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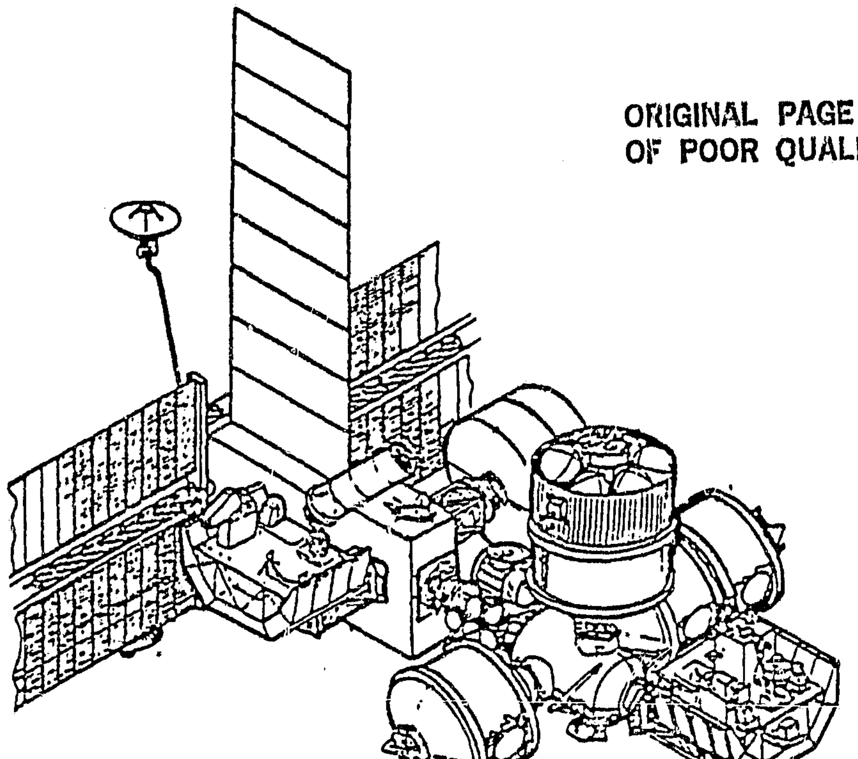

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EVOLUTIONARY SPACE PLATFORM CONCEPT STUDY

VOLUME I – EXECUTIVE SUMMARY

MCDONNELL DOUGLAS CORPORATION

EVOLUTIONARY SPACE PLATFORM CONCEPT STUDY

VOLUME I – EXECUTIVE SUMMARY

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APPROVED BY: FRITZ C. RUNGE
STUDY MANAGER

PREPARED UNDER NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION CONTRACT NAS 8-33592

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-HUNTINGTON BEACH
5301 Bolsa Avenue Huntington Beach, California 92647 (714) 896-3311

FOREWORD

The Evolutionary Space Platform Concept Study encompassed a 10-month effort to define, evaluate and compare approaches and concepts for evolving unmanned and manned capability platforms beyond the current Space Platform concepts to an evolutionary goal of establishing a permanent-manned presence in space.

The study included three parts:

- Part A - Special emphasis trade studies on the current unmanned SASP concept ($50,000)
- Part B - Assessment of manned platform concepts ($250,000)
- Part C - Utility analysis of a manned space platform for defense-related missions ($140,000)

In Part A, special emphasis trade studies were performed on several design and operational issues which surfaced during the previous SASP Conceptual Design Study (reference: MDC G9246, October 1980) and required additional studies to validate the suggested approach for an evolution of an unmanned platform. Studies conducted included innovative basic concepts, image motion compensation study and platform dynamic analysis.

The major emphasis of the study was in Part B, which investigated and assessed logical, cost-effective steps in the evolution of manned space platforms. Tasks included the analysis of requirements for a manned space platform, identifying alternative concepts, performing system analysis and definition of the concepts, comparing the concepts and performing programmatic analysis for a reference concept.

The Part C study, sponsored by the Air Force Space Division (AFSD), determined the utility of a manned space platform for defense-related missions. Requests for information regarding the results of Part C should be directed to Lt. Lila Humphries, AFSD.

The study results from Parts A and B are reported in these volumes:

Volume I - Executive Summary

Volume II - Part A - SASP Special Emphasis Trade Studies

Volume II - Part B - Manned Space Platform Concepts*

Volume III - Programmatics for Manned Space Platform Concepts

Questions regarding this report should be directed to:

Claude C. (Pete) Priest
NASA/George C. Marshall Space Flight Center, PF01
Marshall Space Flight Center, AL 35812
(205) 453-0413

or

Fritz C. Runge, Study Manager
McDonnell Douglas Astronautics Company
5301 Bolsa Avenue
Huntington Beach, CA 92647
(714) 896-3275

*Contains inputs from Hamilton Standard in select areas of ECLSS ($5000 subcontract).

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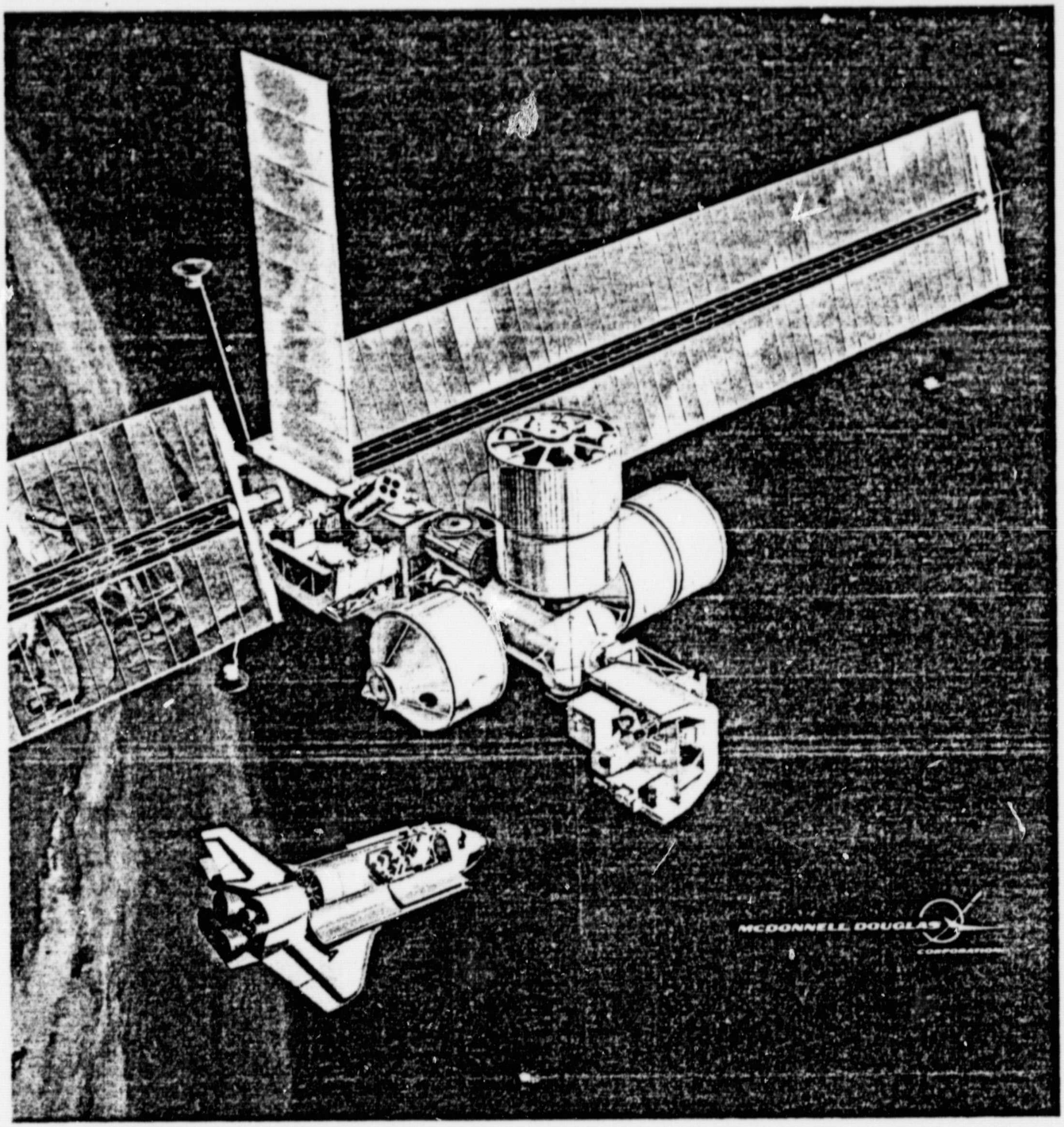

Section 1
INTRODUCTION

The recent launches of the Space Shuttle and the anticipated operation of the Spacelab in the near future are bringing new capabilities to the science and applications communities to accomplish missions in space. These new systems will facilitate the launch, retrieval, refurbishment and reflight of scientific payloads. While the Spacelab sortie mode of operation will continue to be an important tool for the science and applications users, efforts are also in progress to define an approach to provide a simple and cost-effective solution to the problem of long-duration space flight. This approach involves a Space Platform in low earth orbit, which can be tended by the Space Shuttle and which will provide, for extended periods of time, stability, utilities and access for a variety of replaceable payloads. The Shuttle thus permits the placement and revisitation of space platforms which will cost-effectively fly groups of payloads for extended periods. For unmanned payloads, this new mode of flight reaps economics when compared with the provision of individual spacecraft for each payload. For manned payloads, the Space Platform provides an efficient orbital base for groups of habitable modules to support the many payload missions which require long-term crew involvement.

This study established the feasibility of an evolutionary space system which would cost-effectively support both unmanned or manned payloads in groups, using a common Space Platform which provides centralized basic subsystems; see Figure 1-1 following page.

Although the worlds of unmanned and manned space missions are broadly different, they do show two major common needs, namely: (1) the same types of subsystem resources (power, thermal control, communications and data handling, attitude control and reboost propulsion) and (2) innovative ways to offset the burdensome problem of funding constraints. The Space Platform provides an integrated solution to these common needs by providing a common, multi-payload carrier with extensive utilities, plus a traffic-reduction advantage to the Shuttle and TDRSS through payload congregation on one orbit facility.

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Figure 1-1

EVOLUTIONARY SCIENCE AND APPLICATIONS SPACE PLATFORMS

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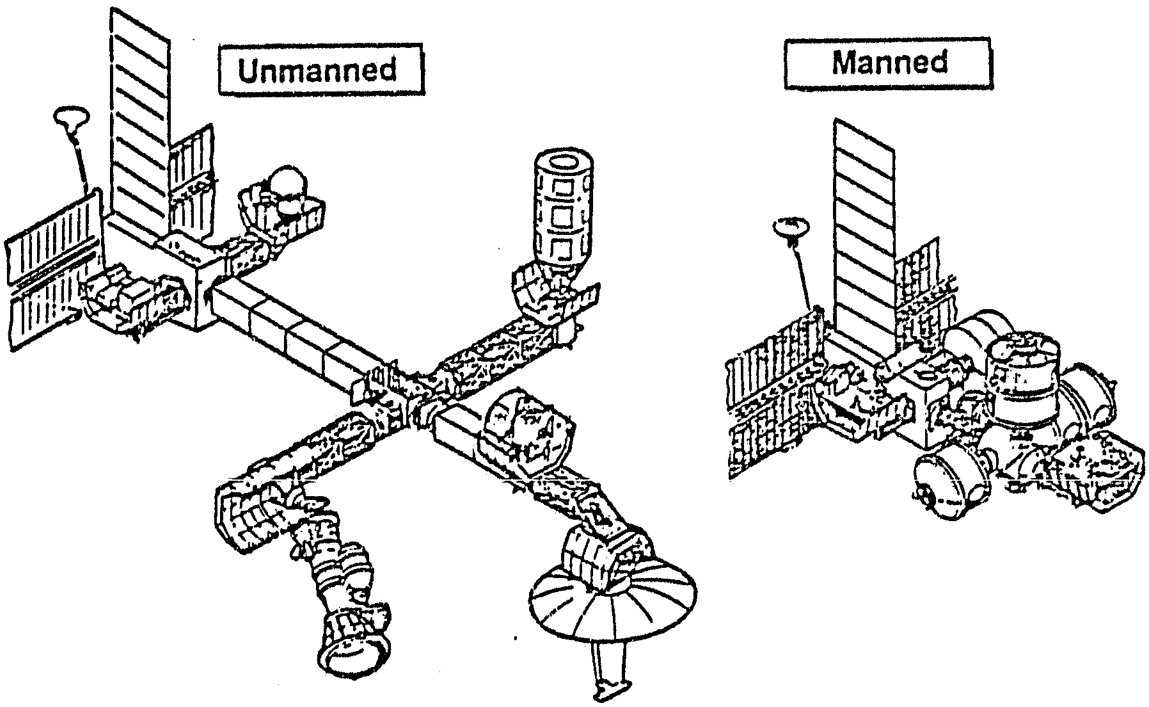

In the world of manned missions, the primary subject of this study, the Space Platform permits the conduct of long-term manned payload operations in low earth orbit as a sequel to, and, expansion of major dimension to the seven-day Spacelab flights on the Shuttle.

The program will be evolutionary in nature. The addition of a habitable module (which could be derived from Spacelab) to the Space Platform will provide a manned orbital system. This manned space platform (space station) in low earth orbit is seen to be the next major capability needed for the areas of science, applications, technology and commerce. Such a capability offers the ultimate approach to capitalizing on the considerable synergism which is possible when man is used to complement equipment in orbit. The vast potential of this type of capability has been proven in Skylab and will be proven shortly again in

Spacelab. Because of the relative short duration of a Spacelab flight, there is considerable interest among some investigators with manned payloads on Spacelab to reside for longer periods.

Moreover, the manned space platform concept must recognize the realities of budget constraints and payload availability, both of which combine to prescribe a vehicle of modest beginnings and yet flexible for growth into service for those major orbital operations that are emerging. It is apparent that the early manned space platform will support Spacelab-type and derivative payloads. Next, in preparation for later major operations, an interim step of advanced capability development must be accomplished. Finally, with such new capabilities, major operations will be implemented to support large structure assembly, orbital transfer vehicle basing and spacecraft servicing. This latter activity is envisioned as feasible by the mid-1990s, if the enabling technology is developed in the early 1990s.

Basically, the technology to provide long-term residence for man in space is in hand and there are now payloads for science, applications and commerce in development which can utilize such a capability. The advanced capability to perform major complex operations must yet be developed and tested in orbit.

The objective for the main part of the study, namely the Manned Space Platform (Part B) was to define, evaluate and select concepts for establishing a permanently manned presence in space early, with a maximum of existing technology. The study included five tasks: Task B1 - Requirements Analysis for a Manned Space Platform, Task B2 - Concepts Identification, Task B3 - System Analysis and Definition, Task B4 - Comparison of Concepts and Task B5 - Programmatics.

Section 2 of this book describes the results of the Manned Platform Study, Sections 2.1 and 2.2, the systems requirements analysis and details of candidate payloads for an early manned space platform. Section 2.3 describes a number of basic concepts for a manned space platform and an evaluation of their features, benefits and constraints, based upon the detailed systems analysis and definition efforts performed.

Section 2.4 summarizes the recommended reference concept including a description of the overall configuration, subsystems features, habitability, safety, mass properties and role of KSC. Section 2.5 presents the cost estimates for the recommended concept. Section 2.6 describes the technology advancement requirements for the early manned space platform concept selected. Section 2.7 compares various approaches to technology utilization on a program level, depending on budget constraints and basic groundrule options. Section 2.8 presents some ideas on early minimum and later growth configurations based on the concept recommended.

Study results and recommendations must be evaluated and compared within the context of the fundamental guidelines and the major assumptions used in performing the analyses and/or developing the conceptual designs. Therefore, to provide such a frame of reference for the material to be discussed, the original study guidelines are summarized as follows:

- The Space Shuttle shall be considered as the earth launch vehicle.
- The Space Platform (illustrated later in Figure 1-4) shall be used as the basic resources module for the manned space platform concept.
- Maximum utilization of existing hardware, technology, experience and facilities is desired.

Lastly, Section 3 presents the results of selected Unmanned Platform studies (Task A) an extension of a prior study subject. It focused on (1) innovative concepts, (2) image motion compensation interfaces, and (3) dynamics.

This study constituted a follow-on to one preceding wherein the unmanned platform was emphasized, but a manned adaption module was also preliminarily defined.

The task flow of the study is shown in Figure I-2 reflecting a classic Phase A approach to the Manned Platform conceptualization. The broad conclusions of the

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study are presented in Figure 1-3. Due to the greater emphasis on the Manned Platform (Task B) in the study, it is covered first in this document, relative to the Unmanned Platform part (Task A).

Figure 1-2

STUDY TASK FLOW

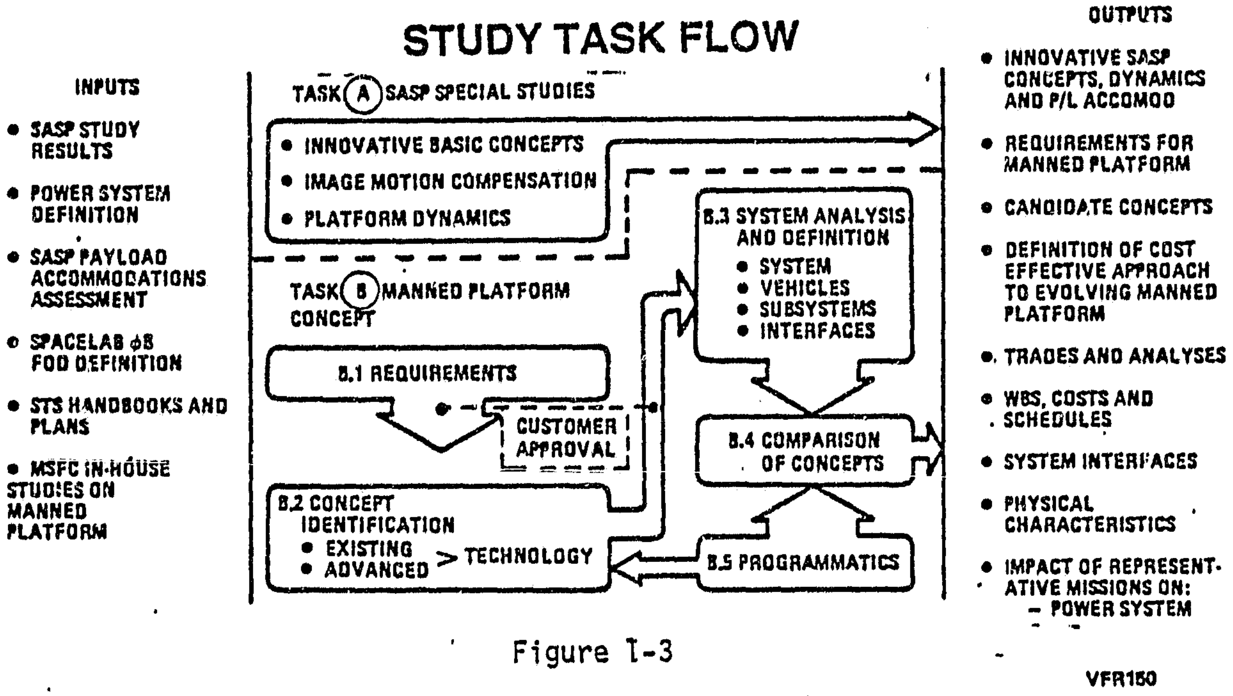

Figure 1-3

STUDY CONCLUSIONS

- **Manned Space Platform ($250K Study)**

  Payloads
  - Initial Phase (First 2 Years) — Modest Size Group for Science and Applications (Loads of 2-4 Pallets + 1-2 Spacelabs)
  - Mid-Phase (3rd-5th Years) — More of the Above Plus Technology Demonstrations for Advanced Capabilities
  - Ultimate Phase (5th Year On) — Large Structure Buildup, OTV Basing and Spacecraft Servicing

  Program Scope — Modest Initially With Growth Flexibility; Slaved to Firm Manned and Unmanned Program Needs

  Vehicle
  - Modest Beginning and Growth Indicated — Initial Crew of Two Growing to Four (Central Module Payload Module Logistics Modules — Habitat Modules Exterior OP's. Module)

  Technology
  - Vehicle — Modified Spacelab Satisfies Habitat and Payload Module Needs
  - Subsystems — Much Existing; Some Adaption Required
  - Advanced Capabilities — Much to Be Done; Demonstrations for Ultimate Operational Phase

- **Unmanned Space Platform ($50K Study)**

  Configuration — Original Concept Selection Verified; Alternates Complex

  Pointing/Dynamics — High-Accuracy Payloads Well-Accommodated/ Controlled

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It is important to note that the Space Platform used as a reference in this study was defined in NASA/MSFC document PM-001 (plus update data). The configuration and features of that system are illustrated in Figure 1-4.

