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SD 71-217-7

MODULAR space station
PHASE B EXTENSION

PRELIMINARY SYSTEM DESIGN
Volume VII: Ancillary Studies

Space Division
North American Rockwell

12214 Lakewood Boulevard, Downey, California 90241

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TECHNICAL REPORT INDEX/ABSTRACT

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DESCRIPTIVE TERMS
*MODULAR SPACE STATION PHASE B, *SORTIE MISSION ANALYSIS, *REDUCED PAYLOAD DIA IMPACT ON MODULAR SPACE STATION, MODULAR SPACE STATION ANCILLARY STUDIES, SPACE SHUTTLE SORTIE MISSION CONCEPTS, SORTIE LAB

ABSTRACT

THIS VOLUME OF THE MODULAR SPACE STATION PRELIMINARY SYSTEM DESIGN REPORT PRESENTS THE RESULTS TO TWO SEPARATE STUDIES. THE FIRST STUDY, SORTIE MISSION ANALYSIS, DISCUSSES A MODULAR SPACE STATION ORIENTED EXPERIMENT PROGRAM TO BE FLOWN BY THE SPACE SHUTTLE DURING THE PERIOD PRIOR TO SPACE STATION IOC. EXPERIMENTS GROUPED INTO EXPERIMENT PACKAGES ARE PRESENTED. MISSION PAYLOADS ARE DERIVED BY GROUPING EXPERIMENT PACKAGES AND BY ADDING SUPPORT SUBSYSTEMS AND STRUCTURE. THE OPERATIONAL AND SUBSYSTEMS ANALYSES OF THESE PAYLOADS ARE DISCUSSED. DESIGN INTEGRATION OF REQUIREMENTS, CONCEPTS AND SHUTTLE INTERFACES IS DISCUSSED. SORTIE MODULE-STATION MODULE COMMONALITY IS PRESENTED. A SORTIE LABORATORY CONCEPT IS DESCRIBED.

THE SECOND STUDY, REDUCED PAYLOADS SIZE IMPACT, DISCUSSES THE EFFECT ON THE MODULAR SPACE STATION CONCEPT OF REDUCED DIAMETER AND REDUCED LENGTH OF THE SHUTTLE CARGO BAY. DESIGN CONCEPTS ARE PRESENTED FOR REDUCED SIZES OF 12 BY 60 FOOT, 14 BY 40 FOOT, AND 12 BY 40 FOOT. COMPARISONS OF THESE CONCEPTS WITH THE PHASE B MODULAR STATION (14 BY 60 FOOT) ARE MADE TO SHOW THE IMPACT OF PAYLOAD SIZE CHANGES.

FOREWORD

This document is one of a series required by Contract NAS9-9953, Exhibit C, Statement of Work for Phase B Extension-Modular Space Station Program Definition. It has been prepared by the Space Division, North American Rockwell Corporation, and is submitted to the National Aeronautics and Space Administration's Manned Spacecraft Center, Houston, Texas, in accordance with the requirements of Data Requirements List (DRL) MSC-T-575, Line Item 68.

Total documentation products of the extension period are listed in the following chart in categories that indicate their purpose and relationship to the program.

ADMINISTRATIVE REPORTS	TECHNICAL REPORTS		STUDY PROGRAMMATIC REPORTS	DOCUMENTATION FOR PHASES C AND D	
				SPECIFICATIONS	PLANNING DATA
EXTENSION PERIOD STUDY PLAN DRL-62 DRD MA-207T SD 71-201	MSS PRELIMINARY SYSTEM DESIGN DRL-68 DRD SE-371T SD 71-217	MSS DRAWINGS DRL-67 DRD SE-370T SD 71-216	EXTENSION PERIOD EXECUTIVE SUMMARY DRL-65 DRD MA-012 SD 71-214	MSS PRELIMINARY PERFORMANCE SPECIFICATIONS DRL-66 DRD SE-369T SD 71-215	MSS PROGRAM MASTER PLAN DRL-76 DRD MA-209T SD 71-225
QUARTERLY PROGRESS REPORTS DRL-64 DRD MA-208T SD 71-213, -235, -576	MSS MASS PROPERTIES DRL-69 DRD SE-372T SD 71-218, -219	MSS MOCKUP REVIEW AND EVALUATION DRL-70 DRD SE-373T SD 71-220			MSS PROGRAM COST AND SCHEDULE ESTIMATES DRL-77 DRD MA-013(REV. A) SD 71-226
FINANCIAL MANAGEMENT REPORTS DRL-63 DRD MF-004	MSS INTEGRATED GROUND OPERATIONS DRL-73 DRD SE-376T SD 71-222	MSS KSC LAUNCH SITE SUPPORT DEFINITION DRL-61 DRD AL-005T SD 71-211			MSS PROGRAM OPERATIONS PLAN DRL-74 DRD SE-377T SD 71-223
	MSS SHUTTLE INTERFACE REQUIREMENTS DRL-71 DRD SE-374T SD 71-221	INFORMATION MANAGEMENT ADVANCED DEVELOPMENT DRL-72 DRD SE-375T SD 72-11			
	MSS SAFETY ANALYSIS DRL-75 DRD SA-032T SD 71-224	MSS COMMON MODULE DESIGN AND MANUFACTURING DRL-78 DRD TM-2K3T SD 72-12			

This document is Volume VII of the Modular Space Station Preliminary System Design Report, which has been prepared in the following seven volumes:

I	Summary	SD 71-217-1
II	Operations and Crew Analysis	SD 71-217-2
III	Experiment Analyses	SD 71-217-3
IV	Subsystem Analyses	SD 71-217-4
V	Configuration Analyses	SD 71-217-5
VI	Trades and Analyses	SD 71-217-6
VII	Ancillary Studies	SD 71-217-7

The Modular Space Station Phase B study primary emphasis was on conceptual definition and preliminary design. In May of 1971 the NR/MSC study team initiated investigation of the sortie-mission mode of flight operation that could occur between the IOC of the space shuttle and IOC of the space station. In mid-July, a study was initiated to investigate the impact on the modular space station concept of a reduction in payload size. The results of both of the ancillary studies are documented in this report.

A briefing brochure (SD 71-238, 17 September 1971) was prepared which summarized the results of the reduced payload size impact study.

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PART I. SORTIE MISSION ANALYSIS

1. INTRODUCTION AND SUMMARY

An analysis of sortie missions has been conducted which defines a modular space station (MSS) oriented experiment program to be flown by the shuttle during the period between the shuttle's first mated orbital flight (April 1978) and the modular space station's IOC (January 1982). During this period, some 45 shuttle flights are scheduled[1]. For the purpose of this analysis, it was assumed that all of these flights would be available for the sortie experiment program.

Many factors were considered in this analysis: the amount of shuttle dependency involved, potential sortie mission module-space station module commonality, shuttle-station-sortie module subsystem commonality, funding requirements, and experiment returns.

The major issues centered around the types of experiments which are best suited for both 7- and 30-day sortie operations, their assembly into packages and payloads, crew skills and number of crew required, the orbit parameters, and the shuttle's capability to fly the desired missions.

OBJECTIVE

The objective of this study was, first, to define an experiment program which would represent a practical program flow from the first sortie flight to the initial station IOC. Secondly, the analysis was to establish if commonality existed between sortie mission modules and subsystems and station modules and subsystems and the value of this commonality toward development of the station.

STUDY GROUND RULES

The ground rules adopted for the sortie analysis were:

1. The NR space shuttle defined by the Phase B study was used.
2. The shuttle orbiter air-breathing engines (ABES) were included in all missions.

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[1]Shuttle Traffic Model, North American Rockwell, Space Division, SD 70-600-23.

3. The sortie missions were flown at inclinations of 28-1/2 degrees, 55 degrees, and 90 degrees with the altitude dictated by the experiments.

4. The orbiter design landing weight (268,000 pounds) was adhered to for all missions. The maximum landing weight (292,000 pounds) was considered for aborts only.

5. The 1971 Experiment Blue Book was used to define sortie experiments.

It must be noted that the choice to retain the ABES for all missions was made on the basis of conservatism and results in a payload penalty of approximately 18,000 pounds.

DEFINITION AND TERMS

The terms "experiment," "experiment package," "experiment payload," and "mission" have specific meanings as they are used in the succeeding pages. They are defined as follows:

Experiment - Scientific or technical investigation utilizing one or more pieces of experiment equipment.

Experiment Package - A group of experiment equipment characterized by being mutually supportive of a compatible set of experiments.

Experiment Payload - A group of experiment packages characterized by being mutually compatible, as well as compatible with a discrete set of mission constraints.

Mission - One flight of an experiment payload.

Figure 1-1 graphically illustrates these terms and also defines the resulting "shuttle payload."

STUDY APPROACH

The approach taken for the sortie analysis is illustrated in the flow of the various tasks (Figure 1-2). These tasks are briefly described as follows:

1. A list of experimental packages suitable for the sortie modes was prepared together with their desired characteristics (i.e., size weight, power requirements, crew involvement, data requirements, pointing, operating time, orbit, etc.). The 1971 Experiment Blue Book was the foundation for these packages.

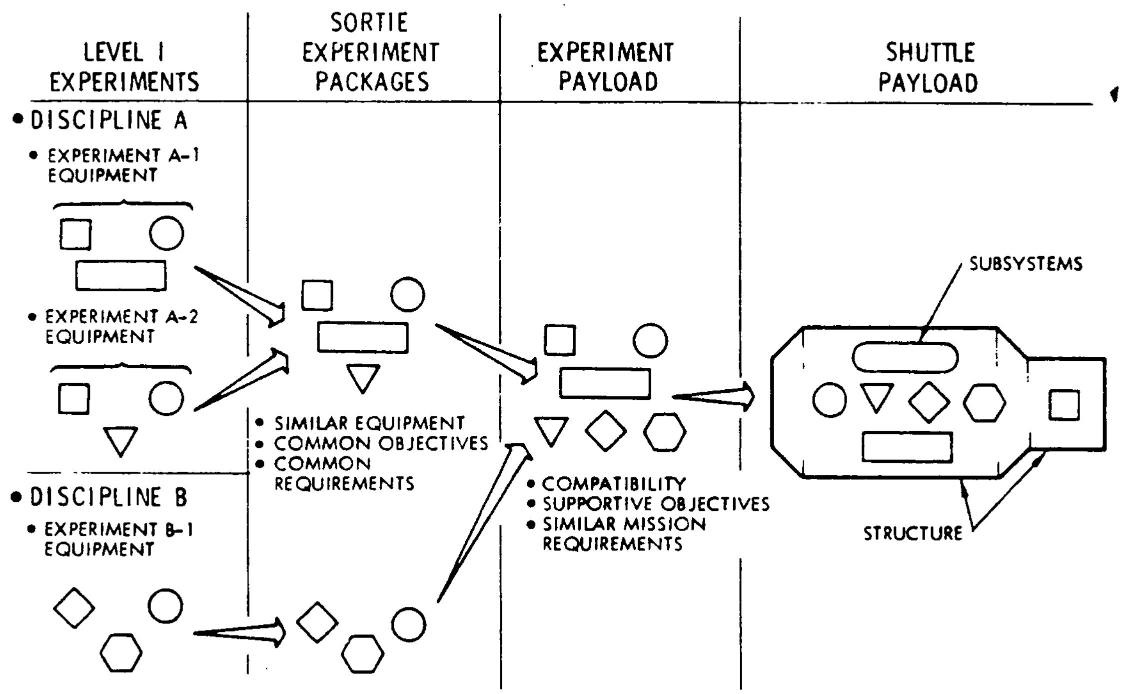


Figure 1-1. Definition of Terms

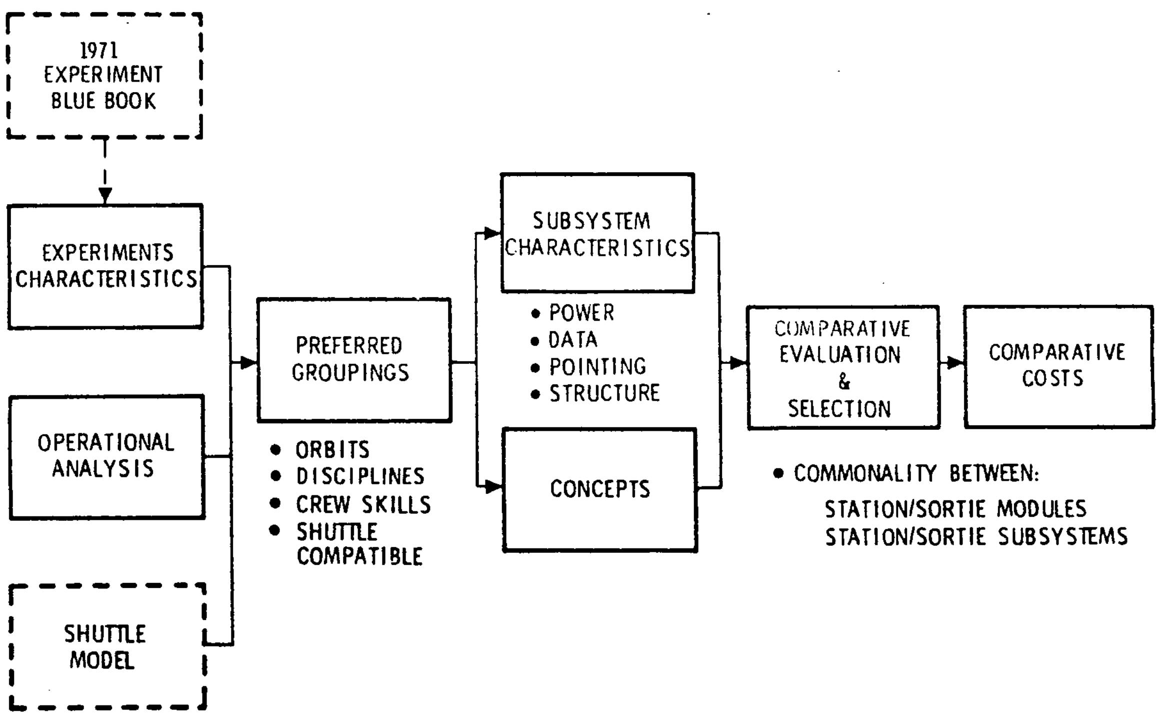


Figure 1-2. Study Flow

2. Operational analyses were conducted of these experiment packages to establish crew size and habitability requirements, duties, work-rest cycles, experiment package groupsings into payloads, phasing, etc.

3. Subsystem support requirements and characteristics (size, weight, power, etc.) were defined based on Steps 1 and 2. Station subsystems were analyzed for possible use.

4. Preliminary sketches of experiment accommodation methods were made and weight estimates prepared to determine each payload's suitability of shuttle launch. For payloads which were not compatible with the shuttle's capability, an iteration was performed to repackage them into more shuttle-compatible units.

5. Conceptual sketches were prepared for the final selected payloads and compared to the space station for commonality in both modules and subsystems.

6. A commonality analysis was then conducted for both modules and subsystems and budgetary and planning cost estimates were made.

SORTIE MISSION DEFINITION

The sortie analysis included three modes of operation. Mode I is a 7-day mission in which the experiments are remotely controlled from the flight compartment of the shuttle orbiter. Mode II also is a 7-day mission; however, in this case, manned access to the experiment payload has been added. Mode III is a 30-day mission in which the payload also is accessible to the crew. In all three modes the payload depends on the shuttle for its primary support. This support is accomplished in two ways: by the basic shuttle subsystems or by augmenting the capabilities of these subsystems as required. This augmentation is discussed later in this document. For the 30-day mission the shuttle's systems (EPS and ECLSS) also must be augmented, as their baseline capability is only 7 days. Figure 1-3 illustrates these modes of operations.

Two ways were selected to accommodate the sortie payloads for the three mission modes previously described.

For the remotely controlled experiments, the payload was pallet-mounted in the payload bay of the shuttle with all the necessary controls and displays located in the flight compartment of the orbiter. For experiments requiring crew access, the payload was located in the payload bay

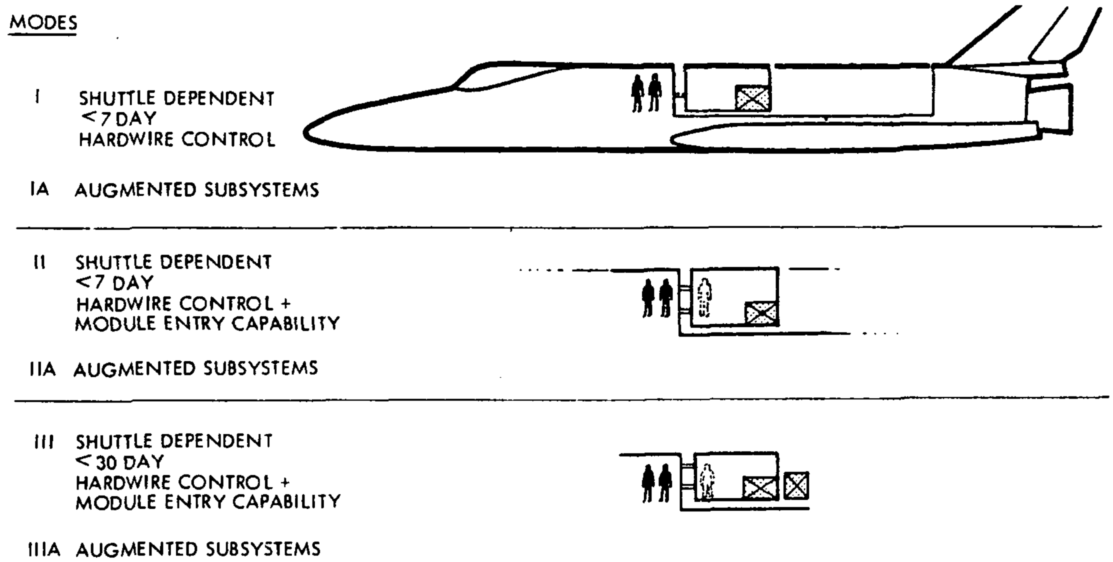


Figure 1-3. Sortie Modes

with access through the interface tunnel from the flight compartment. An alternative means of accomplishing crew access was to move the payload from the payload bay to the shuttle's berthing port by the manipulator. In this position, access is readily available through the shuttle's airlock. Figure 1-4 illustrates these accommodations.

At the conclusion of the analysis, a special study was conducted to define the concept for a multipurpose "sortie lab" (see Section 8). This study utilized the experiment data generated during the main body of the sortie analysis as well as the accommodated mode and support subsystems defined for the sortie payloads using similar experiments.

SUMMARY

The results of the sortie analysis are summarized in terms of the experiments identified and the experiment packages selected for the 7- and 30-day missions, the resulting sortie payloads, their methods of accommodation in the shuttle orbiter, the commonality of their accommodations (i.e., modules and support subsystems) with the corresponding MSS elements, and the results of the cost analysis which illustrates the benefit of this commonality toward the development of the MSS.

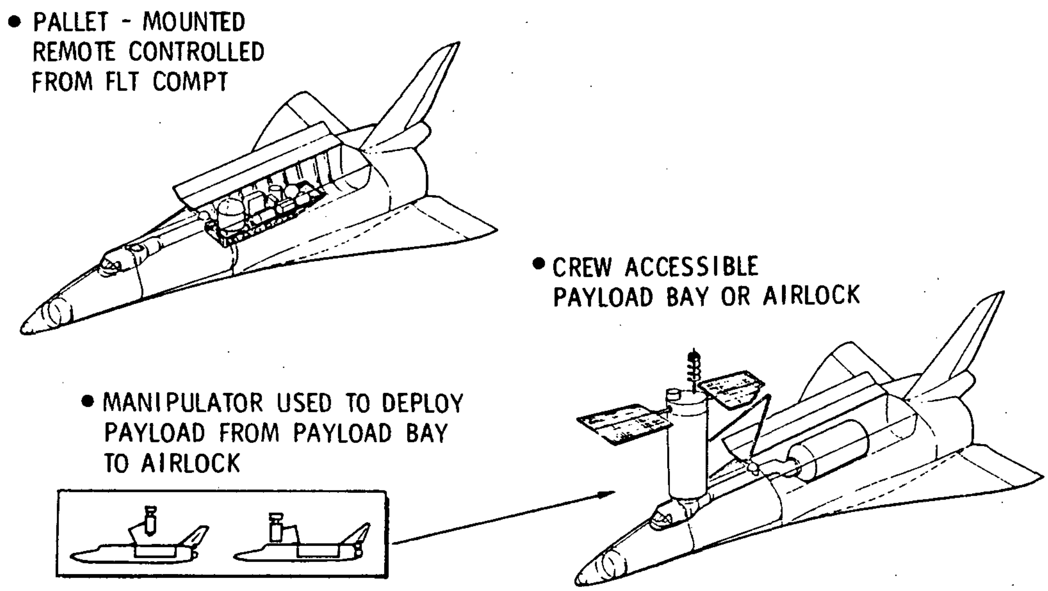


Figure 1-4. Shuttle Payload Accommodations

Sortie Experiments

The experiments selected for the sortie missions are identified in Figure 1-5 for both the 7- and 30-day missions. As may be noted, these total 67, of which 34 are flown on 7-day missions and 33 on 30-day missions.

Their selection was based on an analysis of the 1971 Blue Book for experiments that met Level I criteria (i. e., a precursor to the station, providing early return during the shuttle-station gap period and having operating time commensurate with the 7- and 30-day mission times).

Sortie Experiment Packages

The sortie packages that were assembled from the sortie experiments previously described are listed in Table 1-1. These packages number 14 for the 7-day mission and 17 for the 30-day mission. Thus from the 67 experiments previously defined, 31 experiment packages were established.

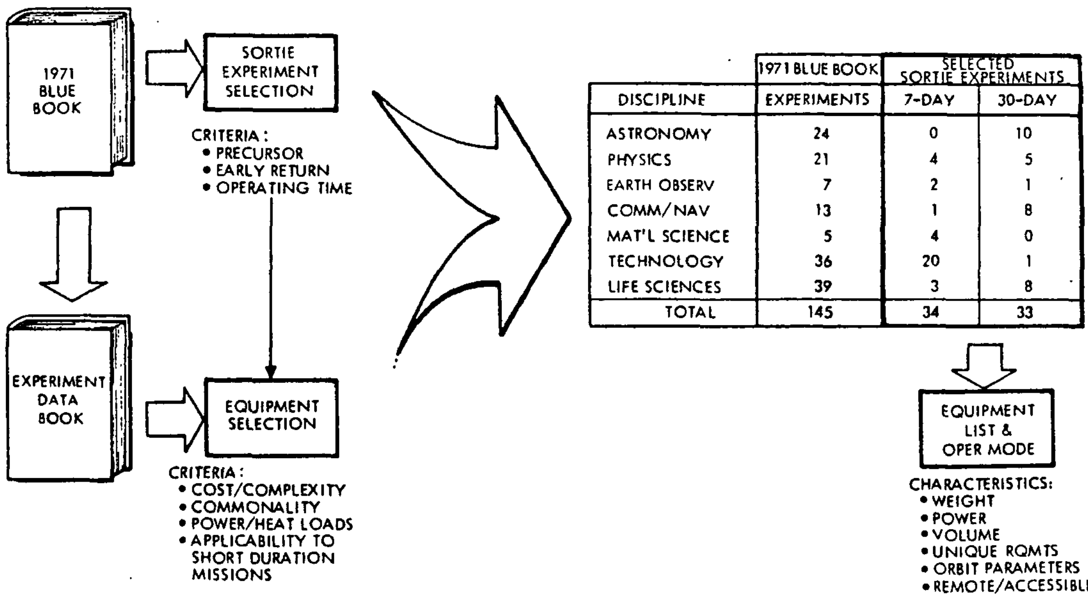


Figure 1-5. Sortie Experiments Selection

Table 1-1. Sortie Experiment Packages

Discipline	No. Experiment Packages 7 Days	30 Days
Astronomy		5
Physics	3	3
Earth Observation	2	1
Communications/Navigation	1	2
Material Science	1	
Technology	5	2
Life Sciences	2	4
Total	14	17

The rationale that went into the assembly of these packages follows the definition of an experiment package previously discussed (i.e., the experiments were mutually compatible and could be supported by similar equipment).

Also, consideration was given to the experiments' support requirements, any unique requirements, their orbit requirements, and operating time required for the experiments.

Sortie Payloads

After assembly of the experiment packages, the experiment payloads were developed by grouping experiment packages that were compatible relative to a set of discrete mission constraints, crew skill requirements, and shuttle volume and weight considerations. Tables 1-2 and 1-3 list the groupings by 7- and 30-day payloads. Payload numbers are coded as follows: The first number or numbers (7, 30) indicate the mission duration, the "M" indicates a manned mission, and the last number or numbers (-1, -2) indicate the payload number within the series.

Table 1-2 7-Day Sortie Mission Payloads

Payload No.	Experiment Package	Inclination (deg.)	Altitude (n. mi.)	Crew Size
7M-1	Earth observation Contamination technology	55	100-300	3
7M-2	Contamination technology Space physics	90	80 x 100/500	2
7M-3	Earth observation Advanced spacecraft systems tests Contamination technology	55	100	2
7M-4	Materials science	28-1/2	200	2
7M-5	Plant growth Cells and tissues evaluation	28-1/2	100	3
7M-6	Plasma physics	55	270	2

Table 1-3. 30-Day Sortie Mission Payloads

Payload No.	Experiment Package	Inclination (deg.)	Altitude (n. mi.)	Crew Size
30M-1	Earth observation Contamination technology	55	100	2
30M-2	Space physics Physics and chemistry	28-1/2	200	2
30M-3	Fluid management	28-1/2	200	2
30M-4	Medical research Bioscience Life support Man systems	28-1/2	100	3
30M-5	X-ray stellar astronomy	28-1/2	400	2
30M-6	Advanced solar astronomy	Sun Synch	220	2
30M-7	Intermediate UV telescope	28-1/2	250	2
30M-8	High-energy stellar astronomy	28-1/2	400	2
30M-9	Infrared astronomy	55	270	2
30M-10	Cosmic ray physics	28-1/2	200	2
30M-11	Communications	55	150	2

Payload Accommodation

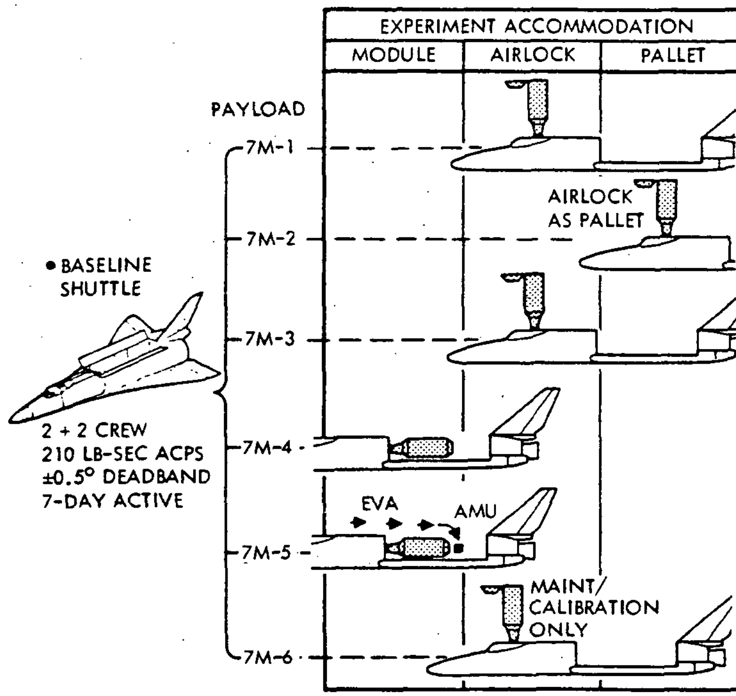
An analysis of the experiment accommodation requirements for the 17 sortie payloads revealed those which required airlocks and/or an unpressurized pallet or a pressurized module with manned entry capability.

For the 7-day missions, four payloads require airlocks or pallets while the remaining two need a pressurized module. For those requiring an airlock, consideration was given to using the MSS airlock or the shuttle orbiter's airlock. The MSS airlock was selected based on the considerations of complexity and interfaces with the orbiter.

For the 30-day missions, all 11 payloads require a pressurized module for extra living accommodations over that provided by the orbiter. In eight cases, a pressurized module also is needed for the experiments while the remaining three utilize a pallet, an airlock, or a combination pallet-airlock.

Figure 1-6 illustrates the integration of the individual seven-day mission payload characteristics with those of the baseline shuttle. It is divided into two sections: experiment accommodations and subsystem characteristics.

Payloads 7M-1 through 7M-3 and 7M-6 utilize an MSS-type airlock while Payload 7M-2 also utilizes the airlock as a deployable pallet for sensor



Payload	CREW	DATA (KBPS)	POWER (KW)	STAB.
7M-1	2 + 2	2000	1.5	210 LB-SEC ACPS + PLATFORM
7M-2	2 + 2	200	2.8	210 LB-SEC ACPS + PLATFORM
7M-3	2 + 2	2000	3.3	210 LB-SEC ACPS + PLATFORM
7M-4	2 + 2	10	4.3	210 LB-SEC ACPS
7M-5	2 + 3	5	0.72	210 LB-SEC ACPS
7M-6	2 + 2	100	1.2	40 LB-SEC ACPS

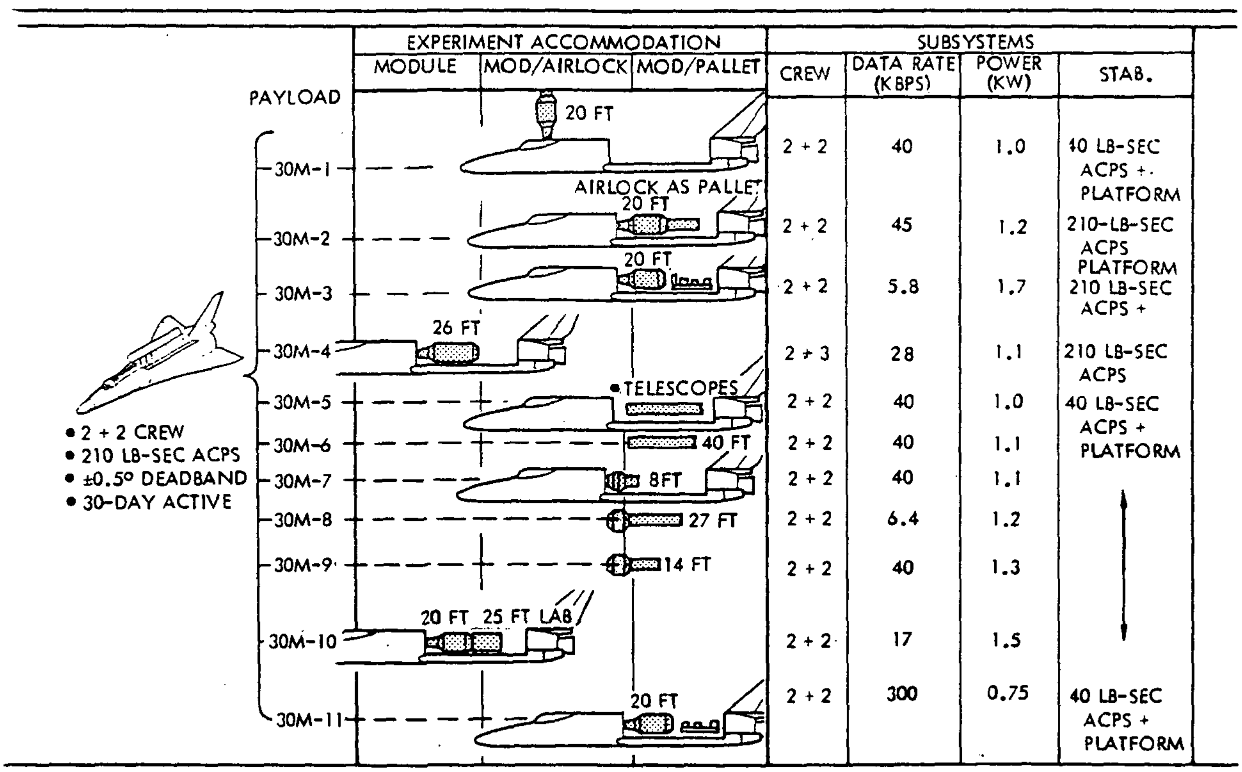
Figure 1-6. 7-Day Mission Payload Characteristics

directing. Payloads 7M-4 and 7M-5 require the addition of habitable modules and Payload 7M-5 also requires EVA capability via the shuttle airlock.

Under subsystems, the additional crew required is indicated in Column 1. Column 2 lists the data rate characteristic which is supplied entirely by the experiment payload. Column 3 lists the power required per payload. These power requirements utilize the shuttle fuel cell power generation capability but the experiment payload provides the cryogenic reactants. These reactants are stored in tanks located in the shuttle bay as part of each experiment payload. Column 4 summarizes the experiment stability characteristics. Payloads 7M-1, 2, and 3 require the addition of stabilized platforms. Payloads 7M-4 and 7M-5 fall within the shuttle baseline capability. Payload 7M-6 requires a refinement of the shuttle characteristics to 40 lb-sec attitude control propulsion system (ACPS). This would be accomplished by the modification of the shuttle reaction control system.

In a like manner, the payload accommodations and support characteristics for the 30-day missions are illustrated in Figure 1-7.

The length of the habitable modules that are required for each payload also is indicated. Payloads 30M-1, 2, 3, 8, 9, and 10 utilize a 20-foot module. Payload 30M-4 requires a 26-foot module, and Payloads 30M-5, 6,



PAYLOAD	EXPERIMENT ACCOMMODATION (MODULE / MOD/AIRLOCK / MOD/PALLET)	SUBSYSTEMS: CREW	DATA RATE (KBPS)	POWER (KW)	STAB.
30M-1	20 FT	2 + 2	40	1.0	40 LB-SEC ACPS + PLATFORM
30M-2	AIRLOCK AS PALLET 20 FT	2 + 2	45	1.2	210-LB-SEC ACPS PLATFORM
30M-3	20 FT	2 + 2	5.8	1.7	210 LB-SEC ACPS +
30M-4	26 FT	2 + 3	28	1.1	210 LB-SEC ACPS
30M-5	TELESCOPES	2 + 2	40	1.0	40 LB-SEC ACPS + PLATFORM
30M-6	40 FT	2 + 2	40	1.1	
30M-7	8FT	2 + 2	40	1.1	
30M-8	27 FT	2 + 2	6.4	1.2	
30M-9	14 FT	2 + 2	40	1.3	
30M-10	20 FT 25 FT LAB	2 + 2	17	1.5	
30M-11	20 FT	2 + 2	300	0.75	40 LB-SEC ACPS + PLATFORM

Figure 1-7. 30-Day Mission Payload Accommodations

and 7 utilize a 10-foot module. The shuttle subsystem characteristics are acceptable to accommodate the experiments except for the stability requirements. Experiment Payloads 30M-1, 30M-2, and 30M-5 through 30M-11 require a stable platform and Payloads 30M-1 and 30M-5 through 30M-11 also require a lower thrust level of the ACPS engines.

Commonality and Cost Analysis

Analyses were conducted to determine the level of commonality between sortie and station modules and subsystem equipment, and the resulting dollar benefit to the MSS development.

To achieve commonality for module configuration, the MSS universal structure concept was selected as illustrated in Figure 1-8. As a result of the sortie payload analysis, three module configuration lengths would be required. Two module lengths could satisfy these requirements by mating the 10- and 20-foot modules for the third module length. The 20-foot module is a derivative of the MSS cargo module. The MSS airlock will be used where an airlock is required.

The results of the subsystem commonality analysis are illustrated by the bar graphs in Figure 1-9. As an example, the video recorder from the information subsystem has five sortie payloads that have 80-percent commonality to the MSS, and four have 30-percent commonality to the MSS. Of these sortie payloads, nine have 30-percent and five have 80-percent video recorder commonality among themselves. The delta percentage differences exist because of additional equipment of physical characteristics differences.

The sortie payload cost analysis was accomplished in three steps: (1) determination of the development cost, assuming that each individual payload was developed separately; (2) recognizing the commonality among payloads, determination of the development cost when the costs of payload-common items were shared among payloads; and (3) based on commonality percentage to the MSS, the dollar benefit to the MSS development was determined.

The results show that approximately 60-percent saving is accomplished by sharing cost among payloads as illustrated in Table 1-4. Approximately a 4-percent cost saving can be contributed to the initial MSS development cost. Intangible savings to the MSS, not expressed in dollar value, are identified as component reliability data, experiment procedures, operational experience, and maintenance procedures.

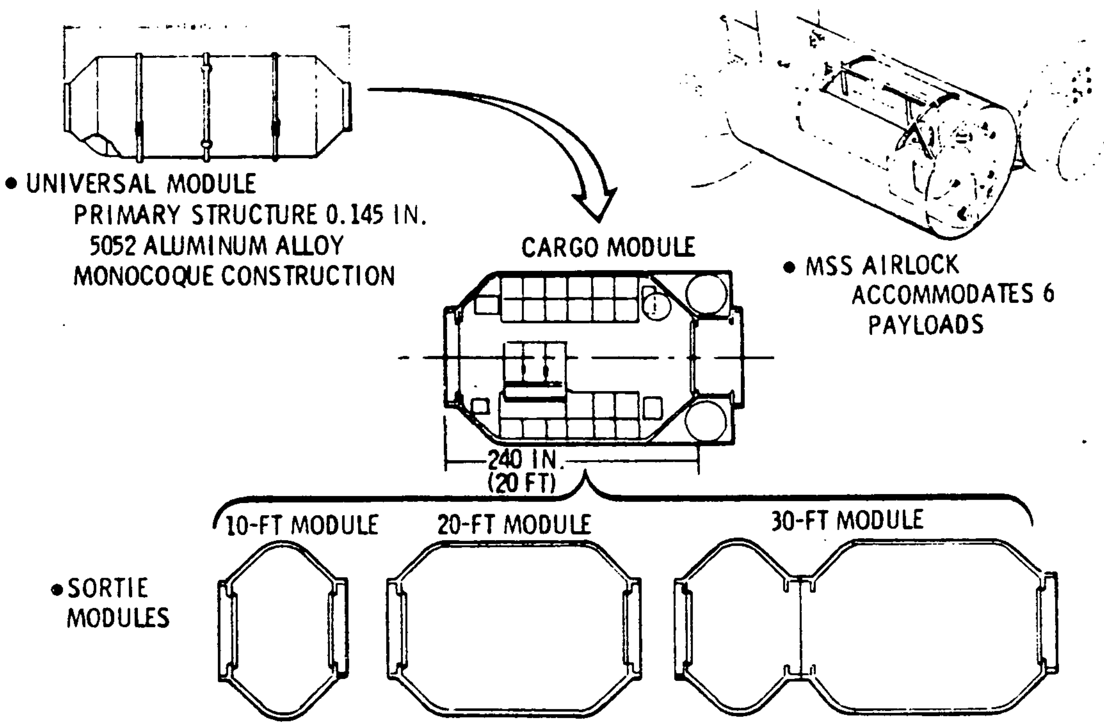


Figure 1-8. Structure Concept Selection

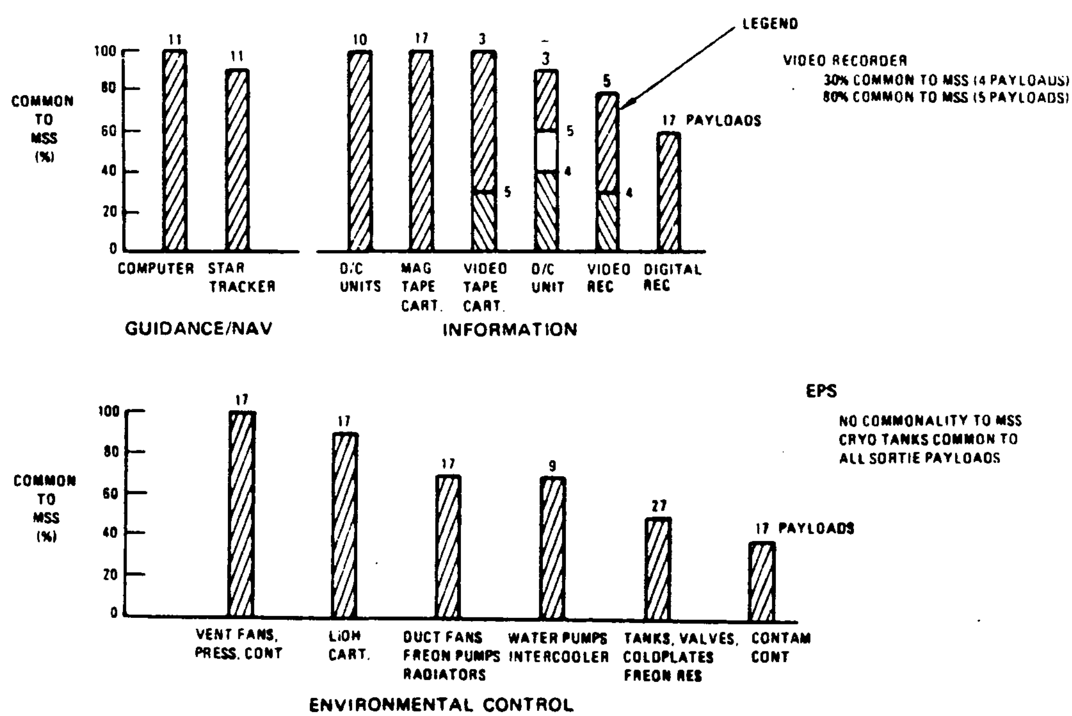


Figure 1-9. Subsystem Commonality

Table 1-4. Cost Analysis Results*

Item	Independent Development ($ million)	Shared Development ($ million)	Savings to MSS ($ millions)
Structure	770	140	28
ECLSS	370	120	27
EPS	120	25	--
G&C	305	235	5
Information	120	30	10
Crew Habitability	115	20	7
Total	1,800	570	77

*Development costs only for 17 sortie payloads; 1972 dollars

Sortie Laboratory

An alternative approach to the accommodation of sortie payloads would be to provide a family of general-purpose laboratories. With this concept, each GPL would support a group of related disciplines and would contain, as an integral part of the module, common laboratory and experimental equipment. The intent would be to minimize the amount of equipment required from the investigator. The GPL's would be designed so as to exploit the reusability made possible by the shuttle. That is, they would be adaptable to a wide range of missions and users with a minimum of reconfiguration. In addition, use will be made of existing ground and aircraft-based laboratory equipment (microscopes, cameras, spectrometers, multimeters, etc.) where practical, to minimize costs.

Table 1-5 shows two approaches that were considered for grouping disciplines into GPL's. The first is a "phenomenon-oriented" family which groups disciplines into GPL's according to the particular aspect of the space environment associated with their objective. The second is a "purpose-oriented" family which groups disciplines into GPL's according to the general nature of their objectives. Based on NR's studies to date, the purpose-oriented approach appears the most desirable.

Table 1-5. GPL Approaches

	APPROACH NO. 1			APPROACH NO. 2		
LAB TYPE	PHENOMENON-ORIENTED			PURPOSE-ORIENTED		
DISCIPLINE	EARTH REMOTE SENSING	SPACE REMOTE SENSING	ZERO-GRAVITY, VACUUM	APPLICATION	TECHNOLOGY	SCIENCE
ASTRONOMY		X				X
PHYSICS		X				X
EARTH OBSERVATIONS	X			X		
COMM/NAV	X				X	
MATERIAL SCIENCES			X	X		
TECHNOLOGY	X	X	X		X	
LIFE SCIENCES			X	X		

For the purposes of this study, an applications laboratory[1] was selected for conceptual definition. Figure 1-10 depicts the application lab concept and points out the location of the various pieces of lab equipment associated with earth observations, material sciences, and life sciences. The lab is 20 feet long excluding the 12-1/2-foot airlock. The upper floor is dedicated to the earth observation and life science labs and the lower floor is dedicated to material science. The lab is fixed in the shuttle payload bay with the necessary sensor exposure obtained through the open payload bay doors. For the earth observation telescope, outward looking is obtained by employing a right-angle aperture. The other design features are indicated.

Figure 1-11 summarizes the major features and capabilities offered by the applications-type sortie lab. The weight of the lab is 20,000 pounds and and the curve indicates the weight available for the mission-unique equipment as a function of the shuttle's capability to various orbit altitudes and inclinations. Capabilities with and without the air-breathing engines are shown. Also summarized is the power available for experiments at the various inclinations as limited by the heat rejection capability of the radiator.

[1] An applications laboratory is defined as being oriented to a high benefits program consisting of earth observation, life science, and material science experiments.

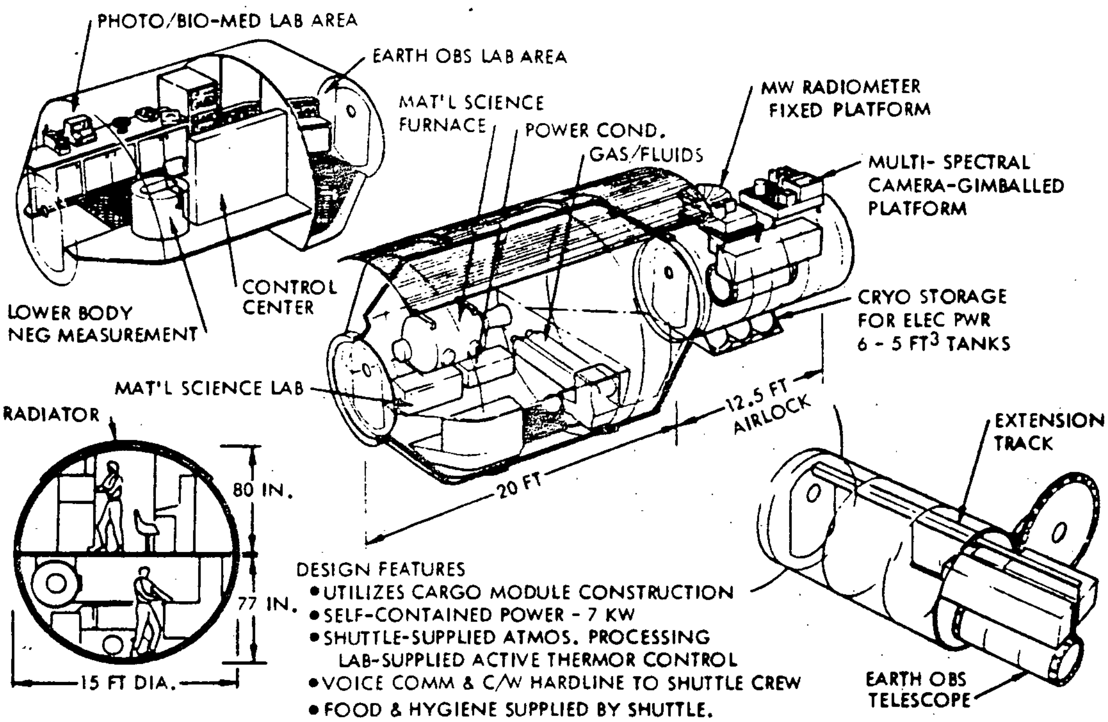
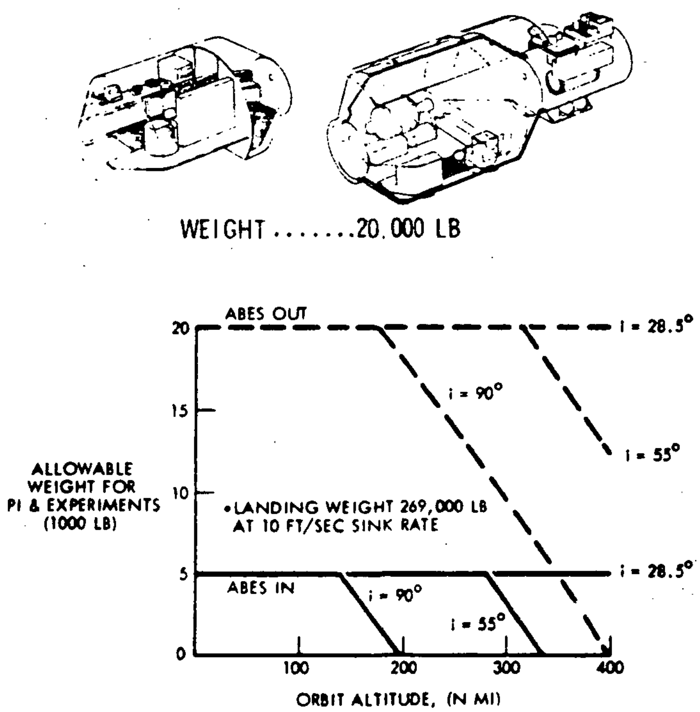


Figure 1-10. Applications-Type Lab



LAB DISCIPLINES:
- EARTH OBS, MATERIAL SCIENCE, LIFE SCIENCE

EXPERIMENT EQUIPMENT:
- RESISTANCE FURNACE
- EARTH OBS TELESCOPE
- MICROWAVE SCANNER
- LOWER BODY NEGATIVE MEASUREMENT
- CONTROL CENTER, RECORDERS, MICROSCOPES
- FILM PROCESSOR & CENTIFUGE

CREW ACCOMMODATIONS - 2

ACTIVE THERMAL CONTROL -250 FT^2 RAD

ELECTRIC POWER - 7.0 KW FUEL CELL WITH CRYOGENIC STORAGE TANKS

POWER/THERMAL LIMIT
- 28.5 DEC INCL 2.5 KW
- 55 DEG INCL 3.0 KW
- 90 DEG INCL 7.0 KW

Figure 1-11. Sortie Lab Capabilities

2. SPACE SHUTTLE DEFINITION

The description of the space shuttle used in conducting the sortie analysis has been obtained from NR's Phase B Space Shuttle Definition Study completed in June 1971.

The major element in the Space Shuttle program which is important to the sortie analysis is the shuttle orbiter. However, only those features of the orbiter which are important from the sortie mission standpoint are described.

The following portions of this section briefly summarize the Space Shuttle Program, the operational concept, and a description of the shuttle orbiter. The environment induced on the payloads while being transported to and from orbit in the payload bay is presented in Appendix B.

SPACE SHUTTLE PROGRAM

The Space Shuttle Program consists of the following major articles:

1. Five orbiter and four booster flight vehicles.
2. An orbiter and booster structural test article.
3. An orbiter and booster main propulsion cluster development test article.

Completion of prelaunch operations for all of the vehicles is as follows:

June 1976 (first horizontal flight)
April 1978 (first manned orbiter flight)
Mid-1979 (shuttle will be operational)

To support the manned orbital flight data noted, the major milestones in the program are as follows:

1. Start Phase C/D in 1 March 1972
2. Complete PDR in May 1973
3. Complete CRD and 95-percent engineering release 1 May 1975

OPERATIONAL CONCEPT

Preparations for space shuttle launch normally require approximately four days. The launch sequence begins with independent premate checkout of the separated booster and orbiter vehicles in the assembly building. Payloads, which themselves may consist of complex systems requiring fueling and monitoring, are installed in the orbiter cargo bay. The two vehicles are then erected to the vertical position, the booster is mounted on the launch umbilical tower, the orbiter is attached to the booster, and the mated vehicles are transported from the assembly building to the launch pad.

At the pad, launch-readiness checkout is performed and a five-hour launch countdown is commenced with loading of propellants. When loading is completed, the crews (and passengers) board the vehicles for terminal countdown and launch.

The booster's 12 main engines are fired, and within three minutes after liftoff the combined vehicles achieve a comparatively level course at an altitude of 200,000 feet. In rapid succession, the orbiter's two rocket engines are ignited, the booster engines are shut down, and the two vehicles separate. As the orbiter accelerates toward orbit, the booster returns to the launch site.

The orbiter continues to accelerate until an elliptical insertion orbit of 50 by 100 nautical miles is achieved. The two main engines are then shut down and the three smaller orbit maneuvering engines are ignited to place the vehicle in the desired circular orbit.

Final critical adjustment of the orbiter into its correct orbital position is accomplished with the attitude control propulsion system consisting of 29 smaller thrusters located at various points on the vehicle. Once the vehicle is stabilized, the cargo bay doors are opened and payload modules are readied for deployment.

Payload module handling is accomplished by means of a pair of articulated manipulator arms described later. Movement and positioning are precisely controlled by cargo specialists located in the cargo-handling station aboard the orbiter. Television monitors and floodlights strategically mounted on the arms assure visibility during these operations.

On completion of the orbital operations, the orbiter is maneuvered to a 100-nautical-mile orbit and rotated to a deorbit attitude. The orbit maneuvering engines are then fired to decelerate the vehicle and initiate descent. During entry, the vehicle attitude is controlled to achieve any lateral crossranging required to assure the closest glide approach to the landing site. At 35,000 feet, four air-breathing turbofan engines are deployed and started to provide maneuvering capability to the launch site. Landing is made with typical aircraft-type landing gear and a drag chute.

Both the orbiter and booster are capable of horizontal takeoff and flight, powered by their air-breathing engine systems only. This capability enables the vehicles to return to the launch site following landings at alternatives sites if required.

Ground turnaround procedures are essentially the same for booster and orbiter. Under normal conditions, the elapsed time between landing and launch-readiness is 14 calendar days. After landing, the vehicle is immediately taxied or towed to a safing area, where the crew (and passengers) deplane, mission flight data are removed, fluids and gas residuals are drained or vented, and the propellant tanks are purged with nitrogen. The safed vehicle is then towed into a maintenance hangar, service stands are installed, and the payload module is removed from the orbiter. This operational sequence is illustrated in Figure 2-1.

Ground Operations

The launch pads, launch rates, yearly traffic and prelaunch operations for the space shuttle orbiter are described in this subsection. It is planned that Launch Pads 39 B and C at KSC will be modified for shuttle use. These pads will then be designed as Shuttle Pads A and B. The average launch rates for Pads A and B, to satisfy the traffic model, are shown in Figure 2-2.

The shuttle traffic model is shown in Figure 2-3. The number in the circle represents the accumulated flights at that time.

From early 1980 to program conclusion the prelaunch operations are as shown in Figure 2-4.

The program is based on two pads and two launch umbilical towers (LUT'S). LUT refurbish time is four to five days. The maximum launch rate per pad is approximately eight to nine days. Figure 2-5 illustrates shuttle-LUT prelaunch configuration.

Orbital Operations

The shuttle's reference mission is logistic resupply of the modular space station in a 270-nautical mile altitutude orbit inclined at 55 degrees. For sortie application other altitudes and inclinations are of interest. The payload capability to the various orbits of interest are presented in Table 2-1. The 18,000-pound penalty associated with the air-breathing engines is included.

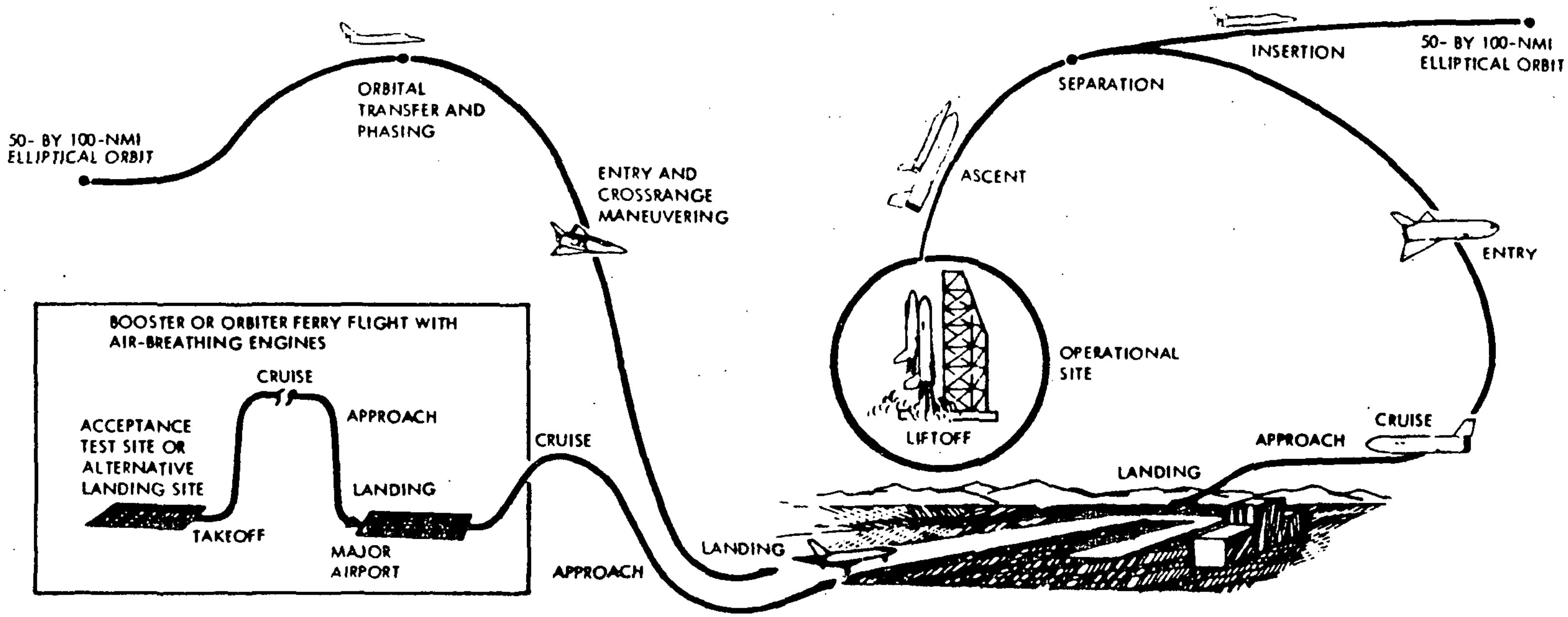


Figure 2-1. Shuttle Operational Sequence

CALENDAR YRS	1980	1981	1982	1983	1984	1985	1986	1987	1988
PAD A	1 EVERY 3 WEEKS	1 EVERY 2 WEEKS			1 EVERY 1-1/2 WEEKS				
PAD B	1 EVERY 3 WEEKS	1 EVERY 2 WEEKS			1 EVERY 1-1/2 WEEKS				

Figure 2-2. Average Launch Rates for Pads A and B

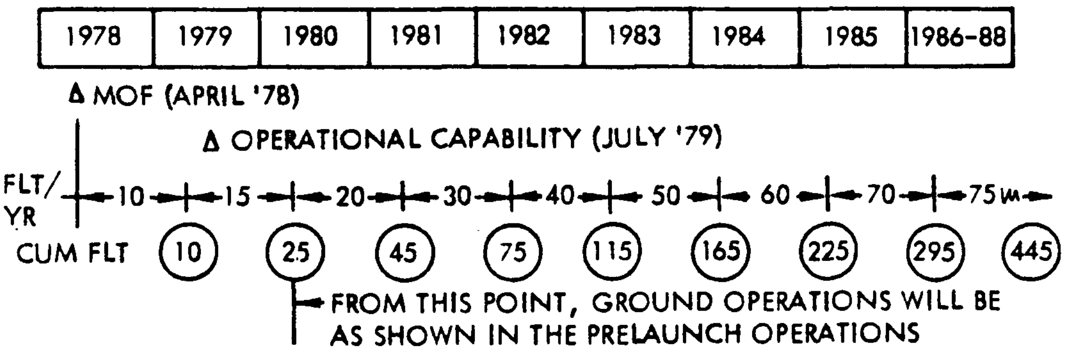


Figure 2-3. Shuttle Traffic Model

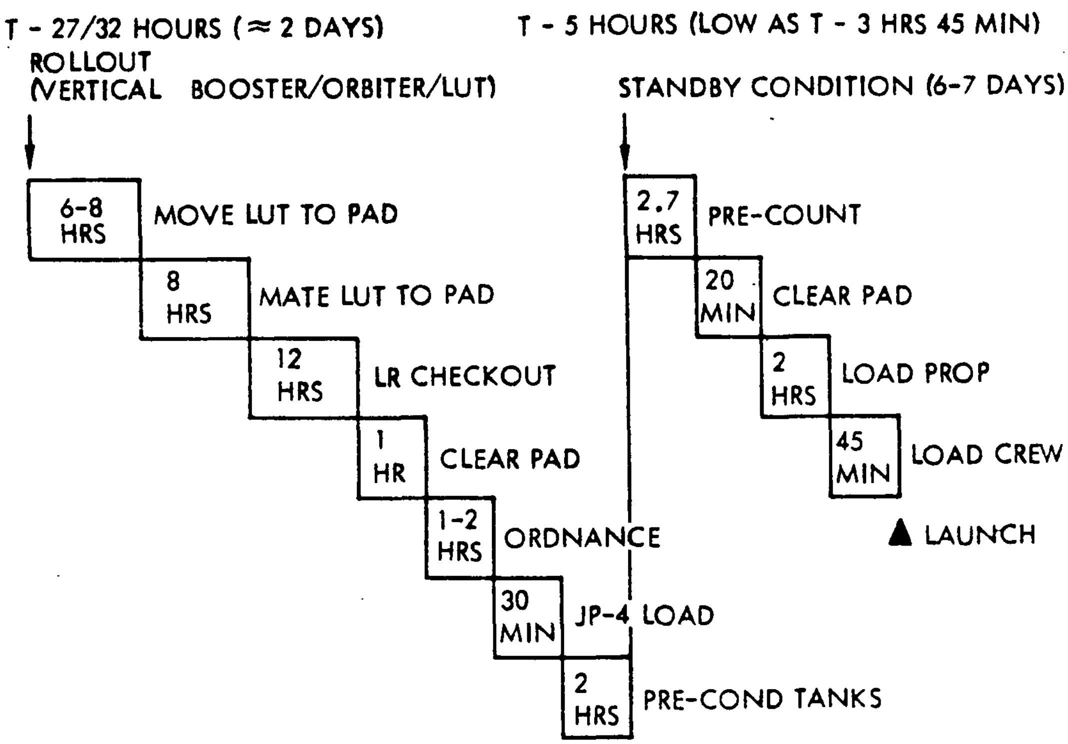


Figure 2-4. Operational Timeline

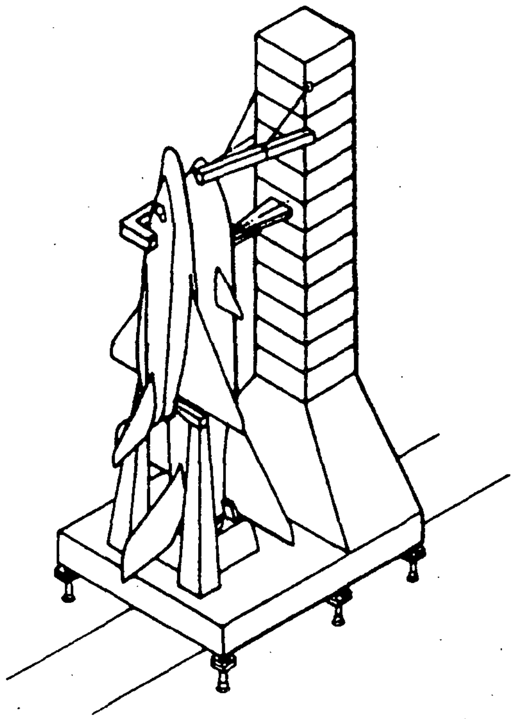


Figure 2-5. Shuttle and LUT at Launch Pad

Table 2-1. Payload Capability (Up and Down)

Inclination (deg.)	Altitude (n. mi.)	Payload (lb.)
55	270	25,000
28-1/2	100	44,000
90	100	22,000

For the reference mission, the shuttle orbiter has sufficient propellant to provide 1500 fps on-orbit ΔV capability in excess of the amount required to attain the 50 by 100-nautical mile insertion orbit. The propellant tanks are sized to provide 2000 fps ΔV.

The total mission time is 7 days with approximately 5 days on-orbit. During this period the orbiter is powered-down and in a free orbital coast mode.

Extended-mission capabilities (i. e., beyond the 7-day mission time and powered-down mode) can be obtained with a corresponding reduction in payload capability. The rules which apply for these extended capabilities are:

1. Crew, crew provisions (in excess of the flight crew of two), and unique mission equipment is charged against the payload.

2. For the 30-day mission:

   a. 23 days of expendables for the flight crew of two are charged against the payload.

   b. 23 days of expendables for the subsystems (e. g., cryogencies) are charged against the payload.

   c. 30 days of expendables (e. g., food, LiOH) for the crew (in excess of the two flight crewmen) are charged against the payload.

3. For the 7-day mission, subsystem expendables required to power-up the orbiter are charged against the payload.

The weight penalties associated with these conditions will be found under the various subsystem descriptions in the following section.

On-Orbit Guidance, Navigation, and Control

The one-sigma uncertainty in orbiter vehicle position and velocity at the time of a state vector update is presented in Table 2-2.

The one-sigma uncertainity in orbiter vehicle attitude at the time of a stellar update, is ±0. 1 degree about each axis (pitch, roll, yaw). The one-sigma uncertainty in orbiter vehicle attitude rate is ±0. 01 degree per second about each axis (pitch, roll, yaw). When the orbiter is tracking a cooperative target, the one-sigma tracking uncertainties are as presented in Table 2-3.

In addition to range and range rate information, the orbiter is capable of optically determining the bearing angle to the target; the one-sigma bearing angle uncertainity is ±0. 02 degree.

Orbiter vehicle translation control rates are defined in Table 2-4.

The orbiter has selectable attitude deadbands of ±0. 5 degree, ±10 degrees, and ±45 degrees. Attitude control rates are defined in Table 2-5.

Table 2-2. Position and Velocity Uncertainty

Component	Position (n. mi.)	Velocity (fps)
Altitude	±0.25	±1.5
In-track	±0.5	±0.6
Cross-track	±0.5	±3.0

Table 2-3. Tracking Uncertainty

Parameter	At 30 n.mi.	At 500 feet
Range	±0.1 n.mi.	±5.0 feet
Range rate	±10 fps	±0.1 fps

Table 2-4. Translation Control Rates (ACPS Thrusters)

Orbiter Axis	Minimum Acceleration (fps^2)	Maximum Acceleration (fps^2)	Minimum Velocity Increment (fps)
X (roll)	0.26	0.78	0.026
Y (pitch)	0.52	1.56	0.052
Z (yaw)	0.26	0.78	0.026

Table 2-5. Attitude Control Rates

Orbiter Axis	Minimum Angular Acceleration (deg/sec^2)	Maximum Angular Acceleration (deg/sec^2)	Minimum Angular Velocity Increment (deg/sec)	Minimum Velocity (deg/sec)
X (roll)	0.5	1.0	0.05	0.025
Y (pitch)	0.5	1.0	0.05	0.025
Z (yaw)	0.6	1.8	0.06	0.03

CONFIGURATION DESCRIPTION

Mated Vehicles

In the mated configuration, the vehicles form a vertical stack 290 feet tall-approximately 75 feet shorter than the Apollo-Saturn vehicle. The orbiter, which is attached at three points to the flat dorsal surface of the booster, extends about 20 feet forward of the booster nose (Figure 2-6).

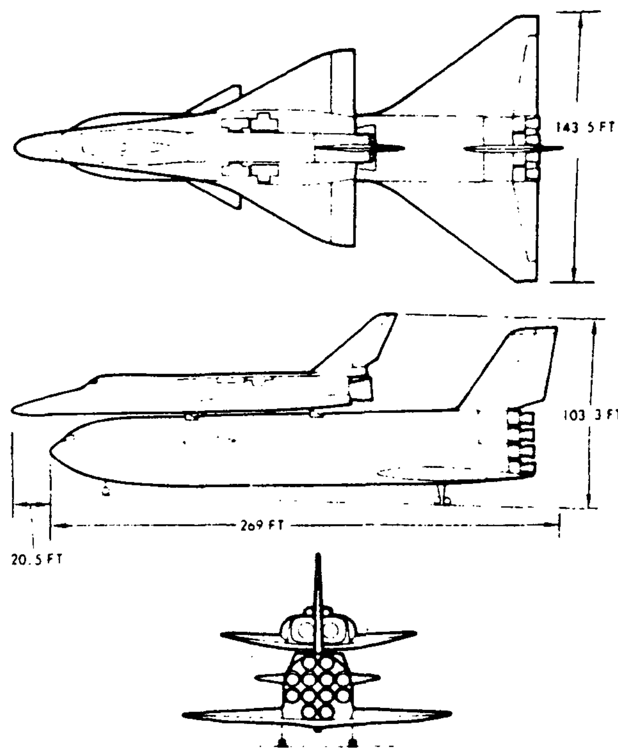


Figure 2-6. Mated Vehicle Configuration

Acting as a single vehicle throughout the ascent phase, the mated orbiter and booster are propelled by the booster's main engines to a separation altitude of approximately 40 miles and a velocity of about 6500 miles per hour.

Orbiter Vehicle

The orbiter configuration defined by the Phase B study is a delta-wing vehicle with an overall length of 206 feet and a wingspan of 107 feet (Figure 2-7). The profile of the orbiter incorporates a wide center fuselage (45.5 feet), which houses the two main liquid-oxygen tanks and a cargo bay of 15 feet wide and 60 feet long. Forward volume of the fuselage is occupied by the main liquid-hydrogen tank and the crew compartment. Protection of internal structures is achieved with reusable heat shielding over all external surfaces subjected to the high heats of boost and reentry.

Extensive use of computerized control and data management permits full orbiter flight operation with a crew of two, commander and pilot. Two additional personnel are carried when payloads are to be deployed, maintained, or taken aboard while in orbit.

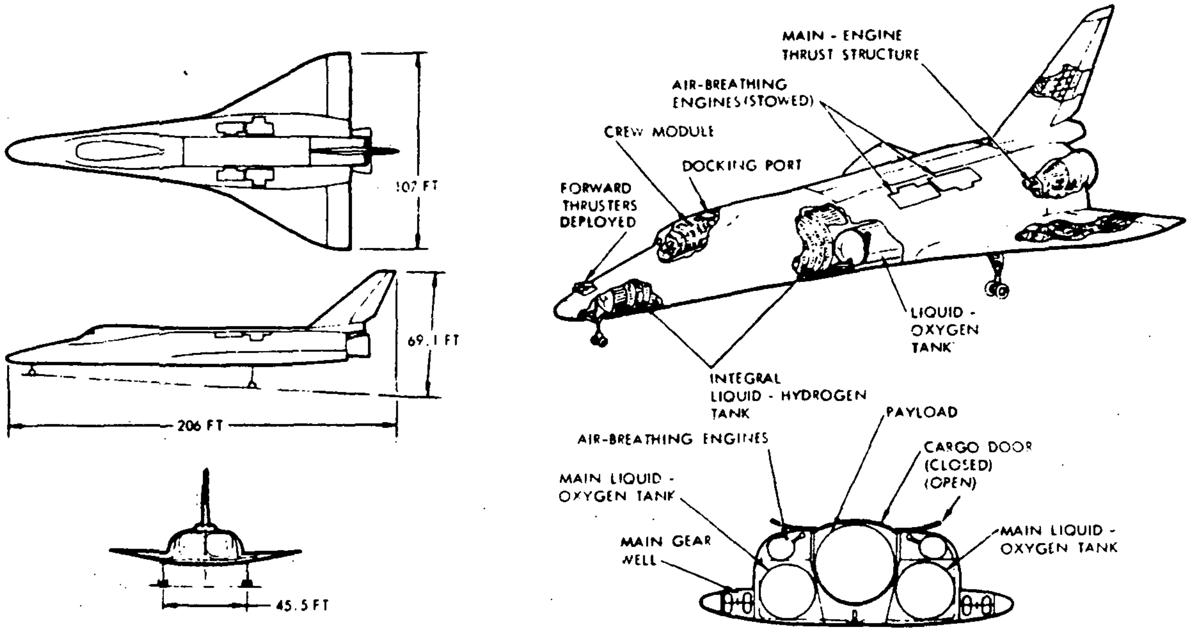


Figure 2-7. Orbiter Configuration

Aerodynamic flight control is achieved with typical rudder and elevons, while exoatmospheric attitude control is sustained with a system of jet thrusters.

The main propulsion system consists of a pair of rear-mounted liquid-propellant rocket engines which develop a vacuum thrust of 632,000 pounds each. The main engines are used to propel the orbiter from booster separation to the initial 50 by 100-nautical mile orbit only. Subsequent orbital transfers and deorbit are accomplished with three smaller orbital maneuvering engines mounted above the main engines. Following entry, four air-breathing turbofan engines are deployed above the center fuselage to provide go-around and landing maneuver capability. The air-breathing engine system, when augmented with a fifth engine mounted beneath the fuselage, delivers sufficient thrust for horizontal takeoff and ferry flight when required.

Mass properties for the orbiter are shown in Table 2-6. Payload longitudinal center-of-gravity locations are shown in Figure 2-8.

