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(NASA-TM-X-69442) SORTIE LABORATORY, PHASE B TECHNICAL SUMMARY (NASA) ~~200~~ 202 p HC $ CSCL 22B G3/31 N74-11697 Unclas 22280

SORTIE LAB
PHASE B
TECHNICAL SUMMARY

SCIENCE AND ENGINEERING

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FOREWORD

This document is based on the results of numerous analyses, trade studies, and other investigations and conceptual design activities resulting in the definition of an autonomous Sortie Lab. These activities were conducted by the MSFC S&E laboratories; each contributed to this document within its area of responsibility. Requests for details of individual areas of study should be addressed to:

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1.0 INTRODUCTION

1.1 Objective

The objectives of the Sortie Lab technical summary are as follows:

a. Summarize the design and operational requirements which have evolved from the Sortie Lab analysis and trade studies performed to date.

b. Support the preparation of future Sortie Lab technical studies.

c. Define the S&E autonomous Sortie Lab, its subsystems, configuration, capabilities and operational characteristics.

This technical summary will also provide a source of requirements for systems and experiment support for the Sortie Lab baseline as previously defined.

1.2 Scope

Basic design data required by the designers and planners of the S&E autonomous Sortie Lab structures, subsystems, components and instrumentation are presented in this document.

Specific areas covered are configuration definition, mission analysis, operations analysis, experiment integration, safety, and logistics.

The technical summary outlines characteristics which reflect the influence of the growth in Sortie Lab capability and the results of the mission and operational analysis.

Each of the selected areas is described in terms of objectives, equipment, operational concept, and support requirements.

1.3 Background

In order to effectively design and operate a multidisciplinary spacecraft such as the Sortie Lab, it is necessary to collect and evaluate the trade studies, design analysis and capabilities at periodic points in the design and development cycle. This technical summary document was written to accomplish this task.

Input for the Sortie Lab technical summary was solicited from the following laboratories within the MSFC Science and Engineering Directorate: Systems/Products, Astrionics, Astronautics, and Aero-Astrodynamics.

The design, operational, programmatic requirements and configuration definition were developed in accordance with the Level I Sortie Lab Guidelines and Constraints dated August 15, 1972.

2.0 PROGRAM DEFINITION

2.1 Level I Guidelines

SORTIE LAB GUIDELINES AND CONSTRAINTS LEVEL I, dated August 15, 1972, Revision No. I lists current guidelines. A brief summary of those guidelines that dictate configuration features necessary to achieve baseline objectives follows.

2.1.1 Design Mission

Sortie Lab will be designed for three classes of missions:

I. Experiment Missions supporting both multidiscipline and single discipline research and applications. The baseline duration of experiment missions will be 7 days. Extended duration of experiment missions will be up to 30 days. Polar orbit capability will be provided.

II. Servicing Missions providing on-orbit maintenance and equipment change-over support to automated, man-tended, free-flying spacecraft.

III. Development Missions in support of Shuttle/Sortie Lab development and of the determination of payload environments. The development missions are to be considered secondary design drivers.

2.1.2 Design Life

The Sortie Lab will be designed for an operational life of at least 50 missions of 7 days duration with ground refurbishment.

2.1.3 Mission Success

The Sortie Lab will be designed for a high probability (.95) of mission success. Mission success will be measured by proper functioning of the module, its systems and subsystems, and experiment support equipment provided to the user. This level of mission success will be assured by component and subsystem reliability, redundancy and on-board maintenance as appropriate. Mission success does not require successful completion of all experiments.

The Sortie Lab subsystems designs will be based on at least a fail safe concept except for the structure which will be based on a safe life concept. Subsystem redundancy will only be used to achieve mission success and fail safe design goals or to reduce cost.

2.1.4 Crew Size

For design of the Sortie Lab, the following numbers of personnel shall be considered:

	Total in Orbit	Payload Dedicated
Baseline	6	4
Maximum	8	6
Minimum	4	2

The Shuttle Orbiter will provide sleep, galley, waste management and personal hygiene accommodations. The weight of all payload dedicated personnel in excess of two including the weight of their seats, equipment and provisions will be chargeable to Sortie Lab.

Note that these numbers assume that "payload dedicated" personnel will spend most of their work time on experiments, experiment support equipment and Sortie Lab subsystems. If shuttle operations on orbit require more than two crewmen for most of their work time, the corresponding numbers for "total in orbit" will increase and weight attributable to the larger crew will be chargeable to Sortie Lab.

2.1.5 Weight

The total weight of the Sortie Lab, the pallet when used, the experimental apparatus, expendables and other necessary devices chargeable to Shuttle payload, all with suitable design weight margins, shall not exceed 80 percent of the Shuttle nominal performance for the particular mission of interest.

2.1.6 Autonomy (Level of Shuttle Support)

The Sortie Lab will make efficient use of Shuttle-provided utility support (i.e. power, communications, environmental control, etc.) consistent with a simple module to orbiter interface and with minimum mutual interference during turn-around activities.

2.1.7 Interface

The baseline Shuttle to payload interfaces will be defined by the following documents:

a. Space Shuttle Program Requirements Document Level I dated April 21, 1972, Revision No. 4

b. Space Shuttle Baseline Accommodations for Payloads MSC-06900 dated June 27, 1972.

A standardized interface concept will be jointly developed with the Shuttle program.

2.1.8 User Provisions

Laboratory utility to the users will be a major consideration in all design and operational concept decisions.

2.1.9 Experiments

Experiment requirements as determined by the special study workshop activities established to define sortie missions shall be a major input and source of design trade studies.

2.1.10 Safety

A system safety plan shall be developed in accordance with NASA Safety Program Directive No. 1 (Rev. A) dated December 12, 1969, and other applicable directives (TBD). Compatibility with applicable shuttle safety directives is required.

No credible hazard associated with the Sortie Lab or its experiment activities shall prevent safe termination of a mission.

The Sortie Lab shall have self-contained protective devices or provisions against all credible hazards generated by its support functions or experiment activities.

EVA (Extra Vehicular Activity) will be minimized in all equipment operations.

2.1.11 Resources

The cost impact will be a major consideration in all major design and operational concept decisions.

2.2 Derived Requirements

The fundamental systems-level requirements derived from the tasks performed during the first part of the Sortie Lab Phase B Study are listed below. Most of these requirements are included in the Sortie Lab Design Requirements Document (SLDRD) dated December 1, 1972.

2.2.1 Operations

General operations requirements are:

a. The Sortie Lab shall be designed to avoid contamination of the outside spacecraft environment by minimizing overboard dumping of waste products during on-orbit experiment operations.

b. Sortie Lab experiment-related crew activities shall not be required during ascent, reentry or landing operations.

c. The Sortie Lab will be designed for multi-shift operation, with staggered crewman activity times permissible as experiment programs dictate.

d. The Sortie Lab nominal crew duty cycle is 24 hours of which 12 hours are a minimum required for off-duty time; e.g., eat, sleep, personal hygiene, exercise and housekeeping. The remaining 12 hours per crewman per day is allocated to service/experiment work, supporting subsystems and performing other work functions.

Sortie Lab operations-related guidelines and constraints are discussed in Section 5.0.

2.2.2 Systems/Subsystems

Some of the basic systems/subsystem design requirements generated during the Phase B study are presented in this section.

2.2.2.1 General

a. The Sortie Lab shall be designed for land, sea and air transportation.

b. No orientation restrictions will be imposed by subsystems.

c. The Sortie Lab shall provide the capability for four payload specialists to work in the Sortie Lab at one time and for two shifts of three men each for a 7-day mission.

d. Sortie Lab hardware which the crew may come in contact with while in the shirtsleeve environment shall be designed so that surface temperature will not exceed $+105^{\circ}F$ (maximum). Equipment surface temperatures below $+60^{\circ}F$ should be avoided to prevent atmospheric moisture from condensing on its surface.

e. Mobility and stability aids (handholds, handrails, and foot restraints) shall be provided as required to aid the crewmen.

f. Fuel cell byproduct water shall have a cleanliness level that is acceptable for crew drinking requirements.

2.2.2.2 Structural

The Sortie Lab structural system shall be designed to withstand simultaneously the critical mission loads and any associated environmental loads without experiencing detrimental deformation using yield safety factors or catastrophic failure using ultimate safety factors. The effects of repeated loads, acoustic and vibration spectrums, repeated pressure cycles and the duration of these type loads shall be considered in the design of all Sortie Lab structure.

a. Design Yield Load: At design yield load there shall be no yielding or deformation of the structure which would result in impairment of any of the functional requirements of the Sortie Lab structural system.

b. Design Ultimate Load: At design ultimate load there shall be no failure or instability of any major assembly, subassembly or component of the Sortie Lab structural system.

c. The following factors of safety shall be used for the design and analysis of all Sortie Lab structure.

- General:

  Yield Factor of Safety = 2.0
  Ultimate Factor of Safety = 3.0

If the primary structure is designed to an ultimate factor of safety less than 3.0, it shall be structurally qualification tested.

- Pressurized Structure:

  Personnel Compartments, Internal Pressure Only:

  Proof Pressure = 1.5 x limit pressure
  Yield Pressure = 1.65 x limit pressure
  Ultimate Pressure = 2.0 x limit pressure

  Windows, Doors, Hatches, etc., Internal Pressure Only:

  Proof Pressure = 2.0 x limit pressure
  Ultimate Pressure = 3.0 x limit pressure

  Hydraulic and Pneumatic Systems, including reservoirs:

  Lines and Fittings, less than 1.5 in. diameter

  Proof Pressure = 2.0 x limit pressure
  Ultimate Pressure = 4.0 x limit pressure

  Lines and Fittings, 1.5 in. diameter or greater

  Proof Pressure = 1.2 x limit pressure
  Ultimate Pressure = 1.5 x limit pressure

  Hydraulic and Pneumatic Tanks and High Pressure Vessels

Proof Pressure = 1.5 x limit pressure
Ultimate Pressure = 2.0 x limit pressure

Actuating Cylinders, Valves, Filters, Switches

Proof Pressure = 1.5 x limit pressure
Ultimate Pressure = 2.0 x limit pressure

- Temperature: A factor of safety of 1.0 shall be applied to all temperature induced loads.

- Malfunction: A factor of safety of 1.0 shall be applied to all load conditions resulting from malfunction or crash.

- Astronaut Tethers and Attachments: The following factors of safety shall be applied to the design and analysis of astronaut mobility aids:

Yield Factor of Safety = 2.0
Ultimate Factor of Safety = 3.0

2.2.2.3 Mechanical

a. Hatches between pressurizable compartments, including airlocks, shall: allow rapid ingress/egress, be operable from either side, provide positive indication of closure, and be provided with a pressure equalizing valve.

b. The Sortie Lab structure and subsystems will be designed to accommodate an operating pressure 14.7 psia in the habitable areas. The structure of the pressurized Sortie Lab shall be designed for a positive pressure only for all mission phases.

c. Mechanical and structural interfaces will be designed for rapid mate, alignment and disconnect.

d. Mating surfaces and seals requiring pressure integrity confirmation shall be designed to eliminate the necessity of vacuum tests of the Sortie Lab.

2.2.2.4 Environmental Control

a. The atmospheric pressure of the Sortie Lab shall be

14.7 psia using a two-gas system composed of nitrogen and oxygen.

b. The nominal cabin environment shall be maintained at a cleanliness level of Class 100,000.

c. The atmosphere supply and control system shall be designed to maintain a positive pressure in the Sortie Lab habitable area with respect to the payload bay area during flight operations.

d. Temperature controls shall be installed in the Sortie Lab to provide independent control from the Shuttle Orbiter.

e. Temperature and humidity levels shall be controlled automatically, with manual adjustment capability provided.

f. The ECS shall be able to maintain an acceptable environment in the Sortie Lab under the most adverse conditions of crew loading, experiment loading, payload deployment, altitude, orbital plane inclination to equator, and spacecraft attitude with respect to the earth and the sun.

g. Local and remote control and shutdown capability shall be provided for the ECS.

h. Means shall be provided to verify the life support suitability of environmentally isolated spaces prior to entry.

i. Active control shall be required for those contaminants which may exceed maximum allowable concentrations during a particular mission. In assessing the concentration levels for control requirements the cabin leakage must be assumed zero.

j. The Sortie Lab method of heat rejection shall not constrain the use of standard laboratory equipment for experiments.

k. The Sortie Lab shall provide the necessary interfaces for maintaining the Sortie Lab/experiments environmental requirements after installation into the Orbiter.

2.2.2.5 Electrical Power

a. The Sortie Lab power system shall be capable of accept-ing an average and peak power load based on the capability of one Shuttle-type fuel cell.

b. An interior Sortie Lab lighting system shall be provided to allow for crew equipment installations, normal and emergency crew activities, and experiment operations.

2.2.2.6 Communications

a. The capability for continuous voice communications between the Sortie Lab and the Shuttle Orbiter shall be provided.

b. All communications to the ground will be through the Orbiter systems.

c. An emergency communications system independent of the normal intercom system shall be provided from the Sortie Lab to the Orbiter.

2.2.2.7 Data Management

a. The Sortie Lab primary data mode shall be for onboard data recording of scientific data.

b. All Sortie Lab systems shall be provided with adequate deactivation and monitoring capability to verify that deactivation is sufficient to prevent personal injury or equipment damage during maintenance activities.

c. Onboard checkout shall be utilized to perform malfunction detection and conduct subsystem and payload equipment checkout, monitoring, and fault isolation to a level optimized for cost, safety, maintenance, and repair requirements.

d. Automated critical control functions shall provide for crew initiated override/interrupt capability.

e. It shall be possible to verify operation of all critical redundant components while they are connected in-place.

f. Built in test points will be provided for interface verification and trouble shooting.

2.2.3 Loads

Design load requirements for the Sortie Lab structural system are presented in the following subsections. All loads presented are limit values unless otherwise specified and shall be used with the appropriate safety factors.

a. The following load factors are appropriate for all handling, erection and transportation operations.

Category	Limit Load Factors (g)		
	Longitudinal	Lateral	Vertical
Handling and Erection	±0.5	±0.5	±2.0
Air Transport	±3.0	±1.0	±3.0
Water Transport	±1.0	±1.5	±3.0
Land Transport	±1.0	±1.5	±3.0

b. The Sortie Lab shall be designed to meet all the loads resulting from prelaunch, launch, boost, reentry, flyback and landing. The Sortie Lab structural system shall be designed to withstand all loads resulting from the static and dynamic acceleration factors presented in Table 2.2-1.

c. The Sortie Lab structure shall be designed to the following crash load factors:

Load Factors (g's)	Direction
Longitudinal	9.0 Forward 1.5 Aft
Lateral	1.5
Vertical	4.5 Down 2.0 Up

These factors are containment factors and no additional dynamic or safety factors should be applied to them. Under these loads the Sortie Lab must be restrained in the payload bay so as to not constitute a hazard to the Orbiter personnel during a crash. The factors defined above should be considered independent and not occurring simultaneously.

Mission Phase	Longitudinal		Lateral				**Total Accelerations (G)					
	Steady (G)	Dynamic(G) 0-60 Hz	Steady (G)		Dynamic (G) 0-60 Hz							
	x	x	y	z	y	z	x_{max}	x_{min}	y_{max}	y_{min}	z_{max}	z_{min}
Thrust Buildup Emergency Rebound	-1.0	±0.5	0	0	±0.3	±0.3	-0.5	-1.5	+0.3	-0.3	+0.3	-0.3
Launch Release	-1.5	±1.9	<0.1*	<0.1*	±0.7	±2.9	+0.4	-3.4	+0.8	-0.8	+3.0	-3.0
Max Q Flight Region	-2.0	±0.3	0.6*	0.8*	±0.3	±0.3	-1.7	-2.3	+0.9	-0.9	+1.1	-1.1
Max Vehicle Acceleration During SRM Burn	-3.0	±0.3	0.3*	0.4*	±0.2	±0.2	-2.7	-3.3	+0.5	-0.5	+0.6	-0.6
SRM Cutoff/Separation	-1.0	±3.0	0.1*	0.3*	±0.3	±0.5	+2.0	-4.0	+0.4	-0.4	+0.8	-0.8
Max Accel - Orbiter Only Boost	-3.0	±0.3	0.1*	-0.6	±0.2	±0.2	-2.7	-3.3	+0.3	-0.3	-0.4	-0.8
Orbiter Cutoff/Separation	<-0.1	±2.0	<0.1*	+0.2	±0.3	±0.4	+1.9	-2.1	+0.4	-0.4	+0.6	-0.2
Reentry	+1.0	±0.4	0.4*	+3.0	±0.3	±1.0	+1.4	+0.6	+0.7	-0.7	+4.0	+2.0
Flyback	0.3*	±0.3	0.2*	+1.0	±0.1	±0.4	+0.6	-0.6	+0.3	-0.3	+1.4	+0.6
Landing/Taxiing/Braking	+1.0	±0.3	<0.1*	+2.0	±0.2	±1.0	+1.3	+0.7	+0.3	-0.3	+3.0	+1.0
Payload Deployment	<0.1*	<±0.1	<0.1*	<0.1*	±0.1	±0.1	+0.2	-0.2	+0.2	-0.2	+0.2	-0.2

* Steady State Accelerations Which May Act In Either A Positive Or Negative Direction From Flight To Flight.

** Design Load Factors (Payload C.G.) Payload Design Should Be Based Upon Any Combination Of x,y, and z Accelerations For Each Mission Phase.

TABLE 2.2-1. PAYLOAD ACCELERATION FACTORS

2.2.4 Physical

The Level I Guidelines dictated the Sortie Lab's weight limitations based on the Shuttle Orbiter's performance capability (reference Section 2.1.5). Weight and configuration requirements established early in the Phase B study are:

a. Based on the maximum weight of the Sortie Lab, pallet, experiment integration equipment, experiment hardware, payload chargeable payload specialists and their equipment will not exceed 32,000 pounds.

b. The Sortie Lab design shall accommodate a payload of 12,000 pounds which includes experiment integration equipment, experiment hardware, payload chargeable payload specialists and their equipment. Both the pallet and the pressurized module shall be independently capable of accommodating the 12,000 pound payload, or any combination up to the 12,000 pound payload.

c. The maximum external diameter of the module and pallet shall be 14 feet. Mechanisms that are external but attached to the module, such as handling rings, attachments for deployment, docking mechanisms, etc., shall be contained, at launch within an envelope of 15 feet diameter.

d. The Sortie Lab shall provide for viewing of pallet mounted and externally extended experiments.

e. The Sortie Lab interior shall be designed for a normal orientation in a horizontal position during maintenance, refurbishment and checkout activities.

f. A clear access opening close to the module diameter shall be provided for ground servicing and payload installation.

g. The pallet shall be in direct viewable area of the pressurized module.

h. The Sortie Lab to tunnel hatch and tunnel to Orbiter hatch shall have windows for viewing from one area to the other.

i. Any support module shall mate with any experiment module.

2.2.5 Safety

Safety of operations throughout the Sortie Lab project shall be an overriding consideration where alternatives of design choice occur.

Two safety-related requirements stemming from the design of a deployable radiator for the MSFC Phase B Sortie Lab configuration are:

a. Instrumentation and interlocks shall be provided to insure the Orbiter payload bay doors are open prior to initiation of radiator deployment and verification that full deployment has occurred, and the Sortie Lab radiator is locked in place.

b. Instrumentation and interlocks shall be provided to insure the Sortie Lab radiator has been retracted and locked in place before closure of the payload bay doors.

Safety related criteria, requirements and provisions are discussed in Section 7.0.

2.2.6 Maintainability

Basic maintainability requirements are:

a. The Sortie Lab shall have no scheduled inflight maintenance performed during the 7-day mission. Unscheduled inflight maintenance of the Sortie Lab shall be limited to minor adjustments and replacement.

b. Sortie Lab subsystems containing limited life components and those requiring inspection, replacement, servicing, calibration or adjustment shall be easily accessible and removable. Preferential access shall be provided for scheduled replacement and higher risk items.

c. Items having the same functional and performance requirements shall be designed to be interchangeable wherever practicable.

2.2.7 Maintenance

Basic maintenance requirements are:

a. Special tools shall be kept to a minimum and commonality in tool requirements shall be implemented.

b. Spares shall be stowed in a manner that allows access to each item in any desired sequence.

c. Spares shall be fully qualified and completely serviceable without testing prior to installation.

d. Primary maintenance of the Sortie Lab shall be accomplished on the ground while demated from the Shuttle Orbiter. Maintenance of system installed equipment shall normally be limited to "remove and replace."

e. The Sortie Lab will be designed to minimize activities between sequential flights. Periodic overhauls will be performed to restore the desired systems confidence.

2.2.8 Payload Integration

Derived payload integration requirements are:

a. Modification and space qualification testing of standard laboratory equipment shall be minimized.

b. The Sortie Lab will have the capability of accommodating commercial hardware in the experimental equipment with minimum modifications.

c. A standardized mechanical, electrical, data bus, and fluid interface between the Sortie Lab and the payload/experiment shall be developed.

d. Experiment mounting provisions, hole spacing, and subsystem interfaces shall be standardized for the Sortie Lab design.

e. Protection for payload instruments and equipment sensitive to contamination shall be provided.

2.2.9 Materials

A control document entitled, "Materials Requirements for Sortie Lab (Spacelab)", dated August 31, 1973, has been published to specify the design requirements for Sortie Lab materials.

This document was developed to specifically state the safety and operational requirements that materials must meet to qualify for Sortie Lab applications. This approach of expressing straight forward requirements rather than referring to numerous and voluminous documents (as normally done by Government contracts) should minimize the need for materials lists and the numerous Military, Federal, and NASA documents that are usually provided. Referenced documents are included in this document primarily for information purposes.

Basic subjects covered are (1) flammability, oxygen compatibility, odor, and offgassing; (2) shatterable and flaking materials; (3) fungus control; (4) cadmium plating; (5) beryllium; (6) titanium; (7) mercury and polyvinyl chloride; (8) electrical circuitry material controls; (9) radioactive materials; (10) elastomeric and natural nubber; (11) potting and molding compounds; (12) adhesive bonding; (13) lubricants; (14) ethylene glycol; (15) corrosion resistance, hydrogen embrittlement, dissimilar metal and stress corrosion; (16) carcinogens; and (17) hazardous materials.

2.2.10 Contamination Control

Preliminary Sortie Lab contamination control requirements have been prepared to define, interpret and expand the broad requirements contained in Sortie Lab program documentation. These requirements were developed from existing programs contamination control requirements and are consistent with Space Shuttle requirements.

These requirements address contamination control of the Sortie Lab and define specific cleanliness levels, allowable contaminant levels and contamination control design and operational constraints. Although contamination may include the presence of any foreign matter or unwanted energy, this specification only addresses contamination in the form of particulate matter, surface films, and gaseous or liquid adulterants which may be detrimental to mission life, technological operations, scientific observations or personnel safety.

Specific requirements are summarized below:

a. Design, manufacturing, handling and operational concepts shall minimize the probability of contamination of critical surfaces, elements and environments or permit convenient and practical, periodic cleaning or replacement.

b. All surfaces shall be cleaned to general conformance to paragraph 5.1.3 of MIL-SPEC-1246 (Level 100A). After cleaning, verification of surface cleanliness shall be performed by visible plus ultraviolet inspection methods in lieu of the detailed measurements specified in MIL-SPEC-1246.

c. Subsequent to surface cleaning specified above, the Sortie Lab, subsystems, components, and experiment packages shall be maintained in a Class 100,000 clean room environment as specified in FED-STD-209 with certain additions which are defined.

d. The manned payload carriers shall maintain active control of the following habitable volume environmental limits. The CO_2 level shall not exceed 7.6 mm Hg at any time during normal operation. The nominal level shall be ≤ 3.0 mm Hg. Odors and toxic gases shall be limited, evaluated and approved based on materials selection and tests specified in NHB 8060.1, paragraph 206.

e. All materials and finishes shall be selected for a minimum outgassing, dusting, powdering, or flaking characteristics or acceptable covers, coatings, or air filters shall be used to contain dusting products. Specific requirements are given for the habitable volume and for external surfaces.

f. All explosively actuated devices shall retain the combustion products in a sealed enclosure. Contamination-sensitive components shall be provided with covers or shields wherever possible. There shall be no venting internally in the Sortie Lab or in the Shuttle payload bay. Any required or proposed venting shall be submitted to the Project Office for definition in the appropriate interface control documents. Experiment/equipment hardware shall be so designed and constructed as to eliminate or contribute minimum degradation to the Sortie Lab environment.

g. In addition to maintaining the Class 100,000 environment, the interior of the Sortie Lab shall be purged with dry air conforming to MSFC-PROC-404.

h. Contamination-sensitive instruments and experiments provided with covers shall not be exposed to the space environment until 6 hours after the Shuttle Payload Bay doors are opened. Operations shall preclude reaction control thruster firings and controlled venting during periods of operation of contamination-sensitive instruments and experiments. Under emergency conditions, the operational CO_2 level specified above may be exceeded up to a maximum concentration of 15 mm Hg with a maximum exposure duration of 2 hours.

2.3 Payloads

The following sections present the representative experiment payloads identified for Sortie Lab use, and the requirements imposed on the Sortie Lab program by these payloads.

2.3.1 Payload Classification

To facilitate mission planning, design, and development of the Sortie Lab, a plan is being developed for a space science and applications program. This program of payload planning can be divided into four major categories and then can be subdivided into various space science and application disciplines. The major categories and typical disciplines are:

- Science
  - Astronomy
  - Solar Physics
  - High Energy Astrophysics
  - Atmospheric and Space Sciences

- Planetary
- Space Physics

- Applications
  - Earth Observations
  - Earth and Ocean Physics
  - Materials Science and Space Processing Applications
  - Communications and Navigation Research Lab
- Life Sciences
- Space Technology

The definition of Sortie Lab Phase B payloads has been an iterative process. For the Sortie Lab Phase B study, two sets of representative payloads were used. In order to differentiate between the two sets of data, they will be referred to as 1972 and 1973 data.

Table 2.3-1 lists by discipline the names of the 1972 payloads and their identification numbers while Table 2.3-2 lists the payloads as defined in 1973 for the Sortie Lab. The number of disciplines have increased from 8 to 10 and the number of payloads have decreased from 45 to 30. It can be seen that the emphasis has shifted, i.e., the 1972 data shows nine earth observations payloads vs. two for the 1973 data; or as in the astronomy area, four payloads vs. seven in 1972. It should be pointed out, however, that the 1973 data does include two disciplines as entities unto themselves (High Energy Astrophysics and Solar Physics) of which some parts had been included in the 1972 astronomy category. Three of the four Space Technology payloads are variations of the Langley Research Center's Advanced Technology Laboratory and are not equivalent to the technology discipline of 1972. Instead they are true multi-disciplinary payloads and the first that have been conceived and defined for Sortie Lab.

Of the 30 payloads defined by 1973 data, 6 are new, 9 are composed of modified 1972 sensors, and 15 contain some or all of the 1972 sensors and/or requirements. In addition, the 1973 data include

Discipline	Number	Description
Astronomy	A-1	One Meter Photoheliograph
	A-2	25 CM XUV Spectroheliograph 32 CM X-Ray Focusing Telescopes Inner and Outer Coronagraphs
	A-3	Stratoscope III
	A-4	Wide Angle UV (0.3 Meter)
	A-5	One Meter Infrared Telescope
	A-6	Small UV Telescope (6" - 12" Aperature)
	A-7	1.5 Meter Photoheliograph
Communications/ Navigation	C/N-1	Communications/Navigation Early Lab
Earth Observations	EO-1	Meteorology and the Atmospheric Sciences
	EO-2	World Land Use Mapping
	EO-3	Air and Water Pollution
	EO-4	Resource Recognition and Identification
	EO-5	Natural Disaster Assessment and Anomalies
	EO-6	Ocean Resources
	EO-7	Atmospheric Cloud Physics Experiment and Lab
	EO-8	Freezing Drop Experiment
	EO-9	Droplet Charging Experiment
Life Sciences	LS-1	Mini - 30 Day Module
Materials Science	MS-1	Biological 1. Separation of Biologicals 2. Preservation of Biologicals
	MS-2	Levitation Experiments 1. Glasses 2. Supercooling 3. Some Crystals
	MS-3	Furnace Experiments 1. Composite 2. Directional Solidification
	MS-4	Small and Low Temperature 1. Physics of Fluids 2. Zone Refining

TABLE 2.3-1. 1972 SORTIE LAB PAYLOADS

Discipline	Number	Description
Planetary	P-1	Intermediate Size Planetary Telescope
Space Physics	SP-1	Atmospheric and Magnetospheric Science
	SP-2	Cometary Physics
	SP-3	Meteoroid Science
	SP-4	Small Astronomy Telescope
	SP-5	Wake Measurement from Station & Booms
	SP-6	Wake Measurement from Subsatellite
	SP-7	Plasma Resources
	SP-8	Wave-Particle Interactions
	SP-9	Electron and Ion Beam Injection
	SP-10	Cosmic Ray Magnetic Spectrometer
	SP-11	Plastic/Nuclear Emulsions
	SP-12	Airlock and Boom Experiments
	SP-13	Flame Chemistry and Laser Experiments
	SP-14	Test Chamber Experiments
Technology	T-1	Contamination Measurements (Experimental)
	T-2	Contamination Measurements (Monitor)
	T-3	Short Term Cryogenics
	T-4	Slush Propellant
	T-5	Non-Cryogenics No. 1
	T-6	Non-Cryogenics No. 2
	T-7	EVA (Astronaut Maneuvering Unit)
	T-8	EVA (Maneuvering Work Platform)
	T-9	Teleoperations (Initial Flight Experiments)
Service Missions	LST	Large Space Telescope
	LSO	Large Space Observatory

TABLE 2.3-1. 1972 SORTIE LAB PAYLOADS (CONTINUED)

Discipline	Number	Description
Astronomy	AS-1 AS-2 AS-3 AS-4	UV Astronomy IR Astronomy Cometary Simulation Meteoroid Simulation
Solar Physics	SO-1 SO-2 SO-3 SO-4 SO-5	LSO Technology and Verification Sounding Rocket Sounding Rocket (Independent Mount) Semi-Automated Solar Platform Large Solar Observatory
High Energy Astrophysics	HE-1 HE-2	Cosmic Ray Survey X-Ray/Gamma Ray Survey
Atmospheric and Space Sciences	AP-1	Plasma Physics and Environmental Perturbation Laboratory
Earth Observations	EO-1 EO-2	Earth Observatory Zero-g Cloud Physics Laboratory
Earth and Ocean Physics	EOP-1	Test Bed Payload
Space Processing Applications	SPA-1 SPA-2 SPA-3 SPA-4 SPA-5 SPA-6	Biological Subelement General Purpose Subelement Furnace Subelement Levitatioh Subelement Core Subelement Automated Levitation/Furnace Unit
Communications and Navigation Research Lab.	CNRL-1	Communication Navigation Research Lab
Life Sciencies	LS-1 LS-2 LS-3 LS-4	Seven Day Dedicated Laboratory Thirty Day Didicated Laboratory Carry-on Mini Laboratory Bio-Research Module
Space Technology	ST-1 ST-2 ST-3 ST-4	ATL Payload #1 ATL Payload #2 ATL Payload #3 Physics and Chemistry Lab

TABLE 2.3-2. 1973 SORTIE LAB PAYLOADS

payloads which are specifically designed to be operated in the pallet-only mode (or some non-Sortie Lab configuration e.g., Free Flyer), whereas the 1972 data included only those payloads which required, in general, significant amounts of pressurized volume. Table 2.3-3 presents a correlation of the 1972 and 1973 payloads. Analysis indicates that, in general, there are no major features of the 1973 data which would preclude the baseline Sortie Lab from satisfying the 1973 requirements.

1973 PAYLOADS	1972 PAYLOADS INCLUDED	MODIFIED 1972 PAYLOADS	NEW
HE-1	SP10	——	——
HE-2	——	——	X
SO-1	A1, A2	A7	——
SO-2	——	——	X
SO-3	——	A2	——
SO-4	A2	——	X
SO-5	A2, A6	A7	——
AP-1	SP-5-SP9	——	——
SER	——	——	——
ST-1	SP14, T3 MS1,CN1 T4	——	——
ST-2	SP4-SP5,SP14,T3,MS1,CN1,EO1	——	——
ST-3	MS1,CN1	——	——
ST-4	SP12,SP13	——	——
CNRL	CN-1	——	——
SPA-1	MS1	——	——
SPA-2	MS4	——	——
SPA-3	MS3	——	——
SPA-4	MS2	——	——
SPA-5	(Core equipment)	——	X
SPA-6	(Pallet mission)	——	X
LS-1	7 day Mission	LS2	——
LS-2	30 day Mission	LS3	——
LS-3	carry-on	LS1	——
LS-4	(BRM)	——	X
EO-1	EO1-EO6	——	——
EO-2	EO7-EO9	——	——
EOP-1	EO1-EO6,CN1	——	——
AS-1	A4,P1,A6	——	——
AS-2	P1	A5	——
AS-3	——	SP2	——
AS-4	——	SP3	——

TABLE 2.3-3. CORRELATION OF 1972 PAYLOAD DATA WITH 1973 PAYLOAD DATA

2.3.2 Payload Requirements

The payload requirements reflect not only what is necessary to accomplish the scientific or applications objective but also requirements that can be derived from these basic requirements. The former of these requirements are weight, volume, average power, duration per cycle, cycles per mission, peak power, peak duration per cycle, peaks per mission, digital data rate, number of skills, EVA hours, pointing accuracy, stability and g-level. The latter, "derived" requirements, include accommodation mode, digital data per day and manhours per day.

Table 2.3-4 summarizes the payload power requirements. Weight requirements for selected experiments used in the longitudinal center of gravity analysis are found in Section 2.6. Manhours per day and data requirements are found in Section 4.0. Other mission requirements are summarized in Section 5.0.

A brief description with general requirements of each of the disciplines previously shown in Table 2.3-1 follows.

2.3.2.1 Astronomy

These payloads are designed to gather data on interstellar space, stars, quasars, the sun and other planets, and other galaxies. The primary requirements are to have the payloads outside the earth's atmosphere, maximize the "dark time" in orbit and minimize earth-sun-moon interference with viewing. Since most scientific direction must be from the ground, excellent communications are necessary. Additional requirements are for a highly stable and pointable platform with no contamination to affect the sensors.

2.3.2.2 Space Physics

The major objectives of this discipline are to improve understanding of the earth's space environment; and, through observations of gamma, cosmic and x-rays, to further the understanding of the energetic processes within or near compact objects and in the diffuse matter between these objects. The orbit must be above the atmosphere, but the

PAYLOAD	PEAK POWER KW	DURATION PER CYCLE HRS	PEAK PER MISSION	AVG. POWER KW	DURATION HRS/DAY	CYCLES PER DAY
A-1	.47	Seconds	Note 1	.45	18.8	4
A-2	.76	.05	Note 1	.66	16.2	6
A-3	.51	.02	96	.47	19.2	16
A-4	.76	.75	NA	.76	24	8
A-5	.76	.05	96	.66	14.4	16
A-6	.46	.25	NA	.42	16	16
A-7	None	None	None	.65	24	16
C/N-1	7.5	.15	5	3.6	12	NA
EO-1	4.3	msecs	10-50	3.4	.5-2.5	2-10
EO-2	5.7	msecs	10-35	4.8	.8-2.8	2-7
EO-3	3.8	msecs	25-30	3.0	1.0-1.2	5-6
EO-4	5.7	msecs	15-35	4.8	.75-1.75	3-7
EO-5	5.4	msecs	10-15	4.6	.10-.15	2-3
EO-6	3.1	msecs	20-50	2.6	1.0-2.5	4-10
EO-7	.2	1.0	24-48	.15	12-24	4-8
EO-8	.1	1.0	36-72	.15	12-24	6-12
EO-9	.1	1.0	36-72	.15	12-24	6-12
MS-1	None	NA	NA	1.63	9	3
MS-2	3.2	.5	60	1.73	8	4
MS-3	1.6	.5	48	1.63	14	4
MS-4	1.43	.4	24	2.73	24	3
P-1	.51	1.0	18	.49	22.5	3
SP-1	1.14	1 msec	4.3×10^3	.69	24	Cont.
SP-2	4	.28	10	1.6	2	2.0
SP-3	.06	1.0	5	.009	22.4	Cont.
SP-4	1.14	1 msec	2.9×10^5	.46	16	Cont.
SP-5	.44	16.0	1	.44	16	1.0
SP-6	.41	.5	4	.41	12	1.0
SP-7	.62	4.0	2	.88	16	1.0
SP-8	.56	.3	1	.56	8	Cont.
SP-9	.77	.3	1	.77	8	Cont.
SP-10	.10	120	1	.10	23.2	Cont.
SP-11	.44	.16	2	.014	23.6	Cont.
SP-12	.27	.1	10	.017	10	Cont.
SP-13	.51	.1	25	.19	10	Cont.
SP-14	2.62	.5	15	.45	9	Cont.
T-1	.82	1.0	4	.47	24	Cont.
T-2	Combined with T-1					
T-3	4.0	6/day	TBD	1.33	24	Cont.
T-4	1.2	.033	TBD	.04	24	Cont.
T-5	.5	.002	TBD	.17	24	Cont.
T-6	1.8	.1	TBD	.89	24	Cont.
T-7	.37	7.5	2	.33	TBD	NA
T-8	.40	9.0	2	.33	TBD	NA
T-9	.77	.5	TBD	.44	5	2

NOTE: 1. 16,488-2,748
NA = Not Applicable

TABLE 2.3-4. POWER REQUIREMENTS FROM 1972 EXPERIMENTS PAYLOAD DEFINITION

Van Allen radiation belts must be avoided. Altitudes may range from 100 to 350 n.mi.. Some of the instrumentation requires a low inclination orbit to avoid the South Atlantic Anomaly while other experiment objectives can only be accomplished with high inclinations.

2.3.2.3 Planetary

The purpose of the planetary discipline is to develop a space telescope that will be devoted to observing planets, comets, and asteroids. The emitting, reflecting and scattering properties of the planetary surfaces and atmospheres in the visible, UV, and IR regions will be used to make synoptic meteorological measurements of entire hemispheres over long intervals of time. These time intervals do not have to be continuous but should be periodic.

2.3.2.4 Earth Observations

This series of missions is designed to increase understanding of the earth and its atmosphere. Orbit altitude may vary over a range from 100 to 300 n.mi. depending on the sensors and specific mission objectives. Inclination is also dependent on mission objectives; the higher the latitude of the sites being observed, the higher the inclination must be. Payloads may be either automated or man operated, but in either mode some real time communication will probably be required. Other factors which may require consideration are lighting constraints and sensor pointing accuracy and stability.

2.3.2.5 Materials Science

This group of experiments is designed to take advantage of the unique environment of space flight to define and improve materials processing methods and technology. There are no orbital requirement constraints applicable to this set of experiments except that as near zero - g as possible be provided.

2.3.2.6 Communication/Navigation Early Lab

The goals of this Communications/Navigation Early Lab are to facilitate continued and expanded application of space technology and satellite systems. Man's unique capabilities as a research scientist in space may be used to provide for increased national and international needs for communications with and between earthbound, airborne, and space-borne terminals, and to improve continually the capabilities for terrestrial, air, and space vehicle navigation and traffic control.

Orbit selection will be determined by sites to be viewed and desired frequency of sightings. Man-in-the-loop will permit improved efficiency, progress monitoring, data evaluation and redirection or termination for optimum results.

2.3.2.7 Life Sciences

Specific areas to be investigated include Biomedicine, Vertebrate Research, Man/Systems Integration, Space Biology, and Advanced Technology (Life Support and Crew Protective Technology, EVA Technology and Teleoperator Technology). The experiments may be flown either on dedicated missions or as "flights-of-opportunity." The only real requirement is that the acceleration level not exceed 10^{-5}g.

2.3.2.8 Technology

The technology discipline can be divided into two basic experiment groups: contamination experiments and fluid management experiments.

The objectives of the contamination experiments, in general, are three-fold:

a. To identify the types, quantities, spatial distributions, and effects of contaminants in the spacecraft-induced external environment.

b. To provide operational support to the manned earth orbital experiment program.

c. To develop the design data needed to control or eliminate contamination effects on future spacecraft and instruments.

The overall goals and objectives of the fluid management experiments are to investigate those fluid phenomena which are greatly affected by gravity. Performing these tests in space utilizing the long-term zero-g or very low-g levels will provide a better basic understanding of fluid physical behavior, and will provide information required for the design of the next generation life support, space propulsion and other fluid systems.

2.3.3 Mission Requirements

One of the first steps taken in mission planning is to translate the mission/experiment objectives proposed for Sortie Lab into a set of parameters which can be selected to satisfy these objectives. This set of parameters are associated with orbit selection, attitude requirements, communications and others.

2.3.3.1 Orbit Requirements

Payload altitude and inclination requirements are presented in Table 2.3-5.

2.3.3.2 Attitude Requirements

The attitude requirements range from continuous inertial for celestial observations, to intermittent local attitudes for earth observations and communications, to that which provides a g-level lower than 10^{-4} specified for the materials science discipline. For example, in general, solar targets require a continuous Z-POP inertial attitude (Z-axis perpendicular to the orbit plane). Sensor gimballing will accommodate β angle variations -- β defined as the angle between the orbit plane and the solar vector. (At $\beta = 90^{\circ}$ sensor viewing will be along Shuttle Z-axis). Other specified celestial targets can require either an X, Y, or Z-POP inertial orientation depending upon the orbit plane/target relationship established at launch. For instance, a Z-POP attitude has been established for the planetary mission.

PAYLOAD	ALT (NMI x 10^2)		INCLINATION (DEG)	
	ACCEPT	PREFERRED	ACCEPT	PREFERRED
ASTRONOMY				
1	2-4	2.5	66.5-90	Cont. Sun
2	2-4	2.5	66.5-90	Cont. Sun
3	2.5-3.6	2.7	Any	Any
4	2-4	2.5-3.6	Any	Any
5	2.5-4	2.5	25-70	28.5
6	1-4	2-3	Any	28.5-50
7	2-4	2.7	Any	Cont. Sun
COMMUNICATIONS NAVIGATION				
1	1.2-4.2	48	N/A	
EARTH OBSERVATIONS				
1	1-2.7	1.0	50	90
2	1-2.7	1.0	50	90
3	1-2.7	1.0	40	70
4	1-2.7	1.0	50	90
5	1-2.7	1.0	40	70
6	1-2.7	1.0	50	90
7	>1.0	2.35	Any	Any
8	>1.0	2.35	Any	Any
9	>1.0	2.35	Any	Any
MATERIALS SCIENCE AND MANUFACTURING IN SPACE				
1	Any	Any	Any	Any
2				
3				
4				
PLANETARY				
1	2.5-5	≥ 3.25	Any	81

PAYLOAD	ALT (NMI x 10^2)		INCLINATION (DEG)	
	ACCEPT	PREFERRED	ACCEPT	PREFERRED
SPACE PHYSICS				
1	>1.0	>1.0	55-90	Polar
2	>1.0	>1.0	Any	Any
3	>1.0	>1.5	Any	Any
4	>1.0	>2.0	Any	Any
5	>1.0	>1.0	28.5-90	>55
6	>1.0	>1.0	28.5-90	>55
7	>1.0	>2.0	≥ 55	90
8	>1.0	>2.0	≥ 55	90
9	>1.0	>2.0	≥ 55	90
10	Any	Low	Any	28
11	2.7	2.0	55	28.5
12	>1.0	TBD	55	Any
13	>1.0	TBD	55	Any
14	>1.0	TBD	55	Any
TECHNOLOGY				
1	Any	NA	Any	Any
2	Any	NA	Any	Any
3	Any	NA	Any	Any
4	Any	NA	Any	Any
5	Any	NA	Any	Any
6	Any	NA	Any	Any
7	Any	NA	Any	Any
8	Any	NA	Any	Any
9	Any	NA	Any	Any

TABLE 2.3-5. ORBIT REQUIREMENTS FROM EXPERIMENTS PAYLOAD DEFINITION

Missions with earth targets such as the USA and Satellite Tracking Data Network (STDN) require fine pointing with the Z-axis toward the earth only over the targets of interest. There are no payload attitude requirements during other portions of the mission. The axis system considered is one in which the X-axis lies along the vehicle axis positive out the tail, the +Y-axis points along the right wing, and the +Z-axis points out the cargo bay.

2.3.3.3 Communications Requirements

The orbiter is presently baselined to provide all communication support for the Sortie Lab and payload by sharing its voice, TV, analog, UHF, VHF, and S-band links to the STDN ground stations. Tracking Data Relay Satellites (TDRS) may be included in the communication interface network.

Maximum requirements have been summarized from a representative field of candidate Sortie Lab payloads and are listed below:

Real Time Payload Support Requirements:

- Digital — 24 MBS
- Analog — 5 MHz
- TV/Video — Color
- Voice — Duplex

Near Real Time Payload Support Requirements:

- Digital — 2.5 MBS
- Analog — 100 KHz
- TV/Video — BW/Color
- Voice — --

In general, the Sortie Lab payloads require less than 1 MBS output to the ground or TDRS.

2.3.3.4 Additional Considerations

Additional requirements may be imposed upon Sortie Lab missions such as satellite deployment, servicing, and retrieval.

Spacecraft for delivery and retrieval missions vary from small, Explorer-class satellites, to free-flying observatories, to planetary and lunar probes. Retrieval missions will allow satellites to be returned for major refurbishment or modifications. These missions may utilize the pallet only or a combination pressurized module and pallet. The pallet would serve as structural support for the payload and the pressurized module, or Orbiter cabin, and would provide support for checkout and activation.

The Sortie Lab also will be designed for man tending large automated satellites such as the Large Space Telescope (LST). It will be outfitted with equipment required to check out , activate, service, repair, or modify the element being serviced.

2.3.4 Payload Integration Equipment Requirements

Compatibility of the payloads with the basic Sortie Lab subsystems was assessed and integration/support equipment was identified. This assessment was accomplished by reviewing the payload requirements and verifying that the subsystem capabilities were adequate to satisfy those requirements. In cases where the Sortie Lab subsystem was inadequate to satisfy the payload/experiment requirements or the effects of the natural or induced environment exceeded what the experiment could stand, equipment was derived (see Table 2.3-6) to bridge the gap between basic capability and requirement. This equipment included: (1) interface or support type equipment (other than basic Sortie Lab equipment) necessary to install the experiment in the Sortie Lab or to adapt the payload/experiment to the space environment and (2) subsystem add-ons constituting additions to basic capabilities.

2.4 Sortie Lab Elements

A set of Sortie Lab elements (Figure 2.4-1) was defined for use during the Phase B study. The elements, consisting of a pressurized module and a pallet satisfied the basic study requirements, Level I guidelines, derived requirements from Task 4.1, and the interface require-

PAYLOAD DISCIPLINE	C & D Console	Film Stowage Cabinet	Vidicon System	Video Tape Recorder	Tape Recorder, Digital & Analog	Gimbal Mount (or SEPB)	Equipment Stowage Racks	Scientific Airlock	EVA Airlock	Oscilloscope	Work Bench	Viewpoint (12")	Variable Power Supply	External Contamination Monitoring	Cryogenic System (for instrument Cooling)	Chill System (Refrigerator)	Photographic Processing Lab	Cryofreezer (low temperature)	Freezer General Purpose	Vacuum Line	Isolation Bench (-10-4g)
Astronomy	X	X	X			X	X		X					X							
Solar Physics	X	X	X				X	X			X									X	X
High Energy Astrophysics	X					X	X														
Atmosphere & Space Physics	X					X	X														
Earth Observations	X	X				X	X								X						
Earth & Ocean Physics	X					X	X							X	X						
Space Processing Applications	X	X	X				X			X						X	X	X			
Communication/Navigation Lab	X	X	X	X	X	X	X					X	X								
Life Science			X		X		X		X										X		
Space Technology	X	X	X	X			X			X	X										
Planetary	X	X	X	X											X						

TABLE 2.3-6. REPRESENTATIVE PAYLOAD INTEGRATION EQUIPMENT REQUIREMENTS

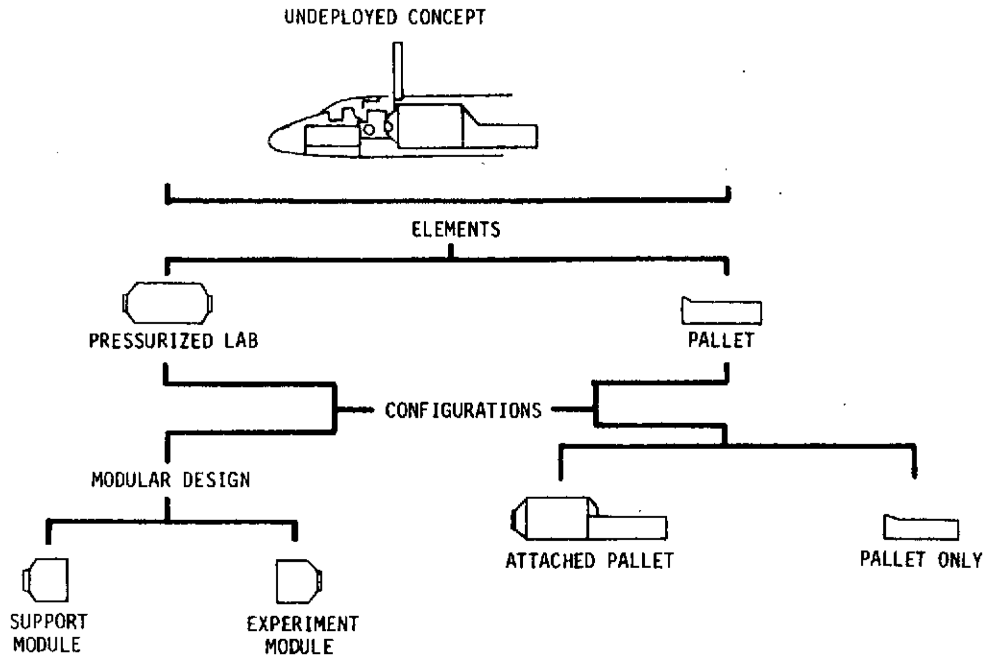


FIGURE 2.4-1. SORTIE LAB CONFIGURATION CONCEPTS

ments. This family of elements permits a variety of options dependent on annual funding level and experiment program requirements. The mounting of external equipment can be accommodated by adding a pallet, which provides the sensor-mounting area. The recommended elements and their required interfaces are summarized in the following sections.

2.4.1 System Interfaces

Interface characteristics are of vital importance since key features of the Sortie Lab configuration are based on the design and capability of the interfacing systems. The Sortie Lab mission requires that the Sortie Lab interface with many program items including the shuttle orbiter, ground facilities and payloads. There are also interface connections between the Sortie Lab elements. A summary of the interface connections for each element is presented in Section 3.5.

