

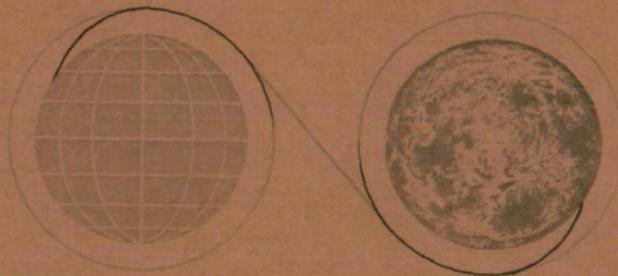
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Grumman Design 378B



Apollo Extension Systems—Lunar Excursion Module Phase B Final Report

X66 14545

FORM 602

(ACCESSION NUMBER)

(THRU)

264

20

(NASA-CR-70909) APOLLO EXTENSION SYSTEMS - N75-75816
LUNAR EXCURSION MODULE, VOLUME 3: PHASE 1
LABORATORY DESIGN ANALYSIS SUMMARY Phase B
Final Report (Grumman Aircraft Engineering
Corp.) 364 p
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Vol. III Phase I Laboratory Design Analysis Summary (U)



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**Apollo Extension Systems – Lunar Excursion Module
Phase B Final Report**

to

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

by

Grumman Aircraft Engineering Corporation
Bethpage, New York

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Vol. III Phase I Laboratory Design Analysis Summary

Contract No. NAS 9-4983
ASR 378B

8 December 1965

Preface

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

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

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

The scope of this study included integration of the experimental payloads with the Shelter and Taxi, but did not include study of the 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 describes the study of the use of an Apollo LEM as an orbital laboratory to provide experiment support for mission durations of up to 14 days. This vehicle, to be operated in conjunction with an Apollo Command and Service Module is known as the Phase I Lab.

The preliminary design data which are provided are intended to permit the selection by NASA a Phase I Lab configuration. The following vehicle-level ground rules were observed during this study. Additional subsystem-level ground rules and assumptions are included in the subsystem and system sections:

- The Phase I Lab shall be converted from a fully assembled LEM in minimum time at Kennedy Space Center
- The Phase I Lab shall be operated with the Block II CSM for a maximum of 14 days earth orbit utilizing a Saturn I-B or Saturn 5 launch vehicle
- The Phase I Lab shall require minimum spacecraft modifications and shall utilize Apollo and Gemini hardware wherever feasible.
- The vehicle shall require minimum modifications to Ground Support Equipment, Acceptance Checkout Equipment and the Manned Spaceflight Network
- Modifications and development must be compatible with the launch schedule as defined in ML-65-1
- The specific modifications required to accomplish rendezvous and/or split launch are not included in the vehicle design
- The orbital characteristics of the Phase I Lab missions are as described in Table II (Revision L) of the Blue Book

The definition of the Phase I Lab is not based upon any specific experiment or group of experiments. The requirements of the vehicle subsystems for experiment support have been selected from a broad survey of the proposed missions and from data available from the first Phase of this study (Apollo Extension System - Earth Orbit Mission Study - Addendum I to Contract NAS 9-3681). The integration of experiments is studied under an addendum to the present contract and as such is not reported upon in this volume.

The analysis of the vehicle is divided into the appropriate subsystem and system areas. Each of the subsystems includes a description of selected configuration choices. These choices include a "recommended", a "baseline", and certain "alternate" choices. The "recommended" choice describes the configuration which now appears most attractive on an overall vehicle basis and is reported on in the third section of each subsystem. The "baseline" configuration is that configuration upon which the PDP costing was based and appears in the fourth section of each subsystem. The various alternates appear in succeeding sections of each subsystem and are presented as possible candidates for NASA selection. "Per flight modifications" are included, where appropriate, as changes to the vehicle which may be attractive only for specific flights.

A tabular listing of these choices, together with other descriptive information, is included in the Configuration Summary.

The logo for Grumman, featuring the word "Grumman" in a stylized, cursive script font.

2. CONFIGURATION SUMMARY

2.1 INTRODUCTION

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

- NASA ground rules as defined in the Work Statement and Blue Book
- Results of Phase A Studies, Contract NAS 9-3681
- Preliminary data from Addendum to Contract NAS 9-4983 (Payload Integration Study)
- Subsystem and system studies
- Vehicle design and integration studies

The vehicle level ground rules that were observed during the study are defined in the Introduction, 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, discussions with NASA personnel, and vehicle design requirements as described in the Blue Book.

2.3 RECOMMENDED CONFIGURATION

The recommended Phase I Lab (Fig. 6.2-1) is a LEM with modifications needed to provide: a mission duration capability of 14 days, and an experiment support capability. The specific subsystems requiring modification are the environmental control, electrical power, stabilization and control, instrumentation, and the structural changes associated with these modifications. Minor modifications have also been made to crew provisions, communications, and displays. 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 4, 5, and 6. Summary descriptions are presented in the following paragraphs. A level I functional block diagram of the recommended Phase I Lab subsystem interfaces is shown in Fig. 2.3-1.

2.3.1 Environmental Control

During the 14-day orbital mission duration, the temperature variations of the various components and subsystems within the vehicle will be controlled by the heat transport section using the same technique as is used on the LEM. The nominal LEM cabin temperature range of $75 \pm 5^{\circ}\text{F}$ is maintained during the environment extremes imposed by the missions. The active thermal control system consists of the LEM water boiler and water supply, plus two additional descent water tanks to provide the capacity required for the 14-day mission. Sufficient cold plate area is made available, within the cabin, to cool 500 w of experiment load. The water provided is capable of handling up to 93 kw-hr of experiment dependent power.

The Lab provides oxygen to compensate for that lost because of leakage and also to support extra-vehicular activity. Five descent stage type GOX tanks have been added to the aft equipment bay to supplement the single descent stage tank normally carried on the LEM. This amount of oxygen is sufficient to repressurize the Lab 18 times, and also to charge the backpack 18 times.

2.3.2 Electrical Power

The housekeeping energy for the Lab, including an allowance for growth and distribution losses, totals 182.9 kw-hr. Since the present LEM carries 68 kw-hr of energy, it is necessary to provide additional batteries. Sixteen LEM descent batteries have been added which, together with the present LEM installation, provide 91.1 kw-hr for experiment use in addition to the housekeeping requirement. The batteries are added outside the four end sections of the descent stage in packs of four batteries each. The batteries are actively cooled using cold rails, identical to the present LEM, which are connected in parallel to the current battery cooling installation.

2.3.3 Stabilization and Control

The Lab carries a stabilization and control section for the purpose of providing attitude hold during orbital operations. On the basis of power, operating life, and thermal considerations, the LEM Abort Guidance and Control Section (AGS) has been selected over the Primary Navigation, Guidance and Control Section (PGNCS). However, some modifications are required to reduce the amount of propellant consumed during undisturbed limit cycle operation. These changes include a modification to the Rate Gyro Assembly to provide an increased sensitivity to determine vehicle rates, and a modification to the Attitude and Translation Control Assembly.

To compensate for system drift, it is necessary to "update" the attitude reference system on a periodic basis. This may be done in the Labs by interfacing the Alignment Optical Telescope to the Abort Electronics Assembly. This interface consists of adding a star catalogue to the AEA program, and implementing the AOT signals into the Data Entry and Display Assembly. Additional sensors, such as horizon scanners or star trackers, may not be required on every flight; therefore, they are not carried as part of the Phase I Lab.

2.3.4 Instrumentation

A data handling section has been added to the Lab to provide for recording, storage, and transmission of experimental data. The section consists of a LEM Pulse Code Modulator and Timing Electronics Assembly (PCMTEA) and two modified CSM-type tape recorders. The recorders provide a dump rate of 409.6 kb/s which give a data compression of eight to one for the high bit rate PCMTEA output (51.2 kb/sec). Low bit rate (1.6 kb/sec) recording is also available and provides a 32 to 1 data compression for the 51.2-kb/sec dump option.

2.4 BASELINE CONFIGURATION

The baseline configuration is summarized in Table 2.3-1 as changes from the LEM configuration. The principal difference between this configuration and the recommended is in the number of additional batteries carried. Only eight batteries were added to the baseline since, earlier in the study, it was assumed that 100 kw-hr of energy would be made available from the CSM.

A change was also made in the Communications Subsystem wherein the experiment data channel was interfaced directly to the FM modulator rather than through the signal processor assembly. This variation takes advantage of a recent change on the LEM and reduces the amount of modification necessary on the Phase I Lab.

2.5 ALTERNATE CONFIGURATIONS

In arriving at the recommended Phase I Lab configuration, alternate methods of achieving the mission requirements were studied. The candidates studied are summarized by subsystem in Table 2.5-1.

2.5.1 Stabilization and Control

The most significant alternates considered to provide the attitude hold requirement are the PGNCS and the present LEM AGS - unmodified.

The PGNCS can provide the attitude hold capability while consuming a minimum of reaction propellant. It also possesses a capability for attitude reference updating and could provide local vertical hold if required. The disadvantages of this system are that it requires 240 watts more power, has a lower operating lifetime, and prevents the installation of experiment cooling loads on the back cabin bulkhead.

The LEM AGS may be used unmodified if its inability to sense reduced vehicle rates can be tolerated. This inability might be allowed if the duration required for fine attitude control is less than 2 days, or if the vehicle disturbance torques are quite large. Since many of the missions, as presently understood, do not satisfy either of these conditions, a modified AGS has been recommended.

2.5.2 Environmental Control

The alternates studied include passive cooling of the aft equipment bay, passive cooling of the additional battery packs, and incorporation of a radiator into the heat transport section.

Passive cooling of the aft equipment bay involves incorporating a mechanical shutter between the equipment and the outer skin and also replacing the outer skin with alzak. This modification produces a water savings of 212 lb. If additional experiment energy is introduced into the Lab, it may be desirable to passively cool the aft equipment bay in lieu of adding additional cooling water tankage.

Passive cooling of the additional battery packs produces a water saving of 85 lb and also eliminates the necessity of interfacing into the coolant loop. Two approaches have been surveyed, one involving the use of battery heaters when required by vehicle orientation, and the other using a mechanical shutter system. Since the heaters impose an energy penalty on the vehicle, the shutters are preferred. However, this approach produces a fixed operating range for the batteries and also creates a requirement for additional testing. Incorporation of a radiator into the heat transport section may be an attractive alternate if weight becomes an important criteria for the Phase I Lab. Two identical panels (15 ft² each) would be incorporated into diametrically opposed positions on the descent stage. This alternate produces a weight saving of 680 lb but requires subsystem modification, development, and testing. Similar radiator panels are carried as part of the recommended configuration on the Phase II Lab and Shelter.

2.5.3 Electrical Power

If additional experiment energy is required, either the Modified Battery Installation or the GE Fuel Cell Power Pack could be provided in lieu of the recommended configuration.

The Modified Battery Installation uses low drain rate 15 kw-hr silver zinc batteries based on Agena type cell design. These cells are packaged in LEM ascent battery containers and are configured in "packs" of five batteries each on the four end panels of the descent stage. The present LEM descent stage installation is deleted. The present two ascent batteries are replaced by the 15 kw-hr batteries. This configuration offers a substantial increase (56 kw-hr) in the experiment energy at approximately the same weight as the recommended configuration.

The GE Fuel Cell Power Pack, used in conjunction with the existing LEM ascent and descent batteries, provides additional experiment energy and a substantial weight reduction (1400 lbs). The power pack is a self-contained module which uses two Gemini type fuel cells and one each Block II CSM hydrogen and oxygen tanks. A water boiler is used in conjunction with a 30-ft² radiator to reject peak heating loads. Although this alternate offers an energy increase of 47 kw-hr, it requires a significant development program.

2.6 POTENTIAL MODIFICATIONS PER FLIGHT

Per flight modifications include the use of a separate cooling loop for experiments, the incorporation of additional storage volume within the vehicle, creation of a narrower deadband for fine attitude control, and the use of descent propulsion.

The recommended configuration of the Phase I Lab is compatible with each of these choices except that the feasibility of controlling the combined LEM-CSM during descent engine firing has not been established. The per flight changes are not included in the vehicle design since their incorporation is strongly mission dependent. These modifications, as listed in Table 2.5-1, are discussed in the appropriate subsystem sections.

Table 2.2-1

GROUND RULES AND ASSUMPTIONS

STRUCTURES

- No holes in the pressure shell.
- No modification to ascent and descent primary structure.
- The retention of existing piping and wiring.
- Maintain commonality of subsystems between all basic vehicles.
- No change to the Spacecraft LEM Adapter (SLA).
- Location of subsystem additions to retain many of the GSE Servicing Requirements in the SLA.
- Experiments will be mounted to the vehicle at existing hardpoints.

STABILIZATION & CONTROL

- All translation and orbital maneuvering capability will be supplied by CSM.
- The LAB will provide the orbital attitude hold capability within the limits of the recommended configuration. Capability beyond these limits will be supplied by the Experiment package.
- There is no electrical interface for control between the Lab and the CSM.
- All missions have RCS in the Lab.
- There is no main propulsion system in the Lab.
- The Lab must include a capability to provide an inertial reference.
- The addition of external sensors such as horizon scanners are experiment dependent and, as such, are not included in the vehicle design.

CREW PROVISIONS

- CM will be the crew living quarters.
- In the event of extremely high radiation or meteoroid activity the CM will be used as a crew shelter.
- The CM is required to provide all potable water for crew use.
- The spacecraft will normally carry a three man crew, with no more than two men in the Lab at one time.
- Untreated biological waste shall not be allowed to become a free residue in space.
- All Phase I Lab missions are to be 14 days long, with crew members in a shirt-sleeve environment.
- The CM environmental control system will supply both the CM and Lab module.
- The waste management/waste disposal systems, personal hygiene, exercise, medical and recreation equipment is assumed to be located in the CM.
- Crew members will sleep in a soft suit on the CM couches. The space suits will normally be dried, serviced and stowed on the couches.
- Food and LiOH for the mission in excess of three man-days will be stored in the Lab.
- Food will be prepared and consumed in the CM.
- Throwaway batteries will be used for the PLSS.
- Each crew member requires a new constant wear garment every two days.
- One pressure garment, one liquid cooled garment and one thermo-meteoroid garment are located in the CM storage containers.

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Table 2.2-1 (cont)

ELECTRICAL POWER SUPPLY

- No interchange of Electrical Power between CSM and Lab.

PROPULSION

- Only hardware which is reasonably accessible will be removed.
- Hardware will be removed during modification operations at KSC.
- Ascent and descent propulsion subsystems will be deleted.

REACTION CONTROL

- The Phase I Lab shall provide attitude hold for all mission experiment phases.
- The CSM RCS shall be used for all transit and orbital slewing functions including rolling operations.
- The Lab Shall be Used Exclusively For Attitude Hold
- Two Deadzone Settings Are Available: ± 3 deg and ± 5 deg
- Gyro Rate Threshold Sensitivity Is Compatible With the Vehicle Mass Properties Unless Otherwise Specified
- CSM RCS Shall Be Used For Transit And Orbital Slewing Functions Including
 - Minimum Impulse (Standard Condition) = $175 \pm .15$ lb sec
 - Specific Impulse (At Minimum Impulse) = 130 sec
 - O/F Ration (At Minimum Impulse) = 1.3
- Engine Life Time Specifications:
 - Burning Time = 1000 sec Total; 500 sec, Steady State; 500 sec Min Impulse Cycling
 - Maximum Number Of Cycles - 10,000
- Modified (Interchanged Propellant Tanks) Tank Capacity Is 1048 lb of Usable Propellant for the Phase II Configuration.

COMMUNICATIONS

- There is no data interface between the CSM and LEM.
- LEM Lab communications and telemetry subsystems are self-sufficient not dependent on CSM.
- TV transmission will be via the CSM S-Band link to Earth (real time only).
- TV requirements will be satisfied by the present Apollo GFE TV Camera. This camera will be deployed from the CSM through the hatches to the Lab, with the power cable extending from the camera to the CSM S-Band subsystem.
- There will be a hardline intercommunications system between the CSM and Lab. The hardline is available when the Lab is depressurized.
- There are no television or data uplink requirements.
- All three astronauts will have continuous audio capabilities.
- EVA communication to the CSM or Lab will be via the VHF link.
- The earth S-band communication link is always available regardless of the intercommunications mode.
- Lab status data will be transmitted to the ground during line-of-sight mission phases.

DISPLAYS & CONTROLS

- The required Lab displays should be incorporated with a minimum modification to the existing console layout.
- Maximum use should be made of LEM type controls and displays for modifications.

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Table 2.2-1 (cont)

MASS PROPERTIES

- Experiment weight is not included in the baseline or recommended laboratory weights.
- 91.1 kw hr of experiment energy is supplied by 20 LEM descent and 2 LEM ascent batteries.
- Water, oxygen, LiOH and PLSS batteries for 21 and 18 EVAs are provided in the baseline and recommended labs respectively.
- The water tanks are assumed to be filled to capacity (1046 lb).
- Food and CSM LiOH for 13 days are carried in the Lab.

ENVIRONMENTAL CONTROL

- The CSM ECS shall provide for the removal of carbon dioxide, excess water vapor, odors, trace contaminants and particulate matter from the combined CM/Lab atmosphere during routine flight.
- The Lab shall be capable of providing oxygen as required to makeup Lab and interface leakage.
- The Lab shall provide for recharging the PLSS.
- The Lab shall provide for the exchange of cabin atmosphere between the Lab and CM as required to maintain the former at acceptable humidity, temperature and carbon dioxide concentration levels.
- Extravehicular activities shall be accomplished using the Lab as an airlock. The Lab shall provide oxygen as required for associated repressurizations.
- The CSM shall provide all water required by the crew for drinking, food preparation and personal hygiene.
- Crew metabolic heat loads are apportioned as follows:
 - CSM ECS: All latent metabolic + sensible metabolic produced by CM occupants
 - Lab ECS: Sensible metabolic produced by Lab occupants
- The Lab is decompressed to effect egress and remains unpressurized during EVA experiments.
- There are no fluid hardware interfaces between the Lab and CSM.
- The Lab ECS returns cabin gas to the CSM at the same temperature at which it is supplied (nominally $75 \pm 5^\circ\text{F}$).
- The Lab suit circuit performs carbon dioxide, excess moisture, odor and particulate matter removal functions in support of EVA experiments only (i.e., PLSS transition and observer support).
- A maximum of 150 watts of experiment power will be dissipated in the low temperature electronic area.
- The housekeeping load is as shown in Section 4.13.
- The most extreme thermal environments were assumed in evaluating the system performance (i.e. min. external heat flux for cold case calculations and max. extreme heat flux, for hot case calculations).
- No restrictions on vehicle orientation have been imposed.

INSTRUMENTATION

- The Lab Module carries its own Communications and Data Handling System.
- There will be no data interface between the Lab and the CSM.
- Video Transmission will be through the CM S-Band Link (real time only).
- Any changes in the operational measurements shall not exceed the present lunar LEM measurements.
- Maximum utilization of the crew for redundancy monitoring and failure mode corrections/operations will be used.

Table 2.2-1

- All Operational data will be presented to the ground during line-of-sight mission phases only. (Real time)
- There will not be any on-board recording capability for operational data.
- All vendor supplied experiments will provide their own signal conditioning compatible with the AES experiment acquisition system.
- All experiment data will be considered "passive" for ground reduction (not requiring real time display). On-board display of selected experiment parameters will be available to the astronauts.
- The data record, dump or redump requirements will be the responsibility of the astronauts and will not require any ground uplink control.
- Existing LEM equipment will not require requalification for "Phase I".
- Experiment data will be on-board recorded during periods of flight not covered by line-of-sight.
- Experiment data set-up, pre or post calibration and operation will be on-board controlled and will not require any ground uplink support capabilities.
- Experiments requiring analog data recovery will utilize the analog portion of the experiment tape system

Vehicle		Recommended Configuration		
Item	Change	Removed	Modified	Added
1.0	Structure (Ascent) (Descent)	<ul style="list-style-type: none"> ● Ascent Engine Cover ● Propellant Tank Supts. ● Water Tank Supports ● Ascent GOX Tank Supts. ● Prop. Tank Shielding ● Base Heat Shield 		<ul style="list-style-type: none"> ● Mid-S ● GOX T ● Lower ● Water ● Batterie 16 Ba
2.0	Stabilization and Controls	<ul style="list-style-type: none"> ● DECA ● GDA 	<ul style="list-style-type: none"> ● AEA (Software change to accommodate star catalog) ● Modify RGA to provide lower rate threshold ● Change Rate gain in ATCA to insure one Pulse limit cycle 	
3.0	Navigation and Guidance	<ul style="list-style-type: none"> ● Landing Radar ● Rendezvous Radar ● IMU ● LGC ● PTA ● PSA ● CDU 		
4.0	Crew Provisions	<ul style="list-style-type: none"> ● Remove lunar specimen return containers ● Remove EVA life line ● Remove water probe and holster ● Remove 1 LiOH (LEM/ARS) canister 	<ul style="list-style-type: none"> ● Revise External Lighting 	<ul style="list-style-type: none"> ● 18 Li Back ● Batterie pack ● Food ● 26 CS ● Add e ● Provi ments ● Add 2 light ● Add 1 ● Add 1 2)

Table 2.3-1

RECOMMENDED VS PDP BASELINE CONFIGURATIONS

	PDP Baseline Configuration		
	Removed	Modified	Added
Section Canister Tank Supports Deck Insulation Tank Supts. Battery Supports (For Batteries)	<ul style="list-style-type: none"> ● Ascent Engine Cover ● Propellant Tank Supts. ● Water Tank Supports ● Ascent GOX Tank Supts. ● Prop. Tank Shielding ● Base Heat Shield* 		<ul style="list-style-type: none"> ● Mid-Section Canister ● GOX Tank Supports ● Lower Deck* Insulation ● Water Tank Supts. ● Battery Supports (For eight Batteries)
	<ul style="list-style-type: none"> ● DECA* 		
	<ul style="list-style-type: none"> ● Landing Radar ● Rendezvous Radar* ● IMU* ● LGC* ● PTA* ● PSA* ● CDU* ● DSKY* 	<ul style="list-style-type: none"> ● AEA 	
LiOH Cartridges for Pack recharge Batteries for 18 back recharges for 13 days 4 LiOH cartridges extra flood lights 21 const. wear gar- work tops & work top seat LEM voice recorder (total	<ul style="list-style-type: none"> * Vehicle must be ca- pable of retaining all items marked with asterisk 	<ul style="list-style-type: none"> ● Revise External Lighting 	

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Vehicle		Recommended Configuration		
Item	Change	Removed	Modified	Added
5.0	Environmental Control	<ul style="list-style-type: none"> o STD LEM Ascent GOX Tanks o Secondary coolant loop Water evaporator o Accessible secondary coolant loop plumbing and valves 	<ul style="list-style-type: none"> o Drain & Cap off secondary coolant loop o Cabin fans (to provide for duct losses) 	<ul style="list-style-type: none"> o ASA Bypass o CSM/Lab o 2 Descent o 5 Descent o Cold Plate 16 Descent 4 Descent
6.0	Landing Gear		<ul style="list-style-type: none"> o Remove Completely 	
7.0	Instrumentation			<ul style="list-style-type: none"> o One PCM o Two mod recorders 409 KB single tion
8.0	Electrical Power	<ul style="list-style-type: none"> o 2 Descent ECA's 		<ul style="list-style-type: none"> o 16 Descent o 5 Modified o 1 Circuit o 1 Bus
9.0	Propulsion	<ul style="list-style-type: none"> o Ascent Engine o Ascent Prop Tank o Ascent He System o Descent Engine o Descent He Tank 		

Table 2.3-1 (Cont'd)

PDP Baseline Configuration			
	Removed	Modified	Added
ss Ricirc Duct t Water Tanks t GOX Tanks tes for cent Batteries cent ECA's			<ul style="list-style-type: none"> o 21 PLSS LiOH Cartridges o CSM/Lab Recirc Fan Assy o 2 Descent Water Tanks o 5 Descent GOX Tanks o Cold Plates for <ul style="list-style-type: none"> 1 PCM 2 Recorders 8 Descent Batteries (1) 4 Descent ECA's
		o Remove Completely	
fied CSM s providing dump rate and phase AC opera-			<ul style="list-style-type: none"> o One PCM (2) o Two CSM Type Recorder o One Selector Switch
nt Batteries ed Descent ECA's t BR Panel Wiring			<ul style="list-style-type: none"> o 8 Descent Batteries o 4 Descent ECA's o 1 Circuit BR Panel o 1 Buss Wiring
	<ul style="list-style-type: none"> o Ascent Engine o Ascent Prop Tank o Ascent He System o Ascent Controls & Control Electronics o Descent Engine* o Descent He Tanks* 		
	* Vehicle must be capable of retaining all items marked with asterisk		(1) Batteries assume active cooling (2) Experiment data sensors, experiment signal conditioning and power to operate same are considered to be an experiment responsibility

13

Vehicle		Recommended Configuration		
Item	Change	Removed	Modified	Added
10.0	RCS	No Change From LEM		No Change
11.0	Communications	<ul style="list-style-type: none">o S-Band Erect Antennao VHF Erect Antenna	<ul style="list-style-type: none">o SPA Mod - Provide for hardline intercom	<ul style="list-style-type: none">o Hardlineo Provide to FM M (409 KE)
12.0	Displays & Controls	<ul style="list-style-type: none">o ACA (1)o TCA (1)o FDAI (1)o DSKYo ASC Eng. controlso Desc. eng. controlso Radar displays	<ul style="list-style-type: none">o DEDAo S & C Panelo Audio Controlo Explosive Devices	<ul style="list-style-type: none">o Control battery and hardwareo Crew Seatso Data hardware and displays

Table 2.3-1 (cont)

	PDP Baseline Configuration		
	Removed	Modified	Added
From LEM	No Change From LEM		No Change From LEM
Intercom Data Channel Modulator (s - Bypass SPA)	<ul style="list-style-type: none"> o S-Band Erect Antenna o VHF Erect Antenna 	<ul style="list-style-type: none"> o SPA 	<ul style="list-style-type: none"> o Hardline Intercom
Controls for additional batteries, water tanks Hardline intercom Safety displays Handling controls Displays	<ul style="list-style-type: none"> o ACA (1) o TCA (1) o FDA 1 (1) 	<ul style="list-style-type: none"> o Revise EPS, COMM o Controls 	<ul style="list-style-type: none"> o Controls for additional batteries, water tanks and hardline intercom.

Table 2.5-1
Phase I Lab
CANDIDATE CONFIGURATIONS

Item	Candidate Configurations	Per Flight Modifications
Structure	<ul style="list-style-type: none"> ● LEM Structure 	<ul style="list-style-type: none"> ● Descent State Compartment
Stabilization & Controls	<ul style="list-style-type: none"> ● Modified Abort Guidance System With Change To RGA And ATCA ● Unmodified Abort Guidance System ● Modified Abort Guidance System Deriving Rate Information From ASA ● Modified Abort Guidance System with New RGA Assembly ● Use Of Primary NAV Guidance System ● Modify Jet Logic To Use All Thrusters 	<ul style="list-style-type: none"> ● Reduce Narrow Deadband to 0.1 deg
Crew Provisions	<ul style="list-style-type: none"> ● Basic LEM With Changes Consistent With Other Subsystems And Additional Storage Of Expendables External To The Vehicle 	<ul style="list-style-type: none"> ● Additional Storage Boxes ● Descent Stage Compartment
Environmental Control	<ul style="list-style-type: none"> ● Basic LEM With Active Battery Cooling For 16 Additional Batteries Replumbing Of Redundant Coolant Pump ASA Bypass ● Basic LEM With Battery Cooling For 8 Additional Batteries (Baseline) ● Passive Cooling Of Aft Equipment Bay ● Battery Package Passive Thermal Control ● Incorporation Of Radiator Into Heat Transport Section ● Utilization Of Propellant Tanks For ECS Oxygen Storage 	<ul style="list-style-type: none"> ● Separate Heat Transport Loops For Experiment Cold Plates
Electrical Power Supply	<ul style="list-style-type: none"> ● 22 Battery Configuration - LEM Batteries ● 14 Battery Configuration - LEM Batteries ● 22 Battery Configuration - Modified Batteries ● GE Fuel Cell Power Pack 	

Table 2.5-1 (Cont.)

Instrumentation	<ul style="list-style-type: none"> ● LEM Operational System With Data Handling System Using CSM Recorders Modified For Single Phase Operation And Output Of 409.6 kbps ● LEM Operational System With Data Handling System Using Unmodified CSM Recorders 	
Propulsion	<ul style="list-style-type: none"> ● Not Applicable (No Main Propulsion In Labs) 	<ul style="list-style-type: none"> ○ Use of Descent Propulsion
RCS	<ul style="list-style-type: none"> ● Basic LEM RCS Configuration Utilizing Sixteen Thrusters ● Basic LEM RCS With Fuel And Ox Lines Reversed 	
Communications	<ul style="list-style-type: none"> ● Hardline Intercom And Additional FM Data Channel 409.6 kbps ● Hardline Intercom And Additional PM Data Channel (Mod Spa) ● Coupled S-Band In Flight Antennas ● Addition Of Internal TV Jack 	
Displays And Controls	<ul style="list-style-type: none"> ● Basic LEM Displays And Controls Modified As Appropriate 	

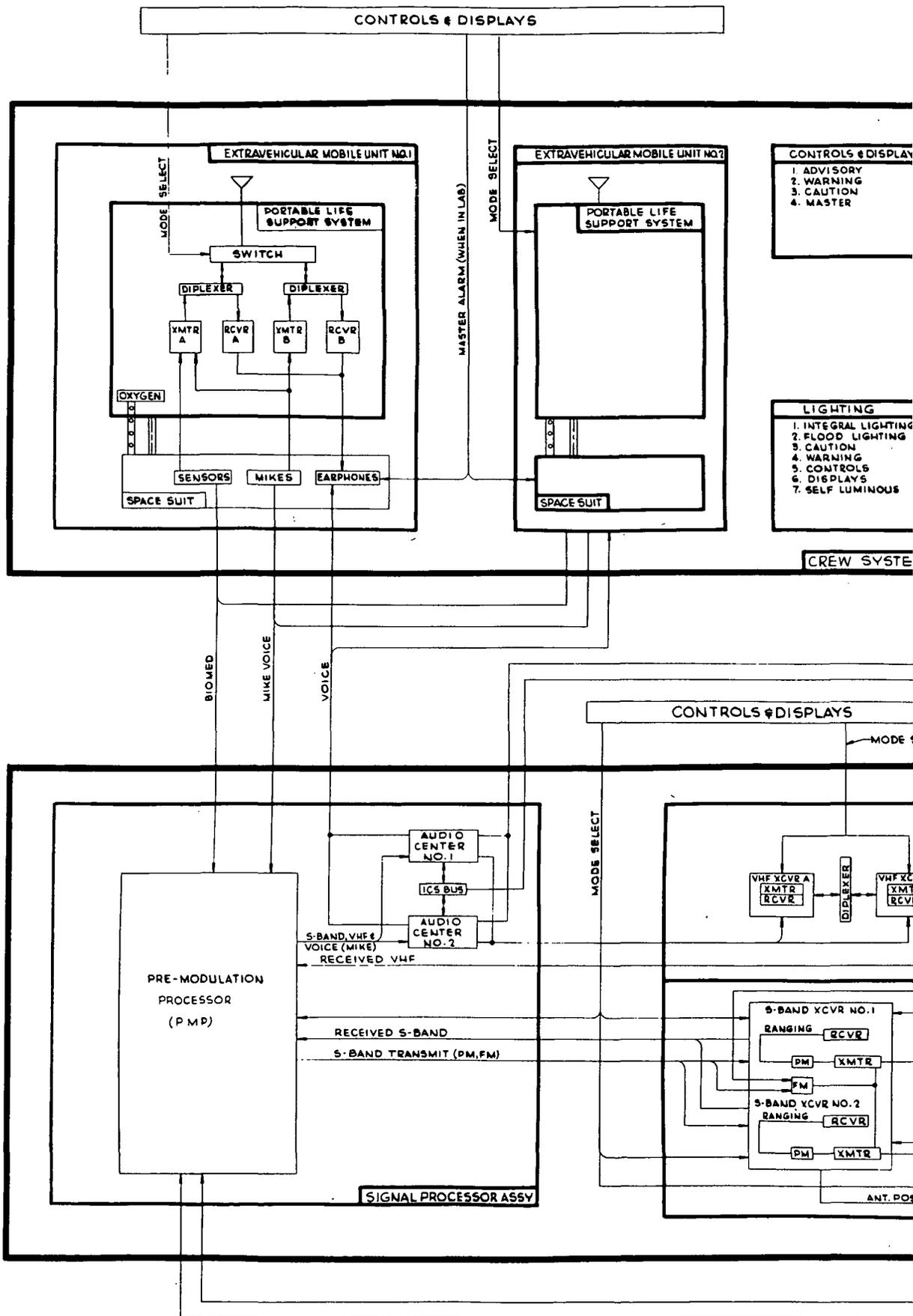
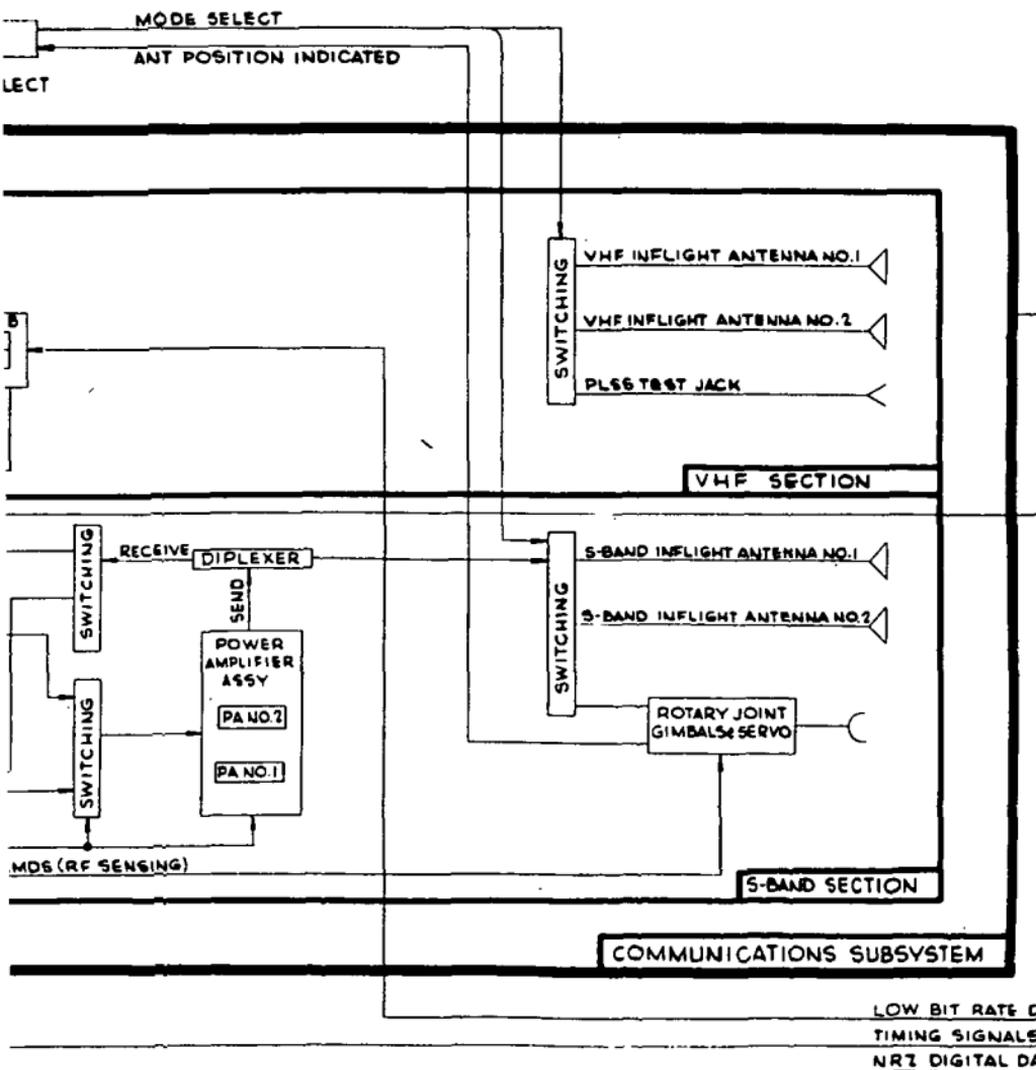
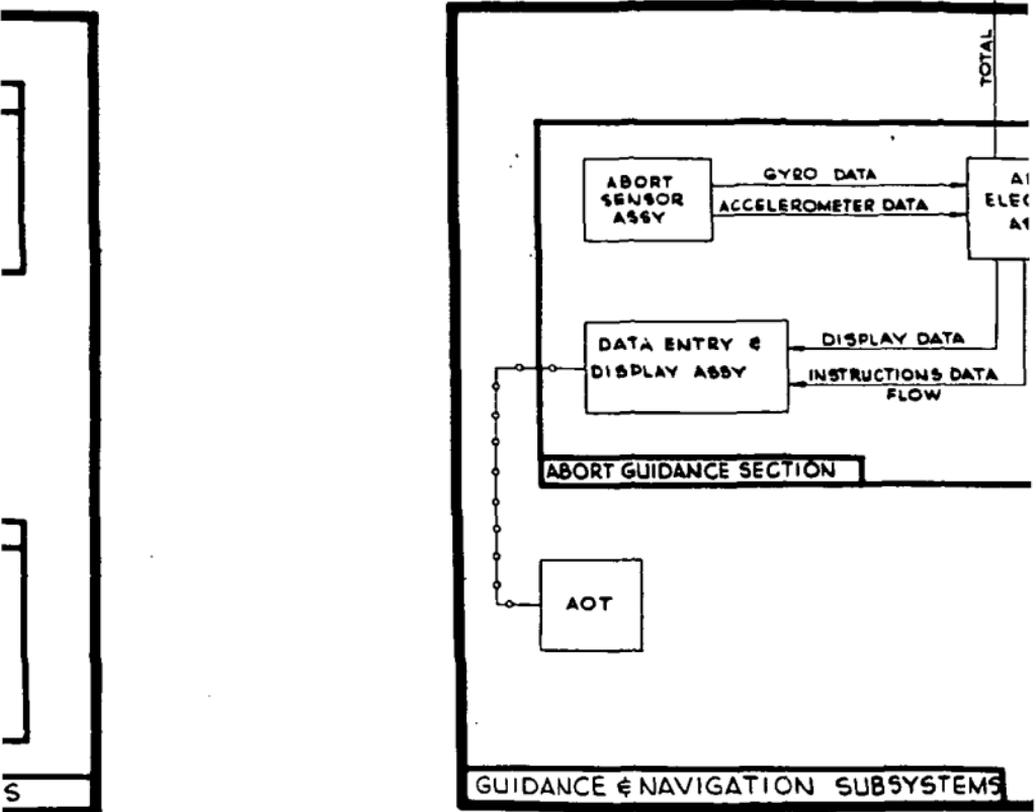
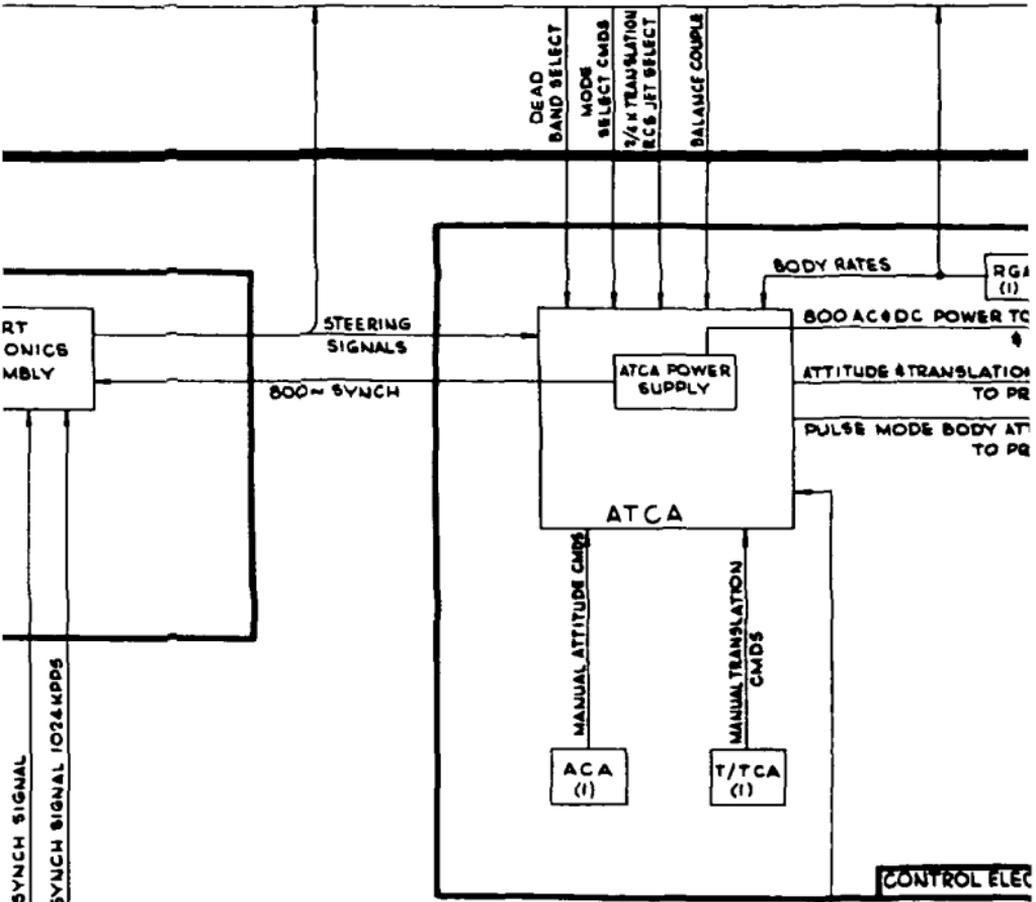


Fig 2.3-1A



213-1A
 (2)

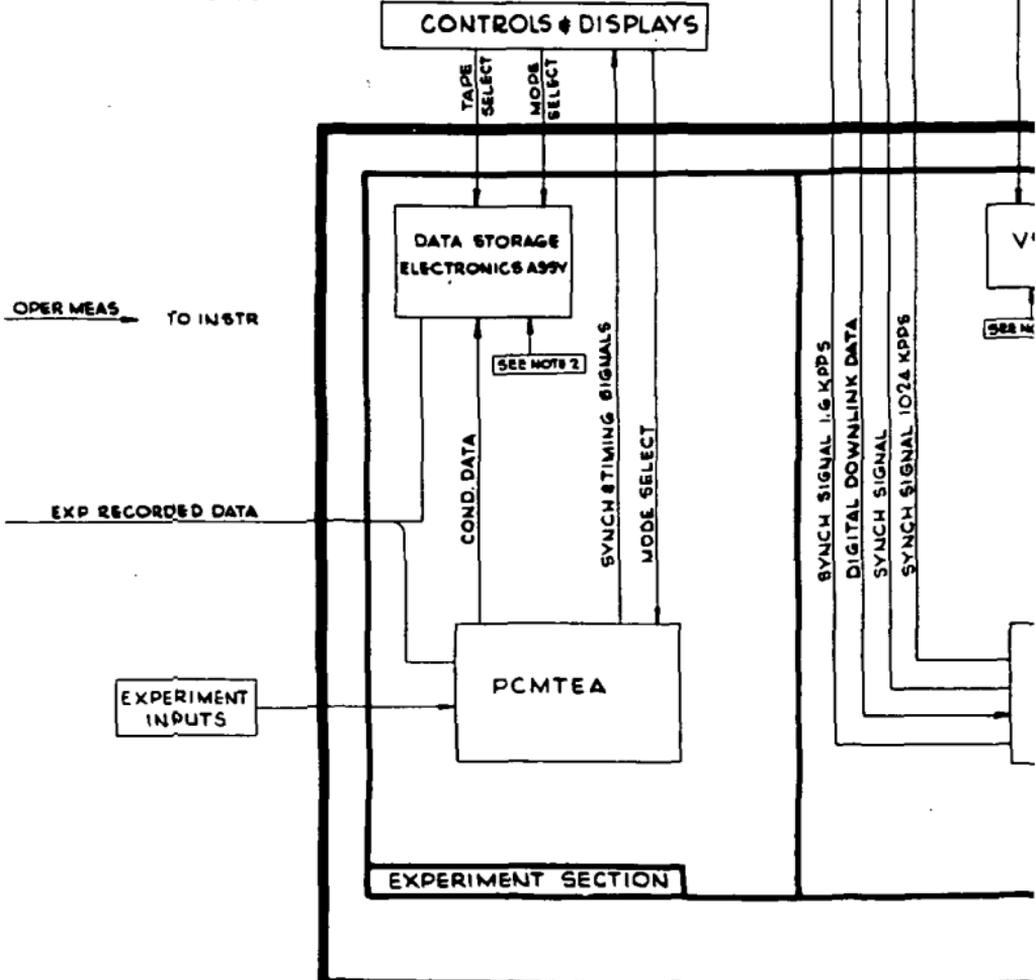
CONTROLS & DISPLAYS



VOICE KEYING

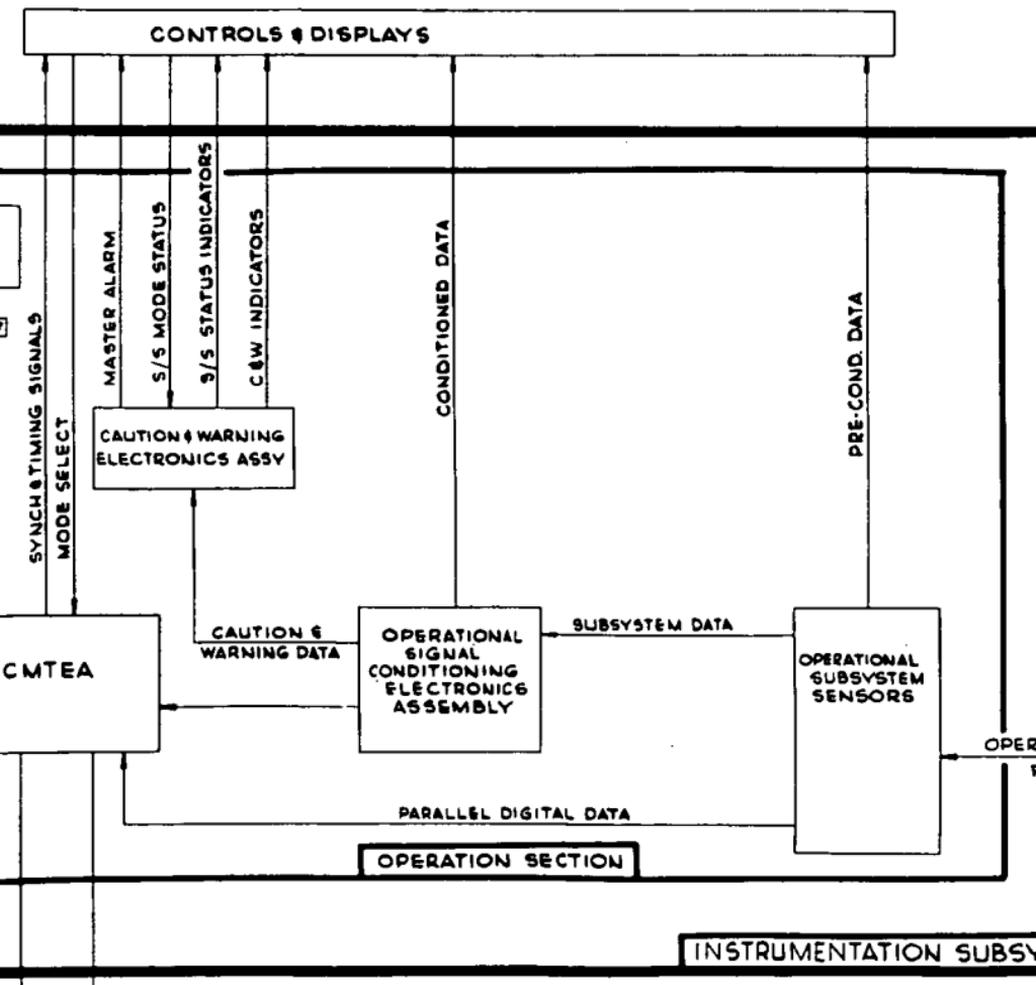
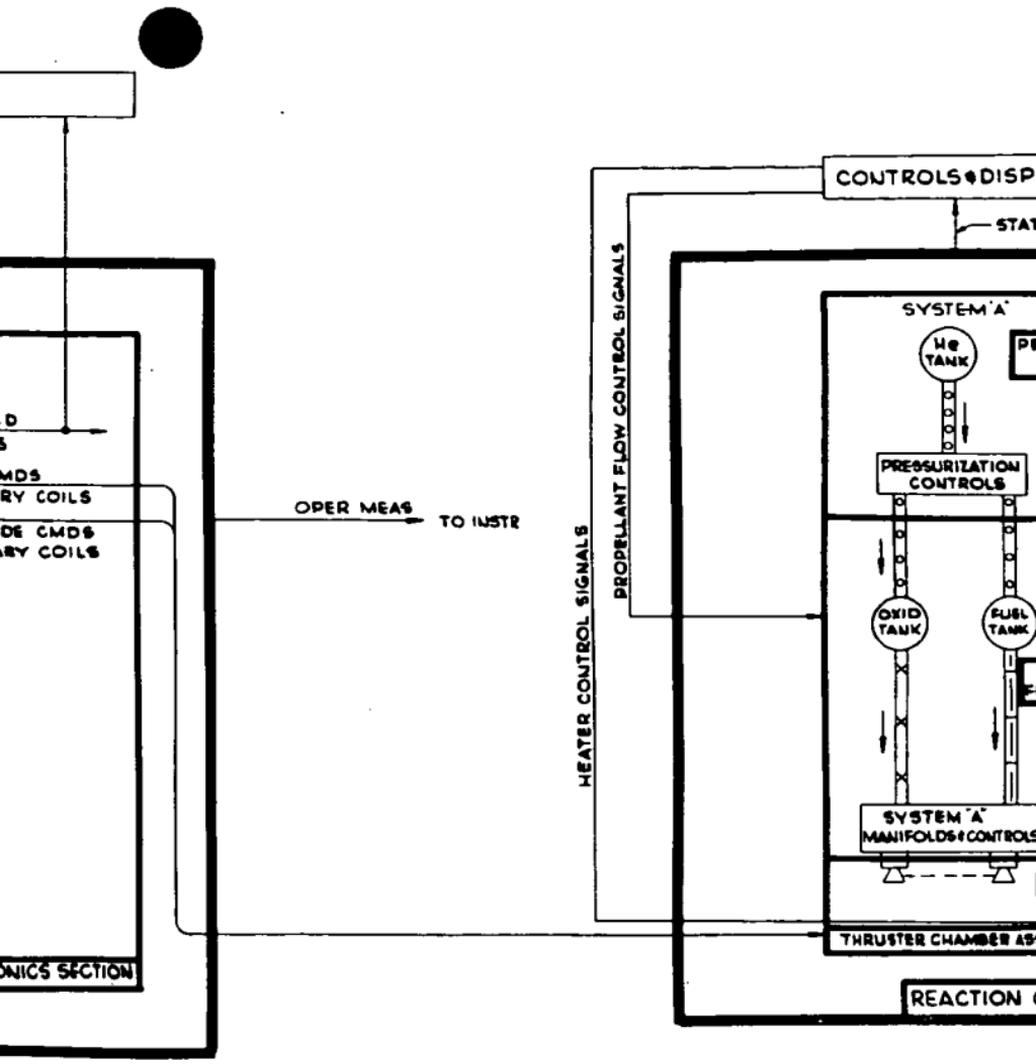
VOICE

CONTROLS & DISPLAYS



2.3-1 A

3



INSTRUMENTATION SUBSYS

2.3-1A

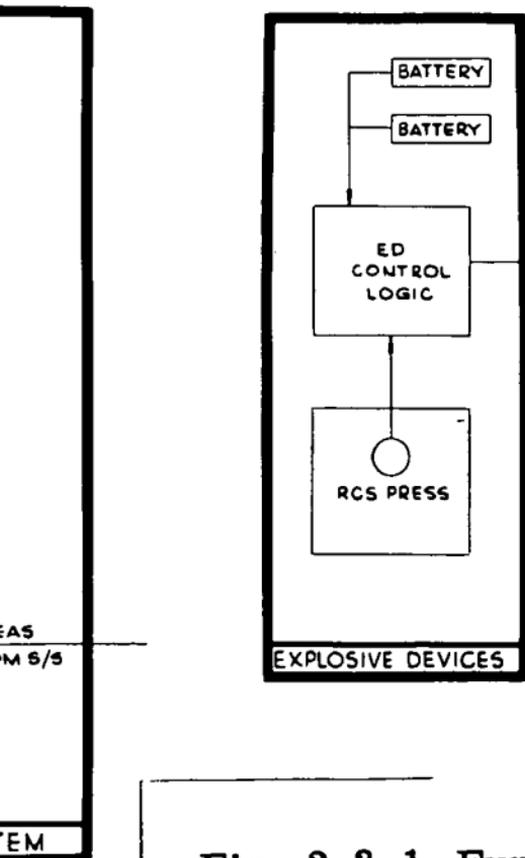
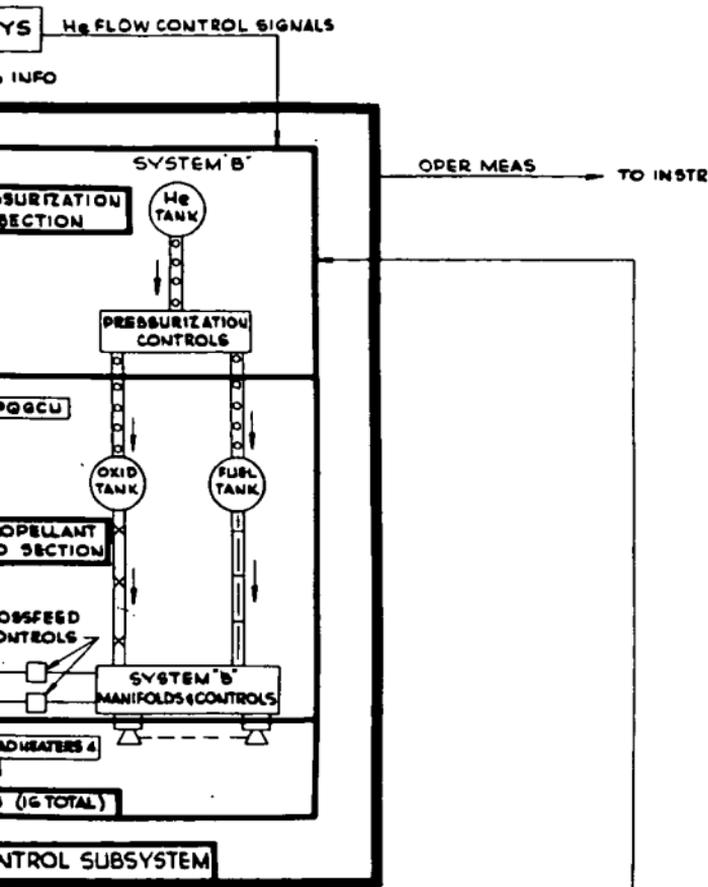
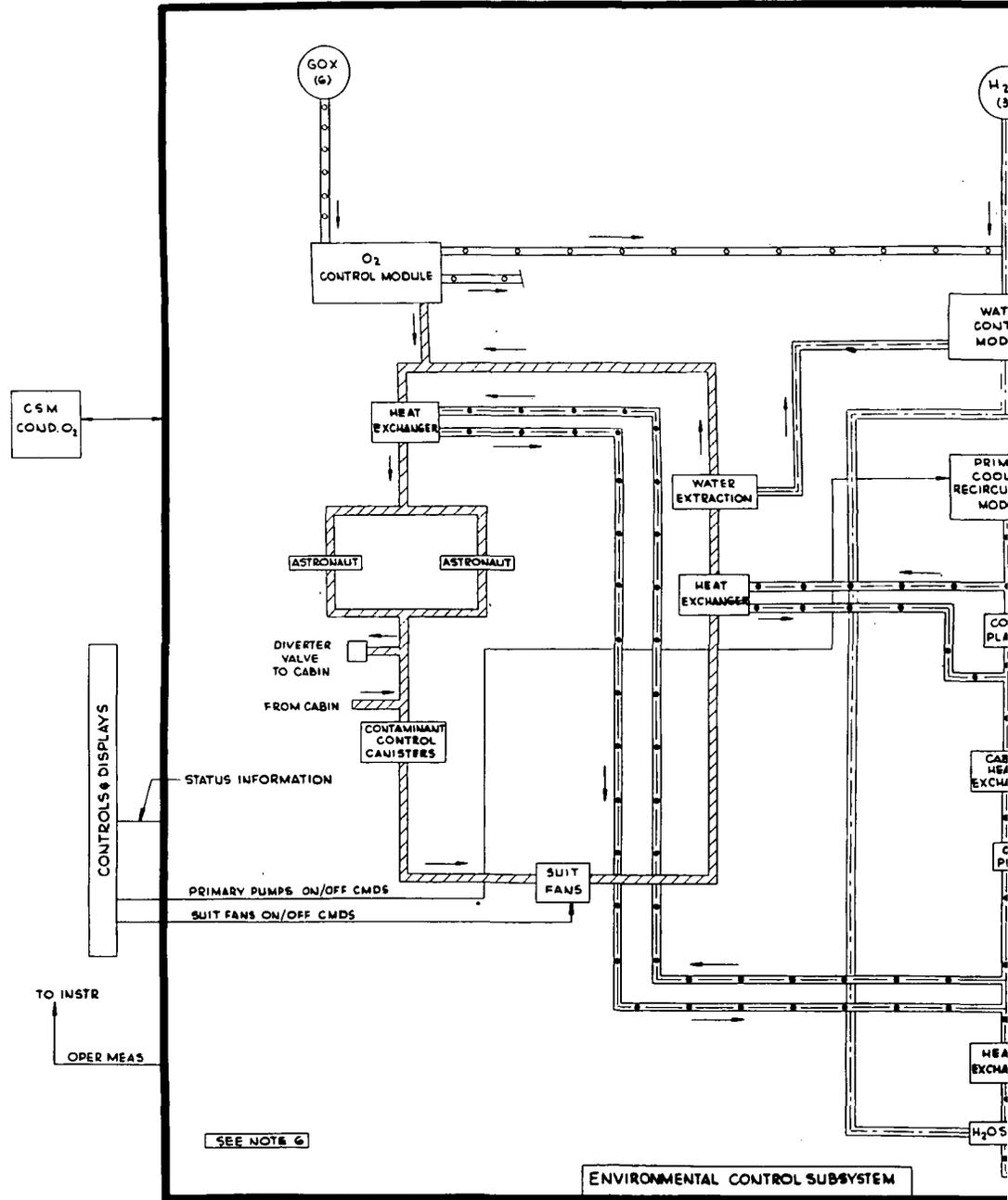


Fig. 2.3-1 Functional Interface
A Diagram (Sheet 1 of 2)

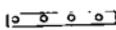
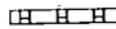
5

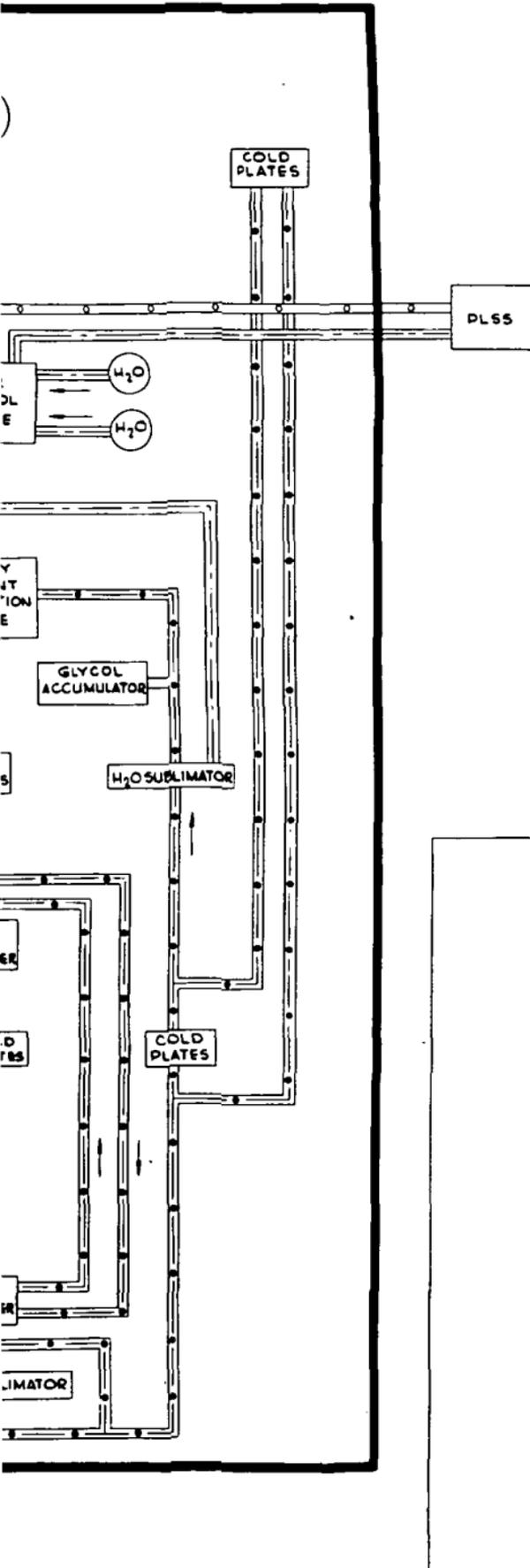


2.3-1B

①

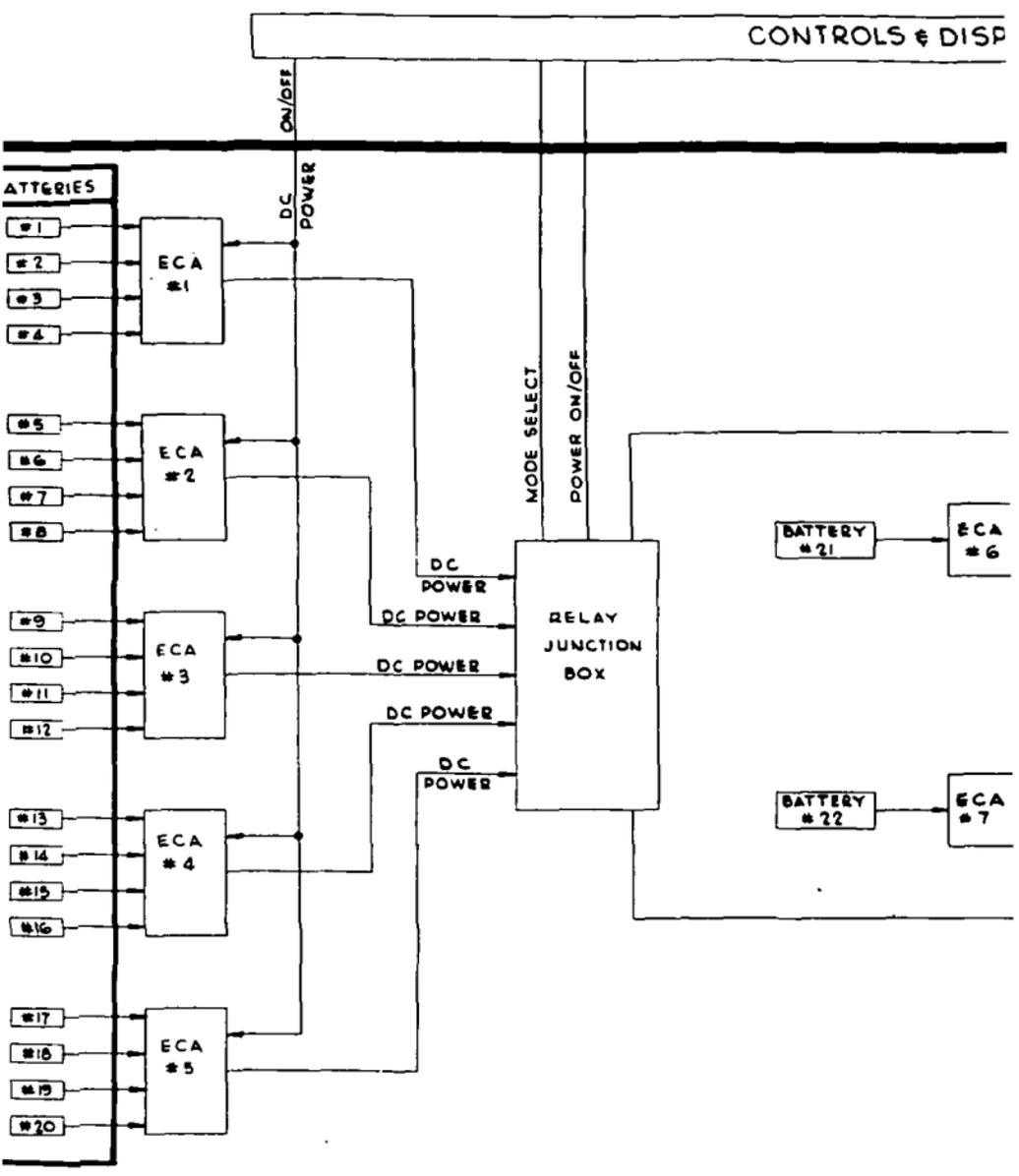
SYMBOLS

-  — OXYGEN
-  — WATER
-  — COOLANT
-  — CONDITIONED OXYGEN
-  — HELIUM
-  — HYDROGEN
-  — OXIDIZER
-  — MECHANICAL LINKAGE



2.3-1B

(2)



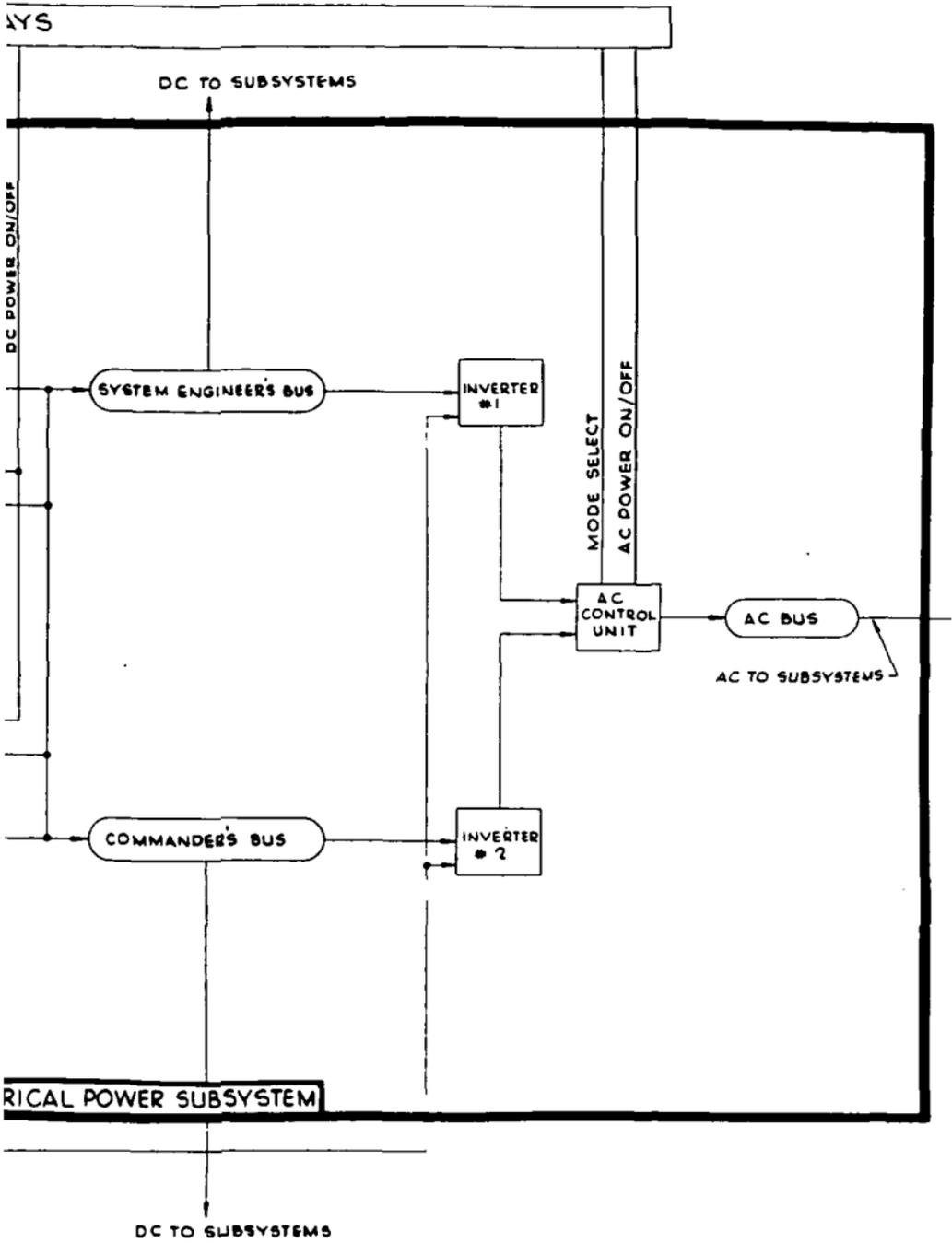
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 (3)



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URES

2-3-10
 (4)

NOTES

1. THIS IS A TENTATIVE FUNCTIONAL DIAGRAM OF THE AES PHASE I LAB.
2. THERE ARE (2) DATA STORAGE UNITS IN THE DSEA
3. THE AES PHASE I LAB MUST BE CAPABLE OF RETAINING THE FOLLOWING :
STRUCTURES - BASE HEAT SHIELD,
LOWER DECK INSULATION
NAVIGATION & GUIDANCE - GDA, DECA, RENDEZVOUS RADAR,
IMU, LGC, PTA, PSA, & CDU.
DISPLAYS & CONTROLS - DSKY
4. LANDING GEAR IS COMPLETELY REMOVED.
5. ADDITIONS TO THE BASIC LEM CONFIGURATION FOR CREW PROVISIONS:
(18) LIOH CARTRIDGES FOR BACKPACK, BATTERIES FOR
(18) BACKPACK RECHARGES, FOOD FOR 13 DAYS,
(26) CSM LIOH CARTRIDGES, EXTRA FLOOD LIGHTS,
(21) CONSTANT WEAR GARMENTS, (2) WORK TOPS & WORK
TOP LIGHTS, & (1) SEAT.
6. DELETIONS FROM THE BASIC LEM CONFIGURATION FOR CREW PROVISIONS:
LUNAR SPECIMEN CONTAINERS, EVA LIFELINE,
WATER PROBE & HOLSTER & (1) LIOH CANISTER.
7. CONTAINS (2) VSR'S (ONE SPARE).

ABBREVIATIONS

OPER - OPERATIONAL
 MEAS - MEASUREMENTS
 GOX - GASEOUS OXYGEN
 SIMP - SIMPLEX
 AOT - ALIGNMENT OPTICAL TELESCOPE
 CMD(S) - COMMAND(S)
 H₂O - WATER
 O₂ - OXYGEN
 C & D - CONTROLS & DISPLAYS
 ATCA - ATTITUDE & TRANSLATION CONTROL ASSEMBLY
 DECA - DESCENT ENGINE CONTROL ASSEMBLY
 SYNCH - SYNCHRONIZATION
 SIG - SIGNAL
 VHF - VERY HIGH FREQUENCY
 EXP - EXPERIMENT
 ECA - ELECTRICAL CONTROL ASSEMBLY
 DC - DIRECT CURRENT
 AC - ALTERNATING CURRENT
 CSM - COMMAND SERVICE MODULE
 ANUN - ANNUNCIATOR
 INFO - INFORMATION
 VSR - VOICE STORAGE RECORDER
 PLSS - PORTABLE LIFE SUPPORT SYSTEM
 S/S - SUB-SYSTEM
 He - HELIUM
 IND - INDICATOR
 C & W - CAUTION & WARNING
 TCA - TRANSLATION CONTROL ASSEMBLY
 ACA - ATTITUDE CONTROL ASSEMBLY
 RGA - RATE GYRO ASSEMBLY
 ASSY - ASSEMBLY
 XMTR - TRANSMITTER
 RCVR - RECEIVER
 XCVR - TRANSCEIVER
 PA - POWER AMPLIFIER
 PM - PHASE MODULATION
 FM - FREQUENCY MODULATION
 ICS - INTERNAL COMMUNICATIONS SYSTEM
 DSKY - DISPLAY KEYBOARD
 INSTR - INSTRUMENTATION
 CONT'S - CONTROLS
 NRZ - NON RETURN TO ZERO
 VOX - VOICE OPERATED SWITCH
 CDU - COUPLING DATA UNIT
 DUP - DUPLEX
 EMU - EXTRA VEHICULAR MOBILE UNIT
 PCM - PULSE CODE MODULATION
 PSA - POWER SERVO ASSEMBLY

Fig. 2.3-1 Functional Interface
 Diagram (Sheet 2 of 2)

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3. MISSION ANALYSIS - PHASE I LAB

3.1 MISSION OBJECTIVES

The Phase I Lab will be utilized in conjunction with an Apollo Block II CSM to perform manned Earth and lunar orbital experimentation missions. The Lab will be required to operate at its nominal design performance level for durations up to 14 days.

The Phase I Lab flights, each one at a specific orbital altitude and inclination, will be required to actively support extensive orbital experiments and observations conducted in the Lab in the areas of:

- Basic scientific research
- Applied science and technology
- Mapping and survey
- Engineering validation of design configurations
- Testing and qualification of crews, systems, subsystems, and components for space missions.

In supporting this activity, the Lab is required to provide electrical power, attitude hold and pointing capability, life support, data handling, telemetry and other support functions to enable crewmen to perform the in-orbit experiments.

3.2 GROUND RULES AND ASSUMPTIONS

The following ground rules and assumptions were utilized in the selection of the basic Phase I Lab configuration:

- Lab I shall provide attitude hold capability with no control interface with the CSM. Slewing capability will be provided by the CSM.
- Lab I will provide oxygen (GOX) for repressurization, leakage and recharging PLSS.
- No crew system water to be carried in the Lab except that required to recharge PLSS.
- Lab I will provide atmosphere circulation between modules.
- Existing CSM Block II/LEM and/or Gemini oxygen tanks to be considered for usage.
- No communications interface with CSM except for TV camera and intercom hardline.
- No power interface with CSM. Phase I Lab provides own power for house-keeping activities and experiments.
- Phase I Lab carries all LiOH and food in excess of 3 man-days.
- RCS engine spec life shall not be exceeded.
- Descent propulsion system is not required.
- No basic structural modifications may be made.
- Facilities for a crew of two men shall be provided.
- Illumination, radiation, and meteoroid environment shall not inhibit or constrain any Lab mission.

3.3 ANALYSIS

3.3.1 General

The detailed study of the Phase I Lab missions has resulted in a determination of the experiment-related average power and energy requirements. These are listed in Tables 3.3-1 through 3.3-4 for Flights 507, 509, 511, and 214. It is noted in Paragraph 5.1 that the Phase I Lab can provide 91 kw-hr for experiment support, including operation of experiment dependent subsystems. Since the maximum amount of experiment energy required for the missions shown is 67 kw-hr, it appears that sufficient energy has been provided. Additional studies are presently being performed within the Payload Integration Contract to better define the energy requirements for experiment dependent subsystem operation.

3.3.2 Subsystem Experiment Support - General

Laboratory attitude hold propellant flow rates were prepared for sizing of the S&CS and RCS (in accordance with the ground rule that the Lab provide orbital attitude hold control and pointing capability for mission experimentation). Attitude hold is provided about all three principal axes within two deadzone limits: ± 5.0 and ± 0.3 deg as discussed in Paragraphs 4.3 and 5.4. Fig. 3.3-1 shows the RCS propellant flow rates for undisturbed limit cycle operation. The existing LEM deadband limits of 5 and 0.3 deg are shown for various rate threshold limits. The present rate threshold limitation (0.01 deg/sec) is shown along with the recommended "design goal" value of 0.001 deg/sec. The minimum impulse line represents the limitation on the system caused by RCS thruster sizing. These data are derived from a more extensive analysis as given in Paragraph 4.2.

As noted in Paragraph 5.1.2.1.1, the housekeeping energy provides for vehicle rate stabilization and a 15% 200-n.mi communication duty cycle capability. Fig. 3.3-2 illustrates the depletion of available experiment energy as a function of attitude hold duration for the AGS and the PGNCS. Fig. 3.3-3 summarizes the energy required for data handling. The energy available for experiments only must, therefore, consider these aforementioned subsystem dependent requirements. In addition, the communication requirements over the housekeeping allowance must be considered. Figs. 3.3-4 and 3.3-5 summarize the communication energy requirements for the 200-n.mi and 19,350-n.mi orbits, respectively, as a function of duty cycle and mission duration.

An investigation was performed into the egress-ingress capability for the Lab, including LiOH canister replenishment, PLSS recharges, and cabin repressurization. A detailed discussion is given in Paragraph 5.2. Fig. 3.3-6 shows the capability of the Phase I Lab to support EVA through Lab repressurizations and backpack (PLSS) recharges. The "nominal design" of 18 infers that weight and volume allocations have been made for 18 backpack batteries and 18 LiOH canisters. Additional batteries may be carried at a weight penalty of 5 lb each, and additional LiOH canisters may be carried at 4.5 lb each.

Fig. 3.3-7 shows the water availability to support PLSS recharges and experiment heat loads. This data shows that, for 18 backpack recharges, the experiment load could be as high as 78 kw-hr for lunar orbital missions, and up to 93 kw-hr for Earth orbital missions.

It is normally assumed that, during EVA by one crew member, a second crew member is operating from the suit loop within the depressurized Lab cabin. This operation involves 152.2-w power expenditure to operate the suit loop fan. This penalty is also considered as experiment dependent subsystem operation.

3.3.3 Subsystem Experiment Support - Sample Calculation

The following procedure is suggested for determining the energy penalty for experiment dependent subsystem operation:

- Sample Mission - Synchronous Orbit - 14-Day Duration
 - Attitude Hold Duration: 60 hr
 - Communication Time: 25% of Mission Duration
 - EVA Time (suit loop operation): 5 hr
 - Data Transmission: 25% (same as communication time)
- Calculation
 - Kw-Hr. available (Fig. 3.3-2) = 80 kw-hr
 - Less:
 - Penalty for data handling
(Fig. 3.3-3) 200-hr record at 25% transmission = 16 kw-hr
 - Penalty for Communications (Fig. 3.3-5) = (6 kw-hr - housekeeping allow) = 3.4 kw-hr
 - Penalty for suit loop operation (152 w x 5 hr) = 0.76 kw-hr
 - Net available for experiments = 59.84 kw-hr

3.3.4 Environmental Protection Requirements

3.3.4.1 Meteoroid Hazard Evaluation

3.3.4.1.1 Environment. 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's trajectory. Shower meteoroids are not included.

3.3.4.1.2 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 configurations with more than two skins or double skins with small separation distances. Such situations were conservatively analyzed by omitting the thinnest skins until the configuration fitted the LEM specification. The analysis was performed for the recommended version of the Lab configuration, with no meteoroid shielding assumed in addition to that provided for the LEM.

Many approximations had to be made to estimate the meteoroid protection provided by the complicated Lab structure of spherical and cylindrical shapes enclosed by flat surfaces. Since the penetration mechanics for the back-up skin are strongly dependent on this skin's distance from the bumper skin, 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 donut area which is a section of the tank area adjoining the cap. The distance from the bumper to each section's point of closest approach was used to ensure conservative calculations (see Fig. 3.3-8).

The critical areas were also sized by their cone of exposure to the isotropic flux. A very conservative 2 π solid angle was applied in most cases. A nominal critical area was added to include the effect of such miscellaneous terms as black boxes, wiring, and tubing.

Though shielding of the descent stage by ascent stage structure, and vice versa, was incorporated, shielding by the SM was not included to make the calculations applicable to missions in which the Lab and SM may separate.

3.3.4.1.3 Computer Program. The Lab basic design was described in terms of critical areas, exposure periods, skin thicknesses, and skin separation distances, and the information fed into the computer program which contained the LEM protection criteria. When a particular combination of skin thicknesses and separation distance for a specified critical area resulted in the 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 both evaluates an existing vehicle's structure for the probability that it will not be damaged by meteoroids during its mission, and can be used to determine those locations where shielding would be most efficiently applied.

3.3.4.1.4 Meteoroid Hazard Results. The results of four missions evaluated for a Phase I Lab configuration are listed below. Mission success is defined as the probability that the Lab will survive 14 days with no penetration of any component required for mission operation. Crew safety is defined as the probability that no pressurized tank or the cabin will be punctured, and it is assumed that the cabin is manned for 14 days.

<u>Mission</u>	<u>Crew Safety</u>	<u>Mission Success</u>
200-n.mi Earth Orbit	0.99959	0.99945
Synchronous Earth Orbit	0.99936	0.99925
20-n.mi Lunar Orbit	0.99950	0.99940
80-n.mi Lunar Orbit	0.99947	0.99936

These numbers are sufficiently high so that additional shielding does not seem to be required.

3.3.4.2 Radiation Environment

3.3.4.2.1 Introduction. The radiation environment assumed for the Phase I Lab missions consists of both the Earth's trapped radiation belt and solar flare particles for the polar and synchronous Earth orbit missions; and trapped radiation belt particles for the low-inclination orbit missions. For lunar missions, only the solar flare events were considered. The solar flare model used was obtained from LSP 470-1A.

3.3.4.2.2 Solar Flares. The effect of solar flares on the polar, synchronous, and lunar orbit missions would be to either: cause mission abort, if the flare were of sufficient intensity to cause the crew in the CM to receive their allowable emergency dose (500 Rad. skin dose); or to postpone the scheduling of crew activities, if the intensity of a flare were such that the crew would receive a dangerous dose in the Lab but were relatively safe within the CM. The latter situation is

more likely since the ratio of dose received in the CM to dose received in the Lab is about a factor of 20. This assumes an equivalent shielding effectiveness of 1 lb/ft² for the Lab, and 10 lb/ft² for the CM. Estimates were made of the probability of mission abort and the probability of rescheduling crew activities, due to solar flare activity, for a 14-day mission. The results are listed below. The reschedule probability is smaller for polar orbits than either synchronous or lunar orbit because the spacecraft is protected by the Earth's magnetic field during a portion of each orbit.

Lab Mission Duration (Days)	Probability of Solar Flares Affecting Mission			
	Polar		Synchronous & Lunar	
	<u>Abort</u>	<u>Reschedule</u>	<u>Abort</u>	<u>Reschedule</u>
7	0.001	0.015	0.001	0.03
14	0.002	0.03	0.002	0.06

The probability of having to abort a polar, synchronous or lunar orbit mission due to solar flare activity is relatively low. However, flare activity could cause a delay in the crew's Lab activities for a period of 48 hr which is the approximate duration of a high-intensity solar flare.

For lunar orbit missions, an abort might be initiated even if the allowable crew dose limit were not exceeded. This is due to a combination of reasons, among them the inability to predict solar flare intensities in advance, the fact that large solar flare events tend to occur in multiples, and of course the relatively long transearth coast times.

3.3.4.2.3 Radiation Belts. A search of the literature indicated that there is a wide variation in the predicted dose rates from the Earth's trapped radiation belts. These variations are mostly due to the uncertainty in the rate of decay of the artificial electron belt at low orbital altitudes, and the large fluctuations that have been observed in the electron fluxes at higher orbital altitudes due to extra-terrestrial disturbances. An estimate has been made of the effect of the trapped radiation belt at a 200-n.mi, 30-deg inclination Earth orbit. The dose rates would be reduced by about a factor of two for a 200-n.mi polar orbit. No consistent estimates were available of the dose rates that would be encountered in a synchronous orbit. The allowable doses in the radiation belts were taken to be the allowable average yearly exposure values of 233 rad skin dose and 27 rad dose to the eyes (Ref LSP-470-1A). Estimates of the average dose rate in a 200-n.mi, 30-deg inclination orbit within the Lab range from 1 to 4 rad/24-hr day. The upper limit of 4 rad/day was chosen to be conservative. Preliminary crew time-line analyses have indicated that no crew member would spend more than 6 hr/day inside the Lab. Thus the average daily 24-hr dose rate inside the Lab becomes 1 rad/day. The accumulated dose inside the CM would be of the order of 0.1 rad/day yielding a total daily dose of 1.1 rad/day in orbit. Therefore, the allowable skin dose would be exceeded after about 24 days in orbit. No additional protection is therefore required for a Phase I Lab.

3.3.5 Simulation Requirements

The increased inertia of the Phase I Lab (combined CSM/LEM) relative to the LEM, and RCS propellant consumption considerations, dictates the need for improved

attitude rate sensitivity sensing (in the range of 0.001 deg/sec). The method selected in the recommended configuration to solve the rate gyro threshold sensitivity problem should be verified by simulation.

Experiments proposed for the Phase I Lab have been examined for possible areas where simulation support would be required for proper experiment integration, especially in the guidance, navigation and control area. The following experiments appear to warrant simulation:

- Control Moment Gyro
- Optical Guidance System for Rendezvous
- On-Board Guidance and Navigation System
- Orbital Maneuvering and Docking
- X-Ray Astronomy
- Small Maneuverable Satellite
- IR Sensing from Orbital Altitudes
- Lunar Surface Probes
- Extendable Rod Performance Tests
- Photographic Investigations
- Passive Microwave Experiments
- RF Reflectivity Measurements
- X-Ray Fluorescence
- Lunar Gravity Measurements

3.4 MISSION DESCRIPTION

The AES Phase I Lab will be required to perform up to 14-day manned experiment missions in the following orbital modes:

- Earth Low-Inclination Orbit
- Earth Polar Orbit
- Earth Synchronous Orbit
- Lunar Low-Inclination Orbit

Mission profiles are shown in Tables 3.4-1 through 3.4-4.

3.4.1 Earth Low-Inclination Orbit

A two-stage Saturn IB is used to launch an unmanned Phase I lab into a 200-n.mi, 28.5-deg inclined circular orbit. A CSM is launched by a two-stage Saturn IB into a similar orbit to achieve rendezvous, docking, and crew transfer. A 14-day experimentation mission is then conducted.

3.4.2 Earth Polar Orbit

A three-stage Saturn V vehicle is used to launch the AES CSM-LAB I in a southeasterly direction from KSC. A yaw-steering maneuver is initiated at the beginning of second stage flight to obtain a 200-n.mi 90-deg inclination polar orbit. The launch azimuth and magnitude of the yaw rate will be selected to minimize launch vehicle impact hazards to populated areas. Minimizing launch vehicle impact hazards may also require yaw-steering during first stage burn.

3.4.3 Earth Synchronous Orbit

The AES CSM-LAB I is launched with a three-stage Saturn V into a 100-n.mi 28.5-deg inclined circular parking orbit. The SIVB stage is re-ignited at the fourth descending nodal crossing to perform a 2-deg plane change, and simultaneously initiate a Hohmann transfer to synchronous orbital altitude of 19,350-n.mi. At apogee the SIVB stage is again ignited to perform a plane change of 17.5-deg and partially circularize the orbit (perigee = 5,140-n.mi). The CSM then transposes and docks to the Lab and the SIVB is jettisoned. Upon completion of one orbit at apogee, the SPS is utilized to inject the CSM-LAB into the final equatorial synchronous orbit.

3.4.4 Lunar Low-Inclination Orbit

A three-stage Saturn V vehicle is used to launch the CSM-LAB into a 10-deg inclination circular lunar orbit at an altitude of 80-n.mi. The spacecraft translunar, lunar orbit, and transearth trajectories and the recovery are similar to that of the current Apollo mission. The free return and "anytime" abort capability of the Apollo mission is retained.

3.5 TIMELINE

General housekeeping and systems checkout information is provided in Table 3.5-1. Also listed is the time required to conduct systems check and status monitoring, as well as suit and PLSS check out and final Lab shutdown time.

The Lab checkout and status monitoring time (averaging 6 min at 2-hr intervals for entire mission) is based on Table 4.4-6 which tabulates the required housekeeping activities and subsystems to be checked. The spacesuit and PLSS checkout time is accomplished prior to every EVA. Crew duty cycles and timelines of a typical day's activity for the Lab is discussed in Paragraph 4.4.

Table 3.3-1

FLIGHT 507: LOW-ALT POLAR EARTH ORBIT, AVG POWER & ENERGY REQMTS

Experiments	Avg Power, Watts	Oper Time, hr	Energy, kw-hr
Radiation Monitoring (0501)	8.3	333	2.76
Photographic Systems	710.0	23.5	16.68
Cartographic & Stellar			
Panoramic			
High-Resolution Spotting (SM Pallet)			
Multispectral			
Infrared Sensing for Orbital Attitudes	385.	23.5	9.05
Passive Microwave Experiments	340	5.0	1.70
Radio Frequency Reflectivity Measurements	30	7.0	.21
Radar Imaging, Altimetry and Surface State	1400	15.0	21.00
Ultraviolet Absorption and Luminescence	20	4.4	.09
X-Ray Fluorescence	17.2	4.4	.08
Remote Geochemical Sensing	19	4.4	.08
Micrometeorite Experiment	5	50	.25
Lunar Gravity Measurements	-	-	-
Detection of Alpha-Emission from the Lunar Surface	6.2	4.4	.03
Gamma-Ray Mapping	14.2	4.4	.06
Lunar Surface Probes	-	-	-
Sub-Total			51.99
Ancillary Equipt (Experiment-Support)	300.	50.	15.00
Total			66.99

Table 3.3-2

FLIGHT 509: SYNCH EQUATORIAL EARTH ORBIT, AVG POWER & ENERGY REQMS

Experiments	Avg Power, Watts	Oper Time, hr	Energy, kw-hr
Radiation Monitoring	8.3	336.0	2.79
X-Ray Astronomy	3.0	13.3	.04
Martian Atmosphere	11.0	1.7	.01
Artificial Comets	8.0	3.0	.02
Far-UV Image Converter	65.0	13.3	.86
Radio Astronomy	150.0	72.0	10.80
Small Maneuvering Satellite	.420	4.0	1.68
Magnetometer	50.0	336.0	16.80
Sub Total			33.00
Ancillary Equipt (Experiment-Support)	140	97	13.60
Total			46.60

Table 3.3-3

FLIGHT 511: LOW-INCL LUNAR ORBIT, AVG POWER & ENERGY REQMS

Experiments	Avg Power, Watts	Oper Time, hr	Energy, kw-hr
Radiation Monitoring (0501)	8.3	312	2.59
Photographic Systems	710	5	3.55
Cartographic & Stellar Panoramic High-Resolution Spotting (SM Pallet) Multispectral			
Infrared Sensing for Orbital Attitudes	385	21	8.08
Passive Microwave Experiments	340	37	12.58
Radio Frequency Reflectivity Measurements	30	5	.15
Radar Imaging, Altimetry and Surface State	1400	17	23.80
Ultraviolet Absorption and Luminescence	20	37	.74
X-Ray Fluorescence	17.2	37	.64
Remote Geochemical Sensing	19	7	.13
Micrometeorite Experiment	5	50	.25
Lunar Gravity Measurements	-	-	-
Detection of Alpha-Emission from the Lunar Surface	6.2	37	.23
Gamma-Ray Mapping	14.2	37	.52
Lunar Surface Probes	26	2.5	.06
Subtotal			53.32
Ancillary Equipt (Experiment-Support)	350	37	12.95
Total			66.27

Table 3.3-4

FLIGHT 214:LOW INCL EARTH ORBIT, AVG POWER & ENERGY REQMS

Experiments	Avg Power, Watts	Oper Time, hr	Energy, kw-hr
Radiation Environment Monitoring (0501)	8.3	333	2.76
Capillary Studies (0601)	30	6.9	.20
Evaluation of Space Suits (1501)			
Manned Locomotion & Maneuvering Capability (1502)	250	26	6.50
Emergency Techniques for Rescue (1503)	1000	9.3	9.30
Development of Personnel & Cargo Transfer Operations (1504)	250	1.5	.37
Propellant Handling Techniques (1506)			
Phase I - Water Transfer	750	5	3.75
Phase II - AMU Propellant Transfer (H ₂ O ₂)	250	10	2.50
Subtotal			25.38
Ancillary Equipt (1501-1504)* (Experiment-Support)	12	71	8.52
Total			33.90

*Power reqd for PLSS, ELSS & MMU of Exper 1501-1504 obtained from throwaway batteries, not charged to exper power reqmts.

Table 3.4-1

MISSION PROFILE, EARTH-ORBIT RENDEZVOUS, S-LB LAUNCH
Low-Incl, 28.5 deg; Alt, 200 n.mi

<u>Mission Phase</u>	<u>Nom Phase Time, hr: min: sec</u>	<u>Objectives Supported</u>
1. Saturn LB Ascent to Orbit (LEM Lab) a) S-LB Firing b) S-IVB Firing c) LES-B.P. Jettison	00:12:00	<ul style="list-style-type: none"> ● Demonstrate integrated mission control. Applicable during all phases thru CSM-Lab docking.
2. Earth Orbit Coast S-IVB Stabilization a) Subsystems status check	03:00:00	<ul style="list-style-type: none"> ● Demonstrate operation of modified LEM systems after being subjected to boost environment.
3. S-IVB Lab Separation a) SIA petal deploy b) LMP initiates Sep. c) LMP shuts down S/S	00:20:00	
4. Earth Orbit Storage (Lab Unstabilized) a) LMP activates S/S for status checks.	To Be Determined	<ul style="list-style-type: none"> ● Demonstrate ability of LEM Lab FCS, EPS, Inst. & Comm. equipment to perform during unmanned orbital storage.
5. Saturn LB Ascent to Orbit (CSM & Crew) a) Same as 1a & b b) LES Jettison	00:12:00	
6. Earth Orbit CSM C/O	00:30:00	
7. CSM-S-IVB Separation	00:05:00	
8. CSM Rendezvous with Lab	Variable	
9. CSM Active Docking a) LMP stabilizes Lab b) CSM docks	00:15:00	<ul style="list-style-type: none"> ● Demonstrate unmanned LEM Lab FCS ability to operate after orbital storage and effect docking with a manned CSM.

Table 3.4-1 (Cont)

<u>Mission Phase</u>	<u>Nom Phase Time, Hr: min: sec</u>	<u>Objectives Supported</u>
10. Lab C/O a) Crew transfer b) Lab C/O	01:30:00	
11. Earth Orbit Lab Experiment Operations: Typical a) Biomedical & behavioral studies b) EVA studies c) Radiation monitoring	14 days 336:00:00	<ul style="list-style-type: none"> ● Evaluate extra vehicular crew operations. ● Evaluate Lab data management system. ● Demonstrate capability of modified LEM ECS & crew provisions to support life. ● Demonstrate performance of modified LEM structure & insulation.
12. Lab shutdown and equipment and data transfer to CSM	01:30:00	
13. Preparation for CM entry a) Lab jettison b) SPS deorbit maneuver c) SM Jettison	00:10:00	
14. Entry	00:11:00	
15. Parachute Descent	00:07:00	
16. Post landing through S/C retrieval	Variable	

Table 3.4-2

MISSION PROFILE, EARTH POLAR ORBIT, S-V LAUNCH
Incl, 90 deg; Alt, 200 n. mi

<u>Mission Phase</u>	<u>Nom Phase Time, hr: min: sec</u>	<u>Objectives Supported</u>
1. Saturn V Ascent to Polar Orbit a) S-1C Firing b) S-11 Firing (Yaw Steering) c) LES Jettison d) S-IVB Firing (Yaw Steering)	00:16:30	<ul style="list-style-type: none"> ● Demonstrate LEM Lab Structural integrity after Saturn V yaw steering maneuvering to effect a polar orbit.
2. Orbit Coast - S-IVB Stabilized a) CSM C/O	03:00:00	
3. CSM Transposition & Docking a) CSM S-IVB Separation b) CSM Transposition c) CSM-LEM Lab Docking d) LEM Lab S-IVB Separation	00:30:00	
4. LEM Lab C/O a) Crew Enters Lab b) Activation & C/O of Lab Subsystems	02:00:00	<ul style="list-style-type: none"> ● Demonstrate performance of modified LEM S/S after being subjected to boost environment.
5. Earth Polar Orbital Lab Experiment Operations: Typical a) Biomedical & behavioral studies b) Lunar survey equipment C/O (Earth mapping) c) Weather studies	14 days 336:00:00	<ul style="list-style-type: none"> ● Evaluate EVA crew operations. ● Demonstrate the Earth pointing capability of Lab flight control system. ● Demonstrate the performance of the modified LEM structure & insulation over a 14-day Earth orbital mission. ● Evaluate radiations levels throughout mission duration. ● Demonstrate the capability of the modified LEM ECS and crew provisions to support life over a 14 days Earth orbital mission.

Table 3.4-2 (Cont)

<u>Mission Phase</u>	<u>Nom Phase Time, hr: min: sec</u>	<u>Objectives Supported</u>
6. LEM Lab shutdown & equipment and data transfer to CSM.	01:30:00	<ul style="list-style-type: none"> ● Evaluate the LEM Lab data management system. ● Demonstrate compatibility of LEM Lab with MSFN for polar orbital operations.
7. Preparation for CM re-entry <ul style="list-style-type: none"> a) Lab jettison b) Service propulsion deorbit maneuver c) SM jettison 	00:10:00	
8. Entry	00:11:00	
9. Parachute descent	00:07:00	
10. Post landing through S/C retrieval	Variable	

Table 3.4-3

MISSION PROFILE, EARTH SYNCH ORBIT, S-V LAUNCH
Incl, Zero; Alt, 19,350 n. mi.

<u>Mission Phase</u>	<u>Nom Phase Time, hr: min: sec</u>	<u>Objectives Supported</u>
1. Saturn V Ascent to 100 n. mi. Parking Orbit 28.5 Deg. Incl. a) Launch azimuth 90 Deg. b) S-1C Firing c) S-11 Firing d) LES Jettison e) S-IVB Firing f) Parking Orbit insertion	00:10:00	
2. Earth Parking Orbit (1-1/4 Orbits) a) CSM Systems Check b) Preparation for transfer orbit Insertion	01:50:00	
3. Transfer Orbit In- sertion a) S-IVB Restart b) Orbit Transfer & Partial Plane Change	00.06.00	
4. Transfer Orbit Coast to 19,350 n. mi.	05:15:00	
5. S-IVB Restart to do Partial Plane Change & Circularize at Synch. Alt.	00:02:00	
6. Transposition & Docking a) CSM S-IVB Separation b) CSM Transposition & Docking with Lab. c) LAB-S-IVB Separation	00:30:00	

Table 3.4-3

<u>Mission Phase</u>	<u>Nom Phase Time, hr: min: sec</u>	<u>Objectives Supported</u>
7. CSM Firing to Complete Plane Change and Circularization. (NOTE: May need to wait for one orbit)	00:01:30	
8. Lab C/O a) Crew transfer to Lab b) Activation and C/O of Lab S/S.	01:30:00	<ul style="list-style-type: none"> ● Demonstrate operation of modified LEM S/S after being subject to boost environments.
9. Earth synch. orbit Lab experiment operations: typical a) Biomedical & behavioral studies b) Astronomical studies and observations c) Small maneuverable satellite studies.	14 days	<ul style="list-style-type: none"> ● Demonstrate LEM Lab thermal control. ● Demonstrate compatibility of LEM Lab with MSFN for synch. orbit mission. ● Evaluate radiation levels. ● Evaluate extra vehicular crew operations. ● Evaluate LEM Lab data management systems. ● Demonstrate capability of the modified LEM ECS and crew provisions for 14 day mission. ● Demonstrate earth pointing capability of LAB FCS.
10. LEM Lab shutdown & equipment and data transfer to CSM.	01:30:00	
11. Preparation for CM re-entry a) Lab jettison b) Service propulsion deorbit maneuver c) SM jettison	05:30:00	

Table 3.4-3

<u>Mission Phase</u>	<u>Nom Phase Time, hr: min: sec</u>	<u>Objectives Supported</u>
12. Entry	00:11:00	
13. Parachute descent	00:07:00	
14. Post-landing through S/C retrieval.	Variable	

Table 3.4-4

MISSION PROFILE, LUNAR ORBIT SATURN-V LAUNCH
Incl, 10 deg; Alt, 80 n. mi

<u>Mission Phase</u>	<u>Nom Phase Time, hr: min: sec</u>	<u>Objectives Supported</u>
1. Saturn-V Ascent to Parking Orbit (100 n. mi.) a) S-1C Firing b) S-11 Firing c) LES Jettison d) S-IVB Firing e) Parking Orbit In- sertion	00:10:00	
2. Earth Parking Orbit a) CSM C/O b) Preparation for Translunar Insertion	02:12:00	
3. Translunar Insertion a) S-IVB Restart	00:10:00	
4. Translunar Coast a) CSM-S-IVB Separation b) Transposition & Docking c) CSM/Lab-S-IVB Separation d) 1st Mid-course Correction e) 2nd Mid-course Correction f) 3rd Mid-course Correction	60:15:00	
5. Lunar Orbit Insertion a) SPS Firing	00:05:00	
6. Lab C/O in Lunar Orbit a) Crew transfer to Lab b) Activate & C/O of Lab systems	01:30:00	o Demonstrate operation modified LEM systems after boost environ- ments.

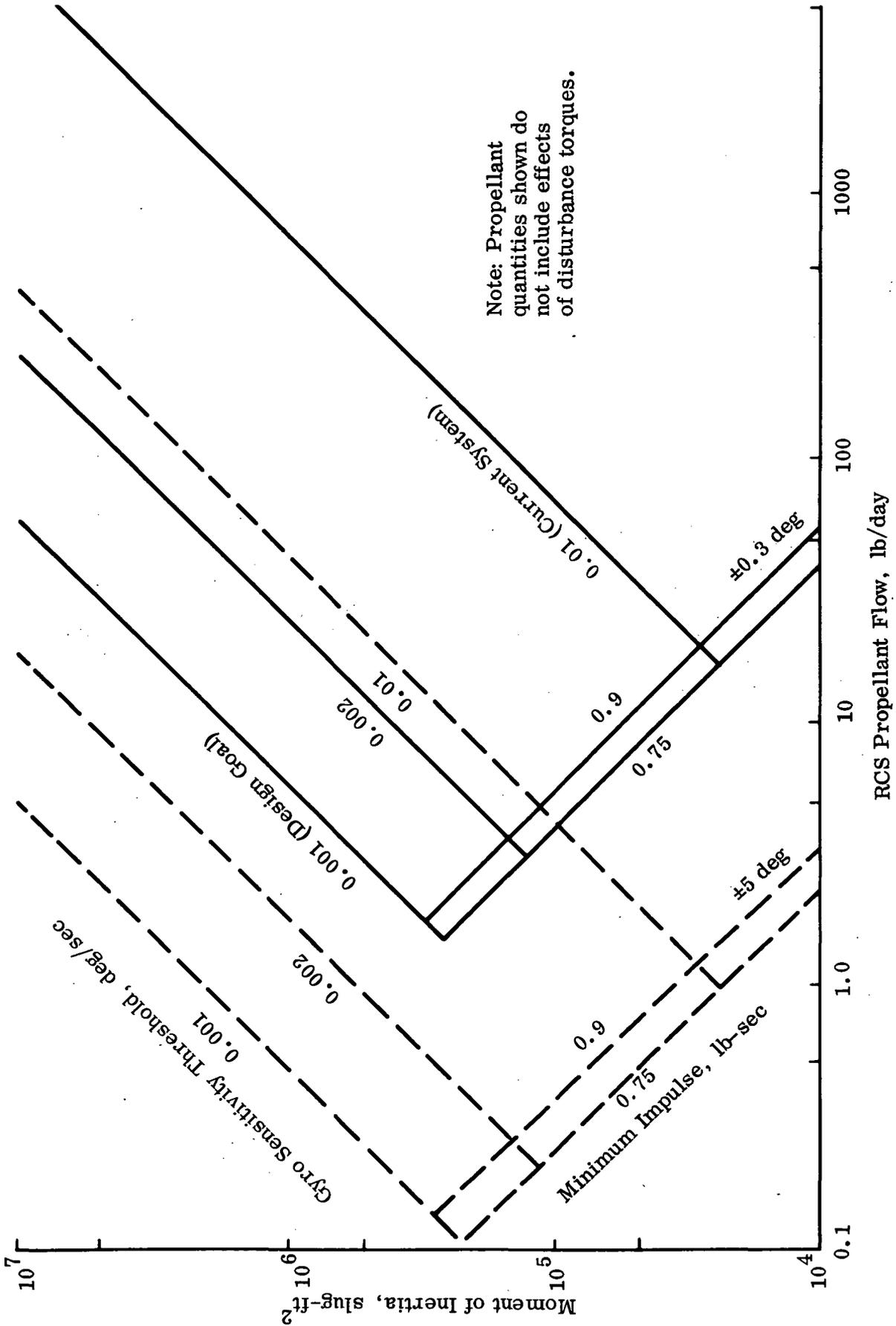
Table 3.4-4 (Cont)

<u>Mission Phase</u>	<u>Nom Phase Time, hr: min: sec</u>	<u>Objectives Supported</u>
7. Lunar Orbit Lab Experiment Operations: Typical a) Biomedical & behavioral studies b) Lunar photographic studies c) Lunar oriented experiments	14 days 336:00:00	<ul style="list-style-type: none"> ● Evaluate radiation and micrometeorite levels in low inclination lunar orbit. ● Demonstrate CSM-LEM Lab 1 mission compatibility for lunar mission thermal vacuum environment. ● Evaluate LEM Lab data management systems.
8. LEM Lab shutdown and equipment and data transfer to CSM	01:30:00	
9. Transearth Injection a) Jettison Lab b) SPS firing	00:05:00	
10. Transearth Coast a) 1st midcourse correction b) 2nd midcourse correction c) 3rd midcourse correction		
11. SPS Deorbit a) SPS Firing b) SM Jettison	00:05:00	
12. Entry	00:11:00	
13. Parachute Descent	00:07:00	
14. Post-landing through S/C Retrieval	Variable	

Table 3.5-1

HOUSEKEEPING & SYSTEM CHECKOUT TIMELINE

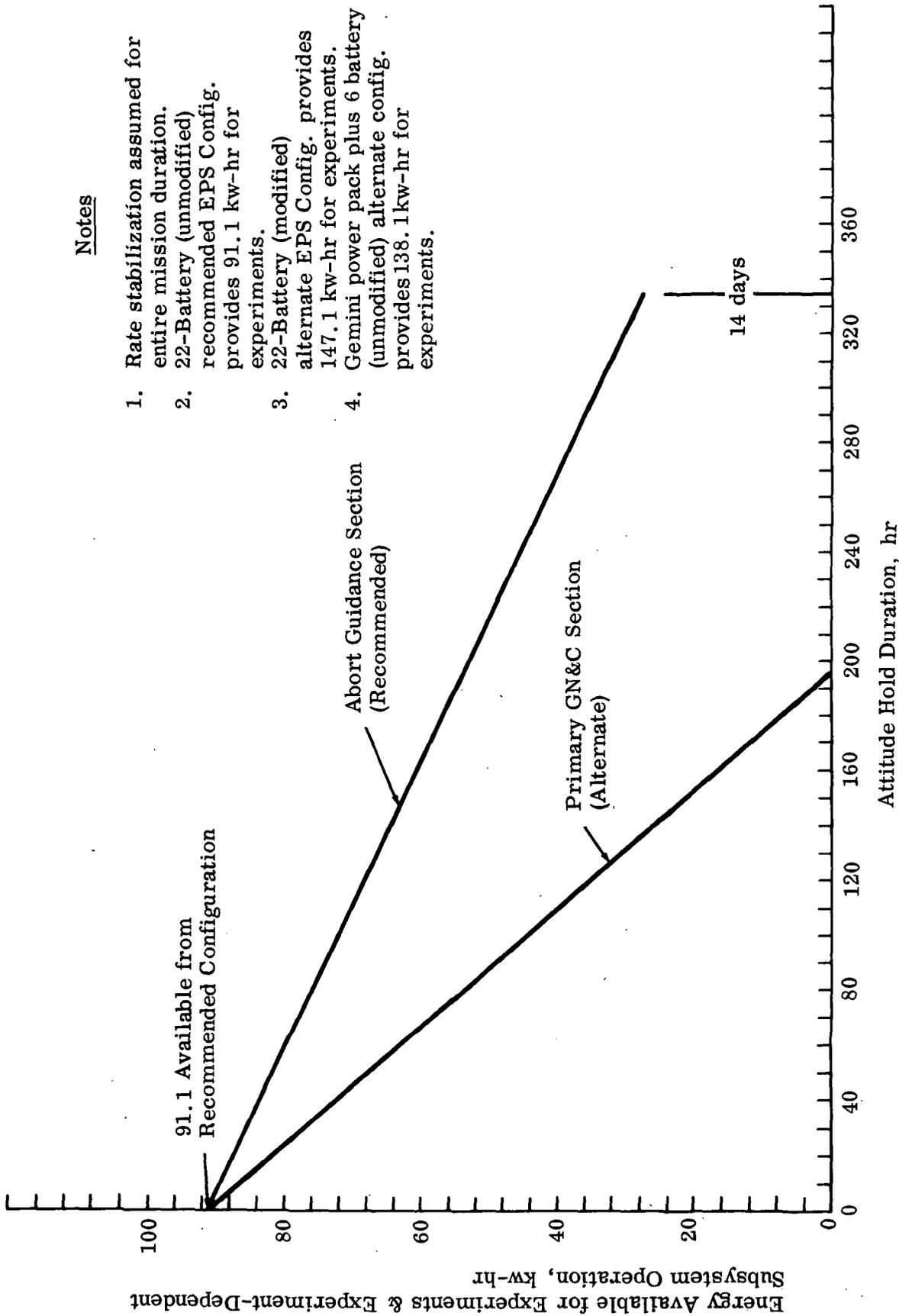
Event Time or Start time, hr: min: sec	Mission Event	Event Duration, min: sec
00:00:00	Astronaut(s) enter lab.	04:00
00:04:00	CSM-Lab communication check.	03:30
00:07:30	Activate C&W System.	00:30
00:08:00	Power distribution status check.	02:00
00:10:00	Activate and check out lighting.	01:00
00:11:00	Activate sensors & displays.	00:20
00:11:20	Check propellants; gases & fluid status.	02:00
00:13:20	Initial status check of ECS.	07:30
00:20:50	Transfer equipment to Lab (PLSS, hand cameras, accessories, etc.).	04:10
00:25:00	Deploy of S-band antenna.	00:30
00:25:30	Communication and instrumentation checkout.	12:00
00:37:30	Completion of ECS checkout.	10:00
00:47:30	Checkout of SCS & RCS Systems.	19:00
01:06:30	Lab subsystem initial checkout & activation completed.	
xx00:00	Lab subsystem status monitoring.	06:00
xx06:00	(Performed at approximately 2-hr intervals for entire flight)	
	Pressurized spacesuit & PLSS checkout for every EVA.	20:00
14th day	Lab I shutdown and astronaut exit to CSM.	15:00



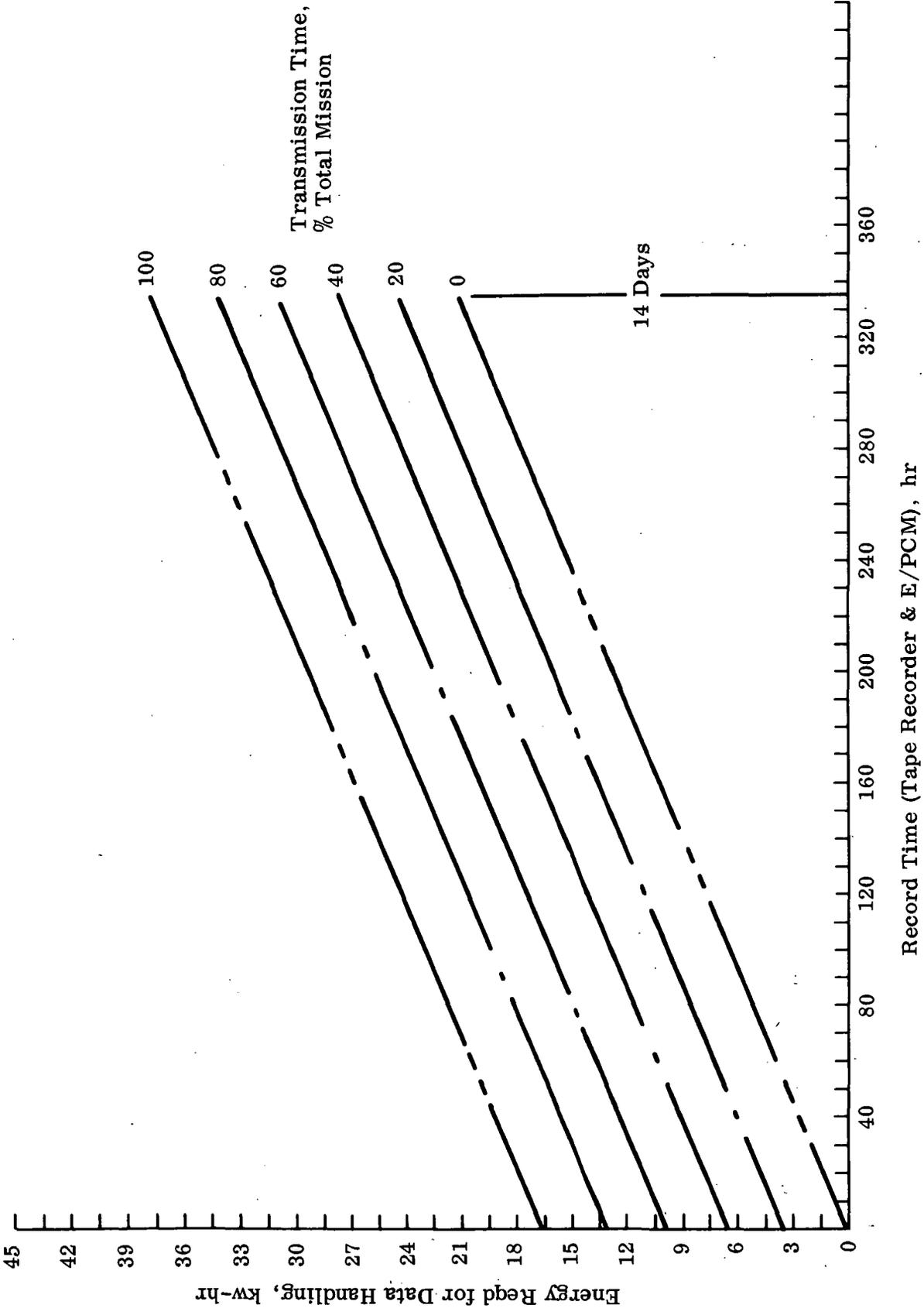
3.3-1 Limit Cycle Propellant Flow Minimum Pulse Bit and Gyro Rate Threshold Bias

Notes

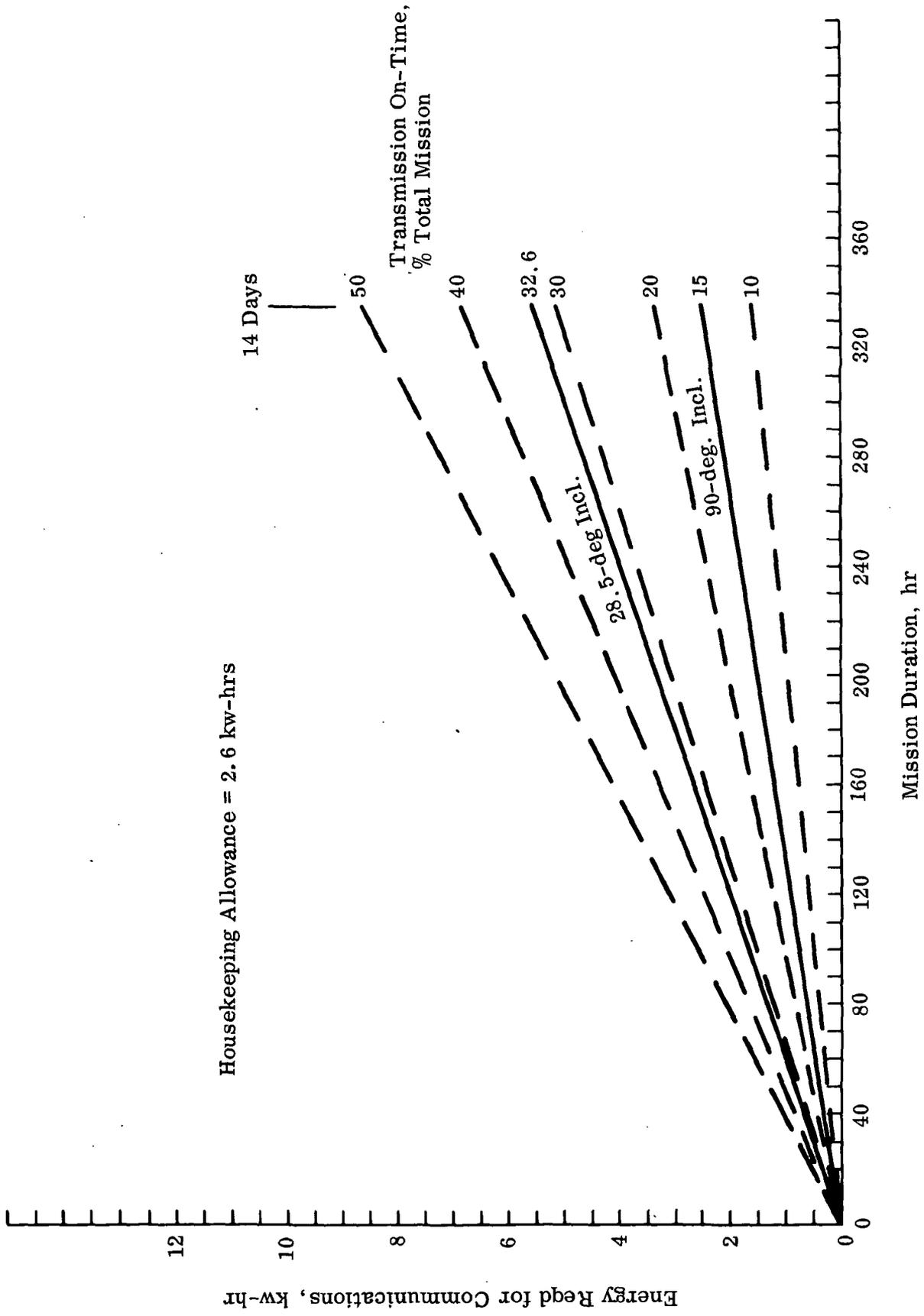
1. Rate stabilization assumed for entire mission duration.
2. 22-Battery (unmodified) recommended EPS Config. provides 91.1 kw-hr for experiments.
3. 22-Battery (modified) alternate EPS Config. provides 147.1 kw-hr for experiments.
4. Gemini power pack plus 6 battery (unmodified) alternate config. provides 138.1 kw-hr for experiments.



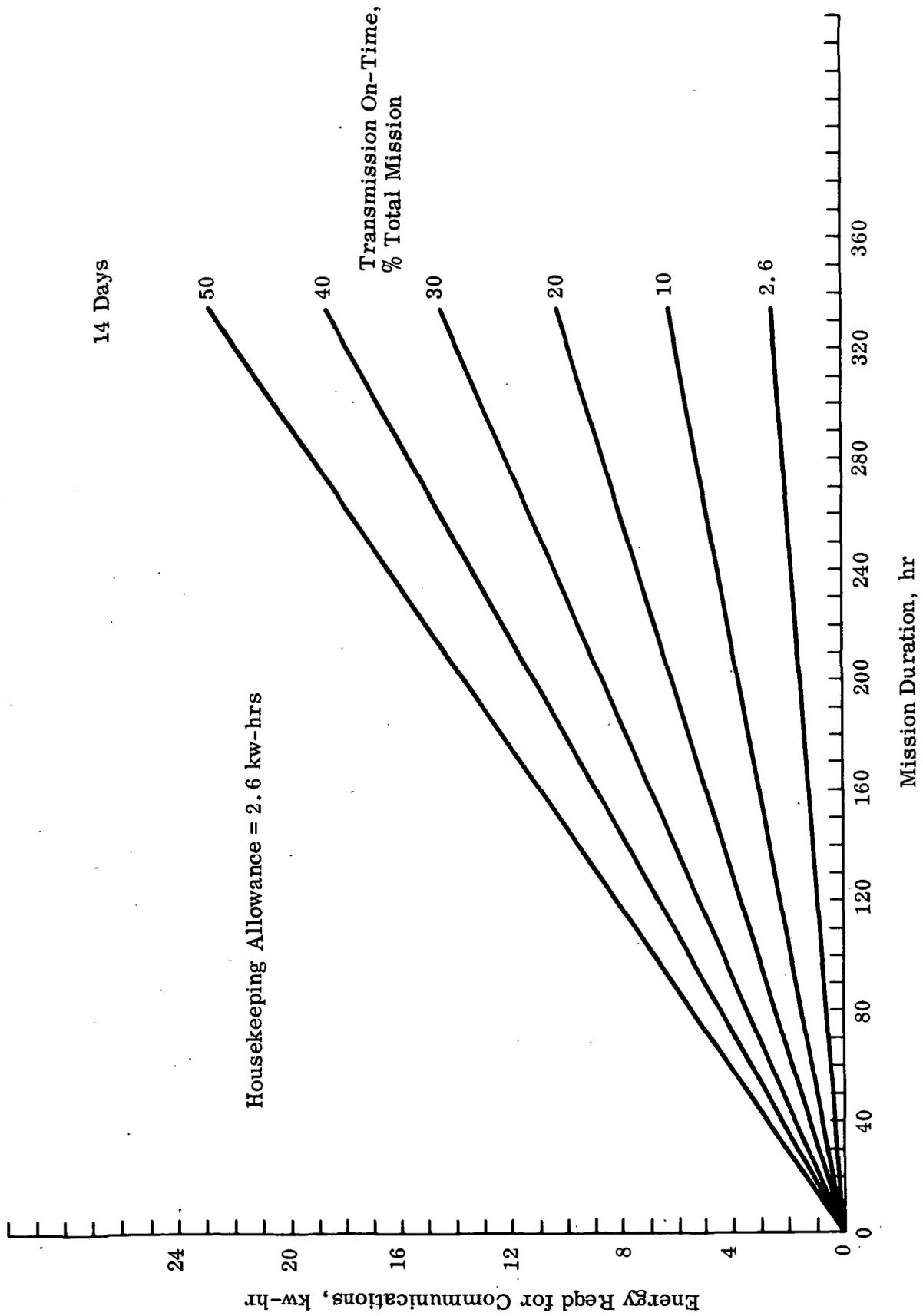
3.3-2 Energy Available For Experiments VS Attitude Hold Duration



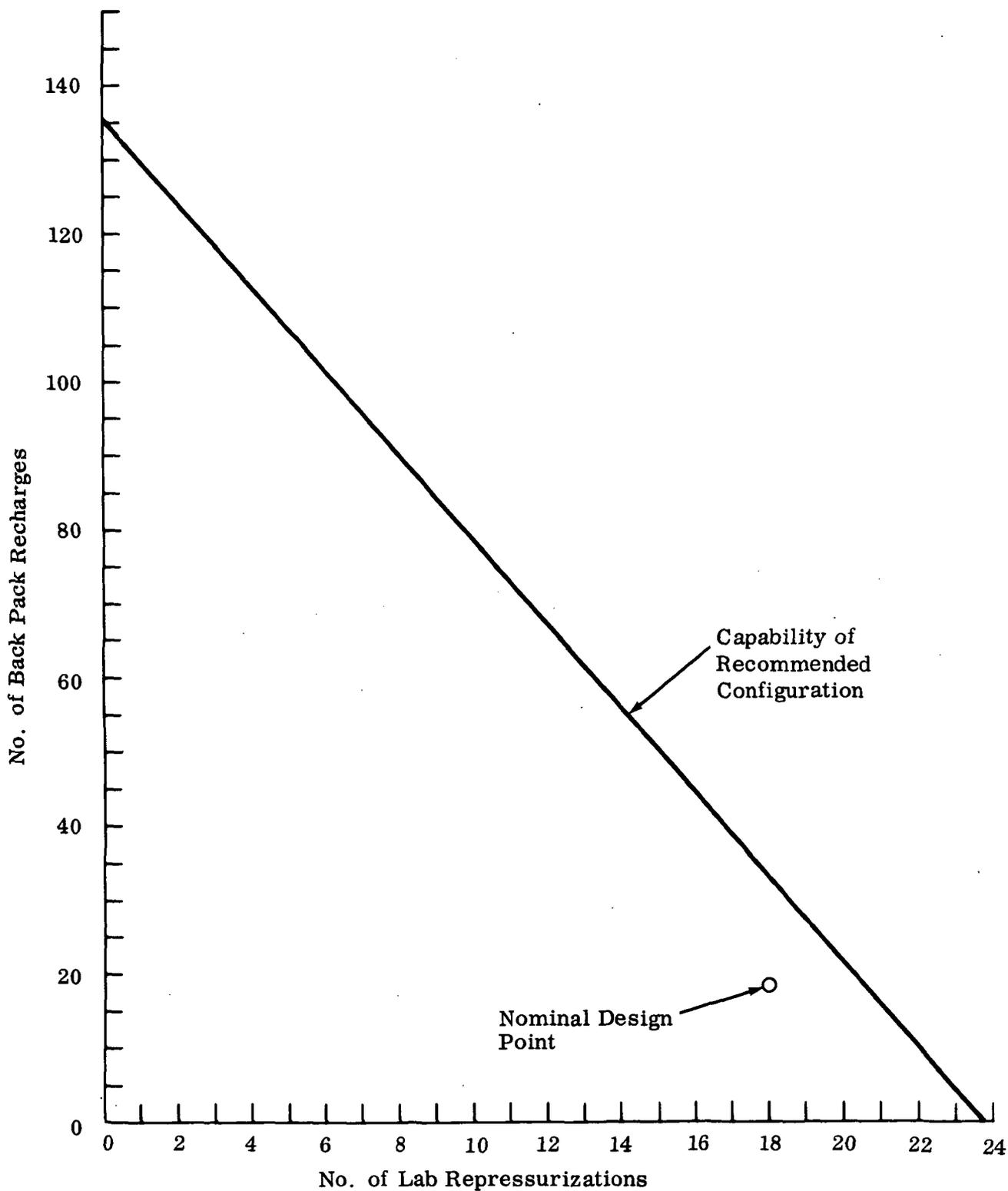
3.3-3 Energy Required for Data Handling



3.3-4 Energy Required for Communications - 200 N. Mi Orbit



3.3-5 Energy Required for Communications - 19, 350 N. Mi Orbit



3.3-6 Eva Capability Based on Oxygen Utilization

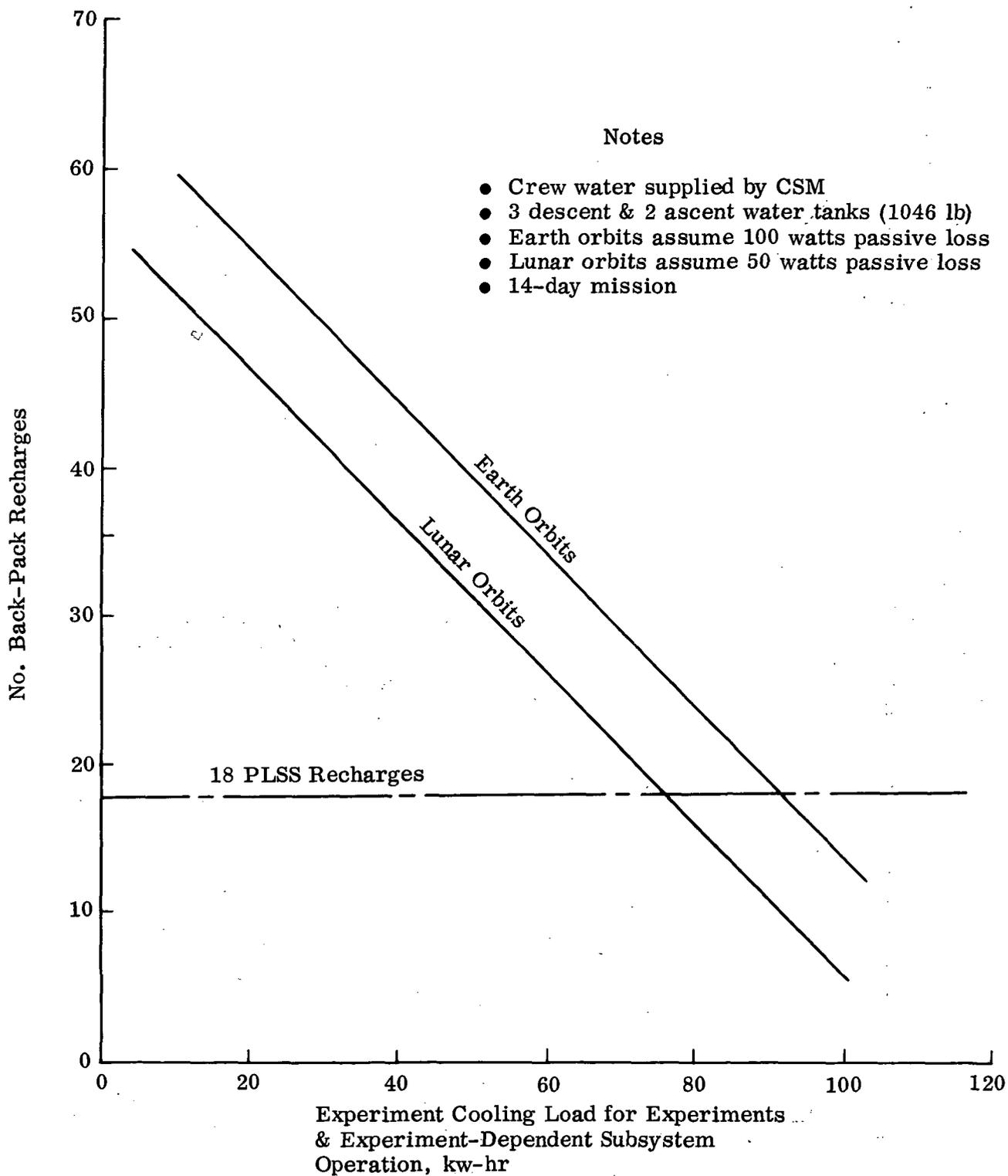


Fig. 3.3-7 ECS Water Utilization

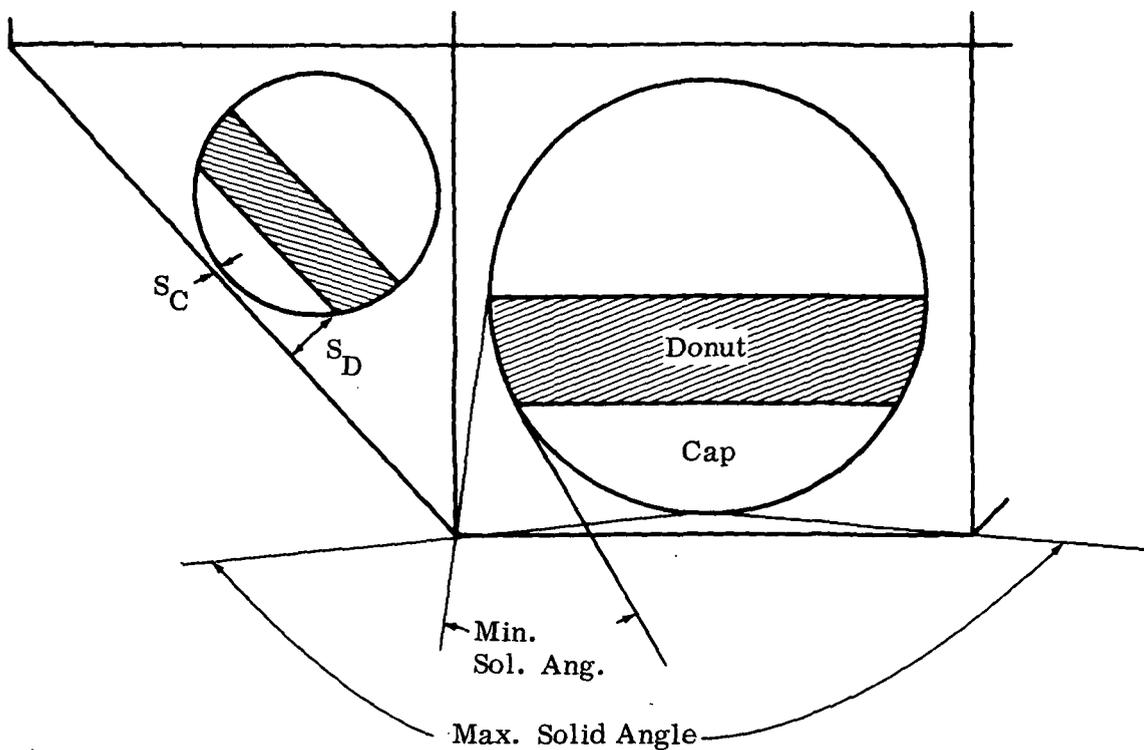


Fig. 3.3-8 Critical Area Sectioning

4. SYSTEM ENGINEERING

4.1 THERMODYNAMICS

4.1.1 Assumptions

The following assumptions are used in evolving the thermodynamic design concepts and associated performance of the Phase I Lab:

- A maximum of 150 watts of experiment power will be dissipated in the low temperature electronic area
- The housekeeping load is as shown in Section 4.13
- The most extreme thermal environments were assumed in evaluating the system performance. (i.e. min. external heat flux for cold case calculations and max. extreme heat flux, for hot case calculations)
- No restrictions on vehicle orientation have been imposed.

4.1.2.1 Cooling Load

The experimental and housekeeping equipment cooling loads are tabulated and discussed in Section 4.1.3, "Recommended Configuration." The structural load variations assumed for the ascent stage is the following:

(+ is gain to vehicle; - is lost by vehicle to space)

<u>Vehicle Area</u>	<u>Max. Sun, Btu/hr</u>	<u>No Sun, Btu/hr</u>
Skin	-270	-450
Window	shade up + 530; shade down 0	shade up -180; shade down 0
Top Tunnel Covered (Non-docked configuration)	+5	-27
RCS	+88**	=52*
Antennas, and other areas	+40	-70

** 23 Watts of heat supplied to 2 Cold Clusters

* 46 Watts of heat supplied to all 4 clusters

Thus the Phase I Labs will have a structural heat loss varying from approximately 100 Btu/hr for a condition of max. sun light with the window shades closed to approximately 700 Btu/hr for the minimum sun light condition with the shades open. In addition there will be various experiments hung off the labs that will contribute to the overall structural heat leaks. The overall estimated heat leak will vary from a minimum of 100 watts to a maximum of 400 watts. This heat loss can be considered as additional cooling capacity. If the minimum heat loss is converted to an equivalent amount of cooling water, it would represent 114 lb of additional water for other uses.

4.1.2.2 Equipment Heater Requirements

Various external antennas, and the RCS Cluster, will require additional heat when exposed to space and not in use or receiving radiant energy from the sun or planetary bodies. In addition, heat is needed to maintain the navigation & guidance equipment above their recalibration temperatures when not in use.

- RCS Cluster Heater Requirements - It is required that the clusters oxidizer valves be maintained above a minimum temperature of 35°F, to prevent the propellant in them from freezing. The electrical heat required for each cluster valve is a function of how much heat is conducted and radiated from the cabin to the cluster can. As the cabin temperature rises, more heat is transferred from the Cabin and the electrical heat required is diminished. Figure 4.1-1 shows the heater requirements as a function of cabin temperature, for a condition of no external heat flux. When the cluster is in direct sun light, no heater power is required. It is estimated that for the laboratories the average heater power required for all four clusters is 30 watts, assuming that 2 out of 4 clusters are in the sun at any one time.
- S-Band Steerable Antenna - The S-Band Antenna, when not in use, requires heater power to maintain the antenna's steering components above its low temperature survival limits. Components such as servomotors, electronic equipment and gimbal mechanism must be maintained above -65°F. It is estimated that 5 watts of heater power will be required to accomplish this during the condition of zero external heat flux. When the antenna is in direct sun light, no extra heat is required.
- Navigational Equipment - The IMU and the ASA are both located above the LEM cabin. Though not exposed to space, they require precise thermal control when in use ($\pm 1^\circ\text{F}$) and close temperature control when not in use. Both units utilize gyro-systems and accelerometers that are extremely temperature sensitive. If the temperature drops below 120°F on the IMU and 105°F on the ASA, the units will go out of calibration. In the Basic LEM, temperature control of the IMU and ASA when in the non-operating mode is achieved by utilizing the cooling loop as well as the heaters. This mode of operation causes excess heater power, since the proportional heater has to over drive the cooling loop. For the Phase I Lab, a bypass valve will be incorporated into the cooling loop, to bypass the IMU and ASA coolant when the units are not operating. Fig. 4.1-2, shows the heater power required by the IMU and ASA to maintain them above their recalibration points as a function of cabin temperature. (The IMU and ASA are conductively coupled to the cabin structure.) The losses to the vehicle skin are minimized by a blanket of 20 layers of aluminized mylar insulation between the units and the vehicle skin. A tabulation of heater power required for the ASA and IMU, for two-cabin temperature, is presented below:

<u>AVERAGE CABIN TEMPERATURE 70°F</u>		
<u>EQUIPMENT</u>	<u>HEATER POWER, WATTS</u>	<u>TEMPERATURE, °F</u>
IMU	9.5/8.5	135/120
ASA	5/4	120/105
<u>AVERAGE CABIN TEMPERATURE 40°F</u>		
IMU	13/11.4	135/120
ASA	7/6	120/105

4.1.2.3 Thermal Environment

The thermal environment comprises the direct solar radiation, reflected albedo radiation and direct I-R radiation incident on the vehicle surfaces. The intensity of thermal radiation depends on the orbit, vehicle orientation, and the location of the sun relative to the orbital plane. The angle between the solar vector and the orbital plane, θ_s , varies as a function of the orbit inclination and the date and time of launch. The following table shows the possible range of θ_s for each of the Phase I Lab flights. In addition, the maximum possible temperature of a surface in thermal equilibrium with the radiation environment is shown for a typical skin surface, $\alpha/\epsilon=0.8$, and a typical radiator surface, $\alpha/\epsilon=0.2$.

Basic Mission Orbits	Orientation	θ_s , deg	Typical Radiator	Typical Skin
			$\alpha/\epsilon=.8$ T max, °F	$\alpha/\epsilon=.2$ T max, °F
200/E90°	Earth	0-90	228	62
19,350E/0°	Space	0-23.5	213	16
80L/10°	Lunar	0-	230	210
200E/28.5°	Earth	0-62	228	62

In Table 4.1-1, the orbital averages of incident thermal radiation are presented for a number of surfaces. Solar, albedo, and I-R radiation intensities are shown for both earth and space oriented labs in earth orbits with varying solar angle, θ_s . Also shown is a lunar oriented orbit with the solar vector in the orbital plane.

In order to give an indication of the variation in incident radiation throughout an orbit, Fig. 4.1-3 is presented. It shows the temporal variation in the thermal environment of upward and downward directed surfaces for earth and lunar orbits, respectively. In both cases, the solar vector is in the orbital plane, the condition which produces the maximum variation during an orbit.

The thermal environment for the synchronous orbit is primarily due to solar radiation. At this orbital altitude, the levels of albedo and I-R radiation are less than 2 Btu/hr sq. ft. Hence, the major factor is the surface orientation relative to the solar vector. Shadowing by the earth for up to 5% of the orbit is also possible. Fig. 4.1-4 shows the percentage time in sunlight for the 200n.mi earth orbit and 80n.mi lunar orbit as well as for the synchronous orbit.

4.1.2.4 Passive and Semi-Passive Temperature Control Capabilities of AES Vehicles

Passive methods for the control of equipment temperatures are characterized by containing no moving parts, or fluids, and requiring no input of power for their operation. Semi-passive control methods differ from passive systems in having moving mechanical parts and components to assist in varying the mode of heat transfer, primarily radiation. This method utilizes differential metallic expansion or fluid expansion to operate switches or move a shutter.

The various passive and semi-passive systems considered for AES vehicles in order of complexity and weight are as follows:

- The equipment radiates its dissipated heat to a low α/ϵ skin, which in turn radiates to space.
- The above scheme with an internal shutter thermostatically operated; whose movement exposes more or less of the radiating surface, thus raising or lowering the heat rejection capabilities of the equipment to the external skin.
- The equipment radiating directly to space, with a shade that is thermostatically controlled, to open or close exposing more or less equipment surface area directly to space. The equipment surface is painted with a low α/ϵ paint, such as LTV 602.
- The above system with the following vehicle orientation restrictions for earth orbiting vehicles:
 - No direct sunlight illuminating the equipment surface
 - For lunar orbiting vehicles:
 - The equipment surface is so oriented that it is exposed to a minimum amount of lunar IR radiation and no direct solar radiation.

The capabilities of the above systems are presented in the following tabulation. The column on the left indicates the maximum wattage that the equipment can dissipate when in a maximum external heat flux orientation, and still be below 135°F. The column on the right is the heat that must be dissipated by equipment to remain above 35°F when in a minimum heat flux orientation. Data is presented for three orbits: synchronous, 200n.mi, and an 80n.mi lunar orbit.

	Heat Dissipated, watts/sq ft					
	Synchronous Orbit		200N.Miles		80-mile Lunar Orbit	
	Q_{max}	Q_{min}	Q_{max}	Q_{min}	Q_{max}	Q_{min}
	135°F	35°F	135°F	35°F	135°F	35°F
A) Radiation to skin	14.6	12.0	15.5	12.0	13.8	9.5
B) Radiation to skin and internal shutter	14.6	4.4	15.5	4.4	13.8	2.9
C) Radiation to space with external shade	23.0	4.6	24.5	4.6	22.5	3.1
D) Same as C except preferred Vehicle orient.	43.0	4.6	38.0	4.6	35.0	3.1

A look at the above tabulation, Configuration A, shows the restraints that passive equipment cooling places on the electronic duty cycle; that is, the minimum load cannot be less than 82% of the maximum load for a synchronous orbit, 78% for a

200n.mi orbit and 69% for the lunar orbit. This illustrates that the equipment cannot be shut off without providing an equivalent amount of heat or a mechanical shutter that reduces the effective emittance of the surface. Where low temperature cooling is required, (IMU, ASA and Batteries) the maximum heat dissipation is fur-diminished.

4.1.3 Recommended Configuration - Active Cooling Utilizing Water Boiling

The major objective of the thermal design for the Phase I Lab is to design a vehicle that will require minimum change to the basic LEM configuration. In keeping with criteria, the following configuration is recommended:

The descent stage will be modified so as to accommodate 16 added batteries mounted externally on the descent stage. Each side will be composed of 4 batteries and 1 ECA cooled by extending the glycol loop to these areas. The present four descent batteries and the 2 ascent batteries will be retained.

The glycol loop will provide all cooling requirements for the batteries, experiments and other housekeeping equipment. The heat absorbed by the glycol system will be transferred to a LEM type water boiler. The distribution of the cooling load is as follows:

Cooling Load, watts

Cabin Heat Load (and pump)	225.2 + 176.	Metabolic heat load (sensible only)
Aft equipment bay	171	4.2w I ² R load for batteries
Battery descent bay	30	42w I ² R load for batteries
Low temperature electronics	24w housekeeping	150w experiment load
49 watts of experiment assumed to be cooled passively	35 watts provided	for external heaters
Total Cooling Load	822.2	Watts
Water Required for Cooling (14-day mission)	Assuming a Minimum Passive Loss	
of 100 watts is	830 lb of H ₂ O	(This corresponds to 242 kw-hr)

The heat loss is primarily a function of vehicle orientation and position of the cabin window shade.

In order to avoid large full scale vehicle thermal balance tests, the uncertainties of the structural heat load will be absorbed by designing a flexible ECS system.

The thermal control system for the Phase I Lab is identical to the LEM except for the removal of the suit circuit and the incorporation of a control on the main water boiler. Removal of the suit circuit requires that the command and service module environmental control system handle the latent metabolic load generated in the LEM cabin.

Fig. 4.1-5 schematically represents the proposed all water boiling system for the Phase I Lab. The figure shows the loads and temperatures throughout the system for the maximum load conditions (Minimum load values are bracketed). The capacity of

weight saving of 212 lbs of cooling water for a 14-day mission. During the cold orientation, the equipment temperature would drop to 35°F for the same maximum power dissipation. In order to achieve reduction in power generation and still remain above 35°F, a mechanical shutter, such as System B described in Section 4.1.2.4 will be required. A shutter system for the aft equipment bay will weigh between 6 and 10 lb. With the shutter, the equipment heat dissipated can be reduced to 90 watts and the temperature will still remain above 35°F.

4.1.6 Alternate Configuration--Battery Package Passively Cooled

Since the average power level of each Phase I Lab battery is much lower than its LEM counterpart, it may be feasible to cool the battery package passively. The battery package will be mounted in a manner similar to that shown for the actively cooled package, except that it will be decoupled thermally from the descent stage. The package is then separated from the temperature fluctuations and uncertainties of the descent structure. The insulation shield will be replaced by an Alzak skin; thus allowing the dissipated heat to be radiated to this skin, which in turn will radiate to space. The effective emittance between the inner surface of the Alzak skin and the front surface of the battery package is sized to maintain the package at a maximum of 80°F during the worst extremes of heat dissipation and environment. The most adverse hot orbit condition occurs when the battery package is in direct sun light for the entire orbit. Under these conditions, the effective emittance required is 0.23 (corresponding to a total heat dissipation of 18 watts including ECA's.) This heat dissipation corresponds to a battery pack output of 152 watts or a vehicle power output of about 825 watts. This emittance can be obtained by selectively painting epoxy blacks stripes on the gold plated surface of the battery. Fig. 4.1-8 shows the effective emittance needed as a function of battery package heat dissipation.

During the cold orbit condition, the battery package must be maintained at the minimum of 40°F. This can be accomplished in one of two ways, as follows:

- Heater System - Since the emittance of the battery is a constant, sized for the maximum power during the hot orbit condition, (Point A in Fig. 4.1-9), it will operate considerably colder during the minimum power cold orbit conditions. In order to increase the operating temperature of the package to 40°F, it will be necessary to attach a strip heater to the surface of each battery. The total heater power required is 20 watts (Point B, Fig. 4.1-9) 5 watts per battery. The heaters will be thermostatically controlled. Since only two battery packages can be in the shade at any one time, the maximum total power required for the heaters during the entire 14-day mission is 13.4 kw-hr. The penalty to the vehicle, therefore, includes the addition of another LEM descent battery.
- Shutter System: A shutter or louvres placed between the battery package and alzak skin can eliminate the need for additional heat. The shutter opens or closes, exposing more or less battery surface, thus raising or lowering the level of heat rejection capabilities of the battery surface to external skin. The shutters are thermally actuated using a bimetallic coil as a sensor-drive mechanism. The shutter assembly has an effective radiating power of 8 Watts in the closed position (at 45°F) and 18 watts in the open position (at 80°F). A Battery pack heat load of 8 watts corresponds to a battery pack output of 54 watts or a per vehicle output of 300 watts. The shutter system can achieve a change in effective emittance of 5 to 1.

the system is adequate without the use of the No. 224 water boiler. In the interest of minimum change, this component has not been eliminated from the system. Instead, the performance of the water boiler is made equal to zero by shutting the water supply to the boiler.

Under maximum load, the system is capable of holding a 75°F cabin with a water consumption rate of 2.47 lb/hr. (A 100-watt structural heat leak is assumed.)

Under minimum load, the system is capable of holding a 70.8°F cabin and the water consumption rate is 1.46 lb/hr. For this case, the experimental load is taken as zero and 250 watts structural heat leak is assumed. To increase the cabin temperature to 75°F would require raising the regenerative heat exchanger effectiveness from 0.795 to 0.822. This could be accomplished by adding a second No. 204 regenerative heat exchanger in series with the present one, which would make the combined effectiveness about 89%. The dry weight of a No. 204 heat exchanger is approximately 3.2lb.

4.1.4 Baseline Configuration

The Baseline Configuration is essentially the same thermal design as the recommended configuration. The cooling load is slightly reduced, however, because the vehicle carries eight less batteries.

4.1.5 Alternate Configuration - Passive Cooling of AFT Equipment Bay

The Phase I Labs have passive cooling capabilities when in Earth or Lunar orbit. This potential can be utilized to cool housekeeping equipment or experimental equipment hung from the Lab structure. The aft equipment bay on the Phase I Lab can best utilize the passive systems discussed in the previous sections. The following is a discussion of the design, performance and modifications need to implement this design.

The aft bay equipment rack of the Phase I Labs contains housekeeping equipment that dissipates between 170 and 190 watts. The rack at present faces an insulated skin. If the following modifications are made, the rack can be cooled passively:

- Remove the insulated skin and replace with an alzak skin painted with epoxy black paint on the interior side.
- Paint all outside surfaces of the equipment with epoxy black paint.

The performance of the passive system was calculated and presented in Fig. 4.1-6. This figure presents the equipment temperature as a function of equipment heat load for a maximum and minimum external heat flux condition. The effects of an internal shutter are also presented.

It should be noted that a portion of the equipment heat will be conducted and radiated to the cabin in the hot equipment condition, and heat will be lost from the cabin in the cold equipment condition. This is shown in Fig. 4.1-7.

Figs. 4.1-6 and 4.1-7 illustrate that for an equipment dissipation of 190 Watts in the hot orientation, the equipment will reach an average temperature of 100°F. Approximately 30 watts will be leaked to the cabin and the remainder lost to space. The 30 watts leaked to the cabin will have to be absorbed by the cabin cooling system, but the remaining 160 watts will be cooled passively. This would represent a

Total weight of each shutter system will be approximately 3 lb. A drawing of this configuration is shown in Section 6.2. It should be noted that the internal shutter system described above has several advantages over an external shutter:

- o The shutter is shielded by the alzak skin from sun light; therefore, there are no orientation restraints on vehicle, as in an external shutter system.
- o The internal system is less sensitive to thermal leaks due to mechanical tolerances and blade alignment.

4.1.7 Alternate Configuration--Gemini Fuel Cell Module

The Fuel Cell Modular Package is composed of two Gemini Fuel Cells, two electronic control assemblies, Apollo Block No. 2 Reactant Tanks and a Fuel Cell Cooling System. The Block 2 reactant tanks have enough reactants to produce an average power of 800 watts over the entire mission which corresponds to a cooling load of 2200 Btu/hr. In order to comply with the philosophy of using existing hardware, many Gemini Cooling System components are utilized along with the same coolant, MCS, No. 198, a low freezing temperature (-145°F) coolant.

The coolant is pumped through the fuel cell, absorbing the heat of reaction; it then flows to the space radiator where this heat is rejected to space. A water boiler is provided to further absorb heat from the coolant when the radiator is receiving the maximum external heat flux, or when the fuel cell is called upon to deliver peak power for short time intervals. The fuel cell is built integral with the radiators and the cooling system components so as to be one self-contained unit.

Section 6.1 includes a drawing of the installed integrated package. A schematic of the cooling system is presented in Section 5.1.

The available room for fuel cells radiators limits the size of the radiators to approximately 30 sq. ft.. The temperature of the coolant leaving the fuel cell is limited to a maximum of 80°F by the manufacturer; therefore, the maximum heat rejection capabilities of the radiator is approximately 1760 Btu/hr when the radiator is receiving the maximum external heat load. The radiator is made up of two sections at right angles to each other; therefore, they both cannot be exposed to direct sunlight at the same time. In order to meet the maximum cooling requirements under these conditions, a water boiler is incorporated into the system. The water generated by the fuel cell is utilized in the boiler. It is further estimated that, if the fuel cell radiator receives the maximum external heat flux for the full 14-day mission, the fuel cell will generate enough water to make up the deficiency in the radiator heat rejection capabilities.

The fuel cells cooling loop is split into two parallel branches, each leg receiving half the total coolant flow of 220 lb/hr. The coolant in each branch experiences a 22°F rise, absorbing the 1100 Btu/hr fuel cell heat dissipation. Restricting the maximum outlet temperature to 80°F limits the maximum inlet temperature to 58°F . The lower limit of coolant inlet temperature is limited to 40°F to prevent freezing of the fuel cell.

The Apollo Block 2 reactant tank will be located in 130°F environment. At this temperature the usage rate exceeds the boil-off rate; therefore, no venting of the tanks is required.

4.1.8 Alternate Configuration--Incorporation of Radiator into Thermal Control System

As an alternative to the proposed ECS, a radiative heat sink system is proposed. This system will be considerably lower in system weight but will represent a greater degree of system modification to the basic LEM configuration. More design information on radiator systems are presented in the Phase II Lab Report (Vol. IV).

The radiative heat sink system is the basic LEM system with a regenerative heat exchanger and radiator installed between the battery and No. 224 water boiler of the basic LEM system. In addition, the system fluid is changed from the 35% glycol-65% water solution to 62.5% glycol-37% water solution. The regenerative heat exchanger is necessary to raise the system glycol temperatures under low load conditions and thus protect the equipment from the low glycol temperatures leaving the radiator. The fluid change is necessary to protect against fluid freezing at the low radiator temperatures.