Figure 1-4

SPACE PLATFORM

(MSFC REF. CONCEPT PM-001)*

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PAYLOAD BERTHING/VIEWING CAPABILITY
- 4 BERTHING PORTS (1 PARK)
- SELECTABLE 4 DIRECTION VIEWING PER PORT
- 3 PAYLOAD ELEMENTS CAN VIEW SAME DIRECTION (DEDICATED PLATFORM)
- NO VIEW OBSCURATION IN AT LEAST ONE DIRECTION

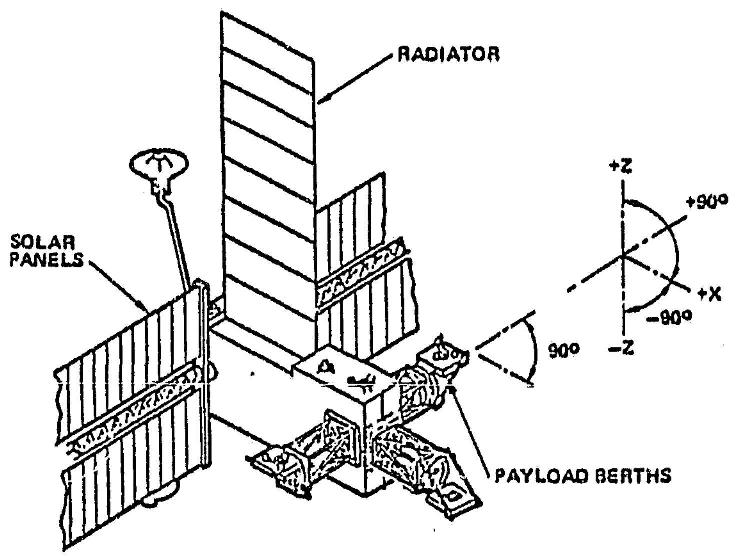
WEIGHT = APPROX 33,000 LB

POWER
- 25 KW
- 120 VDC AND 30 VDC

THERMAL CONTROL
- 25 KW HEAT REJECTION

STABILITY AND CONTROL (CMGS)
- WITHOUT POINTING SYSTEM
  - ACCURACY = 0.3° – 2°
  - STABILITY ±1 ARCMIN
- CROSS POINTING VIA PLATFORM ORIENTATION
- ENVIRONMENTS < 10^{-5} Gs

PROPULSION
- Isp = 230 SEC
- 2000-LB MONOPROPELLANT
- 30-DAY REBOOST



COMMUNICATIONS AND DATA HANDLING
- TDRSS CAPABILITIES (3.00 MBPS)
- DATA STORAGE: 32 MBPS RATE (3.6×10^{10} BITS TOTAL)
- COMPUTERS PROVIDE EXECUTIVE CONTROL (400 KOPS)

*12.5KW VERSION ALSO CONSIDERED

Section 2
MANNED PLATFORM (TASK B)

Overview

The manned platform in low earth orbit is seen to be the next major capability for NASA to support broad space mission goals in the areas of science, applications, technology and commerce. Such a capability offers the ultimate approach to capitalizing on the considerable synergism which is possible when man is used to complement machines in orbit. The vast potential of this type of capability has been proven in Skylab and will be proven even more so in Spacelab. However, since Spacelab flight will only last for a week or so, there is great interest among the principal investigators on many of the manned payloads on that vehicle to reside for much longer periods in orbit. This objective can thus be fulfilled by a permanently occupied manned platform. This then was the primary objective of the study, summarized here, namely to define a concept which effectively fulfills the requirements of those numerous payloads which specifically desire, or need, a permanent manned facility in low earth orbit.

Any concept of this scope must recognize the realities not only of budget constraints but also payload availability, both of which at present view, combine to prescribe a vehicle of modest beginnings and yet flexibility for growth into service of greater scope. It is apparent that the early manned platform will support Spacelab-type payloads and derivations thereof. Next, in preparation for later major operations, an interim step of advanced capability development must be accomplished. Finally, with such newly developed capabilities, major operations will be implemented to support such operations as large structure assembly, orbital transfer vehicle basing and spacecraft servicing. This latter major operational activity is envisioned as being feasible by the mid-1990s, if the enabling technology is developed in the early 1990s.

Basically, the technology to provide long-term residence for man in space is in hand and there are now payloads for science, applications and commerce in development which look forward to utilizing such a capability. The advanced capability to subsequently perform major complex operations must yet be developed and tested in orbit.

These then constitute the evolving mix of uses in prospect for the manned platform and the study covered here analyzed such potential uses and developed a cost-effective, evolutionary concept for fulfilling same, as shown in Figure 2-1.

The major objectives for the manned platform portion of the study were:

Define, evaluate and select concepts for an evolutionary approach to:

- A space station in conjunction with the Space Platform for NASA science, applications and technology.
- A permanently-manned presence in space early, with a maximum of existing technology.

The broad program objectives for the manned platform are as follows:

New Low-earth-orbit Capability

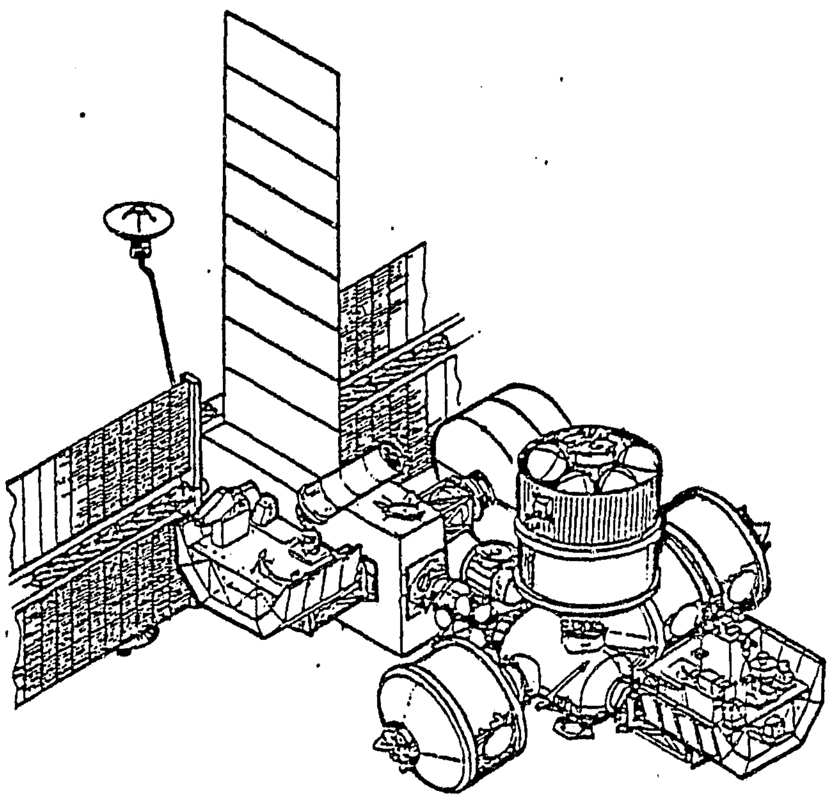
- Long-duration manned presence with periodic Shuttle visits

Schedule, Initial and Future Capabilities

- 1989 - Selected science, applications and technology payloads
- 1995 - Growth to support major operational missions on-site and in remote orbits

Figure 2-1

EVOLUTIONARY MANNED PLATFORM



Relationship to Other Capabilities

- Complement to unmanned spacecraft and short duration Spacelab

Support Systems

- Shuttle and Space Platform

Technology Approach

- Existing hardware wherever cost-effective

Manned, long duration platforms will fill a role in the U.S. inventory of payload carriers which has not been available since September 1973, when the last, or third Skylab crew departed from that great orbital facility, or Workshop, as it was called. In the future, it appears that another even more capable "workshop" will be needed to support not only the needs of science, applications and technology but eventually the centralized basing of major operations at one location in orbit to support a variety of missions performed with vehicles in other orbits, such as geosynchronous. In such a mode, the central orbital base would be used as a staging point for logistics, assembly, servicing of numerous unmanned spacecraft and stages.

In its various roles, the manned platform will thus provide an important and complementary segment of the overall spectrum of service offered by the U.S. payload carrier fleet, as shown in Figure 2-2.

This Task B thus addressed, with classic Phase A methodology, the prospects such a valuable system for the NASA inventory with the realization that it also will have great utility for other U.S. agencies, the world of commerce and international organizations.

In an undertaking of the magnitude in prospect for such an evolutionary manned platform, it is important to identify early those key program considerations which must be addressed, understood and well-defined as a basis for the entire development activity. Figure 2-3 lists those which appear at this time to merit such particular attention.

2.1 SYSTEM REQUIREMENTS (TASK B.1)

There are various categories of requirements which must be fulfilled in an effective, integrated manner. Figure 2-4 illustrates the categories involved in the manned platform system.

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Figure 2-2

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FUTURE SPACE ACTIVITIES VIA SHUTTLE

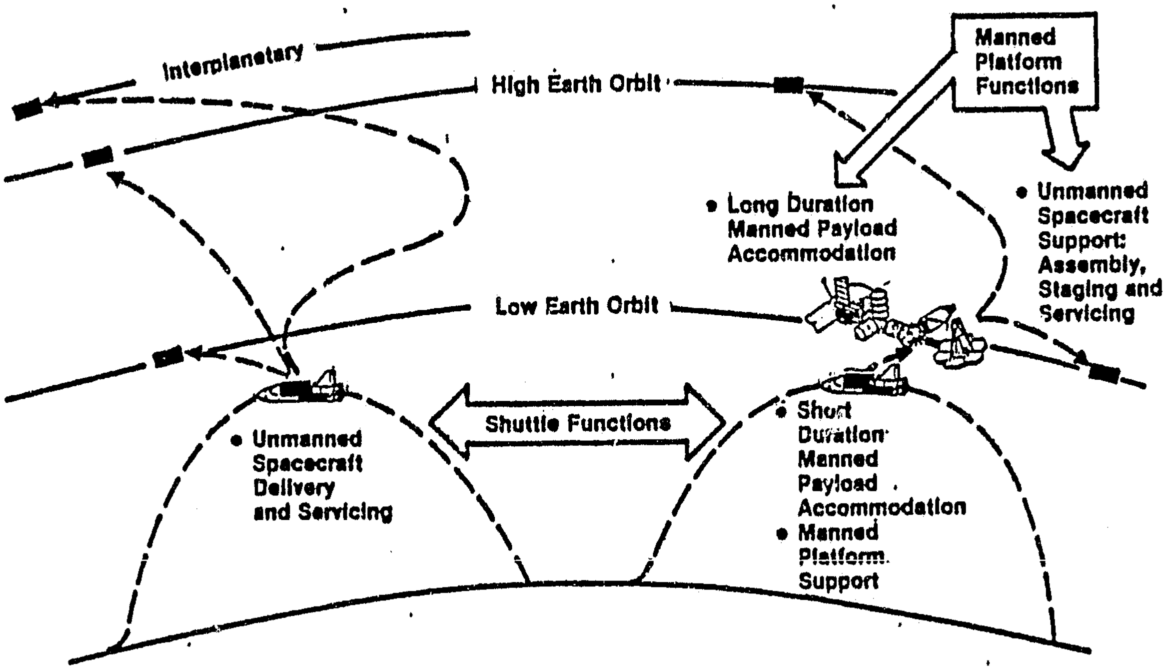

Figure 2-3

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KEY PROGRAM CONSIDERATIONS

- Foundation of Realistic Payloads
- Conservative Budget Assumptions
- Goals for Initial Capability
- Goals for Capability Growth Steps
- Capabilities of Power System
- Extent of Existing Equipment Use
- Revisit/Resupply Logistics Scope
- Safety and Contingency Management
- Involvement and Impacts of Participants Other Than NASA

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Figure 2-4

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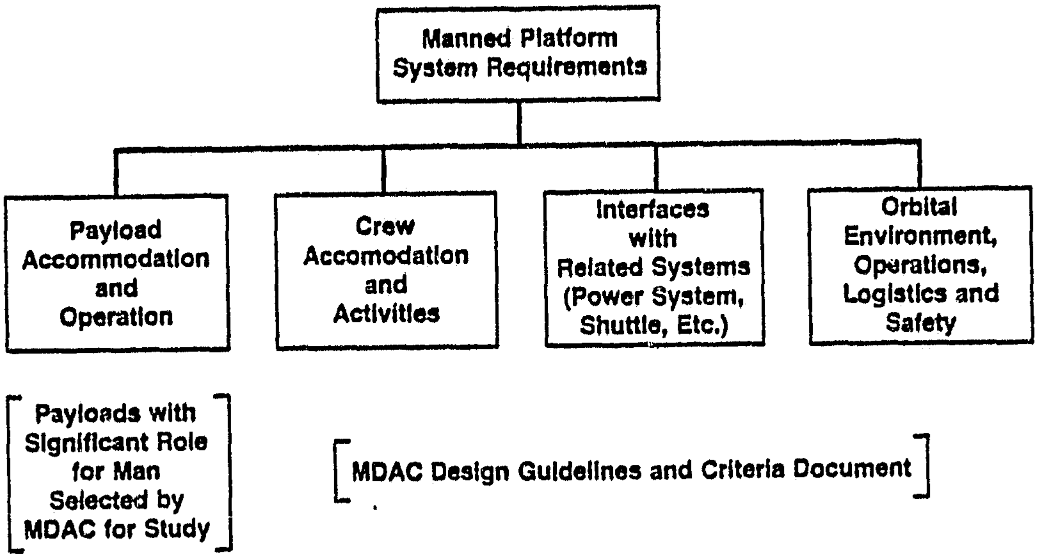
REQUIREMENTS CATEGORIES



2.2 PAYLOAD REQUIREMENTS

Since there is not as yet specific mission model or set of payloads planned for a manned platform, our study began with a survey of potential payload candidates. This survey covered (1) those manned-involvement payloads which are under development for short-duration Shuttle/Spacelab or Shuttle-only flights, (2) future concept payloads which would significantly benefit from manned involvement and (3) future concept missions which would benefit from support from a manned-base for assembly, staging or servicing.

The broad conclusions of this survey are shown in Figure 2-5 and indicate that there is a distinct and substantial role for a manned platform in at least four areas, with the earliest being those short-term flight (weeks) Shuttle/Spacelab payloads which desire and are convertible for longer term manned flight (months).

Specifically, the survey identified payloads of three types, as shown in Figure 2-6. Note that only certain science and applications disciplines are represented in this list.

Figure 2-5

VFL857N

EMERGING NEEDS FOR A MANNED PLATFORM

Longer Flight for Certain Shuttle/Spacelab Payloads

- The Number of Manned Sortie Payloads Is Growing and Many Will Benefit Substantially From Subsequent Flights of Much Longer Duration

New, Innovative Uses of Man

- Many Science, Applications and Commercial Project Plans Include Major Use of Man in Orbital Residence

Laboratory for Advanced Hardware and Techniques

- Many Future Space Missions will Be Large Scale and Require Advance Capability Developments Which Must be Pre-Tested for Long Periods With Man in Orbit to Evaluate Performance

Extensive Crew-Use in Large Scale Mission Support

- Many Weeks of Space Resident Crew Activity Will Be Required to Setup and Checkout Planned Spacecraft With Large Reflectors, Orbital Transfer Vehicles and Periodic Servicing

Figure 2-6

VFO799

MANNED PLATFORM PAYLOADS

Performance of On-Site Missions	• Solar-Terrestrial Science • Oceanography • Materials Processing (Pharmaceutical Experiments) • Life Science	Early Years
Performance of Advanced Capability Testing	• Propellant Storage/Handling • Large Structures • Remote Control Servicing • Environmental Controls • Sensors and Pointing Systems • EVA Techniques and Accessories • Unmanned Vehicle Maneuvering/Docking • Pharmaceutical Pilot Plant	Early Years
Operational Support for Remote Missions	• GEO-Mission Staging • Large Payload Setup/Alignment • Spacecraft Recovery and Servicing • Subsatellites and Targets • Pharmaceutical Production Plant	Later Years

In order to assure a reasonably substantial set of potential users for the manned platform being conceived, the payloads selected were only those which had active NASA sponsorship, either in study or development activity.

2.2.1 Solar Terrestrial Research

Among the classic categories of "viewing" sciences, only the Solar-Terrestrial and Oceanographic disciplines have defined research which specifically calls for man in orbit with viewing instruments for extended durations.

Solar-terrestrial investigators are on record with high interest in monitoring solar phenomenae and the impacts thereof on the earth's environment, such as the magnetosphere for example. Their contention is that the detailed dynamics of solar activity, such as flares, for example, must be observed in real time to shift focus to vernier targets of interest, to continually fine-calibrate instruments and to make protocol changes immediately after experimental deductions which are often based on numerous real-time inputs. These scientists, recalling considerable and valuable Skylab experiences in their discipline, look forward to the use of man on the manned platform as a sequel to the relatively short-duration flight research on Spacelab using modified versions of the same instruments. Figure 2-7 illustrates one group of instruments of specific interest to the solar-terrestrial community.

2.2.2 Oceanographic Research

Oceanographic scientists state that they look forward to a manned platform because viewing of extremely broad ocean areas is a new science and much is to be learned with man in space to determine what instruments and viewing aspects should be pursued, perhaps later unmanned. Also, a whole new realm of mesoscale ocean wave (capillary) phenomenon was introduced with Skylab and much more man-in-orbit and man-on-truth site research needs to be done to benefit not only science but Navy undersea tactics and surveillance (see Figure 2-8.

2.2.3 Biological Processing

High-cost/pound pharmaceuticals can be produced with high-efficiency in zero gravity in a free-flyer monitored continually and tended periodically by the crew of a manned platform as shown in Figure 2-9. Although heavily automated under sterile conditions, manned involvement is necessary not only in various stages of production, as shown in Figure 2-10, but also for rigid FDA quality control functions.