The fully instrumented, environmentally controlled crew and passenger compartment is mounted atop the main hydrogen tank in the forward fuselage assembly. In the forward section are the commander's and pilot's stations with vehicle controls and displays. Also located in this compartment are

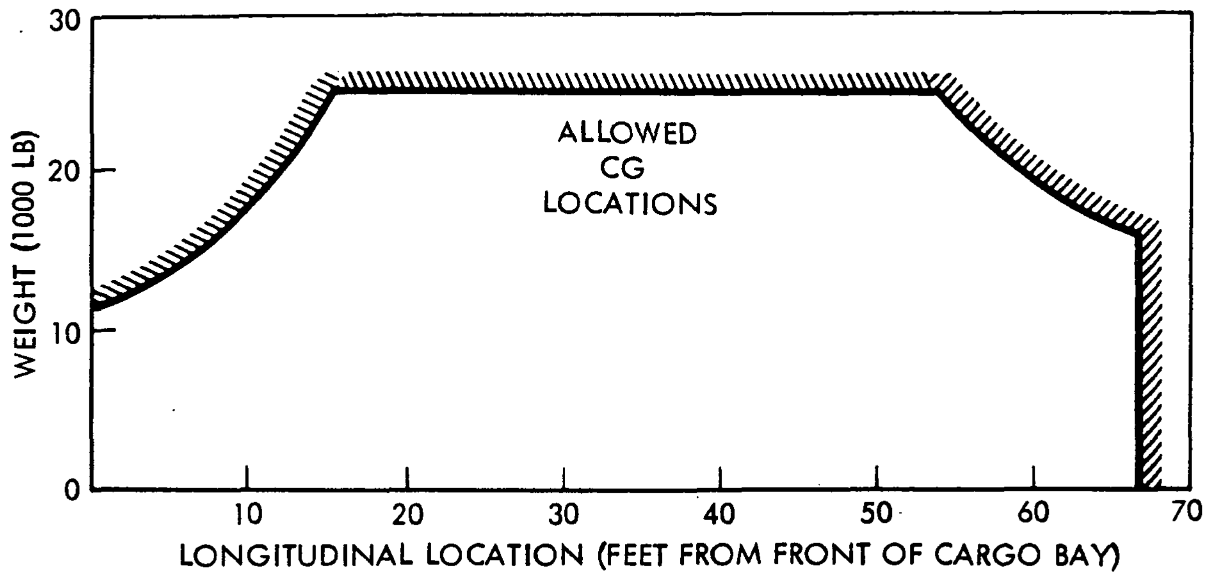


Figure 2-8. Payload Center-of-gravity Envelope

Table 2-6. Mass Properties

Orbit	Parameter	Ascent Burnout	Entry	On-Orbit Average
55° inclination by 270 n. mi.	Weight (lb)	316,940	272,230	294,585
	I_x (slug ft^2)	2.725 $(10)^6$	2.495 $(10)^6$	2.610 $(10)^6$
	I_y (slug ft^2)	19.883 $(10)^6$	17.946 $(10)^6$	18.915 $(10)^6$
	I_z (slug ft^2)	21.495 $(10)^6$	19.351 $(10)^6$	20.423 $(10)^6$
90° inclination by 100 n. mi.	Weight (lb)	302,793	268,706	285,749
	I_x (slug ft^2)	2.574 $(10)^6$	2.401 $(10)^6$	2.488 $(10)^6$
	I_y (slug ft^2)	19.511 $(10)^6$	18.047 $(10)^6$	18.779 $(10)^6$
	I_z (slug ft^2)	21.021 $(10)^6$	19.406 $(10)^6$	20.214 $(10)^6$
28-1/2 inclination by 100 n. mi.	Weight (lb)	327,359	293,706	310,532
	I_x (slug ft^2)	2.599 $(10)^6$	2.425 $(10)^6$	2.512 $(10)^6$
	I_y (slug ft^2)	19.801 $(10)^6$	18.363 $(10)^6$	19.082 $(10)^6$
	I_z (slug ft^2)	21.306 $(10)^6$	19.719 $(10)^6$	20.513 $(10)^6$

accommodations for two other crew members, general life support equipment, and personal stowage provisions. Immediately behind the crew compartment is an airlock with overhead docking port for transfer of crew between the orbiter and a payload module. The docking port also is used for general personnel access while the orbiter is on the ground and as an ingress-egress hatch during extravehicular activity in space. The aft section of the module serves as an electronics bay. A center aisle through the electronics bay leads to a tunnel connected with the cargo bay. Ready passage in a shirtsleeve environment is provided between all manned compartments. Emergency egress for the crew is through overhead hatches. Figure 2-9 illustrates the crew compartment.

The orbiter's docking and payload handling system (Figure 2-10) is designed to carry out the many unique functions associated with orbital operations and the manipulation of a variety of payloads in zero gravity.

The cargo bay is fitted with trunnions and latches for securing a wide variety of payloads. It is also equipped with floodlights and closed-circuit television monitors placed to achieve maximum visibility in all parts of the bay. The two full-length, hydraulically actuated cargo doors, when opened, permit completely unobstructed vertical loading and removal of payload packages.

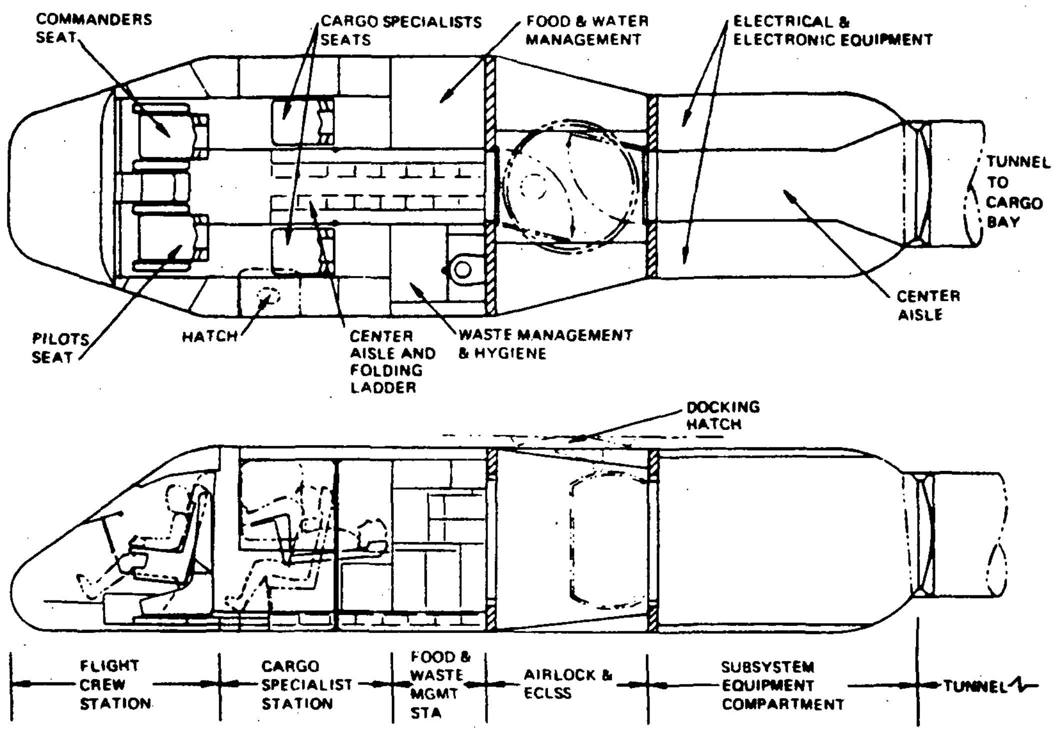


Figure 2-9. Crew Compartment

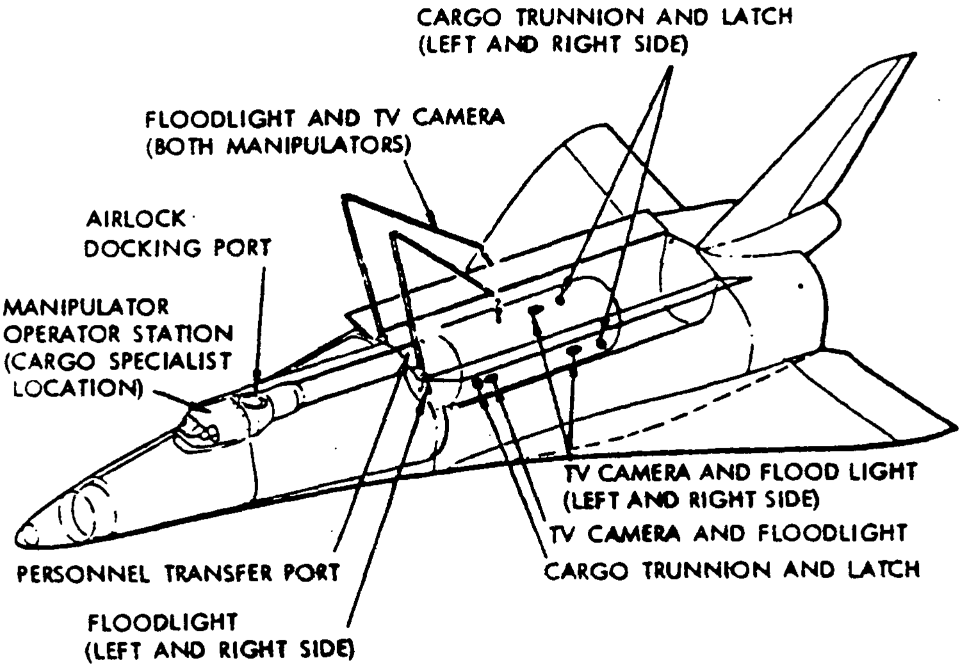


Figure 2-10. Docking and Payload Handling System

Loading, unloading, and critical positioning of payload modules are performed with a pair of jointed, electrically operated manipulator arms located on either side at the forward end of the cargo bay. Stowed inside the cargo compartment when not in use, the arms can be elevated, rotated, and extended to all corners of the bay. Precise control of the manipulators is exercised by the crew. The operator's station is equipped with all necessary television displays, communications outlets, and controls the maneuvering and emplacement of payloads.

Propulsion from the initial orbit established with the main engines is accomplished with three 10,000-pound-thrust rocket engines mounted on the rear compartment just above the main engines. Using liquid hydrogen and liquid oxygen, these engines draw propellants from independent tankage installed in the aft section of the vehicle.

Attitude control is maintained by 29 thrusters located near the fore and aft ends of the fuselage. These 2100-pound-thrust jets provide precision stabilization of pitch, roll, and yaw and are essential to maintaining proper orientation for lateral cross-range maneuvering during reentry. They also may be used as a backup deorbit system. The attitude control propulsion system and orbital maneuvering system, jointly referred to as the auxilliary propulsion system, draw their propellants from common tankage (Figure 2-11). Total system capacity is 46,745 pounds.

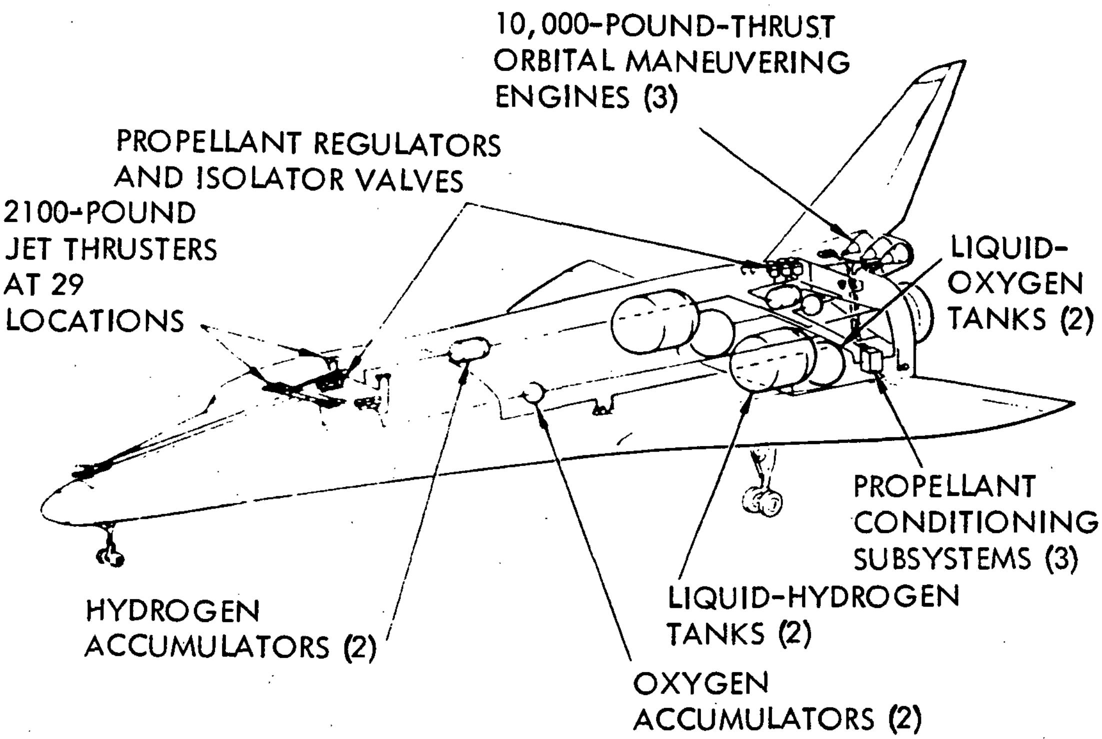


Figure 2-11. Auxiliary Propulsion System

Three 7/10-kilowatt fuel cells, located in the forward fuselage adjacent to the crew compartment, provide primary 28-volt dc power via three central main dc buses. Primary 115/200-volt, three-phase, 400-Herz, ac power is produced by three 20/30-kva ac generators.

The electrical power profile is shown in Figure 2-12. For the baseline profile, only 500 watts (average) of power are allocated to the payload. Total energy is 20 kilowatt-hours. For certain applications, however, additional power up to 5.2 kilowatts can be made available at the expense of adding fuel cell reactants and tankage. Also, where a powered-up orbiter is required, additional reactants are required to maintain the vehicle in this status. The weight penalties associated with these various conditions are also noted in the figure.

Orbiter environmental control and life-support subsystems maintain a shirtsleeve environment for a crew of four for seven days (or for 30 days with extra consumables). The overall subsystem assures appropriate environmental control for manned areas. Environmental maintenance of electronics and other sensitive equipment is essentially limited to temperature regulation and heat dissipation. Among the life-support functions are control of temperature, humidity, air composition, air pressure, contaminants, bacteria count, odors, ventilation, and acoustics.

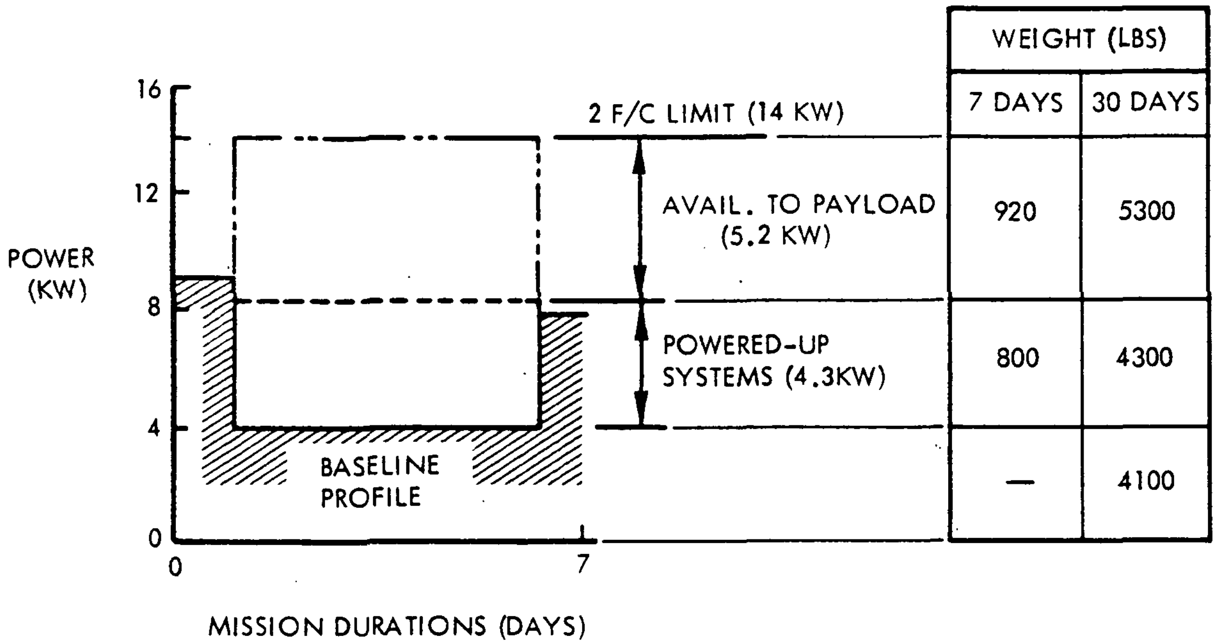


Figure 2-12. Electric Power Profile

Air temperature within the manned compartments is maintained between 65 F and 75 F under normal conditions and between 40 and 110 F during emergencies. Atmospheric temperature control is achieved with a heat exchanger and fan units through which cooled or heated water is circulated. The same water loop also supplies cooling water to the avionics compartment coldplates. Avionics coldplates in unpressurized locations are cooled by the Freon loop. Cabin air pressure may be selected at any point between 10 psi and one atmosphere, depending on mission code.

Gaseous and liquid wastes may be disinfected and dumped overboard, while solid wastes are decontaminated and retained in onboard storage tanks for removal during ground maintenance. Air contaminants, including bacteris, particulate matter, and odors, are removed from the cabin atmosphere with filters.

Food management incorporates a food packaging concept for storage of food serving cans, dehydratables, and drink packages. A freezer-locker compartment is used for food storage.

For the 7-day sortie mission, no change is required in the ECLSS for the flight crew of two and two passengers. For the 30-day missions, however, additional nitrogen, oxygen, food, food storage, LiOH, and waste management is required. Table 2-7 presents the weight penalties that are changed against the payload.

Table 2-7. ECLSS Weight Penalties

ECLSS	Missions	
	7-Day	30-Day
Hardware (lb)	-	81
Expendables (lb)	112	487*
Total (lb)	112	568

*Includes cabin leakage makeup and metabolic oxygen supplied by the 200-pound excess volume in the EPS cryogenic tank.

The orbiter's two passengers are defined as experimenters capable of conducting experiments for 10 hours per day each. In addition, the orbiter's flight crew of two will be capable of assisting the experimenters in some skill-related tasks for 6 hours per day each for the orbital coast period only. During this period, one crew member (equivalent) will be on flight duty at all times.

Crew provisions include seats, restraints, and fixed life support items. For the 7-day mission, the current orbiter crew compartment has sufficient volume for the four men. For the 30-day mission, however, additional living accommodations, clothing, and medical supplies are required. These must be supplied by the payload. Table 2-8 presents the weight penalties for these accommodations.

Table 2-8. Crew Provision Penalties

Provisions	Mission	
2 Flight Crew (lb)	Baseline	Baseline
2 Experimenters (lb)	360	360
Crew Provisions (lb)	280	2980*
Total (lb)	640	3340

*Includes a 10-feet long module, 14 feet in diameter used for sleeping, recreation, storage, etc. This volume (and weight) can be integrated into an experiment payload module when used.

The integrated avionics assembly is used to coordinate operation of all orbiter flight systems. Major subsystems governed by the data and control management assembly are guidance and navigation, communications, displays and controls, and power distribution and control. This assembly also performs the critical function of onboard checkout and fault isolation.

Sensor inputs for guidance and navigation are derived from three independent units: the inertial measurement unit, star tracker, and precision ranging system with onboard transceiver and ground and space station transponders. The inertial unit is the primary navigation assembly, the star tracker and ranging assembly serving as corrective devices only.

The orbiter communications subsystem provides two-way voice and data transmission, range and range-rate data for space rendezvous, and information for atmospheric navigation and landing. A unified S-band subassembly provides primary onboard voice and data intercommunication as well as two-way transmission with the manned spacecraft network. Additional voice and data communication with the ground is accomplished with a VHF FM subassembly via a stationary communications satellite, while two-way simplex voice transmission with civil and military air traffic control stations and with the booster vehicle is performed with UHF AM equipment. Precision ranging interrogators provide data for cooperative-target range and range-rate determination, on-orbit state vector updating, and atmospheric navigation and landing. A radar altimeter is part of the precision ranging system. Fifteen flush-mounted antennas are installed at various points on the orbiter fuselage. Antenna selection, as well as overall subsystem checkout and control, is accomplished by the central data and control management system. The data management assembly allocates 5 kbps to the payload with access to the antennas for transmission. Payload requirements in excess of this must be payload-supplied.

3. EXPERIMENT ANALYSIS AND SUPPORT REQUIREMENTS

As the space shuttle system progresses from its early development flights toward fully operational capability, it becomes desirable to include scientific payloads of complexity increasing with the shuttle capability. For this reason, the space station-oriented 1971 Blue Book experiment program was analyzed for experiments which would be compatible with the shuttle and which were logical choixes to be performed between the shuttle IOC and the modular space station IOC. This section describes the experiment package selection rationale and the resulting support requirements for both the 7-day and 30-day sortie missions.

EXPERIMENT SELECTION RATIONALE

The experiments selected for application to sortie missions were limited by the physical characteristics of the shuttle payload compartment, the performance capability of the shuttle, and to some extent by the subsystems support capability of the shuttle. However, the primary objectives of the shuttle sortie experiment selection was to provide an economical and useful step in the evolution of the complete manned earth-orbit scientific program. Thus, experiments which are precursors to Level II or Level III scientific investigations would be natural candidates for the early sorties[1]. Likewise, the experiments which can be accomplished on short-duration missions (7 to 30 days) or with interrupted operations would be suitable candidates for sortie missions. The candidate experiments from which the shuttle sortie activities were selected consisted of those Blue Book Experiments assigned to Level I.

Two durations of missions were considered, 7 days and 30 days, with preference given in experiment assignment to the shorter-duration case. Since specific shuttle schedules were not available for the experiment mode selection, the emphasis on 7-day sortie assignments provides flexibility in specific mission assignments.

Analysis of the evolutionary concept of accomplishing the 1971 Blue Book experiment objectives resulted in the selection of 31 experiment packages for sortie missions. Table 3-1 provides a listing of these packages showing an identification symbol and a title. This title is directly associated with the applicable Blue Book scientific discipline and FPE which will be supported by the recommended package.

[1]See MSS Preliminary Design, Vol. III - Experiment Analyses, SD 71-217-3 (MSC-02471).

Table 3-1. Experiment Packages for Shuttle Sortie Missions

Payload Package ID*	Title
A1-I	X-Ray Stellar Astronomy
A3-I	Advanced Solar Astronomy
A4-I	Intermediate Size UV Telescope
A5-I	High Energy Stellar Astronomy
A6-I	Infrared Astronomy
P1-I	Space Physics
P1-II	Space Physics
P2-I	Plasma Physics
P2-II	Plasma Physics
P3-I	Cosmic Ray Physics
P4-I	Physics and Chemistry
ES1-I	Earth Observations (Meteorology)
ES1-II	Earth Observations (Land Use)
ES1-III	Earth Observations (Resource Identification)
MS1-I	Materials Science
C/N1-I	Transmitter Breakdown Test
C/N1-II	Optical Frequency and Millimeter Wave Communication and Propagation Demonstration
C/N1-III	Search, Navigation and RF Propagation
T1-I	Contamination Technology
T1-II	Contamination Technology
T2-I	Fluid Management
T2-II	Fluid Management
T2-III	Fluid Management
T3-I	Extravehicular Activity
T4-I	Advanced Spacecraft Systems Test
LS1-I	Medical Research
LS3-II	Plant Growth Transients
LS4-II	Cells and Tissues
LS4,5-I	Biosciences
LS6-I	Life Support
LS7-II	Man Systems

*Alpha character = Experiment discipline
Arabic numbers = FPE number
Roman numbers = Experiment package number for partial or complete FPE.

Each experiment package, consisting of the equipment required to perform a set of experiments selected for sortie implementation and the support requirements, are presented in Appendix A.

4. OPERATIONAL ANALYSIS

This section covers the analysis of the experiment packages developed in Section 3 that permitted their grouping into experiment payloads. It also examines the experiment payloads' orbital requirements and assesses the shuttle's ability to carry the equipment and supporting manpower to the desired altitude and inclination.

Ground rules were developed for phasing the various types of 7-day and 30-day flights. The impact of this experiment schedule on a crew training program is discussed.

APPROACH

The approach followed in defining a sortie experiment program to meet the study objectives can be summarized in four basic steps as shown in Figure 4-1.

First, a set of candidate experiment payloads was assembled from all of the previously defined experiment packages by analyzing operational-related characteristics and accommodation requirements. Secondly, these candidate experiment payloads were then tested for compatibility with the space shuttle capability model (i.e., payload weight, crew size, electrical power capability, etc.). As a result of this second step, shuttle-compatible experiment payloads were identified.

Having identified these experiment payloads, the next step was to identify sortie payloads which could be flown on specific missions. Sortie payloads consist of the compatible experiment payloads, the structure to house all hardware, and the necessary support subsystems. The total sortie payload weight was then compared to the orbiter's capability to achieve the preferred orbital inclination and altitude. When a negative capability arose, the analysis was repeated against alternative acceptable orbits. Orbiter inability to achieve these alternative conditions necessitated a sortie payload resynthesis.

Finally, once a valid set of sortie payloads was defined, a sortie experiment program was generated for the time frame of interest, based on the NASA shuttle fleet size, delivery data, and launch rate described in Section 2.

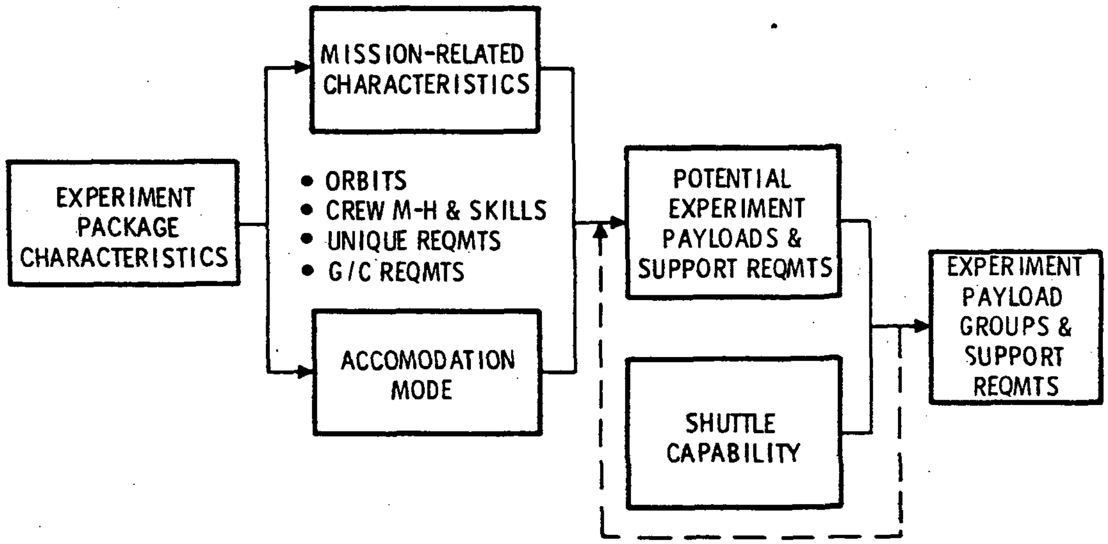


Figure 4-1. Operation Analysis Approach

EXPERIMENT PACKAGE-EXPERIMENT PAYLOAD EVALUATION

Sortie experiment packages defined in Section 3 are summarized in Table 4-1, with emphasis on the parameters which were used to group them into payloads. Evaluation parameters consist of (1) inclination, (2) preferred orbit altitude, (3) experiment equipment weight, and (4) manpower requirements. In general, payloads are identified by their duration (i.e., 7M representing a seven-day mission and 30M representing a 30-day mission). There are a total of six 7-day experiment payloads and eleven 30-day experiment payloads.

Orbit Inclination

Experiment packages were grouped into payloads with first consideration for compatibility of orbital inclinations. No consideration was given to time sharing of different orbital inclinations by making plane changes on a flight because of the prohibitive demand on orbiter propellant.

Table 4-1. Principal Requirements for Experiment Payload Synthesis

7-Day			
Exp Pkg	i (degrees)	h (n mi)	Weight (lb)
P1-I	90	100 - 500	854
P2-I	55	270 (165-330)	130
P2-II	55	550	702
ES1-II	70 (50)	100 (270)	6454
ES1-III	90 (55)	100 (270)	5763
C/N1-I	>28	80, 160, 240, 320, 400	270
MS1-III	Any	Any	4227
T1-I	Any	Any	1416
T3-I	0 - 60	100 - 300	265
T4-I	55	270	540
L3-II	Any	Any	626
L4-II	Any	Any	800

( ) = Acceptable alternate i or h

30-Day			
Exp Pkg	i (degrees)	h (n mi)	Weight (lb)
A1-I	0 (0 - 55)	400 - 500 (370 - 740)	3000
A3-I	sun sync (0 - 55)	270 (2 - 400)	6475
A4-I	28 - 70 (Any)	250 - 360 (200 - 400)	1060
A5-I	0 (0 - 55)	- 500 (200 - 400)	2445
A6-1	50 - 60 (25 - 70)	270 - 300 (250 - 400)	4400
P1-II	Any	>100	233
P3-I	28.5 (55)	200 (270)	10,500
P4-I	Any	>100	345
ES1-I	70 (50)	100 (270)	4849
C/N1-II	90 (>28)	100 - 300	690
C/N1-III	90 (>28)	100 - 300	911
T1-II	Any	Any	1416
T2-I	Any	>270	3856
T2-II	Any	>270	3505
T2-III	Any	>270	1450
LS1-I	Any	Any	400
LS4,5-I	Any	Any	854
LS6-I	Any	Any	1051
LS7-I	Any	Any	223

Table 4-2. Experiment Payload Requirements Summary

Payload No.	Experiment Package	Incl. (deg)	Alt. (n. mi.)	Crew		Power		Data Quan/Rate	G&C Ptg/Stab.
				No.	Skills	kwh	kw		
7M-1	ES 1 - III T1 - I	55	270	2+2	6, 12, 19, 26	5.5	2.0	1.37×10^{11} bpd 2×10^{6} bps	±.05 deg ±.05°/sec
7M-2	P1 - I T1 - I C/N 1 - I	90	80-500	2+2	5, 6, 10, 12, 17	37.6	2.8	1.7×10^{10} bpd 2×10^{5} bps	±2 min ±.01°/sec
7M-3	ES1 - II T4 - I T1 - I	50	270	2+2	6, 8-12, 19, 27	54	3.5	1.52×10^{11} bpd 2×10^{6} bps	±.05 deg ±.05°/sec
7M-4	MS1-III	28.5	200	2+2	12, 23, 24	71	5.0	4.3×10^{8} bpd 1×10^{4} bps	- -
7M-5	LS3 - II LS4 - II T3 - I	28.5	100	2+3	1, 3, 12	3.1	0.4	1.5×10^{8} bpd 5×10^{3} bps	- -
7M-6	P2-I P2-II	55	270	2+2	6, 12	9.0	0.8	8.6×10^{9} bpd 1×10^{5} bps	±0.5 deg ±1°/min
30M-1	ES1 - I T1 - II	70	100	2+2	6, 12, 16, 18	5.6	1.0	2.6×10^{9} bpd 1.24×10^{5} bps	±.05 deg ±.01°/sec
30M-2	P1 - II P4 - I	28.5	200	2+2	6, 12, 25	16.6	4.0	4.1×10^{9} bps 4.5×10^{4} bps	±2 deg ±.01°/sec
30M-3	T2 - I T2 - II T2 - III	28.5	300	2+2	9, 12	17.3	4.0	4.8×10^{7} bpd 5.8×10^{3} bps	- -

Table 4-2. Experiment Payload Requirements Summary (Cont)

Payload No.	Experiment Package	Incl. (deg)	Alt. (n. mi.)	Crew		Power		Data Quan/Rate	G&C Ptg/Stab.
				No.	Skills	kwh	kw		
30M-4	LS1 - I LS4, 5-I LS6 - I LS7 - II	28.5	100	2+3	1, 2, 11, 12, 13, 21, 22	1.9	0.3	3.3×10^7 bpd 2.8×10^4 bps	- -
30M-5	A1 - I	0	400-500	2+2	5 or 6, & 10, 14 or 15	4.8	0.3	5×10^8 bpd 4×10^4 bps	±1 sec ±1 sec/hr
30M-6	A3 - I	Sun sync	270	2+2	5 & 12 or 14	8.6	0.7	6×10^8 bpd 4×10^4 bps	±1 sec, ±.1 sec/ 2700 sec
30M-7	A4-I	28-70	250-360	2+2	5, 12	4.8	0.3	1.6×10^9 bpd 4×10^4 bps	±5 sec, ±5 sec/ 1 hr
30M-8	A5 - I	0	400-500	2+2	5, 6, 10	1.6	0.2	5.4×10^8 bpd 6.4×10^3 bps	6 min, 1 min/ 30 min
30M-9	A6-I	50-60	270-300	2+2	5, 12	5.5	0.3	1.2×10^9 bpd 4×10^4 bps	1 sec, 1 sec/ 50 min
30M-10	P3-I	28.5	200	2+2	7, 12	13.2	0.7	1.5×10^9 bpd 1.7×10^4 bps	- -
30M-11	C/N1 - II C/N1 - III	90	150	2+2	10, 12, 14, 17	2.5	0.7	1.27×10^9 bpd 3×10^5 bps	±0.01 deg ±0.1°/sec

Orbit Altitude

Next, compatibility of altitudes was examined. When a compromise could not be found, multiple altitudes were considered. This does not impose a significant penalty on propellant or payload, although it would require time sharing if performed on the same flight. If multiple cycles of an experiment were conducted over the course of several flights, then, of course, altitude may be different on each flight.

Crew Skill Requirements

When the payload comprises different experiments for the same discipline, crew skills are likely to be compatible and requirements for more than two skills per crew member are few. However, when disciplines are mixed, little compatibility in crew skills occurs and more cross-training is required. Two skills per man has been the nominal requirement in the space station studies and also appears to be reasonable for the sortie missions.

Experiment Payloads

The experiment payloads resulting from the experiment package evaluation discussed are presented in Table 4-2, which also defines their support requirements used in the support subsystem selection discussed in Section 5. Four of the six 7-day mission payloads are multidisciplinary while only one of the 30-day mission payloads is multidisciplinary. In the case of payload 7M-2, the altitude is made variable through the use of an elliptical orbit to satisfy experiment requirements.

Commonality of crew skills for all payloads is presented in Tables 4-3 and 4-4. Payload 7M-3 is the only one that tends to exceed the two skills per man requirement, indicating seven skills for two men (experiment operations crew). Closer examination, however, shows that an arrangement in skills assignment as illustrated in Table 4-5 would reasonably satisfy the support requirement.

SORTIE PAYLOAD DEFINITION

Using the experiment payloads previously described, candidate sortie payloads were defined which took into account a preliminary assessment of their support subsystem weights, such as modules and airlocks, pallets, power, crew, crew accommodations, shuttle 30-day duration kit, and shuttle maneuvering propellant and attitude hold propellant. This total weight was used in testing the shuttle's capability to achieve the specified orbit.

Table 4-3. Seven-Day Experiment Payload Skills Commonality

Experiment Payload	Exp Pkg	Skill																										
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	ES1-III																			X							X	
	T1-I						X						X															
2	P1-I					X	X						X															
	T1-I						X						X															
	C/N1-I										X							X										
3	ES-1-II								X											X								X
	T1-I						X						X															
	T4-I									X	X	X	X															
4	MS1-III												X											X	X			
5	LS-3-III	X																										
	LS-4-II	X		X																								
	T3-I												X															
6	P2-I						X						X															
	P2-II						X						X															

Table 4-4. Thirty-Day Experiment Payload Skills Commonality

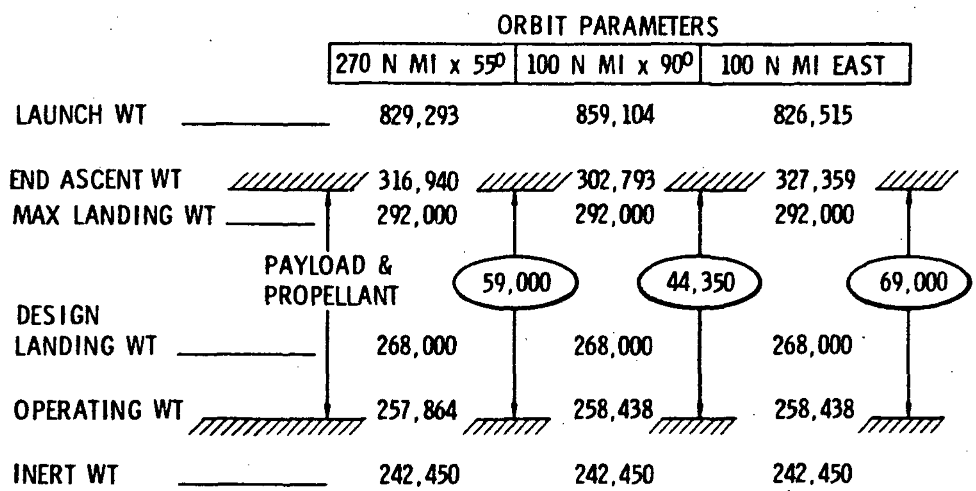
Experiment Payload	Exp Pkg	Skill																										
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	ES1-I																X		X									
	T1-II						X						X															
2	P1-II						X						X															
	P4-I						X						X													X		
3	T2-I									X			X															
	T2-II									X			X															
	T2-III									X			X															
4	LS-1-I	X												X														
	LS-4,5-I	X	X																									
	LS-6-I		X									X																
	LS-7-I																					X						
5	A1-I					X					X				X													
6	A3-I					X									X													
7	A4-I					X							X															
8	A5-I					X	X				X																	
9	A6-I					X							X															
10	P3-I							X					X															
11	C/N1-II										X				X			X										
	C/N1-III										X		X		X			X										

Table 4-5. Payload 7M-3 Crew Skills Assignments

Skill		Experiment Package					
		ES1-II T4-I		ES1-II T1-I		ES1-II	
		Payload Configuration					
		A		B		C	
No.	Name	Experiment Crewman					
		1	2	1	2	1	2
6	Physicist				X		
8	Photo technician/cartographer		X	X		X	
9	Thermodynamicist	X					
10	Electronic engineer	X					
11	Mechanical engineer	X					
12	Electromechanical technician	X		X			
19	Physical geologist		X		X		X
27	Geographer		X		X		X

Figure 4-2 summarizes the shuttle's mass properties characteristics for each of the three reference missions (28.5, 55, and 90-degree orbit inclinations) and indicates the allowable weight for payload and propellant in each case.

The propellant needed for each mission is that required to achieve the final circular orbit altitude above the 50- by 100-nautical mile orbit. In addition, since the shuttle orbiter attitude control propulsion system (ACPS) utilizes the same propellant tanks as the (orbital maneuvering system OMS) the total propellant weight requirement must also include the propellant needed to maintain vehicle attitude. Since the propellant requirement varies with each sortie mission, the amount of propellant needed must be calculated for each mission. However, there are a certain number of maneuvers that are common to all sortie missions and these are defined in Table 4-6 together with their propellant requirements.



INERT WT = DRY WT + FLIGHT CREW (2) + RESIDUALS
OPERATING WT = INERT WT + RESERVES + IN-FLT LOSSES & ABES PROPELLANT

Figure 4-2. Mass Properties Characteristics

Table 4-6. Common Mission Maneuvers and Propellant Requirements

Event	Propellant Weight (lb.)
Orbit injection (50 x 100 n. mi.)	400
Deorbit (from 100 n. mi.)	360
Preentry	150
Entry	1200
Total	2100

The shuttle's payload capability as a function of attitude for each of the three reference missions is presented in Figures 4-3 through 4-5. Accompanying the payload capability is a definition of the corresponding propellant required to achieve the altitude desired. There are constraints imposed on the shuttle that place certain restrictions on its payload capability which are included in the curves of Figures 4-3 through 4-5. These are defined as:

1. In order to have the capability of a "once-around" orbiter abort, there must be at least 1000 feet per second ΔV propulsion available. This requires 20,000 pounds of OMS propellant.

2. The orbiter bay has a structural limit of 65,000 pounds of payload. Therefore, no payloads above 65,000 pounds are permissible, regardless of the ΔV capability.

3. The orbiter has a design landing rate of sink requirement of 10 feet per second. This, in turn, imposes a landing weight limit on the total orbiter vehicle which results in a limitation on the "down" payload weight for certain cases (particularly the due east launch, 28.5 degrees).

As previously mentioned, in order to maintain attitude, the orbiter utilizes propellant from the OMS/ACPS propulsive ΔV tanks. Figure 4-6 provides a means of computing the amount of propellant needed to achieve various attitude deadbands used in this analysis.

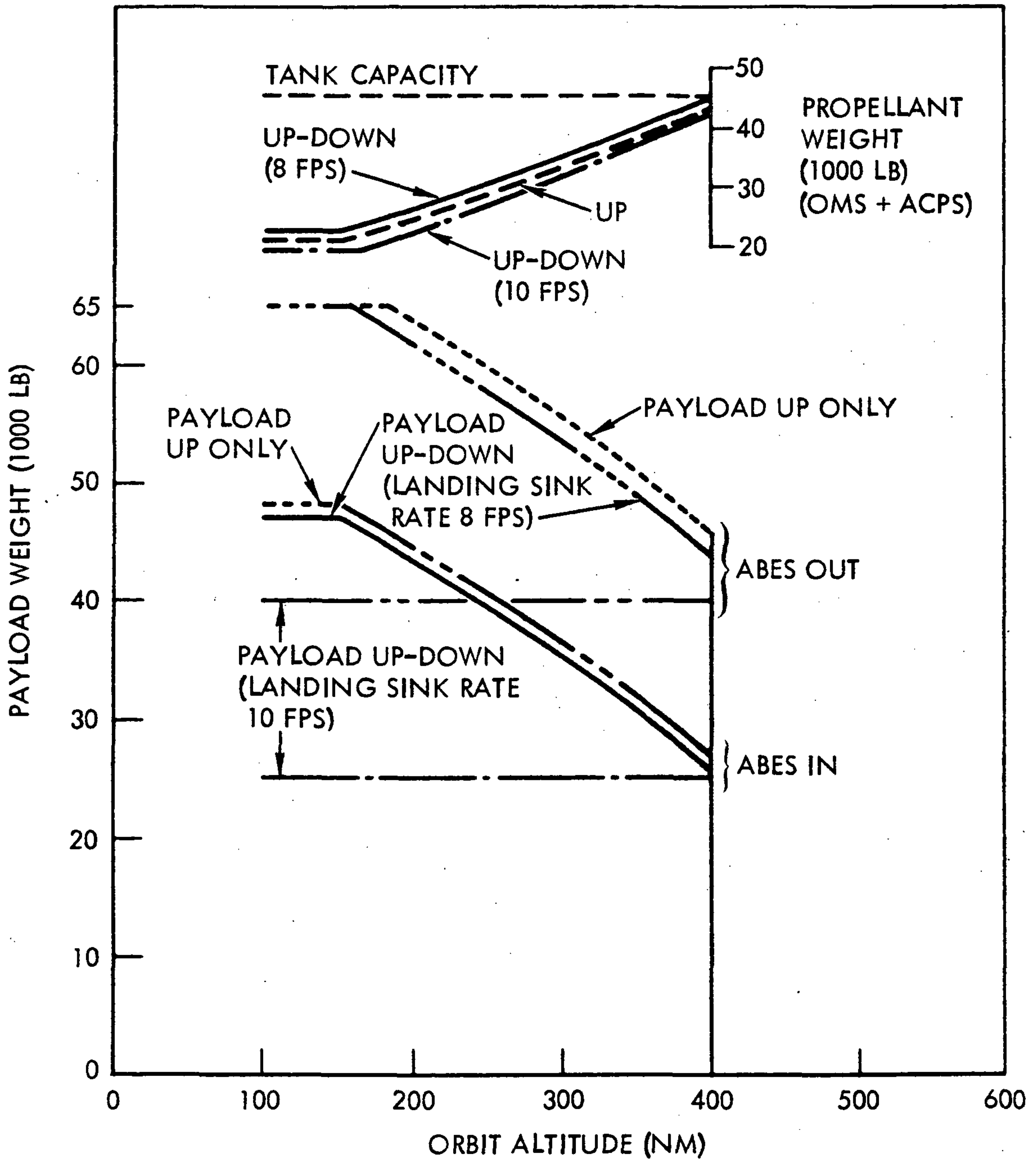


Figure 4-3. Payload Capability-Propellant Requirements: 28.5° Inclination Angle

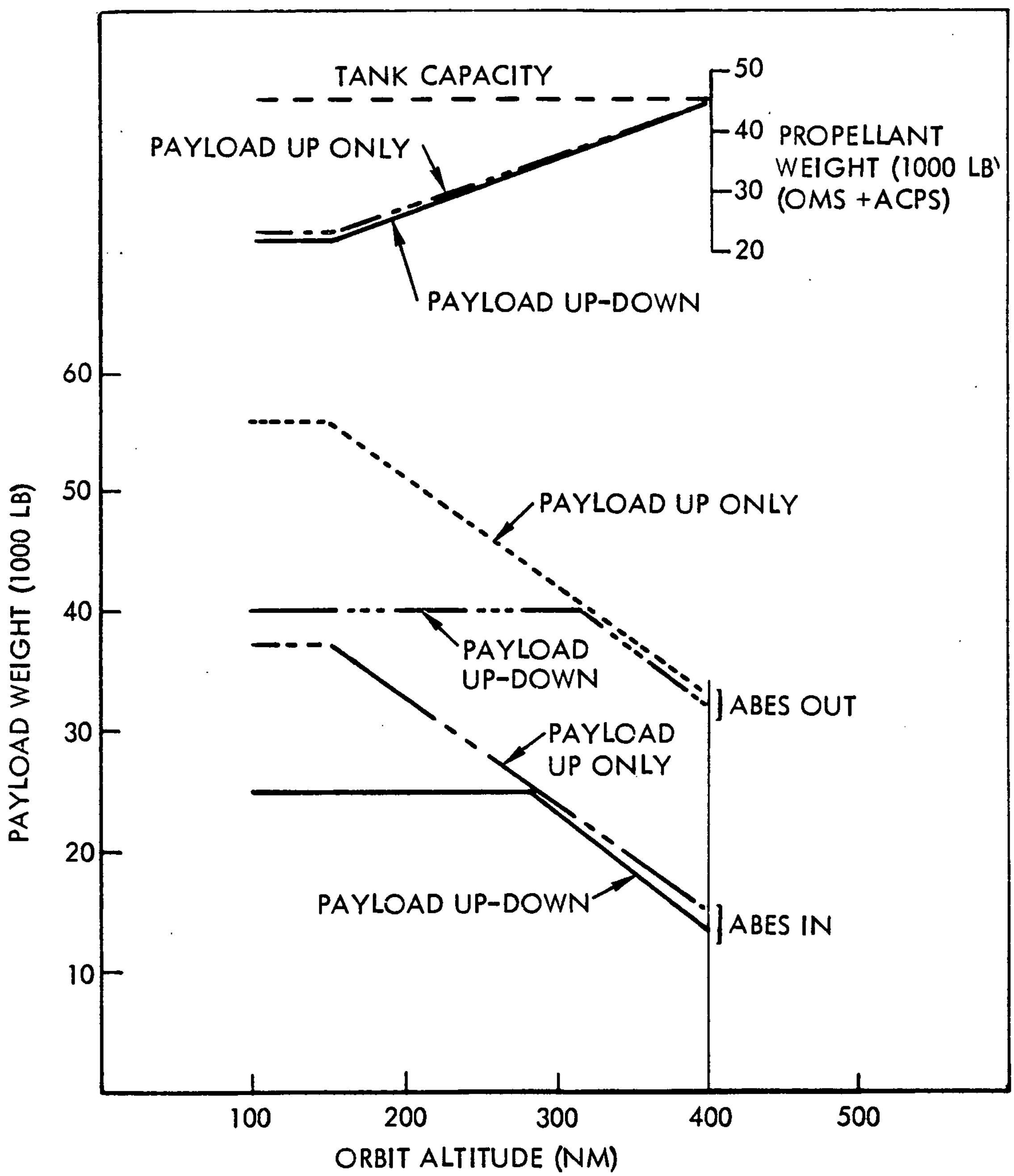


Figure 4-4. Payload Capability-Propellant Requirements: 55° Inclination Angle

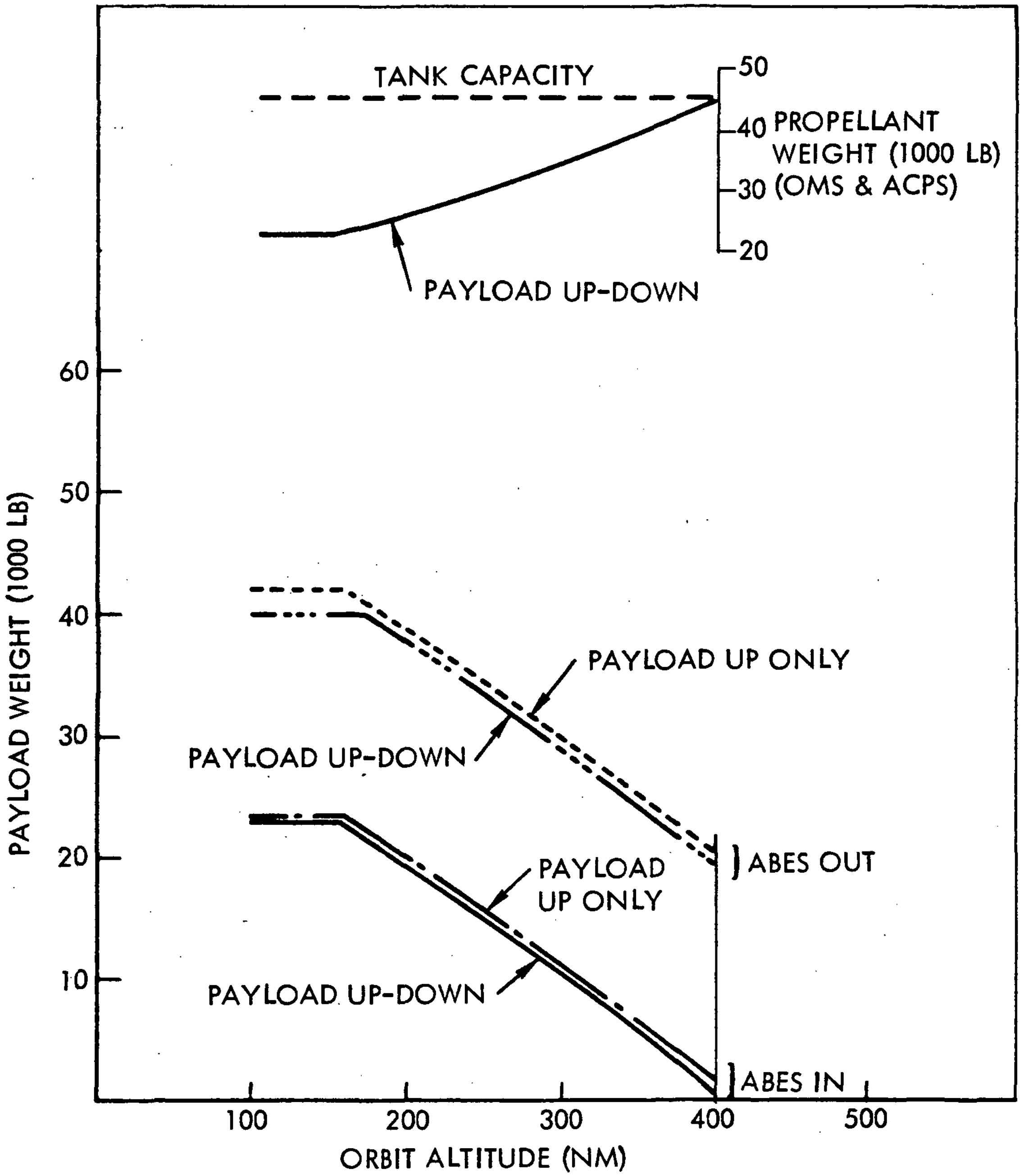


Figure 4-5. Payload Capability-Propellant Requirements: 90° Inclination Angle

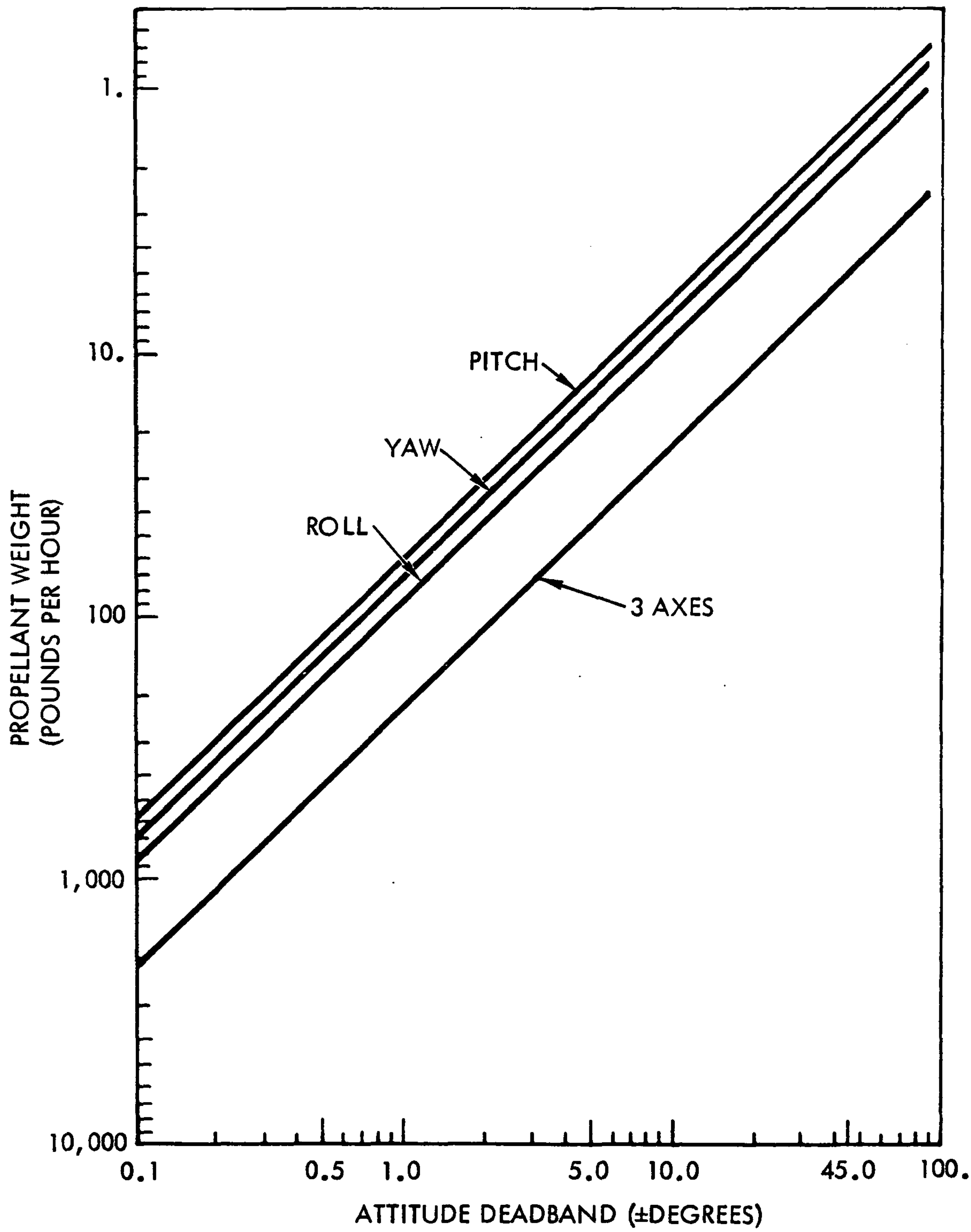


Figure 4-6. Attitude Hold, ACPS Propellant Requirement

Sortie Payload Analysis Results

Using the foregoing data, it was found that not all of the initially selected payloads were compatible with the shuttle's payload capability, hence a second iteration was required. Table 4-7 presents the results of this second iteration and indicates the payloads in which modifications to their requirements were made. During this process each payload's support requirements were better defined, hence in many cases a different weight margin between the first and second iteration will be noted.

The characteristics of the selected sortie payloads resulting from this analysis are presented in Tables 4-8 and 4-9.

EXPERIMENT PROGRAM

The selected sortie payloads are organized here for the purpose of developing a time-phased experiment program. The first step in this process is the establishment of rules that will govern the scheduling order, plus the adoption of guidelines for assigning payloads to particular shuttles.

The first rule adopted was that the sortie missions would not be initiated until after 12 shuttle R&D flights. Figure 4-7 indicates the availability of the orbiters as they are delivered to flight test and the period during which the R&D flights are conducted. It will be noted that the sortie missions are started about one month prior to the twelfth R&D flight.

The second rule adopted was that 30-day missions would not be flown until after one year of operations with 7-day flights. This recognizes the plan that orbiters will initially be delivered without the 30-day duration kit, thereby necessitating installation of the kits as a ground modification. The rule provides an interval to accomplish this work on a non-interference basis with the routine turnaround maintenance.

Experiment priorities were set equal to those established for the space station study based on a system for evaluating "worth, benefit, and rank". The priority for scheduling payloads follows the order of the highest ranking experiment within a payload. Tables 4-10 and 4-11 identifies these priorities for the various FPE's. For example, payload No. 1 is rated as priority two because this is the priority of ES-1-III. The tables also show the number of flights required to satisfy each experiment objective.

The experiment evaluation system is discussed in Volume III, Experiment Analyses (SD 71-217-3) of the MSS Preliminary Systems Design report.

Table 4-7. Payload Summary

Payload No.	* Weight Margin (lb)		Second Iteration Remarks
	Old	New	
7M-1	-10,000	+8640	Reduced inclin 90° to 55°
7M-2	-12,000	+143	Changed orbit from 300 - 500 n.mi circ to 80 x (100 - 500) ellip.
7M-3	-5700	+4750	Reduced inclin 70° to 55° Eliminated P-1-I from payload
7M-4	+27,000	+32,219	
7M-5	+39,000	+35,309	
7M-6	+20,000	+18,740	
30M-1	-3000	+4290	Reduced inclin from 70° to 55°
30M-2	+29,000	+21,849	
30M-3	+16,000	+2799	
30M-4	+27,000	+16,929	
30M-5	+12,000	+379	
30M-6	-4000	+523	Reduce struct. weight (radiation) Reduce alt. 270 n.mi.to 220 n.mi.
30M-7	-8000	+4529	Reduce struct. weight (radiation) Reduce alt, 250-360 n.mi.to 250 n.mi.
30M-8	+12,000	+1169	
30M-9	+10,000	+1490	
30M-10	+25,000	+5389	
30M-11	-	+1453	

*Note: Weight margin is the difference between the shuttle's payload capability and the payload weight

Table 4-8. Selected Sortie Payloads - 7-Day Sortie Missions

Payload No.	Experiment Package	Inclination (deg)	Altitude (n. mi.)	Crew Size
7M-1	Earth observation Contamination technology	55	100- 300	2
7M-2	Contamination technology Space physics	90	80x100/500	2
7M-3	Earth observation Advanced spacecraft systems tests Contamination technology	55	100	2
7M-4	Materials science	28-1/2	200	2
7M-5	Plant growth	28-1/2	100	3
7M-6	Plasma physics	55	270	2

Table 4-9. Selected Sortie Payloads - 30-Day Sortie Missions

Payload No.	Experiment Package	Inclination (deg)	Altitude (n. mi.)	Crew Size
30M-1	Earth observation Contamination technology	55	100	2
30M-2	Space physics Physics and chemistry	28-1/2	200	2
30M-3	Fluid management	28-1/2	300	2
30M-4	Medical research bioscience Life support Man systems	28-1/2	100	3
30M-5	X-ray Stellar Astronomy	28-1/2	400	2
30M-6	Advanced Solar Astronomy	Sun Synch	220	2
30M-7	Intermediate UV Telescope	28-1/2	250	2
30M-8	High-Energy Stellar Astronomy	28-1/2	400	2
30M-9	Infrared Astronomy	55	270	2
30M-10	Cosmic Ray Physics	28-1/2	200	2
30M-11	Communications	55	150	2

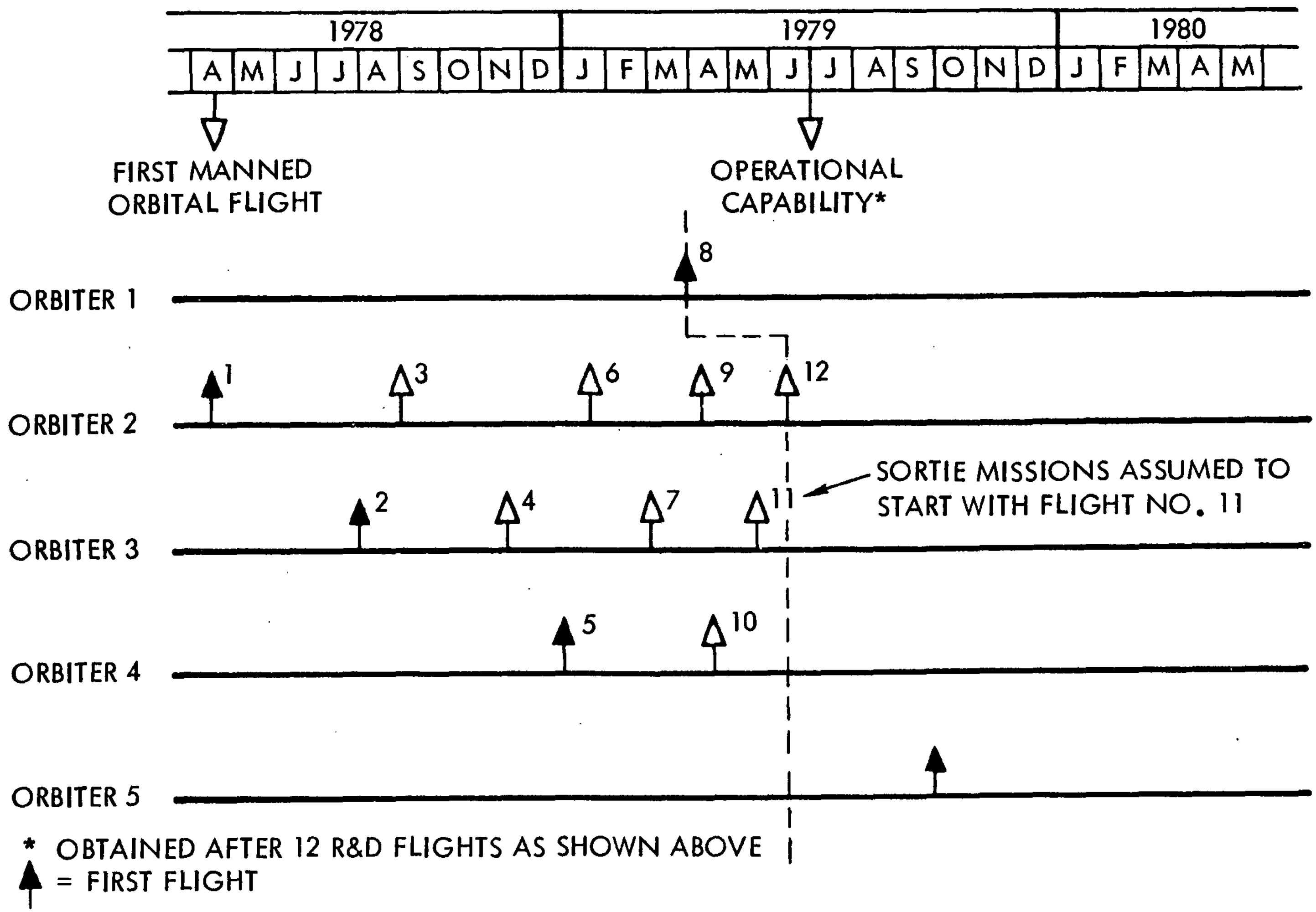


Figure 4-7. Shuttle Delivery and R&D Flight Schedule

Table 4-10. Payload Priorities - 7-Day Missions

Payload ID	Experiment Package	Title	Priority	No. Flights Required
1	ES1-III	Earth observations	2	28
	T1-I	Contamination technology	25	5
2	P1-I	Space physics	6	1
	T1-I	Contamination technology	25	1
	C/N1-I	Search navigation & RF propagation	7	1
3	ES1-II	Earth observation	2	28
	T1-I	Contamination technology	25	5
	T4-I	Advanced spacecraft systems test	8	8
4	MS-1-III	Materials science	7	18
	LS-3-II	Plant growth transients	14	5
5	LS-4-II	Cells and tissues	14	5
	T3-I	EVA	12	2
6	P2-I	Plasma physics	1	4
	P2-II	Plasma physics	1	4

Table 4-11. Payload Priorities - 30-Day Missions

Payload ID	Experiment Package	Title	Priority	No. Flights Required
1	ES1-I	Earth observations	2	15
	T1-II	Continuous technology	1	2
2	P1-II	Space physics	6	1
	P4-I	Physics & chemistry	1	2
	T2-I	Fluid management	29	2
3	T2-II	Fluid management	29	2
	T2-III	Fluid management	29	2
	LS-1-I	Medical research	4	8
4	LS-45-I	Biosciences	14	5
	LS-6-I	Life support	25	10
	LS-7-II	Man systems	11	3
5	A1-I	X-ray stellar astronomy	5	2
6	A3-I	Advanced solar astronomy	3	5
7	A4-I	Intermediate UV telescope	13	2
8	A5-I	High-energy stellar astronomy	5	6
9	A6-I	IR astronomy	9	5
10	P3-I	Cosmic ray physics	5	7
11	C/N1-II	Search navigation & RF propagation	7	4
	C/N1-III	Search navigation & RF propagation	7	1

The sequence of scheduling sortie flights (Figure 4-8) was to honor the priorities for two consecutive flights with the same payload on the same orbiter and then rotate through the various disciplines to achieve some early returns in all disciplines. This procedure was found to accomplish a reasonably varied experiment program over the first six months of operations. A day or so spacing between shuttle launches would actually occur, although the time scale of the chart makes it appear concurrent in some places.

When possible, payload-orbiter associations were repeated in case some peculiar interfaces between payload and shuttle should develop.

It was assumed that two shuttles might be dedicated to space station support; this was reflected in Figure 4-8 as alternating periods of buildup flight and rescue standby for Orbiters 1 and 2 starting in mid-1981.

Distribution of new skills over the sortie experiment program are shown by quarterly requirements in Table 4-12. This chart gives a broad indication of the training schedule requirement for the various crew skills.

The sortie experiment program schedule is summarized in Figure 4-9. Up to the time of initial space station IOC, a total of 84 seven-day and 33 thirty-day missions are accomplished. Sixty percent of these are conducted for the earth observations discipline. Table 4-13 totals the amount of mission time realized by each of the experiment disciplines.

Table 4-12. Crew Skills Utilization

Crew Skill	1979			1980				1981			
	2	3	4	1	2	3	4	1	2	3	4
1. Biological technician		X	X			X		X	X	X	X
2. Microbiological technician						X		X	X	X	X
3. Biochemist		X	X								
4. Physiologist											
5. Astronomer/astrophysicist		X			X		X	X	X	X	X
6. Physicist	X	X	X			X	X			X	X
7. Nuclear physicist							X	X	X	X	X
8. Photo technician/cartographer		X	X	X	X	X	X				
9. Thermodynamicist		X	X	X		X	X				
10. Electronic engineer		X						X	X	X	X
11. Mechanical engineer		X				X		X	X	X	X
12. Electromechanical technician	X	X	X	X	X	X	X	X	X	X	X
13. Medical doctor						X					
14. Optical technician								X	X	X	X
15. Optical scientist								X	X	X	X

Table 4-12. Crew Skills Utilization (Cont)

Crew Skill	1979			1980				1981			
	2	3	4	1	2	3	4	1	2	3	4
16. Meteorologist										X	X
17. Microwave specialist		X						X	X	X	X
18. Oceanographer										X	X
19. Physical geologist	X			X	X	X	X	X	X		
20. Photo geologist						X		X	X	X	X
21. Behavioral scientist											
22. Chemical technician						X		X	X	X	X
23. Metallurgist		X	X	X	X						
24. Material scientist		X	X	X	X						
25. Physical chemist						X	X				
26. Agronomist							X	X	X		
27. Geographer				X	X	X	X				

Table 4-13. Discipline Mission Time

	Number of Flights		Number of Days on Orbit
	7 Days	30 Days	
Astronomy	0	20	600
Physics	5	9	305
Earth observations	56	15	842
Material sciences	18	0	126
Communications navigation	1	4	127
Technology	16	4	232
Life sciences	5	10	335

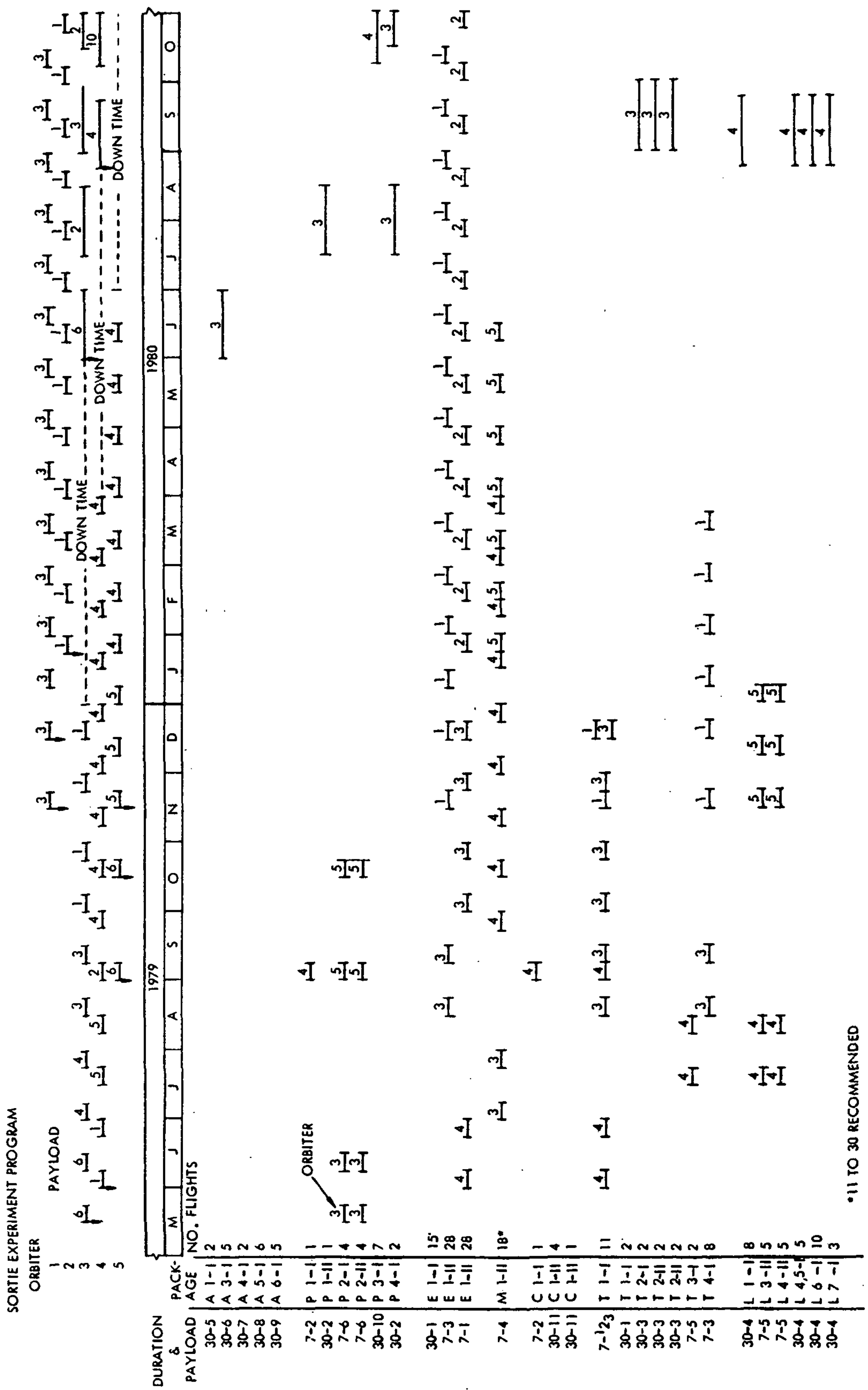


Figure 4-8. Sortie Schedule (Sheet 1 of 2)

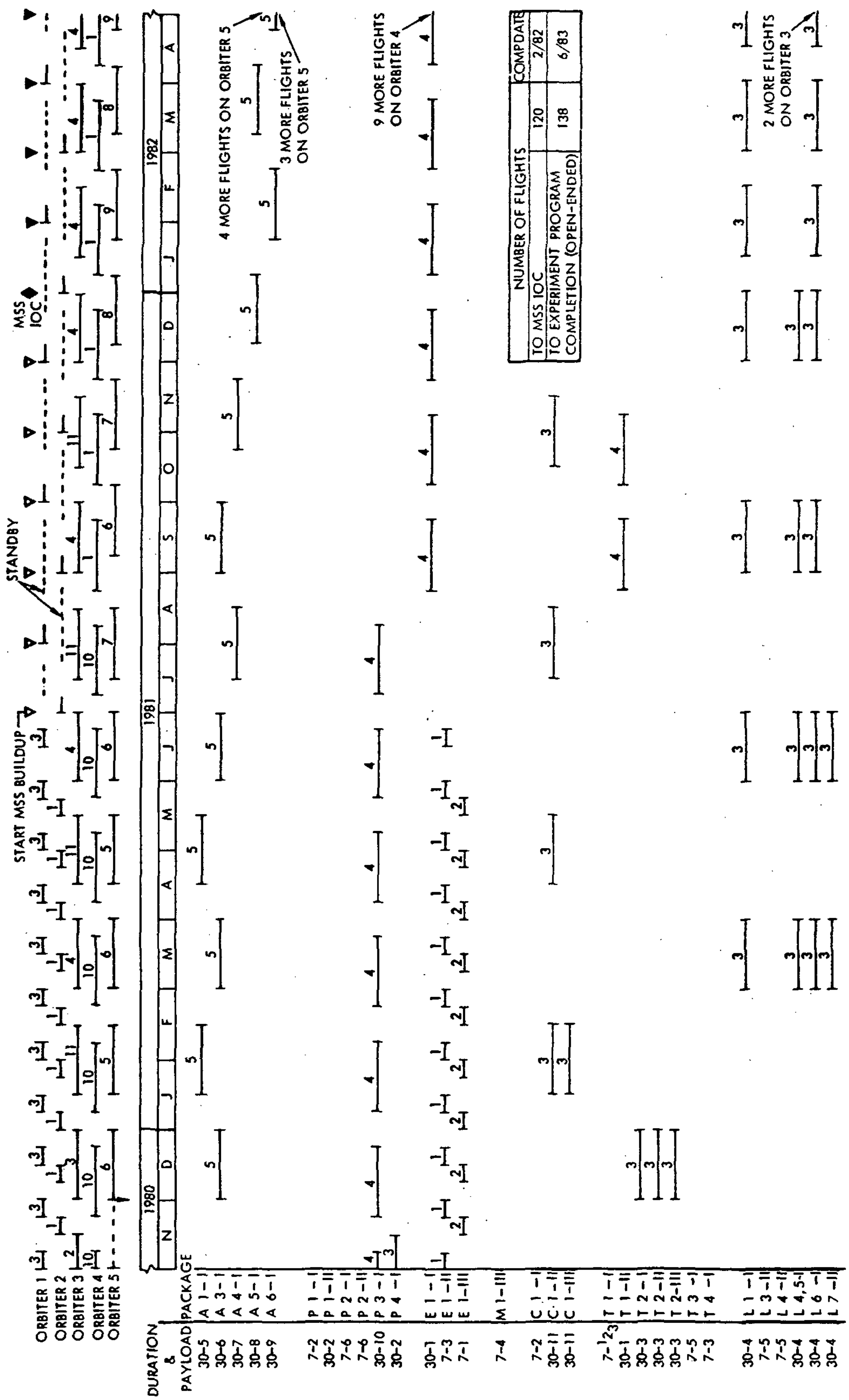


Figure 4-8. Sortie Schedule (Sheet 2 of 2)

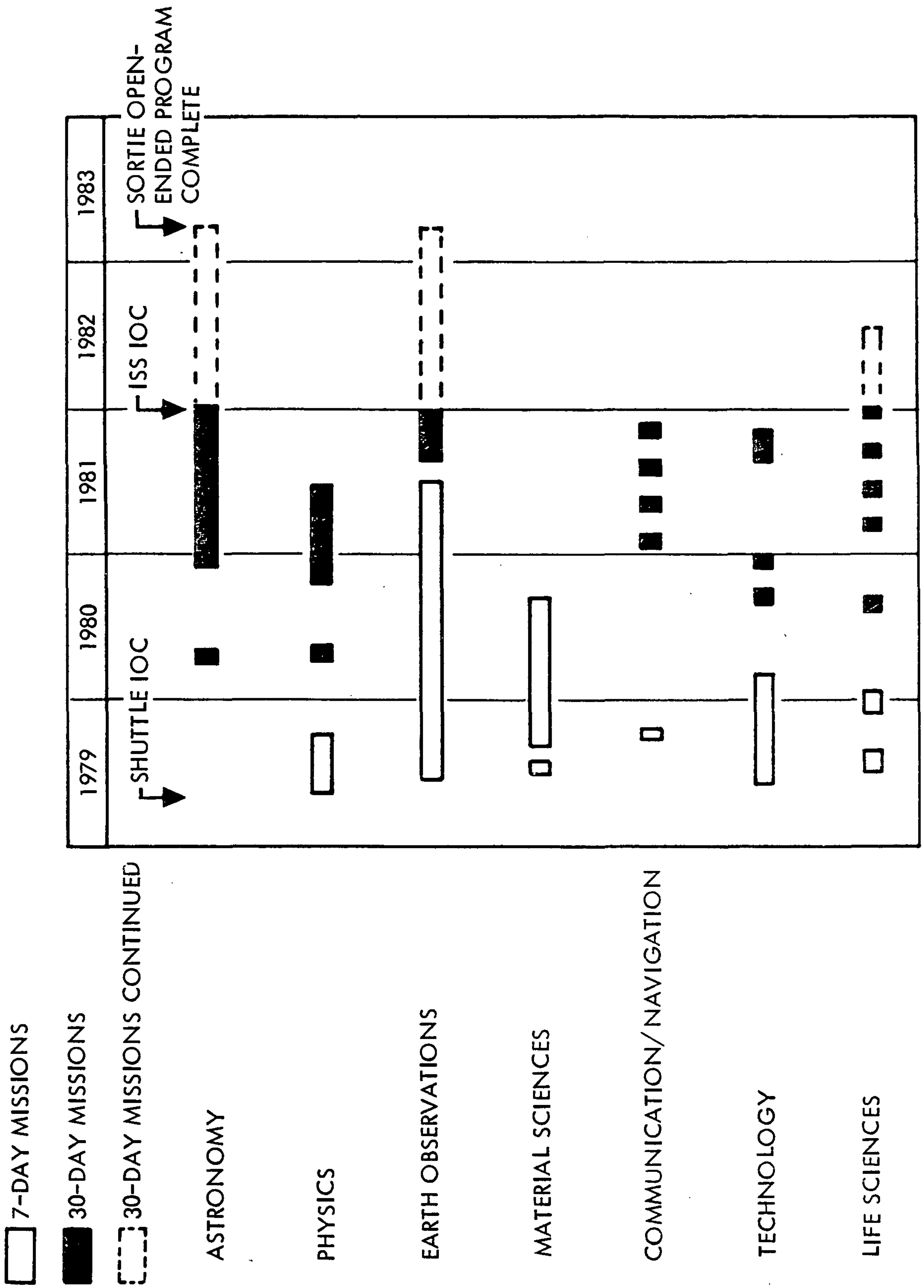


Figure 4-9. Sortie Distribution by Discipline

5. SUBSYSTEM ANALYSIS

This section presents the results of the sortie support subsystem analysis. In the subsystem concept selection process, the main theme was to satisfy sortie payload requirements with a minimum cost impact on the program. As a result, emphasis was placed on commonality between sortie support subsystems and shuttle orbiter or space station equipment. Support subsystem analyses and trades commenced with the identification of sortie payload requirements and terminated with concept selection definition and subsystem characteristic description for the following subsystems: electrical power (EPS), environmental control and life support (ECLSS), information (ISS), and guidance and control (G&C).