2.4.2 Pressurized Module

The primary purpose of the pressurized module is to provide an enclosed, protective environment for the application of scientific research. The enclosed environment permits direct involvement by principal investigators or their representatives in a shirtsleeve mode. The modules, singly or in combination, contain the subsystems necessary to maintain the habitable environment and provide direct support to experiment apparatus such as structural mounts; power; thermal control; communications; data management; and supplemental facilities such as airlocks for unique experiment requirements. Additionally, the pressurized Sortie Lab provides an interface between the payloads and shuttle orbiter. A detailed description of the pressurized module is provided in Section 3.0.

2.4.3 Pallet

The primary purpose of the pallet is to provide a mounting surface for large payloads requiring direct exposure to space and real time, manned, participation with no maintenance of the external experiment during on-orbit operation. Sortie Lab pallets are applicable either attached to a pressurized module that provides the subsystem service provisions for the pallet or in a pallet only mode where the subsystems provisions are supplied by the Shuttle. A detailed description of the pallet is provided in Section 3.3.

2.5 Summary User Provisions

2.5.1 Payload Support Equipment

In addition to the basic Sortie Lab module and pallet there is under definition special ancillary payload support equipment that can be provided as optional add-ons when required by a specific mission. This equipment includes such items as: scientific airlocks, a stable platform, a film vault, and optical windows. Any or all of this equipment can be included on any given mission depending on the specific mission requirements. Descriptions of some of these major add-on items follow.

2.5.1.1 Scientific Airlock

The airlock is intended for use in deploying experiments to the space environment. The experiments can be mounted to an experiment platform that is connected to an extension or deployment mechanism (for localized deployment out of the airlock) or to a stabilized platform that is mounted on the experiment platform. Extension mechanisms of 30 feet and 200 feet lengths are currently being evaluated. The airlock will have an approximate volume of 46 cubic feet with a 44-inch diameter and will be 52 inches in length. See Section 3.2 for further discussion of the scientific airlock.

2.5.1.2 Stable Platform

A pallet-mounted stable platform will augment the orbiter's stabilization provisions by accommodating experiments requiring high pointing accuracies and stabilities. The platform or Standard Experiment Pointing Base (SEPB) will accommodate instruments up to 85 inches in diameter and 15 feet long. The SEPB consists of a set of coarse, wide angle gimbals and a set of fine, narrow angle gimbals. The fine gimbals used in conjunction with the coarse gimbals provide a pointing accuracy capability of 1 arc second. See Section 3.3.10 for further discussion of the SEPB.

2.5.1.3 Film Vault

A radiation shielded stowage container suitable for storing exposed and unexposed film will be provided. Approximate dimensions and weight of the film vault are: volume - 7.5 cubic feet, wall thickness - 0.5 inch, and weight - 100 pounds.

2.5.1.4 Optical Windows

Several windows suitable for scientific observation will be available.

2.5.1.5 View Ports

View ports will be available in the pressurized module for viewing the pallet and experiments. One 12-inch diameter port will be located in the module's sidewall and an 8-inch port will be located in each pressure hatch.

2.5.1.6 External Contamination Monitor

A system for measuring the amount and type of contamination collection on the outside of the orbiting body will be available.

2.5.1.7 Vacuum System

A vacuum system will be available to connect instruments and/or equipment inside the pressurized module to the surrounding vacuum.

2.5.1.8 Miscellaneous

In order to effectively support a broad spectrum of scientific disciplines, certain special design features are inherent to the basic Sortie Lab concept for universal experiment payload accommodation. These features include work benches, removable equipment racks, replaceable hatches for instrument mounting, deployable booms, data processing and recording equipment, storage lockers and utility services with standardized interconnects.

2.5.2 Resources Available to Experiments

A summary of Sortie Lab resources available for experiment use is given in Table 2.5-1. Resources to maintain basic Sortie Lab functions and support are not included in the values given.

2.6 Mass Properties Summary

A weight summary of the weight baseline Sortie Lab is presented in Table 2.6-1. This particular configuration consists of a 14-foot tunnel, 5-foot sidewall Support Module (SM), 10-foot sidewall Experiment Module (EM) and 10-foot pallet. This configuration was weight tracked (compared) to the 20,000 pound Sortie Lab design weight during Phase B.

PARAMETER	PRESSURIZED MODULE	PALLET
Physical		
Payload Weight	12,000 lb (Sortie Lab pressurized and unpressurized)	20,000 lb (Pallet Only Mission)
Dimensions	14 ft	
Floor Width	11.3 ft	12 ft
Length	8.75 - 18.75 ft (EM)	5 ft and 10 ft segments. (With combinations of the 5 ft and 10 ft segments pallet lengths to 60 ft are theoretically possible.)
Environment		
Composition	80% N_2/20% O_2	
Pressure	14.7 psia	
Temperature	74 + 2° F	
CO_2 Partial Pressure	0-7.6 mm Hg (Design Req.) $\leq$3 mm Hg (Expected Nominal)	
Relative Humidity	45 $\pm$ 5% at 70° F	
Cleanliness Level	Class 100,000	
Thermal Control		Fluid lines connected to either the pressurized module or Orbiter
Heat Rejection (Total available)	4-5 kw	1 kw
Air Cooling		N/A
Cabin (70 + 10° F)	1 kw	
Racks (75 - 105° F)	3-4 kw	
Cold Plates (45 - 86° F)	4-5 kw	1 kw
Electrical Power	Derives power from the Sortie Lab fuel cell and the Orbiter. Orbiter Provisions: 3 kw av. 6 kw peak See Section 3.1.4	Derives power from either the pressurized module or the Orbiter. See Section 3.1.4
Average	4.1 kw	
Peak	6.0 kw (for 6 minutes)	
Type	28 v dc and 115 v 400 hz ac	
Total Energy Available	293 kwh	
Communications	Via Shuttle Orbiter	
Control & Monitor		Hardline to the pressurized module; TV cameras
Data Management		Serviced by the pressurized module or a payload furnished computer located in the orbiter
Computers		
Word Length	32 bits	
Memory Size	13k	
Speed	2-4 microseconds	
Data Stowage	40 reels (Digital & Video)	
Recorders		
Digital		
Response	Up to 50 mbps	
Time/Reel	30 minutes	
Data Management (Cont'd)		
Recorders (Cont'd)		
Video	Color	
Control and Display	Integrated Console	See Communications
Stabilization & Control	Accuracy / Acceleration	Accuracy / Acceleration
RCS in the orbiter	$\pm$ 0.5° / 10^{-4} g	
CMG's		$\pm$ 1 min / 10^{-5} g
Standard Experiment Pointing Base (SEPB)		
Coarse Gimbals		$\pm$ 1 min
Fine Gimbals		$\pm$ 1 sec

TABLE 2.5-1. RESOURCES AVAILABLE TO EXPERIMENTS

	Weight
Pallet (10 feet)	1407
Tunnel (14 feet)	815
Structure	
Support Module & Forward Bulkhead (7.75 feet)	2982
Experiment Module & Aft Bulkhead (12.75 feet)	3124
Environmental Control System	3139
Electrical Power System	2116
Electronics	1872
Crew Systems	685
Experiment Provisions	800
Expendables/Residuals (at landing)	843
TOTAL	17783

TABLE 2.6-1. SORTIE LAB WEIGHT SUMMARY (POUNDS)

The following items are weight charged to the 12,000 pounds Experiment Design Weight if they are required for a particular mission:

Experiment(s)

Experiment integration equipment

OMS kit(s) 1 = 2350 pounds at landing

2 = 3505 pounds at landing

3 = 4715 pounds at landing

Scientific Airlock, 350 pounds

*Crew and their equipment in excess of the 2 + 2 crew weight charged to the orbiter

*Extended mission (duration >7 days) consumables, etc.

Pallet lengths can be 10, 15, 20, 25, etc. feet, i.e., the first section is 10 feet plus a pallet adapter which overlaps the aft bulkhead of the pressurized module. The adapter can be omitted on pallet only missions. A 25-foot pallet was the maximum length required to

*See Table 2.6-2

	MISSION DURATION			
	7 Days		30 Days	
	Launch	Landing	Launch	Landing
4 Man crew (Shuttle)	-	-	2398.5	2090.9
5 Man crew (Shuttle & Sortie Lab)	517.8	498.5	3677.6	3225.6
6 Man crew (Shuttle & Sortie Lab)	1035.4	996.7	4768.4	4256.6
7 Man crew (Shuttle & Sortie Lab)	1549.9	1491.9	5789.6	5217.9
8 Man crew (Shuttle & Sortie Lab)	2068.2	1990.8	7334.6	6703.1
EVA Equipment	399.1	399.1	399.1	399.1
ECS	-	-	302.9	150.3
EPS	-	-	11924.0	4024.3

TABLE 2.6-2. WEIGHT (POUNDS) PENALTY FOR MISSIONS WITH LARGE CREWS AND EXTENDED DURATION (CHARGEABLE TO SORTIE LAB)

accommodate the 1972 experiments; pallet lengths to 60 feet are theoretically possible. Pallet weights are presented in Table 2.6-3.

The flexible tunnel, 2 to 14 feet, weighs 815 pounds. For missions requiring longer tunnels to meet orbiter longitudinal center of gravity constraints weight is added at the rate of 50 pounds per foot.

Pressurized module subsystem weights are presented in Table 2.6-4 for SM/EM combined sidewall lengths of 11, 15 and 21 feet, i.e., 5-foot SM plus 6, 10, and 6 + 10 foot EM(s).

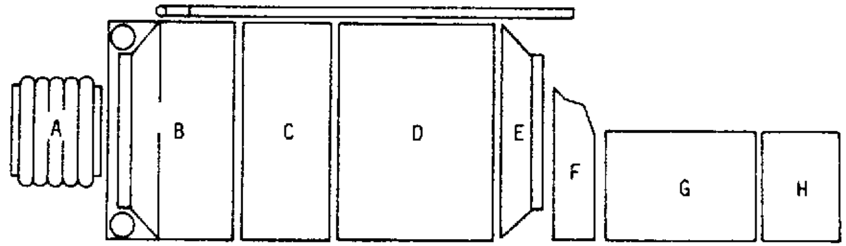
A longitudinal center of gravity (CG) analysis of the Sortie Lab in various mission configurations, utilizing the Phase B, 1972 grouping of experiments is presented in Table 2.6-5. A summary curve is presented in Figure 2.6-1 in which all payloads are plotted against the 2 percent orbiter CG curve (65 to 67 percent spread) as reported in specification JSC 07700, Volume X, "Space Shuttle Flight and Ground System Specification," dated March 20, 1973. In this analysis, each Sortie Lab configuration is positioned as far aft as possible and a tunnel long enough

PALLET LENGTH (FT)	10	15	20	25
PALLET WT. (LBS)	1407	1970	2533	3096

TABLE 2.6-3. PALLET WEIGHT SUMMARY

	WEIGHT (POUNDS) FOR EX/SUPT MODULE LENGTHS OF		
	11 FT.	15 FT.	21 FT.
Structure	5113	6106	7722
ECS	2952	3139	3418
EPS	2116	2116	2116
Electronics	1872	1872	1872
Crew Systems	685	685	685
Expt. Provisions	800	800	800
Expend/Residuals at Landing	789	843	922
	14,327	15,561	17,535

TABLE 2.6-4. EXPERIMENT MODULE/SUPPORT MODULE WEIGHTS



UNIT	FLEX TUNNEL	SUPPORT MODULE (SM)	EXPERIMENT MODULES (EM)		AFT BKHD	ADAPTER	PALLET	
LENGTH (FT)	2-14	7.75	6	10	2.75	OVERLAP	10	5
WEIGHT (LB)	815	11849(0'EM) 12196(6'EM) 12437(10'EM) 12795(16'EM)	1681	2674	450	263	1144	563

PAYLOAD	SORTIE LAB WEIGHT (LB)	SORTIE LAB X (FT)	CG CURVE MARGIN WEIGHT (LB)	CG CURVE MARGIN X (FT)	TOTAL L (FT)	EXPERIMENT INT (LB)	EXPERIMENT EXT (LB)	PALLET LENGTH (FT)	MODULES	CONFIGURATION
E07A	16113.	33.94	26770.	12.06	60.0	200.	0.	0.00	25 8 11 32	AABCE
E08A	16113.	33.94	26770.	12.06	60.0	200.	0.	0.00	25 8 11 32	AABCE
E09A	16113.	33.94	26770.	12.06	60.0	200.	0.	0.00	25 8 11 32	AABCE
LS1	27282.	37.57	37718.	7.78	60.0	10135.	0.	0.00	25 9 12 31	AABDE
LS2	24376.	38.49	40624.	10.06	60.0	5255.	0.	0.00	25 10 13 30	AABCDE
MS1	19535.	35.75	37630.	10.49	60.0	2388.	0.	0.00	25 9 12 31	AABDE
MS2	22168.	37.83	42832.	10.67	60.0	3047.	0.	0.00	25 10 13 30	AABCDE
MS3	21866.	37.73	43134.	10.76	60.0	2745.	0.	0.00	25 10 13 30	AABCDE
MS4	19021.	35.58	36383.	10.75	60.0	1874.	0.	0.00	25 9 12 31	AABDE
SP10	16014.	33.90	26643.	12.14	60.0	101.	0.	0.00	25 8 11 32	AABCE
SP14	16526.	34.10	27295.	11.73	60.0	613.	0.	0.00	25 8 11 32	AABCE
A1	29079.	38.16	35921.	7.66	60.0	429.	10500.	20.00	5 8 11 16	AABCEFGHH
A4A	25646.	40.11	39354.	11.05	60.0	426.	7900.	10.00	25 8 11 14 30	AABCEFG
A6	19264.	32.18	15261.	7.14	60.0	364.	750.	20.00	5 8 11 16	AABCEFGHH
A7A	30299.	35.26	22113.	4.33	60.0	346.	11490.	25.00	2 8 11 17	AABCEFGHHH
E01	24246.	31.14	6716.	2.78	60.0	2976.	2086.	20.00	3 9 12 16	AABCEFGHH
E02	24773.	30.90	5454.	2.26	60.0	3877.	1712.	20.00	3 9 12 16	AABCEFGHH
E03	23269.	34.15	20921.	6.33	60.0	3413.	985.	15.00	23 9 12 15	AABDEFGH
E04	24706.	30.91	5559.	2.31	60.0	3787.	1735.	20.00	3 9 12 16	AABDEFGHH
E05	24201.	30.69	5439.	2.36	60.0	3540.	1477.	20.00	3 9 12 16	AABDEFGHH

TABLE 2.6-5. LONGITUDINAL CENTER OF GRAVITY ANALYSIS

PAYLOAD	SORTIE LAB WEIGHT (LB)	SORTIE LAB X (FT)	CG CURVE MARGIN WEIGHT (LB)	CG CURVE MARGIN X (FT)	TOTAL L (FT)	EXPERIMENT INT (LB)	EXPERIMENT EXT (LB)	PALLET LENGTH (FT)	MODULES	CONFIGURATION
E06	23495.	26.52	-2276.	-1.42	60.0	2910.	1088.	25.00	21 9 12 17	ABDEFGHHH
SP1	19594.	37.12	45406.	11.81	60.0	397.	639.	10.00	24 9 12 14	AABDEFG
SP2	19278	36.77	45722.	11.72	60.0	487.	233.	10.00	24 9 12 14	AABDEFG
SP3	18999.	36.58	46001.	11.77	60.0	366.	75.	10.00	24 9 12 14	AABDEFG
SP4	19121.	36.71	45879.	11.79	60.0	353.	210.	10.00	24 9 12 14	AABDEFG
SP5	17898.	35.69	38565.	11.88	60.0	3.	575.	10.00	25 8 11 14 30	AABCEFG
SP6	19609.	36.80	45391.	11.48	60.0	912.	139.	10.00	24 9 12 14	AABDEFG
SP7	17724.	35.54	37243.	11.90	60.0	4.	400.	10.00	25 8 11 14 30	AABCEFG
SP8A	19124.	35.88	39336.	10.95	60.0	1404.	400.	10.00	25 8 11 14 30	AABCEFG
SP9A	17964.	35.48	36447.	11.61	60.0	444.	200.	10.00	25 8 11 14 30	AABCEFG
SP12	24830.	40.66	40170.	12.00	60.0	838.	5434.	10.00	24 9 12 14	AABDEFG
SP13	24970.	40.67	40030.	11.94	60.0	978.	5434.	10.00	24 9 12 14	AABDEFG
T1/2	22195.	33.41	17768.	6.23	60.0	1146.	191.	10.00	7 26 9 12 14	(DM)AABDEFG
T3	31339.	36.39	33342.	5.12	60.0	1250.	10905.	20.00	3 9 12 16	AABDEFGHH
T5	23728.	37.71	41272.	9.63	60.0	5090.	80.	10.00	24 9 12 14	AABDEFG
T6	21352.	36.65	43648.	10.02	60.0	2110.	1405.	15.00	6 8 11 15	AABCEFGH
T7	26048.	28.32	-1866.	-0.92	60.0	1538.	1490.	15.00	7 27 10 13 15	(DM)ABCDEFGH
T8	28820.	30.64	663.	0.24	60.0	1552.	4248.	15.00	7 27 10 13 15	(DM)ABCDEFGH
T9	19789.	36.40	45117.	10.94	60.0	600.	1352.	15.00	6 8 11 15	AABCEFGH
A2	32880.	39.52	32120.	7.78	60.0	450.	14280.	20.00	5 8 11 16	AABCEFGHH
A3PA	30892.	31.77	2111.	0.64	60.0	430.	10900.	15.00	22 8 11 15 18	ABCEFGH(OMS)
A4P	27371.	30.65	2151.	0.82	60.0	426.	7900.	10.00	4 8 11 14 30 18	AABCEFG(OMS)
A5PA	28217.	30.99	2266.	0.82	60.0	430.	8225.	15.00	22 8 11 15 18	ABCEFGH(OMS)
A7P	31398.	31.93	2203.	0.65	60.0	346.	11490.	15.00	22 8 11 15 18	ABCEFGH(OMS)
P1PA	43458.	34.15	674.	0.10	60.0	429.	23467.	15.00	22 8 11 15 18	ABCEFGH(OMS)
SP8P	20849.	27.72	2253.	1.45	60.0	1404.	400.	10.00	4 8 11 14 30 18	AABCEFG(OMS)
SP9P	19689.	27.62	3234.	2.23	60.0	444.	200.	10.00	4 8 11 14 30 18	AABCEFG(OMS)
E07P	17838.	26.71	3647.	2.96	60.0	200.	0.	0.00	4 8 11 32 18	AABCE(OMS)
E08P	17838.	26.71	3647.	2.96	60.0	200.	0.	0.00	4 8 11 32 18	AABCE(OMS)
E09P	17838.	26.71	3647.	2.96	60.0	200.	0.	0.00	4 8 11 32 18	AABCE(OMS)

TABLE 2.6-5. LONGITUDINAL CENTER OF GRAVITY ANALYSIS (CONTINUED)

MODULE	WEIGHT (LB)	X (FT)	LENGTH (FT)
2 Flex Tunnel	1040.0	9.250	18.500
3 Flex Tunnel	1090.0	9.750	19.500
4 Flex Tunnel	961.0	8.458	16.917
5 Flex Tunnel	1290.0	11.750	23.500
6 Flex Tunnel	1540.0	14.250	28.500
7 Docking Module	2700.0	3.083	8.000
8 Supt Mod,UNDPL 6	12196.0	5.650	7.750
9 Supt Mod,UNDPL 10	12437.0	5.912	7.750
10 Supt Mod,UNDPL 16	12795.0	6.440	7.750
11 6 Ft Exp Mod	2131.0	4.088	8.750
12 10 Ft Exp Mod	3124.0	6.095	12.750
13 16 Ft Exp Mod	4740.0	9.018	18.750
14 10 Ft Pallet	1407.0	4.184	10.000
15 15 Ft Pallet	1970.0	6.560	15.000
16 20 Ft Pallet	2533.0	8.992	20.000
17 25 Ft Pallet	3096.0	11.448	25.000
18 OMS Kit No 1	2350.0	53.750	12.500
21 Flex Tunnel	840.0	7.250	14.500
22 Flex Tunnel	915.0	8.000	16.000
23 Flex Tunnel	1340.0	12.250	24.500
24 Flex Tunnel	1590.0	14.750	29.500
25 Flex Tunnel	1586.0	14.708	29.417
26 Flex Tunnel	1190.0	10.750	21.500
27 Flex Tunnel	815.0	5.250	10.500
28 Flex Tunnel	815.0	3.500	7.000
30 Radiator Overhang	0.0	2.000	4.083
31 Radiator Overhang	0.0	5.000	10.083
32 Radiator Overhang	0.0	7.000	14.083

TABLE 2.6-5. LONGITUDINAL CENTER OF GRAVITY ANALYSIS (CONTINUED)

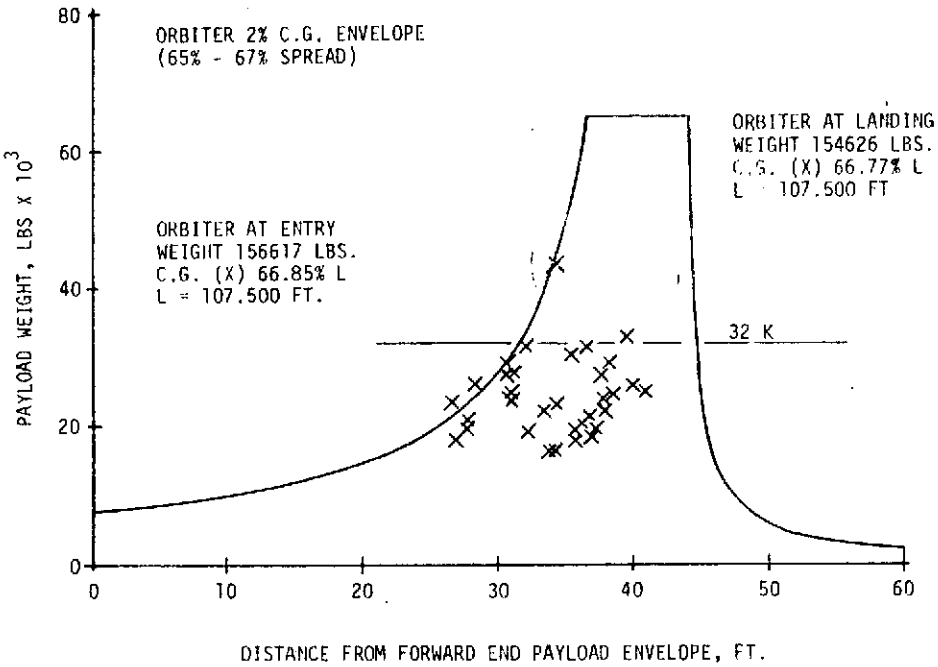


FIGURE 2.6-1. SORTIE LAB CENTER OF GRAVITY

to reach the SM is provided. In some cases the radiator overhang limits positioning of the Sortie Lab aft in the bay. The baseline radiator is 26 feet long and measures 22.83 feet from the aft end of the SM (no aft bulkhead). As the experiment payloads become more firmly defined additional CG analyses will be necessary and requirements will be imposed to assure that all payloads fall within the CG constraints.

Mass properties of individual modules are summarized in Table 2.6-6.

For module mass properties accounting purposes, the EM(s) and aft bulkhead consist of structure only. All other subsystems weight is accounted for in the SM (Table 2.6-6). The following are those items on or in the EM(s) and/or aft bulkhead, which are weight charged to the SM.

	6'EM + BHD	10'EM + BHD	16'EM + BHD
Thermal coating & insulation	178 lb	263 lb	388 lb
ECS ducting	112 lb	185 lb	296 lb
Misc. supports	122 lb	203 lb	325 lb
	412 lb	651 lb	1009 lb

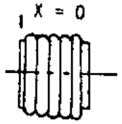
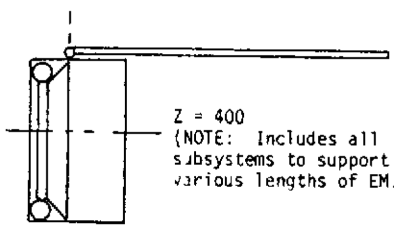
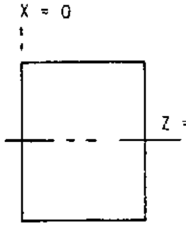
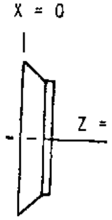
MODULE	DESCRIPTION	WEIGHT (LBS)	CENTER OF GRAVITY INCHES X	Y	Z	MOMENT OF INERTIA SLUG - FT^2 I_X	I_Y	I_Z
 X = 0 Z = 400 (NOTE: Basic tunnel length is 14 Ft. Add 50 pounds/foot for additional tunnel lengths.)	* Tunnel - 2 Ft - 14 Ft - 20 Ft - 30 Ft	815.0 815.0 1115.0 1615.0	12.0 84.0 120.0 180.0	0.0 0.0 0.0 0.0	400.0 400.0 400.0 400.0	171.1 171.1 234.0 339.0	94.0 499.0 1272.2 3934.2	94.0 499.0 1272.2 3934.2
 X = 0 Z = 400 (NOTE: Includes all subsystems to support various lengths of EM.)	Support Module (0' EM) Support Module (6' EM) Support Module (10' EM) Support Module (16' EM)	11849 12196 12437 12795	32.5 34.8 37.9 44.3	0.2 0.2 0.2 0.2	403.6 403.5 403.4 403.3	12871.0 13209.0 13443.0 13790.0	12541.0 12700.0 12810.0 12973.0	11865.0 12023.0 12132.0 12295.0
 X = 0 Z = 400 (NOTE: Structure only.)	Exp. Module - 6 Ft Exp. Module - 10 Ft Exp. Module - 16 Ft	2131 3124 4740	49.0 73.1 108.2	0.0 0.0 0.0	382.0 379.6 375.9	2251.0 3345.0 5198.0	1425.0 2750.0 6427.0	1611.0 3092.0 6973.0
 X = 0 Z = 400	Aft Bulkhead	450	18.0	0.0	400.0	290.0	148.0	148.0

TABLE 2.6-6. MASS PROPERTIES STATUS

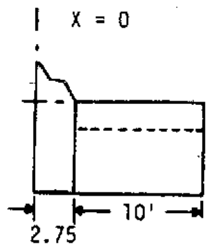
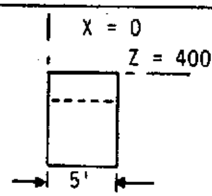
MODULE	DESCRIPTION	WEIGHT (LBS)	CENTER OF GRAVITY INCHES			MOMENT OF INERTIA SLUG - FT^2		
			X	Y	Z	I_X	I_Y	I_Z
 (NOTE: Pallet includes weight of overlap.)	Pallet - 10 Ft	1407	49.2	0.0	353.3	913.0	1143.0	1325.0
	Pallet - 5 Ft	563	30.0	0.0	352.9	354.0	175.0	238.0
* For variable lengths of tunnel over 14 feet. L = Total length - Ft W = 115 + 50(L) Lbs I_x = .209907(W) Slug - Ft^2 $I_y = I_z = \frac{W(486.25 + 12L^2)}{4633}$ Slug - Ft^2								

TABLE 2.6-6. MASS PROPERTIES STATUS (CONTINUED)

3.0 CONFIGURATION DEFINITION

The autonomous Sortie Lab design study concluded with a definition of a family of Sortie Lab elements that were fully responsive to the study requirements. The elements consist of a pressurized module and a pallet. The pressurized elements are: (1) flexible tunnel, (2) variable length experiment module (3) a 5.0-foot support module and (4) two 2.75-foot bulkheads. The addition of a variable length structural pallet provides a mounting area to accommodate externally mounted payloads.

The MSFC Phase B concept of the Sortie Lab is basically a self- sufficient system with minimum shuttle interface to minimize shuttle refurbishments costs and recycle time. Some of the orbiter capability, however, is used by the Sortie Lab. This includes the crew seats and restraints during boost and entry, sleeping accommodations, food and hygiene facilities for two payload crewmen, and communication and electrical power resources.

Descriptions of the Sortie Lab family elements, (pressurized and unpressurized) resulting from the design study effort are described in this section.

Major features are:

a. A 14-foot-diameter pressure shell variable in overall length.

b. Subsystems that provide essential resources for the crew and experiment payload.

c. An interior arrangement consisting of a control and display console for management of subsystem and selected experiments and provisions for easy installation and removal of experiment equipment peculiar to each payload.

d. Provisions for interfaces with the orbiter and shuttle ground support facilities.

e. A removable bulkhead, which can be removed for installing experiments, or replaced by special bulkheads for external experiment sensors.

The general arrangment of the Sortie Lab is presented in Figure 3.0-1. Sortie Lab characteristics for a typical payload are listed in Table 3.0-1.

3.1 Support Module Definition

3.1.1 Configuration

The support module's primary structure consists of a 14 foot diameter, constant-section cylinder 5 feet in length. A 32-degree conical bulkhead is attached at the forward end of the cylinder. The forward conical section is mated to a flexible crew transfer tunnel that forms the physical interface with the orbiter. A 40-inch diameter hatch is located at the forward bulkhead and crew tunnel interface and opens inward. Atmospheric storage bottles are located around the forward conical section (Figure 3.1-1). Located within the forward skirt, are two cryogenic oxygen tanks, three cryogenic hydrogen tanks, 2 nitrogen gas tanks, one fuel cell, fuel cell ancillary equipment, thermal control components and an interface panel (see Section 3.1.4). Attached at the forward bulkhead and cylinder intersection is a 26-foot deployable radiator. The forward conical bulkhead is penetrated by fuel cell cabling, forward external control and monitor circuit, thermal control fluid lines, and the cabin atmosphere relief and vent valve.

External to the constant-diameter section of the support module is protective insulation and a meteoroid bumper.

The internal features of the support module are styled by the horizontal floor arrangement. The floor location is 44.00 inches below the vehicle horizontal centerline. The interior floor is the primary and direct structural interface with most of the internal subsystems and experiment equipment.

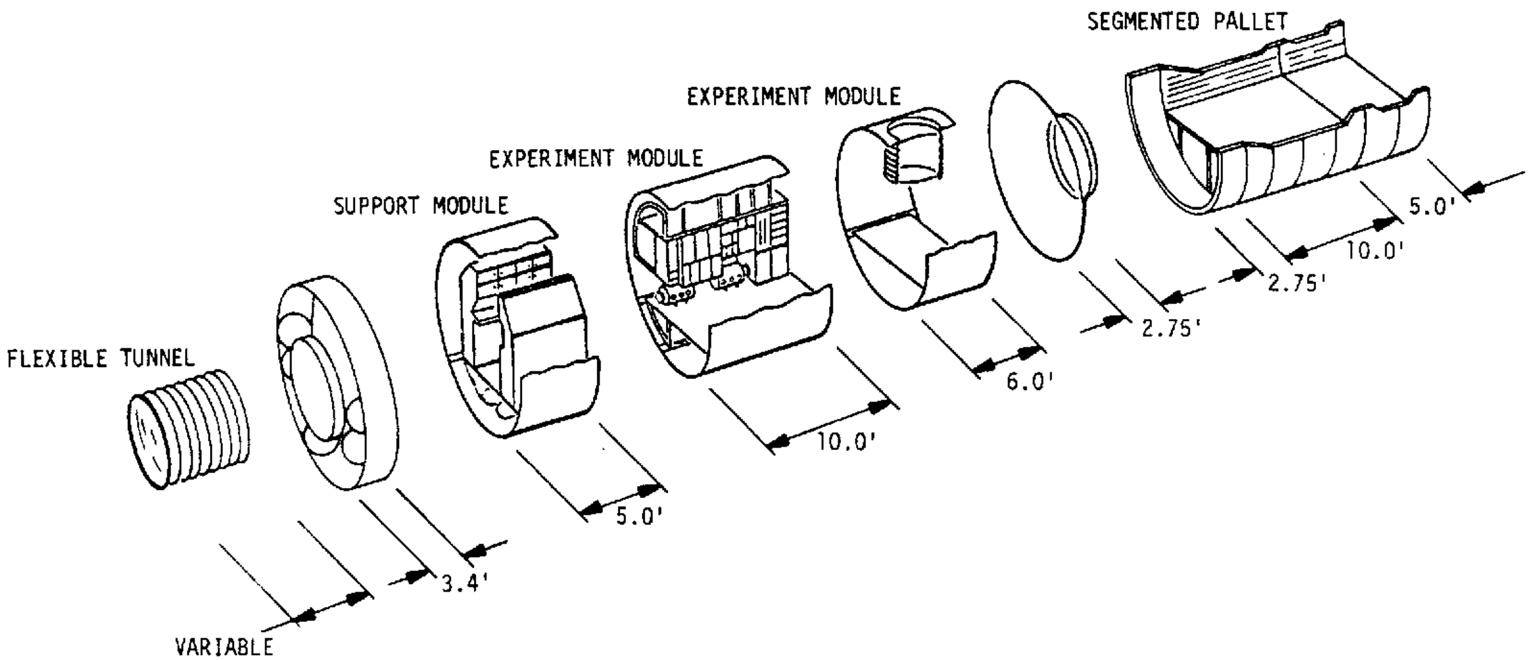


FIGURE 3.0-1. SORTIE LAB CONFIGURATION

OVERALL LENGTH	253.8 in. (21.1 ft.)
CONSTANT SECTION SIDE WALL LENGTH	180.0 in. (15.0 ft.)
INTERNAL DIAMETER, PRESSURE SHELL	162.0 in. (13.5 ft.)
EXTERNAL DIAMETER	168.0 in. (14.0 ft.)
INTERNAL VOLUME	2488 ft^3
FLOOR ARRANGEMENT	LONGITUDINAL
SUPPORT FITTINGS (QUANTITY)	3
HATCHES	2 AT 39.0 in. DIA
VIEWPORTS	1 AT 12.0 in. DIA IN SIDEWALL 2 AT 8.0 in. DIA IN HATCH
CREW COMPLEMENT	6 MAX
MISSION DURATION	7 DAYS NOMINAL
ELECTRICAL POWER SYSTEM	
POWER SOURCE	1-7 KW CONT DUTY FUEL CELL
LO_2 TANKS, 26.5 in. O.D.	2-SHARED WITH LIFE SUPPORT
LH_2 TANKS, 31.8 in. O.D.	3
DISTRIBUTION VOLTAGE	28 VDC; 115 VAC, 400 HZ
COMMUNICATIONS	SHUTTLE PROVIDED
DATA MANAGEMENT SYSTEM DATA HANDLING	TAPE RECORDING
ENVIRONMENTAL CONTROL SYSTEM	
ATMOSPHERE PRESSURE	14.7 PSIA; pp O_2 3.1 PSIA
pp CO_2	$\leq$3 mm HG
ATMOSPHERE TEMPERATURE	SELECTABLE
WASTE WATER TANKS	1
H_2O BY-PRODUCT STORAGE TANKS	1
N_2 TANKS 25.3 in. O.D., 3000 PSIA	2
CO_2 REMOVAL	LiOH
THERMAL CONTROL SYSTEM	
EXTERNAL LOOP	FREON 21
INTERNAL LOOP	H_2O
EQUIPMENT COOLING	AIR
RADIATOR AREA	750 ft^2
COOLING CAPACITY, RADIATOR	29.200 BTU/HR MAX
PRELAUNCH & POST LANDING	GSE
CONTROLS AND DISPLAYS CONSOLE	INTEGRATED CONSOLE
HABITABILITY	SHUTTLE PROVIDED
WEIGHT	22,173 LBS

TABLE 3.0-1. PRESSURIZED MODULE CHARACTERISTICS FOR EXPERIMENT EO-4

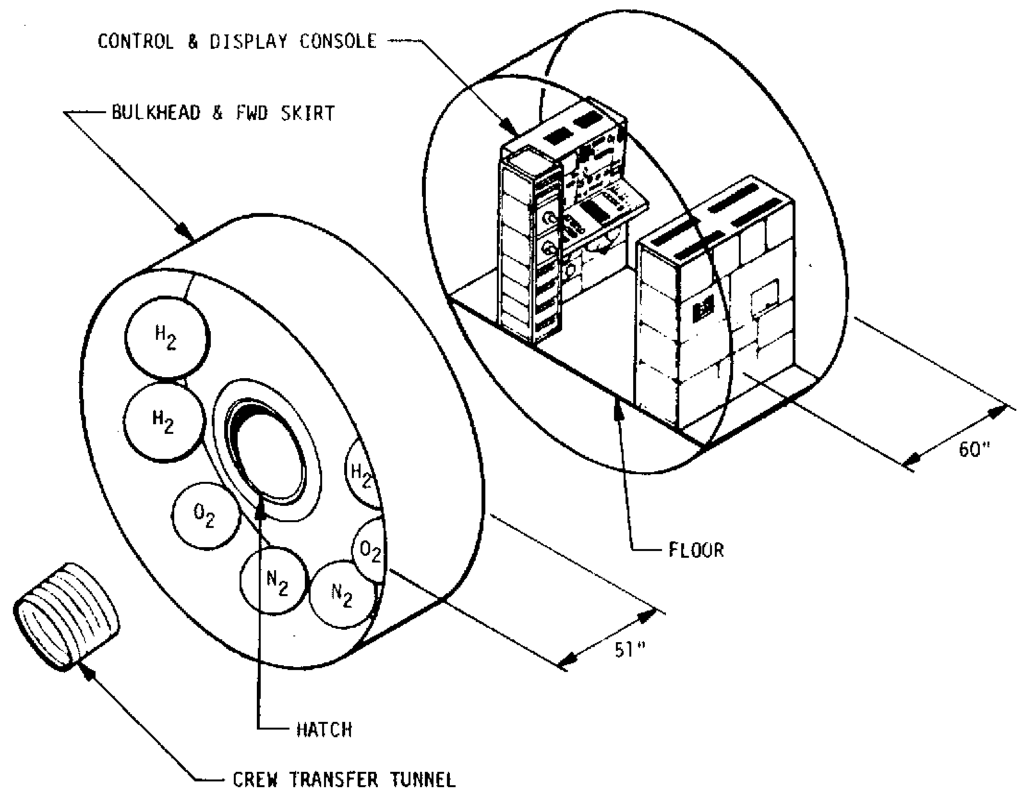


FIGURE 3.1-1. SORTIE LAB SUPPORT MODULE

The ECS subsystem and ducting influence the internal arrangement. The active components are located radially around the pressure shell, with supply ducting routed around the side of the cylindrical section and then rearward with return ducting under the floor.

The major equipment items (exclusive of experiment payloads) are the control and display console, components of the communication and data system, atmosphere regulation and control components, water stowage tank, and the electrical power subsystem.

3.1.2 Structure

The support module is the forward 5 feet of the pressurized module. It is a metal structure of 2219 Al alloy. The principal sections of the structure are the flexible crew transfer tunnel, forward skirt, conical bulkhead, and the cylindrical section.

3.1.2.1 Flexible Crew Transfer Tunnel

The flexible crew transfer tunnel (Figure 3.1-2 and 3.1-3) is an inflatable cylindrical structure with envelope dimensions as shown in Figure 3.1-4. A system of cables and tension rings (Figure 3.1-5) are incorporated to maintain tunnel stability. End plates or bulkheads at the ends of the tunnel provide support points for the cable pulleys and serve as the attachment ring for the tunnel fabric. In addition, the end plates establish the interface for the Sortie Lab and Shuttle with the tunnel.

The tunnel wall structural details are shown in Figure 3.1-6. The tunnel wall consists of four structural elements: inner pressure bladder, fabric structural sleeve, micrometeoroid barrier and outer cover.

3.1.2.2 Forward Skirt

The forward skirt is 51 inches long, 14 feet in diameter and basically is an extension of the cylindrical section. The skirt serves as a mount for the cryogenic tanks, fuel cells, and subsystems components (Figure 3.1-7). All structural components of the forward skirt are 2219 Al alloy.

3.1.2.3 Conical Bulkhead

The 32-degree conical bulkhead provides the transition between the 14-foot diameter cylindrical sidewall and the pressure hatch. The bulkhead is constructed of 2219 Al alloy segments. The segments are 0.100 inches thick skin with integrally machined stiffeners, 0.125 inches thick by 1.250 inches deep on equally spaced 4-degree centers (Figure 3.1-8). The bulkhead bolts to the primary end ring of the cylindrical section at the aft end and also mates to the flexible crew transfer tunnel on the forward end.

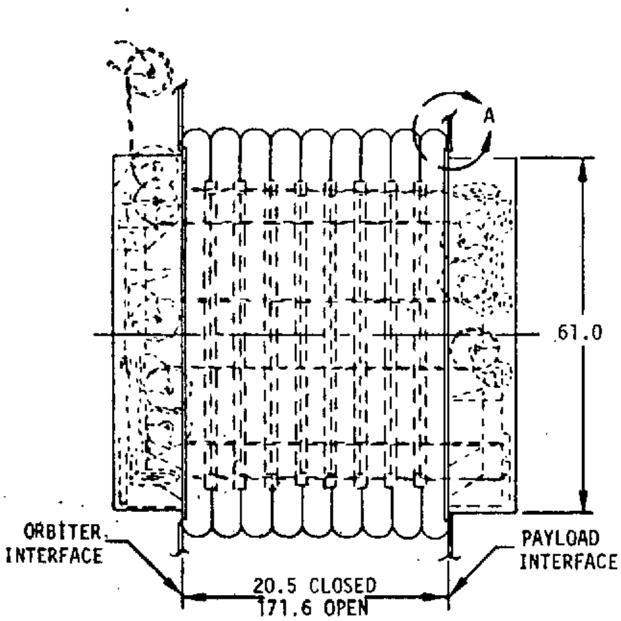


FIGURE 3.1-2. SORTIE LAB FLEXIBLE TUNNEL CONFIGURATION

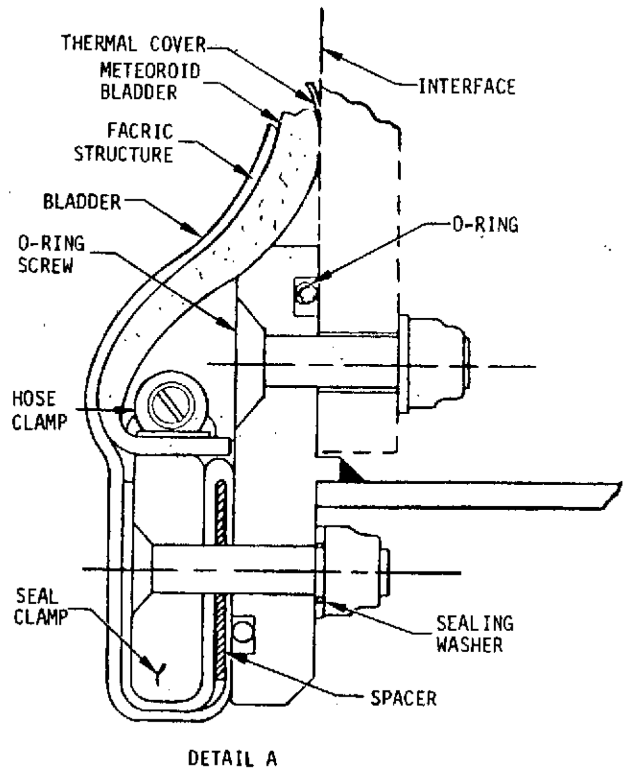


FIGURE 3.1-3. SORTIE LAB FLEXIBLE TUNNEL INTERFACE CONCEPT

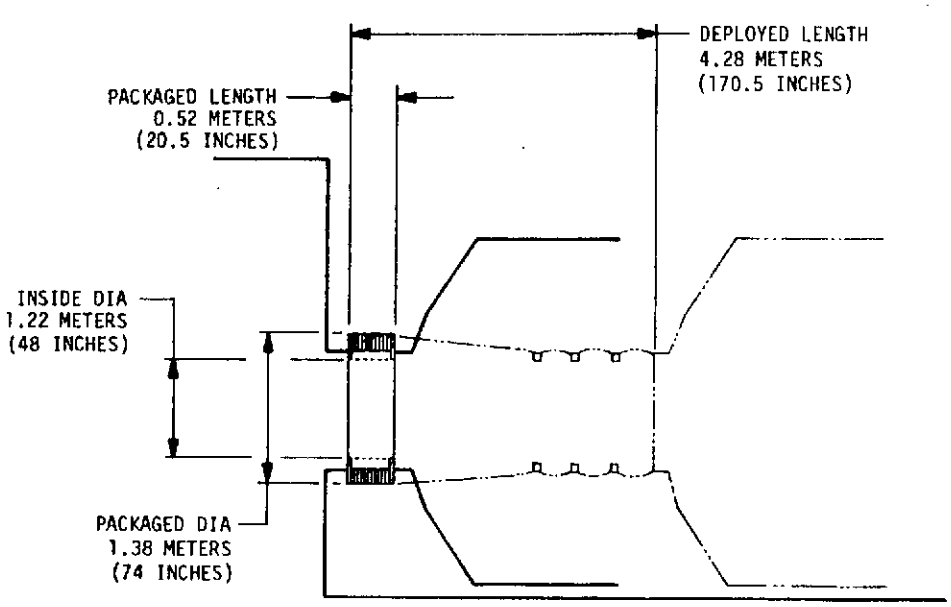


FIGURE 3.1-4. SORTIE LAB FLEXIBLE TUNNEL ENVELOPE DIMENSIONS

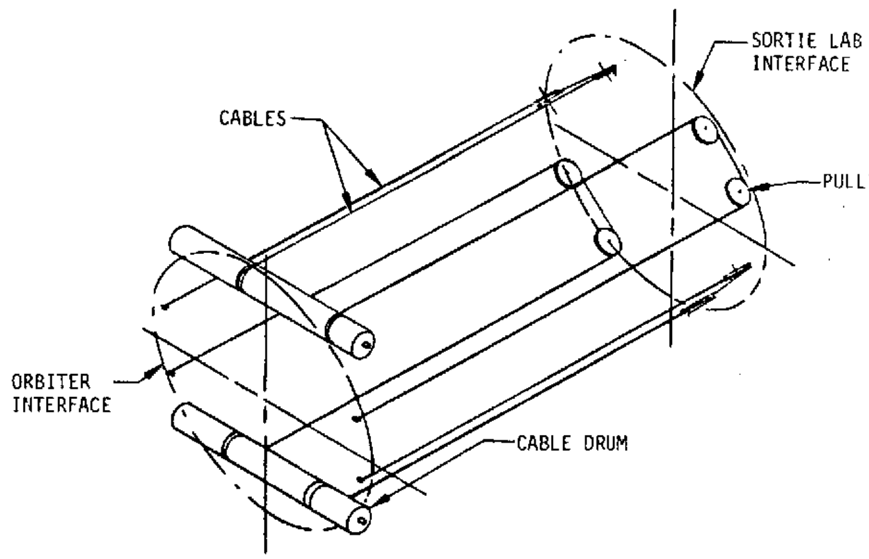


FIGURE 3.1-5. CABLE DIAGRAM

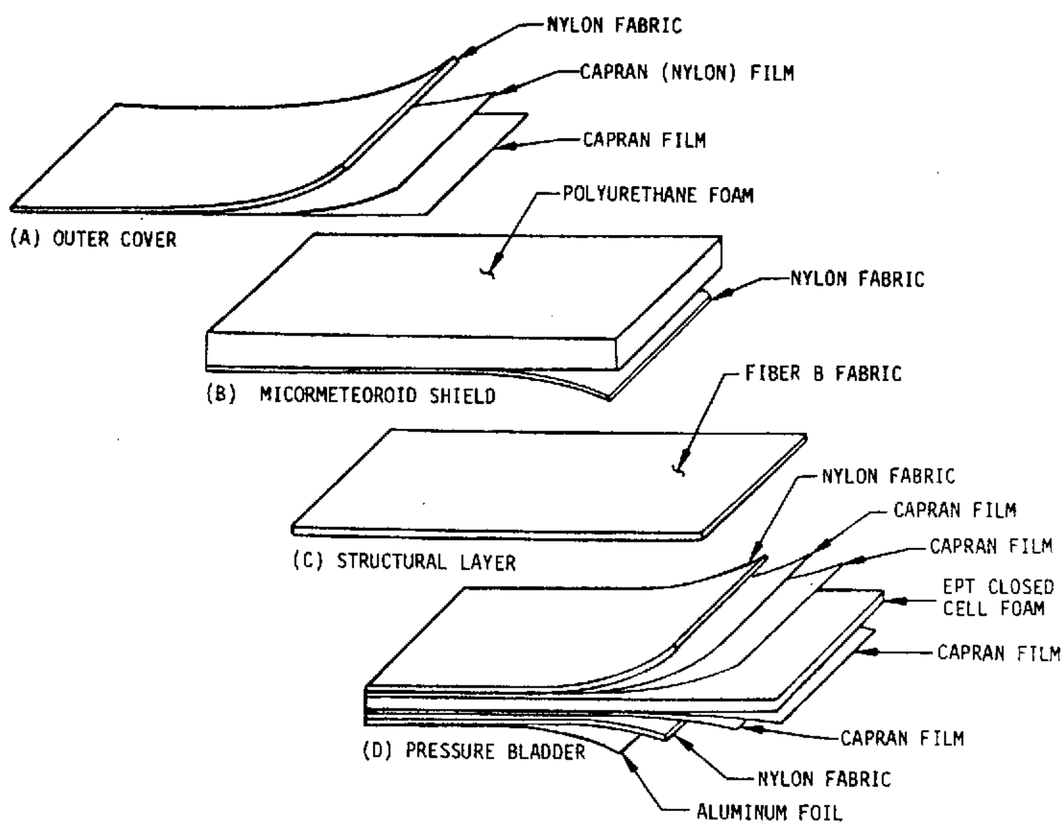


FIGURE 3.1-6. SORTIE LAB FLEXIBLE TUNNEL SCHEMATIC OF TUNNEL WALL MATERIALS

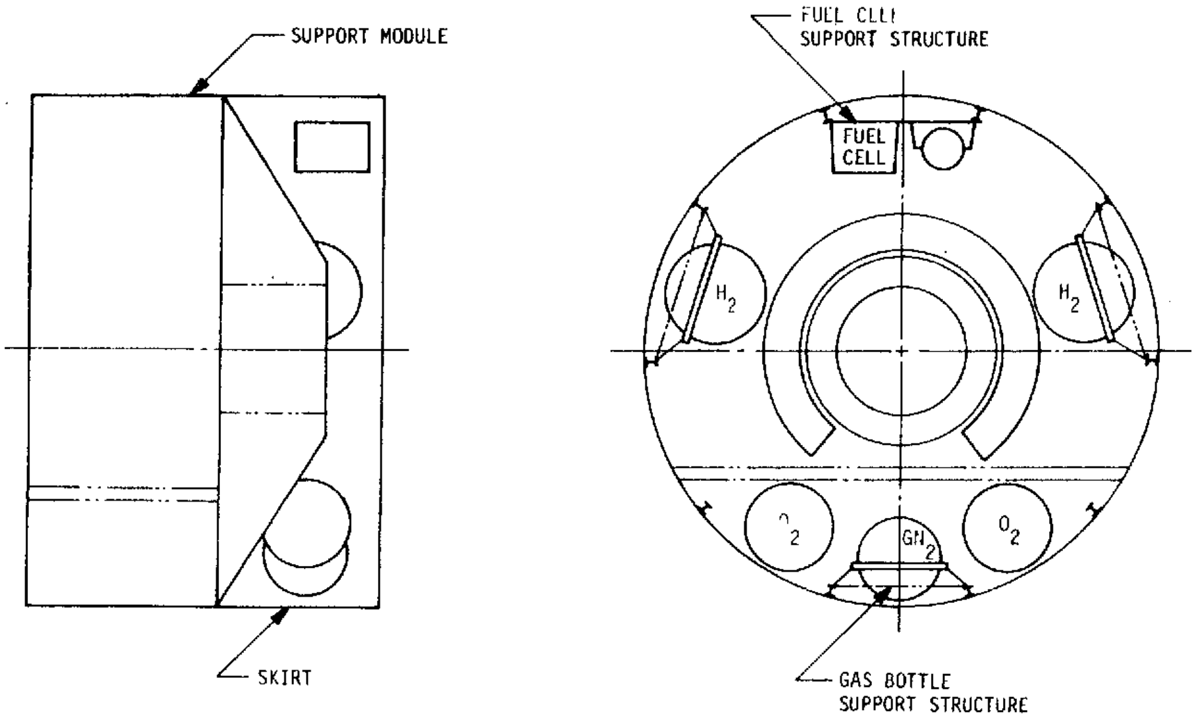


FIGURE 3.1-7. TYPICAL SECONDARY STRUCTURE

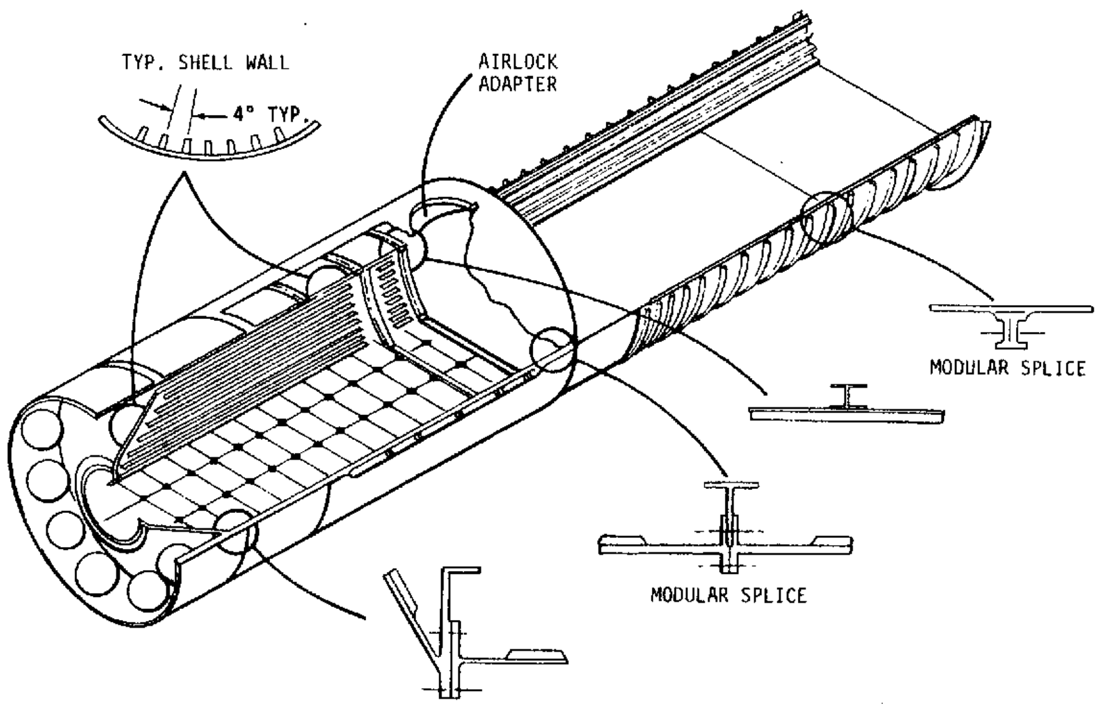


FIGURE 3.1-8. SORTIE LAB STRUCTURE

3.1.2.4 Cylindrical Section

The cylindrical section is 14-foot in diameter; the forward end mates to the primary end ring and the aft end to the field splice joint (Figure 3.1-8). All components are 2219 Al alloy. The cylinder is constructed of 0.100 inch thick panels with 0.125 inches thick by 1.250 inches deep integrally machined stringers equally spaced on 4-degree centers. For additional strength, (external rings) "I" beams 3.00 inches deep are equally spaced along the longitudinal axis.

