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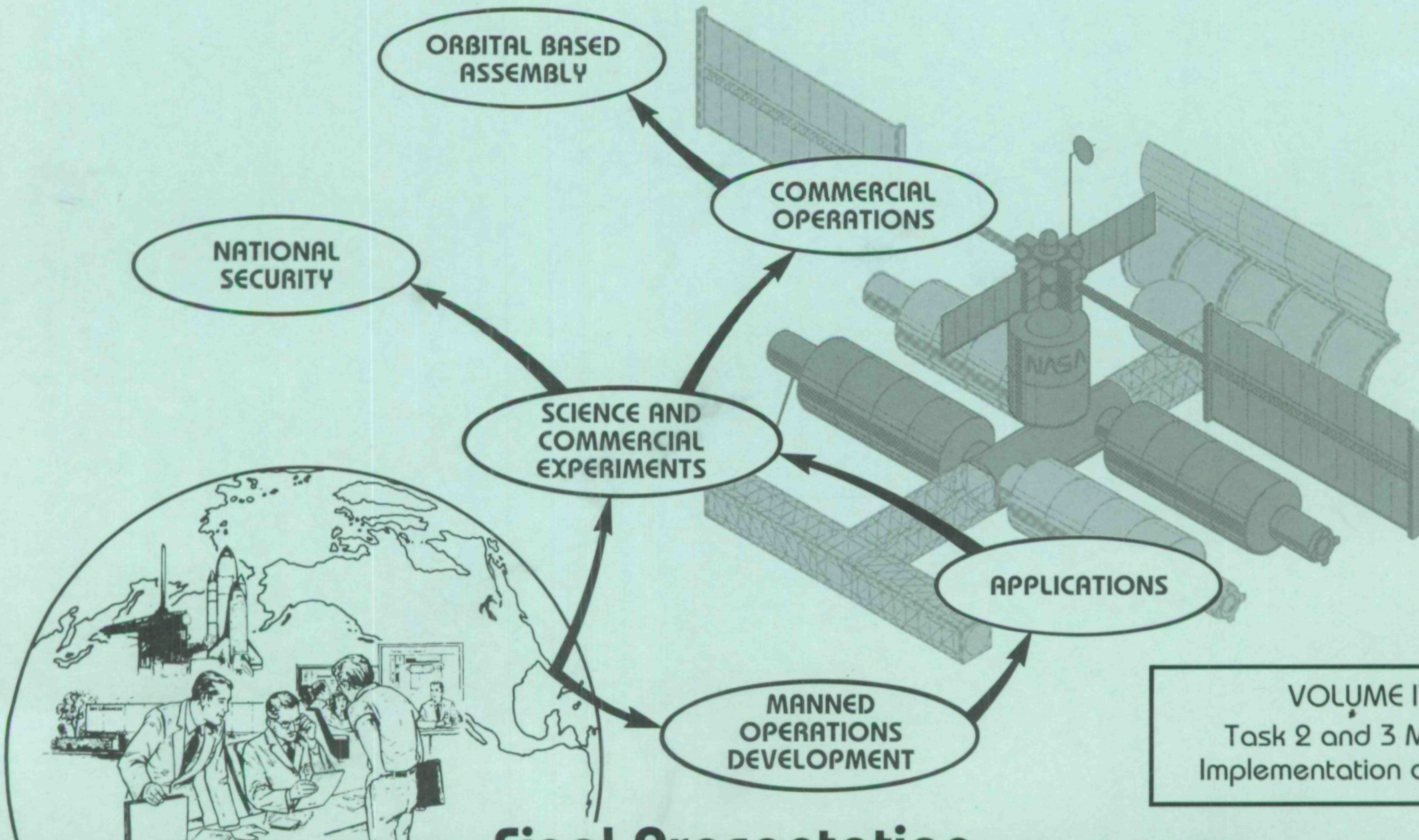
LMSC-D889718
5 APRIL 1983

NASA Space Station Needs, Attributes and Architectural Options



VOLUME IV
Task 2 and 3 Mission Implementation and Cost

Final Presentation

Lockheed Missiles & Space Company, Inc.

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NASA Space Station Needs, Attributes, and Architectural Options

FINAL PRESENTATION

CONTRACT NAS3684

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VOLUME IV

Task 2 and 3 Mission
Implementation and Cost

Prepared For **NASA Headquarters**
Washington, D.C.

Prepared By *Lockheed Missiles & Space Company, Inc.*
Sunnyvale, California 94088

SPACE STATION PROGRAMS

TASK 2—MISSION IMPLEMENTATION CONCEPTS

2.1 MISSION SCENARIO ANALYSIS AND ARCHITECTURAL CONCEPTS
2.2 ALTERNATIVE SYSTEMS CONCEPTS
2.3 MISSION OPERATIONS ARCHITECTURAL DEVELOPMENT
2.4 ARCHITECTURAL ANALYSIS TRADES
2.5 EVOLUTION
2.6 CONFIGURATION
2.7 TECHNOLOGY DEVELOPMENT
2.8 CONCLUSIONS

Lockheed

MISSION IMPLEMENTATION CONCEPTS AND OBJECTIVES

The objectives of this part of the study are to define space station system concepts in terms of functional architecture and configuration that will accommodate the projected mission requirements for the 1990 to 2000 era, and to define evolutionary steps to implement the system.

The terminology used throughout this part of the study is as follows:

- Space station - a manned assembly in low earth orbit (LEO)
- Space station system - space station element and other operating payload, experiment, and support elements
- Experiment - a collection of hardware designed to achieve a single investigative objective
- Payload - a grouping of multiple experiments designed to achieve a major objective, either single purpose or multipurpose
- Configuration - a pictorial structural arrangement of major hardware that depicts a space station
- Attached payload or experiment - physically attached to space station
- Detached payload or experiment - physically separated from space station; may be in orbit alone or tethered to space station
- Free flyer - a vehicle in orbit alone, may have single or multiple payloads or experiments
- Satellite or spacecraft - a single mission vehicle in orbit alone
- Platform - an unmanned assembly in separate orbit
- Support elements - major interfacing operational elements of the total space infrastructure consisting of the space communication satellites (TDRSS, MILSATCOM); ground-based tracking, communications, and control; and the Space Transportation System (STS) launch base and Shuttle vehicle
- Orbit transporters/services - teleoperator maneuvering system (TMS) and orbit transfer vehicle (OTV)

MISSION IMPLEMENTATION CONCEPTS OBJECTIVES

TO IMPLEMENT MISSION REQUIREMENTS FOR 1900 - 2000 ERA

- DEFINE AND ANALYZE A RANGE OF ALTERNATIVE SYSTEM CONCEPTS TO MEET MISSION AND SATISFY OPERATIONAL REQTS.
- DEVELOP AND ANALYZE ARCHITECTURAL OPTIONS
- DEFINE A PLAN FOR EVOLUTION OF SPACE STATION

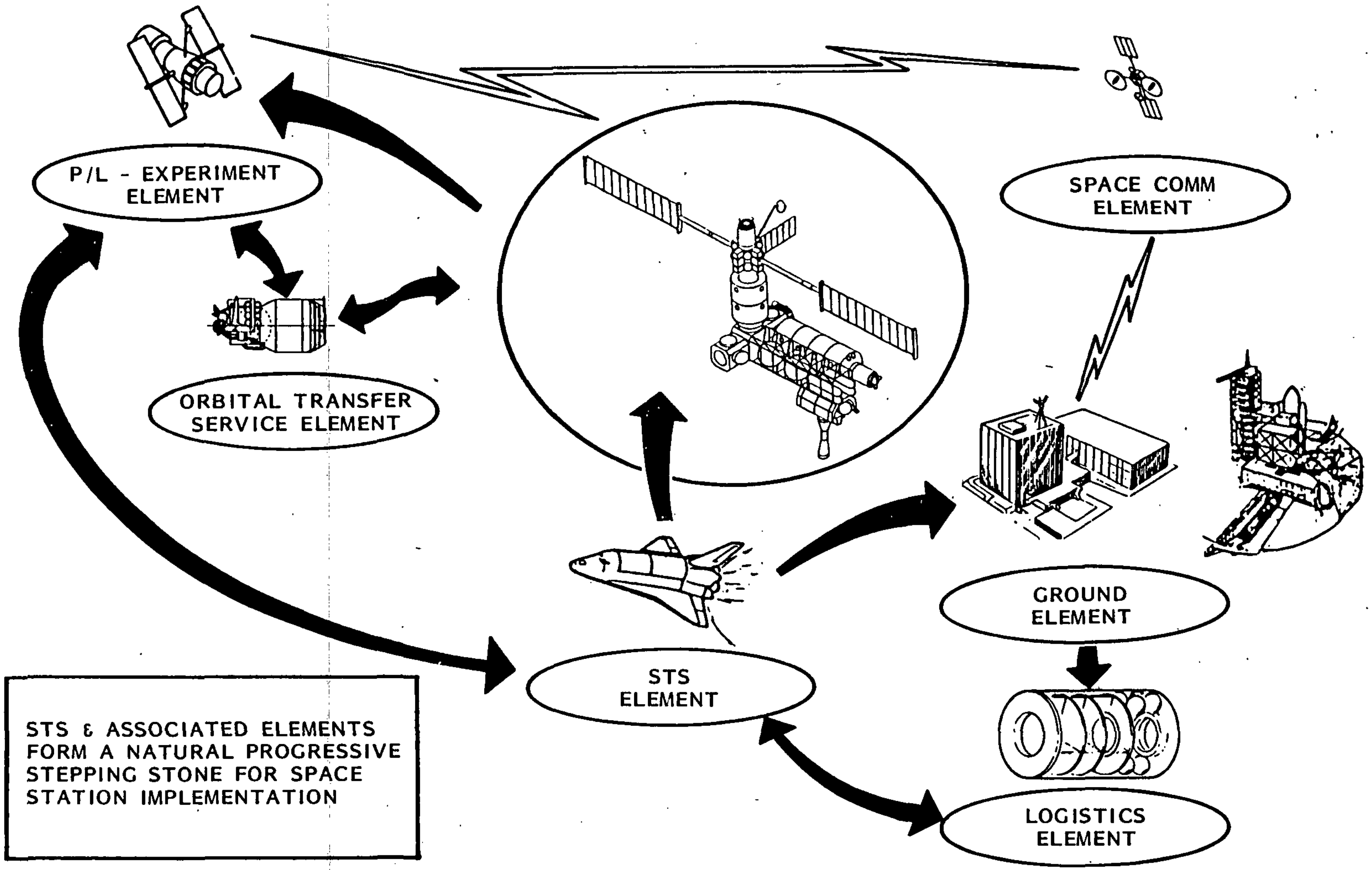
SPACE STATION SYSTEM INFRASTRUCTURE AND TOTAL SYSTEM ARCHITECTURE

An abbreviated overview of the basic station infrastructure is illustrated on the facing page. This architectural overview does not include classified U.S. national security elements; however, the infrastructure is highly applicable at the element level. A strong case is made for the natural and progressive evolution of the station using the basic Space Transportation System (STS) as the stepping stone to achieve a smooth transition and cost-effective implementation.

An important element of the infrastructure, which to date appears to have received less emphasis but is highly important, is the integrated logistics support (ILS) element of the overall station infrastructure. Both nominal and emergency ILS factors must be considered very early in the station concept development sequence as they can substantially affect the basic station and support element architecture. Pivotal also is the inherent need for an orbital transport system capability that is key to servicing and spacecraft positioning scenarios and associated mission needs. Communication is also an extremely important element and the basic issue of station autonomy versus ground support will be a key trade study and system and subsystem architectural impact and driver.

SPACE STATION PROGRAMS

SPACE STATION SYSTEMS INFRASTRUCTURE & TOTAL SYSTEMS ARCHITECTURE



STS & ASSOCIATED ELEMENTS FORM A NATURAL PROGRESSIVE STEPPING STONE FOR SPACE STATION IMPLEMENTATION

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SPACE STATION PROGRAMS

TASK 2—MISSION IMPLEMENTATION CONCEPTS

2.1 MISSION SCENARIO ANALYSIS AND ARCHITECTURAL CONCEPTS
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2.8 CONCLUSIONS

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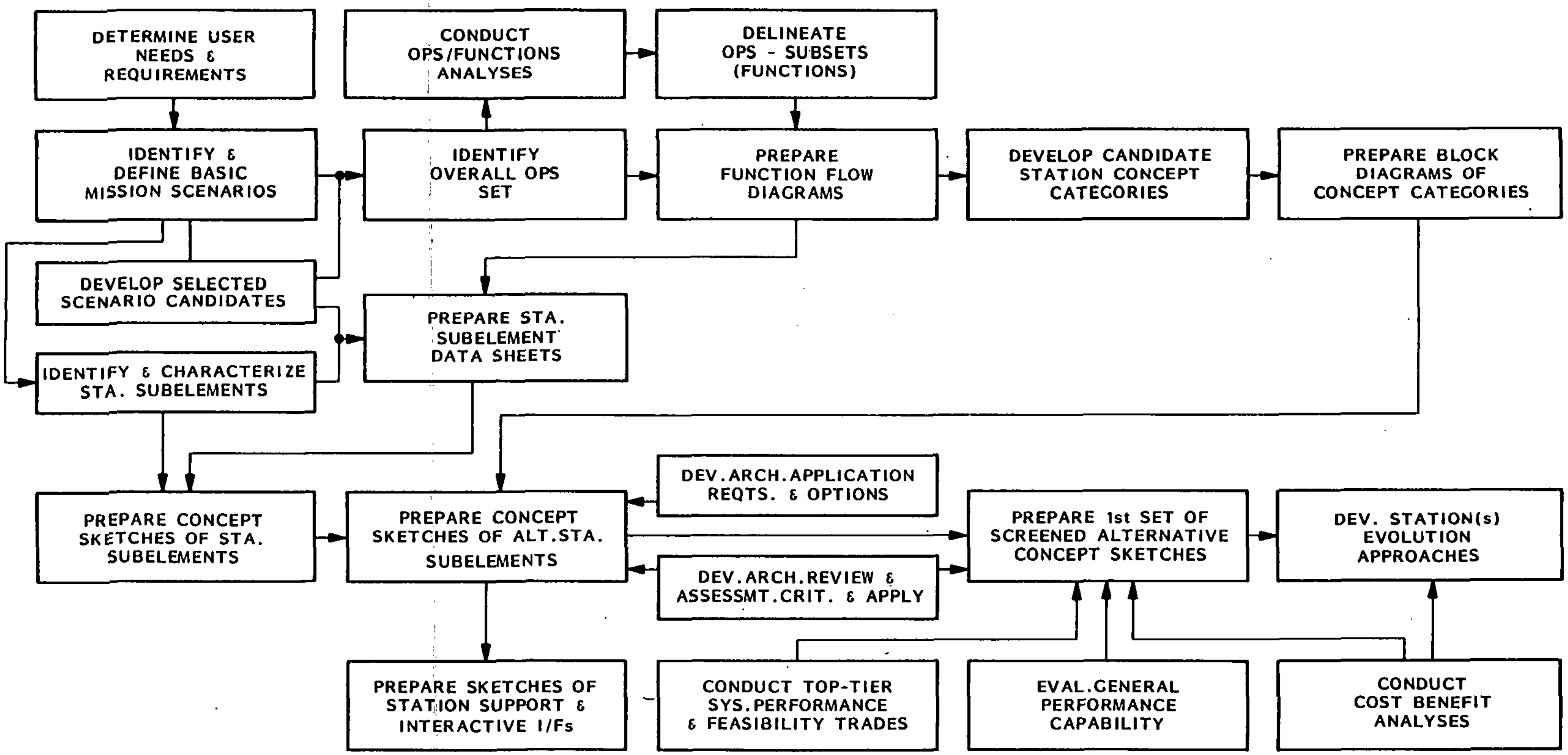
APPROACH TO DEFINING MISSION IMPLEMENTATION CONCEPTS

The basic approach to the station architectural development study effort is portrayed on the facing page. Certainly, the effort was substantially influenced by the user needs and requirements developed in Task 1 of this study. Significant effort in Task 1 was also given to development of the set of mission scenarios that formed the basis of the operation/function analyses then conducted. A number of scenario operation/function flow diagrams were prepared from which a basic set of architectural concept definitions were developed. Data sheets indicating station subelement characteristics were then generated which, in concert with the aforementioned information provided by the basic data base, were used in the architectural development activity.

A wide range of architectural station concepts were prepared and evaluated as to potential practicality, feasibility, mission suitability, cost, and support potential. Simultaneously, top-tier requirements and general assumptions were then prepared for subsequent design activity. Also concurrently, basic station support functions and interface needs were delineated for operational criteria input. Architectural review and assessment criteria were prepared for use in subsequent examination of the proposed set of station alternative concept approaches. Initial sketches of the cadre of station candidate concepts were prepared and screened according to previously prepared criteria. Again, top-tier requirements were imposed and several performance and feasibility trades conducted. Rationale for station evolution was defined and applied to the more promising candidate station concepts. Concurrently, costing analyses were conducted relative to the more viable station concept(s) to further substantiate the evolutionary approach and to support the reference initial and full-up station concept configuration.

APPROACH TO DEFINING MISSION IMPLEMENTATION CONCEPTS



MISSION IMPLEMENTATION SCENARIOS

Fifteen mission description scenarios developed from results of user surveys and evaluation of projected NASA and DoD mission models in Task 1 of this study are shown here. Detailed mission descriptions are included in Attachment 2, Volume I. These scenarios are representative of the range of missions in the science, applications, commercial, U.S. national security, and space operation categories anticipated for the 1900 to 2000 era.

Each scenario is analyzed to develop functional sequences and to identify functional support requirements. Functions are grouped in significant subelements to define a system architecture and to identify major interfaces. From the defined functions and interfaces, the role and attributes of the space station are defined to implement each mission.

Two of the seven missions listed for space operations were analyzed in detail, scenario 14 (On-Orbit Satellite Servicing) and scenario 15 (Large Structures Assembly). An overview evaluation of the other five missions for astronomy platform support, space telescope maintenance, prompt satellite replacement, Shuttle crew rescue vehicle, and GEO satellite resupply, has shown that the space station attributes to accommodate these five missions are essentially satisfied by those attributes identified for scenarios 14 and 15. A discussion of these space operation missions is given in Task 1.1.4.

MISSION IMPLEMENTATION SCENARIOS

MISSION CATEGORY	MISSION DESCRIPTION	EARLIEST USE	SCENARIO NO
SCIENCES	LIFE SCIENCE HUMAN RESEARCH LAB	1990	1
	LIFE SCIENCE NON-HUMAN RESEARCH LAB	1990	2
	CELESTIAL OBSERVATORY	1990	3
	SPACE ENVIRONMENT FACILITY	1990	4
APPLICATIONS	EARTH OBSERVATION FACILITY	1990	5
	GLOBAL HABITABILITY OBSERVATION LABORATORY	1990	6
	METEORLOGICAL FACILITY	1990	7
COMMERCIAL	MATERIAL PROCESSING RESEARCH LAB	1990	8
	MATERIAL PROCESSING FACILITIES	+ 5 YRS	9
U.S. NATIONAL SECURITY	SPACE OBSERVATION DEVELOPMENT LABORATORY	1990	10
	OCEANOGRAPHIC OBSERVATORY DEVELOPMENT LAB	1990	11
	ORBITING NATIONAL COMMAND POST - NASA IMPACT	1990	
	- OPERATIONAL	1998	12
	SPACE OBJECTS IDENTIFICATION SYSTEM	1995	13
SPACE OPERATIONS	ON ORBIT SATELLITE SERVICING-LEO (ITSS, SBR, GPS)	1993	14
	LARGE STRUCTURES ASSEMBLY (SBR)	1992	15
	ASTRONOMY PLATFORM SUPPORT	1990	WITHIN SCOPE OF (14) (15)
	SPACE TELESCOPE MAINTENANCE	1990	
	PROMPT SATELLITE REPLACEMENT	1993	
	SHUTTLE CREW RESCUE VEHICLE	1990	
	GEO SATELLITE RESUPPLY	1990	

SCENARIO 1--LIFE SCIENCE HUMAN RESEARCH LABORATORY--MISSION FUNCTIONAL SEQUENCE

The objective of this mission is to understand and mitigate effects of the space environment on humans so that a varied segment of the population can be qualified for indefinite presence and operations in weightlessness, to increase our understanding of the space environment on biological processes, and to use the space environment to better understand life processes on Earth.

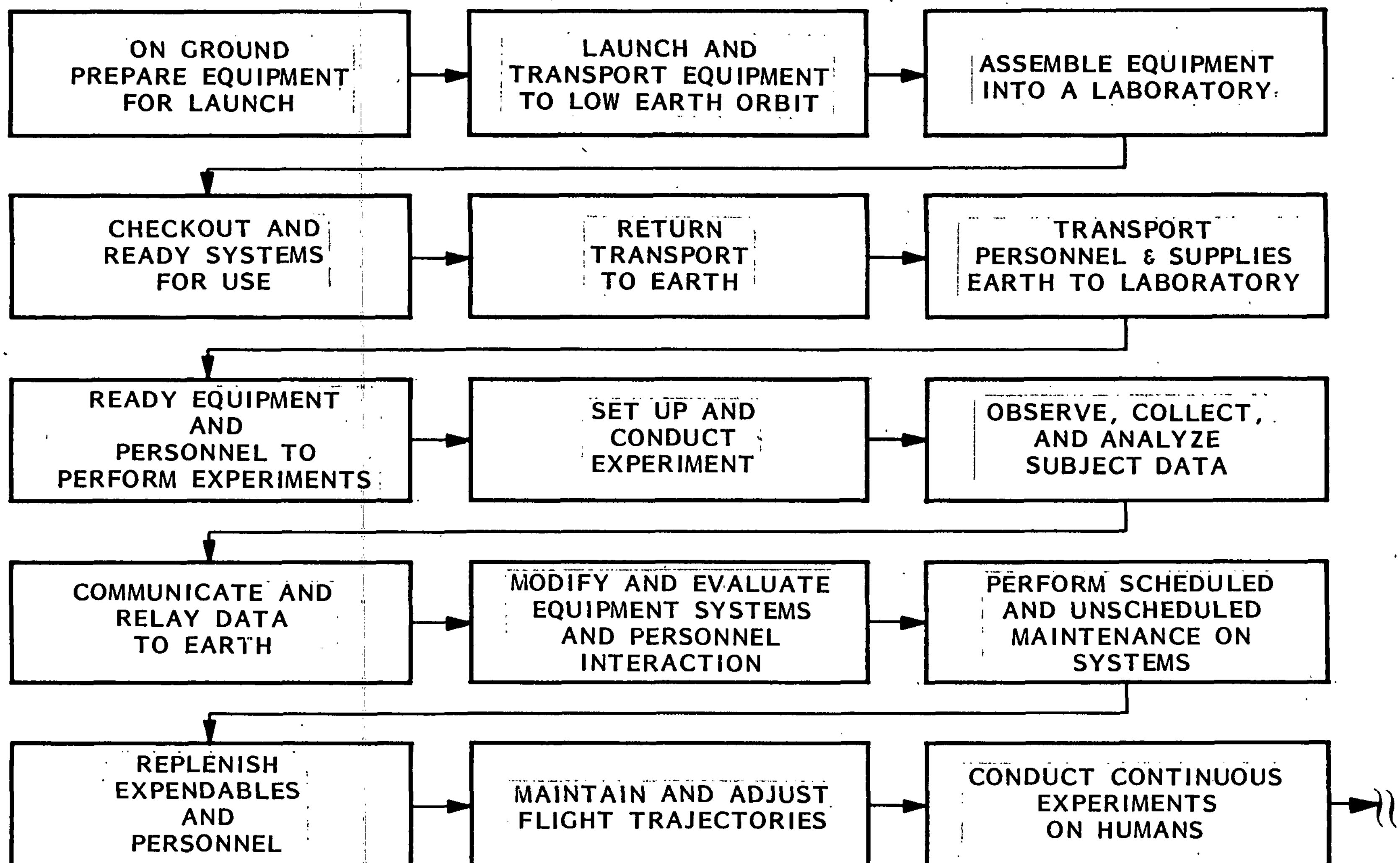
Short-, medium-, and long-duration experiments will be conducted on personnel in a controlled, shirtsleeve laboratory. Human subjects for the experiments will be exchanged periodically to provide an extended sample population sample.

The functional sequence to position and operate a life science human research laboratory in LEO is shown here.

SPACE STATION PROGRAMS

LIFE SCIENCE HUMAN RESEARCH LABORATORY MISSION FUNCTIONAL SEQUENCE

SCENARIO 1



SCENARIO 1--LIFE SCIENCE HUMAN RESEARCH LABORATORY ARCHITECTURAL CONCEPT

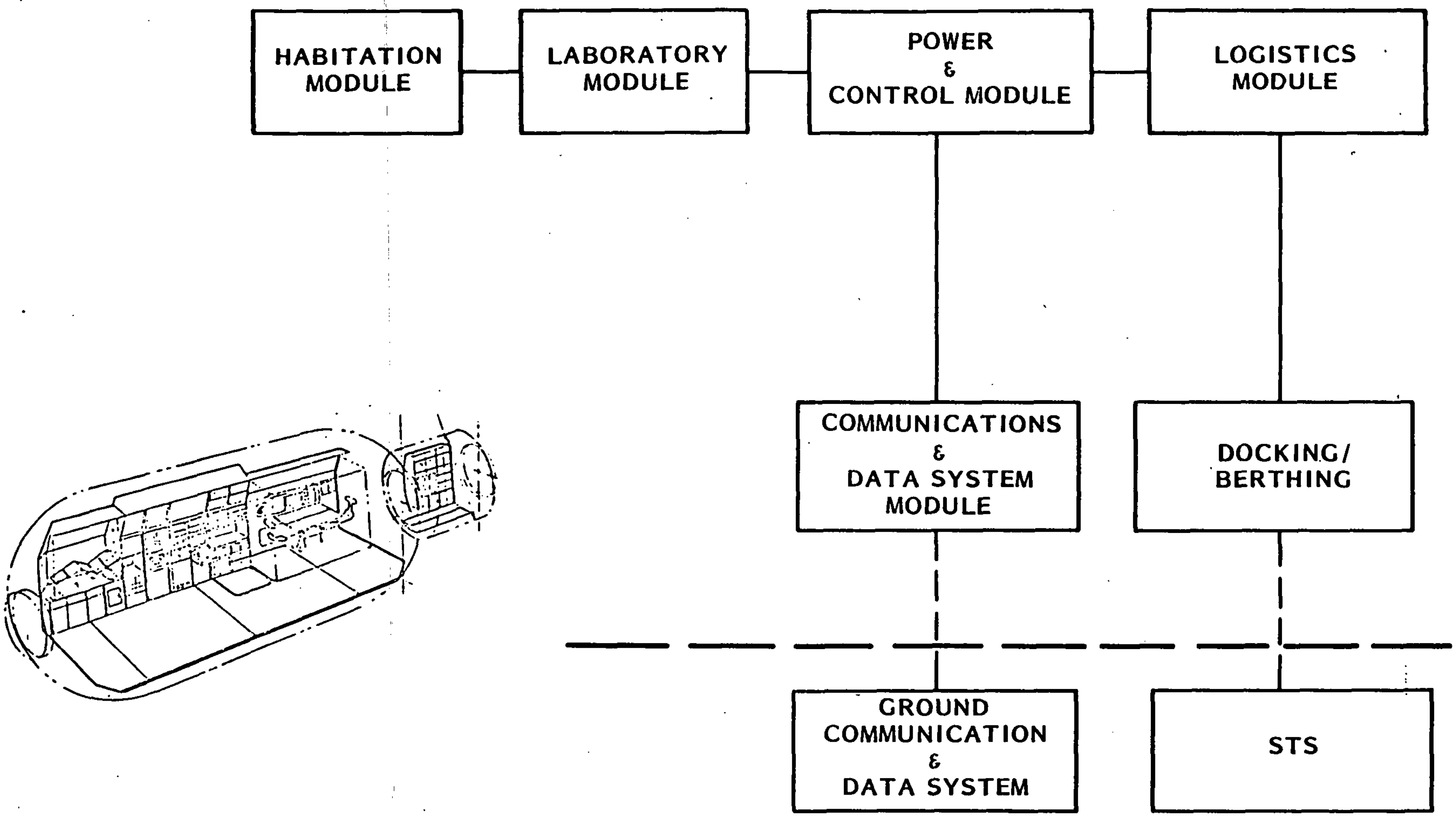
The system architecture for the human research laboratory is shown here. An enclosed laboratory-type module is directly coupled to basic space station subelements, allowing personnel to move freely from habitation quarters to the controlled laboratory. This permits continuous observation of subjects. The STS provides direct support to initially transport the laboratory module to LEO and to continue logistic support for consumables and personnel rotation during mission lifetime.

Functions of the system architecture are presented below:

	Module	Functions
1.	Habitation	Living and maintenance of crew
2.	Laboratory	Hands-on human experiment setup and test
3.	Power and control	Electrical power, attitude stabilization, and control
4.	Communication and data system	Voice and data link, data evaluation, and display
5.	Docking/berthing	Docking/berthing for Shuttle; transfer personnel, equipment, and supplies
6.	Logistics	Storage for facility and payload supplies
7.	Ground communication and data	Tracking, voice/data communication, and data distribution
8.	STS	Shuttle ground to space transport, resupply logistics

LIFE SCIENCE HUMAN RESEARCH LABORATORY ARCHITECTURAL CONCEPT

SCENARIO 1



SCENARIO 1--ROLE OF SPACE STATION TO SUPPORT HUMAN RESEARCH LABORATORY

The space station provides direct, continuous, long-term support to the human research laboratory mission. The subjects can be crewmembers or special subjects housed in the habitation module. The station provides direct power and environmental interfaces and supports onboard data analysis and conferencing communication and data transfer to the ground. Equipment maintenance, service, and exchange is conducted continuously.

Space station attributes to support this mission are shown here.

SPACE STATION PROGRAMS

SCENARIO 1

ROLE OF SPACE STATION TO SUPPORT HUMAN RESEARCH LABORATORY

ATTRIBUTES

- PROVIDE LONG-DURATION HABITATION FOR PERSONNEL
- PROVIDE SHIRTSLEEVE INTERACTIVE "HANDS ON" LABORATORY
- PROVIDE ELECTRICAL POWER AND DATA/COMMUNICATIONS INTERFACE
- PROVIDE VOICE AND DATA LINK TO GROUND
- PROVIDE ALTITUDE AND ATTITUDE ORIENTATION
- PROVIDE PERIODIC REPLENISHMENT OF EXPENDABLES AND PERSONNEL
- PROVIDE SCHEDULED AND UNSCHEDULED MAINTENANCE
- PROVIDE DOCKING AND OPERATIONAL INTERFACE WITH STS

SCENARIO 2--LIFE SCIENCE NON-HUMAN RESEARCH LABORATORY--MISSION FUNCTIONAL SEQUENCE

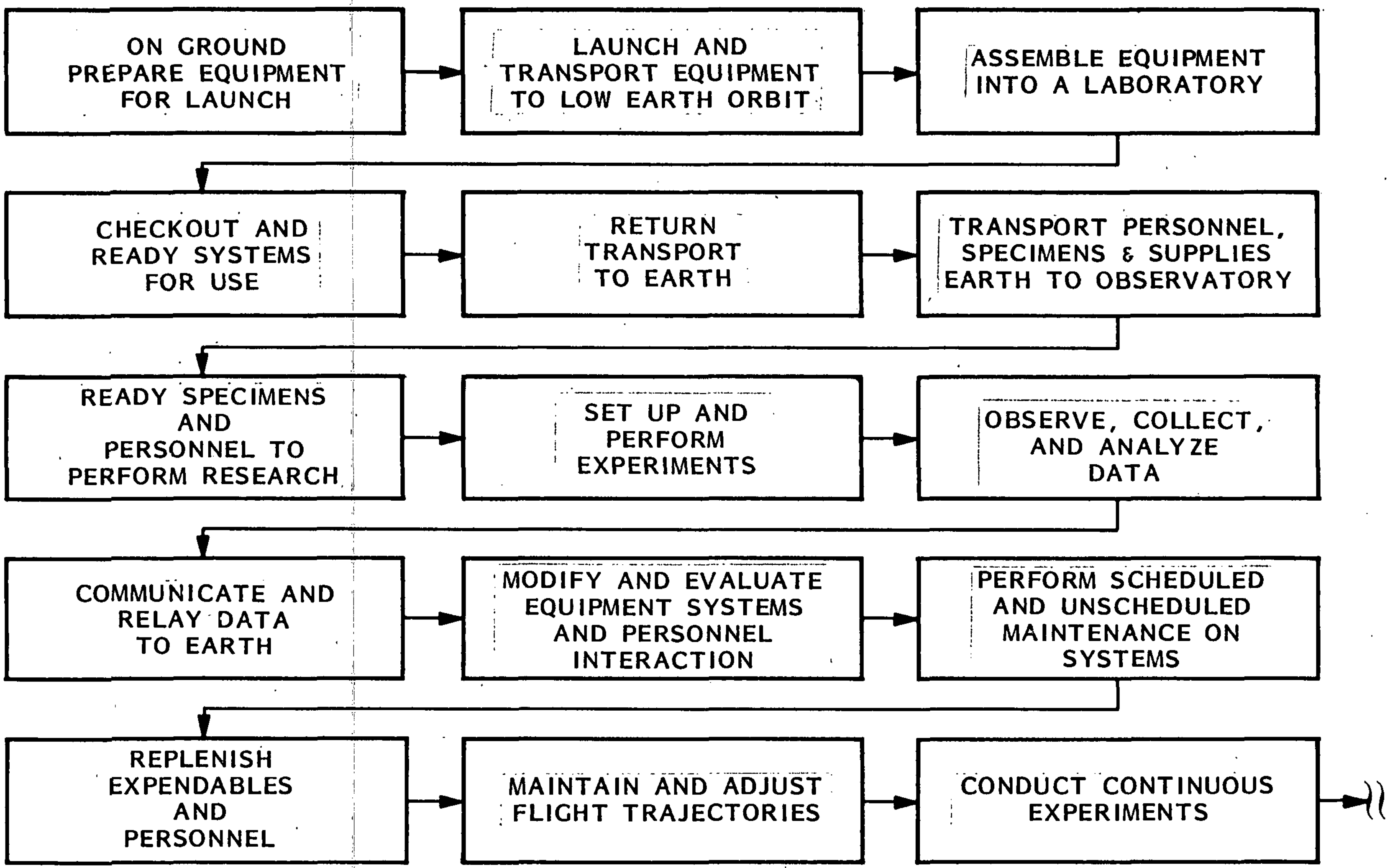
The objectives of this mission are to provide data and verify research findings to support qualification of man for indefinite exposure to weightlessness, to further understand zero-g biology in plant, bacteria, and animal development, and to conduct research in a controlled ecological life support system (CELSS). These objectives will be achieved by conducting invasive or prolonged research on non-human specimens to further understand biological effects of space.

The functional sequence to position and operate a non-human research laboratory in LEO is shown here.

SPACE STATION PROGRAMS

LIFE SCIENCE NON-HUMAN RESEARCH LABORATORY FUNCTIONAL SEQUENCE

SCENARIO 2



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SCENARIO 2--LIFE SCIENCE NON-HUMAN RESEARCH LABORATORY ARCHITECTURAL CONCEPT

The system architecture for the non-human research laboratory is shown here. An enclosed laboratory-type module is directly coupled to space station subelements as a separate module isolated from the crew habitation module. This laboratory will house specimen holding facilities for animals and plants, and will include laminar flow workbenches and other laboratory-type instruments.

The non-human research laboratory will also include equipment required to evaluate biological life support system development for future long-duration missions. Most life science experiments require crew manipulation; therefore, the primary non-human laboratory must be attached to the space station, with crewmembers transferring from the habitation module to the non-human life sciences laboratory in a shirtsleeve environment.

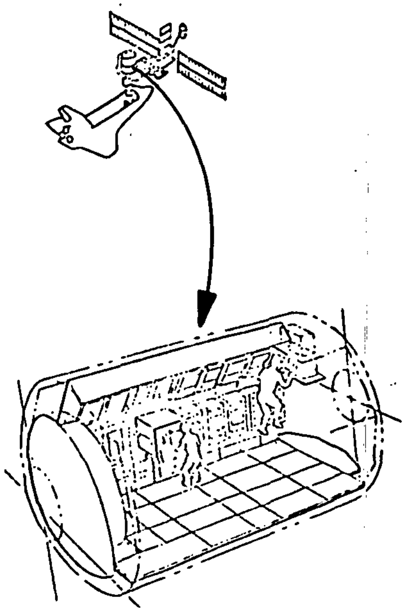
Functions of the system architecture are presented below:

	Module	Functions
1.	Habitation	Living and maintenance of crew
2.	Laboratory	Hands-on human experiment setup and test
3.	Power and control	Electrical power, attitude stabilization, and control
4.	Communication and data system	Voice and data link data evaluation and display
5.	Docking/berthing	Docking/berthing for Shuttle; transfer personnel, equipment, and supplies
6.	Logistics	Storage for facility and payload supplies
7.	Ground communication and data	Tracking, voice/data communication, and data distribution
8.	STS	Shuttle ground to space transport, resupply logistics

SPACE STATION PROGRAMS

LIFE SCIENCE NON-HUMAN RESEARCH LABORATORY ARCHITECTURAL CONCEPT

SCENARIO 2



HABITATION MODULE

LABORATORY MODULE

POWER & CONTROL MODULE

LOGISTICS MODULE

COMMUNICATIONS & DATA SYSTEM MODULE

DOCKING/ BERTHING

GROUND COMMUNICATION & DATA SYSTEM

STS

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SCENARIO 2--ROLE OF SPACE STATION TO SUPPORT NON-HUMAN RESEARCH LABORATORY

The space station provides direct, continuous long-term support to the non-human research laboratory mission. Crewmembers (science investigators) provide hands-on interaction with specimens and conduct experiments. The station provides direct power and environmental interfaces and supports onboard data storage and evaluation, communications, and data transfer to the ground. Equipment maintenance, service, and logistics resupply are conducted continuously.

Space station attributes to support this mission are shown here.

SPACE STATION PROGRAMS

ROLE OF SPACE STATION TO SUPPORT NON-HUMAN RESEARCH LABORATORY

SCENARIO 2

ATTRIBUTES

- PROVIDE LONG-DURATION HABITATION FOR PERSONNEL
- PROVIDE SHIRTSLEEVE INTERACTIVE "HANDS ON" LABORATORY
- PROVIDE ELECTRICAL POWER AND DATA/COMMUNICATIONS INTERFACE
- PROVIDE VOICE AND DATA LINK TO GROUND
- PROVIDE ALTITUDE AND ATTITUDE ORIENTATION
- PROVIDE PERIODIC REPLENISHMENT OF EXPENDABLES AND PERSONNEL
- PROVIDE SCHEDULED AND UNSCHEDULED MAINTENANCE
- PROVIDE DOCKING AND OPERATIONAL INTERFACE WITH STS

SCENARIO 3--CELESTIAL OBSERVATORY--MISSION FUNCTIONAL SEQUENCE

The objective of this mission is to use the STARLAB, a 1-m, ultraviolet/visible, wide-field telescope, coupled with a direct imager and a spectrograph, to observe celestial sources. Operations will be conducted continuously to observe, catalog, and evaluate light sources from the celestial sphere (galactic, extragalactic, solar system) continuously.

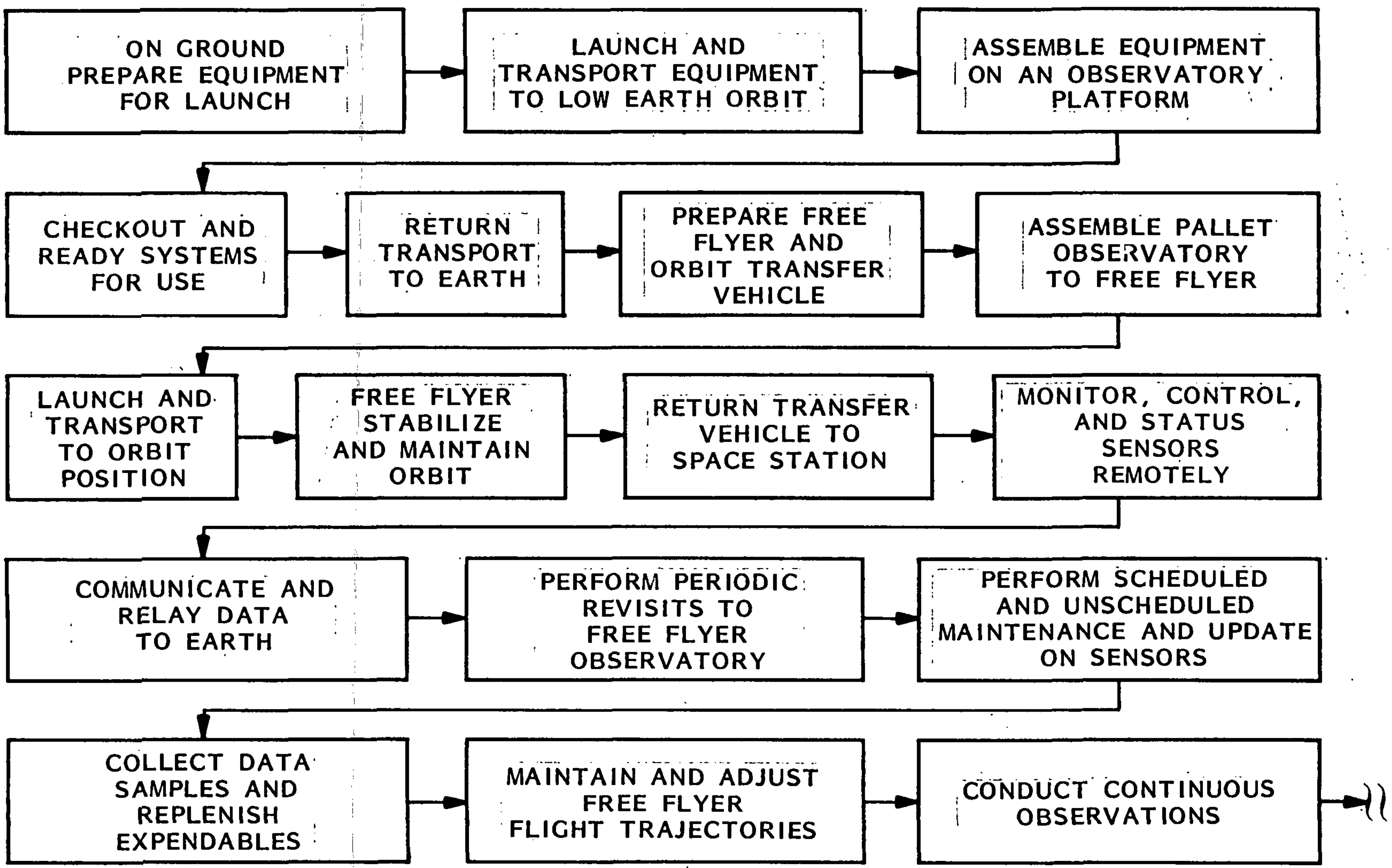
Since the sensing instruments are sensitive to contamination and the instrument's viewing sequence can be automated on a relatively steady-state basis, there is no requirement for direct hands-on manned interaction. This mission is best implemented by a free-flying-type observatory that is detached, controlled and monitored by the space station, and maintained and serviced periodically.

The functional sequence to position and operate a celestial observatory in a free-flying mode in LEO is shown here.

SPACE STATION PROGRAMS

CELESTIAL OBSERVATORY MISSION FUNCTIONAL SEQUENCE

SCENARIO 3



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SCENARIO 3--CELESTIAL OBSERVATORY ARCHITECTURAL CONCEPT

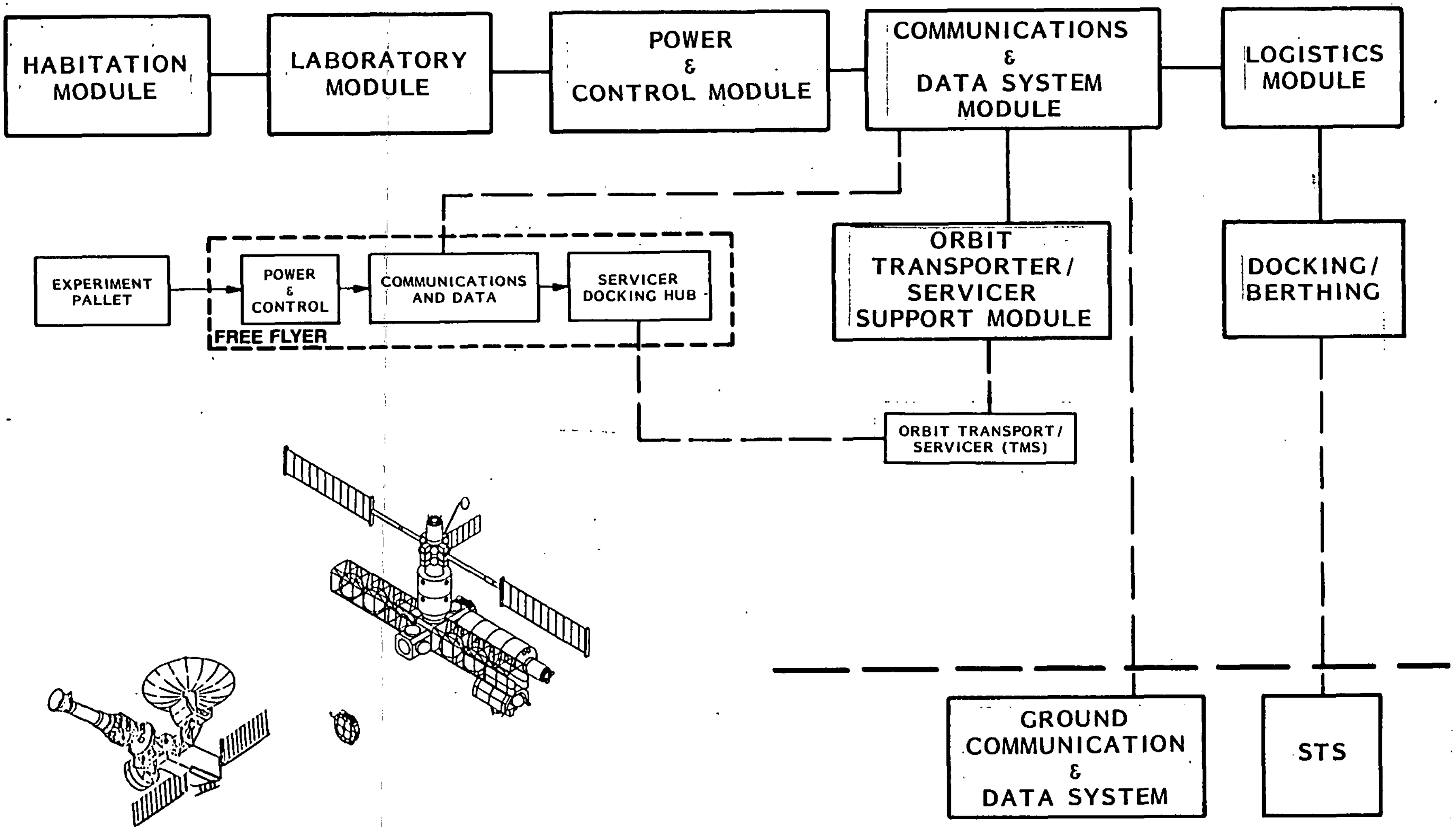
The system architecture for the celestial observatory is shown here. An open-pallet-type observatory is directly coupled to a free-flyer vehicle. The free flyer provides direct electrical power and communication data interface to observatory instruments. Communications and data are operationally interfaced to the space station and then to the ground system. The STS provides direct support to initially transport the observatory to the station and to provide logistics support during the mission life. A station-based orbit transporter vehicle such as TMS transports the observatory/free flyer to an orbit position detached from the station and services the observatory during its mission lifetime.

Functions of the sytem architectural elements are presented below:

	Module	Functions
1.	Habitation	Living and maintenance of crew
2.	Laboratory	Hands-on experiment, sensor setup and checkout
3.	Experiment pallet	Remote experiment, sensor testbed
4.	Power and control	Electrical power, attitude stabilization, and control
5.	Communication and data system	Voice and data link data evaluation and display
6.	Docking/berthing	Docking/berthing for Shuttle; transfer personnel, equipment, and supplies
7.	Logistics	Storage for facility and payload supplies
8.	Ground communication and data	Tracking, voice/data communication, and data distribution
9.	STS	Shuttle ground to space transport, resupply logistics
10.	Orbit transporter/servicer	Thrust, guidance, rendezvous docking to transport items to/from station to other orbits; automated and remotely controlled servicing and maintenance
11.	Free flyer	Power communications, attitude control, structural and docking interface
12.	Orbit transporter/ servicer support	Docking, service, checkout, assembly, propellant/gas loading

CELESTIAL OBSERVATORY ARCHITECTURAL CONCEPT

SCENARIO 3



SCENARIO 3 - ROLE OF SPACE STATION TO SUPPORT CELESTIAL OBSERVATORY

The space station provides continuous, long-term support to the free-flyer celestial observatory. After detached orbit placement of the free flyer, communication and control and data interfaces are maintained to monitor, evaluate, and transfer data. Maintenance, service, and logistics resupply are performed by the station-based TMS at periodic intervals on a long-term basis.

Space station attributes to support this mission are shown in this chart.

SPACE STATION PROGRAMS

ROLE OF SPACE STATION TO SUPPORT CELESTIAL OBSERVATORY

SCENARIO 3

ATTRIBUTES

- PROVIDE LONG-DURATION HABITATION FOR PERSONNEL
- PROVIDE SHIRTSLEEVE INTERACTIVE "HANDS ON" LABORATORY
- PROVIDE INSTRUMENTATION/SENSOR CALIBRATION AND CHECKOUT
- PROVIDE ELECTRICAL POWER AND DATA/COMMUNICATIONS INTERFACE
- PROVIDE VOICE AND DATA LINK TO GROUND
- PROVIDE ALTITUDE AND ATTITUDE ORIENTATION
- PROVIDE PERIODIC REPLENISHMENT OF EXPENDABLES AND PERSONNEL
- PROVIDE SCHEDULED AND UNSCHEDULED MAINTENANCE
- PROVIDE SERVICING AND SUPPORT FOR ORBIT TRANSPORTER/SERVICER
- PROVIDE ORBIT PLACEMENT/RECOVERY FOR FREE FLYER CELESTIAL OBSERVATORY
- PROVIDE SERVICING/TENDING FOR FREE FLYER CELESTIAL OBSERVATORY
- PROVIDE REMOTE OPERATIONS SUPPORT FOR FREE FLYER CELESTIAL OBSERVATORY
- PROVIDE DOCKING AND OPERATIONAL INTERFACE WITH STS

SCENARIO 4--SPACE ENVIRONMENT--MISSION FUNCTIONAL SEQUENCE

The objective of this mission is to develop instrumentation and procedures and to measure environmental characteristics of space on a continuous, long-duration basis. A solar terrestial observatory (STO) containing 17 flight experiments operating in an extensive simultaneous and continuous mode will provide environmental data in the following areas: solar variability, wave-particle processes, magnetosphere-mass transport, global electric circuit, upper atmospheric dynamics, middle atmosphere chemistry and energetics, lower atmospheric turbidity, and planetary atmospheric waves.

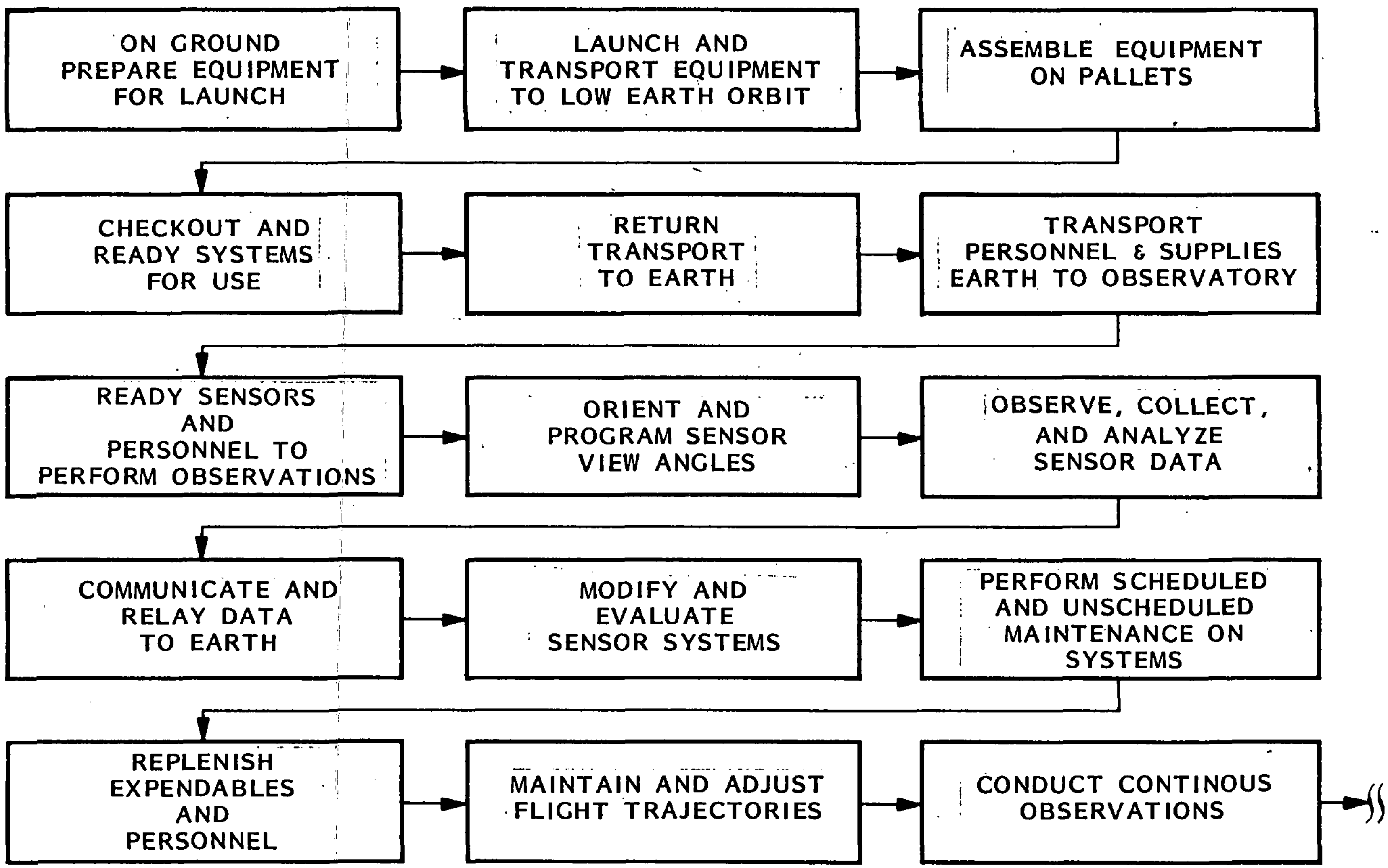
Direct interaction with the instruments by crew scientists will be used to evaluate and develop sensors and operating procedures in the actual space environment and to provide on-the-spot dynamic response for evaluating and investigating transient observed phenomena.

The functional sequence to assemble and operate a space environment facility is shown here.

SPACE STATION PROGRAMS

SCENARIO 4

SPACE ENVIRONMENT MISSION FUNCTIONAL SEQUENCE



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SCENARIO 4--SPACE ENVIRONMENT FACILITY ARCHITECTURAL CONCEPT

The system architecture for the space environment facility is shown here. An enclosed laboratory-type module in combination with open-faced experiment pallet(s) is directly coupled to the basic space station subelements. This permits personnel to perform hands-on interaction with experiments in the laboratory and remote interaction with experiments on the pallet(s). The STS provides direct support to initially transport the laboratory module, pallets, and experiments to LEO and to continue logistics support for consumables, crew scientist rotation, and experiment modifications during misison lifetime. Data evaluation is conducted onboard the space station, and data are transmitted to the ground data systems via the space station to ground communication link.