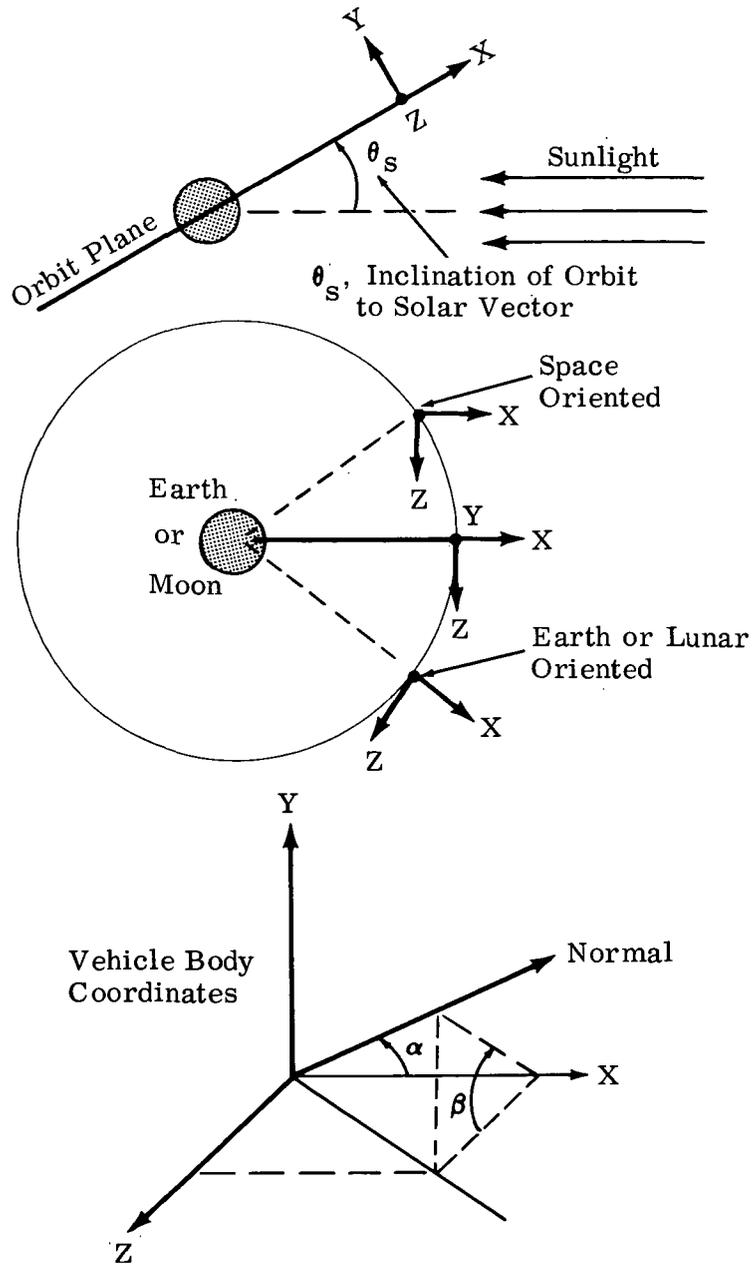
The system is shown schematically on Fig. 4.1-10 and shows loads and temperatures throughout the system for maximum and minimum loads. Minimum load values are shown bracketed. The capacity of the system is adequate without the use of either boiler. The water supply to No. 209 water boiler is always shut; the water supply to No. 224 boiler can be turned on when loads greater than that defined by maximum average load is experienced. This could be accomplished by sensing the glycol temperature downstream of the battery.

The radiator is a 30-sq ft radiator with 15 sq ft sections located 180° apart. The maximum average absorbed radiation will be about 35 Btu/hr/sq ft. This radiator with its associated hardware should weigh less than 60 lb. The regenerative heat exchanger consists of two No. 204 LEM heat exchangers with a dry weight of approximately 6.4 lb.

Under maximum load, the radiator system is capable of holding a 75°F cabin temperature with no water consumption. Maximum load is identical to the maximum load of the water boiling system (Section 4.1.3).

Under minimum load conditions, the system can hold a 75°F cabin temperature with no water consumption. Minimum load consists of zero watts experimental and 250 watts structural heat leak. The proposed radiator system can also hold the cabin at 75°F, if the 150 watt experimental load is turned on and the cabin heat leak is increased to 400 watts (Same total load).

The weight savings of this alternate configuration are as described in Section 5.2.7.



Altitude, n mi
Orbit
 θ_s , deg

Surface Orientation, deg		Solar Rad
α	β	
45	0	13
	45	11
	90	9
	135	11
	180	13
	225	11
	270	9
90	0	9
	45	6
	90	6
	135	6
	180	9
	225	6
	270	6
135	0	3
	45	2
	90	2
	135	2
	180	3
	225	2
	270	2
0	-	14
180	-	

4.1-1

(1)

→ 200
Earth (Earth-Oriented)
→ Zero

200
Earth (Earth-Oriented)
30

200
Earth (E
60

ation	Albedo Radiation	Direct IR Radiation	Solar Radiation	Albedo Radiation	Direct IR Radiation	Solar Radiation	Alb Rac
0.118	2.089	2.546	117.519	1.811	2.546	70.534	1
0.892	2.081	2.546	56.578	1.647	2.546	0.	0
0.698	2.072	2.546	23.039	1.576	2.546	0.	0
0.895	2.081	2.546	56.581	1.647	2.546	0.	0
0.121	2.089	2.546	117.522	1.811	2.546	70.535	1
0.855	2.081	2.546	158.937	1.966	2.546	177.388	1
0.636	2.072	2.546	177.703	2.027	2.546	235.230	1
0.852	2.081	2.546	158.934	1.966	2.546	177.388	1
0.493	16.655	20.290	84.053	14.438	20.290	58.270	8
0.129	16.636	20.291	18.142	13.711	20.291	0.	7
0.053	16.611	20.286	0.	13.401	20.291	0.	6
0.128	16.636	20.290	18.142	13.711	20.291	0.	7
0.492	16.655	20.290	84.054	14.438	20.290	58.271	8
0.091	16.636	20.290	115.855	15.142	20.291	157.484	9
0.	16.610	20.286	138.243	15.426	20.290	279.284	10
0.091	16.636	20.291	115.854	15.142	20.291	157.483	9
0.923	37.643	45.858	37.572	32.627	45.858	32.790	18
0.684	37.635	45.858	9.865	31.769	45.858	0.	17
0.475	37.626	45.858	0.	31.411	45.858	0.	16
0.680	37.635	45.858	9.863	31.769	45.858	0.	17
0.919	37.643	45.858	37.570	32.627	45.858	32.789	18
0.667	37.634	45.858	45.751	33.474	45.858	101.859	20
0.462	37.625	45.858	40.843	33.823	45.858	159.741	21
0.670	37.634	45.858	45.753	33.474	45.858	101.858	20
0.949	0.	0.	122.078	0.	0.	70.456	0
0.731	50.280	61.253	9.011	43.580	61.253	17.117	21

4, 1-1
②

Table 4.1-1
 AVERAGE INCIDENT RADIATION TO
 SATELLITE FOR ONE ORBIT

Earth-Oriented)		200	Earth (Earth-Oriented)		80	Lunar (Lunar-Oriented)		Zero
		90			Zero			
Incident Radiation in Btu/hr-sq ft								
Albedo	Direct IR Radiation	Solar Radiation	Albedo Radiation	Direct IR Radiation	Solar Radiation	Albedo Radiation	Direct IR Radiation	Albedo Radiation
0.054	2.546	0.031	0.190	2.546	136.012	0.244	34.0	0.244
0.786	2.546	0.	0.006	2.546	120.885	0.243	34.0	0.243
0.680	2.546	0.	0.	2.546	99.653	0.241	34.0	0.241
0.786	2.546	0.	0.006	2.546	120.887	0.243	34.0	0.243
0.054	2.546	0.031	0.190	2.546	136.014	0.244	34.0	0.244
0.338	2.546	221.952	0.644	2.546	120.846	0.243	34.0	0.243
0.461	2.546	313.888	0.902	2.546	99.631	0.241	34.0	0.241
0.338	2.546	221.953	0.644	2.546	120.844	0.243	34.0	0.243
0.386	20.291	0.023	1.289	20.286	97.845	2.551	34.0	2.551
0.166	20.291	0.	0.196	20.291	69.207	2.546	34.0	2.546
0.671	20.290	0.	0.000	20.290	0.055	2.540	34.0	2.540
0.166	20.291	0.	0.196	20.290	69.206	2.546	34.0	2.546
0.386	20.290	0.022	1.289	20.286	97.844	2.551	34.0	2.551
0.646	20.291	313.884	3.060	20.290	69.168	2.546	34.0	2.546
0.178	20.290	443.900	4.050	20.290	0.	2.540	34.0	2.540
0.646	20.291	313.885	3.060	20.291	69.168	2.546	34.0	2.546
0.939	45.858	0.031	2.589	45.855	44.181	6.154	83.0	6.154
0.470	45.858	0.	1.018	45.858	29.040	6.152	83.0	6.152
0.866	45.858	0.	0.437	45.858	7.826	6.150	83.0	6.150
0.470	45.858	0.	1.018	45.858	29.037	6.152	83.0	6.152
0.939	45.858	0.031	2.589	45.858	44.178	6.154	83.0	6.154
0.425	45.858	221.952	4.430	45.858	29.023	6.152	83.0	6.152
0.045	45.858	313.888	5.263	45.858	7.820	6.150	83.0	6.150
0.425	45.858	221.953	4.430	45.858	29.026	6.152	83.0	6.152
0.	0.	0.023	0.	0.	140.942	0.	0.	0.
0.294	61.253	0.023	3.392	61.253	11.068	8.357	113.0	8.357

4.1-1
 (3)

200
Earth (Space-Oriented)
Zero

200
Earth (Space-Oriented)
30

Direct IR Radiation	Solar Radiation	Albedo Radiation	Direct IR Radiation	Solar Radiation	Albedo Radiation	Direct IR Radiation	Scattered Radiation
324	190.276	7.142	24.718	169.477	6.199	24.718	
302	190.278	6.108	23.237	100.329	5.014	23.238	
277	190.228	5.296	22.078	71.634	4.165	22.078	
302	190.156	6.116	23.237	100.203	5.019	23.237	
324	190.104	7.153	24.718	169.299	6.207	24.718	
302	190.103	6.116	23.237	238.447	5.603	23.238	
276	190.153	5.296	22.078	267.142	5.044	22.078	
302	190.225	6.108	23.237	238.573	5.597	23.237	
745	0.122	19.264	24.718	0.125	16.699	24.717	
667	0.124	17.741	22.078	0.	14.672	22.079	
567	0.053	16.542	20.200	0.	13.353	20.216	
667	0.	17.754	22.078	0.	14.680	22.077	
745	0.	19.281	24.718	0.	16.712	24.717	
666	0.	17.753	22.078	97.664	16.107	22.079	
565	0.	16.541	20.200	138.243	15.369	20.216	
666	0.049	17.741	22.078	97.841	16.096	22.077	
800	0.	33.466	24.718	0.	28.999	24.718	
735	0.	32.433	23.237	0.	27.390	23.238	
686	0.	31.622	22.078	0.	26.419	22.078	
735	0.	32.443	23.237	0.	27.396	23.237	
800	0.	33.480	24.718	0.	29.009	24.718	
733	0.	32.442	23.237	0.	28.830	23.238	
683	0.	31.621	22.078	0.	28.392	22.078	
733	0.	32.433	23.237	0.	28.822	23.237	
	268.972	2.655	24.718	239.553	2.309	24.717	
715	0.	39.886	24.718	0.	34.555	24.717	

9.1-1

(4)

200
Earth (Space-Oriented)
60

200
Earth (Space-Oriented)
90

Solar Radiation	Albedo Radiation	Direct IR Radiation	Solar Radiation	Albedo Radiation	Direct IR Radiation
14.171	3.635	24.718	0.204	1.433	24.719
0.	2.622	23.239	0.	0.489	23.241
0.	1.974	22.078	0.	0.210	22.079
0.	2.623	23.237	0.	0.488	23.238
12.964	3.637	24.718	0.	1.431	24.719
53.638	3.636	23.239	221.913	2.503	23.240
11.553	3.493	22.078	313.950	3.060	22.079
53.785	3.634	23.237	222.115	2.504	23.238
0.146	9.704	24.717	0.201	1.435	24.719
0.	7.726	22.080	0.	0.212	22.081
0.	6.647	20.215	0.	0.000	20.213
0.	7.726	22.077	0.	0.211	22.077
0.	9.707	24.717	0.	1.433	24.719
97.380	10.198	22.080	313.742	3.063	22.081
79.284	10.141	20.215	443.900	4.034	20.213
97.587	10.194	22.077	314.028	3.065	22.077
0.	16.802	24.718	0.080	1.438	24.719
0.	15.055	23.239	0.	0.492	23.240
0.	14.190	22.078	0.	0.212	22.079
0.	15.056	23.237	0.	0.491	23.238
0.	16.804	24.718	0.	1.436	24.719
25.502	17.538	23.239	221.789	2.510	23.241
83.417	17.612	22.078	313.826	3.068	22.079
25.649	17.535	23.237	221.991	2.511	23.238
61.318	1.384	24.718	0.088	1.431	24.719
0.	20.006	24.718	0.	1.438	24.719

4.1-1

(5)

Gumman

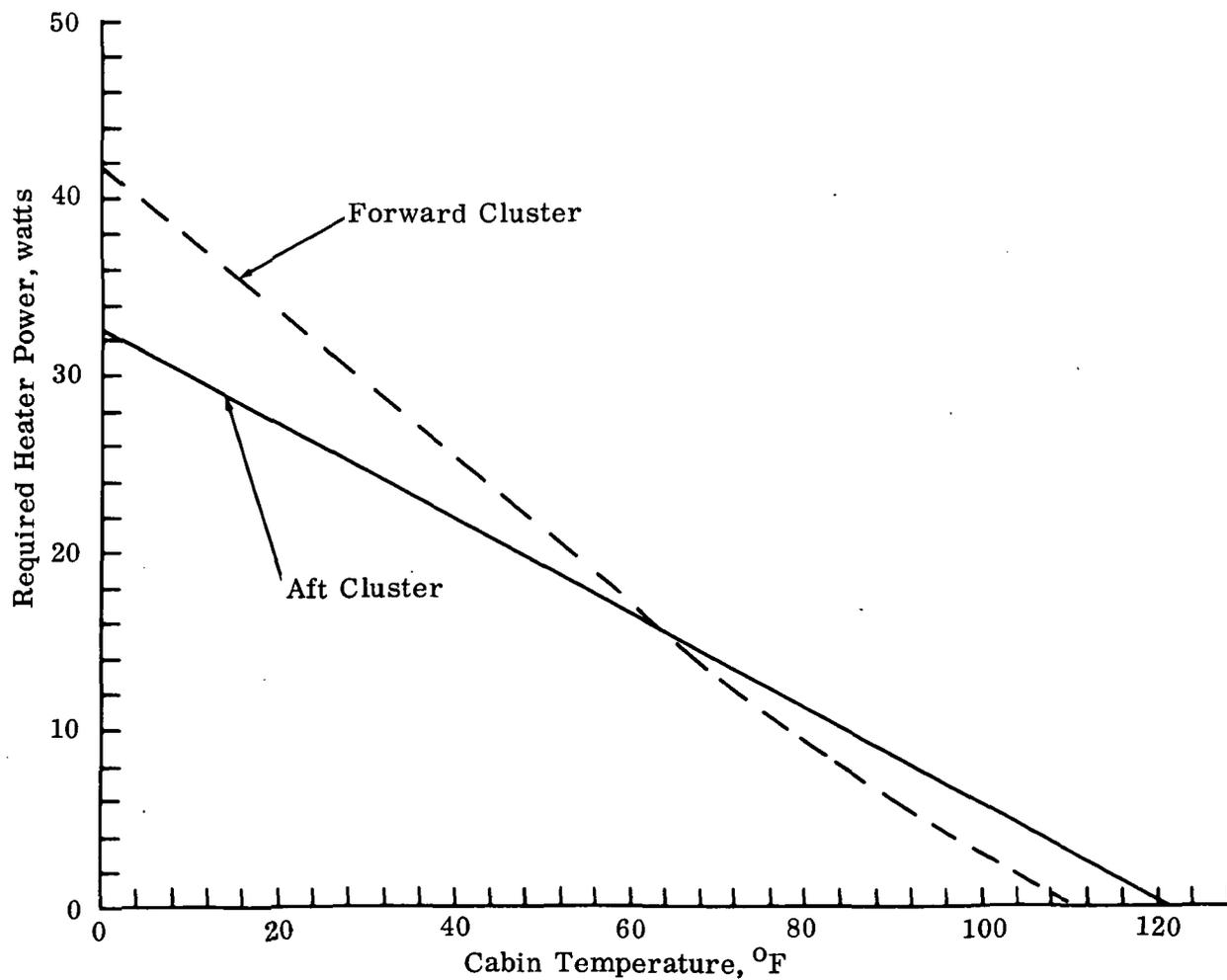


Fig. 4.1-1 RCS Electrical Heater Power vs Cabin Temperature

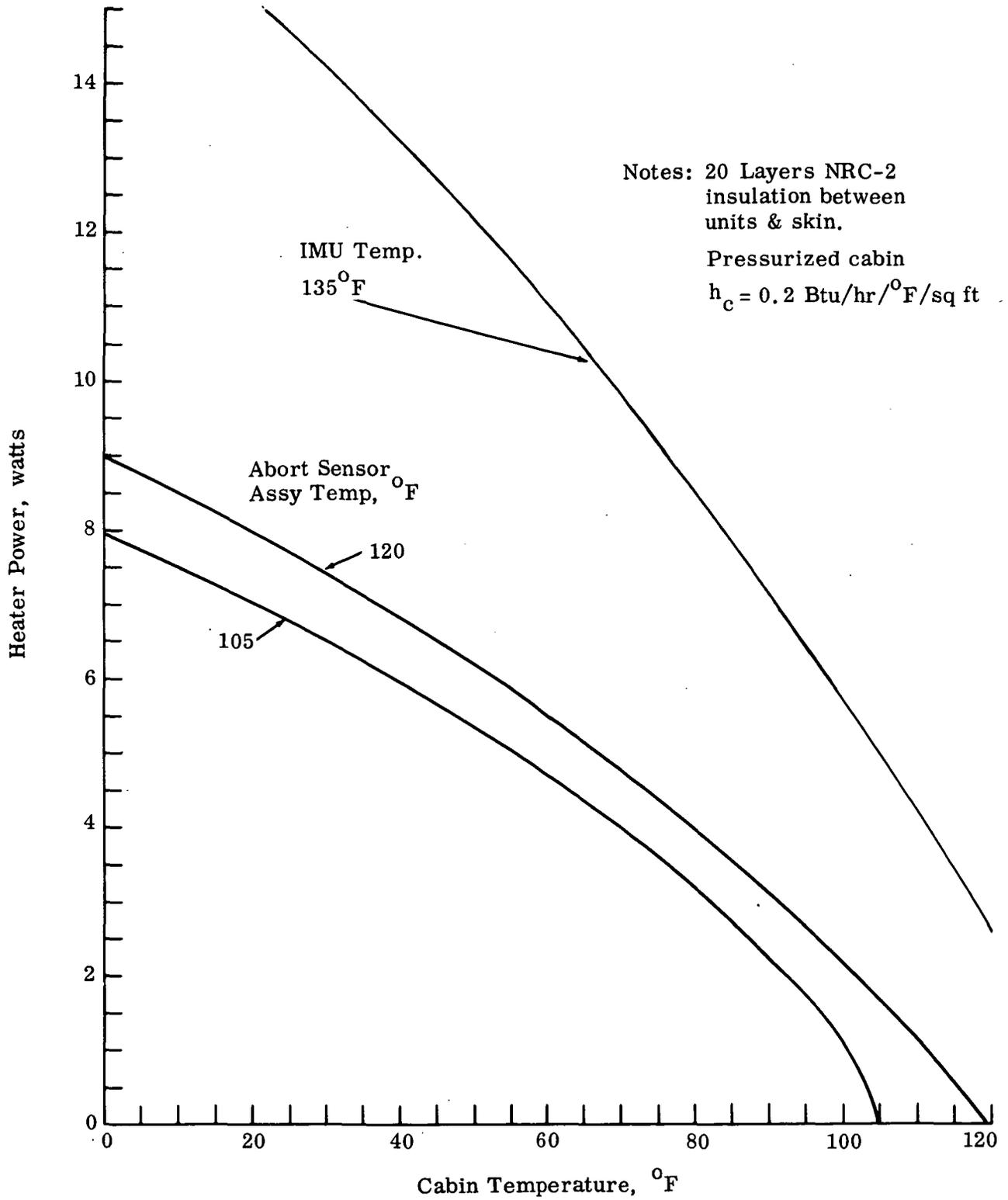
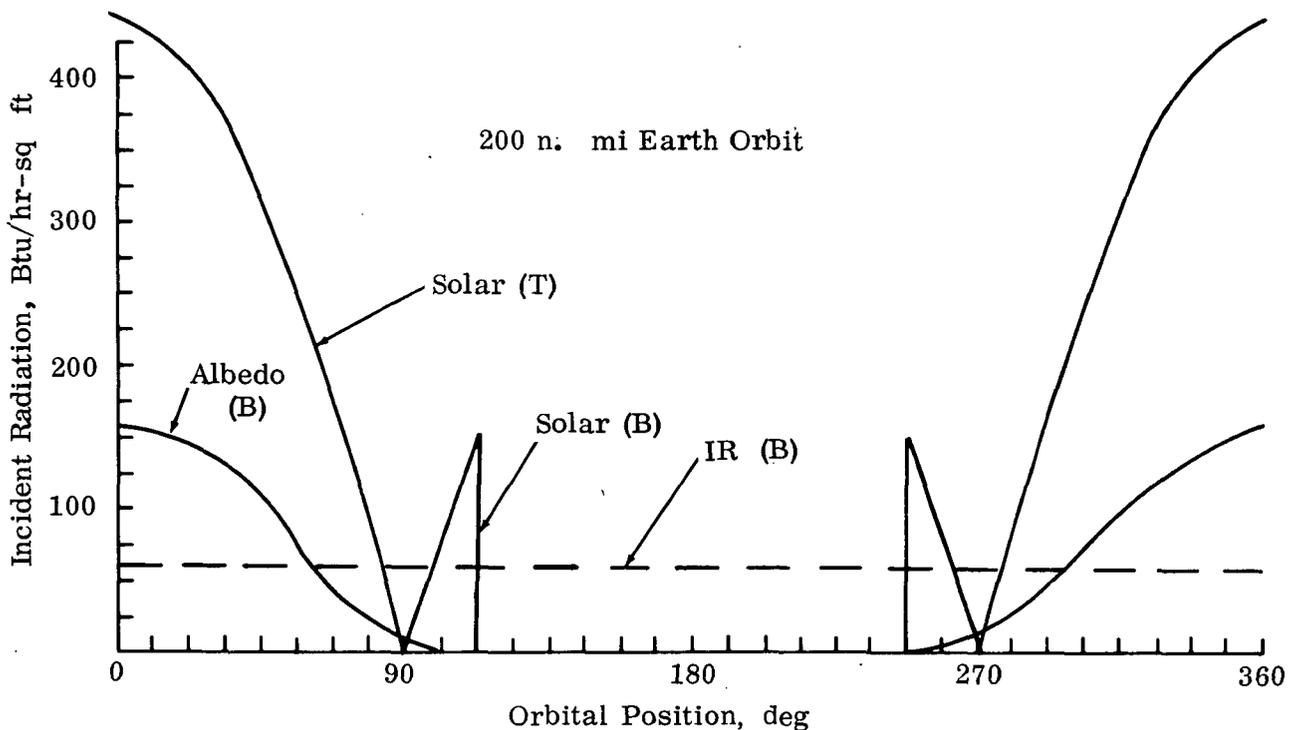


Fig. 4.1-2 IMU and ASA Heater Power vs Cabin Temperature



Key B: Bottom Surface
T: Top Surface

Note: Solar Vector Parallel
To Orbital Plane

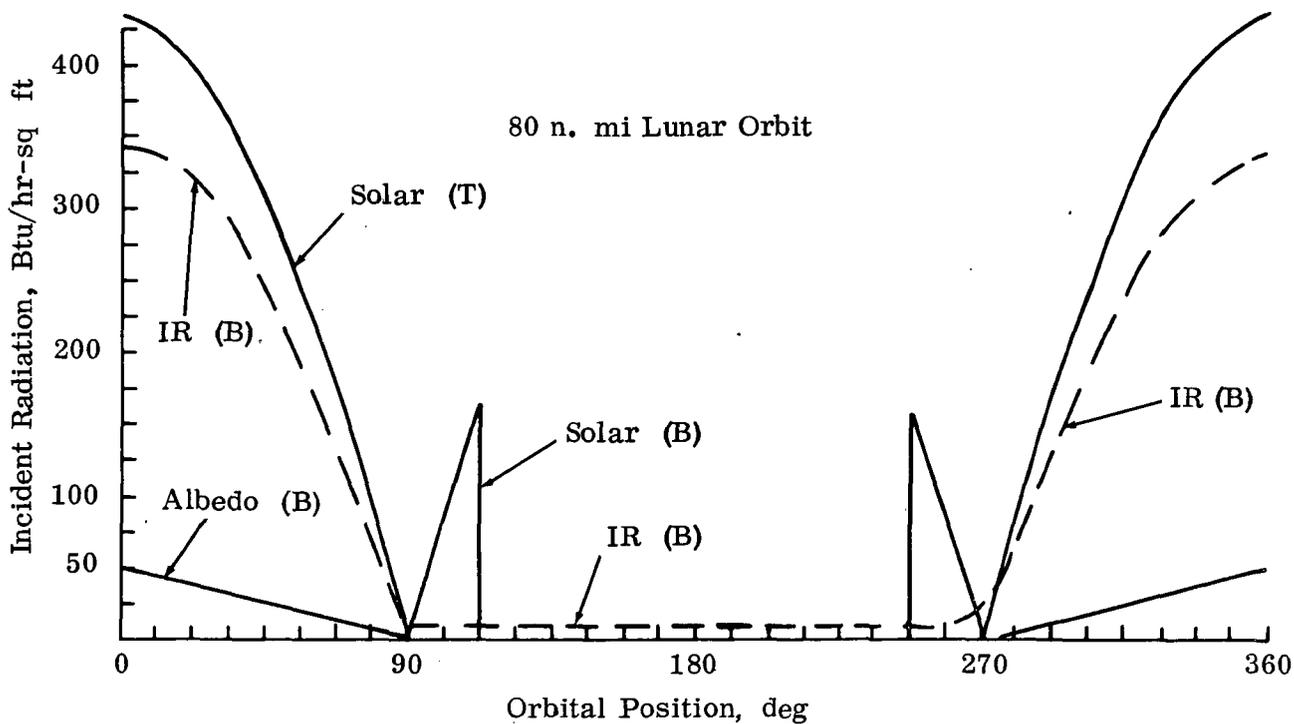


Fig. 4.1-3 Variation in Thermal Environment

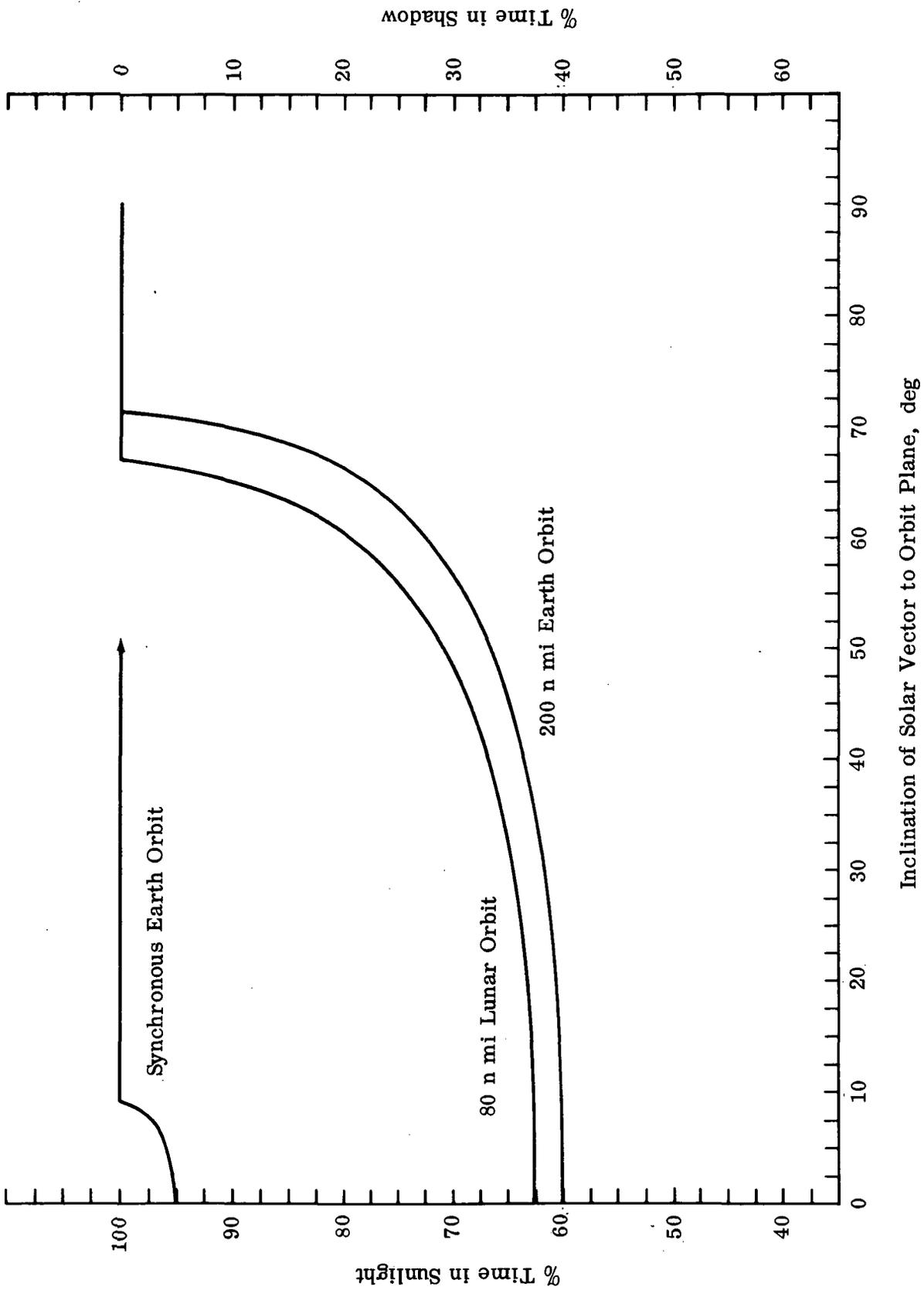
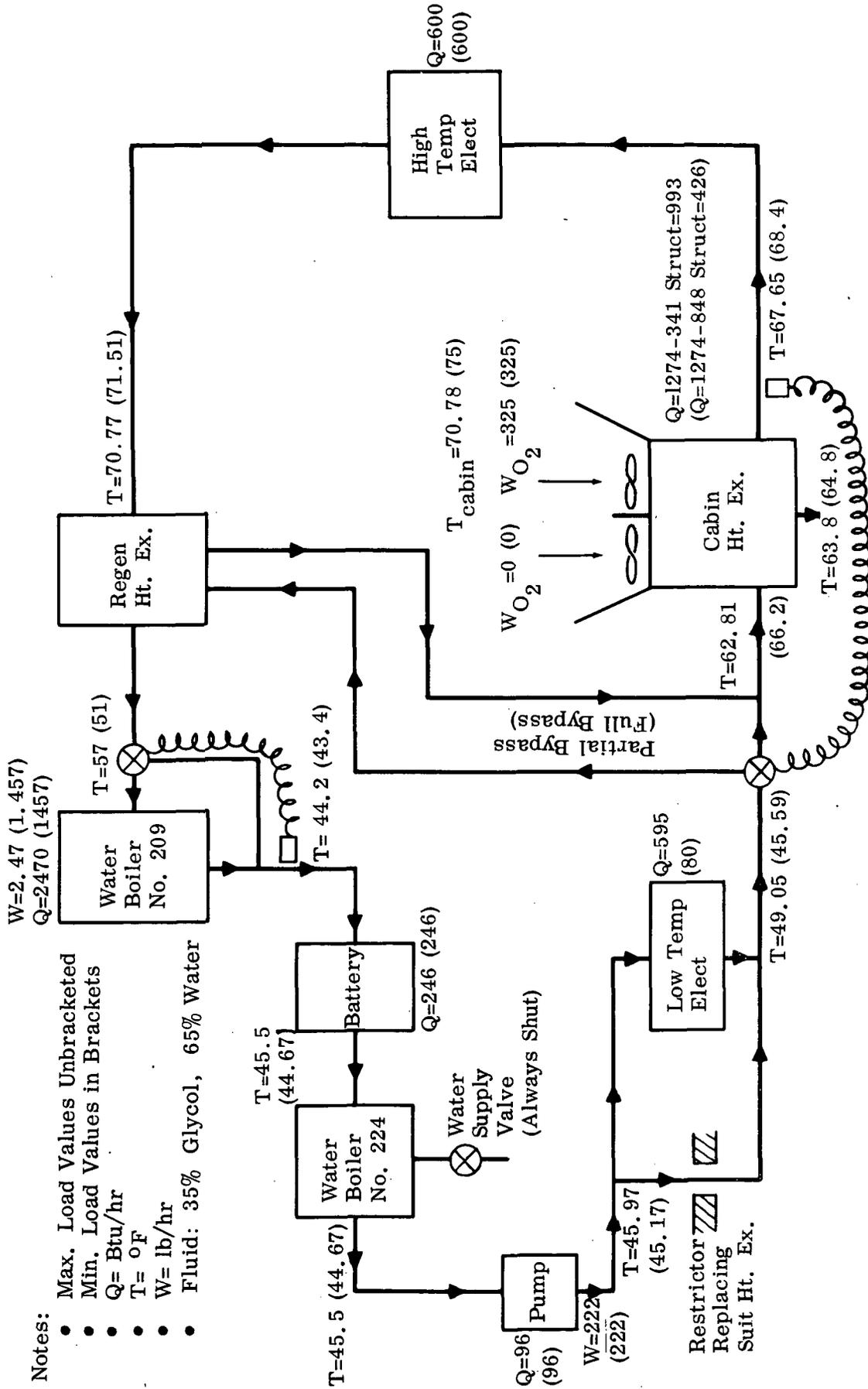


Fig. 4.1-4 Percent Time in Sun for Phase One Labs.



Notes:

- Max. Load Values Unbracketed
- Min. Load Values in Brackets
- $Q=$ Btu/hr
- $T=$ °F
- $W=$ lb/hr
- Fluid: 35% Glycol, 65% Water

Fig. 4.1-5 ECS System All Water Boiling

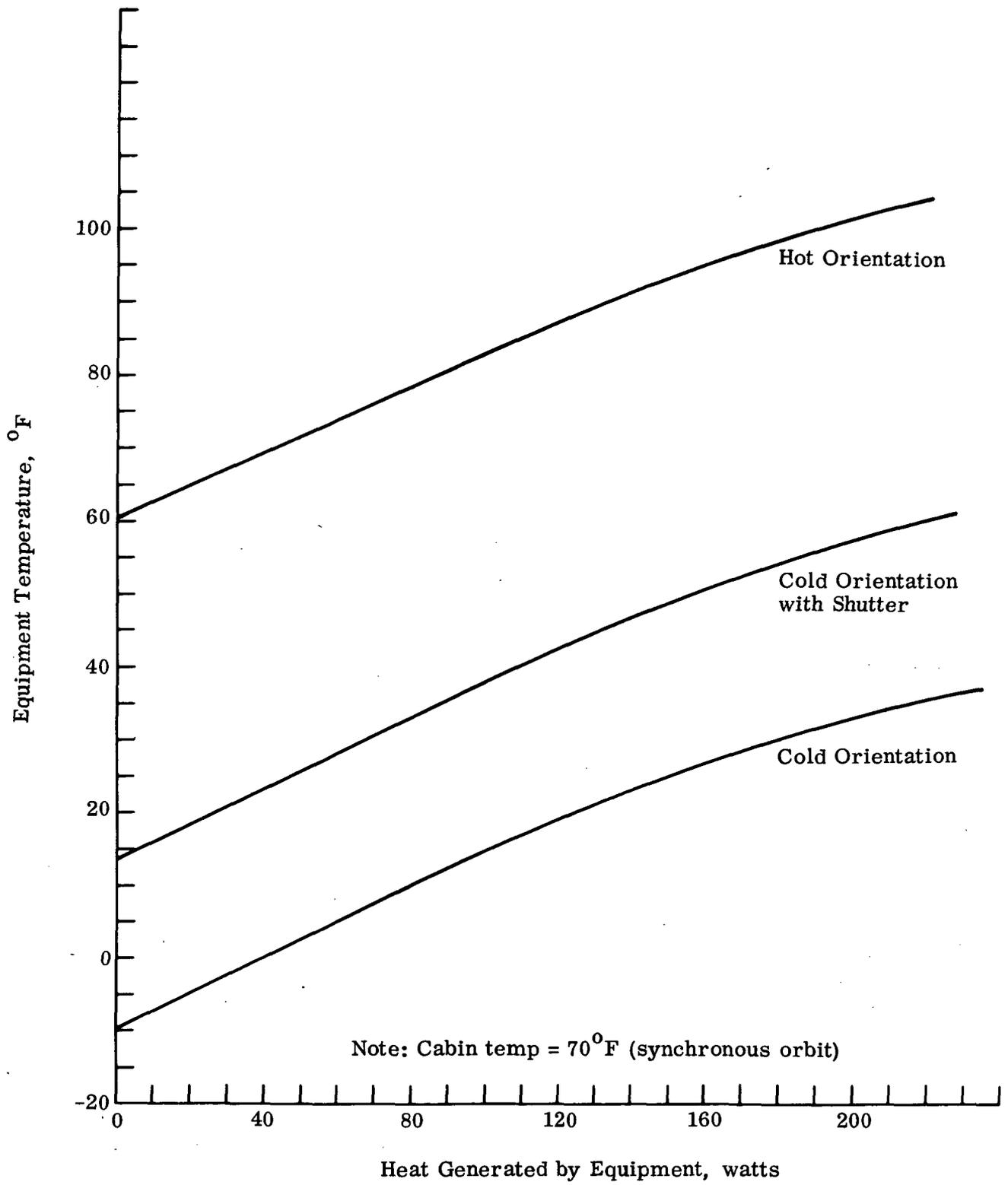


Fig. 4.1-6 Aft Equipment Bay Passive Cooling Design Equipment Temperature vs Heat Generated

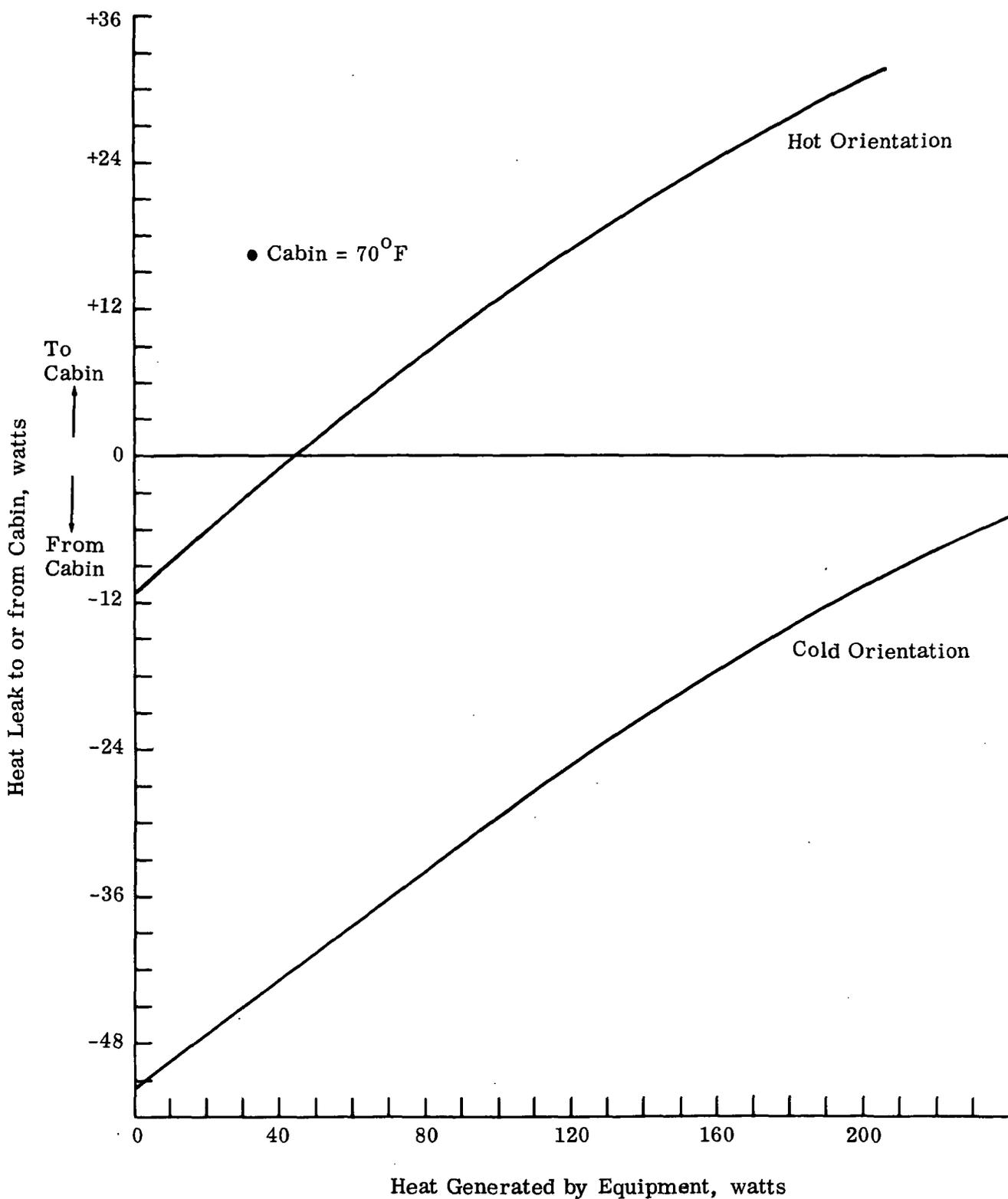


Fig. 4.1-7 Aft Equipment Bay Heat Leak to or From Cabin

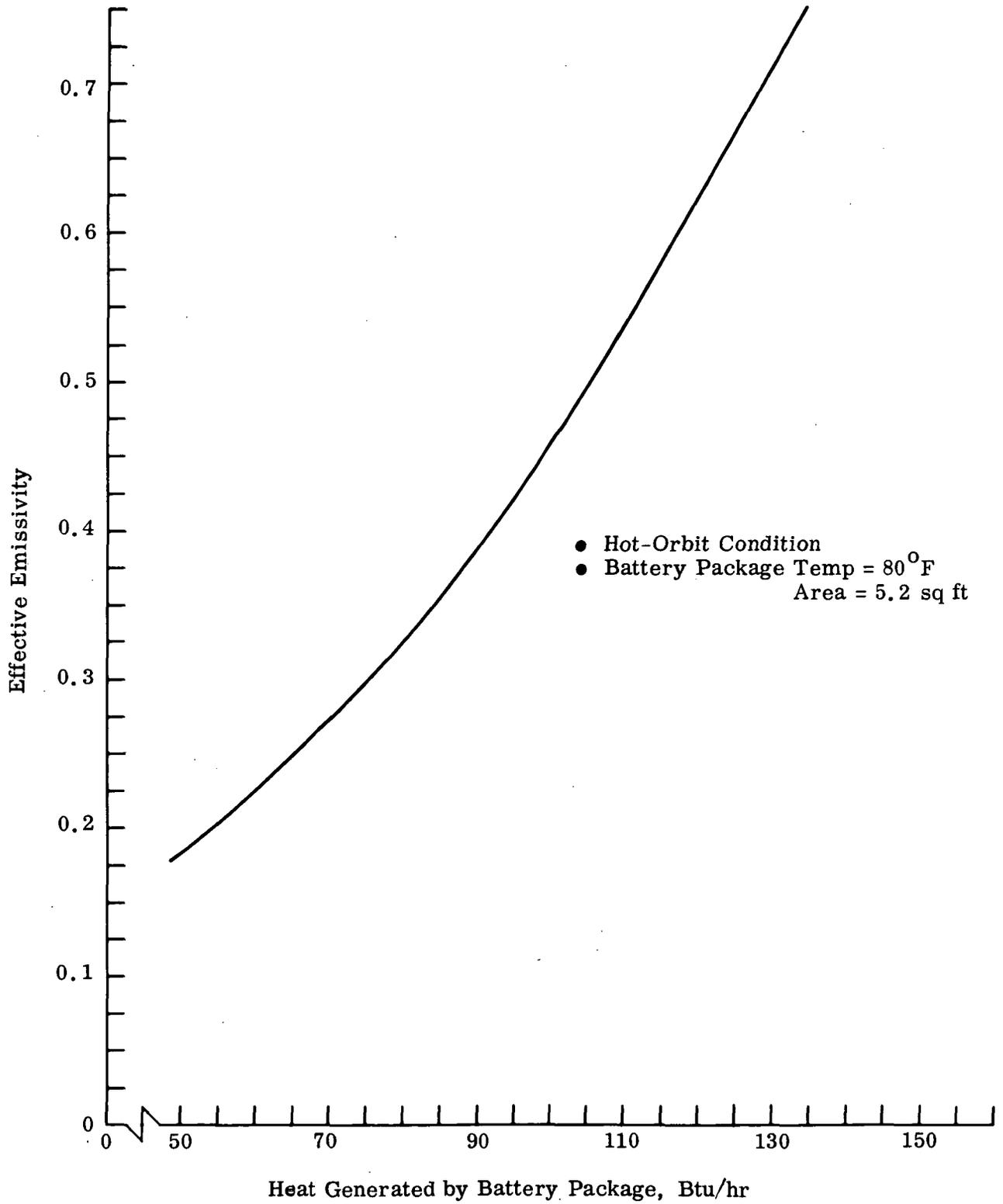


Fig. 4.1-8 Battery to Skin Effective Emittance vs Heat Generated

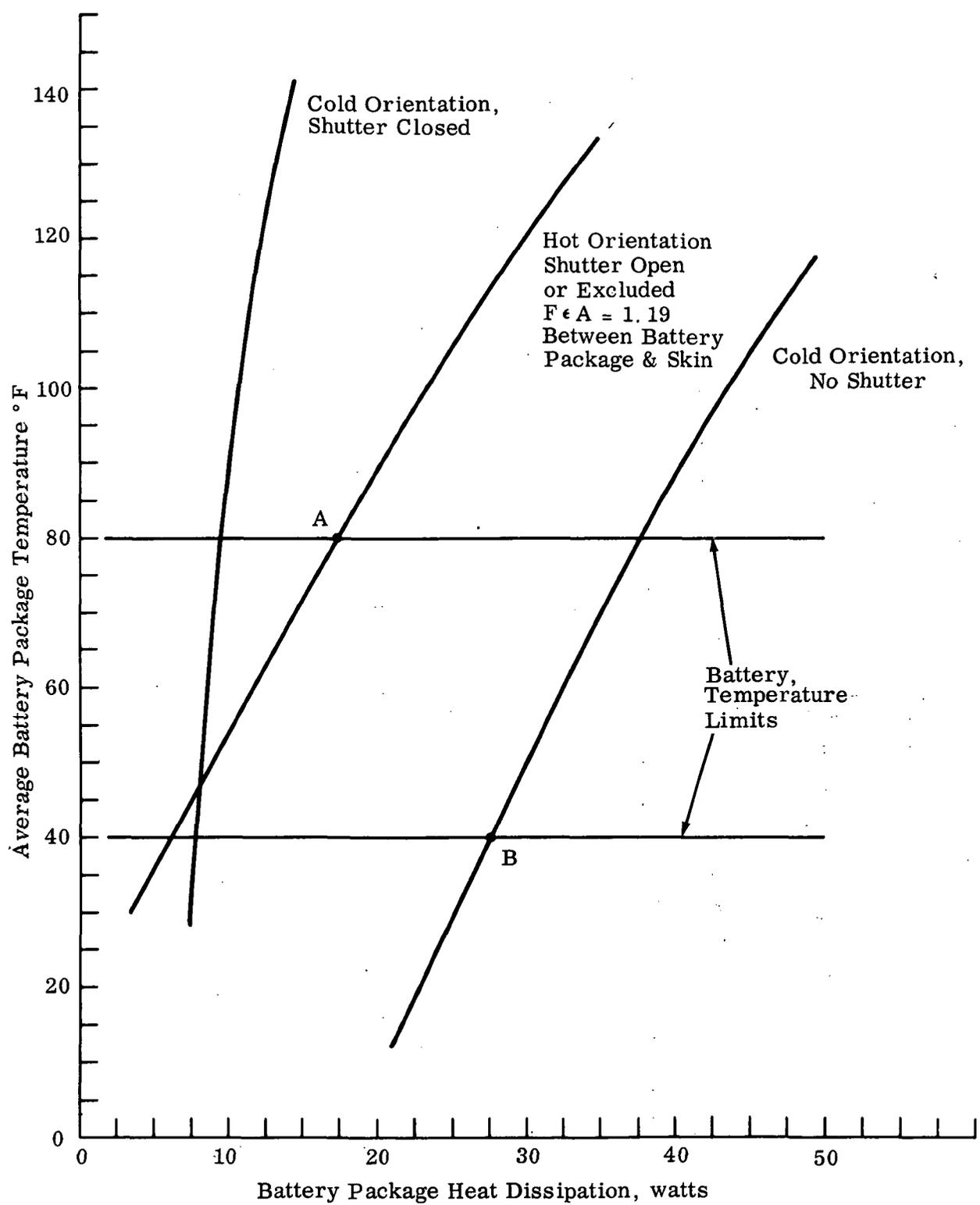


Fig. 4.1-9 Performance of Battery Package with Internal Shutter
Battery Temperature vs Heat Dissipation

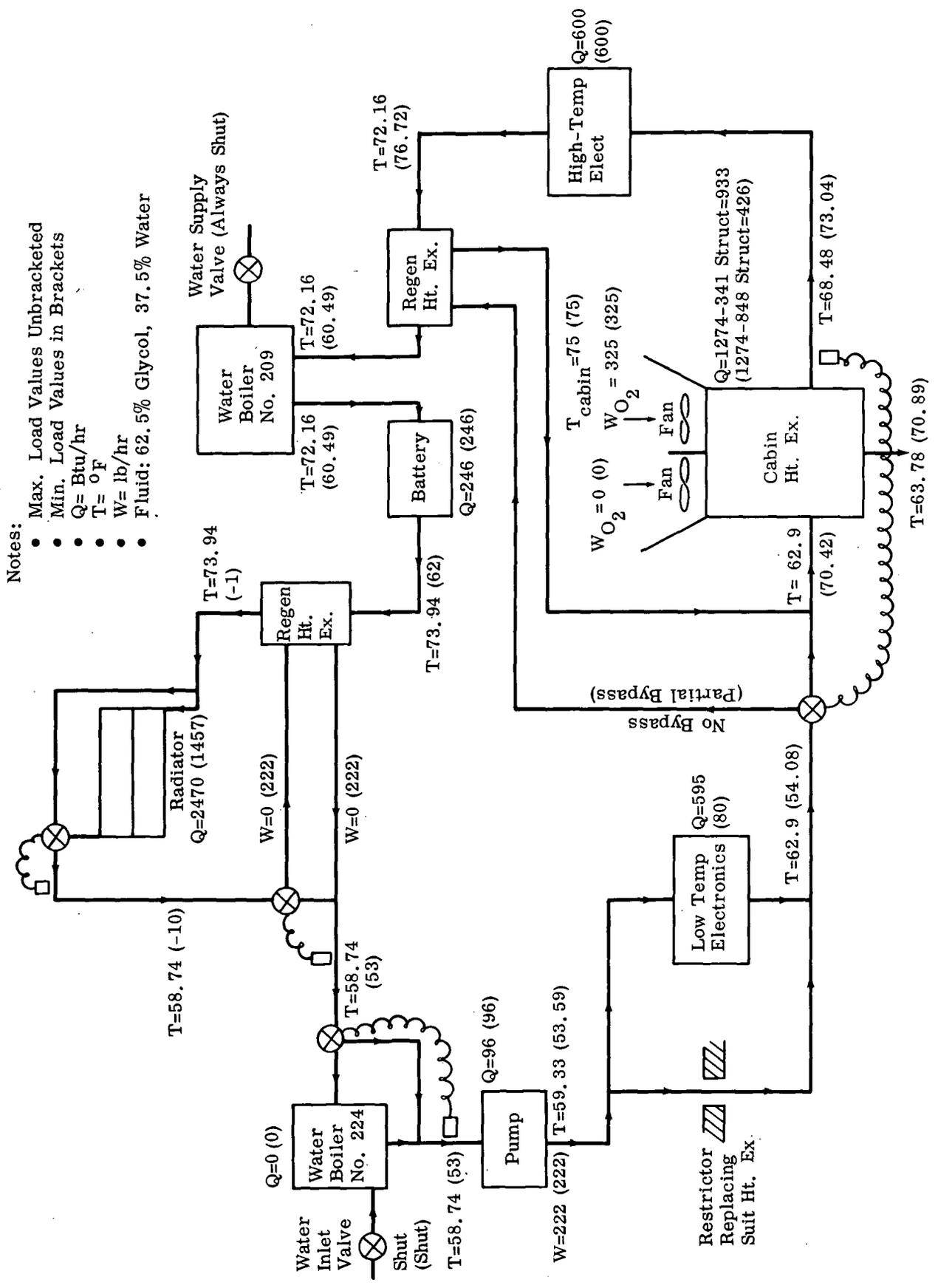


Fig. 4.1-10 ESC Loop with Space Radiator

4.2 INTEGRATED GUIDANCE AND CONTROL

4.2.1 Assumptions

Major assumptions made in defining the IGNC for the Phase I Labs were:

- All translation and orbital maneuvering capability will be supplied by CSM.
- Lab will provide the orbital attitude hold capability within the limits of the recommended configuration. Capability beyond these limits will be supplied by the Experiment package.
- There is no electrical interface for control between the Lab and the CSM.
- All missions have RCS in the Lab
- There is no main propulsion system in the Lab.

4.2.2 Background Data

4.2.2.1 Control System Schematic

Figure 4.2-1 is the simplified block diagram for the AGS control system configuration. Location and numbering sequence for the RCS thrusters is shown in Fig. 4.2-2. The characteristics of the RCS given in Reference 4.2-1 were used in the various analyses. Since there is no requirement for translational capability, consideration of rotations resulting from translation thrusting along the $\pm Y$ or $\pm Z$ axes were omitted.

4.2.2.2 Environmental Disturbance Torques

A preliminary analysis of the external disturbance torques affecting the lab in Earth orbit was reported in Ref. 4.2-9. Gravity gradient and aerodynamic torques were estimated to be the most significant. Magnetic disturbance torques are dependent upon: vehicle shape, ambient field, and location and magnetic qualities of ferromagnetic elements stored in the vehicle and the induced fields due to electrically powered components. Therefore, computing a reasonable estimate of the magnetic torque is not feasible at this time. This is due to the fact that the field-producing components cannot be located adequately in a vehicle configuration which is not fully defined.

For purposes of defining reference torques for the Lab, a configuration showing high moments of inertia was used. This configuration is shown in Fig. 4.2-3. Moments of inertia about the X, Y, and Z body axes were estimated to be 40,629, 237,531, and 235,721 slug-ft², respectively. Five percent of the Z-axis moment of inertia (i.e., 11,786 slug-ft²) was used as an estimate of the cross-products of inertia.

A peak gravity gradient torque of 0.374 ft-lb can be expected for this vehicle in an inertially oriented mode. One-half of the peak value (i.e., 0.187 ft-lbs) is assumed to be the most probable average value. The peak aerodynamic torque is 0.079 ft-lb; the average value is taken as half the peak value, or 0.040 ft-lbs.

The figures for aerodynamic torque include a factor of 5 to account for diurnal and seasonal variations in dynamic pressure. The following summarizes the torque environment for the reference flight with the vehicle in a fixed inertial orientation.

<u>Source</u>	<u>Average (Ft-lbs)</u>	<u>Peak (Ft-lbs)</u>
Gravity Gradient	0.187	0.380
Aerodynamic	0.040	0.079
TOTAL	0.227	0.388 (RSS)

For an inertially-oriented vehicle, the procedure used to obtain the total from all sources is similar to that used in the definition of the torque environment of the OAO. Average values are summed, but peak values are computed on a root-sum-squared basis since it is probable that each component of torque will not peak at the same time point in the orbit.

For the case where the reference flight is oriented to within ± 5 -deg of the local vertical (assumed dead band limits), the maximum bias torque due to the gravity gradients will be 0.0295 ft-lbs. Aerodynamic torques which result from an angle of attack corresponding to the ± 5 -deg deviation from the local vertical, are negligible compared to the gravity gradient torque.

The gravity gradient torques were computed using methods based upon the following procedures. The total gravity torque vector always lies in the horizontal plane, (i.e., the plane normal to the local vertical direction) and is dependent upon the angles between the vehicle principal axes of inertia and the local vertical. The maximum torque occurs when the minimum moment of inertia axes is at an angle of 45 deg from the vertical. An attitude which places two of the vehicle's principal axes in the horizontal plane and the third axis along the vertical which will result in zero-g gradient torque.

Figure 4.2-4 indicates the torque-producing effects of variations in vehicle attitude relative to the local vertical. These curves have been developed for general application to any vehicle in a 200-n.mi altitude circular orbit. In generating the data for Fig. 4.2-4, cross products of inertia were assumed to be zero. Rotations about the vehicle's X axis were not considered. Figure 4.2-5 demonstrates the cyclic characteristics of the gravity gradient torque for the reference vehicle, held in an inertial orientation.

The aerodynamic torques shown in Fig. 4.2-6 and 4.2-7 were calculated for various AES configurations using a free-molecule flow analysis. Aerodynamic pressure and shear stresses were calculated based on incremental surface area elements of the idealized vehicle configuration shown in Fig. 4.2-3. The analysis includes the effects of structural shadowing of the aerodynamic flow.

The solid and dashed curves of Fig. 4.2-7 represent the aerodynamic torque variation for the maximum and minimum X-axis excursion of the vehicle cg, measured from the base of the CM. Computation of the torque profile was based on the ARDC 1962 Standard Atmosphere. However, the dynamic pressure can be assumed to be at least 5 times the standard dynamic pressure at 200 n.mi due to:

- Diurnal atmospheric bulge
- Seasonal variations
- Density changes caused by solar activity

Until a more detailed review of research in the area of atmospheric variations can be performed, a confidence factor of 5 is applied to the aerodynamic torques purposes of computing propellant requirements.

Maximum aerodynamic torques are experienced at attitudes which place the vehicle's X axis normal to the relative wind (assumed to lie at the intersection of the horizontal plane and the plane of the orbit). Minimum aerodynamic torques are experienced when the vehicle's X axis is parallel to the relative wind.

4.2.2.3 Orbital Decay

The orbital decay of the Lab stored in orbit is a consideration that could affect GN&C requirements. If orbital decay is severe, stabilization of the vehicle and a subsequent reset of the orbit using the GN&C Subsystem would be required. Figure 4.2-8 shows the initial Lab circular orbit altitude required to achieve a 200-n.mi orbit after 60 days as a function of the ballistic parameter, $W/C_D S$. Figure 4.2-9 presents the ballistic parameters for several Lab configurations. For the Lab alone, a ballistic parameter of no less than 30 is expected. Since $W/C_D S$ will never be less than 30, the maximum initial orbital altitude can be as low as 210 n.mi. This will assure a 200-n.mi altitude for up to 60 days.

4.2.2.4 Ground Tracking Coverage for Earth Orbital Missions

Analyses were performed to determine tracking station coverage in terms of time of entrance to and exit from the station coverage. This data was generated for several typical AES Earth orbit missions. The following assumptions were made:

- Parking orbit insertion is taken as mission initiation
- Thrusting maneuvers, involving Hohmann transfers to the higher operational orbits, were not considered
- All orbits were assumed circular.

The 11 Near Space Instrumentation Facility Stations were included in the tracking model. For polar orbit missions, the Fairbanks, Alaska, site also was included. Table 4.2-1 presents a typical data output for 14 orbits, assuming 28.5-deg inclination, 200-n.mi altitude orbit. Additional data has been compiled for as many as 50 orbits. An evaluation of this data can be found in Paragraph 5.5.

4.2.3 Recommended Configuration

The recommended attitude control system configuration which provides for flexibility and future growth, consists of the following LEM assemblies:

- Abort Sensor Assembly (ASA)
- Abort Electronics Assembly (AEA)
- Modified Rate Gyro Assembly (RGA) *
- Attitude and Translation Control Assembly (ATCA)
- Attitude Controller Assembly (ACA)

* RGA modified to sense rates of $3.25/I_m$ rad/sec., where I_m is maximum moment of inertia in slug-ft².

- Translation Controller Assembly (TCA)
- Reaction Control System (RCS)

A block diagram of this attitude control system is presented in Fig. 4.2-1. The 16 RCS thrusters which provide the required control torques, are located and numbered as shown in Fig. 4.2-2. The characteristics assumed for the thrusters are given in Ref. 4.2-1.

References 4.2-2 and 4.2-3 were used to establish jet selection for rotational control about a desired axis (Table 4.2-2). The symbolic logic showing routing of signals is presented in Fig. 4.2-10a and 4.2-10b. Note that since main engine signals are non-existent, rotation about Y (pitch) and Z (roll) axes for the recommended configuration is restricted to two-jet operation. Similarly, since no Y or Z translation commands are assumed, X (Yaw) axis rotation will also be restricted to a two-jet operation.

Propellant flow rates for limit cycle operation using this logic are presented in Figs. 4.2-11, 4.2-12, and 4.2-13 for the non-disturbed condition (normal) and in the presence of external disturbance torques. Typical limit cycles for normal and disturbed conditions are shown in Fig. 4.2-14. Figure 4.2-13 is included to show system propellant flow rate for extremely small disturbance torques. It should be noted that minimum point shown on these curves is dependent upon control system deadband and vehicle moment of inertia. This point can be extracted from Fig. 4.2-15 for various values of vehicle moment of inertia and control system deadband for the minimum impulse limit cycle, depicted in Fig. 4.2-14c. The dotted portion of Fig. 4.2-13 represents the transition from a disturbed limit cycle (Fig. 4.2-14c) to a normal limit cycle (Fig. 4.2-14a). Figures 4.2-16 and 4.2-17 present the remaining torque-disturbed limit cycle characteristics which are required to completely define the disturbed limit cycle (Fig. 4.2-14c), parametrically. Similarly, Fig. 4.2-18 presents the normal limit cycle period (Fig. 4.2-14a) which, in conjunction with Fig. 4.2-11, defines the normal limit cycle characteristics, parametrically.

The discussion of the recommended configuration has assumed two-jet rotation about all vehicle axes. An impending change to LEM is to perform all yaw rotations using four jets. This change will be accomplished by causing relay K3 in Fig. 4.2-10b to be de-energized at all times. This would increase yaw axis propellant flow rates by a factor of four.

4.2.4 Baseline Configuration

The baseline configuration attitude control system is identical to that of the recommended configuration except that the present LEM RGA, with an 0.01-deg/sec threshold, is used. This will yield a normal limit cycle of the type depicted in Fig. 4.2-14b, with the propellant flow rates indicated in Fig. 4.2-19. The increasing, rather than decreasing, propellant flow rate as a function of vehicle moment of inertia is attributed to the inability to sense rates less than 0.01 deg/sec (RGA threshold, Refs. 4.2-4, 4.2-5, and 4.2-6).

It can be seen by comparing Figs. 4.2-11 and 4.2-19 that a severe penalty is paid in terms of required propellant, if the present RGA is used. However, disturbed-limit-cycle propellant flow rate is still obtained from Fig. 4.2-12, but the flow rate for extremely small torque disturbances cannot be defined as was done for the recommended configuration (Fig. 4.2-13).

4.2.5 Alternate - Modify ASA and AEA to Provide Rate Information

The feasibility of this approach, based upon deriving rate from attitude information using the AEA, has not been verified for the rate threshold being considered (0.001 deg/sec). Additional analyses are being performed, but the approach does not look promising. This approach which would require hardware modification of the AGS, is competitive with the alternate discussed below.

4.2.6 Alternate Configuration - Use of PGNCs in Lieu of AGS

The LEM abort GN&C Subsystem is the recommended configuration because it is functionally adequate, requires less power, is lighter, and has a higher design operating life (5000 vs 2000 hr for the PGNCs). However, the inherent capabilities of the PGNCs, defined in Refs. 4.2-7 and 4.2-8, afford considerably more mission planning flexibility and some significant advantages when overall control system requirements (including RCS functions) are considered. Tables 4.2-3 and 4.2-4 summarized some of the more significant characteristics.

It can be seen that the PGNCs has the inherent capability of providing low rate thresholds which will result in a near-minimum impulse limit cycle, at all vehicle inertias, in the absence of external torques. Undisturbed limit cycle propellant flow rates and periods for this configuration are shown in Figs. 4.2-11 and 4.2-18. Provision is also made for adjusting (maximizing) electrical thruster signal pulse width to compensate for disturbance torques about the Y and Z axes. This will tend to maximize the I_{sp} . The propellant flow rates, therefore, will approach the ideal values shown in Fig. 4.2-12 (without making any system changes).

The most severe limitation in planning the use of PGNCs is its design operating life of 2000 hr. At present, no attempt has been made to assess the improvement in reliability that might be achieved by use of replaceable spares or by redesign of critical elements. It is understood that AC Spark Plug is currently studying such approaches under contract to NASA. It is assumed that pertinent results from these studies will be made available in timely fashion to the AES associate contractors (GAEC). A considerable improvement in reliability for both the AGS and the PGNCs is possible, if the failure rates of elements not essential to the Lab missions, as currently defined, are excluded.

Scheduling (availability) of PGNCs for missions is also an important consideration which must be assessed by NASA. The schedule does indicate, however, that a considerably larger amount of test data (and time) should have been accumulated for the PGNCs prior to the scheduled launches of early Phase I Labs. Thus, it is expected that a higher level of confidence in this equipment will exist at that time. As the AGS design reaches maturity, a crossover point is anticipated, beyond which the AGS should be able to demonstrate better reliability than the PGNCs at higher confidence levels.

4.2.7 Alternate Configuration - Logic Modification

The recommended configuration, using the LEM ATCA jet select logic, will use only eight RCS thrusters to maintain attitude hold. A modification of the jet select logic, to allow selection of alternate jet pairs, will yield improved mission reliability because of the control redundancy obtained. The other eight RCS thrusters will never be used (Figs. 4.2-10a and 4.2-10b). This modification has no impact on the limit cycle characteristics of the recommended configuration (Paragraph 4.2.3).

4.2.8 Discussion of Configuration Choices

These studies have verified that the Apollo LEM IGNCs equipment can meet the basic requirements for AES missions as presently defined. From an overall cost effectiveness standpoint, a modified version of the LEM abort guidance system is recommended. It provides the desired capability of holding attitudes established by the CSM, weighs less, and requires less power than the PGNCs. It has a design operating life of 5000 hr, as compared to 2000 hr for the PGNCs, and the elements required to provide attitude hold represent the least severe development challenge.

The major control problem will be that associated with the management of momentum exchange phenomena. Thus, any meaningful analysis will be highly dependent on adequate mission/experiment definition and precise knowledge of the vehicle geometry and equipment distribution. Consideration of such factors has underscored the significance of considering detailed dynamic characteristics of control elements, such as the rate gyro and the RCS thrusters, in computing parametric curves for propellant flow rates. On the basis of such results, several alternates to the recommended configuration were presented.

The most significant issues are those relevant to a choice between the AGS and the PGNCs. The latter offers considerably more capability than has been currently specified; it also offers more flexibility and growth potential in accommodating changes to the mission plan or experiment requirements. Greater utilization of this potential possibly could be realized if the opportunity for improved insight to the PGNCs design and into the LGC program structure was afforded Grumman.

The initial edge in confidence level that the PGNCs appears to have is felt to be temporary and would probably diminish as the AGS reaches greater design maturity. However, should "sparing" become desirable, it might be feasible to realize some support of the CSM system with elements from the LEM System. "Sparing" has not been considered to date.

The greatest improvement in reliability can be achieved by judicious scheduling of equipment duty cycles. For instance, the duty cycle of either the AGS or the PGNCs attitude reference equipment could be reduced by making use of the rate gyros in the rate command mode. Thus, a thorough cost effectiveness review depends upon availability of schedules and other mission/experiment planning factors which must be weighed in making decisions on the following factors:

- Automatic Star Tracker or AOT
- Selection of IGNCs configuration from alternates presented
- Define specific reference missions in detail so attitude profiles can be optimized to allow effective control (or use) of all external and internal torques
- Identification of significant design constraints which will have significant impact upon design analyses (i.e., CSM RCS thermal design considerations)
- Philosophy on items, such as "sparing".

Grumman will use these inputs to perform more detailed system performance analyses based upon consideration of detailed dynamic characteristics of all control elements and preparation of an internal torque summary. This will allow appropriate updating and release for approval of specifications for the operational, functional, and performance requirements for the Phase I Lab IGNCs.

Table 4.2-1
TRACKING STATION COVERAGE

Rev	Time In hr min	Time Out hr min	Span, min	Station	Rev	Time In hr min	Time Out hr min	Span, min	Station	
1	0, 1.10	0, 8.67	7.56	GUAYMAS S-BAND	9	13, 35.21	13, 36.79	1.58	ASCENSION FPS-16	
	0, 4.29	0, 11.84	7.55	CORPUS S-BAND		14, 18.65	14, 19.51	0.86	GUAM	
	0, 8.29	0, 15.85	7.56	CCTMA FPS-16		10	15, 14.33	15, 20.83	6.50	CANARY S-BAND
	0, 8.88	0, 16.42	7.54	BAHAMA						
2	0, 12.16	0, 18.88	6.72	BERMUDA FPS-16	11	16, 39.92	16, 46.41	6.49	ANTIGUA FPS-16	
	0, 13.98	0, 20.65	6.66	ANTIGUA FPS-16		16, 51.14	16, 58.67	7.54	CANARY S-BAND	
	0, 28.97	0, 34.83	5.86	ASCENSION FPS-16		17, 29.24	17, 34.31	5.07	CARNARVON FPS-16	
	1, 0.67	1, 8.12	7.45	CARNARVON FPS-16	12	18, 15.94	18, 19.85	3.92	BAHAMA	
	1, 26.66	1, 34.17	7.51	HAWAII FPS-16		18, 16.87	18, 24.30	7.43	ANTIGUA FPS-16	
	1, 38.68	1, 46.24	7.56	GUAYMAS S-BAND		18, 19.50	18, 23.55	4.09	BERMUDA FPS-16	
	1, 41.87	1, 49.43	7.56	CORPUS S-BAND		18, 28.69	18, 36.24	7.55	CANARY S-BAND	
	3	1, 45.92	1, 53.03	7.11	CCTMA FPS-16	19, 5.30	19, 12.75	7.46	CARNARVON FPS-16	
		1, 46.49	1, 53.77	7.28	BAHAMA	13	19, 48.65	19, 53.29	4.64	CORPUS S-BAND
		1, 51.19	1, 53.93	2.74	BERMUDA FPS-16		19, 51.35	19, 58.17	6.81	CCTMA FPS-16
1, 51.21		1, 58.71	7.50	ANTIGUA FPS-16	19, 51.44		19, 58.71	7.27	BAHAMA	
2, 5.63		2, 13.04	7.41	ASCENSION FPS-16	19, 55.17		20, 2.08	6.91	BERMUDA FPS-16	
4		2, 39.16	2, 44.11	4.95	CARNARVON FPS-16	20, 6.26	20, 13.75	7.53	ANTIGUA FPS-16	
		2, 50.62	2, 57.33	6.71	GUAM	20, 42.88	20, 50.30	7.42	CARNARVON FPS-16	
		3, 4.51	3, 11.61	7.10	HAWAII FPS-16	14	21, 22.03	21, 28.35	6.32	GUAYMAS S-BAND
		3, 16.25	3, 23.67	7.42	GUAYMAS S-BAND		21, 24.50	21, 31.82	7.32	CORPUS S-BAND
		3, 19.60	3, 26.43	6.83	CORPUS S-BAND		21, 28.34	21, 35.88	7.55	CCTMA FPS-16
	3, 24.94	3, 28.26	3.32	CCTMA FPS-16	21, 28.77		21, 36.32	7.54	BAHAMA	
	5	3, 25.30	3, 29.32	4.02	BAHAMA	21, 32.23	21, 39.58	7.35	BERMUDA FPS-16	
		3, 30.11	3, 34.46	4.35	ANTIGUA FPS-16	21, 34.22	21, 38.95	4.77	ANTIGUA FPS-16	
		3, 45.02	3, 49.13	4.11	ASCENSION FPS-16	21, 44.11	21, 50.57	6.45	CANARY S-BAND	
		4, 27.80	4, 35.06	7.26	GUAM	22, 20.68	22, 28.03	7.35	CARNARVON FPS-16	
4, 42.58		4, 49.37	6.79	HAWAII FPS-16	22, 49.36	22, 52.25	2.90	HAWAII FPS-16		
6		4, 54.44	4, 59.53	5.09	GUAYMAS S-BAND	14	21, 22.03	21, 28.35	6.32	GUAYMAS S-BAND
		5, 6.58	6, 11.64	4.65	GUAM		21, 24.50	21, 31.82	7.32	CORPUS S-BAND
		6, 20.14	6, 27.50	7.36	HAWAII FPS-16		21, 28.34	21, 35.88	7.55	CCTMA FPS-16
		7, 57.72	8, 4.93	7.21	HAWAII FPS-16		21, 28.77	21, 36.32	7.54	BAHAMA
7		10, 17.88	10, 24.09	6.20	ASCENSION FPS-16	21, 32.23	21, 39.58	7.35	BERMUDA FPS-16	
	11, 0.81	11, 7.50	6.70	GUAM	21, 34.22	21, 38.95	4.77	ANTIGUA FPS-16		
8	11, 54.84	12, 2.24	7.40	ASCENSION FPS-16	21, 44.11	21, 50.57	6.45	CANARY S-BAND		
	12, 38.04	12, 45.40	7.36	GUAM	22, 20.68	22, 28.03	7.35	CARNARVON FPS-16		

- Node: 178.58
- Alt: 200 n.mi
- Incl: 28.5 deg.

TABLE 4.2-2

THRUSTER IGNITION FOR ROTATIONAL CONTROL

Type of Signal	Thrusters Used for Response	Mode
<u>Single Axis</u>		
Q ₁	9, 14	} Two-Jet Rotation
Q ₂	10, 13	
R ₁	5, 10	
R ₂	6, 9	
P ₁	7, 15	
P ₂	3, 11	
Q ₁	2, 5, 9, 14	} Four-Jet Rotation
Q ₂	1, 6, 10, 13	
R ₁	1, 5, 10, 14	
R ₂	2, 6, 9, 13	
P ₁	4, 7, 12, 15	
P ₂	3, 8, 11, 16	
<u>Combined Rotations</u>		
Q ₂ R ₁	1, 6, 10, 13 & 1, 5, 10, 14	} All Modes
Q ₂ R ₂	1, 6, 10, 13 & 2, 6, 9, 13	
Q ₁ R ₁	2, 5, 9, 14 & 1, 5, 10, 14	
Q ₁ R ₂	2, 5, 9, 14 & 2, 6, 9, 13	

TABLE 4.2-3

ATTITUDE CONTROL SYSTEM PERFORMANCE
DURING UNDISTURBED LIMIT CYCLES

- No Main Engine Thrust
- No Exterior Torques
- Attitude-Hold Mode of Operation

		Control System*	
		Present Primary	Present Abort
I= 24,000 Slug-ft ²	RCS Jet Pulses/sec	2	Up to 4
	Max Angular Rate in Symmetrical Limit Cycle, deg/sec	0.0086	Up to 0.0173
	Period, min/cycle	2.46	Down to 1.34
	Avg Propellant Consumption, lb/min	0.011	Up to 0.041
I= 200,000 Slug-ft ²	RCS Jet Pulses/sec	2	Up to 18
	Max Angular Rate in Symmetrical Limit Cycle, deg/sec	0.00097	Up to 0.0097
	Period, min/cycle	21.3	Down to 2.58
	Avg Propellant Consumption, lb/min	0.00124	Up to 0.097
	Minimum Predictable or Measurable Angular Rate, deg/sec	Zero (Limited by drift rate of primary sys & dig comptr sealing)**	0.01
	Error Sources	Errors in RCS jet thrust could cause larger limit cycles & higher propel- lant consumption.**	Rate gyro threshold & resolution
	Possible Changes for Improved Performance at High Vehicle Inertias	None anti- cipated.**	Decrease rate gyro resol. inaccuracies & thresh. Increase rate gain to 8.0
	Type of Change	-	Hardware
	Limiting Factor if System	Computer calculation interval.**	PRM threshold & D-A converter resolution**

*System Deadband = 0.3 deg
 Min. RCS jet output pulse = 0.6 lb-sec
 For Abort Sys:
 Min PRM output pulse length = 0.01 sec
 Rate gain = 1.5

} IMO 500-339

**Requires further study.

33

P G N C S

1. More severe penalties in weight, power, thermal areas than AGS.
2. Better rate derivative capability ... can obtain better limit cycle performance without hardware change (i.e., software only). Causes "optimum" convergence (for a combined minimum fuel and time performance criterion) from any point in the phase plane to a closed limit cycle.
3. Compensates for torque disturbances about Y and Z axes, affording reduction of 2:1 in propellant flow rates.
4. Changes in deadband and logic will essentially require software modification which could be accomplished on a "per mission" basis.
5. Has extensive capability beyond the baseline attitude hold requirement, such as the following:
 - Capable of self-alignment to stellar-inertial reference, and could afford degraded alignment of CSM attitude reference via voice link.
 - May have adequate inherent capability for tracking, local vertical--may simplify interface and negate need for horizon scanner or other external sensor.
 - Affords added flexibility for mission concepts requiring storage of Lab in Earth orbit.
6. If prelaunch testing is limited to 1,200 hr, the design operating life of 2,000 hr leaves 800 hr for Lab mission. Preliminary reliability studies to investigate simplification and deletion of circuitry, etc. are possible in light of Phase I Lab requirements. This should make reliability figures compare favorably with those for AGS. Proper scheduling should preclude any conflict with the 30-day recalibration requirement.
7. Considerable lack of information --It is assumed the major performance limitation is lack of all-attitude capability, however, other performance capabilities to be established are as follows:
 - Performance at low angular rates
 - Performance over long periods of time
 - Effect of RCS jet thrust level errors (could cause multiple-pulse limit cycle)
 - Effect of undetected jet failures (stability)
8. Anticipate higher level of confidence (than LEM AGS) for early need dates on Phase I Labs due to commonality with and prior flight experience (scheduled for) the CSM Apollo PGNC Earth orbital missions.

TABLE 4.2-4

& AGS FOR LABORATORY APPLICATION

A G S

1. Lighter, requires less power than PGNCS.
2. Requires modification of RGA and ATCA gain change to provide propellant consumption comparable to PGNCS for undisturbed limit cycle operation.
3. No logic to permit widening electrical pulses in presence of disturbance torques...costs propellant penalty.
4. Changes in deadband, gain and modification to obtain 2 - jet control about X-axis require hardware changes.
5. Must modify AEA to include star catalog if self alignment is desired. If NASA decides to make the AST a part of the basic LEM, the AEA must be modified to accommodate the AST hardware interface.
6. Requires external sensors and additional ATCA hardware interface change to accommodate same to provide local vertical tracking. This is expected to be a relatively simple interface.
7. Must modify Program Reader Assembly (PRA) for use in Earth orbital storage concept.
8. Design operating life is 5000 hr--Preliminary reliability studies indicate simplification and deletion of circuitry, etc. are possible in light of Phase I Lab requirements. Reliability projections compare favorably with data available for PGNCS. Proper scheduling should preclude conflict with maintainability requirements.
9. Performance data in presence of noise, effect of D/A converters and other AEA delays on performance must be established in the future. Problem similar to that for PGNCS.
10. Anticipate lower level of confidence (than PGNCS) for early need dates due to limited test experience. Ultimately, the AGS should be able to yield higher levels of confidence and reliability due to relative simplicity in mechanization as compared to PGNCS.
11. Use of AGS permits use of cold plate areas in cabin provided by deletion of PGNCS components.

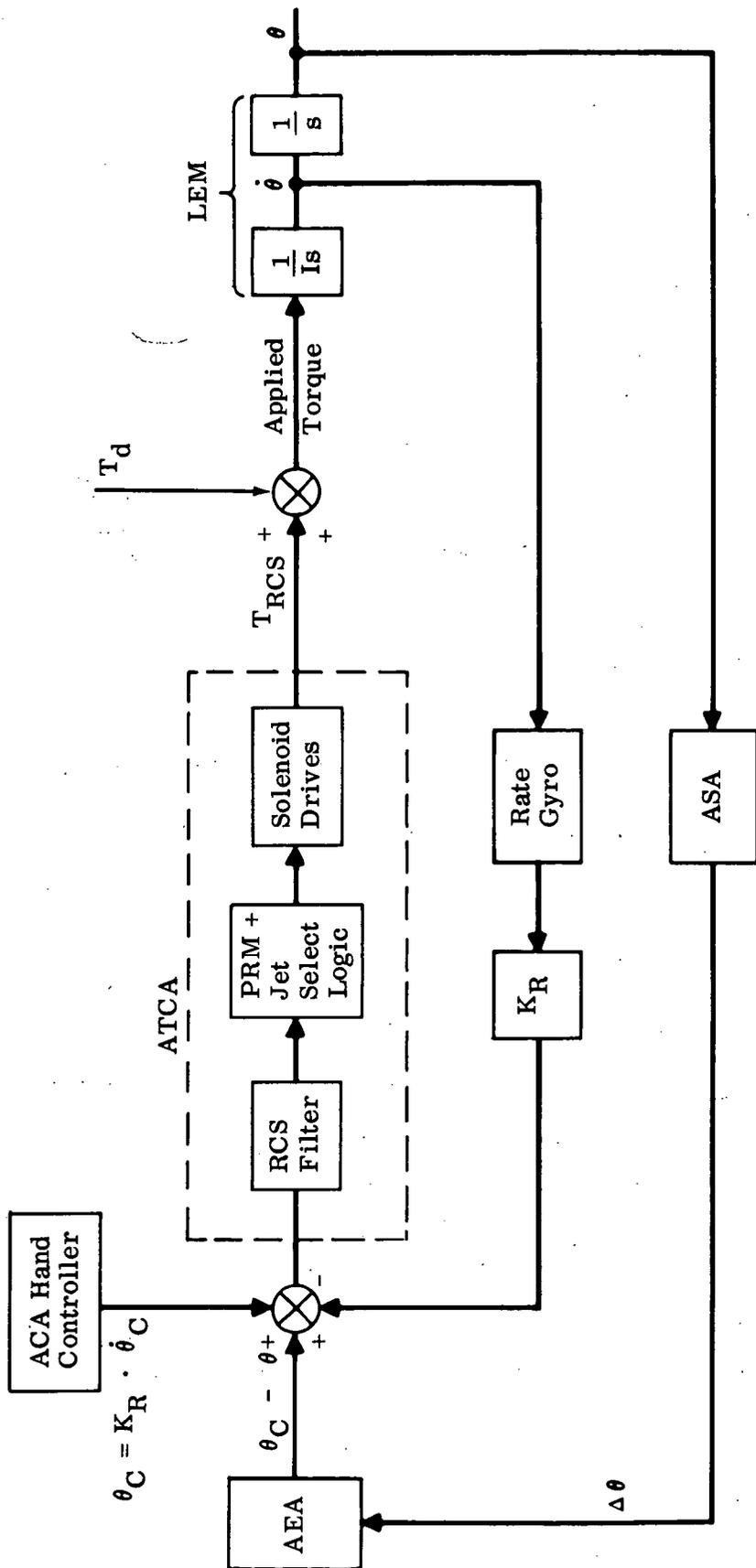


Fig. 4.2-1 AGS Control System

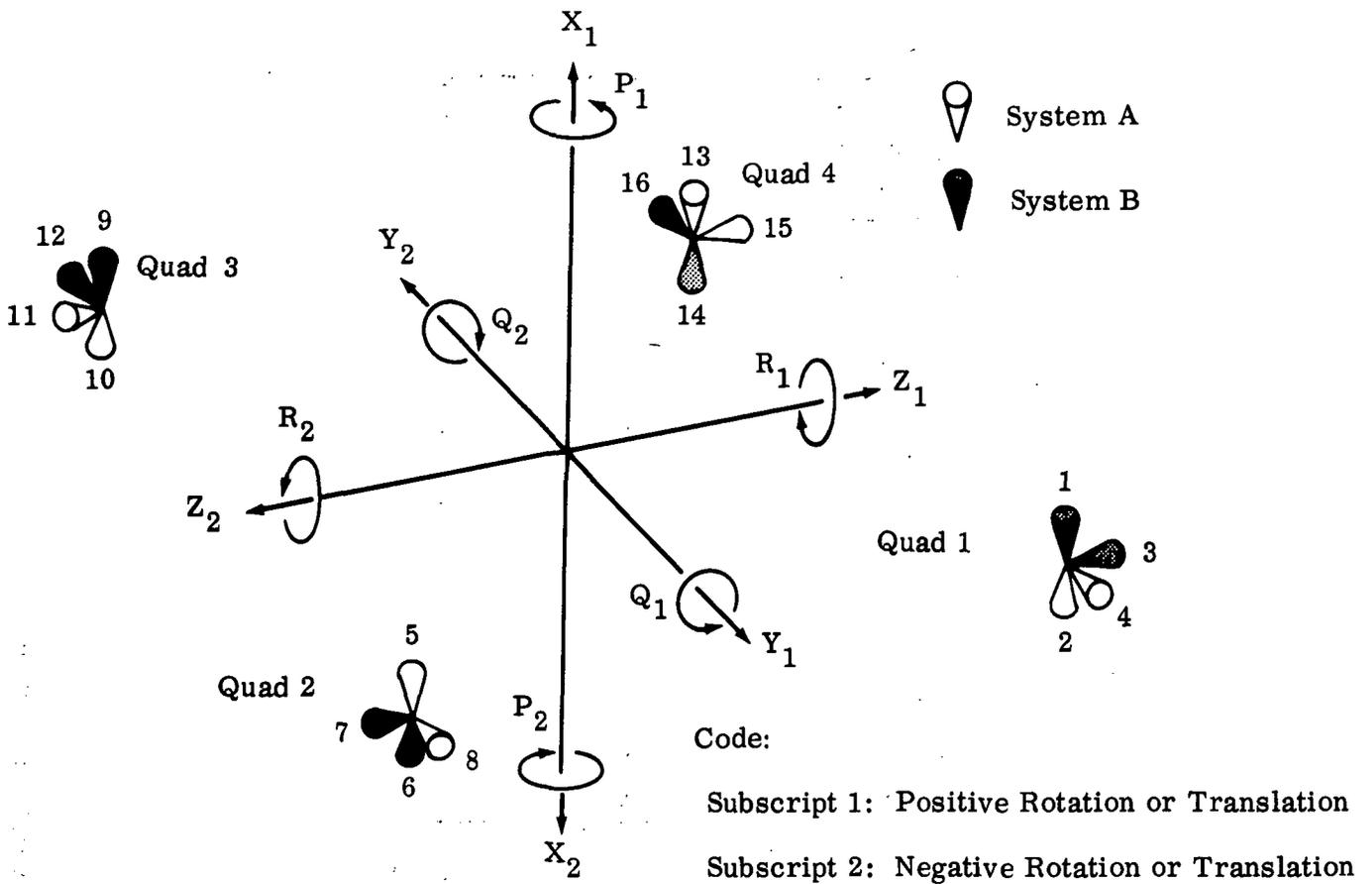


Fig. 4.2-2 RCS Jet Thruster Configuration

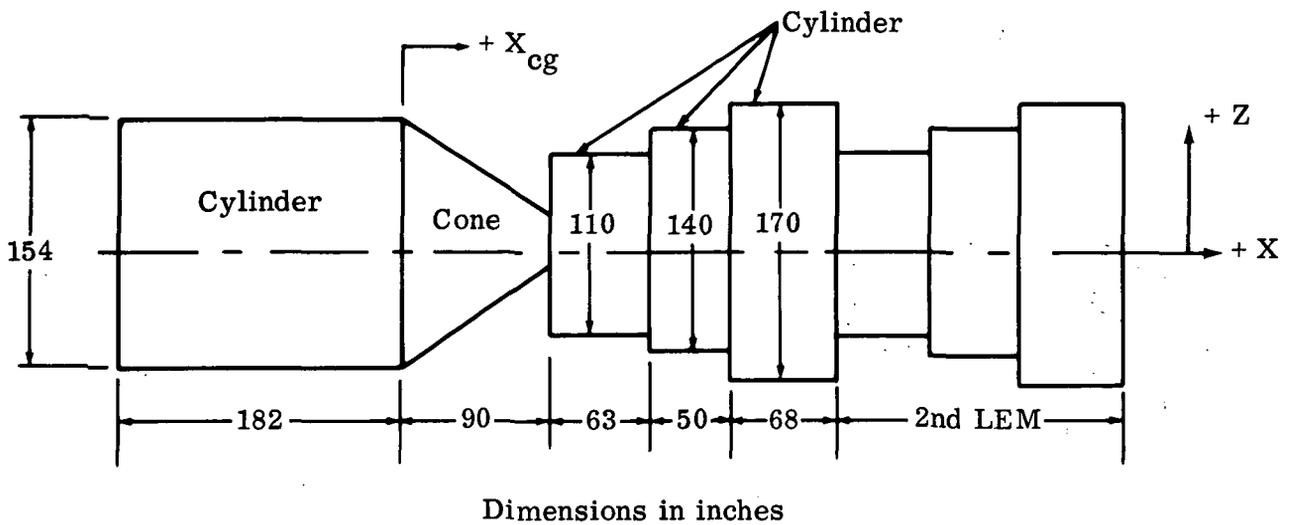


Fig. 4.2-3 Idealized AES-LEM-LAB Configuration

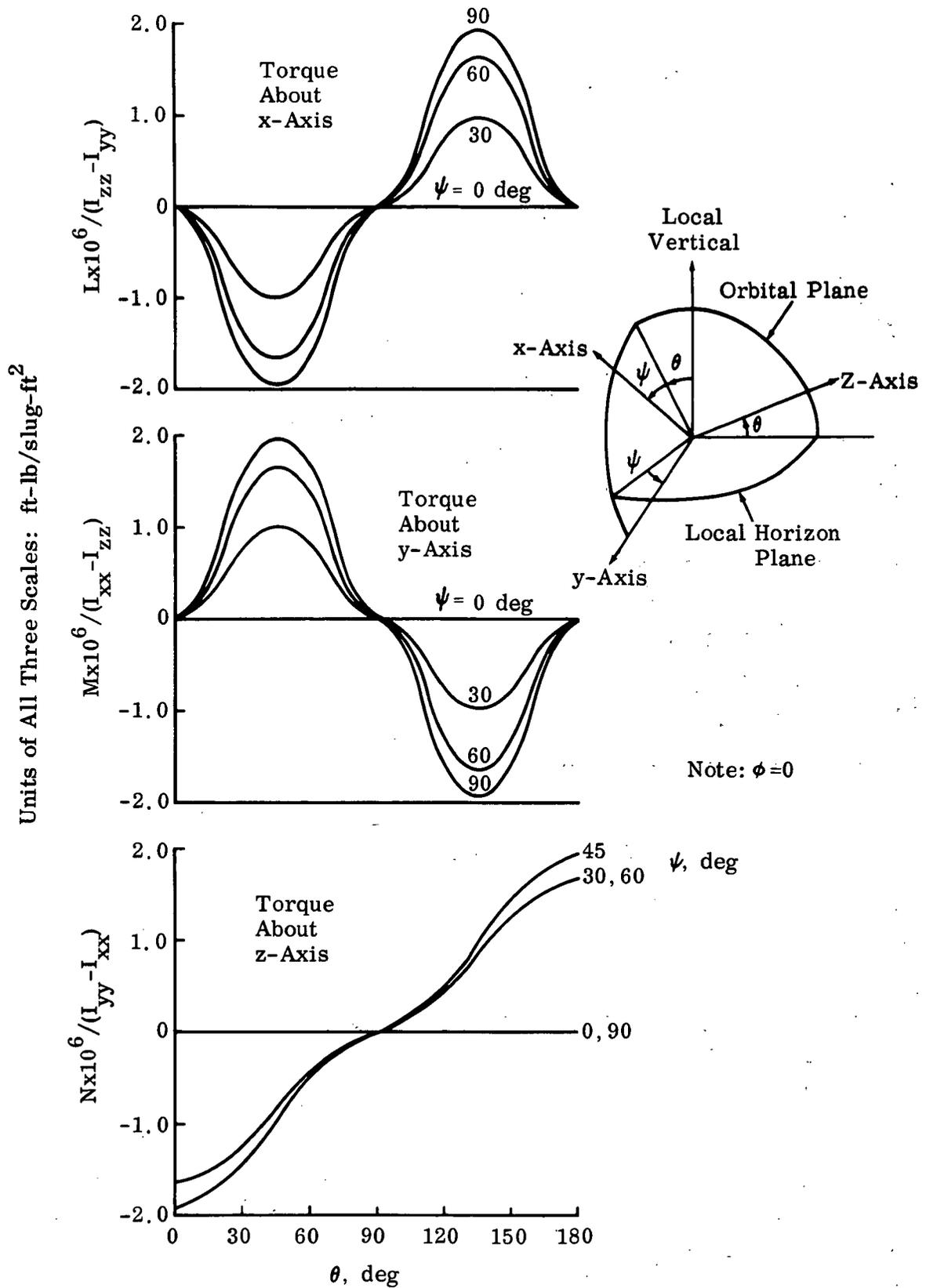
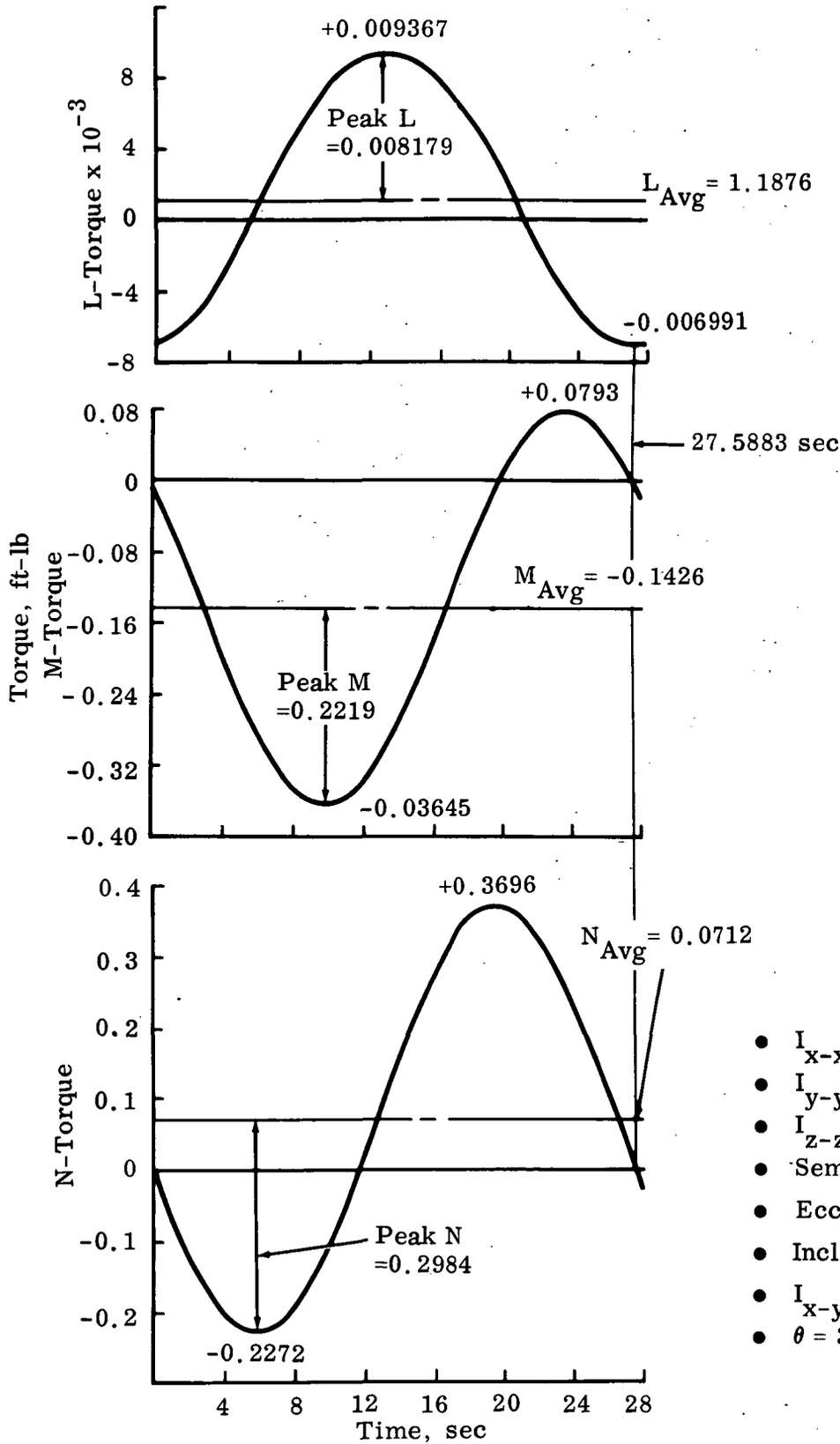


Fig. 4.2-4 Gravity Gradient Torque Parameter



Notes:

- $I_{x-x} = 40,629$
 - $I_{y-y} = 237,530$
 - $I_{z-z} = 235,720$
- } slug-ft²
- Semi-major Axis = 2.2142×10^7 ft
 - Eccentricity = zero
 - Inclination = 28.5 deg
 - $I_{x-y} = I_{y-z} = I_{z-x} = \text{zero}$
 - $\theta = 30, \psi = 90, \phi = \text{zero deg}$

Fig. 4.2-5 Gravity Disturbance Torque

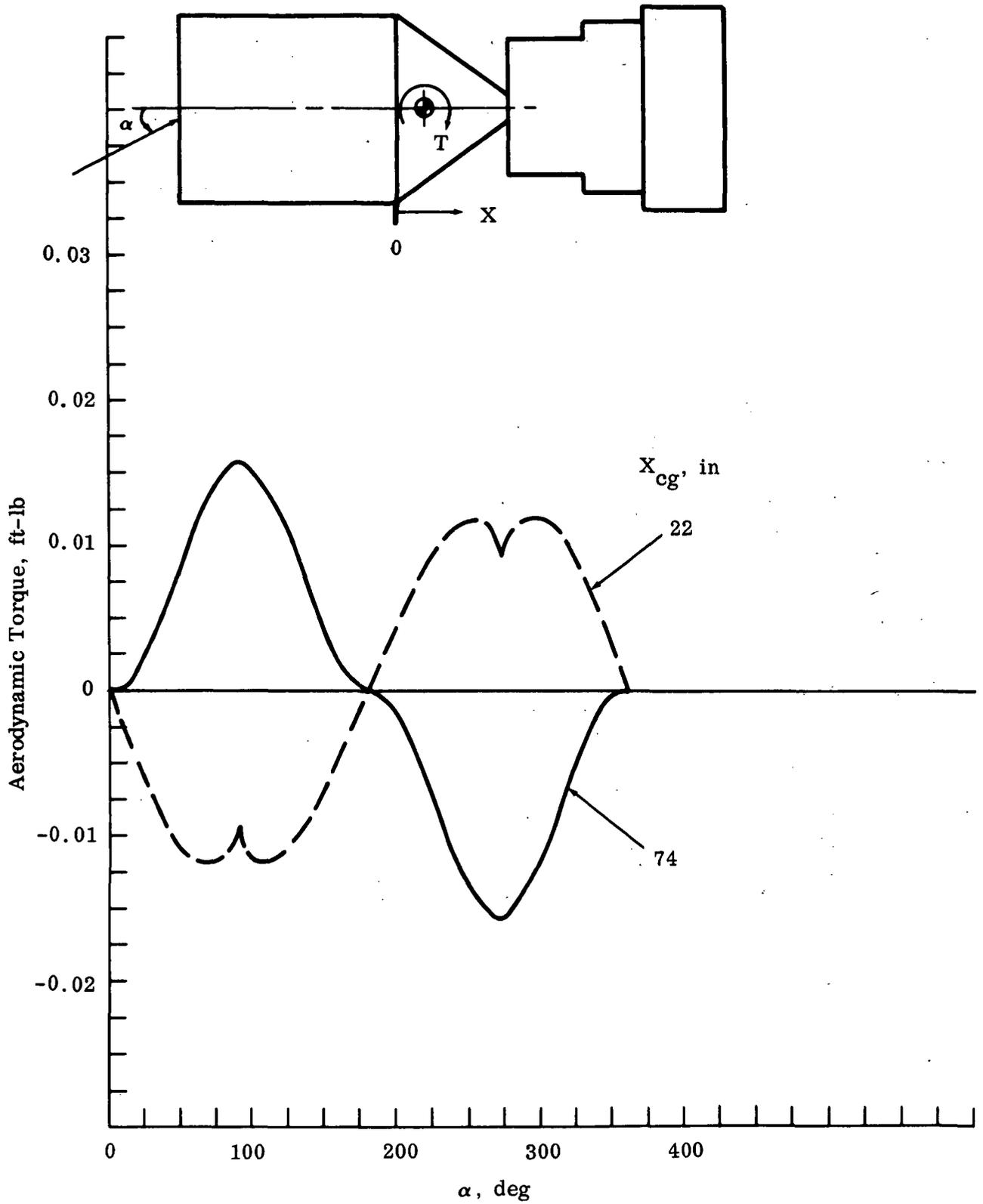


Fig. 4.2-6 Aerodynamic Torques

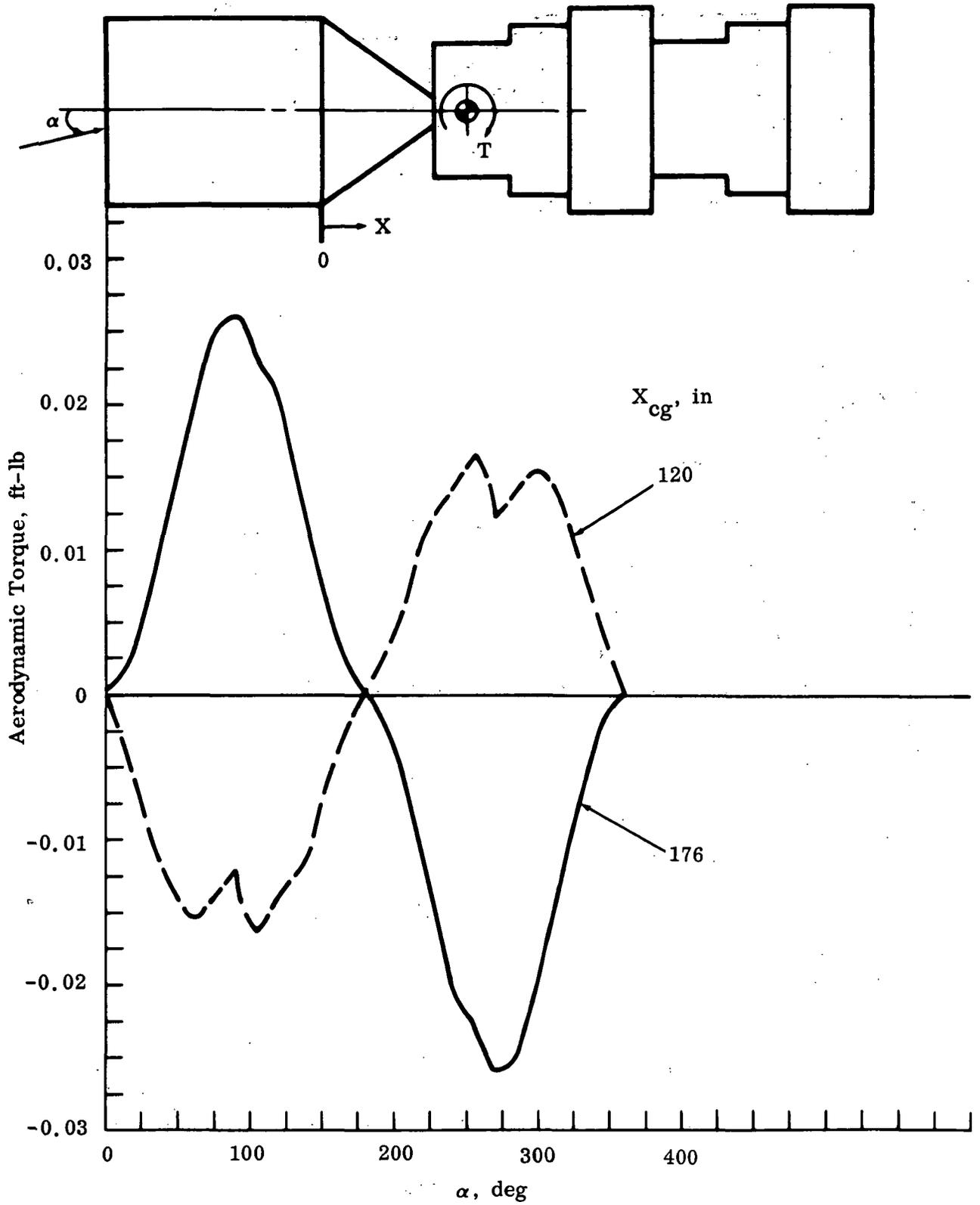


Fig. 4.2-7 Aerodynamic Torques

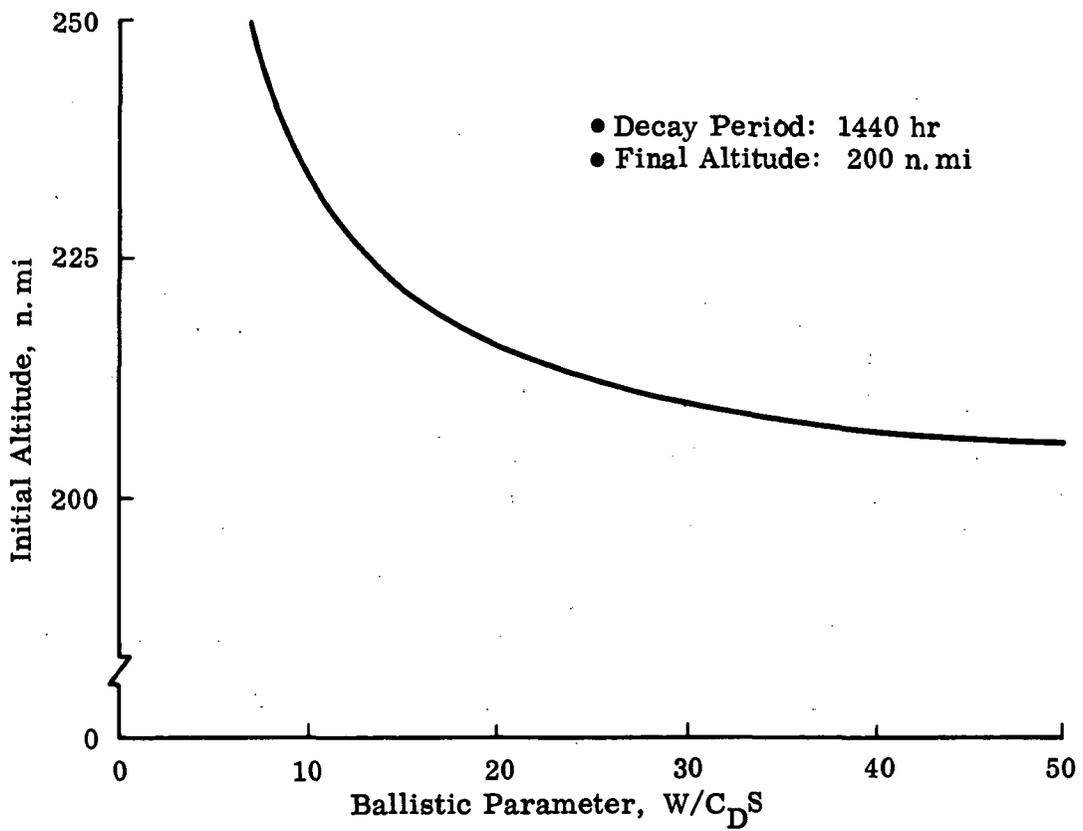


Fig. 4.2-8 Orbital Decay, Earth LEM LAB

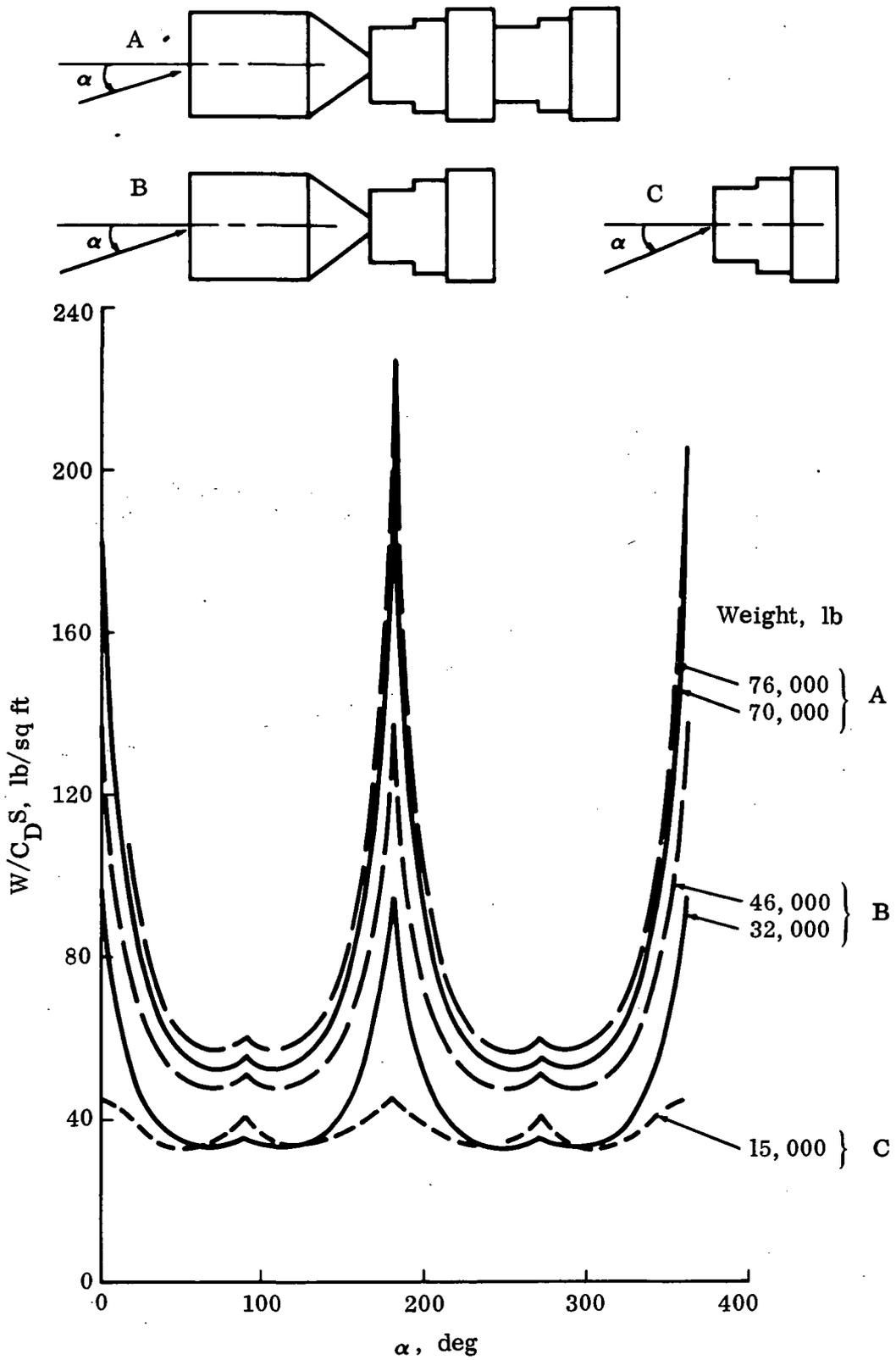


Fig. 4.2-9 Ballistic Parameters for Several CSM-LEM Configurations

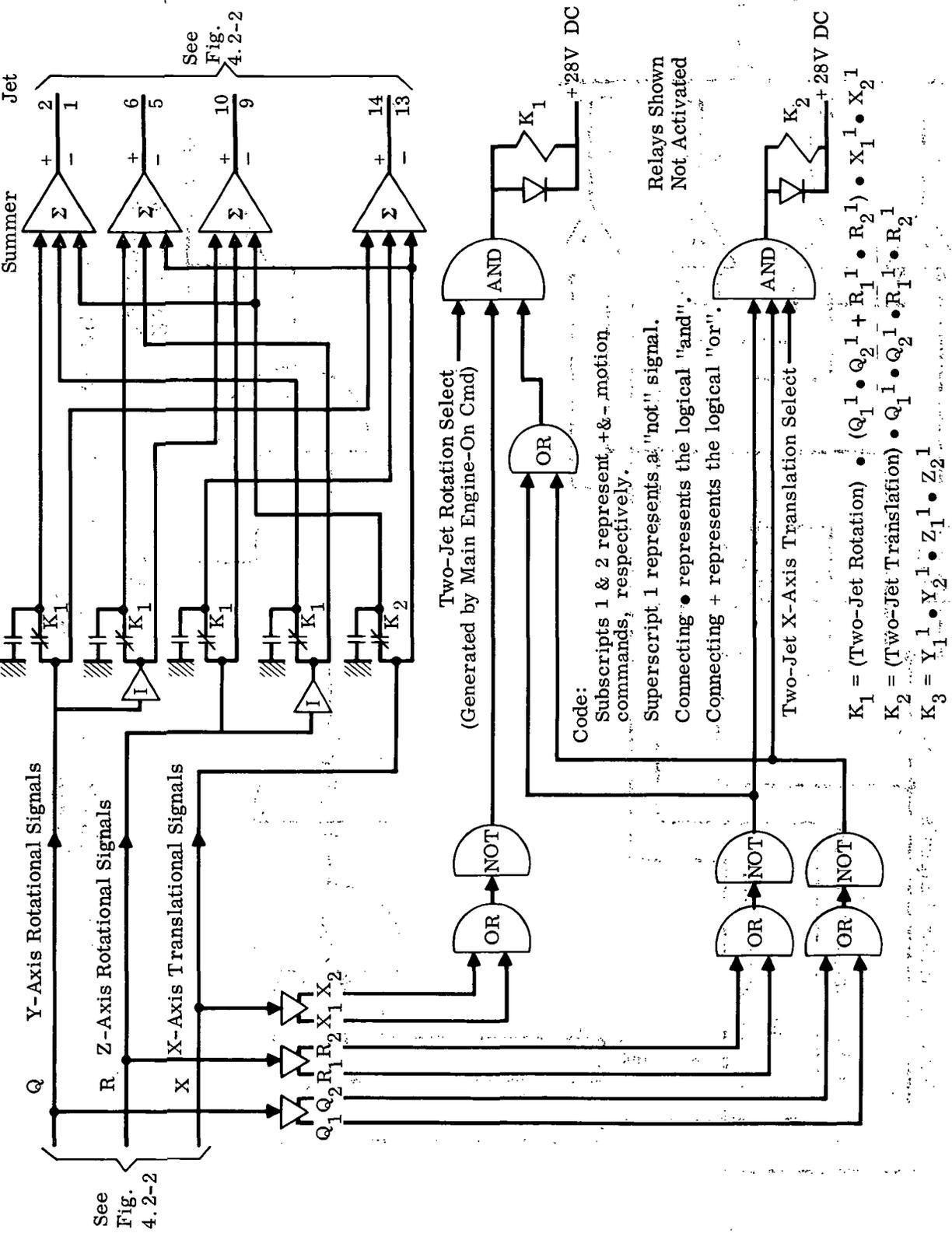


Fig. 4.2-10a Symbolic Logic RCS Vertical Jet Select Attitude and Translation Control

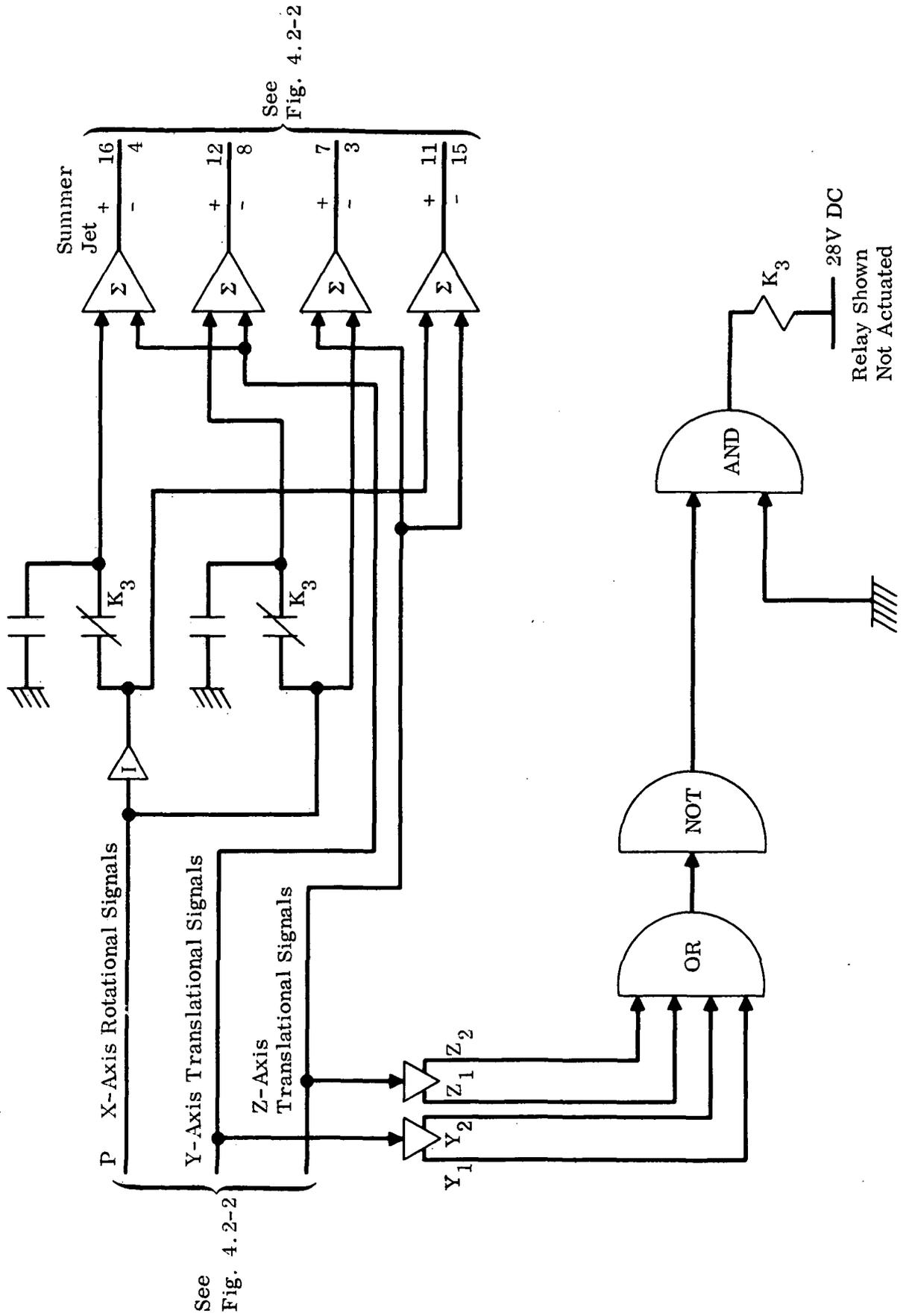


Fig. 4.2-10B Symbolic Logic RCS Horizontal Jet Select Attitude and Translation Control

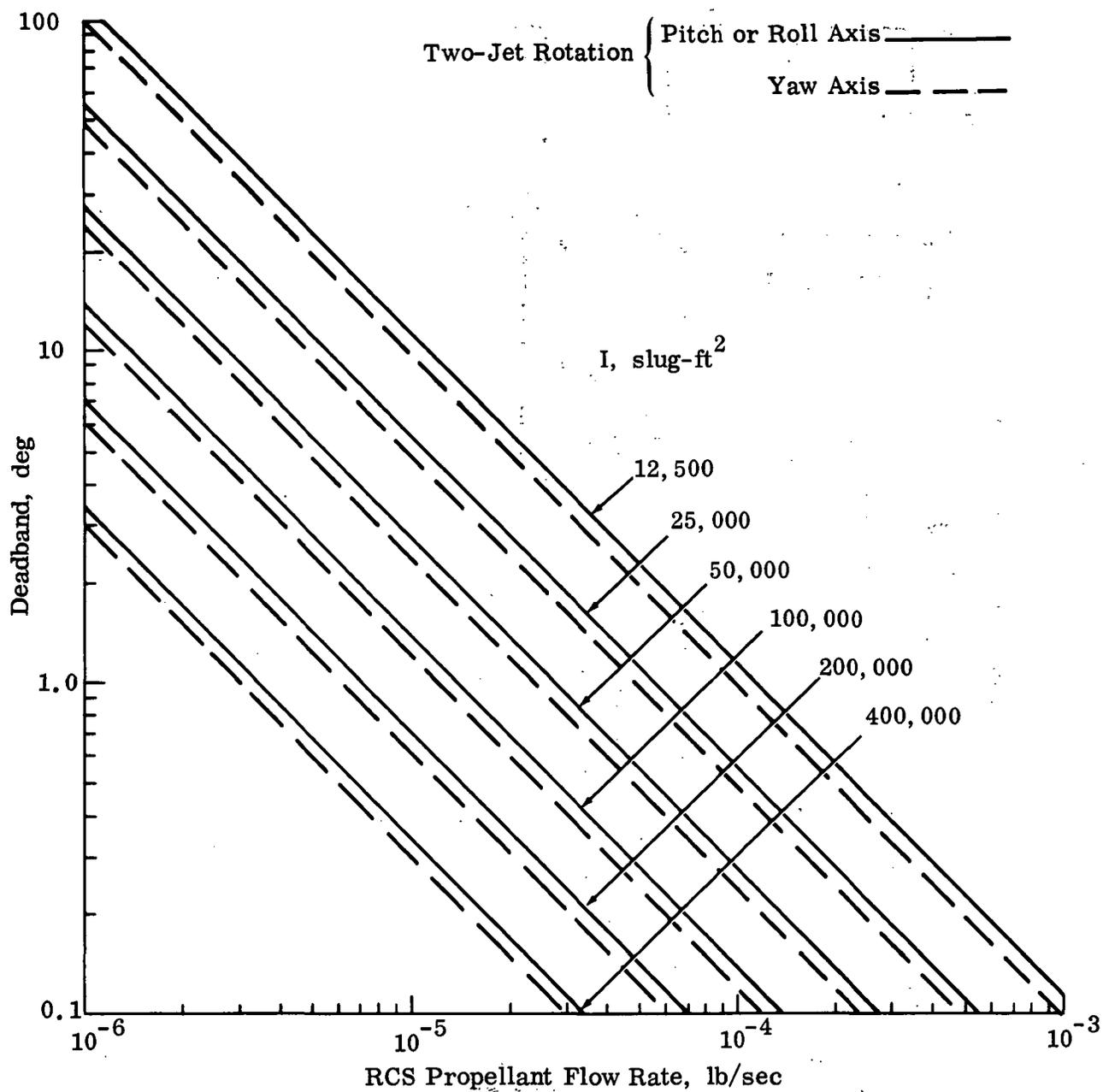


Fig. 4.2-11 Normal Limit Cycle Propellant Flow Rate

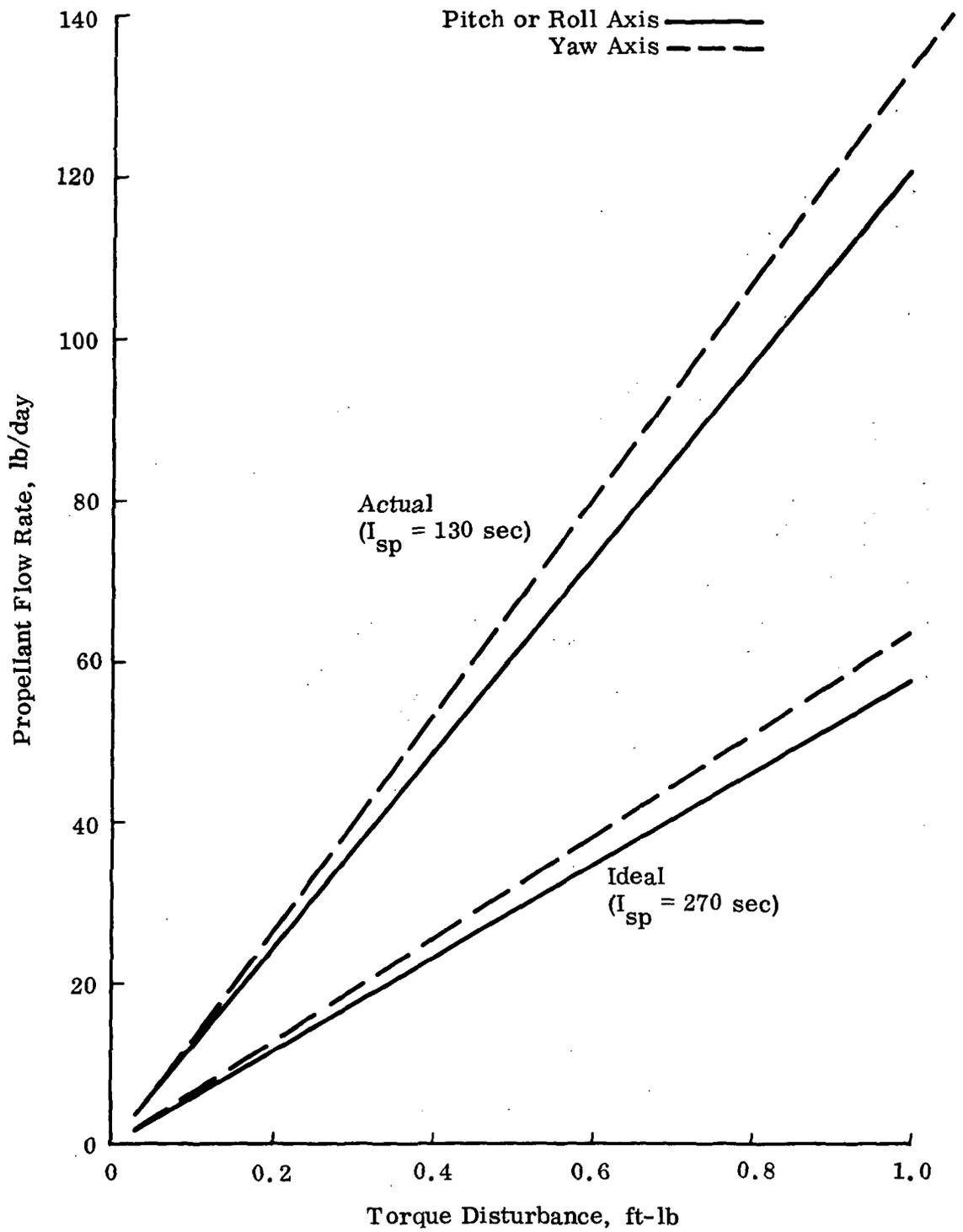


Fig. 4.2-12 Torque Disturbance VS Propellant Flow Rate

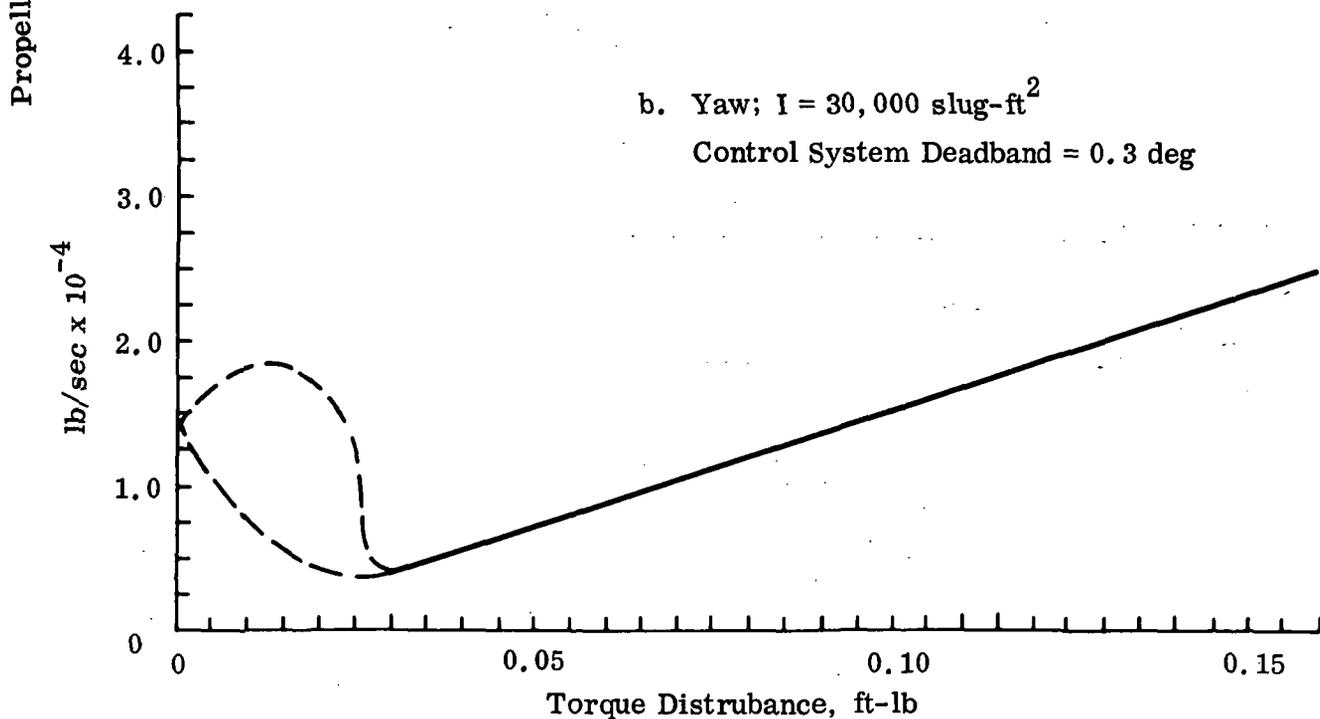
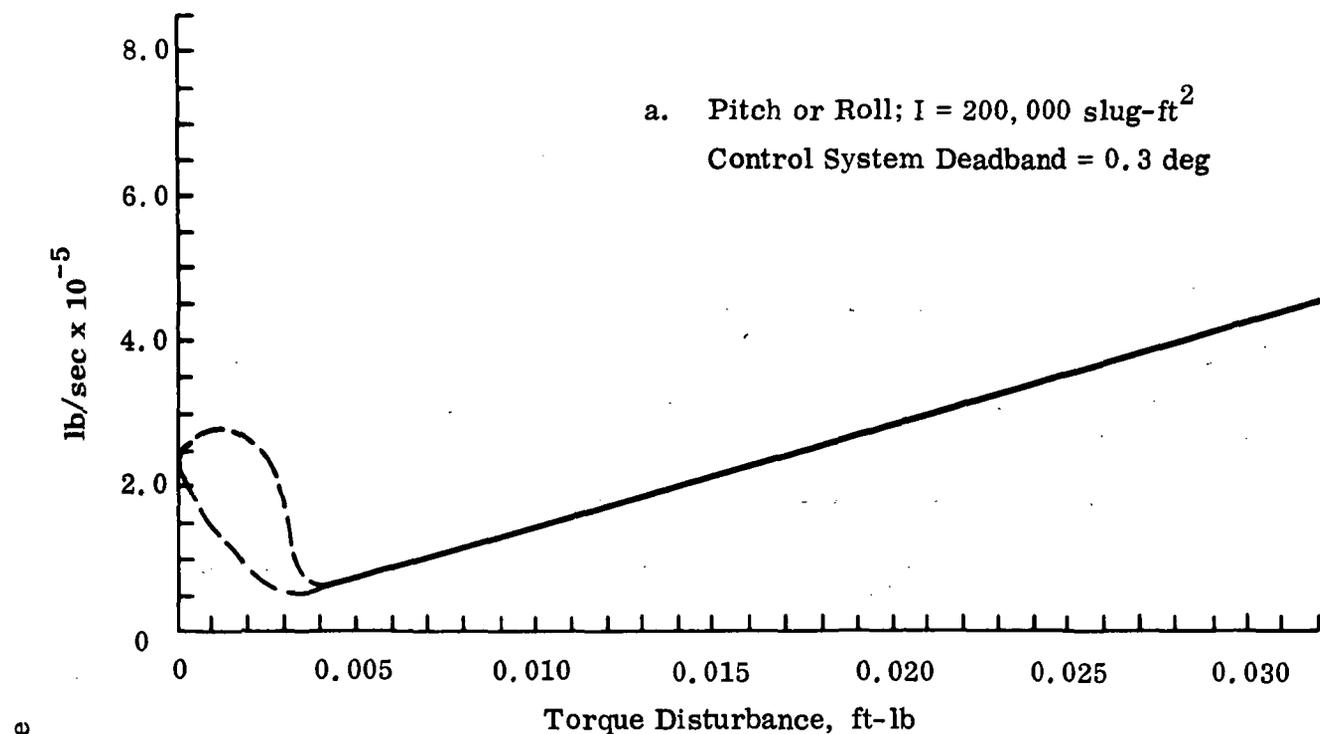
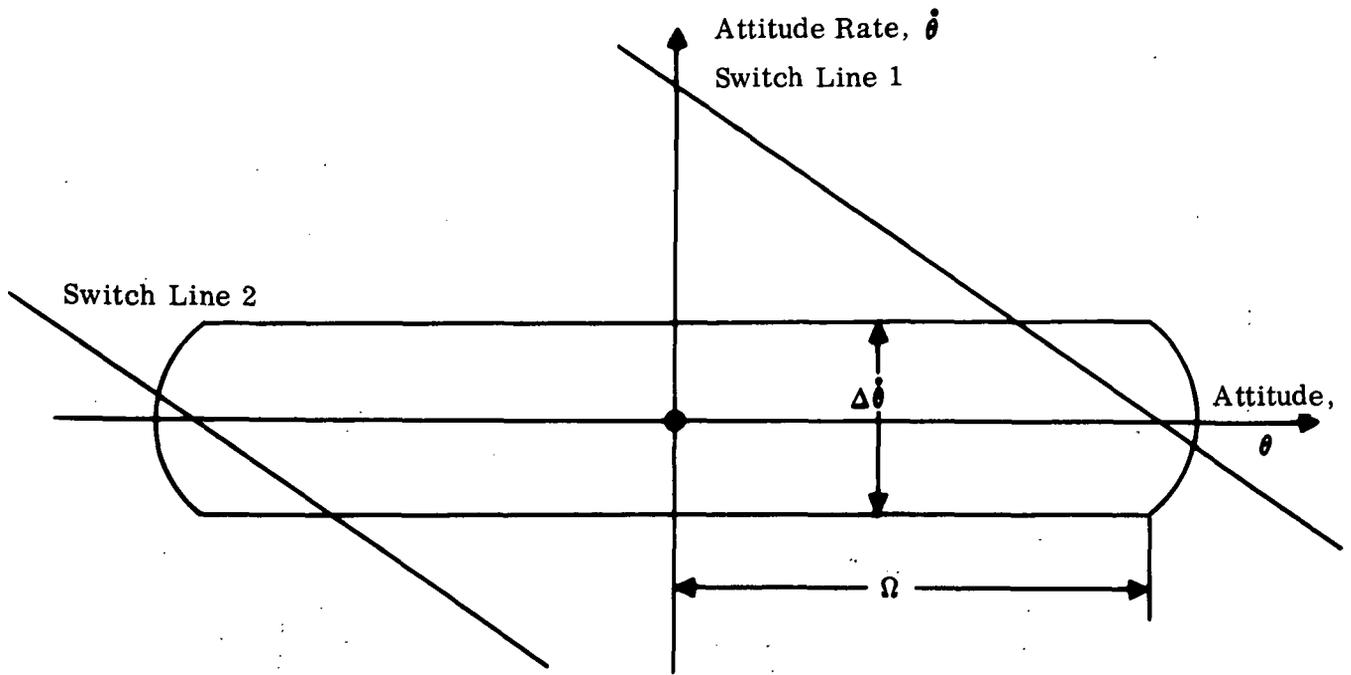
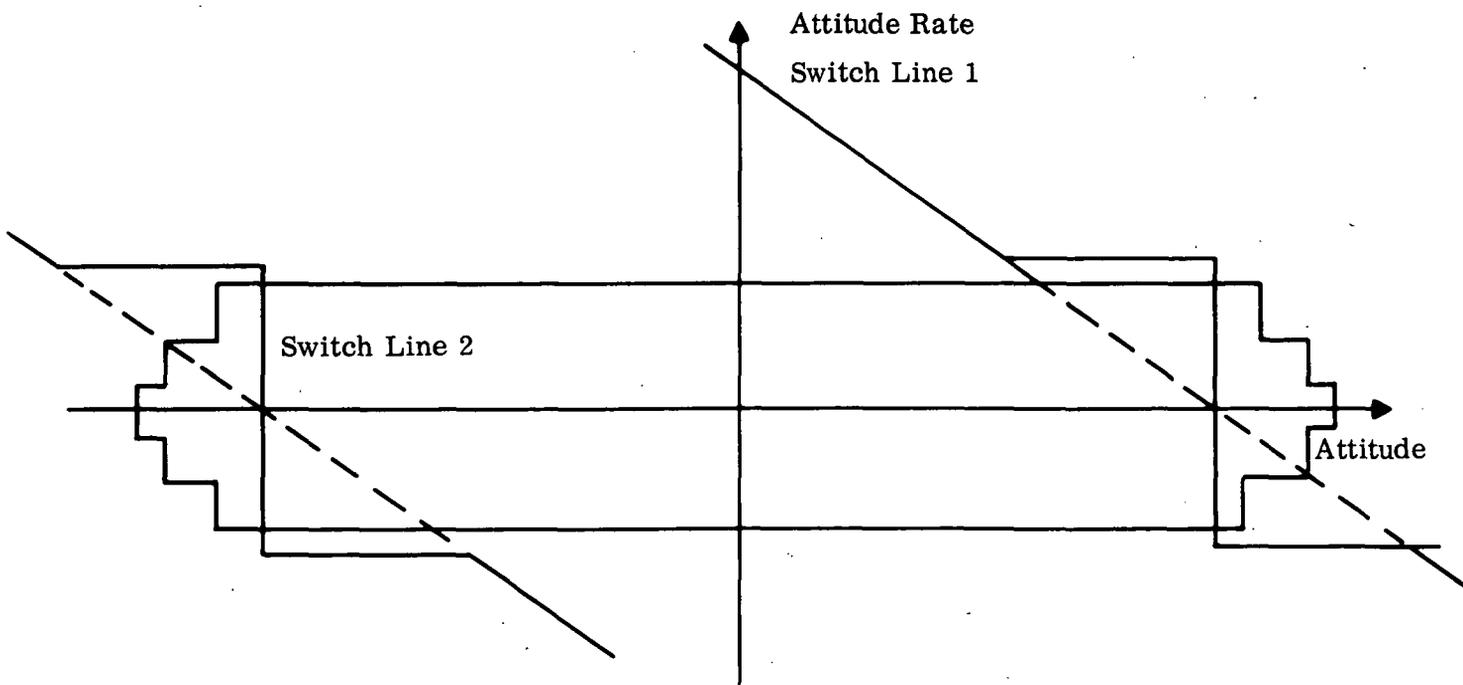


Fig. 4.2-13 Torque Disturbance VS Propellant Flow Rate



a) Normal Limit Cycle Operation



b) Normal Limit Cycle Operation Within Rate Gyro Deadzone (Threshold)

Fig. 4.2-14 Typical Limit Cycles For Normal and Disturbed Condition

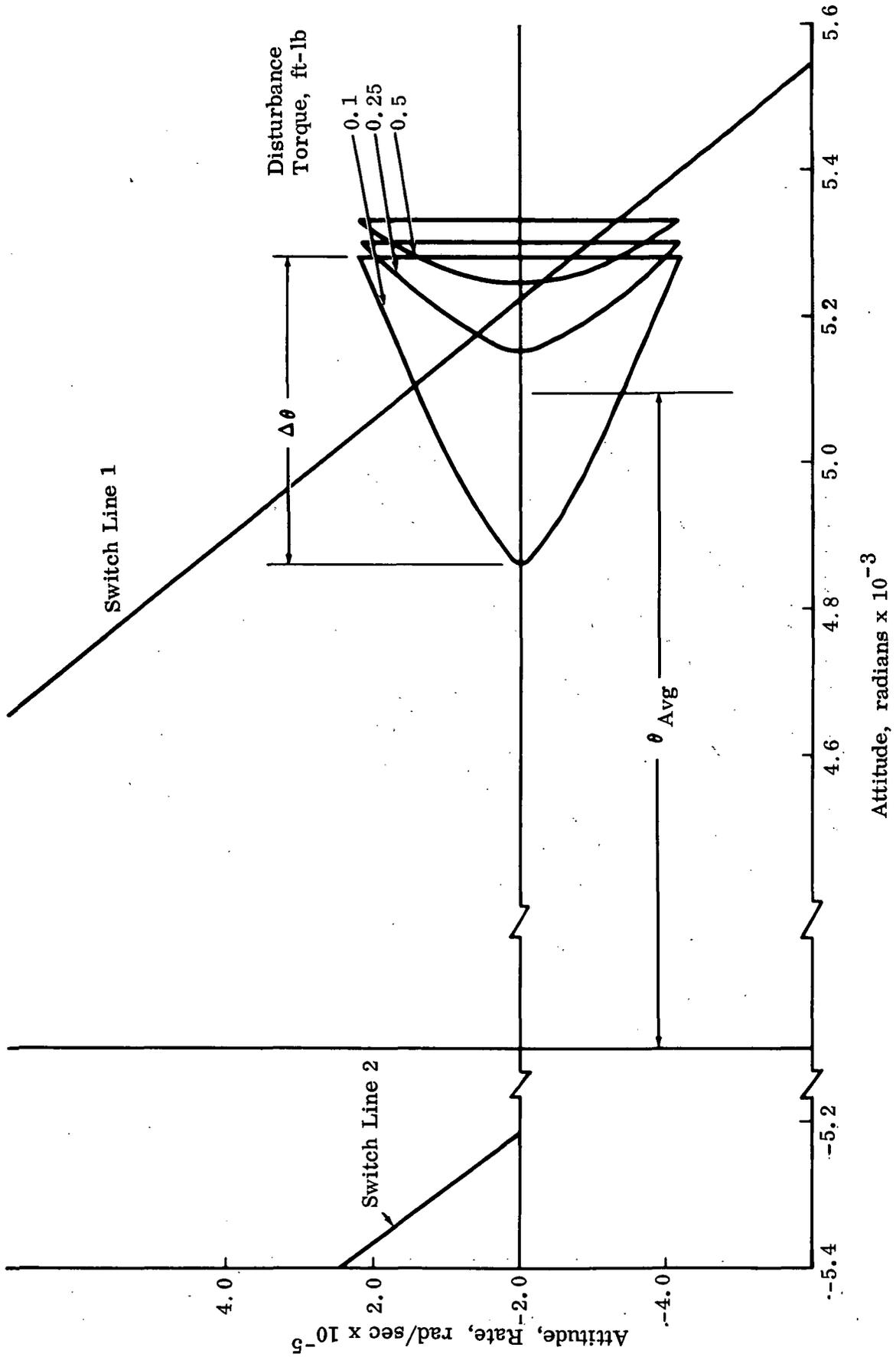


Fig. 4.2-14c Typical Limit Cycles for Normal and Disturbed Conditions

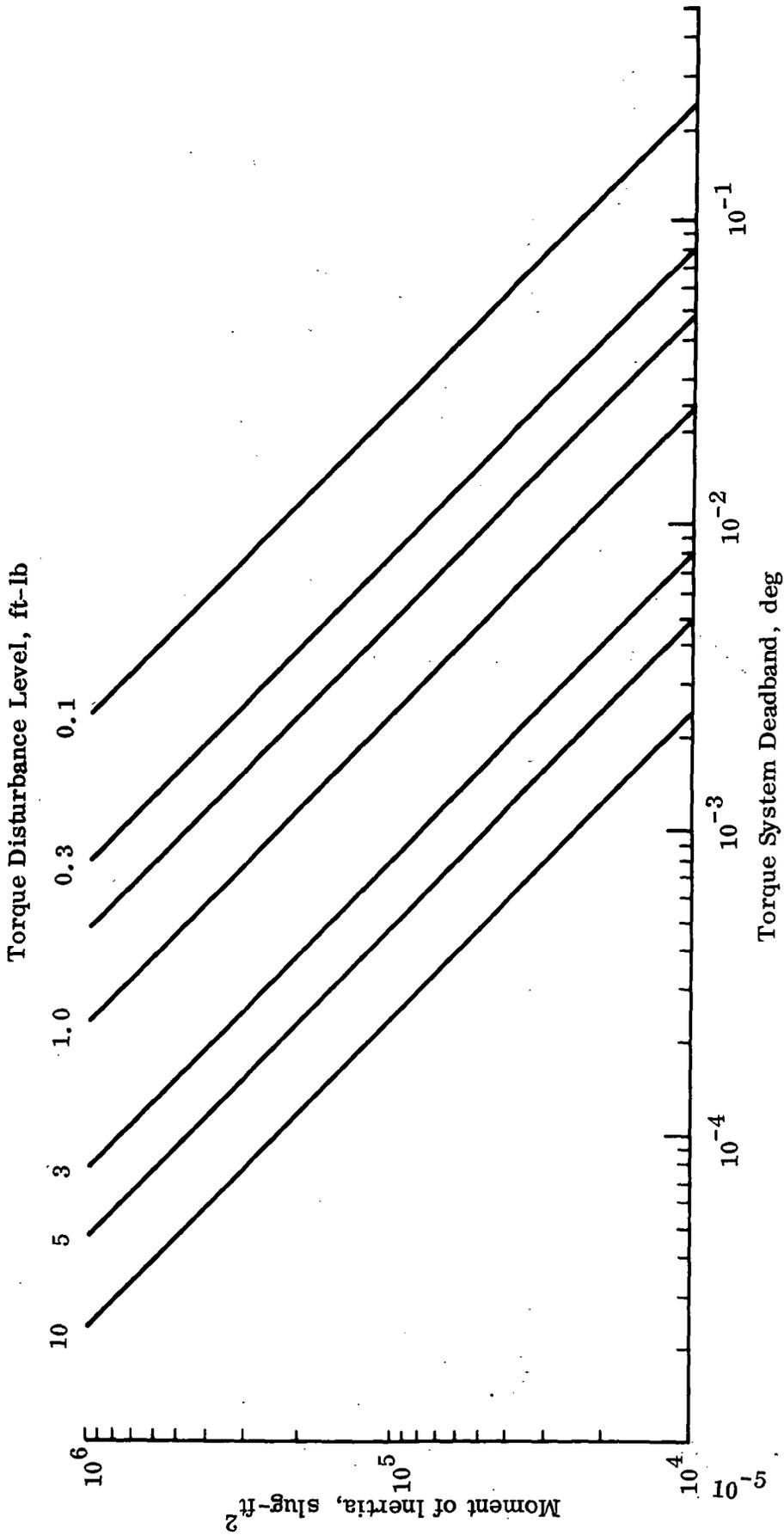


Fig. 4.2-15 Loci for Determining Switch Line 2 Intersection for Disturbed Limit Cycle Shown in Fig. 4.2-14c

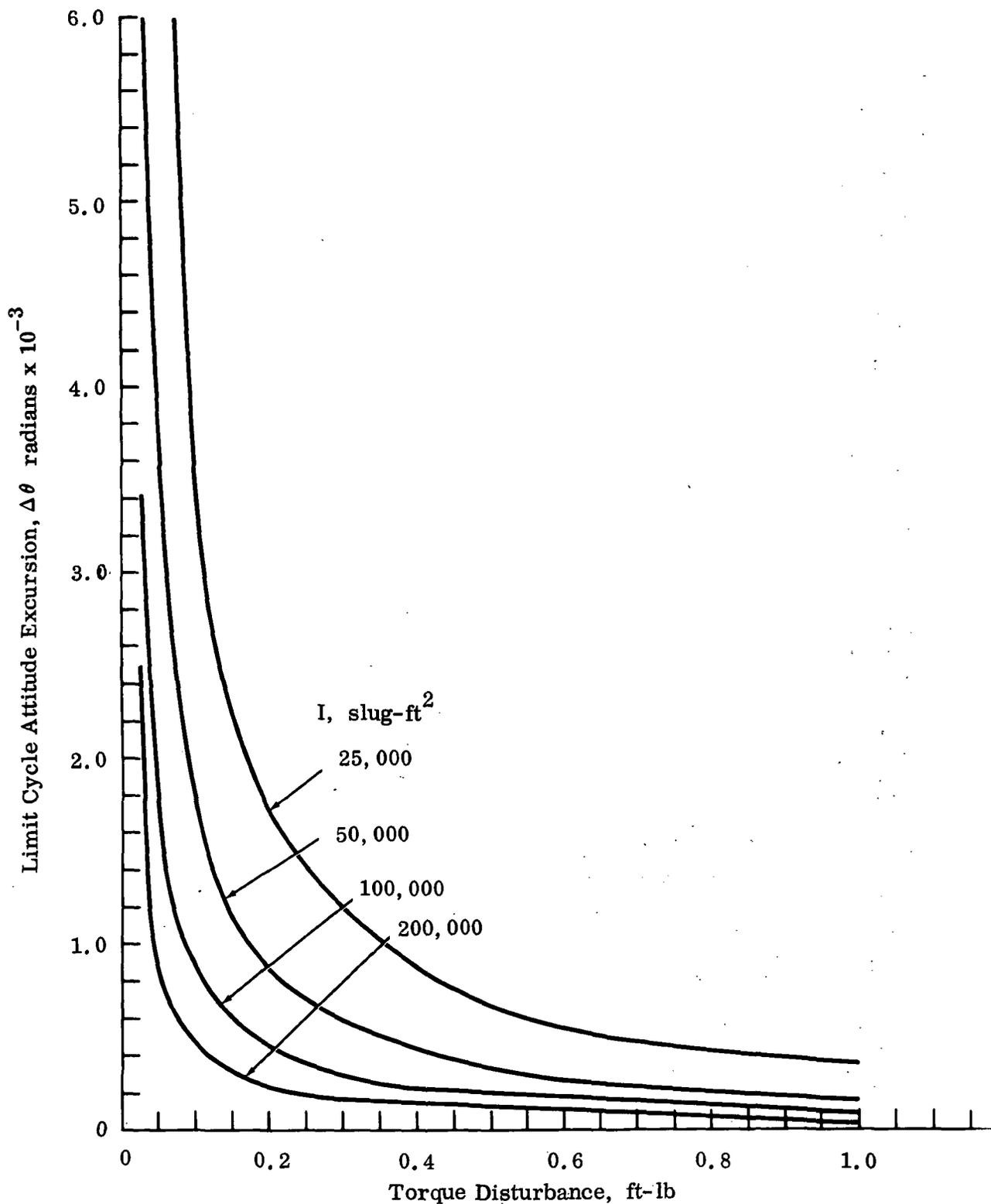
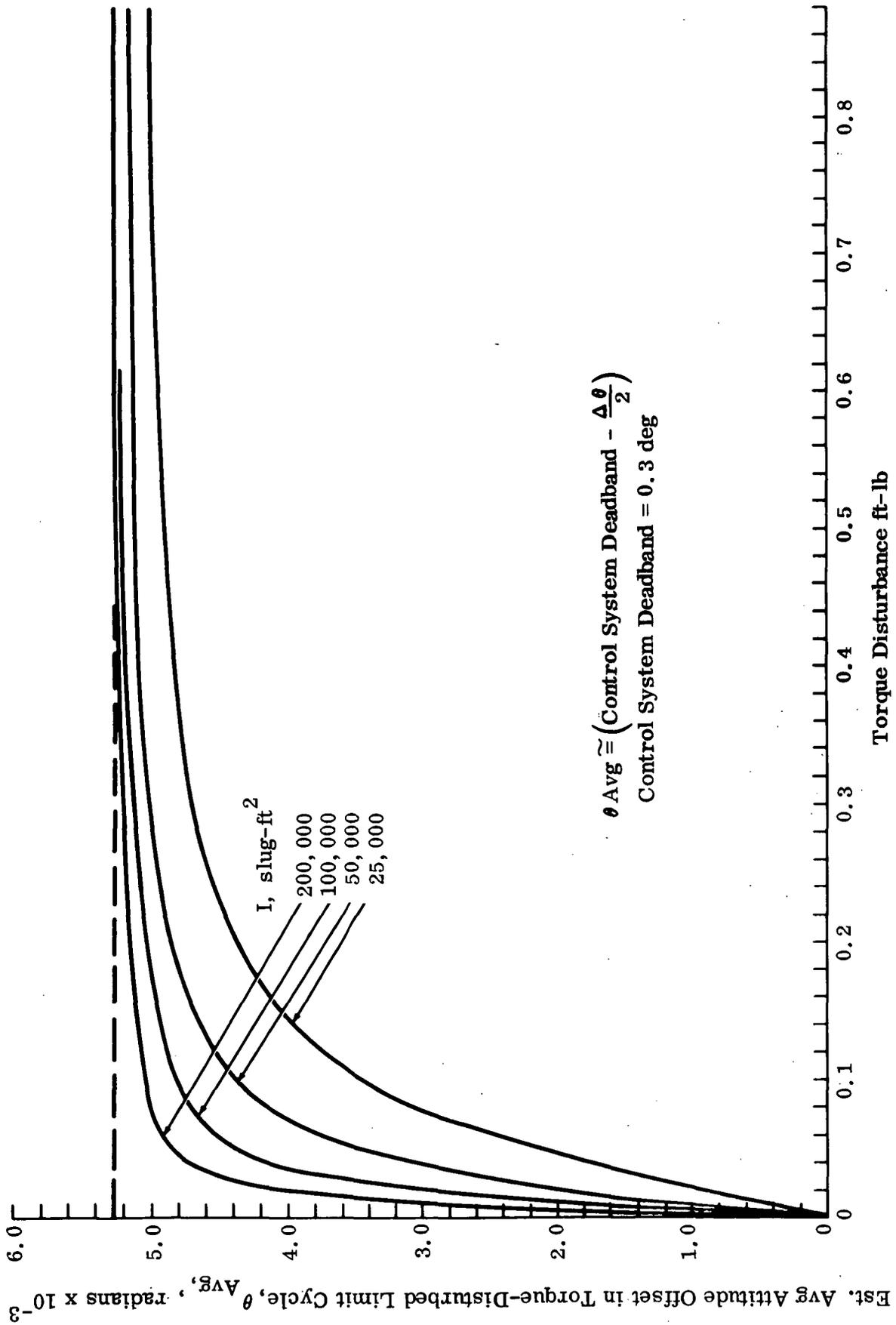


Fig. 4.2-16 Torque Dist. VS Limit Cycle Attitude Excursion-
Two Jet Rotation



$$\theta_{Avg} \cong \left(\text{Control System Deadband} - \frac{\Delta\theta}{2} \right)$$

Control System Deadband = 0.3 deg

Fig. 4.2-17 Torque Disturbance VS Average Attitude Offset

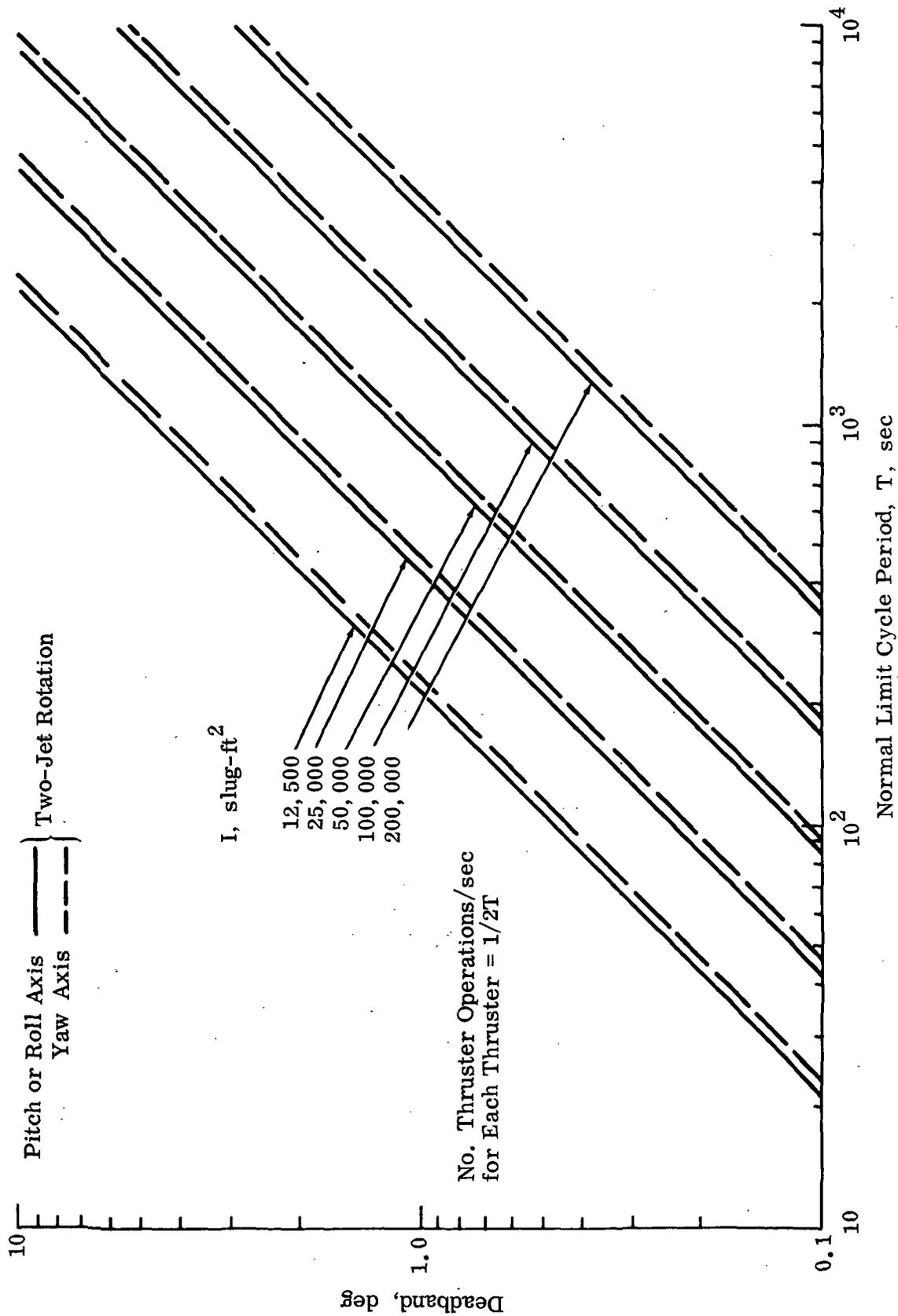


Fig. 4.2-18 Normal Limit Cycle Period VS Control System Deadband

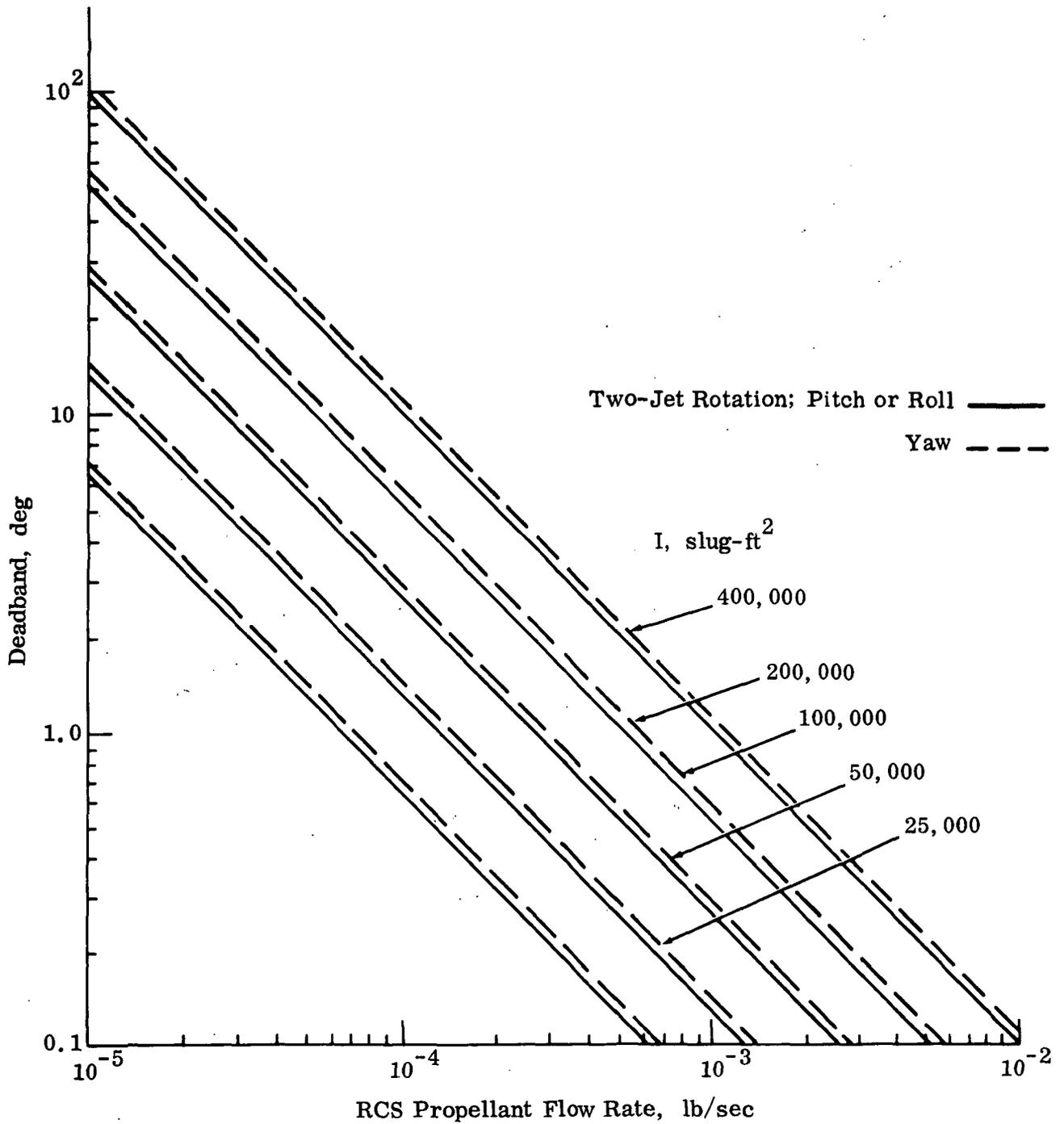


Fig. 4.2-19 Maximum Normal Limit Cycle Propellant Flow Rate VS Control System Deadband for $I > 25,000$ Slug-Ft² and Rate Gyro Threshold of 0.01 Deg/Sec

4.3 REACTION CONTROL AND PROPULSION

4.3.1 Assumptions

- Lab shall be used exclusively for attitude hold
- Two deadzone settings are available: ± 0.3 and ± 0.5 deg
- Gyro rate threshold sensitivity is compatible with the vehicle mass properties unless otherwise specified.
- Marquardt 100-lb thruster performance is as follows:
 - Minimum impulse (standard conditions) = 0.75 ± 0.15 lb-sec
 - Specific impulse (at minimum impulse) = 130 sec
 - O/F ratio (at minimum impulse) = 1.3
- Engine life time specifications:
 - Burning time = 1000 sec, total; 500 sec, steady state; 500 sec min impulse cycling
 - Maximum Number of Cycles = 10,000
- Unmodified propellant tank capacity is 423 lb of usable propellant
- Modified (interchanged propellant tanks) tank capacity is 524 lb of usable propellant

4.3.2 Background Data

4.3.2.1 Propellant Tank Sizing For Phase I Labs

Estimated RCS propellant expenditure for undisturbed limit cycle operation is shown in Fig. 4.3-1 and 4.3-2. Two Rate Gyro thresholds are shown: 0.001, and 0.01 deg/sec. The former threshold represents an order of magnitude increase in rate gyro sensitivity than now exists using the LEM Rate Gyro Assembly (RGA). The characteristics of the system which define the desirability of modifying the rate gyro threshold are defined in Paragraphs 4.2 and 5.3.