3.1.2.5 Secondary Structure

The secondary structure encompasses the floor, utility tunnels, ceiling components, and the external equipment support structure. The floor is horizontal with a removable panel through the center. The floor's outer edges are supported by angles, secured to the pressure wall and primary end ring. Support for the inboard edge of the fixed floor panels consists of vertical struts extending to the pressure shell. Intercostals are the only support for the center removable section.

Typical secondary structure includes mounting hardware for external subsystem equipment such as the N_2 bottles for the ECS and the cryogenic bottles for the electrical power subsystem (EPS). Each of these bottles are individually truss mounted. Other equipment such as the water sublimator, thermal storage elements, and freon control valves are platform mounted and attached either to the bulkhead or forward skirt structure (Figure 3.1-7).

3.1.2.6 Environment Protection

The entire surface (Figure 3.1-9) of the pressurized module is covered with a 2.25-inch thick insulation blanket.

This system is made up of layers of .25 mil thick crinkled single aluminized mylar (CSAM) reflectors with the crinkles in the reflector acting as the spacer. The normal layer density is 70 layers to the inch. If this system is purged the reflectors should be perforated.

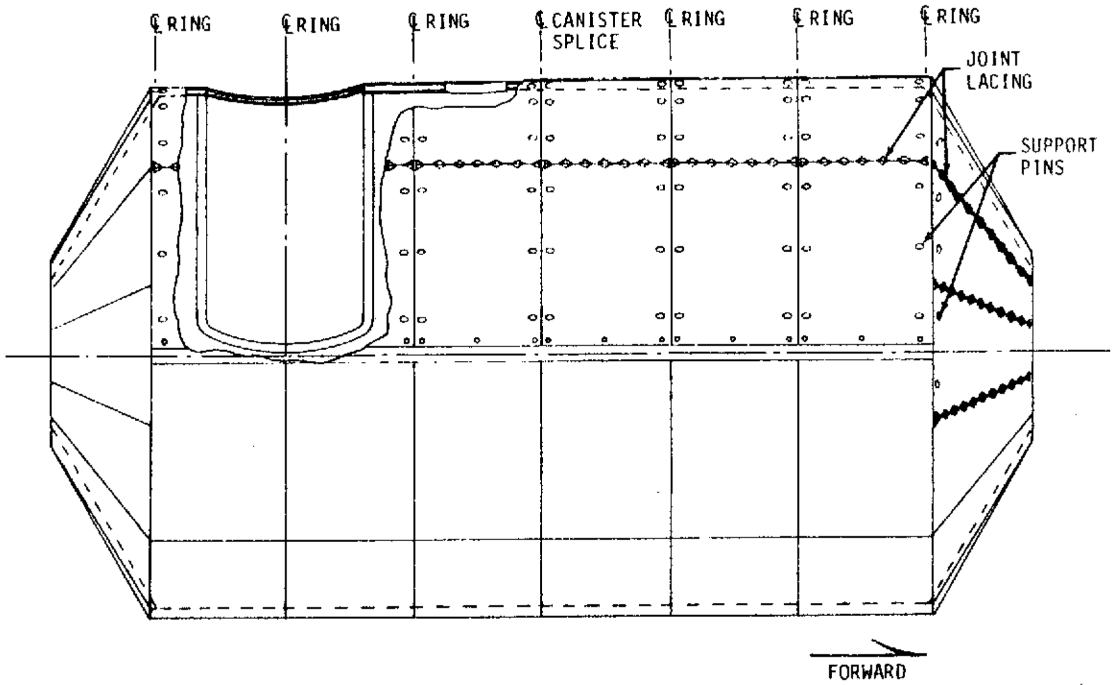


FIGURE 3.1-9. SORTIE LAB ENVIRONMENT PROTECTION SYSTEM

Insulation blankets can be fabricated by using drop threads and buttons or, face sheets or grids, and drop threads, or by bonding layers together and using support pins. Blanket joints must be overlapped and taped or interleaved and taped.

This system is very light and can be formed to multiple contours very well. If properly constructed the blankets have a very high degree of strength and reliability. The most outstanding problem area of this system is maintaining the blanket thickness (See Figures 3.1-10 and 3.1-11). The meteroid bumper is made of 0.016 inch single aluminum skin. Blanket attach points are utilized to attach the meteroid bumper.

3.1.2.7 Mobility Stability Aids

Crew mobility/stability aids are required to assist the crewmen in performing operations and maintenance tasks. These crew aids consist of hand-rails, foot restraints, tether attach points, etc. Location of aids will be determined when tasks are identified. Mobility/stability aids must meet requirements identified in MSFC-STD-267. Representative aids are shown in Figure 3.1-12.

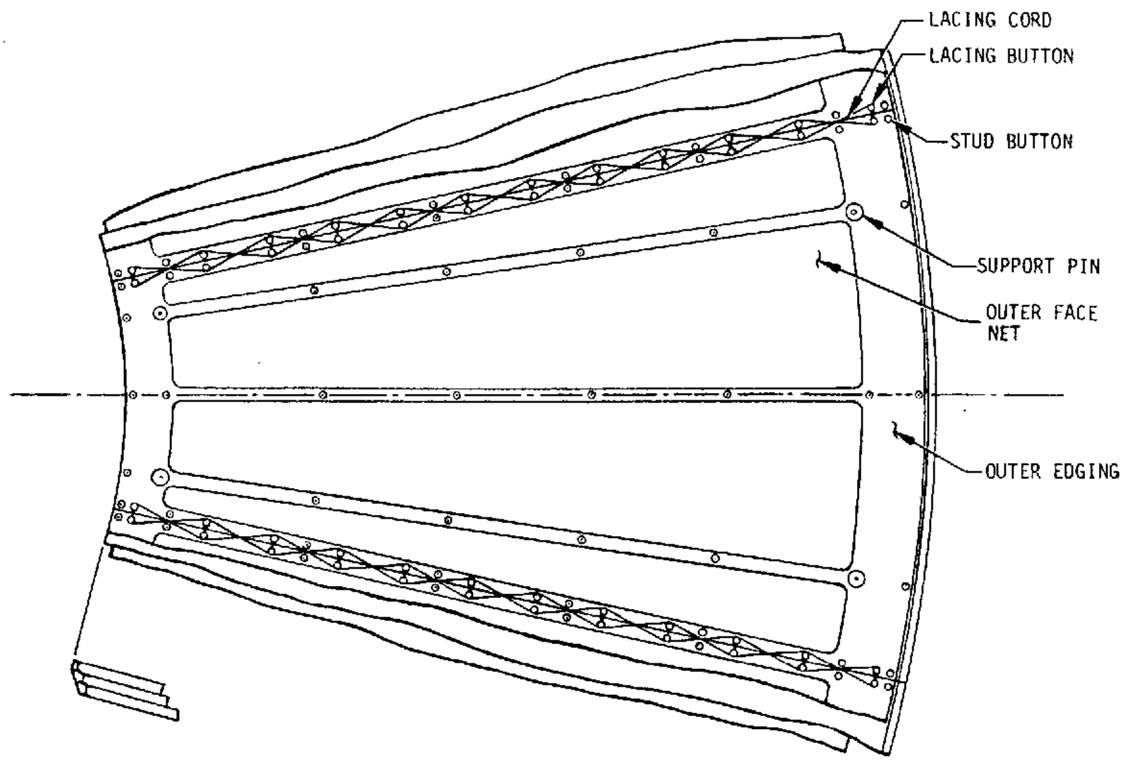


FIGURE 3.1-10. INSULATION PANEL INSTALLATION

3.1.2.8 Pressure Hatch

Two forty-inch diameter pressure hatches are located in the Sortie Lab; one at the forward bulkhead and crew tunnel interface and one in the aft bulkhead. Figures 3.1-13 and 3.1-14 depict the hatch concept which is hinge mounted to the bulkhead. Incorporated into the hatch is an 8.0-inch diameter view port, which permits viewing into the module or observation of pallet mounted experiments, also located on the hatch is a pressure equalization valve, used to equalize the pressure across the hatch prior to operating.

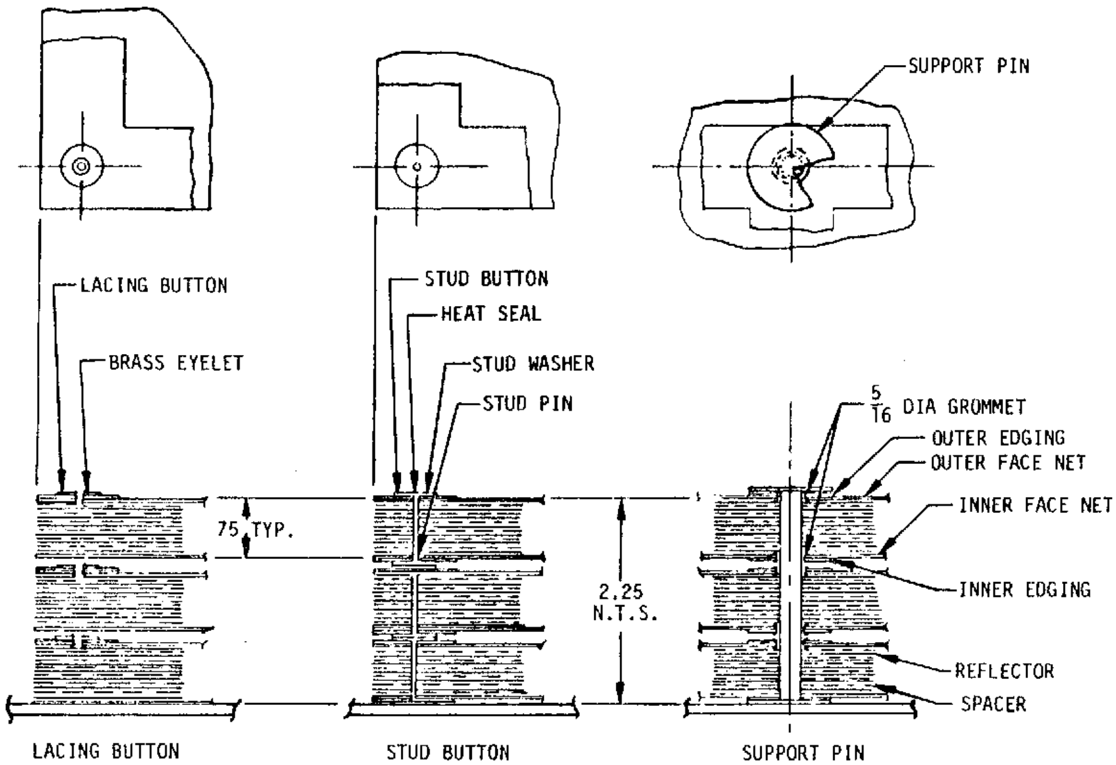


FIGURE 3.1-11. INSULATION PANEL CROSS SECTION

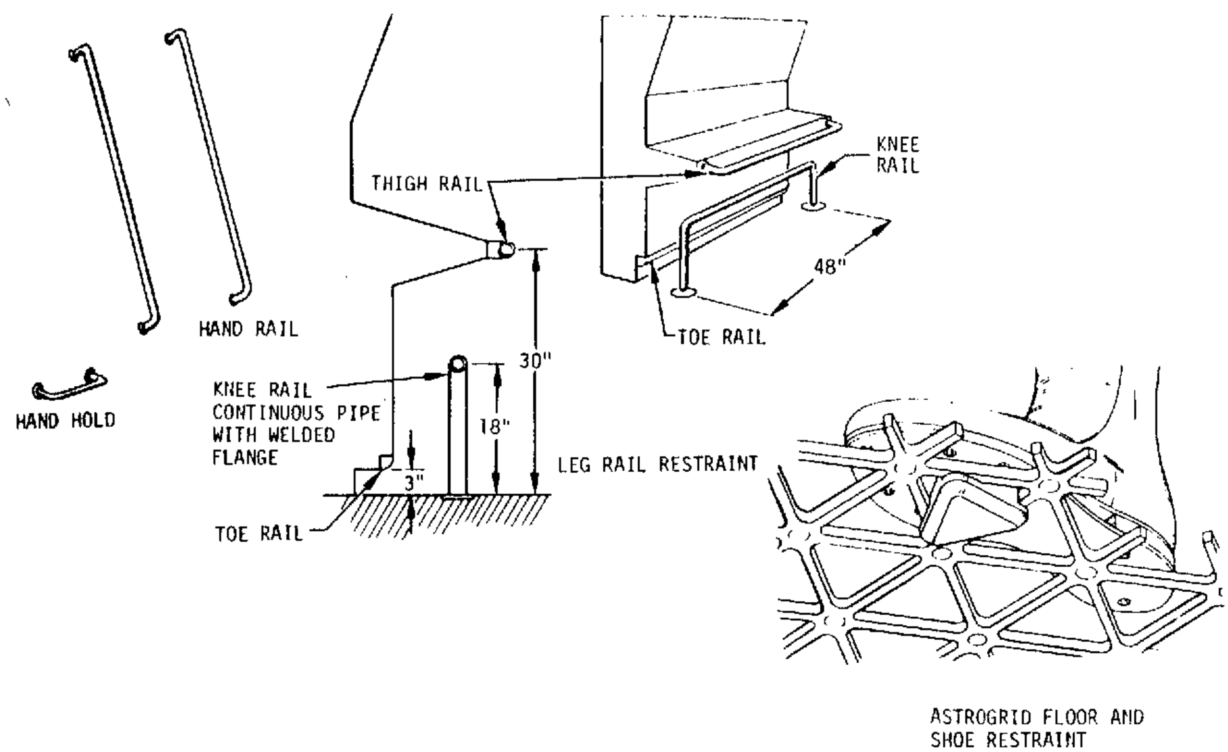


FIGURE 3.1-12. SORTIE LAB CREW MOBILITY/STABILITY AIDS

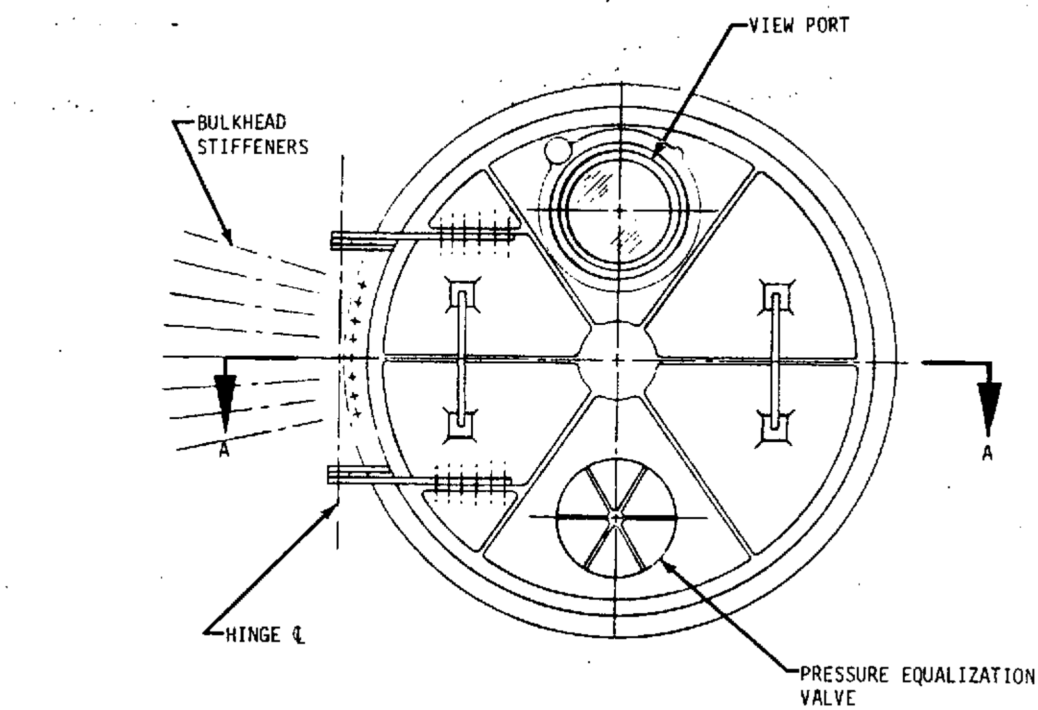


FIGURE 3.1-13. PRESSURE HATCH CONFIGURATION

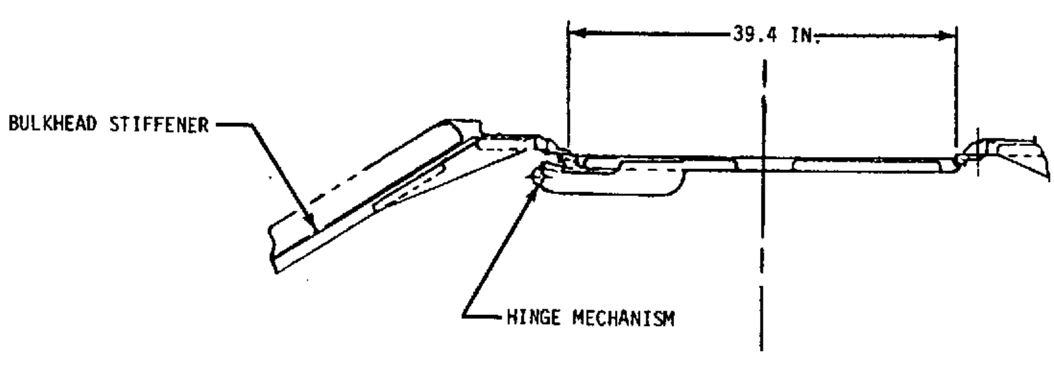


FIGURE 3.1-14. VIEW A-A, FIGURE 3.1-13

3.1.3 Environmental Control System (ECS)

The Sortie Lab ECS definition has to consider a variety of design options to satisfy the experiment requirements, interface with other Sortie Lab/Shuttle subsystems, maintain a flexible design concept and provide a low cost program approach. Previous sortie mission studies such as the RAM Phase B and Sortie Lab Phase A provided good background data for satisfying the ECS design goals. A factor which has influenced all of these studies for the past two years is the lack of firm Shuttle interface design data. For this reason, the best design approach for the payload ECS has been to be as independent of the Shuttle designs as possible. This approach provides an advantage to both programs by minimizing sensitivity of (a) Sortie Lab program to Shuttle design changes and (b) impacting Shuttle designs with changing or variable experiment requirements.

The basic ECS functions required by the Sortie Lab are given in Table 3.1-1.

FLUID SUPPLY AND CONTROL	ATMOSPHERE CONDITIONING	THERMAL CONTROL
• O_2/N_2 Storage and Supply	• Circulation	• Crew Comfort
• Cabin Pressure Control	• Temperature Control	• Structural Heat Leak
• Airlock and Module Depressurization and Repressurization Control	• Humidity Control	• Subsystem Conditioning
• Experiment Requirements	• CO_2 Control	• Experiment Conditioning
• Water Management	• Contaminant Control	• Heat Rejection
• Cryogens	• Particulate Control	

TABLE 3.1-1. MAJOR FUNCTIONS FOR SORTIE LAB ENVIRONMENTAL CONTROL SYSTEM

The Shuttle will provide the following facilities for the Sortie Lab crew:

- Food Management
- Personal Hygiene (crew water and waste management)
- Sleeping Areas
- Launch and Reentry Provisions

Although the baseline ECS design that has evolved is primarily independent of Shuttle Orbiter functions, there is considerable commonality in the design approaches. Both systems operate at 14.7 psia ambient pressure, shirt sleeve crew environments, water coolant circuit in the pressurized areas and a Freon - 21 coolant circuit in the unpressurized areas. The basic method of heat rejection on-orbit is via space radiators.

The ECS is designed to support a crew equivalent to 21 man-days for missions of 7 days. The ECS will perform the following functions:

a. Maintain cabin atmosphere temperature, pressure, humidity and composition within specified limits.

b. Provide cooling for experiment and subsystem equipment.

c. Collect and store water generated by fuel cells and condensate removed from the cabin atmosphere.

d. Supply water as required for experiment use or heat rejection purposes.

e. Reject waste heat to space through radiators or sublimator during flight and to GSE during preflight operations

The basic capabilities of the system as baselined are summarized as follows:

- Provides for up to 7 kw air cooling in cabin.
- Experiment cooling available = 4 to 5 kw. (All air cooled if required).
- Heat rejection via radiators = 8.5 kw (orbital average)
- Total heat rejection using radiators plus sublimator = 10 to 11 kw (orbital average)
- Normal cabin temperature = $74 \pm 2^{\circ}F$
- Normal CO_2 levels $\leq$ 3mm Hg
- Normal dew point temperature = $45 \pm 5^{\circ}F$

- Cabin air filtration for 100μ airborne particles
- Eliminates all overboard dumping of water (fuel cell
- generated plus condensate) for all payload sensitive missions.

An ECS block diagram is shown in Figure 3.1-15. The radiator coolant loop rejects to space all heat generated within the Sortie Lab cabin or external components via the space radiator. A thermal capacitor is provided in the radiator coolant loop as a supplementary heat sink for transient conditions when the radiator is unable to reject the prevailing system's thermal load. The cabin coolant loop removes all heat generated within the cabin and rejects it to the radiator coolant loop via the interface heat exchanger. A sublimator is provided in the cabin coolant loop as supplementary heat rejection for operating conditions when the Sortie Lab/radiator interface heat exchanger is unable to remove the entire cabin heat load. The cabin coolant loop receives heat inputs from three sources: the cabin air revitalization system, the cabin ventilation system, and the equipment ventilation system. The cabin air revitalization system removes CO_2 and moisture produced by crew activity plus some sensible loads. The cabin ventilation system filters the cabin air, removes cabin air thermal loads, and supplies conditioned air to the cabin via an air handling system. The cabin ventilation system is the controlling agent of the cabin dry bulb temperature. The equipment ventilation system provides air circulation for the enclosed equipment racks and removes heat produced by subsystems and experiments. The two gas control system maintains the Sortie Lab total pressure and partial oxygen pressure by adding O_2 or N_2 as required. The N_2 supply for the two-gas controller is contained in high pressure bottles and the O_2 supply is stored under super critical conditions. The super critical O_2 supply and an H_2 super critical supply is used to store reactants for the O_2/H_2 fuel cell. Product water from the fuel cell is stored by the water management system for delivery to the sublimator upon demand.

An electromechanical schematic is given in Figure 3.1-16. Figure 3.1-17 is an illustration of the internal support module configuration with cabin layouts given in Figures 3.1-18, 3.1-19 and 3.1-20.

Throughout the design of the ECS, maximum use of Skylab hardware has been made to minimize cost and development time. The baseline designs are summarized as follows.

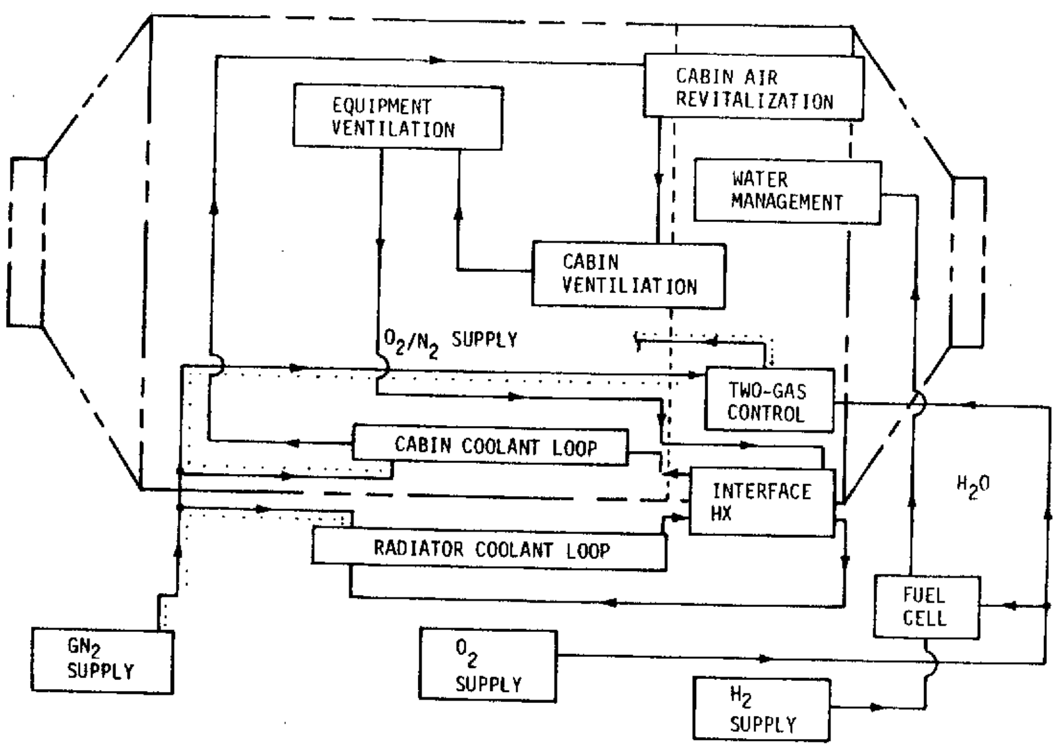


FIGURE 3.1-15. ECS BLOCK DIAGRAM

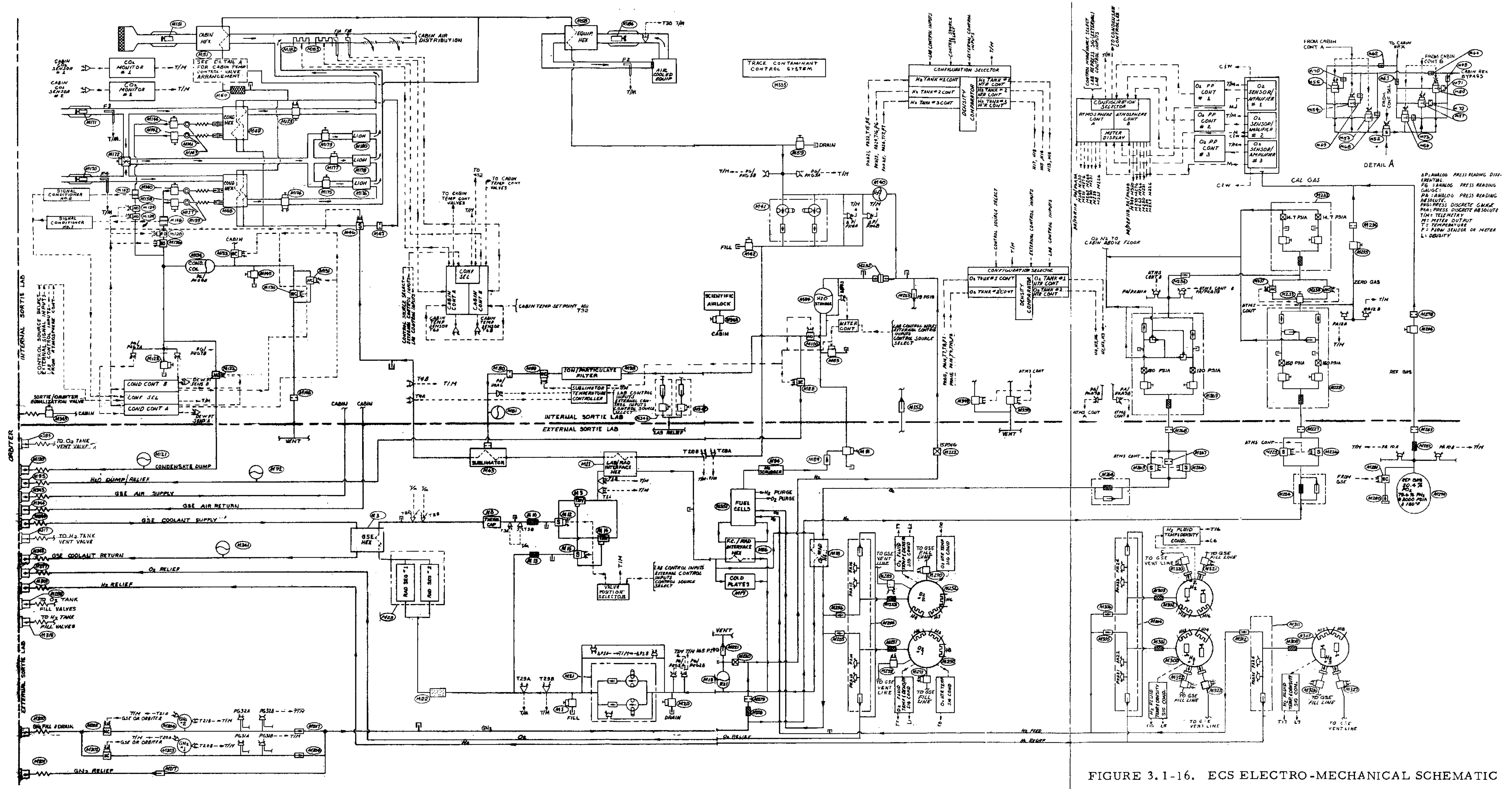


FIGURE 3.1-16. ECS ELECTRO-MECHANICAL SCHEMATIC

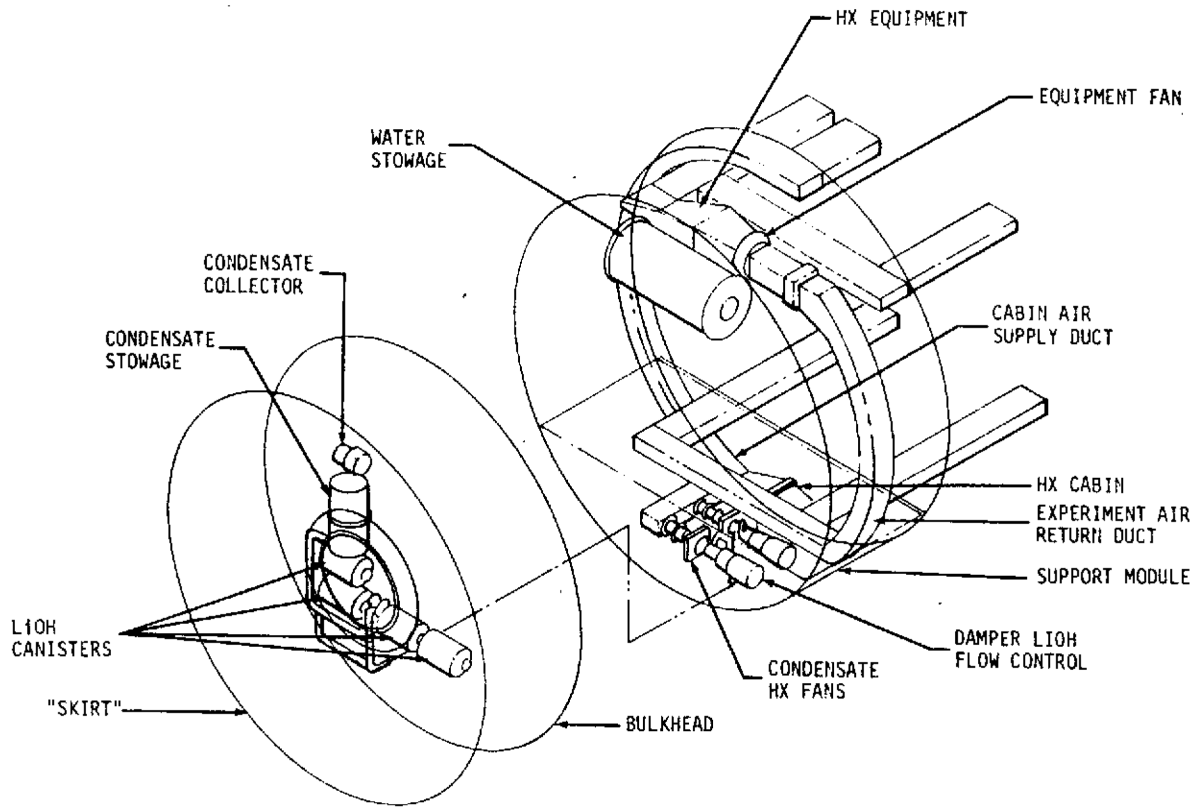


FIGURE 3.1-17. INTERNAL ENVIRONMENTAL CONTROL SYSTEM CONFIGURATION (SUPPORT MODULE)

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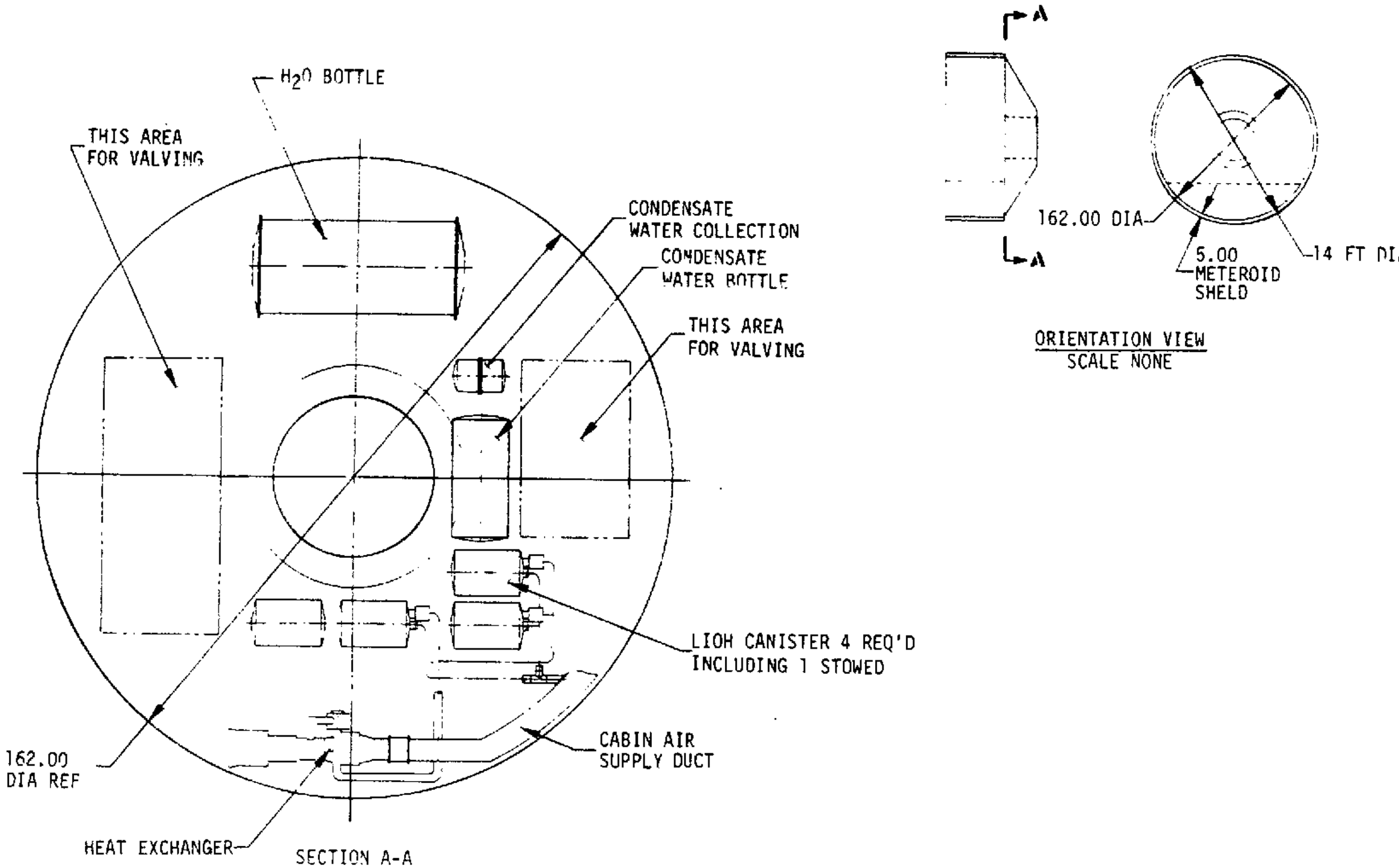


FIGURE 3.1-18. ECS SUPPORT MODULE LAYOUT

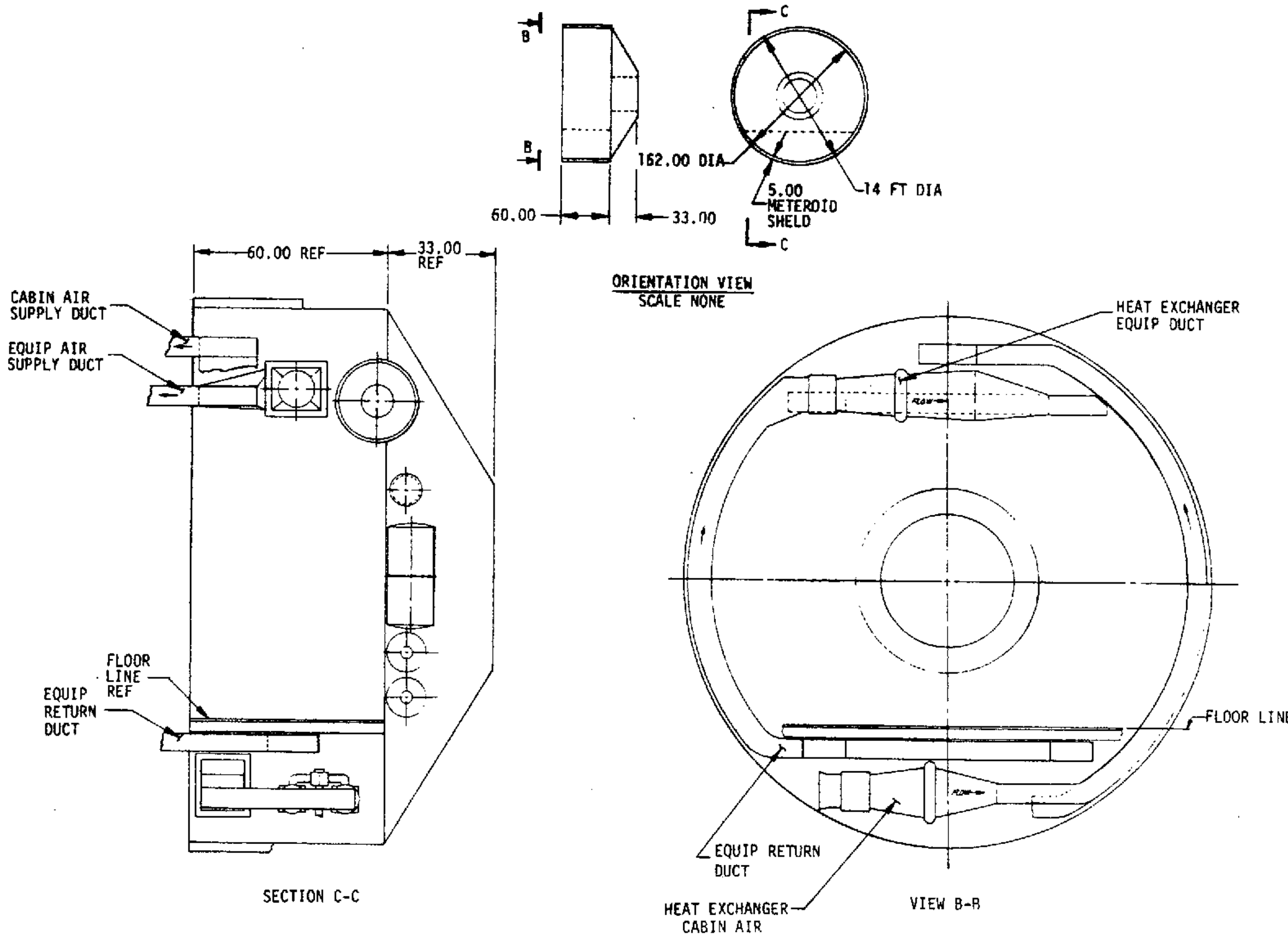


FIGURE 3.1-19. ECS SUPPORT MODULE DUCTING

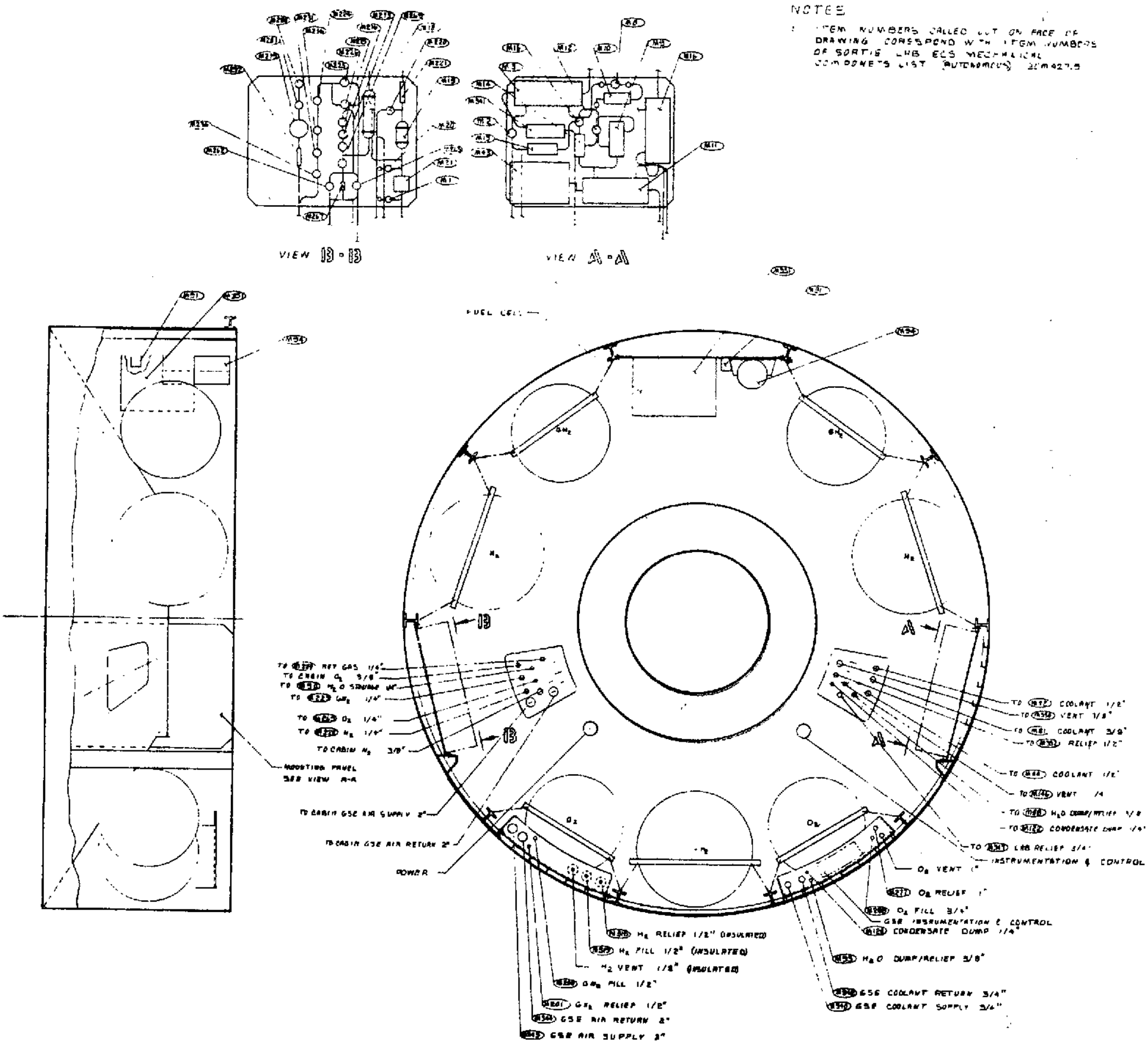


FIGURE 3.1-20. FORWARD BULKHEAD INTERFACES

3.1.3.1 Radiator Design

A deployed radiator (approximately 750 ft^2) is the required method of heat rejection for the non-deployed Sortie Lab concept. (The radiator thermal coating is a white paint.) The coolant in this circuit is Freon-21 which is also the selected coolant for the Shuttle orbiter program. This loop provides a closely controlled inlet temperature ($38 \pm 3^{\circ}F$) at the heat exchanger which interfaces with the cabin water coolant loop. Temperature control is maintained by a temperature mixing valve which allows bypass of warm fluid around a cold radiator for low thermal loads. Other major items that are conditioned by the radiator loop are pallet cold plates, O_2 heat exchangers, and fuel cell coolant. The pump package maintains the system flow at 2000 lb/hr. The thermal capacitor, which contains a phase change material ($T_{melt} = 40^{\circ}F$), is used to absorb heat during transient periods in which the space radiator performance is inadequate. The ground cooling heat exchanger is for cooling of the Freon loop (radiator by-passed) during ground operations. This allows prelaunch cooling of the thermal capacitor and thermal conditioning of the Sortie Lab (if required). In addition to the thermal capacitor, a water sublimator has been baselined as a supplemental heat rejection method for radiator loads higher than average orbital thermal loads of 8.5 kw (29,200 BTU/hr). The space processing payloads normally require heat rejection in excess of the space radiator capabity. These payloads are sensitive to external contamination and rather than over size a radiator for them the use of the fuel cell generated water for thermal control was selected. The total heat rejection capability of the radiator plus sublimator is 10 to 11 kw (Depending on the total amount of water available for thermal control).

3.1.3.2 Structural Heat Leak

The total structural heat leak (gain or loss) to the pressurized module has been minimized to free the thermal design from any orbital attitude constraints. In the preliminary design a total allowable heat leak of 500 BTU/hr was assumed through Sortie Lab elements such as the tunnel, sidewalls, bulkheads, scientific airlock, and windows. High performance insulation was used extensively to maintain these structural heat leak designs.

3.1.3.3 Cabin Air Temperature Control

The cabin thermal control system removes heat from the interior of the Sortie Lab and rejects the heat to the radiator loop through the liquid-to-liquid (Freon/water) interface heat exchanger. The cabin coolant is water and is circulated through the system at 500 lb/hr. The water flows from the pump through the interface heat exchanger, sublimator, condensing heat exchanger, cabin heat exchanger, equipment heat exchanger and back to the pump. The water is cooled in the interface heat exchanger and/or sublimator to 40 to 45°F. Two condensing exchangers are connected in parallel and remove moisture from the cabin atmosphere as required to maintain the desired cabin humidity. One condensing heat exchanger is required for a crew of two. Both units are required for a crew of three to four. A fan in each condensing heat exchanger circuit provides 45 CFM air flow across the heat exchanger. For a nominal two-man crew, only one fan is operating. For a four-man crew, both fans are operating. This design concept has operating flexibility to accommodate variable crew sizes and provides the low humidity levels required for optimum cabin air temperature control. Condensate from the heat exchangers will be stored for the duration of the 7-day mission. The maximum quantity of condensate to be stored is 124 pounds.