Figure 2-7

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MANNED PLATFORM — SOLAR/ TERRESTRIAL PAYLOAD CANDIDATES

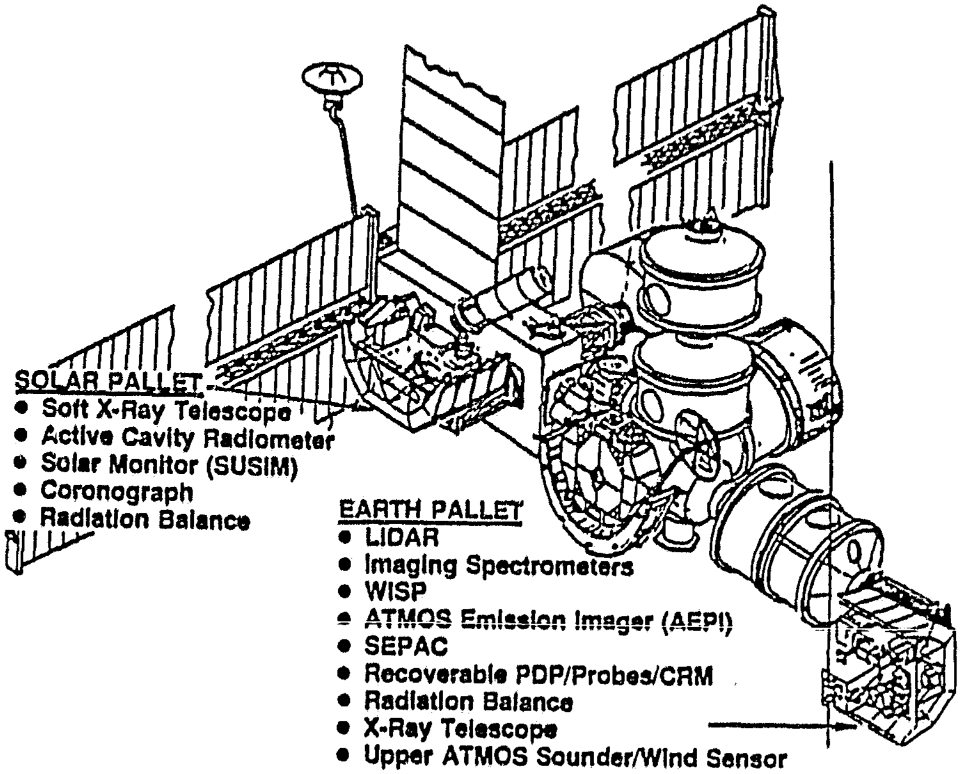

Figure 2-8

VFO365

ROLE OF MAN IN OCEANOGRAPHIC SCIENCE/APPLICATIONS FROM SPACE

Areas of Interest

- Resources (Fish, Biota, Minerals)
- Location of Phenomena
- Fluctuation of States
- Tracking and Prediction

Capabilities Required

- Trained Observers
- Synthetic Aperture Radar and Hasselblad Camera
- Truth Site Coordination
- Computer/Graphics

Role of Man

- Directing Observations Based on Multiple Inputs/Experiences and Viewing Eddies, Slicks With Sun Glitter, Etc

Skylab

- Crew Observations and Photos Contributed to New Awareness of Mesoscale Phenomena; Stimulated Truth Site Verification

Columbia

- Crew Observations, Synthetic Aperture Radar and Hasselblad Photos Provide Spectacular New Findings on Surface and Subsurface Phenomena

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Figure 2-9

PHARMACEUTICAL PRODUCTION

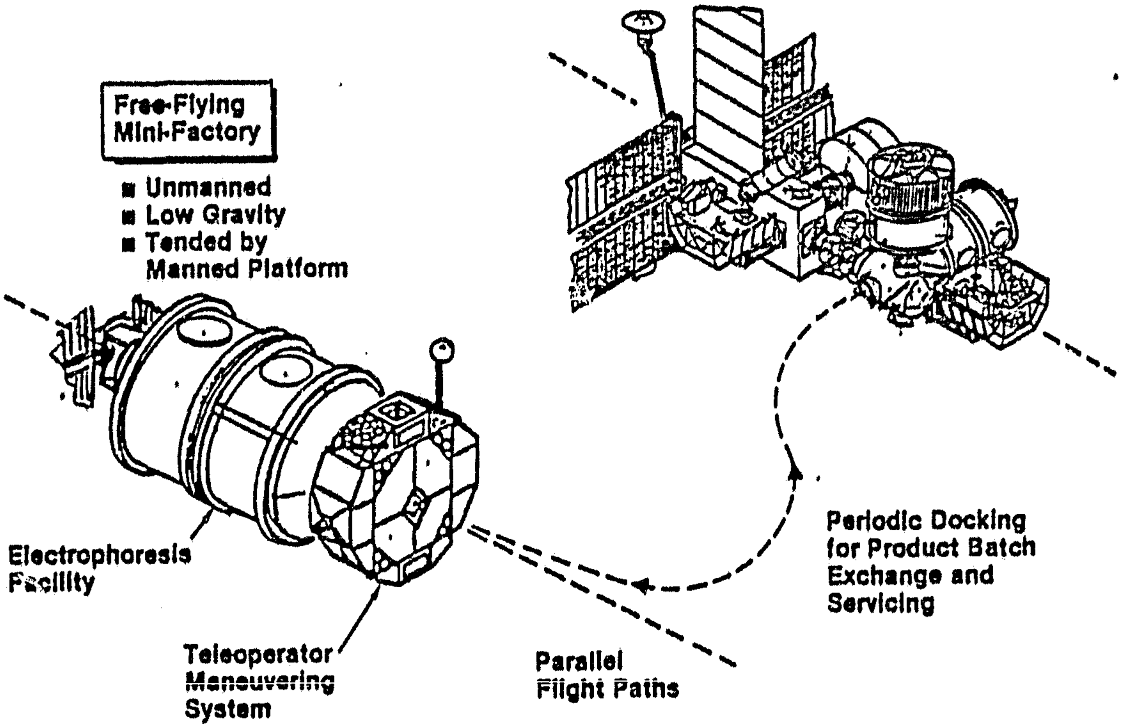
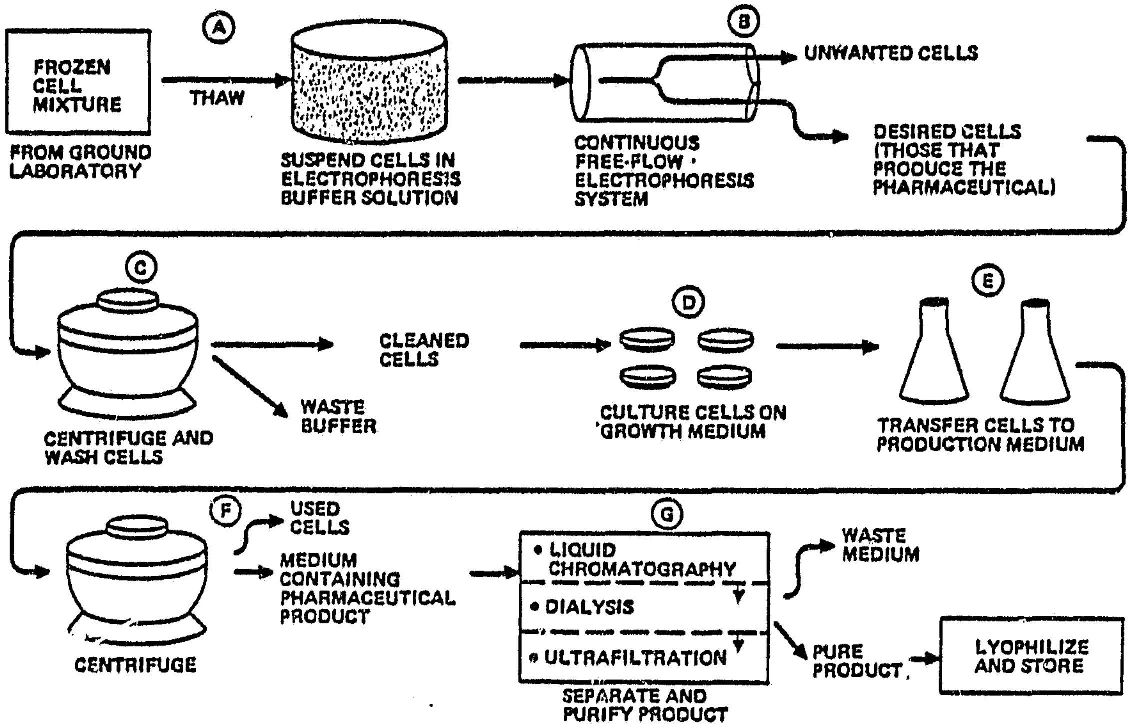


Figure 2-10

TYPICAL SPACE PHARMACEUTICAL PILOT PLANT
(Manned Involvement: Circled Letters)



2.2.4 Life Science Research

Life sciences, including biomedical and biological research, have long been an important user and proponent of manned platforms. Priorities in this science, as defined by MSFC, are (1) man's problems using man himself where feasible, (2) man's problems using non-human models and (3) basic biological phenomena and principles using a wide range of test species. Among the Spacelab payloads in this discipline are many which look forward to longer and more in-depth experimentation on a manned platform. Figure 2-11 illustrates how the equip- ment would change (escalate in scope of function) when a given experiment transitions from Spacelab to the manned platform. Note the additional prime and support function equipment involved in the later, more-detailed, involve- ment of the principal investigators with the specimens.

2.2.5 Technology Demonstration

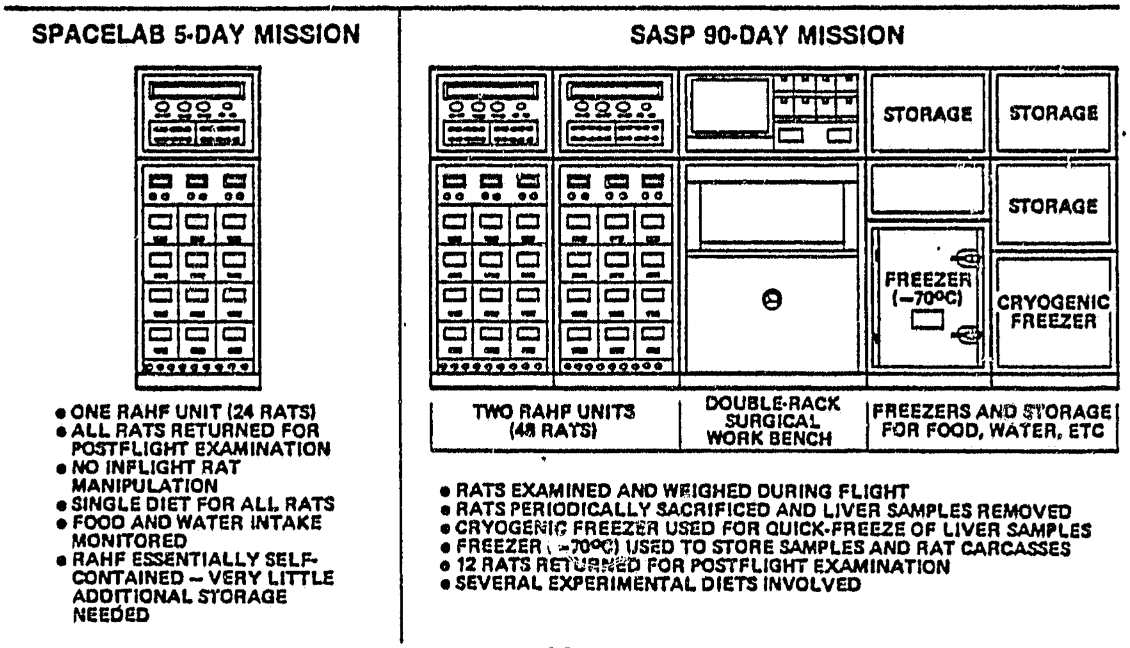
So much for science and commercial interests. The next six subjects pertain to "technology" demonstration or test experiments which are required to develop the advanced operational capabilities envisioned for the manned platform, namely large structure assembly/alignment, spacecraft servicing and orbital transfer vehicle basing.

Figure 2-11

SPACELAB 5-DAY MISSION VERSUS SASP 90-DAY MISSION APPROACH AND FACILITY REQUIREMENTS

VFK721N

Illustrative Experiment: Effect of Microgravity on Liver Function (Conversion of Carbohydrates to Lipids) in the Rat



2.2.5.1 ECLSS Technology Demonstration

Although our basic manned platform concept incorporates an environmental control and life support system (ECLSS) based on current state of the art components, (adapted from Spacelab and Shuttle); growth versions of the platform will require advanced technology.

Much NASA investment has gone into the development of such technology. However, for a given new operational system design, much is yet to be accomplished in this area. Much of such work can be accomplished in earth-based development laboratories but certain prototype equipment demonstrators can only be conducted in the space flight environment. The advanced equipment developed in such an activity would be highly-modular and easy to install in-orbit by the crew to upgrade capability by replacing support equipment.

Examples of the type of technology experiments suggested by Hamilton-Standard, a subcontractor in this study, are shown in Figure 2-12, in three areas, zero-g sensitive items, critical technology items and system integration items.

Figure 2-12

CANDIDATE ECLS TECHNOLOGY EXPERIMENTS

VFS238

Zero "g" Sensitive

- Electrolysis (Solid Polymer)
- Water Distillation (Phase Change Process)
- Shower
- Clothes Washer

Critical Technology

- Regenerable CO_2 Removal (Solid Amine)
- Atmosphere Monitor (Mass Spec)
- Water Quality Monitor
- Refrigerator/Freezer (Thermoelectric)
- Commode Change-out
- Trash Compactor
- Equipment Maintenance

System Integration

- Advanced Air Revitalization System
- Total Wastewater Processing System

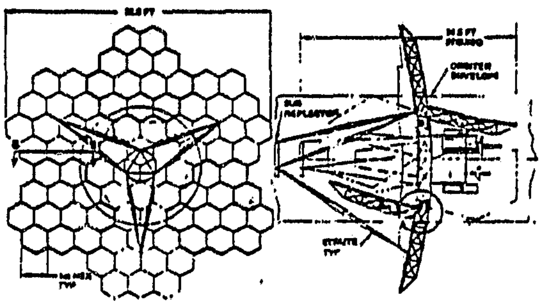
2.2.5.2 Large Reflector Structure Technology Demonstration

Future payload plans of both NASA and the DoD include many large (10 - 30 meter diameter) reflector systems for infrared, submillimeter and laser applications. Such structures have high-accuracy segmented mirrors backed by truss work, all foldable or separable in subassemblies, which include many hinges, latches or mechanisms for deployment, rigidization and alignment. Considerable crew time will be involved in activating such systems. Although such reflectors will be part of an unmanned spacecraft which flys somewhere separate in a solo mode, it requires a space station for buildup and checkout. Figure 2-13 lists the operations and structures challenges inherent on this prospect, plus an MDAC design for a representative payload, namely the Ames/JPL large deployable reflector.

Figure 2-13

LARGE OPTICAL-CLASS REFLECTOR PAYLOADS

VFM059N



Operations Challenges

- Deployment, Assembly, or Hybrid Setup
- Support Structure Rigidization
- Thermal Stabilization/Compensation
- Figure Control Activation and Checkout
- Shape Measurement and Alignment (Partial/Total)
- Spacecraft Integration (Upper Stage If Required)
- Spacecraft Checkout and Launch
- Time Required: Probably Weeks Vs Days (Platform Vs Shuttle)

Structure Challenges

- Support Structures Must be Compactable Yet Rigidizable
- Compactable Structures Have Many Articulation Joints, Which are by Nature:
  - Free To Move In At Least One Axis
  - Difficult To Analyze/Predict As To Dynamics
  - Difficult To Solidify Rigidize
- Rigid Structures Require High-Load, Rigid Joints
- Bolted Joints (EVA) Probably Have Benefits Over Automatically Actuated Joints (Load Capability, Dynamics, Cost and Reliability)

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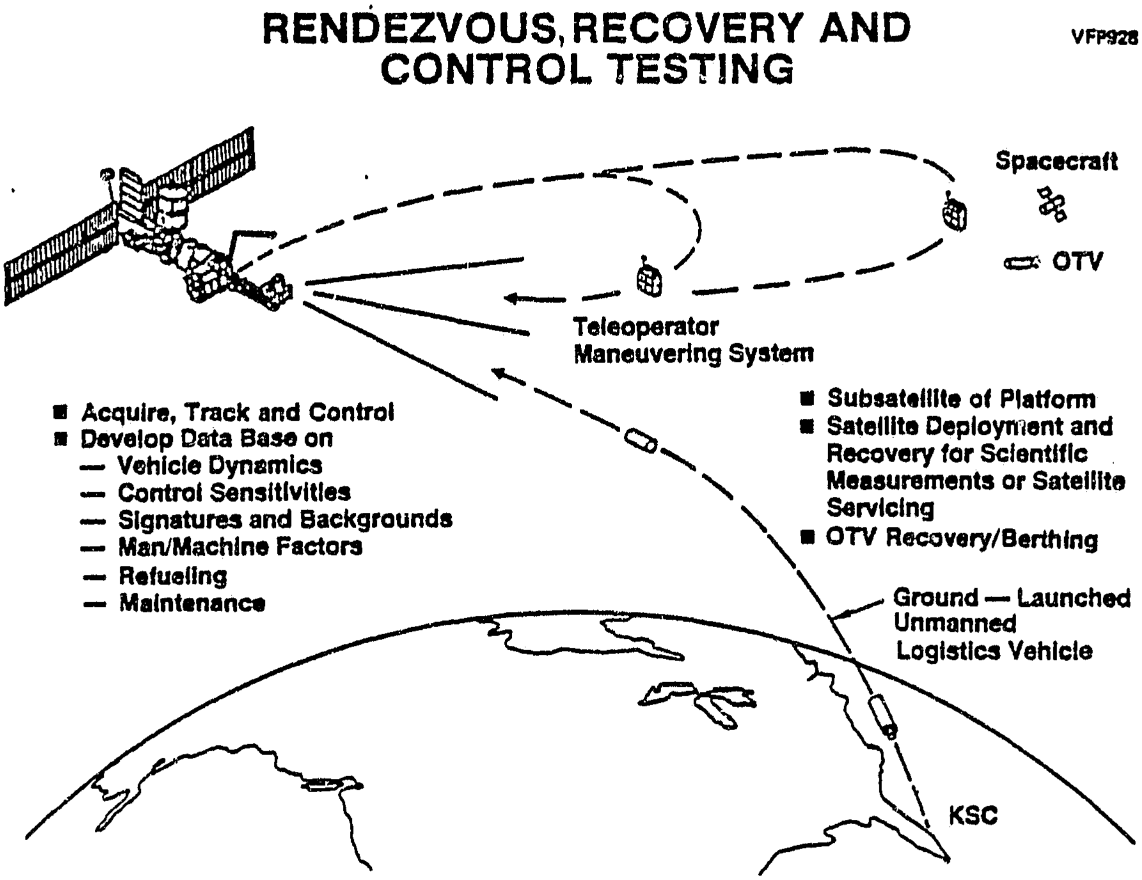
2.2.5.3 Rendezvous and Recovery Technology Demonstration

Many prospective orbital operations require the launch, rendezvous and recovery of subsatellite vehicles for target deployment, spacecraft servicing, orbital transfer vehicles and unmanned logistics vehicles.

This overall operational activity requires considerable demonstration testing ranging from subsystems through system demonstrations. Figure 2-14 lists the numerous areas of challenge in prospect for the development and demonstration of such capabilities, which are crew intensive in the development and operational phases.

Figure 2-14



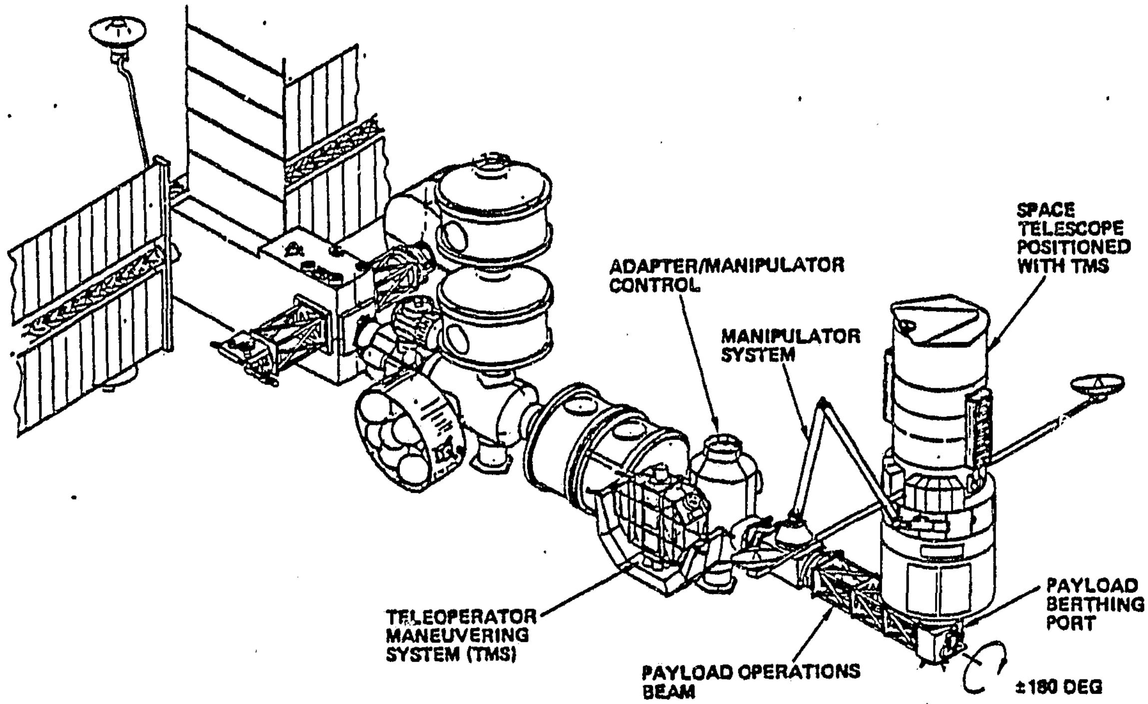
2.2.5.4 Spacecraft Servicing Technology Demonstration

Teleoperator vehicles can be used to retrieve spacecraft for servicing on the space station. Although considerable study has been devoted to remote control and EVA servicing in orbit, much remains to be developed once a particular space station design is finalized. A broad array of special servicing accessories must be integrated such as remote manipulators, lighting, EVA aids, berthing beams, interior servicing areas, etc. Again, here early technology demonstrations will be required before a full capability can be implemented as a routine orbital function. Figure 2-15 illustrates one example (Space Telescope) which is already designed for on-orbit servicing.

