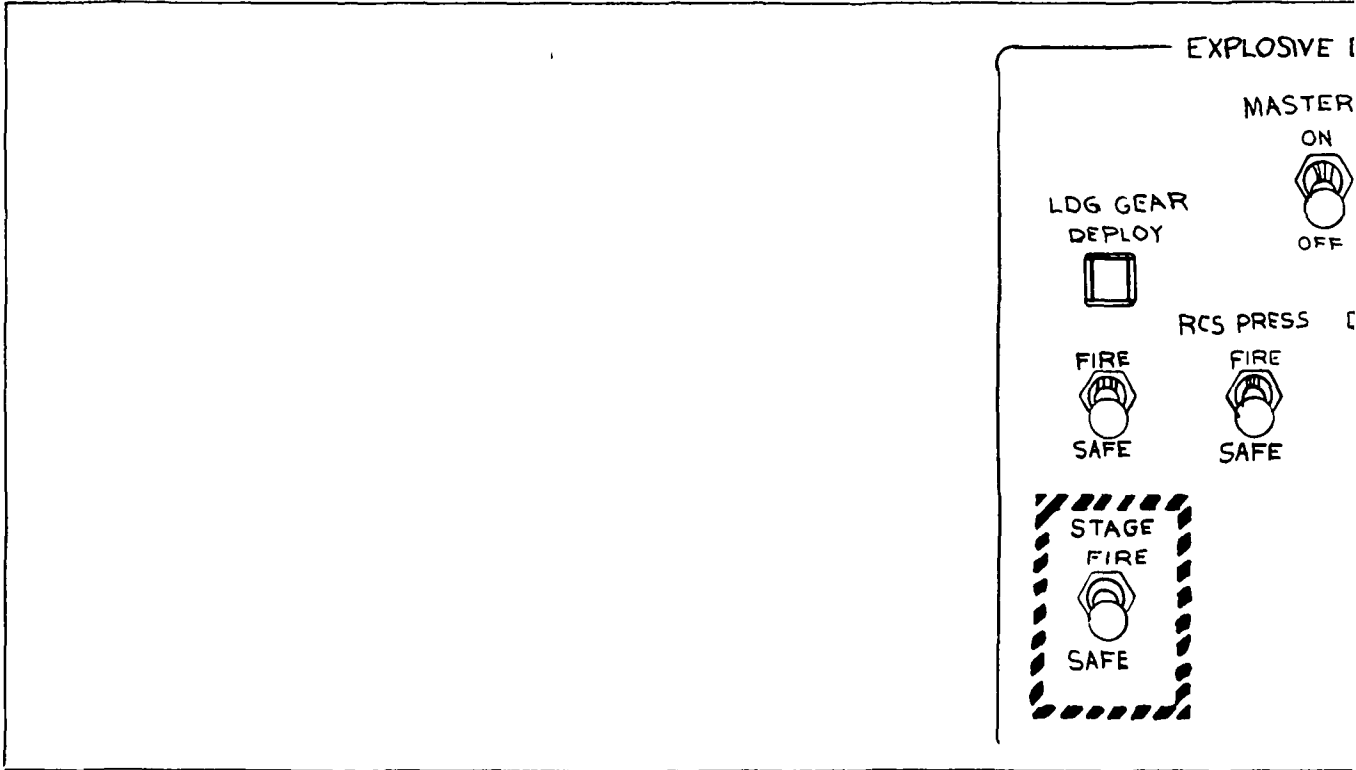


Fig. 5.7-4 Controls & Displays Panel IV

(145)



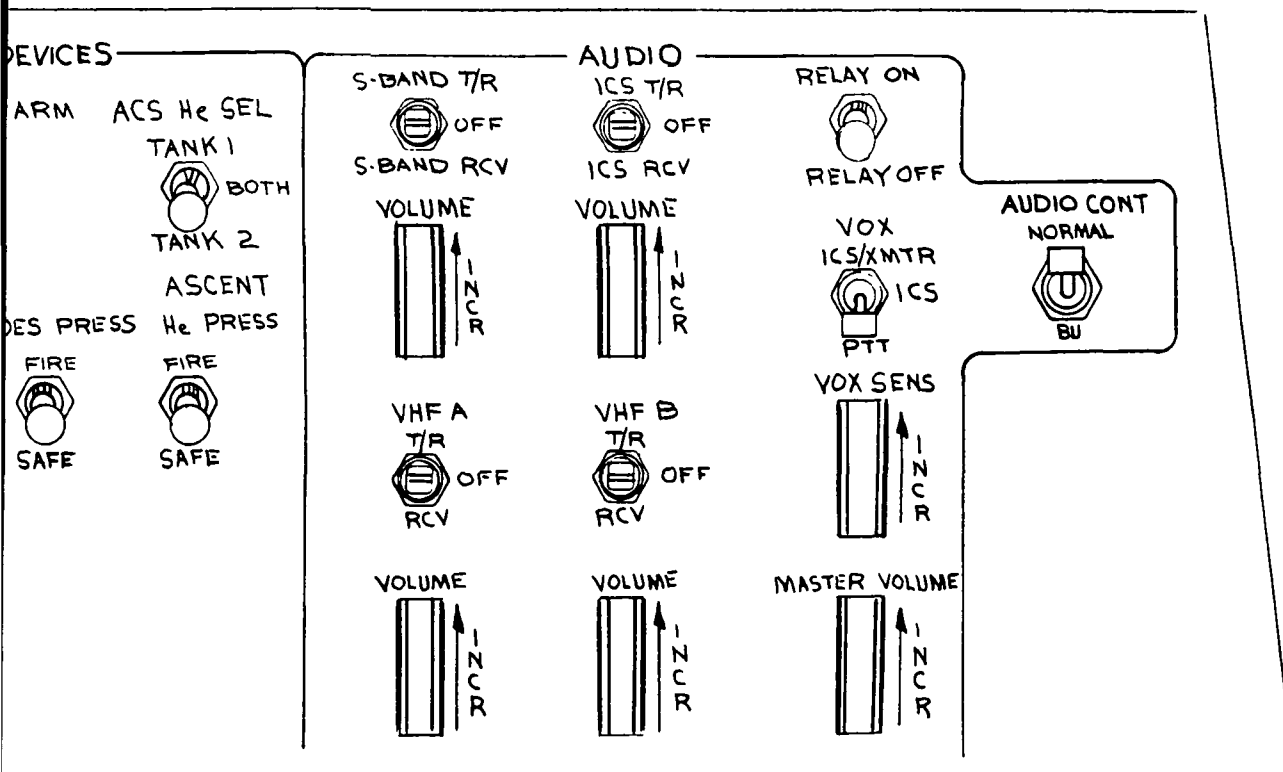
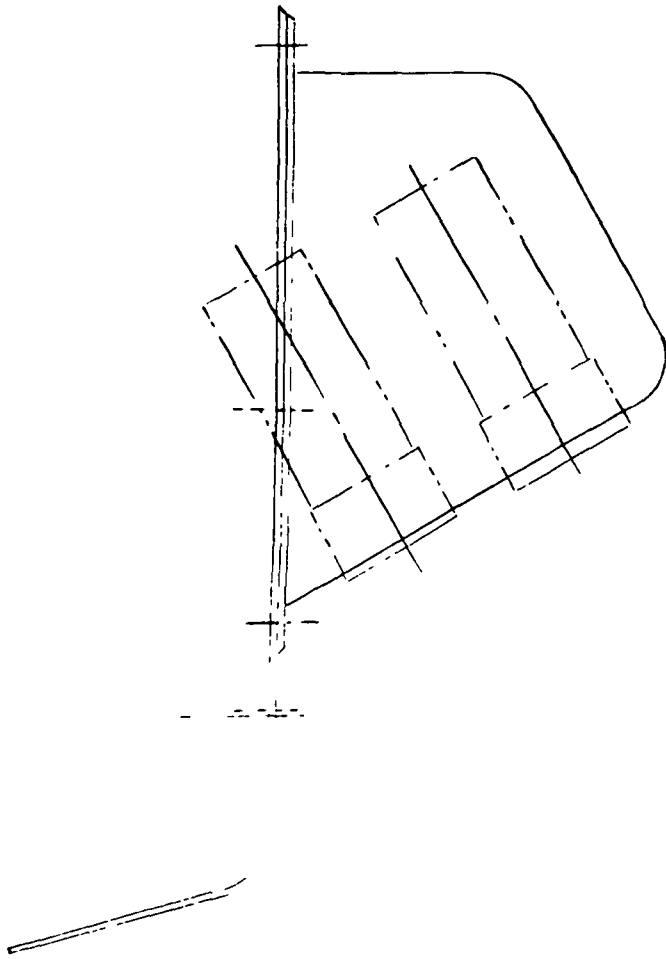
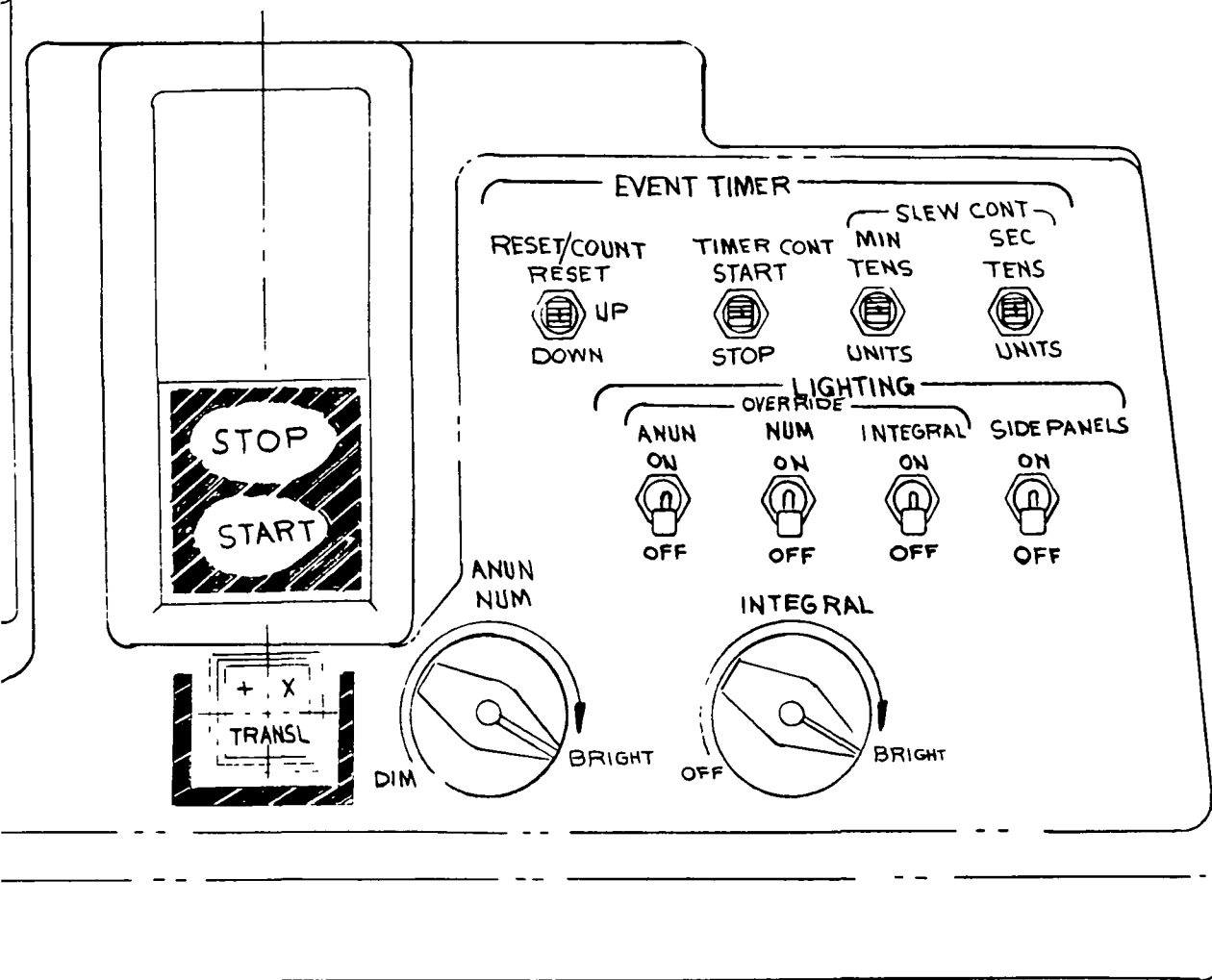


Fig. 5. 7-5 Controls & Displays Panel VI

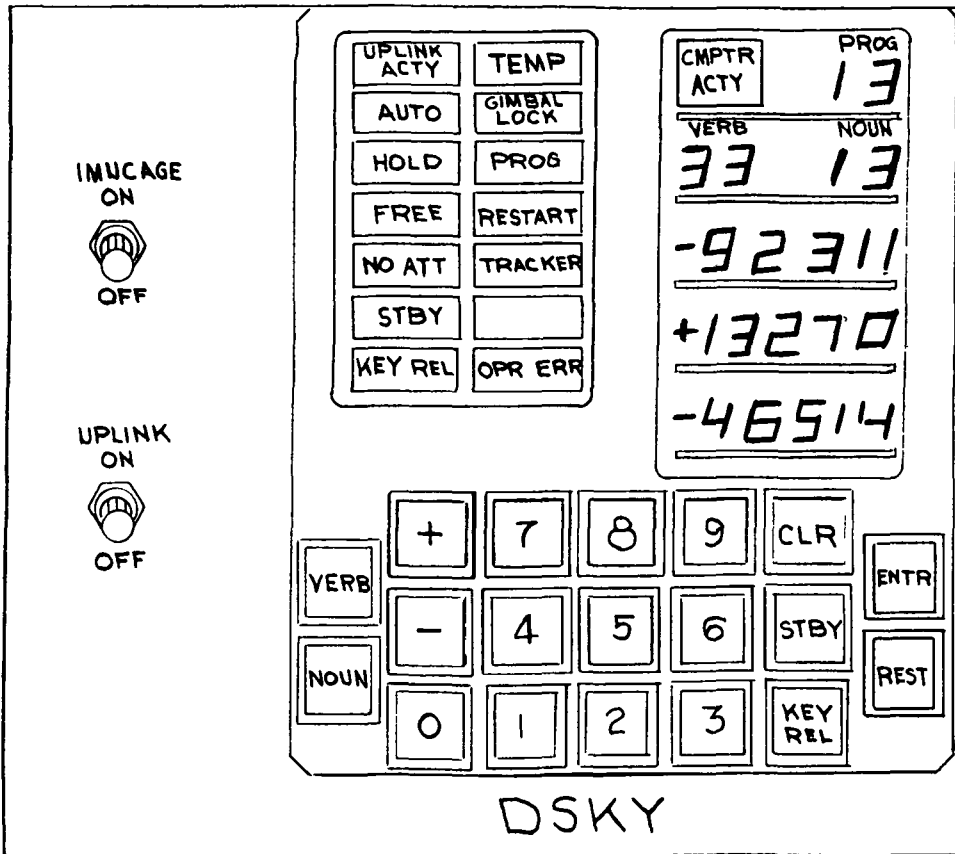
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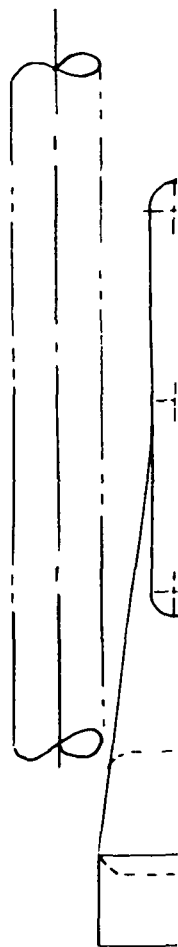
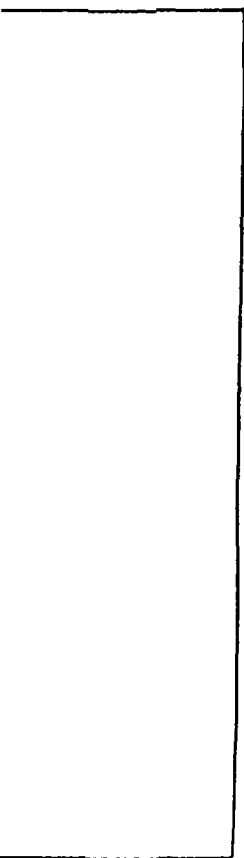


VII

Fig. 5.7-6 Controls & Displays
Panel VII



5.7-7



5.7-7

(a)

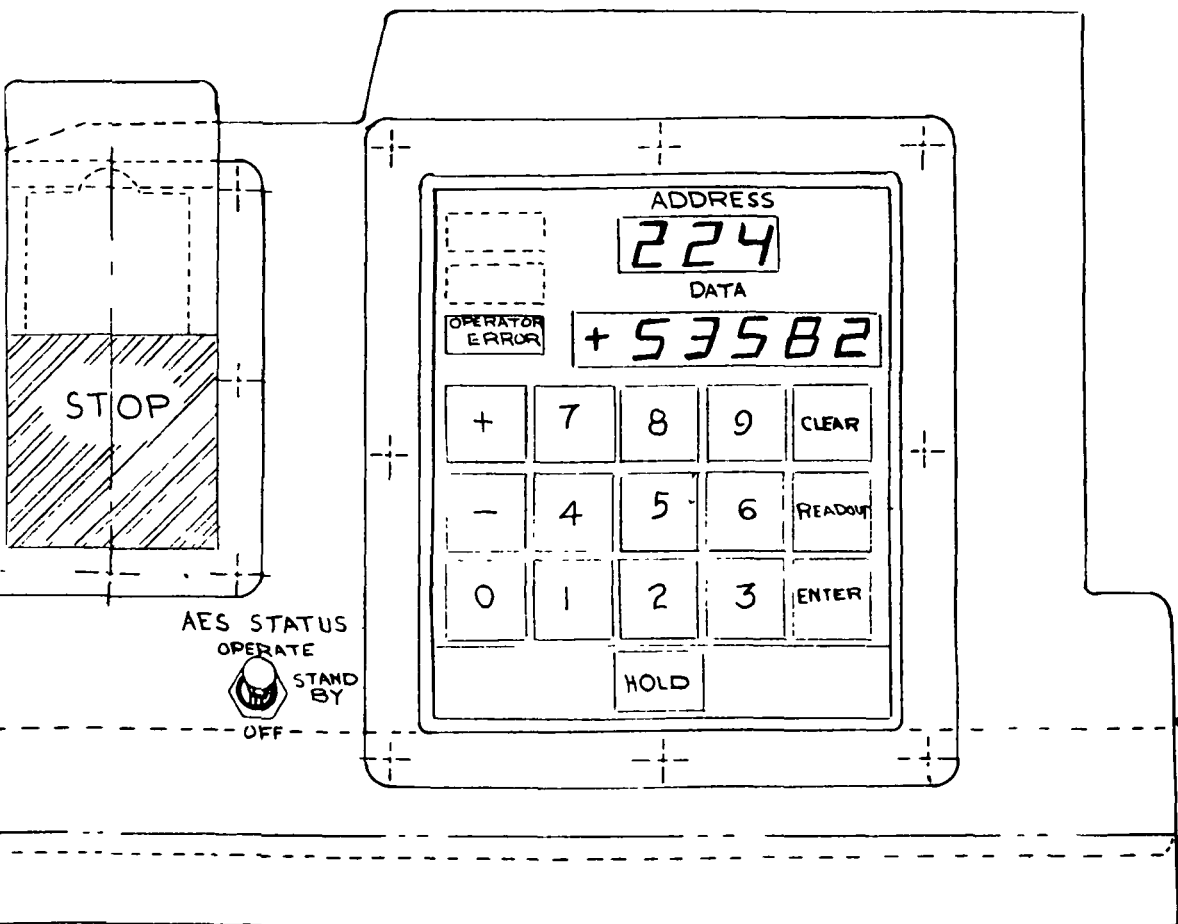
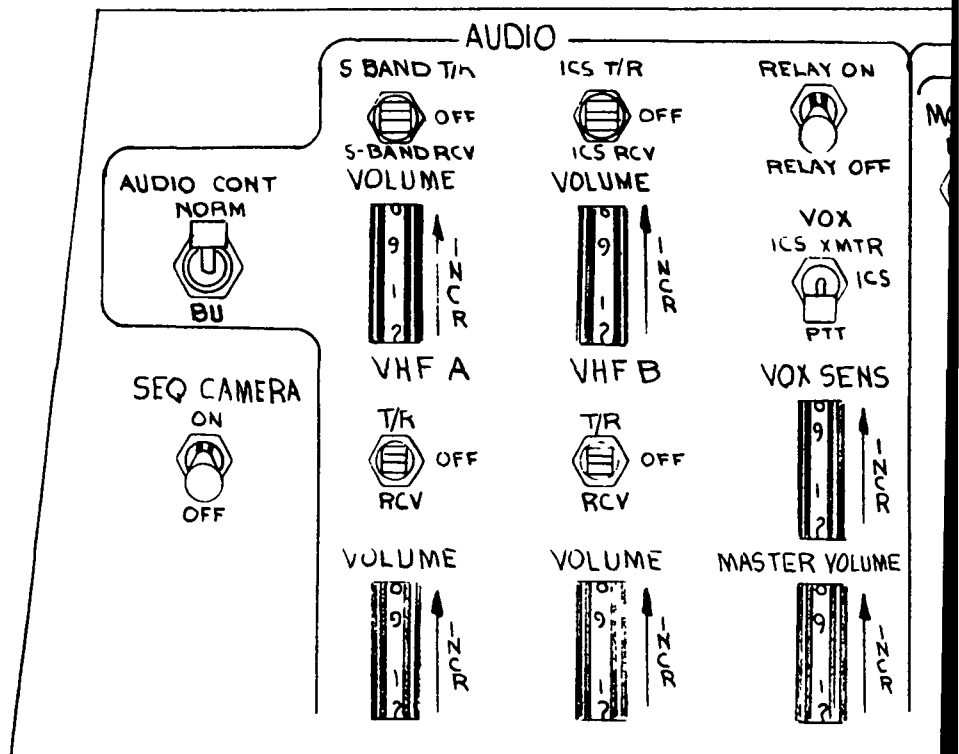
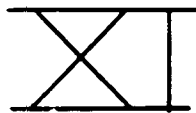
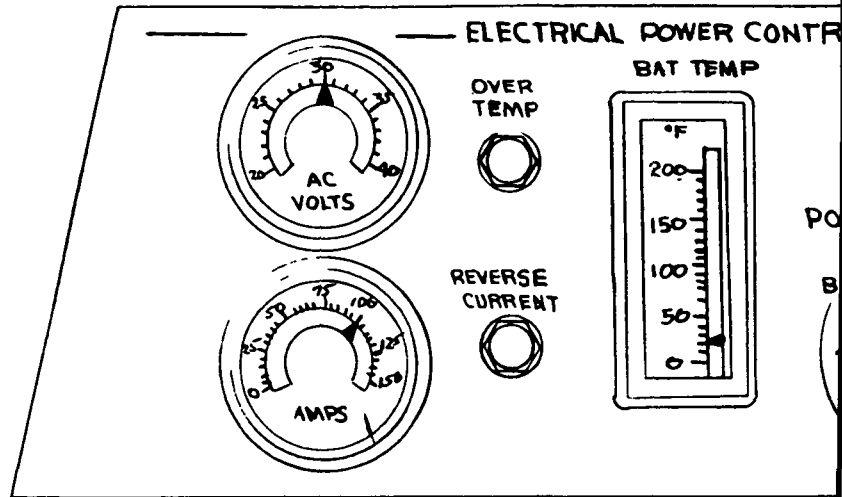
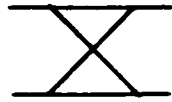
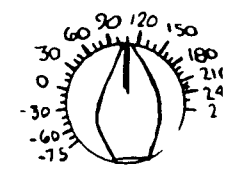
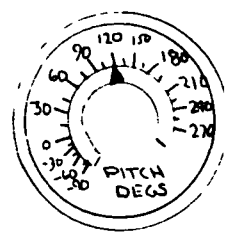
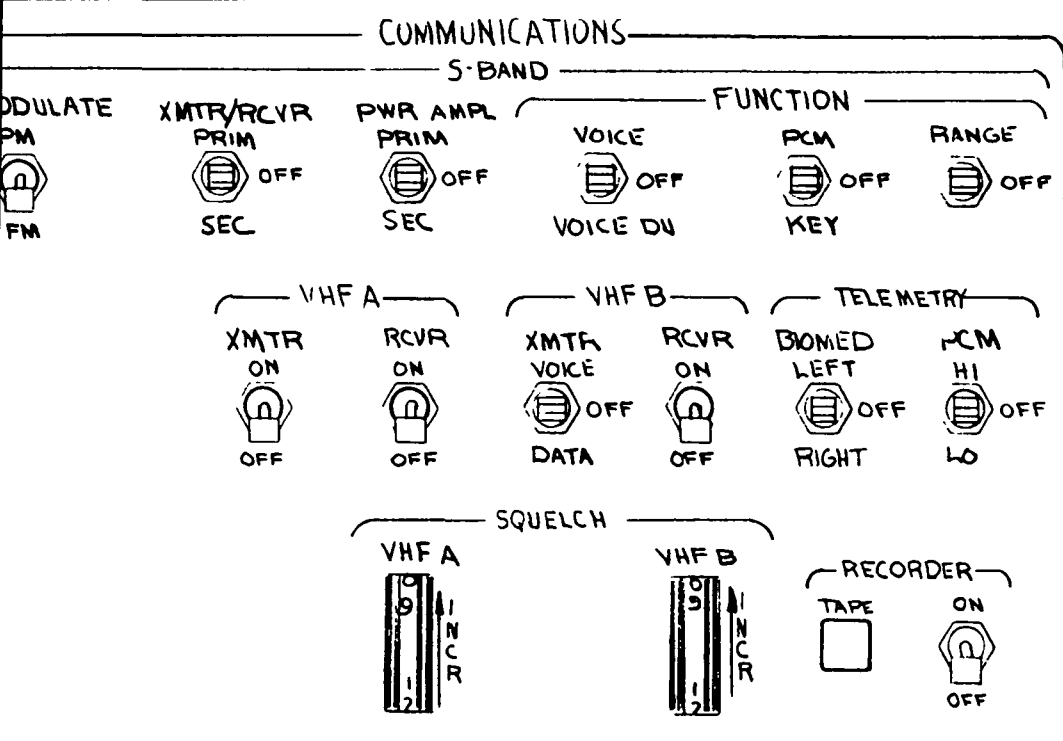
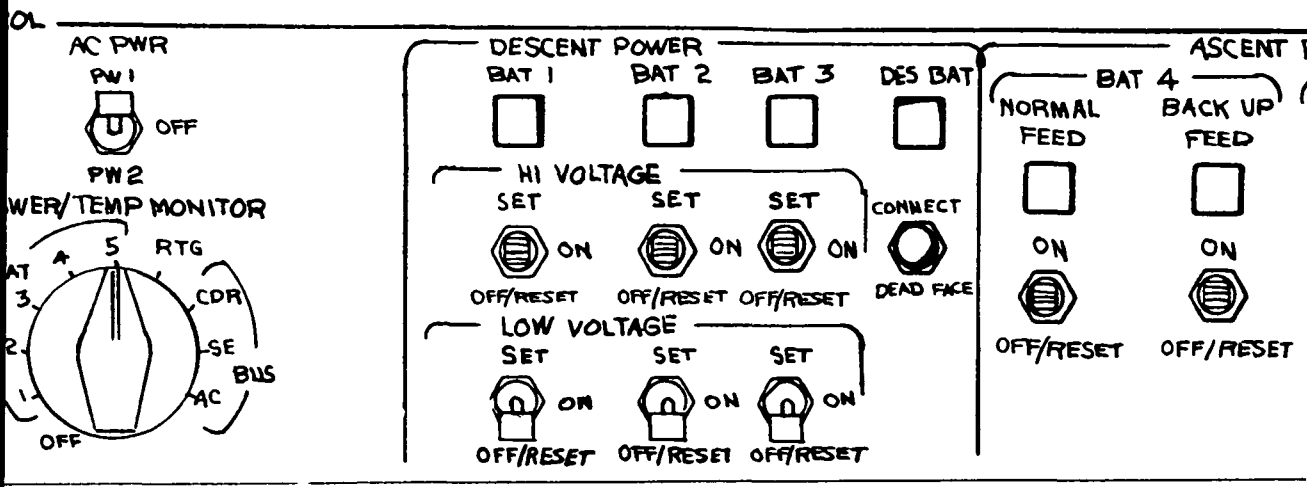