The cabin heat exchanger is located in the cabin ventilation ducting and maintains the air temperature control for crew comfort. A total air flow of 540 CFM across the heat exchanger is provided by the cabin heat exchanger fan. A step flow control valve controls coolant flow through the cabin heat exchanger as required to maintain cabin air temperature at the set-point. The maximum heat removal capability of the cabin air circuit for crew comfort is 10,000 BTU/hr ($\sim$ 3 kw) at an ambient temperature of $74 \pm 2^{\circ}F$. This includes the heat removal capacity of the condensing heat exchangers. The allowed split in subsystem and experiment thermal loads for this circuit are still to be determined.

3.1.3.4 Atmosphere Supply and Control

The atmosphere supply and control design maintains the pressurized module at 14.7 psia, supplies gaseous oxygen and nitrogen for repressurization of the scientific airlock, supplies oxygen for metabolic consumption. The design also includes vent and relief components which permit the pressurized module to be vented to the outside environment and prevent its structure from being exposed to excessive internal or external pressure differentials. Also the nitrogen gas supply is used for pressurization of the accumulators in the coolant circuits and the water storage tanks. The 7-day mission atmosphere consumables carried by the Sortie Lab ECS are 54 pounds of nitrogen. The ECS oxygen requirements, are integrated with the fuel cell cryogenic tankage, and constitute a 5 to 10 percent increase above the oxygen reactant required for power generation.

The oxygen gas for ECS is supplied from the fuel cell cryogenic tankage at 900 psia and $-297^{\circ}F$. Through an interface with the radiator loop the oxygen is heated to a minimum of $-40^{\circ}F$ and the pressure is then reduced to 120 psia by a pressure regulator. Gaseous nitrogen is stored in a high pressure bottle (3000 psia). Nitrogen gas pressure is reduced to 900 psia prior to entering the cabin and is further reduced to 160 psia by a pressure regulator. Redundant pressure regulators are provided in both the oxygen and nitrogen supply lines.

The shutoff valve immediately upstream of the appropriate regulator is closed when a regulator failure is detected.

The major portion of the two gas control system consists of the pressure sensors, controllers, the mechanical components used to control the flow and pressure of the oxygen and nitrogen. Normally, the system supplies nitrogen to the cabin atmosphere as required to maintain the total pressure in the module at the desired level. When the oxygen partial pressure sensing system determines that the oxygen partial pressure is below the desired value, the supply of nitrogen is stopped and oxygen is supplied to the cabin as required to maintain the total pressure in the cabin at the desired level. When the oxygen partial pressure reaches the desired value, the oxygen is shut off and nitrogen is again supplied to the cabin. A source of reference gas with associated control components is provided for inflight calibration of the oxygen partial pressure sensors.

3.1.3.5 CO_2 Removal

The CO_2 removal system consists of three lithium hydroxide (LiOH) canisters connected in parallel and integrated with the humidity control system (see Figure 3.1-21).

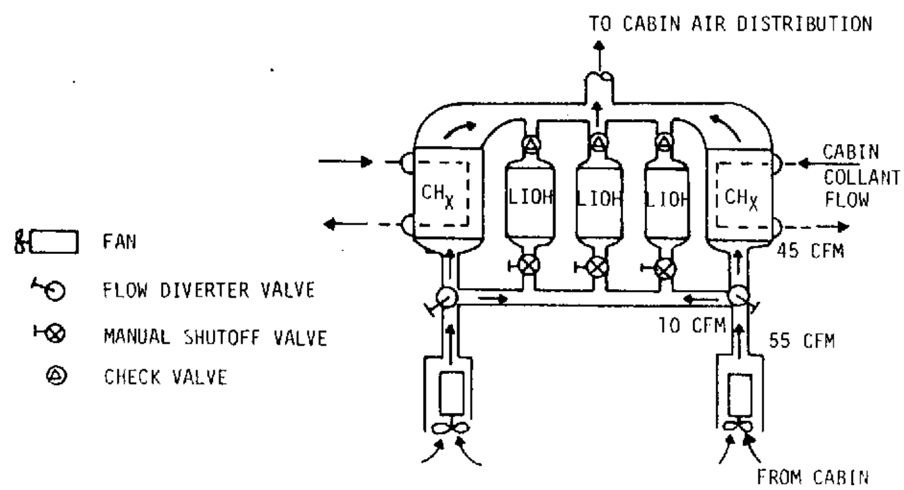


FIGURE 3.1-21. DESIGN CONCEPT FOR CO_2 REMOVAL/HUMIDITY CONTROL

For a nominal two-man crew, only one fan is operating. This fan provides air flow through both the condensing heat exchanger (45 CFM) and the LiOH canister (10 CFM). For a four-man crew, both fans are operating. Each condensing heat exchanger has 45 CFM air flow and the total air flow through the LiOH canister is 20 CFM. As each LiOH canister is expended the crew diverts the air flow to a fresh canister.

3.1.3.6 Trace Gas Contaminant Control

A study of the potential trace gases in Sortie Lab and appropriate control methods was begun during Phase B studies but has not developed to the point where trace gas removal systems can be incorporated into a Phase B schematic. Additional studies and testing to determine the magnitude of the trace contaminant problem will be required before this can be done.

Current information indicates that the generation of trace contaminants can be a problem for Sortie Lab (depending on assumed generation rates and mission duration). Also, the Sortie Lab contaminants could in turn contaminate the Shuttle orbiter cabin if the two atmospheres are exchanged. This is due to the different design philosophies of integrating equipment into the respective cabin design. In the Shuttle, the Skylab type materials control program is applied to all equipment located in the crew compartment. The Shuttle avionic bays are located outside of the Shuttle cabin area and are designed to incorporate all equipment not compatible with the Skylab type materials control. The bays are designed to leak overboard at a controlled rate and are maintained at a constant pressure differential (0.4 psid) below the cabin pressure to preclude avionics generated trace contaminants from migrating into the Shuttle cabin. Sortie Lab currently has no such provision for controlled overboard leakage of equipment racks and as a consequence heating expansion and cooling contraction of air circulating inside the racks will cause pumping of air between the equipment racks and the Sortie Lab cabin through any available leak point. This could allow any contaminants generated internal to the racks to contaminate the Sortie Lab cabin. Reliable pressure sealing of the racks to prevent air ex-changes and the required materials control necessary to eliminate a contaminant source within the rack is probably unacceptable to many experiment payloads. This makes some form of contaminant control necessary for Sortie Lab.

Preliminary analyses of Sortie Lab contaminant control concepts show a catalytic oxidizer system could control 64 out of 74 contaminants within safe levels with water adsorption and/or chemical adsorption to control the remaining 10 contaminants. Water adsorption will occur within the condensing heat exchangers during normal condensate removal operations. Chemical adsorption could be conducted with lithium hydroxide and copper sulfate layers incorporated into the Sortie Lab particulate filters. The feasibility of these proposed control methods can be verified only by additional studies and testing.

3.1.4 Electrical Power

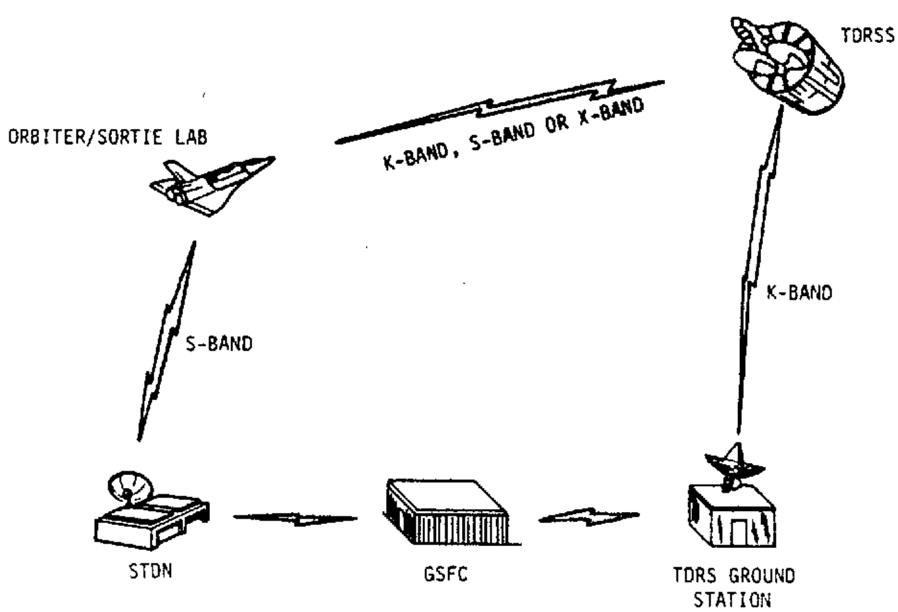
The major elements of the electrical power subsystem (EPS) include fuel cell, battery kits, water storage, reactants and tankage. To meet pallet only mission power requirements studied and to provide a common sub-module interface for all missions, the fuel cell was placed on the pallet. However, later structural studies deleted the pallet on selected missions. This resulted in a proposed relocation of the fuel cell to the forward bulkhead skirt of the support module. The power distribution system is to be routed to the support module providing power distributors for distributing electrical power to the subsystems hardware. Section 3.3.4 provides an overall description of the EPS.

3.1.5 Habitability

The Shuttle Orbiter habitability system will provide accommodations for the Sortie Lab personnel during the pre-launch, orbital flight and horizontal flight phases. Accommodations for their comfort, convenience, and well-being as a function of mission duration will be provided in a compartment immediately adjacent to and connected with the flight deck. The Shuttle Orbiter habitability system procedures and operations should be "incidental" with minimum expenditure of of time and effort. The habitability elements considered are: (a) Facilities - personal hygiene and galley (food, water and housekeeping), (b) Furnishings - seats, sleeping provisions, garments and personal gear, living accommodations, off-duty equipment, mobility aids and restraints, and passageways, and (c) Environmental Requirements - acoustics, temperature, lighting, air flow and interior design.

3.1.6 Communications

All Sortie Lab communications to and from the earth and other vehicles are routed through the Shuttle Orbiter Communication subsystems. Any requirements exceeding the capabilities provided by the Orbiter (none defined at this time) will be handled by unique add-on equipment on the Sortie Lab. The typical Orbiter interfaces with the ground are shown in Figure 3.1-22.



GSFC - Goddard Space Flight Center
STDN - Space Tracking and Data Network
TDRS - Tracking and Data Relay Satellite

FIGURE 3.1-22. COMMUNICATIONS CONCEPT

The baseline Sortie Lab concept assumes that the Orbiter interfaces with both the TDRS and the STDN. The basic Sortie Lab requirements are to be met using the Orbiter/TDRS link, with the Orbiter/STDN link providing backup capability. The TDRS provides the high data rate capability to meet Sortie Lab requirements and allows nearly continuous real-time transmission capability. It should be noted that an experiment dedicated communications capability is being considered to avoid conflicts with Orbiter and Sortie Lab subsystem requirements.

The Orbiter provides both downlink (Orbiter to ground) and uplink (ground to Orbiter) capability thru the TDRS or STDN. The Sortie Lab downlink capability through the Orbiter are:

- High Data Rate - digital data at 50 mbps or a 5 MHz Analog/Video data link, both through the Ku-Band.
- Voice - a duplex, digital voice link through Ku-or S-Band
- Telemetry - a 25 kbps telemetry downlink capability through the Ku- or S-Band.

The uplink capabilities provided are:

- Command - an 8 kbps command link through Ku or S-Band
- Voice - A duplex, digital voice link through Ku or S-Band
- Video - TBD capability through Ku-Band

In addition, some limited capability is provided through the Orbiter to STDN link and internal Orbiter/Sortie Lab voice communications is available with the onboard intercom system.

For Sortie Lab analog data transmitted by the Orbiter, the Sortie Lab shall provide communication and subcarrier oscillators compatible with Orbiter transmitter circuitry. For digital data, the payload shall provide the required coding for compatibility with the Orbiter transmitter.

3.1.7 Data Management and Onboard Checkout Subsystems

The data management subsystem (DMS), in conjunction with the controls and displays, performs the control, monitor, and checkout of all subsystems and experiments. The DMS, as illustrated in Figure 3.1-23, includes the computer and data acquisition and distribution (DA&D) subsystems.

A 32-bit, floating point, micro-programmable, central processor unit has been baselined for the computer subsystem. Software implementation features a modular structure under control of an executive. A higher-order- language selected from those under current development is proposed to reduce software development and verification time.

The DMS provides for two-way data transmission on two twisted, shielded pair cables. The cable used for commands and data transfers to the digital interface unit (DIU) is designated the supervisory bus while the cable used for data transfers from the DIU is called the reply bus. The speed of each bus is two mega bits.

The DIU provides standard interface for all Sortie Lab subsystems and experiments and is made up of the following:

- Up to 128 Discrete Inputs (DI's)
- Up to 128 Discrete Outputs (DO's)
- Up to 128 Analog Inputs (AI's)
- Up to 4 Analog Outputs (AO's)
- Up to 8 Record In/Record Out Channels (Digital Data)

Data bus control is by the computer subsystem to accommodate varying data acquisition and distribution rates. The Input/Output Processor (IOP) controls all transfers with the data bus.

The computer interface unit (CIU) provides parallel-to-serial conversion on data transferred to the bus and serial-to-parallel conversion on data received from the bus. Additionally, the CIU checks for bus errors and generates timing for the bus.

High rate experiment data (50MBPS) is routed through the data exchange control unit (DECU) where it is switched to recorders on

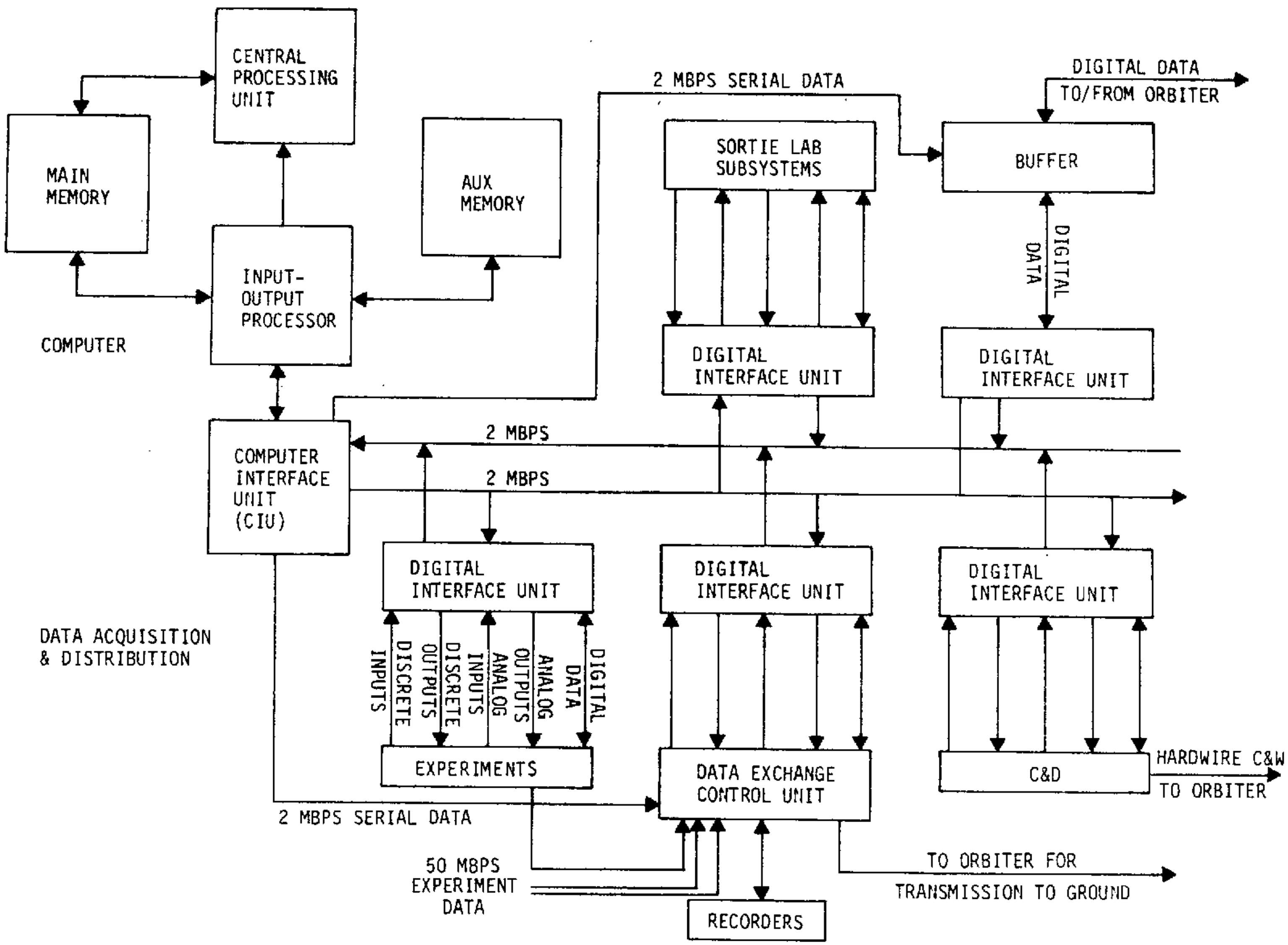


FIGURE 3.1-23. DMS DESIGN REFERENCE MODEL

the Sortie Lab or routed to the orbiter for transmission to the ground. Recorders presently selected have a capability for up to 50 MBPS input with a 30 minute record time per 14 inch reel. However, the present baseline is to use the orbiter/TDRS link which provides a near continuous return link to earth.

A digital data path exists between the Sortie Lab via a buffer and the orbiter. This interface is used for navigation updates.

Table 3.1-2 is an estimate of the number of instructions, main memory, auxiliary memory, and equivalent operations per sec required for the Sortie Lab subsystems. Instructions are assumed to be 16 bits while data are assumed to be 32 bits; thus one data storage location in memory is equivalent to two instructions. The estimates in this table do not include operations or control of the data bus. This may take between 150×10^3 to 200×10^3 equivalent operations per second.

	MEMORY			Operations Per Sec.
	INSTR.	MAIN	AUX.	
COMPUTER SYSTEM	2,370	1,812	586	1,040
POINTING ATTITUDE AND CONTROL	9,370	5,750	- -	133,820
CONTROL AND DISPLAY	4,868	2,576	4,770	5,480
DATA ACQ. AND DIST.	3,546	899	1,000	3,000 (1)
ELECT. POWER AND DIST.	154	168	- -	- - -
ENVIRONMENTAL CONTROL SYSTEM	354	188	- -	- - -
ONBOARD CHECKOUT	6,600	700	26,044 (2)	402 (3)
STRUCT. AND MECH.	120	100	- -	- - -
SUBTOTAL:	27,382	12,193	32,400	143,742
CONTINGENCY (50%)	13,691	6,097	16,200	35,935
TOTAL (4)	41,073	18,290	48,600	179,677

(1) Does not include Data Bus Control (estimated to be 150 - 200K OPS)
(2) Used only during ground checkout
(3) Flight Phase only
(4) No allowances made for use of higher order languages

TABLE 3.1-2. DMS COMPUTER SIZING

Table 3.1-3 gives an estimate of the measurements which will be required in the subsystem. From this table, the data bus load due to the subsystems were derived and are shown in Table 3.1-4. Analog measurements are assumed to be 10 bits in length, digital words 32 bits long, and each discrete word a single bit. The total traffic on the bus in flight due to the subsystems is less than 80×10^3 BPS. This does not, however, include supervisory or bus control data which flows on the other 2 MBPS bus. The above estimate indicates that only 5 to 10 percent of the full capability of the bus is being used by the subsystems; the remainder would be available for the experiments.

	INPUTS*			OUTPUTS*		
	ANALOG	DIGITAL	DISCRETE	ANALOG	DIGITAL	DISCRETE
POINTING ATTITUDE & CONTROL	300	100	- -	260	3	- -
CONTROL & DISPLAY	54	- -	20	- -	921	- -
MEASUREMENTS (FLIGHT ONLY)	340	- -	- -	- -	1,003	339
ONBOARD CHECKOUT (FLIGHT & GND)	60	- -	60	- -	60	60
ONBOARD CHECKOUT (GND ONLY)	1,056	- -	1,055	- -	1,819	1,055
COMMANDS	- -	2	- -	- -	- -	2
TOTAL FLIGHT	754	102	419	260	1,987	421
TOTAL GND CO	1,410	102	1,075	260	2,743	1,075

* Expressed in data words per sec

TABLE 3.1-3. SUBSYSTEM MEASUREMENTS

The onboard checkout subsystem (OCS) is shown in Figure 3.1-24 and is integrated into and utilizes all the data management system resources such as memory, data bus, and control and displays. Some special built-in test circuits and equipment may have to be provided in the subsystems and experiments. In addition, it may be desirable to provide a special recorder for trend and fault analysis. The OCS is used both during prelaunch and in flight. It provides stimuli to

FLIGHT

	DATA WORDS	NUMBER BITS	TOTAL BITS
ANALOG	1,014	10	10,140
DIGITAL	2,089	32	66,578
DISCRETE	840	1	840
TOTAL NUMBER OF DATA BITS			77,550

GROUND CHECKOUT

	DATA WORDS	NUMBER BITS	TOTAL BITS
ANALOG	1,670	10	16,700
DIGITAL	2,845	32	91,040
DISCRETE	2,150	1	2,150
TOTAL NUMBER OF DATA BITS			110,890

TABLE 3.1-4. DATA BUS SUBSYSTEM LOADING

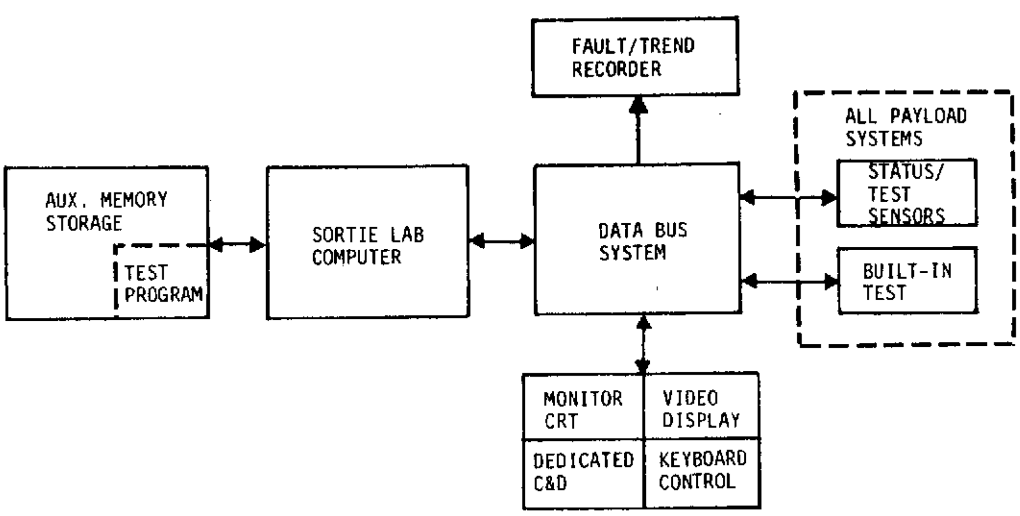


FIGURE 3.1-24. ONBOARD CHECKOUT

activate the subsystem for checkout and then monitors, checks and displays the test data and results. Testing may either be automated or controlled by an operator at the control and display console. For prelaunch checkout, the present philosophy is to provide as much autonomy in the Sortie Lab as possible.

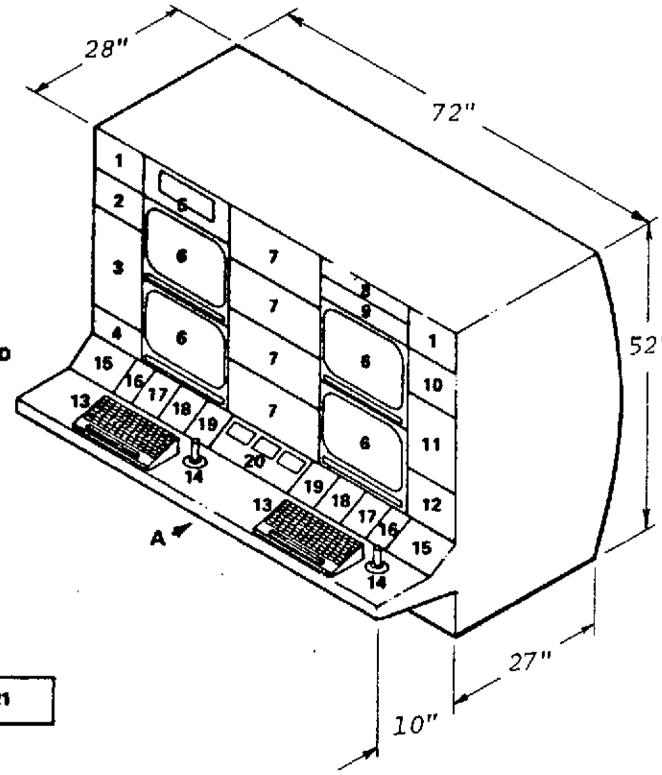
3.1.8 Controls and Display (C&D) Subsystem

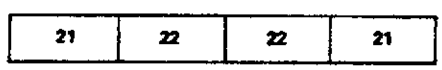
The support module C&D subsystem provides onboard control and display capability for Sortie Lab subsystems and experiments, and it provides the central control of the subsystems and experiments during on-orbit operations. Some additional pre-entry C&D capability is located in the Orbiter for monitoring and operation of the Sortie Lab prior to crew entry into the Sortie Lab habitable area.

The support module C&D console provides the capability for independent operation by two Sortie Lab crewmen simultaneously. The support module C&D console is shown in Figure 3.1-25. The six-foot C&D console was baselined for a ten-foot SM. That console length exceeds the 5-foot support module baseline that was adopted later. The same general configuration but a five foot length would be employed in the 5-foot support module. This console interfaces with the Sortie Lab computer, other subsystems, and experiments via the data management subsystem data bus. Limited hardwire connections are provided for certain critical starting functions (such as those which must function when the DMS is not fully activated) and for special experiment signals which do not readily lend themselves to data bus transmission.

The primary components in the C&D subsystem are the multifunction displays and hand controllers. Two display systems are provided and each includes two cathode ray tube (CRT) display units, one alphanumeric keyboard and one multifunction display symbol generator. Each multifunction display provides the capability for independent display of computer generated alphanumeric and graphics data as well as video information. Two 3-axis hand controllers are provided for pointing TV cameras, telescopes, cameras, celestial sensors and trackers, SEPB slew commands, and for vehicle attitude positioning by inputting rate

1. VIDEO SWITCHING UNIT
2. COMPUTER CONTROLS
3. ELECTRICAL POWER SUBSYSTEM DEDICATED C&D
4. CONSOLE CIRCUIT BREAKERS
5. ADVISORY PANEL
6. CRT DISPLAY INDICATOR UNIT
7. EXPERIMENT DEDICATED C&D
8. CAUTION & WARNING
9. TBD
10. DATA ACQUISITION DEDICATED C&D
11. ENVIRONMENT CONTROL SUBSYSTEM DEDICATED C&D
12. STABILITY & ATTITUDE CONTROL SUBSYSTEM DEDICATED C&D
13. ALPHANUMERIC KEYBOARD
14. HAND CONTROLLER
15. TAPE RECORDERS CONTROLS
16. MICROFILM TO VIDEO CONVERTER CONTROLS
17. AUDIO UNIT
18. CCTV CONTROLS
19. VIDEO SWITCHING CONTROLS
20. TIME DISPLAY UNIT
21. MULTIFUNCTION DISPLAY SYMBOL GENERATOR
22. MICROFILM TO VIDEO CONVERTER





A-A

FIGURE 3.1-25. SUPPORT MODULE C&D CONSOLE

commands to the CMG subsystem.

General purpose display services are also provided in the baseline design. Advisory display and caution and warning (C&W) panels are provided for low priority malfunction queues and for critical subsystem and experiment malfunctions. Time displays and an intercom system are provided for time references and internal communications. Microfilm to video converters are provided to convert cassette microfilm for TV display and video switching units are provided for closed circuit TV (CCTV), experiment video and microfilm output switching.

Additonal console space is provided for dedicated subsystem and experiment C&D. This provides the space for mounting unique experiment C&D and for selected critical and initial activation of subsystem and experiment functions which are hardwired to the C&D.

3.1.9 Pointing and Attitude Control Subsystem (PACS)

The major elements of the PACS are to be located on the pallet. These elements include the standard experiment pointing base (SEPB), and the advanced double gimballed CMG's. An overall description of PACS is provided in Section 3.3.10.

3.1.10 Mass Properties

The estimated mass properties (weight, center of gravity, and moment of inertia) can be found in Section 2.6. Mass properties shown include all subsystems required to support indicated lengths of EM(s).

The support module when utilized will require a flex tunnel. The flexible tunnel, 2 to 14 feet, weights 815 pounds. For missions requiring longer tunnels to meet orbiter longitudinal center of gravity constraints, weight is added at the rate of 50 pounds per foot.

3.1.11 User Provisions

Table 3.1-5 describes the provisions and capabilities in the Sortie Lab avionic subsystems for the performance and support of experiments. Other Sortie Lab user provisions may be found in Table 2.5-1.

3.2 Experiment Module Definition

3.2.1 Configuration

The Experiment Module (see Figure 3.2-1) primary structure consists of a 14-foot diameter constant section cylinder with modular lengths (6 to 16 feet). A 32-degree conical bulkhead is attached at the rear of the experiment module. The conical section at the aft end is removable to permit access and facilitate experiment installation and removal. This bulkhead is penetrated by viewports, subsystem control and data circuits lines and plumbing for thermal control of pallet mounted equipment.

PARAMETER	TOTAL CAPABILITY	NET CAPABILITY FOR EXPERIMENTS	NOTES
1. Electrical Power	7.0 KW, 650 KWH	4.1 KW, 293 KWH	• One to four peaking kits (500-AH batteries) may be added, as needed. • Regulated and unregulated 28vdc, and 115/208 vac Hz power provided.
2. Computer Processing	Memory - 32 K words	Memory - 13 K words	
3. Controls & Displays	Redundant multifunctioning displays and keyboards plus dedicated panels.	Normally, one multi-functioning display and keyboard, plus dedicated panels	• C&W panel, intercom, closed circuit TV, and microfilm viewers provided.
4. Communications Transmission Capicity	Return Link - Digital 50 mbps - Analog/video 5 MHz - Voice - - - Telemetry Forward Link - Command 8 kbps - Voice - - - Video TBD	Return Link - Digital up to 50 mbps - Analog/video to 5 MHz - Telemetry TBD Forward Link - Command TBD - Video TBD	• Shuttle Provided; using Ku through TDR'S and S-Band to STDN
5. Pointing and Attitude Control			
- Pointing (SEPB)	1 $\widehat{\text{sec}}$	1 $\widehat{\text{sec}}$	
- Stability	10^{-5} g	10^{-5} g	
6. Data Acquisition			
Rate (max)	50 mbps	50 mbps	• Tape recorders; redundant units provide for continuous recording.
Stowage (reels)	40 reels (digital & video)	40 reels (digital & video)	

TABLE 3.1-5. AVIONIC SYSTEM SUPPORT CAPABILITIES

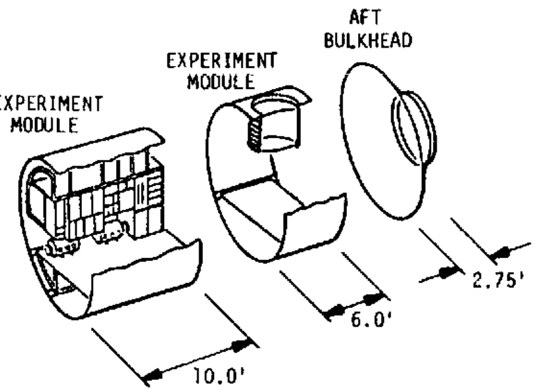


FIGURE 3.2-1. SORTIE LAB EXPERIMENT MODULE

Experiment equipment and payload-integration equipment are located in the experiment module. Internal mounting of this equipment is by a removable rack attached to the floor, pressure wall, and overhead structure. Temperature control for the equipment in the consoles and racks is integrated into the thermal control subsystem, and is accomplished by air cooling.

The payload-peculiar scientific airlock which is a significant addition to the basic structure is depicted in Figure 3.2-2. For a select group of payloads it is installed in the sidewall of the experiment module and can be separately pressurized and operated. Cover plates are provided for the unused opening when the airlock is not required. The airlock is configured with the driving requirements being the length of booms and the experiment package envelope. Figure 3.2-3 shows an experiment deployment concept, utilizing a scissors mechanism for the boom structure, that permits experiment deployment for a length of 30 feet.

3.2.2 Structure

The experiment module is similar to the support module as it has essentially the same design, construction and structural characteristics (Reference Section 3.1.2). The experiment module sizes are 6 feet, 10 feet, and 16 feet. Whereas the support module requires a forward skirt the experiment module has a structural interface with the pallet adapter.

The aft conical bulkhead has an integrally machined frame designed to accommodate viewing ports.

The six-foot module's cylindrical sidewall segment is modified to include structural accommodation for the scientific airlock.

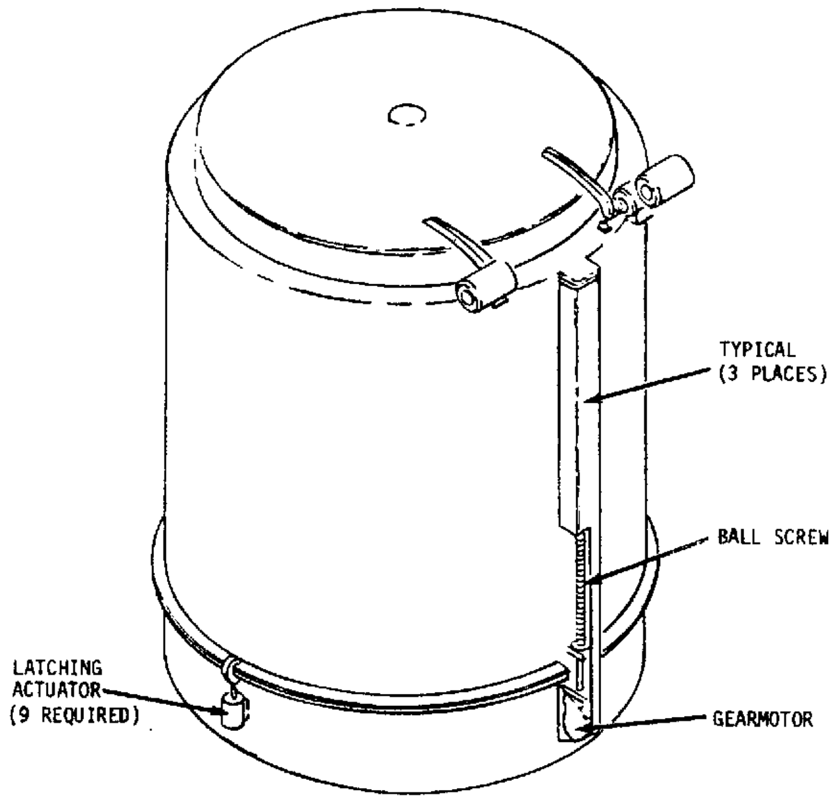


FIGURE 3.2-2. SORTIE LAB SCIENTIFIC AIRLOCK

3.2.3 Environmental Control System (ECS)

Although Section 3.1.3 provides some discussion of experiment accommodations, specific accommodations are reviewed in this section.

The ECS is designed for maximum flexibility of experiment equipment with available thermal control. The rationale of the study

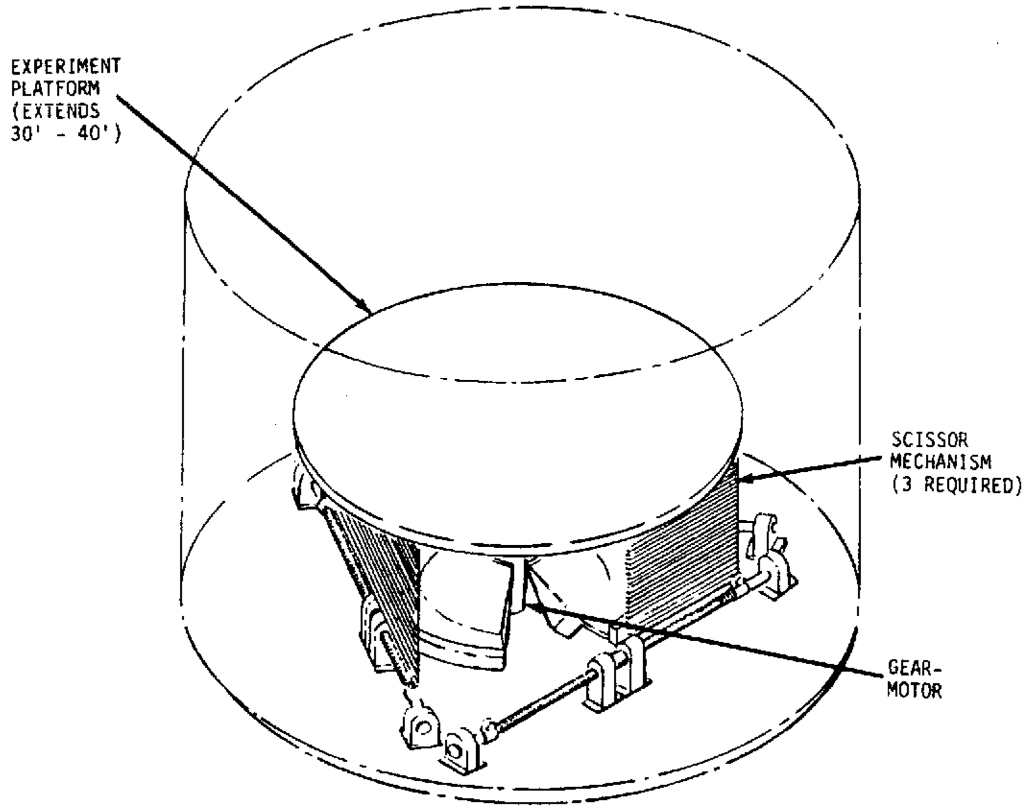


FIGURE 3.2-3. SORTIE LAB SCIENTIFIC AIRLOCK EXPERIMENT DEPLOYMENT CONCEPT

has been to have all equipment accommodated by the electrical power subsystem also accommodated with heat rejection capability. The resources planned provide the following capability and characteristics for experiments:

THERMAL CONTROL RESOURCE AVAILABLE	ALLOWABLE EXPERIMENT THERMAL LOADS
Maximum Heat Rejection (Average per orbit)	4 to 5 kw
Air Cooling	
- Cabin Circuit ($70\pm10^{\circ}F$)	1 kw
- Racks (75 to $105^{\circ}F$)	3 to 4 kw
Cold Plates (45 to $86^{\circ}F$)	4 to 5 kw

The cabin thermal design is oriented toward primarily air cooling of equipment rather than cold plates. If requirements are identified, cold plates can be integrated into the cabin but the total heat rejection available to experiments (air cooled plus cold plates) is 4 to 5 kw. The latest experiment resource allocation studies indicate experiment power will be reduced to 3.4 kw_e average and the subsystem power is 3.6 kw_e average. Therefore, the total heat rejection capability of the cabin is still adequate ($\sim$ 7 kw) but the split in available resources for subsystems and experiments is about equal.

Until better information is obtained, the following design approach has been taken for thermal air conditioning of additional laboratory equipment. An air distribution and thermal conditioning circuit specifically for equipment racks (separate from the crew comfort circuit) will be designed for handling up to 14,000 BTU/hr ($\sim$ 4 kw) air cooling loads. The heat exchanger selected for this circuit is the same type as the cabin heat exchanger. The maximum air flow across the heat exchanger is 700 CFM. The air and water coolant temperatures in this circuit are a function of cabin and rack thermal loads. The maximum return air temperature from the racks is 105°F. The cabin circuit uses the floor as a return duct, whereas, the equipment circuit has return ducts. The baseline design tends to isolate contaminants that might occur due to off-gassing from electronic equipment (particularly odors).

Experimenters must provide their own cooling system for required temperatures below that provided by the radiator (40°F).

An illustration of the internal experiment module configuration is presented in Figure 3.2-4.

3.2.4 Electrical Power

For an overall description of the EPS see Section 3.3.4.

3.2.5 Habitability

Sortie Lab habitability accommodations are discussed in Section 3.1.5.

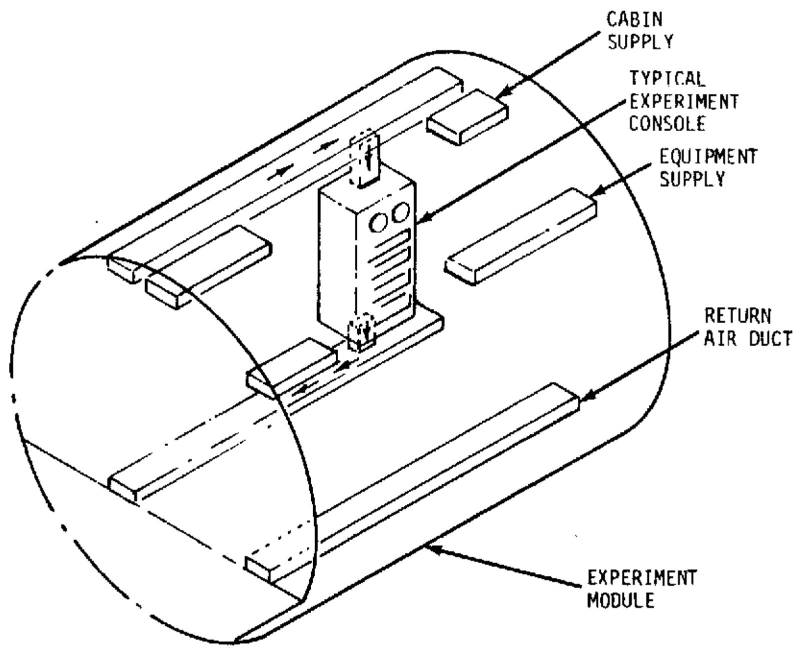


FIGURE 3.2-4. INTERNAL ECS CONFIGURATION (EXPERIMENT MODULE)

3.2.6 Communications

Sortie Lab communications are discussed in detail in Section 3.1.6.

3.2.7 Data Management and Onboard Checkout Subsystems

Data management and onboard checkout subsystem information is outlined in Section 3.1.7.

3.2.8 Controls and Display (C&D) Subsystem

The support module C&D subsystem provides onboard control and display capability for Sortie Lab experiments, and it provides the central control of the experiments during on-orbit operations. Since the C&D console is located in the support module, the C&D subsystem is outlined in Section 3.1.8.

3.2.9 Pointing and Attitude Control Subsystem (PACS)

An overall description of PACS is provided in Section 3.3.10.

3.2.10 Mass Properties

The estimated mass properties (weight, center of gravity and moment of inertia) can be found in Section 2.6. For module mass properties accounting purposes, the EM(s) and aft bulkhead consist of structure only. The following are those items on or in the EM(s) and/or aft bulkhead, which are weight charged to the SM.

	6'EM + BHD	10'EM + BHD	16'EM + BHD
Thermal coating and insulation	178 lb	263 lb	388 lb
ECS ducting	112 lb	185 lb	296 lb
Miscellaneous supports	122 lb	203 lb	325 lb
	412 lb	651 lb	1009 lb

3.2.11 User Provisions

The provisions and capabilities of Sortie Lab avionic subsystems are described in Section 3.1.11. Other Sortie Lab user provisions may be found in Table 2.5-1.

3.3 Pallet Definition

Some experiment payloads require large areas for mounting and operations. Pallet lengths can be 10, 15, 20, 25 feet, etc., the first section is always 10 ft. with increments of 5 or 10 ft.

3.3.1 Configuration

The Sortie Lab pallet shown in Figure 3.3-1 has the design capability to interface with the pressurized module or mate to the Orbiter. The design is driven by structural rigidity requirements, payload size, and viewing/exposure requirements. It also provides utility services distribution to external payload experiments. Pallet characteristics for a typical payload are presented in Table 3.3-1.

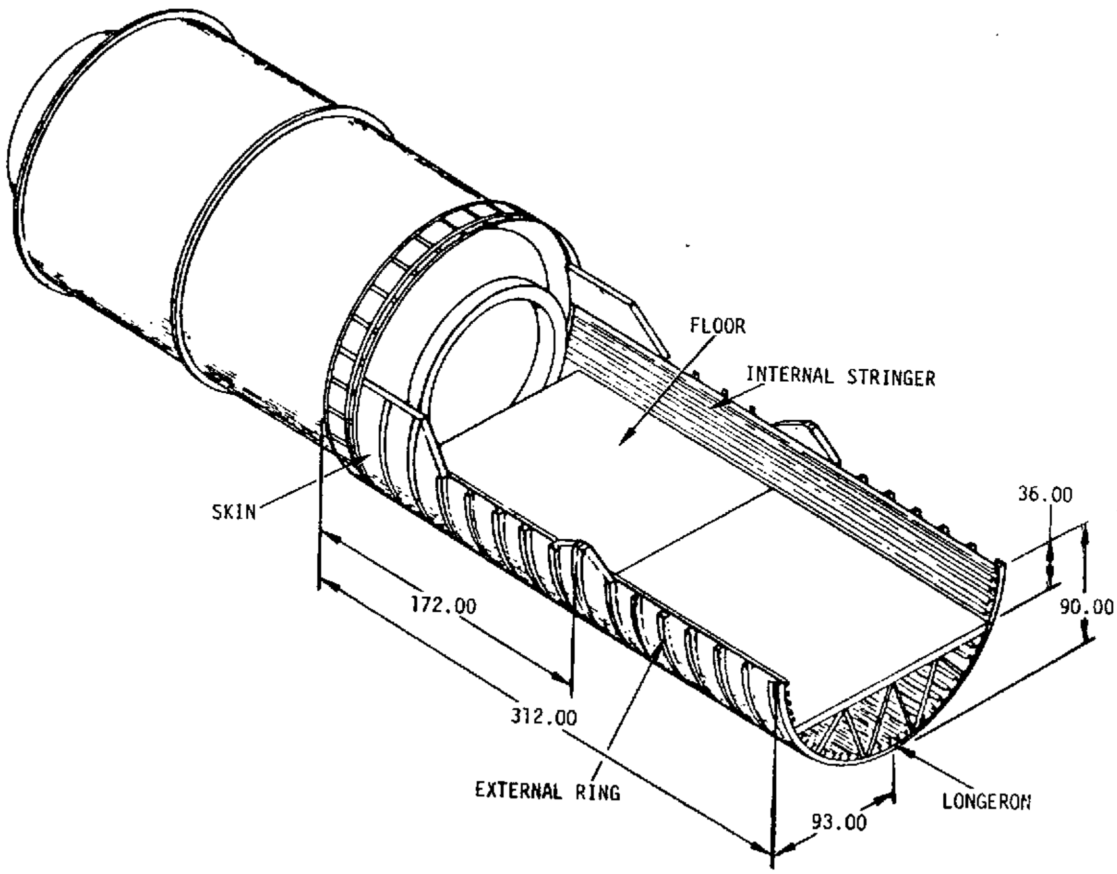


FIGURE 3.3-1. SHELL-TYPE PALLET STRUCTURE

Payloads having fine pointing requirements are satisfied by the use of add-on items such as the standard pointing base or large CMG's. This capability plus the mounting flexibility provided by the sheet/stringer construction enables the pallet to accommodate payloads with wide variations in mounting requirements.

The forward end of the 168 inch diameter pallet interfaces directly to a 33 inch long pallet adapter which serves as the direct attachment link to the pressurized module primary structure. The pallet adapter is necessary in order to accommodate pallet segments because of the protuberance of the aft bulkhead into the pallet floor area. The pallet adapter will not be required for the pallet only mode. The pallet adapter as well as the pallet structure is a shell of sheet/stringer construction and uses aluminum alloys with riveted joints.

Feedthroughs from the pressurized module aft conical bulkhead provide umbilical connects for direct cabling power, ECS commands and data to experiment apparatus. Electrical power, communications, and data management, and thermal control for the payload will be provided by the pressurized module. Support equipment on the pallet will be data terminal components, freon fluid lines and cold plates. See Sections 3.1.4 and 3.3.4.

PARAMETER	CONFIGURATION
OVERALL LENGTH	274.0 in. (22.8 ft)
NOMINAL WIDTH	168.0 in (14.0 ft.)
MAX HEIGHT	87.0 in (7.2 ft.)
FLOOR-NOMINAL SIZE; GROSS AREA	142.0 in. x 240.0 in.; 34,080 in^2
SUPPORT FITTINGS	1
TYPE OF CONSTRUCTION	SHEET/STRINGER HALF SHELL
MATERIAL	ALUMINUM ALLOY
ELECTRICAL POWER	28 VDC; 115 VAC, 400 HZ
COMMUNICATIONS	
CONTROL AND MONITOR	HARD LINE TO SORTIE LAB
TV CAMERAS	2
THERMAL CONTROL	FLUID LINES PLUMBED TO SORTIE
DATA MANAGEMENT	HARD LINE TO SORTIE LAB
STABILIZATION & ATTITUDE CONTROL	
CMG	PROVISIONS FOR 3
GIMBALS	PROVISIONS FOR 1
WEIGHT	2533 LBS

TABLE 3.3-1. PALLET CHARACTERISTICS FOR EXPERIMENT EO-4

3.3.2 Structure

The Sortie Lab pallet structure, Figure 3.3-2, is essentially a half cylinder made from sheet metal. It is 108 inches in diameter and has modular segments 60 and 120 inches long. It has a large frame at the aft end, which is used to mount the pallet/orbiter attach fittings. The forward end of the pallet has a bolt ring flange (Figure 3.3-3), that mates with a similar ring on the pressurized module with high strength

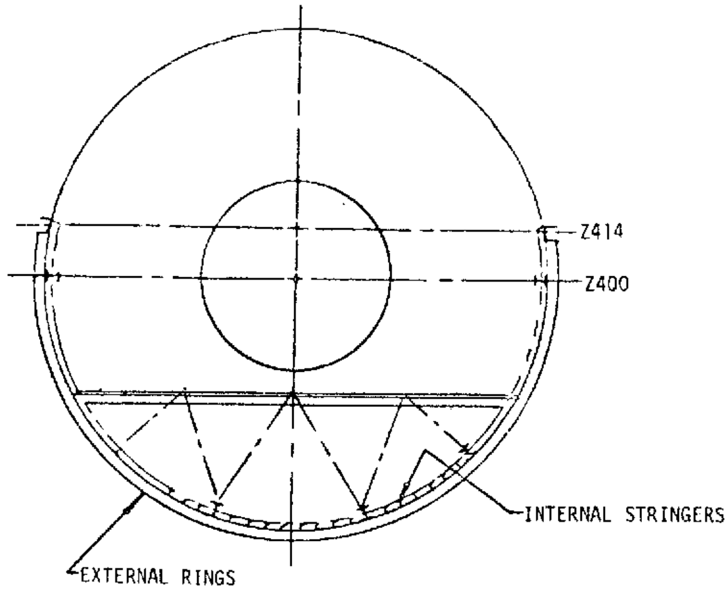


FIGURE 3.3-2. PALLET-END VIEW

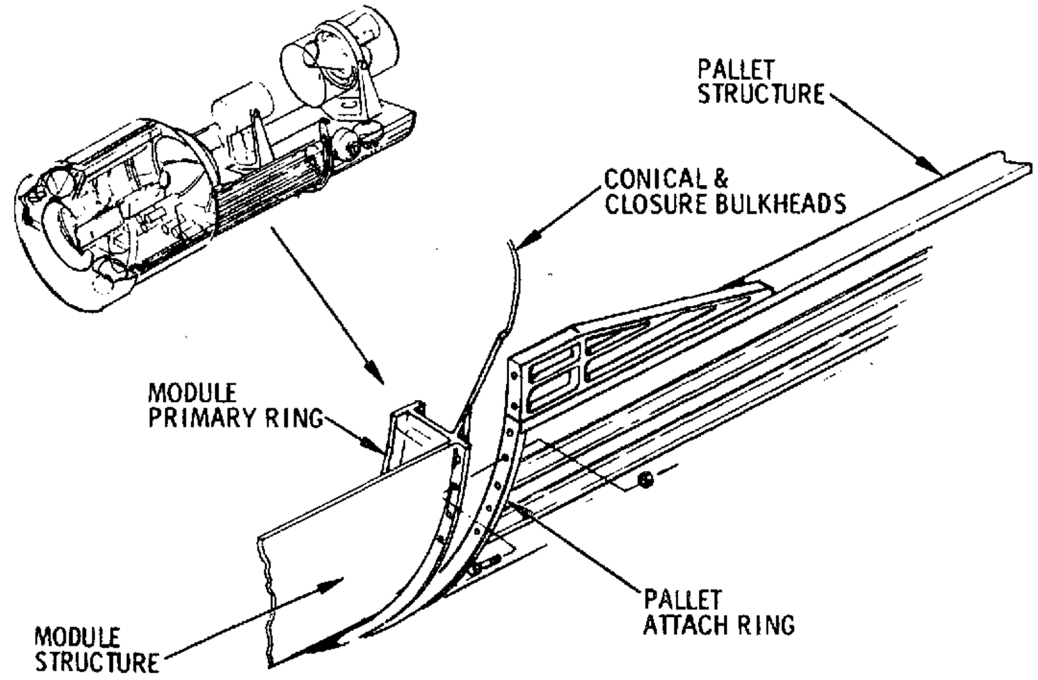


FIGURE 3.3-3. SORTIE LAB PRESSURIZED MODULE TO PALLET MECHANICAL INTERFACE

bolts. The forward ring may also be used to mount pallet/orbiter attach fittings for the pallet only mode.