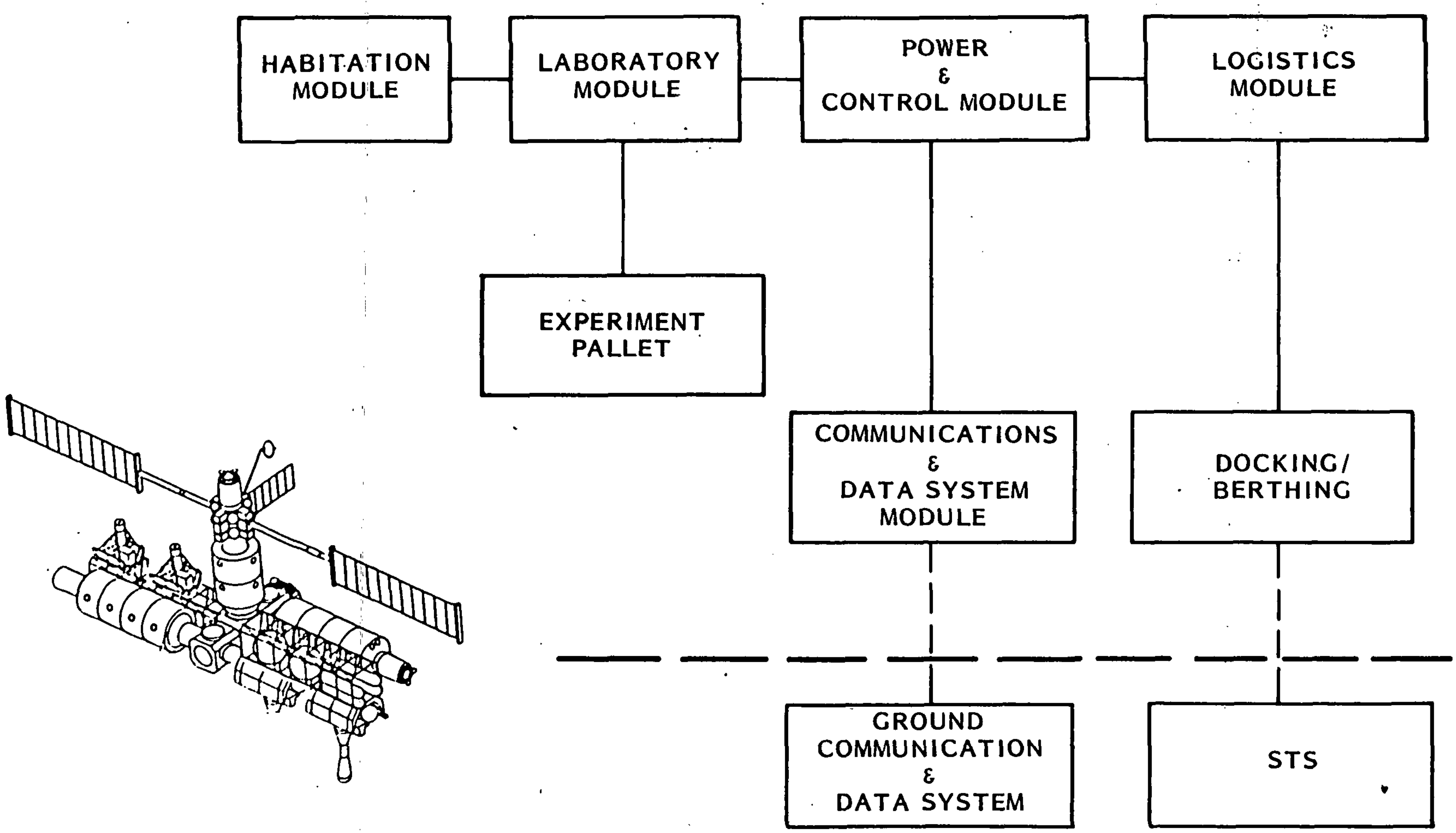
Functions of the system architecture are presented below:

	Module	Functions
1.	Habitation	Living and maintenance of crew
2.	Laboratory	Hands-on human experiment, sensor setup and remote operations
3.	Experiment pallet	Remote experiment, sensor testbed
4.	Power and control	Electrical power, attitude stabilization, and control
5.	Communication and data system	Voice and data link data evaluation and display
6.	Docking/berthing	Docking/berthing for Shuttle; transfer personnel, equipment, and supplies
7.	Logistics	Storage for facility and payload supplies
8.	Ground communication and data	Tracking, voice/data communication, and data distribution
9.	STS	Shuttle ground to space transport, resupply logistics

SPACE STATION PROGRAMS

SCENARIO 4

SPACE ENVIRONMENT FACILITY ARCHITECTURAL CONCEPT



SCENARIO 4--ROLE OF SPACE STATION TO SUPPORT SPACE ENVIRONMENT FACILITY

The space station provides direct, continuous, long-term support to the space environment facility mission. The station provides direct electrical power and environmental interfaces and supports onboard data analysis and conferencing communications and data transfer to the ground. Direct EVA-type support is provided to service and maintain experiments mounted on open pallet(s). Laboratory equipment maintenance and service and consumable replenishment is conducted continuously.

Space station attributes to support this mission are shown in this chart.

SPACE STATION PROGRAMS

ROLE OF SPACE STATION TO SUPPORT SPACE ENVIRONMENT FACILITY

SCENARIO 4

ATTRIBUTES

- PROVIDE LONG-DURATION HABITATION FOR PERSONNEL
- PROVIDE SHIRTSLEEVE INTERACTIVE "HANDS ON" LABORATORY
- PROVIDE REMOTE INSTRUMENTATION/SENSOR TESTBED PALLETS
- PROVIDE ELECTRICAL POWER AND DATA/COMMUNICATIONS INTERFACE
- PROVIDE VOICE AND DATA LINK TO GROUND
- PROVIDE ALTITUDE AND ATTITUDE ORIENTATION
- PROVIDE PERIODIC REPLENISHMENT OF EXPENDABLES AND PERSONNEL
- PROVIDE SCHEDULED AND UNSCHEDULED MAINTENANCE
- PROVIDE DOCKING AND OPERATIONAL INTERFACE WITH STS

SCENARIO 5--EARTH OBSERVATION FACILITY--MISSION FUNCTIONAL SEQUENCE

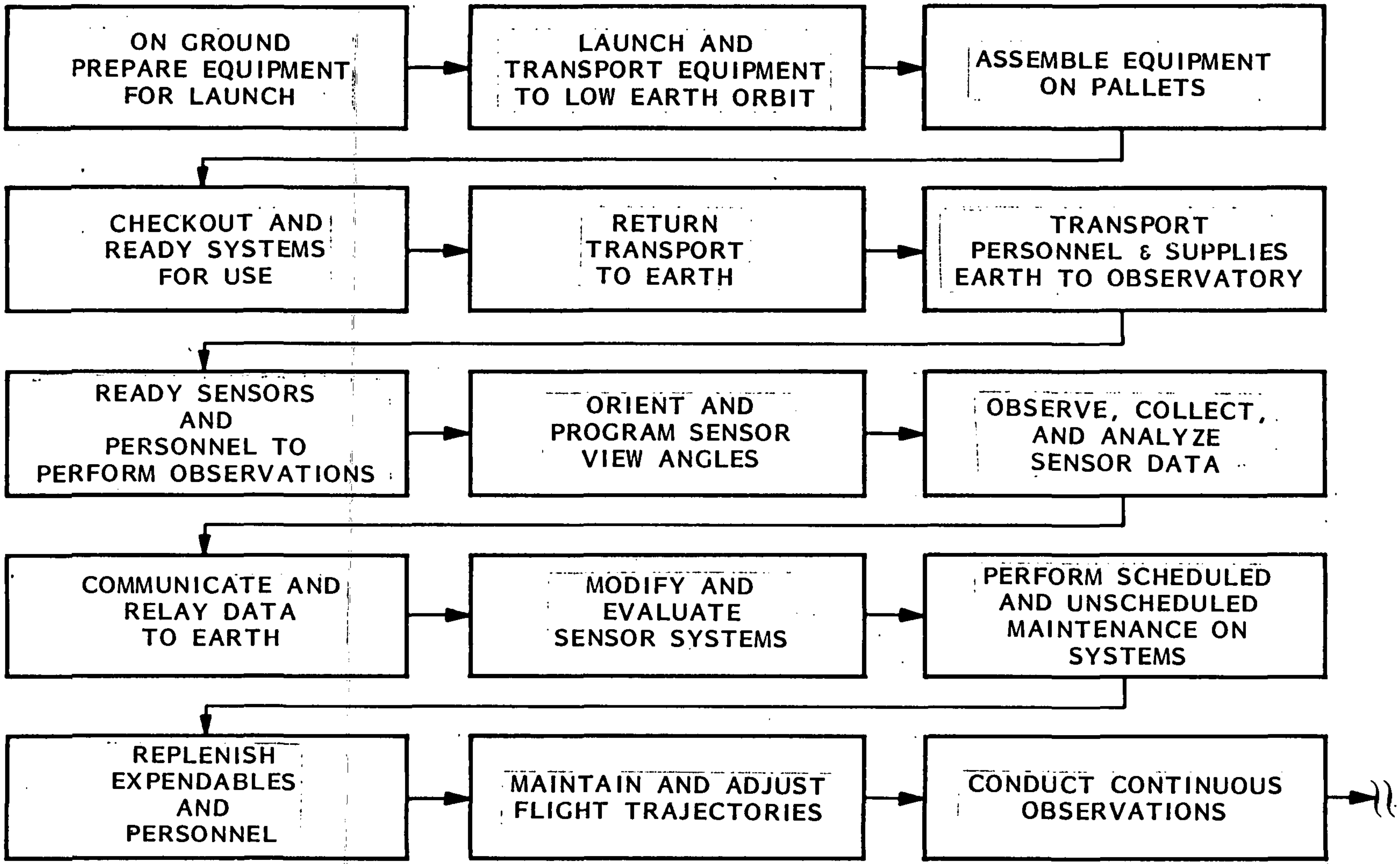
The objective of this mission is to develop instrumentation and procedures for monitoring Earth resources on a continuous, long-duration basis. The facility will use a synthetic aperture radar (SAR) with electronic beamsteering and mechanical tilting to acquire targets. In addition, an imaging spectrometer fed by a 3-m telescope mounted on a fine guidance and pointing mount will be used. These and other instruments will be used to detect and monitor geodetic characteristics, determine thermal absorption and radiation characteristics, and status renewable and nonrenewable material resources.

Direct interaction with the instruments by crew scientists will be used to evaluate and develop sensors and operating procedures in the actual space environment and to provide on-the-spot dynamic response for evaluating and investigating transient observed phenomena.

The functional sequence to assemble and operate a space environment facility is shown here.

SCENARIO 5

EARTH OBSERVATION FACILITY MISSION FUNCTIONAL SEQUENCE



SCENARIO 5--EARTH OBSERVATION FACILITY ARCHITECTURAL CONCEPT

The system architecture for the Earth observation facility is shown here. An enclosed laboratory-type module in combination with open-faced experiment pallet(s) is directly coupled to the basic space station subelements. This permits personnel to perform hands-on interaction with experiments in the laboratory and remote interaction with experiments on the pallet(s). The STS provides direct support to initially transport the laboratory module, pallets, and experiments to LEO and to continue logistics support for consumables, crew scientist rotation, and experiment modifications during mission lifetime. Data evaluation is conducted onboard the space station, and data are transmitted to the ground data systems via the space station to ground communication link.

Functions of the system architecture are presented below:

	Module	Functions
1.	Habitation	Living and maintenance of crew
2.	Laboratory	Hands-on experiment, sensor setup and remote operations
3.	Experiment pallet	Remote experiment, sensor testbed
4.	Power and control	Electrical power, attitude stabilization, and control
5.	Communication and data system	Voice and data link, data evaluation, and display
6.	Docking/berthing	Docking/berthing for Shuttle; transfer personnel, equipment, and supplies
7.	Logistics	Storage for facility and payload supplies
8.	Ground communication and data	Tracking, voice/data communication, and data distribution
9.	STS	Shuttle ground to space transport, resupply logistics

SPACE STATION PROGRAMS

EARTH OBSERVATION FACILITY ARCHITECTURAL CONCEPT

SCENARIO 5

HABITATION MODULE

LABORATORY MODULE

POWER & CONTROL MODULE

LOGISTICS MODULE

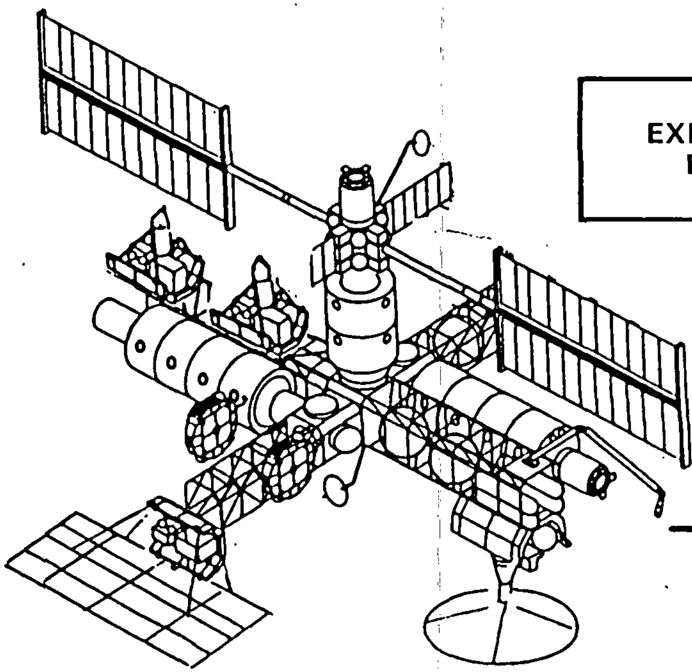
EXPERIMENT PALLET

COMMUNICATIONS & DATA SYSTEM MODULE

DOCKING/ BERTHING

GROUND COMMUNICATION & DATA SYSTEM

STS



SCENARIO 5--ROLE OF SPACE STATION TO SUPPORT EARTH OBSERVATION FACILITY

The space station provides direct, continuous, long-term support to the Earth observation facility mission. The station provides online direct electrical power and environmental interfaces and supports onboard data analysis and conferencing communications and data transfer to the ground. Direct EVA-type support is provided to service and maintain experiments mounted on open pallet(s). Laboratory equipment maintenance and service and consumable replenishment is conducted continuously.

Space station attributes to support this mission are shown in this chart.

ROLE OF SPACE STATION TO SUPPORT EARTH OBSERVATION FACILITY

SCENARIO 5

ATTRIBUTES

- PROVIDE LONG-DURATION HABITATION FOR PERSONNEL
- PROVIDE SHIRTSLEEVE INTERACTIVE "HANDS ON" LABORATORY
- PROVIDE REMOTE INSTRUMENTATION/SENSOR TEST BED PALLETS
- PROVIDE ELECTRICAL POWER AND DATA/COMMUNICATIONS INTERFACE
- PROVIDE VOICE AND DATA LINK TO GROUND
- PROVIDE ALTITUDE AND ATTITUDE ORIENTATION
- PROVIDE PERIODIC REPLENISHMENT OF EXPENDABLES AND PERSONNEL
- PROVIDE SCHEDULED AND UNSCHEDULED MAINTENANCE
- PROVIDE DOCKING AND OPERATIONAL INTERFACE WITH STS

SCENARIO 6--GLOBAL HABITABILITY OBSERVATORY--MISSION FUNCTIONAL SEQUENCE

The objective of this mission is to develop instrumentation and operational procedures for assessing global habitability to meet the needs of the growing Earth population. The observatory will use sensing instruments for realtime continuous observation and evaluation of the interactions between land, ocean, and atmosphere that affect the ability of Earth to sustain human, animal, and plant habitation. It is anticipated that the observatory will be used initially to develop sensor equipment, sensing techniques, and to verify man-machine interactions that affect sensing and control measures. Once operational, the space facility can be used to continuously assess changes in Earth's environment.

Direct interaction with the instruments by crew scientists will be used to evaluate and develop sensors and operating procedures in the actual space environment and to provide on-the-spot dynamic response for evaluating and investigating transient observed phenomena.

The functional sequence to assemble and operate a global habitability observatory is shown here.

GLOBAL HABITABILITY OBSERVATORY MISSION FUNCTIONAL SEQUENCE

SCENARIO 6

1. ON GROUND PREPARE EQUIPMENT FOR LAUNCH
2. LAUNCH AND TRANSPORT EQUIPMENT TO LOW EARTH ORBIT
3. ASSEMBLE EQUIPMENT INTO AN OBSERVATORY AND ON PALLET
4. CHECKOUT AND READY SYSTEMS FOR USE
5. RETURN TRANSPORT TO EARTH
6. TRANSPORT PERSONNEL & SUPPLIES EARTH TO OBSERVATORY
7. READY SENSORS AND PERSONNEL TO PERFORM OBSERVATIONS
8. ORIENT AND PROGRAM SENSORS VIEW ANGLES
9. OBSERVE, COLLECT AND ANALYZE SENSOR DATA
10. COMMUNICATE AND RELAY DATA TO EARTH
11. MODIFY AND EVALUATE SENSOR SYSTEMS AND PERSONNEL INTERACTION
12. PERFORM SCHEDULED AND UNSCHEDULED MAINTENANCE ON SYSTEMS
13. REPLENISH EXPENDABLES AND PERSONNEL
14. MAINTAIN AND ADJUST FLIGHT TRAJECTORIES
15. CONDUCT CONTINUOUS EARTH OBSERVATIONS

SCENARIO 6--GLOBAL HABITABILITY OBSERVATORY ARCHITECTURAL CONCEPT

The system architecture for the global habitability observatory is shown here. An enclosed-laboratory-type module in combination with open-faced experiment pallet(s) is directly coupled to the basic space station subelements. This permits personnel to perform hands-on interaction with experiments in the laboratory and remote interaction with experiments on the pallet(s). The STS provides direct support to initially transport the laboratory module, pallets, and experiments to LEO and to continue logistics support for consumables, crew scientist rotation, and experiment modifications during mission lifetime. Data evaluation is conducted onboard the space station, and data are transmitted to the ground data systems via the space station to ground communication link.

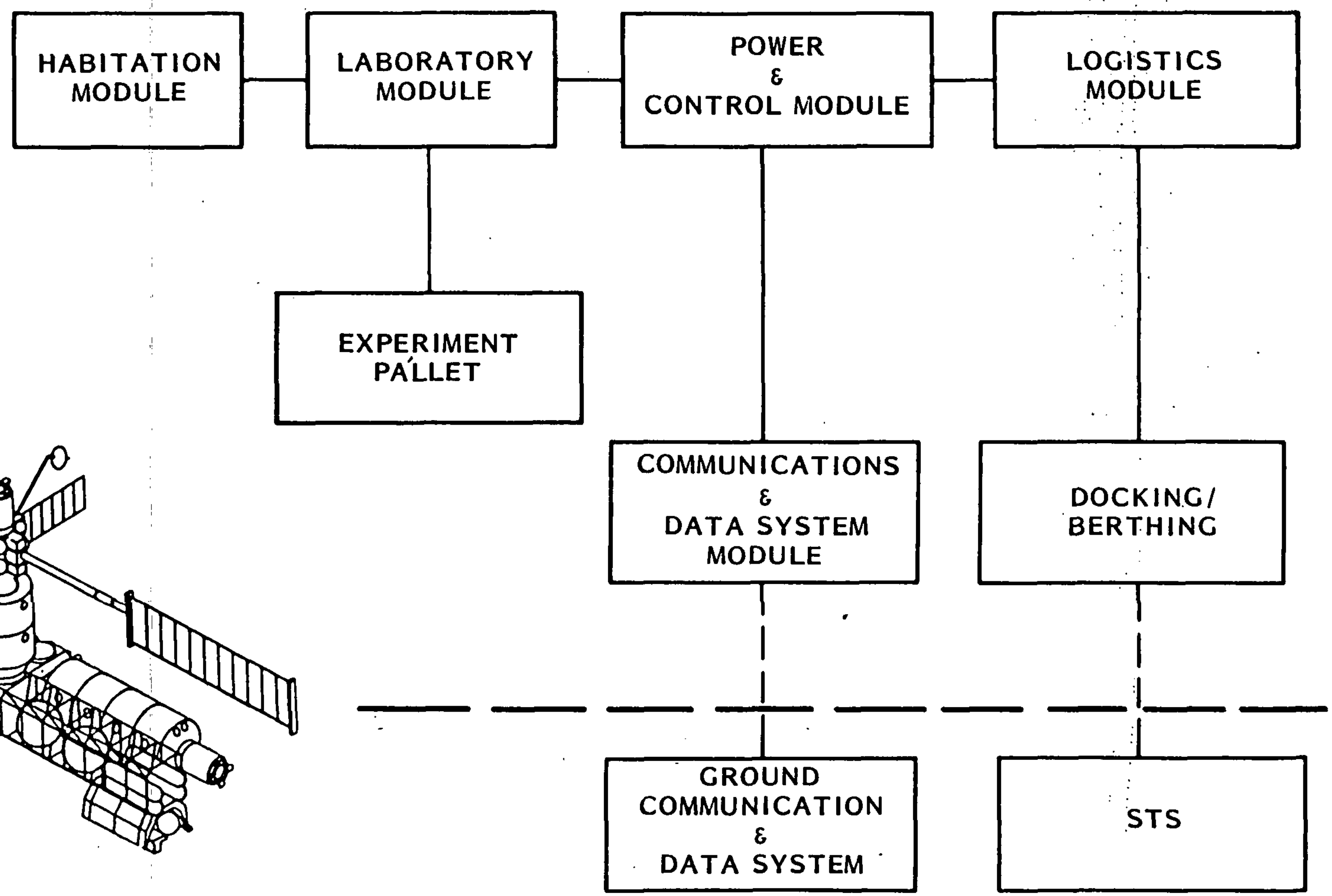
Functions of the system architecture are presented below:

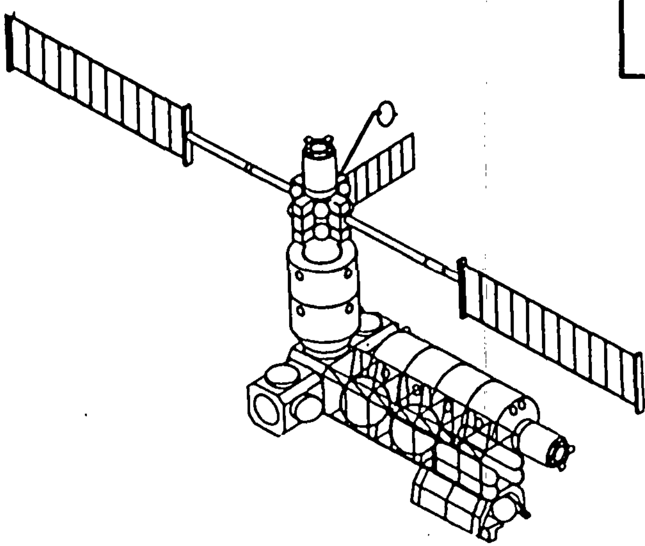
Module	Functions
1. Habitation	Living and maintenance of crew
2. Laboratory	Hands-on experiment, sensor setup and remote operations
3. Experiment pallet	Remote experiment, sensor testbed
4. Power and control	Electrical power, attitude stabilization, and control
5. Communication and data system	Voice and data link, data evaluation and display
6. Docking/berthing	Docking/berthing for Shuttle; transfer personnel, equipment, and supplies
7. Logistics	Storage for facility and payload supplies
8. Ground communication and data	Tracking, voice/data communication, and data distribution
9. STS	Shuttle ground to space transport, resupply logistics

SPACE STATION PROGRAMS

GLOBAL HABITABILITY OBSERVATORY ARCHITECTURAL CONCEPT

SCENARIO 6





SCENARIO 6--ROLE OF SPACE STATION TO SUPPORT GLOBAL HABITABILITY OBSERVATORY

The space station provides direct, continuous, long-term support to the global habitability observatory mission. The station provides online direct electrical power and environmental interfaces and supports onboard data analysis and conferencing communication and data transfer to the ground. Direct EVA-type support is provided to service and maintain experiments mounted on open pallet(s). Laboratory equipment maintenance and service and consumable replenishment are conducted continuously.

Space station attributes to support this mission are shown here.

SPACE STATION PROGRAMS

ROLE OF SPACE STATION TO SUPPORT GLOBAL HABITABILITY OBSERVATORY

SCENARIO 6

ATTRIBUTES

- PROVIDE LONG-DURATION HABITATION FOR PERSONNEL
- PROVIDE SHIRTSLEEVE INTERACTIVE "HANDS ON" LABORATORY
- PROVIDE REMOTE INSTRUMENTATION/SENSOR TESTBED PALLETS
- PROVIDE ELECTRICAL POWER AND DATA/COMMUNICATIONS INTERFACE
- PROVIDE VOICE AND DATA LINK TO GROUND
- PROVIDE ALTITUDE AND ATTITUDE ORIENTATION
- PROVIDE PERIODIC REPLENISHMENT OF EXPENDABLES AND PERSONNEL
- PROVIDE SCHEDULED AND UNSCHEDULED MAINTENANCE
- PROVIDE DOCKING AND OPERATIONAL INTERFACE WITH STS

SCENARIO 7--METEOROLOGICAL FACILITY--MISSION FUNCTIONAL SEQUENCE

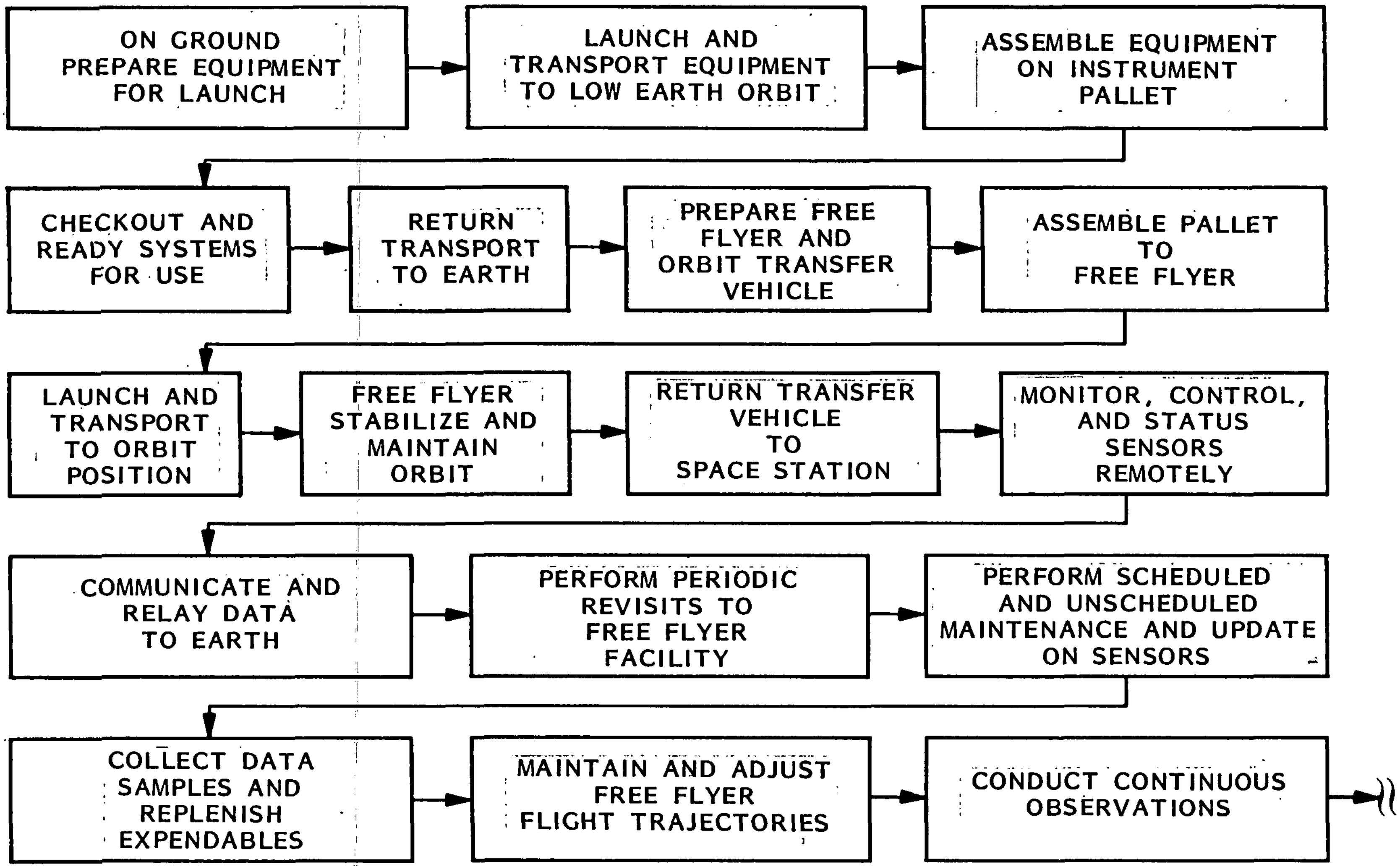
The objective of this mission is to provide continuous meteorological data of Earth for input into numerical weather prediction models for ground-based weather forecasting. Operations will be conducted continuously to observe near-Earth environmental characteristics. Sensors such as the advanced moisture and temperature sounder (AMTS), advanced microwave sounding unit (AMSU), and microwave pressure sounder (MPS) will be used to measure Earth surface and atmospheric temperature, pressure, and moisture characteristics.

Since the sensing instruments are sensitive to contamination and the instrument's viewing sequence can be automated on a relatively steady-state basis, there is no requirement for direct hands-on manned interaction. This mission is best implemented by a free-flying-type observatory that is detached, controlled and monitored by the space station, and maintained and serviced periodically.

The functional sequence to position and operate a meteorological facility in a free-flying mode in LEO is shown here.

METEOROLOGICAL FACILITY MISSION FUNCTIONAL SEQUENCE

SCENARIO 7



SCENARIO 7--METEOROLOGICAL FACILITY ARCHITECTURAL CONCEPT

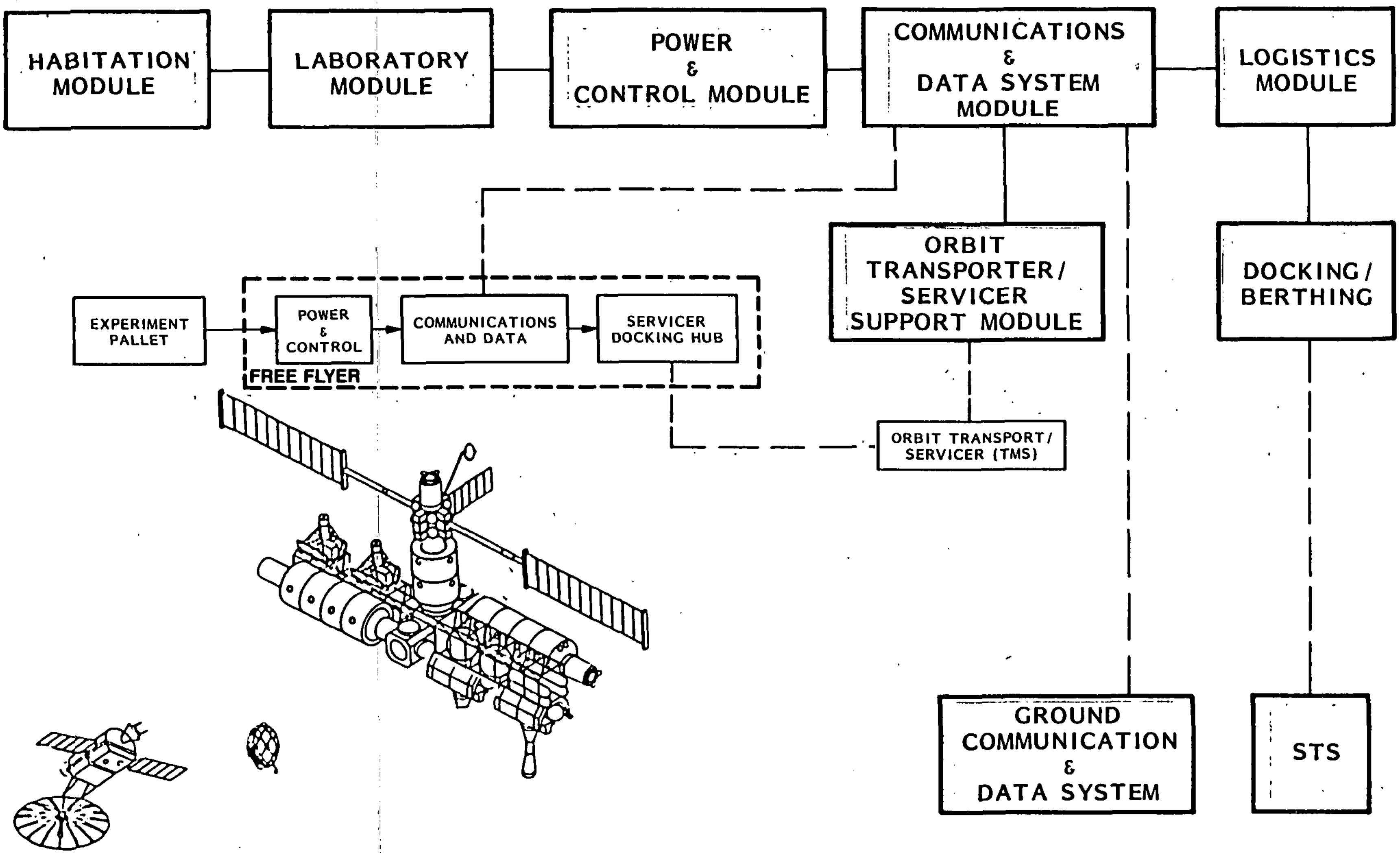
The system architecture for the meteorological facility is shown here. An open pallet-type observatory is directly coupled to a free-flyer vehicle. The free flyer provides direct electrical power and communication data interface to observatory instruments. The communications and data are operationally interfaced to the space station and then to the ground system. The STS provides direct support to initially transport the observatory to the station and to provide logistics support during mission life. A station-based orbit transporter vehicle such as TMS transports the observatory/free flyer to an orbit position detached from the station and services the observatory during its mission lifetime. Functions of the system architectural elements are presented below:

	Module	Functions
1.	Habitation	Living and maintenance of crew
2.	Laboratory	Hands-on experiment, sensor setup, calibration, and checkout
3.	Experiment sensor pallet	Remote experiment, sensor mounting
4.	Power and control	Electrical power, attitude stabilization, and control
5.	Communication and data system	Voice/data link, data evaluation, and display
6.	Docking/berthing	Docking/berthing for Shuttle; transfer personnel, equipment, and supplies
7.	Logistics	Storage for facility and payload supplies
8.	Ground communication and data	Tracking, voice/data communication, and data distribution
9.	STS	Shuttle ground to space transport, resupply logistics
10.	Orbit transporter/servicer	Thrust, guidance, rendezvous, docking to transport items to/from station to other orbits; automated and remote controlled servicing and maintenance
11.	Free flyer	Power communications, attitude control, structural, and docking interface
12.	Orbit transporter/servicer	Docking, service, checkout, assembly, propellant/gas loading support

SPACE STATION PROGRAMS

METEOROLOGICAL FACILITY ARCHITECTURAL CONCEPT

SCENARIO 7



SCENARIO 7--ROLE OF SPACE STATION TO SUPPORT METEOROLOGICAL FACILITY

The space station provides direct, continuous, long-term support to the free-flyer meteorological facility. After detailed orbit placement of the free flyer, communication and control and data interface are maintained to monitor, evalute, and transfer data. Maintenance, service, and logistics resupply are performed by the station-based TMS periodically on a long-term basis.

Space station attributes to support this mission are shown here.

SPACE STATION PROGRAMS

ROLE OF SPACE STATION TO SUPPORT METEOROLOGICAL FACILITY

SCENARIO 7

ATTRIBUTES

- PROVIDE LONG-DURATION HABITATION FOR PERSONNEL
- PROVIDE SHIRTSLEEVE INTERACTIVE "HANDS ON" LABORATORY
- PROVIDE INSTRUMENTATION/SENSOR CALIBRATION AND CHECKOUT
- PROVIDE ELECTRICAL POWER AND DATA/COMMUNICATIONS INTERFACE
- PROVIDE VOICE AND DATA LINK TO GROUND
- PROVIDE ALTITUDE AND ATTITUDE ORIENTATION
- PROVIDE PERIODIC REPLENISHMENT OF EXPENDABLES AND PERSONNEL
- PROVIDE SCHEDULED AND UNSCHEDULED MAINTENANCE
- PROVIDE SERVICING AND SUPPORT FOR ORBIT TRANSPORTER/SERVICER
- PROVIDE ORBIT PLACEMENT/RECOVERY FOR FREE FLYER METEOROLOGICAL FACILITY
- PROVIDE SERVICING/TENDING FOR FREE FLYER METEOROLOGICAL FACILITY
- PROVIDE REMOTE OPERATIONS SUPPORT FOR FREE FLYER METEOROLOGICAL FACILITY
- PROVIDE DOCKING AND OPERATIONAL INTERFACE WITH STS

Lockheed

SCENARIO 8--MATERIAL PROCESSING RESEARCH LABORATORY--MISSION FUNCTIONAL SEQUENCE

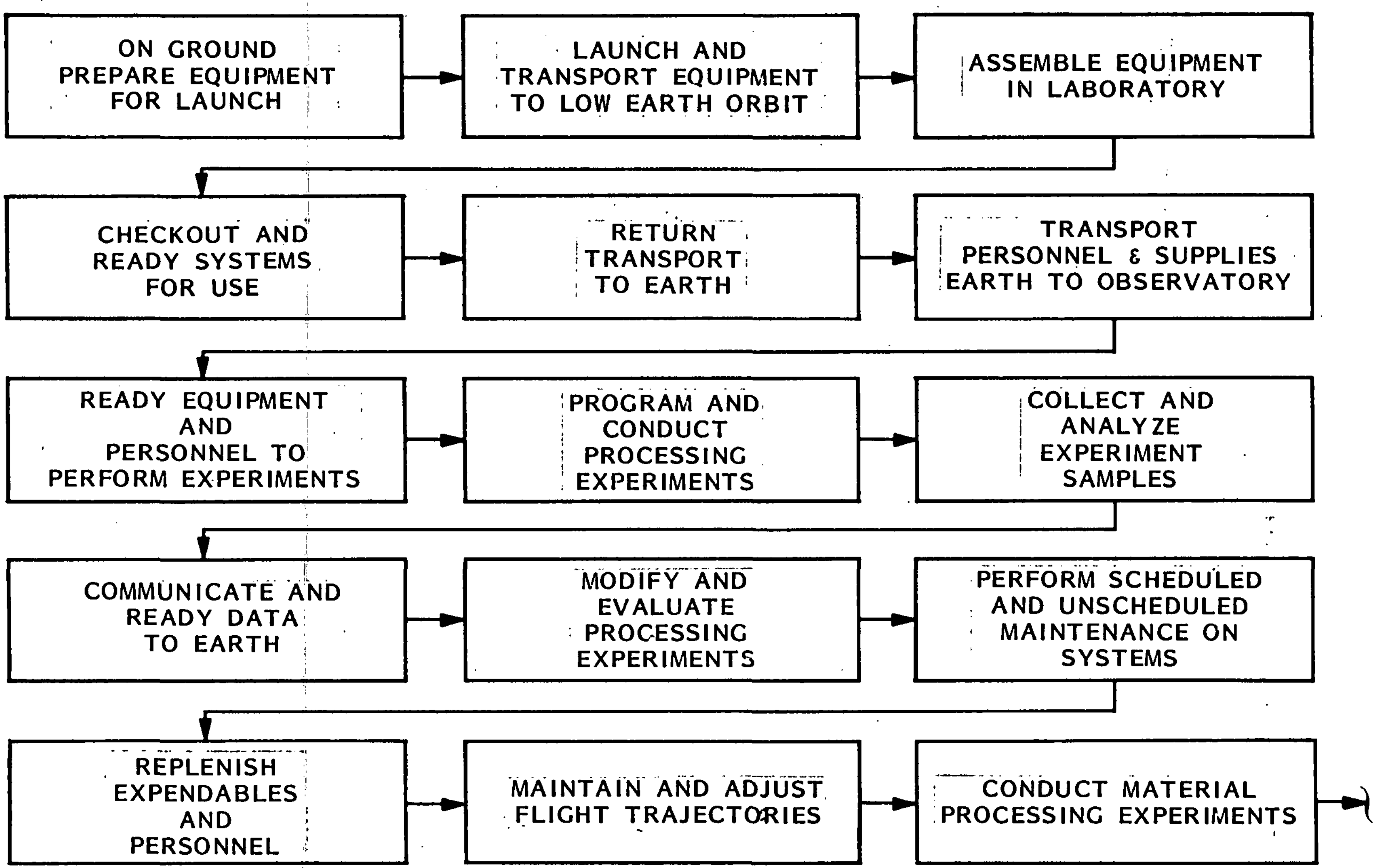
The objective of this mission is to conduct research on material processes and to conduct proof-of-principle experiments under long-term microgravity condition.

Short-, medium-, and long-duration experiments will be set up and conducted on material processing by crew scientists under controlled laboratory-type conditions.

The functional sequence to position and continue operating a laboratory in LEO is shown here.

MATERIALS PROCESSING RESEARCH LABORATORY MISSION FUNCTIONAL SEQUENCE

SCENARIO 8



SCENARIO 8--MATERIAL PROCESSING RESEARCH LABORATORY ARCHITECTURAL CONCEPT

The system architecture for the material processing research laboratory is shown here. An enclosed shirtsleeve laboratory-type module is directly coupled to basic space station subelements, allowing personnel to move freely from habitation quarters into the controlled laboratory. This permits continuous setup and conduct of research experiments on material processes. The STS provides direct support to initially transport the laboratory module to LEO and to continue logistics support for consumables, material samples, and crew scientists rotation during mission lifetime.

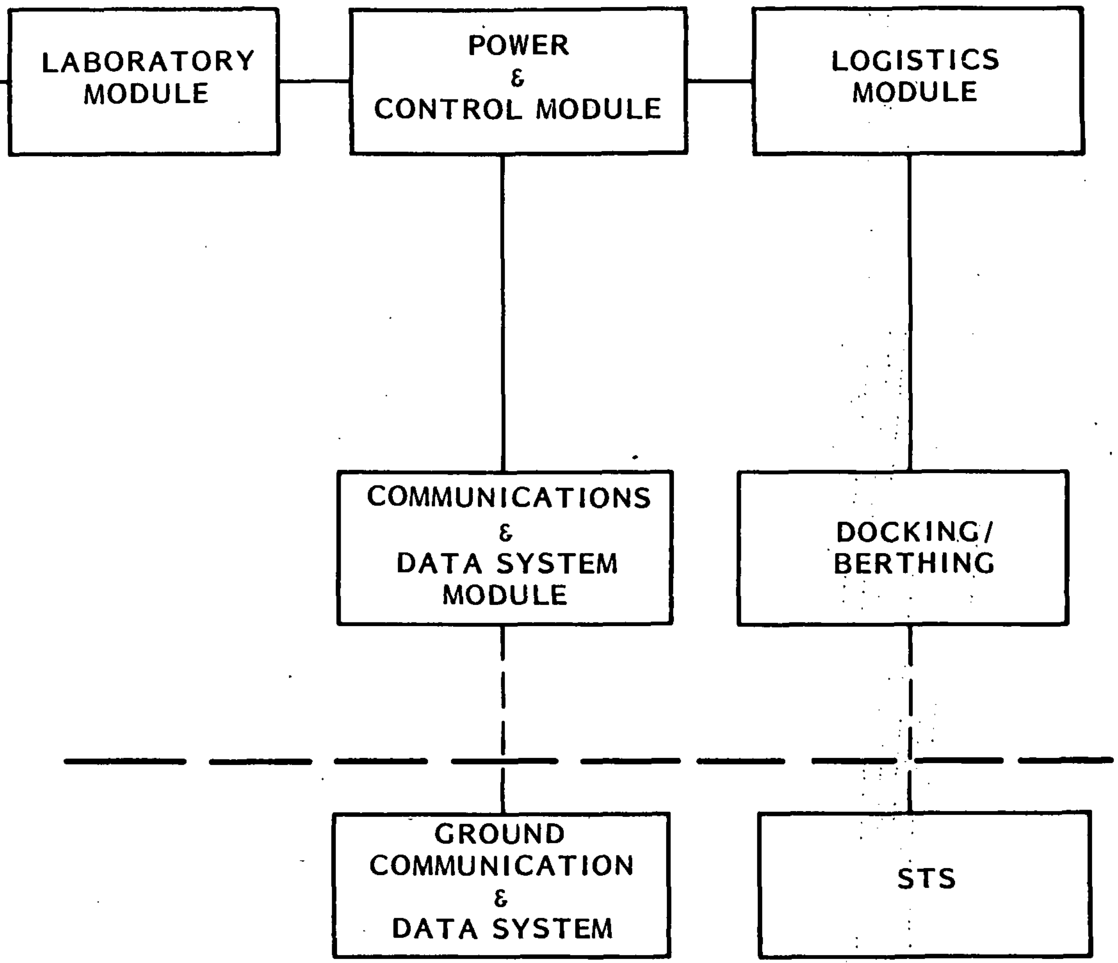
Functions of the systems architectural are presented below:

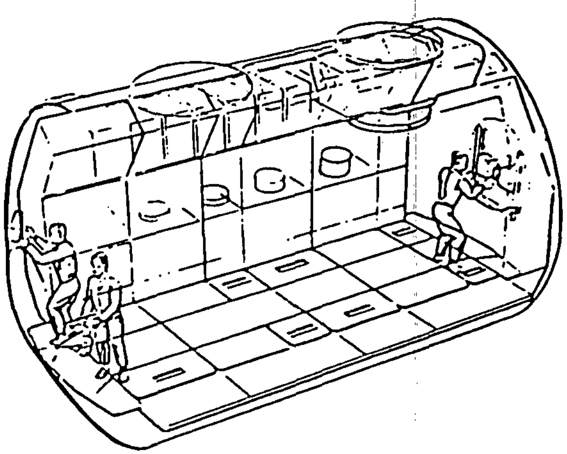
	Module	Functions
1.	Habitation	Living and maintenance of crew
2.	Laboratory	Hands-on experiment setup and test
3.	Power and control	Electrical power, attitude stabilization, and control
4.	Communication and data system	Voice and data link, data evaluation, and display
5.	Docking/berthing	Docking/berthing for Shuttle; transfer personnel, equipment, and supplies
6.	Logistics	Storage for facility and payload supplies
7.	Ground communication and data	Tracking, voice and data communication, and data distribution
8.	STS	Shuttle ground to space transport, resupply logistics

SPACE STATION PROGRAMS

SCENARIO 8

MATERIAL PROCESSING RESEARCH LABORATORY ARCHITECTURAL CONCEPT





SCENARIO 8--ROLE OF SPACE STATION TO SUPPORT MATERIAL PROCESSING RESEARCH LABORATORY

The space station provides direct, continuous, long-term support to the material processing research laboratory mission. Living accommodations and health maintenance for crew experimenters are provided in the habitation module. The station provides direct power and environmental interfaces to the laboratory module and supports onboard data analysis and conferencing communication and data transfer to the ground. Equipment maintenance, service, and exchange are conducted continuously.

Space station attributes to support this mission are shown here.

SPACE STATION PROGRAMS

SCENARIO 8

ROLE OF SPACE STATION TO SUPPORT MATERIALS PROCESSING RESEARCH LABORATORY

ATTRIBUTES

- PROVIDE LONG-DURATION HABITATION FOR PERSONNEL
- PROVIDE SHIRTSLEEVE INTERACTIVE "HANDS ON" LABORATORY
- PROVIDE FOR COLLECTION AND STORAGE OF MATERIAL SAMPLES
- PROVIDE ELECTRICAL POWER AND DATA/COMMUNICATIONS INTERFACE
- PROVIDE VOICE AND DATA LINK TO GROUND
- PROVIDE ALTITUDE AND ATTITUDE ORIENTATION
- PROVIDE PERIODIC REPLENISHMENT OF EXPENDABLES AND PERSONNEL
- PROVIDE SCHEDULED AND UNSCHEDULED MAINTENANCE
- PROVIDE DOCKING AND OPERATIONAL INTERFACE WITH STS

SCENARIO 9--MATERIAL PROCESSING FACILITY--MISSION FUNCTIONAL SEQUENCE

The objective of this mission is twofold: assemble and test prototype pilot model material processing production facilities and use these facilities to process material commercially. Products to be processed include metals, semiconductors, polymers, ceramics, pharmaceuticals, and improved microbiological processes such as fermentations and genetic engineering.

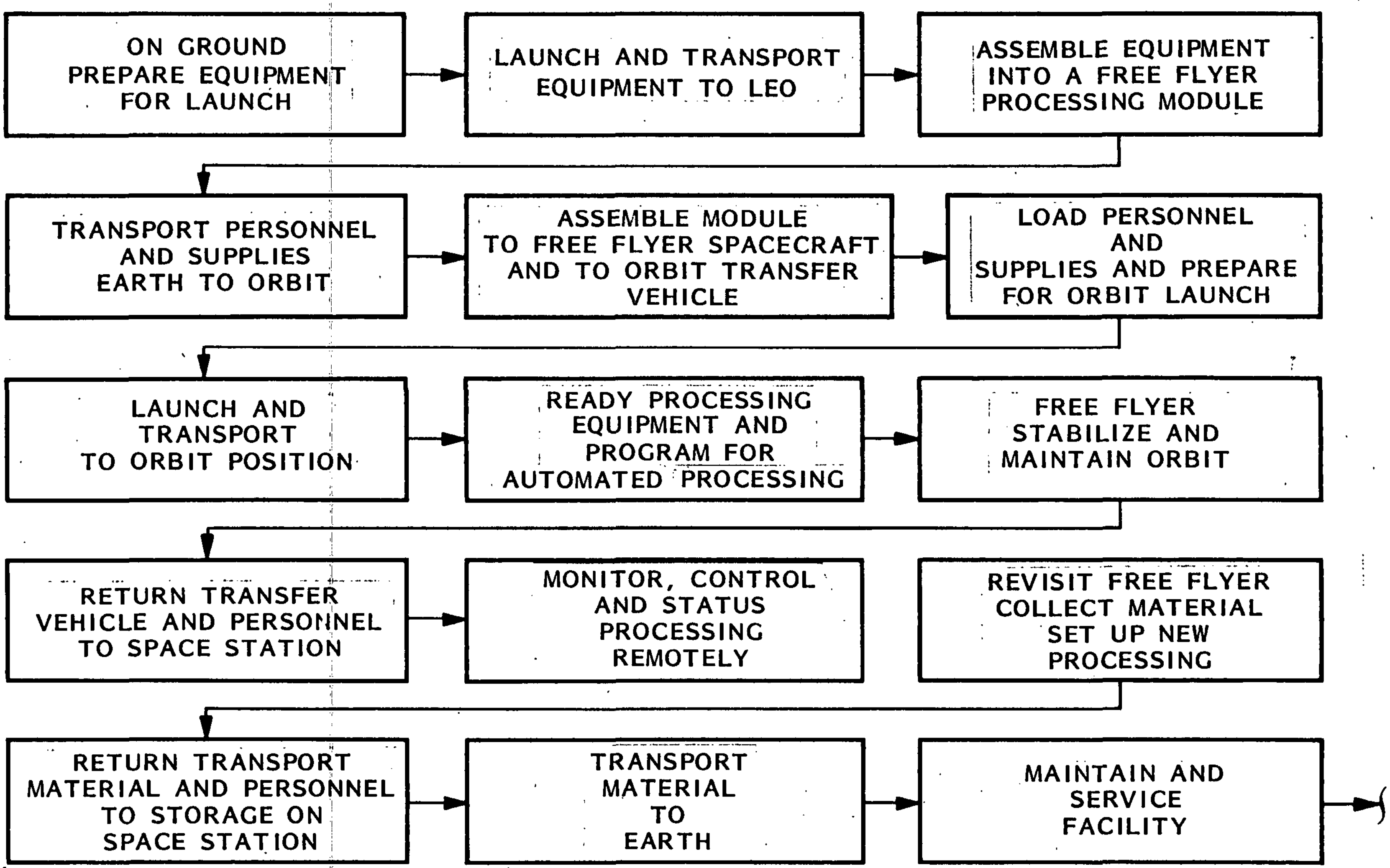
Since low-g levels are required for extended time periods and since the production processor can be automated, manned interaction on a hands-on basis is only needed periodically for setup, modification, maintenance, and material recovery. The mission is best implemented by a free-flying-type facility controlled and monitored by the space station and tended from the space station periodically.

The functional sequence to position and operate a material processing facility in a free-flying mode in LEO is shown here.

SPACE STATION PROGRAMS

MATERIALS PROCESSING FACILITY MISSION FUNCTIONAL SEQUENCE

SCENARIO 9



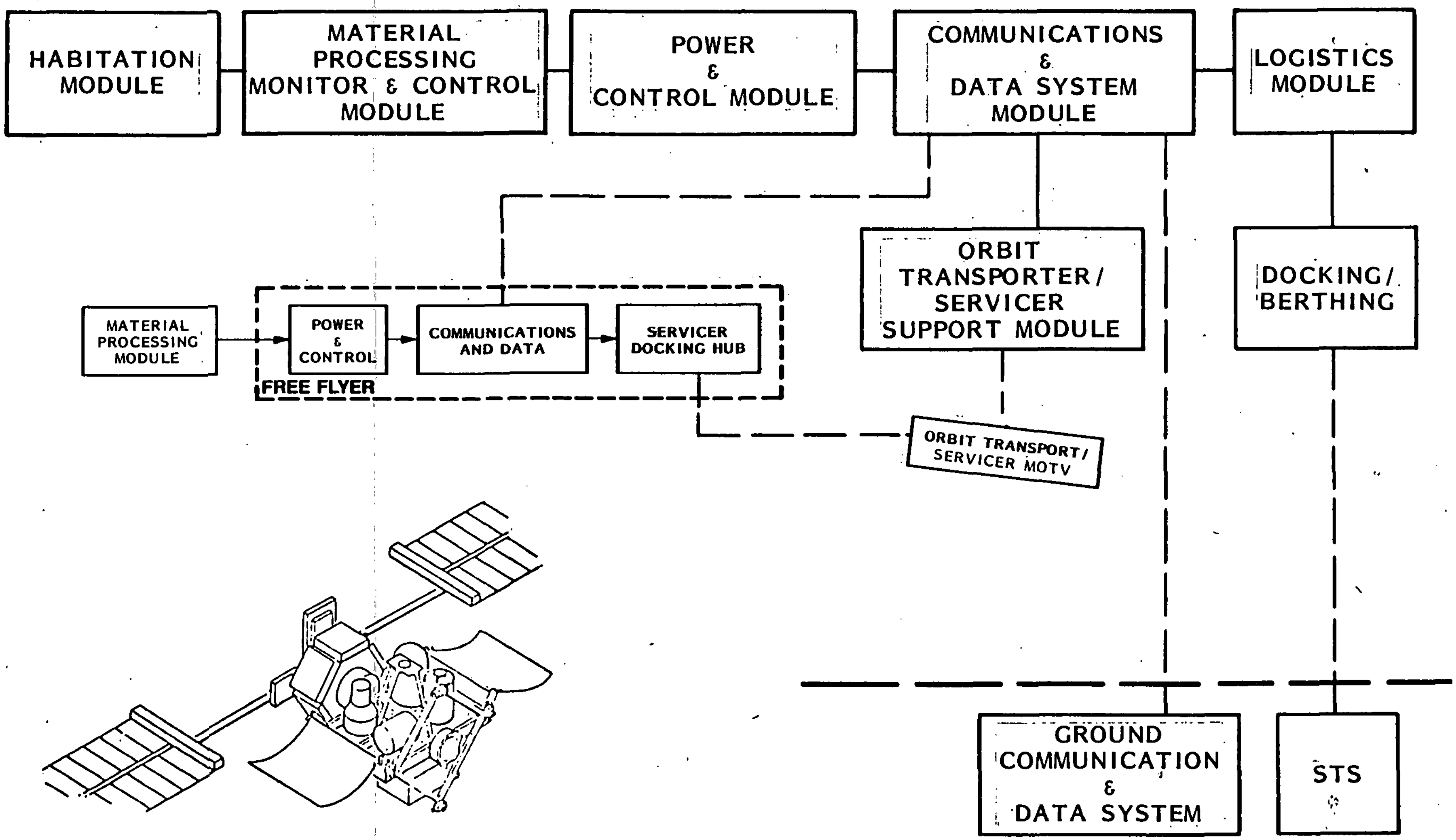
SCENARIO 9--MATERIAL PROCESSING FACILITY ARCHITECTURAL CONCEPT

The system architecture for the material processing facility is shown here. A material processing module is directly coupled to a free-flyer vehicle. The free flyer provides direct electrical power and communication data interface to the space station material processing monitor and control module. The communications and data are interfaced operationally to the space station and then to the ground system. The STS provides direct support to initially transport the observatory to the station and to provide logistics support during mission life. A station-based manned orbit transporter vehicle (OTV/TMS) transports the material processing facility/free flyer to an orbit position detached from the station and services the facility during its mission lifetime. Functions of the system architectural elements are presented below:

	Module	Functions
1.	Habitation	Living and maintenance of crew
2.	Materials processing monitor	Remote display monitor and control of detached processing and control
3.	Materials processing	Automated production and handling of material
4.	Power and control	Electrical power, attitude stabilization, and control
5.	Communication and data system	Voice/data link, data evaluation, and display
6.	Docking/berthing	Docking/berthing for Shuttle; transfer personnel, equipment, and supplies
7.	Logistics	Storage for facility and payload supplies
8.	Ground communication and data	Tracking, voice/data communication, and data distribution
9.	STS	Shuttle ground to space transport, resupply logistics
10.	Orbit transporter/servicer (manned)	Thrust, guidance, rendezvous, docking to transport items to/from station to other orbits; automated and remote controlled servicing and maintenance
11.	Free flyer	Power communications, attitude control, structural, and docking interface
12.	Orbit transporter/servicer	Docking, service, checkout, assembly, propellant/gas loading support

MATERIAL PROCESSING FACILITY ARCHITECTURAL CONCEPT

SCENARIO 9



SCENARIO 9--ROLE OF SPACE STATION TO SUPPORT MATERIAL PROCESSING FACILITY

The space station provides continuous, long-term support to the free-flyer materials processing facility. After detached orbit placement of the free-flyer facility, communication and control and data interfaces are maintained to monitor, evaluate, and transfer data. Manned visits for short time periods are made for maintenance, service, production setup, and material resupply and recovery by the station-based OTV (manned) throughout the mission lifespan.

Space station attributes to support this mission are shown here.

