LMSC-A980306
VOLUME II
DECEMBER 14, 1970

(NASA-CR-115648) INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY MEASUREMENT SYSTEM. VOLUME 2: SYSTEM CONSIDERATIONS Final Report (Lockheed Missiles and Space Co.) 47 p
N77-77531
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X72-10515
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imblms

INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY MEASUREMENT SYSTEM

Final Report For
PHASE B.4 PROJECT DEFINITION
(CONTRACT NAS9-10742)

VOLUME II
SYSTEM CONSIDERATIONS

OFFICE OF PRIME RESPONSIBILITY

LOCKHEED MISSILES & SPACE COMPANY
A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION
SPACE SYSTEMS DIVISION • SUNNYVALE, CALIFORNIA

LMSC-A980306
Volume II
December 14, 1970

FINAL REPORT FOR

INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY MEASUREMENT SYSTEM

(IMBLMS)

Phase B.4 Project Definition

Volume II

SYSTEM CONSIDERATIONS

LOCKHEED MISSILES & SPACE COMPANY

IMBLMS

The National Aeronautics and Space Administration is sponsoring studies to develop an Integrated Medical and Behavioral Laboratory Measurement System. IMBLMS will be a highly flexible, state-of-the-art system, capable of acquiring, displaying, analyzing, and recording a wide variety of medical, biochemical, microbiological, and behavioral measurements and experiments designed to study in detail man's well being and operational capability during long-duration space missions. IMBLMS also includes a comprehensive clinical capability for conducting routine physical examinations and providing treatment in the event of injuries or other medical emergencies.

IMBLMS work stations and peripheral equipment modules are designed for ease of maintenance and adaptability of the measurements and experiments to meet changing requirements, based on the trend analysis of previously collected data and the development of more advanced measurement techniques.

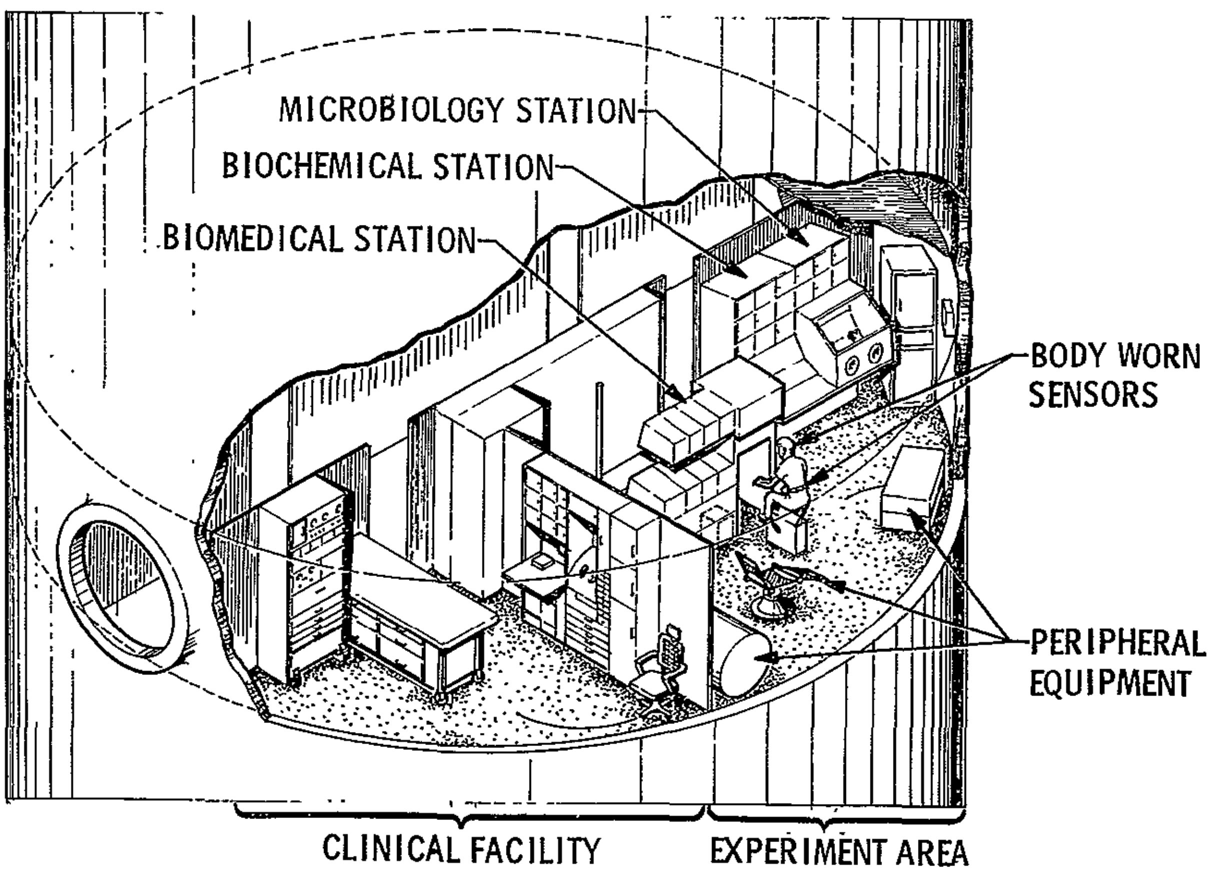
As evolved through several study phases, IMBLMS consists of two major work stations – biomedical/behavioral and biochemical – and a variety of peripheral systems and equipment. Major items of peripheral equipment include a lower body negative pressure device, a bicycle ergometer, and a rotating litter chair. Central to IMBLMS operations is a data management system, which provides for controlling, processing, recording, and transmitting information derived from the various measurements.

The major measurement categories are as follows:

Neurological and sensory	Microbiological
Cardiovascular	Biochemical
Metabolic	Behavioral
Respiratory	Clinical

Deployment of IMBLMS will involve the development of baseline data in all measurement areas. Primary emphasis is placed on detection and evaluation of incipient problems that may occur with extended manned spacecraft missions. Flexibility in measurement capabilities, scheduling, and interpretations is essential to an effective program in order to focus on specific findings.

The first flight version of IMBLMS is intended for use on the first Space Station – both as an experiment and as a clinical facility. Because of its compactness and scientific potential, it is also suitable for use in any of the planned manned space vehicles, such as Skylabs or an interplanetary craft. Furthermore, its dual role of scientific experiment and clinical facility makes it a logical candidate for use on lunar bases and, of impressive spinoff value, in earth-based medical facilities.



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FOREWORD

This is one of the several documents constituting the Lockheed Missiles & Space Company Final Report for Phase B.4 of the Integrated Medical and Behavioral Laboratory Measurement System Program, which is sponsored by the NASA Manned Spacecraft Center, Contract NAS9-10742.

The report consists of the following volumes:

I	Introduction and Summary	(LMSC-A980305)
II	System Considerations	(LMSC-A980306)
III	Measurement Considerations	(LMSC-A980307)
IV	Preliminary Design	(LMSC-A980308)
V	Mission Operations	(LMSC-A980309)
VI	Flight and Ground Support	(LMSC-A980310)
VII	Program Plans	(LMSC-A980311)
VIII	Specifications and Drawings	(LMSC-A980312)
Appendixes		(LMSC-A981477)
A	Psychomotor Measurements	(LMSC-A980461)
B	Measurement Requirement Data Sheets	(LMSC-A980462)
C	Laboratory Verifications	(LMSC-A980463)
D	Supporting Analyses	(LMSC-A980464)

ABBREVIATIONS

ECLSS	environmental control and life support subsystem
EDT	engineering development test
EDU	engineering development unit
EVA	extravehicular activity
FMEA	failure mode and effects analysis
IMBLMS	Integrated Medical and Behavioral Laboratory Measurement System
I/M	instrument module
IVA	intravehicular activity
LBNP	lower body negative pressure system
MAC/DAC	McDonnell Douglas Corporation
NAR	North American Rockwell Corporation
RCS	reaction control system
REE	Responsible Equipment Engineer
RLC	rotating litter chair
S-II	Saturn II
SIV	Saturn IV

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CONTENTS

Section | Page

Section 1
INTRODUCTION

IMBLMS is being developed for use aboard any manned space vehicle. It is important therefore to consider briefly the configurations, operations, and environments of the potential host vehicles and the IMBLMS relationship with the pertinent systems. This relationship is discussed in this volume with respect to the Space Station, the Skylab, and the Space Shuttle.

Section 2
HOST SYSTEM CONSIDERATIONS

2.1 SPACE STATION

NASA has been studying Space Station designs for nearly a decade and has recently sponsored a series of Phase B Space Station definition studies. North American Rockwell (NAR) has one contract, monitored by NASA/MSC, and McDonnell-Douglas (MAC/DAC) has another, monitored by NASA/MFSC. Their reports provide the basis the most of the information presented in this section.

2.1.1 Configuration

The general structural configuration of one design, shown in Fig. 2-1, is typical of all of those evolved in the Phase B definition studies. The four-deck area is about 33 ft in diameter and 35 ft long. Decks 1 and 2 have one pressure volume and 3 and 4 another. In this concept IMBLMS will occupy about half of Deck 1; in another design, it will occupy half of Deck 2. The associated major hardware for test and mission support is shown in Fig. 2-2. An IMBLMS prototype is to be integrated into the ground intergration test article, which is a compatibility mockup; one of the IMBLMS flight units will subsequently be integrated into the mission support vehicle.

The launch configuration is shown in Fig. 2-3. The booster was adopted from the Saturn V by removing the SIV stage.