A structural floor runs the length of the pallet. Two major longerons are attached to the shell structure edge at the centerline to react the large bending loads. A machined fitting is attached to these longerons at the pressurized module's end to spread the load into the module's structure. The floor is supported at the shell by other longerons and a series of floor truss members.

The shell structure is a typical semi-monocoque structure with external stringers and internal rings. Attached to the floor longeron are I-beam sections that span the cylindrical shell and support the floor.

The floor of the pallet is a honeycomb structure designed to accept cutouts or to which machined plates can be attached. The machined plates are used for equipment mounts.

The pallet structure uses aluminum alloys and has a riveted construction.

3.3.3 Environmental Control System (ECS)

Life support/atmospheric conditioning provisions are not required for the Sortie Lab pallet. Thermal control for the pallet is provided by the pressurized module. Pallet cold plates are conditioned by the pressurized module's radiator loop.

Further work is needed to define the Freon flow arrangement to the pallet and tradeoff a pallet interface heat exchanger between an independent pallet loop and the cabin water loop. In this regard it appears a single fluid loop between the cabin and radiator would greatly enhance system simplicity and flexibility. It is anticipated that much of the equipment on the pallet can be passively thermally controlled. Passive thermal control consists of insulation, proper optical coatings and heaters. Final design must await more detailed experiment definition. In any case one kilowatt cold plate cooling is available to pallet mounted experiment equipment.

3.3.4 Electrical Power

The electrical power subsystem (EPS) as illustrated in Figure 3.3-4 consists of a single Shuttle-type, 7 kw average, 10 kw peak fuel cell with silver oxide-zinc (AgZn) batteries for peak power purposes. These sources feed a centralized control and conditioning system with local distributors in each module. EPS distribution is achieved with standardized modules, which utilize a data bus interface and/or hardwire for their control and monitoring. A system utilizing two pallet mounted fuel cells rather than replaceable peaking batteries is an alternative under consideration for use in one of the Sortie flight modules.

The 7 kw fuel cell will meet all load requirements, except for seven of the presently defined payloads. The allocation of electrical power for the baseline system is shown in Table 3.3-2.

	Peak Power	Average Power	Total Energy
Experiments	6.0 kw	4.1 kw	293 kwh
Subsystems	4.0 kw	2.9 kw	357 kwh
Basic Size	10.0 kw	7.0 kw	650 kwh

TABLE 3.3-2. ELECTRICAL POWER REQUIREMENTS

One of four peaking kits (500 AH Batteries) are required to meet all payload requirements. Electrical power available from the orbiter is 1 kw average power during peak orbiter usage and 3 kw average during normal orbiter usage with a total of 50 kwh available. This electrical power is allocated for use during transport to and from orbit and for a back-up energy source during orbital operations.

It is proposed to mount the fuel cell, battery kits, water storage, reactants and tankage together on the pallet. This arrangement will facilitate test and checkout of the power supply as a unit, minimize fluid interfaces, and provide the option to use the fuel cell

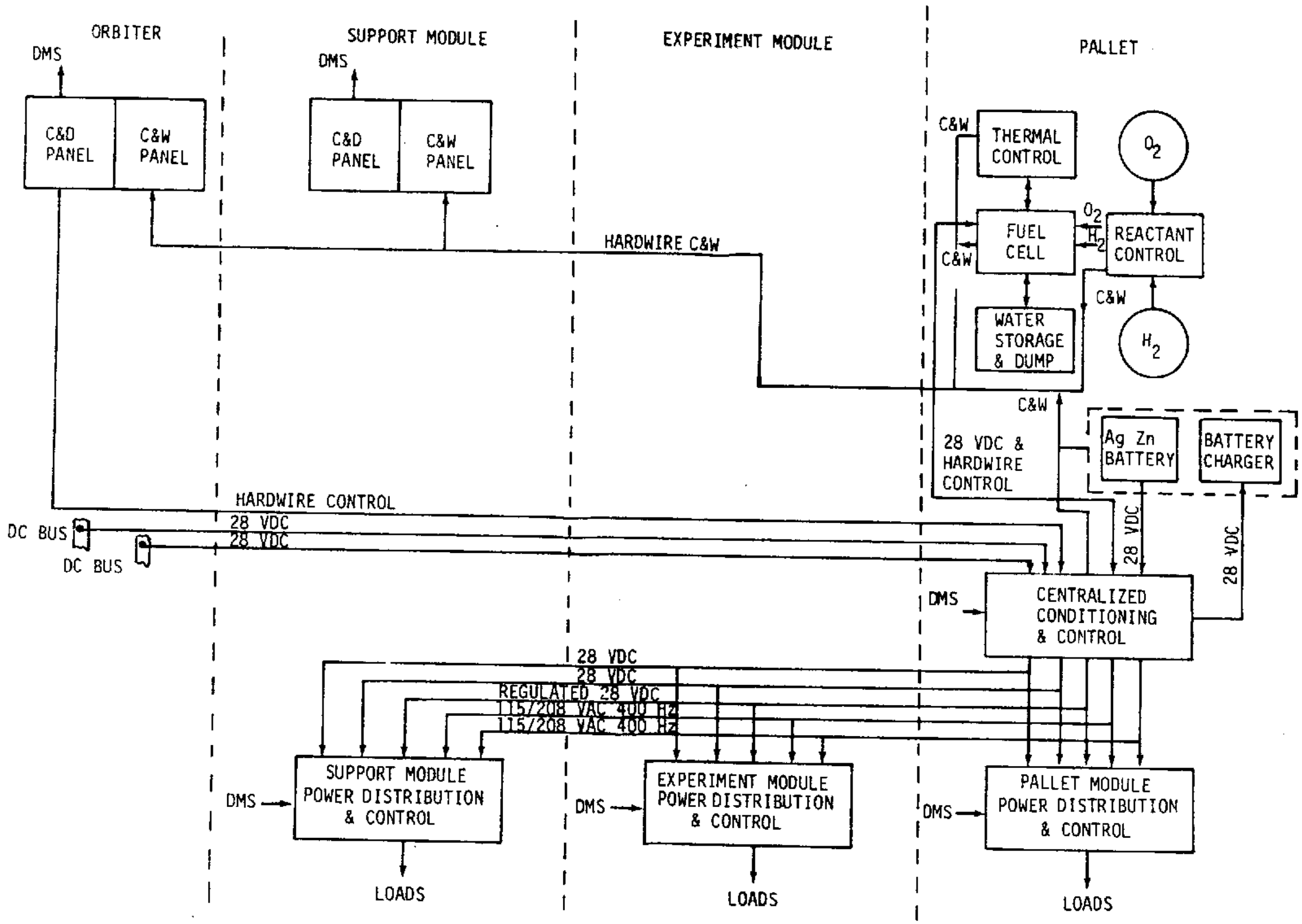


FIGURE 3.3-4. SORTIE LAB EPS BLOCK DIAGRAM (PALLET-MOUNTED FUEL CELL)

pallet for pallet only missions. Weight and volume of the baseline system is 3150 pounds, including reactants, and 107 ft^3, respectively.

3.3.5 Communications

Section 3.1.6 provides a detailed discussion of Sortie Lab Communications.

3.3.6 Data Management and Onboard Checkout Subsystems

Data management and onboard checkout sybsystems information is outlined in Section 3.1.7.

3.3.7 Controls and Display (C&D Subsystem)

The support module C&D subsystem provides onboard control and display capability for Sortie Lab experiments, and it provides the central control of the experiments during on-orbit operations. There will be provisions for visual monitoring of operations and inspection of equipment mounted on the pallet.

Since the C&D console is located in the support module, the C&D subsystem is outlined in Section 3.1.8.

3.3.8 Mass Properties

Pallet lengths can be 10, 15, 20, 25 feet, etc., i.e., the first section is always 10 feet with increments of 5 or 10 feet.

The estimated mass properties (weight, center of gravity, and moment of inertia) can be found in Section 2.6.

3.3.9 User Provisions

The data bus subsystem and the electrical power distribution subsystem are to be routed to the pallet. The digital interface units (DIUs) and power distributors are to be located to facilitate interfacing with the experiment and subsystems equipment located on the pallet.

Sortie Lab user provisions may be found in Table 2.5-1.

3.3.10 Pointing Attitude and Control Subsystem (PACS)

Sortie missions must accommodate a number of different experiment disciplines with a wide range of pointing and stabilization requirements which must be provided by the PACS. The following is a list of requirements indicating ranges:

- Targets (Stellar, Solar, Earth, None)
- Maximum Observation Time (15 sec to 300 min)
- Maximum g-level (No requirement to 10^{-5}g)
- Pointing Accuracy (No requirement to 1 $\widehat{sec}$)
- Pointing Stability (No requirement to .05 $\widehat{sec}$)
- Contamination (No requirement to stringent requirement)
- Mission duration (7 days or 30 days)

As a result of the variation in requirements the optimum configuration for the PACS varies from mission to mission according to the experiment payload. The PACS design is, therefore, a modular concept in which sensors, actuators and related equipment can be added or removed as a function of the experiment payload. The PACS design reference model with optional kits designated is shown in Figure 3.3-5.

When the experiment payloads require pointing accuracies no less than 0.5 degrees, allow accelerations up to 10^{-4}g, and have no stringent contamination requirements, the orbiter attitude control propulsion system with low thrust RCS is sufficient.

For those payloads requiring low contamination, pointing accuracies less than 0.5 degrees, and/or accelerations less than 10^{-4}g. four 3000 ft-lb-sec advanced Skylab DGCMGs are mounted on the pallet and are utilized for pointing and stabilizing the Orbiter/Shuttle vehicle. A strapdown rate gyro package is mounted on the pallet to provide attitude sensing. The strapdown calculations are periodically updated from the Orbiter.

For astronomy and earth resources experiments, an SEPB (Standard Experiment Pointing Base) is mounted on the pallet. The SEPB has a set of three coarse gimbals and a set of three fine gimbals

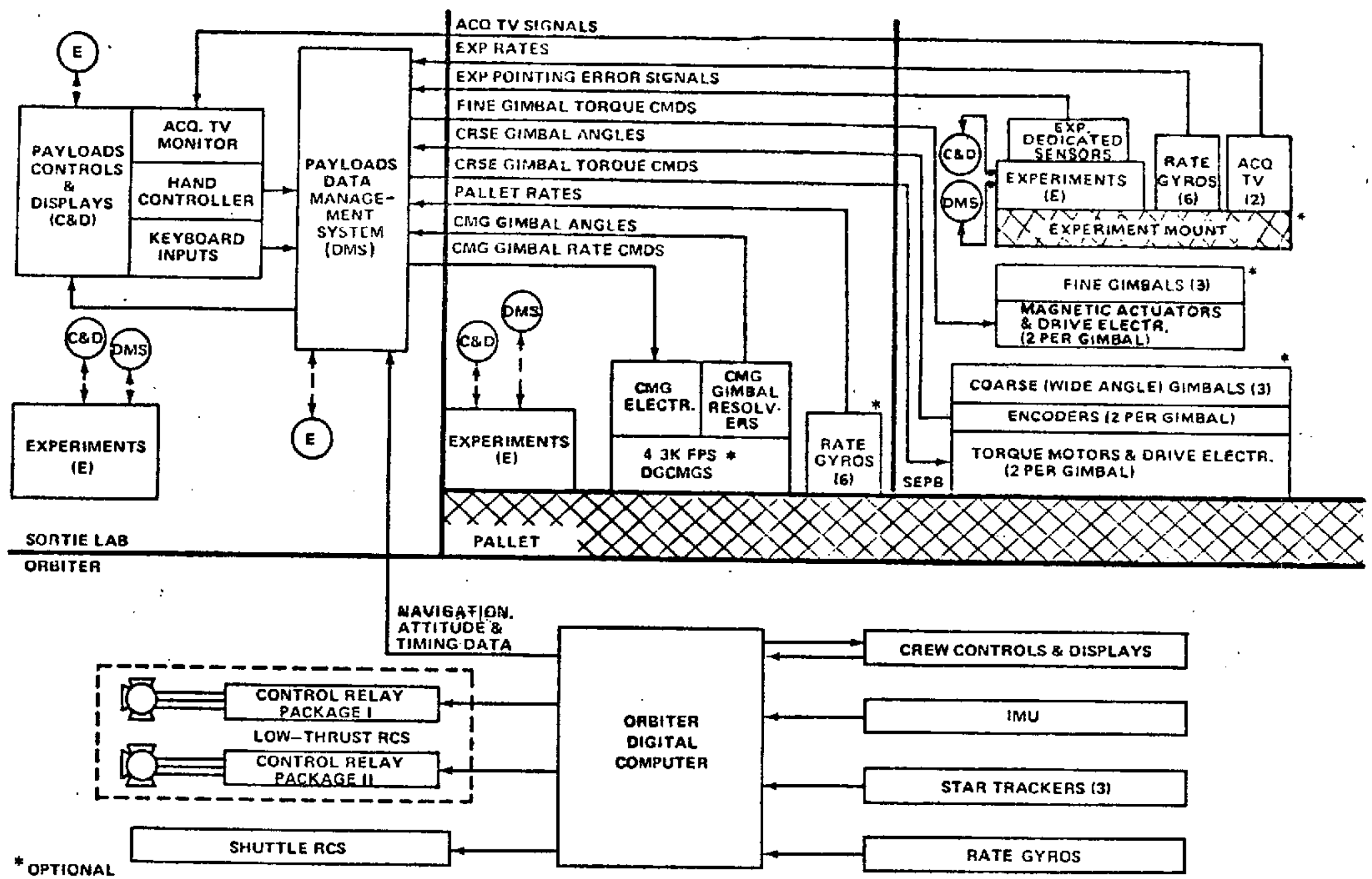
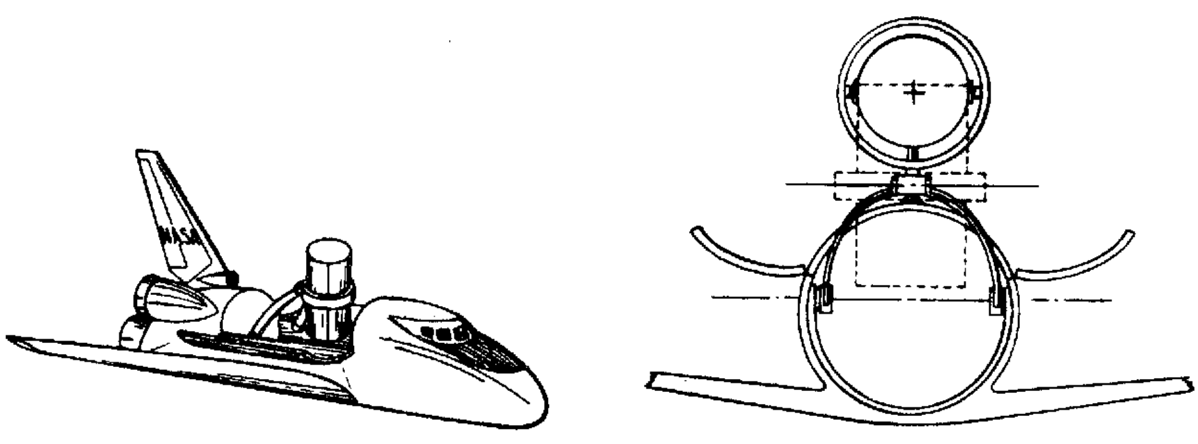


FIGURE 3.3-5. PACS DESIGN REFERENCE MODEL

for slewing, pointing, and stabilizing to a fine accuracy about three axes. See the illustration in Figure 3.3-6. The fine gimbals, utilizing magnetic actuators and rotating on an air bearing system, are active only during the fine pointing mode (data taking) after target acquisition. They have a range of ± 2.5 degrees and an accuracy less than ± 1.0 arc sec. The coarse gimbals are driven by torque motors to provide coverage of the entire hemisphere above the payload bay and to roll ± 45 degrees about the experiment line of sight. They are used to maneuver or hold the SEPB with respect to the Orbiter/Sortie vehicle and to maintain the fine gimbals near their null position during the fine pointing mode. An acquisition TV is mounted on the SEPB to provide the experimenter with a view of the target to perform final target acquisition by a hand controller after the SEPB has been maneuvered by automatic command to obtain the target within the TV coarse field of view, ± 10 degrees. A high precision rate gyro package is mounted on the SEPB and used in a strapdown configuration to provide an attitude reference. This reference is updated periodically from the experiment fine guidance sensor.



S.E.P.B. DEPLOYED

FIGURE 3.3-6. SEPB CONCEPT

3.4 Pallet Only

Missions that are classified as pallet only are those that have payloads that do not require pressurized module support and need a large area for mounting and operating experiments or sensors.

3.4.1 Configuration

The pallet only configuration is the same as described in Section 3.2.1 without the pressurized module. The Orbiter attach fittings are mounted on the forward ring. Support functions for all pallet only experiment payloads are furnished by the Orbiter. These functions are provided through umbilicals and are distributed to the external experiment payloads. (See Figure 3.4-1.)

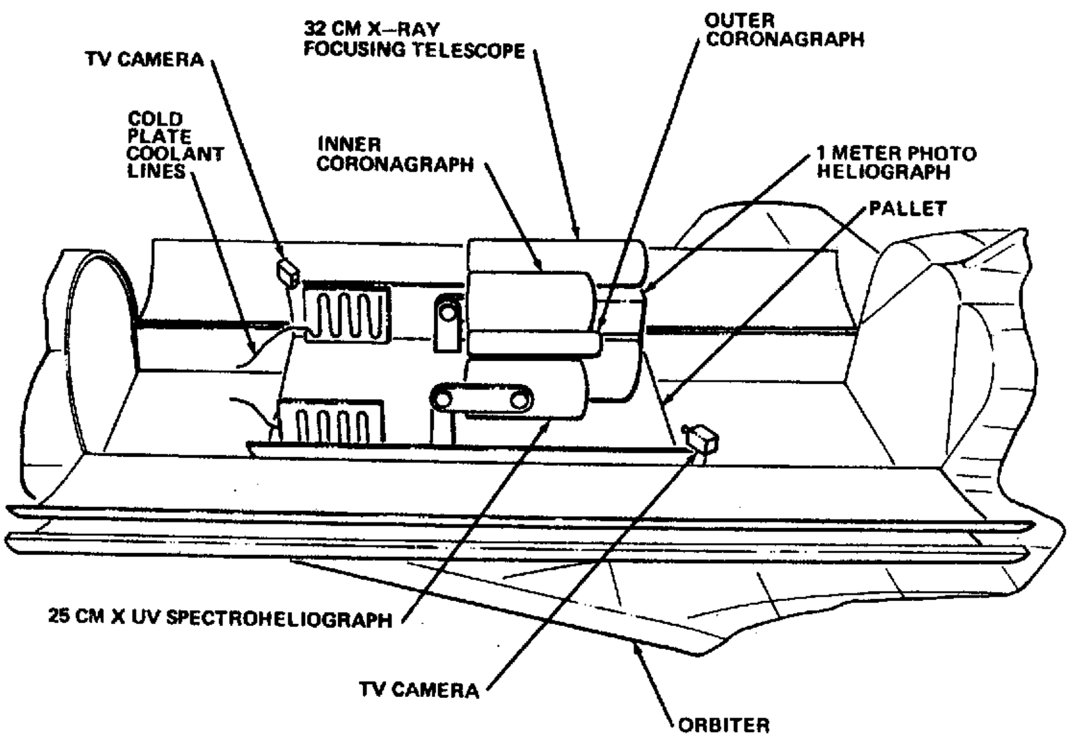


FIGURE 3.4-1. REPRESENTATIVE PALLET ONLY MISSION (ASTRONOMY)

3.4.2 Structure

The structure of the pallet only concept is the same as that described in Section 3.3.2 with the exception of the attach fittings added to the forward ring to provide support capability.

3.4.3 Environmental Control System (ECS)

The discussion in Section 3.3.3 applies also to pallet only missions with the exception that thermal resources will be provided by either the Orbiter or pallet-located passive thermal equipment.

3.4.4 Electrical Power Subsystem

The electrical power subsystem is the same for the pallet only configuration as defined in Section 3.3.4 except that the power distribution subsystem will be modified to provide power distributors as needed to facilitate interfacing with the experiment and subsystems hardware.

3.4.5 Habitability

For Sortie Lab pallet-only missions the Shuttle rbiter will provide the necessary habitability elements for Sortie Lab personnel. The habitability elements are: (a) Facilities - personal hygiene and galley (food, water and housekeeping), (b) Furnishings - seats, sleeping provisions, garments and personal gear, living accommodations, off-duty equipment, mobility aids and restraints, and passageways, and (c) Environmental Requirements - acoustics, temperature, lighting, air flow and interior design.

3.4.6 Communications

The communications subsystem is the same as defined in Section 3.1.6.

3.4.7 Data Management and Onboard Checkout Subsystems

The data management and onboard checkout subsystems' functions and hardware requirements are the same as defined in Section 3.1.7 except all major components (except the tape recorders) are mounted on the pallet and the data bus routing is modified to provide digital interface units (DIU) located as needed to interface with the subsystems and experiment hardware. The recorders must be located in the Orbiter in a controlled environment to permit the crew to change reels, as needed.

3.4.8 Control and Display Subsystem

The pallet only C&D console provides the central control for Sortie Lab subsystems and experiments during orbit operations. The pallet only C&D console interfaces with the Sortie Lab computer, other subsystems and experiments via the data management subsystem's data bus. Limited hardwire connections exist for critical start up functions which must operate independent of the data bus.

The pallet only C&D console provides the same type capabilities as provided by the support module C&D console. The pallet only C&D console is located in the Orbiter and configured for only one man operation as shown in Figure 3.4-2 and includes multifunction control and display components for both subsystems (Sortie Lab subsystems are located either on the pallet or in the Orbiter) and experiment control, dedicated C&D components for subsystem control, and space for dedicated experiment-supplied C&D components (See Section 3.1.8 for further explanation of the C&D console functions).

3.4.9 Pointing and Attitude Control Subsystem (PACS)

The pointing and attitude control subsystem (PACS) is the same as defined in Section 3.3.10.

3.4.10 Mass Properties

For the pallet only mission the pallet mass properties are the same as those listed in Section 2.6 with the exception of the pallet adapter (263 lbs) which is not required.

3.4.11 User Provisions

The user provisions provided are the same as defined in Sections 2.5.2 and 3.1.11 except only one control station is provided

1. DEDICATED EXPERIMENT C&D
2. ADVISORY PANEL
3. THERMAL CONTROL SUBSYSTEM DEDICATED C&D
4. STABILITY & ATTITUDE CONTROL DEDICATED C&D
5. MULTIFUNCTION CRT INDICATOR UNIT
6. MICROFILM TO VIDEO CONVERTER
7. MULTIFUNCTION DISPLAY SYMBOL GENERATOR
8. CAUTION & WARNING
9. COMPUTER & DATA ACQUISITION C&D
10. ELECTRICAL POWER SUBSYSTEM DEDICATED C&D
11. ALPHANUMERIC KEYBOARD
12. HAND CONTROLLER (3 AXIS)
13. TAPE RECORDER CONTROLS
14. TBD
15. CCTV CONTROLS
16. TIME DISPLAY UNIT
17. VIDEO SWITCHING
18. HAND CONTROLLER MODE & ENABLE CONTROLS
19. AUDIO UNIT

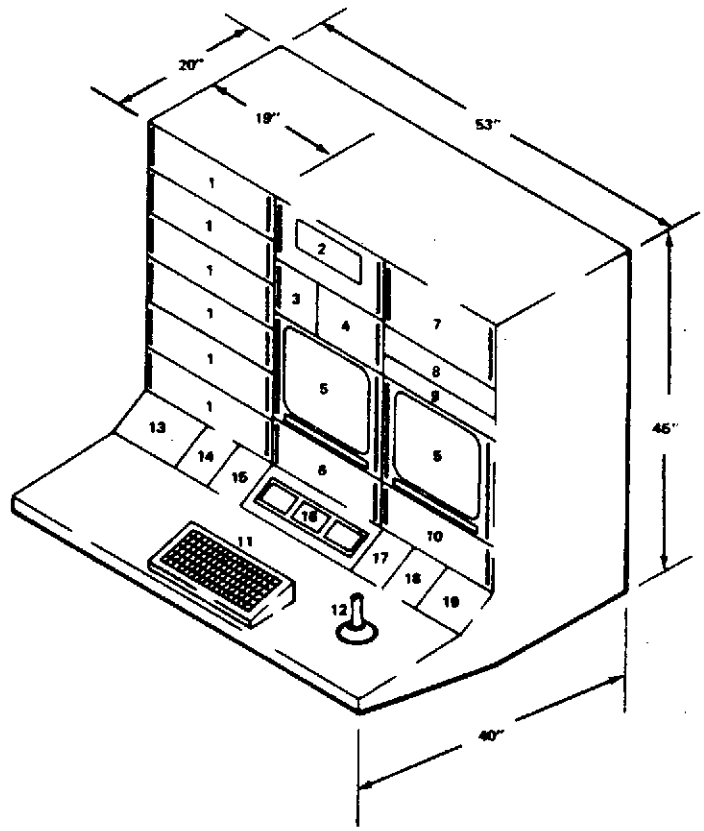


FIGURE 3.4-2. PALLET ONLY C&D CONSOLE

in the C&D and this station must be time shared between experiments and subsystems.

3.5 System Interfaces

The Sortie Lab mission requires that Sortie Lab elements interface with other programs including the space shuttle, ground facilities, and payloads as shown in Figure 3.5-1. These interfaces are of importance to Sortie Lab design, since the Sortie Lab system must be compatible with the interfacing system and is dependent on the support received from these systems. Another category of interfaces is the interface connection between the Sortie Lab elements.

3.5.1 Intersystem Interface

To meet the requirements of major interfaces between the Sortie Lab and other systems, interfaces that were insensitive to

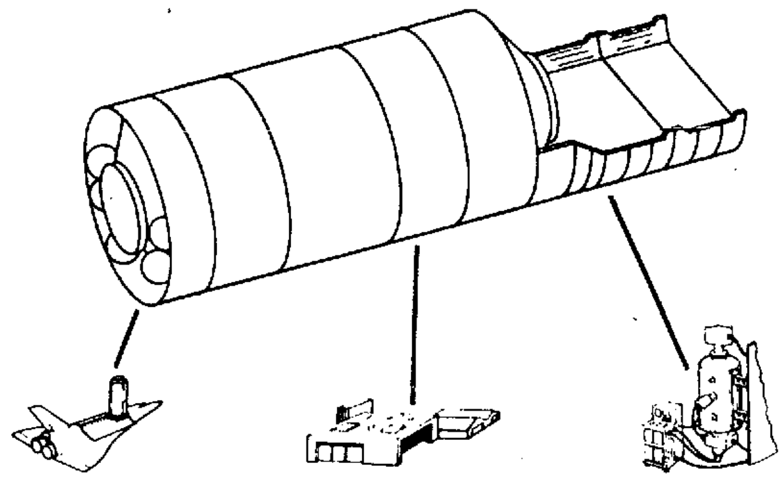


FIGURE 3.5-1. SORTIE LAB SYSTEM INTERFACES

changes, economical, and flexible to changing Sortie Lab payload requirements were considered. In taking the approach, the Sortie Lab interfaces were simplified and minimized the impact of the Sortie Lab project on the interfacing systems.

3.5.1.1 Shuttle Interfaces

Sortie Lab was designed to be essentially self-sufficient, thereby having minimum interface with the Shuttle system. Figures 3.5-2, 3.5-3, and 3.5-4 present the typical Sortie Lab payload mechanical and functional interfaces with the Shuttle.

The electrical interfaces between the Sortie Lab and the Shuttle Orbiter subsystems are shown in Figure 3.5-5. Shuttle electrical power is provided during transport to and from orbit and is provided as a back-up source during orbit operations. Redundant power buses are provided. A two way link is provided between the Sortie Lab data management subsystem, the Shuttle computer subsystem for requesting and receiving navigational and timing data and for receiving commands/data from the ground. All data for transmission to the ground network stations is routed through the Sortie Labs data exchange control unit which interfaces with the Shuttle communications subsystem. For the pallet only configuration experiment data may be routed

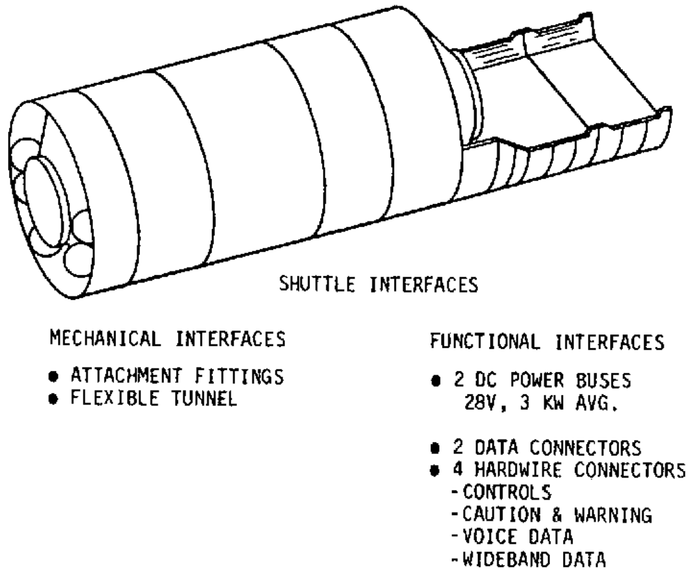


FIGURE 3.5-2. SORTIE LAB TO SHUTTLE INTERFACES

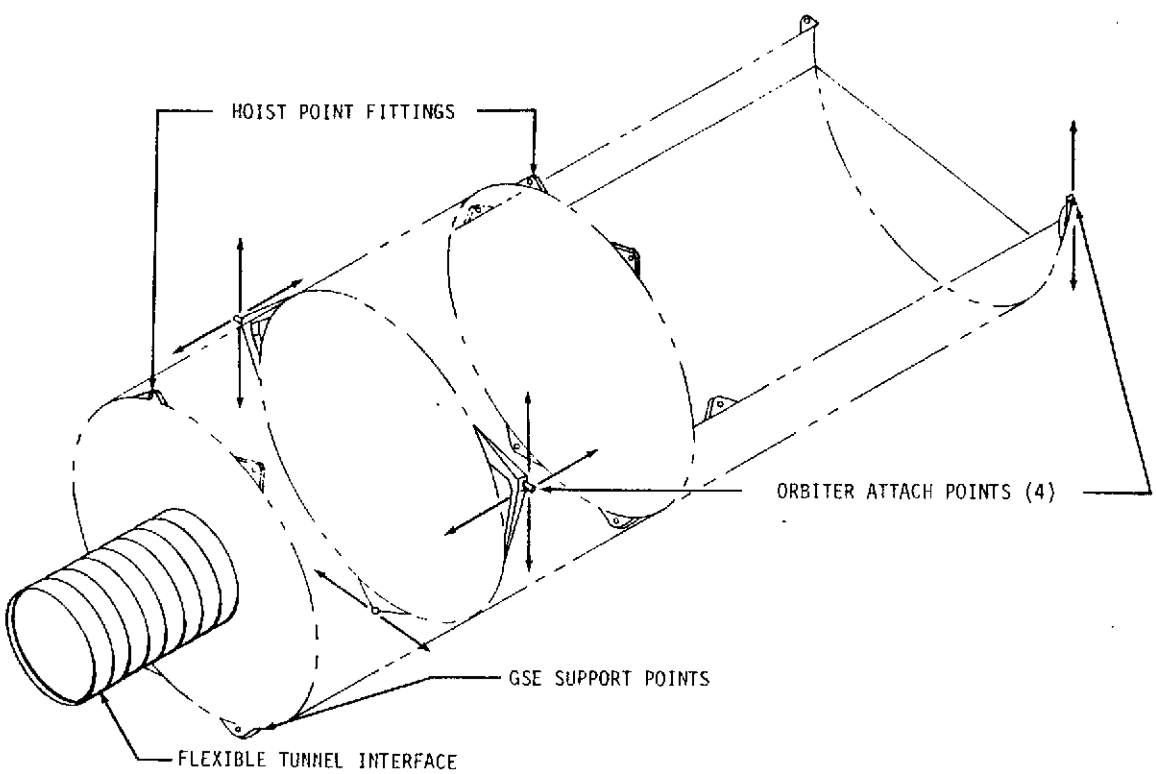
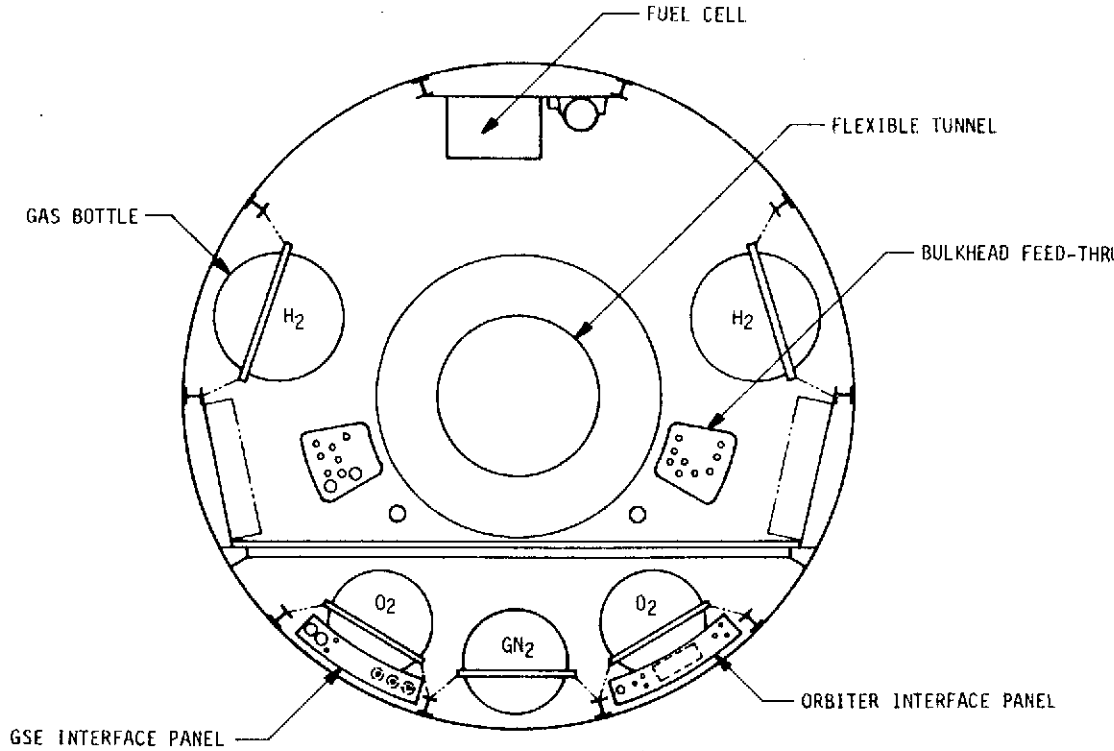


FIGURE 3.5-3. SORTIE LAB MECHANICAL INTERFACES



END VIEW OF SORTIE LAB SUPPORT MODULE

FIGURE 3.5-4. SORTIE LAB TO ORBITER FUNCTIONAL INTERFACES

to the payload support station recorders located in the Orbiter. A caution and warning interface is provided to satisfy the Shuttle requirement for safety monitoring the payload subsystems by the orbiter crew. An interface is provided between the Sortie Lab electrical power system and the environmental control system and with the orbiter control and display subsystem to provide the capability to power the Sortie Lab subsystems up-down from the orbiter and to provide needed status data prior to the crews entry into the Sortie Lab. Also, a two way voice link is provided between the orbiter and Sortie Lab.

During ground checkout and prelaunch operations the electrical support equipment will supply electrical power, communications, and those command, control and data collection and evaluation functions needed to assure flight readiness.

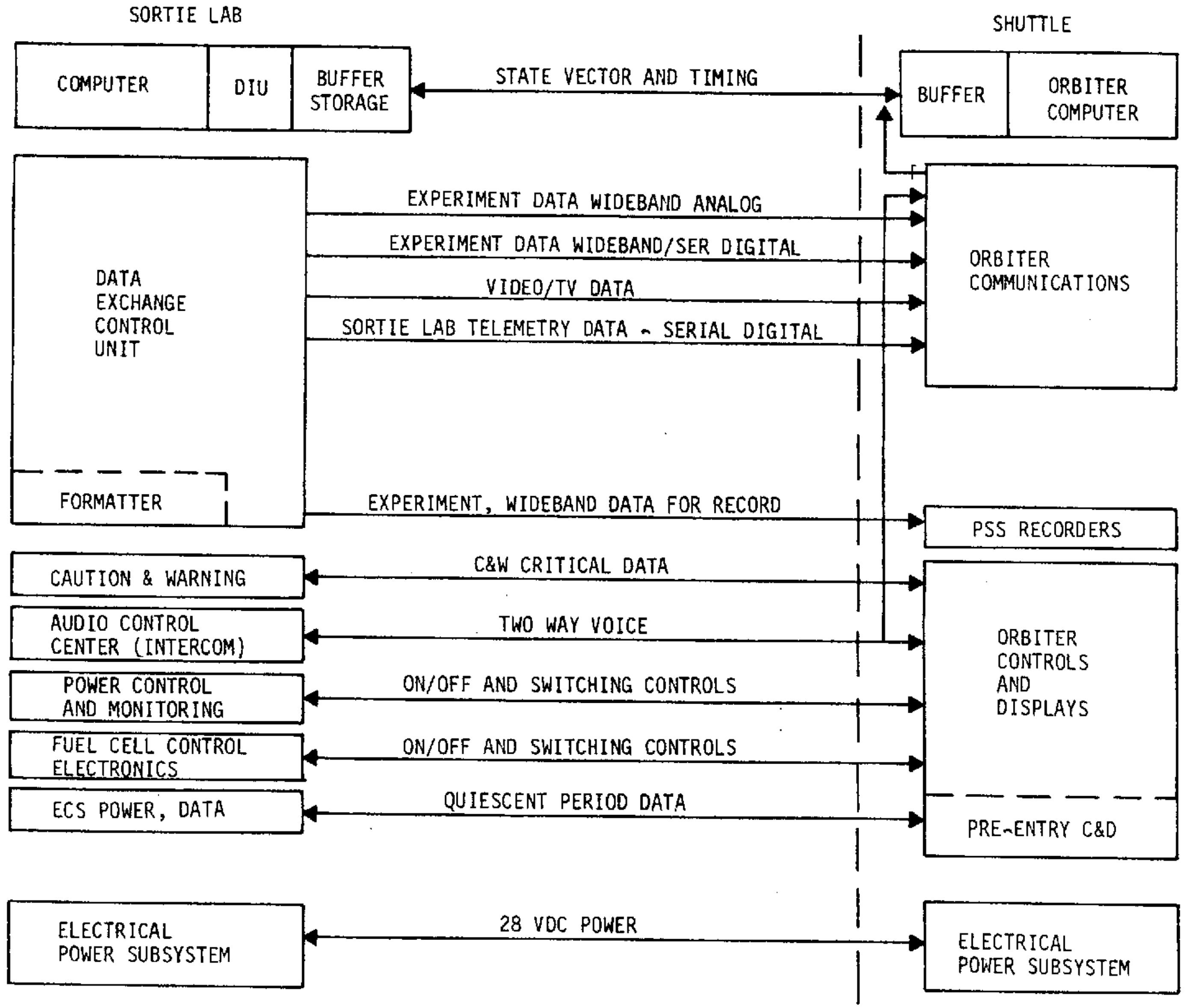


FIGURE 3.5-5. SORTIE LAB TO ORBITER ELECTRICAL INTERFACES

3.5.1.2 Experiment Payloads

The approach to payload integration has had as an objective the design of laboratories that will economically provide the versatility required to be responsive to experiment requirements. The approach for the physical integration of payloads has been to provide each Sortie Lab with a basic capability with respect to subsystems performance and accommodation volume. For specific payloads with greater or more stringent requirements, add-on subsystems are provided.

Flexibility in the mounting of various internal payload equipment is provided by removable racks that do not affect the basic structure of the Sortie Lab (Figures 3.5-6 and 3.5-7). This arrangement permits rapid removal and replacement of payloads.

3.5.1.3 Ground Facilities Interface

The ground servicing panel is the interface connection for providing resources while the Sortie Lab is mated to the Shuttle Orbiter vehicle at the launch pad and, after post landing, in the Orbiter safing area (Figures 3.5-8 and 3.5-9). Umbilicals provide the service lines that connect the Sortie Lab ground servicing panel through the Orbiter payload service panel. Services provided by the ground system at the launch pad include electrical power, cooling loop, cryogenic fluids, and gaseous fluids.

3.5.1.4 Pallet Only Interfaces

The pallet only interfaces to the Shuttle Orbiter are shown in Figures 3.5-10 and 3.5-11. Shuttle resources are transmitted to the experiments on the pallet by umbilicals connected to the Orbiter services feed-thru. Services provided by the Orbiter include electrical power, cooling loop, data and control circutis.

3.5.2 Intrasystem Interfaces

Interface requirements were defined for the Sortie Lab elements. Within the family of basic Sortie Lab elements, various combinations of configurations have been configured to support diverse technology and scientific investigations and practical applications in earth orbit. Figures 3.5-12 and 3.5-13 illustrate a standard interface between the pressurized module and the pallet. The pallet mounted payloads receive their functional support from the pressurized module and includes such services as electrical power, data management, communications and thermal control.

Two Sortie Lab modules employed in the Sortie mission mode which are always combined are the support and experiment modules. Figures 3.5-14, 3.5-15 and 3.5-16 illustrate representative interfaces. The support module supplies the resources and services to conduct experiments in the experiment module. As shown, there is a relatively large number of interface functions between the two modules.

Interfaces for electrical power, data management, and communications must be provided for each of the Sortie Lab's major elements (support module, experiment module and pallet). For electrical power, a power distributor and control unit is to be located on or in each major element and interconnected to the centralized power conditioning and control unit which is located in the pallet. Power is to be distributed to subsystem and experiment hardware from these power distributors. The signal/data interfaces for data management and communications are provided by the data bus. Digital interface units (DIUs) are located at or near each major item of equipment requiring signal/data interchange with other subsystems. The DIUs are interconnected to the bus control unit using two twisted shield pairs of wire. The bus control unit is located in the support module near the central computer.