Fig. 5.7-7 Controls & Displays
Panel VIII and XII

3



5.7-8
①



5,7-8
②

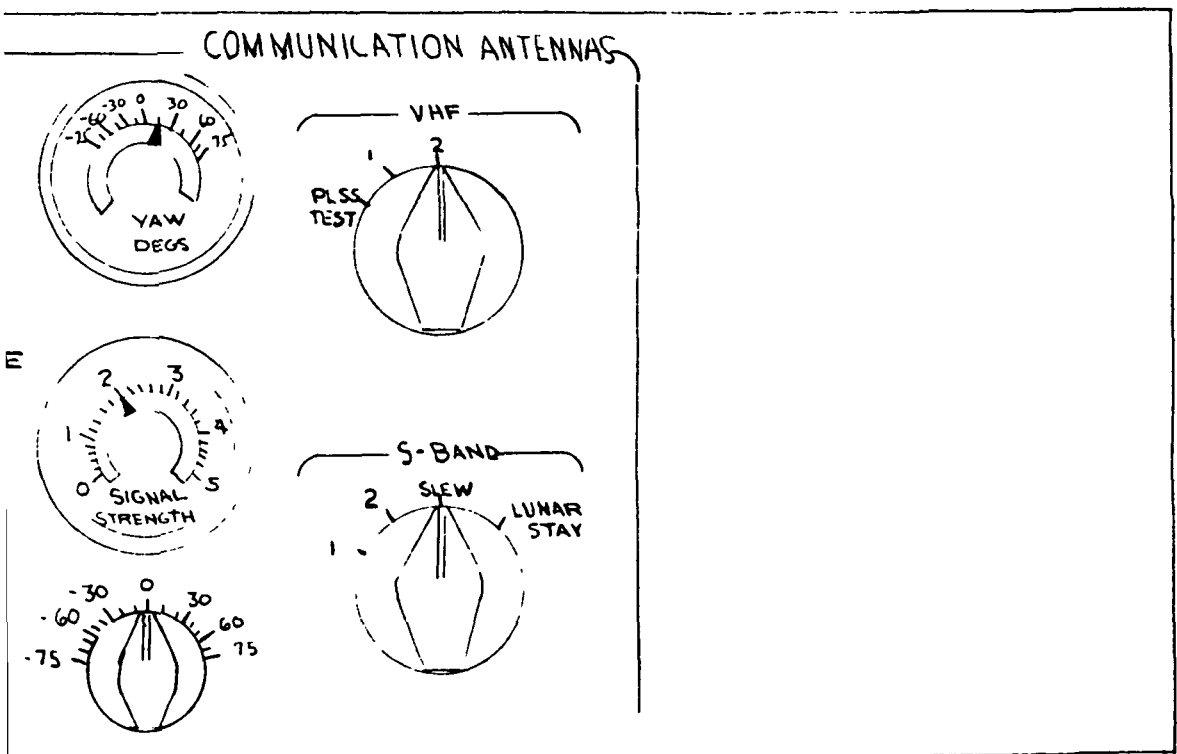
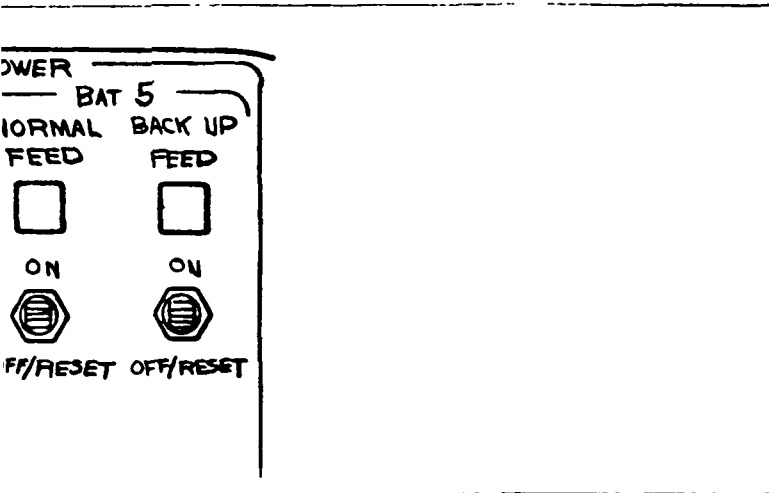
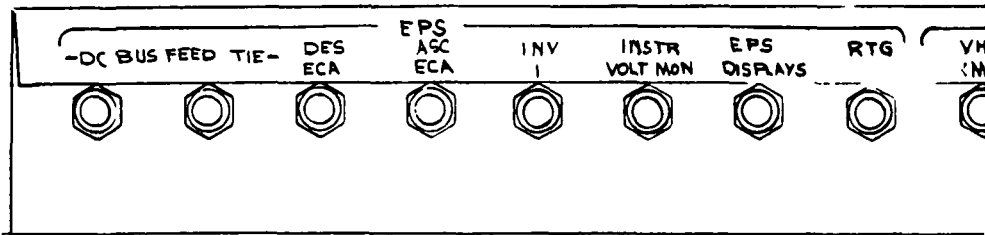
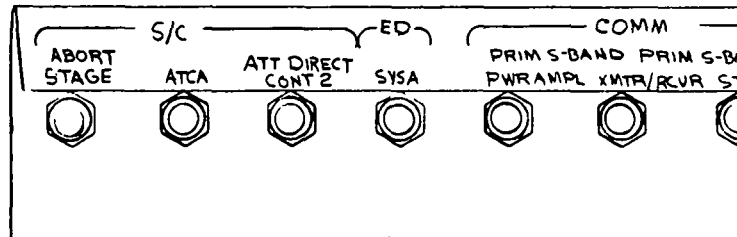
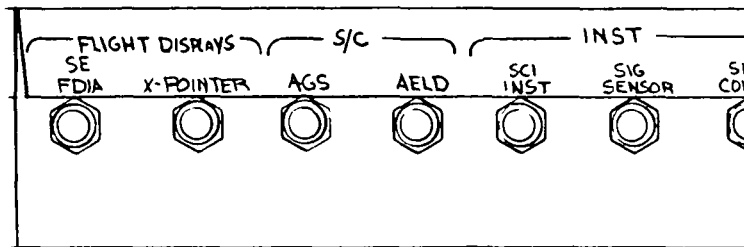
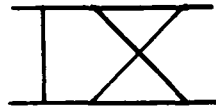
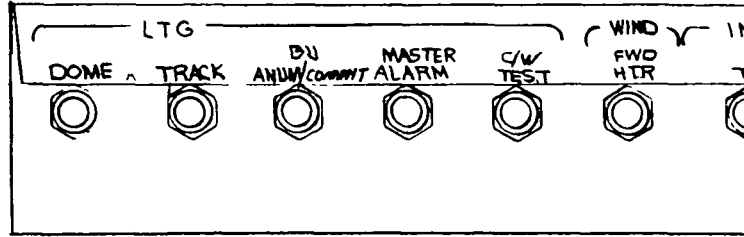


Fig. 5.7-8 Controls & Displays Panel IX and X

3

153



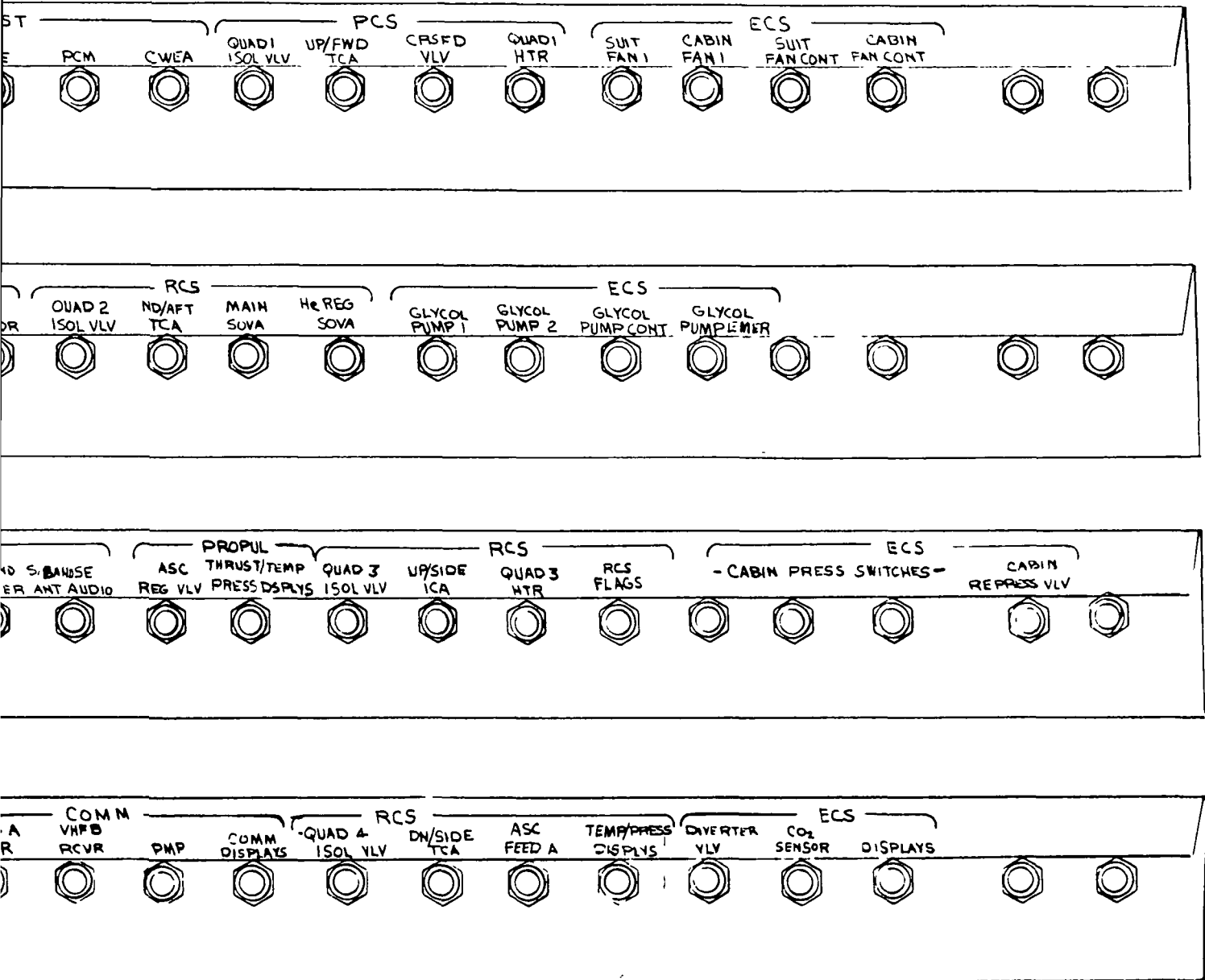


Fig. 5.7-9 Controls & Displays Panel XI

6. VEHICLE DESIGN AND INTEGRATION

6.1 SPACECRAFT DESIGN

6.1.1 Ground Rules

There were no NASA ground rules unique to this portion of the study.

6.1.2 Assumptions and Background Data

The philosophy guiding the development of the vehicle design is to keep the present LEM intact to the maximum extent possible, satisfying increased subsystem requirements by additions, rather than by modifications. Wherever possible, these additions have been designed as packages that could be incorporated into the vehicle in minimum time.

The following ground rules have been used during the Phase B study:

- No holes in the pressure shell .
- No modification to ascent and descent primary structure
- Retention of existing piping and wiring
- Maintain commonality of subsystems between all AES vehicles
- No change to the Spacecraft LEM Adapter (SLA)
- Location of subsystem additions to retain many of the GSE servicing requirements in the SLA
- Where possible, subsystems are to be located in the descent stage to reduce the complexity that modifications to the ascent stage would require
- Experiments will be mounted to the vehicle at existing hardpoints.

Figures 6.1-1 through 6.1-6 are LEM drawings and are provided for comparison with the AES vehicles. For details not shown on the AES configuration drawings, these figures clearly define the structure.

6.1.3 Recommended Configuration

The recommended configuration of the Taxi is shown in Fig. 6.1-7. The modifications required to convert from the LEM to the Taxi are in the micrometeoroid shielding, thermal, and electrical power supply areas. Thermal modifications include support changes, increased insulation, and heat input to the ascent stage cabin during a lunar night mission. The electrical power supply utilizes three modified descent batteries and one radioisotope thermoelectric generator (RTG) mounted in the descent stage.

The RTG is assumed launched on the Shelter and brought over to the Taxi prior to shutdown for quiescent storage. The RTG mounting provisions are the same on the Taxi and the Shelter. The RTG is mounted to a shelf which is inserted into truss supported rails in the scientific equipment bay (-Y, -Z quadrant) of the descent stage (Fig. 6.1-8). The RTG is insulated on five sides with approximately 1 in. of insulation. The sixth side is open allowing the RTG to radiate to space. The RTG unit used in this study is the SNAP 27 Unit, being developed by for the LEM Scientific Emplaced Package.

The batteries are located in the +Y, +Z quadrant of the descent stage, as on the LEM (Fig. 6.1-9). This quadrant permits access for battery checkout in the same manner as on the LEM and LEM battery mounting hardpoints are used.

Thermal coupling of the descent stage structure to the descent stage batteries and water tank was reduced. The batteries are mounted to a rack which, in turn, is truss mounted to the descent stage structure. The truss supports offer a low thermal conductivity which is a result of a high-length to cross-sectional-area ratio. A lower thermal conductivity material was substituted for the existing LEM water tank truss supports. In addition, a heater and insulation was added to the water tank to prevent freezing during a night mission.

A thermal insulating cover is added to the ascent stage to cover the docking tunnel (at the top hatch) during quiescent stay (Fig. 6.1-10). Hinge fittings for the cover are added to the top of the -Z27 bulkhead. The cover is held open by a latch during launch and translunar flight. After lunar landing, redundant pyrotechnic devices sever the latch, and torsion springs close the cover over the docking tunnel. The top hatch hinge pins are pyrotechnically removed before ascent from the lunar surface. Thermal covers, common to the Taxi and Shelter, are added to each window prior to Taxi shutdown. The astronaut installs each window cover with three simple clip devices (Fig. 6.1-11). The top hatch is jettisoned and the window covers are manually removed before ascent into lunar orbit.

A thermostatically controlled steam heating loop, utilizing RTG waste heat, is installed between the RTG and the ascent stage cabin structure. This installation is the same on the Taxi and Shelter. The boiler located behind the RTG in the scientific equipment bay sends steam up through an umbilical in the descent stage to the ascent stage cabin. The five condenser pipes (one on each cabin wall) are attached by small brackets or clips to the cabin structure with no structural modifications. This "heat pipe" is shown in more detail in Fig. 6.1-12.

The increased mission time for the Taxi would impose additional micrometeoroid protection requirements to avoid penetration of critical areas of the vehicle and subsystems. The simplest method of providing additional micrometeoroid protection would be to make the spacecraft outer skin as thick as necessary. The attachment of these skins through thermal insulators to the basic vehicle structure would follow similar installation techniques as presently used for LEM.

6.1.4 Baseline Configuration

The Taxi baseline configuration was essentially the same as the recommended configuration described above.

6.1.5 Alternate Configuration - Top Hatch Thermal Cover

An alternate thermal cover, Fig. 6.1-13, for the top hatch would be the same as described in the recommended configuration, except without a pyrotechnic device to pull the hinge pins for jettison capability. The disadvantage of this design is the weight penalty incurred by having to carry the cover back into lunar orbit.

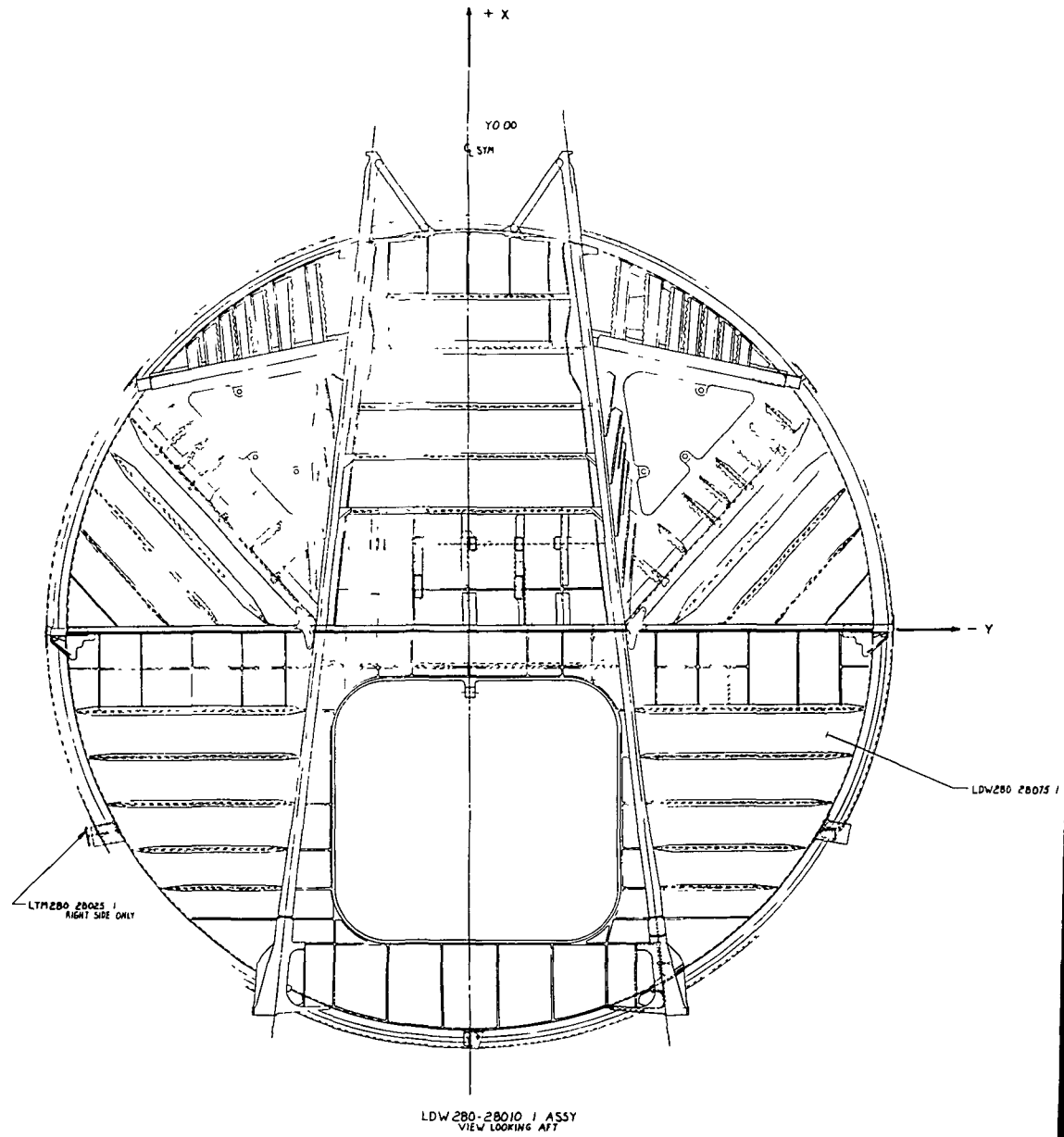
6.1.6 Alternate Configuration - RTG Location

An alternate RTG location, common to the Taxi and Shelter, shown in Fig. 6.1-14, mounts the RTG unit on a sheet metal structure spanning the descent stage main beams over quadrant +Y, +Z of the descent stage. The RTG is shrouded within an insulated box with a hinged door facing the ascent stage cabin structure. A thermal sensor is mounted to the ascent stage structure, remote from the radiant heat field of the RTG. Ascent stage temperature causes either expansion or contraction of a fluid in the sensor, which, in turn, operates the actuator and door. The disadvantage of this installation, for the Taxi, is that the crewman must lift the RTG up to the top of the descent stage. This would probably require some form of mechanical lifting aid.