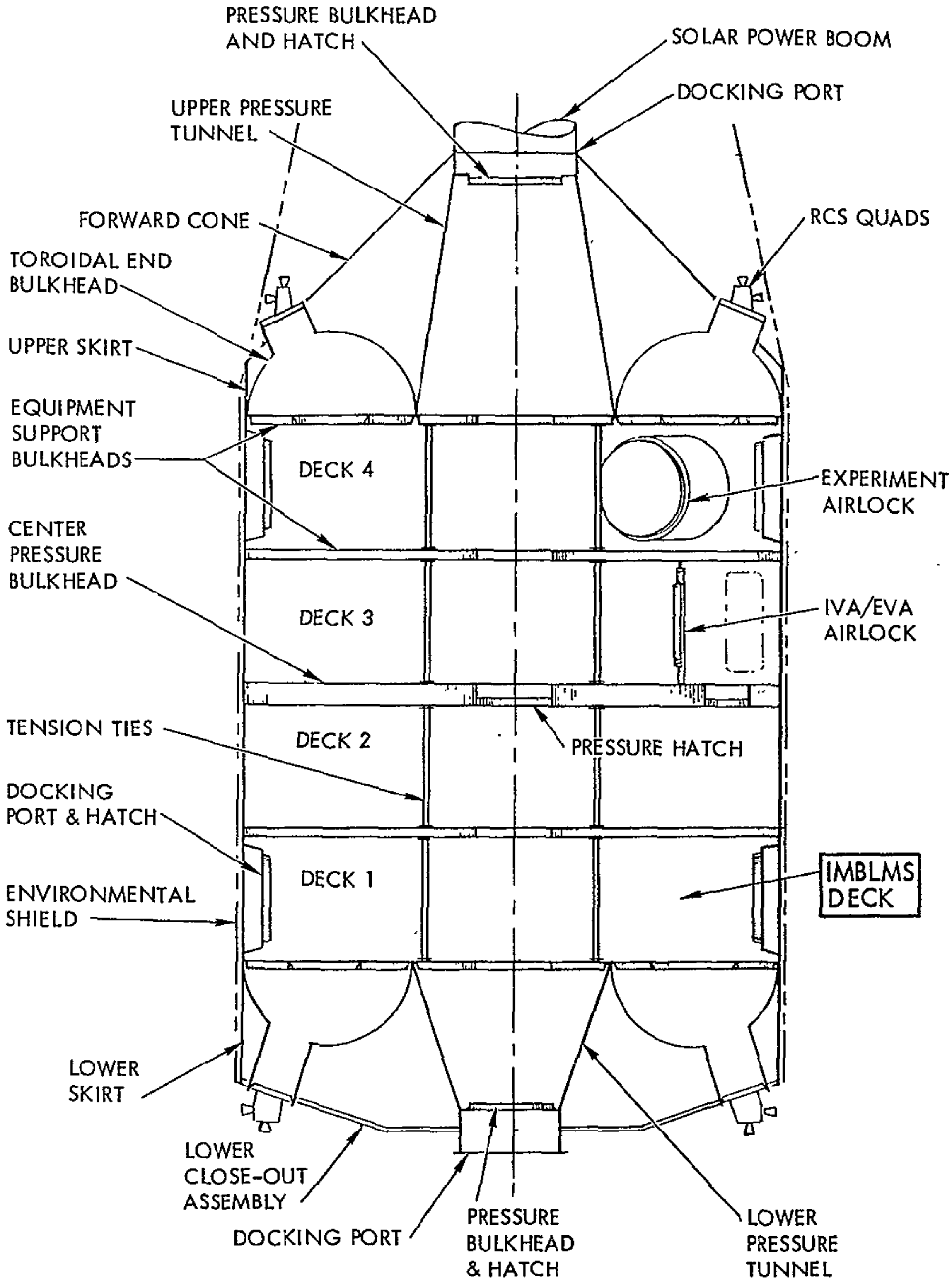


Fig. 2-1 Core Module Structural Configuration

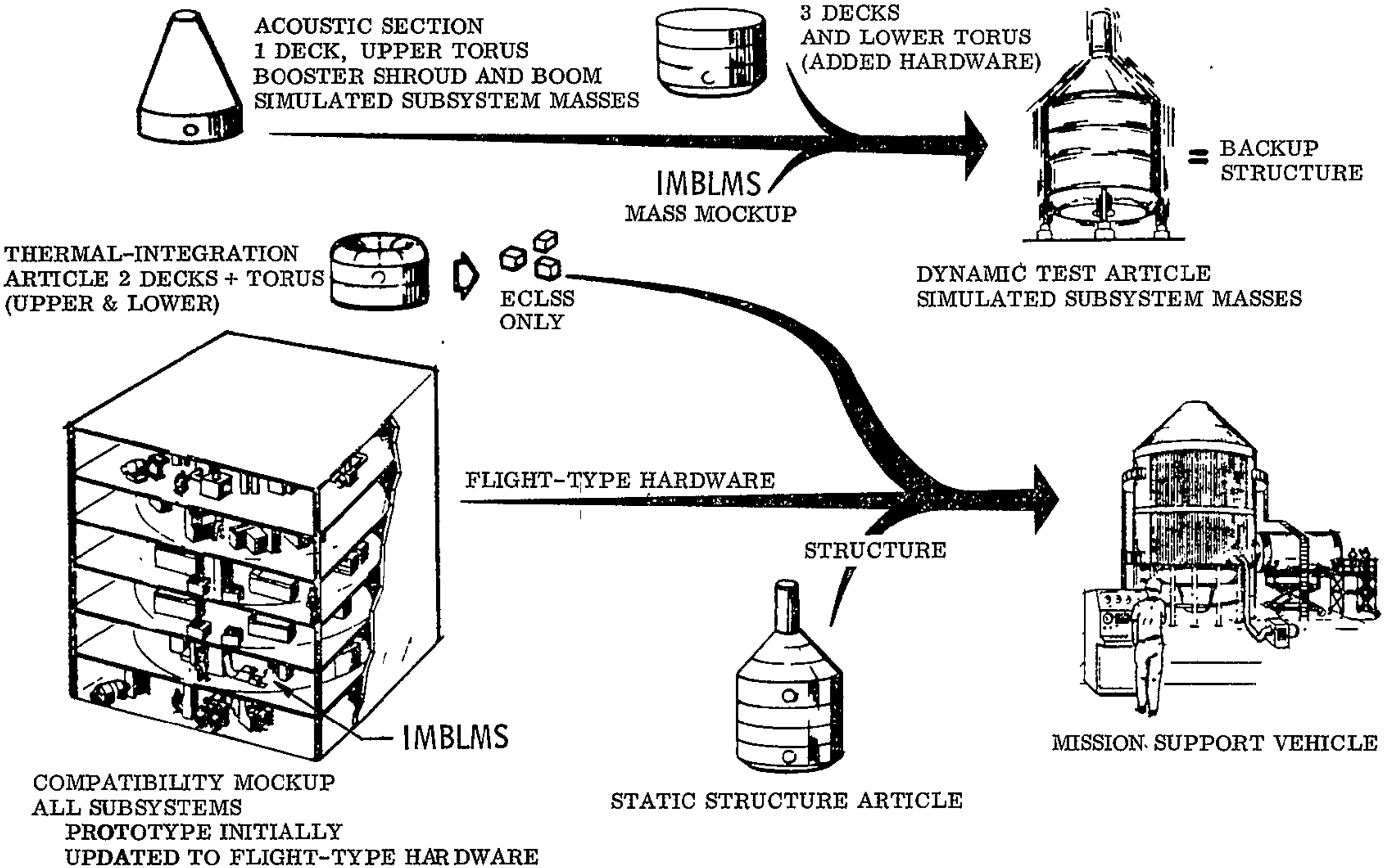


Fig. 2-2 Major Test Hardware Utilization

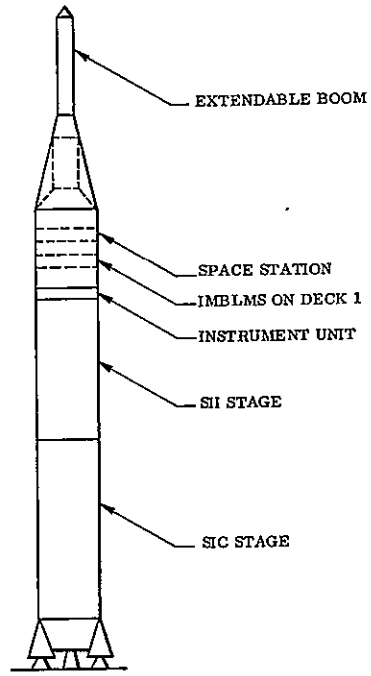


Fig. 2-3 Space Station Launch Configuration

A layout of the LMSC IMBLMS design is shown for both Space Station configurations in Figs. 2-4 and 2-5, respectively. In Fig. 2-4, the access openings lead to a lower equipment bay. Presumably IMBLMS spares could be stored there for easy access.

Passageways for the configuration (shown in Fig. 2-4) are as follows:

- 5-ft diameter through docking port
- 5-ft width through deck corridor
- 5-ft diameter through vertical corridor
- 5-ft diameter to final installation as required
- 3-ft aisles

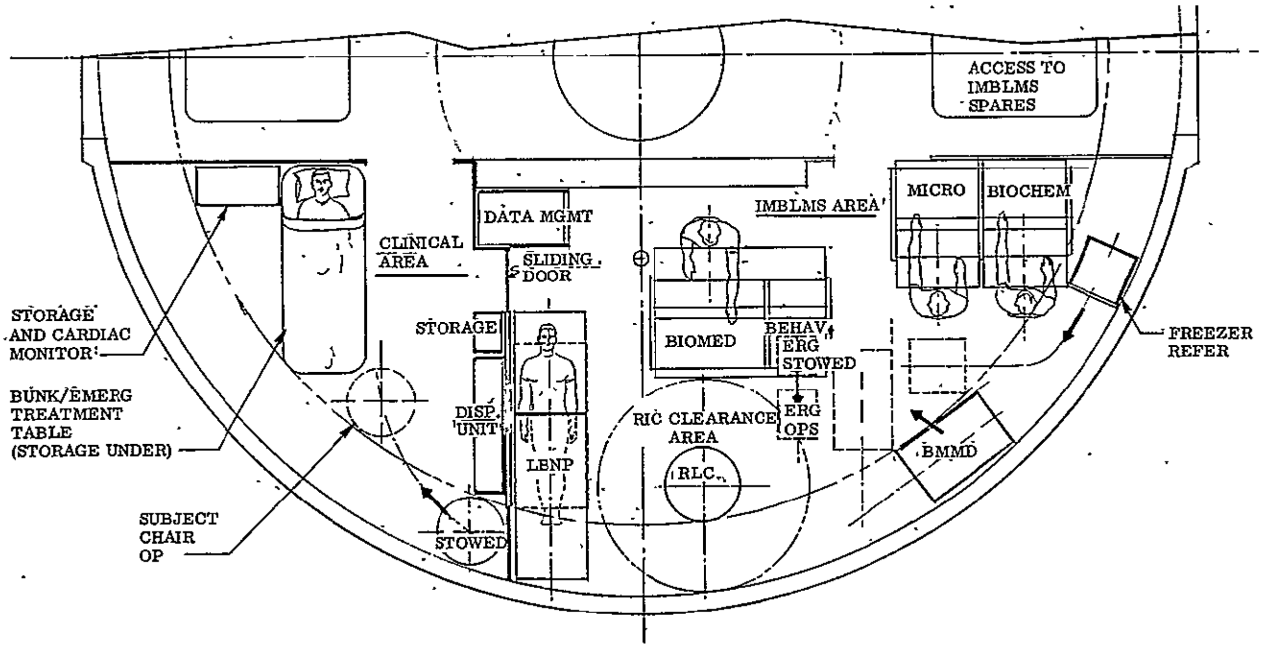


Fig. 2-4 IMBLMS/Clinical Layout for Space Station (NAR)

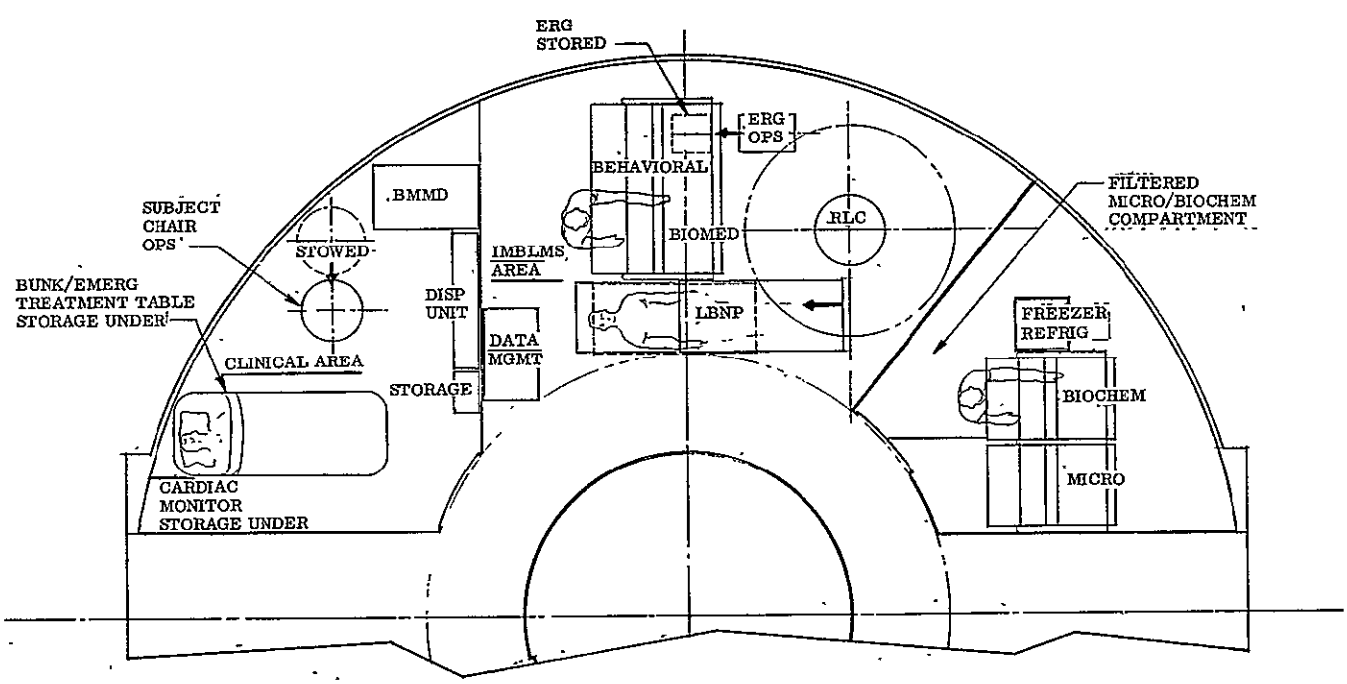


Fig. 2-5 IMBLMS/Clinical Area for Space Station (MAC/DAC)

2.1.2 Operations

The Space Station will be launched, unmanned, with a gross launch weight of over 192,000 lb and follow an initial sequence of events similar to the following:

Day	Activities
1 to 4	Station is unmanned while fuel residuals are safely vented into space.
4	After safing and subsystem status verification, the shuttle is launched with crew and supplies when the station orbital plane coincides with the shuttle launch site. Rendezvous with the station is achieved in 6 to 24 hr. The shuttle then circumnavigates the station for visual inspection.
5	The crew/cargo module is extended from the shuttle and docked to the station. Crew and cargo are then transferred, an operation that can require as long as a day.
6	Equipment, such as IMBLMS, is activated and checked out and subsystems deployed as required. Manned operation begins, with the initial crew possibly remaining for as long as 6 months.