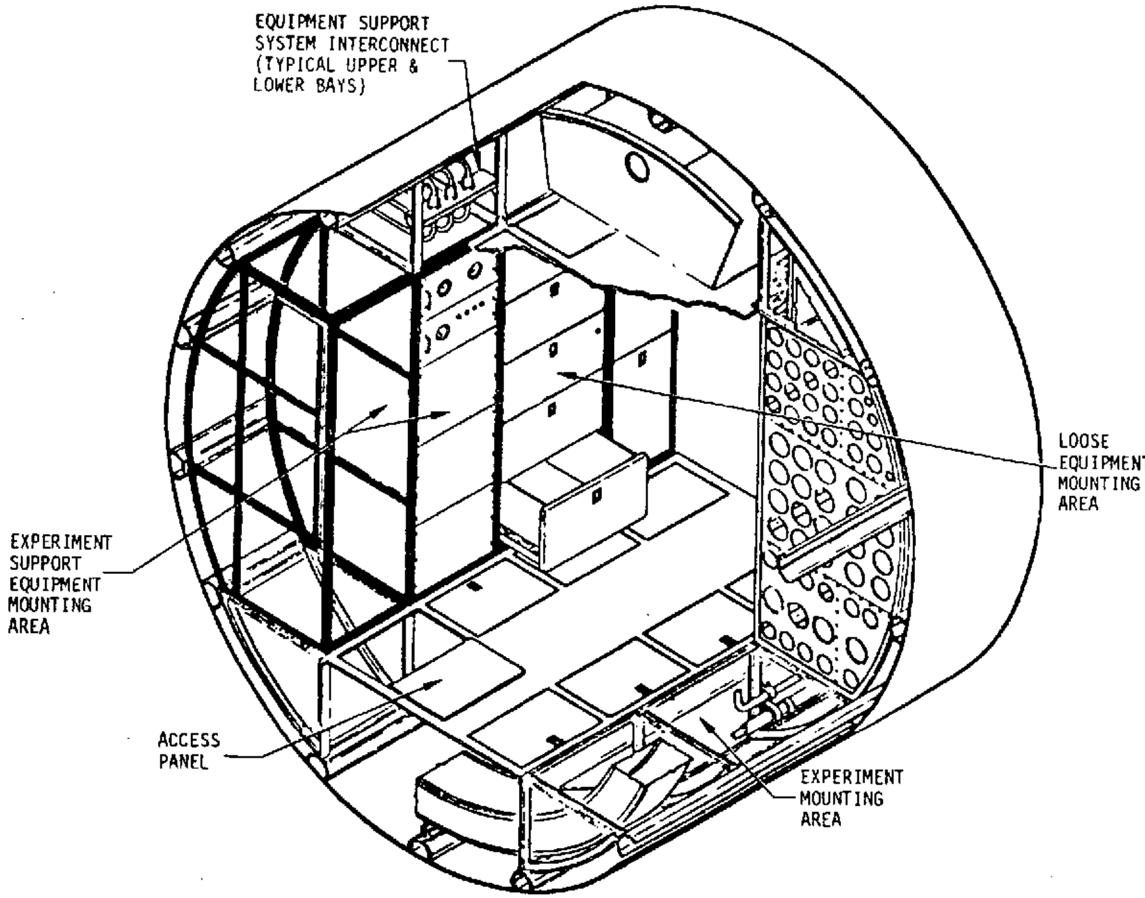


FIGURE 3.5-6. EXPERIMENT MOUNTING

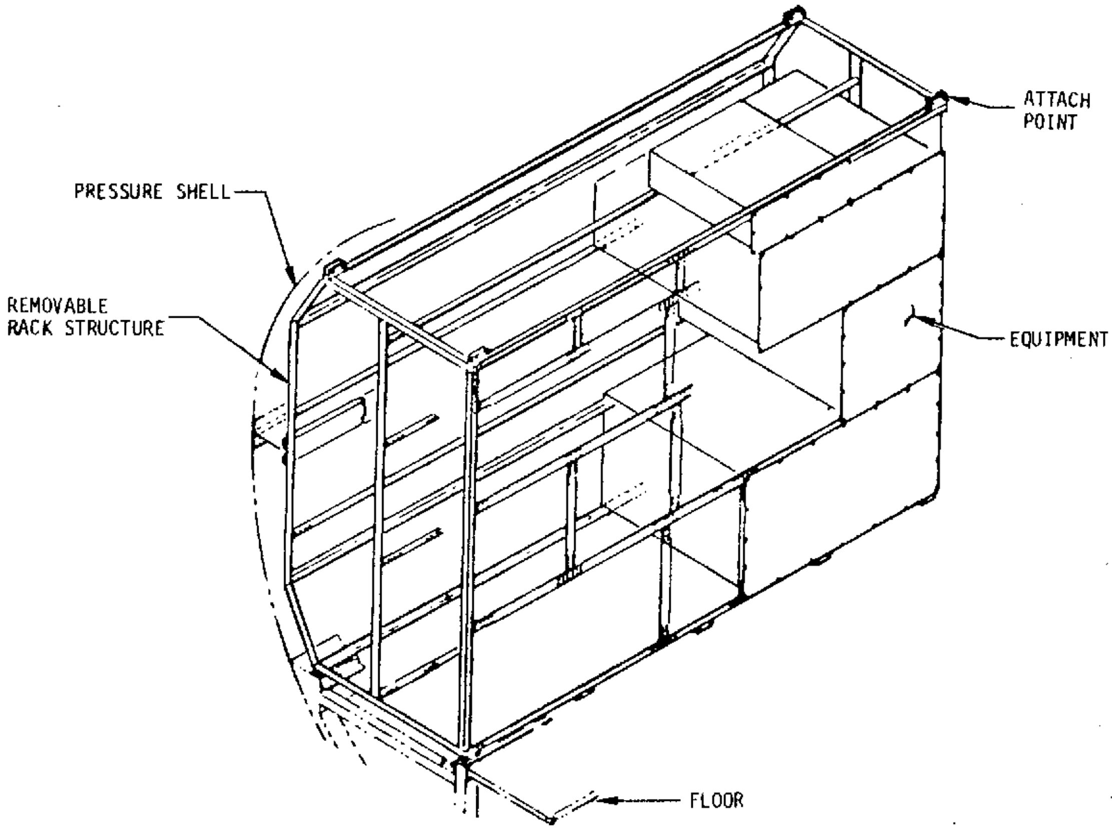


FIGURE 3.5-7. EQUIPMENT MOUNTING

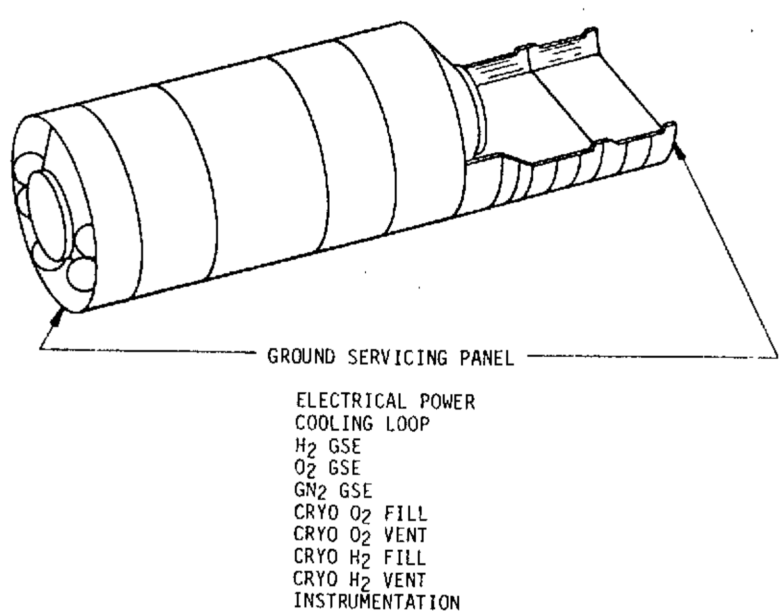


FIGURE 3.5-8. SORTIE LAB TO GSE INTERFACE

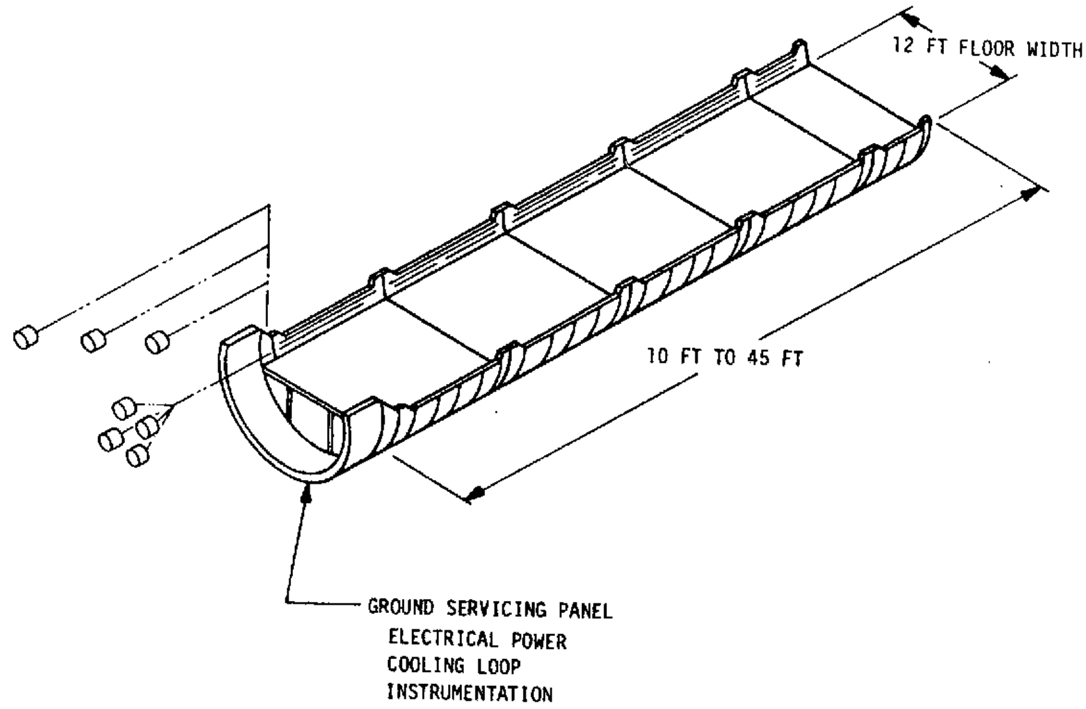


FIGURE 3.5-9. SORTIE LAB PALLET ONLY GSE INTERFACE

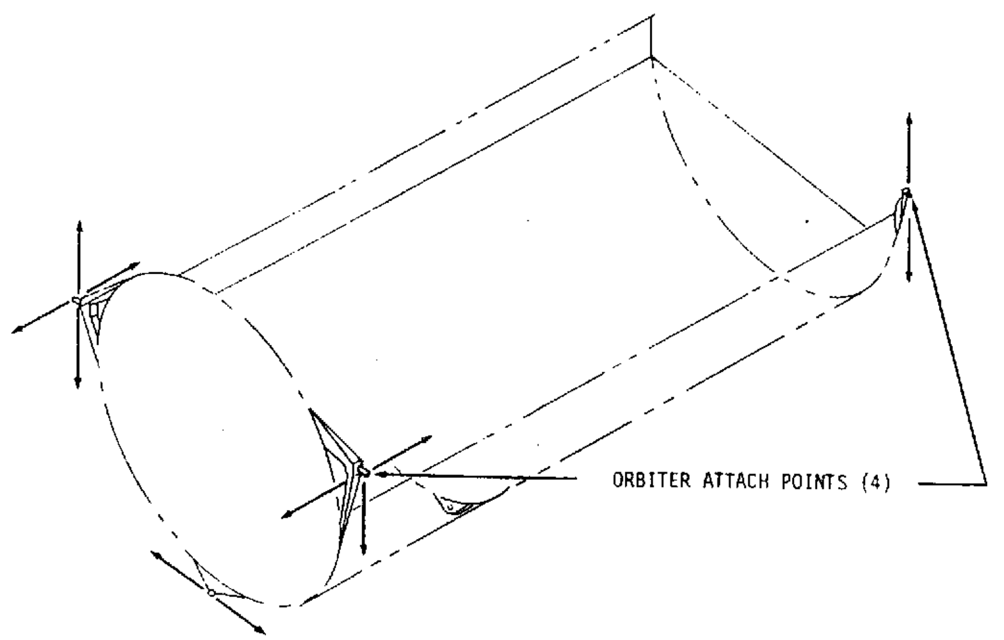


FIGURE 3.5-10. SORTIE LAB PALLET ONLY MECHANICAL INTERFACE

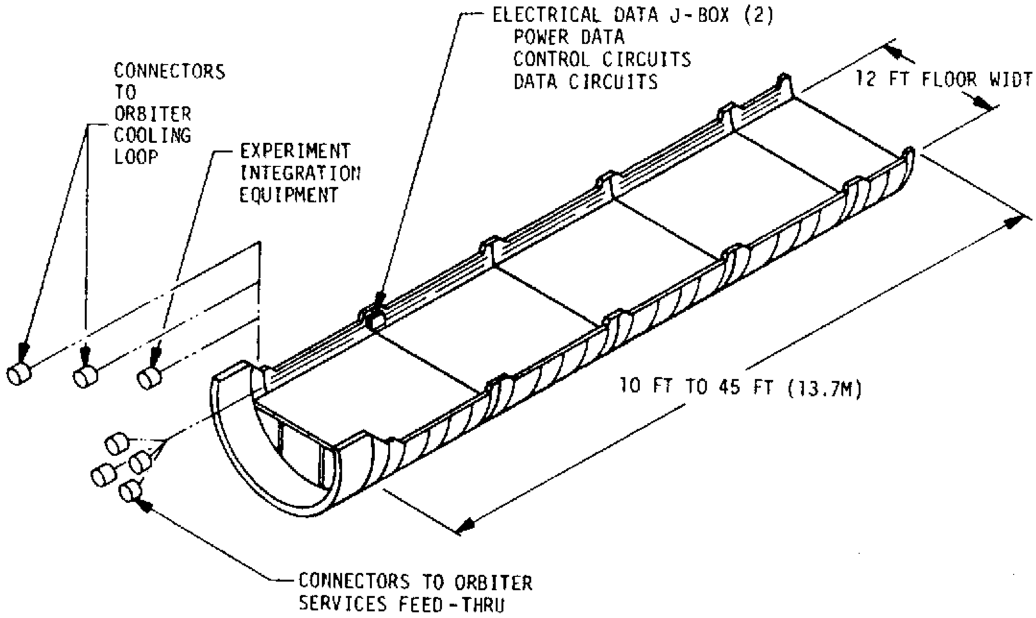


FIGURE 3.5-11. SORTIE LAB PALLET ONLY FUNCTIONAL INTERFACE

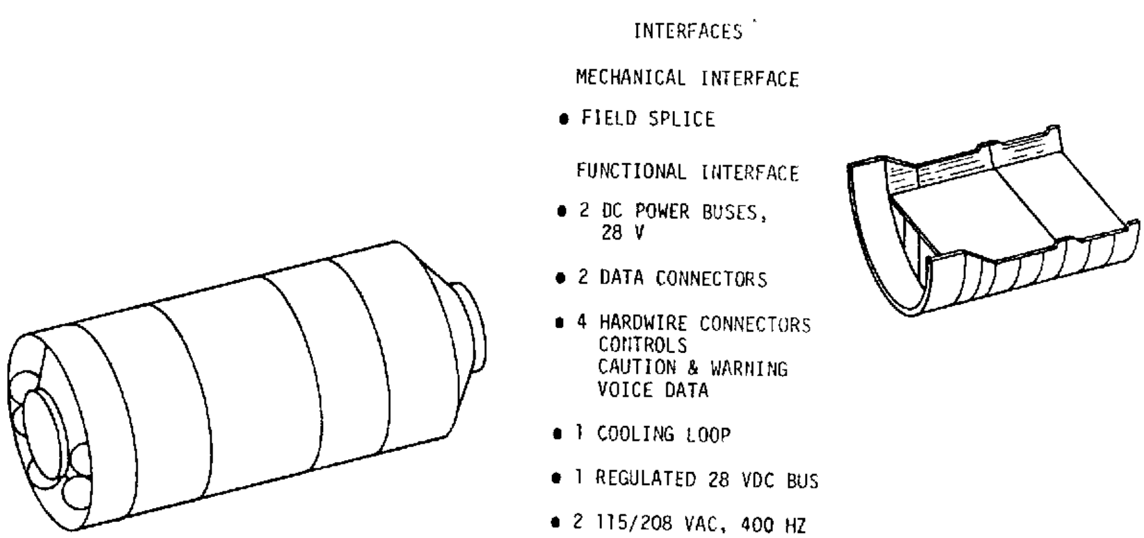


FIGURE 3.5-12. SORTIE LAB PRESSURIZED MODULE TO PALLET INTERFACES

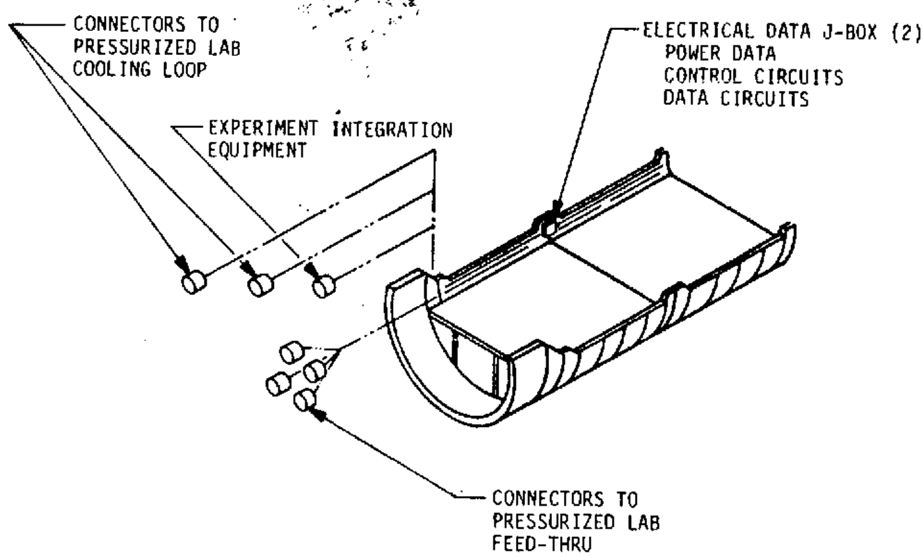


FIGURE 3.5-13. SORTIE LAB PRESSURIZED MODULE TO PALLET FUNCTIONAL INTERFACES

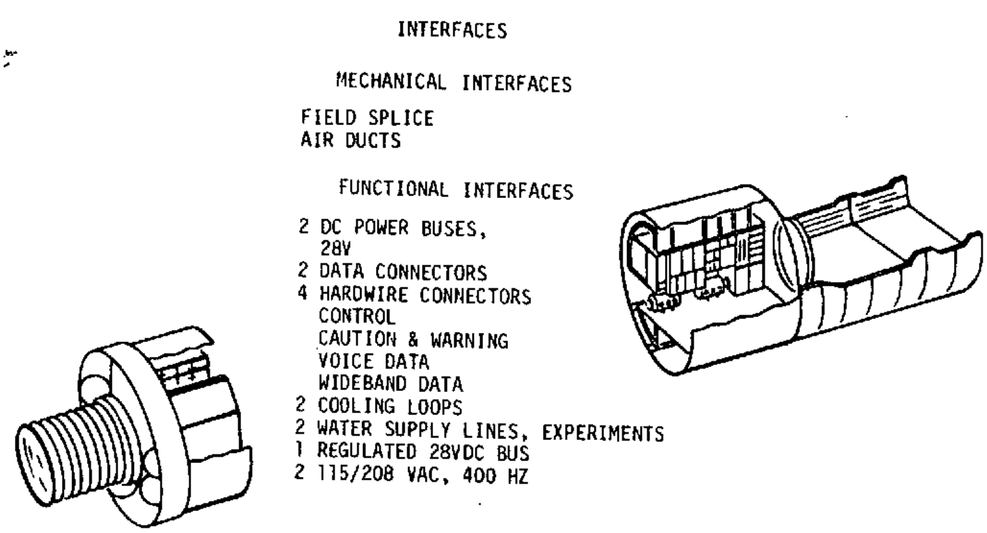
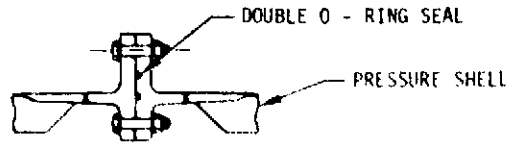
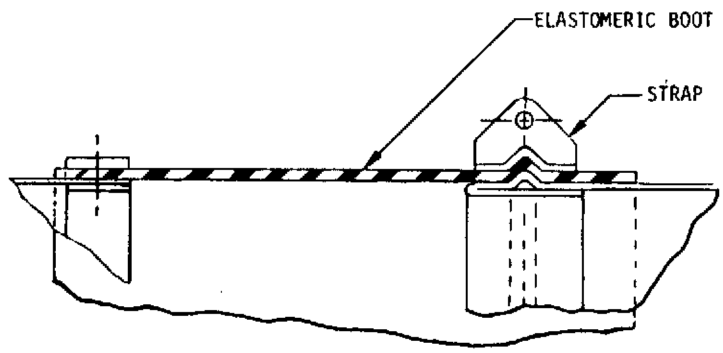


FIGURE 3.5-14. SORTIE LAB SUPPORT MODULE TO EXPERIMENT MODULE INTERFACES



TYPICAL FIELD SPLICE JOINT



TYPICAL AIR DUCT INTERFACE

FIGURE 3.5-15. SORTIE LAB SUPPORT MODULE TO EXPERIMENT MODULE MECHANICAL INTERFACE

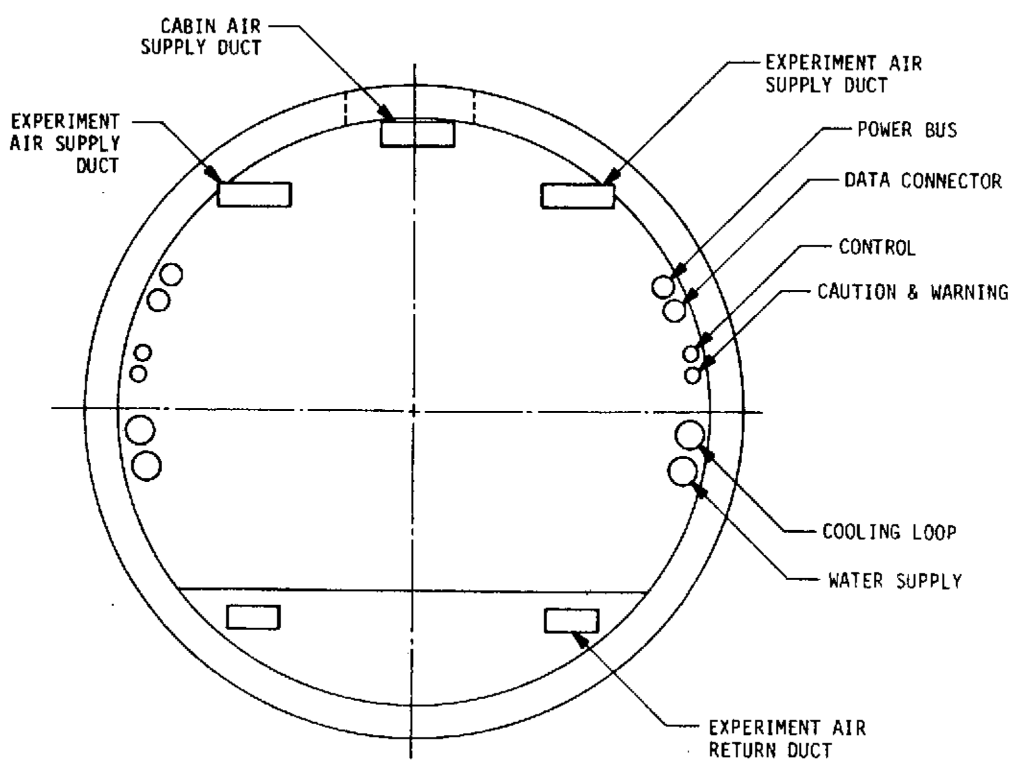


FIGURE 3.5-16. SORTIE LAB SUPPORT MODULE TO EXPERIMENT MODULE FUNCTIONAL INTERFACE

4.0 MISSION ANALYSIS

This section will discuss some of the general mission analysis work that has been performed in support of Sortie Lab. The information presented is general in nature, and the results are intended more to show how certain problems have been analyzed and illustrate sensitivities rather than provide specifics on any mission. Those missions discussed should be considered representative and the results or conclusions reached are dependent upon the assumptions made.

4.1 Sortie Missions

The Sortie Lab is a special payload carrier supporting both multidiscipline and single discipline research and applications experiment missions. The baseline duration of experiment missions is seven days nominally with extended duration capability up to thirty days provided. The capability of supporting experiments in orbits with inclinations equal to the latitude-of-launch site (ETR) to near polar is provided. The Sortie Lab remains in the Orbiter payload bay and is connected to the Orbiter crew compartment by an access tunnel at the front-end. The crew, including the mission specialists, principal investigators, scientists, and/or passengers, ride in the Orbiter during launch, reentry and landing operations. On orbit, the specialists normally work in the Sortie Lab but their habitability provisions (such as food management, personal hygiene and sleeping accommodations), are provided in the Orbiter. Once on initial orbit, the payload bay doors are opened exposing the contents to the space environment.

4.1.1 Mission Operations

4.1.1.1 Orbit Selection

Orbit selection for some payloads, such as Earth Observations payloads, is influenced by factors such as sensor field-of-view, location of sites to be observed, desired frequency of observation and lighting constraints. These factors are referred to as mission objectives and are categorized as "desired" and "acceptable." "Acceptable" indicates the minimum necessary to assure satisfactory attainment of goals; "desired" would provide redundancy, allow more data samples, etc. Also the subgroups having differing objectives may require viewing of different groups of sites. This complexity of requirements dictates the requirement for several orbit profiles. It is desirable to minimize the number of different orbits required and still accomplish the desired (or at least the acceptable) objectives of the experiment groups. The technique used will be to study each experiment group and, depending on the experiment priority and orbital observation requirements, select the experiment groups to be optimized. Next, a quantitative objective achievement criteria will be established to determine how well the orbits selected for these groups will satisfy the mission objectives for all the experiment groups.

Once an experiment group has been selected, the orbit which best satisfies its objectives and constraints will be developed. Those parameters which must be optimized include: number of sites intercepted; time over site; and time over sites within lighting constraints. Additionally, an optimizing parameter, which is proportional to the number of passes per day per site for the mission is considered. Determination of the optimum orbit for a given experiment is accomplished by varying parameters such as: altitude, inclination, descending node, time in phasing orbit, and launch date and time. It is also necessary to evaluate repeating orbits; those whose groundtracks repeat after specified intervals.

As an example of the above philosophy, consider the Earth Observations series of experiments. Analysis has shown that with only two orbit profiles, missions may be flown which satisfy 95 percent of the "acceptable" objectives and 89 percent of the "desired" objectives of all 28 experiment groups. The required orbits are defined as follows.

Parameter Units	Orbit Profile 1	Orbit Profile 2
Altitude-n.mi.	190.0	280.0
-km	352.0	519.0
Inclination-deg	41.7	84.1
Phasing Angle-deg	11.0	5.0
Launch Date	Sept. 1	May 1
Launch Time-hrs GMT	14:00	15:00
OMS Kit Required	No	Yes

Orbit selection for astronomy payloads must be responsive to a number of constraints imposed on celestial viewing. These constraints are functions of the instruments, the experiments and mission objectives. The following considerations for viewing will be made:

a. Viewing is not to take place within a certain number of degrees of the sun and the moon. The values assigned to these constraints are a function of the instrument making the observations and the amount of shielding provided to the instrument.

b. Viewing is restricted to occur above some altitude of the earth's atmosphere. This constraint is due to several reasons -- air glow, refraction, absorption of certain frequencies, contamination, etc.

c. Maximize or optimize the continuous viewing area on the celestial sphere.

d. Maximize the dark time in orbit which in turn maximizes the celestial viewing area for darkness viewing.

Other considerations such as radiation levels, communications coverage, etc. also enter into the orbit selection.

4.1.1.2 Crew Time and Skills

The crew times and skills required to accomplish the mission objectives of 25 selected payloads are presented in Table 4.1-1. The magnitude of the crew hours required by each of the payloads is not significant in itself, but becomes significant when linked to the number of crew skills required, the length of the crew work day, the number of days in the mission, the crew size and the crew work shift. The number of days available for experiment operations are reduced from the nominal by the time required to complete launch to orbit (which may include orbital transfer and phasing required for target-dependent payloads) and to perform the deboost and landing phases. Typically there remain 5.5 and 6.5 days available for experiment operations.

The work shift is a function of crew size and the number of crewmen required to perform the experiments. For example, if two crewmen are required to operate the instruments, they are scheduled to work on the same (single) shift. If more experiment performances are required, then a crew of four men on staggered shifts would be used. Similarly, if only one man is required to operate the payload, an essentially 24 hour per day operation may be achieved with a two man crew working staggered work shifts. Increasing the crew from two to four crewmen would have virtually no effect on mission accomplishment.

The effects of crew size and work shift on mission accomplishment are presented in Table 4.1-2 for the 25 payloads. In general, doubling the crew size and changing from a single shift to multiple (staggered) shifts will have the effect of significantly increasing the mission accomplishment parameters. For target-related payloads this, however, also assumes an even distribution of target opportunities.

4.1.1.3 Extended Mission Duration Effects on Sortie Lab Payloads

The 47 Sortie Lab payloads listed in Table 2.3-1 were analyzed

DISCIPLINE	PAYLOAD	NUMBER OF CREWMEN	MANHOURS REQUIRED	NUMBER OF SKILLS REQUIRED	SKILLS REQUIRED
EARTH OBSERVATIONS	EO-2	2	111.5	6(2)	Electromechanical Technician, Optical Technician, Agronomist, Geologist Hydrologist, Geographer
	EO-3	2	33.25	6(2)	Phototechnician/Cartographer, Electromechanical Technician, Optical Technician, Meteorologist, Oceanographer, Hydrologist
	EO-6	2	43.0	4(2)	Electromechanical Technician, Optical Technician, Meteorologist, Oceanographer
	EO-7	1	60.0	1	Technologist with Cloud Physics training
COM/NAV	C/N-1	2	66.8(1)	2	Electrical Engineer, Optical Technician
ASTRONOMY	A-1	2	92.4	1	Astronomer/Astrophysicist
	A-2	2	72.6	1	Astronomer/Astrophysicist
	A-3	2	59.85	1	Astronomer/Astrophysicist
MATERIALS SCIENCE	MS	4	277.8	4(2)	Biological Technician, Matallurgist, Materials Scientist, Electromechanical Technician
TECHNOLOGY	T-1/2	2	74.2	2	Electromechanical Technician, Thermodynamicist
PLANETARY	P-1	2	54.5	1	Technician
SPACE PHYSICS	SP-1	2	128.0	2	Electromechanical Technician, Physicist
	SP-2	2	30.0	2	Electromechanical Technician, Physicist
	SP-3	1	10.5	2(2)	Electromechanical Technician, Physicist
	SP-4	1	42.0	2(2)	Electromechanical Technician, Physicist
	SP-5	2	20.0	2	Electromechanical Technician, Physicist
	SP-6	2	20.0	3(2)	Electromechanical Technician, Physicist Pilot/Navigator
	SP-7	2	20.0	2	Electromechanical Technician, Physicist
	SP-8	2	44.0	3(2)	Electromechanical Technician, Physicist Pilot/Navigator
	SP-9	2	32.0	2	Electromechanical Technician, Physicist
	SP-10	1	15.0	1	Physicist
	SP-11	1	2.0	1	Electromechanical Technician
	SP-12	2	75.0	3(2)	Physicist, Physical Chemist, Electromechanical Technician
	SP-13	2	100.0	4(2)	Physicist, Physical Chemist, Thermodynamicist, Electromechanical Technician
	SP-14	2	75.0	3(2)	Physicist, Thermodynamicist, Electro, mechanical Technician

NOTE: (1) Obtained from Sortie Lab Task 4.1.2.4.1 updates.

(2) Cross-Training required.

TABLE 4.1-1. EXPERIMENTER SKILLS REQUIREMENTS

DISCIPLINE	PAYLOAD	CREW SIZE[1] (NUMBER OF CREWMEN) 1	2	3	4	WORK SHIFT[2] (TYPE) SINGLE	STAGGERED	AVAILABLE MANHOURS UTILIZED (PERCENT)
EARTH OBSERVATIONS	EO-2		106			104		89
	EO-3		132			68		35
	EO-6		180			298		59
	EO-7		227				241	100
COMMUNICATION/ NAVIGATION	COM/NAV		58			70		32
ASTRONOMY	A-2		100				100	46
	A-1/2		100				100	57
	A-3		100				100	38
MATERIALS SCIENCE	MS				53[1]		58	52
TECHNOLOGY	T-1/2		100			100		52
PLANETARY	PLANETARY		100				100	47
SPACE PHYSICS	SP-3,4,10,11	100[1]				N/A		*29[3]
	SP-1,2,5,6,7, 8,9,12,13,14		100			N/A		*73
*Arithmetic mean.								

1. The values in this column represent the percent of required manhours scheduled.
2. The values in this column represent the percent of experiment hours scheduled.
3. Average value for payloads listed.

TABLE 4.1-2. PAYLOAD SPECIALIST, SIZE, WORK SHIFT, AND UTILIZATION FOR SELECTED SORTIE LAB PAYLOADS FOR 7-DAY MISSIONS to determine if they would benefit (1) from extending the mission duration from 7 to 30 days and, (2) from repeated 7 day missions versus an extended mission. The principal sources of data for this analysis were the NASA "Blue Books" (NHB 7150.1 dated 15 January 1971). The scientific objectives of each payload were analyzed to determine the nature of the phenomena under investigation and importance of extended and/or multiple observations. It was recognized that there are many other factors that will impact the mission duration and number of flights required for each payload. The more important of these are probably mission optimization parameters such as lighting, ground track and cloud cover; and programmatic parameters such as development and launch schedules, costs and number of flights. These were, however, outside the scope of this study and, therefore, were not considered.

Based solely on the Blue Books, all of the payloads shown in Table 4.1-3 benefit from extending the mission beyond 7 days except for payloads T-4 (Slush Propellants), T-9 (Teleoperations), SP-2 (Cometary Physics), and three of the Earth Observations payloads. The Slush Propellants payload (T-4) requires only 36 hours for completion, including setup and shutdown procedures. Therefore, this payload can easily be completed in only one 7 day mission. The initial flight for Teleoperations (T/O) will be conducted to demonstrate the flight performance and safety characteristics. This can be accomplished in 104 operating hours; therefore, it will not require more than 7 days. The Cometary Physics payload (SP-2) requires 90 minutes per run. This run time includes both the setup and calibration (60 minutes) and 30 minutes for both the gaseous cloud release and spectrometric measurements. Several runs are required to establish confidence in the measurements. Since it is possible to perform 80 runs during a 7 day mission, this payload would not benefit from extending the mission duration. No decision was reached for payloads EO-7 (Atmospheric Cloud Physics Experiment and Lab), EO-8 (Freezing Drop Experiment), and EO-9 (Droplet Charge) because the experiment durations have not been established in the Blue Book.

PAYLOAD (CODE AND NAME)		BENEFITED BY EXTENDED MISSION	BENEFITED BY REPEATED 7 DAY MISSIONS
EO-1	METEOROLOGICAL AND ATMOSPHERIC SCIENCES	YES (1)	YES
EO-2	LAND USE MAPPING	YES (1)	NO (5)
EO-3	POLLUTION	YES (1)	NO
EO-4	RESOURCE RECOGNITION	YES (1)	NO (5)
EO-5	DISASTERS ASSESSMENT	YES (1)	NO
EO-6	OCEAN RESOURCES	YES (1)	NO
EO-7	ATMOSPHERIC CLOUD PHYSICS EXP. AND LAB.	TBD (2)	TBD (2)
EO-8	FREEZING DROP EXPERIMENT	TBD (2)	TBD (2)
EO-9	DROPLET CHARGE	TBD (2)	TBD (2)
C/N-1	COMMUNICATION/NAVIGATION	YES (1)	NO
MS-1	BIOLOGICAL	YES (1)	YES
MS-2	LEVITATION	YES (1)	YES
MS-3	FURNACE	YES (1)	YES
MS-4	SMALL AND LOW TEMPERATURE	YES (1)	YES
A-1	1M PHOTOHELIOGRAPH	YES (1)	NO
A-2	SOLAR SPAR	YES (1)	NO
A-3	STRATOSCOPE III	YES (1)	NO
A-4	WIDE ANGLE UV (0.3 M)	YES (1)	NO
A-5	IR TELESCOPE	YES (1)	NO
A-6	SMALL UV TELESCOPE	YES (1)	NO
A-7	1.5 M PHOTOHELIOGRAPH	YES (1)	NO
T-1	CONTAMINATION MEASUREMENTS	YES (1)	NO
T-2	MONITOR	YES (1)	NO
T-3	SHORT TERM CRYOGENICS (3)	YES (1)	NO
T-4	SLUSH PROPELLANTS	NO	NO
T-5	NON-CRYOGENICS (A)	YES (1)	NO
T-6	NON-CRYOGENICS (B)	YES (1)	NO
T-7	ASTRONAUT MANEUVERING UNIT	YES (1)	YES
T-8	MANEUVERABLE WORK PLATFORM	YES (1)	YES
T-9	TELEOPERATIONS	NO (4)	NO (6)
P-1	PLANETARY TELESCOPES	YES (1)	NO
SP-1	ATMOSPHERIC AND MAGNETOSPHERIC SCIENCE	YES (1)	NO
SP-2	COMETARY PHYSICS	NO	NO
SP-3	METEOROID SCIENCE	YES (1)	NO
SP-4	SMALL ASTRONOMY TELESCOPE	YES (1)	NO
SP-5	WAKE MEASUREMENTS FROM STATION AND BOOMS	YES (1)	NO
SP-6	WAKE MEASUREMENTS FROM SUBSATELLITE	YES (1)	NO
SP-7	PLASMA RESONANCE	YES	NO
SP-8	WAVE PARTICLE INTERACTIONS	YES (1)	NO
SP-9	ELECTRON AND ION BEAM INJECTION	YES (1)	NO
SP-10	COSMIC RAY MAGNETIC SPECTROMETER	YES (1)	NO
SP-11	PLASTIC/NUCLEAR EMULSION	YES (1)	NO
SP-12	AIRLOCK AND BOOM EXPERIMENT	YES (1)	NO
SP-13	FLAME CHEMISTRY AND LASER EXPERIMENT	YES (1)	NO
SP-14	TEST CHAMBER EXPERIMENTS	YES (1)	NO
LS-1	MINI-30	YES (1)	NO
LS-2	MINI-7	YES (1)	NO

EO - Earth Observations
C/N - Communication/Navigation
MS - Materials Science
A - Astronomy
T - Technology
P - Planetary
SP - Space Physics
LS - Life Sciences

1. Would prefer mission durations of greater than 30 days.
2. Experiment duration has not been established in the Blue Book.
3. The requirements for Long Term Cryogenics were used because the Short Term Cryogenics payload was not in the Blue Book.
4. No on initial flight, yes on subsequent flights.
5. Yes, if repeated 7-day flights provide overlapping coverage in excess of 30 days.
6. Yes, if more than one development flight required.

TABLE 4.1-3. PAYLOAD SUMMARY

Only seven of the payloads presented in Table 4.1-3 benefit from repeated 7-day missions. These seven payloads are listed below:

- EO-1 (Meterological and Atmospheric Sciences)
- MS-1 (Biological)
- MS-2 (Levitation)
- MS-3 (Furnace)
- MS-4 (Small and Low Temperature)
- T-7 (Astronaut Maneuvering Unit)
- T-8 (Maneuverable Work Platform)

The Meteorological and Atmospheric Sciences payload (EO-1) prefers a mission duration in excess of 30 days, but only requires three observations per week. Therefore, this payload would benefit from repeated 7-day missions. The remaining six payloads (MS-1, MS-2, MS-3, MS-4, T-7, and T-8) also prefer to have mission durations in excess of 30 days, but need to have periodic supporting tests and evaluations performed on the ground. For instance, the MS-2 (Levitation) payload is used to perform glass preparation experiments in support of a variety of programs conducted at glass research laboratories on the ground. The experimental runs will be used primarily to supply samples for evaluation and research by the laboratories. The T-7 (Astronaut Maneuvering Unit) payload is used for the purpose of developing understanding and control over the problems associated with astronaut maneuverability in extravehicular activity (EVA). This objective is to be met by evaluating the Astronaut Maneuvering Unit (AMU) during tethered and untethered EVA. Data will be collected to evaluate the AMU system, and later repetitions of the flight tests may be performed, following changes to hardware design or operational procedures. Therefore, these payloads would benefit from the repeated 7-day flights since the time between flights could be used for evaluation and any needed improvements or corrections would be made before the next flight.

Because of the long duration inherent in extended missions, it was decided that a new operational philosophy should be determined. Skylab mission operations were examined and compared to those developed for Sortie Lab. The work day for extended missions was reduced from 12 hours to 10 hours per day in order to provide for mission planning and off-duty time, and to allow additional time for systems housekeeping and meals. The crew cycle developed for extended missions is presented in Table 4.1-4. It can be seen from Table 4.1-4 that no time was allotted in the crew cycle for exercise. It was assumed that this activity (0.5 hour per day per crewman) could be performed during the work period. Only one payload (EO-7) utilizes 100 percent of the available manhours. The average crew utilization for the other payloads were approximately 56 percent, therefore, there should be ample time available each day for crew exercise. In addition to the shorter workday, approximately every seventh day (mission days 8, 15, and 22) are designated as a non-work day. It was determined that part, and in some cases, all of the first and last days of the mission would not be available for experiment operations because of orbit phasing and Sortie Lab checkout.

CREWCYCLE ACTIVITY	NUMBER OF PERFORMANCES PER DAY PER CREWMAN	TOTAL TIME PER DAY (HRS)
EAT - MEALS	3	3.0
PH - PERSONAL HYGIENE	2	.5
S/HK - SYSTEMS HOUSEKEEPING	1	.5 (1)
MP - MISSION PLANNING	1	1.0
OD - OFF DUTY	1	1.0
EX - EXERCISE	1	0.0 (2)
SLEEP - SLEEP	1	8.0
WORK - TIME FOR EXPERIMENTATION	1	10.0
TOTAL		24.0

(1) BASED ON 4 MAN CREW (2 MANHOURS PER DAY)
(2) PERFORMED DURING WORK PERIOD (.5 HOURS PER DAY)

TABLE 4.1-4. CREWCYCLE FOR EXTENDED MISSIONS

New payload performance requirements were developed for extended missions. It was decided that the extended mission payload performance requirements should be based on the available number of crew hours.

Different scale factors were developed for each payload based on (1) the shorter crew work day (10 vs. 12 hours), (2) the number of non-experiment days (3 days) and (3) whether the payload was originally operated for 5, 5.5, 6, or 6.5 days during the 7-day mission. These scale factors, the payloads and the corresponding experiment operation times for both the 7-day missions and the extended missions are presented in Table 4.1-5. These factors were then used to arrive at the extended mission performance requirements. The performance requirements for both the 7-day missions and the extended missions are shown in Table 4.1-6.

The impact of extended missions on the Sortie Lab subsystems was determined by applying the scale factors (Table 4.1-5) to the payloads analyzed. The number of performances and the number of operating hours which were scheduled for the 7-day missions were scaled up to show what could be expected for the extended missions and are presented in Table 4.1-7. The energy and data storage (digital, analog, and film) required to support the extended missions were also scaled up from the 7-day missions and are presented in Table 4.1-8.

The increases in energy noted in Table 4.1-8 for the longer duration missions will have a significant impact on the electrical power subsystem. This impact will be manifested in the increased weight of the fuel cell reactants (O_2 and H_2), the by-product of the reaction (H_2O), and in the attendant plumbing and tankage required for storage. There will also be a significant increase in the volume required to accommodate the reactants and the H_2O produced by the fuel cells.

The data storage subsystem will be impacted by the weight and volume of the additional reels of tape and film required to return the larger quantities of data as presented in Table 4.1-8.

The extended missions also will impact those payloads, such as Materials Science, which require samples for experimentation.

PAYLOAD	7-DAY MISSION EXPERIMENT OPERATION TIME		EXTENDED MISSION EXPERIMENT OPERATION TIME		SCALE FACTOR[1]
	HOURS/MAN	DAYS	HOURS/MAN	DAYS	
EO-2	66.	5.5	255.	25.5	3.9
EO-3	60.	5.0	250.	25.0	4.2
EO-6	66.	5.5	255.	25.5	3.9
EO-7	66.	5.5	255.	25.5	3.9
C/N-1	60.	5.0	250.	25.0	4.2
A-1/A-2	78.	6.5	265.	26.5	3.4
A-2	78.	6.5	265.	26.5	3.4
A-3	78.	6.5	265.	26.5	3.4
MS-1, MS-2, MS-3, MS-4	72.	6.0	260.	26.0	3.6
T-1, T-2	72.	6.0	260.	26.0	3.6
P-1	60.	5.0	250.	25.0	4.2
SP-1	72.	6.0	260.	26.0	3.6
SP-2[2]	60.	5.0	250.	25.0	4.2
SP-3	60.	5.0	250.	25.0	4.2
SP-4	60.	5.0	250.	25.0	4.2
SP-5	12.	1.0	TBD[3]	TBD	TBD
SP-6	12.	1.0	TBD	TBD	TBD
SP-7	12.	1.0	TBD	TBD	TBD
SP-8	24.	2.0	TBD	TBD	TBD
SP-9	24.	2.0	TBD	TBD	TBD
SP-10	60.	5.0	250.	25.0	4.2
SP-11	60.	5.0	250.	25.0	4.2
SP-12	60.	5.0	250.	25.0	4.2
SP-13	60.	5.0	250.	25.0	4.2
SP-14	60.	5.0	250.	25.0	4.2

1. Based on the ratio of work hours available per crewman per day.
2. Included for information only, requires less than 7 days for completion as defined in the Blue Book.
3. To be determined.

TABLE 4.1-5. SCALE FACTORS

PAYLOAD	7 DAY MISSION			EXTENDED MISSION			
	NUMBER OF PERFORMANCES REQUIRED	OPERATE TIME REQUIRED (HRS)	MANHOURS REQUIRED	NUMBER OF PERFORMANCES REQUIRED	OPERATE TIME REQUIRED (HRS)	MANHOURS AVAILABLE	MANHOURS REQUIRED
EO-2	11	4.6	111.5	43	17.9	510.	434.9
EO-3	25	5.0	33.3	105	21.0	500.	139.9
EO-6	20	5.0	43.0	78	19.5	510.	167.7
EO-7	20	40.0	60.0	78	156.0	510.	234.0
C/N-1	39	6.1	66.8	164	25.6	500.	280.6
A-1/A-2	1	149.4	92.4	1	508.0	530.	314.2
A-2	1	149.4	72.6	1	508.0	530.	246.8
A-3	1	150.6	59.9	1	512.0	530.	203.7
MS-1, MS-2, MS-3, MS-4	130	720.0	277.8	540	2592.0	1040.	1000.1
T-1, T-2	41	697.0	74.2	148	2509.2	520.	267.1
P-1	15	120.0	54.5	63	504.0	500.	228.9
SP-1	1	120.0	128.0	1	432.0	520.	460.8
SP-2 [1]	10	10.0	30.0	42	42.0	500.	126.0
SP-3	1	112.0	10.5	1	470.4	250.	44.1
SP-4	5	80.0	42.0	21	336.0	500.	176.4
SP-5	1	16.0	20.0	TBD	TBD	TBD	TBD
SP-6	1	12.0	20.0	TBD	TBD	TBD	TBD
SP-7	1	16.0	20.0	TBD	TBD	TBD	TBD
SP-8	2	16.0	44.0	TBD	TBD	TBD	TBD
SP-9	2	16.0	32.0	TBD	TBD	TBD	TBD
SP-10	1	115.0	15.0	1	483.0	250.	63.0
SP-11	1	118.0	2.0	1	495.6	250.	8.4
SP-12	5	50.0	75.0	21	210.0	500.	315.0
SP-13	5	50.0	100.0	21	210.0	500.	420.0
SP-14	5	45.0	75.0	21	189.0	500.	315.0

1. Included for information only, requires less than 7 days for completion as defined in the Blue Book.

TABLE 4.1-6. PERFORMANCE REQUIREMENTS

PAYLOAD	7 DAY MISSION		EXTENDED MISSION	
	NUMBER OF PERFORMANCES SCHEDULED	OPERATE TIME SCHEDULED (HRS)	NUMBER OF PERFORMANCES SCHEDULED	OPERATE TIME SCHEDULED (HRS)
EO-2	39	4.8	152	17.3
EO-3	36	3.4	151	14.3
EO-6	44	14.9	172	58.1
EO-7	48	97.0	187	378.3
C/N-1	75	11.6	315	48.7
A-1/A-2	1	149.4	1	508.0
A-2	1	149.4	1	508.0
A-3	1	150.6	1	512.0
MS-1 MS-2 MS-3 MS-4	86	418.5	310	1506.6
T-1 T-2	41	697.0	148	2509.2
P-1	15	120.0	63	504.0
SP-1	1	120.0	1	432.0
SP-2[1]	10	10.0	42	42.0
SP-3	1	112.0	1	470.4
SP-4	5	80.0	21	336.0
SP-5	1	16.0	TBD	TBD
SP-6	1	12.0	TBD	TBD
SP-7	1	16.0	TBD	TBD
SP-8	2	16.0	TBD	TBD
SP-9	2	16.0	TBD	TBD
SP-10	1	115.0	1	483.0
SP-11	1	118.0	1	495.6
SP-12	5	50.0	21	210.0
SP-13	5	50.0	21	210.0
SP-14	5	45.0	21	189.0

1. Included for information only, requires less than 7 days for completion as defined in the Blue Book.

TABLE 4.1-7. EXPECTED EXPERIMENT PERFORMANCES SCHEDULED

PAYLOAD	7-DAY MISSION				EXTENDED MISSION			
	ENERGY REQUIRED (KWH)	DIGITAL DATA STORAGE REQUIRED (KB)	ANALOG DATA STORAGE REQUIRED (MIN)	FILM DATA STORAGE REQUIRED (FRAMES)	ENERGY REQUIRED (KWH)	DIGITAL DATA STORAGE REQUIRED (KB)	ANALOG DATA STORAGE REQUIRED (MIN)	FILM DATA STORAGE REQUIRED (FRAMES)
EO-2	62.9	86.8×10^7	NONE	19.4×10^3	245.3	338.5×10^7	NONE	75.7×10^3
EO-3	38.8	62.8×10^7	NONE	18.4×10^3CM	163.0	263.8×10^7	NONE	77.3×10^3CM
EO-6	66.1	27.5×10^8	NONE	80.0×10^3CM	257.8	107.3×10^8	NONE	312.0×10^3CM
EO-7	19.2	4100 FT	NONE	21.0×10^4	74.9	15990 FT	NONE	81.9×10^4
C/N-1	292.3	18.0×10^5	720.	5 REELS 35MM 5 ROLLS 16MM	1227.7	75.6×10^5	3024.	21 REELS 35MM 21 ROLLS 16MM
A-1/A-2	166.2	46.3×10^5	NONE	153.5×10^3	565.1	157.4×10^5	NONE	521.9×10^3
A-2	106.9	95.6×10^4	NONE	33.1×10^3	363.5	325.0×10^4	NONE	112.5×10^3
A-3	72.4	11.9×10^5	NONE	4.5×10^3	246.2	40.5×10^5	NONE	15.3×10^3
MS-1 MS-2 MS-3 MS-4	486.0	4.8×10^8	NONE	NONE	1749.6	17.3×10^8	NONE	NONE
T-1 T-2	72.6	41.8×10^6	NONE	NONE	261.4	150.5×10^6	NONE	NONE
P-1	57.8	13.6×10^7	NONE	1.0×10^3	242.8	57.1×10^7	NONE	4.2×10^3
SP-1	88.4	16.9×10^7	7200.	NONE	318.2	60.8×10^7	25920.	NONE
SP-2 [1]	38.7	7.2×10^5	NONE	8.0×10^2	162.5	30.2×10^5	NONE	33.6×10^2
SP-3	1.3	1.6×10^2	NONE	NONE	5.5	6.7×10^2	NONE	NONE
SP-4	42.2	25.9×10^6	NONE	9.6 x 10.2	177.2	108.8×10^6	NONE	40.3×10^2
SP-5	7.9	10.4×10^6	90.	NONE	TBD	TBD	TBD	TBD
SP-6	9.7	2.6×10^6	NONE	NONE	TBD	TBD	TBD	TBD
SP-7	7.5	7.6×10^6	NONE	9.6×10^2	TBD	TBD	TBD	TBD
SP-8	14.1	17.2×10^5	800.	NONE	TBD	TBD	TBD	TBD
SP-9	13.6	6.8×10^6	960.	NONE	TBD	TBD	TBD	TBD
SP-10	11.8	21.6×10^5	NONE	NONE	49.6	90.7×10^5	NONE	NONE
SP-11	1.8	NONE	NONE	NONE	7.6	NONE	NONE	NONE
SP-12	2.3	8.1×10^6	NONE	8.0×10^2	9.7	34.0×10^6	NONE	33.6×10^2
SP-13	10.8	10.8×10^7	NONE	8.0×10^2	45.4	45.4×10^7	NONE	33.6×10^2
SP-14	34.7	4.7×10^6	NONE	40.0×10^2	145.7	19.7×10^6	NONE	168.0×10^2

1. Included for information only, requires less than 7 days for completion as defined in the Blue Book.

TABLE 4.1-8. ENERGY AND DATA STORAGE REQUIREMENTS

Extra weight and volume will be required for storage of the additional samples for the longer mission durations.

The environmental control system (ECS) will be impacted by the additonal O_2/N_2 required for the crew. This impact will be manifested in the increased weight and volume of the O_2/N_2 and the attendant plumbing and tankage required for storage. There will also be a requirement for more lithium hydroxide canisters for CO_2 removal.

The extended mission will also have an impact on the crew provisions required. Additional food, water, and waste management provisions will be required. Also, additional clothing and personal hygiene provisions will be necessary. In general, any subsystem having consumables or time-dependent components will be similarly affected.

4.1.2 Experiment Flight Operations Requirements

4.1.2.1 Orbit Environment

Many of the Sortie Lab experiments and payloads are sensitive to the orbital environment in which they are to operate. Radiation and g-level environments are two factors which can be analyzed and controlled to some degree through orbit selection.

High radiation levels can produce intolerably high noise levels during measurements and arcing of high voltage equipment, generally resulting in significant degradation of overall systems performance. The South Atlantic Anomaly region of the Van Allen radiation belt is a particularly significant source of this potentially harmful radiation (high energy protons and electrons).

In general, orbits having inclinations of 35 to 45 degrees will spend the most time in the high radiation regions and the amount of time spent in these radiation regions increases with altitude. For those missions that are radiation sensitive, the course of action would be to select orbits which have both low inclinations and low altitudes. This may not always be the best course of action from a total mission point-of-view and it would be highly desirable to be able to trade off experiment degradation and reduced systems performance caused by radiation versus overall mission objectives and performance. It may be both desirable and cost effective to provide sufficient shielding for the various experiments which are radiation sensitive and thereby allowing more productive orbits to be chosen from an overall mission standpoint.

Most experiments and payloads are not overly sensitive to g-level constraints. Figure 4.1-1 gives a somewhat worst case look at what g-levels might be expected. These g-levels are referenced to the 1970 Jacchia density model, a $+2\sigma$ solar activity predictions during the peak of the next solar cycle (as shown in Figure 4.1-3), a Shuttle/payload mass of 95,254 kg (210,000 pounds), and a linear interpolation of the drag coefficients (C_DA in square meters) between the following altitudes: C_DA value for 185 km (100 n. mi.) is 662.09 m^2, C_DA value for 370 km (200 n. mi.) is 878.25 m^2, and C_DA value for 555 km (300 n. mi.) is 884.10 m^2. These g-levels can be scaled to any other ballistic coefficient (m/C_DA) by multiplying the g-level shown by the ratio of m/C_DA (used to generate curves) divided by m/C_DA (desired). The drag coefficients given above are for the Shuttle holding an inertial attitude throughout each orbit. As can be seen for altitudes above 278 km (150 n. mi.) the g-levels are on the order of 10^{-6} or less which should be sufficiently low for all payloads and experiments. Figure 4.1-2 illustrates similar g-level information based on a prediction of the expected value or nominal solar activity during this same time frame. These g-levels are reduced considerably should the Shuttle maintain an orbital attitude where either the nose or tail of the Shuttle is maintained along the orbital velocity vector (local horizontal attitude).