6.1.7 Alternate Configuration - RCS Cluster Covers

RCS cluster covers may be used to improve the thermal characteristics of the vehicle. An automated system would impose a severe weight penalty. Manual covering is considered feasible; however, the operation is hampered somewhat by inaccessibility. A ladder and/or work platform may be required to provide this capability. The covers themselves could be simple insulating bags with draw strings so that they could be securely fastened. Another possibility involves the use of an insulating bag of the end of a long stick. This scheme, "a butterfly net with draw strings", would eliminate the requirement to climb up a ladder. These concepts would require additional study to arrive at a suitable method.

6



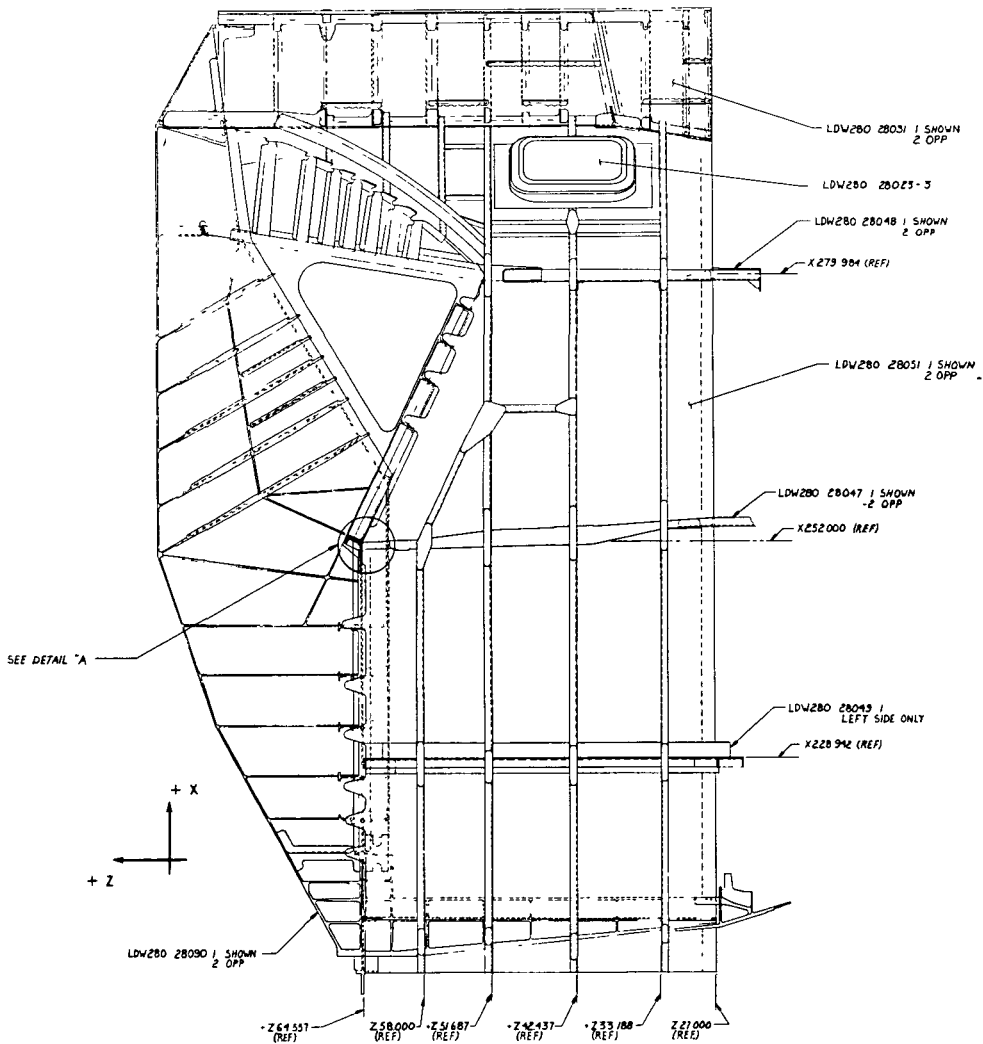
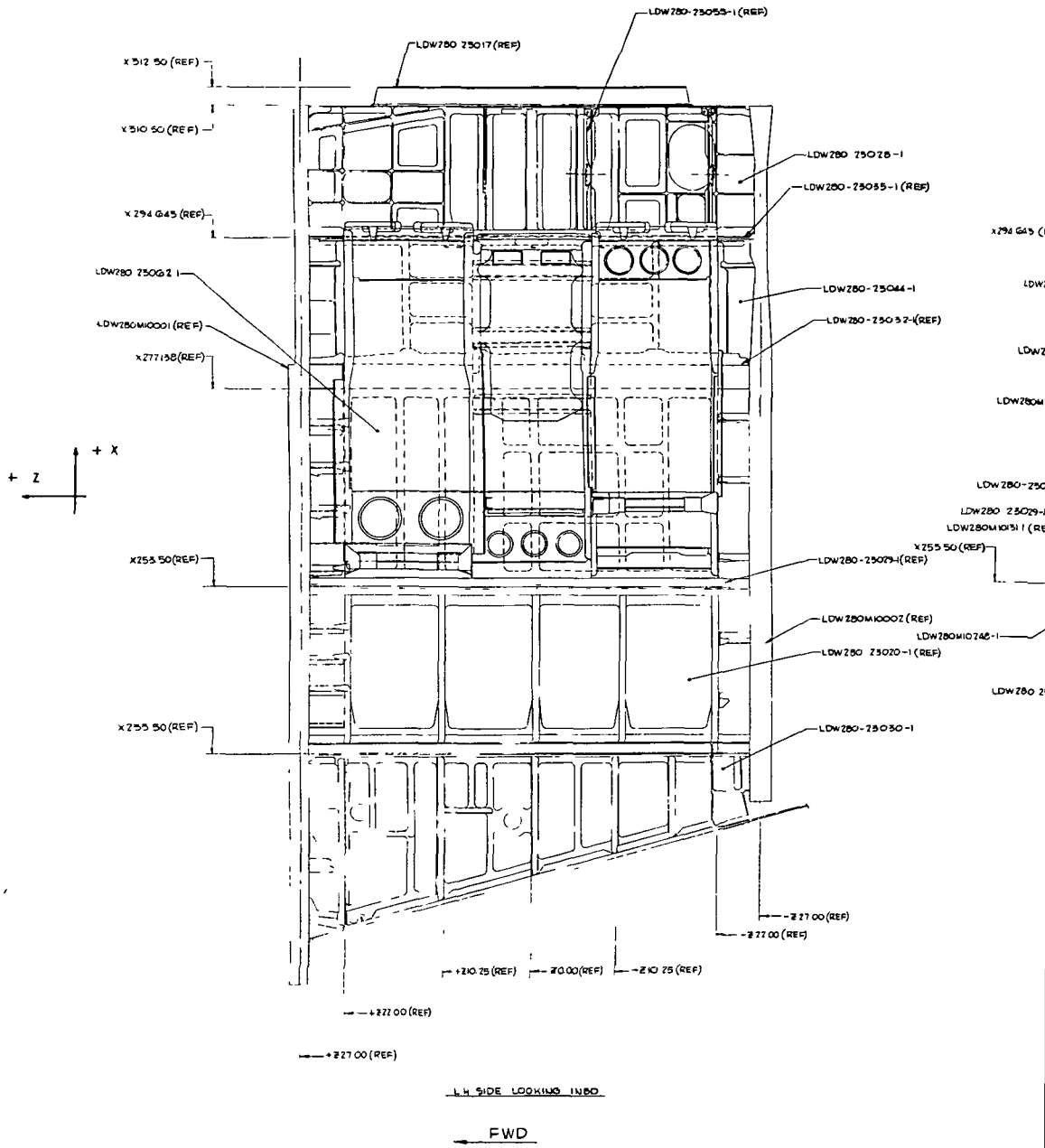


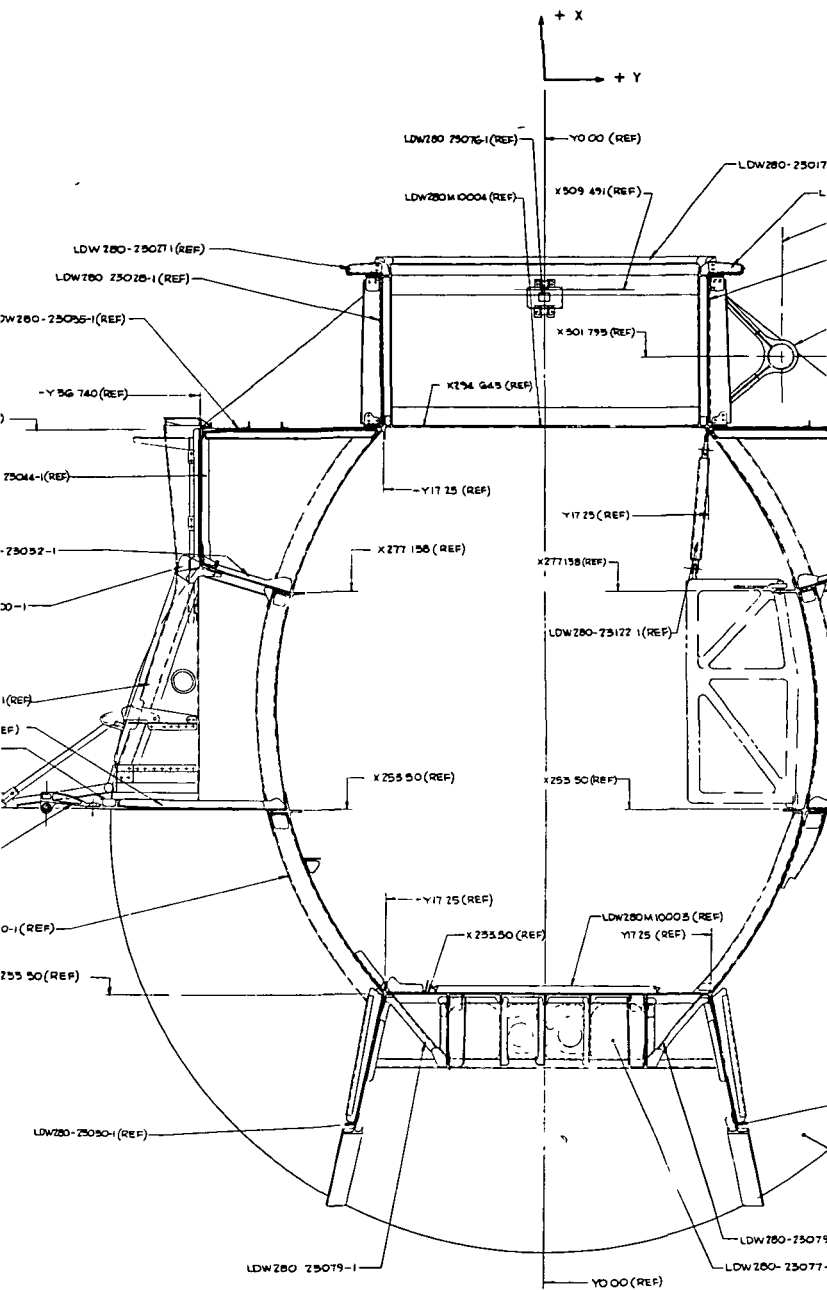
Fig. 6.1-1 LEM Structural Arrangement
Ascent Stage-Fwd Cabin

(VI) 6-7/8



6.1-3





SECT A A (ZONE 9A SHS)
 (ROTATED CW 90°)
 VIEW LOOKING FWD

6.1-3
 (2)

.F)

:80-250272(REF)

Y75 00 (REF)

LDW 280-75028-5 (REF)

LDW 280-25055-3 (REF)

LDW 280 25055-3(REF)

Y56 74(REF)

LDW 280-25044-2(REF)

X294 645(REF)

LDW 280-25032-2(REF)

LDW 280M 10700-1(REF)

LDW 280 25070-1(REF)

LDW 280-25062 1(REF)

LDW 280 25029-3(REF)

LDW 280M 10197-1(REF)

LDW 280-25050 2(REF)

LDW 280M 10001 (REF)

X512 50 (REF)

X310 50 (REF)

X294 645(REF)

X277 158 (REF)

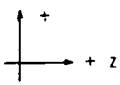
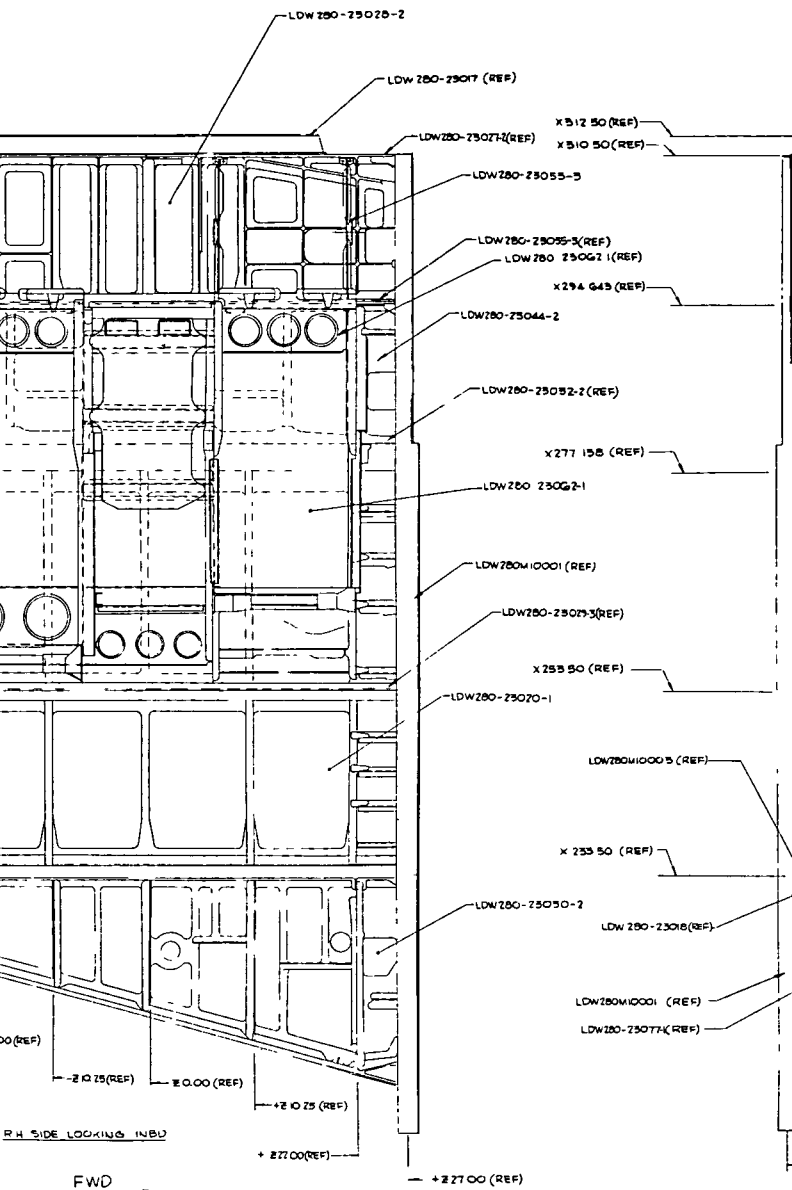
LDW 280M 10002(REF)

X255 50(REF)

X235 50 (REF)

-12700(REF)