The RCS propellant consumption shown assumes attitude hold is required 100% of the mission time; part of the time at ± 0.3 deg, and the remainder at ± 5.0 deg. Figures 4.3-3 and 4.3-4 show RCS propellant consumption for attitude holds only at ± 5.0 deg or ± 0.3 deg for an 0.001-deg rate gyro threshold. Figure 4.3-5 gives the same information for a 0.01-deg rate threshold. Note that all propellant consumption quoted assumes attitude hold about all three axes. One set of propellant tanks will provide a capability of 0.3-deg limit cycling for the entire mission with ideal rate sensing (0.001-deg/sec rate threshold) provide no disturbance torques are present. Retention of the current RGA, (0.01-deg/sec rate threshold) results in approximately a 15 fold increase in RCS propellant consumption. Table 4.3-1 summarizes RCS attitude hold capability using either an unmodified RGA (0.01-deg/sec rate threshold) or a modified RGA with a rate threshold of 0.001 deg/sec. Further discussion on rate threshold effects is given in Paragraph 4.2.

4.3.3 Recommended Configuration

Based on the current LEM RCS propellant tank system, the maximum utilization of propellant in limit cycle mode (minimum impulse, $O/F = 1.3$) is 423 lb. If the oxidizer and fuel tanks are interchanged, the maximum propellant utilization increases to 524 lb (1048 lb for two sets of tanks). Estimated RCS propellant expenditure during disturbed inertial attitude hold operation is shown in Fig. 4.3-6. The minimum torque values at which these data are valid is given in Paragraph 4.2 (Fig. 4.2-15). The time average of external torque disturbances for Phase I Lab 200-n.mi missions is currently estimated to be between 0.2 and 0.3 ft-lb. The effect of internal disturbance torques, however, has not been analyzed. A precise knowledge of both CSM and Lab operations will be required for this analysis.

4.3.3.1 RCS Contingency Requirements

The above data, considered a good estimate of propellant requirements, is based on a limited amount of data on experiment payload, vehicle design, pointing requirements, and disturbance torques. The normal limit cycling rate about a vehicle axis for moments of inertia above 23,500 slug-ft² is a function of engine minimum impulse bit. Above this value "Gyro Rate Bias" exists wherein the propellant flow is determined by rate gyro sensitivity. The minimum impulse bit of the Marquardt RCS engine, although bracketed by an estimate, is undefined. Within tolerance limits, the engine minimum impulse bit may vary between 0.35 and 1.45 lb-sec. This variation includes engine to engine performance, power supply voltage, system pressure and environmental changes. The upper limit of minimum impulse bit is the most severe condition for limit cycle operation, possibly quadrupling the propellant flow rate (from rates shown in Fig. 4.3-1 through 4.3-5). An analysis of tolerance limit engine performance will be undertaken in Phase C. Since the present LEM system satisfies the vehicle requirements, as now understood, no change from the LEM is suggested.

4.3.3.2 Feed System Dynamics

The influence of feed system dynamics upon reaction control engine performance has been studied using the basic tools developed for the LEM RCS.* The reaction control system for the Labs will be used exclusively for attitude hold; therefore, the engines will be operated in a mode which requires one or more minimum impulse bits upon command. The results reported below use the computer mode for dynamic interaction developed for the LEM RCS. The duty cycle for all pulse modes was 10-ms "on-time" followed by 130-ms "off-time" (Fig. 4.3-7). The following are the possible RCS operational modes:

- Single Engine Firing a Single Pulse: The total impulse developed from the single pulse is reproducible from pulse to pulse as long as the time between pulses is greater than the time required for the feed system to return to equilibrium. The dynamic model of the RCS indicates that the time to return to equilibrium depends on the physical position of the engine in the system but is on the order of 0.500 sec.

* Dynamic Interaction Analysis and Computer Model - LEM Reaction Control Propulsion System, Volume 1, R. Bowlin, R. Rose, Advanced Technology Laboratory Report, General Electric Company, Schenectady, New York

- Single Engine Firing Multiple Pulses: In the example analyzed, the total impulse of each pulse was not the same; the deviation being about 20% between the largest and smallest impulse bit. The total impulse produced by an RCS jet after the first pulse is in part a function of the time between pulses and the physical position of the engine in the system.
- Two Engines Firing a Single Pulse in Phase: Figure 4.3-8 shows, as a function of time, the chamber pressure (P_c), and the total impulse of two engines firing a pulse in phase. The engines are those in the "A System" which are used for a +Z rotation. The chamber pressure-time trace shows that neither peak chamber pressure, nor the total impulse from each engine is the same. A secondary peak, probably caused by "water hammer" effects appears in each trace at different times.
- Two Engines Firing Multiple Pulses in Phase: Figure 4.3-9 shows, as a function of time, the chamber pressure and the total impulse of two engines firing multiple pulses in phase. The engines are those in the "A System" which are used for a +Z rotation. It should be noted that none of the three pulses of either engine give the same total impulse; the deviation between largest and smallest pulse being 28.7% for Engine 10, and 40.2% for Engine 13. While the total impulse for each additional pulse diminishes, the cumulative difference in total impulse increases with each succeeding pulse. Figure 4.3-10 shows, as a function of time, chamber pressure and total impulse for Engine 5 and Engine 10 in the "A System"; these jets are used for -Y rotation. Engine 5 has less total impulse than Engine 10 for the first pulse, but has more on the succeeding pulses. There is a 40% deviation in total impulse between the largest and smallest pulse by Engine 10, but only a 12% deviation for Engine 5.
- Two Engines: Firing a Single Pulse Not in Phase, and Firing Multiple Pulses Not in Phase: Conceptually, to get a pure couple, two engines on either side of the vehicle must fire with the same total impulse at the same time. However, due to control system electronics, this situation rarely occurs. One engine will fire slightly sooner than the other. From a vehicle control point of view, this will cause no problems; however, from a feed system dynamics point of view, this could cause considerable difficulty. The total impulse and peak chamber pressure is a strong function of the static pressure of the propellants at the engine valve. If the propellant valves on the second engine open, just as the rarefaction wave caused by the first engine's valve movement passes, the static pressure may be so low that cavitation will occur. The second engine will be fed only gaseous propellant, and no firing will occur. Conversely, if the valve on the second engine opens, just as a reflected wave is passing, the static pressure may be considerably higher than nominal, and the engine will use more propellant and develop a much greater than nominal impulse bit. Either of these situations obviously is bad. Provisions have been made to analyze these cases when the magnitude of the delays is made known.

4.3.4 Baseline Configuration

The baseline configuration is the same as the recommended configuration.

4.3.5 Alternate Configuration

The only alternate considered is the reversing of the fuel and oxidizer lines. This increases the effective capacity of the tanks from 423 to 524 lbs.

Table 4.3-1

SUMMARY OF RCS ATTITUDE-HOLD CAPABILITY

		Max Attitude Hold Duration, days			
		Sets of RCS Tanks			
		1 Unmod		1 Mod	
Deadzone, deg		±0.3	±5.0	±0.3	±5.0
RGA Threshold, deg/sec	0.01 (Unmod)	2.63	43.2	3.26	53.5
	0.001 (Mod)	24.8	415	30.8	513.0
$I_{x-x} = 30,000 \text{ slug-ft}^2$ $I_{y-y} = I_{z-z} = 200,000 \text{ slug-ft}^2$					

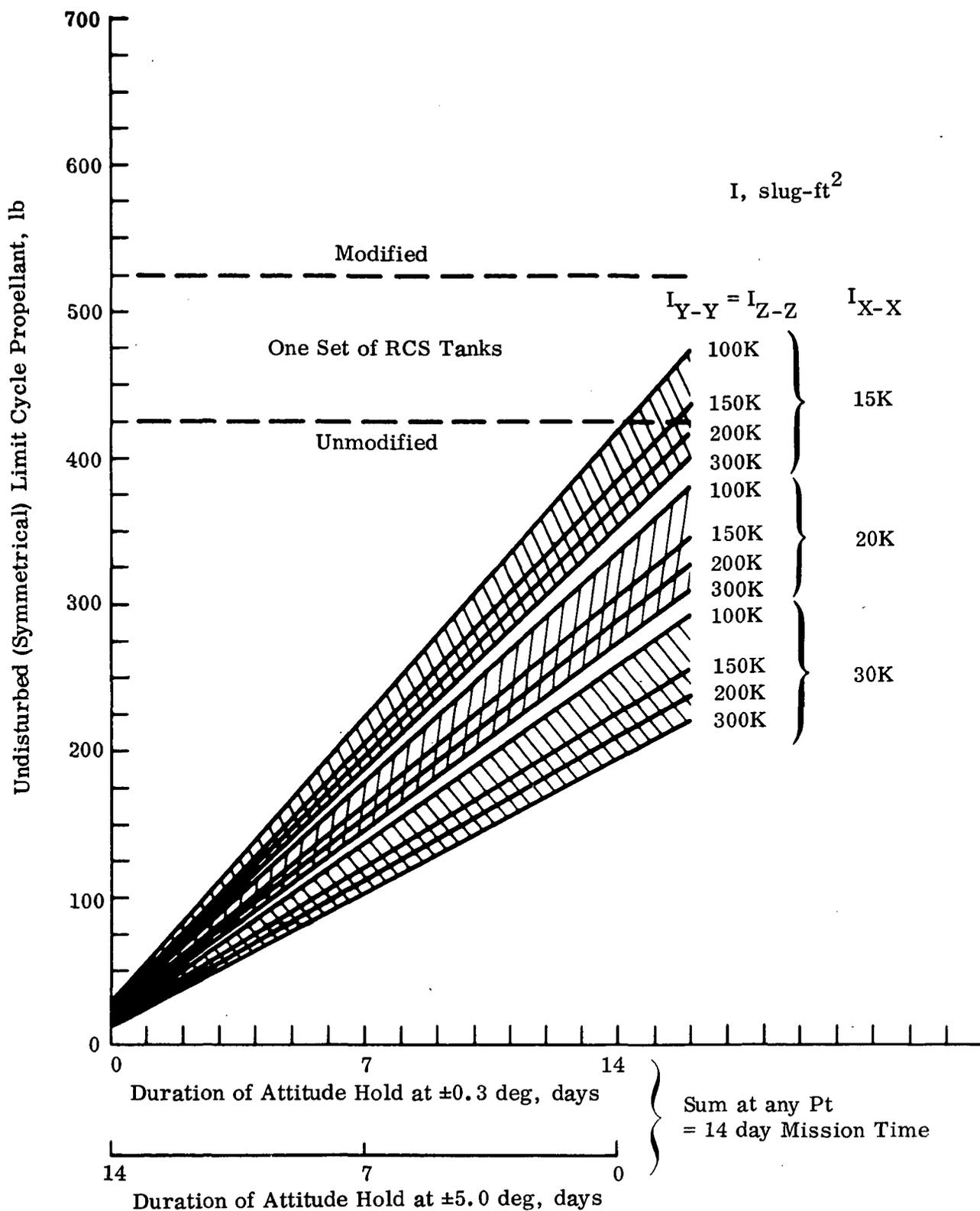


Fig. 4.3-1 Phase 1 Lab Undisturbed Attitude Hold RCS Propellant 0.001 Deg/Sec Rate Threshold Undisturbed Attitude Hold RCS Propellant Requirements 0.01 Deg/Sec Rate Threshold

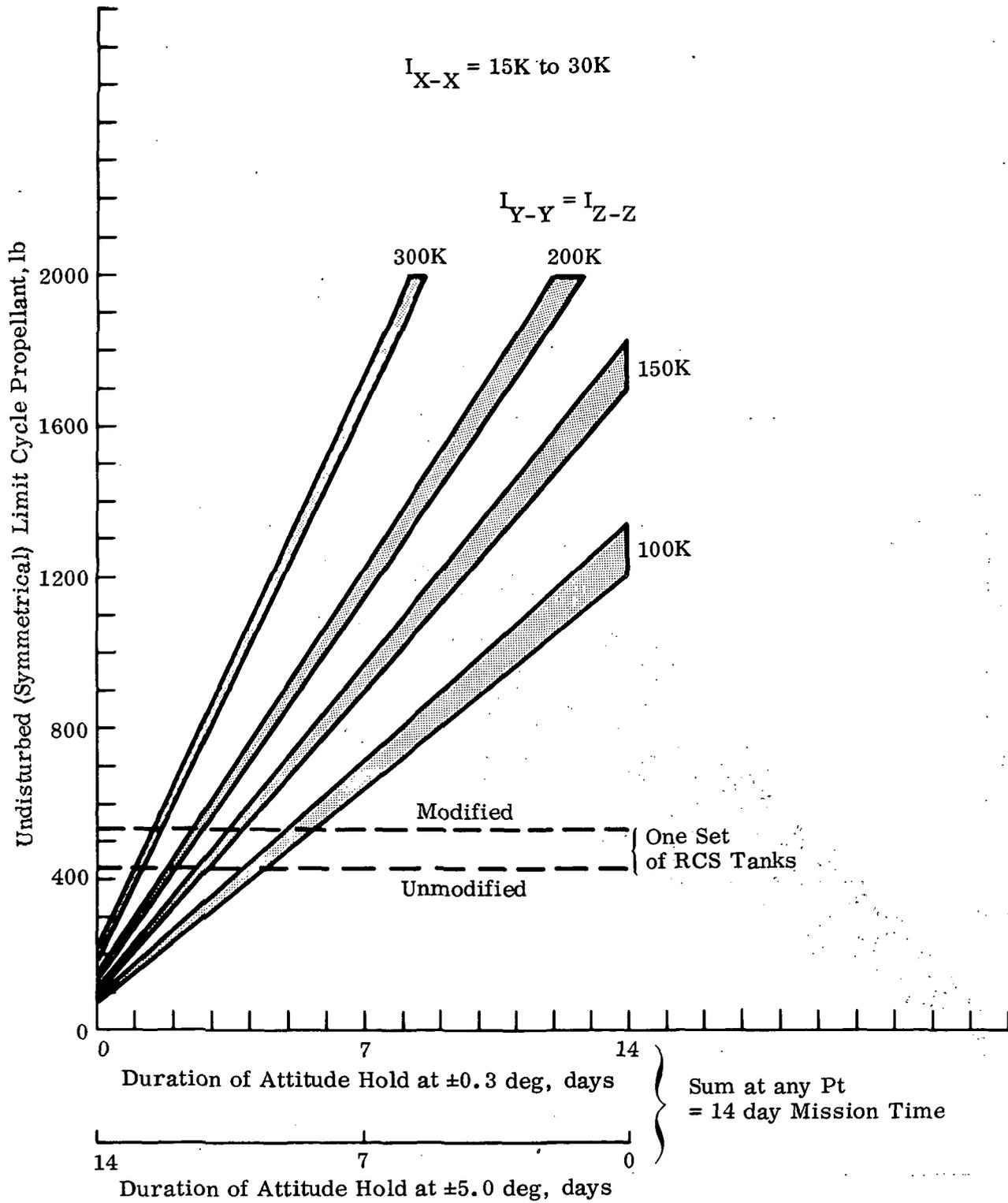


Fig. 4.3-2 Undisturbed Attitude Hold RCS Propellant Requirements
0.01 Deg/Sec Rate Threshold

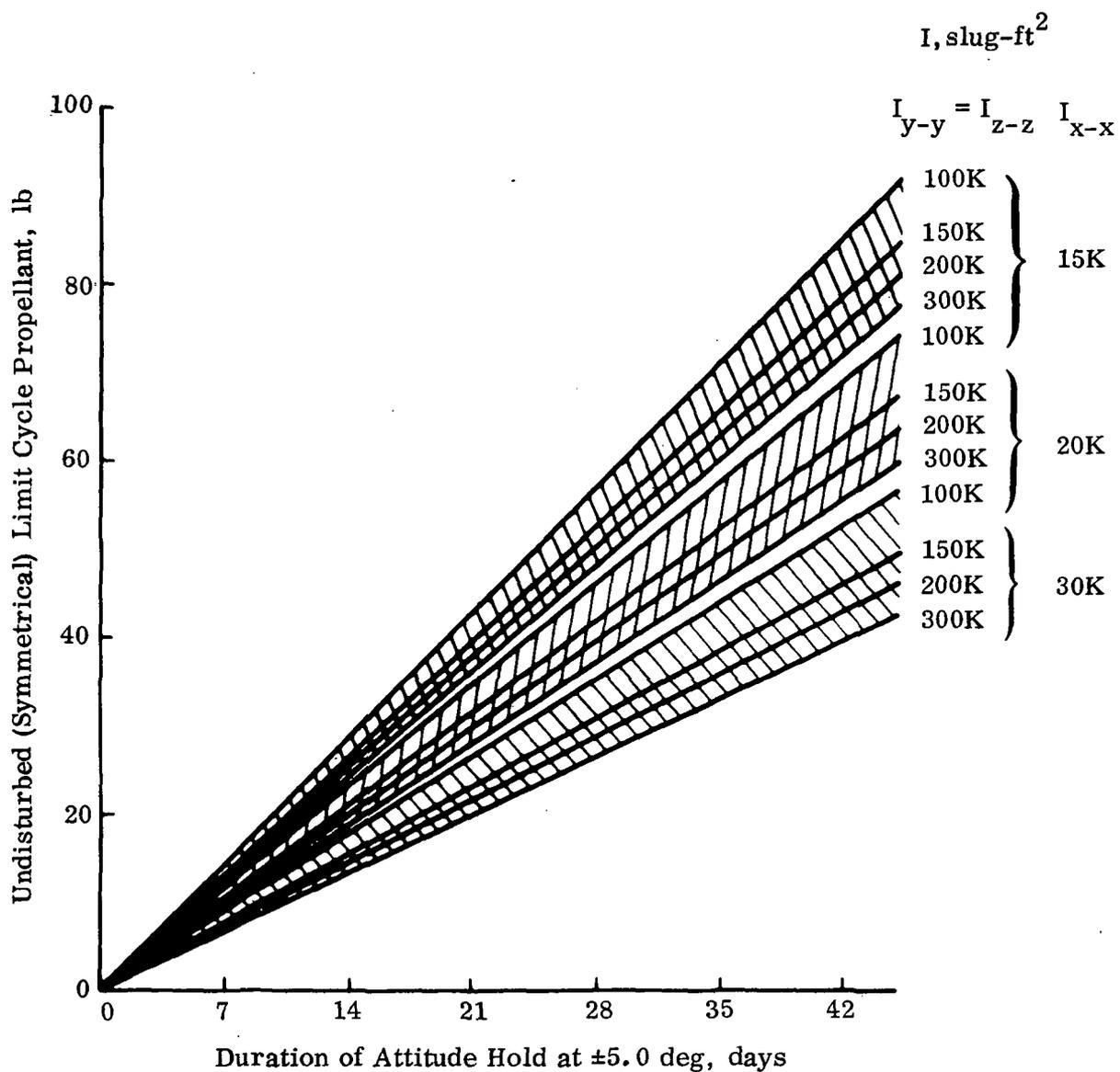


Fig. 4.3-3 Undisturbed Limit Cycle RCS Propellant Requirements for ± 5.0 deg Deadzone .001 Deg/Sec Rate Threshold

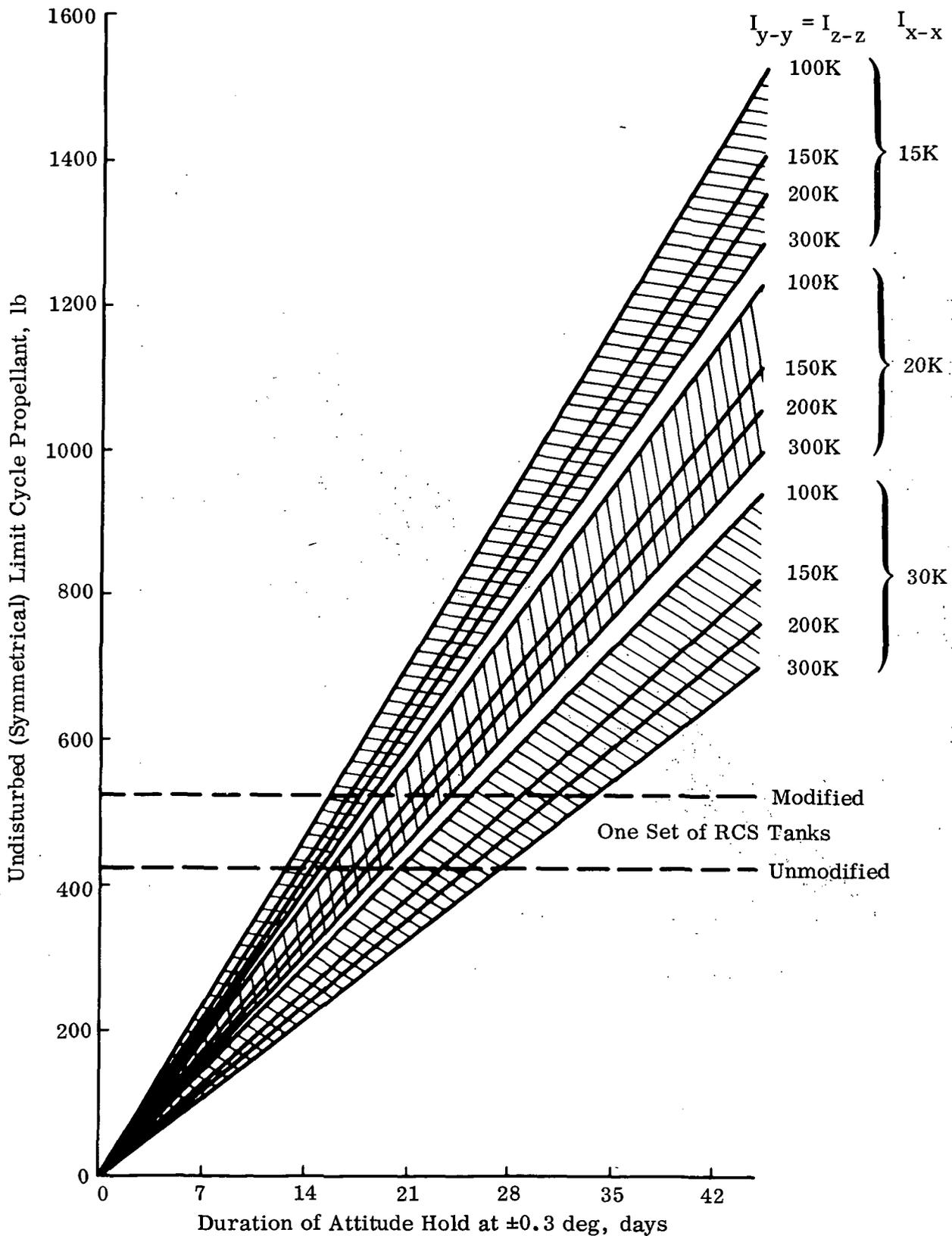


Fig. 4.3-4 Undisturbed Limit Cycle RCS Propellant Requirements for ± 0.3 Deg/Sec Rate Threshold

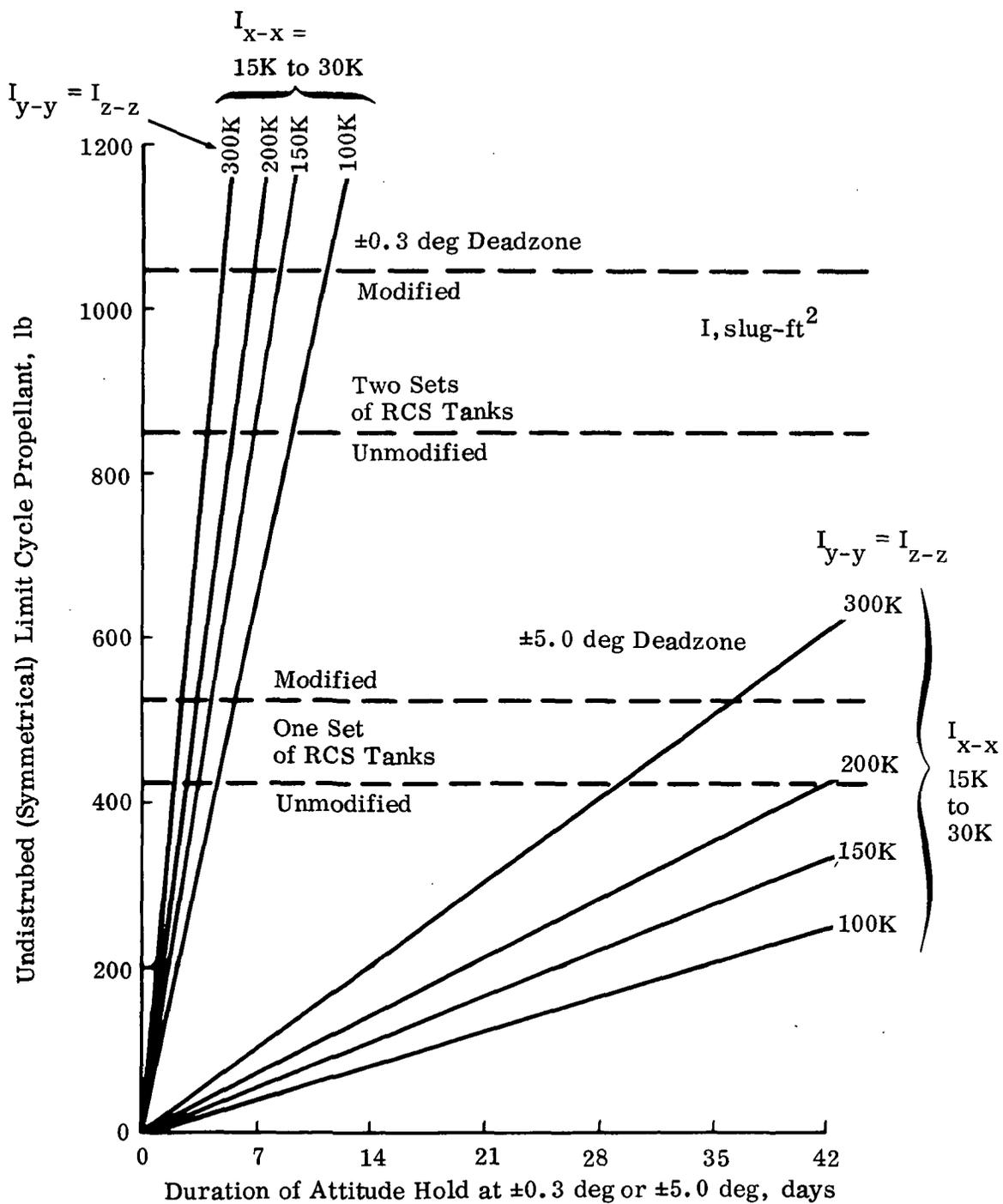


Fig. 4.3-5 Undisturbed Limit Cycle RCS Propellant Requirements for ± 5.0 Deg/Sec or ± 5.0 Deg/Sec or ± 0.3 deg. Deadzone 0.01 Deg/Sec Rate Threshold

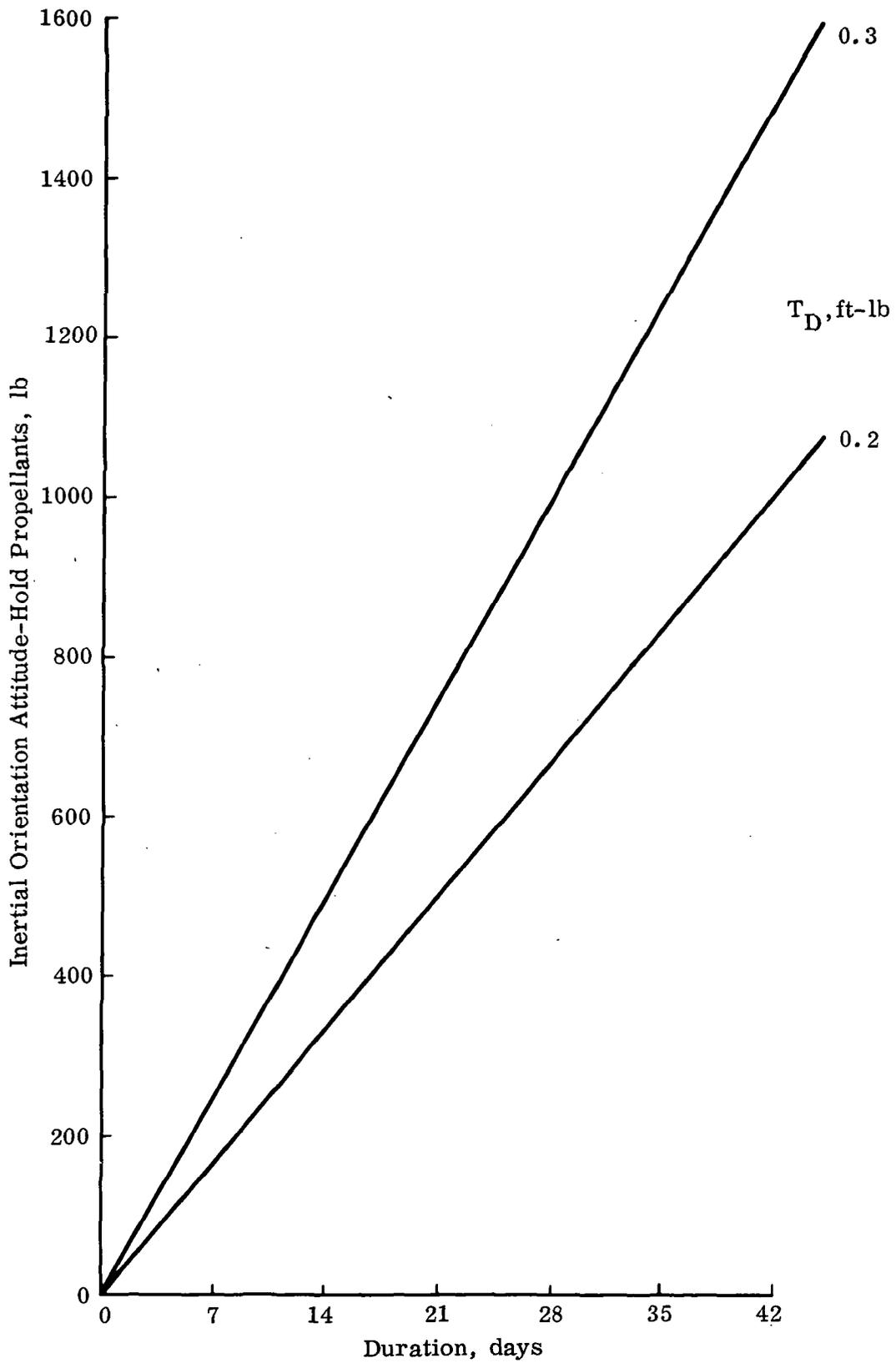
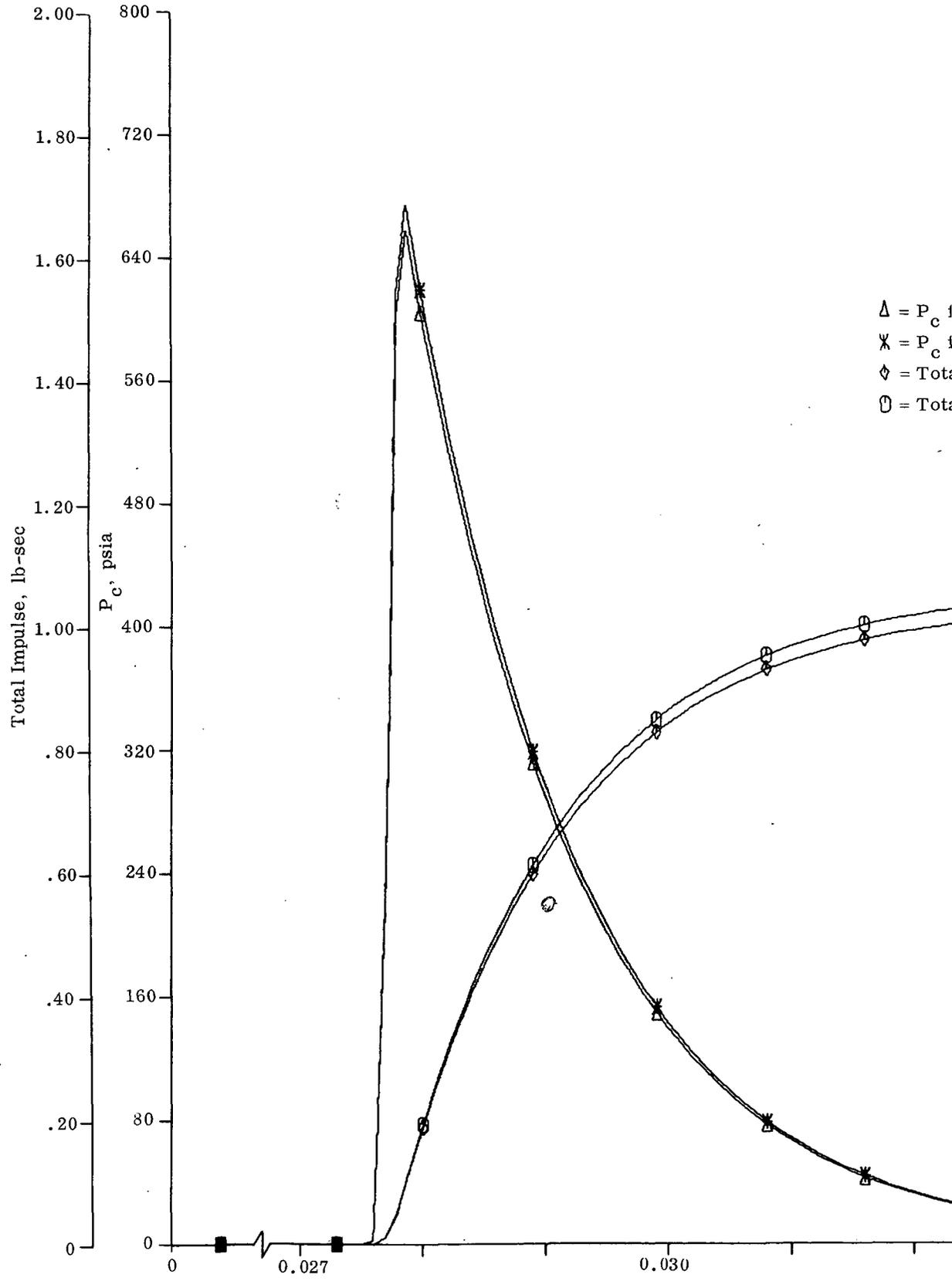


Fig. 4.3-6 Disturbed Attitude Hold Propellant Requirements

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Symbols
r Engine 5
r Engine 10
Impulse, Engine 5
Impulse, Engine 10

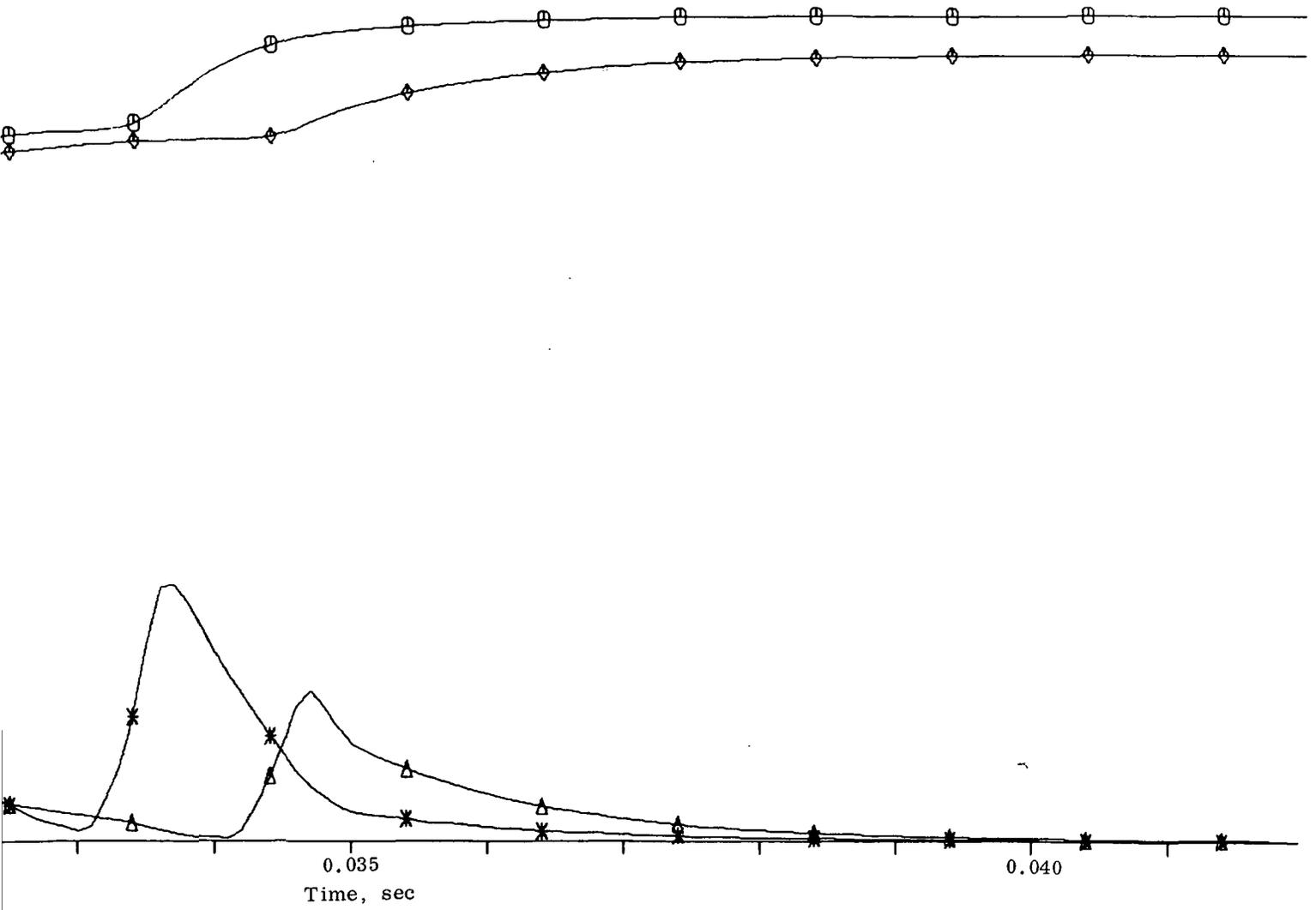
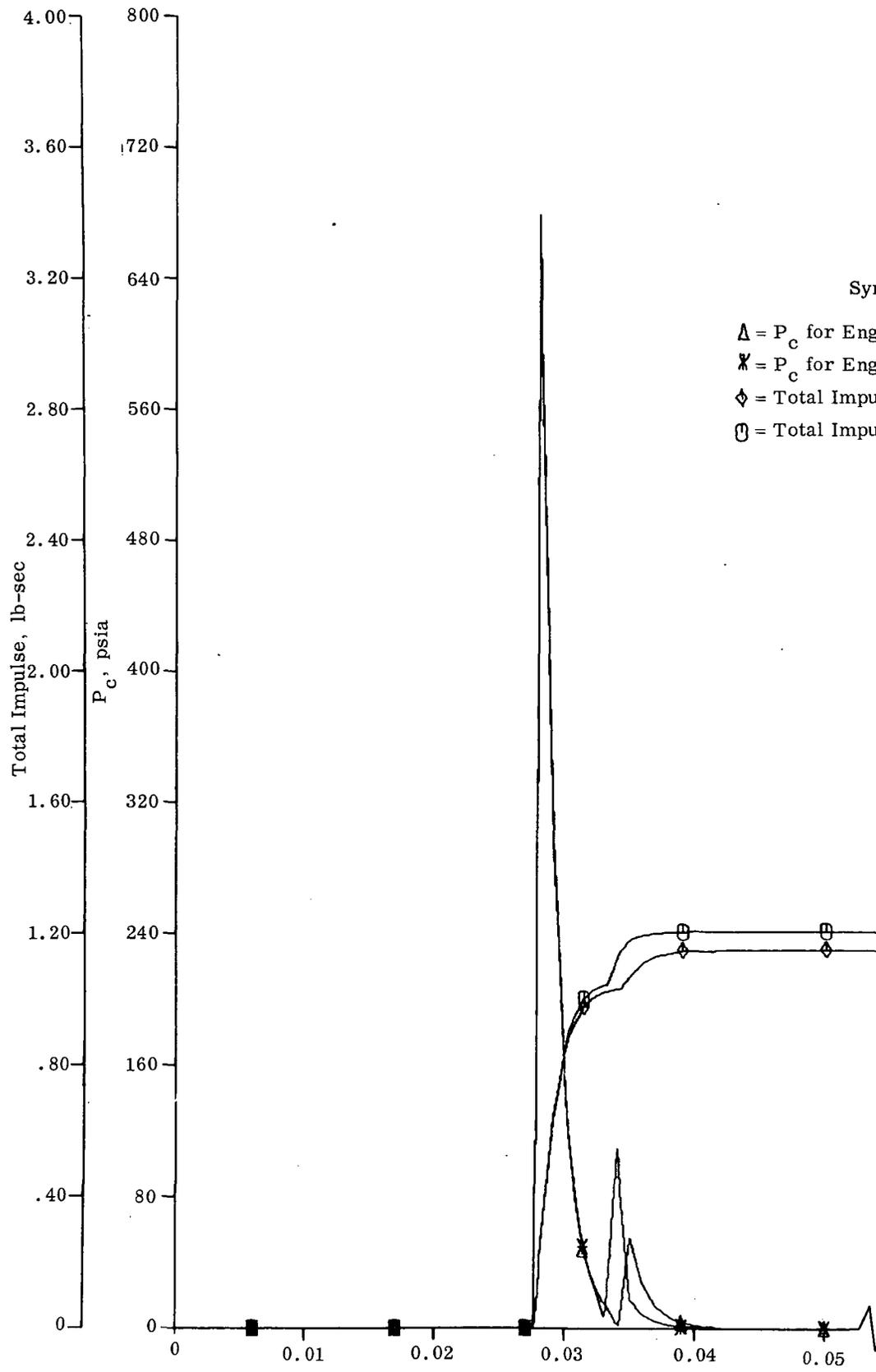


Fig. 4.3-8 Two Engines Firing A Single Pulse in Phase + Z Rotation

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Syn

- Δ = P_c for Eng
- \times = P_c for Eng
- \diamond = Total Impul
- \square = Total Impul

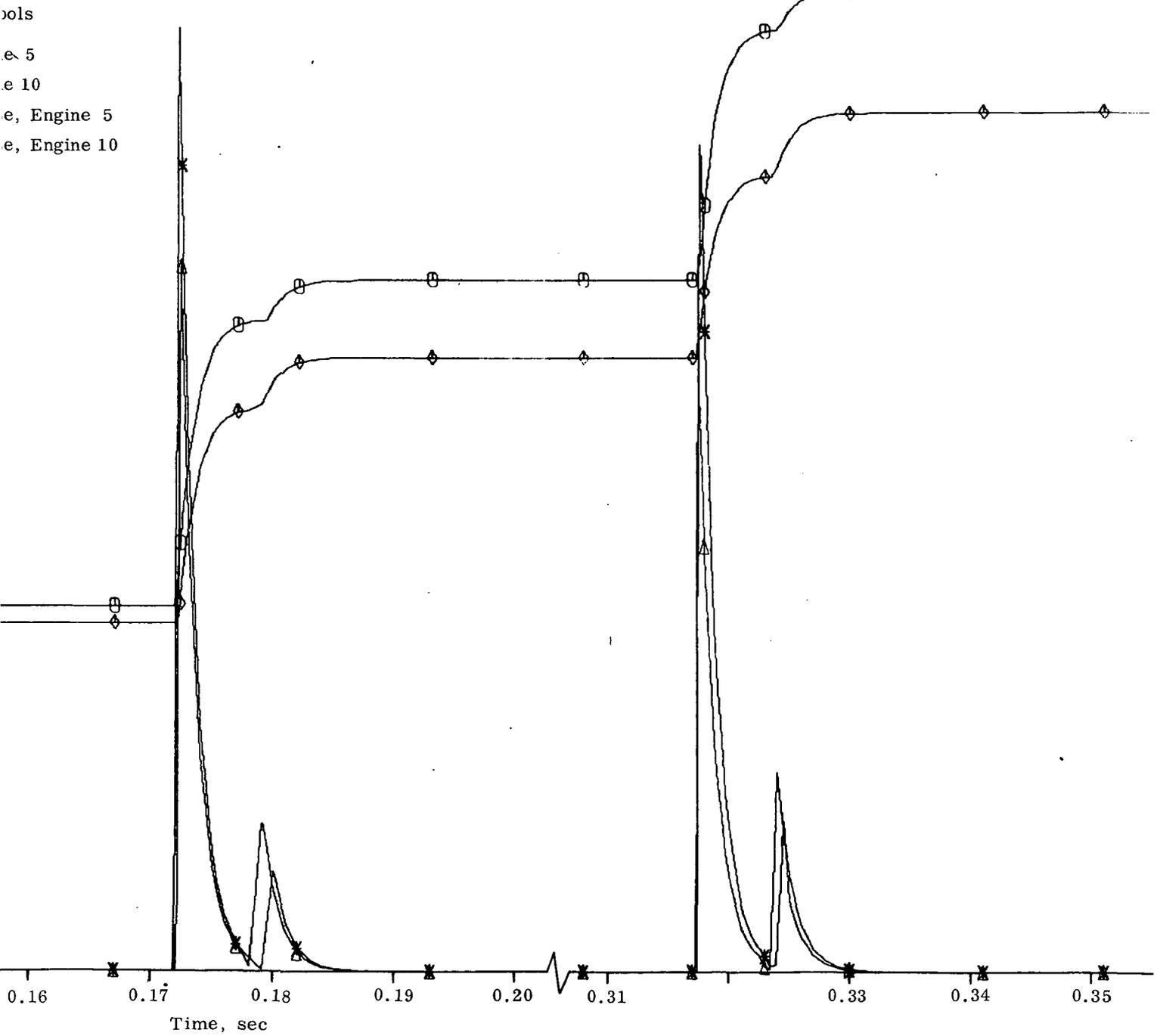
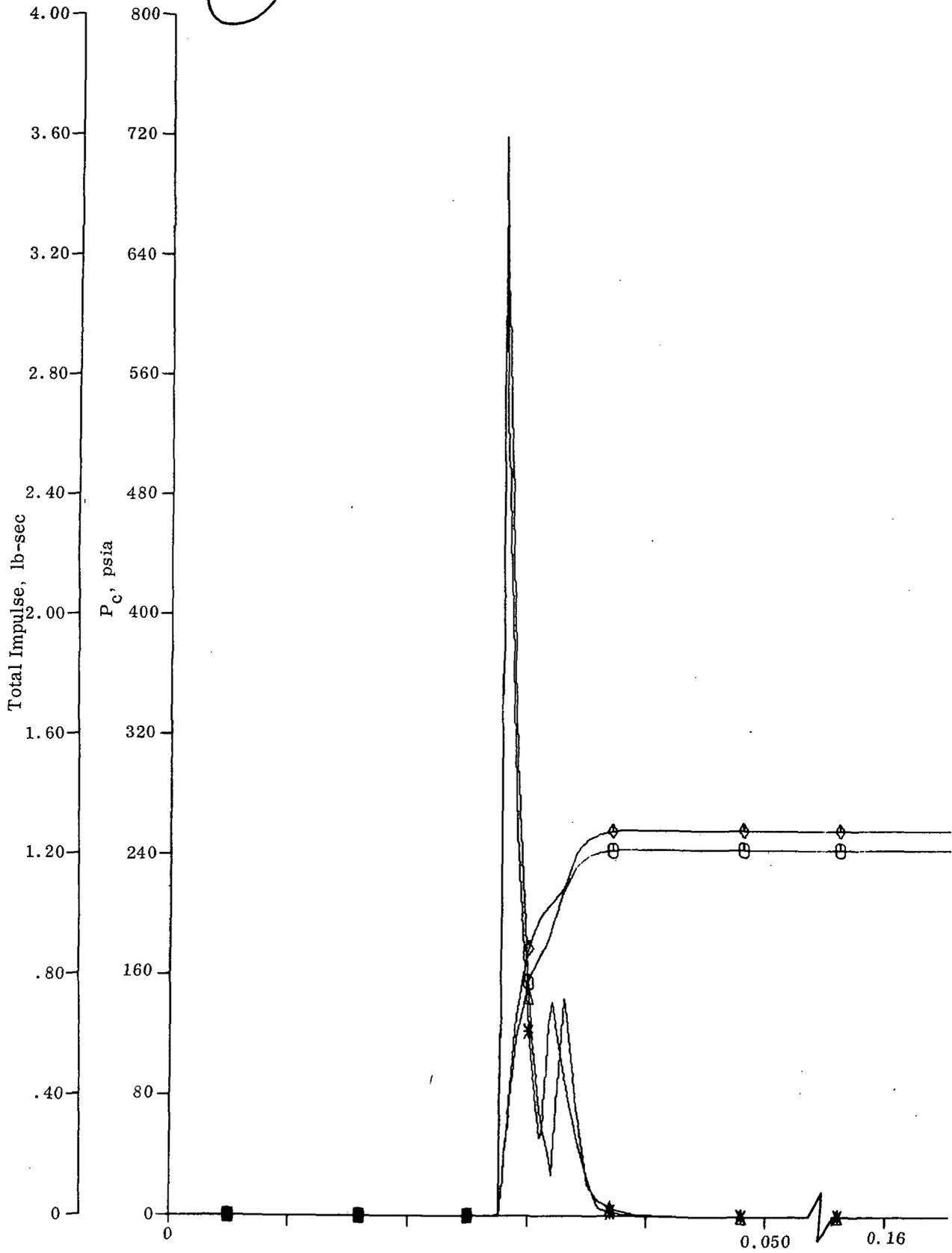


Fig. 4.3-9 Two Engines Firing Multiple Pulses in Phase + Z Rotation

71



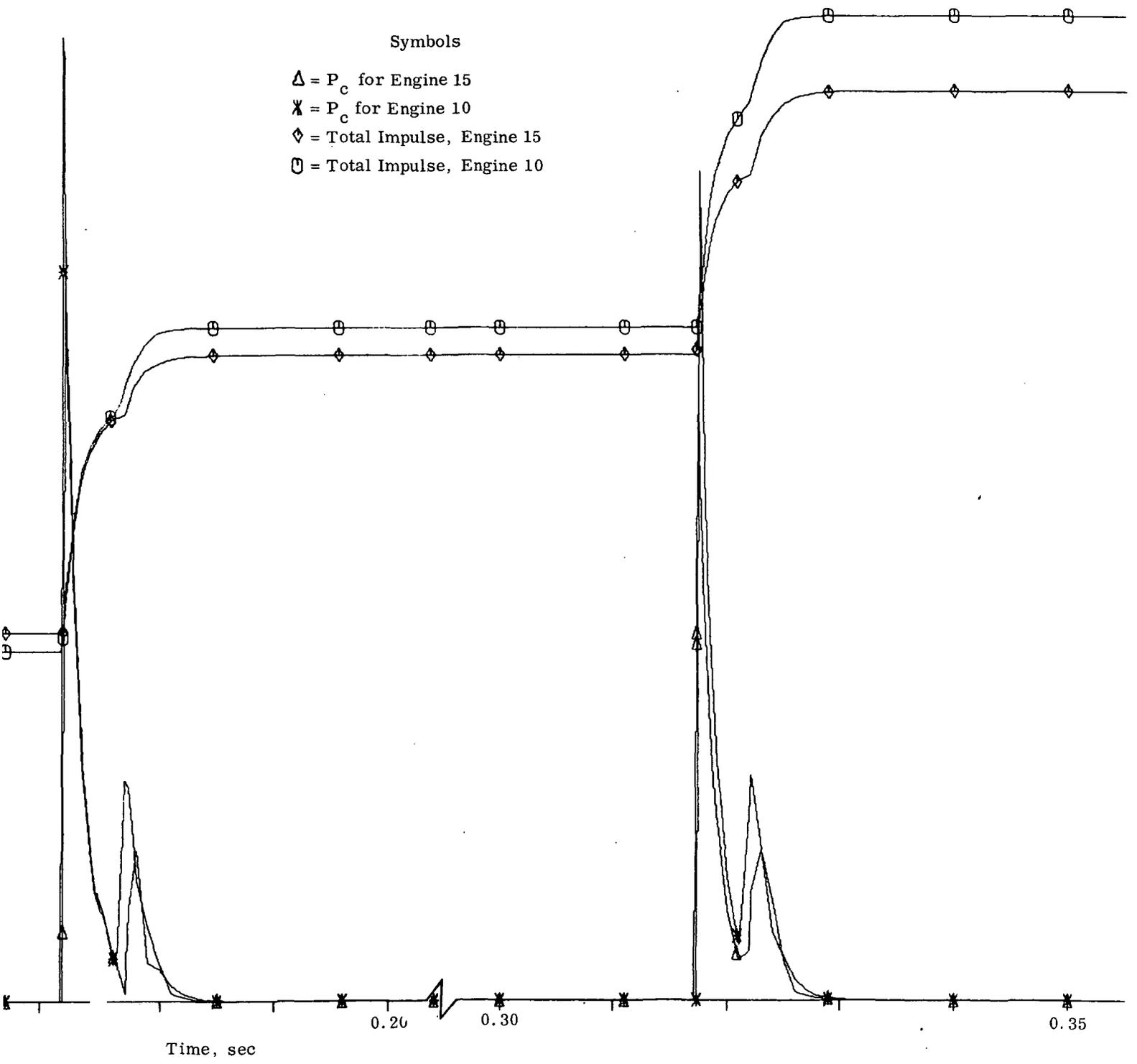


Fig. 4.3-10 Two Engines Firing Multiple Pulses in Phase -Y Rotation

4.4 CREW SYSTEMS

4.4.1 Assumptions

The responsibility of Crew Systems is to insure that all hardware with which man must interface is designed to satisfy man's role within the context of the mission (Ref. 4.4-1 through 4.4-7). In satisfying this requirement, the following assumptions have been made:

- Waste management functions will be handled by the CM
- Crew safety package will be utilized in the Lab
- Suit loop will be utilized in the Lab
- Three-man crew (2 in the Lab, 1 in the CM during work activity) (in shirt sleeves)
- 10-hr work/14-hr non-work per man per day
- Lab work activities will include housekeeping and experiments

4.4.2 Background Data

Crew Systems requirements include such areas as:

- Life support
- Radiation monitoring
- Volume
- Crew training

4.4.2.1 Life Support Requirements (Fig. 4.4.1)

4.4.2.1.1 Environment. The environment is made up of a single-gas constituent, oxygen, which is compatible with the design and requirements of the environmental control system. The total barometric pressure is equal to 259 mm Hg (5 psia), based on the following partial pressures:

- $O_2 = 243$ mm Hg
- $CO_2 = 5$ mm Hg
- $H_2O = 11$ mm Hg

Control of oxygen in the atmosphere is accomplished by cryogenic storage ranging from 110 to 425 mm Hg in partial pressure.

To control the atmosphere, certain constituents such as carbon dioxide must be removed or rendered capable of utilization. Carbon dioxide will be removed via LiOH canister. Oxygen is stored cryogenically and in quantities satisfactory for mission completion.

Ventilation flow rates are important for environmental control of temperature and comfort. Flow-rate requirements depend on the level of activity in a given area commensurate with metabolic loads expressed in btu. The following values are given as general requirements for ventilation flow rates.

- | | |
|-------------------------------|-----------|
| ● Living area | = 240 cfm |
| ● Personal hygiene and toilet | = 240 cfm |
| ● Work area | = 400 cfm |
| ● Sleeping area | = 40 cfm |

Trace contaminant removal will be obtained with the filtering of gas flow used for other ambient control functions. Odors are absorbed by charcoal. Microbiological growth is controlled by ultraviolet radiation and the use of germicides. Aerosol (mist or fog) is removed by filtration.

4.4.2.1.2 Metabolism. A schedule of activities for the crew has been assumed and metabolic rates have been assigned to the duration of the activity in a 24-hr day. Based upon a practical distribution time and activity for a given day, the energy expenditure ranges between 300 to 2400 btu, with a total expenditure of approximately 12,000 btu/man-day. This value requires a level of energy of approximately 3000 calories/man-day.

4.4.2.1.3 Food and Water. Food quantity is estimated to be approximately 1.5 lb/man-day, where the amount of carbohydrates, protein, fat, and water totals approximately 1.32 lb/man-day, and the remaining 0.28 lb/man-day consists of the calorifically valueless foods and unassimilated food. This is commensurate with the metabolic parameters defined in the schedule of events and the substrate required.

Water may be required in the preparation of certain foods. Total water requirements for input, independent of sanitation, is 2.6 lb/man-day. Five lb of wash water per man-day is estimated for personal hygiene; it may subsequently be used for laundry.

4.4.2.1.4 Waste Management. Waste management (Table 4.4-1) will be a functional requirement of the CSM.

4.4.2.1.5 Clothing. The clothing required for the crew consists of extravehicular suits and undergarments, and flight garments and undergarments. The undergarments may be expendable. Normal operation inside the Lab will be a shirt-sleeve environment. Space suits will be used to protect the occupants in the event a decompression is required to effect a minor repair. Pressure suit compatibility is therefore considered in the design of the interior.

4.4.2.1.6 Personal Hygiene. Personal Hygiene activities will include the use of:

- Treated, throwaway, wash cloths that the astronaut will use to cleanse his entire body
- Toilet and urinal facilities to collect and store urine
- Means of collection and storage nails, hair, skin, etc. of solid waste, i.e.

4.4.2.2 Personnel Radiation Safety Monitoring Package

Radiation exposure of astronauts in a parking earth orbit remains a potential rather than a definite hazard (Ref. 4.4-1). The level of exposure of astronauts in the Mercury and the recent Gemini mission were within allowable limits. However, the following parameters still remain critical for any radiation analysis:

- Solar flares
- Duration of exposure
- Type and amount of vehicle and personnel shielding
- Quantitative chronological record of exposure of the individual crew member

- Age of the crew member
- Maximum permissible critical organ dosage.

Tolerance limits which have been recommended for Apollo are listed in Table 4.4-2.

In view of the importance and complexity of the problem and the difficulty of getting adequate direct information on the effects of space radiation on the genetic makeup of the crew, the indirect evaluation is considered the best indicator of these biological effects of space radiation. Table 4.4-3 lists techniques for personnel radiation monitoring.

4.4.2.3 Volume

4.4.2.3.1 Pressurized Volume. A pressurized volume of approximately 250 cu ft is available to accommodate the necessary hardware and two astronauts. This includes 183.5 cu ft in the front work area and 66.5 cu ft in the bulkhead area.

4.4.2.3.2 Usable Volume. A usable volume (free space) of approximately 210 cu ft is available to accommodate the astronauts. This insures 105 cu ft of free volume per man during the duration of the mission. According to Ref. 4.4-2 and 4.4-3, a free space volume of 100 cu ft per man is desired, while 60 cu ft/man is minimum for 2-weeks confinement.

4.4.2.4 Crew Training

The AES flight crew training requirements and training equipment documents proposed by the Support Group have been reviewed and found to be generally acceptable at this time. A review of a sample of MSC training documents prepared for the Gemini Project has revealed certain guidelines which may be of importance in the AES training plans. These are:

- Crew members are normally scheduled as teams in designated positions
- Cross-seat and cross-team training is required on critical tasks
- Backup crew training should be equivalent to the primary crew
- Only one crew member participates in less critical tasks (reg. spacecraft tests and meetings)
- Gemini and Agena craft schedules are basic to other crew training schedules
- Thorough training in basic spacecraft systems is required
- The crew commander is responsible for his crew-training activities.

4.4.3 Recommended Configuration

The recommended configuration shall include the following crew system inputs:

- Crew safety package
- Suit loop
- Crew duty cycle
- Lighting
- Color scheme
- Furnishings.

4.4.3.1 Crew-Safety Package

The crew safety package will display respiration rate, and heart rate; the minimum requirement for crew safety (Ref. 4.4-4). The astronaut and ground monitoring stations will be able to observe these rates whenever the biomedical umbilical is plugged into the jack provided in the control panel. This safety package is necessary for:

- Real-time evaluation of astronaut's physical condition
- Simplicity of required instrumentation
- Medical significance
- Minimizing medical and physical hazard
- Minimizing time and crew training requirements.

4.4.3.2 Suit Loop Requirements

It is assumed that normal work activity is accomplished with the astronauts in the shirtsleeve environment, however, the suit loop is needed in the Lab to accomplish suit checkout and provide life support whenever the astronauts must "suit up." Suit up will be required of both astronauts whenever an EVA is scheduled. Although only one of the astronauts may be required to egress from the Lab, the second astronaut must be ready to egress the Lab if he is needed as an extra pair of hands (in accomplishing a given task) or, more importantly, in the event of emergency life saving conditions. While in the Lab, the second astronaut will operate suited and pressurized. The suit loop will keep him comfortable while he continues to observe the first crewman and/or perform any other tasks. Tables 4.4-4 and 4.4-5 indicate the general activity in preparation for EVA and the specific procedures for the suit loop and PLSS.

4.4.3.3 Crew Duty Cycle

4.4.3.3.1 Guidelines.

- Each operator will be on a 10-hr work/14-non work schedule
- Non-work schedule will include:
 - Compatible recreation, socialization, and eating periods for the operators (e.g., Operator A and B eat together twice a day for 0.5 hr each and socialize twice/day for 0.5 hr each; operator B and C schedule and operator A and C schedule is compatible).
 - An extended period of 6 hr minimum, 8 hr maximum for each operator for eating, personal hygiene, and undisturbed sleep. This is staggered for each operator.
- Work schedule will include:
 - 4 hr of undisturbed work followed by a non-work period of 4 hr, (a 4:4:2, 4:2:4, or 2:4:4 work schedule is desired).
 - At least one operator always awake
 - All three operators awake during EVA
 - EVA period of 3.5 hr is maximum with PLSS (tethered operator).

- PLSS Usage
 - PLSS will use throwaway batteries.
 - If using the same PLSS after an EVA, 1 hr is required to bring PLSS up to requirements and checking out prior to going on next EVA.
 - If switching PLSS after an EVA, 25 min is required prior to going on next EVA.

4.4.3.3.2 Work Routine. The normal work routine will include such activities as:

- Housekeeping
- Operational and experimental (not discussed here for basic Lab)

Housekeeping is an ongoing activity which follows a prescribed routine of monitoring system status, communicating with ground stations, checking out pressure suits, performing EVA's, and replacing LiOH canisters (Table 4.4-6).

The data shown below is a daily breakdown of time required for housekeeping activities for the Lab and the CSM, and the time available to run experiments and perform other necessary work. It is based upon a 10-hr/day maximum work load per astronaut.

	Time; Hr:Min	
	<u>Per Man</u>	<u>Total</u>
Housekeeping activities for the Lab	0:23	1:09
Housekeeping activities for the CSM*	0:47	2:20
Total Housekeeping AES	1:10	3:29
Experimental Time and Worktime Available	8:50	26:31
Total on Duty Time	10:00	30:00

4.4.3.3.3 Duty Cycle Description. The duty cycle is compatible with crew guidelines. Refer to Fig. 4.4-2:

- Maximum utilization made of the time where two astronauts can eat meals or rest together in the CM (example: hr 6-7 for crewmen 1 and 2, and hr 9:30-10:00 for crewmen 1 and 3, and hr 14-15 for crewmen 1 and 3, and hr 20-21 for crewmen 1 and 2).
- Two astronauts can also perform experiments and work together in the Lab (example: hr 11-14 for crewmen 1 and 3, and hr 16-19:30 for crewmen 1 and 2). In the case of the EVA, during hours 7:20 to 9, all three crewmen are awake, and crewmen 1 and 2 are suited.

4.4.3.4 Lighting

The mission requirements of the Lab necessitate the placement of additional lighting both interior and exterior to supplement the existing sources provided for the LEM. The light package for the Lab will include:

*Ref. NAA Housekeeping Time Line for Phase I Flights, CSM orbital phase.

- Interior
 - Worktop
 - Flood: panel and ceiling
 - Dome: overall illumination of cabin interior mid-section
 - EL: controls and displays
- Exterior
 - Floods: two located at lower corners of descent stage, 180-deg apart, illuminating underneath, away from, and along sides of vehicle. Can be controlled from exterior or interior switch.
 - Docking Lights: same as the existing LEM

The present lighting array should supply the total light source needs. Power requirements are based on the worst possible case, i.e., no natural light source, direct or indirect.

4.4.3.5 Color Scheme

The color scheme shall be the same as for the LEM.

4.4.3.6 Furnishings

The work space equipment, and layout are as follows:

- Two work top desk tables, 18 x 24 in., located in either side of the immediate front section of the forward cabin with suitable console lamps to uniformly light the entire perimeter of each desk. These desk tops serve as recreation tables, and are of the fold-down type with appropriate wall recess and bracket for storage. They are an addition to the existing LEM.
- One swivel-type seat, 14 in. ID, located beneath desk tables. Adjustable swivel seats with vertical pin-break hinge to facilitate storage. This is an addition to the existing LEM.
- Storage areas, totaling 17.38 cu ft of storage space, are available in various locations (both in the forward cabin and in the mid-section of the Lab). This space is expected to be for the storage of experimental equipment.

4.4.4 Baseline Configuration

The baseline configuration is the same as the recommended configuration.

Table 4.4-1

MAN'S WASTE PRODUCTION

Source	Quantity, lb/man-day
Urine	3.2
Feces	0.3
Water Vapor	5.3
Carbon Dioxide	2.3
Flatus	5×10^{-3}
Hair	7×10^{-4}
Nails	2×10^{-5}
Microorganisms	4×10^{-4}
Skin Cells	7×10^{-3}
Mucus	9×10^{-4}

TABLE 2
RADIATION EXPOSURE DOSE LIMITS

Critical organ	Maximum Permissible Intergrated Dosage, rem	Relative Biological Effectiveness, rem/rad	Average Yearly Dose, rad	Max. Permissible Single Acute Emergency Exposure, rad	Location of dose point
Skin of whole body	1600	1.4 (approx)	250	500	Depth of 0.70 mm from surface of cylinder 2 at highest dose-rate point.
Blood forming	270	1.0	55	200	5 cm Depth of cylinder 2.
Feet, ankles and hand	4000	1.4	550	700	Depth of 00.7 mm from surface of cylinder 3 at the highest dose point.
Eyes	270	2	27	100	Depth of 3 mm from surface on cylinder 1 along eyeline.

Table 4.4-3
PERSONNEL RADIATION MONITORING

Equipment	Weight, lb	L x W x H, in. (Volume)	Frequency	Comments
Tissue Equivalent Ionization Chamber (Integrating)	1 each (3 total)	3 x 2 x 1/2	Up to 500 rad.	One chamber per man plus 1 charger shared by all. This unit is worn on the apparel and must be read. Requires recharging depending upon dose encountered.
Tissue Equivalent Ionization Chamber (Rate Meter)	2 each (4 total)	4 x 3 x 3	0.1 to 100 rad/hr	Two portable battery-operated units/man. Recommend shelf mounting 1 unit near minimum shielding location in vehicle; 2nd unit should be moved to wherever astronauts are working. Gives off sound after danger level is reached; must be read.
Film Packs (21 packs total)	1.5	2 x 2 x 1/8	Up to 1000 rad	Seven film packs required for each astronaut.

Grumman

Table 4.4-4
STE-UP FOR EVA, USING SUIT LOOP

<u>Time</u> <u>min:sec</u>	<u>Crewman No. 1</u>	<u>Crewman No. 2</u>	<u>Time</u> <u>min:sec</u>
06:00	● Don Suit (Less Helmet)		
00:15	● Hook up to Suit Loop (For cooling)		
01:00	● Don Emergency Oxygen Supply (EOS)		
02:00	● Erect PLSS Donning Station		
01:00	● Attach PLSS No. 1 to Donning Station and Prepare PLSS No. 1 for checkout	● Don Suit (Less Helmet) ● Hook up to Suit Loop (for cooling)	06:00 00:15
01:30	● Checkout PLSS No. 1 Commun- ication/Telemetry/Warning	○ Don EOS	01:00
01:30	● Check PLSS No. 1 coolant		
00:15	● Don Helmet		
03:30	● Checkout PLSS No. 1 O ₂ Supply and Suit Leakage - Connect PLSS Line - Disconnect ECS Umbilicals - Pressurize Suit thru PLSS		
01:30	● Prepare PLSS No. 1 for Standby		
02:30	● Don PLSS	● Assist Crewman No. 1	02:30
00:15	● Hook up to Suit Loop		
	● (Remain on Suit Loop until Cabin is Re-Pressurized at Completion of EVA)	● Attach PLSS No. 2 to Donning Station and Prepare for Checkout	02:00
		● Checkout PLSS No. 2 Communi- cations/Telemetry/Warning	01:30
		● Checkout PLSS No. 2 Coolant	01:30
		● Don Helmet	00:15
		● Checkout PLSS No. 2 O ₂ Supply and Suit Leakage - Connect PLSS Line - Disconnect ECS Umbilical - Pressurize Suit Thru PLSS	03:30
		● Enable PLSS No. 2 for Egress	02:00
02:30 sec	○ Assist Crewman No. 2 in Donning	● Don PLSS No. 2	
00:30 sec	○ Close Hatch between LEM and CSM		
02:00 sec	○ Dump Cabin Pressure		
		● Open Forward Hatch	00:30
		● Egress into Space	
<u>Suit Loop Time</u>			
Astronaut No. 1 = 15 min 30 sec (Initially), then all EVA time			
Astronaut No. 2 = 21 min 30 sec (Prior to EVA)			
Total Suited Time			
Astronaut No. 2 - 26 min 30 sec			

Table 4.4-5

END OF EVA USING SUIT LOOP

Time min:sec	Crewman No. 1	Crewman No. 2	Time min:sec
00:30	● Open Hatch	● Ingress Lab	1:00
		● Connect to Lab Systems	2:00
		- Hookup to Suit Loop	
		- Disconnect & Shutdown PLSS No. 2	
00:30	● Secure Hatch		
01:20	● Initiate Cabin Re- pressurization to 5.0 psia		
03:00	● Assist Crewman No. 2	● Doff PLSSS No. 2	03:00
00:30	● Open Hatch between LEM/CSM	● Stow PLSS No. 2	01:00
		● Remove & Stow PLSS Donning Station	01:00
03:00	● Remove PLSS No. 1	● Assist Crewman No. 1	03:00
01:00	● Stow PLSS No. 1	● Disconnect Suit Loop	00:15
10:00	● Assist Crewman No. 1	● Doff Suit & Accessories & Hang to air dry prior to stowing	10:00
00:15	● Disconnect Suit Loop	● Assist Crewman No. 1	10:00
10:00	● Doff Suit & Accessories & Hang to air dry prior to stowing		
Suit Loop Time			
Astronaut No. 1 = 19 min 35 sec			
Astronaut No. 2 = 10 min 15 sec			
Total Suited Time			
Astronaut No. 2 = 21 min 15 sec			

Table 4.4-6
 PHASE I LAB HOUSEKEEPING ACTIVITIES

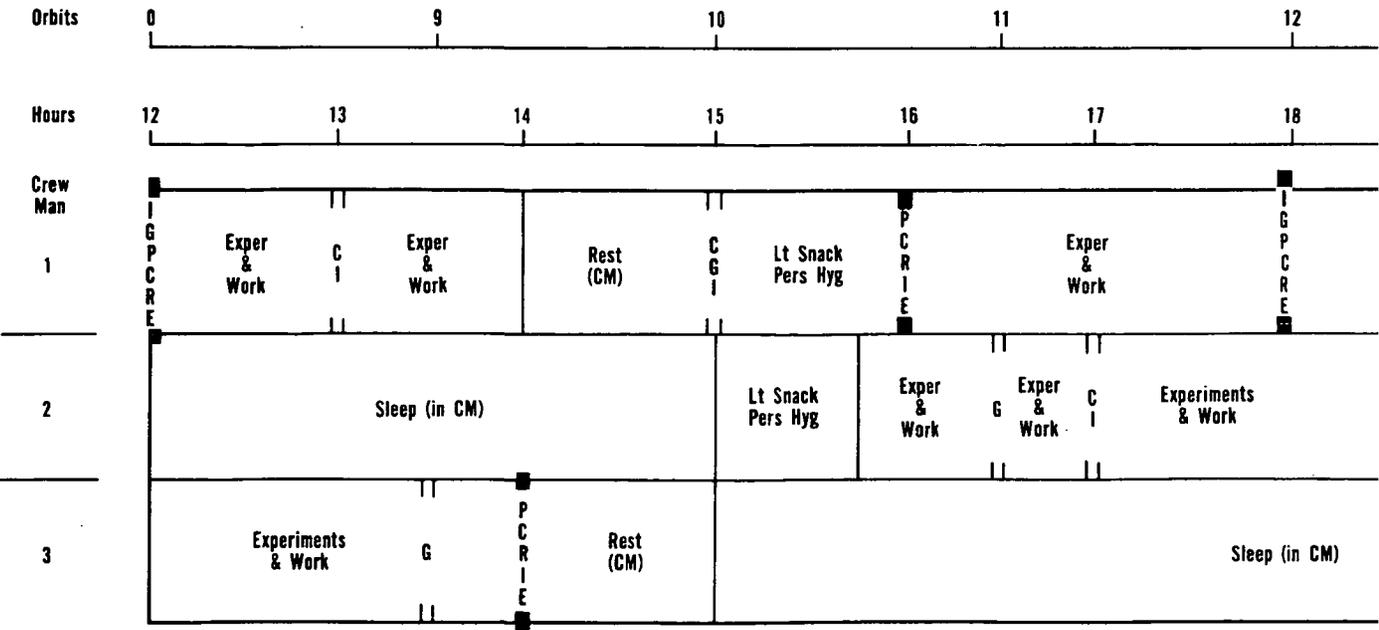
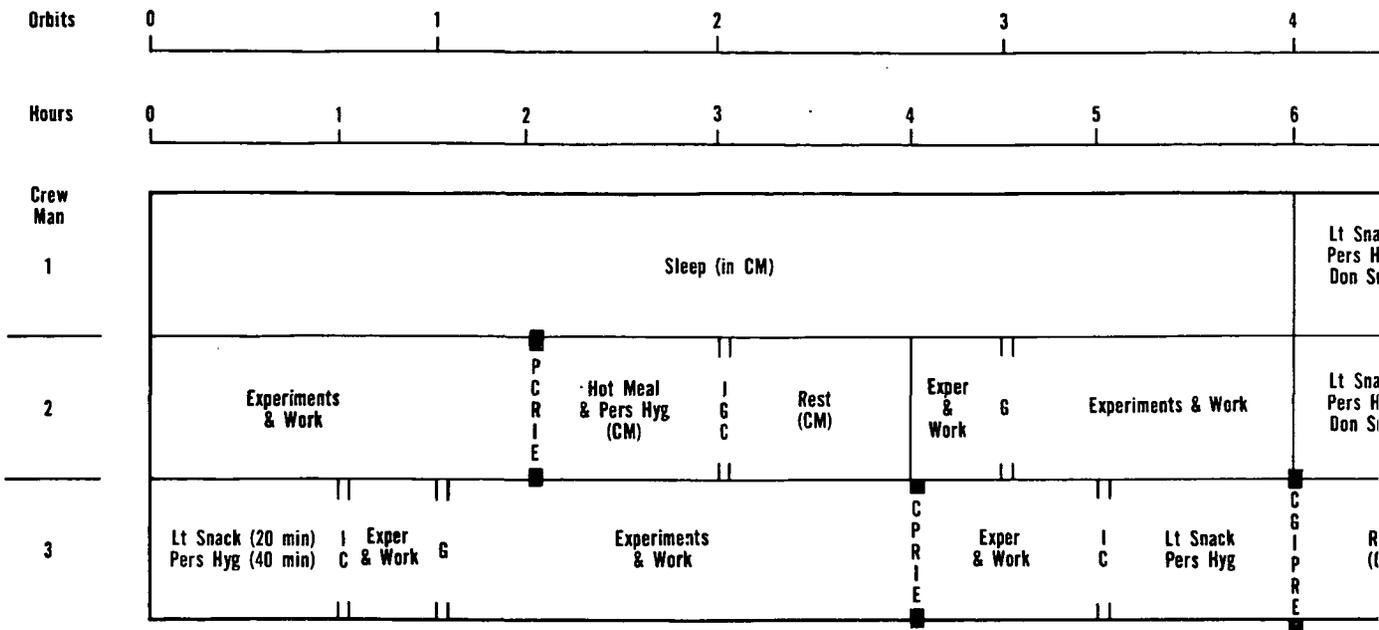
Subsys	Frequency, Every:	Time min:sec	Work Activity Description
EPS	2 hr	0:30	Monitor display panel for battery status.
Comm	45 min (Approx)	0.10	Turn on & off. Talk while in range of station (0-40 min).
RCS	2 hr	0:30	Check pressure and temperature
GN & C	90 min	1:00	Visual check and adjust if necessary.
Instr	1 hr	1:00	Visual check of displays.
ECS	2 hr	1:00	Visual check of gauges and lights.
Suit & PLSS	EVA	20:00	Test of sealing, maneuverability, pressure, etc.
LiOH	7 days	5:00	Unloading used canisters; loading and setup of fresh canister.

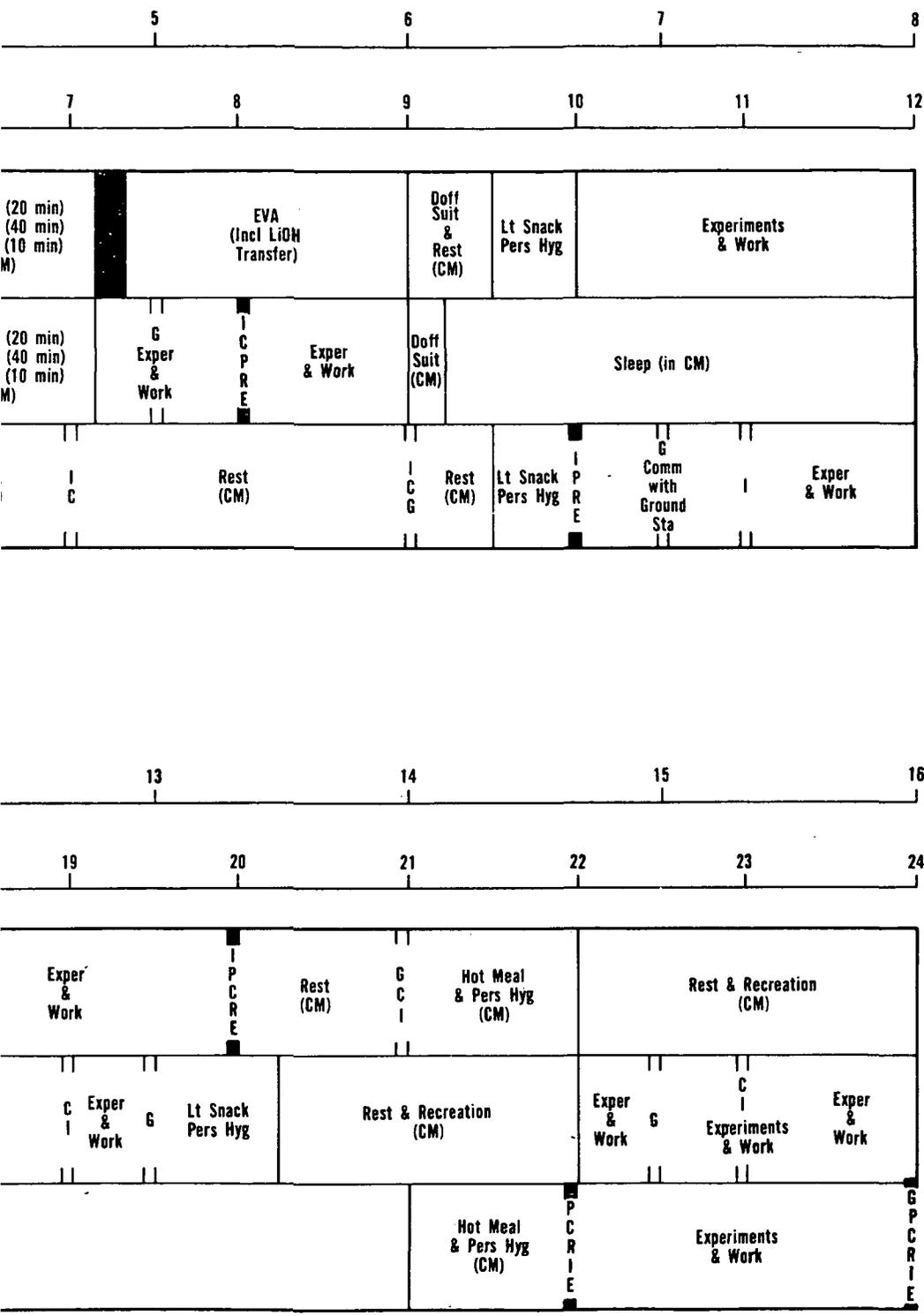
<ul style="list-style-type: none"> ● Atmosphere 	Atmosphere Control
100% O ₂ zero N ₂ CO ₂ (30 mm Hg Max.) H ₂ O vapor (13 mm Hg Max.) Barometric pressure, 5 psi Ventilation - Living Area - Pers Hyg & Toilet - Work Area - Sleep Area Contamination - Odor - Low mol wt contaminants - Microbiological - Germicides & Aerosol	Cryogenic Storage, 110-425 mm Hg N/A with One-Gas System LiOH Absorption Partial Pressures of Constituents 240 240 400 40 } cu ft/min Flow Rate Charcoal Absorption Catalyst Bed UV Radiation Filtration
<ul style="list-style-type: none"> ● Wastes, lb/man-day 	Waste Control
H ₂ O vapor, 5.3 Urine, 3.2 Feces, 0.3 CO ₂ , 2.3 H ₂ O, 5.0	Absorption Decontamination/Vented Store LiOH Absorption Vented

- Metabolism: 300 to 2400 Btu depending on level of activity (sleeping, eating, exercise, recreation, housekeeping, personal maintenance, system monitoring, and experimental work). Total energy expenditure = 12,000 Btu/man-day.
- Food: 3000 calories/man-day, 1.5 lb/man-day (GFE Diet).
- Water: 2.6 lb/man-day, drinking and food preparation.
5.0 lb/man-day, sanitation and hygiene.
- Clothing: EVA suits, undergarments, and flight garments.
- Interfaces: Pressure suit accessories, life support pack, shelter, and EVA clothing.
- Requirements: storage, donning space, O₂ and H₂O tank filling, air-lock operation, ECS checkouts, bacteriological decontamination, communications system mobility, waste handling, and biomedical instrumentation.
- Work-Rest Activities
 - Duty: console monitoring, experimentation, EVA.
 - Unscheduled: experiment reporting.
 - Rest: relaxation and sleeping.
 - Exercise: body conditioning.
- Personal: toilet and general grooming.

Fig. 4.4-1 Life Support Requirements

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- Housekeeping
Work Activity
in Lab
- EPS (P)
 - Comm (C)
 - RCS (R)
 - GN&C (G)
 - Instr (I)
- █ ECS (E)
- Suit, PLSS
 - LiOH

- Notes:
- Wash-up before meals; personal hygiene & toilet duties (if reqd) after meals.
 - Tasks designated with bars top & bottom relate to housekeeping tasks.
 - Astronauts on a 10-hr work, 14-hr non-work schedule
 - All tasks in Lab except when specified CM (Command Module).
 - Except for EVAs, all work done with astronauts in shirtsleeves.

Fig. 4.4-2 Typical Day Activity



4.5 RELIABILITY AND MAINTAINABILITY

4.5.1 Assumptions

4.5.1.1 Mission Profile

A time-line summary for a Phase I Lab design reference 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 and K factors, as well as the 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.

4.5.1.2 Vehicle Configuration Definition

Mission success probability calculations are based on the recommended vehicle configuration defined in Table 2.3-1.

4.5.1.3 Mission Success Definition

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

4.5.1.4 Failure Rate Data

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 elsewhere in this report.

4.5.2 Background Data - Comparison of Stabilization & Control Subsystems

The S&CS of the Phase I Lab plays a major role in the determination of overall vehicle reliability. Because of this, and since there is more than one possible S&CS, a special study was undertaken to define the reliability of the S&CS choice. The S&CS function of the recommended Lab configuration consists of equipment required for rate stabilization, and equipment required for attitude hold. The equipment considered to be the minimum requirement for the recommended configuration is:

- Rate Stabilization Equipment: Rate Gyro Assembly (RGA), Attitude and Translation Control Assembly (ATCA), and Attitude Controller Assembly (ACA).
- Attitude Hold Equipment: Abort Sensor Assembly (ASA), and Abort Electronics Assembly (AEA).

4.5.2.1 Abort Guidance System

4.5.2.1.1 Rate Stabilization Section. This section consists of three assemblies:

- ATCA: This may be divided into two parts:
 - Input section, consisting of the limiters, gradient amplifiers, summing amplifiers, demodulators, and deadband.
 - Output section, consisting of jet select logic, vertical and horizontal summing amplifiers, pulse ratio modulators, preamps, and jet drivers.

Based on a grouping of the pulse ratio modulators in two sets of four each, one set for the horizontal thrusters and one set for the vertical thrusters, the circuits of the output section may be divided in the same manner. In the group of vertical circuits there is full capability if three out of four operate. In the group of horizontal circuits, if three out of four operate full X-rotation capability is retained. For Y and Z translation, one thruster is used in one-half of the cases, and a pulsed couple balances out the torque caused by one thruster operating. Thus automatic control remains intact, but with a fuel and time penalty for Y and Z translation only. If we do not include this penalty in the reliability calculation, we have the reliability model shown in Fig. 4.5-1.

- RGA: This assembly is included with a failure rate of 99.1×10^{-6} failures/hr.
- ACA: This assembly is included with a failure rate of 33.4×10^{-6} failures/hr.

The reliability of the Rate Stabilization Section is

$$R_S = R_A (R_1 R_2 R_3 R_4 + Q_1 R_2 R_3 R_4 + R_1 Q_2 R_3 R_4 + R_1 R_2 Q_3 R_4 + R_1 R_2 R_3 Q_4) \\ (R_5 R_6 R_7 R_8 + Q_5 R_6 R_7 R_8 + R_5 Q_6 R_7 R_8 + R_5 R_6 Q_7 R_8 + R_5 R_6 R_7 Q_8) \\ R_{RGA} R_{ACA}$$

4.5.2.1.2 Attitude Hold Section - It has been assumed that two alternatives are possible for the Lab: one which does not require accelerometers, and one which does require them for small translational changes. If accelerometers are not required, a considerable reduction in failure rate can be realized. If accelerometers are required, the configuration will be the same as for LEM. The reduction in failure rate is not anticipated as due to physical removal of subassemblies, a removal which would have undesirable thermal side-effects, but simply due to a mathematical reduction.

The failure rates, based on actual parts count, are as follows:

<u>Assembly</u>	<u>LEM Failure Rate</u> <u>Failures per Million Hr</u>	<u>AES Failure Rate</u> <u>Failures per Million Hr</u>
ASA	370.29	265.35
AEA	<u>1016.00</u>	<u>802.80</u>
	1386.29	1068.15
ATCA	132.00	51.34
ACA	33.40	33.40
RGA	<u>99.10</u>	<u>99.10</u>
	<u>264.50</u>	<u>183.84</u>
	Total: 1650.79	1251.99

If the Rate Stabilization Section operates at 100% duty cycle and the Attitude Hold Section operates at 50% duty cycle, the following values indicate the reliability of both sections of the S&CS for 5, 10, 30, 65, 100, and 300 hr, for a configuration which does not require accelerometers.

<u>Equivalent</u> <u>Time (Hr)</u>	<u>$\Sigma K \lambda t$</u>	<u>Reliability</u>
5 hr	0.003587	0.99647
10	0.007174	0.99285
30	0.021523	0.97871
65	0.046633	0.95444
100	0.071743	0.93077
300	0.215230	0.80635

The operating time of the basic S&CS is not fixed because the experiments may require various other types of stabilization, guidance, and control, each with its own operating time.

4.5.2.2 Primary Guidance System

If the guidance system consists of the Primary Guidance and Navigation subsystem (PGNS), and if accelerometers are not required, mathematical reduction in failure rates may be realized, as with the Abort Guidance System.

Regarding the IMU, if accelerometers are not required, three PIPA's and three Power Amplifiers can be deleted from reliability calculations.

Regarding the PTA, circuitry associated with accelerometers can be deleted from reliability calculations.

Regarding the LGC, circuits not required for acceleration can be put to other uses. Failure rates based on those given in the specification for the PGNS, are as follows:

<u>Subassembly</u>	<u>LEM Failure Rate Failures per Million Hr</u>	<u>AES Failure Rate Failures per Million Hr</u>
IMU	137	69
PSA	126	126
PTA	62	12
CDU (181 ea)	905 (5)	543 (3)
LGC	<u>352</u>	<u>352</u>
	1582	1102
ATCA	132	1
ACA	<u>33.4</u>	<u>34.4</u>
	Total: 1747.4	1136.4

Note, the DSKY is considered as part of Displays and Controls. If other types of sensors are used during some experiments, thus allowing the PGNS to be shut down, the RGA and ATCA would be used. The following failure rates are for the configuration used under these conditions:

<u>Subassembly</u>	<u>LEM Failure Rate Failures per Million Hr</u>	<u>AES Failure Rate Failures per Million Hr</u>
IMU*	7.8	7.8
Electronics*	6.3	6.3
ATCA	132.0	51.34
RGA	99.1	99.1
ACA	33.4	33.4
TCA	<u>31.0</u>	<u>----</u>
	Total: 309.6	197.94

If the PGNS is assumed to operate at a 50% duty cycle, the following values indicate the reliability of the system when using the PGNS:

<u>Equivalent Time</u>	<u>$\Sigma K \lambda t$</u>	<u>Reliability</u>
5	0.003335	0.996669
10	0.006671	0.993350
30	0.020015	0.980184
65	0.043366	0.957561
100	0.066717	0.935476
300	0.200151	0.819025

* Standby Failure Rate

Figure 4.5-2 shows reliability vs time for the stabilization and attitude hold function using the AGS. The reliability of stabilization only, of attitude hold only, and of both, but with duty cycles for attitude hold of 50% and 100% is shown. Similar information is shown in Fig. 4.5-3 for the PGNS.

The choice of system reliability and duty cycle depends on what other systems are available for guidance, navigation and control during the various experiments, and the reliability desired. Thus, if a lower reliability can be tolerated, the operating time can be extended, whereas if overall planning requires a high reliability, operating time would be curtailed and other types of systems would be used for other portions of the mission.

It is assumed that the minimum time between shut-down and turn-on for the PGNS or the AGS is 1/2 hr, due to the time required for thermal stabilization. Another factor limiting the number of on-off cycles is the failure rate associated with this cycling. It is desirable to arrange the experiments of the Lab according to the type of guidance system required, so that the operating times can be grouped, thus avoiding excessive on-off cycling.

4.5.2.3 Comparison of Systems

The reliability estimates of the AGS and PGNS have been made by independent sources and are therefore not subject to comparison. Consideration of the equipment, as to its design and adaptability to mission requirements, is more meaningful under the circumstances than a consideration of the reliability numbers available.

It should be noted that the PGNS in the LEM configuration has a higher failure rate than the AGS. However, if acceleration measurements are not required, the PGNS will have a lower failure rate than the AGS. This is because when the accelerometers and associated circuits are deleted from reliability calculations, the reduction for the PGNS is greater than for the AGS.

The specified operating life for the AGS is 5000 hr, whereas the specified operating life of the PGNS is only 2000 hr. The respective specifications for each equipment require 1000-hr periods free of scheduled maintenance for the AGS, whereas the maintenance-free mission of the PGNS is limited to 30 days or 720 hr. Thus the PGNS would be available for a maximum mission of 720 hr, from the erection of the spacecraft onto the assembled launch vehicle through mission accomplishment. The AGS would be available for a maximum mission of 1000 hr. These times apply if no maintenance is allowed on either system.

4.5.3 Recommended Configuration - Reliability Estimates

Subsystem reliability math models, functional block diagrams (Fig. 4.5-4), and equipment utilization times (Table 4.5-2) were developed to determine subsystem and recommended configuration reliability estimates.

4.5.3.1 Subsystem Reliability Estimates

4.5.3.1.1 Stability and Control. The S&CS recommended configuration for the Lab is considered to be a minimum configuration capable of rate stabilization and attitude hold. In the absence of definitive information as to the time of required

use for this equipment, it is assumed that the rate stabilization is required for 100% of the mission, and attitude hold for 50% of the mission. This yields a 0.785779 subsystem reliability. The subsystem housekeeping reliability, assuming 100% rate stabilization without attitude hold capability, is 0.940130. A detailed analysis including the ATCA failure rate derivation is described in Paragraph 4.5.2.

4.5.3.1.2 Reaction Control Subsystem. Reliability analysis of the RCS involves the attitude and fine translation capabilities of the vehicle, including: helium, oxidizer, and propellant storage; as well as regulation and thrust capability. The reliability math model is:

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

Insertion of the element reliability values into the math model, yields a 0.936157 RCS reliability.

The propellant tank bladders are the major contributing factor to unreliability because of their high failure rate. No additional problem areas are pointed out, since the reliability of the Phase I Lab RCS is greater than the value available from the LEM mission. Therefore, RCS reliability improvement can be achieved only if the inherent reliability of each component in the subsystem is upgraded.

4.5.3.1.3 Electrical Power Subsystem. The EPS utilizes 20 LEM descent stage batteries and two LEM ascent stage batteries with associated control assemblies for the experiment and housekeeping power requirements. LEM failure rates for the descent/ascent batteries and the electronic control assemblies (ECA) were used for assessing the battery configuration. All batteries were considered to be required for successful completion of the 14-day mission. This configuration yields a success probability of 0.7098. An analysis was made to determine the system reliability based on fulfilling only the housekeeping functions, (16 batteries and seven ECA are considered to be required for the entire 14 days). The success probability, based on 16 out of 22 batteries and all seven ECA required, is 0.9539.

4.5.3.1.4 Environmental Control System. The ECS consists of four integrated sections: atmosphere revitalization, heat transport, oxygen supply and cabin

pressure control, and water management. The mathematical model was developed using the following guidelines and assumptions which were incorporated into the ECS model for reliability assessment:

- Heat transport, oxygen supply, and water management systems are considered pressurized (operating) during the entire mission.
- Atmosphere revitalization section is considered operative during EVA time (based on maximum EVA of 54.0 hr).
- Ascent and descent water tanks are each assumed to undergo one operating cycle during the 14-day mission.
- Component failure rates presented in LED-550-58, 18 June 1965, and source data supplied by Hamilton Standard are the bases of reliability estimates.

The reliability assessment based on the above yields a success probability of 0.990130.

4.5.3.1.5 Communications Subsystem. The reliability analysis of the Phase I Lab Communications Subsystem consists of an investigation into the S-band transmission and receiving capabilities between the crew and earth, including status data, and the VHF communications mode during EVA and experimentation. This analysis has assumed that the ranging requirement capability necessary for mission success is fulfilled by the CSM ranging network. The ranging function is an inherent capability of the Phase I Lab, using S-band equipments (PM modulating functional capability is backup to CSM ranging potentials) which operate for large portions of the mission time, with insignificant degradation of subsystem reliability.

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. This is in fact assuming complete interdependency of internal components. This assumption is justified because the signal processor assembly is of paramount importance to the successful operation of the communications subsystem in every mode of operation. The analysis based on the above assumption depicts a "worst case" reliability estimate. Configuration analysis reflecting interdependency of operational functions within the Signal Processor Assembly is beyond the present scope of work, since a parts count of the assembly (including filters) is approximately 1700 items.

Another assumption is that 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 expression for the communications subsystem is:

$$R_C = R_1(2 - R_1)R_2R_3(2 - R_3) \left[1 - (1 - R_4)(1 - R_5)^2 \right] R_6R_7R_8(2 - R_7R_8) \\ R_9(2 - R_9)R_{10}(R_{11A} + R_{11B} - R_{11A}R_{11B})(R_{12A} + R_{12B} - R_{12A}R_{12B})$$

When the combined factors are introduced for each reliability block established above, the product run through the equation yields a reliability of the Communications Subsystem equal to 0.978342. As mentioned before, the prime degrading component for this analysis is the Signal Processor Assembly. Aside from the SPA, no additional problem areas are pointed out and improvement in the reliability of the Communications Subsystem can be achieved only if the inherent reliability of each component in the system is upgraded.

4.5.3.1.6 Instrumentation. The Lab I configuration has instrumentation required for basic housekeeping and instrumentation recommended for the experiments. The former consists of the transducers, signal conditioners, caution and warning electronics, status displays related to C&WEA, and the PCM/TEA. The latter consists of a second PCM/TEA and two recorders. Switching functions are not included.

Insofar as caution and warning indications can be checked by telemetry and voice communications, and trends indicated by telemetry can be relayed via communications to the astronauts, the PCM is shown as providing a backup to the C&WEA and status displays. It is assumed that communications are available at all times during the orbital period. Since the timing equipment (TEA) is required for other functions, it is shown as a serial item.

4.5.3.1.7 Controls and Displays Subsystem. The reliability analysis of the C&D Subsystem consisted of an examination of all of the individual controls and displays required by the other subsystems in the Phase I Lab. The overall C&D Subsystem reliability was obtained from the following mathematical model:

$$R_{C\&D} = R_1R_2R_3R_4R_5R_6(2 - R_6)R_7R_8R_9(R_{10} + R_{11} - R_{10}R_{11})R_{12} \\ R_{13}(2 - R_{13})R_{14}(2 - R_{14})R_{15}(2 - R_{15})R_{16}(2 - R_{16})R_{17}(2 - R_{17}) \\ \left[1 - (1 - R_{18})^2(1 - R_{19})^2 \right] R_{20}(2 - R_{20})R_{21}(R_{22} + R_{23} - R_{22}R_{23}) \\ (R_{24} + R_{25}R_{26} - R_{24}R_{25}R_{26})R_{27}R_{28}R_{29}$$

Applying time (t), environmental factor (K), and failure rates (λ), to this equation and solving yields a reliability equal to 0.908644.

4.5.3.2 System Reliability Analysis

A summary of subsystem reliability estimates for the Phase I Lab and Phase I Lab housekeeping are shown in Table 4.5-3, together with pertinent LEM data.

Approximation of Structure and Explosive Subsystem Reliabilities were obtained by utilizing LEM estimates with exponential degradation allowed for the extended duration.

In general,

$$R = e^{-K \lambda t}, \text{ and } Q = 1.0 - R$$

For small values of $K \lambda t$,

$$Q \approx K \lambda t, \text{ and } K \lambda \approx \frac{Q}{t}$$

then

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

$$Q_2 \approx \frac{Q_1}{115.567} \times 336 \approx 2.9074 Q_1$$

where subscript 1 represents LEM and subscript 2 represents AES.

<u>Subsystem</u>	<u>Q₁</u>	<u>Q₂</u>	<u>R₂</u>
Controls & Displays and Instrumentation	0.000622	0.001808	0.998192
Structure	0.000022	0.000064	0.999936
Explosives	0.000076	0.000221	0.999779

The values above for Controls & Displays and Instrumentation show the effect of not including sensor reliabilities.

Figure 4.5-5 represents vehicle reliabilities for mission durations of 6 to 14 days. The curves shown are based on an exponential degradation of reliability with mission duration, and therefore represent close approximations to the actual estimates. Also included in Fig. 4.5-5 are curves representing experiment package reliabilities plotted against a scale which indicates the product of vehicle and experiment package reliabilities.

Although the Phase I Lab housekeeping reliability curve indicates values in excess of the LEM estimate curve, both fall below the LEM specification goal. Further study is required to determine reliability improvement potential by applying maintainability and/or configuration modification concepts.

4.5.3.3 Identification of Wearout Items

Although the LEM equipments have not been designed to optimize in-flight maintenance characteristics, approximately 80 out of 250 items investigated would permit in-flight and/or lunar surface maintenance. Further effort is required to investigate each of these applicable items for the Phase I Lab configuration to determine the degree of maintenance significance.

As a minimum, before any of these items become actual candidates, each will be analyzed with respect to:

- Availability requirements
- Failure rates and failure modes
- Constraints of the maintenance task on the time line
- Complexity of the maintenance task (skill, training, and tool requirements)
- Accessibility (for removal, replacement, calibration, adjustment and/or servicing)
- Alternate modes of operation
- Fault diagnostic aids requirement.

For each maintenance candidate, a figure of merit or maintainability index (MI) will be apportioned. The MI will be a quantitative expression of the desired or optimized goal for performing the maintenance task in a prescribed time. As each candidate is analyzed, its inherent maintainability will be necessary. If the measure of maintainability is less than the index, means for maintainability improvement will be recommended and the impact will be traded off with reliability, weight, cost, schedule, etc., such that overall system effectiveness and/or mission success may be enhanced.

Table 4.5-4 presents a potential wearout list which indicates that a number of items are potential AES problems. Items identified by an "X" indicate a high probability of wear out while those identified by an "*" indicate that wear out problems are suspected but further study and information is required to be more conclusive.

Concern has been expressed over the life characteristics of kynar seals and teflon seats in the RCS to meet mission requirements when exposed to propellants or propellant vapors. The LEM project has initiated a change request (number 94 dated 10/26/65) to extend qualification tests to 44 days, such that the LEM mission requirements can be met. These test results will be monitored for AES applications.

The maximum estimated time that the RCS will be exposed to propellant or propellant vapors for the AES mission is as follows:

	Time (days)
Load propellant (prior to launch)	5
Allowable launch window	3
Time for prelaunch recycle	30
Orbital time	<u>14</u>
Total:	52

Another potential problem under study is the ability of the electro-luminescent displays to meet AES mission requirements. The AES/LEM window panel assembly has been identified as another AES life-limited item.

Table 4.5-1
 PHASE I LAB DESIGN REFERENCE MISSION

Nom Phase	Phase Description	Boost Time $K_o = 10.0$ $K_{no} = 0.01$	Non-Boost Time $K_o = 1.0$ $K_{no} = 0.001$	Total Time
1	Launch	0.1656	0.0011	0.1667
2	Earth Parking Orbit	0.0082	0.02083	0.02903
3	Hohmann Transfer	0.00316	0.99683	0.99999
4	Orbital	0.00306	334.8012	334.80428

TABLE 4.5-2

SUBSYSTEM EQUIP. USAGE & FAILURE RATES

A. Stabilization & Control Subsystem

(R = .785779 for 100% Rate Stab, 50% Attitude Hold)

(R = .940130 for 100% Rate Stab, No Attitude Hold)

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
1	Attitude & Translation Control Ass'y	51.34		335.82	0.18	
2	Attitude Controller Ass'y	33.4		335.82	0.18	
3	Rate Gyro Ass'y	99.1		335.82	0.18	
4	Abort Sensor Ass'y	265.35		167.91	0.18	
5	Abort Electronics Ass'y	802.80		167.91	0.18	

B. Reaction Control Subsystem (R = .936157)

1	Helium Pressure Vessel	.04	.2456	335.754	0	0
2	Pressure Transducer (4)	.05	.2456	335.754	0	0
3	Manifold	.04*	.2456	335.754	0	0
4	Temperature Transducer (5)	.05	.2456	335.754	0	0
5	Helium Initiate Squib Valve	.06	.2456	335.754	0	0
6	Helium Filter	.31	.2456	335.754	0	0
7	Shutoff Valve-Solenoid	14.20	.2456	335.754	0	0
8	Pressure Regulator-Fail Open	13.67	.0656	0	0	0
9	Pressure Regulator-Fail Closed	13.67	.0656	0	0	0
10	Quad Check Valve-Oxidizer-Fail Closed	8.7*	.0656	0	0	0
11	Quad Check Valve-Fuel-Fail Closed	8.7*	.0656	0	0	0
12	Quad Check Valve-Oxidizer-Fail Open	8.7*	.18	335.754	0	0
13	Quad Check Valve-Fuel-Fail Open	8.7*	.18	335.754	0	0
14	Burst Disc (2)	.11	.2456	335.754	0	0
15	Pressure Relief Valve	5.7	.2456	335.754	0	0
16	Test Point	12.5	.2456	335.754	0	0
17	Burst Disc	.11	.2456	335.754	0	0
18	Oxidizer Tank (bladder)	8400.0	0	1.0	0	0
19	Fuel Tank (bladder)	8400.0	0	1.0	0	0
20	Main Shutoff Valve	3.09	.2456	335.754	0	0
21	Fill valve	3.66	.2456	335.754	0	0
22	Cap	80.0	.2456	335.754	0	0

*Assumed vendor estimate.

TABLE 4.5-2 (Cont'd)

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
23	Fill Valve } (30 redundancies in series)	3.66	.2456	335.754	0	0
24		80.0	.2456	335.754	0	0
25	Thrust Chamber Assembly-Fire (4)	1057.9	.0656	0	0	0
26	Thrust Chamber Assembly-No Fire (4)	1057.9	0	0	.18	335.754
27	Isolation Valve (16)	3.09	.2456	335.754	0	0
28	Propellant Inlet Filter (16)	.31	0	0	.2456	335.754
29	Lines, Joints, Fittings (80)	.05	.2456	0	0	0
30	Thrust Chamber Assembly Injector Valve-Fire (16)	34.40	.0656	0	0	0
31	Thrust Chamber Assembly Injector Valve-No Fire (16)	34.40	0	0	.18	335.754

C. Electrical Power Subsystem (R = .709800)

1	Descent Battery (20)	*40	.180	335.82		
2	Descent ECA (5)	*20	.180	335.82		
3	Ascent Battery (2)	40	.180	335.82		
4	Ascent ECA (2)	20	.180	335.82		

* LEM Battery & ECA failure rates assumed.

D. Communications Subsystem (R = .978342)

1	S-band omnidirectional antenna	.025	0	110.534	.18	225.286
2	S-band Diplexer	1.7	0	110.534	.18	225.286
3	Transmit-Receive Electronic Replaceable Assembly	52.90	0	110.534	.18	225.286
4	F.M. Modulator	.162	0	110.534	.18	225.286
5	P.M. Modulator	.757	0	110.534	.18	225.286
6	Signal Processor Assembly	64.549	0	335.82	.18	0
7	Headset Audio Receiver	.30	0	335.82	.18	0
8	Headset Microphone	.120	0	335.82	.18	0
9	VHF Omnidirectional Antenna	.025	0	54.0	.18	281.82
10	VHF Diplexer	1.7	0	54.0	.18	281.82
11A	VHF Transmitter A	12.067	0	54.0	.18	281.82
11B	VHF Transmitter B	12.067	0	54.0	.18	281.82
12A	VHF Receiver A	13.252	0	54.0	.18	281.82
12B	VHF Receiver B	13.252	0	54.0	.18	281.82

Table 4.5-2 (Cont'd)

E. Instrumentation Subsystem (R = .911101)

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
1	Transducers	49.06		335.82	0.18	285.45
2	SCEA	122.69		335.82	0.18	
3	PCM #1	20.00		50.37	0.18	
4	C & W E A	59.55		335.82	0.18	
5	Status Displays	121.00		335.82	0.18	
6	TEA	8.2		335.82	0.18	35.82
7	PCM #2	20.0		300.00	0.18	
8	Tape Recorder #1	80.4		150.00	0.18	
9	Tape Recorder #2	80.4		150.00	0.18	
10	TEA #2	8.2		300.00	0.18	

F. Controls & Displays Subsystem (R = .908644)

1	Reaction Control System	42.0	.066		.180	335.754
2	Environment Control System	37.7		335.82	.180	
3	Explosive Devices	2.6		335.82	.180	
4	Electrical Power System	48.0	.180	335.82		
5	Caution & Warning*	64.8		335.82	.180	
6	C & W - Master Alarm*	1.2		335.82	.180	
7	Stabilization & Control	116.3		335.82	.180	
8	Flight Displays	51.6		335.82	.180	
9	Communications	17.05		335.82	.180	
10	Communications - VHF A	1.11		335.82	.180	
11	Communications - VHF B	1.21		335.82	.180	
12	Communication Antennas	12.1		335.82	.180	
13	Audio - Master Volume	0.51		335.82	.180	
14	Audio - VOX	0.91		335.82	.180	
15	Audio - ICS	0.91		335.82	.180	
16	Audio - S-Band	0.91		335.82	.180	
17	Audio - Relay Control	0.3		335.82	.180	
18	Audio - VHF A	0.91		335.82	.180	
19	Audio - VHF B	0.91		335.82	.180	
20	Audio - Audio Control	0.51		335.82	.180	
21	Lighting Control	9.0		335.82	.180	
22	Lighting - Integral Control	0.2		335.82	.180	
23	Lighting - Integral Override	0.3		335.82	.180	
24	Lighting - Anun/Num Control	0.2		335.82	.180	
25	Lighting - Anun Override	0.3		335.82	.180	
26	Lighting - Non Override	0.3		335.82	.180	
27	Heater Controls	11.7		335.82	.180	
28	Instrumentation	10.3		150.0	.180	
29	Bio Med	6.8		335.82	.180	

* Failure rate accounted for by Instrumentation Subsystem.

Table 4.5-2 (Cont'd)

G. Environmental Control Subsystem (R = .99013)

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
1	GOx Tank (6)	.04	.180	335.82		
2	O ₂ Filter	.05	.180	335.82		
3	O ₂ Shutoff Valve	2.43	.180	335.82		
4	Repressurization Emergency Valve	0.0	.180	335.82		
5	Flow Limiter	.05	.180	335.82		
6	O ₂ Demand Valve	6.48	.180	335.82		
7	Descent/Ascent H ₂ O Tanks (5)	296.0/6	1 cycle			
8	Fill Valve	3.66	.180	335.82		
9	Cup	80.0	.180	335.82		
10	Check Valve (13)	.67	.180	335.82		
11	Water Tank Select Valve	.90	.180	335.82		
12	Water Pressure Regulator (3)	1.46	.180	335.82		
13	Shutoff Valve (3)	.30	.180	335.82		
14	Select Valve	.81		54.00	.180	281.82
15	Check Valve	.67		54.00	.180	281.82
16	H ₂ O Separator	1.01		54.00	.180	281.82
17	Suit Circuit Regen Heat Exchanger	2.0		54.00	.180	281.82
18	Suit Circuit Assy	2.95		54.00	.180	281.82
19	Suit Circuit Relief Valve	7.54		54.00	.180	281.82
20	LIOH Cannister	.14		54.00	.180	281.82
21	Selector Valve	.09		54.00	.180	281.82
22	Suit Ckt. Fan	15.50				
23	Fan Check Valve	.44				
24	Pressure Control	22.17				
25	Pressure Sensor	2.0				
26	Suit Circuit Heat Exchanger	2.0				
27	Water Evaporator	2.0				
28	Pri H ₂ O Boiler	2.0	.180	335.82		
29	Glycol Accumulator	1.34				
30	Glycol Pump	16.1				
31	Check Valve	2.0				
32	Bypass Relief Valve	1.12				
33	Cabin Heat Exchanger	2.0				
34	Regen Heat Exchanger	2.0				
35	Water Boiler	2.0				
36	Cabin Fans	8.58	.180	281.82		54.0
37	Temperature Control Valve	.05	.180	335.82		
38	Cabin Dump Valve	3.41	.180	335.82		
39	H ₂ O Hose	.10				

TABLE 4.5-2 (Cont'd)

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
40	H ₂ O Disconnect	1.33	1.80	355.82		
41	H ₂ O Assembly	.05	↓	↓		
42	O ₂ Relief Valve	3.37				
43	O ₂ Manual Shutoff Valve	2.43				
44	O ₂ Filter	.05				
45	O ₂ Hose	.05				
46	O ₂ Disconnect	.24				
47	O ₂ Hose Assembly	.05				

Table 4.5-3

RELIABILITY SUMMARY TABLE

Subsystem	LEM ●			AES	
	Safety	Apport	Estim	Ph.I Lab H	Ph.I Lab
Stab & Control	.999651	.990700	.988205	.940130 ▲	.785779
Descent Propulsion } Ascent Propulsion }	.999899	.999075 .999961	.998764 .998300	Not Reqd. Not Reqd.	Not Reqd. Not Reqd.
Reaction Control	.997807	.999804	.919600	.936157	.936157
Electrical Power	.999993	.998600	.963896	.953900 ■	.709800
Environ Control	.999994	.999446	.994760	.990130	.990130
Communications		.999910	.997680	.978342	.978342
Instrumentation } Controls & Displays }		.999500	.999378*	.998192**	.911101
Structures	.999999	.999950	.999978	.999936**	.999936**
Explosives	.999954	.999980	.999924	.999779**	.999779**
Crew Provisions		.999990	Not Avail	Not Avail	Not Avail
System		.987	.866	.810	.417

*Does not include sensors.

**Utilizes LEM Estimate with Exponential Degradation for Extended Duration.

▲ Does not include Attitude-Hold Capability.

■ Assumes 16 out of 22 batteries & 7 ECAs required for housekeeping.

● Values obtained from LPR-550-9, Quarterly Reliability Status Report, 1 August 1965

Table 4.5-4

POTENTIAL WEAR-OUT ITEMS

Comm.	Equip	Dwg Ref No.	Spec Life		
			hr	days	Cycles
	Pwr Divider *	LSC 380-00143	2000		
	Pwr Divider *	LSC 380-00151	2000		
	<u>Crew Provisions</u>				
	Waste Mgmt Equip *	LSC 340-201	2000		
	EL Lamps *	LSC 340-201	2000		
	Floodlight Interior *	LSC 340-403-1 thru 5 & 71	1000		
	<u>Displays & Controls</u>				
	Attitude Ind *	LSC 350-301		Unknown	
	Digital Event Timer *	LSC 350-307	1200		
	RCS Quant. Gage *	LSC 350-401	1200		
	D'Arsonval Meter *	LSC 350-801	Unknown		
	Flag Ind. *	LSC 350-804	2000		
	Helium Temp & Pres Ind. *	LSC 350-201	1200		
	<u>Environmental Control</u>				
	Cabin Fan *	LSC 330-102	1250		
	Cartridge (LiOH) X	LSC 330-122	20		
	PLSS Refill X	LSC 330-125	5		
	Suit Circuit Assy *	LSC 330-190	2500		
	Cabin ARS *	LSC 330-191	2500		
	Coolant Pump *	LSC 330-201	Unknown		
	Cabin Temp Cont Valve *	LSC 330-203	2500		5000
	Suit Temp Cont Valve *	LSC 330-208	2500		3000
	Coolant Accum. *	LSC 330-210	2500		500
	Water Control Module *	LSC 330-490	2500		
	<u>Electrical Power</u>				
	Inverter, Gen. Purpose *	LSC 390-6	1000		
	Relay Box-ECS *	LSC 390-21051	Unknown		
	Relay Box EED *	LSC 390-2 1052	Unknown		
	<u>Instrumentation</u>				
	SCEA requires investigation-.*				
	Design presently in development				
	Sensors: additional info req *				
	<u>Reaction Controls</u>				
	Ox Sensing Unit A X	LSC 310-5-11	144		100
	Fuel Sensing Unit B X	LSC 310-5-12	144		100
	Control Unit Assy X	LSC 310-5-21	144		100
	Ox Inlet Filter *	CSC 310-125-3		30	
	Fuel Inlet Filter *	LSC 310-125-4		30	
	He, Quad Check Valve *	LSC 310-306-1 thru 4	720		8000
	He, Coupling Disconnect *	LSC 310-308			400

Table 4.5-4 (Con't)

Equip	Dwg Ref No.	Spec Life		
		hr	days	Cycles
He, Coupling, Test Port *	LSC 310-308			400
Ox, Coupling Fill *	LSC 310-401-101		30	400
Fuel, Coupling Fill *	LSC 310-401-202		30	400
Ox Coupling, Bleed *	LSC 310-401-402		30	400
Fuel Coupling, Bleed *	LSC 310-401-402		30	400
Ox Coupling, Disconnect *	LSC 310-401-501		30	400
Fuel Coupling Disconnect *	LSC 310-401-602		30	400
Ox Tank Vent Disconnect *	LSC 310-401-701		30	400
Fuel Tank Vent Disconnect *	LSC 310-410-802		30	400
Ox Isolation Valve *	LSC 310-403-101		30	165
Fuel, Main S/O Valve *	LSC 310-403-202		30	165
Fuel, Crossfeed Valve *	LSC 310-403-202		30	165
Ascent Inlet Feed Valve *	LSC 310-403-202		30	165
Ox, Main S/O Valve *	LSC 310-403-301		30	165
Ox Isolation Valve *	LSC 310-403-301		30	165
Ox Crossfeed Valve *	LSC 310-403-301		30	165
Ox Ascent Intconnect *	LSC 310-403-301		30	165
Fuel Isolation Valve *	LSC 310-403-402		30	165
Tank, Oxidizer *	LSC 310-405-1	1500		
Tank Fuel *	LSC 310-405-2	1500		
Ox, Filter, Asc. I Intconnect *	LSC 310-406-1		30	
Fuel, Filter Asc. Intconnect *	LSC 310-406-2		30	
Stabilization & Control Gimbal Drive Act *	LSC 300-170-1	1000		
Structures				
Panel Assy *	LDW 280P101-24-3	600		
Panel Assy *	LDW 280P101 24-4	600		
Panel Assy *	LDW 280-10141-3	600		

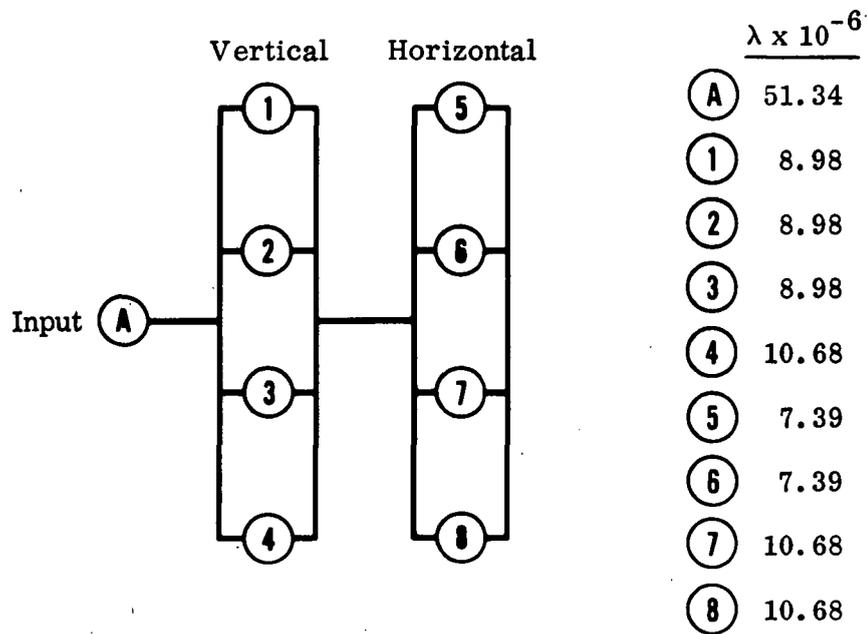


Fig. 4.5-1 ATCA Reliability Block Diagram

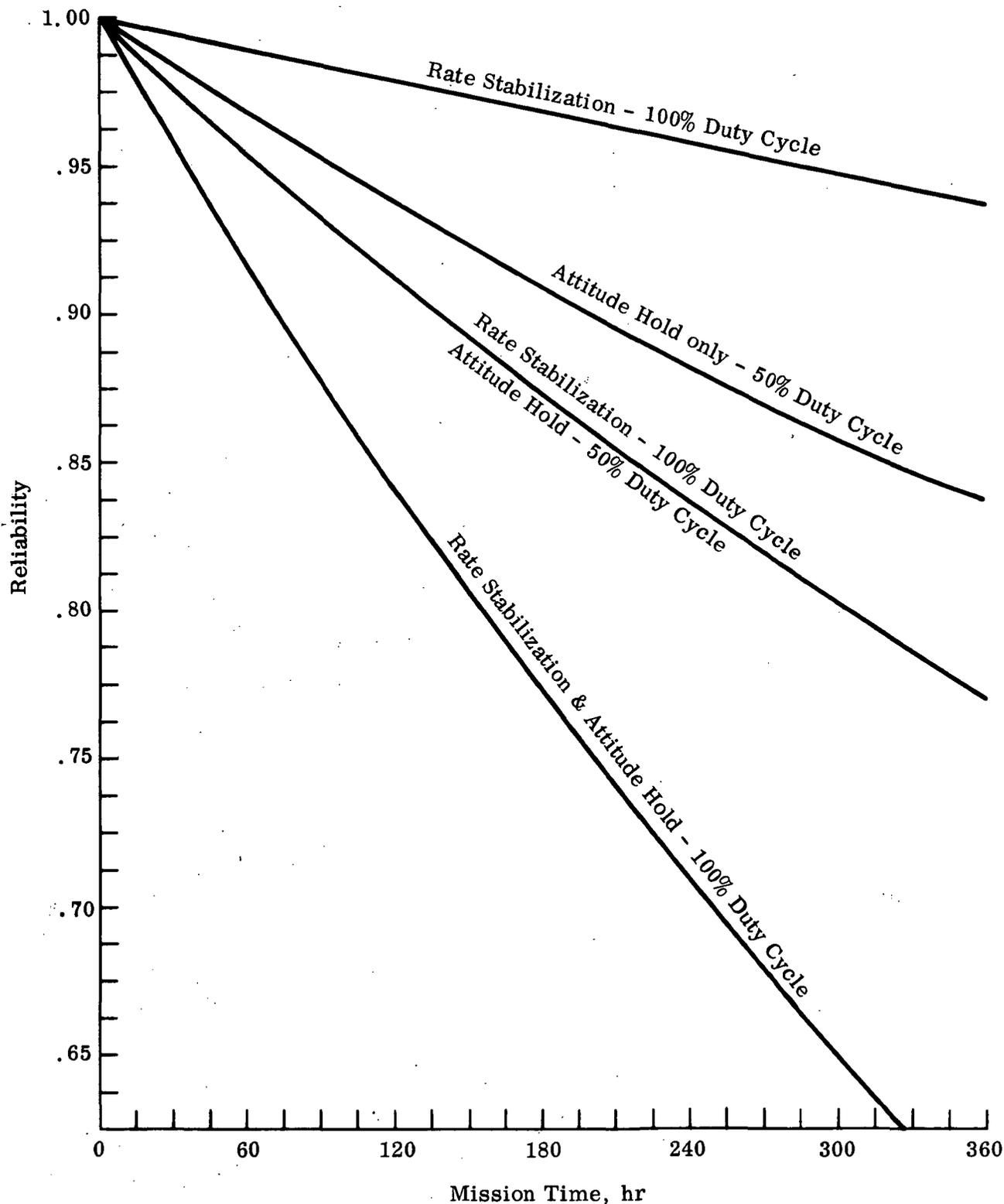


Fig. 4.5-2 AGS-Stabilization & Attitude Hold Reliability

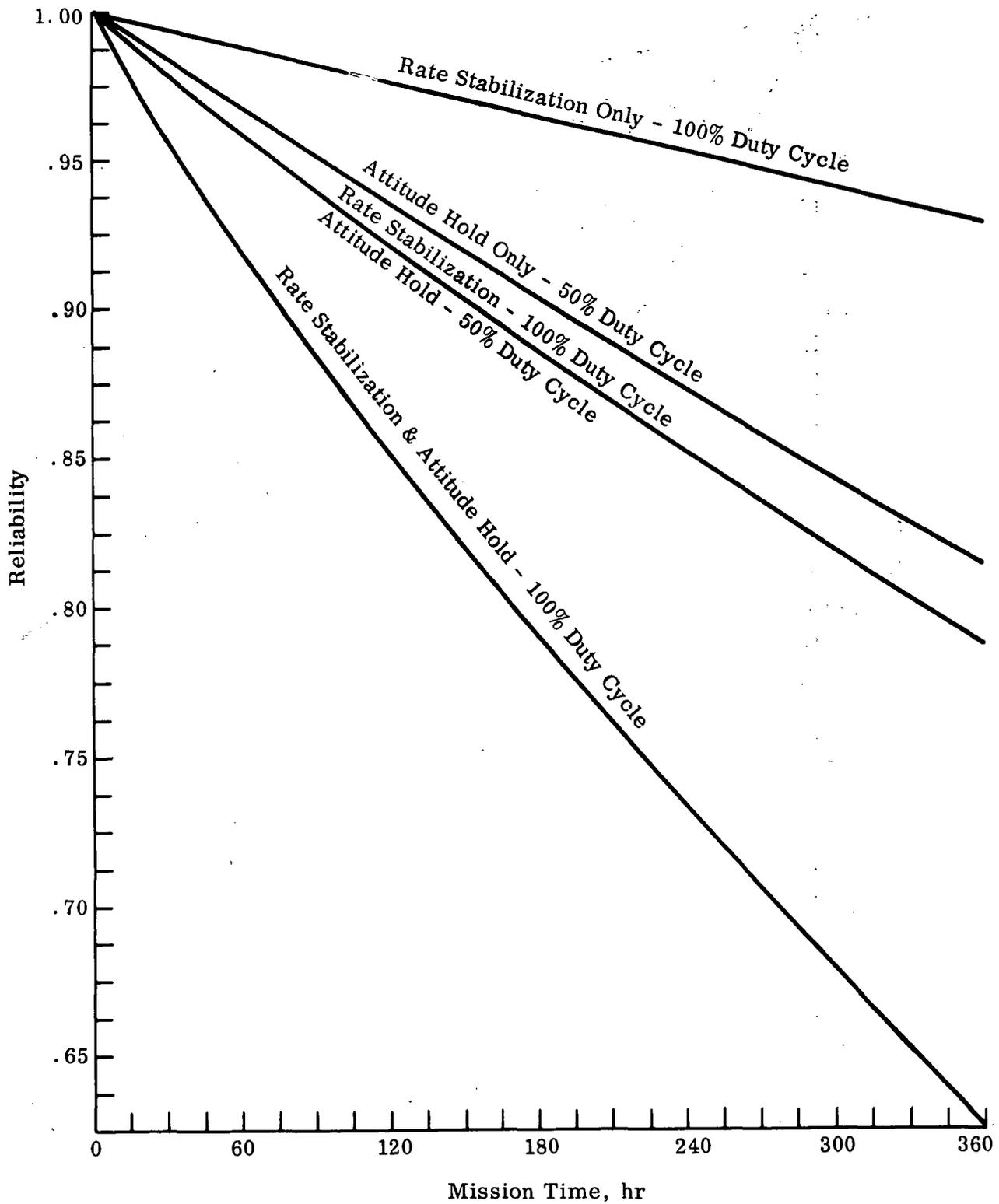
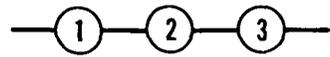


Fig. 4.5-3 PGNS - Stabilization and Attitude Hold Reliability



100% Rate Stab, 50% Att Hold

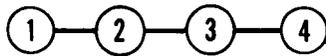


100% Rate Stab, No Att Hold

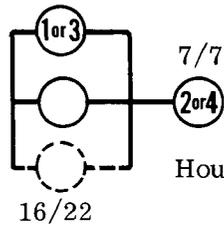


A. Stability & Control Subsystem

B. React



Housekeeping & Experiments

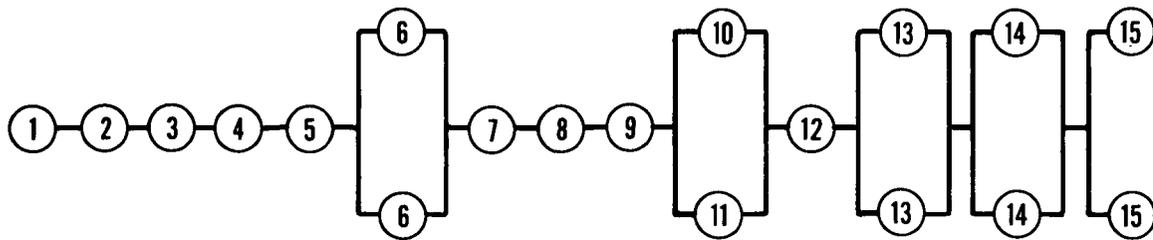


7/7

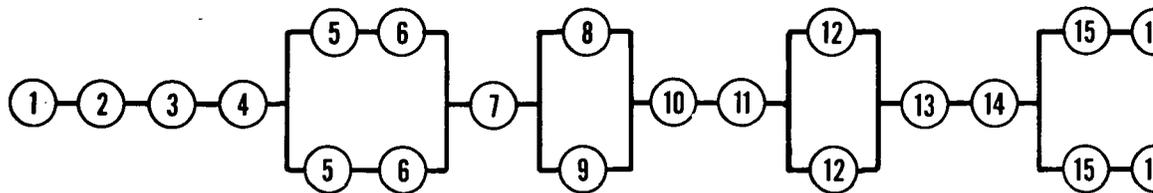
Housekeeping

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C. Electrical Power Subsystem

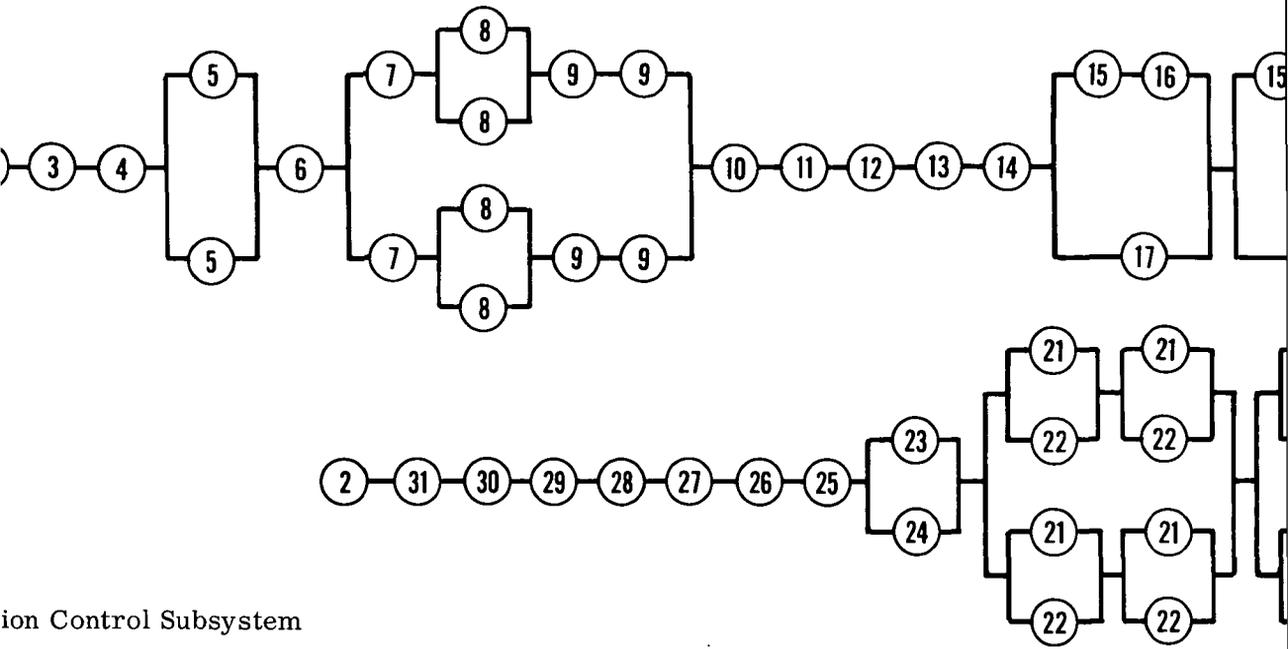


F. Controls & Displays Subsystem

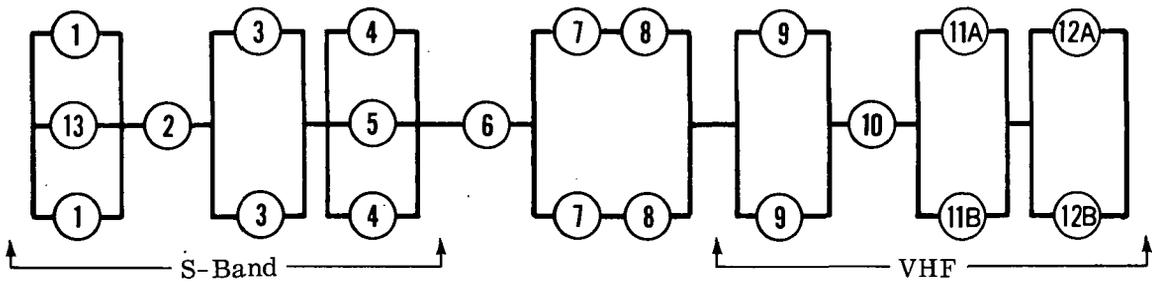


G. Environmental Control Subsystem

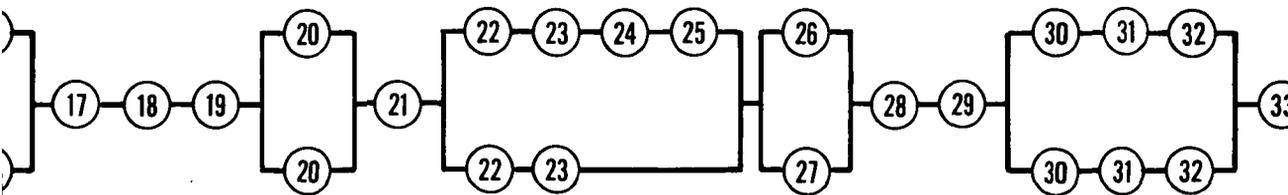
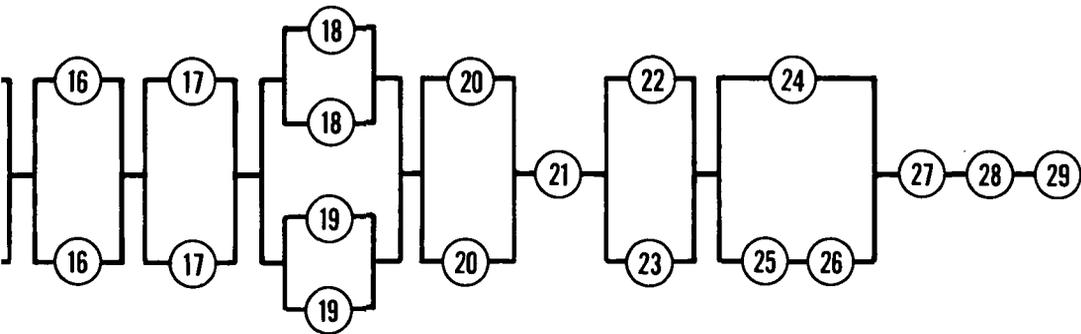
U-5-4
①



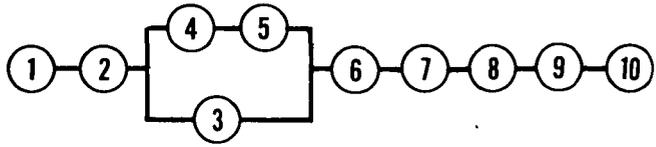
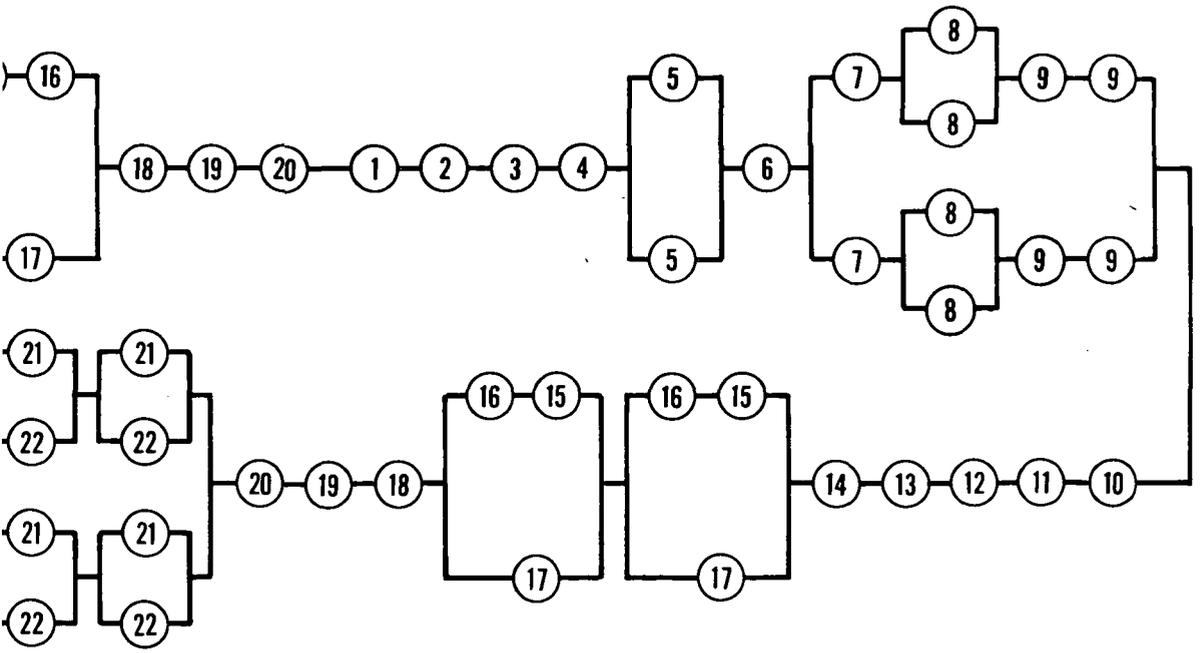
Position Control Subsystem



D. Communications Subsystem



4.5-4
 (2)



E. Instrumentation Subsystem

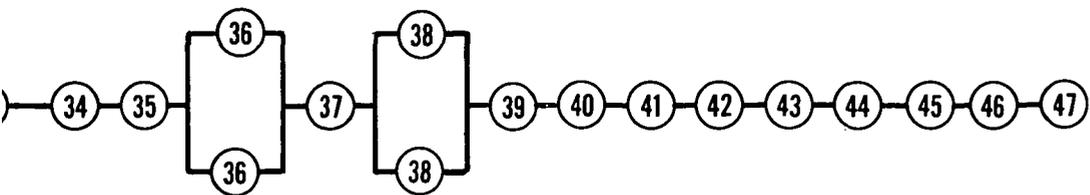


Fig. 4.5-4 Subsystem Reliability Block Diagram

3

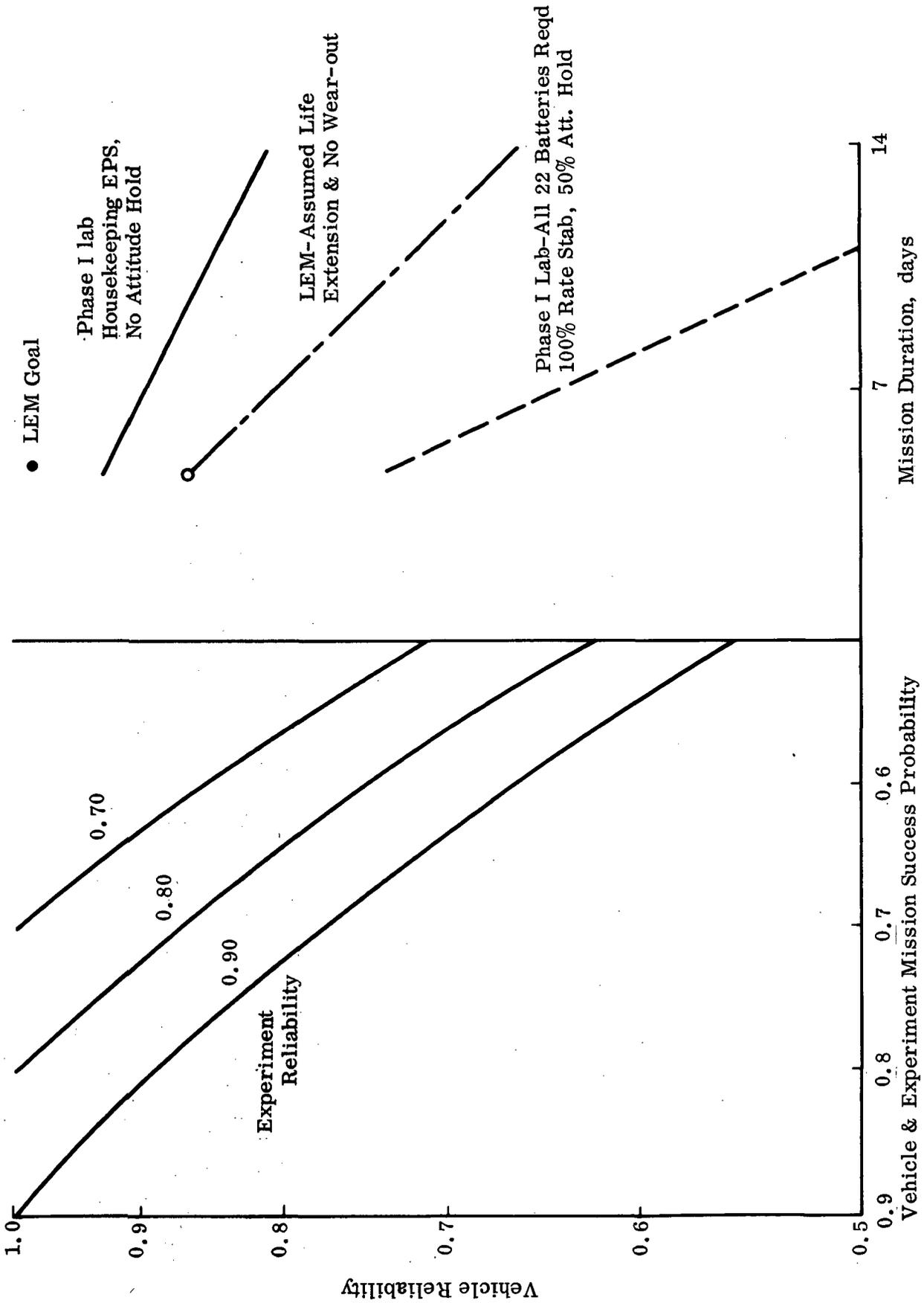


Fig. 4.5-5 Mission Success Probability

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4.6 MASS PROPERTIES

4.6.1 Ground Rules

The major ground rules affecting the mass properties analysis are tabulated in the configuration summary section of this report. The weight limitations for various Phase I flights as listed in Table IV of the Blue Book are:

Flight 507	75,100 lb allowable, Lab and experiment weight
509	23,900
214	TBD (To be determined)
511	TBD
216	TBD

The 11 August 1965 coordination meeting generated the following ground rule:

"There are no restrictions on the cg positions or inertias for the lab missions".