ELECTRICAL POWER SUBSYSTEM

A number of payloads were considered in the analysis. Various experiment combinations were iterated until a final list of payloads could be selected. The electrical requirements for combinations constituting final payloads are shown in Table 5-1. Total support requirements size the electrical power subsystem. The average power level required ranges from 720 to 4290 watts for the 7-day sorties and 760 to 1720 watts for 30-day sorties. A major electrical power support requirement is the ISS power for data support.

Present Phase B shuttle definitions limit available electrical energy for payloads to 20 kilowatt-hours and an average power level of 500 watts (800 watts peak). This is not sufficient to permit payloads support. Further study of shuttle power loads, reactant supply, and fuel cell capability showed that for 7-day missions more power can be made available to support payloads. This resulted in a new definition at 5.24 kilowatts based on data shown in Figure 5-1. A constraint of two fuel cells operating is assumed, with basic powered-down shuttle housekeeping loads set at 4.1 kilowatts, an additional 2.37 kilowatts required to power up shuttle subsystems, and 2.0 kilowatts required for thermal control. Assuming two fuel cells capable of providing 14.0 kilowatts, the new load profile gives a balance of 5.24 kilowatts for payload, accounting for losses. Additional fuel cell reactant will be charged to the payload.

Trades

The trade tree options for electrical power source are shown in Figure 5-2. Free flyers were eliminated from this study effort; therefore,

Table 5-1. Electrical Power Support Requirements

Payload Number	Duration (Days)	Experiment Requirements: 24 Hour Energy (KWH)	Experiment Requirements: Maximum Sustained (KW)	Experiment Requirements: Peak (KW)	Total Support Reqmt*: 24 Hour Energy (KWH)	Total Support Reqmt*: Avg. Power (KW)	Total Support Reqmt*: Peak Power (KW)	Comments
7M-1	7	5.5	1.9	2.0	37.2	1.55	4.55	
7M-2	7	37.6	2.0	2.8	67.2	2.80	5.18	
7M-3	7	54.0	3.5	3.5	79.5	3.32	5.70	
7M-4	7	71.0	5.0	5.0	103.0	4.29	7.35	6.54 KW Peak (2 Fuel Cells)
7M-5	7	3.05	0.33	0.37	17.3	0.72	1.14	
7M-6	7	9.0	0.25	0.75	28.8	1.20	2.61	
30M-1	30	5.64	1.04	1.04	24.5	1.02	2.26	
30M-2	30	16.56	1.14	4.0	29.3	1.22	5.35	
30M-3	30	17.3	1.3	4.0	41.3	1.72	5.64	
30M-4	30	1.92	0.19	0.30	26.4	1.10	1.40	
30M-5	30	4.8	0.283	0.283	23.7	0.99	1.79	
30M-6	30	8.6	0.72	0.91	27.6	1.15	2.39	
30M-7	30	4.8	0.30	0.30	26.6	1.11	1.87	
30M-8	30	1.6	0.065	0.19	28.5	1.19	2.56	
30M-9	30	5.5	0.30	0.30	32.4	1.35	2.10	
30M-10	30	13.2	0.55	0.70	36.7	1.53	2.58	
30M-11	30	2.5	0.65	0.70	18.2	0.76	2.32	

*Includes supporting subsystem requirements for ISS, ECLSS and G&C.

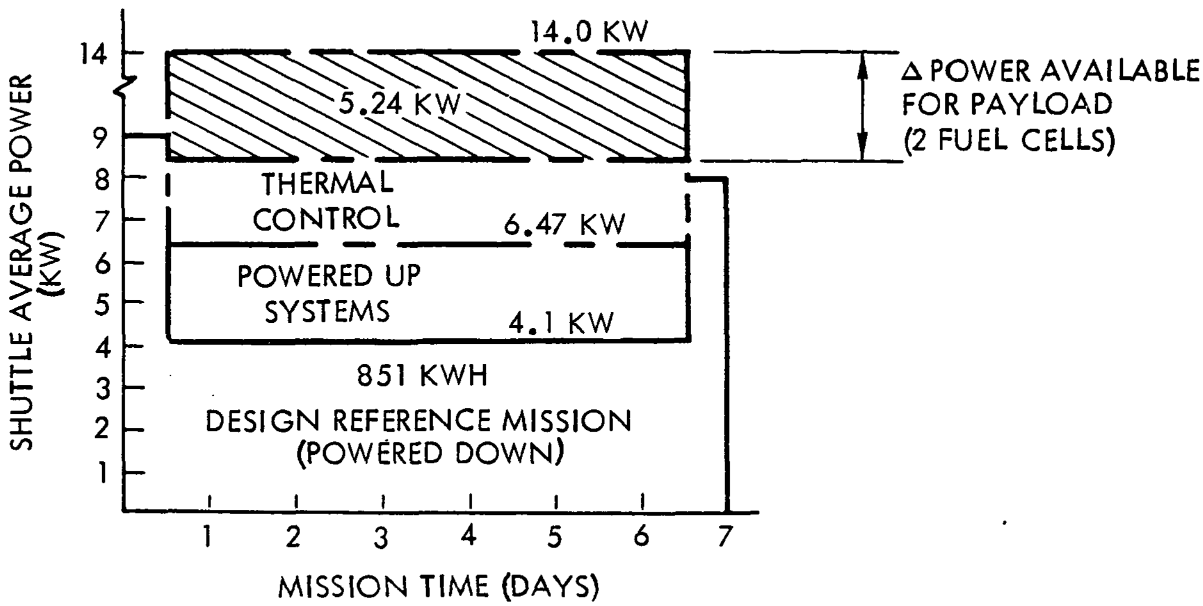


Figure 5-1. Shuttle Power Availability

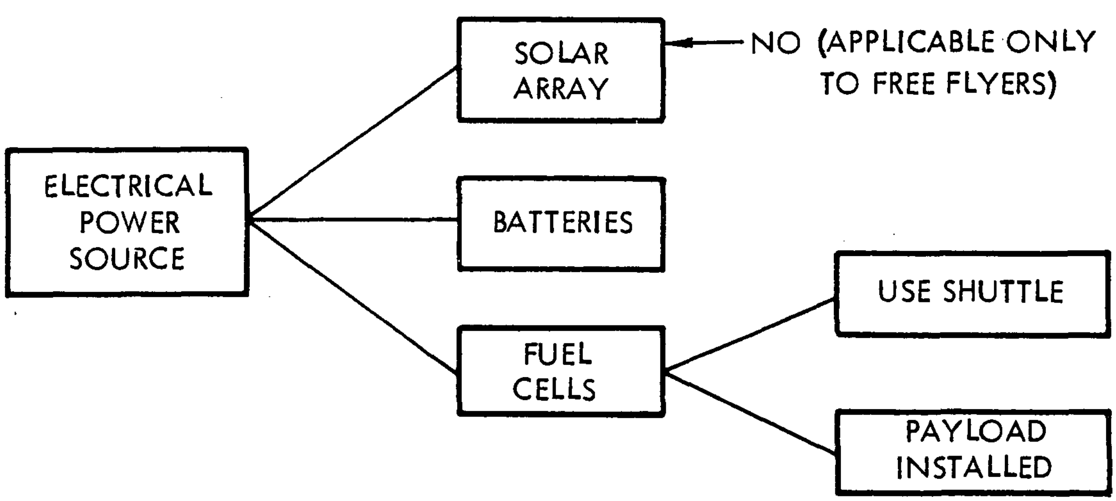


Figure 5-2. EPS Trade Tree

only fuel cells and batteries were viable options (i.e., no solar arrays). Major consideration was given to the comparison between using shuttle fuel cells versus supplying separate payload fuel cells. The power requirements for all payloads are within the available power profile of Figure 5-1. The definition of available shuttle power is conservative because it assumes only two fuel cells operating. Separate power sources for the payload will result in more weight and cost; however, it does minimize the shuttle-payload interface. The definition model of Figure 5-1 includes an oxygen storage capability of 200 pounds by the shuttle without additional tank penalty to the payload. This means that if the payload provides hydrogen storage capability of 22.2 pounds plus the reactants, the shuttle can supply 247 kilowatt-hours at a weight penalty of:

Hydrogen	22.2 pounds
Hydrogen tank	66.5 pounds (at 3 pounds per pound of H_2)
Oxygen	200.0 pounds
Oxygen tank	0
Subtotal	288.7 pounds or 858 watt-hr/pound

Primary batteries typically achieve 40 to 80 watt-hours per pound. Adding fuel cells to the payload penalizes the subsystem by about 35 pounds per kilowatt.

MSS Subsystem Comparison

The MSS electrical subsystem is a 120/208-volt ac, 3-phase, 400-Hertz distribution design. Shuttle design (NR) calls out a low-voltage 28-volt dc design. The sortie power conditioning and distribution selection will be made on the basis of minimum cost and will utilize commonality to a maximum extent. If commonality with MSS is to be achieved the sortie would be a basic 120/208-volt ac system.

Selection

Energy requirements for sorties exceed the point where batteries can be considered as the primary energy source (Table 5-2) with possible exception of some 7-day sorties (e.g., 7M-1, -5, and -6). Batteries may be considered for peaking and to supplement shuttle fuel cells if heat rejection constraints limit available power below payload requirements.

Based on weight, it was decided to utilize shuttle maximum available power for all experiment payloads compatible with Figure 5-1. All of the payloads can be met within this definition by using shuttle power. Peak power requirements of 7M-4 will exceed the two-fuel cell case requiring more consideration being to utilizing three fuel cells or supplementary

Table 5-2. Battery—Fuel Cell Weight Comparison

Payload Identification	Total Energy (KWH)	Weight Comparisons (Pounds)								
		Primary Batteries	Cryo Weight		No. Tanks		Tank Weight		Total F/C Weight Penalty
			Oxygen	Hydrogen	Oxygen	Hydrogen	Oxygen	Hydrogen	
7M-1	186	3,090	232	29	1	1	80	80	421
7M-2	336	5,600	418	52.3	1	2	80	160	710
7M-3	397	6,600	496	62	1	3	80	240	878
7M-4	515	8,550	640	80	2	3	160	240	1120
7M-5	86.5	1,440	107	13.4	0	1	--	80	200
7M-6	144	2,400	178	22.3	0	1	--	80	280
30M-1	735	12,200	435	54.5	2	2	160	160	810
30M-2	880	14,600	622	78	2	3	160	240	1100
30M-3	1240	20,600	1102	138	4	5	320	400	1640
30M-4	792	13,150	702	88	2	3	160	240	1190
30M-5	710	11,800	632	79	2	3	160	240	1110
30M-6	828	13,800	731	91.5	3	3	160	240	1233
30M-7	798	13,300	724	90.5	3	3	240	240	1305
30M-8	855	14,200	762	95	3	4	240	320	1417
30M-9	975	10,200	867	108	3	4	240	320	1535
30M-10	1100	18,300	989	111	3	4	240	320	1660
30M-11	547	9,100	485	60.5	2	2	160	160	866

peaking power capability by primary batteries. A standard payload to shuttle power and control interface will be defined. A 28-watt dc shuttle fuel cell output will require additional power conditioning. Since the payload requires high power transfer, it is felt that this conditioning should be done at or near the shuttle fuel cells. The EPS weight and volume characteristics are summarized in Table 5-3, which also presents the ground rules and assumptions which were employed.

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM

The environmental control and life support subsystem (ECLSS) provides a habitable environment for crew and equipment by providing oxygen and nitrogen (gaseous storage), carbon dioxide removal (CO_2 management), temperature-humidity-contaminate control (atmospheric control), heat rejection (thermal control), crew water (water management), a toilet (waste management), handwashing units and towels (hygiene), food (food management), and fire control (special life support).

Approach and Analysis

Three approaches could be taken in designing the sortie ECLSS:

1. Design a separate sortie ECLSS independent of the shuttle.
2. Utilize the shuttle ECLSS and add delta assemblies to the sortie as required.
3. Utilize the shuttle ECLSS and add expendables as required.

Before a decision could be made, the capacity of the shuttle had to be investigated. The shuttle ECLSS basically can handle four men, though certain functions can be stretched to handle five men. The shuttle, according to the guidelines of this study, is responsible only for the consumables for two men for seven days. However, the shuttle has enough volume for four men and seven days.

With these data, the approach in designing the sortie ECLSS could be determined. First, only the atmospheric control and thermal control functions are sensitive to configuration and heat load. All other functions are crew-sensitive. Therefore, a combination of Approaches 2 and 3 was utilized, and two major factors were discovered. First, the shuttle atmospheric control can handle a maximum of only five men (humidity control exchanger). This forced the various sortie payloads to limit the crew to five men (2 crew plus 3 experimenters), with a tendency not to exceed four unless absolutely required. The second factor involved power loads and the resultant heat rejection requirements. First, the shuttle's heat rejection

Table 5-3. EPS—Sortie Weight and Volume Characteristics

Payload	Power Conditioning		Cryo Tanks	
	Weight (lb)	Volume (ft^3)	Weight (lb)	Volume (ft^3)
7M-1	200	5	160	14
7M-2	200	5	240	19
7M-3	240	6	320	26
7M-4	320	8	400	31
7M-5	45	1	80	7
7M-6	110	3	80	7
30M-1	90	3	320	24
30M-2	220	6	400	31
30M-3	200	5	720	55
30M-4	60	2	400	31
30M-5	60	2	400	31
30M-6	100	3	480	36
30M-7	80	2	480	36
30M-8	110	3	560	43
30M-9	90	3	560	43
30M-10	110	3	560	43
30M-11	100	2.5	320	24

(1) Power conditioning is based on 40 lb/kWe with 40% of the weight allocated to wiring (volume estimates do not include wiring).

(2) Payloads 7M-1 through 7M-6 assume 200-lb oxygen storage capability provided by shuttle with no additional tank penalty (not applicable to 30M-1 through 30M-11).

(3) Cryo tanks utilize standard tanks:
Oxygen tanks = 80 lb (5 ft^3 @ 350 lb capacity)
Hydrogen tanks = 80 lb (7 ft^3 @ 30.8 lb capacity)

capacity is sized for the shuttle orbital loads and not additional large experiment loads. Also, the shuttle must rely on water boiling for large heat rejection loads and some experiments cannot tolerate water in the space environment when they are operating. Therefore, the payload's thermal loop was made separate from the shuttle. This decision influenced experiment packaging in order to avoid large radiator requirements.

The various proposed experiments for the sortie missions are compiled in Table 5-4 with their required heat rejection, tentative thermal control concepts, and number of men required. The information in Table 5-4 was used to generate Figure 5-3. The data in Table 5-4 and Figure 5-3 were used as one of the inputs in determining how to group the various experiment packages into the various sortie payload modules. The basic assumption used to generate the parametric weights and heat rejection rates in Figure 5-3 and Table 5-4 were:

1. The shuttle is responsible for intermittent manning heat loads.

2. Constantly manned experiments are penalized for man's metabolic heat load.

3. To obtain a reasonable metabolic sustainedheat load, the maximum number of men times the average metabolic heat generation rate of 496 Btu/man-hour was used.

4. Sustained peaks (loads greater than 1 hour) were utilized.

5. Radiators reject 35 Btu/hour-feet^2. It was assumed that the various orbital parameters have negligible effects on weight. However, radiator area is affected by several orbital parameters. Note that this assumption applies only to experiment packages in Table 5-4 and Figure 5-3.

6. All normally unattended experiments can use a single Freon radiator concept instead of a dual loop water-Freon concept. Continuously manned experiments will utilize the dual loop water-Freon concept.

7. Three experiments—P3-I, CNI-I, and CN1-III—can be passively cooled. The low heat rejection rates may require no thermal control penalty depending on the size and orbit of the module.

8. The assumed temperature ranges are 40 to 80 F for all experiments. No data for actual temperature ranges are available.

Table 5-4. Heat Rejection Rates

Experiment ID Number	Heat Rejection Concept	Sustained Heat Rejection Btu/hr	Number of Men (Maximum)
A1-I	F[(1)]	967	-
A3-I	F	2,455	-
A5-I	F or P[(1)]	228	-
P3-I	F	1,875	
T4-II	F	649	
A4-I	F	1,095	
A6-I	F/W[(1)]	1,023	-
P1-I	F/W	6,953	3
P1-II	F/W	4,863	2
P2-I	F/W	341	-
P2-II	F/W	426	-
P4-I	F/W	2,270	3
ES1-I	F/W	4,534	2
ES1-II	F/W	6,764	3
ES1-III	F/W	6,290	2
MS1-III	F/W	18,548	3
T1-I	F/W or P	205	-
T1-I	F/W	2,253	-
T1-II	F/W or P	955	-
T1-I	F/W	2,221	2
T1-II	F/W	2,221	2
T2-I	F/W	5,431	2
T2-II	F/W	2,357	2
T2-III	F/W	1,127	2
T3-I	F/W	2,115	1 (+2)[(2)]
T4-I	F/W	14,939	4
LS1-I	F/W	1,661	3
LS3-II	F/W	1,046	1
LS4-II	F/W	1,094	2
LS4,5-I	F/W	1,164	2
LS6-I	F/W	3,163	5
LS7-II	F/W	1,042	2

NOTES: (1) F=freon, W=water, P=passive

(2) 1 man unsuited, 2 men suited so that metabolic load is removed by PLSS.

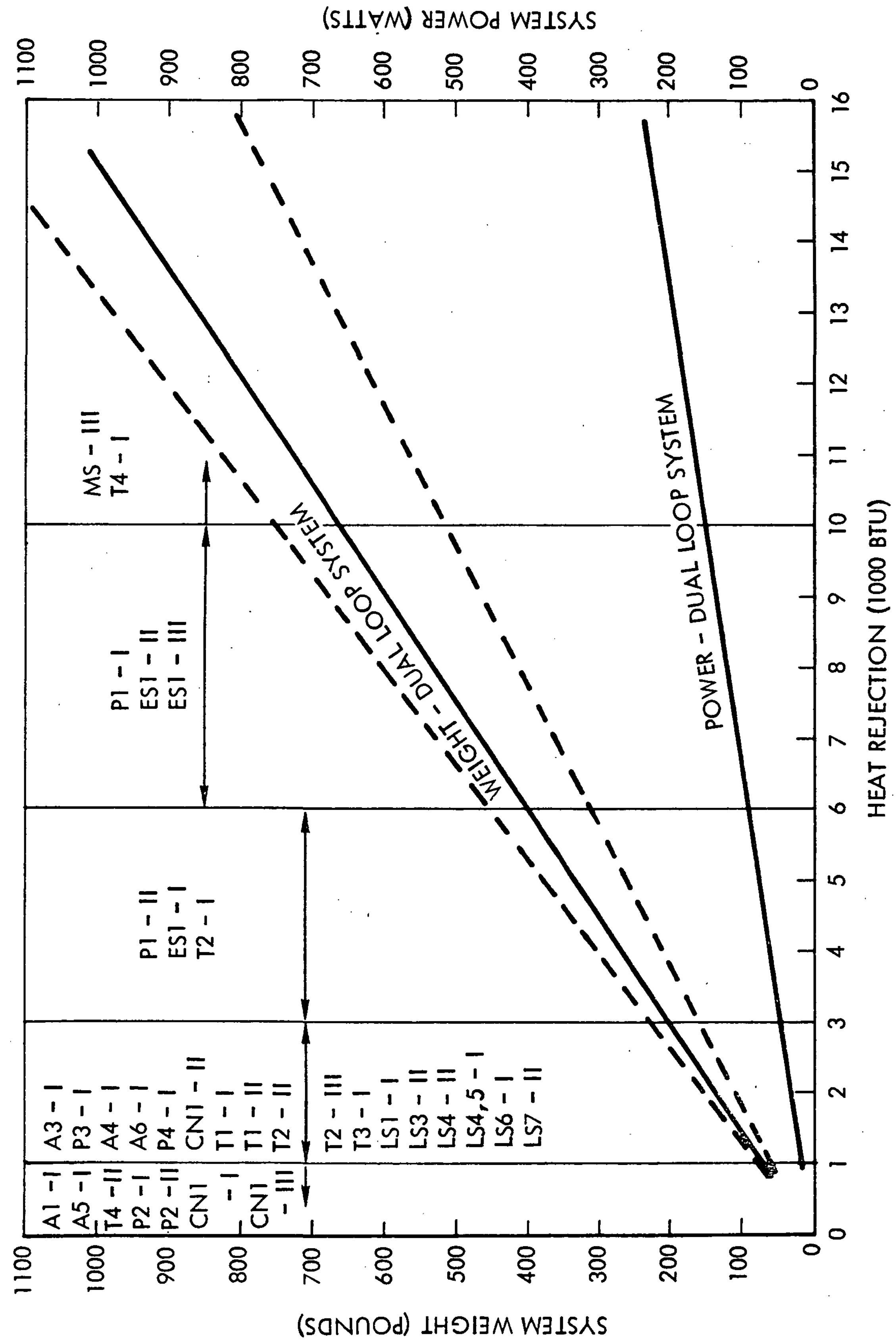


Figure 5-3. Thermal Control-Heat Rejection Characteristics

After the various sortie module payloads were defined, the radiator heat rejection was redefined as follows:

1. Near 3-° inclination - 35 Btu/hr-ft^2
2. Near 70° inclination - 50 Btu/hr-ft^2
3. Polar and sun synchronous - 100 Btu/hr-ft^2 with radiator always viewing deep space (on dark side of module)

These heat rejection values were assumed because normally for lower inclination orbits, the effects of the earth, sun, albedo, module placement, etc., are higher resulting in less heat rejection per square foot of radiator. The 35 Btu/hour-feet^2 was derived from an orbit and radiator location similar to the MSS. Table 5-5 lists the sortie payloads with their inclination and the heat rejection per square foot utilized to calculate radiator requirements. Note that sortie payloads are listed as well as the experiment packages which make up the sortie module payloads.

Also, after the experiments were regrouped into payloads, all had heat rejection requirements greater than 1,000 Btu/hour (≈ 300 watts). Therefore, it was assumed that the passive thermal control option could be discarded.

After the various experiment packages had been grouped into sortie module payloads and the crew size and thermal control concept selected, the ECLSS characteristics could be calculated. The following section covers the selected ECLSS concepts and characteristics.

Subsystem Selection and Description

The selected approach for the sortie ECLSS is to utilize the shuttle ECLSS and only provide expendables, atmospheric control ducting, and thermal control independent of the shuttle ECLSS. The following paragraphs cover the sortie ECLSS for shuttle sortie experiment operations. The sortie ECLSS assemblies discussed are:

1. Gaseous storage
2. CO_2 management
3. Atmospheric control
4. Thermal Control
5. Water management
6. Waste management

7. Hygiene*
8. Food management**
9. Special life support

Table 5-5. Sortie Payload Radiator Sizing Parameter

Sortie Payload	Experiment Packages	Orbital Inclination (Degrees)	Radiator Heat Rejct. (Btu/hr-ft^2)
7M-1	ES-1-III, T1-I	90	100
7M-2	P1-I, T1-I, C/N-1-I	90	100
7M-3	ES-1-II, T4-I, T1-I	55	35
7M-4	MS1-III	28 1/2	35
7M-5	LS-3-II, LS-4-II, T-3-I	28 1/2	35
7M-6	P-2-I, P-2-II	55	35
30M-1	ES-1-I, T-1-II	70	50
30M-2	P-1-II, P-4-I	28 1/2	35
30M-3	T-2-I, T-2-II, T-2-III	28 1/2	35
30M-4	LS-I-I, LS-4, 5-I, LS-6-I, LS-7-II	28 1/2	35
30M-5	A-1-I	0	35
30M-6	A-3-I	Sun Sync	100
30M-7	A-4-I	28 - 70	35
30M-8	A-5-I	0	35
30M-9	A-6-I	50 - 60	35
30M-10	P-3-I	28 1/2	35
30M-11	C/N-1-II, C/N-1-III	90	100

*Some of the items considered here are part of crew and habitability subsystems on shuttle and modular space station programs.

**On the shuttle program this assembly is part of the ECLSS; on the modular space station this assembly is part of the habitability subsystem.

Gaseous Storage

The shuttle provides oxygen and nitrogen for seven days of shuttle leakage and metabolic oxygen for two men for seven days. Thus, the sortie ECLSS must provide for metabolic oxygen for any crew above the two-man limit as well as the experiment module oxygen and nitrogen leakage for 7-day missions. For 30-day missions, metabolic oxygen for any crew above the two-man limit is provided as well as 23 days worth for the two-man shuttle crew. Thirty days of leakage oxygen and nitrogen is provided for the experiment module, and 23 days of shuttle leakage is provided. Table 5-6 presents the leakage rates.

Table 5-6. Metabolic and Leakage Rates

Item	Shuttle	Experiment Module
Metabolic oxygen (lb/man-day)	1.84	1.84
Leakage oxygen (lb/day)	1.86	0.233
Leakage nitrogen (lb/day)	6.85	0.767

Since the shuttle has no extra storage capacity for crew atmosphere quality oxygen, the sortie ECLSS will provide the additional supercritical oxygen and associated tankage. The experiment sortie ECLSS also will provide additional high-pressure (3000-psia) nitrogen and high-pressure nitrogen tank.

No pumpdown subassemblies or makeup gases are provided by the sortie ECLSS. Further definition of the experiment module will be required to determine pumpdown support. For now, it is assumed that the experiment payloads provide pumpdown or airlock gas makeup. Also, no contingency gas supplies have been provided.

CO_2 Management

For compatibility with the shuttle, the sortie ECLSS utilizes the LiOH for CO_2 removal. For the crew sizes which are equal to five persons, the four-man shuttle LiOH system is utilized with cartridges changed more frequently and slightly higher fan flow rates.

As in the gaseous storage assembly, the shuttle provides 14 man-days of LiOH cartridges. For the larger crews and longer missions additional

LiOH cartridges are provided by the sortie ECLSS. Note that the shuttle CO_2 production rate of 2.12 pounds per man-day was utilized in calculating the expendable. The modular space station uses a rate of 2.25 pound man-day.

Atmospheric Control

The shuttle has a condensing heat exchanger and sensible heat exchanger which are designed to accommodate four men. These two units can be stretched to accommodate five men. However, to cover experiment air loads, a small sensible heat exchanger was added to the sortie ECLSS for all payloads except 7M-1, 7M-2, and 7M-6.

Payloads 7M-1, 7M-2, and 7M-6 are pallet loads and because they are only 7 days duration no delta habitable volume exists and therefore the ducting, fans, and sensible heat exchanger were not required. The shuttle provides the necessary atmospheric control for the latent loads in all the payloads.

Since the shuttle and sortie module both perform temperature control, (except for 7M-1, 7M-2, and 7M-6) an interconnecting duct arrangement was required. Figure 5-4 illustrates the ducting arrangement. The shuttle return and supply ducts connect the sortie module duct work with the shuttle heat exchanger and condenser which in turn are connected to the CO_2 management (LiOH) assembly. Distribution ducting for circulation of the processed air is allocated to the experiment module. Four local ventilation fans are also provided.

Pressure control for all payloads is provided by the shuttle pressure control. (Thus, the sortie nitrogen tanks are plumbed into the shuttle nitrogen distribution lines.) Contaminant control is provided solely by the charcoal in the LiOH canisters.

Thermal Loop

The thermal loop is one of the few sortie ECLSS assemblies which is completely independent of the corresponding shuttle ECLSS assembly. Payloads 7M-1 to 7M-5, 30M-1 to 30M-4, and 30M-11 have an internal water loop and external Freon heat rejection loop. These loops, each sized for the specific payload, are identical in concept to that on the modular space station. Table 5-7 presents the heat rejection loads.

Radiator rejection rates are defined for the various inclinations in Table 1A.

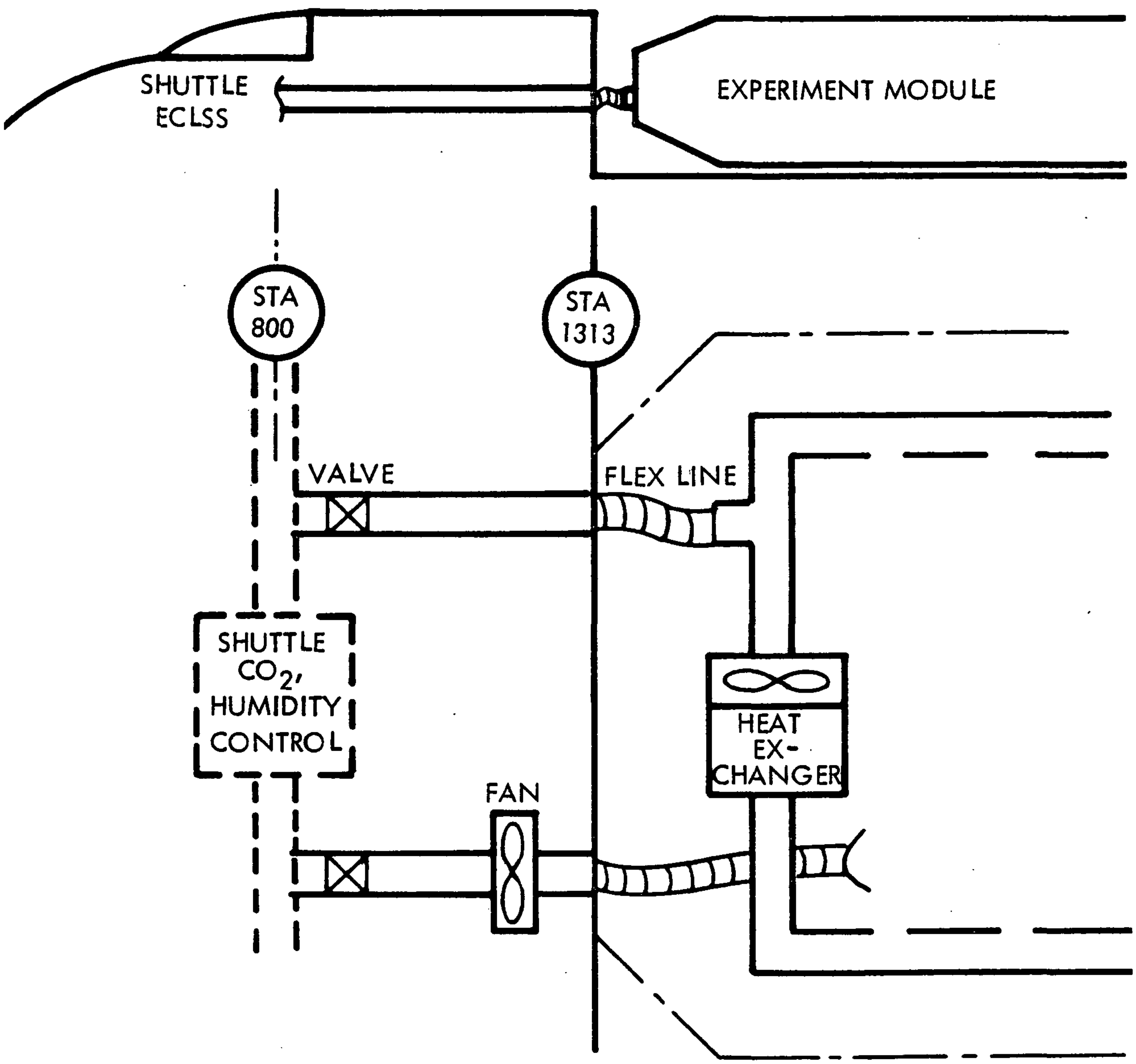


Figure 5-4. Sortie ECLSS Ducting

Table 5-7. Heat Rejection Loads Used to Size Thermal Control Assembly

Payload	Required Heat Rejection (Btu/hr)	Payload	Required Heat Rejection (Btu/hr)
7M-1	12, 942	30M-3	8, 234
7M-2	17, 372	30M-4	4, 832
7M-3	24, 222	30M-5	2, 570
7M-4	21, 254	30M-6	4, 099
7M-5	5, 275	30M-7	2, 661
7M-6	2, 031	30M-8	3, 092
		30M-9	2, 661
30M-1	9, 584	30M-10	4, 400
30M-2	8, 534	30M-11	5, 802

Payloads 7M-6 and 30M-5 to 30M-10 do not have a water-Freon thermal control subassembly. Since they are only infrequently manned, the water loop was eliminated to save weight. Only a Freon loop is utilized.

Note that since excess water is available (see following discussion on water management), there may be merit in connecting the shuttle water sublimator to the sortie thermal control loop through an interconnecting heat exchanger (and lines) if the sortie module radiator becomes too large.

Water Management

The shuttle water requirement is 6.25 pounds per man-day (compared to an equivalent MSS requirement of 6.54 pound per man-day. The shuttle fuel cells, at minimum load, produce 4 pound per hour of water and can range up to 14 pound per hour. Thus, for worse case, the daily water requirement for a five-man crew is produced in 8 hours. More than enough water is available. In addition, the shuttle water storage capacity of 360 pounds (fresh plus waste tank capacity) is more than sufficient. Therefore, no water hardware or expendables have to be stored by the sortie ECLSS. (However, the sortie EPS must store oxygen and hydrogen for the fuel cells.)

Waste Management

The shuttle waste management assembly consists of a vacuum dry toilet with slinger and an attached water flush urinal which is adequate for all sortie missions. Only additional expendables such as filters and fecal storage containers need to be provided.

Hygiene

The shuttle has a hygiene assembly consisting of wet and dry wipe (towels) and storage. The storage area is adequate for 7-day missions but the sortie needs to supply more storage for the 30-day missions. Also, expendables are furnished by the sortie ECLSS for crew sizes greater than two men.

Food Management

The shuttle has a dry and wet food mix, but no frozen foods. The food rate is 2.68 pound per man-day (versus the MSS rate of 2.86 pound per man-day) including packaging.

The sortie ECLSS needs only to supply additional food and (disposable) eating utensils (0.04 pound per man-day rate for napkin plus utensil) for crew sizes over two men and seven days. The shuttle reconstitution unit and resistance oven are adequate for sortie missions.

Special Life Support

The only equipment for this assembly is two fire extinguisher packages and one fire detector. The shuttle-type aqueous gel extinguisher was utilized instead of the MSS CO_2 extinguisher. The MSS-type fire detector was utilized since the shuttle fire detector is undefined.

Summary and Characteristics

Table 5-8 summarizes the sortie ECLSS implementation. Most ECLSS functions are accomplished by storing more expendables. The only major assemblies - as far as fixed hardware is concerned - is in the atmospheric control and thermal control assemblies. Tables 5-9 through 5-11 present the weight, power, and volume of the sortie ECLSS deltas to the shuttle.

Note that expendable weight and volume credits were given to the items furnished by the shuttle (as 14 man-days of metabolic oxygen) and to assemblies located in the shuttle (as the toilet, water, etc.)

Table 5-8. Sortie ECLSS Implementation

Assembly/Function	Approach
Gaseous storage	
Oxygen supply	Provide necessary gas expendable. Assume existing OMS or other supercritical tank is available for storage.
Nitrogen supply	Add necessary expendable gas and necessary 3000-psia nitrogen tanks. Connect tanks into shuttle nitrogen pressure control.
Pumpdown	Insufficient data to size. No capability provided by ECLSS. Gas loss also neglected.
CO_2 management	
CO_2 removal*	Use shuttle canisters and provide necessary expendables. For 7M-3 add a delta housing and ducting.
Atmospheric control	
Circulation	Add ducting and duct fan in sortie module. Add local ventilation fans.
Temperature control*	Use shuttle sensible heat exchanger via interconnecting ducting with a booster fan. Also, add sensible heat exchanger for any other air loads in sortie experiment module.
Humidity control*	Use shuttle condensing heat exchanger via interconnecting ducting as above.
Pressure control	Use shuttle concept.
Contaminant control	Use shuttle concept**
Thermal control	Use separate Freon/water loops with radiator for payloads 7M-1 to 7M-5, 30M-1 to 30M-4, and 30M-11. Use separate Freon loop with radiator for payloads 7M-6 and 30M-5 to 30M-10
Water management	
Water storage	Shuttle fuel cells provide adequate water. Storage tanks provide adequate capacity. No deltas to the shuttle system are required.
Waste management	
Fecal collection Urine collection Trash processing	Shuttle hardware is adequate. Provide only expendables.
Hygiene	Shuttle assembly used. Provide only expendables.
Food management	Shuttle concepts system used. Provide only food and utensil expendables.
Special life support	
Fire control	Add shuttle-type fire extinguisher packages to sortie module. Add MSS-type fire detector.

*Assumes shuttle capability can be stretched to 5-man capacity by increased air flow without new hardware.
**Charcoal for contaminant control is in LiOH canisters.

Table 5-9. Sortie ECLSS Weight Deltas Over Shuttle Capability

Assembly	Payload (Crew Size***)															
	7M-1 (4)		7M-2 (4)		7M-3 (4)		7M-4 (4)		7M-5 (5)		7M-6 (4)		30M-1 (4)		30M-2 (4)	
	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp
Gaseous storage																
O_2 (gas)	0	27	0	27	0	27	0	27	0	40	0	27	0	330	0	330
O_2 (tank)	7	0	7	0	7	0	7	0	10	0	7	0	82	0	82	0
N_2 (gas)	0	5	0	5	0	5	0	5	0	5	0	5	0	181	0	181
N_2 (tank)	6	0	6	0	6	0	6	0	6	0	6	0	212	0	212	0
Pumpdown	Not Provided by ECLSS															
CO_2 management																
CO_2 removal LiOH	0	56	0	56	0	56	0	56	0	88	0	56	0	608	0	608
Atmospheric control																
Circulation																
Ducting	0*	0	0*	0	200	0	200	0	0	0	200	0	200	0	200	0
Duct fans	0	0	0	0	25	0	25	0	0	0	25	0	25	0	25	0
Ventilation fans (4)	0	0	0	0	40	0	40	0	0	0	40	0	40	0	40	0
Temperature control (1)	0	0	0	0	35	0	35	0	0	0	35	0	35	0	35	0
Pressure control	Shuttle Provides															
Contaminant control	Shuttle Provides															
Thermal control																
Internal loop																
Coldplate, valves, tube**	267	0	350	0	470	0	451	0	120	0	35	0	200	0	185	0
Water pumps (2)	20	0	30	0	50	0	30	0	7	0	0	0	15	0	12	0
Heat rejection loop																
Radiator	138	0	186	0	740	0	651	0	162	0	62	0	204	0	261	0
Intercoolers (2)	95	0	120	0	170	0	150	0	34	0	0	0	59	0	52	0
Freon pumps (2)	30	0	40	0	66	0	40	0	10	0	18	0	25	0	20	0
Freon reservoir (2)	20	0	39	0	50	0	39	0	5	0	13	0	20	0	15	0
Water management	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste management																
Fecal collection	0	0	0	0	0	0	0	0	0	0.6	0	0	0	8	0	8
Trash bags	0	0	0	0	0	0	0	0	0	4.0	0	0	0	4	0	4

*Pallet-mounted, shuttle ventilation should be adequate

**Includes water and Freon valves and tubes.

***Includes 2-man shuttle crew.

Table 5-9. Sortie ECLSS Weight Deltas Over Shuttle Capability (Cont)

Assembly	Payload (Crew Size***)															
	7M-1 (4)		7M-2 (4)		7M-3 (4)		7M-4 (4)		7M-5 (5)		7M-6 (4)		30M-1 (4)		30M-2 (4)	
	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp
Hygiene																
Wipes, etc.	0	83	0	83	0	83	0	83	0	125	0	83	50	904	50	904
Food management																
Food	0	38	0	38	0	38	0	38	0	57	0	38	0	407	0	407
Utensils	0	0.6	0	0.6	0	0.6	0	0.6	0	0.8	0	0.6	0	4	0	4
Special life support																
Fire extinguisher (2)	0	0	0	0	76	0	76	0	76	0	76	0	76	0	76	0
Fire detector (1)	0.5	0	0.5	0	0.5	0	0.5	0	0.5	0	0.5	0	0.5	0	0.5	0
	583	210	778	210	1936	210	1751	210	731	320	218	210	1244	2446	1266	2446

***Includes 2-man shuttle crew.

Table 5-9. Sortie ECLSS Weighı ıttle Capability (Cont)

Assembly	30M-3 (4)		30M-4 (5)		30M-5 (4)		30M-6 (4)		30M-7 (4)		30M-8 (4)		30M-9 (4)		30M-10 (4)		30M-11 (4)	
	Payload (Crew Size***)																	
	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp
Gaseous storage																		
O_2 (gas)	0	330	0	385	0	330	0	330	0	330	0	330	0	330	0	330	0	330
O_2 (tank)	82	0	96	0	82	0	82	0	82	0	82	0	82	0	82	0	82	0
N_2 (gas)	0	181	0	181	0	181	0	181	0	181	0	181	0	181	0	181	0	181
N_2 (tank)	212	0	212	0	212	0	212	0	212	0	212	0	212	0	212	0	121	0
Pumpdown	Not Provided by ECLSS																	
CO_2 management																		
CO_2 removal LiOH	0	608	0	736	0	608	0	608	0	608	0	608	0	608	0	608	0	608
Atmospheric control																		
Circulation																		
Ducting	200	0	200	0	200	0	200	0	200	0	200	0	200	0	200	0	200	0
Duct fans	25	0	25	0	25	0	25	0	25	0	25	0	25	0	25	0	25	0
Ventilation fans (4)	40	0	40	0	40	0	40	0	40	0	40	0	40	0	40	0	40	0
Temperature control (1)	35	0	35	0	35	0	35	0	35	0	35	0	35	0	35	0	35	0
Pressure control	Shuttle Provides																	
Contaminant control	Shuttle Provides																	
Thermal control																		
Internal loop																		
Coldplate, Valves, Tube	180	0	110	0	50	0	97	0	53	0	65	0	53	0	105	0	125	0
Water pumps (2)	12	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
Heat rejection loop																		
Radiator	252	0	148	0	79	0	44	0	82	0	94	0	82	0	135	0	62	0
Intercoolers (2)	47	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0
Freon pumps (2)	20	0	10	0	19	0	20	0	19	0	20	0	19	0	22	0	18	0
Freon reservoir (2)	15	0	5	0	17	0	20	0	17	0	18	0	17	0	20	0	10	0
Water management	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste management																		
Fecal collection	0	8	0	10	0	8	0	8	0	8	0	8	0	8	0	8	0	8
Trash bags	0	4	0	5	0	4	0	4	0	4	0	4	0	4	0	4	0	4

*Includes 2-man shuttle crew.

Table 5-9. Sortie ECLSS Weight Deltas Over Shuttle Capability (Cont)

Assembly	Payload (Crew Size***)																	
	30M-3 (4)		30M-4 (5)		30M-5 (4)		30M-6 (4)		30M-7 (4)		30M-8 (4)		30M-9 (4)		30M-10 (4)		30M-11 (4)	
	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp
Hygiene																		
Wipes, etc.	50	904	50	1083	50	904	50	904	50	904	50	904	50	904	50	904	50	904
Food management																		
Food	0	407	0	488	0	407	0	407	0	407	0	407	0	407	0	407	0	407
Utensils	0	4	0	5	0	4	0	4	0	4	0	4	0	4	0	4	0	4
Special life support																		
Fire extinguisher (2)	76	0	76	0	76	0	76	0	76	0	76	0	76	0	76	0	76	0
Fire detector (1)	0.5	0	0.5	0	0.5	0	0.5	0	0.5	0	0.5	0	0.5	0	0.5	0	0.5	0
Total	1247	2446	1044	2893	886	2446	902	2446	892	2446	918	2446	892	2446	1003	2446	976	2446

***Includes 2-man shuttle crew.

Table 5-10. Sortie ECLSS Power Deltas Over Shuttle Capability

Assembly	Payload															
	7M-1		7M-2		7M-3		7M-4		7M-5		7M-6		30M-1		30M-2	
	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max
Gaseous storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CO_2 management (see atmospheric control)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric control																
Circulation																
Duct fans	0	0	0	0	175	175	175	175	175	175	0	0	175	175	175	175
Ventilation fans	0	0	0	0	56	112	56	112	56	112	0	0	56	112	56	112
Temperature control fans	0	0	0	0	35	35	35	35	35	35	0	0	35	35	35	35
Pressure control	Shuttle Provides															
Contamination control	Shuttle Provides															
Thermal control																
Internal loop																
Water pumps	95	95	131	131	180	180	207	207	50	50	0	0	80	80	72	72
Heat rejection loop																
Freon pumps	101	101	132	132	187	187	115	115	30	30	31	31	65	65	57	57
Water/waste management, Hygiene/food management, Special life support	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	196	196	263	263	633	689	588	644	346	402	31	31	411	467	395	451

Table 5-10. Sortie ECLSS Power Deltas Over Shuttle Capability (Cont)

Assembly	Payload																	
	30M-3		30M-4		30M-5		30M-6		30M-7		30M-8		30M-9		30M-10		30M-11	
	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max
Gaseous storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CO_2 management (see atmospheric control)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric control																		
Circulation																		
Duct fans	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175
Ventilation fans	56	112	56	112	56	112	56	112	56	112	56	112	56	112	56	112	56	112
Temperature control fans	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Pressure control	Shuttle Provides																	
Contamination control	Shuttle Provides																	
Thermal control																		
Internal loop																		
Water pumps	70	70	43	43	0	0	0	0	0	0	0	0	0	0	0	0	47	47
Heat rejection loop																		
Freon pumps	55	55	30	30	39	39	62	62	40	40	47	47	40	40	67	67	31	31
Water/waste management Hygiene/food management Special life support	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	391	447	339	395	305	361	328	384	306	362	313	369	306	362	333	389	344	400

Table 5-11. Sortie ECLSS Volume Deltas Over Shuttle Capability

Assembly	Payload															
	7M-1		7M-2		7M-3		7M-4		7M-5		7M-6		30M-1		30M-2	
	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp
Gaseous storage																
O_2 tank (cryogenic)	0.4	0	0.4	0	0.4	0	0.4	0	0.6	0	0.4	0	4.5	0	4.5	0
N_2 tank (high-pressure)	0.4	0	0.4	0	0.4	0	0.4	0	0.4	0	0.4	0	12.2	0	12.2	0
CO_2 management																
CO_2 removal*																
LiOH (storage)	0	0	0	0	0	0	0	0	0	1.5	0	0	0	16.7	0	16.7
Atmospheric control																
Circulation																
Ducting	0	0	0	0	(9" dia x 136')						0	0	(9" dia x 136')			
Duct fans	0	0	0	0	0.4	0	0.4	0	0.4	0	0	0	0.4	0	0.4	0
Ventilate fans (4)	0	0	0	0	5.2	0	5.2	0	5.2	0	0	0	5.2	0	5.2	0
Temperature control	0	0	0	0	0.8	0	0.8	0	0.8	0	0	0	0.8	0	0.8	0
Thermal control																
Internal loop																
Water pump (2)	1.0	0	1.3	0	1.6	0	1.1	0	0.4	0	0	0	0.9	0	0.8	0
Heat rejection loop																
Radiator (ft^2)	(129)	0	(174)	0	(692)	0	(608)	0	(151)	0	(58)	0	(192)	0	(244)	0
Intercooler (2)	3.0	0	4.0	0	6.1	0	6.1	0	1.1	0	0	0	2.0	0	1.7	0
Freon pump (2)	1.2	0	1.4	0	1.7	0	1.1	0	0.6	0	0.8	0	1.0	0	0.9	0
Freon reservoir (2)	0.2	0	0.5	0	0.7	0	0.5	0	0.1	0	0.1	0	0.2	0	0.2	0
Water management	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste management*	0	Neg	0	Neg	0	Neg	0	Neg	0	Neg	0	Neg	0	Neg	0	Neg
Hygiene*	0	0	0	0	0	0	0	0	0	0.9	0	0	8.0	13.2	8.0	13.2
Food management	0	0	0	0	0	0	0	0	0	1.0	0	0	0	12.5	0	12.5
Special life support																
Fire extinguisher (2)	0	0	0	0	1.2	0	1.2	0	1.2	0	1.2	0	1.2	0	1.2	0
Fire detector (1)	0	0	0	0	Neg	0	Neg	0	Neg	0	Neg	0	Neg	0	Neg	0
Total	6.2	0.0	8.0	0.0	18.5	0.0	17.2	0.0	10.8	3.4	2.9	0.0	36.4	42.4	35.9	42.4

*Credit given for room in Shuttle. (This is valid for all payload cases. Shuttle has room for 4 man expendables for 7 days).

Table 5-11. Sortie ECLSS Volume Deltas Over Shuttle Capability (Cont)

Assembly	Payload																	
	30M-3		30M-4		30M-5		30M-6		30M-7		30M-8		30M-9		30M-10		30M-11	
	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp	Fix.	Exp
Gaseous storage																		
O_2 tank (cryogenic)	4.5	0	5.3	0	4.5	0	4.5	0	4.5	0	4.5	0	4.5	0	4.5	0	4.5	0
N_2 tank (high-pressure)	12.2	0	12.2	0	12.2	0	12.2	0	12.2	0	12.2	0	12.2	0	12.2	0	12.2	0
CO_2 management																		
CO_2 removal*																		
LiOH (storage)	0	16.7	0	22.5	0	16.7	0	16.7	0	16.7	0	16.7	0	16.7	0	16.7	0	16.7
Atmospheric control																		
Circulation																		
Ducting									(9" dia x 136 ft)									
Duct fans	0.4	0	0.4	0	0.4	0	0.4	0	0.4	0	0.4	0	0.4	0	0.4	0	0.4	0
Ventilation fans (4)	5.2	0	5.2	0	5.2	0	5.2	0	5.2	0	5.2	0	5.2	0	5.2	0	5.2	0
Temperature control	0.8	0	0.8	0	0.8	0	0.8	0	0.8	0	0.8	0	0.8	0	0.8	0	0.8	0
Thermal control																		
Internal loop																		
Water pump (2)	0.8	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Heat rejection loop																		
Radiator (ft^2)	(235)	0	(138)	0	(73.5)	0	(41.0)	0	(76.1)	0	(88.4)	0	(76.1)	0	(126)	0	(58)	0
Intercooler (2)	1.4	0	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0	0
Freon pump (2)	0.9	0	0.6	0	1.0	0	1.0	0	1.0	0	1.0	0	1.0	0	1.2	0	0.8	0
Freon reservoir (2)	0.2	0	0.1	0	0.7	0	0.6	0	0.1	0	0.3	0	0.1	0	0.6	0	0.1	0
Water management	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste management*	0	Neg	0	Neg	0	Neg	0	Neg	0	Neg	0	Neg	0	Neg	0	Neg	0	Neg
Hygiene*	8.0	13.2	8.0	17.5	8.0	13.2	8.0	13.2	8.0	13.2	8.0	13.2	8.0	13.2	8.0	13.2	8.0	13.2
Food management*	0	12.5	0	16.5	0	12.5	0	12.5	0	12.5	0	12.5	0	12.5	0	12.5	0	12.5
Special life support																		
Fire extinguisher (2)	1.2	0	1.2	0	1.2	0	1.2	0	1.2	0	1.2	0	1.2	0	1.2	0	1.2	0
Fire detector (1)	Neg	0	Neg	0	Neg	0	Neg	0	Neg	0	Neg	0	Neg	0	Neg	0	Neg	0
Total	35.6	42.4	35.1	56.5	34.0	42.4	33.9	42.4	33.4	42.4	33.6	42.4	33.4	42.4	34.1	42.4	34.7	42.4

*Volume credit given for 28 man-days storage in shuttle.

INFORMATION SUBSYSTEM

The ISS studies were conducted in support of the sortie payloads for the orbiter. The study began with an evaluation of requirements and then proceeded to the identification of support equipment and description of physical characteristics. An ISS concept was developed to support the sortie experiments which consists of control/display, recording (video and digital), and external communications equipment.

Study Guidelines

The guidelines for the sortie payload ISS are summarized as follows:

1. Design of the sortie payload ISS will be self-sufficient so that interface with the orbiter data management system will be minimized.

2. Closed-circuit color television will be provided from the sortie module to the orbiter payload control and display station. The ability to relay color TV to the ground will be provided through the orbiter payload control and display station.

3. The sortie module ISS will provide the capability for checkout, command, control, monitoring, and display of sortie module subsystems operation. Automation will be implemented where it is possible to relieve the crew from routine and repetitive tasks; however, the crew override capability will be available at all times.

4. Sortie module subsystem safety parameter signals will be provided for display at both the orbiter crew station and the orbiter payload control and display station.

Approach

The approach used to determine the ISS equipment consisted of four major steps: (1) establish ground rules for the ISS, (2) analyze requirements of each experiment and the defined groups of experiments for each payload to establish the ISS payload requirements, (3) perform studies to relate the requirements to technology, and (4) determine the ISS physical characteristics based on the ISS requirements.

Ground Rules

The ground rules used for the study as related to the ISS were:

1. The ISS concepts and components as defined for the MSS will be utilized for the sortie payloads to reduce development of equipment.

2. The orbiter's information system will be evaluated and its capability utilised on a noninterfering basis.

3. The monitoring and control of the payload subsystems would be accommodated through the orbiter system. This will be accomplished with the 5 kbps which have been allocated to the payloads.

Requirements

An analysis was made of each experiment to determine its ISS requirement. The experiments were then analyzed as a payload package and digital data acquisition, data external transmission, data storage, and display requirements defined. These requirements are listed in Tables 5-12 and 5-13 for the 7-day and 30-day sortie missions.

Analyses and Technology Selection

Analyses of the requirements for each of the payloads showed that the requirements in almost all areas exceeded the capability allocated to the payload by the orbiter. This included data required to be transmitted to the ground, recording of video and digital data, and command control and monitoring of the experiment operations and their data.

The internal communications functions of voice telecomm between experiment personnel and the orbiter crew and ground could be accomplished, however, using the orbiter equipment. The monitor and alarm function for the experiments payload would also be accomplished using the 5 kbps allocated to the payload. The data from the payload would enter the orbiter through its ACT (acquisition control and test) unit.

External Communication

Studies were conducted to select an optimum method of transmitting between 1.5 x 10^9 bits of experiment data and 2 megaHertz of TV per day to the ground. Two options were available: K band and S band. The S-band option was selected because it is lighter, less complex, and costs less. The S-band subassembly will utilize fixed semidirective antennas.

Table 5-12. Seven-Day Sortie Payload ISS Requirements

Payload Number	Experiment Package	Digital Data Acquisition		Transmission		Mission Storage		Display		
		Peak Rate	24 Hr. Avg.	Digit. Data 24 Hr Delay	TV Delay.	Total (bits) Digit. Data	TV Hrs.	Digital Data Type	Digital Data Util. (hrs)	TV (Hrs.)
7M-1	ES1-III; T1-I	2×10^6 bps	1.4×10^{11} bits	1.35×10^{10} bits	--	9.6×10^{11}	2 (1)	M	8.7	2 (1)
7M-2	P1-I; T1-I; CN1-I	2×10^5 bps	1.7×10^{10} bits	----	--	1.2×10^{11}	2 (1)	M	6.1	2 (1)
7M-3	ES1-II; T4-I; T1-I	2×10^6 bps	1.5×10^{11} bits	1.5×10^{10} bits	--	1.1×10^{12}	2 (1)	M	4.2	2 (1)
7M-4	MS1-III	1×10^4 bps	4.3×10^8 bits	----	0.06 Hrs	3.0×10^9	0.3	TV	--	0.3
7M-5	LS3-II; LS4-II; T3-I	5×10^3 bps	1.5×10^8 bits	----	--	1.1×10^9	-	M	11.3	8.0
7M-6	P2-I; P2-II	1×10^5 bps	8.6×10^9 bits	2.15×10^9 bits 2 MHz-Analog	--	1.2×10^{11} 9 Hrs Anal. 5 Hrs Anal.	-	M	2.4	0.9 (Anal.)

(1) High Resolution TV

M - Multiformat; D - Dedicated

Table 5-13. Thirty-Day Sortie Payload ISS Requirements

Payload Number	Experiment Package	Digital Data Acquisition		Transmission		Mission Storage		Display		
		Peak Rate	24 Hr. Avg.	Digit. Data 24 Hr Delay	TV Delay.	Total (bits) Digit. Data	TV Hrs.	Digital Data Type	Digital Data Util. (hrs)	TV (Hrs.)
30M-1	ES1-I; T1-II	1.2×10^5 bps	2.6×10^9 bits	2.2×10^7 bits	--	7.7×10^{10}	2 (1)	M	4.13	2 (1)
30M-2	P1-II; P4-I	4.5×10^4 bps	4.1×10^9 bits	------	--	1.2×10^{11}	-	M	0.1	--
30M-3	T2-I; T2-II; T2-III	5.8×10^3 bps	4.8×10^7 bits	------	--	1.5×10^9	-	TV	--	24
30M-4	LS1-I; LS4,5-I; LS6-I; LS7-II	2.8×10^4 bps	3.3×10^7 bits	------	--	7.4×10^8	-	M	17.31	14 (2)
30M-5	A1-I	4×10^4 bps	5×10^8 bits	5×10^7 B/O 5×10^8 B/D	--	1.5×10^{10}	-	D (3)	--	0.5
30M-6	A3-I	4×10^4 bps	6×10^8 bits	6×10^8 bits	--	1.8×10^{10}	-	TV	--	0.6
30M-7	A4-I	4×10^4 bps	1.6×10^9 bits	4×10^8 bits	--	4.8×10^{10}	1.9	--	--	--
30M-8	A5-I	6.4×10^3 bps	5.4×10^8 bits	5.4×10^7 bits	--	1.6×10^{10}	-	M	3.5	--
30M-9	A6-I	4×10^4 bps	1.2×10^9 bits	3×10^8 bits	--	3.6×10^{10}	7.9	--	--	--
30M-10	P3-I	1.7×10^4 bps	1.5×10^9 bits	------	--	4.5×10^{10}	-	D (4)	2.5	--
30M-11	C/N1-II; C/N1-III	3.0×10^5 bps	1.3×10^9 bits	3.8×10^8 bits	--	3.8×10^{10} 1 Hr/Day - Analog	- -	Exp. Pro-vided	--	--

(1) High Resolution TV; (2) TV Displayed - 14 Hrs. per 30 days; M - Multiformat; D - Dedicated
B/O - Bits per Operation; B/D - Bits per Day; (3) 6 Displays; (4) 12 Displays

Data Processing

Studies to select the optimum method for recording 7.4×10^8 to 1.1×10^{12} bits of experiment data for each mission considered the following technologies: (1) solid state, (2) magnetic tape, (3) rotating media, and (4)optical storage media. All techniques required read and write capabilities. Solid-state devices include plated wire, core, and transistor-type techniques. Magnetic tape involves continuous-run tape recorders which transfer data in large blocks of data bits. The rotating medium is a magnetic disk and drum. The optical storage medium operates by having a laser beam or electron beam record on a metallic-coded photographic emulsion.

The magnetic tape technology was selected on the basis of less weight, complexity, and cost when compared to the other technologies considered.

Command Control and Monitoring

Two options were available for the displays and controls required to manage from $3.3 \times 10^7 \times 10^{11}$ bits of experiment data per mission: dedicated meters and controls and a multiformat display (callable alphanumerics with TV and keyboard control). Analysis was of weight, volume, power, complexity, flexibility, and cost factors resulted in selection of the multiformat display.

ISS Concept

The ISS concept to meet sortie requirements is shown in block diagram form in Figure 5-5. The diagram shows experiment data entering a switching and control unit from which it is routed to the various data depositories (i.e., recorders, display, or RF links). The physical characteristics of the ISS for each payload was based on the components required to perform the functions for each payload defined in the block diagram. The physical characteristics, as a function of the payload, are listed in Tables 5-14 through 5-17.

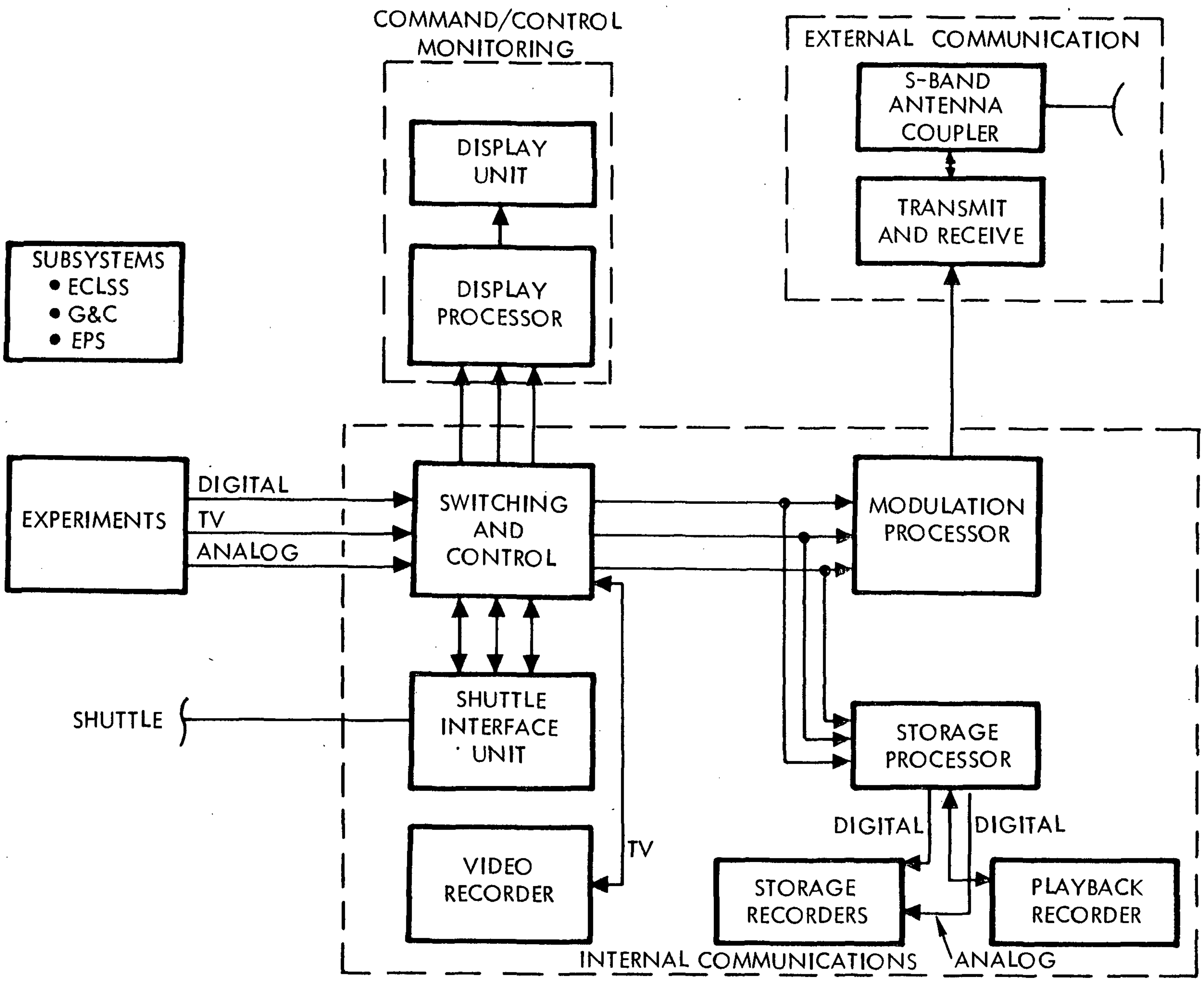


Figure 5-5. Sortie ISS Block Diagram

Table 5-14. ISS Physical Characteristics - 7-Day Missions

ISS Equipment	7M 1	7M 2	7M 3	7M 4	7M 5	7M 6	Unit Characteristics Weight(lb)	Volume (Ft^3)
S-Band	1	-	1	1	-	1	26	0.5
Playback/recorder	1	-	1	-	-	1	47	0.7
Digital recorder 1	1	1	1	1	1	1	64	1.0
Digital recorder 2	1	1	1	-	-	1	38	0.7
Video recorder 1	1	1	1	1	-	1	72	1.5
Video recorder 2	1	1	1	1	-	1	60	1.3
Multiformat display	-	-	-	-	1	1	111	5.9
Multiform. Disp. w/Hi-Res. TV	1	1	1	-	-	-	116	5.9
TV Display	-	-	-	1	-	-	25	0.8
Digital tape cartridge (additional)	63	7	70	-	-	7	8	0.3
Video tape cartridge (additional)	2	2	2	-	-	21	10	0.7
Total Weight (lbs)	947	426	1003	247	175	684		
Total Volume (ft^3)	31.9	13.9	34.0	5.1	6.9	28.4		

Table 5-15. ISS Power Requirements - 24-Hour Energy (KWH) and Peak Watts) - 7-Day Missions

ISS Equipment	7M-1		7M-2		7M-3		7M-4		7M-5		7M-6	
	Engy	Peak	Engy	Peak	Engy	Peak	Engy	Peak	Engy	Peak	Engy	Peak
S-Band	0.2	102	-	-	0.2	102	0.2	102	-	-	0.2	102
Playback/recorder	0.1	50	-	-	0.1	50	-	-	-	-	0.1	50
Digital recorder 1	2.7	112	2.7	112	2.7	112	2.7	112	2.7	112	2.7	112
Digital recorder 2	-	45	-	45	-	45	-	-	-	-	-	45
Video recorder 1	0.2	78	0.2	78	0.2	78	0.1	78	-	-	0.9	78
Video recorder 2	-	45	-	45	-	45	-	45	-	-	-	45
Multiformat display	-	-	-	-	-	-	-	-	5.8	510	1.2	510
Multiform. Disp. w/Hi-Res. TV	4.5	515	3.1	515	2.2	515	-	-	-	-	-	-
TV display	-	-	-	-	-	-	0.1	225	-	-	-	-
Totals	7.7 KWH	947 W	6.0 KWH	795 W	5.4 KWH	947 W	3.1 KWH	572 W	8.5 KWH	622 W	5.1 KWH	942 W

Table 5-16. ISS Physical Characteristics - 30-Day Missions

ISS Equipment	30M 1	30M 2	30M 3	30M 4	30M 5	30M 6	30M 7	30M 8	30M 9	30M 10	30M 11	Unit Characteristics	
												Wt.(lbs)	Vol. (Ft^3)
S-Band	1	-	-	-	1	1	1	1	1	-	1	26	0.5
Playback/recorder	1	-	-	-	1	1	1	1	1	-	1	47	0.7
Digital recorder 1	1	1	1	1	1	1	1	1	1	1	1	64	1.0
Digital recorder 2	1	1	-	-	-	-	1	-	1	-	-	38	0.7
Video recorder 1	1	-	-	-	-	-	1	-	1	-	1	72	1.5
Video recorder 2	1	-	-	-	-	-	-	-	-	-	-	60	1.3
Multiformat display	-	1	-	1	-	-	-	1	-	-	-	111	5.9
Multiform. Disp. W/Hi-Res. TV	1	-	-	-	-	-	-	-	-	-	-	116	5.9
Dedicated Display	-	-	-	-	1	-	-	-	-	1	Exp. Prov.	20	0.8
TV Display	-	-	1	-	1	1	-	-	-	-	-	25	0.8
Digital Tape Cartridge (additional)	4	7	-	-	-	1	2	1	1	2	2	8	0.3
Video Tape Cartridge	2	-	-	-	-	-	3	-	14	-	1	10	0.7
Total Weight (lbs)	475	269	89	175	182	170	293	265	395	100	235		
Total Volume (ft^3)	14.2	9.7	1.8	6.9	3.8	3.3	7.1	8.4	14.5	2.4	5.0		

Table 5-17. ISS Power Requirements - 24-Hour Energy (KWH) and Peak (Watts) - 30-Day Missions

ISS Equipment	30M-1		30M-2		30M-3		30M-4		30M-5		30M-6		30M-7		30M-8		30M-9		30M-10		30M-11	
	Egy	Pk	Egy	Pk	Egy	Pk	Egy	Pk	Egy	Pk	Egy	Pk	Egy	Pk	Egy	Pk	Egy	Pk	Egy	Pk	Egy	Pk
S-band	0.2	102	-	-	-	-	-	-	0.2	102	0.2	102	0.2	102	0.2	102	0.2	102	-	-	0.2	102
Playback/recorder	0.1	50	-	-	-	-	-	-	0.1	50	0.1	50	0.1	50	0.1	50	0.1	50	-	-	0.1	50
Digital recorder 1	2.7	112	2.7	112	2.7	112	2.7	112	2.7	112	2.7	112	2.7	112	2.7	112	2.7	112	2.7	112	2.7	112
Digital recorder 2	-	45	-	45	-	-	-	-	-	-	-	-	-	45	-	-	-	45	-	-	-	-
Video recorder 1	0.2	78	-	-	-	-	-	-	-	-	-	-	0.1	78	-	-	0.6	78	-	-	0.2	78
Video recorder 2	-	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Multiformat Display	2.0	510	-	-	-	-	8.8	510	-	-	-	-	-	-	1.8	510	-	-	-	-	-	-
Multiform. Display w/Hi-Res. TV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dedicated display	-	-	-	-	-	-	-	-	0.1	20	-	-	-	-	-	-	-	-	0.1	20	-	-
TV display	-	-	-	-	5.4	225	-	-	0.1	225	0.1	225	-	-	-	-	-	-	-	-	-	-
Total	5.3 KWH	947 W	2.8 KWH	667 W	8.1 KWH	337 W	11.5 KWH	622 W	3.2 KWH	509 W	3.1 KWH	489 W	3.1 KWH	387 W	4.8 KWH	774 W	3.6 KWH	387 W	2.8 KWH	132 W	3.2 KWH	342 W

Table 5-18. G&C Requirements Summary

Payload Number	Ephemeris	Pointing	Rate Limits	Accel.
7M-1	1 nm 3 axes	0.05°	0.05 °/sec	
7M-2		2 min	0.01 °/sec	
7M-3	1 nm 3 axes	0.05°	0.05 °/sec	
7M-4				0 ± 10^{-4}g
7M-5				10^{-5}g 90%
7M-6	1 nm altitude	± 0.5°	0.016 °/sec	
30M-1		± 0.05°	0.01 °/sec	
30M-2		± 2°	0.01 °/sec	
30M-3				
30M-4				
30M-5	1 nm	± 1 sec	1 sec/hr	
30M-6	1 nm	± 1 sec	0.1 sec/45 min	
30M-7	1 nm	5 sec	5 sec/hr	
30M-8	0.5 nm	6 min	1 min/30 min	
30M-9	1 nm	1 sec	1 sec/50 min	
30M-10	Altitude	5° (assumed)		
30M-11		±.01°	0.1°/sec	

GUIDANCE AND CONTROL SUBSYSTEM

This section documents the guidance and control studies conducted in support of the shuttle sortie analysis. The study began with an evaluation of requirements and proceeded to the identification of support equipment physical characteristics. A concept was established that supplements shuttle stabilization performance yielding a capability in the low arc-minute region. This section is concluded with a brief discussion of problem areas.

Requirements Analysis

The G&C requirements for the individual sortie payloads are summarized in Table 5-18. Each payload includes several experiments. The data shown in the table are an extraction of the most stringent control requirements. The format is not consistent throughout the table - note that various units are used. The intent was to preserve the experiment documentation format.