6.1-3
②



6.1-3

4

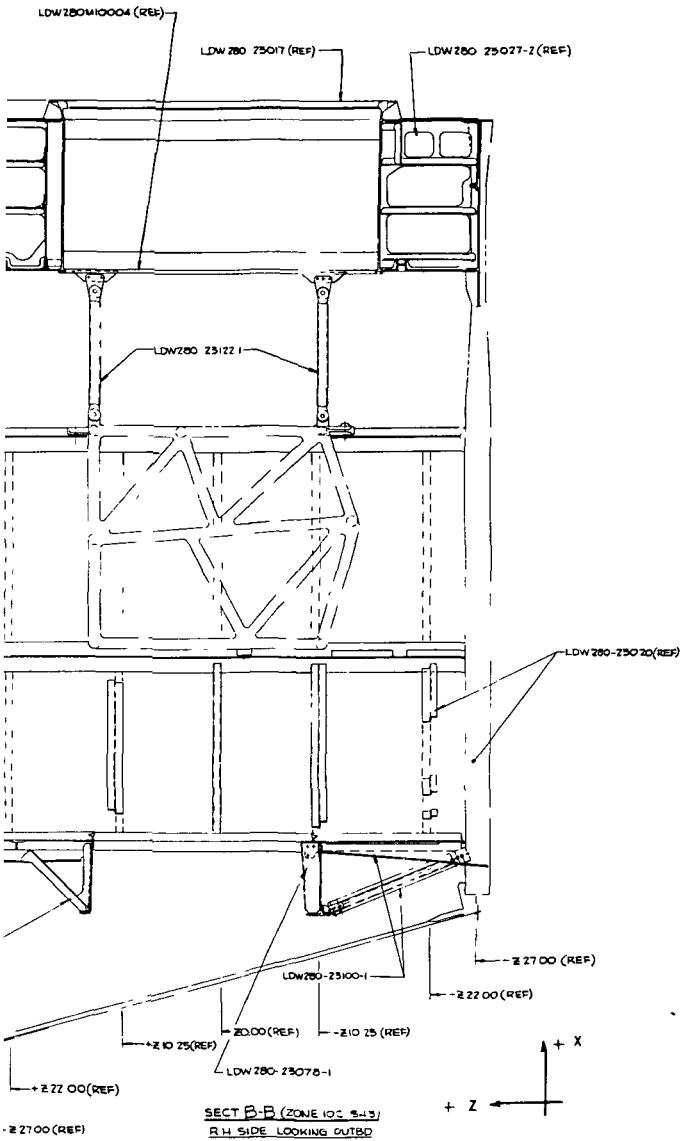


Fig. 6.1-3 LEM Structural Arrangement
Ascent Stage-Aft Cabin

5

Grumman

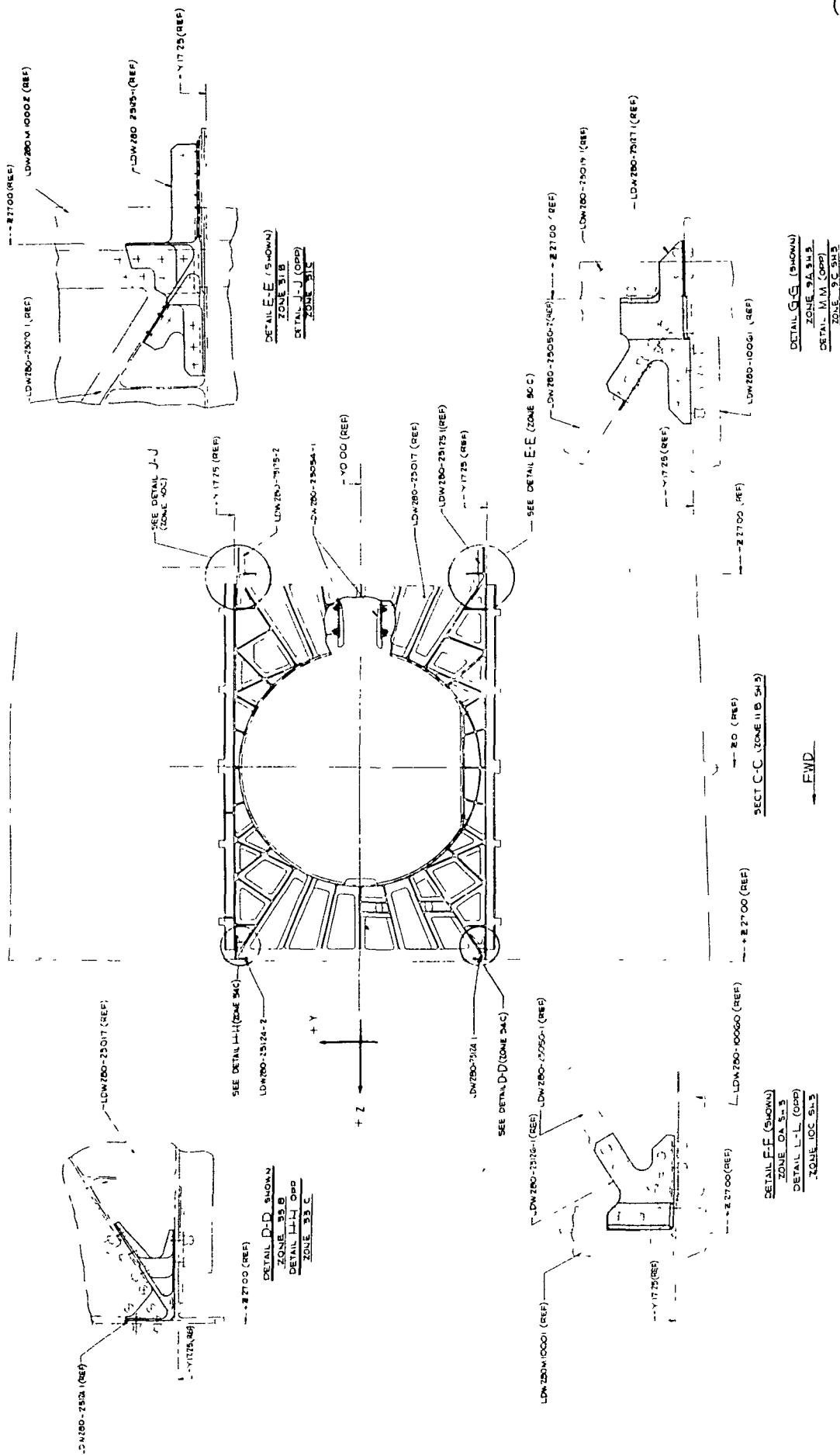
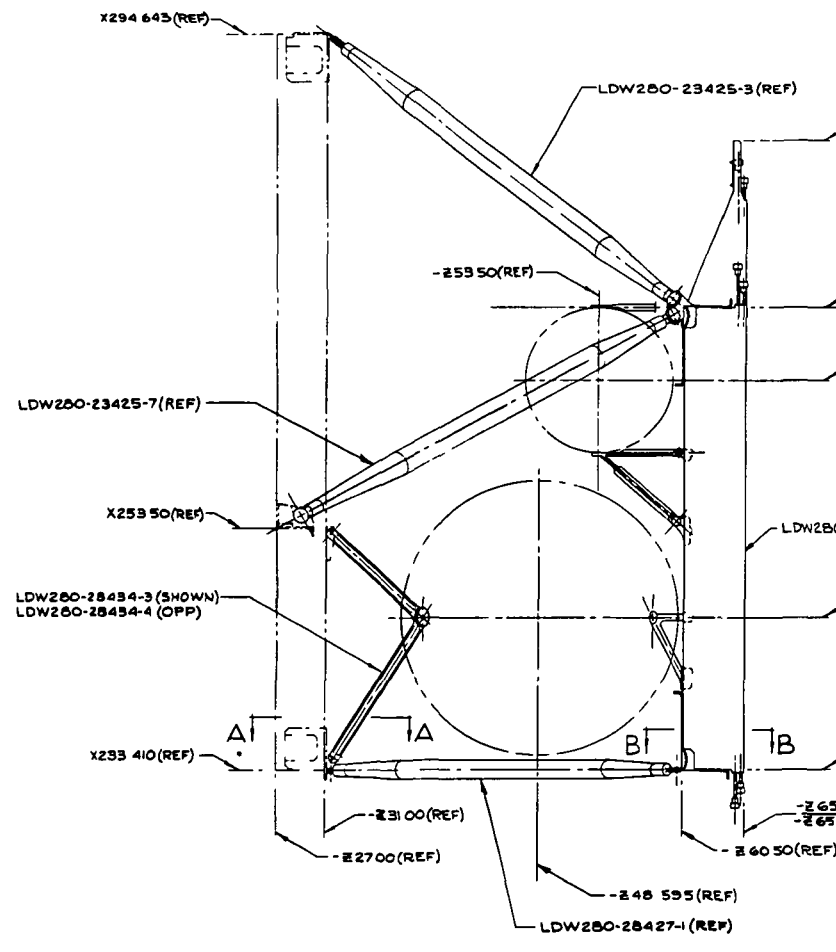
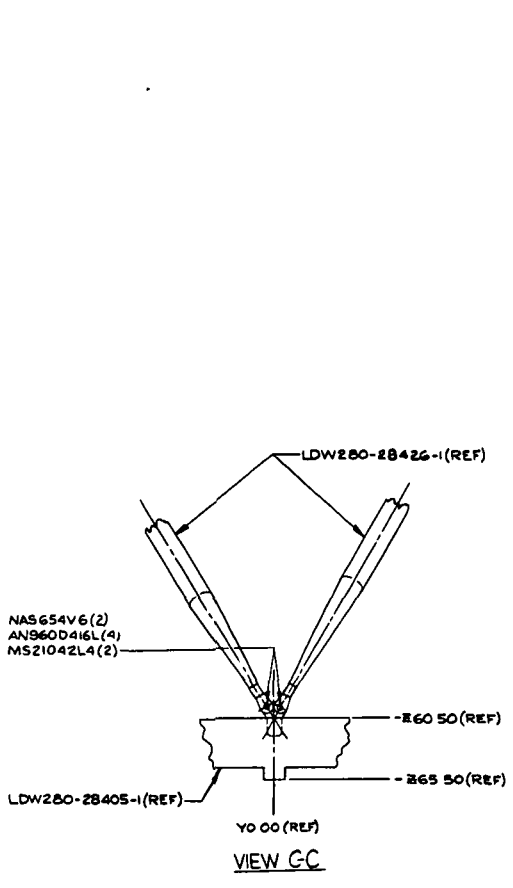
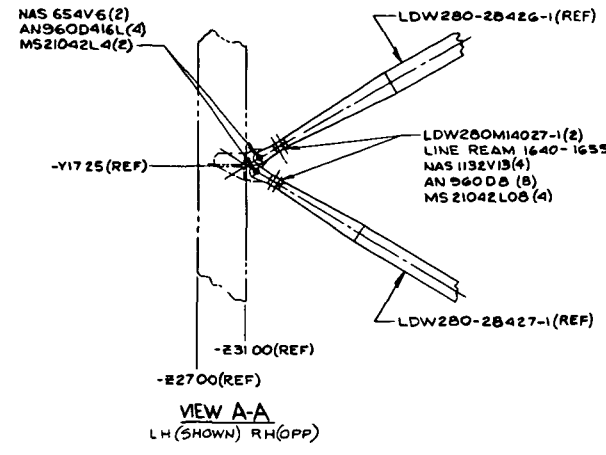
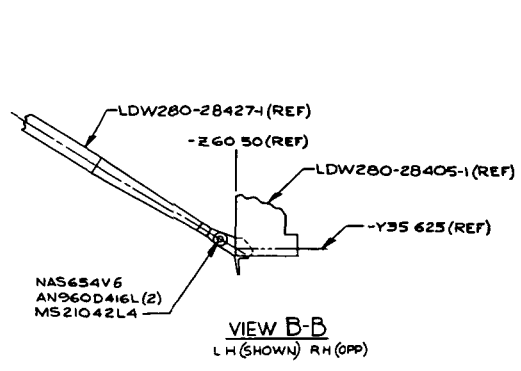
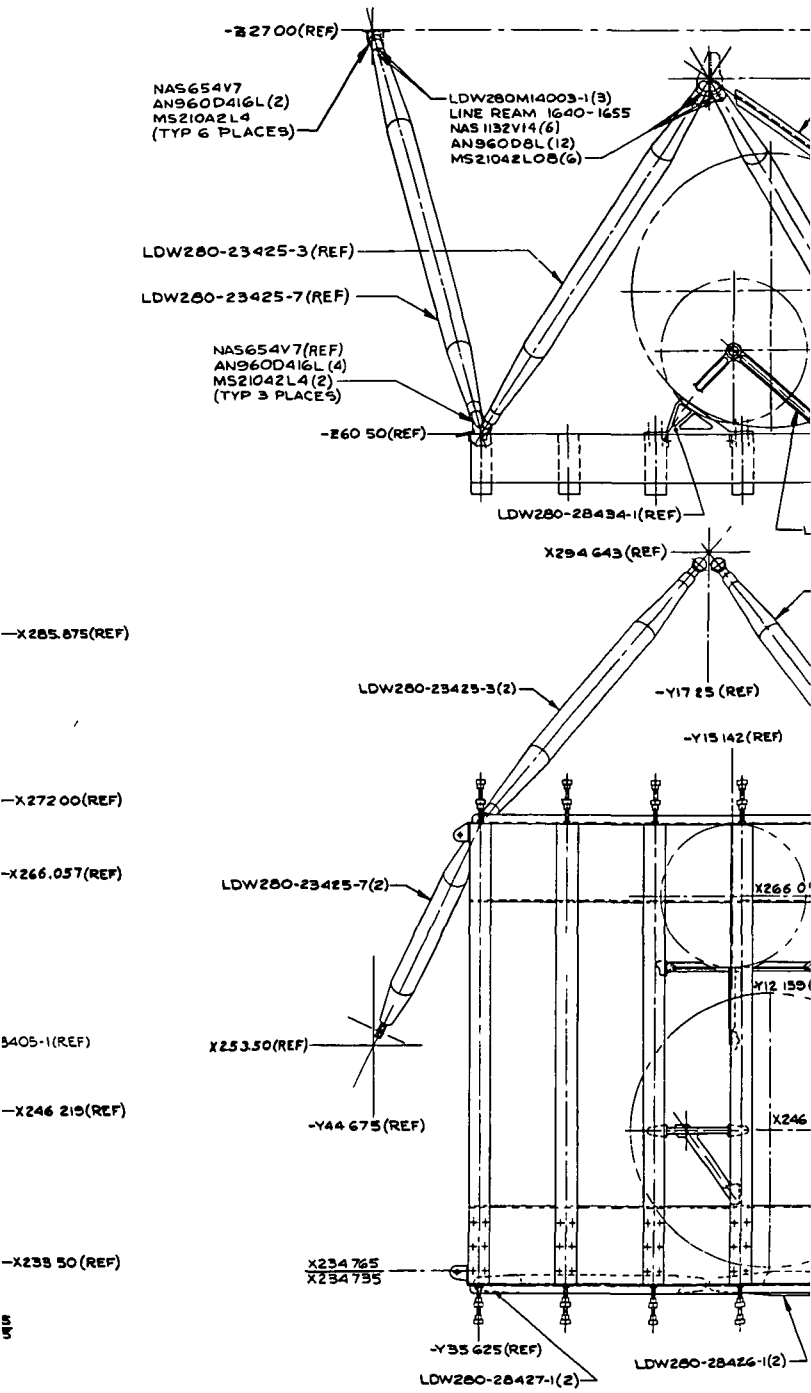


Fig. 6.1-4 LEM Structural Arrangement
Ascent Stage-Aft Cabin

13



1



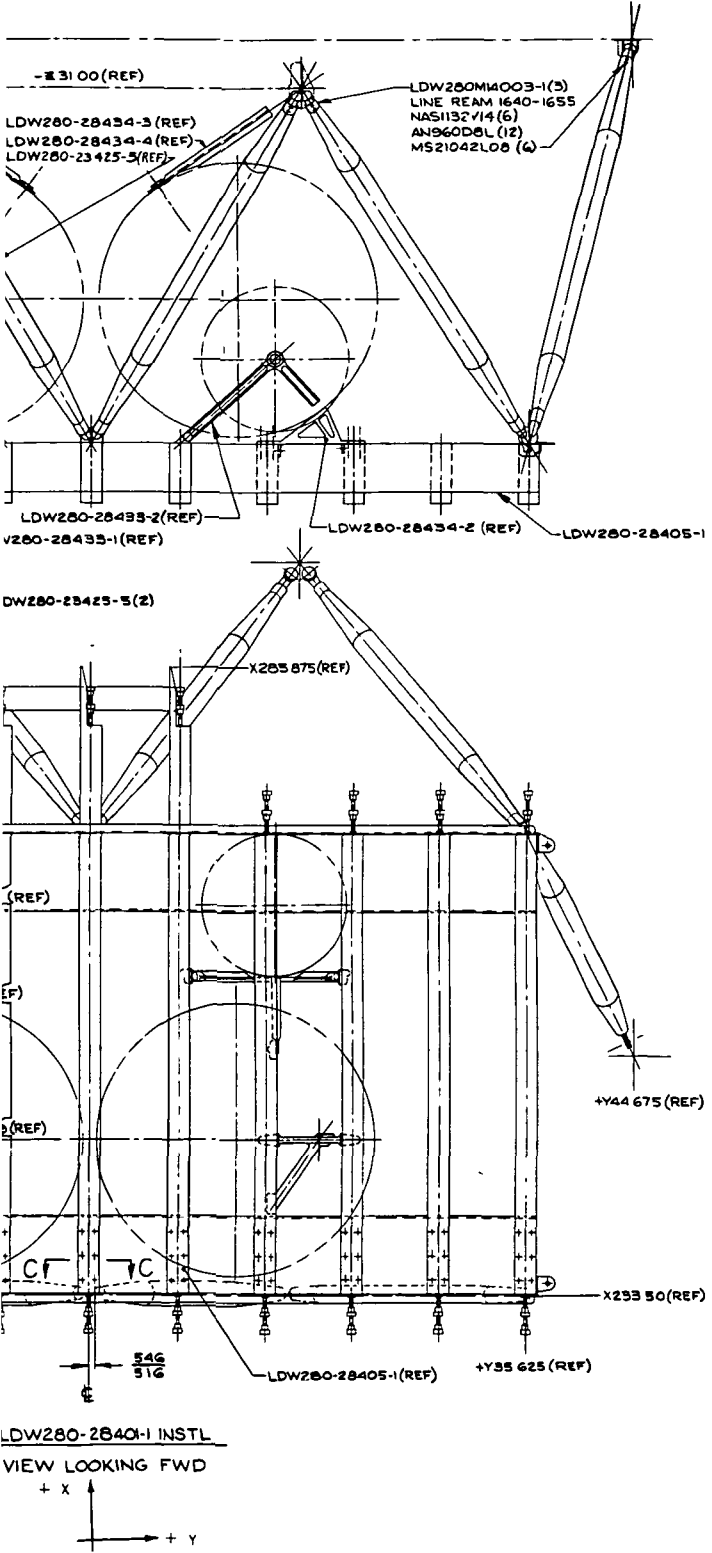
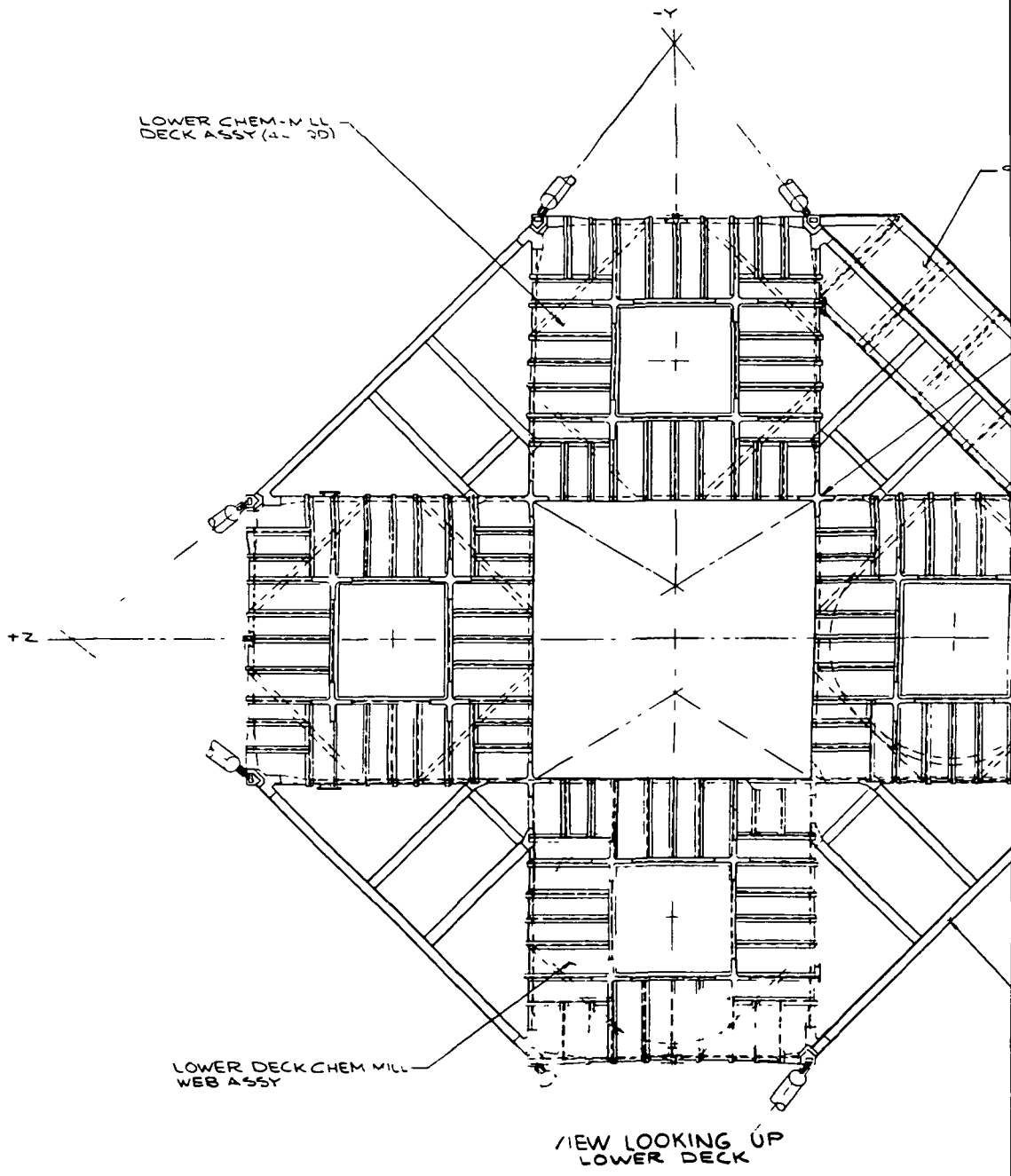


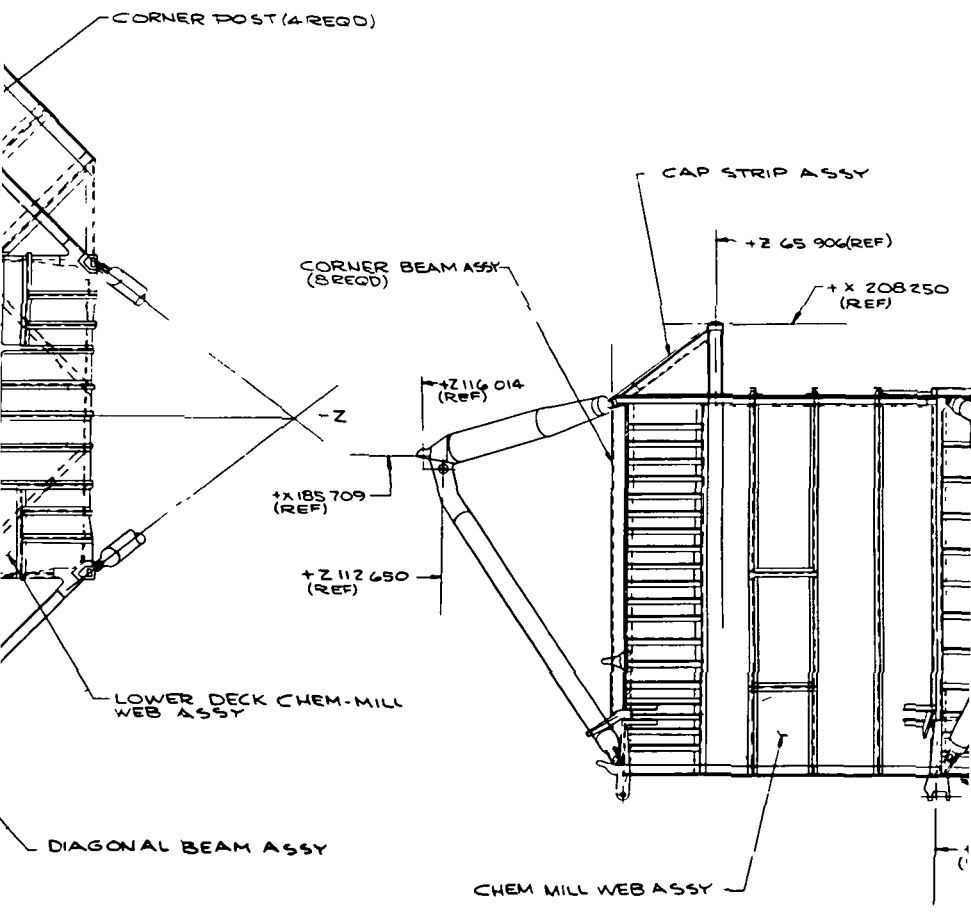
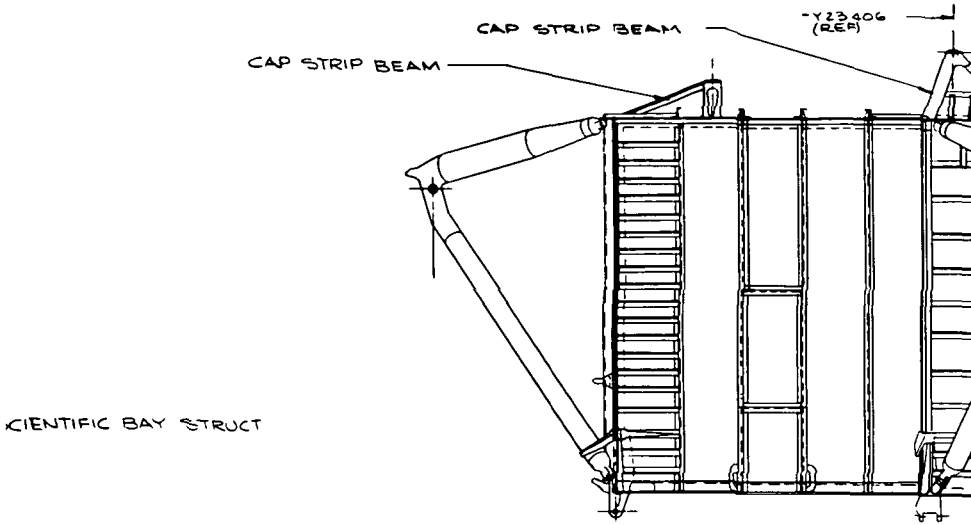
Fig. 6.1-5 LEM Structural Arrangement Ascent Stage-Aft Equipment Bay

3

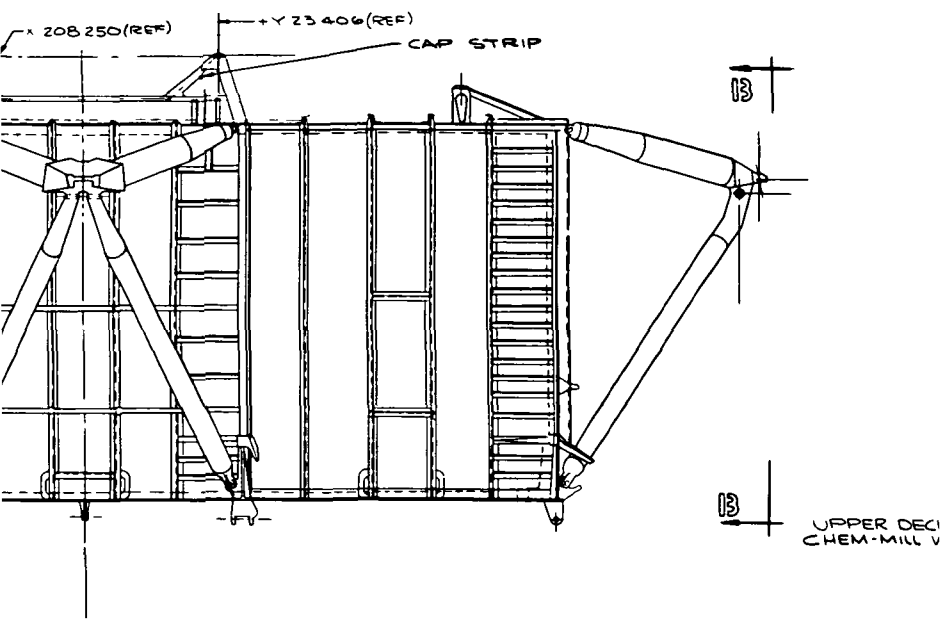
Grumman



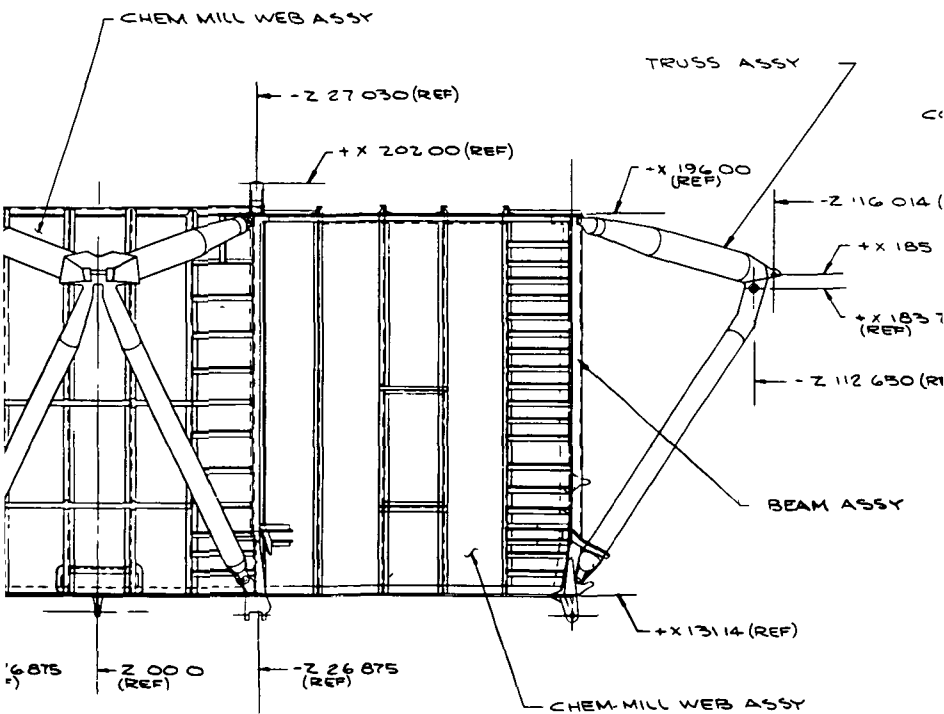
6.1.6 ①



6.1.6
 (2)