It will be injected at an altitude of 200 to 300 nm and an orbit inclination between 28.5 to 55 deg with respect to the equator. The probable inclination is 55 deg, since this maximizes earth coverage within that inclination band. Activities and phenomena pertinent to an earth resources survey are shown in Fig. 2-6. Of these 90 percent are covered at 55-deg inclination. The choice of altitude will largely depend on the orbit earth trace desired. At 274 nm, the trace repeats daily; at 244 nm, the trace repeats every 6 days. If 274 nm is used, with the trace over the shuttle launch site, this will facilitate emergency return of patients from the IMBLM clinical facility.

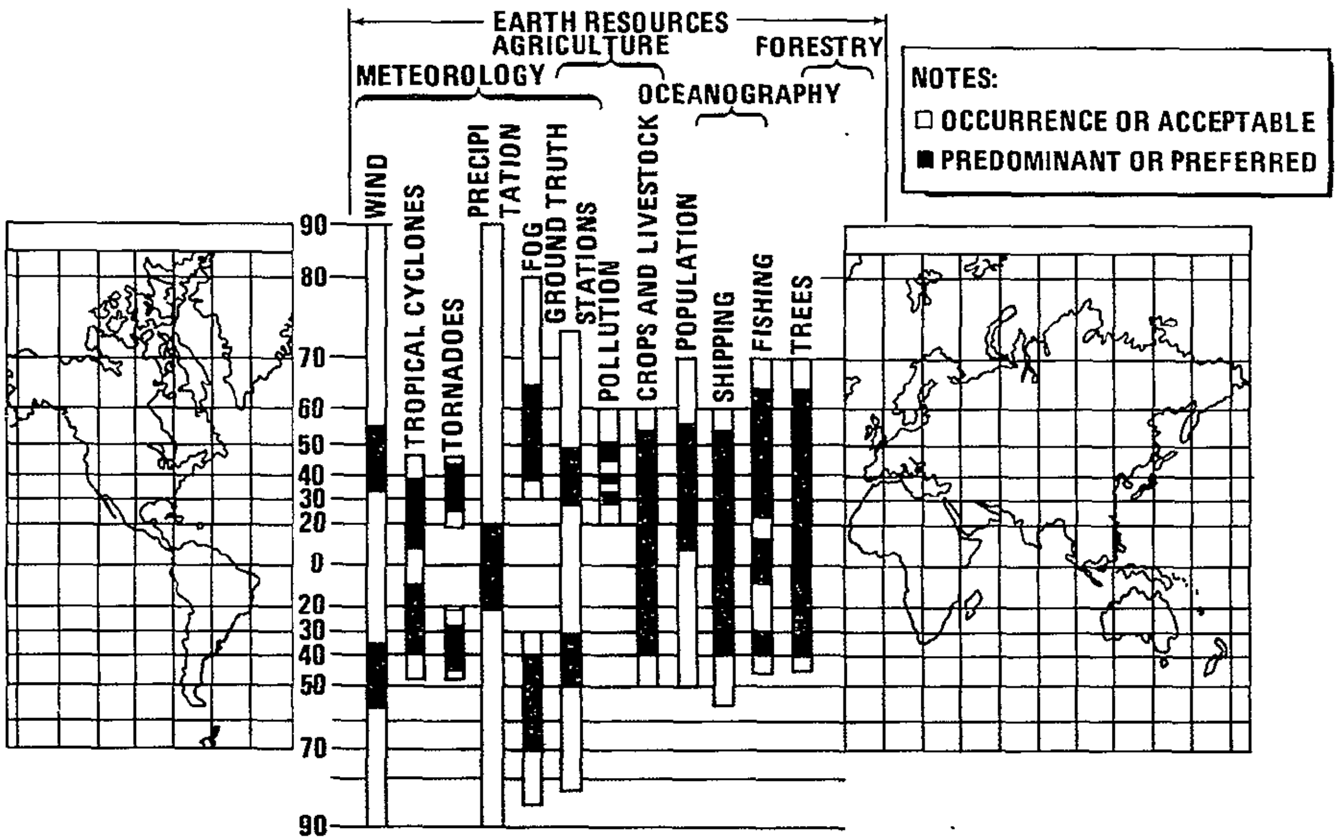
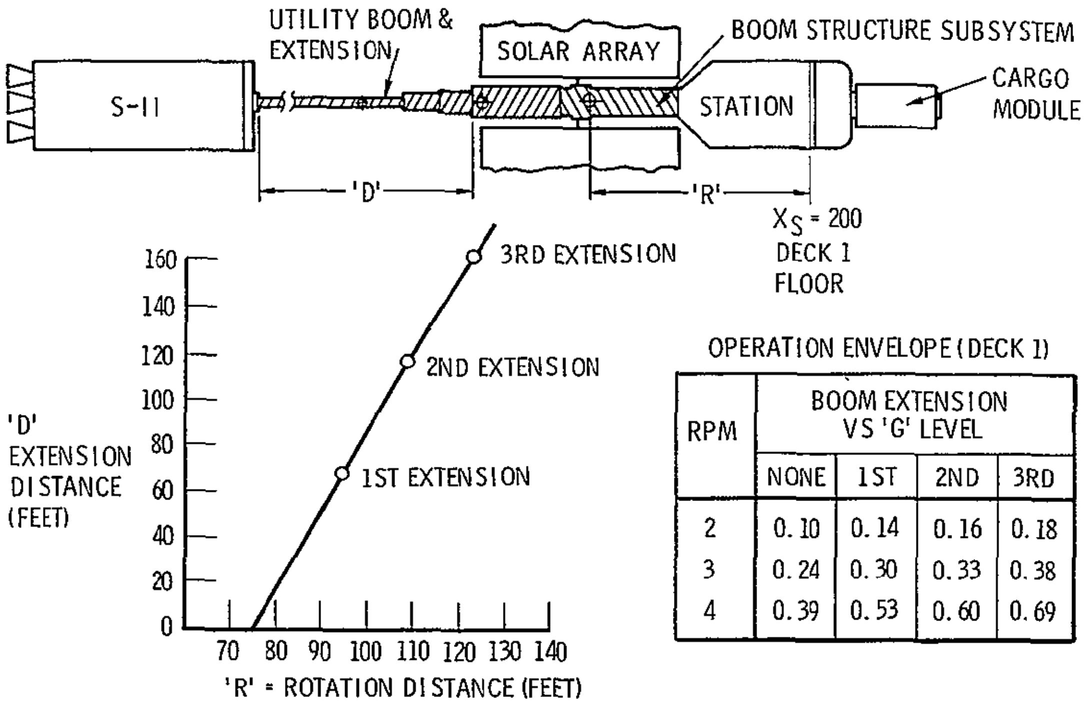


Fig. 2-6 Distribution of Earth Resources

IMBLMS is to operate in the range from 0 to 1 g. For artificial g operation, one proposed procedure is illustrated in Fig. 2-7. The S-II launch stage is positioned on the end of an extendable boom, where it acts as a counterweight. The assembly can then be made



OPERATION ENVELOPE (DECK 1)

RPM	BOOM EXTENSION VS 'G' LEVEL			
	NONE	1ST	2ND	3RD
2	0.10	0.14	0.16	0.18
3	0.24	0.30	0.33	0.38
4	0.39	0.53	0.60	0.69

Fig. 2-7 Artificial g Provision

to spin, with a center of rotation near the solar array. The inserted table shows the resulting g's as a function of degree of boom extension and rotation rate. In this design, Deck 1 contains IMBLMS. The manner in which the station can rig for artificial g, starting with the S-II stage attached below Deck 1 which is the IMBLMS deck in this configuration, is shown in Fig. 2-8.

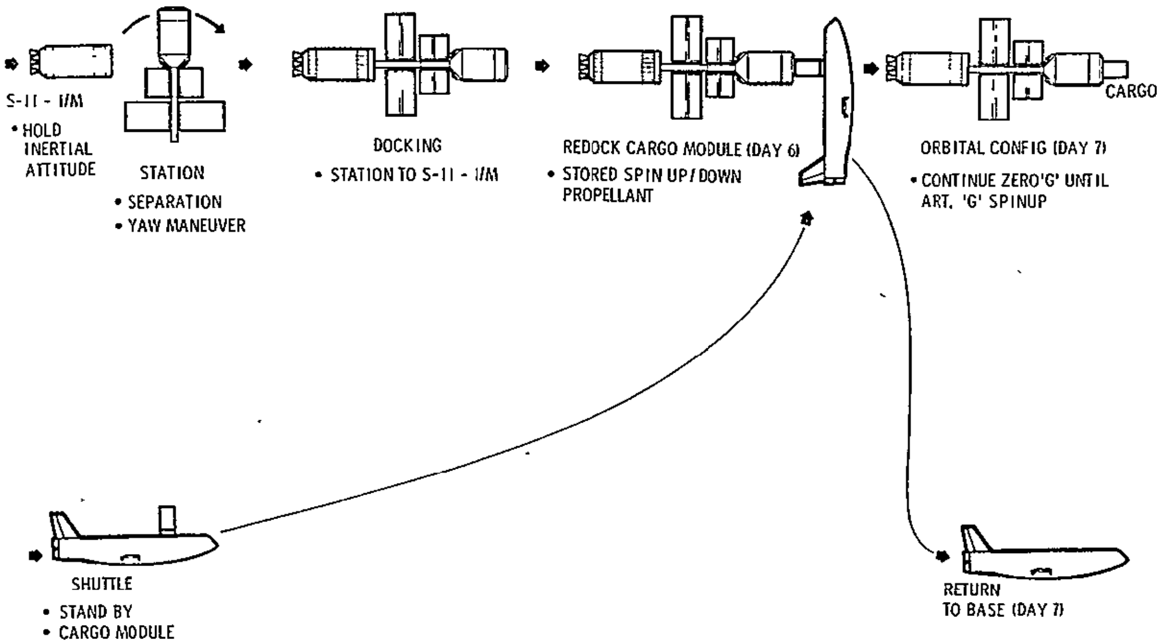


Fig. 2-8 Rigging for Artificial g

The crew makeup for the Space Station is generally expected to be as follows:

- Station commander
- Chief scientist
- Physicist
- Physician
- Medical/biological technician
- Earth resources scientist
- Astronomer
- Chemist/film technician
- Mechanical system and experiment engineer
- Electrical and instrumentation system engineer
- Biologist
- Optics engineer

The physician and medical/biological technician will be primarily concerned with IMBLMS. A typical daily schedule for the crew is presented in Fig. 2-9.