4.6.2 Assumptions and Background Data

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

Specific assumptions affecting the mass properties of the recommended Phase I Lab are:

- Experiment weight is not included in the baseline or recommended laboratory weights
- 91.1 kw/hr of experiment energy is supplied by 20 LEM descent and 2 LEM ascent batteries
- Water, oxygen, LiOH, and PLSS batteries for 21 and 18 EVA's are provided in the baseline and recommended Labs respectively
- The Water tanks are assumed to be filled to capacity (1046 lb)
- Food and CSM LiOH for 13 days are carried in the Lab
- Experiment weight must include the following dependent items in addition to the experiment itself:
 - Supports and mounts
 - Micrometeoroid and thermal shielding
 - Signal conditioning and sensors
 - Electrical wiring
 - Controls and displays
 - G, N and C for special requirements
 - Electrical power, propellant, oxygen, and water (and associated hardware) for requirements in excess of above.

4.6.3 Recommended Configuration

Tabulations of the recommended configuration mass properties summary by mission phase (Table 4.6-1) and mass properties summary by subsystem (Table 4.6-2) are presented herein. These tables describe the weight, cg, and moments of inertia for

each of the mission phases or subsystems listed. Table 4.6-4 presents a mass property summary, by module, of an orbiting spacecraft including CSM (Blue Book Values), lab and the experiments of Flight 507 (as described in Contract Addendum - Payload Integration Study).

A detailed weight statement for the recommended configuration is presented in Table 4.6-5. This weight statement is a listing of the applicable information from the IBM cards used in determining the mass properties of the Phase I Lab. In most cases, the initial weight in each subsystem is a one-line entry taken directly from LEM; the subsequent weights indicate additions or deletions from the basic LEM subsystem. Where only one or two items from the LEM are used, these are listed as separate cards and the subsystem weight is built up.

The weight changes to the baseline configuration resulting in the recommended configuration, are detailed in Table 4.6-7. In addition, brief reasons for the change are presented.

4.6.4 Baseline Configuration

The following tables define the baseline configuration:

- 4.6-1, Mass Properties Summary by Mission Phase
- 4.6-3, Mass Properties Summary by Subsystem
- 4.6-6, Detailed Weight Statement
- 4.6-8, Changes to the Baseline Configuration.

The changes shown in Table 4.6-8 represent an updating to the mid-term report resulting from corrections and/or omissions

4.6.5 Alternate Configurations

Weight estimates have been made of the various alternates being offered. The delta effects of these alternates on the recommended configuration orbiting mass properties are presented in Table 4.6-9. A detailed tabulation of the various alternates appears in Table 4.6-10 which shows the details of items removed and added, and their weight impact, as a delta, on the orbiting configuration weight.

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Table 4.6-1

PHASE I LAB MASS PROPERTIES SUMMARY BY MISSION PHASE

Mass Property		Dry		Burn-out		Earth Launch	
		Base*	Rec*	Base	Rec	Base	Rec
Weight, lb		7,781	8,997	8,207	9,390	9,966	11,249
cg, in. from Ref. Datum	x	208	202	208	202	206	202
	y	5	4	5	4	-1	-1
	z	-3	-2	-3	-2	-9	-7
Moments of Inertia (cg), slug-ft ²	I _{x-x}	7,218	9,230	7,251	9,283	8,735	10,729
	I _{y-y}	7,574	10,286	7,680	10,381	9,594	12,391
	I _{z-z}	8,953	9,388	9,073	9,499	11,183	11,754
*Base: Baseline							
Rec : Recommended							

- Notes:
- cg Given in inches from Ref. Datum.
 - x-cg In LEM stations (Ascent/Descent separation plane is LEM Sta. 200.0)
 - y & z cg Measured from vertical center line.
 - Moments of Inertia in slug-ft² about vehicle cg.

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TABLE 4.6-2

MASS PROPERTIES SUMMARY
PHASE I RECOMMENDED LABORATORY

Code	Subsystem	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)
1.0	Structure - Ascent	1328	259	-1	8	699	729	423
	- - Descent	1493	162	1	-1	1734	1057	1051
2.0	Stabilization & Control	96	275	15	-26	69	76	11
3.0	Navigation & Guidance	32	297	0	58	6	1	1
4.0	Crew Provisions	111	245	2	47	17	11	22
5.0	Environmental Control	682	237	1	-28	296	467	465
7.0	Instrumentation	280	250	-13	-52	42	42	13
8.0	Electrical Power Supply	3758	183	10	0	4989	3823	3725
9.0	Propulsion	654	156	0	-3	426	289	278
10.0	Reaction Control	303	265	0	-3	276	132	164
11.0	Communications	105	265	29	-35	51	51	52
12.0	Controls & Displays	155	267	1	53	55	38	25
	Total Dry Weight	8997	202	4	-2	9230	10,286	9388
	Trapped & Residual							
4.0	Crew Provisions	189	196	0	0	0	13	13
5.0	Environmental Control	163	208	3	-5	11	43	43
10.0	Reaction Control	41	264	0	0	19	2	18
	Total Wt. @ Burn Out	9390	202	4	-2	9283	10,381	9,499
	Expendables							
4.0	Crew Provisions	102	260	0	0	0	0	0
5.0	Environmental Control	1316	176	-37	-48	309	846	1018
10.0	Reaction Control	441	264	0	0	214	23	194
	Total Wt. @ Orbiting and Earth Launch	11,249	202	-1	-7	10,729	12,391	11,754

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Table 4.6-3
 PHASE I BASELINE LAB MASS PROPERTY SUMMARY BY SUBSYSTEM

Code	Subsystem	Wt, lb	Properties cg, in.*			Moments of Inertia, slug-ft ²		
			x	y	z	I _{xx} (roll)	I _{yy} (pitch)	I _{zz} (yaw)
1.0	Structure - Asc	1,324	259	- 1	8	699	727	422
	- Desc	1,393	162	1	- 1	1,557	872	1,042
2.0	Stab & Cont	92	275	15	-26	67	74	11
3.0	Nav & Guid	32	297	0	58	0	1	1
4.0	Crew Provisions	119	235	3	31	24	18	19
5.0	Environ Cont	627	237	3	-32	305	422	422
7.0	Instrumentation	283	249	-13	-52	42	41	12
8.0	Elect Power	2,680	191	15	0	3,102	1,679	3,656
9.0	Propulsion	654	156	0	- 3	426	289	278
10.0	Reaction Control	303	265	0	- 3	276	132	164
11.0	Communications	119	263	29	-28	62	62	54
12.0	Cont & Displ	155	267	0	53	55	38	25
	TOTAL DRY WT	7,781	208	5	- 3	7,218	7,574	8,953
	<u>TRAPPED & RESIDUAL</u>							
4.0	Crew Provisions	200	190	0	0	0	0	0
5.0	Environ Cont	185	215	2	- 5	12	59	56
10.0	Reaction Control	41	264	0	0	19	2	2
	TOT WT AT BURN-OUT	8,207	208	5	- 3	7,251	7,680	9,073
	<u>ORBITING EXPENDABLES</u>							
4.0	Crew Provisions	102	260	0	0	0	0	0
5.0	Environ Control	1,216	170	-40	-54	204	572	725
10.0	Reaction Control	441	264	0	0	214	23	194
	TOT WT AT EARTH LCH & ORBITAL INSERT'N	9,966	206	-1	-9	8,735	9,594	11,183

* From Ref Datum.

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Table 4.6-4

MASS PROPERTIES SUMMARY OF FLT 507 SPACECRAFT IN ORBITING CONFIGURATION

Module	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)
Command Module	10,900	374	0	7	5000	4600	4200
Service Module	10,700	502	-4	9	6800	11,700	11,600
Retro Propellant	1,300	577	12	2	600	100	600
Total CSM & Prop.	22,900	445	-1	8	12,484	40,666	40,723
Recommended Phase I Lab	11,249	202	-1	-7	10,729	12,391	11,754
Flight 507 Experiments	6,769	160	-25	17	6,418	12,220	13,559
Total Lab & Exper'ts	18,018	186	-10	2	18,198	26,746	27,447
Total Spacecraft Orbiting Configuration	40,918	331	-5	5	30,921	213,610	214,468

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AES RECOMMENDED PHASE 1 LAB DRY						
CODE	TITLE	WEIGHT POUNDS	C.G.			Z
			X	Y		
1.0001	AST STRUCT	1326	259	1		9
1.313	ENG COVER	13	245	0		2
1.315	CANISTER	13	215	0		2
1.3821	FUEL TK ST-	3	228	45		27
1.3822	FUEL TK ST-	2	239	59		27
1.3823	OX TNK SPT-	1	238	45		27
1.3824	OX TNK SPT-	2	228	34		27
1.3825	FUEL TK BR-	14	222	50		47
1.0010	CNT WT INC	18	259	1		9
1.323	PROP SHIEL-	11	252	0		0
1.486	GOX TK SPT	20	254	0		60
1.4861	GOX TK SPT-	2	245	25		57
1.4862	GOX TK SPT-	1	282	0		38
1.0	ASCENT STR	1328	259	-1		8
1.0002	DST STRUCT	1499	156	2		0
1.16	BS HT SHLD-	262	124	0		0
1.1111	BATT SUPT	50	164	90		0
1.1111	BATT SUPT	50	164	90		0
1.1111	BATT SUPT	50	164	0		90
1.1111	BATT SUPT	50	164	0		90
1.16	LWR DK INS	30	124	0		0
1.1511	H2O TNK SP	13	147	64		43
1.1511	H2O TNK SP	13	147	43		64
1.0	DSCENT STR	1493	162	1		-1
2.0001	S+C WQ DEC	87	273	16		31
2.2	MODIFY ATCA	3	263	18		-63
2.3	MODIFY RGA	1	302	9		54
2.621	MODIFY AEA	5	307	0		63
2.0	STAB + CNT	96	275	15		-26
3.12	AQT TELES	26	295	0		59
3.17	NAV BASE	6	307	0		55
3.0	NAV+GUID	32	297	0		58
4.19	ST REPR KT	10	238	37		49
4.31	RESTRAINTS	18	255	22		40
4.32	RESTRAINTS	17	255	22		40
4.42	INT LIGHTG	3	252	0		46
4.61	WAST MANAG	7	215	40		46
4.62	WAST MANAG	8	215	40		46
4.7	EXT LIGHTG	5	200	0		90
4.71	FLOOD LITE	5	280	0		60
4.81	WORK TOP	8	252	22		45
4.811	WORK LIGHT	2	260	0		45
4.82	WORK TOP	8	252	-22		45
4.83	SEAT	5	245	-22		45
4.85	MISC	15	250	0		45
4.0	CREW PROVS	111	245	2		47
5.0001	AST E					
5.7	GLYCO					
5.8	EXPEN					
5.0002	DST E					
5.8	EXPEN					
5.311	GOX T					
5.312	GOX T					
5.31	GOX T					
5.32	GOX T					
5.33	GOX T					
5.34	GOX T					
5.35	GOX T					
5.4	H2O T					
5.4	H2O T					
5.51	GOX P					
5.52	H2O P					
5.63	CP BA					
5.63	CP BA					
5.64	CP BA					
5.64	CP BA					
5.65	CP PC					
5.66	CP RE					
5.91	ASA B					
5.92	REC IR					
5.0	ENV CO					
7.0001	INSTR					
7.12	PCMTA					
7.13	VOICE					
7.15	TAPE					
7.15	TAPE					
7.0	INSTRU					
8.0001	AST E					
8.0002	DST E					
8.122	ECA					
8.112	BATTY					
8.112	BATTY					
8.112	BATTY					
8.112	BATTY					
8.122	MOD IF					
8.122	MOD IF					
8.122	MOD IF					
8.122	MOD IF					
8.122	MOD IF					
8.122	MOD IF					
8.321	CRKT					
8.323	BUSS					
8.333	WIRNG					
8.48	CABLE					
8.48	CABLE					
8.5	EXPT					
8.0	ELECT					
9.0001	AST S					
9.0002	DST P					
9.12	TRPD					
9.321	HE TN					
9.34	HELIU					
9.42	DST E					

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Table 4.6-5

DETAILED WEIGHT STATEMENT PHASE I LAB

RECOMMENDED CONFIGURATION

PS	347	269	12	0	9.0 PROPULSION	654	156	0	- 3	5.445 OXYGEN TRD	2	184	40	-40
ABLS-	37	255	10	- 10	10.001RCS	386	265	0	- 2	5.4446GLYCOL	37	255	10	- 10
ABLS-	61	293	2	- 3	10.1 PROPELLANT-	81	264	0	0	5.4447ECS LIQH A	117	190	0	0
AS	302	156	19	46	10.32 HELIUM	-	2	263	- 2 0	5.0 T+R ECS	163	208	3	- 5
ASC	213	148	30	47	10.0 RCS	303	265	0	- 3	10.444TRPD PROP	39	264	0	0
ASC	- 3	266	-14	-53	11.001AST COMM	100	267	37	- 35	10.445HELIUM	2	263	2	0
ASC	- 3	266	14	-53	11.002DST COMM	16	138	44	44	10.0 T+R RCS	41	264	0	0
ANK	47	270	12	-48	11.25 SB ERT ANT-	12	138	34	49	REC PHI LAB B/O	9390	202	4	- 2
ANK	46	270	-12	-48	11.3 TV + ACCES-	9	240	40	35	AES RECOMMENDED PHASE 1 LAB ORBITING				
ANK	47	249	24	-48	11. INTRCOM HL	10	270	0	0	CODE TITLE WEIGHT C.G.				
ANK	46	249	-24	-48	11.0 COMMUNICTNS	105	265	29	-35	POUNDS X Y Z				
ANK	47	249	0	-48	12.001DISP + CON	213	267	1	58	REC PHI LAB B/O	9390	202	4	- 2
ANK	24	147	64	43	12.217S+C CNTS -	1	279	2	71	4.4446FOOD	102	260	0	0
ANK	24	147	43	64	12.218S+C CNTS -	1	279	9	72	4.0 EXP PRQV	102	260	0	0
MBG	25	260	0	-40	12.219S+C CNTS -	1	279	13	70	5.441 OXYGEN EXP	45	270	12	-48
MBG	15	147	-50	-50	12.211S+C FDIA -	8	273	10	72	5.442 OXYGEN EXP	45	270	-12	-48
+ECA	5	164	90	0	12.211S+C CNTS -	2	279	9	72	5.443 OXYGEN EXP	45	249	24	-48
+ECA	5	164	0	90	12.211S+C CNTS -	5	294	4	71	5.444 OXYGEN EXP	45	249	-24	-48
+ECA	5	164	0	90	12.211S+C CNTS -	7	273	0	72	5.445 OXYGEN EXP	45	249	0	-48
+ECA	5	164	90	0	12.211S+C GASTA -	1	270	0	72	5.446 OXYGEN EXP	45	184	40	-40
CORD	2	249	18	64	12.21 S+C CNTS -	1	270	0	72	5.444 WATER EXP	322	145	-49	-49
YPASS	2	250	20	60	12.22INDIFY DEDA	2	256	43	47	5.444 WATER EXP	322	147	-64	-43
YDUC	1	260	0	0	12.231S+C ACA -	3	250	10	58	5.444 WATER EXP	322	147	-43	-64
YDUC	4	280	0	0	12.232S+C ATCA -	4	250	34	58	5.444 WATER EXP	40	300	27	19
CONTROL	682	237	1	-27	12.3 N+G CNTS -	22	256	3	65	5.444 WATER EXP	40	300	-27	-19
MMNTN	202	249	11	48	12.8 EPS CNTS	4	262	1	56	5.0 EXPEND ECS	1316	176	-37	-48
RCDR	39	249	18	64	12.9 PROP CNTS-	10	276	4	68	10.446OXIDIZER	124	262	45	15
RCDR	3	285	0	-35	12.11 COMM CNTS	1	257	23	53	10.446FUEL	96	266	45	- 15
RCDR	18	250	20	60	12.0 DISP+CNTS	155	267	1	53	10.446OXIDIZER	125	262	45	- 15
RCDR	18	250	20	60	REC PHI LAB DRY	8997	202	4	- 2	10.446FUEL	96	266	45	15
MMNTN	280	250	-13	-52	AES RECOMMENDED PHASE 1 LAB BURN OUT	4.445 PLSS BATTS	90	190	0	0				
PS	767	255	1	- 28	CODE TITLE WEIGHT C.G.	4.444 PLSS LIQH	81	190	0	0				
PS	656	162	58	33	POUNDS X Y Z	4.444 CLOTHES 21	18	250	0	0				
PACK	556	171	44	36	REC PHI LAB DRY	8997	202	4	- 2					
PACK	556	164	90	0	4.0 T+R PRQVS	189	196	0	0					
PACK	556	164	0	90	5.445 OXYGEN TRD	1	270	12	-48					
PACK	556	164	0	90	5.445 OXYGEN TRD	2	270	-12	-48					
ECA	12	171	44	36	5.445 OXYGEN TRD	1	249	24	-48					
ECA	12	156	0	90	5.445 OXYGEN TRD	2	249	-24	-48					
ECA	12	156	90	0	5.445 OXYGEN TRD	1	249	0	-48					
ECA	12	156	-90	0	5.445 OXYGEN TRD	1	270	12	-48					
ECA	12	156	0	-90	REC P1 LAB ORBIT	11249	202	- 1	- 7					
BRKP	7	258	40	58	4.445 PLSS BATTS	90	190	0	0					
BRKP	4	258	40	58	4.444 PLSS LIQH	81	190	0	0					
DIST	30	164	0	0	4.444 CLOTHES 21	18	250	0	0					
DIST	14	164	0	0	4.0 T+R PRQVS	189	196	0	0					
DIST	14	164	0	0	5.445 OXYGEN TRD	1	270	12	-48					
SWBD	20	250	0	- 60	5.445 OXYGEN TRD	2	270	-12	-48					
POWER	3758	183	10	0	5.445 OXYGEN TRD	1	249	24	-48					
POWER	15	220	0	0	5.445 OXYGEN TRD	2	249	-24	-48					
PROP	1640	147	3	4	5.445 OXYGEN TRD	1	249	0	-48					
FUEL	455	129	0	1	5.445 OXYGEN TRD	1	270	12	-48					
DES-	95	148	49	46	5.445 OXYGEN TRD	2	249	-24	-48					
DES-	50	156	8	8	5.445 OXYGEN TRD	1	249	0	-48					
ENGINE-	400	154	0	2	5.445 OXYGEN TRD	1	249	0	-48					

Table 4.6-6

DETAILED WEIGHT STATEMENT BASELINE PHASE I LAB

S-	96	148	49-	46	4.444 PLSS LIQH	95	190	0	0	10.446 FUEL	96	266-	45	15
-	50	156	8-	8	4.445 PLSS BATT	105	190	0	0	10.0 EXP RCS	441	264	0	0
IE-	400	154	0	2	4.0 T+R PROV	200	190	0	0	-----				
W	654	156	0	- 3	5.4444 ECS LIQH L	23	265	0	0	P1 LAB ORB 3966 206 - 1 - 9				
	386	265	0-	2	5.4445 TRPD OX	8	254	0-	60					
IT-	81	264	0	0	5.4446 GLYCOL	37	255	10-	10					
-	2	263-	2	0	5.4447 ECS LIQH A	117	190	0	0					
	303	265	0	- 3	5.0 T+R ECS	185	215	2	- 5					
	100	267	37-	35	10.444 TRPD PROP	39	264	0	0					
	16	138-	44	44	10.445 HELIUM	2	263-	2	- 0					
NT-	12	138-	34	49	10.0 T+R RCS	41	264	0	0					
ND	5	267	0	0	-----									
HL	10	270	0	0	PHI LAB BQ	8207	208	5	- 3					
NS	119	263	29	-28	-----									
	213	267-	1	58	AES BASELINE PHASE I LAB ORBITING									
	1	279-	2	71	CODE TITLE WEIGHT C.G.									
	1	279-	9	72	POUNDS X Y Z									
	1	279	13	70	-----									
	8	273-	10	72	PHI LAB BQ	8207	208	5	- 3					
	2	279-	9	72	4.4446 FOOD	102	260	0	0					
	5	294-	4	71	4.0 EXP PROV	102	260	0	0					
	7	273	0	72	5.4448 OXYGEN	271	254	0-	60					
	1	270	0	72	5.4449 WATER	315	145-	49-	49					
IA	2	256-	43-	47	5.444 WATER	315	147-	64-	43					
	3	250-	10	58	5.444 WATER	315	147-	43-	64					
	4	250-	34	58	5.0 EXP ECS	1216	170	-40-	-54					
	22	256-	3	65	10.446 OXIDIZER	124	262-	45	15					
	4	262	1	56	10.446 FUEL	96	266	45-	15					
IS-	10	276-	4	68	10.446 OXIDIZER	125	262	45-	15					
IS	1	257	23	53	-----									
S	155	267	1	53	-----									
RY	7781	208	5	- 3	-----									
PHASE I LAB BURN OUT														
WEIGHT C.G.														
POUNDS X Y Z														
RY	7781	208	5	- 3										

TABLE 4.6-7

MASS DATA CHANGES - BASELINE TO RECOMMENDED PHASE I LAB

Code	Subsystem	Item	Wt. Change	Description of Change
1.381	Structure	Asc H ₂ O Tank Supt.	+4	Ascent water tanks should be retained
1.1111	Structure	Battery Supports	+50	Add supports for additional batteries
1.111	Structure	Battery Supports	+50	Add supports for additional batteries
2.2	Stab. & Cont.	Modify ATCA	+3	Modify rate gain to insure one pulse limit cycle
2.3	Stab. & Cont.	Modify RGA	+1	Modify to provide lower rate threshold
4.51	Crew Provisions	Water Probe	-1	Remove water probe and holster
4.8	Crew Provisions	Furnishings	-7	Better definition of furnishing items
5.311	Environ. Control	Ascent GOX Tank	-3	Remove LEM Ascent GOX tank
5.312	Environ. Control	Ascent GOX Tank	-3	Remove LEM Ascent GOX tank
5.51	Environ. Control	GOX Plumbing	+25	Added allowance for GOX plumbing
5.52	Environ. Control	Water Plumbing	+15	Added allowance for water plumbing
5.64	Environ. Control	Cold Plates -Batt & ECA	+10	Added cold plates for additional batteries and ECA's
5.41	Environ. Control	Asc. Water Tanks	+11	LEM ascent water tanks are retained
7.13	Instrumentation	Voice Recorder	+3	Additional voice recorder required
7.16	Instrumentation	Selector Switch	-6	Eliminated experiment selector switch
8.122	Electrical Power	Electric Control Ass'ys	-54	Replace LEM ECA's with modified units
8.333	Electrical Power	Wiring & Distribution	+6	Remove relay boxes; add allowance for distribution
8.112	Electrical Power	Battery Packs	+1112	Added 8 batteries to provide power previously assumed available from CSM
8.48	Electrical Power	Cables	+14	Added cables for additional batteries
11.3	Communications	T. V. Camera	-9	Removed television and accessories
11.0	Communications	Signal Processor	-5	Remove modification to signal processor
		Dry Weight Changes	+1216	
4.444	Crew Provisions	PLSS Batteries	-15	Reduced recommended EVA's and back pack recharges to 18
4.445	Crew Provisions	PLSS LiOH	-14	
4.444	Crew Provisions	Constant Wear Garments	+18	
5.444	Envir. Control	LEM ECS LiOH Cartridge	-23	CSM now responsible of atmosphere control
5.445	Envir. Control	Trapped oxygen	+1	1 lb additional trapped oxygen
		Trapped & Residual Weight Changes	-33	
5.44	Envir. Control	Expendable Oxygen	-1	Bookkeeping change to trapped
5.44	Envir. Control	Expendable Water	+101	Filled descent and ascent water tanks
		Expendable Weight Changes	+100	
		Total Changes	+1283	

Table 4.6-8
 BASELINE PHASE I LAB MASS DATA CHANGES; MID-TERM TO PRESENT

Code	Subsystem	Item	Δ Wt, lb	Reason for Change
2.621	Stab & Control	Abort Elect Assy (AEA)	+5	Mod. to AEA omitted by error from Mid-Term Report.
3.17	Nav & Guid	Navigation Base	+6	Base must be retained.
4.0	Crew Provisions		-26	Total erroneously incl. 26 lb from Nav & Guid.
5.6	Environmental	Cold Plates	+14	These changes from the basic LEM were omitted by error from Mid-Term Report.
5.91	Control	ASA Bypass	+ 1	
5.92		Recirculating Duct	+ 4	
9.321	Propulsion	Descent He Tank	-96	
12.221	Displ & Cont	Modify DEDA	+ 2	
		DRY WT Δ s	-90	
4.444	Crew	PLSS LiOH	-45	Reduced no. of back-pack recharges to 21.
4.445	Provisions	PLSS Batteries	-50	
		TRAPPED & RESIDUAL Δ s	-95	
10.446	Reaction Control	Propellant	-134	Max. usable propellant reduced as result of decreased O/F.
		EXPENDABLE Δ	-134	
		TOTAL WT CHANGES	-319	

Table 4.6-9

MASS PROPERTIES SUMMARY
OF DELTA CHANGES DUE TO ALTERNATE
TO THE RECOMMENDED CONFIGURATION

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)
Provide New RGA	0	0	0	0	0	0	0
Modify ASA & AEA	7	280	14	-9	6	7	1
Retain Primary N & G - Remove AGS	124	276	-7	21	-9	15	13
Integrate Radiator into Cooling Loop	-648	143	-61	-60	179	81	183
Provide Passive Battery Cooling	-98	150	-54	-36	-46	-20	-27
Carry COX in Descent Propellant Tanks	-261	350	7	-47	-52	968	917
Reverse RCS Fuel and Oxidizer Lines	105	348	0	0	23	-126	-114
Provide Passive Cooling in Aft Equipment Bay	-207	143	-66	-42	8	22	28
Use Modified (15 KWHR) Batteries	78	199	-492	-285	-4928	-955	-4024
Use GE Fuel Cell Power Pack Delete Batteries	-1537	129	-2	34	-3283	-221	-1190

NOTE: All inertias are about the alternate delta change c.g.

DETAILED WEIGHT
TO THE REC

ALTERNATES TO RECOMMENDED PH1 LAB							5.63 CP BATT+ECA	
PROVIDE NEW RGA FOR LOWER RATE							5.64 CP BATT+ECA	
CODE TITLE WEIGHT C.G.							5.64 CP BATT+ECA	
POUNDS X Y Z							5.444 WATER EXP	
2.3	USE NEW RGA	0	0	0	0	DELTA WEIGHT		
DELTA WEIGHT							0 0 0 0	
MODIFY ASA + AEA FOR LOWER RATE							5.3 PLUMBING	
CODE TITLE WEIGHT C.G.							5.4 TRAPD GOX	
POUNDS X Y Z							5.4 EXPEND GOX	
2.61	MODIFY ASA	3	307	0	63	1.486 GOX TK SPT		
2.62	MODIFY AEA	4	260	25	-63	5.32 GOX TANK		
DELTA WEIGHT							5.33 GOX TANK	
7 280 14 - 9							5.34 GOX TANK	
RETAIN PRIMARY N+G REMOVE AGS							5.35 GOX TANK	
CODE TITLE WEIGHT C.G.							5.51 GOX PLMBG	
POUNDS X Y Z							5.31 GOX TANK	
3.11	INU PLATFORM	42	307	0	50	5.445 OXYGEN TRD		
3.12	AOT TELSCPE	26	295	0	59	5.445 OXYGEN TRD		
3.13	LGC COMPUTER	58	248	0	-24	5.445 OXYGEN TRD		
3.16	LGC-PSA CBL	10	261	0	-26	5.445 OXYGEN TRD		
3.18	PTA TORQUER	12	305	0	30	5.445 OXYGEN TRD		
3.110	CDU CONVTR	33	265	0	-24	5.441 OXYGEN EXP		
2.61	ABORT SNSER	-20	307	0	63	5.442 OXYGEN EXP		
2.62	ABORT ELECT	-37	260	25	-63	5.443 OXYGEN EXP		
DELTA WEIGHT							5.444 OXYGEN EXP	
124 276 - 7 21							5.445 OXYGEN EXP	
INTEGRATE RADIATOR INTO COOLG LOOP							DELTA WEIGHT	
CODE TITLE WEIGHT C.G.							REVERSE RCS FUEL +	
POUNDS X Y Z							CODE TITLE WEI	
5.92	RADIATOR	30	165	85	0	POU		
5.93	RADIATOR	30	165	-85	0	10.0 PLUMBING		
5.94	PLUMBING	10	180	0	0	10.4 FUEL EXP		
5.95	MDFY GLYCL	15	247	16	-13	10.4 FUEL EXP		
1.151	H2O TNK SP	-13	147	-64	-43	10.4 OXID EXP		
1.151	H2O TNK SP	-13	147	-43	-64	10.4 OXID EXP		
5.4	H2O TANK	-24	147	-64	-43	10.446OXIDIZER		
5.4	H2O TANK	-24	147	-43	-64	10.446FUEL		
5.444	WATER EXP	-322	147	-64	-43	10.446OXIDIZER		
5.444	WATER EXP	-322	147	-43	-64	10.446FUEL		
5.52	H2O PLMBG	-15	147	-50	-50	DELTA WEIGHT		
DELTA WEIGHT							-648 143 -60 -60	
PROVIDE PASSIVE BATTERY COOLING							PROVIDE PASSIVE CO	
CODE TITLE WEIGHT C.G.							CODE TITLE WEI	
POUNDS X Y Z							POU	
5.9	SHUTTER	1	164	90	0	5.9 SHUTTER		
5.9	SHUTTER	1	164	0	90	5.444 WATER EXP		
5.9	SHUTTER	1	164	0	-90	DELTA WEIGHT		
5.9	SHUTTER	1	164	-90	0	-		
5.63	CP BATT+ECA	-5	164	90	0	-		

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ole 4.6-10

STATEMENT ALTERNATES
RECOMMENDED PHASE I LAB

5	164	0	90
5	164	0	-90
5	164	-90	0
82	147	-64	-43
98	150	-54	-36

PROP TANKS

HT	C.G.			
	X	Y	Z	
DS	X	Y	Z	
15	164	0	0	
10	164	0	-50	
71	164	0	-50	
20	254	0	-60	
46	270	-12	-48	
47	249	24	-48	
46	249	-24	-48	
47	249	0	-48	
25	260	0	-40	
47	270	12	-48	
1	270	12	-48	
2	270	-12	-48	
1	249	24	-48	
2	249	-24	-48	
1	249	0	-48	
2	184	40	-40	
45	270	-12	-48	
45	270	-12	-48	
45	249	24	-48	
45	249	-24	-48	
45	249	0	-48	
45	184	40	-40	
61	350	7	-47	

OXIDIZER LINES

HT	C.G.			
	X	Y	Z	
DS	X	Y	Z	
0	0	0	0	
19	280	45	15	
18	280	-45	-15	
54	280	40	15	
55	280	-40	-15	
24	262	45	15	
96	266	45	15	
25	262	45	15	
96	266	45	15	

LING AFT BAY

HT	C.G.			
	X	Y	Z	
DS	X	Y	Z	
8	254	0	-70	
15	147	-64	-43	
07	143	-66	-42	

USE MODIFIED (15 KWHR) BATTERIES

CODE	TITLE	WEIGHT POUNDS	C.G.		
			X	Y	Z
8.113	MOD BATTYS	715	164	-90	0
8.113	MOD BATTYS	715	164	90	0
8.113	MOD BATTYS	715	164	0	-90
8.113	MOD BATTYS	715	164	0	90
8.112	REC BATTYS	-556	164	-90	0
8.112	REC BATTYS	-556	164	90	0
8.112	REC BATTYS	-556	164	0	-90
8.112	REC BATTYS	-556	164	0	90
8.112	LEM BATTYS	-556	159	63	36
1.111	BATTY SUPT	-50	164	57	36
8.122	MOD IFD ECA	-12	171	44	36
1.112	MOD SUPTS	15	164	-90	0
1.112	MOD SUPTS	15	164	90	0
1.112	MOD SUPTS	15	164	0	-90
1.112	MOD SUPTS	15	164	0	90

DELTA WEIGHT 78 199-492-285

USE GE POWER PACK DELETE BATTERIES

CODE	TITLE	WEIGHT POUNDS	C.G.		
			X	Y	Z
8.01	GE F/C + MT	99	209	17	-70
8.01	GE F/C + MT	99	209	-17	-70
1.41	STRUCT SPTS	34	218	0	-61
1.42	TANK TRUSSS	10	219	0	-51
1.43	WEB DOUBLRS	5	192	0	-59
8.02	ECA	32	223	-17	-69
8.03	O2 TANK DRY	90	219	15	-44
8.04	H2 TANK DRY	90	219	-18	-44
8.05	RADIATOR	78	218	0	-62
8.06	PLUMBING	48	220	0	-44
8.07	WIRING	35	220	0	-44
8.08	MISC	25	220	0	-44
5.45	WATER TANK	13	223	17	-70
8.44	H2 TRD+EXP	29	219	-18	-44
8.44	O2 TRD+EXP	326	219	15	-44
8.112	BATTY PACK	-556	164	90	0
8.112	BATTY PACK	-556	164	-90	0
8.112	BATTY PACK	-556	164	0	90
8.112	BATTY PACK	-556	164	0	-90
8.122	MOD IFD ECA	-12	156	0	90
8.122	MOD IFD ECA	-12	156	90	0
8.122	MOD IFD ECA	-12	156	-90	0
8.122	MOD IFD ECA	-12	156	0	-90

8.323	WIRNG+DIST	-30	164	0	0
8.48	CABLES	-14	164	0	0
8.48	CABLES	-14	164	0	0
5.63	CP BAT+ECA	-5	164	90	0
5.63	CP BAT+ECA	-5	164	0	90
5.64	CP BAT+ECA	-5	164	0	-90
5.64	CP BAT+ECA	-5	164	90	0
1.1111	BATT SUPT	-50	164	90	0
1.1111	BATT SUPT	-50	164	-90	0
1.1111	BATT SUPT	-50	164	0	90
1.1111	BATT SUPT	-50	164	0	-90

DELTA WEIGHT -1537 129 - 2 35

5. SUBSYSTEM ENGINEERING

5.1 ELECTRICAL POWER SUBSYSTEM

5.1.1 Ground Rules

The Phase I Lab Electrical Power Subsystem (EPS) shall be designed in accordance with the following ground rule:

- No interchange of electrical power between the CSM and the Lab.

5.1.2 Assumptions and Background Data

5.1.2.1 Power and Energy Requirements

5.1.2.1.1 Housekeeping Design Profile. The EPS Electrical Housekeeping Design Profile for the Phase I Lab is shown in Fig. 5.1-1. This profile is composed of all those loads required to maintain the vehicle in an operable condition. Loads directly associated with performance of experiments have been included in the integrated profile. The housekeeping load analysis and its profile have been generated on the following assumptions:

- 7.5% distribution losses for all loads
- 20% growth allowance for the total of all loads
- Specific load and duty cycle assumptions are shown in Phase I Lab Load Analysis Sheet, Table 5.1-1. (Where LEM equipment was used, the LEM current status values or the vendor's latest test data was used.)
- 336-hr in-orbit mission time
- GN&C equipment provides for vehicle stabilization
- Communication and instrumentation equipment required for data handling are on a 15% duty cycle (max. total transmission on-time duty cycle for a 200-n.mi 90°-deg orbit)

Except for the launch through transposition phase, there is no similarity between the LEM and Phase I Lab missions; thus, the power, energy, and profiles bear no similarity. However, the housekeeping loads are based on using LEM equipment; thus, these estimates should be as good as the present LEM's current status values. Including 20% growth and 7.5% distribution losses, housekeeping loads average 544-w, and use 182.9 kw-hr of energy over the 336-hr mission. Actual power levels vary from 480 to 840-w.

A 152.2-w suit fan motor has been assumed to be used during the 5th and 9th mission days. On these days, it was assumed that the astronauts would use their space suits for 45 min for EVA to replenish their LiOH supply.

The 37.5-w dome light load has been included to provide the visibility needed to operate equipment in the mid-section area. The power for the average of two cluster heaters on continuously has been included to maintain RCS thrusters in shadow within their minimum temperature range. A considerable power drain was saved

in bypassing the coolant loop around the Abort Sensor Assembly (ASA) during standby operations. With this configuration, only 5-w of power will be required; without the bypass, 73-w of power would have to be consumed.

The individual AC loads are noted under their own subsystems. The inverter supplying these loads has been assumed to operate at a 65% efficiency, and its losses have been included under the EPS breakdown of loads.

5.1.2.1.2 Integrated Design Profile. The EPS Electrical Integrated Design Profile for the Phase I Lab is the combination of housekeeping and experimental loading and is shown in Fig. 5.1-2. At the time of this report, the experimental power requirements have not as yet been finalized. To illustrate a typical mission of housekeeping and experimental power requirements, a mapping radar mission was selected. The mapping radar was used since it presented the highest power requirements of all the experiments reviewed. The power level of the mapping radar was assumed to be 2.5-kw since the equipment is still under development and actual values are not known to Grumman. To complete the energy requirements, the mapping radar was considered to be on for a total of 14 hr or 1 hr/day. An average base load of 146-w was included over the 14-day mission. The total experimental energy assumed over the 14-day mission is 91.1 kw-hr.

5.1.2.2 Silver-Zinc Batteries

To meet the ground rule of minimum modification, the use of LEM descent and ascent batteries was studied. These batteries can be operated in parallel at a low-average rate (between 1 to 1.5 amp) to increase capacity and reliability. The capacity available will be increased by 25 amp hr over the LEM capability of 400 amp hr because of the reduced discharge rate. The terminal voltage will be higher as a result of lower internal voltage losses and the heat dissipation will also be decreased. In addition, the bus voltage will be increased because of the reduced IR drop in the distribution feeders. Tables 5.1-2 summarize the present LEM descent and ascent battery design characteristics. Fig. 5.1-3 and 5.1-4 illustrate the descent and ascent battery voltages as a function of percent capacity for various discharge rates.

Because of the extremely low discharge rates obtained by operating the batteries in parallel, the use of more efficient type cells with merit factors of up to 100 w-hr/lb was also investigated.

By modification of the ascent cell plates for the low discharge rates and the elimination of one cell, a 19-cell battery, with a capacity of 500 amp hr packaged in an ascent battery container, can be obtained at approximately the same weight as the present descent batteries. Other modifications to the LEM ascent and descent batteries are tabulated in Table 5.1-3.

As in the LEM, the modified descent batteries have a 17-cell tap to reduce the initial overvoltage characteristic, and as in the LEM, is switched to the battery's full-cell complement subsequent to transposition.

Since the Phase I Lab mission is 8 days longer than for the LEM, the battery stand-life is increased by that length of time. However, at the reduced generating temperatures expected at the lower discharge rate, the separator degradation will be hardly changed and perhaps decreased.

Two ascent batteries can also be operated at a reduced discharge rate and hence cooler than in the LEM. This low discharge rate will possibly require a slightly increased pre-discharge to reduce the high initial peroxide voltage. Alternately, the ascent batteries could pick up the entire load during initial operation.

An alternate to the high ascent battery voltage is to eliminate one cell and provide a 17-cell tap.

5.1.2.3 Battery Electrical Control Assembly (ECA)

The initial approach to the design of the EPS for the Phase I Lab was to use LEM components wherever possible. However, it became apparent that the functional requirements and restraints for the battery ECA had changed appreciably between the LEM and the Phase I Lab:

- Crew safety does not depend on the EPS.
- Mission time more than doubled (increased by approximately 8 days)
- Number of descent batteries to control increased to 20, (5 times the number in LEM).

With a recommendation from the battery vendor, Eagle-Picher, it was decided to operate the batteries in parallel to increase their capacity and reliability. In addition, it was felt that the control system would be less complex and more reliable than sequentially discharging the batteries. If the LEM-type battery ECA were used to support the Phase I Lab, approximately 5-w of control power would be required for each battery. The total control energy requirements would be 5-w x 22 batteries x 336 hr = 37 kw-hr. This would require approximately three descent batteries to supply the energy. These new batteries would require ECA which would consume an additional 3.9 kw-hr of energy.

Because of these factors, new approaches were investigated to devise the battery controls with lower power consumption. Grumman and the ECA vendor, General Electric, resolved a ECA configuration that could control from one to five batteries in a smaller envelope than the LEM's descent ECA with a 2-w control power requirement.

A total of 5-w heat dissipation would be generated in the control of four batteries (five batteries would be slightly higher). With this approach, 20 descent batteries, controlled in groups of four by a total of five ECA would require only 19-w of control power, or 3.36 kw-hr of energy for the mission.

The modified ECA would monitor its batteries as a package of four or five depending on the required configuration. Individual current monitoring could be achieved by turning off all but the desired battery in its ECA group. Over-voltage sensing and protection and reverse current sensing would be included if required. The individual batteries will be paralleled at the ECA through diodes, to isolate any battery failures from affecting good batteries or the rest of the system.

Besides the saving in power consumption (33 kw-hr), very significant savings in weight and volume would also be achieved. The savings in the number of production units required per vehicle was estimated as being able to cover the cost of the design, development, and qualification of this modification.

5.1.3 Recommended Configuration

5.1.3.1 System Description

As in the LEM, the primary power for the Phase I Lab is DC power except for the prelaunch phase when both AC and DC power requirements are provided by GSE power sources.

The recommended configuration uses 22 batteries connected in a parallel configuration, to supply a total of 274 kw-hr of energy. There are two LEM ascent stage batteries, each controlled by their own electrical control assembly (ECA), exactly as in the present LEM. The LEM configuration of four descent batteries plus 16 additional LEM descent batteries installed in packs of four to complete the complement of 22 batteries. Each descent four pack and the standard LEM descent group of four batteries are controlled by a modified ECA. The two standard LEM descent ECA will be removed. Fig. 5.1-5 is a schematic of the recommended configuration. The new ECA will parallel and control four batteries. A diode in series with each battery prevents reverse current flow. These diodes are tied to a common point within the ECA so that the output line from each ECA carries the current from the four batteries.

The LEM inverters provide the power to supply AC load requirements. Although the loads are a fraction of the capacity of the LEM inverter, the minimum modification approach dictates their use. As in the LEM, the second inverter is used only if the first fails.

5.1.3.1.1 Feeder Configuration. Five feeders from the five new ECA outputs shall connect to the Relay Junction Box (RJB), where they are paralleled with the ascent batteries. The feeder lines leading into the cabin remain the same as in the LEM. The dead-face relay function of the LEM is not required in the Phase I Lab and is eliminated.

5.1.3.1.2 Bus Configuration. The bus configuration is that used in the LEM.

5.1.3.1.3 Protection and Control Equipment. The protection equipment is the same as in the LEM except for the new ECA which control groups of four descent batteries. These ECAs also provide a short-circuit current limiting function, since the short circuit capability of 22 batteries could cause catastrophic damage if not limited.

5.1.3.1.4 Batteries. In line with the "min-mod" approach, standard LEM ascent and descent batteries have been chosen for this configuration. However, in consideration of their new configuration requirements (low-rate discharge) they have been up-rated to 9.5 and 12.75 kw-hr, respectively.

5.1.3.2 Performance

The DC and AC voltage limits for the EPS shall be the same as the LEM since the same batteries, inverters, and distribution equipment will be used. However, because of the parallel operation of the large number of descent batteries, the nominal operating voltages will be somewhat higher than the standard LEM.

Total energy requirements and capacities are described below:

	<u>Energy Available (Kw-Hr)</u>	<u>Maximum Assumed Use of Energy (Kw-Hr)</u>	
2 Ascent Batteries	19	Housekeeping	182.9
20 Ascent Batteries	255	Experiments	91.1
TOTAL DC ENERGY	274		274

	<u>Power Rating</u>	<u>Max. Power Used (Watts)</u>
2 115-V, 400-Cps inverters (ea)	350 VA	Housekeeping 28.7
(one used as back-up only)		Experiments 92.0*
TOTAL AC POWER		120.7

5.1.2.2 Location and Integration of Components

There are no major modifications for EPS equipment other than the installation of the 16 new descent batteries and the modified ECA. Cooling and other requirements will be essentially the same as the LEM with exception of the lower heat dissipation of the batteries. It was estimated that in the recommended configuration the batteries would generate between 7 and 15 btu/hr.

The additional 16 descent batteries are to be mounted to the outside of the vehicle in the space between the surface of the vehicle and the landing gear trusses, four batteries per side with their ECA. The modified ECA shall fit between the same "cold" rails as the batteries and are estimated to be smaller than the present descent ECA. (Refer to Paragraph 6.2 for structural design and installation details.)

5.1.4 Baseline Configuration

The baseline configuration was based on the ground rule that 100 kw-hr of energy would be available from the CSM at the LEM bus. This configuration consisted of the LEM with its two ascent and four descent batteries, plus eight descent batteries to complete the requirement for 268 kw-hr of energy (68 kw-hr from the standard LEM configuration, 100 kw-hr from the eight additional descent batteries and 100 kw-hr from the CSM). Effort on this configuration was stopped when it was learned that Grumman should work on the ground rule that there shall be no interchange in electrical energy between the LEM and the CSM. At this point, the present recommended configuration evolved by adding an additional eight descent batteries above the baseline configuration to make up the 100 kw-hr of energy that could no longer be assumed from the CSM. The baseline EPS schematic is shown in Fig. 5.1-6.

* Assumed two tape recorders (at 46-w each) converted for use with single-phase power in lieu of its present design for three-phase power.

5.1.5 Alternate Configuration - 15-Kw-Hr Silver Zinc Batteries

This all-battery configuration is a modification of the recommended configuration, utilizing redesigned batteries optimized to provide higher energy capabilities. When used in the same number as the recommended configuration batteries, they can provide an additional 56 kw-hr of energy.

The basis for the battery redesign centers about the Phase I Lab's low discharge rate battery requirements accruing due to the parallel operation of the large number of batteries. At the low rates encountered, a cell design similar to that used in the Agena-type batteries could be utilized. An optimum 15-kw-hr, 143-lb battery can be obtained by installing 19 of these cells in the ascent battery container envelope (20 cells are used for LEM design), and redesigning the container internal heat conducting paths. See Table 5.1-2 for estimated 15-kw-hr battery characteristics; and Fig. 5.1-7 for estimated voltage vs percent capacity. Thus, with a complement of 22 batteries, the total energy available would be 330 kw-hr.

Two of these batteries would be installed in the ascent stage in place of its present ascent batteries. The remaining 20 batteries would be installed in four groups of five batteries. Each group would be mounted on an outrigger bulkhead with one modified ECA controlling the five batteries. The existing LEM four descent battery installation in Quadrant IV would be removed. However, if additional energy is required, utilization of this area could be reconsidered. (Refer to Paragraph 6.2 for installation details.)

5.1.5.1 System Description

Fig. 5.1-8 is a schematic of this configuration indicating the proposed manner by which these batteries would be tied into the distribution section. Protection and control of the battery system are provided by the battery ECAs. The ECA for the descent stage batteries will be the same as those used in the recommended configuration with an additional battery control included (five instead of four for the recommended configuration). The control power consumed will be the same; but the heat dissipation will be approximately 1-w higher. The ascent stage batteries will be controlled by the present LEM ECA. Control logic, overall feeder configuration, and operational procedure and performance will not differ in any significant way from the recommended configuration with the exception of the 330 kw-hr vs 274 kw-hr available in the respective configuration.

5.1.5.2 Interface with other Subsystems

The thermal requirements for the batteries will be the same as the recommended configuration. Heat generated by the batteries will be in the range of 7 to 15 btu/hr. For maximum capacity and reliability, the batteries should not be operated for any appreciable time above 80°F.

5.1.5.3 Weight

The weight breakdown for major power generation and control components are as follows:

<u>Ascent Stage</u>	<u>lbs</u>
2 15-Kw-Hr Batteries	286
2 LEM ECA	20
Total Ascent Stage Weight	306

<u>Descent Stage</u>	
20 15-Kw-Hr Batteries	2860
4 Modified ECA	48
Total Descent Stage Weight	2908
Total Ascent & Descent Stage Wt	3214

5.1.6 Alternate Configuration - GE Fuel Cell Power Pack Plus 6 LEM Batteries

An alternate configuration for the Phase I Lab power generation section is a fuel cell, cryogenic tank "power pack" used in conjunction with the existing LEM ascent and descent batteries. Fig. 5.1-9 is a block diagram of the configuration. The power pack is a self-contained module which makes maximum use of hardware that is now available or will be available for use on the Phase I Lab by virtue of its use on other space programs. The power pack consists of the following components:

- Two Gemini fuel cells (D membrane)
- One Apollo CSM Block II cryogenic hydrogen tank
- One Apollo CSM Block II cryogenic oxygen tank
- One Gemini coolant pumping assembly
- One Gemini coolant pump power supply (inverter)
- One modified Gemini plate-fin water boiler
- 30-sq ft of radiator surface, integral with the power pack structure
- Two fuel cell electrical control assemblies
- Two cryogenic reactant pre-heaters
- One water storage tank
- Plumbing, feed components, and electrical wiring
- Mounting and support structure

Fig.'s 5.1-10 and 5.1-11 are schematic diagrams of the coolant and reactant supply sections, respectively.

5.1.6.1 Performance

The total output performance of this configuration is as follows:

- Batteries
 - 28 to 32.5 v
 - 48 kw-hr (four descent batteries)
 - 18 kw-hr (two ascent batteries)
 - 66 kw-hrs total available energy

- Power Pack
 - 28 to 32.5 v
 - 850-w peak power at 28 v
 - 255 kw-hr total available net energy
 - 30 kw-hr power pack parasitic energy to run coolant pump
 - 2000-btu/hr heat rejection rate at 850 w.
 - 252 lb of water generated
- Total Vehicle
 - 28 to 32.5 v
 - 3450-w peak power at 28 v
 - 321 kw-hr total available net energy
 - 30 kw-hr power pack parasitic energy to run coolant pump
 - 252 lb of water generated

The vehicle is capable of handling the peak power levels and the transients of the Phase I Lab power profile by virtue of parallel operation of the power pack and the existing batteries.

The fuel cell power pack design characteristics, i.e., heat rejection, polarization curve, reactant consumption and step load capability are shown on Fig. 5.1-12, -13, -14, and -15, respectively.

5.1.6.2 Expendables

The reactant supply for the power pack is as follows:

Fluid	Tank	O.D. (in.)	Usable Fluid Capacity (lb)	Amount Loaded (lb)	Dry Wt. (lb)	Residual	Min. Flow Rate at 130°F (lb/hr)
H ₂	CSM Block II	31.8	28	28 lbs.	79	1.2	0.045
O ₂	CSM Block II	26.5	320	224 lbs.	82	6.4	0.44

Since stoichiometric consumption of 28 lb of H₂ requires only 224 lb of O₂, the O₂ tank is not loaded to full capacity. The additional O₂ storage capacity is used for ECS storage on the Apollo CSM, however, since the Phase I Lab has its own ambient oxygen storage and supply of sufficient capacity for the mission, fluid interface can be avoided between the Lab and the power pack by keeping the ECS O₂ storage separate from the power pack. However, two GOX tanks could be removed from the recommended configuration if the excess capacity is utilized. The minimum reactant flows required by the fuel cells for the Phase I Lab power profile are 0.533 lb/hr of O₂, and 0.067 lb/hr of H₂, which are compatible with the minimum flows from the cryogenic storage tanks.

5.1.6.3 Operation

The fuel cells will be activated on the launch pad by means of vehicle and GSE connections provided on the power pack. Shortly before launch, the cryogenic tank feed system will reach supercritical pressure and will start to supply reactants to the fuel cell. The coolant loop will be operating at this time to pre-heat the cryogenic reactants and maintain temperature control of the power

pack. The LEM descent and ascent batteries, as well as the fuel cells will be paralleled on the buses from the time the fuel cells are started. Whenever the demand for power from each fuel cell exceeds 425 w, the fuel cell voltage will drop to 28 v, the batteries will then start supplying power, maintaining vehicle voltage levels and meeting peak vehicle power loads.

The coolant flow is in parallel between each fuel cell assembly and in series through the invertèr, the ECA, and the cryogenic reactant pre-heaters. The coolant then flows through the space radiator, the water boiler, and the pumping assembly completing the loop. A temperature controlled by-pass valve regulates the coolant flow through and around the radiator to maintain a minimum radiator coolant outlet of 40°F. A second temperature controlled by-pass valve regulates the coolant flow through and around the water boiler to maintain a maximum boiler coolant outlet of 60°F. For a radiator coolant outlet of 60°F or less, the coolant will completely by-pass the water boiler. A temperature controlled valve senses the temperature of the steam leaving the boiler and regulates the water inlet flow rate to the boiler to maintain a minimum steam temperature of 45°F for water boiling at 40°F, insuring economical use of the cooling water. The water boiler supplements the space radiator under high fuel-cell power conditions and/or high external-heat flux to the radiator. All the water required for supplemental cooling of the power pack is available from the fuel-cell by-product water production. The fuel cells and cryogenic storage of the power pack require additional vehicle control and display panels. These panels will be similar to the ones used on Gemini for the fuel cells, and Apollo CSM for the cryogenic storage.

5.1.6.4 Interface Requirements

The power pack is a self-contained power generating unit having its own reactant storage and supply, coolant pump and loop, heat rejection, water storage, and AC power supply provisions. The interfaces between the power pack and the Lab include the following:

- Electrical
 - Main feeder wires
 - Instrumentation and telemetry
 - Displays and controls
- Structural mounting provisions.

The interfaces between the power pack and the launch pad include the following:

- Cryogenic H₂ and O₂ servicing fill and vent points
- Fuel cell start-up purge and reactants supply points
- Fluid and electrical test points.

5.1.6.5 Performance of Components

5.1.6.5.1 Coolant Pumping Assembly and Power Supply. The coolant pumping assembly is a completely redundant unit containing two pumps and is compatible with the MCS 198 coolant. The MCS 198 coolant has a freezing point of 145°F and is used in the Gemini ECS coolant loop. The power supply is completely redundant, containing two inverters, either one is capable of supplying AC power to the pump assembly while drawing 80 w of DC power. Pump characteristics are as follows:

- Total flow: 22 lb/hr
- Pressure rise: 75 psi.

5.1.6.5.2 Radiator. The maximum radiator area that can be accommodated is 30 sq ft made up of two 15-sq-ft panels, at right-angles to each other.

5.1.6.5.3 Water Storage Tank. The water tank is sized to store the total quantity of water generated by the fuel cells. Its capacity is 252 lb of H₂O.

5.1.6.6 Modifications to Basic LEM

- Structural beef-up to support power pack
- Power distribution changes to accept and control power from power pack
- Cryogenic, fuel cell, and coolant display and control panels.

5.1.6.7 Total Weight

The total weight of the power pack is 842 lb. A weight breakdown of the power pack is listed below:

<u>Component</u>	<u>Weight (lb)</u>
Fuel cells (2)	190
ECA (2)	28
Oxygen	224
Hydrogen	28
Oxygen tank	88*
Hydrogen tank	80*
Pump package	25
Radiator	60
Water boiler	5
Water tank	25
Heat exchangers	3
Lines, fittings, feed components	18
AC power supply (inverter)	18
Structure	<u>50</u>
Total	842

*Includes residual

5.1.8 Discussion of Configuration Choices

Table 5.1-4 summarizes the weight of the major components and energy capabilities of the selected configurations.

The recommended configuration was derived by adhering to the minimum modifications concept for power sources and evaluating the experiment requirements of both the Phase A LEM Utilization Study - 14-day Lab missions, and the Phase I Lab Payload Integration Study. The experiment energy requirements appeared to "home in" around 90 kw-hr. Therefore, the total housekeeping and experiment energy requirement of 274 kw-hr is met by utilizing two ascent and 20 descent LEM batteries. The use of the LEM batteries "as is" negates a vendor development program and requires a minimal Grumman integration program. The modified ECA is selected on the basis of weight, power, and system simplification (refer to Paragraph 5.1.2.3 for details).

The 15-kw-hr battery alternate configuration offers a substantial increase (56 kw-hr) in the experiment energy at approximately the same weight as the recommended configuration. However, the Grumman integration program will be complemented by a vendor development program.

The fuel cell alternate offers both a substantial increase (47 kw-hr) in experiment energy and a decrease (1400 lb) in EPS weight; but does require a significant development program at Grumman to integrate Gemini fuel cells, Apollo CSM cryogenic tanks, and LEM batteries.

TABLE 5.1-1

ALL-BATTERY LOAD ANALYSIS; 14-DAY MANNED MISSION, 200 n.mi E.O.

	Subsystems	Power, Watts	Duty Cycle	Avg. Power, watts
ECS	Glycol Pump	28.0	Cont	28.0
	Cabin fan	39.0	Cont	39.0
	CO ₂ Sensor	1.0	Cont	1.0
	ECS Relay Box	7.4	10%	0.7
	Suit Fan	152.2	0.5%	0.7
RCS	Cluster Heater (2)	15.0 ea	Cont	30.0
DISPLAYS	Meters & Indicators	40.4	Cont	40.4
	Indicators	11.2(AC)	Cont	11.2
INSTR	Transducers	9.6	Cont	9.6
	Sig Cond Elect Assy	42.7	Cont	42.7
	Caution & Warning	22.0	Cont	22.0
	Timing Equipt	5.5	Cont	5.5
	Pulse Code Mod	7.4	**15%	1.1
	Voice Storage Recorder	2.3(AC)	6%	0.1
CREW PROV	EL Lighting	6.2(AC)	Cont	6.2
	Flood Lights	75.0	50%	37.5
	Dome Lights	37.5	12 1/2%	4.7
GN&C	ATCA	126 pk/25 min - 70 avg	Operating mode	70.0
	ASA	288 pk/5 min - 5 avg	***Standby	5.0
COMM*	Audio centers (P/O Sig Proc Assy)	11.0	Cont	11.0
	Sig Proc Assy (PMP)	4.5	**15%	0.7
	Transceiver	36.0	**15%	5.4
EPS	Lighting Cont Assy	5.0	Cont	5.0
	Lighting Cont Assy	9.0 (AC)	Cont	9.0
	Inverter Losses (assumed 65% eff.)	15.5	Cont	15.5
	Battery ECAs	20.0	Cont	20.0
			Subtotal	= 422.0
			Dist. Losses (7 1/2%)	31.6
			Current Status Avg Pwr	453.6
			Growth Allow. (20%)	90.6
			Design Avg. Power	544.2
			Design Energy = (336hr x 544.2 w)	= 182.9kw-hr
Notes	* For lunar orbit missions, add 6w cont. for S-Band heater.			
	** For 200 n. mi, 90-deg inclination			
	*** With coolant loop bypass & 70°F cabin temperature.			

Table 5.1-2
Eagle-Picher Battery Characteristics

Characteristics	Ascent (LEM/Taxi) (Ph I Lab Recmd Config)	Descent (LEM) (Ph I Lab Recmd Config)	Mod Descent (Estim.) (Ph I Lab Alt Config)
Designation	Asc-1C	Desc II-B	Desc.(Mod Agena)
No. Cells	20	20	19
Weight, lb	130.5	139	143
Volume, cu in.	1545	1500	1500
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 17.5
Capacity amp-hr	340/300*	400 425	500
Energy, kw-hr	10.2/9.0*	12 12.75	15
watt-hr/lb	78/69*	87 LEM 91 Ph I	105
watt-hr/cu in	6.6/5.8*	8.0 8.2 Lab	10
Mission watt-hr/lb	62 LEM 60 Taxi 73 Ph I	82 93	87
watt-hr/cu in.	5.2 LEM 5.0 Taxi 6.1 Lab	7.5 8.5	8.3
Wt of Terminals & Other Hdwe, lb	Zero	0.4	0.4
Canister Weight, lb	10.5	10.0	10.0
Canister Material	Mg	Mg	Mg
Reliability Estimate	0.995(LEM) 0.9915 Ph I Lab	0.995(LEM)0.9915 Ph I Lab	0.993
Cycling Capability	3	3 (Test only)	3 (Test only)
Cell Weight, lb	6.0	6.28	6.8
Silver Weight/Cell, gm	952	956	
Zinc Weight/Cell, gm	746	850	
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 1.77 x 9.25
without Terminal	4.9 x 1.82 x 7.0	4.3 x 1.68 x 8.75	4.3 x 1.77 x 8.75
No. Cells, Positive/Negative	12/13	9/10	7/8
Total Effective Cell Area, sq in.	620	494	384 (est)
Separator System	Polyamide, Cellulose,	Polyamide, Cellu- lose, Rayon	Polyamide, Cellu- lose, Rayon
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
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	14	14 (5-Batt Pack) 10 (1-Batt)

* After Predischarge

** Normal LEM Mission/Abort (1 Battery)

*** 4 Battery/3 Battery LEM Mission

± Based on 14-day Taxi Mission

Table 5.1-3

CANDIDATE BATTERY CONFIGURATIONS

Battery Configuration	No. Cells	Wt, lb	amp-hr	kw-hr (At 30 V)**
• Present LEM descent battery LEM rating 400 amp-hr, (12 kw-hr)	20	139	425	12.75 Recommended
• Present LEM descent battery with 1 cell removed	19	134	425	12.75
• Mod descent battery, present LEM descent battery container; cells designed for low-rate discharge	19	139	475	14.25
• Present LEM ascent battery, LEM rating 300 amp-hr, (9 kw-hr) (pre-discharged)	20	130	315*	9.5* Recommended
• Present LEM ascent battery with battery tap	20 19	130 125	375	11.2
• Mod ascent battery, present LEM ascent battery container; cells designed for low-rate discharge	19	143	500	15.0 Alternate

* Grumman estimates; all other values were obtained from Eagle-Picher

** Both 19- and 20-cell batteries will supply the mission loads within the required voltage regulation. The 20-cell battery will operate at approximately 5% higher voltage and power. However, no advantage is taken of the extra energy delivered by the 20-cell battery; thus both batteries were carried at same energy level for trade-off comparison.

Note: From 30 min, the cycle shown is based on a critical combination of cycling loads assumed typical for entire mission.

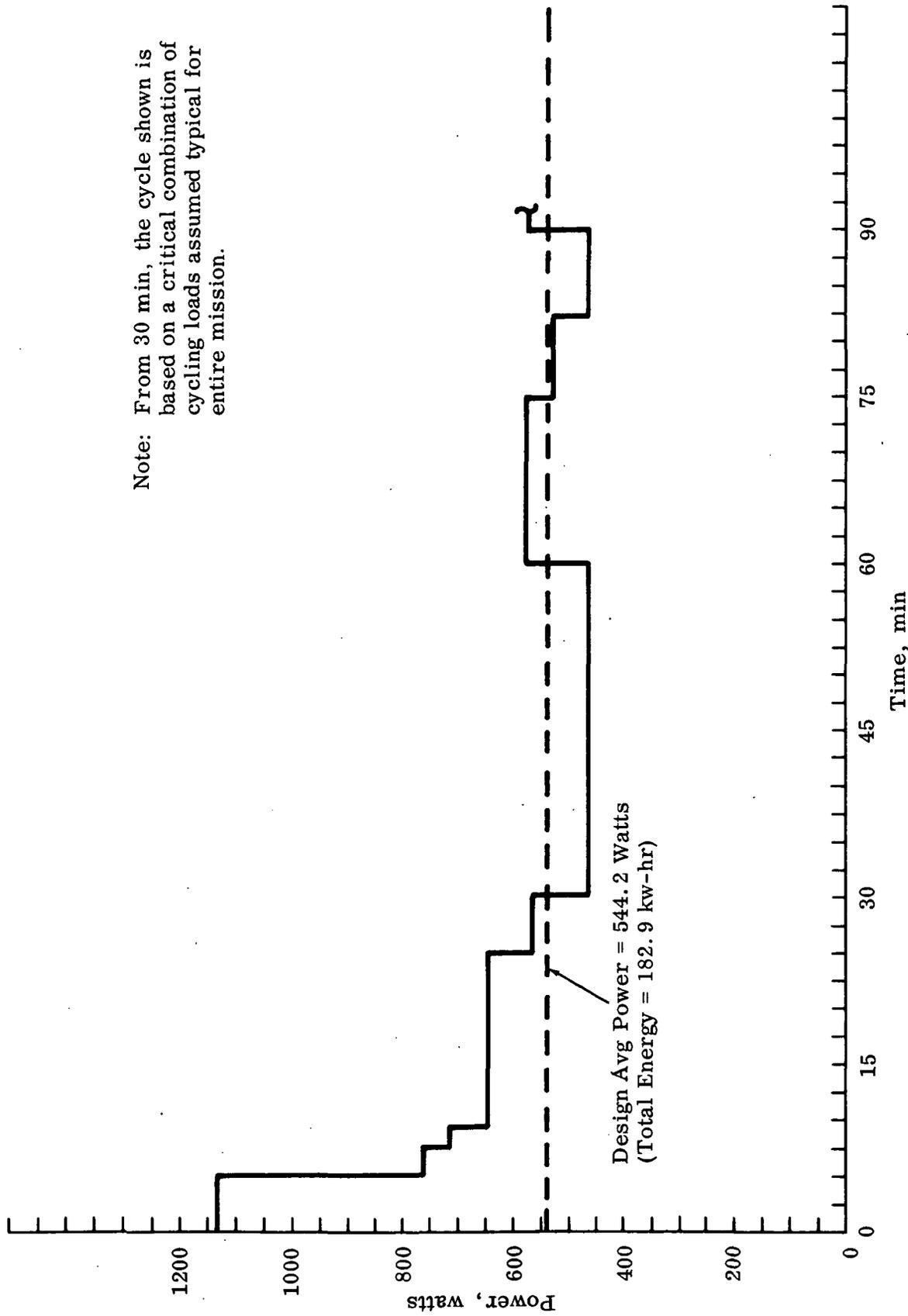
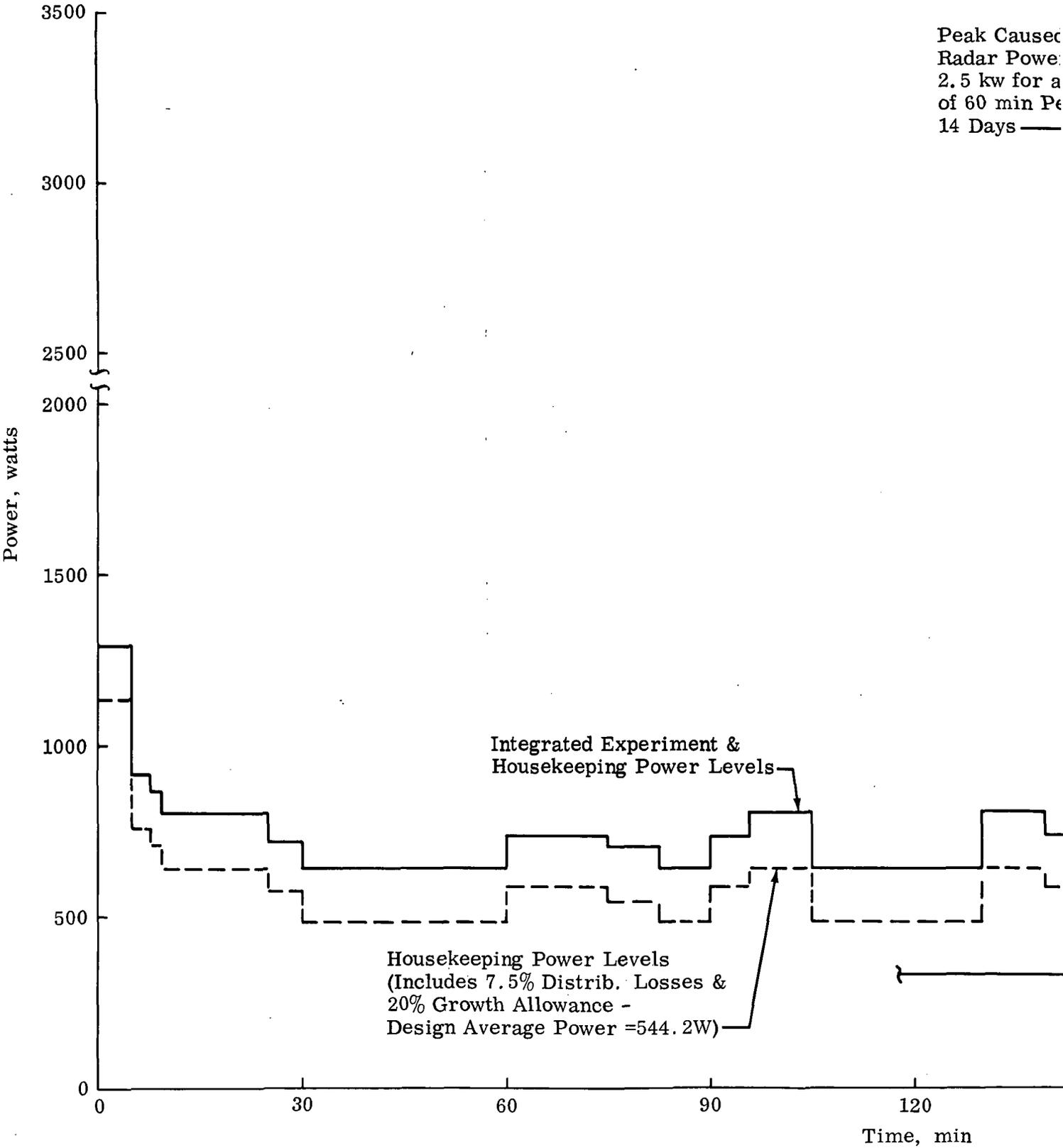
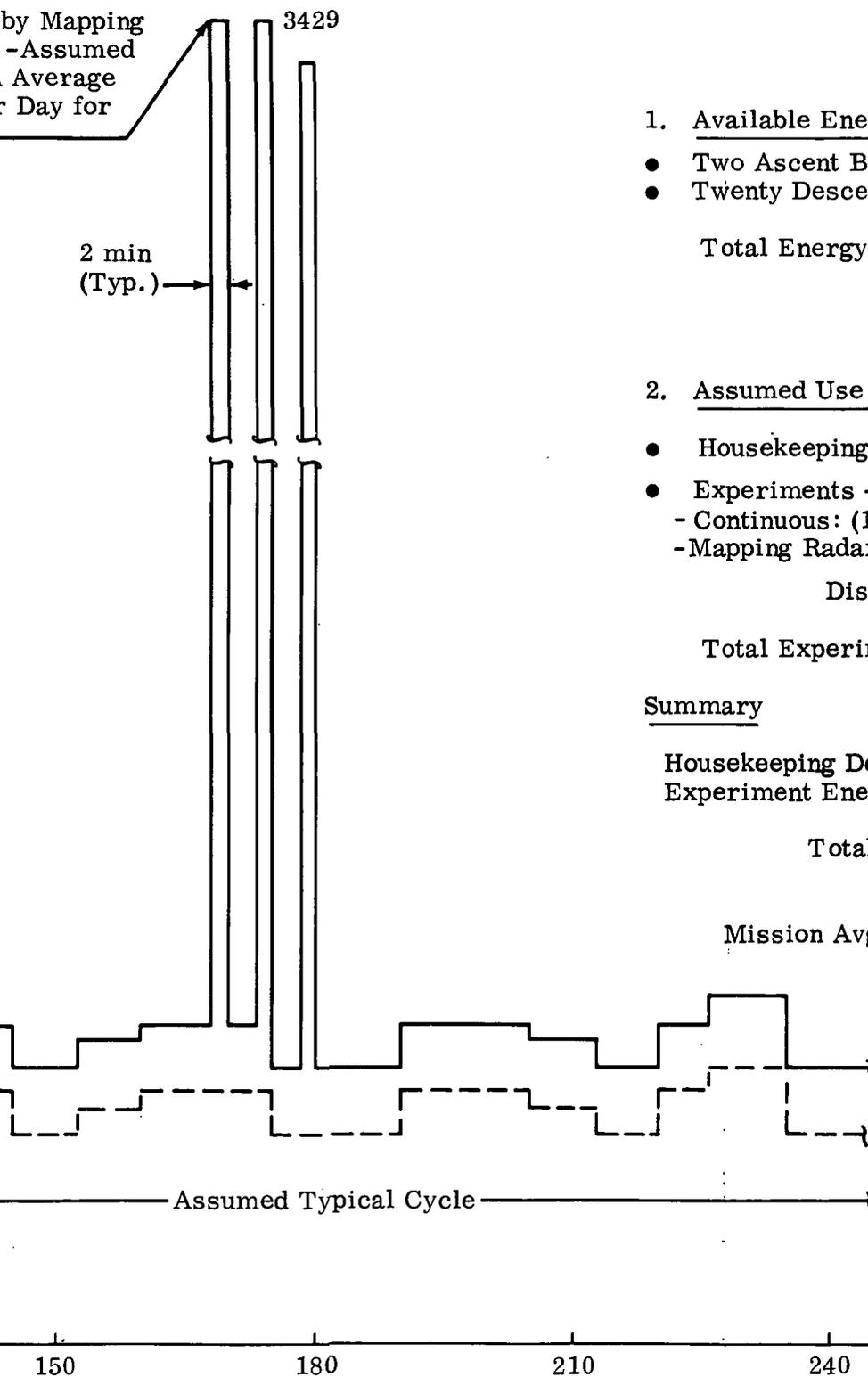


Fig. 5.1-1-1 Electrical Power Housekeeping Design Profile (Based on EPS Recommended Configuration)

(17)

Peak Caused
Radar Power
2.5 kw for a
of 60 min Pe
14 Days —





1. Available Energy	<u>kw-hr</u>
● Two Ascent Batteries @ 9.5 kw-hr	= 19
● Twenty Descent Batteries @ 12.75 kw-hr	= 255
Total Energy Available	<u>= 274</u>

2. Assumed Use of Energy	
● Housekeeping - Design Energy	= 182.9
● Experiments -	
- Continuous: (146w x 336 hr) =	49.1
- Mapping Radar (2.5 kw x 1 hr x 14)	= 35.0
Distrib Losses	= 7.0
Total Experiment Energy	<u>= 91.1</u>

Summary

Housekeeping Design Energy	= 182.9
Experiment Energy	= 91.1
Total Energy Used	<u>= 274.0</u>

Mission Avg. Power = 815.5 watts

Fig. 5.1-2 Electrical Power Integrated Design Profile



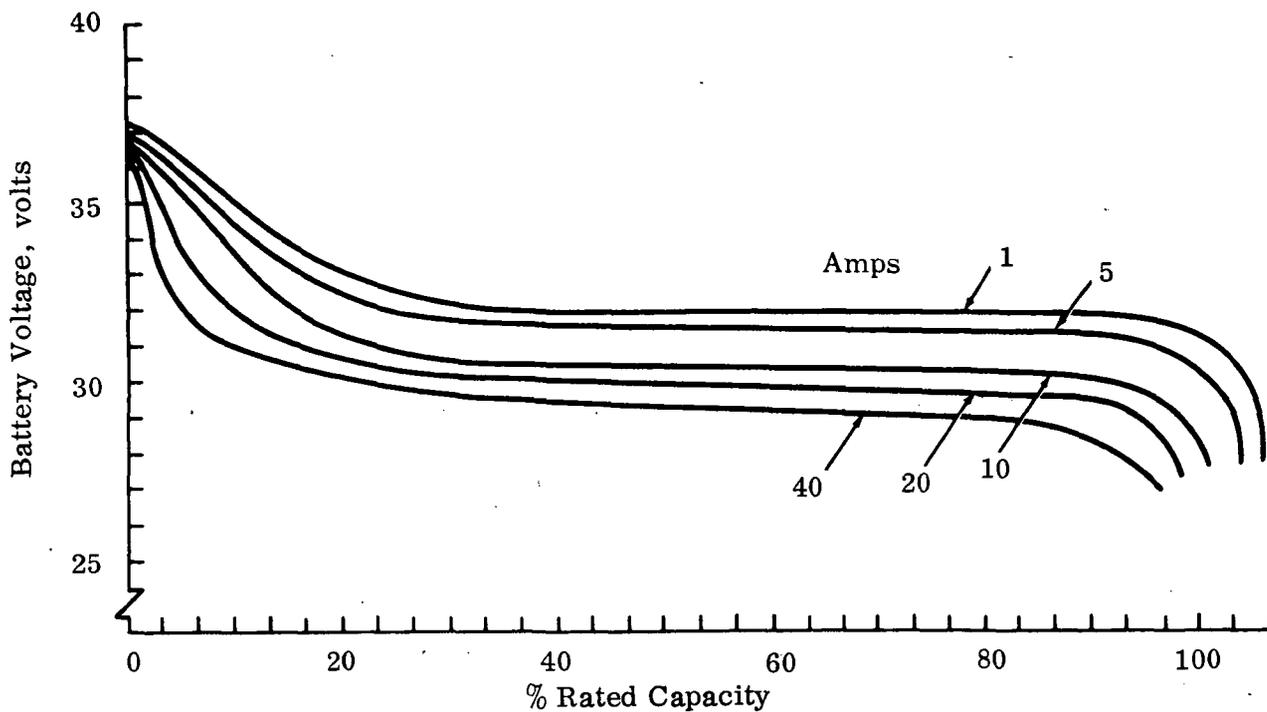


Fig. 5. 1-3 Descent Battery Voltage VS Percent Capacity at 80° F

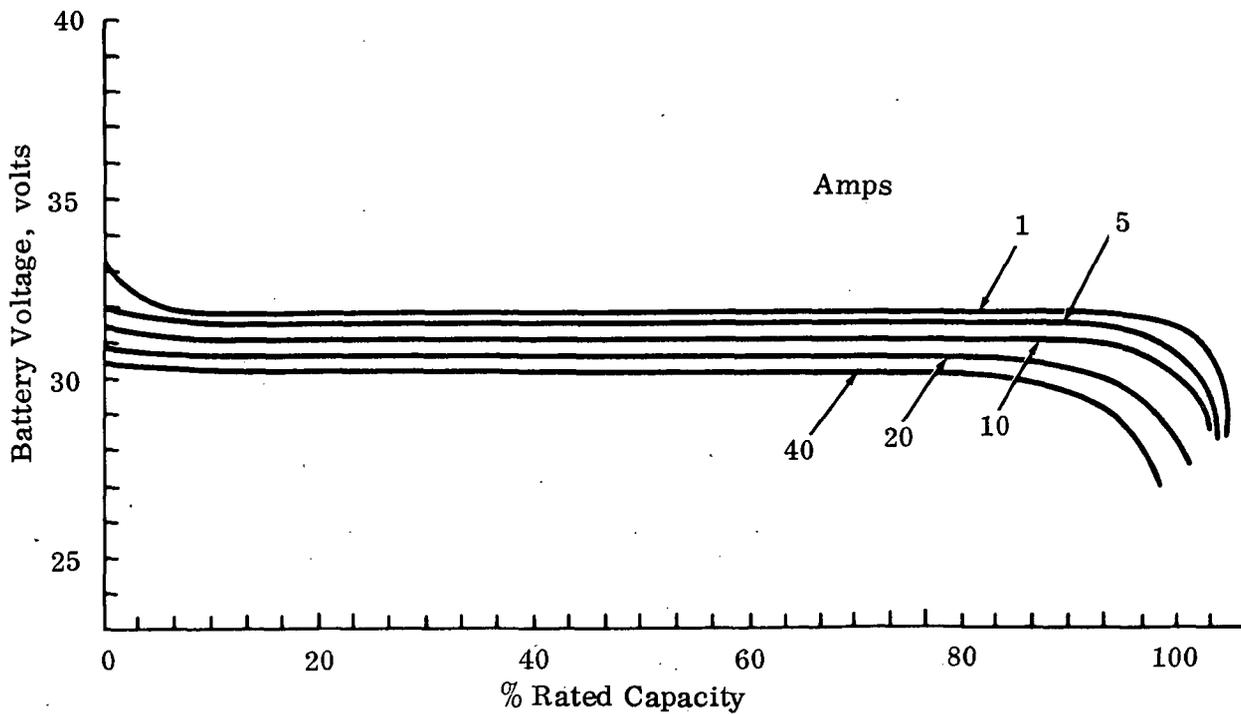


Fig. 5. 1-4 Ascent Battery Voltage VS Percent Capacity at 80° F

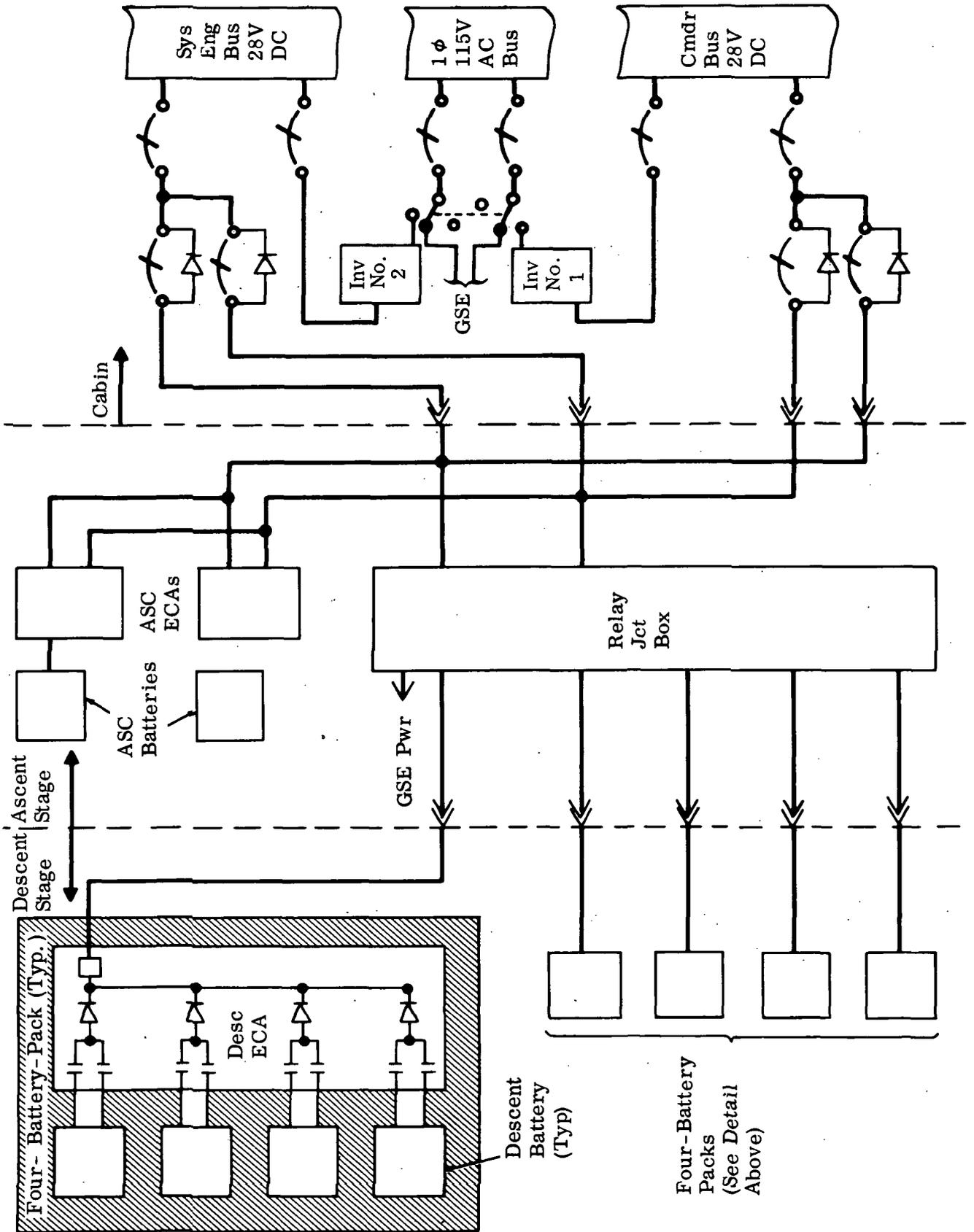


Fig. 5.1-5 EPS Schematic Recommend Configuration

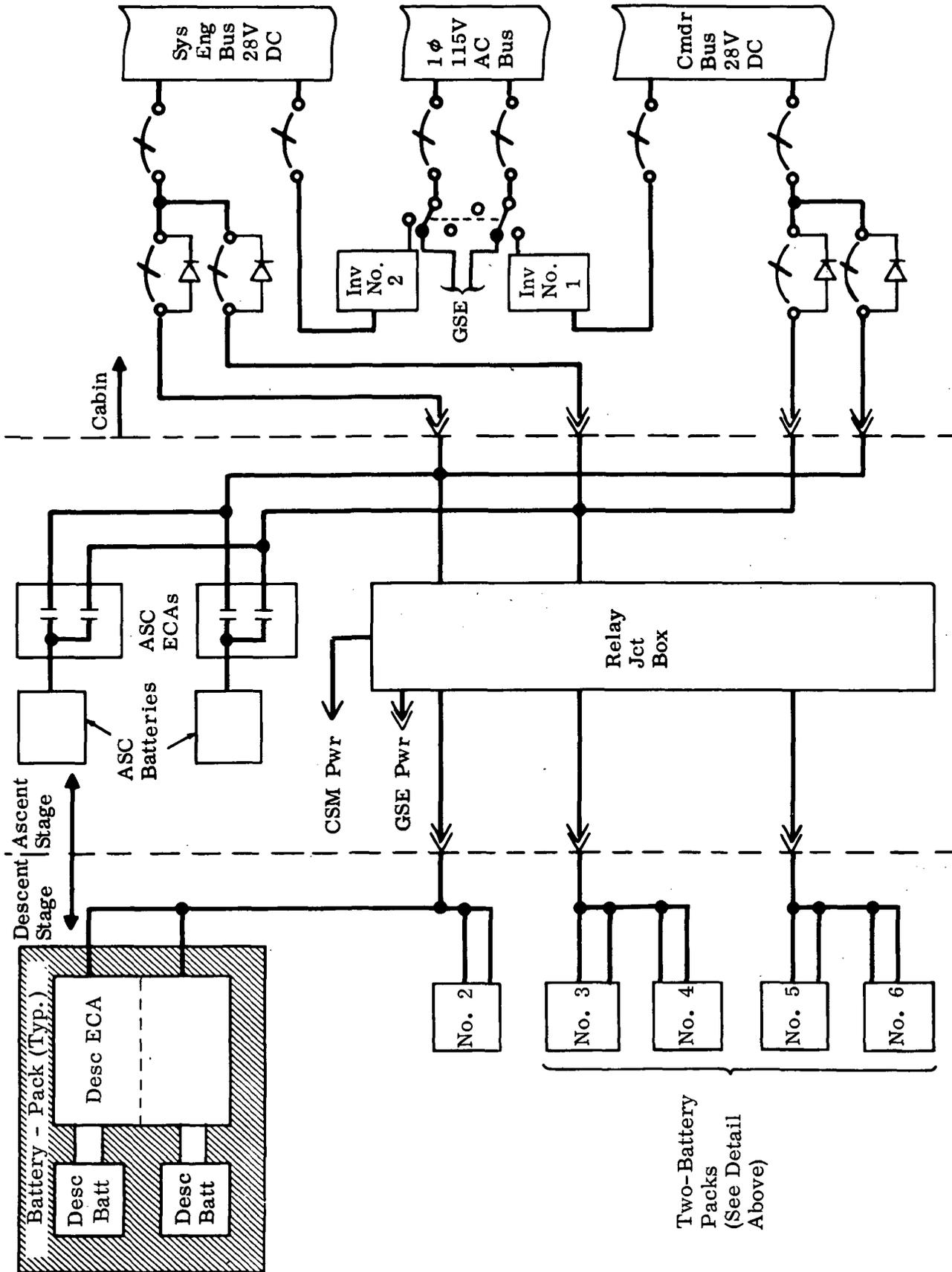


Fig. 5.1-6 EPS Schematic Baseline Configuration

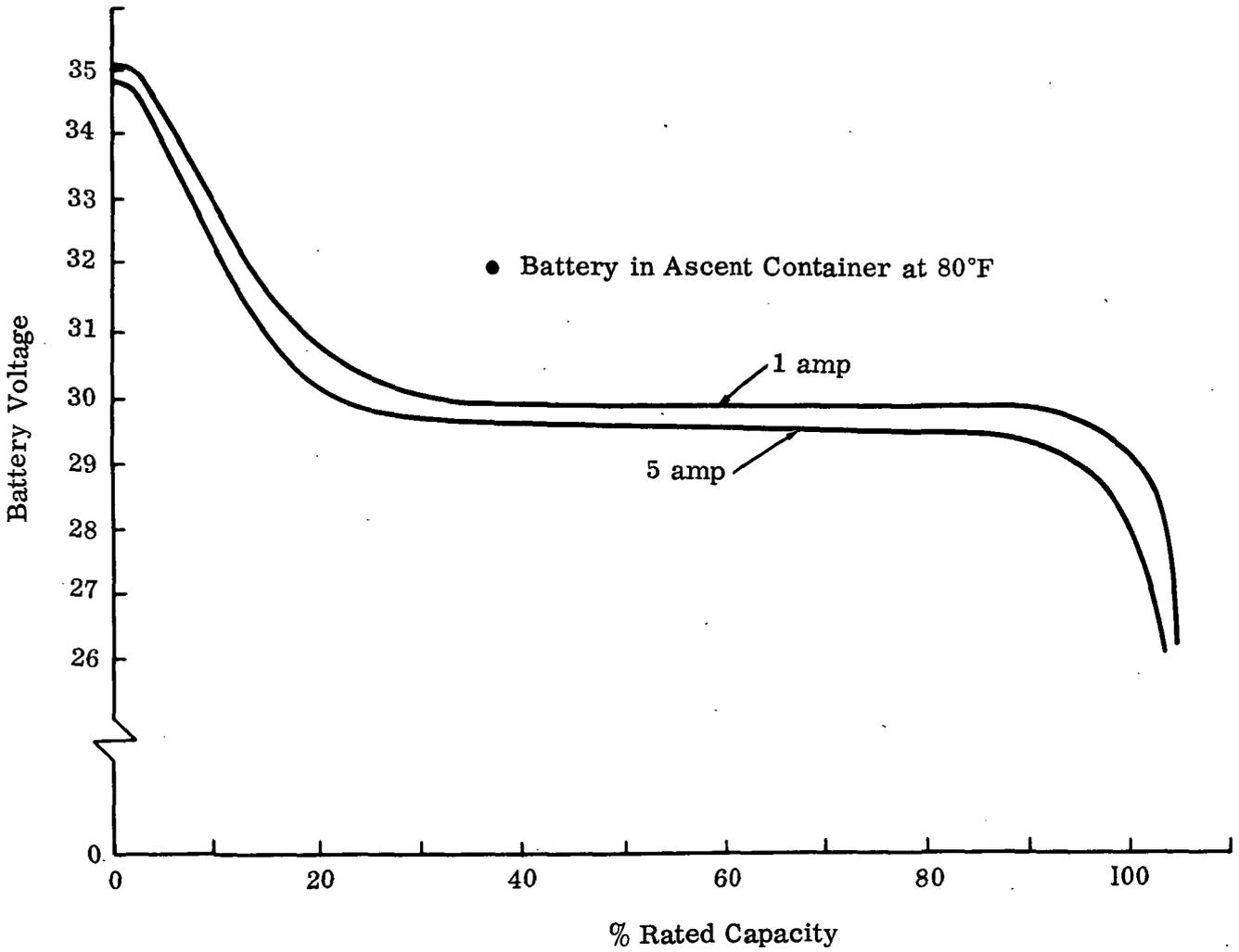


Fig. 5.1-7 Estimated Performance of 15 Kw-hr Battery

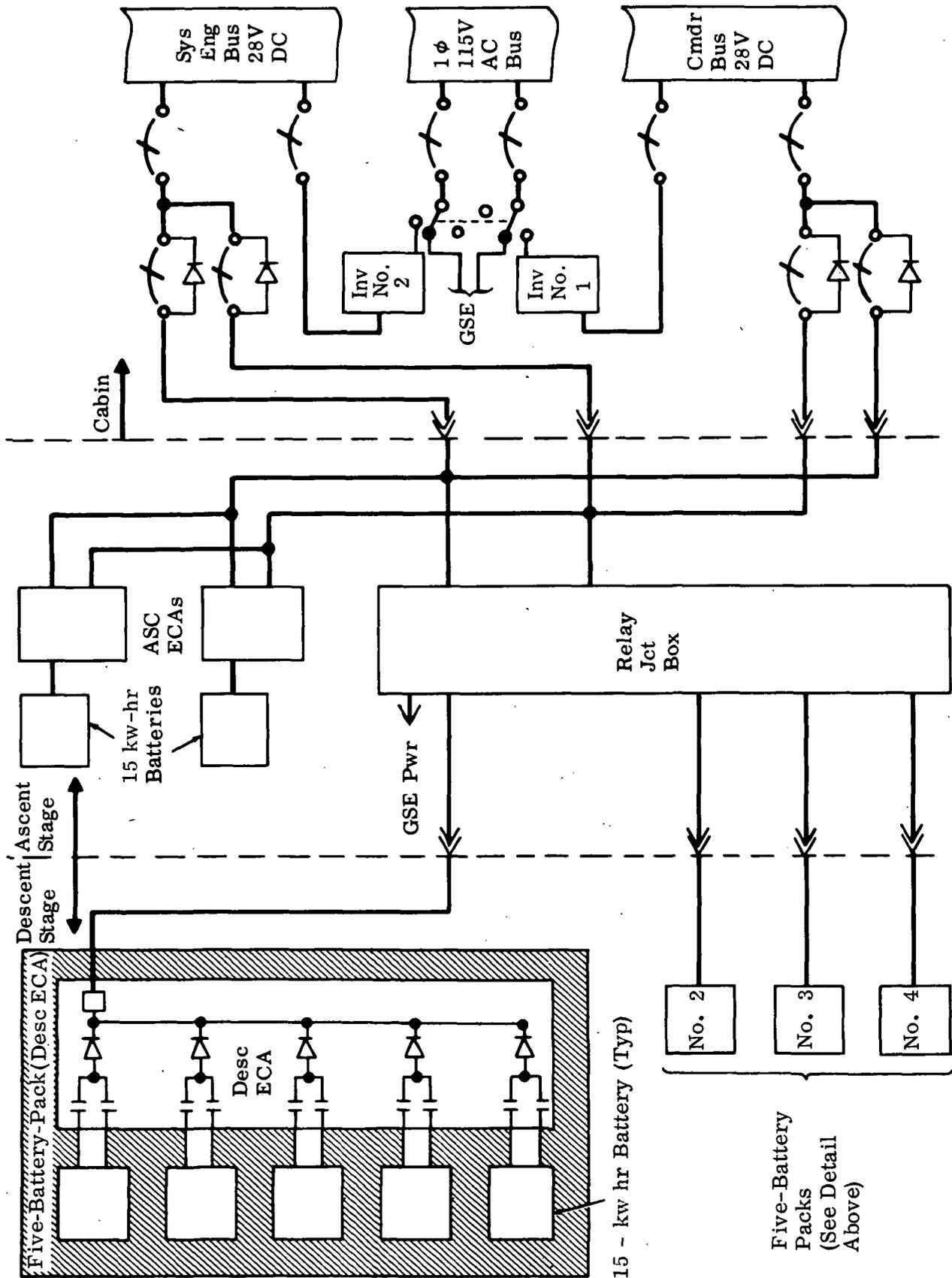


Fig. 5.1-8 EPS Schematic Alternate Configuration 15 Kw-hr Batteries

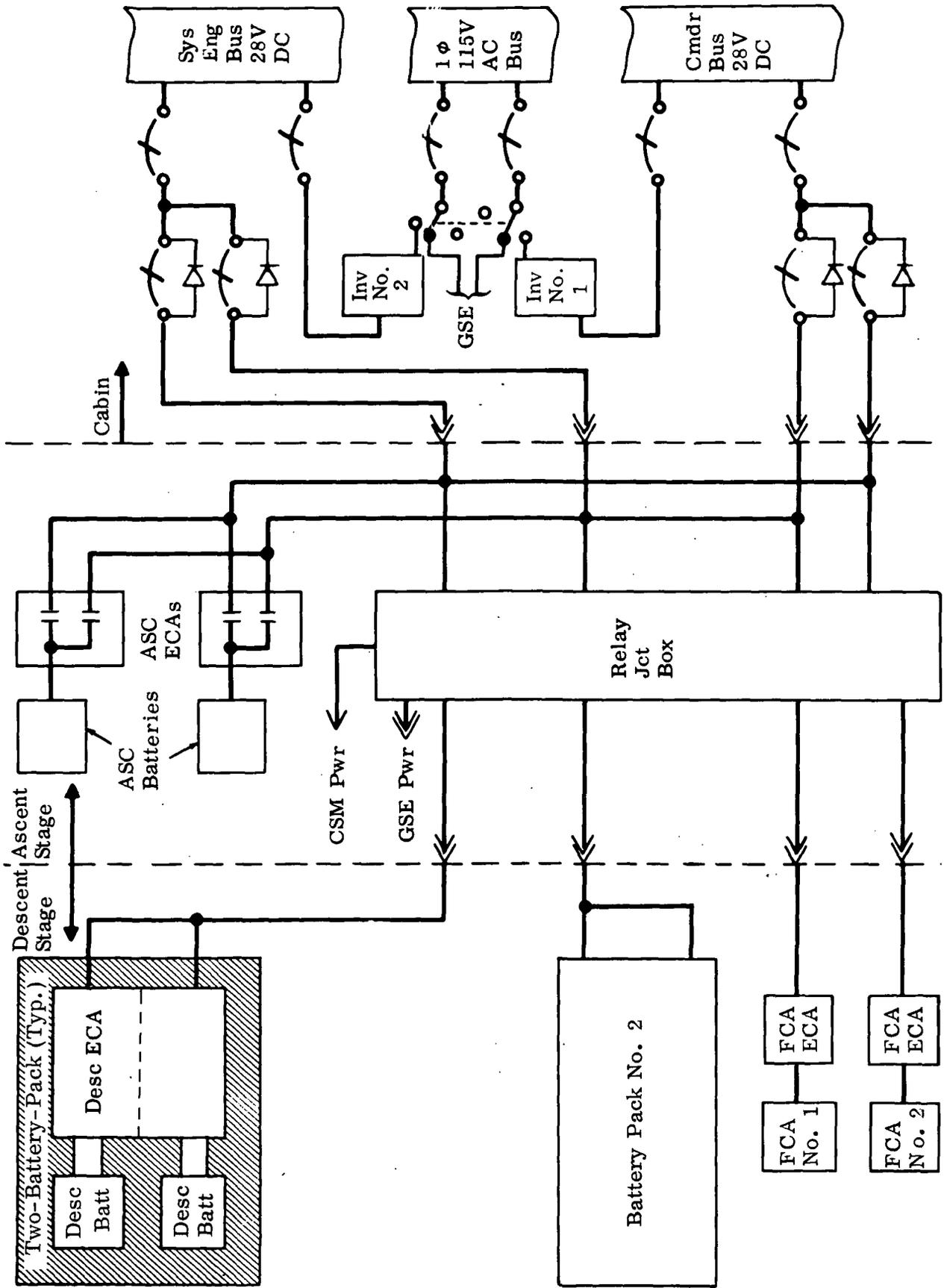


Fig. 5.1-9 EPS Schematic Alternate Configuration GE Power Pack and Batteries

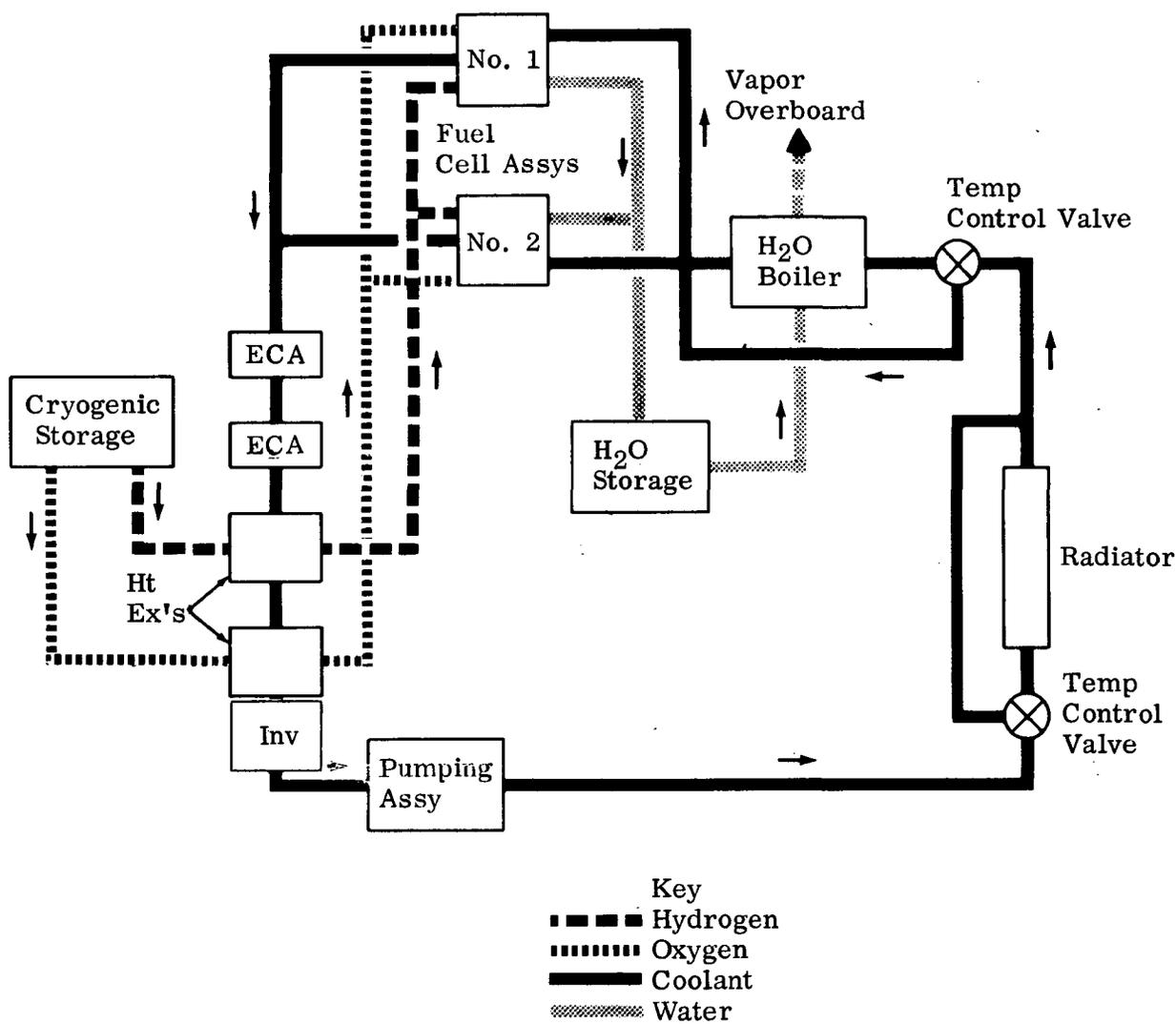


Fig. 5.1-10 Fuel Cell Coolant Supply Section Schematic

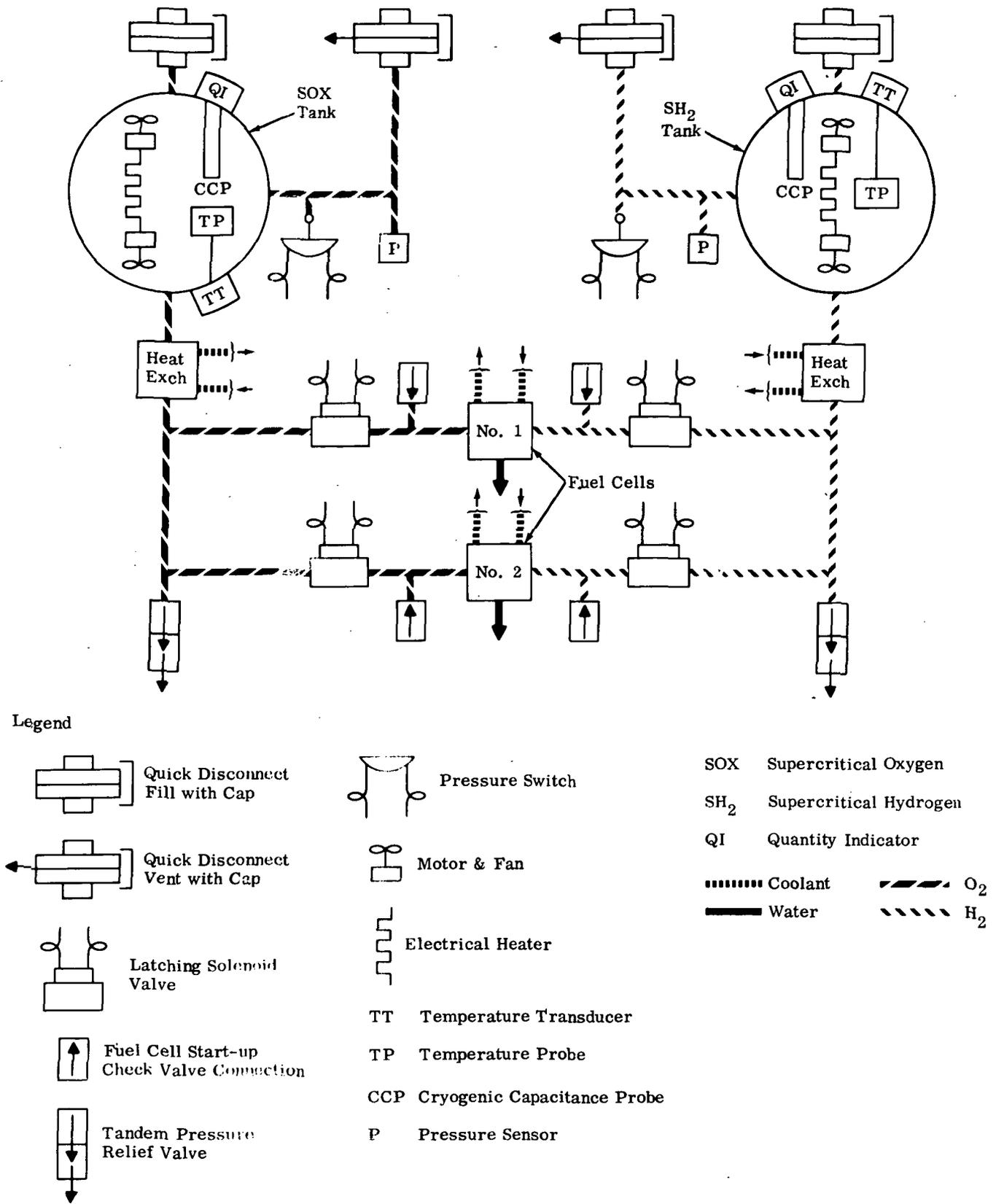


Fig. 5. 1-11 Fuel Cell Reactant Supply Schematic

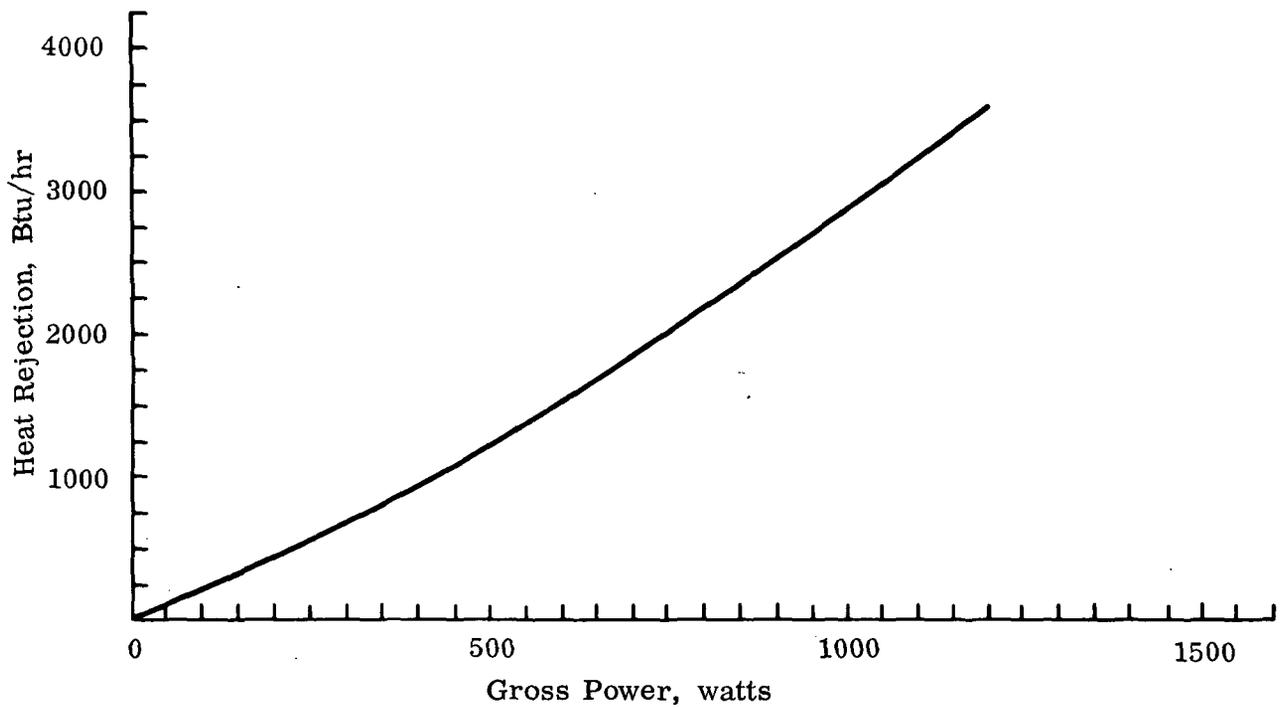


Fig. 5.1-12 GE Fuel Cell Heat Rejection per Fuel Cell

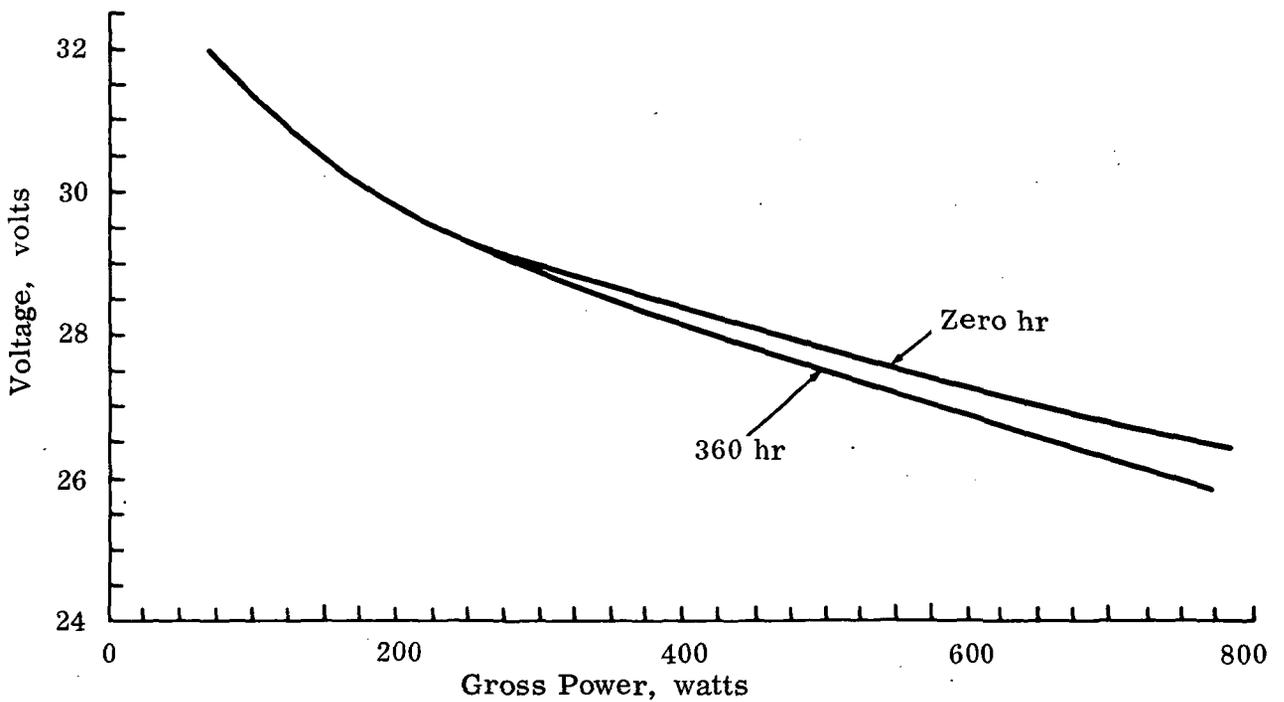


Fig. 5.1-13 GE Fuel Cell Polarization Curve - per Fuel Cell

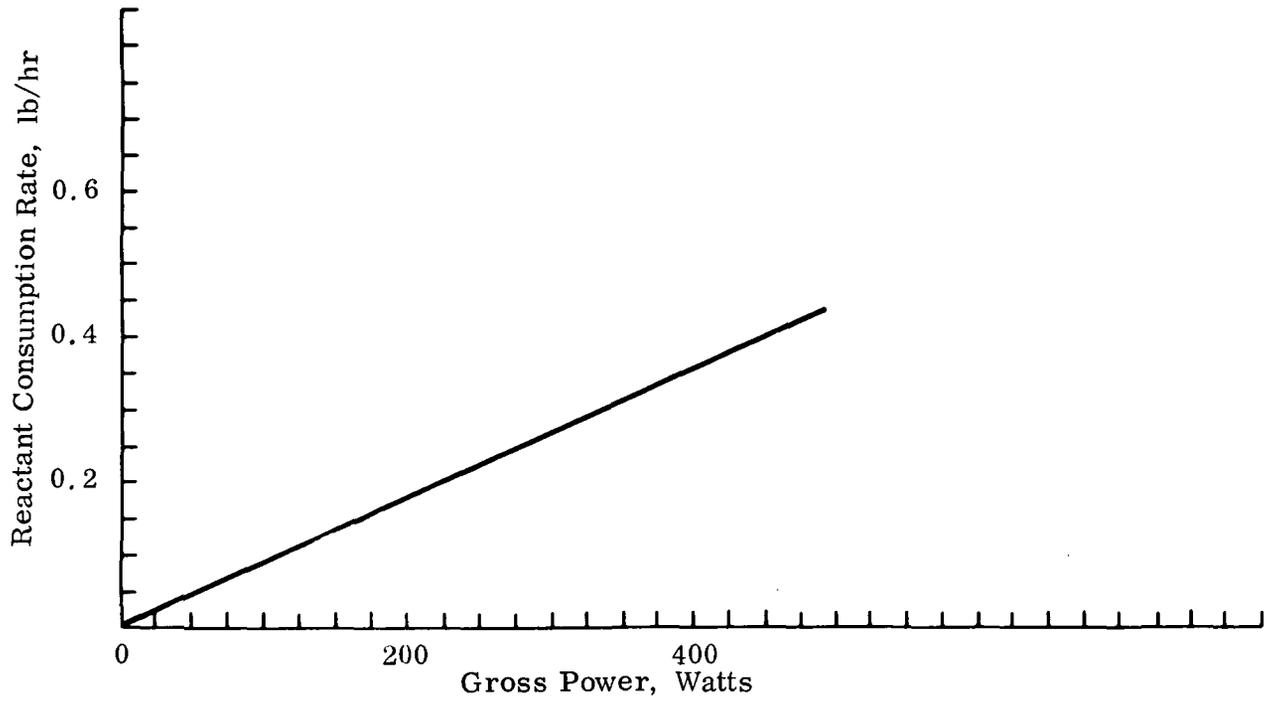


Fig. 5.1-14 Fuel Cell Reactant Consumption Rate

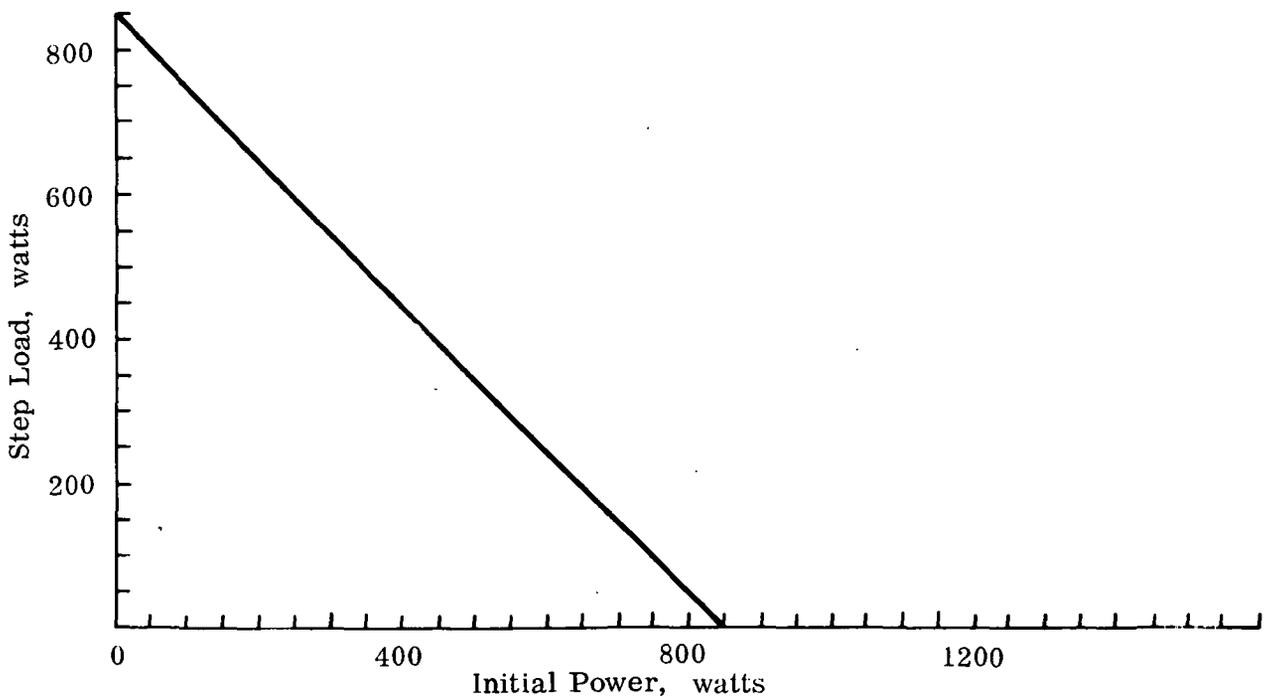


Fig. 5.1-15 Two GE Fuel Cells Step Load Capability (to 28 Volts Minimum Voltage)

5.2 ENVIRONMENTAL CONTROL SUBSYSTEM (ECS)

5.2.1 Groundrules

The following basic NASA groundrules have been adhered to in the establishment of preliminary ECS functional design requirements and the subsequent development of subsystem configurations for Phase I Labs:

- The CSM ECS shall provide for the removal of carbon dioxide, excess water vapor, odors, trace contaminants and particulate matter from the combined CM/LAB atmosphere during routine flight
- The Lab shall be capable of providing oxygen as required to makeup Lab and interface leakage
- The Lab shall provide for re-charging the PLSS
- The Lab shall provide for the exchange of cabin atmosphere between the Lab and CM as required to maintain the former at acceptable humidity, temperature and carbon dioxide concentration levels
- Extravehicular activities shall be accomplished using the Lab as an airlock. The Lab shall provide oxygen as required for associated repressurizations
- The CSM shall provide all water required by the crew for drinking, food preparation and personal hygiene.

5.2.2 Assumptions and Background Data

During the development of ECS configurations, it has been necessary to make several assumptions with regard to the functional requirements of Lab equipment. These assumptions have been formulated within the groundrules itemized in Paragraph 5.2.1 and, in general, reflect an attempt to provide a clean interface between Lab and CSM Environmental Control Subsystems.

- Crew metabolic heat loads are apportioned as follows:
 - CSM ECS: all latent metabolic + sensible metabolic produced by CM occupants
 - Lab ECS: Sensible metabolic produced by Lab occupants
- The Lab is decompressed to effect egress and remains unpressurized during EVA experiments
- There are no fluid hardware interfaces between the Lab and CSM
- The Lab ECS returns cabin gas to the CSM at the same temperature at which it is supplied (nominally $75 \pm 5^{\circ}\text{F}$)
- The Lab suit circuit performs carbon dioxide, excess moisture, odor and particulate matter removal functions in support of EVA experiments only (i.e., PLSS transition and observer support).

5.2.3 Recommended Configuration

The recommended ECS configuration is characterized by a conservative interpretation of allowable Phase I modifications and by an essentially total utilization of hardware developed for the basic LEM vehicle. Equipments whose functional requirements are unique to the LEM mission have been deleted only where practical from the standpoint of accessibility or where their retention would penalize experiment integration or subsystem performance.

Of the four basic ECS sections only the Heat Transport Section configuration has been significantly affected since it is required to accommodate a 274 kw-hr all

battery power supply, to provide a capability for the support of experimental equipment and to provide for the maintenance of cabin temperature throughout wide variations in thermal load profiles. Oxygen supply and water management equipment is affected only in that expendables storage capabilities must be expanded to meet increased demands for heat rejection and EVA support.

The following paragraphs briefly describe the recommended Phase I Lab ECS with emphasis on the manner in which it differs from its LEM counterpart.

5.2.3.1 Atmosphere Revitalization Section

The Atmosphere Revitalization Section recommended for the Phase I Lab is comprised of the LEM suit circuit assembly, the LEM atmosphere recirculation assembly and equipment associated with the forced exchange of the Lab and CM internal atmosphere.

As indicated in Paragraph 5.2.1, it has been assumed that suit circuit functions are performed by the CSM ECS during routine flight. The LEM suit circuit is retained, however, on Phase I Labs to provide suit ventilation and removal of carbon dioxide, excess water vapor, odor and particulate matter in support of suited operations associated with EVA experiments. Specifically, this equipment is required for the following reasons:

- The suit circuit is used extensively during checkout procedures associated with the transition to extravehicular life support systems
- The suit circuit is required to support an observing crew member in the unpressurized Lab cabin during EVA experiments.

Since the functional and operational requirements of this equipment are identical to those of the present LEM, the suit circuit assembly is not modified for Phase I Labs.

The atmosphere recirculation assembly provides for ventilation and temperature control in the Lab cabin. It consists of two cabin fans and a coolant to oxygen heat exchanger equipped with wicking material for the collection and re-evaporation of condensate. This assembly is retained intact and will remove all sensible heat loads introduced into the cabin atmosphere by Lab structure, equipment and occupants.

Since carbon dioxide and excess water vapor are removed by the CSM ECS during routine flight, provisions must be made for the exchange of Lab and CM atmospheres at a rate that will maintain the former at acceptable humidity and carbon dioxide concentration levels. A flexible duct, approximately four inches in diameter connected to the cabin heat exchanger fan assembly is recommended. The CSM atmosphere is drawn through the duct to the Lab cabin and returned through the open docking tunnel hatches.

The Phase I Lab Atmosphere Revitalization Section is shown schematically in Fig. 5.2-1. Two suit circuit LiOH canisters are sufficient to support the EVA capability of the recommended Lab configuration.

5.2.3.2 Heat Transport Section

The Heat Transport Section (HTS) recommended for the Phase I Lab has the following functional capabilities:

- Provision of active thermal control for all electronic equipment associated with Lab "housekeeping" functions
- Thermal control of experiment payloads associated with the design power profile
- Provisions for sensible cooling or heating as required to maintain cabin temperature
- Cooling or heating of recirculated ARS oxygen prior to and during periods of EVA
- Temperature control of all EPS batteries and associated electronics
- Transport and rejection by water evaporation of all waste heat associated with the above functions.

The recommended configuration shown schematically as Fig. 5.2-2 conforms very closely to the current LEM-HTS. The changes made have been limited to areas in which the basic LEM could be modified at the launch site within a reasonable time. These changes are as follows:

- Delete operational capability of redundant coolant loop.
- Plumb redundant coolant loop pump in parallel with primary coolant loop pumps
- Replace Inertial Measuring Unit coldplate with a simulated restrictor
- Add a manual bypass capability to the Abort Sensor Assembly (ASA) coldplate, thereby reducing the ASA heater requirements from 73 w to 5 w. Add a restrictor to the bypass leg to simulate the pressure drop of both the IMU restrictor and the ASA leg
- Add 15 coldrails for EPS batteries in the descent stage
- Add a modulating diverter valve for the main water boiler

Due to the deletion of various electronic assemblies from the basic LEM, the following coldplates are available for experiment payloads on the lab:

<u>Deleted Electronics</u>	<u>Location</u>	<u>Coldplate Size, in.</u>
Beacon Light Electronics	Unpressurized Area Above Cabin	To Be Determined
Gimbal Angle Sequence Transformer Assy	Read of Display Panel in Cabin	4 x 10
Pulse Talk Assy	Unpressurized Area Above Cabin	10 x 13
LEM Guidance Computer	Z-27 Pressure Bulkhead	3x24 (2 Available)
Power Servo Assy	Z-27 Pressure Bulkhead	9 x 21
Coupling and Display Unit	Z-27 Pressure Bulkhead	3x20 (2 Available)

It is anticipated that the LGC coldplates will be used to cool the two additional recorders being added to the basic Lab.

Experiments requiring coldplate cooling may be installed on any of the remaining plates provided that they are dimensionally and thermally compatible. The maximum cooling capability of the remaining coldplates is approximately 500 w. This is limited by the available coldplate area (500 sq in.) and a nominal heat flux of 1 w/sq in. Based on current experimental loads, the lab has a coldplate cooling growth potential of approximately 350 w without adding additional plates.

New coldplates could be added to the high temperature section of the coolant network to enlarge the lab's cooling capability as long as these additional coldplates do not increase the Heat Transport Section's pressure drop more than 5 psi, in which case pump redesign would be required.

Table 5.2-1 lists the maximum and minimum heat loads of housekeeping equipment, cabin structure and the experimental payload. These loads were used in the performance analysis illustrated in Figs. 5.2-3, 5.2-4 and 5.2-5 and reflect maximum and minimum instantaneous values. Lab water requirements were calculated utilizing the average load analysis discussed in Section 4.1. As shown on Fig. 5.2-3 at the minimum load condition, with one man in the loop, the cabin temperature reaches 65°F. For this reason, it is recommended that a valve be added to automatically modulate flow around the water boiler during this low load phase in order to keep the cabin atmosphere above 70° as shown in Fig. 5.2-4. A LEM part, the cabin temperature control valve (Item 203) would be used for this application requiring only that the temperature sensing element be replaced by one with a lower temperature setting. The projected response characteristics of the valve are shown on Fig. 5.2-6. It is also recommended that the battery water evaporator remain inoperative except on flights with high thermal loads. For the maximum load condition, (as shown on Fig. 5.2-5), the maximum growth capability for experiment cooling based on waste heat rejection is 7440 Btu/hr with both evaporators operating. The lab must store 830 lb of water to provide heat rejection for the recommended configuration loads.

Active Cooling of Additional Descent Stage Batteries. - In the current LEM configuration there are four batteries and two ECA's in the descent stage. The batteries have a relatively short operating life (36 hours), with a high current drain rate. Heat dissipation from the batteries is directly proportional to the power delivery rate, and varies from a minimum of 144 w during the lunar stay to a maximum of 449 w during LEM descent. The average cooling load imposed on the LEM heat transport section by the batteries is 204 w, resulting in a coolant flow rate of 150 lb/hr to the descent stage.

In the Phase I Lab configuration, the 20 descent batteries have a considerably longer life (336 hr) compared to the LEM batteries. The associated waste heat produced is a maximum of 100 w due to the higher efficiency at lower loads while the ECA's dissipate an additional 20 w. The total waste heat dissipation by all batteries and ECAs in the Phase I Lab descent stage is therefore 120 w--84w less than the present LEM. The cold rails for the four additional battery packs (16 batteries total, 4 in each pack) will be connected in parallel with the present LEM descent stage battery cold rails as shown in Fig. 5.2-2. The coolant loop pressure drop for the parallel flow through each of the battery pack rails is estimated to be below the LEM pressure drop, in spite of the increase in line lengths. This assures that no additional load is imposed on the coolant recirculation assembly.

5.2.3.3 Water Management Section

The functional requirements of the Phase I Lab Water Management Section are identical to those of the present LEM; however, the extent to which they are performed is different in the Lab. These functions are as follows:

- Storage and delivery of water required for the rejection of Lab waste heat
- Storage and delivery of water required for PLSS recharge in support of EVA experiments
- Collection and distribution of metabolic condensate during suited Lab operations associated with EVA experiments.

Since the CSM is responsible for providing all water required by the crew for drinking, food preparation and personal hygiene (see Paragraph 5.2.1), no such capability exists in the Lab WMS.

As indicated in Paragraph 5.2.3.2, 830 lb of water are required for the rejection of all waste heat generated by Lab equipments and occupants. In addition, 123 lb are required to support the eighteen EVA capability that characterizes the recommended vehicle configuration (6.8 lb water per PLSS recharge).

To accommodate the total water storage requirement of 953 lb, all LEM tankage is retained and two LEM descent stage tanks are added providing a total water storage capability of 1,046 lb. Approximately 93 lb are thereby available for growth in heat rejection or PLSS recharge requirements. Fig. 5.2-7 illustrates the manner in which the water storage capability may be apportioned between the rejection of experiment heat loads and the support of EVA experiments.

The WMS is shown schematically in Fig. 5.2-8. The water feed lines to the secondary coolant network have been capped due to the functional deletion of this equipment (see Paragraph 5.2.3.2). All water controls are retained from the basic LEM. Water requirements and storage provisions are summarized below.

PHASE I LAB ECS WATER REQUIREMENTS

Use	Basis	Quantity, lb
Thermal Control	830,000 Btu x 1 lb/1000 Btu	830
PLSS Recharge	6.8 lb/charge x 18 charges	123
Total Water Requirement		953
Water Storage Capability		1046

5.2.3.4 Oxygen Supply and Pressurization Control Section (OSPCS)

The pressure regulating and delivery equipment associated with the Oxygen Supply and Pressurization Control Section of the ECS has been retained for Phase I Labs. The Section has been modified only in that its oxygen storage capability has been increased by the addition of LEM tanks to meet the demands of Lab missions.

The following functions are performed by this ECS section:

- Storage and delivery of oxygen required to support EVA's (PLSS recharge and Lab cabin repressurization)
- Storage and delivery of oxygen as required to maintain cabin pressure due to Lab and docking tunnel structural leakage

- Storage and delivery of oxygen for suited operations prior to and during EVA experiments.

The recommended configuration, shown schematically in Fig. 5.2.-9 is capable of performing these functions to the extent described in the following paragraphs.

To achieve the Phase I Lab's capability to support eighteen EVA experiments, 147 lb of oxygen must be stored for this purpose. Each cabin repressurization requires 6.9 lb of oxygen and it has been conservatively assumed that a full PLSS recharge (0.91 lb) is required subsequent to each ingress. In addition, 6 lb of oxygen are required to support the suited operations in the Lab associated with EVA experiments. Fig. 5.2-10 illustrates the manner in which the Lab oxygen storage capability may be apportioned between recharging the PLSS and repressurizing the cabin.

In conformance with the groundrule in Paragraph 5.2.1, 107 lb of oxygen is provided to make up Lab and docking tunnel leakage. It is impractical for CSM and Lab equipment to perform the leakage makeup function simultaneously. Cabin pressure tolerances are such that the respective regulators could not effectively operate together even if modifications were attempted. It is recommended that leakage makeup be shared on a pre-programmed basis with only one set of equipment operating in a given time period. Since oxygen is stored at cryogenic temperatures in the CSM it appears that the middle of the mission, during the period of maximum heat leak into CSM tanks, would be the best time for the CSM ECS to provide leakage makeup. Since oxygen is stored at ambient temperatures in the Lab, there is no corresponding consideration.

Due to their limited storage capacity (4.4lb usable) LEM ascent stage oxygen tanks have been deleted from the recommended Phase I Lab configuration. The current LEM descent stage tank has been retained and five additional such tanks added to the ascent stage aft equipment bay. The retained descent stage GOX tank is isolated from the other five in order to extend the PLSS recharge capability. After the pressure of the five manifolded tanks falls below the recharge pressure requirements, subsequent recharges are accomplished from the sixth tank. Except for the extended recharge capability and staging, the system functions the same as in the current LEM. Oxygen from the storage tank, regulated to 1,000 psi maximum, enters the Oxygen Control Module where it is filtered and made available for cabin repressurization, PLSS recharge, and regulation as ARS supply. Oxygen requirements and storage capabilities are summarized below:

Phase I Lab ECS Oxygen Requirements

Use	Basis	Quantity, lb
Leakage (Lab & Docking Tunnel)	0.38 lb/hr x 282 hr*	107.2
EVA Repressurization	6.9 lb/repress x 18 repress	124.2
PLSS Recharge	0.91 lb/charge x 18 charges	16.4
Metabolic Consumption (EVA time)	2.0 lb/man-day x 3 man-days	6.0
Total Oxygen Requirements		253.8
Oxygen Storage Capability	45.2 lb/tank x 6 tanks	271.2

*Total Time-Lab Pressurized

5.2.4 Baseline Configuration

The baseline Phase I Lab ECS configuration, developed at mid-study for the purpose of defining program costs and schedules, differs slightly from the configuration described in the previous paragraphs for the following reasons:

- The basic LEM Heat Transport Section has been reconfigured due to battery cooling considerations
- Eight descent stage batteries have been added to the Phase I Lab in the recommended configuration since the CSM is no longer providing electrical energy to the Lab
- The baseline configuration was not required to make up Lab and docking tunnel oxygen leakage
- Performance analyses have indicated the need for refinements to the baseline configuration

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 water evaporator. As mentioned in Paragraph 5.2.3.2 this evaporator is not required for the design flight.

Cold rails and associated plumbing are added to the descent stage in the recommended configuration to service the eight additional batteries as described in Paragraph 5.2.3.2.

No configuration changes have been made to accommodate the requirement that the Lab ECS make up Lab and docking tunnel leakage. The baseline capability of support for 31 EVA's has been decreased to 18 to provide oxygen required for leakage makeup.

Minor changes, such as the addition of a bypass control valve for the HTS water evaporator (see Paragraph 5.2.3.2) have been dictated by the results of subsystem performance analyses. Refinements of this nature will continue and should not be classified as configuration changes.

5.2.5 Alternate Configuration - Passive Cooling of Aft Equipment Bay Electronics

The aft equipment bay coldrails of the Phase I Lab contain housekeeping equipment that dissipates an average of 190 thermal watts. As described in Section 4.1, this equipment could be cooled passively by a) modifying the surfaces of the equipment to maximize their heat dissipation by radiation and b) removing the thermal shield from the aft bay and replacing it with (1) and alzak skin to maximize heat rejection when the aft bay is sun oriented and (2) shutters to provide a capability of minimizing heat rejection when the aft bay is dark space oriented. The cold rails would be functionally deleted from the Heat Transport Section, however they would remain in the vehicle as structural members to support the electronic packages so that structural change could be kept to a minimum.

If the passive cooling approach for aft bay housekeeping equipment were incorporated, the capability would exist to provide additional coldplates for cooling of experimental packages elsewhere in the vehicle whose pressure drop and cooling capacity would be the same as those deleted from the aft bay; namely 3.5 psi and 2400 Btu hr respectively.

5.2.6 Alternate Configuration - Battery Package Passive Thermal Control

An alternate passive approach to the thermal control of storage batteries added to the Phase I Lab is described in Section 4.1. A significant decrease in HTS complexity and in water storage requirements can be realized as described below:

The current LEM descent stage contains four batteries which are flange mounted on actively cooled cold rails. The recommended configuration is characterized by an additional sixteen batteries in the descent stage. As discussed in Paragraph 5.2.3, active cooling can be provided for the twenty batteries in the Phase I Lab with no increased demands on the HTS. The additional batteries are located such that passive cooling is possible. The four basic LEM descent stage batteries, because of their location, cannot be adapted to passive cooling and must remain on the glycol loop. Passive battery cooling is thereby considered only for additional batteries. If passive cooling is selected, no modifications would be required in the descent stage coolant network and the additional battery heat load would be removed from the coolant loop. However, no glycol pumping power savings can be expected because of the parallel arrangement recommended and the decreased glycol flow rates which would result. Passive battery cooling would yield a significant saving (85 lb) in required onboard water storage.

5.2.7 Alternate Configuration - Incorporation of Radiators into the Heat Transport Section

As an alternate to the recommended configuration for the Phase I Lab's Heat Transport Section, radiators are proposed in lieu of water evaporation as a means to reject waste heat during all but peak load phases. The system is shown schematically in Fig. 5.2.-11. In addition to the radiators, two LEM regenerative glycol heat exchangers are used to maintain coolant temperature within acceptable limits during low load conditions. The LEM cabin temperature control valve (Item 203) with a new temperature sensing element would also be used for radiator control. The radiators would consist of two 15 sq ft panels located in the descent stage on two quadrant outer surfaces 180 deg apart. This location requires two additional coolant lines between the ascent and descent stages.

Although the weight of this additional equipment totals approximately 90 lb, the corresponding system weight would be reduced by 680 lb. This is because only 60 lb of water would be required for the rejection of peak heat loads.

5.2.8 Alternate Configuration - Utilization of Propellant Tanks for ECS Oxygen Storage

Four LEM descent stage propellant tanks are retained in the Phase I Lab configuration due to structural and accessibility considerations. These tanks may be used as an alternate method for storing Lab ECS oxygen. Each tank has a volume of 63.3 cu ft and a design pressure of 250 psia. With an initial pressure of 250 psia and an ullage pressure of 75 psia (same as LEM), 247 lb of usable oxygen may be stored in these tanks. This amount surpasses the quantity of oxygen that can be stored in the recommended five LEM descent stage GOX tanks located in the ascent stage aft equipment bay. The one descent stage tank in the current LEM would be retained as a high pressure source for PLSS refill. The OSPCS remains the same as the recommended configuration except for the deletion of the five tanks and the addition of supply lines from the propellant tanks.

This storage method is offered as an alternate because the propellant tanks are constructed of titanium which has been shown to be incompatible with liquid oxygen and high pressure gaseous oxygen. However, titanium may prove to be compatible with oxygen at low pressure; a verification test is necessary. Should compatibility prove questionable, two alternatives are possible: a barrier or inhibitor may be applied to the inside of the tanks or a bladder may be used. An existing 14-in. diameter access in each tank would facilitate either treatment of the tank or the installation of a bladder.

In utilizing the propellant tanks, 115 lb could be saved, but the predominant advantage is the space that would be made available in the aft equipment bay.

5.2.9 Potential Modifications per Flight - Separate Heat Transport and Rejection Loops for Experiment Cold Plates

The recommended Phase I Lab ECS configuration integrates experiment cold plates in the primary heat transport section (HTS) which services the entire vehicle. The additional heat load of the experiment cold plates associated with the recommended configuration may be imposed on the HTS without exceeding its design limits, since some of the LEM electronic packages requiring cold plate cooling have been deleted. Although some of the deleted equipment heat loads have been replaced by the heat loads of the experiment cold plates, a considerable over-capacity still exists for future growth of experiment loads. This excess cooling capacity is discussed in Paragraph 5.2.3.2.

If this inherent excess cooling capacity should be exceeded by the demands of finalized experiment programs it is possible to provide a separate coolant circuit to service experiment cold plates. This can be done by utilizing the existing network associated with the LEM redundant heat transport section, since the functions of this equipment are unique to the LEM mission (thermal control of critical components during abort).

The primary advantages of adopting the existing LEM redundant loop for servicing experiments are as follows:

- Coolant lines are already installed and available in the cabin and the aft equipment bay
- Water sublimator and associated water lines are installed
- Cabin pressure shell alterations would not be required
- GSE connections are available

The redundant coolant pump, which is structurally integral with the coolant recirculation assembly, provides coolant circulation in the redundant loop and may be used to service experiment cold plates. The following considerations would, however, favor the use of another LEM coolant recirculation assembly for an experiment cold plate loop:

- The LEM coolant recirculation assembly is not presently required to operate two coolant pumps simultaneously
- No coolant pump redundancy would exist for the experiment cold plate coolant loop
- The coolant pump selector switch is not presently capable of selecting two pumps for simultaneous operation.

In addition to a separate or modified coolant recirculation assembly the following modifications would be required to adapt the LEM redundant glycol loop as a separate HTS for experiment cold plates:

- Addition of a glycol accumulator
- A control valve and by-pass for the water module
- By-passes for dual passage cold plates.

The redundant evaporator performance is shown in Fig. 5.2-12. The coolant recirculation assembly flow rate is 222 lb/hr; however, the flow rate may be decreased by installing a parallel bypass orifice similar to that used with the redundant pump on the present LEM.