Figure 2-15

SERVICING RETRIEVABLE SPACECRAFT

VFM278N



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2.2.5.5 Orbital Transfer Vehicle (OTV) Technology Demonstration

There is a considerable potential for orbit-based OTV's to support growing needs of geosynchronous payload traffic. However, the berthing, storage, repair, refueling and launching of such vehicles is not an existing technology. Therefore, since there is not much of a design data base for such a system, particularly if it is to be cryogenic, considerable in situ (orbit) technology testing is required. As shown in Figure 2-16. Such testing would be performed in the second phase of the station activity as a precursor to the final routine operational mode.

Figure 2-16

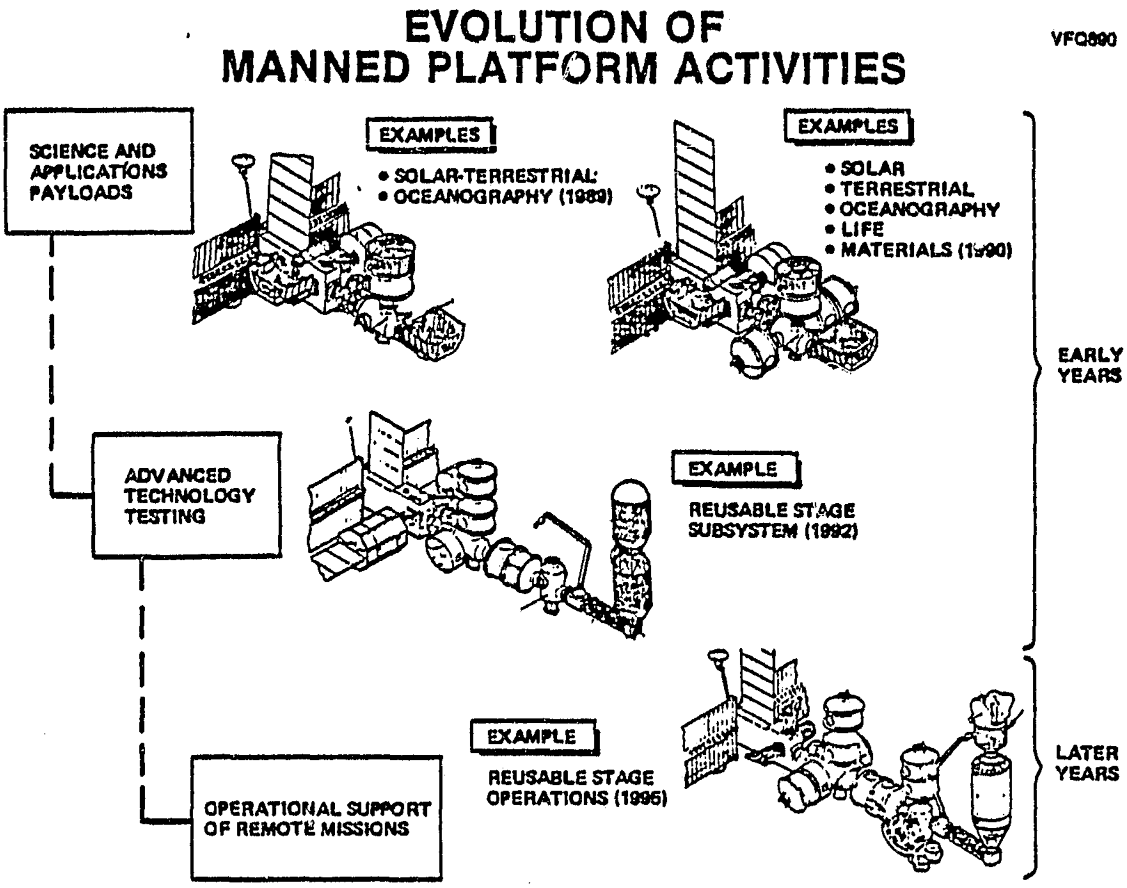

Figure 2-17 lists the technology experiments required to enable the development of a reusable cryogenic OTV, all selected because of an express need for demonstration in the actual orbital environment.

Figure 2-17

CRYOGENIC OTV EXPERIMENTS

VFM27114

Propellant Fill and Drain

- **Transfer Line Childown**
- **Tank Prechill (In-Orbit Chilldown vs Ground Chilldown)**
- **Tank Fill Without Venting**
- **Loading Accuracy**
- **Loading Times With Partial Acquisition Device on Tanker**

Propellant Storage (Long-Term)

- **Insulation — MLI vs MLI/VCS**
- **Zero-G Vent System**

Tank Assembly

- **Latching**
- **Umbilical Sealing**

Monitoring and Maintenance

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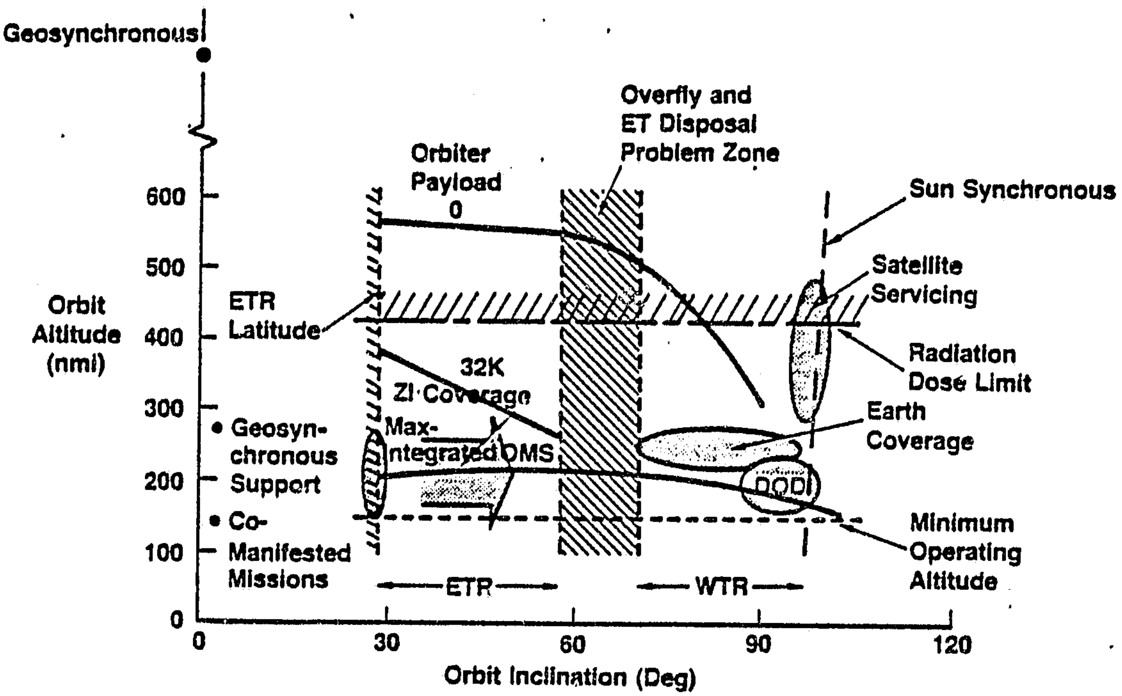
2.2.6 Mission Aspects

The orbit requirements and capabilities are summarized in the altitude-inclination chart of Figure 2-18. Orbit inclination is bounded by the launch site constraint 28.5° to 57° for ETR and above 70° for WTR. Missions dealing with logistics to higher energy orbits (primarily geosynchronous) would prefer the east launch inclination to maximize plane change velocity from LEO to GEO. Earth coverage missions would be better served with increased inclination, much coverage at 50° and total global coverage at 90°. Sun synchronous missions may well serve some specific long term earth viewing missions. The Orbiter delivery payload capability must be considered and is seen to decrease with increased inclination. The upper curve shows the upper limit; the zero payload altitude-inclination curve.

Figure 2-18

MISSION CAPABILITIES/REQUIREMENTS

VFK593N



In terms of orbit altitude the lower limit of 150 nm is determined by life-time and controllability due to aerodynamic drag. The upper limit of about 400 nm is due to radiation dose limits; it could be extended by adding shielding. Operating orbit altitude is primarily selected by a compromise

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between lifting capability of the Orbiter and orbit lifetime. The lower performance curve is the altitude of maximum payload delivery using the Orbiter integral OMS. (This allows full payload bay volume for payloads.) When both the Orbiter payload capability and drag propellant increases with decreased orbit altitude curve were considered and coupled with orbit lifetime in various contingency situations, an altitude of about 215 nm was selected for low inclination (ETR) and 170 nm for 90° (WTR).

The specific missions for the manned platform are not yet selected or funded. It is anticipated that they will be commensurate with a low cost early capability concept and thus deal heavily in the science and applications areas. Therefore, an initial orbit of 57° and 215 nm was selected to provide the earth and solar coverage and payload capability needs anticipated.

Should later operational missions warrant it another location would be 28.5° to serve the geosynchronous traffic and finally polar for total global capability.

The MSP requirements are summarized in Figure 2-19. IOC of 1990 is consistent with the needs of growing Orbiter and Spacelab mission demands and

Figure 2-19 VFM209N

MSP SUMMARY REQUIREMENTS

- IOC — 1990
- Orbit Requirements
  - Inclination — 57 Deg → 28.5 Deg → Polar
  - Altitude — (200-400) 215 Nominal
- Evolving Capability

	1989	1990	1992
• Crew	2-3	3-4	5-6
• Pallets	2	3	5
• Modules	1-2	3-4	5-6

- Simultaneous Multiple Orientation — Solar, Earth, Low g
- Logistics Compatibility — Orbiter, TMS, Stages, Logistics Vehicle

with a potential implementation schedule. The orbit evolution was decreased above and would proceed according to the dictates of planned mission needs.

The suggested crew capability needs are initially a two-man crew for activation with four men needed to accommodate a reasonable set of science and applications missions. Four men would provide the needed skill mix, two-shift operation and manhours per day.

The need for simultaneous multiple orientation capability is specified at the outset to take full advantage of the measurements being taken of the sun and the earth.

2.3 CONCEPT IDENTIFICATION, ANALYSIS/DEFINITION AND COMPARISON/SELECTION (TASKS B.2, B.3 AND B.4)

2.3.1 Introduction

Based on the requirements of payloads, interfacing systems and the crew, Task B.2 developed different candidate concepts for a manned platform. Then the prospects of each concept were evaluated. This resulted in two being selected for system analysis and definition (Task B.3) and the eventual selection of one for recommendation (Task B.4).

2.3.2 System Activity Profile

In order to fundamentally shape the configuration in prospect for the manned platform, a profile of the complete spectrum of activities was defined, as shown in Figure 2.3-1. This included not only a great variety of interior and exterior payload operations but also the crew habitation and operations support functions, as well as the initial activation and periodic Shuttle-based logistics visit functions that created significant interface considerations. Exterior operations would be substantial in number and would grow more complex through the years, which created significant influences on the congregation or dispersal of functions.

Figure 2.3-1

VFK496N

MANNED PLATFORM ACTIVITY SPECTRUM

Interior

- Payload Operations
  - Life Science
  - Material Processing Applications
  - Technology (Habitation Enviromental Controls, Etc)
- Control Center(s) for:
  - Interior Operations
  - Exterior Operations
  - Exterior Payloads
- Habitation
- Maintenance/Logistics
- Traffic (Daily Routine and Logistics)

Exterior

- Attached Payload Operations
  - Solar-Terrestrial Instruments
  - Oceanographic Instruments
  - Large Space Systems
  - Development of:
    - Technology (Prototypes, Performance Measurement)
    - Operations (Assembly, Alignment, EVA)
    - Assembly Accessories
  - Geo-Vehicle Buildup/Stowage/Launch
  - Spacecraft Servicing
- Attached/Detached Payload Operations (Tended/Tethered/Teleoperatored)
  - Material-Processing Experiments/Production
  - Free Flyers for Environmental Monitoring, Rendezvous Testing, Tow/Dock Services and Low-G Payloads
- Platform Sustaining Resource Installations
- Space Platform Interface
- Shuttle Interaction Operations

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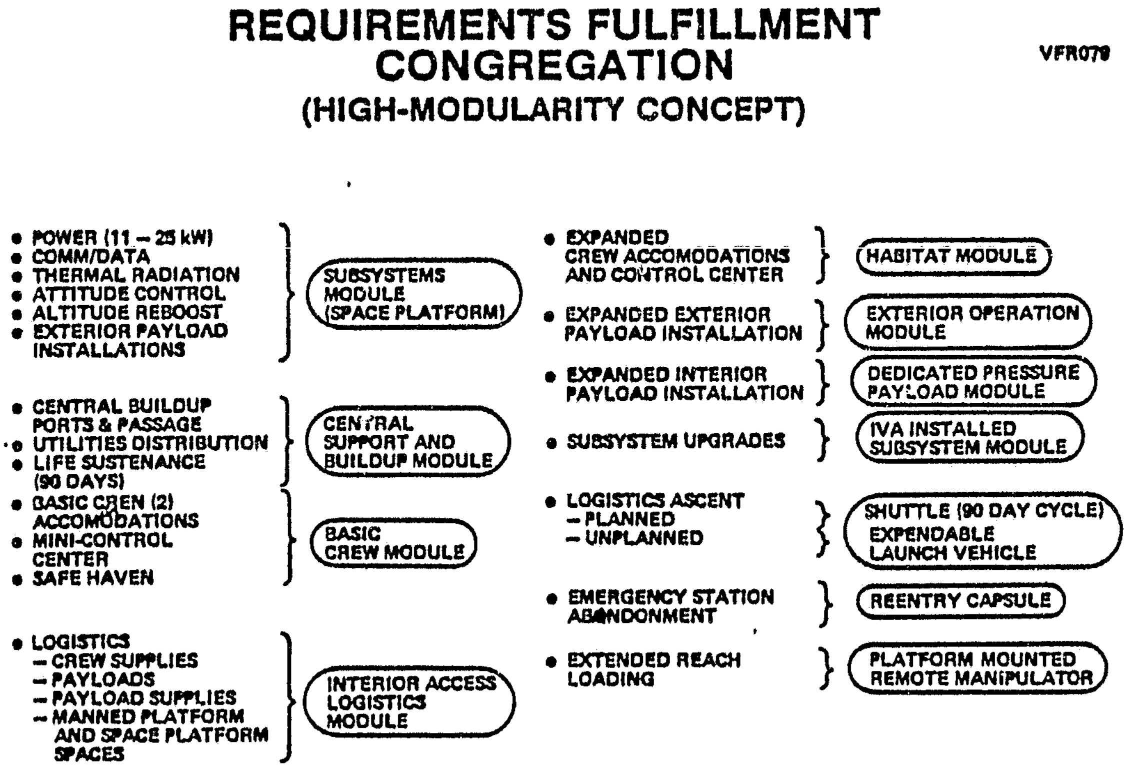
Planning of the system architecture began with the congregation of various prospective functions into modules, as shown in Figure 2.3-2. From past experience on Skylab and many NASA Space Station studies, much has been learned about the separate versus complementary nature of different functions. In particular, functions such as basic resources, central-buildup, habitation, contingency retreat, logistics and payloads are best modularized into separate entities for many reasons, although common elements could be used among them.

Figure 2.3-2.

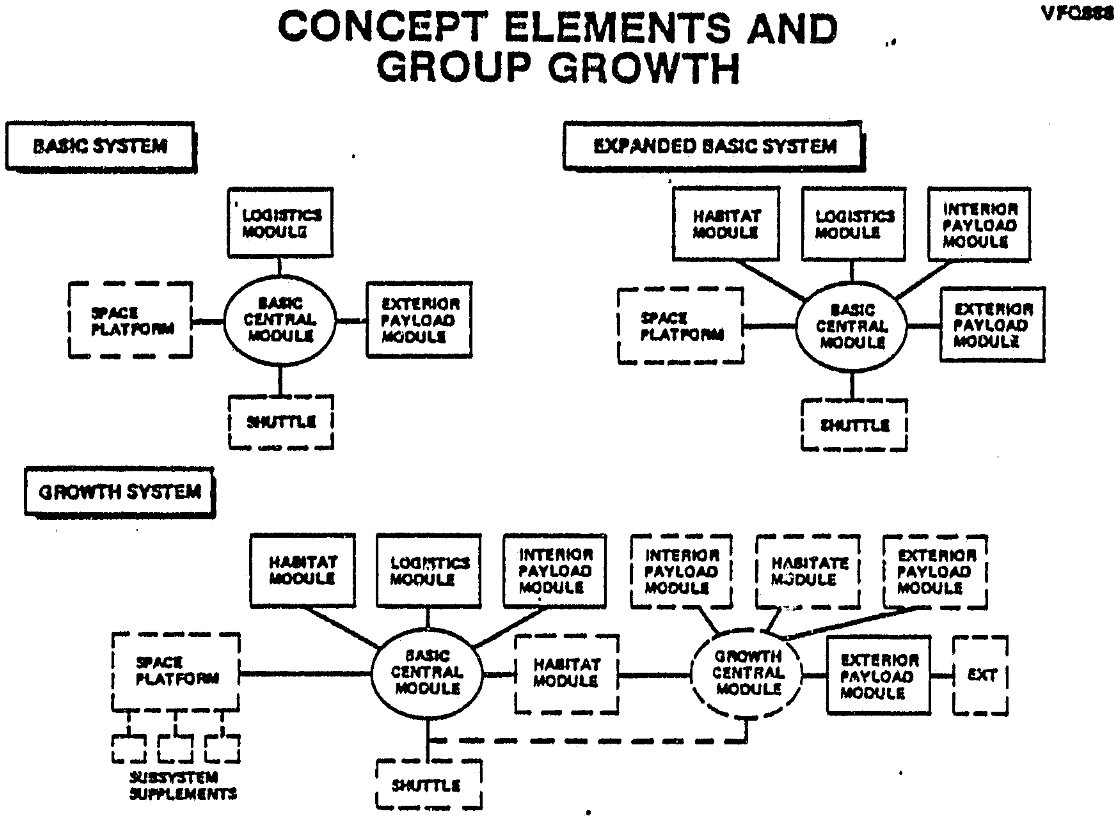


Since the size of the crew will most likely grow gradually from an early R&D activity level to eventual major operational activities, the habitats should be small (two- to three-man) in size and replicated for growth. Interior payload modules, whether dedicated to one payload or sharing a mix of payloads, should also be sized for modest beginnings and yet growth flexibility, i.e., probably the smaller the better.

The great increase in scope of exterior operations indicated modularity of increasing size to suit larger payload assembly and OTV and related propellant storage, payload assembly and launching, all of which indicate numerous berth or docking port requirements, multiple remote manipulators and above all an effective plan for growth.

As a sequel to congregating functions and assigning them to categorical modules, the elemental grouping of modules was mapped as shown in Figure 2.3-3. Reflected here are those consitutents needed for a basic manned capability, an expansion thereof and major growth additions. Inherent in this modular map therefore, are the berthing and subsystem interfaces created by the roles and location of each module. Here then we have the basic framework on which the evolving concepts were based. Note that the options include a "basic capability" which would provide a modest-cost introductory step, which has minimal accommodations for crew and interior payloads. This option was only considered briefly in the study.