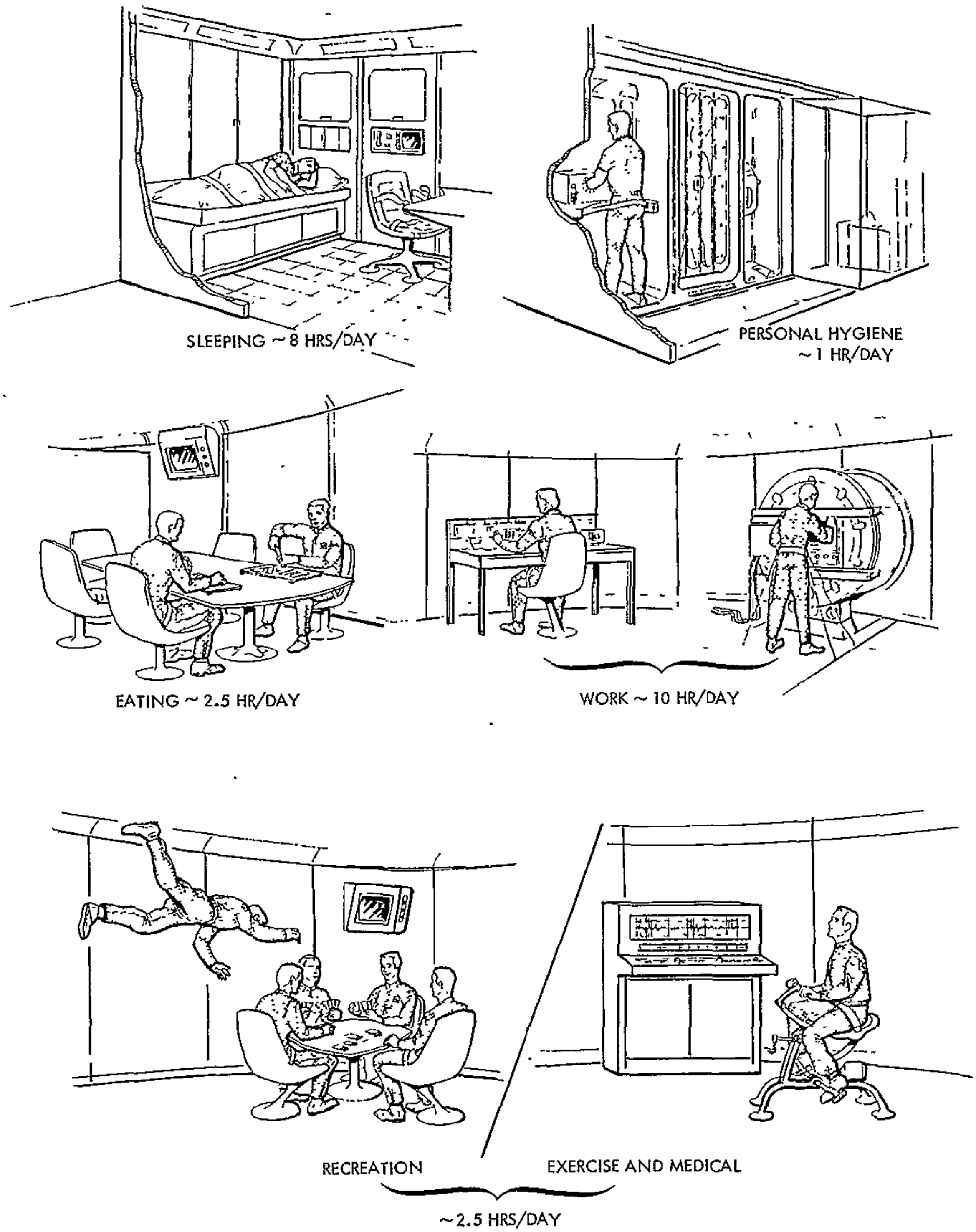


Fig. 2-9 Typical Daily Schedule

The work performed will include scientific and technological research, public services, and further development of space flight capability. The crew will also service and maintain unmanned satellites and, of course, serve as subjects for IMBLMS experiments.

Logistics support for IMBLMS will be provided by the Space Shuttle, for which a flight will be scheduled every 45 to 90 days, depending on study assumptions. Since the current shuttle concept provides for less cargo capacity than was considered for the Space Station studies, 45 to 60 days is a more probable range. Supplies, crew replacements, equipment spares, and the like will be brought up and solid waste, specimens, samples records, film, and data returned, as will crew members who have finished their tour. A cargo container is docked to the station by the shuttle, the shuttle then returns to earth, and the container remains as a pantry for the station crew. The mechanics of removing it and docking a new one on the next shuttle visit require further consideration. It could be ejected and picked up later by the shuttle, or the new container could be docked at another port.

2.1.3 Environment

The Space Station environment in which IMBLMS must operate is presented in Table 2-1.

Table 2-1

IMBLMS DESIGN REQUIREMENTS

Environmental Factors	Ground (Non-Operating)	Launch/Ascent (Non-Operating)	Orbital and Ground (Operating)
Temperature (°F)	-15 to 115	TBD[(a)]	65 to 75
Pressure (psia)	10 to 15.2	14.7 ±0.3	10 to 15.2[(b)]
Humidity (% RH)	0 to 100[(c)]	21 to 76	21 to 76
Salt Fog	Protectively packaged[(c)]	NA	NA
Fungus	All equipment to be certified as non-nutrient to fungus		
Acceleration	(d)	Lateral – 3 g Axial – 3 g forward; 5 g aft	0 to 1 g when rotating 0.035 g max. transient
Shock	(d)	30-g, 11-ms pulse with half-sine pulse, per MIL-STD-810B	NA
Acoustics	(d)	140 db overall from 4 to 9600 Hz	NA
Vibration	(d)	Random 20 to 50 Hz, 0.05 g^2/Hz 50 to 100 Hz, 6 dB/octave rise 100 to 500 Hz, 0.2 g^2/Hz 500 to 1000 Hz, 6 dB/octave roll off Overall, 15.5 g (rms) Duration, 3-min along each of three mutually perpendicular axes. Sweep time-3 min on each axis	NA

(a) Information not available and not required for IMBLMS Phase B-4 (to be determined in Phase C)
(b) For 48-hour non-operating pressure of 10^{-8} psia after a slow depressurization; test to 10^{-2} mm Hg is adequate
(c) Protected by proper packaging against rain and saltfog until placed in space-vehicle controlled environment
(d) Protectively packaged to avoid exceeding launch and ascent environment

Table 2-1 (Cont.)

Environmental Factors	Ground (Non-Operating)	Launch/Ascent (Non-Operating)	Orbital and Ground (Operating)
Vibration (Cont.)	(d)	Sine Lateral 5 to 12 5 Hz, 0.25 in. DA (peak to peak) 12.5 to 400 Hz, 2.0 g (0 to peak) Axial 5 to 15 Hz, 0.25 in. DA (peak to peak) 15 to 400 Hz, 3.0 g (0 to peak) At primary resonances of the console, reduce input levels to 0.5 g lateral and 1.0 g axial Sweep, 3 min/octave	NA

(d) Protectively packaged to avoid exceeding launch and ascent environment

2.2 SKYLAB

In the IMBLMS design effort, consideration has been given to the "probability of IMBLMS being included in whole or in part in the second dry launch Saturn workshop payload (Skylab B)... Accordingly, a flight system must be ready for spacecraft installation no later than November 1973." The use of IMBLMS on Skylab would yield these advantages:

(1) The necessary in-flight measurements could be made to predict man's performance in flights of longer duration.

(2) Much additional information could be collected to influence the Space Station design.

(3) The prototype testing of IMBLMS would ensure the most mature design for the Space Station.

2.2.1 Configuration

The Skylab will be boosted into orbit by the same type booster as that used for the Space Station. The launch configuration is shown in Fig. 2-10, and the on-orbit configuration is shown in Fig. 2-11. The airlock module, between the multiple docking adapter and the workshop, is the nerve center of the vehicle. It provides storage, distribution, and conditioning of the cabin air; electrical power control; instrument timing; data management; and provisions for space/ground communications. IMBLMS would be on the lower deck, outside the ward room and waste and sleep compartments.

2.2.2 Operations

The Skylab Flight 1 mission will begin with an unmanned launch from Kennedy Space Center's Launch Complex 39. Skylab will be injected into a near circular orbit at about 235 nm, with a nominal orbit inclination of 50 degrees. The solar arrays and the Apollo telescope mount will then be deployed and the crew area pressurized at 5 psia with an oxygen/nitrogen mixture. The Flight 2 launch will be from Complex 34 about 1 day later. This Skylab will carry a three-man crew in a command service module. It will rendezvous and dock, as shown in Fig. 2-10. The crew will then enter the spacecraft and complete activation for habitation. Experiments will be conducted

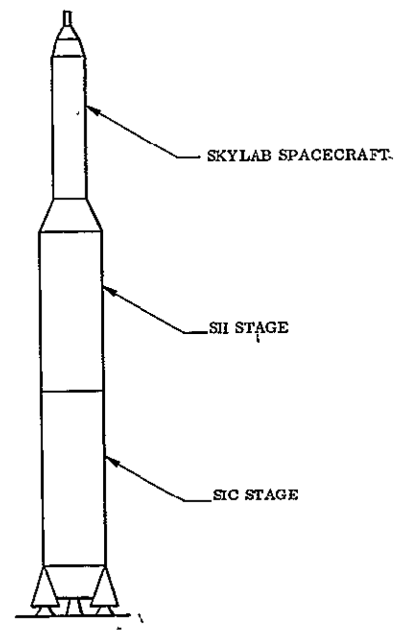


Fig. 2-10 Skylab Launch Configuration

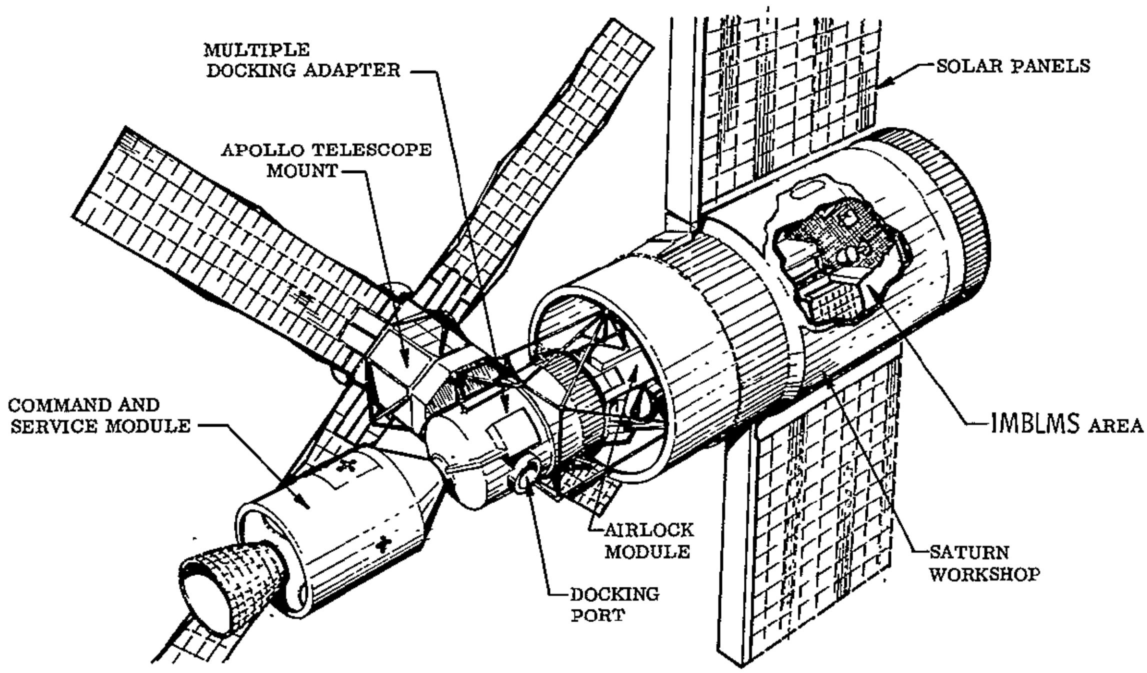


Fig. 2-11 Skylab Spacecraft

for a nominal 28-day period, after which the crew will prepare the Skylab for orbital storage. Nominally, they will deorbit in the command service module on the 29th mission day for splashdown in the West Atlantic recovery area.

A second and third crew will visit the spacecraft and each remain for up to 56 days, for a total of three missions.

At least one mission will have a qualified astronomer aboard, and the second mission will probably have a physician as one of the three-man crew.

2.2.3 Environment

The pertinent environmental factors for Skylab, given in Table 2-2, reflect the environmental conditions to which IMBLMS can be subjected.

Table 2-2

ENVIRONMENTAL CRITERIA – SKYLAB

Measurement	Prelaunch, Operating	Prelaunch, Nonoperating	Launch/Ascent	Normal Orbit Operations	Orbital Storage
Temperature (^{o}F)	30 to 115	-40 to 160	10 to 120	0 to 110	0 to 110
Relative Humidity (%)	60	100	20 max	30 to 95	100 (ice)
Pressure (mm Hg)	760 to 1350	86.9 to 1350	10^{-8} to 1350	10^{-8} to 320	10^{-8} to 320
Atmosphere 0_2 (%)	20	20	0	70-100	0-100
N_2 (%)	80 to 100	80	100	30	
Acceleration		2 g fore & aft, 1 g lateral	7 g flight axis, 3 g lateral		

2.3 SPACE SHUTTLE

The Space Shuttle will provide logistics support for IMBLMS and may, in fact, be used to inject a modular-type station for assembly on orbit. Both shuttle stages are manned, and the operational concept is shown in Fig. 2-12. At an altitude of about 40 nm, the first stage separates and is flown back to base for refurbishment. The orbit element continues to complete the mission, injecting into low-earth orbit a payload currently estimated at 25,000 lb. For cargo injection, however, about 30 percent of this weight will be required for structure and subsystems.