Table 5.2-1

PHASE I LAB ECS THERMAL LOADS, BTU/HR
2 MEN IN CABIN

Std Config Exper's	Cabin Heat Exchanger		max	175	
			min	175	
	Coldplates	Low Temp	max	515	
		min	515		
		High Temp	max	0	
			min	0	
Housekeeping	Cabin Heat Exchanger	Sensible Metabolic	max	772	
			min	594	
		Electrical	max	1032	
				min	479
			Windows & Structure	max	-850
			min	-340	
	Coldplates	Low Temp	max	304	
			min	82	
		Batteries	max	400	
			min	177	
		High Temp	max	671	
			min	600	
Coolant Pump		max	105		
		min	105		

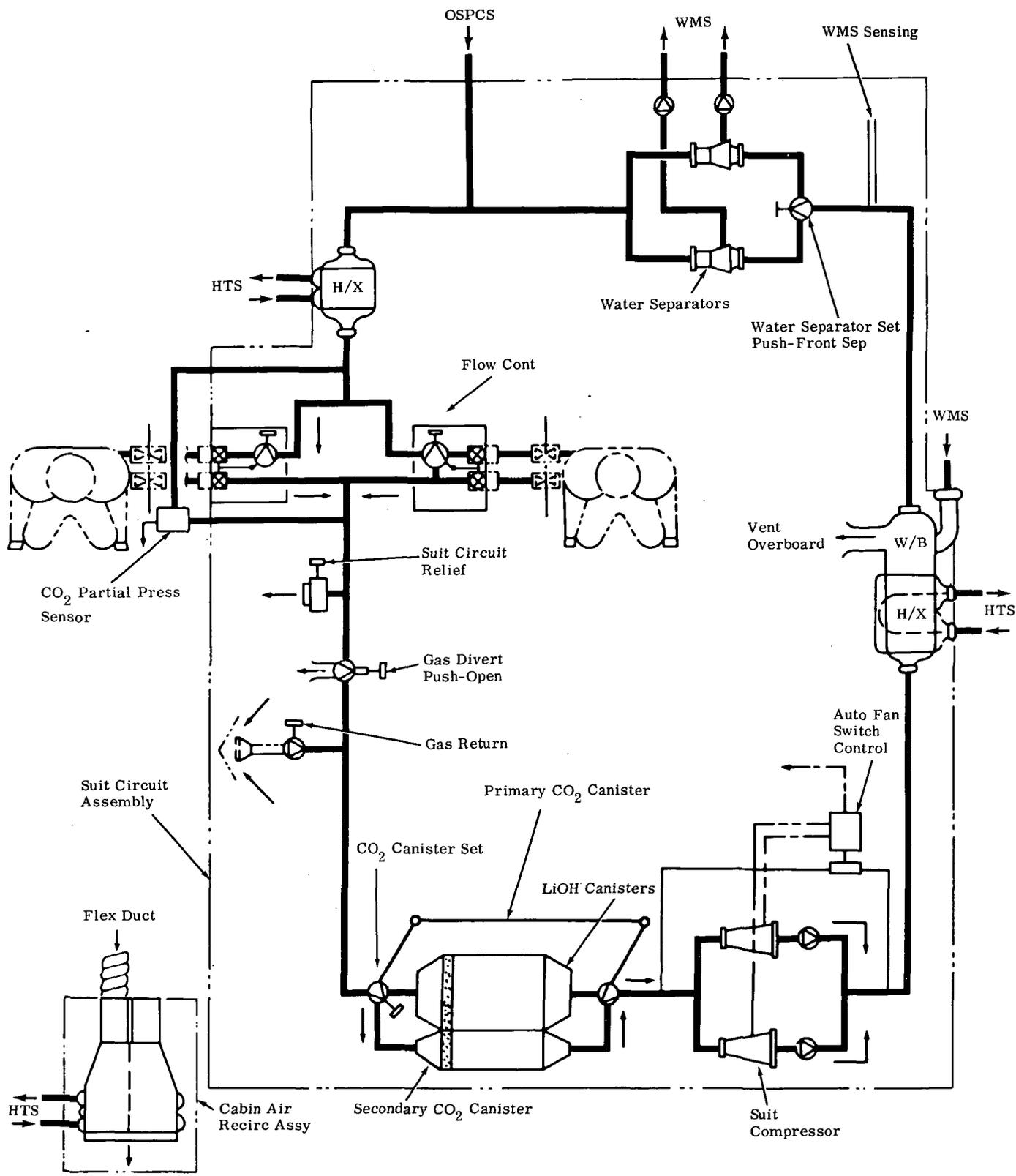
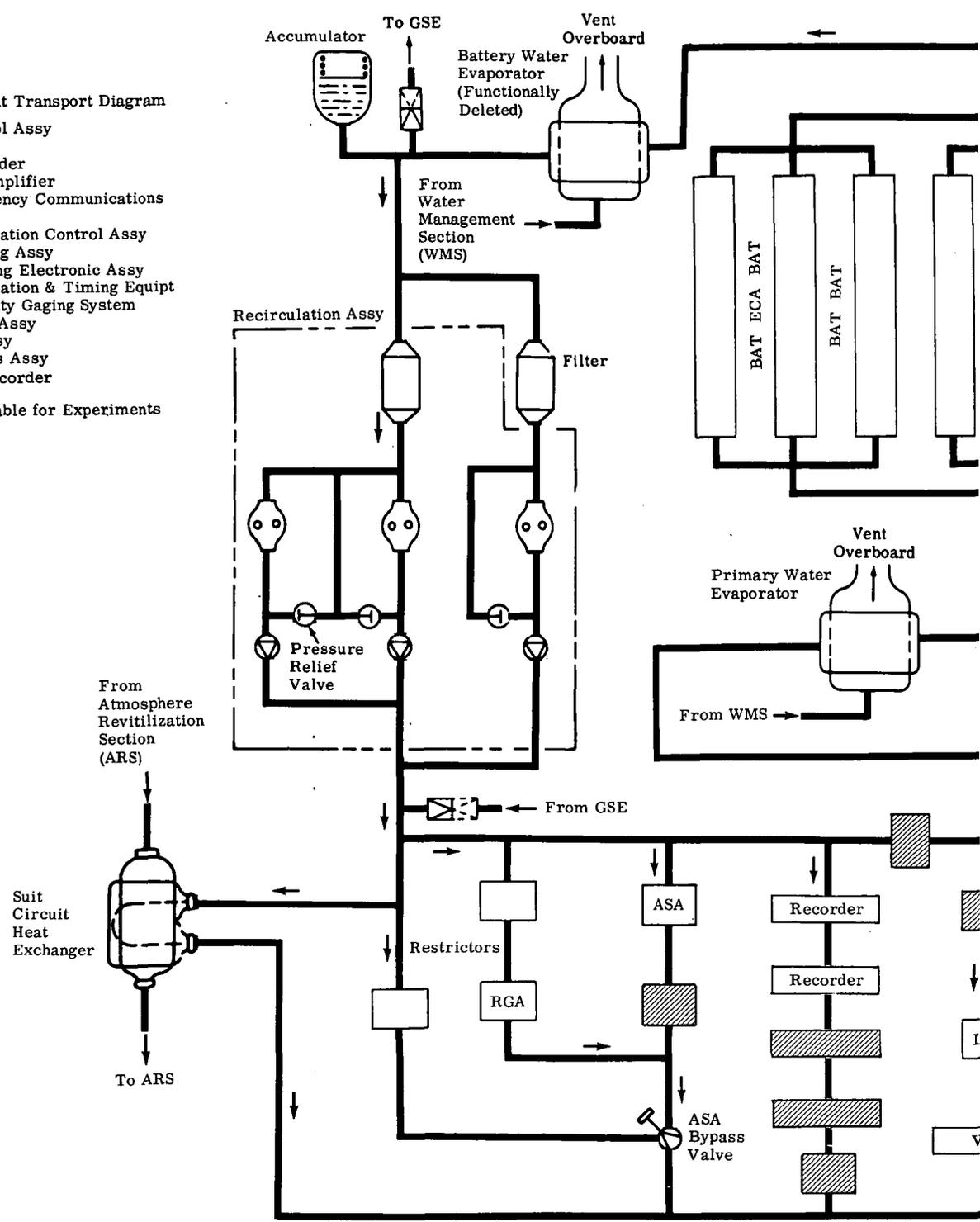


Fig. 5.2-1 Atmosphere Revitalization Section

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Abbreviations Used on Heat Transport Diagram

- 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 & Timing Equipt
- PQGS Propellant Quantity Gaging System
- LCA Lighting Control Assy
- ASA Abort Sensor Assy
- AEA Abort Electronics Assy
- VSR Voice Storage Recorder
-  Coldplates Available for Experiments



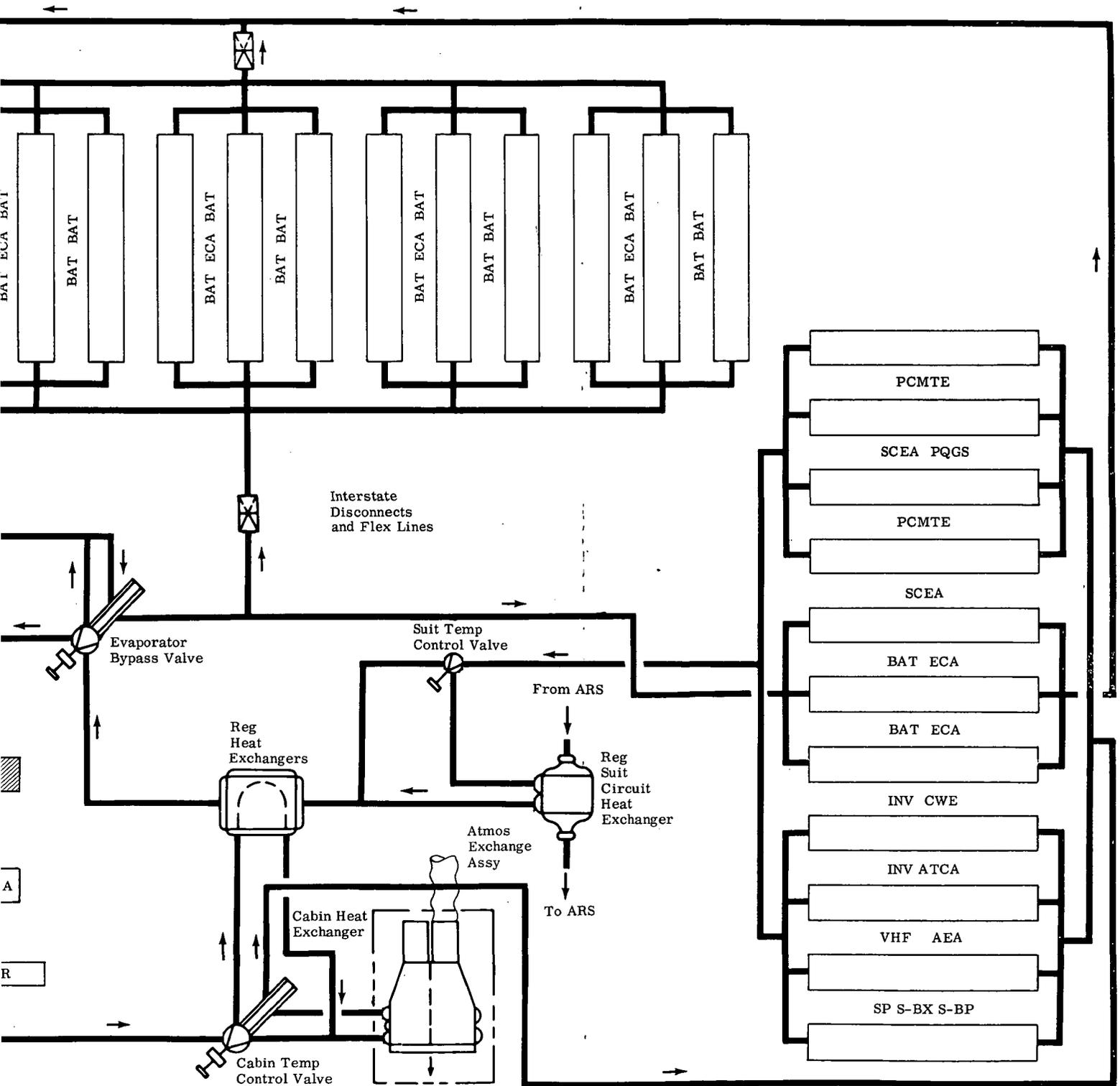


Fig. 5.2-2 Heat Transport Section Schematic

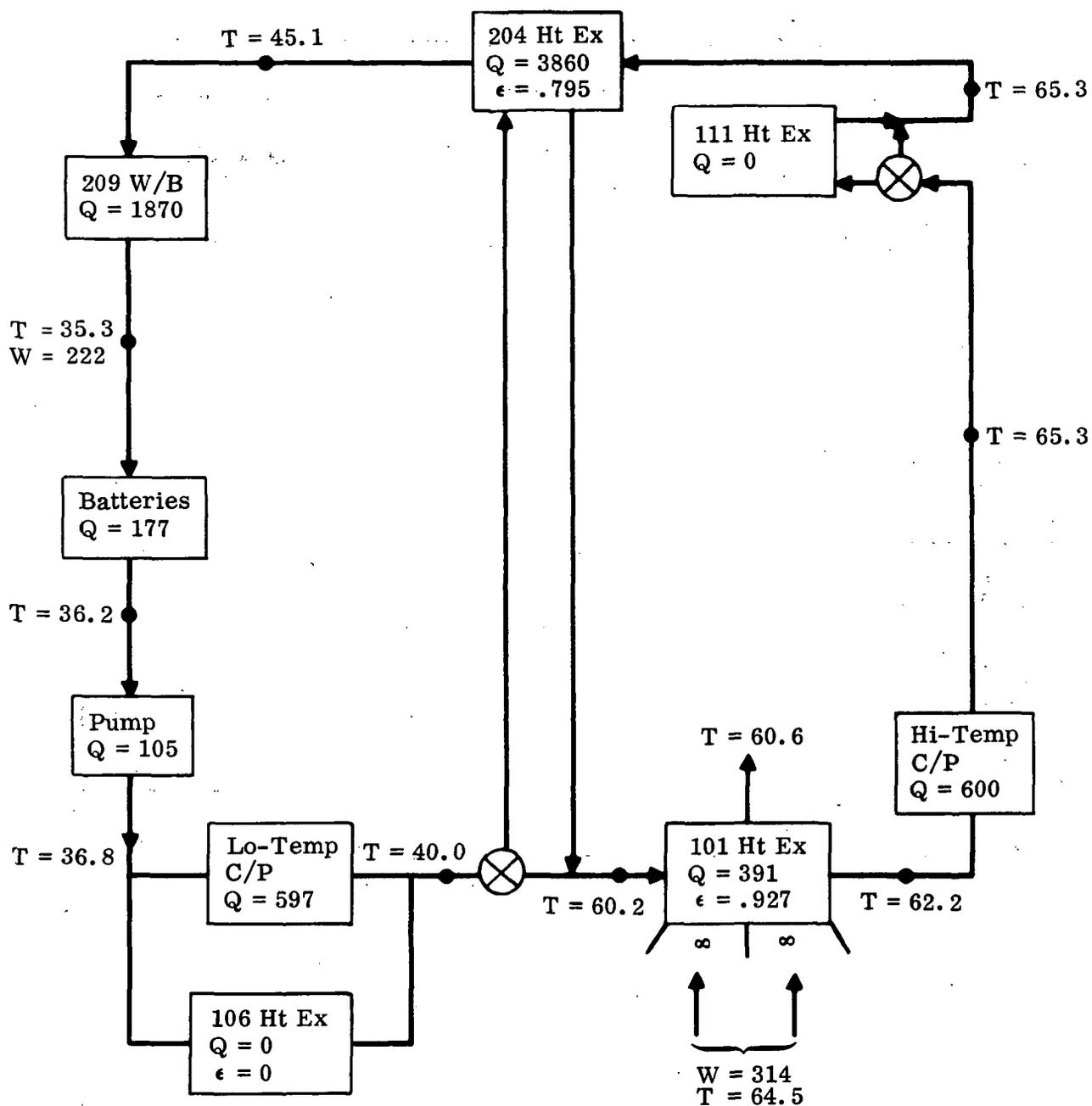


Fig. 5.2-3 Coolant Circuit Performance - Min. Load
2 Men Resting - No Water Evaporation Control

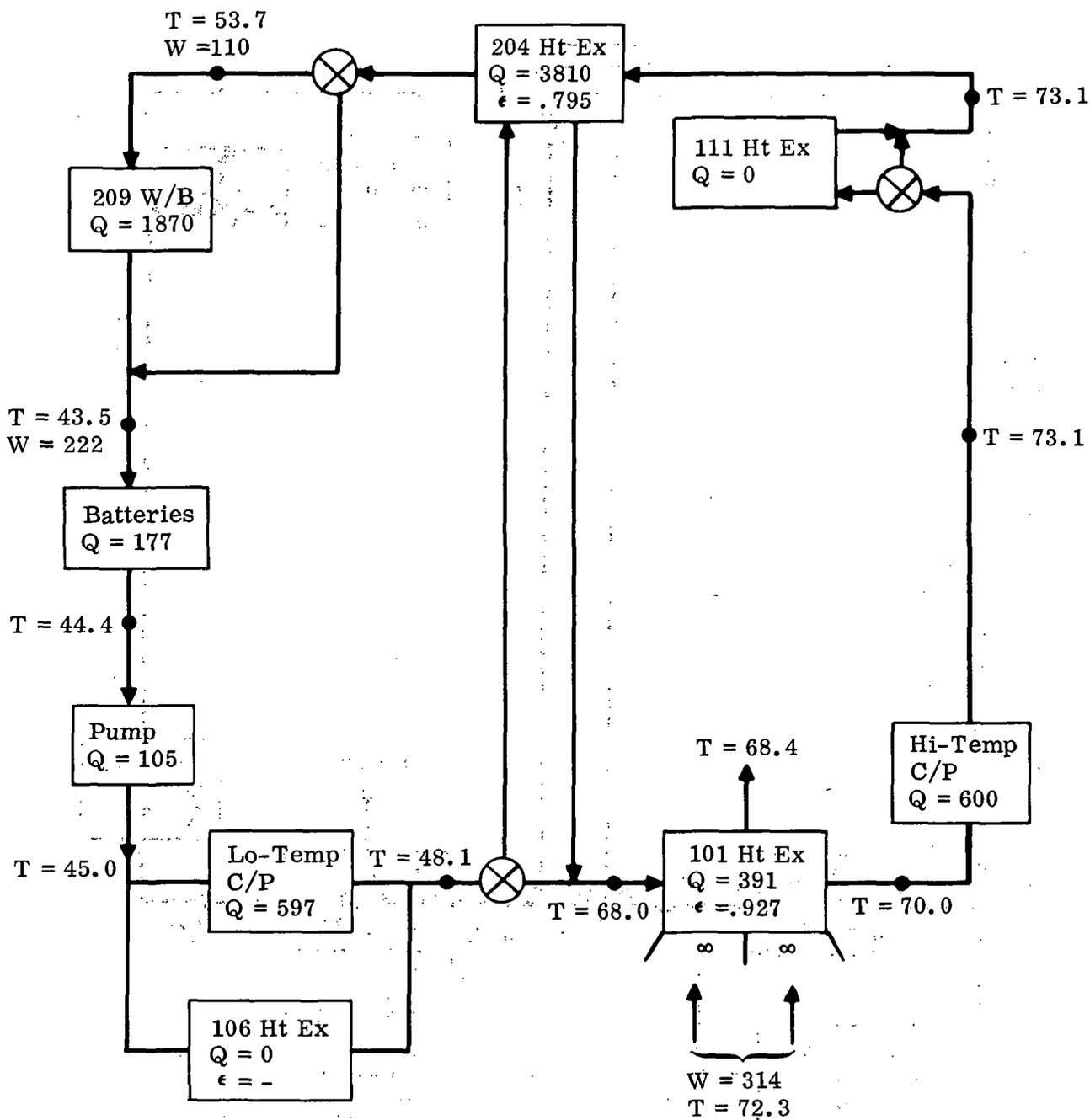


Fig. 5.2-4 Coolant Circuit, Min Load, 2 Men Resting, with Water Evaporator Control

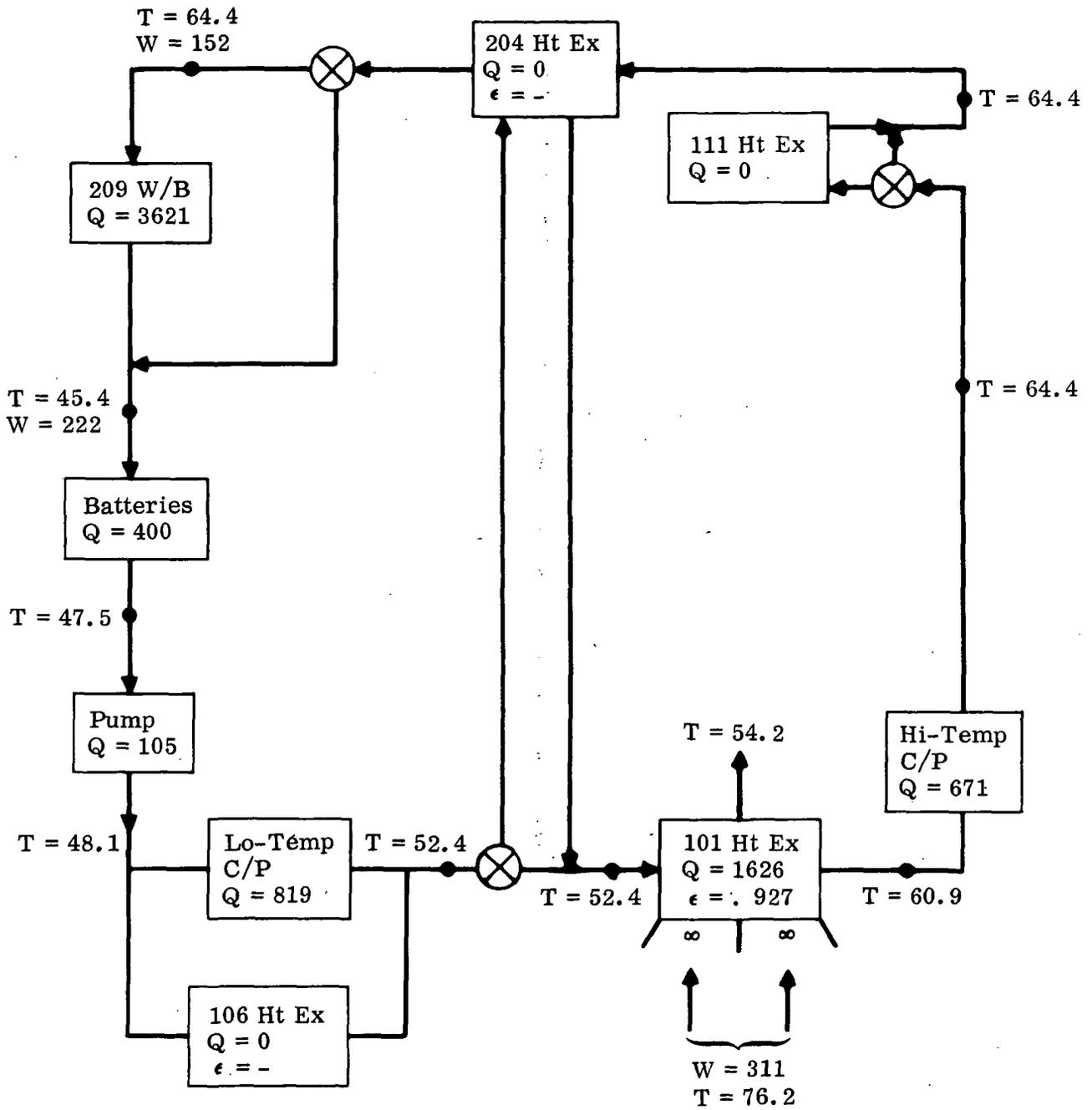


Fig. 5.2-5 Coolant Circuit, Max Load, 2 Men on Duty, with Water Evaporator Control

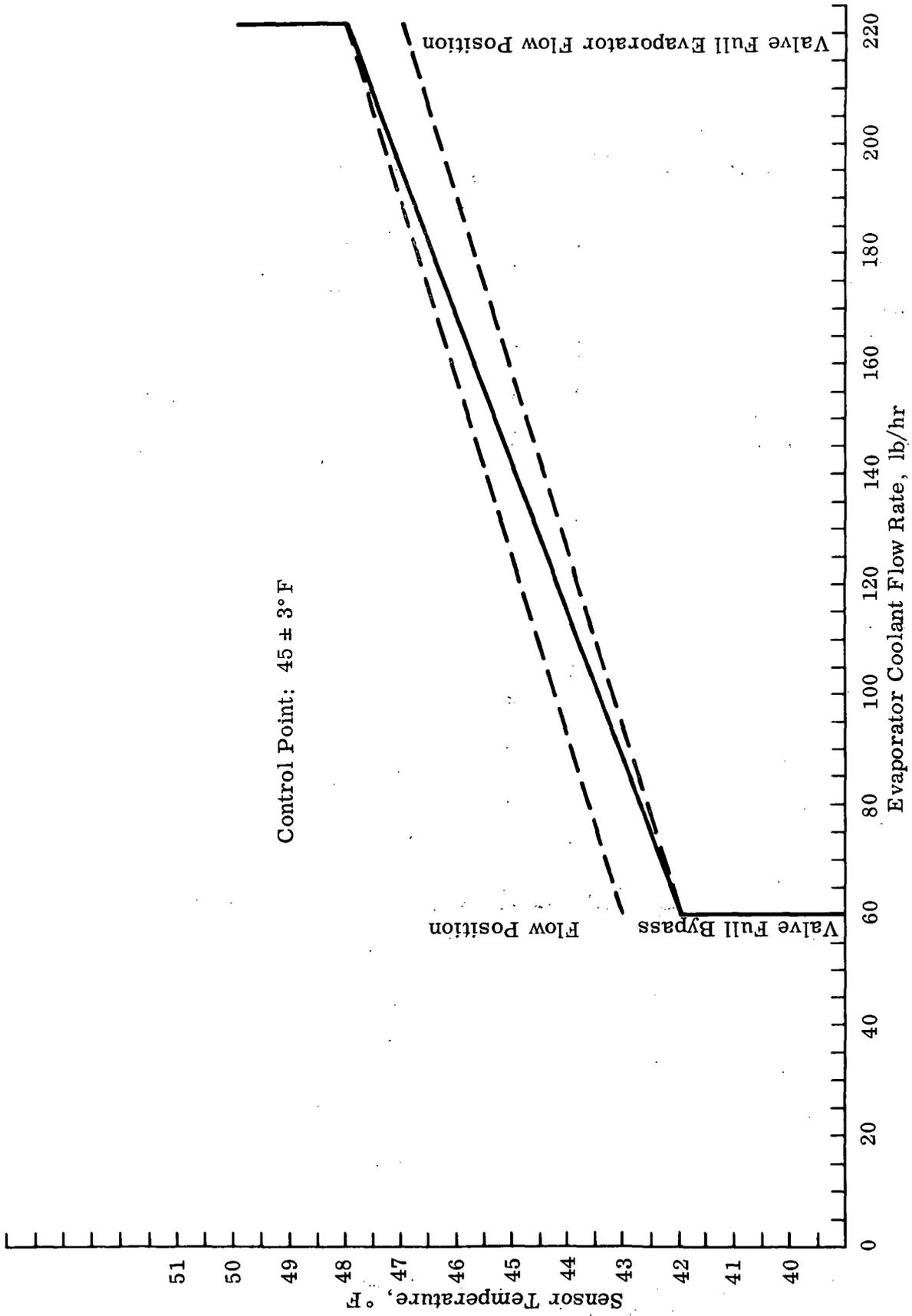


Fig. 5.2-6 Response Characteristics Evaporator Control Valve

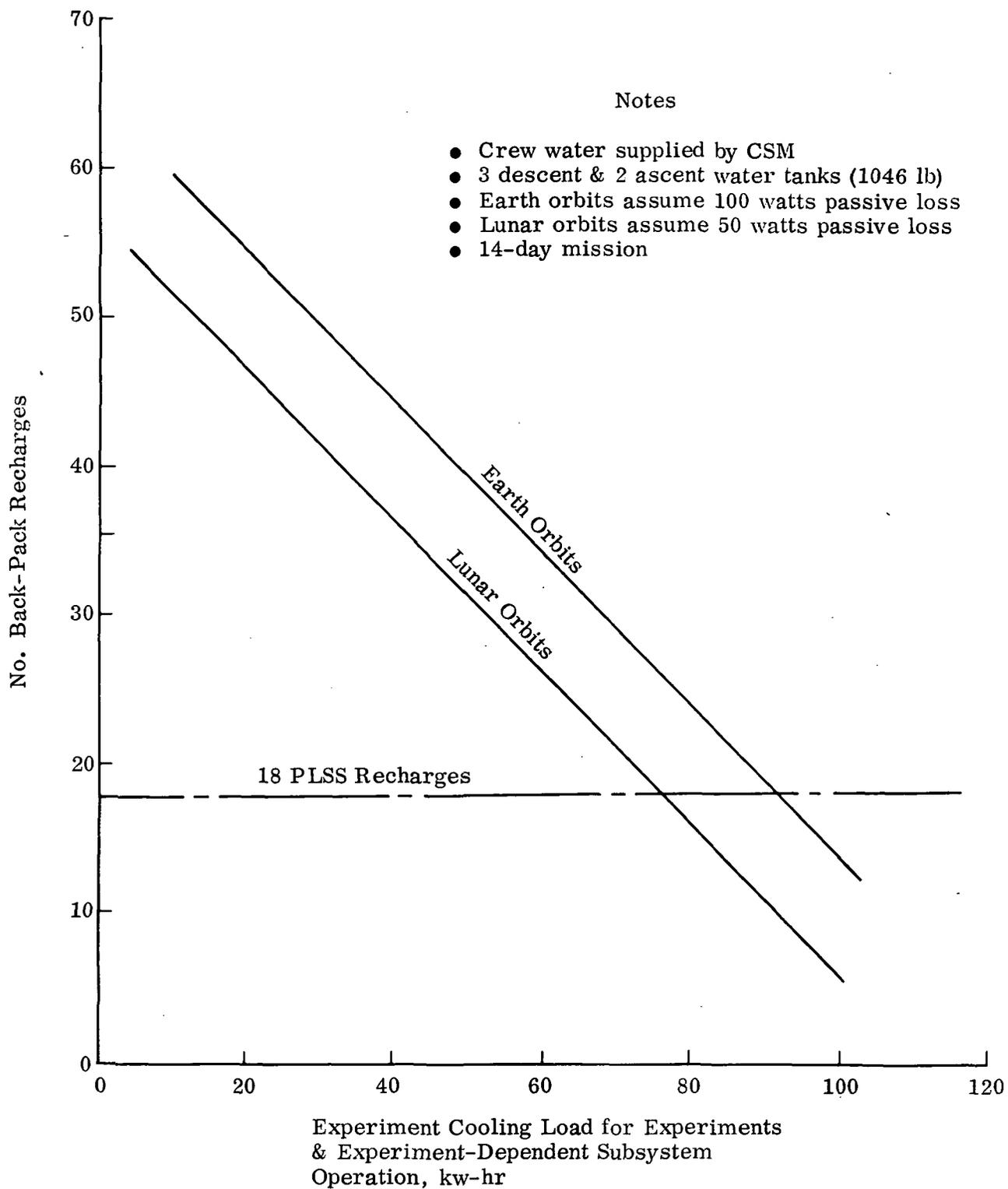


Fig. 5.2-7 ECS Water Utilization

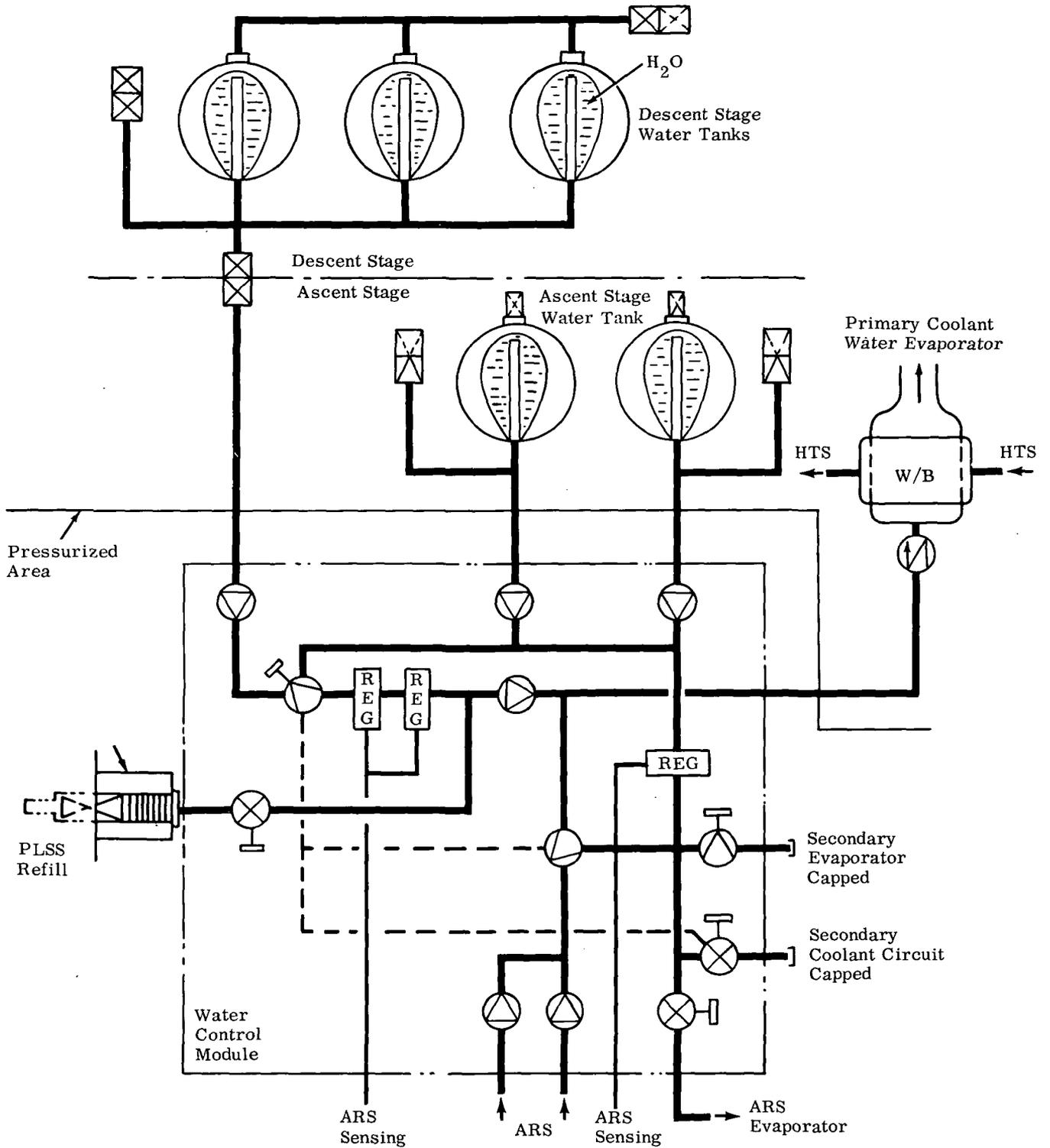


Fig. 5.2-8 Water Management Section Schematic

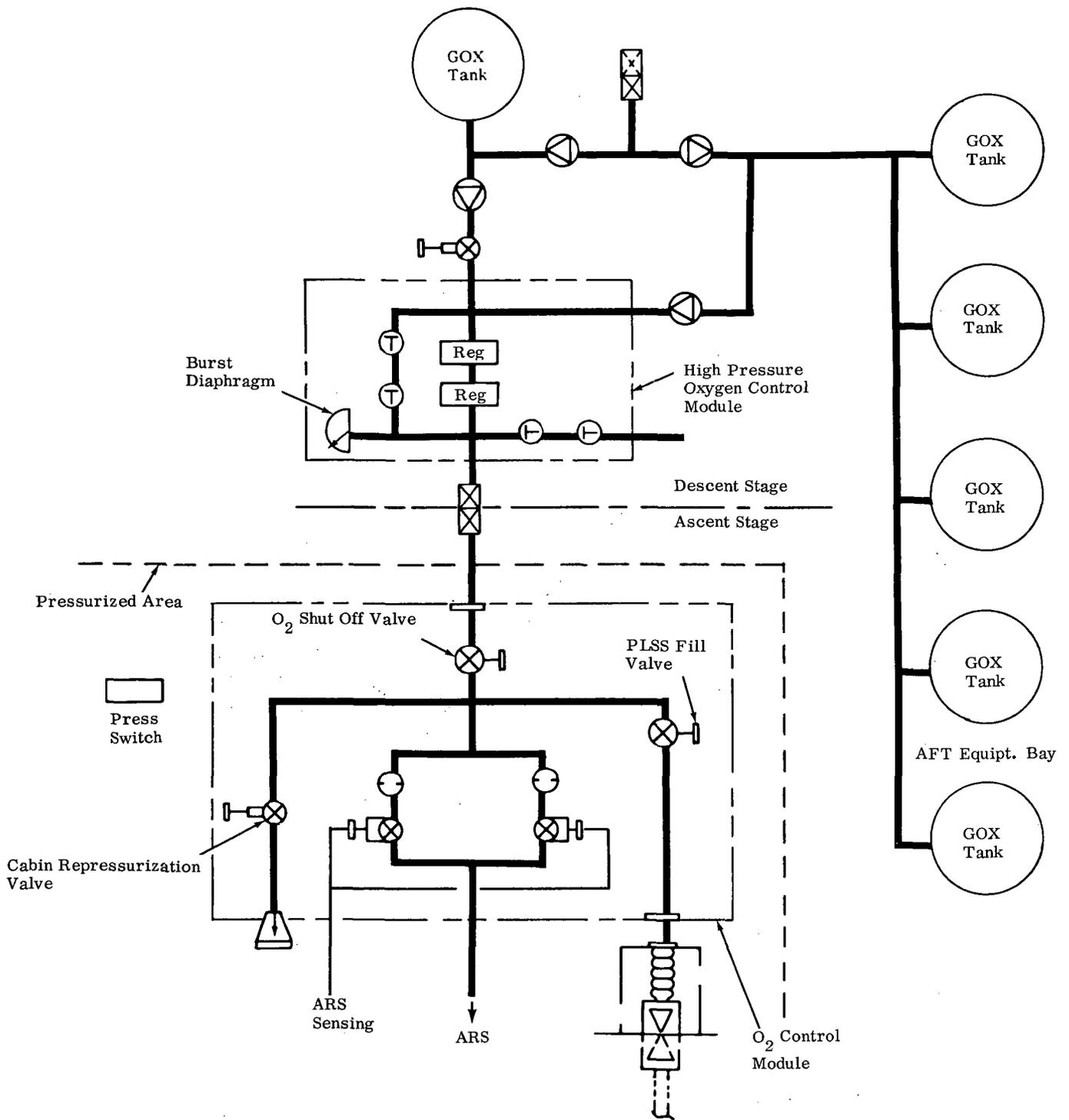


Fig. 5.2-9 Oxygen Supply and Pressurization Control Section Schematic

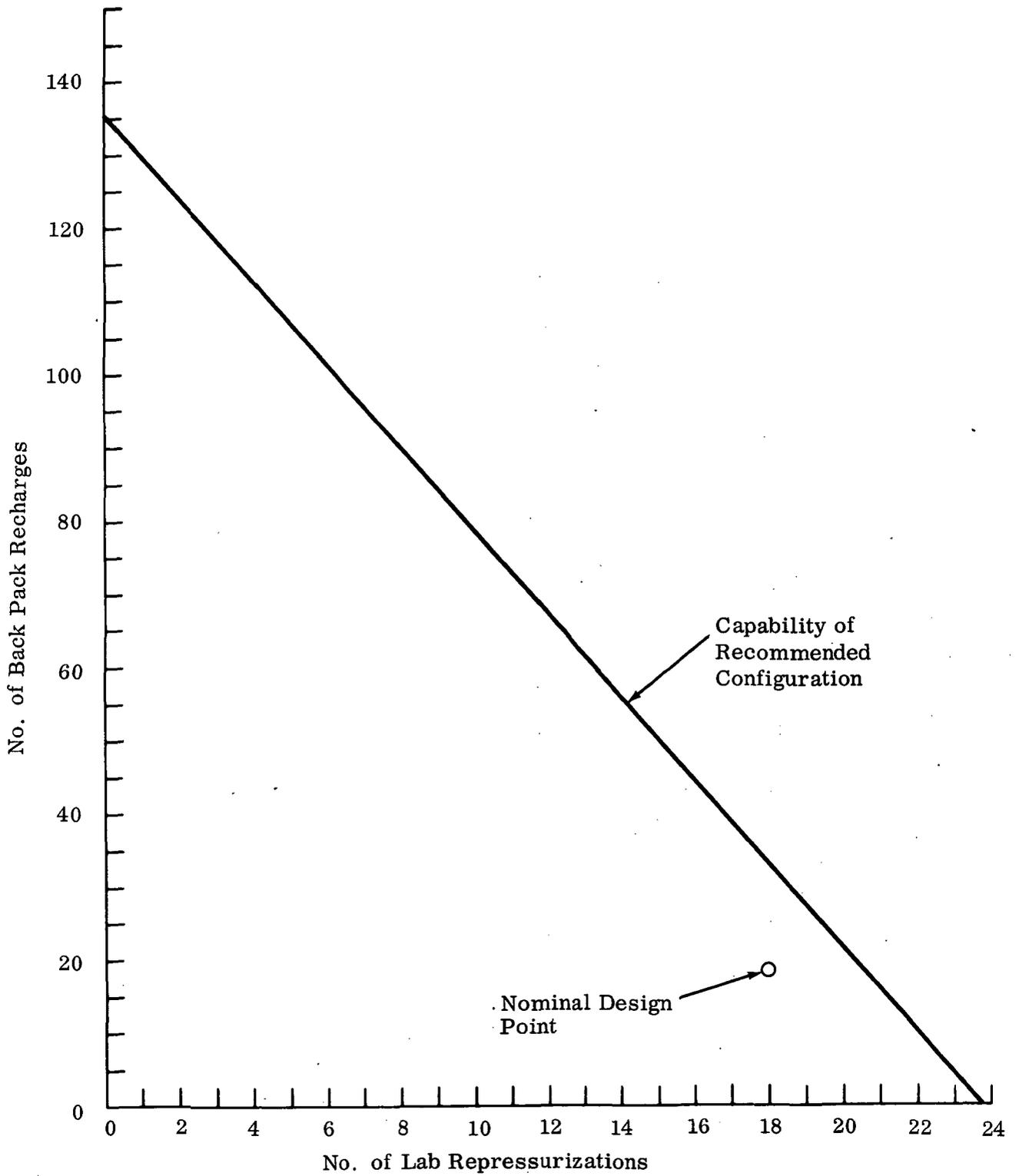


Fig. 5.2-10 EVA Capability Based on Oxygen Utilization

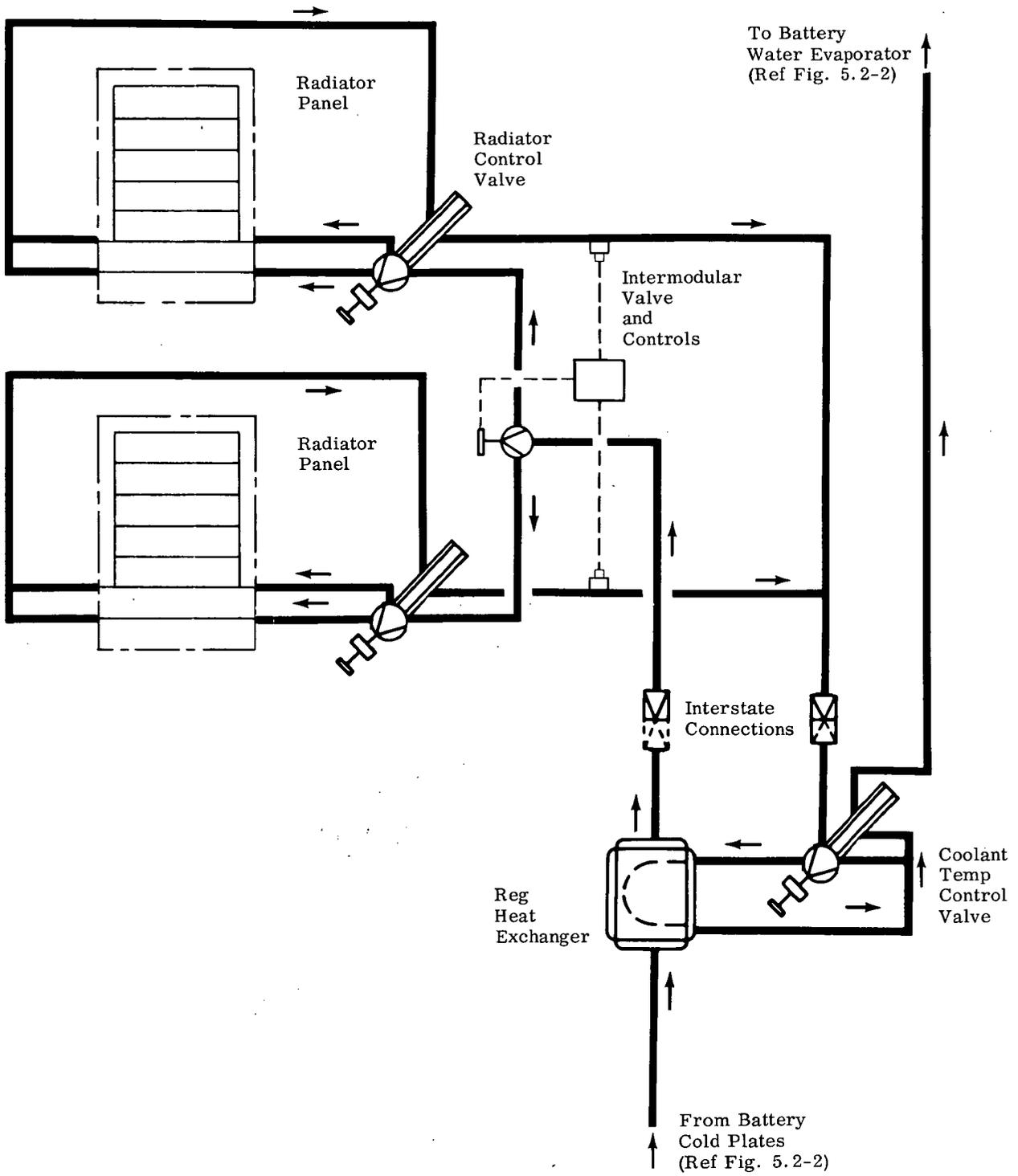


Fig. 5.2-11 Radiator Integration Schematic

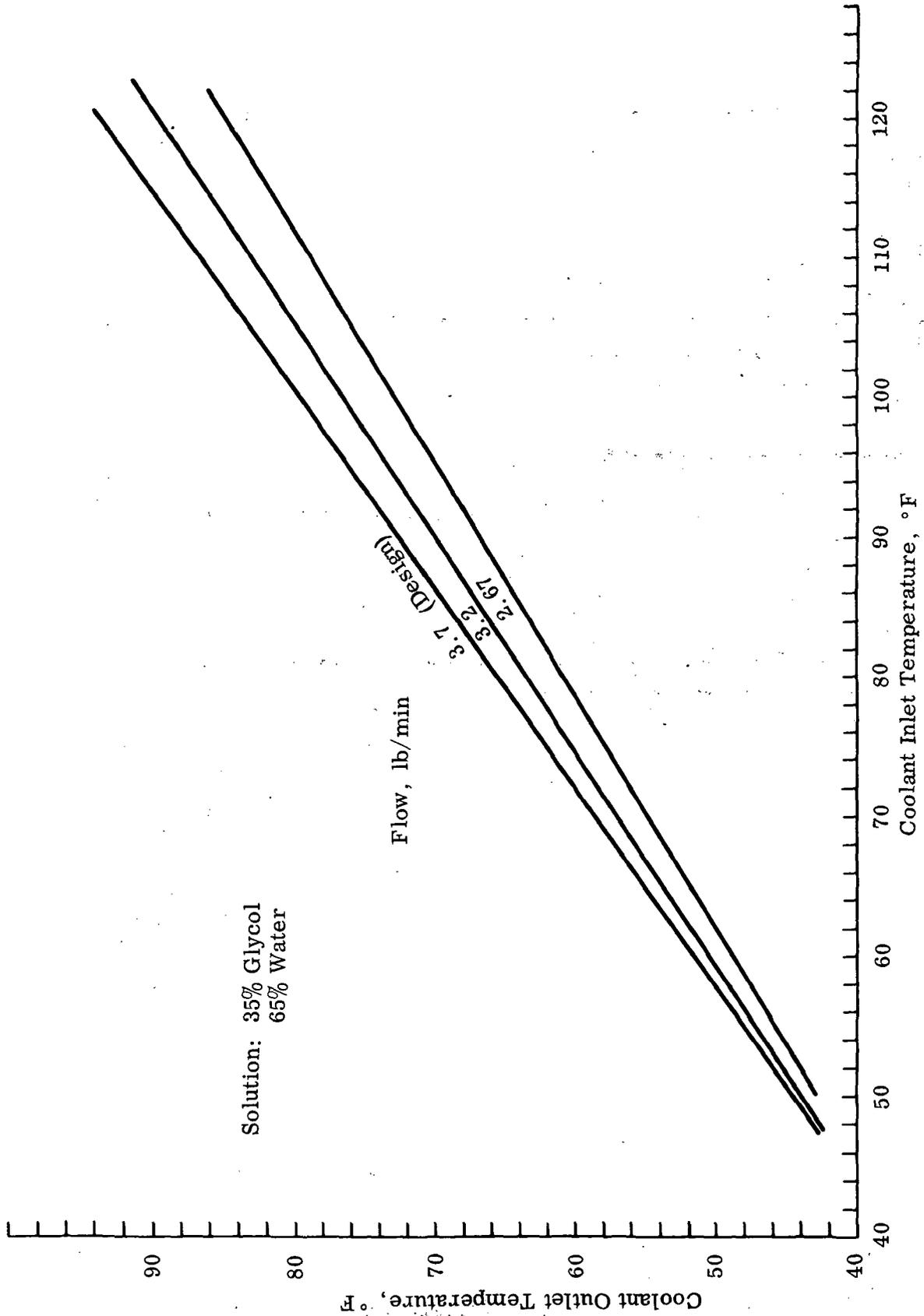


Fig. 5.2-12 LEM Redundant Evaporator Performance

5.3 GUIDANCE NAVIGATION & CONTROL (GN&C)

5.3.1 Ground Rules

The ground rules used in this study are:

- All translation and orbital maneuvering capability will be supplied by CSM
- The Lab will provide the orbital attitude hold capability within the limits of the recommended configuration. Capability beyond these limits will be supplied by the Experiment package
- There is no electrical interface for control between the Lab and the CSM
- All missions have RCS in the Lab
- There is no main propulsion system in the Lab.

5.3.2 Assumptions and Background Data

The assumptions used in this study include:

- The Lab must include a capability to provide an inertial reference
- The addition of external sensors such as horizon scanners are experiment dependent and, as such, are not included in the vehicle design.

The list of missions from the Phase A study plus the "Blue Book" was used as a basis for determining the recommended configuration. The missions can be divided into four categories for purposes of a GN&C evaluation. The first category, being composed largely of medical and biological experiments does not require a control system. The second category requires only rate stabilization. This requirement can be satisfied by the Primary Guidance, Navigation and Control Section (PGNCS) or the Abort Guidance Section (AGS) as configured in the present LEM. The third category requires coarse attitude hold. Again, this requirement can be satisfied by the AGS or PGNCS. The fourth category of mission requires very accurate attitude hold. The order of magnitude of accuracy required would require a complete redesign of the GN&C subsystem.

The recommended GN&C configuration will provide control for the first, second and third mission categories. Capability to provide control for the fourth category must be a function of the experiment package. The choice of the AGS for the recommended Lab configuration was made primarily on the basis of weight and power. The details of the choice are shown in 5.3.3 and in 5.3.7.

Some of the experiments require earth pointing capability. Two methods of providing this were evaluated. The first is to use a horizon scanner or similar type sensor. The second method is to insert a rate bias command from the computer into the control system to provide approximate earth pointing. This bias signal can be updated to provide the required accuracy, however, update frequency may be a problem. The first method requires hardware and the second method requires software changes. This capability must be provided as part of the experiment or on a per-flight modification basis, and is not part of the recommended configuration.

5.3.3 Recommended Configuration

The recommended GN&C subsystem is as shown in Fig. 5.3-1. The configuration is that of a modified AGS with changes to the Rate Gyro Assembly (RGA) and the Attitude and Translation Control Assembly (ATCA). The AGS is recommended on the basis

of power and weight parameters. A comparison of the AGS with the PGNCS will be found in Paragraph 5.3.7. At the present time there is no basis for comparison of the reliability of the two systems since the reliability estimates for each system are derived from different bases. A more complete discussion of reliability analysis of these two systems is given in Section 4.5.

The recommended change in the RGA is a shift in the dynamic range of the rate gyros to provide a .001°/sec. threshold sensitivity. This is a change of 10:1 from the present system and requires a 10:1 change in the maximum rate capability from 25°/sec. to 2.5°/sec. With the Lab only required to provide attitude hold capability this maximum rate change is acceptable. A change in the restoring spring constant will provide the necessary range shift while improved selection of wheel bearings will tighten tolerances if necessary.

The change to the ATCA provides a 1 pulse limit cycle for the RCS jets in the presence of no disturbance torques. This, in conjunction with the increased threshold sensitivity, provides a minimum impulse response to a small rate change, which results in less fuel used and decreased firing cycles for the RCS jets. The proposed modification is a change in the ATCA rate gain from a range of 1 to 4 to a desired range of 1 to 10. The implementation of this change will be determined by GAEC in conjunction with the equipment manufacturer.

The modifications to the Abort Electronics Assembly (AEA) and the Data Entry and Display Assembly (DEDA) are required to permit the use of the Alignment Optical Telescope (AOT) with the AGS as a means of providing update information for attitude reference in the LEM Labs.

The modification to the AES consists of adding a star catalogue and processing routines to the program complement. A catalogue of approximately 45 stars using triple precision coordinates and the necessary processing routines requires an estimated 400 memory locations. The deletion of the Rendezvous Radar and any rendezvous maneuvers releases an estimated 200 memory locations for this catalogue. The remaining 200 locations required are provided by a reduction in the memory requirements for Alignment, Calibration and Explicit Guidance of approximately 800 locations.

The modification of the DEDA is the implementation of the AOT discrete signals, Mark X, Mark Y, Mark Bar, and Reject Mark, in the DEDA. The azimuth detent positions and the elevation readings of the AOT will be entered into the AEA through the DEDA.

The System performance will be the same as that specified for the Apollo LEM system with the exception of those changes specified in the modifications detailed above. This performance is summarized as follows:

Limit Cycle	Deadband, deg	Rate Limit, Deg/sec
Wide	5	3 1/2
Narrow	0.3	0.2

AGS Drift Rate = 1.1 deg/hr

5.3.4 Baseline Configuration

The differences between baseline and the recommended configuration described in paragraph 5.3.3 are as follows:

- The ATCA would be identical to the LEM ATCA.
- The RGA would be identical to the LEM RGA.

This system was not recommended because of the high propellant consumption rates for attitude hold. (See Sections 4.2 and 4.3).

5.3.5 Alternate Configuration - Deriving Rate Information from ASA

An alternate configuration consists of the replacement of the RGA by deriving rate information on the AEA from the Abort Sensor Assy. (ASA)

As presently configured (Fig. 5.3-2) each of the three gyros in the ASA generates a gated pulse train which is sent to an input register in the AEA. The AEA provides for the continuous accumulation of these pulses and their processing every 20 msec. Program control provides a true positive or negative angular increment. The accumulated pulses are processed in the AEA to update a coordinate transformation matrix. These rotations, together with initial conditions, are combined with orientation commands and processed through the inverse transformation matrix to yield body axis components of attitude error.

There is, therefore, data available within the AGS which will allow the computation of the components of angular velocity. By using the gyro pulse outputs accumulated within the AEA input section and suitably processing it, angular rate data can be provided in an explicit form and the rate information from each gyro is independent of that of the other gyros. This prevents loss of all rate information in the event of a malfunction of one of the gyros.

There are two methods of providing angular velocity components from the gyro pulses. The first method processes the data through the computer memory logic and second method processes the data through circuitry that is independent of this logic. This second method provides the capability of deriving rate data during times when the computer is not activated. The first method requires the least change to the present AEA and for that reason is the method considered.

The rate data derived by the computer can be used in one of two ways. It can be multiplied by the rate feedback gain and combined with the attitude error signals within the computer to form the total error. The total error can then be converted to the proper analog signal. For the Rate Command Mode, the hand controller signals are introduced directly into the AEA (Fig. 5.3-3). Within the ATCA the logic and pulse modulation circuits would be the same as the present design. For the second method the derived rate data and the attitude error data are separately converted to proper analog signals and combined in the ATCA (Fig. 5.3-4). The remainder of the system is the same as the present design, the rate gain change as a function of dead band will be handled in the ATCA.

System I and System II require additional analog/digital or digital/analog converters and interface changes as shown in Figs. 5.3-3 & -4.

The software requirements are based on the assumption that the gains, limits and deadband requirements were the same for all channels. An additional mode switch requirement is included to provide deadband min-max selection in Rate Derived System I (Fig. 5.3-3). The running time of the program is not significantly increased (due to deadband selection) but there will be an increase in memory locations required.

The mechanization of System I is based on the equations shown below for one channel. System II requires the same basic computation and timing.

$$\beta_{in} = k_D \epsilon_{in} \quad , \quad |k_D \epsilon_{in}| < |\beta_{iL}|$$

$$\text{if } k_D \epsilon_{in} \geq \beta_{iL} \quad , \quad \beta_{in} = +\beta_{iL}$$

$$\text{if } k_D \epsilon_{in} \leq -\beta_{iL} \quad , \quad \beta_{in} = -\beta_{iL}$$

$$\dot{\theta}_{in} = \frac{k_R}{T} \left(\frac{\epsilon}{T} \Delta a_{in} \right)$$

Where ϵ_{in} is the computation interval in the $\dot{\theta}_{in}$ loop $\epsilon_{in} = \beta_{in} - \dot{\theta}_{in}$

The programming flow chart is shown in Fig. 5.3-5. Approximately 1 msec is required for the added programming running time for both Systems I and II. System I requires 60-75 memory locations and System II requires 40-50 memory locations.

Table 5.3-1 indicates that there is memory core area available for this additional program.

The AES Lab I Vehicle as presently configured is assumed to require a threshold sensitivity of 0.001 degrees/sec. angular rate. The AGS as configured for LEM has a 25 degree/sec maximum vehicle rate capability. The gyro electronics package has a 32,000 PPS data pulse rate.

$$\text{Value of one pulse from ASA} = \frac{25 \text{ deg/sec}}{32,000 \text{ PPS}} = 0.00087 \text{ deg/pulse}$$

$$\frac{\text{Value of one pulse}}{\text{Minimum angular rate}} = \frac{.87 \times 10^{-3} \text{ deg/pulse}}{1 \times 10^{-3} \text{ deg/sec}} = .870 \text{ sec/pulse}$$

This means that under present LEM configuration a pulse from the ASA will reach the AEA computer every 870 milliseconds. Computations in the AEA's digital loop will add 40 milliseconds for a total of 910 milliseconds between pulses to the RCS engines.

The studies set forth here lead to the following conclusions: The AEA computer has enough memory capacity, as the program is described above to fulfill the software requirements of an internally derived rate program.

The existing LEM-AEA using ASA gyro information can provide a pulse to the RCS jets at the rate of 890 to 910 milliseconds per pulse, while attempting to hold a 0.001 degree-per-second angular vehicle rate.

The computation time of the AEA is sufficient for the above derived vehicle angular rate program. The independent variable for increasing response time of the rate loop is the scaling of the ASA gyros.

Further studies by GN&C Analysis & Integration incorporating computer simulation are needed in order to define the AES-Lab guidance requirements. These studies should take into account the increased sensitivity requirements, rate filters, loop stability, moment unbalance, increased inertia, and RCS propellant conservation.

5.3.6 Alternate Configuration - New RGA Assembly

An alternate configuration would be the Baseline Configuration with a new RGA using rate integrating gyros to provide an improved threshold sensitivity. This approach uses torquing amplifiers to null the gyros. Since the precession rate of the gyro is proportional to the torque applied, the torquing current would provide a direct measurement of the input rate. The threshold of this system would be a function of the sensitivity of the torquer amplifier, its current measuring device and the gyro drift rate. Assuming good electronics, most of the gyros considered (See Table 5.3-2) had at least a factor of 10 better threshold sensitivity than the present gyro without sacrificing maximum rate input. However, all these gyros are larger than the rate gyros now used in the LEM RGA. Thus this approach would require redesign of the RGA in addition to including an electronics package.

5.3.7 Alternate Configuration - Use of Primary Nav. Guidance

Another alternate would be the use of the PGNCS instead of the AGS. This system was not recommended for the following reasons:

- Power requirements for the PGNCS are more than twice that required for the AGS (See Table 5.3-3)
- Weight of the PGNCS is approximately three times that of the AGS (See Table 5.3-3)
- The PGNCS has the possibility of a gimbal lock occurring in the IMU when the middle and outer gimbal axes coincide or fall within 20° of each other during a vehicle attitude maneuver. The gimbal lock warning light goes on when the angle between the middle and outer gimbals is greater than 55° . Using the AGS there are no singularities in the equations used to derive the attitude error signals and there is no possibility of a gimbal lock
- The PGNCS requires the use of a Gimbal Angle Sequence Transformation Assembly (GASTA) to provide a rotation of the angular coordinate system used by the IMU to that used by the FDIA.

This transformation is not required for the AGS

5.3.8 Potential Per Flight Modification

For improved system performance a reduced limit cycle deadband is desirable. The present deadband is 0.3° and a desired deadband is 0.1° . In as much as the LEM system had a 0.1° deadband at one time, this should not be a problem. A brief look at the total null error voltages confirms the feasibility of a 0.1° D.B.

Refer to Fig. 5.3-6. An output signal of 0.21 VDC corresponds to 0.1° attitude input. The null signals from the various sources are:

- RGA (in Phase) 1.4 MV Deadband x 22.5 = 31.5 MV
- ACA No Spec on in-phase but assume 1.4 MV = 31.5 MV
- AEA 10 MV (In Phase) x 7 = 70. MV

In Phase Total Null = 133 MVDC

From this, the 0.1° deadband is feasible, however, GAEC in conjunction with the equipment manufacture, must determine equipment modification requirements.

5.3.9 Discussion of Configuration Choices

With no requirement for an abort capability in the Lab, the minimum non-redundant system capable of accomplishing a reasonable percentage of the mission requirements was the criterion for the recommendation. Therefore the AGS was recommended as a consequence of its lighter weight (approximately 100 lb less) and its lower power consumption (approximately 240 watts less).

The modifications recommended to the AEA, DEDA, RGA and ATCA do not change the power requirements and weight of the system while providing an improved mission capability.

As was mentioned previously no comparison of reliability estimates is possible, due to the difference in the reliability base used in the two approaches. The AGS may have an advantage in that there are fewer components in this system than in the primary system.

Table 5.3-1
PROGRAM LENGTH

Function	LEM		AES
	Flight Program	Interim Program	Labs
Attitude Ref & Display	346	358	346
Alignment	155	135	50
Input Processing & Compensation	172	172	172
Calibration	100	100	0
Initialization	130	130	130
Navigation	194	324	194
Explicit Guidance	830	0	0
Steering	375	0	375
Radar Filter	153	0	0
CSM Acquisition	46	0	0
Telemetry	49	0	49
Executive & Housekeeping	467	0	467
Self - Tests	245	780	245
DEDA Processing	250	0	250
Service Subroutines	109	119	109
Star Catalog	0	0	400
AES Guidance	0	0	200
TOTAL	3621	2118	2987
15% Estimating Factor			450
"Scratch Pad"			500
			3937
Remainder			159
TOTAL MEMORY CAPACITY			4096

Table 5.3-2

RATE INTEGRATING GYROS

Manufacturer	Designation	Dimensions Dia. x length, in.	Random Drift Rate, Deg/hr	Max. Torque Rate, Deg/sec
Honeywell	GG 8001	2.0 x 2.8	0.02	3.5
Honeywell	GG 250	1.6 x 3.2	7.2	150
Kearfott	C702516	1.8 x 2.8	0.03	5.5
Nortronics	GI-K7	1.6 x 2.5	0.05	17
Reeves	12IG	1.3 x 2.5	0.1	20/40
Sperry	SYG 1040	2.0 x 2.8	0.5	20
Systron Donner (Greenleaf Div.)	HIG-3	1.3 x 2.1	4	30
Kearfott	LEM Rate Gyro	1.0 x 2.1	36*	25

* Rate Threshold Sensitivity

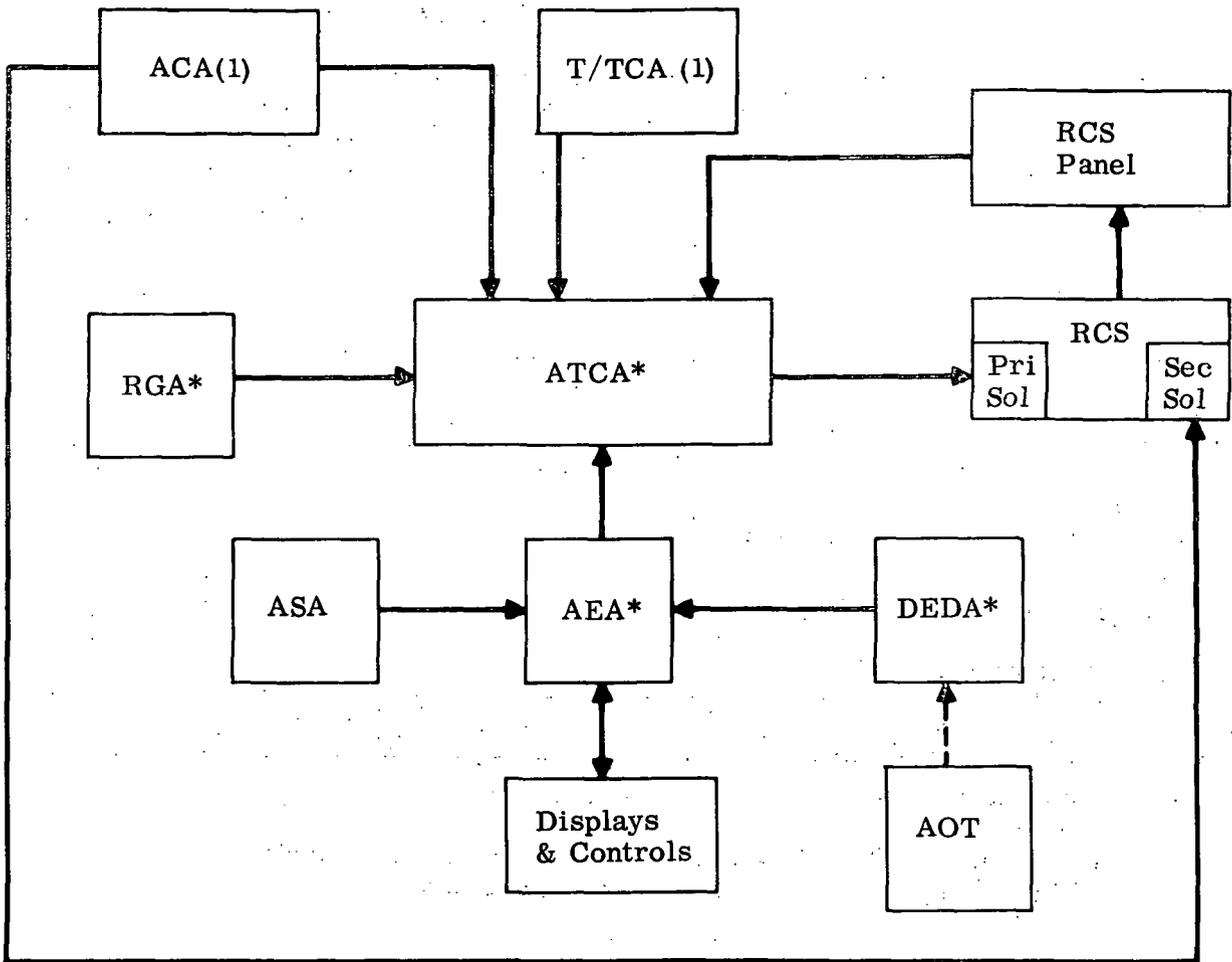
Table 5.3-3

PGNCS VS AGS POWER & WEIGHT COMPARISON

PGNCS	Power, Watts	Weight lb	AGS	Power watts	Weight lb
CDU	430 283.8 105 5.63 Steady-State DC 17.8 Steady-State AC	36.8	ASA	76.0	21.0
IMU		41.3	AEA	90.0	32.0
PTA		14.8	DEDA	8.0	8.0
PSA		20.1	RGA	8.5	1.8
LGC		70.0	SCS (Panel)	3.0	6.0
DSKY		17.5			
GASTA		7.4			
Totals	412.23 to 453.43 *	207.9	Totals	176.5	68.8

* Information not clear if 412.23 includes CDU's.

Note: Harness "A" & "B", weighing 23.5 lb, must be added to PGNCS; harness required by AGS not included.



*Modified Units

Deleted from LEM

Legend

ACA (1)

T/TCA (1)

DECA

GDA

LR

RR

IMU

DSKY

LGC

PTA

PSA

CDU

AOT Alignment Optical Telescope

ATCA Attitude & Translation Control Assy

ASA Abort Sensor Assy

AEA Abort Electronics Assy

ACA Attitude Control Assy

RGA Rate Gyro Assy

DEDA Data Entry & Display Assy

RCS Reaction Control System

T/TCA Thrust/Translation Control Assy

Fig. 5.3-1 Recommended Configuration

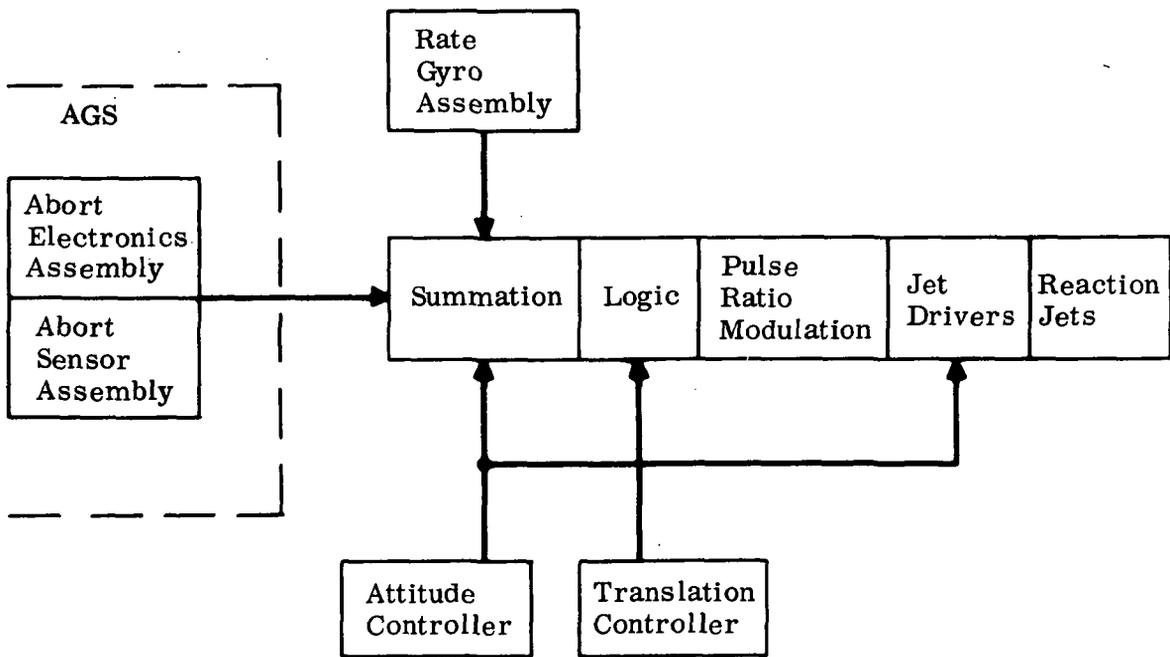
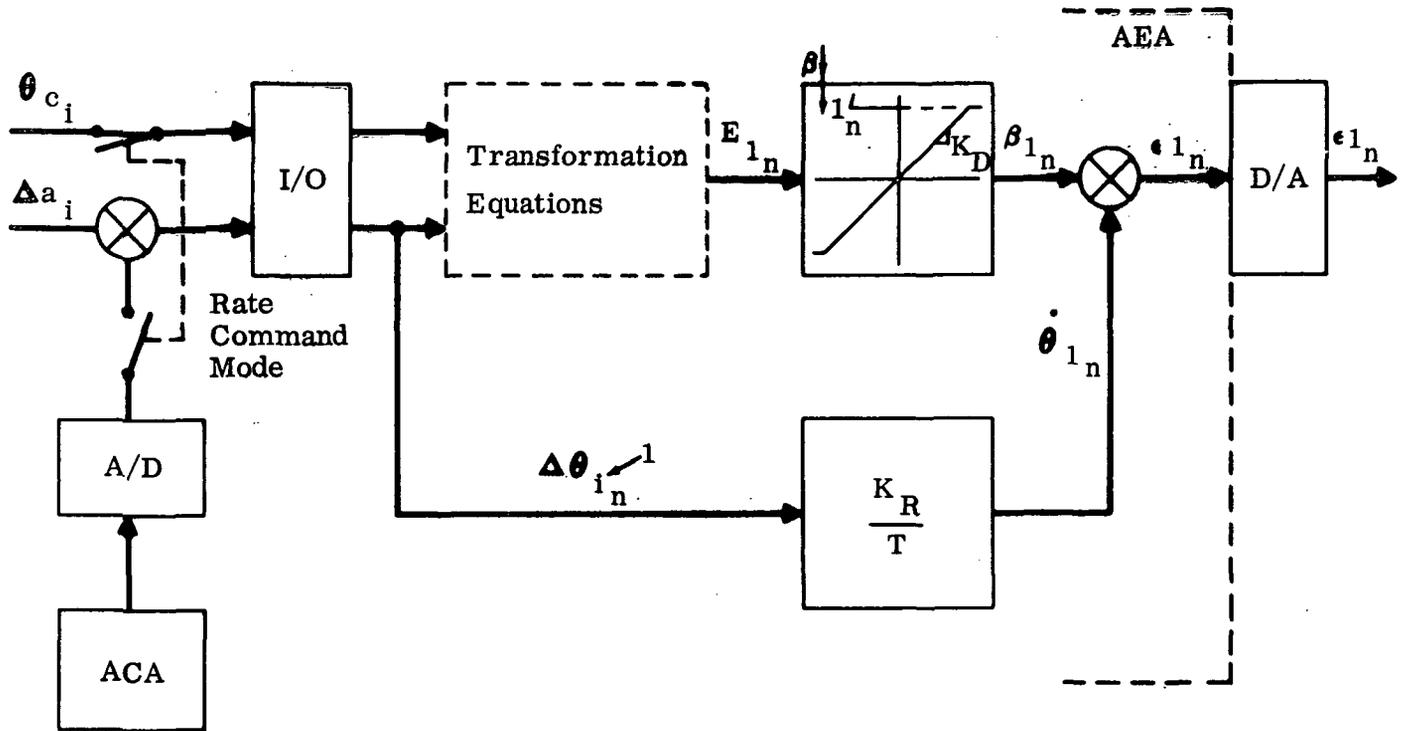


Fig. 5.3-2 Present AES-LAB S and C Comparison



Legend

- θ^{c_i} Attitude Information
- Δa_i Incremental Rotation
- β_{1n} Computer Attitude Output
- K_D Attitude Gain
- ϵ_{1n} Computer Rate + Attitude Output
- β_{1n}^L Limit of Angular Rate
- K_R Rate Gain (Function of Selected Dead-Band)
- T Sampling Period in $\dot{\theta}$ Loop
- $\dot{\theta}_{1n}$ Computer Rate Output

Fig. 5.3-3 Rate Derivative System I

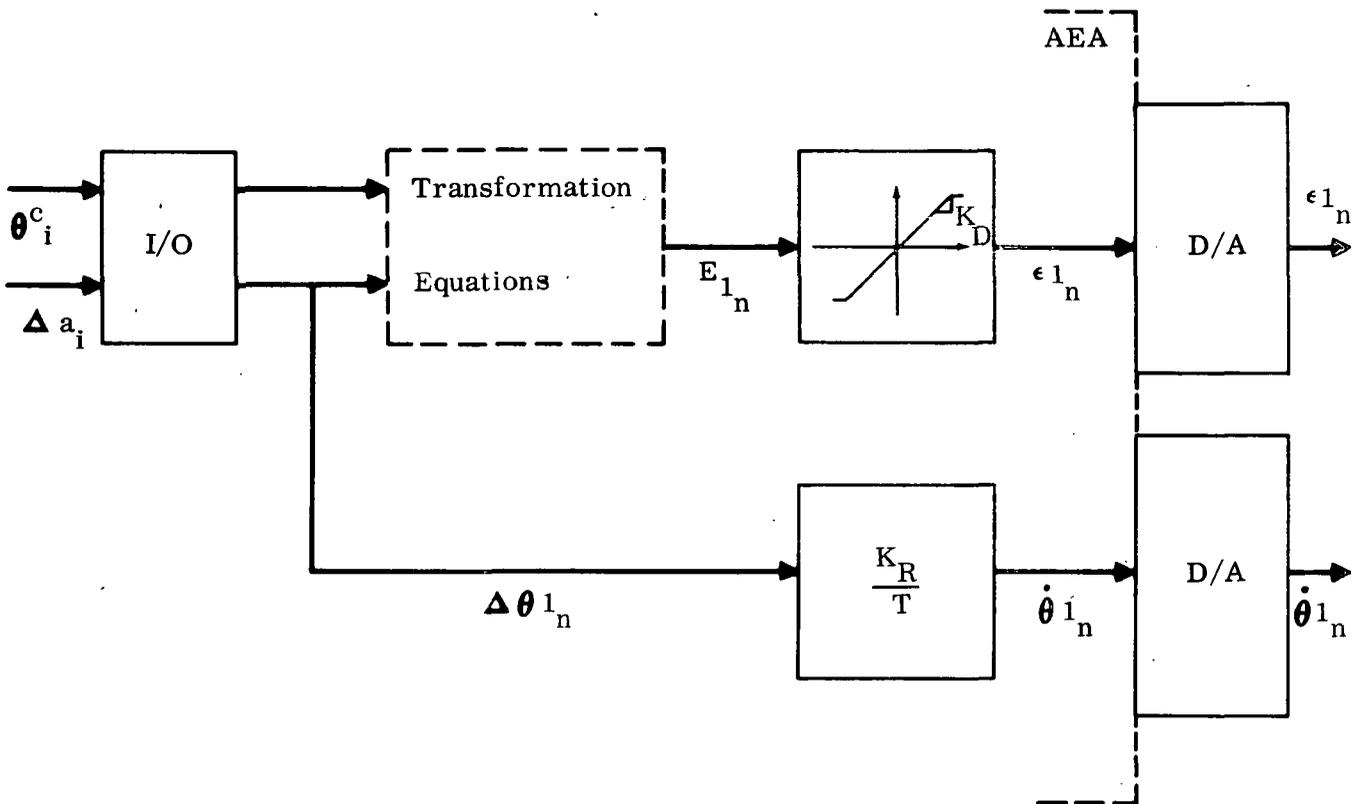


Fig. 5.3-4 Rate Derivative System II

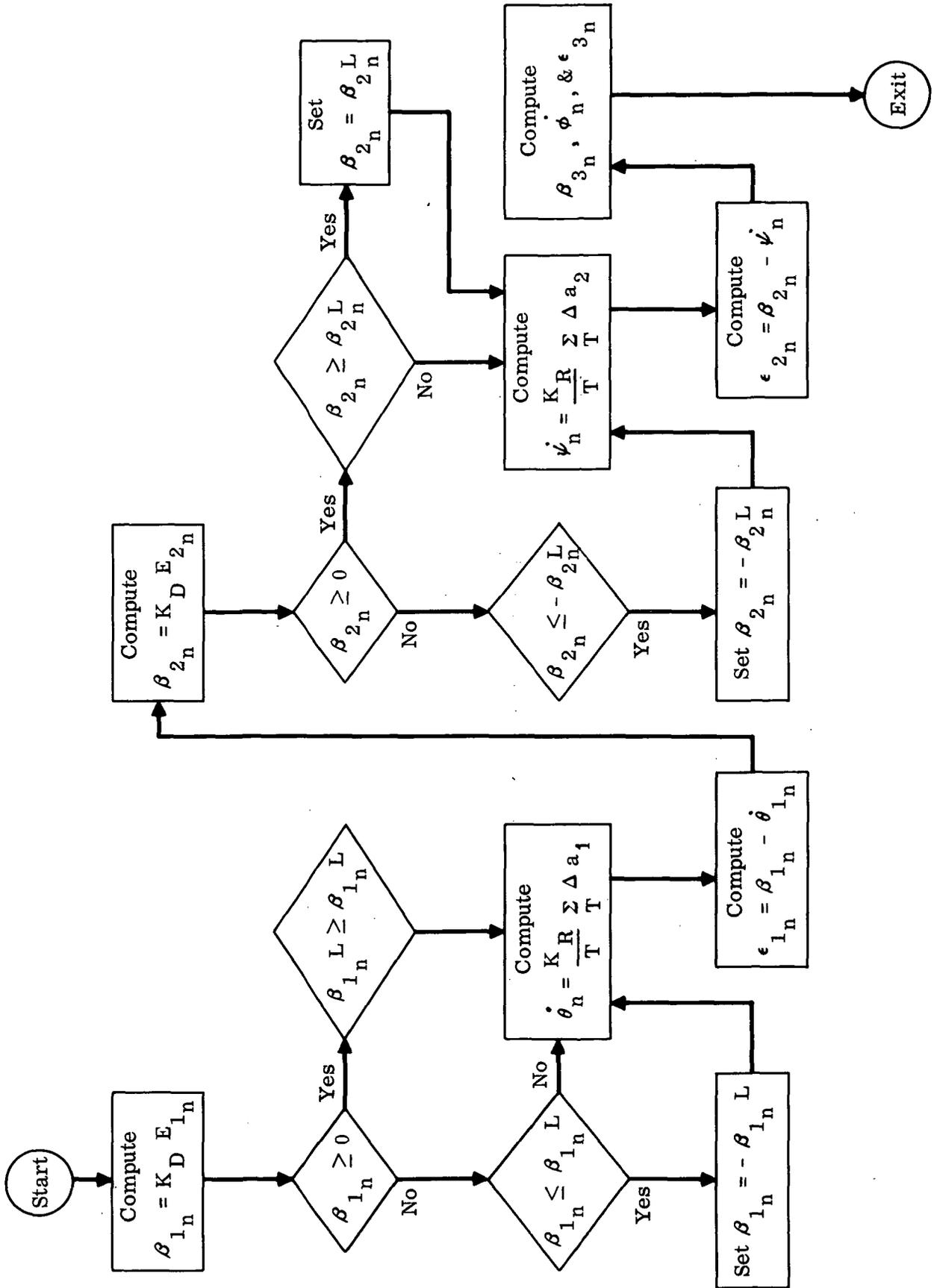
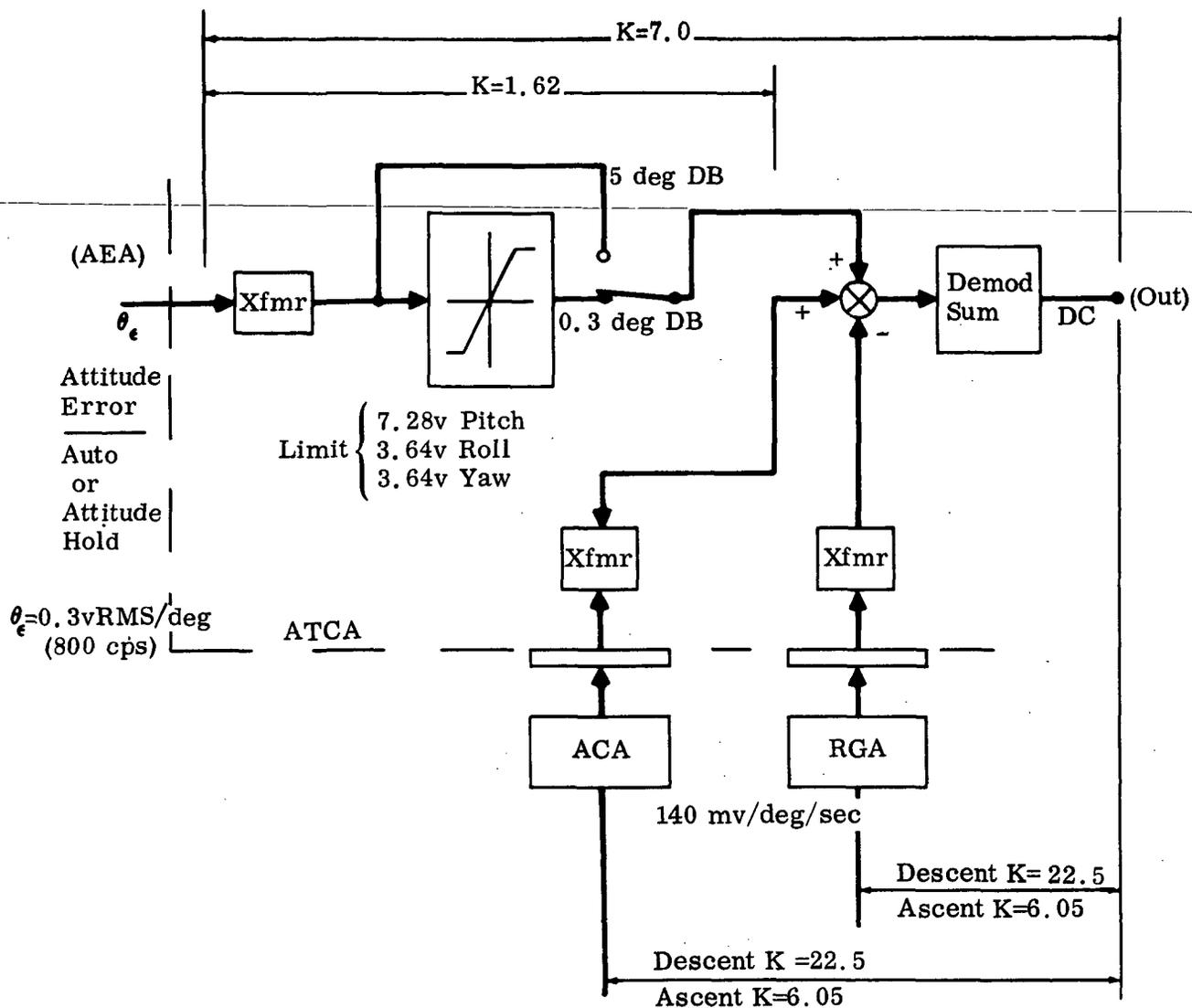


Fig. 5.3-5 Program Flow Chart



Null Signal Summary

RGA	Threshold	0.01 deg/sec = 1.4mv
	Null	30 mv RMS (Noise, Quad, Harmonics)
ACA	Total	30 mv RMS
AEA	Attitude Error Signals	10 mv In Phase 50 mv Total 17 mv Harmonic

Fig. 5.3-6 Block Diagram - Deadband Calculations

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5.4 REACTION CONTROL AND PROPULSION

5.4.1 Ground Rules

- The Phase I Lab RCS shall provide attitude hold for all mission experiment phases
- The CSM RCS shall be used for all transit and orbital slewing functions including rolling operations
- Ascent and descent propulsion subsystems will be deleted.

5.4.2 Assumptions and Background Data

The following assumptions were made in the course of the study:

- Only hardware which is reasonably accessible will be removed
- Hardware will be removed during modification operations at KSC
- Descent propulsion is not required for injection into a synchronous earth orbit.

A review of Phase A studies and estimates of probable experiment requirements has shown that the basic LEM RCS with the present tankage will be capable of performing the Phase I Lab missions. The 14 day mission time should not present propellant storage problems since the LEM tankage has a 30 day propellant exposure requirement. By properly allocating the propellant among the redundant thrusters, the specified engine life of 1000 sec and 10,000 cycles will not be exceeded.

An improvement in propellant consumption with a corresponding increase in attitude hold duration could be achieved by using RCS engines with smaller minimum impulse bit firing capability than the LEM engines. Changes in the control system would be required to take advantage of this feature. Actually, only the undisturbed limit cycle propellant consumption would be reduced; consumption due to disturbance torques such as aerodynamic and gravity gradient would not be affected. To assist in studying this possibility, the following information on alternate lower level thruster configurations was obtained:

- Marquardt - 5 lb thrust (developed for Syncom)
Min. impulse bit - 0.05 lb-sec (0.010 sec pulse width)
Nominal Specific Impulse - 195 sec (pulsing)
Propellants - $N_2O_4/50\%$ UDMH, 50% N_2H_4
- Marquardt - 22 lb thrust (developed for Advent)
Min. impulse bit - 0.20 lb-sec (0.010 sec pulse width)
Nominal Specific Impulse - 215 sec (pulsing)
Propellants - N_2O_4/MMH .
- Rocketdyne - 25 lb thrust (used on Gemini OAMS)
Min. impulse bit - 0.35 lb-sec (0.015 sec pulse width)
Nominal Specific Impulse - 170 sec. (pulsing)
Propellants - N_2O_4/MMH

Although a comprehensive industry survey was beyond the scope of this study, a trend of minimum impulse bit vs thrust is indicated by these data. There appear to be no technical problems in adapting smaller thrusters to the LEM Lab, although further studies would be required if a particular thruster were selected, and it appears likely that some additional development work would be required to insure

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adequate thruster life. New tankage, or less efficient utilization of present tankage, might be required if the O/F ratio differed considerably from the LEM design value of 2:1.

5.4.3 Recommended Configuration

5.4.3.1 Reaction Control Subsystem

The basic LEM RCS configuration utilizing sixteen thrusters and a dual helium and propellant feed system should be retained for the Phase I Lab. In addition, the ascent system propellant-interconnect valves, filters and switches should be removed and the propellant lines at the valves should be capped. Total usable propellant provided by this arrangement is 423 lb.

5.4.3.2 Ascent Propulsion Subsystem

With the exception of those portions of the ascent propulsion manifolds which may be inaccessible, the ascent propulsion subsystem will be completely removed during the modification operations at KSC. The hardware to be removed is listed in Table 5.4-1. The interconnect between the ascent propulsion subsystem and RCS will be removed and the RCS propellant manifold capped as discussed above.

5.4.3.3 Descent Propulsion Subsystem

Except for the descent propellant tanks and inaccessible portions of the descent manifolds, the descent propulsion subsystem will be completely removed during the modification operations at KSC. It has been determined that the propellant tanks cannot be removed without some descent stage structural modifications. Therefore, the tanks will be retained. The hardware to be removed is listed in Table 5.4-1.

5.4.4 Baseline Configuration

Same as recommended configuration.

5.4.5 Alternate Configuration - Reversing RCS Fuel and Oxidizer Lines

By interchanging oxidizer and fuel lines, 524 lb of usable propellant can be provided instead of the recommended configuration value of 423 lb. This propellant capacity gain results from the fact that the RCS engine operates on the LEM duty cycle at an average O/F ratio of 2:1, whereas, the Lab duty cycle results in a ratio of 1.3:1. This phenomenon occurs because the mixture ratio is a function of electrical pulse width, and the attitude hold operation for the Lab mission requires only minimum width pulsing.

The LEM tanks are sized to accommodate the different propellant densities at an O/F of 2:1. Therefore, operation at an O/F of 1.3:1 cannot use all of the oxidizer and some may be off-loaded, as shown in the following table.

Grumman

RCS Propellant Tankage Capacity

	O/F	Ox	Fuel	Total
a.	2:1	368	184	552 lb.
b.	1.3:1	239	184	423 lb.
c.	1.3:1	296	228	524 lb.

- a. Present LEM Usable Propellants (REF)
- b. Lab, using present LEM tankage arrangements and off-loading oxidizer
- c. Lab, using Ox tanks for Fuel and Fuel tanks for Ox.

By coincidence, interchanging the ox and fuel tanks will give almost exactly the correct volume ratio for 1.3:1 O/F. This change is permissible since the tanks are compatible with either fluid. The effective interchange of tanks would probably be accomplished by interchanging propellant lines rather than physical movement of tanks.

Feeding the engine fuel through the present oxidizer supply system and vice versa would lead to very "hard starts" and engine failure, due to the internal design of the engine which requires a fuel lead for proper operation. It is necessary to maintain the present engine oxidizer and fuel feedlines as described above.

5.4.6 Potential Modifications per Flight - Use of Descent Propulsion

Consideration of the use of descent propulsion for attaining synchronous orbit was generated by the mission profile originally described in the NASA Blue Book. This requirement has since been deleted (revision J) but is reported on herein should a future requirement for this operation be created.

The propellant loading requirement was established by Table XVII of the Blue Book, as 16,290 lb compared with the descent tanks' capacity of 17,360 lb of usable propellant.

The subsystem would be identical to LEM's with the exception that the propellants would be off loaded and vent valves would be added to depressurize the helium and propellant tanks after engine shutdown. The use of vent valves was dictated by the desire to eliminate uncontrolled (random) venting of the tanks and safety considerations. Without additional vent valves, the cold helium used to pressurize the propellant tanks will increase in temperature with a corresponding increase in tank pressure. Within approximately 24 hours the pressure will be sufficient to rupture the burst disc and open the relief valve. Subsequently, random venting of pressure will occur. It is desirable to control this venting to eliminate unwanted disturbance torques which may affect the experiments being conducted. The main problem from the viewpoint of safety is the prevention of catastrophic failure of the tanks. Tank failures can occur in at least two ways: the increase in tank pressure from increased helium temperature combined with a failed-closed relief valve, and micro-meteoroid penetration of a tank at pressures higher than 40 psi. Based on the helium and propellant 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 use of vent valves to de-pressurize shortly after descent engine shutdown will eliminate these problems.

A preliminary review of the descent engine capability to meet the synchronous orbit requirements indicates it will be able to fulfill these requirements. A full thrust engine burn of approximately 535 sec is required. The LEM Descent Engine Test Plan requires a demonstration of the engine capability to burn 17,931 lb of propellants at full thrust (approximately 590 sec burn time).

The use of descent propulsion for the synchronous orbit would require a revision to at least one LEM operational procedure. Since the descent engine controls must be on the Lab (no control interfaces between Lab and CSM), it is necessary to enter the Lab prior to attaining the final orbit. The ramifications of this procedure were not explored.

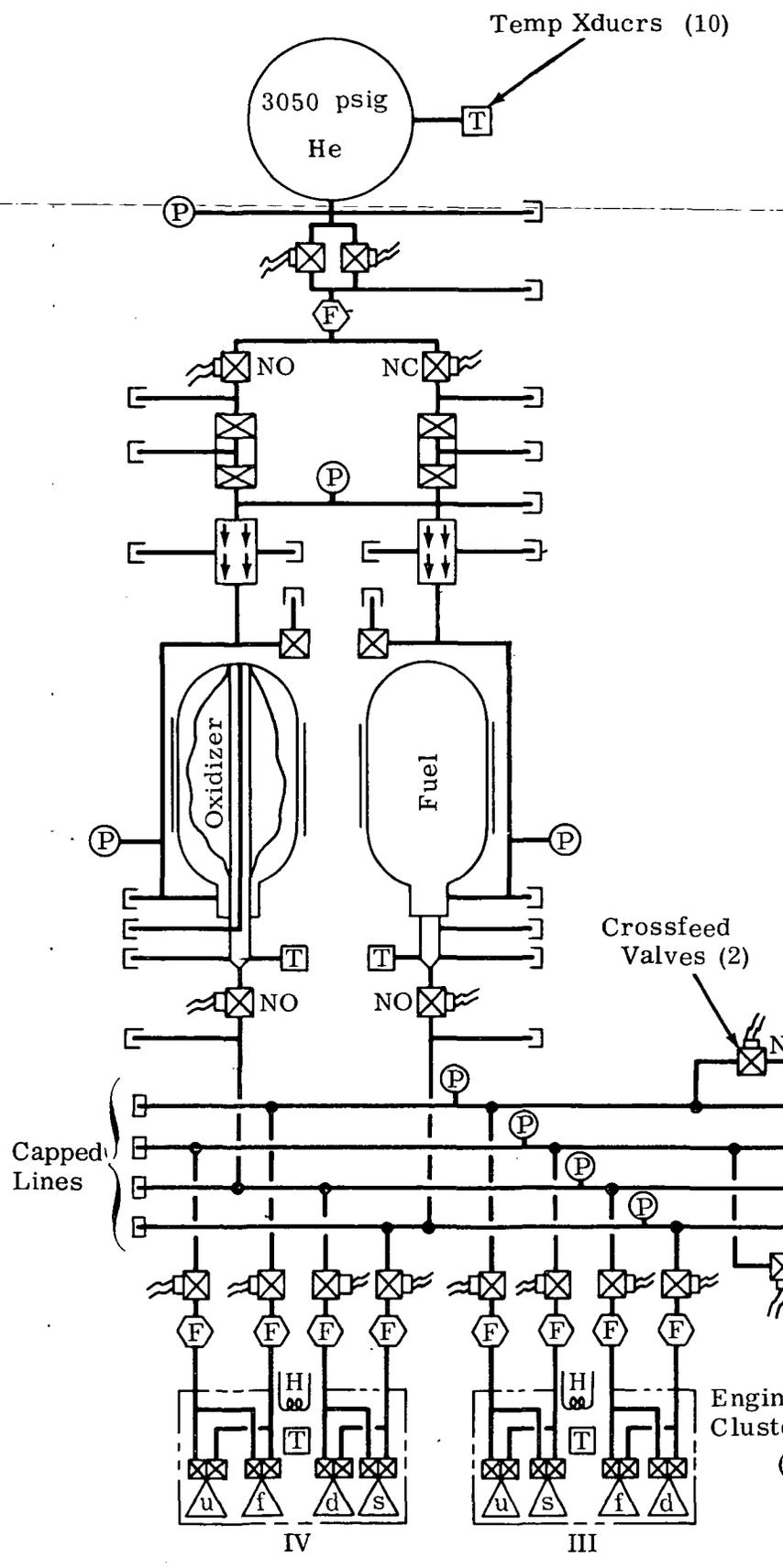
5.4.7 Discussion of Configuration Choice

The basic LEM RCS, as shown in Fig. 5.4-1, has been proposed on the basis of it being able to satisfactorily accomplish the Phase I Lab mission experiments as defined in Phase A studies. The ascent propellant-interconnect valves, filters and switches may be eliminated with minor effort to save hardware cost. Propellant consumption is discussed in Section 4.3. If required, the alternate configuration, with minor changes, as described in Paragraph 5.4.6, may be utilized to make available 101 lb of additional propellant capacity. In a limit cycle minimum impulse bit mode of operation, this alternate configuration (524 lb usable propellant) will be within the 10,000 cycle - 1,000 sec specification life.

TABLE 5.4-1
MAIN PROPULSION HARDWARE

Hardware Removed	Remarks
Ascent Engine	
Ascent propellant feed section	Portions of propellant manifolds may be retained.
Ascent propellant tanks	Including support mounts
Ascent pressurization section	Portions of helium manifolds may be retained.
Ascent helium tanks	
Descent Engine	
Descent propellant feed section	Portions of propellant manifolds may be retained.
Descent pressurization section	Portions of helium manifolds may be retained.
Descent helium tanks	

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NAME

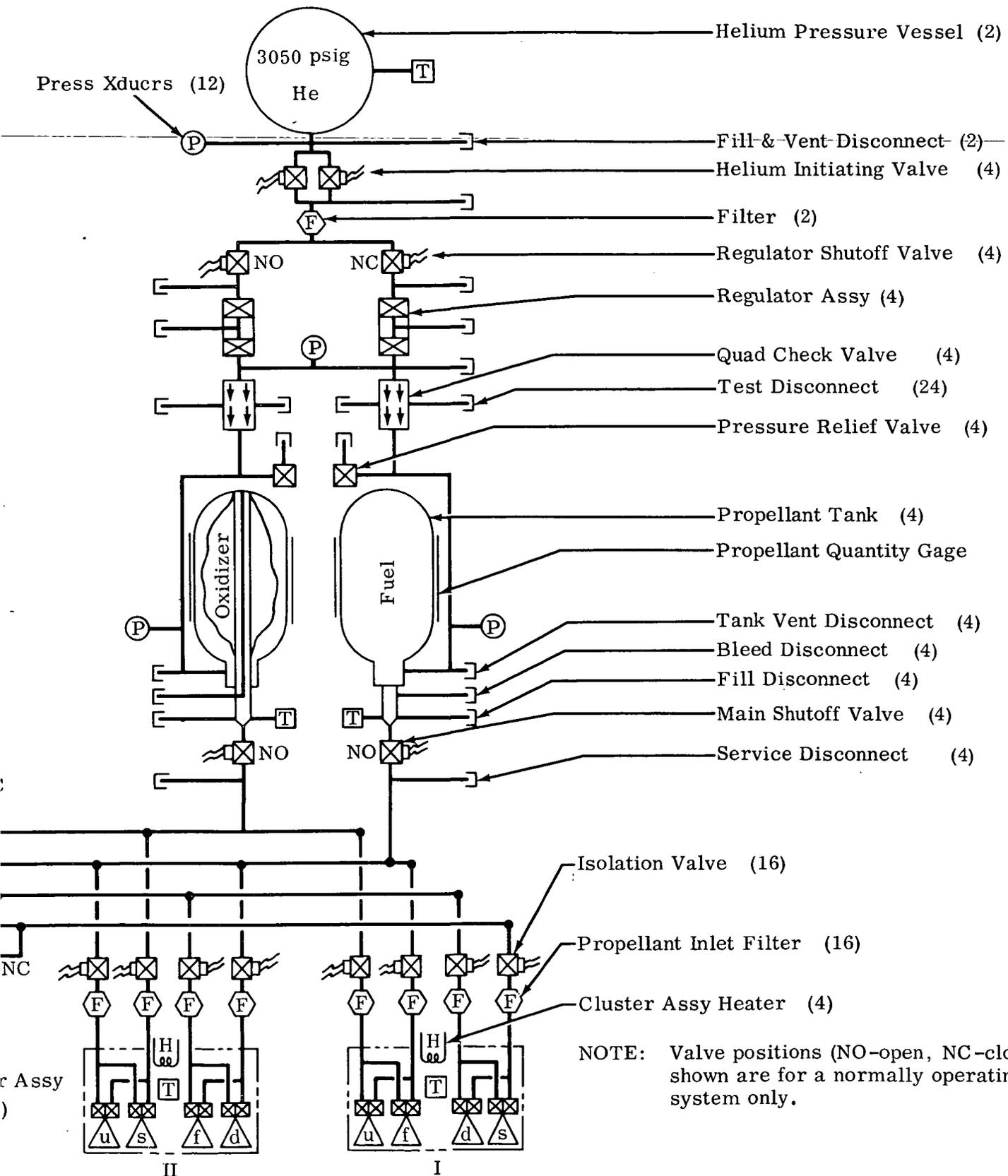


Fig. 5.4-1 Reaction Control Subsystem Phase I Lab

5.5 COMMUNICATIONS

5.5.1 Ground Rules

- There is no data interface between the CSM and Lab
- Lab communications and telemetry subsystems are not dependent on CSM
- Maximum use shall be made of Apollo hardware with minimum modification
- TV transmission will be via the CSM S-Band link to Earth (real time only)
- TV requirements will be satisfied by the present Apollo GFE TV camera. This camera will be deployed from the CSM through the hatches to the Lab, with the power cable extending from the camera to the CSM-S Band subsystem.
- There will be a hardline intercommunications system between the CSM and Lab. The hardline can be used when the Lab is depressurized and the CSM pressurized.

5.5.2 Assumptions and Background Data

5.5.2.1 Assumptions

- There are no TV or data uplink requirements.
- All three astronauts will have continuous audio capabilities.
- EVA communication to the CSM or Lab will be via the VHF link.
- Earth S-band communication link is always available regardless of the intercommunications mode.
- Lab status data will be transmitted to the ground during line-of-sight mission phases.

5.5.2.2 Background Data

The following is a brief description of the LEM communications capabilities upon which the Lab communications are based.

5.5.2.2.1 Communications. Figure 5.5.-1 is a block diagram of the LEM Communications Subsystem showing the changes which convert it to a Lab system. In particular, the S-Band section provides capabilities for:

- Transmission of voice, biomedical data, and telemetry to Earth.
- Aid in tracking and ranging - receives and re-transmits, in phase coherence, a pseudo random noise (PRN) coded signal to enable the MSFN to track the LEM during deep space phases.
- Receiving voice transmission.

The Earth is used as a relay station at S-Band to extend the range of communications between the LEM and CSM. The S-band section is a replica of the unified S-Band concept (i.e., voice, bio-med and telemetry are multiplexed on a common S-Band carrier).

The PM modulators are used for the coherent operational mode, whereas the FM modulator is used for the non-coherent transmission mode. Transmission of both modes or simultaneous operation of the driver-multiplier chains are both precluded. Only one power amplifier is used at a time.

The VHF section is used for LEM/EVA and LEM/CSM communications. The VHF operational modes are:

- Duplex voice with CSM or EVA
- Receive voice/bio-med from EVA
- Transmit 1600 bits/sec data to the CSM.

The VHF B transmitter (259.7 mc) is the only one capable of transmitting PCM data. Either voice or data can be transmitted at one time (not simultaneously). The VHF receiver (259.7 mc) is the only one capable of receiving EVA voice and bio-med data. These are received simultaneously. The LEM/EVA operational modes can be summarized as follows:

- Primary Mode:
 - VHF B = 259.7 mc, duplex-EVA voice and bio-med to LEM (EMU)
 - VHF A = 296.8 mc, duplex voice only LEM to EVA
- Back-up Mode:
 - VHF A = 296.8 mc, duplex voice only EVA to LEM
 - VHF B = 259.7 mc, duplex voice only LEM to EVA

The LEM/CSM link via the antenna system (no hardline).

The signal Processing Assembly (SPA) consists of the pre-modulation processor (PMP) and the two audio centers. The SPA provides the switching and processing for signals within the communications subsystem.

5.5.2.2.2. Antenna System. The LEM antennas applicable to the Phase I Lab are:

- S-band steerable antenna - This is a 26-in. diameter dish antenna mounted on the LEM. It is highly directional and is used for the AES lunar and synchronous orbiting missions.
- Two VHF in-flight antennas - These support the VHF link between the EVA and Lab. These antennas are used for the CSM and Lab link when the vehicles are separated. Only one antenna is used at a time, the operational antenna being selected by the astronaut.
- Two S-band in-flight antennas - These are used as a back-up system to the S-band steerable antenna. For the AES Lab near-Earth orbiting missions, this antenna system is the predominant one. Only one antenna can be used at a time; the astronaut selects the antenna for operation.

To define antenna performance accurately, it is necessary to illustrate and define the radiated signal strength distribution over the spherical surface enveloping the LEM. Figure 5.5-2 illustrates the LEM at the center of the radiation sphere and the superposition of the rectangular and spherical coordinate systems used to describe antenna performance. Also indicated are the locations of reference points on the two dimensional display of the spherical surface which describes antenna radiation distribution plots. With this geometrical scheme, it is possible to determine the effect of vehicle attitude on the Earth communication link. All the diagrams in the further discussion of antennas angular coverage and radiation patterns use this reference coordinate system.

The S-band steerable antenna is a gimballed, circularly polarized antenna which has a gain of 20 db. Angular coverage is approximately 330 by 150 deg (Fig. 5.5-3). The angular coverage is predominately on one side of the LEM. Consequently, during any Lab mission the vehicle may roll to a position requiring use of the S-band in-flight antennas. For synchronous orbit missions, the in-flight antennas can be used for only a limited number of communication operating modes. For the lunar orbiting Lab, the Earth link could be lost because of vehicle roll, since at lunar distances, the in-flight antennas cannot maintain the Earth link.

The S-band in-flight antennas are two circularly polarized log conical spirals mounted on the LEM ascent stage, one along the +Z axis, the other along the -Z axis. Each antenna theoretically provides hemispherical radiation on each side of the vehicle, producing spherical composite coverage. The specified radiated signal strength distribution of these antennas is: "...gain shall be greater than -3 db with respect to right-handed circularly polarized isotrope over no less than 85% of the sphere". The requirement of 85% spherical coverage is met when the radiation patterns of each antenna are superimposed over the sphere.

Figures 5.5-4 and 5.5-5 are composites of antenna model test radiation distribution plots taken with the Apollo LEM at the transmitting and receiving frequencies. The legs are extended and, although the Labs do not have landing legs, these same interference effects may be created by typical experiments. Figure 5.5-6 is a plot of percent coverage vs signal strength relative to an isotropic source. As indicated, there is greater than -3 db gain over 85% of the sphere. These patterns substantiate use of the S-band in-flight antennas for Lab near-Earth orbiting missions.

The VHF in-flight antennas are circularly polarized and have the requirement that antenna gain be greater than -6 db with respect to a linear isotrope over no less than 85% of the sphere. The VHF antennas are used for the LEM/EVA and LEM/CSM (when separated) links. Although antenna test patterns are not presently available, early Apollo experimental test patterns indicated radiation distribution similar to the S-band in-flight antennas. These antennas are adequate for the Lab.

5.5.2.2.3 Ground Station Performance and Capability.

- 200-n.mi Earth Orbit - The following ground stations were used to determine the available communication time (ground station coverage) for inclinations of 28.5, 50 and 90 deg: Antigua, Ascension, Bermuda, Cape Kennedy, Carnarvon, Grand Canary Island, Guam, Grand Bahama Island, Guaymas, Hawaii, and Corpus Christi. These stations each utilize a 30-ft dish antenna capable of tracking the Lab up to 5 deg above the horizon. Since the tracking rate of the 85-ft dishes (3 deg/sec) at other ground stations encompasses the angular rate of a 200-n.mi Lab (approx 0.7 deg/sec), slightly greater ground coverage could be achieved by including these other ground stations (Canberra, Goldstone, and Madrid).

A computer program used for determining ground station coverage indicated the time available for line-of-sight (LOS) communications to Earth from the Lab. An analysis was also done to determine the corresponding operating time of the transmitter.

Figure 5.5-7 illustrates the method used to develop Table 5.5-1. The "ON" step indicates that the S-band transceiver equipment is On, but not in communications

with Earth. This table summarize the communications time and equipment operating time for the various Earth orbits. Figures 5.5-8 through 5.5-10 provide a detailed communications timeline for each of the cases of interest.

- Lunar Orbiting Lab - All of the lunar orbits provide communications time to earth at least equal to 50% of the time. Since telemetry will be transmitted to earth at a bit rate either equal to or greater than that recorded in the Lab, the availability of communication time is not a problem.
- Earth Synchronous Orbiting Lab - For this mission continuous communication time is available. Restrictions imposed by vehicle attitude will govern the time available for communication.

5.5.3 Recommended Configuration

The recommended configuration for the Lab maintains the Apollo LEM Communication and Antenna Subsystems, with the following two minor modifications:

- Modified SPA to accommodate the hardline intercom
- Provision of an additional PCM data channel

These modifications and the resulting performance characteristics follow.

5.5.3.1 Modified SPA

The audio control center portion of the SPA will be modified to accept the intercom input from the CSM and to provide the Lab signal to the CSM (Fig. 5.5-11).

This system provides a variable output intercom system (ICS) amplifier for each vehicle. By turning down the ICS amplifier, the intercom can be disabled to allow an astronaut to sleep undisturbed in the CM. The ICS amplifier may be turned up, and the astronaut in the CM aroused, if required. With this system, each occupant can contact the other vehicle or carry on normal operation without disturbing the routine in the other vehicle.

5.5.3.2 Additional PCM Data Channel

For the earth orbiting Lab missions, the data handling capabilities of the S-band section may be inadequate. To increase the data handling capability, an additional data channel is provided by using the TV baseband spectrum of 0 to 500 kc. This design approach is available because the AES TV requirements will be satisfied via the CSM S-band RF link. The proposed system provides greatly extended Lab telemetry capability with no modification to the communication subsystem.

Previously, a bit rate of 409.6 kilobits/sec (kb/s) had been selected for this additional data channel. A final value depends on further mission requirement analysis and the equipment modifications that are acceptable. Figure 5.5-13 shows bit rates (NRZ data) vs bandwidth for various bandwidth/bit rate ratios. Using the LEM/BR value of 2.94, the available LEM TV baseband bandwidth of 500 kc will provide a data handling capability of 340 kb/s. Using the AES recommended value of 2.35, the system provides a capability of 410 kb/s. It should be noted that the NRZ bit rate is divided by 2 (bits/cycle) to obtain the fundamental frequency of the data.

The design approach is illustrated in Fig. 5.5-12 which reflects a recently incorporated change in the Apollo LEM communication hardware. The figure shows the 410-kb/s data input in place of the TV input for AES PCM data use. This method bypasses the SPA and feeds the PCM signal directly into the S-band FM modulator. The matrixed signals from the PMP FM mixing network (PCM 51.2 kb/s and voice bio-med) are fed through a high-pass filter to remove intermodulation distortion. This clean composite signal is then combined with the PCM signal in the linear adder circuit to form a new complex composite signal. This signal is applied to the voltage controlled oscillator (VCO), where frequency modulation is effected, i.e., the changing input signal voltage yields a changing output frequency from the VCO. This output is then passed through a power FM limiter to remove any residual amplitude variations and then proceeds to the S-band driver multiplier chain. As indicated in Fig. 5.5-12, no modifications to the equipment are required, and an additional FM PCM data-channel of 410 kb/s is provided. The only requirement presently foreseen for this approach is the assurance of matched impedances at the present TV input and compatible signal levels.

5.5.3.3 Performance Characteristics

The AES Lab communication subsystem is illustrated in Fig. 5.5-1 and the operational modes indicated in Fig. 5.5-14. Frequency allocation is designated in Fig. 5.5-15. The following operational formats are selected:

- PRN Ranging - This mode is on PM and involves a received and retransmitted signal to ground (Paragraph 5.5.2.2.). The PRN ranging will not be required when the Lab and CSM are docked. The CSM will provide range information via its S-band system. This will allow the Lab to use the full FM mode as required when a large quantity of experimental data is being accumulated.
- Lab Spacecraft Status Data - This is transmitted by FM or PM on a 1.024-mc subcarrier (51.2 kb/s normally) to ground when in LOS.
- Recorded Experiment Data - This data is transmitted by FM at the rate of 410 kb/s over the TV baseband (0 to 500 kc) in place of the LEM TV mode.
- Voice Bio-Med - Voice is received on a 30-kc subcarrier from ground. Astronauts' voice and bio-med are transmitted to ground simultaneously on a 1.25-mc subcarrier. This mode can include an EVA. A PM back-up mode exists on the 0 to 14 kc band. Bio-med of only one of the Lab occupants can be accommodated at one time

The full FM mode consists of experiment data, status data, and voice/bio-med transmitted simultaneously. The full PM mode consists of PRN ranging, status data, and voice/bio-med transmitted simultaneously.

During EVA when the two vehicles are docked, the hardline intercom will be used for the inter-vehicle voice link and the EVA astronaut will utilize the VHF link to both vehicles.

In addition to this general operational format, further consideration is given to mission related circuit margins and antenna characteristics.

5.5.3.3.1. Mission Related Circuit Margins. Circuit performance margins were determined for the 200-n.mi and synchronous Earth orbit missions, as well as the lunar orbit mission. The analysis is that presently used on the Apollo LEM (LIS 380-15006). The same modulation index is used for the additional data channel (410 kb/s)

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as that used for the LEM TV. In the analysis, assigned antenna gains are 20 db for the S-band steerable and -3 db for the S-band in-flight antennas. The listed circuit performance margins are greater than the S/N system requirements.

- 200-n.mi Altitude Orbit - A 30-ft dish antenna at the ground station is assumed.
 - Full FM mode: PCM (410 kb/s)/PCM (51.2 kb/s)/voice and bio-med
 - 20 watts to steerable

C/N	+46.6 db
S/N (410)	+58.9 db
S/N (51.2)	+50.9 db
S/N (voice, bio-med)	+49.2 db
 - 3/4 watt to steerable

C/N	+30 db
S/N (410)	+42.4 db
S/N (51.2)	+44.4 db
S/N (voice, bio-med)	+32.6 db
 - 20 watts to in-flight antennas

C/N	+21.5 db
S/N (410)	+33.9 db
S/N (51.2)	+35.9 db
S/N (voice, bio-med)	+24.1 db
 - 3/4 watt to in-flight antennas

C/N	+ 4.9 db
S/N (409.6)	+17.3 db
S/N (51.2)	+19.3 db
S/N (voice, bio-med)	+ 7.5 db
 - Full PM mode: PRN ranging/PCM (51.2 kb/s)/voice
 - 3/4 watt to in-flight antennas

C/N	+42.3 db
S/N (PRN)	+25.3 db
S/N (51.2)	+14.4 db
S/N (voice)	+15.8 db
- Synchronous Orbit - The circuit performance margins presented are those for a 30-ft dish antenna at the ground unless otherwise indicated. Where the 30-ft dish is used, the circuit margins can be updated for larger dishes by adding 9 db for an 85-ft dish, and 18 db for the 210-ft dish.
 - Full FM mode: PCM (410 kb/s)/PCM (51.2 kb/s)/voice and bio-med
 - 20 watts to steerable

C/N	+ 6.6 db
S/N (410)	+18.9 db
S/N (51.2)	+10.4 db
S/N (voice, bio-med)	+ 9.2 db

- 3/4 watt to steerable, 210-ft ground dish
 - C/N + 8.0 db
 - S/N (410) +20.4 db
 - S/N (51.2) +11.8 db
 - S/N (voice, bio-med) +27.2 db
- 20 watts to in-flight antennas, 210-ft ground dish
 - C/N - 0.4 db
 - S/N (410) +11.9 db
 - S/N (51.2) + 3.3 db
 - S/N (voice, bio-med) + 2.1 db

o PCM mode: PCM (51.2 kb/s)/voice

- 3/4 watt to steerable, 85-ft ground dish
 - C/N +38.8 db
 - S/N (51.2) +10.8 db
 - S/N (voice) +12.2 db
- 20 watts to in-flight, 210-ft ground dish
 - C/N +39.3 db
 - S/N (51.2) +12.7 db
 - S/N (voice) +13.5 db

o PM mode: PCM (1.6 kb/s)/voice, bio-med

- 20 watts to steerable
 - C/N +46.4 db
 - S/N (1.6) +26.6 db
 - S/N (voice, bio-med) +23.9 db
- 3/4 watt to steerable
 - C/N +29.8 db
 - S/N (1.6) + 9.9 db
 - S/N (voice bio-med) + 7.3 db
- 20 watts to in-flight antennas, 85-ft ground dish
 - C/N +30.3 db
 - S/N (1.6) +10.5 db
 - S/N (voice, bio-med) + 7.8 db

These circuit performance margins illustrate the inherent flexibility for accommodating unfavorable vehicle attitudes during experiment operation. Communications and telemetry capability always exists for this mission.

• Lunar Orbit

o Full FM mode: PCM (410 kb/s)/PCM (51.2 kb/s)/voice and bio-med

- 20 watts to steerable, 210-ft ground dish
 - C/N + 4.6 db
 - S/N (410) +16.9 db
 - S/N (51.2) + 8.4 db
 - S/N (voice, bio-med) + 7.2 db

- o PM mode: PCM (51.2 kb/s)/voice
 - 20 watts to steerable, 85-ft ground dish
 - C/N +35.4 db
 - S/N (51.2) + 8.8 db
 - S/N (voice) + 9.5 db

- o Full PM mode: PRN ranging/PCM (51.2 kb/s)/voice
 - 20 watts to steerable, 210-ft ground dish
 - C/N +43.3 db
 - S/N (PRN) +23 db
 - S/N (51.2) +14 db
 - S/N (voice) + 9.3 db

Although this mission is limited in operational modes some operating flexibility is made available because of the longer communication time available.

5.5.3.3.2 Mission-Related Antenna Characteristics. The antenna system is sensitive to the Lab experiment payload package in that radiation can be obstructed and destructive interference can be caused by multiple reflections. In addition, the mated vehicle configuration can produce unfavorable results. The proposed antenna system can only be confirmed after antenna model tests.

The EVA backpack antenna is a monopole with linear polarization. (Backpack has a transmitting power of 75 mw.) Since both the CSM and Lab have circularly polarized antennas, there will be a variable power loss due to the differences in polarization. The maximum one-way power loss vs voltage axial ratio is plotted in Fig. 5.5-16. The radiation distribution plot, in the vicinity of the descent stage and the power loss due to arbitrary polarization, will require analysis to insure that signal strength is adequate to maintain the EVA link.

The data presented (antenna patterns and circuit margins) indicate that the S-band in-flight antennas can be used as the primary antenna system for the 200-n.mi Earth orbit mission, thereby placing a minimum constraint on vehicle attitude.

5.5.4. Baseline Configuration

The baseline configuration was based on using the PM mode for incorporating the additional PCM data channel. This involved a modification to the PMP portion of the SPA. Recent developments in the Apollo Program allow the use of the TV baseband in the FM mode with no modification to the SPA.

The resulting operational format changes, particularly for the 200-n.mi Earth orbit missions, are:

- FM is now the primary full operational mode for communications and telemetry.
- The Lab will provide PRN ranging only as a back-up to the CSM (contingency mode) or when the Lab and CSM are separated.

5.5.5 Alternate Configuration - Coupled S-Band/VHF In Flight Antennas

The S-band in-flight antenna patterns and circuit margins presented earlier substantiate the use of these antennas for the 200-n.mi Earth orbit missions. It appears desirable to couple these antennas and remove the need for manual switching from one antenna to another.

A system of coupling the two antennas can be devised and developed. In particular, systems of two, three, and four in-flight antennas were analyzed to determine their radiation characteristics. Each system's antennas were distributed symmetrically about the vehicle. Utilizing ray theory and vector summation, distribution patterns were derived. These studies indicated that the two-antenna system is the more practical for the Lab missions. The circuit performance margins would allow the -3-db loss. The radiation distribution for this system is shown in Fig. 5.5-18. A computer program is being used to determine the pattern envelope in more detail and accuracy over the regions ranging from 260 to 280 deg and 80 to 100 deg. Some pattern scalloping should be realized in these regions. Determining the nature and extent of the scalloping requires the vector summation to be taken over finer intervals of 1 deg, whereas 5-deg intervals were chosen for the initial analysis.

Similarly, the VHF in-flight antennas could be coupled to remove the need for antenna switching. Although the coupled VHF multifilar helix antennas were not analyzed, an approach similar to that used for the S-band antennas could be used. The resultant determined radiation would not be as free from nulls as with the S-band patterns, since early experimental tests indicated that the VHF radiation distribution contains null areas.

5.5.6 Alternate Configuration - S-Band Transceiver Cycling

As stated previously, the preceding ground station will notify the Lab as to the time interval of the next ground station contact. The S-band transceiver is then cycled manually by the astronaut, or cycling may be provided automatically by the addition of a timer-relay to the equipment. The astronaut could use this additional component when required (intervals between ground stations greater than 15 min). The automatic cycling is more practical due to the anticipated amount of astronaut activity during the Lab missions.

5.5.7 Alternate Configuration - Addition of Internal TV Jack

The addition of an internal TV jack to the Lab will allow for TV transmission directly from the vehicle. TV transmission would be time shared with the 410-kb/s data channel in the full FM mode. Additional cables and switching would be required.

5.5.8 General Discussion and Conclusions

The recommended communications systems satisfy the requirements of the Lab. Table 5.5-2 summarizes the approaches to providing the additional data channel.

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Table 5.5-1
COMMUNICATIONS TIME

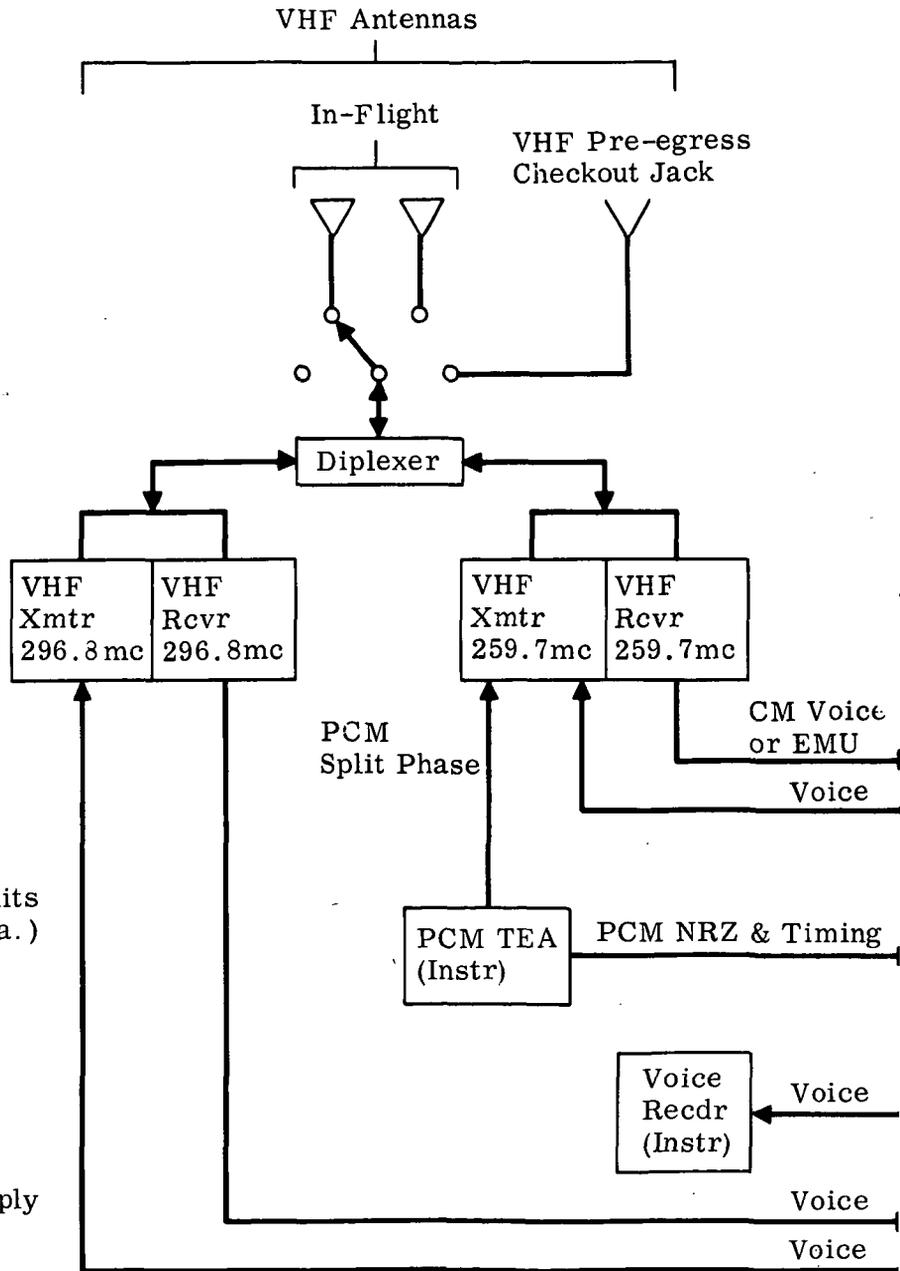
Orbit Alt, n.mi	200		200		200	
Inclination, deg	28.5		50		90	
Rev No.	Transit Time, min	T/R On, min	Transit Time, min	T/R On, min	Transit Time, min	T/R On, min
1	17.43	73	0	0	11	14
2	16.38	36	8.96	19	1.78	5
3	39.23	68	17.88	39	6.21	9.5
4	38.62	53	33.2	49.5	13.39	22.5
5	17.9	29	14.5	17.5	4.69	15.5
6	13.52	19	10.75	14	11.61	18.5
7	10.79	23.5	3.66	7	15.85	20
8	8.33	15	6.28	9.5	7.55	10
9	4.67	8	6.36	9.5	7.43	10.5
10	7.27	10.5	7.51	10.5	4.87	8
11	6.7	10	7.27	10.5	4.17	7.5
12	2.92	6	10	16	7.9	14
13	7.1	10.5	7.35	13.5	13.36	19
14	21.23	32	17	23	7.52	11
15	24.44	35	11	14	16.7	23
16	29.85	39	14.5	17.5	12	18
17	27.89	39	13	19	7.5	11
18	33.31	52	18	32	0	0
19	36.22	57	19.1	37	7.53	11
20	32.76	55	22.16	32.5	0	0
21	19.45	34	23.3	38	21.12	29
22	11.96	23	6.8	10	6.29	16
23	7.19	10.5	2.76	6	15.38	22
24	4.22	17.5	7.5	10.5	7.4	10.5
25	13	19	0	0	7.54	11
26	14.72	21	11.78	18	0	0
27	0	0	16.5	25	7.22	10.5
28	6.54	10	7.3	10.5	13.35	19.5
29	16.89	27	14.37	20.5	7.73	11
30	24.29	31.5	12.5	18.5	15	22
31	25.66	36	18.5	21.5	16	22.5
32	26.41	36.5	9.75	16	7.54	11
33	33.35	54.5	9	15	5.74	9
34	34.87	52	17.5	33	3.16	6.5
35	38.25	51	12.9	27	6.37	10
36	29.4	48	22.5	34	8	17
37	13	23	8.85	12	13.48	19
38	9	22	0	0	13.6	20
39	12	27	4.5	7.5	18	25
40	12	18	2.6	4	8	11
41	8.5	14.5	6.17	11.5	6.78	10
42	9	12	7.29	10.5	0	0
43	5	8	15.03	21.5	7.26	10.5
44	15.5	27	9.23	19	0	0
45	21	32	14.6	18	21.9	29.5
46	26	36.5	16.4	22.5	.97	4
47					18.21	24.5
48					7.63	11
	Per 46 Revs		Per 46 Revs		Per 47 Revs	
Max. Comm Time Available, min	833.76		543.86		417.1	
Total Xcvr Time On, min	1362.0		820.5		629.5	
On-Off Cycles	68		64		58	

Table 5.5-2

SUMMARY OF POSSIBLE MODES OF ADDITIONAL DATA TRANSMISSION

Mode	Data Rate, k-bits/sec	Mods	To be Determined or Req'd
1. PM ● On 500-kc baseband	402.6	To SPA	<ul style="list-style-type: none"> ● Ability of ground to handle wideband data in FM mode. ● Details of mod.
2. FM ● On 500-kc baseband (RECOMMENDED)	409.6	None	<ul style="list-style-type: none"> ● Ability of ground to track 200 n.mi Lab in FM mode. ● Exact nature of added hardware. ● See Note.

Note: It is assumed that the ground stations can process the FM wideband data because of their ability to receive and process the Apollo TV signal.



Note: EMU (Extravehicular Mobility Unit Transmits both EVA voice & data.)

*Change from present LEM system.

Key
P → Power Supply
→ Signal

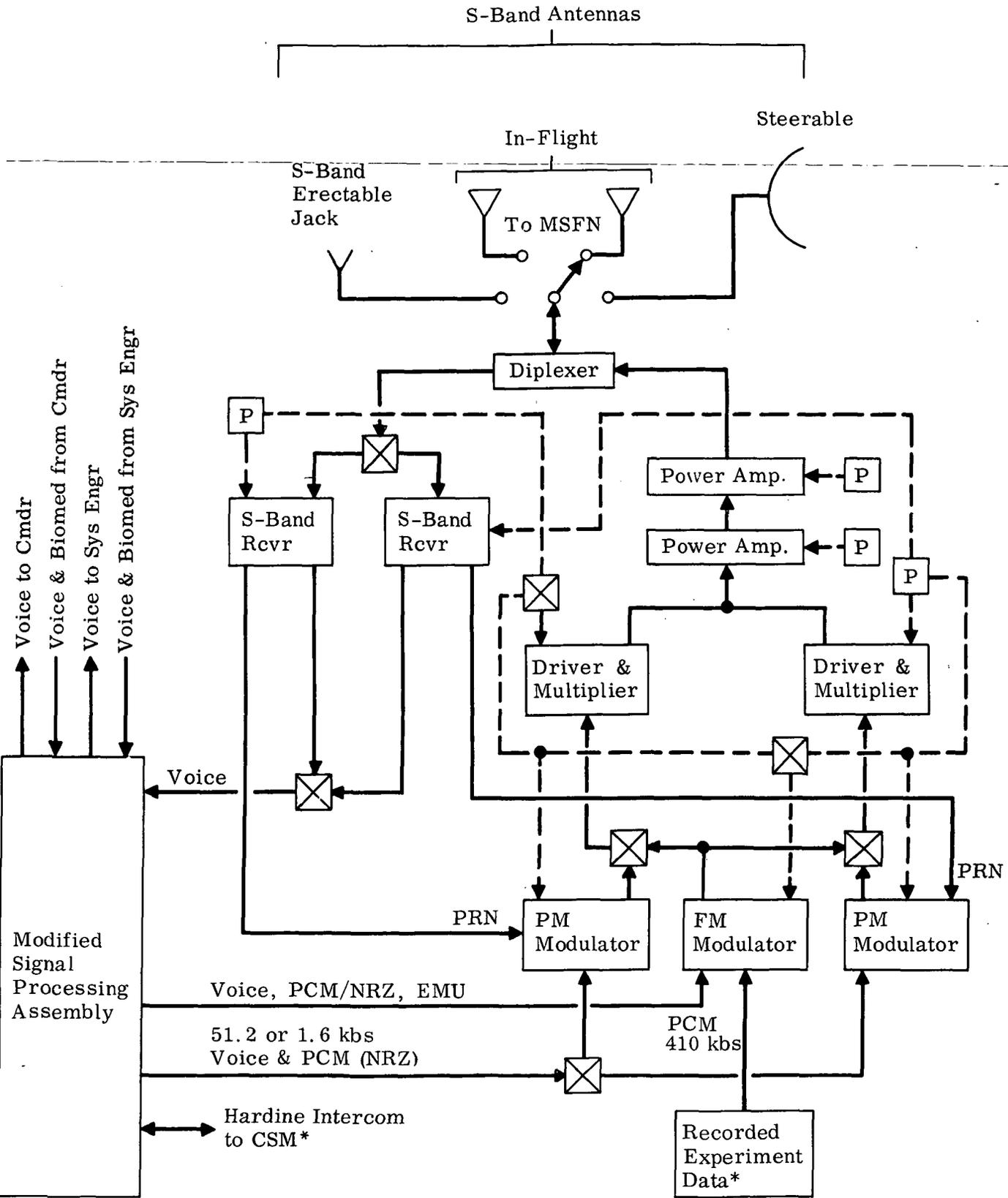


Fig. 5.5-1 Communications System Schematic

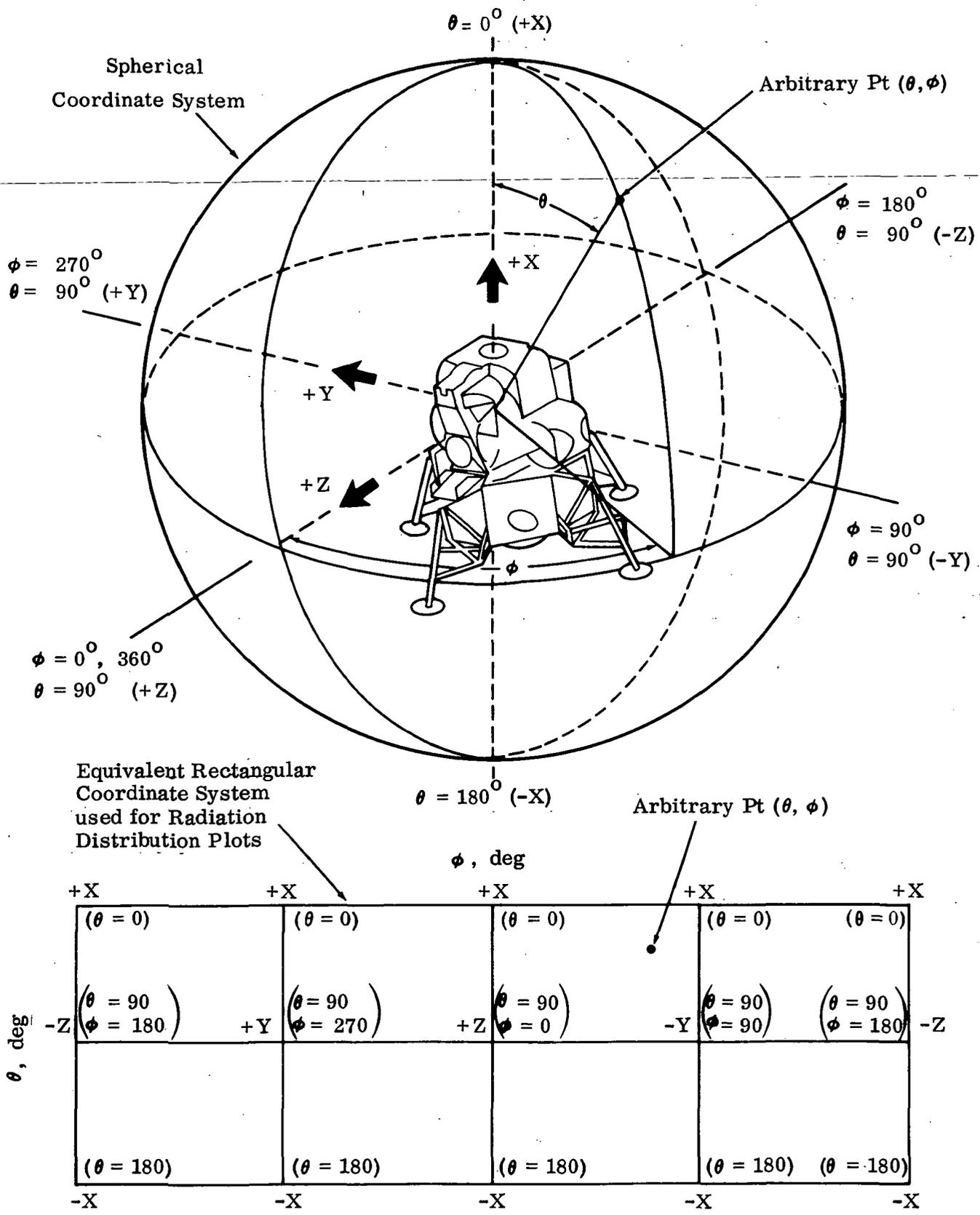


Fig. 5.5-2 Spherical/Rectangular Coordinate Transformation

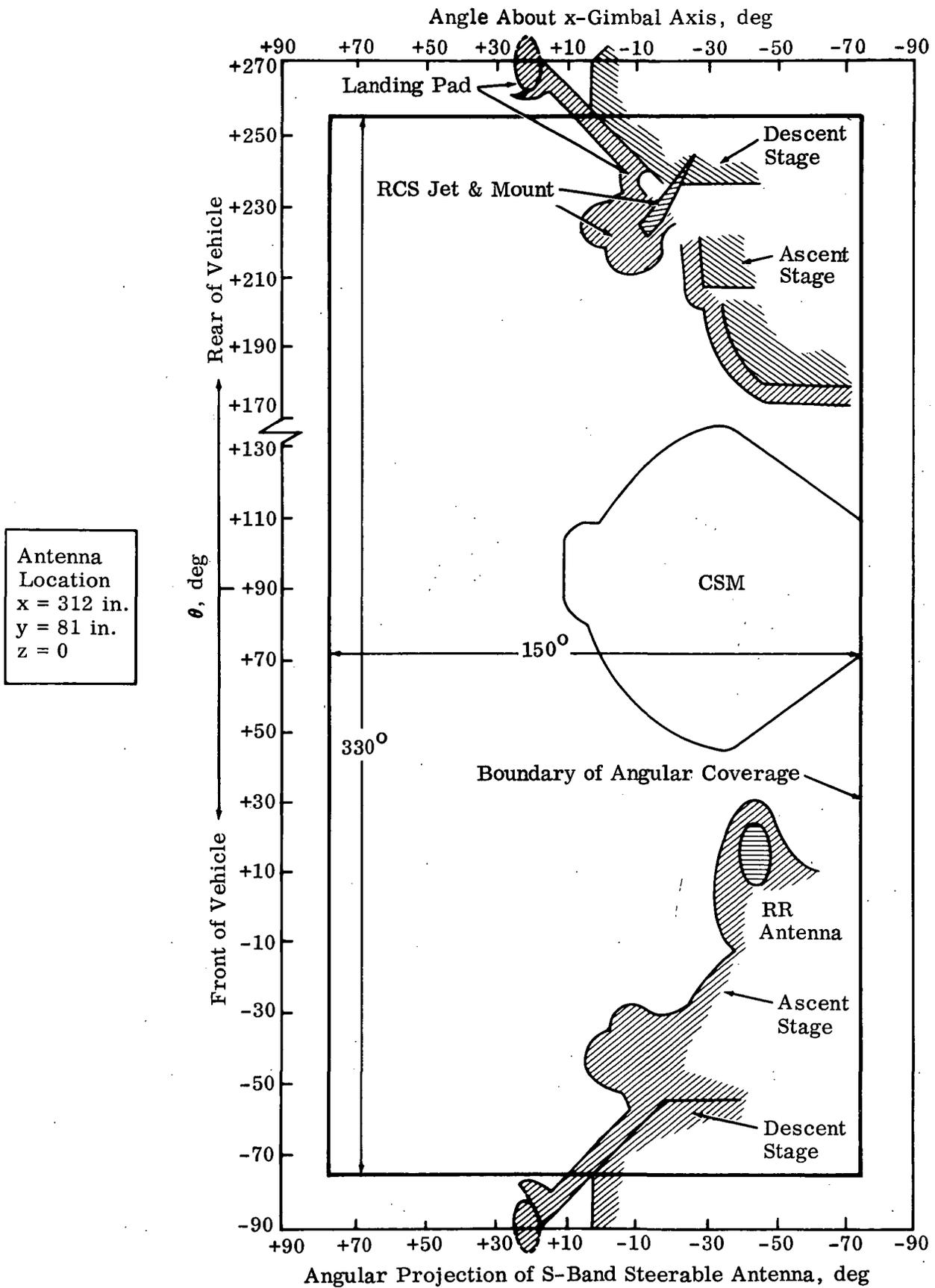
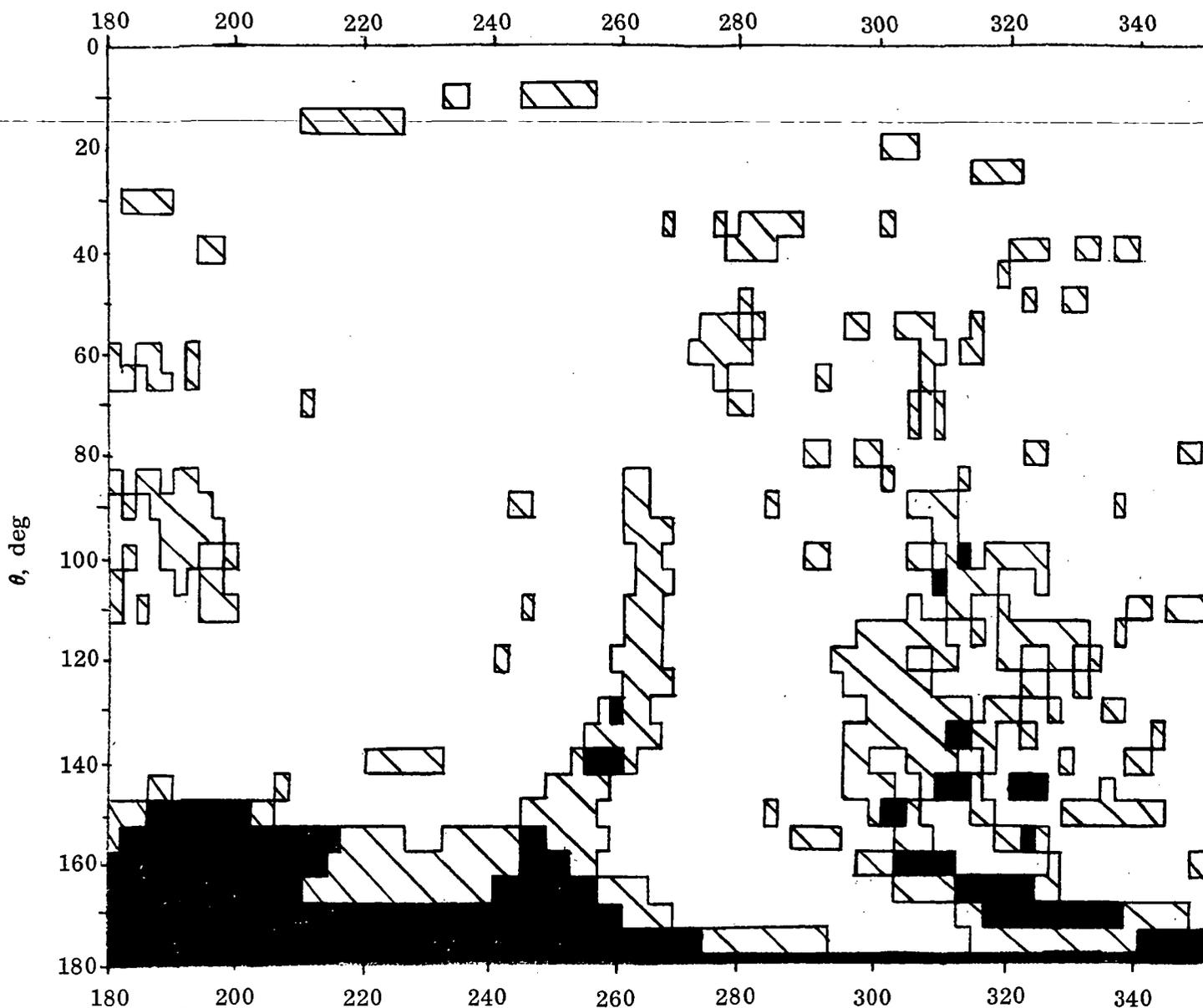


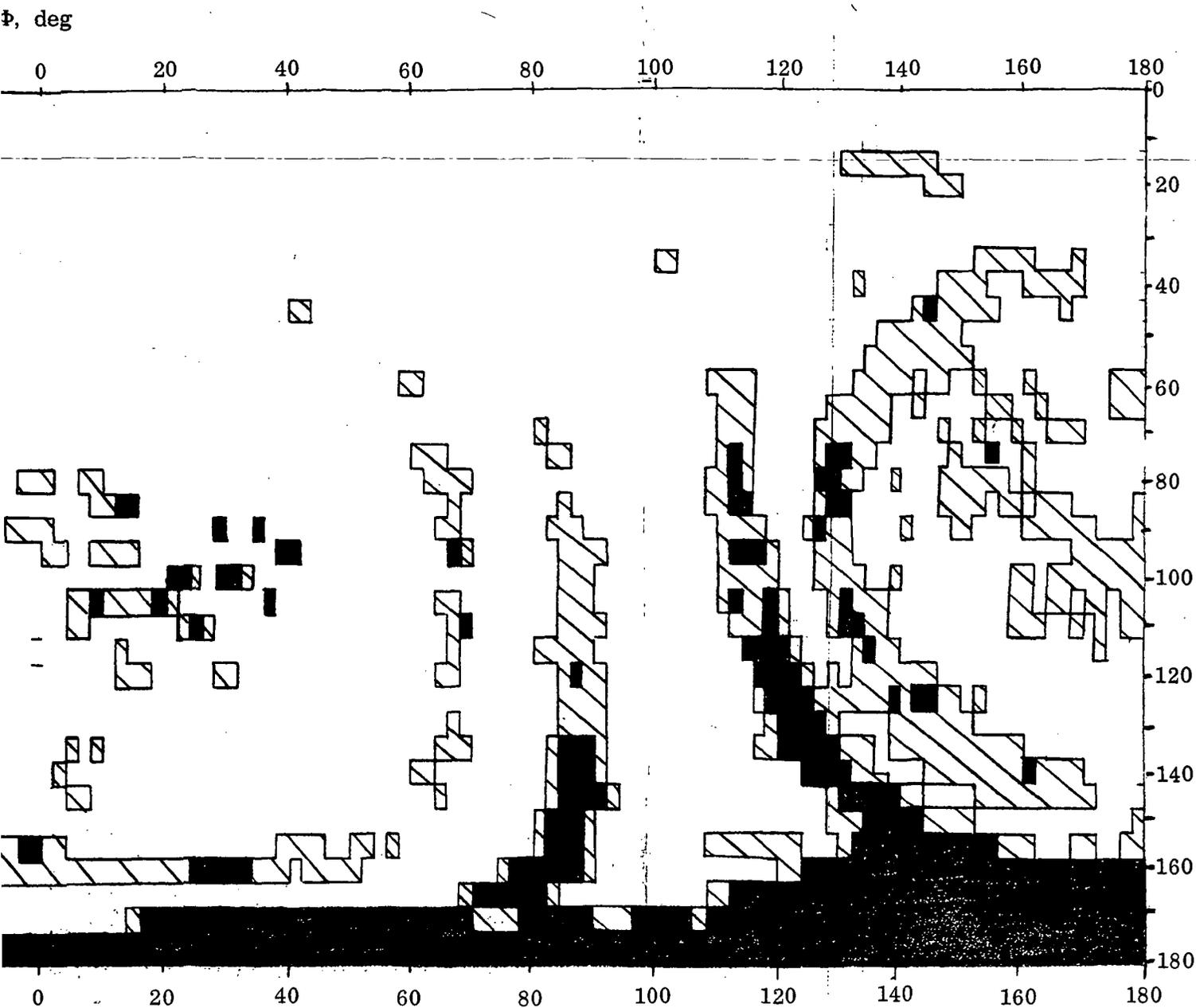
Fig. 5.5-3 S-Band Steerable Antenna Angular Coverage on a Projection of 2 Sphere

91



-  Greater than zero db
-  Zero to -3db
-  Less than -3db

- LEM Program: S-Ba
- Full Scale Frequenc
- Predominant Polariz
- Antenna Type: Conic
- Model Scale: 1/6
- Model Scale Frequen



and System
: 2101mc
ation: RCP
1 Log Spiral
y: 12.6 Gc

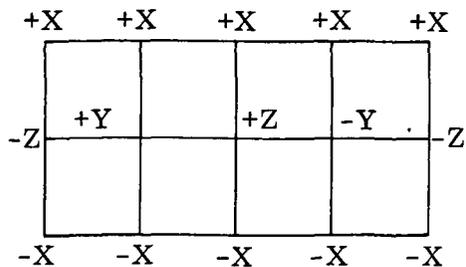
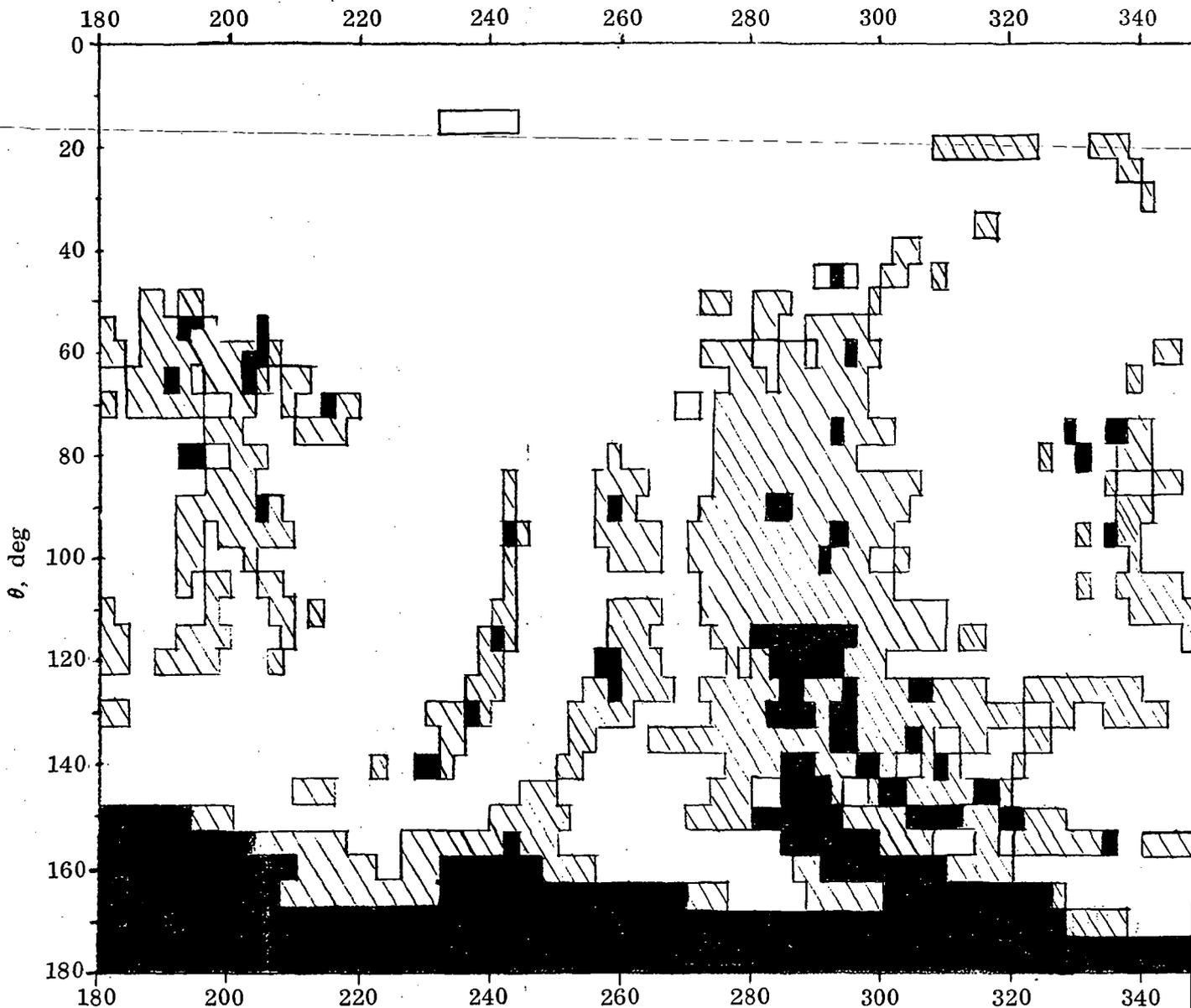


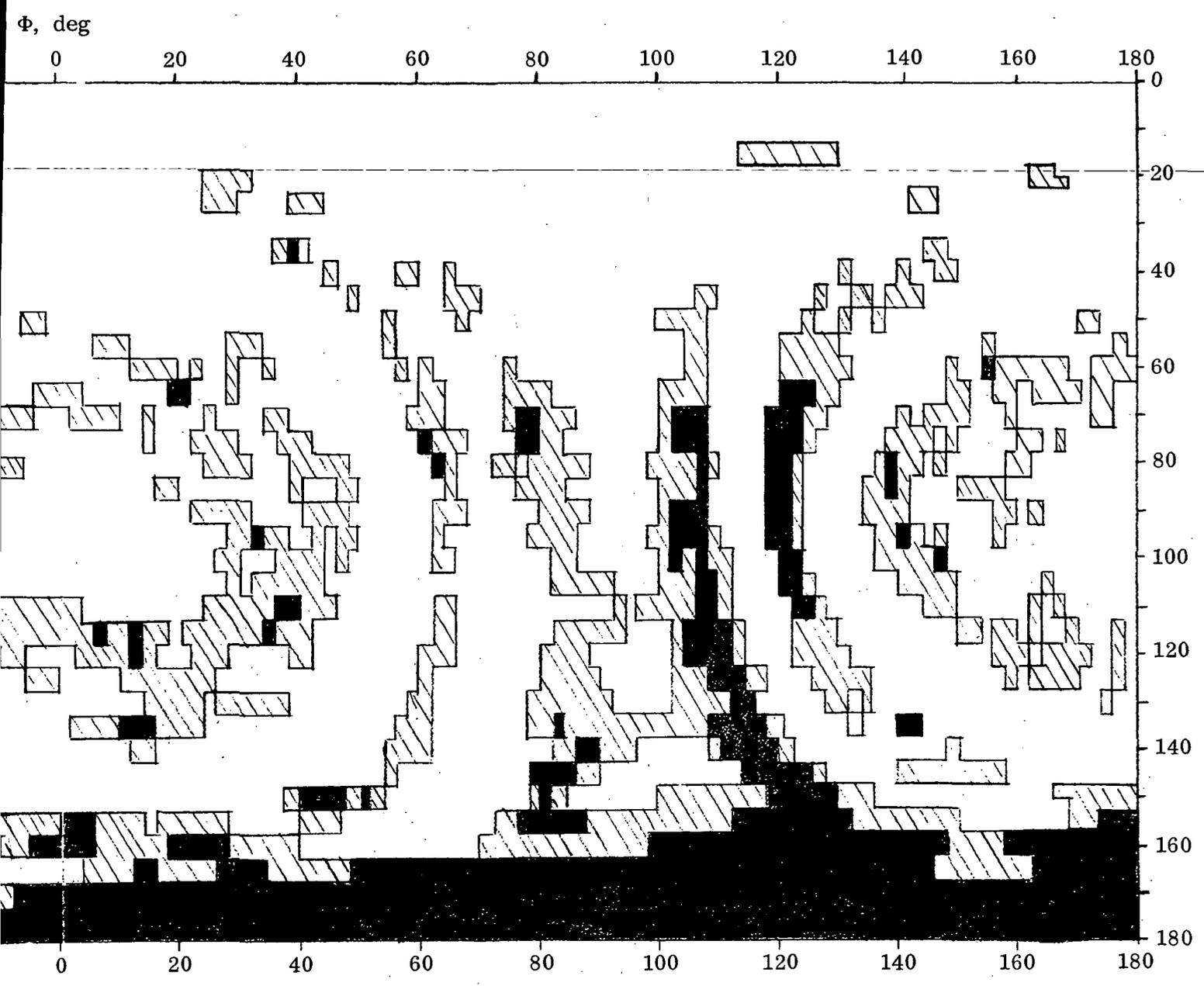
Fig. 5.5-4 S-Band In-Flight Antenna Receive

(53)



-  Greater than zero db
-  Zero to -3db
-  Less than -3db

- LEM Program: S-Band
- Full Scale Frequency: 2
- Predominant Polarization
- Antenna Type: Conical I
- Model Scale: 1/6
- Model Scale Frequency:



ystem
 32 mc
 RCP
 g Spiral
 3.7 Gc

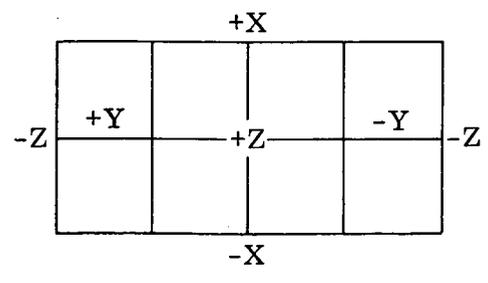


Fig. 5.5-5 S-Band In-Flight Antennas Transmit

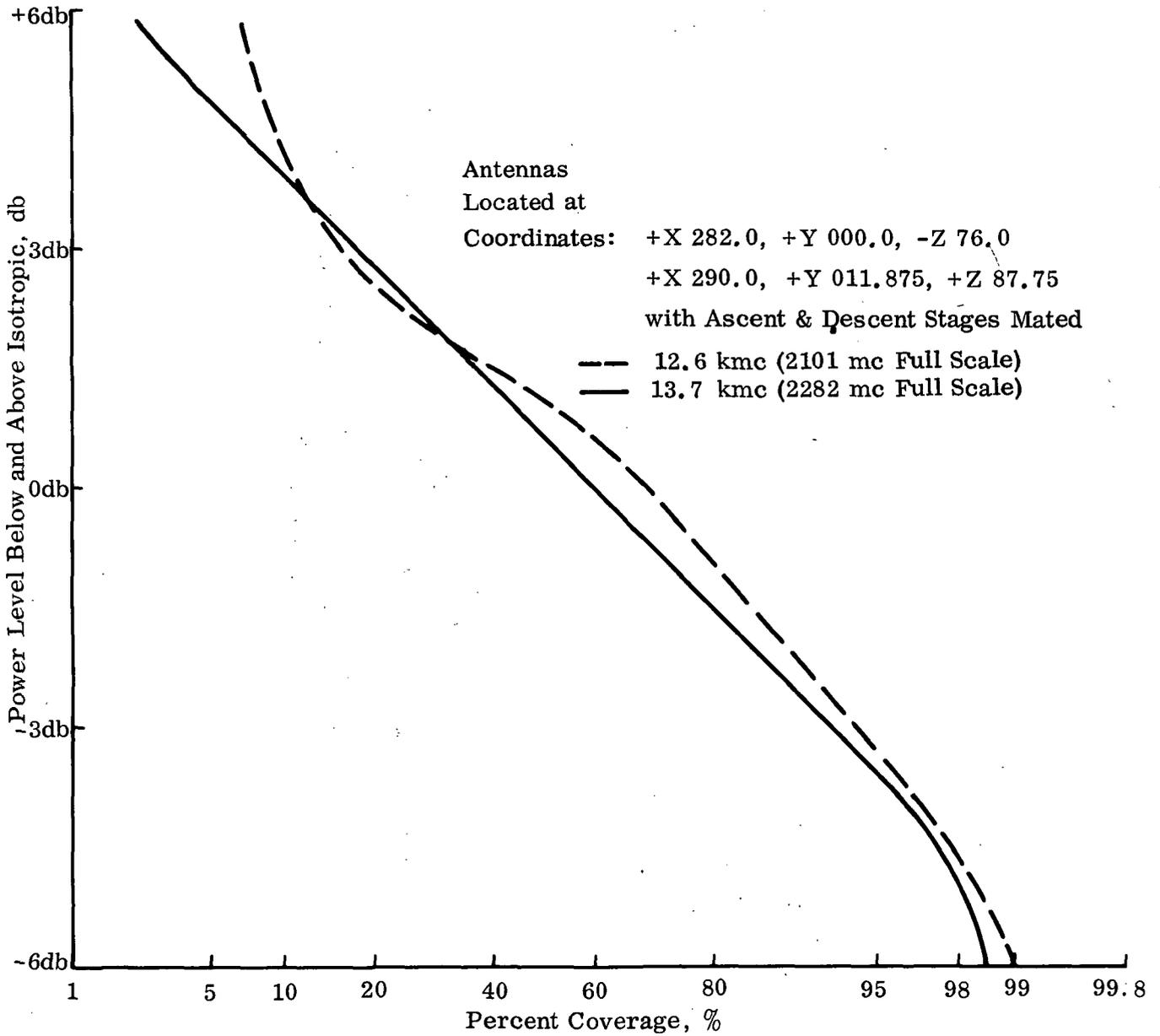
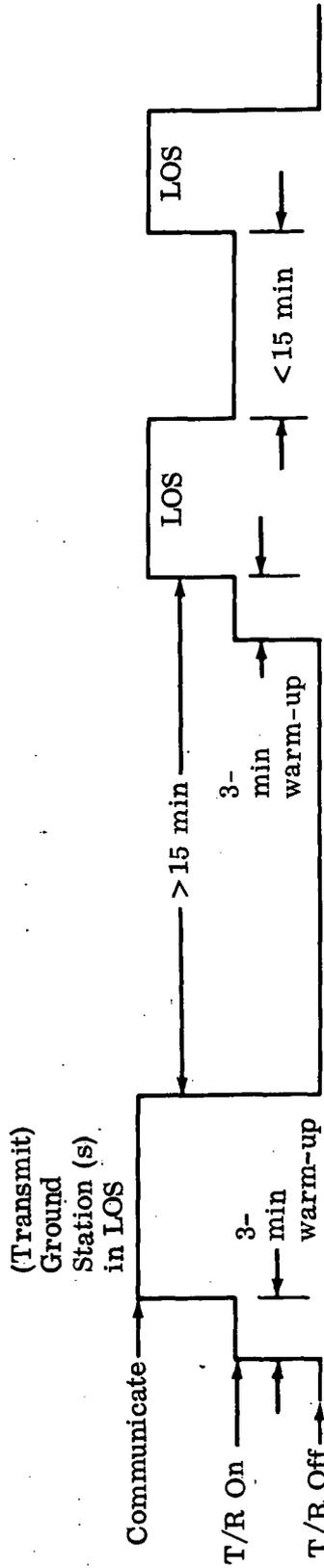


Fig. 5.5-6 S-Band In-Flight Antennas, Percent Coverage



Assumptions: • Transmitter Warm-Up Time = 3 min

- When the Interval Between Ground Stations is Less Than 15 min, the Equipment is Left On To Reduce Off-On Cycling.