SPACE STATION PROGRAMS

ROLE OF SPACE STATION TO SUPPORT MATERIALS PROCESSING FACILITY

SCENARIO 9

ATTRIBUTES

- PROVIDE LONG-DURATION HABITATION FOR PERSONNEL
- PROVIDE SHIRTSLEEVE INTERACTIVE "HANDS ON" LABORATORY
- PROVIDE ELECTRICAL POWER AND DATA/COMMUNICATIONS INTERFACE
- PROVIDE VOICE AND DATA LINK TO GROUND
- PROVIDE ALTITUDE AND ATTITUDE ORIENTATION
- PROVIDE PERIODIC REPLENISHMENT OF EXPENDABLES AND PERSONNEL
- PROVIDE SCHEDULED AND UNSCHEDULED MAINTENANCE
- PROVIDE SERVICING AND SUPPORT FOR ORBIT TRANSPORTER/SERVICER
- PROVIDE ORBIT PLACEMENT/RECOVERY FOR FREE FLYER MATERIALS PROCESSING FACILITY
- PROVIDE SERVICING/TENDING FOR FREE FLYER MATERIALS PROCESSING FACILITY
- PROVIDE REMOTE OPERATIONS SUPPORT FOR FREE FLYER MATERIALS PROCESSING FACILITY
- PROVIDE DOCKING AND OPERATIONAL INTERFACE WITH STS

SCENARIO 10--SPACE OBSERVATION DEVELOPMENT LABORATORY--MISSION FUNCTIONAL SEQUENCE

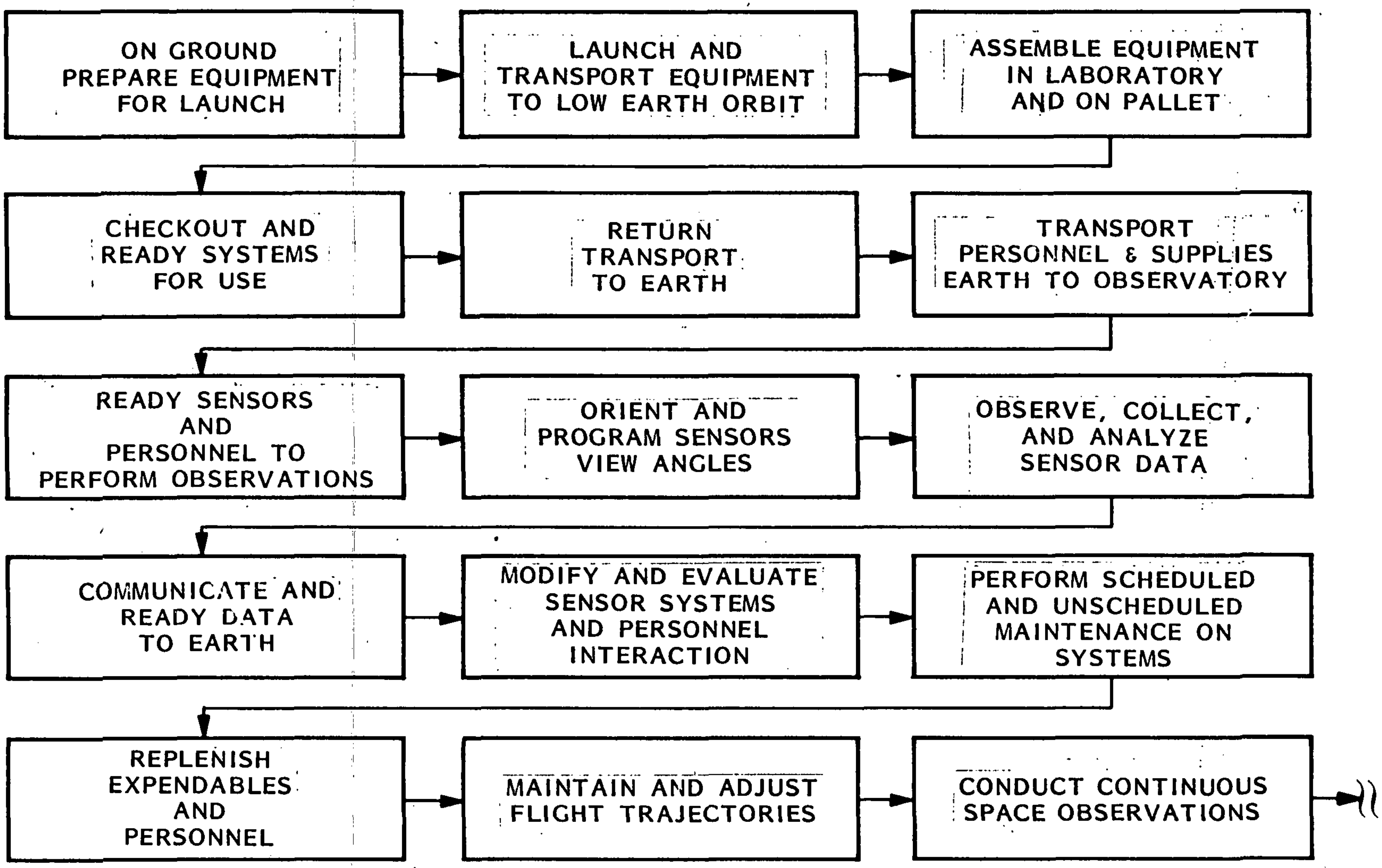
The objective of this mission is to provide a development laboratory and testbed in space where sensor instruments, systems, and operating procedures intended for use in space surveillance can be developed and evaluated. By means of equipment, the operation of characteristics and man's role in controlling sensor targeting and interpreting sensor data can be evaluated.

The functional sequence to position and operate a space observation development laboratory is LEO is shown here.

SPACE STATION PROGRAMS

SCENARIO 10

SPACE OBSERVATION DEVELOPMENT LABORATORY MISSION FUNCTIONAL SEQUENCE



Lockheed

SCENARIO 10--SPACE OBSERVATION DEVELOPMENT LABORATORY ARCHITECTURAL CONCEPT

The system architecture for the space observation development laboratory is shown here. An enclosed laboratory-type module in combination with an open-faced experiment pallet is directly coupled to the basic space station subelements. This permits personnel to perform hands-on interaction with experiments in the laboratory and remote interaction with experiments on the pallet. The STS provides direct support to initially transport the laboratory module, pallets, and experiments to LEO and to continue logistics support for consumables, crew scientist rotation, and experiment modifications during mission lifetime. Data evaluation is conducted onboard the space station, and data are transmitted to the ground data systems via the space station to ground communication link.

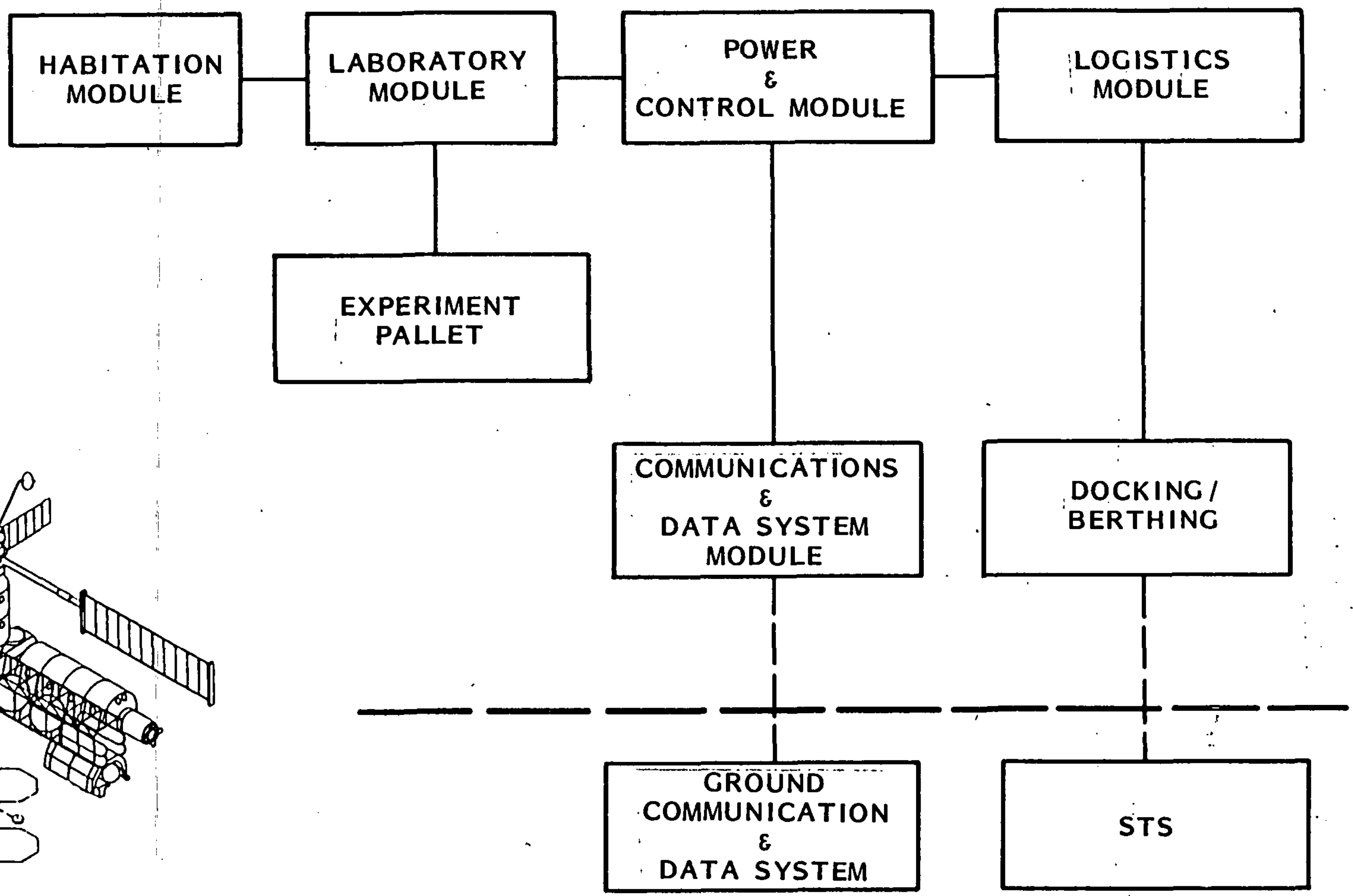
Functions of the system architecture are presented below:

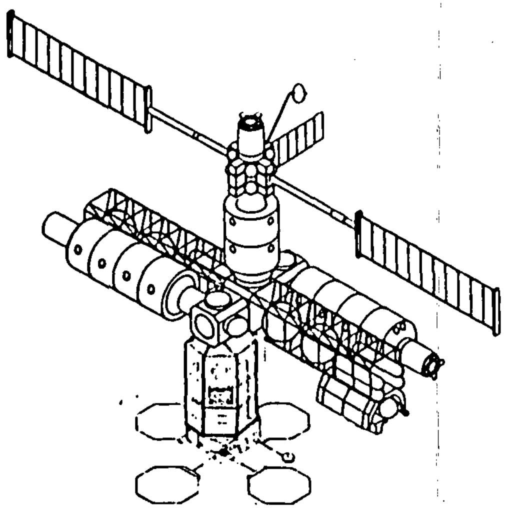
	Module	Functions
1.	Habitation	Living and maintenance of crew
2.	Laboratory	Hands-on experiment, sensor setup and operations
3.	Experiment pallet	Remote experiment, sensor testbed
4.	Power and control	Electrical power, attitude stabilization, and control
5.	Communication and data system	Voice and data link, data evaluation, and display
6.	Docking/berthing	Docking/berthing for Shuttle; transfer personnel, equipment, and supplies.
7.	Logistics	Storage for facility and payload supplies
8.	Ground communication and data	Tracking, voice and data communication, and data distribution
9.	STS	Shuttle ground to space transport, resupply logistics

SPACE STATION PROGRAMS

SPACE OBSERVATION DEVELOPMENT LABORATORY ARCHITECTURAL CONCEPT

SCENARIO 10





SCENARIO 10--ROLE OF SPACE STATION TO SUPPORT SPACE OBSERVATION DEVELOPMENT LABORATORY

The space station provides direct, continuous, long-term support to the space observation development mission. The station provides online direct electrical power and environmental interfaces and supports onboard data analysis and conferencing communications and data transfer to the ground. Direct EVA-type support is provided to service and maintain experiments mounted on the open pallet. Laboratory equipment maintenance and service and consumable replenishment are conducted continuously.

Space station attributes to support this mission are shown on this chart.

SPACE STATION PROGRAMS

SCENARIO 10

ROLE OF SPACE STATION TO SUPPORT SPACE OBSERVATION DEVELOPMENT LABORATORY

ATTRIBUTES

- PROVIDE LONG-DURATION HABITATION FOR PERSONNEL
- PROVIDE SHIRTSLEEVE INTERACTIVE "HANDS ON" LABORATORY
- PROVIDE REMOTE INSTRUMENTATION/SENSOR TESTBED PALLET
- PROVIDE ELECTRICAL POWER AND DATA/COMMUNICATIONS INTERFACE
- PROVIDE VOICE AND DATA LINK TO GROUND
- PROVIDE ALTITUDE AND ATTITUDE ORIENTATION
- PROVIDE PERIODIC REPLENISHMENT OF EXPENDABLES AND PERSONNEL
- PROVIDE SCHEDULED AND UNSCHEDULED MAINTENANCE
- PROVIDE DOCKING AND OPERATIONAL INTERFACE WITH STS

SCENARIO 11--OCEANOGRAPHY OBSERVATORY DEVELOPMENT LABORATORY--MISSION FUNCTIONAL SEQUENCE

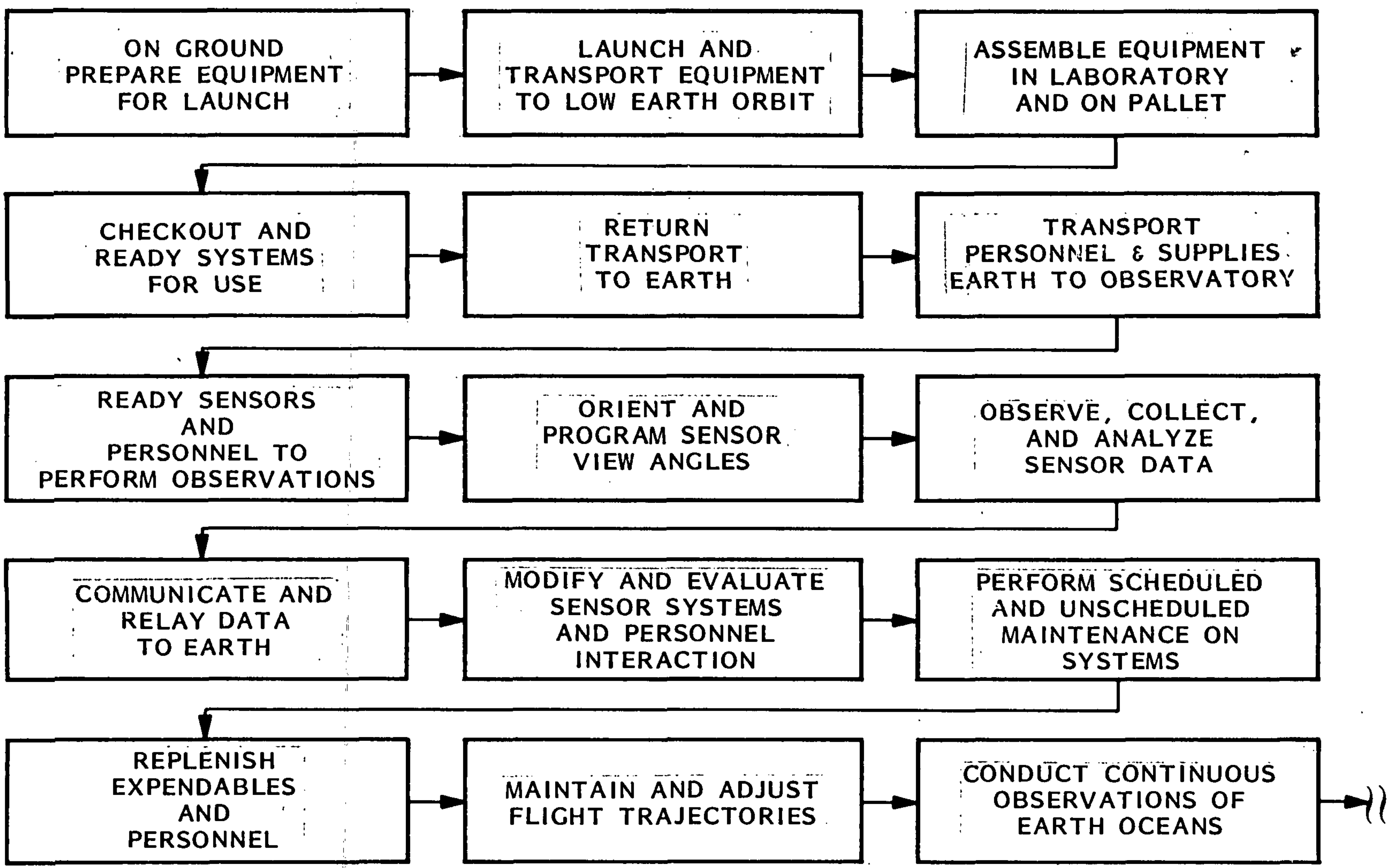
The objective of this mission is to provide a development laboratory and testbed in space where sensor instruments, systems, and operating procedures intended for use in ocean surveillance can be developed and evaluated. By means of direct crew scientist hands-on interaction with breadboard and development equipment, the operational characteristics and man's role in controlling sensor targeting and interpreting sensor data can be evaluated.

The functional sequence to position and operate an oceanography observatory development laboratory in LEO is shown here.

SPACE STATION PROGRAMS

SCENARIO 11

OCEANOGRAPHY OBSERVATORY DEVELOPMENT LABORATORY MISSION FUNCTIONAL SEQUENCE



SCENARIO 11--OCEANOGRAPHY OBSERVATORY DEVELOPMENT LABORATORY ARCHITECTURAL CONCEPT

The system architecture for the oceanography observatory development laboratory is shown here. An enclosed laboratory-type module in combination with an open-faced experiment pallet is directly coupled to the basic space station subelements. This permits personnel to perform hands-on interaction with experiments in the laboratory and remote interaction with experiments on the pallet. The STS provides direct support to initially transport the laboratory module, pallets, and experiments to LEO and to continue logistics support for consumables, crew scientist rotation, and experiment modifications during mission lifetime. Data evaluation is conducted onboard the space station, and data are transmitted to the ground data systems via the space station to ground communication link.

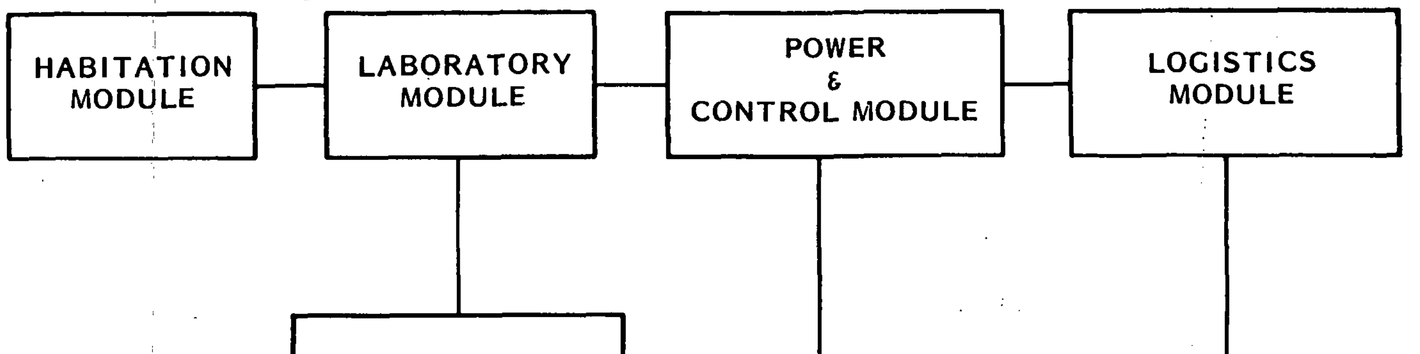
Functions of the system architecture are presented below:

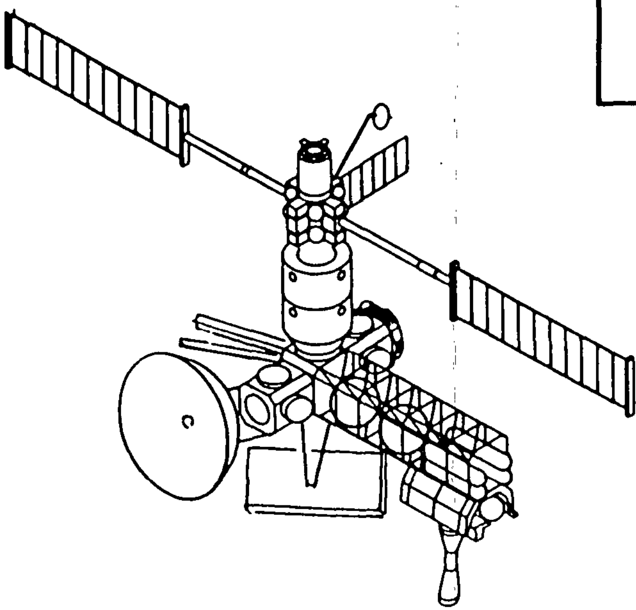
	Module	Functions
1.	Habitation	Living and maintenance of crew
2.	Laboratory	Hands-on experiment, sensor setup and operations
3.	Experiment pallet	Remote experiment, sensor testbed
4.	Power and control	Electrical power, attitude stabilization, and control
5.	Communication and data system	Voice and data link, data evaluation, and display
6.	Docking/berthing	Docking/berthing for Shuttle; transfer personnel, equipment, and supplies
7.	Logistics	Storage for facility and payload supplies
8.	Ground communication and data	Tracking, voice/data communication, and data distribution
9.	STS	Shuttle ground to space transport, resupply logistics

SPACE STATION PROGRAMS

SCENARIO 11

OCEANOGRAPHY OBSERVATORY DEVELOPMENT LABORATORY ARCHITECTURAL CONCEPT





SCENARIO 11--ROLE OF SPACE STATION TO SUPPORT OCEANOGRAPHY OBSERVATORY DEVELOPMENT LABORATORY

The space station provides direct, continuous, long-term support to the oceanography observatory development laboratory mission. The station provides online direct electrical power and environmental interfaces and supports onboard data analysis and conferencing communications and data transfer to the ground. Direct EVA-type support is provided to service and maintain experiments mounted on the open pallet. Laboratory equipment maintenance and service and consumable replenishment are conducted continuously.

Space station attributes to support this mission are shown here.

SPACE STATION PROGRAMS

ROLE OF SPACE STATION TO SUPPORT OCEANOGRAPHY OBSERVATORY DEVELOPMENT LABORATORY

SCENARIO 11

ATTRIBUTES

- PROVIDE LONG-DURATION HABITATION FOR PERSONNEL
- PROVIDE SHIRTSLEEVE INTERACTIVE "HANDS ON" LABORATORY
- PROVIDE REMOTE INSTRUMENTATION/SENSOR TESTBED
- PROVIDE ELECTRICAL POWER AND DATA/COMMUNICATIONS INTERFACE
- PROVIDE VOICE AND DATA LINK TO GROUND
- PROVIDE ALTITUDE AND ATTITUDE ORIENTATION
- PROVIDE PERIODIC REPLENISHMENT OF EXPENDABLES AND PERSONNEL
- PROVIDE SCHEDULED AND UNSCHEDULED MAINTENANCE
- PROVIDE DOCKING AND OPERATIONAL INTERFACE WITH STS

SCENARIO 12--ORBITING NATIONAL COMMAND POST MISSION SEQUENCE

The objective of this mission is to provide a national command post operational in LEO. Orbital elements of the system are assembled in LEO using the transport and assembly capabilities of the STS (orbiter, RMS, and EVA). When activated and operational, it will be manned and operating autonomously on a continuous, long-term basis. Periodic logistic support to replenish expendables, rotate personnel, and maintain and update equipment will be conducted throughout mission lifetime.

The functional sequence to transport, assemble, and operate the command post in LEO is shown here.

SPACE STATION PROGRAMS

ORBITING U.S. NATIONAL COMMAND POST MISSION SEQUENCE

SCENARIO 12

1. ON GROUND PREPARE EQUIPMENT FOR LAUNCH
2. LAUNCH AND TRANSPORT EQUIPMENT TO LOW EARTH ORBIT
3. ASSEMBLE EQUIPMENT INTO COMMAND POST
4. CHECK OUT AND READY SYSTEMS FOR USE
5. RETURN TRANSPORT TO EARTH
6. TRANSPORT PERSONNEL & SUPPLIES EARTH TO COMMAND POST
7. ACTIVATE COMMUNICATION DATA LINKS AND DISPLAY & CONTROL SYSTEMS TO PERFORM OPERATIONS
8. CONDUCT COMMAND POST OPERATIONS
9. EVALUATE AND UP-DATE SYSTEMS AND PERSONNEL INTERACTION
10. PERFORM SCHEDULED AND UNSCHEDULED MAINTENANCE
11. REPLENISH EXPENDABLES AND PERSONNEL
12. MAINTAIN AND ADJUST ORBIT PARAMETERS
13. MAINTAIN AND ADJUST FLIGHT TRAJECTORY
14. CONDUCT CONTINUOUS COMMAND POST OPERATIONS

SCENARIO 12--ORBITING NATIONAL COMMAND POST ARCHITECTURAL CONCEPT

The system architecture for the orbiting national command post is shown here. The functional element modules are assembled inside a modified Shuttle external tank (ET). Crew/operations personnel are housed in a habitation module that directly accesses an operations center module where continuous command post operations are performed. Personnel constantly interact with visual control and display consoles, data evaluation, and teleconferencing with ground command centers. The command post is autonomous and maintains both secured and nonsecured links to ground communication systems. Either the STS or the space station OTV system will provide logistics support.

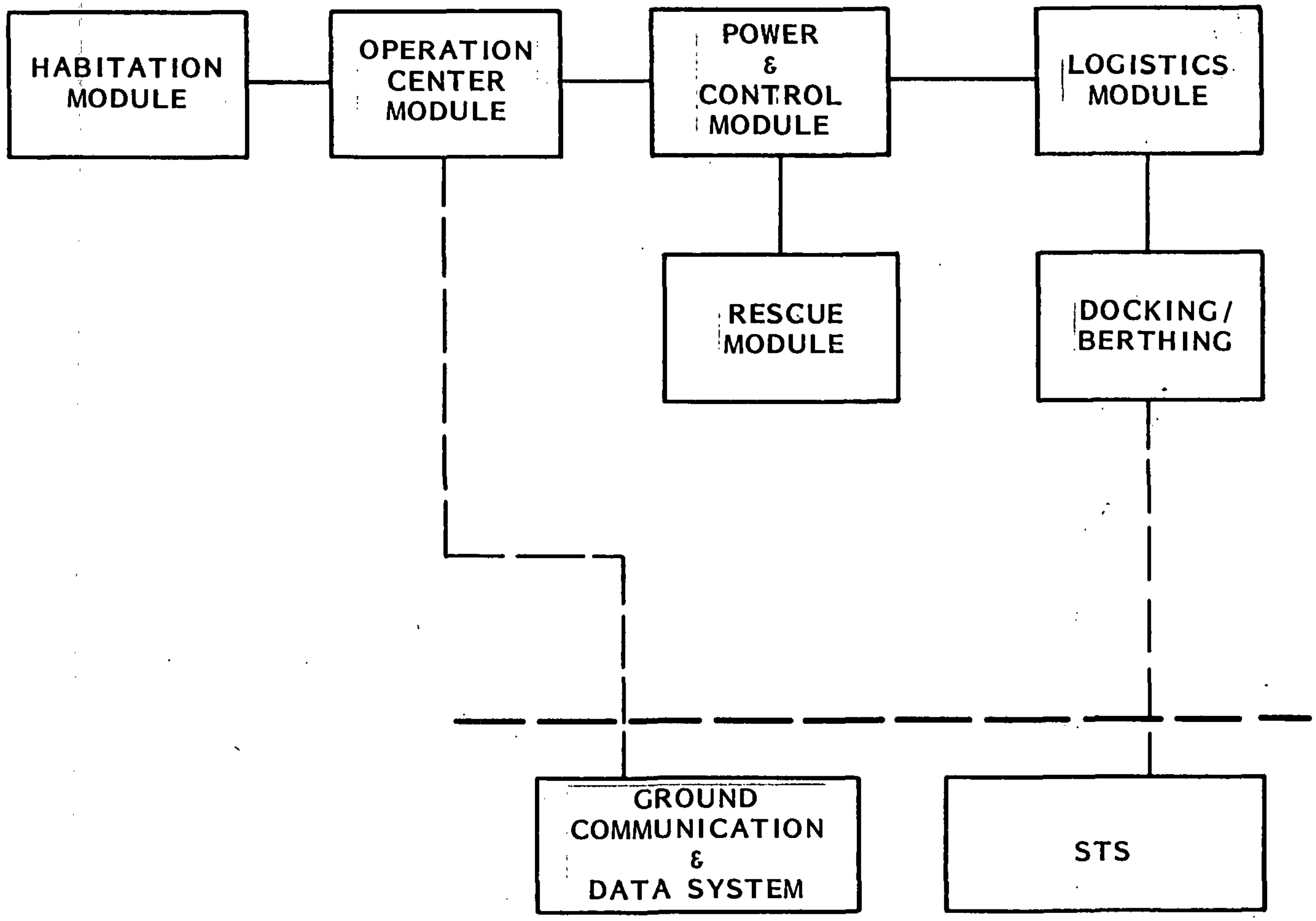
Functions of the system architecture are presented below:

	Module	Functions
1.	Habitation	Living and maintenance of crew
2.	Rescue module	Emergency temporary life support
3.	Operations center	Display, voice communication and operations control, data storage and evaluation, and flight planning
4.	Power and control	Electrical power, attitude stabilization, and control
5.	Docking/berthing	Docking/berthing for Shuttle/orbit transporter vehicles, transfer personnel, equipment, and supplies
6.	Logistics	Storage for facility and housekeeping supplies
7.	Ground communication and data	Tracking, voice and data communication, and data distribution
8.	STS	Shuttle ground to space transport, initial station assembly/ placement, and resupply logistics

SPACE STATION PROGRAMS

ORBITING NATIONAL COMMAND POST ARCHITECTURAL CONCEPT

SCENARIO 12



PICTORIAL IN DOD STUDY SUMMARY

ATTACHMENT 1
VOLUME II

SCENARIO 12--ROLE OF SPACE STATION TO SUPPORT ORBITING NATIONAL COMMAND POST

The orbiting national command post is expected to be operational in 1998. The mission is unique and oriented toward national security. It will be implemented by an autonomous system group of hardware elements that will operate independently of a space station.

The space station will support the national command post in two key roles. First, since it will precede the command post in orbit operations, it will provide a precursor orbital testbed where technology, design, and operations can be developed to support those planned for the command post. Second, after the command post is operational, it can provide a space-based transportation and logistics function with possible backup redundancy for communication and data storage and evaluation. Additional details of the national command post are given in Attachment 1, Volume II.

Space station attributes to support this mission are shown here.

SPACE STATION PROGRAMS

ROLE OF SPACE STATION TO SUPPORT U.S. NATIONAL COMMAND POST

SCENARIO 12

- PROVIDE AN ORBITING PRECURSOR TEST BED FOR DEVELOPMENT/VERIFICATION OF EQUIVALENT/COMMON DESIGN AND OPERATIONAL CONCEPTS TO BE USED FOR CP
  - STS DOCKING INTERFACE AND FLIGHT PROCEDURES
  - HABITATION MODULE CREW LIVING,HEALTH MAINTENANCE,AND WORK AREAS
  - PERSONNEL-EQUIPMENT INTERACTION
  - REGENERATIVE ECLSS
  - ON-ORBIT BUILT IN TEST, CHECKOUT AND MAINTENANCE
  - CREW RESCUE AND SAFE HAVEN
  - AUTONOMOUS SPACE OPERATIONS
  - SPACE TO SPACE AND SPACE TO GROUND COMMUNICATIONS
  - ON BOARD DATA PROCESSING AND GROUND DATA INTERFACE
  - SPACE STRUCTURAL ASSEMBLY AND EVA AND ROBOTIC TECHNIQUES
  - ORBIT DETERMINATION, ORBIT MAINTENANCE, AND FLIGHT PLANNING
  - FLIGHT OPERATION STATION KEEPING TECHNIQUES
- PROVIDE AN ON-LINE REAL TIME SUPPORT SYSTEM TO THE CP
  - EMERGENCY RESCUE-SAFE HAVEN
  - CREW ROTATION
  - TMS MAINTENANCE/LOGISTICS SPARES
  - PROPELLANT STORAGE
  - BACK UP REDUNDANCY - COMMUNICATIONS AND DATA SYSTEM

SCENARIO 13 -- SPACE OBJECTS IDENTIFICATION SYSTEM MISSION FUNCTIONAL SEQUENCE

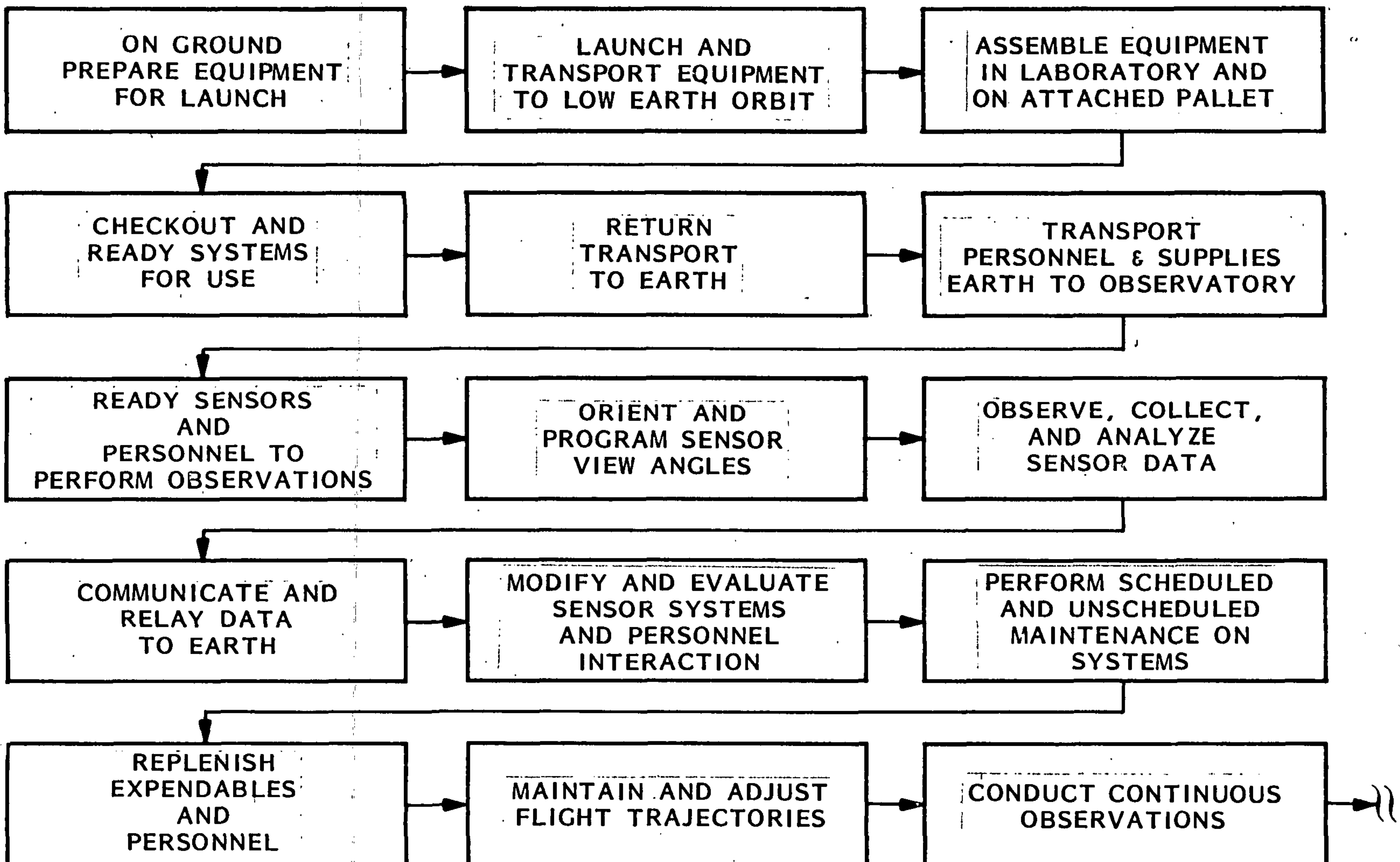
The objective of this mission is to provide a development laboratory and testbed in space where sensor instruments, system, and operating procedures intended for space object surveillance and identification can be developed and evaluated. Once the system has been developed, it is anticipated that it will be placed in an operational mode while some part of the laboratory will continue to provide technology development and evaluation functions. By means of direct crew hands-on interaction with development equipment, operational characteristics and procedures for controlling sensor targeting and interpreting sensor data can be evaluated.

The functional sequence to position and operate a space object identification system development and operational laboratory in low earth orbit (LEO) is shown in this chart.

SPACE STATION PROGRAMS

SPACE OBJECTS IDENTIFICATION SYSTEM MISSION FUNCTIONAL FLOW

SCENARIO 13



SCENARIO 13 -- SPACE OBJECTS IDENTIFICATION SYSTEM ARCHITECTURAL CONCEPT

The system architecture for the space objects identification system is shown on this chart. An enclosed laboratory-type module in combination with an open-faced experiment pallet is directly coupled to the basic space station subelements. This permits personnel to perform hands-on interaction with experiments in the laboratory and remote interaction with experiments on the pallet. The STS provides direct support to initially transport the laboratory module, pallets, and experiments to LEO and to continue logistics support for consumables, crew scientist rotation, and experiment modifications during mission lifetime. Data evaluation is conducted onboard the space station and data are transmitted to the ground data systems via the space station to ground communication link.

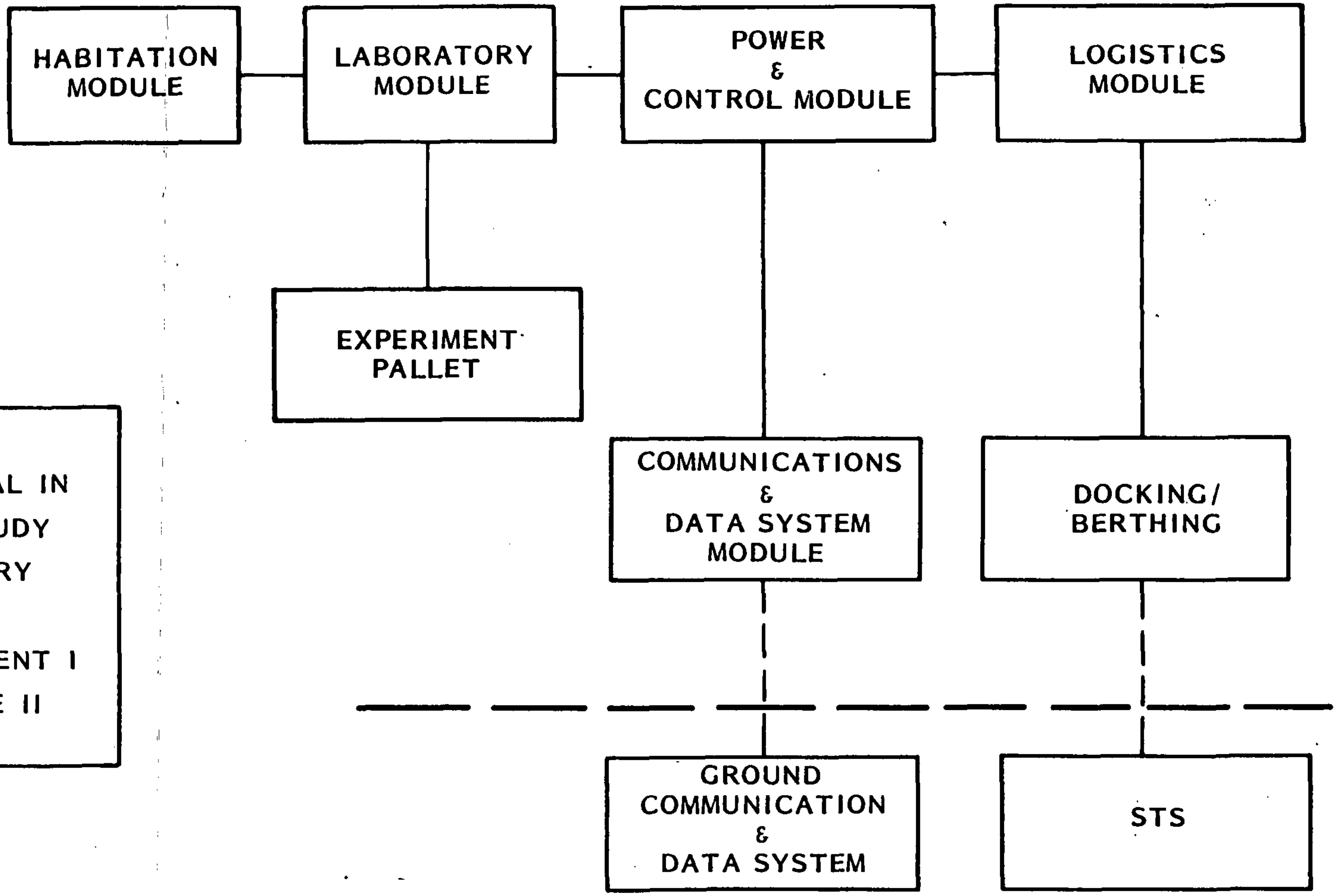
Functions of the system architecture are as follows:

Module	Function
1. Habitation	Living and maintenance of crew
2. Laboratory	Hands-on experiment/sensor setup and operations
3. Experiment pallet	Remote experiment/sensor testbed
4. Power and control	Electrical power, attitude stabilization and control
5. Communication and data system	Voice and data link, data evaluation and display
6. Docking/berthing	Docking/berthing for Shuttle, transfer personnel, equipment, and supplies
7. Logistics	Storage for facility and payload supplies
8. Ground communication and data	Tracking, voice/data communication, data distribution
9. STS	Shuttle ground to space transport, resupply logistics

SPACE STATION PROGRAMS

SPACE OBJECTS IDENTIFICATION SYSTEM ARCHITECTURAL CONCEPTS

SCENARIO 13



PICTORIAL IN DOD STUDY SUMMARY

ATTACHMENT I VOLUME II

SCENARIO 13 -- ROLE OF SPACE STATION TO SUPPORT SPACE OBJECTS IDENTIFICATION SYSTEM

The space station provides direct, continuous long-term support to the Space Objects Identification System mission. The station provides online direct electrical power and environmental interfaces. It supports security maintained onboard data analysis and conferencing communications and data transfer to the ground. Direct EVA-type support is provided to service and maintain experiments mounted on the open pallet. Laboratory equipment maintenance and service and consumable replenishment are conducted on a continuous basis. Additional details of the Space Objects Identification System are given in Attachment 1, Volume II.

Space station attributes to support the mission are shown in this chart.

ROLE OF SPACE STATION TO SUPPORT SPACE OBJECTS IDENTIFICATION SYSTEM

SCENARIO 13

ATTRIBUTES

- PROVIDE LONG-DURATION HABITATION FOR PERSONNEL
- PROVIDE SHIRTSLEEVE INTERACTIVE "HANDS ON" LABORATORY
- PROVIDE REMOTE INSTRUMENTATION/SENSOR TESTBED
- PROVIDE ELECTRICAL POWER AND DATA/COMMUNICATIONS INTERFACE
- PROVIDE VOICE AND DATA LINK TO GROUND
- PROVIDE ALTITUDE AND ATTITUDE ORIENTATION
- PROVIDE PERIODIC REPLENISHMENT OF EXPENDABLES AND PERSONNEL
- PROVIDE SCHEDULED AND UNSCHEDULED MAINTENANCE
- PROVIDE DOCKING AND OPERATIONAL INTERFACE WITH STS

SCENARIO 14 -- ON-ORBIT SATELLITE SERVICING MISSION OPERATIONAL SEQUENCE OF EVENTS - SERVICING AT SATELLITE

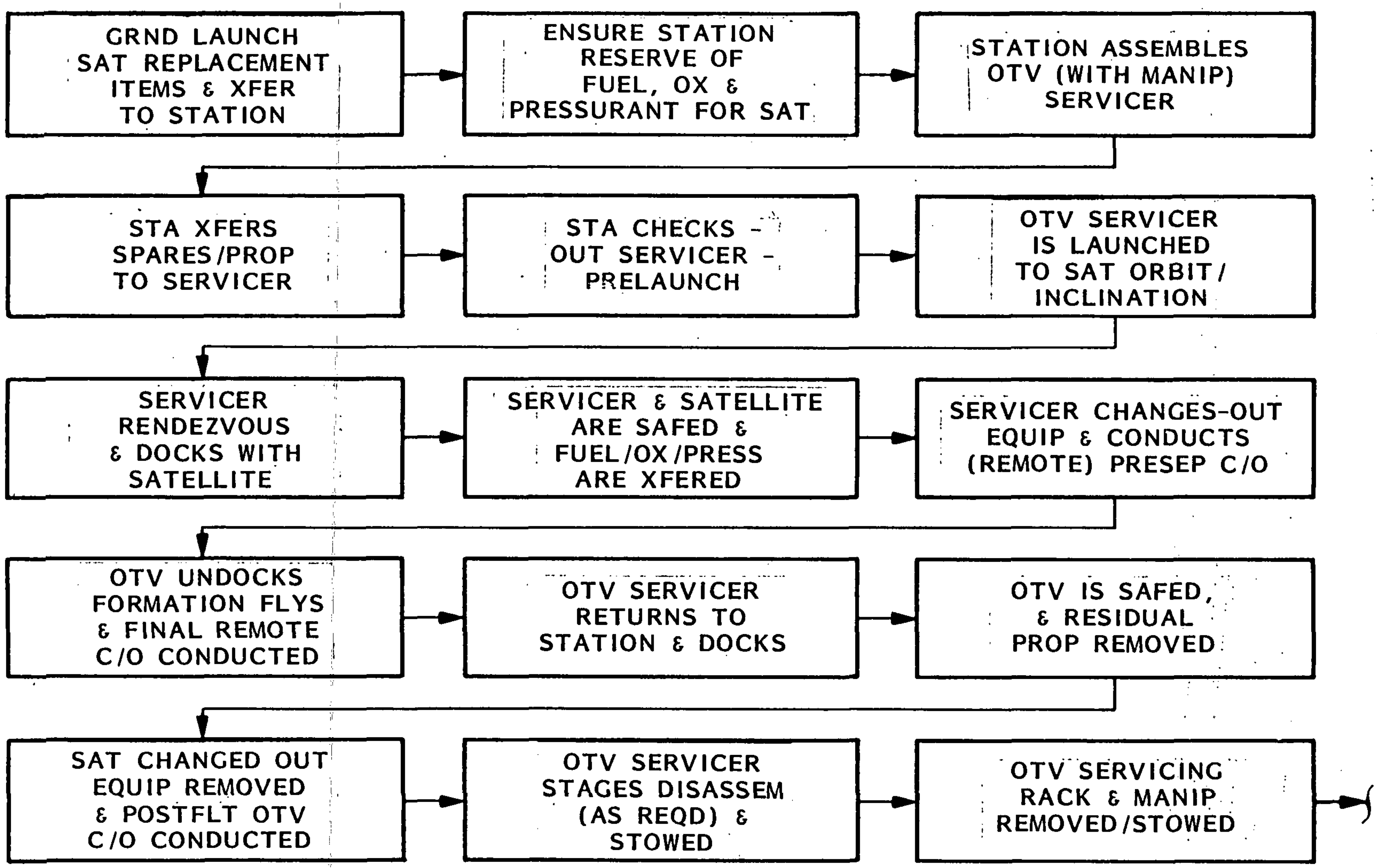
The objective of this mission is to perform servicing tasks on orbiting satellites using the space station as a base of operations. Two operational modes are envisioned, one in which servicing is conducted at the satellite orbiting position and one in which the satellite is recovered from its orbit position and brought to the space station for servicing. For either mode, a station-based orbit transport/service vehicle will be used for off-station remote operations. For servicing at satellite orbits, hands-on manned interaction may be required to supplement a robotic capability of the remotely operated service vehicle. For servicing at the space station, hands-on EVA and robotic manipulation will be used.

The functional sequence to prepare an OTV at the space station and to transport to the orbiting satellite and conduct servicing is shown on the facing page. The chart shows the functional sequence for recovering a satellite and returning to the station for servicing.

SPACE STATION PROGRAMS

ON-ORBIT SATELLITE SERVICING AT SATELLITE (WITH OTV) MISSION OPERATIONAL SEQUENCE

SCENARIO 14



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ON-ORBIT SATELLITE SERVICING AT SPACE STATION MISSION OPERATIONAL SEQUENCE

SCENARIO 14-1

GRND LAUNCH S/C REPLACEMT ITEMS & XFER TO STATION

ENSURE STA RESERVE OF FUEL, OX & FOR ITSS PRESSURANT

STA ASSEMBLES OTV (WITH DOCKING & XFER CAP)

STA XFERS PROP TO SERVICER

STA CHECKS OUT SERVICER - PRELAUNCH

OTV SERVICER IS LAUNCHED TO S/C ORBIT/ INCLINATION

SERVICER RENDEZVOUS & DOCKS WITH S/C

SERVICER & S/C ARE SAFED

SERVICER RETURNS S/C TO STATION

OTV & S/C DOCKS WITH STATION & BOTH ARE SAFED

S/C IS SERVICED - EQUIP CHKOUT & PROP REPLENISHMT

S/C & OTV CHECKED OUT BEFORE S/C RELAUNCH

OTV TRANSFERS S/C TO APPROPRIATE ALT/INCL

OTV UNDOCKS & STA KEEPS DURING REMOTE S/C CHECKOUT

OTV MANEUVERS TO NEXT S/C & DOCKS

S/C IS SAFED & OTV MANEUVERS S/C BACK TO STA

OTV/S/C IS CAPTURED BY STA & BERTHED

S/C IS UNCOUPLED FROM OTV & POSITIONED AT STA SERVICING AREA

OTV DEACTIVATED & STOWED UNTIL RELAUNCH OF S/C CURRENTLY AT STATION

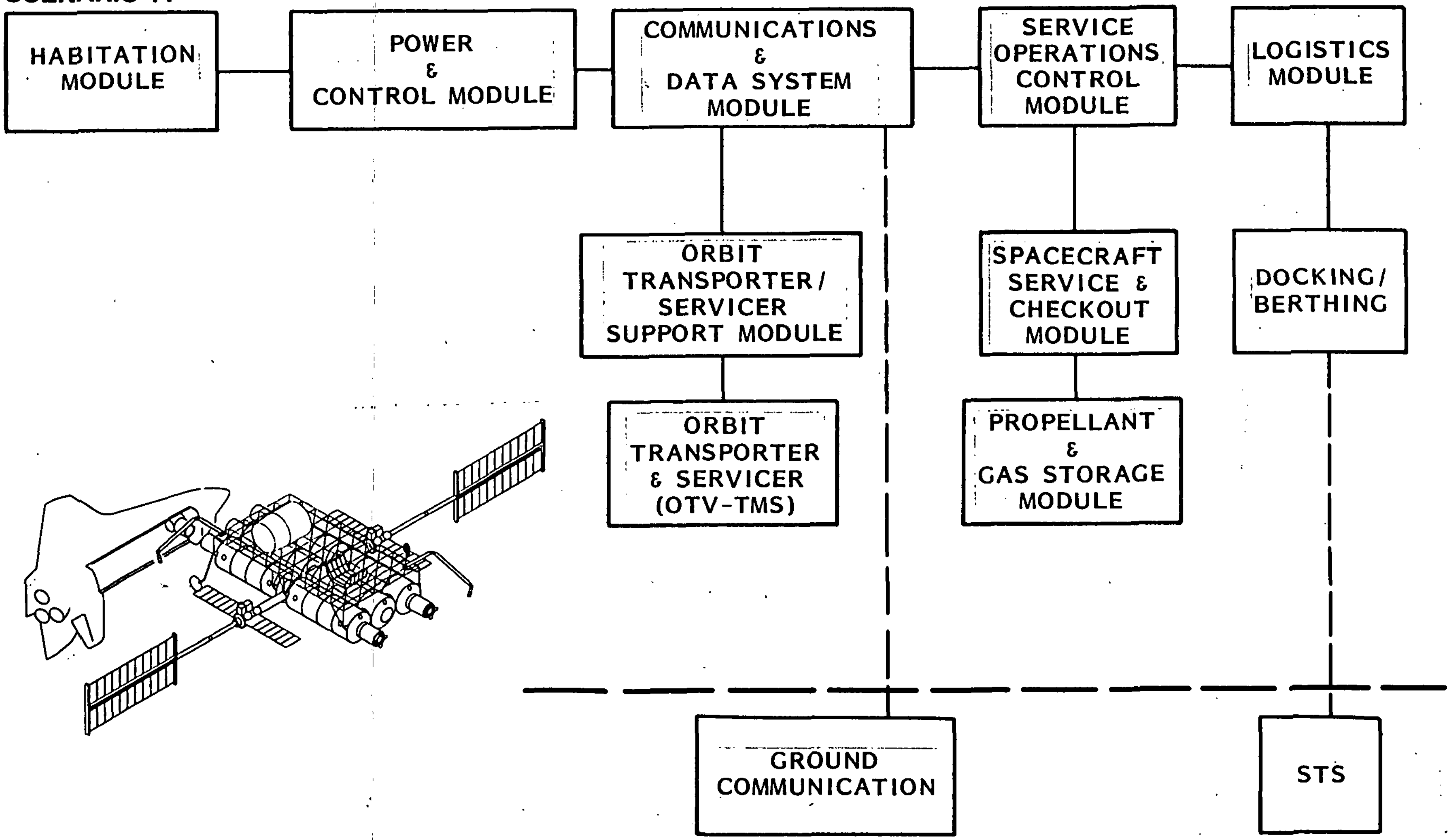
SCENARIO 14 -- ON-ORBIT SATELLITE SERVICING ARCHITECTURAL CONCEPT

The system architecture for on-orbit satellite servicing is shown on this chart. A propellant and gas storage module (tanks) is added to a basic logistics module (warehouse) to provide propellant for transfer vehicles and for servicing satellites. An orbit transporter support module provides capability to dock, maintain, assemble, and launch/recover OTV and TMS type vehicles. A spacecraft service and checkout module (enclosed or open hangar) provides the capability to assemble/disassemble, maintain, and check out satellite vehicles. A service operations control module acts as an operation control center for coordinating all remote and on-station service operations. Orbit transport vehicles (OTV and TMS type) are based at the station. The STS provides direct support to transport modules, equipment, and propellants initially to the station and to continue logistics support for consumables, crew rotation, and flight hardware during station lifetime. Data evaluation is conducted onboard the space station, and data are transmitted to the ground data systems via the space station to ground communication link. Functions of the system architecture are as follows:

	Module/Element	Function
1.	Habitation	Living and maintenance of crew
2.	Power and control	Electrical power, attitude stabilization and control
3.	Communication and data system	Voice and data link, data evaluation
4.	Docking/berthing	Docking/berthing for Shuttle, transfer personnel, equipment, and supplies
5.	Logistics	Storage for facility and payload supplies
6.	Ground communication and data	Tracking, voice/data communication
7.	STS	Shuttle ground to space transport, logistics
8.	Propellant/gas storage	Store propellants and gases
9.	Orbit transporter/servicer	Thrust, guidance, rendezvous docking to transport items to/from station to other orbits - automated and remotely controlled servicing/maintenance
10.	Orbit transporter docking and support	Docking, assembly, checkout, servicing - propellant/gas loading
11.	Spacecraft service and checkout	Maintenance, repair, replacement, assembly, test, and service
12.	Service operations control	Operator monitor, display, status and control of service operations

ON-ORBIT SATELLITE SERVICING ARCHITECTURAL CONCEPT

SCENARIO 14



SCENARIO 14 -- ROLE OF SPACE STATION TO SUPPORT ON-ORBIT SERVICING MISSION

The space station provides direct and continuous long-term support to the on-orbit servicing mission. The station provides online direct electrical power and environmental interfaces to servicing modules. It supports onboard data analysis and communications and data transfer to the ground. Direct EVA-type support is provided by crewmembers to assemble, service, and maintain OTVs and satellites. Maintenance of servicing support equipment and consumable replenishment is conducted continuously.

Space station attributes to support the mission are shown in this chart.

SPACE STATION PROGRAMS

SCENARIO 14

ROLE OF SPACE STATION TO SUPPORT ON-ORBIT SATELLITE SERVICING

ATTRIBUTES

- PROVIDE LONG-DURATION HABITATION FOR PERSONNEL
- PROVIDE ELECTRICAL POWER AND DATA/COMMUNICATIONS INTERFACE
- PROVIDE VOICE AND DATA LINK TO GROUND
- PROVIDE ALTITUDE AND ATTITUDE ORIENTATION
- PROVIDE PERIODIC REPLENISHMENT OF EXPENDABLES AND PERSONNEL
- PROVIDE SCHEDULED AND UNSCHEDULED MAINTENANCE
- PROVIDE PROPELLANT AND GAS HANDLING, STORAGE, TRANSFER
- PROVIDE SERVICE AND SUPPORT FOR ORBIT TRANSPORTERS, SERVICERS
- PROVIDE OPERATIONS CONTROL CENTER FOR ORBIT TRANSPORT
- PROVIDE SPACECRAFT SERVICE AND CHECKOUT AT STATION
- PROVIDE DOCKING AND OPERATIONAL INTERFACE WITH STS

SCENARIO 15 -- LARGE SATELLITE STRUCTURAL ASSEMBLY IN LEO MISSION

The objective of this mission is to assemble a large satellite structure such as a space-based radar satellite in LEO before the satellite transfers to a higher orbit position. Elements of the satellite structure are transported to the space station from the Earth launch site and prepared for assembly in orbit. Using manipulator assemblies, EVA crew personnel, and teleoperator maneuvering system (TMS) vehicles structural elements are assembled. The satellite is checked out as an operating system and prepared for launch and transport to a higher orbit position. Satellite propellant tanks are filled and attached for the transfer orbit.

The functional sequence of events to assemble and prepare the satellite for launch from the space station is shown in this chart.

SPACE STATION PROGRAMS

SCENARIO 15

LARGE SATELLITE STRUCTURAL ASSEMBLY IN LEO MISSION OPERATIONAL SEQUENCE (SPACE-BASED RADAR SATELLITE)

1. LAUNCH SBR ELEMENTS FROM EARTH TO STATION & STOW AT CONSTRUCTION SITE
2. PREPARE STA FOR SBR CONSTRUCT & C/O CONSTRUCT HDWR & SUPPORT ITEMS
3. CONSTRUCT ALL STRUCTURE & LAY-IN ELECT PWR DIST SYS, LINES, J-BOXES, ETC.
4. INSTALL ROTARY JOINT ASSY & BATTERY SYS MODULE
5. INSTALL SOLAR ARRAY CANISTER ASSEMBLIES & 2 RCS MODULES
6. INSTALL 225 M REFLECTOR MODULE, TRANSMITTER, PROCESSOR & RECEIVER
7. INSTALL 15 M LENS, TELESCOPIC BEAMS/BOOMS & TARGET
8. INSTALL 2 RCS MODULES & SYSTEMS CONTROL MODULE
9. CONDUCT A 30-DAY C/O PERIOD - STATION ATTACHED
10. SHUTTLE BASED TELEOP DELIVERS 5 FULLY FUELED PROP MODULES TO STA/SBR
11. INSTALL 5 FUELED PROP MODULES TO SBR
12. CHECKOUT PROP MODULES & PREPARE (RECONFIG) SBR FOR GEO ORBIT DELIVERY
13. RECONFIGURE & DEACTIVATE STA CONSTR./LAUNCH SYS UNTIL NEXT OPS USE

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SCENARIO 15 -- LARGE SATELLITE STRUCTURAL ASSEMBLY IN LEO ARCHITECTURAL CONCEPT

The system architecture for performing large satellite structural assembly in LEO is shown on this chart. A propellant and gas storage module (tanks) is added to a basic logistics module (warehouse) to provide propellant/gas for transfer vehicles and satellites. An assembly operation control module acts as an operation control center for coordinating all assembly, service, and checkout operations. An assembly and construction platform with stationary/tracked manipulator assemblers provides a surface work area for assembly tasks. A teleoperator maneuvering system (TMS) docking and support module provides docking, maintenance, and servicing for the TMS-type vehicle. The TMS vehicle is based at the station.