VIEW A-A
ROTATED 90°

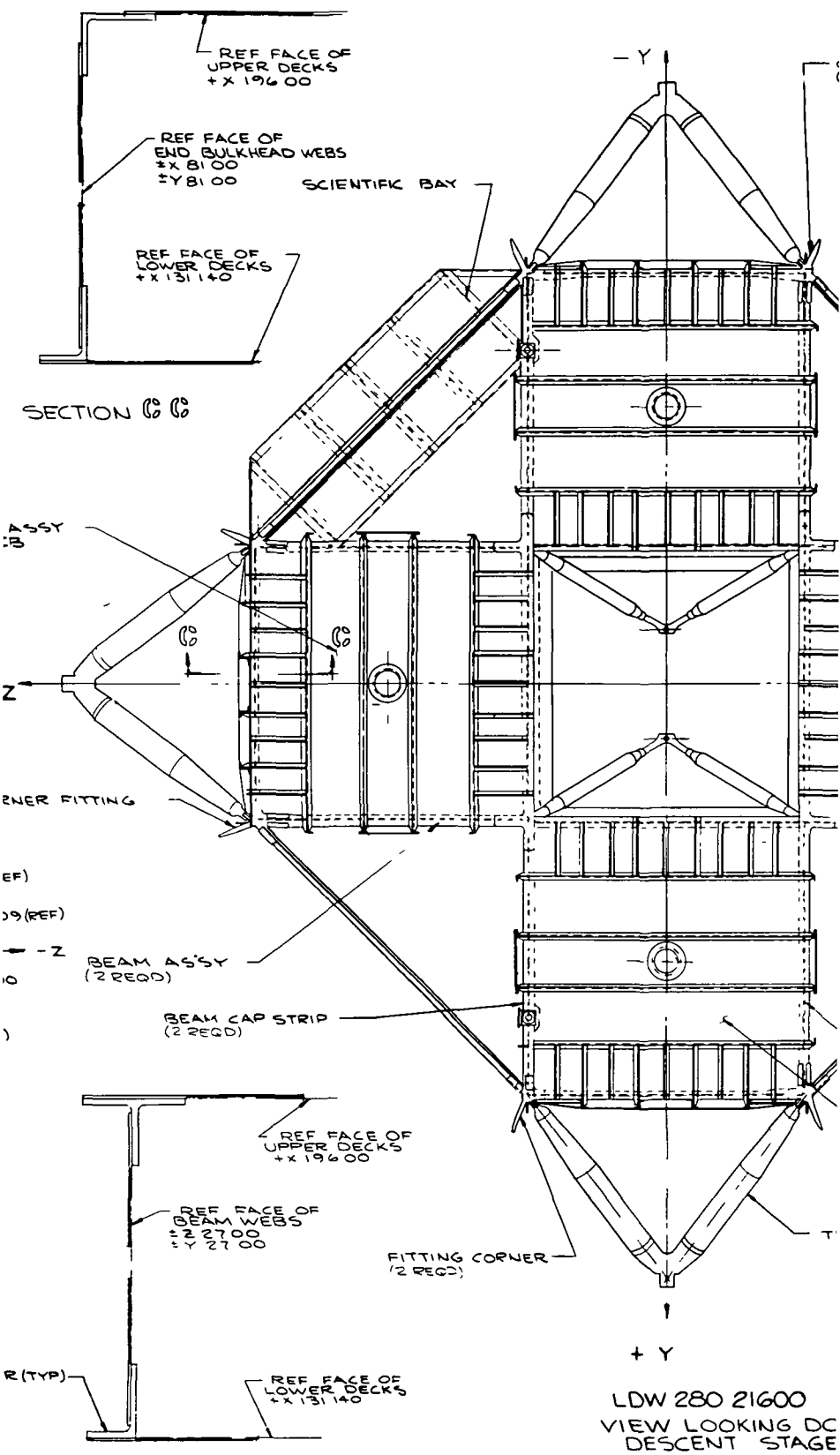


13-13

BEAM LOW

VIEW LOOKING INBD
-Y 8100 / -Y 2700

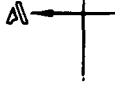
6.1-6
(3)



SECTION D D
ROTATED 90°

6.1-6
④

CORNER FITTING
(REQD)



NOTES
THE LEM DESCENT STAGE SHALL
BE FABRICATED OF THE FOLLOWING
MATERIAL

1. 7075 AL ALY SHEET, PLATE,
EXTRUSIONS, & HAND FORGINGS

2. 7079 AL ALY HAND FORGINGS

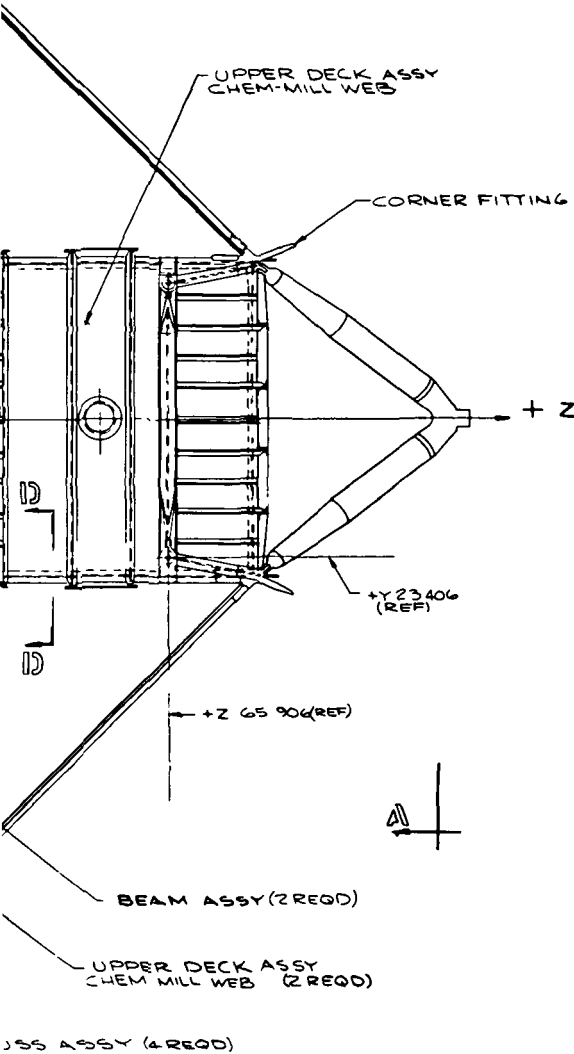


Fig. 6.1-6 LEM Structural Arrangement
Descent Stage

5

Key

Antennas

- 1 Landing Radar*
- 2 S-Band Erectable*
- 3 S-Band in Flight*
- 4 VHF In-Flight*
- 5 S-Band Steerable*
- 6 Rendezvous Radar*

Tanks

- 7 Fuel (Desc Propul)*
- 8 GOX*
- 9 He (Desc Eng)(*
- 10 He (RCS)*
- 11 RCS Fuel*
- 12 RCS Oxidizer*
- 13 Water*
- 14 He (Asc Eng)*

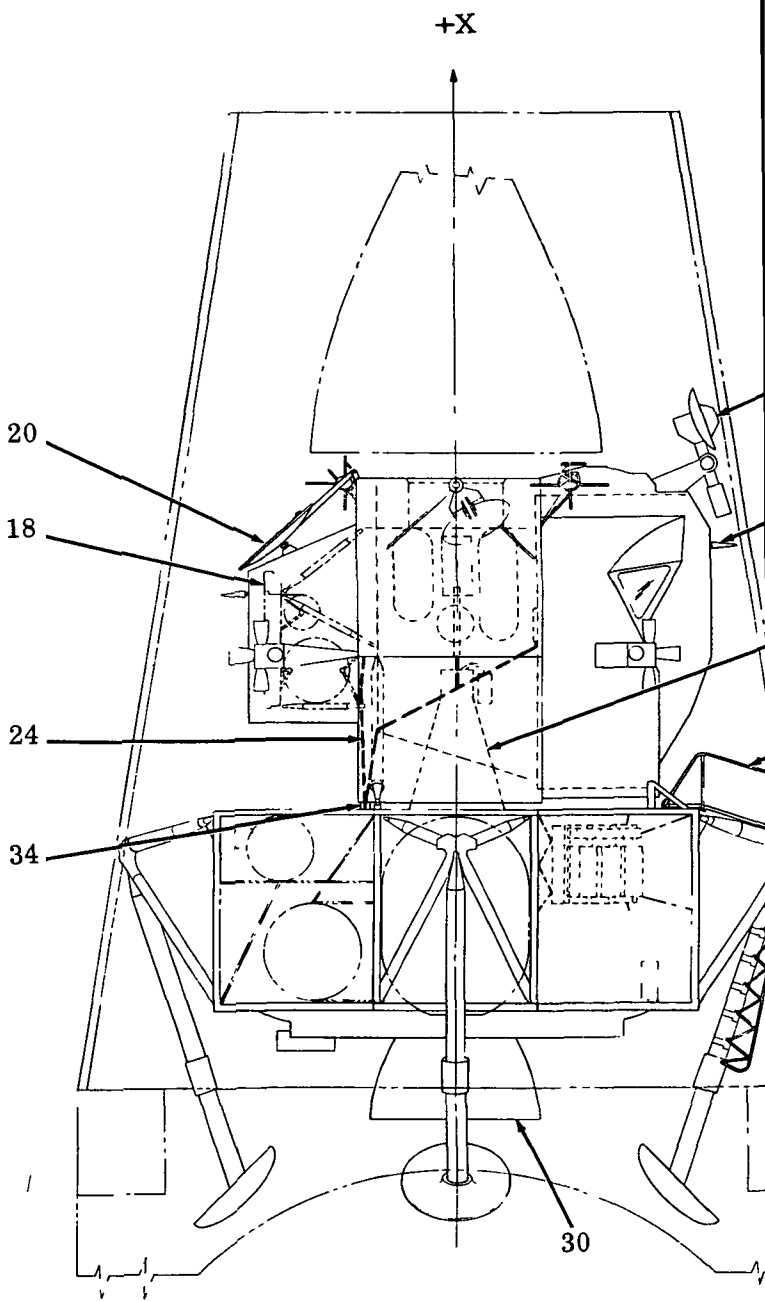
Electrical Power Supply

- 15 Desc Stg Batt's
 - 16 Desc Stg ECA
 - 17 PLSS Batt's
 - 18 Asc Stg Batt's*
 - 19 RTG (Quiescent State Only)
 - Thermal Insul & Protect
 - 20 Upper Hatch Cover
 - 21 Upper Hatch Cover
 - (Closed For Quiescent Stay)
 - 22 Ascent Stage*
 - 23 Descent Stage*
 - 24 Heat Pipe
- } Thermal Shields

Miscellaneous

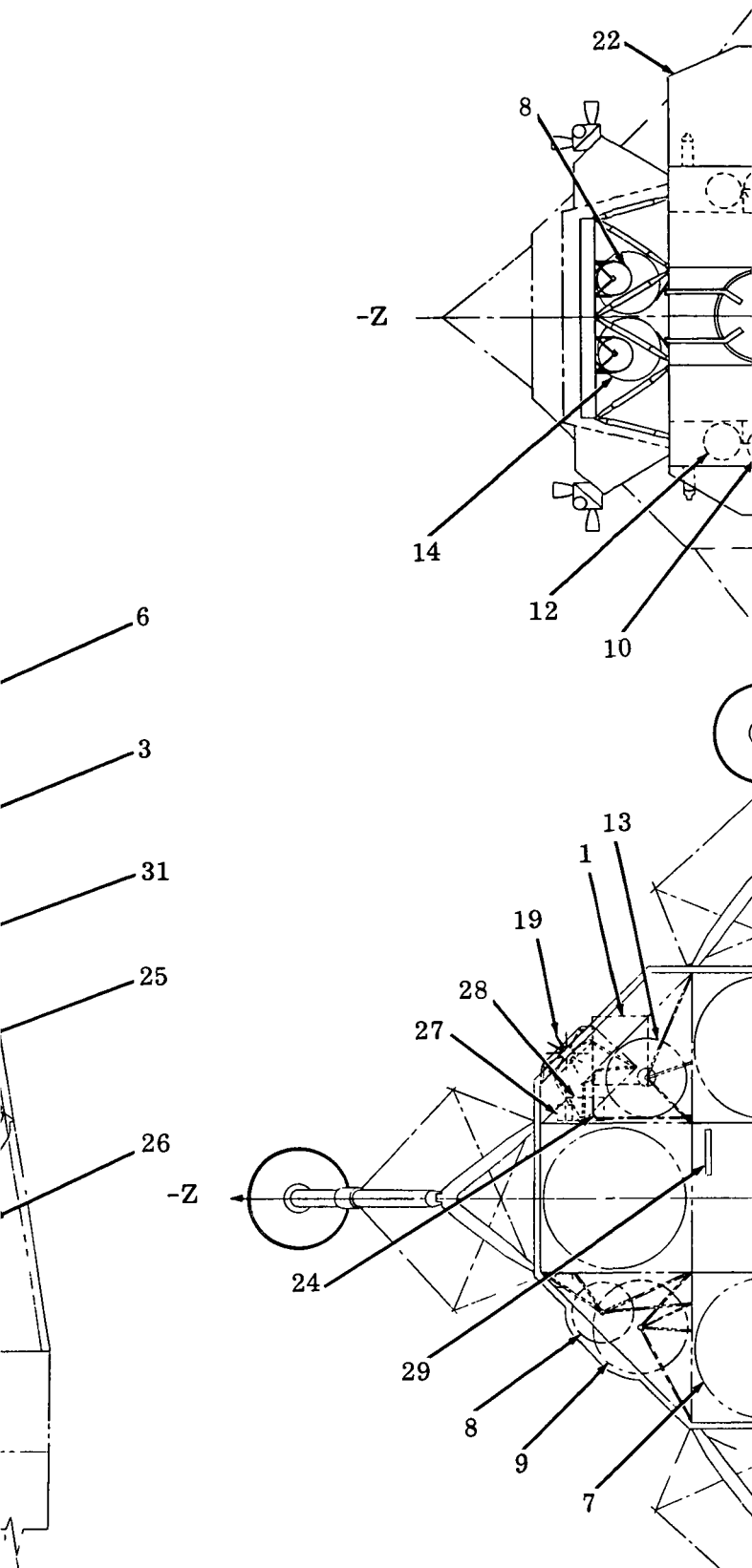
- 25 Ingress/Egress Platform*
 - 26 Ladder*
 - 27 Ldg Radar Electronic Assy*
 - 28 He Press Module*
 - 29 Heat Exchanger*
 - 30 Descent Engine*
 - 31 Ascent Engine*
 - 32 RCS
 - 33 RCS He Press Unit*
 - 34 Heat Pipe Int'stage Disconnect
 - 35 Pyro Batt's*
 - 36 Pyro Relay*
 - 37 GOX Press Module*
 - 38 S-Band Cable*
 - 39 Ext Pwr Connect (Outlet)*
 - 40 Int'stage Umbilical & Guillotine*
 - 41 O₂ & Glycol Int'stage Disconnect*
- * Existing LEM Hardware

6.1.7 (0)



Launch Configuration

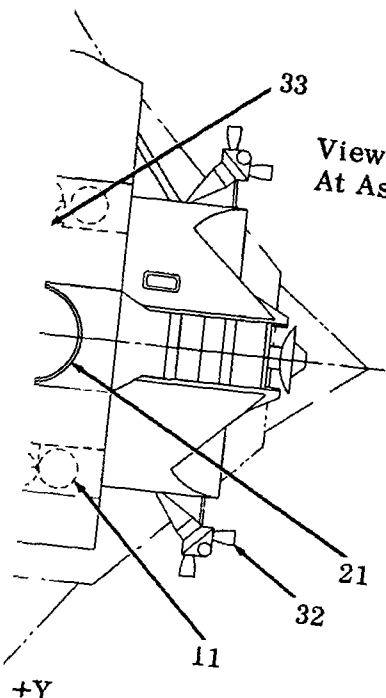
6.1-7 (2)



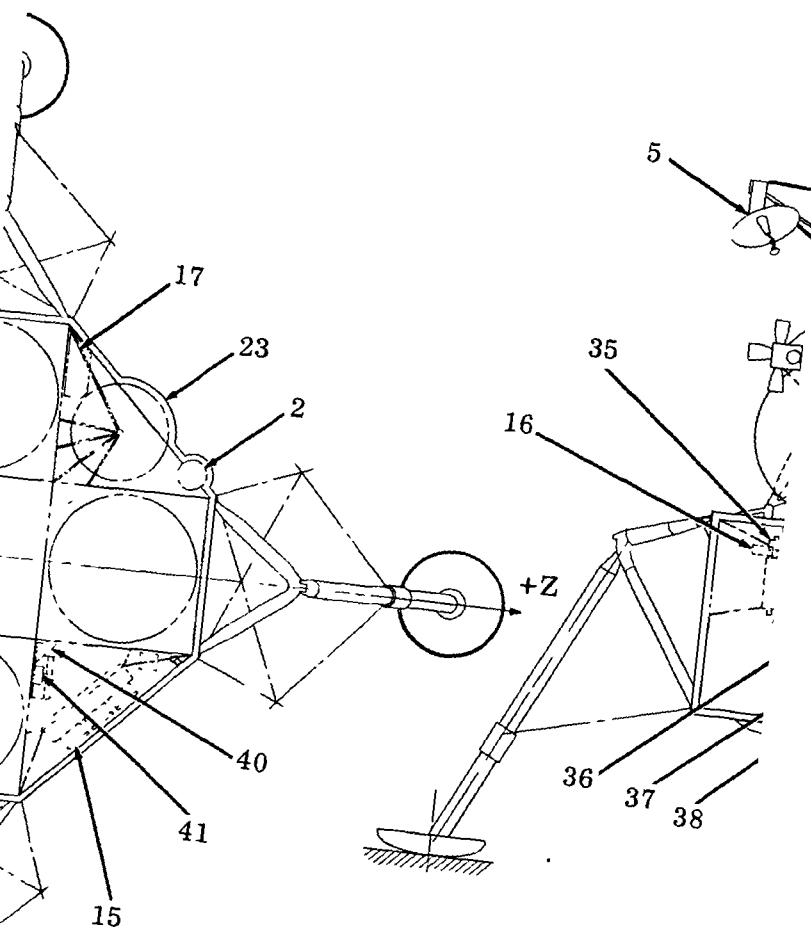
View Looking Down
At Descent Stage

6.1-7
③

View Looking Down
At Ascent Stage



+Y



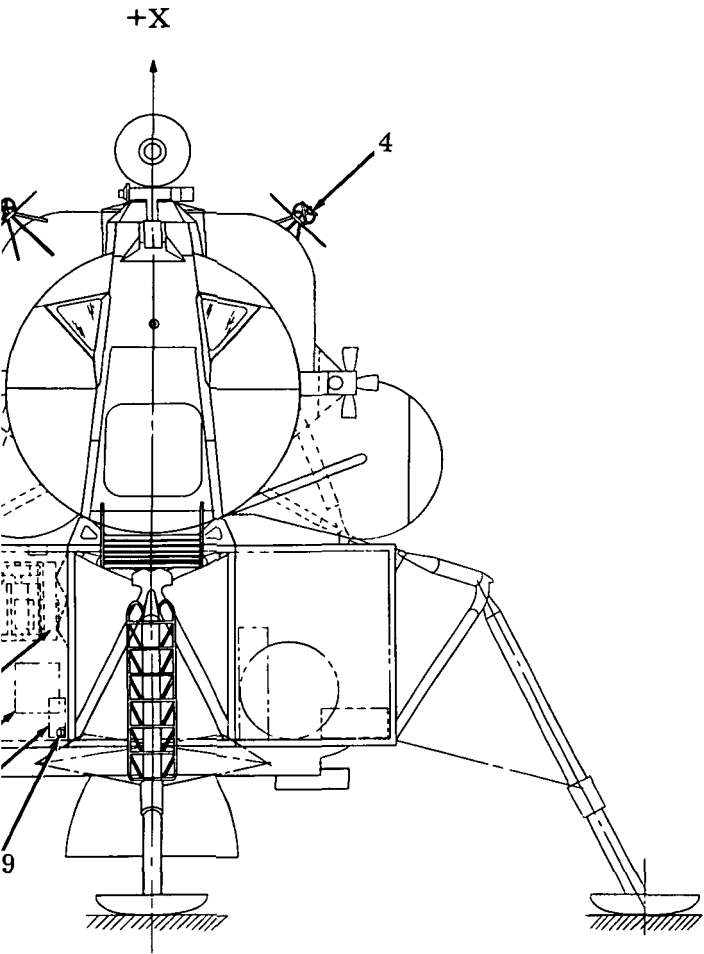
+Z

0 20 40 60 80 100

Scale, in.