4.1.2.2 Payload Crew Work Cycles

Other programs have shown that, when an experimenter is working his problem he may actually tend to rest in an irregular pattern of short periods to increase the overall duration of experimentation performed over a recognized limited period of opportunity. This type motivation can most assuredly be expected in Sortie Lab operations.

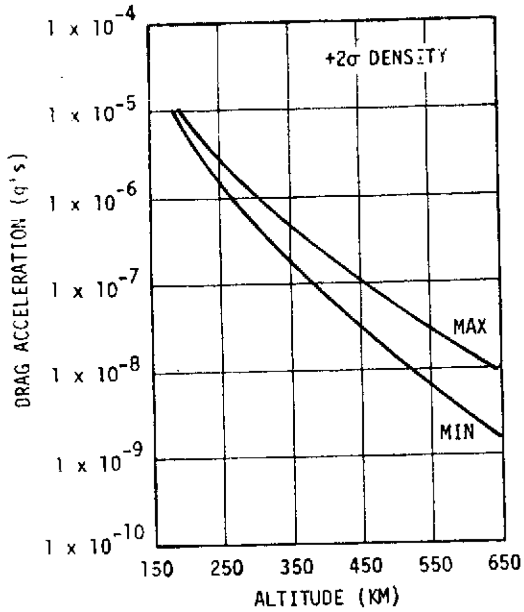


FIGURE 4.1-1. PREDICTED WORST CASE g-LEVELS

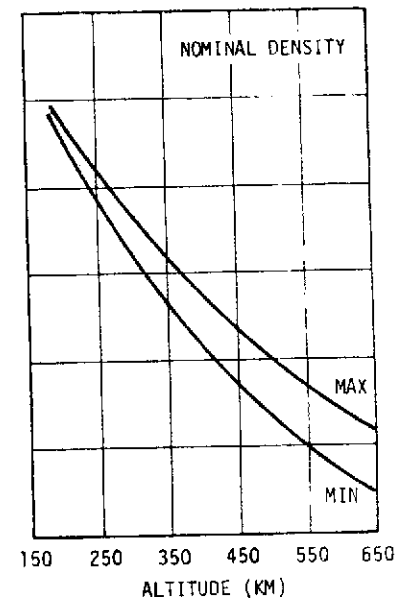


FIGURE 4.1-2. PREDICTED NOMINAL g-LEVELS

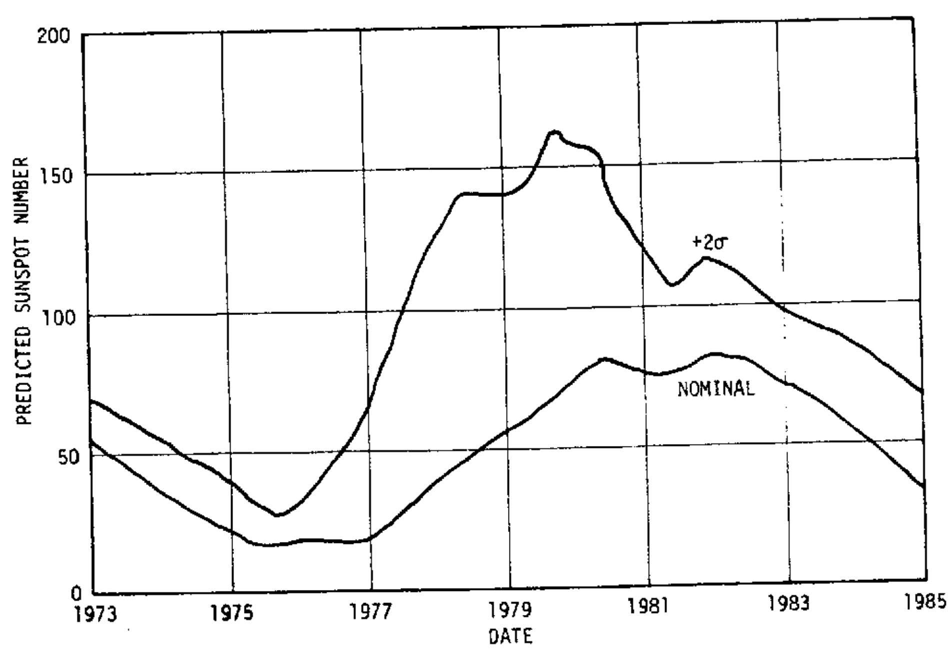


FIGURE 4.1-3. SOLAR ACTIVITY PREDICTIONS

The extent to which a necessarily disciplined flight plan and systems limitation can accommodate relative improvisation or "free wheeling" by experimenters is the subject for considerable analysis, but may well be the key to the Shuttle systems payoff and acceptance by the scientific and commercial communities.

Allocation of crew activities from past studies along with an improvised "free wheeling" option are presented below:

	Baseline	Alternate 1	Alternate 2
Sleep	8 hrs	8 hrs	5 to 8 hrs
Personal Hygience (PH)	1-1/2 hrs	1-1/4 hrs	1-1/4 hrs
Eat	1-1/2 hrs	1-3/4 hrs	1-1/4 hrs
Exercise (EX)	1/4 hr	1/2 hr	1/4 hr
Housekeeping(HK)	3/4 hr	3/4 hr	3/4 hr
Work	12 hrs	11 hrs	12 to 15 hrs
Planning		3/4 hr	1/2 hr

Figure 4.1-4 presents a representative baseline four-man crew activities timeline for 24 hours.

4.1.3 Sortie Mission Orbit Capability

Sortie mission orbit capability is dependent upon the operational requirements of each sortie mission and upon the Shuttle vehicle characteristics. The type of rendezvous technique, orbital transfer requirements, mission duration, pointing requirements, operational constraints, etc., must be determined when calculating the orbit and payload capabilities of the Space Shuttle system. The data contained in this section represent typical sets of operational requirements. A detailed definition of the Space Shuttle transportation system and associated payload accommodations used in this study is contained in Space Shuttle System Payload Accommodations, JSC 07700, dated April 13, 1973. For mission planning, the weight of the Sortie Lab plus pallet plus Orbiter payload weight chargeable items should be added in constructing the total mission weight (reference Section 2.6). This total weight can then be compared to the performance curves (Figures 4.1-5 and 4.1-6) to verify the capability of the Space

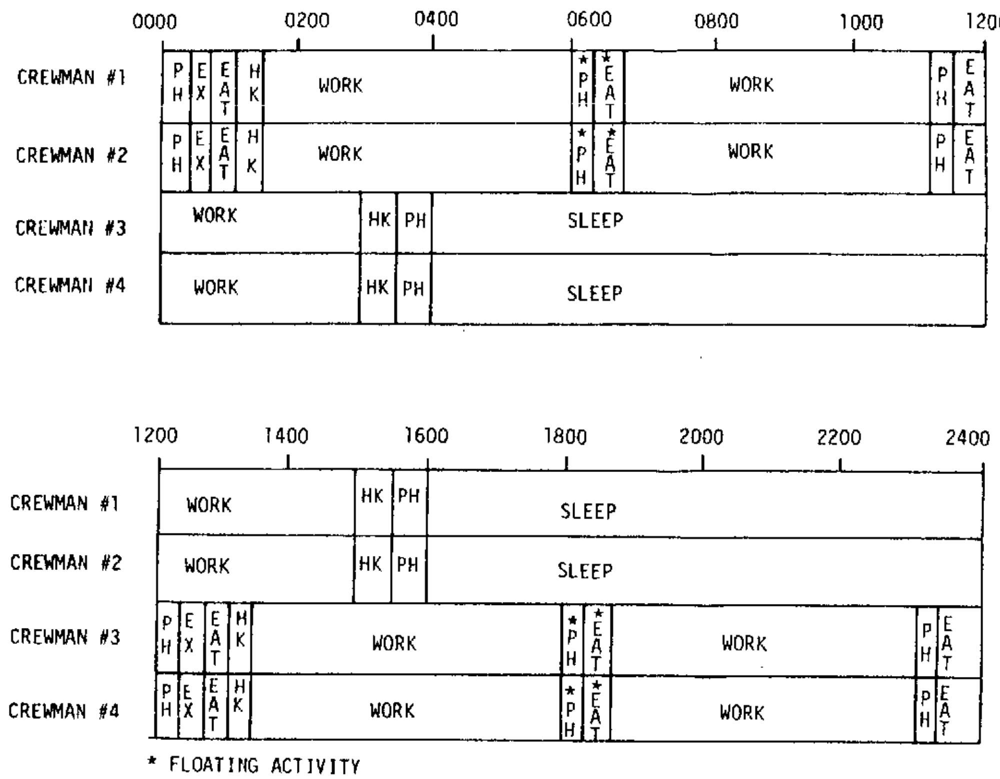


FIGURE 4.1-4. REPRESENTATIVE 4-MAN CREW DUTY CYCLE

Shuttle system to perform the particular sortie mission. Since both WTR and ETR are planned launch sites, the launch azimuth constraints for both are shown in Figure 4.1-7.

Figures 4.1-5 and 4.1-6 were constructed based on no phasing constraints (range alignment between vehicles or vehicle and point in orbit) and on carrying the entire payload weight throughout all mission maneuvers. If on-orbit phasing is required either to shift the ground track to achieve Sortie Lab experiment objectives or for rendezvous purposes, additional orbital maneuvering system (OMS) propellant is required; consequently, payload capability to a given altitude is reduced by the amount of additional OMS propellant and associated tankage.

The Orbiter's integral OMS tankage has been sized to provide 1,000 fps delta-velocity capability to the Orbiter with 65,000 lbs of payload. Up to three extra OMS kits can be installed for increased operational mission capability. Each kit contains one-half as much usable propellant as

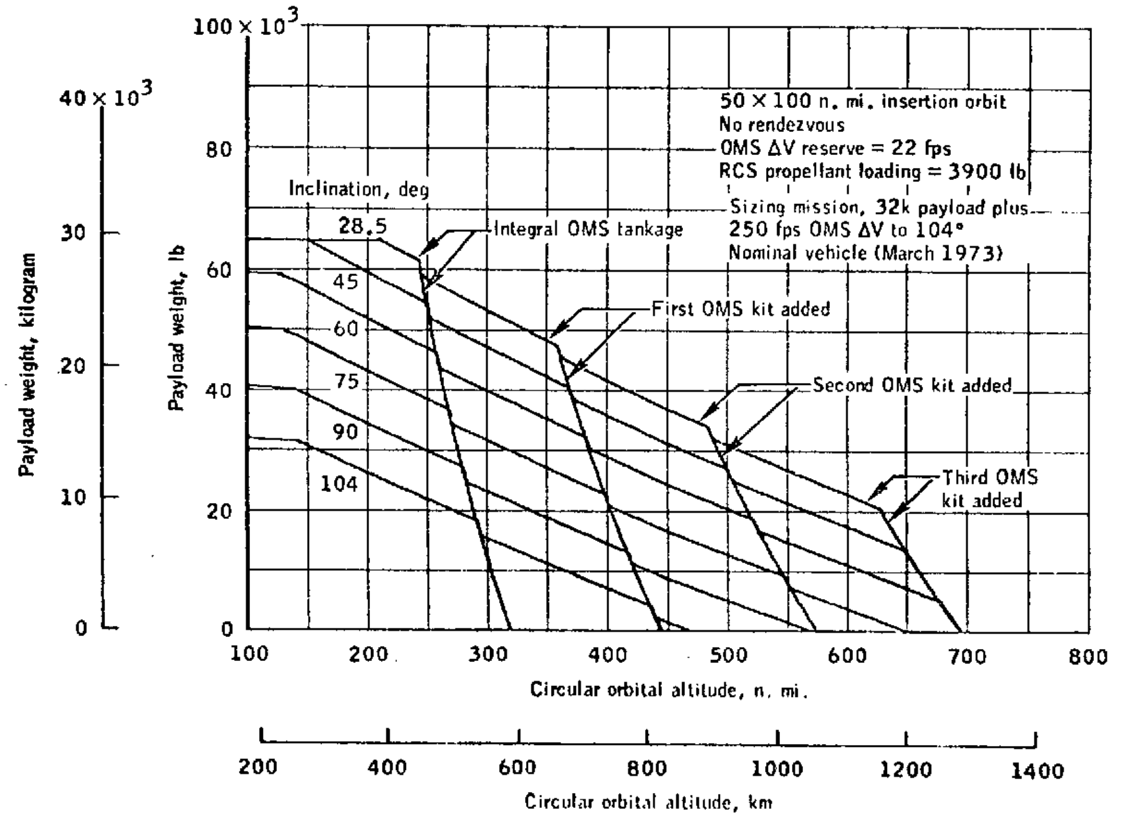


FIGURE 4.1-5. PAYLOAD WEIGHT VS. CIRCULAR ORBITAL ALTITUDE AT VARIOUS INCLINATIONS, DELIVERY ONLY

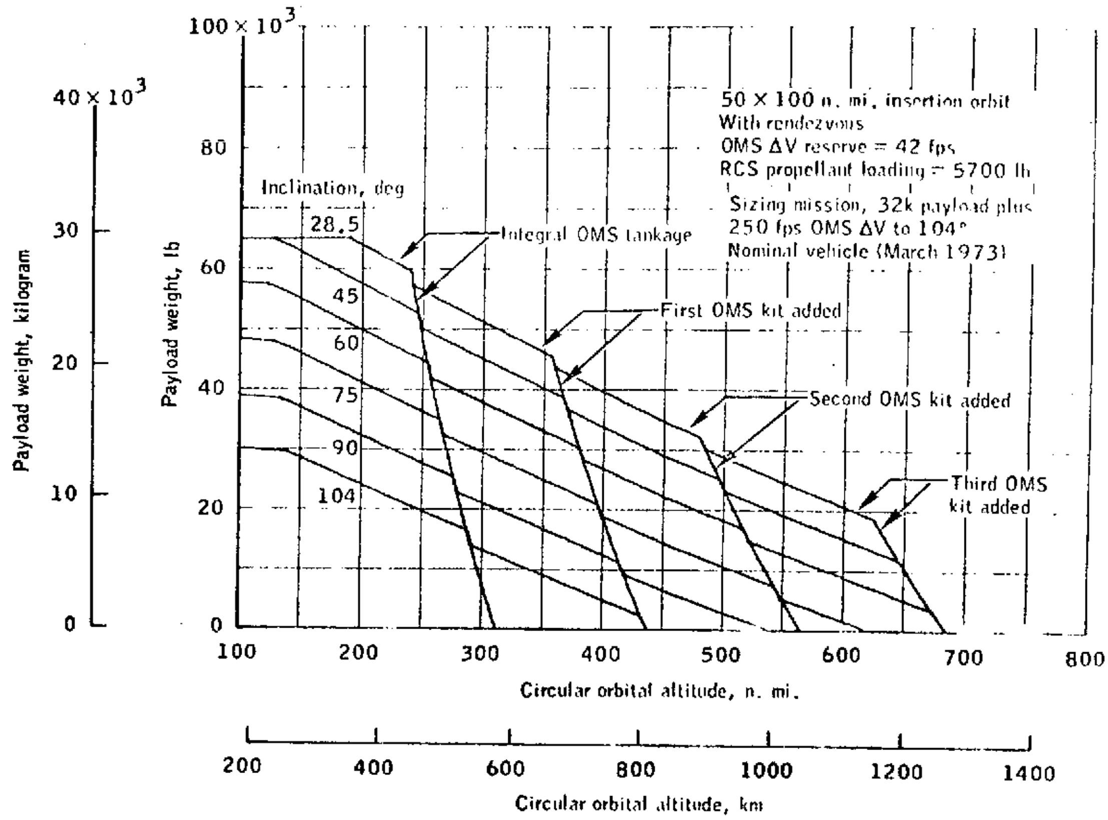


FIGURE 4.1-6. PAYLOAD WEIGHT VS. CIRCULAR ORBITAL ALTITUDE AT VARIOUS INCLINATIONS, DELIVERY AND RENDEZVOUS

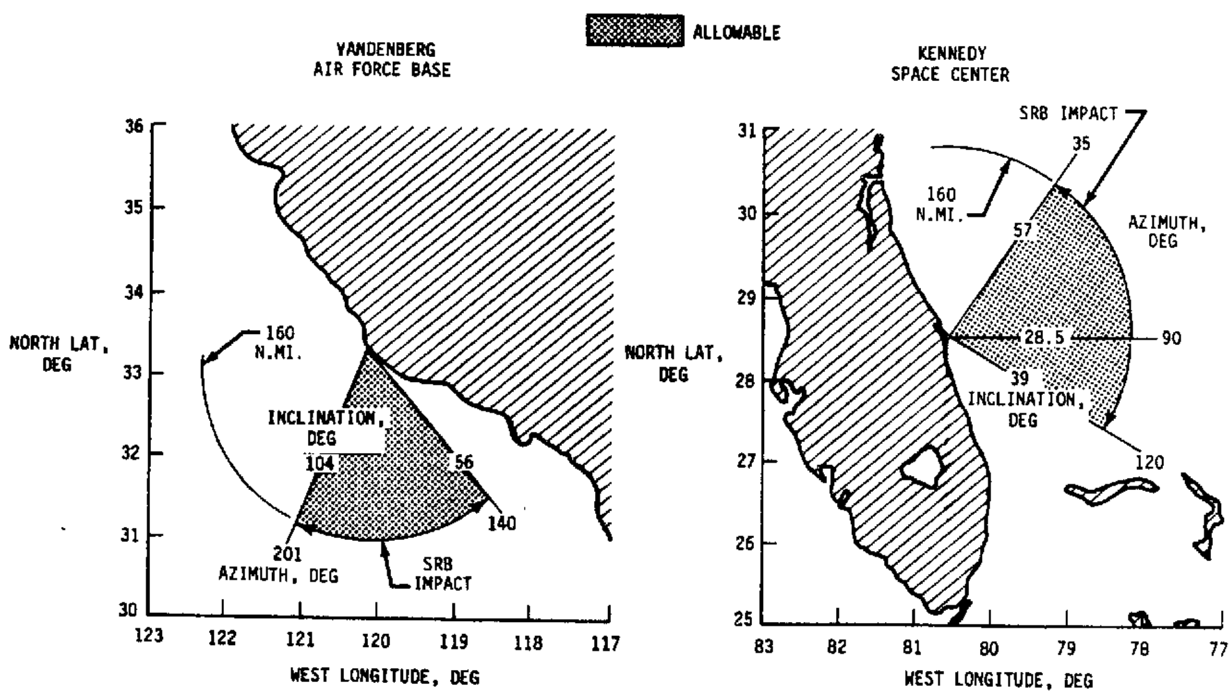


FIGURE 4.1-7. LAUNCH AZIMUTH AND INCLINATION LIMITS FROM WTR AND ETR

the integral OMS tankage resulting in a total propellant capacity 2.5 times that of integral tankage. The OMS kits are located in the cargo bay and their weight and volume are charged to the payload.

Sortie mission orbit capability greater than the currently designed 7-day missions may become desirable for some Sortie Lab missions for such purposes as conducting experiments, making observations of objects that could not normally be scheduled within 7 days, increasing experiment or observation time, etc. Since the Shuttle design is assumed to include the capability of remaining in orbit for up to 30 days, the primary impact to the payloads would be weight and length reductions due to the Shuttle having to carry extra consumables, tanks, and plumbing that would be charged to the payload. A preliminary analysis of extending the mission duration up to 30 days has been performed considering the impact on electrical power (EPS), environmental control and life support, and reaction control (RCS) propellant for pointing requirements and for orbit maintenance.

A major impact to the payloads resulted from the additional electrical energy capability required primarily for the extended operation of the orbiter and secondarily for the payloads. Effects of the other subsystems on performance was generally small, although RCS requirements for orbit maintenance for low orbits ($\sim$ 100 n. mi.) was large.

Since the Space Shuttle vehicle design is continually changing, the sortie mission orbit capability is preliminary and should be reassessed as the Shuttle design matures. In particular, the current Shuttle design employs the OMS system for orbit insertion and hence must employ the OMS kits at lower altitudes than were employed in these Sortie Lab Phase "B" studies (for additional information, see revision "A" of SSS PLA, JSC 07700, dated July 16, 1973).

5.0 OPERATIONS ANALYSIS

5.1 Flight Operations

The Sortie Lab major flight operations phases consist of: launch to orbit, pre-experiment operations, lab deactivation and configuration for deboost, reentry and landing, ground refurbishment, and payload integration. The launch to orbit and reentry flight phases will not be discussed in detail, since they are primarily Shuttle operations.

Liftoff occurs with all Orbiter main engines and the twin solid rocket boosters (SRB's) burning.

SRB end-of-web action time occurs at 106 sec into the flight and the SRB's are separated at 116 sec. Water impact occurs approximately 124 n. mi. downrange. From there, the SRB's are towed back to the launch facility.

The Shuttle maintains an intact abort capability, permitting recovery of the crew and payload after an abort inducing failure at any time during the mission.

Following orbit insertion, residual external tank (ET) propellants are dumped and the vehicle maneuvers to an attitude appropriate for ET disposal. At the proper time into the coast, the ET is separated with a velocity magnitude and orientation such that it will impact into the Indian Ocean in a low shipping density area.

Following ET separation, the Orbiter is free to begin on-orbit operations, including the circularization burn at apogee of the transfer ellipse.

5.1.1 On-Orbit Operations

After orbital insertion the Sortie Lab is activated, if required, before experiment operations are begun. A representative activation sequence is presented in Table 5.1-1.

Following Sortie Lab activation (if required) experiments are conducted over about a six-day period. During this phase, the Shuttle is required to: 1) minimize acceleration levels when zero-g

FUNCTION	SEQUENCE	REQUIREMENTS/REMARKS
FLIGHT OPERATIONS - ACTIVATION	6 hr 24 hr 48 hr 7 days	
Complete Initial Activation	TB_1 + 5 hr 43 min ΔT = 4 hr	Verify Sortie Lab pressure 14.7 ± TBD psia, temperature 70° F ± 30° F, partial pressure O_2 3.1 ±.6 psia, and partial pressure CO_2 ≤ 10 MMHG.
• Open Cargo Bay Doors		
• Deploy Sortie Lab Radiator		
• O_2 and N_2 Supply Valves to open		From orbiter. Fans are already on for mixing.
• Equalize Orbiter/Tunnel/Sortie Lab Pressure		
• Open Tunnel Hatch and Latch Open		
• Turn On Sortie Lab Initial Entry Lights		From orbiter.
• Open Sortie Lab Hatch and Latch Open		
• Turn On General Illumination Lighting		
• Visual Inspection		Verify absence of fire, smoke, structural damages, etc.
• Complete ECS Activation		
• Position all Source Select Switches to Internal		Condensate system, fan control, temperature controller, radiator control, pump control and water storage control.
• Condensate Transfer Pressure to ON		
• Condensate Launch Switch to Normal		
• Water Storage Controller Power ON		
• Complete EPS Activation		Source select switch to internal.
• Final C&W System Activation		
• Final C&D Console Activation		
• Activate Data Management System		

TABLE 5.1-1. FLIGHT OPERATIONS - ACTIVATION

laboratory experiments are being conducted, 2) hold specific attitudes with a $\pm$ 0.5 degree accuracy for earth observation measurements lasting up to 30 minutes per opportunity during repeated passes over the target area, and 3) hand over attitude control to the payload carrier control moment gyros (CMG's) for extended periods (days) when extremely high pointing accuracy and stability and a minimum contamination environment are necessary (during celestial observation experiments).

5.1.1.1 Payload Crew Operations

Payload crew operations consist primarily of setup, checkout, calibration, operation, analysis, and data management, of scientific and applications experiments. The typical Sortie Lab payload crew (experimenter/user crew) is comprised of payload specialists who are responsible for payload/instrument operations. These specialists will have a detailed knowledge of instruments, payload operations, experiment requirements, experiment objectives, and supporting equipment.

The Sortie Lab flight operations planning at the time of this effort adhered to the following guidelines and constraints relative to payload crew operations:

a. Experiment/user-related crew activities shall not be required during ascent, reentry, or landing operations.

b. The Sortie Lab shall not require the participation of the Orbiter crew for activities other than to monitor caution and warning systems and those Orbiter-peculiar experiment requirements such as maneuvering.

c. The Orbiter crew will coordinate Orbiter thruster operations and venting of onboard gases with the Sortie Lab and vice versa.

d. Alternating or staggered crew activity periods will be permitted.

e. Continuous work periods of more than four hours without a break should be avoided.

f. The experiment/user crew shall perform limited onboard status checks.

g. Preflight adjustment to the crew's work/rest relationship may be dictated by payload requirements. (Certain payloads may require experiments to be performed at a time when, if the crewman were on the ground, he would be asleep.)

h. Variations in the crew day are permissible to accomplish operational or scientific objectives.

   (1) Sleep period can be shortened in order to accomplish experiment objectives.

   (2) Eating periods should not be rigidly scheduled.

   (3) Breaks can occur at any convenient time.

i. The crew day is designed for a mission length of 7 days nominal. Longer missions will require additional considerations.

j. The Sortie Lab experimenter/user crew complement shall consist of up to four members, with not more than three active in the Sortie Lab at any one time.

5.1.1.2 Representative Payload Operations and Support Requirements

Resource requirements necessary to support on-board operations are primarily dependent upon the schedule of crew and experiment operations for each particular payload.

Baseline Sortie Lab resource characteristics available to the payload are summarized in Table 2.5-1. A number of experiment operations timelines have been generated in order to drive out typical resource requirements for the payloads and to indicate the extent of payload experiment operations available under any constraints such as target availability and conflicting crew/equipment activity.

Experiment operations timelines were determined based on 1972 data. The principal source of data for this task was the Experiment Payload Definition report. A total of 47 payloads were defined in this report for the Sortie Lab Phase B study.

Representative payloads were selected from each experiment discipline. The payloads were selected for analysis based on maximum requirements for manhours, power, energy, data acquisition rate and total data stored. The distribution of the 47 payloads among the eight disciplines and the payloads selected for analysis are presented in Table 5.1-2. Twenty-five payloads were selected for analysis.

DISCIPLINE	NUMBER OF PAYLOADS	
	DEFINED FOR SORTIE LAB STUDY	SELECTED FOR ANALYSIS
Earth Observations	9	4
Communication/Navigation	1	1
Astronomy	7	3
Materials Science	4	1*
Technology	9	1**
Planetary	1	1
Space Physics	14	14
Life Sciences	2	0
TOTAL	47	25

* All four payloads combined into one payload for analysis

** Two payloads combined into one payload for analysis.

TABLE 5.1-2. SORTIE LAB PAYLOADS

Four payloads were selected for Earth Observations: Land Use Mapping (EO-2) to maximize power and crew hours; Pollution (EO-3) to maximize number of experiment performances; Ocean Resources (EO-6) to maximize area coverage and Atmospheric Cloud Physics (EO-7) because it represented the non earth-pointing Earth Observations payloads. Only one payload was defined for the Communication/Navigation discipline and hence, was used in the analysis. In Astronomy, three payloads were selected - Solar Spar (A-2), the combined Photoheliograph (A-1) and Solar Spar, and the Stratoscope III (A-3). The Solar Spar and Stratoscope III payloads were originally selected to represent the solar and stellar areas. Later, the 1M Photoheliograph and Solar Spar were combined into one payload because it was scientifically desirable.

All four of the Materials Science payloads were combined into one for this analysis because their individual requirements were rather low. In Technology, the Contamination Measurement (T-1) and Monitor (T-2) payloads were combined, again because the individual requirements for crew and subsystem support were minimal, and because the data from the two payloads were mutually complementary. Only one Planetary payload was defined, the Intermediate Size Planetary Telescope. This payload was included in the analysis because of the long duration pointing and stability requirements. All 14 payloads defined for Space Physics were included in the analysis because of the variety of subdisciplines and support requirements required. A representative sequence of activities to be performed during a typical Life Sciences mission was not defined; therefore, crew and experiment operations timelines could not be generated.

Operations models of each of the above described payloads were developed for use in the analyses.

Representative schedules of activities were generated for each of the selected payloads. In addition, crew and experiment timelines, and resource utilization histories were developed (Table 5.1-3). The results of the Experiment Operations Timeline analysis are summarized in Figure 5.1-1.

DISCIPLINES/PAYLOADS	EXPERIMENT OPERATIONS: PERFORMANCES REQUIRED	EXPERIMENT OPERATIONS: PERFORMANCES SCHEDULED	EXPERIMENT OPERATIONS: OPERATING TIME (HOURS) REQUIRED	EXPERIMENT OPERATIONS: OPERATING TIME (HOURS) SCHEDULED	CREW UTILIZATION: MANHOURS (TOTAL/MISSION) AVAILABLE	CREW UTILIZATION: MANHOURS (TOTAL/MISSION) REQUIRED	CREW UTILIZATION: MANHOURS (TOTAL/MISSION) SCHEDULED	ELECTRIC POWER: POWER (WATTS) AVG OPERATING	ELECTRIC POWER: POWER (WATTS) PEAK (W)	ELECTRIC POWER: POWER (WATTS) PEAK (MIN)	ELECTRIC POWER: ENERGY (KWH) AVG DAILY	ELECTRIC POWER: ENERGY (KWH) MISSION TOTAL
EARTH OBSERVATIONS												
EO-2 LAND USE	11	39	4.6	4.8	132.3	111.5	117.9	4800.0	5700.0	MSECS	11.8	62.9
EO-3 POLLUTION	25	34	5.0	3.4	126.0	33.3	44.0	3000.0	3800.0	MSECS	7.8	38.8
EO-6 OCEAN RESOURCES	20	44	5.0	14.9	132.0	43.0	77.8	2600.0	3100.0	MSECS	12.2	66.1
EO-7 ATMOSPHERIC CLOUD PHYSICS	20	48	40.0	97.0	136.0	60.0	136.0	150.0	200.0	60.0	3.4	19.2
COMMUNICATIONS/NAVIGATION												
C/N-1	39	71	6.1	11.8	120.0	66.8	38.7	≅ 6000.0	9548.0	1.5	≈ 36.8	≈ [illegible]
ASTRONOMY												
A-1/A-2 1 M PHG/SOLAR SPAR	1	1	149.4	149.4	162.6	92.4	92.4	1110.7	1265.7	50.0 MSEC	25.6	[illegible]
A-2 SOLAR SPAR	1	1	149.4	149.4	158.3	72.6	72.6	656.0	792.0	50.0 MSEC	16.5	106.9
A-3 STRATOSCOPE III	1	1	150.6	150.6	156.8	59.9	59.9	465.0	510.0	1.0	11.1	72.4
MATERIALS SCIENCE												
MS/MS-1, MS/MS-2, MS/MS-3, MS/MS-4 COMBINED INTO ONE PAYLOAD	130	86	620.0	418.5	288.0	277.8	148.5	3730.0	7730.0	30.0	81.0	485.0
TECHNOLOGY												
T-1/T-2 CONTAMINATION/MONITOR	41	41	697.0	697.0	144.0	74.2	74.2	470.0	1285.0	16.2	12.1	[illegible]
PLANETARY												
P-1 INTERMEDIATE SIZE TELESCOPE	15	15	120.0	120.0	117.0	54.5	54.5	578.7	678.7	30.0	11.6	[illegible]
SPACE PHYSICS												
SP-1 ATMOSPHERIC AND MAGNETOSPHERIC SCIENCE	1	1	120.0	120.0	144.0	128.0	128.0	690.0	1137.0	1 MSEC	16.6	88.4
SP-2 COMETARY PHYSICS	10	10	10.0	10.0	120.0	30.0	30.0	1600.0	4000.0	18.0	7.7	38.7
SP-3 METEOROID	1	1	112.0	112.0	60.0	10.5	10.5	9.0	60.0	60.0	0.3	1.3
SP-4 SMALL ASTRONOMY TELESCOPES	5	5	80.0	80.0	60.0	42.0	42.0	458.0	1137.0	1 MSEC	8.0	42.2
SP-5 WAKE MEASUREMENTS FROM STATION AND BOOM	1	1	16.0	16.0	24.0	20.0	20.0	438.0	438.0	960.0	7.9	7.9
SP-6 WAKE MEASUREMENTS FROM SUBSATELLITE	1	1	12.0	12.0	24.0	20.0	20.0	300.0	411.0	120.0	3.7	9.7
SP-7 PLASMA RESONANCES	1	1	16.0	16.0	24.0	20.0	20.0	616.0	616.0	240.0	7.5	7.5
SP-8 WAVE PARTICLE INTERACTIONS	2	2	16.0	16.0	48.0	44.0	44.0	345.0	560.0	20.0	9.3	14.1
SP-9 ELECTRON ION BEAM INJECTION	2	2	16.0	16.0	48.0	32.0	32.0	340.0	774.0	20.0	8.4	13.6
SP-10 COSMIC RAY MAGNETIC SPECTROMETER	1	1	115.0	115.0	60.0	15.0	15.0	100.0	100.0	6900.0	2.4	11.8
SP-11 PLASTIC/NUCLEAR EMULSION	1	1	118.0	118.0	60.0	2.0	2.0	14.0	440.0	10.0	0.3	1.8
SP-12 AIRLOCK AND BOOM EXPERIMENTS	5	5	50.0	50.0	120.0	75.0	75.0	40.0	270.0	6.0	0.4	2.3
SP-13 FLAME CHEMISTRY AND LASER EXPERIMENTS	5	5	50.0	50.0	120.0	100.0	100.0	190.0	510.0	6.0	2.1	[illegible]
SP-14 TEST CHAMBER EXPERIMENTS	5	5	45.0	45.0	120.0	75.0	75.0	450.0	2615.0	10.2	6.6	34.7

TABLE 5.1-3. MISSION REQUIREMENTS SUMMARY

DISCIPLINES/PAYLOADS	DATA HANDLING AND STORAGE						COMMENTS
	ACQUISITION			STORED			
	DIGITAL (KBPS)	ANALOG (KHZ)	FILM (FRAMES/MIN)	DIGITAL (KB)	ANALOG (MIN)	FILM (FRAMES)	
EARTH OBSERVATIONS							AMOUNT OF ANALOG DATA IS GIVEN IN TERMS OF TOTAL TIME DURING WHICH DATA IS TAKEN
EO-2 LAND USE	50100.0	NONE	67.0	86.8×10^7	NONE	19352	
EO-3 POLLUTION	51300.0	NONE	90 CM/MIN	62.8×10^7	NONE	18.4×10^3 CM	
EO-6 OCEAN RESOURCES	51300.0	NONE	90 CM/MIN	27.5×10^8	NONE	90.0×10^3 CM	
EO-7 ATMOSPHERIC CLOUD PHYSICS	7.5(1)	NONE	1920.0	4100 FT	NONE	21.0×10^4	(1) INCHES PER SEC
COMMUNICATIONS/NAVIGATION							
C/N-1	≈ 203.0	10.0	1 REEL 35 MM/DAY 1 ROLL 16 MM/DAY	16.6×10^5	720.0	5 REELS 35 MM 5 ROLLS 16 MM	
ASTRONOMY							
A-1/A-2 1 M PHG/SOLAR SPAR	8.6	NONE	17.7	46.3×10^5	NONE	153.5×10^3	
A-2 SOLAR SPAR	1.8	NONE	3.7	95.6×10^4	NONE	33.1×10^3	
A-3 STRATOSCOPE III	2.2	NONE	0.5	11.9×10^5	NONE	4.5×10^3	
MATERIALS SCIENCE							
MS/MS-1 MS/MS-2 MS/MS-3 MS/MS-4 — COMBINED INTO ONE PAYLOAD	300.0	3300.0	NONE	4.8×10^6	NONE	NONE	
TECHNOLOGY							
T-1/T-2 CONTAMINATION/MONITOR	105.0	NONE	NONE	41.8×10^6	NONE	NONE	
PLANETARY							
P-1 INTERMEDIATE SIZE TELESCOPE	3.3	NONE	2.0	13.6×10^7	NONE	1.0×10^3	
SPACE PHYSICS							
SP-1 ATMOSPHERIC AND MAGNETOSPHERIC SCIENCE	391.0	330.0	NONE	16.9×10^7	7200.0	NONE	
SP-2 COMETARY PHYSICS	20.0	NONE	160 frames/day	7.2×10^5	NONE	800	
SP-3 METEOROID	312.0(2)	NONE	NONE	1.6×10^2	NONE	NONE	(2) BITS PER EVENT
SP-4 SMALL ASTRONOMY TELESCOPES	120.0	NONE	192 frames/day	25.9×10^6	NONE	960	
SP-5 WAKE MEASUREMENTS FROM STATION AND BOOM	180.0	20000.0	NONE	10.4×10^6	90.0	NONE	
SP-6 WAKE MEASUREMENTS FROM SUBSATELLITE	60.0	NONE	NONE	2.6×10^6	NONE	NONE	
SP-7 PLASMA RESONANCES	700.0	NONE	8 frames/hour	7.6×10^6	NONE	96	
SP-8 WAVE PARTICLE INTERACTIONS	30.0	600.0	NONE	17.2×10^5	800.0	NONE	
SP-9 ELECTRON ION BEAM INJECTION	120.0	1000.0	NONE	6.8×10^6	960.0	NONE	
SP-10 COSMIC RAY MAGNETIC SPECTROMETER	5.0	NONE	NONE	21.6×10^5	NONE	NONE	
SP-11 PLASTIC/NUCLEAR EMULSION	NONE	NONE	EMULSION 1 SHEET	NONE	NONE	NONE	
SP-12 AIRLOCK AND BOOM EXPERIMENTS	45.0	NONE	160 frames/day	8.1×10^6	NONE	800	
SP-13 FLAME CHEMISTRY AND LASER EXPERIMENTS	2400.0	NONE	160 frames/day	10.8×10^7	NONE	800	
SP-14 TEST CHAMBER EXPERIMENTS	65.0	NONE	800 frames/day	4.7×10^6	NONE	4000	

TABLE 5.1-3. MISSION REQUIREMENTS SUMMARY (CONTINUED)

PH - Personal Hygiene

EX - Exercise

EAT - Eat

S/HK - Systems Housekeeping

SLEEP - Sleep

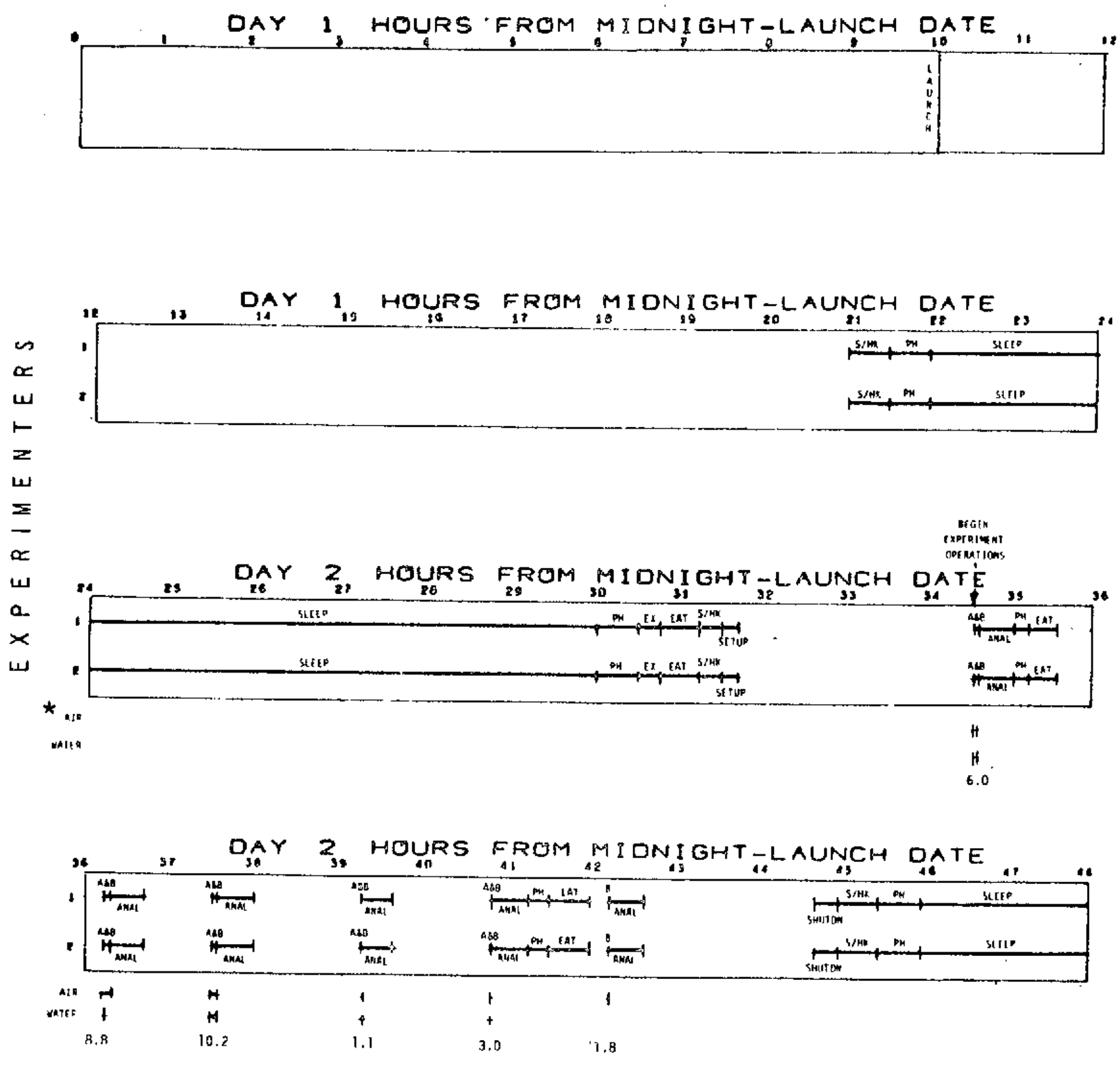
SETUP - Experiment setup

SHUTDN - Experiment shutdown

B - Data acquisition for air pollution experiment

A - Data acquisition for water pollution experiment

ANAL - Data analysis /Standby



*Target opportunities in minutes

FIGURE 5.1-1. CREW AND EXPERIMENT TIMELINE (EO-3)

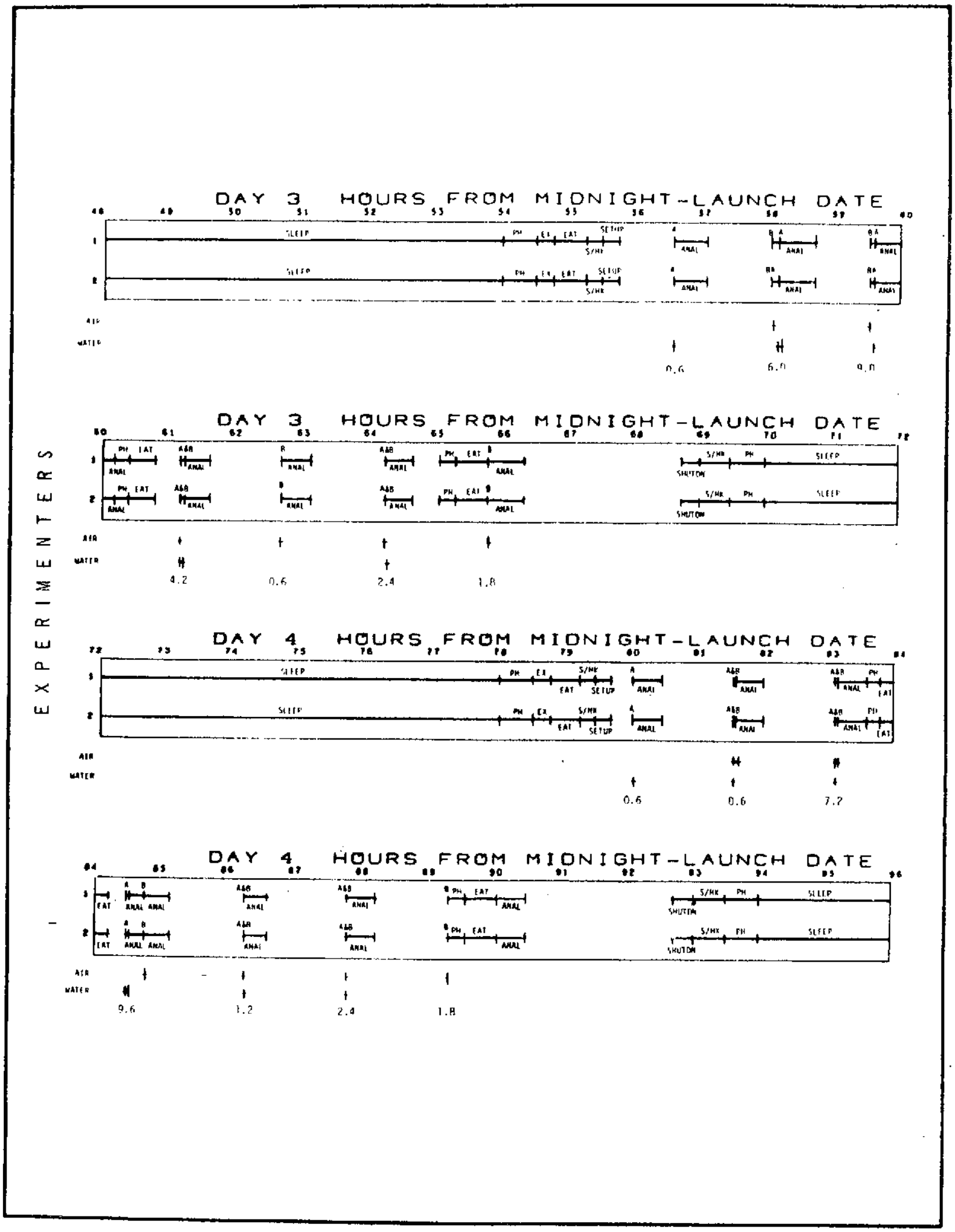


FIGURE 5.1-1. CREW AND EXPERIMENT TIMELINE (EO-3) (CONTINUED)

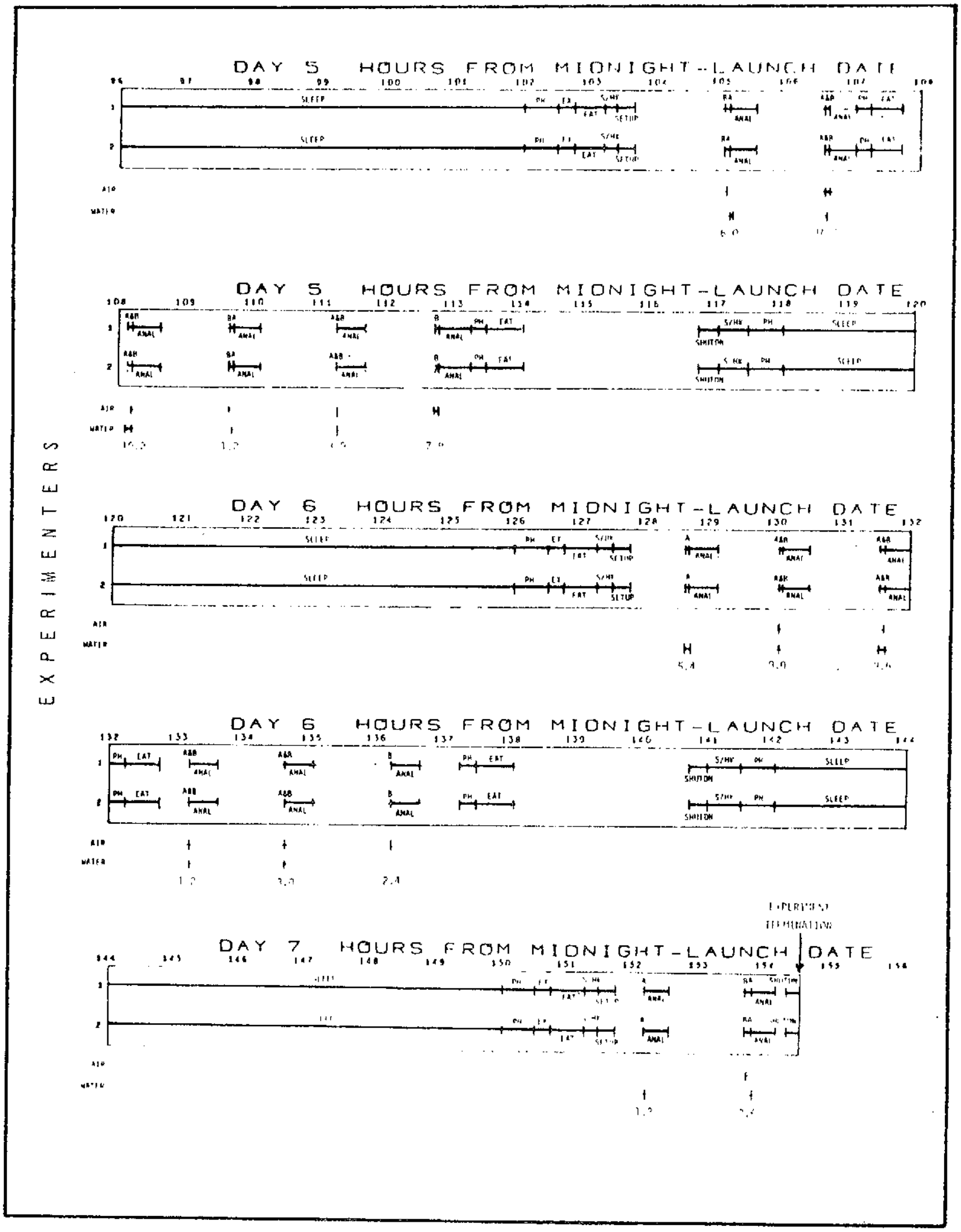


FIGURE 5.1-1. CREW AND EXPERIMENT TIMELINE (EO-3) (CONTINUED)

At the conclusion of the experimentation period deactivation of the Sortie Lab is performed (if required) and the vehicle is configured for reentry (see Table 5.1-4).

FUNCTION	SEQUENCE	REQUIREMENTS/REMARKS
FLIGHT OPERATIONS - DEACTIVATION	ΔT = 3 hr	
Deactivate Data Management System		
Initial C&D Console Deactivation		
Initial C&W Deactivation		
Visually Inspect Sortie Lab		
Return ECS Control to External		
Return EPS Control to External		
Turn Off General Illumination Lighting		
Turn On Entry Lights		
Close Sortie Lab Hatch and Lock		
Turn Off Sortie Lab Initial Entry Lights		
Close Tunnel Hatch and Lock		
O_2 and N_2 Supply Valves to Closed		This ensures O_2 and N_2 regulators not pressurized during reentry. Commanded from Orbiter.
Retract Sortie Lab Radiator		Must be completed prior to cargo doors close to prevent damage to radiator, lab, or pallet.
Close Cargo Bay Doors		To protect Lab during reentry.
Return ECS to Preflight Configuration		

TABLE 5.1-4. FLIGHT OPERATIONS - DEACTIVATION

5.1.2 Reentry

From the mission operations viewpoint, the main influences of reentry on mission planning are landing at the desired landing site, which together with the ranging capability of the Shuttle, determines the deboost opportunities during the mission; the thermal integrity of the vehicle, which determines the characteristics of the deboost transfer orbit to atmospheric reentry and which may require pre-deboost attitude maneuvers for thermal conditioning of the orbiter; the structural integrity of the vehicle upon landing, which affects the landed payload weight; and the stability of the orbiter during aerodynamic maneuvers, which affects the allowable payload CG location during entry (and ascent, because of possible emergency abort and landing).