Accommodation Approach

A major objective was to use the shuttle as is unless the inherent shuttle capability was not adequate. In these cases, supplementary equipment was added.

It was assumed that the ephemeris requirements could be satisfied by the basic shuttle system. Referring to Table 5-18, the most severe requirement is 0.5-nautical-mile position accuracy. It is assumed that automatic ground beacon tracking is available for shuttle navigation. That concept should be adequate to meet the required performance.

The computation required for stabilization and control could be provided by the shuttle computation complex. An alternative apporach would be to provide an independent capability using, for example, one of the modular space station G&C preprocessors.

The pointing requirements specified in Table 5-18 indicate the need for a broad range of support capability. At one extreme, the requirements can be satisfied by the basic shuttle system. At the other extreme, multiple-level control will be necessary. A spectrum of pointing concepts was postulated for evaluation against the individual payload requirements. The concepts, listed in order of increasing complexity, are:

1. Shuttle as is
2. Shuttle with ACPS modification to provide smaller minimum impulse

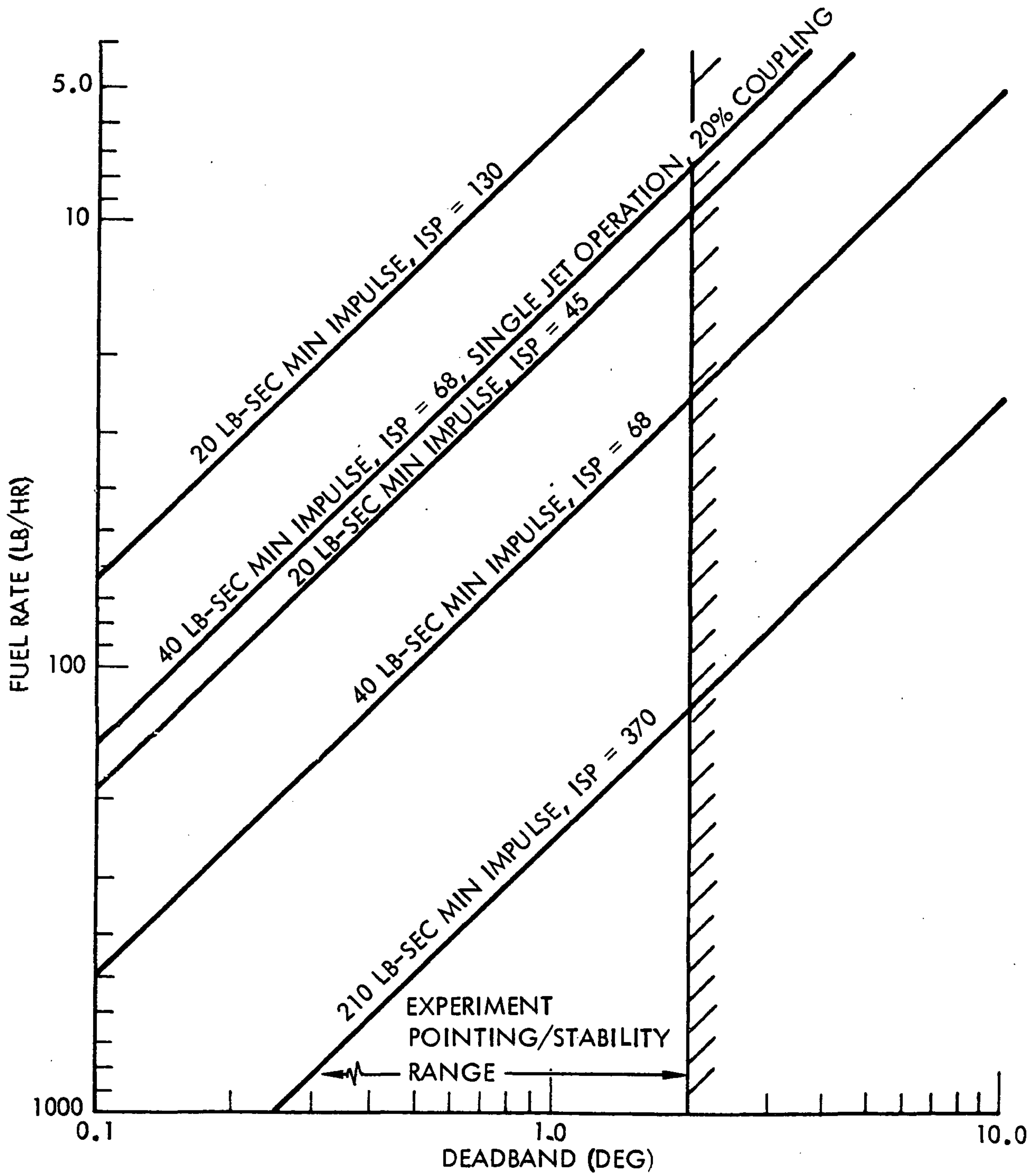


Figure 5-6. Fuel Rate Characteristics

3. Shuttle plus isolation platform

4. Shuttle with ACPS modification and plat form

5. Shuttle with ACPS modification and platform and fine pointing within experiment

ACPS Considerations

The ACPS modification is necessary to obtain prolonged attitude holds with reasonable fuel expenditures. Figure 5-6 shows symmetrical limit cycle fuel rate as a function of deadband size for several values of minimum impulse bit. The data used in constructing the plots are:

$I_{xx} = 2.79 \times 10^6$ SL-ft	Pitch jet arm = 50 feet
$I_{yy} = 17.3 \times 10^6$	Roll jet arm = 9 feet
$I_{zz} = 18.5 \times 10^6$	Yaw jet arm = 62 feet

It is evident from the plots that fine deadband stabilization (0.5 degree) is prohibitive in terms of fuel rate if the minimum impulse available from the ACPS is large (210 lb-sec). Long term, fine deadband stabilization will require the provision of a smaller minimum impulse capability. Single jet operation should also be evaluated as a means of lowering the propellant required for fine deadband stabilization. This technique would lower the propellant rate to one-fourth that required for two jet operation, neglecting cross-coupling effects. The actual fuel rate for single jet operation would be influenced by coupling effects and a more detailed analysis is required to quantitize the effect. An example of the fuel rate for 40 lb-sec, single-jet operation assuming a coupling penalty of 20 percent is shown on Figure 5-6.

Pointing and Stabilization Concept

The isolation platform concept is used to provide finer pointing and stabilization than can be achieved using the basic shuttle hardware. The concept would use either one- or two-axis gimbaled platforms upon which the experiments could be mounted.

Figure 5-7 presents a functional diagram of the concept. Each gimbal axis is provided with angular position encoders and torquers for control about that axis. A rate sensor package is mounted on the stable element for rate stabilization. The interface electronics unit would include any necessary power conditioning, servo amplifiers, and control logic circuitry.

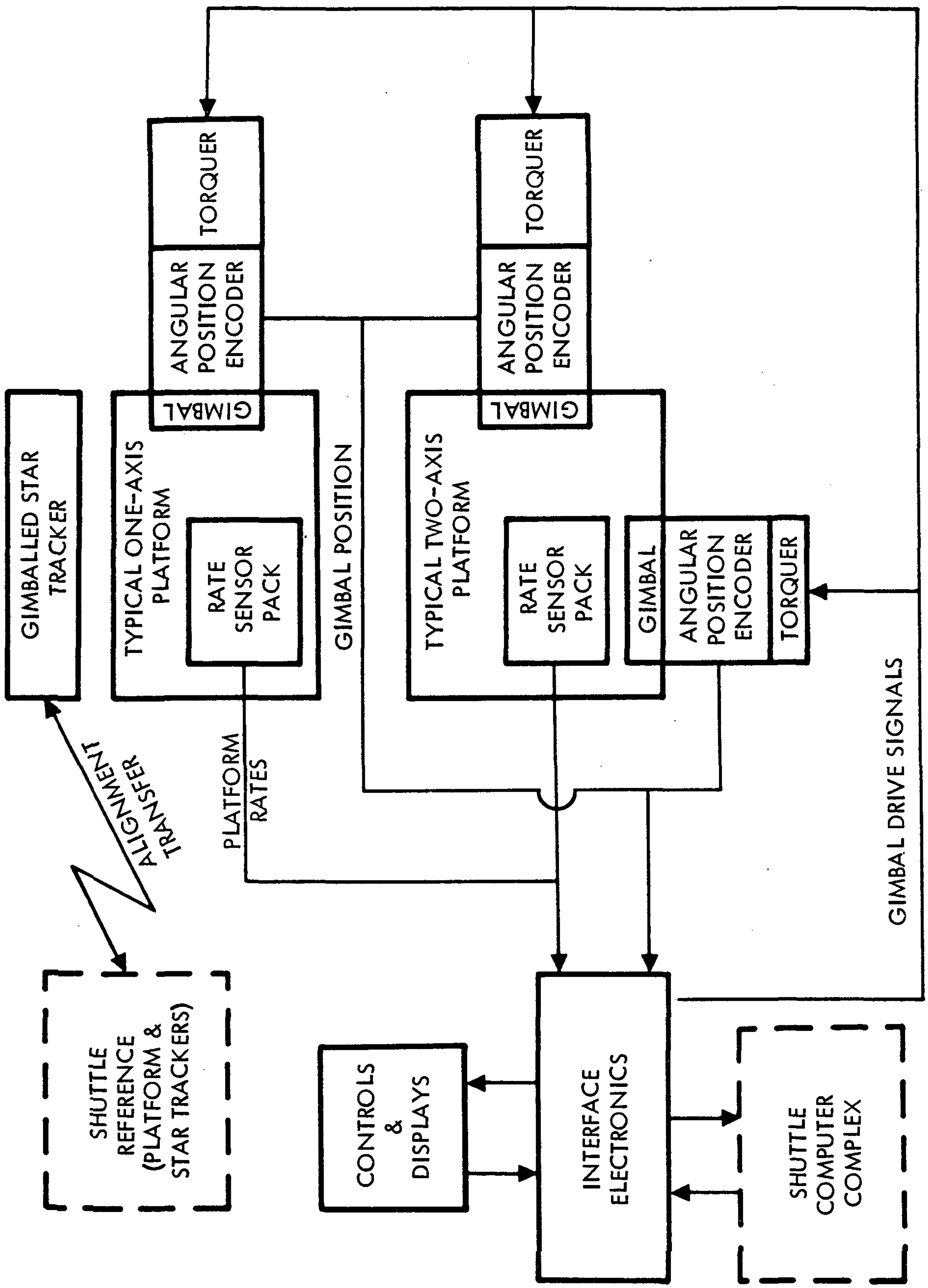


Figure 5-7. Platform Control Concept

The functional diagram indicates the potential use of the shuttle inertial reference system consisting of a gimbaled inertial measurement unit and star trackers for updating the interital unit. Because of the remote location of the shuttle reference equipment, an alignment transfer technique is required. One approach is to mount a gimbaled star tracker on the experiment pallet and make simultaneous sightings on common stars. The relative alignment of the pallet (with respect to the shuttle reference) can then be computed.

It is expected that the platform concept described would yield pointing performance in the low arc-minute region and would be adequate for the earth survey payloads such as 7M-1 and 7M-3. The low arc-second requirements (30M-5, 30M-6, and 30-M9) probably exceed the capability of a gimbaled platform isolation system. These requirements will probably necessitate an additional level of control within the experiment itself. An alternative concept is to use air-bearing isolation such as that developed by Owens-Illinois for NASA/Ames, which provides about 3 arc-second pointing of a telescope in an airborne application. Preliminary work by Owens-Illinois projects improved performance for a shuttle bay application - due in part to a less severe disturbance environment. Pointing in the 1 arc-second region is predicted.

Concept Selections and Characteristics

The alternative concepts discussed were evaluated for each of the candidate payloads and support levels were established. The selected concept for each payload is identified in Table 5-19.

The estimated physical characteristics for G&C support of the payloads is presented in Tables 5-20 and 5-21. The ACPS propellant requirements are based on the assumption that a free drift mode would be used whenever possible. The weight quantities were obtained by surbeying the individual experiment items in each payload, determining that portion required pointing support, and finally estimating the equipment weight as a percentage, slightly over 50 percent, of the weight to be pointed. The scaling factor was extracted from previous preliminary design work onthe earth surveys module for the NR 33-foot space station, which included comparable equipment. The estimated electrical power requirements are presented in Tables 5-20 and 5-22.

Problem Areas

Payload Package 30M-3, as originally configured, required the application of controlled low-G levels for extensive periods. For example, 10.4 hours at 10^{-3}g and 70 hours at 10^{-5}g are desired. These requirements appear to be incompatible with operation attached to the shuttle. A thrusting technique to obtain these acceleration levels for the requested durations

Table 5-19. G&C Concept Selections

Payload	Shuttle As Is	RCS Mod	Isolation Platforms	Experiment Control	Vehicle Control Provisions
7M-1	-	-	X	-	Continuous @ ± 10°
7M-3	-	-	X	-	Continuous @ ± 10°
7M-2	-	-	X	-	Continuous @ ± 10°
7M-4	X	-	-	-	All free drift
7M-5	X	-	-	-	All free drift
7M-6	-	X	-	-	90 hrs @ ± 0.5°
30M-1	-	X	X	-	720 hrs @ ± 10°
30M-3	?	?	?	-	All free drift
30M-4	X	-	-	-	All free drift
30M-2	-	-	X	-	85 hrs @ ± 10°, 5 hrs @ ± 2°
30M-5	-	X	X	X	720 hrs @ ± 10°
30M-6	-	X	X	X	
30M-7	-	X	X	X	
30M-8	-	X	X	-	
30M-9	-	X	X	X	720 hrs @ ± 10°
30M-10	-	X	-	-	385 hrs @ ± 5°
30M-11	-	X	X	-	720 hrs @ ± 10°

Table 5-20. G&C Concept Characteristics - 7-Day Missions

Payload Number	Weight (lbs)	Power (watts)	Shuttle RCS (lbs)
7M-1	1300	550 avg	4000
7M-2	800	250 avg	4000
7M-3	900	250 avg	4000
7M-4	-	-	200
7M-5	-	-	200
7M-6	-	-	2700

Table 5-21. G&C Concept Characteristics - 30-Day Missions

Payload Number	Weight (lbs)	Power (watts)	Shuttle RCS (lbs)
30M-1	1100	550 avg	1000
30M-2	200	250 avg	2710
30M-3	-	-	200
30M-4	-	-	200
30M-5	1400	550	1000
30M-6	3400	550	1000
30M-7	600	250	1000
30M-8	700	250	1000
30M-9	800	250	1000
30M-10	-	-	1150
30M-11	100	50 avg	1000

would require approximately 260,000 pounds of propellant. It should be noted that the majority of the fuel is associated with the 10^{-3}g, and the 10^{-5}g requirement can be satisfied using less than 2000 pounds of fuel.

Other concepts have been postulated for satisfaction of the applied low-g requirements. These concepts include spinning the vehicle and utilization of aerodynamic drag. The rotational concept suffers from the complex nature of the dynamic environment (Coriolis forces, for example). The aerodynamic drag concept is hampered by the variable density of the atmosphere over periods as short as one orbit. Further analysis is required to evaluate the feasibility of these concepts.

At present, no reasonble techniques are known to be suitable for satisfying the applied low-g requirement.

6. DESIGN INTEGRATION

The design integration portion of the study consisted of determining the most satisfactory methods for accommodating the experiment payloads and their supporting subsystems. This includes pressurized modules, unpressurized pallets, and airlocks. Conceptual arrangements of each of the 17 sortie payloads resulted from this effort and they are included in this section along with a weight summary of each.

PAYLOAD ACCOMMODATION REQUIREMENTS

Initially, the 17 payloads were reviewed to determine their accommodation requirements. These are summarized in Figure 6-1.

The analysis of the experiment accommodation requirements for the 17 sortie payloads revealed those which required airlocks, an unpressurized pallet, or both, or a pressurized module with manned entry capability.

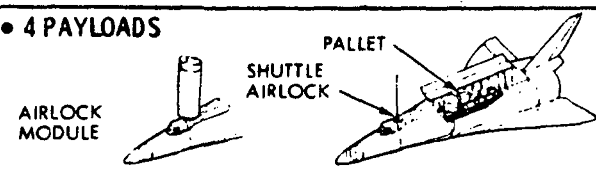
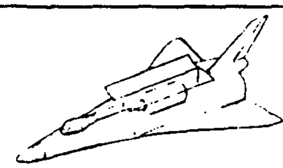
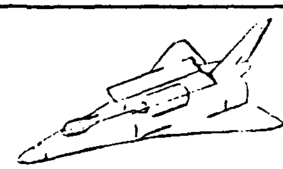
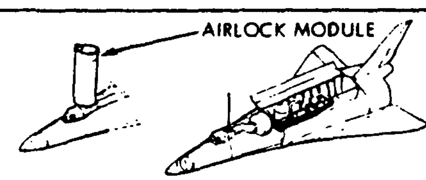
MISSION	REQUIREMENT	ACCOMMODATION
7-DAY MISSIONS (6 PAYLOADS)	PALLET AND AIRLOCK	• 4 PAYLOADS 
	PRESSURIZED MODULE	• 2 PAYLOADS 
30-DAY MISSIONS (11 PAYLOADS)	PRESSURIZED MODULE	• 11 PAYLOADS 
	PALLET AND AIRLOCK	• 1 AIRLOCK PAYLOAD • 1 PALLET PAYLOAD • 1 COMBO 

Figure 6-1. Payload Accommodation Requirements

For the 7-day missions, four payloads require airlocks and pallets while the remaining two need a pressurized module. For those requiring an airlock, consideration was given to using the MSS airlock on the shuttle orbiter's airlock.

For the 30-day missions, all 11 payloads require a pressurized module for extra living accommodations over that provided by the orbiter. In eight cases, a pressurized module also is needed for the experiments while the remaining three utilize a pallet, an airlock, and a combination pallet-airlock.

The volume requirements for the payloads are presented in Table 6-1. These data were used to define the size of the modules and pallets. Payloads which require an airlock for their operation are noted.

PAYLOAD ACCOMMODATION SELECTION

The selection of the best accommodations for the experiment payload included not only the experiment volumes but consideration of the supporting subsystem volumes, shuttle orbiter crew compartment volume, and the use of its airlock.

Airlock Utilization

As noted in Table 6-1, six experiment payloads require an airlock for their operations. These are 7M-1, -2, -3, and -6, and 30M-1, -2, and -3. An airlock is necessary in these cases because of the need to obtain a contamination sample, to eject a canister, and for experiment maintenance and calibration.

To satisfy these conditions, the MSS airlock and the shuttle orbiter airlock were compared for possible utilization. The MSS airlock configuration is shown in Figure 6-2 which illustrates the earth observation arrangement as used for the MSS. The airlock has a volume of 436 cubic feet.

A review of the unpressurized volume requirements (Table 6-1) for the six payloads reveals that the MSS airlock has ample volume to accommodate them. Also, sufficient sensor viewing area was found to be available. It was also decided that the application of the MSS airlock would be less complex than utilizing the orbiter's airlock for this purpose, particularly since an unpressurized module (or pallet) is needed anyway. It was also felt that the interface problems would be less severe as well.

Orbiter Pressure Volume Utilization

When the MSS airlock is used for the unpressurized experiment equipment of these six payloads, the pressurized compartment of the orbiter is

Table 6-1. Experiment Payload Volume Requirements

Payload	Experiment Package	Title	Pressurized Volume (cu. ft.)	Unpressurized Volume (cu. ft.)	Airlock
7M-1	ES1-III T1-I	Earth Observations Contamination Tech.	124.2	140	✓
7M-2	P1-I T1-I C/N1-I	Space Physics Contamination Tech. Search Nav. & RF Propog.	4.2	49	✓
7M-3	ES1-II T1-I T4-I	Earth Observation Contamination Tech. Adv. SC Systems Test	163.8	103.5	✓
7M-4	MS1-III	Materials Science	562		
7M-5	LS3-II LS4-II T3-I	Plant Growth Transients Cells and Tissues EVA	374	20	
7M-6	P2-I P2-II	Plasma Physics Plasma Physics	2.75	231	✓
30M-1	ES1-I T1-II	Earth Observations Contamination Tech.	167.0	157	✓
30M-2	P1-II P4-I	Space Physics Physics and Chem.	336	64	✓
30M-3	T2-I T2-II T2-III	Fluid Management Fluid Management Fluid Management	259	2573	
30M-4	LS1-I LS4,5-I LS6-I LS7-II	Medical Research Biosciences Life Support Man Systems	561		
30M-5	A1-I	X-Ray Stellar Astronomy		2400	
30M-6	A3-I	Adv. Solar Astronomy		2634	
30M-7	A4-I	Intermed. Size UV Tel.		334	
30M-8	A5-I	High Energy Stellar Astr.		348	
30M-9	A6-I	1R Astron.		1360	
30M-10	P3-I	Cosmic Ray Physics	48	Lab	
30M-11	C/N1-II C/N1-III	Search Nav. & RF Propog. Search Nav. & RF Propag.		46	

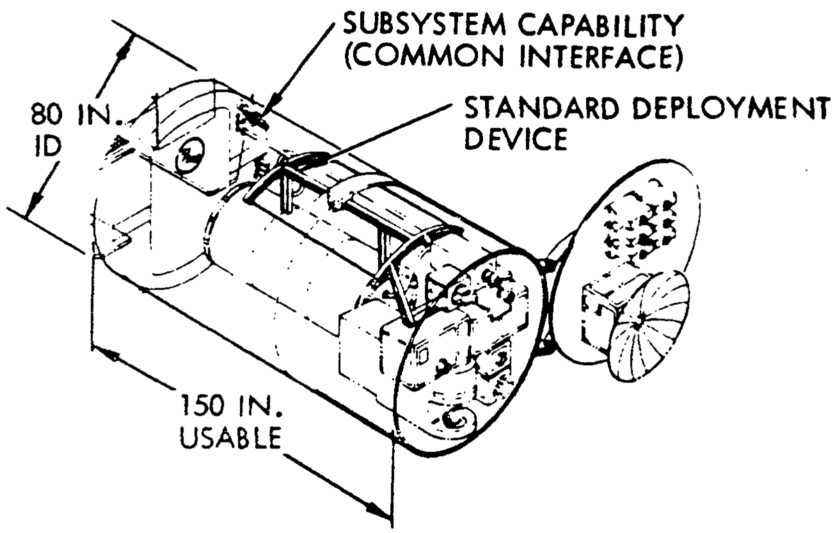


Figure 6-2. Airlock

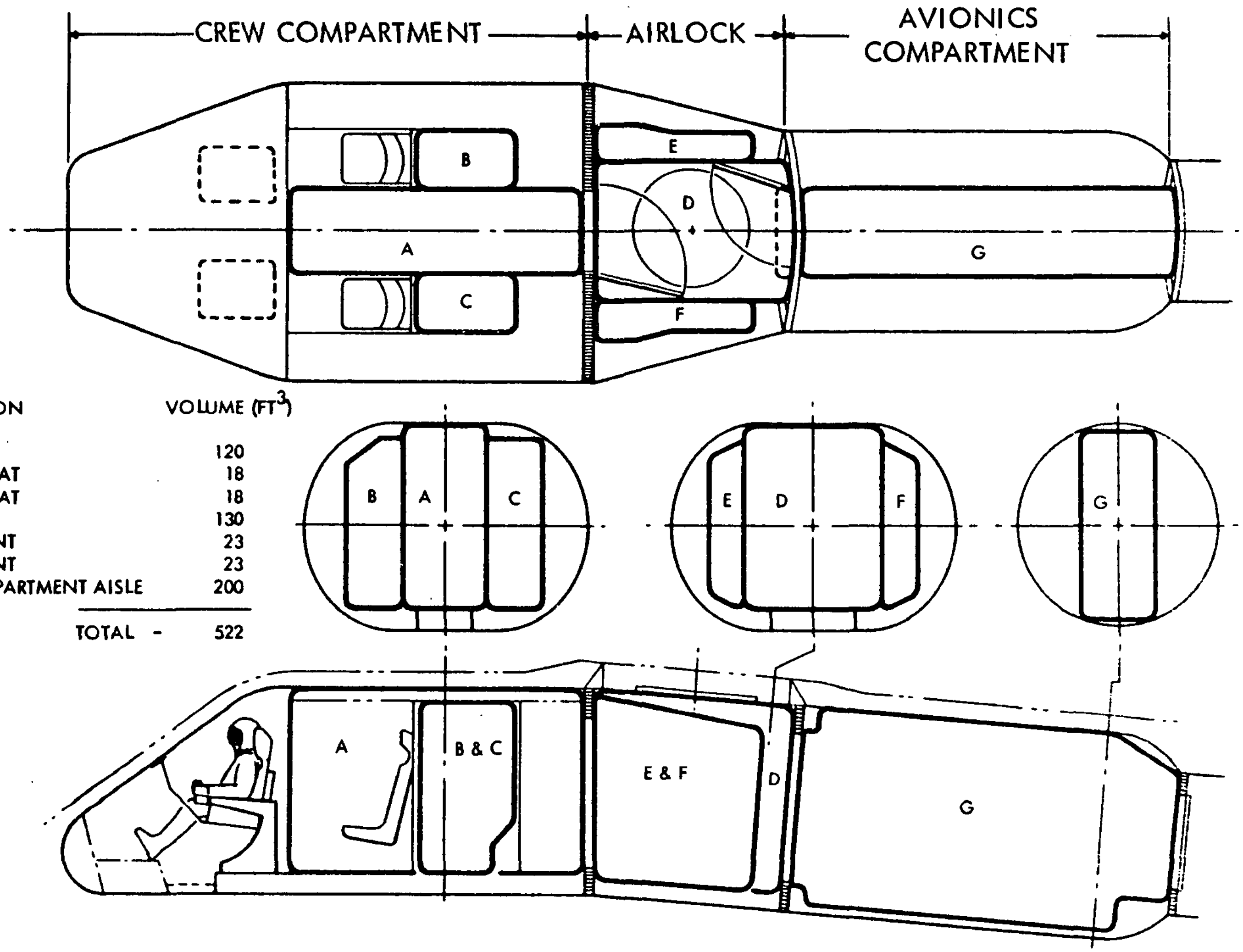
used for those peices of equipment requiring this environment (Table 6-1). These are primarily related to controls and displays, computers, recorders, etc. Figures 6-3 and 6-4 illustrate the volume in the pressurized compartment of the orbiter which would be utilized for this purpose and a possible arrangement for controls and displays. It is apparent that sufficient volume is available to accommodate the experiments' requirements.

Pallet Utilization

The unpressurized experiment volume requirements for the sortie payloads presented in Table 6-1 have been satisfied by the use of the MSS airlock in six cases as discussed previously. That is, the airlock module not only serves the need for an operational airlock but in turn acts as a pallet in supporting the experiments in the space environment.

Payload 30M-3, however, has such a large unpressurized volume requirement that the airlock module is inadequate; hence, a special pallet is required to accommodate it.

Payloads 30M-5 through 30M-10 are telescopes and are themselves pallets.



LOCATION	VOLUME (FT^3)
A - CENTER AISLE	120
B - RH PASSENGER SEAT	18
C - LH PASSENGER SEAT	18
D - AIRLOCK	130
E - RH EVA EQUIPMENT	23
F - LH EVA EQUIPMENT	23
G - ELECTRICAL COMPARTMENT AISLE	200
TOTAL -	522

Figure 6-3. Orbiter Unused Pressure Volume

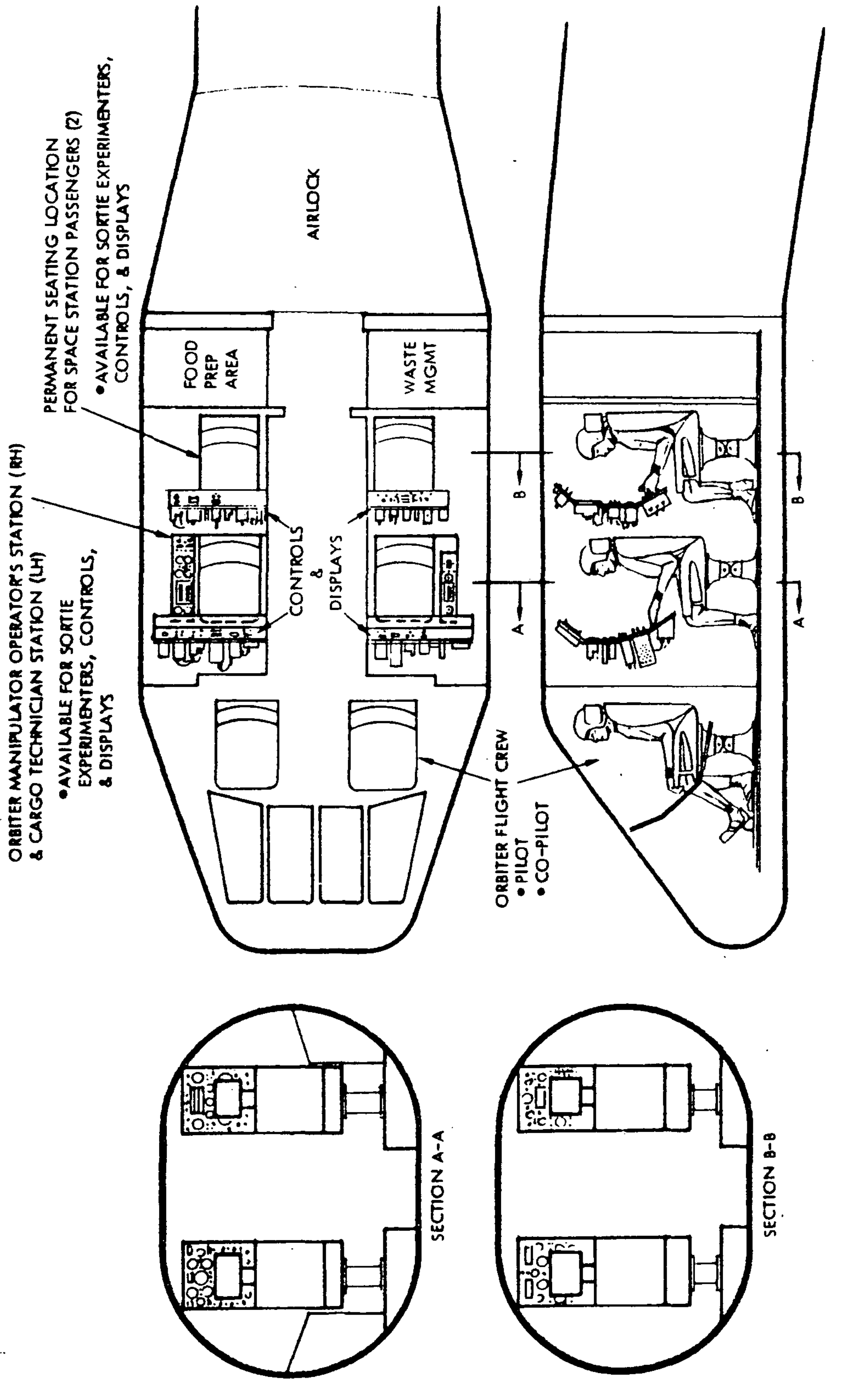


Figure 6-4. Shuttle Orbiter Flight Compartment

Payload 30M-11 requires a small pallet to mount deployable antennas in the payload bay.

Pressurized Modules

For the remaining payloads of Table 6-1 (i.e., 7M-4, 7M-5 and all 11 of the 30-day mission payloads), pressurized modules are required to accommodate the experiments, the subsystems, and the crew.

Crew volume determination consisted of both living and experiment operation requirements.

For the 7-day missions the shuttle orbiter provides the necessary living accommodations. For the 30-day missions, however, additional volume was found necessary for sleeping, recreation, etc.; a minimum of 240 cubic feet was established for this purpose. A layout of this module revealed that the smallest module which could be developed with MSS structural components contained 598 cubic feet; this was therfore the value used.

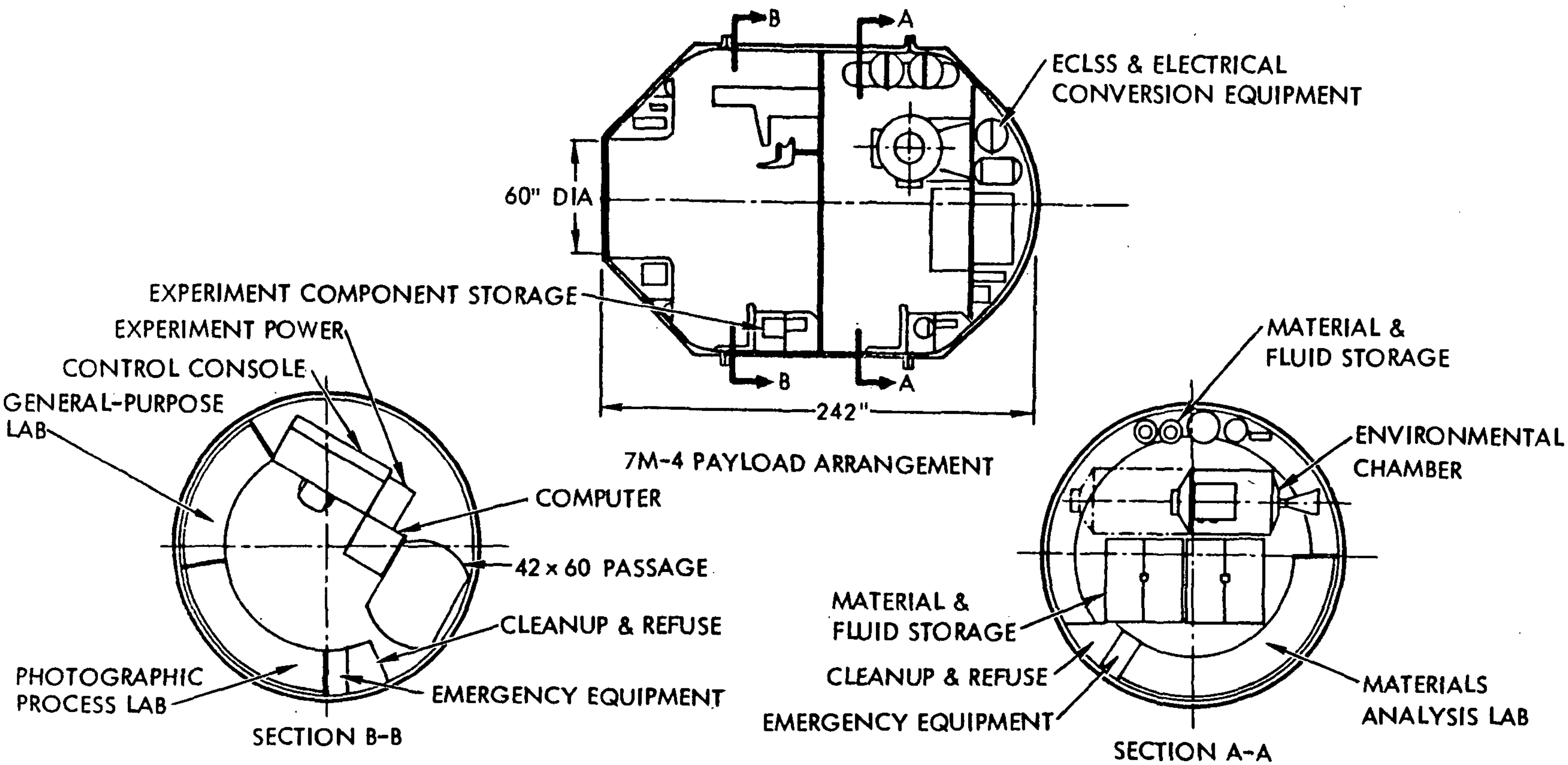
The experiment operation volume was determined by layout. For this purpose, payload 7M-4 was selected as typical. The total volume was determined after the experiment equipment, its operating space, and the supporting subsystems had been arranged. The total module volume was found to be 3.3 times that required for the experiments and the subsystem. Figure 6-5 illustrates the layout of Payload 7M-4 used for this purpose.

Total module volume requirements for these payloads and the resulting lengths of each are presented in Table 6-2. As noted in the table, the experiment (except Payloads 30M-5 through 30M-11 which do not require a pressure volume), subsystem, and crew habitability volumes are given. The total module volume is the product of the combined volumes of the forementioned elements and the 3.3 scale factor. The exceptions are Payloads 30M-5 through 30M-11 where this scale factor does not apply and the minimum module volume of 598 cubic feet was used.

It must be noted that there is a considerable variation in module length resulting from this analysis. The commonality analysis which is discussed in Section 7 reduces these variations to only three modules—10, 20, and 26 feet in length. These lengths are therefore used in the final sortie payload conceptual arrangements which follows.

SORTIE MISSION CONCEPTS

The sortie mission conceptual arrangements described and illustrated in the following pages incorporate the results of the commonality analysis



ITEM	VOLUME (FT^3)
EXPERIMENT EQUIPMENT	562
SUBSYSTEM	25
TOTAL	587 FT^3
MODULE TOTAL	1935 FT^3

WORKING VOLUME RATIO:

$$\frac{\text{TOTAL MODULE VOLUME}}{\text{TOTAL EQUIPMENT VOLUME}} = \frac{1935}{587} = 3.3$$

Figure 6-5. Working Volume Ratio

Table 6-2. Payload Module Volume Requirements

Payload No.	Experiment Volume (cu. ft.)	Subsystem Volume (cu. ft.)	Crew Habitability Volume (cu. ft.)	Combined Volume (cu. ft.)	Total Module Volume (cu. ft.)	Module Length (ft.)
7M-4	562.0	24.6	--	586.6	1930	20
7M-5	374.0	16.0	--	390	1290	15
30M-1	167.0	134.1	240	541.1	1790	18
30M-2	336.0	73.8	240	649.8	2140	20
30M-3	259.0	64.0	240	563.	1850	18
30M-4	561.0	66.9	295.5	923.4	3060	26
30M-5	--	80.4	240	320.4	598	10
30M-6	--	79.3	240	319.3	598	10
30M-7	--	78.3	240	318.3	598	10
30M-8	--	78.6	240	318.6	598	10
30M-9	--	75.6	240	315.6	598	10
30M-10	--	64.0	240	304.	598	10
30M-11	--	--	240	240.	598	10

noted above with respect to the pressurized modules, length, number of the shuttle's fuel cell reactants, cryogenic tanks, and the radiators. The more important features of the arrangements are pointed out.

Payload 7M-1

This payload consists of earth observation experiment package ES1-III and contamination technology experiment package T.1.1. It utilizes an MSS-type airlock as an airlock and a pallet for equipment. The airlock is deployed to the shuttle berthing port to provide sensor viewing and separation from the antenna. It has 140 square feet of radiator attached to the airlock. Antennas are located in and deployed from the shuttle bay. Two EPS cryogenic tanks (one LO_2/one LH_2) are installed in the shuttle bay to supply the shuttle fuel cells for experiment power. A stabilized platform is required for sensors and is provided by the payload. The shuttle pressurized volume is utilized for work area. Figure 6-6 shows the general arrangement. The major payload characteristics are:

	Data rates/quantities	
Orbit - 100-300 n.mi. x 55°	Acquisition (peak) -	2×10^6 bps
Crew - 2 plus 2	Transmission -	13.5×10^9 bits
Power - 1.5 kw	Storage (digital data) -	961.8×10^9
Stability - 210 lb-sec ACPS plus stabilized platform	Storage (TV) -	2 hrs

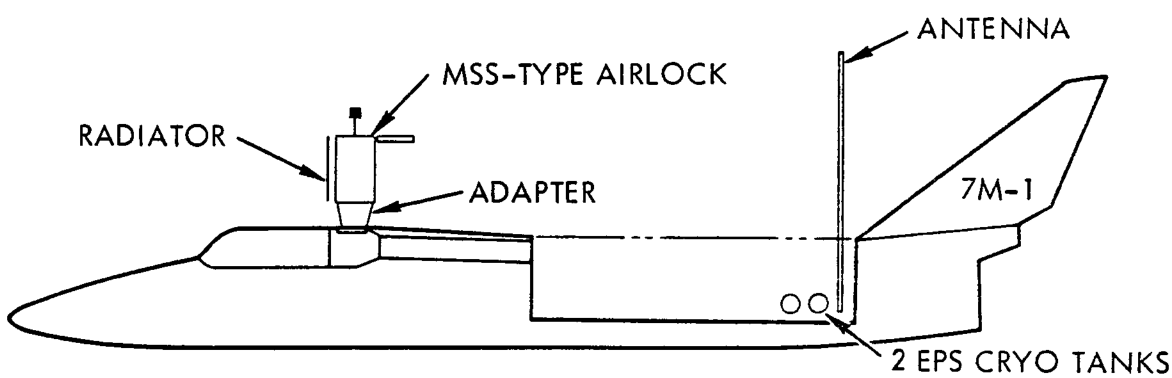


Figure 6-6. 7M-1 Payload General Arrangement

Payload 7M-2

This payload consists of space physics experiment package P1-I, contamination experiment package T1.1, and communications experiment package CN1-I. It utilizes an MSS-type airlock also used as a pallet for equipment. The airlock is deployed to the shuttle berthing port to provide sensor viewing. It has 210 square feet of radiator attached to the airlock. Three EPS cryogenic tanks (one LO_2/two LH_2) are installed in the shuttle bay to supply the shuttle fuel cells for experiment power. The shuttle pressurized volume is utilized for work area. Figure 6-7 shows the general arrangement. The major payload characteristics are:

	Data rates/quantities	
Orbit - 80 x 100/150 n.mi. x 90°	Acquisition (peak)	- 2×10^5 bps
Crew - 2 plus 2	Transmission	-
Power - 2.8 kw	Storage (digital data)	- 121.5×10^9
Stability - 210 lb-sec ACPS	Storage (TV)	- 2 hr

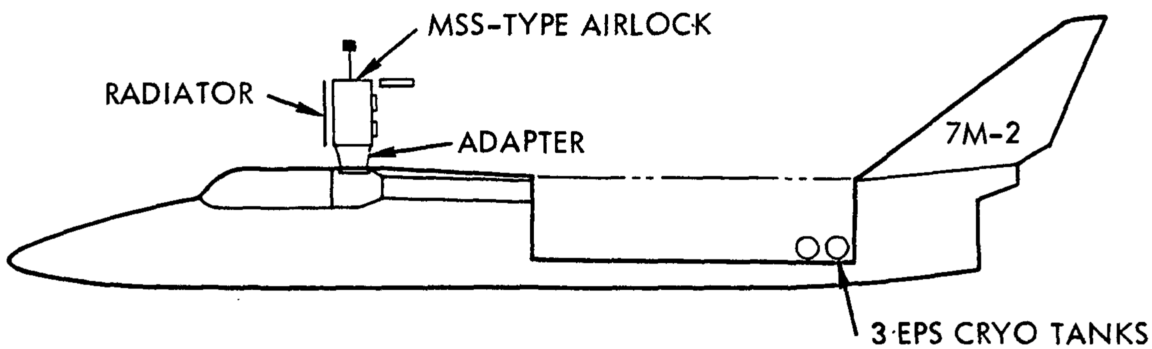


Figure 6-7. 7M-2 Payload General Arrangement

Payload 7M-3

This payload consists of earth observation experiment package ES1-II, advanced spacecraft systems experiment package T4-1, and contamination experiment package T1-I. It utilizes an MSS-type airlock also used as an equipment pallet. The airlock is deployed to the shuttle berthing port for sensor viewing and antenna separation. A stabilized platform is provided by the payload. It has 420 square feet of radiator attached to the airlock. Antennas are mounted in the shuttle bay and deployed. Four EPS cryogenic tanks (one LO_2 and three LH_2) are installed in the shuttle bay to supply shuttle fuel cells for experiment power. The shuttle pressurized volume is utilized for work area. Figure 6-8 shows the general arrangement. The major payload characteristics are:

	Data rates/quantities	
Orbit - 100 n. mi. x 55°	Acquisition (peak)	- 2×10^6 bps
Crew - 2 plus 2	Transmission	- 15×10^9 bits
Power - 3.3 kw	Storage (digital data)	- 10.68×10^{11}
Stability - 210 lb-sec ACPS plus stabilized platform	Storage (TV)	- 2 hr

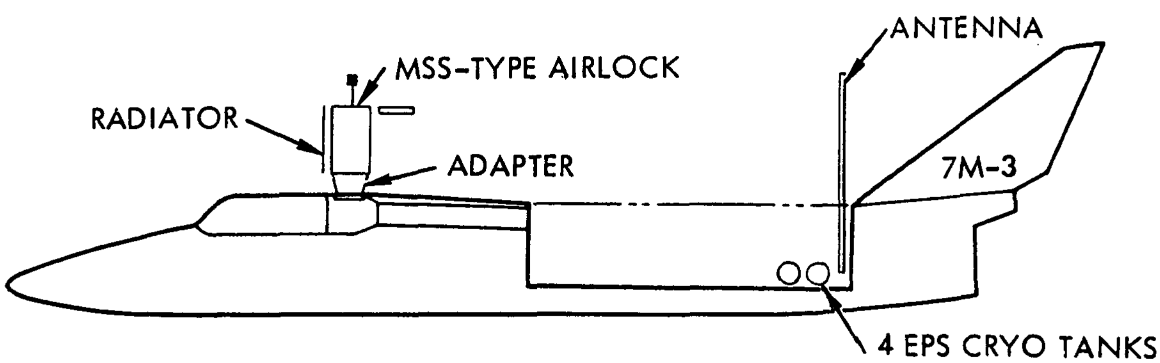


Figure 6-8. 7M-3 Payload General Arrangement

Payload 7M-4

This payload consists of material science experiment package MS-III. It uses a 20-foot-long module which is fixed in the shuttle bay and connected to the shuttle pressurized compartment with a pressurized tunnel. It has 700 square feet of radiator which is installed in the shuttle bay and deployed when required. Five EPS cryogenic tanks (two LO_2 and three LH_2) are installed in the shuttle bay to supply the shuttle fuel cells for experiment power. Figure 6-9 shows the general arrangement. The major payload characteristics are:

	Data rates/quantities	
Orbit - 200 n. mi. x 28.5°	Acquisition (peak)	- 1×10^4 bps
Crew - 2 plus 2	Transmission (TV)	- 0.06 hr.
Power - 4.3 kw	Storage (digital data)	- 3.024×10^9
Stability - 210 lb-sec ACPS	Storage (TV)	- 0.3 hr.

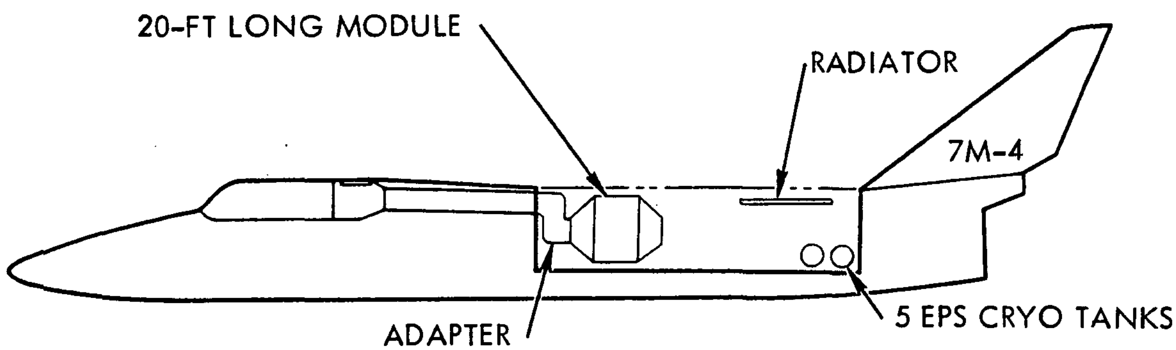


Figure 6-9. 7M-4 Payload General Arrangement

Payload 7M-5

This payload consists of life sciences experiment package (plant growth) LS3-II, life sciences experiment package (cells and tissue) LS4-II, and space technology experiment package (extravehicular activity) T3-I. It uses a 20-foot-long module which is fixed in the shuttle bay and connected to the shuttle pressurized compartment with a pressurized tunnel. The module contains a 10-foot-diameter centrifuge. An astronaut maneuvering unit is stored in the shuttle bay and reached by extravehicular means. The shuttle airlock is utilized to achieve space access. A 210-square-foot radiator is installed in the shuttle bay. One EPS LH_2 cryogenic tank is installed in the shuttle bay to supply the shuttle fuel cells for experiment power. Figure 6-10 shows the general arrangement. The major payload characteristics are:

Orbit - 100 n. mi. x 28.5°

Crew - 2 plus 3

Power - 0.72 kw

Stability - 210 lb-sec ACPS

Data rates/quantities

Acquisition (peak)	- 5×10^3 bps
Transmission	-0.06 hr. delayed TV
Storage (digital data)	- 3.024×10^9
Storage (TV)	- 0.3 hr.

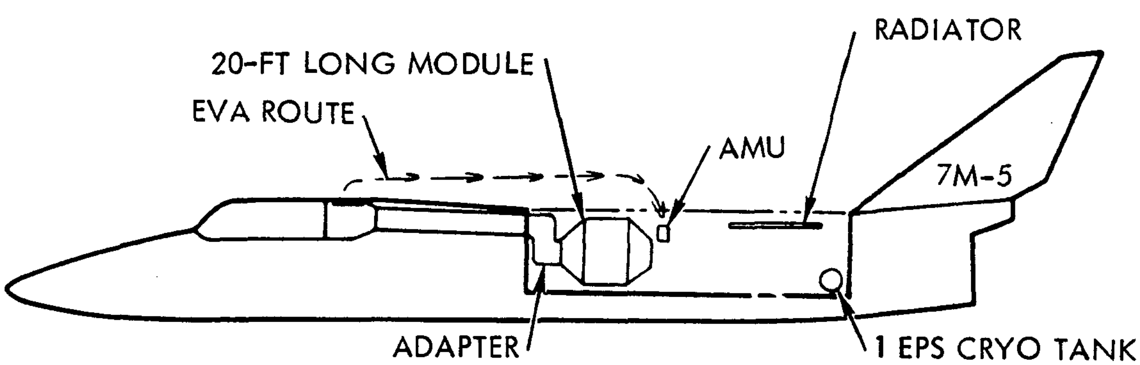


Figure 6-10. 7M-5 Payload General Arrangement

Payload 7M-6

This payload consists of plasma physics experiment packages P2-I and P2-II. An MSS-type airlock is used as a pallet for the experiment. The airlock is deployed to the shuttle berthing port so that the experiment instruments may be reached for maintenance and calibration. A 70-square-foot radiator is located on the airlock. One EPS LH_2 cryogenic tank is installed in the shuttle bay to supply the shuttle fuel cells for experiment power. Figure 6-11 shows the general arrangement. The major payload characteristics are:

Orbit - 270 n. mi. x 55°

Crew - 2 plus 2

Power - 2.8 kw

Stability - 40 lb-sec ACPS

Data rates/quantities

Acquisition (peak)	- 1×10^5 bps
Transmissition (digital data)	- 2.15×10^9 bits
Storage (digital data)	- 120.4×10^9 bits

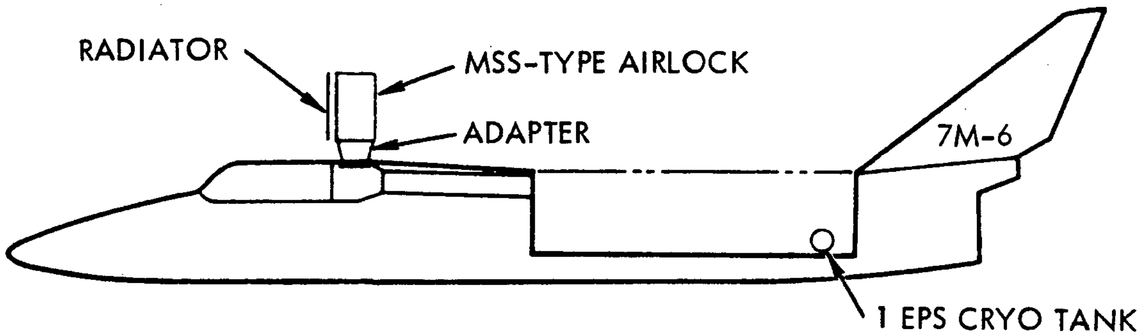


Figure 6-11. 7M-6 Payload General Arrangement

Payload 30M-1

This payload consists of meteorology and atmospheric science experiment package ES1-I and contamination technology experiment package T1-II. A 20-foot-long module is used for habitability and laboratory facilities. An MSS-type airlock is attached to the module. The combined unit is deployed to the shuttle berthing port for sensor and antenna separation and airlock utilization. A stabilized platform is provided by the payload. A 210-square-foot radiator is attached to the module. Antenna and deployment booms are located in the shuttle bay. Four (two LO_2 and two LH_2) EPS cryogenic tanks are located in the shuttle bay to supply fuel to the shuttle fuel cells for experiment power. Figure 6-12 shows the general management. The major payload characteristics are:

Orbit - 100 n.mi. x 55°

Crew - 2 plus 2

Power - 1.0 kw

Stability - 40 lb-sec ACPS plus stabilized platform

Data rates/quantities:

Acquisition (peak)	- 12.4×10^4 bps
Transmission (digital data)	- 2.23×10^7 bits
Storage (digital data)	- 77.2×10^9
Storage (TV)	- 2 hr.

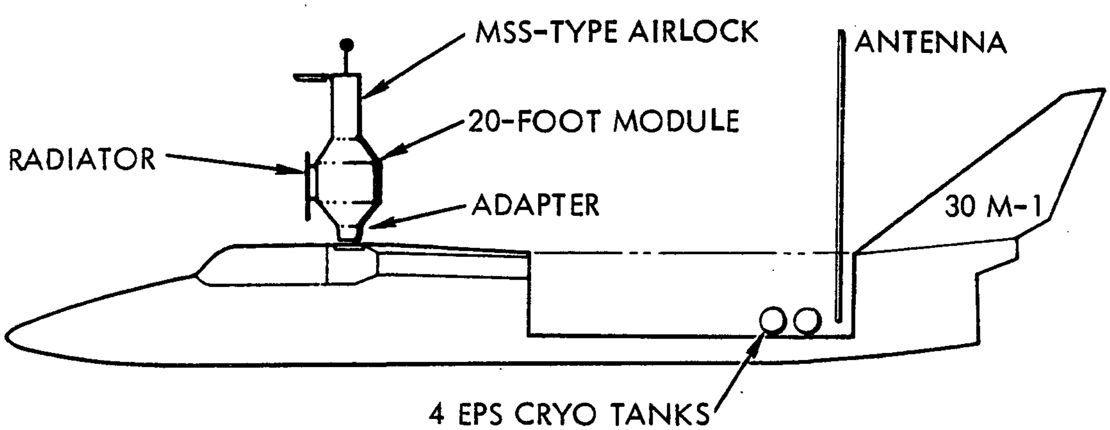


Figure 6-12. 30M-1 Payload General Arrangement

Payload 30M-2

This payload consists of space physics experiment package P1-II and physics and chemistry experiment package P4-I. A 20-foot-long module is required for habitability and laboratory facilities. An MSS-type airlock is attached to the module and is also used as a pallet. The module is connected to the shuttle with a pressurized transfer tunnel. A stabilized platform is provided by the payload. A 280-square-foot radiator is attached to the module. Five (two LO_2 and three LH_2) EPS cryogenic tanks are located in the shuttle bay to supply fuel to the shuttle fuel cells for experiment power. Figure 6-13 shows the general arrangement. The major payload characteristics are:

Orbit - 200 n. mi. x 28.5°

Crew - 2 plus 2

Power - 1.2 kw

Stability - 210 lb-sec ACPS plus stabilized platform

Data rates/quantities:

Acquisition (peak)	- 4.5×10^4 bps
Transmission (digital data)	-
Storage (digital data)	- 122.2×10^9

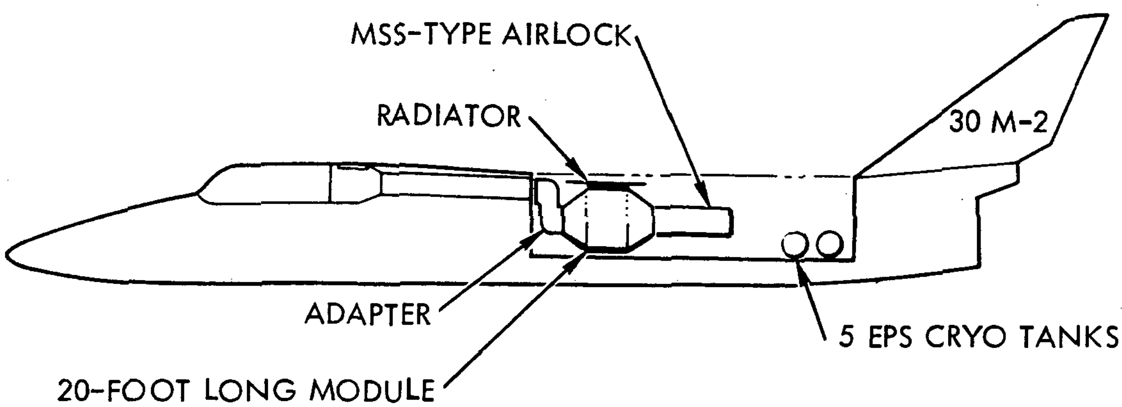


Figure 6-13. 30M-2 Payload General Arrangement

Payload 30M-3

This payload consists of fluid management experiment packages T.2-I, T.2-II, and T.2-III. A 20-foot-long module is required for habitability and laboratory facilities. The module is connected to the shuttle living area with a pressurized transfer tunnel. A pallet for experiment provisions is installed in the shuttle bay. A 140-square-foot radiator is attached to the module. Nine (four LO_2 and five LH_2) EPS cryo tanks are installed in the shuttle bay to supply fuel to the shuttle fuel cells for experiment power. Figure 6-14 shows the general arrangement. The major payload characteristics are:

Orbit - 300 n.mi. x 28.5°

Crew - 2 plus 2

Power - 1.7 kw

Stability - 210 lb-sec ACPS

Data rates/quantities:

Acquisition (peak) - 5.78×10^3 bps

Transmission (digital data)

Storage (digital data) - 14.61×10^8

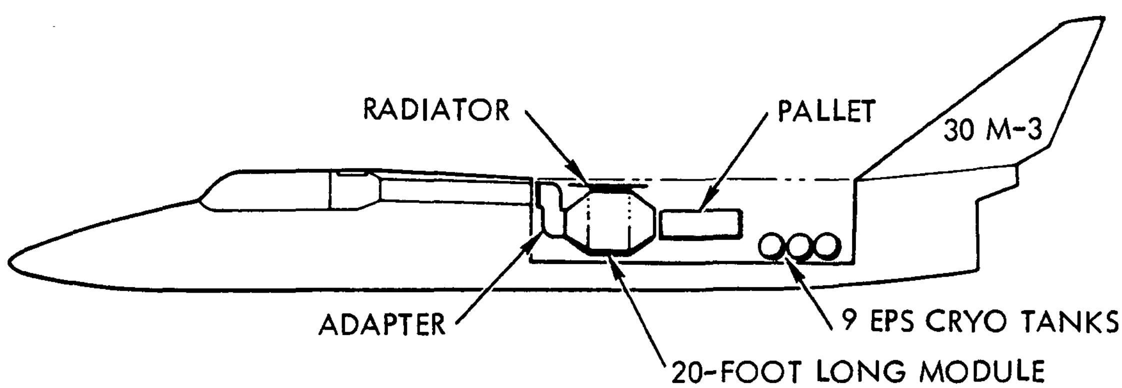


Figure 6-14. 30M-3 Payload General Arrangement

Payload 30M-4

This payload consists of medical research experiment package LS1-I, bioscience experiment package LS4, 5-I, life support experiment package LS6-I, and man systems experiment package LS7-II. A 26-foot-long module is required for habitability and laboratory facilities. An alternative of one 20-foot and one 10-foot module interconnected could be used in place of a single 26-foot module. The module contains a 10-foot-diameter centrifuge for experiments. The module is connected to the shuttle with a pressurized transfer tunnel. A 140-square-foot radiator is attached to the module. Five (two LO_2 and three LH_2) EPS cryogenic tanks are installed in the shuttle bay to supply fuel to the shuttle fuel cells for experiment power. Figure 6-15 shows the general arrangement. The major payload characteristics are:

	Data rates/quantities	
Orbit - 100 n.mi. x 28.5°	Acquisition (peak)	- 28×10^4 bps
Crew - 2 plus 3	Transmission	-
Power - 1.1 kw	Storage (digital data)	- 74.34×10^7
Stability - 210 lb-sec ACPS		

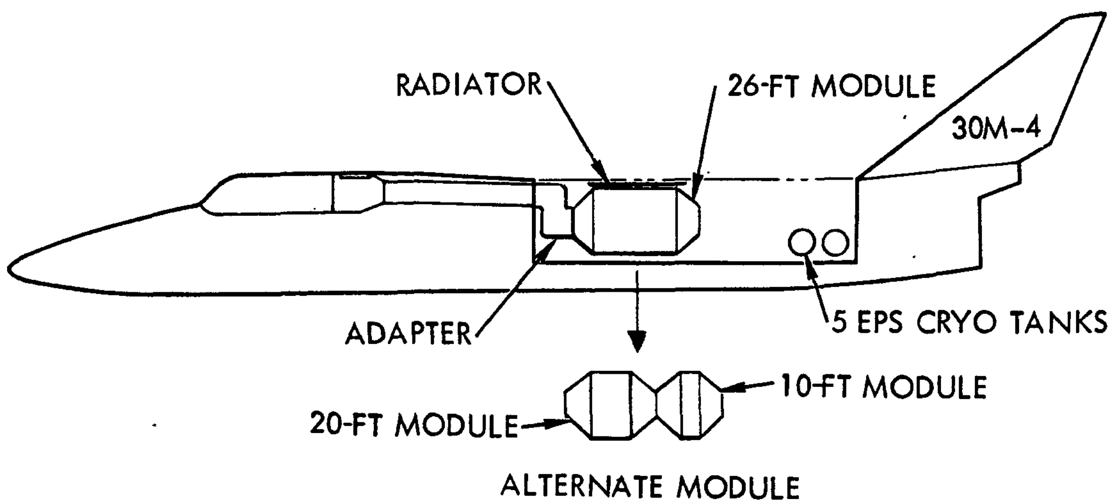


Figure 6-15. 30M-4 Payload General Arrangement

Payload 30M-5

This payload consists of X-ray stellar astronomy experiment package A1-I. A 10-foot-long module is provided for crew habitability provisions. The module is connected to the shuttle with a pressurized transfer tunnel. A deployable pallet with a stabilized mount for a 45-foot telescope is provided. A 140-square-foot radiator is attached to the module. Five (two LO_2 and three LH_2) EPS cryogenic tanks are installed in the shuttle fuel cells for experiment power. Figure 6-16 shows the general arrangement. The major payload characteristics are:

Orbit - 400 n. mi. x 28.5°

Crew - 2 plus 2

Power - 1.0 kw

Stability - 40 lb-sec ACPS plus stabilized mount

Data rates/quantities:

Acquisiton (peak) - 4×10^5 bps

Transmission (digital data) - 5×10^8 B/D, 5×10^7 B/D

Storage (digital data) - 5×10^9

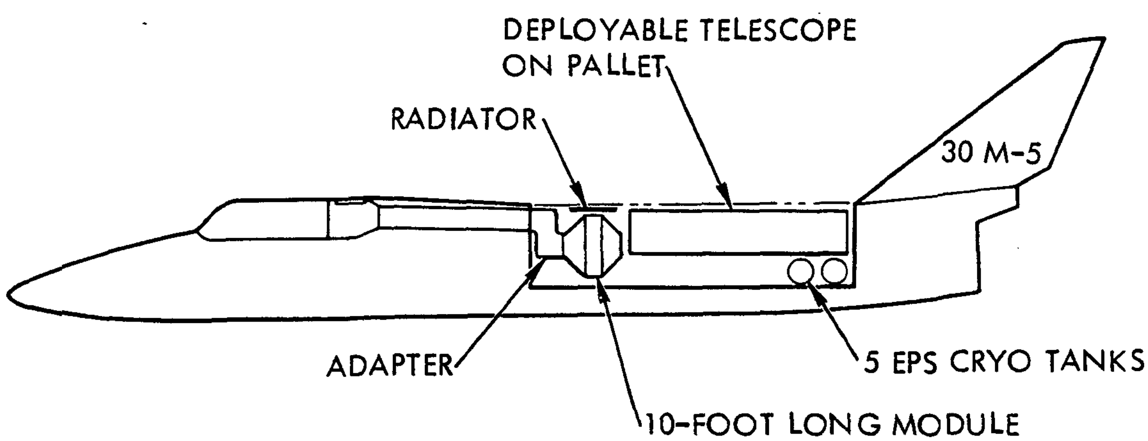


Figure 6-16. 30M-5 Payload General Arrangement

Payload 30M-6

This payload consists of advanced solar astronomy experiment package A3-I. A 10-foot-long module is provided for crew habitability provisions. The module is connected to the shuttle with a pressurized transfer tunnel. A deployable pallet with a stabilized mount for 40-foot, 11-foot and 23-foot telescopes is provided. A 140-square-foot radiator is attached to the module. Six (three LO_2 and three LH_2) EPS cryogenic fuel tanks are installed in the shuttle bay to supply the shuttle fuel cells for experiment power. Figure 6-17 shows the general arrangement. The major payload characteristics are:

Orbit - 220 n. mi. x 90°

Crew - 2 plus 2

Power - 1.1 kw

Stability - 40 lb-sec ACPS plus stabilized mount

Data rates/quantities:

Acquisition (peak) - 4×10^4 bps

Transmission (digital data) - 6×10^8 bits

Storage (digital data) - 18×10^9 bits

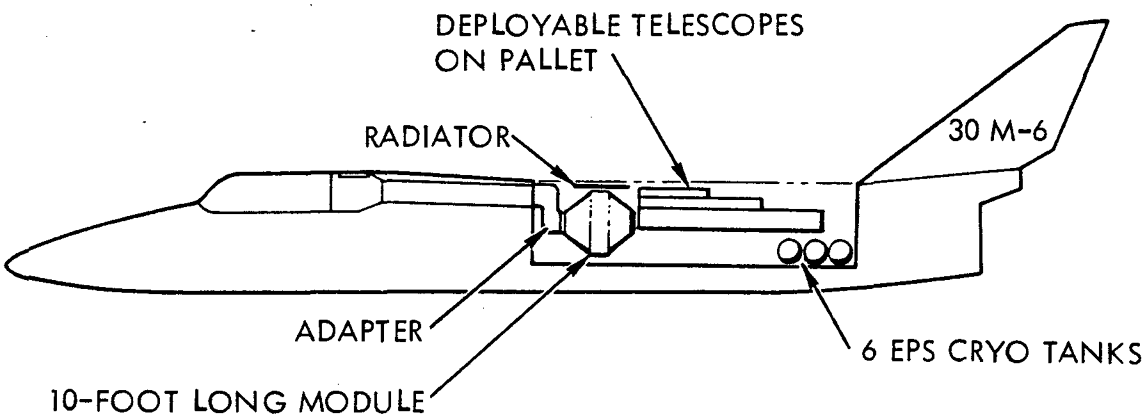


Figure 6-17. 30M-6 Payload General Arrangement

Payload 30M-7

This payload consists of intermediate size ultraviolet telescope experiment package A4-I. A 10-foot-long module is provided for crew habitability provisions. The module is connected to the shuttle with a pressurized transfer tunnel. A deployable pallet with a stabilized mount for an 8-foot telescope is provided. A 140-square-foot radiator is attached to the module. Six (three LO_2 and three LH_2) EPS cryogenic fuel tanks are installed in the shuttle bay to supply the shuttle fuel cells for experiment power. Figure 6-18 shows the general arrangement. The major payload characteristics are:

Orbit - 250 n. mi. x 28.5°

Crew - 2 plus 2

Power - 1.1 kw

Stability - 40 lb-sec ACPS plus stabilized mount

Data rates/quantities

Acquisition (peak)	- 4×10^4 bps
Transmission (digital data)	- 4×10^8 bits
Storage (digital data)	- 48×10^9 bits
Storage (TV)	- 1.9 hr.

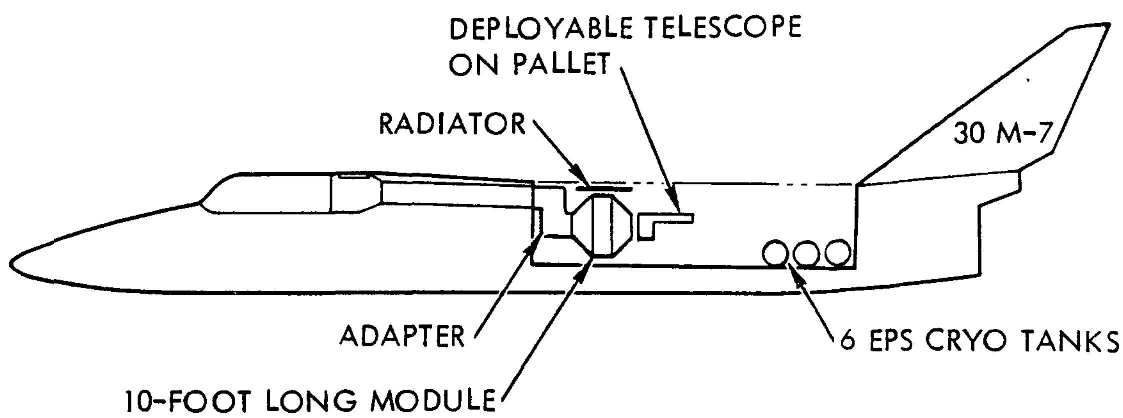


Figure 6-18. 30M-7 Payload General Arrangement

Payload 30M-8

This payload consists of high-energy stellar astronomy experiment package A5-I. A 10-foot-long module is provided for crew habitability provision. The module is connected to the shuttle with a pressurized transfer tunnel. A deployable pallet with a stabilized mount for a 27-foot and a 13-foot telescope is provided. A 140-square-foot radiator is attached to the module. Seven (three LO_2 and four LH_2 EPS cryogenic tanks are installed in the shuttle bay to supply the shuttle fuel cells for experiment power. Figure 6-19 shows the general arrangement. The major payload characteristics are:

Orbit - 400 n. mi. x 28.5°

Crew - 2 plus 2

Power - 1.2 kw

Stability - 40 lb-sec ACPS plus stabilized mount

Data rates/quantities:

Acquisition (peak) - 6.4×10^3 bps

Transmission (digital data) - 5.4×10^7 bits

Storage (digital data) - 16.2×10^9 bits

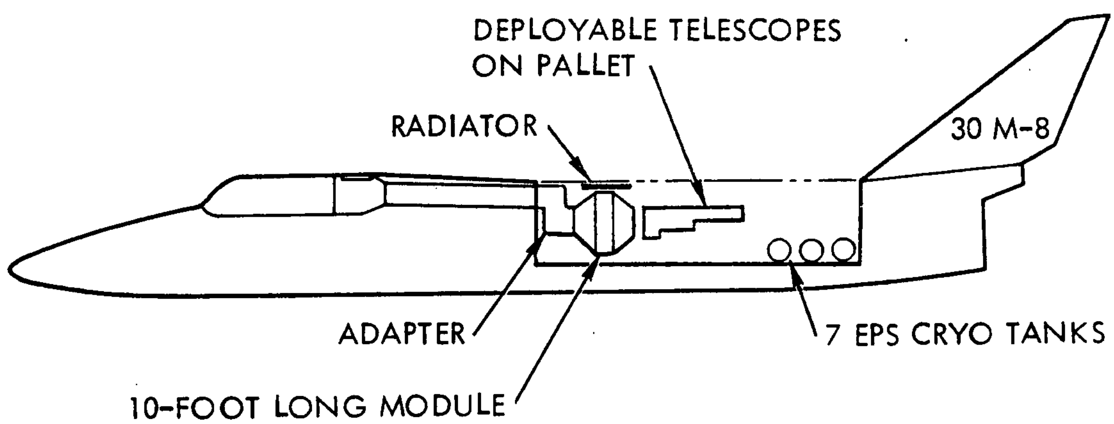


Figure 6-19. 30M-8 Payload General Arrangement

Payload 30M-9

This payload consists of infrared astronomy experiment package A6-I. A 10-foot-long module is provided for crew habitability provisions. The module is connected to the shuttle with a pressurized transfer tunnel. A deployable stabilized pallet is provided for the 12-foot telescope. A 140-square-foot radiator is attached to the module. Seven (three LO_2 and four LH_2) EPS cryogenic tanks are installed in the shuttle bay to supply the shuttle fuel cells for experiment power. Figure 6-20 shows the general arrangement. The major payload characteristics are:

Orbit - 270 n. mi. x 50°

Crew - 2 plus 2

Power - 1.3 kw

Stability - 40 lb-sec ACPS plus stabilized mount

Data rates/quantities

Acquisition (peak)	- 4×10^4 bps
Transmission (digital data)	- 3×10^8 bits
Storage (digital data)	- 36×10^9 bits
Storage (TV)	- 7.9 hr.