6.1-7



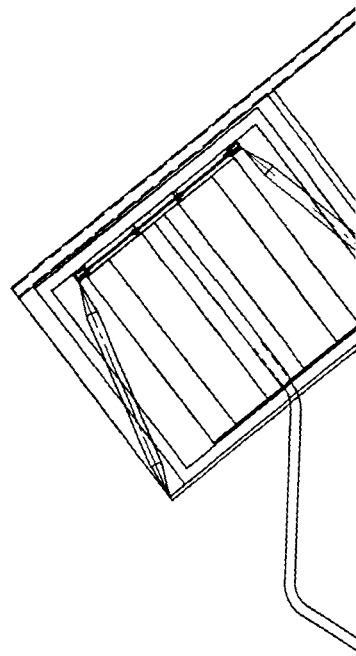


Landed Configuration

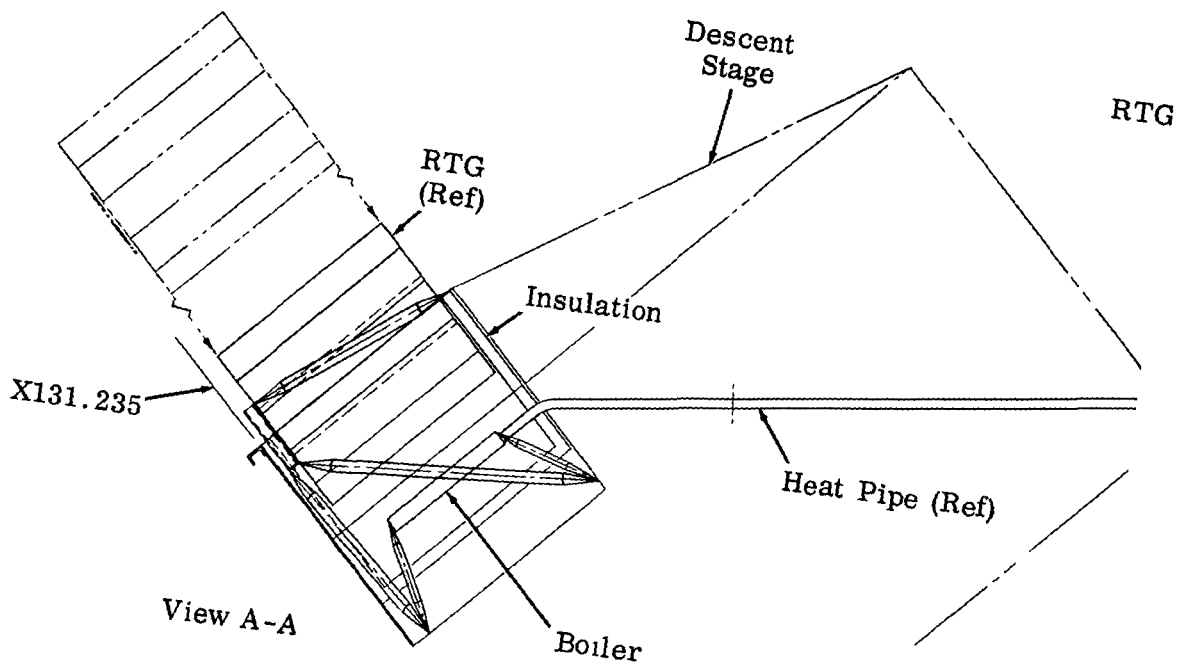
Fig. 6.1-7 Recommended Taxi General Arrangement

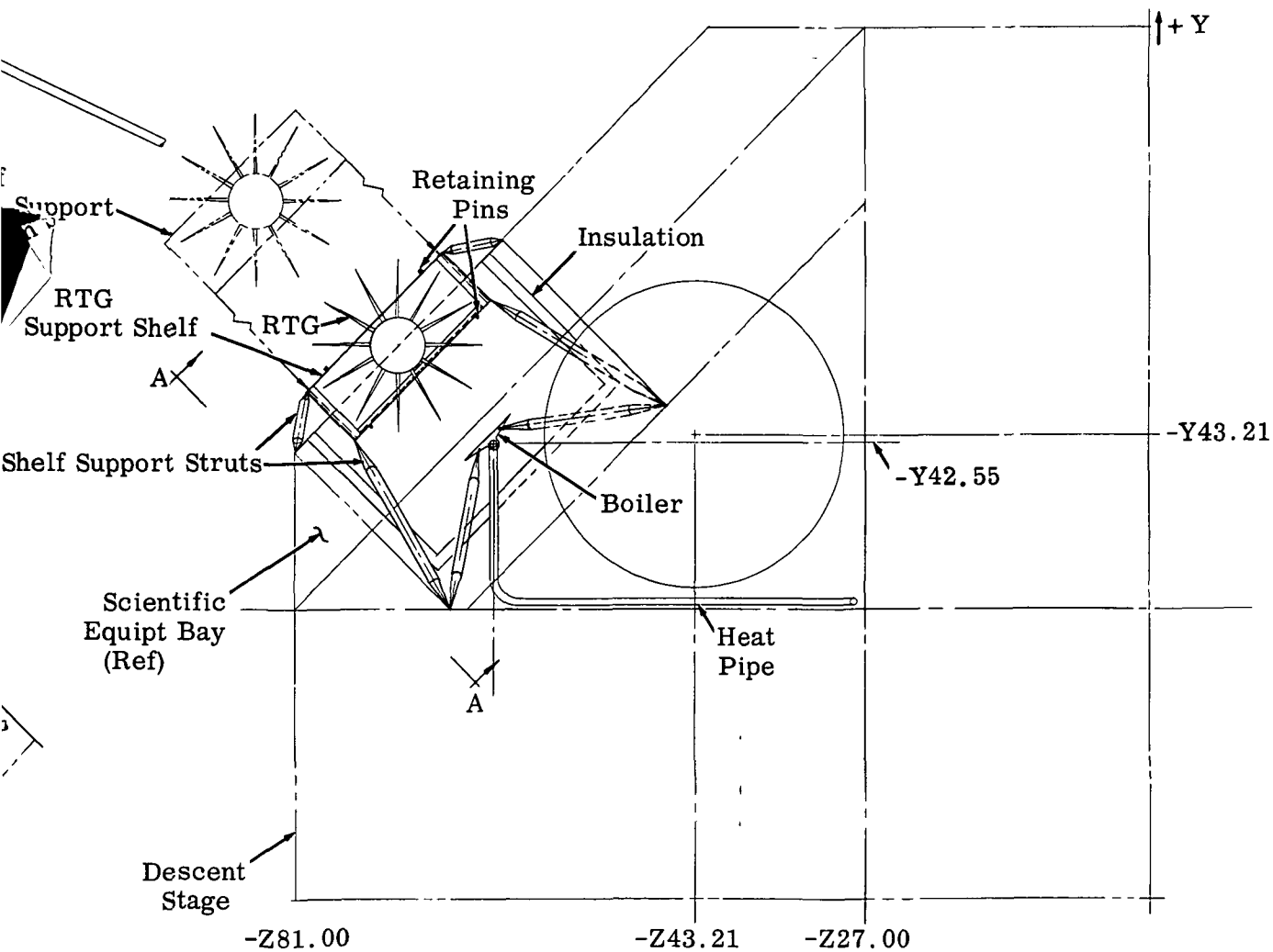
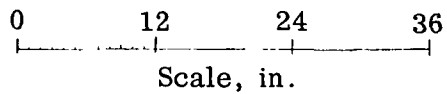
5

Grumman



RTG & Shell
Removed from





View Looking Down

Fig. 6.1-8 Recommended RTG Installation

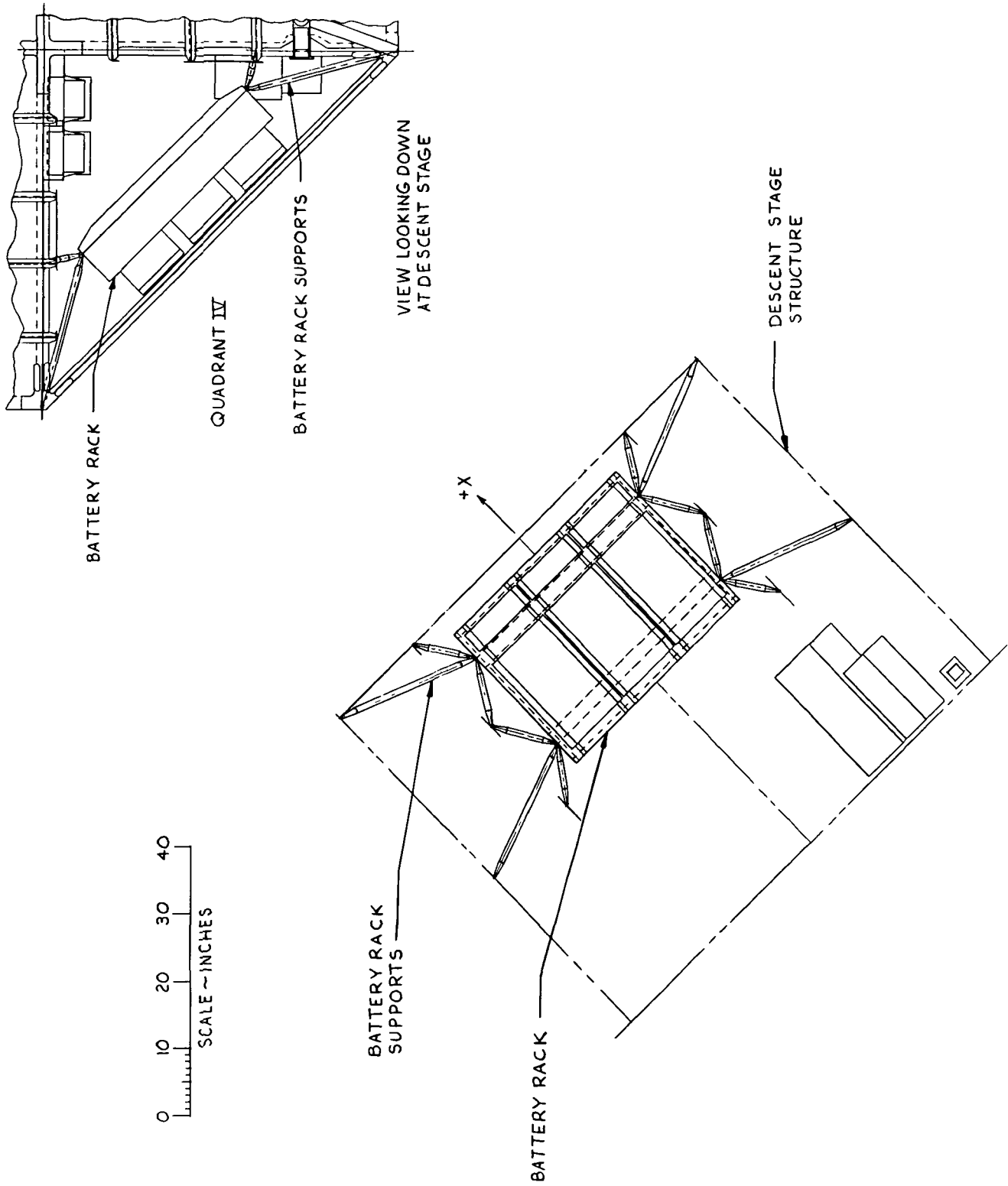


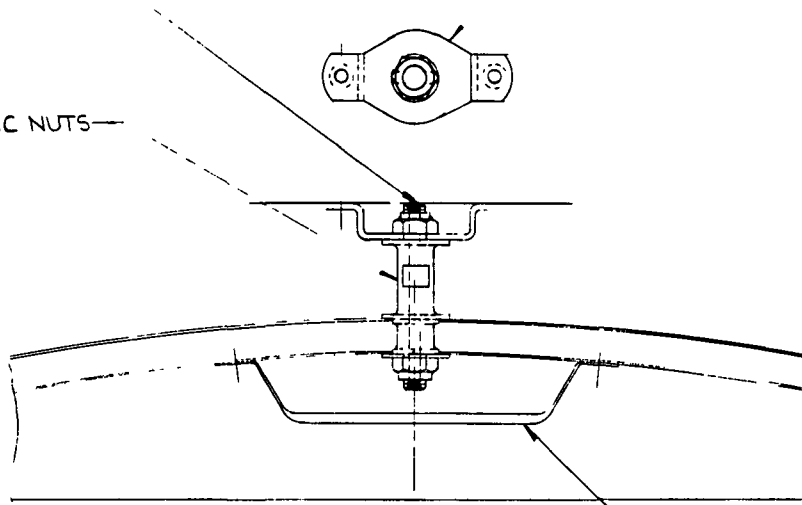
Fig. 6.1-9 Descent Stage Battery Installation

23

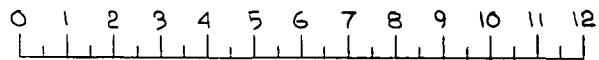
NOTE
ENGAGEMENT OF BOLT AND EXPLOSIVE NUTS—
SHOWN FOR OPEN POSITION OF THERMAL COVER

—BRACKET FASTENED TO
TAXI, AFT OF DOOR

BOLT WITH PYROTECHNIC NUTS—

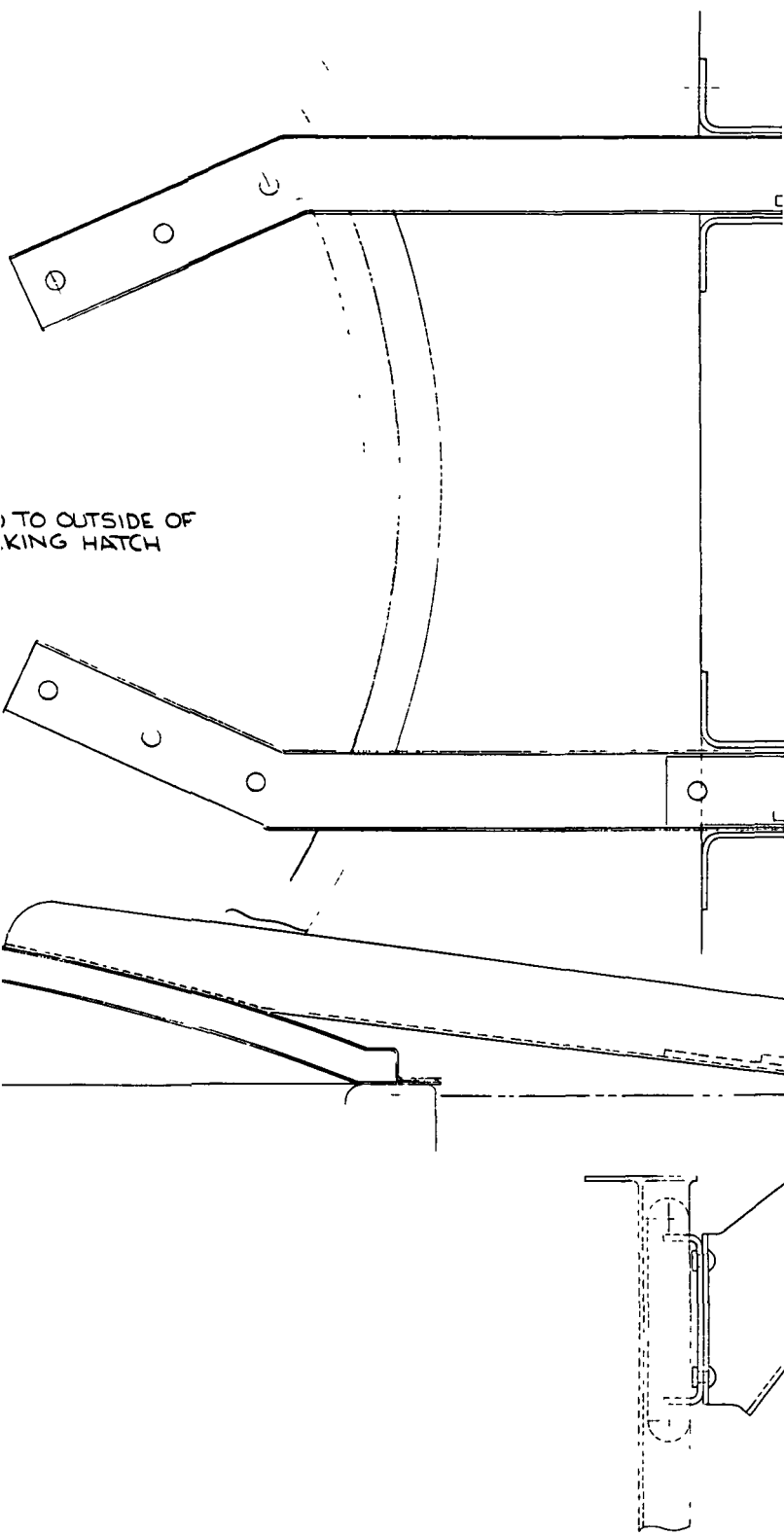


—HANDLE



SCALE INCHES

|



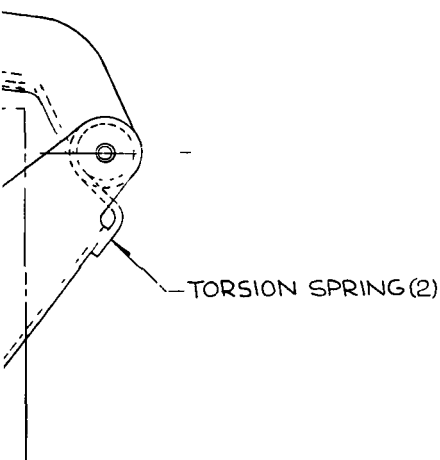
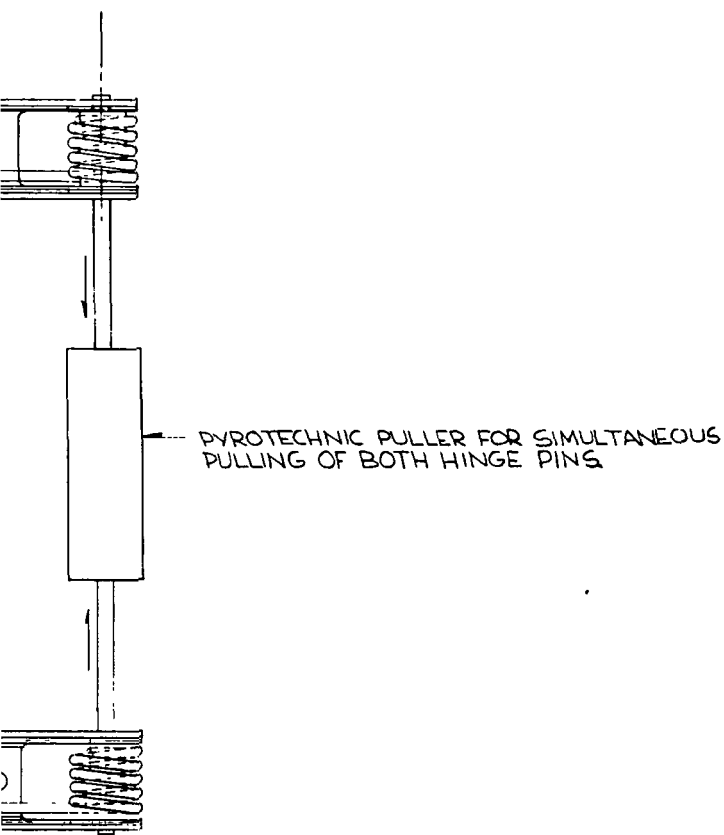


Fig. 6.1-10 Recommended Top Tunnel Thermal Cover

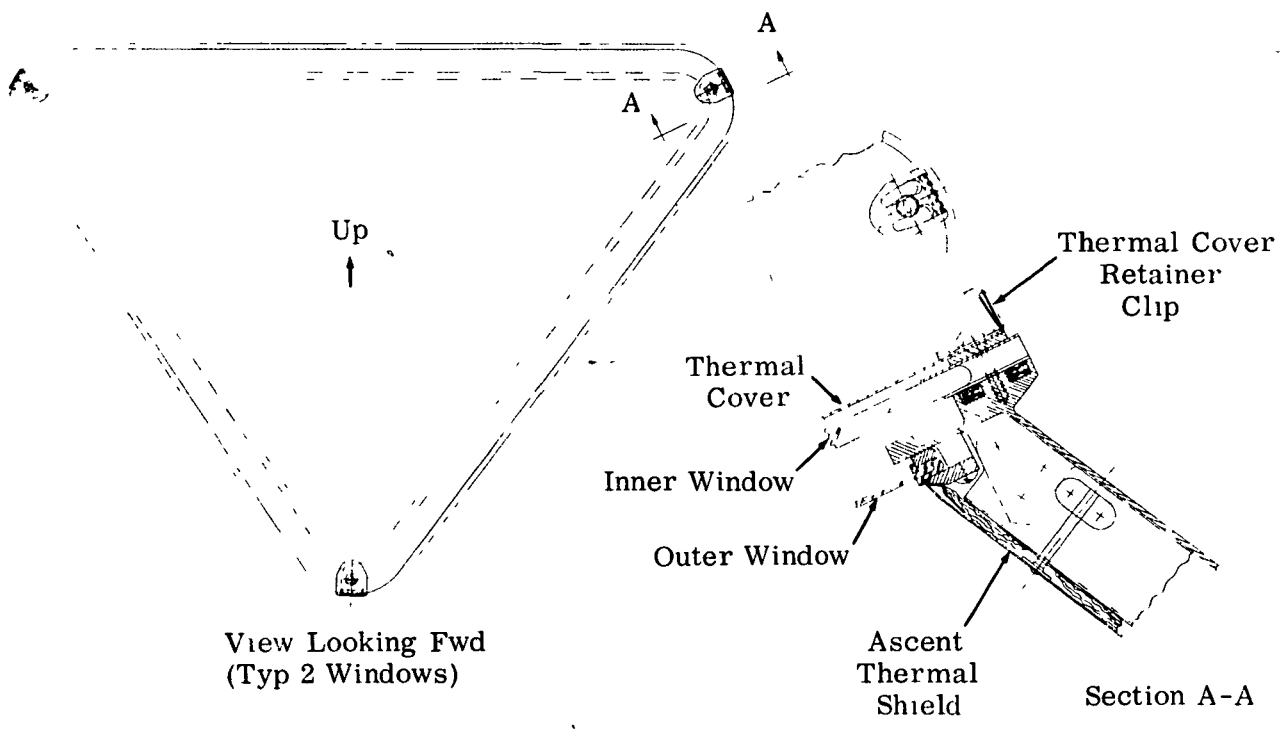
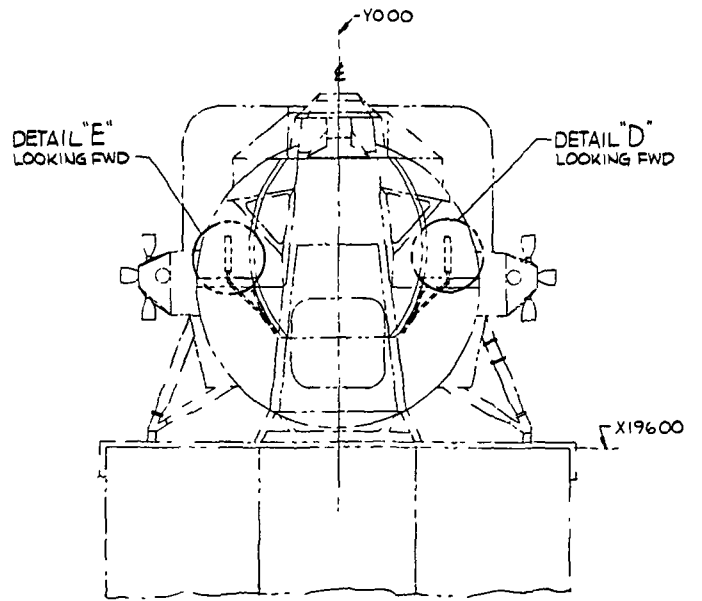
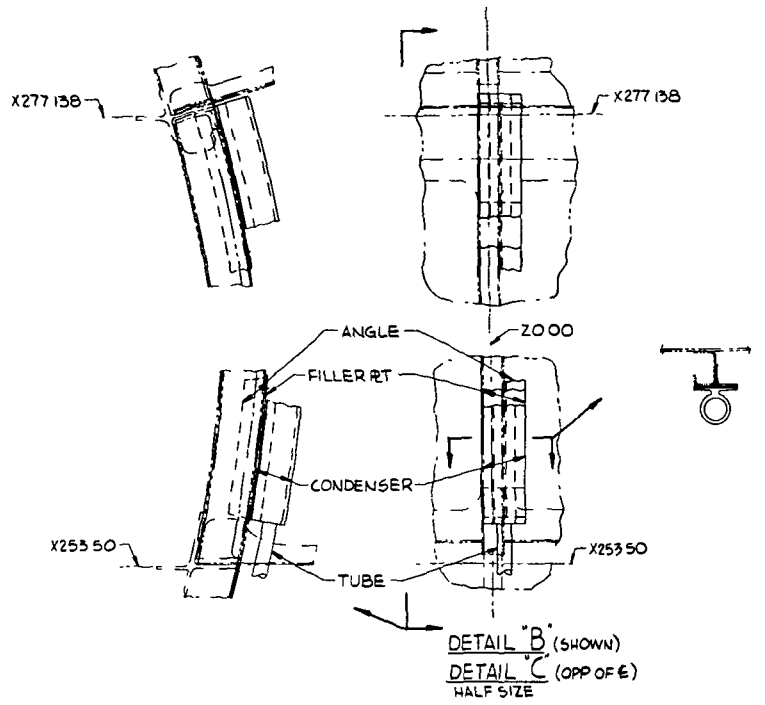
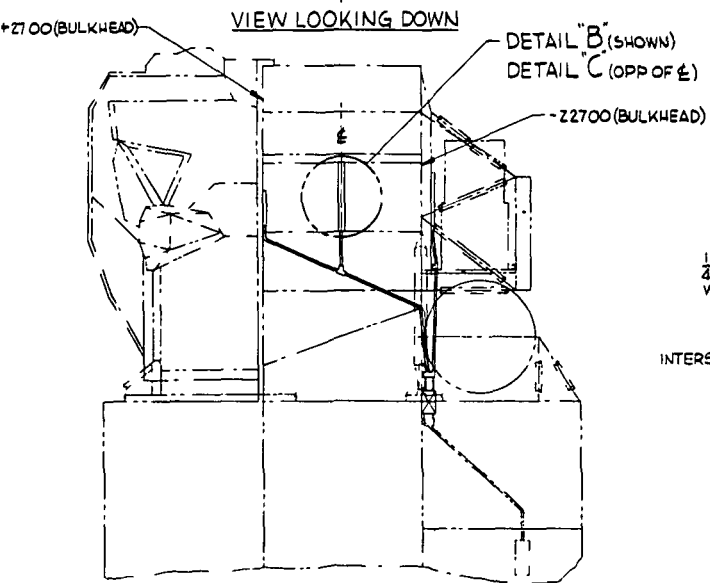
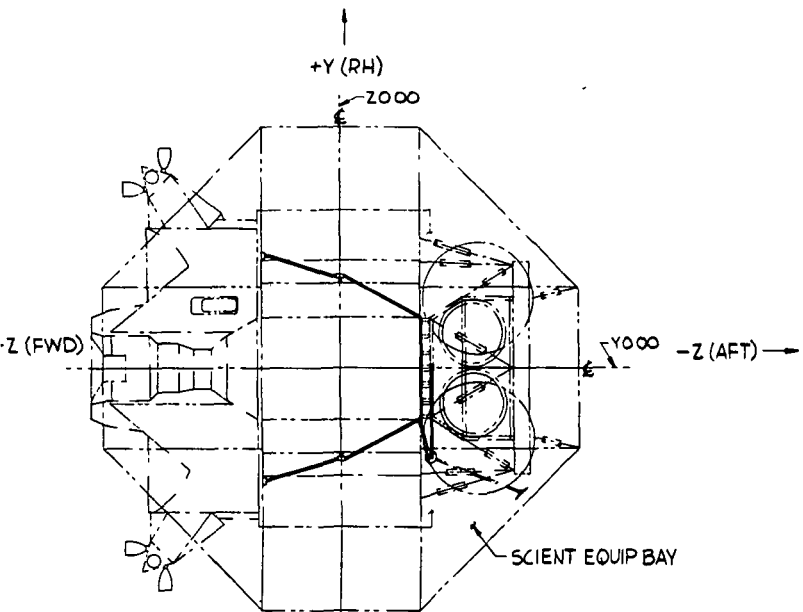
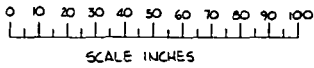