One concept for a 12-man modular Space Station, which the Space Shuttle could inject by repeated flights, is shown in Fig. 2-13. In this configuration, the IMBLMS/clinical area will occupy one module. Possible IMBLMS layouts for such a station are illustrated in Fig. 2-14.

The Space Shuttle brings a number of unique advantages to space operations. With respect to IMBLMS, for example, it can offer the following:

(1) Deliver equipment to the station with much lower g loadings than by conventional boosters, a reduction from about 5 to about 3 g.
(2) Provide an emergency service to return to earth ill or injured crew members.
(3) Bring non-astronaut passengers up to aid in IMBLMS experiments.
(4) Economically deliver IMBLMS spares and new or upgraded modules.

Since there is no planned constraint on launch azimuth, cargo capability need not be reduced to provide fuel for dog-leg maneuvers. Passengers can be of normal health without a requirement for extensive training or physical conditioning. The internal atmosphere will be earth-like, with maximum accelerations less than three times gravity.

2.4 OTHER IMBLMS HOSTS

Configurations of other NASA space vehicles in which IMBLMS could be used would include interplanetary flight or lunar bases, as well as lunar space stations and stations in earth geocentric orbit. They are not yet sufficiently defined to consider in any detail,

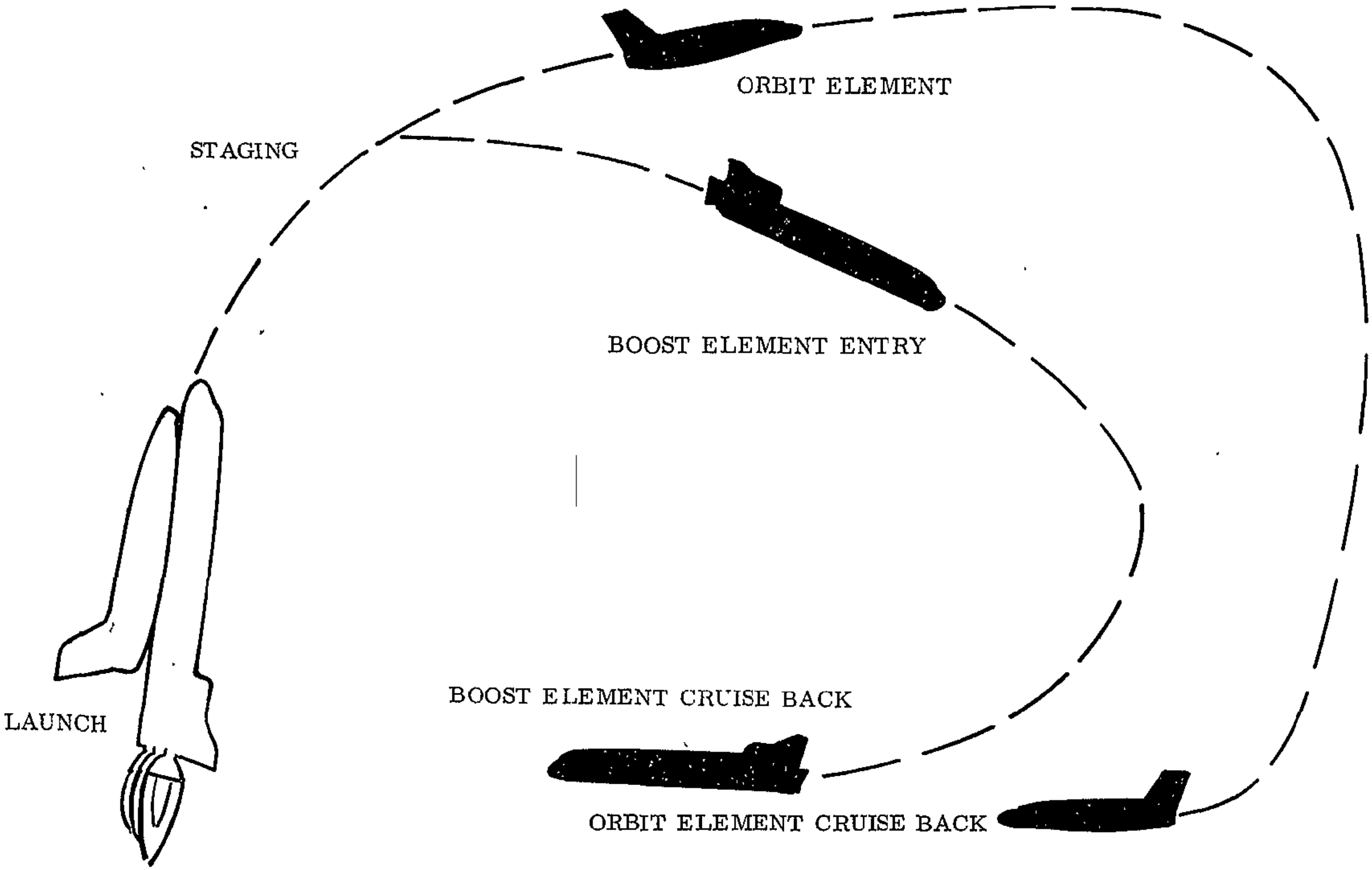


Fig. 2-12 Space Shuttle – Operational Concept

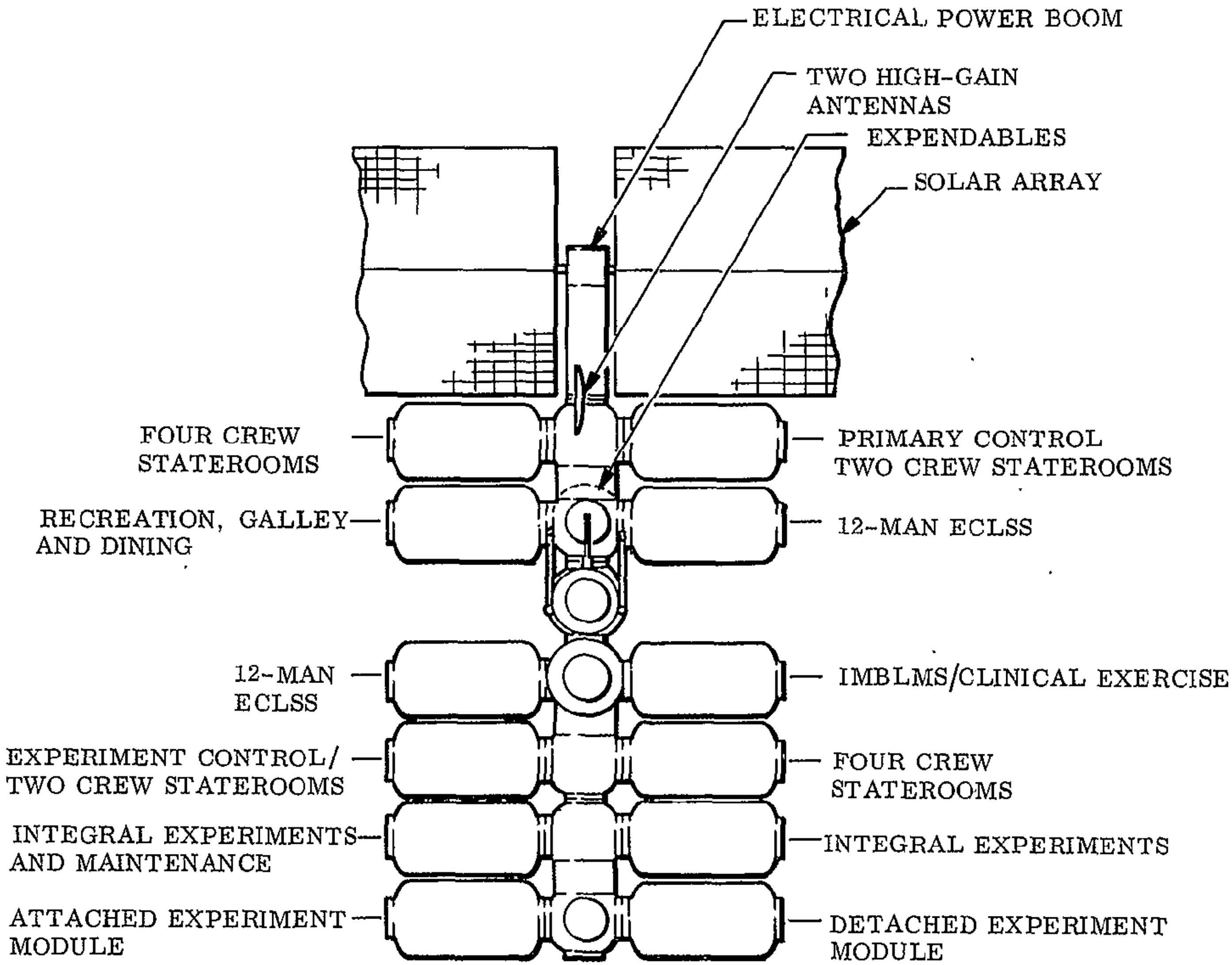


Fig. 2-13 12-Man Modular Space Station Concept

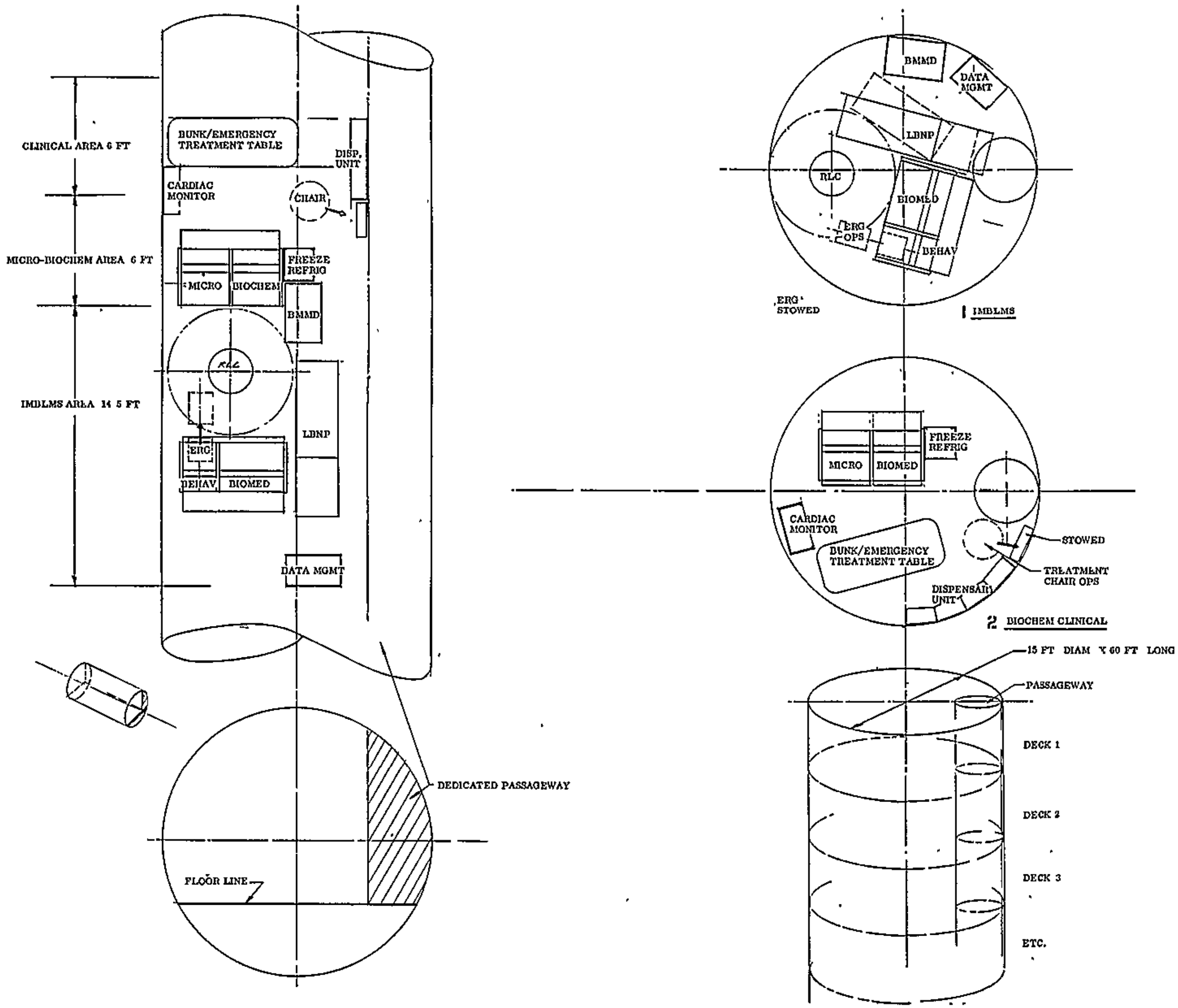


Fig. 2-14 IMBLMS Arrangements for 12-Man Space Station Concept

but they should be similar in design to the Space Station. Another interesting host vehicle for the future is the 60-man Space Base, of which a possible design is illustrated in Fig. 2-15. The Y-like attachment contains the nuclear power source, and each of the four modules attached to a center core is equivalent to one for the Space Station concept. IMBLMS would grow in size, occupying the indicated deck.