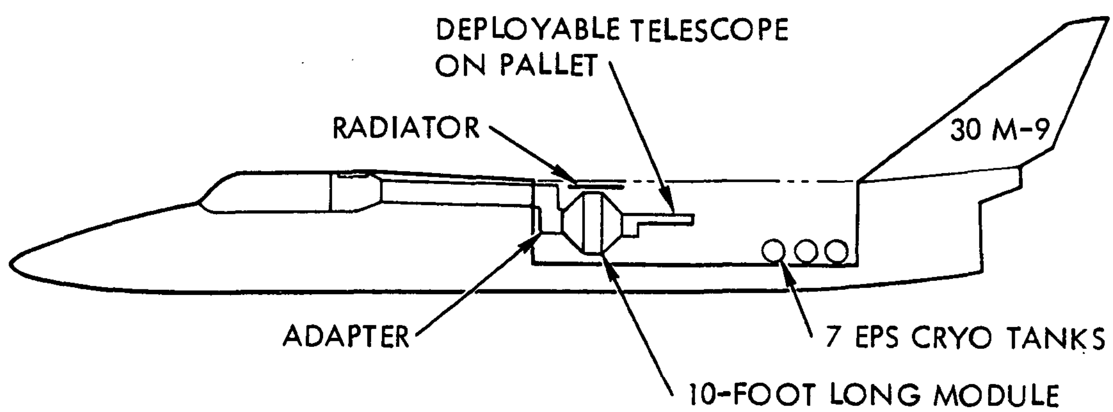


Figure 6-20. 30M-9 Payload General Arrangement

Payload 30M-10

This payload consists of cosmic ray experiment package P. 3-I. A 10-foot-long module is provided for crew habitability provisions. The module is connected to the shuttle with a pressurized transfer tunnel. A 13-foot-diameter by 25-foot-long pressurized experiment laboratory is attached to the module and is accessible from the module. A 140-square-foot radiator is attached to the module. Seven (three LO_2 and four LH_2) EPS cryogenic tanks are installed in the shuttle bay to supply the shuttle fuel cells for experiment power. Figure 6-21 shows the general arrangement. The major payload characteristics are:

Orbit - 200 n. mi. x 28.5°

Crew - 2 plus 2

Power - 1.5 kw

Stability - 40 lb-sec ACPS

Data rates/quantities:

Acquisition (peak)	- 1.7×10^4 bps
Transmission	-
Storage	- 45×10^9 bits

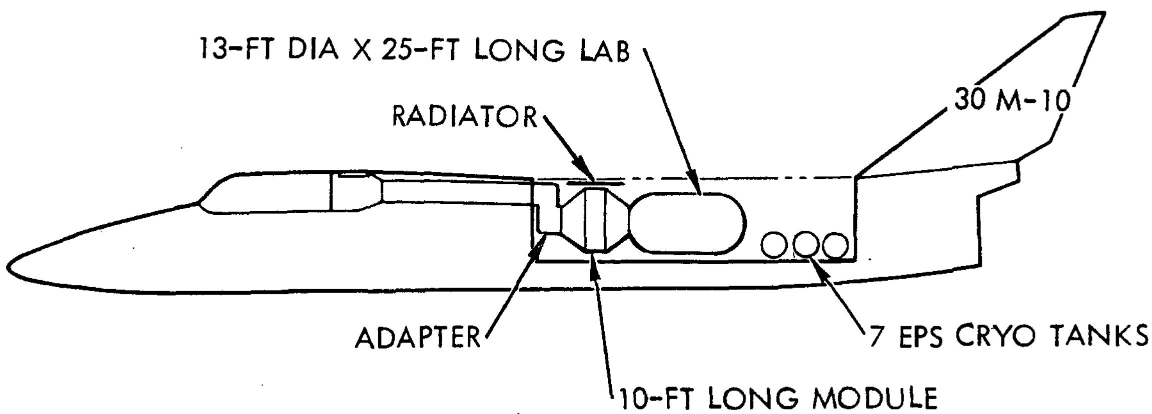


Figure 6-21. 30M-10 Payload General Arrangement

Payload 30M-11

This payload consists of optical frequency, millimeter wave, and navigational tests experiment package C/N. 1-II and search, navigation, and RF propagation experiment package C/N. 1-III. A 10-foot-long module is provided for crew habitability. The module is connected to the shuttle with a pressurized transfer tunnel. A pallet is provided for experiment equipment. Large antennas are deployed from the pallet. A 140-square-foot radiator is attached to the module. Four (two LO_2 and two LH_2) EPS cryogenic tanks are installed in the shuttle bay to supply the shuttle fuel cells for experiment power. Figure 6-22 shows the general arrangement. The major payload characteristics are:

Orbit - 150 n. mi. x 90°

Crew - 2 plus 2

Power - 0.75 kw

Stability - 40 lb-sec ACPS

Data rates/quantities:

Acquisition (peak)	- 30×10^4 bps
Transmission (digital data)	- 37.9×10^7 bits
Storage	- $38. \times 10^9$ bits
	- 1 hr. /day analog

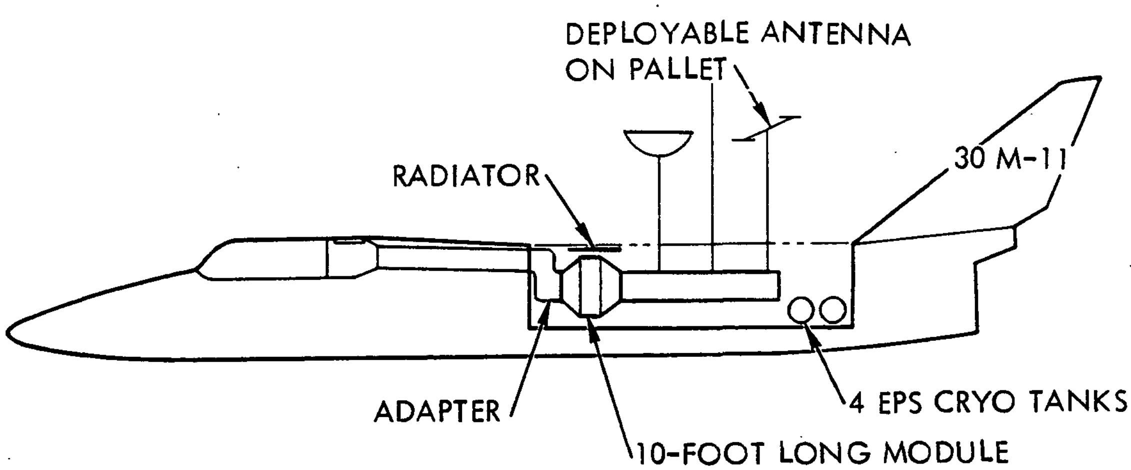


Figure 6-22. 30M-11 Payload General Arrangement

SHUTTLE INTERFACES

The interfaces of sortie mission payloads with the shuttle fall into two general categories: structural and systems.

Structural Interface

The physical interface of attaching payloads to the shuttle is broken down as follows:

1. Modules

   a. Shuttle Bay Interface - The basic structure of each module is the same; only the length is variable. These modules have identical shuttle payload bay trunnion attach fittings. However, because the length varies, they do not all have the same fore and aft locations. Therefore, additional hard points must be coordinated with the shuttle.

   b. Berthing Port Interface - During the orbital mode, some modules are deployed to the shuttle berthing port. This location requires the use of an MSS-type berthing adapter for the structural interface between the sortie modules and the shuttle berthing port.

   c. Manipulator pickup points must be provided on all modules that are displaced from the shuttle bay to the shuttle berthing port. The pickup fitting configuration is identical to those utilized by the MSS.

2. Airlocks

   a. Shuttle Bay Interface - The MSS-type airlock is smaller in diameter than a sortie module; therefore, it will require an adapter to reach the shuttle attaching hard points.

   b. Sortie Module Interfaces - Some payloads require the MSS-type airlock to be attached directly to the sortie module. Sortie modules will have berthing rings identical to those developed for the MSS modules; therefore, airlocks will structurally interface directly to the modules.

   c. Shuttle Berthing Port Interface - During orbital operations, some airlocks are deployed to the shuttle berthing port. This location requires the use of an MSS-type berthing adapter for the structural interface between the MSS-type airlock and the shuttle berthing port.

3. Pallets - Experiment equipment pallets have two possible structural interfaces, depending on their size and use.

   a. Sortie Module Interfaces - Pallets will attach directly to the sortie module berthing ring.

   b. Shuttle Bay Interface - Pallets will interface with the shuttle bay attaching provisions.

4. Cryo Tanks - Experiment cryo fuel tanks are mounted in packages that are attached directly to shuttle structure, and are plumbed to the shuttle fuel cells. These packages may be installed or removed as required.

5. Antenna Packages - In some cases, antennas and deployment mechanisms are mounted in packages that are attached directly to shuttle structure. These packages may be installed or removed as required.

Systems Interface

The shuttle systems that are utilized by the sortie missions have various interfaces depending on the sortie payload.

All sortie habitable modules have a standard MSS-type berthing ring and feedthrough arrangement at the forward end. Installation of this module in the shuttle bay requires an adapter which interfaces with the sortie module berthing ring and the shuttle tunnel. This adapter is the subsystem interface link. It is also a pressurized tunnel for personnel transfer. Figure 6-23 illustrates the subsystem interface.

The other shuttle interface is at the shuttle berthing port. When the module is deployed to this position, an MSS-type berthing adapter is required (Figure 6-24). This adapter is stored in the shuttle bay and when required is moved by the shuttle manipulator to the shuttle berthing port prior to the deployment of the sortie module. The adapter provides the pressurized passage to the module as well as the subsystem feedthrough.

SORTIE PAYLOAD WEIGHTS

Weight summaries for each of the sortie concepts previously described are presented in Table 6-3 and 6-4. These weights reflect experiment equipment, support subsystem and consumable weights which make up the sortie payloads, and shuttle dry weight and the propellants required to fly each specific mission. All payloads fall within the shuttle's capabilities for end-of-ascent and orbiter landing weights.

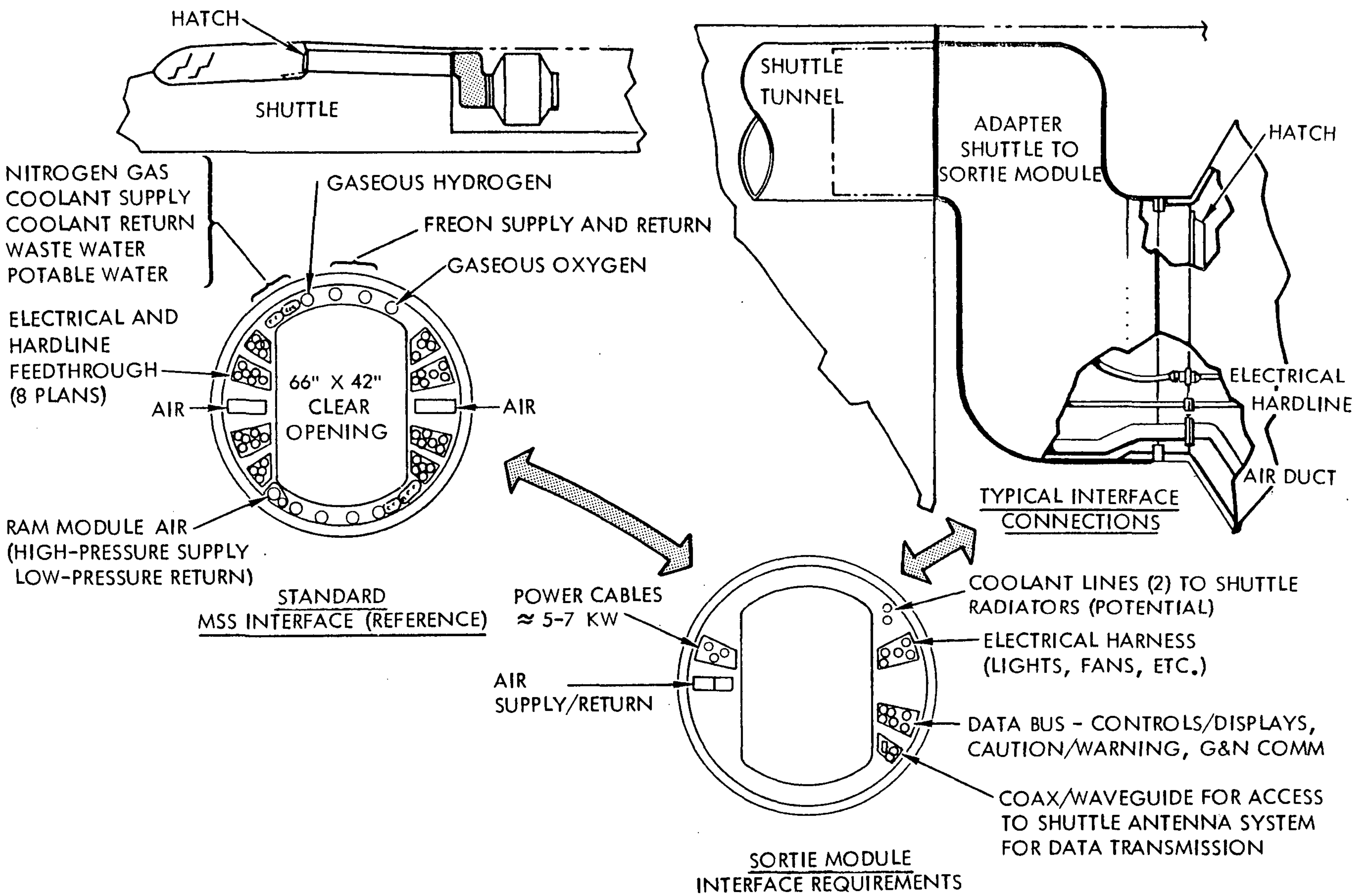


Figure 6-23. Sortie Module to Shuttle Interface

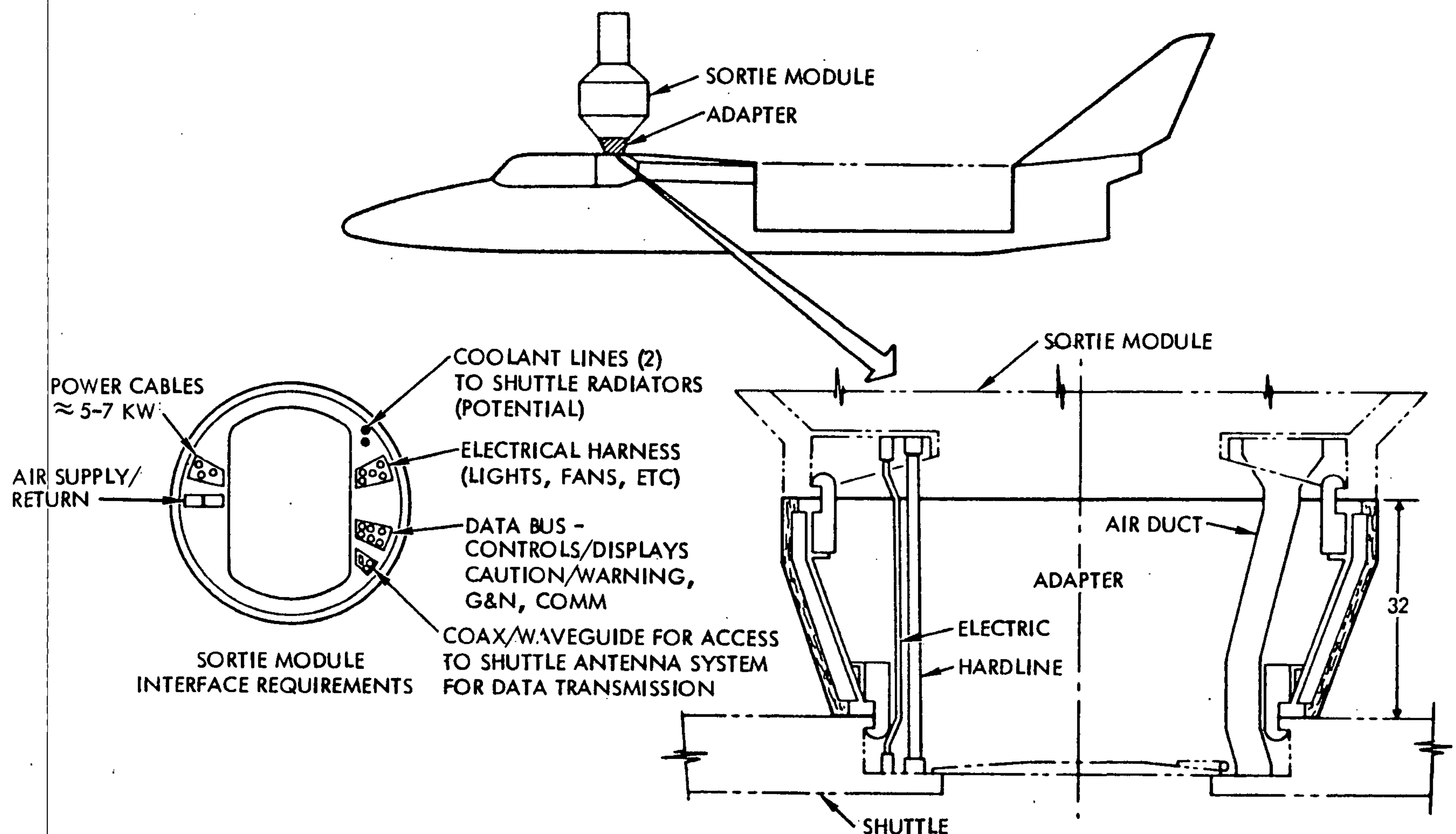


Figure 6-24. Sortie Module-Shuttle Berthing Port Interface

Table 6-3. *Weight Summary - 7-Day Sortie Payloads*

Items	Payloads					
	7M-1	7M-2	7M-3	7M-4	7M-5	7M-6
Shuttle Dry Weight	237,329	237,329	237,329	237,329	237,329	237,329
Flight Crew (2) and Residuals	4,691	4,691	4,691	4,691	4,691	4,691
Resources, Inflight Losses, ABES Propellant	15,310	15,310	15,310	15,310	15,310	15,310
Sortie Payload	14,470	9,120	17,360	16,810	11,720	6,670
Structural provisions	2,220	2,090	2,310	6,870	6,720	2,000
ECLSS hardware	618	821	2,023	1,832	770	542
Electrical power provisions	410	508	654	835	145	221
G&C provisions	1,430	880	990	0	0	0
Information provisions	985	443	1,043	257	182	514
Crew and habitability provisions	601	601	601	601	798	601
Powerup and housekeeping tankage	300	300	300	300	300	300
Sortie consumables	1,007	1,217	1,309	1,468	984	950
Experiment equipment	6,376	1,807	7,279	4,165	1,175	1,122
Experiment consumables	103	33	431	62	16	0
Crew	420	420	420	420	630	420
Shuttle Propellant	36,500	36,200	37,500	21,000	23,000	34,200
Drag makeup propellant	0	0	1,000	0	1,000	0
Attitude control propellant	4,000	4,000	4,000	200	200	2,700
ΔV maneuver propellant	32,500	32,200	32,500	20,800	21,800	31,500
End Ascent Gross Weight	308,300	302,650	312,190	295,140	292,050	298,200
Consumables	52,920	42,760	54,550	39,840	40,310	51,460
Shuttle propellant	36,500	26,200	37,500	23,000	24,000	35,200
Experiment consumables	103	33	431	62	16	0
Sortie consumables	1,007	1,217	1,309	1,468	984	950
Reserves, inflight loss, etc.	15,310	15,310	15,310	15,310	15,310	15,310
Landing Reserves	430	430	430	430	430	430
Landing Gross Weight (Limit = 268,000 lb.)	255,810	250,320	258,070	257,730	253,170	248,170

Table 6-4. Weight Summary - 30-Day Sortie Payloads

Items	Payloads										
	30M-1	30M-2	30M-3	30M-4	30M-5	30M-6	30M-7	30M-8	30M-9	30M-10	30M-11
Shuttle Dry Weight	237,329	237,329	237,329	237,329	237,329	219,329*	237,329	237,329	237,329	237,329	237,329
Flight Crew (2) and Residuals	4,691	4,691	4,691	4,691	4,691	4,691	4,691	4,691	4,691	4,691	4,691
Resources, Inflight Losses, ABES Prop.	15,310	15,310	15,310	15,310	15,310	15,310	15,310	15,310	15,310	15,310	15,310
Sortie Payload	28,120	23,680	32,320	26,100	23,850	30,740	21,000	23,060	24,620	36,690	20,810
Structural provisions	6,950	8,230	8,060	8,430	5,420	6,270	5,030	5,280	5,440	11,500	5,170
ECLSS hardware	1,392	1,413	1,400	1,201	1,024	1,033	1,022	1,049	1,026	1,141	1,115
Electrical power provisions	487	726	1,093	560	554	692	670	792	780	812	497
G&C provisions	1,210	220	0	0	1,540	3,740	660	770	880	0	110
Information provisions	494	280	93	182	189	177	305	266	421	104	243
Crew and habitability provisions	643	643	643	869	643	643	643	643	643	643	643
Powerup and housekeeping tankage	2,120	2,120	2,120	2,120	2,120	2,120	2,120	2,120	2,120	2,120	2,120
Sortie consumables	8,839	9,050	9,590	9,580	9,060	9,170	9,165	9,200	9,320	9,450	8,890
Experiment equipment	5,324	578	8,811	2,498	2,880	6,475	950	2,520	3,370	10,500	1,601
Experiment consumables	241	0	0	30	0	0	15	0	200	0	0
Crew	420	420	420	630	420	420	420	420	420	420	420
Shuttle Propellant	27,200	24,500	35,000	27,000	45,800	33,200	44,500	45,800	33,500	27,950	23,200
Drag makeup propellant	4,000	0	0	4,000	0	0	0	0	0	0	0
Attitude control propellant	1,000	2,700	200	200	1,000	1,000	1,000	1,000	1,000	1,150	1,150
ΔV maneuver propellant	22,200	21,800	34,800	22,800	44,800	32,200	40,500	44,800	32,500	26,800	22,200
End Ascent Gross Weight	312,650	305,510	324,560	310,430	326,980	302,270	322,830	326,190	315,450	321,970	301,340
Consumables	51,590	49,860	47,900	51,920	48,170	47,680	57,990	48,310	58,330	48,710	47,400
Shuttle propellant	27,200	25,500	23,000	27,000	23,800	23,200	33,500	23,800	33,500	23,950	23,200
Experiment consumables	241	0	0	30	0	0	15	0	200	0	0
Sortie consumables	8,839	9,050	9,590	9,580	9,060	9,170	9,165	9,200	9,320	9,450	8,890
Reserves, inflight loss, etc.	15,310	15,310	15,310	15,310	15,310	15,310	15,310	15,310	15,310	15,310	15,310
Landing Reserves	430	430	430	430	430	430	430	430	430	430	430
Landing Gross Weight (Limit = 268,000 lbs.)	261,490	257,080	265,090	258,940	257,240	264,020	254,270	256,310	257,550	269,690	254,370

*ABES OUT

7. COMMONALITY AND COST ANALYSES

This section presents the results of the commonality analysis conducted on the sortie modules and subsystems and the MSS modules and subsystems. The cost analysis presents the development cost of the 17 sortie payloads and their value to the development of the MSS.

MODULE COMMONALITY ANALYSIS

Module commonality analysis fell into two categories: commonality among sortie modules and MSS modules, and commonality among sortie payload modules. A description of the various modules involved and their related commonality follows:

MSS Common Module Description

The MSS common module, using universal structure, was utilized to provide a basepoint configuration for sortie module commonality. The common module is designed so that the pressure shell will assume all primary structure loads; floors and partitions are thus secondary structural elements. In addition, the structure must provide radiation protection on orbit and meet the shuttle orbiter crash-landing condition during return from orbit or abort.

The module has been designed for low-cost monocoque construction, using 0.145-inch 5052 aluminum alloy augmented by a 0.030-inch aluminum meteoroid bumper. Three frames are utilized outside the pressure shell, which accommodate the shuttle attach points and manipulator sockets. Kapton-lined insulation is located inside the meteoroid bumper and acts as a secondary bumper.

MSS Cargo Module Description

The MSS cargo module was an alternative to use for sortie module commonality. This module is 14 feet in diameter and 24 feet in overall length. The structure characteristics of the pressurized portion are similar to the MSS common module. This section of the cargo module is 20 feet, 6 inches long. Structural construction is monocoque with 0.145-inch 5052 aluminum alloy, as is the MSS common module.

Sortie Modules Description

Five sortie module lengths evolved during the study. These five modules associated with the 17 experiment payloads were sized for the individual experiment requirements. The weight margins resulting from the sortie-shuttle integration analysis gave the additional shuttle payload capability for each individual sortie payload. These data, utilizing the five module lengths, are depicted in Table 7-1.

Table 7-1. Module Utilization

Payload	Module Length (feet)	Weight Margin (lb)
7M-4	20	+27,000
7M-5	15	+39,000
30M-1	18	+2,500
30M-2	20	+29,000
30M-3	18	+16,000
30M-4	26	+27,000
30M-5	10	+12,000
30M-6	10	0
30M-7	10	0
30M-8	10	+12,000
30M-9	10	+10,000
30M-10	10	+25,000
30M-11	10	+11,800

Further evaluation was conducted to reduce the number of modules required. This was accomplished by taking advantage of the weight margin capabilities shown previously; that is, the module may be increased in length (and weight accordingly), but cannot be decreased and still satisfy experiment requirements. This evaluation reduced the number of different required module lengths to three. The module reduction is as shown in Figure 7-1.

Sortie payload 30M-5 requires a 10-foot module because of experiment length restricted by the shuttle bay length. Payloads 30M-6 and 30M-7 are weight-limited and can use only a 10-foot module. Payload 30M-4 requires the largest module length, a minimum of 26 feet, because of the experiment size. All other payloads can utilize the 20-foot length module.

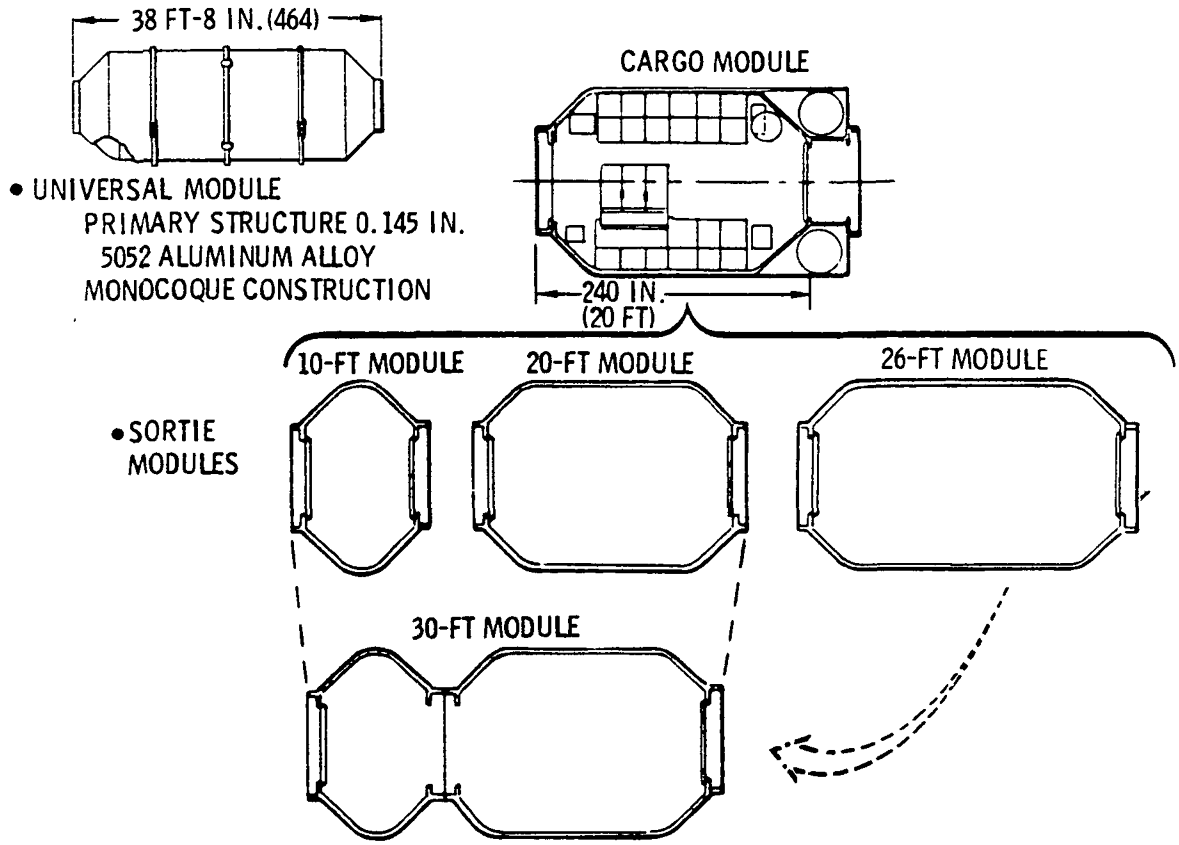


Figure 7-1. Module Variation and Selection

Several alternatives exist to accommodate sortie payload 30M-4, which requires the 26-foot length module. This payload could be restructured by eliminating an experiment such as the centrifuge to allow use of a 20-foot module. Another approach is reducing the 3.3 scale factor (total volume-to-experiment volume) used for defining module volume. A more definitive analysis would be required to show this percentage number lower for larger pieces of equipment, therefore reducing the requirement from the 26-foot length module to be compatible with the 20-foot module. Another alternative was to combine the 10-foot and the 20-foot to replace the single 26-foot module. This approach would reduce the number of different modules to two.

The three shuttle sortie modules (SSM) and the alternative of combining two are depicted in Figure 7-2. This figure also indicates the commonality of the sortie modules with the MSS elements. A module weight comparison is shown in Figure 7-3.

PAYLOAD		MODULE LENGTH (FT)				
	TITLE	10	15	18	20	26
7M-4	MATERIAL SCIENCE				✓●	○
7M-5	LIFE SCIENCE SPACE TECHNOLOGY		✓○	○	●	○
30M-4	LIFE SCIENCE					●
30M-2	SPACE PHYSICS				●	○
30M-3	FLUID MANAGEMENT			✓○	●	○
30M-1	EARTH OBSERVATIONS CONTAMINATION			✓○	●	○
30M-5	X-RAY STELLAR	✓● LENGTH LIMITED				
30M-6	ADVANCED SOLAR	✓● WEIGHT LIMITED				
30M-7	INTERMEDIATE UV	✓● WEIGHT LIMITED				
30M-8	HIGH-ENERGY STELLAR	✓○	○	○	●	
30M-9	INFRARED	✓○	○	○	●	
30M-10	COSMIC RAY	✓○	○	○	●	
30M-11	COMMUNICATIONS	✓○	○	○	●	
		(7)	(1)	(2)	(2)	(1)

Figure 7-2. Sortie Module Alternatives

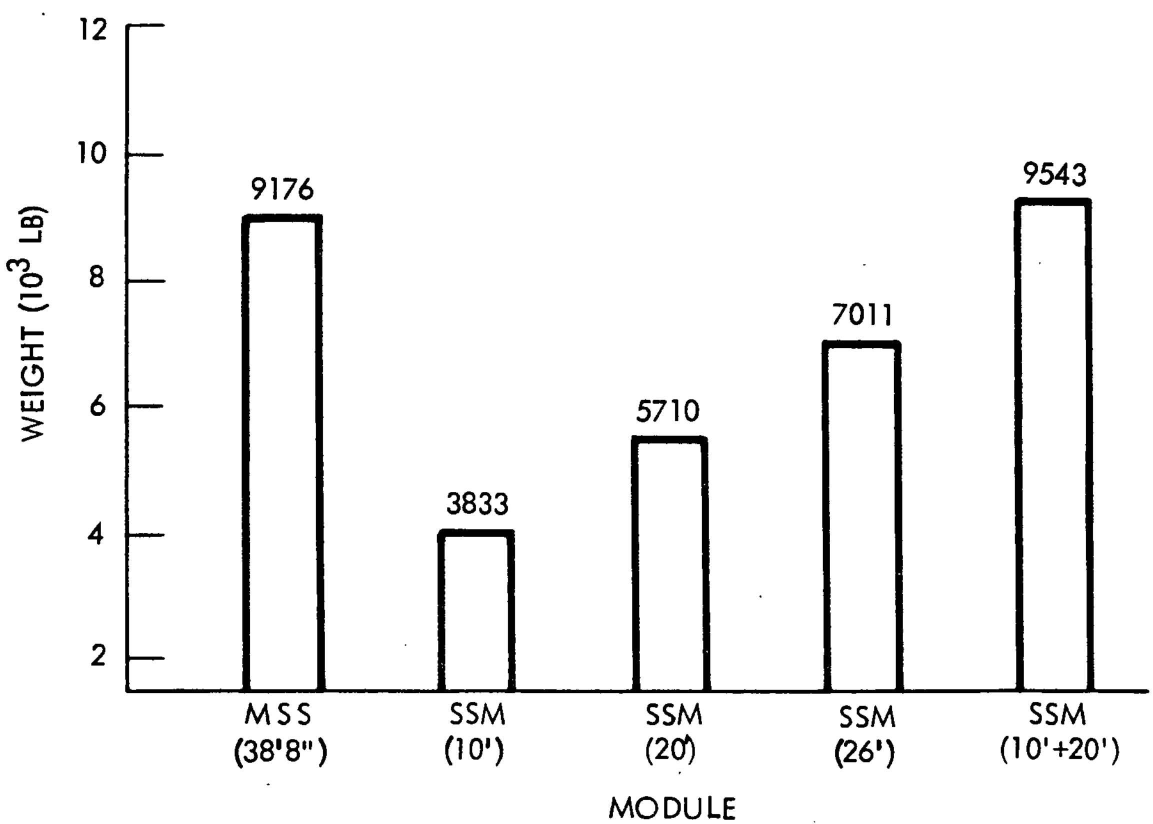


Figure 7-3. Module Weight Comparison

The sortie module analysis concluded:

1. A 100-percent commonality in design characteristics between sortie module structural and MSS modules was achieved except for length.

2. Two different length modules—10-foot and 20-foot—will satisfy sortie payload requirements.

3. It is desirable to utilize the 20-foot module, which is the same as the cargo modules and has similar operating conditions (up-down cycles and space environment).

4. The 10-foot module can be developed merely by reducing the constant section-length of the 20-foot module.

Airlock-Pallet

Seven of the 17 sortie payloads require an airlock or pallet accommodations. Several alternatives are available for these accommodations:

1. MSS airlock plus pallet (as required)

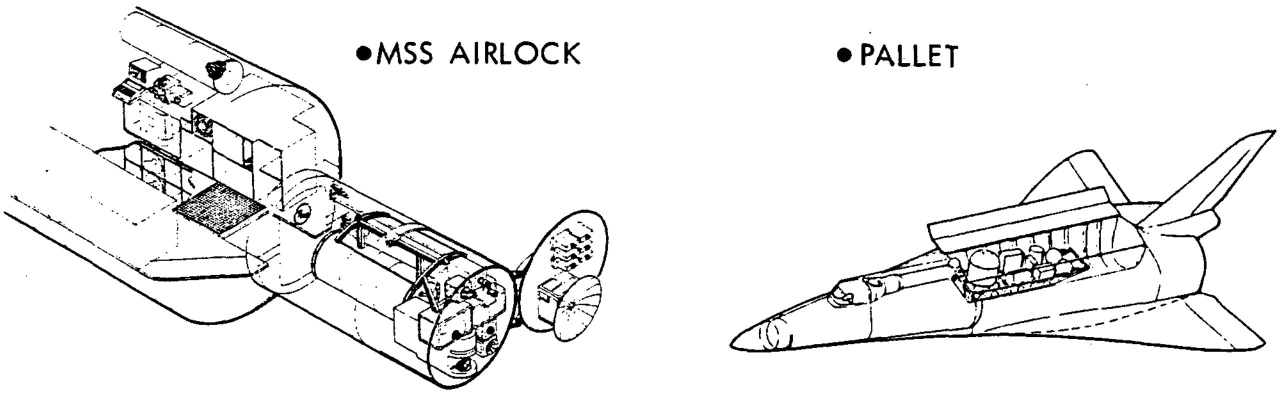
2. Shuttle airlock plus pallet

3. Use MSS airlock as pallet

These alternatives for the various sortie payloads were discussed in Section 6.

The MSS experiment airlock configuration was selected over the shuttle airlock, primarily because of operational complexity and interfaces with the shuttle.

From the pallet standpoint, all experiments except 30M-3 could operate with an extendible rack or rail system from the MSS airlock. Therefore, six payloads can be accommodated by the airlock and the seventh payload, 30M-3, requires a pallet because of the experiment length. These data are depicted in Figure 7-4.



ACCOMMODATES:	ACCOMMODATES:
7M-1 7M-2 7M-3 7M-6 30M-1 30M-2	30M-3

Figure 7-4. Pallet-Airlock Summary

SUBSYSTEM COMMONALITY ANALYSIS

Analyses have been conducted at the component level to define commonality between sortie and MSS subsystems and also among sortie payloads. Commonality data at the component level, based on having the same physical and functional characteristics as the MSS component, are presented in subsequent paragraphs and expressed in percentage of commonality.

Information Subsystem

Six items have been identified as having some degree of commonality to the MSS. Two items—S-band antenna and transponder and magnetic tape cartridges—have 100-percent commonality to the MSS for physical and functional characteristics. Four items—display and control unit, digital recorder, video recorder, and video tape cartridges—have a percentage of commonality to the MSS. These data are depicted in Figure 7-5.

The display and control unit for three sortie payloads has 90 percent commonality or 10-percent uniqueness. Five sortie payloads have a 60-percent commonality or 40-percent uniqueness. Four sortie payloads have 40-percent commonality or 60-percent uniqueness. The uniqueness is

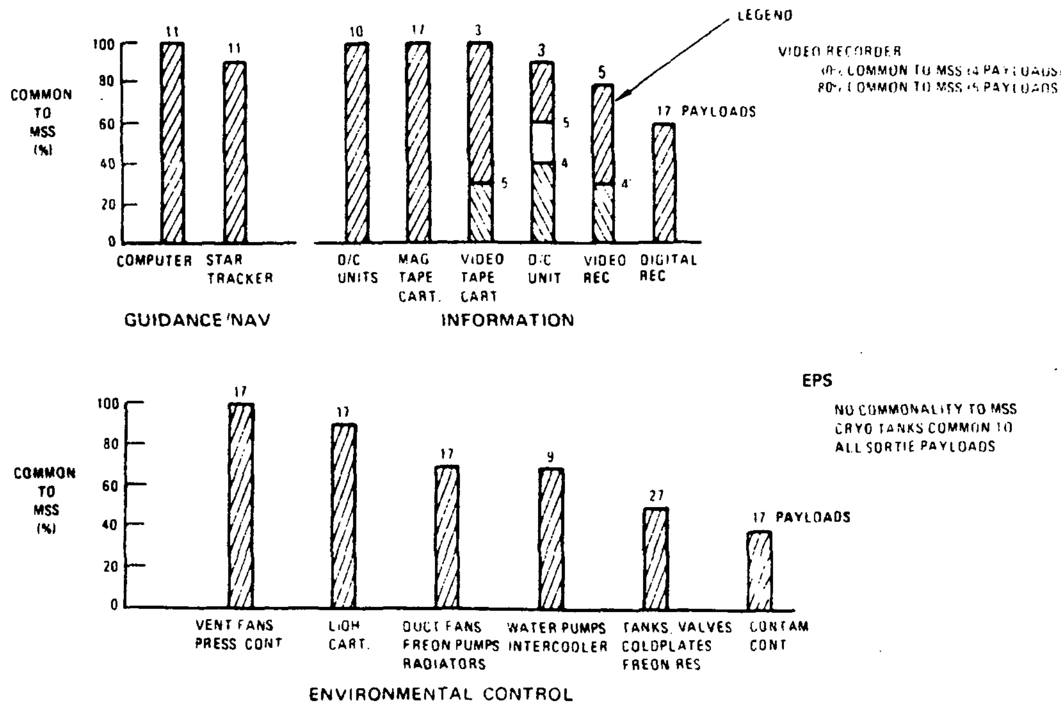


Figure 7-5. Subsystem Equipment Commonality to MSS

caused by having to have additional equipment such as high-resolution TV, switching controls, and variations in the mounting structure and packaging.

Digital recorders for all 17 payloads have a 60-percent commonality or a 40-percent uniqueness. This uniqueness is caused by having additional equipment such as signal conversion units and formatting with variations in the mounting structure and packaging.

Video recorders for five sortie payloads have an 80-percent commonality or 20-percent uniqueness. Four sortie payloads have 30-percent commonality or 70-percent uniqueness. The uniqueness for this item is caused by requiring additional equipment, different mounting structure, and packaging.

Video tape cartridges for three sortie payloads have 100-percent commonality. Five sortie payloads have a 30 percent commonality or 70 percent uniqueness. Again, the uniqueness is caused by requiring additional equipment, different mounting structure and packaging.

ECLS Subsystem

In the ECLS, 16 items have been identified as having some degree of commonality to the MSS. Two items—vent fans and pressure control units—have 100-percent commonality. These data are presented in Figure 7-5.

Tanks for 17 sortie payloads have 50-percent commonality or 50-percent uniqueness. This uniqueness is caused by different size tanks which require new tooling.

LiOH cartridges have 90-percent commonality or 10-percent uniqueness. This latter is caused only by assembly size.

Ducting for 17 sortie payloads have 20-percent commonality with 80-percent uniqueness. This uniqueness is due to the length, shape, etc. Duct fans have 70-percent commonality or 30-percent uniqueness. This uniqueness is caused by different sizes and different operating characteristics.

Contamination control units for 17 sortie payloads have 40-percent commonality or 60-percent uniqueness. The uniqueness is caused by capacity capability (size); identical components are the valves, etc.

Coldplates and valves 17 payloads have 50-percent commonality; uniqueness is caused only by size, shape, and length. Radiators commonality is 70 percent; uniqueness is caused only by size, shape, and length.

Freon pumps 17 payloads have 70-percent commonality, uniqueness is due to size or flow rate capability. Freon reservoirs have 50-percent commonality; again, uniqueness is caused by size and shape.

Temperature fans for 16 of the payloads have 40-percent commonality or 60-percent uniqueness caused by the size and operating characteristics. Heat exchangers for 16 payloads have 40-percent commonality; the 60-percent uniqueness is due to the size and shape.

The humidity control unit for one sortie payload has 50-percent commonality. Uniqueness is caused by size and shape.

Water pumps and intercoolers for nine sortie payloads have 70-percent commonality; uniqueness is caused by size and operating characteristics.

Guidance and Control Subsystem

Only two items have been identified for commonality to the MSS. One, a computer, has 100-percent commonality, and the other, the gimballed star tracker, has 95-percent commonality. These data are presented in Figure 7-5. The 5-percent uniqueness of the star tracker is caused only by the mounting structure variation.

Electrical Power Subsystem

The electrical power subsystem has commonality to the MSS only at the component level (i. e., wire, switches, circuitbreakers, connectors, etc.).

Crew and Habitability Subsystem

The crew and habitability subsystem has only two items with some degree of commonality. The first item—O_2 mask, medical kit, and radiation dosimeters (considered as one item)—has 100-percent commonality. The second item—bunks, tables, and seats—has 90-percent commonality. The 10-percent uniqueness is caused by the mounting provisions needed to satisfy shuttle launch and recovery phases.

Subsystem Commonality Conclusions

The commonality value of items that have some degree of commonality to the MSS will be reflected in the cost analysis. For other hardware not listed (fuel cells, tanks, etc.) there will be some degree of commonality to the shuttle hardware.

EPS Cryogenic Tanks

To achieve maximum commonality among payloads, two specific sizes of tanks were selected. These sizes and the quantity required by the payloads are presented in Table 7-2.

Table 7-2. Tank Utilization

Payload	Tanks Required		Remarks
	Oxygen	Hydrogen	
7M-1	1	1	200 pounds of oxygen stored in shuttle tanks
7M-2	1	2	
7M-3	1	3	
7M-4	2	3	
7M-5	0	1	
7M-6	0	1	
30M-1	2	2	
30M-2	2	3	
30M-3	4	5	Standard apollo tanks:
30M-4	2	3	
30M-5	2	3	Oxygen - 5 ft^3, capacity - 350 lb.
30M-6	3	3	Hydrogen - 7 ft^3, capacity - 30.8 lb.
30M-7	3	3	
30M-8	3	4	
30M-9	3	4	
30M-10	3	4	
30M-11	2	2	

Radiators - ECLSS

Heat rejection requirements dictated various radiator sizes for each payload. These requirements are delineated in the Section 5 of this report. To obtain maximum commonality, an analysis was made which resulted in the selection of 70-square-feet radiator segments which would be combined to satisfy the heat rejection requirements. The number of segments required by each payload is depicted in Table 7-3.

Table 7-3. Required Radiator Size, Number of Segments

Payload	Area Required (ft^2)	No. Segments*
7M-1	129	2
7M-2	174	3
7M-3	692	10
7M-4	608	10
7M-5	151	3
7M-6	58	1
30M-1	192	3
30M-2	244	4
30M-3	235	4
30M-4	138	2
30M-5	73.5	2
30M-6	41	1
30M-7	76.1	2
30M-8	88.4	2
30M-9	76.1	2
30M-10	126	2
30M-11	58	1

*Each segment provides 70 square feet

ESTIMATED COST COMPARISON

The study objectives for this task were to determine comparative costs of sortie payloads and the value of commonality with the MSS applied to MSS development costs.

Approach

The approach used, as depicted in Figure 7-6, is explained in the three steps. Step 1 was to determine costs (nonrecurring) of 17 payloads assuming that each was developed separately and that there was no relationship among them.

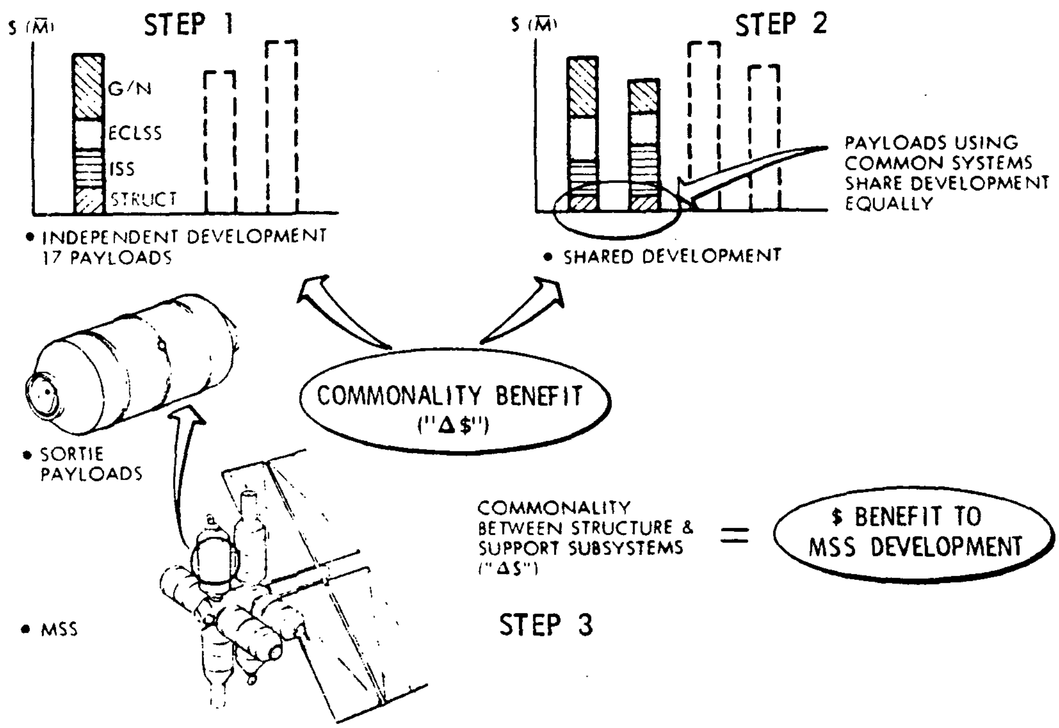


Figure 7-6. Cost Analysis Approach

Step 2 was to recognize commonality among payloads and determine development costs which would reflect this. Thus, nonrecurring costs would be spread over all payloads. The difference in costs for payloads developed in Step 1 and Step 2 is the cost savings due to commonality.

Step 3 was to determine how much the commonality between sortie payload components and MSS components was worth in terms of reduction of MSS development. Thus, if an element of the sortie payload is 40-percent common to MSS, its nonrecurring costs are assumed to be 40 percent of MSS costs. Developing the sortie payloads first would save 40 percent of MSS development in this area. The sum of all sortie component costs which have some commonality to MSS represents the savings to MSS by having the sortie payloads share part of the total development cost.

Development cost estimates were prepared for the 17 sortie payloads. The methodology used to estimate these costs was based on NR cost-estimating relationships (CER's) for nonrecurring DDT&E costs.

Cost Analysis Results

The cost analysis results (Figure 7-7) show that approximately 30-percent savings is accomplished by sharing cost among payloads. Approximately a 4 percent cost savings can be contributed to the initial MSS development cost. Other benefits that can be realized, but cannot be expressed in dollar value, are:

1. Obtain early experience in operational, procedural, and technique of operating experiments.

2. Reliability data on hardware elements.

In addition, certain subsystem hardware will have some degree of commonality with the shuttle, resulting in a further reduction of development costs.

- 17 SORTIE PAYLOADS
- DEVELOPMENT COSTS ONLY
- 1972 DOLLARS

ITEM	INDEPENDENT DEVELOPMENT ($)	SHARED DEVELOPMENT ($)	SAVINGS TO MSS ($)
STRUCTURE	770	140	28
ECLSS	370	120	27
EPS	120	25	-
G/C	305	235	5
INFORMATION	120	30	10
CREW/HAB.	115	20	7
TOTAL	1,800	570	77

- INTANGIBLE SAVINGS TO MSS
  - COMPONENT RELIABILITY DATA
  - EXPERIMENT PROCEDURES
  - OPERATIONAL EXPERIENCE
  - MAINTENANCE PROCEDURES

?$

Figure 7-7. Cost Analysis Results

8. SORTIE LABORATORY

At the conclusion of the sortie mission analysis, an alternative approach to the accommodation of sortie payloads was conceived. This would provide a family of general-purpose laboratories. With this concept, each GPL would support a group of related disciplines and would contain, as an integral part of the module, laboratory and experiment equipment. The intent would be to minimize the amount of equipment required from the investigator.

The GPL's would be designed so as to exploit the reusability made possible by the shuttle. That is, they would be adaptable to a wide range of missions and users with a minimum of reconfiguration. In addition, use will be made of existing ground and aircraft-based laboratory equipment (microscopes, cameras, spectrometers, multimeters, etc.) where practical, to minimize costs. The philosophy behind this concept is illustrated in Figure 8-1 and described in the following paragraphs.

The functional capability of the GPL would evolve from the actual performance of experiments (Level I) to the support of experiments (Level III, as described in Volume III, Experiment Analysis, of the MSS Preliminary design report). This evolving role for the GPL is consistent with an evolutionary program. In the shuttle sortie period (Level I) when funds are limited and mission durations are short, the emphasis will be on low-cost means of achieving a wide range of experiments, with little or no on-orbit support functions (e.g., data processing, maintenance, calibration, etc.). In the space station period (Level III), when a large family of dedicated discipline-oriented laboratories will be available, the GPL will accommodate the support functions required across all the dedicated labs.

The lower right-hand portion of Figure 8-1 depicts commonality across a family of Level I GPL's. As discussed in Section 6, the first level of commonality (structure and subsystems) is common across not only all GPL's in this family but also other program elements such as space station modules. The next level (general-purpose experiment equipment) is that level common across all types of GPL's within the family. The third level (laboratory experiment equipment) is that level common to a substantial number of experiments within the individual GPL's area of interest. The top level is experiment-unique, and this level of equipment would normally be supplied by the investigator.

The objective of this task was to define a Level I shuttle general-purpose laboratory.

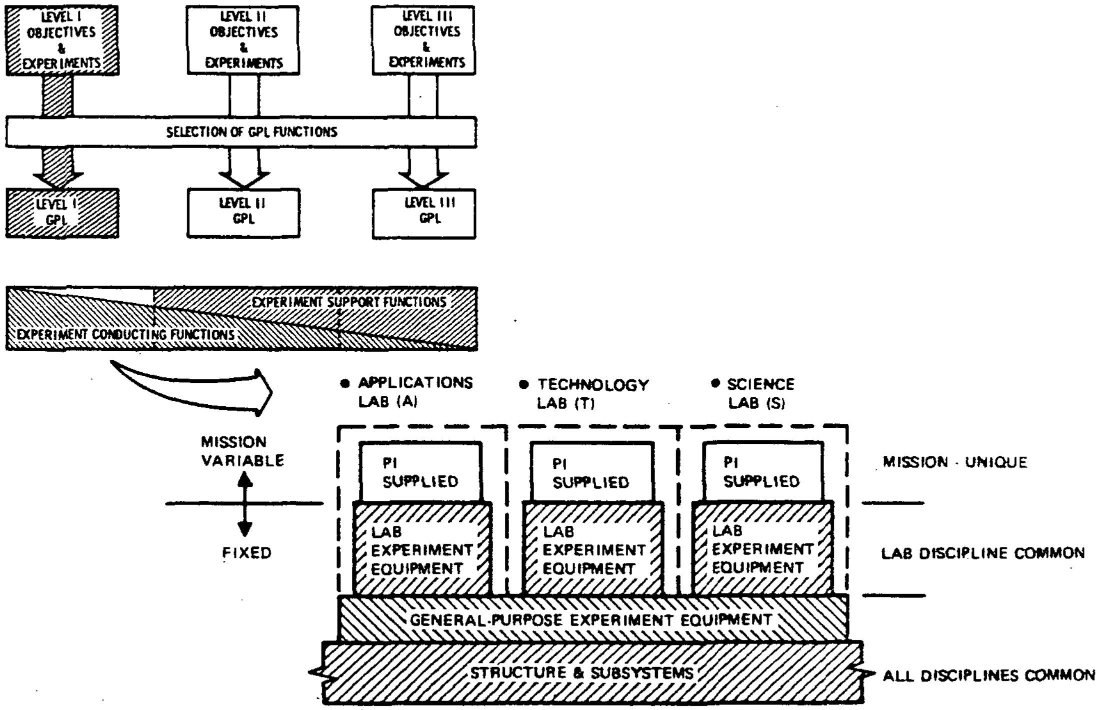


Figure 8-1. Sortie Lab Philosophy

APPROACH

The approach used was to select a typical Level I GPL capable of performing viable experiments while being flown initially in the purely shuttle era and throughout the space station era. An arbitrary selection was made to define a seven-day applications GPL (A) which would perform a high-benefit experiment program.

The high-benefit program as defined in earlier in-house studies consists of the following experiments (FPE's):

ES-1 — earth observations
LS-1 — medical research
MS-1 — materials science

The objectives of this high-benefit experiment program are:

1. Evaluate individual sensor performance.

2. Study effects of atmosphere on target signatures.

3. Develop total earth surveys information management system.

4. Gather data on slowly varying phenomena.

5. Perform precursor experiments as early as possible.

6. Select early experiments least dependent on precursor data.

7. Select early experiments for high return and minimum equipment to delay costs.

8. Observe short-duration effects of space flight on man.

9. Investigate means of predicting onset of undesirable effects.

10. Verify new instrumentation (post-Skylab) and measurement techniques.

The primary consideration in deriving the GPL concept definition was to minimize the interface impact with the shuttle. Consequently, the following assumptions were made:

1. GPL module to be as self-sufficient as practical.

2. Any data analysis to be performed would be done in the GPL.

3. The primary method of data collection, storage, and return to be via magnetic tape.

4. Real-time data to the earth to be compatible with the present shuttle telemetry capability (5 kbps).

5. Minimum data samples to be returned.

REQUIREMENTS

Table 8-1 indicates the support-type equipment required above the normal experiment equipment. In most cases, the same equipment is shown as recommended for the Level II GPL's. The envelope dimensions may differ but the general MSS configuration should be used.

Table 8-1. General Purpose Laboratory Equipment

Item No.	Nomenclature	Support Area	Dimensions W	D	H
G043	Multipurpose test bench and work area	A/L work area	60	30	60
G045	Storage for portable instruments (below deck)	Distributed as required	TBD		
---	Experiment conduct area and airlock loading space	A/L work area	144 length		
G053	Medical workbench (partial)	Biomed	54 x	30 x	30
G021	Control console (experiment)	C&D	36 x	24 x	48
G027	Tape deck and strip chart recorders	C&D	30 x	30 x	42
G022	Work bench and desck	C&D	76 x	30 x	36
G026	Video tape unit	C&D	combine with G027		

Tables 8-2 through 8-4 indicate the equipment to be included into the subject GPL along with the general area of location and deployed and stowed envelopes as applicable.

DESCRIPTION

Figure 8-2 illustrates the general arrangement of the sortie lab based on the experiment equipment and ground rules described previously.

Since the fundamental principle of efficiency (lowest program cost) was paramount, a study was made to utilize potential space hardware. This study resulted in the selection of the MSS cargo module and the MSS airlock combination as the basic module shell. This selection not only has the advantage of using potential hardware but virtually eliminates the structural interface problem with the shuttle since that interface has been accomplished as part of the MSS program.

A minimum modification will be required to the MSS cargo module shell to add floors, partitions, etc.

Table 8-2. Earth Observations

Item No.	Equipment Nomenclature	Envelope
E001	Metric camera	51" x 46" x 31"
E002	Stellar camera	
E003	Multispectral camera	24" x 24" x 14"
E005	Multispectral scanner	33" x 18" x 60"
E006	Passive microwave scanner	160" x 160" x 12" (stow 15" d x 57" 1)
E007	Microwave radar	180" x 6" x 6" (stow 8" d x 22" 1) Boom stow. (28" d x 54" 1)
E008	Multispectral radiometer	10" d x 24" 1
E009	Microwave radiometer	360" d x 36" deep (stow 25" d x 85" 1) Boom 28" d x 54" 1
E010	Scatterometer/radiometer	44" d x 20" 1 (24" x 24" x 24" elec)
E011	Multispectral spectrometer	20" x 30" x 18"
E012	Aeronomy spectrometer	35" d x 80" 1
E013	Polarimeter	12" x 12" x 12"
E014	Sferics detector	18" d x 5" 1
E015	Absorption spectrometer	12" x 12" x 12"
E017	Observation telescope	96" x 22" x 18"
E021	Controls and displays	Uses GPL G021

Table 8-3. Medical Research

Item No.	Equipment Nomenclature	Envelope
L002	ECG/VCG assembly	Small
L003	EEG assembly	Small
L008	Leg & plethysmographs	Small
L015	Lower body negative pressure	24" x 30" x 38"
L019	Blood pressure assembly	Small
L020	Stowage container	24" x 30" x 12"
L050	Movie camera	See M037

Table 8-4. Materials Science

Item No.	Equipment Nomenclature	Envelope
M002	Environmental chamber 'A" passive cooling	55" x 36" x 36"
M007	General purpose lab. installation	64" x 58" x 24"
M008	Instrum. and control center	58" x 58" x 40"
M009	Atmosphere supply and control system	40" x 24" x 20"
M010	Power conditioning and distribution system	46" x 24" x 20"
M011	Resistance heated furnace - 1600 C	20" x 12" x 12"
M033	Miscellaneous internal attachments	12" x 9" x 9"
M036	Chill system	24" x 12" x 12"
M037	Motion picture camera	12" x 9" x 4"
M038	TV camera	9" x 9" x 3"
M039	Remote measuring (mass and dimension)	20" x 9" x 9"
M040	Mixing unit	9" x 9" x 4"
M050	VHF power unit	24" x 4" x 4"
M051	External molds and container	12" x 9" x 9"
M055	Cleanup and refurbishment equipment	40" x 20" x 20"
M060	Accident control system	40" x 20" x 20"

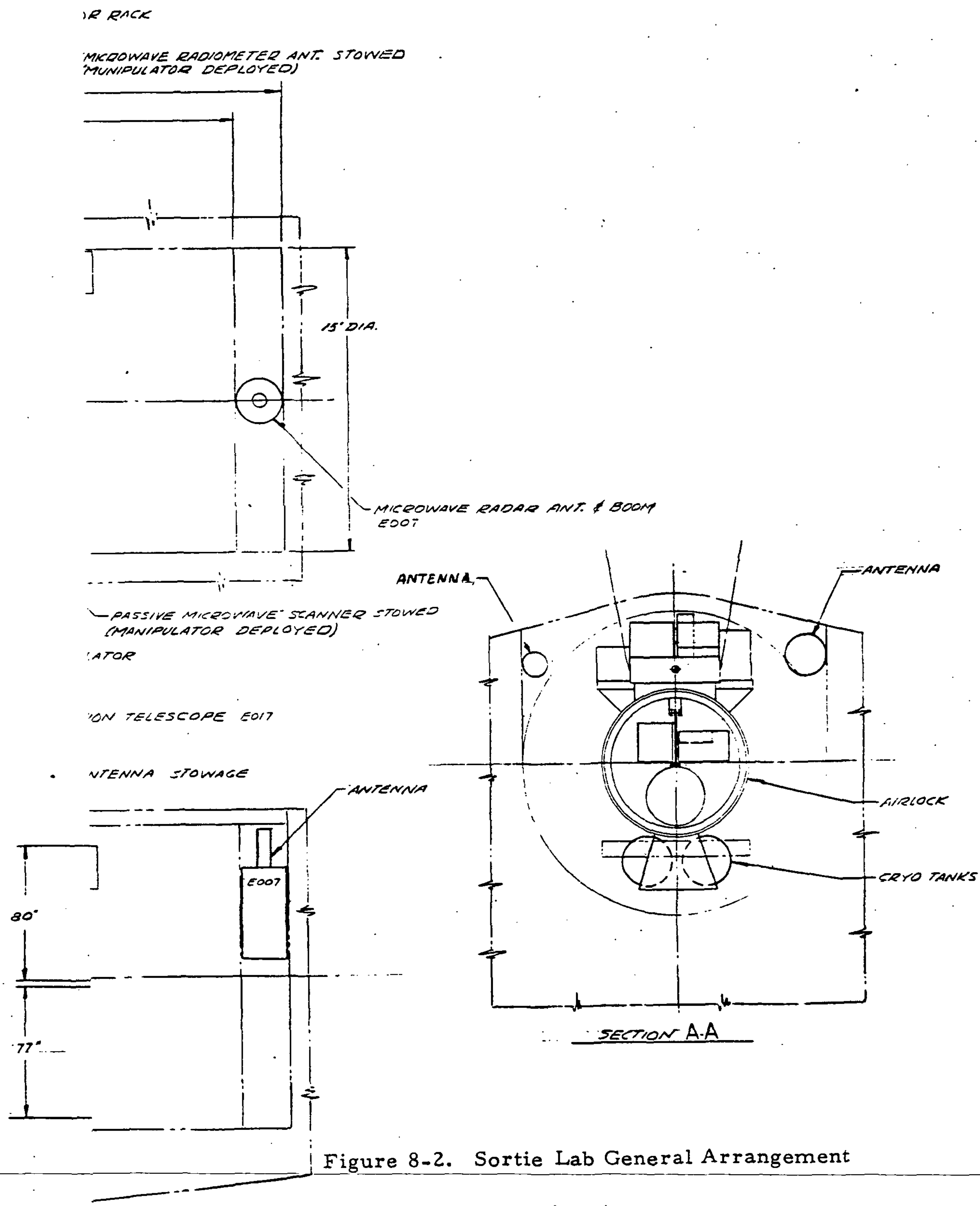


Figure 8-2. Sortie Lab General Arrangement

General Arrangement

A basic guideline was established to use a longitudinal floor arrangement. This guideline was established by the ground handling aspect of the experiment setup and checkout. Using this guideline, a study was made to determine the most efficient use of the volume. This study resulted in a split-level arrangement. The two-level portion of the module attains the maximum amount of bench and instrument area to the full height passage area. The single-level area was dictated by the need to load and service experiment sensors on the extendible airlock boom. This boom can be extended into the module as well as into space when the airlock is utilized.

Equipment Arrangement

The selected equipment was arranged to keep associated experiment equipment in localized areas. A secondary goal was to utilize work benches and controls for various types of experiments. The equipment arrangement as seen on the drawing resulted from these considerations. Generally, the upper level is devoted to medical and photographic subjects with controls and displays on one side. The lower level consists of power supplies, material sciences equipment, and analysis space.

The single-level area is used for earth observation experiments, carry-on equipment storage, and loading and servicing the equipment on the extendible boom and in the airlock. The airlock serves a dual function. It is primarily an airlock for servicing and calibrating equipment that must be deployed to a space environment. It also serves as a pallet which can support equipment that has no specific requirements or sensors that require a space environment but do not need to point. The airlock also serves as a pallet on which is mounted a saddle platform for sensors that need to point but do not need servicing or calibrating. A second saddle platform which is gimballed is provided for pointing sensors that require closer tolerance pointing than the shuttle can provide and that do not require on-orbit maintenance and calibration.

The radiator for the lab is shown fixed to the space-exposed side of the module. Further studies may reveal a need for a larger radiator and possibly one that is deployable.

Shuttle Subsystem Utilization

In line with the basic philosophy of efficiency, the shuttle subsystems are utilized wherever possible. The following systems are affected:

1. Electrical Power - The fuel cells (similar to the shuttle) are used to supply electrical power for the laboratory. However, the

reactants for this conversion are supplied from the laboratory and are stored as cryogenic gas in tanks mounted on the airlock.

2. Environmental Control - The shuttle ECLSS is used to supply the laboratory through ducts to the module.

3. Guidance and Control - Whenever pointing requirements permit, the shuttle guidance subsystem is used to orient the experiment.

4. ISS - The laboratory has its own ISS but utilizes the shuttle antennas for information relay.

5. Habitability - Since the shuttle normally has a large capability for habitability, this capability is utilized in the following areas: Seating, food preparation, waste management, emergency equipment, etc.

All other subsystems are an integral part of the sortie lab module. The sortie lab subsystem interface is accomplished with an adapter which is basically a pressurized personnel transfer tunnel. One end of this adapter interfaces with the berthing port end on the sortie lab and the other end interfaces with the shuttle bay tunnel. This adapter is not only a pressurized tunnel but provides the physical link for the subsystems.

A weight summary for a 7-day applications sortie lab is presented in Table 8-5.

Table 8-5. Weight Summary (lbs)

Item	Sortie Lab	Lab Provisions in Shuttle	Total
Structural and mechanical	7,504		7,504
Environmental control/life support	750		750
Electrical power	978		978
Guidance and control	500		500
Information	246		246
Crew habitability	35	300	335
On-board experiments	8,415		8,415
Dry weight	18,428	300	18,728
PLSS (2) and PGA's (2)		354	354
2 crew		400	400
Reactants		500	500
Leakage make up O_2 - N_2		100	100
Consumables (food)		63	63
Atmosphere	200		200
Gross Weight	18,628	1,717	20,345

APPENDIX A. SORTIE EXPERIMENT PACKAGES AND EQUIPMENT/SUPPORT REQUIREMENTS

The sortie experiment packages, equipment requirements, and support requirements are summarized in 31 groups of tables. Each package consists of two tables. The first table indicates the 1971 Blue Book experiments supported, the equipment items required for the experiment operations to be performed on the type of sortie mission indicated, and a short description of the desired operational concept for the sortie.

Further details of the experiment descriptions and equipment items are available in the 1971 Blue Book in the related FPE and experiment descriptions. The tables list equipment titles together with an equipment identification number utilized during the study.

The operational concept includes a recommended number of missions. This is guided by an estimate of the activity required to comply with the objectives of the 1971 Blue Book. The final entry of the experiment description tables provides a total weight estimate for the list of equipment identified for the experiment package. This value does not, in general, include mounting structure or allowance for support requirements such as electrical power and data relay. The experiment package summaries are shown in Tables A-1 through A-31.

The support requirements for the identified packages are indicated in the companion set of tables, Tables A-1A through Table A-31A. The subsystem requirements data of this second sheet are based on the following definition:

1. Electrical Energy Per 24 Hours - This is the 24-hour average rate at which the electrical power must be provided for experiment operations. These 24-hour averages may be scaled linearly to longer time intervals with confidence.

2. Maximum Sustained Electrical Power - This is the maximum rate at which electrical energy must flow to the payload package for sustained periods (defined as periods exceeding one hour).

3. Peak Electrical Power - This is the maximum instantaneous rate at which electrical energy must flow at the payload package, excluding transients, for periods of less than one hour.

4. Crew Support Requirements - The 24-hour average number of crew man-hours required to support the laboratory are presented, broken down by skill. Skills are selected from the following list:

   1. Biological technician
   2. Microbiological technician
   3. Biochemist
   4. Physiologist
   5. Astronomer/astrophysicist
   6. Physicist
   7. Nuclear physicist
   8. Photo technician/cartographer
   9. Thermodynamicist
   10. Electronic engineer
   11. Mechanical engineer
   12. Electromechanical technician
   13. Medical doctor
   14. Optical technician
   15. Optical scientist
   16. Meteorologist
   17. Microwave specialist
   18. Oceanographer
   19. Physical geologist
   20. Photo geologist
   21. Behavioral scientist
   22. Chemical technician
   23. Metallurgist
   24. Material scientist
   25. Physical chemist
   26. Agronomist
   27. Geographer

5. Quantity of Data Per 24 Hours - This is the total amount of data generated after internal processing and which thus must be accommodated during each 24-hour interval. It is broken down by major classification, such as TV, digital, analog, samples, film, magnetic tape.

6. Maximum Data Output Rate - This is the maximum rate at which data are generated after any internal processing, broken down by major classification.

7. Data Disposition Requirements - For each class of data output identified above, the first major function which must be performed on it after leaving the laboratory is specified, and the portion of the output data subjected to this function will be estimated. The functions considered include display, storage, real-time or near real-time transmission to ground, and real-time onboard processing.

8. Data Input Requirements - These are the data which must be provided to the payload package in order to support its operations. Examples include ephemeris and attitude data, time signals, externally generated experiment data previous runs, and commands.

9. Guidance and Control Requirements - These are requirements for the stabilization, attitude control, or limitation of attitude rates of the laboratory as a whole. Data generated by the G&C subsystem to be used in controlling a portion are specified under Data Input Requirements.

10. Operational Requirements - Each payload package may have certain special operational requirements such as flight mode (inertial or local vertical reference) or environmental requirements (acceleration, vibration, temperature) which are specified here.

In summary, the data are presented at the individual package level; the packages may be combined but may not be broken down further without additional analyses.

To assist in the planning and scheduling of specific experiment packages and combination of packages for shuttle sortie missions, an analysis was made of the extimated volume requirements for each of the 31 reference experiment packages. These volume requirements are summarized in Table A-32. Where possible, the volume requirement is stated for a complete experiment group for an experiment payload package. In other cases, several separate volumes are stated for a given set of experiment equipment items. The required experiment package envelopes are separated into two categories, pressurized volume and unpressurized volume, to assist in the assignment of a given package to a pressurized support module or to an unpressurized pallet.

Table A-1. X-Ray Stellar Astronomy (A1-1)

Experiments Supported

A-1.1 High Resolution X-Ray Telescope Experiments
A-1.3 Proportional Counter Array Experiments

Equipment Items

ID Number	
A001	High Resolution X-Ray Telescope
A002	Aspect Optics
A003	Aspect Detector
A004	Imaging Detector
A005	Transmission Grating
A006	Filter Wheel
A007	Spectrometer (Crystal)
A008	Radioactive Calibration Source
A015	Proportional Counter Array

Operational Concept

Duration: 30 days

Recommended Number of Missions: 2 (minimum)

Orbital Parameters:

Altitude:	400-500 n mi (desired) 370-740 n mi (acceptable)
Inclination:	0 deg (desired) 0 deg to 55 deg (acceptable)

Recommended Mode: Housed in manned attached module with access to shuttle

Special Requirements: Minimum contamination. Supplementary pointing capability of 1 arc sec.

Total Weight: 2880 pounds

Table A-1A. X-Ray Stellar Astronomy (A1-I) Subsystem Support

PARAMETER	SORTIE MODE: 30 Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY 4.8 KWH	MAX SUST PWR 283 W	PEAK POWER 283 W	24 HR ENERGY	MAX SUST PWR	PEAK POWER
CREW SUPPORT	Skill Code 5 or 6 10, 14 or 15	Hrs/Day 4 1	5 Man $\frac{\text{Hrs}}{\text{Day}}$ (10 on 1st Day) (5 on 1st Day)			
DATA OUTPUT	24 HR QUANTITY 5×10^8 Bits/24 Hr 0.7 lb Hard Data		MAX SUST RATE 4×10^4 BPS$^{(1)}$	24 HR QUANTITY		MAX SUST RATE
DATA DISPOSITION	Digital Store: 100% Transmit: 10% Within One Orbit 100% Within One Day Display: 10% TV					
DATA INPUT	Ephemeris Data Data to Support Attitude Stability of 1 Arc Sec/Hr					
GUIDANCE AND CONTROL/ OPERATIONS	Attitude: 1 Arc Sec Pointing$^{(2)}$ 1 Arc Sec/Hr Stability					

Notes:

(1) Internal processing assumed - reduces max rate to 4×10^4 BPS from ~10^7 BPS

(2) Supplemental stabilization of sensors required for finer pointing than available from Shuttle

Table A-2. Advanced Solar Astronomy (A3-1)

Experiment Supported

A-3.1 Photoheliograph Experiments
A-3.2 XUV Spectroheliograph Experiments
A-3.3 X-Ray Grazing Incidence Telescope Experiments

Equipment Items

ID Number	
A034	1.5-Meter Photoheliograph
A036	Alignment and Calibration Equipment
A037	Aspect Sensor
A038	Echelle Spectrograph
A039	Lyot Birefringent Filter
A040	Electronic Imaging Camera
A041	Optical Transmission Filters
A042	Magnetograph Analyzer
A043	0.25 Meter XUV Spectroheliograph
A044	Band Selection Grating
A045	0.5 Meter X-Ray Telescope
A046	X-Ray Imaging Sensor
A047	Transmission Grating
A048	Proportional Counter
A049	Crystal Spectrometer

Operational Concept

Duration: 30 days

Recommended Number of Missions: 5 (minimum)

Orbital Parameters:

Altitude:	270 n mi (desired) 200-400 n mi (acceptable)
Inclination:	Sun synchronous (desired) 0 to 55 degrees (acceptable)

Recommended Mode: Housed in manned attached module with access to shuttle

Special Requirements: First and possibly second missions could be flown at low inclinations with frequent logistics visits for film transport. Following missions use electronic imagery instead of film and are performed in solar synchronous orbit. Supplemental stabilization of sensors required for finer pointing than shuttle can provide. Simultaneous time-correlated measurements of moving solar phenomena are required.