The STS provides direct support to transport modules, equipment, and propellants initially to the station and to continue logistics support for consumables, crew rotation, and flight hardware during station lifetime. Data evaluation is conducted onboard the space station, and data are transmitted to the ground data systems via the space station to ground communication link. Functions of the system architecture are as:

	Module/Element	Function
1.	Habitation	Living and maintenance of crew
2.	Power and Control	Electrical power, attitude stabilization and control
3.	Communication and data system	Voice and data link, data evaluation
4.	Docking/berthing	Docking/berthing for Shuttle, transfer personnel, equipment, supplies
5.	Logistics	Storage for facility and payload supplies
6.	Ground communication and data	Tracking, voice/data communication
7.	STS	Shuttle ground to space transport, logistics
8.	Propellant/gas storage	Store propellants and gases
9.	Assembly operations control	EVA monitor, disply, status and control of assembly operations
10.	Assembly and construction platform	Working area/space for EVA assist assembly and build up
11.	TMS docking and support	Docking, checkout, propellant/gas loading
12.	Manipulator assemblers	Handling, positioning, joining subelements
13.	TMS	Handling, transport, robotic assembly

SPACE STATION PROGRAMS

LARGE SATELLITE STRUCTURAL ASSEMBLY IN LOW EARTH ORBIT ARCHITECTURAL CONCEPT (SPACE-BASED RADAR SATELLITE)

SCENARIO 15

HABITATION MODULE

POWER & CONTROL MODULE

COMMUNICATIONS & DATA SYSTEM

ASSEMBLY OPERATIONS CONTROL MODULE

LOGISTICS MODULE

TMS DOCKING & SUPPORT MODULE

TMS

ASSEMBLY AND CONSTRUCTION PLATFORM

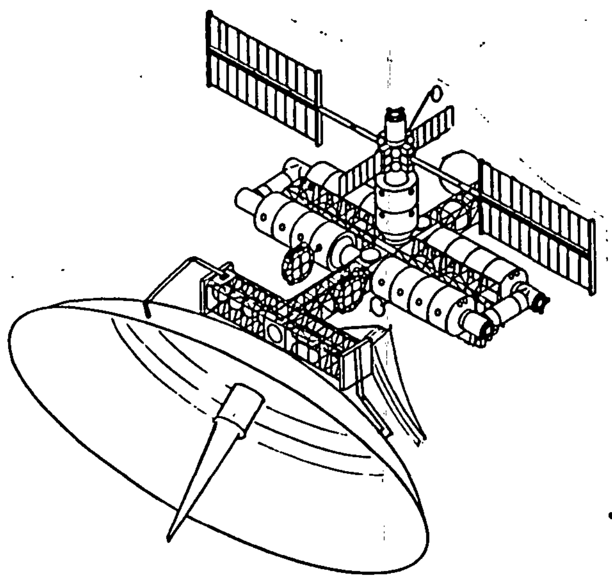
MANIPULATOR ASSEMBLERS

PROPELLANT & GAS STORAGE MODULE

DOCKING/ BERTHING

GROUND COMMUNICATIONS & DATA SYSTEM

STS



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SCENARIO 15 -- ROLE OF SPACE STATION TO SUPPORT LARGE SATELLITE STRUCTURAL ASSEMBLY IN LEO

The space station provides direct and continuous support to the on-orbit servicing mission. The station provides online direct electrical power and environmental interfaces to the assembly support modules. It supports onboard data analysis and communications and data transfer to the ground. Direct EVA-type support is provided by crewmembers to assemble, service, and check out and prepare the satellite for space launch. Maintenance of servicing support equipments and consumable replenishment are conducted continuously.

Space station attributes to support the mission are shown in this chart.

SPACE STATION PROGRAMS

SCENARIO 15

ROLE OF SPACE STATION TO SUPPORT LARGE SATELLITE ASSEMBLY IN LEO

ATTRIBUTES

- PROVIDE LONG-DURATION HABITATION FOR PERSONNEL
- PROVIDE ELECTRICAL POWER AND DATA/COMMUNICATIONS INTERFACE
- PROVIDE VOICE AND DATA LINK TO GROUND
- PROVIDE ALTITUDE AND ATTITUDE ORIENTATION
- PROVIDE PERIODIC REPLENISHMENT OF EXPENDABLES AND PERSONNEL
- PROVIDE SCHEDULED AND UNSCHEDULED MAINTENANCE
- PROVIDE PROPELLANT AND GAS HANDLING, STORAGE, TRANSFER
- PROVIDE WORK PLATFORM FOR ASSEMBLY AND CONSTRUCTION
- PROVIDE OPERATIONS CONTROL CENTER FOR ASSEMBLY OPERATIONS
- PROVIDE TMS DOCKING AND SUPPORT
- PROVIDE DOCKING AND OPERATIONAL INTERFACE WITH STS

SUMMARY OF SPACE STATION ATTRIBUTES TO SUPPORT MISSION SCENARIOS

Space station attributes to support the spectrum of missions analyzed previously are given in this chart. Most significantly, the greater number of attributes (functional capabilities) are required to support the category of space operations type mission such as servicing satellites in co-orbiting and other LEO positions and performing satellite structural assembly in LEO.

SPACE STATION PROGRAMS

SUMMARY OF SPACE STATION ATTRIBUTES TO SUPPORT MISSION SCENARIOS

ATTRIBUTES \ MISSIONS	BASIC SPACE STATION	HUMAN LIFE SCI. RESEARCH LAB	NON-HUMAN LIFE SCI RESEARCH LAB.	CELESTIAL OBSERVATORY LABORATORY	SPACE ENVIROMENT FACILITY	EARTH OBSERVATION FACILITY	GLOBAL HABITABILITY OBSERVATORY LAB	METEOROLOGICAL FACILITY	MATERIAL PROCESSING RESEARCH LABORATORY	MATERIAL PROCESSING OPERATIONS FACILITY	SPACE OBSERVATION DEVELOPMENT LAB	OCEANOGRAPHY OBS. DEVELOPMENT LAB	ORBITING NATIONAL COMMAND POST	SPACE OBJECTS IDENTIFICATION SYSTEM	SATELLITE SERVICING LEO	LARGE SATELLITE STRUCTURE ASSEMBLY
• CREW, OPERATORS HABITATION	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
• POWER, ALTITUDE, ATTITUDE CONTROL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
• OPERATOR HANDS ON EXPERIMENT INTERACTION		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓
• OPERATOR ATTACHED EXP. REMOTE INTERACTION					✓	✓	✓				✓	✓		✓		
• OPERATOR DETACHED EXP. REMOTE INTERACTION				✓				✓		✓						
• PAYLOAD HANDLING ASSEMBLY, CHECKOUT		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
• COMMUNICATIONS & DATA HANDLING	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
• TRANSPORT PERSONNEL & SUPPLIES	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
• SHUTTLE DOCKING AND LOGISTICS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
• MAINTAIN & SERVICE ATTACHED PAYLOADS/EXPMTS		✓	✓		✓		✓		✓		✓	✓		✓		
• MAINTAIN & SERVICE DETACHED PAYLOADS/EXPMTS				✓				✓		✓						
• MAINTAIN & SERVICE CO-ORBITING SATELLITES															✓	
• MAINTAIN & LAUNCH/RECOVER TRANSPORT STAGES				✓				✓		✓			✓		✓	
• ASSEMBLE, CHECKOUT, INTEGRATE SATELLITES				✓				✓		✓					✓	✓
• CRYOGEN STORAGE & RESUPPLY															✓	
• PROPELLANT/GAS STORAGE & RESUPPLY															✓	✓
• ASSEMBLE, ERECT, TRANPORT LARGE STRUCTURES																✓
• MAINTAIN AND SERVICE ATTACHED EQUIPMENTS		✓	✓						✓							

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SUMMARY OF SPACE STATION ARCHITECTURAL ELEMENTS TO SUPPORT MISSION SCENARIOS

Architectural elements of the space station to support the 15 mission scenarios previously analyzed are shown in this chart. The basic manned space station consists of a habitation module, power and control module, communications module, and a Shuttle STS docking module. With these minimum elements, the space station can support a permanent manned presence in space. To accommodate the assortment of missions analyzed, the various mission-peculiar support elements must be added to the basic station.

From a configuration viewpoint, the space operations missions for satellite servicing and large structural assembly need the most supporting elements. At this stage of the analysis, the conclusion is that the missions that will be the major factor in driving the design and operations of the space station will be the space operations category missions.

SPACE STATION PROGRAMS

SUMMARY OF SPACE STATION ARCHITECTURAL ELEMENTS

ELEMENTS \ MISSIONS	BASIC SPACE STATION	HUMAN LIFE SCIENCE RESEARCH LAB.	NON-HUMAN LIFE SCI RESEARCH LAB.	CELESTIAL OBSERVATORY LABORATORY	SPACE ENVIRONMENT FACILITY	EARTH OBSERVATION FACILITY	GLOBAL HABITABILITY OBSERVATORY LAB.	METEOROLOGICAL FACILITY	MATERIAL PROCESSING RESEARCH LABORATORY	MATERIAL PROCESSING OPERATIONS FACILITY	SPACE OBSERVATION DEVELOPMENT LAB	OCEANOGRAPHY DEVELOPMENT LAB	ORBITING NATIONAL COMMAND POST	SPACE OBJECTS IDENTIFICATION SYSTEM	SATELLITE SERVICING	LARGE SATELLITE STRUCTURE ASSEMBLY
MANNED HABITATION MODULE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
POWER AND CONTROL MODULE																
SOLAR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
NUCLEAR													✓			
COMMUNICATIONS AND DATA MODULE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
SHUTTLE DOCKING MODULE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LOGISTICS MODULE		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LABORATORY MODULE																
ATTACHED (SHIRTSLEEVE ENVIRONMENT)		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		
DETACHED FREE FLYER				✓				✓		✓						
ATTACHED NON-HUMAN			✓													
EXPERIMENT/SENSOR PALLET																
ATTACHED					✓	✓	✓				✓	✓		✓		
DETACHED FREE FLYER				✓				✓		✓						
OPERATIONS CONTROL AND MONITOR MODULE										✓						
TMS				✓				✓								✓
OTV															✓	✓
MOTV										✓						
PROPELLANT & GAS STORAGE MODULE															✓	✓
SATELLITE/SPACECRAFT SERVICE & CHECKOUT MODULE															✓	✓
TMS/OTV SUPPORT MODULE				✓				✓		✓					✓	✓
SERVICE/ASSEMBLY OPERATIONS CONTROL MODULE															✓	✓
ASSEMBLY AND CONSTRUCTION PLATFORM																✓
OPERATIONS CENTER MODULE													✓			
EXTERNAL TANK STRUCTURE													✓			
CO-ORBITAL EXTERNAL TANKS													✓			

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SUMMARY OF MISSION CHARACTERISTIC DISCRIMINATORS AND SYSTEM IMPLEMENTATION CONCEPTS

The space station total system concepts to implement the 15 mission scenarios analyzed in this study are given in this chart. The mission characteristic discriminators are derived from the detailed mission scenario descriptions given in Attachment 2, Volume I, of this report.

The implementation elements shown on the chart identify those mission-peculiar support elements that are added to a basic space station to perform the missions. The basic manned space station consists of a man habitation module, power and control module, communication/data system module, and a STS docking module.

All missions involving experiments and observations where direct manned interaction is needed or desired are implemented by using an enclosed laboratory or pallet attached to the basic space station. Those missions where contamination is critical and where direct hands-on interaction is not needed are implemented by using a detached free flyer. Where free flyers are used, an orbit transporter/servicer-type vehicle is used to transport and tend the detached free flyer throughout mission life. To achieve autonomy and to provide maximum operational flexibility, these OTVs are based at the space station.

Space orbit communication uses the NASA and Air Force communication relay satellites (TDRSS and MILSTAR) to provide communication interface with the flight and ground elements involved in the missions. Space and ground communications will use a space station ground operations control center (SSOCC) supported by mission-peculiar payload operations control centers (POCC) when required. The existing NASA and Air Force ground tracking networks will directly support the ground control centers.

SPACE STATION PROGRAMS

SUMMARY OF MISSION CHARACTERISTICS DISCRIMINATORS AND SYSTEM IMPLEMENTATION CONCEPTS

MISSIONS	CHARACTERISTICS DISCRIMINATORS									IMPLEMENTATION CONCEPTS														
										ATTACHED TO SPACE STATION			DETACHED FREE FLYER		ORBIT TRANSPORTER/SERVICER		SPACE/ORBIT COMMUNICATIONS					SPACE/GROUND COMMUNICATIONS	
	INCLINATION (DEG)	ALTITUDE (NM)	DURATION	ENVIRONMENT	MAN INTERACTION CONTINUOUS	MAN INTERACTION PERIODIC	ACCURATE TARGETING	DEVELOPMENTAL	OPERATIONAL	INTERNAL MANNED LABORATORY	EXTERNAL PALLET	OPERATION CONTROL CENTER	DEDICATED SATELLITE	UNMANNED PLATFORM	TMS	OTV	TDRSS	MILSTAR	TO FREE FLYER	TO SHUTTLE	TO TMS/OTV	SPACE STATION OPERATIONS CONTROL CENTER	PAYLOAD OPERATIONS CONTROL CENTER
SCIENCE AND APPLICATIONS -																							
GLOBAL HABITABILITY OBSERVATION LAB	57	500	M-Y		✓				✓	✓	✓						✓			✓		✓	✓
CELESTIAL OBSERVATORY	28.5	300	Y	C		✓	✓	✓		✓			✓		✓		✓		✓	✓	✓	✓	✓
SPACE ENVIRONMENT FACILITY	57	400	M-Y	C		✓			✓	✓	✓						✓			✓		✓	
EARTH OBSERVATION FACILITY	57	500	Y	C	✓		✓	✓		✓	✓						✓			✓		✓	
METEOROLOGICAL FACILITY	57	400	Y	C		✓			✓	✓			✓		✓		✓		✓	✓	✓	✓	✓
LIFE SCIENCE NON-HUMAN RESEARCH LAB	28.5	300	D-M		✓			✓		✓							✓			✓		✓	
LIFE SCIENCE HUMAN RESEARCH LAB	28.5	300	D-M		✓			✓		✓							✓			✓		✓	
COMMERCIAL -																							
MATERIALS PROCESSING RESEARCH LAB	28.5	300	D-M	LOW C	✓			✓		✓							✓			✓		✓	
MATERIALS PROCESSING OPERATIONS FACILITY	28.5	300	M-Y	LOW C		✓			✓				✓	✓		✓	✓		✓	✓	✓	✓	✓
OPERATIONS -																							
ON ORBIT SATELLITE SERVICING IN LEO	28.5	300	M-Y		✓				✓		SERVICE MODULE	✓				✓	✓		✓	✓	✓	✓	
LARGE STRUCTURES SATELLITE ASSEMBLY	28.5	300	M-Y		✓				✓		ASSEMBLY PLATFORM				✓		✓			✓	✓	✓	
U.S. NATIONAL SECURITY-																							
SPACE OBSERVATION DEVELOPMENT LAB	28.5	300	M-Y	C	✓	✓		✓		✓	✓						✓			✓		✓	
ORBITING NATIONAL COMMAND POST	28.5	500	Y		✓				✓	OPNS. CENTER MODULE								✓		✓		✓	✓
OCEANOGRAPHY OBSERVATORY DEV. LAB	57	300	M-Y	C	✓			✓		✓	✓						✓			✓		✓	
SPACE OBJECTS IDENTIFICATION SYSTEM	57	500	M-Y	C	✓		✓		✓	✓	✓							✓		✓		✓	✓

LEGEND: ENVIRONMENT
C - Contamination
Low C $<10^{-6}$ C

DURATION
D - Days
M - Months
Y - Years

SPACE STATION PROGRAMS

TASK 2—MISSION IMPLEMENTATION CONCEPTS

2.1 MISSION SCENARIO ANALYSIS AND ARCHITECTURAL CONCEPTS

2.2 ALTERNATIVE SYSTEMS CONCEPTS

2.3 MISSION OPERATIONS ARCHITECTURAL DEVELOPMENT

2.4 ARCHITECTURAL ANALYSIS TRADES

2.5 EVOLUTION

2.6 CONFIGURATION

2.7 TECHNOLOGY DEVELOPMENT

2.8 CONCLUSIONS

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ALTERNATIVE SPACE STATION SYSTEM CONCEPTS TO IMPLEMENT MISSION SCENARIOS

From the data tabulated in the previous chart and mission requirements data developed in Task 1, a compatibility analysis was performed to define alternative system concepts to implement the 15 mission scenarios.

Missions were grouped on the basis of commonality of orbit characteristics, functional requirements, and unique national security needs. Analysis results indicate that no single space station concept can satisfy all missions. Five system concepts were selected to implement the mission grouping as shown in this chart.

- Concept A is a basic space station with attached enclosed laboratory configuration in a 57-deg inclination orbit and will accommodate those missions to perform space environment, ground, and ocean Earth observation.
- Concept B is a basic space station with attached enclosed laboratory configuration in a 28.5 deg inclination orbit and will accommodate those missions to perform life science and materials processing investigations.
- Concept C is a basic space station supporting detached free-flyer satellites in a 28.5-deg inclination orbit and will accommodate automated observation facilities for celestial and meteorological investigations and a man-tended automated materials production facility.
- Concept D is a basic space station with attached facilities for performing maintenance and servicing of satellites and structural assembly and launch on orbit of large structure satellites.
- Concept E are space station supported unique applications for U.S. national security and will include an attached enclosed laboratory for space objects identification and a detached autonomous orbiting command post.

ALTERNATIVE SPACE STATION SYSTEM CONCEPTS TO IMPLEMENT MISSION SCENARIOS

CONCEPT A

ATTACHED LABORATORY
57° INCLINATION

No.
- 11 - OCEAN OBSERVATORY LABORATORY
- 6 - GLOBAL HABITABILITY LABORATORY
- 4 - SPACE ENVIRONMENT FACILITY
- 5 - EARTH OBSERVATION FACILITY

CONCEPT B

ATTACHED LABORATORY
28.5° INCLINATION

No.
- 10 - SPACE OBSERVATION LAB
- 8 - MAT'L PROCESSING LAB
- 2 - NON-HUMAN RESEARCH LAB
- 1 - HUMAN RESEARCH LAB

CONCEPT C

DETACHED FACILITIES
28.5° INCLINATION

No.
- 3 - CELESTIAL OBSERVATORY
- 9 - MAT'L PROCESSING FACILITY
- 7 - METEOROLOGICAL FACILITY

CONCEPT D

SPACE-BASED SERVICING
AND STRUCTURAL ASSEMBLY
LEO - 28.5° INCL.

No.
- 14 - SATELLITE SERVICING
- 15 - STRUCTURAL ASSEMBLY

CONCEPT E

U.S. NATIONAL SECURITY
28.5° INCLINATION

No.
- 12 - ORBITING COMMAND POST
- 13 - SPACE OBJECTS IDENTIFICATION

ALTERNATIVE CONCEPTS - SYSTEM ELEMENT INTERFACES AND FEATURES
CONCEPT A - ATTACHED LABORATORY - 57-deg ORBIT

Based on the five alternative systems concepts shown in the previous chart, the major system element interfaces and features were defined. The following series of charts tabulates these major element interfaces and features to implement the 15 mission scenarios. These data are used in subsequent analyses to define, evaluate, and select configurations for the space station system.

Element interfaces and features for alternative space station Concept A are shown in this chart.

ALTERNATIVE CONCEPTS — ELEMENT INTERFACE AND FEATURES

CONCEPT A - ATTACHED LABORATORY - 57° ORBIT

MISSION	
11	OCEANOGRAPHY OBSERVATORY DEVELOPMENT LABORATORY
6	GLOBAL HABITABILITY OBSERVATION LABORATORY
4	SPACE ENVIRONMENT FACILITY
5	EARTH OBSERVATION FACILITY

ELEMENT INTERFACE	FEATURES
GROUND OPERATIONS CONTROL CENTER	• GROUND TRACKING - EPHEMERIS PREDICTION - FLIGHT PLANNING • VOICE AND DATA LINK VIA TDRSS/MILITARY SAT COM • GROUND DATA ROUTING TO PAYLOAD/EXPERIMENT INVESTIGATORS • INVESTIGATOR REALTIME TELECONFERENCING
SPACE TRANSPORTATION SYSTEM	• CARGO INTEGRATION OF SPACE STATION MODULES, EXPERIMENTS, REPLENISHMENT ITEMS, PERSONNEL
- LAUNCH SITE	• INITIAL TRANSPORT PLACEMENT, ORBITAL ASSEMBLY VIA EVA
- ORBITER	• LONG-TERM LOGISTICS RESUPPLY - RENDEZVOUS AND DOCKING TRANSFER AND HANDLING PERSONNEL, SUPPLIES, EQUIPMENT. UP/DOWN
ATTACHED ENCLOSED LABORATORY	• STRUCTURALLY RIGID ATTACHMENT, POWER, COMMUNICATIONS AND DATA TRANSFER. DATA ANALYSIS AND EVALUATION. SHIRTSLEEVES ENCLOSED LABORATORY. BENCH/RACK MOUNT AND GIMBALLED POINTING MOUNTS FOR SENSORS. HANDS ON INTERACTION WITH EXPERIMENTS. PERSONNEL READY ACCESS TO/FROM HABITATION QUARTERS.
- EXPERIMENT PALLET	• PALLET EXPERIMENTS REMOTE INTERACTION, CONTAMINATION CONTROLLED.

ALTERNATIVE CONCEPTS - SYSTEM ELEMENT INTERFACES AND FEATURES

CONCEPT B - ATTACHED LABORATORY - 28.5-deg ORBIT

Element interfaces and features for alternative space station C^ncept C are shown in this chart.

SPACE STATION PROGRAMS

ALTERNATIVE CONCEPTS — ELEMENT INTERFACE AND FEATURES

CONCEPT - B ATTACHED LABORATORY 28.5° ORBIT

MISSION 10 SPACE OBSERVATION DEVELOPMENT LABORATORY
8 MATERIAL PROCESSING RESEARCH LABORATORY
2 LIFE SCIENCE NON-HUMAN RESEARCH LABORATORY
1 LIFE SCIENCE HUMAN RESEARCH LABORATORY

ELEMENT INTERFACE	FEATURES
GROUND OPERATIONS CONTROL CENTER	• GROUND TRACKING - EPHEMERIS PREDICTION - FLIGHT PLANNING • VOICE AND DATA LINK VIA TDRSS/MILITARY SAT COM • GROUND DATA ROUTING TO PAYLOAD/EXPERIMENT INVESTIGATORS • INVESTIGATOR REALTIME TELECONFERENCING
SPACE TRANSPORTATION SYSTEM - LAUNCH SITE - ORBITER	• CARGO INTEGRATION OF SPACE STATION MODULES, EXPERIMENTS REPLENISHMENT ITEMS, PERSONNEL • INITIAL TRANSPORT PLACEMENT, ORBITAL ASSEMBLY VIA EVA • LONG-TERM LOGISTICS RESUPPLY - RENDEZVOUS AND DOCKING TRANSFER AND HANDLING PERSONNEL, SUPPLIES, EQUIPMENT. UP/DOWN
ATTACHED ENCLOSED LABORATORY	• STRUCTURALLY RIGID ATTACHMENT, POWER, COMMUNICATIONS AND DATA TRANSFER. DATA ANALYSIS AND EVALUATION. SHIRTSLEEVE ENCLOSED LABORATORY. BENCH/RACK MOUNT FOR SENSORS. ANIMAL/PLANT VIVARIA. HANDS ON INTERACTION WITH EXPERIMENTS. PERSONNEL READY ACCESS TO/FROM HABITATION QUARTERS

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ALTERNATIVE CONCEPTS - SYSTEM ELEMENT INTERFACES AND FEATURES
CONCEPT C - DETACHED FACILITIES - 28.5-deg ORBIT

Element interfaces and features for alternative space station Concept C are shown in this chart.

SPACE STATION PROGRAMS

ALTERNATIVE CONCEPTS — ELEMENT INTERFACE AND FEATURES

CONCEPT C - DETACHED FACILITIES - 28.5° ORBIT

MISSION 3 CELESTIAL OBSERVATORY FACILITY
9 MATERIALS PROCESSING FACILITY
7 METEROLOGICAL FACILITY

ELEMENT INTERFACE	FEATURES
GROUND OPERATIONS CONTROL CENTER	• GROUND TRACKING - EPHEMERIS PREDICTION - FLIGHT PLANNING • VOICE AND DATA LINK VIA TDRSS/MILITARY SAT COM • GROUND DATA ROUTING TO PAYLOAD/EXPERIMENT INVESTIGATORS • INVESTIGATOR REAL TIME TELECONFERENCING
SPACE TRANSPORTATION SYSTEM	• CARGO INTEGRATION OF SPACE STATION MODULES,REPLENISHMENT ITEMS,PERSONNEL
- LAUNCH SITE	• INITIAL TRANSPORT PLACEMENT,ORBITAL ASSEMBLY VIA EVA
- ORBITER	• LONG TERM LOGISTICS RESUPPLY - RENDEZVOUS AND DOCKING TRANSFER AND HANDLING PERSONNEL,SUPPLIES,EQUIPMENT. UP/DOWN
ATTACHED ENCLOSED LABORATORY	• STRUCTURALLY RIGID ATTACHMENT,POWER,COMMUNICATIONS AND DATA TRANSFER. DATA ANALYSIS AND EVALUATION. SHIRTSLEEVE ENCLOSED LABORATORY. REMOTE MONITOR AND CONTROL INTERACTION WITH DETACHED EXPERIMENTS/PAYLOADS. PERSONNEL READY ACCESS TO/FROM HABITATION QUARTERS.
FREE FLYING SATELLITE - EXPT PALLET AND SUPPORT FACLTS	• RIGID DOCKING. REMOTE PROPELLANT/GAS SERVICING. AUTOMATED REPLACEMENT OF DATA CASSETTES,EQUIPMENT. DATA TRANSFER
SPACE COMMUNICATIONS AND CONTROL	• SPACE TRACKING AND PREDICTION OF FREE FLYER ORBITS. COMMUNICATIONS,CONTROL EXECUTION FOR DATA TRANSFER FOR HEALTH & STATUS AND EXPERIMENT/PAYLOAD.
ORBIT TRANSFER/SERVICE VEHICLE	• RIGID DOCKING - PROPELLANT AND GAS SERVICING - PAYLOAD EXPERIMENT REMOVAL/ATTACHMENT. HEALTH/STATUS MONITOR - AUTOMATED CHECKOUT. PRE-LAUNCH ASSEMBLY - AUTOMATED LAUNCH. REMOTE FLIGHT MONITOR AND CONTROL. PROGRAMMING AND CONTROL FOR RENDEZVOUS AND DOCKING/CAPTURE. TRANSFER OF RAW MATERIALS AND RECOVERY/HANDLING OF MANUFACTURED MATERIALS.

ALTERNATIVE CONCEPTS - SYSTEM ELEMENT INTERFACES AND FEATURES
CONCEPT D - SPACE-BASED SERVICING AND STRUCTURAL ASSEMBLY - 28.5-deg ORBIT

Element interfaces and features for alternative space station Concept D are shown in this chart.

ALTERNATIVE CONCEPTS — ELEMENT INTERFACE AND FEATURES

CONCEPT D - SPACE BASED SERVICING AND STRUCTURE ASSEMBLY - 28.5° ORBIT

MISSION 14 ON-ORBIT SATELLITE SERVICING IN LEO
15 ON-ORBIT LARGE STRUCTURE ASSEMBLY IN LEO

ELEMENT INTERFACE	FEATURES
GROUND OPERATIONS CONTROL CENTER	• GROUND TRACKING - EPHEMERIS PREDICTION - FLIGHT PLANNING • VOICE AND DATA LINK VIA TDRSS/MILITARY SAT COM • GROUND DATA ROUTING TO PAYLOAD/EXPERIMENT INVESTIGATORS • INVESTIGATOR REALTIME TELECONFERENCING
SPACE TRANSPORTATION SYSTEM - LAUNCH SITE - ORBITER	• CARGO INTEGRATION OF SPACE STATION MODULES,EXPERIMENTS REPLENISHMENT ITEMS,PERSONNEL • INITIAL TRANSPORT PLACEMENT,ORBITAL ASSEMBLY VIA EVA • LONG-TERM LOGISTICS RESUPPLY - RENDEZVOUS AND DOCKING TRANSFER AND HANDLING PERSONNEL,SUPPLIES,EQUIPMENT. UP/DOWN
FREE-FLYING SATELLITES - EXPERIMENT PALLETS AND FACILITIES SPACE COMMUNICATIONS AND CONTROL	• RIGID DOCKING. REMOTE PROPELLANT/GAS SERVICING. AUTOMATED REPLACEMENT OF DATA CASSETTES,EQUIPMENT. DATA TRANSFER • SPACE TRACKING AND PREDICTION OF FREE FLYER ORBITS. COMMUNICATIONS,CONTROL EXECUTION FOR DATA TRANSFER FOR HEALTH & STATUS AND EXPERIMENT/PAYLOAD.
ORBIT TRANSFER/SERVICE VEHICLE	• RIGID DOCKING - PROPELLANT AND GAS SERVICING - PAYLOAD EXPERIMENT REMOVAL/ATTACHMENT. HEALTH/STATUS MONITOR - AUTOMATED CHECKOUT. PRELAUNCH ASSEMBLY - AUTOMATED LAUNCH. REMOTE FLIGHT MONITOR AND CONTROL. PROGRAMMING AND CONTROL FOR RENDEZVOUS AND DOCKING/CAPTURE.
LARGE STRUCTURE SATELLITE	• COMPONENT ASSEMBLY AND BUILDUP AT STATION. ROBOTIC MANIPULATORS AND ASSEMBLERS. MAN INTERACTION. EVA SUPPORT CHECKOUT AND LAUNCH PREPARATION. PROPELLANT/GAS LOADING. LAUNCH SUPPORT FROM STATION.

ALTERNATIVE CONCEPTS - SYSTEM ELEMENT INTERFACES AND FEATURES
CONCEPT E - U.S. NATIONAL SECURITY - 28.5-deg ORBIT

Element interfaces and features for alternative space station Concept E are shown in this chart.

SPACE STATION PROGRAMS

ALTERNATIVE CONCEPTS — ELEMENT INTERFACE AND FEATURES

CONCEPT E - U.S. NATIONAL SECURITY

MISSION 12 ORBITING NATIONAL COMMAND POST
13 SPACE OBJECTS IDENTIFICATION SYSTEM

ELEMENT INTERFACE	FEATURES
GROUND OPERATIONS CONTROL CENTER (AIR FORCE SPACE COMMAND)	• GROUND TRACKING - EPHEMERIS PREDICTION - FLIGHT PLANNING • VOICE AND DATA LINK VIA TDRSS/MILITARY SAT COM SECURE • GROUND DATA ROUTING TO NATIONAL AND MILITARY COMMANDS • SITUATION REALTIME TELECONFERENCING
SPACE TRANSPORTATION SYSTEM - LAUNCH SITE - ORBITER	• CARGO INTEGRATION OF SPACE HARDWARE MODULES,SENSORS REPLENISHMENT ITEMS,PERSONNEL • INITIAL TRANSPORT PLACEMENT,ORBITAL ASSEMBLY VIA EVA • LONG-TERM LOGISTICS RESUPPLY - RENDEZVOUS AND DOCKING TRANSFER AND HANDLING PERSONNEL,SUPPLIES,EQUIPMENT. UP/DOWN
ATTACHED ENCLOSED LABORATORY AND EXPERIMENT PALLET (SPACE OBJECTS IDENTIFICATION SYSTEM)	• STRUCTURALLY RIGID ATTACHMENT,POWER,COMMUNICATIONS AND DATA TRANSFER. DATA ANALYSIS AND EVALUATION. SHIRTSLEEVE ENCLOSED LABORATORY. BENCH RACK MOUNT AND GIMBALLED POINTING MOUNTS FOR SENSORS. HANDS ON INTERACTION WITH EXPERIMENTS. PERSONNEL READY ACCESS TO/FROM HABITATION QUARTERS. • PALLET SENSORS. REMOTE INTERACTION,CONTAMINATION CONTROLLED.

SPACE STATION PROGRAMS

TASK 2—MISSION IMPLEMENTATION CONCEPTS

2.1 MISSION SCENARIO ANALYSIS AND ARCHITECTURAL CONCEPTS

2.2 ALTERNATIVE SYSTEMS CONCEPTS

2.3 MISSION OPERATIONS ARCHITECTURAL DEVELOPMENT

2.4 ARCHITECTURAL ANALYSIS TRADES

2.5 EVOLUTION

2.6 CONFIGURATION

2.7 TECHNOLOGY DEVELOPMENT

2.8 CONCLUSIONS

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ARCHITECTURAL OPTIONS DEVELOPMENT AND ASSESSMENT

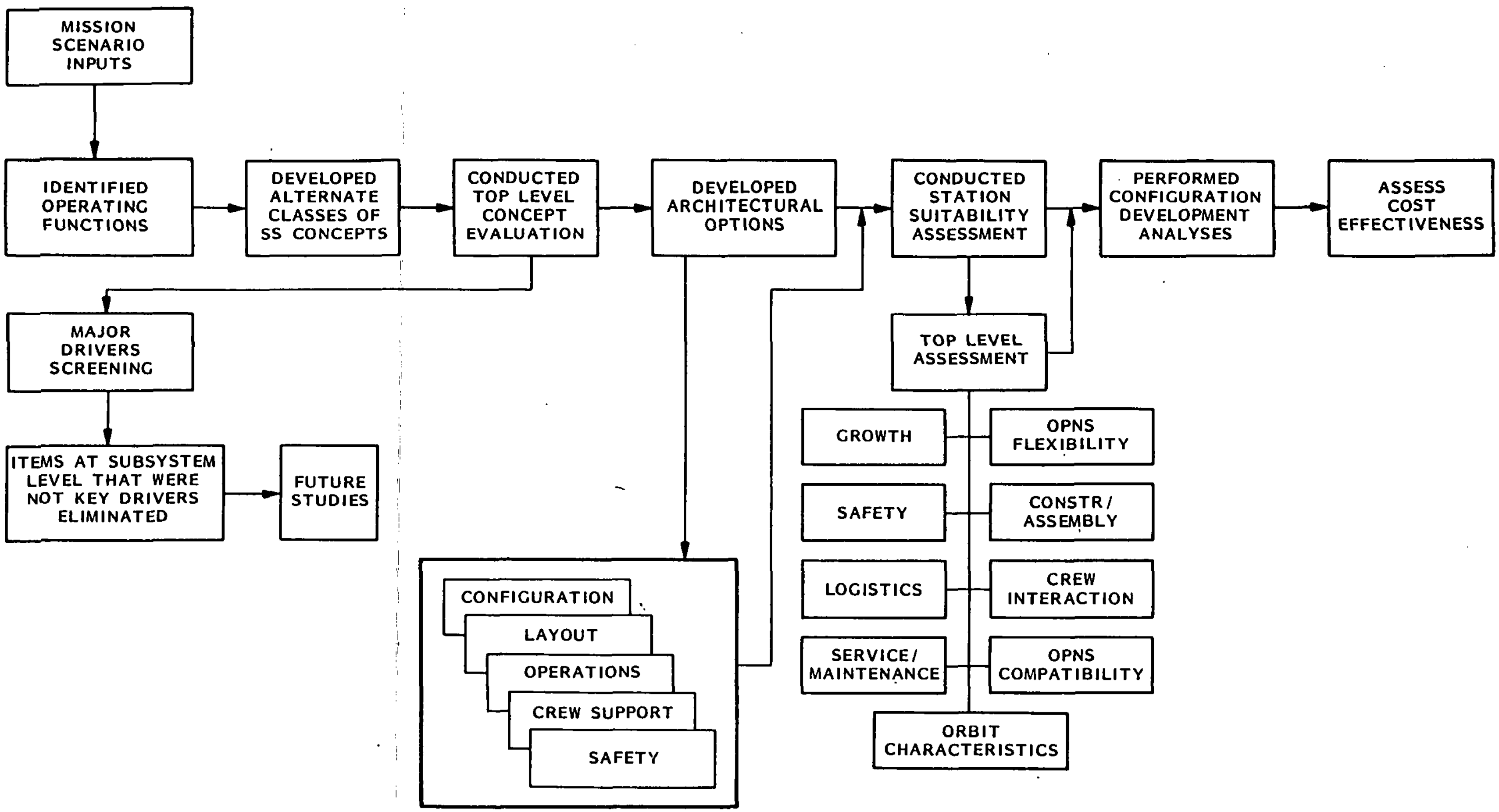
We analyzed fifteen (15) classes of potential space missions within the categories of Science, Applications, Commercial, US National Security and Operations. From these operations analysis space station system functions and architectural groupings were identified. On a basis of functional commonality and operations compatibility, we identified five top level system concepts and the system functional interfaces. These essentially define the space station systems to accomodate the mission sets that were evaluated.

This next section of our report describes the development and assessment of architectural options in accordance with the process as shown on this accompanying chart. Initially a top-level evaluation was performed of the alternate system concepts to identify the major influences on the station architecture. Since our emphasis during this study has been to concentrate on the conceptual framework for a space station rather than on detail design, we set aside most of the subsystem influencing factors as candidates for future studies. We did consider those subsystem drivers which will influence overall configuration arrangement and layout, such as habitation sizing and work area arrangements for personnel and for performing station satellite servicing and construction/assemblying operations.

Architectural options were explored from a standpoint of configuration, layout arrangement, operations activities, crew support and safety. Station performance capability was evaluated based on criteria such as growth, safety, logistics support needs, servicing and maintenance needs, orbital environmental needs, operational flexibility on orbit construction/assembly needs, crew interaction needs and operational compatibility with space infrastructure including space transportation elements and communication networks.

Results of the station suitability assessment were used in supporting configuration development analysis and cost effectiveness analysis to identify candidate space station configurations.

ARCHITECTURAL OPTIONS DEVELOPMENT AND ASSESSMENT PROCESS



STATION ARCHITECTURE - FUNCTIONAL I/F FACTORS

During the course of the operational functions development effort, it became apparent that a number of important interfaces could be identified. Accordingly, these were listed and categories established which were:

1. Payload experiment
2. Orbit transfer & servicing
3. Space Transportation System
4. Logistics
5. Ground
6. Communications

The listing provided on the facing page indicates a preliminary compilation of these station interfaces, however, it is patently obvious that the list is not exhaustive but rather intended to provide a starting point for the architectural design effort. It would be naturally expected that as the architectural design, analysis, and studies continue, the interface list would expand, be modified, and provide a very important reference and adherence base from which to examine and assess the referenced station configuration concepts. The list also provides a 'checklist' of the interaction of the station infrastructure thereby assuring that the 'total system' would be addressed, particularly as it relates to early costing implications.

STATION ARCHITECTURE—FUNCTIONAL I/F FACTORS

ELEMENTS

P/L-EXPERIMT.

- ALT/INCLIN.
- SERVICABLE
- LIFETIME
- QUANTITY
- CONSTRAINTS
- TIME-FRAME
- DATA PROCESS.
- COMM NEEDS
- EXPENDABLE
- LOGISTICS
- DoD VS CIVIL

ORB.XFER & SERVICER

- PROP.CAPABILITY
- 1-WAY VS 2-WAY
- P/L WT.CAPABIL.
- 1 VS ASSEMBLED
- SERVICE FEATURES
- CONTAMINATION
- AUTONOMY
- DoD VS CIVIL
- STD.VS AERO-BRAKE
- TELEOP CAPABILITY
- CONSTRAINTS

STS

- ALT/INCLIN
- CARGO BAY SIZE
- EMER.RETURN
- UTILITIES SUPPORT
- WT. VS PACKAGING
- RMS(s) USE
- STAY TIME
- FLTS/YR AVAIL.
- COST/FLIGHT
- CONSTRAINTS
- DoD VS CIVIL

LOGISTICS

- UP TO 60K.LB+
- PACKAGING
- ENVIRON.PROJECT.
- CONDITIONING
- 'PIGGYBACK'
- CREW VS EQUIP.
- FREQUENCY
- FLEXIBILITY
- XFER TECHNIQUE
- CONSTRAINTS
- DoD VS CIVIL

GROUND

- MCC
- TRACK STA I/F
- SCIENCE CENTER(s)
- 'VAB' & CARGO I/F
- LAUNCH FACILITY
- REFURB DEPOT
- LOGISTICS CENTER
- P/L ASSY-C/O FACILITY
- TRANSPORTATION
- PERSONNEL & TRNG
- DoD VS CIVIL

SPACE COMM.

- INFO TYPE
- RATES
- FREQUENCIES
- DOWNLINKS
- LOS I/F
- CAPACITY
- ENCRYPTION
- BACKUP
- AVAILABILITY
- CONSTRAINTS
- DoD VS CIVIL

OPERATIONS INFRASTRUCTURE (TYPICAL)

During the early identification and definition of station operations, two major categories of operational support evolved. These categories are:

1. Nominal & non-nominal indigenious station operations

2. Nominal & non-nominal station support fuctions

The basic station operations are listed in the facing page and are indicative of the top-tier operations only, as considerable more detail was fleshed-out in subsequent analysis. These sub-categories served, then, as the catalyst for more detailed effort relative to operations definition and identification conducted in support of the architectural configuration design and layout activities.

OPERATIONS INFRASTRUCTURE (TYPICAL)

A. SPACE STATION OPERATIONS:

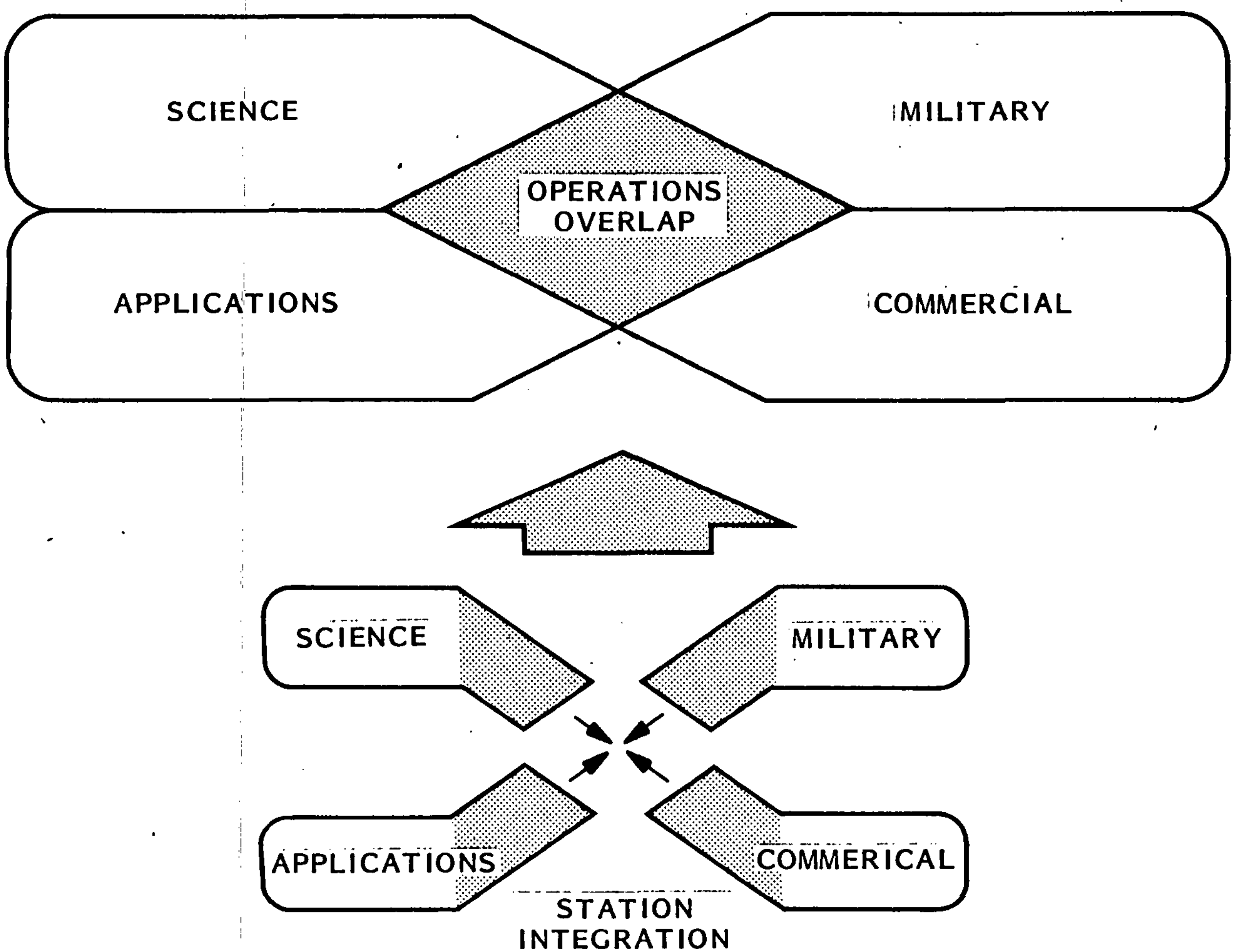
1. NOMINAL AND NON-NOMINAL STATION FUNCTIONS, e.g.:
   - SYSTEM/SUBSYSTEMS OPS
   - HOUSEKEEPING
   - LOGISTICS
   - MAINTENANCE/REPAIR
   - DEGRADED SYS OPS
   - CREW ROTATION/TRNG
   - FUEL/LIQUIDS MGMT
   - DOCKING AND TRANSFER
   - ASSEMBLY/CONSTRUCTION
   - EMERGENCY/RESCUE OPS

2. NOMINAL AND NON-NOMINAL STATION SUPPORT FUNCTIONS, e.g.:
   - SPACECRAFT SERVICING
   - STAGE BASING/ASSY & C/O
   - EXPERIMENT OPS
   - BASIC RESEARCH
   - TECHNOLOGY DEVELOPMENT
   - FLUID XFER/MGMT
   - DEMONSTRATIONS
   - PROOF-OF-CONCEPT VALIDATIONS
   - INDUSTRIAL MFG/MATERIALS PROCESSING
   - MILITARY APPLICATIONS
   - RESUPPLY/LOGISTICS
   - REMOTE OPS

OPERATIONS OVERLAP

From the outset of the study it became patently obvious that the operations area overlapped the other basic study factors, e.g., Science, Applications, US National Defense, and Commercial. This overlap is simply illustrated on the facing page. The amalgamation of these four (4) factors, and the newly created category entitled Technology Demonstration, into the station development concept resulted in an integration flow as illustrated. Thus, as the integration process evolved, the obvious operations overlap logically and systematically occurred. Accordingly, one of the major thrusts of Task 1 was to identify and define the operations (and inherent functions) such that the resultant could be fed into the architectural development study, layout, and trade activities.

OPERATIONS OVERLAP



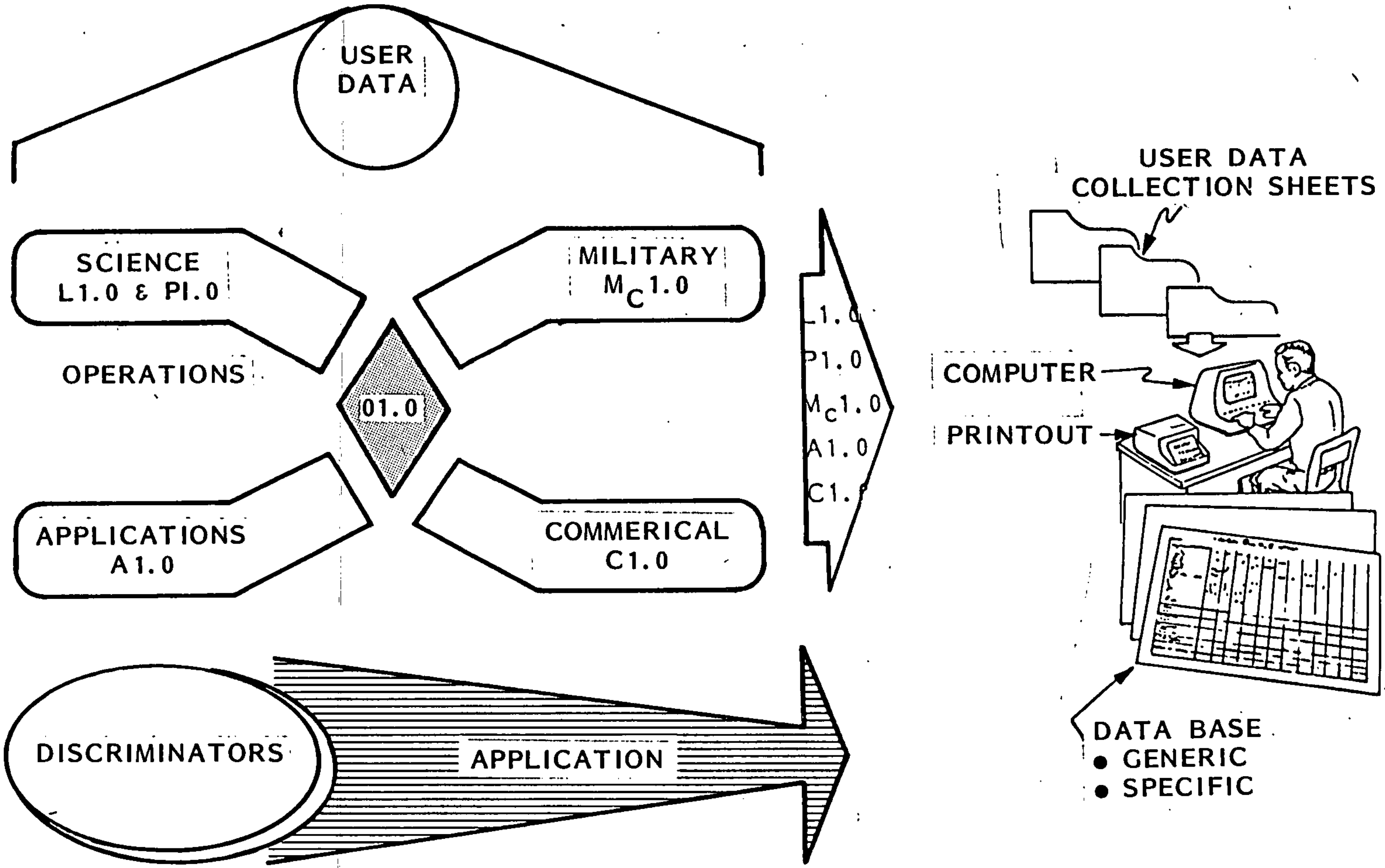
OPERATIONS - DATA SORT/COMPARISON APPROACH

Considerable operations data was obtained in the user needs survey. As shown on the facing page, the operations data was initially cataloged within each of the major study element areas, e.g., science, applications, military, and commercial*. Through the use of the computer sort capability, the operations data was obtained from the user data collection sheets and recompiled into output sheets which related operations to mission needs. This information was coded for ease of retrieval and update as necessary.

The operations data was next subjected to a set of criteria or discriminators to 'cull-out' those factors which were either insignificant and/or had no significant bearing on the analysis effort. The resultant was the development of the basic operations data base which included both generic and specific operations factors. As will be discussed in subsequent pages, these operations factors were categorized and numerous sub-category detail identified. This effort ultimately was used in the information package promulgated to the design team for use in the architectural definition effort.

*Later on during the course of the study, a category was added - Technology Demonstration

OPERATIONS — DATA SORT/COMPARISON APPROACH



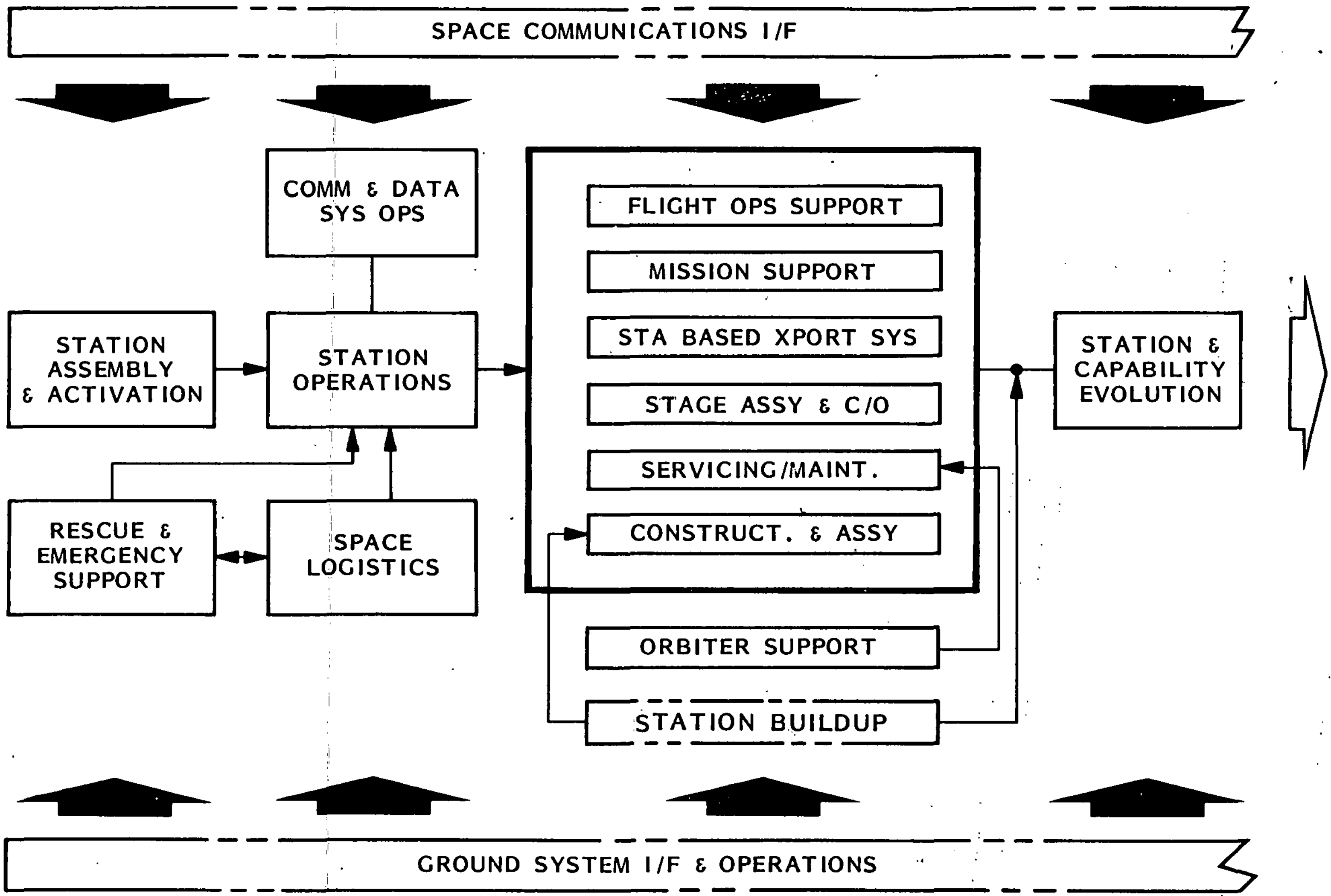
STATION OPERATIONS INFRASTRUCTURE

As the study evolved, it became more clear that the overall station operations infrastructure required early definition as a means of assuring that the functional needs would be identified and could then be amplified. The facing page illustrates in simplified form the basic station infrastructure as invisioned at this time. Of importance to note is the continuing operational interaction with the ground and space communications asset. Integral to this infrastructure are the National Security operations, however, that aspect is not covered herein and will be presented in an accompanying classified volume.

Two operational factors which, to date, have received less than adequate attention are the areas of rescue and emergency support, and space logistics (more aptly referred to as the integrated space logistics system). These two areas form an important part of the overall architectural definition and, as importantly, significantly influence the costing efforts. Accordingly, added effort was given to these areas to assure overall inclusion in the study.

SPACE STATION PROGRAMS

STATION OPERATIONS INFRASTRUCTURE



STATION OPERATIONS

One of the most important pre-curser efforts needed to initiate architectural design was the definition of the basic station operations. Thus, effort was undertaken to identify the range of operations/functions which could be logically allocated to the station in support of the basic mission needs, logistics, ground interaction, and communications. This effort resulted in some 12 categories being established for inclusion of these operations/functions; these categories are:

1. Station assembly & activation
2. Station indigenous operations
3. Rescue & emergency support
4. Space logistics (including ground)
5. Communication & data system ops
6. Flight ops support
7. Mission support
8. Station based transport system ops
9. Stage assembly & checkout
10. Servicing & maintenance - spacecraft
11. Construction & assembly
12. Orbiter support

The following pages present these 12 categories and associated operations/functions. As the station definition effort matures and the mission/user needs become further defined, this list can be further expanded, modified, and updated to provide a formal data base for use in the architectural development studies. At present, the list provided substantial aid and insight to the configuration development activity, particularly, as a means of identifying functions that had to be incorporated into both general and special station architectural capability. As the design effort matured, the list ultimately became a 'checklist' of functions which were then cross correlated to station design capabilities.