Figure 2.3-3



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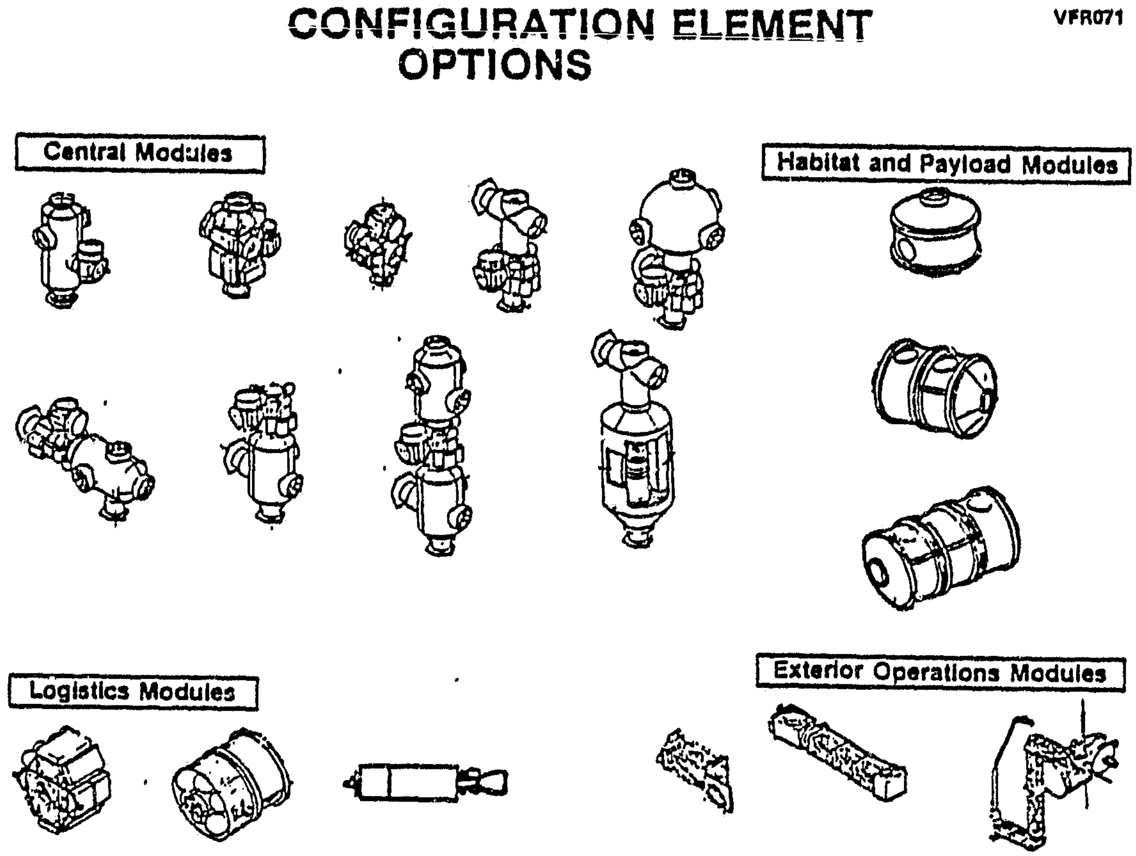
Next in the study, the features of the various modules were developed as shown in Figure 2.3-4. Central module options ranged from rack-tunnel types through designs with considerable interior volumes. Habitat and Payload Modules, (using cargo-bay-sized cylinders) were considered in three lengths, i.e., 1, 2 and 3 units of volume generally associated with a crew of two, some ten standard racks of equipment, plus appropriate access and passage. Logistic module options included again a rack-tunnel-type, one with greater interior volume and an unmanned/expendable launch vehicle-delivered unit. Exterior operations module options ranged from simple early versions for pallet mounting to highly-articulated, multi-arm units for assembly and servicing. These options were then evaluated from a standpoint of contributory value in various configuration buildups.

Figure 2.3-4



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After considering various combinations of modules, several emerged as more promising. These were selected as candidate approaches, and they are listed in Figure 2.3-5, including the important gradations in program scale or scope, namely ultra-low, low and medium-cost start options. Basically, the approaches coupled various types of central modules, habitats and logistics modules, a variety of cost-to-start options and some unique features applicable to the main options. Three special feature options were also included at this time, namely (1) lateral expansion, i.e., parallel rather than normal to the solar arrays to probe possible cluster advantages, (2) emergency crew return (some sort of reentry capsule) and (3) an unmanned logistics vehicle (akin to the USSR Progress vehicle which supports Salyut 6 frequently but really conceived in the 1968 MDAC study for MSFC on the S-IVB Space Station). These then are the candidates which will be studied and narrowed to two for detailed definition. The general configurations of the assemblages represented in these options are shown in Figures 2.3-6 and -7.

Figure 2.3-5

CANDIDATE APPROACHES TO SYSTEM EVOLUTION

VFR078

		FEATURES / APPROACH	SHUTTLE FUNCTION	OPERATIONAL PHASE: ULTRA-BASIC	OPERATIONAL PHASE: BASIC	EXPANSION PHASES: I	EXPANSION PHASES: II	EXPANSION PHASES: III
	①	3 SEG MODULES/AFT EXP INTEGRAL HAVEN/HABITAT TUNNEL RACK ADAPTER EVA/UMBIL/MODUL LOGIST MEDIUM COST START	DELIVERY / REVISIT		HABITAT, ADAPTER AND LOGISTICS MODULES	ADD HABITAT & EXT OPS MODULES	ADD GEO STAGING MODULES	ADD MAJOR GEO BUILDUP MODULES
	②	2 & 1 SEG MODULES/AFT EXP INTEGRAL HAVEN/ADAPTER IVA/UMBIL/MODUL LOGIST ULTRA-LOW COST START	DELIVERY / TENDING / REVISIT	CENTRAL MODULE AND SPACE PLATFORM	ADD LOGISTICS MODULE	ADD EXPANSION HABITAT	ADD INT & EXT PAYLOAD MODULES	ADD GEO STAGING MODULES
	③	2 & 1 SEG MODULES/AFT EXP INTEGRAL HAVEN/ADAPTER IVA/UMBIL/MODUL LOGIST LOW COST START	DELIVERY / REVISIT	CENTRAL MODULE AND SPACE PLATFORM	ADD LOGISTICS MODULE	ADD EXPANSION HABITAT	ADD INT & EXT PAYLOAD MODULES	ADD GEO STAGING MODULES
	④	2 & 1 SEG MODULES/AFT EXP INTEGRAL HAVEN/ADAPTER IVA/UMBIL/MODUL LOGIST MEDIUM COST START	DELIVERY / REVISIT		CENTRAL, LOGISTICS & HABITAT MODULES	ADD INT & EXT PAYLOAD MODULES	ADD GEC STAGING MODULES	ADD MAJOR GEO BUILDUP MODULES
SPECIAL	⑤	LATERAL EXPANSION	DELIVERY & REVISIT			ADD INT & EXT PAYLOAD MODULES	ADD GEO STAGING MODULES	ADD MAJOR GEO BUILDUP MODULES
SPECIAL	⑥	EMERG CREW RETURN	DELIVERY	INTRODUCTION TIMING OPTIONAL				
SPECIAL	⑦	EMERG UNMD LOG	DEL/RET	INTRODUCTION TIMING OPTIONAL				

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Figure 2.3-6

CANDIDATE EVOLUTIONARY APPROACHES

VFR077

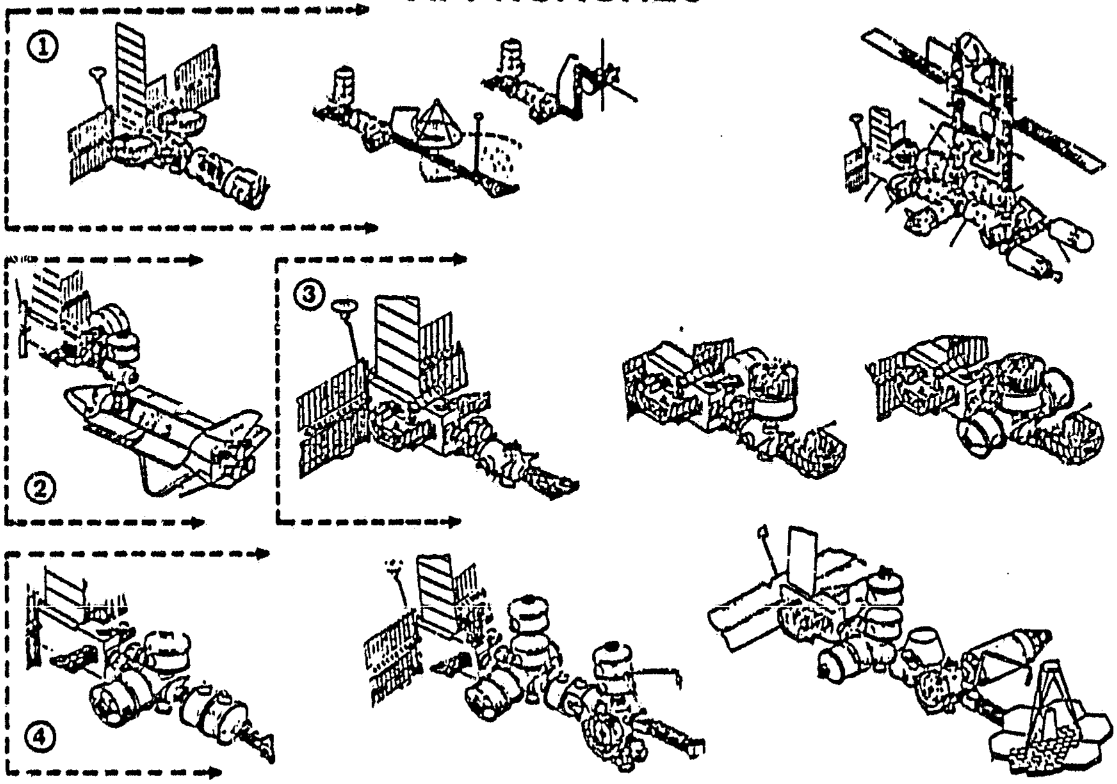
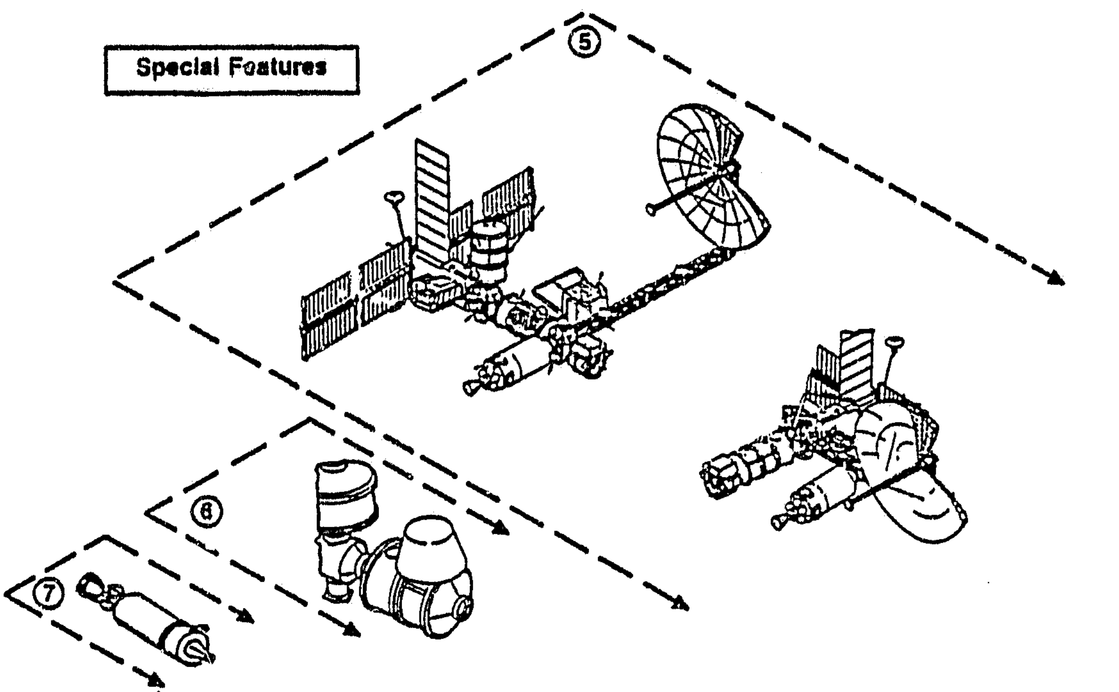


Figure 2.3-7

CANDIDATE EVOLUTIONARY APPROACHES (CONT)

VFR072



After comparing Concepts #1 and #4, Concept #4 was selected for more detailed definition plus costing. Key conclusions in the elimination of Concept #1 were the following:

1. A rack/tunnel-type central module did not offer the internal crew volume needed to incorporate a safe-haven capability which we concluded was vital to the central module function.

2. A three-segment habitat module was judged to be too large for a basic element of initial and future growth configurations because (a) it was too large to be delivered in one launch with the type of central module envisioned, (b) it fostered the configuration of too many payload activities in the same volume with crew staterooms and (c) it represented a major modification to the largest Spacelab module if such (European participation) were involved.

3. A rack/tunnel-type logistics module would not provide the substantial internal volume anticipated as needed for stowing interior payloads or "camper"-type quarters for potential low-cost increases in crew size.

4. In the special feature category the lateral expansion approach was dropped because of restrictions in "operating" room and attitude control. The emergency crew return vehicle was deferred as a concept for further study. An unmanned contingency logistics vehicle concept was developed but also deferred for further "need" study.

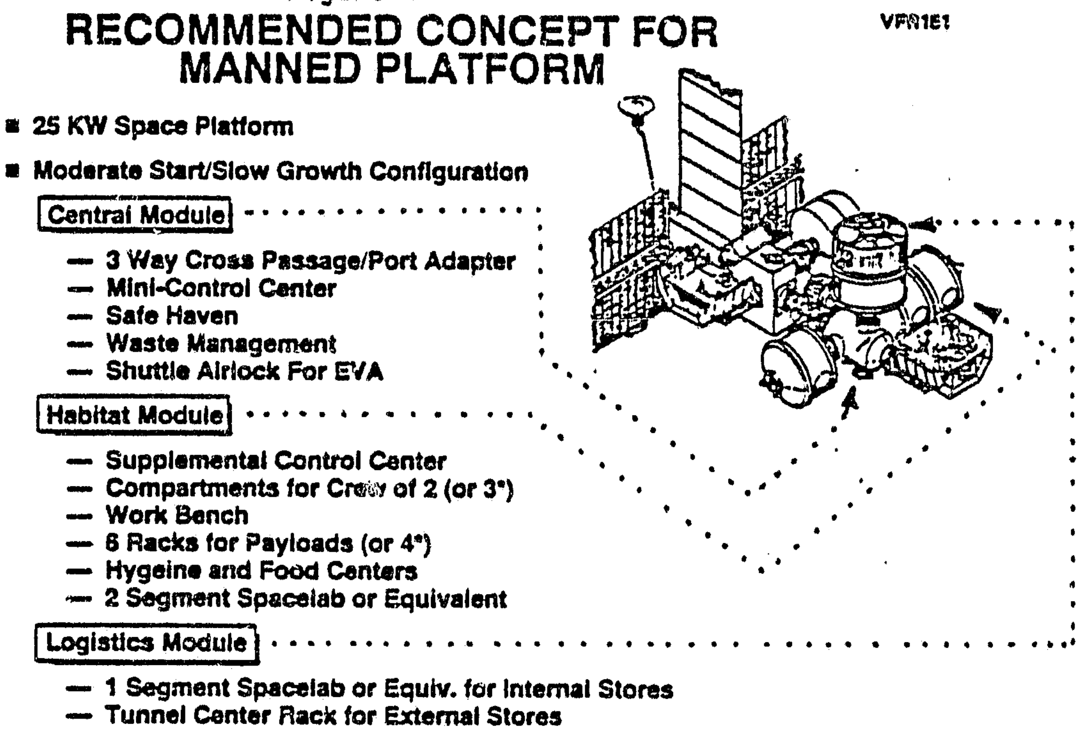
Thus the #4 concept was recommended as optimum from numerous standpoints as opposed to Concept #1 and any of the special features evaluated.

2.4 RECOMMENDED CONCEPT FOR MANNED PLATFORM

The basic configuration recommended, shown in Figure 2.4-1, incorporates a 25 kW Space Platform berthed to a pressurized Central Adaptor Module with a two-segment habitat attached, serviced by a pressurized logistics system. It provides accommodations for a crew of two to four for 90 days, exterior and interior payloads, significant use of existing hardware and potential for substantial future growth.

The 25 kW Space Platform provides power, heat rejection, communication/data management and attitude stabilization. Provisions are provided to accommodate exterior palletized payloads as well as pressurized payload modules. The earth-viewing payloads are berthed to a truss beam relocated to the aft port of the central adaptor from the 25 kW Space Platform. This beam provides necessary rotation for continual earth tracking.

Figure 2.4-1



2.4.1 Central Module (Airlock/Adapter)

During the concept formulation phase it was determined that the Airlock/ Adapter was the key element. As a result, key subsystem functions were

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incorporated such as mini-control center, waste management, atmospheric gases, ECLS elements, EVA support and backup supplies. Components were identified, interface parameters established and envelope restrictions were defined. Physical characteristics of nine concepts, ranging from a minimum transfer tunnel to an all up "workshop" were measured against the various requirements. The 8.12 m long, internally stiffened aluminum shell concept, shown in Figure 2.4.1-1 emerged as the configuration that provided the largest adapter compatible with a two-segment Habitat in a single launch and still provided maximum payload berthing plus maximum interior volume. The internal volume provides a safe haven for up to four persons in an emergency situation and will provide adequate habitat provisions for two crewmen for 120 days.

The unit serves as a distribution center for services and passageway to each berthed module and it provides all services required to support EVA, including suit drying and repair.