Fig. 5.5-7 Time Line Code

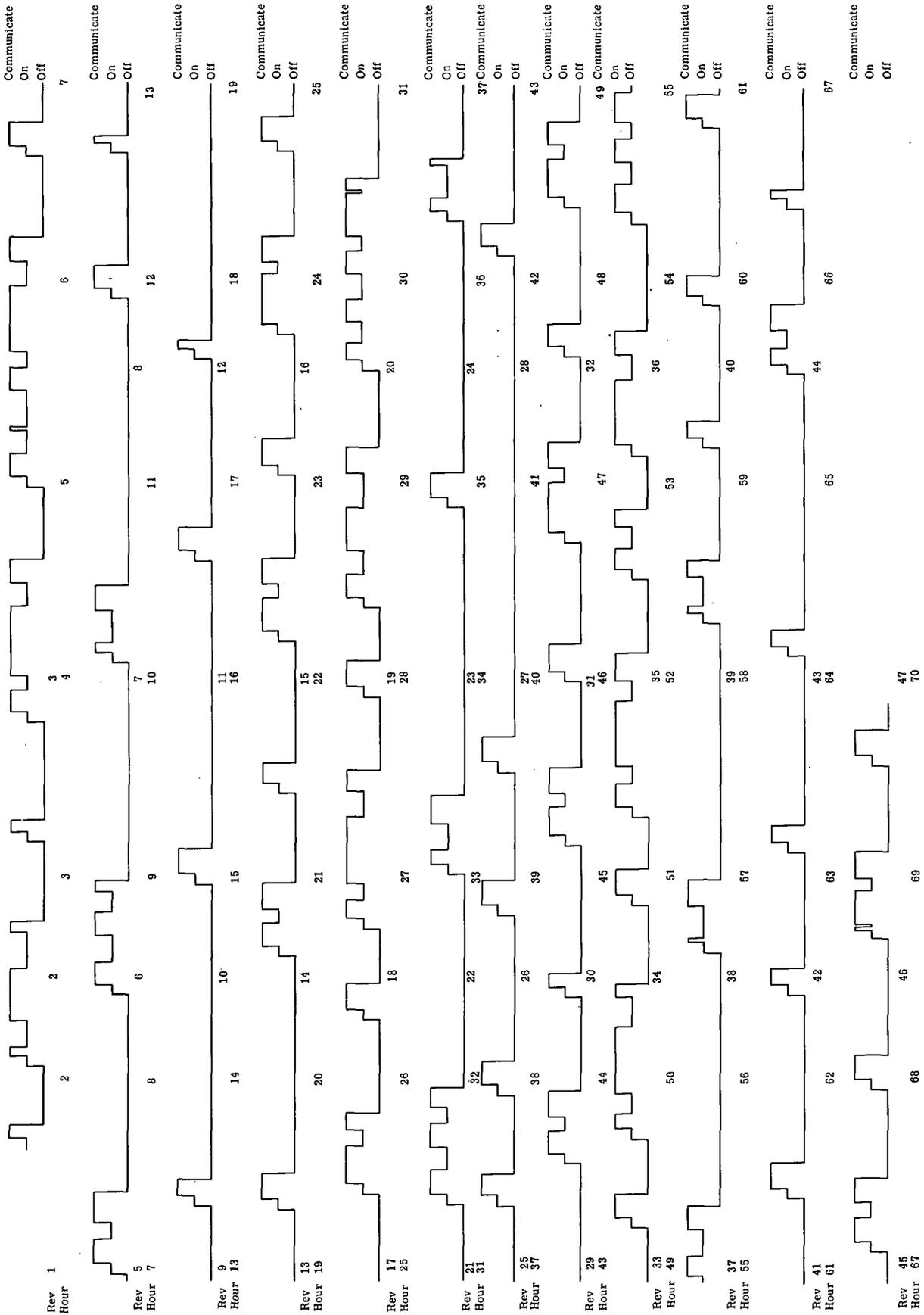


Fig. 5.5-8 Communication Profile - 200 N. Mi and 28.5° Inclination

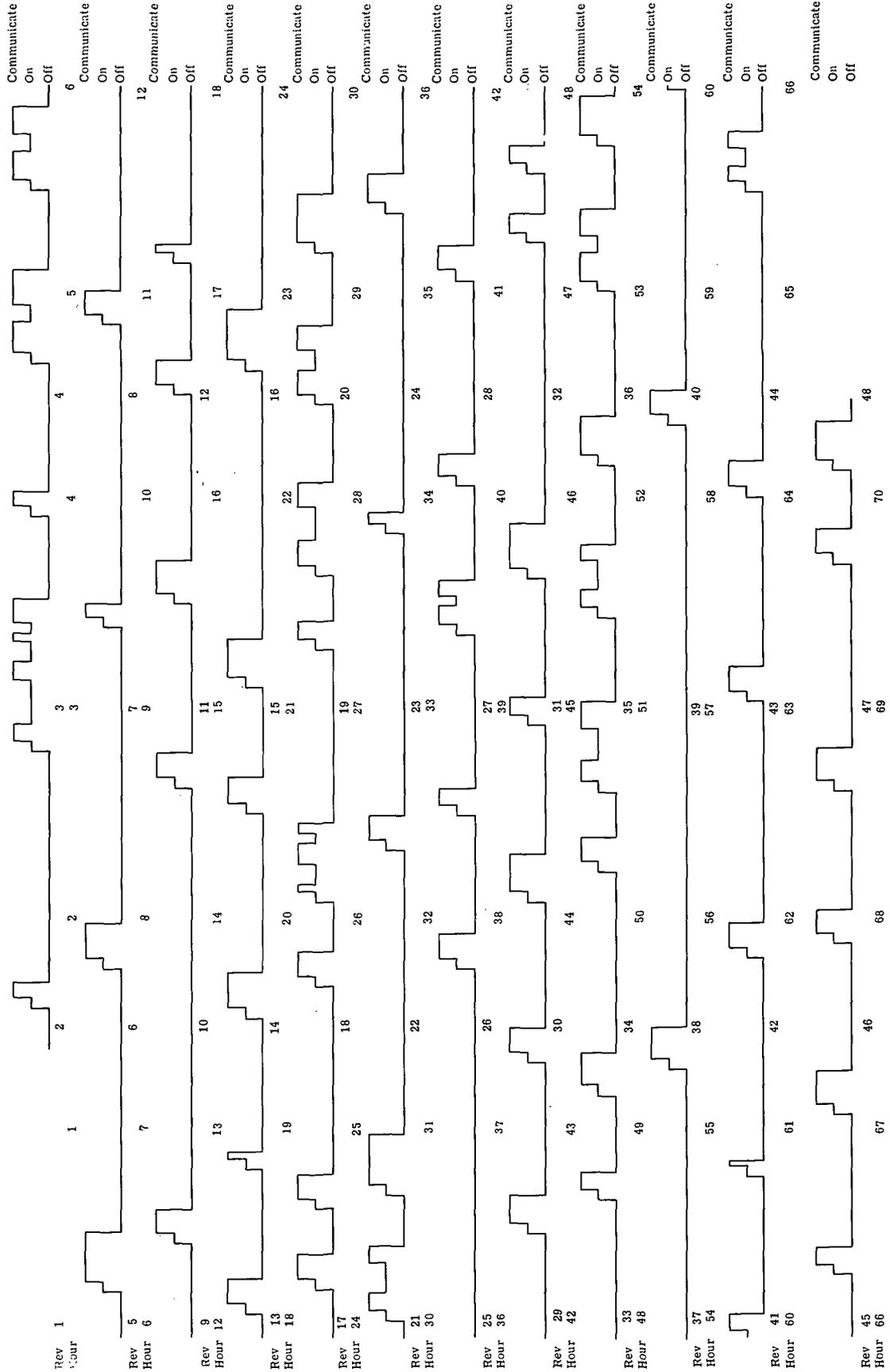


Fig. 5.5-9 Communication Profile - 200 N. Mi and 90° Inclination

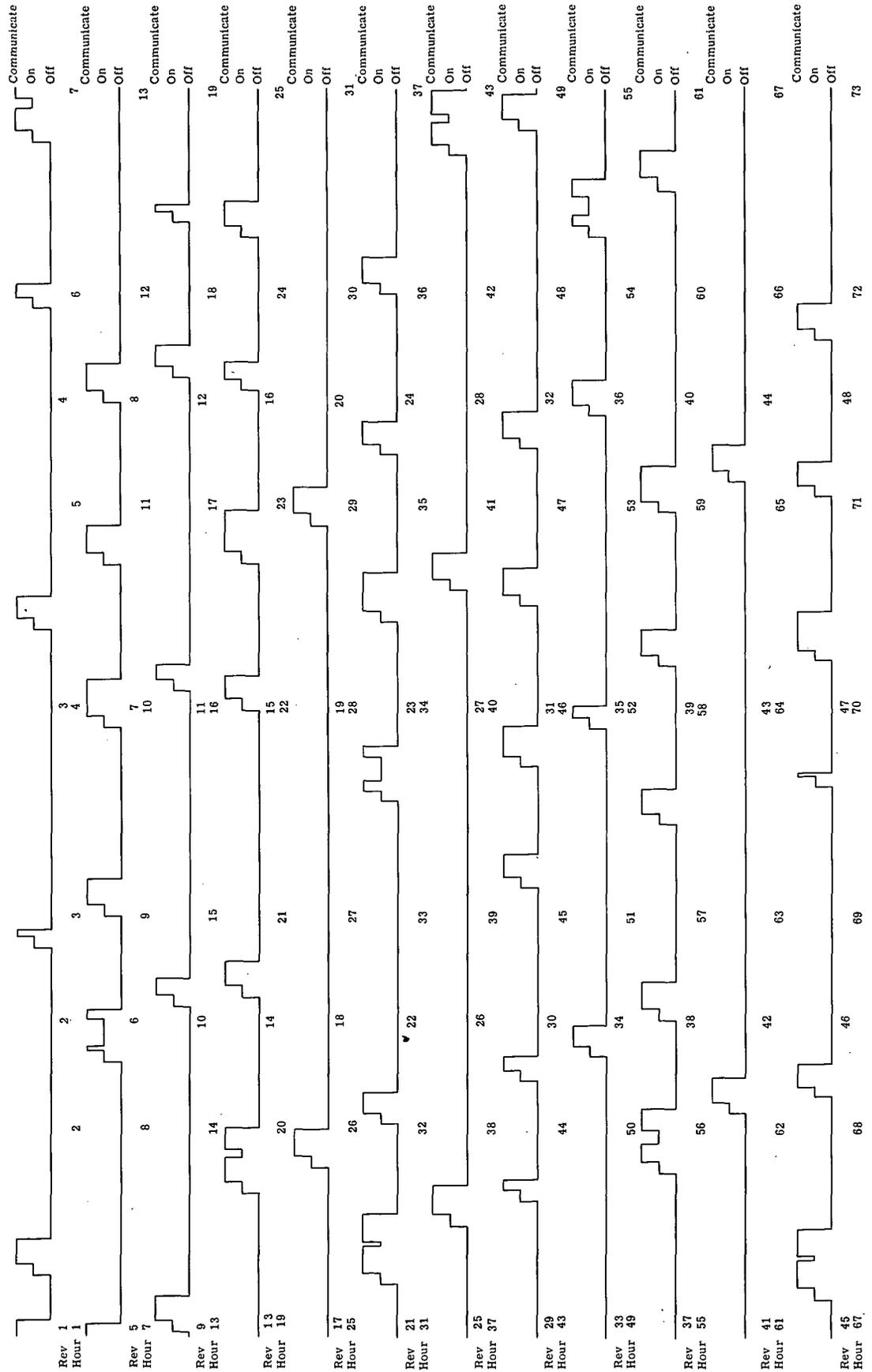


Fig. 5.5-10 Communication Profile - 200 N. Mi and 90° Inclination

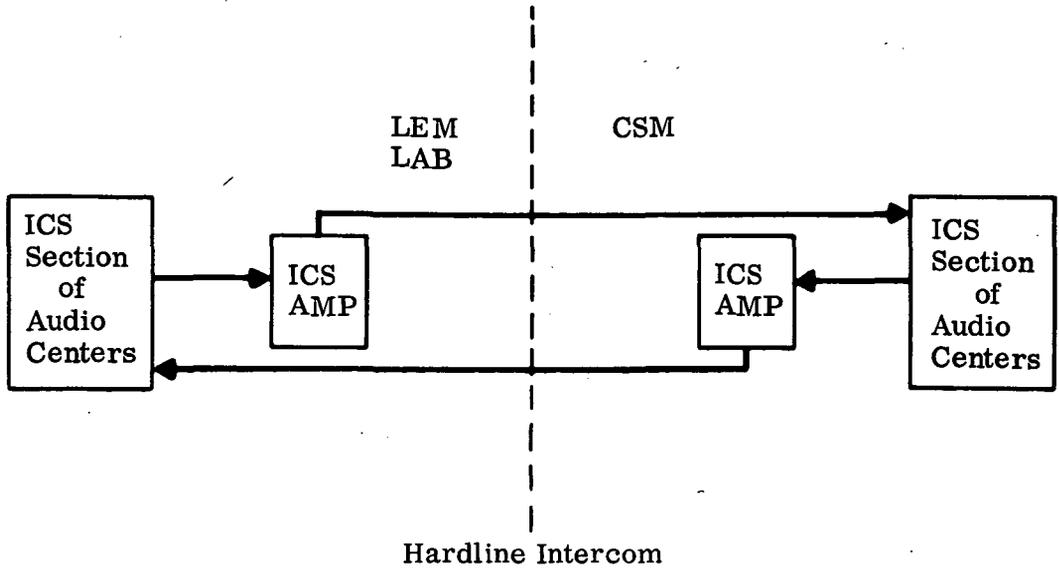


Fig. 5.5-11 CSM/Lab Intercom

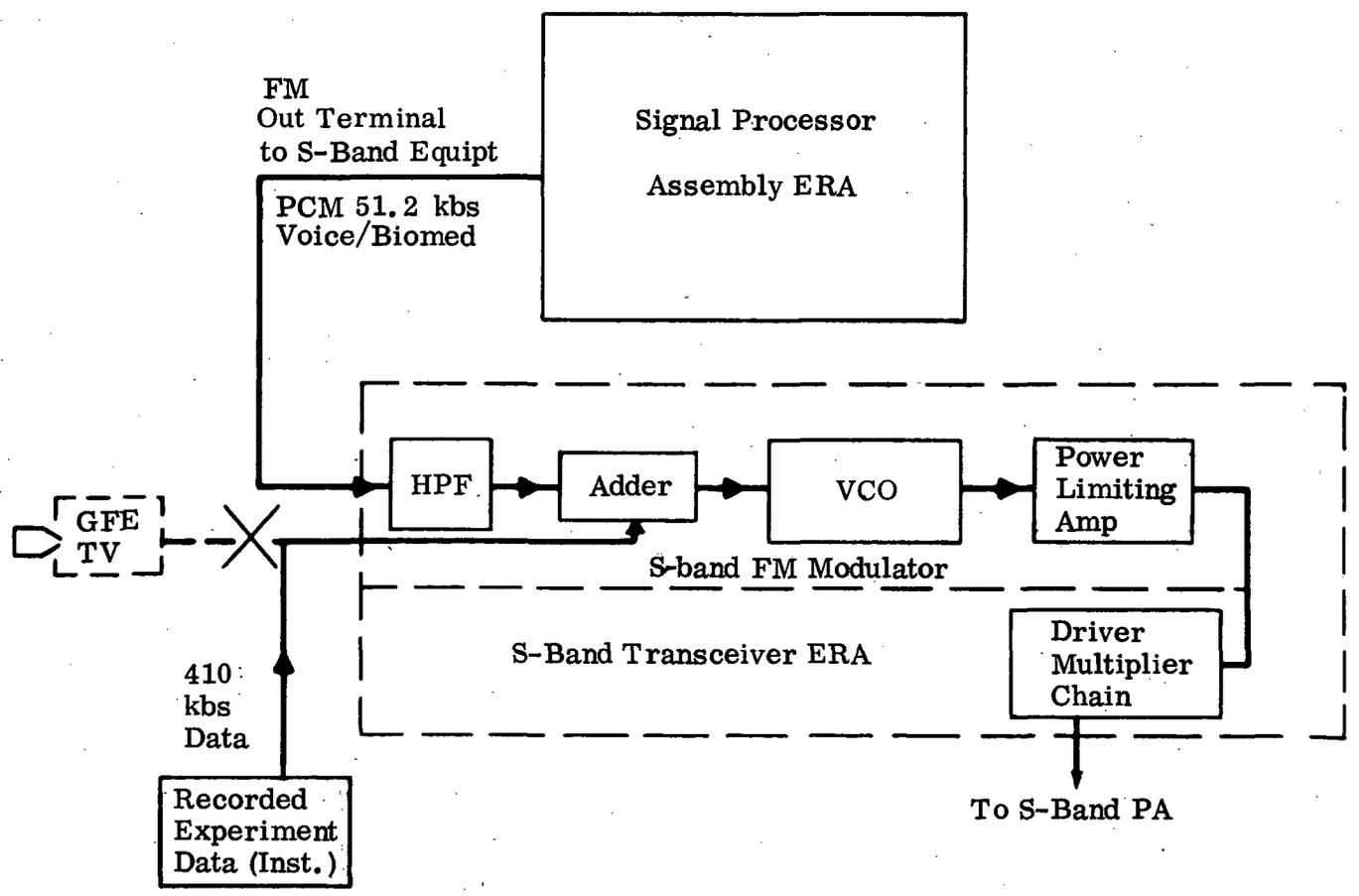


Fig. 5.5-12 Additional PCM Data Channel

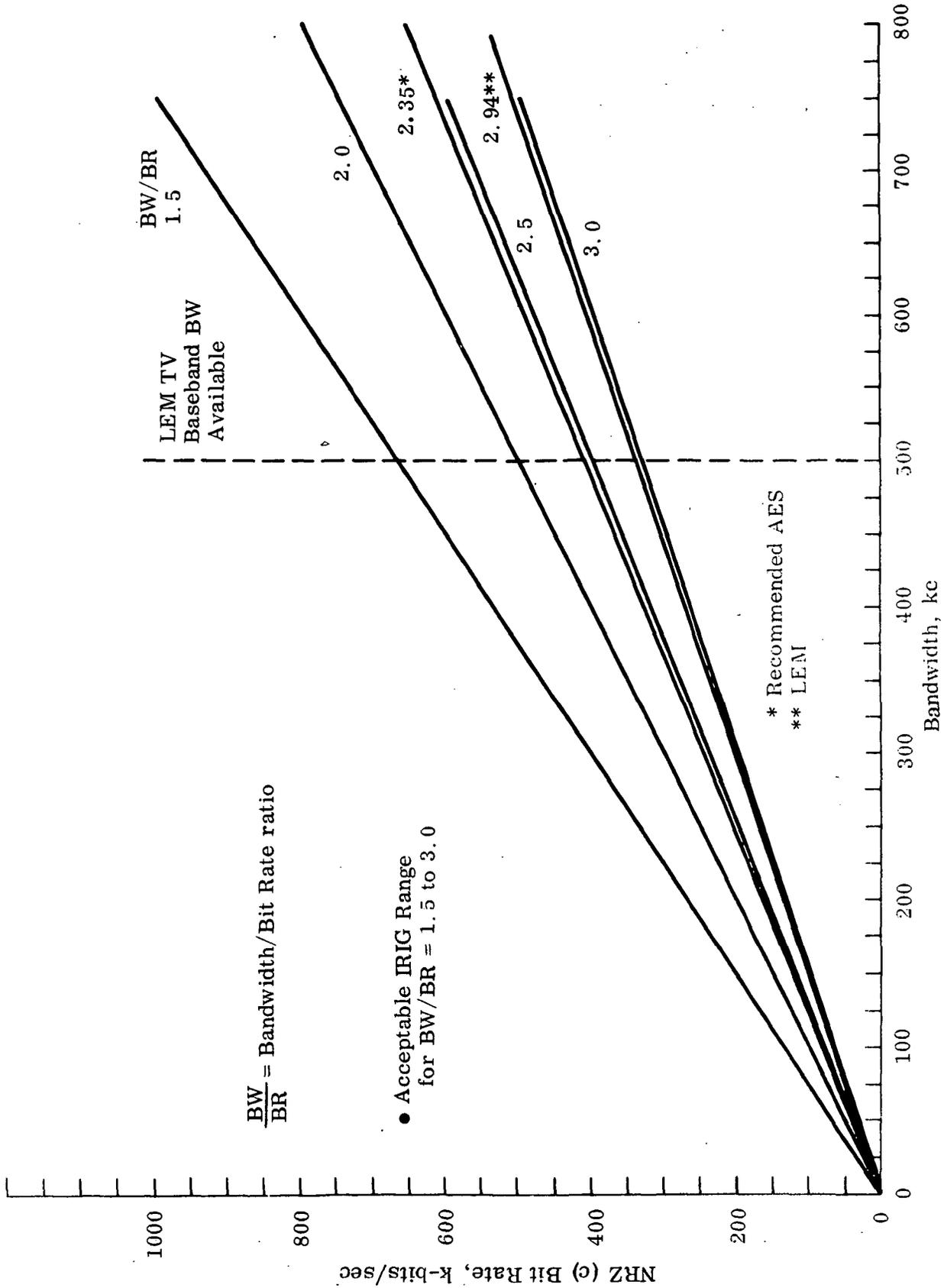
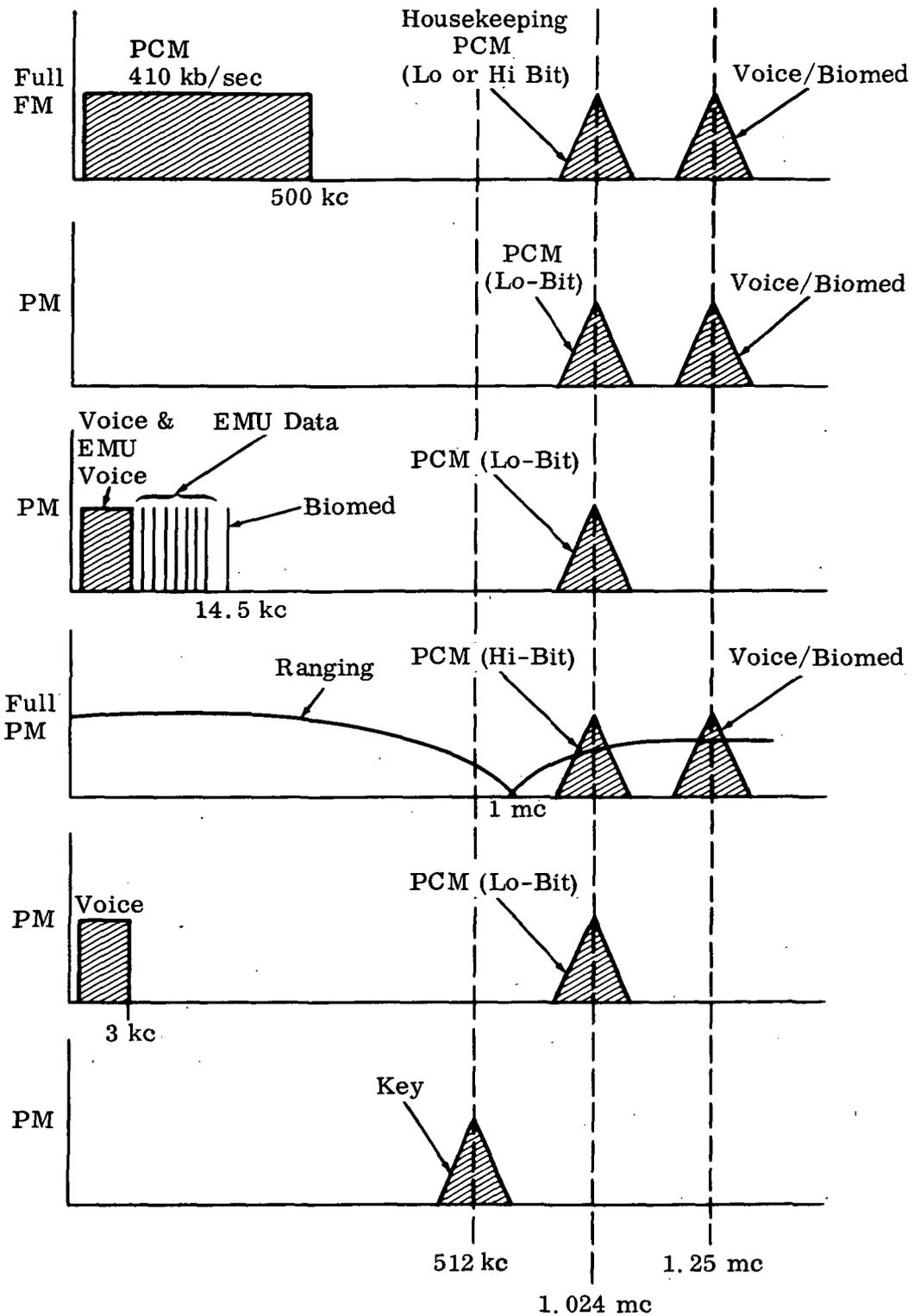


Fig. 5.5-13 Bandwidth and NRZ (C) Bit Rates for Various Bandwidth to Bit Rate Ratios



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. 5.5-14 Lab Operation Modes

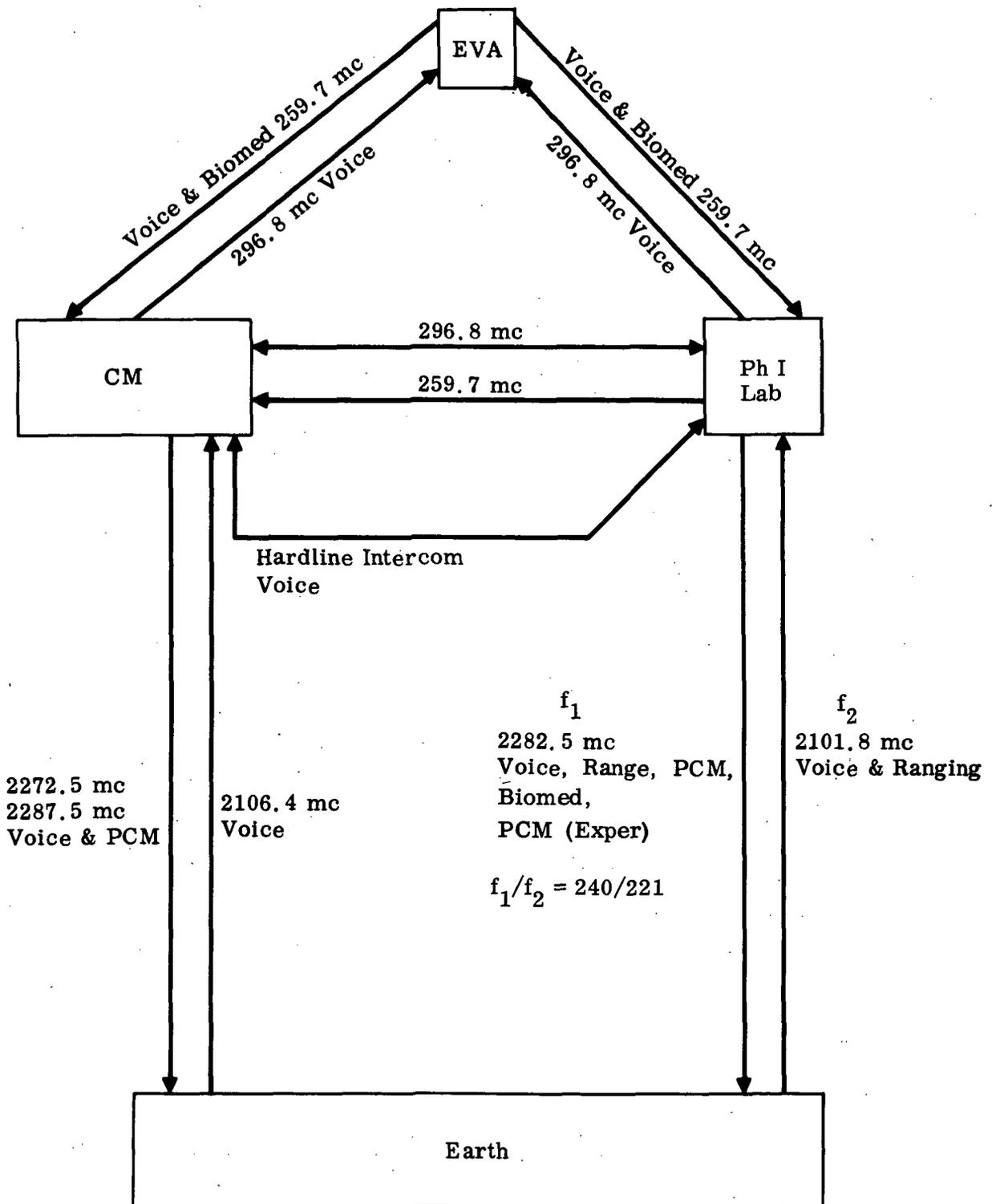


Fig. 5.5-15 Lab Frequency Allocation

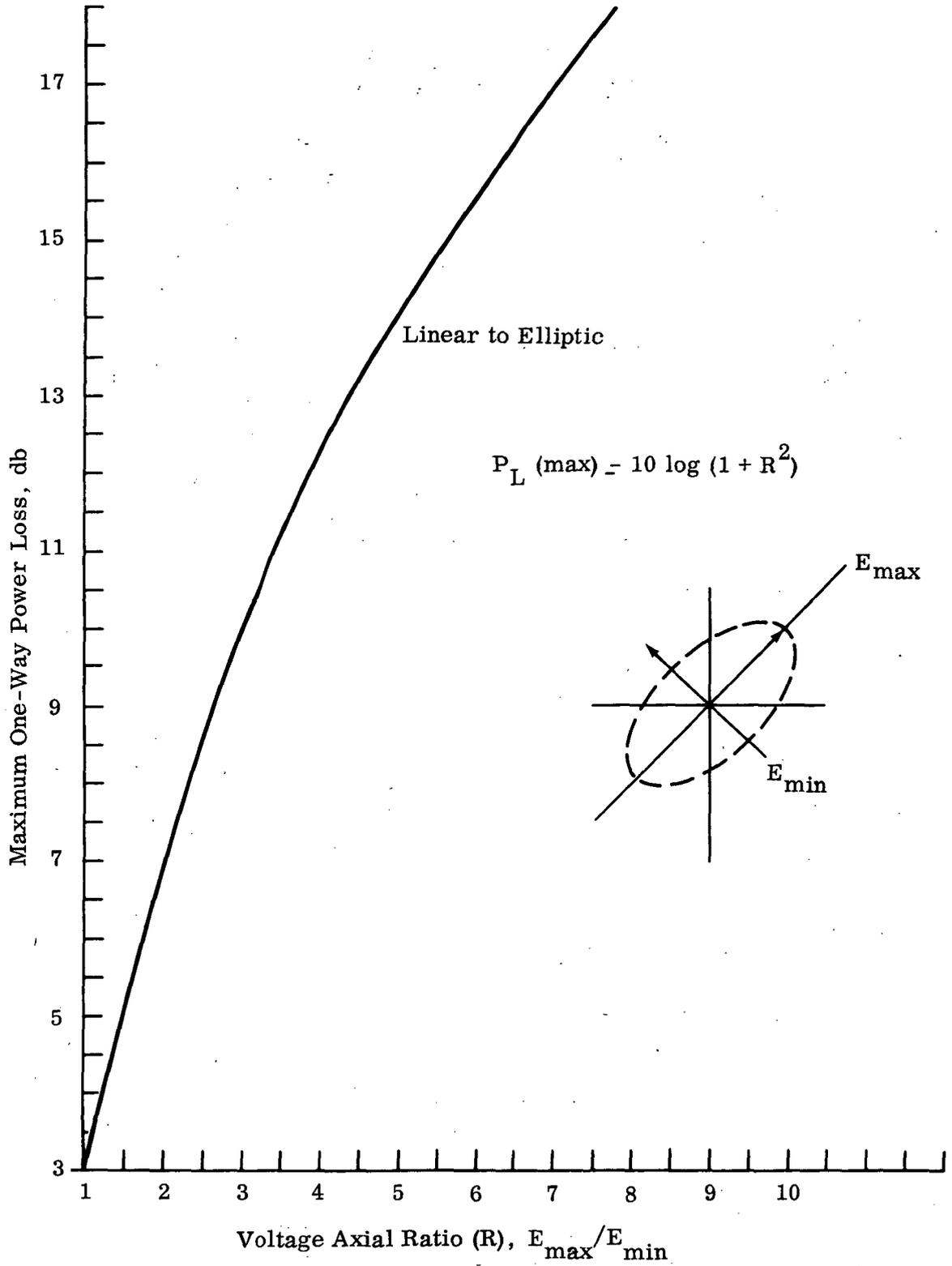
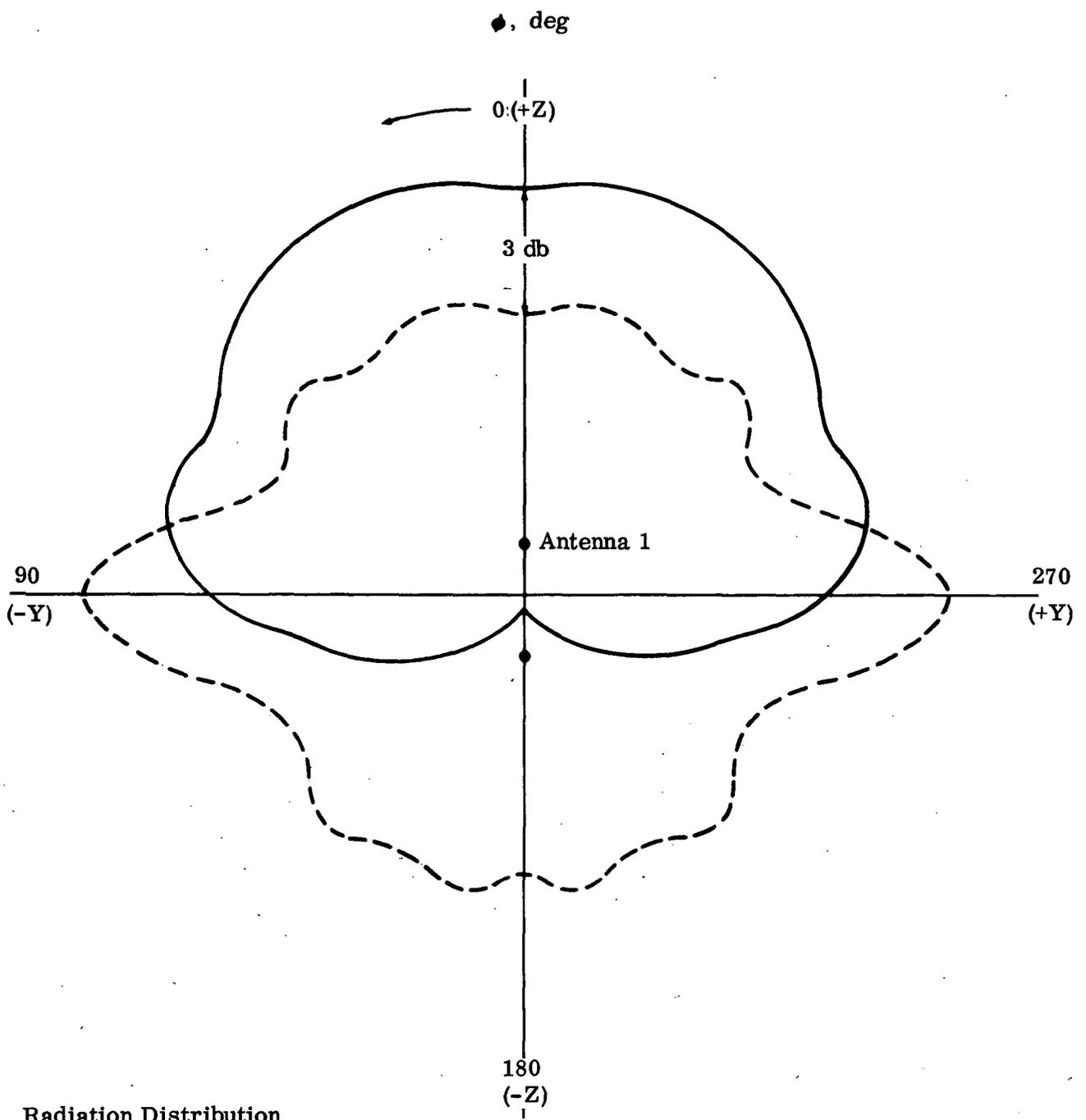


Fig. 5.5-16 Maximum One Way Power Loss VS Voltage Axial Ratio



Radiation Distribution of Two S-Band In Flight Antennas (Log Conical Spirals) When Coupled and Fed In Time Phase.

Key

- One Conical Log Spiral
- - - - Two Conical Log Spirals Fed in Time Phase Simultaneously

Fig. 5.5-17 Coupled Omni - Antenna Radiation Pattern

5.6 INSTRUMENTATION

5.6.1 Ground Rules

The following is a list of ground rules used for the Phase "B" effort:

- The Lab will carry its own Communications and Data Handling System
- There will be no data interface between the Lab and the CSM
- Video Transmission will be through the CM-S-Band Line (real time only)

5.6.2 Assumptions and Background Data

The following assumptions were used in standardizing an approach for the operational and experiment acquisition sections of the Phase I vehicles:

- Any changes in the operational measurements shall not exceed the present LEM measurements
- Maximum utilization of the crew for redundancy monitoring and failure mode corrections/operations will be used
- All Operational data will be presented to the ground during line-of-sight mission phases only (real time)
- There will not be any on-board recording capability for operational data
- All vendor supplied experiments will provide their own signal conditioning compatible with the AES experiment acquisition system
- All experiment data will be considered "passive" for ground reduction (not requiring real time display). On-board display of selected experiment parameters will be available to the astronauts
- Data record, dump, or re-dump requirements will be the responsibility of the astronauts and will not require any ground uplink control
- All experiment data routed to other subsystems, in addition to the Instrumentation Subsystem; shall be routed through separate outputs
- Existing LEM equipment will not require re-qualification for Phase I
- Experiment data will be on-board recorded during periods of flight not covered by line-of-sight
- Experiment data set-up, pre- or post-calibration, and operation will be on-board controlled and will not require any ground uplink support capabilities
- Experiments requiring analog data recovery will utilize the analog portion of the experiment tape system or it is assumed part of the experiment.

The primary function of the Operation Instrumentation Section is to acquire and present spacecraft housekeeping data to the astronauts and ground monitoring personnel (Fig. 5.6-1). In reviewing the measurement requirements of the standard vehicle, it was concluded that the existing LEM equipment would continue to fulfill this task. The number of excess handling capabilities remaining is sharply limited, and handling of experiment data within the system cannot be performed for the following reasons:

- Operational Instrumentation Section is tailored to support the spacecraft subsystems and provides no provisions for growth
- Present system offers no data storage or recording and would limit any experiment operation
- Remaining PCMTEA input channels are few and the experiments would be required to conform to its fixed format.

An independent experiment data acquisition system was chosen to handle experiment data (Fig. 5.6-2). The investigation of preliminary data requirements, conforming to the maximum use of existing Apollo hardware, has delineated the use of a LEM PCMTEA to provide the multiplexing, timing, and encoding functions for the following reasons:

- Suitable mechanical configuration
- Qualified for expected environment
- Capable of operating without external timing inputs
- Diversity of data handling capability

The prevalence of experiment data acquisition requirements in the absence of ground station coverage indicates the need for experiment data storage capabilities. An investigation of available qualified flight tape recorders yielded the result that two adapted Apollo "Command Module" tape recorders best fulfilled the data storage requirements. Some of the major advantages of these recorders over the others investigated are:

- Existing Apollo hardware
- In-flight reloading capability
- Suitable mechanical configuration
- Qualified for expected environment
- Accepts LEM PCMTEA data directly
- Provides data compression capability.

The requirement for two recorders stems from the fact that the time duration of data storage requirements for some experiments exceeds the record time capability of a single recorder. The loss of data during rewind and dump or possibly tape reloading intervals is avoided by use of a second recorder.

5.6.3 Recommended Configuration

5.6.3.1 Spacecraft Operational Section

The recommended Operational Instrumentation Section for the AES "standard" Phase I Lab is mainly comprised of existing LEM assemblies or components. The existing LEM assemblies have certain built-in flexibility which allows for some minor configuration changes. The measurements list (Table 5.6-6) prepared for the Phase I Lab 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.

5.6.3.1.1 Transducers. The sensors of the standard vehicle 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. LEM transducers exhibit some of the following characteristics:

- Light weight (small volume)
- Low power consumption
- Deliver a high-level output
- High accuracy.

New spacecraft subsystem measurement requirements demand additional transducers, consideration will be given first to LEM proven units. Any measurement unique to the Phase I Labs which requires transducers not previously used on LEM will be selected using similar characteristics as listed above and will meet AES qualification standards. Preference shall be given to transducers which have been developed for other space missions and have a high-level output, therefore requiring no additional signal conditioning. A summary of the parameters to be measured on the Phase I Lab appears in Table 5.6-2. Allocated transducer weight and power consumption is listed on the enclosed measurements list (Table 5.6-6).

5.6.3.1.2 Signal Conditioning. The 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 operational PCMTEA, Caution and Warning System (C&WEA), or on-board displays. The SCEA fulfills the following basic functions:

- Acts as a junction and routing assembly for all analog measurements and signals being monitored
- Supports the signal conditioning subassemblies which condition the measurement input signals.

The SCEA consists of two separate chassis assemblies. Each assembly can accommodate up to 24 separate subassembly modules. Once the measurements are determined for a given AES mission, an analysis is performed on each measurement to assign a signal conditioning circuit to that measurement. The total number of signal conditioning subassemblies for the mission are then packaged into the two assemblies (SCEA). The Phase I Lab measurements list (Table 5.6-6) reflects deletion of some existing LEM measurements and the addition of new measurements required for the AES. A review of this listing indicates that the changing requirements for measurements can still be accommodated within the existing SCEA, using adaption techniques presently employed by LEM. No modification to either the assembly or its subassemblies, as now used by LEM, is anticipated, based on the measurements summarized in Table 5.6-3. The units, however, will require re-wiring of the input-output routings and a new configuration of subassemblies for each assembly is required. The following constraints are applicable to the rework required:

- Subassembly circuits are bench calibrated and adjusted for each measurement. To accommodate another measurement within any subassembly circuit would require a readjustment and recalibration of this circuit. This would require that the SCEA be returned to the calibration clean room for readjustment.
- Input signals are grouped in subassemblies by types of conditioning required, not by subsystems; therefore, the elimination of a vehicle subsystem does not preclude the deletion of any modules.

5.6.3.1.3 Caution and Warning Equipment. This assembly advises the astronauts of the spacecraft subsystem status by continual monitoring of critical parameters. During the mission the C&WEA performs two basic functions:

- The caution function advises the astronaut of a malfunction which requires his action to correct
- 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 LEM operates on discrete voltage changes or switch closures. Deletion of some subsystems from the LEM will make available some monitoring channels for the additional subsystem requirements. However, the analog input channels have preset limits which require re-setting of values for any new measurement.

5.6.3.1.4 Pulse Code Modulation and Timing Equipment. The PCMTEA in the recommended configuration consists of an unmodified LEM assembly. The data acquisition capability of this unit include the multiplexing, encoding, and timing of high-level analog, parallel digital, and serial digital data. The number of channels, sampling rates, and word lengths 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 LEM, including accepting a timing reference from the LEM Guidance Computer and providing various timing signals to interfacing subsystems. The NRZ(C) data output is routed to the Communications Subsystem for real-time transmission. Operation of the PCMTEA in the reduced data rate mode is not anticipated in Phase I missions.

5.6.3.1.5 Voice Storage Recorder. This magnetic tape recorder, originally referred to as the "Data Storage Electronics 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 10 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 module
- To support EVAs
- To record comments of vehicle status when off station coverage
- To record proprietary information

5.6.3.1.6 Operational Measurements. The measurement requirements for the Phase I Lab (Table 5.6-6) were initiated by the various AES-LEM subsystems, reviewed by the Operations Section to assure proper and complete checkout support, compared against the mission objectives (to assure adequate coverage), and used as the basis for sizing the Operational Instrumentation Acquisition System. 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 vehicles subsystems. These measurements support the spacecraft 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, impedance pneumograms (respiration) with associated power converters, vest, harness, and electrodes. This information is transmitted via the VHF link to

the module for re-transmission to Earth. During the on-board stay, however, only electrocardiogram is monitored for transmission to Earth.

5.6.3.2 Experiment Instrumentation Section

The Experiment Instrumentation Section is an independent section of the Instrumentation Subsystem which offers the capability for acquisition and storage of experiment data. The Experiment/Pulse Code Modulation and Timing Electronic Assembly (E/PCMTEA) provides the acquisition capability, and the Experiment/Data Storage Equipment (E/DSE) provides the data storage capability. The weight and power requirements of this section are presented in Table 5.6-1.

5.6.3.2.1 Transducer and Signal Conditioners. The Experiment Instrumentation Section accepts only isolated preconditioned signals. All transducers, signal conditioners, and isolation buffers required in support of an experiment are considered to be provided by the experiment package. The isolation requirements fall into two basic categories:

- **Outputs to other subsystems:** All signals to be monitored by other subsystems in addition to the Instrumentation Subsystem shall be presented to the Instrumentation Subsystem through a separate isolated output.
- **Multiple signals:** The isolation between signals and signal grounds to be monitored by the E/PCMTEA shall conform with the LEM PCMTEA input requirements.

5.6.3.2.2 E/PCMTEA. The E/PCMTEA, in the recommended configuration consists of an unmodified LEM assembly. The data acquisition capability of this assembly includes the multiplexing, encoding, and timing of analog, parallel digital, and serial digital data. The unit operates at a normal bit rate of 51,200 bits per second and a reduced bit rate (commanded remotely) of 1,600 bits per second. The number of channels, sampling rates, and word lengths available for the three data forms are presented in Table 5.6-4. The E/PCMTEA will operate independent of an external timing reference. When operating in this fashion the timing stability is accurate to two parts per million. The NRZ(C) data output is routed either to the F.M. Modulator of the Communications Subsystem for real-time transmission, or to the E/DSE for data storage, depending upon the ground station coverage available at the time.

5.6.3.2.3 E/DSE. The E/DSE consists of two identical Experiment/Data Storage Units (E/DSU-1 & E/DSU-2). Each E/DSU is an Apollo CSM Block II tape recorder which has been modified as follows:

- Modified to operate from the LEM single-phase A-C power source rather than a three-phase source. This modification is required to provide compatibility with present LEM power conditioning equipment.
- Modified to dump 51.2 kbps NRZ(C) data recorded at 15 ips at an output rate of 409.6 kbps (i.e. 120 ips). The implicit 8:1 data compression ratio is needed since the 51.2 kbps record time requirements greatly exceed the ground station coverage on many of the Phase I flights. The modification sharply reduces the necessity for in-flight tape reloading and physical return of recorded tape via the CSM.

- Modified to be capable of driving a remote tape quantity display. This modification provides a visual reference by which an astronaut can determine the available record time available on a reel of tape. It also provides a data location index thereby enabling an astronaut to initiate the dumping or redumping of specific portions of a given recording.
- Elimination of automatic dump speed selection electronics (with the inclusion of second modification above, the dump speed is fixed at 120 ips).

As indicated in Fig. 5.6-2, the E/PCMTEA NRZ(C) output (including a data rate timing signal) is routed to the E/DSE through a remotely activated switch (PCM record select). The appropriate E/DSU is placed in the record mode at a tape speed compatible with the E/PCMTEA data rate; Low (3.75 ips) for 1.6 kbps, and Normal (15 ips) for 51.2 kbps. When a recording is to be dumped, the appropriate E/DSU output is routed to the Communications Subsystem by means of a second remotely activated switch (data output select). While one tape is being dumped it is possible to continue recording experiment data on the second recorder. Continuous recording is possible, therefore, under conditions where the total E/DSE record time capability is exceeded by the time interval between available ground station coverage. Each E/DSU is also capable of recording experiment analog data directly. The present Communication Subsystem cannot simultaneously support both digital and analog data from the experiment section. Therefore, no provisions are made for the routing of the E/DSE analog outputs to the F.M. Modulator. Analog recordings will be physically returned via the CSM. A summary the E/DSE data handling capabilities is presented in Table 5.6-5.

The external controls for the E/DSE are located in the Controls & Displays Subsystem. Switches actuate the appropriate relays in each E/DSU to provide the following operating modes:

- Electronic Control
 - Record - energizes record electronics
 - Off - de-energizes E/DSU electronics
 - Dump - energizes reproduce electronics
- Direction Control
 - Forward - starts tape moving in forward direction
 - Stop - stops tape in any direction
 - Reverse - starts tape moving in reverse direction at 120 ips and de-energizes electronics
- Speed Control
 - High - command E/DSU to move tape at 120 ips
 - Normal - commands E/DSU to move tape at 15 ips
 - Low - commands E/DSU to move tape at 3.75 ips.

The E/DSE also provides internal controls in each E/DSU as follows:

- Internal protection against altering recorded data in rewind mode
- End-of-tape sensing and automatic transport shut off in both directions without loss of tape threading
- Interlocks to prevent erroneous or damaging operation of the E/DSE.

5.6.4 Baseline Configuration

5.6.4.1 Spacecraft Operational Section

The Baseline Configuration used for the Phase I, standard vehicle is the same as the Recommended Configuration, as described above.

5.6.4.2 Experiment Instrumentation Section

The Baseline Configuration of the Experiment Instrumentation Section is similar to the Recommended Configuration with the exception of the E/DSE. It is important to note that this configuration depends upon the availability of three-phase A-C power to the Instrumentation Subsystem. Since the use of Pratt and Whitney fuel cells was also included in the Baseline Configuration, the availability of three-phase A-C power was assured.

5.6.6.2.1 Transducers and Signal Conditioners. Identical to the requirements described under the Recommended Configuration (paragraphs 5.6.3.1.1 and 5.6.3.1.2).

5.6.4.2.2 E/PCMTEA. Consists of an unmodified LEM PCMTEA as described under the Recommended Configuration (paragraph 5.6.3.2.2).

5.6.4.2.3 E/DSE. The E/DSE in the Baseline Configuration consists of two unmodified CSM Block II tape recorders. The advantage of this approach lies in the fact that standard Apollo hardware is utilized. The data handling capability of this configuration, however, is inferior to that of the Recommended Configuration. Because of this, the Baseline Configuration cannot provide adequate experiment support on most of the Phase I missions unless the experiment data requirements diminish considerably from those now indicated by the preliminary definition.

The unmodified tape recorders operate on three-phase A-C power (approximately 35 watts each). Each unit records 1.6 kbps data at 3.75 ips and 51.2 kbps data at 15 ips. The 1.6 kbps recordings are dumped at 120 ips, and the 51.2 kbps recordings are dumped at 15 ips (the same speed at which it is recorded). All digital data, therefore, is dumped at 51.2 kbps. The analog recording capability is the same as that of the Recommended Configuration.

5.6.5 Alternate Configuration

There were no alternate configurations studied because of the ability of the recommended system to provide suitable performance.

5.6.6 Potential Modifications (Per Flight)

5.6.6.1 Spacecraft Operational Section

There are no recommended modifications envisioned for this vehicle based on a review of existing measurement requirements and the capabilities of the existing system.

5.6.6.2 Experiment Instrumentation Section

The wiring between the inputs of the Experiment Instrumentation Section and the data outputs of the experiments will have to be designed for each specific flight.

Other potential per-flight modifications, although not anticipated on the majority of Phase I missions, involve changes to the input format of the E/PCMTEA to comply with unusual experiment data requirements.

5.6.7 Discussion of Configuration Choices

5.6.7.1 Experiment Instrumentation Section

A comparison of the capabilities of the E/DSE portion of the Baseline and Recommended Experiment Instrumentation Section Configurations points out these significant differences between the two approaches:

- The Baseline Configuration tape recorders require three-phase A-C power. This power must be made available to the Instrumentation Subsystem if the Baseline Configuration is chosen.
- Preliminary investigation of experiment data requirements indicate the necessity for the E/PCMTEA to operate at 51.2 kbps during most of the experiments. The unmodified tape recorders, limited to a 51.2 kbps dump rate, must dump this data at the same speed at which it was recorded. Consideration of this constraint in the light of present experiment data requirements and available ground station indicates a severe limitation on the quantity of experiment data that can be transmitted to Earth. With the Baseline Configuration, therefore, a large percentage of the recorded data would have to be returned to Earth via the CSM on many of the missions. The Recommended Configuration, on the other hand, is capable of dumping data at 409.6 kbps. The 8:1 data compression ratio provided by this method greatly increases the amount of data that can be transmitted with the same amount of ground station coverage. With the Recommended Configuration the requirement for returning tapes via the CSM is greatly reduced.

Table 5.6-1

WEIGHT & POWER SUMMARY - INSTRUMENTATION SUBSYSTEM

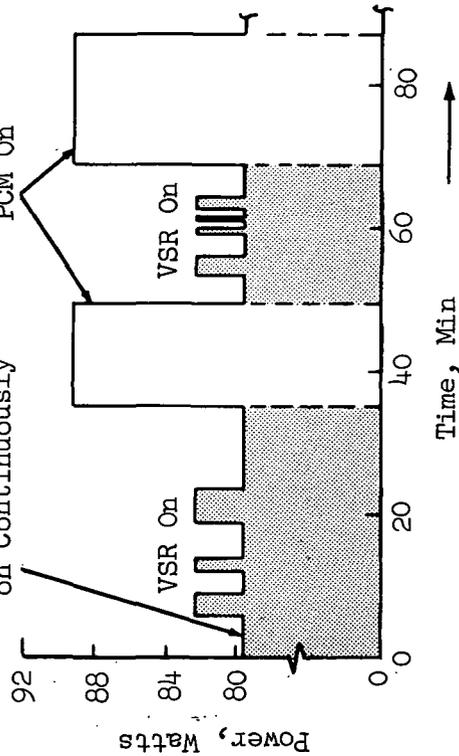
Section	Transducers	SCEA		C & WEA	PCMTEA		VSR	E/DSE		E/PCMTEA	Total
		ERA I	ERA II		PCM	TEA		E/DSU 1	E/DSU 2		
Oper'l	Weight, lb	15.7	40.8	25.0	37.0	5.0	5.0 (2)				164.9
	Power, watts	9.6	19.1	22	7.4	5.5		2.3			
Exper	Weight, lb							40	40	37	117
	Power, watts							46*	46*	12.9	104.9

* Denotes Recorder Powered By Single-Phase AC.

Operational Instrumentation Section

Transducers
SCEA, C & WEA,
& Timing Electronics
on Continuously

On Station
Off Station



Experiment Instrumentation Section

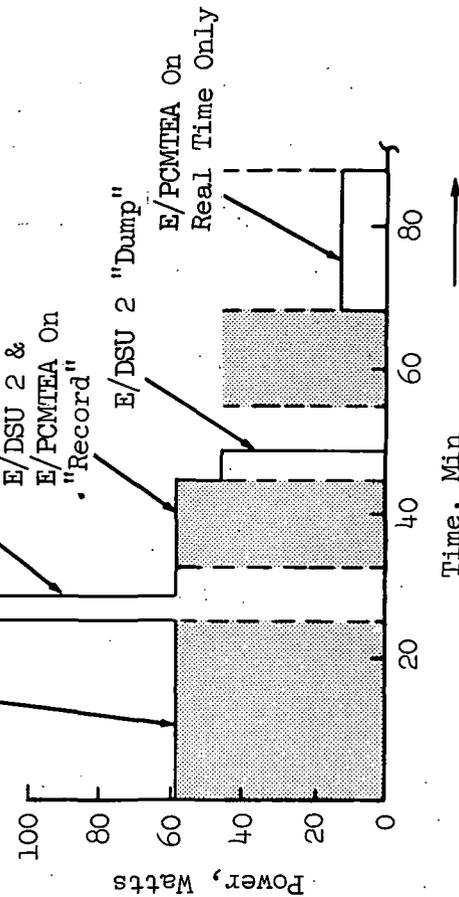
E/DSU 1 &
PCMTEA On
"Record"

E/DSU 1 "Dump"

E/DSU 2 & PCMTEA Only

E/DSU 2 "Dump"

E/PCMTEA On
Real Time Only



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PHAS

Parameter Subsystem	Acceleration	Phase	Current	Vibration	Power	Frequency	Force	Position	Biomedical
Structures									
Thermodynamics									
Electrical Power			22			1			
Environ Control									
Nav & Guid									
Radars									
S & C - CES									
S & C - AGS									
Instrumentation						2			
Propulsion - Ascent									
Propulsion - Descent									
Reaction Control									
Communications		1			4				2
Pyrotechnics									
Totals		1	22		4	3			2

Note: All battery configuration used for thi

Table 5.6-2

I LAB OPERATIONAL MEASUREMENT SUMMARY

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

sizing.

Table 5.6-3
 PHASE I LAB SCEA SUMMARY

	SCEA Subassembly Type LSP-360-													TOTAL
	502-2	502-3	503-2	503-3	504-1	504-2	504-3	504-4	504-5	505-1	506-2	507-1	509-1	
Total Measurement Circuits	36	2	4	1	14	16	28	65	28	1	41	3	-	239
Circuits/Subassy	4	4	3	3	4	10	12	12	12	3	4	4	4	-
Quantity of Subassys Reqd	9	1	2	1	4	2	6	3	3	1	11	1	-	44
No. Spare Circuits	-	2	2	2	2	4	7	8	8	2	3	1	-	41
ERA No. 1	9	-	-	-	-	-	-	-	-	-	11	-	-	20
ERA No. 2	-	1	2	1	4	2	6	3	3	1	-	1	-	24

TABLE 5.6-4 PCMTEA AND E/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
Analog - High Level	17	100	8	1700
Analog - High Level	6	50	8	300
Analog - High Level	35	10	8	350
Analog - High Level	137	1	8	137
Digital Parallel	1	200	16	400
Digital Parallel	3	100	8	300
Digital Parallel	4	50	8	200
Digital Parallel	1	10	8	10
Digital Parallel	37	1	8	37
Digital Serial	1	50	40	250
Digital Serial	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
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.				

* Normalized to 8 bit words

NOTE: IDENTICAL FORMAT IS USED FOR BOTH THE OPERATIONAL AND EXPERIMENT PCM

TABLE 5.6-5 E/DSE DATA HANDLING CAPABILITY

The E/DSE consists of two E/DSUs each with the following capability:		NRZ (C) & Clock		Analog Type A	Analog Type B
<ul style="list-style-type: none"> • Record/Dump one channel of NRZ (C) E/PCWTEA data including data rate clock. Five tracks; serial data is converted to parallel and stored on four tracks. A synchronization signal is stored on the fifth track. • Record two channels of analog type A data (two tracks) and three channels of analog type B data (three tracks). • Has provisions for the addition of four additional analog type B channels (four tracks). 		1 (5 tracks)		2 (2 tracks)	3 (3 tracks)
Data Rate		1.6kb/s	51.2kb/s	300 cps to 2,800 cps	300 cps to 2,800 cps
Record Speed, ips		3.75	15	3.75	15
Record Time, hr		2	1/2	2	1/2
Dump Speed, ips		120	120	RECORD ONLY	
Dump Time, min		4	4	Analog recordings are physically returned to Earth via CSM.	
Dump/Record Ratio		32:1	8:1		
Dump Data Rate, kbps		51.2	409.6		

Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 2				
BASELINE E.O. LAB PHASE I		NOVEMBER 8, 1965				
ID	MEASUREMENT	FREQ A S S S B G O M H C F A X	XDCR	FREQ A OSY	REFERENCES	
CODE	NAME AND LOCATION	LOW NORM HIGH UNIT RATE C R S G T D S C S L W L D X	RANGES OR C C / I R P C S / / / X	OR C NIP XDCR XDCR	OR	
			LOW HIGH RATE C DGE	-PMR	WT.	NOTES
ELO021-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 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 3	
BASELINE E.D.-LAB PHASE I		NOVEMBER 8, 1965	
ID	MEASUREMENT	FREQ A S S B G O M H C F A X	XOCR
CODE	NAME AND LOCATION	OR C / I R P C S / / / X RANGES	OR C NIP 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 DGF -PHR WT.	
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.			

REFERENCES C H

OR

NOTES G

Table 5.6-6 (cont)

CONTRACT NUMBER MAS9-4983 PAGE NUMBER 4
BASELINE E.O. LAB. PHASE 1 NOVEMBER 8, 1965

INTEREST RANGES OR C C / I T P C S / / X RANGES OR C NIP XDCR XDCR REFERENCES. H
MEASUREMENT OR C C / I T P C S / / X RANGES OR C NIP XDCR XDCR OR
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 MT. NOTES. G.

SCR

TRANSDUCER PROCUREMENT SOURCE CODE.

S-SUBCONTRACTOR

I-INSTRUMENTATION

G-GROUND SUPPORT EQUIPMENT

N-NASALGFEI 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)

B.I.

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 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 6			
BASELINE E.O. LAB PHASE I		NOVEMBER 8, 1965			
ID	MEASUREMENT	FREQ A S S B G O M H C F A X	XDCR	FREQ A QSY	REFERENCES
CODE	NAME AND LOCATION	OR C C / I I R P C S / / / X	RANGES	OR C NIP XDCR XDCR	OR N
		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.	NOTES
F/L		INTEREST			
		RANGES			
		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.	
A/D		INDICATES AN ADVISORY FLAG(F)OR LIGHT(L).			
XXX		INDICATES AN INPUT TO AN ANALOG(A)OR DIGITAL(D)DISPLAY.			
XDCR		TIME SHARED SWITCHING CODE 1-9			
RANGES		SELECTED OR ALLOCATED TRANSDUCER RANGE.			
LOW HIGH					
FREQ		ALLOCATED EQUIPMENT RESPONSE CAPABILITY.			
OR					
RATE					
ACC		END-TO-END SYSTEM ACCURACY EXPRESSED IN PERCENT FULL SCALE OF			
		ALLOCATED RANGE.			



Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983 BASELINE E.O. LAB PHASE 1		ELECTRICAL POWER										PAGE NUMBER 8 NOVEMBER 8, 1965												
ID CODE	MEASUREMENT NAME AND LOCATION	LOW	NORM	HIGH	INTEREST RANGES	ELECTRICAL POWER										C T	REFERENCES OR NOTES							
						FREQ A	S S	B G	O M	H C	F A	X X	XDCR	FREQ A	DSY			C NIP	XDCR	XOCR				
						UNIT	RATE	C R	S G	T D	S C	S L	W L	D X	LOW	HIGH	RATE	C DGE	-PWR	WT.				
EC0071-V	VOLTAGE, INVERTER BUS	105	115	125	VRMS	SS	5	5	1	H	8	8	2	R	L	C	A	0	130	SS	3-3	--	EL4046	
EC0155-F	FREQ, INVERTER BUS	390	400	410	CPS	SS	5	5	1	H	8	8	2	R	L	C	A	0	380	420	SS	5-1	--	EL4046
EC0201-V	VOLTAGE, BATTERY NO.1	20	28	40	VDC	SS	5	5	1	H	8	8	2	L	A	A	0	40	SS	2-2	--	--		
EC0202-V	VOLTAGE, BATTERY NO.2	20	28	40	VDC	SS	5	5	1	H	8	8	2	L	A	A	0	40	SS	2-2	--	--		
EC0203-V	VOLTAGE, BATTERY NO.3	20	28	40	VDC	SS	5	5	1	H	8	8	2	L	A	A	0	40	SS	2-2	--	--		
EC0204-V	VOLTAGE, BATTERY NO.4	20	28	40	VDC	SS	5	5	1	H	8	8	2	L	A	A	0	40	SS	2-2	--	--		
EC0205-V	VOLTAGE, BATTERY NO.5	20	28	40	VDC	SS	5	5	1	H	8	8	2	L	A	A	0	40	SS	2-2	--	--		
EC0206-V	VOLTAGE, BATTERY NO.6	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0207-V	VOLTAGE, BATTERY NO.7	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0208-V	VOLTAGE, BATTERY NO.8	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0209-V	VOLTAGE, BATTERY NO.9	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0210-V	VOLTAGE, BATTERY NO.10	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0211-V	VOLTAGE, BATTERY NO.11	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0212-V	VOLTAGE, BATTERY NO.12	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0213-V	VOLTAGE, BATTERY NO.13	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0214-V	VOLTAGE, BATTERY NO.14	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0215-V	VOLTAGE, BATTERY NO.15	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0216-V	VOLTAGE, BATTERY NO.16	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0217-V	VOLTAGE, BATTERY NO.17	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0218-V	VOLTAGE, BATTERY NO.18	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0219-V	VOLTAGE, BATTERY NO.19	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0220-V	VOLTAGE, BATTERY NO.20	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0221-V	VOLTAGE, BATTERY NO.21	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0222-V	VOLTAGE, BATTERY NO.22	20	28	40	VDC	SS	5	5	1	H	8	8	2	H	A	A	0	40	SS	2-2	--	--		
EC0301-V	VOLT COMMANDER'S BUS	20			VDC	SS	4	5	1	H	8	8	2	R	L	A	0	40	SS	2-3	--	--		



Table 5.6-6 (cont)

CONTRACT NUMBER MAS9-4983		PAGE NUMBER 9																			
BASELINE E.O.LAB PHASE 1		NOVEMBER 8, 1965																			
ID	MEASUREMENT	ELECTRICAL POWER										REFERENCES									
		INTEREST RANGES		FREQ A S S B G D M H C F A X		XDCR RANGES		OR C NTP XDCR XDCR		OR											
CODE	NAME AND LOCATION	LOW	NORM	HIGH	UNIT	CR	ST	GT	DS	CS	SL	WL	DX	LOW	HIGH	RATE	C	DGE	PMR	WT.	NOTES
EC0301-V	VOLT COMMANDER'S BUS	26.5			VDC	SS										SS					EL4047
EC0302-V	VOLT SYSTEM ENGR'S BUS	20	40		VDC	SS	4	5	1	H	8	B	2	R	L	A	0	40	SS	2-3	
EC0302-V	VOLT SYSTEM ENGR'S BUS	26.5			VDC	SS										SS					EL4047
EC1201-C	CURRENT, BATTERY NO.1	0	60		AMPS	SS	5	S	I	H	8	B	2	L	A	0	60	SS			
EC1202-C	CURRENT, BATTERY NO.2	0	60		AMPS	SS	5	S	I	H	8	B	2	L	A	0	60	SS			
EC1203-C	CURRENT, BATTERY NO.3	0	60		AMPS	SS	5	S	I	H	8	B	2	L	A	0	60	SS			
EC1204-C	CURRENT, BATTERY NO.4	0	60		AMPS	SS	5	S	I	H	8	B	2	L	A	0	60	SS			
EC1205-C	CURRENT, BATTERY NO.5	0	60		AMPS	SS	5	S	I	H	8	B	2	L	A	0	60	SS			
EC1206-C	CURRENT, BATTERY NO.6	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1207-C	CURRENT, BATTERY NO.7	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1208-C	CURRENT, BATTERY NO.8	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1209-C	CURRENT, BATTERY NO.9	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1210-C	CURRENT, BATTERY NO.10	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1211-C	CURRENT, BATTERY NO.11	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1212-C	CURRENT, BATTERY NO.12	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1213-C	CURRENT, BATTERY NO.13	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1214-C	CURRENT, BATTERY NO.14	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1215-C	CURRENT, BATTERY NO.15	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1216-C	CURRENT, BATTERY NO.16	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1217-C	CURRENT, BATTERY NO.17	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1218-C	CURRENT, BATTERY NO.18	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1219-C	CURRENT, BATTERY NO.19	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1220-C	CURRENT, BATTERY NO.20	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1221-C	CURRENT, BATTERY NO.21	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			
EC1222-C	CURRENT, BATTERY NO.22	0	60		AMPS	SS	5	S	I	H	8	B	2	H	A	0	60	SS			

Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983 BASELINE E.O. LAB. PHASE 1		PAGE NUMBER 10 NOVEMBER 8, 1965																											
ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	ELECTRICAL POWER										REFERENCES OR NOTES																
			FREQ A	S	S	B	G	D	M	H	C	F		A	X	XOCR	FREQ A	OSY											
		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.		
EC3501-I	TEMPERATURE, BATTERY NO.1	0	200	DEGF	SS	5	S	I	H	8	B	2	L	A	20	200	SS	6-2	0	0									
EC3502-I	TEMPERATURE, BATTERY NO.2	0	200	DEGF	SS	5	S	I	H	8	B	2	L	A	20	200	SS	6-2	0	0									
EC3503-I	TEMPERATURE, BATTERY NO.3	0	200	DEGF	SS	5	S	I	H	8	B	2	L	A	20	200	SS	6-2	0	0									
EC3504-I	TEMPERATURE, BATTERY NO.4	0	200	DEGF	SS	5	S	I	H	8	B	2	L	A	20	200	SS	6-2	0	0									
EC3505-I	TEMPERATURE, BATTERY NO.5	0	200	DEGF	SS	5	S	I	H	8	B	2	L	A	20	200	SS	6-2	0	0									
EC3506-I	TEMPERATURE, BATTERY NO.6	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3507-I	TEMPERATURE, BATTERY NO.7	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3508-I	TEMPERATURE, BATTERY NO.8	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3509-I	TEMPERATURE, BATTERY NO.9	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3510-I	TEMPERATURE, BATTERY NO.10	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3511-I	TEMPERATURE, BATTERY NO.11	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3512-I	TEMPERATURE, BATTERY NO.12	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3513-I	TEMPERATURE, BATTERY NO.13	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3514-I	TEMPERATURE, BATTERY NO.14	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3515-I	TEMPERATURE, BATTERY NO.15	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3516-I	TEMPERATURE, BATTERY NO.16	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3517-I	TEMPERATURE, BATTERY NO.17	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3518-I	TEMPERATURE, BATTERY NO.18	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3519-I	TEMPERATURE, BATTERY NO.19	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3520-I	TEMPERATURE, BATTERY NO.20	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3521-I	TEMPERATURE, BATTERY NO.21	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC3522-I	TEMPERATURE, BATTERY NO.22	0	200	DEGF	SS	5	S	I	H	8	B	2	H	A	20	200	SS	6-2	0	0									
EC4361-X	HIGH VOLT TAP BATT. NO1																												
EC4362-X	LOW VOLT TAP BATT NO1																												
EC4363-X	HIGH VOLT TAP BATT NO2																												



Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 11				
BASELINE F.O. LAB PHASE 1		NOVEMBER 8, 1965				
ID CODE	MEASUREMENT NAME AND LOCATION	ELECTRICAL POWER				REFERENCES OR NOTES
		INTEREST RANGES	FREQ A S S B C O M H C F A X	XDCR RANGES	FREQ A OSY	
	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.					
EC4364-X	LOW VOLT TAP BATT NO2	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4365-X	HIGH VOLT TAP BATT NO3	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4366-X	LOW VOLT TAP BATT NO3	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4367-X	HIGH VOLT TAP BATT NO4	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4368-X	LOW VOLT TAP BATT NO4	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4379-X	HIGH VOLT TAP BATT NO5	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4380-X	LOW VOLT TAP BATT NO5	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4381-X	HIGH VOLT TAP BATT NO6	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4382-X	LOW VOLT TAP BATT NO6	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4383-X	HIGH VOLT TAP BATT NO7	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4384-X	LOW VOLT TAP BATT NO7	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4385-X	HIGH VOLT TAP BATT NO8	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4386-X	LOW VOLT TAP BATT NO8	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4387-X	HIGH VOLT TAP BATT NO9	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4388-X	LOW VOLT TAP BATT NO9	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4389-X	HIGH VOLT TAP BATT NO10	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4390-X	LOW VOLT TAP BATT NO10	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4391-X	HIGH VOLT TAP BATT NO11	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4392-X	LOW VOLT TAP BATT NO11	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4393-X	HIGH VOLT TAP BATT NO12	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4394-X	LOW VOLT TAP BATT NO12	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4395-X	HIGH VOLT TAP BATT NO13	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4396-X	LOW VOLT TAP BATT NO13	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4397-X	HIGH VOLT TAP BATT NO14	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0
EC4398-X	LOW VOLT TAP BATT NO14	CONTACT CLOSURE	SS	S I E I B 2 R H F	CC	SS 4-4 0 0

Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 13																		
BASELINE E.D. LAB PHASE 1		NOVEMBER 8, 1965																		
ID CODE	MEASUREMENT NAME AND LOCATION	ELECTRICAL POWER				INTEREST RANGES	CONTACT CLOSURE	UNIT	LOW	NORM	HIGH	RATE	C	DGE	-PMR	MT.	REFERENCES			
		FREQ A	S	B	G													D	M	H
EC6320-X	REVERSE/OVER CUR BAT 10	SS	S	I	E	I	B	2	P	H	C	CC	SS	4-3	0	0	EL4047			
EC6321-X	REVERSE/OVER CUR BAT 11	SS	S	I	E	I	B	2	R	H	C	CC	SS	4-3	0	0	EL4047			
FC6322-X	REVERSE/OVER CUR BAT 12	SS	S	I	E	I	B	2	R	H	C	CC	SS	4-3	0	0	EL4047			
EC6323-X	REVERSE/OVER CUR BAT 13	SS	S	I	E	I	B	2	P	H	C	CC	SS	4-3	0	0	EL4047			
EC6324-X	REVERSE/OVER CUR BAT 14	SS	S	I	E	I	B	2	P	H	C	CC	SS	4-3	0	0	EL4047			
EC6325-X	REVERSE/OVER CUR BAT 15	SS	S	I	E	I	B	2	R	H	C	CC	SS	4-3	0	0	EL4047			
EC6326-X	REVERSE/OVER CUR BAT 16	SS	S	I	E	I	B	2	P	H	C	CC	SS	4-3	0	0	EL4047			
EC6327-X	REVERSE/OVER CUR BAT 17	SS	S	I	E	I	B	2	P	H	C	CC	SS	4-3	0	0	EL4047			
EC6328-X	REVERSE/OVER CUR BAT 18	SS	S	I	E	I	B	2	R	H	C	CC	SS	4-3	0	0	EL4047			
EC6329-X	REVERSE/OVER CUR BAT 19	SS	S	I	E	I	B	2	R	H	C	CC	SS	4-3	0	0	EL4047			
EC6330-X	REVERSE/OVER CUR BAT 20	SS	S	I	E	I	B	2	R	H	C	CC	SS	4-3	0	0	EL4047			
EC6331-X	REVERSE/OVER CUR BAT 21	SS	S	I	E	I	B	2	R	H	C	CC	SS	4-3	0	0	EL4047			
EC6332-X	REVERSE/OVER CUR BAT 22	SS	S	I	E	I	B	2	R	H	C	CC	SS	4-3	0	0	EL4047			

Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 14						
BASELINE E.O.LAB PHASE 1		NOVEMBER 8, 1965						
ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	ENVIRONMENTAL CONTROL				REFERENCES	
			LOW NORM HIGH UNIT RATE	C R S G T D S C S L W L O X	LOW HIGH RATE C DGE	-PWR WT.		C T
EF1081-X	PRIME SUIT COMP. SELECT	CONTACT CLOSURE	SS	S I E I B 2 H	CC	SS	4-5 0 0	
EF1082-X	SPARE SUIT COMP. SELECT	CONTACT CLOSURE	SS	S I E I B 2 H	CC	SS	4-5 0 0	
EF1083-X	PRIME SUIT COMPRESS.FAIL	CONTACT CLOSURE	SS	S I E I B 2 R H C	CC	SS	4-3 0 0	
EF1084-X	SPARE SUIT COMPRESS.FAIL	CONTACT CLOSURE	SS	S I E I B 2 R H W	CC	SS	4-3 0 0	
EF1087-X	SELECT SUIT COMPRESS FAIL	CONTACT CLOSURE	SS	L	CC	SS	4-4 0 0	
EF1111-R	RATE,H2O SEPERATOR NO 1	3500 RPM SS	S	C L	500 3600	SS	-.25 .23	EF9999
EF1112-R	RATE,H2O SEPERATOR NO 2	3500 RPM SS	S	C L	500 3600	SS	-.25 .23	EF9999
EF1201-X	SUIT INLET VPI NO1 CLOSED	CONTACT CLOSURE	SS	S I E I B 2 H	CC	SS	4-5 0 .13	
EF1202-X	SUIT INLET VPI NO2 CLOSED	CONTACT CLOSURE	SS	S I E I B 2 H	CC	SS	4-5 0 .13	
EF1211-X	SUIT PRESS.RLF VPI CLOSED	CONTACT CLOSURE	SS	S I E I B 2 H	CC	SS	4-5 0 .13	
EF1212-X	SUIT PRESS.RLF VPI OPEN	CONTACT CLOSURE	SS	S I E I B 2 H	CC	SS	4-5 0 .13	
EF1221-X	SUIT DIVERTER VPI CLOSED	CONTACT CLOSURE	SS	S I E I B 2 R H	CC	SS	4-5 0 .13	
EF1231-X	CABIN GAS RETURN VPI CLO	CONTACT CLOSURE	SS	S I E I B 2 L	CC	SS	4-5 0 .13	
EF1232-X	CABIN GAS RETURN VPI OPEN	CONTACT CLOSURE	SS	S I E I B 2 H	CC	SS	4-5 0 .13	
EF1241-X	CO2 CARTRIDGE IN SEC POS	CONTACT CLOSURE	SS	S I E I B 2 H	CC	SS	4-5 0 .13	
EF1242-X	CO2 CARTRIDGE IN SEC POS	CONTACT CLOSURE	SS	L	CC	SS	4-4 0 .13	EF9993
EF1251-X	H2O SEPARATOR NO2 SELECT	CONTACT CLOSURE	SS	S I E I B 2 R L	CC	SS	4-5 0 0	
EF1281-T	TEMP,SUIT INLET	30 60 100 DEGF	SS	S I H 8 B 2 R L	A 30 110	SS	6-2 0 .12	
EF1291-T	TEMP,SUIT NO.1 OUTLET	30 80 100 DEGF	SS	S I H 8 B 2 H	30 110	SS	6-2 0 .12	
EF1292-T	TEMP,SUIT NO.2 OUTLET	30 80 100 DEGF	SS	S I H 8 B 2 H	30 110	SS	6-2 0 .12	
EF1301-P	PRESS,SUIT OUTLET	0 5 10 PSIA	SS	S I H 8 B 2 R L	0 10	SS	4-1 .28	.31
EF1301-P	PRESS,SUIT OUTLET	0 10 PSIA	SS	A	0 10	SS	-- --	--
EF1301-P	PRESS,SUIT OUTLET	3.2 PSIA	SS	W	3.2	SS	-- --	--
EF1521-P	PRESS,CO2 PARTIAL	0 2 30 MMHG	SS	S I H 8 B 2 R L C L	0 30	SS	4-1 1.00	2.70 EF9993
EF1522-P	PRESS,CO2 PARTIAL	0 30 MMHG	SS	A	0 30	SS	-- --	--



Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 18		
BASELINE E.O. LAB PHASE I		NOVEMBER 8, 1965		
ID CODE	MEASUREMENT NAME AND LOCATION	STABILITY AND CONTROL-CES		REFERENCES OR NOTES
		INTEREST RANGES LOW NORM HIGH UNIT RATE C R S G T D S C S L W L O X	FREQ A S S B G O M M H C F A X XDCR OR C C 7 I R P C S 7 / / X RANGES OR C NTP XDCR XDCR C DGE -PMW WT.	
EHI429-V	VOLTI, JET 12DRIVER OUT, 28V 6PPS	MAX, 10-400 MS	200E 1 B 2 R H W 0 / 28	4-2 0 0
EHI430-V	VOLTI, JET 13DRIVER OUT, 28V 6PPS	MAX, 10-400 MS	200E 1 B 2 R H W 0 / 28	4-2 0 0
EHI431-V	VOLTI, JET 14DRIVER OUT, 28V 6PPS	MAX, 10-400 MS	200E 1 B 2 R H W 0 / 28	4-2 0 0
EHI432-V	VOLTI, JET 15DRIVER OUT, 28V 6PPS	MAX, 10-400 MS	200E 1 B 2 R H W 0 / 28	4-2 0 0
EHI433-V	VOLTI, JET 16DRIVER OUT, 28V 6PPS	MAX, 10-400 MS	200E 1 B 2 R H W 0 / 28	4-2 0 0
EHI461-V	VOLTI, YAW RG SIG (.8KC)	-3.5 +3.5 VRMS 2C 2	10H 8 B 2 R L -3.5 +3.5 2C	7-1 0 0
EHI462-V	VOLTI, PITCH RG SIG (.8KC)	-3.5 +3.5 VRMS 2C	10H 8 B 2 R L -3.5 +3.5 2C	7-1 0 0
EHI463-V	VOLTI, ROLL RG SIG (.8KC)	-3.5 +3.5 VRMS 2C 2	10H 8 B 2 R L -3.5 +3.5 2C	7-1 0 0
EHI492-V	VOLT -4VDC SUPPLY	-4 VDC SS	W SS	4-1 0 0
EHI493-V	VOLT +6VDC SUPPLY	+6 VDC SS	W SS	2-2 0 0
EHI494-V	VOLT -6VDC SUPPLY	-6 VDC SS	W SS	2-2 0 0
EHI497-V	VOLT YAW RGA SIG (.8KC)	-3.5 +3.5 VRMS	A -3.5 +3.5	- -- --
EHI498-V	VOLT PITCH RGA SIG (.8KC)	-3.5 +3.5 VRMS	A -3.5 +3.5	- -- --
EHI499-V	VOLT ROLL RGA SIG (.8KC)	-3.5 +3.5 VRMS	A -3.5 +3.5	- -- --
EHI603-X	DEADBAND SELECT	TBA	SS 1 E 1 B 2 R H	SS 4-5 0 0
EHI608-X	SCS MODE SELECT (AUTO)	TBA	SS 1 E 1 B 2 R H	SS 4-5 0 0
EHI609-X	SCS MODE SELECT (ATT HOLD)	TBA	SS 1 E 1 B 2 R H	SS 4-5 0 0
EHI615-X	ROLL ATT CONT SEL (PULSED)	TBA	SS 1 E 1 B 2 R H	SS 4-5 0 0
EHI616-X	PITCH ATT CONT SEL (PULSED)	TBA	SS 1 E 1 B 2 R H	SS 4-5 0 0
EHI617-X	YAW ATT CONT SEL (PULSED)	TBA	SS 1 E 1 B 2 R H	SS 4-5 0 0
EHI618-X	ROLL ATT CONT SEL (DIRECT)	TBA	SS 1 E 1 B 2 R H	SS 4-5 0 0
EHI619-X	PITCH ATT CON SEL (DIRECT)	TBA	SS 1 E 1 B 2 R H	SS 4-5 0 0
EHI620-X	YAW ATT CONT SEL (DIRECT)	TBA	SS 1 E 1 B 2 R H	SS 4-5 0 0
EHI893-X	*X* TRANS OVERRIDE	TBA	SS 1 E 1 B 2 H	SS 4-5 0 0
EHI896-X	UNBALANCED COUPLES	TBA	SS 1 E 1 B 2 H	SS 4-5 0 0

Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 19					
BASELINE E.O. LAB PHASE 1		NOVEMBER 8, 1965					
ID	MEASUREMENT	STABILITY AND CONTROL-AGS				REFERENCES	
		INTEREST RANGES	FREQ A S S B G Q M MH C F A X	XDCR 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 DGE	-PWR	WT.	OR	NOTES
E10001	DIGITAL WORD	TBA	50S B 2				
E13137-V	VOLT +/-Y DELTA VELOCITY		B 2				
E13138-V	VOLT +/-Z DELTA VELOCITY		B 2				
E13151-V	VOLT DISP TOT, SIN ALP. 8KC -26	+26 VRMS		A	-26 +26		
E13152-V	VOLT DISP TOT, COS ALP. 8KC -26	+26 VRMS		A	-26 +26		
E13153-V	VOLT DISP TOT, SIN BET. 8KC -26	+26 VRMS		A	-26 +26		
E13154-V	VOLT DISP TOT, COS BET. 8KC -26	+26 VRMS		A	-26 +26		
E13155-V	VOLT DISP TOT, SIN GAM. 8KC -26	+26 VRMS		A	-26 +26		
E13156-V	VOLT DISP TOT, COS GAM. 8KC -26	+26 VRMS		A	-26 +26		
E13166-V	VOLT YAW ATT ERR TO DIS			A			
E13167-V	VOLT PITCH ATT ERR TO DIS			A			
E13168-V	VOLT ROLL ATT ERR TO DIS			A			
E13171	YAW INCREMENTAL ANGLE		B 2				
E13172	ROLL INCREMENTAL ANGLE		B 2				
E13173	PITCH INCREMENTAL ANGLE		B 2				
E13175	ASA CLOCK	TBA	B 2				
E13176	BLOCK TEMP REFERENCE	TBA	B 2				
E13177	COU ZERO	TBA	B 2				
E13184	PNGS T/M DNLINK DATA PUL	TBA	B 2				
E13185	1024 CLOCK	TBA	B 2				
E13201-V	VOLT +DELTA V TO DISPLAY			D			
E13202-V	VOLT -DELTA V TO DISPLAY			D			
E13203-V	VOLT ALT TO DISPLAY			A			
E13204-V	VOLT ALT RATE TO DISPLAY			A			
E13205-V	VOLT LAT VEL TO DISPLAY			A			

Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 20			
BASELINE E.D.LAB PHASE I		NOVEMBER 8, 1965			
ID CODE	MEASUREMENT NAME AND LOCATION	STABILITY AND CONTROL-AGS		REFERENCES OR NOTES	
		INTEREST RANGES	C T		
	LOW NUM HIGH UNIT RATE C P S G T D S C S L W L D X LOW HIGH RATE C DGE -PWR WT.	FREQ A S S B G D M H C F A X XDCR FREQ A DSY			
E13214-V	+32 VDC ASA	32	W	2-2 0 0	C
E13215-V	+12 VDC ASA	12	W	2-2 0 0	H
E13216-V	-12 VDC ASA	-12	W	2-2 0 0	N
E13217-V	+6 VDC ASA	6	W	2-2 0 0	G
E13218-V	+4 VDC ASA	4	W	4-1 0 0	
E13219-V	-2 VDC ASA	-2	W	4-1 0 0	
E13221-V	AGS POWER SUPPLY FAIL		W	4-1 0 0	
E13232	AEA TEST MODE FAIL		W	4-1 0 0	
E13301-T	TEMP, ASA		S	6-2 0 .13	
E13305-X	AGS MODE (WARMUP)		S S I E I	SS	--
E13306-X	AGS MODE (STANDBY)		S I E I	SS	--
E13311-V	VOLT +/-X DELTA VELOCITY		B 2		--
E13340	YAW ATTITUDE ERROR NULL		B 2		
E13341	PITCH ATT ERROR NULL		B 2		
E13342	ROLL ATTITUDE ERROR NULL		B 2		
E13343	ASA X AXIS SMRD		B 2		
E13344	ASA Y AXIS SMRD		B 2		
E13345	ASA Z AXIS SMRD		B 2		

Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983 BASELINE E.O. LAB PHASE 1		PAGE NUMBER 217 NOVEMBER 8, 1965				
ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	INSTRUMENTATION FREQ A S S B G D M H C F A X OR C / I R P C S / / X RANGES	XDCR OR C NTP XDCR XDCR	FREQ A DS OR C HIGH RATE C DGE -PWR	REFERENCES OR NOTES
EL0300	FRAME SYNCH + ID		I P 328 2 R L			
EL0300-	FRAME SYNCH + ID		50P 328 2 R H			
EL0302	FORMAT ID		I P 8 B 2 R L			
EL0401	CALIB 85 PCT HL	4.24 4.25 4.26 VDC SS	I H 8 B 2 R L	0 5 SS		
EL0401-	CALIB 85 PCT HL	4.24 4.25 4.26 VDC SS	10H 8 B 2 R H	0 5 SS		
EL0402	CALIB 15 PCT HL	.741 .75 .759 VDC SS	I H 8 B 2 R L	0 1 SS		
EL0402-	CALIB 15 PCT HL	.741 .75 .759 VDC SS	10H 8 B 2 R H	0 1 SS		
EL0411	OUTPUT REG ALL ZERO CK		I P 8 B 2 L			
EL0501-W	TIME, GREENWICH MEAN		I P 328 2 R H			
EL0501-W	TIME, GREENWICH MEAN		10P 328 2 R L			
EL0801-V	VOLT PCMTÉ 1024KC TIM SIG		B 2		SS	
EL4021-X	(60S1) TBA	CONTACT CLOSURE	L	CC	SS	
EL4025-X	60S5 TBA	CONTACT CLOSURE	L	CC	SS	
EL4026-X	CFS AC PWR SUPP FAIL(60S6)	CONTACT CLOSURE	I E 1 2 H	CC	SS	
EL4026-X	CFS AC PWR SUP FAIL(60S6)W	CONTACT CLOSURE	I E 1 2 H L	CC	SS 4-4 0 0	
EL4027-X	CES DC PWR SUP FAIL(60S7)W	CONTACT CLOSURE	I E 1 2 L L	CC	SS 4-4 0 0	
EL4028-X	AGS PWR SUPP FAIL (60S8) W	CONTACT CLOSURE	I E 1 2 L L	CC	SS 4-4 0 0	
EL4031-X	60S11 RCS TCA JET FAIL W	CONTACT CLOSURE	L	CC	SS	
EL4032-X	60S12 PR RCS HE REG A OUTW CONTACT CLOSURE	CONTACT CLOSURE	L	CC	SS	
EL4033-X	60S13 PR RCS HE REG B OUTW CONTACT CLOSURE	CONTACT CLOSURE	L	CC	SS	
EL4034-X	60S14 TBA W	CONTACT CLOSURE	L	CC	SS	
EL4035-X	60S15 TBA W	CONTACT CLOSURE	L	CC	SS	
EL4036-X	60S16 CABIN WARNING W	CONTACT CLOSURE	L	CC	SS	
EL4037-X	60S17 SUIT/FAN WARNING W	CONTACT CLOSURE	L	CC	SS	
EL4040-X	60S20 TBA W	CONTACT CLOSURE	L	CC	SS	

Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 22					
BASELINE E.O. LAB PHASE 1		NOVEMBER 8, 1965					
ID	MEASUREMENT	INSTRUMENTATION				REFERENCES	
		INTEREST	FREQ A S S B G O M H C F A X	XDCR	FREQ A O S Y		
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 C / I T R P C S / / / X RANGES	OR C NIP XDCR	OR	NOTES	
EL4043-X	60S23 TBA C	CONTACT CLOSURE	SS	L	CC	SS	
EL4044-X	60S24 TBA C	CONTACT CLOSURE	SS	L	CC	SS	
EL4046-X	60S26 TBA C	CONTACT CLOSURE	SS	L	CC	SS	
EL4047-X	60S27 TBA C	CONTACT CLOSURE	SS	L	CC	SS	
EL4048-X	60S28 TBA C	CONTACT CLOSURE	SS	L	CC	SS	
EL4049-X	60S29 TBA C	CONTACT CLOSURE	SS	L	CC	SS	
EL4050-X	60S30 TBA C	CONTACT CLOSURE	SS	L	CC	SS	
EL4051-X	60S31 TBA C	CONTACT CLOSURE	SS	L	CC	SS	
EL4052-X	60S32 RCS CAUTION C	CONTACT CLOSURE	SS	L	CC	SS	
EL4053-X	60S33 HEATER CAUTION C	CONTACT CLOSURE	SS	L	CC	SS	
EL4054-X	60S34 TBA C	CONTACT CLOSURE	SS	I E I B 2	L	CC	SS
EL4055-X	60S35 TBA C	CONTACT CLOSURE	SS	L	CC	SS	
EL4056-X	60S36 ECS CAUTION C	CONTACT CLOSURE	SS	L	CC	SS	
EL4057-X	60S37 ECS 02 ACCUM PRES C	CONTACT CLOSURE	SS	L	CC	SS	
EL4058-X	60S38 GLYCOL CAUTION C	CONTACT CLOSURE	SS	L	CC	SS	
EL4059-X	60S39 DES-ASC H2O QUAN C	CONTACT CLOSURE	SS	L	CC	SS	
EL4060-X	60S40 TBA C	CONTACT CLOSURE	SS	L	CC	SS	
EL4069-X	C+WE MASTER ALARM ID		SS	I E I B 2	L	L	SS
EL4111-V	VOLT C+WE WRN IN REF V 1	-4.995 -5 -5.005 V	SS	B 2	0	-5	SS
EL4112-V	VOLT C+WE WRN IN REF V 2	-4.995 -5 -5.005 V	SS	B 2	0	-5	SS
EL4113-V	VOLT C+WE WRN IN REF V 3	-4.995 -5 -5.005 V	SS	B 2	0	-5	SS
EL4114-V	VOLT C+WE CAUT IN REF V	-4.995 -5 -5.005 V	SS	B 2	0	-5	SS
EL4201-F	FREQ DSEA MONI HD OUTPUT	3 3KCP5	3KC	A 1			SS
EL4202-F	FREQ DSEA BIAS OSC OUTPUT	36 36KCP5	TBA	A 1			SS
EL9501-U	TCA FAILURE PR 4A		SS	F			SS



Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983 BASELINE E.O. LAB PHASE 1		INSTRUMENTATION										PAGE NUMBER 23 NOVEMBER 8, 1965	
ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES		OR C / I R P C S / 7 / X		RANGES		XDCR		FREQ A OSY		REFERENCES	
		LOW	NORM	HIGH	UNIT	LOW	HIGH	LOW	HIGH	LOW	HIGH	OR	NOTES
EL9502-U	TCA FAILURE PR 4B	SS				F				SS			
EL9503-U	TCA FAILURE PR 3A	SS				F				SS			
EL9504-U	TCA FAILURE PR 3B	SS				F				SS			
EL9505-U	TCA FAILURE PR 2A	SS				F				SS			
EL9506-U	TCA FAILURE PR 2B	SS				F				SS			
EL9507-U	TCA FAILURE PR 1A	SS				F				SS			
EL9508-U	TCA FAILURE PR 1B	SS				F				SS			

Table 5.6-6 (cont.)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 24																
BASELINE F.O. LAB PHASE I		NOVEMBER 8, 1965																
ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	REACTION CONTROL				REFERENCES OR NOTES											
			FREQ A	S S	B G	O M		H C	F A	X XDCR	FREQ A	DSY						
		LOW NORM HIGH UNIT RATE C R S G T D S C S L W L O X LOW HIGH RATE C DGE -PWR WT.																
ER1101-P	PRESSURE, HELIUM TANK A	3000 3050 3250 PSIA	SS	3	I	H	8	2	R	L	A	0	3500	SS	4-1	.28	.25	
ER1101-P	PRESS HELIUM TANK A	0	1000 PSIA	SS							C	0	1000					
ER1102-P	PRESSURE, HELIUM TANK B	3000 3050 3250 PSIA	SS	3	I	H	8	2	R	L		0	3500	SS	4-1	.28	.25	
ER1102-P	PRESS HELIUM TANK B	0	1000 PSIA	SS							C	0	1000	SS				
ER1121-T	TEMP, HELIUM TANK A	40 70 100 DEGF	SS	3	I	H	8	2	R	L	A	20	120	SS	6-2	0	.16	
ER1122-T	TEMP, HELIUM TANK B	40 70 100 DEGF	SS	3	I	H	8	2	R	L	A	20	120	SS	6-2	0	.16	
ER1201-P	PRESS, HE REGULATOR A OUT	171 191 250 PSIA	SS	3	I	H	8	2	R	L		0	350	SS	4-1	.28	.25	
ER1201-P	PRESS HE REG A OUTPUT	0	175	SS							W	0	175	SS				
ER1202-P	PRESS, HE REGULATOR B OUT	171 191 250 PSIA	SS	3	I	H	8	2	R	L		0	350	SS	4-1	.28	.25	
ER1202-P	PRESS HE REG B OUTPUT	0	175	SS							W	0	175	SS				
ER1461-X	HE SHUTOFF VLV A-1, CLOSE	CONTACT CLOSURE	SS	S	I	E	I	B	2	R	H	F	CC	SS	4-4	0	Z.05	
ER1462-X	HE SHUTOFF A-2 NOT CLOSED	CONTACT CLOSURE	SS	S	I	E	I	B	2	R	L	F	CC	SS	4-4	0	Z.05	
ER1463-X	HE SHUTOFF VLV B-1, CLOSE	CONTACT CLOSURE	SS	S	I	E	I	B	2	R	H	F	CC	SS	4-4	0	Z.05	
ER1464-X	HE SHUTOFF B-2 NOT CLOSED	CONTACT CLOSURE	SS	S	I	E	I	B	2	R	L	F	CC	SS	4-4	0	Z.05	
ER2101-P	PRESSURE, FUEL TANK A	171 191 250 PSIA	SS	I	I	H	8	2	R	L	A	0	350	SS		.28	.25	
ER2102-P	PRESSURE, FUEL TANK B	171 191 250 PSIA	SS	I	I	H	8	2	R	L	A	0	350	SS		.28	.25	
ER2121-T	TEMPERATURE, FUEL TANK A	40 70 100 DEGF	SS	I	I	H	8	2	R	L	A	20	120	SS	6-2	0	.16	
ER2122-T	TEMPERATURE, FUEL TANK B	40 70 100 DEGF	SS	I	I	H	8	2	R	L	A	20	120	SS	6-2	0	.16	
ER2141-Q	QUANTITY, FUEL TANK A	0	99 PCT	SS	S	I	P	8	2	R	L		0	99	SS			
ER2142-Q	QUANTITY, FUEL TANK B	0	99 PCT	SS	S	I	P	8	2	R	L		0	99	SS			
ER2143-Q	QUANTITY FUEL TANK A	0	99 PCT	SS							0	0	99	SS				
ER2144-Q	QUANTITY FUEL TANK B	0	99 PCT	SS							0	0	99	SS				
ER2201-P	PRESS, A FUEL MANIFOLD	171 191 250 PSIA	SS	3	I	H	8	2	R	L	H	A	0	350	SS	4-1	.28	.25
ER2202-P	PRESS, B FUEL MANIFOLD	171 191 250 PSIA	SS	3	I	H	8	2	R	L	H	A	0	350	SS	4-1	.28	.25
ER2361-X	FUEL MNFL XFEED VLV NO CL	CONTACT CLOSURE	SS	S							* F	CC	SS		0	Z.05	ER9613	



Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983		PAGE NUMBER 25,		NOVEMBER 8, 1965		C T		C		
BASELINE E.O. LAB PHASE 1		REACTION CONTROL		C T		C		H		
ID	MEASUREMENT	INTEREST	FREQ A	S S B G O	M H C F A X	XDCR	FREQ A	OSY	REFERENCES	
CODE	NAME AND LOCATION	RANGES	OR	C C / / / X	RANGES	OR	C NIP	XDCR	OR	
		LOW NORM HIGH UNIT	RATE	C R S G T D S C	SL W L D X	LOW HIGH	RATE	C DGE	WT.	
		CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	
ER2362-X	OXID MNFL XFEED VLV NO CL	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	ER9613
ER2461-X	FUEL MAIN FEED S/O A CL	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	ER9609
ER2462-X	FUEL MAIN FEED S/O B CL	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	ER9610
ER3101-P	PRESSURE+OXIDIZER TANK A	171 191 250 PSIA	SS	3 I I H 8 B 2 R L	A	0 350	SS	-	.28	.25
ER3102-P	PRESSURE+OXIDIZER TANK B	171 191 250 PSIA	SS	3 I I H 8 B 2 R L	A	0 350	SS	-	.28	.25
ER3121-T	TEMP+OXIDIZER TANK A	40 70 100 DEGF	SS	3 I I H 8 B 2 R L	A	20 120	SS	6-2	0	.16
ER3122-T	TEMP+OXIDIZER TANK B	40 70 100 DEGF	SS	3 I I H 8 B 2 R L	A	20 120	SS	6-2	0	.16
ER3141-Q	QUANTITY+OXID.TANK A	0 99 PCT	SS	3 S I P 8 B 2 R L	L	0 99	SS	-	--	--
ER3142-Q	QUANTITY+OXID.TANK B	0 99 PCT	SS	3 S I P 8 B 2 R L	L	0 99	SS	-	--	--
ER3143-Q	QUANTITY+OXIDIZER TANK A	0 99 PCT	SS	3	D	0 99	SS	-	--	--
ER3144-Q	QUANTITY+OXIDIZER TANK B	0 99 PCT	SS	3	D	0 99	SS	-	--	--
ER3201-P	PRESSURE+OXID.MNFLO A	171 191 250 PSIA	SS	3 I I H 8 B 2 R H	A	0 350	SS	-	.28	.25
ER3202-P	PRESSURE+OXID.MNFLO B	171 191 250 PSIA	SS	3 I I H 8 B 2 R H	A	0 350	SS	-	.28	.25
ER3461-X	OXID MAIN FEED S/O A CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	ER9609
ER3462-X	OXID MAIN FEED S/O B CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	ER9610
ER4261-X	TCA ISOL FUEL VLV 1A CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	ER9661
ER4262-X	TCA ISOL FUEL VLV 1B CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	ER9662
ER4263-X	TCA ISOL FUEL VLV 2A CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	ER9663
ER4264-X	TCA ISOL FUEL VLV 2B CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	ER9664
ER4265-X	TCA ISOL FUEL VLV 3A CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	ER9665
ER4266-X	TCA ISOL FUEL VLV 3B CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	ER9666
ER4267-X	TCA ISOL FUEL VLV 4A CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	ER9667
ER4268-X	TCA ISOL FUEL VLV 4B CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	ER9668
ER4269-X	TCA ISOL OXID VLV 1A CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	ER9661
ER4270-X	TCA ISOL OXID VLV 1B CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0 Z.05	ER9662

Table 5.6-6 (cont)

CONTRACT NUMBER MAS9-4983		PAGE NUMBER 26									
BASELINE E.O. LAB PHASE 1		NOVEMBER 8, 1965									
ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES	REACTION CONTROL				REFERENCES OR NOTES				
			LOW NORM	HIGH UNIT	C.R. S.G.T.D.S.C.SL.W.L.D.X	F.A.X.XDCR		FREQ. A.DSY			
ER4271-X	TCA ISOL OXID VLV 2A CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0	Z.05	ER9663
ER4272-X	TCA ISOL OXID VLV 2B CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0	Z.05	ER9664
ER4273-X	TCA ISOL OXID VLV 3A CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0	Z.05	ER9665
ER4274-X	TCA ISOL OXID VLV 3B CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0	Z.05	ER9666
ER4275-X	TCA ISOL OXID VLV 4A CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0	Z.05	ER9667
ER4276-X	TCA ISOL OXID VLV 4B CLSD	CONTACT CLOSURE	SS	S	* F	CC	SS	-	0	Z.05	ER9668
ER5001-X	O/F RATIO A OUT, TOLER	CONTACT CLOSURE	SS	S I E I B 2 P H C	CC	SS	SS	4-3	0	Z.05	
ER5002-X	O/F RATIO B OUT, TOLER	CONTACT CLOSURE	SS	S I E I B 2 P H C	CC	SS	SS	4-3	0	Z.05	
ER5011-P	PRESS TCA FUEL INLT PR 1A 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER5012-P	PRESS TCA FUEL INLT PR 1B 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER5013-P	PRESS TCA FUEL INLT PR 2A 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER5014-P	PRESS TCA FUEL INLT PR 2B 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER5015-P	PRESS TCA FUEL INLT PR 3A 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER5016-P	PRESS TCA FUEL INLT PR 3B 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER5017-P	PRESS TCA FUEL INLT PR 4A 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER5018-P	PRESS TCA FUEL INLT PR 4B 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER5019-P	PRESS TCA OXID INLT PR 1A 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER5020-P	PRESS TCA OXID INLT PR 1B 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER5021-P	PRESS TCA OXID INLT PR 2A 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER5022-P	PRESS TCA OXID INLT PR 2B 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER5023-P	PRESS TCA OXID INLT PR 3A 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER5024-P	PRESS TCA OXID INLT PR 3B 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER5025-P	PRESS TCA OXID INLT PR 4A 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER5026-P	PRESS TCA OXID INLT PR 4B 171	191 250 PSIA	SS	3 S	F	0	175	SS	-	-	
ER6001-T	TEMP, QUAD CLUSTER NO. 1	0 200 DEG F	SS	3 I I H B 2 R H	0	200	SS	6-2	0	.08	



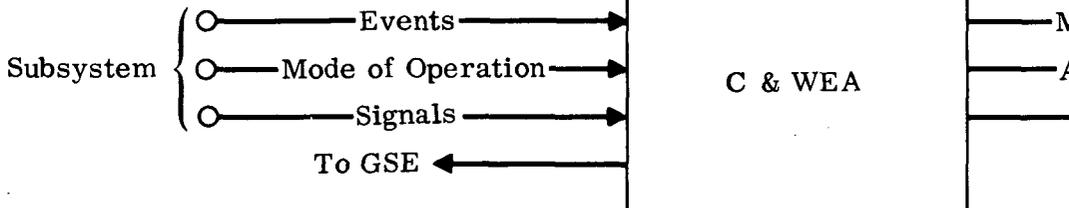
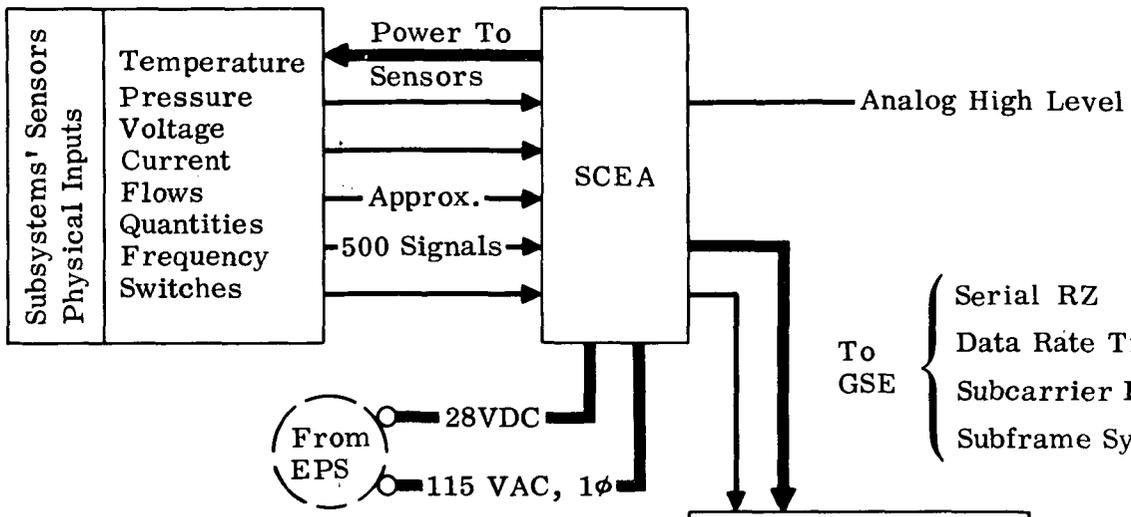
Table 5.6-6 (cont)

ID CODE	MEASUREMENT NAME AND LOCATION	LOW NORM HIGH UNIT RATE	C R S G T D S C S L W L D X	M H C F A X	XDCR RANGES	FREQ A OR C NIP	OSY XDCR	REFERENCES	COMMUNICATIONS		
									FREQ A	OSY	REFERENCES
									C	T	G
ET0105	PCM NRZ DATA INPUT	TBA		A 1							
ET0106	TE 512KC SYNC IN	TBA		A 1							
ET0107	PCM SPLIT PHASE IN	TBA		A 1							
ET0108	512KC SUBCARRIER REF IN	TBA		A 1							
ET0161-V	VOLT, PMP BACK-UP VOICE	TBA		A 1							
ET0163	VHF RCVD VOICE IN A	TBA		A 1							
ET0164	VHF RCVD VOICE IN B	TBA		A 1							
ET0201-E	POWER, SBAND PA RF PWR OUT	0 18	25 WATTS	SS	S I H B B 2 P L						
ET0202-E	PWR, SBAND PA RF REFLECTED	0 .3	.5 WATTS	SS	S I H B B 2 H						
ET0226-E	PWR VHF XMTR A+B RF OUT	TBA		B 2							
ET0504-V	VOLT, SBAND RCVR AGC	0	4.2 VDC		A 0 5						
ET0511	SBAND XPNDR FM INPUT	TBA		A 1							
ET0513	SBAND XPNDR PM INPUT	TBA		A 1							
ET0555	S BD RCVR SBCAR WVF0RM 0T	TBA		A 1							
ET0604-V	VOLT, VHF RCVR A AGC	0	4.2 VDC	SS	B 2						
ET0605-V	VOLT, VHF RCVR B AGC	0	4.2 VDC	SS	B 2						
ET0992-B	PHASE, ST PH ER, SLCTD S7B	-15 0	+15 DEG	2C	S 10H B B 2 R L						
ET0993-E	PWR, SLCTD SBAND XMTR RF	.5 .75	1 WATT	SS	S I H B B 2 R L						
ET0994-V	VOLT, SLCTD SBAND RCVR AGC	0	4.2 VDC	2C	S 10H B B 2 R L						
ET9991-J	7 SPACE SUIT/PL55 MPX OUT 4KC		12.4K								SBAND
ET9999-J	ELECTROCARDIOGRAM NO. 172		14.5K								SBAND

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CONTRACT NUMBER NAS9-4983
BASELINE E.O. LAB PHASE I

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Key



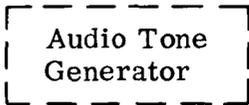
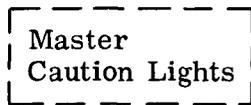
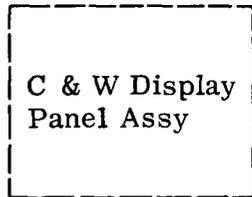
Not Part of Instr. Subsys.

SCEA: Signal Conditioning Electronics Assy

C&WEA: Caution & Warning Electronics Assy

PCMTEA: Pulse Code Modulation & Timing Electronic Assy

SPA: Signal Processing Assy



From EPS
From GN
Par
51.2
C
D

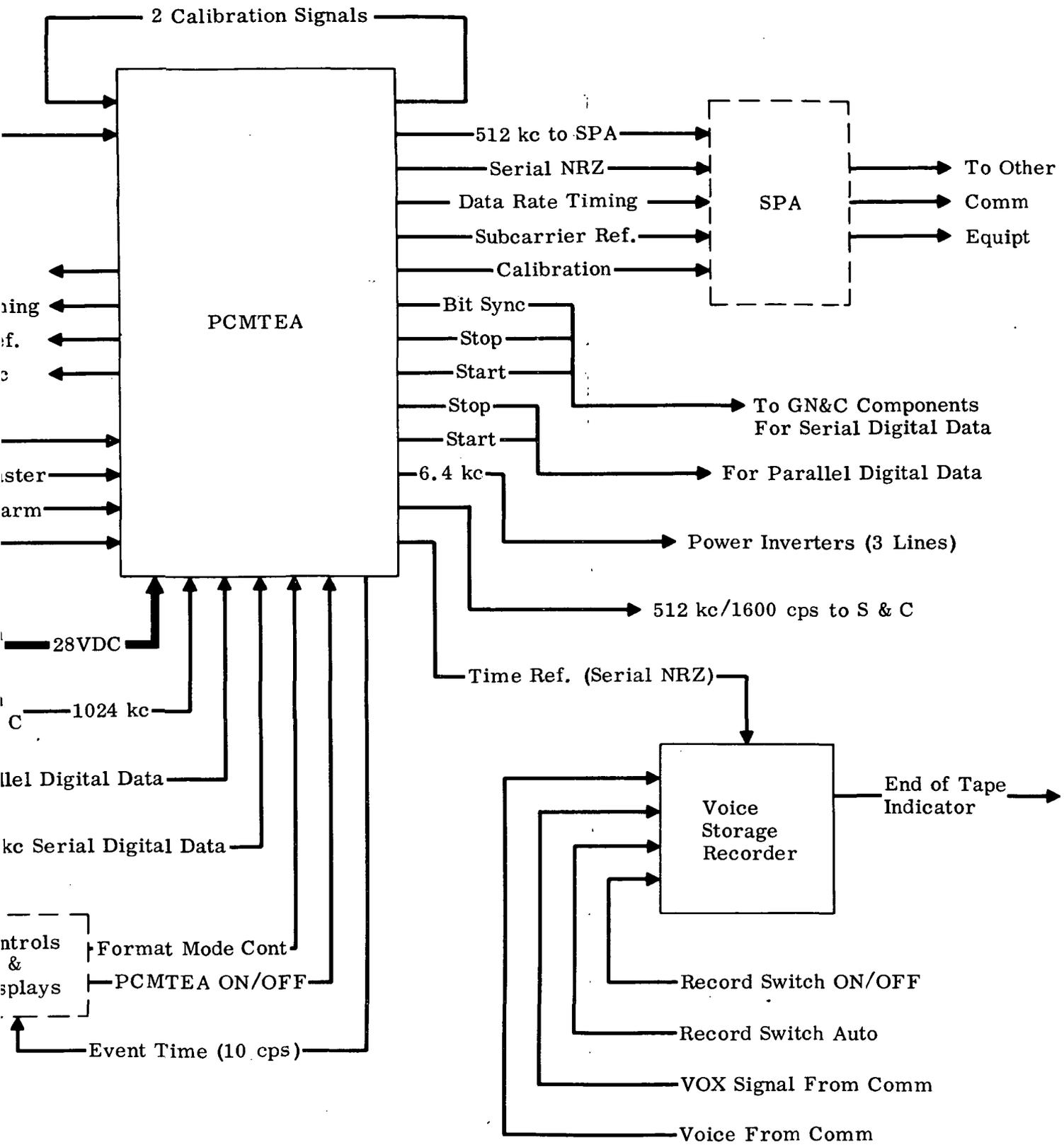


Fig. 5.6-1 Functional Diagram Operational Instrumentation Section

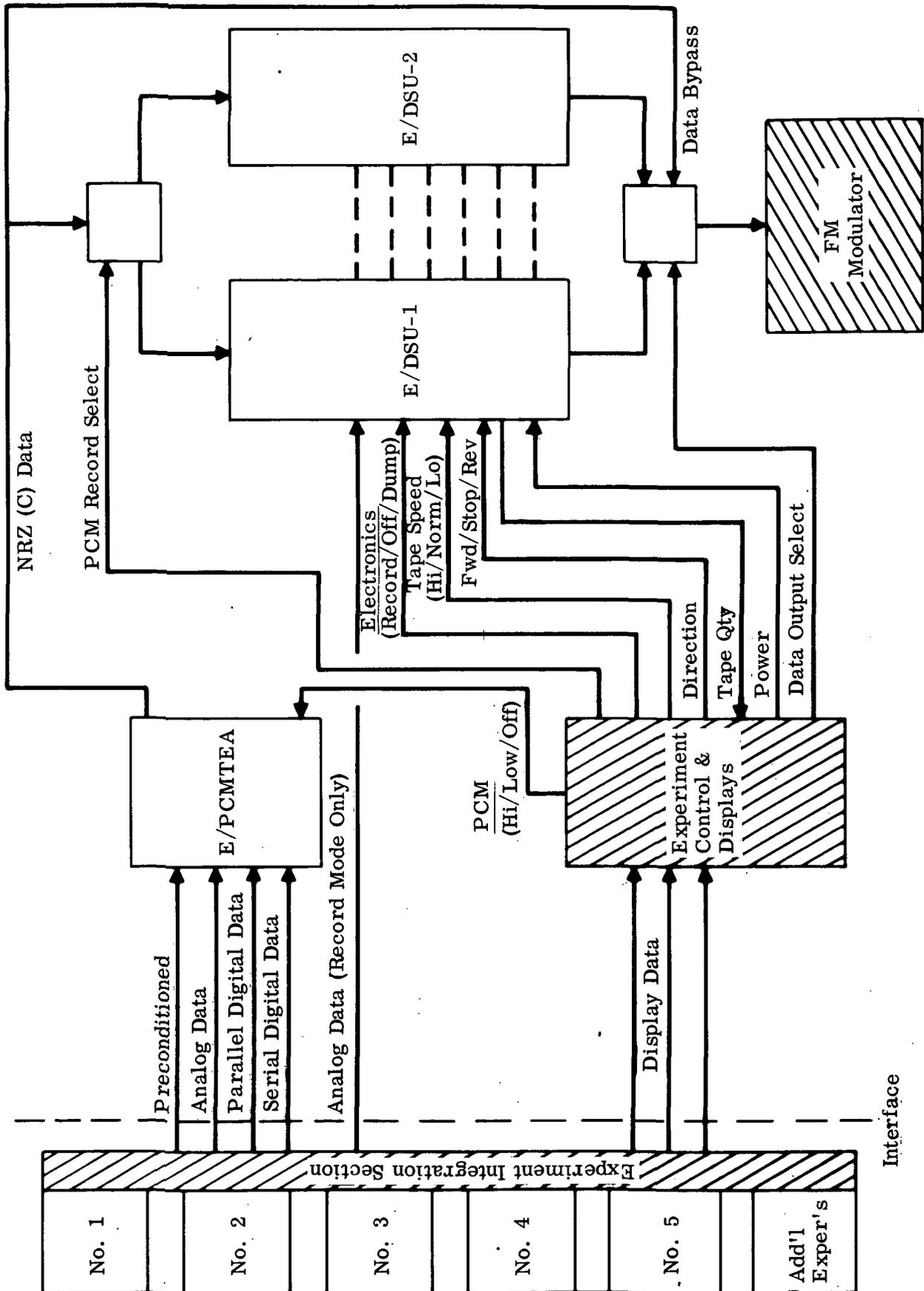


Fig. 5.6-2 Functional Diagram Experiment Instrumentation Section

5.7 CONTROLS AND DISPLAYS

5.7.1 Ground Rules

The ground rules are as shown:

- The required Lab displays should be incorporated with a minimum of modification to the existing console layout
- Maximum use should be made of LEM type controls and displays for modifications and new equipment employed in the Lab.

5.7.2 Assumptions and Background Data

5.7.3 Recommended Configuration

Requirements for the Phase I Lab differ only slightly from the present LEM and in general, the required Lab displays are incorporated in the basic LEM configuration with a minimum of console modification.

The following LEM controls and displays, or modification thereof, are recommended for integration into the Phase I Lab:

- Navigation and Guidance (modified)
- Stabilization and Control
- Reaction Control
- Instrumentation (modified)
- Communication
- Electric Power (modified)
- Environmental Control
- Caution and Warning.

The mission-oriented controls and displays are grouped as follows:

- Biomedical
- Behavioral
- Radiation Monitoring
- Communications Hardline
- Data Handling Package.

Fig. 6.3-4 shows the Commander's and System Engineer's controls and displays.

Commander's Panel:

- Panel No. IV, (Fig. 5.7-1), consists of circuit breaker panels that have circuit breakers for instrumentation, flight displays, subsystem displays, primary Guidance and Navigation Subsystem, Electrical Power Subsystem, Stabilization and Control, Internal Lighting and signal sensors.
- The audio controls, Panels I & XI (Figs. 5.7-2B & 5.7-3), enable the audio center to accept received S-Band and VHF/AM voice transmission and to route microphone amplifier outputs from within the Lab to the premodulation processor for S-band and VHF/AM equipment. The controls also enable reception and transmission of voice signals via the intercom system, establishing a voice conference capability between the extravehicular astronaut and the astronaut in the Lab and provide power to the voice operated transmission (VOX) Control circuitry in the audio center.
- The abort guidance panel, XII (Fig. 5.7-4) provides backup for the Guidance and Navigation Subsystem, using the Lab guidance computer (IGC) for guidance for aborts.

- The Commander's lighting control panel VII (Fig. 5.7-5) controls the side console lighting, integral lights and the dome light.
- The Stabilization and Control panel III (Fig. 5.7-6) permits selection of five modes of attitude control. The automatic mode provides fully automatic attitude control. The attitude hold mode is the primary attitude control mode for docking phases of the mission. The rate command mode is the same as the attitude hold mode, except it does not provide a neutral position. The pulse mode is an open-loop attitude control mode providing full RCS jet thrusting for attitude changes in all three axes.
- The Flight Controls related to controls and displays are as follows:
 - 1 Flight Director Attitude Indicator, events timer and events timer start-stop switch.
- The Flight Director Attitude Indicator displays the attitude, attitude rates, and attitude errors of the Lab, in all three axes.
- The clock on panel I (Fig. 5.7-3)
- The warning indicators, panel I (Fig. 5.7-3), warn of an emergency malfunction requiring immediate action. Lighting of a warning indicator, (red lights) is accompanied by an audible tone in the astronaut's headset. There is also a master alarm switch which also lights up when a malfunction occurs. Pushing this button will stop the audible tone.

Systems Engineer's Panel:

- The yellow-light caution indicators on panel II (Fig. 5.7-7) alert the astronaut to a situation or malfunction which requires attention but is not critical at the moment. When the caution lights indicate a malfunction both the master alarms switch lights and audible tone function. Both master alarm switch lights are extinguished and the audible tone is silenced by pressing either master alarm switch-light.
- The Reaction Control panel II (Fig. 5.7-7) contains the following controls and displays:
 - Temperature and pressure indicators to display the temperature and pressure of the helium, fuel, and oxidizer tanks, and fuel or oxidizer manifolds of system A and system B.
 - The oxidizer and fuel quantity indicators display percentages of oxidizer and fuel quantities of system A and system B.
 - The system A and system B switches and status flags indicate the status of their respective latch-type solenoid valve, and four regulator switches and two main shutoff switches.
 - The thruster pair switches and status flags consist of eight 3-position status flags that indicate the status of their pair of latch-type solenoid valves, and eight thruster pair switches.
 - The crossfeed switch controls two latch type, solenoid-operated fuel and oxidizer valves that interconnect the propellant valves of system A and B.
 - The test switch is used to check for a leak in the line downstream of the TCA isolation valves.
- The Environmental Control panel II (Fig. 5.7-7) contains the following controls and displays:
 - The suit/cabin temperature and pressure indicators. Displays of carbon dioxide partial pressure in the suit circuit. The glycol temp/press indicator display temperature and pressure of the coolant in the heat transport

section. The gaseous oxygen pressure-water and gaseous oxygen displays gaseous oxygen pressure, water quantity and gaseous oxygen quantity. The suit fan select switch, selects an operating fan (1, 2 or 3) and a failure light with each position.

- The Systems Engineer's panel XI (Fig. 5.7-2B) consists of a Communication Panel, Communications Antennas Panel and Data Handling display.
- The Communications Panel has switches and controls that start the operation of the S-band, VHF AM, emergency key, telemetry control, tape recorder, and selection of backup S-band equipment. The VHF AM control select simplex or duplex voice operation; a squelch control establishes the degree on noise limiting in the operating duplex receiver. The telemetry controls permit high-or-low-bit rate premodulation processor transmission. The keyer is energized by setting the EMER KEY switch to ON. Provisions for a hardline communications to the CSM for both astronauts has been incorporated enabling either astronaut to talk directly to the CSM.
- The Communication Antennas Panel has indicators, switches and pitch and slew sych. switches for pointing the S-band steerable antenna toward Earth. The VHF switch selects either of two inflight omnidirectional antennas. The S-band switch selects the steerable antenna or slew positions.
- The Data Handling Panel (Fig. 5.7-2B) consists of a display for modified PCM and two tape recorders. The tape recorders have a two speed switch and digital readouts of tape remaining and a record-dump switch.
- The Systems Engineer's Lighting Control panel III (Fig. 5.7-6) consists of exterior lighting switch, lamp tone test switch, docking light and recognition lights. Fig. 5.7-8 contains the Systems Engineer's circuit breaker panels that have circuit breakers for interior lighting, reaction control subsystem, electrical power subsystem, environmental control, and communications.
- The Systems Engineer controls the electrical power distribution panels X & II (Figs. 5.7-2A & 5.7-7) which receives power from 22 batteries. These batteries are controlled by high and low voltage power switches. Selecting the set position will place the batteries on high or low voltage tap on the line. If either switch is released it will snap to on, and power will continue to be supplied. Selecting off/reset position disconnects the battery from the line. For both sets of switches, (high or low voltage switches) one status flag to indicate when the battery is on the line. The battery temperature, volts and amps are displayed.
- The crew safety package located on panel I (Fig. 5.7-3) displays respiration rate, heart rate and cabin radiation level, these are minimum requirements for crew safety.

The following systems and subsystems have been slightly modified or deleted to meet mission requirements. They are as follows:

- | | |
|---------------------------|-------------------------|
| ● Main Propulsion | ○ Environmental Control |
| ● Navigation and Guidance | ○ Electrical Power |
| ● Engine Thrust Controls | ○ Explosive Devices |
| ● Reaction Controls | |

Both ascent and descent propulsion subsystems have been deleted, to comply with the mission definitions of the basic Lab. The engine thrust control work in conjunction with the Main Propulsion System and are therefore also deleted. The panel area left vacant by the propulsion and engine thrust will become available for experiments.

Since Navigation and Guidance has deleted the primary guidance systems there is no need for the GASTA or DSKY computer. There is only one FDAI in the baseline Lab, therefore, the abort guidance system can handle GASTA error correction duties.

The radar (both rendezvous and landing radar), has been deleted since the Lab is an earth orbiter and will not perform a landing, rendezvous or docking maneuver. The radars can be added as a per-flight modification when required for experiments.

The heater control panel has been modified to accommodate the S-band heater controls and the removal of the radar heater controls.

Due to the deletion of the Main Propulsion ascent and descent engines, the ascent feed switches and lights can be removed from the Reaction Control Subsystem.

The Electrical Power Subsystem (EPS) has increased the number of batteries to comply with the increased mission and thus increased power requirements. Each battery must be controlled individually therefore, it is necessary to modify the controls and displays for 20 descent batteries and 2 ascent batteries. Since the existing EPS panel is unable to provide enough area hold for these additional displays, it becomes necessary to use the area left vacant by the Systems Engineer's FDAI for the monitoring meters.

The Explosive Devices have been slightly modified to reflect the changes in the systems on board. Explosive devices for the landing gear, ascent pressure, ascent tankage and descent pressure are removed.

The Environmental Control System has added five descent O₂ tanks and removed two ascent O₂ tanks, therefore, the O₂ pressure/H₂O quantity monitor select switch must be modified.

The circuit breakers have been added or deleted in accordance with system and subsystem modifications. The extra circuit breakers will be utilized by the experiments on board.

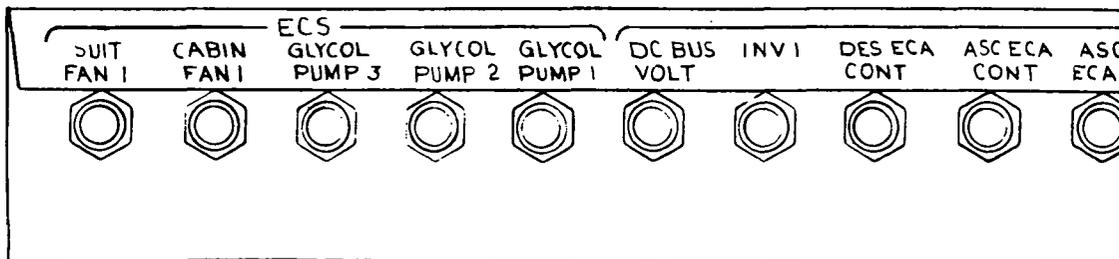
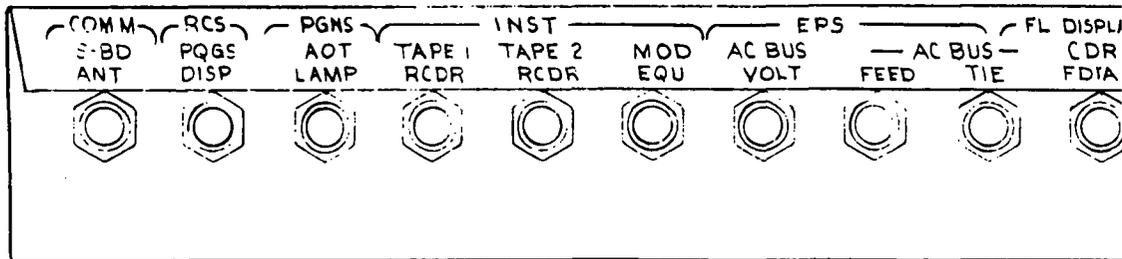
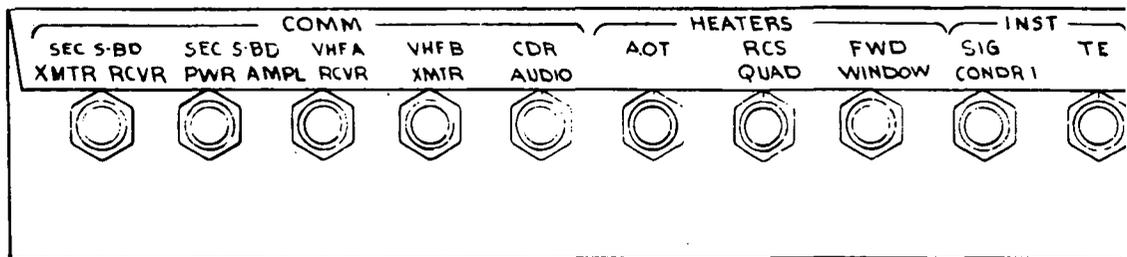
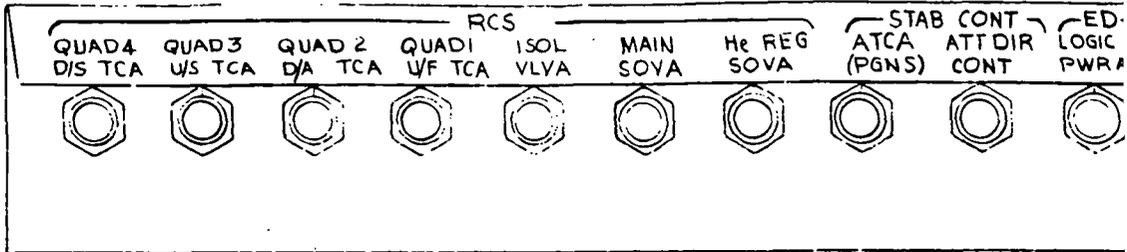
The display and control functions provided should give the Lab flight crew sufficient information and command access to the vehicle systems and subsystems to enable the crew to successfully accomplish the following operations during the mission:

- Manual Lab operation as required under normal mission conditions.
- Safe shutdown of the Lab equipment, if necessary.
- Monitoring Lab systems and subsystems as required for normal mission or contingency operations.
- Recognize malfunctions to the crew, vehicle or mission and display a warning to the crew.
- Monitor the Lab subsystem condition such as:
 - Power sources
 - Propellant quantity
 - H₂O and O₂ quantities

In general, displays that were redundant and which did not affect crew safety, the mission, or controlling the vehicle were deleted. Areas made available from modified or deleted equipment has been allocated for experiments integration. The approximate panel area for experiment controls and displays is 561 sq. in. If the Rendezvous Radar and DSKY are not used, the available area increases to 637 sq. in.

The required Lab displays were incorporated in the basic LEM configuration with a minimum of modification to the existing console layout. Subsystems that required a new or redesigned display panel were located in the same hard points, to provide a commonality between vehicles. That is, even though the displays for a subsystem may be different their location will remain the same. This will enable the Astronauts to move from vehicle to vehicle with a minimum of confusion as to location of displays.