SPACE STATION PROGRAMS

STATION OPERATIONS

STA.ASSY & ACTIVATION	STATION OPERATIONS	RESCUE & EMER SUPPORT
• ELEMENT LAUNCH • PRE-DEPLOY C/O • ORBITER ASE.ACTIVATION • PRE-RELEASE ASSY. • IVA/EVA - SUPPORT • FREE FLYER SUPPORT • ELEMENT MATING • STA.RELEASE • STA.APPENDAGE DEPLOY • PARTIAL STA.ACTIVATION/VER. • ORB.RENDEZVOUS/BERTH • ATTACH REMAINING SUB-ELEMENTS • FLT.CREW XFER • FULL STATION ACTIVATION • STA.CHECKOUT/VERIFICATION • ORB.RELEASES STA. • ORBITER 'STATION-KEEPS' • ORBITER EARTH RETURN	• STA.SAFETY IMPLEM. • STA.SUB-SYS OPS - GN&C - DATA MGMT - ECLSS - COMM - EPS - LIGHTING - RCS - C&W • FLT.CREW SUPPORT - HYGIENE/WASTE MGMT.OPS - FOOD SERVICE OPS - CREW AIDS OPS - SLEEP/REST SUPPORT OPS - EXERCISE/RECREATION OPS - CLOTHES/WIPES HANDLING OPS - HOUSEKEEPING MGMT. OPS • HEALTH CARE MAINT.OPS • INTERNAL STA.SUB/SYS MAINT.OPS • STA.STORES/LOGISTICS SERVICE OPS • CREW/SCIENTIST TRNG.OPS • CREW ROTATION/CHANGEOVER OPS • CREW EVA SUPPORT OPS • CREW TRANSFER OPS • LOGISTICS SUPPLY OPS • DELIVERY SUPPLY OPS • EXPENDABLE RESUPPLY	• STA C&W SUBSYS. OPS • PRESS.VOL.HATCH CLOSE-OUT OPS • ECLSS SUBSYS.EMER.OPS • AIRLOCK OPS • ON-SITE RESCUE VEH.C/O OPS • CREW PORT.BREATHING-GEAR OPS • SUIT STATUS & RECHARGE STA.OPS • SUIT DON/DOFF OPS • EMER.STA.DEACTIVATION • CREW XFER & ACTIVATION OF RES.VEH. • RES.VEH.UNDOCK & XLATE FROM STA. • RES.VEH.ORBIT OPS/RE-ENTRY/LAND • ORB.LAUNCH & STA.I/F-EMER.SUPPORT • CREW RESCUE & XFER TO ORB.OPS

STATION OPERATIONS (Continued)

SPACE LOGISTICS	COMMUNICATION & DATA SYSTEM OPS	FLIGHT OPS SUPPORT
• ON-BOARD LOG. SYS. INVEN. OPS • STA TO GRND LOG. COMM OPS • ORB. XFER. OF LOG. ITEMS TO STA. • LOG. S/C RENDEZVOUS/DOCK. OPS • XFER OF LOG. FROM LOG. S/C TO STA. • STA. LOG. RECEIPT/STOW/ACCESS OPS • LOG.CONDITIONING/MAINT.OPS • REPAKAGING EARTH-RETURN LOG. • XFER OF RE-PKG LOG.TO ORBITER • MONITORING CONST/ASSY LOGISTICS • SAFETY MONITOR OF 'VOLATILE' LOG. • MONITOR & C/O OF EMER.LOG.	• COMM & TRACKING OPS - CONFIG COMM SYS. - I/F WITH RELAY SATS - PERFORM EVA COMM - CONDUCT VOICE COMM - I/F WITH FREE FLYERS • CLOSED CIRCUIT TV OPS - CONFIG.CCTV SUBSYSTEM - CAMERA & MONITOR OPS • DATA HANLDING/MGMT.OPS - INFO/DATA ACQUISITION - DISTRIBUTION & LINK OPS - INFO/DATA PROCESS/SYNTHESIS - STOWAGE/CALL-UP OPS - ENTRY/DISPLAY OPS • SYS TIMING - TIMING GENERATION/UPDATE - ACQUISTION & DISTRIBUTION - TIMING CONTROL/MONITOR OPS	• ORBITER RENDEZVOUS/DOCK • ORBITER-STATION SAFEING • ORBITER DELIVERY OPS (E.G.) - PROPULSIVE STAGES - SATELLITES - PROPELLANTS/PRESSURANTS - HAB/LAB MODULES - MISSION HARDWARE - STA.BUILD-UP HARDWARE - CREW & LOGISTICS • STA.STOWAGE/CONDITIONG OPS • UNIT TURN-AROUND & PKGING.OPS • HARDWARE/EQUIP.SAFEING OPS • ORBITER PRE-EARTH RETURN OPS • ORBITER UTILITIES SUPPORT OPS • PRE-LAUNCH CHECKOUT OPS • SUPPORT HDWR.MAINTENANCE • PLUME & CONTAMINATION AVOIDANCE OPS • SCHEDULING & CREW SUPPORT OPS • CREW EARTH RETURN OPS

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SPACE STATION PROGRAMS

STATION OPERATIONS (Continued)

MISSION SUPPORT	STATION BASED TRANSPORT SYSTEM	STAGE ASSY. & CHECKOUT
• INSTALL/ACCOMODATION SUPPORT	• XPORT FACILITY ACTIVATION	• STAGE FACILITY ACTIVATION
• UTILITIES MONITOR-C/O OPS	• FACILITY MONITOR & C/O	• STAGE FAC.MONITOR & C/O
• PLUME/CONTAM.AVOIDANCE OPS	• XPORT SYS.DELIVERY OPS	• RMS (&/OR CRANE) OPS
• STA.GN&C/RCS SUPPORT	• XPORT SYS RETURN DOCKING OPS	• STAGE DELIVERY RECEIPT
• COMM & TRACKING SUPPORT	• UMBILICAL(s) MATE/DEMATE	• STAGE HAND-OFF FROM ORBITER
• CREW SCHEDULE DEV.OPS	• SERVICES MONITORING & C/O	• STAGE RETURN CAPTURE
• CREW INTERACTION OPS	• ASE UTILIZATION OPS	• UMBILICAL(s) MATE/DEMATE
• LOGISTICS RESUPPLY	• XPORT SYS.SAFEING & C/O	• ASE UTILIZATION OPS
• SAMPLE PCKGING/CONDITIONING	• P/L INSTALLATION/REMOVAL OPS	• STAGE SAFEING & C/O
• ON-BOARD DATA HANDLING	• PROP/PRESSURANT XFER OR PURGE*	• STAGE MATING & ASSY.
• DATA DUMP OPS	• XPORT SYSTEM SERVICING	• EVA CREW SUPPORT OPS
• EVA SERVICE SUPPORT	• EVA CREW SUPPORT OPS	• CONSUMABLES RESUPPLY
• REMOTE I/F OPS	• LOGISTIC RESUPPLY	• P/L CHANGEOUT
• ASE INSTALL/OPS & C/O	• STA.CREW SCHED.DEV.OPS	• FULL STAGE-P/L C/O & MONITOR
• HDWAR CLOSE-OUT & EARTH RETURN	• XPORT SYS & P/L MONITOR & C/O	• PROP/PRESSURANT XFER*
• GROUND 'EXPER' CENTER I/F	• PRE-DEPLOY CREW PROC.OPS	• STAGE-P/L SAFEING MONITOR
	• CREW XFER TO XPORT SYS (MOTV)	• PRE-DEPLOY CREW PROCEDURES OPS
	• DEPLOYMENT OPS	• DEPLOYMENT OPS
	• XPORT SYS FLIGHT MONITOR	• STAGE FLIGHT MONITOR & OPS
	• XPORT SYS STA.REMOTE CONTROL	

*AT STATION &/OR REMOTE

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STATION OPERATIONS (Continued)

SERVICING & MAINT. (SPACECRAFT)

- SERVICING FACILITY ACTIVATION
- ASE UTILIZATION OPS
- SERVICING FAC.MONITOR & C/O
- RMS &/OR CRANE OPS
- S/C RENDEZVOUS & CAPTURE OPS
- S/C DELIVERY TO STA.VIA XPORT SYS/ORBITER
- BERTH/DOCK S/C TO STA.
- UMBILICAL(s) MATE/DEMATE OPS
- S/C SAFEING & C/O OPS
- SERVICING/MAINT.OF S/C AT STA.
  - EXAM & CHECKOUT
  - SAFE SUB-SYSTEMS
  - EQUIP.CHANGEOUT
  - UP-DATE EQUIP/SUBSYSTEM
  - RECONFIGURE
  - MAINTAIN/FIX
  - REMOVE ITEM & PCKG FOR EARTH RETURN
  - PROP/CONSUMABLES RESUPPLY*
- EVA CREW SUPPORT
- IVA CREW INTERACTION OPS

*AT STATION OR REMOTE

SERVICING & MAINT. (S/C)-CONTINUED

- XFER CHANGED-OUT EQUIP TO STOWAGE
- PCKG DEBRIS & XFER TO STOWAGE
- ENVIRON.CONDITION ITEMS AS REQD.
- XFER EQUIP/DEBRIS TO ORBITER FROM STOW.
- CONFIGURE S/C FOR RE-DEPLOYMENT
- ACTIVATE & C/O DELIVERY SYSTEM
- DEPLOY S/C VIA ORBITER/'SERVICER' OR SELF
- MONITOR S/C DELIVERY FROM STA.
- FLY 'SERVICER' TO S/C VIA STA.CONTROL
- DOCK/BERTH OR GRASP S/C WITH 'SERVICER'
- MATE/DEMATE UMBILICAL(s)
- REMOTE SERVICING/MAINT.OF S/C VIA STA.OPS
  - EXAM - C/O & SAFEING OPS
  - APPENDAGE RETRACT AS REQD.
  - EQUIP.CHANGEOUT
  - CONSUMABLES RESUPPLY
- UNDOCK 'SERVICER' FROM S/C VIA STA OPS
- FLY 'SERVICER' BACK TO STA VIA STA OPS
- DOCK 'SERVICER' - SAFE & DEACTIVATE

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SPACE STATION PROGRAMS

STATION OPERATIONS (Continued)

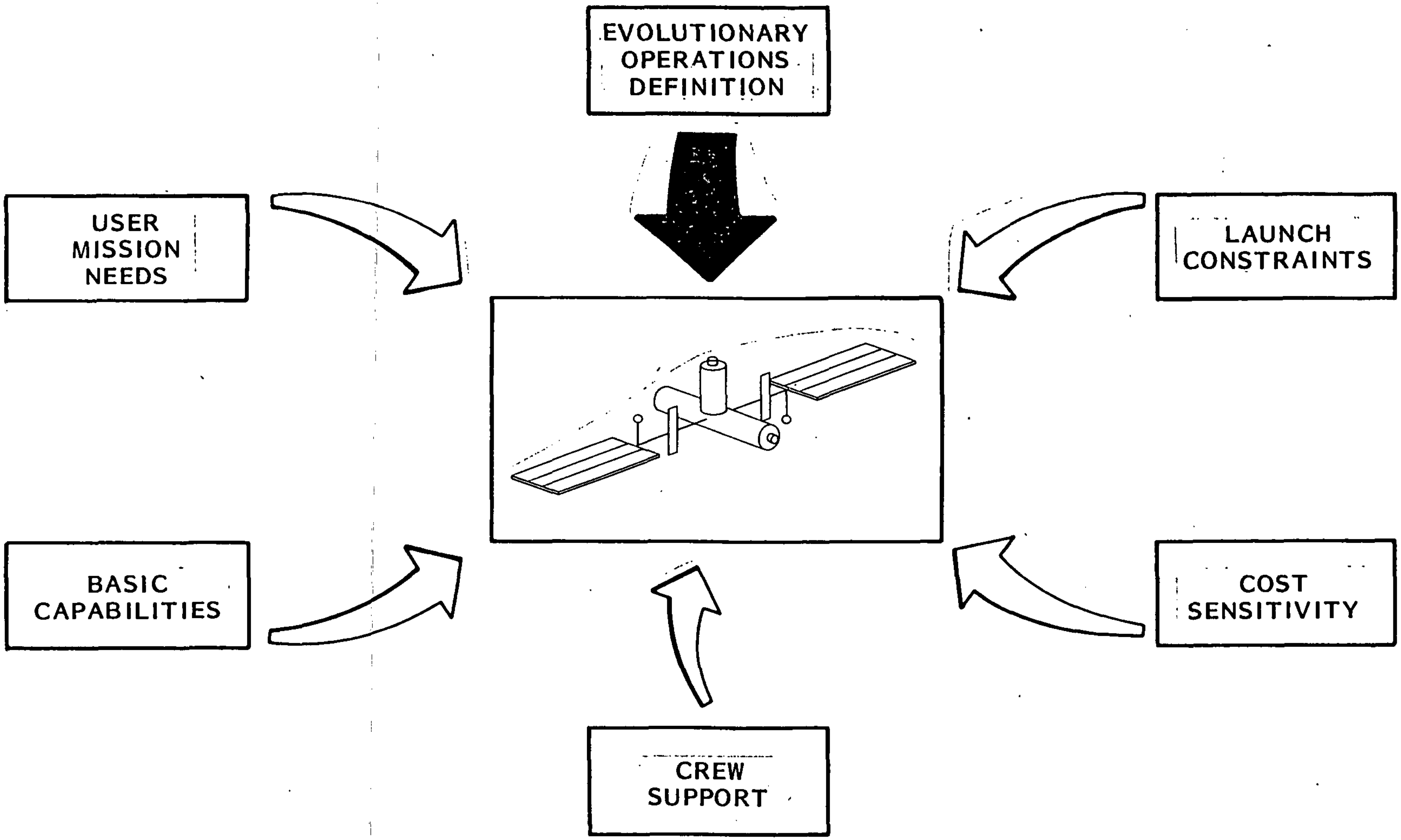
CONSTRUCTION & ASSEMBLY	ORBITER SUPPORT
• STA.ASSY.OF PLTFM/PIER FOR C&A OPS	• DOCKING INTERFACE OPS
• RMS &/OR CRANE UTILIZATION OPS	• UTILITIES PROVISIONING OPS
• LAUNCH-DELIVERY OF CONST./ASSY.HDWR.	• PROP/PRESSURANT RESUPPLY
• LAUNCH-DELIVERY OF CONST./ASSY.SUPPLIES	• INSPECTION & C/O OPS
• ASSEMBLY ATTACHMENT TO STA.PLTFM/PIER	• INSULATION SURFACE RE-APPLICATION
• XFER OF CONSTR./ASSY HDWR TO STA.	• CONTINGENCY CREW RESCUE
• XFER OF CONSTR./ASSY SUPPLIES TO STA.	• EMERGENCY CREW RESCUE
• SET-UP OF CONSTR./ASSY HDWR & C/O	• EMERGENCY PARKING PROVISION
• IVA & EVA SUPPORT OPS	• OFFLOAD CARGO P/L (PERMIT RETURN)
• UTILITIES I/F PROVISION OPS	• PRE-REENTRY C/O
• BASIC CONSTR./ASSY OPERATIONS	
• INTEGRAL RMS/CRANE OPS	
• POSITION & HOLDING AIDS OPS	
• AUTOMECHANISM CONSTR. DEVICE OPS	
• SUPPLY XFER & MGMT.OPS	
• SAFETY & MONITORING OPS	
• FINAL CONSTR./ASSY CLOSE-OUT	
• C/O & MONITOR OF CONSTR.ELEMENT	
• ADD-ON (IF REQD.) OF BOOST 'STAGES'	
• PRE-BOOST C/O	
• SEPARATION FROM STATION	
• STA.MONITOR 'DEPLOY-BOOST SEQUENCE'	

OPERATIONS APPEAR TO BE MAJOR DRIVER

As a result of the operations and functions definition effort, it became more and more apparent that these two factors were the primary drivers for the station. The facing page illustrates a simplified interaction of the major summarized synthesized station influencing factors. One of the most elusive factors in the study was cost due to the overall complexity and magnitude of this study element. Additionally, out-year funding estimates, program start-up dates, procurement ceilings, etc., all added to the costing 'challenge'. Nonetheless, when examining the station, it was determined that the build-up and/or evolution could be paced to the costing groundrules and implications. However, the operations and functions requirements loomed as the major driving factor on the station in that the basic operations/functions had to be inherently provided (even in a growth pattern) in order to meet mission needs and support requirements. Consequently, the architectural design effort was substantially influenced by the operational/function needs established early in the study. Obviously, certain of these operations and functions needs had greater impact that others and, as such, were given higher prioritization scores in the rating system since the majority of these needs were translated into top-tier design criteria, assumptions, and/or guidelines.

SPACE STATION PROGRAMS

OPERATIONS APPEAR TO BE MAJOR DRIVER



SPACE STATION PROGRAMS

TASK 2—MISSION IMPLEMENTATION CONCEPTS

2.1 MISSION SCENARIO ANALYSIS AND ARCHITECTURAL CONCEPTS
2.2 ALTERNATIVE SYSTEMS CONCEPTS
2.3 MISSION OPERATIONS ARCHITECTURAL DEVELOPMENT
2.4 ARCHITECTURAL ANALYSIS TRADES
2.5 EVOLUTION
2.6 CONFIGURATION
2.7 TECHNOLOGY DEVELOPMENT
2.8 CONCLUSIONS

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FUNCTIONAL NEEDS TRANSLATED INTO ARCHITECTURAL DRIVERS

Upon completion of the development of the basic scenarios, a number of station influencing impact factors were identified. This effort resulted in the identification of some 23 categories within which numerous sub-category impact drivers were listed. The opposite page illustrates these categories within which numerous sub-category items were examined. Each of the items was then evaluated and where possible quantitatve numbers/values, etc., developed for each. This permitted the analyst to then 'determine' the overall impact on the station through the use of a rating score (low-medium-high). The results of this analysis were then promulgated to the architectural design team and used as a basis for preparation of basic input criteria and guidelines.

The evaluation results and summary of this effort are presented in subsequent pages herein. The activity was also closely keyed to the configuration concept analysis and assessment effort, and provided the backbone of design inputs used in the architectural definition effort.

FUNCTIONAL NEEDS TRANSLATED INTO ARCHITECTURAL DRIVERS

ENVIRONMENT	9
SHUTTLE MANIFESTING	10
LOGISTICS	11
POINTING & CONTROL	12
APP/DEPART ENVELOPES	5
STATION ASSY	11
MODULARITY	9
HABITATS	12
ENCLOSED VESSEL	11
OPEN PLATFORM	10
APPENDAGES	15
MECH. PROVISIONS	12
CREW	17
COMM I/F	11
MISSION HDWR SUPPORT	15
SUPPORT ELEMENTS	30
SERVICING & STAGE SUPT.	16
SUPPORT SERV. & UTILITIES	14
SUPPORT SUBSTATIONS	16
CONSTRUCT & ASSY	13
SAFETY	12
VULNER/HAZARDS	13
ARTIFICIAL GRAVITY	9

OVER 280 INDIVIDUAL POTENTIAL STATION IMPACT INFLUENCERS EXAMINED

A. INFLUENCE IMPACT CHARACTERIZED FOR EACH CATEGORY ELEMENT

B. EACH IMPACT INFLUENCE RATED
- HIGH
- MEDIUM
- LOW

C. LOW ITEMS SCREENED OUT

D. HIGH/MED IMPACTS PRIORITIZED

FUNCTIONAL NEEDS & ARCHITECTURAL DRIVERS - EXAMPLE VULNERABILITY/HAZARDS

An example on the facing page of one of the 23 categories of functional impact on the station architecture is portrayed. The example illustrates the potential hazards and vulnerabilities of the station relative to the specific sub-listing within this category, each area (sub-listing) was examined relative to the potential influence on the station and a qualitative judgement made as to the extent of that influence, e.g., high, medium or low.

This page (opposite) represents the level of effort expended for each of the aforementioned 23 categories. The complete list is provided in an Attachment 2 to this document.

SPACE STATION PROGRAMS

VULNERABILITY/HAZARDS

AREAS	INFLUENCES	RATING (HML)
• MICRO-METEORITE	ADDED 'SHIELDING'-DOUBLE BUMPER ∿0.02 & 0.01 AL (EXAMPLE)	L+
• SOLAR FLARE	AVER.LESS THAN 20% OF PRIMARY RAD DOSE;MAX FLARE(1956) REQUIRES 500 G/CM^2	M-
• DEBRIS	SCANING RADAR;BUMPER PROTECTION;MULTI-PURPOSE SCAVAGING VEH.	M-
• DOCKING OVERLOAD	MAX IMPACT ∿0.2 FT/SEC;HABITAT 'CLOSE-OUT';ADDED DOCK SYS. SAFETY FACTOR	M-
• COLLISION	CRIT.OF DOCK PORT LOCATION;EMERG.CREW RETREAT;S/C-SHUTTLE OPS APPROACH CONSTR.	M+
• PRESSURE LOSS	EMER.CREW RETREAT;∿0.90 NO PUNCTURE PROB.;EMERGENCY RESCUE REQT.	M+
• REMOTE HANDLINC DAMAGE	RMS/CRANE MAX REACH(50'-100'); ORBITER RMS(50');TELEOP WITH ARMS ∿10'	M-
• PLUME IMPINGEMENT	ORBITER ∿10^{-2} TO 10^{-6} DIRECT PRCS PRESSURE;EJECTA ENVELOPE ORB/OTV/TMS	M+
• SUN SHADOWING	DOCKING PORT(S) LOCATION;RADIATOR POSITION;RESULT IN S.A.SHADOW	H-
• POWER LOSS	SAFETY CRITICAL;BACK-UP SYSTEM;POSSIBLE CREW RESCUE/EARTH RETURN	M+
• THERMAL IMBALANCE	THERMAL OVERLOAD = REDUCED FUNCTIONS (SUPPORT); ADDED EQUIP/RADIATORS	M
• CONTAMINATION	DOCKING PORT(S) LOCATION;APPROACH/DEPART ENVELOPES;PLUME EJECTA	M+
• RADIATION	LEO (QUARTERLY): BONE MARROW 5CM DEPTH - 35REM;SKIN 0.1 MM DEPTH = 105 REM; LENS 3MM DEPTH = 52 REM; TESTES 3CM DEPTH = 18 REM. 60° ORBIT ∿20 TO 23 REM/24 HRS;90° MORE SEVERE SHIELDING RANGE: 28½° ∿0.1 G/CM^2 & 60° ∿0.3 G/CM^2	M

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SIGNIFICANT ARCHITECTURAL INFLUENCING FACTORS PER ASSESSMENT CATEGORY

The facing page indicates the number of medium + and high scores for each of the 23 basic categories of operational functions examined to determine the potential architectural influence. Within each identifier is an indication of the basic category title, e.g., environment. At the bottom of the identifier are the number of items examined within that category, e.g., nine (9). A few categories had no medium +, and/or high scores, e./g., enclosed vessel. These scores accounted for over 100 factors which were scored in the medium + to high range. Accordingly, they were integrated into the overall architectural design criteria for use in the configuration design concept layout studies.

SPACE STATION PROGRAMS

SIGNIFICANT ARCHITECTURAL INFLUENCING FACTOR PER CATEGORY

Category	Medium Plus	High	No. of Items Assessed
ENVIRONMENT	1	6	9
SHUTTLE MANIFESTING	4	3	10
LOGISTICS	1	3	11
POINTING & CONTROL	3	4	12
APPROACH/DEPART ENVELOPES	1	3	5
STATION ASSEMBLY	5	0	11
MODULARITY	2	0	9
HABITATS	0	2	12
ENCLOSED VESSEL	0	0	11
OPEN PLATFORM	4	0	10
APPENDAGES	3	3	15
MECHANICAL PROVISIONS	3	0	12
CREW	0	2	17
COMMUNICATION I/F	3	1	11
MISSION HDWR SUPPORT	2	2	15
SUPPORT ELEMENTS	8	5	30
SERVICING & STAGE SUPPORT	5	2	16
SUPPORT SERVICES & UTILITIES	2	2	14
SUPPORT SUBSTATIONS	1	0	16
CONSTRUCTION & ASSY.	4	5	13
SAFETY	3	1	12
VULNERABILITY/HAZARDS	4	0	13
ARTIFICIAL GRAVITY	6	3	9

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LEVEL OF ARCHITECTURAL/FUNCTION FACTORS INFLUENCE ON STATION DESIGN

The facing page summarizes the rating analysis conducted on the operational functions previously identified. Four major categories were used to compile the impact factors into for convenience. These categories as shown were: (1) envelopes; (2) system drivers; (3) location access; and (4) size/quantity. The columns opposite each category indicate the range of the score, e.g., medium + and high. Opposite each score (in nearly all cases) is a triangle facing the score. This triangle indicates if the score included both medium + and high (open triangle) or only a high score (solid triangle). In cases where there is no triangle, the score was only a medium plus (+).

From this chart it can be readily observed that there were 8 factors which scored in the high range only; these factors were:

- Assembly/construction
- Solar array & radiator size & articulation
- Crew quantity
- Altitude /inclination
- Orbiter cargo bay constraints
- Habitats/laboratories
- Antennas/reflectors
- Launch vehicle cargo packaging and weight

Other factors were equally important to the above; however, in the overall rating they frequently received other scores than high depending on the nature of the operational functions, e.g., docking/berthing which ranged from medium to high. Nonetheless, all of the synthesized factors within the four categories indicated on the opposite page were used as identified architectural influencing factors.

LEVEL OF ARCHITECTURAL/FUNCTIONAL FACTORS INFLUENCE ON STATION DESIGN

ENVELOPES	RANGE	
1. ASSY/CONSTRUCTION	H	◄
2. RMS/CRANE - FIXED	M+ TO H	◁
3. TRACKED RMS/CRANE MOBIL	M+ TO H	◁
4. ITEM TRANSFER SWEPT VOL	M+	
5. DOCKING/BERTHING	M+ TO H	◁
6. ORBITER-S/C APPROACH/DEPART	M+ TO H	◁
7. STAGING VOLUMETRICS	M+ TO H	◁
8. SA & RADIATOR SIZE/ARTICULATION	H	◄
9. PLUME PRESS/CONTAMINATION	M+ TO H	◁
10. SHADOWING	M+ TO H	◁
11. LINE OF SIGHT	M+	
12. BOOM/PIER/BEAM/TETHER ZONES	M+ TO H	◁
13. ANTENNAS/REFLECTORS	M+ TO H	◁

SYSTEM DRIVERS	RANGE	
1. POINTING & CONTROL	M+ TO H	◁
2. RIGID VS FLEXIBLE BODIES	M+ TO H	◁
3. POWER TYPE	M+ TO H	◁
4. I/F DYNAMICS	M+ TO H	◁
5. CREW QUANTITY	H	◄
6. ALTITUDE/INCLINATION	H	◄

LOCATION ACCESS	RANGE	
1. DOCKING/BERTHING	M+ TO H	◁
2. AIRLOCKS	M+	
3. STOWAGE	M+ TO H	◁
4. SHELTER/HANGAR	M+	
5. HOLDING/POSITION DEVICES	M+	
6. SAFE HAVEN	M+	
7. SERVICING (NON-STATION) AREA	M+ TO H	◁
8. STAGING AREA	M+ TO H	◁
9. ORBITER CARGO BAY	H	◄
10. TANKAGE	M+ TO H	◁

SIZE/QUANTITY	RANGE	
1. POWER SYSTEM	M+ TO H	◁
2. RADIATORS	M+ TO H	◁
3. SHELTERS/HANGARS	M+	
4. HABITATS/LABS	H	◄
5. PLATFORMS	M+ TO H	◁
6. PIERS/BEAMS/BOOMS/COLUMNS	M+ TO H	◁
7. TANKS	M+ TO H	◁
8. ANTENNAS/REFLECTORS	H	◄
9. LAUNCH VEH.CARGO PK/WT.	H	◄

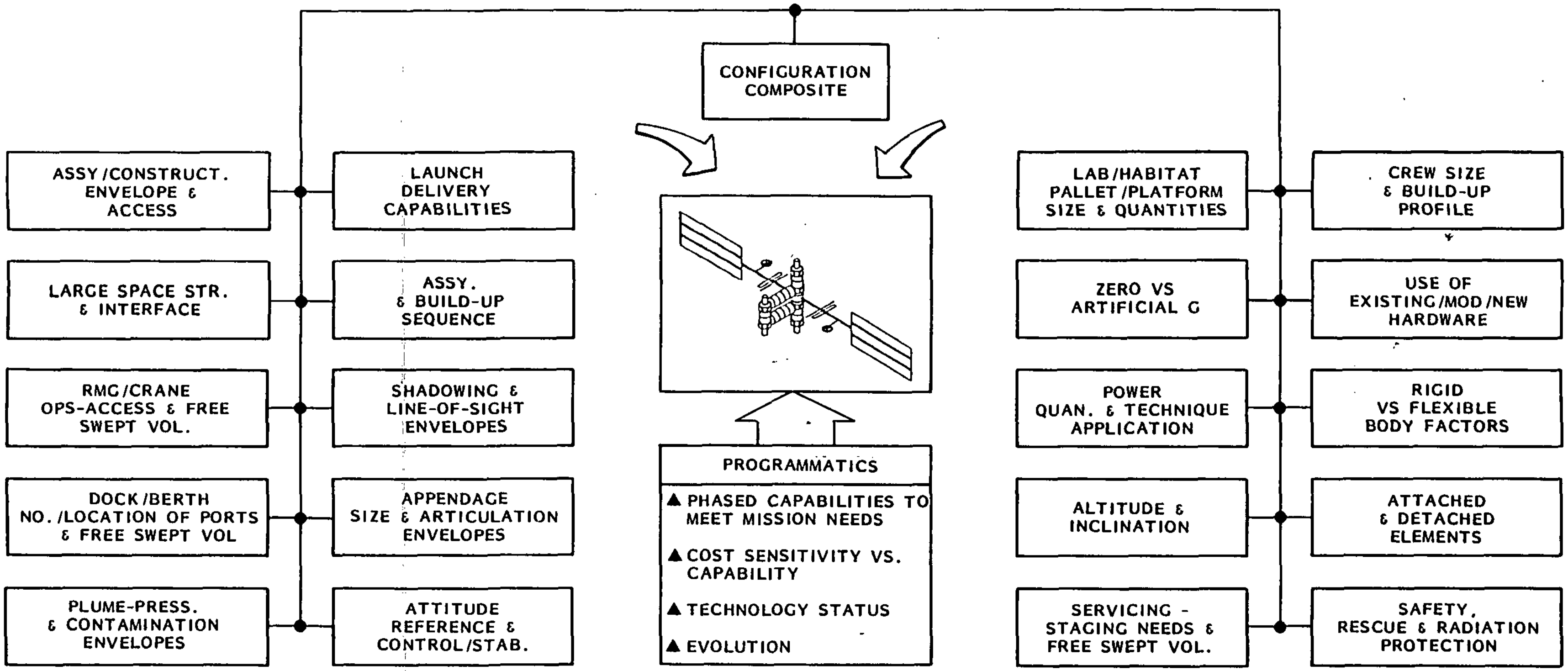
MAJOR ARCHITECTURAL DRIVERS
(SUMMARY)

As a result of the extensive analysis and evaluation effort previously reported, a specific set of architectural drivers has been identified for the station. These drivers are illustrated on the opposite page and include operational, physical, dynamic, 'procedural', environmental, and programmatic. Each of the statements has been defined in sufficient detail so as to provide an impact characterization factor(s) for use in the architectural definition process.

Of all areas considered, those factors associated with programmatics have been the most difficult to identify and/or define. In particular, those factors associated with cost have been most difficult to forecast for the NASA out-year schedules. Similarly, the downstream mission needs, as yet not fully defined, also promote concern relative to comprehensibility with respect to levels and credibility of depth. Evolution of the station is based on a myriad of parameters, issues, and current unknowns including cost; nonetheless, bogus ceilings can be established and used as a basis of departure. Thus, in concert with the operational, physical, dynamic, 'procedural', and environmental drivers, cost was used as a major driving element in the overall assessment of impact factors.

These factors were provided in summary from to the design team for incorporation as criteria guides used in the architectural definition process. Similarly, as the design progressed, these criteria were also used with the evolution rationale to aid in the station build-up sequence effort reported upon in subsequent charts.

MAJOR ARCHITECTURAL DRIVERS (SUMMARY)



ARCHITECTURAL IMPACT ANALYSIS

Upon completion of the mission scenario development effort, activity was initiated on the identification of the operations and associated functions relative to the basic missin study elements which were:

- Science
- Applications
- Commercial
- US National Security
- Space Operations
- (Technology Demonstration - A newly created category)

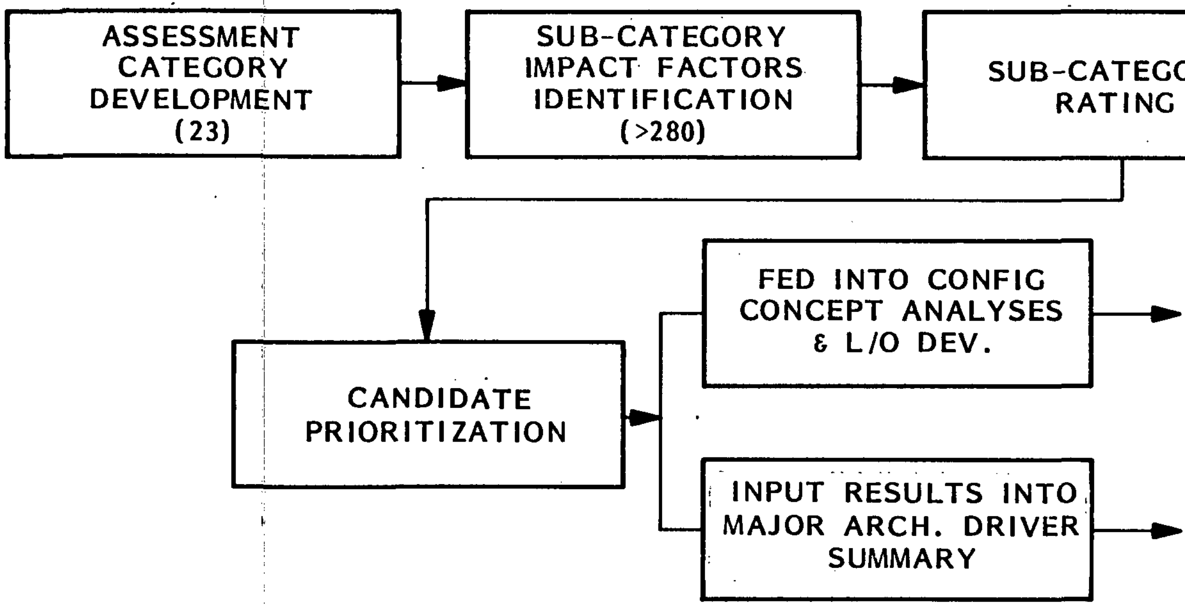
The methodology for this activity is presented in the chart on the facing page. As indicated, 23 basic operational function categories were identified and within this composite, over 280 subcategory architectural influencing factors were derived. Each factor was then examined and rated on a low, medium, and high basis. Examination of the multitude of ratings revealed that those factors exhibiting a medium to high rating score should be considered architectural impacts. Accordingly, 104 factors, approximately 40%, were then incorporated into other design criteria and used as a basis for subsequent design and layout of the candidate station configurations.

ARCHITECTURAL IMPACT ANALYSIS

A. 23 OPERATIONAL FUNCTIONS CATEGORIES IDENTIFIED

B. OVER 280 SUB-CATEGORY ARCHITECTURAL INFLUENCES FACTORS DELINEATED

C. EACH FACTOR ASSESSED ON A RANGE BASIS OF IMPACT (LOW TO HIGH)



D. 104 FACTORS (40%) WERE IDENTIFIED WHICH WERE RATED AS HAVING SIGNIFICANT ARCHITECTURAL IMPACT

CONFIGURATION CONCEPTS EVALUATION

The facing page presents the results of evaluation of 11 of the 32 space station configuration developed in this study. Results for the evaluation of the other 21 configurations are given in Attachment 2 to this report.

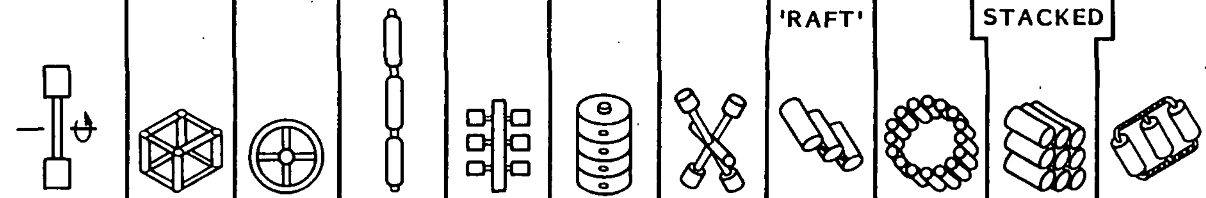
Each of the 32 concept configurations were subjected to a KTA evaluation to determine overall practicality, mission suitability, and utility. The evaluation criteria used was as follows:

1. Orbiter Considerations
   - No. of Orbiter launches
   - Config. fits cargo bay vol.
   - Adaptable to Orbiter support
2. Feasibility
   - Structural stability
   - Technical dev. practicality
   - Ease of on-orbit assembly
3. Flexibility
   - Permits large struct. assy.
   - Multiple docking ports & access
   - Adaptability to growth
   - Permits artificial g
   - Meets mission/operations needs
4. Programmatics
   - Permits existing hdwr. application
   - Cost sensitive & cost practical
5. Performance Capability
   - Meets mission needs
   - Allow 0 to partial g

Each concept was individually rated one against the other based on the above criteria. Scores were then summed for each configuration concept and the concepts rank ordered. Results of this evaluation are presented in the Architectural Concept Configuration Evaluation Summary chart following these charts.

SPACE STATION PROGRAMS

CONFIGURATION CONCEPTS EVALUATION



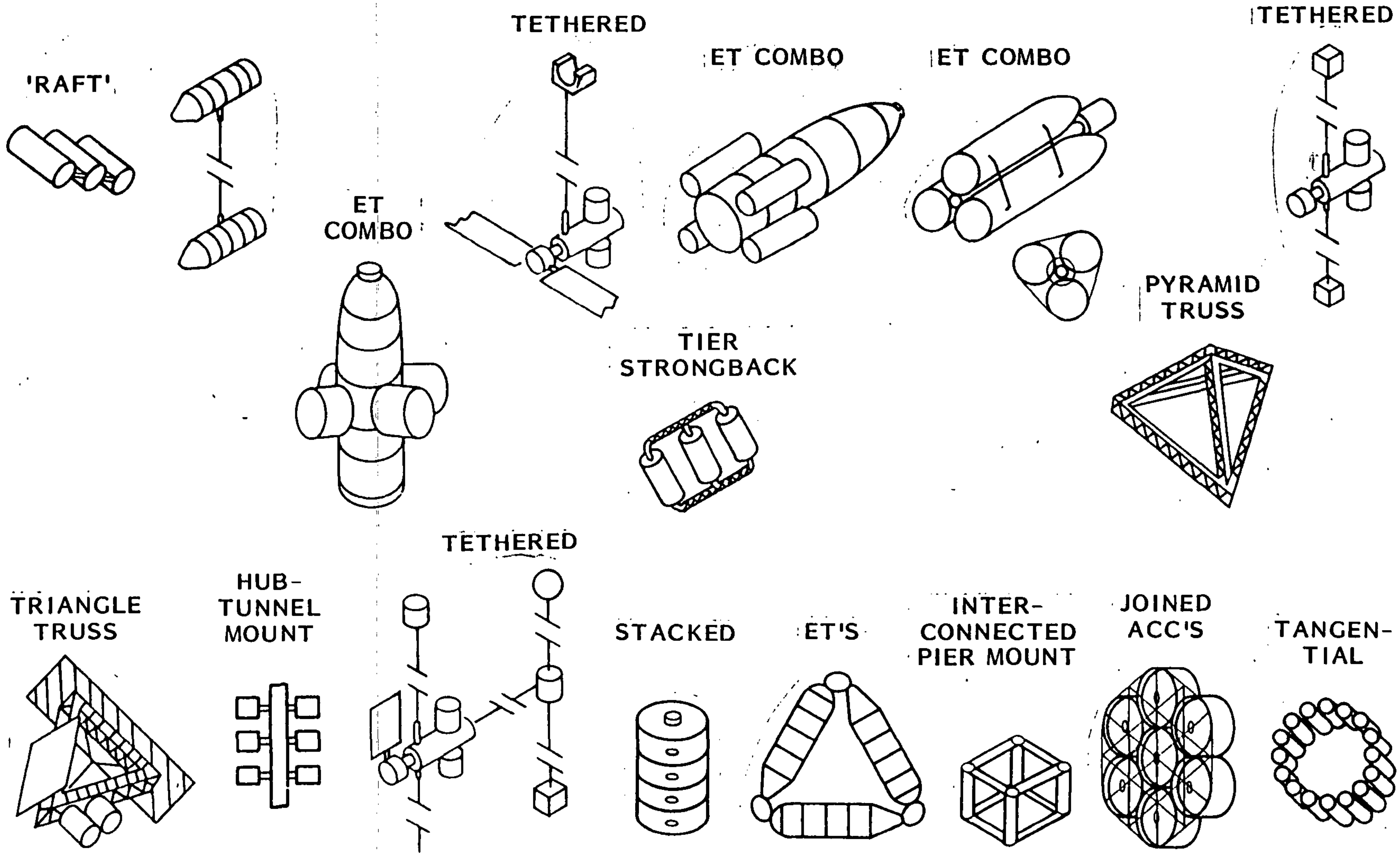
CONFIGURATION TYPES / ELEMENT TYPES	DUMBELL	INTERCONNECTED PIER MOUNT	RING/SPOKE MT.	LONGITUDINAL	HUB-TUNNEL MOUNT	STACKED	CLUSTER PAC: RADIAL HUB MT.	CLUSTER PAC: 'RAFT'	CLUSTER PAC: TANGEN-TIAL	CLUSTER PAC: STACKED	CLUSTER PAC: TIER STRONGBACK
ORB. I/F • NO. OF ORBITER LAUNCHES	9	6	3	8	5	6	5	8	3	3	6
ORB. I/F • CONFIG. FITS BAY VOLUME	9	8	2	9	8	5	7	9	9	9	9
ORB. I/F • MEETS LAUNCH WT. LIMITS	9	4	2	7	4	6	5	7	1	1	6
ORB. I/F • ADAPTABLE TO ORB. SUPPORT	8	9	6	7	9	6	6	8	9	9	9
FEAS. • STRUCTURAL STABILITY	2	6	8	2	6	9	4	8	8	9	7
FEAS. • TECH. DEV. PRACTICALITY	5	6	3	8	9	6	9	9	8	8	8
FEAS. • ASSY EASE ON-ORBIT	9	4	2	7	6	9	4	8	5	5	6
FLEX. • PERMITS LG. STRUCT. ASSY	3	9	3	4	5	7	6	8	8	8	9
FLEX. • MULTI-DOCK PORTS & ACCESS	5	9	2	5	8	7	7	7	9	9	8
FLEX. • ADAPTABILITY TO GROWTH	6	8	1	2	7	9	2	9	7	9	8
PROG. • COST	7	5	2	8	7	7	4	8	6	6	7
PROG. • EXIST. HDWR. APPLICATION	3	2	1	2	2	1	2	2	2	2	2
NEW • MEETS MISSION NEEDS	1	8	1	7	8	7	4	8	7	7	8
NEW • ALLOW O TO PARTIAL G	9	1	9	1	6	1	9	1	3	1	1
TOTAL	85	85	45	77	89	89	72	100	85	79	94

CONFIGURATION CONCEPTS

The facing figure and next page present a reduced composite of the total aggregate of station configurations examined. More than 50 differing configurations were developed from which 32 were synthesized for further evaluation. Some 14 classes were delineated and each configuration categorized accordingly. These classes were:

- Dumbbell
- Interconnected Pier Mount
- Ring/Spoke Mount
- Longitudinal
- Hub-Tunnel Mount
- Stacked
- Radial-Hub Mount
- Cluster Pac
- Combinations
- Tethered
- Rigid Truss
- Aft Cargo Carrier
- Beaded
- External Tank

CONFIGURATION CONCEPTS



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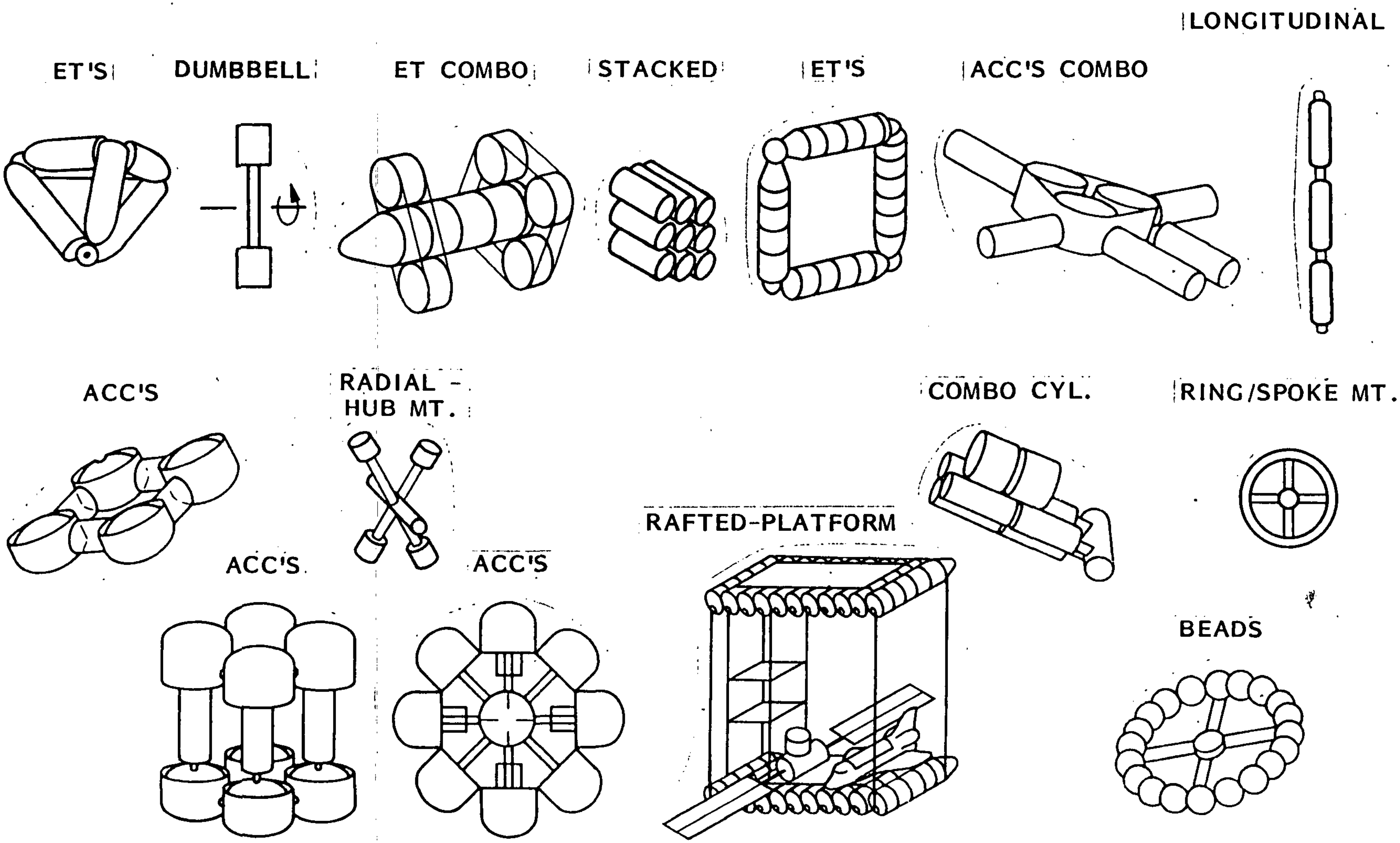
SPACE STATION PROGRAMS

CONFIGURATION CONCEPTS



ARCHITECTURAL CONCEPT CONFIGURATION EVALUATION
RESULTS SUMMARY

The opposite page indicates the extent and nature of the architectural concept evaluation undertaken during this study. As indicated well over 50 different architectural concepts were examined (see previous charts) as a means of assuring that the majority of alternate methods to layout a station had been identified. From this initial cadre, some 32 station concepts were selected against which the assessment criteria was applied.

A numerical evaluation assessment technique was applied (KTA approach) for the composite concept list. A ranking scale (0 = low, and 10 = best) was used. Each concept was examined against some 14 specific criteria within the 4 categories indicated. From this assessment effort, 5 architectural family concepts emerged which indicated value for further study. These 5 families were:

- Cylindrical - hub/tunnel
- Raft - side by side cylinders
- External tank(s)
- Triangle & strongback truss
- Stacked cans

The aforementioned concepts appeared to represent a good overall composite from which to intitate more formal archtectural design activities. The resultant of this effort confirmed that the concepts examined could meet the basic scenario and missin needs, thereby, substantiating the use of these concepts for further architectural definition.

ARCHITECTURAL CONCEPT CONFIGURATION EVALUATION (SUMMARY)

A. LMSC EXAMINED OVER 50 DIFFERENT ARCHITECTURAL CONFIGURATION CONCEPTS
   1. 13 FAMILY CATEGORIES DEFINED
   2. 32 CONCEPTS USED IN EVALUATION BASE

B. NUMERICAL EVALUATION ASSESSMENT TECHNIQUE EMPLOYED
   1. KTA TYPE OF EVALUATION TECHNIQUE USED
   2. RANKING RANGE FROM 0 TO 10 (0 LOW [POOREST] & 10 HIGH [BEST])
   3. 14 SPECIFIC EVAL. CRITERIA WITHIN THE FOLLOWING 4 GENERAL CATEGORIES
      - ORBITER I/F (4)
      - FEASIBILITY (4)
      - FLEXIBILITY (4)
      - PROGRAMMATICS (2)

C. RESULTS
   1. 5 ARCHITECTURAL FAMILY CONCEPTS REPRESENTED IN TOP RATED CONFIGURATIONS:
      - CYLINDRICAL HUB/TUNNEL
      - RAFT (SIDE BY SIDE CYLINDERS)
      - EXTERNAL TANKS
      - TRIANGULAR & STRONGBACK TRUSS
      - STACKED CANS
   2. CONCEPTS REPRESENT A VERY REASONABLE SPECTRA OF ARCHITECTURAL CONFIGURATIONS WHICH SUGGEST FURTHER STUDY

EXTERNAL TANK & AFT CARGO CARRIER APPLICATIONS

An examination was made of the possible applications of the external tank (ET) and aft cargo carrier (ACC) to the composite of mission operations/functions (needs) established upon conclusion of the scenario development effort. This facing page (and subsequent page) indicate the potential candidate uses of these two concepts for the functions listed. Several application categories were determined as necessary to identify the potential uses. Categories considered were:

- Clustered: Interlocked spacecraft and formation flying free flyers
- Single unit: An individual spacecraft (ET or ACC) which is in a free flying mode
- Tethered items: Spacecraft (individual or multiple) attached to a station based tether system
- Station attached: Either the ET or ACC is directly attached to the station
- Artificial G Possibility: The potential for the ET or ACC to be configured such that it can be rotated about a center point to create artificial gravity for the outboard mounted habitats

In many instances both the ET and ACC appeared applicable for the functional need or application. The far column indicates only that an ET or ACC may be applicable to the functional need/application, however, no distinction was made relative to selection of either two.

SPACE STATION PROGRAMS

EXTERNAL TANK & AFT CARGO CARRIER APPLICATIONS

CANDIDATE USES / HDWR CONFIG.	CLUSTERED: INTER-LOCKED	CLUSTERED: FORM. FLY	SINGLE UNIT	TETHERED TO STATION	STATION ATTACHED	ARTIFICIAL G POSSIBILITY
1. PROPELLANT TANKAGE (SUPPLY & SCAVENGING)	E	E	E	E		▲
2. ECO FARM (SPACE FARMING)		E	E/A	E/A	A	▲
3. LOGISTICS BASE/SUPPLY DEPOT		E	E	E/A	A	
4. ARTIFICIAL G 'COUNTER WEIGHT' OR MASS				E		▲
5. COMMAND POST MODULE			E	E		
6. SERVICE DEPOT		E/A	E/A	E	A	
7. POWER UNIT (E.G. NUCLEAR)				E/A		
8. RESCUE POD &/OR SAFE HAVEN			A	A		
9. HEALTH CARE UNIT (POSSIBLE COMBINATION)		E/A	E/A	E/A		▲
10. RECREATION COMPLEX-FLIGHT CREWS (POSSIBLE COMBINATION)		E/A	E/A	E/A		▲
11. RECREATION COMPLEX-'VISITORS' (POSSIBLE COMBINATION)		E/A	E/A	E/A		▲
12. CONSTRUCTION BASE	E	E	E	E	E	
13. S/C AND/OR OTV STOWAGE HANGAR		E/A	E/A	E/A	A	
14. R & D FACILITY	E/A	E/A	E/A	E/A	A	
15. EXPERIMENT MODULE		E/A	E/A	E/A	A	
16. OBSERVATION PLATFORM		E/A	E/A		A	
17. MATERIALS PROCESSING LAB		E/A	E/A			
18. LARGE STRUCTURE ASSEMBLY STRONGBACK	E	E			E	
19. MANUFACTURING FACILITY	E	E/A	E/A			
20. TANK STAGE/HOUSING FOR OTV	E	E	E	E		▲
21. QUARANTINE FACILITY		E/A	E/A	E/A	A	
22. HABITAT	E/A	E/A	E/A	E/A	A	▲
23. WASTE/DEBRIS CONTAINER		E/A	E/A	E/A		

E = EXTERNAL TANK
A = AFT CARGO CARRIER

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EXTERNAL TANK & AFT CARGO CARRIER APPLICATIONS

CANDIDATE USES (HDWR CONFIG.)	CLUSTERED		TETHERED			
	INTER-LOCKED	FORM FLY	SINGLE UNIT	TO STATION	STATION ATTACHED	ARTIFICIAL G POSSIBILITY
24. BASIC STATION BUILDING BLOCK	E/A	E/A	E/A	E	A	
25. GENERAL PURPOSE HANGAR		E/A	E/A	E/A	A	
26. DOCKING MODULE		E/A	E/A	E	A	
27. TMS ENCLOSURE	A		A		A	
28. HUB FOR CRANE (MANNED OPS)			E/A		A	
29. LARGE STRUCTURE PLATFORM	E/A	E	E	E	E/A	
30. SHIRT-SLEEVE WORKSHOP		E/A	E	E/A	A	
31. WAREHOUSE		E	E/A	E/A	A	▲
32. 'WET' LAB		E	E/A	E/A	A	

E = EXTERNAL TANK
A = AFT CARGO CARRIER

CREW HABITABILITY FACTORS HAVING RELEVANT ARCHITECTURAL IMPACT

The facing page presents an assessment summary of those crew factors having both primary and secondary impact on the basic station architecture. Crew size and support were identified as the principal interface factors against which the habitability factors were examined. The most significant major driver established, as would be expected, was the number of habitats (enclosed structures which are capable of maintaining an internal pressure of approximately 14.7 PSI). A second major driver was the number of tunnels needed for inter-habitability interconnect. Airlock numbers also were important as was the sizing of the shelter (if not integral to the airlock). These factors were folded into the overall criteria used in the development of the architectural concept candidates. Finally, rescue capability was relegated to a separate station sub-element, e.g., rescue vehicle, and thereby, considered in a separate category of station architectural drivers.

SPACE STATION PROGRAMS

CREW HABITABILITY FACTORS HAVING RELEVANT ARCHITECTURAL IMPACT

CREW FACTORS \ ARCHITECTURAL IMPACT	NO. OF HABITATS	SIZE OF HABITATS	NO. OF XFER TUNNELS	SIZE/NO. OF AIRLOCKS	RMS CREW WORK STA.	SHELTERS/SAFE ZONES	STOWAGE VOLUMES	RESCUE/RE-ENTRY S/C	POWER	FREE SWEPT VOL.
A. CREW SIZE										
1. HABITABILITY FREE VOL.	●	●			○	●		●		
2. WORK/SUPPORT/SLEEP VOL.	●	●			●					
3. ECLSS HDWR/DUCT VOL.	○	●						●	●	
4. TUNNEL/LOCOMOTION VOLS.			●			○				○
5. CREW ACCOMMODATIONS	○	●			○			●		
6. REDUNDANT LIFE ZONES	●		●			●				
B. CREW SUPPORT										
1. LOGISTICS STOWAGE	○	○		○			●			
2. SAFETY SHELTER(S)			●	○		●		●		
3. AIRLOCKS			○	●		○				
4. CONSOLES/RACKS	●	●							●	
5. MAINT. ACCESS	○									○
6. SAFETY PATHS	●		●	●		●				
7. RESCUE/RETURN	●		●	●		●		●		●

● PRIMARY IMPACT ○ SECONDARY IMPACT

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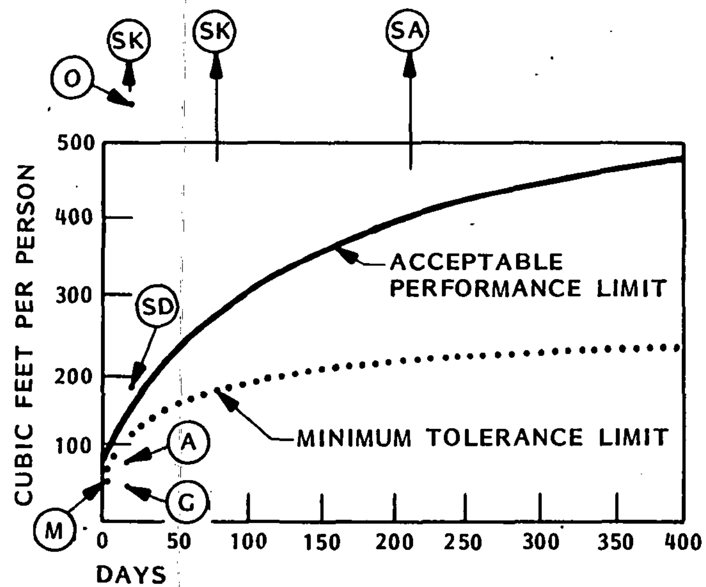
SPACECRAFT HABITABILITY VOL. COMPARISON

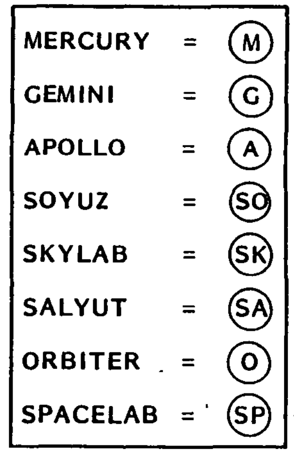
A number of spacecraft were examined relative to available cubic volume per crew member. The opposite page indicates the available volume for some 8 spacecraft/stations orbited to date. The chart also indicates the number of flight crew persons, maximum orbital time, and the pressurized volume per spacecraft. Obviously, the numbers provided do not take into account (for all cases) the amount of equipment volume which must be subtracted from the total available volume. Consequently, certain available volumes may appear to be extremely large in comparison to the early spacecraft. No attempt was made to determine 'lost volume' for any of the spacecraft. As shown in the previous page, the CPM available habitability volume falls above the minimum tolerance limit.

As a result of the studies consulted, actual spacecraft flight hardware values, and current NASA habitability criteria, a value of not less than 275 cu. ft. of free volume per crew person has been assumed as baseline for this study. Accordingly, this value (275 cu. ft.) has been utilized as the criteria for and during the architectural design phase.