Figure 2.4.1-1

AIRLOCK/ADAPTER INBOARD PROFILE

(PORT SIDE)

VFO487

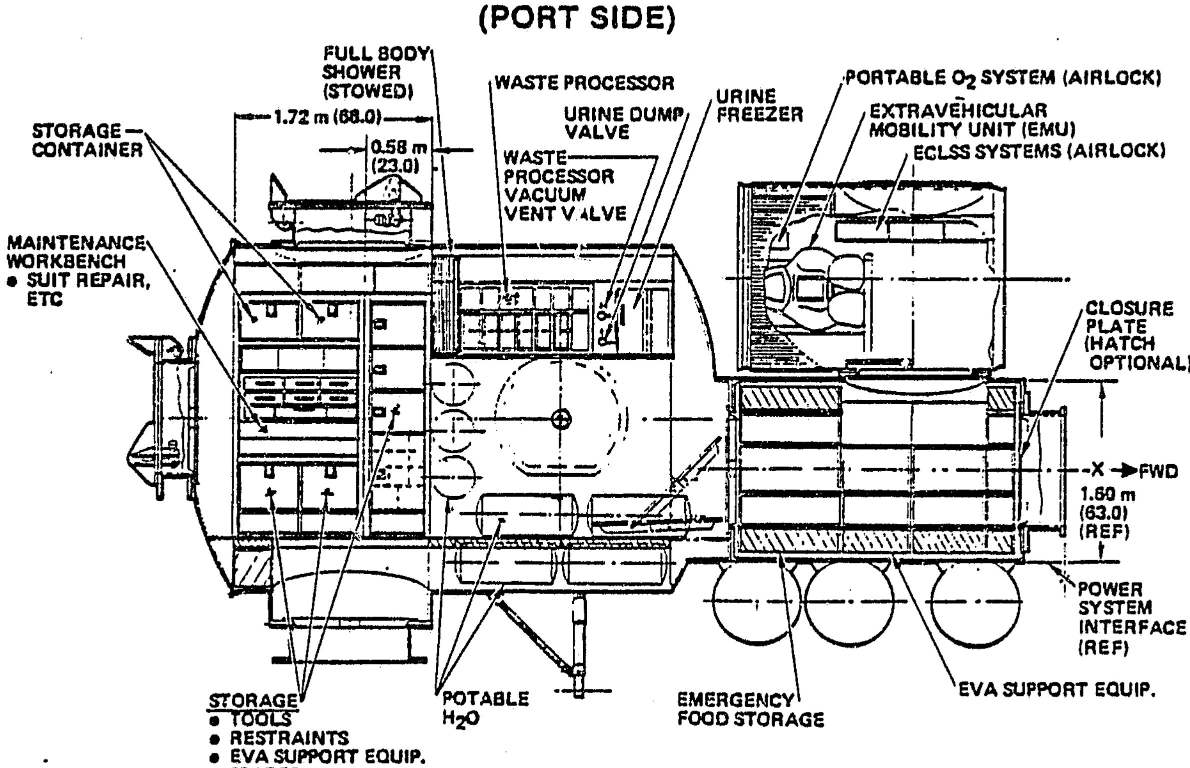

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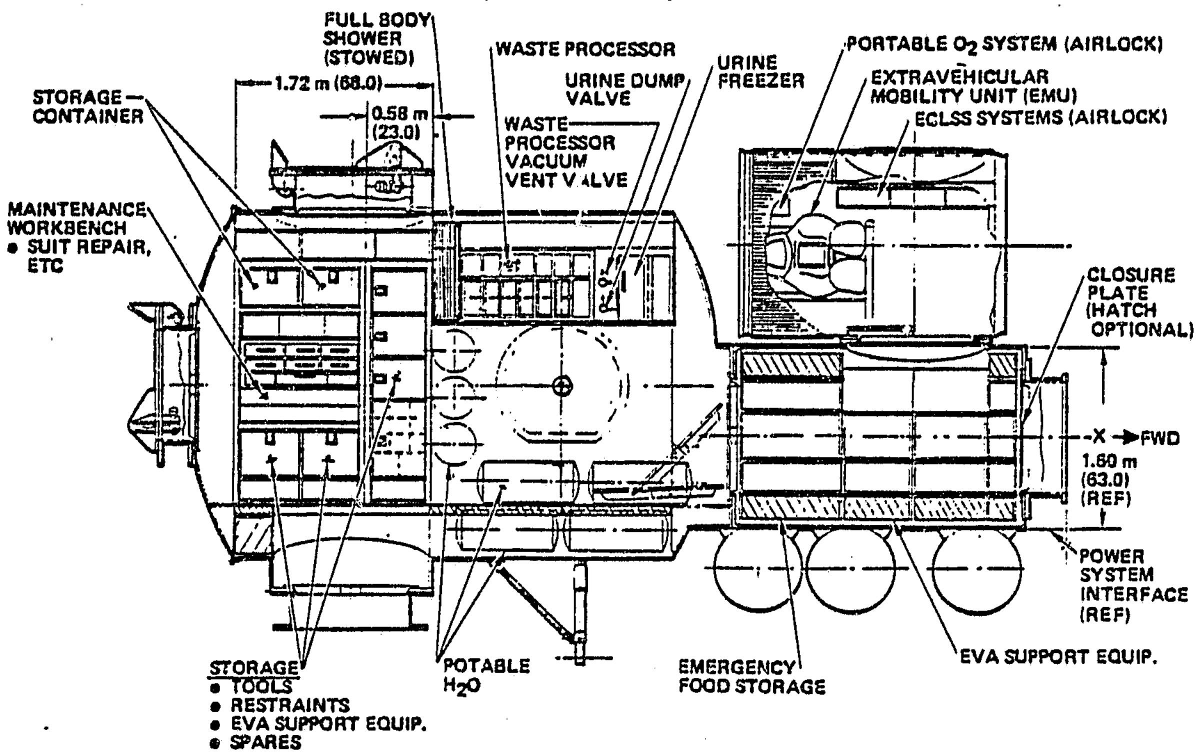
Figure 2.4.1-1

AIRLOCK/ADAPTER INBOARD PROFILE VFO487

(PORT SIDE)



2.4.2 Habitability Module

Sizing and configuration of the Habitat depended on assumptions for manning and payload requirements and subsystem functions allocated to the module. A multi-trade concept formulation process assisted in identifying the choices available and established the basic approach. One key issue was use of existing Spacelab hardware versus new development. It was concluded that maximum use of such existing equipment was both feasible and cost-effective. Another basic trade involved a new three-segment versus the existing two-segment Spacelab analysis, the latter being selected. The inherent flexibility of the Spacelab permits selective internal rearrangement to accommodate the crew. Crews of two, three or four were considered for periods up to 120 days. Four arrangements for sleeping were studied with the full 2.8 m^3 volume, upright compartment selected as best fulfilling the requirements. Body waste and hygiene functions were also of major concern. Based on Skylab experience the waste management system was located in the adapter while the hygiene facility was placed in the Habitat. A Skylab-type food management system, sized for 14 days of meals, is incorporated with 0.418 m^3 of frozen food storage.

The arrangement shown in Figure 2.4.2-1, accommodates three crewmen plus two double racks of mission payload equipment. The opposite side (not shown) would have one or two crew quarters depending on a crew size of two or three.

2.4.3 Logistics Module - 180-day Configuration

In evaluating five methods of providing crew sustenance resupply, including total EVA, IVA/EVA mixture and total IVA methods, it became obvious that a large pressurized volume would be required for payload exchange or resupply and possible extra crew bunking. Operations scenarios indicated that use of a logistics system sized for 180-day resupply cycle would minimize cargo bay volume impacts associated with resupply. Crew exchange is possible at 90-day intervals with payload only launches or resupply flights.

The module shown in Figure 2.4.3-1 is configured to provide pressurized, controlled environment for cargo requiring such, plus an unpressurized section for atmospheric tankage. A one-segment Spacelab is used with a "birdcage"-type interior rack system. The rack is sized to accommodate 19.0-inch wide equipment

Figure 2.4.2-1

VFO485

HABITABILITY MODULE INBOARD PROFILE
(STARBOARD SIDE)

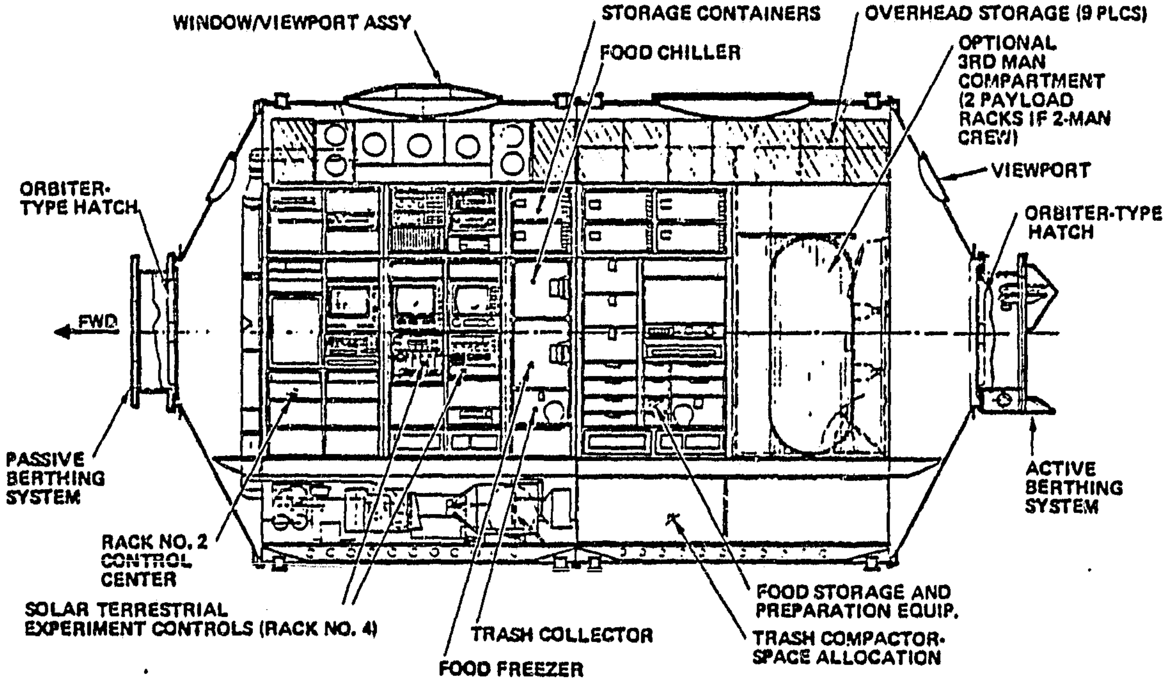
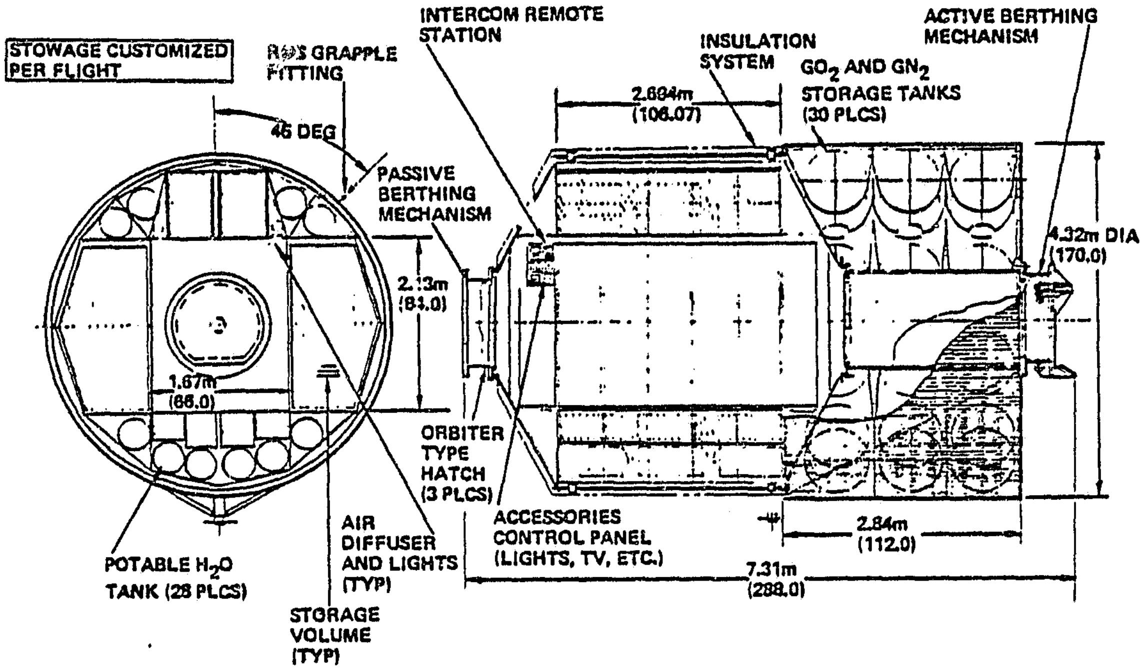


Figure 2.4.3-1

VFO585

LOGISTICS MODULE — 180-DAY CONFIGURATION



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and/or storage containers. Thirty GO_2 and GN_2 tasks are housed in an unpressurized structural element 2.84 m long. The 1.14 m diameter tunnel through this section provides IVA and/or EVA passage. Contingency isolation, with an activatable ECLSS kit is envisioned.

The module shown is a multipurpose unit. It not only delivers the supplies but becomes the on-orbit pantry, trash collection storage area and it can be an alternate safe haven in emergency situations.

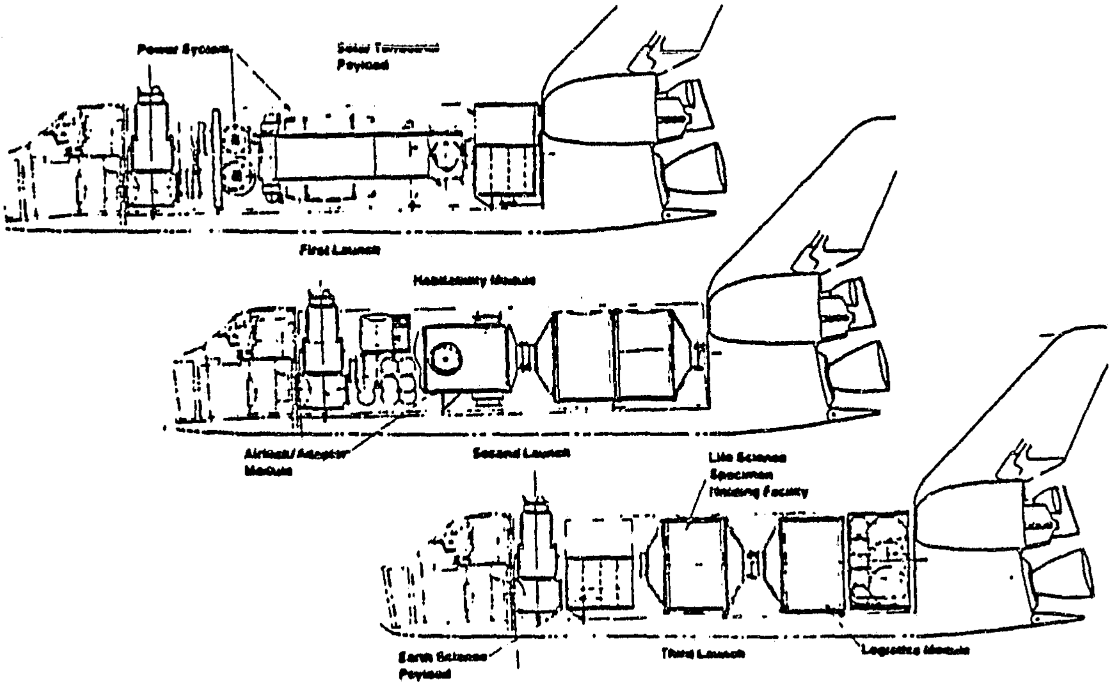
2.4.4 Initial Operational Launch Sequence

The favored MSP operational launch sequence (shown in Figure 2.4.4-1) begins with launch of the 25 kW Space Platform and one palletized payload. The Space Platform is verified, activated and with payload attached, placed on-orbit to await delivery of the MSP. The second launch delivers the Central Airlock/Adapter Module and the two-segment Habitability Module. After berthing, checkout and verification, the cluster is manned and placed on-orbit with a crew of three with supplies for 90 days. After 90 days, the third launch

Figure 2.4.4-1

INITIAL OPERATIONAL LAUNCH SEQUENCE

VFQ097



delivers the Logistics Module, a single segment research facility and the Earth Science payload. With two launches, the MSP is a permanently manned platform with some research facilities for three persons, however, with additions of the third launch elements, the MSP is a complete manned orbital facility, with considerable interior and exterior payload capability.

2.4.5 Environmental Control and Life Support Subsystem (ECLSS)

Key features of the selected ECLSS, highlighted in Table 2.4.5-1, include use of the basic Spacelab ECLSS which has been improved with the addition of condensate water recovery and a regenerative CO_2 removal. These improvements reduce resupply and represent cost savings partly due to a reduced number of water tanks and LiOH expendables.

Built-in redundancy for critical functions results in fail operational capability for each of the two separate ECLSS subsystems. Since each ECLSS is sized to accommodate the full crew, a 100 percent overload capability exists for crew turnover operations. Maintenance capability enables replacement of failed

HAMILTON STANDARD

Table 2.4.5-1

VFO543

KEY FEATURES OF MSP ECLS

- Regenerable CO_2 Removal
- Partial Water Loop Closing
- Fail-Operational/Fail-Safe
- Maintainable Equipment
- 100% Crew Overload Capability
- No Throwaway Growth Design
- Optimum Use of Existing Qualified Equipment
- Low Cost and Low Program Risk

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or outdated components so that the subsystem can be restored to initial or changed to improved capability.

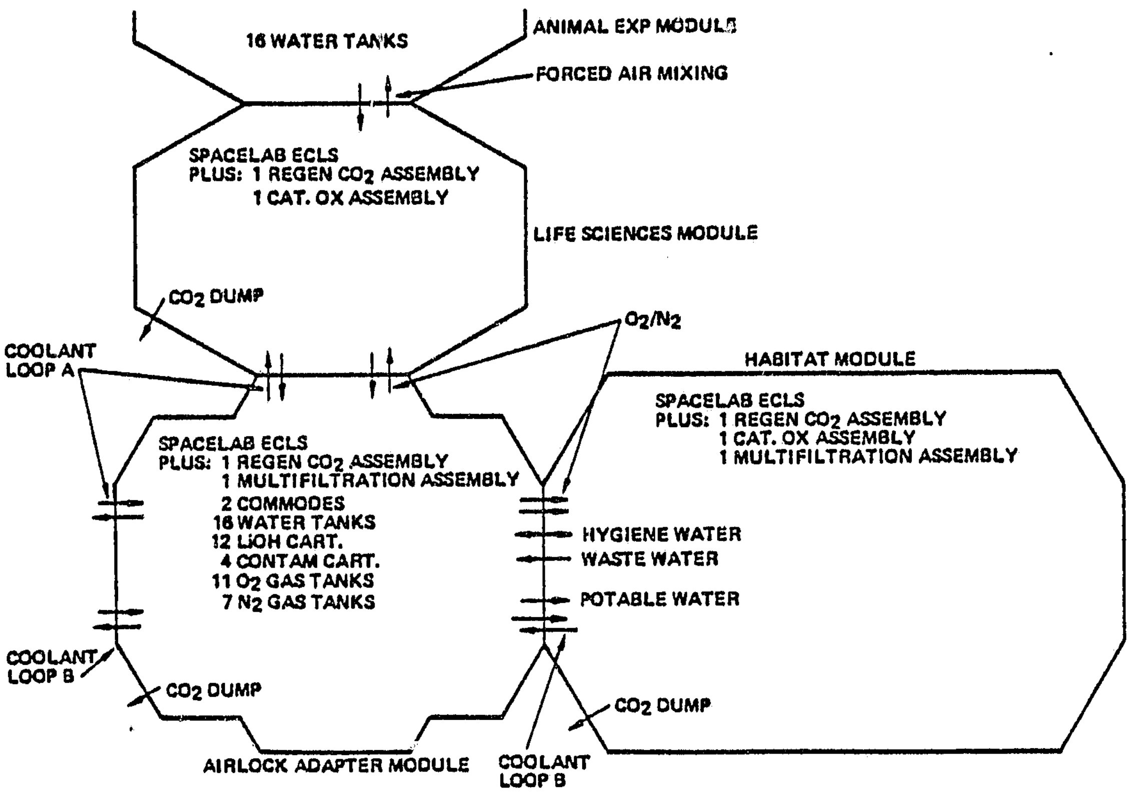
The design has a no-throwaway feature in that the solid Amine CO_2 removal system can be used in the growth version. Instead of the CO_2 being directed overboard, it will be directed to a Sabatier unit for O_2 recovery. The condensate recovery unit will be used for cleanup of water processed in a vapor compress./distill. or thermoelect. integr. membrane evap. subsystem.

Trade results indicated that an optimum design should include about 75 percent of Spacelab and Orbiter existing qualified hardware. This feature along with no requirement for advanced technology results in a low cost and low program risk design.

The ECLSS equipment is arranged to provide for two separate and independent units servicing the two separate compartments shown in Figure 2.4.5-1. The Habitat module forms one compartment, the second compartment consists of the

Figure 2.4.5-1

HAMILTON STANDARD **BASIC MSP ECLS EQUIPMENT LOCATION** VF0648



Airlock/Adapter, the Logistics Module and the Payload Module. No forced circulation exists between the two compartments and each is serviced by a separate cooling water loop.

Each major module contains a Spacelab ECLSS and a regenerative CO_2 removal unit. The Spacelab CO_2 control assembly is used for odor/contaminant control by replacing the LiOH canisters with charcoal canisters. Twelve LiOH canisters are retained in storage for emergency CO_2 control. Catalytic oxidizers are located in the Life Sciences Module and the Habitat Module.

Condensate processing (multifiltration) assemblies are located in the Habitat Module and the Airlock/Adapter. Contingency water is stored in the Airlock/Adapter; normal resupply water resides in the Logistics Module.

Contingency oxygen and nitrogen are stored on the exterior of the Airlock/Adapter; normal resupply tanks are mounted on the exterior of the Logistics Module.