Discussing these in order, the orbiter currently has a cross range capability of $\pm$ 1085 n.mi. and a downrange capability of 5475 n.mi. $\pm$ 1000 n.mi. from 400,000 ft altitude. The deboost maneuver must be initiated at the proper time and position in space to interface with atmospheric entry at the interface altitude of 400,000 ft with the proper range to go. In general, the deboost opportunities occur in groups on successive orbital revolutions, with the number of opportunities in a group inversely proportional to inclination (strong dependence) and to altitude (weak dependence). For 28.5 degrees inclination, there is one opportunity band per day with roughly six opportunities on consecutive orbits in the band and roughly 15 hours from the end of one band to the beginning of the other; for 90 degrees inclination, there are two bands per day, roughly equally spaced, with one or two opportunities in each band. The time when deboost opportunities occur must be considered in deciding when a sortie mission must be terminated to configure for deboost.

Thermal integrity of the orbiter may dictate up to a maximum of seven hours of attitude maneuvers for thermal conditioning prior to deboost, depending on the thermal history of the Orbiter on the particular mission. In addition, the atmospheric entry trajectory is shaped to provide flight within the region yielding sufficient crossrange to meet the once-around crossrange requirements and to provide a favorable balance between heat rate and total heat load. In order to maintain a constant heating rate independent of the altitude from which the deboost maneuver is performed, it is necessary to establish a functional relation between the velocity and the flight path angle at the reentry interface. Entry at too large a path angle for a given velocity will result in excessive heating for the thermal protection system (TPS). Entry at too shallow an angle will result in uncontrolled skipping of the trajectory. The target line represents an average value between the heating limit and the skipout condition. It is necessary to target the deboost maneuver at the end of the on-orbit operations to intersect the 400,000 ft. altitude along the target line. A contingency OMS loading of 22 fps is provided on each mission to avoid depleting the OMS propellant during reentry.

Considering now the structural integrity of the Orbiter, the vehicle is designed to land at 180K gross weight at a sink rate of 10 fps and a velocity of 165 knots. This gross weight corresponds to a 32,000 lb payload. Larger payloads can be landed at lower sink rates and higher touchdown speeds. However, there is an operational risk in landing with larger than the design payload, and the Sortie Lab is designed for a landed weight not to exceed 32,000 lbs.

Finally, the requirement for aerodynamic stability throughout entry, landing approach, flare, and touchdown sets limits on the gross vehicle CG range in all three axes (limits depend, of course, on the Shuttle Orbiter aerodynamic configuration and other factors). Given the Shuttle landing CG and landing weight, this range for the gross CG can be translated into payload CG limits in X, Y, and Z axes as a function of payload weight.

The X and Z CG limits are the most constraining on the Sortie Lab and are shown in Figures 4-6 and 4-7 of JSC 07700, Volume XIV, "Space Shuttle Payload Accommodations," dated April 13, 1973. As mentioned, the Sortie Lab payloads must also conform to this CG range during ascent since, in case of abort during ascent, the vehicle goes through atmospheric glide, landing approach, flareout, etc., in the process of returning to and landing at the launch site in either suborbital return to the launch site abort or once-around the earth abort.

5.1.3 Critical Operations

Sortie Lab experiment operations are conducted with the Sortie Lab in the Shuttle Orbiter cargo bay, therefore, both the Sortie Lab and Orbiter operations are critical to mission success. Guidance and Navigation functions are provided by the Shuttle Orbiter. Pointing accuracy and stability control exceeding the capability of the Orbiter is provided by the Sortie Lab/Payload. Electric power and communication/data facilities are available from the Orbiter. The environmental control functions are provided by both the Orbiter and the Sortie Lab. A checkout console is located in the Orbiter and a monitor console is located in the Sortie Lab. The operation of all of the above subsystems is critical in the successful completion of the on orbit payload operations.

In addition to those listed above, contamination must be controlled to insure the integrity of the scientific data.

Specific on orbit operations (if necessary) that have been identified as being critical to experiment operations include but are not limited to the following:

- Sortie Lab activation
- Sortie Lab radiator deployment
- Airlock operation
- Boom deployment/retraction
- Lens cover removal/replacement
- Controlled venting/thruster firing
- Gimbal Operations
- CMG Spin-Up

5.2 Ground Operations

The current Sortie Lab ground operations operational processing flow, as shown in Figure 5.2-1 is based on the processing of Sortie Lab experiment elements, experiment modules and pallet sections, and accomplishment of experiment integration activities at a central integration site, a facility located away from the launch site, and the processing of the support module and accomplishment of integrated Sortie Lab checkout at the launch site.

Detail descriptions of the current Sortie Lab operational processing concepts and activities are presented in the Spacelab Ground Operations Plan, MSFC Document 68M00032 dated October 23, 1973 and the Spacelab Ground Operations Guidelines and Groundrules dated October 27, 1973. These documents identify and describe the significant Sortie

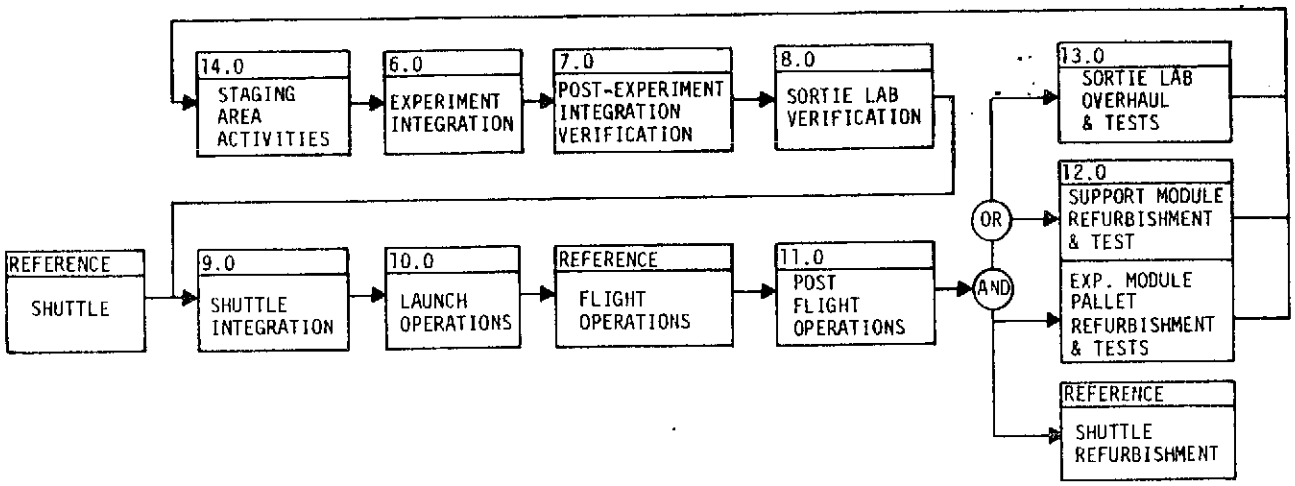


FIGURE 5.2-1. SORTIE LAB OPERATIONAL PROCESSING FLOW

Lab operational processing requirements, guidelines, and groundrules; and provide a detailed summary of the operational activities associated with the routine between mission processing of Sortie Lab hardware including applicable Shuttle Orbiter interfaces and processing activities.

Sections 5.2.1 through 5.2.5 identify and briefly describe the prime activities of the Sortie Lab ground operations. These activities are based on the nominal operational phase processing of a split module Sortie Lab consisting of a standardized flex tunnel, support module, experiment modules and pallet sections.

5.2.1 Payload Carrier/Payload Integration

This operation is defined for the purpose of ground operations analysis as consisting of the assembly of Sortie Lab experiment elements, the installation of experiments and experiment support hardware on these elements, and post-experiment installation checkout of the assembled experiment package. These tasks would normally be accomplished at the central integration site; but could be accomplished, in whole or part, at a user location as depicted in Figure 5.2-2.

Experiment post installation checkout operations include those unique experiment activities associated with experiment post installation operational checkout, alignments, and servicing which will normally be accomplished through the use of experiment user provided experiment support equipment.

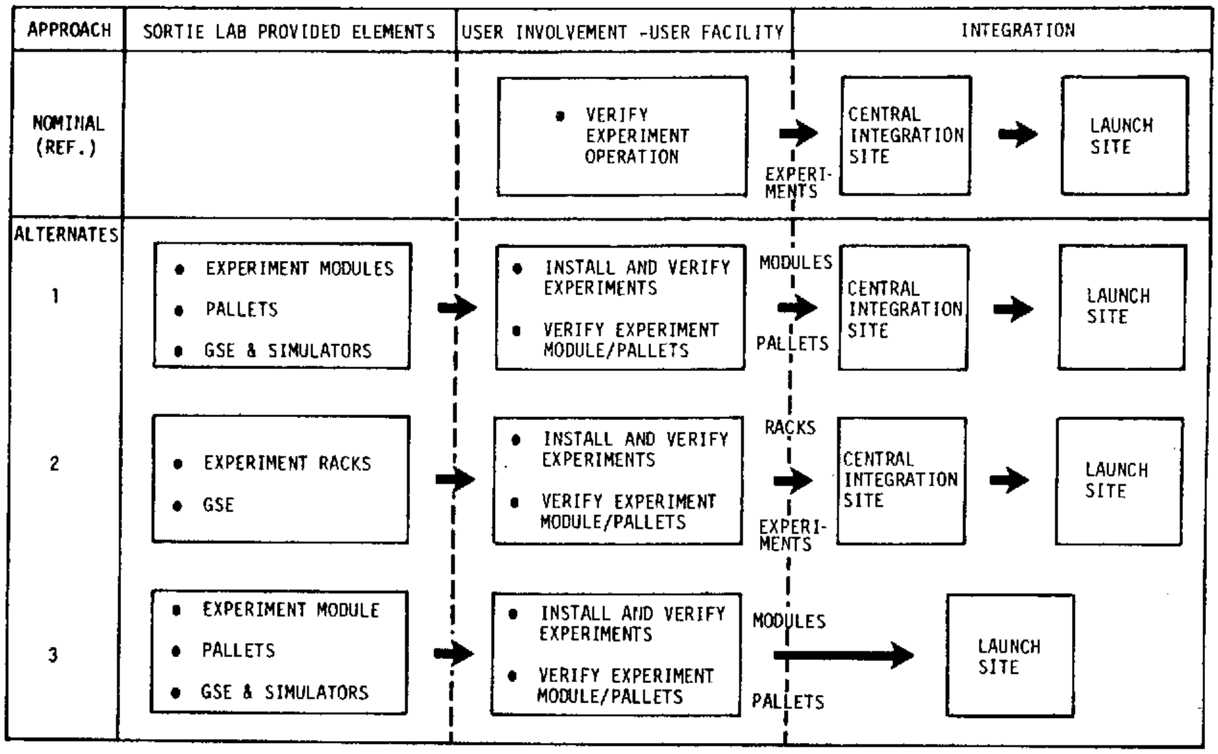


FIGURE 5.2-2. ALTERNATE EXPERIMENT INTEGRATION APPROACHES

Following completion of experiment installation and post-installation checkout operations the assembled experiment related elements will be mated with the support module simulator for power-up verification of the assembly and interface verification. This interface verification will include validation of all systems and experiment interfaces mated during experiment module and pallet assembly and experiment installation, and will accomplish those checks necessary to validate experiment compliance with man/machine interfaces and safety requirements. Following completion of these operations the experiment flight hardware elements will be prepared for transportation and moved to the launch site for mating with the support module and accomplishment of integrated checkout.

5.2.2 Prelaunch Operations

This operation begins with the receipt of the assembled experiment elements at the launch site (ETR) and includes the installation of the support module and flex tunnel on the experiment module, the accomplishment of integrated Sortie Lab checkout, the servicing of non-time critical items and installation of the Sortie Lab in the Shuttle Orbiter.

Integrated Sortie Lab checkout activities involved include the loading of the flight software, the verification of support module-to-experiment module interfaces, and final operational checks of Sortie Lab systems and experiments including pressure seal integrity tests and weight and/or center-of-gravity checks on selected payloads. Following completion of this testing, which will be accomplished in the Sortie Lab assembly area, the assembled Sortie Lab will be moved to the Shuttle Orbiter integration facility where installation in the Orbiter cargo bay and integrated Sortie Lab-to-Shuttle Orbiter interface verification will be accomplished.

Sortie Lab-to-Shuttle Orbiter interface verification will consist of an operational check of each electrical, data, fluid and mechanical interface and will include a leak check of the flex tunnel-to-Shuttle Orbiter pressure seal. These test activities will be limited to that effort necessary to verify interfaces and critical functions only, (in particular, all Sortie Lab to Shuttle Orbiter monitor, command, and support functions) and will not include an operational verification of each Sortie Lab system or experiment.

5.2.3 Launch Operations

Sortie Lab activities during vertical Shuttle Orbiter processing will be limited to support of the Shuttle Orbiter testing, cabin closeout and final servicing, the monitoring and pre-launch activation of selected Sortie Lab systems and/or experiments, and the loading of the Sortie Lab flight crew into the Shuttle Orbiter.

Sortie Lab participation in the Shuttle Orbiter testing will include a limited reverification of critical Sortie Lab-to-Shuttle Orbiter interfaces and limited validation of selected caution and warning and display system functions. Final servicing will include the loading of time-critical experiment samples, and the servicing of fluids, gases or cryogenics.

5.2.4 Post Flight Operations

Sortie Lab activities associated with Orbiter recovery operations include the safing and securing of Sortie Lab systems and experiments, the initiation of ground support functions (purges, thermal conditioning, ground power, etc.), the recovery of time-critical experiment and flight data, and the removal of Sortie Lab from the Orbiter cargo bay. Additional activities planned for this operation include the return of the Sortie Lab to the Sortie Lab Assembly Area where the flex tunnel and support module would be demated and the experiment elements prepared for return to the Sortie Lab central integration site for disassembly and maintenance.

5.2.5 Maintenance and Refurbishment Operations

Sortie Lab maintenance operations include those activities associated with rework or repair of Sortie Lab elements following use. Included in the current Sortie Lab operational processing concepts are maintenance activities, refurbishment and overhaul, which are defined in the following paragraphs.

Refurbishment is defined as the routine servicing of Sortie Lab hardware following each mission. This operation will include the replacement of failed or marginal line replaceable units (LRU's) based on the results of visual inspections and flight data evaluations, the verification of repairs and replacements made, and nominal post-mission servicing and cleaning activities.

Overhaul is envisioned as an extensive maintenance operation which will be used for reconditioning of Sortie Lab hardware, primarily the support module systems, after a specified number of operational hours, cycles or missions. This activity will include the removal of systems for bench level servicing and functional checks, the rework and repair of structural elements, the re-installation of reworked, repaired, or new hardware, and performance of a complete end-to-end acceptance test of the assembled systems. Overhaul requirements for the Sortie Lab sub-systems or modules that need not be performed off-line will be performed, when possible, during Sortie Lab refurbishment/

maintenance operations. This does not preclude a phased maintenance approach where maintenance activities may differ from one turnaround cycle to another.

Basic to the Sortie Lab maintenance approach is the philosophy that refurbishment and overhaul activities will follow a predetermined processing plan which will schedule these activities based on ground test information obtained during previous element maintenance and buildup activities; established maintenance schedules for repair, replacement and/or servicing of time and cycle-critical components or systems; and flight data from the previous mission. Of prime importance to the current maintenance concept is the use of Sortie Lab flight data as a basic source for identification of Sortie Lab systems and component maintenance requirements and the accomplishment of trend analysis. This use of flight data is envisioned to eliminate or minimize the requirement for post mission operation of Sortie Lab systems to establish operational status information or accomplish fault isolation of failures.

6.0 EXPERIMENT INTEGRATION

A task was initiated to define a Sortie Lab Experiment Integration Plan. During the development of the plan, integration approaches used by other programs and major operational test facilities were investigated for useable information. Experiment Integration was defined and an integration process was tentatively recommended. A draft of the Preliminary Plan was released and its contents are summarized in this section.

6.1 Definition of Experiment Integration

Experiment Integration is defined as those Sortie Lab program activities that are performed to assure physical and functional compatibility of all elements of experiments with the Sortie Lab, with other experiments, with GSE, with ground and flight operations, and with operations personnel.

6.2 Experiment Integration Plan

The preliminary plan described below was based upon trade studies, experience gained on other programs and the Spacelab Program Level I Guidelines and Constraints.

6.2.1 Responsibilities

6.2.1.1 Payload Management Lead Responsibilities

The recommended payloads management responsibility functions for the various NASA program offices involved with Sortie Lab are delineated in Table 6.2-1.

The Sortie Lab Program Office is responsible for experiment integration and will work with the Experiment Development Lead Centers to accomplish this task. Although the integration may not occur at its facility, the responsibility will remain with the Experiment Integrator.

SCIENCE & APPLICATION PROGRAM OFFICES	MISSION & PAYLOAD INTEGRATION OFFICE	SORTIE LAB PROGRAM OFFICE	SHUTTLE PROGRAM OFFICE
Experiments Definition	• Experiment Grouping Analysis	• Sortie Lab and Ancillary Hardware Development and Testing	• Sortie Lab Integration into Shuttle
Identify User Requirements	• Initial Mission Planning	• Detailed Sortie Lab Mission Planning	• Shuttle Launch
Experiment Development and Testing	• Standard Shuttle Resource Support	• Experiment/Payload Integration into Sortie Lab	• Shuttle On-Orbit Operations and Sortie Lab Support
		• Integrated Payload/ Sortie Lab Testing	• Communication to the Ground
Support to Experiment, Installation and On-Orbit Operations		• User Interface	• Landing
Analysis of Experimental Data		• Sortie Lab On-Orbit Operations	
Publish and Archive Experiment Results		• Ship Experiment Equipment to User for Refurbishment and Reuse	
DOD Commercial and ESRO Furnished Experiments		• Refurbishment of Sortie Lab and Ancillary Equipment	
		• Data Processing	
		• Sortie Lab Peculiar Interface Requirements	

TABLE 6.2-1. PROGRAM LEAD RESPONSIBILITIES

6.2.1.2 Sortie Lab Program Responsibilities

The NASA headquarters program office within the OMSF shall provide the overall direction required to plan and implement the Sortie Lab Program including the experiment integration tasks.

The Marshall Space Flight Center (MSFC) is the Sortie Lab "lead center" within NASA and is responsible for Sortie Lab utilization, integration and operations. To achieve maximum program effectiveness and efficiency it is anticipated that the majority of the Sortie Lab experiment integration will be performed at MSFC.

6.2.1.3 Experiment Integrator Responsibilities

The Experiment Integrator is responsible for all analytical, mockup and other related activities leading to the establishment and verification of plans and requirements for experiment payload and Sortie Lab development verification and operation. Experiment integration will be accomplished under the direction of an experiment integration manager who will be responsible for the analytical activities including tracking and control of each experiment payload.

The role and relationships between the experiment integration functions and other related activities is portrayed in Figure 6.2-1. Although experiment installation and checkout is not performed within the experiment integration function the Experiment Integrator interfaces with the operations engineering function on matters relating to policy and levies requirements for installation and checkout of the experiment payload.

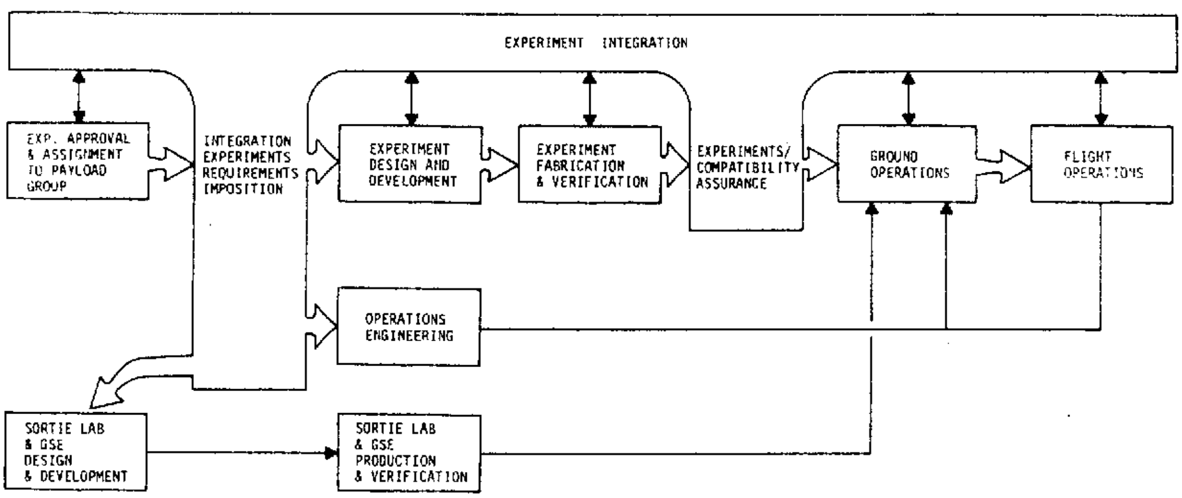


FIGURE 6.2-1. EXPERIMENT INTEGRATION ROLE

6.2.2 Experiment Integration Approach

The overall objective of the experiment integration approach will be to minimize program cost and optimize scientific returns by:

a) Standardization of experiment to Sortie Lab structural, electrical, and other connections and attachment interfaces.

b) Keeping documentation to the minimum level necessary to assure safety and Sortie Lab/experiment compatibility. Keep burden of document preparation on the Experiment Integrator.

c) Foregoing repetitive functional test of individual experiments, by giving the Experiment Development Lead Centers sole responsibility for design, fabrication, qualification and functional operation of experiments.

d) Using established organizations and existing facilities and equipment to the maximum extent feasible.

e) Assigning within the Sortie Lab Program Office an experiment integration manager responsible for the overall integration of each payload and experiment integration engineers to support the integration of individual experiments.

f) Utilizing when warranted relatively low cost mock-ups and simulators to verify concepts and identify interface and procedural problems early in the experiment integration cycle.

g) Providing for laboratory support and on-the-spot modifications and adjustments when experiment problems arise during installation and checkout.

h) Keeping the experimenters in the loop throughout the integration phase.

i) Continuously making an agressive effort to reduce and simplify the integration process and requirements through the introduction of innovative techniques. Initially familiar integration concepts will be used, however, as experience increases innovative techniques are developed, and incorporated to bring the process to maturity.

Coordination and control of the experiment integration effort will be accomplished primarily through frequent informal contacts between the experiment integration manager and all participants, scheduled reviews, and interface control.

6.2.2.1 Schedule Management

Master schedules depicting the time phased experiment integration activities for each payload will be developed and maintained.

Experiment Integration schedules will be coordinated with the appropriate Experiment Development Lead Centers, JSC, operations, and the launch site representatives.

6.2.2.2 Configuration Control

Configuration control of individual experiments will be the responsibility of the Experiment Development Lead Centers. The Experiment Integrator will accomplish interface control of experiment to Sortie Lab interfaces through Configuration Control Boards.

6.2.2.3 Documentation

Documentation will be kept to the minimum necessary to accomplish the integration effort. The burden of writing and distributing experiment integration documentation will be upon the Experiment Integrator. The experimenters will provide information as required and in certain cases will be required to concur with a document prior to release.

6.2.2.4 Simulation

The approach will be to effectively utilize mock-ups and breadboards when needed to provide early payload concept verification, fit and clearance verification, and training aids. Breadboards and experience developed in the Concept Verification Test (CVT) program and during the ESRO Spacelab Development Program will be utilized to the fullest extent in the experiment integration effort.

6.2.2.5 Safety

Safety activities conducted during Experiment Integration will include both flight and ground operations safety.

In the complexity of the experiment hardware so requires, a Hazards Analysis will be accomplished by the Experiment Integrator.

It is anticipated that lists of approved commerical equipment will be provided Experimenters and that the Experiment Integrator will assist the experiment developer in the area of materials compatibility.

When required the Experiment Integrator will conduct special safety studies including structural analysis and define and conduct special safety tests such as proof tests of pressure vessels.

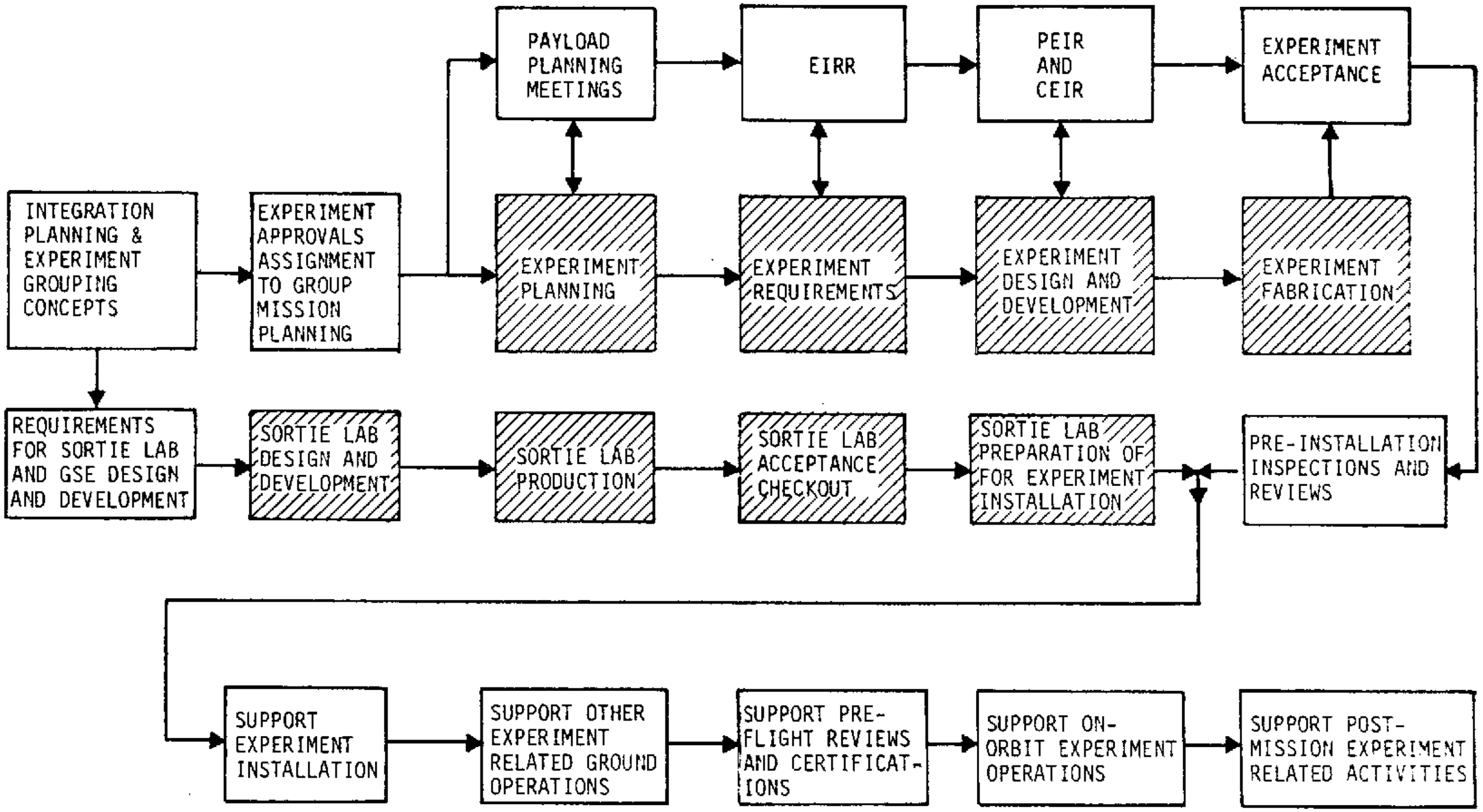
Safety will be one criterion applied to acceptance and grouping of experiment payloads for Sortie Lab missions. Therefore, the Experiment Integrator will assist in performing preliminary safety analysis when required to define potential hazards and means of elimination or reduction of hazards prior to selection of experiments.

6.2.3 Integration Process

Figure 6.2-2 depicts a typical unabridged payload build-up sequence as envisioned during the operational phase of the Sortie Lab Program, when modules and pallets are already in the depot inventory. The task relationships between the Experiment Integrator and the experimenters are also shown. A payload may include many experiments and may involve several centers. For purposes of illustration, a formal design review process is depicted for both experimenter and Experiment Integrator.

6.3 Approaches Used by Other Program and Test Facilities

Major findings and conclusions from studying the Experiment and Facility Integration procedure of other programs are summarized below.



LEGEND:

Denotes Experiment Integration Involvement

Denotes Activities of others, shown for Reference.

EIRR Experiment Integration Requirements Review
PEIR Preliminary Experiment Integration Review
CEIR Critical Experiment Integration Review

FIGURE 6.2-2. EXPERIMENT INTEGRATION PROCESS

6.3.1 Convair 990 (Assess Program)

The similarities between the Sortie Lab and Convair 990 program are:

- Multidisciplinary nature of experiment payloads
- Carry on experiments are accepted
- Several missions in various stages of development concurrently in progress.

The Convair 990 integration plan had the experimenter involved in all aspects of the mission. The experimenter had total responsibility for successful operation of experiment. The only constraints were aircraft availability, flight safety, available electrical power, and the aircraft environment. Experiment integration from the program side involved payload grouping, assigning a point of contact and maintaining the flight operations and installation facilities.

Each CV 990 mission begins with a pilot proficiency flight, which serves as a check on aircraft maintenance and allows the flight crew to evaluate any new installation pertinent to aircraft operations. The second flight, normally a local flight, provided an initial operational shakedown of the various experiments and an opportunity for new experimenters to become accustomed to the aircraft environment. Subsequent flights are the data flights to meet mission objectives.

Minimum documentation, physical proximity of all facilities and the single point of contact assigned throughout the mission contribute to quick turn-around and minimum schedule impact.

User involvement and user responsibility for the experiment equipment are applicable to the Sortie Lab Program. A more thorough integration and checkout process prior to flight will be required for Sortie Lab, however, the cost of a Shuttle flight prohibits shakedown flights.

6.3.2 Skylab

Skylab's experiments are good examples of the types to be carried on the Sortie Lab. However, since Skylab was a one-payload program, the experiments and carrier were designed and fabricated simultaneously which required a large, new integration effort. The Sortie Lab payloads will generally be designed to be compatible with the carrier since it is a general purpose lab which should allow a simpler method.

The Skylab program provides an excellent source for the areas which should be considered in Experiment Integration.

6.4 Experiment Integration Trade Studies

Trade studies are in progress to define the best locations for accomplishing the integration efforts for each type payload. Also, options within the integration process are being identified and traded.

7.0 SYSTEM SAFETY

The Sortie Lab system safety effort will be a planned and coordinated program which is an integral part of all phases of development.

The system safety program will be implemented on all Sortie Lab systems, subsystems, operations, experiments and support equipment. The objectives of this program are:

- To develop safety criteria and requirements for the design of the Sortie Lab and experimental payloads.
- To systematically identify hazards/undesired events within the Sortie Lab and inherent to the experimental payloads that could lead to death or injury to personnel, system loss or damage.
- To identify corrective action to eliminate or reduce the likelihood or occurrence of the hazards/undesired events.
- To provide management visibility of hazards/risks being incurred in program activities and the acceptability of these hazards/risks.

7.1 Sortie Lab Safety Philosophy

The Sortie Lab system safety program is based on the following philosophies:

- Safety is a primary consideration throughout the total project.
- The Sortie Lab design and operation shall be compatible and consistent with safety requirements of the Space Shuttle Orbiter.

- Safety considerations shall be in the following order:
  - Crew safety
  - Orbiter safety
  - Sortie Lab safety
  - Experiment safety
- The Sortie Lab System Safety Program shall be designed, developed and conducted in an efficient and economical manner.
- In implementing the Sortie Lab System Safety Program the outputs from interfacing disciplines (Design, Reliability, Quality, Test, etc.) shall be used to prevent duplication of effort and aid in achieving low cost.
- Safety documents shall be updated and revised whenever new data and information concerning system performance and operation must be incorporated.
- Hazard analysis of the Sortie Lab, subsystems, operations, experiments and support equipment shall be conducted to identify hazards within these elements, and between interacting elements, for the purpose of their elimination or control.
- Hazards, as defined by NASA SPD-1A, shall be eliminated or controlled by means of safety devices, warning devices, or procedures. Controlled hazards and other remaining hazards shall be identified as residual hazards with the risk involved and rationale for acceptance provided in the Project Hazard Summary.
- Capability shall be provided for performing critical functions at an emergency level for Sortie Lab areas occupied by crewmen until the affected function can be restored or the crewmen evacuated to a safe area.

- Safety activity will be implemented consistent with project phase and level of definition.

- When changes are proposed for equipment design or procedures, a thorough review shall be performed for the proposed configuration to identify and resolve possible hazards that may be introduced by the change into the system.

- The Sortie Lab shall meet the safety requirements established by the Air Force Eastern Test Range (AFETRM 127-1) and the Air Force Western Test Range (AFWTRM 127-1). Waivers or deviations to these requirements must be identified and justified.

- On- the-ground safety or any non-flight safety equipment required shall be supplied as part of the GSE.

- The Space Shuttle Orbiter is the safe refuge for all personnel while in orbit. Egress route from the Sortie Lab to the Orbiter shall have a shirt-sleeve environment.

7.2 Sortie Lab Systems Safety Responsibilities

The following are the responsibilities for the Sortie Lab (and associated GSE) systems safety program:

7.2.1 Sortie Lab Developer

- Develop a safety plan that defines the general safety requirements to be considered in the planning and implementation of the safety program during development.

- Define and schedule safety milestones, such as completion date of safety plan and analyses.

- Establish safety criteria and requirements for the design of the Sortie Lab.

- Perform hazard analyses to identify all hazards.
- Recommend corrective action to eliminate control, or minimize identified hazards.
- Establish hazard tracking procedures to assure corrective action recommended has been accomplished.
- Provide management visibility of all hazards/risks during the development of the Sortie Lab, the status of corrective action and the hazard level of residual hazards.

7.2.2 NASA/MSFC

- Assure that the Sortie Lab Level I Guidelines and Constraints are observed. These guidelines state, in part, that:

  The Sortie Lab will have specific equipment, devices and procedures:

  (a) to protect the Sortie Lab, Space Shuttle and crew from whatever hazards may be generated by the research and applications experiment activities.

  (b) to relieve the user of as much of the cost of space-qualifying and man-rating his or her equipment as practical.
- Provide to the Sortie Lab developer safety guidelines for the Sortie Lab systems safety program.
- Establish the Sortie Lab systems safety philosophy.
- Develop an overall Sortie Lab Systems Safety Plan.
- Evaluate the Sortie Lab developer's systems safety documentation.

- Analyze Sortie Lab and experiment payloads for characteristics, performance and operational requirements to determine their safety impacts. Continuously evaluate Sortie Lab and experiment payloads as they are defined and developed.
- Perform gross hazard analysis of Sortie Lab and experiments to identify potential safety hazards to the Orbiter, Sortie Lab and crews. Perform safety analyses of Sortie Lab ground and flight operations.
- Determine the Shuttle safety requirements that apply to the Sortie Lab.
- Develop safety criteria and requirements consistent with Sortie Lab and experiments and their operation.
- Analyze Sortie Lab and experiment payload design concepts and designs for implementation of safety criteria and requirements.
- Assure safety requirements are met during integration of experiment payloads into the Sortie Lab.
- Perform safety analysis on MSFC peripheral equipment.

7.3 Accomplishments

MSFC has accomplished the following safety tasks since the inception of the Sortie Lab Program:

7.3.1 Sortie Lab

- Determined safety guidelines for the Sortie Lab systems safety program.
- Established the Sortie Lab systems safety philosophy.
- Developed the Sortie Lab Systems Safety Plan.

- Initiated a study to determine the Shuttle safety requirements that apply to Sortie Lab.
- Prepared a preliminary top-level hazard analysis for Sortie Lab.
- Prepared an initial list of safety requirements used in defining the S&E autonomous Sortie Lab, its subsystems and configuration.

7.3.2 Sortie Lab Experiment Payloads

- Determined performance and operational characteristics of equipment hardware as presently defined in the following experiment disciplines:
  - Astronomy
  - Solar Physics
  - High Energy Astrophysics
  - Atmospheric and Space Physics
  - Earth Observations
  - Earth and Ocean Physics
  - Space Processing Applications
  - Communication/Navigation
  - Life Sciences (includes Teleoperator)
  - Space Technology
- Developed working relations with other organizations in each of the above discipline areas.
- Prepared an initial experiment payloads hazards list based on data from other MSFC organizations.
- Compiled a preliminary list of experiment safety criteria and requirements.

7.4 Other Safety Activities

The foregoing philosophy, responsibilities and accomplishments are related to specific safety activities performed as part of an overall system safety effort. However, there are other aspects of the Sortie Lab program that are performed for non-safety activities but that have safety as a consideration during the effort. Some of these are trade studies, configuration selection criteria, ground operations and design efforts. Examples from these four areas are provided below.

7.4.1 Trade Studies

- Methods for emergency EVA egress and rescue operations from the Sortie Lab were studied for three Sortie Lab configurations.
  - Sortie Lab with scientific airlock
  - Sortie Lab with no airlock
  - Sortie Lab two-man airlock

  Data from the study was submitted for management decision.

- Deployment versus nondeployment of the Sortie Lab was studied for three cases:
  - The deployed Sortie Lab concept
  - The nondeployed Sortie Lab concept
  - The deployed radiator configuration of the non-deployed concept

The results of the study indicated that a deployed radiator and a nondeployed Sortie Lab be selected as the baseline concept.

- Other studies that have been performed that have applications to safety are:
  - Advantages and disadvantages of a fail safe, crack-stopper shell with a conventional ring-stringer shell.

Conclusion:

Fail safe construction provides a structure with a much higher fatigue life than conventional ring-stringer construction. However, it is not yet certain that the Sortie Lab will require such a high fatigue life.

- Meteoroid protection analyses of the conceptual designs of the Sortie Lab

Conclusion:

Analyses submitted for management consideration.

- Feasibility of high inclination Shuttle flights from the Eastern Test Range (ETR). (This study was motivated by the Western Test Range (WTR) being unavailable for accommodating high inclination missions for the Space Shuttle/Sortie Lab program until 1983.)

Conclusion:

South polar launches are not possible without exceeding acceptable sonic boom levels or land overflight.

If it is decided that, because of the intact abort capability of the Shuttle, overflight of the Continental United States is allowable during Orbiter alone flight, then northerly flight of the Shuttle would be feasible during the operational phase without encountering land impact of the SRB or excessive sonic boom levels.

7.4.2 Configuration Selection Criteria

The safety criteria and rationale for selecting the Sortie Lab configuration are provided below:

- Ease of rescue: Chances of rescue are enhanced as system becomes more passive (Level I guidelines indicate that rescue without EVA will be provided)

- Rapid egress: Ability to escape a dangerous area quickly improves chances of survival.
- Minimal Interfaces: Seals are potential sources of failure.
- Minimum Exposure to Meteoroids: Probability of puncture increases with exposed surface area.

7.4.3 Ground Operations

The Spacelab Ground Operations Plan and the Spacelab Ground Operations Guidelines and Groundrules documents contain several provisions that are related to safety:

- The servicing of Spacelab hardware following installation in the Shuttle Orbiter will be limited to those items which are time or safety-critical.
- All Spacelab systems shall include provisions for deactivation and monitoring as required to assure personnel and hardware safety. Design of the Spacelab should consider the maximum possible isolation of the flight systems in the event of a lightning strike during ground operations.
- Mating surfaces and seals will be designed to eliminate the need for conducting vacuum chamber or proof pressure testing during the operational phase. Pressure seals between elements (experiment modules, support modules, and flex tunnel) shall be designed so that seal replacement or refurbishment can be accomplished without disconnecting related interface electrical or fluid lines. In addition, the Spacelab structure shall be designed such that seals used in detachable connections are easily accessible for inspection, checkout and replacement.
- Where feasible, pyrotechnic devices shall be Category B.* This will allow for installation and hookup of the pyrotechnic units prior to payload bay door closing in the horizontal configuration.

* Reference, AFETRM - 1270 - Range Safety Manual, U.S.A.F. Eastern Test Range.

- Pyrotechnic initiators shall not be susceptible to ignition in the EMI environment of the Spacelab, the Shuttle flight vehicle and/or its launch/landing area.

- The design and routing of flight and GSE cables and fluid lines shall be such that these cables and fluid lines not pose any obstruction to Spacelab egress or be subject to damage.

- Pad access shall be limited to those required functions that must be performed during this period such as the servicing of time or safety critical items, stowage of experiment critical samples, etc.. Access to the Spacelab on the pad shall be limited to the support module/experiment module for final switch/control setting and verification. Access to the pallet during pad operations shall be limited to contingency requirements.

- Provisions will be included in the Orbiter crew compartment which will provide the capability for safety of flight caution and warning, Spacelab required command/control and monitoring of Spacelab system and experiments during pre-launch and post-landing when Spacelab access is not available.

- All platforms, transporters, workstands, hydraulic or pneumatic GSE, lifting devices and storage fixtures shall be subjected to a proof load test prior to acceptance. This requirement is also applicable to all interconnecting hoses and lines which interface with the GSE.

- Transportable containers of hazardous materials shall have adequate handles and lids and shall indicate when they are positively closed. Also, easy-to-recognize markings identifying contents, antidote information or special handling notes shall be provided.

7.4.4 Design Efforts

An example of safety related design efforts was the preliminary design of a contaminant control system for Sortie Lab. This design effort was precipitated due to results of preliminary investigations which indicated that for currently expected contaminants and generation rates, maximum allowable concentrations (MAC's) of a significant number of toxic contaminants would be reached, from zero concentration at launch, within a few hours thereby posing a threat to the crew of even a seven day mission.

7.5 Conclusions

- The Preliminary Top Level Hazard Analysis indicated that the Sortie Lab/Shuttle access hatch is a critical safety area requiring thorough evaluation and test to assure the final design will provide reliable operation throughout the mission.
- Since firm experiment payloads definition will lag Sortie Lab design, considerable flexibility must be incorporated into the Sortie Lab design to assure safe accommodation of the experiments.

8.0 LOGISTIC REQUIREMENTS

8.0 LOGISTICS

8.1 Logistics Concepts

Logistics support for the Sortie Lab Program entails the consideration of planning for, and providing elements of support that will enable the Sortie Lab Program to be accomplished effectively and economically. Logistics planning begins with preliminary design and continues throughout the operational life cycle of the Sortie Lab Program. The support elements include the following:

a. Maintenance
b. Supply Support
c. Support Equipment (GSE)
d. Support Documentation
e. Transportation
f. Packaging and Handling
g. Personnel and Training
h. Support Management

These elements will be examined in an effort to minimize the operational program costs. Variations in the number of geographical locations where maintenance, manufacturing, alunch and other functions are performed have a definite effect on program operational costs. It is presently planned that maintenance and refurbishment of the experiment module/pallet will be performed at the Integration Site. The support module will be refurbished at the Launch Site. No scheduled in-flight maintenance of experiments will be performed. The Sortie Lab maintenance turn-around time is planned to be 21 days.

8.2 Maintenance Planning

Maintenance Planning to support the Sortie Lab Program will establish specific policies and procedures for levels of maintenance, spares, etc. Sortie Lab mission profile time constraints will goven the required Sortie Lab "Ground Turn-Around" maintenance and refurbishment time cycles.

8.2.1 Maintenance Concepts and Locations

It is planned that the Sortie Lab will require the support of three levels of maintenance. The Sortie Lab maintenance concept is to remove and replace or repair in place utilizing minimum repair equipment other than that normally required for test and checkout purposes. This concept forms the baseline for the first level of maintenance.

First-level maintenance will consist of "remove and replace" action to the functional line replaceable unit (LRU) by test and checkout operations personnel.

Second-level maintenance (repair of removed units) will be performed at a special facility with the capability for detailed repair work by mechanics and technicians. Normally second-level maintenance requirements as related to Sortie Lab GSE will be performed at the launch site.

Third-level maintenance of items and units that have failed and require major repair may be returned to the applicable Sortie Lab contractor for appropriate maintenance. It is planned that all GSE failed items requiring maintenance and not repaired by site personnel may be returned to the respective Sortie Lab contractor for third-level maintenance.

8.2.2 Inflight Maintenance Requirements (IFM)

It is not planned to have any scheduled IFM and very limited unscheduled IFM on the 7-day missions. Experience derived from previous space programs indicates this is a practical approach, Necessary replacement of items such as Lithium Hydroxide cylinders will be considered as crew operational tasks rather than IFM. Moreover, it is a design goal that such replacement will not require any tools, if possible. Scheduled IFM tasks and related onboard support may be feasible for the longer 30 day missions, but IFM will only be considered for those tasks which involve critical equipment where the probability of failure justifies it. The number of inflight tools required will be minimized if the attaching hardware (nuts, bolts, screws) for replaceable items is compatible with similar hardware in the Orbiter. Thus in many cases the same tools can be used for both the Sortie Lab and the Orbiter.

8.2.3 Refurbishment

Refurbishment of the Sortie Lab will be accomplished at the Integration Site, which may or may not be at the same location as the launch site. After the Sortie Lab is removed from the Orbiter and passivated, the support module will be demated from the experiment module/pallet prior to refurbishment. The required cleaning, servicing, resupplying, removing, replacing, repairing, reworking, modifying and installing mission peculiar equipment will be accomplished simultaneously on the separate modules prior to mating and checkout. It is planned to have highly trained Sortie Lab field engineering personnel (technical representatives) present for necessary consultation and advice when refurbishment is accomplished.

8.3 Supply Support

Supply Support includes the timely provisioning, distribution, and inventory replenishment of spares, repair parts, and special supplies such as Sortie Lab element subsystem consumables. The cost of supply support is directly related to the number of locations where a supply support inventory of material is maintained. In the concepts under consideration, an emergency supply of spares, as well as subsystem consumables, will be required at the launch site. Minimizing this investment in emergency spares can be achieved by utilizing a high-speed transportation system and a rapidly responsive inventory control system. Accomplishing Sortie Lab maintenance at the Integration Site has the advantage of fewer locations for stocking spares and repair parts, and permits keeping stock levels at an absolute minimum.

An important consideration in supply support entails the cost of obsolescence of spare parts resulting from incorporation of changes. Combining activities at the Integration Site reduces the total number of spares required, and therefore the least number of possible obsolete parts.

8.4 Ground Support Equipment

The GSE and facility requirements for the Sortie Lab program have been identified and are documented in the Spacelab Ground Operations document. Further definition is required as the airborne hardware specifications are developed. GSE end item listings and usage allocations will be prepared and published as a Spacelab GSE Allocation Document. Each end item of GSE will be designed and specified by an end item Design Criteria Sheet, which will specify the overall physical and performance characteristics of the GSE. All GSE interface requirements are yet to be defined, but will be defined and documented in a GSE Interface Requirements Document.

Currently, over 118 major functional items of mechanical and electrical support equipment have been identified to support the option B processing flow. This number excludes any Western Test Range requirements, which would necessitate an additional 116 like items. These numbers are expected to increase significantly when definition to a more finite level of detail is completed, based on a refined definition of the ground operations processing flow.

Facility area requirements for the Central Integration and Launch Facilities have been defined and require approximately 55,000 and 10,000 square feet, respectively. These areas include office space, storage areas, experiment checkout, module integration, inspection, refurbishment, cleaning, etc.

The MGSE required for the Sortie Lab program has been functionally identified to the point of end-item identification/description in the conceptual studies performed to date. Thirty-eight distinct end-items of MGSE have been identified and specified in the MGSE Configuration and Utilization Concepts Document and Design Criteria Sheets. Preliminary design and fabrication cost estimates for the first unit of each MGSE end-item have been prepared. Estimates of those items of existing MGSE from previous programs which could be utilized in the Sortie Lab program have also been prepared.

8.5 Support Documentation

Support documentation includes all technical data required to logistically support the operational Sortie Lab program. A major portion of the task entails the development and distribution of formal documentation necessary to conduct operations, maintenance, overhaul and structural repair of Sortie Lab, GSE, Line Replaceable Units (LRU's), and components. Technical data provides the link between personnal and equipment. It includes drawings; operating, maintenance and modification instructions; provisioning and facilities information; specifications; inspection, test and calibration procedures; instruction cards and equipment placards; special purpose computer programs and other forms of audio/visual presentation required to guide people performing operations and support tasks.

Technical data planning must be based upon information obtained from equipment operations and maintenance planners (e.g., system/equipment use, design characteristics, operations and maintenance methods and personnel tasks, frequency and time to repair, supply provisioning and inventory items and procedures).

The combining of manufacturing, experiment integration, and maintenance functions at one location reduces support documentation to a minimum. Formal documentation could be limited to that data required at the launch site for the operations concerned with the installation of the Sortie Lab payload carrier. Data to support a combined maintenance and integration activity at the Integration site can be limited to the data necessary for management of the maintenance program plus an expansion of the manufacturing and engineering paperwork to include troubleshooting and checkout procedures.

8.6 Personnel and Training

Skilled personnel are required for manufacturing, experiment integration, maintenance, and support of launch operations. A training program utilizing on-the-job training, classroom instruction, and training equipment is required to achieve the necessary proficiency. The cost of the training program is affected by the number of personnel to be trained and the extent of the training equipment required. The number of personnel to be trained can be kept to a minimum by transferring the knowledge gained during manufacturing to the experiment integration and maintenance operations. The manufacturing and development test programs permit a high degree of on-the-job training on real hardware, thereby reducing the requirements for training equipment.

8.6.1 Mission Support Team

The baseline concept incorporates an engineering support team composed of Sortie Lab experienced personnel. The team will be composed of subsystem specialists and will be centrally located in the U.S. Team members will be deployed as integration, launch, mission and post-mission requirements dictate. The team will provide engineering, procedure, and logistics support.

8.7 Support Management

The support management task entails the organizing, controlling, scheduling, accomplishing, and reporting the status of the logistics elements in a cost effective manner and in harmony with all other interfacing programs and systems. An inventory control system is required to provide the configurationand maintenance status and the location of all payloads, Sortie Lab elements, spares, spare parts, and expendables for purposes of program management. The system must be supported by a disciplined and accurate configuration control and documentation system. The requirements for data recording and transmission are such that electronic data processing will be required to provide timely data for program management.

The cost of the inventory control system is related in part to the number of locations where material is located. Minimizing the number of separate spares locations as well as the number of locations for Sortie Lab elements and payloads will result in minimum cost inventory control system.

Consolidating the Sortie Lab program functions of experiment integration, and maintenance at one location permits development of efficient management techniques. The shorter communication lines permit rapid reaction and response to program contingencies. Scheduling problems can be resolved rapidly and least cost approaches can be used in program problem solutions.