Total Weight: 6475 pounds

Table A-2A. Advanced Solar Astronomy (A.3-I) Subsystem Support

PARAMETER	SORTIE MODE: 30 Day			SORTIE MODE:		
	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
ELECTRICAL POWER	8.6 KWH	720 W	910 W			
CREW SUPPORT		Skill Code	Hr/Day			
	6 Man Hr/24 Hr	5	5.5			
	6 Hr to Set up	12 or 14	0.5			
	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
DATA OUTPUT	6×10^8 Bits 5 Lb Hard Data		4×10^4 BPS (1)			
DATA DISPOSITION	Digital 100% Stored 100% Transmitted Within 1 Day 10% Display TV					
DATA INPUT	Time Signals Location: $\pm$ 1 n.mi ECSI Coordinates					
GUIDANCE AND CONTROL/ OPERATIONS	Attitude: 1 Arc Sec Pointing 0.1 Arc Sec/2700 Sec (2)					

Notes:

(1) Internal processing assumed - reduces max rate from imaging sensors to 4×10^5 BPS

(2) A.3-1 desires 0.017 arc-sec/OBS period but acceptable support is given in BB as 0.1 arc-sec/OBS period

Supplemental stabilization of sensors required for finer pointing than available from Shuttle

Table A-3. Intermediate Size UV Telescope (A4-I)

Experiment Supported

A-4.2 Wide-Field UV Telescope Survey Experiments

Equipment Items

ID Number

A059	Optional Star Tracker/Inertial Reference Assembly
A060	0.3 Meter Wide-Field UV Telescope
A062	Broad Band Filters
A063	Wide-Field UV Electronic Camera Assembly
A064	Backup Film Holder and Film Magazine Assembly
A065	Pattern Recognition Star Field Lock-On Unit

Operational Concept

Duration: 30 days

Recommended Number of Missions: 4

Orbital Parameters:

Altitude:	250-360 n mi (desired) 200-400 n mi (acceptable)
Inclination:	28 deg to 70 deg (desired) Any (acceptable)

Recommended Mode: Pallet mounted in shuttle bay -- remote control by man ; limited access by man to retrieve film and/or service telescope

Special Requirements:

(a) Contamination control of shuttle effluents
(b) Equipment prefers 10^{-6} torr environment
(c) Temperature range - Stowed 283 to 298 K
Operating 290 to 291 K

Total Weight:		
Equipment	950	lb
Consumables	15	lb
	965	

Table A-3A. Intermediate Size U-V Telescope (A.4-I) Subsystem Support

PARAMETER	SORTIE MODE: 30 Day			SORTIE MODE:		
	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
ELECTRICAL POWER	4.8 KWH (1)	.30 KW	.30 KW			
CREW SUPPORT	Skill 12 5	Man Hr/Day (1) 4 8				
	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
DATA OUTPUT	TV - 5×10^{10} 1 Lb Film 1.6×10^{9} Bits Digital	(3)	4×10^{4} BPS (Dig.) 7×10^{6} Hz (TV)			
DATA DISPOSITION	TV - Store 100% Digital - Transmit 25%, Store 100% Film - Store 100%					
DATA INPUT	Commands 100 BPS Position: ±1 n.mi, all axes.					
GUIDANCE AND CONTROL/ OPERATIONS	5 Arc Sec (2); 5 Arc Sec/1 Hour Inertial Reference					

Notes:

(1) Power, crew support and data requirements are based upon 10 hours of operation per day, in two 5 hour cycles; 1.6 KWH are standby powers.
(2) Stabilization duration required for 1 hour - experiment provided platform is presumed.
(3) Internal processing assumed to reduce maximum rate to 4×10^{4} BPS.

Table A-4. High Energy Stellar Astronomy (A5-I)

Experiments Supported

A-5.2 X-Ray Source Mapping (1-20 kev)
A-5.4 Large Area X-Ray Counter Measurements (0.1 -100 kev)

Equipment Items

ID Number	
A067	Aspect Sensor
A071	Composite Alignment and Calibration Equipment
A072	Venetian Blind X-Ray Telescope
A075	Large X-Ray Counter Array
A076	Mapping Module
A077	Modulation Collimators
A078	Control Gas Source

Operational Concept

Duration: 30 days

Recommended Number of Missions: 6

Orbital Parameters:

Altitude: 400-500 n mi (desired)
200-400 n mi (acceptable)

Inclination: 0 deg (desired)
0 deg to 55 deg (acceptable)

Recommended Mode: Housed in manned module with access to shuttle

Special Requirements: Additional stabilization to provide 6 arc min per observation period

Total Weight: 2520 pounds

Table A-4A. High Energy Stellar Astronomy (A.5-I) Subsystem Support

PARAMETER	SORTIE MODE: 30 Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	1.6 KWH	65 W	193W			
CREW SUPPORT	Skill Code 5 6 10	Hrs/Day 8 2 3	13 Man Hr/Day			
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	5.4×10^8 Bits		6.4×10^3 BPS			
DATA DISPOSITION	100% Storage 10% Transmit to Ground 15% Display (During Calibration)					
DATA INPUT	Location $\pm$ 0.5 mi all Directions Time Signals Commands: 100 BPS					
GUIDANCE AND CONTROL/ OPERATIONS	Attitude: 360 Arc-Sec Pointing(1) 60 Arc-Sec/3000 Sec-24 Hr Mode: Inertial					

Notes:
(1) Requires additional experiment-provided stable platform to supplement Shuttle stability in inertial mode of ± 0.5 deg/30 min.

Table A-5. Infrared Astronomy (A6-I)

Experiments Supported:

A6.2	Radiometry
A6.3	High Resolution Spectrometry

Equipment Items:

ID Numbers

A063	Wide-Field UV Electronic Camera Assembly
A064	Backup Film Holder and Film Magazine Assembly
A085	Telescope
A086	Aspect Sensor Guide Star Trackers
A087 and A088	Cooling Equipment (each)
A089	Alignment and Calibration Equipment
A090	Linear Detector Array
A091	Michelson Interferometer

OPERATIONAL CONCEPT

Duration: 30 day mission

Recommended Number of Missions: 4

Orbit Parameters: Preferred 50^o to 60^o inclination @ 270 to 300 n.mi.
Acceptable 25^o to 70^o inclination @ 250 to 400 n. mi.

Recommended Mode: Mounted on pallet which can be boom deployed from shuttle bay.

Special Requirements:
(a) Contaminant control of shuttle effluents required.
(b) IR telescope will be delivered to orbit chilled down to 27^oK; thermal protection during launch to orbit insertion is required.
(c) Retrieve film pack prior to entry.
(d) Equipment prefers 10^{-6} TORR.
(e) Temperature Range: Stored 27.6^oK (Prechill)
Operating 2^oK (Detector Array and Spectrometer)

Total Weight: Equipment 3370 lbs
Consumables 200 lbs
3570 lbs

Table A-5A. Infra-Red Astronomy (A. 6-I) Subsystem Support

PARAMETER	SORTIE MODE: 30 Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	5.5 KWH (2)	.30 KW	.30 KW			
CREW SUPPORT	Skill 5 12	Man Hr/Day (2) 8 8				
DATA OUTPUT	24 HR QUANTITY	(2) Film	MAX SUST RATE (1)	24 HR QUANTITY		MAX SUST RATE
	TV 2.0×10^{11} Bit Dig. 1.2×10^{9} Bit	1 Lb	4×10^{4} BPS (Dig) 7×10^{6} BPS (TV)			
DATA DISPOSITION	TV - Store 100% Digital - Store 100%; Transmit - 25% Film - Store.					
DATA INPUT	Position ± 1 n.mi - All Axes Commands - 65 BPS					
GUIDANCE AND CONTROL/ OPERATIONS	1 Arc Sec (3) Inertial Reference	1 Arc Sec/50 Min.				

Notes:

(1) Assumed internal processing reduces maximum data rate to 4×10^{4} BPS.

(2) Power, crew and data requirements are based upon 10 orbits of observations per day; 1.8 KWH are standby power.

(3) Stabilization requirements are for 50 minutes/orbit.

Table A-6. Space Physics (P. 1-I)

Experiments Supported

P.1.1 Atmospheric and Magnetospheric Sciences
P.1.4 Small Astronomy Telescope

Equipment Items

ID Numbers

P001	Photometric Cluster
P002	Interferometer Spectrometer
P003	Scanning Grating Spectrometer
P004	EUV Spectrometer
P005	Image Isocon Television
P006	Image Tube Optical System
P007	Open Source Mass Spectrometer
P008	Closed Source Mass Spectrometer
P009	Neutral Gas Temperature Exper. Equipment
P010	Ion Mass Spectrometer
P011	Ion Trap
P012	Electrostatic Probe
P013	Electric Field Probes
P014	Flux Gate Magnetometer
P015	Magnetometer Coil
P016	VLF Sensor
P017	Aluminum Foil Exposure Device
P018	Particle Sensor Cluster

OPERATIONAL CONCEPT

Duration: 7 Days

Recommended Number of Missions: 5

Orbit Parameters:

Mission No.	Orbital Alt. (n.mi.)	Orbital Inclination (Deg)
1	100	90
2	200	90
3	300	90
4	400	90
5	500	90

Recommended Mode: Housed in module - manned

Special Requirements: Sensors are pallet-mounted on extendable booms deployed through airlock. Requirement for 4-channel video recorder for P005 image isocon TV may be met by Shuttle ISS

Total Weight: 854 Lbs.

Table A-6A. Space Physics (P. 1-I) Subsystem Support

PARAMETER	SORTIE MODE: 7 Days			SORTIE MODE:		
	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
ELECTRICAL POWER	35.6 KWH	1604 W	2284 W			
CREW SUPPORT	12 Man Hr/24 Hr	Skill Code 5 6 12	Hr/Day 3 5 4			
	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
DATA OUTPUT	1.5×10^{10} Bits		2×10^{5} BPS Digital or 2.4×10^{5} HZ Analog			
DATA DISPOSITION	10% On-Board Display 100% Storage					
DATA INPUT	Time Signals Data to Support $\pm$ 2 min Pointing on a Stable Platform					
GUIDANCE AND CONTROL/ OPERATIONS	Altitude: $\pm$ 1 n.mi Attitude: $\pm$ 2 min Pointing for P-1.1 $\pm$ 0.01 Deg/Sec Stability P-1.1 (Vel. Vector) P-1.4 (Stellar Inertial)					

Table A-7. Space Physics (P. 1-II)

Experiments Supported

P.1.2 Cometary Physics

Equipment Items

P003	Scanning Grating Spectrometer
P019	NH_3 Release Device
P020	ICN Release Device

OPERATIONAL CONCEPT

Duration: 30 Days

Recommended Number of Missions: 1

Orbit Parameters:

Altitude: 100 n. mi.
Inclination: No requirement

Recommended Mode: Housed in module - manned

Special Requirements: Scanning grating spectrometer must be deployed through airlock for UV measurements.

Mechanism for gas release from canisters at a distance from shuttle module for safety and non-contamination considerations must be provided. Also provisions for ejection of canisters from airlock by spring-loaded impulse mechanism or by subsatellite are to be evaluated.

Total Weight: 233 Lbs.

Table A-7A. Space Physics (P. 1-II) Subsystem Support

PARAMETER	SORTIE MODE: 30 Days			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	11 KWH	1137 W	4000 W for 1000 Sec			
CREW SUPPORT	2 Man Hr/Day	Skill Code: 6 12	Hr/Day: 1 1			
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	10% On-Board Display 100% Storage					
DATA DISPOSITION	Time Signals Distance to Cloud					
DATA INPUT	Attitude: ± 2 Deg Pointing					
GUIDANCE AND CONTROL/ OPERATIONS						

Table A-8. Plasma Physics (P. 2-I)

Experiments Supported

P.2.1 Investigation of the plasma wake around orbital bodies

Equipment Items

ID Numbers

P026	Electron Density and Temperature Measurement Device
P027	Planar Thermal Ion Trap
P028	Quadrupole Mass Spectrometer
P029	Measurement of AC Electric Field
P030	Measurement of DC Electric Field
P031	Fluxgate Magnetometer
P032	Suprathermal Electron Measurement
P033	Cylindrical Electrostatic Probe
P034	Transmitter VLF
P035	VLF Antenna
P039	Balloon-Sphere
P040	Balloon-Cylinder
P161	Transmitter

OPERATIONAL CONCEPT

Duration: 7 Days

Recommended Number of Missions: 4

Orbit Parameters:

Altitude: 270 n.mi. preferred, 165-330 n.mi. acceptable
Inclination: 55°

Recommended Mode: Manned attached module

Special Requirements: Articulated boom for wake sensors

Total Weight: 420 Lbs.

Table A-8A. Plasma Physics (P.2-I) Subsystem Support

PARAMETER	SORTIE MODE: 7 Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	6.6 KW-Hr	250 W	750 W			
CREW SUPPORT	18.5 Man-Hr/24 Hr	Crew Skill: 6 12	Hr/Day: 10 8.5			
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	8.6×10^9 Bits		1×10^5 BPS Digital 1 MHZ Analog (1)			
DATA DISPOSITION	10% Display 25% Real Time Transmission 100% Storage & Shuttle Return					
DATA INPUT	Time Signals & Ephemeris Data Data to Support 1 Deg/Min Stability					
GUIDANCE AND CONTROL/ OPERATIONS	Altitude: ±1 n.mi Attitude: ±0.5 Deg Pointing ±1 Deg/Min Stability (2)					

Notes:
(1) 9 Channels
(2) Shuttle provides ± 2.0 deg in Earth-referenced attitude hold with Shuttle. Yaw axis at nadir & pitch axis perpendicular to orbital plane for period of (TBD) days

Table A-9. Plasma Physics (P. 2-II)

Experiments Supported

P.2.4 Investigation of Electron and Ion Beam Propagation

Equipment Items

ID Numbers

P038	Hemispherical Analyzer
P048	VLF Electronic Receiver
P049	High Energy Measurement Device
P050	Low Energy Range Analyzer
P051	Electron Accelerator
P158	Particle Detectors 0-2 KeV
P159	Particle Detectors 0.5 -20 KeV
P160	Particle Detectors 10 - 500 KeV
P161	Transmitter

OPERATIONAL CONCEPT

Duration: 7 Days

Recommended Number of Missions: 4

Orbit Parameters:

Altitude: 550 n.mi. preferred
Inclination: 55^o

Recommended Mode: Manned attached module

Special Requirements: Second unmanned satellite located at geomagnetic field conjugate point is desirable, but may be deferred.
Return current system for reducing changing of acceleration platform and RAM.

Total Weight: 702 Lbs.

Table A-9A. Plasma Physics (P. 2-II) Subsystem Support

PARAMETER	SORTIE MODE: 7 Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	2.4 KWH	100 W	300 W			
CREW SUPPORT	5 Man-Hr/24 Hr	Skill Code 6 12	Hr/Day 3 2			
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	8.6×10^9 Bits		10^5 BPS Digital 1 MHZ Analog (1)			
DATA DISPOSITION	20% Real Time Trans. to Gnd. 100% Storage					
DATA INPUT	Time Signals Ephemeris Data Rate to 0.01 Deg/Sec					
GUIDANCE AND CONTROL/ OPERATIONS	Altitude: $\pm$ 1 n.mi Attitude: $\pm$ 1 Deg Pointing $\pm$ 1 Deg/Min Stability (2)					

Notes:

(1) 9 Channel

(2) Shuttle provides $\pm$ 2.0 deg in Earth referenced attitude hold with Shuttle yaw axis at nadir and pitch axis to orbital plane for period of (TBD) days.

Table A-10. Cosmic Ray Physics (P.3-I)

Experiments Supported

P.3.2 Electron and Position Energy Spectra
P.3.3 Isotopic Composition of Light Elements

Equipment Items

ID Numbers

P053	Total Absorption Device
P054	Total Absorption Shower - Counter (TASC)
P055	TASC Photomultipliers
P056	Magnet-Dewar Assembly
P057	Liquid Cerenkov Counter
P058	Spectrometer Assembly
P059	Detector Bay 1
P060	Detector Bay 2
P064	Control Console
P067	Microfilm Storage

OPERATIONAL CONCEPTS

Duration: 30 Days

Recommended Number of Missions: 7

Orbit Parameters:

Altitude: 200 n.mi. preferred, 270 n. mi. acceptable
Inclination: 28.5 deg. preferred, 55 deg. acceptable

Recommended Mode: Pallet-mounted instrumentation

Special Requirements: These experiments are performed in the absence of the 24,000 lb. Total Absorption Device (TAD) but space should be provided for adding it piecewise in 350 lb. segments to the cosmic ray RAM at later dates, if this accommodation technique is anticipated.

Total Weight: 10,500 Lbs.

Table A-10A. Cosmic Ray Physics (P. 3-I) Subsystem Support

PARAMETER	SORTIE MODE: 30 Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	13.2 KWH	550 W	700 W			
CREW SUPPORT	8 Man Hr	Skill Code: 7 12	Hr/Day: 4 4			
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	1.5×10^9 Bits		1.7×10^4 BPS			
DATA DISPOSITION	10% Display 100% Shuttle Return (Store)					
DATA INPUT	Time Signals, Orbital Altitude Knowledge of Pointing to $\pm$ 1 Deg Inertial Coordinates					
GUIDANCE AND CONTROL/ OPERATIONS	No Pointing Requirement Other Than That Experiment Channels Scan Mostly Celestial Sphere with Minimum Earth Viewing					

Table A-11. Physics and Chemistry (P. 4-I)

Experiments Supported

P.4.2 Gas-surface Interactions
P.4.6 Gas Reaction in Space

Equipment Items

ID Number

P068	Airlock (2)	P109	Acceleration Sensors
P069	Feedthroughs	P110	Special Purpose Power Supplies
P070	View Ports - Visible	P111	Polarimeter
P071	View Ports - IR	P116	Quartz Microbalance
P072	View Ports - UV	P117	Energy Transfer Probe
P073	Bench Area	P118	Test Surfaces
P081	Glove Boxes - Vacuum	P119	Data Monitor
P082	Glove Boxes - Clean	P138	Canisters
P083	Glove Boxes (Hazardous)	P139	EUV Photometer
P085	Extendible Boom	P140	Electron Probe
P086	Data Acquisition System	P141	EUV Spectrometers (2)
P087	Camera Cine'	P142	Visible - IR Spectrometer
P088	Camera Still	P143	Cine' Camera
P089	Camera TV	P144	Mass Spectrometer - Sub Sat/Boom
P091	Mass Spectrometer	P145	Electron Probe S/S-Boom
P095	Data Displays	P146	Electrometer S/S-Boom
P097	Voltmeters	P147	Temperature Probe S/S-Boom
P098	Ammeters		
P099	Frequency Meter		
P106	Temperature Sensors		
P107	Displacement Sensors		
P108	Velocity Sensors		

OPERATIONAL CONCEPT

Duration: 30 Days

Recommended Number of Missions: 2

Orbit Parameters:

Altitude: 100 n.mi.
Inclination: Any

Recommended Mode: Housed in module - manned

Special Requirements: Both experiments require instrumentation mounted interchangeably on extendable boom in "air stream." P.4.6 requires a means of ejecting canisters of chemicals to be released at a distance to avoid contamination from shuttle effluents. Possibilities are a spring-type ejection from airlock or a sub-satellite. P.4.6 requires a viewing port inside module for near UV, visible and near IR sensors.

Total Weight: 345 Lbs.

Table A-11A. Physics & Chemistry (P. 4-I) Subsystem Support

PARAMETER	SORTIE MODE: 30 Days			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	5.5 KWH	230 W	300 W			
CREW SUPPORT	16 Man Hr/24 Hr	Skill Code 6 12 25	Hr/Day 6 5 5			
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	4×10^9 Bits Digital Microfilm & Polaroid: 1 Lb		4.5×10^4 BPS			
DATA DISPOSITION	100% Storage & Shuttle Return 25% on Board Processing					
DATA INPUT	Time Signals, Real Time Link with Ejected Cannister. Knowledge of Local Vertical & Velocity Vector to ± 1 Deg					
GUIDANCE AND CONTROL/ OPERATIONS	No Pointing or Stability Req. Except ± Deg Pointing of Boom Instrumentation into Air Stream or to Cloud					

Table A-12. Earth Observations (ES1-I)

Experiment Supported

ES-1.1 Meteorology and Atmospheric Sciences

Equipment Items

ID Number

E001	Metric Camera
E002	Stellar Camera
E006	Passive Microwave Scanner
E008	Multispectral Radiometer
E009	Microwave Radiometer
E010	Scatterometer/Radiometer
E011	Multispectral Spectrometer
E012	Aeronomy Spectrometer
E013	Polarimeter
E014	Sferics Detector
E017	Observation Telescope
E018	Telescope Computer
E020	Cloud Chamber
E021	Controls and Displays
E022	Data Analysis Electronics
E024	Maintenance and Repair

OPERATIONAL CONCEPT

Duration: 30 days

Recommended Number of Missions: 15 over 2 year period (may be grouped - 2 sensor development, 1 for sensor qual., 12 consecutive for signature research)

Orbit Parameters: 100 nm and 70° inclination preferred, 270 nm and 50° inclination are acceptable

Recommended Mode: Partially housed in manned module (E001, E002, E012, E017, E018, E020 thru E022, E024)- partially mounted on pallet (E006, E008 thru E011, E013, E014)

Special Requirements:

a. Sensor spacing required to satisfy clear field of view of up to 120° cone (fixed) and 150° cone (30° cone gimballed ± 60°)

b. Sensor pointing accuracy = ± 0.5 deg and attitude hold rate = .01 deg/sec - max. constraints

c. Sensor scanning/tracking - mechanization for up to ± 60° in both in-track and cross-track directions

d. Sensor erection/deployment/retraction - antennas up to 30 ft dia. (gimballed ± 60°) and 14 ft x 14 ft square (fixed, looking 40° forward)

Total Weight: (including consumables)

Equipment	=	4641
Consumables	=	208
Totals		4849 Lbs.

Table A-12A. Earth Observations, Meteorology (E3.1-I), Subsystem Support

PARAMETER	PHASE: ES.1-I, 30 Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	3.6 KWH	1.04				
CREW SUPPORT	Skill Code	Hrs/Day	Total M-Hrs/Day			
	16 18	4.5* 4.5*	9*			
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	2.232×10^8 Bits 7.3 Lbs		124 KBPS 51 Lb/Wk			
DATA DISPOSITION	Display - 25% Store - 100% Transmit - 10%					
DATA INPUT	Time Code	Ephemeris	Attitude			
	$\pm 1\ \mu$ sec	$\pm$ 1 Mile All Axes	$\pm$0.1 Deg			
GUIDANCE AND CONTROL/ OPERATIONS	$\pm$ 0.5 Deg .01 Deg/Sec Local Vertical Ref.					

Notes: * NR Estimate, No Blue Book Data

Table A-13. Earth Observations (ES1-II)

Experiment Supported

ES-1.2 Land Use Mapping

Equipment Items

ID Number

E001	Metric Camera
E002	Stellar Camera
E033	Multispectral Camera
E005	Multispectral Scanner
E006	Passive Microwave Scanner
E007	Microwave Radar
E008	Multispectral Radiometer
E010	Scatterometer/Radiometer
E011	Multispectral Spectrometer
E013	Polarimeter
E017	Observation Telescope
E018 E018	Telescope Computer
E021	Controls and Displays
E022	Data Analysis Electronics
E023	Photo Analysis
E024	Maintenance and Repair

OPERATIONAL CONCEPT

Duration: 7 Days

Recommended Number of Missions: 28 over 2 year period (may be grouped - *12 for sensor development, *4 for sensor qual., 12 at one month intervals for signature research)

Orbit Parameters: 100 nm and 70° inclination preferred; 270 nm and 50° inclination are acceptable

Recommended Mode: Partially housed in manned module (E001, E002, E003. E017, E018, E021 thru E024) - partially mounted on pallett (E005 thru E008, E010, E011, E013)

Special Requirements:

a. Sensor spacing required to satisfy clear fields of up to 120° cone (fixed) and 150° cone (30° cone gimballed ± 60°)

b. Sensor pointing accuracy = ± 0.5 deg and attitude hold rate = .05 deg/sec - max. constraints

c. Sensor scanning/tracking - mechanization for up to ± 60° in both in-track and cross-track directions.

d. Sensor erection/deployment/retraction - antennas up to 15 ft long x 5 ft wide (fixed, looking 45° side-track) and 14 ft x 14 ft square (fixed, looking 40° upward)

Total Weight: Equipment = 6056
Consumables 398
Total 6454 Lbs.

* Equivalent 30 day missions could be substituted for sensor development and qualification.

Table A-13A. Earth Observations, Land Use (ES. 1-II) Subsystem Support

PARAMETER		PHASE: ES.1-II, 7 Day
ELECTRICAL POWER	24 HR ENERGY / MAX SUST PWR / PEAK POWER	24 HR ENERGY / MAX SUST PWR / PEAK POWER 7.0 KWH / 1.55 KW /
CREW SUPPORT		Skill Code / Hrs/Day / Total M-Hrs/Day 8 / 3* / 9* 27 / 3* 19 / 3*
DATA OUTPUT	24 HR QUANTITY / MAX SUST RATE	24 HR QUANTITY: 1.5×10^{11} Bits, 80 Lbs MAX SUST RATE: 50 1 MBPS, 398 Lb/5 Days (See Note 1)
DATA DISPOSITION		Display - 25% Store - 100% Transmit - 10%
DATA INPUT		Time Code: ± 1 u Sec Ephemeris: ± 1 Mile All Axes Attitude: ± 0.1 Deg
GUIDANCE AND CONTROL/ OPERATIONS		± 0.5 Deg .05 Deg/Sec Local Vertical Ref.

Notes:

(1) Limit digital data rate, to I.S.S., to 2×10^6 BPS by data compression by laboratory equipment.

* NR estimate, no BB data.

Table A-14. Earth Observations (ES1-III)

Experiment Supported

ES-1.4 Resource Recognition and Identification

Equipment Items

ID Numbers

E001	Metric Camera
E002	Stellar Camera
E003	Multispectral Camera
E005	Multispectral Scanner
E006	Passive Microwave Scanner
E007	Microwave Radar
E008	Multispectral Radiometer
E011	Multispectral Spectrometer
E015	Absorption Spectrometer
E017	Observation Telescope
E018	Telescope Computer
E019	Data Collection System
E021	Controls and Displays
E022	Data Analysis Electronics
E023	Photo Analysis
E024	Maintenance and Repair

OPERATIONAL CONCEPT

Duration: 7 Days

Recommended Number of Missions: 28 over 2 year period (may be grouped - *12 for sensor development, *4 for sensor qual., at 1 month intervals for signature research)

Orbit Parameters: 100 nm and 90° inclination preferred, 270 nm and 55° inclination acceptable

Recommended Mode: Partially housed in manned module (E001, E002, E003, E013, E015, E017, E018, E021 thru E024) - partially mounted on pallet (E005 thru E008, E011, E019)

Special Requirements:

a. Sensor spacing required to satisfy clear fields of view of up to 120° cone (fixed) and 150° cone (30° cone gimballed ± 60°).

b. Sensor pointing accuracy = ± .05 deg and attitude hold rate = .05 deg/sec - max. constraints

c. Sensor scanning/tracking - mechanization for up to ± 60° in both in-track and cross-track directions

d. Sensor erection/deployment/retraction - antennas up to 15 ft long x 5 ft wide (fixed, looking 45° side-track) and 14 ft x 14 ft square (fixed, looking 40° forward)

Total Weight:		
	Equipment:	5693
	Consumables:	70
	Total	5763 Lbs.

* Equivalent 30 day missions could be substituted for sensor development and qualification.

Table A-14A. Earth Observations, Resource Identification (ES-1-III), Subsystem Support

PARAMETER	SORTIE MODE: Phase ES.1-III, 7 Day			SORTIE MODE:		
	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
ELECTRICAL POWER	3.5 KWH	1.55 KW				
CREW SUPPORT *NR Est-No B/B data	skill code 26 19	hrs/day 4.5* 4.5*	total m-hrs/day 9*			
	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
DATA OUTPUT	1.35 x 10" Bits 23.4 lbs		50 MBPS to lb/3 days (see note 1)			
DATA DISPOSITION	display - 25% store - 100% transmit - 10%					
DATA INPUT	time code ± 1 M sec	Ephemeris ± 1 Mile all axes	Attitude ± 0.1 degree			
GUIDANCE AND CONTROL/ OPERATIONS	± 0.5 Degree .05 Degree/Second					

NOTE: 1. Limit digital data rate to I.S.S, to 2×10^6 BPS by data compression by laboratory equipment.

* NR estimate, no BB data.

Table A-15. Materials Science (MS. 1-I)

Experiments Supported

- MS. 1.1.1 Composite Materials
- MS. 1.1.2 Metal Foams and Controlled-density Materials
- MS. 1.2.1 Crystal Growth from Solution
- MS. 1.5.1 Fluid Convection

Equipment Items

ID Numbers

M002	Environmental Chamber 'A', Passive Cooling
M007	General Purpose Lab Installation
M008	Instrumentation and Control Center
M009	Atmosphere Supply and Control System
M010	Power Conditioning and Distribution System
M011	Resistance Heated Furnace (1600°C)
M016	Mold Insertion System
M022	Dispersion Control System
M023	Susceptor for Silicate Melts
M025	Seed Injector
M032	Molds, Cavities, Crucibles (Sets)
M033	Miscellaneous Internal Attachments
M036	Chill System
M037	Motion Picture Camera
M038	TV Camera
M039	Remote Measuring Mass Dimension
M040	Mixing Unit L/S, L/L
M041	Mixing Unit L/G
M043	Vibrator
M044	Microscope Stage Attachment
M045	Photometric Densitometer
M048	Model Zone Refiner
M049	Isotope Tracer Counter
M050	VHF Power Unit
M051	External Molds and Containers
M052	Minor External Components
M053	Process Control Computer
M054	Heat Rejection System
M055	Cleanup and Refurbishment Equip
M056	Materials Analysis Equipment
M057	Photographic Processing Lab
M058	Open Materials and Fluid Storage
M060	Accident Control System

OPERATIONAL CONCEPT

Duration: 7 Days

Recommended Number of Missions: 11 (minimum) to 30

Orbit Parameters: Any altitude, any inclination

Recommended Mode: Housed in module - manned

Special Requirements: Large diameter duct to hard vacuum from equipment item M009, heat rejected by equipment items M053 thru M058 and M060 to be absorbed by shuttle thermal control equipment, acceleration to be limited to 0 ± 10^{-3} g for periods up to 8 hours and 0 ± 10^{-4} g for periods up to 2 hours.

Total Weight (Including Consumables):

Equipment	4165 Lbs.
Consumables	62 Lbs.
	4227 Lbs.

Table A-15A. Materials Science (MS. 1-I) Subsystem Support

PARAMETER	SORTIE MODE: 7 Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	71 KWH	5 KW	5KW (10KW)			
CREW SUPPORT	SKILL CODE	HRS/DAY	TOTAL M/HRS			
	12	4	12			
	23	4				
	24	4				
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	4.32×10^{8} bits-data		10^{4} BPS-Data			
	1.02×10^{10} bits-TV		10^{7} BPS-TV			
	6.6 lbs - samples/film		6.6 lbs/day			
DATA DISPOSITION	Digital data - display 25%, store 100% TV & voice - direct 20%, store/replay 100% Film - store 100% Samples - store 100%					
DATA INPUT	Time code Acceleration level					
GUIDANCE AND CONTROL/ OPERATIONS	0 ± 10^{-4}g - 2 hours 0 ± 10^{-3}g - 8 hours					

NOTES:
(1) Value indicated in parentheses is supplied from laboratory batteries
(2) Maximum power demand on spacecraft = 5 KW, including 2 KW continuous requirement for battery charging and support equipment

Table A-16. Transmitter Breakdown Test (C/N. 1-I)

Experiments Supported

C/N 1.7 Transmitter Breakdown Tests

Equipment Items

ID Numbers

C001	Voice Communication System to Ground
C003	DC Ammeter
C005	AC Voltmeter
C006	Multimeter 20 Hz-700 MHz
C007	Power Meter
C008	Oscilloscope 50 MHz 0.1 μs/cm
C009	Wideband Spectrum 10 MHz-40 GHz Analyzer
C011	VSWR Meter
C013	Function Generator
C016	RF - Transmitter Common Blocks
C017	Modulator
C030	Ensemble of Dipole Array and Antennas
C034	Analog Recorder (10 Channel)
C037	35 mm Camera
C038	70 mm Camera
C049	Modulator Peculiar Blocks
C054	IM Antenna (Parabola)
C063	Instrument Probes - Optical
C064	Instrument Probes-Plasma
C065	Instrument Probes - Pressure
C066	Instrument Probes-Temperature
C067	Mass Spectrometer
C071	Transmitter and Modulator
C073	Microwave Receiver and Processor

OPERATIONAL CONCEPT

Duration: 7 Days

Recommended Number of Missions: One

Orbit Parameters: 28° inclination or more
Five separate altitudes with two repetitions at each altitude:

80 n mi
160 n mi
240 n mi
320 n mi
400 n mi

Recommended Mode: Pallet Mounted Equipment

Special Requirements:
Measurements in all flight regimes, possibly including boost

Total Weight: 270 Lbs.

Table A-16A. Communications/Navigation (C/N. 1-I) Subsystem Support

PARAMETER	SORTIE MODE: 7 Day			SORTIE MODE:		
	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
ELECTRICAL POWER	42 watt hrs		60 watts			
CREW SUPPORT	skill code MH/D 10 - - - - - - 1.5 ● 17 - - - - - - 1.5		Total 3 MH/D			
	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
DATA OUTPUT	Digital 3.6×10^6 bits Film -- Frames		Digital 30 KBS			
DATA DISPOSITION	Store - 100% Digital Film Store -- 100%					
DATA INPUT	Time, Ephemeris and Altitude					
GUIDANCE AND CONTROL/ OPERATIONS	No Requirement					

Table A-17. Optical Frequency and Millimeter Wave Communication and Propagation Demonstration (C/N. 1-II)

Experiments Supported

C/N 1.1 Optical Frequency Demonstration

C/N 1.2 Millimeter Wave Communication System and Propagation Demonstration

Equipment Items

ID Numbers

C001	Voice Communication System to Ground
C002	Telemetry System to Ground
C003	DC Digital Voltmeter
C004	DC Ammeter
C005	AC Voltmeter
C006	Multimeter 20 Hz-700 MHz
C007	Power Meter
C008	Oscilloscope 50 MHz 0.1 μs/cm
C009	Wideband Spectrum 10 MHz - 40 GHz Analyzer
C010	μ Wave and mm Wave Noise Generators
C011	VSWR Meter
C012	Frequency Counters
C013	Function Generator
C014	Calibrated Waveguide
C015	RF-Receiver Common Blocks
C016	RF - Transmitter Common Blocks
C017	Modulator
C018	Demodulator
C019	Data Processor (common blocks)
C020	Clock
C021	Multiplexer/Demultiplexer
C022	A-D/D-A Converter
C023	Encoder/Decoder
C025	Bit Error Counter
C028	Antenna Tracking System
C029	Antenna Position Readout
C030	Ensemble of Dipole Array and Antennas
C031	Boresight Telescope
C032	Ephemeris Data Presentation
C033	C/NRF Integrated Altitude Control
C034	Analog Recorder (10 Channel)
C035	Narrow Band Recorder
C037	35 mm Camera
C038	70 mm Camera
C041	Optical Transmitter
C042	Optical Auxillary Acquisition Transmitter
C046	Optical Receiver
C047	Optical Auxillary Acquisition Receiver
C049	Modulator Peculiar Blocks
C051	Communication to Deep Space Probe
C053	Subsatellite
C054	1m Antenna (Parabola)
C055	Antenna (3)
C060	Laser Tracking Systems

OPERATIONAL CONCEPT

Duration: 30 Days

Recommended Number of Missions: Four -30 day missions (performed seasonally)

Orbit Parameters: Polar orbit desired (greater than 28 degrees acceptable)

Altitude: 100-300 NM (acceptable)

Recommended Mode: Pallet mounted instrumentation

Special Requirements: Special precautions required for protection from laser transmission beam, if EVA is involved.

Total Weight: 690 Lbs.

Table A-17A. Communications/Navigation (C/N. 1-II) Subsystem Support

PARAMETER	SORTIE MODE:			SORTIE MODE: 30-Day		
	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
ELECTRICAL POWER				1575 W Hr	350 Watts	350 Watts
CREW SUPPORT				Skill Code / MH/D: 10 / 6; 14 / 5; 17 / 5		Total: 16 MH/D
	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY	Note (1)	MAX SUST RATE
DATA OUTPUT				Digital - 9.6×10^6 Bits Film - 80 Frames		Digital - 30 KBS
DATA DISPOSITION				Transmit Digital - 10% at 30 KBS Film Store - 100% Display - 15% Store - 100%		
DATA INPUT				Time, Altitude and Ephemeris		
GUIDANCE AND CONTROL/ OPERATIONS				Point Acc - 0.01 deg Rate Limits - 1.0 deg/sec Note (2)		

NOTES: (1) Assume data for 3 orbits (4.5 hours) for days operated on 30-day sortie.

(2) Guidance and Control requirement is 10 minutes for operating orbit.

Table A-18. Search, Navigation and RF Propagation (C/N. 1-III)

Experiments Supported

C/N 1.3	Surveillance and Search and Rescue Systems Demonstration
C/N 1.4	Satellite Navigation Techniques for Terrestrial Uses
C/N 1.5	On-board Laser Ranging
C/N 1.6	Autonomous Navigation Systems for Space
C/N 1.10	Susceptibility of Terrestrial Systems to Satellite Radiated Energy
C/N 1.12	Plasma Propagation Measurements

Experiment Items

ID Numbers

C001	Voice Communication System to Ground
C002	Telemetry System to Ground
C003	DC Ammeter
C005	AC Voltmeter
C006	Multimeter 20 Hz-700 MHz
C007	Power Meter
C008	Oscilloscope 50 MHz 0.1μs/cm
C009	Wideband Spectrum 10 MHz-40 GHz Analyzer
C010	μ Wave and mm Wave Noise Generators
C011	VSWR Meter
C012	Frequency Counters
C013	Function Generator
C014	Calibrated Waveguide
C015	RF-Receiver Common Blocks
C016	RF - Transmitter Common Blocks
C017	Modulator
C018	Demodulator
C019	Data Processor (common blocks)
C020	Clock
C021	Multiplexer/Demultiplexer
C022	A-D/D-A Converter
C023	Encoder/Decoder
C024	General Purpose Computer
C025	Bit Error Counter
C026	AMD Space Erectable Antenna
C027	Changeable Feeds, Transmission Line 3 for WB
C028	Antenna Tracking System
C029	Antenna Position Readout
C030	Ensemble of Dipole Array and Antennas
C031	Boresight Telescope
C032	Ephemeris Data Presentation
C033	C/NRF Integrated Altitude Control
C034	Analog Recorder (10 Channel)
C035	Narrow Band Recorder
C036	Wideband Recorder
C037	35 mm Camera
C038	70 mm Camera
C041	Optical Transmitter
C042	Optical Auxillary Acquisition
C046	Optical Receiver
C047	Optical Auxillary Acquisition Receiver

Table A-18. Search, Navigation and RF Propagation (C/N. 1-III) (Cont)

Experiment Items

ID Numbers

C049	Modulator Peculiar Blocks
C050	IR Horizon Scanner
C051	Communication to Deep Space Probe
C052	Transponder
C053	Subsatellite
C054	1m Antenna (Parabola)
C055	Antenna (3)
C056	Power Output Scales
C057	Receiving Transponder Electronics
C058	Clock and Code Generator
C059	Antenna (2/5)
C060	Laser Tracking Systems
C061	Electromagnetic Sensors
C075	Expandable Antennas 3m
C076	Expandable Antennas 5m
C077	Modulation Envelope Generator
C078	Antenna - VHF
C079	SHF - Polarized Horn

OPERATIONAL CONCEPT

Duration: 30 Days

Recommended Number of Missions: One mission for 30 days

Orbit Parameters:

Altitude: 100-300 NM (acceptable)
Inclination - Polar orbit preferred
(any inclination > 28° acceptable)

Recommended Mode: Pallet mounted instrumentation

Special Requirements: Several large antennas require deployment, may cause docking interference with shuttle if not folded prior to docking.

Total Weight: 911 Lbs.

Table A-18A. Communications Navigation (CN. 1-III) Subsystem Support

PARAMETER	SORTIE MODE: 30-Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	912 W Hr	310 Watts	350 Watts			
CREW SUPPORT	Skill Code / MH/D: 10 / 8; 12 / 2; 14 / 2; 17 / 6		Total: 18 MH/D			
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	Digital - 126×10^7 Bits Film - 60 Frames		Digital - 300 KBS Analog - 2 MHz			
DATA DISPOSITION	Digital - Transmit - 30% Film - Store - 100% Digital - Store - 100%					
DATA INPUT	Time, Ephemeris and Altitude					
GUIDANCE AND CONTROL/ OPERATIONS	Pointing Accuracy - 0.01 deg Rate Limits - 0.1 deg/sec (Sensor Requirements)					

NOTE: Guidance/Control worst case requirement is for 1 hour. Otherwise 10 minutes/operating orbit.

Table A-19. Contamination Technology (FPE T1-I)

Experiments Supported

T.1.1 Sky Background Brightness Measurements
T.1.2 Real Time Contamination Measurements
T.1.4 Contaminant Cloud Composition Measurement
T.1.5 Contaminant Disposal Measurements

Experiment Items

ID Numbers

T011	Photoelectric Polarimeter
T002	Control Panel # 1
T003	Contaminant Gage (16 req'd)
T004	Control Panel # 2
T005	Transit Case (4 req'd)
T006	Portable Spectroreflectometer
T009	Mass Spectrometer (2 req'd)
T010	Operating Panel # 4 (2 req'd)
T011	Camera (2 req'd)
T012	Film Magazine (2 req'd)
T013	Operating Panel # 5 (2 req'd)
T014	TV Camera

OPERATIONAL CONCEPT

Duration: 7 Days

Recommended Number of Missions: One Shuttle, without payload

Orbit Parameters: Any altitude, any inclination

Recommended Mode: Housed in module, manned (see below) with modified experiment plans, this payload can be flown "housed in module - no man entry" or "pallet mounted - no man"

Special Requirements: Airlocks and deployment booms required for recommended mode, deployment booms only required for alternate modes

Total Weight:

Experiment Equipment	293 Lbs.
Deployment Devices	390 Lbs.
Airlock	700 Lbs.
Expendables	33 Lbs.
	1416 Lbs.

Table A-19A. Contamination Technology (T. 1-I) Subsystem Support

PARAMETER	SORTIE MODE: 7-Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY 2040 W Hr	MAX SUST PWR 360 Watts	PEAK POWER 400 Watts	24 HR ENERGY	MAX SUST PWR	PEAK POWER
CREW SUPPORT	Skill Code / MH/D 6 / 3 12 / 12	Total: 9 MH/D				
DATA OUTPUT	24 HR QUANTITY 2.35×10^9 Bits 10 MHz (TV)x2 Hr		MAX SUST RATE 40.8 KBPS 10 MHz	24 HR QUANTITY		MAX SUST RATE
DATA DISPOSITION	Digital Data - Display 25%, Store 100% TV - Display & Store 100% Film - Store 100% Samples - Store 100%					
DATA INPUT	Sensor Orientation S/C Orientation Time Code Operational Data (S/C)					
GUIDANCE AND CONTROL/ OPERATIONS	± 0.05 degree 0.05 deg/sec					

NOTES: (1) No shuttle light leaks during operation of T.1.1.
(2) Computer controlled scan pattern for T.1.1, T.1.4, and T.1.5.
(3) Station operational data correlation required.

Table A-20. Contamination Technology (FPE T1-II)

Experiments Supported

T.1.1 Contamination Measurements
T.1.2 Real Time Contamination Measurements
T.1.4 Contaminant Cloud Composition Measurements
T.1.5 Contaminant Dispersal Measurements

Equipment Items

T001	Photoelectric Polarimeter
T002	Control Panel # 1
T003	Contaminant Gage (16 req'd)
T004	Control Panel # 2
T005	Transit Case (4 req'd)
T006	Portable Spectroreflectometer
T009	Mass Spectrometer (2 req'd)
T010	Operating Panel # 4 (2 req'd)
T011	Camera (2 req'd)
T012	Film Magazine (2 req'd)
T013	Operating Panel # 5 (2 req'd)
T014	TV Camera

OPERATIONAL CONCEPT

Duration: 30 Days

Recommended Number of Missions: One Shuttle, without payload
One for each venting/emitting payload

Orbit Parameters: Any altitude, any inclination

Recommended Mode: Housed in module, manned (see below)
With modified experiment plans, this payload can be flown "housed in module - no man entry" or "pallet mounted - no man"

Special Requirements: Airlocks and deployment booms required for recommended mode, deployment booms only required for alternate modes

Total Weight:

Experiment Equipment	293 Lbs.
Deployment Devices	390 Lbs.
Airlock	700 Lbs.
Expendables	33 Lbs.
	1416 Lbs.

Table A-20A. Contamination Technology (T. 1-II) Subsystem Support

PARAMETER	SORTIE MODE: 30-Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	2040 W Hr	360 Watts	400 Watts			
CREW SUPPORT	Skill Code 6 12	MH/D 3 12	Total: 9 MH/D			
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	2.35×10^9 Bits 10 MHz (TV) x 2 Hr		40.8 KBPS 10 MHz			
DATA DISPOSITION	Digital Data - Display 25%, Store 100% TV - Display & Store 100% Film - Store 100% Samples - Store 100%					
DATA INPUT	Sensor Orientation S/C Orientation Time Code Operational Data (S/C)					
GUIDANCE AND CONTROL/ OPERATIONS	± 0.05 deg 0.05 deg/sec					

NOTES: (1) No shuttle light leaks during operation of T-1.1.
(2) Computer controlled scan pattern for T.1.1, T.1.4, and T.1.5.
(3) Station operational data correlation required.

Table A-21. Fluid Management (T2-I)

Experiments Supported

T.2.1 Liquid/Vapor Interface Stability
T.2.4 Condensing Heat Transfer
T.2.6 Propellant Transfer in Space
T.2.10 Channel Flow Systems
T.2.11 Conical Flow Systems

Equipment Items

ID Numbers

T022	Fluid
T023	Tanks
T024	Structure
T025	Instrumentation
T039	Conditioning Pack
T040	Support Equipment
T041	Fluids
T042	Cameras
T043	Heat Sink
T044	Power Supply
T045	Instrumentation
T046	Controls
T047	Miscellaneous
T050	Tanks and Structure
T051	LH_2
T052	GHe
T053	Fill and Vent System
T054	Instrumentation
T055	Insulation
T056	Test Equipment
T057	TV
T058	Pressurization System
T079	Test Section
T080	Support
T081	Instrumentation
T082	Test Section
T083	Support
T084	Instrumentation

OPERATIONAL CONCEPT

Duration: 7 Days

Recommended Number of Missions: Two

Orbit Parameters:

Altitude: Above 270 nm to facilitate controlled low g intervals at 10^{-3} to 10^{-5} g.

Inclination: Any

Recommended Mode: Module, man entry

Special Requirements: Controlled low g intervals , varying up to 12 hours at 10^{-3}g.
Total Weight: 3856 Lbs.

Table A-21A. Fluid Management (T. 2-I) Subsystem Support

PARAMETER	SORTIE MODE: 7-Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	13.0 KWH	1.3 KW	4.0 KW			
CREW SUPPORT	Skill Code: 9, 12	Hr/Day: 10, 40	Total: 351 Hr Note (1)			
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	Digital: 3.6×10^7 Bits		5780 Bits/Sec 5.8 MHz (TV)			
DATA DISPOSITION	Record Digital (100%) Film - Return to Earth Display TV (100%)					
DATA INPUT	Controlled "G" levels versus time					
GUIDANCE AND CONTROL/ OPERATIONS	Provide sustained low "G" intervals, 10^{-3} to 10^{-5} G					

NOTE: 351 manhours estimated for complete runs of all experiments but may accomplish major objectives with 200 manhours or greater.

Table A-22. Fluid Management (T2-II)

Experiments Supported

T.2.2 Boiling Heat Transfer
T.2.3 Capillary Studies
T.2.5 Two-phase Flow Regimes
T.2.9 Two-phase Dynamics

Equipment Items

T026	Tanks
T027	Structure
T028	Propellant
T029	Transducer System
T030	Vent System
T031	Pressurization System
T032	Instrumentation
T033	Chambers
T034	Tanks
T035	Methanol
T036	Ethanol
T037	Pentane
T038	Support
T048	Structure
T049	Fluid
T076	Test Section
T077	Support
T078	Instrumentation

OPERATIONAL CONCEPT

Duration: 7 Days

Recommended Number of Missions: Two

Orbit Parameters:

Altitude: Above 270 nm to facilitate controlled low g intervals at 10^{-3} to 10^{-5} g.

Inclination: Any

Recommended Mode: Module, man entry

Special Requirements: Controlled low g intervals, varying up to 10.4 hrs. at 10^{-3} g and 70 hours at 10^{-5} g levels

Total Weight: 3505 Lbs.

Table A-22A. Fluid Management (T.2-II) Subsystem Support

PARAMETER	SORTIE MODE:			SORTIE MODE: 7-Day		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
				4.0 KWH	0.4 KW	1.0 KW
CREW SUPPORT				Skill Code 9 12	MH/D 13 26	Total: 274 MH
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
				Digital: 6.9×10^6 Bits		192 Bits/sec 5.8 MHz (TV)
DATA DISPOSITION				Record Digital (100%) Film - Return to Earth Display TV (100%)		
DATA INPUT				Controlled "G" levels versus time		
GUIDANCE AND CONTROL/ OPERATIONS				Provide sustained low "G" intervals, 10^{-3} to 10^{-5} G		

Table A-23. Fluid Management (T2-III)

Experiment Supported

T.2.8 Slush Propellant Behavior

Equipment Items:

T068	Tank and Insulation
T069	Heaters
T070	Structures
T071	Pressurization System
T072	Test Equipment
T073	Slush Propellant System
T074	Fill and Vent
T075	Instrumentation

OPERATIONAL CONCEPT

Duration: 30 Days

Recommended Number of Missions: Two

Orbit Parameters:

Altitude: Above 270 nm to facilitate controlled low g intervals at 10^{-5} to 10^{-3} g.

Inclination: Any

Recommended Mode: Module, man entry

Special Requirements: Controlled low g intervals including 3.6 hrs at 10^{-3}, 42 hrs at 10^{-4} g, and 152 hrs at 10^{-5} g.

Total Weight: 1450 Lbs.

Table A-23A. Fluid Management (T. 2-III) Subsystem Support

PARAMETER	SORTIE MODE: 30-Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	0.4 KWH	0.04 KW	1.2 KW			
CREW SUPPORT	Skill Code 9 12	MH/D 5 5	Total: 74 MH			
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	Digital: 5.8×10^6 Bits		160 Bits/sec			
DATA DISPOSITION	Record Digital (100%)					
DATA INPUT	Controlled "G" levels versus time					
GUIDANCE AND CONTROL/ OPERATIONS	Provide sustained low "G" intervals, 10^{-3} to 10^{-5} G					

Table A-24. Extravehicular Activity (T3-I)

Experiments Supported

T.3.1 Astronaut Maneuvering Unit

Equipment Items

T085	Astronaut Maneuvering Unit
T086	CCTV and Video Recorder
T087	Motion Picture Camera
T088	TLM Receiver and Data Displays
T089	Voice Communication Link and Recorder

OPERATIONAL CONCEPT

Duration: 7 Days

Recommended Number of Missions: Two

Orbit Parameters:

Altitude: $<$ 300 nm

Inclination: $<$ 60 degrees

Recommended Mode: Module with manned entry

Special Requirements: Experiment requires 3 crewmen simultaneously during experiment operation including two in space suits. Airlock.

Total Weight: 265 Lbs.

Table A-24A. Extravehicular Activity, Astronaut Maneuvering Unit (T.3-I) Subsystem Support

PARAMETER	SORTIE MODE: 7-Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	1.6 KWH	330 W	370 W			
CREW SUPPORT	Skill Code 12 12 12	MH/D 8 8 8	Total: 24 MH/D			
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	Digital: 1.44×10^8 Bits		500 Bits/sec			
DATA DISPOSITION	Digital: Record (100%) Film: Return to Earth Display TV					
DATA INPUT	Voice Communicate to EVA					
GUIDANCE AND CONTROL/ OPERATIONS	Limit Shuttle maneuvers during EVA					

Table A-25. Advanced Spacecraft Systems Test (T4-I)

Experiments Supported:

T.4.2 Maintainable Flight Electronics Package Experiment
T.4.5 Leak Detection and Repair
T.4.7 Ball Bearing Lubrication
T.4.9 Space Calibration of Solar Cell Standards
T.4.12 Fire Sensing and Suppression

Equipment Items

ID Numbers

T100	Maintainable Electronics Package
T105	Absorption Refrigeration Cycle System
T106	Radiator
T107	Leak Detector
T108	Support Equipment
T110	Motor Mounting System
T111	Control Panel
T116	Solar Cell Package
T125	IR Scanner Fire System
T126	Fire Detection System
T127	Ciné Camera (2 Req'd)
T128	Fire Extinguisher System (8 Req'd)
T129	Consumables
T130	Combustibles
T131	Propane
T132	Film

OPERATIONAL CONCEPT

Duration: 7 Days

Recommended Number of Missions: Four

Orbit Parameters:

Altitude: None
Inclination: None

Recommended Mode: Housed in module - manned

Special Requirements: Airlock

Total Weight: 540 lbs.

Table A-25A. Advanced Spacecraft Systems Tests (T. 4-I) Subsystem Support

PARAMETER	SORTIE MODE: 7-Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	89.9 KWH	3.8 KW	3.8 KW			
CREW SUPPORT	Skill Code: 9, 10, 11, 12	MH/D: 2, 5, 7, 10	Total: 14 MH/D			
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	Digital: 2.1×10^8 Bits		2.4×10^3 BPS			
DATA DISPOSITION	Record Digital (100%) Film - Return to Earth					
DATA INPUT	Solar Vector versus Shuttle Attitude					
GUIDANCE AND CONTROL/ OPERATIONS	Platform pointing to ± 0.1 degree					

Table A-26. Medical Research (LS1-I)

Experiments Supported

LS.1.1.2 Neurological Function
LS.1.2.1 Cardiovascular Function

Equipment Items

ID Number	
L002	ECG/VCG (leads and preamp)
L003	EEG (leads and preamp)
L008	Leg Plethysmographs
L015	Lower body Negative Pressure Device (LBNP)
L019	Blood Pressure Assembly
L020	Stowage Container
L021	Ear Canal Temperature Probe
L051	Metabolic Cage - Rat

OPERATIONAL CONCEPT

Duration: 30 Days

Recommended Number of Missions: 8

Orbit Parameters: None

Recommended Mode: Housed in module - manned

Special Requirements: Subject requires isolation and the LBNP (L015) requires vacuum control and overhead clearance to allow one man to stand in it.

Total Weight:

Equipment	380 Lbs.
Consumables	20 Lbs.
	400 Lbs.

Table A-26A. Medical Research (LS. 1-I) Subsystem Support

PARAMETER	SORTIE MODE: 30-Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	0.25 KWH/D	0.050 KW	0.25 KW			
CREW SUPPORT	Skill Code Subject (1) 1 13	MH/D 2.35 1.25 1.1				
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	1.2×10^7		28 kbps			
DATA DISPOSITION	25% Display - 75% Store					
DATA INPUT	None					
GUIDANCE AND CONTROL/ OPERATIONS	None					

NOTE: (1) Subject refers to any skill.

Table A-27. Plant Growth Transients (LS3-II)

Experiments Supported

LS.3.2.2 Graviception and Tropism

Equipment Items:

ID Numbers

L041	Microscope
L151	Control/Display and Data Management
L060	Roll Film Camera
L094	Plant Lighting System
L095	Photo/TV Accessories
L096	Clock and Timer
L097	Rack and Cabinet System
L098	Growth and Support Containers
L099	Miscellaneous Tools and Hardware
L100	Plant Holding Unit
L101	Rack and Manifold System
L109	Clinostats
L111	Gas Analysis Equipment

OPERATIONAL CONCEPT

Duration: 7 Days

Recommended Numer of Missions: 5

Orbit Parameters: None

Recommended Mode: Housed in module - manned

Special Requirements: Vibration, isolation and accommodation of angular momentum due to the centrifuge

Total Weight:

Equipment	110 Lbs.
Centrifuge	500 Lbs.
Consumables	16 Lbs.
	626 Lbs.

Table A-27A. Cells and Tissues (LS. 3-II) Subsystem Support

PARAMETER	SORTIE MODE: 7-Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	1.0 KWH/D(1)	0.120 KW	--			
CREW SUPPORT	Skill Code 1	MH/D 5(2)				
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	8.6×10^6		100 bps			
DATA DISPOSITION	Display - 25%; Store 75%					
DATA INPUT	None					
GUIDANCE AND CONTROL/ OPERATIONS	10^{-3}g - 90% 10^{-2}g - 10%					

NOTES: (1) Electrical power requirements are to be doubled for centrifuge.
(2) Crew times are to be doubled for centrifuge use.

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Table A-28. Cells and Tissues (LS4-II)

Experiments Supported

LS.4.2.1 Effect of the Space Environment in Genetic, Sub-cellular and Molecular Phenomena

LS.4.3.2 Role of Gravity in Interspecies Relationships

Equipment Items

L041	Microscope
L060	Roll Film Camera
L105	Voice Recorder
L112	Standard Holding Units
L113	Holding Unit Lighting
L114	Rack and Cabinet System (Lab)
L115	Rack and Cabinet System (Centrifuge)
L116	Miscellaneous Hardware (Lab)
L117	Miscellaneous Hardware (Centrifuge)
L125	Experiment Package

OPERATIONAL CONCEPT

Duration: 7 Days

Recommended Number of Missions: 5

Orbit Parameters: None

Recommended Mode: Housed in module - manned

Special Requirements: Centrifuge (10 ft. diameter)

Total Weight:

Experiment	300 Lbs.
Centrifuge	500 Lbs.
Consumables	-
	800 Lbs.

Table A-28A. Cells and Tissues (LS. 4-II) Subsystem Support

PARAMETER	SORTIE MODE:			SORTIE MODE: 7-Day		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
				0.5 KWH/D	0.03 KW	--
CREW SUPPORT				Skill Code 1 3	MH/D 2 - 2 Times 2	
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
				1.7×10^6		20 bps
DATA DISPOSITION				Display 25%; Store 75%		
DATA INPUT				None		
GUIDANCE AND CONTROL/ OPERATIONS				10^{-5}g - 90% 10^{-4}g - 10%		

Table A-29. Biosciences (LS4-5-I)

Experiments Supported

LS. 4.1.4 Role of Gravity in Life Processes of Microscopic Organisms

LS. 5.2.2 Effect of Space Environment on Invertebrate Behavior

Equipment Items

ID Number

L112	Standard Holding Units
L113	Holding Unit Lighting
L114	Rack and Cabinet System (Lab)
L115	Rack and Cabinet System (Cont)
L116	Miscellaneous Hardware
L117	Miscellaneous Hardware
L135	Experiment Management and Display Equipment

OPERATIONAL CONCEPT

Duration: 30 Days

Recommended Number of Missions: 5

Recommended Mode: Housed in module - manned

Special Requirements:

Total Weight:

Equipment	344 Lbs.
Centrifuge	500 Lbs.
Consumables	10 Lbs.
	843 Lbs.

Table A-29A. Bioscience (LS. 4, 5-I) Subsystem Support

PARAMETER	SORTIE MODE: 30-Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	0.75 KWH/D	0.05	--			
CREW SUPPORT	Skill Code 2 1	MH/D 2.5 - 9 Days 1.0 - 21 Days				
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	2×10^7		100 bps			
DATA DISPOSITION	Display - 25%; Store - 75%					
DATA INPUT	None					
GUIDANCE AND CONTROL/ OPERATIONS	$10^{-3}g$ - 5% $10^{-4}g$ - 95%					

Table A-30. Life Support (LS6-I)

Experiments Supported

LS 6.1 Water Recovery Methods and Components
LS 6.4 Zero-gravity Whole-body Shower
LS 6.9 Advanced Trace-contaminant Control and Monitoring Subsystem

Equipment Items

ID Number	
L050	Movie Camera
L060	Roll Film Camera
L105	Voice Recorder
L149	Life Support Subsystem Test Unit
L150	Water Recovery Subsystem
L151	Data Management and Display
L152	Biochemical and Microbial Analysis Equipment
L158	"0" -g Whole Body Shower
L163	Advanced Trace Contaminant Control/Monitor

OPERATIONAL CONCEPT

Duration: 30 Days

Recommended Number of Missions: 10

Orbit Parameters: None

Recommended Mode: Housed in module - manned

Special Requirements: Shower use will require humidity control

Total Weight:

Equipment	1051 Lbs.
Consumables	-
	1051 Lbs.

Table A-30A. Life Support (LS. 6-I) Subsystem Support

PARAMETER	SORTIE MODE: 30-Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER	24 HR ENERGY	MAX SUST PWR	PEAK POWER
	0.60 KWH/D	0.200 KW	0.3 KW			
CREW SUPPORT	Skill Code / MH/D Subject / 0.5(1) 2 / 1.5 11 / 2.4	Skill Code / MH/D 12 / 3.0 22 / 0.5				
DATA OUTPUT	24 HR QUANTITY		MAX SUST RATE	24 HR QUANTITY		MAX SUST RATE
	5×10^5		11.0 bps			
DATA DISPOSITION	Display - 25%; Store - 75%					
DATA INPUT	Atmospheric composition					
GUIDANCE AND CONTROL/ OPERATIONS	None					

NOTE: (1) For one thirty-day period an additional 1.6 manhours per day are required.

Table A-31. Man-Systems Integration (LS7-II)

Experiments Supported

LS.7.2.1 Performance Capability Assessment

Equipment Items

ID Number

L105	Voice Recorder
L171	Video Camera (Color)
L172	Video Tape Recorder
L177	Portable Metabolic Analyser
L179	Portable Accelerometer
L180	Event Timer
L181	Selected Restraints and Locomotion Aids

OPERATIONAL CONCEPT

Duration: 30 days

Recommended Number of Missions: 3

Orbit Parameters: None

Recommended Mode: Housed in module - manned

Special Requirements: Shuttle maneuvers should not be performed during the cargo handling

Total Weight:

Equipment: 223 Lbs.

Table A-31A. Man-Systems (LS. 7-II) Subsystem Support

PARAMETER	SORTIE MODE: 30-Day			SORTIE MODE:		
ELECTRICAL POWER	24 HR ENERGY 0.35 KWH/D	MAX SUST PWR --	PEAK POWER 0.220 Watt	24 HR ENERGY	MAX SUST PWR	PEAK POWER
CREW SUPPORT	Skill Code Subject 21	MH/D 7.0 7.0	Two times per mission			
DATA OUTPUT	24 HR QUANTITY 5.4×10^5		MAX SUST RATE 100 bps TV - 4 MHz	24 HR QUANTITY		MAX SUST RATE
DATA DISPOSITION	Display - 25%; Store - 75% TV - Display All					
DATA INPUT	None					
GUIDANCE AND CONTROL/ OPERATIONS	No maneuvers during handling.					

Table A-32. Experiment Package Envelopes

Experiment Package		Envelopes: Pressurized Volume (Dimensions in Feet)	Envelopes: Unpressurized Volume (Dimensions in Feet)
A.1-I			45 x 8-1/3 Dia.
A.3-I	(3.1)		40.5 x 8.25
	(3.2)		11.25 x 4.5 x 3.0
A.4-I	(3.3)		23.5 x 3.1
A.5-I	(5.2)		27.0 x 3.33 x 2.83
	(5.4)		13.0 x 3.5 x 2.0
A.6-I			12.0 x 12.0 Dia.
P.1-I			8 x 6.0 x 3.0
P.1-II			5 x 4.0 x 4.0
P.2-I		1 x 1 x 1.75	5 L x 6.6 D.
P.2-II		1 x 1 x 1	6 x 5.0 x 2.0
P.3-I		4 x 6 x 2.0	25 x 13.5 Dia.
P.4-I	Bench	12 x 3.0 x 3.0	
	Storage	4 x 3.0 x 1.5	
	Glove Box	3 x 2.0 x 3.0	
	Airlock	5 x 3.0 Dia.	
MS.1-I	Basic	Vol. (183.5 Ft^3)	
	Internal	Vol. (14.8 Ft^3)	
	Support	Vol. (363. Ft^3)	
	Radiator	7.0 Ft^2 x .5 inches	
ES.1-I		20 x 1.5 x 4	17.4 x 13.4 x 6.7
			30 Dia. x 3.0 Deployable
ES.1-II		20 x 1.5 x 4	19.1 x 13.4 x 4.0
			15.0 x .5 x .5 Deployable
ES.1-III		20 x 1.5 x 4	18.4 x 13.4 x 2.5
			15.0 x 5 x .5 Deployable
T.1-I & T.1-II		1.2 x 2.9 x 1.2 Panel	
		1.4 x 1.8 x 2.8 Stored	
		3.2 x 3.2 x 4.0 Airlock	
T.2-I	2.1	5 x 5 x 2	
	2.4	6 x 5 x 2.5	
	2.6	2 x 2 x 1.5	8 x 12 x 18
	2.10	2 x 2.7 x 4.0	
	2.11	2 x 3 x 3.5	
T.2-II	2.2	2 x 3 x 6.0	
	2.3	3 x 3 x 3.0	3 (1 x 1 x 1)
	2.5	2 x 2 x 3.0	
	2.9	2 x 2 x 2.5	
T.2-III		2 x 2 x 1	7 x 12 x 10
T.3-I		Airlock for two men	2 x 2 x 5
T.4-1	4.2	1 x 1 x 1.2	
	4.4	2 x 1.5 x 1.2	200 Ft x .5' (Radiator)
	4.5	1 x 1 x 1	
	4.7	1 x 2.0 x .25	2 x 1 x 1.5
	4.9	1 x 1 x .25	2 x 2 x .5
	4.12	3.0' Dia x 5.0' Equip.	
		1 x 1 x 3 storage	

Table A-32. Experiment Package Envelopes (Cont)

Experiment Package	Envelopes: Pressurized Volume (Dimensions in Feet)	Envelopes: Unpressurized Volume (Dimensions in Feet)
LS.1-I	2.0 D x 4 2 x 2 x 1.25 Store 4 x 5 x 1.5 Console	
LS.3-I	6 x 1.5 x 1.5 3 x 1.5 x 1.5 Store 10 Dia. x 4 Depth Centrifuge	
LS.4-II	3 x 4 x 1.5 8 x 3 x 1.5 Store 10 Dia x 4 Depth, Centrifuge	
LS.4,5-I	3 x 4 x 1.5 8 x 3 x 1.5 Store 10 Dia x 4 Depth Centrifuge	
LS.6-I	4.6 x 5 x 2.5 4 x 5 x 1.5 3 x 2 x 2 6 x 5 x 1.5	
LS.7-I	2 x 2 x 1 (Recorder)	

APPENDIX B. INDUCED ENVIRONMENT

The environment induced on the payload while in the payload bay during transportation to and from orbit is described in the following paragraphs.

PURGE AND VENT

The cargo bay is purged with dry gaseous nitrogen before liftoff. The nitrogen dew point is -65 F; temperature, 75±5 F; pressure is 15.2±0.5 psia.

The cargo bay is vented during launch and entry, and will be unpressurized during the orbital phase. The pressure differential between the cargo bay and the external environment will be exceeded 2 psi.

FLIGHT LOADS

Orbiter flight load factors are presented in Table B-1. These load factors are quasi-steady state and are equal to the total externally applied load divided by the total vehicle weight; factors carry the signs of the externally applied loads.

Table B-1. Orbiter Limit Load Factors

Condition	LOAD FACTOR (g)		
	X	Y	Z
Liftoff	1.6	±0.5	-0.5
High Q boost	1.9	±0.35	+0.5 -0.7
Booster end burn	3.0	±0.1	-0.5
Orbiter end burn	3.0	±0.1	-0.5
Entry	±0.25	±0.5	-2.5
Flyback	±0.25	±0.5	+1.0 -2.5
Landing and braking	+0.8 -1.0	±0.5	-2.5*

*Consists of 1.0 g of aerodynamic lift plus 1.5 g's of landing impact loads.

The load factors were computed using rigid body analysis methods. Estimated dynamic magnification factors used to account for elastic body effects are summarized in Table B-2.

Table B-2. Dynamic Magnification Factors

Condition*	Magnification Factor	
	X	Y, Z
High Q boost	1.1	1.2
Booster end burn	1.1	1.1
Orbiter end burn	1.1	1.1
Landing	1.2	1.2

*For other conditions listed in Table B-1, the dynamic magnification factors equal 1.

TEMPERATURE

The internal wall temperatures for the cargo bay are presented in Table B-3.

ACOUSTICS

The noise level in the cargo bay is 153 db. The associated acoustic spectrum is presented in Figure B-1.

VIBRATION

The vibration environment in the cargo bay is 18 rms for vibration aeroacoustically induced by the booster main engines, and 22 rms for vibration mechanically transmitted from the orbiter main engines (where the mechanically induced vibration applies from fuselage station 1890 aft). No mass loading effects are included. The associated vibration spectra are presented in Figure B-2.

SHOCK

Only the booster-orbiter stage separation will be initiated by pyrotechnic devices. Severe high-frequency transients are likely in the region of these devices. For normal staging, transient acceleration change during separation are 1.8 g's axially and 0.4 g's normally. The associated time histories are presented in Figure B-3.

Table B-3. Temperature Limits for Internal Walls of Cargo Bay

Payload External Surface Temperature (°F)	Prelaunch*		Launch		On-Orbit (Doors Closed)		On-Orbit (Doors Open)		Entry	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Cargo Bay Doors										
100	80	120	80	150	-100	150	N/A**	N/A**	-100	250
70	50	120	50	150	-100	150	N/A	N/A	-100	250
0	-20	120	-20	150	-100	150	N/A	N/A	-100	250
-300	-100	120	-100	150	-150	150	N/A	N/A	-150	250
-420	-100	120	-100	150	-150	150	N/A	N/A	-150	250
Other Cargo Bay Areas (sides, bottom, ends)										
100	80	120	80	130	0	130	0	130	0	200
70	50	120	50	130	-25	130	-25	130	-25	180
0	-20	120	-20	130	-75	130	-75	130	-75	160
-300	-290	120	-290	130	-300	130	-300	130	-300	150
-420	-290	120	-290	130	-420	130	-420	130	-420	150

*Cargo bay is purged with dry GN_2 for ground thermal conditioning. For bare LH_2 tanks, special provisions (e.g., He purging) will be required to prevent liquid air formation.

**The exposed surfaces of the payload will be subjected to the deep space environment which includes a black body radiation sink at 4 K and direct sun radiation.