SPACE STATION PROGRAMS

SPACECRAFT HABITABILITY VOL COMPARISON





SPACECRAFT	PRESSURIZED VOL (CU.FT.)	MAX ORBITAL TIME (DAY/HR/M)	NO. OF FLT.CREW	CU.FT. VOL/CREWMAN
MERCURY	54	1-10-20	1	54
GEMINI	88	13-18-35	2	44
APOLLO	210	12-13-51	3	70**
SOYUZ*	364	17-16-59	2	182**
SKYLAB	9,550 (USEFUL)	84-1-15	3	3183**
SALYUT	3178	211-x-x	2(+3 FOR 7 DAYS)	1589**
ORBITER	2331	28-x-x(POSTULATED)	4	583**
SPACELAB	2543	27-x-x(POSTULATED)	4+x	636**

*ORBITAL COMPT. & RE-ENTRY MODULE (134.2 CU.FT.) **INTERIOR EQUIP & 'LOST VOL'NOT INCLUDED

CREW HABITABILITY VOL. FOR THE CPM

An examination was made of the total cubic volume available for the flight crew in the Command Post Module concept. This concept employs an external tank for the overall enclosure within which is located several sub-modules as follows:

- 1 Living sub-module
- Airlock
- Transfer tunnels
- 1 Command & Control sub-module
- Interconnect tunnels and hatches
- 1 to 2 Rescue Vehicles
- Pallets located circumferentially around the perimeter of the sub-modules but still within the interior of the ET

The living sub-module, and command & conrol sub-module were both examined for total available volume and the internal locted equipment/hardware subtracted from the total to determine the actual available volume. As illustrated on the facing page, the total volume for a flight crew of 16 equals 279 cu. ft. which is above the NASA established acceptable performance curve for 90 days. The available volume only includes that for the two sub-modules: (1) Living quarters; and (2) Command and control sub-module. The total flight crew number of 16 was developed in response to the mission needs for an orbiting C^2 requirement. Thus, the available habitability volume falls just slightly above the acceptable level and within the optimal level as 'currently defined'.

SPACE STATION PROGRAMS

CREW HABITABILITY VOL FOR THE CPM

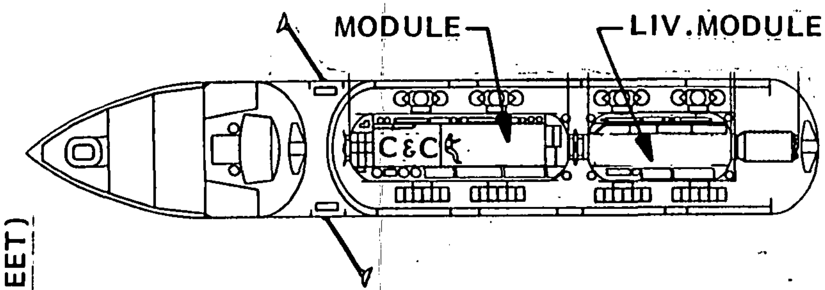
- FLT. CREW OF 16
- SLEEP QTRS PER CREWMAN = 104/208 CU.FT.
- STAGGERED USE (ADJACENT) SLEEP QTRS
- THREE-SHIFT OPS
- 'OPEN' EATING SUITE
- FROM 8 TO 12 C & C WK. STA. CONSOLE/RACKS

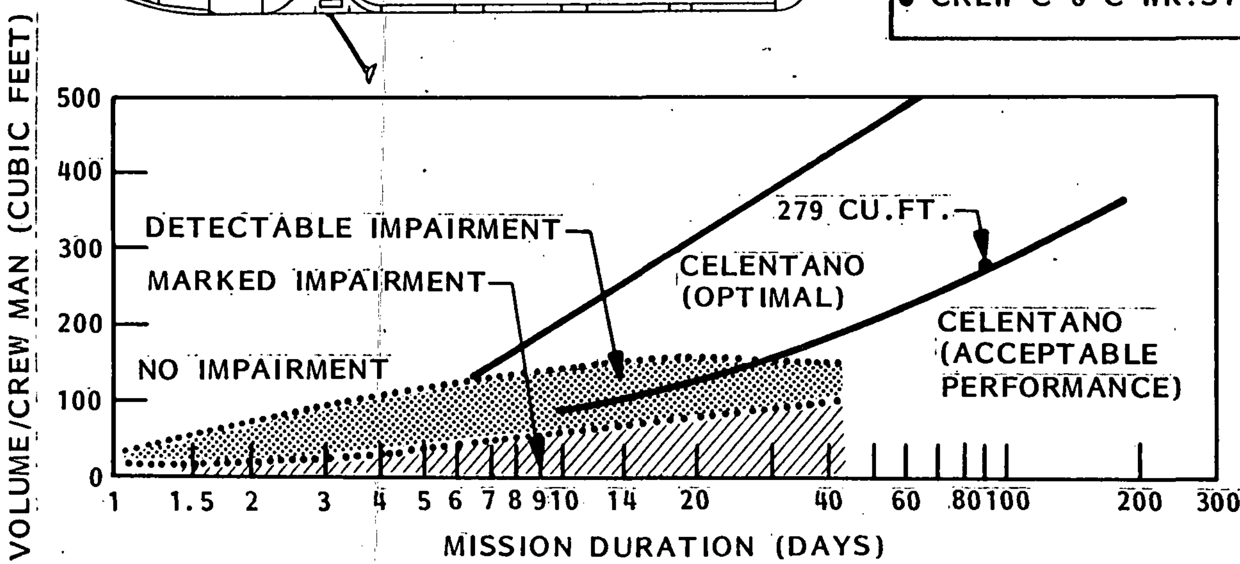
CU. FT. VOL. AVAILABLE

LIVING MODULE	CU.FT.
• SLEEP QUARTERS	104
• HYGIENE AREA*	340
• FOOD*	340
• TUNNEL	255

△ INTERCONNECT TUNNEL
□ DOCKING MODULE - A/L

C & C CENTER	CU.FT.
• REC/EXERCISE AREA	510
• HEALTH CARE/CONFER AREA	340
• CREW C & C WK.STA.AREA*	2570
TOTAL	4459





* EQUIPMENT VOL. SUBTRACTED (2030 CU. FT.) FROM OPEN VOL. (4459 CU. FT.)

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CPM - CONCEPT A

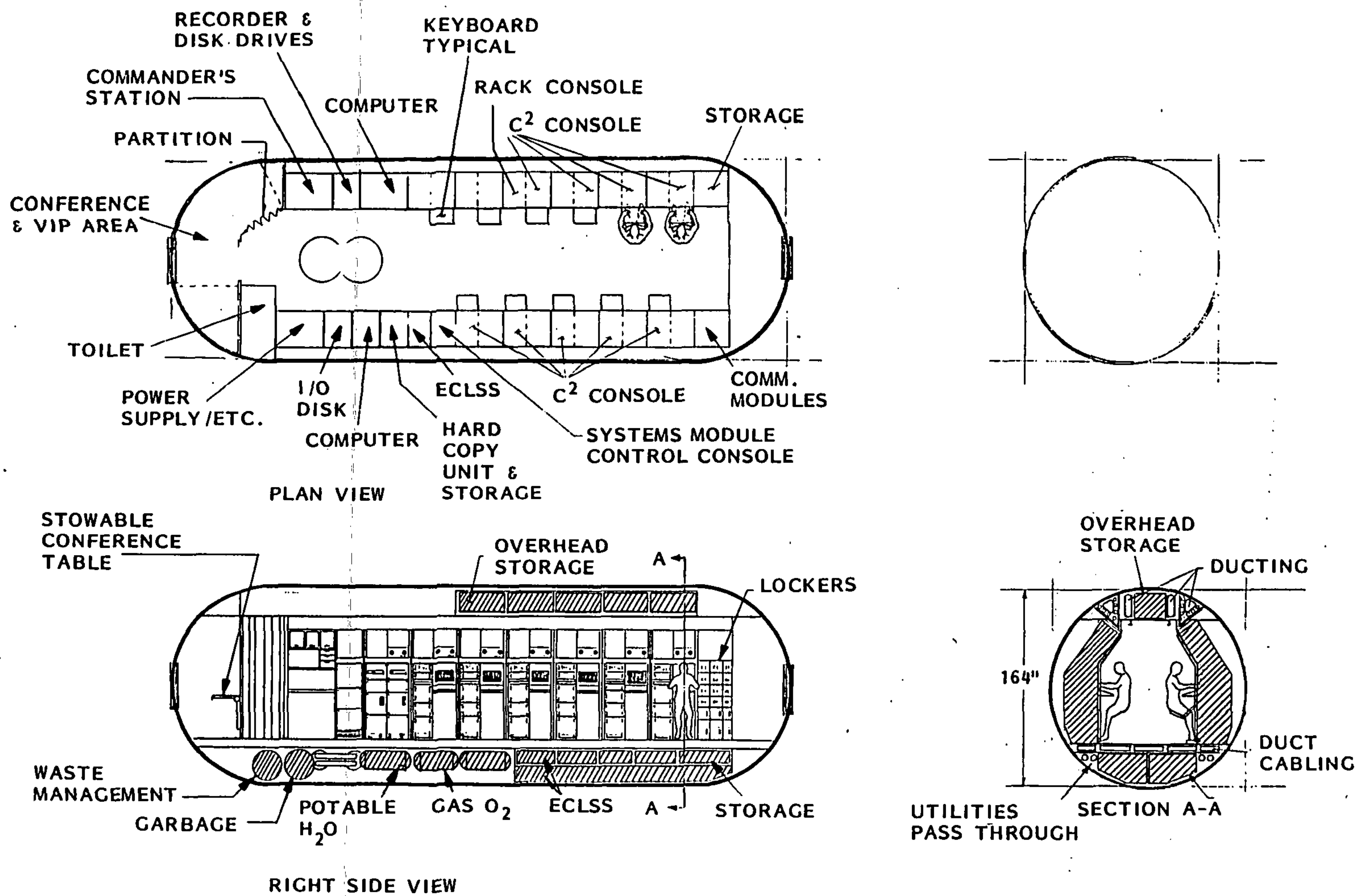
A number of concept layouts of a crew inhabited pressure vessel used for CPM command and control operations were developed. Each portray a different layout relative to internal arrangement of the basic C^2 requirements. Major features included in each are as follows:

- Hatches - I/F to tunnels and/or airlocks
- Below deck utility runs and ECLSS installation
- Overhead stowage & utility stowage
- Commanders sub-station
- Conference area with partition/curtain
- Security features/provisions/equipment
- Toilet/wash basin
- Consoles - vertical and/or see-over
- Equipment racks (front and/or rear access)
- Auxiliary equipment (rcdrs, drives, comptrs., pwr., converters, hard copy, etc.)
- Group display & projectors
- Other needs to support the living habitat

The facing page layout (Concept A) illustrates an arrangement wherein the basic operating console positions were mounted facing the inner cabin wall. Additionally, all equipment racks and associated communications and security hardware was also mounted against the internal bulkhead cabin wall. This arrangement provides a maximum internal open (free) volumetric approach; however, a major constraint is blatently obvious - maintenance/servicing. All consoles and racks/equipment would have to be front accessed for maintenance which would impact continuity of nominal and emergency operations. It would be feasible to pursue the Spacelab rack technology for this approach which offers, therefore, a counter advantage.

SPACE STATION PROGRAMS

CPM — CONCEPT A

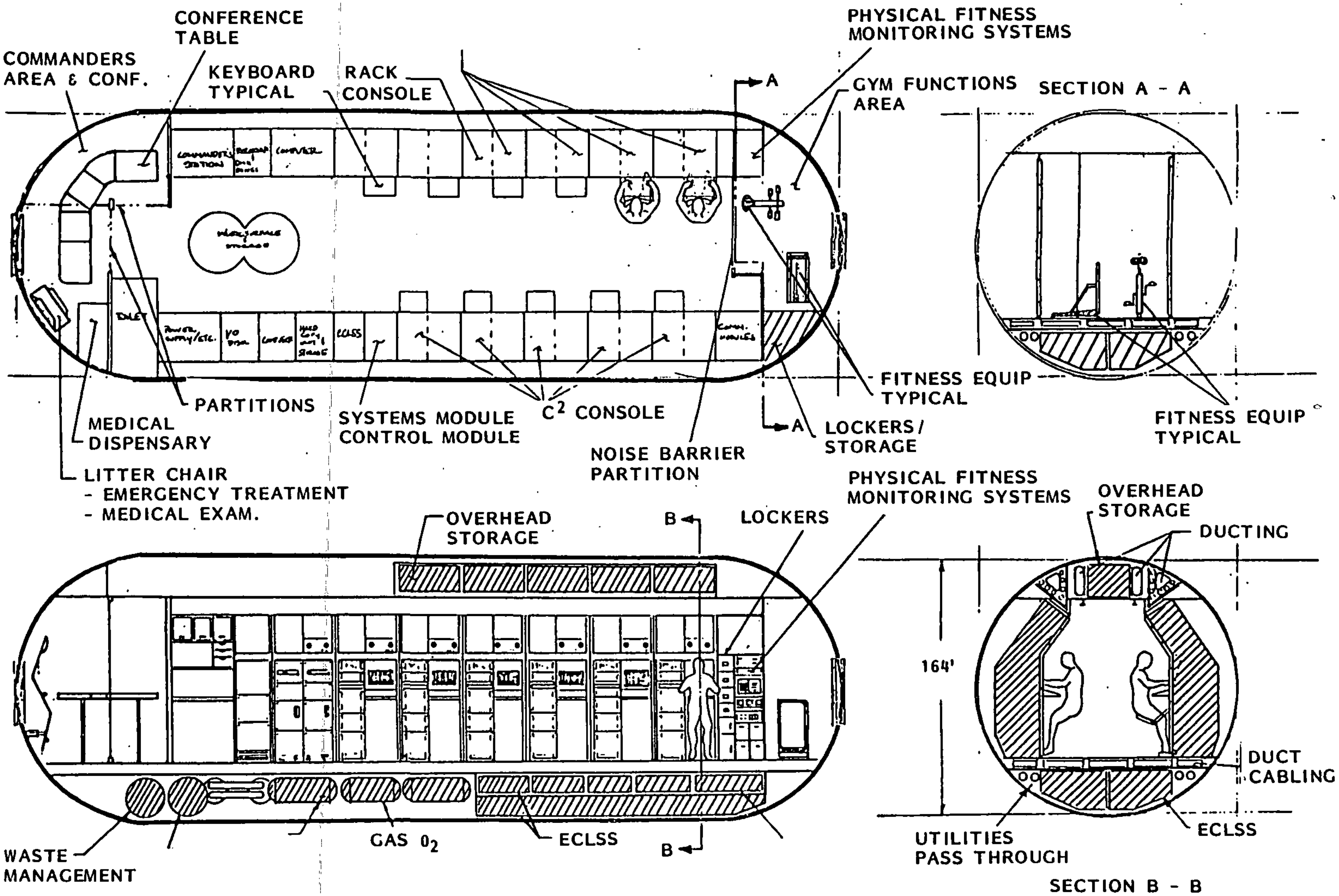


CPM - CONCEPT A - 1

This configuration is identical in basic arrangement to Concept A although several changes are to be noted as illustrated on the facing page. The living module has been designed to accommodate up to 16 crew persons, and its length was limited since both the living sub-module and C^2 sub-module are planned for installation within the external tank; therefore, certain functions had to be transferred into the C^2 sub-module. Specifically, exercise/physical fitness and associated stowage lockers were positioned in the aft dome end of the sub-module. Also located in this area is a 'bio-medical' panel which can be used in conjunction with the exercise regimes.

At the opposite end, a mini-health care/maintenance sub-compartment has been located. This area serves a dual purpose through provision for a commanders conference area when the dispensary type functions are not being conducted. Since there will be limited EVA, no laboratory functions, and reduced typical external station missions (free flyers, tethered platforms, etc.) support, a mini-health care and dispensary capability was considered adequate. These capabilities (dispensary and exercise area) have also been incorporated in further concepts presented in this sequence (Concepts B through E).

CPM — CONCEPT A-1



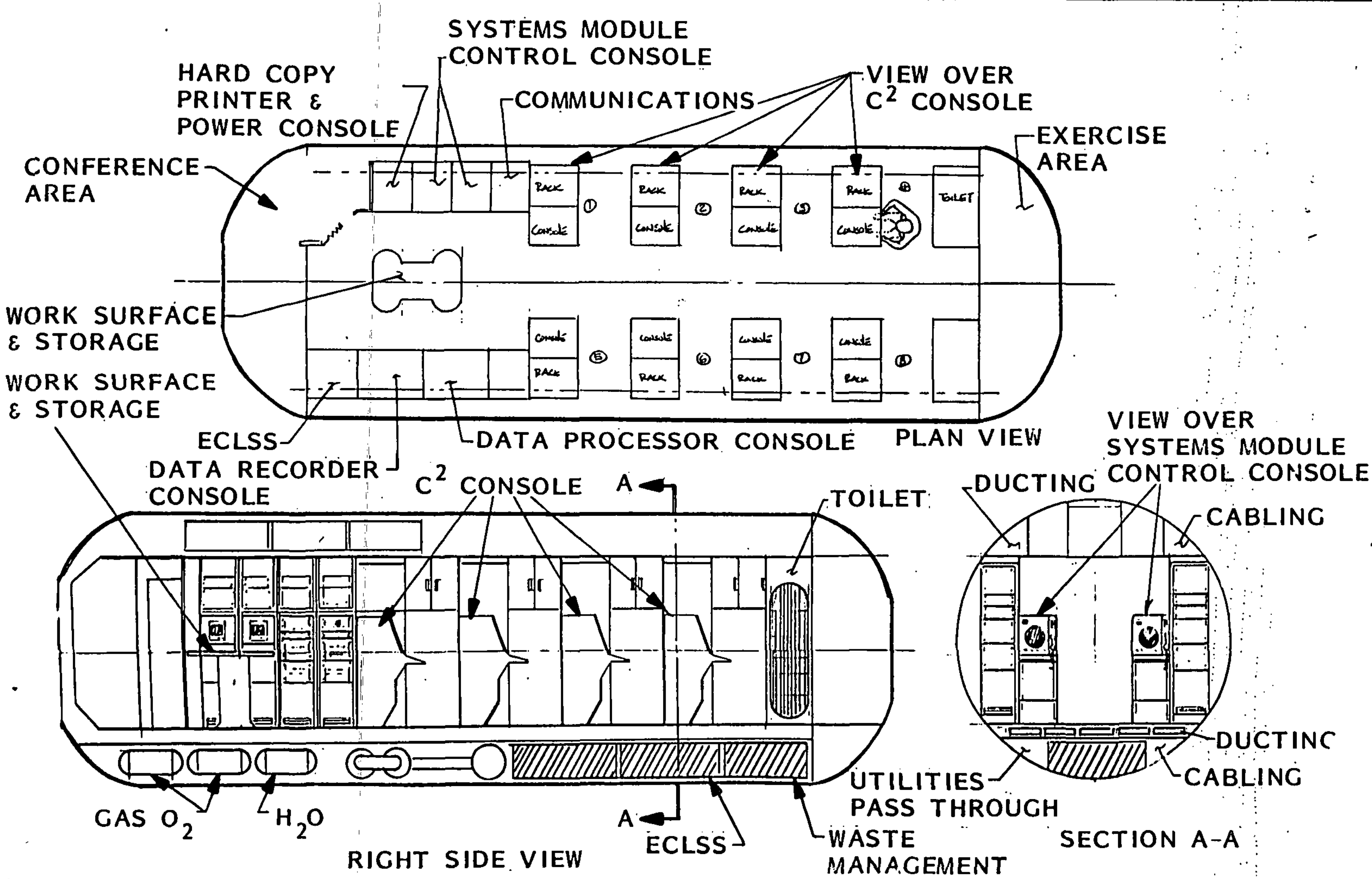
CPM - CONCEPT B

The CPM layout presented on the facing page differs in that the operator consoles are associated with an adjacent rack and, additionally, are see-over configurations. This concept permits the operational crew to view group displays and commander briefings/instructions. This layout provides for 8 personnel at the consoles with a systems console/commanders sub-station located in the forward area. A conference area is provided and a center located work surface and stowage unit is positioned in the commanders position. Other details are generally similar to the data presented for Concept A.

At present, this layout presents the reference configuration of the command and control sub-module of the overall CPM. In particular, the console see-over capability and the potential for both frontal and rear maintenance access make this an attractive design layout.

SPACE STATION PROGRAMS

CPM — CONCEPT B



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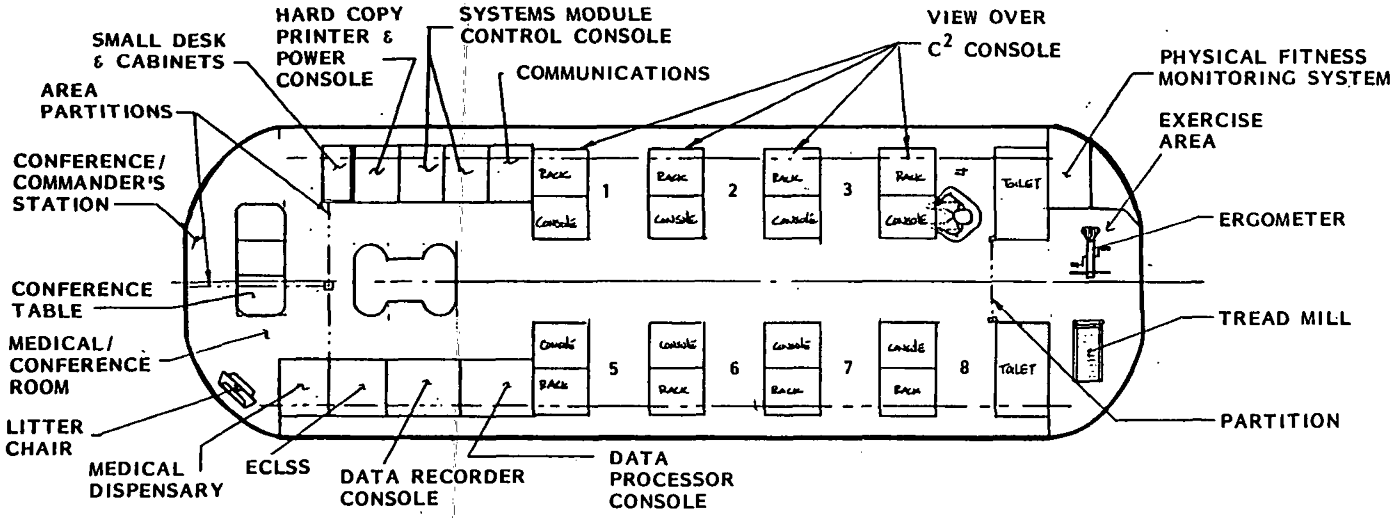
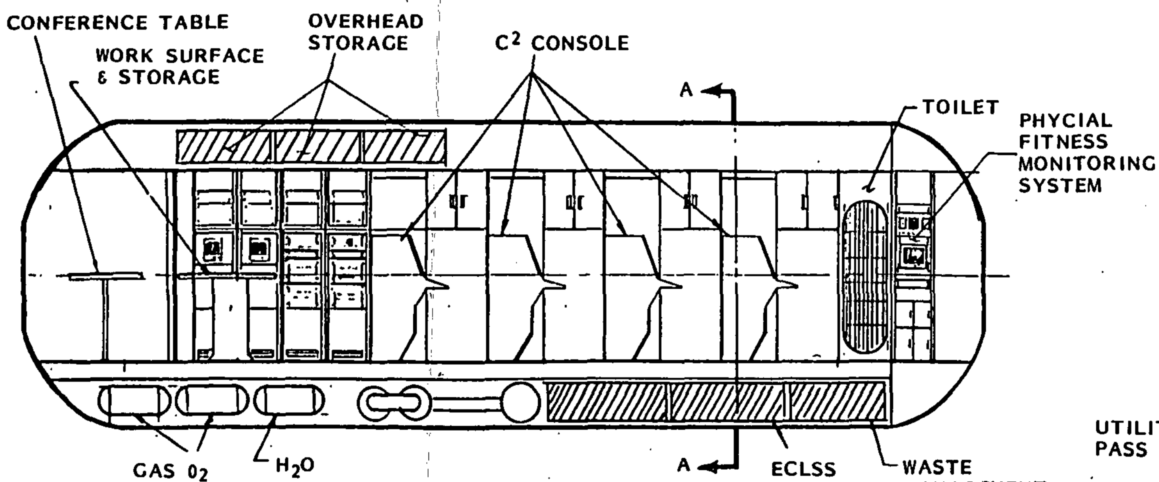
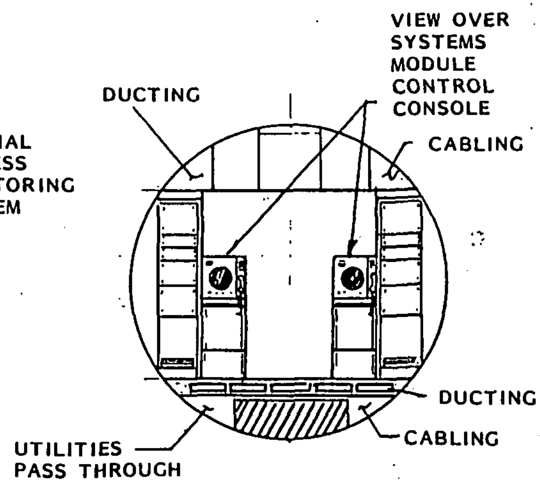
CPM - CONCEPT B - 1

The concept presented in the adjacent page is identical in basic layout to Concept B with the exception that the exercise/physical fitness, and mini-health/maintenance care areas have been added. Each of these aforementioned areas have been added to the forward and aft domes of the pressure vessel. All feature details presented for Concept B have direct application to this concept.

CPM — CONCEPT B-1







SECTION A - A

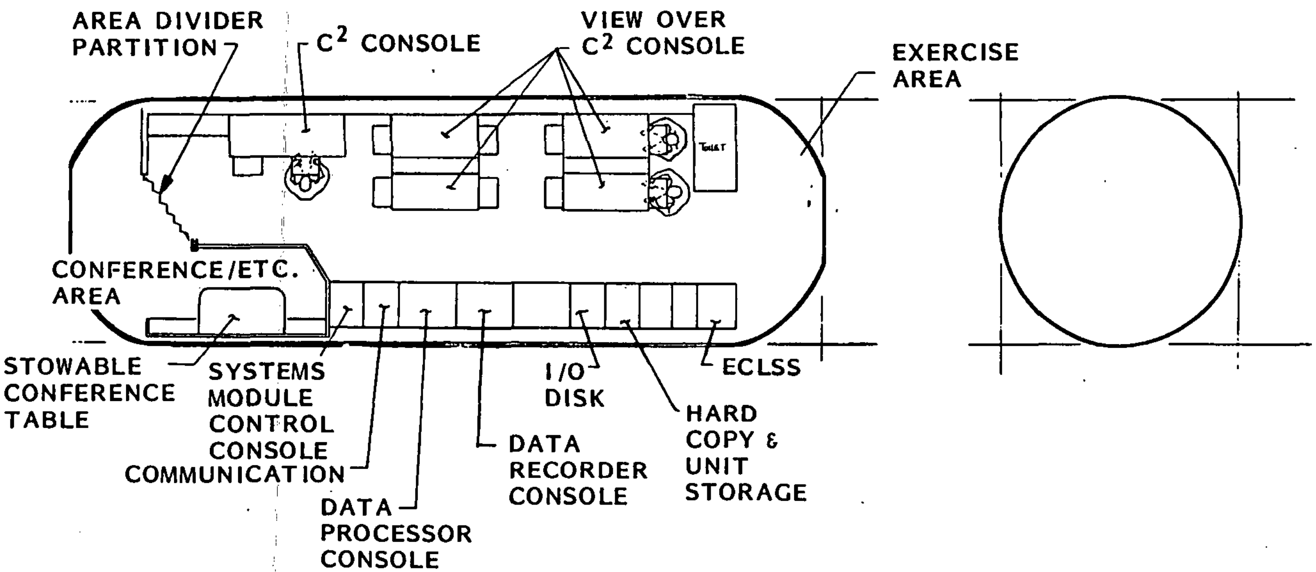
CPM - CONCEPT C

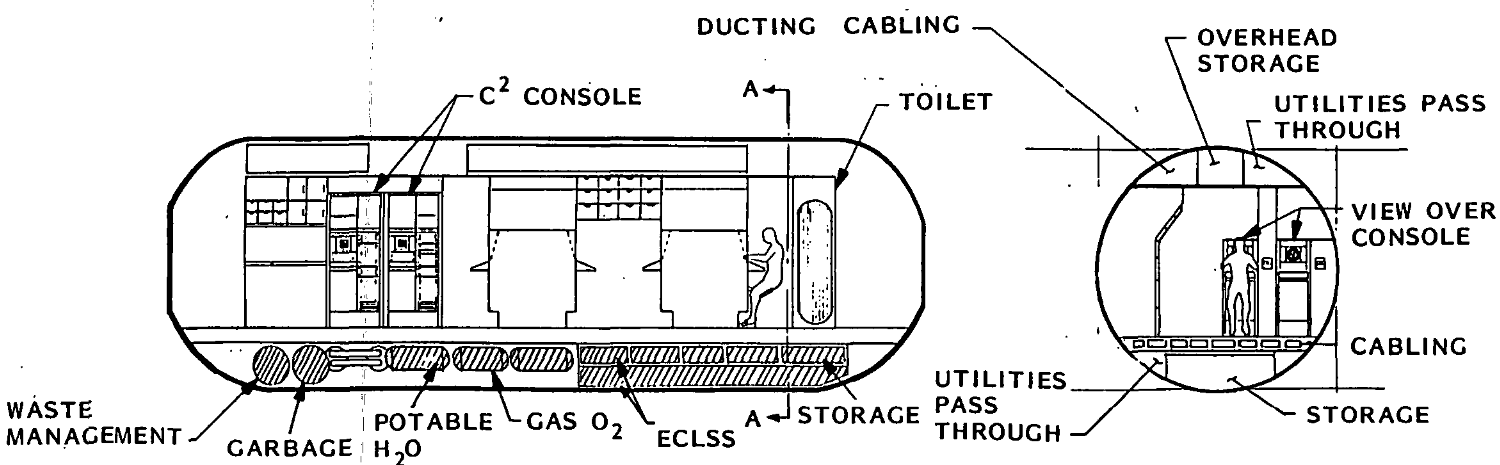
This configuration provides a cross between the previous two concepts (A&B). As shown in the opposite page, the consoles are arranged in a 'back-to-back' layout. The basic equipment support racks are positioned against the opposite interior cabin wall. Additionally, the conference area has been expanded along the longitudinal wall of the cabin. Considerable more volume exists on the forward end (dome area) of this sub-module than presented in the previous concept layouts.

The forward and aft end dome areas are provided with the mini-health care/maintenance, and exercise/physical fitness (respectively) as in the case of the previous concepts. Adequate volume exists in these two area for the aforementioned needs.

As in Concept A, maintenance of both the consoles and racks is relegated to front access only. Accordingly, maintenance during nominal and emergency operations would be disruptive to the operational routine. More that adequate translation area exists through the center of the sub-module for crew mobility and maintenance activities.

CPM — CONCEPT C





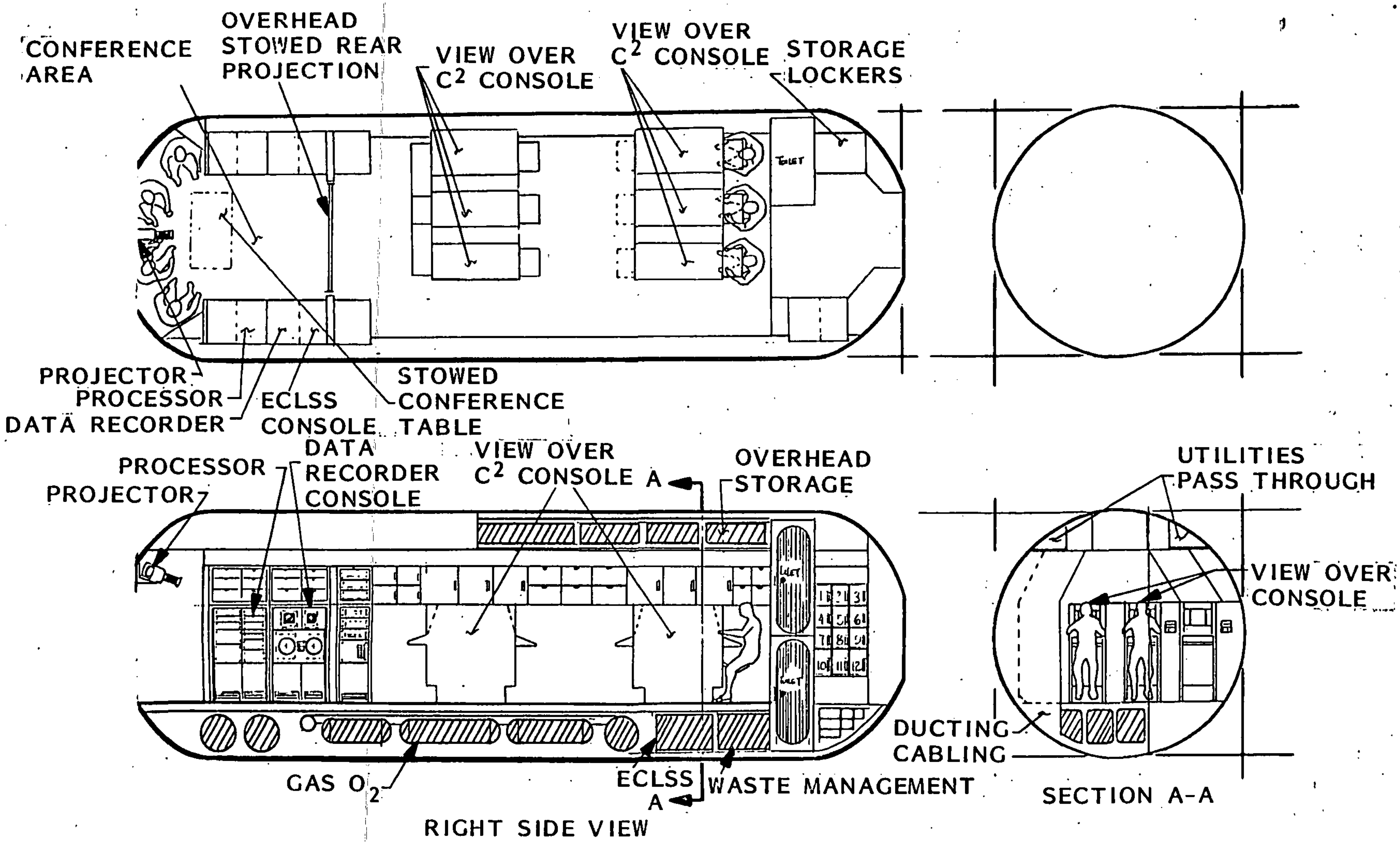
CPM - CONCEPT D

In the facing page layout, a significant departure from the previous concepts has been prepared. In this example, the back-to-back consoles are arranged on one side while the opposite side has been relegated to minimum depth stowage. The supporting equipment racks, and associated hardware are positioned toward the forward end of the compartment. A pull screen has been provided on the forward end to be used as a group display for forward facing personnel.

Lesser volume exists on the forward end dome for standard medical/health maintenance activities as compared with Concepts A through C. As in the previous layouts both of the medical/health maintenance, and exercise/physical fitness areas are arranged in the forward and aft dome areas, repectively. More than adequate volume exists in this concept for crew translation and rack (front access) maintenance. As can be readily determined, access from the rear for both the consoles and racks is very limited or non-existent. Layout details are as identified in Concept A and B.

SPACE STATION PROGRAMS

CPM — CONCEPT D



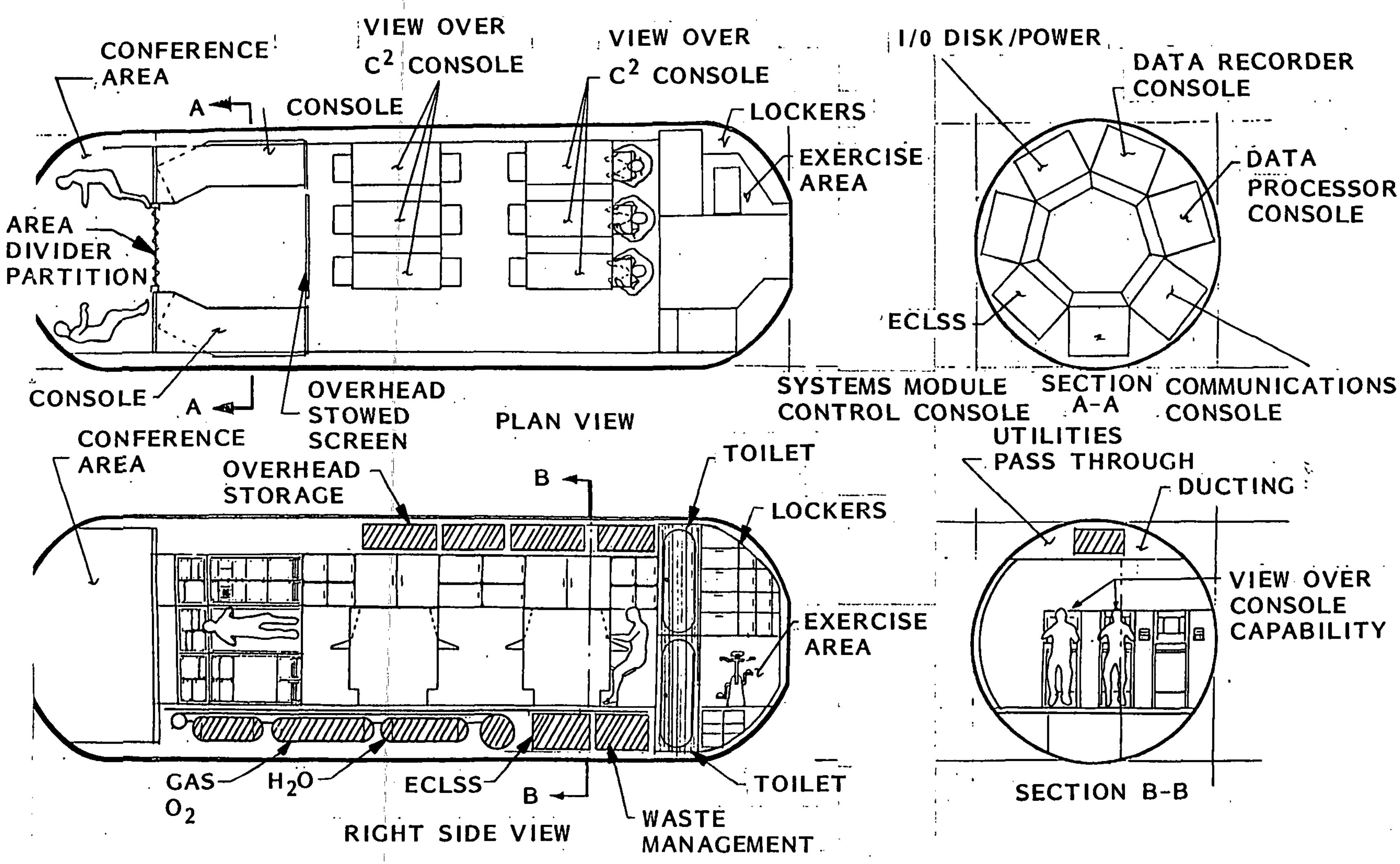
CPM - CONCEPT E

In the configuration shown in the opposite page, console arrangement is as per Concept D - a back to back console integration. However, in this layout, the equipment racks are arranged circumferentially about the internal radius of the pressure vessel interior at the forward end. In this case, maintenance is accomplished from the front, top, and/or 'bottom'. Both the forward and aft dome ends are left open to accommodate the medical/health maintenance, and exercise/physical fitness areas. Internal translation volume through the sub-module is adequate as is the volume for maintenance. However, rear access to both the racks and consoles is not provided in this arrangement.

Other aspects and details are as presented for Concepts A and B. This arrangement also includes crew interaction in two different axis; the 'standard' vertical to the long X axis and parallel to the same axis. Thus, a differing spatial relationship and visually perceived reference is portrayed. Nonetheless, alternative layouts such as this should continue to be examined to determine potentially advantageous arrangements which may benefit from the zero-g environment to the advantage of the configuration.

SPACE STATION PROGRAMS

CPM — CONCEPT E



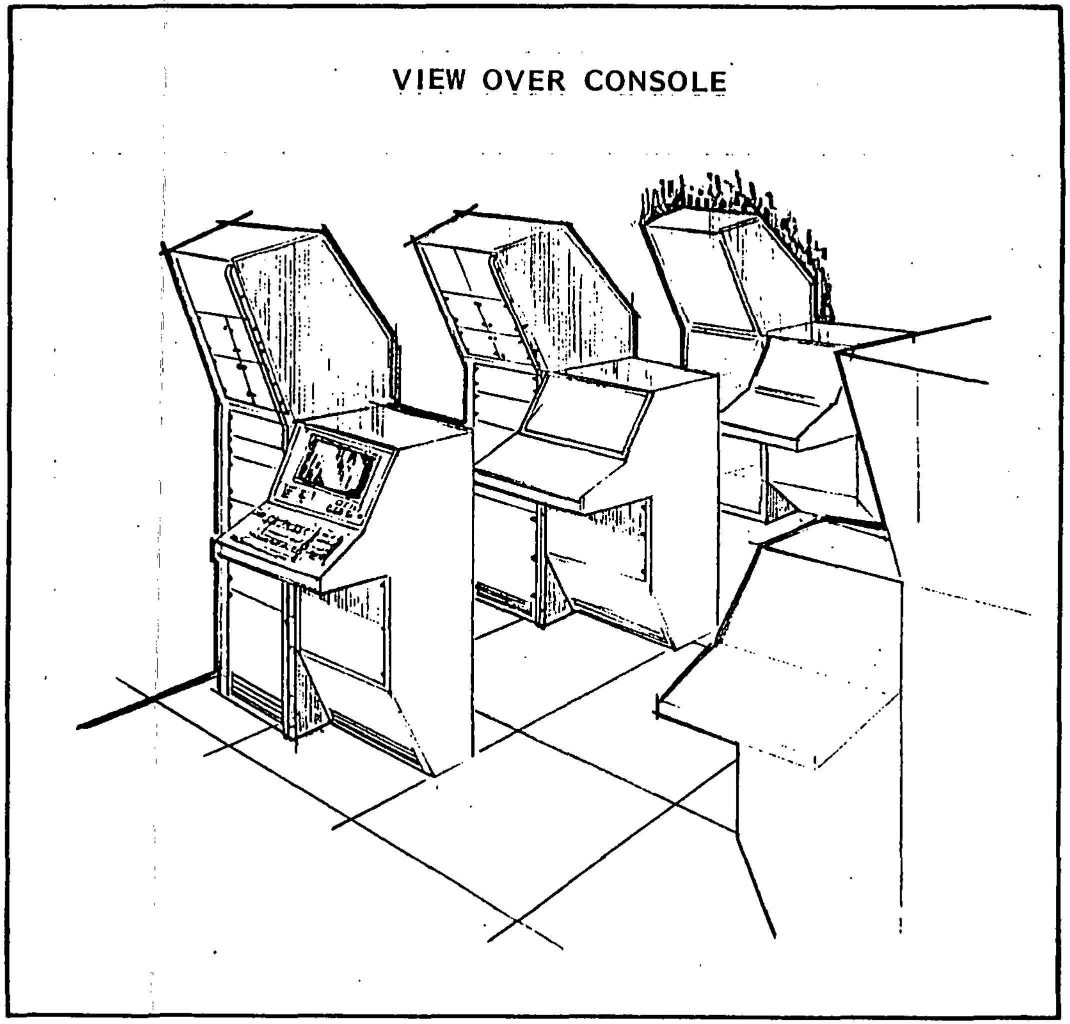
CPM C^2 CONSOLE CONCEPT

As part of the CPM, data management, communications, instrumentation, and special equipment sub-systems are arranged within the interior, and several console concepts were then defined for potential application. Console work stations which are back-to-back, facing the outer bulkhead interior wall, or are floor to ceiling, all exhibit an isolation from the overall group display and commander communication interface. Thus, a 'see-over' console and adjacent floor to ceiling rack was conceived to facilitate 'forward' facing operators which can, as required, divide attention between console operations and group display/commander information. On-board maintenance can be readily accomplished with this approach, and both front and rear access is practical.

Consoles will be designed for 0-g operations and crew anthropometric interface. The console will be located in a typical C^2 mission center environment keyed to military type command hierarchy. Several consoles will be provided with 'overlap' functional capability in the event of equipment failure and/or partial malfunction. The number of consoles will be dictated by mission support needs; present evaluation indicates approximately 6 to 8 basic positions manned 24 hours a day. Thus, checkout and maintenance access including spares and replacement scenarios is of concern in the internal architectural layout.

SPACE STATION PROGRAMS

CPM C^2 CONSOLE CONCEPT



ALTERNATE SERVICING/STAGE ASSEMBLY FACILITY CONCEPTS

The facing and following page present a series of 12 alternative layouts for a combined servicing and stage assembly facility concept. Each concept (identified by title) was based on operational/functional needs established early in the Task 2 effort. Each of these concept sketch layouts was prepared to meet these functional needs in various ways. Principal consideration was given to fullfilling needs with lesser attention to architectural and structural detail.

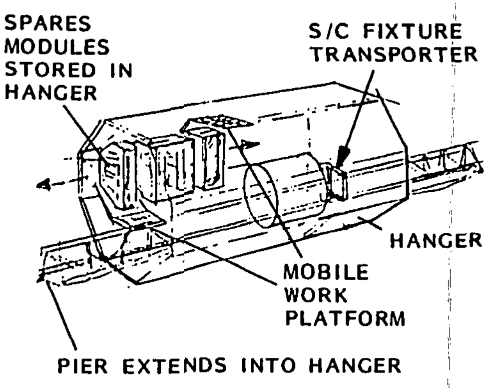
The 12 layouts were then subjected to a criteria evaluation assessment exercise and subsequently to a KTA type of rating analysis. The concepts were then rank ordered (best to least acceptable) and the top rated concepts further examined relative to station operations and mission support suitability.

From this effort emerged the desire to further explore the octagon tube concept and incorporate several features of the spares mounted concept within the overall layout. This concept was then prepared in more detail and provided in a subsequent chart herein.

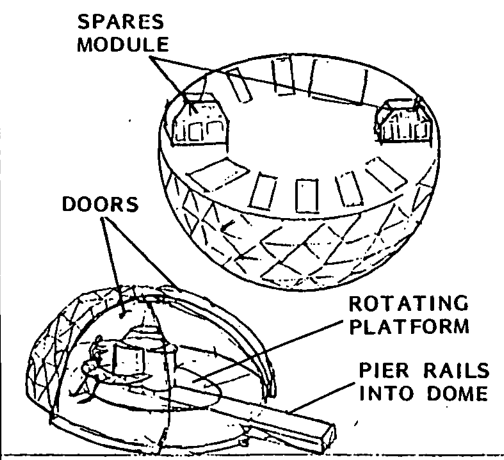
SPACE STATION PROGRAMS

ALTERNATE SERVICING/STAGE ASSEMBLY FACILITY CONCEPTS

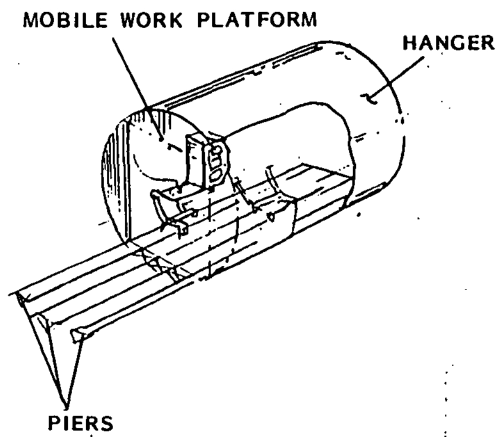
OCTAGON TUBE CONCEPT



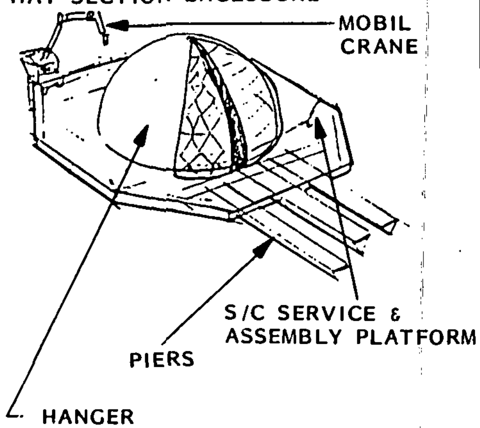
DOME ENCLOSURE CONCEPT



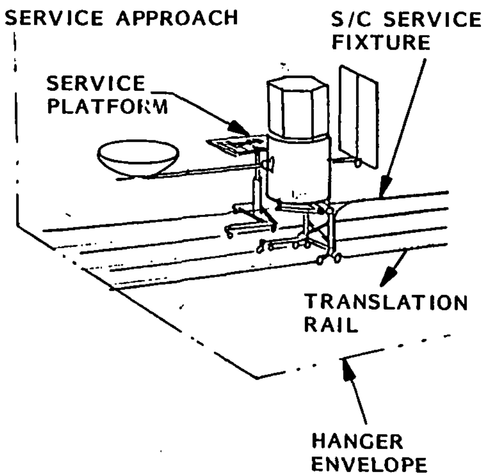
TUBE ENCLOSURE



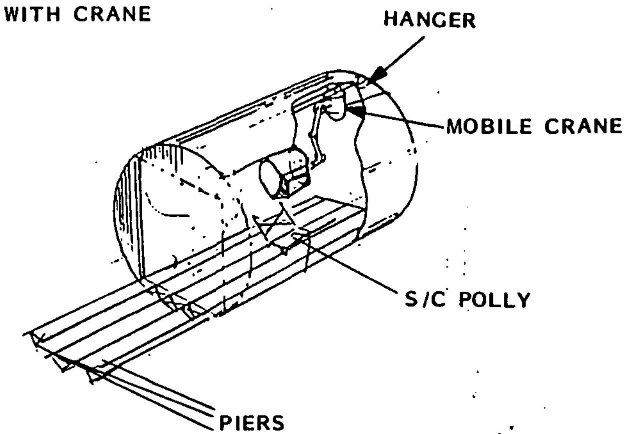
HAT SECTION ENCLOSURE



SERVICE APPROACH



TUBE ENCLOSURE WITH CRANE



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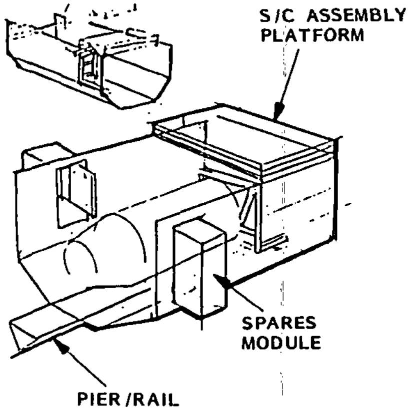
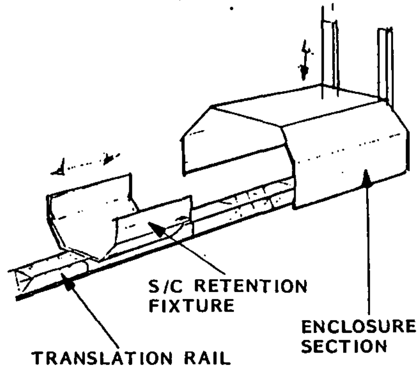
ALTERNATE SERVICING/STAGE ASSEMBLY FACILITY CONCEPTS (Continued)

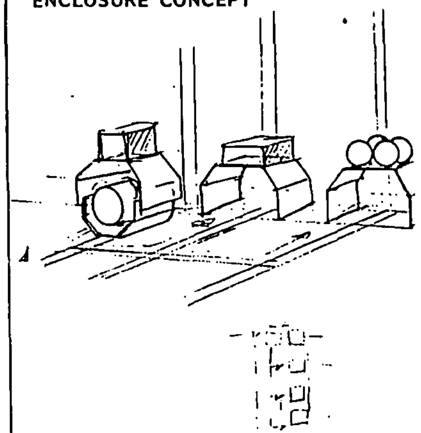
PALLET ENCLOSURE CONCEPT



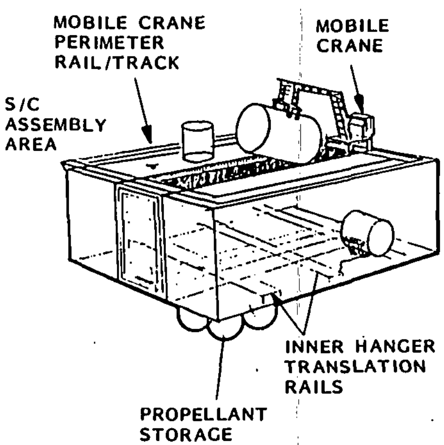
SPLIT ENCLOSURE CONCEPT



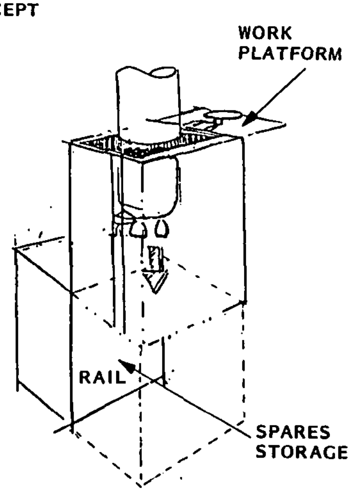
DEDICATED SPLIT ENCLOSURE CONCEPT



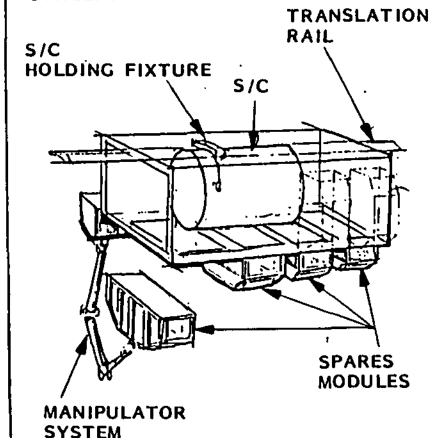
DUAL ENCLOSURE CONCEPT



RIGHT ANGLE ACCESS ENCLOSURE CONCEPT



SPARES MOUNTED CONCEPT



SERVICING/STAGE ASSEMBLY FACILITY

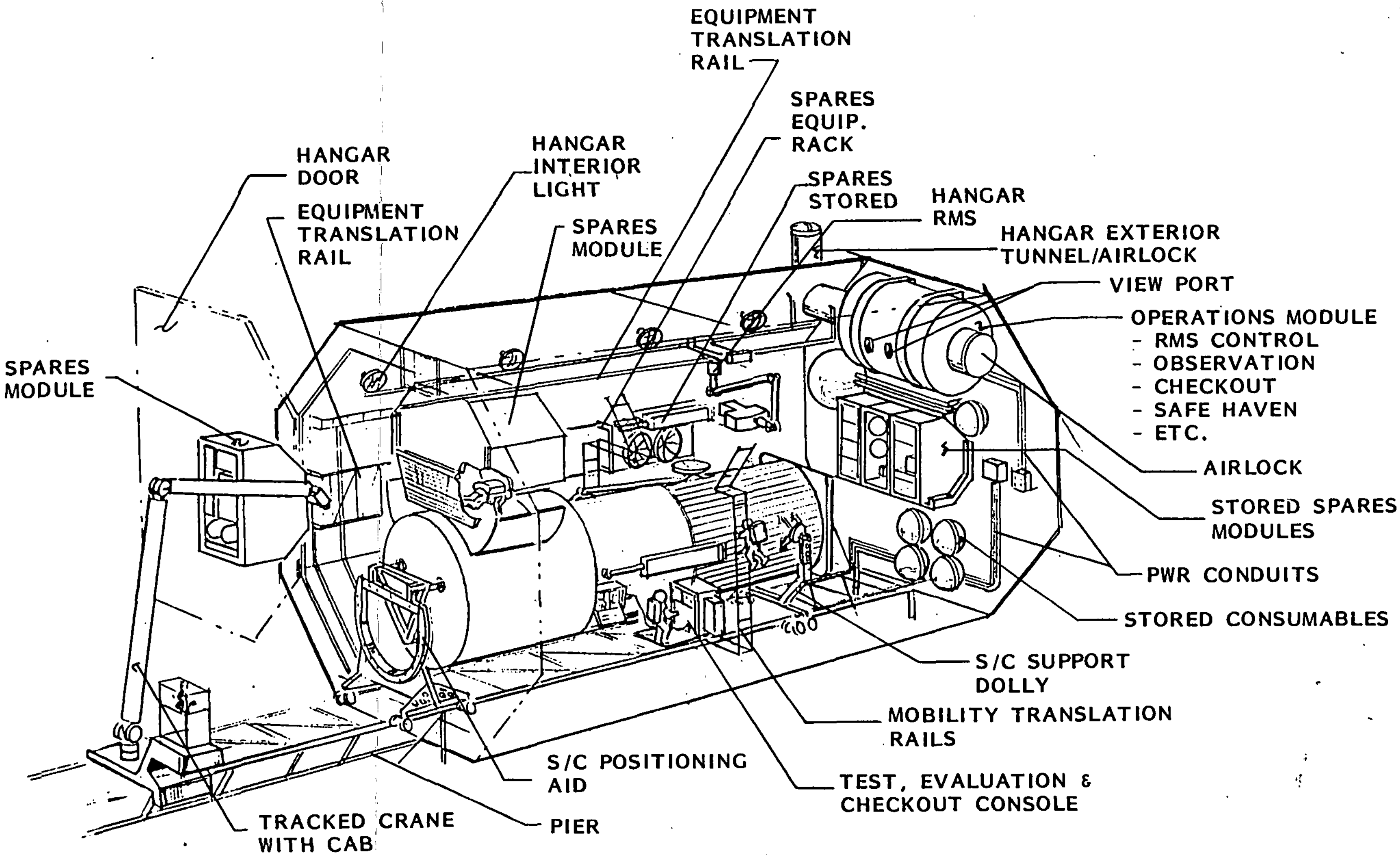
Twelve alternative servicing and stage assembly facility concept layouts have been prepared. Each concept incorporated a multi-functional capability to facilitate a variety of functional needs previously established in the operations/functions analysis section of Task 2 of this report. Basic functional capabilities include:

- Logistics resupply receiving
- Logistics fluids/pressurant receiving
- Operations module
- Spacecraft/stage handling equipment
- Transport & positioning rails
- Fixed & tracked RMS/Crane
- Spares (ORU's) handling aids
- Crew translation aids/restraints
- Illumination & CCTV aids
- Utilities services
- Checkout consoles (EV used)
- Rotation/tilt fixture

The facility shown opposite is a basic frame structure with the option of providing a 'screen-like' material around the entire assembly to assist in 0-g 'containment' operations. An option would be to additionally cover the structure with multi-layer insulation (MLI) to control both thermal and illumination environments. A hangar 'door' might also be provided to facilitate 'enclosure' of basic internal conducted functions. The facility would be attached to the main station via a 'pier' structural interface which also doubles as a track mounting platform for a mobil RMS and/or Crane used for spacecraft capture.