Then, too, there is the possible use of IMBLMS on earth, where it might be modified into a small and efficient mobile clinic to reduce the burden on present public health facilities. A more complex IMBLMS, stationed at central locations, could support the field IMBLMS. *

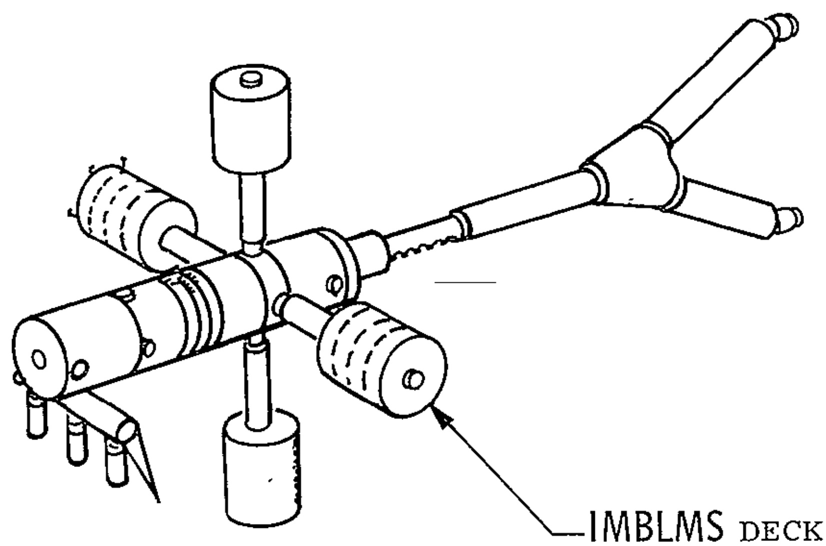


Fig. 2-15 Space Base Configuration

*The NASA Program for an Integrated Medical and Behavioral Laboratory Measurement System, N. Belasco and S. L. Pool, M.D., NASA MSC, Houston, Texas

Section 3
SPECIFIC IMBLMS CONSIDERATIONS

3.1 PHASES C/D GROUNDRULES

The groundrules for Phases C/D, submitted to LMSC during Phase B.4, call for a reduction in the number of hardware end items and testing requirements, emphasizing the use of Skylab-developed items.

3.1.1 Program Plan Summary

During Phase C, the effort will center on the design and development of an engineering development unit (EDU). Aside from documentation, the major tasks will be as follows, with the work performed sequentially:

(1) Complete the design of and fabricate an EDU
(2) Conduct engineering development tests on the EDU
(3) Update and optimize the EDU flight design
(4) Update the EDU to that design
(5) Integrate the EDU into the ground integration test article

In Phase D, these additional major tasks will be performed:

(1) Manufacture a mass mockup
(2) Manufacture two flight units, one for the mission support vehicle and one for the flight vehicle (the former to be used for backup and training)
(3) Provide operational support

3.1.2 Testing

Qualification testing will be conducted specifically on items critical to safety or total mission success. For the remaining items, qualification test disciplines are integrated into the total test program. A qualification/certification matrix will be established to ensure qualification by analysis and similarity considerations. The functional concept of the LMSC test program is illustrated in Fig. 3-1; the test plan is presented in Volume VII of this report.

3.1.3 Skylab Equipment Utilization

Utilization of Skylab equipment will be to the maximum extent possible. For example, the bicycle ergometer and mass measuring devices are being modified only to the extent necessary to integrate them into the IMBLMS stations. In addition, the lower body negative pressure equipment is being modified to servie the additional function of measuring total body volume.

3.2 FUNCTIONAL OBJECTIVES

IMBLMS will consist of the hardware and software required for the performance of human physiological, laboratory analysis, and behavioral measurements and their related data-handling functions; it will be flexible and modular in design to accommodate changes in experiments and choice of host vehicle. Specifically, IMBLMS will be capable of performing numerous measurements in the following areas:

- Clinical
- Neurological and sensory
- Cardiovascular
- Respiratory
- Laboratory analysis
- Metabolic
- Behavioral
- Microbiology
- Environmental

In addition, the IMBLMS must contain a comprehensive clinical capability to diagnose and treat a broad spectrum of mishaps, accidents, and diseases. The system will be able to function in all environments encountered from prelaunch through orbital and will be capable of sensing, processing, and displaying measurement data over a range of operating modes.

IMBLMS capabilities and equipment will comply with the following guidelines:

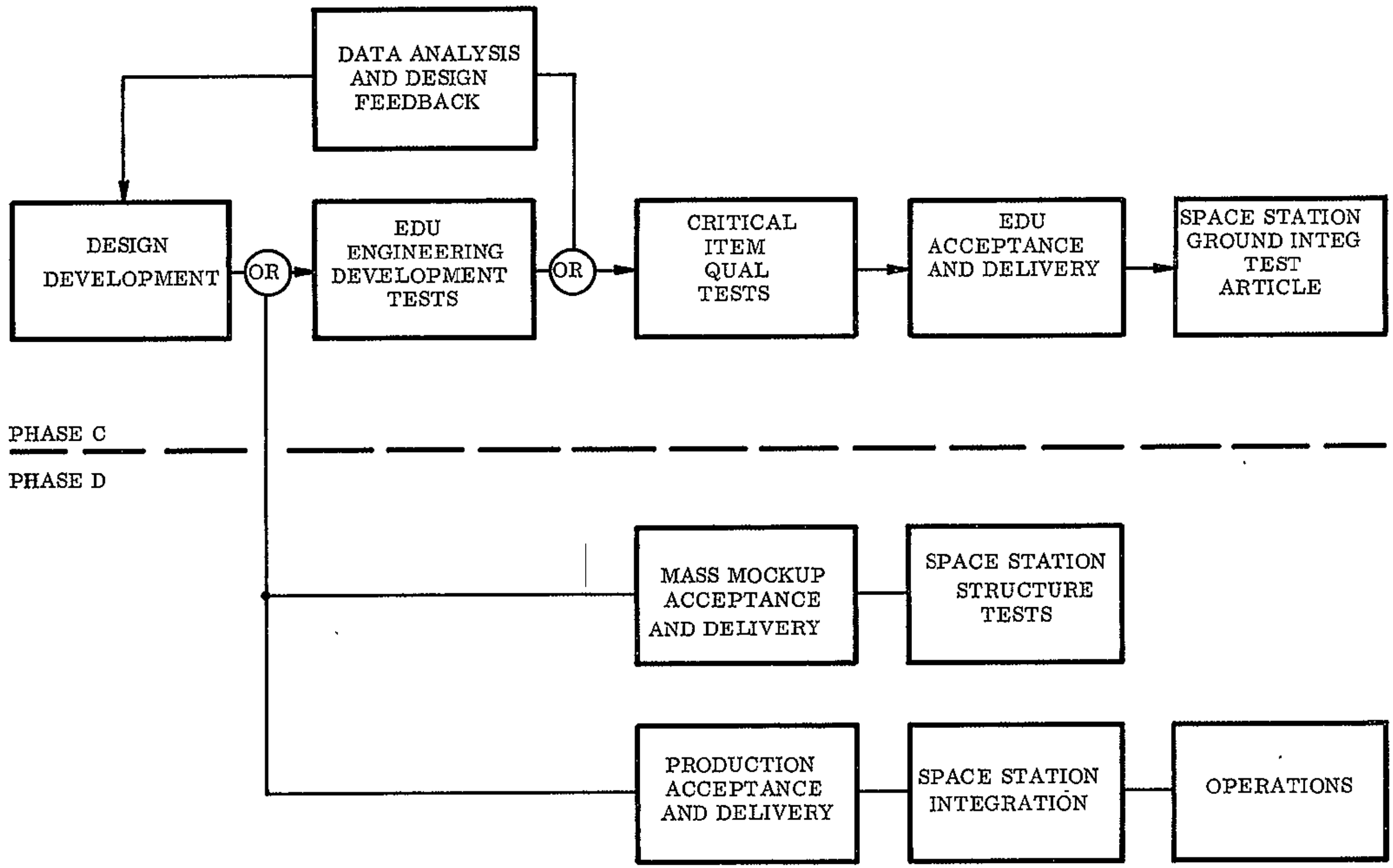


Fig. 3-1 LMSC Test Program – Functional Concept

(1) Provision for evolutionary growth
(2) Utilization of general-purpose equipment, as practical
(3) Flexibility for change in measurement requirements
(4) Provision of automatic operation

3.3 DESIGN GROUNDRULES

Flexibility is imperative for IMBLMS; the long program life, variety of host vehicles, richness of potential experiments, and long operating life demand that the IMBLMS design be characterized by the following:

(1) Modularity – The functional support system capacity can be increased by adding system elements. Hence, the mix of medical experiments can be modified without adversely affecting the Space Station interface.
(2) Adaptability – The design permits changing the mission complement of medical experiments during resupply with minimum effort on the part of the crew.
(3) Fail/Safe Design – No IMBLMS failures will impair the safety of the crew, and no single experiment will adversely affect any other experiment.
(4) Design Conservation – The IMBLMS design incorporates flight-qualified components where they are available. Derating of components has been applied to new designs.

Continuing emphasis will be placed on minimum cost, but not at the expense of compromise to crew safety or total mission success. Maximum use of developed items is a firm requirement, not only those from Skylab but any suitable ones from government and industrial programs.

Simplicity in equipment design has been stressed. Where less complex operation will suffice without significant compromise in product effectiveness, it has influenced design. Simplicity also tends to bring less demand on Space Station resources in terms of weight and electrical power. Furthermore, it ensures greater reliability with less demand on crew time for maintenance and repair. Thus, if a manually operated piece of equipment is essentially as effective as a highly sophisticated and complex electronic one, the former has been chosen.

The IMBLMS design must also contribute to reducing setup, operating, and maintenance time spent by the crew. This capability has been accomplished by the following means:

(1) Where practical, use of replaceable controls and displays that can be made the same as those in the spacecraft

(2) Use of standard fault detection and isolation procedures for all experiments

(3) Establishment of line-replaceable units as the lowest level of replacement normally permitted, with fault isolation to the line-replaceable unit provided automatically

(4) Provision for adaptable calibration through computer programming that automatically scales the measurement, based on known calibration points

Finally, it must be emphasized again that flexibility is a key design objective of IMBLMS. Further, IMBLMS will have the capability to accommodate future biomedical experiments that may be submitted by the biomedical community without the need for extensive engineering development to provide for such unique requirements. IMBLMS must be able to accept any new medical experiment that might reasonably be conceived and make it part of the integrated whole.

3.4 OPERABILITY

3.4.1 Reliability and Maintainability

The overall IMBLMS reliability goal is to carry out extended mission operations without system failure. The corresponding maintainability goal is to make any necessary hardware replacements during predicted downtimes in accordance with predetermined schedules. A primary function is the reliability program to establish component capability for long life while a complementary function in the maintainability program is to provide for in-flight maintenance with fault isolation and replacement.

It is evident that reliability and maintainability must be considered together. The essence of the combined program is as follows:

(1) Identify and control failure modes

(2) Conduct design reviews

(3) Conduct an integrated development/acceptance/qualification test program
(4) Identify and correct production and test failures

The first and fourth items assure the element of dependability; the other two items assure the elements of design capability and availability, or the measure of system effectiveness.

The failure mode and effects analysis (FMEA) is a systematic, organized procedure for identifying, evaluating, and analyzing potential failures in the system. From these analyses, appropriate corrective action can be formulated to eliminate or mitigate the effects of failure modes. The FMEA will uncover the need for design changes and improvements and detect these needs at an early stage of the design, when they can be most effectively accomplished.