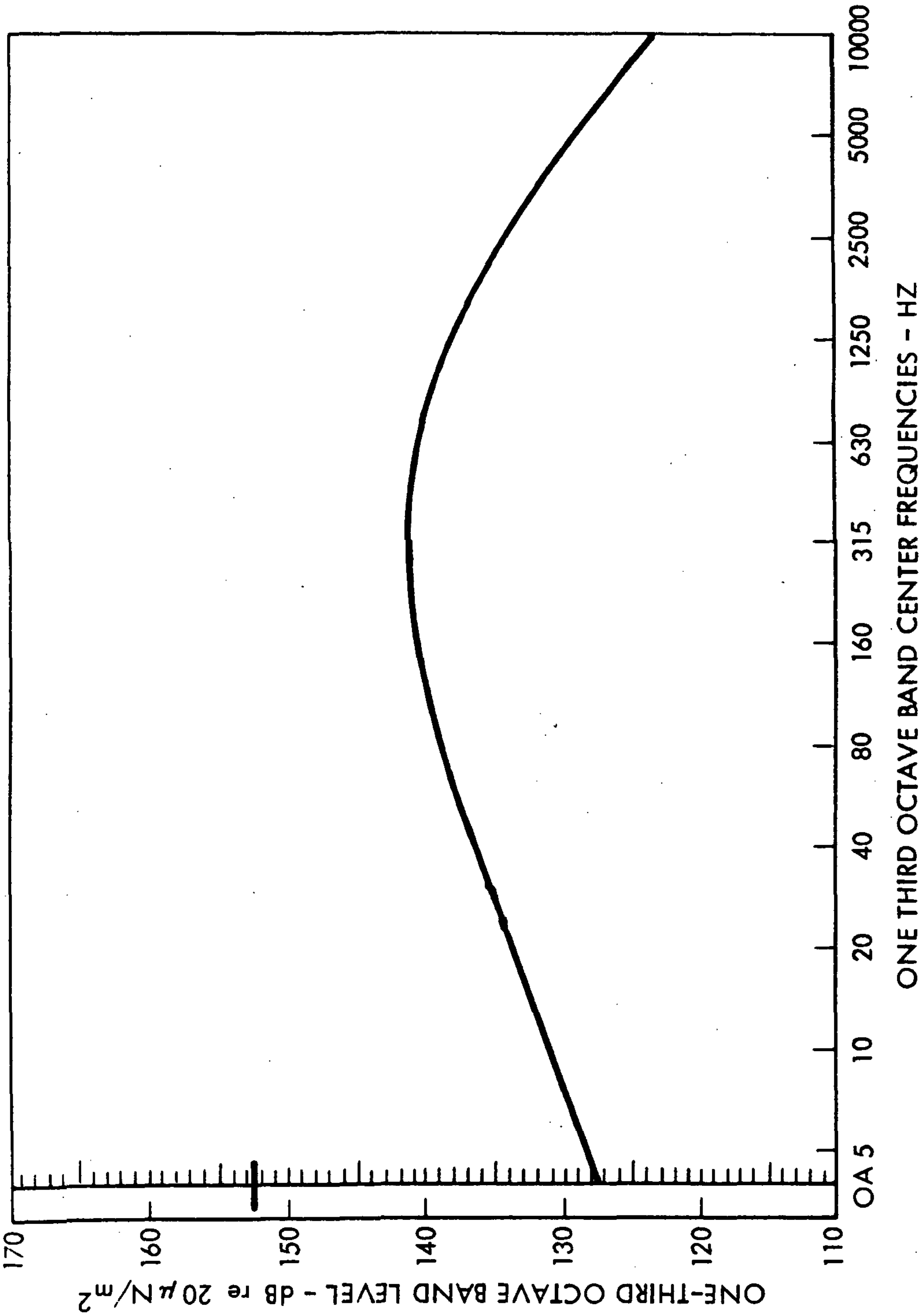


Figure B-1. Cargo Bay Acoustic Spectrum

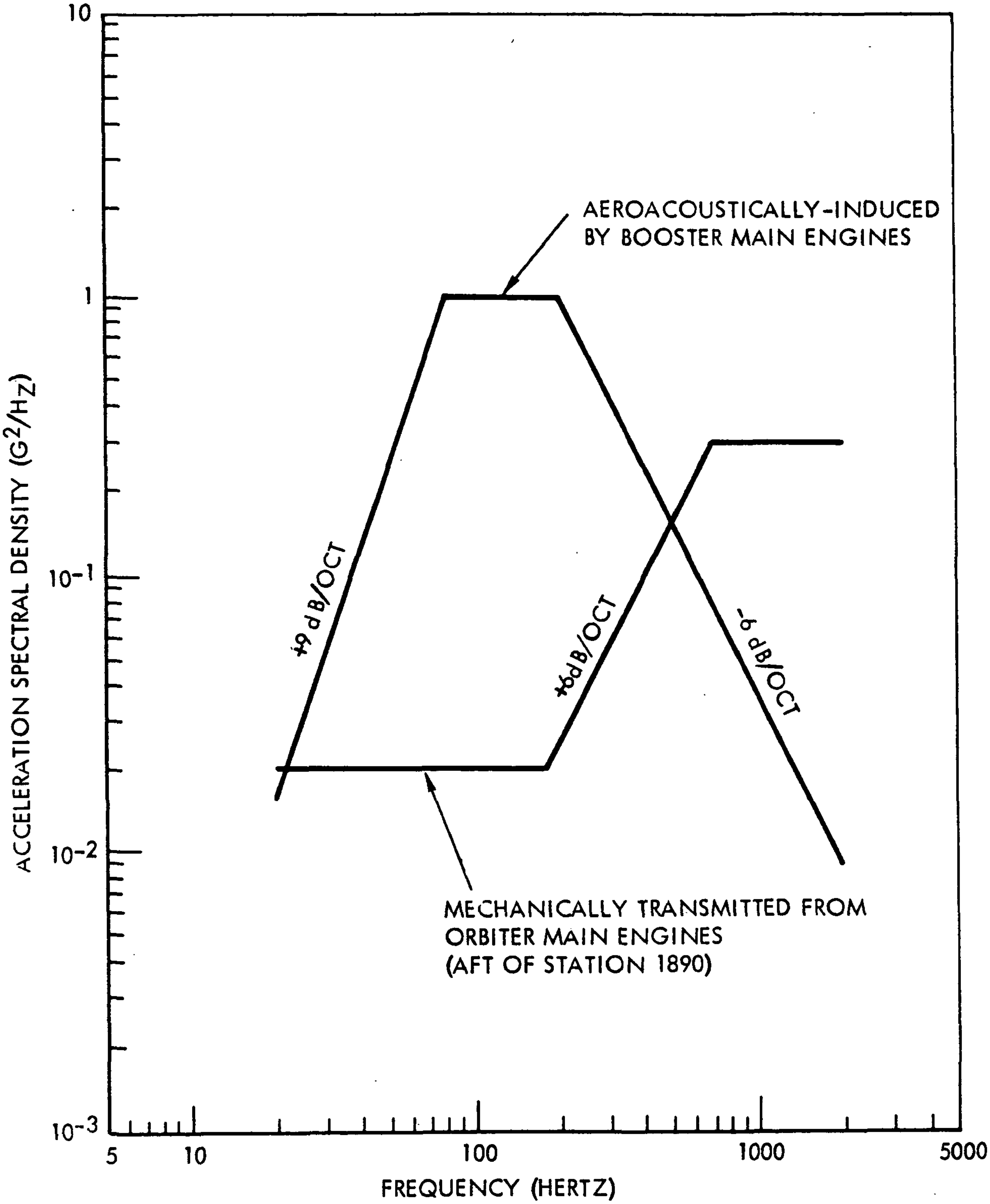


Figure B-2. Cargo Bay Vibration Spectra

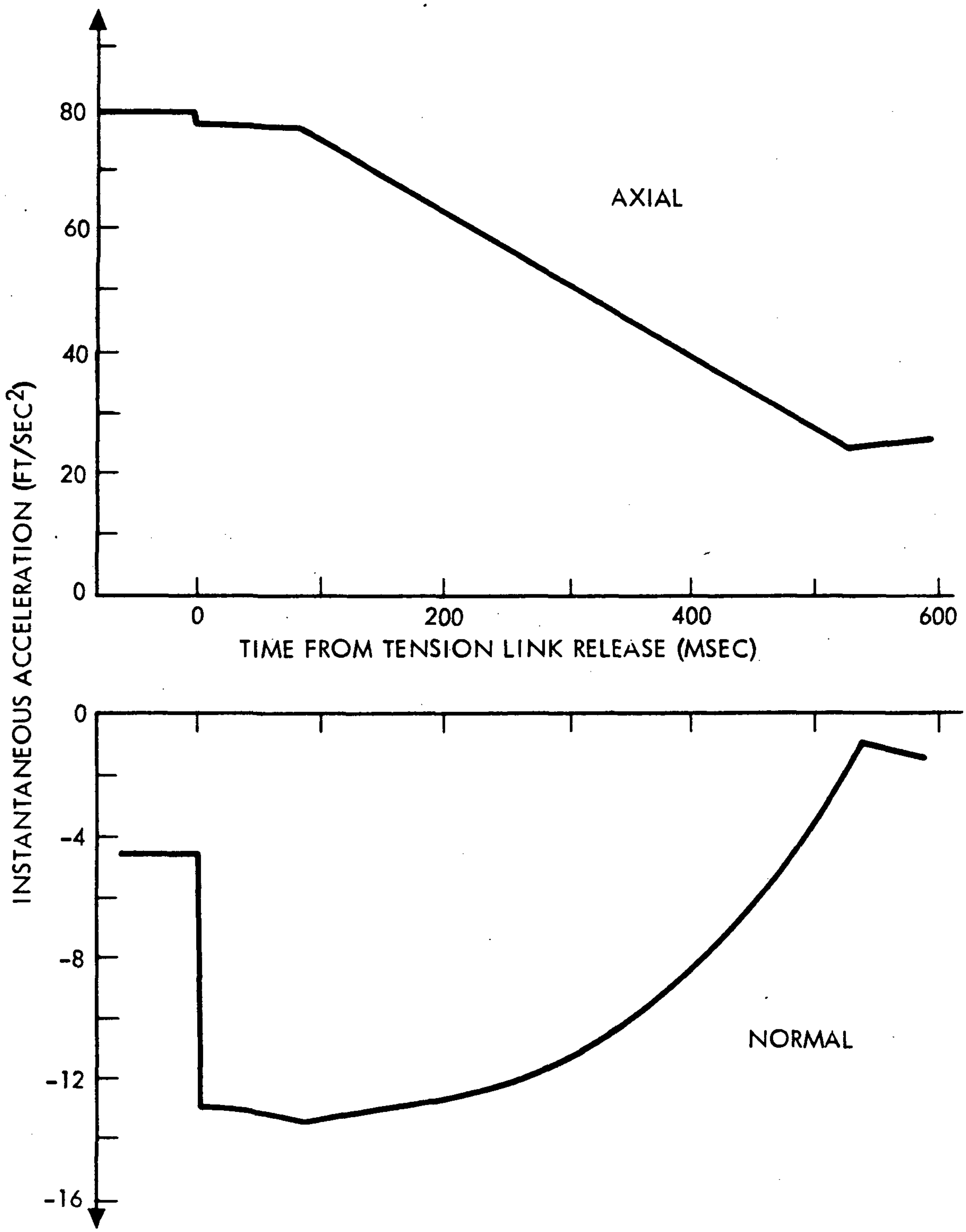


Figure B-3. Orbiter Acceleration Time History for Booster-Orbiter Separation

Landing shock is 1.5 g's in the minus Z direction. The landing shock criterion is presented in Table B-4.

Table B-4. Landing Shock

Acceleration (g peak)	Duration (n sec)	Probability
0.23	170	0.18
0.28	280	0.29
0.35	330	0.26
0.43	360	0.15
0.56	350	0.08
0.72	320	0.03
1.50	260	0.01

OUTGASSING AND EFFLUENTS

Effluent rates from the orbiter vehicle are listed in Table B-5.

Table B-5. Maximum Effluent Rates

Component	Source	Rate	Remark
Water	Fuel cells	190 lb/day	All-up avionics; can hold for 24 hours
	ECLSS boiler	220 lb/day	Radiators looking at sun
	Cabin leakage	0.2 lb/day	
	ACPS firings	280 lb/hr	±0.5° deadband
Hydrogen	Auxiliary propulsion Heat exchanger	0.4 lb/hr	Prevents boiloff
	Main propulsion venting	10. lb/min	360 lb. total residuals
	ACPS firings	50 lb/hr	±0.5° deadband
Oxygen	Main propulsion venting	6 lb/min	1800 lb. total residuals
	Cabin leakage	2 lb/day	
Nitrogen	Cabin leakage	7 lb/day	
Carbon dioxide	Cabin leakage	0.07 lb/day	
Urine	Waste management	3 lb/man-day	Can hold for 24 hours
Fecal vapors	Waste management	0.25 lb/man-day	Can hold for 24 hours

PART II. REDUCED PAYLOADS SIZE IMPACT STUDY

1. INTRODUCTION AND SUMMARY

This section of DRL 68, Volume VII, summarizes the effects on the modular space station (MSS) of reducing the shuttle payload bay size. The Reduced Payload Size Impact Study was performed as a contract change, authorization (CCA6) under the Phase B Extension, Contract NAS 9-9953.

The study objective was to identify the modular space station effects resulting from a reduction in the diameter and length of individual modules. The effects of a reduction in diameter and length of individual modules are summarized at the conclusion of this section. Impacts are defined for 12- by 40-foot, 14- by 40-foot, and 12- by 58-foot modules and associated shuttle payload bay sizes. The configuration utilized for comparison and identification of impacts was the preliminary design, Phase B 14-foot module configuration (denoted as the reference concept). The benefits and penalties for design, subsystems, and ground and on-orbit operations are identified.

Guidelines and constraints and ground rules for conducting the study were specified as follows:

1. Impacts will be defined for 12- by 40-foot modules, 14- by 40-foot modules, and 12- by 58-foot modules

2. Space station and modules will satisfy Phase B Programs Definition Study Modular Space Station Guidelines and Constraints document, MSC-03696, Rev. 7, dated 30 July 1971, except Guideline 1.112A. Guideline and Constraint 1.112A specifies the MSS Phase B module envelope size and the shuttle cargo bay size. For the three modules size studies, the corresponding shuttle bay sizes are defined.

Concept	Module	Shuttle Bay
1	12 x 40 ft (max)	12 x 40 ft
2	14 x 40 ft (max)	15 x 40 ft
3	12 x 58 ft (max)	12 x 60 ft

3. Only effects on station modules and special modules will be identified for initial and growth stations

4. Subsystem selection is the same as the current Phase B study

5. Station accommodation and size requirements are the same as the current Phase B study

6. Comparison will be made with Phase B preliminary design configuration and characteristics

7. The 60-foot shuttle manipulator will be used unchanged

8. The Lockheed solar array concept will be utilized

9. The defined configurations will be compatible with berthing and adaptable to docking

The internal accommodations for crew habitability, station operation, and all general purpose laboratory facilities were ground ruled to be the same as the Phase B station for all reduced payload size options. Thus, modular stations assembled from all of the options will have essentially similar experiment capability except for configuration impacts.

The reduced payload size impact study flow is illustrated on Figure 1. This figure denotes the maximum allowable module lengths for the various study configurations. The final lengths will be established so as to be consistent with the maximum launch weight (20, 000 pounds) and functional accommodation considerations. The main study effort was concentrated in the concept of the 12- by 40-foot module configuration (Concept 1) based on crew, station operations and experiments accommodations requirements, and subsystems selection used for the 14- by 58-foot Phase B modules (Reference Concept). Comparison 1 was an indepth comparison of the 12- by 40-foot concept configuration with the 14-foot Phase B preliminary design configuration. Comparison 2 and 3 for the 14- by 40-foot modules (Concept 2) and 12- by 58-foot modules (Concept 3) respectively, were accomplished on an abbreviated basis utilizing the depth of the configuration study of the 12- by 40-foot module to provide the final diameter and length effects.

Figure 2 presents a comparison between the Concept 1 growth configuration and the 14-foot Phase B growth configuration. The Concept 1 configuration is comprised of six station modules and two 40-foot core modules for the initial station and is comprised of eight station modules and two 40-foot core modules for the growth station. The Concept 1 initial station exceeds the length of the 14-foot Phase B initial station by 40 percent and the growth station by 22 percent with appropriate increase in moments of inertia and control penalties.

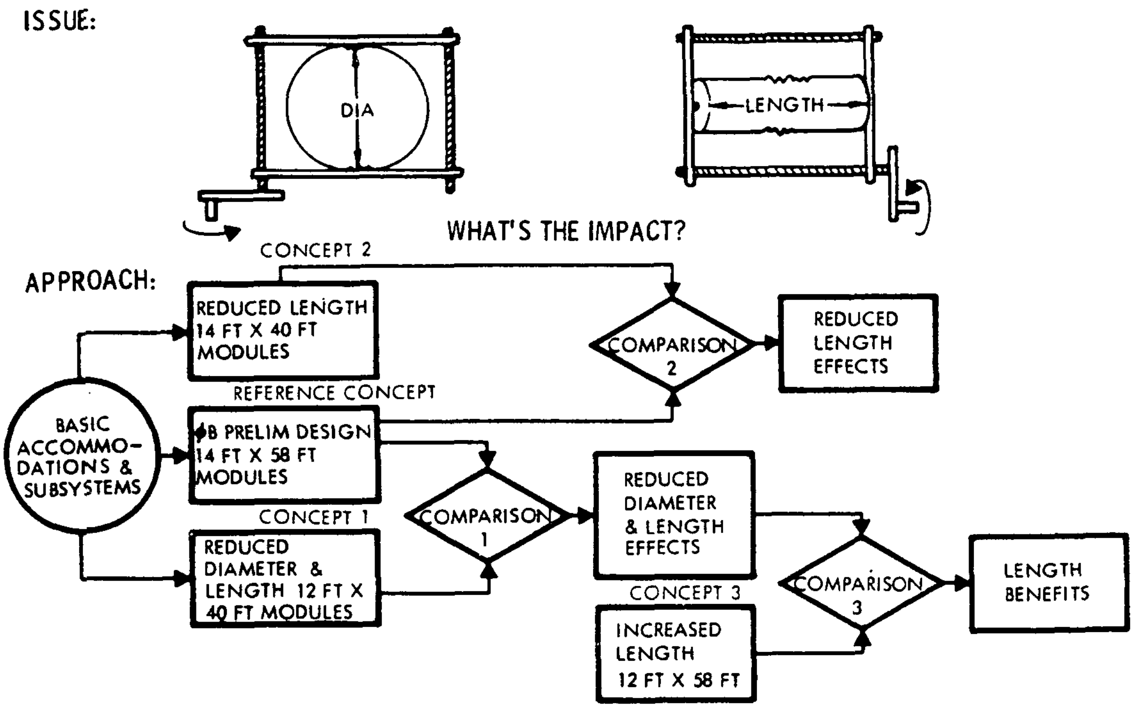


Figure 1. Reduced Payload Size Impact Study

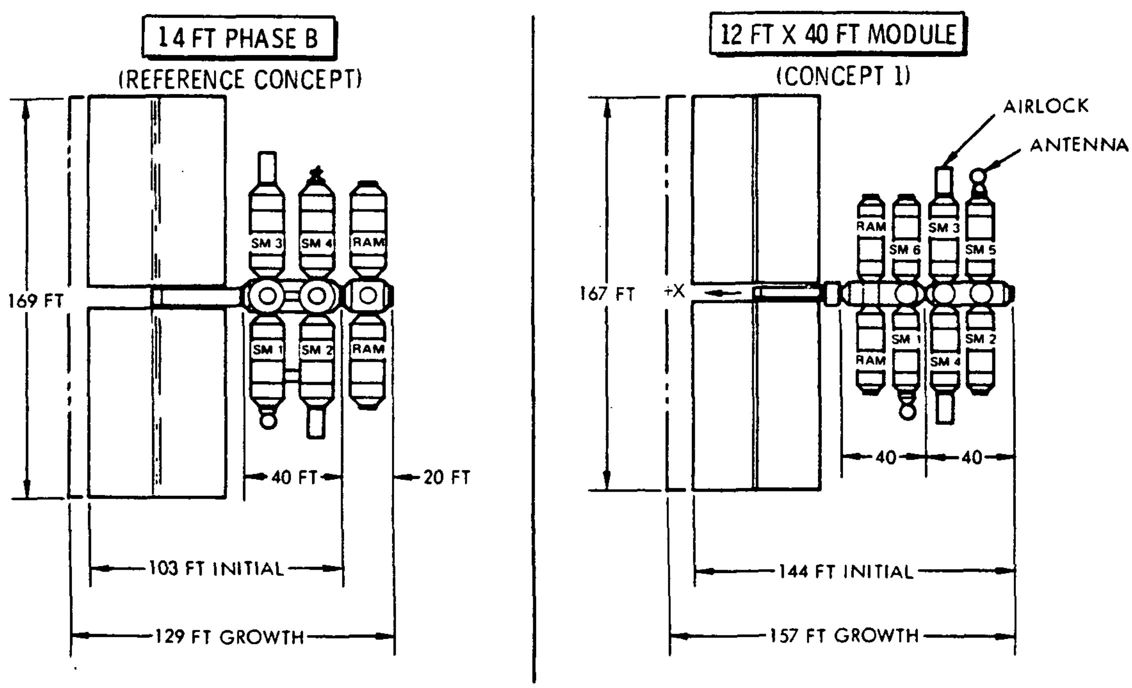


Figure 2. Reduced Payload Size Concept Dimensions

The reduction in module diameter and the increased configuration length contribute to a general overall reduction in structural stiffness and dynamic characteristics.

Figure 3 provides a comparison of the 14-foot Phase B and the reduced diameter Concept 1 and Concept 3 configurations. The Concept 2 reduced length configuration is not shown since it is identical to the 14-foot Phase B configuration.

The 14-foot Phase B initial space station configuration is characterized by a balanced split of station modules between Volume 1 (V_1) and Volume 2 (V_2) with a minimum of growth scars. The Concept 1 space station configuration requires two additional station modules to provide the equivalent accommodations of the 14-foot Phase B. These additional station modules result in a 2 by 4 split between V_1 and V_2. An additional core is required by the initial station resulting in growth scars of additional berthing ports and associated increase in complexity The Concept 3 space station configuration requires five station modules of less than 49-feet in length. This configuration also dictates an uneven 2 by 3 split between V_1 and V_2. The growth scar of this configuration is further increased over the initial station, since the side berthing ports cannot be totally utilized.

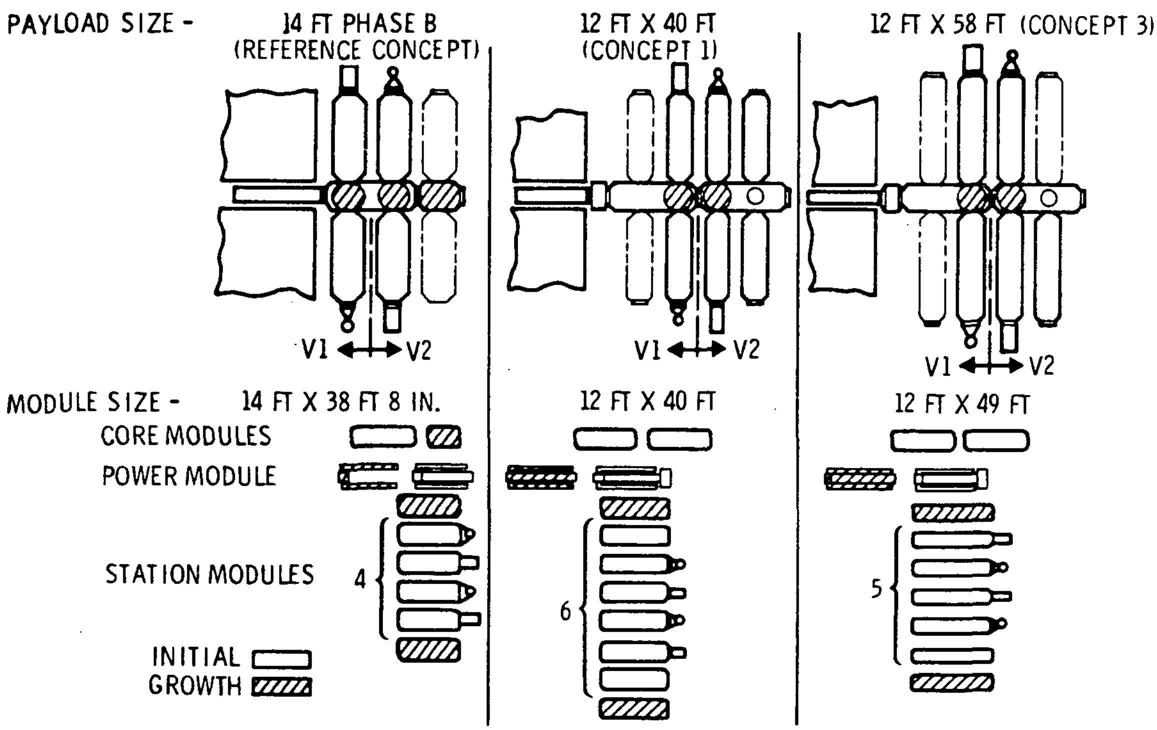


Figure 3. Configuration Comparison

The reduced diameter power module can be packaged within the 12- by 40-foot envelope at a launch weight below 20,000 pounds. The growth 10,000-foot array conversion is accomplished by replacing the array and power boom and retaining the gas storage section on orbit.

A payload size effects matrix comparison of the 14-foot Phase B initial space station and the Concept 1 and Concept 3 space stations are displayed on Figure 4.

The 14-foot Phase B space station has been optimized for initial station where the Concept 1 and Concept 3 space stations tend to be optimized to the growth station. This is driven by the increased number of station modules requiring an additional core for the initial station.

The reduction in diameter results in marginal stiffness characteristics of the power module. To accommodate equipment installation, an expanded diameter gas storage section has been added to the power module. For growth, the gas storage section is retained and only the power boom is replaced. The emergency egress feature is retained through the power boom.

There is a general increase in interface complexity due to the increased number of modules, the increased configuration overall length and additional core module, and the reduction in available volume and area in the vicinity of the berthing ports.

The Concept 1 and Concept 3 configuration core modules have a marked increase in complexity traceable to: the recessed ports and the reduced interface volume at the berthing ports for distribution of basic subsystem service and utilities from one module to another. The Concept 1 and Concept 3 station modules are of single level internal arrangement driven by the reduction in diameter. The single level arrangement generally expands the traffic patterns, compromises the location of particular accommodations, and contributes to a substantial increase in machinery noise in the station living and operating areas.

In addition, the Concept 3 station modules must be located in the XZ plane to meet dual egress requirements. This results in an unbalance which must be countered with the cargo module placement causing an operation penalty or an RCS consumables penalty. The Concept 3 station modules can be as long as 49 feet before they exceed the 20,000-pound launch weight limit. Because of this increased length, the modules must be spaced to 5-1/2 feet to be adaptable to a direct docking mode.

	POWER MODULE	CORE MODULE	STATION MODULE
14 FT PHASE B (REFERENCE)	• STRUCTURAL SIMPLICITY • GAS-STORAGE IN POWER BOOM	• SINGLE MODULE (INITIAL) • WEIGHT SENSITIVE	• MINIMUM NO OF MODULES
12 FT X 40 FT (CONCEPT 1)	• MARGINAL STIFFNESS & INTERNAL ACCESS • EXPANDED DIAMETER FOR GAS STORAGE	• VOLUME SENSITIVE • STRUCTURAL COMPLEXITY (PARTS RECESSED) • INTERFACE COMPLEXITY • INCREASE NO BERTHING PORTS	• MEET MINIMUM REQMTS • HIGHER NOISE IN LIVING AREAS • ACCOMODATION LOCATIONS COMPROMISED
12 FT X 58 FT (CONCEPT 3)			• XZ PLANE UNBALANCE • INCREASED MODULE SEPARATION

9PDS110298

	CONFIGURATION	SUBSYSTEMS	OPERATIONS
14 FT. PHASE B (REFERENCE)	• OPTIMIZED FOR INITIAL	BASELINE	• END BERTH MANIPULATION
12 FT X 40 FT (CONCEPT 1)	• MARGINAL STIFFNESS CHARACTERISTICS • ON ORBIT WEIGHT INCREASE = 28,000 LB • INCREASED INTERFACE COMPLEXITY	• POWER +475 W • WEIGHT +830 (EPS) +4600 (ECLSS) • INCREASED CMG SIZE • BETTER SUBSYSTEM ACCESSIBILITY	• +3 FLIGHTS TO IOC • +2 FLIGHTS FOR ADAPTER AIRLOCK & ANTENNAS • SIDE BERTH MANIPULATION • SPACE FOR SHUTTLE TARIFF
12 X 58 (CONCEPT 3)	• POTENTIAL SINGLE CORE WEIGHT LIMITED AT APPROX. 49 FT	(NOT ANALYZED)	(NOT ANALYZED)

Figure 4. Reduced Payload Size Effects

The Concept 1 configuration requires a subsystem electrical power increase of 475 watts and a weight increase of 5400 pounds for the electrical power subsystem (EPS) and the environmental control and life support subsystem(ECLSS). The CMG size is increased, accountable to the general increase in configuration size. The increase in CMG size tends to drive CMG technology beyond that required for the 14-foot Phase B.

Five additional shuttle flights are required to build up the initial Concept 1 space station: (1) three additional flights to IOC and (2) two flights for shuttle adapter experiment airlocks and antenna packages. Because of the increased configuration length, side berthing of the shuttle is required for manipulation. With the 40-foot shuttle bay, space for shuttle tariff is impacted and would be required packaged within MSS modules or internal to the shuttle orbiter.

Figures 5 and 6 summarize cost assumptions and delta cost effects, respectively, for the Concept 1 initial space station program. The cost changes attributable to a 12-foot diameter station versus a 14-foot Phase B were analyzed at the subsystem (WBS Level 5) level, using 14-foot Phase B cost estimating relationships (CER's). The factors considered were changes in applicable know-how, complexity, weight, subsystem flight hardware entities, and additional major test hardware. The know-how ratio is based on rankings adapted from AFSCM 173-1. In the ECLSS and RCS, this ratio represents the judgment that the additional equipment is either a minor modification or requires additional integration effort. The ratio greater than one for G&C indicates that less is known regarding design problems for the 12-foot-diameter configuration. Complexities are assumed equal to the 14-foot Phase B station except for the core structures, which is considered more complex because of the recessed docking ports and the additional difficulty of accommodating utilities distribution and equipment installation. The deltas to the ECLSS were considered less complex than the overall ECLSS because the additions consisted mainly of tanks and radiators. The D&D and flight hardware costs derived by procedures described above amount to slightly over $70 million for the initial MSS. The estimate of major test hardware (MTH) increased in cost, about $40 million, are even more approximate. MTH estimates are based on a rough estimate of increased test hardware weight at an overall flight hardware cost per pound. Estimates have been included for integration costs attendant to the increased interface complexity expected by the addition of more modules, and for project support and floating items. Based on initial cost estimates for the baseline 14-foot Phase B configuration, the 12-foot Concept 1 station would cost approximately 12.5 percent more than the 14-foot Phase B configuration.

	KNOW-HOW RATIO 12' D VS 14' D Ø B	COMPLEXITY % OF 14' DIA. Ø B	DELTA WT ONLY	ADDITIONAL ITEMS
STRUCTURES & MECHANISMS (S&M)	1	115% (RECESSED DOCKS) ON CORES, 100% SM's		CORE - 2, SM-5, SM-6
ECLSS	1 TO 3	60% (TANKS, RADIATORS)		
EPS	1	100%	√	
CREW HABITABILITY	1	SEE S&M & ECLSS	√, 85% TO S&M 15% TO ECLSS	
G&C	3.25 TO 3.00	100%		
RCS	1 TO 4	100%		
ISS (SOFTWARE DELETED)*	1	100%	√	

NOTE: MAJOR TEST HARDWARE (MTH) INCLUDES 1.5 EQUIVALENT SETS OF CORE 2 & SM-5

* SOFTWARE ASSUMED IDENTICAL FOR BOTH CONFIGURATIONS

√ COST INCREASE BASED ON WEIGHT INCREASE ONLY

Figure 5. Summary of Cost Assumptions

	DRY WEIGHT	INCREASE IN COST ($ MILLION, 1971 VALUE)		
	INCREASE (LB)	D&D	FLT. HARDWARE	DELTA
STRUCTURES & MECHANISMS	17,675	$ 29.1	$ 9.2	$ 38.3
ECLSS	3,230	10.7	4.3	15.0
EPS	638	3.2	2.1	5.3
G&C	173	1.1	0.5	1.6
RCS	60	0.9	1.0	1.9
ISS	596	6.5	3.1	9.4
TOTAL	22,372	$ 51.3	$ 20.2	$ 71.5
MAJOR TEST HARDWARE				$ 40.5
INCREASED INTEGRATION COMPLEXITY				13.0
TOTAL INCREASE, ABOVE COST ITEMS				$ 125.0
SUPPORT & FLOATING ITEM COSTS @ APPROXIMATELY 100%				125.0
TOTAL PROJECT COST INCREASE				$ 250.0
APPROXIMATE INCREASE OVER 14' STATION				12.5%

Figure 6. Summary of Cost Changes - Initial Station

The study results conclude that modular space stations configured with 12-foot diameter and reduced length modules do meet requirements. Problems unique to these configurations appear to be solvable. As driven by the diameter reduction and increase in numbers of modules, program costs are increased.

The further increase in complexity is a prime issue and concern that resulted from the study. Because of this general increase in complexity of the MSS concept, it is recommended that the reduced diameter modules be avoided.

2. DESIGN INTEGRATION ANALYSIS

The design integration configuration concept development and comparison with the 14-foot Phase B module configuration was accomplished in three segments. An in-depth development of baseline and concept configurations for the 12- by 40-foot modules (Concept 1), followed by an abbreviated development and analyses of the 14- by 40-foot (Concept 2) and 12- by 58-foot (Concept 3) configurations.

The 14-foot Phase B accommodations requirements (Table 1) were allocated with equipment to establish a Concept 1 baseline configuration. From the baseline configuration, initial mass properties were established providing a basis to evaluate special module (power and core) and station module design requirements. From the baseline configuration a concept configuration was derived. The concept configuration was compared with the 14-foot Phase B configuration to define the final reduced diameter and length effects. The concept configuration, as compared to the 14-foot Phase B, is shown on Figure 2.

Structures shall provide within the MSS complex two pressure isolatable volumes with facilities allocated as shown in Table 1.

CONCEPT 1 (12- BY 40-FOOT) COMPARISON

Special Modules

The special modules include the power and core modules. Figure 7 compares the concept configuration for the initial station power module for a 12-foot diameter as compared with the 14-foot Phase B version. The initial station power module shown will fit into the 12- by 40-foot shuttle bay. The solar array is a 7000-square-foot Lockheed array; a gas storage section, enlarged to the full 12-foot diameter, has been added to store emergency O_2 and N_2 repressurization gases and 30-day H_2 and O_2 high pressure gases for fuel cell electrical power during buildup. The remainder (60 days) of the buildup H_2 and O_2 high pressure gases for electrical power are located in core module 1.

On-orbit conversion to the growth power configuration is accomplished by replacing all except the enlarged gas storage section with a longer boom turret and array assembly containing the larger 10,000-square foot solar array. The growth station array and boom are also compatible with the 12- by 40-foot constraint.

Table 1. 14-Foot Phase B Accommodation Requirements

Functional Area	No. Reqd		Min Sq Ft/Fac	Storage Cu Ft/Fac	Functional Area	No. Reqd		Min Sq Ft/Fac	Storage Cu Ft/Fac
	Vol 2	Vol 1				Vol 2	Vol 1		
General stateroom	2	2	50	30	GPL	x	x	590	
Commanders stateroom/ office/backup control	0	1	90	55	Prime crew care/ exercise	1	0	220	140-190
Executive stateroom	1	0	90						
Personal Hygiene - With Shower	0	1	55	30	Backup medical care/ exercise	0	1	60	2
Without shower	1	0	40		Photo laboratory	0	1	40	TBD
Primary control center (2)	1	0	50	50	Data analysis	0	1	95	TBD
Primary control center (1)	0	1	50	TBD					
Primary galley	0	1	85	TBD	EVA/IVA airlock	1	1	35	0
Backup galley	1	0	15	TBD					
Dining/recreation	0	1	160	TBD	Experiment airlock	1	1	TBD	0

NOTES: Where two volumes appear in storage column, the first represents the volume required in the immediate area, the second is the total volume required for the facility on the space station.

Convenient access to personal hygiene areas is required. Privacy is a prime consideration with capabilities to accommodate male and female crewmembers (not necessarily at the same time).

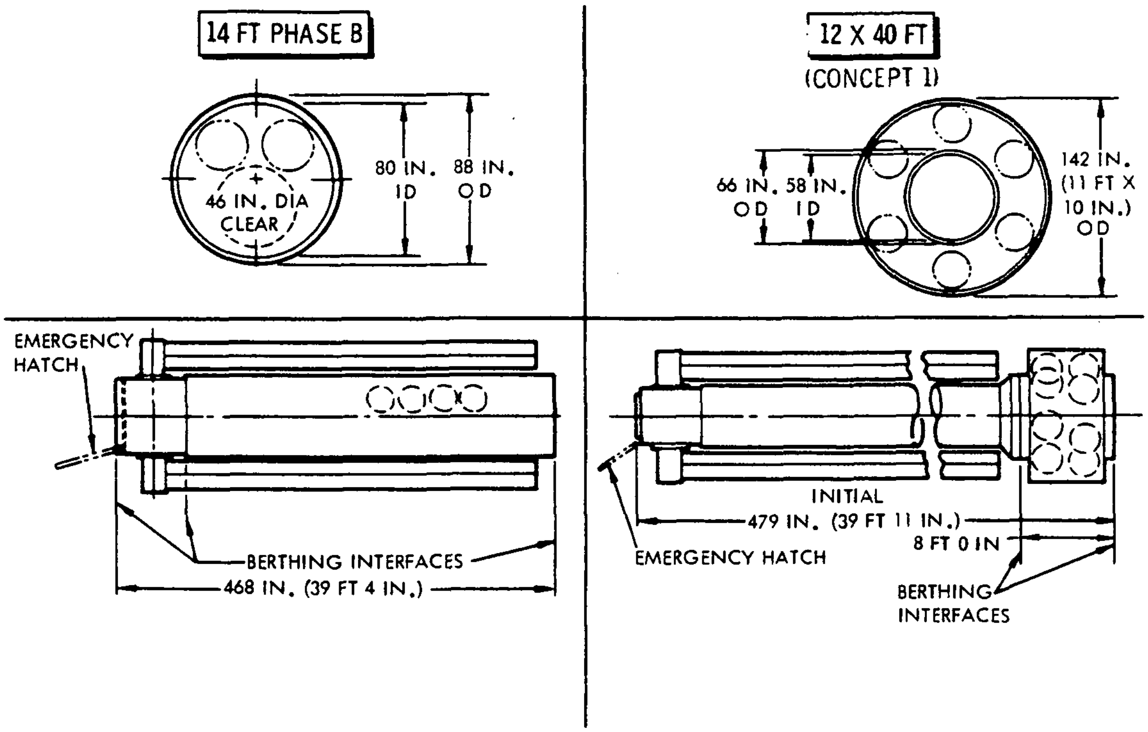


Figure 7. Special Module (Power)

The staggered and in-plane berthing port core configurations studied are illustrated on Figure 8.

The selected core module configuration incorporates features from various arrangements. The "in-plane" feature allows all berthing ports in line longitudinally to be equally spaced so that all "flexports" can be identical with no restrictions on habitable module location. The 12-foot-diameter payload limitation reduces the core cross-section area significantly so that the four in-plane berthing port arrangements cannot be employed with the type of construction used in the 14-foot Phase B core module because of insufficient utility run area. This area can be increased by recessing the berthing ports in an expanded core cylinder diameter. The resulting two-core module configuration minimizes the overall core length while providing the necessary number of initial and growth berthing ports and the internal volume required. The area for utility runs in the vicinity of the berthing ports is still minimal, however, and dictates the removal and remote storage or return to earth of all berthing port covers not required to be retained in the core.

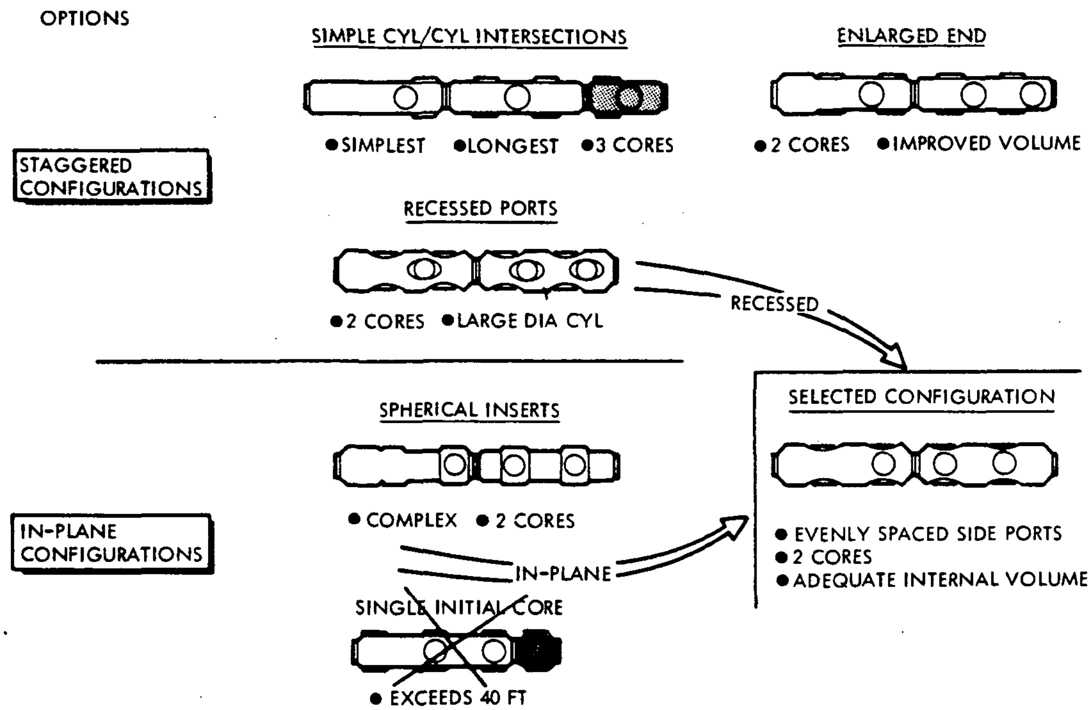
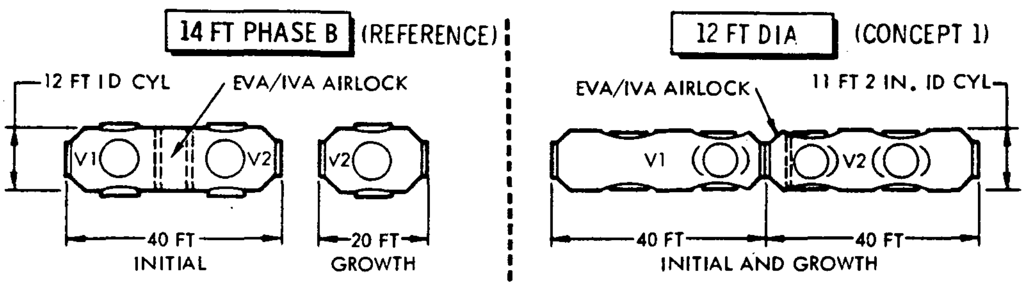


Figure 8. Special Modules (Core) Berthing Port Configuration



		14 FT PHASE B (REFERENCE)	12 FT DIA (CONCEPT 1)
REQUIREMENTS			
• SIDE BERTHING PORTS		8 INITIAL	10 GROWTH
		12 GROWTH	14 GROWTH
• EVA/IVA AIRLOCK		MEETS RQMTS	MEETS RQMTS
CHARACTERISTICS			
• LENGTH:	INITIAL	40 FT	80 FT
	GROWTH	60 FT	80 FT
• WEIGHT: (WET)	CORE NO. 1	21,640 LB	18,770 LB
	CORE NO. 2		16,080 LB
• DIAMETER:	12 FT ID		11 FT 2 IN. ID

Figure 9. Special Module (Core)

Figure 9 displays a comparison of the 12 x 40-foot (Concept 1) core configuration with the 14-foot Phase B. The recessed berthing port construction is more complex than that used on the 14-foot Phase B core modules, but it offers an 11-foot 2-inch-inside diameter cylinder which is only a 10-inch diametrical reduction for a 2-foot reduction in payload diameter. Both Concept 1 core modules are required for the initial station to provide sufficient berthing ports and the two required isolatable pressure volumes. The 12-foot-diameter station requires two core modules for the initial station; hence, the overall length is 40 feet longer than the 14-foot-diameter Phase B core of the initial station. The two core modules are also required for the growth station which is 20 feet longer than the 14-foot-diameter core of the growth station. The 14-foot Phase B is optimized for the initial station where Concept 1 is optimized toward growth. The drivers are the reduction in core module volume and the increased numbers of berthing ports. The growth scar on the Concept 1 initial core module is four berthing ports while on the 14-foot Phase B, the berthing port scar is zero.

The split between Volume 1 and Volume 2 occurs at the end of core module 2 coincident with the interface between the two core modules. The volume of the airlock is irregularly shaped and smaller than the one in the 14-foot-diameter station. No equipment other than that required for airlock operation is located within it, while guidance and navigation equipment occupies space in the 14-foot version.

Station Modules

Station modules house all of the basic station functions for crew habitability, station operations, experiments (GPL), and experiments operations. These functions and accommodation requirements are listed in Table 1, and have been met as indicated in the following paragraphs.

The comparison of station module cross section (Figure 10) shows the deck of the 12-foot-diameter module located for maximum above-deck volumetric efficiency. The above-deck area provides a more rectangular shape to help compensate for the smaller diameter cylinder. Below-deck equipment location has been reduced to utility runs and minimal storage as a penalty to this above-deck optimization. The deck clears the end berthing port hatch openings so that the cutouts at each end of the 14-foot-diameter module deck are not required on this configuration. The environmental systems equipment, located below deck on the 14-foot modules, is located above deck on these modules. Noise insulation which may be afforded by the deck thickness and volume isolation on the 14-foot arrangement may have to be provided by added enclosure material in these above-deck locations. Access to below-deck utilities will be through access openings in the deck. Overhead utility access is comparable to the 14-foot module.

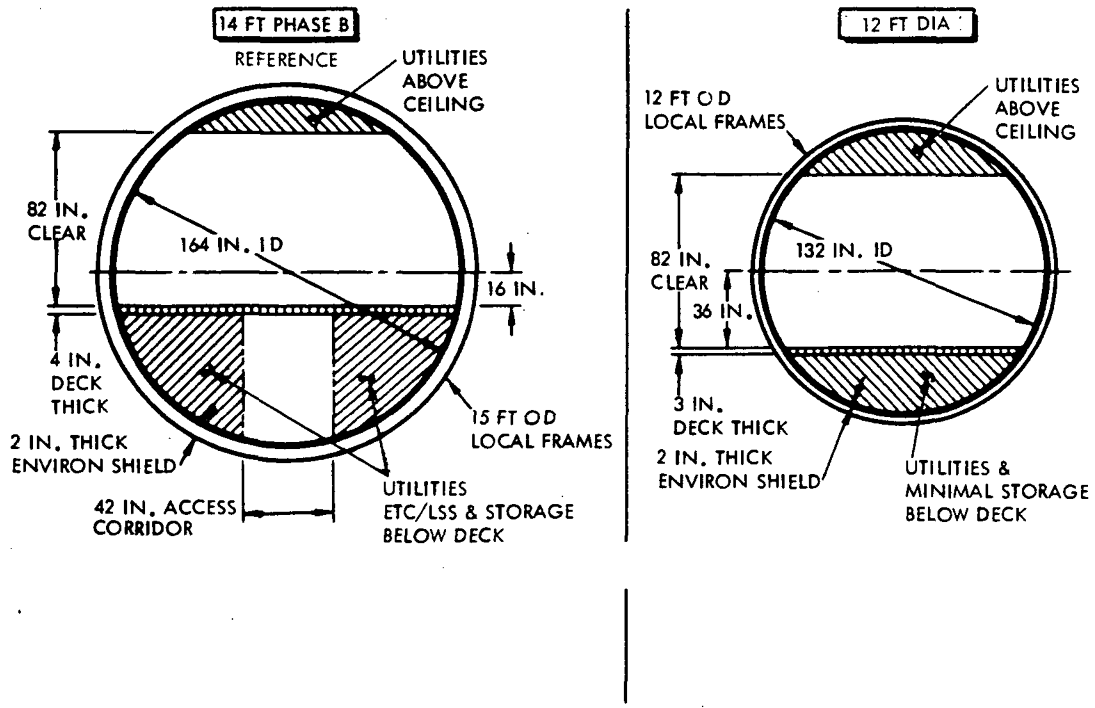


Figure 10. Station Modules - Cross Section Arrangement

The following paragraphs are a comparative evaluation of each basic accommodation of the Concept 1 initial space station compared with the 14-foot Phase B.

The crew stateroom average head height compares favorably with the 14-foot arrangement (Figure 11). The split level arrangement of the 14-foot module provided increased habitable deck area, but somewhat reduced habitable volume per square foot of deck area.

The personal hygiene areas (Figure 12) on the smaller diameter modules exemplify the expected longer and narrower shape when compared to the 14-foot arrangement. An advantage of this shape can be taken into account by partitioning the shower from the rest of the area for added privacy which may be desired in the case of crews comprised of both sexes. The waste management machinery associated with the personnel hygiene area is located across the corridor, mounted on the deck. The plumbing runs are overhead or below deck, and are longer runs than those on the 14-foot module which has this machinery located directly below the hygiene area. The personal hygiene area is located in a separate module from the crew quarters which is considered a distinct disadvantage.

Figure 13 displays a comparison of control centers and galleys. The control center area is located adjacent to the commander's stateroom as on

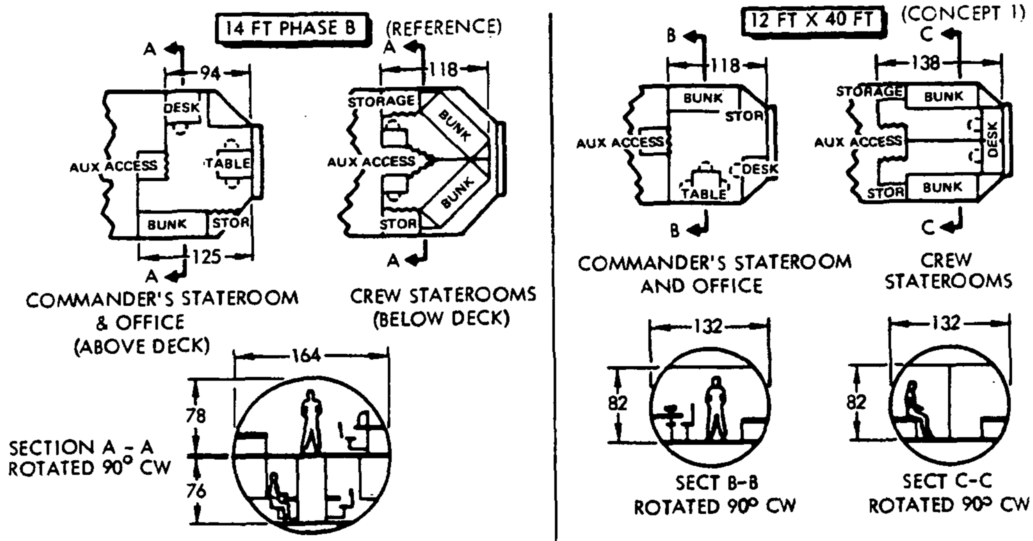
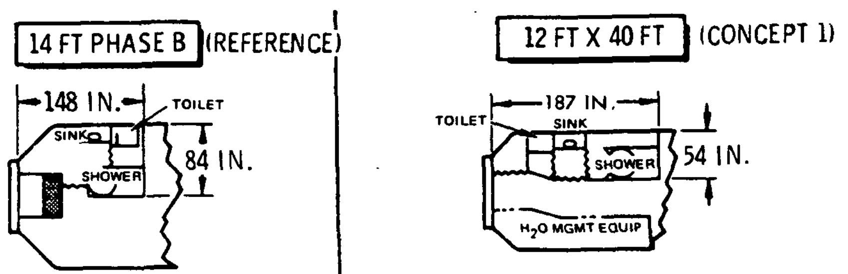


Figure 11. Station Modules Facilities - Staterooms



FEATURES

- AREA: REQUIRED - 55 FT^2 WITH SHOWER
  40 FT^2 W/O SHOWER
  - MEETS REQUIREMENTS
- SHORT PLUMBING RUNS
- H_2O MGMT EQUIPMENT BELOW DECK

FEATURES

- AREA: REQUIRED - 55 FT^2 WITH SHOWER
  40 FT^2 W/O SHOWER
  - MEETS REQUIREMENTS
- SHOWER DRESSING AREA PRIVACY (MIXED CREWS)
- NEAR COMMANDER/EXEC STATEROOM
- SEPARATE MODULE FROM OTHER CREW QUARTERS

Figure 12. Station Modules Facilities - Personal Hygiene

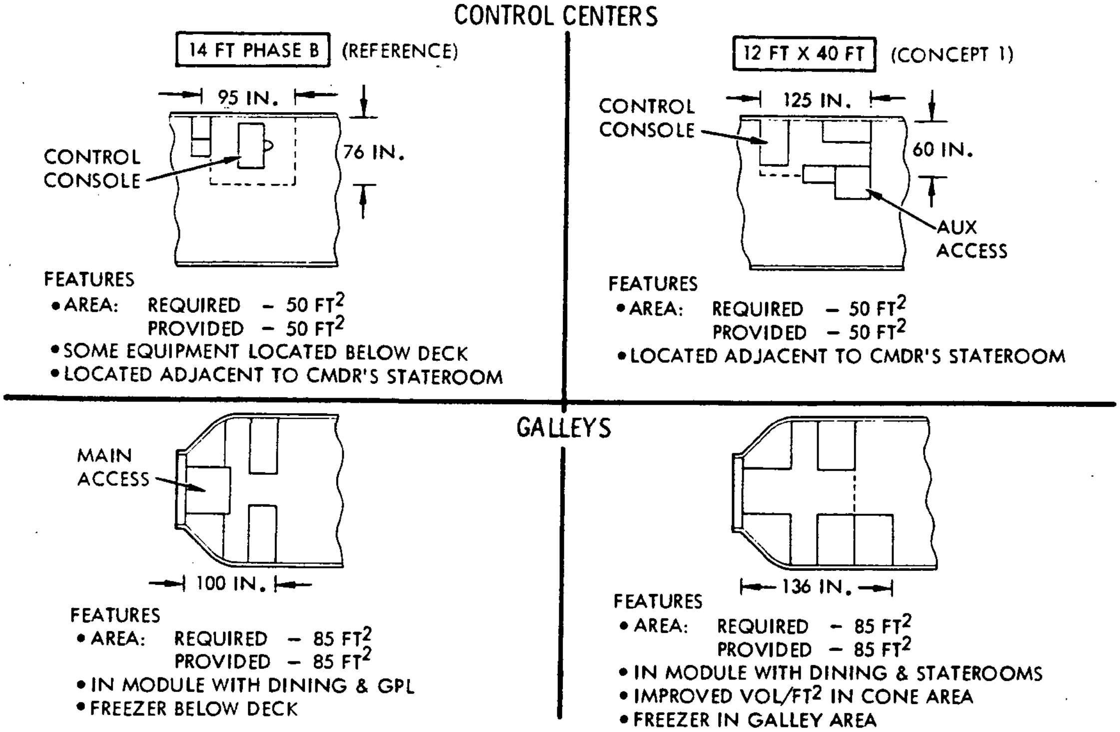


Figure 13. Station Module Facilities

the 14-foot version. The areas are equal on the two stations. All equipment in the 12-foot module can be monitored from a central position, and all equipment is located in the immediate control center area. The arrangement in the 14-foot module is such that the control console is visible from the commander's stateroom side, but access to some control center equipment must be gained from behind the console. Some associated equipment is located below the deck on the 14-foot module, and wiring runs may be shorter when pieces of interconnected equipment are located directly above and below each other.

Primary galley arrangements are similar with equipment accessible from the corridor and intersecting aisles. The food freezer in the 14-foot Phase B module is located below the deck while the 12-foot module food freezer is located in the immediate area of the galley.

Figure 14 shows a comparison of the dining/recreation areas and the primary crew care/exercise area. The dining area in the 12-foot module is generally longer and narrower than the area in the 14-foot module. Permanent dining accommodations for eight people are provided. The nearby hobby areas may be utilized for additional seating and table space if required for growth or crew overlap periods. The 14-foot arrangement utilizes tables which expand into the corridor area for these purposes.

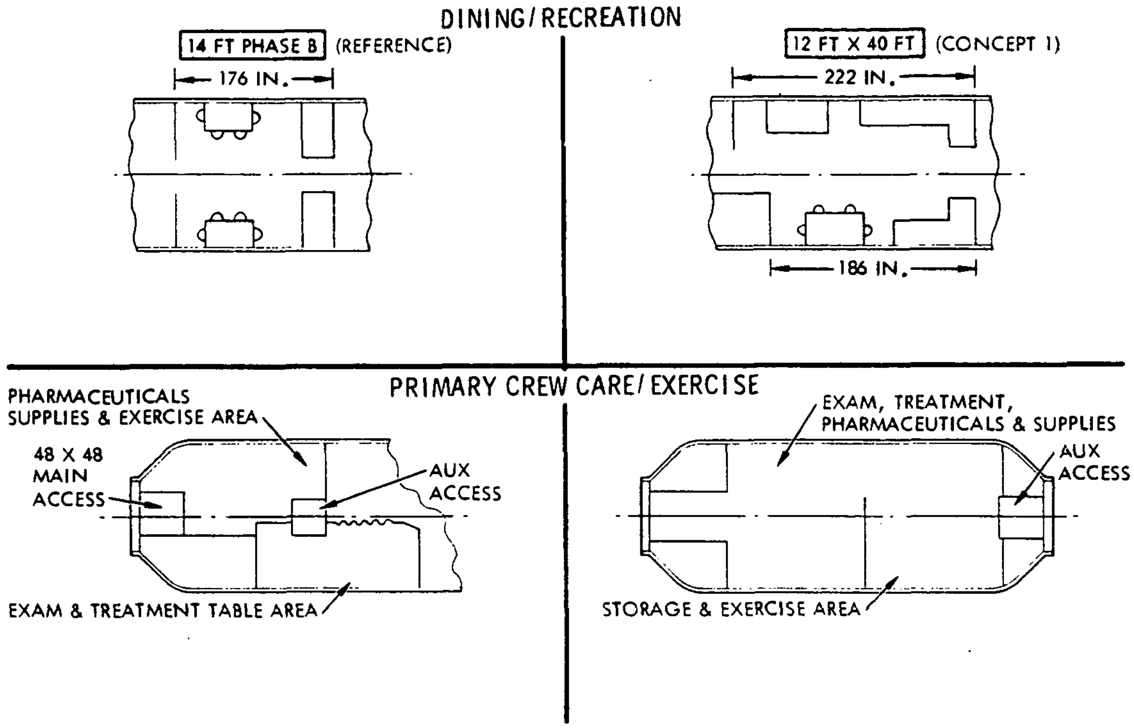


Figure 14. Station Module Facilities - Dining and Recreation

The primary crew care and exercise area must have the capability of biological isolation of a patient. The layout in both modules provides this capability, although it can be accomplished in the 14-foot module arrangement with less interaction with other module functions. The supplies and pharmaceuticals are kept in the area surrounding the examination and treatment table in the 12-foot module, but only minimal storage of these items is provided for in the area immediate to the table in the larger module.

Module arrangement comparison of backup medical care/exercise and data analysis centers is shown on Figure 15. The backup medical care and exercise area is normally open for isotonic exercise with the examination and treatment table folded out of the way. For use, the table is extended and an isolation curtain can be moved into place. As shown, this curtain would block one access route to the module in the 12-foot layout.

The data analysis center in both modules is located adjacent to the control center. The 12-foot-diameter area is more nearly square in this instance, but both have a rectangular arrangement with all equipment located in the immediate area.

Internal station experiment accommodations are provided in the form of the general purpose laboratory area (Figure 16) and two experiment airlocks (Figure 17).

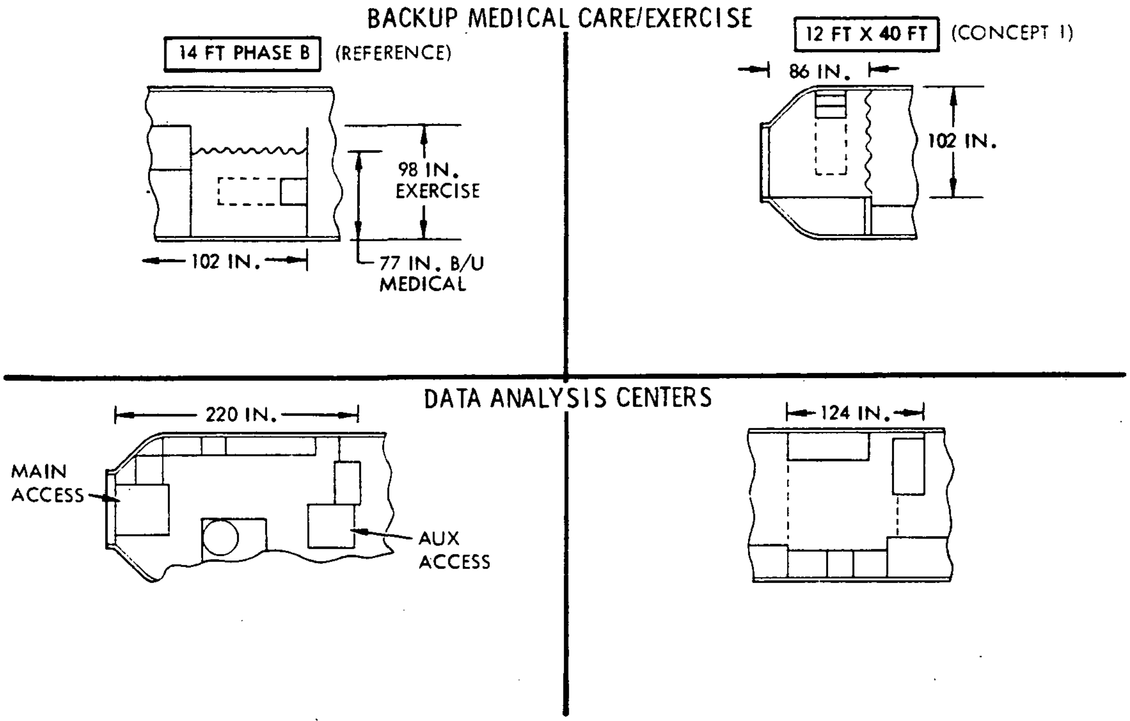


Figure 15. Station Module Facilities - Backup Medical Data Analysis

The general purpose laboratory (GPL) area in both stations is divided into two areas occupying the ends of two modules. An experiment airlock is adjacent to each area on the end of the modules. The division of the areas is more nearly equal in this arrangement. Experiment storage area is provided immediately below the GPL area in both modules of the 14-foot arrangement.

The greater volume of the 12-foot module should provide some storage space above deck. Some below deck storage can also be provided in this version. Two experiment airlock modules are provided, one nadir-oriented, and one zenith oriented as on the 14-foot station. For both stations, they are located adjacent to GPL areas as previously discussed. The 80-inch diameter by 150-inch length requirements can be provided as required.

A slightly larger photo processing area (Figure 16) is provided in the 12-foot-diameter module. This facility is located in a GPL module area, and is adjacent to the data analysis laboratory in the 14-foot module.

The facility comparisons show that equivalent areas are provided on the 12- by 40-foot (Concept 1) station as were provided on the 14-foot Phase B station. The reduced diameter modules of approximately the same length

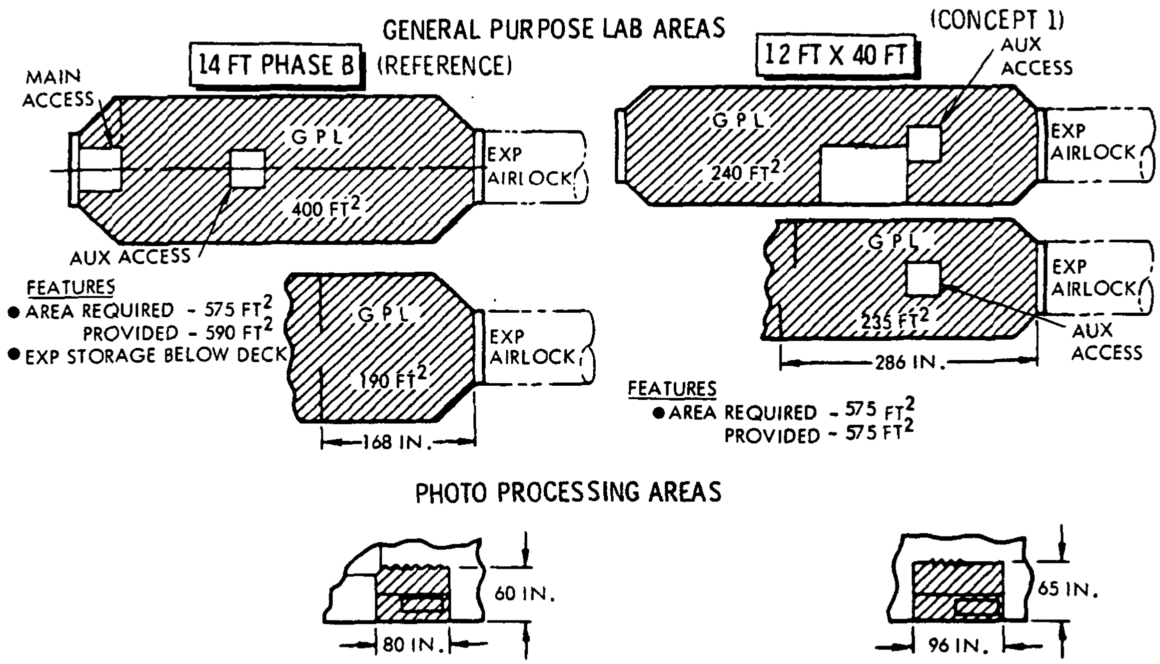


Figure 16. Station Module Facilities - General Purpose Area

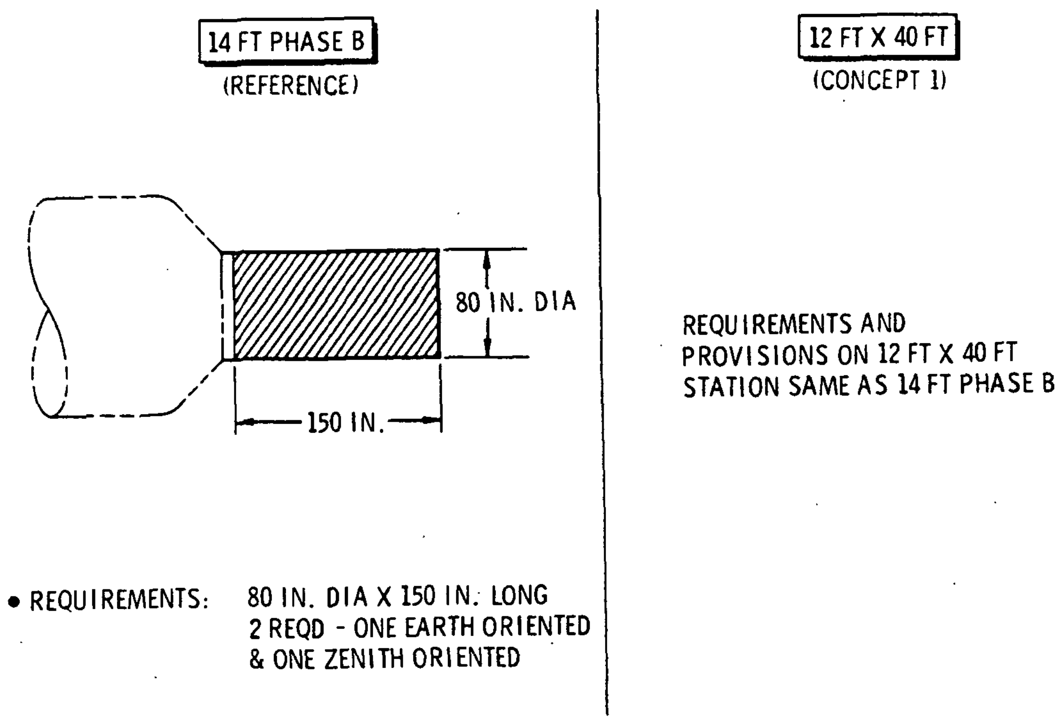


Figure 17. Experiment Airlocks

as the larger 14-foot Phase B modules require two additional modules to house the same facility. A station module summary is shown on Figure 18. The Concept 1 modules of approximately the same length as the larger diameter modules require two additional modules to house the same facilities. The 12-foot initial station volumes are divided such that two station modules are in one volume and four modules are in the other. The two-module volume houses one-half of all required crew accommodations, while the four modules in the other volume house the other half of these accommodations and those remaining that do not require division between the isolatable volumes. For growth, a module containing three crew staterooms, a personal hygiene facility, and environmental control equipment for six men is added to each volume. No added core module facilities are required for growth since they were contained in the initial core configuration. The integrated internal arrangements of the six Concept 1 initial station modules are shown in Figure 19.

CONCEPT 2 (14- BY 40-FOOT) COMPARISON

The station configuration associated with the Concept 2 module (Figure 20) was determined to be identical to the 14-foot Phase B configuration. However, if the shuttle cargo bay is limited to a 40-foot length, a number of elements attached to the modules will exceed this length. These elements (1) two antenna modules, (2) two experiment airlocks, and (3) a shuttle-station adapter, require additional shuttle launches, and must be assembled to the station on-orbit.

The reduced cargo bay length raises a major concern for locating the shuttle tariff consumables and station buildup support equipment. These items are needed to extend the shuttle operation on-orbit in the "powered up" phase, and module leakage makeup, etc. Special provisions for installing this equipment temporarily in the module being delivered will be required. Means to remove and return this used equipment must be devised. The net effect of reducing the length of the 15- by 60-foot shuttle cargo bay is an increase in the number of shuttle launches required during initial station buildup.

CONCEPT 3 (12- BY 58-FOOT) COMPARISON

Internal arrangements of the maximum length modules were made to determine the number of modules required to accommodate the required station functions listed in Table 1. The four 12- by 58-foot modules (Figure 20) required had a total deck area, 2250 ft^2, equal to the total deck area of the six 12- by 40-foot modules in the concept configuration. These arrangements reveal that the shape factor of the deck does not materially change the arrangement efficiency. A mass property analysis revealed the four module arrangements at the full 58-foot module length resulted in exceeding the 20,000-pound module lanuch weight.

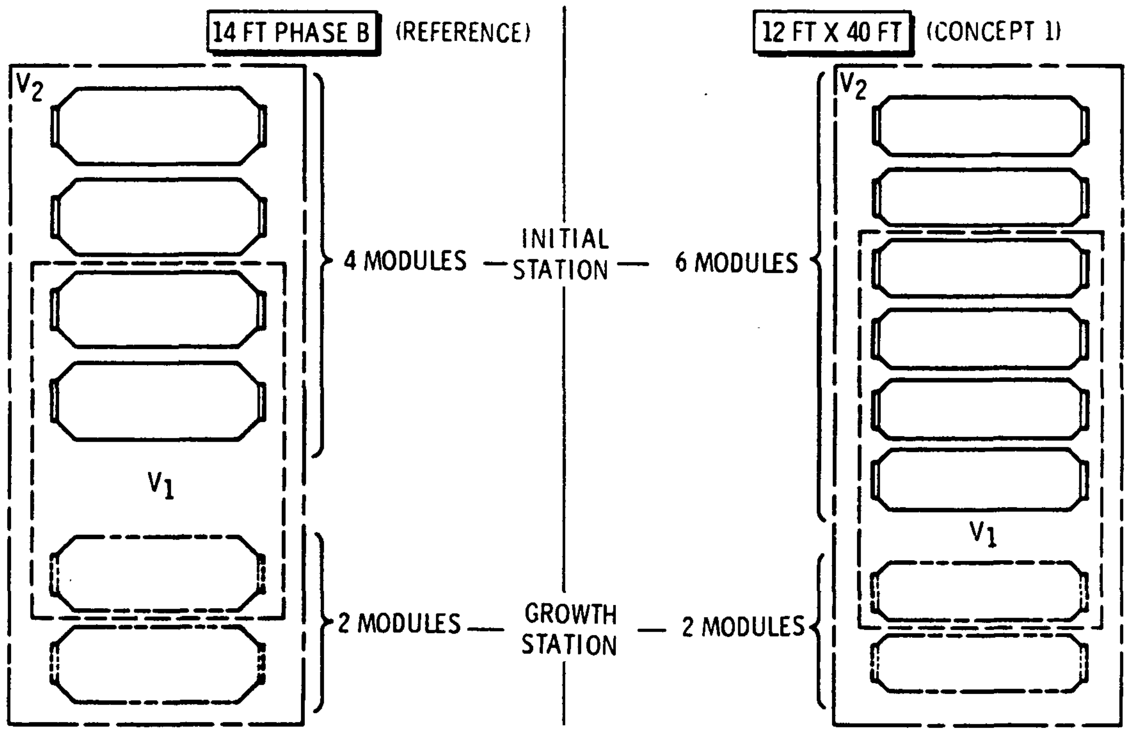


Figure 18. Station Modules Summary

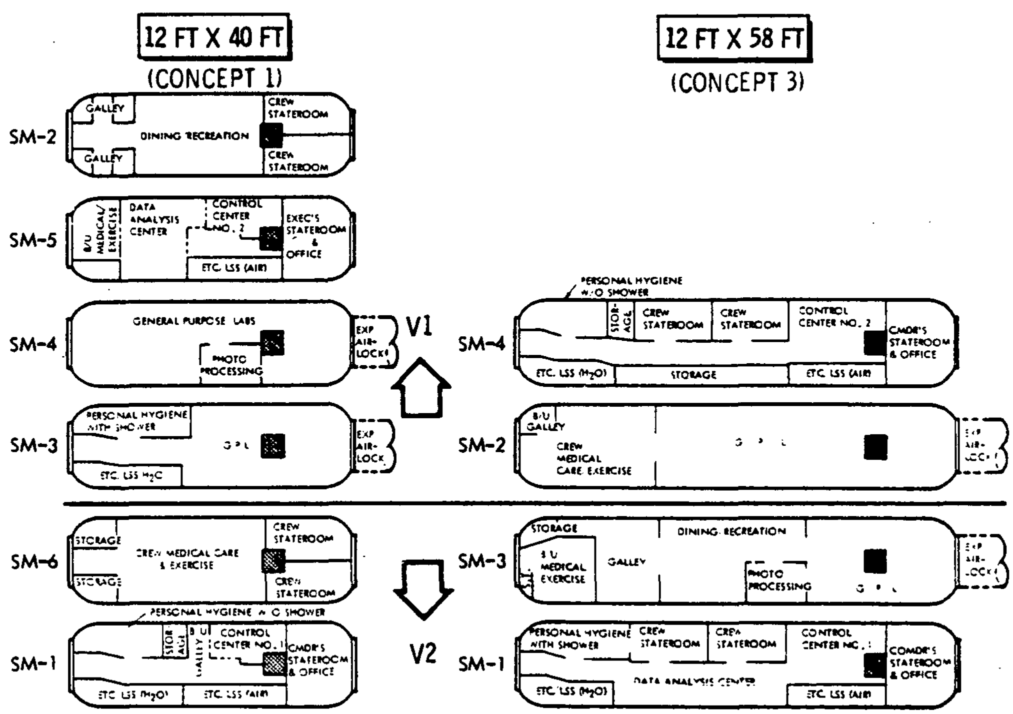


Figure 19. Station Modules (Concepts 1 and 3)

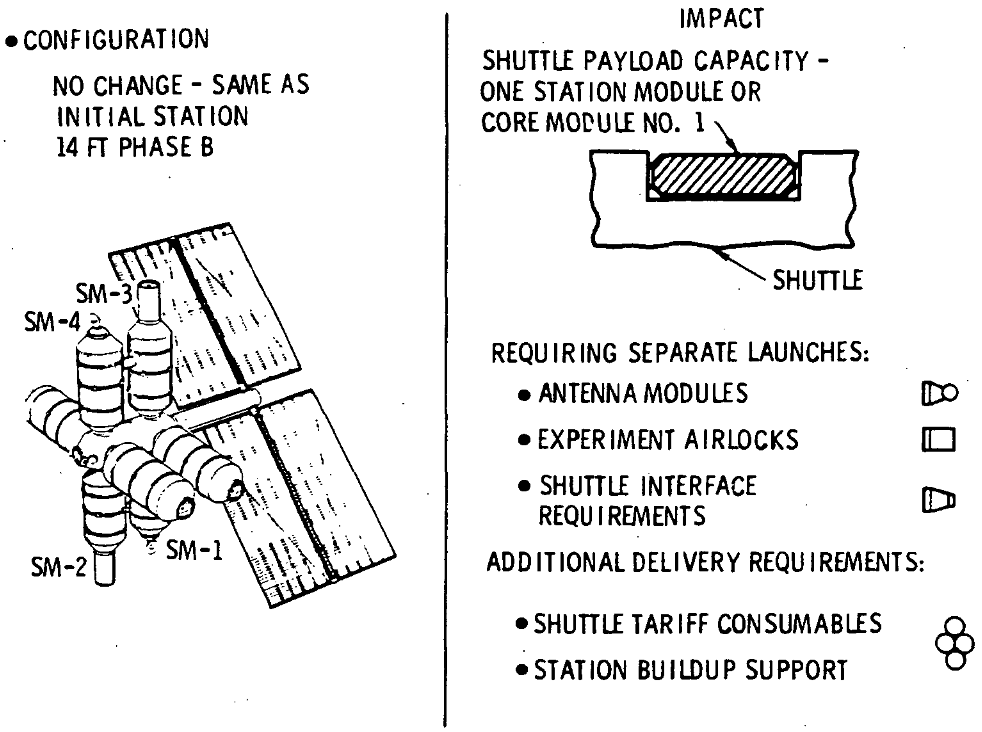


Figure 20. Reduced Payload Bay Length Impact - Concept 2 (14- by 40-Foot Modules)

A weight analysis was made utilizing parametric data (Figure 21). This analysis indicated a 12-foot-diameter module not exceeding 49 feet would meet the launch weight requirements. This analysis assumed the same approximate loading density of the 12- by 40-foot modules (2 lb/ft^3). Five of the 49-foot modules approximate the equivalent deck area as the six 40-foot modules and the four 58-foot modules.

Figure 22 illustrates the increased length advantages of the 60-foot shuttle cargo bay. The 60-foot-long, 12-foot-diameter shuttle bay used in conjunction with 40-foot-long modules, permits piggy-back and concurrent launches of station accessory packages and modules. A reduction in the number of shuttle launches results, with related accrued benefits of shortened IOC time and reduced buildup consumable requirements.

The benefits derived with 49-foot modules lessen as indicated on Figure 22. The shuttle adapter and tariff items could be launched with a module, but an airlock module or antenna package could not.

Optimizing a Concept 3 space station for a five-module-configuration (i. e., the area just equals that of six 49-foot modules) results in modules 46.5 feet long. With these modules in the 60-foot bay, any accessory package, except the airlock module, will fit in the cargo bay with a station module.