This concept can be added to or simplified as functional station needs are more firmly defined particularly with respect to amalgamation of functions (e.g., servicing and stage assembly) vs independent allocation of functions and associated support facilities. Considerable more effort must be allocated to this area of architectural definition and layout prior to fully understanding the station impact (architectural) involved in the incorporation of this station sub-element.

CONCEPT FOR A SERVICING/STAGE ASSY FACILITY



STRAWMAN NONHUMAN RESEARCH FACILITY

Various requirements data (Task 1) provided the basis for the general arrangement of the Strawman Nonhuman Research Facility. This example assumes that the carrier tradeoff indicated use of a Spacelab long module and that maximum use of existing hardware is optimum. A flight system/mission assumption is made in favor of an early manned space station where the onboard crew is involved in the Life Sciences activity only in the event of an equipment malfunction.

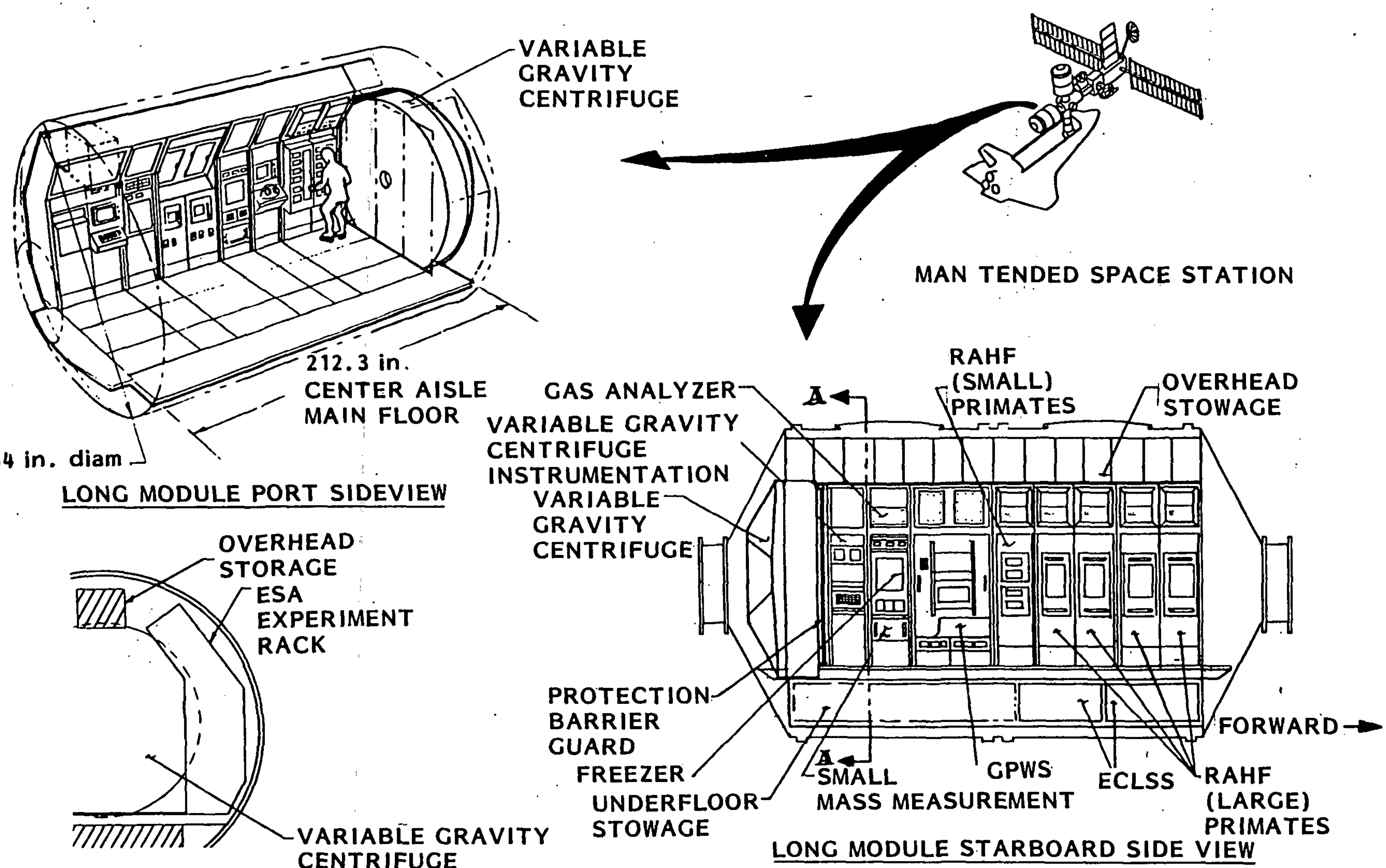
Based on the previous data on 90-day vivarium capacities, two rodent, one small primate, and four large-primate single-rack holding facilities would be required in the vivarium portion of the research facility. The centrifuge and the two plant holding facilities also would be located in the vivarium area.

The general arrangement is responsive to the experiment requirements and allows a smooth workflow with adequate accessibility.

For the purpose of illustration, a strawman research facility has been developed for a mission where a life sciences research facility is attached permanently to the space station. At intervals of 90 days, life scientists visit the station and conduct required research for periods up to 10 days. The visiting experimenters bring new plants and animals as required and carry back specimens for postflight analysis.

SPACE STATION PROGRAMS

STRAWMAN NONHUMAN RESEARCH FACILITY



Lockheed

HUMAN RESEARCH AND HEALTH MAINTENANCE FACILITY

The Human Research and Health Maintenance Facility has been laid out in the equivalent of a three-segment-long Spacelab module with an internal pressurized volume of approximately 4,000 ft. Both manned research and health care are combined within the laboratory which includes the following basic functional areas:

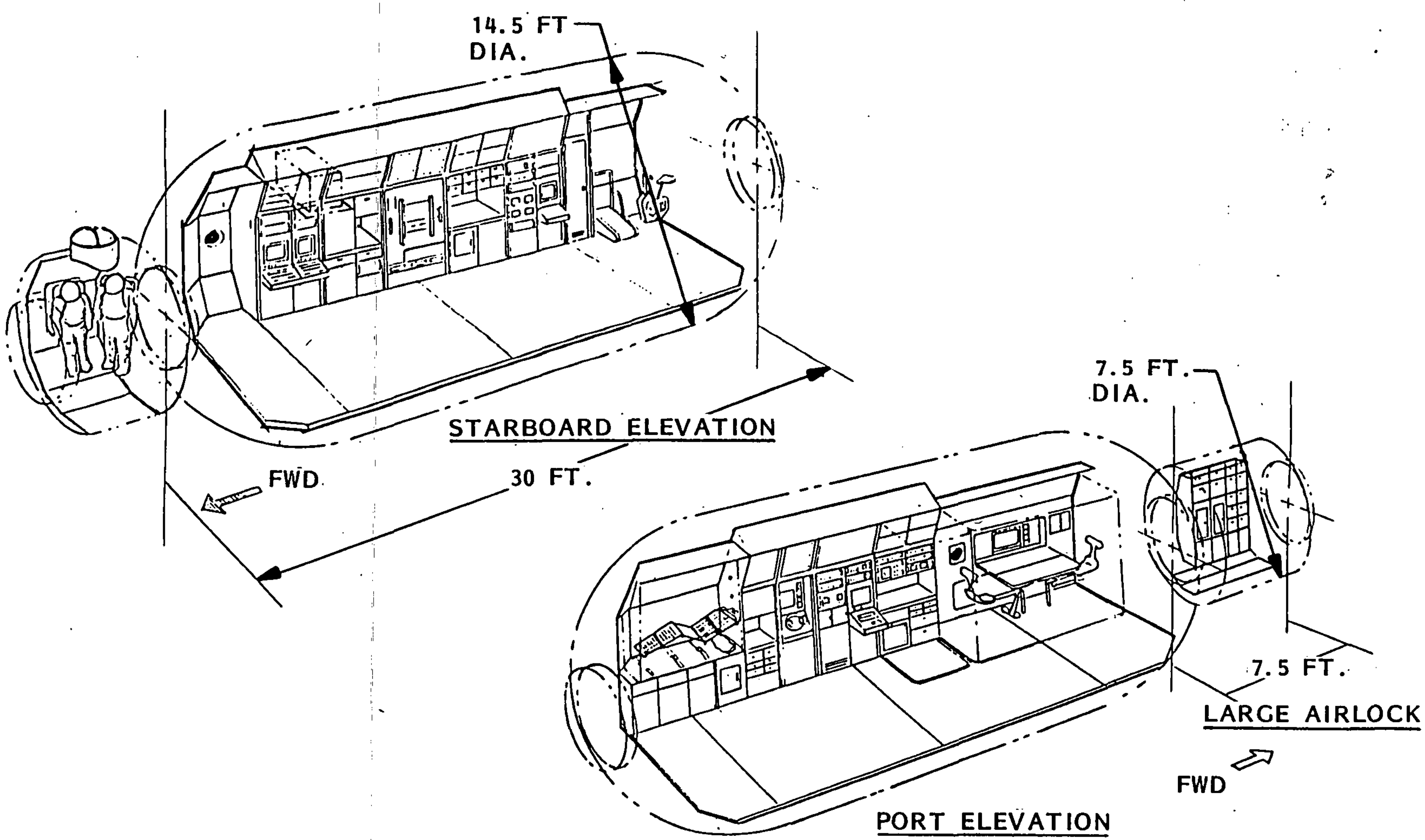
- Basic Health Maintenance
  - Medical/Surgical
  - Dispensary
  - Dental
  - Isolation & Beds
- Human Research
  - Experiment Unique Hardware
  - Common Support Hardware
- Large Airlock
  - EVA Familiarization & Training
  - Suit/PLSS Experiments/Research
  - EVA Tools/Aids Evaluations
- Exercise Area
  - Medical Monitoring
  - Standard Physical Fitness
- Hyperbaric Chamber (within airlock)
- Data Handling/Processing Work Station
- Maintenance Demonstration Work Bench
  - Assessment/Evaluation & /Checkout
  - Techniques & Procedures Development
- Social-Behavioral Study Area (with privacy)
  - Equipment Arrangement & Layout
  - Tether & restraint
  - Mobility & Locomotion
  - Color/Sound/Texture Research

This facility provides an integral human health care and research program potential isolated from other functinal laboratories and/or habitats. Crew members can participate either on the basis of 'off-hours' volunteer duty and/or direct assignment. Initial capability will be planned for Health Maintenance (including Dispensary) with other capabilities to follow as a function of station needs and crew size, tied to an increasing experiment/research evolution.

This facility also could be considered for the solar flare radiation shelter, providing the thicker shield over this entire surface.

SPACE STATION PROGRAMS

HUMAN RESEARCH AND HEALTH CARE LABORATORY



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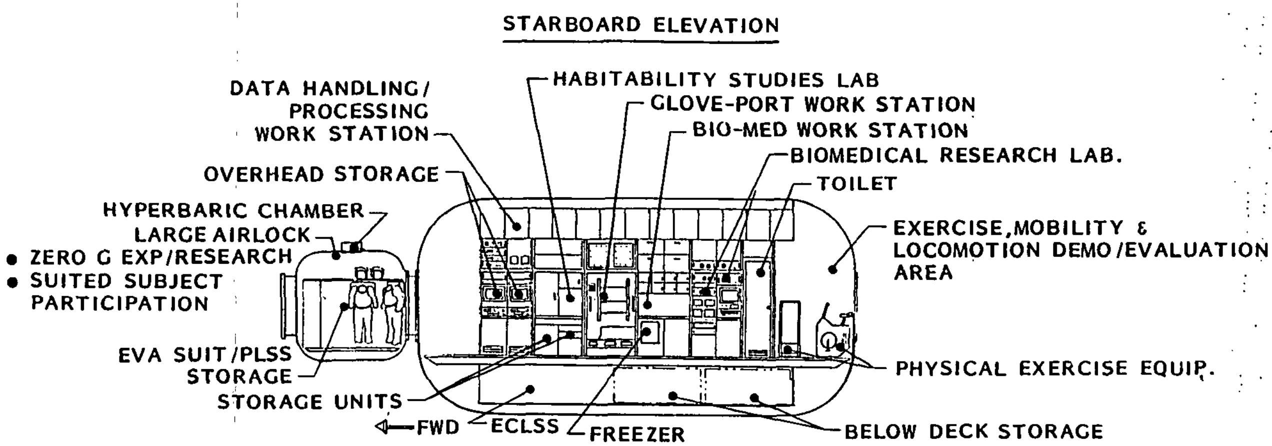
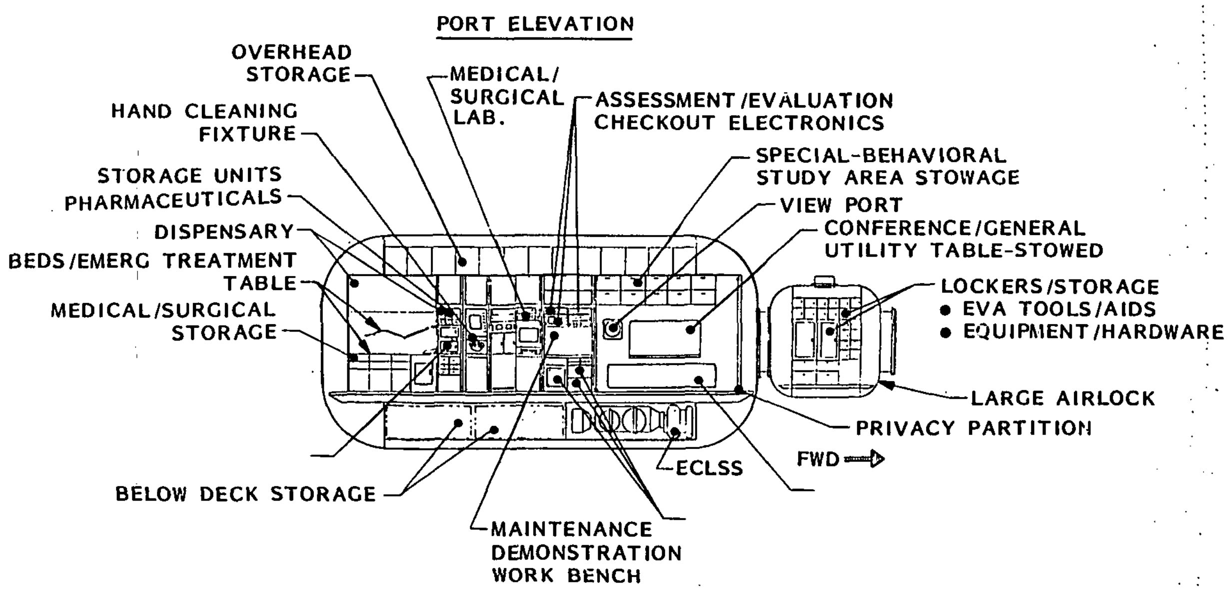
HUMAN RESEARCH AND HEALTH CARE LABORATORY (Continued)



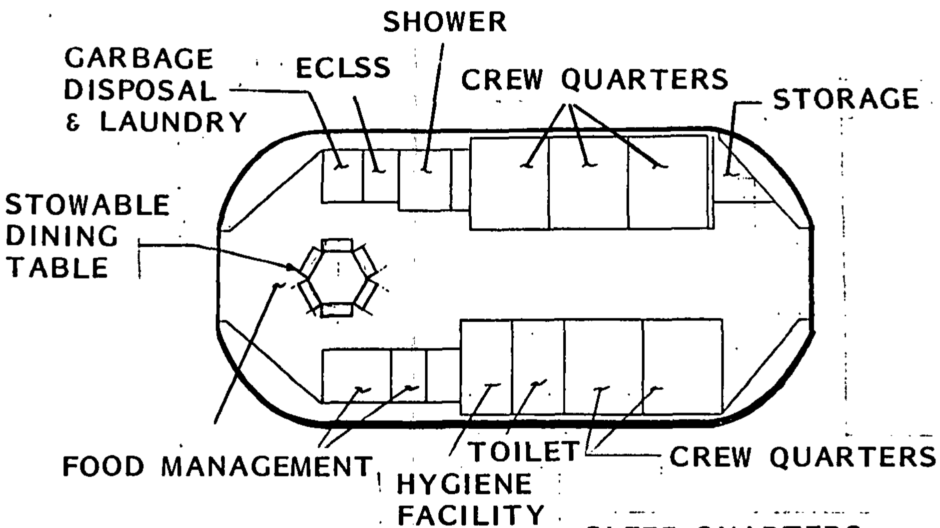


SLEEP QUARTERS CONCEPT A

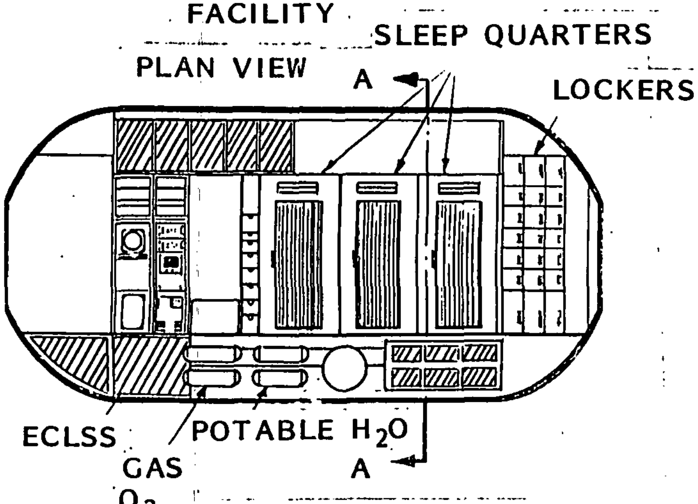
A variety of sleep quarters concepts have been developed over the years for a number of space applications including stations, lunar habitats, long duration planetary missions, and the current orbiter. Most present arrangements indicate that the sleep quarters are oriented in a vertical position with respect to the long axis of the habitat (although several past concepts for large stations or spherical pressure volumes have included a variety of arrangements). In the example on the facing page, a vertical sleep quarter/bunk arrangement has been provided. It should be noted that this vertical arrangement does not necessarily utilize the volume consumed in the most expeditious manner. The volume allocated for each sleep quarter bunk is approximately 103 cu. ft. and includes (in all probability) a 'sleep sack', personal item stowage, and other individual sub-compartment accouterments. Thus, based on this larger volume use vs the number of crew quarter/bunk allocations, a decision was made to explore alternative installation layouts; these are presented in the following pages.

SPACE STATION PROGRAMS

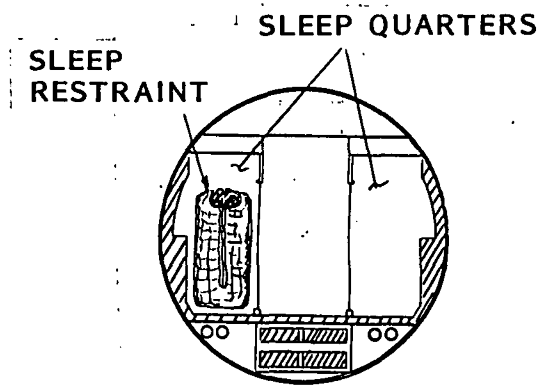
SLEEP QUARTERS CONCEPT A



PLAN VIEW



RIGHT SIDE VIEW



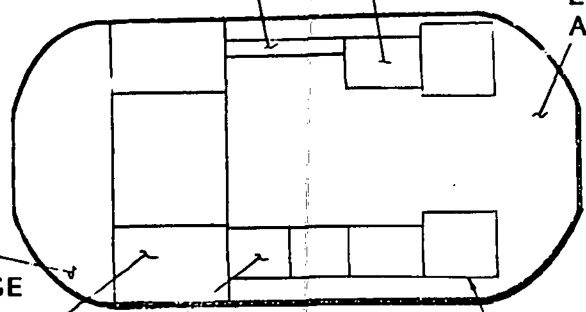
SECTION A - A

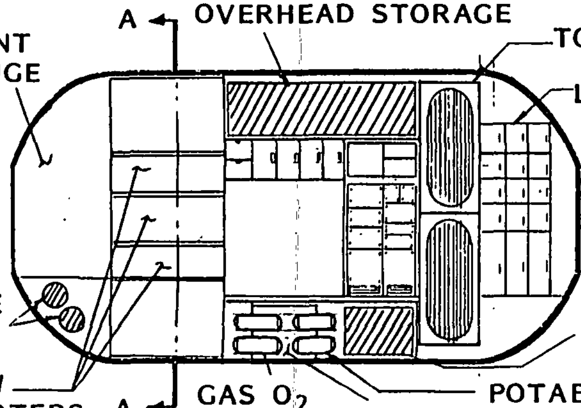
SLEEP QUARTERS CONCEPT B

This layout as presented on the facing page illustrates a single stack of crew sleep bunks. In this configuration some 7 to 8 personnel can beaccommodated. Galley, hygiene, exercise, and suit (EMU) stowage isaccommodated within this living habitability area. Toilets are perpendicular to the long axis of the habitat and the same plane as the Galley. The forward portion of the compartment (dome Volume) is allocated to stowage and a silent refuge area.

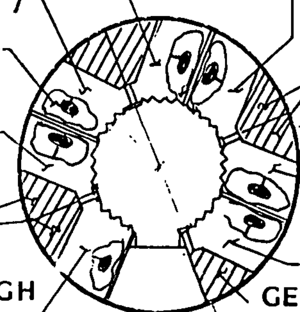
SPACE STATION PROGRAMS

SLEEP QUARTERS CONCEPT B





CIRCULAR SLEEP MODULE



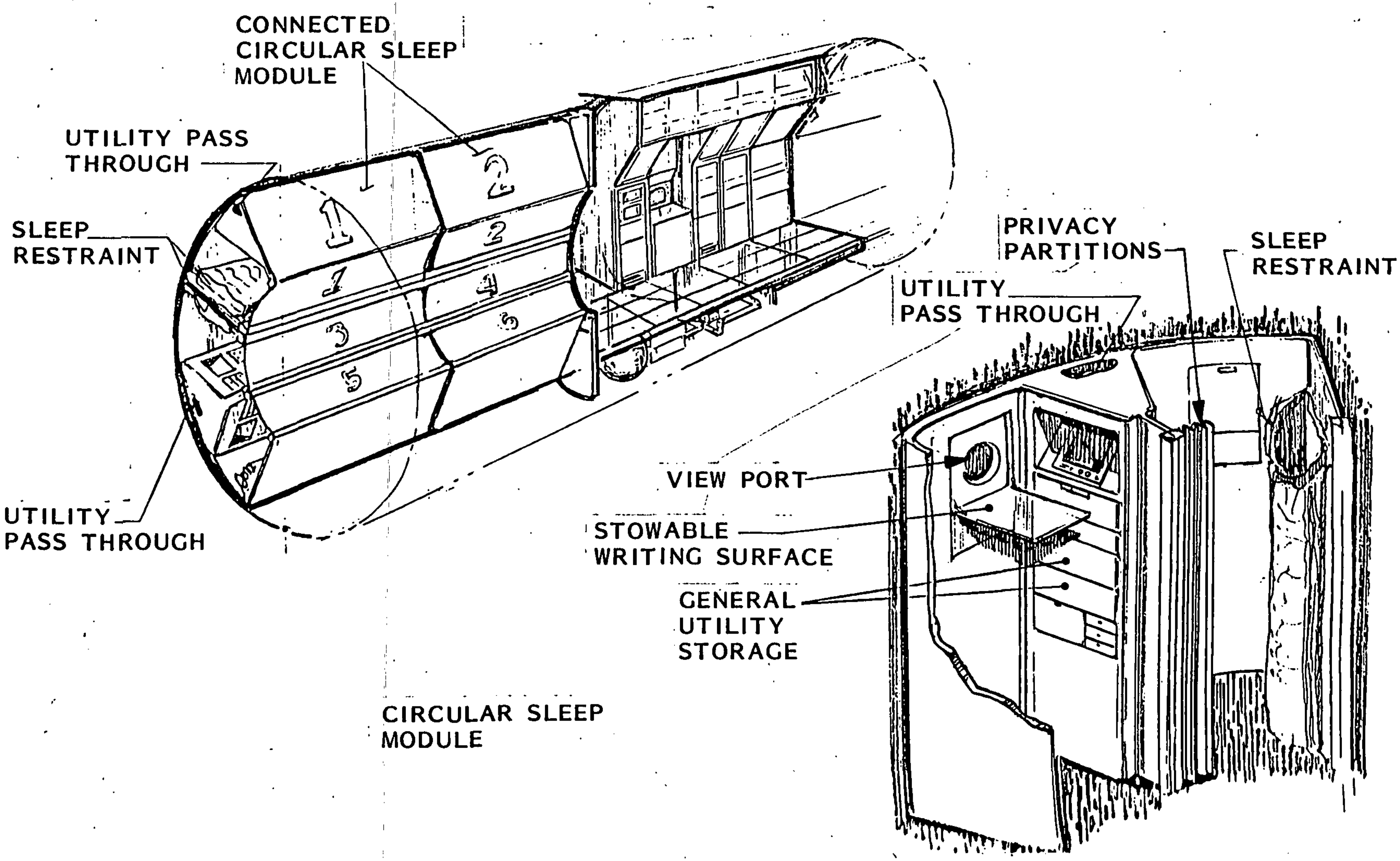
SLEEP QUARTERS CONCEPT

Maximum effective utilization of the cylindrical habitat volume has been an architectural design goal, particularly as increased numbers of crew will be housed aboard the station as it evolves. Thus, a relatively new arrangement concept has been developed and is illustrated on the opposite page. This concept, dubbed the 'turret approach', locates the sleep quarter bunks in a circumferential arrangement around the periphery of the interior diameter of the habitat. Thus, 7 or 8 bunks can be accomodated within a 14.0 ft. inner diameter in this turret-like layout. This configuration provides approximately 104 cu. ft. of volume. Previous NASA habitability requirements indicate a minimum of 63 cu. ft. for the sleep bunk, however, no information is provided for volume relative to associated space (cu. ft.) needed for stowage, comm, general utilities, writing surface, etc. Thus, it would be anticipated that the NASA allocated bunk volume (63 cu. ft.) would be increased appropriately for these added features.

As shown in the opposite page, two turret sets of 7 to 8 sub-compartments have been stacked end-to-end thereby providing the possibility of totally enclosed bunk areas for up to 14 to 16 personnel. Various of the features are presented in the figure for this circular sleep 'module' or sub-compartment. Access is gained to the bunk area via the 'always free' 60 in. pass through.

SPACE STATION PROGRAMS

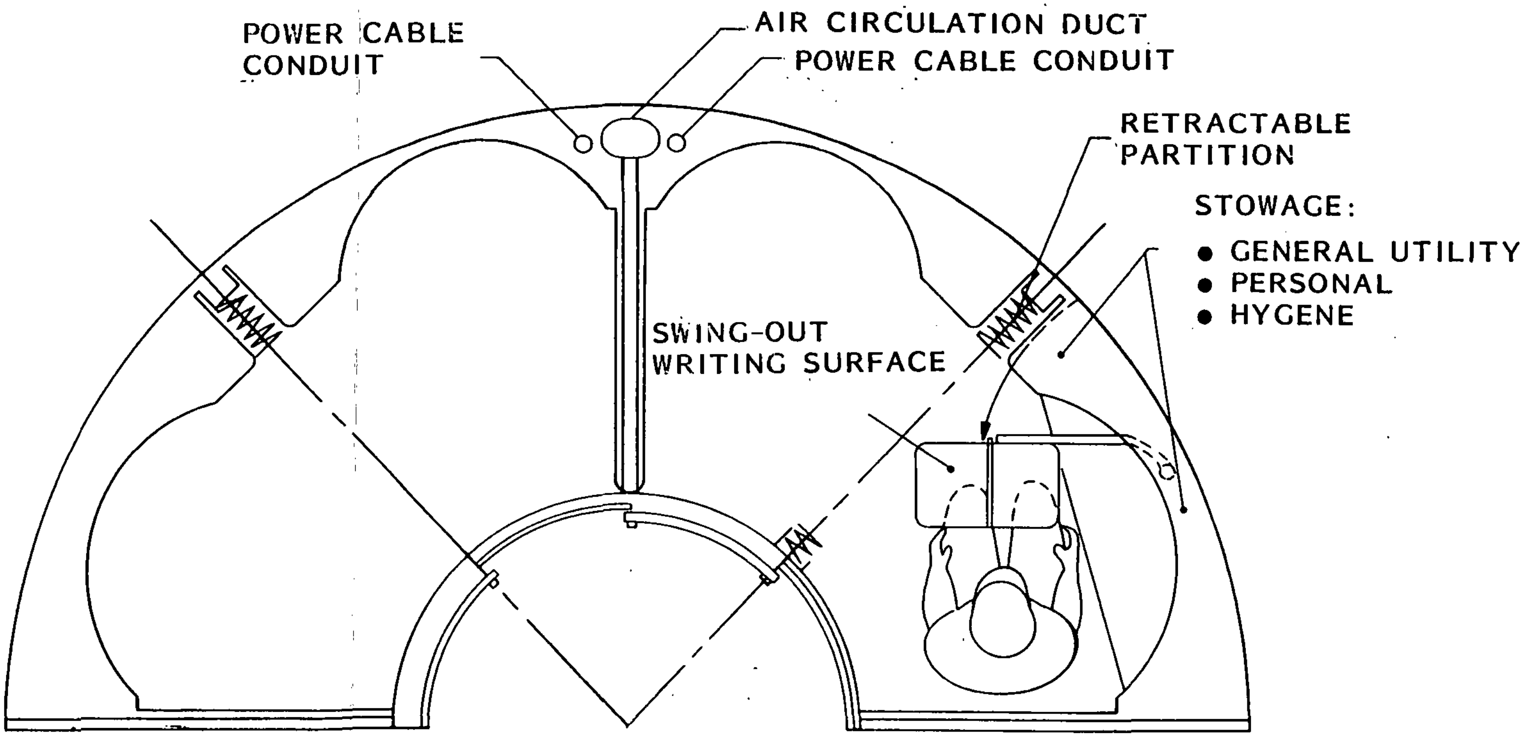
SLEEP QUARTERS CONCEPT



SLEEP BUNK - PLAN VIEW

Layout of the crew sleep quarters bunk area is presented in the opposing page. This concept follows the 'turret approach' layout configuration. Thus, up to eight bunk areas can be provided circumferentially around the interior of the cylindrical habitat. Since the largest crew is 16 personnel (DoD Command Post Module), 16 bunk areas have been provided in the living quarters habitat. Through the use of alternate work rest cycles and associated bunk assignments, each individual retreating to the sleep quarters/bunk will encounter an adjacent bunk which is 'uninhabited'. Consequently, since each bunk is provided with a retractable partition, the crew person who retires for the sleep shift enters his/her own bunk and can open the partition to the unoccupied bunk adjacent to theirs. Thus, a much larger (208 cu. ft.) volume and open spatial relationship is available to the individual. Also, the crew person can leave the privacy door to their sub-compartment open and is able to view and communicate with another simultaneous bunked individual located adjacent to his/her bunk. Therefore, the sleep assigned individual is able to open his or her subcompartment to a much larger open space immediately adjacent and across the 'aisle', thereby, providing fairly extensive open or openly accessible spatial areas (space, color, texture, configuration). Note the more than adequate area for cable and utility trunk lines available volume. Addionally, certain personal functions can be accomodated within the bunk area, e.g., stowage, writing, communication, clothes changing, minor hygiene, etc.

SLEEP BUNK—PLAN VIEW



SLEEP COMPARTMENT - BUNK AREA DETAILS

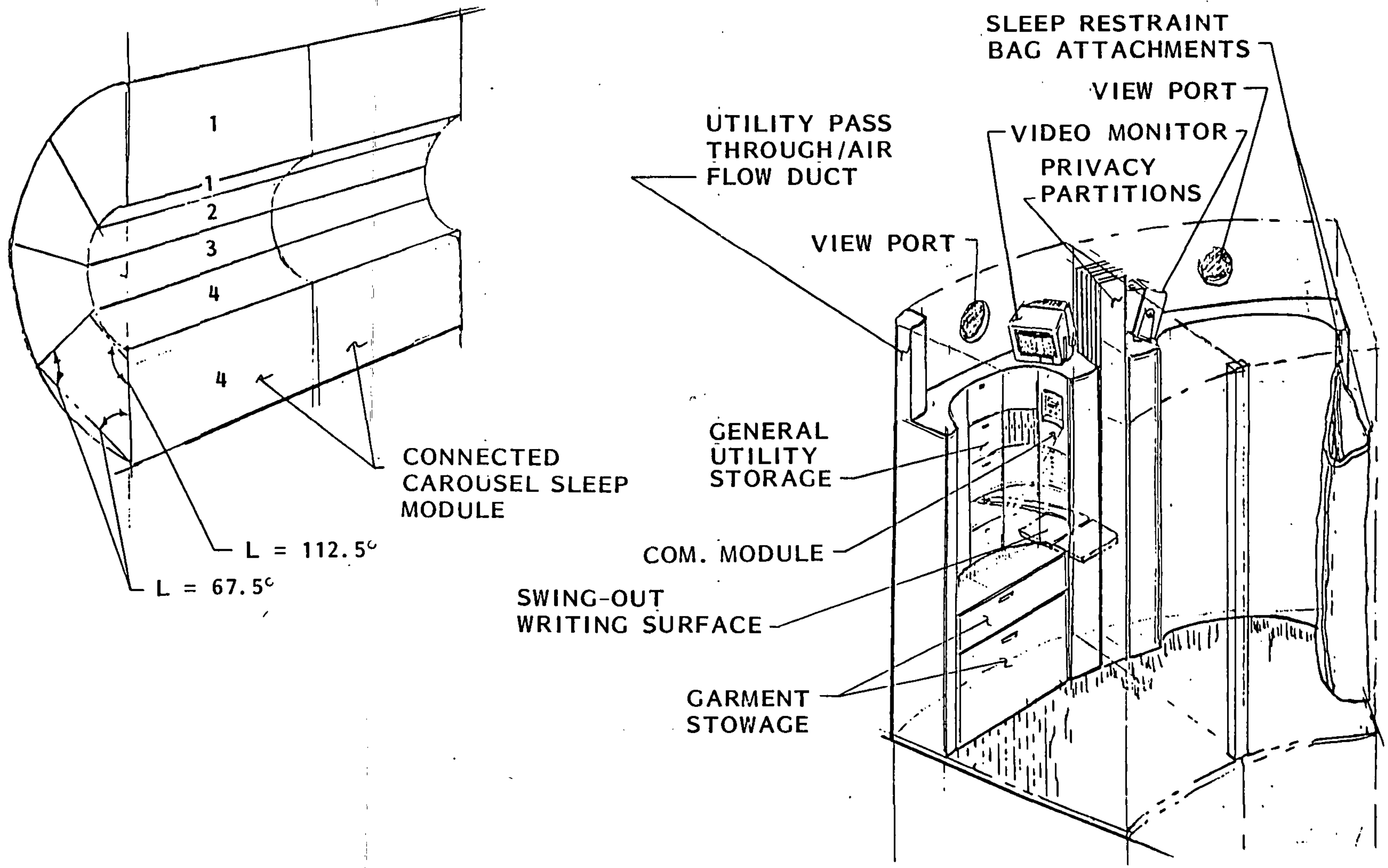
The opposite page figure illustrates the turret-like sleep quarters bunk area layout. Each sub-compartment area is provided with a pair of privacy 'screens'/'partitions as integral features. Besides the sleeping sack/bag, numerous other features are provided.

- Utilities duct and interface
- Video monitor
- View Port (CCTV may have to substitute)
- General utility stowage
- Interior command/monitor panel
- Swing-out writing surface
- Garment stowage
- Privacy partition or screen
- Restraints
- Crew handholds/aids

Each compartment is similarly equiped as above. When the adjoining door partition is disengaged and stowed, both compartment volumes now become available, e.g. over 200 cu. ft. Interior surface texture, color, configuration, and sizing/color configuration of accounterments will be carefully analyzed. Of importance is the fact that this configuration consumes less overall habitat internal volume than the vertical concepts identified to date.

SPACE STATION PROGRAMS

SLEEP COMPARTMENT — BUNK AREA DETAILS



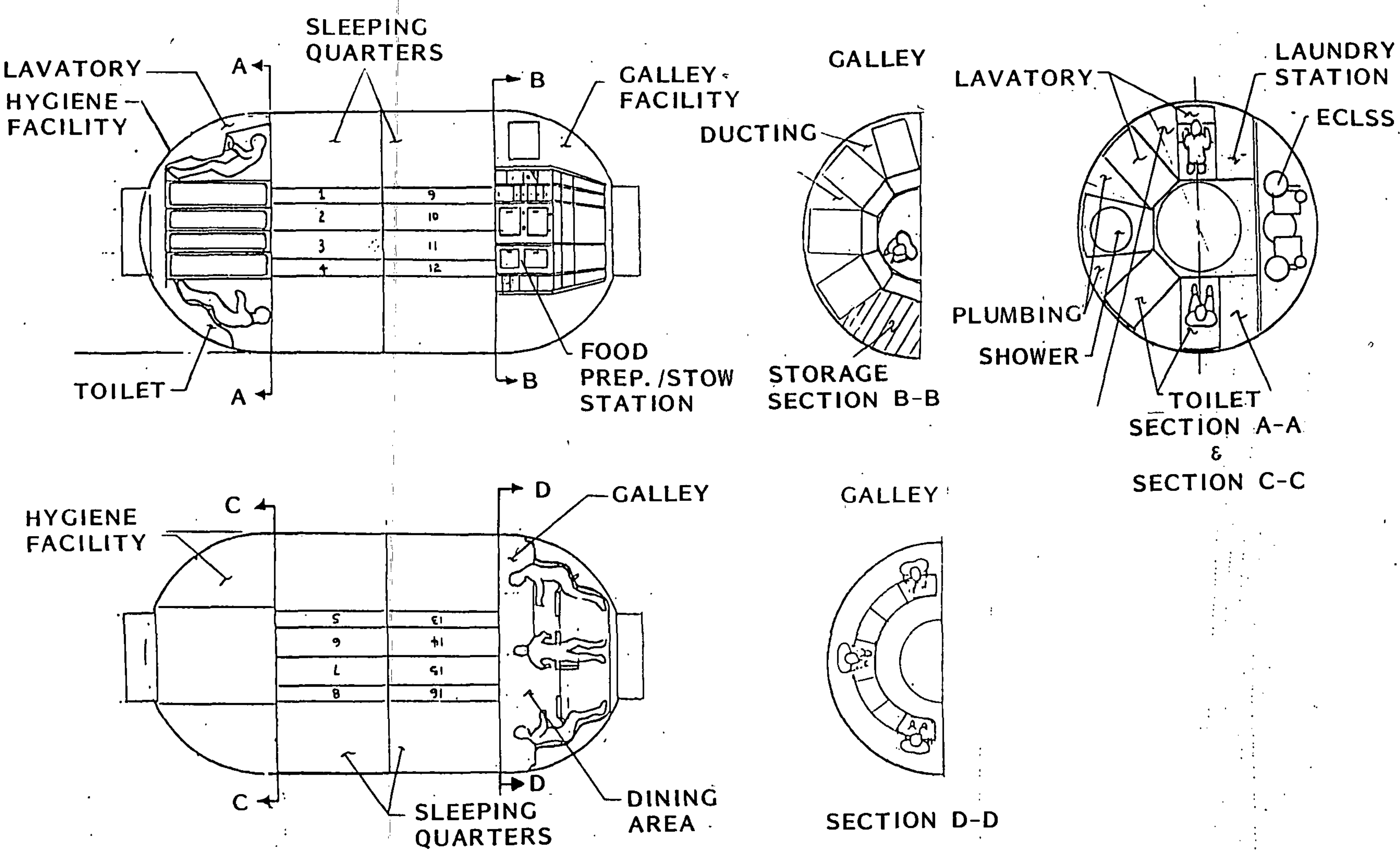
Lockheed

LIVING QUARTERS HABITAT - HYGIENE & GALLEY (CONCEPT A)

A series of habitat layouts have been prepared to determine potential station architecture impacts particularly as a basic indicator of overall length and diameter. Fundamental to this effort was the layout of the hygiene and galley sub-elements of the habitat. Concept A, shown on the facing page, illustrates a dome allocation for both sub-elements. The hygiene stations (toilet, lavatory, laundry, shower, storage and ECLSS interface) are shown with the crew person functioning in a 'horizontal' or 'long axis' orientation. A similar layout has been provided for the galley. In the case of the galley, a primary requirement for 'openness' has been achieved to promote maximum visual surrounding and spaciousness to facilitate crew interaction, communication, and group dynamics.

SPACE STATION PROGRAMS

LIVING QUARTERS HABITAT — HYGIENE & GALLEY (CONCEPT A)

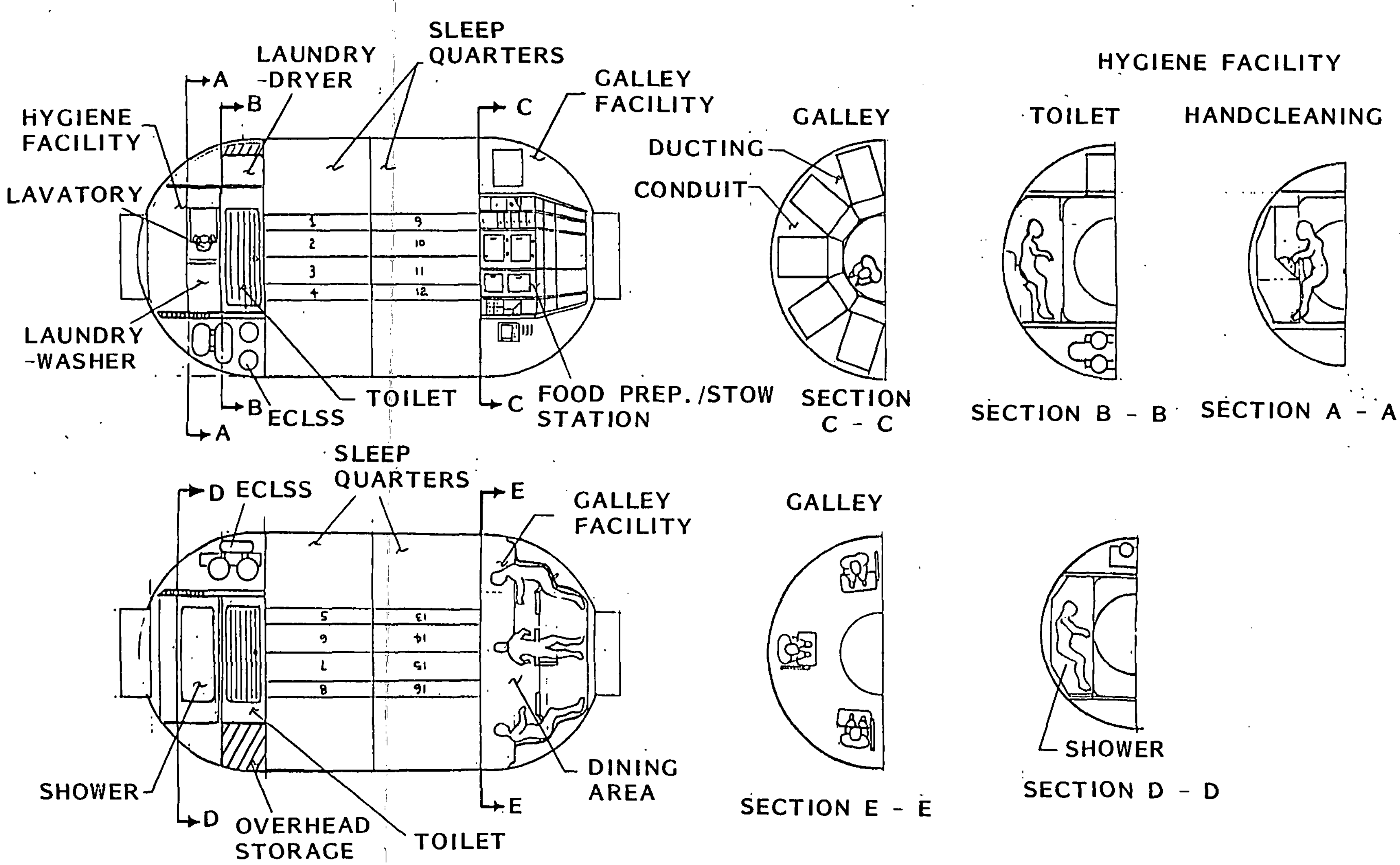


LIVING QUARTERS HABITAT - HYGIENE & GALLEY (CONCEPT B)

In this habitat the Hygiene sub-element (toilet, lavatory, laundry, shower, & ECLSS interface) has been laid-out in a 'vertical' or perpendicular to the long axis of the habitat. Since the sleep quarters separate the Galley from the hygiene area, the differential relationship was not viewed as significantly 'disturbing' to crew visual and spatial relationships. The Galley sub-element was laid-out as in the previous (Concept A) configuration. The vertical arrangement of the Hygiene sub-element is in keeping with the current station study concepts. However, when relegating this area to a dome (end cap) considerable useful space (volume) is lost thereby negating to some degree the usefulness of this dome volume for utilitarian functions.

SPACE STATION PROGRAMS

LIVING QUARTERS HABITAT—HYGIENE & GALLEY (CONCEPT B)

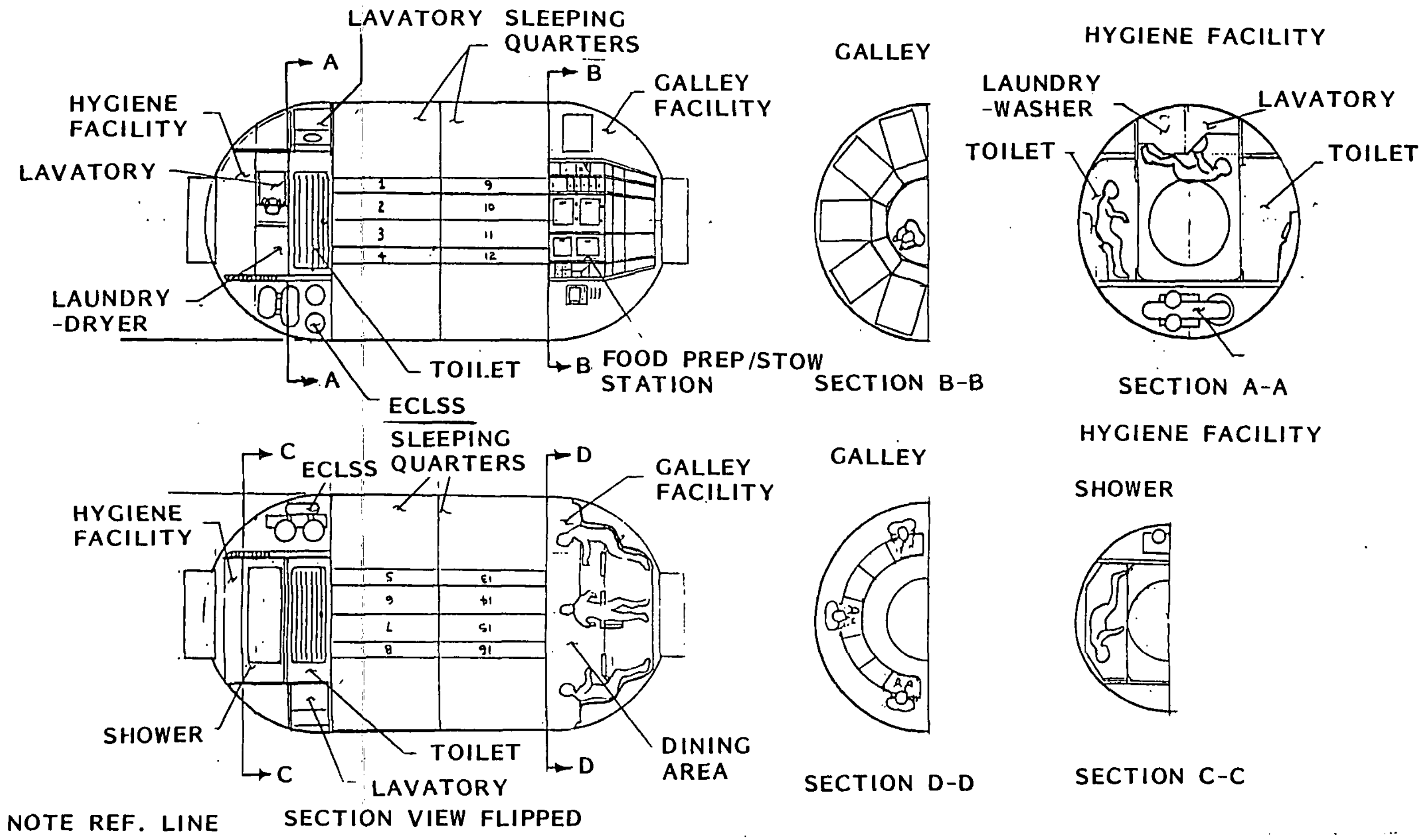


LIVING QUARTERS HABITAT - HYGIENE & GALLEY (CONCEPT C)

This configuration shown on the facing page deviates from the two previous layouts in the arrangement of the Hygiene sub-element. Whereas the two previous layouts were relegated to either a vertical or horizontal configuration for the Hygiene area, this arrangement provides a '180°' approach. As can be seen in this layout the lavatory is arranged at a 90° angle to the other two toilet compartments. As in the previous two Concepts (A and B), privacy 'doors' or folding partitions have been included for toilet and shower privacy. The lavatory has a 'pull curtain' for privacy provisions. This arrangement somewhat violates the concept of 'standard earth architecture' and common spatial relationships with respect to a common reference position. This Hygiene sub-element layout appears to create an ECLSS and plumbing interface difficulty relative to arrangement and pass-through. However, provisionally adequate volume has been determined as available to route the plumbing through the individual sub-compartments of the lavatory and toilet sub-compartment.

SPACE STATION PROGRAMS

LIVING QUARTERS HABITAT — HYGIENE & GALLEY (CONCEPT C)



MULTI-PURPOSE UTILITY CREW VEHICLE

During the evolution of station concepts from the early 1960s on , a substantial need has arisen for a multi-purpose crew vehicle. Principal among the needs for such a vehicle is the requirement for crew rescue and potential earth return using said vehicle. A number of concepts were examined and a sketch prepared (see opposite page) of a concept which could, under emergency situations, accomodate up to 10 crew persons. This vehicle is designed using the basic concepts employed in the Apollo Command Module re-entry vehicle and the ablative forward heat shield. The number ten was selected to be compatible with maximum NASA station crew loading foreseen through at least the first five years of the on-orbit operations. Addionally, two such vehicles could accommodate the maximum crew envisioned for the DoD National Command Post Module (CPM) - up to 16 personnel.

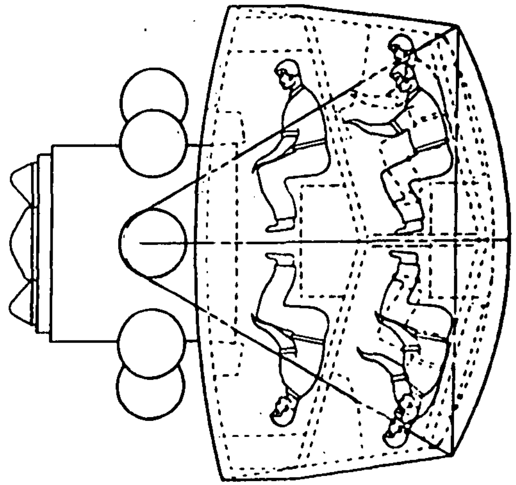
As illustrated on the opposing page, a number of other highly functional uses for this vehicle have been postulated and to a significant degree verified through the mission analysis and user needs effort. The rescue capability was expanded to include the station, orbiter, MOTV, and potentially tethered items such as a safety habitat. The overall support functions are listed as an adjunct to the rescue/emergency function. Obviously, modular 'front-ends' would have to be developed to achieve the multi-functional flexibility suggested.

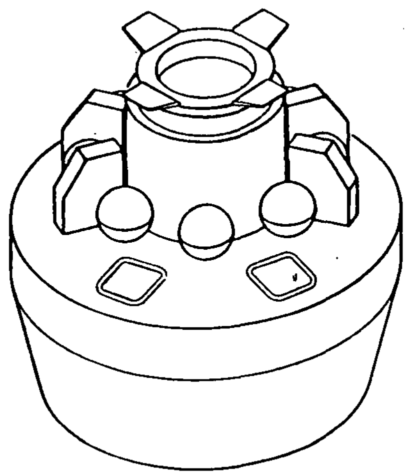
SPACE STATION PROGRAMS

MULTI-PURPOSE UTILITY CREW VEHICLE

A. RESCUE/EMERGENCY
- RESCUE - REENTRY
- SAFE HAVEN
- RADIATION WELL
- INCAPACITATED CREW CARRIER
- QUARANTINE HABITAT
- SICK/INJURED CREW HABITAT

B. SUPPORT FUNCTIONS
- CARGO CARRIER
- 'SHORT RADIUS' WORK TUG
- OBSERVATION UNIT
- PARTIAL G FACILITY
- TETHER MASS
- SMALL CENTRIFUGE ENCLOSURE
- 'CLOSED' MINI-LAB
- MINI-SAMPLE EARTH RETURN
- CREW TRANSFER





OPERATIONS & STATION ARCHITECTURE (SELECTED INFLUENCES)

A number of operations have been previously identified which through a series of evaluations represent significant influences on the basic station architecture. Certain of these more impactful influences are indicated on the facing page. As indicated, operations appear to be the single most important and influencing factor resulting from the basic six areas studied:

- Science
- Applications
- Commercial
- US National Security
- Space Operations
- Technology Demonstrations

It should be pointed out that the US National Security mission(s) resulted in a separate habitat (external tank) with a total complement of associated subsystems and support features. Accordingly, this architectural concept deviated substantially from the overall basic architectural NASA reference station developed as a result of this study. However, a majority of the basic reference station sub-elements are genuinely applicable thus demonstrating the evolutionary application and cross-fertilization of NASA hardware with the DoD needs.