Reliability and maintainability engineers, located in the design areas, will review documentation continually as the design evolves. Parts specialists will assist with criteria for parts and materials applications. Principal aims will be to design for maximum component life by selection of established parts and materials and by circuit simplification and parts derating, as well as full consideration of the future maintenance actions. These reviews, together with the more formal design review meetings, will provide the optimum product design reliability and maintainability.

Assurance that the system and its components can meet all prescribed design and performance requirements is the purpose of qualification. A qualification matrix will be established. By judicious planning for development and acceptance testing, as well as qualification testing itself, and by application of all available prior test data, qualification will be accomplished in the most cost-effective manner.

Investigation of production and test failures will be thorough. By establishing the basic cause for equipment failures, with diagnostic failure testing used where necessary, corrective measures will be implemented to assure that the operational mission will be accomplished.

Assurance that the above procedures will be rigorously and comprehensively undertaken is provided by the designation of a Responsible Equipment Engineer (REE) to maintain cognizance over each of one or more pieces of IMBLMS equipment. He will participate in the design and monitor all other activities from which an optimized engineering development unit will eventually emerge. He will be the principal point of contact for any detailed information on his equipment.

3.4.2 Safety

The application of system safety techniques, such as hazards analysis and establishment of design safety guidelines, in addition to stringent safety surveillance, will be employed to assure the safety in all IMBLMS operations. Established system safety guidelines will be used as configuration drivers to ensure that catastrophic and critical hazards will be eliminated or controlled.

The basic IMBLMS safety requirements are as follows:

(1) IMBLMS will be compatible with the Space Station interfaces from the standpoint of physical and environmental safety.

(2) IMBLMS operations will in no way result in safety degradation in Space Station functions.

(3) IMBLMS will be designed for inherently safe care of sick or injured personnel.

(4) The IMBLMS design will be in compliance with NASA-Manned Spacecraft safety criteria.

The primary electrical power source for IMBLMS will be from the Space Station. Provisions will be made in IMBLMS design to prevent and control any possible overload condition to preclude any possible interference with the Space Station operators.

RF energy radiated from body-worn telemetry for the acquisition of IMBLMS medical data will be energy-controlled to prevent injury to personnel and interference with the Space Station.

The man-machine operational characteristics and design techniques will be considered from a commonality and simplicity viewpoint. The sensing and monitoring devices used in the man-machine interface will be designed in accordance with NASA manned space programs established practices.

The use of existing and new clinical equipment and instruments under zero gravity will require the development of new hardline techniques and the application of personnel injury prevention training programs. In addition, specialized equipment aids to minimize potential operational hazards will be important design considerations.

Section 4

IMBLMS/HOST VEHICLE INTERFACES

4.1 IMBLMS/SPACE STATION INTERFACE

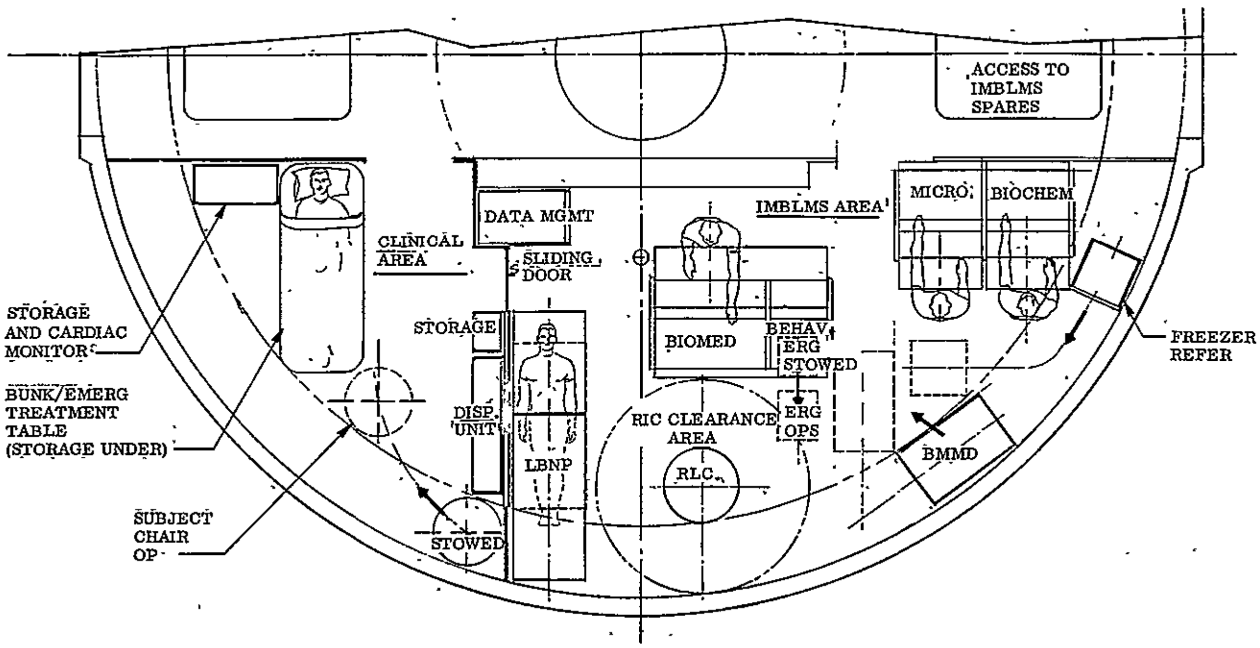
Since the Space Station has not been firmly defined, precise interface data are not yet available; indeed, the two candidate configurations differ markedly. The flexibility of IMBLMS, however, ensures that it will be completely compatible with the final design. Pertinent information made available to LMSC from North American Rockwell (NAR) and McDonald/Douglas (Mc/D) reports is presented in the following paragraphs.

4.1.1 Structural and Mechanical

For the ascent mode, fixed IMBLMS equipment is installed and dynamic loads are picked up through mounting flanges, attached to the deck. For the orbital mode, the equipment will be prevented from shifting position by the same mounting flanges. Under zero g, the equipment will remain in position in much the same manner as equipment on the ground.

The Space Station area available for IMBLMS and the clinical facility are shown in plan view in Fig. 4-1 for both design configurations. Key interface features are as follows:

(1) Deck mounting by tiedown
(2) Flexible location and relocation
(3) Overhead provision for utilities
(4) Movable partitions



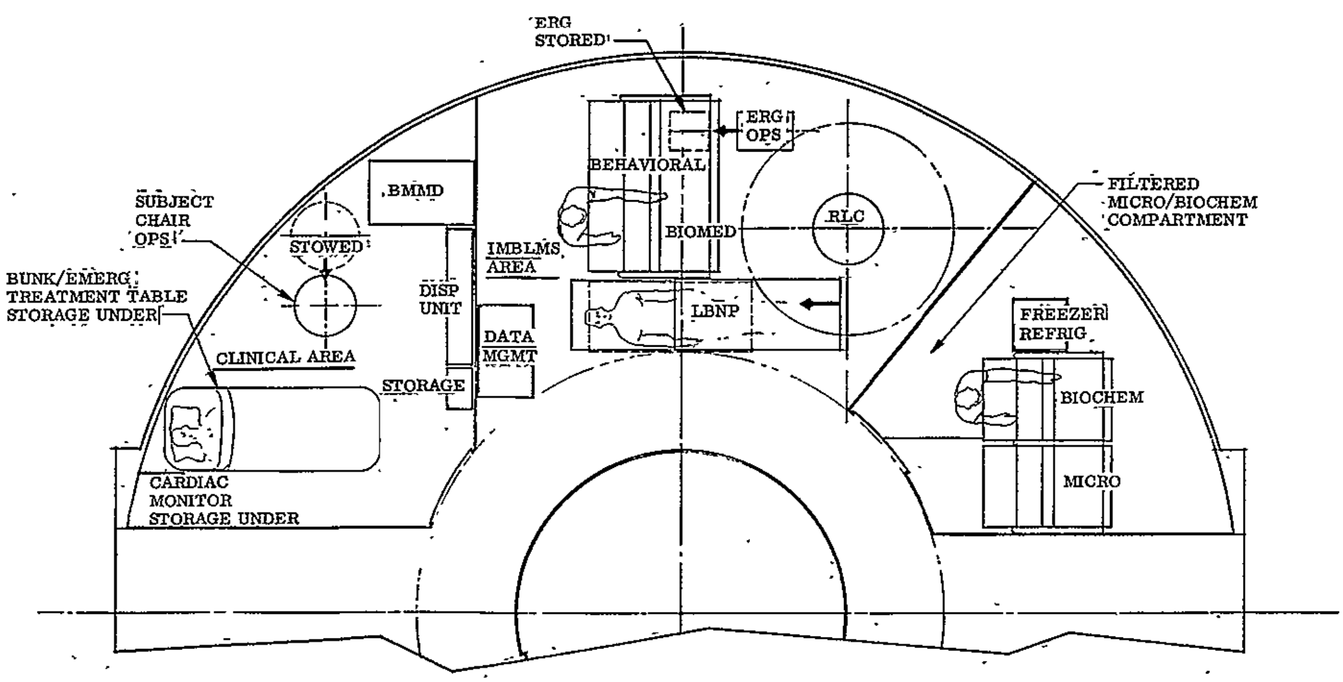


Fig. 4-1 Two Candidate Configurations – IMBLMS/Clinical Area in Space Station

4.1.2 Electrical

Voltage characteristics for IMBLMS are as follows:

AC	120/208 volts, 3-phase, 400 Hz
DC steady state	27.5 ±2.5 volts
Transient voltages	21 to 32 volts with recovery to steady state within 1 second
Ripple voltage	1 volt PP
Power failure	up to 5 msec

4.1.3 Information Management

Information management system characteristics differ between the two configurations as follows:

	NAR	MAC/DAC
Maximum expended data rate:		
Onboard (bits/day)	1.58×10^{11}	7.5×10^{11}
Realtime (bits/day)	None	5×10^{11}
Delayed (bits/day)	2×10^{9}	None
Tape and film (lb/day)	57	30
Ground communications:		
Analog (MHz)	6.5	40
Digital (bits/sec)	5×10^{6}	10×10^{6}
Computer:		
Operations/sec	10^{7}	1.2×10^{6}
Number of processors	5	6
Mass memory size (words)	2.5×10^{6}	7×10^{6}

IMBLMS will have a hardline connection to the Space Station information management system. This will be a logical connection with status and control lines. To be determined are the amount of data and operations for station use. The data generated by IMBLMS can be entirely self-contained or fed in whole or part to the Station, as required.

External data links for the NAR Space Station configuration are shown in Table 4-1.

Table 4-1

SPACE STATION EXTERNAL COMMUNICATIONS LINKS (MSC)

Nomenclature	DRSS Line		Direct to Ground		Remote Module		Logistics	
	Up Link	Down Link	Up Link	Down Link	SS to RM	RM to SS	SS to Log	Log to SS
Digital data	1×10^6 bps	1×10^7 bps	1×10^6 bps	1×10^7 bps	1×10^4 bps	3×10^6 bps	1×10^4 bps	1×10^4 bps
Voice channels	4 at 4 KHz	4 at 4 KHz	4 at 4 KHz	4 at 4 KHz	1 at 4 KHz	1 at 4 KHz	2 at 4 KHz	1 at 4 KHz
Audio	1 at 10 KHz		1 at 10 KHz					
Video	1 comm color at 4.5 MHz	1 comm color at 4.5 MHz	1 comm color at 4.5 MHz	1 comm color at 4.5 MHz		TV at 3×10^6 Hz		
Tracking	PRU ranging at 1×10^6 bps	PRN ranging at 1×10^6 bps	PRN ranging at 1×10^6 bps	PRN ranging at 1×10^6 bps	PRN range at 1×10^6 bps	PRN range at 1×10^6 bps	PRN range at 1×10^6 bps	

4.1.4 Environmental Control

Interface information pertinent to IMBLMS extracted from the Space Station Phase B Definition Study, MSC Compatibility Data for Contract NAS9-9953, Experiments Panel, June 19, 1970, is as follows:

CO_2 Control

The Station shall maintain the atmosphere at 5 MMHG nominal CO_2 partial pressure. Non-metabolic, animal and experiment produced CO_2 shall be controlled by the experiment. CO_2 control for the crew shall be provided for integral, attached, and detached experiments.