2.4.6 Command and Data Management Subsystem (CDMS)

A CDMS concept has been developed for the manned platform that accommodates a wide range of missions and crew activities and can be implemented with low risk. The key features of the CDMS concept are shown in Table 2.4.6-1. The

Table 2.4.6-1 VFO672

CDMS FEATURES

- **Utilizes Developed Equipment**
- **Provides Flexible Crew Accommodation**
- **Accommodates SP and Orbiter Interfaces**
- **Exhibits Improved Reliability**
- **Accommodates Platform Growth**

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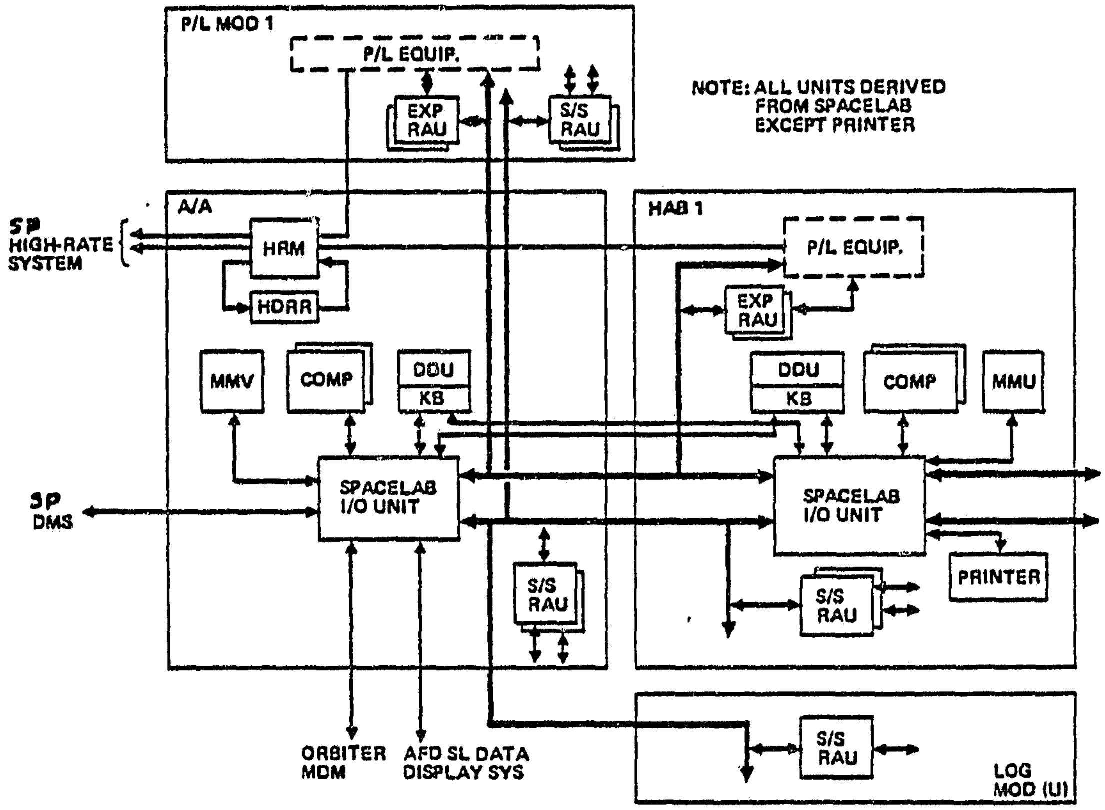
concept was based on existing equipment designs to show that such an approach is feasible. However, it is apparent that significant gains in performance, reliability and weight are available by using CDMS equipment that is based on current electronics technology. The selected concept uses hardware elements from the Orbiter and Spacelab CDMS's and enhances the subsystem reliability by using additional on-line redundancy plus onboard spares that can be installed by crew members. Platform growth is accommodated in the CDMS through the use of multiple-access data buses for data acquisition and distribution and by the use of standard module-to-module interfaces for data exchange.

Figure 2.4.6-1 shows that part of the CDMS that acquires, stores, processes, displays and distributes subsystem and experiment data. Spacelab CDMS equipment is widely used. Modifications are required to the Input/Output (I/O) units to accommodate the Space Platform interface and to be compatible with the additional redundant units (e.g., computer and MMU). The data buses can be extended to additional modules as the platform evolves. These added modules could have Remote Acquisition Units (RAU) under control of the central computer

Figure 2.4.6-1
PLATFORM
DATA MANAGEMENT SUBSYSTEM



complex or could have I/O units and processors to accommodate a more autonomous data processing approach.

In addition to these services, the CDMS provides capabilities for audio communications, both intra-vehicle and with the ground, Orbiter and other external elements, video acquisition, display and communication, timing signal generation and distribution and caution and warning display. The hardware required to implement these functions is not a difficult development and can, for the most part, be derived from Shuttle and Spacelab.

The software key features and issues inherent in this CDMS prospect are listed in Tables 2.4.6-2 and -3.

2.4.7 Power Distribution Subsystem

This subsystem must interface with the Space Platform (Power System) and distribute regulated 30 VDC main bus power to subsystems and experiments in the

Table 2.4.6-2

VFR428

MSP SOFTWARE — KEY FEATURES

- **Standardized, Tightly Controlled Interfaces**
  - **Data Formats and Definition**
  - **Data Transfer Protocols**
  - **Display Formats**
- **Common Executive Designed to Support Transportable Applications Modules**
- **Single HOL**
- **Selected Use of Distributed, Embedded Processors**
- **Extensive Ground Validation Prior to On-Orbit Configuration Changes**
- **Build on Spacelab Software**

Table 2.4.6-3

MSP SOFTWARE — KEY ISSUES

VFR426

- Multiple Hardware Configurations
- On-Orbit System Integration
- Flight System Autonomy
- Development Cost and Schedule

MSP core modules and attached payloads. In addition, a three-bus 30 VDC interface is provided at the Orbiter berthing port. The basic EPS must retain flexibility to accommodate platform growth and to distribute power over increased line lengths to subsystem and experiment load centers.

The concept for this susbsystem is sized to accept the 25 kW rated output of the Space Platform at the three-bus 30 VDC interface. The design makes maximum use of Spacelab equipment and subsystem design. Emergency power buses are derived from the main buses in the Airlock/Adapter power distributor. Design features are summarized in Table 2.4.7-1.

Trades and issues studied include (a) impact of subsystem power requirements, (b) configurations for supplying AC power, (c) EPS growth options, (d) considerations of emergency power, and (e) insufficiency of a 12.5 kW SP.

Subsystem power consumption based on using Spacelab equipment accounts for nearly one-half of the power from the 25 kW Space Platform and over 90% in the case of a 12.5 kW Space Platform. Average DC and AC power requirements for the platform subsystems by module location are given in Table 2.4.7-2. Possible means for reducing subsystem power consumption are identified in the study.

Table 2.4.7-1

SELECTED ELECTRICAL POWER DISTRIBUTION SUBSYSTEM DESIGN

VFR362

- Spacelab Derived Design
- Nominal 25 kW Rating
- 30 VDC Main and Emergency Power Buses
- AC Power from Local Inverters
- Combination Manual/Automatic Power Management
- Single Point Ground
- Growth Provisions

Table 2.4.7-2

SUBSYSTEM AVERAGE POWER IN WATTS

VFR363

	Logistics Module		Airlock/ Adapter		Habitability Module		Payload(1) Modules	
Subsystem	DC(2)	AC(3)	DC	AC	DC	AC	DC	AC
CDMS	19	—	1274	154	1232	154	179	—
ECLS	45	—	362	1502	416	1601	335	592
HAB	120	—	2	10	153	6	—	—
EPDS(4)	44	—	651	—	719	88	429	30
Subtotals	228	—	2326	1749	2483	1849	943	622
Total DC and AC	228		4075		4332		1565	

(1) Initial Version — Total for Two Life Science Payload Modules
(2) 28 Vdc
(3) 115/200 Vac 400 Hz
(4) Includes Allowances for Subsystem Wiring and Inverter Losses

The selected scheme for AC power distribution (distributed inverters) is based on the use of Spacelab inverters and AC load transfer provisions that are compatible with Spacelab AC power switching.

Power distribution options for accommodating platform growth include extension of the main 30 VDC power buses and utilization of the Space Platform 120 VDC interface. Voltage drops through the system can result in unacceptable low voltages at the experiments for an extended 30 VDC system. Utilizing the 120 VDC interface introduces a double penalty for regulation, i.e., 120 VDC regulators in the Space Platform and 30 VDC regulators on the manned modules. The preferred alternative is to take power directly from the Space Platform unregulated high voltage buses.

Provisions for emergency power byond the emergency buses in the baseline design depend on requirements for contingency operation. Backup batteries could be added to assure continuous operation of critical control functions. In the extreme, additional batteries could be required as part of a crew survival/rescue kit.

2.4.8 Structural/Mechanical Subsystem

An overall assessment of the MSP structure was made to surface concerns that must be addressed in the future. Concerns for each of the MSP modules and the assembled platform are listed in Table 2.4.8-1. From a systems standpoint, docking joint compliances and thermal distortion effects on pointing are the most significant items.

Docking joint compliances require an in-depth analysis to ascertain dynamic response/MSP attitude control interaction. Attention must be paid to design details that affect joint compliance and an iterative design/analysis process may be required to solve the compliance problem.

Thermal distortion is a pointing problem because orbit position and structural temperatures are related and are transient parameters. Estimates of stable temperatures, temperature gradients and repetitive temperature changes are necessary to adequately predict structural deformation and the capability for fine pointing. Experiment location on the platform is also a factor in

Table 2.4.8-1

STRUCTURAL/MECHANICAL CONCERNS VF0738

Spacelab Module

- **End Dome Strength For Docking Loads**
- **10-Yr Life Limitations**

Airlock/Adapter Module

- **High Pressure System Design Assurance**
  - **Design Factors of Safety**
  - **Fracture Mechanics Analysis**
  - **Meteoroid Penetration Protection**
- **Airlock Fatigue Life**

Assembled Platform

- **Docking Joint Compliances Increase Assembly Flexibility (Dynamics/Control Problem)**
- **Thermal Distortions Affecting Pointing Requirements**
- **Design For "Leak-Before-Failure" Condition to Preclude Catastrophic Pressure Loss**
- **Reboost Loads on Modules and Connections**

pointing when more than one experiment is pointing at the same time. A design limit needs to be established for platform controlled pointing. A systems study of experiment pointing requirements is needed to define the limit. Any requirements exceeding the limit will necessitate auxiliary pointing equipment on the experiment.

2.4.9 Attitude Control Aspects

An orbital disturbance moment analysis was performed to assess whether the Reference Space Platform (SP) CMG and magnetic torquer sizing was adequate for a typical Manned Space Platform (MSP) configuration. The results are preliminary because the MSP flight requirements and the momentum management operational scheme are not well defined. The results were generated based on assumptions and conditions which are shown on Figure 2.4.9-1.

The moment disturbances on the MSP which were analyzed were aerodynamic, gravity gradient and gyroscope (local vertical orientations). Past analyses have shown that aerodynamic moment can be significant at the orbital altitudes

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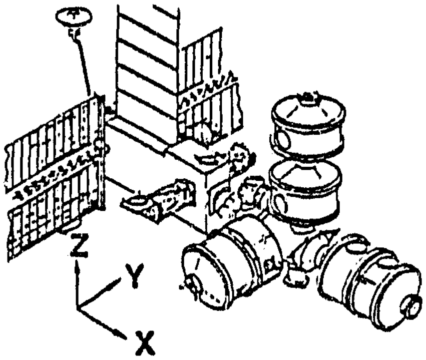
Figure 2.4.9-1

VF0724

REFERENCE SP ACS SIZING ANALYSIS



Reference Space Platform (25 kW)

- **Three Modified Skylab CMGs**
- **Four Space Telescope Magnetic Torquers**

Conditions Analyzed

- **200 and 235 nmi Altitudes**
- **0, 40, and 80 deg β-Angles**
- **57.5-deg Inclination**
- **Medium, High, and Worst-Case Atmospheric Densities**
- **June 21 — Time of Year**
- **Five Inertial Orientations**
- **Two Local Vertical Orientations**

planned for MSP (370-435 km). Three atmospheric densit conditions were assumed, representing medium, high and worst-case conditions. The density histories were generated with the Jacchia III atmosphere model (NASA SP-8021, March 1973).

The MSP configuration chosen in the analysis is shown on Figure 2.4.9-1. The solar array size corresponds to a 25 kW electrical power capability to the payloads. The Space Platform payload modules include an habitability/payload module (opposite end from solar arrays), an airlock adapter (connects modules to Reference SP), a logistics module (left side), a life science research laboratory (second from top).

Typical results of the MSP external disturbance analysis are shown in Figure 2.4.9-2. The results are in terms of how long an orientation can be maintained without saturating the CMG momentum capability and do not reflect orientation restrictions due to other considerations such as heat rejection or electrical power. In all cases, a 25 percent CMG momentum margin was maintained.

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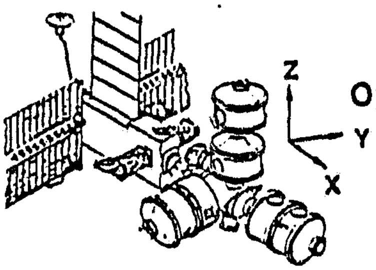


Figure 2.4.9-2 VF0725

REFERENCE 25 KW PS ACS ORIENTATION HOLD CAPABILITY FOR MSP

Medium Atmospheric Density

Principal Axes Orientation	Orientation Hold Duration (Orbits)					
	235 nmi			200 nmi		
β (deg)	0	40	80	0	40	80
XPOP-YPSL	∞	∞	∞	∞	∞	∞
XPOP-ZPSL	∞	∞	∞	∞	∞	∞
YPOP-ZPSL	120	∞	∞	4	550	∞
ZPOP-YPSL	44	∞	∞	3	∞	∞
ZSI-XIOP	∞	3	26	8	2	13
ZLV-XPOP (YVV)	12	16	15	2	2	2
ZLV-YPOP (XVV)	∞	∞	∞	∞	∞	∞

Three Skylab CMGs and Four Space Telescope Electromagnets

The Reference Space Platform ACS design of three Skylab CMGs and four Space Telescope electromagnets will allow operations of the MSP configuration studied. Operations may be restricted at times with respect to orientation hold duration for some orientations, especially at lower altitudes and higher atmospheric densities. The XPOP-YPSL orientation is relatively easy to control and is desirable for a number of reasons including good electrical power, heat rejection and payload viewing capabilities. The XLV-YPOP(XVV) local vertical orientation is also relatively easy to control, but electrical power capabilities degrade approximately as the cosine of orbit Beta angle and may only be useful for low Beta angle orbits. The other local vertical orientation (ZLV-XPOP) has good electrical power and heat rejection at high Beta angles but may have limited hold duration because of the large thermal radiator-induced aero torques.

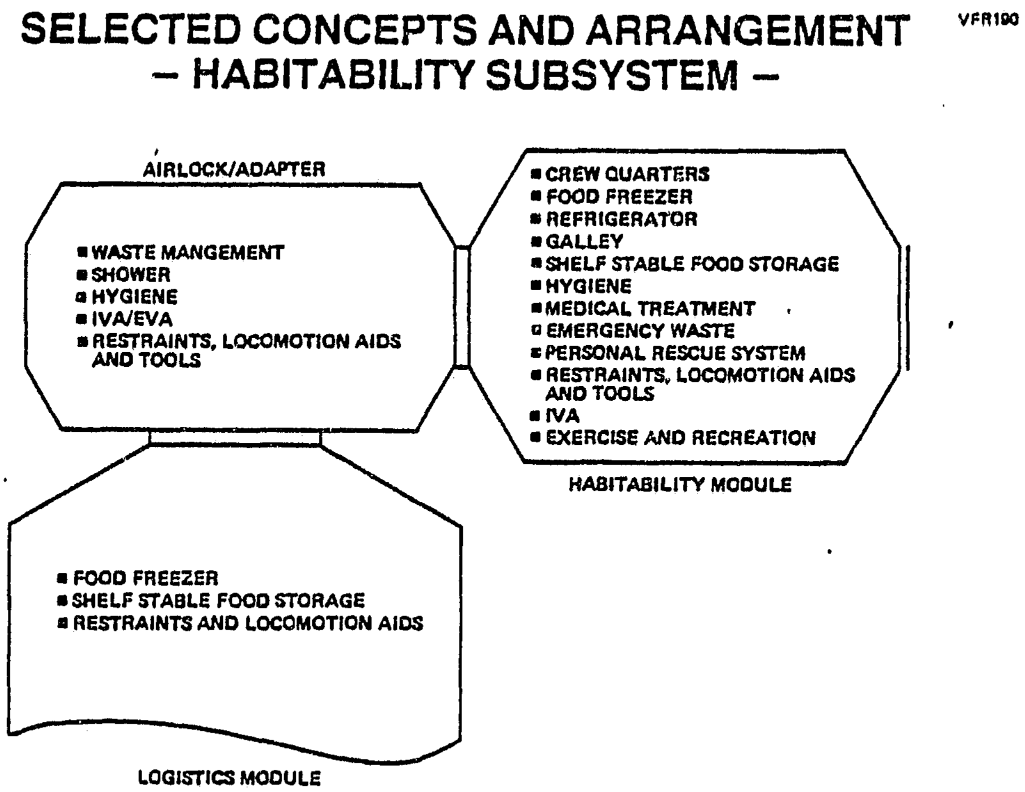
It should be noted that at 235 nmi altitude, all orientations studied can be held for at least one orbit and usually much more. Additional momentum control capability may be desirable, however, if a good orientation selection is required at lower altitudes. Also, additional momentum control capability may be desirable to maximize operational capability in the event a CMG or electromagnet fails.

2.4.10 Habitability Subsystem

This subsystem is designed to satisfy the two separate compartment requirements as shown in Figure 2.4.10-1. All essential functions are provided in the Habitation Module and duplicated in the Airlock Adapter or Logistics Module. These essential features include food and water supplies and emergency waste management. Emergency escape capability consists of IVA, EVA, and Personal Rescue Systems.

Primary habitation functions are provided in the Habitation Module where the crew quarters are located. These features include a galley, food storage, hygiene, medical treatment, and exercise and recreation provisions.

Figure 2.4.10-1



The primary waste management facility is located in the Airlock/Adapter and consists of the Orbiter Waste Management unit. Since the existing Orbiter design would necessitate changeout on orbit, consideration is being given to locating the units in the Logistics Module so changeout can be done on the ground. Another alternate is to modify the Orbiter design to facilitate changeout. Backup waste disposal items are stored in the Habitat.

The food diet consists primarily of frozen and shelf staple foods which are supplemented with fresh food during Shuttle revisits. The food resupply weighs 1400 lb. per 180 days for the Basic MSP. The bulk of the food is stored in the Logistics Module, but 7 to 14 days supply is maintained in the Habitation Module for emergency use.

Eight of the twelve major habitability items are existing Shuttle and Spacelab designs, some of the items require improvements. Items requiring new designs include the trash compactor and freezer/refrigerator.

2.4.11 Safety

Because the crew of MSP has no immediate escape capability (as in Apollo on Skylab) the MSP design incorporates several features dedicated solely to crew support and safety including emergency provisions and hazard retreat areas. These are highlighted in Figure 2.4.11-1. Contingencies are provided for in the MSP basic configuration and remedial safety aspects as on-board warning systems, 180-hour emergency supplies, 30-day contingency supplies, escape routes, and Orbiter rescue.

The approach to achieving an acceptable level of safety for the MSP has featured retreat-refuge (and recovery) rather than abandonment. Hazards have been minimized throughout design, operations and conceptual configuration effort, with special attention to location of potentially hazardous material. Backup provisions will permit operation of the MSP from either the Habitat/Payload module or the Airlock/Adapter module with full recovery possibilities if retreat from either module is required. Every pressurized module berthed to the MSP is a safe refuge area for a minimum of 180 hours. If recovery from a contingency is not possible, Orbiter rescue is always available as the final backup.