Fig. 6.1-11 Window Thermal Covers

27



VIEW LOOKING AFT



1/4" DIA TUBE
WITH INSU

INTERSTAGE FITTING

VIEW LOOKING INBD

1

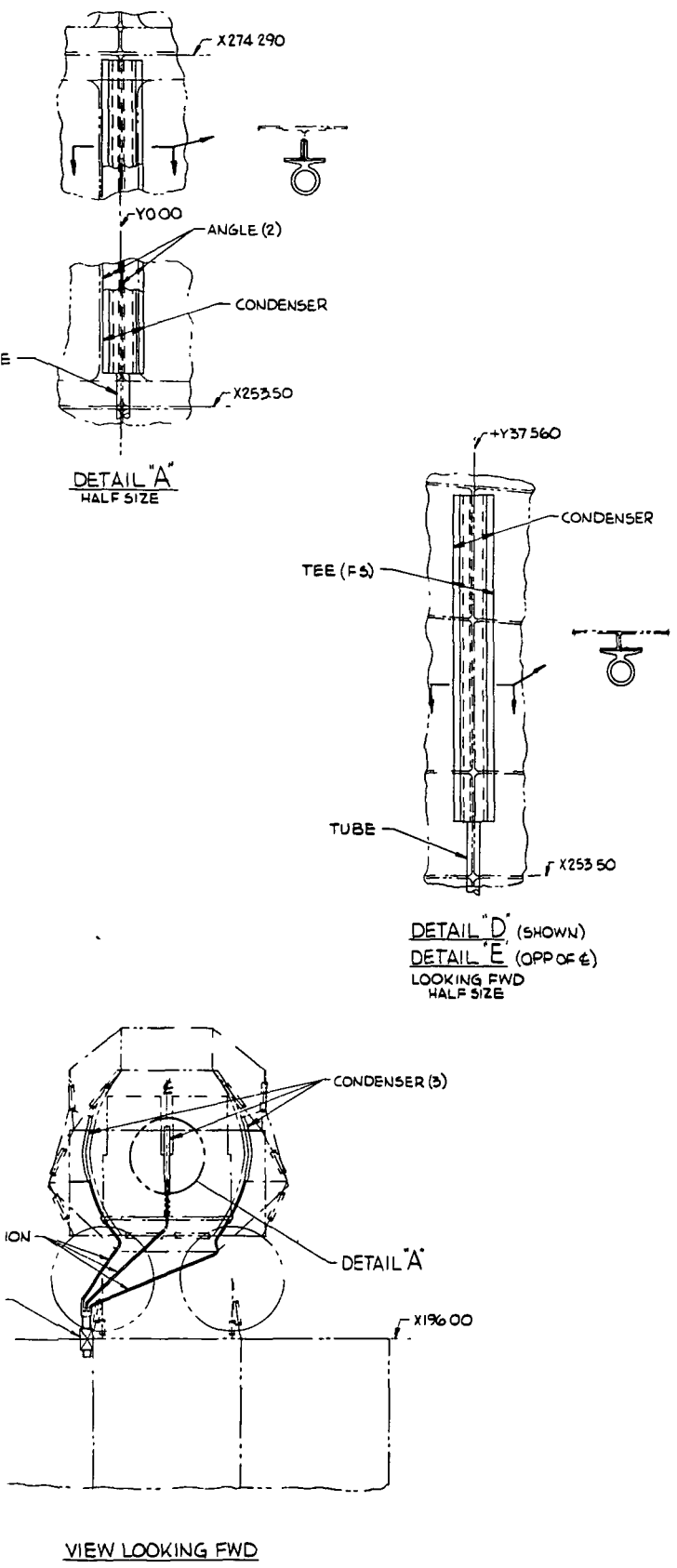
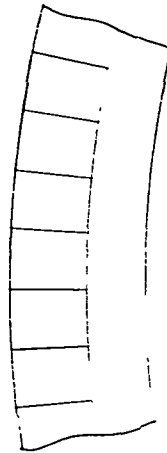
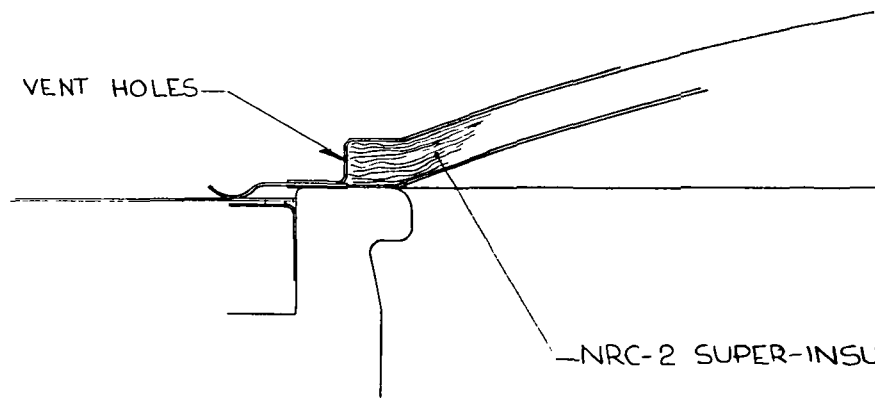


Fig. 6.1-12 RTG Heat Pipe Installation

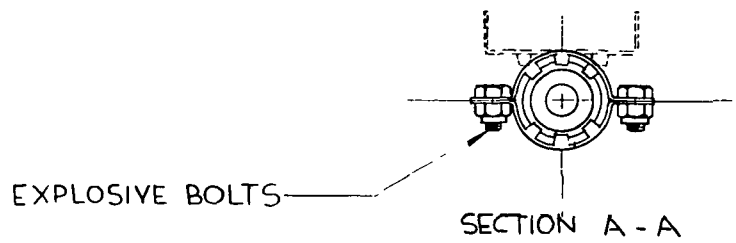


SECTION OF RIM SHOWING
SEALING STRIP FINGERS



VENT HOLES

NRC-2 SUPER-INSU



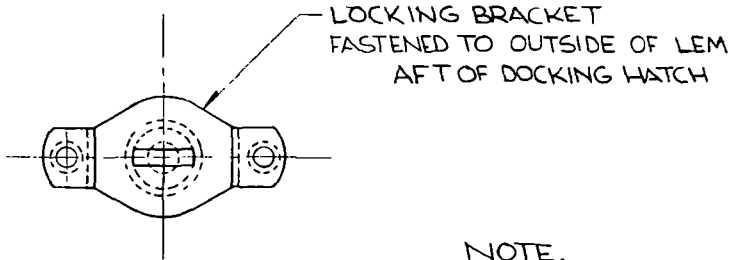
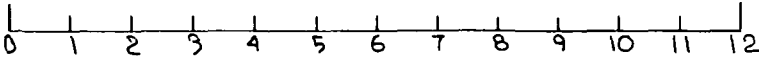
EXPLOSIVE BOLTS

SECTION A - A

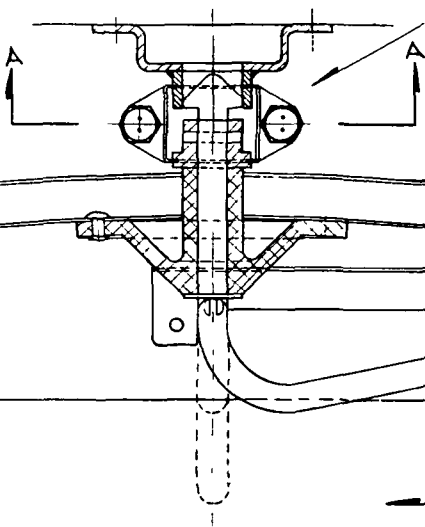
6.1-13

①

SCALE IN INCHES



LOCKING BRACKET
FASTENED TO OUTSIDE OF LEM
AFT OF DOCKING HATCH

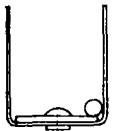


NOTE.
ENGAGEMENT OF LOCKING MECHANISM
BOLTS-AND-CLAMP-ASS'Y, AND BRACKET
SHOWN IS FOR OPEN POS. OF THE

DETENT WITH 2 POS. 90° /

TURN 90° TO LOCK
IN OPEN POSITION

ATION



SECTION B - B

6.1-13

②

M, EXPLOSIVE
ACKET AS
ERMAL COVER.

PART.

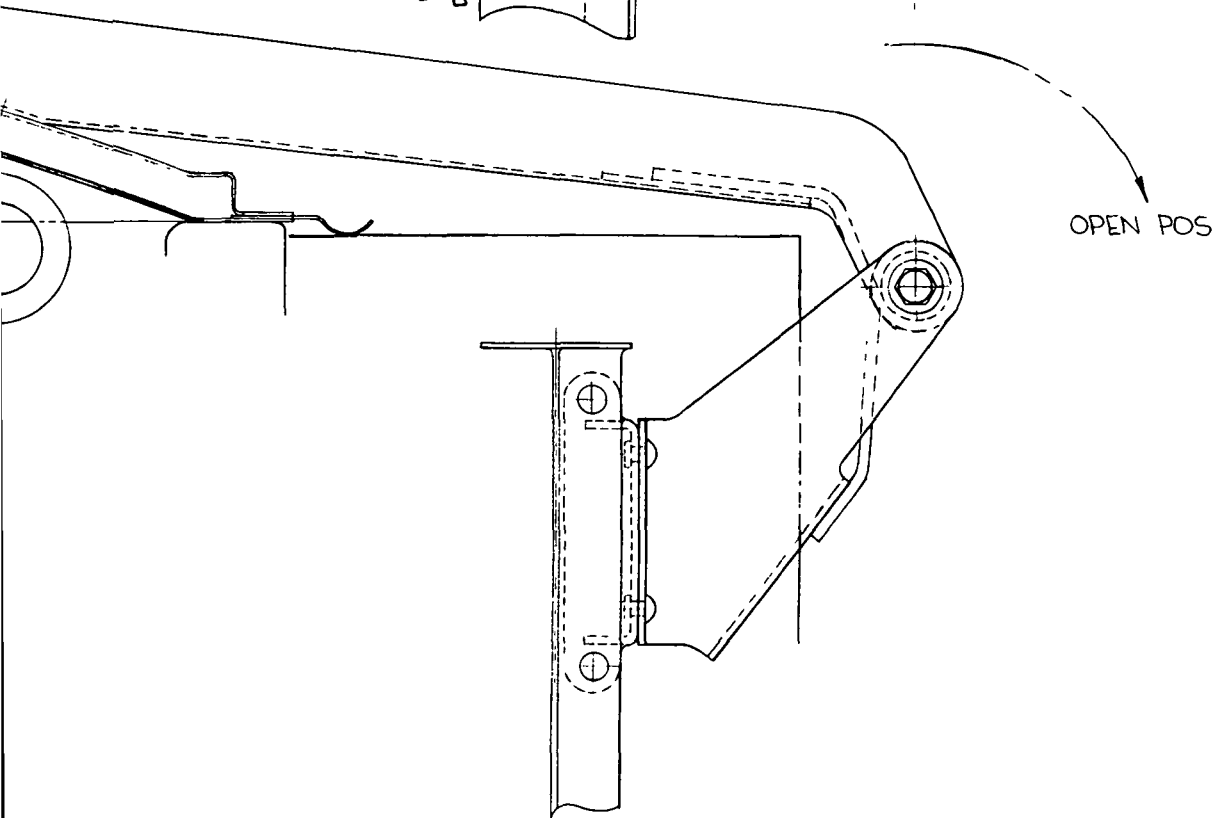
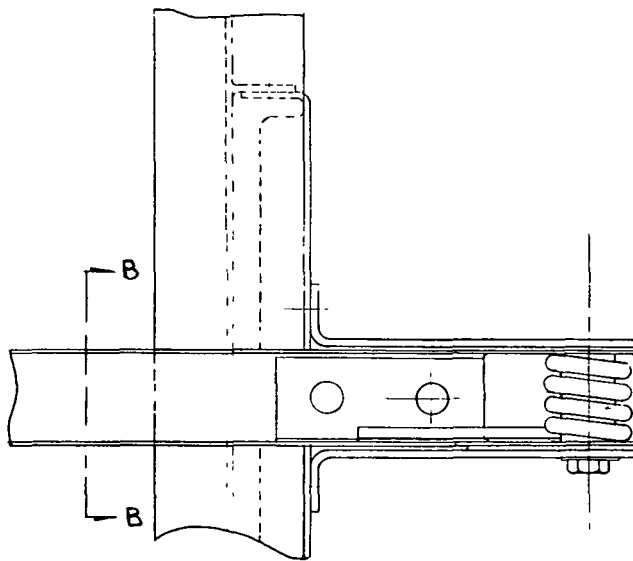


Fig. 6.1-13 Alternate Top Tunnel Thermal Cover

3

Grumman

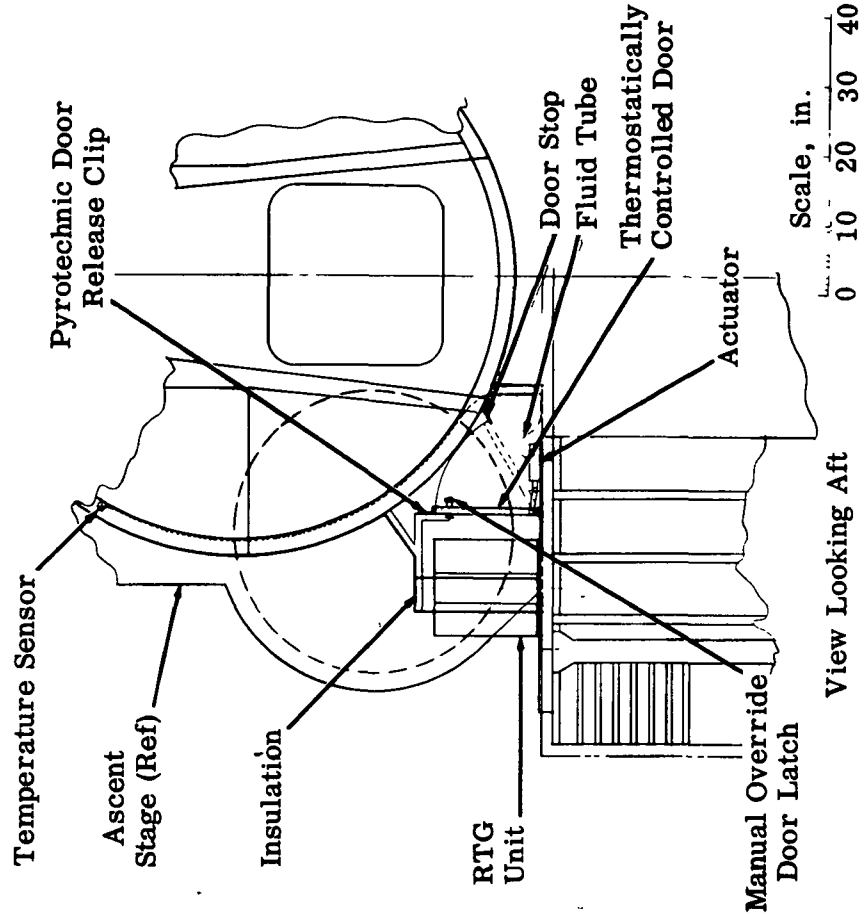
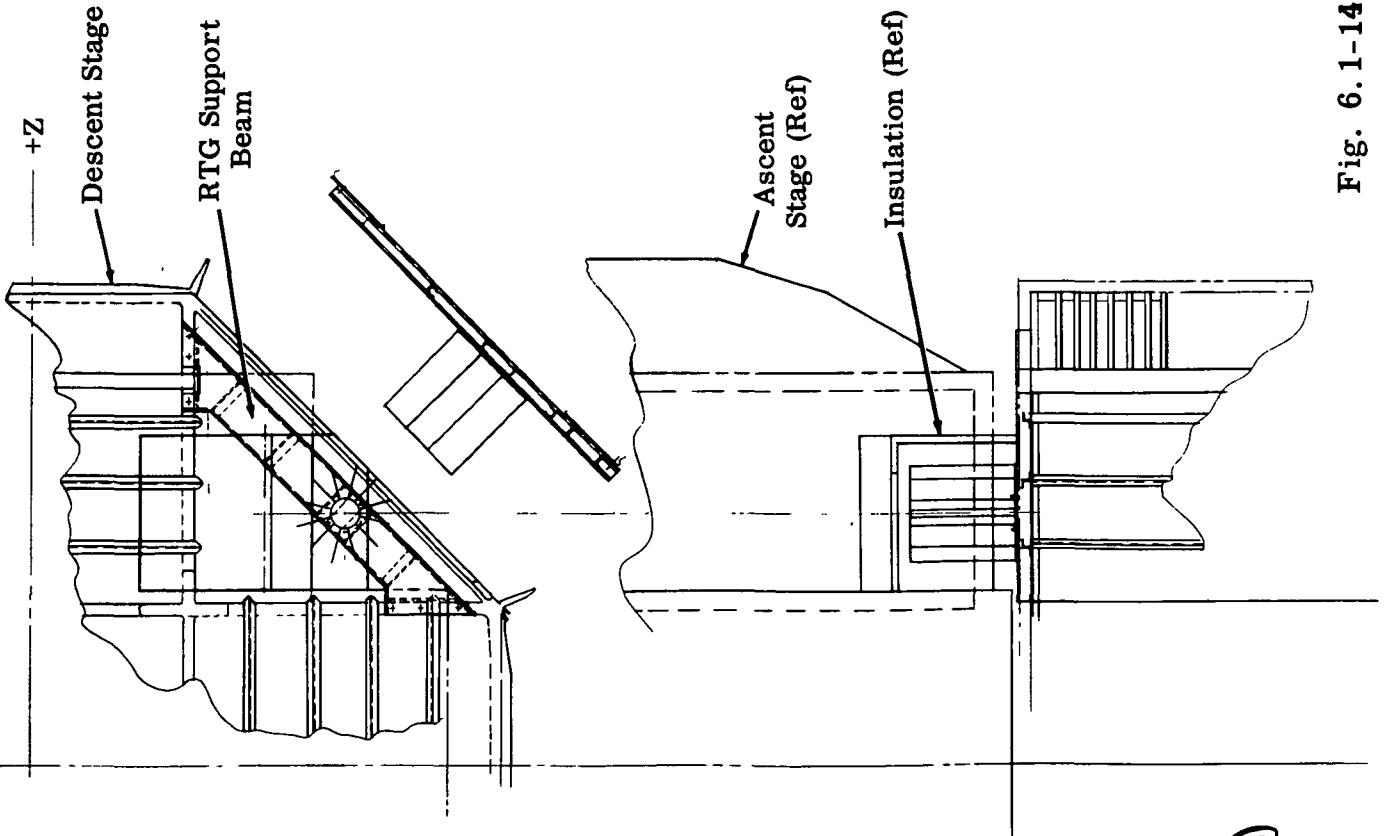


Fig. 6.1-14 Alternate RTG Installation

6.2 CREW PROVISIONS

6.2.1 Ground Rules

The Taxi will support the Shelter by providing a design goal return payload capability of approximately 250 lb.

6.2.2 Assumptions and Background Data

Based on mission requirements, it is assumed that the crew provisions efforts relating to the design of the Taxi will reflect a minimum modification to the existing LEM. The proposed changes are to reflect minor subtractions and modifications primarily based on differences in consummable requirements. The locations of existing controls, displays, and crew provisions are retained where possible; new equipment is treated as additions to the vehicle.

In addition, it is assumed that the Taxi is to support the over-all Taxi-Shelter mission by providing astronaut support items, such as: soft space suits, liquid cooled garments, and PLSS.

On the basis of there being no separate Taxi scientific mission considerations without the associated Shelter, the LEM scientific equipment is removed.

6.2.3 Recommended Configuration

The recommended configuration for the Taxi is shown in Fig. 6.2-1. This inboard profile highlights those items which reflect a change from the LEM. Provisions are incorporated which allow for the addition of 250 lb of specimen return containers. Food, LiOH cartridges, and PLSS batteries are reduced as a function of decreased Taxi crew stay time. A Time Sequencer is provided for programming of the vehicle status data during the quiescent stay.

Further details with regard to the above modifications are as follows:

- **PLSS Batteries:** Two PLSS batteries are removed. Of the remaining four, two are stored on the left side of the mid section and one each in the two backpacks.
- **PLSS LiOH Cartridges:** Two PLSS LiOH cartridges are removed. Of the remaining four, two are stored in the existing LEM storage facilities on the left side of the mid section and one each in the two backpacks.
- **Food Packages:** Approximately four lb of food are removed. The 5.2 lb required for the Taxi mission are stored in a portion of the existing LEM food lockers located in the left side of mid section.
- **Specimen Return Containers:** An allocation of space has been made to provide for a design goal of 250 lb of return payload. This represents an increase of 170 lb over the LEM. The filled containers are to be transferred from the Shelter for the Taxi return trip, and will be located on the left side of the mid section, aft of the engine housing in the mid section, and on the right side of the cabin underneath the side consoles. Provisions for securing these containers in their respective locations are included.

The items listed below have been removed from the LEM consistent with the Taxi mission requirements.

- Scientific equipment
- TV camera and portable cable.

In addition, the voice storage recorder has been retained and is located on the left side of the cabin on the forward side of the +Z27 bulkhead.

The following items are transferred from the Taxi to the Shelter to avoid redundancy and allow for an efficient utilization of available hardware consistent with Shelter-Taxi mission requirements:

- Two soft space suits
- Two liquid cooled garments
- Emergency oxygen system
- Two PLSS units
- Two thermal/antimeteoroid protective garments
- Two pairs of lunar boots
- Two suit repair kits and spare parts
- One water probe.

The above items are to be returned to the Taxi at the conclusion of the mission for support of the crew during the return Taxi mission.

Fig. 6.2-2 shows the Taxi control and display panel layouts. Minor modifications are indicated primarily in the battery display area (Panel X). Controls for one descent battery have been removed, reflecting the differences in LEM and Taxi battery configurations. In addition, the Power/Temperature Monitor Switch on Panel X has been modified by the deletion of the No. 6 Battery Position. A RTG notation replaces this nomenclature. Panel VI has also been modified by the removal of the TV plug-in and its associated control.

6.2.4 Baseline Configuration

The PLSS calibration unit was removed from the LEM, in addition to the previously mentioned modifications. This unit represents the only difference between the the baseline and recommended configuration.