Temperature Control

Integral Experiments — The Station shall provide selectable temperature control between 65 and 75 deg F for integral experiments. Capability shall be provided in the Experiments area on Deck 4 to supply air selectable between 60 and 75 deg F. The Station atmosphere shall accommodate 2250 watts of sensible heat maximum from the integral experiments. (Sized on the basis of 25 percent to the atmosphere of a maximum 9000 watts.)

Pressure Control

The Station shall provide total pressure control and oxygen partial pressure control for integral, attached and docked detached modules to the same condition as the Station atmosphere. The Station and experiments atmosphere shall be controlled to 14.7 psia (with variation to 10 psia allowable) and oxygen partial pressure at 3.1 psia. Experiment pressure requirements different from the Station shall be provided by experiments.

Contamination Control

Toxic, corrosive or bacteriological contaminants shall be removed by the experiments before the atmosphere is returned to the Station system. The Station contaminant control assembly may be utilized by experiments for the control of contaminants with maximum generation rates to be specified.

Humidity Control

The Station shall provide atmosphere at 8 to 12 MMH_G partial pressure of water for integral, attached, and docked detached experiments. Humidity control to a different level shall be provided by the FPE. Excessive experiment caused humidity (greater than approx 0.5 lb/hr of non-human water to the atmosphere) shall be removed by experiment facilities.

Water Management

Storage and/or generation capability for supplying 35 lb/day maximum of potable water shall be provided by the Station ECLSS. The water shall have the same potability and purity requirements as the Station (NASA-MSC specification PF-Spec-1B-Command Module/Lunar Module potable water specification – 25 June 1969). This capability shall be provided for use by each experiment mode (integral, attached or detached). However, the combined use by the three modes at any one time shall not exceed the 35 lb/day limit.

ECLSS Prototype Experiments

The Station ECLSS subsystem distribution and controls shall be available for prototype functional and operational experiments. The prototypes must be capable of being integrated with/into the Station ECLSS in a manner such that the Station subsystem can take over operation in the event of any prototype malfunction.

Waste Management

The station shall provide capability for processing a total of 67 pounds per month of waste and trash material from experiments such as IMBLMS. This material will be vacuum dried and stored for return to earth.

For active thermal control, the MSC design has a coolant fluid outlet temperature of $35^{o}F$.

4.2 IMBLMS/SKYLAB INTERFACE

4.2.1 Structural and Mechanical

A plan view of the IMBLMS decks on Skylab, shown in Fig. 4-2, is a typical equipment layout. Being highly flexible, IMBLMS can readily adapt to the area shown.

In Skylab, the basic experiment equipment is to be floor mounted. The auxiliary equipment will be both floor and wall mounted.

The experiments associated with the scientific airlocks and the maneuvering experiments, together with their stowage containers, are to be located in the forward compartment.

The environment sampling experiment is to be initially mounted on the forward side of the ceiling (its most frequently used location). Mounting brackets will also be provided in the head, the wardroom, and the sleep compartment. The experiment will be hand-held at all other sampling stations.

Heavy experiments will be located at points where the floor has its greatest load-bearing capability.

Most experiments will be permanently installed at the location of their activities. All installations are hard-mounted to the tank wall, crew quarters partitions, ceiling, or floor. If shock mounting is required, the supplying contractor will provide the necessary protection within his experiment or stowage container.

The attachments between the experiments and the support structure are to be oriented to coincide with the standardized astrogrid, whether floor or wall, in order to standardize and minimize interface problems.

Provisions on the experiment mounting structure will be made for electrical bonding.

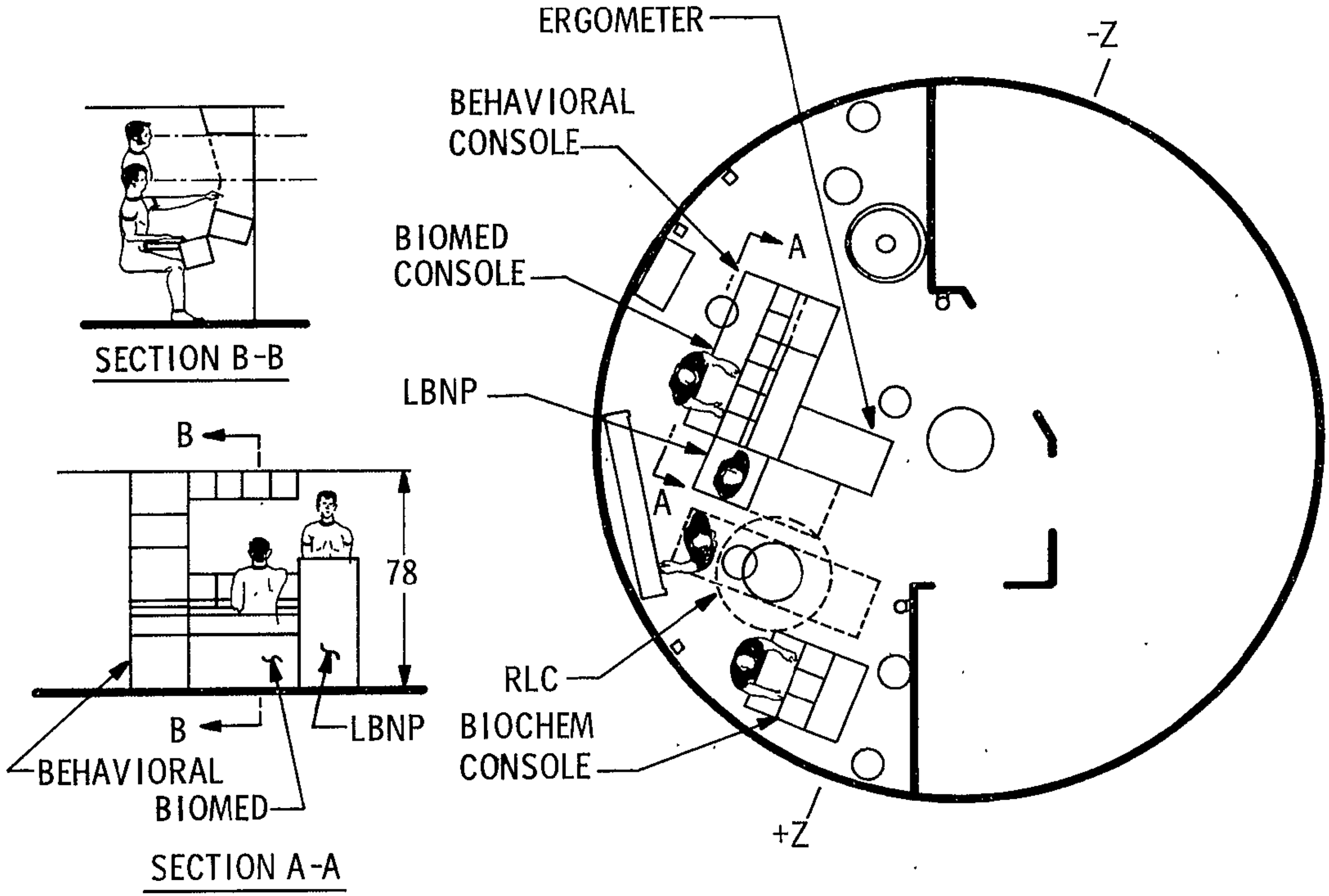


Fig. 4-2 Skylab Plan View

4.2.2 Electrical

Solar panels on the workshop provide as much as 11,900 watts in the form of 28 volts dc. Continuous power available is about 3700 watts.

4.2.3 Information Management

The command and control data link will be 51.2 kbits/sec. Telemetry signals can be sent to the ground an average of 25 percent of the time. A TV camera on board can be used to transmit pictures to the earth. For IMBLMS, these can be time and motion studies, microscope images, and the like.

4.2.4 Environmental Control

During manned periods in orbit, the crew quarters will be pressurized to 5.0 psia, with O_2 partial pressure at 3.7 psia and N_2 partial pressure at 1.3 psia. The atmosphere temperature will be normally maintained between 65^oF and 75^oF, with humidity normally maintained between 40 to 60 percent relative. A control will permit temperature to be selected over a range of 60^o to 90^oF.

Section 5

SCHEDULE

The preliminary NASA schedule for the Space Station is presented in Fig. 5-1. In Phase C, an EDU will be developed over a period of about 2 years. It will then undergo engineering development testing, after which the design will be updated and optimized and the EDU upgraded for integration in the ground integration test article. Subsequently, Phase D will begin. Two flight units will be manufactured – one for the flight vehicle and one for the mission support vehicle.

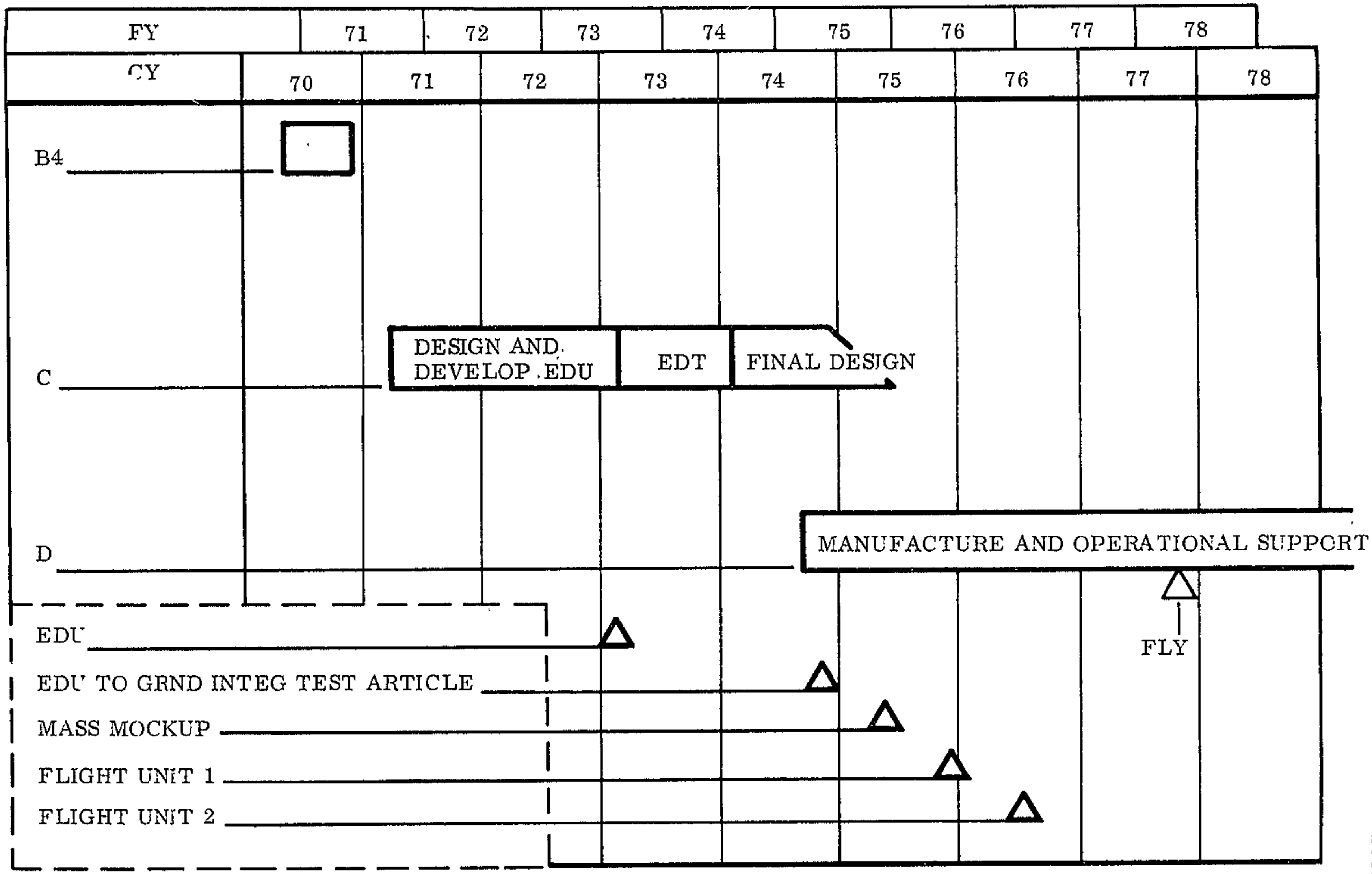


Fig. 5-1 Program Plan and Schedule for Space Station IMBLMS