Figure 2.4.11-1

VFM320N

KEY SAFETY FEATURES OF BASIC CONFIGURATION

- **2 Separate Pressurized Habitable Volumes**
- **Separate Subsystems for Each Volume**
- **Repressurization Stores For Largest Pressurized Volume**
- **3 Isolated Power Source Buses**
- **Emergency Power Distribution Provided**
- **Overpressure Protection and Emergency Atmosphere Dump Capability in Each Pressure Volume**
- **Critical Subsystem Functions Are Fail-Operational/Fail-Safe**
- **EVA Rescue Routes Provided in Each Separate Habitable Volume**

2.4.12 Mass Properties

The weights of each of the Manned Platforms are given in Figure 2.4.12-1 with groupings for each of the three launches required to emplace the system.

2.4.13 KSC Operations

Prelaunch and sustained Logistics operations at this center will require a considerable planning and process management activity. Prospects for Logistics are listed in Figure 2.4.13-1.

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Figure 2.4.12-1

VFS239

MANNED PLATFORM LAUNCH WEIGHT SUMMARY

Elements	First Launch	Second Launch	Third Launch	Orbital Assembly
Manned Platform Modules		32,244	20,333	55,005
Airlock Adapter	—	16,112	—	16,112
Habitability	—	16,132	—	16,132
Logistic	—	—	20,333	20,333
Payloads	7,231		14,741	21,972
Solar Terrestrial (Pallet)	7,231		—	7,231
Earth Science (Pallet)	—		5,141	5,141
Life Science Specimen Facility	—		9,600	9,600
Space Platform	29,887			29,887
25.0 Kw type System with Reboost Module	27,459			27,459
Mini-Arms (3)	2,428			2,428
Orbiter Support	6,748	6,410	6,571	510
Crew (3)	—	510	—	510
Docking Module	3,900	3,900	3,900	—
Orbiter Payload Restraints	2,768	1,920	2,591	—
Orbiter Payload Flight Kits	80	80	80	—
Total (Lb)	43,866	38,654	41,645	107,374

Note: Contingency Incorporated in Individual Elements

Figure 2.4.13-1

VFR272

KSC ROLE IN LOGISTICS

- Manned Platform Logistics Management
  - Requirements Analysis
  - Planning and Scheduling
  - Facility Utilization
  - Training
  - Operations Control
- Logistics Integration Operations
  - Manned Module Support
  - Space Platform Support
  - Interior Payload Modules
  - Exterior Payload Modules
  - Large Structure Build Up
  - OTV Basing/Resupply
  - Spacecraft Servicing
  - Subsatellite Servicing
- 180 Day Logistics Module Turnaround (Typical)
  - Unload
  - Refurbish
  - Load Internal/Externally Stored Consummables for Manned Modules and Space Platform
  - Load Payload Resupplies
  - Load New Payloads
  - Load On-Orbit Operations Aids
- Training for On-Orbit Logistics and Related Operations

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2.5 COST ESTIMATES

Figure 2.5-1 shows the costs of the major categories of the Manned Space Platform. The costs assume the availability and use of a large amount of Spacelab hardware, a second buy of the Space Platform (Power System) and a follow-on buy of the Orbiter Airlock. The cost for the Space Platform, Orbiter Airlock and Spacelab hardware was furnished by NASA. The cost of all the new hardware, the modifications to the existing hardware and integration of all the hardware was estimated by MDAC.

The relatively low development cost compared to the recurring cost reflects the extensive use of existing hardware. The relatively high proportion of the systems test cost to the rest of the development cost reflects the low engineering costs and also the need for some additional testing to verify the Spacelab items will meet the requirements for longer life (lower leakage) in this program. In addition, the test includes the hardware required for the mockup and labor to refurbish the test specimens to permit maximum multiple use of each item.

Figure 2.5-1

VFR440

MANNED SPACE PLATFORM COST DATA
(THOUSANDS OF 1981 DOLLARS)

	NONRECURRING	RECURRING	TOTAL
• BASIC PLATFORM			
• SPACE PLATFORM	–0–	180,000	180,000
• AIRLOCK/ADAPTER	57,500	135,100	192,600
• LOGISTICS MODULES	46,000	218,200	264,200
• SOFTWARE	23,300	–0–	23,300
• INTEGRATION AND COMMON HARDWARE	73,800	43,000	116,800
• TESTING	297,600	49,300	346,900
• SUPPORT EQUIPMENT	34,200	–0–	34,200
• MISSION OPERATIONS	–0–	21,100	21,100
• PROGRAM MANAGEMENT	26,300	32,300	58,600
• HABITAT MODULE	457,200	330,800	788,000
	1,015,900	1,009,800	2,029,700

The recurring cost includes an allowance for an interruption in the Spacelab production lines. It is assumed all the qualified Spacelab vendors are available and their production lines intact when the hardware is processed for this program.

The costs do not include any NASA inhouse costs, Shuttle-related launch costs or on-orbit/crew costs.

The expanded configuration includes the Space Platform, a Habitability Module, a central Airlock/Adapter module and two Logistics Modules.

2.6 TECHNOLOGY ADVANCEMENT

Technology prospects for the type of system addressed here fall into two categories, namely:

- Accommodation, sustenance and protection of man
- Innovative utilization of man with machines in space

Because of the technology developed on Skylab, Shuttle and Spacelab much of the basic technology exists for the accommodation, sustenance and protection of man for long periods in orbit. However, for a given new vehicle configuration and for the application of new technology developed in the 80's, certain enhancement technology programs must be initiated to assure maximum performance and safety in any new system.

On the other hand, the sophisticated payload mission operations envisioned for the new space station do require the development of numerous all-new technological capabilities. Therefore, as shown in Figure 2.6-1, there are two categories of technological advancement recommended for the manned space platform, namely:

- Enhancement of basic manned system capability
- Enablement of advanced manned capabilities

Figure 2.6-1

VFR134

TECHNOLOGY FOR THE EVOLUTIONARY MANNED PLATFORM

Enhancement of Basic Manned System Capability

- Command and Data Management
  - Fault-Tolerant Computers
  - Fiber Optic Data Bus
- Power Distribution
  - Remote-Control Breakers
  - Rotating Interfaces
- Environmental Control and Life Support
  - Regenerative Carbon Dioxide Control
  - Wastewater Recovery
- Attitude Control
  - Manned Motion Isolation
  - Large Momentum Storage and Desaturation
- Unmanned Logistics
- EVA Services

Enablement of Advanced Manned Capabilities

- Large Structures
  - Deployment
  - Assembly
  - Alignment
- Orbital Transfer Vehicle Basing
  - Propellant Storage
  - Propellant Handling
  - Payload Integration
  - Checkout/Launch
- Servicing
  - All of the Above
  - Spacecraft
- Remote Vehicle Retrieval/Control
  - All of the Above

2.7 TECHNOLOGY UTILIZATION OPTIONS

The Manned Platform can incorporate a variety of options as to technology use. As shown in Figure 2.7-1, technology use can range from maximum-existing to maximum-advanced. It is interesting that, in <u>any</u> optional approach, a number of key elements will be all new, or advanced,namely, the all-important, multi-use (initial and growth) Central Crew/Dock Module (a major cost item), Thermal/Radiation Shields, the Dock/Berth Mechanism (used in considerable quantity) and some Command/Date Management equipment. Also, in <u>any</u> optional approach, numerous Shuttle items will be used such as the airlock/latch, ECLSS, Communications/Data and crew systems equipment.

Thus, the number of decisions required to "make new" or "use existing," is relatively restricted in this concept.

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Figure 2.7-1

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TECHNOLOGY UTILIZATION OPTIONS*

	TECHNOLOGY USED		
	MAXIMUM EXISTING	EXISTING/ NEAR-TERM	MAXIMUM ADVANCED
EXISTING TECHNOLOGY			
• CONFIGURATION/STRUCTURES			
– SPACELAB (2 SEG) HABITAT/PAYLOAD MODULE	X		
– SPACELAB (1 SEG) DEDIC PAYLOAD MODULE	X	X	
– SHUTTLE AIRLOCK/HATCH	X	X	X
• SUBSYSTEMS			
– SPACELAB ECLSS, POWER & DATA MGT (MOD)	X	SOME	
– SHUTTLE ECLSS COMMUNICATIONS/DATA CREW SYSTEMS	X X X X	X X X	SOME X
NEAR-TERM TECHNOLOGY			
• SUBSYSTEMS			
– SPACE PLATFORM			
• POWER DISTRIBUTION		X	
• THERMAL CONTROL DISTRIBUTION		X	
• COMMAND/DATA MGT		SOME	
ADVANCED TECHNOLOGY			
• CONFIGURATION/STRUCTURES			
– CENTRAL CREW/DOCK MODULE	X	X	X
– HABITAT/PAYLOAD MODULE		X	X
–PAYLOAD MODULE			X
–THERMAL/RADIATION SHIELD	X	X	X
–DOCK/BERTH MECHANISM	X	X	X
• SUBSYSTEMS			
– ENVIRONMENTAL CONTROL/LIFE SUPPORT		X	X
–POWER DISTRIBUTION			X
–COMMAND/DATA MANAGEMENT	(SOME)	(SOME)	X

*ASSUMES USE OF SPACE PLATFORM VEHICLE

2.8 MINIMUM AND GROWTH CONFIGURATIONS

For special reasons, such as "early capability" or "low-budget" demonstrations, the particular modularity of the Recommended Configuration lends itself to significant demonstrations with only two of the modules, namely the Central and Logistics Modules. As shown in Figure 2.8-1 an internal volume equivalent to that of the USSR/Salyut vehicle could be provided with two highly-useful exterior pallets of payloads plus about 6 racks for interior payload equipment. Presumably such a vehicle could be operated for months and years with high utility for science, applications and even the military.

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Figure 2.8-1

BASIC MANNED PLATFORM WITH RESUPPLY (RELATED DATA)

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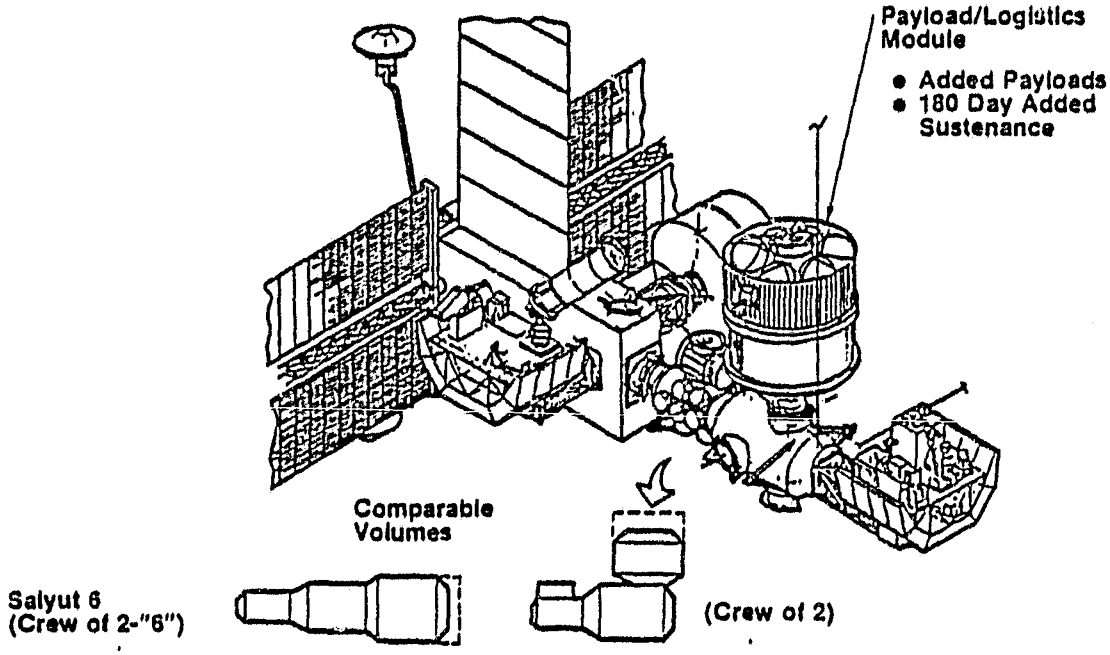

Considerable growth is anticipated and "scars" incorporated earlier to permit expansion for operations in the later years of the Manned Platform to accommodate large payload assembly, upper stage basing and spacecraft servicing. Figure 2.8-2 illustrates two options for such configuration buildup. The extensive utility and attitude control resources of the 25 kW Space Platform can accommodate many future operations envisioned. However, data management equipment supplements and decentralization will be broadly employed for the customized needs of data for major payload operations.

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Figure 2.8-2

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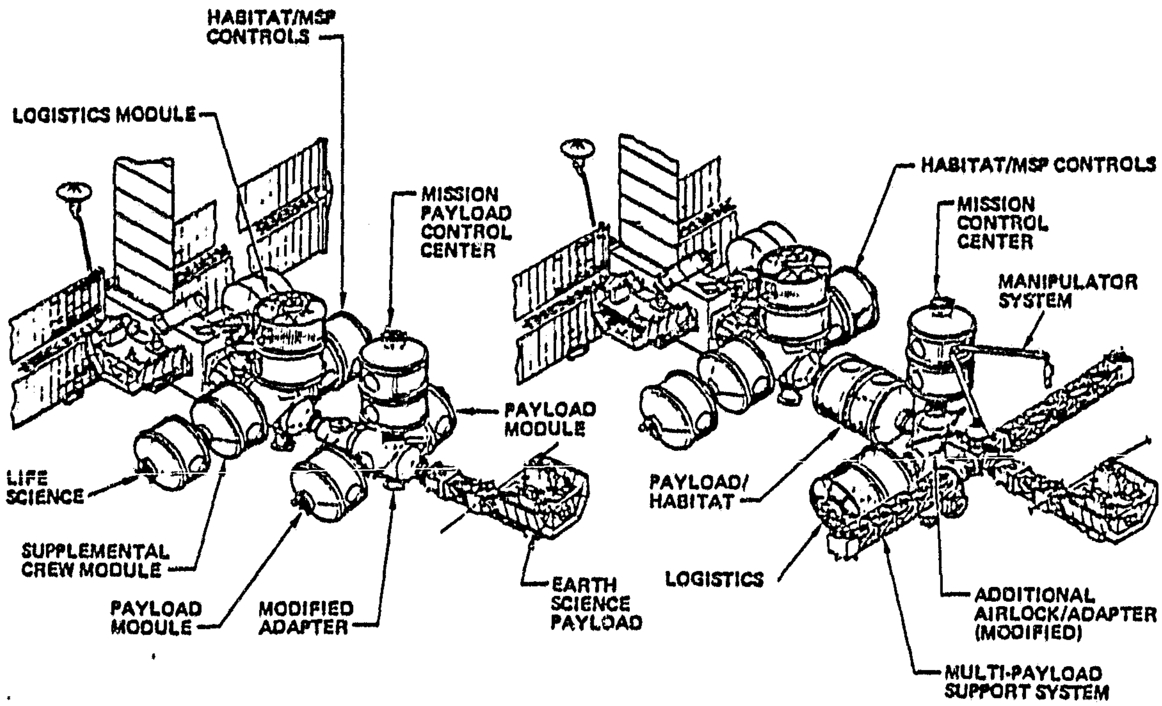
MANNED PLATFORM GROWTH OPTIONS



Section 3
UNMANNED PLATFORM STUDIES (TASK A)

This task constituted one-sixth ($50K) of the study, as opposed to the $250K Manned Platform (Task B) part. It constituted a sequel to the $400K (Unmanned-dominant) study of 1980-1981 and addressed selected issues. First of all it included a once-more review of candidate configuration options. Next, the accommodation aspects of the high-pointing accuracy payload interfaces were studied. Finally, the structural dynamics of the three-arm configuration were analyzed to greater depth. Figure 3-1 lists the nature and conclusions of this Task A.

Figure 3-1

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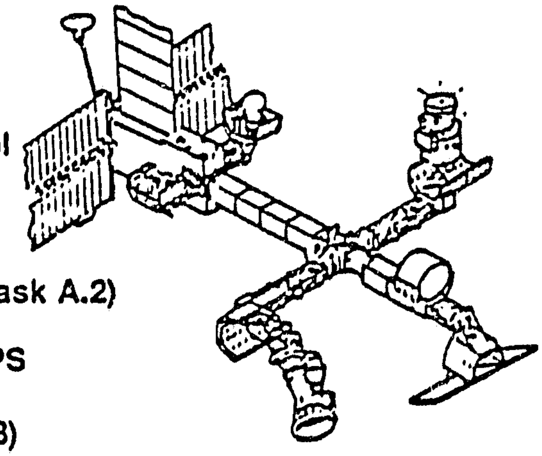
UNMANNED PLATFORM STUDIES
TASK A



- Innovative SASP Concepts (Subtask A.1)
  - Arm Concepts Description/Rationale
  - Viewing, Pointing, Dynamics and Control
  - Magnetic Arm Coupling
  - Tethered Satellites
- Image Motion Compensation Study (Subtask A.2)
  - SP, APS and IMC Capabilities
  - SP Accommodation of SIRTF with No APS
- Platform Dynamics Analyses (Subtask A.3)
  - Configurations
  - Damping

SUMMARY

- Previously Recommended 2nd Order SASP Concept Still Considered Best Approach
- IMC System Designs Can Accommodate Many Direct Mounted Pointing Payloads From a Stability Viewpoint
- Viewing Operations Make a Large Angle Coarse Gimbal Capability Very Desireable Particularly for Simultaneous Payload Operations
- The Payload Will Have to Pick up Certain APS Functions Such as Rate Gyros and Attitude Sensors
- A Platform/Payload Attitude Interface May be Required to Update Platform Rate Gyros
- Structural Dynamics Now Better Understood; Localized Dampers Can Provide Significant System Damping
- Vehicle Dynamic Model Defined Including Viscoelasticity
- Model Run on Computer and Frequencies and Transfer Functions Available for Interpretation (Dynamics and Controls)
- Transfer Functions Reviewed so far Indicate Non-Proportional Damping Adds Significant System Damping
- Further Controls Analysis Required to Define Closed-Loop Characteristics

APPENDIX - ACRONYMS

ACS	Attitude Control Subsystem
AEPI	Atmospheric Emission Photometric Imaging
AFD	Aft Flight Deck
AFSD	Air Force Space Division
CAT. OX.	Catalytic Oxidizer
CDMS	Communication and Data Management Subsystem
CMG	Control Moment Gyro
CO_2	Carbon Dioxide
DDU	Data Display Unit
DMS	Data Management Subsystem
ECLS	Environmental Control/Life Support
EPDS	Electrical Power Distribution Subsystem
EPS	Electrical Power Subsystem
ETR	Eastern Test Range
EVA	Extravehicular Activity
EXT	Extension
FDA	Federal Drug Administration
GEO	Geosynchronous Orbit
GN_2	Gaseous Nitrogen
GO_2	Gaseous Oxygen
HDRR	High Data Rate Recorder
HOL	High Order Language
HRM	High Rate Multiplexer
IOC	Initial Operating Capability
I/O	Input/Output
IOP	In-orbit Plane

JPL	Jet Propulsion Laboratory
KSC	Kennedy Space Center
LEO	Low Earth Orbit
LIDAR	Light Detection and Ranging
LiOH	Lithium Hydroxide
LOG	Logistics
MLI	Multi-layer Insulation
MMU	Mars Memory Unit
MSFC	Marshall Space Flight Center
MSP	Manned Space Platform
OMS	Orbital Maneuvering System
OPS	Operations
OTV	Orbital Transfer Vehicle
PDP	Plasma Diagnostic Package
P/L	Payload
PS	Power System
POP, PSL	Perpendicular-to-Orbit Plane, Perpendicular-to-Sunline
RAHF	Reusable Animal Holding Facility
RAU	Remote Acquisition Unit
RMS	Remote Manipulator System
SASP	Science and Applications Space Platform
SEG	Segment
SEPAC	Space Experiments/Particle Acceleration
SIRTF	Shuttle Infrared Telescope Facility
SL	Spacelab
S/S	Subsystem
STS	Space Transportation System
SUSIM	Solar Ultraviolet Spectral Irradiance Monitor
TDRSS	Tracking and Data Relay Satellite System
UNMD	Unmanned

VCS	Vacuum Containment System
WBS	Work Breakdown Structure
WISP	Waves in Space Plasma
WTR	Western Test Range