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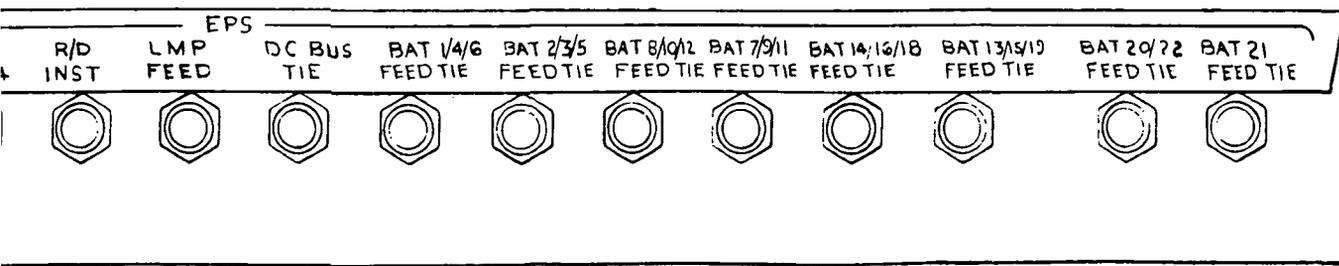
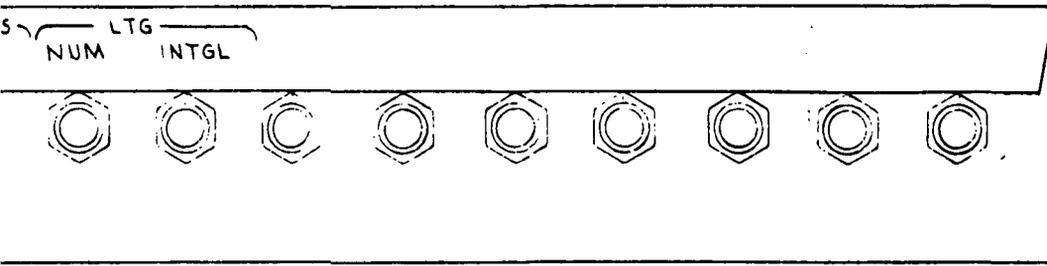
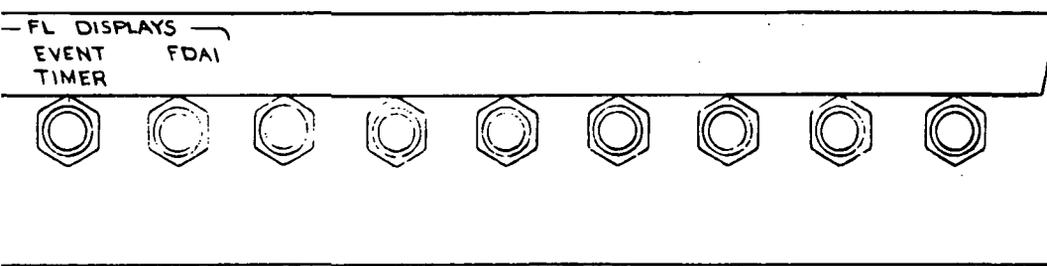
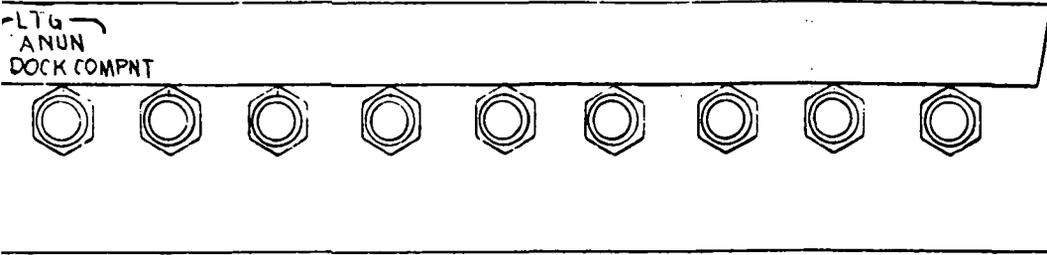
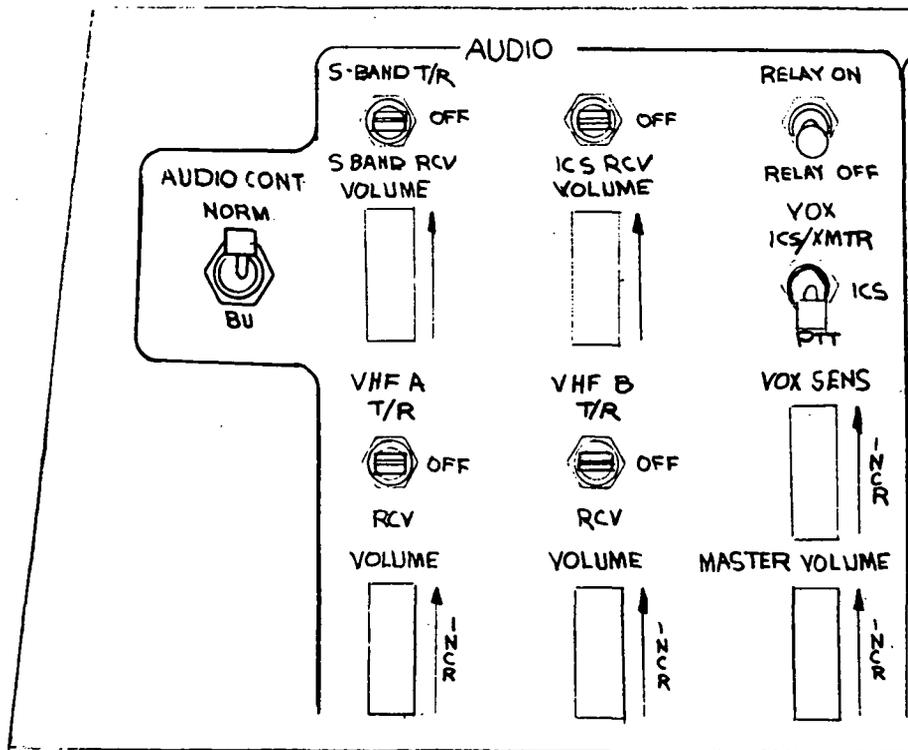
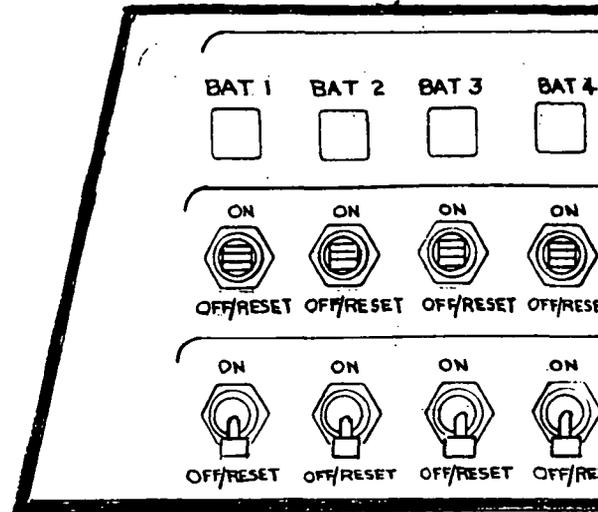


Fig. 5.7-1 Panel No. 4



5-7-26
 0

ELECTRICAL POWER CONTROL

BAT 5	BAT 6	BAT 7	BAT 8	BAT 9	BAT 10	BAT 11	BAT 12	BAT 13	BAT 14	BAT 15	BAT 16
<input type="checkbox"/>											
HI VOLTAGE											
<input checked="" type="checkbox"/>											
OFF/RESET											
LO VOLTAGE											
<input checked="" type="checkbox"/>											
OFF/RESET											

MODIFIED

COMMUNICATIONS

S-BAND

<p>MODULATE</p> <p>PM <input type="checkbox"/></p> <p>FM <input checked="" type="checkbox"/></p>	<p>XMTR/RCVR</p> <p>PRM <input type="checkbox"/></p> <p>SEC <input checked="" type="checkbox"/></p>	<p style="text-align: center;">FUNCTIONS</p> <p>VOICE <input type="checkbox"/></p> <p>VOICE BU <input checked="" type="checkbox"/></p> <p>PCM <input type="checkbox"/></p> <p>KEY <input checked="" type="checkbox"/></p> <p>RANGE <input type="checkbox"/></p> <p>TV <input checked="" type="checkbox"/></p>
<p>HEAD SET & BIOMED</p>	<p style="text-align: center;">VHF A</p> <p>XMTR <input checked="" type="checkbox"/></p> <p>RCVR <input checked="" type="checkbox"/></p>	<p style="text-align: center;">VHF B</p> <p>XMTR <input checked="" type="checkbox"/></p> <p>RCVR <input checked="" type="checkbox"/></p> <p>DATA <input type="checkbox"/></p>
<p>AUDIO HARDLINE TO CSM</p> <p>CSM 1 <input type="checkbox"/></p> <p>CSM 2 <input type="checkbox"/></p> <p>VOLUME <input type="checkbox"/></p> <p>RCN <input type="checkbox"/></p>	<p style="text-align: center;">SQUELCH</p> <p>VHF A <input type="checkbox"/></p> <p>VHF B <input type="checkbox"/></p>	<p style="text-align: center;">TELEMETRY</p> <p>BIOMED LEFT <input type="checkbox"/></p> <p>RIGHT <input type="checkbox"/></p> <p>PCM HI <input type="checkbox"/></p> <p>LO <input type="checkbox"/></p>
<p style="text-align: center;">AUDIO RECORDER TAPE</p> <p><input type="checkbox"/></p> <p><input checked="" type="checkbox"/></p>		

PITCH DEGS

TRACK MOD

AUTO

NO T

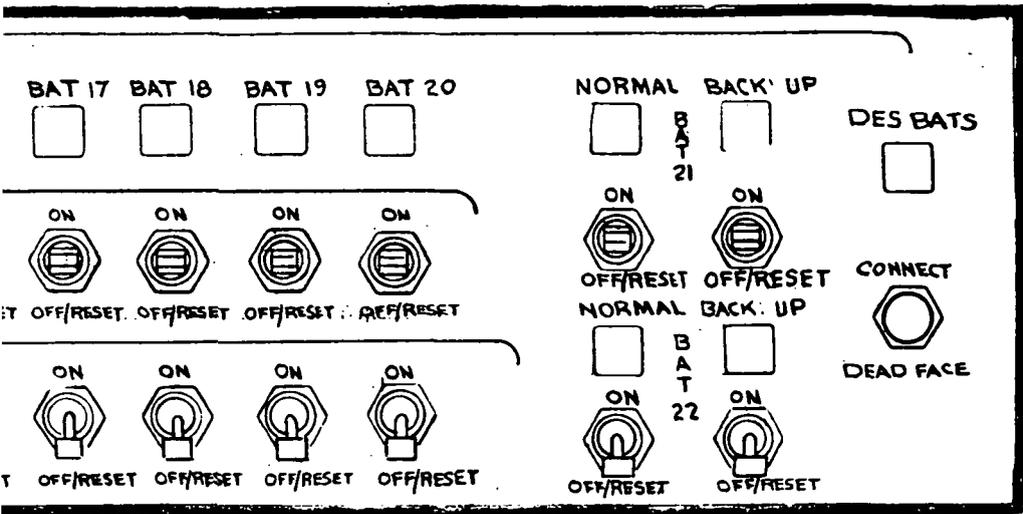
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PITCH

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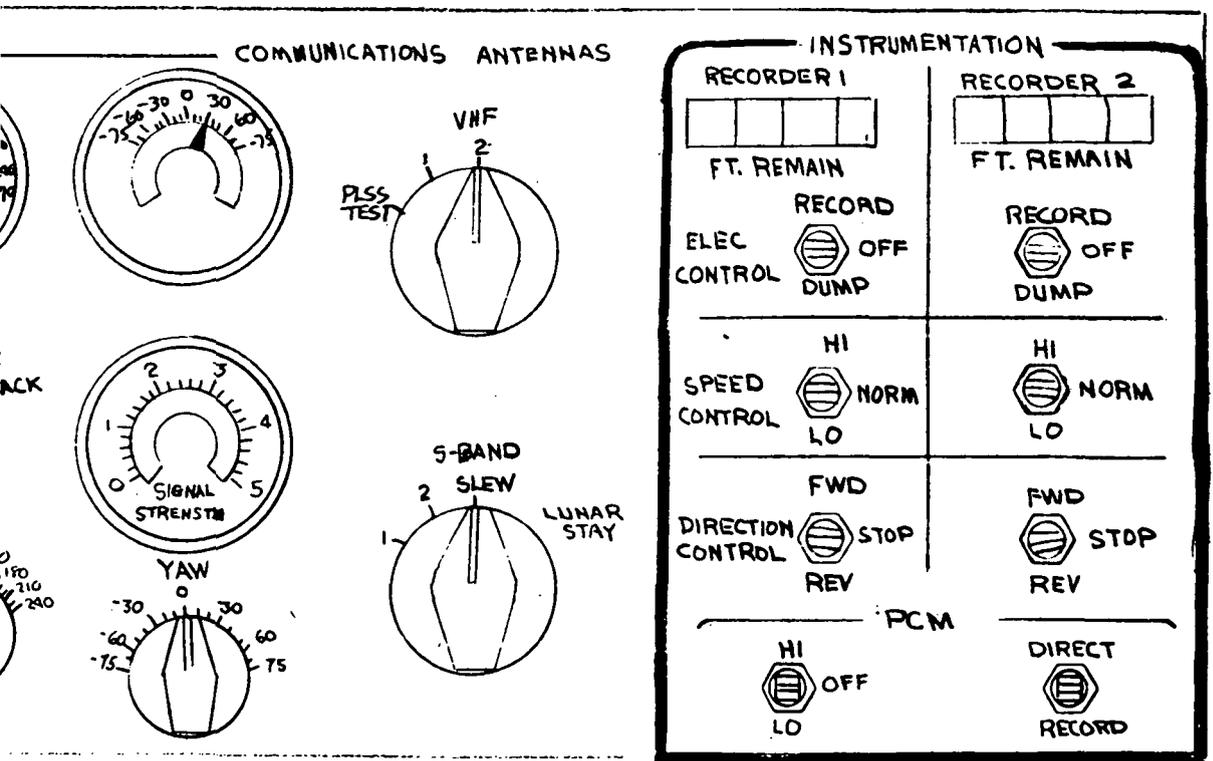
5-7-2b

2



PANEL

Fig. 5.7-2a Panel No. 10



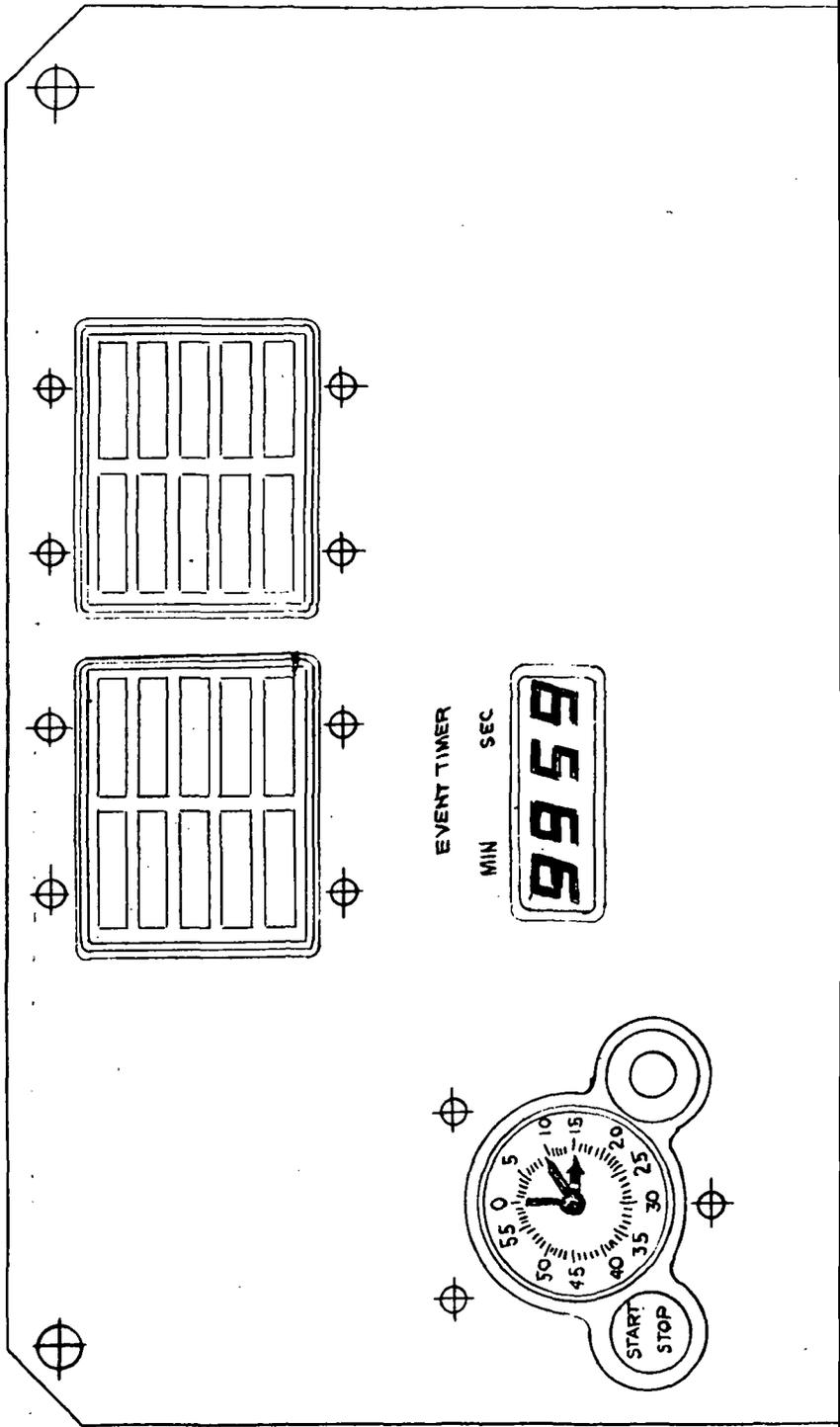
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Fig. 5.7-2b Panel No. 11

3

Grumman

167



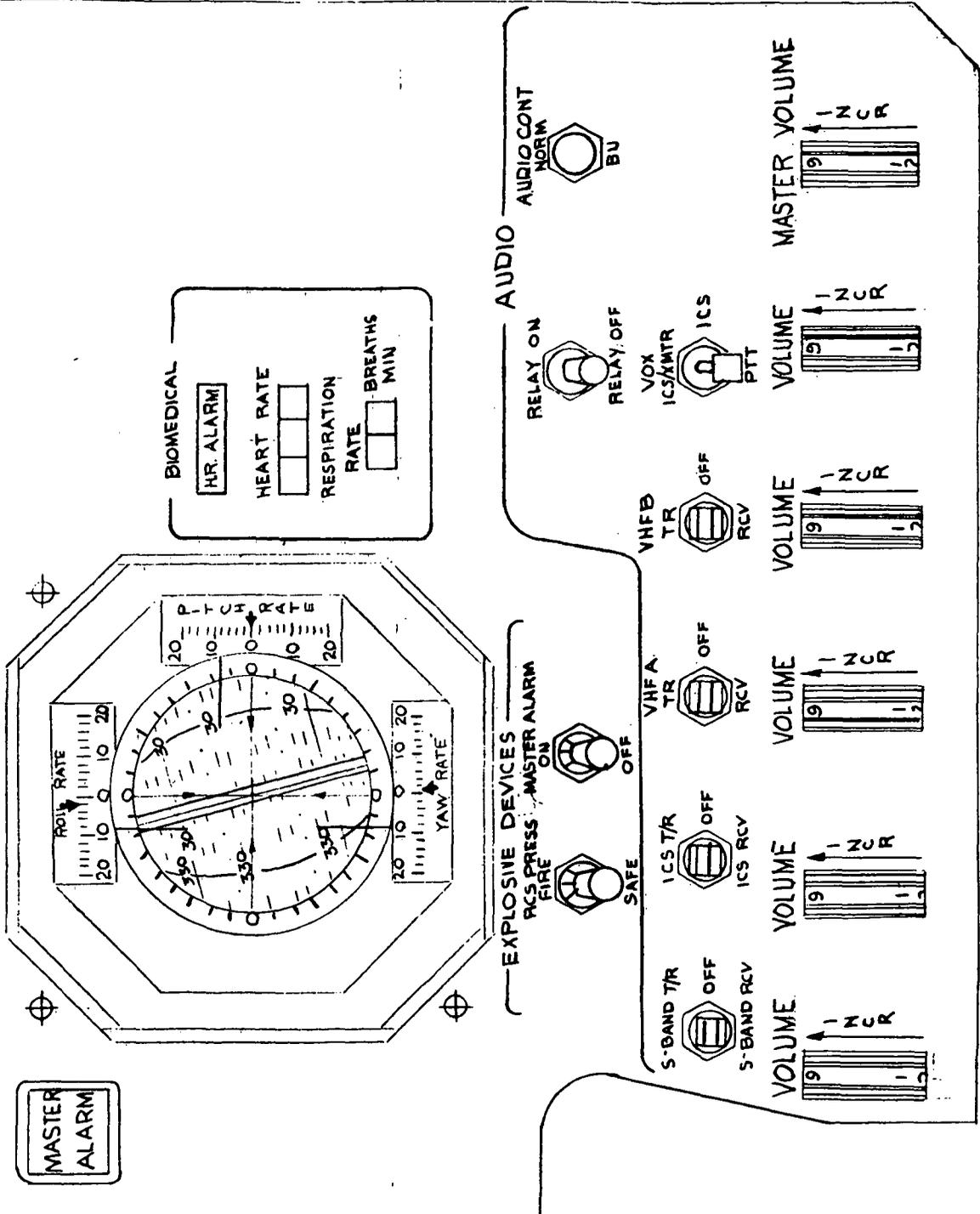


Fig. 5.7-3 Panel No. 1



YE+ 1450

YE+ 30.00

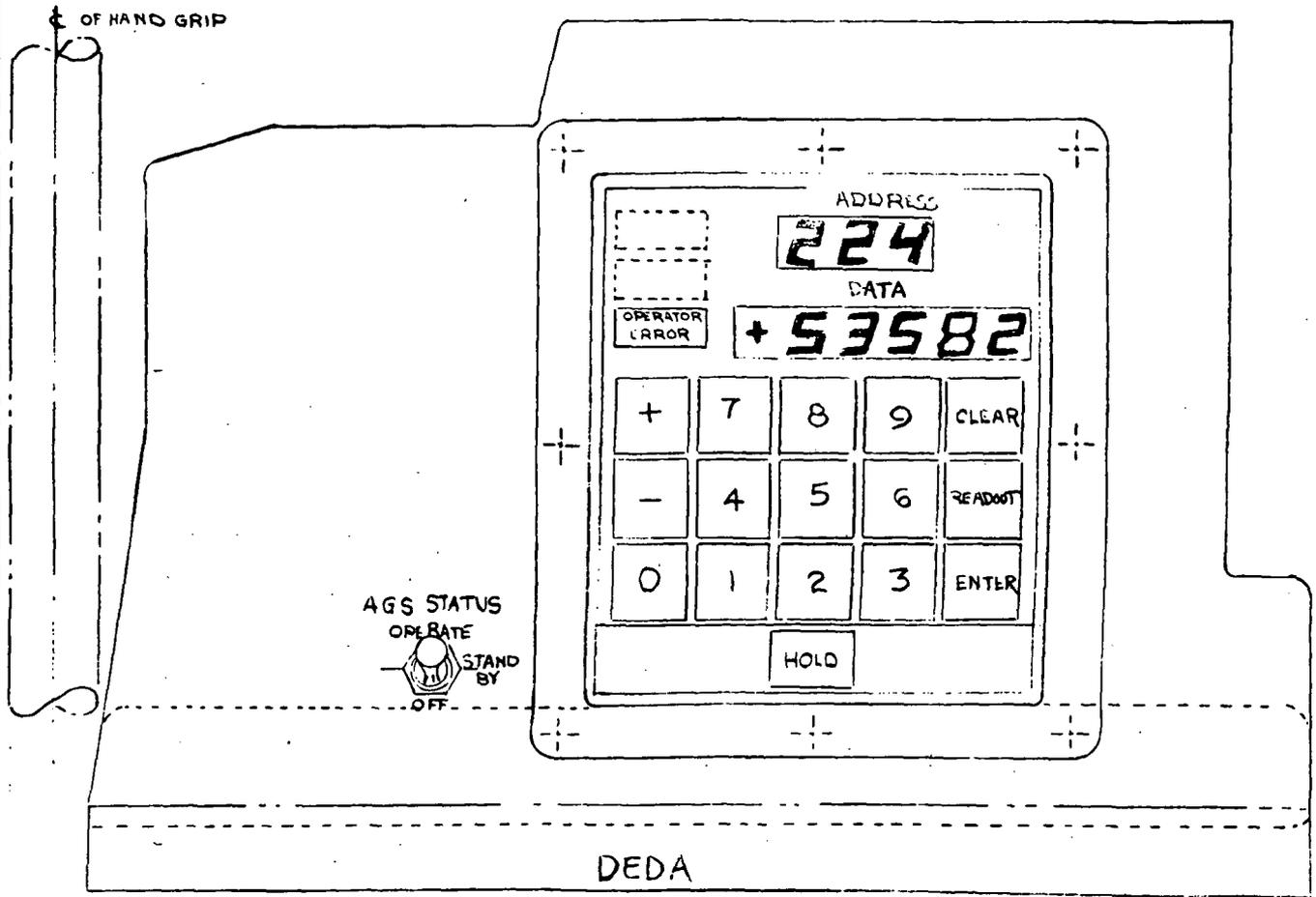
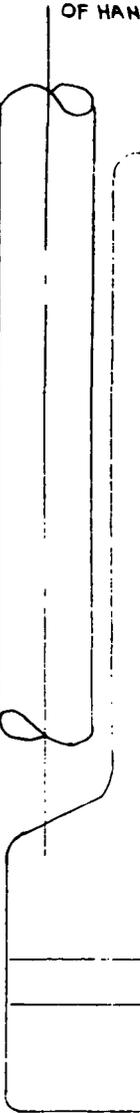
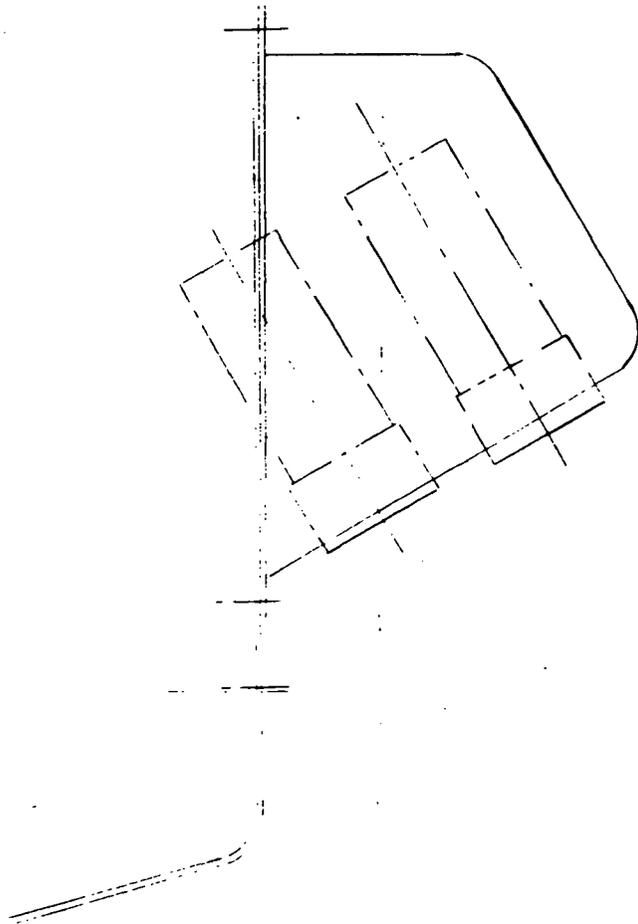


Fig. 5.7-4 Panel No. 12

165



GRIP

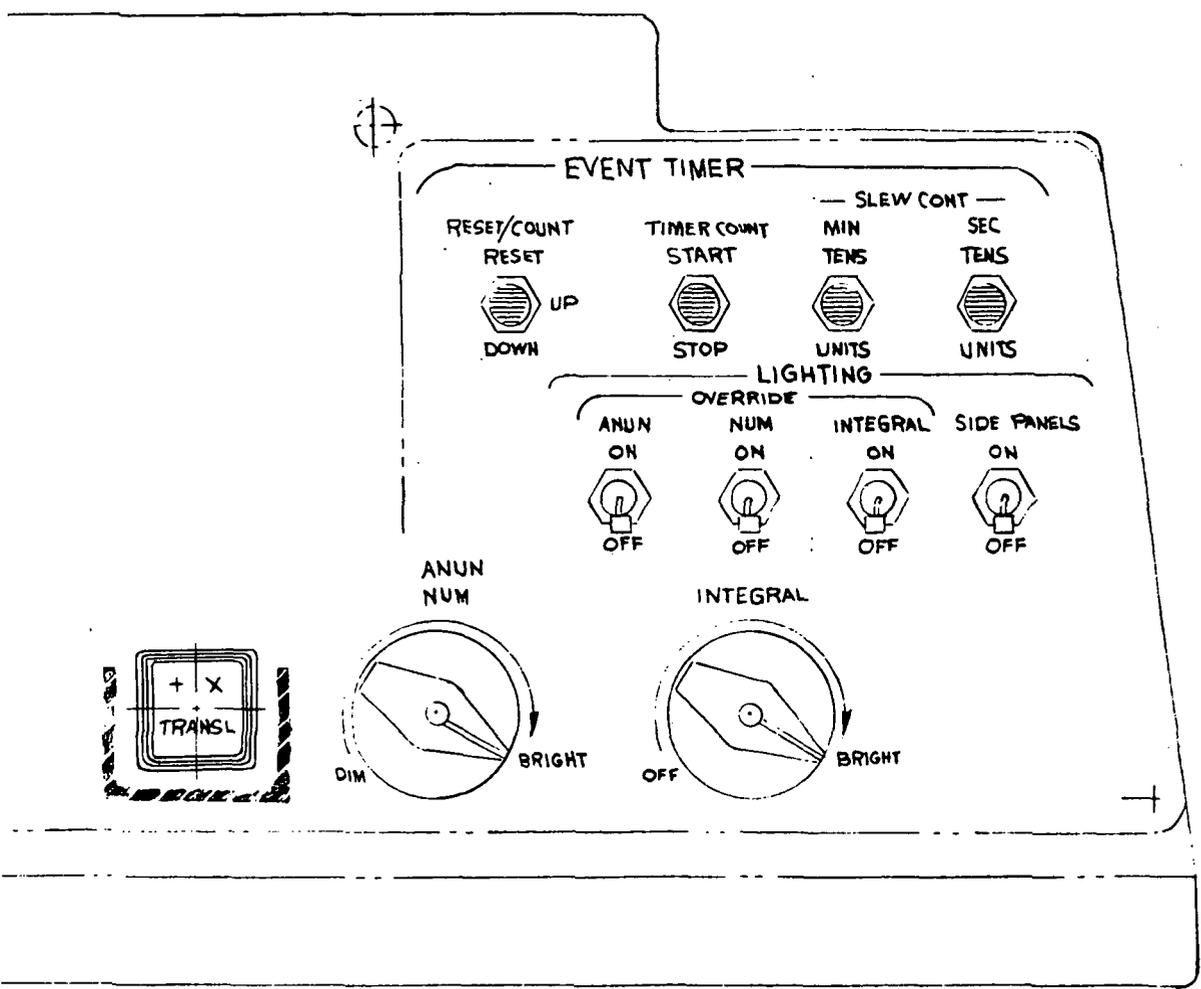


Fig. 5.7-5 Panel No. 8

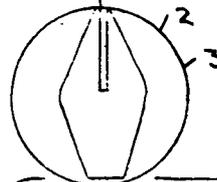
167

RADAR

AVAILABLE EXCEPT
WHEN RENDZ.
RADAR IS USED

STABILIZATION/CONTROL

DEAD BAND



ROLL GYRO TEST POS RT



PITCH



NEG RT

YAW

ATTITUDE CONTROL

ROLL

PITCH

YAW

MODE CONT

MODE CONT

MODE CONT



PULSE



PULSE



PULSE

DIR

DIR

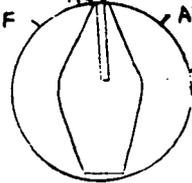
DIR

MODE CONTROL

OFF

HOLD

AUTO



RATE
CMD

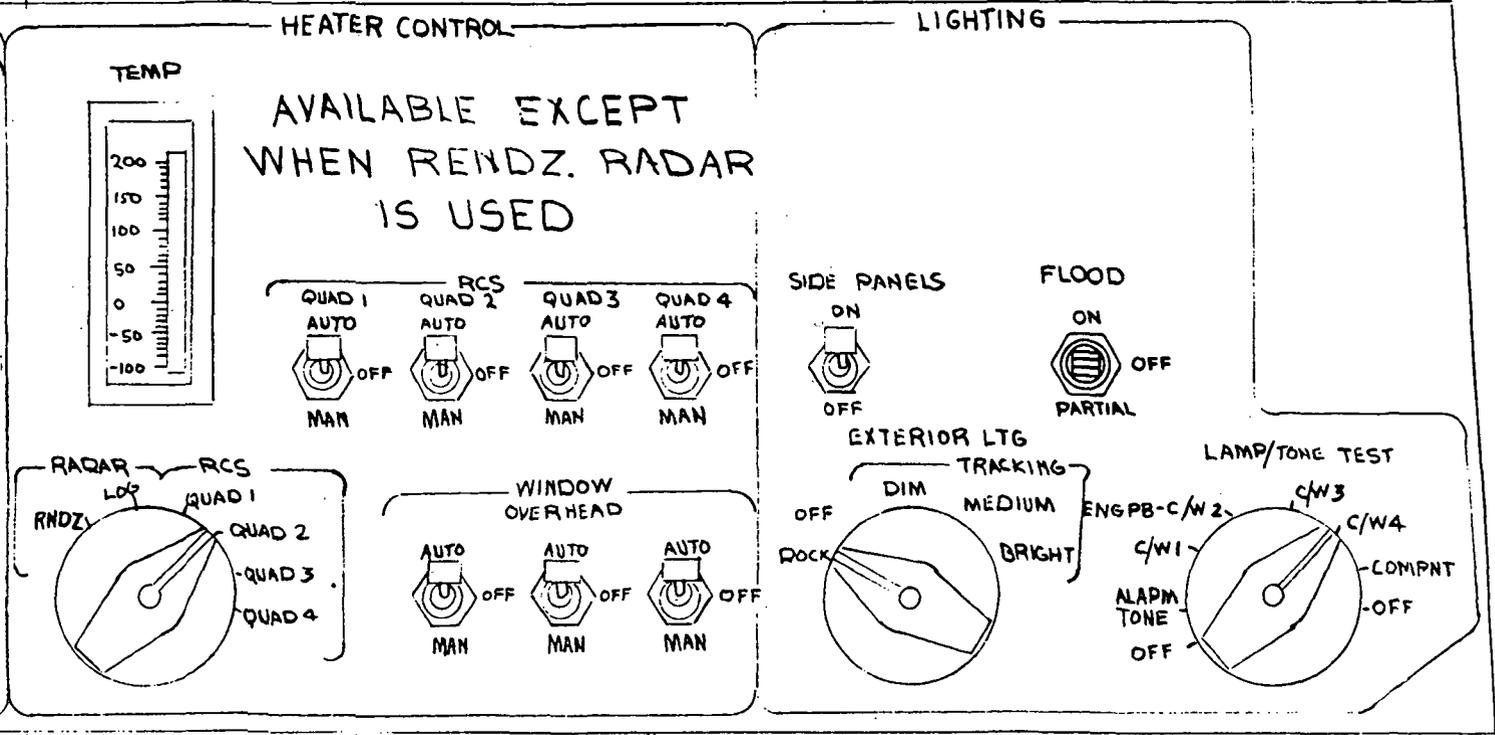
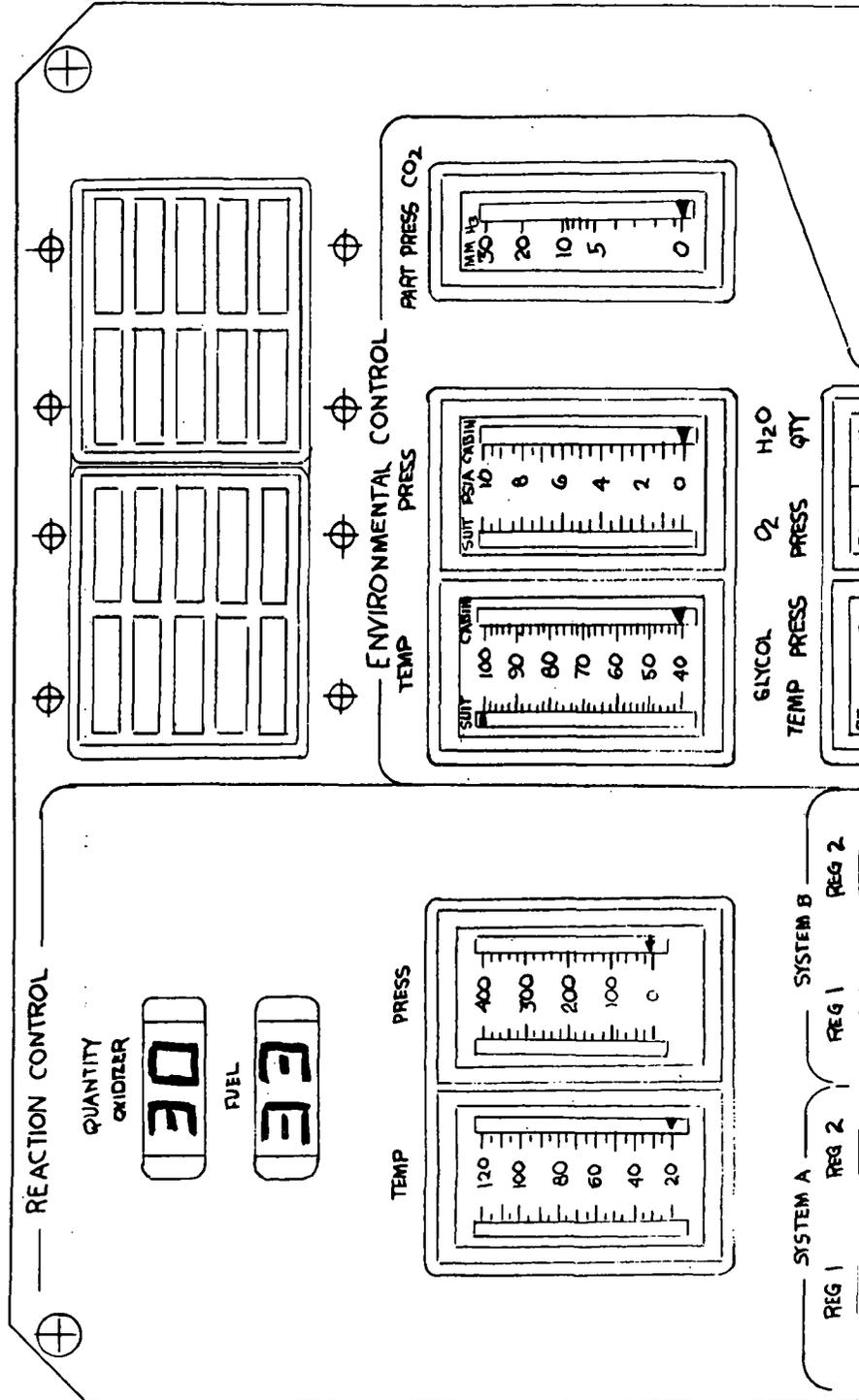


Fig. 5.7-6 Panel No. 3

169



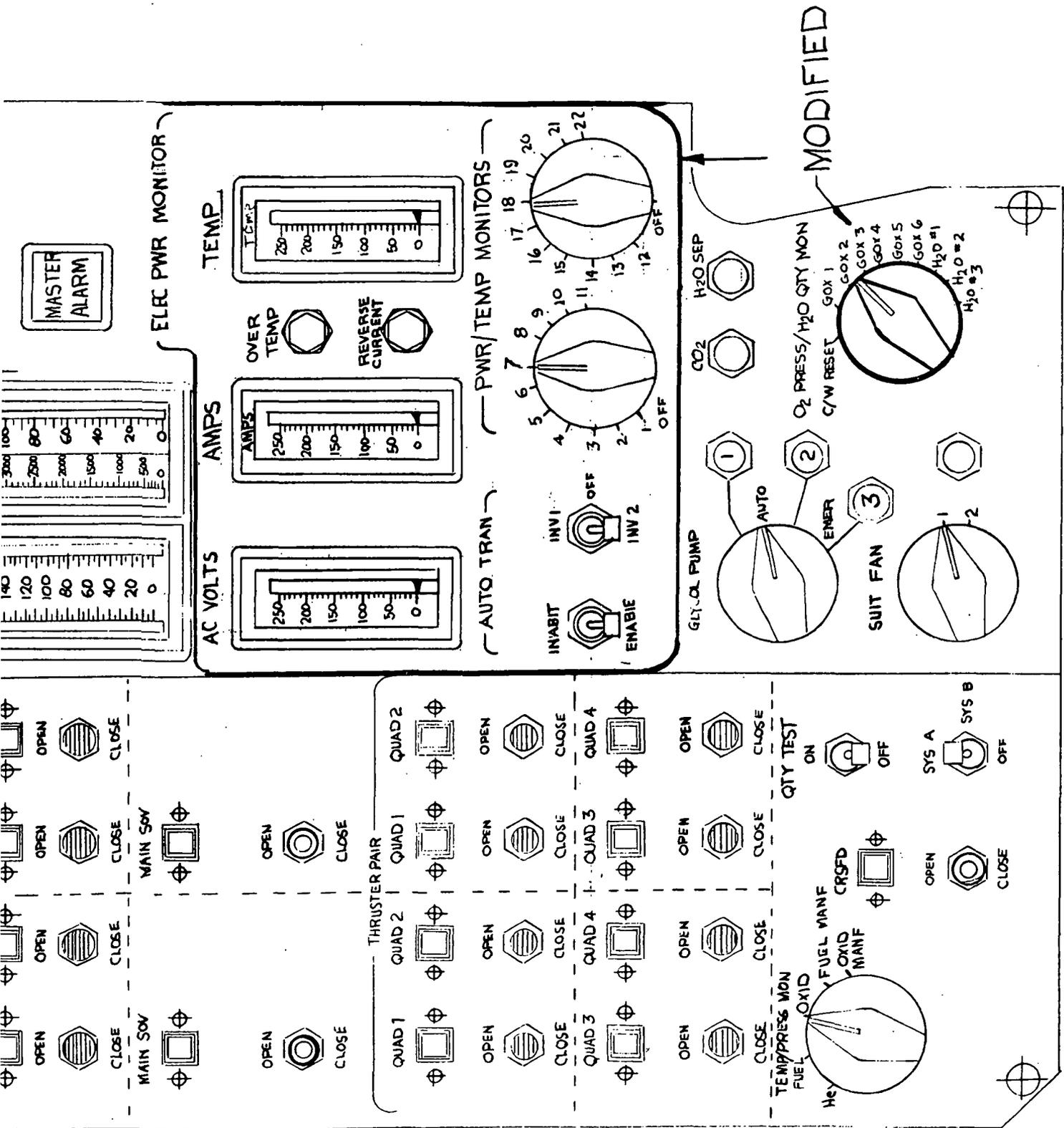
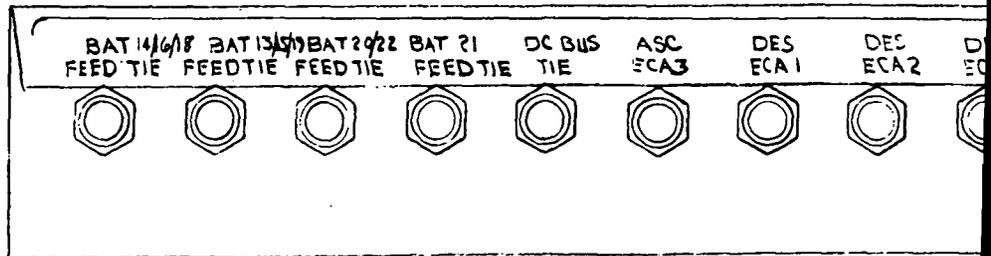
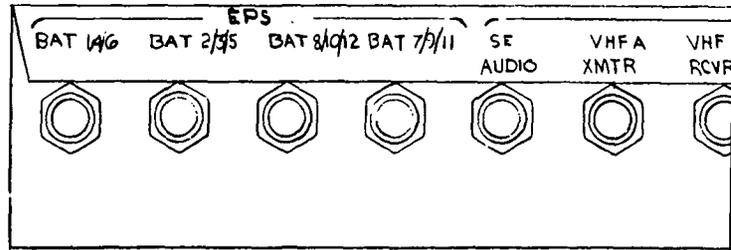
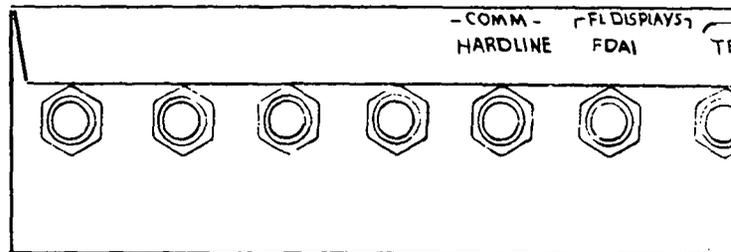
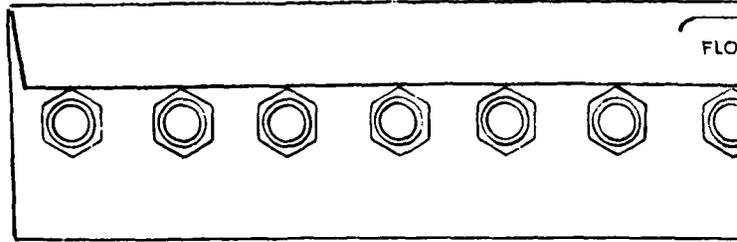


Fig. 5.7-7 Panel No. 2



17



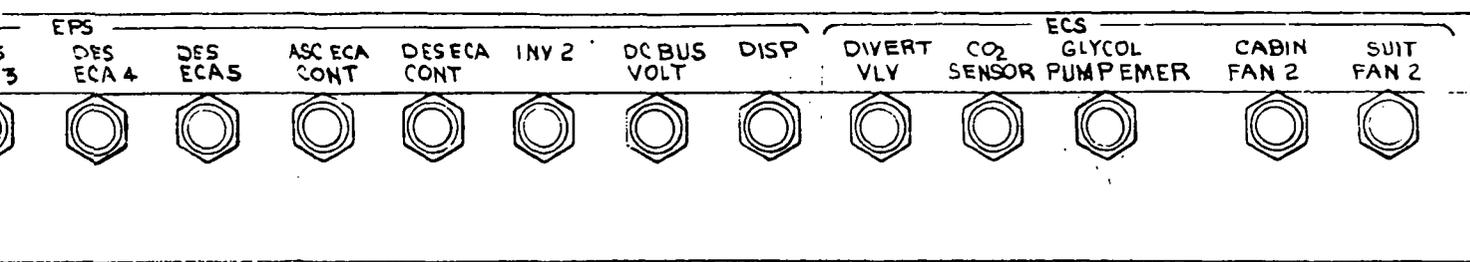
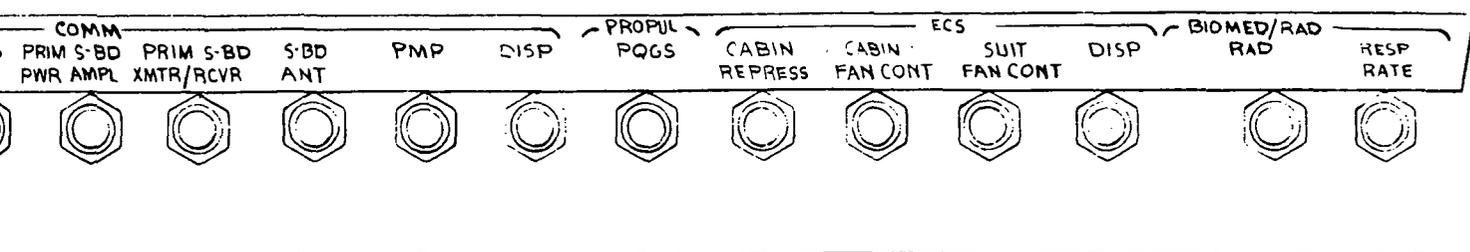
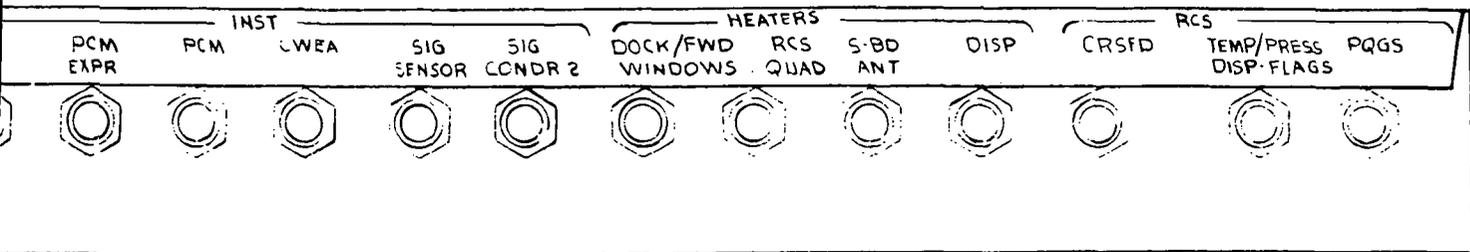
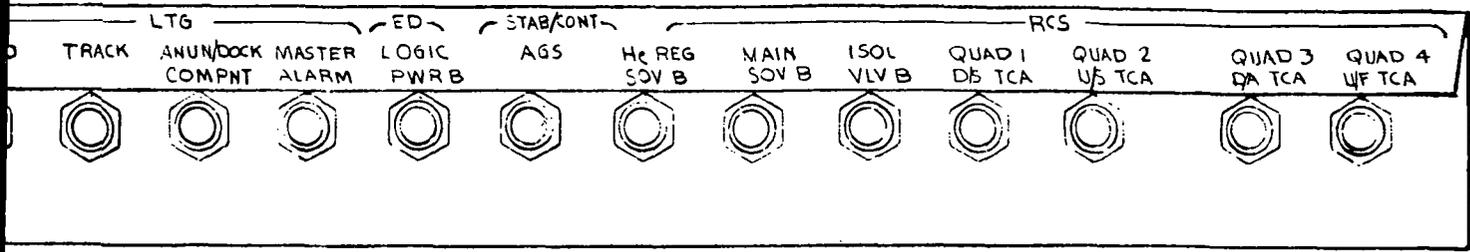


Fig. 5.7-8 Panel No. 9



6. VEHICLE DESIGN AND INTEGRATION

6.1 INTRODUCTION

6.1.1 Ground Rules and Assumptions

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 battery packs are examples of this approach.

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
- The retention of existing piping and wiring
- Maintain commonality of subsystems between all basic 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
- Crew provisions in the crew compartment that may be different from the LEM are to be as additions to the vehicle, preserving the location of as many Controls and Displays and Crew Requirements as possible
- Experiments will be mounted to the vehicle at existing hardpoints.

6.1.2 Background Data

A set of Apollo LEM drawings are provided to be used for comparison with the AES vehicles. For details not shown on the AES configuration drawings, the attached drawings, Figs. 6.1-1, 6.1-2, 6.1-3, 6.1-4, 6.1-5 and 6.1-6, clearly define the structure. Also included are drawings of the volumes and hard points available for experiments. These drawings have been updated from the Phase "A" study and are shown in Figs. 6.1-7 and 6.1-8.

6.1.3 Configuration Definition

The baseline vehicle is the first pass at describing a configuration that is a complete and integrated spacecraft design, capable of providing a specified experiment support capability at its interface with experiment payloads.

The recommended configuration is a refined definition of the baseline vehicle selected from the group of alternate designs.

The alternates are a group of designs showing the different locations and installation of a variety of subsystem configurations. These alternates have been analyzed for the feasibility of structurally attaching and methods of manufacturing.

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6.2 SPACECRAFT DESIGN

6.2.1 Assumptions

The following subsystems, assemblies, and components have been removed from the basic LEM in defining the Phase I Lab:

- Ascent Propulsion Subsystem
- Right-Hand Flight Control Station
- Descent Propulsion Subsystem (with the exception of the fuel and oxidizer tanks)
- Landing Gear and Actuation Subsystem
- Base heat shield
- Ascent stage GOX tanks.

The descent propulsion fuel and oxidizer tanks are retained because of the extensive structural rework required to the descent stage for removal. Studies are continuing to determine possible utilization of the descent propellant tanks for storage of consumables and/or experiments.

The LEM thermal micrometeoroid shielding is retained and modified in local areas where required. For example, where the ascent propulsion fuel tanks are removed, the shielding is redesigned to provide protection for expendables stowed in that area. Other local modifications will be required where experiment components penetrate the shielding. The internal and external stowage of expendables shown in the Phase I Lab configuration are sufficient to sustain a three-man crew on a 14-day mission.

6.2.2 Recommended Configuration

The recommended configuration for Phase I Lab is shown in Fig. 6.2-1. The vehicle is the same as the LEM except as noted.

6.2.2.1 Ascent Stage

The interior of the ascent stage is modified to enable it to perform the laboratory work area function. Display panels, experiment control consoles, and stowage provisions for experiments and expendables are installed. The interior arrangement is completely described in Section 6.3, Crew Provisions.

In the space vacated by the removal of the LEM ascent engine, a canister, (Fig. 6.2-2) is installed which will provide a pressurized volume of 7.5 cu ft for experiment stowage. This canister is sealed to the structure in the same manner as the ascent engine cover (with a Marmon-type clamp) and requires no structural modification other than removal of the engine support lugs from the ring. Auxiliary support members are attached to the top of the descent stage.

Five LEM descent stage GOX tanks are installed in the aft equipment bay, (Fig. 6.2-3). These tanks are mounted to the forward side of the Electronic Replaceable Assembly (ERA) cold plate structure, which can be readily reworked.

Some of the cold plate support truss members are replaced to accommodate the weight of the added tanks.

External stowage for the required quantity of LiOH canisters and backpack batteries is provided on both sides of the ascent stage where the ascent propulsion fuel and oxidizer tanks were removed. The expendables are located inside of the thermal micrometeoroid shielding for thermal control. Access is through a hinged door in the shielding, making the expendables readily available to a crew member during extra-vehicular activities.

One additional connector is added to the LEM-CSM interface to provide a hardline communications link, (Fig. 6.2-4).

6.2.2.2 Descent stage

The Electrical Power Subsystem battery installation (Fig. 6.2-5) is a modular installation of four LEM descent stage batteries and associated Electrical Control Assemblies mounted on the end bulkheads. This installation is identical at each of the four end bulkheads. The inlet and outlet coolant connections of each installation are plumbed in parallel with the existing battery installation to the interstage disconnect. These four installations add 16 batteries to the four-battery LEM installation which is retained.

Two additional descent stage type water tanks are installed in Quadrant -Y, -Z (Fig. 6.2-6). This installation requires removal of the LEM scientific bay support structure and a local modification to the thermal shielding.

A flat thermal/micrometeoroid panel is installed on the bottom of the descent stage to close the gap left by removal of the descent engine and base heat shield. This is fastened to the base heat shield beams which are retained.

6.2.3 Baseline Configuration

The Phase I Baseline Configuration (Fig. 6.2-7) differs from the recommended (as outlined above) only in the number of descent stage batteries carried. Eight batteries were added to the Baseline in two four-battery modules installed on the +Z and -Z end bulkheads, for a total of 16 externally mounted batteries. This modification of the Baseline was required because an assumed 100 kw/hr of energy from the CSM is not available.

6.2.4 Alternate Configuration - Self-Contained Power Pack

The Electrical Power Subsystem (EPS) power package (Fig. 6.2-8) is a completely self-contained power supply which is manufactured and checked out before shipment to Kennedy Spacecraft Center. It is attached to the LEM after minor structural modifications are accomplished, and connected to the EPS Buss. It consists of two Gemini fuel cells, CSM Block II cryogenic storage tanks, (1 oxygen and 1 hydrogen) radiators, a glycol loop, and regulating controls. It is mounted beneath the aft equipment bay in a manner such that most of the support is furnished by the descent stage. Structural modifications are limited to the addition of small fittings which pass the supporting loads to existing stiffeners on the descent stage beam webs and top deck. In addition, small fittings are added to the bottom of the ERA cold plate structure to provide lateral support.

6.2.5 Alternate Configuration - Modified Batteries

A battery EPS which uses low-drain rate cells designed into a modified LEM ascent stage battery container, is shown in Fig. 6.2-9. This battery has a 15-kw/hr capacity versus 12-kw/hr for the present LEM descent stage battery. Using the same number of batteries (20) in the descent stage, this configuration uses a five-battery installation at each of the four end bulkheads, the existing LEM battery installation is removed.

6.2.6 Alternate Configuration - Passive Battery Cooling

If passive cooling for the EPS batteries is desired, an automatic shutter system may be used in the battery shielding. The shutters are thermally actuated using a bimetallic coil as a sensor-driver mechanism. The temperature at which the louvers begin to open is adjustable over a wide range, and the effective louvered areas can be adjusted by either adding or removing louver assemblies or individual louver blades. A design for passive thermal control is shown in Fig. 6.2-5.

6.2.7 Potential Modifications Per Flight

A review of Phases A studies was made to identify modifications required on individual missions which would affect the spacecraft configuration. These were studied using the Phase B ground rules and are presented as follows.

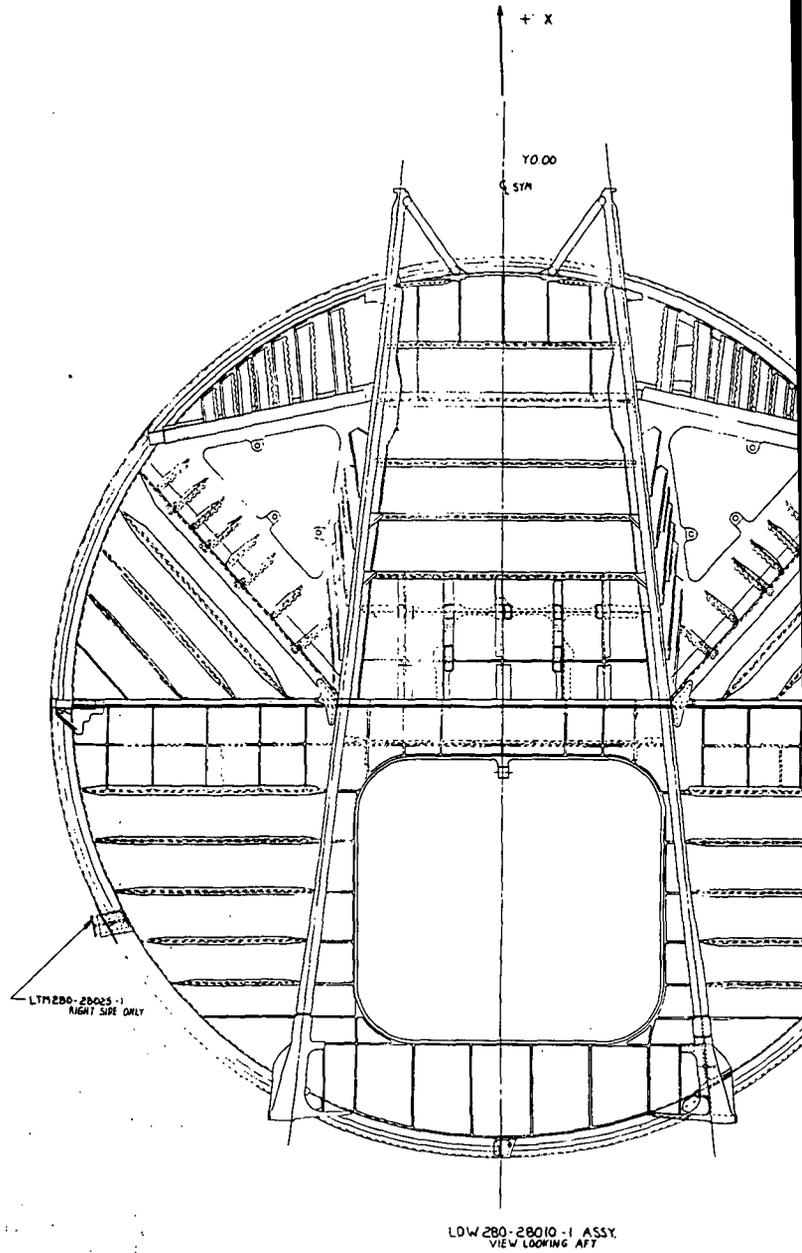
6.2.7.1 Viewfinder

An optical viewfinder telescope is required for lunar orbit and Earth surveillance missions. To meet the ground rule of "No Change to the Pressure Shell", an attempt was made to arrive at a scheme which would not require requalification of the pressure shell. One such scheme is shown in Fig. 6.2-10. A Kollsman view finder is installed in a fitting which replaces the right-hand cabin window. This fitting is installed and sealed in the same manner as the window. In this location the optical path is direct to the eye-piece which is readily available to the crewman for viewing or camera changing. Thus by qualifying the pressure integrity of the viewfinder to the local fitting and by maintaining an identical structural and seal joint between the fitting and LEM structure (as the existing LEM window has), requalification of the ascent stage pressure shell will not be required.

6.2.7.2 Additional Pressurized Volume

If additional pressurized volume is required for work area or experiment stowage, a configuration as shown in Fig. 6.2-11 can be used in lieu of the canister (Fig. 6.2.-2). This design is based upon one of the airlock configurations shown for the Phase II Lab and may become available for one of the late Phase I flights. It consists of a 47-in. diameter, 85-cu-ft pressurized container which is installed in the descent engine bay and supported at the descent engine mount fittings. It is structurally isolated from but sealed to the ascent engine cover ring. A 20.5-in. diameter access passage is available without modification to the ascent stage structure.

5



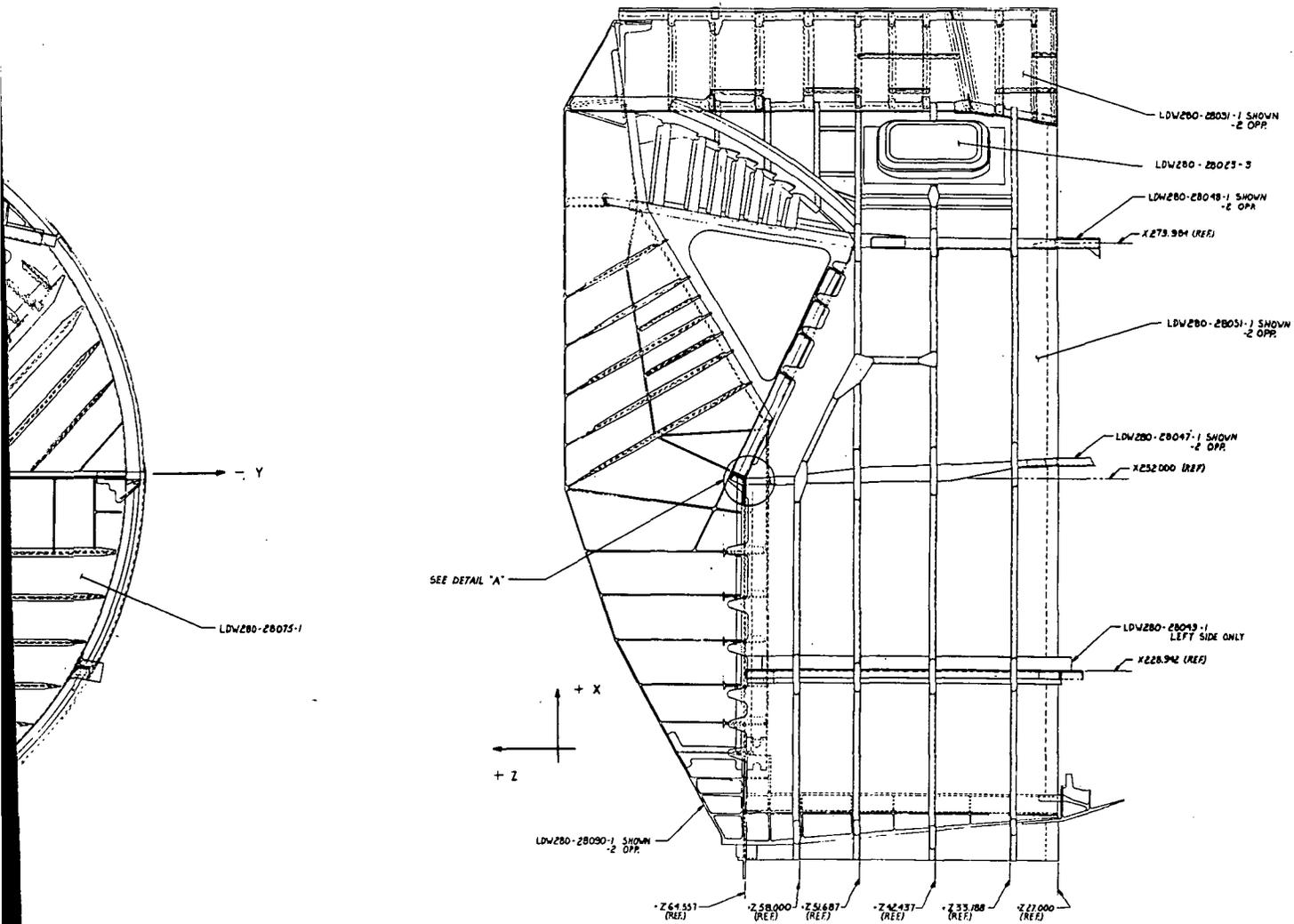
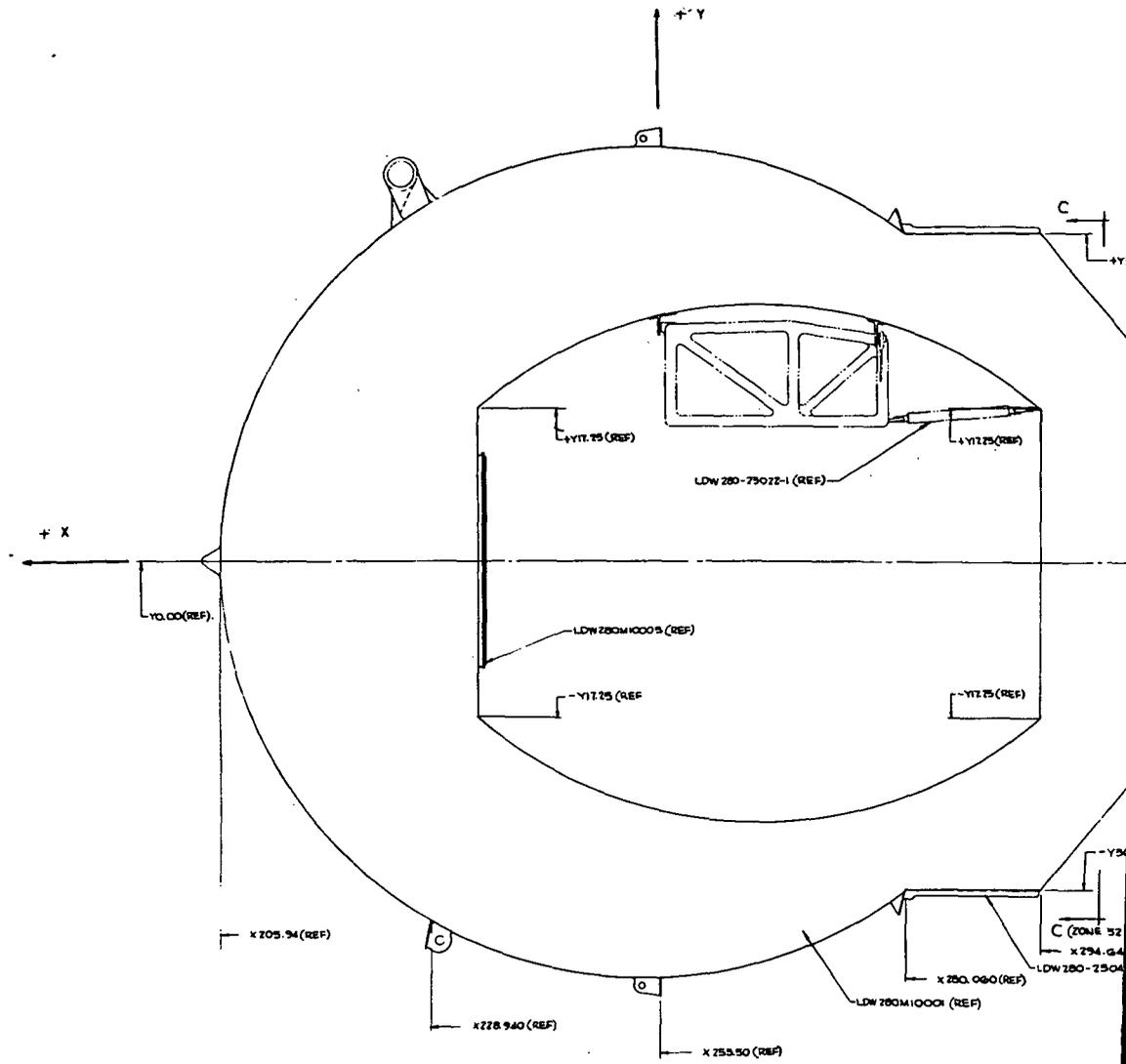


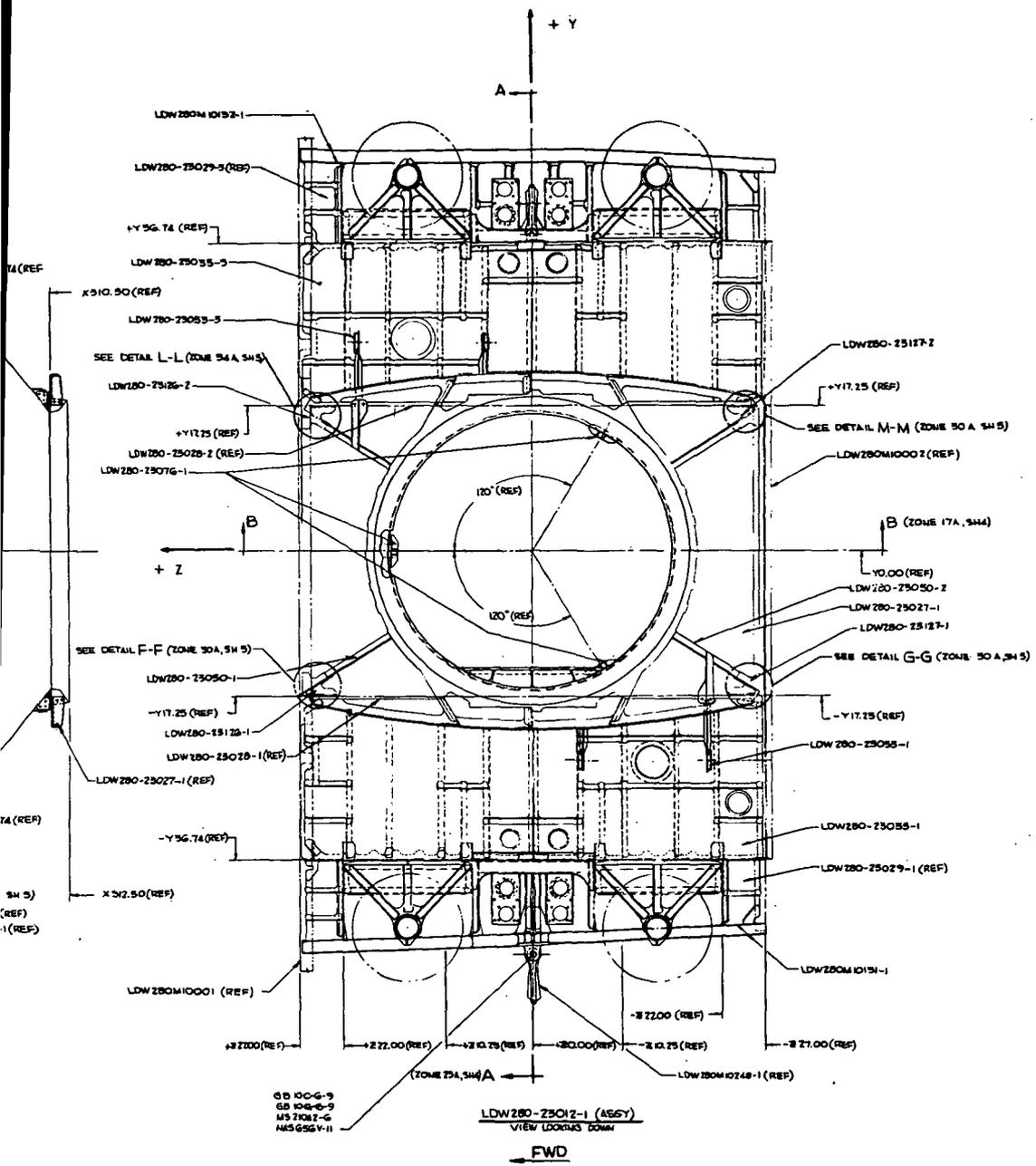
Fig. 6.1-1 LEM Structural Arrangement
Ascent Stage Forward Cabin



VIEW LOOKING AET

6.1-2

①



65 100-9
 65 100-9
 M5 2002-6
 M5 655V-11

601-2
 ②

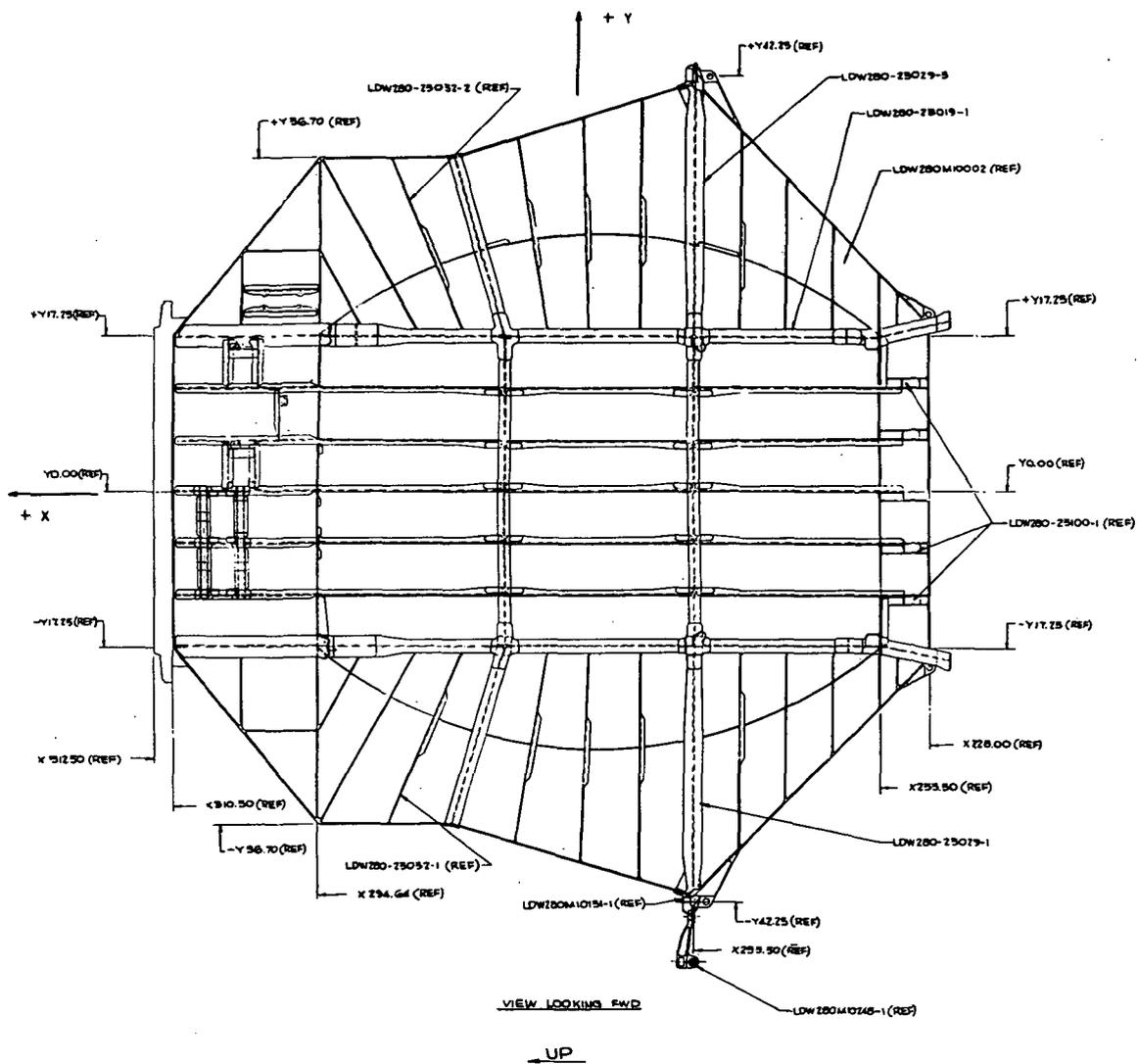


Fig. 6.1-2 LEM Structural Arrangement
Ascent Stage Aft Cabin

3

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017 (REF)

LDW280-23027-2(REF)

Y23.00 (REF)

LDW280-23028-5 (REF)

LDW280-23053-3 (REF)

LDW280-23053-3(REF)

Y36.74 (REF)

LDW280-23044-2 (REF)

X174.643 (REF)

LDW280-23052-2(REF)

LDW280M10700-2(REF)

LDW280-23020-1(REF)

LDW280-23062-1(REF)

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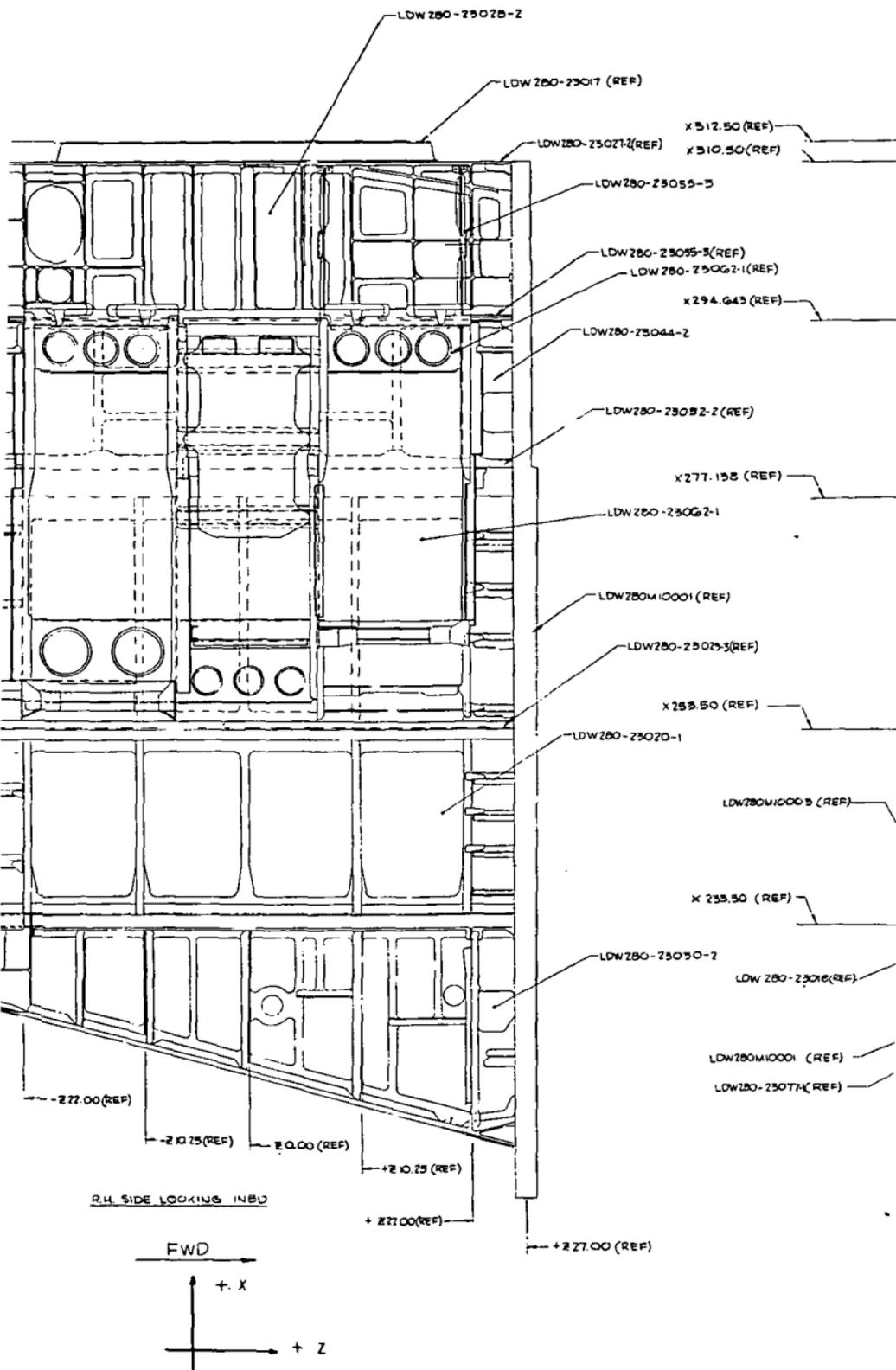
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079-2

177-1

6-1-3
③



6.1-3

4

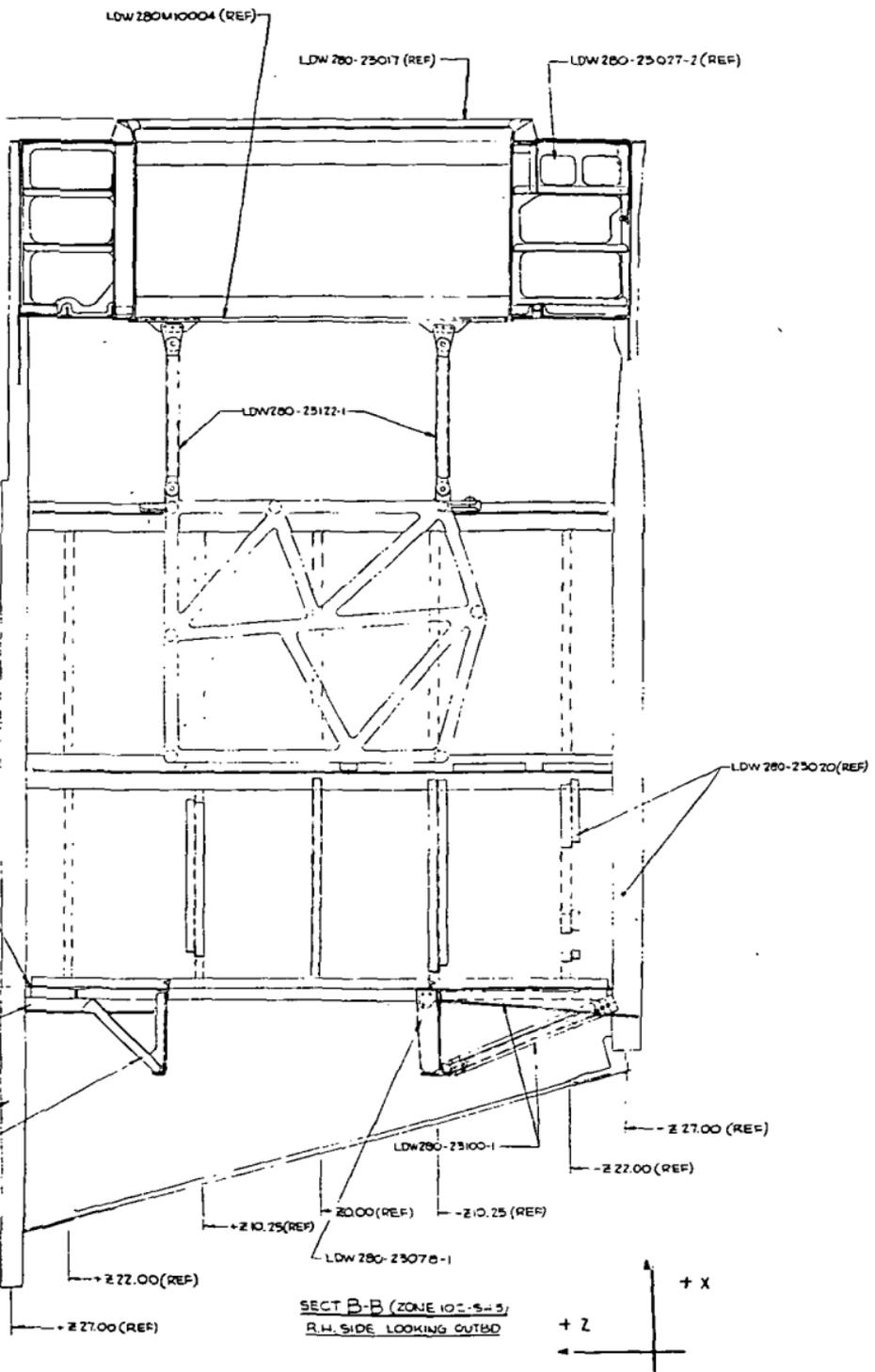
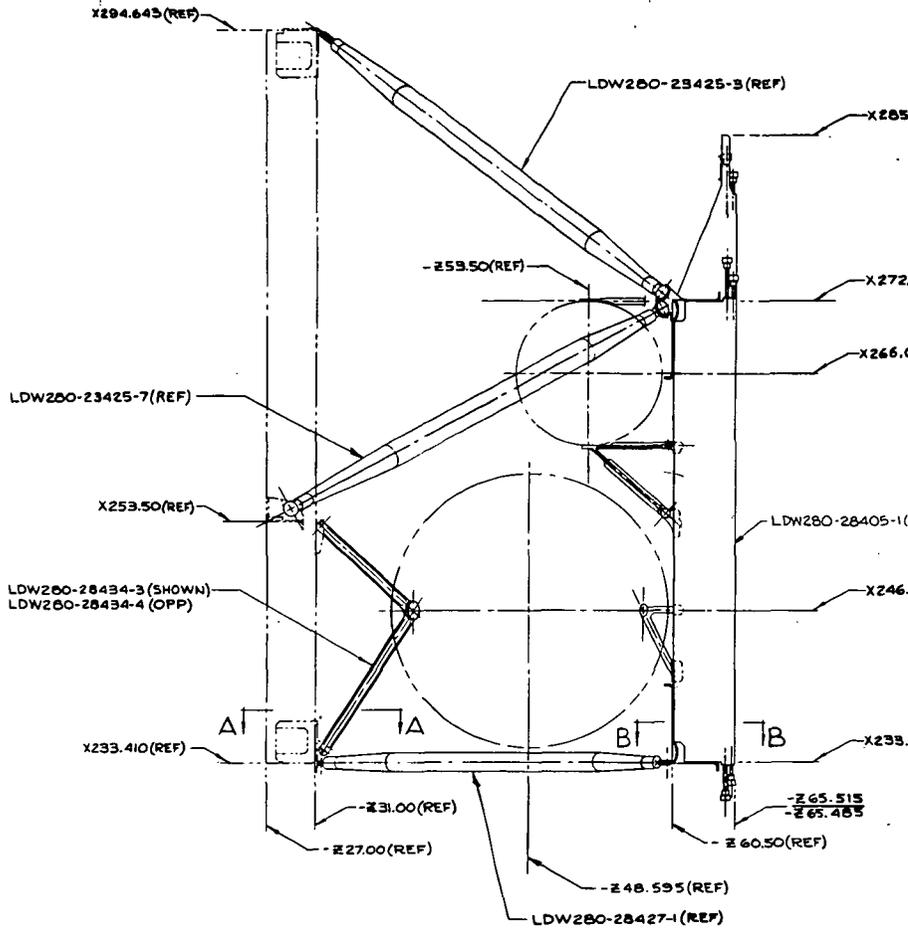
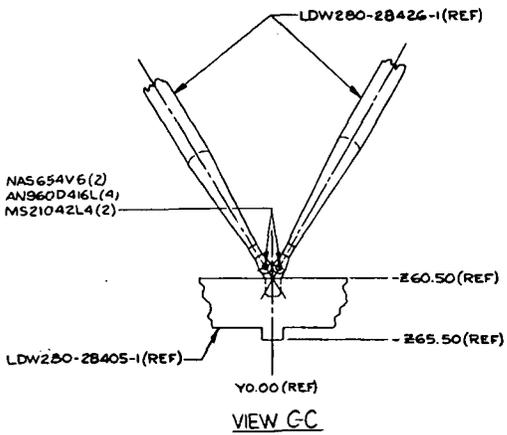
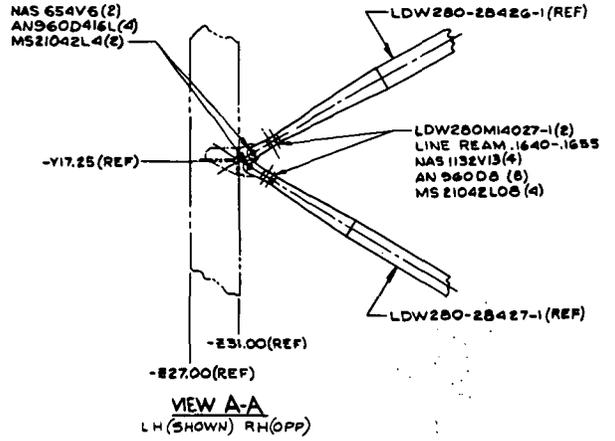
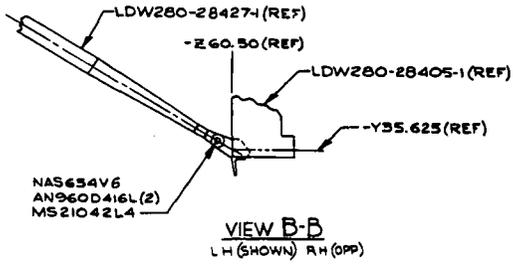


Fig. 6.1-3 LEM Structural Arrangement
Ascent Stage Aft Cabin

5

Grumman



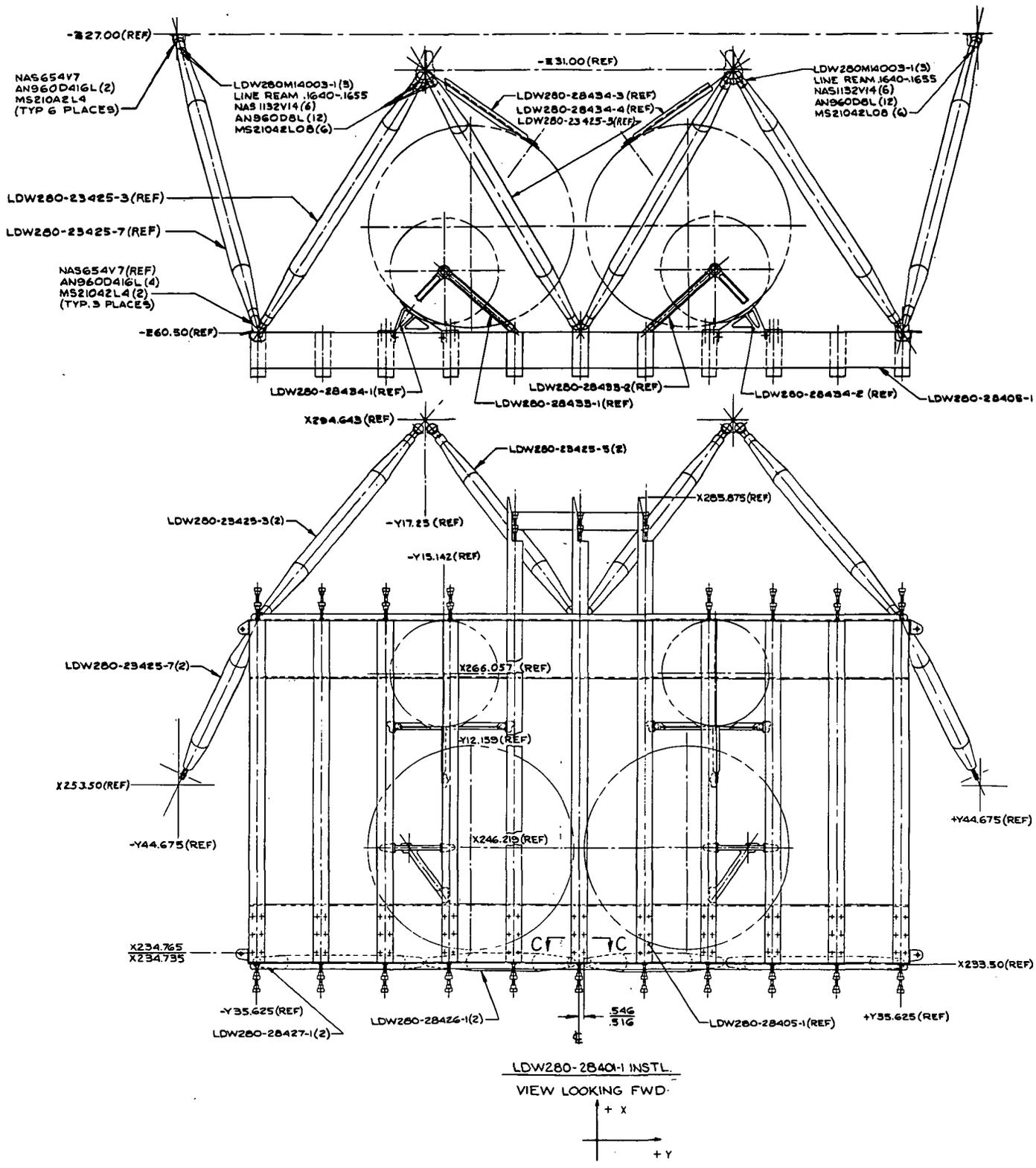
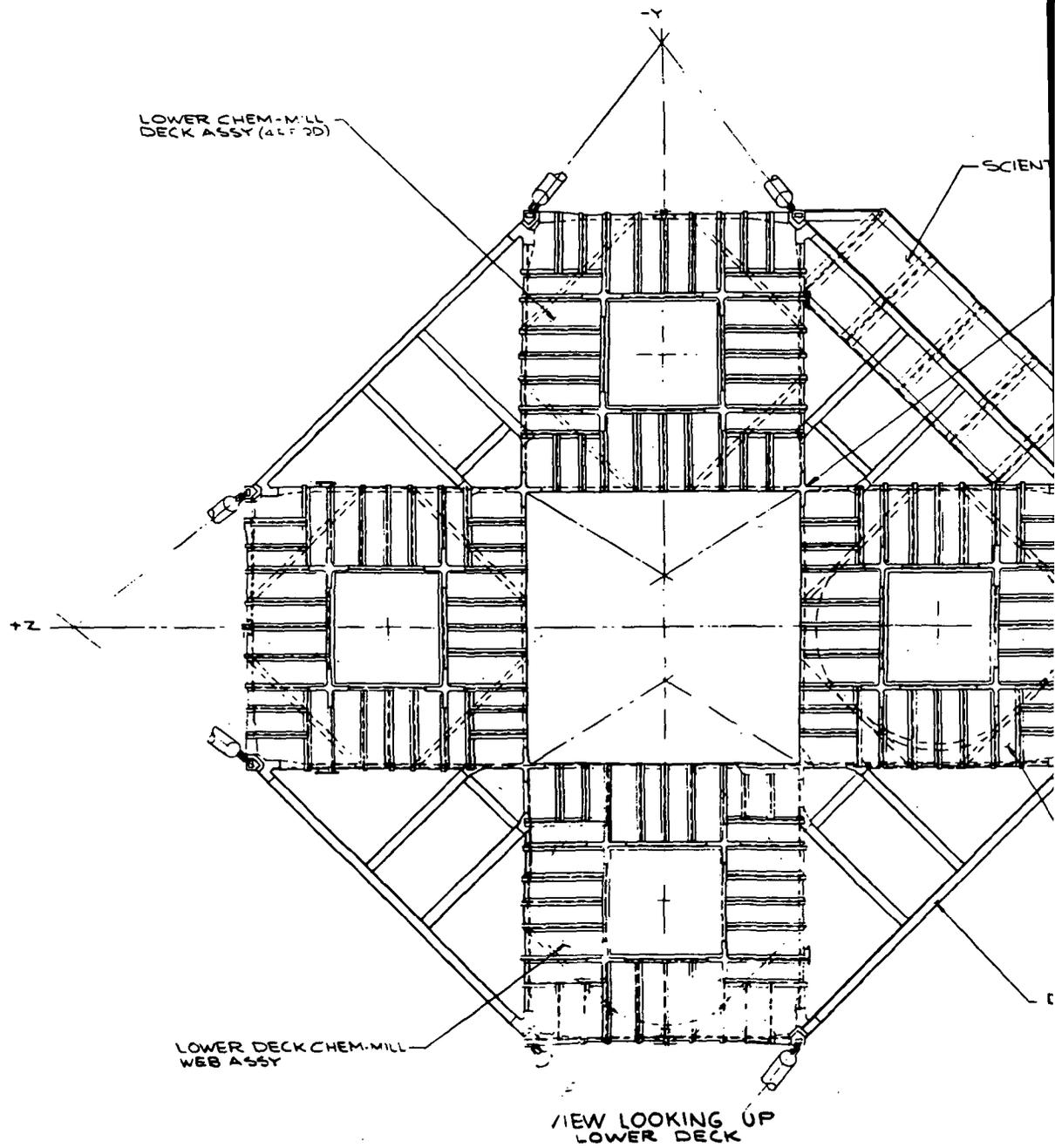
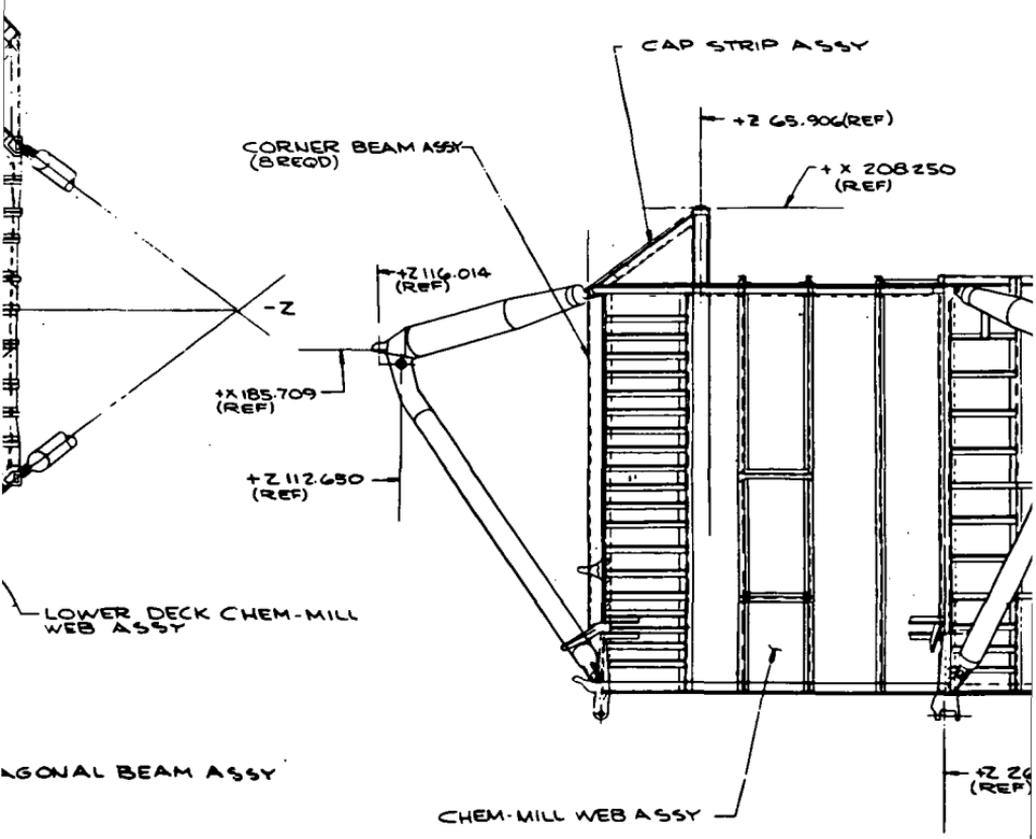
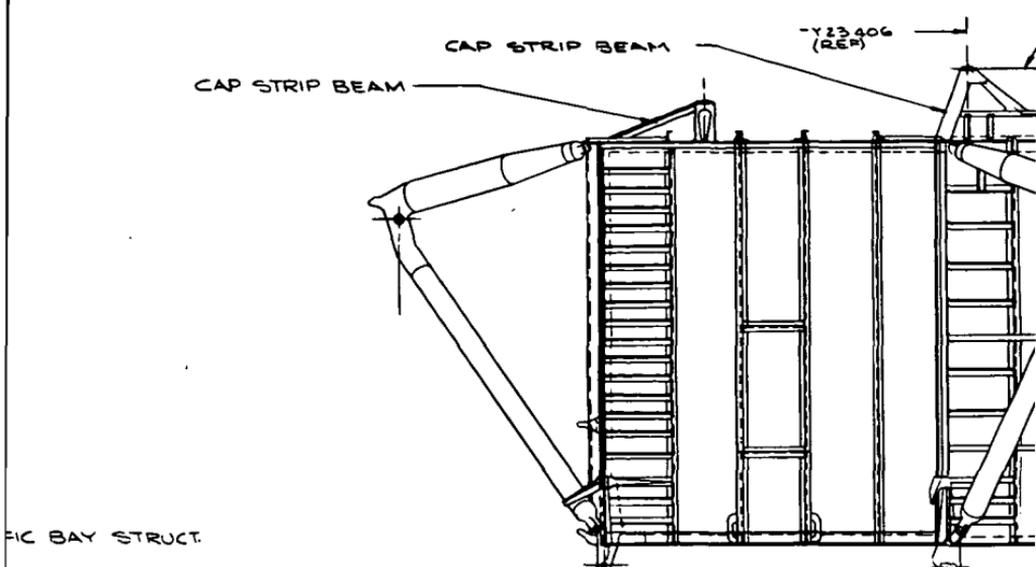


Fig. 6.1-5 LEM Structural Arrangement
Ascent Stage Aft Equipment
Compartment

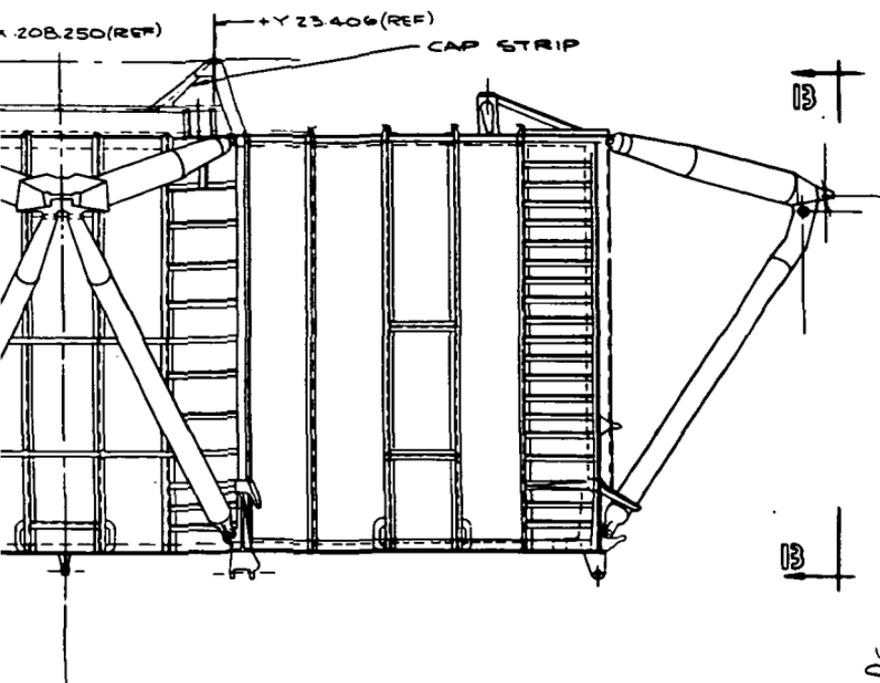




6.1-6
①

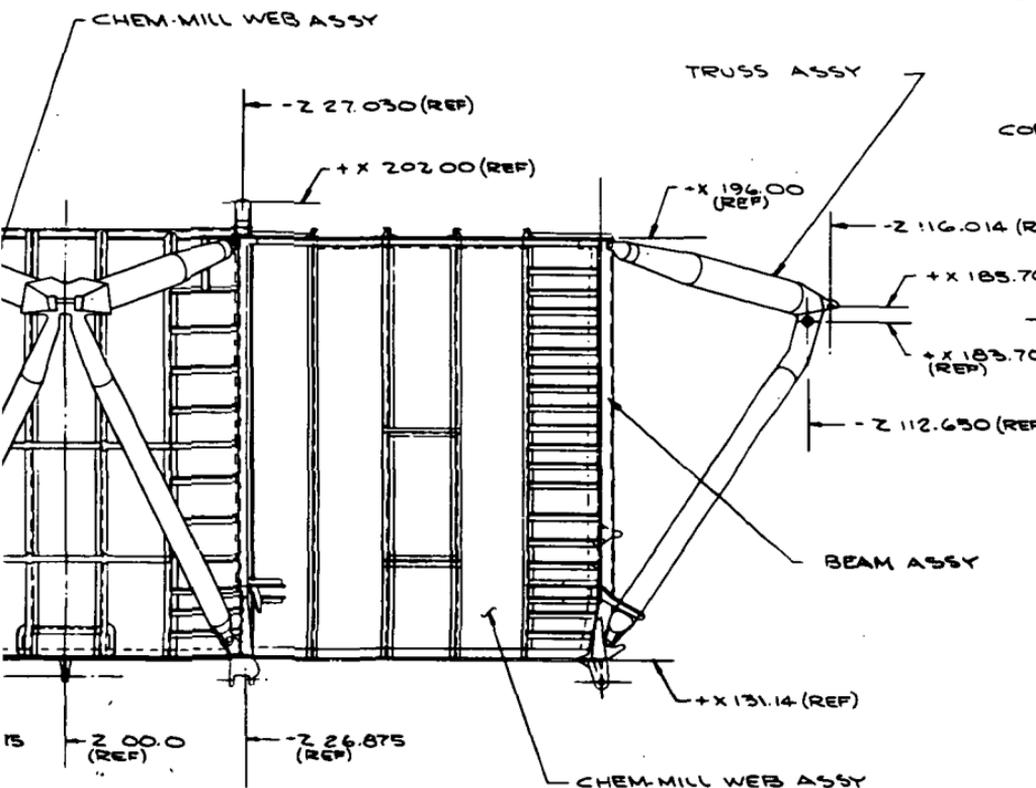


6.1-6
 (2)



UPPER DECK
CHEM-MILL WEB

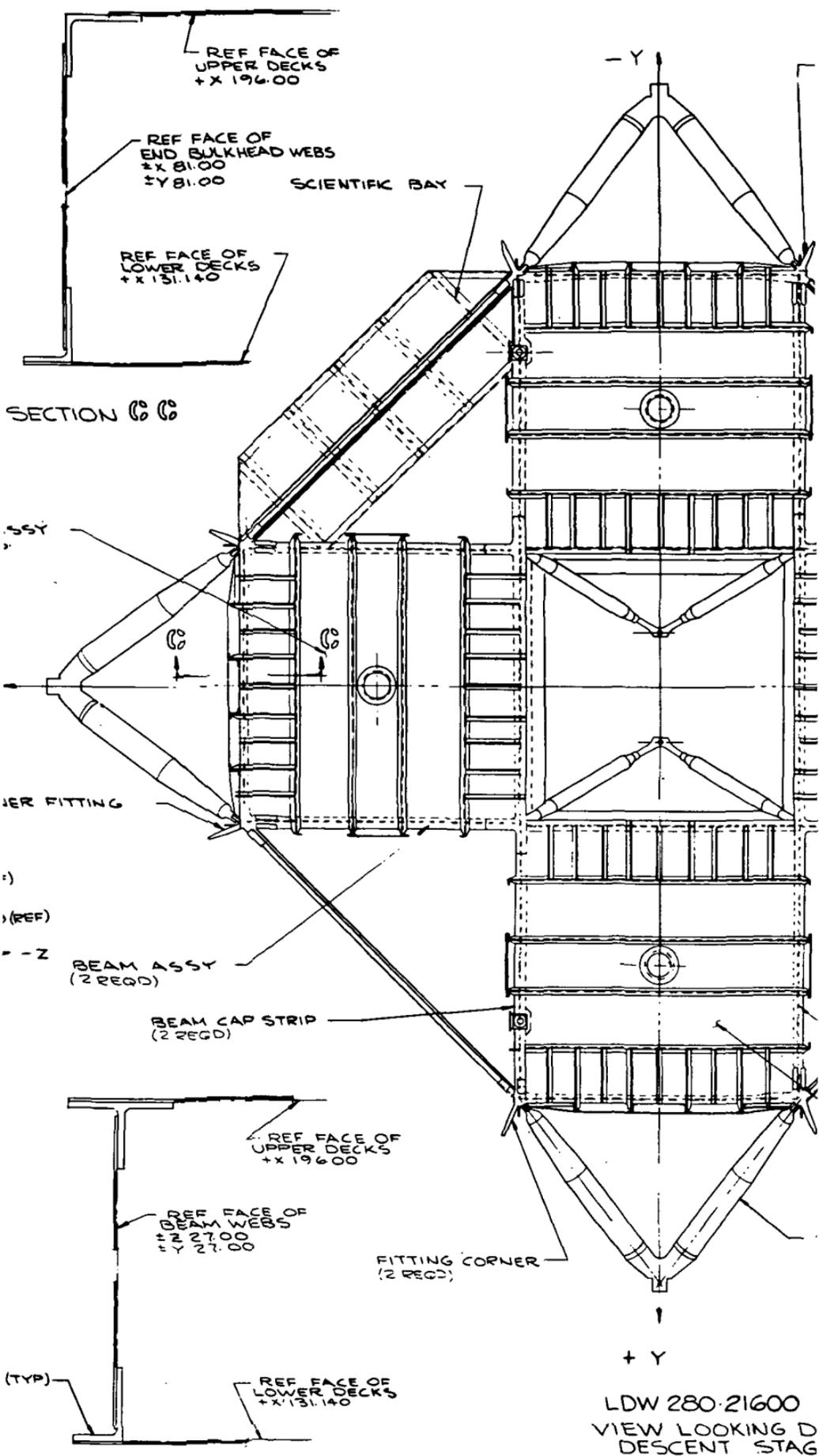
VIEW A-A
ROTATED 90°



BEAM LOWER

13-13
BEAM LOWER
81.00 / -Y 27.00

6.1-6
③



SECTION C C

SSY
 C C
 BEAM FITTING

Z Z
 BEAM ASSY
 (2 REQD)

BEAM CAP STRIP
 (2 REQD)

REF FACE OF UPPER DECKS
 +X 196.00

REF FACE OF END BULKHEAD WEBS
 ±X 81.00
 ±Y 81.00

REF FACE OF LOWER DECKS
 +X 131.140

REF FACE OF BEAM WEBS
 ±Z 27.00
 ±Y 27.00

REF FACE OF LOWER DECKS
 +X 131.140

(TYP)

SECTION D D
 ROTATED 90°

LDW 280-21600
 VIEW LOOKING DOWN
 DESCENT STAG

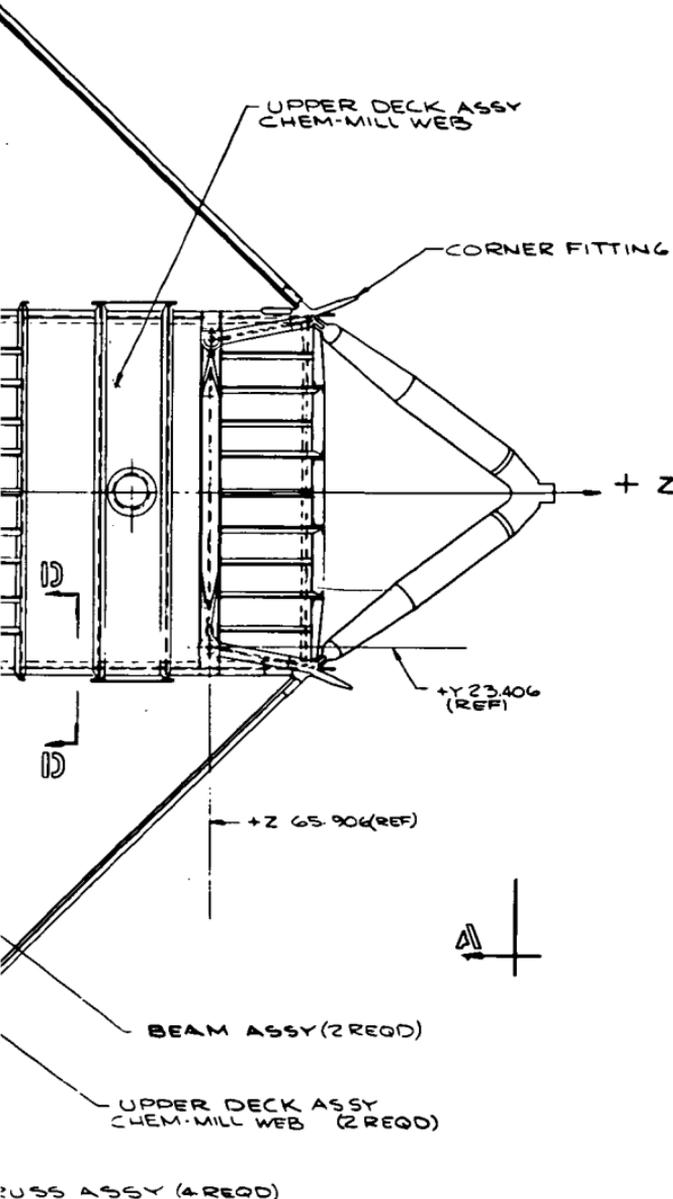
6.1-6
 (4)

CORNER FITTING
(2 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

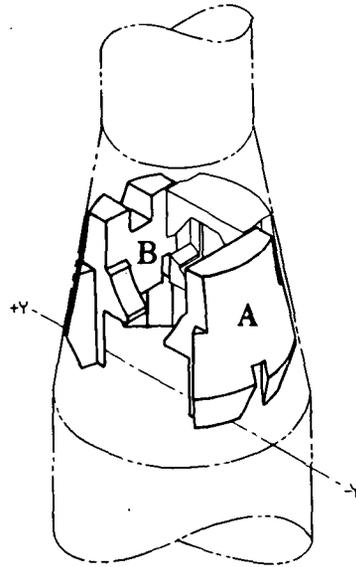
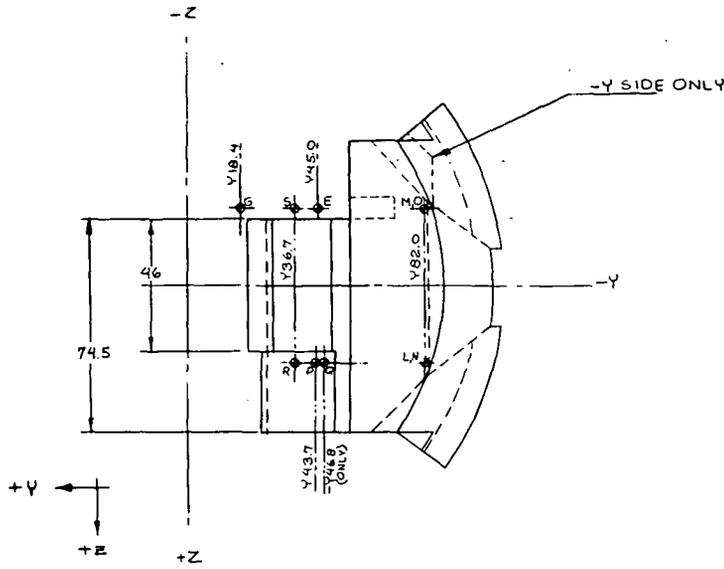


WN

6.1-6 LEM Descent Stage Structural Arrangement

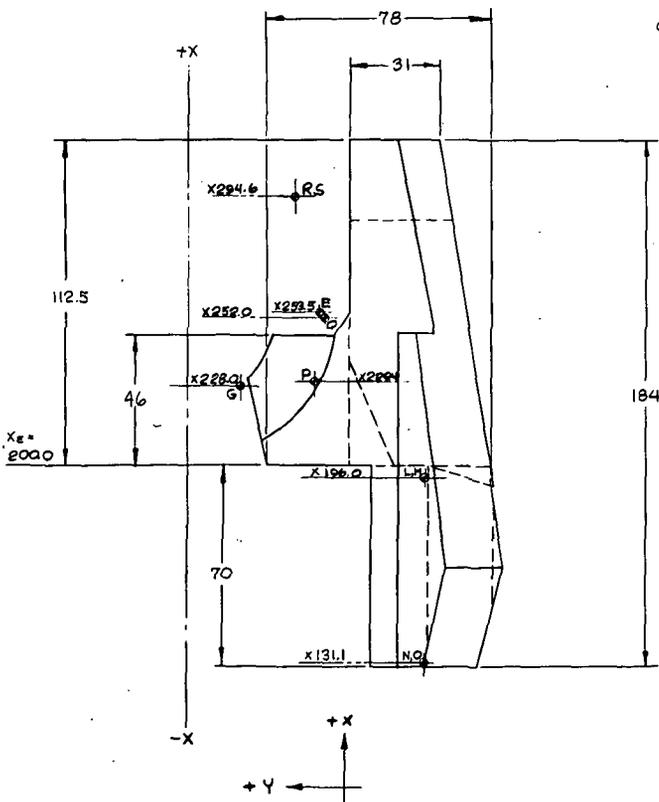
7/6 (5)

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NOTES:

- 1- ENVELOPE **A** SHOWN OPPOSITE, EXCEPT AS NOTED
- 2- ENVELOPE CLEARS ADAPTER & ASCENT STAGE, DESCENT STAGE STRUCTURE BY 7 IN. AND IS TANGENT TO THE 1180° F ISOTHERM OF THE RCS THRUSTER PLUME
- 3- LOCAL PROTRUSIONS CAN BE ALLOWED IN SOME AREAS.
- 4- LETTERS 'A' THRU 'S' INDICATE LOCATIONS OF EQUIPMENT ATTACHMENT HARDPOINTS.



CLEARANCE FOR S-BAND ANTENNA, +Y SIDE ONLY

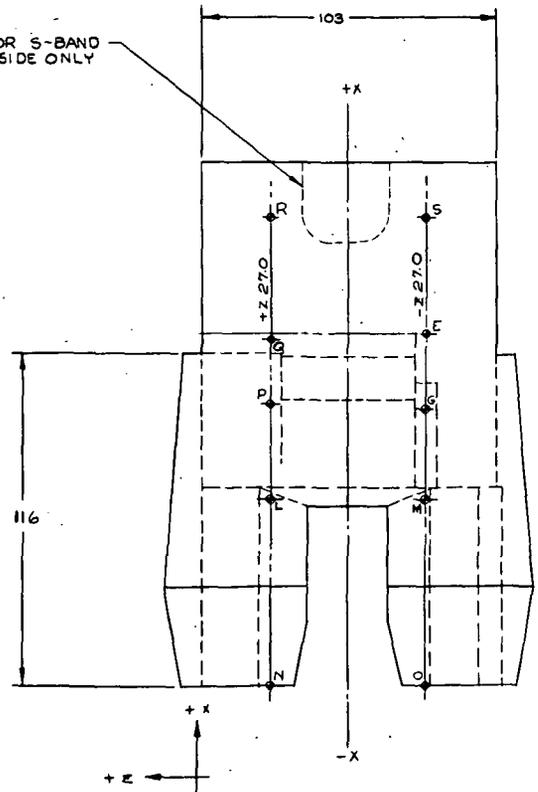


Fig. 6.1-7 Volumes and Hard Points Available for Experiments

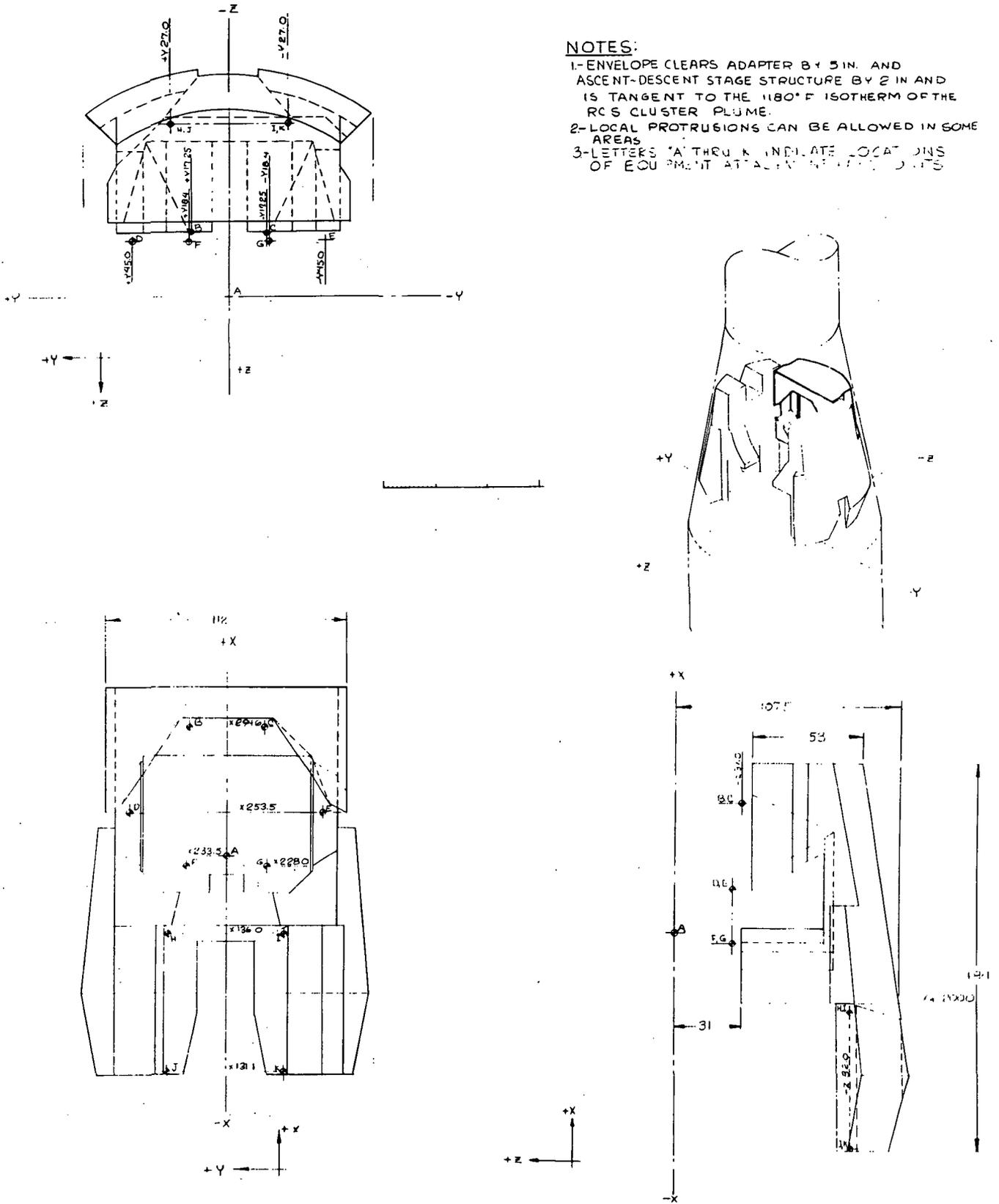
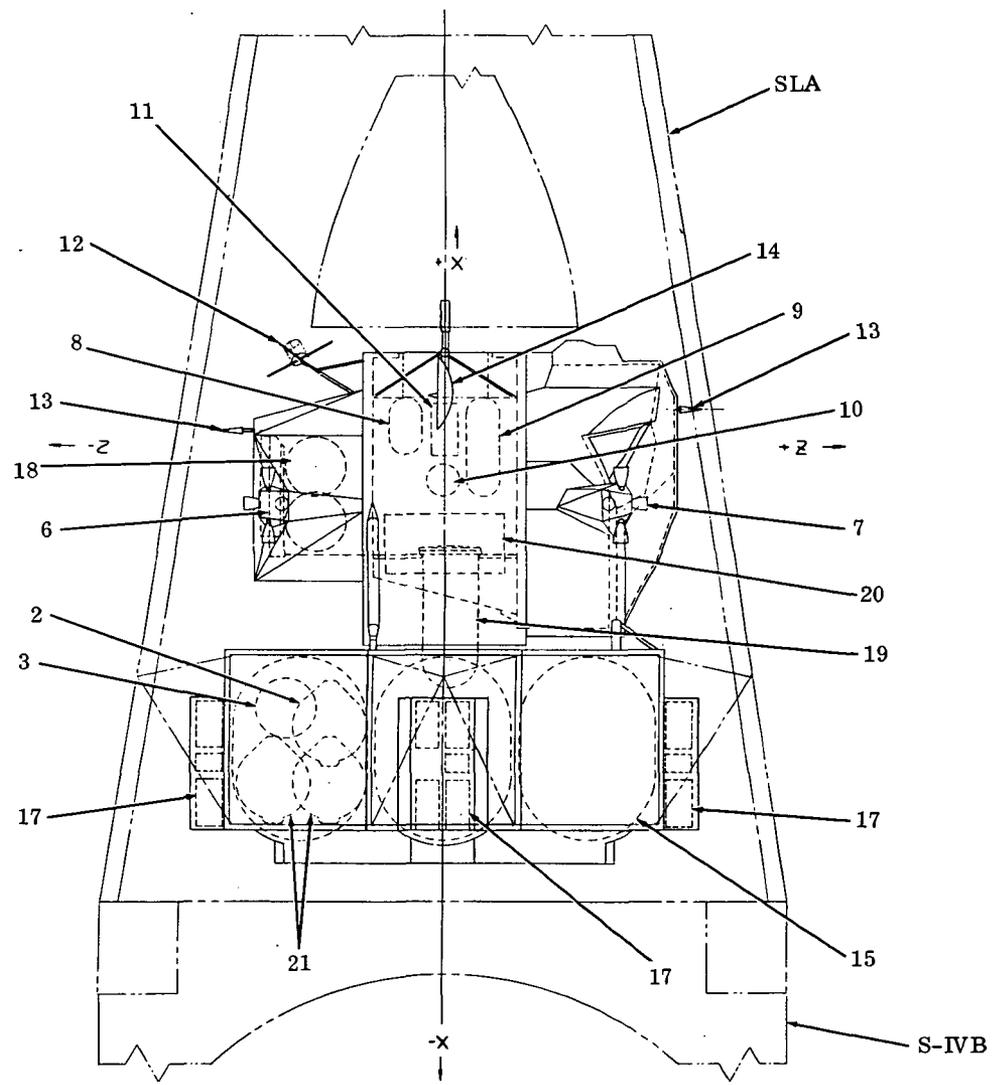


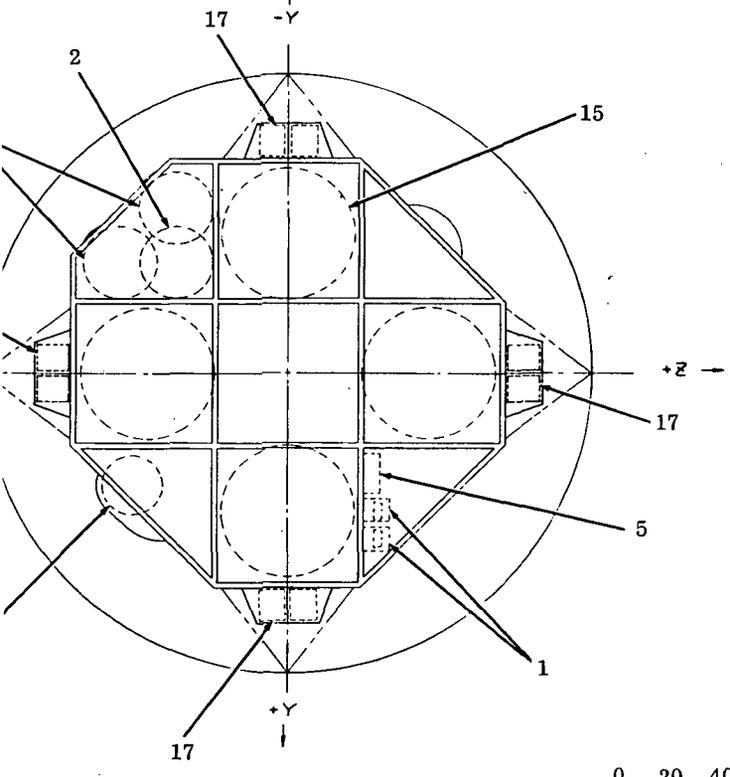
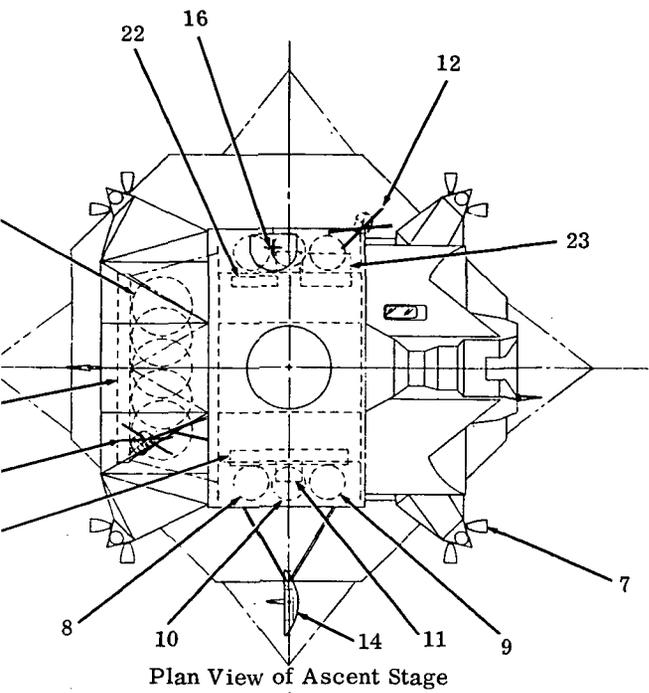
Fig. 6.1-8 Volumes and Hard Points for Experiments

Key

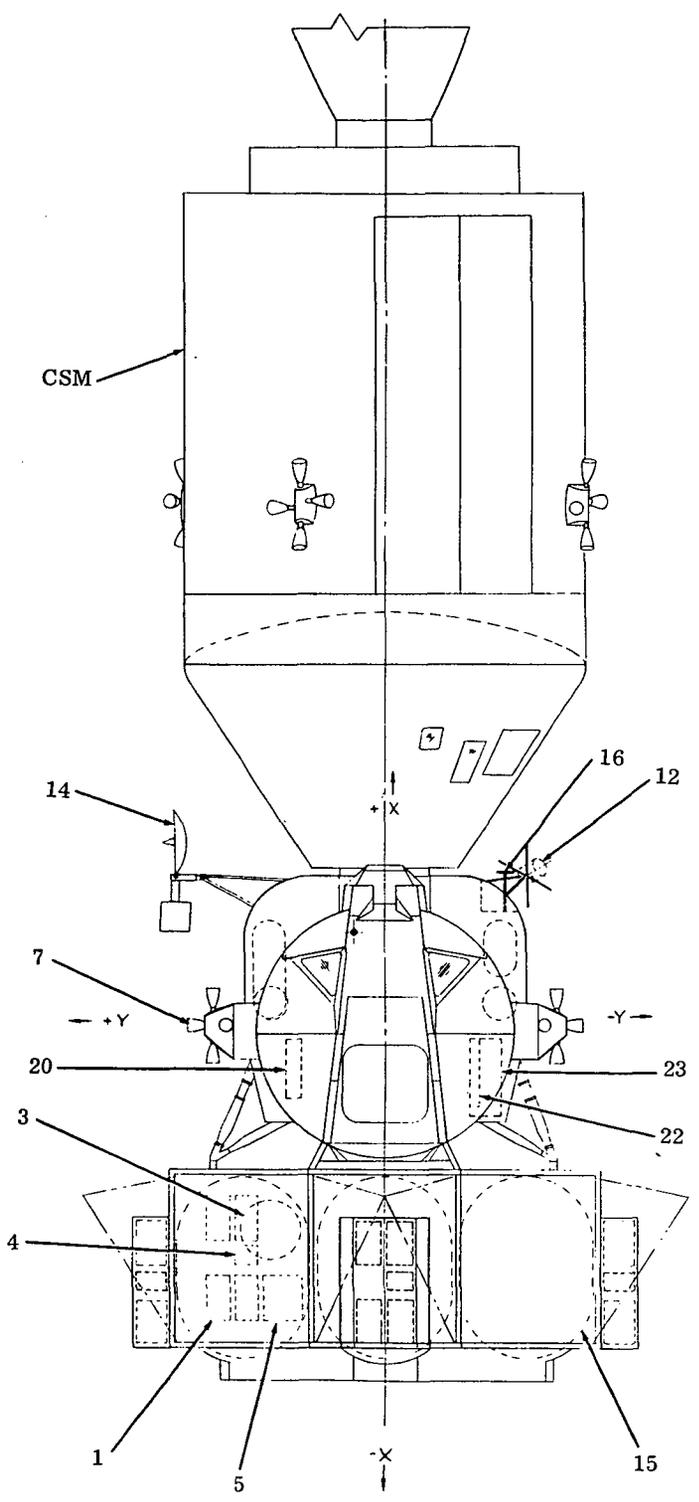
- | | |
|----------------------------|------------------------------|
| 1 Battery* | 14 S-Band Steerable Antenna* |
| 2 Water Tank* | 15 Descent Propellant Tank* |
| 3 GOX Tank* | 16 Docking Target* |
| 4 Electric Cont Assy (ECA) | 17 Four-Battery Module** |
| 5 GOX Pressure Module* | 18 GOX Tanks (5) ** |
| 6 ERA Cold Plate* | 19 Canister |
| 7 RCS Thrusters* | 20 PLSS Battery Stowage |
| 8 RCS Fuel* | 21 Water Tank** |
| 9 RCS Oxidizer* | 22 CSM LiOH Stowage |
| 10 RCS Helium* | 23 CSM LiOH Stowage |
| 11 RCS Valves* | |
| 12 VHF Antenna* | |
| 13 S-Band Antenna* | |
- *Existing LEM Instl
**Existing LEM Hardware



Launch Configuration



0 20 40 60 80 100
Scale, in.



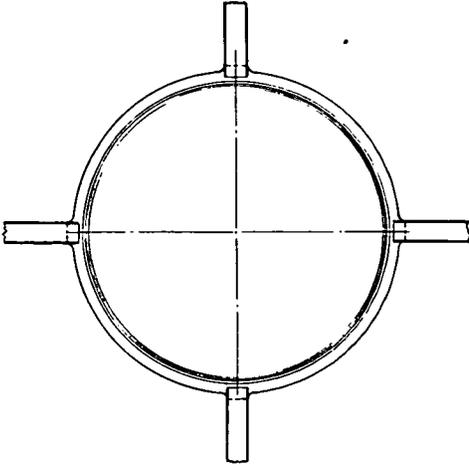
Plan View of Descent Stage

Orbiting Configuration

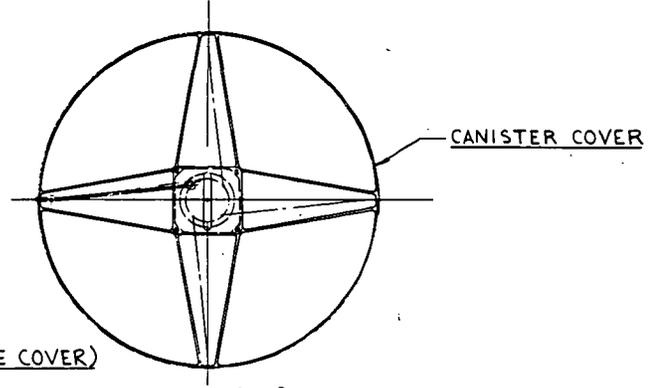
6.2-1 Recommended Phase I Lab General Arrangement



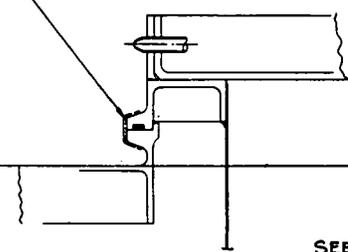
21



SECT 13-13



CLAMP (SAME AS ASCENT ENGINE COVER)

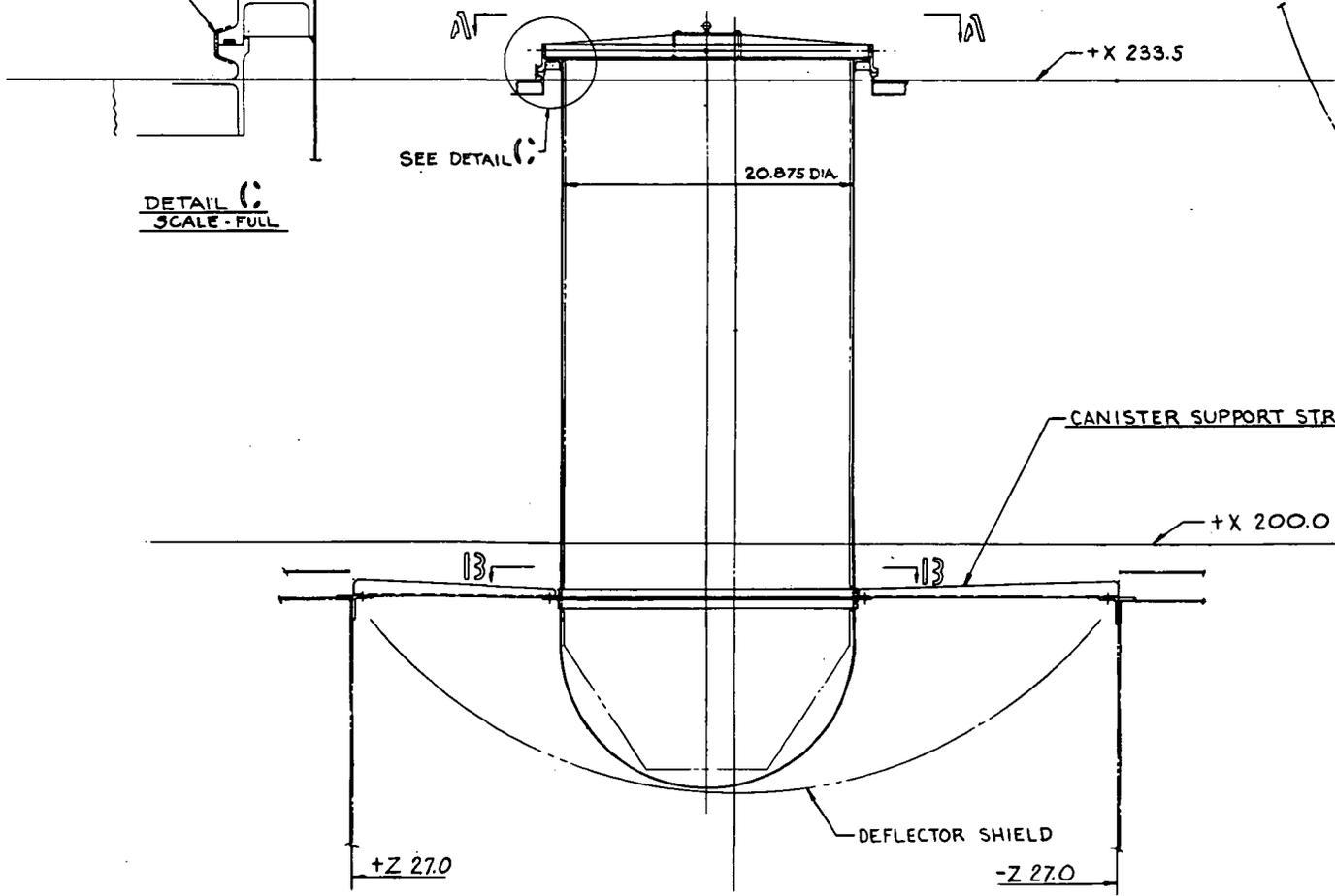


DETAIL C
SCALE - FULL

SEE DETAIL C

VIEW A-A

AFT CABIN



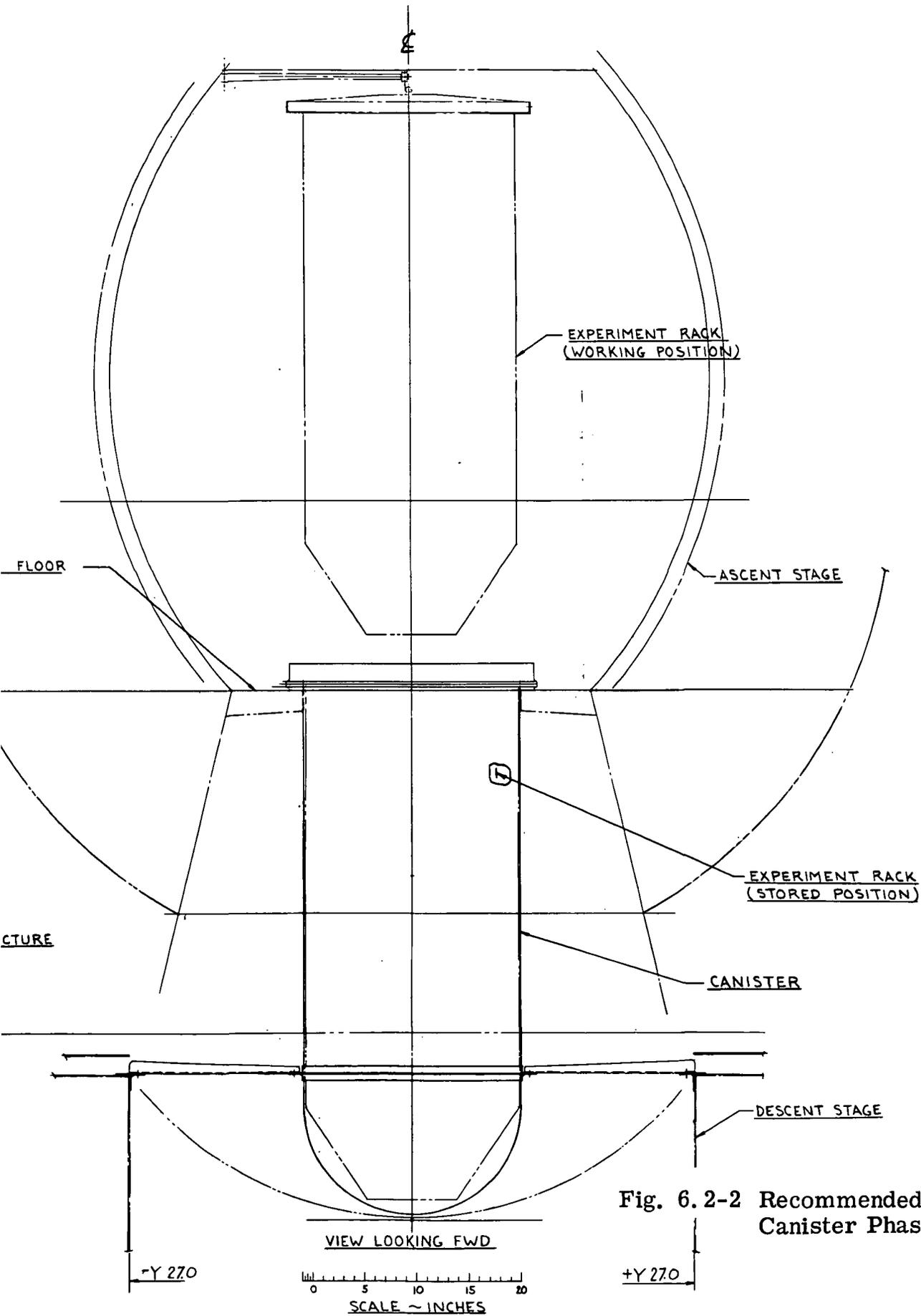
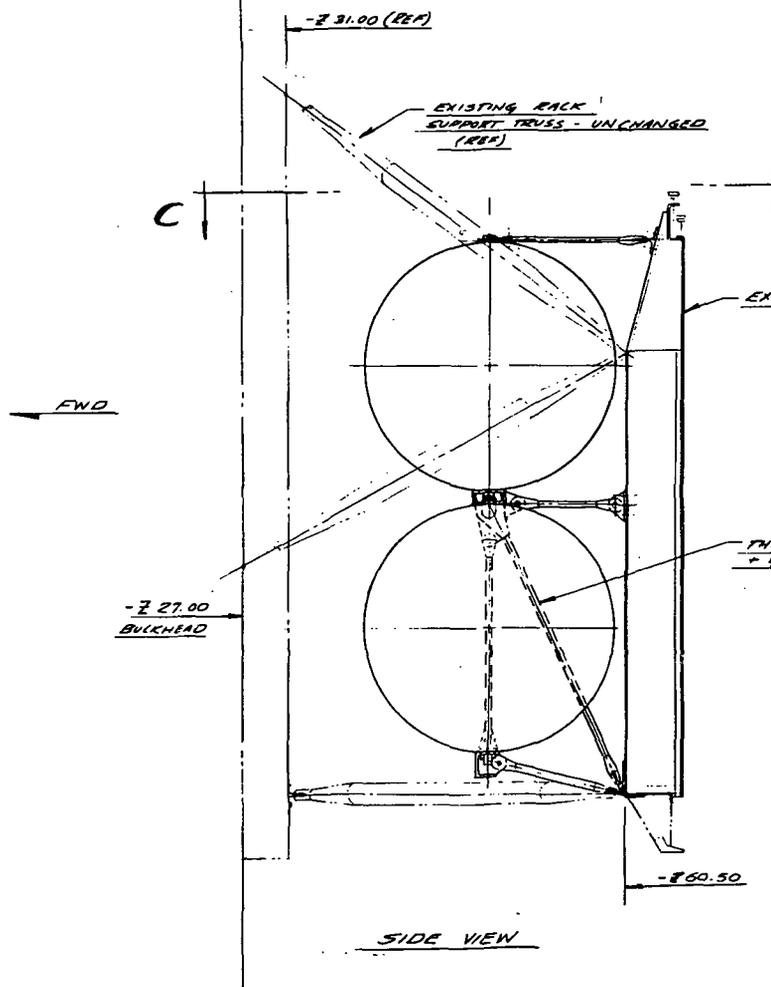
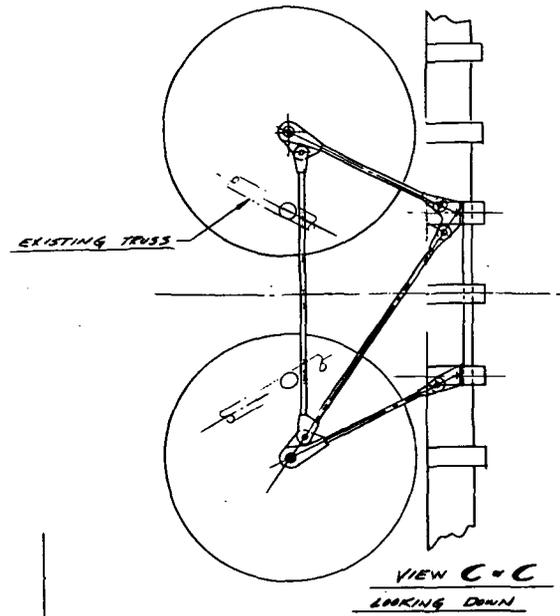
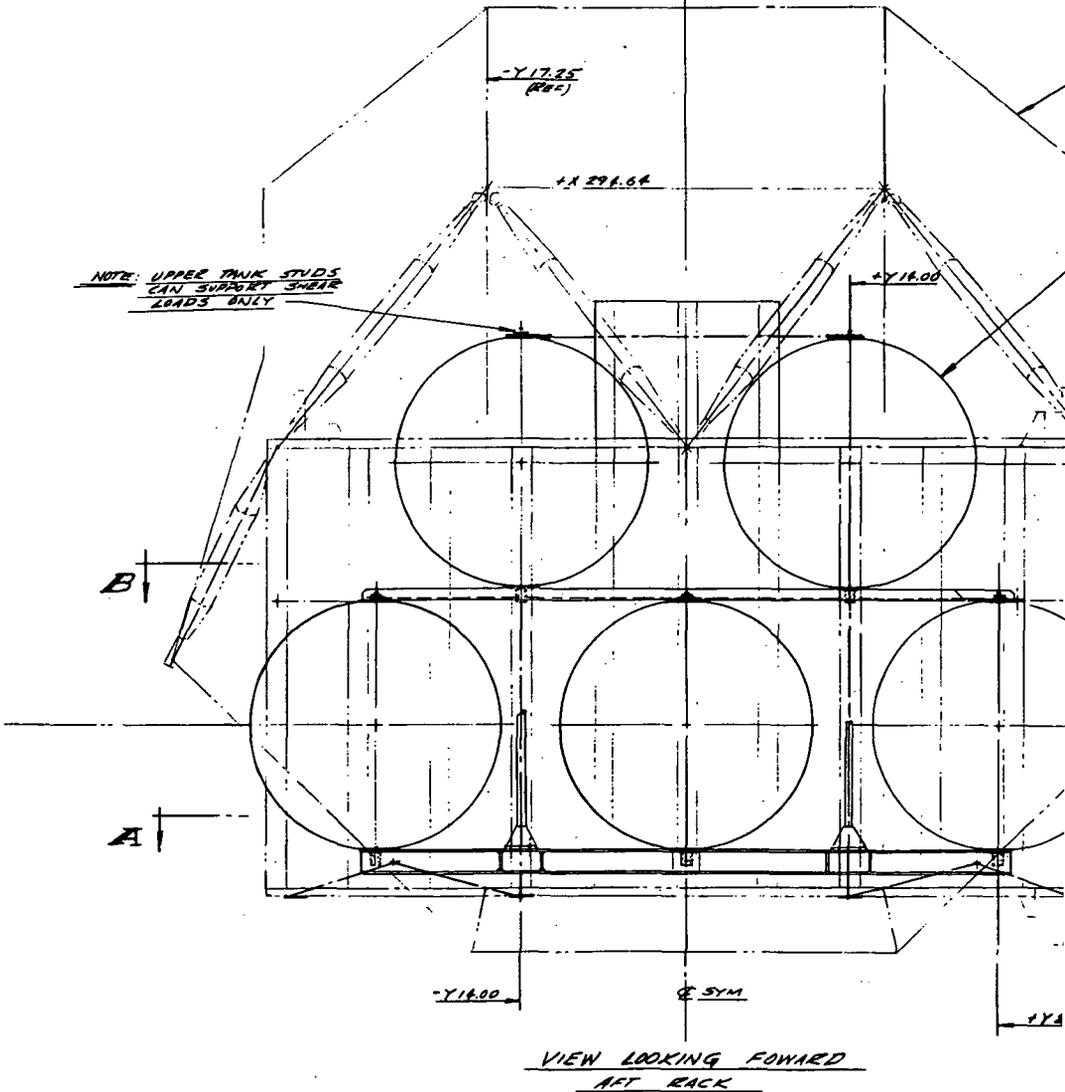
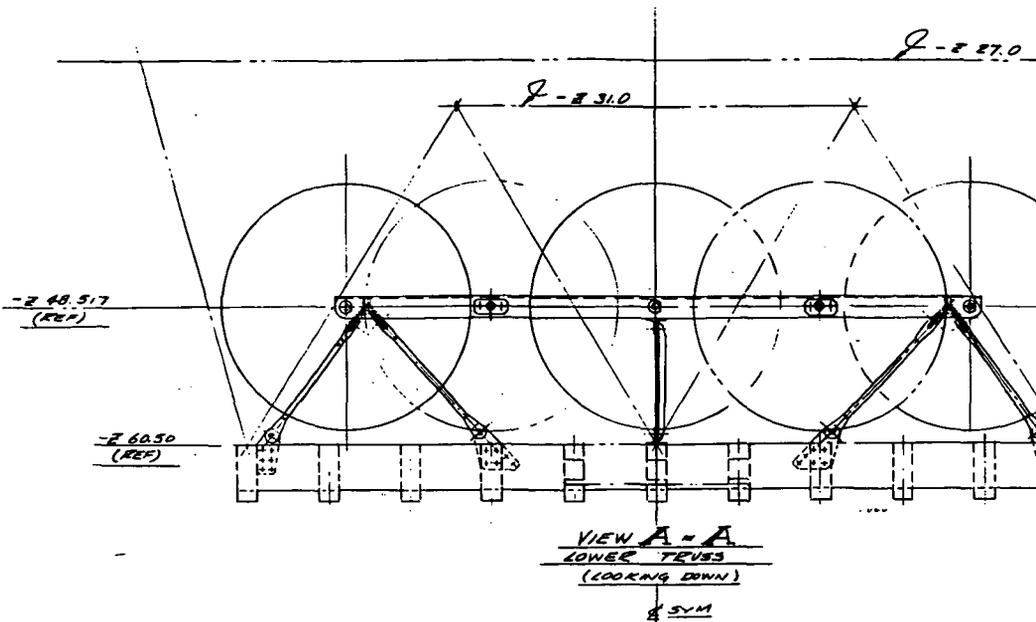


Fig. 6.2-2 Recommended Mid-Section Canister Phase I Lab



6.2-3
①



6-2-3
②

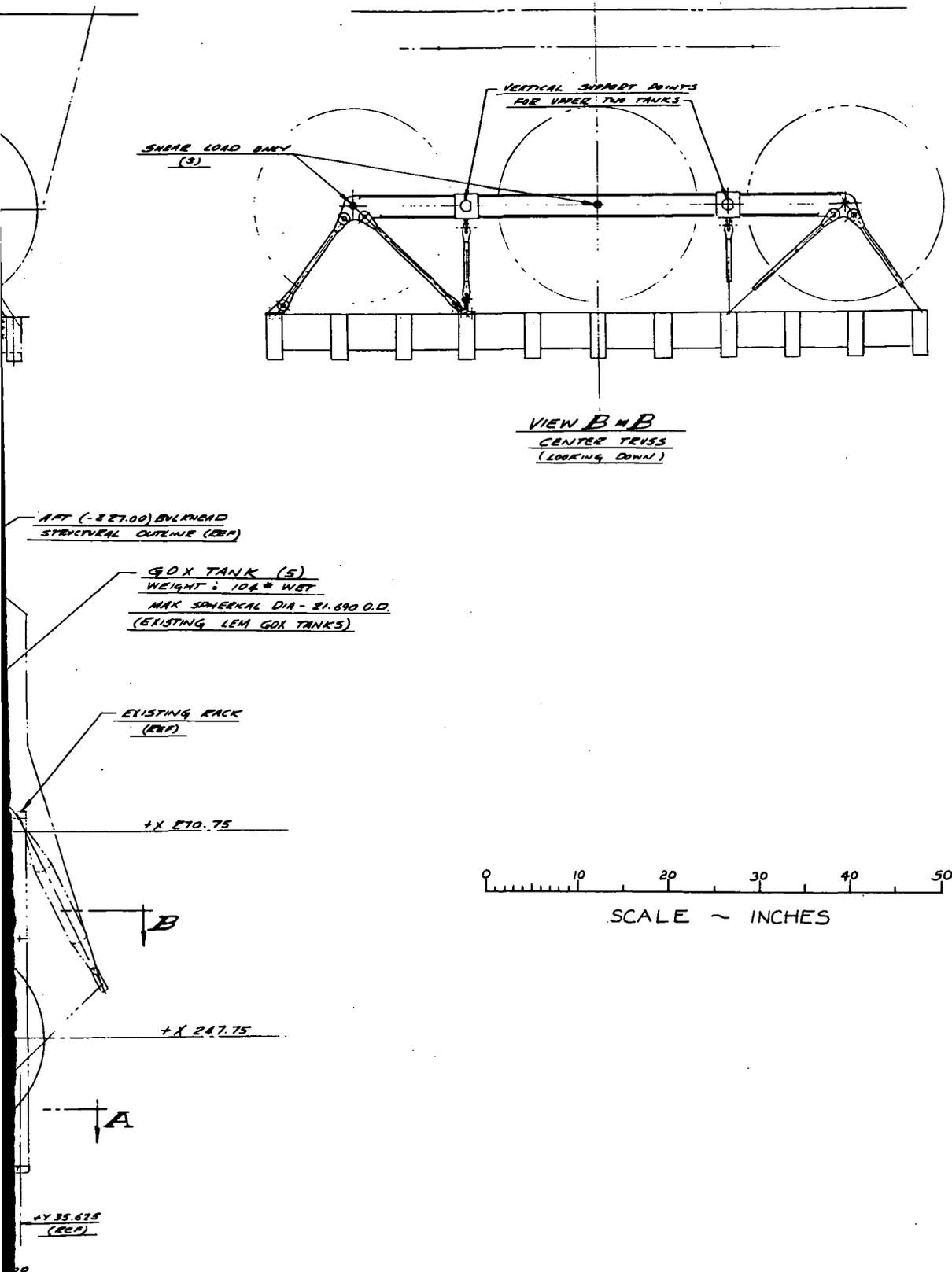
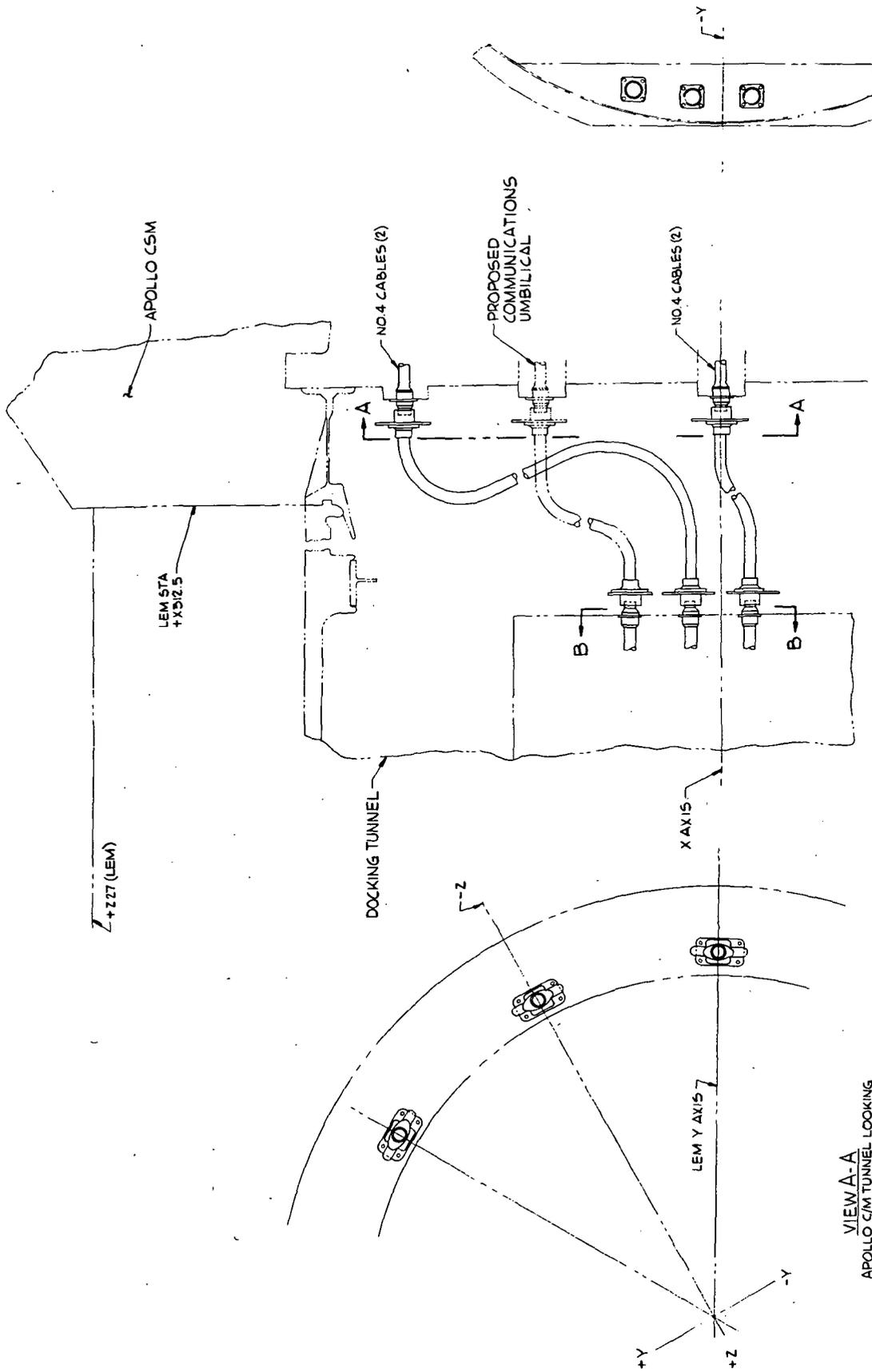


Fig. 6.2-3 Recommended GOX Tank Installation Phase I Lab

3

Grumman



VIEW B-B
LEM TUNNEL LOOKING
TOWARD LEM LAB

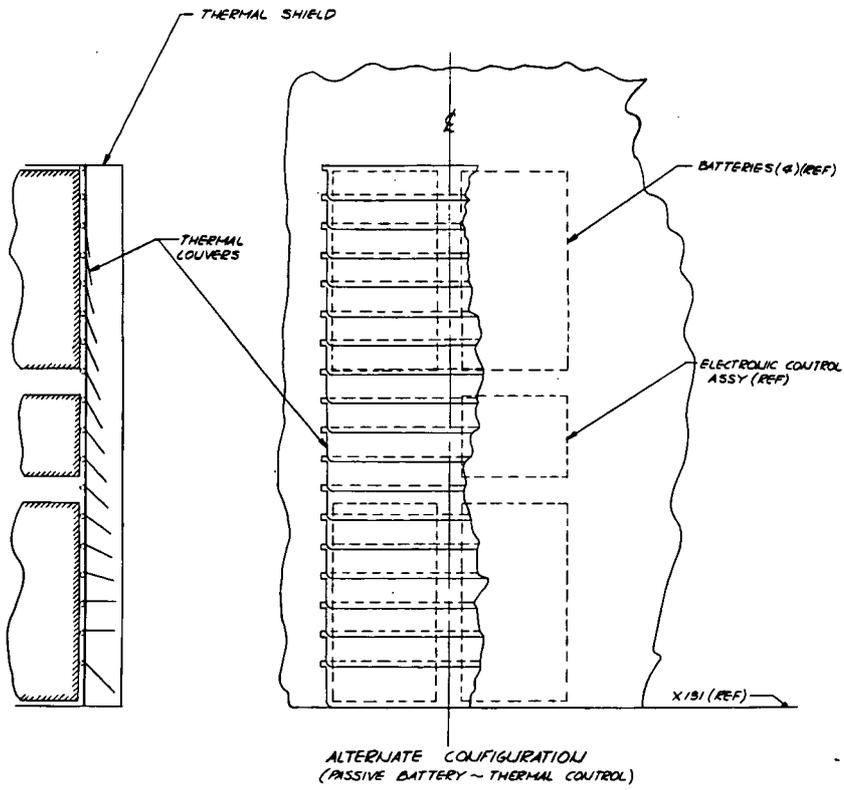
VIEW A-A
APOLLO C/M TUNNEL LOOKING
IN X DIRECTION TOWARD SM

Fig. 6.2-4 Lab-CSM Interface



27

0 5 10 15 20
SCALE ~ INCHES



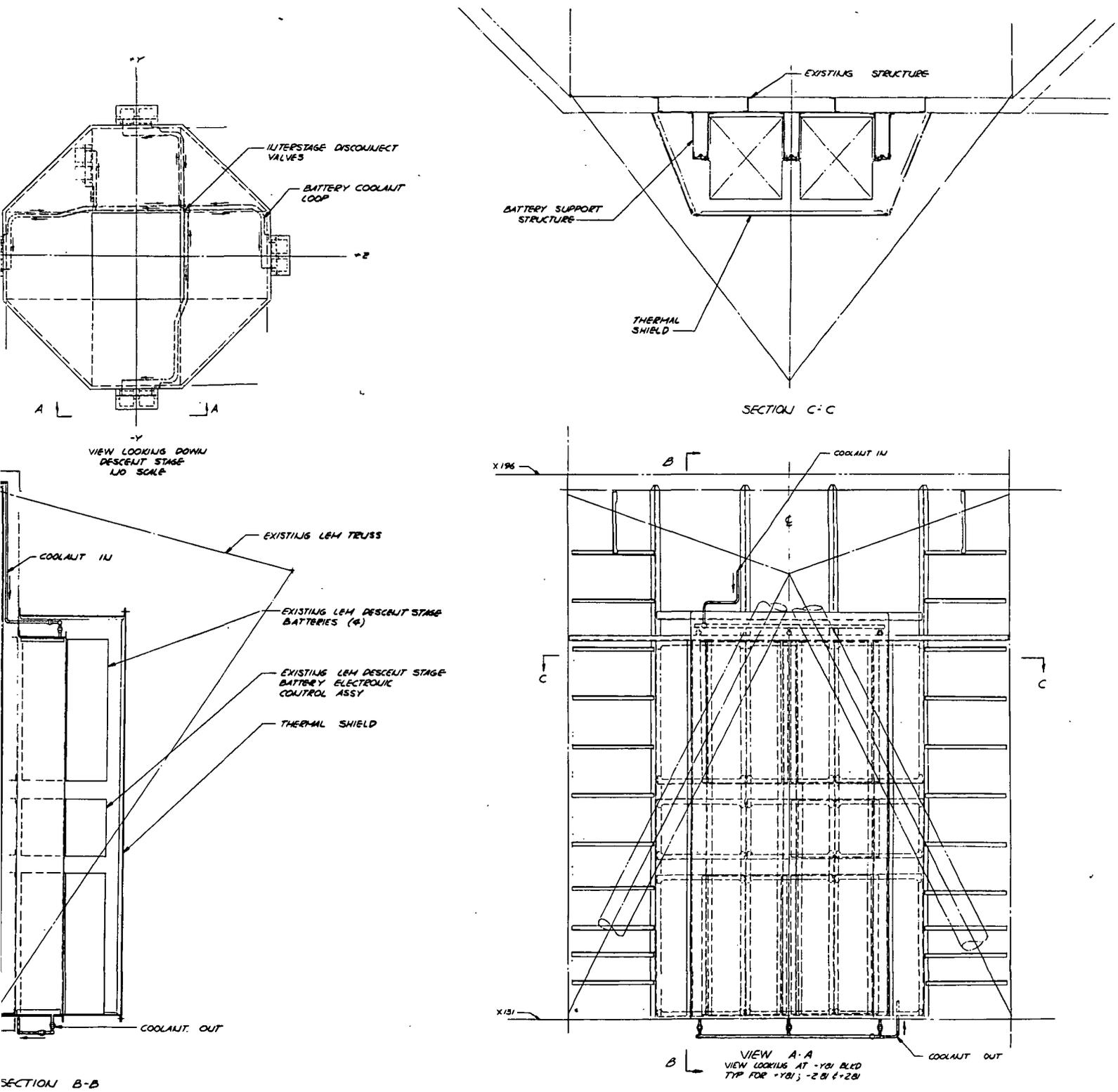


Fig. 6.2-5 Recommended Battery Installation Phase I Lab

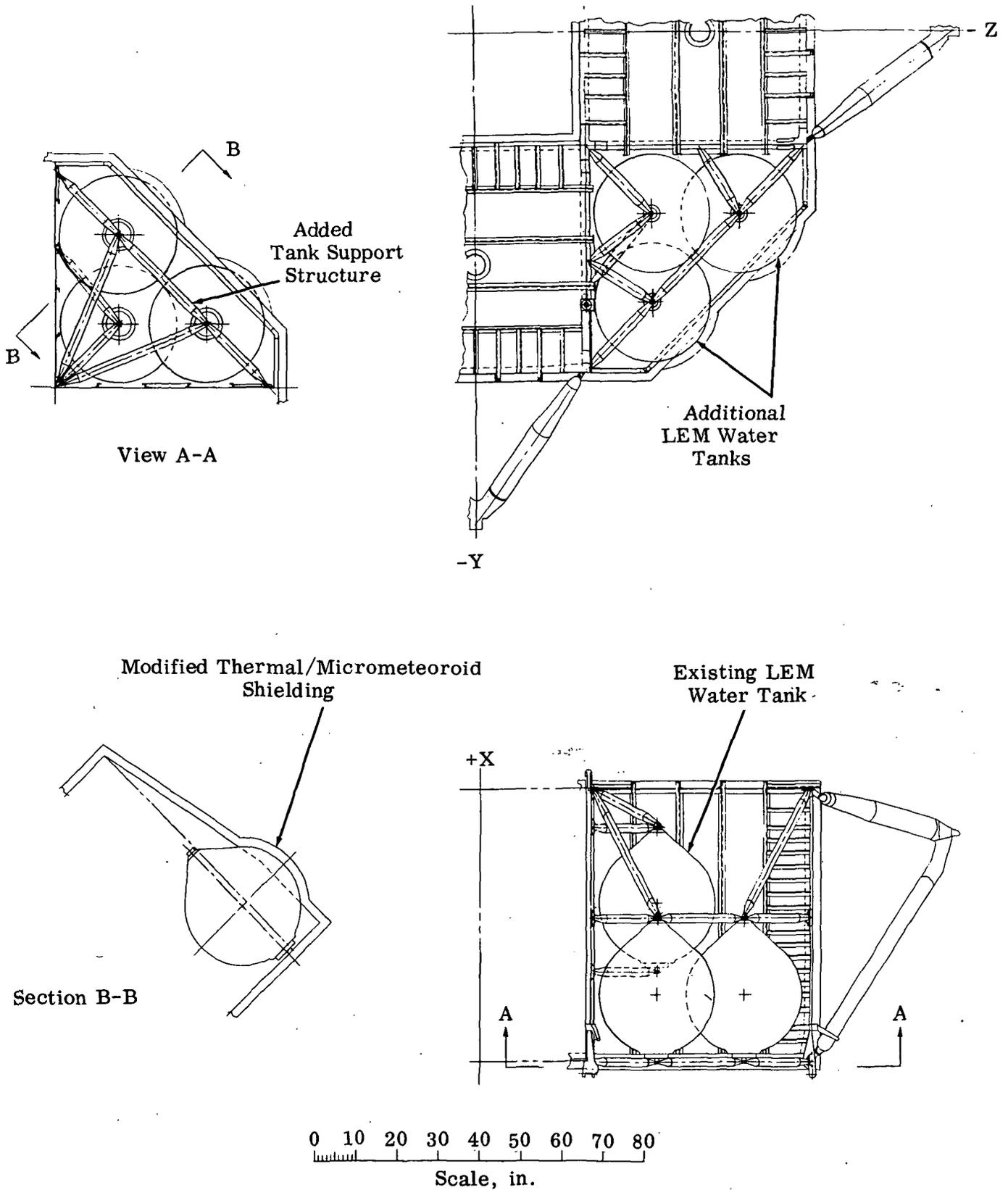
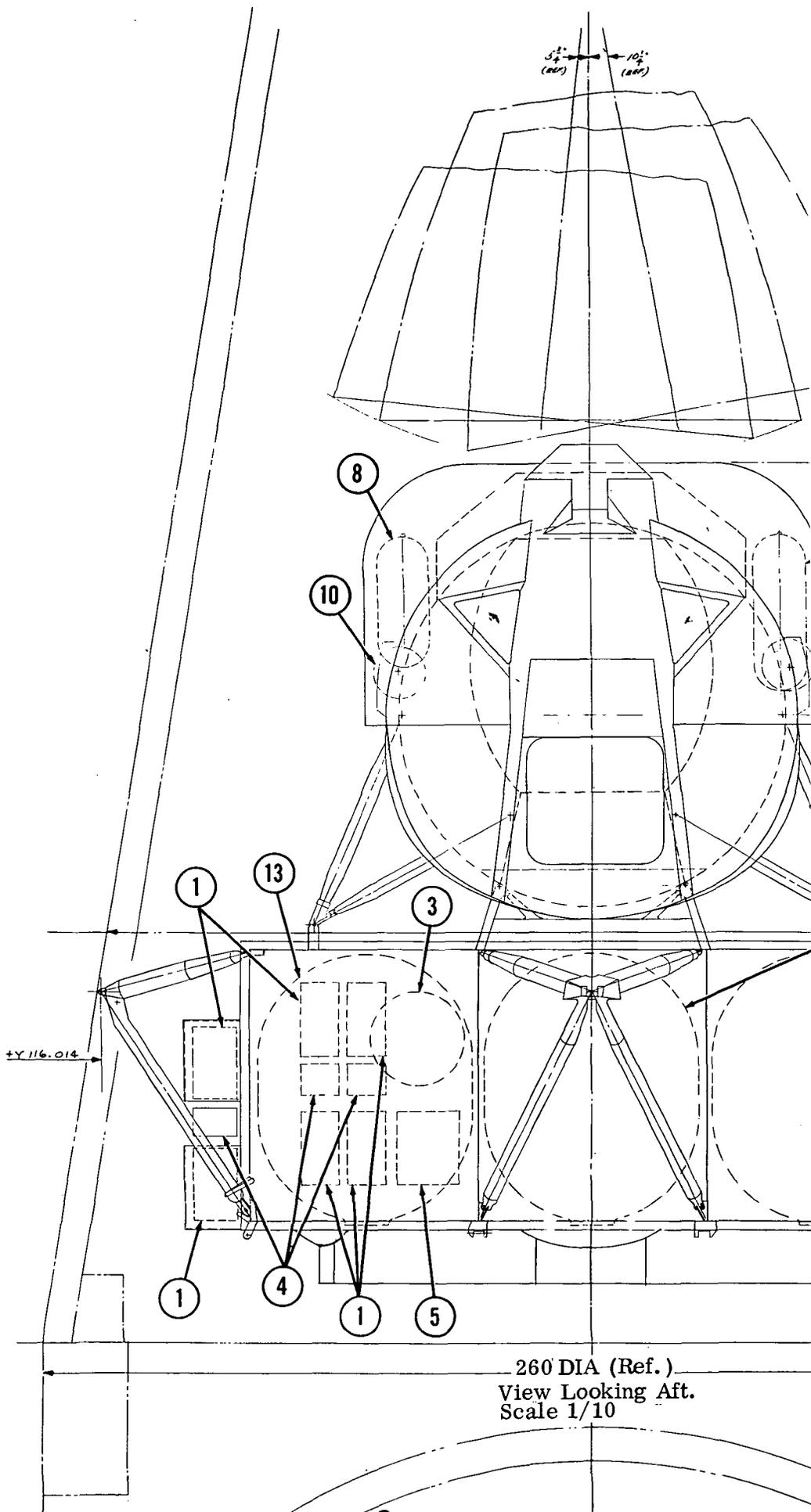


Fig. 6.2-6 Recommended Water Tank Installation Phase I Lab



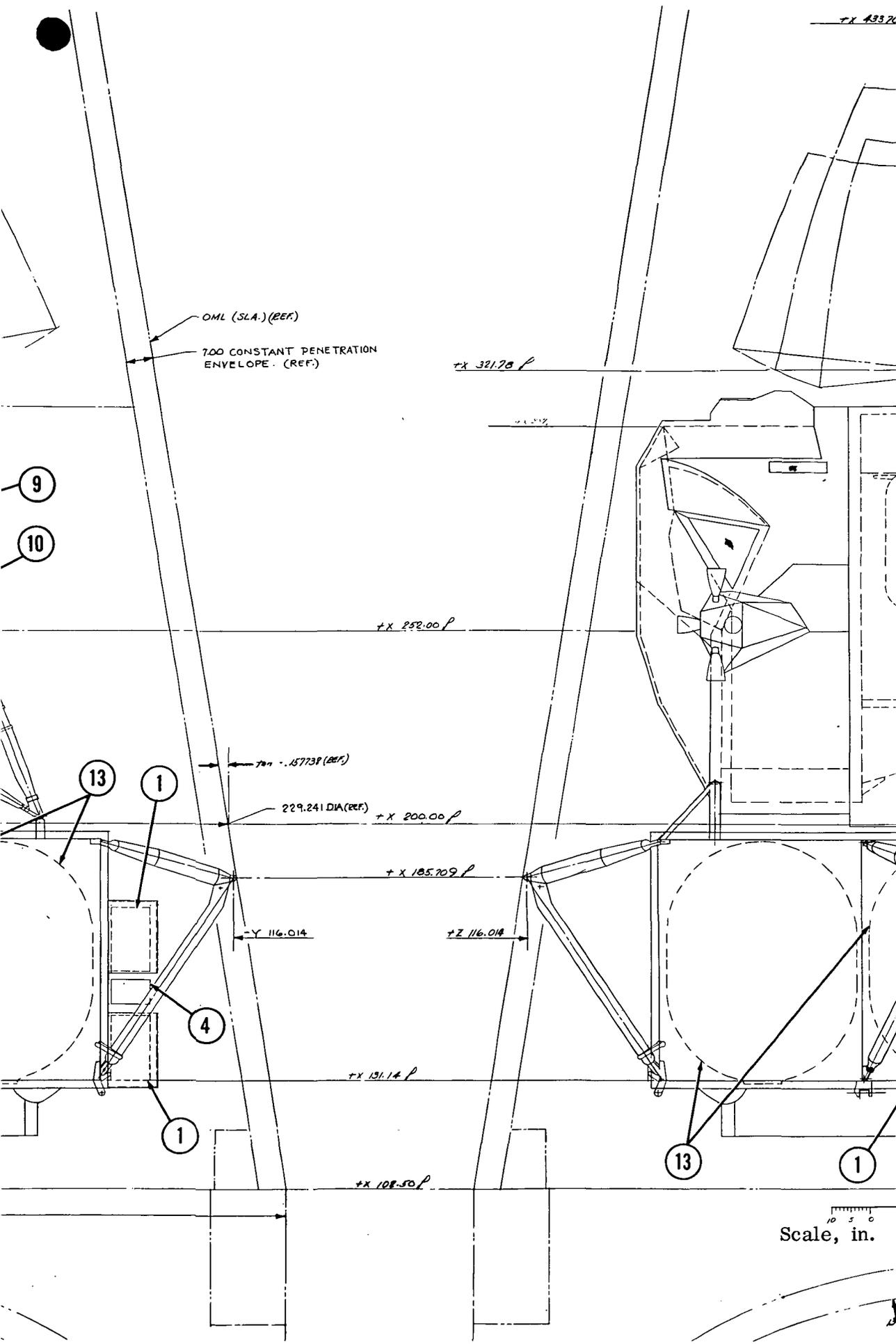
5 1/2°
(RCP)

10 1/2°
(RCP)

+Y 116.014

260 DIA (Ref.)
View Looking Aft.
Scale 1/10

6.2-7
①^A



10 5 0

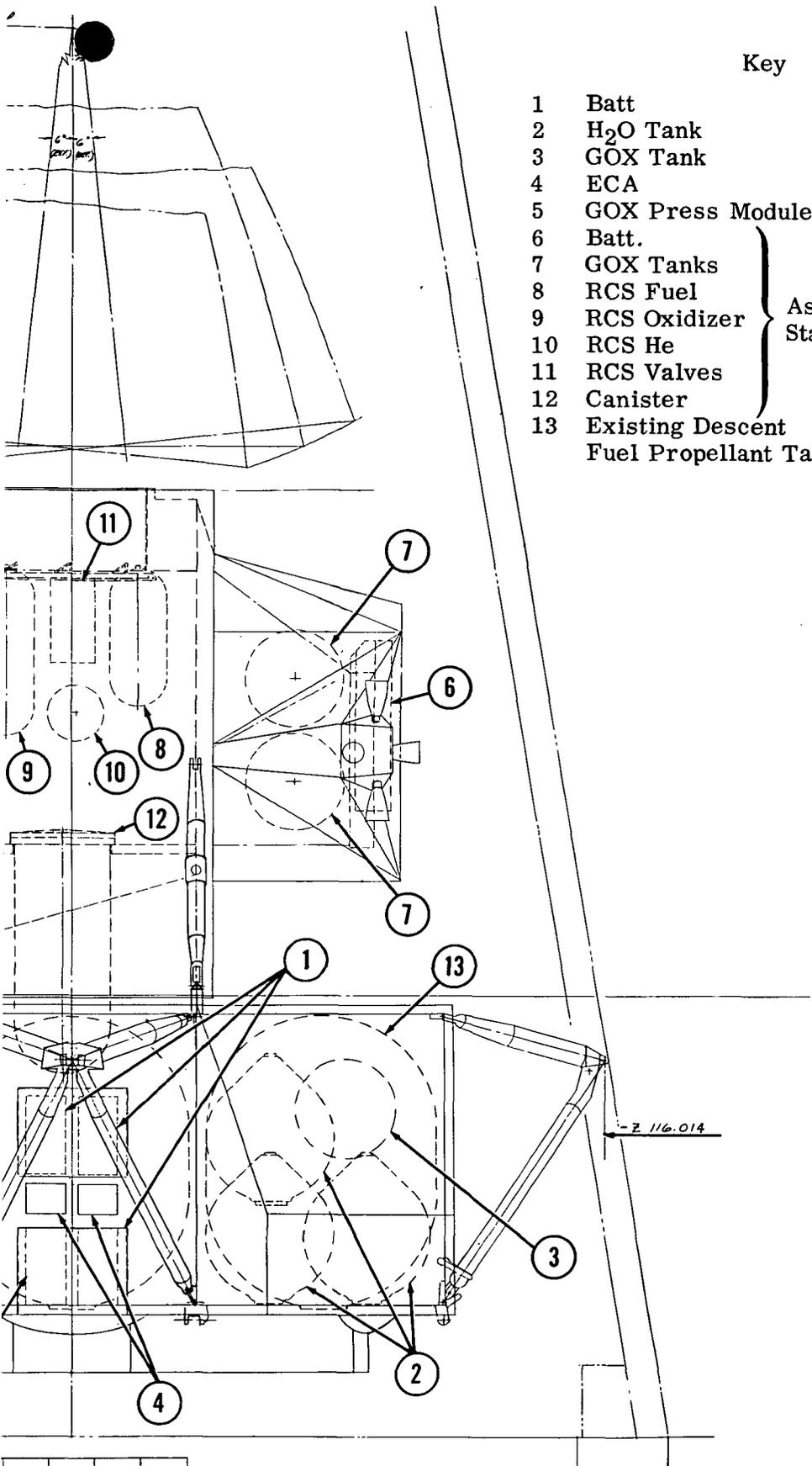
Scale, in.