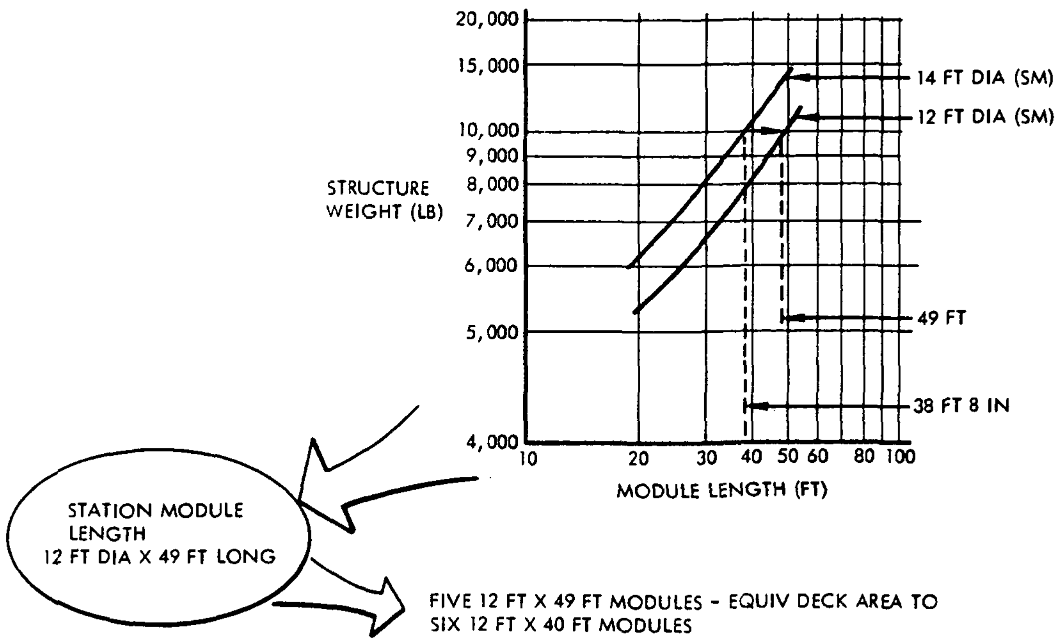


Figure 21. Weight Analysis

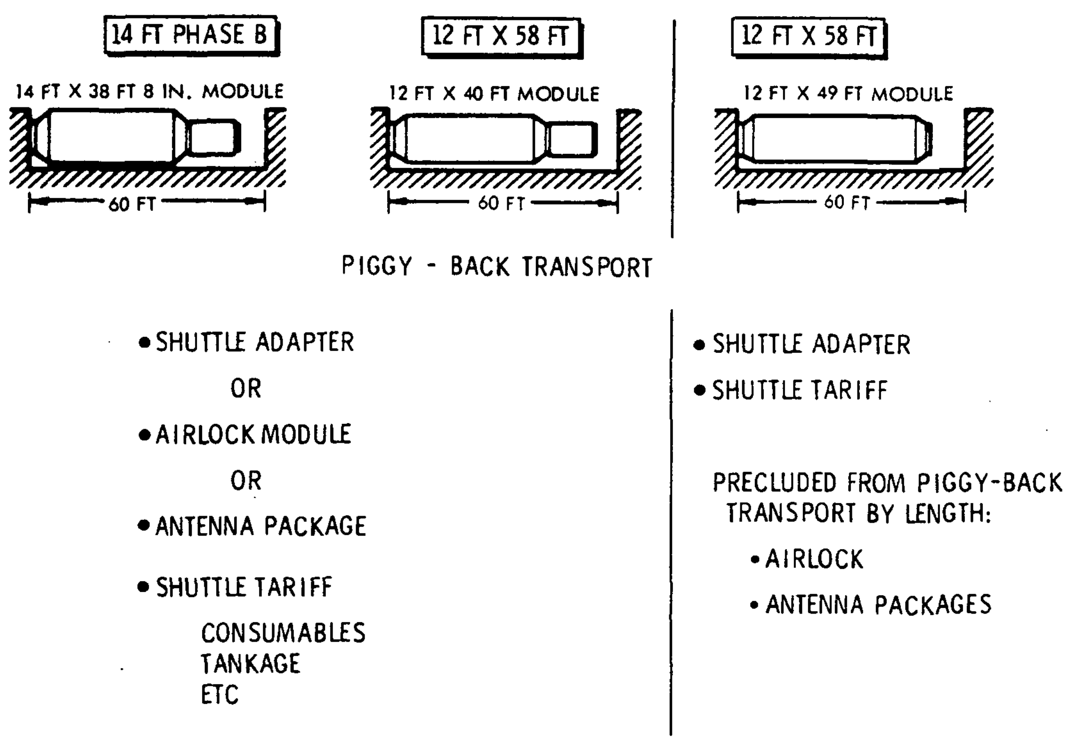


Figure 22. Shuttle Bay Length Increase

Because of the increased module length of 46.5 feet over the concept configuration of a 40-foot module, module spacing requirements were examined for the Concept 3 configuration to facilitate berthing or docking. Figure 23 shows the parametric relationship between module length and module spacing as influenced by station stability and shuttle stability, and position accuracy. The plotted data is for the docking mode which requires the greatest space. Accumulation of shuttle attitude stability and position accuracy is plotted in the lower curve for increasing module lengths. A 30 percent margin of uncertainty is added to this plot to determine the actual module spacing. The spacing for 46.5- or 49-foot modules is 5-1/2 feet or an increase of 1/2 foot over the 14-foot Phase B station.

CONFIGURATION COMPARISON

Figure 24 compares the final configurations for the Concept 1 and Concept 3 space stations with the 14-foot Phase B. The 12-foot diameter station configuration results in an increased number of modules, and therefore berthing interfaces, since the diameter reduction cannot be compensated by increasing the module length without exceeding module weight requirements. Increasing the length to width ratio of the special and station modules has resulted in a general reduction in structural modal frequencies toward unacceptable values. The 12-foot-diameter station generally meets requirements but not with the degree of efficiency accomplished by the 14-foot-diameter station.

Table 2 compares the mass properties of the three configurations. Individual modules of the 12-foot-diameter stations are lighter in each case except for the power module, which contains added gas storage provisions.

The attached RAM accommodations for all versions are identical in number, but vary in location and orientation (Figure 25). The 14-foot Phase B station has RAM's located away from the solar arrays; they are oriented in the Y - Y directions initially and cannot be nadir or zenith-oriented until the growth core module is assembled. The 12-foot-diameter station, conversely, has RAM's located next to the solar arrays initially, but they are nadir and zenith-oriented . Detached RAM accommodations are comparable. It is concluded that experiment provisions of the 12-foot and the 14-foot Phase B stations are generally equivalent.

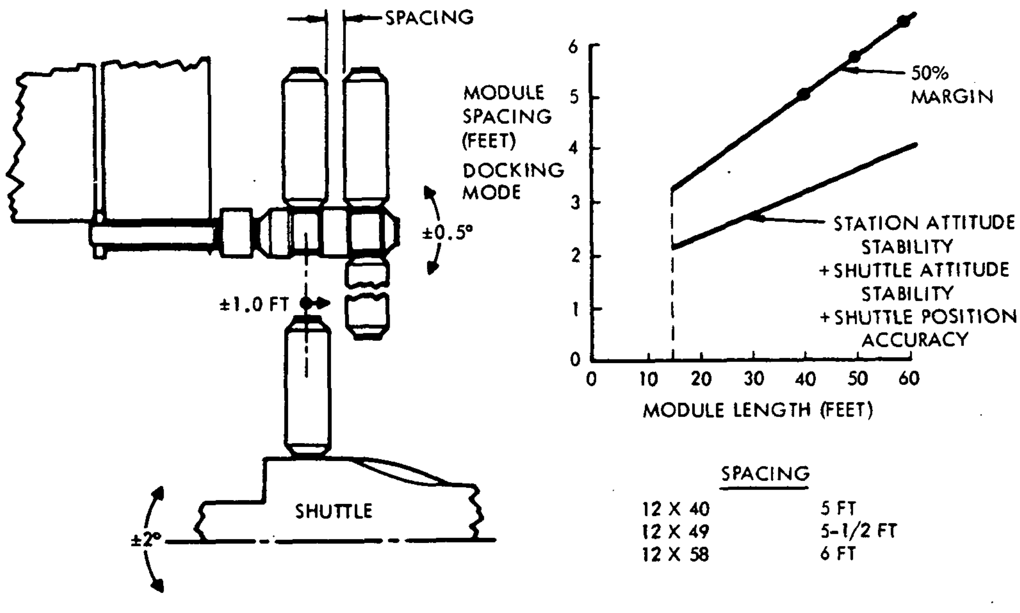


Figure 23. Module Spacing

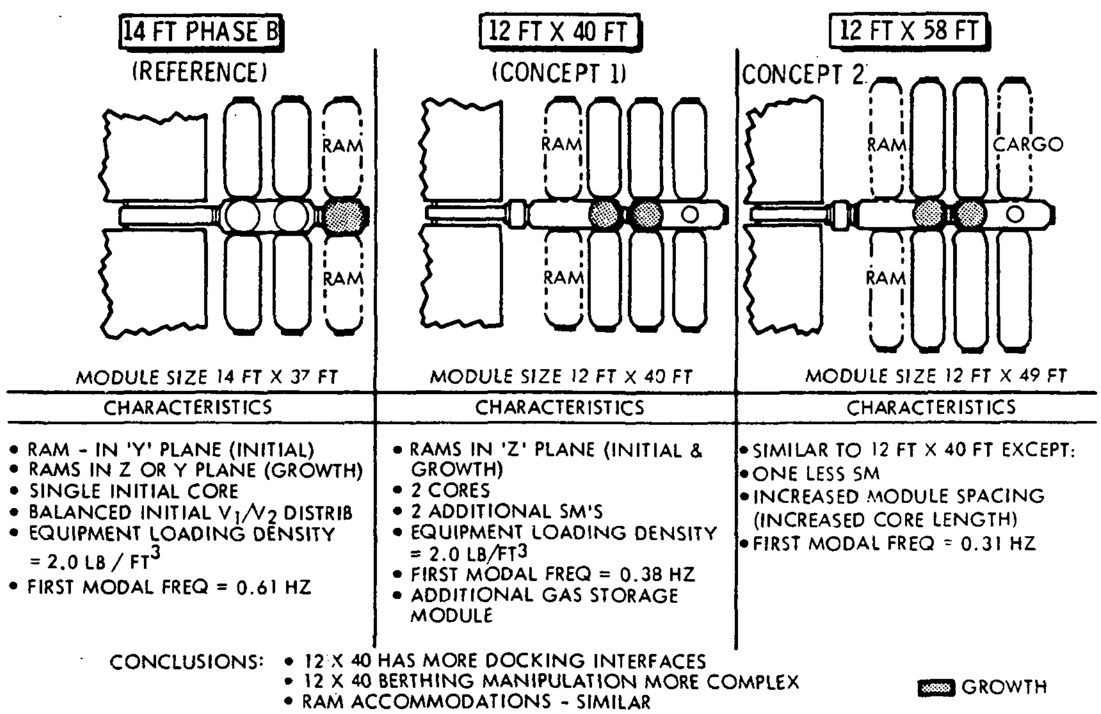


Figure 24. Configurations

Table 2. Mass Properties (Initial Station)

	14 FT PHASE B (LB)	(CONCEPT 1) 12 FT & 40 FT (LB)	(CONCEPT 3) 12 FT X 49 FT (LB)
CORE MODULE 1	21,640	19,850	20,000
CORE MODULE 2	———	15,300	15,300
POWER MODULE	13,980	14,750	14,750
STATION MODULE	(4) 82,010	(6) 95,640	(5) 93,140

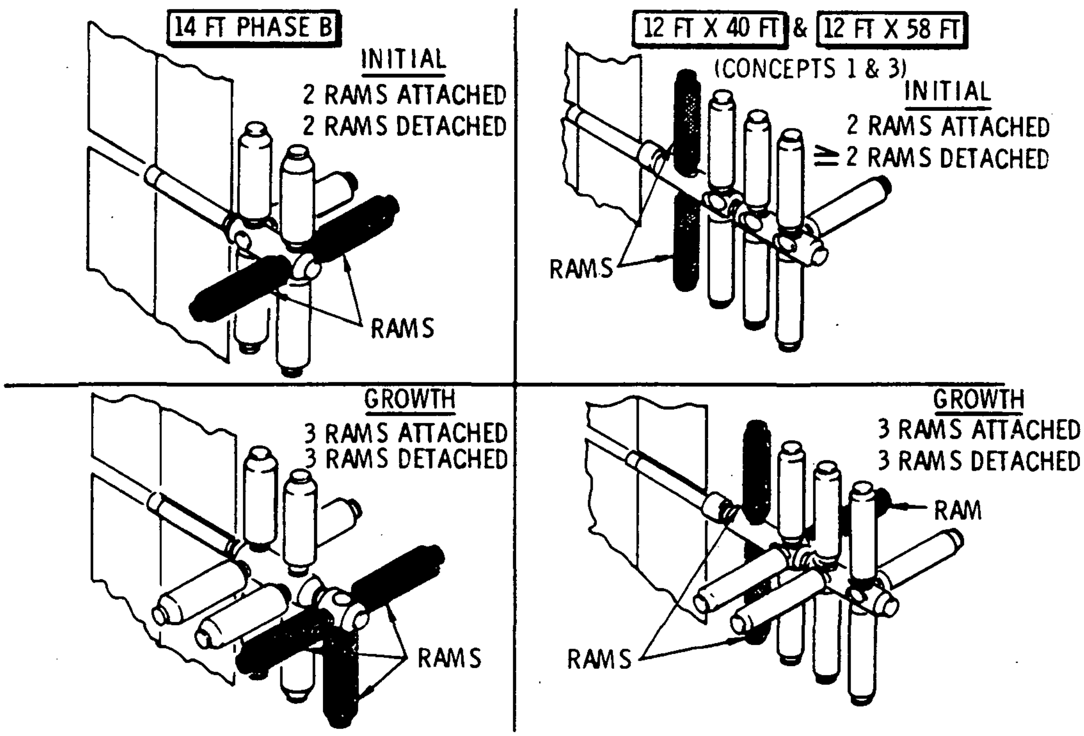


Figure 25. RAM Accommodations

3. SUBSYSTEMS ANALYSIS

The subsystems baseline for the reduced payloads size impact study are those subsystem selections resulting from the Modular Space Station Phase B Preliminary Design. A summary of the MSS Phase B preliminary design subsystem selection and basic characteristics is provided for each subsystem, followed by the Concept 1, reduced module size impacts. Subsystem impacts for Concept 3 were not analyzed.

ELECTRICAL POWER SUBSYSTEM

The electrical power subsystem (EPS) provides for the functions of: (1) primary power generation, (2) secondary power generation, (3) energy storage, (4) power conditioning, (5) distribution control and wiring, and (6) lighting (Figure 26).

The EPS MSS Phase B preliminary design subsystem selection and basic characteristics are shown on Figure 27.

The primary power generation assembly is a 7000 feet^2 solar array using the Lockheed technology concept. The only change incorporated was power switching on the solar array.

Energy storage is accomplished by four regenerative fuel cell assemblies (one per primary bus). The fuel cells also serve the function of secondary (emergency) power generation when supplied by high-pressure stored gases.

The primary buses have been selected as 240/416 vac, 400 Hz, 3-phase power and the secondary buses at both the high 240/416 vac and the low 120/208 vac, 400 Hz, 3-phase power. The selection again was made on cost and availability considerations. The hardware for switching large blocks of power is available only for ac power. The fact that commercial and military aircraft are tending toward all ac systems, utilizing computer-controlled solid state circuit breakers, was a main consideration in the selection. This minimized the cost/development risks to the program for inverters, regulators, transformers/filters solid state circuit breakers, or switching devices and software.

SCOPE

- ELECTRICAL POWER GENERATION
  - PRIMARY POWER GENERATION — NORMAL OPERATIONS
  - SECONDARY POWER GENERATION — BUILDUP & EMERGENCY
- POWER TRANSFER & CONDITIONING
- POWER DISTRIBUTION
- ENERGY STORAGE FOR ORBITAL DARK POWER
- SPACECRAFT WIRING
- GENERAL LIGHTING

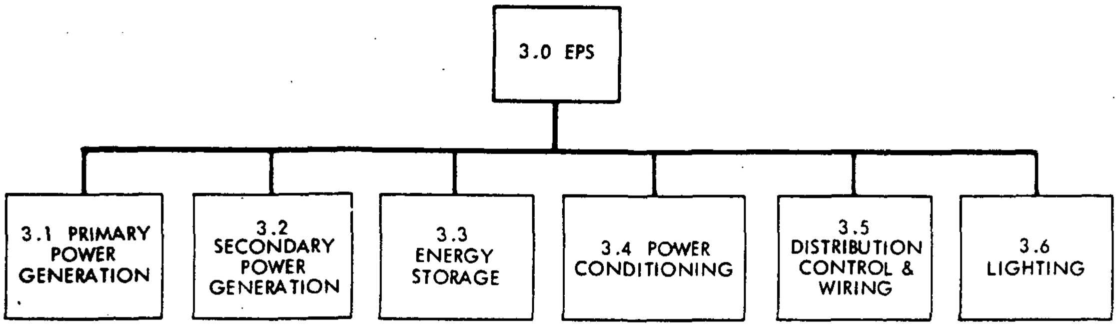


Figure 26. Electrical Power Subsystem (EPS)

- PRIMARY POWER GENERATION
  - 7000 FT^2 SOLAR ARRAY
  - LOCKHEED TECHNOLOGY
- ENERGY STORAGE
  - REGENERATIVE FUEL CELLS
  - FUEL CELL (SHUTTLE)
    - RATED POWER = 7.0 KW/FC (4 REQD)
  - ELECTROLYSIS (ECLSS)
    - REACTANT RATE = 3 LB/HR (4 REQD)
    - SPEC. PWR CONSUMPT. = 2.32 KWH/LB H_2O)
  - ACCUMULATORS
    - H_2 = 33 IN. DIAM. (4 REQD)
    - O_2 = 27 IN. DIAM. (4 REQD)
- SECONDARY POWER GENERATION
  - ENERGY STORAGE FUEL CELLS
  - HIGH PRESSURE STORAGE
- POWER CONDITIONING & DISTRIBUTION
  - PRIMARY BUSSES 240/416 VAC, 400 Hz
  - SECONDARY BUSSES 240/416 VAC, 400 Hz
    120/208 VAC, 400 Hz
    56 VDC

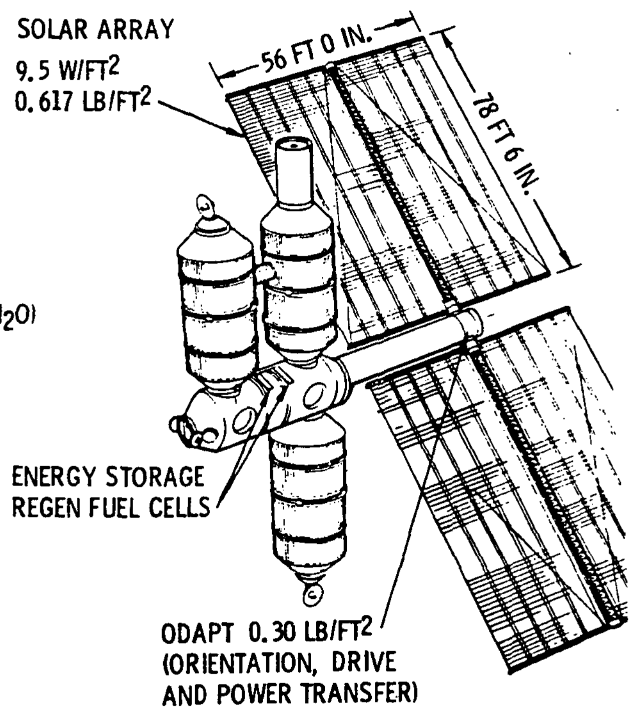


Figure 27. EPS Concept Selection - 14-Foot Phase B

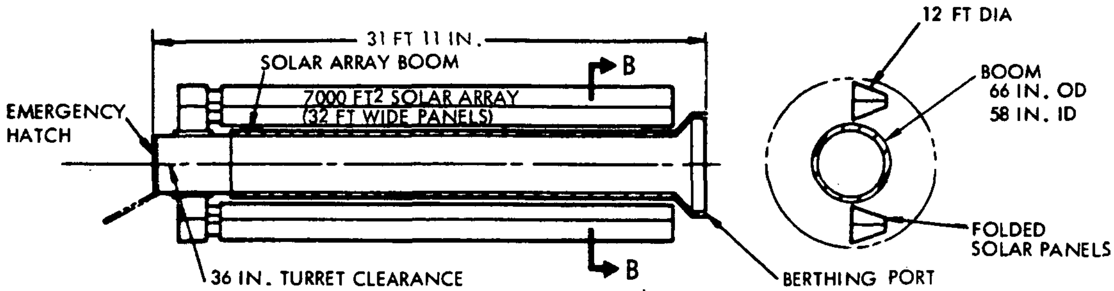
The largest impact imposed on the EPS by reduction in shuttle payload size to 12 by 40 feet is the packaging of the 10,000 feet^2 solar array (growth station). Conferences with Lockheed indicated that the power boom diameter and turret would have to be reduced. This results in reduced turret clearance for maintenance, and for utilization of the outboard end of the turret as an emergency exit. With the reduction in boom diameter, the docking port between the solar array turret and the power boom must be deleted. This means that the solar array replacement requires power boom replacement. Subsystem power requirements are increased by 473 watts average power. This is broken down by subsystem deltas accordingly, ECLSS + 94 watts, ISS + 55 watts, EPS (lighting) + 304 watts, and RCS + 20 watts.

The additional core module and increased number of station modules dictate additional lighting and secondary power buses, and the relocation of primary power buses and energy storage equipment.

Figure 28 shows the packaging concept for the initial and growth station solar arrays. The power boom internal diameter is 58 inches which results in a turret clearance of 36 inches. This was considered to be sufficient for utilization of the turret end of the solar array for an emergency exit hatch. Clearance for maintenance will be more restricted. The change to incorporate power switching on the solar array will provide a zero power condition at the power transfer slip rings which reduces potential hazards in the turret area. The overall solar array/power boom length for the initial station is approximately 32 feet (7000 ft^2 SA) and for the growth station is about 38 feet. Both concepts are within the 40-foot payload allowance.

The initial station EPS delta weight is estimated at 824 pounds. This represents extra primary buses, feeders and lighting in core module 2, and secondary buses and lighting in two additional station modules.

CONCEPTS 1 & 3 POWER MODULE CHARACTERISTICS



- GROWTH STATION 10,000 FT^2 SOLAR ARRAY - 38.3 FT OVERALL LENGTH

DELTA EQUIPMENT

WIRING	200 LB
LIGHTING FIXTURES	313
SECONDARY BUSSES (4)	160
SOLAR ARRAY (150 FT^2)	96
MOUNTS / SUPPORTS	55
	824 LB

Figure 28. EPS Delta Characteristics

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM

The environmental control and life support subsystem (ECLSS) provides for the functions of: (1) gaseous storage, (2) CO_2 management, (3) atmospheric control, (4) thermal control, (5) water management, (6) waste management, (7) hygiene, and (8) special life support. In addition, the electrolysis units of the CO_2 management assembly are used to supply the RCS propellants (Figure 29).

The ECLSS MSS Phase B preliminary design subsystem selection uses a closed water and oxygen recovery concept with cargo module storage of consumables (N_2, O_2, H_2O). The CO_2 management assembly uses an H_2 depolarizer for CO_2 removal, a Sabatier for CO_2 reduction, and solid polymer H_2O electrolysis for O_2 recovery. Water control utilizes a central humidity condenser for humidity control, a catalytic burner and nonregenerative charcoal for contamination control with monitoring by gas chromatograph and mass spectrometer. An active dual coolant loop central thermal control concept is used with 180-degree segmented, body-mounted radiators. Water reclamation utilizes the vapor compression technology with thermal and silver ion purity control.

SCOPE
- GASEOUS STORAGE
- HABITABLE ENVIRONMENTAL CONTROL
- OXYGEN & WATER RECOVERY
- THERMAL CONTROL OF CREW, EQUIPMENT, & STRUCTURE
- UTILITY PROVISIONS FOR
  - CREW: WATER, WASTE, HYGIENE
  - SUBSYSTEM: THERMAL CONTROL, RCS PROPELLANTS
  - EXPERIMENT: THERMAL CONTROL, WATER RECOVERY
- SPECIAL LIFE SUPPORT
  - FIRE DETECTION & CONTROL
  - IVA/EVA SERVICING

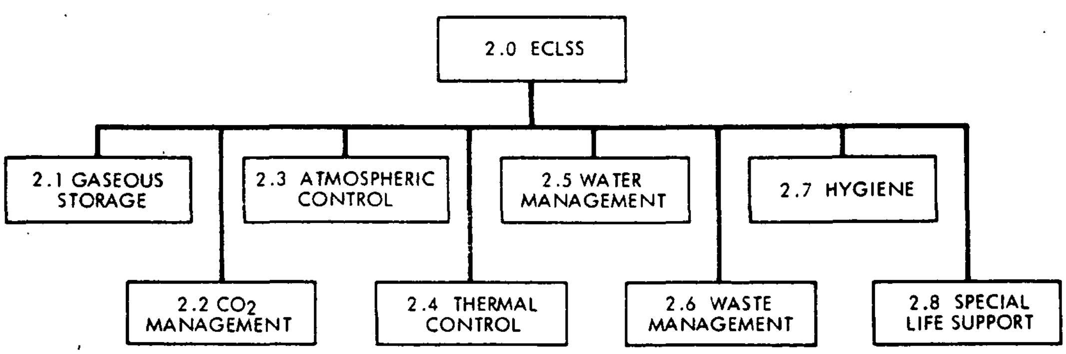


Figure 29. Environmental Control and Life Support Subsystem (ECLSS)

The waste management assembly uses the "dry John" concept with vacuum drying. Trash and waste processing are conducted during the 10-hour crew night to satisfy the 12-hour no vent experimental requirement. Wall-mounted urinals with water flush are provided with the hygiene facilities.

The drivers for the ECLSS are primarily configuration and number of modules. The initial 12-foot-diameter MSS uses two core modules and six station modules. This results in an increase in volume for V_1 and V_2 to approximately 17,680 feet^3 as a repressurization volume requirement.

The location of the modules in the configuration results in a change in heat rejection capability. The approximate heat rejection capability for the six station modules is indicated for three conditions: (1) initial station without side-docked (Y-axis) cargo modules, (2) initial station with side-docked cargo modules, and (3) growth station with side-docked station modules (no radiators), RAM's and cargo modules. The heat rejection capability is 60.8 kw (30.3 kw required) for the initial station and 56.4 kw (44.8 kw required) for the growth station. The growth station assumed no radiators on the side-docked station modules (SM-7 and SM-8). Utilizing radiators on these modules would increase the capability by about 3 kw per module. The increased number of modules for the 12-foot-diameter MSS has greatly increased the heat rejection capability.

The improved heat rejection capability provides two options: (1) reduce the radiator area until capability equals requirements, or (2) simplify the thermal control assembly by removing the redundant freon loops. With 60-kw heat rejection capability, failures of up to 20 radiator panels or two modules can be sustained before heat rejection degraded operation results. It was concluded to delete the redundant freon coolant loop which simplifies the thermal control assembly and reduces the cost.

The option for radiators on the growth station modules 7 and 8 is left open. Present calculations indicate that radiators on these modules are not required. In addition, the added capability is low (Δ3 kw/module); however, for reliability purposes and to retain a single freon loop concept, they can be utilized.

Table 3 itemizes the ECLSS subassembly and consumable weight increases.

The additional modules resulted in an increased ECLSS equipment weight of 3803 pounds and increased stored consumables. The leakage requirements for the 14-foot-diameter MSS of 10 pounds per day initial station, and 15 pounds per day growth station were retained for the 12-foot-diameter MSS, and therefore no increase in leakage consumables is shown.

Table 3. ECLSS Delta Characteristics

GASEOUS STORAGE
- HIGH PRESSURE (3000 PSIA) FOR ECLSS/EPS/RCS
- CARGO MODULE & POWER MODULE STORAGE

CO_2 MANAGEMENT
- CO_2 REMOVAL H_2 DEPOLARIZER (LiOH 96 HR EMERGENCY)
- CO_2 REDUCTION SABATIER CH_4 DUMP
- O_2 RECOVERY SOLID POLYMER H_2O ELECTROLYSIS

ATMOSPHERIC CONTROL
- HUMIDITY CONTROL CENTRAL HUMIDITY CONDENSER
- CONTAMINANT CONTROL NON-REGENERABLE CHARCOAL & CATALYTIC OXIDIZER
- MONITORING GAS CHROMATOGRAPH, MASS SPECTROMETER

THERMAL CONTROL
- ACTIVE CENTRAL DUAL COOLANT (H_2O & FREON 21)
- 180° SEGMENTED RADIATORS ON STATION MODULES

WATER MANAGEMENT
- WATER RECLAMATION VAPOR COMPRESSION
- PURITY CONTROL 160 F & SILVER IONS

WASTE MANAGEMENT
- DRY JOHN LOW TEMPERATURE VACUUM DRYING
- TRASH COMPACTORS
- URINALS WALL MOUNTED, WATER FLUSH

HYGIENE
- FULL BODY SHOWER, SINKS, VACUUM CLEANING

SPECIAL LIFE SUPPORT
- FIRE CONTROL CONDENSATE NUCLEI DETECTOR CO_2 FIRE EXTINGUISHER
- IVA AIR & WATER PLUMBING
- EVA PLSS SERVICING HP O_2, H_2O, LiOH

REACTION CONTROL SUBSYSTEM

The reaction control subsystem (RCS) provides thrust for stabilization and berthing, orbit maintenance, control moment gyro (CMG) desaturation, and maneuvers (Figure 30). In addition, under the integrated subsystem concept the RCS is responsible for providing the H_2 and O_2 accumulators that will store all the gases provided by the ECLSS electrolysis. This includes the orbital dark period H_2 for the Sabatier, and the H_2 and O_2 for the depolarizer. The propellant (H_2O) storage has been integrated into the ECLSS (cargo module storage) and/or the EPS (on-board storage).

The RCS MSS Phase B preliminary design subsystem selection is summarized in Figure 31.

The RCS H_2 and O_2 propellants are supplied by H_2O electrolysis of the ECLSS. The accumulators are sized for the 6-orbit firing interval, and utilize four each of the H_2 and O_2 accumulators to meet the failure criteria. Another success path would utilize the EPS regenerative fuel cell accumulators. The accumulators are designed to operate at 300 psia.

The engine quads utilize 10-pound engines with an oxydizer/fuel O/F) ratio of 8:1. This is the combination ratio of H_2 and O_2, and was selected to minimize venting from the station. Some penalty is Isp was accepted (419 versus 320). The engines are inflight maintainable by rotation of the mounting supports into the core module.

The configuration and flight mode are the major drivers on the RCS. Table 4 shows the comparison of impulse requirements for the 12 and 14-foot-diameter MSS. The 120-day impulse requirement increased by 84,000 pound-second (29%) for the 12-foot-diameter MSS.

Figure 32 summarizes Concept 1 configuration influences on the RCS.

The 12-foot-diameter Concept 1 MSS utilizes two core modules. Core module 1 will require RCS quads at each end of the module (on the Z-axis) to meet the buildup failure criteria. Core module 2 will require two additional quads at the -X end for the normal station operations. This delta equipment is estimated at 60 pounds.

The increased impulse requirements resulted in an increase in water storage requirements of about 4.25 cubic feet. Since water storage tanks are located in the cargo module, no delta weight is accounted to the station.

SCOPE

PROVIDE THRUST FOR
- STABILIZATION & CONTROL
- CONTROL OF DOCKING TORQUES
- ORBIT MAINTENANCE
- CMG DESATURATION
- MANEUVERS

PROVIDE STORAGE FOR ECLSS H_2 & O_2 FOR SABATIER & HYDROGEN DEPOLARIZER OPERATION

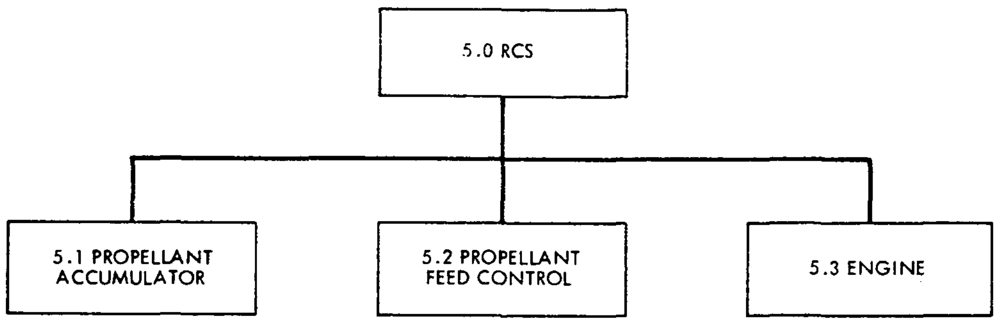


Figure 30. Reaction Control Subsystem (RCS)

- PROPELLANTS
  - GASEOUS H_2 & O_2 SUPPLIED BY H_2O ELECTROLYSIS (ECLSS)
    - EPS ELECTROLYSIS AS BACKUP SUPPLY AND BUILDUP SUPPLY
  - 4 H_2 & O_2 ACCUMULATORS
    - SIZED FOR 6 ORBIT FIRING INTERVAL (ORBIT MAKEUP + CMG DESATURATION)
    - PROVIDES ECLSS SABATIER & H_2 DEPOLARIZER ORBITAL NIGHT SUPPLIES
  - ACCUMULATORS DESIGNED FOR 300 PSI OPERATION

- ENGINE QUADS
  - 10 LB ENGINES
  - 8.1 O/F RATIO
  - 320 ISP
  - INFLIGHT MAINTAINABLE

NOM	P_A	=	300 PSIA
MIN	P_A	=	50 PSIA
ECLSS:	O_2	=	0.109 LBm
	H_2	=	0.014 LBm

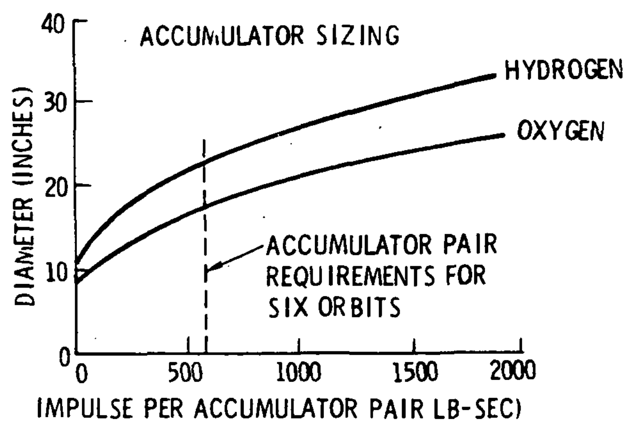


Figure 31. RCS Concept Selection (14-Foot Phase B)

Table 4. RCS Sizing Influences (12-Foot Diameter MSS)

- IMPULSE REQUIREMENTS*

	12 FT DIA	14 FT PHASE B
ORBIT MAKEUP CMG DESATURATION	248,000	166,000
MANEUVERS	35,500	47,750
SHUTTLE DOCKED	28,000	28,000
CONTINGENCY	62,400	47,750
TOTAL 120 DAY	373,900	284,500 LB SEC

*X-POP, Z-LV, 240 N MILE
Z AXIS QUADS
2 σ JACCHIA MEAN ATMOSPHERE

- RELOCATE ACCUMULATORS COMPATIBLE WITH ECLSS

- DELTA EQUIPMENT

2 QUADS (NON-MAINTAINABLE FOR BUILDUP)	60 LB
120 DAY CONSUMABLE STORAGE (H_2O TANKS)	4.25 FT^3

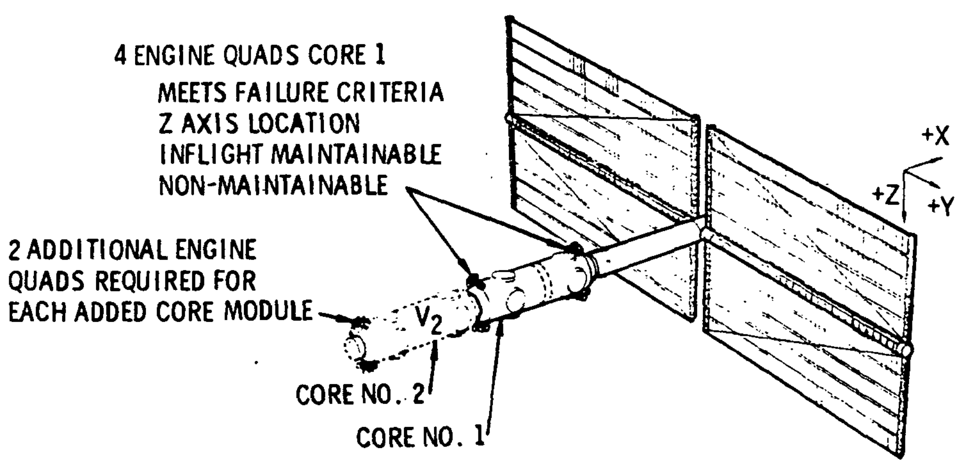


Figure 32. RCS Delta Characteristics

GUIDANCE AND CONTROL SUBSYSTEM

The responsibilities of the guidance and control subsystem (Figure 33) include: determination of the positions of the station and free-flying RAM's, issuance of commands to correct station and RAM positions, and determination and control of station attitude. Included in the G&C hardware are dedicated remote processors and their related software.

- SCOPE

  STATE VECTOR DETERMINATION & GUIDANCE COMMANDS
  - STATION
  - FREE FLYING RAMS

  STATION CONTROL
  - ATTITUDE HOLD
  - MANEUVERS

- HARDWARE

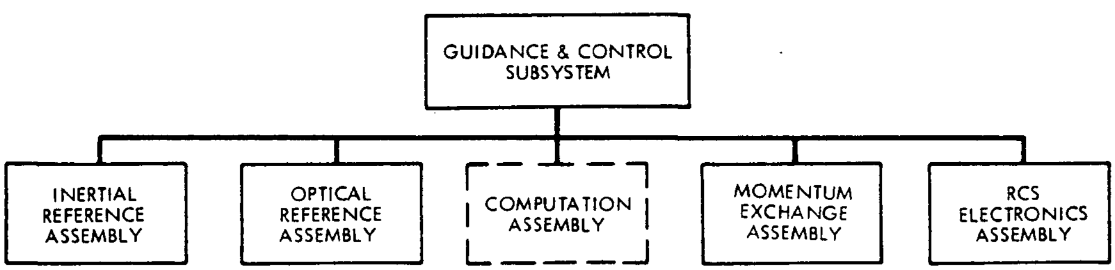


Figure 33. Guidance and Control Subsystem (G&C)

The phase B preliminary design selected concepts for the G&C subsystem are listed as follows:

- Inertial Reference Assembly

  Six gyro skew-symmetric (dodecahedron) strapdowns
  Preprocessor

- Optical Reference Assembly

  Two double-gimbal star trackers
  One four-head horizon edge tracker
  One manual sextant/telescope
  Two three-axis autocollimaton alignment links
  Preprocessor

- Momentum Exchange Assembly

  Three double-gimbal control moment gyros (planar array)
  Preprocessor

- RCS Electronics Assembly

  Sixteen RCS jet driver electronics
  Two remote processors

As mentioned previously, the G&C contains dedicated remote processors to perform the required high-speed computations for such functions as firing commands, star angle, steering computations, etc. The manual sextant/telescope is used to orient and periodically check the reference platform. At other times it is available for use by experiments.

The Concept 1 station differs from the 14-foot Phase B station in that it is less symmetrical. The 12-foot-diameter station has more modules in the vertical of X-Z and less in the X-Y plane. As a result, the surface area normal to the velocity vector is increased, thus increasing the orbit makeup requirements. The decrease in vehicle symmetry also increases the gravity gradient torques, resulting in doubling the momentum storage requirements. These requirements reflect in larger CMG's for the 12-foot station relative to the 14-foot station. The three CMG's required are increased in size as summarized in Table 5.

Table 5. CMG Delta Characteristics

Characteristics	14-Ft Phase B Reqmts	Deltas
Electrical power	161.3 watts	8.3 watts avg
Weight	1115 pounds	236 pounds
Wheel diameter	22.2 inches	3.7 inches
Momentum	6900 ft-lb-sec	3600 ft-lb-sec

INFORMATION SUBSYSTEM

The responsibilities of the information subsystem (ISS) (Figure 34) include: communications between the station modules (internal) and between the station, shuttle, detached RAM's, and the ground (external); and display, control, and computational functions as required to permit the management and maintenance of station operations by the crew.

SCOPE

- PROVIDE COMMUNICATIONS BETWEEN MSS TO/FROM SPACE SHUTTLE, DETACHED RAMS, GROUND COMPLEX, EVA
- DETERMINE RANGE & RANGE RATE OF COOPERATIVE TARGETS
- PROVIDE INTERNAL COMMUNICATIONS BETWEEN STATION MODULES
- PROVIDE THE PRIMARY INTERFACE BETWEEN THE CREW & THE SUBSYSTEM/EXPERIMENTS
- AUTOMATIC CONTROL & CHECKOUT (MANUAL ASSISTED) OF THE SUBSYSTEMS
- ONBOARD MANAGEMENT (SHORT TERM) OF STATION & EXPERIMENT ACTIVITY

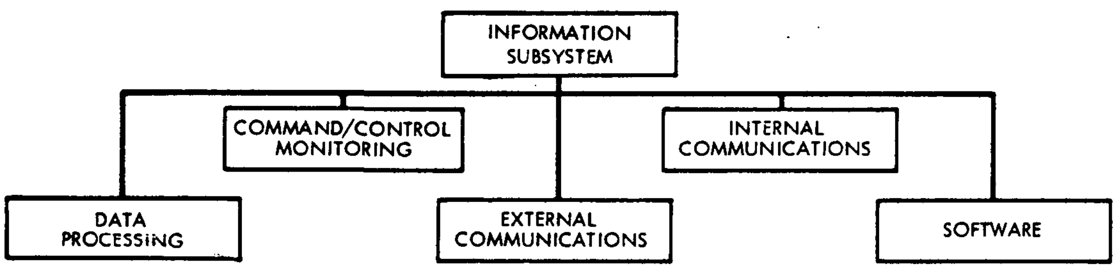


Figure 34. Information Subsystem (ISS)

Since computer software (programming) will strongly interact with the development of ISS hardware, NR has elevated this item to the assembly level.

The ISS MSS Phase B preliminary design subsystem selection is summarized as follows:

- Data Processing Assembly

  Central processing (multiprocessors)
  Universal distributing and acquisition

- Command/Control Monitoring Assembly

  Universal multiformat—callable operational console
  Commanders multiformat—callable console
  Portable control and checkout
  Local monitor alarm
  Emergency G&C control

- External Communications

  K-bnad—Narrow beam, steerable
  S-band—Semidirectional
  VHF—Semidirectional

- Internal Communications

  Private phone
  Intercomm and paging
  TV cameras and monitors (color and black and white)
  Recorders (audio, video, digital, alarm)

- Software

  Computer programs
  Microfilm
  Paper (printer and facsimile)

The selected concept for the data processing assembly (DPA) is a central multi-processor connected with the subsystems through a digital data bus and remote acquisition and control units (RACU).

The crew interfaces with the ISS through a series of multipurpose display and control consoles located throughout the station.

Wide-band high-data rate external communication is by way of a K-band directive antenna through the tracking and data relay satellite (TDRS), backed up by an S-band semidirective through MSFN. Voice and low data rate is VHF through the TDRS.

Internal communications is via dial-type private phone and centrally controlled paging.

The 12-foot space station characteristics that drive the ISS are the increased number of core and station modules. ISS control functions are more spread out and increased components are required. These components are of the general type which allow the crew to communicate with various areas of the station. The resulting delta characteristics are listed in Table 6.

Table 6. ISS Delta Characteristics

Subassembly	Additional Quantity	Additional Weight (lb)
Portable control console	1	55
Local monitor alarm	2	6
Microfilm projector	1	35
Audio video units	-1	-9
Hardwire intercom	2	20
TV camera (color)	2	10
TV monitors	5	125
Total		242

SUBSYSTEM COMPARISON SUMMARY, CONCEPT 1 CONFIGURATION

The Concept 1 subsystem effects as compared with the 14-foot-diameter Phase B preliminary design are summarized in the following paragraphs:

The total increase in subsystems power requirements is 473 watts. The EPS delta weight is estimated at 824 pounds. The EPS solar array requires repackaging with a reduction in dimensions of the turret assembly. The solar array replacement requires power boom replacement. The reduced power boom diameter imposes a requirement for a special gas storage module to provide fuel cell reactants for buildup and emergency repressurization supply.

The improved heat rejection provides the capability to delete the redundant freon coolant loop with attendant reduction in costs for the thermal control assembly. The ECLSS equipment weight increases are 3800 pounds with an increase in stored consumables.

The RCS requires two additional nonmaintainable quads located on core module 1 for builup with an increase in equipment weight of 60 pounds. The increased impulse requirements increase cargo module water storage requirements.

The information subsystem is affected by the increased number of modules, causing an increase in internal communications components and control functions; an increase in attendant weight is 242 pounds.

The G&C subsystem is affected principally by increased CMG sizing.

4. OPERATIONS ANALYSIS

The operations analysis portion of the study includes the 12- by 40-foot (Concept 1) comparison as it relates to mission operations and ground operations. Mission operations factors analyzed are the fuildup sequence, functions per module, operational complexity, and normal operations. Ground operations factors analyzed are ground checkout, development, and system testing.

MISSION OPERATIONS

In determining the buildup sequence, the decision as to what module goes up first or precedes another depends on the major functions contained within each module. Table 7 summarizes module designation, name, and major functions allocated to each module for the 14-foot Phase B modular station. This concept requires a total of six modules: one core, one power, and four station modules.

Table 8 summarizes the designation, name, and major functions within each of the nine basic modules of Concept 1 station. The functions play an important role in determining the buildup sequence. The 12-foot-diameter concept configuration consists of two core, one power boom, and six station modules.

The resultant buildup to IOC is summarized in Figure 35 for the 14-foot Phase B configuration. The selection of the core module for the first launch was based upon fewer activation requirements, minimum scars due to buildup requirements, less complexity in orbit operations, and less sensitivity to subsystem weight growth than would be realized by the selection of another module.

Selection of the power module for the second launch was based upon limited energy storage in the core module and complexity of cargo resupply However, the arrays remain retracted because active solar array operations require primary control.

Primary control is subsequently provided in the third launch and, when activated, permits the use of the solar arrays, automatic attitude control

Table 7. 14-Foot Module Designations

MODULE		
DESIGNATION	NAME	MAJOR FUNCTIONS
CM-1	CORE MODULE	EVA/IVA AIRLOCK, G&C, RCS, CMG'S, POWER GENERATION & CONVERSION
PB	POWER BOOM	SOLAR ARRAY, EMERGENCY HATCH
SM-1	CONTROL/CREW	COMMANDER STATEROOM, BACK-UP MEDICAL, CC NO. 1, DATA ANALYSIS, PHOTO LAB, PERSONAL HYGIENE, 2 CREW STATEROOMS, WASTE & WATER MANAGEMENT EQUIPMENT
SM-2	ECS/LABS	MECH. LAB, OPTICS/ELEC LAB, BIOSCIENCE/EARTH OBSERVATION LAB, NADIR AIRLOCK, AIR REVITALIZATION EQUIPMENT VOL 2
SM-3	ECS/LABS	GALLEY, ZENITH AIRLOCK, PHYSICS/BIOMEDICAL LAB, DINING & RECREATION, AIR REVITALIZATION VOL 1
SM-4	CONTROL/CREW	EXEC. STATEROOM, 2 STATEROOMS, MEDICAL & CREW CARE, PERSONAL HYGIENE, WASTE & WATER MANAGEMENT EQUIPMENT, CONTROL CENTER NO. 2

Table 8. 12-Foot Module Designations

MODULE		
DESIGNATION	NAME	MAJOR FUNCTIONS
CM-1	CORE MODULE	CMG'S, RCS, G&C, POWER GENERATION & CONVERSION
PB	POWER BOOM	SOLAR ARRAY, EMERGENCY HATCH
SM-1	STATEROOM/ CONTROL CENTER	COMMANDER STATEROOM, CC #1, BACKUP GALLEY, PERSONAL HYGIENE W/O SHOWER, WASTE & WATER MANAGEMENT, AIR REVITALIZATION VOL. 1
CM-2	CORE MODULE	EVA/IVA AIRLOCK, POWER GENERATION & CONVERSION, RCS
SM-4	GENERAL PURPOSE LAB	GPL, PHOTO PROCESSING, NADIR AIRLOCK
SM-2	STATEROOM/ DINING	PRIMARY GALLEY, DINING/RECREATION, 2 CREW STATEROOMS
SM-6	STATEROOM/ MEDICAL EXERCISE	CREW MEDICAL CARE/EXERCISE, 2 CREW STATEROOMS
SM-3	GENERAL PURPOSE LAB	PERSONAL HYGIENE WITH SHOWER, GPL, ZENITH AIRLOCK, WATER MANAGEMENT
SM-5	STATEROOM/ CONTROL CENTER	BACKUP MEDICAL CARE/EXERCISE, AIR REVITALIZATION VOL. 2, DATA ANALYSIS CENTER, CONTROL CENTER #2, EXEC'S STATEROOM

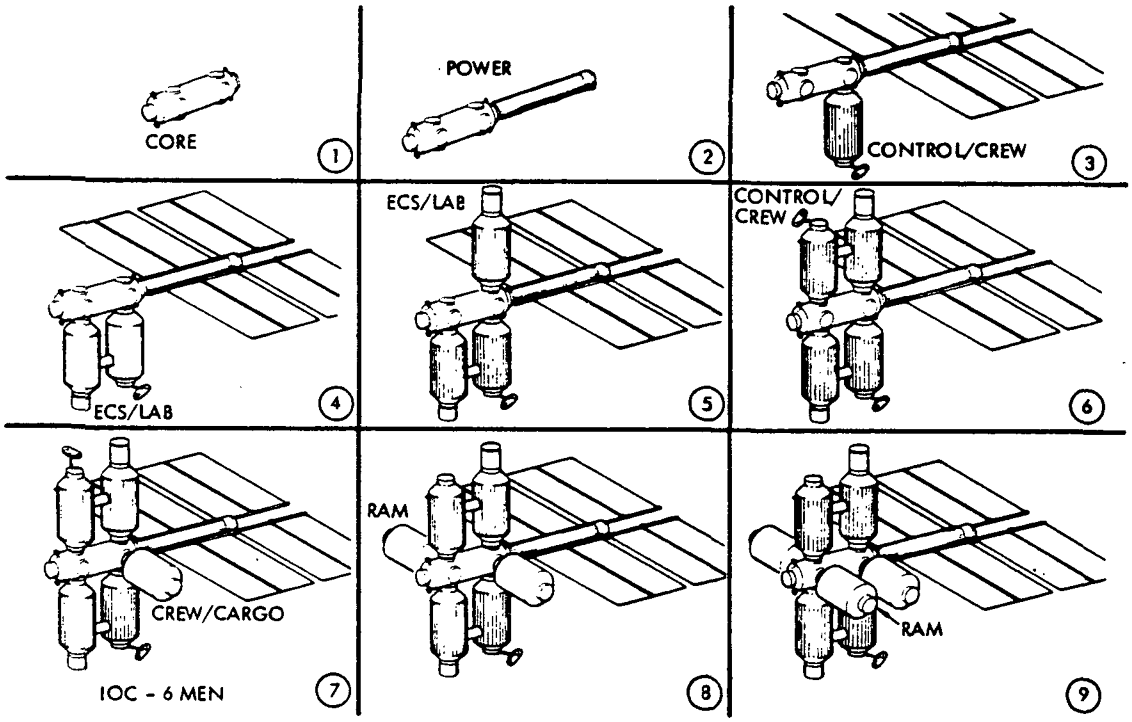


Figure 35. MSS Buildup Sequence—14-Foot Phase B

and orientation, regenerative fuel cell operation, and active (automatic) thermal control. In addition, this module provides living quarters for the crew.

The fourth launch provides ECS/LAB capability, thus completing the basic functions to operate the station. Subsequent launches provide redundant subsystems and complete the general purpose laboratories for the initiation of experiment operations.

The rationale for selecting the sequence of core, power, and control (Figure 36) for the 12-foot-diameter concept configuration MSS is the same as for the 14-foot-diameter Phase B MSS. An additional launch is required to place a module/shuttle adapter in orbit for the reduced diameter concept, if a 40-foot-long shuttle cargo bay is utilized. This requirement does not exist if the 60-foot-long shuttle cargo bay is provided.

A marked difference can be noted with the fifth launch which consists of the second core module housing the EVA/IVA airlock. Only one core was required by the 14-foot Phase B MSS which provided the V_1/V_2 volume capability at the initial launch.

Subsequent launches, 6 through 10, provide the remaining subsystems and redundancies for station operations. An eleventh launch is required to

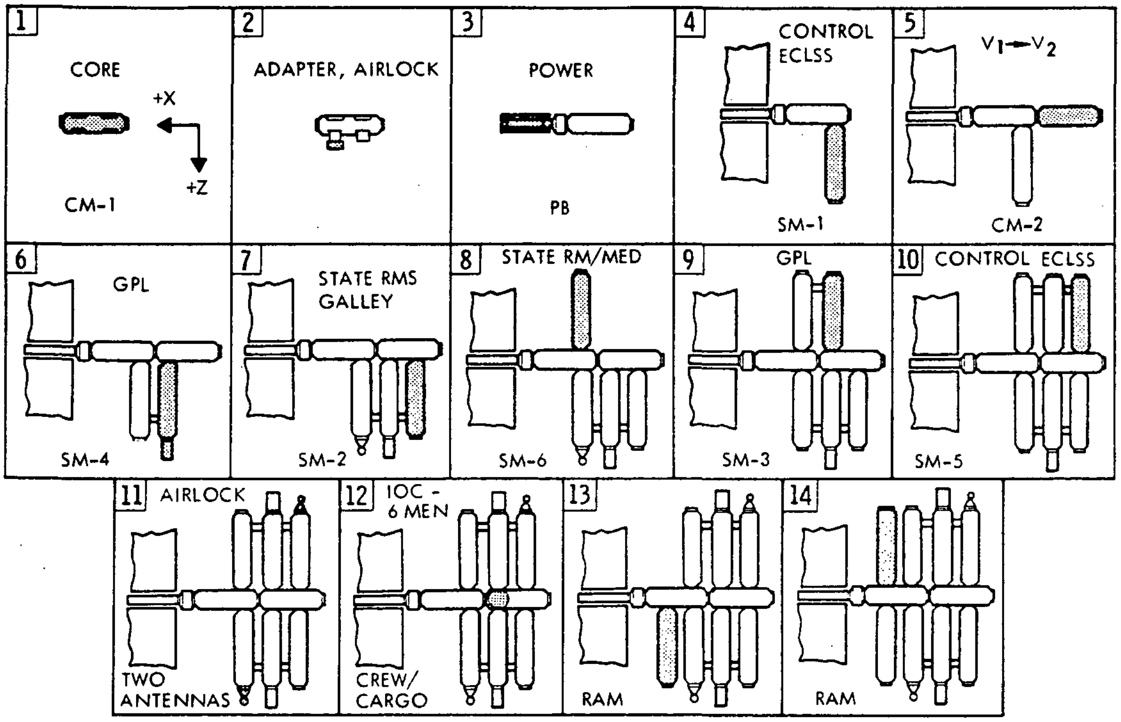


Figure 36. 12-Foot Module Initial MSS Buildup Sequence

deliver the antennas and airlock if the 40-foot shuttle cargo bay is utilized.

IOC for the 12-foot-diameter concept configuration MSS occurs on the twelfth launch as compared to the seventh for the 14-foot-diameter Phase B MSS.

Figure 37 summarizes the 12-foot concept and 14-foot Phase B accumulative buildup of major functions on-orbit with each flight. As shown, five additional launches are required for the 12-foot MSS to reach the IOC.

Figure 38 indicates that normal operations for the 14-foot Phase B MSS in the initial station configuration can be conducted by the shuttle berthed at the -X-axis end docking port with the 60-foot shuttle-based manipulator.

The 14-foot Phase B growth station (Figure 39) requires shuttle berthing operations at the +Y-axis docking port, located on the cargo module. This position is required for access to modules SM-1 and SM-3. End berthing at the -X-axis port is also required.

Concept 1 MSS (Figure 40) permits shuttle end berthing at the -X-axis port in order to service the modules attached to core module 2. This berthing mode is available to both initial and growth configurations.

FUNCTIONS	MONTHS/FLIGHTS													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CORE	○ ●				○									
ADAPTER		○												
POWER		●	○											
COMMANDERS ROOM			●	○										
CC NO. 1			●	○										
BACKUP GALLEY				○ ●										
HYGIENE-NO SHOWER			●	○										
WASTE & WATER MANAGEMENT			●	○										
AIR REVITALIZATION, VOL 1				○ ●										
EVA/IVA AIRLOCK	●				○		▲ IOC 14-FOOT PHASE B STA							
MECH LABORATORY				●		○								
OPTICS LABORATORY				●		○								
BIO/EARTH LABORATORY				●		○								
PHOTO PROCESSING			●			○						▲ IOC 12-FOOT STA		
NADIR AIRLOCK		○		●										
PRIMARY GALLEY					●		○							
DINING/RECREATION					●		○							
2 CREW STATEROOMS			●				○							
MEDICAL CARE/EXPERIMENTS						●		○						
2 CREW STATEROOMS						●		○						
HYGIENE WITH SHOWER						●			○					
PHYSICS/BIOMED LAB					●				○					
ZENITH AIRLOCK					●						○			
WASTE & WATER MANAGEMENT						●			○					
BACKUP MEDICAL CARE/EX			●							○				
AIR REVITALIZATION, VOL 2					●					○				
DATA ANALYSIS CENTER			●							○				
CC NO. 2						●				○				
EXECUTIVES ROOM						●				○				
ANTENNA PODS											○			
CREW/CARGO							●					○		
RAM 1								●					○	
RAM 2									●					○

○ 12 FOOT ● 14 FOOT

Figure 37. Deltas to Buildup

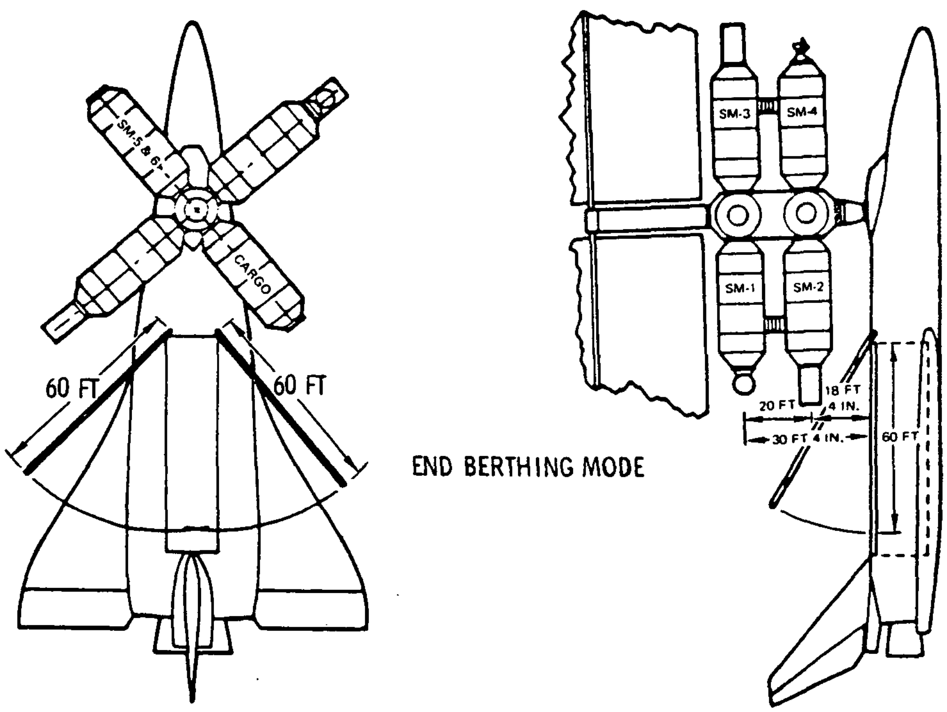


Figure 38. Shuttle/Station Berthing Mode - Initial Station, 14-Foot Diameter

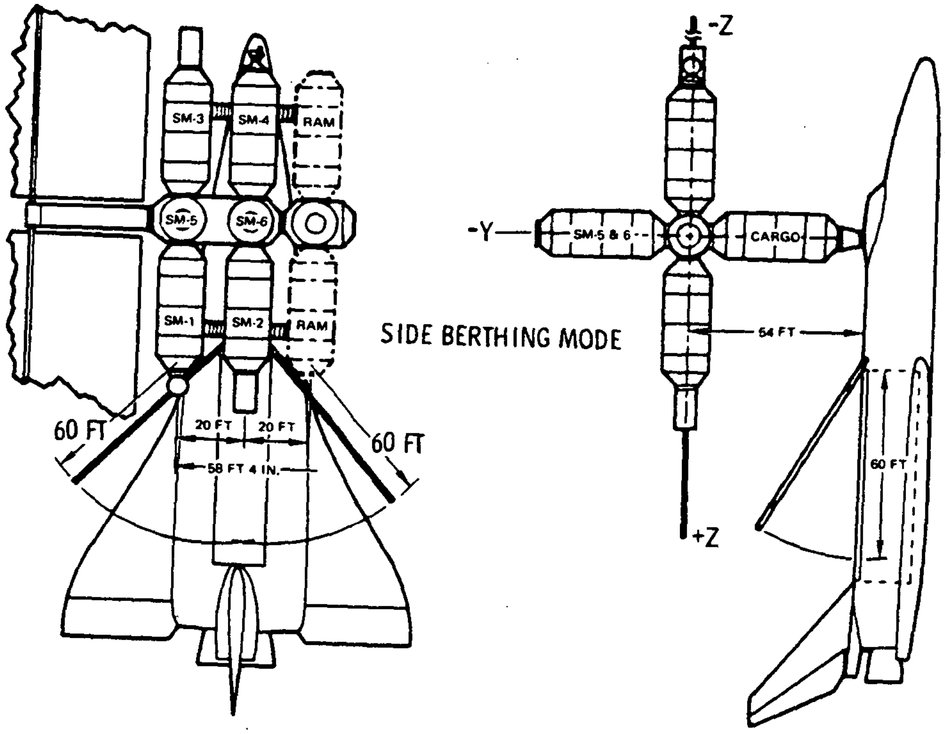


Figure 39. Shuttle/Station Berthing Mode - Growth Station, 14-Foot Diameter

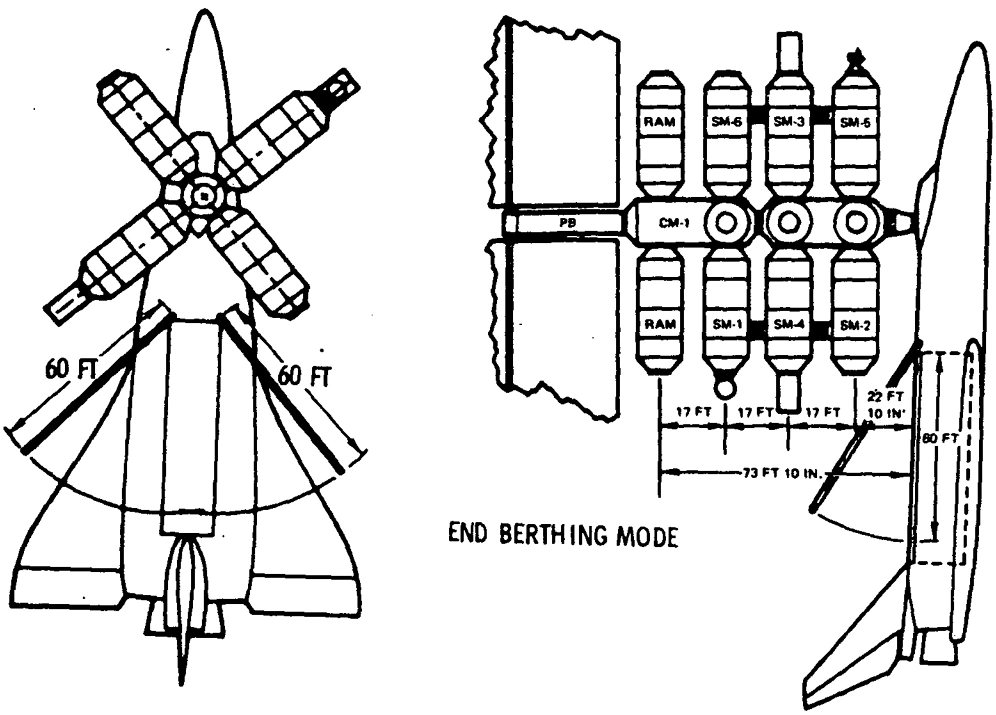


Figure 40. Shuttle/Station Berthing Mode - Initial Growth Station, 12-Foot Diameter

Figure 41 shows that in order to service the modules located on core module 1, side berthing is required. Side berthing on the relocated cargo module is required for both the initial and growth station. This is an added complexity of the Concept 1 MSS.

Table 9 summarizes the mission operations benefits and penalties of the Concept 1 configuration. The reduced diameter results in a 5-month delay in IOC and the subsequent experiment program. This delay is a direct consequence of the five additional launches required to assemble the MSS. Three launches are required for each of these additional station modules, and two are required for the station/shuttle adapter, airlocks, and high gain antenna packages. These additional launches are required only if the 40-foot shuttle cargo bay is utilized. This is not a requirement for the 60-foot shuttle cargo bay.

The length of the initial station has been increased by the addition of a second 40-foot core module. This condition creates the requirement for side-berthing the shuttle to the cargo module in order to conduct normal operations with the 60-foot shuttle-based manipulator.

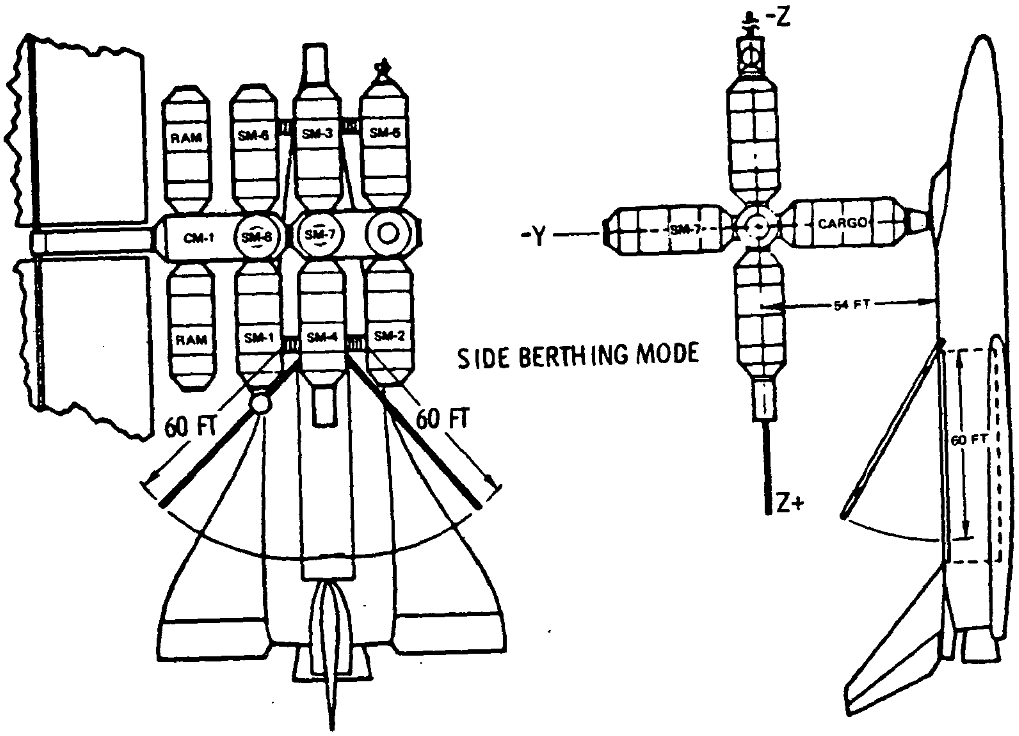


Figure 41. Shuttle/Station Berthing Mode - Initial/Growth Station, 12-Foot Diameter

Table 9. Mission Operations Benefits/Penalties

FACTORS	14-FOOT PHASE B STATION	CONCEPT 1 STATION
SPECIAL LAUNCH FOR ADAPTER	NONE	ONE
NO. OF MODULES TO ASSEMBLE	NINE	12 + 2 AIRLOCKS + 2 ANTENNA
SPECIAL LAUNCH FOR AIRLOCK & ANTENNAS	NONE	ONE
MANIPULATOR REACH (REQUIRES SHUTTLE BERTHING TO CARGO MODULE)	GROWTH STATION ONLY	INITIAL AND GROWTH
RAM LOCATION OPTION: VERTICAL OR HORIZONTAL	GROWTH STATION ONLY	INITIAL AND GROWTH
INITIAL OPERATIONAL CAPABILITY (IOC)	7TH LAUNCH	12TH LAUNCH
FLIGHTS TO FULL-UP INITIAL STATION STATUS (2 RAMS)	NINE	FOURTEEN
BERTHING MODES	INITIAL -- END BERTHING GROWTH -- END & SIDE BERTH	INITIAL -- END & SIDE BERTH GROWTH -- SAME
LOGISTICS IMPACT	--	NEGLIGIBLE
EXPERIMENT PROGRAM IMPACT	--	5-MONTH DELAY IN IOC

GROUND OPERATIONS

Ground operations were assessed to determine the prime effects for the Concept 1 configuration. Ground operations are assessed in four major areas: (1) structural and dynamic testing, (2) compatibility assessment vehicle, (3) mission support vehicles, and (4) flight modules checkout vehicle.

STRUCTURAL AND DYNAMIC TESTING

The 14-foot Phase B structural and dynamics test program involves the programming of a station module, a core module, and a power module for station and dynamic testing. This testing program would not be affected by the Concept 1 module configuration. A single power module, core module, and station module are required for both the 14-foot Phase B program and the Concept 1 program.

COMPATIBILITY ASSESSMENT VEHICLE

Figure 42 illustrates the differences between the 14-foot Phase B and the Concept 1 compatibility assessment and mission support vehicles.

The purpose of the compatibility assessment vehicle (CAV) is the integration and verification of the station modules and software. Plans for the 14-foot CAV require flight size and configured modules to be physically mated during conduction of these tests. The 12-foot station, because of its added height, will require either new facilities or major modification to existing facilities. The two core modules add complexity to the 12-foot support stands, in that more capabilities are required to reconfigure for the various test conditions. One of the major tests performed in the CAV will be the demonstration of one volume of the station controlled by the control center in the opposite volume. To satisfy this requirement on the 12-foot station requires two core modules and two control centers. The SM-3 module will be utilized to demonstrate the interfaces of the remaining modules.

MISSION SUPPORT VEHICLES

The mission support vehicle is configured with the same modules that are programmed for the compatibility assessment vehicle, therefore, the same effects also exist on the mission support vehicle.

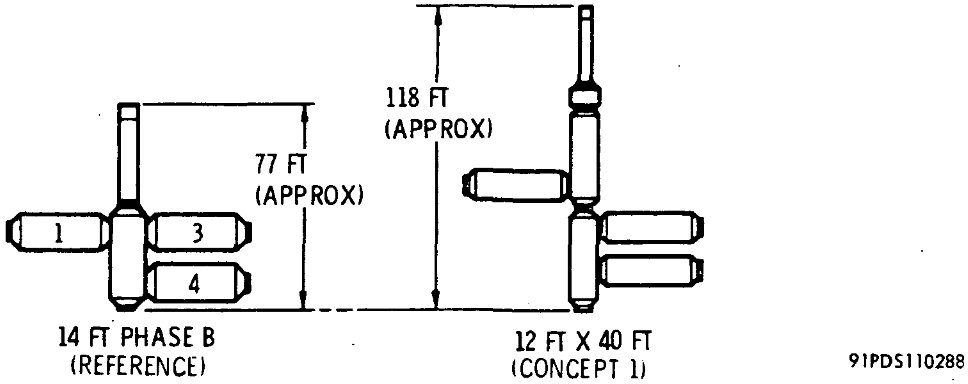


Figure 42. Compatibility Assessment and (3) Mission Support Vehicles

FLIGHT MODULES CHECKOUT VEHICLE

A flight modules checkout vehicle, as illustrated in Figure 43 is provided for acceptance testing of the MSS flight modules. This vehicle is composed of groups of modules requiring acceptance level testing prior to initiating launch preparation activity preceding module launch.

In the Ground Operations Guidelines from the 14-foot Phase B Study, the following guideline was used for acceptance testing of the flight modules: "Combined tests of those modules required to accomplish the basic station functions; i.e., multiple berthing power generation, and subsystem control, will be conducted prior to launch of the initial module." To satisfy this guideline, two combinations of modules are required for the 12-foot station. The first group of modules do not impact the flow since the test and launch order are compatible. The second group consists of the core module (V-2), launched fourth; and the second control module, launched nineth. The difference in launch order necessitates long storage and probably some subsequent delta checkout.

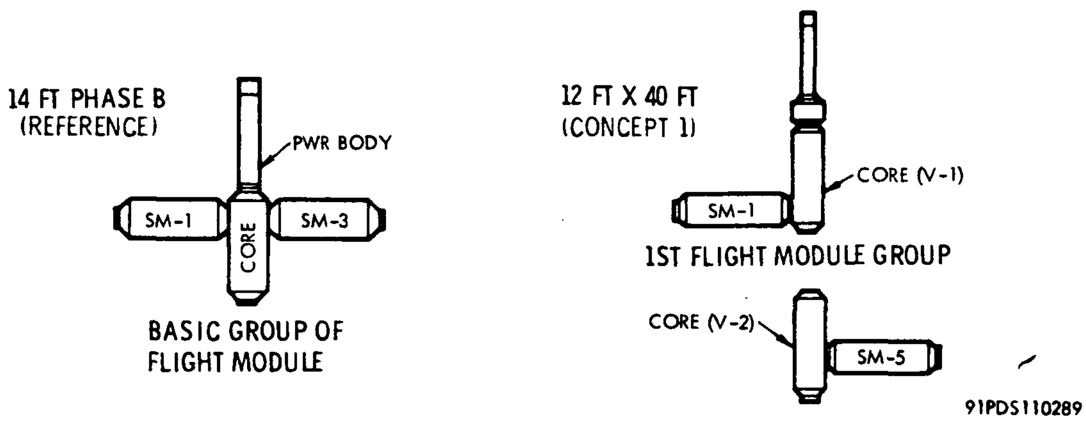


Figure 43. Flight Modules Checkout Vehicle

GROUND OPERATIONS IMPACT SUMMARY

1. Additional lengths of test stacks for compatibility assessment vehicle and mission support vehicle increases test facility and GSE costs by 50 percent.

2. Additional modules required for the 12-foot configuration increases checkout flow time and costs by 20 percent.

3. Additional mockup cost will be incurred to demonstrate the additional module configurations and features.