6.2.5 Alternate Configuration - Exterior Lighting

One alternate to the recommended configuration was considered; providing exterior lighting on the Taxi to illuminate the local area during the night portion of the mission. It may be possible to provide any necessary lighting from the Shelter payload mobility aid. However, if this is not possible and lighting is required, exterior flood lights could be provided at two corners of the descent stage, 180 deg apart, to illuminate under the descent stage, along the sides of the vehicle, and the terrain away from the vehicle. One light would provide illumination of the alighting ladder area. The lights could be portable self-contained battery types or fixed installations serviced by vehicle power with exterior and interior switching capability.

6.2.6 Potential Modifications Per Flight

No per flight modifications were considered for the Taxi.

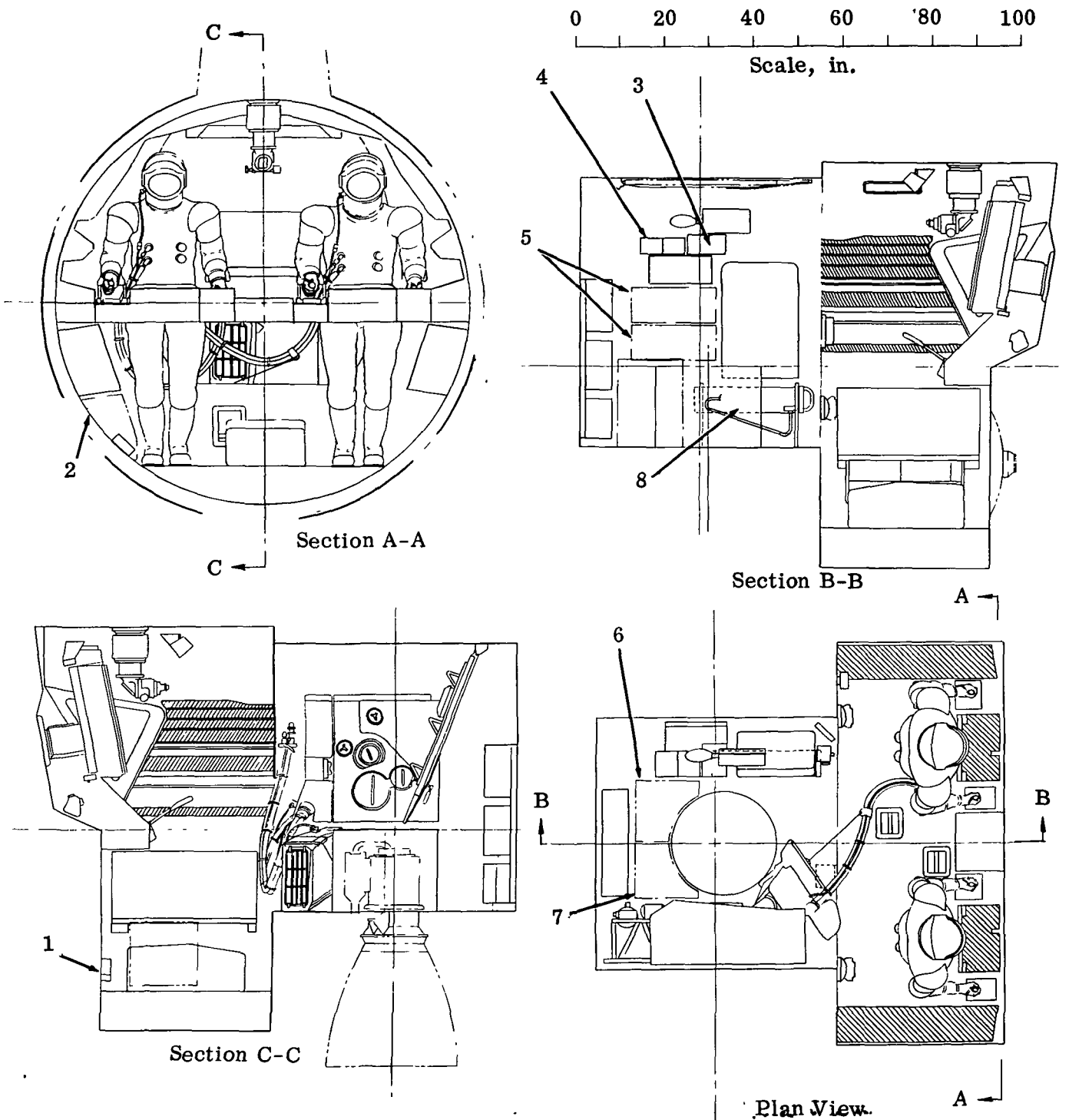
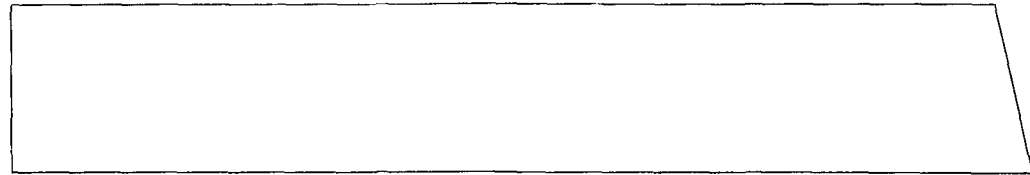
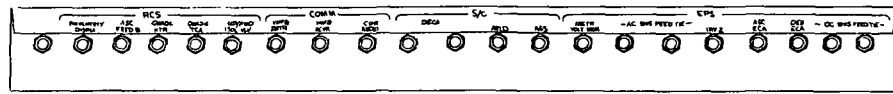
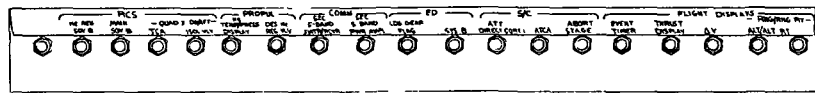
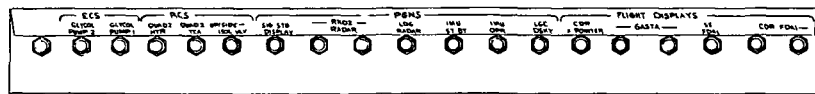
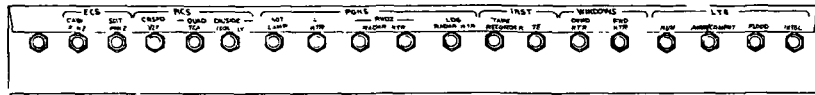
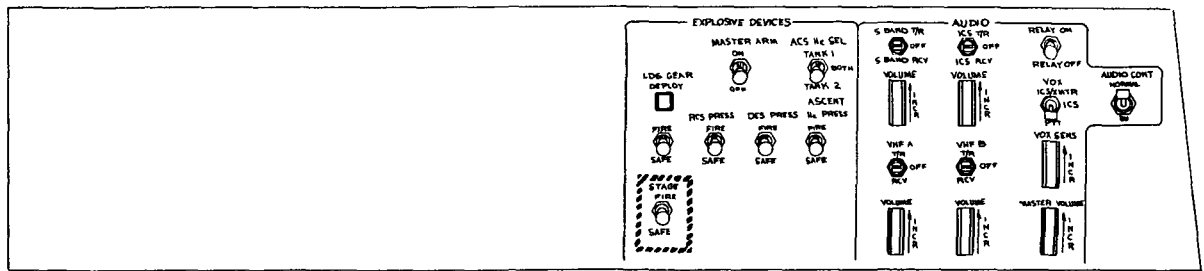


Fig. 6.2-1 Inboard Profile-Taxi Recommended Configuration

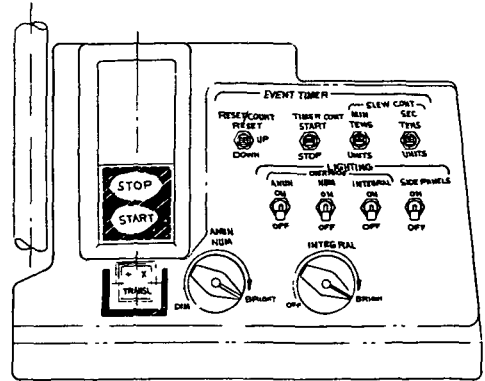
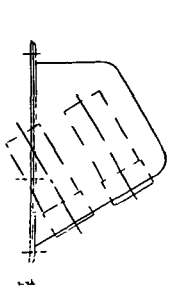


IV

V



VI



VII

6.2-2



I

Control panel I features several key components:

- Event Timer:** A digital display showing 9959 with MIN and SEC indicators.
- Main Propulsion:** A digital display showing 2800 with HELIUM and THRUST indicators.
- Thrust, Temp, and Press Gauges:** Three vertical gauges for monitoring engine performance.
- Navigation and Status:** Includes a compass, a digital altitude display (13200), and various indicator lights for engine and system status.
- Control Buttons:** A grid of buttons for engine thrust control (ASC, DES, HOLD, STOP), abort/stage functions, and other system operations.

II

Control panel II is dedicated to reaction and environmental control:

- Reaction Control:** Features a quantity oxidizer display (30) and a fuel display (33).
- Environmental Control:** Includes temperature and pressure gauges for cabin and suit environments.
- System A and B:** Multiple columns of control buttons for various systems, including THRUST PANS and QUAD controls.
- Master Alarm and Indicators:** A prominent master alarm button and various status indicators.

X

Control panel III manages radar, stabilization, and lighting:

- Radar:** Includes a radar display and control buttons for RHO, SLEW RATE, and other radar functions.
- Stabilization Control:** Features attitude control buttons for ROLL, PITCH, and YAW, along with gyro test and mode control buttons.
- Heater Control:** Includes a temperature gauge and buttons for RINSE, STOP TEMP, and other heater functions.
- Lighting:** Controls for exterior and interior lighting, including side panels and lamp/tone tests.

XI

III

The DSKY (Data Storage Keyboard) is used for data entry and system control:

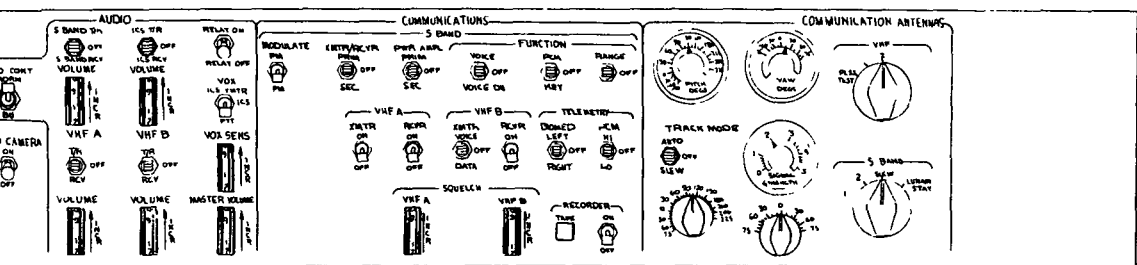
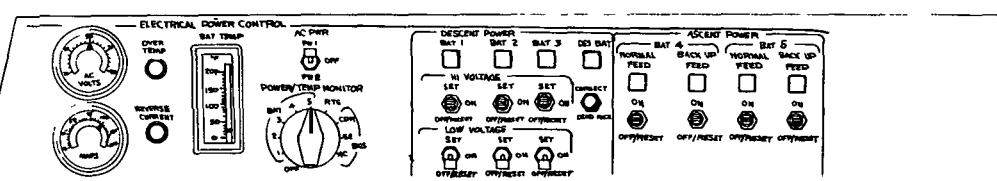
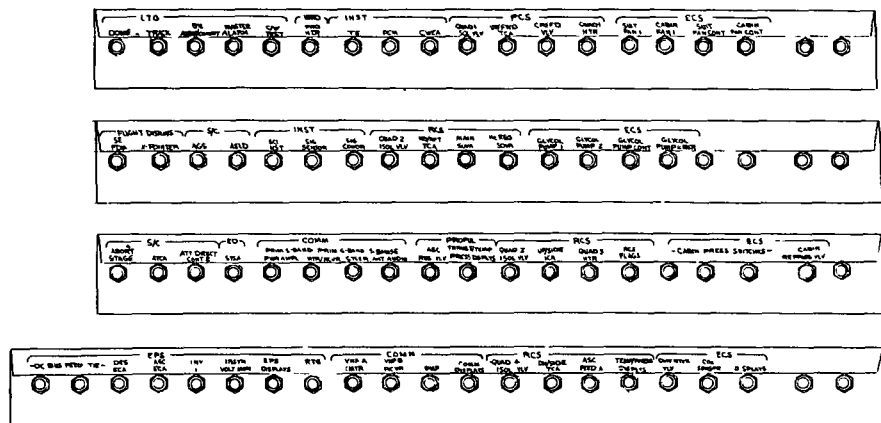
- Display:** Shows a series of numbers and codes: 13, 33, 13, -92311, +13270, -46514.
- Keypad:** Includes a numeric keypad (0-9), function keys (TEMP, AUTO, HOLD, FREE, NO ATTY, STBY, KEY DEL), and a CLR key.
- Buttons:** Includes INSCAKE and UPLINK control buttons.

VIII

6.2-2

(2)

IX



XII

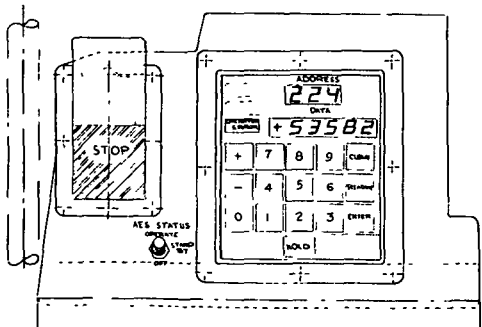


Fig. 6.2-2 Controls and Displays General Arrangement

3

6.3 STRUCTURAL ANALYSIS

6.3.1 Ground Rules

The following ground rule is unique to this portion of the study:

- Structural and dynamic interface between spacecraft and launch vehicles for all AES missions shall be compatible with the basic Apollo Program.

6.3.2 Assumptions and Background Data

The design criteria and environments established for the LEM have been used to establish subsystem design concepts and feasibility for this study. It is anticipated that these conditions will not be exceeded when the final configurations, including payloads, have been determined.

Inasmuch as the total LEM launch, separation, and landing gross weights will not be exceeded by the Taxi, it may be assumed that the basic structure will not require modification.

Tables 6.3-1 through 6.3-7 summarize the pertinent LEM design requirements which have been used to establish the integrity of the basic vehicle and subsystems. A safety factor of 1.50 is applied to the limit conditions to obtain ultimate loads. Fig. 6.3-1 shows the Taxi reference axes.

An estimate of docking loads for the CSM and LEM with the S-IVB Stage is shown below for the indicated masses, moments of inertia, and criteria.

- Probe Contact

Axial velocity 0.1 to 1.0 fps
 Radial velocity 0.0 to ± 0.5 fps
 Angular misalignment ± 10 deg
 Angular velocity ± 1.0 deg/sec
 Miss distance at probe ± 1 ft

- Loads

$F_x = 2235$ lb
 $F_z = 3118$ lb
 $M = 8134$ ft-lb

- Mass Properties

Active Vehicle M = 2000 slugs
 (CSM) I = 74000 slug-ft²
 Target Vehicle M = 2200 slugs
 (S-IV B + LEM) I = 1,150,000 slug-ft²

- Final Hard Surface Contact

(Max. permissible for single-point contact on non-parallel surfaces)

Axial velocity = 0.15 fps
 $F_x = 5000 \text{ lb}$

6.3.3 Recommended Configuration

The basic LEM structure will not require modification. However, because of the longer mission time (14 days on the lunar surface), the micrometeoroid protection requirements may necessitate an increase in material thickness. The shielding design and support structure will be the same configuration as presently used on LEM.

While micrometeoroid penetration considerations will determine the minimum average gage and skin spacing from the protected structure, the shielding must be designed for its ability to withstand sonic fatigue during the launch and boost condition.

For LEM, the micrometeoroid shielding, which also acts as thermal shielding, is a 0.006-aluminum-alloy skin held away from the main structure by nylon standoffs. The standoffs offer point support and are spaced approximately 12 in. apart.

While the basic structure will not require modification, there may be particular materials used by LEM which will not satisfy the longer mission time and revised environment.

Non-metallic materials are now evaluated for a total of 3 days in contrast to the 14-day Taxi mission time. Since the quantity of outgassed products per material may be unacceptable for the increased mission time and increased degradation may also take place, retesting may be necessary. Other areas apart from a toxicity standpoint where testing may be necessary are: compatibility effect of extended exposure of both metallic and non-metallic materials to propellants, oxygen, and hydrogen; effect of prolonged UV radiation on visibility through window material; extended mission times, combining high- and low-temperature cycling and hard vacuum, could have detrimental effects on sealants and non-metallics; and stable thermal control coatings. The extent to which these potential problem areas will alter the original materials chosen will be studied further in Phase C.

6.3.4 Baseline Configuration

The Taxi structure for the baseline configuration is the same as for the recommended configuration.

6.3.5 Alternate Configuration - Micrometeoroid Shielding

Alternate methods of construction for the micrometeoroid shielding were investigated using the techniques of ref. 6.3-2. A general comparison was made of the following types of construction which are listed in order of preference from a weight standpoint:

- Honeycomb panels
- Skin with bonded doublers and ribs
- Skin and rib
- Corrugated panels
- Beaded panels.

Since the design reference data used were developed for aircraft applications, the lowest number of design cycles considered were a factor of 10 to 100 times greater than those anticipated during the launch and boost conditions. The gages required were, therefore, 5 to 30 times greater than that used for LEM. An exception was the honeycomb construction where the sum of the two face gages was only 1.5 to 2 times as great.

While these alternate methods of shielding are more efficient fatigue-wise, it is not planned to apply them to the Taxi. The total mission time for the Taxi is 14 days as compared to 7 days for LEM; it is felt that a slight increase in skin gage will provide a sufficiently high probability of no penetration.

6.3.6 Potential Modifications Per Flight

No per flight modifications were considered for the Taxi in this area.

6.3.7 Discussion of Configuration Choices

For micrometeoroid shielding, the LEM-type construction was selected for the Taxi with an increase of skin gage as required for the 14-day mission period. Although the increase in gage is usually beneficial with regard to fatigue, a change in dynamic characteristics, especially of the substructure, will occur. Acoustic testing of the new configuration would therefore be required later in the program.

6.3.8 References

- 6.3-1 ITR-905-11001: "Results of Vibration Tests, LEM Structural Elements", C. Birn, Grumman, April 1965.
- 6.3-2 ASD-TDR-63-820: "Structural Design for Acoustic Fatigue," Air Force Flight Dynamic Laboratory, Wright Patterson Air Force Base, October 1963.

Table 6.3-1

LAUNCH & BOOST ACCELERATIONS

Condition	N_x (g)	N_y or N_z (g)
Lift-off	1.6	0.65
Max $q \alpha$	2.07	± 0.30
End boost	4.9	± 0.10
1st-stage cut-off	1.7	± 0.10
End 2nd-stage boost (engine hard-over)	2.15	± 0.40

Table 6.3-2

VIBRATION INPUT TO EQUIPT SUPPORTS FROM EXTERIOR PRIMARY STRUCTURE

Random			Sinusoidal	
10 - 23 cps	12 db/oct rise		5 - 18.5 cps	0.15 ⁴ in. D. A.
23 - 80 cps	0.0148 g^2 /cps		18.5 - 100 cps	2.69 g peak
80 - 105 cps	12 db/oct rise			
105 - 950 cps	0.0444 g^2 /cps			
950 - 1250 cps	12 db/oct decrease			
1250 - 2000 cps	0.0148 g^2 /sec			

Table 6.3-3

VIBRATION INPUT TO EQUIPT SUPPORTS FROM INTERIOR PRIMARY STRUCTURE

Random			Sinusoidal		
10	-	23 cps	12 db/oct rise	5 - 16 cps	0.154 in. D. A.
23	-	80 cps	0.0148 g ² /cps	16 -100 cps	1.92 g peak
80	-	100 cps	12 db/oct rise		
100	-	1000 cps	0.0355 g ² /cps		
1000	-	1200 cps	12 db/oct decrease		
1200	-	2000 cps	0.0148 g ² /cps		

Table 6.3-4

ACOUSTIC ENVIRONMENT

Octave Band, cps	C-5 at Max q Level, db
9 - 18.8	136
18.8 - 37.5	142
37.5 - 75	146
75 - 150	143
150 - 300	139
300 - 600	135
600 - 1200	130
1200 - 2400	125
2400 - 4800	119
4800 - 9600	113
overall	150

(Sound pressure levels in db external
to LEM, Re: 0.0002 dynes/sq cm)

Table 6.3-5

SPACE FLIGHT ACCELERATION

Axis Acceleration	X		Y		Z	
	g	$\frac{\text{rad}}{\text{sec}^2}$	g	$\frac{\text{rad}}{\text{sec}^2}$	g	$\frac{\text{rad}}{\text{sec}^2}$
SM Propul Sys Operating	-0.36	-	± 0.062	± 1.99	± 0.062	± 1.99
Not Operating	0	0	0	0	0	0

Table 6.3-6

DESCENT ACCELERATIONS

Phase	Vertical Accel, Earth g	Lateral Accel, Earth g	rad/sec^2 about	rad/sec^2 about
	\bar{X}	Y&Z	Y&Z	\bar{X}
At Separation	+0.368	± 0.0378	± 0.192	± 0.091
Elliptic Orbit	+0.372	± 0.0383	± 0.193	± 0.092
Start of Hover	+0.707	± 0.0728	± 0.448	± 0.166
End of Hover	+0.815	± 0.084	± 0.645	± 0.189
Transfer Orbit	0	0	0	0

Table 6.3-7

LANDING ACCELERATIONS

Landing Accelerations at LEM cg	Axis	X		Y		Z	
		g	$\frac{\text{rad}}{\text{sec}^2}$	g	$\frac{\text{rad}}{\text{sec}^2}$	g	$\frac{\text{rad}}{\text{sec}^2}$
Case 1		.798	± 0.036	± 1.778	-0.16	0	± 14.56
Case 2		.798	0	0	17.60	1.778	0
Case 3		.857	± 15.82	± 0.095	9.05	-.421	± 5.73
Case 4		2.74	0	0	± 28.1	± 5.14	0
Case 5		2.74	.01	± 5.14	-.055	0	± 23.3

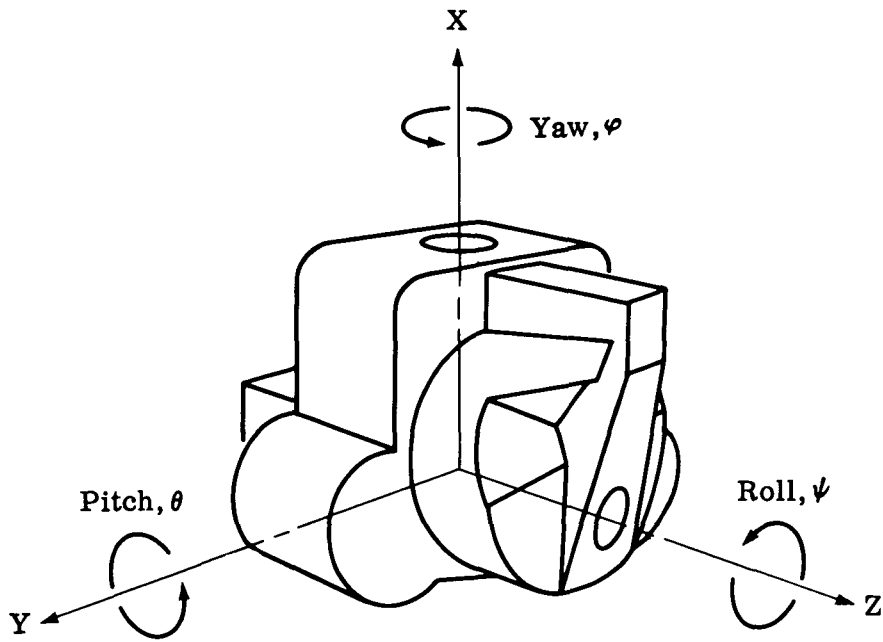


Fig. 6.3-1 Taxi Reference Axes

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Grumman Aircraft Engineering Corporation • Bethpage, New York

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