6.2-7A

2

Key

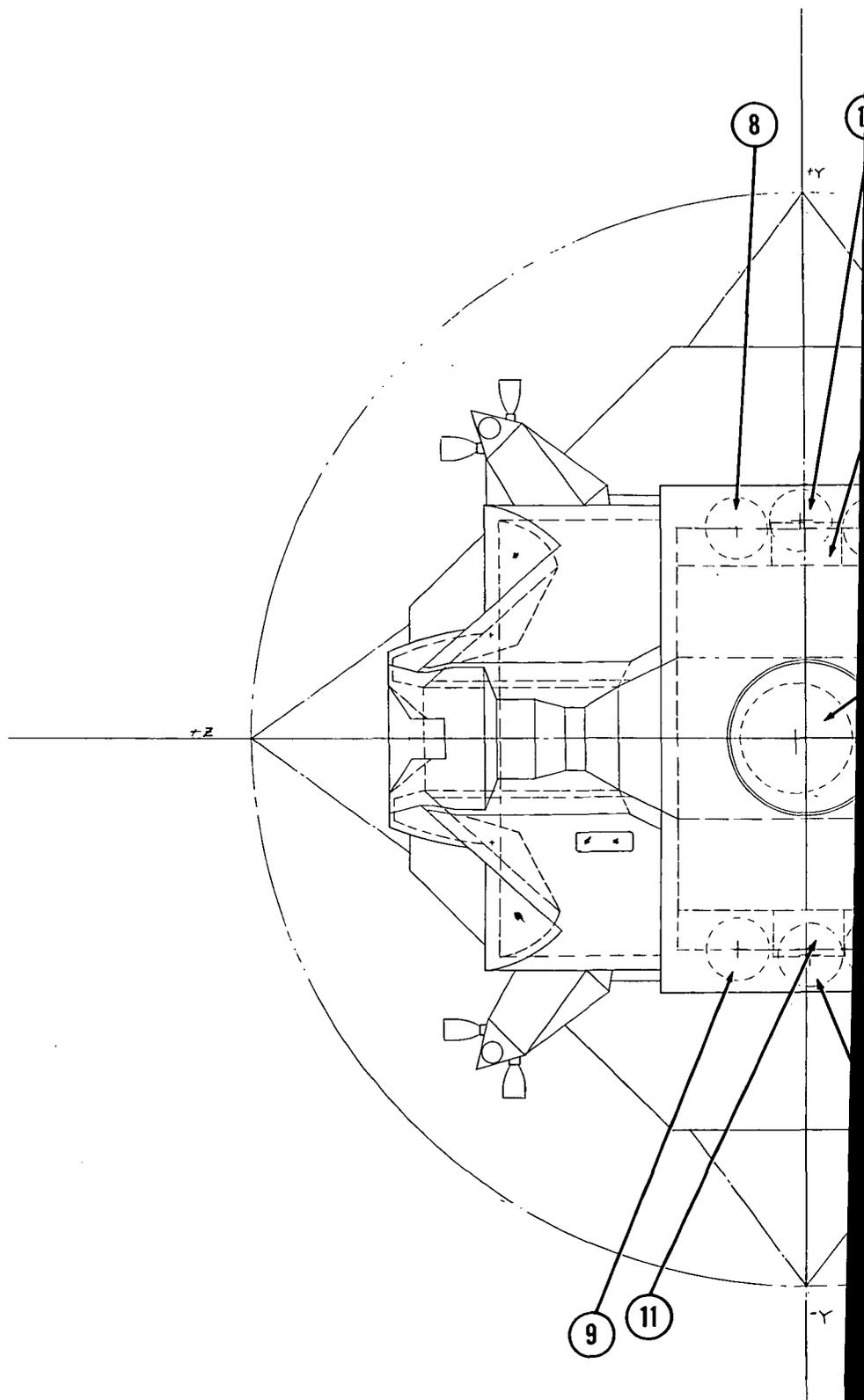
- 1 Batt
 - 2 H₂O Tank
 - 3 GOX Tank
 - 4 ECA
 - 5 GOX Press Module
 - 6 Batt.
 - 7 GOX Tanks
 - 8 RCS Fuel
 - 9 RCS Oxidizer
 - 10 RCS He
 - 11 RCS Valves
 - 12 Canister
 - 13 Existing Descent Fuel Propellant Tanks
- } Descent Stage
 } Ascent Stage



Side View
← FWD →

Fig. 6.2-7 General Baseline Arrangement
A Phase I Lab (Sheet 1 of 2)

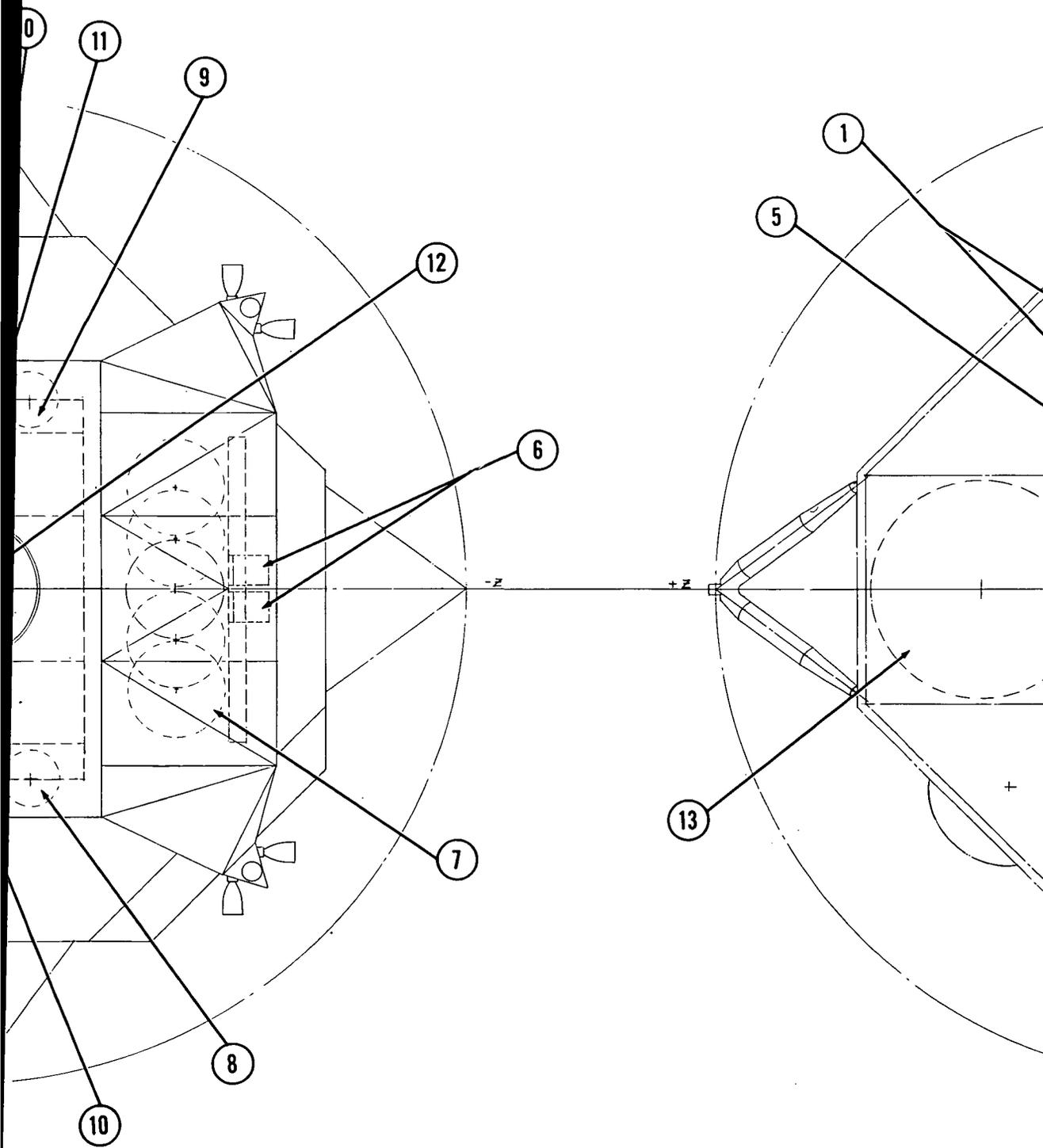
3



Plan View
 Ascent S
 Scale 1/1

6.2-7 B

①



w
stage
LO

6-2-7 B

(2)

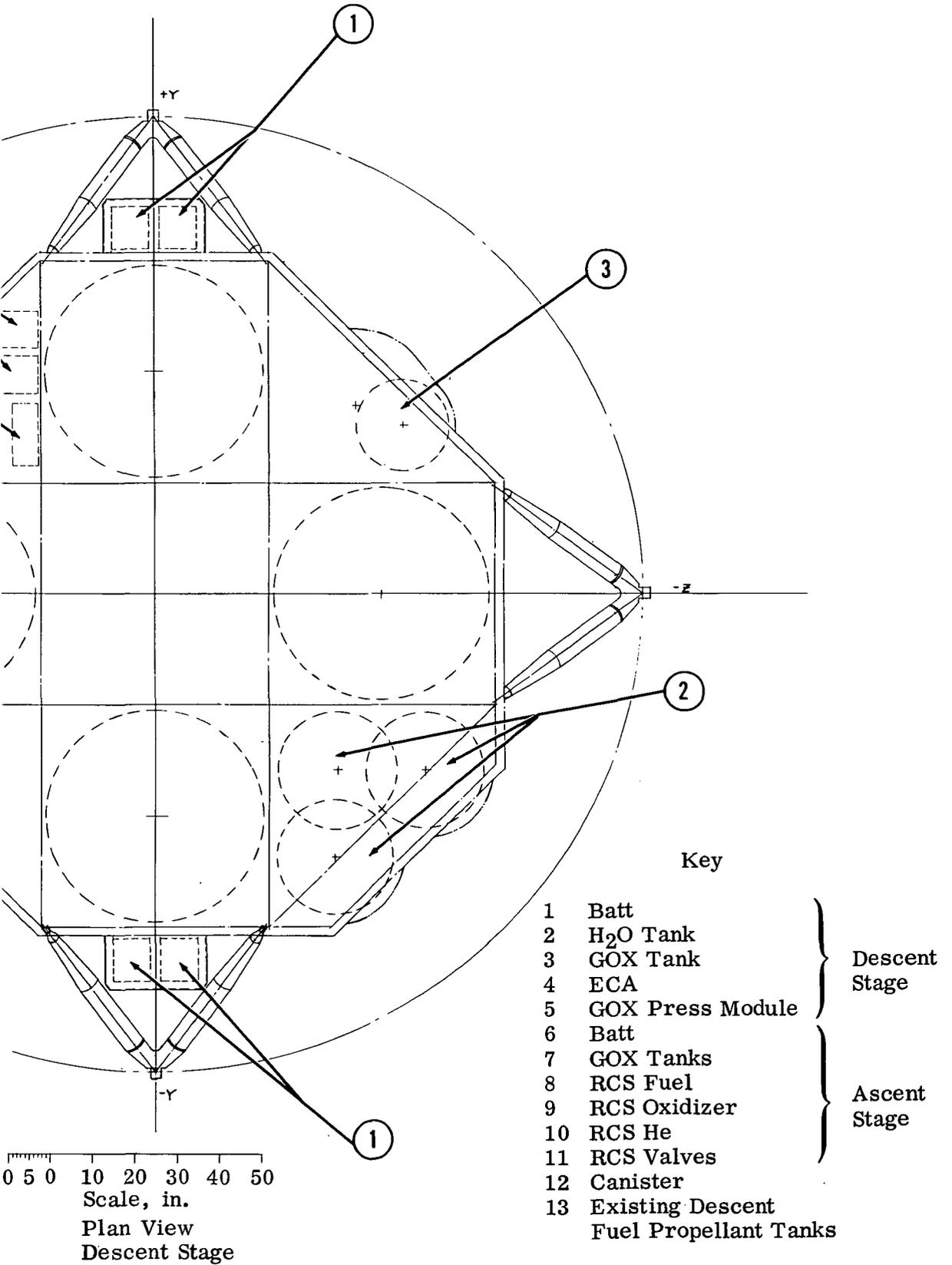
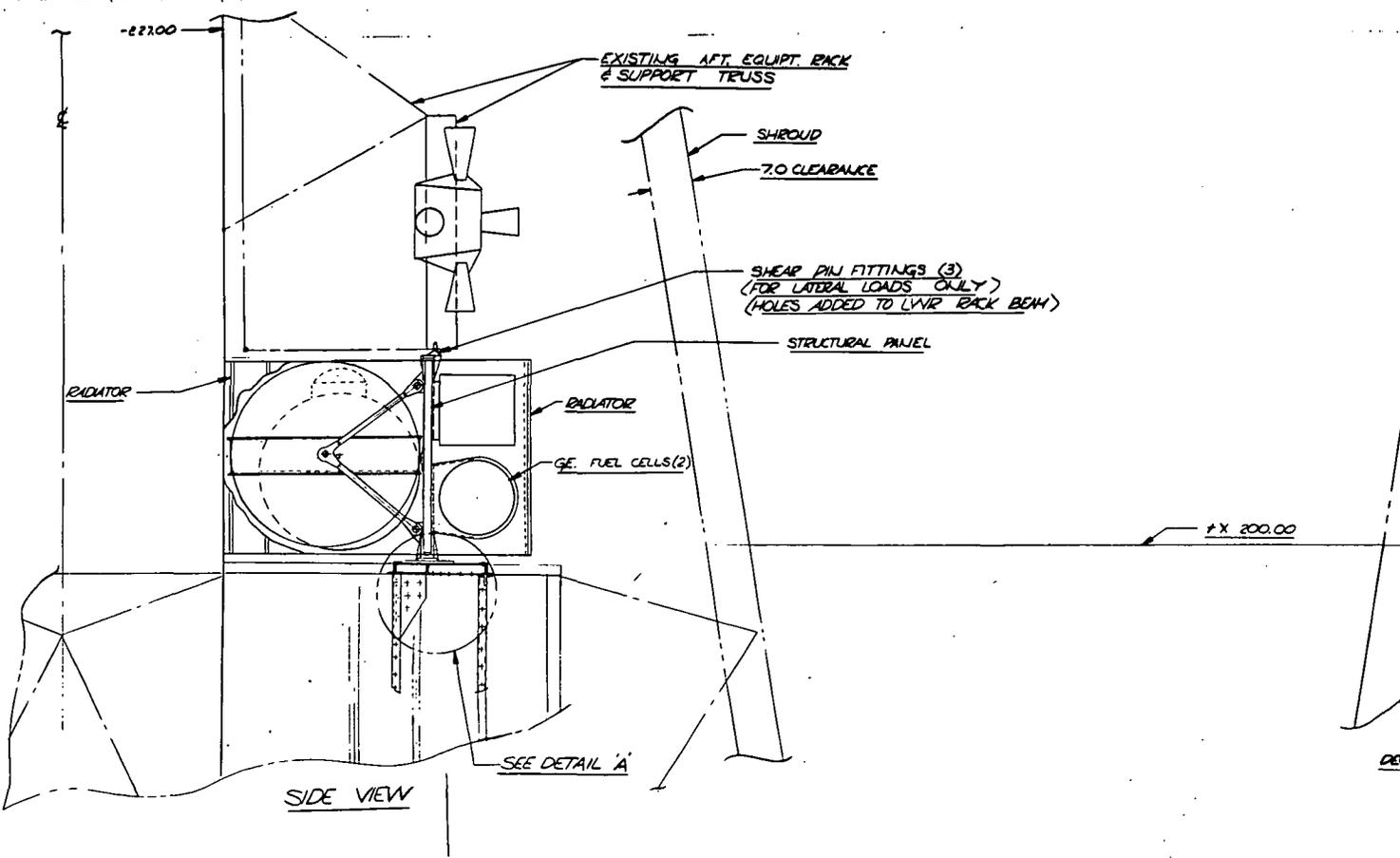
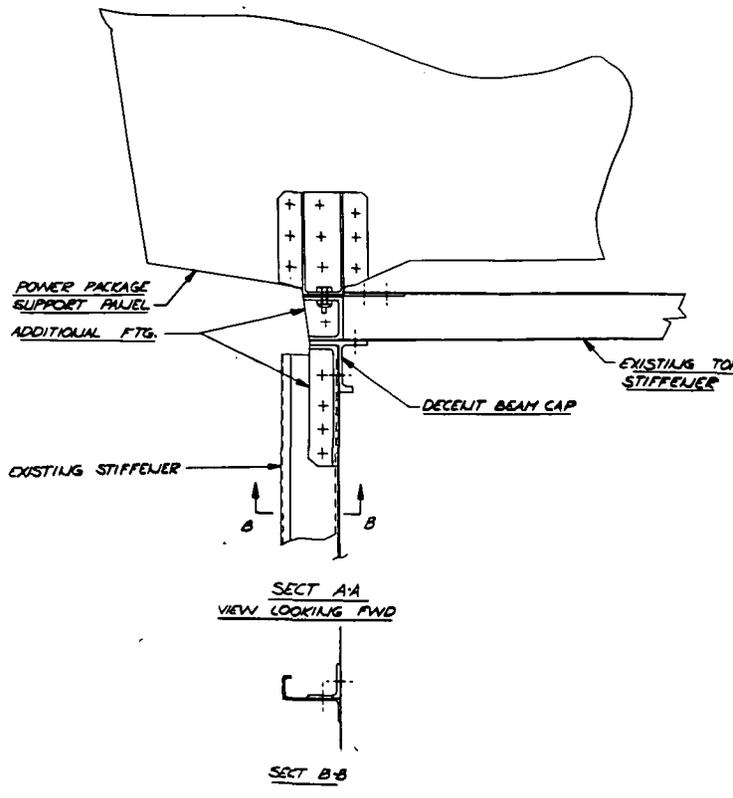
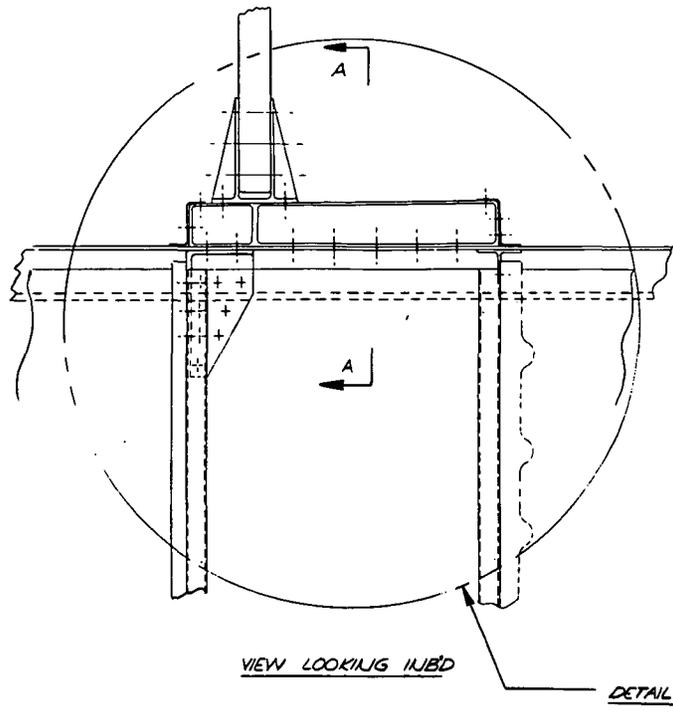


Fig. 6.2-7 General Baseline Arrangement Phase I Lab (Sheet 2 of 2)

8

Grumman

35



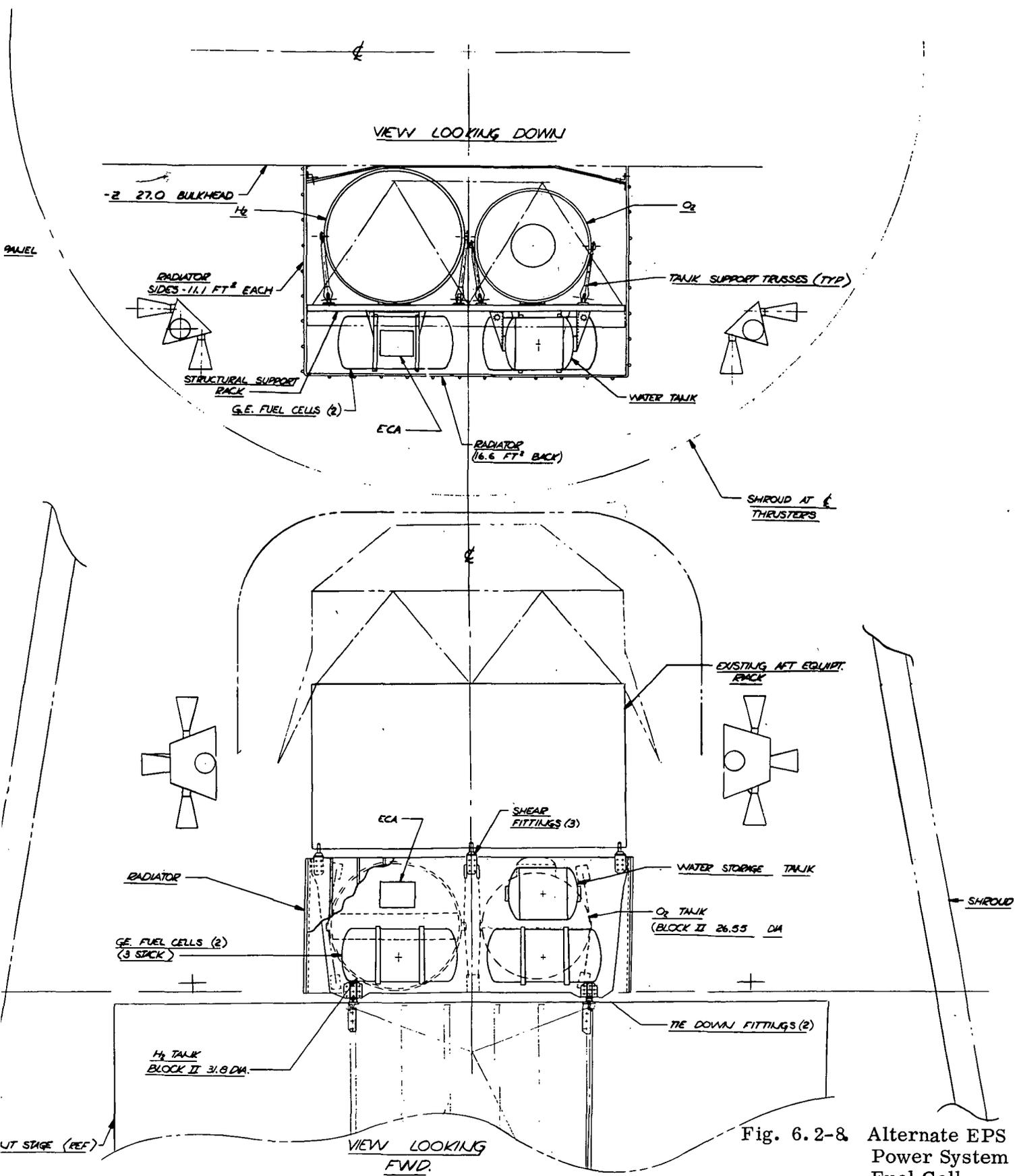
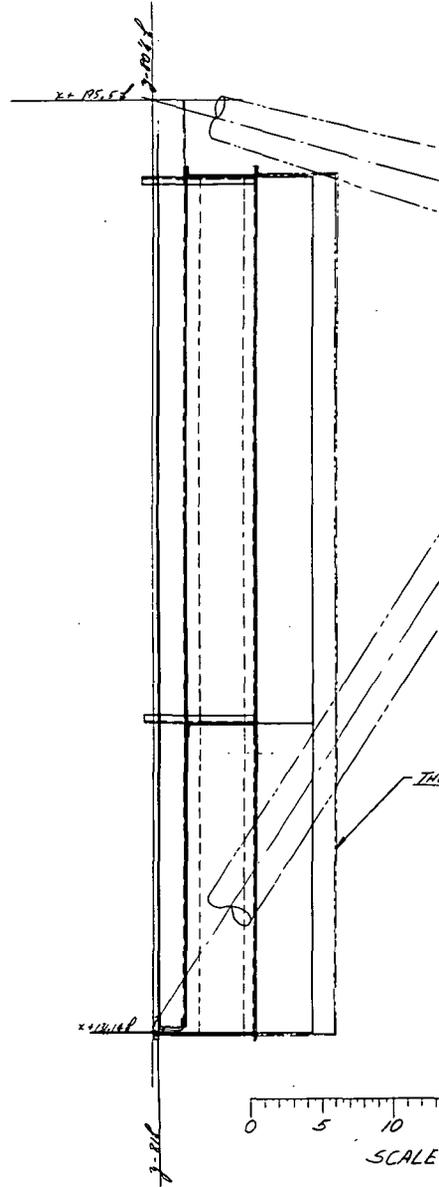
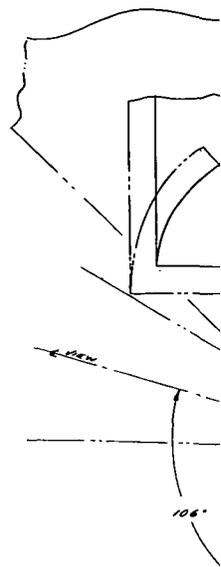
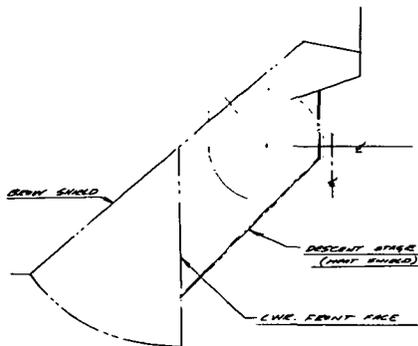


Fig. 6.2-8 Alternate EPS Power System Fuel Cell Configuration

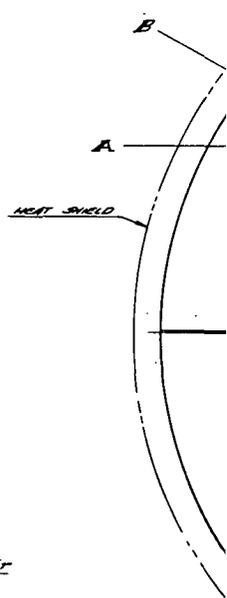
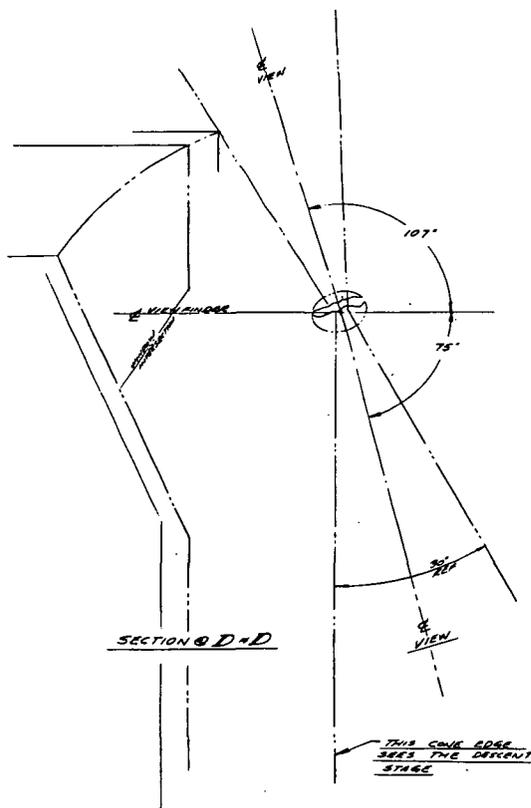


37



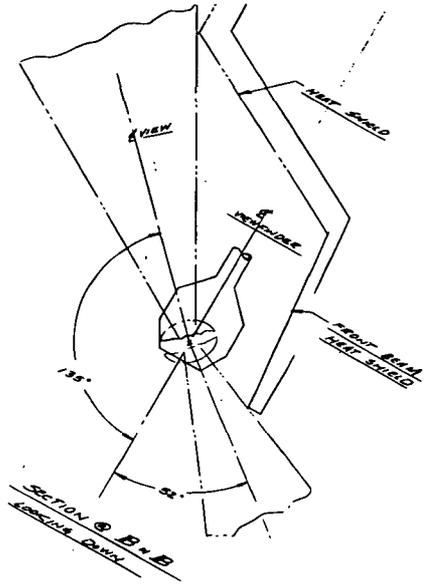
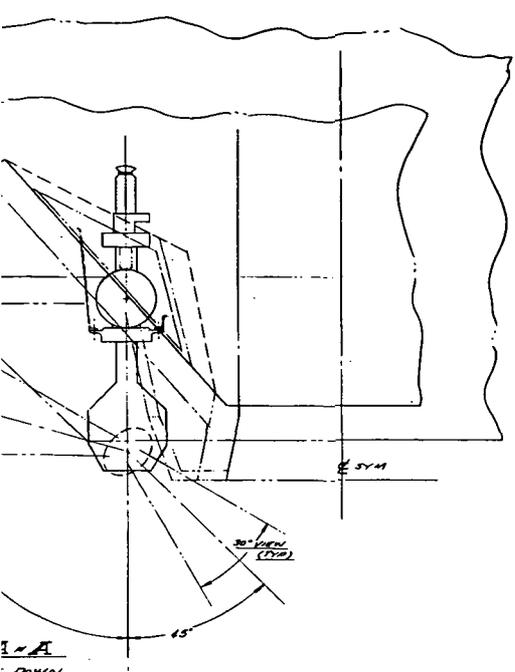


SECTION C
VIEW LOOKING

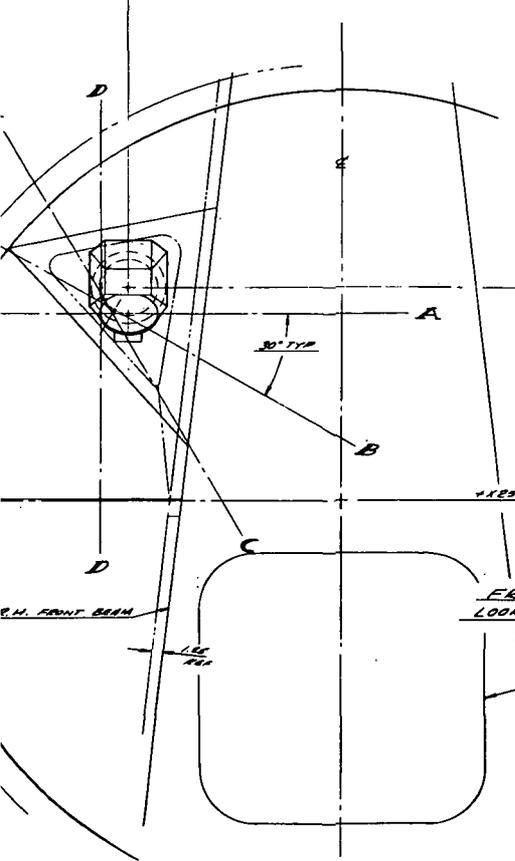


6-2-10



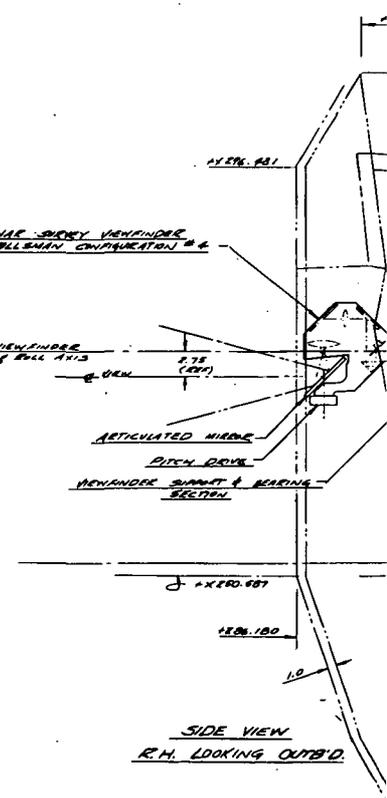


1 = A
DOWN

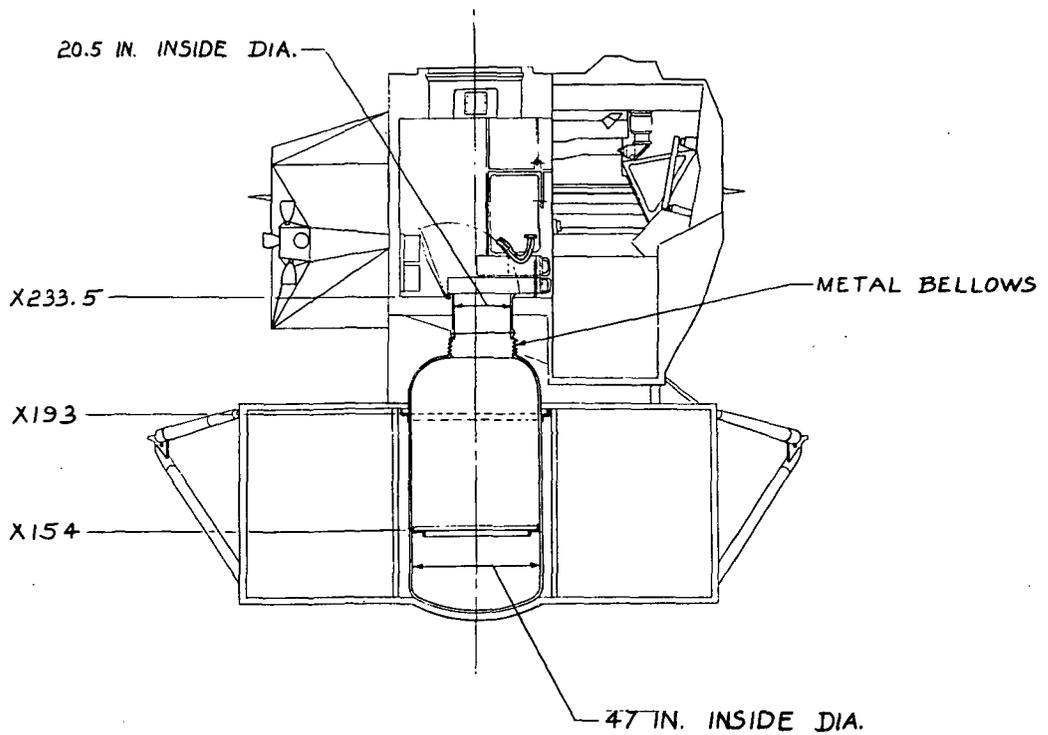


FRONT VIEW
LOOKING AFT

LENS & SIGHT VIEWING
KYLEBANK CONSTRUCTION # 2



6.2-10
2



SCALE ~ INCHES

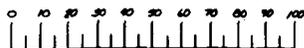


Fig. 6.2-11. Per Flight Modification Additional Internal Volume

6.3 CREW PROVISIONS

6.3.1 Ground Rules

The ground rules are as shown below:

- The CM is to be considered the basic mission and communication center
- CM will be the crew living quarters
- In the event of extremely high radiation or meteoroid activity the CM will be used as a crew shelter
- The CM is required to store three man-days of food and lithium hydroxide (LiOH) and to provide all potable water for crew use.
- The spacecraft will normally carry a three man crew, with no more than two men in the Lab at one time
- Untreated biological waste shall not be allowed to become a free residue in space.

6.3.2 Assumptions and Background Data

The assumptions and background data are as shown:

- All Phase I Lab mission are to be of 14 day duration, with crew members in a shirt-sleeve environment
- The CM environmental control system will supply both the CM and Lab module
- The waste management/waste disposal systems, personal hygiene, exercise, medical and recreation equipment is assumed to be located in the CM
- Crew members will sleep in a soft suit on the CM couches. The space suits will normally be dried, serviced and stowed on the couches
- Food and LiOH for the mission in excess of three man-days will be stored in the Lab
- Food will be prepared and consumed in the CM
- Throwaway batteries will be used for the PLSS
- Each crew member requires a new constant wear garment every two days
- One pressure garment, one liquid cooled garment and one thermo-meteoroid garment are located in the CM storage containers.

6.3.3 Recommended Configuration

6.3.3.1 General Description

Fig. 6.3.1 is a general arrangement depicting storage, console areas and general work areas of the recommended configuration. The view looking forward shows the cabin section consoles. The console format adheres to the basic LEM arrangement, with the addition of folding work tops on the right and left hand sides of the cabin. A stowable stool is provided and can be used at either work top. Food storage to sustain the three man crew for the duration of the mission is located under the cabin floor and in the existing LEM food storage area.

Garment stowage areas are unchanged except for the type of garments stowed. Suit servicing kit stowage is also unchanged. Two PLSS units are stored, one on the inside of the forward hatch and the other in the recharge station.

The view looking outboard, r.h. side, shows the ECS package and related equipment unchanged from the basic LEM except for the addition of the flexible vent to the blower.

The view looking outboard, l.h. side, shows the batteries, CM LiOH, food, tape recorder, "lunar" boots and PLSS recharge station. The LiOH cartridges occupy the area which formerly housed the LEM specimen return containers. Other LiOH and batteries are stored on top of the existing structural support members. The PLSS recharging station and food containers remain unchanged. The voice storage recorder is stored next to the "lunar" boots.

The aft bulkhead (sta. Z - 27.0) stores the CSM tape recorders and extra tapes.

The floor of the mid section contains a pressurized canister in the area formerly occupied by the ascent engine.

The shaded areas indicate available experiment storage volume, which totals approximately 17.4 cu ft. The alternate configuration shows the maximum growth potential of available storage volume, with the addition of movable storage containers having a volume of approximately 7.5 cu ft.

6.3.3.2 Equipment List

The following items are removed from the basic LEM:

- Cabin Section:

- Two Arm rests (r.h. side)
- One Translator assembly (r.h. side)
- One Attitude controller (r.h. side)
- TV camera and lenses (r.h. side)
- Extra film (sequence camera) (r.h. side)
- Film and tape (r.h. side)
- One Thermal garment (l.h. side)
- Restraint system (r. and l.h. sides).

- Mid Section:

- Waste management system
- Two Specimen-return containers (l.h. side)
- Still camera (mounted on engine cover)
- Water probe and holster (l.h. side)
- One LiOH container (engine cover)
- One EVA life line.

- Z-27 Bulkhead:

- | | |
|-------|----------------------|
| ○ CDU | ○ Signal Conditioner |
| ○ LCG | ○ Cold Plate. |
| ○ PSA | |

- External:
 - Recognition light.

The following items are to be added or modified:

- LiOH cartridges:

The 14 day mission requires 28 LiOH cartridges for the CSM ECS, two per day for 14 days, or one cartridge per 1-1/2 man-days. The ground rules dictate three man-days of LiOH (two cartridges) to be stored in the CSM. Therefore the Phase I Lab must store 26 cartridges (7.25 x 7.25 x 5.3 in. each). To maintain maximum experimentation volume, nine cartridges are stored internally in the mid-section, l.h. side, (Fig. 6.3-1) and the remaining 17 cartridges stored externally, (Fig. 6.3-2). This approach requires two EVA's to replace these stores. On the fifth day of the mission, 10 cartridges would be replaced and on the tenth day of the mission the remaining seven would be brought in. Spent cartridges replace full cartridges in the external storage racks. During the resupply there is always a full cartridge available in the CM. Alternate schedules can be developed for CM LiOH canister replacement so that they are coincident with planned experiment EVA's.

- PLSS Batteries:

The quantity of PLSS batteries required for a 14 day earth orbit mission is dependent upon the planned number of EVA's. Eighteen batteries are recommended for Phase I Lab. These are of the thrown away type, measuring 5.62 x 5 x 3.14 in. each, with a useful life expectancy of three hr plus one hr emergency. Six batteries will be stored in the mid section l. h. side, and two within the PLSS units (Fig. 6.3-1). The remaining ten batteries will be stored externally (Fig. 6.3-2). Resupply of used batteries can be accomplished on any planned EVA.

- PLSS LiOH:

The quantity of PLSS LiOH cartridges carried in the Phase I Lab is consistent with mission requirements and the number of PLSS batteries. Ten LiOH cartridges are stowed externally (Fig. 6.3-2). The present LEM has eight cartridges stored internally for a total of 18. Five are stored in canisters in the mid section on the l.h. side, one is stored in each PLSS, and one spare is stored in the ECS package. The last is a back-up cartridge for the ECS package (Fig. 6.3-1). Resupply from the external stores can be accomplished on any EVA.

- ECS LiOH (Lab):
Since the CSM ECS facilities are used for environmental control, the demand on the Lab ECS package is reduced. The Lab ECS carries only one LiOH cartridge in the system, with one PLSS cartridge as a back-up, and would be used primarily in a suit loop mode.
- ECS Duct:
Environmental control of the Lab will be supplied from the CSM by means of a flexible duct feeding through the Lab docking tunnel to the blower assembly. The duct will have a quick-disconnect fitting in the tunnel area to provide separation and allow hatch closure for EVA depressurization and for emergencies (Fig. 6.3-1).
- Food:
Food storage for three men for a 14 day earth orbit mission requires a volume of 4.35 cu ft based on 3000 K calories (179.14 cu in.) per man per day. The CM is required to store three man-days (0.31 cu ft) of food. LEM storage containers in the mid section, l.h. side, are retained in the Phase I Lab (0.21 cu ft). The remainder of food required, 3.83 cu ft is stored under the floor in the cabin section.
- Voice Storage Recorder:
Two voice storage recorders will be carried in the Lab, one located on the Z+27.0 bulkhead, l.h. side, in the "record" location. The second is stored in the mid section, l.h. side (Fig. 6.3-1). Each recorder measures 5-7/16 x 4 x 1-3/4 in.
- CSM Tape Recorders:
There are two CSM recorders, each mounted on a cold plate located on the Z-27.0 bulkhead. One extra tape is stored on the cover of each recorder. The recorder measures 9.5 x 5.5 x 22 in. and each tape is 8.0 in. diameter and 1 in. deep.
- Garments:
Facilities are included in the Phase I Lab for storage of the following:
 - Constant wear garment (CWG) (21)
 - Liquid cooled garment (LCG) (2)
 - Thermo meteoroid garment (TMG) (1)
 - Pressure garments (2)

The 14 day Earth-orbit mission requires 21 constant wear garments, allowing for changes every other day. Each crewman will initially be wearing one garment for a total of three. The remaining 18 will require approximately 2.0 cu ft for stowage.

The two liquid cooled garments have a stowed volume of 1.0 cu ft. Both the constant wear and liquid cooled garments are stowed on the l.h. side of the cabin section beneath the lower side console as shown in Fig. 6.3-1.

The CM stores one pressure garment, one constant wear and one liquid cooled garment for contingency use by the crew member occupying this station.

- Work Tables

Work tables measuring 17 x 24 in. are installed on both sides of the cabin, hinged on the lower side consoles. When stowed, they lay flat against the face of the garment stowage sections (Fig. 6.3-1). A secure latching mechanism is provided in both positions.

- Seats

One seat is included and is of a dual-action design, hinged from Z+27.0 bulkhead with a 360 deg swivel head. Both joints have a mechanical braking device to hold the seat in any position. The seat head can be folded and locked for stowage against the stowed table top (Fig. 6.3-1).

Two hinge fittings are supplied on Z+27.0 bulkhead to permit use of the seat on either side of the cabin. The same procedure for stowing is incorporated on both sides of the cabin.

A crew member restraint belt is attached to the seat head.

- Lighting

A dome light is incorporated in the mid section to illuminate the mid cabin.

Individually controlled lighting for both work tables in the cabin section is provided in the middle side consoles.

Two external flood lights are provided on the descent stage. Each light is separately controlled from inside and outside the vehicle.

- PLSS Units

The Lab carries two PLSS units, one at the recharging station in the mid section (as in the basic LEM), and the other stored on the inside of the forward ingress/egress hatch (orbit mode).

6.3.3.3 Restraint

The current restraint harness concept is illustrated in Fig. 6.3-3, which shows the vest used for body attachment and the installed harness in a shirt-sleeve environment.

The harness consists of a vest, fitting the human body such as to maintain contact with and transmit load to the trunk, thru contact with the shoulder, rib and waist.

Adjustment is provided in the chest and waist areas. The waist portion of the vest contains a number of hooks which are designed to pass through holes in an outer garment such as coveralls. An outer adjustable belt would then be attached to the hooks. A semi-rigid strap runs between the legs and fastens to the front and rear of the outer belt. A flexible, quick disconnect cable assembly picks up the strap. Included in the cable assembly is a spring and turnbuckle load cell which attaches through a universal joint to a pickup point in the floor. With the astronaut in an erect standing position, the turnbuckle is adjusted so that the load between the feet and the floor equals full or partial body weight. The applied load can be relieved by use of the quick disconnect or by double knee flexion and the astronaut will find himself tethered but unloaded.

When positioned at a work station, the universal joint attached at the floor will allow for controlled body rotation of 360 deg. The combination of spring and universal joint provides for extended reach actions as well as limited side-to-side motion.

6.3.3.4 Experiment Volume Available

Section	Location	Volume, cu ft
Cabin	L. H. below side console	1.20
	R. H. below side console	1.00
Section	L. H. garment storage comp.	.50
	R. H. forward console inboard	.35
	R. H. forward console outboard	.28
	Z -27.0 bulkhead	3.50
Mid	L. H. side	3.15
	Canister below floor	7.50
Total		17.48

6.3.3.5 Control and Displays

The cabin section console arrangement has been modified to reflect the requirements of the AES Phase I Lab, as illustrated in Fig. 6.3-4. Panel area available for experimentation controls and displays is tabulated below:

Panel or Console Number	Available Panel Area Area, sq in.
5	150
6	262
1	137
3	<u>12</u>
Total	561

The following additional area is available if the rendezvous radar and DSKY are not used.

3 (Radar)	64
8 (DSKY)	<u>112</u>
	176

6.3.4 Baseline Configuration

Differences between the Baseline and Recommended configurations are reflected in the quantities of PLSS LiOH and batteries carried as tabulated below:

Item	Recommended	Baseline
PLSS LiOH	18	21
PLSS Batteries	18 throw-away	21 rechargeable

6.3.5 Potential Modifications Per Flight

6.3.5.1 Additional Storage Boxes

The internal storage capacity of the Phase I Lab can be expanded to accommodate 7.5 cu ft of experiment equipment. This is accomplished by the addition of two portable containers, measuring 8 x 28 x 20 in. and 22 x 22 x 18 in., in the mid-section as shown in Fig. 6.3-5.

Equipment covered by these containers is reached by releasing their tiedown fittings and moving them to another section of the cabin.

6.3.5.2 Descent Stage Compartment

A pressurized compartment below the mid section floor occupying the area previously allotted to the ascent and descent engines (Fig. 6.2-4), will provide an additional 85.0 cu ft for experimentation or equipment storage.

The compartment is 47.0 in. diameter, 88.0 in. high and is integrated into the descent stage with an expansion joint attaching it to the Phase I Lab. Access is gained through a 20.5 in. tunnel and hatch in the Lab mid section floor.

This design is derived from considerations primarily developed for the Phase II Lab but could be used on a Phase I flight if schedules permit (Fig. 6.3-5).

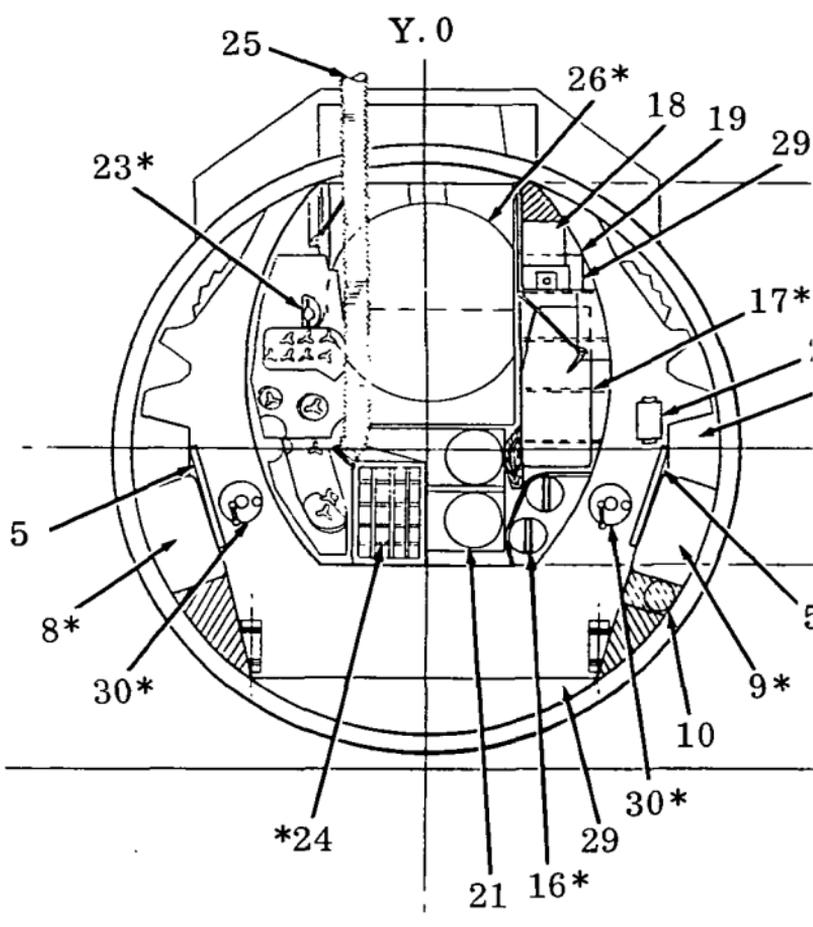
1. Fwd Panels & Consoles
2. Side Consoles & Breaker Panels
3. Attitude Controller Ass'y & Armrest
4. Translator Controller Ass'y & Armrest
5. Work Table
6. Fwd Hatch (Ingress /Egress)
7. PLSS (Back Pack)
8. Thermal Meteoroid Garment
9. Constant Wear & Liquid Cooled Garments
10. Suit Servicing Kits
11. Adjustable Seat - (Working Position)
12. Adjustable Seat - (Stowed Position)
13. A. O. T.
14. Work Table Light
15. Flood Lights
16. PLSS LiOH
17. PLSS/Recharge Station
18. CSM LiOH
19. PLSS Batteries
20. Voice Storage Recorder
21. CSM Tape Recorder, Tapes & Cold Plate
22. Lunar Boots
23. ECS Package/Suit Loop
24. Cabin Blower
25. Flexible Duct From CSM
26. Docking Hatch (Open)
27. Dome Light
28. Storage Compartment
29. Food
30. Emergency Oxygen
31. Seat Mount Fitting

NOTE:

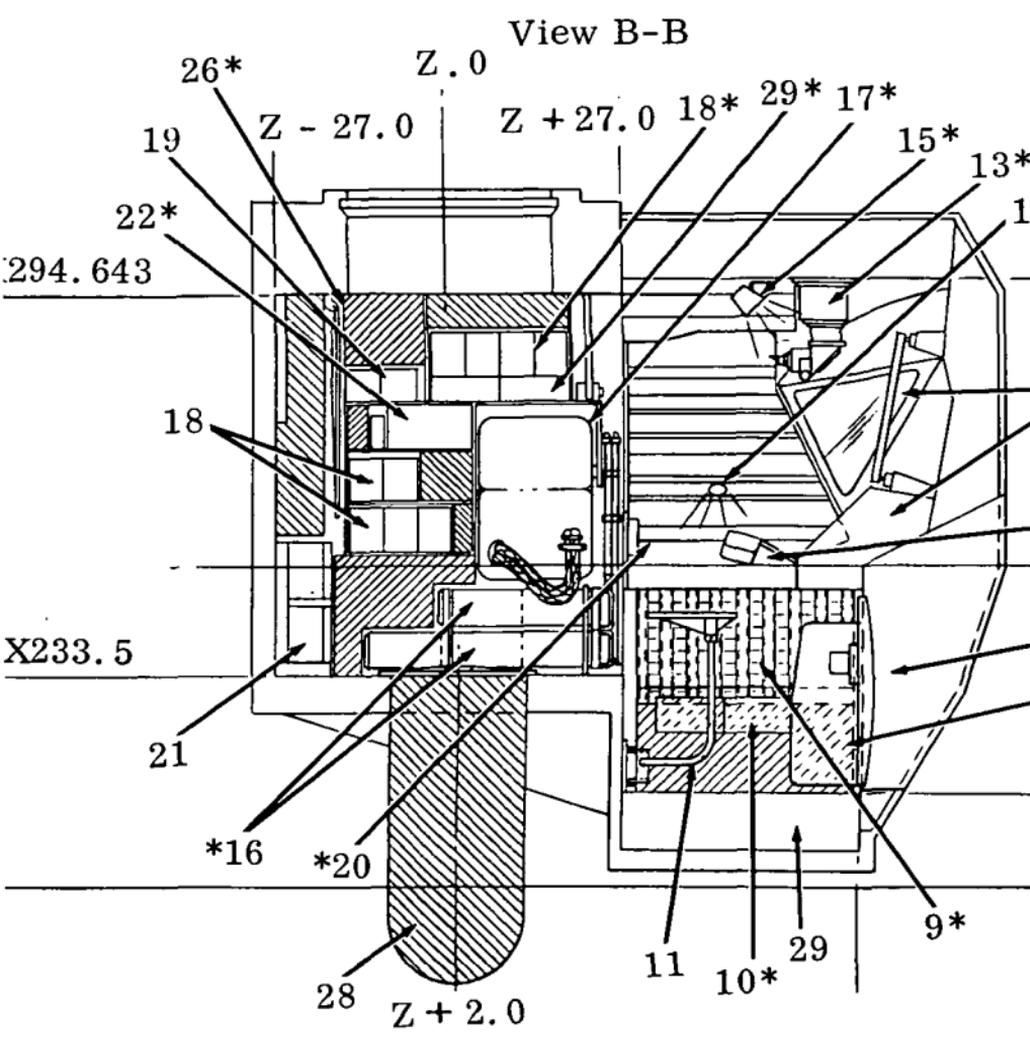
1. Items Marked (*) Are Existing or Modified Equipment On The Present LEM Vehicle.
2. The Shaded Areas Indicate Available Experiment Storage Volume, Approximately 17.4 cu ft.

6.3-1





View Looking Aft + 27.0



View Looking Out'd
L. H. Side

6.3-1
⑫

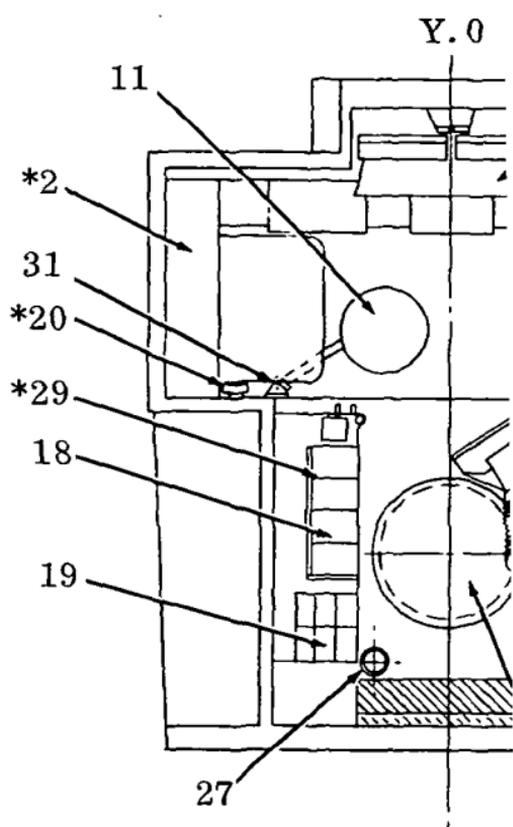
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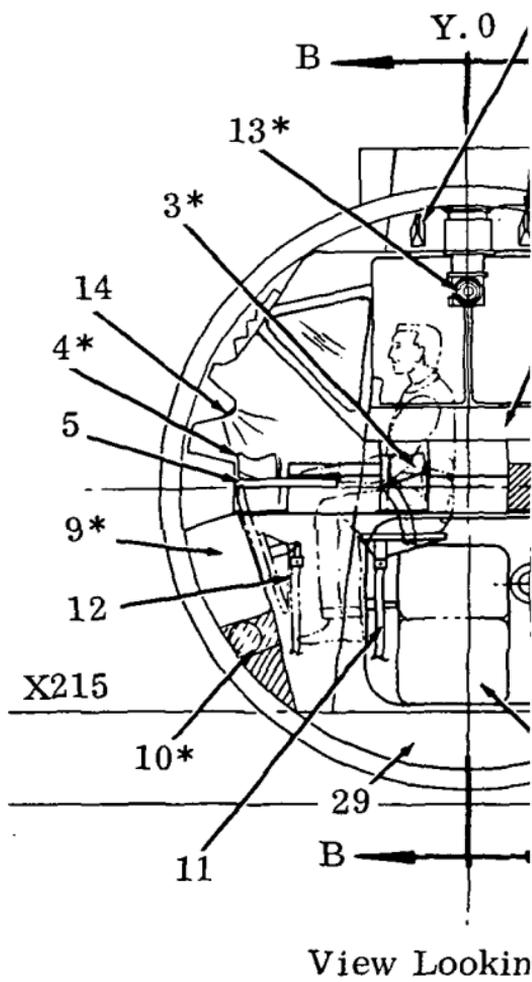
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-6*

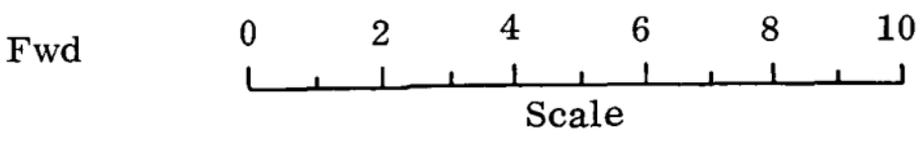
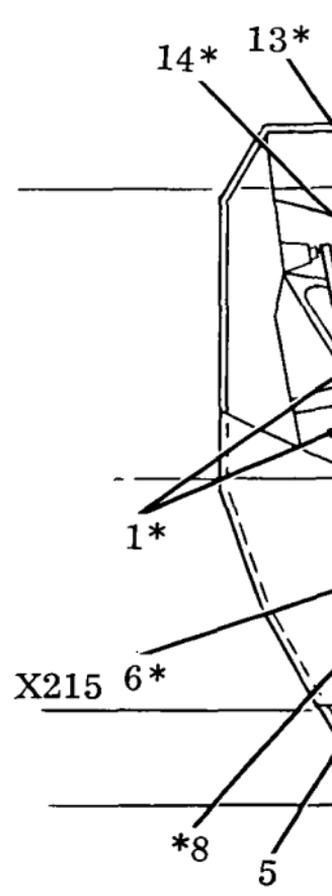
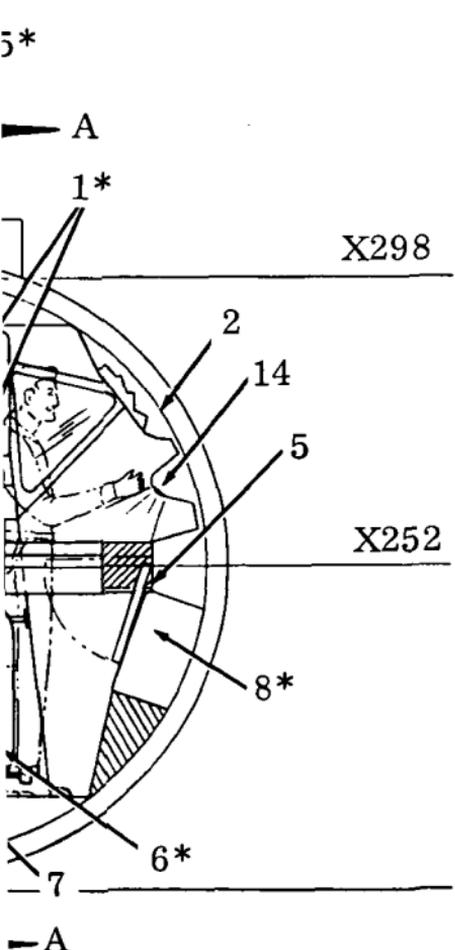
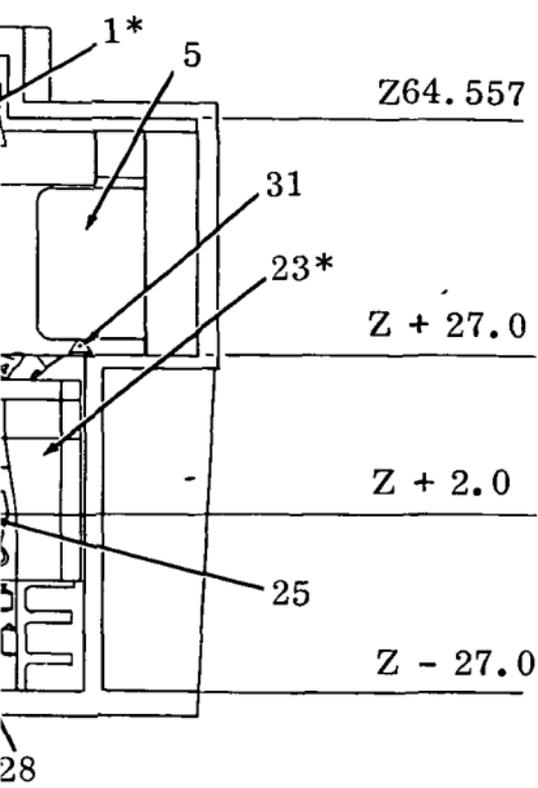
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X215

X200

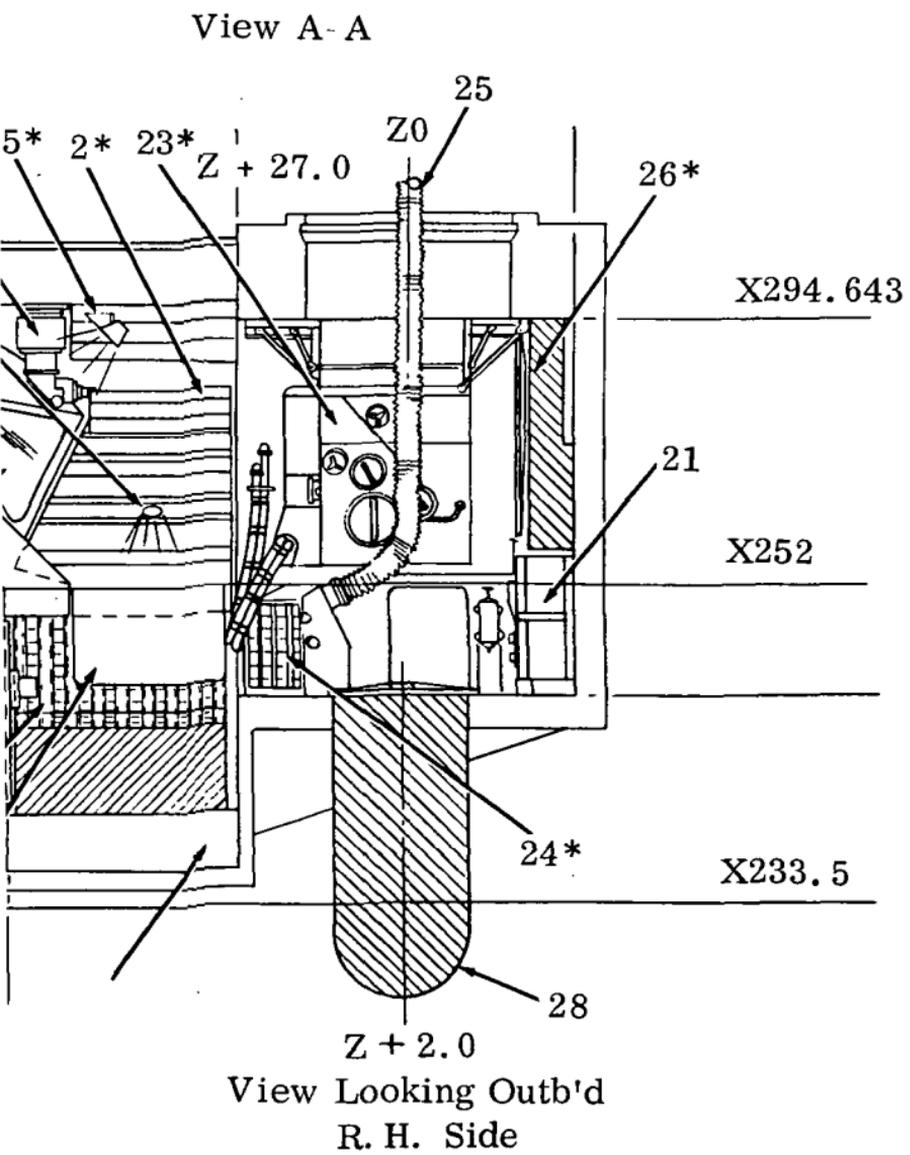


6-3-1
③



6.3-1
 (4)

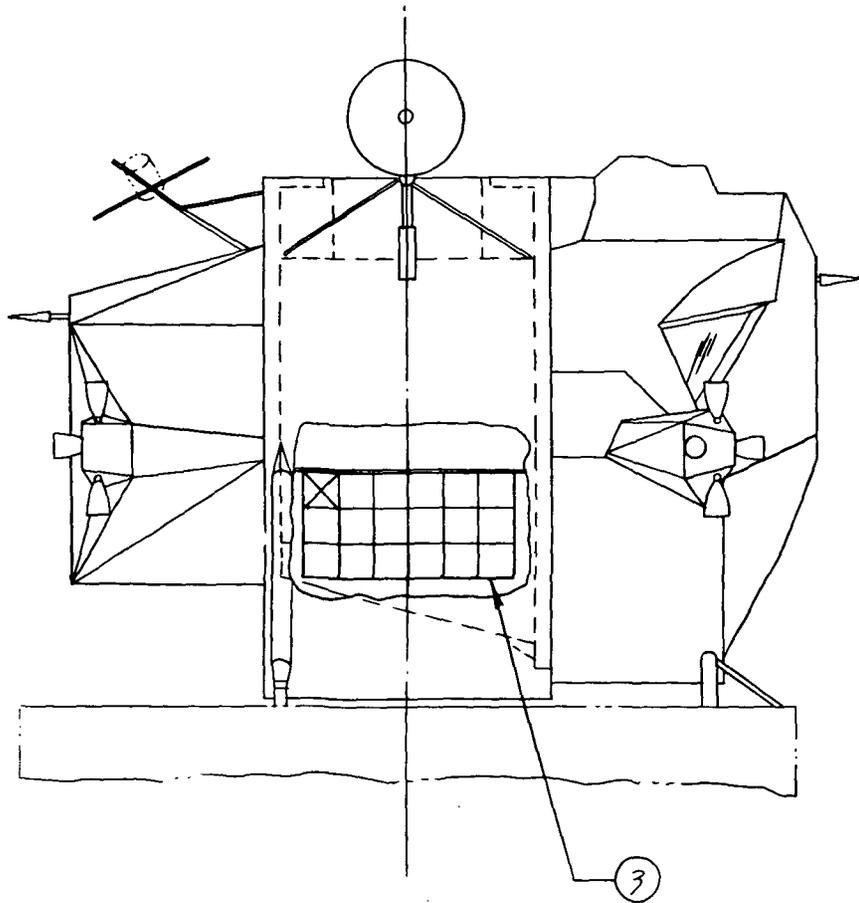
Fig



6.3-1 Phase 1 Lab General Arrangement

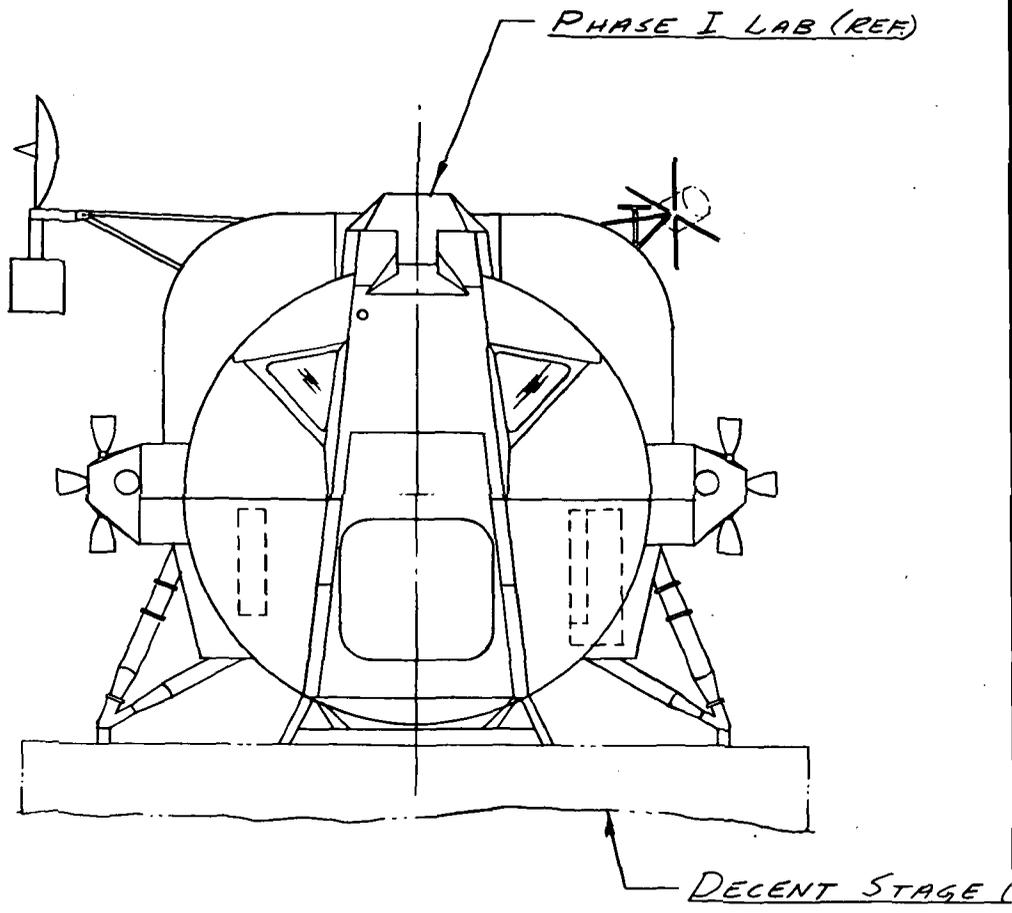
5

Grunman



VIEW LOOKING INBOARD
R.H. SIDE

6.3-2
①

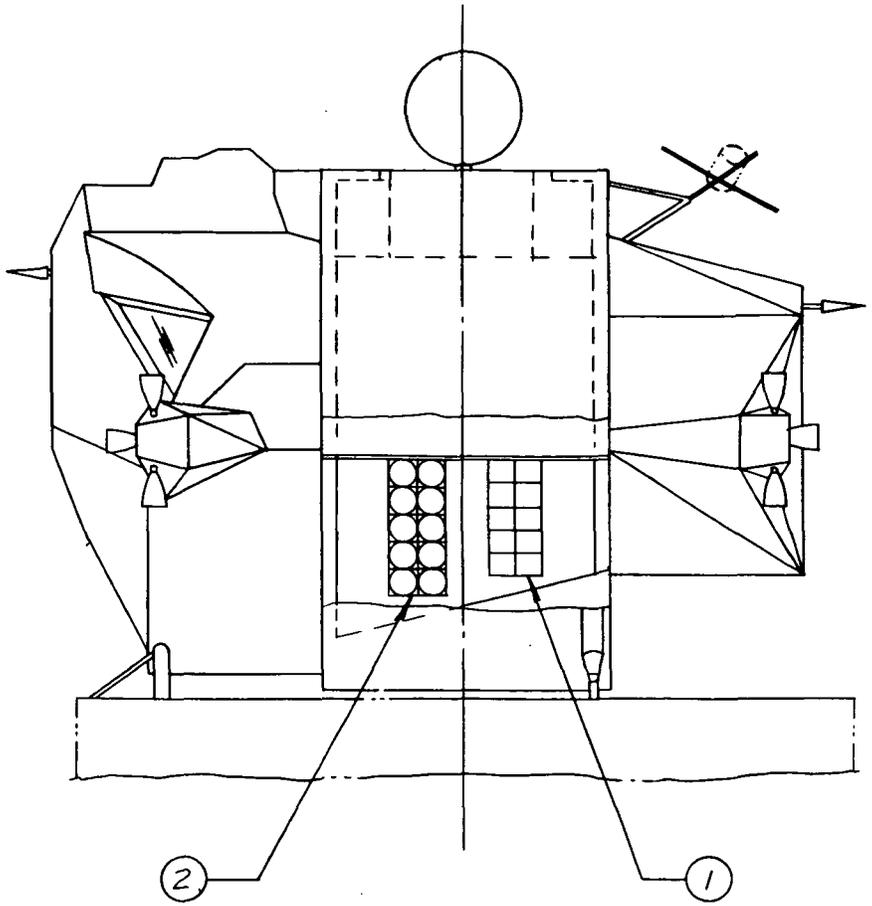


VIEW LOOKING AFT

- KEY:
- 1. PLSS BATTERIES (10)
 - 2. PLSS L₂OH (10)
 - 3. CSM L₂OH (17)

6-3-2

2



(REF)

VIEW LOOKING INBOARD
L. H. SIDE

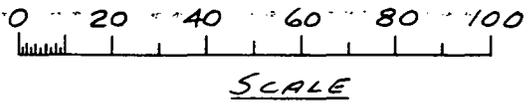


Fig. 6.3-2 Recommended Configuration External Stores

5

Grumman

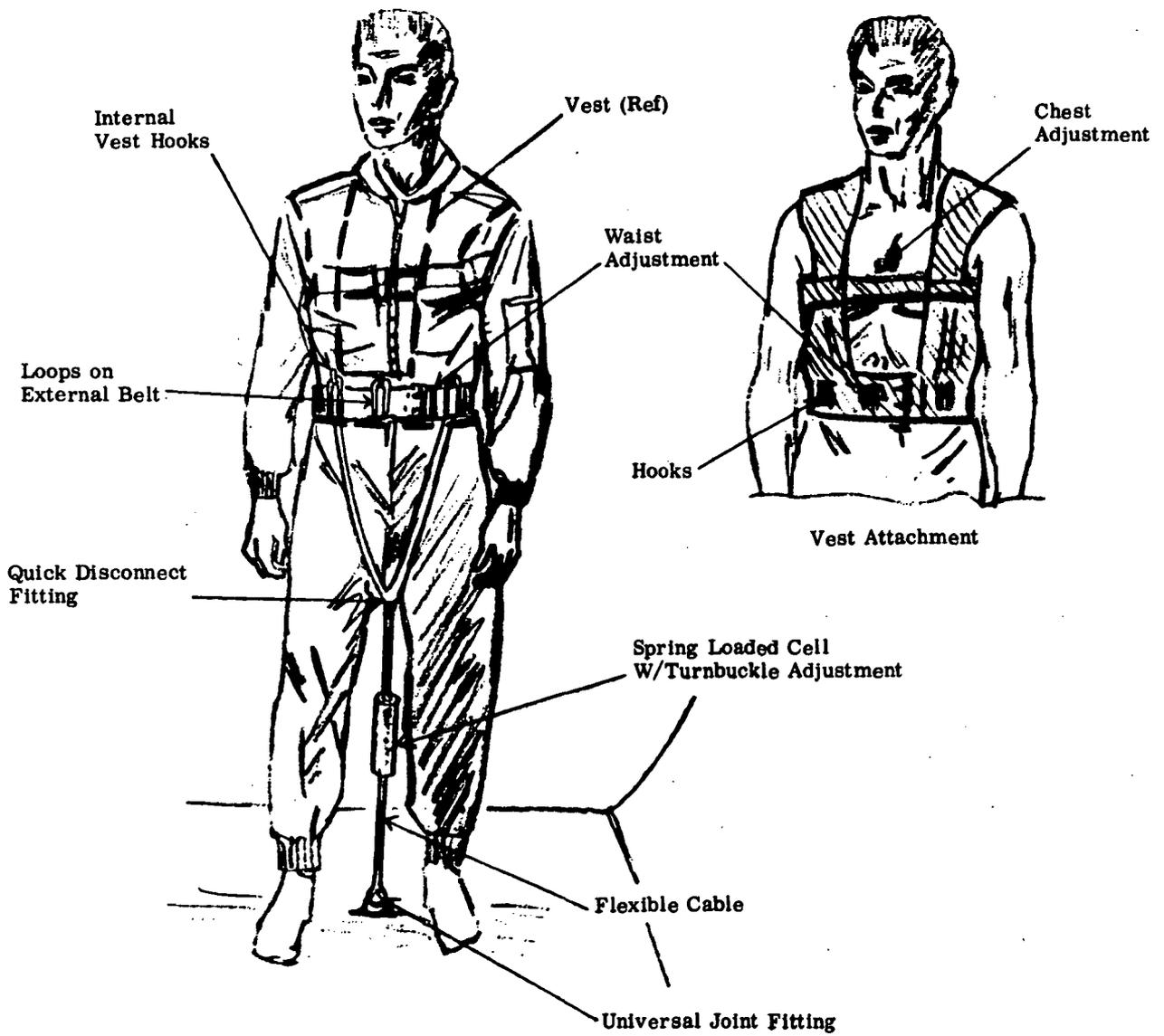
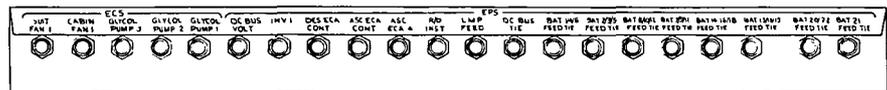
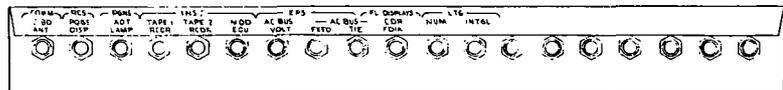
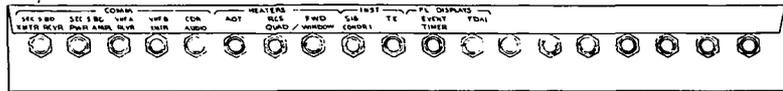
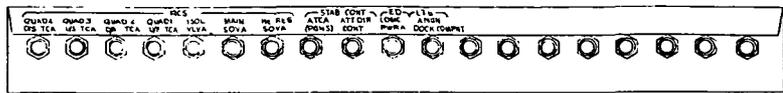


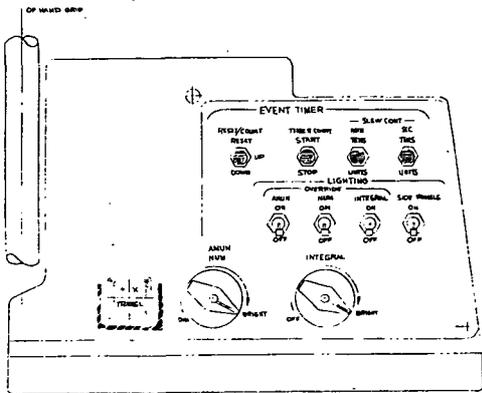
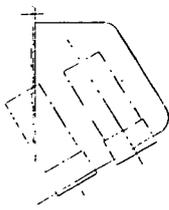
Fig. 6.3-3 Restraint Harness



IV

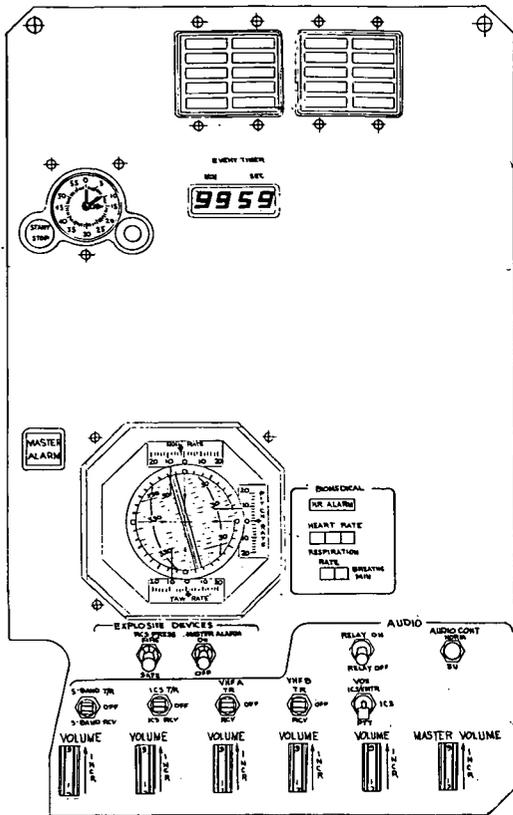
AVAILABLE FOR EXPERIMENT DISPLAYS

AVAILABLE FOR EXPERIMENT DISPLAYS

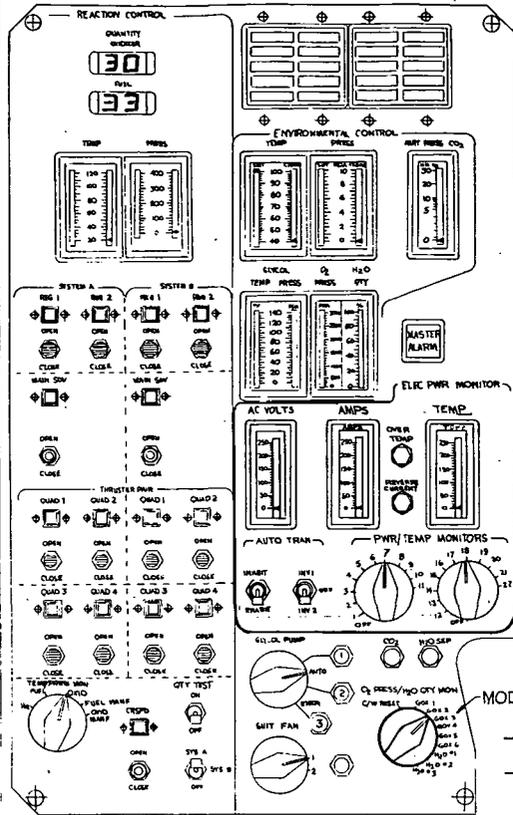


6.3-40

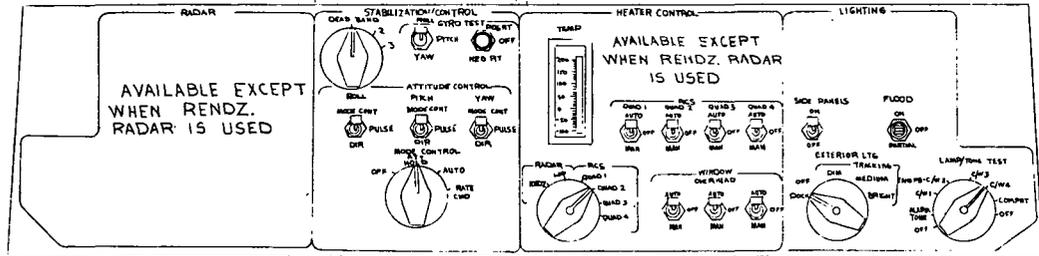
I



II



VI

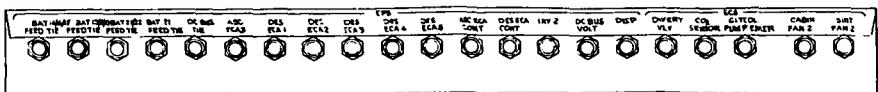
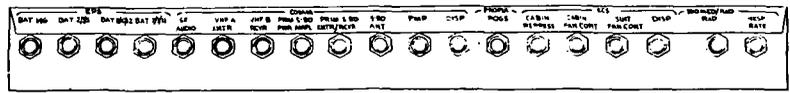
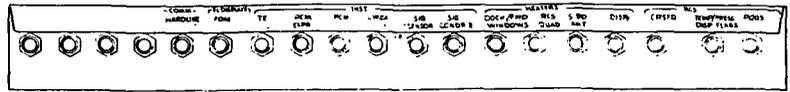
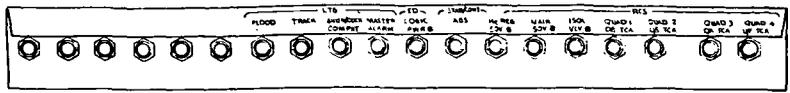


VII

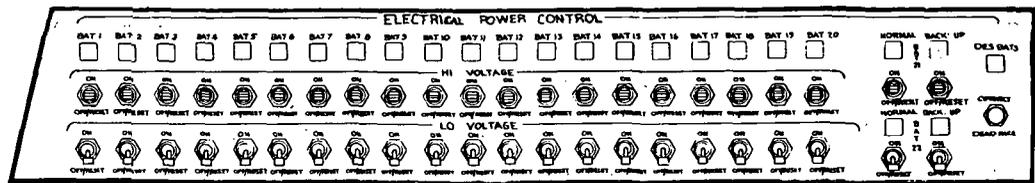
AVAILABLE EXCEPT WHEN DSKY IS USED

VIII

6-3-4
 (2)

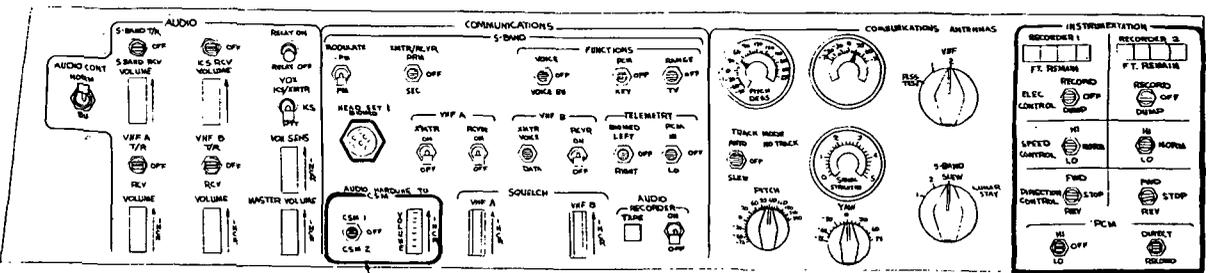


IX



MODIFIED

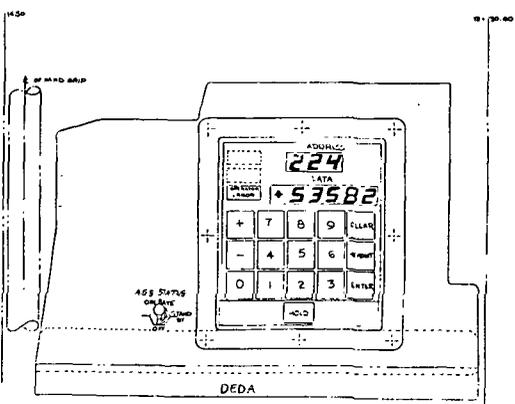
MODIFIED PANEL



MODIFIED

MODIFIED

XII

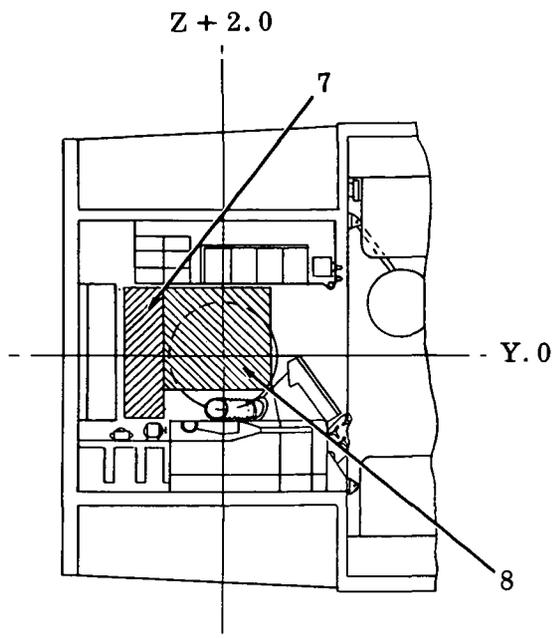


MODIFIED AREA

Fig. 6. 3-4 Controls and Displays

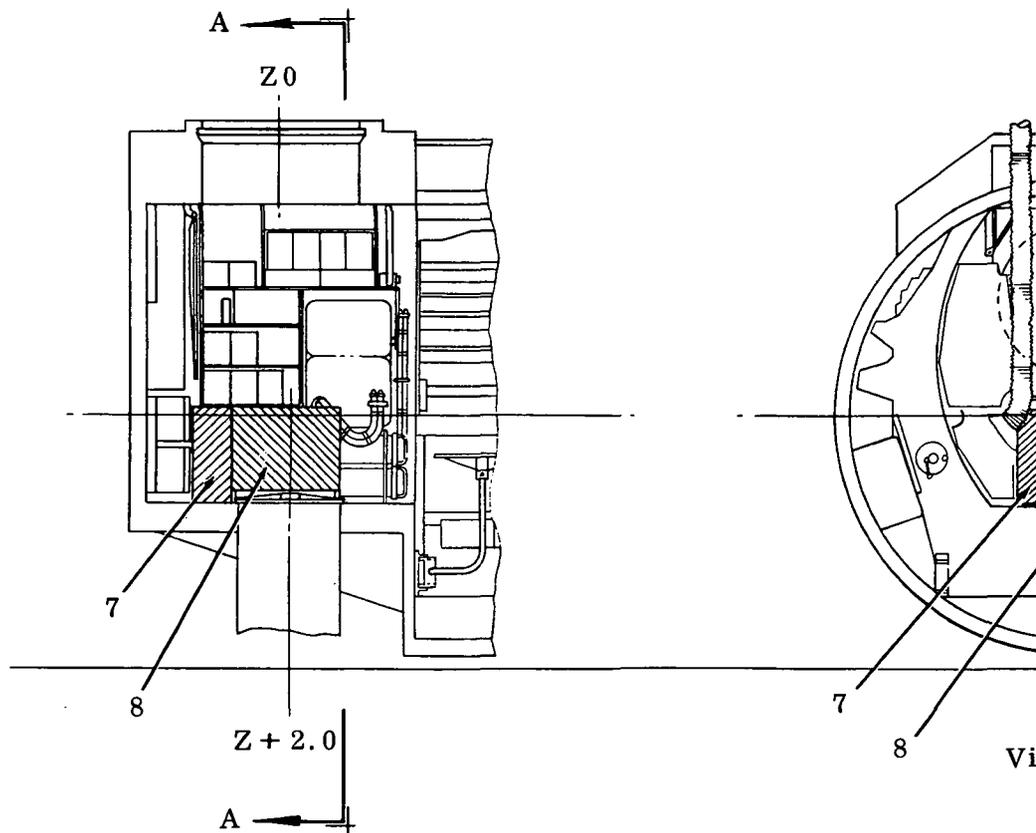
3





Key

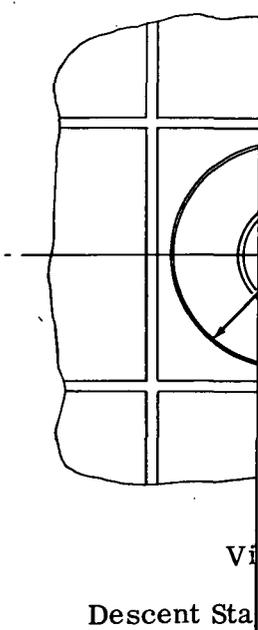
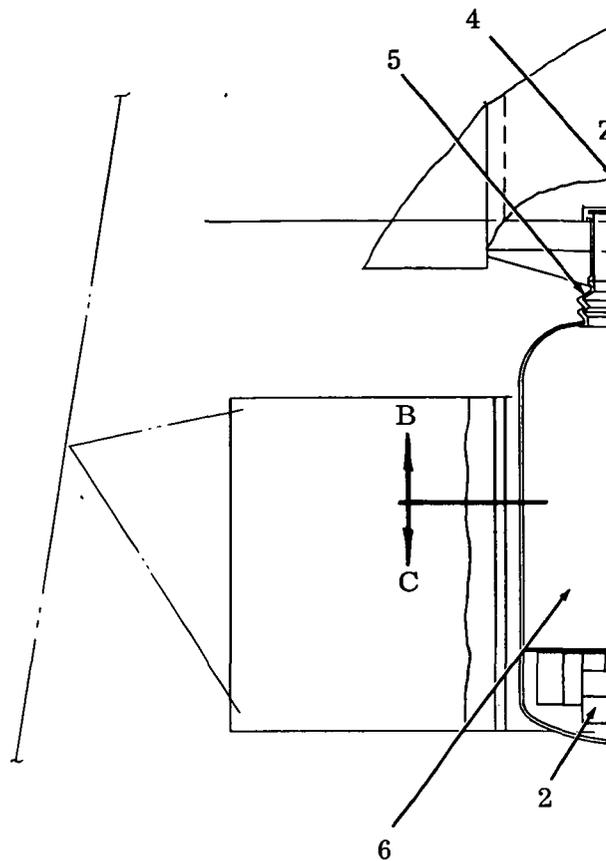
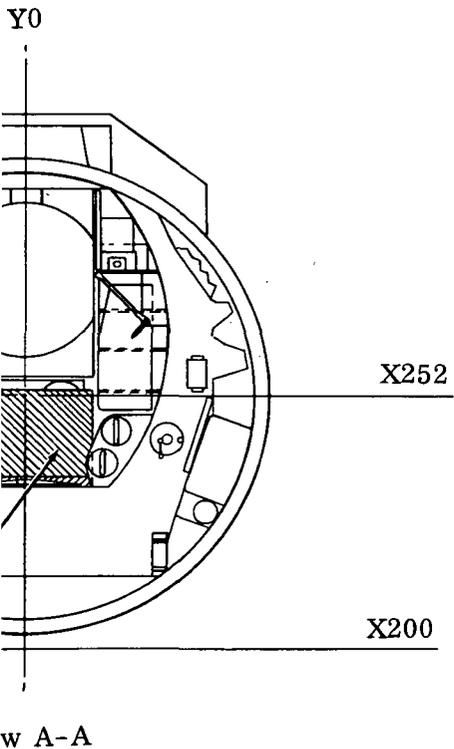
- 1. PLSS LiO
- 2. CSM LiC
- 3. PLSS Ba
- 4. Access P
- 5. Expansio
- 6. Availabl
- 7. Portable
- 8. Portable



Portable Storage Containers

6-3-5
①

H (10) } Stored External On
 I (17) } Recommended
 Series (10) } Configuration
 Hatch
 Joint
 Volume
 Container 8 x 28 x 20 in.
 Container 22 x 22 x 18 in.



Vi
 Descent Sta

6.3-5
 (8)

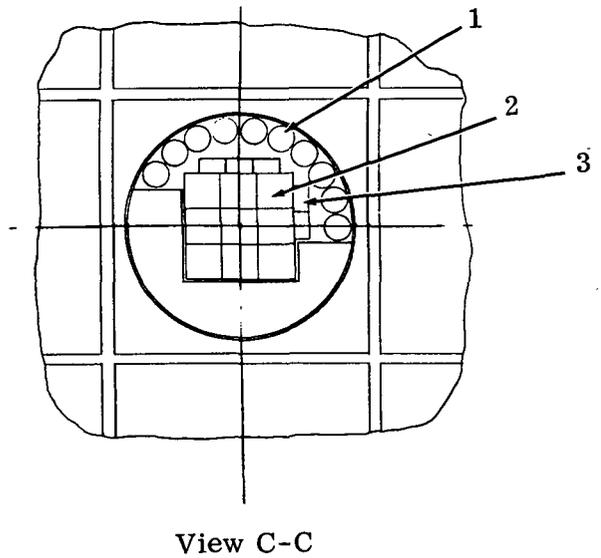
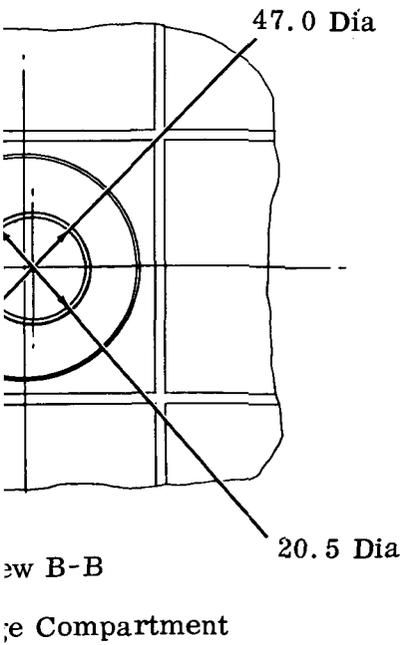
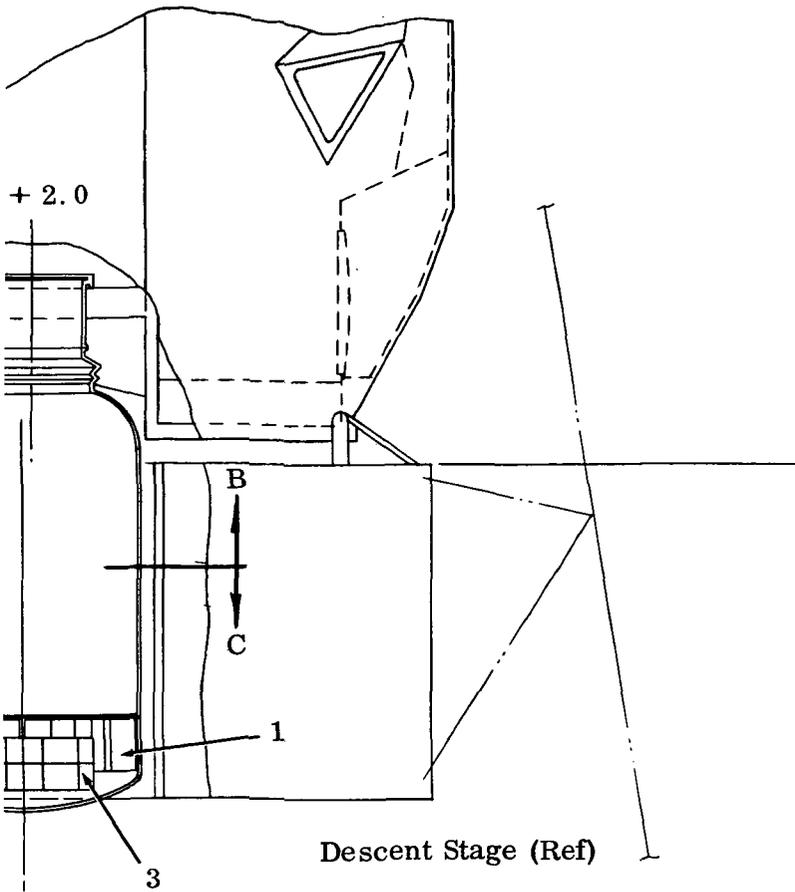


Figure 6.3-5 Phase I Lab Per Flight Modifications

3

6.4 STRUCTURAL ANALYSIS

6.4.1 Design Conditions

The Phase I LEM Labs are being studied to satisfy the requirements resulting from the various phases of the mission profile for each particular flight configuration. Where applicable, due to the same environmental conditions, the design criteria and environments established for the LEM have been used to establish subsystem design concepts and feasibility for this study. It is also anticipated that these or similar requirements will not be exceeded when the final configurations, experiments, and payloads have been determined. This study has included the effect of mission profile differences from the LEM where these differences exist. The flight configurations being considered for the Phase I Labs are:

- 200-N.Mi, 90-deg Earth orbit
- 19,350-N.Mi, 0-deg synchronous Earth orbit
- 80-N.Mi Lunar orbit
- 200-N.Mi, 28.5-deg Earth orbit

The total time of the mission for any particular flight is equal to or less than 14 days. The maximum expected gross weight for the projected Phase I Labs is approximately 20,000 lb. Inasmuch as the Phase I Labs do not have a landing requirement, the design criteria resulting from descent, lunar landing, and ascent are not considered in the analysis for these vehicles. Future studies will consider the effect of the change of launch trajectory of the above missions versus the environments resulting from LEM trajectories.

6.4.1.1 Launch and Boost - C-5

The pertinent design requirements used to establish the integrity of the basic vehicle and subsystems are listed below. A safety factor of 1.50 is applied to the limit conditions to obtain ultimate loads. The Phase I Lab coordinate axes are shown in Fig. 6.4-1.

Limit Accelerations, g	X	Y	Z
Lift-off	+1.60	±0.65	±0.65
Max. (S-IC)	+2.07	±0.30	±0.30
Boost (S-IC)	+4.90	±0.10	±0.10
Cut off (S-IC)	-1.70	±0.10	±0.10
Engine hardover (S-II)	+2.15	±0.40	-----
Earth orbit	0	0	0

6.4.1.1.1 Vibration - The mission vibration environment is represented by the following random and sinusoidal envelopes considered separately:

- From exterior primary structure

- Random

10 to 23 cps	12 db/octave rise to
23 to 80 cps	0.0148 g ² /cps
80 to 105 cps	12 db/octave rise to
105 to 950 cps	0.0444 g ² /cps
950 to 1250 cps	12 db/octave decrease to
1250 to 2000 cps	0.0148 g ² /cps

- Sinusoidal

5 to 18.5 cps	0.154 inches D.A.
18.5 to 100 cps	2.69 g peak

- From interior primary structure

- Random

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

- Sinusoidal

5 to 16 cps	0.154 inches D.A.
16 to 100 cps	1.92 g peak

For design purposes, the above random spectrum applied for 5 minutes along each of the three mutually perpendicular axes (X, Y, Z) in addition to the corresponding sinusoidal spectrum acting for 5 seconds at the natural frequency of the equipment being designed will adequately represent the environment.

6.4.1.1.2 Acoustics. Sound pressure levels in db external to LEM (Re. 0.0002 dynes/cm²) are as follows:

Octave Band (cps)	C-5 at max.q level (db)
9 to 18.8	136
18.8 to 37.5	142
37.5 to 75	146
75 to 150	143
150 to 300	139
300 to 600	135

600 to 1200	130
1200 to 2400	125
2400 to 4800	119
4800 to 9600	113
Overall	150

6.4.1.2 Space Flight

	X		Y		Z	
	g	rad/sec ²	g	rad/sec ²	g	rad/sec ²
SM Prop. Syst. Operating	-0.36	---	+0.62	+1.99	+0.62	+1.99
SM Prop. Syst. not operating	0	0	0	0	0	0

6.4.1.3 Preliminary Docking Loads (Limit) and Criteria

● Probe Contract:

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 at Probe:

$F = 2235$ lb
 $F^x = 3118$ lb
 $M^z = 8134$ ft-lb

● Mass Properties:

Active Vehicle, $M \approx 2000$ slugs	}	C/M + S/M
$I \approx 74000$ slug-ft ²		
Target Vehicle, $M \approx 2200$ slugs	}	S-IV B + LEM
$I \approx 1,150,000$ slug-ft ²		

● Final Hard Surface Contact:

Axial velocity, 0.15 fps Max. permissible for single point
 $F_x = 5000$ lb contact on non-parallel surfaces

6.4.2 Hardpoint Provisions for Payload and Experiment Support Structure

6.4.2.1 General

A basic requirement for the integration of experiments and payload on to the spacecraft is that the primary structure will not require major modification. Where necessary, additional localized strength will be incorporated into the ascent and descent stages to provide attachment points for payload support structure.

Some preliminary studies and analysis have been carried out to determine the magnitude of additional local load capability at various potential hard points on the ascent and descent stage structures. In general, these hardpoints may be characterized into two groups. The first are those points at which no fittings or local stiffeners exist currently for LEM, but which may be adapted for concentrated load application through the use of attachment fittings, stiffeners and skin doublers.

By this means, concentrated payload support structure reaction forces can be delivered into the primary structure for internal load equilibrium without over-loading the existing members. The second group are those hardpoints at which fittings and stiffeners currently exist on LEM. These points may be used to react additional concentrated loads providing enough strength exists for the combined input loads. When necessary, it may be possible to increase the strength of these attachments by adding material thickness. The current studies are based solely on static load conditions to determine structural feasibility; in later phases of the program, dynamic response analyses of equipment and payload items with support structures will be conducted to verify structural integrity. In addition to analyzing each payload and experiment local input into the primary structure, each flight configuration must be checked for the critical loading environments to ensure the overall structural integrity of the primary structural members.

6.4.2.2 Ascent Stage Hardpoints

Figures 6.4-2 and 6.4-3 show existing hardpoints in the LEM ascent stage. The loads shown applied to these points are ultimate allowable loads with the fuel and oxidizer propellant tanks removed. These loads may be used for local design, but are not necessarily applied simultaneously. The critical condition for the Labs is the 7.35g boost. The loads shown may be combined with the interstage loads from the descent stage for this condition only when applied in the directions shown.

Points R and S do not have existing fittings but may be adapted for the concentrated loads shown with minor modification. The remaining points have existing truss members joined to them by fittings or bulkhead lugs and may be readily picked up.

6.4.2.3 Descent Stage Hardpoints

For effective usage of the LEM descent stage, hardpoint load distribution should remain unchanged. Basic hardpoints on the existing LEM are located at coordinates such as engine mounts, tank mounts, equipment shelf mounts, etc. The LEM descent stage primary structure, as well as the local structure, is designed for these loads. The loads are then transmitted by the structure to the trunion point. Obviously, any new hardpoint requirement has to be analyzed utilizing the above constraints. As previously out-lined, both a structural and dynamic analysis would be required to verify integrity. Any Phase I Lab must remain within the total weight and inertia envelope as required by the LEM structure. All primary structural changes are to be compensated for by providing alternate load paths. For example, the tie rod which is to be removed to allow the new water tank structural placement will not have its local path altered, but instead the loads will pass through the tank truss.

The landing gear structure will be removed in its entirety since no landing is required for the Phase I Lab. Also, the descent engine will be removed. The descent engine tanks are to remain, but in empty status.

The summary of the LEM descent stage hardpoints is presented below:

Hard Point	X	Y	Z	ΔP_x	ΔP_y	ΔP_z
U ₁	+196	+82	+27	+1400 lb	+1170 lb	+1600 lb
U	+196	+82	-27	+1400 lb	+1170 lb	+1600 lb

The Δ loads are load increments which may safely be added to existing loads without requiring major reanalysis. Values shown are 1g (Earth g) values and will be valid for all loading conditions. The above is based on the premise that equipment shown on Figure 6.4-4 is removed.

6.4.3 Modifications to 64-Inch LEM Descent Stage

For the Lab I configurations (utilizing the 64-in descent stage) which are similar to LEM except for minor modifications, the launch and boost criteria will be the same as that of LEM. Altogether these include 35 loading conditions. They are subdivided into seven groups, namely:

- 1) End of boost with $\Delta T = T_{ext} - T_{in} = 400 - 70 = 330^\circ F$
- 2) End of boost with $\Delta T = 0$ ($T_{in} = 70^\circ F$)
- 3) Lift off
- 4) Max $q \alpha$
- 5) End of 2nd stage boost
- 6) First stage cut-off with $a \Delta T$
- 7) First stage cut-off with $\Delta T = 0$ ($T = 70^\circ F$)

The above group is further divided into five conditions representing various axial and side load combinations.

Primary structural interface loads were calculated for the combined vehicle. A more recent IBM Astral run, utilizing a finer grid on the descent stage and thus compensating for tank cut-outs in the lower deck, was made in which the final 64-in descent stage loads were computed. It is this data which will be utilized to check the existing LEM descent stage modified for Lab I use. Primary structure, aside from the landing gear, should remain unchanged. Various local areas will be altered structurally to allow for the installation of equipment peculiar to the Phase I Lab. The battery bank rack attached to each end of the four bays is an example of minor local modification. It encompasses the shear tie of several Z sections to a deck which has shelves carrying batteries. The shear tie to the existing end face will ultimately carry loads to the LEM mount truss. This in effect will be added structural assembly. The water tank mount, however, will be an assembly installation which will replace some existing structure. Removal of the base heat shield incurs no structural problem. When removed, the descent engine, associated equipment (mount truss), fuel, and tanks provide a number of hardpoints which are utilized for equivalent masses.

6.4.4 Micrometeoroid Shielding (Acoustic Fatigue)

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

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

Vibration tests have been conducted on a flat specimen of this type construction.* A flat specimen was conservatively chosen since curved panels, such as those on the ascent stage, will offer greater resistance to acoustic fatigue. A partial failure of the nylon standoff washer head was encountered. The failure was not serious, however, since the standoff still continued to support the aluminum face sheet. After completion of these tests the specimen was exposed to an acoustical test at an overall sound pressure level of 150 db for 2 minutes (which is design level) and no failures were observed. However, when the overall sound pressure level was increased to 154 db (which is an overload condition), the washer heads of three nylon standoffs failed. These failures allowed the face sheet to slide along the posts thus eliminating the skin spacing required for protection. The standoffs are currently being redesigned to eliminate the stress concentration at the juncture of the washer and post. It is anticipated that this redesign will eliminate this type of failure.

Alternate methods of construction (Fig. 6.4-5) were investigated using other techniques.** The following types of construction which are listed in a decreasing order of preference for weight criterias were compared:

- 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.

It is planned that the LEM type construction with improved design be used for the Phase I Labs with an increase of skin gage as required for meteoroid shielding 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 sub-structure, will occur. Acoustic testing of the new configuration is therefore planned later in the program. As alternate design approaches, honeycomb or perhaps crushed honeycomb (bond-o-lite) face sheets will be investigated because of the apparent advantages over single sheet construction. Since the honeycomb may not provide the best meteoroid protection due to its tendency to contain the generated gases in a single-core cell, it is planned to also investigate the use of the above mentioned configurations as alternatives.

* Reference Grumman LTR 905-11001: Results of Vibration Tests, LEM Structural Elements, C. Birn, April 1965.

** Reference ASD-TDR-63-820: Structural Design for Acoustic Fatigue, Air Force Flight Dynamics Laboratory, Wright Patterson Air Force Base, Oct. 1963.

6.4.5 Equipment Supporting Structure

6.4.5.1 Lab Aft Equipment Bay

The aft equipment rack is attached to the Z-27 bulkhead at points A, B, H, A¹, B¹, H¹ (Fig. 6.4-6). The existing LEM aft equipment rack is designed for a gross weight of 990 lb. The design loads in the various truss members for the gross weight are given in the table. It is proposed that five 104-lb GOX tanks in the aft equipment bay replace two 67-lb GOX tanks and two 8-lb Helium tanks. This change increases the design gross weight from 990 to 1360 lb, and moves the center of gravity forward approximately 6-in to Z-57. Based on a change in gross weight and neglecting the small shift in center-of-gravity, there would be a 39 percent increase in the truss member loads for the boost condition. Truss members AC and BC would have to be redesigned for the increased load in the 7.35-g boost condition. In addition, local redesign would be required where these members are attached to the Z-27 bulkhead. See Table 6.4-1 for the axial loads in rack truss members.

6.4.5.2 Viewfinder Installation

An optical viewfinder, weighing approximately 30 lb, is mounted in the LEM window opening by means of an adapter that replaces the window. An acceleration factor 7.35 g (boost and launch condition) gives a total of 30 lb x 7.35 g or 220 lb. This load has a moment arm of approximately 2 in. relative to the peripheral connecting points producing a moment about the periphery of 441 in.-lb. The reactive couple of 440/10 in. or 44 lb is assumed acting sinusoidally over the periphery. This sinusoidal distribution produces a maximum coordinate load of ± 6.92 lb. The internal cabin pressure of 11.5 psi produces a peripheral load of $11.5 \times \pi D^2/4 \times D$, or 28.75 lb/in. over a 10-in. diameter circle. The maximum total applied load is therefore 28.75 + 6.92, or 35.67 lb.

The window bolting pattern was established primarily to prevent rotation of the joint, thereby maintaining air-tightness integrity. Therefore, the new load will not influence the overdesigned bolting pattern since strength was not the original prerequisite.

6.4.5.3 Mid-Section Canister - Ascent Stage

The mid-section canister is a cylindrical container pressurized to 11.5 psi, and carries a maximum load of 125 lb. It is supported at X = 233.5 and 2 in. off centerline. A vertical acceleration of 7.35 g (ultimate) and a lateral acceleration of 0.6 g is experienced by the payload during launch and boost. These accelerations produce loads equivalent to 920 lb in the vertical direction and 75 lb in the lateral direction. The cg of the load is assumed at 25 in. below the top of the containers resulting in a moment at the top of 1875 in.-lb. The Canister is shown in Fig. 6.2-2.

The vertical component of 920 lb gives a peripheral reaction on the supporting rim of approximately 13 lb/in. The lateral load of 75 lb (or 1875 in.-lb) produces a reaction on the supporting rim which varies as a sinusoidal distribution. As an average the moment divided by the diameter gives a reactive load of 82 lb. Assuming the 82 lb acting over a quarter of the periphery, we get a reaction of ± 4.5 lb/in. The total unit load per in. then becomes $13 \pm 4.5 = 17.5$ lb/in. maximum. This load is not critical and therefore the arrangement is feasible.

6.4.5.4 Water Tank and Battery Installation - Descent Stage

The proposed water tank installation is shown in Fig. 6.4-7. The member loads shown are generated from launch data and must be superimposed on existing structural loads. Any added members providing additional restraint to the basic structure must be analyzed for secondary loads. Another modification are the four battery banks, one located in each of the descent stage bays. Each bank contains four batteries and one ECA unit. Loads shown on Figure 6.4-7 are for 1-g (Earth) loads.

A preliminary detail analysis using these loads was carried out for the tank support structures as well as the battery supports. The design of members for these structures does not present any significant problem. The loads induced at the reaction points on the descent stage can be accounted for by the installation of local external reinforcements, such as clip, fittings, and stiffeners. The installation of these minor structural changes can be phased into the modification period allocated for the Phase I Labs.

6.4.6 Materials

The major materials problems associated with the Phase I Lab missions over and above that of the LEM are those imposed by the increased mission time and the different environmental conditions created by the various mission profiles. These conditions in many cases will affect or alter the choice of materials originally made for the LEM. Some of these material areas where changes, and in most cases additional testing, would be required are discussed in the following paragraphs since these areas may be potential problems for the Phase I Lab. Other areas, such as radiators, which do not exist on the LEM, also will involve material study.

6.4.6.1 Non-metallics

The toxicity and materials outgassing analysis as established by Engineering Materials and Crew Systems for LEM are being reviewed in light of present Phase I Lab requirements. The knowledge and experience gained from the more than 80 materials already evaluated for LEM is proving invaluable. It may be assumed that those materials already rejected for use on LEM will also be rejected for use on Phase I Lab; however, a close look and possible re-evaluation of approved materials will be necessary. Materials are now evaluated for a total of 3 days in contrast to contemplated missions of 14 days and more. Since the quantity of outgassed products per material may have to be reduced because of increased mission time and the fact that increased degradation may take place, retesting in some cases may be necessary.

6.4.6.2 Compatibility

One of the more difficult problems arising from extended missions is one of compatibility. Many of the materials, metallics and non-metallics alike, would be questionable under extended exposure to duels and/or oxidizers. The use of gaseous oxygen may also present problems for certain materials. The use of the titanium propellant tanks to store gaseous oxygen is suggested in Paragraph 5.2.8. Titanium, in contact with oxygen, is impact sensitive and is not a recommended combination. However, the use of liners could possibly eliminate this problem. A sprayable Teflon which is under consideration to alleviate the titanium-N₂O₄ compatibility problem on LEM, would be permeable to oxygen and may not be usable in this application. Liner materials such as vinyls and polyesters could be studied if this utilization of the propellant tanks is required.

6.4.6.3 Transparencies

The mission profile and time of some of the AES missions would require additional testing of these materials. The visibility required (effect of prolonged UV radiation on the visibility), the number of micrometeoroid hits the windows must withstand, and other criteria would affect and possibly alter the materials under evaluation for LEM.

6.4.6.4 Thermal Control Coatings

The requirements for these coatings vary depending on the mission profile. Stable coatings (such as LTV-602 white silicone paint) are available; however, the weight penalty in using these may be excessive. Anodize as a thermal control coating is being used on LEM and with varying processing parameters could answer many Phase I Lab requirements; however, the thermal control system used on LEM was established for its own specific mission and as the mission profile changes, so do the thermal control coatings required.

6.4.6.5 Sealants and Non-Metallic Structural Materials

Many non-metallics are presently being used in structural applications. The effect of prolonged exposure to the space environment in not only the outgassing properties, but the mechanical properties should be determined. High- and low-temperature cycling, hard vacuum, and other space parameters have detrimental effects on many of the non-metallic structural materials being used.

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Axial

Truss Member	Landing Conditions							
	IA	IC	IIB	IIC	IIIA	IIID	IVB	IVC
AC	-1484	+2163	-1713	-2083	-1539	-2020	-2370	-2020
BC	+2270	-3094	+2471	+2776	+1560	+1957	+3150	+3150
BD	+ 932	-1013	+1429	+ 55	+ 461	-1325	+1114	+ 1114
KH	+ 340	- 317	+ 261	+ 144	- 316	- 469	+ 144	+ 144
HE	+ 529	- 477	+1801	-1213	+1278	-2638	+1112	- 866
A'C'	-1484	+2163	-2083	-1713	-2020	-1539	-2613	-2020
B'C'	+2270	-3094	+2776	+2471	+1957	+1560	+3351	+3351
B'D'	+ 932	-1013	+ 55	+1429	-1325	+ 461	+ 212	+ 1114
K'H'	+ 340	- 317	+ 144	+ 261	- 469	- 316	+ 67	+ 144
H'E'	+ 529	- 477	-1213	+1801	-2638	+1278	- 866	+ 1112

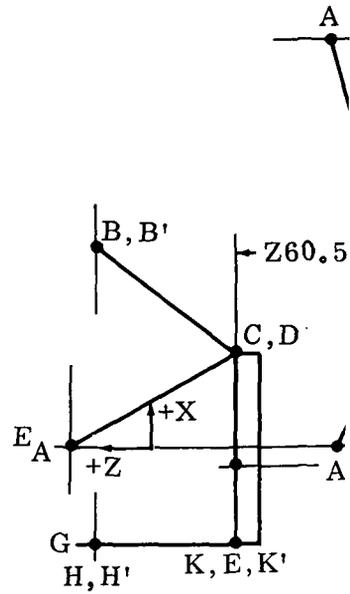
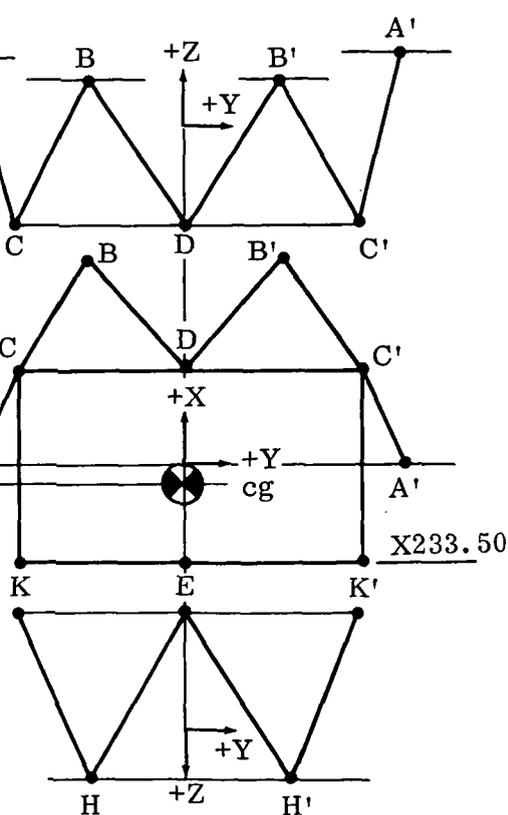


Table 6.4-1

Loads in Rack Truss Members (Gross Wt = 990 lb)

	Boost				Vibratory Conditions, *Random gs					
	7.35g		$n_z = +.1g$	$n_z = -.1g$	$n_y = +3.5g$	$n_y = -3.5g$	$n_x = +3.5g$	$n_x = -3.5g$	F_{3a}	F_{3b}
	A_1	A_2	F_{1a}	F_{1b}	F_{2a}	F_{2b}	F_{4a}	F_{4b}		
3	-3029	-3053	+1168	-1996	- 689	- 138	-1862	+1034	-2662	+1782
51	+3688	+3687	- 97	+1101	+ 729	+ 274	+2258	-1254	+1423	- 391
12	+ 343	+ 373	+1986	-1888	- 975	+1072	+ 219	- 122	-2787	+2787
57	- 91	- 118	+1137	-1165	- 102	+ 73	- 64	+ 35	-1478	+1478
56	- 299	- 165	+1889	-1952	-2277	+2213	- 142	+ 79	-2320	+2320
70	-3006	-3077	+1168	-1996	- 138	- 689	-1862	+1034	-2662	+1782
50	+3669	+3706	- 97	+1101	+ 274	+ 729	+2258	-1254	+1423	- 391
14	+ 431	+ 285	+1986	-1888	+1072	- 975	+ 219	- 122	-2787	+2787
44	- 83	- 125	+1137	-1165	+ 73	- 102	- 64	+ 35	-1478	+1478
12	- 107	- 357	+1889	-1952	+2213	-2277	- 142	+ 79	-2320	+2320

* All Conditions Include $N_x = +1g$

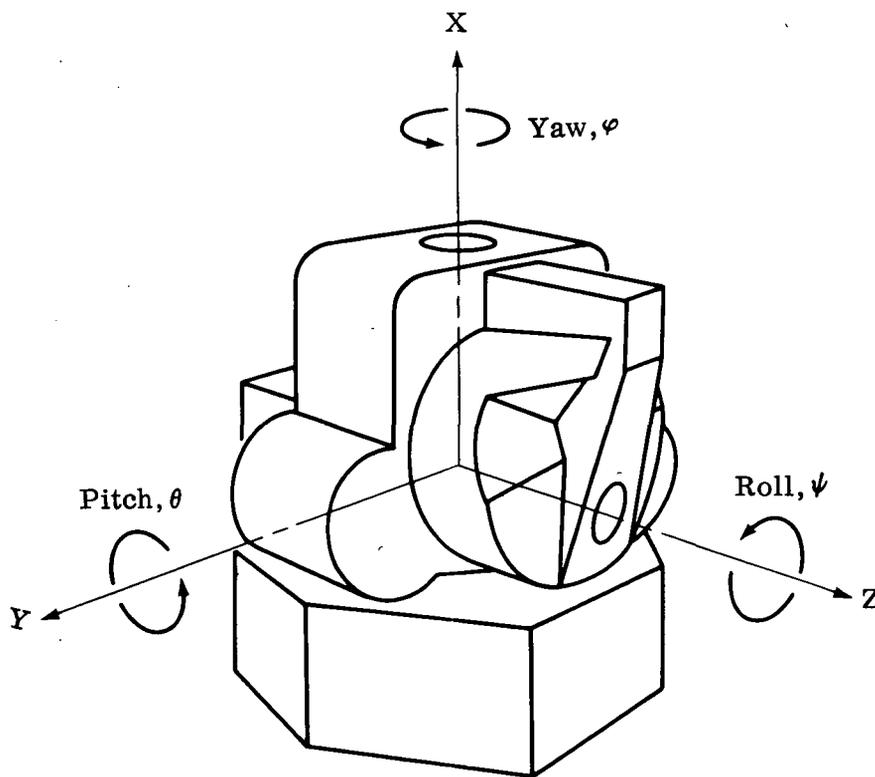
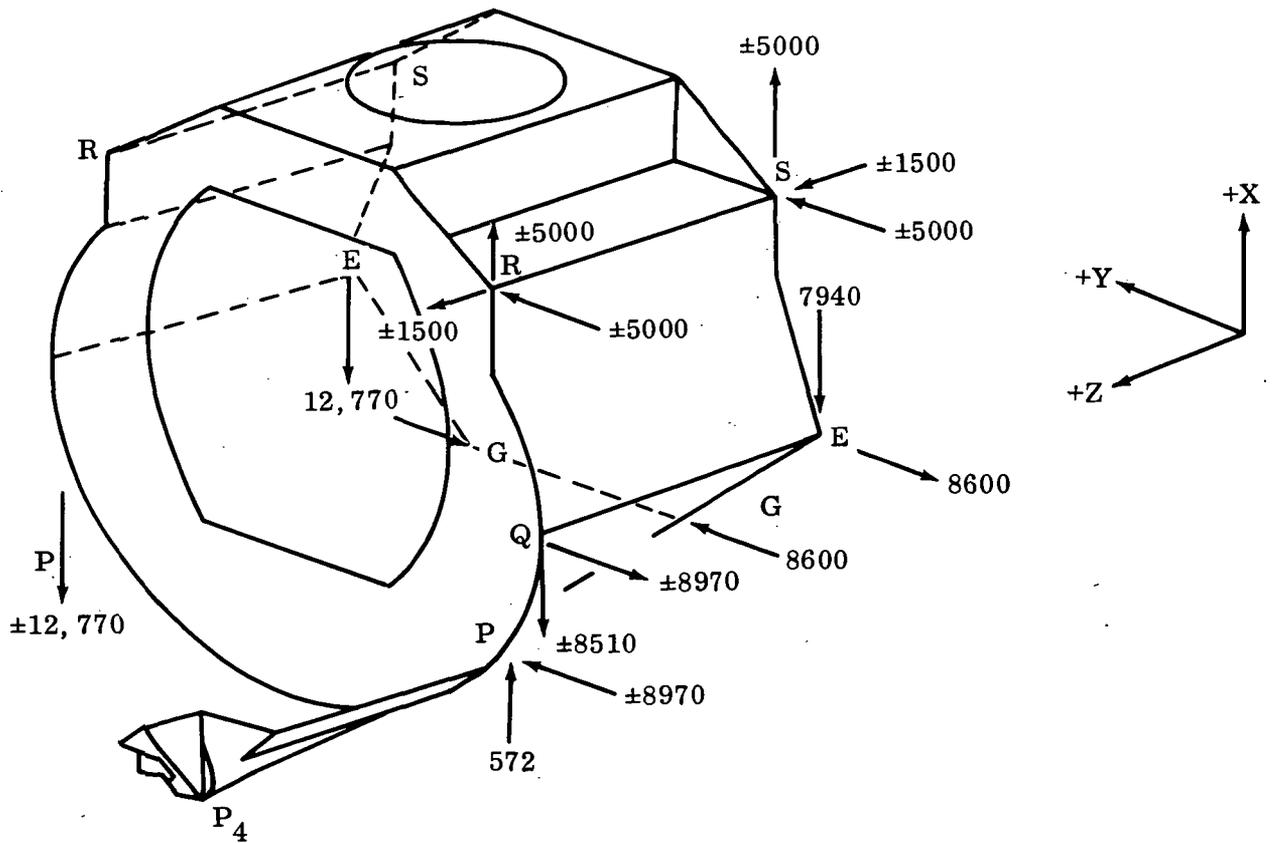


Fig. 6.4-1 Axes Designation

Hard Pt.	X	Y	Z
E	253.5	±45.0	-27
G	228.0	±18.4	-27
S	294.6	±36.7	-27
R	294.6	±36.7	+27
Q	252.0	-46.8	+27
P	229.4	±43.7	+27
P ₄	211.3	±22.5	+64.6



Note: Loading (in lb) is symmetrical except where shown.

Fig. 6.4-2 Ascent Stage

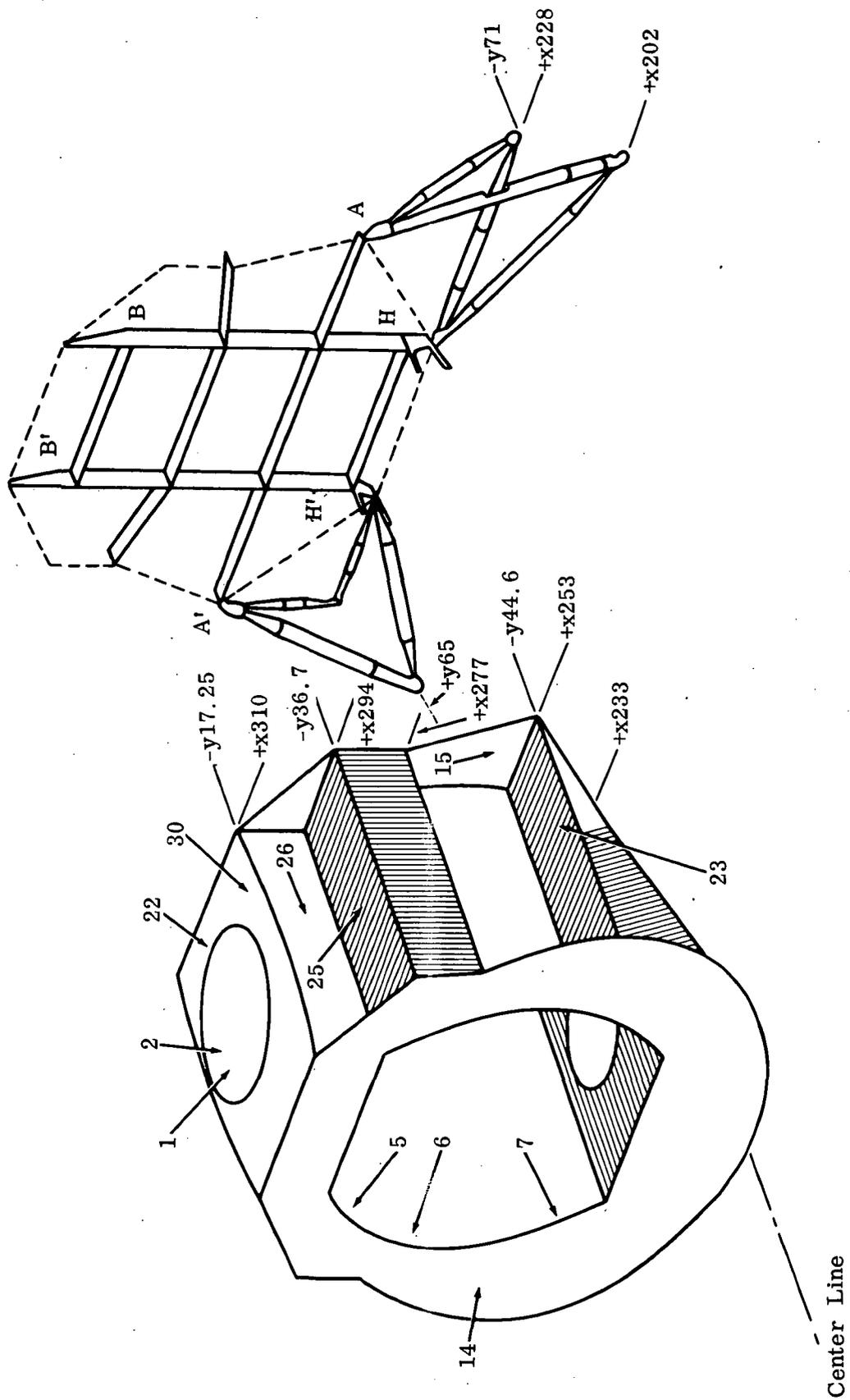


Fig. 6.4-3 Ascent Stage Midsection

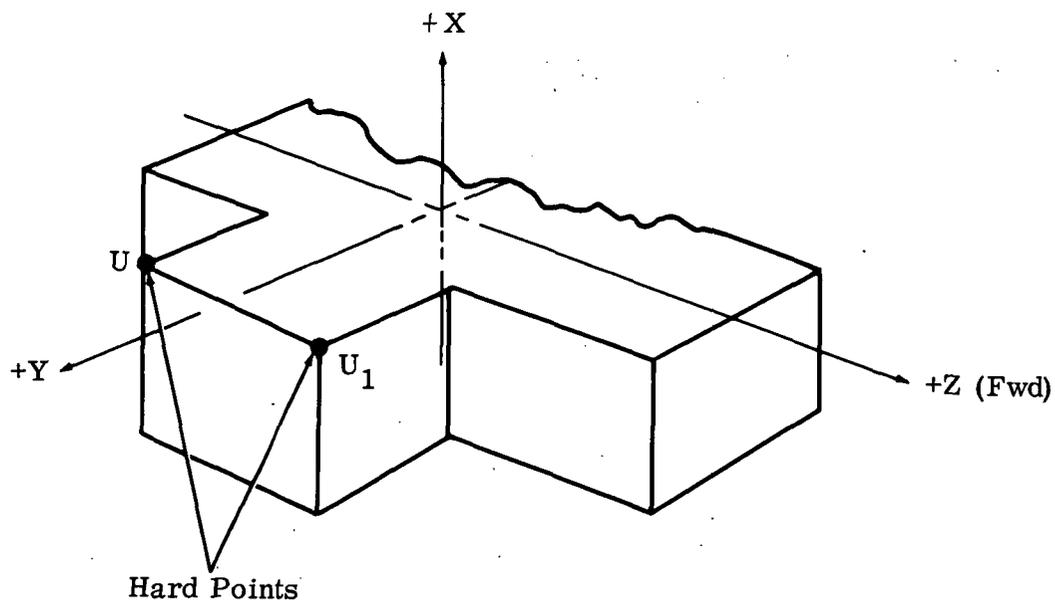
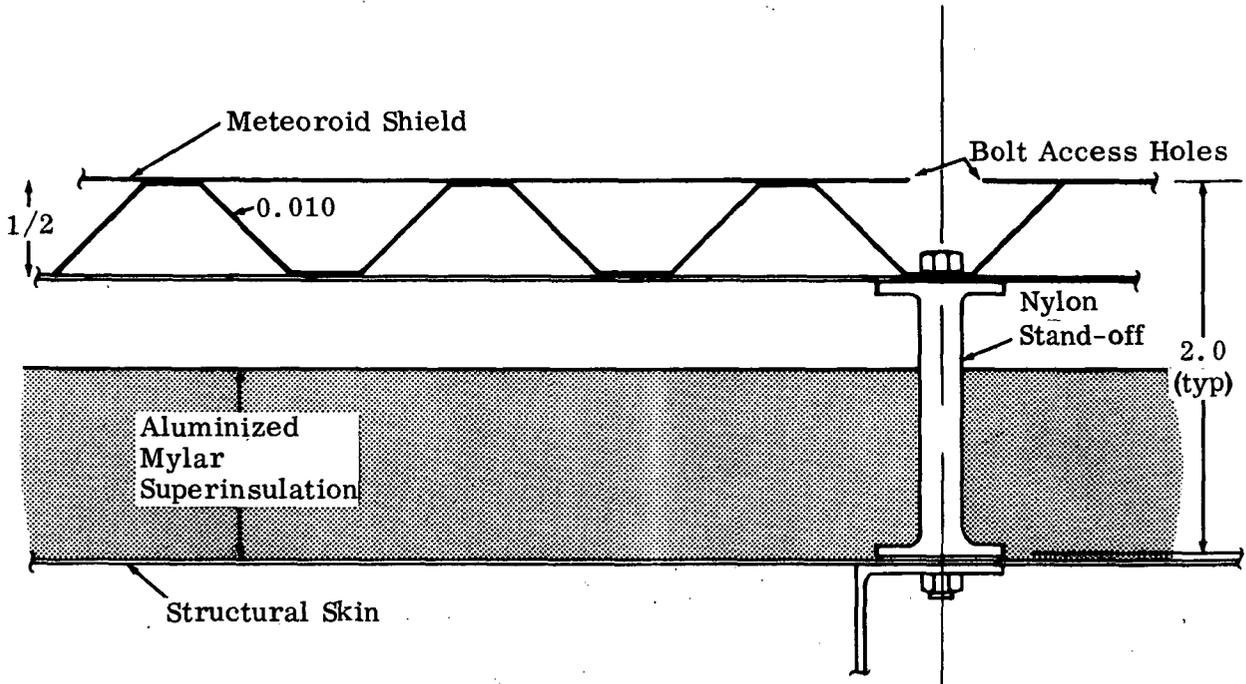
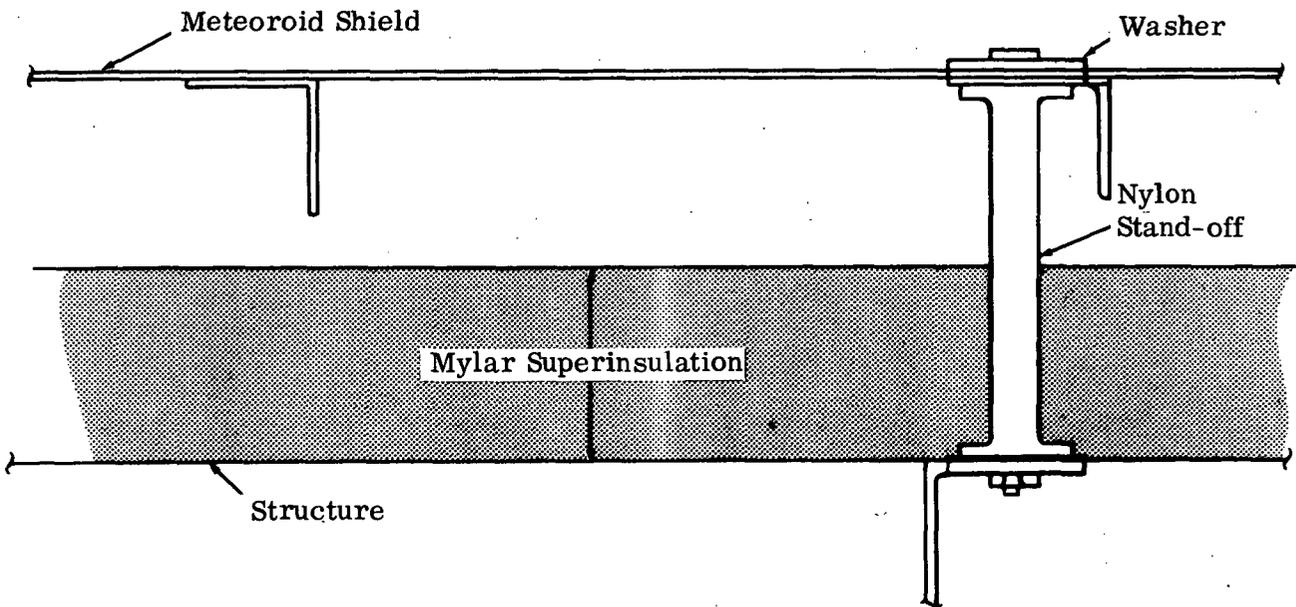


Fig. 6.4-4 Descent Stage Hard Point Location



A. Corrugation-Stiffened Shield



B. Sheet - Stiffener Shield

Fig. 6.4-5 Meteoroid Shield

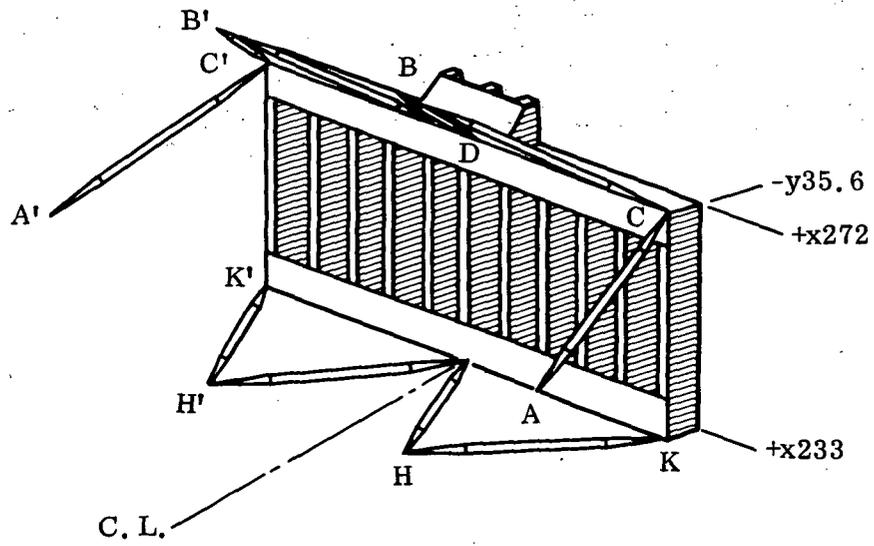


Fig. 6.4-6 Equipment Rack

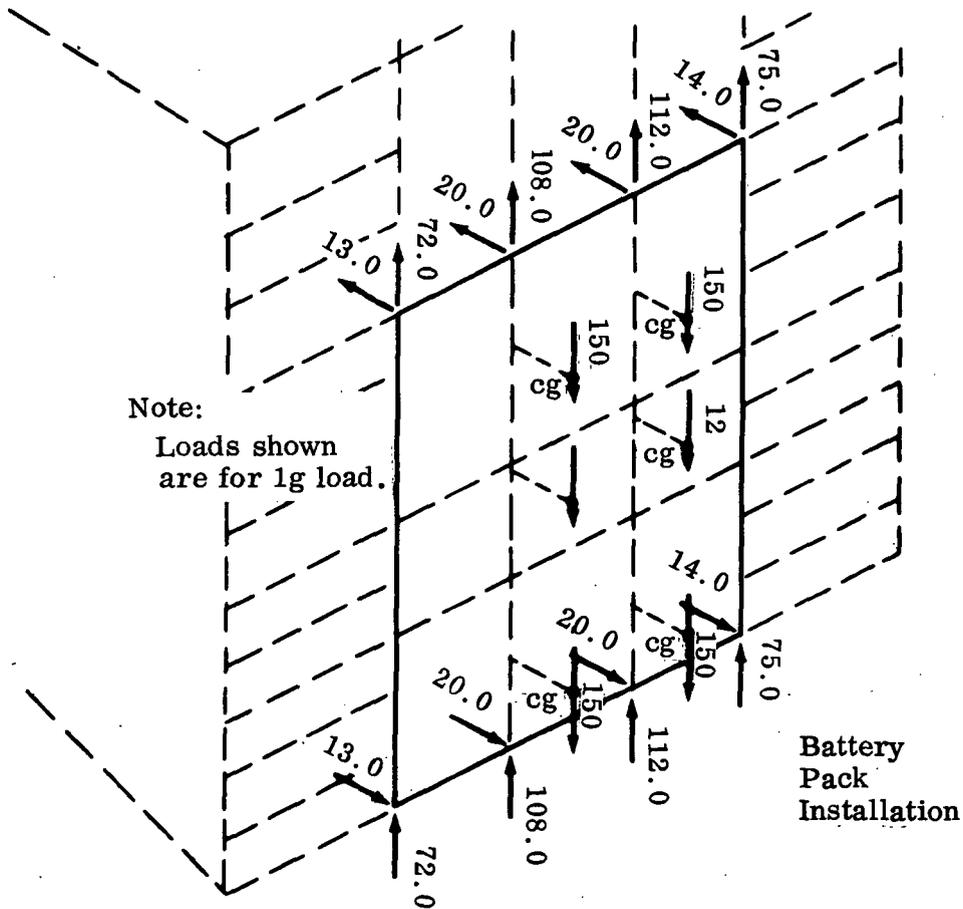
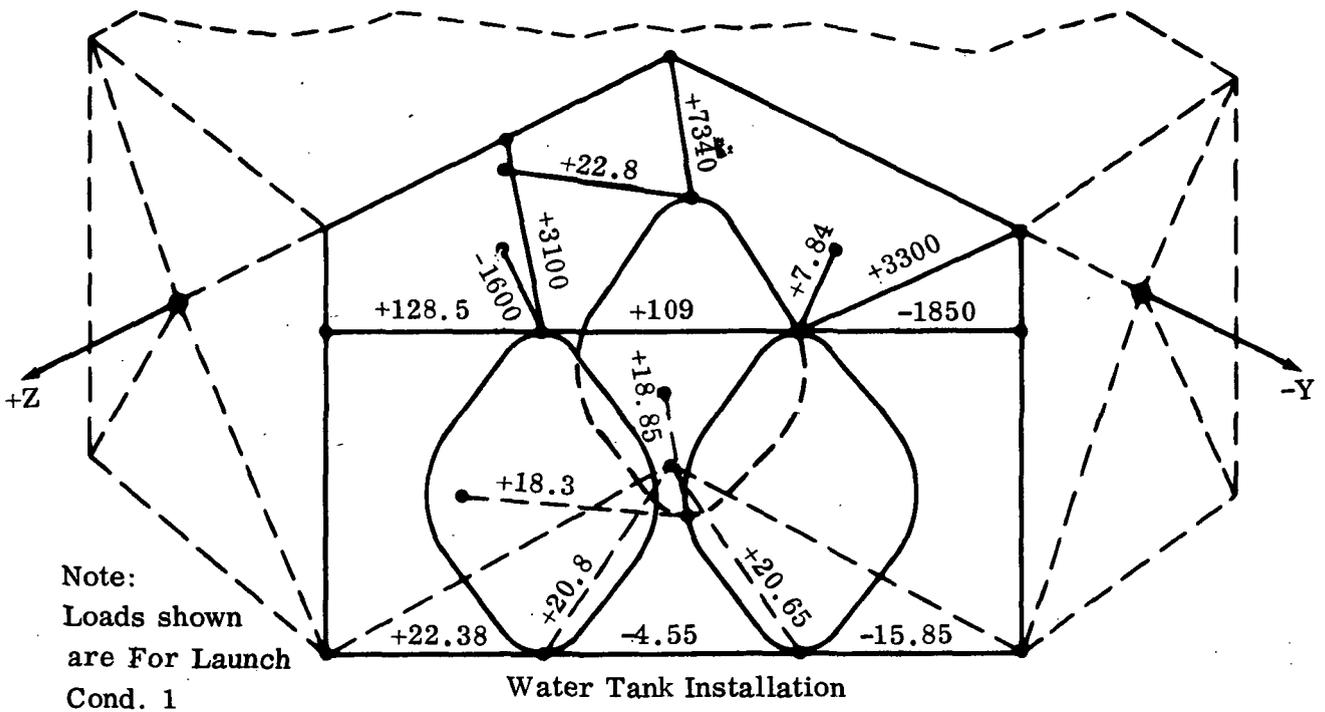


Fig. 6.4-7 Descent Stage Equipment

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