OPERATIONS & STATION ARCHITECTURE (SELECTED INFLUENCES)

A. SEVERAL OF THE OPERATIONS PREVIOUSLY IDENTIFIED SIGNIFICANTLY INFLUENCE STATION ARCHITECTURE

B. SIX (6) OF THE MORE IMPACTFUL OPS INFLUENCES HAVE BEEN ILLUSTRATED TO INDICATE THE NATURE OF THE IMPACT:
- PLUME ENVELOPES - PRESSURE & EJECTA (CONTAMINATION)
- DOCKING APPROACH/DEPART ENVELOPES
- RMS REACH & TRACKED ENVELOPES
- LOGISTICS - LOCATION
- PARTIAL GRAVITY IMPACT ON THE STATION
- STAY-OUT-ENVELOPES

C. OPERATIONS, FOR THE MOST PART, TENDS TO DICTATE STA. ARCHITECTURE:
- UTILITY SUPPORT
- FREE SWEPT VOL. NEEDS
- ASSY/CONSTRUCTION
- SUPPORT AREAS
- BERTHING/DOCKING
- CREW SIZE
- SAFETY
- ATTITUDE/REF CONTROL
- SHADOWING & LOS
- CONTAMINATION

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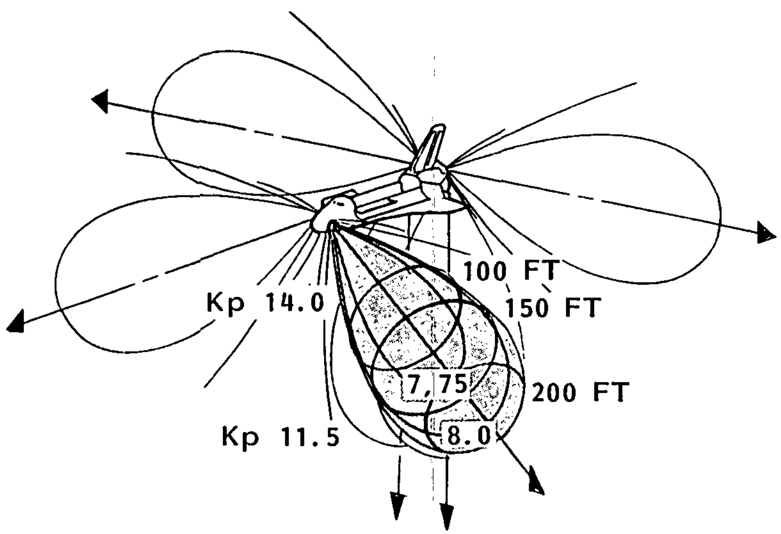
VRCS PLUME CONSTANT DENSITY & FLUX RATE



- VRCS PLUME CONSTANT DENSITY CONTOURS

  P_t = TRUST CHAMBER DENSITY

  P = LOCAL GAS DENSITY

  $K_p = \text{LOG} \frac{P_t}{P}$

  REF. NASA 1980 (2)
  ICD 1-19001, FIG 11-18

- VRCS CONTAMINANTS CONSTANT MASS-FLUX-RATE CONTOURS (SHADED AREA)

  REF. NASA 1980 (a)
  ICD 2-19001, FIG 11-19

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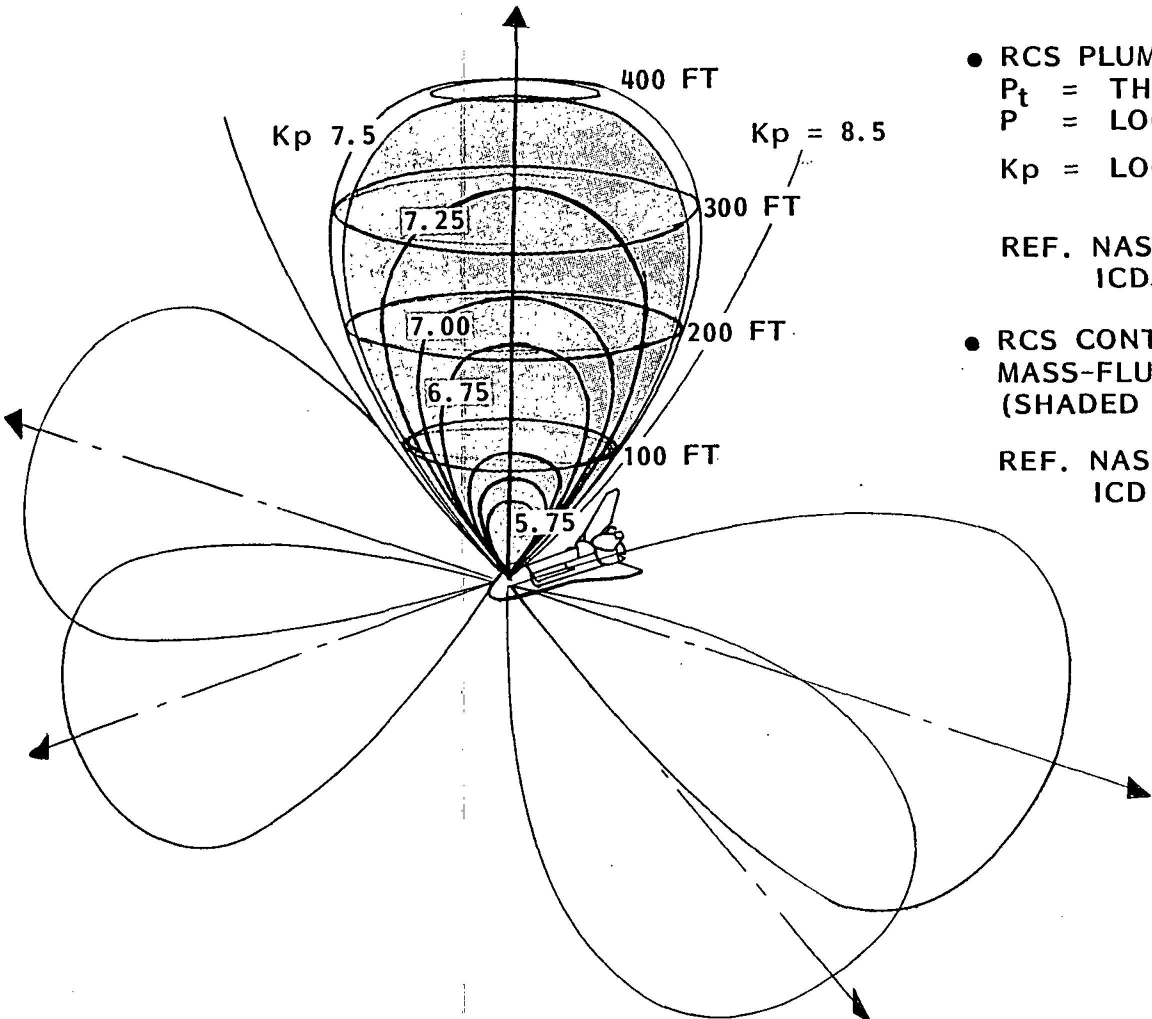
RCS PLUME CONSTANT DENSITY & FLUX RATE



- RCS PLUME CONSTANT DENSITY CONTOURS

  P_t = THRUST CHAMBER DENSITY

  P = LOCAL GAS DENSITY

  $Kp = \text{LOG} \frac{P_t}{P}$

  REF. NASA 1980 (a)
  ICD 2-19001, FIG 11-18

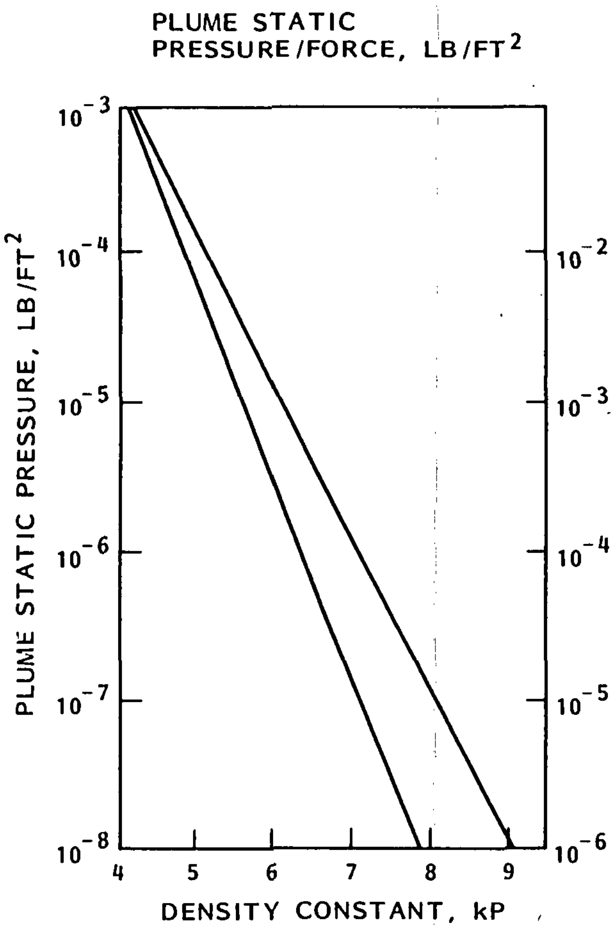
- RCS CONTAMINANTS CONSTANT MASS-FLUX-RATE CONTOURS (SHADED AREA)

  REF. NASA 1980 (a)
  ICD 2-19001, FIG 11-19

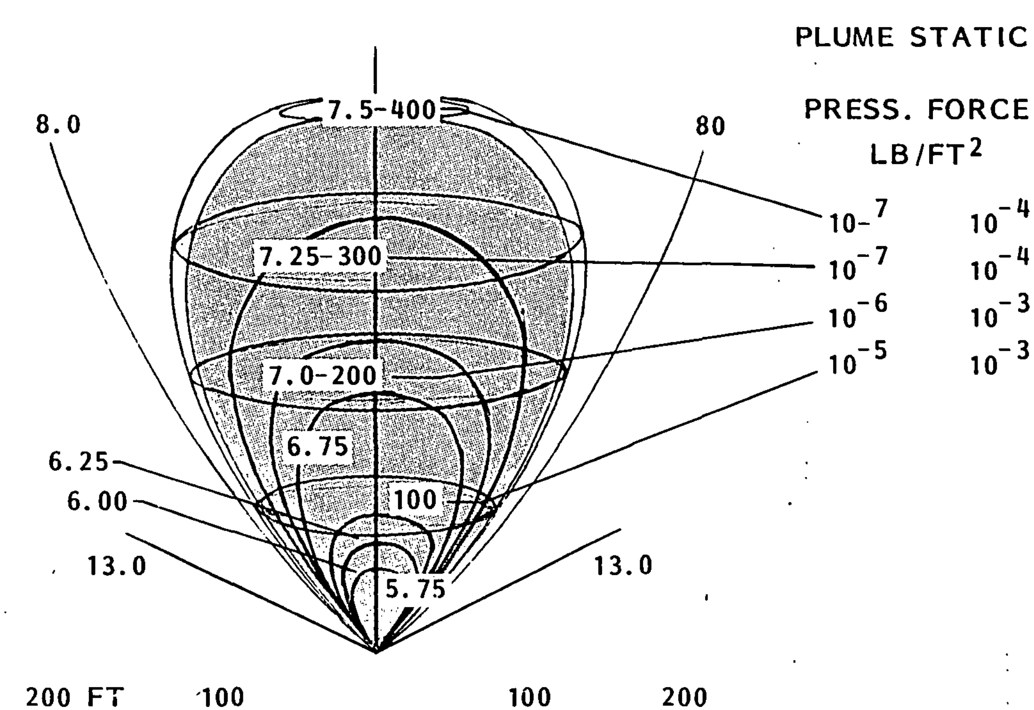
ORBITER PRCS PLUME DYNAMICS

The plume envelope presented on the opposite page indicates the nature of that exhibited by the Orbiter during approach and depart thrusting proximity operations. The plume constant density contours (K_p) are illustrated for a typical envelope as shown. Values ranging from the Orbiter mold line of the thrusters up to 400 ft. are shown and can be referenced to the left hand graph to determine static pressure and impingement force.

PRCS PLUME DYNAMICS



RCS PLUME STATIC PRESSURE AND IMPINGEMENT FORCE AS A FUNCTION OF DENSITY CONSTANT, Kp



PLUME IMPACT - SUMMARY

The facing page indicates a synthesized summary of the potential plume affects relative to station design and architectural considerations. Both plume pressure and contamination are of concern particularly relative to large appendages (solar arrays) and to highly contaminant sensitive sensors and instruments. As shown, direct plume impingement from the Orbiter at the closer approach distances, e.g., 10 to 100 ft. can impose a significant plume impact on the station. Thus, Orbiter approaches which minimize plume impingement are highly desirable, however, such approaches consume considerably more Orbiter fuel than the other proximity operation techniques.

Thus, the engine ejecta constituant gases, particles, and thermal characteristics comprise an important concern to the station as does the overall plume pressure envelope. Further studies are needed to determine similar concerns associated with free flyers which incorporate active thruster systems used for docking with the station.

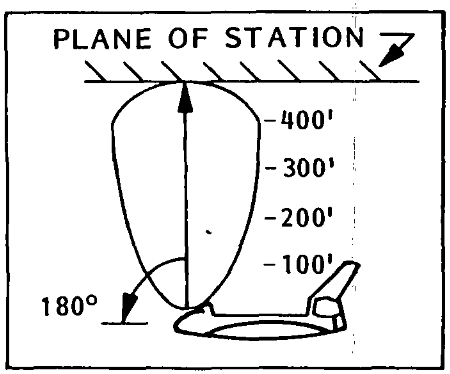
SPACE STATION PROGRAMS

PLUME IMPACT — SUMMARY

A. PLUME EFFECTS CAN IMPACT STATION:

1. DOCKING & SEPARATION
2. ON-ORBIT CONTROL OF:
   - ORBITER/STATION
   - STATION/HABITAT
   - STATION/STRUCTURE-PLTFM.
   - STATION/APPENDAGE
3. CONTAMINATION OF:
   - SOLAR ARRAYS
   - VIEW PORTS
   - SENSORS
   - CRITICAL SURFACES
4. EFFECTS DEPENDENT ON SUCH FACTORS AS:
   - MASS DISTRIBUTION
   - GEOMETRY
   - ITEM CONTAM.SENSITIVITY
   - VEHICLE PLUME ENVELOPES
   - MATERIAL PROPERTIES

EXAMPLE



5. POTENTIAL 90° DIRECT PLUME IMPACT ON STATION REFERENCE PLANE WITH PRCS:

FACTOR \ DISTANCE	100 FT	200 FT	300 FT	400 FT
PRESSURE (LB/FT^2)	10^{-5}	10^{-6}	10^{-7}	10^{-7}
IMPINGMT FORCE (LB/FT^2)	10^{-3}	10^{-3}	10^{-4}	10^{-4}

6. PLUME PRESSURE IS SIGNIFICANT:
   - IMPACT ON SOLAR ARRAYS
   - CONTAMINATION ON OPTICAL/SENSOR PALLET
   - TORQUE DISTURBANCES MINOR BUT EVIDENT

Lockheed

GENERAL DOCKING CONTACT PARAMETERS

A very preliminary set of docking parameters for the station have been assembled on the facing page. Previous docking results have provided initial data, and Orbiter RMS berthing operations data will further provide pertinent information. Assuming the Orbiter docking module is funded and flown, considerably more applicable docking parameter data will become available. However, initial docking concepts and associated hardware play a key role in the architectural definition of the station. Of particular note is the 'size' of the spacecraft planned for docking to the station. Preliminary data indicate that spacecraft ranging from small Orbiter cargo bay sized payloads (6 to 14.5 ft. dia.) to larger elements (e.g., 27 ft. dia.) such as an AFT Cargo Carrier or ET segment should be considered.

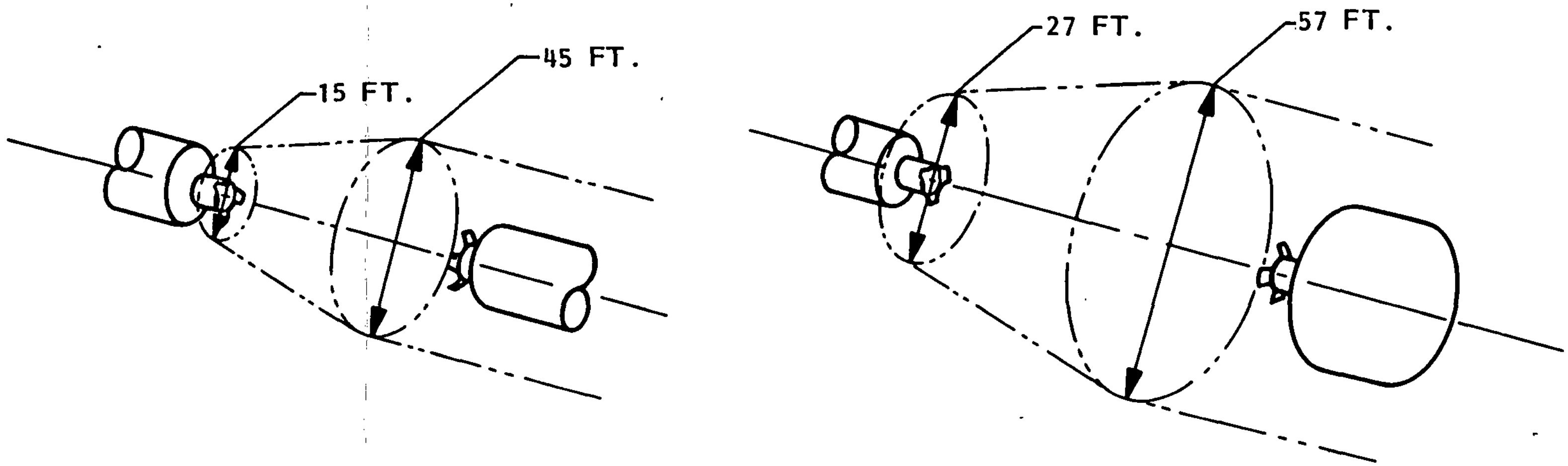
The data presented on the opposing page should be considered very preliminary and subject to further orbit mechanics analysis, structures design, command & control authority analysis, and basic S/C RCS capabilities and constraints studies. Actual approach/depart cones obviously influence surrounding hardware and/or appendages. Docking impact loads and post impact gyration (and associated dynamics) also will influence station stability, and pointing and control requirements.

SPACE STATION PROGRAMS

GENERAL DOCKING CONTACT PARAMETERS

RELATIVE CONTACT VELOCITY (-Z)	0.5 FPS (0.05 FPS LOW LIMIT)
RELATIVE LATERAL VELOCITY (X & Y)	0.±0.1 FPS
RELATIVE ANGULAR VELOCITY (3 AXES)	±1.0 DEG/SEC ABOUT ANY AXIS
RELATIVE LATERAL MISALIGNMENT (ORBITER X,Y)	0±0.5 FT
RELATIVE ANGULAR MISALIGNMENT (ORBITER PITCH & ROLL)	0±5 DEG ABOUT EACH AXIS
RELATIVE ROTATION MISALIGNMENT (ORBITER YAW)	0±7 DEG
POST IMPACT GYRATION	MAX 10° IN ONE POSITION

ORBITER



GENERAL SPACE STATION RMS SUPPORT NEEDS

A number of RMS support needs have been identified relative to the Space Station. The opposing page illustrates a conceptual station configuration (rafted concept) and the associated RMS. Typical of the functions the RMS can support and the associated hardware are the following:

1. Assembly of Basic Structure
   - SRMS (Orbiter Transition RMS)
   - Orbiter Mounted Holding Fixture
   - Special End Effectors
2. 'Mid-Development' Station
   - Additional Turn/Tilt tables
   - Long Reach RMS
3. Advanced Space Station
   - Extended Track for RMS
   - Tethered Flying RMS
   - Free Flying RMS/TMS
4. Space Station R&D
   - Track Mounted RMS
   - RMS Control Station
   - Turn/Tilt Table

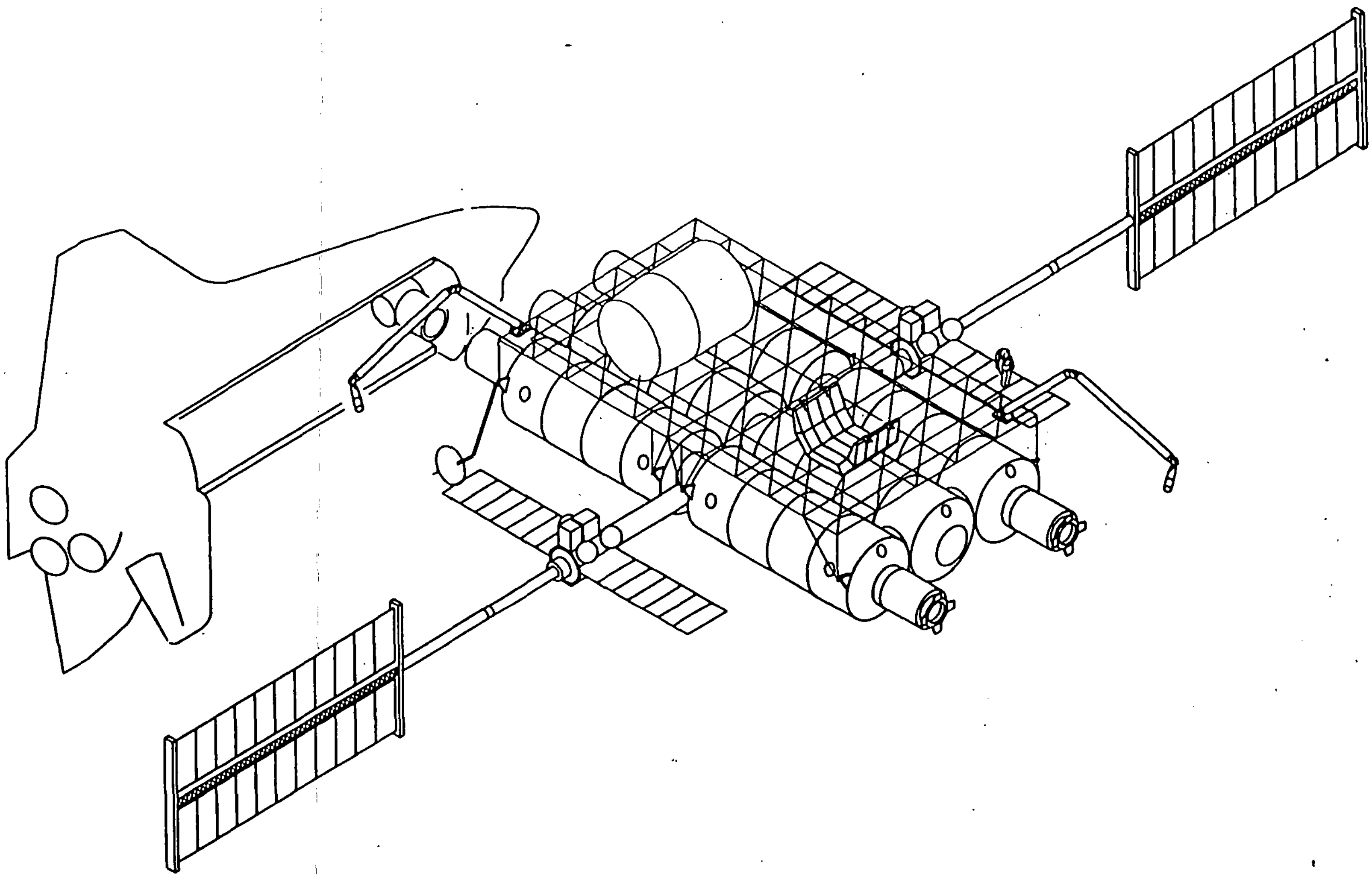
As the station design evolves and matures, it is expected that more definitive RMS associated equipment lists will be available. This list was developed in concert with SPAR of Canada:

1. RMS
   - A. Current
     - Per Orbiter Ops (Possible added travel in certain joints)
   - B. Advanced
     - Positioning/Holding Aid
     - Aft Mounted SRMS
     - Extended Reach (100' or more)
     - Additional Dexterity
     - Turn/Tilt Table
   - C. Tracked
     - Basic SRMS or P&HA mounted on carriage, initial straight track, later on curved or switch tracks
   - D. Control Station
     - Station mounted 'cockpit', cab-fixed or railed cab vs relocatable cab
2. Teleoperator Station
   - A. Tethered
   - B. Free Flyer
3. Other
   - A. End Effectors & Grapple Fixtures
   - B. Developed from Existing Hardware
   - C. Tools, e.g.,
     - Rod Holding
     - Plate Holding
     - Module Replacement
     - Universal Tool

EVA Support & Associated Equipment
- Cherry Picker - Closed or Open
- Stabilizer Arm
- Proximity Sensing
- Force Feedback

SPACE STATION PROGRAMS

GENERAL SPACE STATION RMS SUPPORT NEEDS



RMS UTILIZATION

A typical set of RMS construction and assembly functions have been identified in the facing page. The list is not intended to be exhaustive, but rather to be representative of those functions anticipated in association with station operations. A number of items with which the RMS interacts (and possible crane provided in later years) is also indicated. The list of items is also intended to be only representative as the actual equipment, hardware, and logistics/supply and construction/assembly materials will evolve and expand as further definition is achieved.

These functions and the equipment/item/material list were used as the foundation for subsequent RMS studies which were conducted with SPAR of Canada who supported LMSC during the early architectural definition analysis and requirements development efforts.

RMS UTILIZATION

CONSTRUCTION/ASSEMBLY	ITEMS
A. TRANSPORT OF MATERIALS/ITEMS/MODULES (FIXED BASE)	1. MODULES
B. POSITIONING (ANGULAR ORIENTATION)	2. AIRLOCKS/TUNNELS
C. HOLDING OR MAINTAINING ESTABLISHED LOCUS	3. INTERFACE UNITS/DEVICES/STRUCTURES
D. END EFFECTOR UTILIZATION (SINGLE & REPETITIVE USE)	4. BEAMS/GIRDERS/STRUTS
E. TRANSPORT OF MATERIALS/ITEMS/MODULES (MOVING BASE)	5. PLATFORMS/BASES
F. JOINING/ENGAGING/MATING/FASTENING	6. SUN SHADES
G. INSERTION/WITHDRAWAL	7. MICROMET. BUMPERS
H. CLOCKING/INDEXING	8. APPENDAGES/BOOMS
I. REMOVING/REPLACING	9. PALLETS/RACKS
J. TRANSPORT OF CREW (OPEN OR CAB)	10. TELESCOPING UNITS
K. CAMERA MANEUVERING/POSITIONING	11. DOCKING MODULES/PORTS
L. CONSTRUCTION DEVICE MANEUVERING/POSITIONING	12. TANKS/PRESSURE VESSELS
M. CABLE REELING/POSITIONING	13. SUPPLIES & RAW STOCK
N. MEASUREMENT OR C/O DEVICE MANEUVERING/POSITIONING	14. TOOLS/AIDS/JIGS
	15. CABLING
	16. FASTENERS
	17. MECHANISMS
	18. TRACKS
	19. GUIDES/LOCATORS
	20. DEBRIS
	21. PLUMBING/VALVE ASSEMBLIES
	22. CONDUIT/PWR BOXES/PWR CABLE

RMS REQUIREMENTS

The facing sheet presents a summary of the top-tier requirements established for both the fixed and mobil RMS and Crane. It is envisioned that as the station operations become even further defined and the mission support needs delineated in more detail, these requirements can be expanded and revised. Additionally, early station build-up will require assembly and construction support by the Orbiter based RMS, and as the station evolves, it is anticipated that a station based RMS(s) and/or crane will be outfitted to the station to support both indigenous and demonstration efforts.

Both an internal station positioned RMS console work station and 'external' located RMS operator cab may formulate the basic operational work stations for the crew person. It is anticipated that the external cab approach could initially be an 'open cab' later on evolving to a closed environment for shirt sleeve opertions. Accordingly, requirements are foreseen as continually evolving in this area, thereby suggesting that technology needs be carefully examined and appropriate supporting programs undertaken.

SPACE STATION PROGRAMS

RMS REQUIREMENTS

FIXED - RMS/CRANE	MOBILE - RMS/CRANE
• MANIPULATE AND BERTH MODULES UP TO 15,422 Kg (34,000lbs) and 15.24m (50-FT) LONG WITH ONE ARM • MANIPULATE AND POSITION ASSEMBLY PARTS UP TO 1,136 Kg (2,500 lbs) and 15.24m (50-FT) LONG WITH ONE ARM • 35-M REACH AND GENERAL GRASPING CAPABILITY • DEGREES OF FREEDOM -RMS/CRANE (YAW) -SHOULDER JOINT (PITCH AND YAW) -ELBOW JOINT (PITCH) -WRIST JOINT (PITCH,YAW,AND ROLL) • ARM TIP FORCE CAPACILITY OF 89N (20 lbf) • ARMS OPERATED SEQUENTIALLY,BUT NOT SIMULTANEOUSLY • MANUAL AND AUTOMATIC SIX DOF CONTROL OF EACH ARM • GOOSENECK OR VERNIER CONTROL FOR FINE POSITIONING • AUXILIARY CONTROL FROM CHERRY-PICKER CAGE • TV CAMERA AND LIGHTS ON EACH RMS/CRANE ARM PLUS REMOTE • UNOBSTRUCTED VIEW FOR OPERATOR • TWO OR MORE HANDHOLDS PER MODULE • OPEN CORRIDOR ON WHICH THE FIXED CRANE IS POSITIONED • SOLAR ARRAYS LOCKED OR ANGLE LIMITED DURING TRANSFER ACROSS • COLLISION AVOIDANCE SOFTWARE AND/OR MAX TORQUE OVERRIDE • AUTOMATIC JOINT LOCK IN CASE OF JOINT MOTOR FAILURE	INCREASED REQUIREMENTS FOR MOBILE RMS/CRANE • TWELVE HANDHOLDS PER MODULE • RECHARGEABLE BATTERIES (1,500 W-HR) • ON-BOARD RADIO AND EMERGENCY HOMING BEACON • LIFE SUPPORT TO LAST TBD HR,PLUS TBD HR RESERVE • CIRCUIT TO PREVENT ACCIDENTAL RELEASE OF LAST GRASPER ON BASE REDUCED REQUIREMENTS FOR MOBILE RMS/CRANE • ARM REACH REDUCED TO 15.24m (50 FT) • OPEN CORRIDOR NOT REQUIRED

RMS INTERFACES

An early assessment of the potential RMS interfaces was made relative to the candidate items with which the RMS may have to interact. The facing page portrays at the top-tier level those candidate interfaces and the associated sizing parameters, weight ranges, and general access envelopes. This list should be considered very preliminary and is highly subject to station architectural drivers and configurations. Further, mission support needs require further delienation and definition before the full sizing and mass characteristics can be established. Large space structure interfaces have not been included at this time due to lack of firm definition of these structures.

RMS INTERFACES

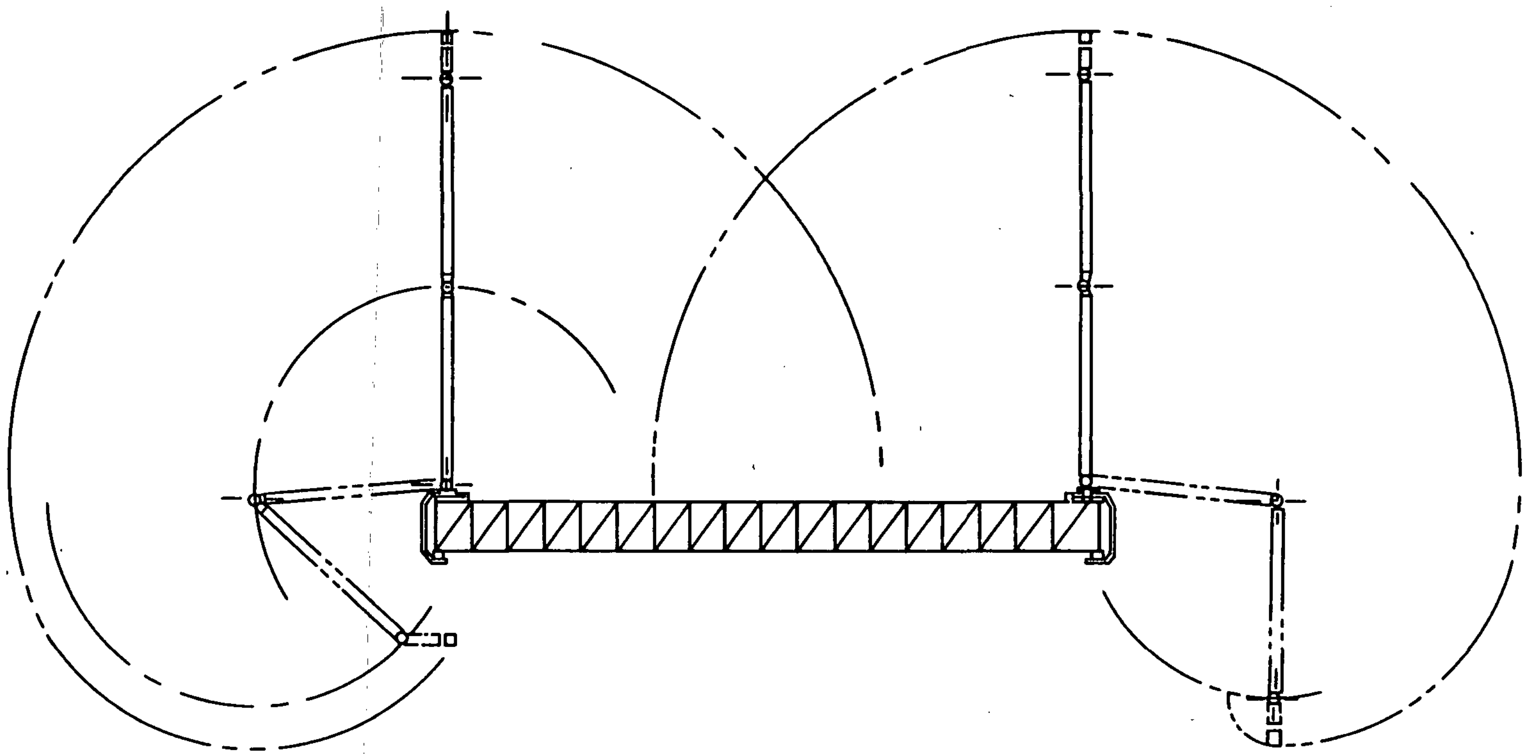
CANDIDATE SYSTEM	SIZE (FT.) L	W	D	WEIGHT (LBS)	ACCESS
A. SPACECRAFT					
1. SPACE TELESCOPE/AXAF	43	14.5	DIA	24K	360° - FULL LENGTH
2. USAF SPACE VEHICLE	55	14.5	DIA	60K	360° - FULL LENGTH
3. MULTI-MODULAR S/C	12	10	DIA	12K	360° - FULL LENGTH
B. PALLET/RACK					
1. ESA PALLET	9.5	14.5	10	<10K	FWD/AFT/TOP
2. USAF RACK	12	14.5	10	<14K	FWD/AFT/TOP
C. STAGES					
1. MULTI STAGE IUS	35	13	DIA	81K	360° - FULL LENGTH
2. ORBIT TRANSFER VEHICLE (A)	85	14	DIA	138K	360° - FULL LENGTH
3. ORBIT TRANSFER VEHICLE (B)	52	14.5	DIA	63K	360° - FULL LENGTH
D. HABITABILITY MODULE	24/50	14.5	DIA	16 TO 52K	FWD/AFT
E. LOGISTICS MODULE	24/50	14.5	DIA	21 TO 55K	FWD/AFT
F. AIRLOCK/DOCKING MODULE	52	14.5	DIA	16 TO 35K	FWD/AFT
G. POWER MODULE	10/40	14.5	DIA	15/30K	360° - FULL LENGTH

RMS REACH ENVELOPES (PIER MOUNTED)

The facing page illustrates RMS reach envelopes for a typical pier mounted installation. Current RMS joint envelopes are not compatible with this concept, however, interaction with SPAR (of Canada) personnel indicate that the joint articulation ranges illustrated here are certainly witin the capability of current design technology. The RMS reach lengths can be readily examined as a function of station placement location. Accordingly, length increases (or decreases!) can be logically considered with respect to the current RMS arm (50 ft in length). As length increases significantly, it can be anticipated that diameter (cross section) will increase as will joint sizing/strength to achieve the necessary stiffness and rigidity required along with the obvious need for dynamic compliance. Thus, weights can be expected to increase.

It is also anticipated that control logic changes will have to be made in addition to software package updates/modifications and that new FMEAS be conducted to assure maximum design for safety. Further, as the RMS is changed, it can be expected that the display/control work station will also have to be modified. However, the current orbiter RMS provides a concrete basis for the necessary technological evolution to support further effort relative to larger RMS hardware.

RMS REACH ENVELOPES (PIER MOUNTED)



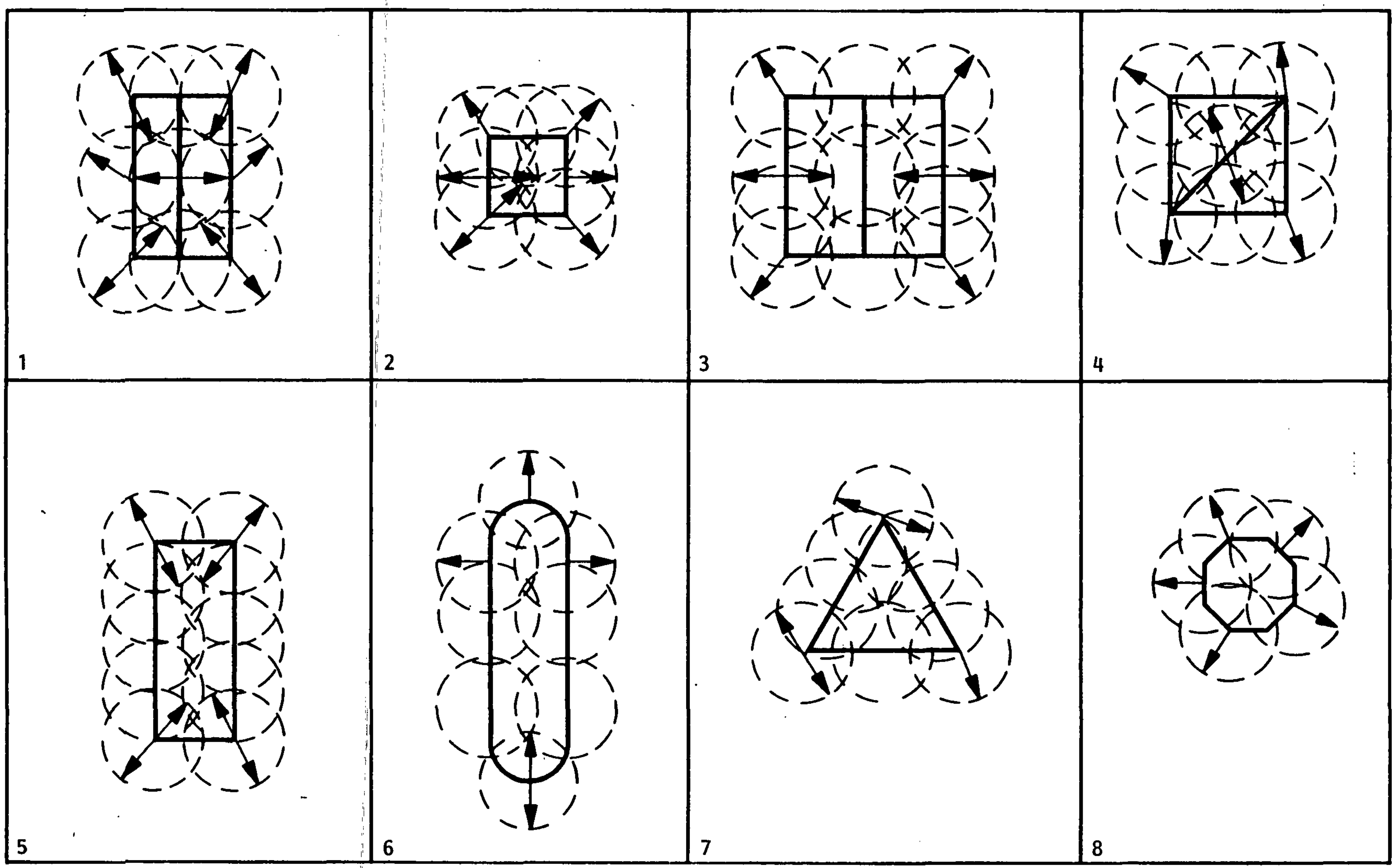
RMS REACH ENVELOPES

The opposing page provides a geometric set of potential RMS reach envelopes as might be associated with a variety of station architectures. Both single and dual RMS's were included in the reach layouts. Although difficult to portray, the 8 different arrangements represent the basic cadre of spacecraft architectures used as the candidates for station study, e.g., cylinders, triangular strongbacks, tank version, aft cargo carrier stacked approach, rafted cylinders, etc. The reach envelopes were principally developed to aid in assessment of two major operations: (1) Station build-up; and (2) Large structure construction and assembly.

As can be readily observed, the judicious location of the RMS or RMS's results in extensive reach capability. This is particularly evident when a tracked capability is provided. However, the use of a track and the corresponding reach envelopes and associated reach constraints certainly impact the architecture and, as such must be considered as elemental drivers in the station criteria. Consideration must also be given to absolute needs for the following as they reflect envelope reach capabilities:

- Numbers of RMS's and/or Crane(s)
- Dual simultaneous operation of 2 RMS's
- Reach envelope requirements
- Free swept volumetrics
- Mass vs stopping envelopes
- Positioning accuracies
- Stay-out zones
- Collateral damage potential
- Operational complexity
- Automated vs direct man-in-the-loop functions
- Physical station structure, e.g., appendages

RMS REACH ENVELOPES

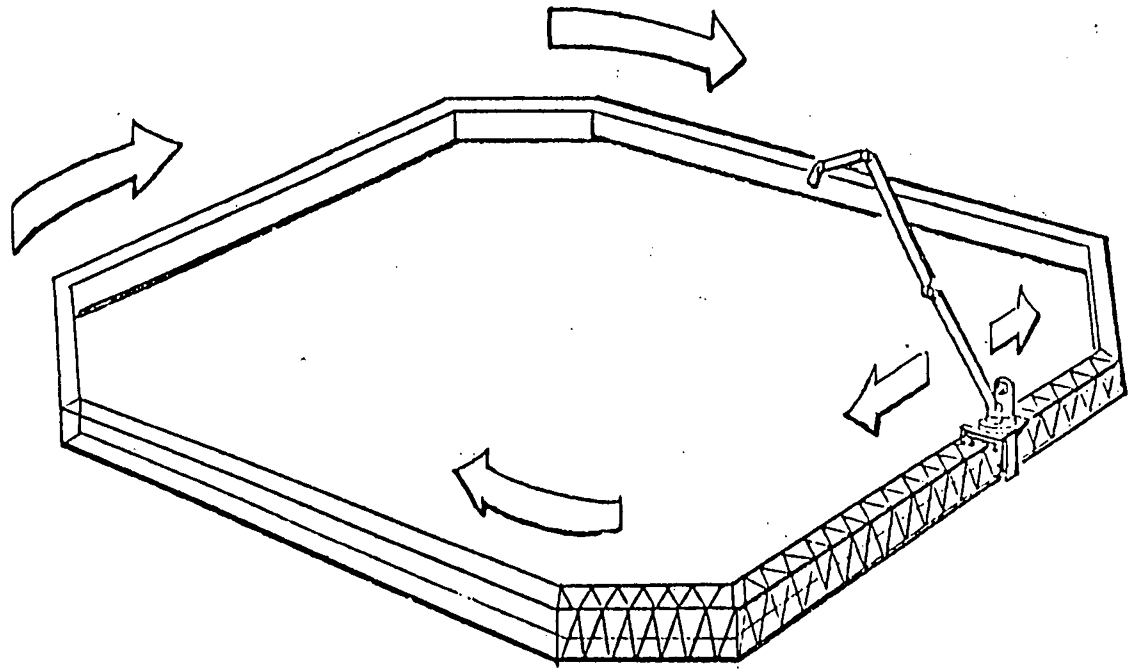


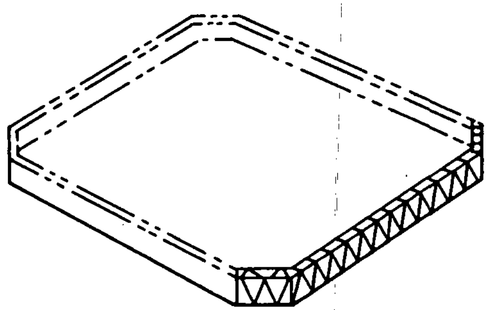
TRACKED CRANE CONCEPT

The concept for a pier mounted tracked crane is presented on the opposing page. In this example, the crane is placed on a track which is mounted around the perimeter of the station 'base'. Thus, the reach envelope is substantially increased by several times when compared to a fixed base RMS. The tracked crane concept offers several advantages such as increased access, larger field of coverage, multi-position support, etc.

Notwithstanding the obvious advantages, several concerns also surface when using a tracked approach. Both power and signal input to the RMS are dependent on 'transfer' from the rail to the RMS or some other approach such as coiled cables on a 'follower' with a long umbilical. Stability while attached to the track appears feasible but must be carefully designed. Thermal effects on the track may also be of concern as will the obvious illumination disparities. Use of a moving crane while conducting operations such as object transport, item positioning, fine course positioning, etc., needs considerable further analysis, definition, and subsequent simulation to establish feasibility and practicality.

TRACKED-CRANE CONCEPT



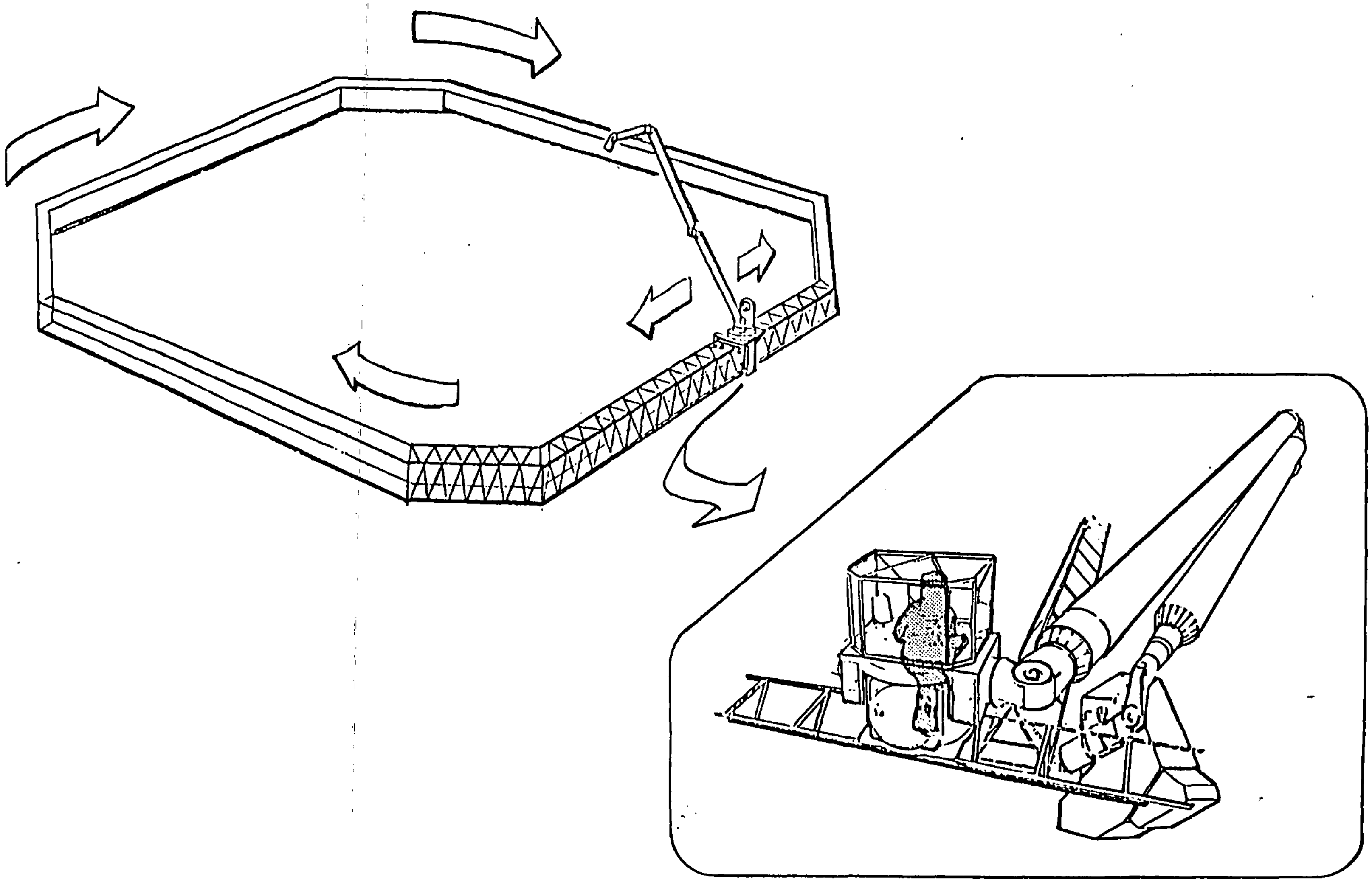


TRACKED CRANE WITH CAB

Consideration has been given to a tracked crane with an associated cab as shown on the opposite page. Initially, the cab could be open, thus, requiring a suited operator. As the station evolves, it would be quite feasible to enclose the cab, thereby, providing the operator with a shirt sleeve operating environment.

The cab would be mounted to the moving crane assembly base and therefore follow the crane as it makes its 'operational rounds.' The close proximity of the cab/operator to the crane provides a somewhat similar operational transition from the Orbiter configured RMS. The closer relationship of the cab/operator to the crane functions offers a number of obvious advantages. Safety implications are equally apparent, particularly with respect to collateral damage potential and damage to the cab (hence possible crew risk). It is patently straight forward in approach utilizing expected ancillary aids such as CCTV and various located illumination devices.

TRACKED CRANE WITH CAB



LOGISTICS SUPPORT - CREW OF 8 FOR 90 DAYS

The crew number for the command post module (CPM) has initially been sized at 16. Accordingly, logistics support for the re-supply flights has been sized to correspond to this crew size. As indicated on the facing page and page continued thereafter, only crew support and environmental control and life support items have been included in this tabulation. However, it is expected that station spares, and mission support equipment spares would also complement the total logistics requirement for each re-supply flight.

It should be noted that since a closed regenerative life support system has been assumed for the CPM, logistic resupply has been limited to the following items relative to ECLSS and/or the EMU:

- PLSS Re-Charge
  - Oxygen
  - Lithum Hydroxide
  - Water
- Spacecraft Leakage

It is further assumed tht the logistics transfer will be from the Orbiter via one of two modes. Mode A could be changeout of tanks while Mode B could be transfer of gases/water. LiOH replenishment may be accomplished using a canister concept. The overall weight of approximately 6800 lbs and about 600 cu. ft. volume appear to be well within the resupply range of the Orbiter and can be packaged in various configurations to accommodate other cargo length and volume restrictions within the Orbiter cargo bay.

SPACE STATION PROGRAMS

LOGISTICS SUPPORT — CREW OF 8 FOR 90 DAYS

ITEM	WT (LBS.)	VOL (CU.FT.)
A. FOOD		
• SHELF STORABLE	950	240
• FROZEN	760	
B. WASTE SYSTEM	312	48
• LINERS/WIPES		
• DISINFECTANTS		
• MISCELLANEOUS		
C. PERSONAL ITEMS	1312	89
• HYGIENE SUPPLIES		
• RECREATION ITEMS		
D. ECLSS ELEMENT	960	118
• CHEMICALS		
• FILTERS		
• SPARE CONSUMABLES		
E. HOUSEKEEPING	660	42
• FILTERS/SEALS		
• BAGS/WIPES		
• DATA/LOGS		
• TAPES/DISKS		
• ETC.		
F. LIFE/HOUSEKEEPING MAINT.HDWR.	160	8
G. ECLSS RESUPPLY		
• SPACECRAFT LEAKAGE (5 LB/DAY)	450	32
• EVA 'MAKE-UP'		
✓ AIRLOCK (1.33 LB/EVA-12 EVA's)	16	1.5
✓ PLSS (24 EVA SORTIES)		
- O_2 (1.22 LBS/8 HR.)	29	2
- LiOH (1.6 LBS/8 HR.)	38	3
- H_2O (8 LBS/8HR.)	96	7
H. GARMENTS (NO WASHER/DRYER)	1040	14
TOTAL	6815	607

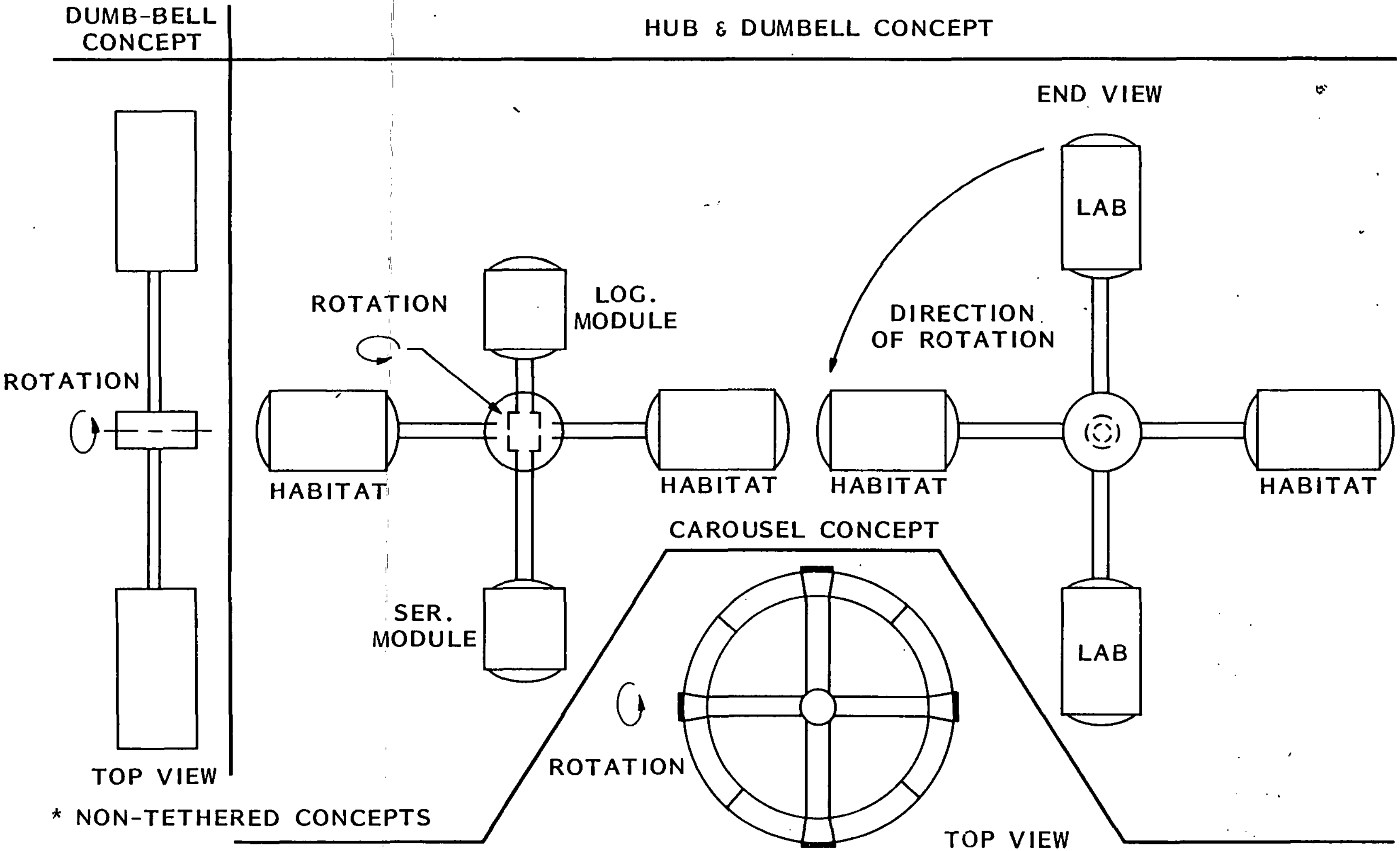
Lockheed

PARTIAL GRAVITY STATION EXAMPLES - SCHEMATIC

The opposing page presents three selected rotation space station schematic representations. Each rotate about a central hub, thereby providing partial gravity at the extremeties, e.g., outer habitat/lab or ring segment. Numerous studies indicate that the radius from the rotational hub must be, at a minimum, at least 100 ft. and preferably 200 ft. for a gravity of over 0.5 g's and a rotation rate of about 4 rpm in order not to increase the crew persons' weight in excess of 15 to 20% due to the Coriolis and velocity-toward-rotation effects. Thus, as can be seen in the facing figures, significant impact on the station architecture is encountered in order to provide the necessary distance from the rotational hub. This constraint and others are further elaborated upon in the next pages.

SPACE STATION PROGRAMS

PARTIAL GRAVITY STATION EXAMPLES—SCHEMATICS (SELECTED EXAMPLES)



* NON-TETHERED CONCEPTS

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TETHER IMPLICATIONS & ARTIFICIAL GRAVITY

The following two charts indicate the nature of the utilization of 'tethered' spacecraft and/or elements to the station. Initial utilization of the tether was with the Gemini 6/7 Mission wherein the spacecraft was tethered to the Agena vehicle. Since that time, numerous studies have been made relative to the use of tethers for advanced space programs. Two recent study contracts have resulted in the selection of a U.S. aerospace contractor working in concert with a European contractor to develop a tethered satellite 'suspended' from the orbiter. The next two pages briefly outline the advantages of the tethered station-spacecraft, applications of artificial G in the station, and general applications of artificial G for various tethered elements. Results of this analysis have been provided for the basic station configuration layout studies associated with tethered elements.

Of particular interest to this study were three aspects of the early analysis of tethers and are (1) Ability to 'reel in/out' pallets/platforms to support the station; (2) Possible power availability; and (3) Tether 'release energy' for 'launch or reentry' trajectories. Nonetheless, it is felt that additional study be applied before more substantial application of the tether principals be incorporated into the evolution of the station architectural framework.

SPACE STATION PROGRAMS

TETHER IMPLICATIONS & ARTIFICIAL GRAVITY

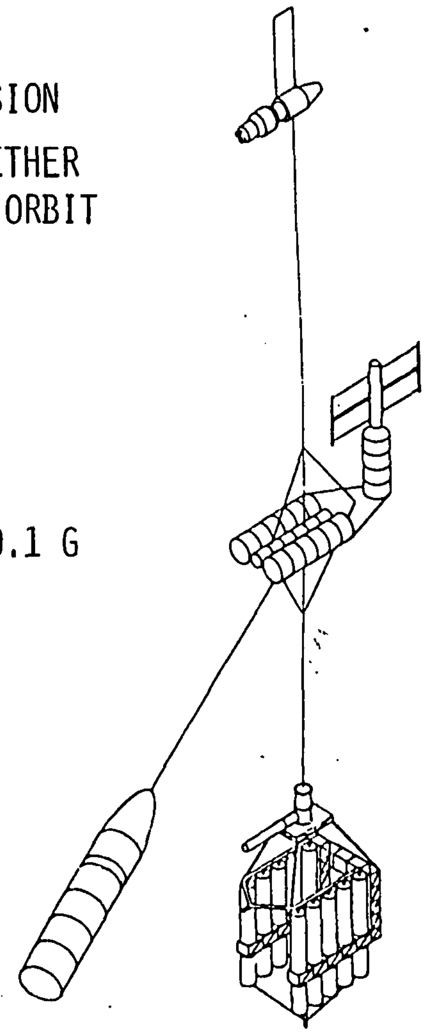
A. TETHERING SPACECRAFT WAS INITIALLY ATTEMPTED ON GEMINI 6/7 MISSION

B. LEVEL OF G (GRAVITY) OBTAINABLE IS PROPORTIONAL TO LENGTH OF TETHER FROM CENTER OF SYSTEM MASS & EQUALS 4×10^{-4} G/KM IN LOW EARTH ORBIT

C. ADVANTAGE:
1. FREE OF THE LARGE 'FLOOR TO CEILING' G VARIATIONS AND
2. DEBILITATING/UNPLEASANT CORIOLIS EFFECTS
3. TWO AXIS STABILIZATION

D. G-LEVEL ATTAINABLE:
1. TETHER BECOMES SIGNIFICANT PART OF STATION MASS TO ACHIEVE 0.1 G
2. TETHER MASS IS RELATIVELY MINOR FOR 0.05 G's OR LESS

E. APPLICATIONS AT 0.01 TO 0.1 G IN A STATION:
1. SIMPLIFICATION OF CERTAIN CREW AIDS/ACOUTREMENTS (IVA)
2. FACILITATE LIQUID'S FLOW (SHOWER/TOILET) - (IVA)
3. MINIMIZATION OF SMALL LOOSE FLOATING OBJECTS (IVA)
4. ENHANCEMENT OF TOOL USE VIA TETHER ELIMINATION (IVA)
5. VARIABLE G FOR PHYSICS/LIFE SCIENCE/COMMERCIAL RESEARCH



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TETHER IMPLICATIONS & ARTIFICIAL GRAVITY (Continued)

F. GENERAL APPLICATIONS OF ARTIFICAL G FOR TETHERED 'ELEMENTS':

1. LARGE FACILITY (TANK FARM, WAREHOUSE, ASSY./PLTFM., HANGAR, ETC) I/F
2. FACILITATE PROPELLANT ACQUISITION/STOWAGE/TRANSFER
3. REMOTE DOCKING PORT
4. LOGISTICS STOWAGE
5. SAFETY/RESCUE SHELTER
6. CONSTELLATION GROUPING
7. DISCONNECT ENERGY SOURCE
8. POWER GENERATION
9. SCIENCE APPLICATIONS (E.G.):
   - LOW ALTITUDE
     - GRAVITY & MAGNETIC FIELD MAPPING
     - POLLUTANT MEASUREMENTS
     - CALIBRATION OF SENSORS
     - RE-ENTRY RESEARCH
     - EARTH OBSERVATION
     - PLASMA PHYSICS
   - RELEASE OF CHEMICALS TO STIMULATE VARIOUS UPPER ATMOSPHERIC EFFECTS
   - ALPHA WAVE ANALYSES
   - TOWING OF AERODYNAMIC MODELS

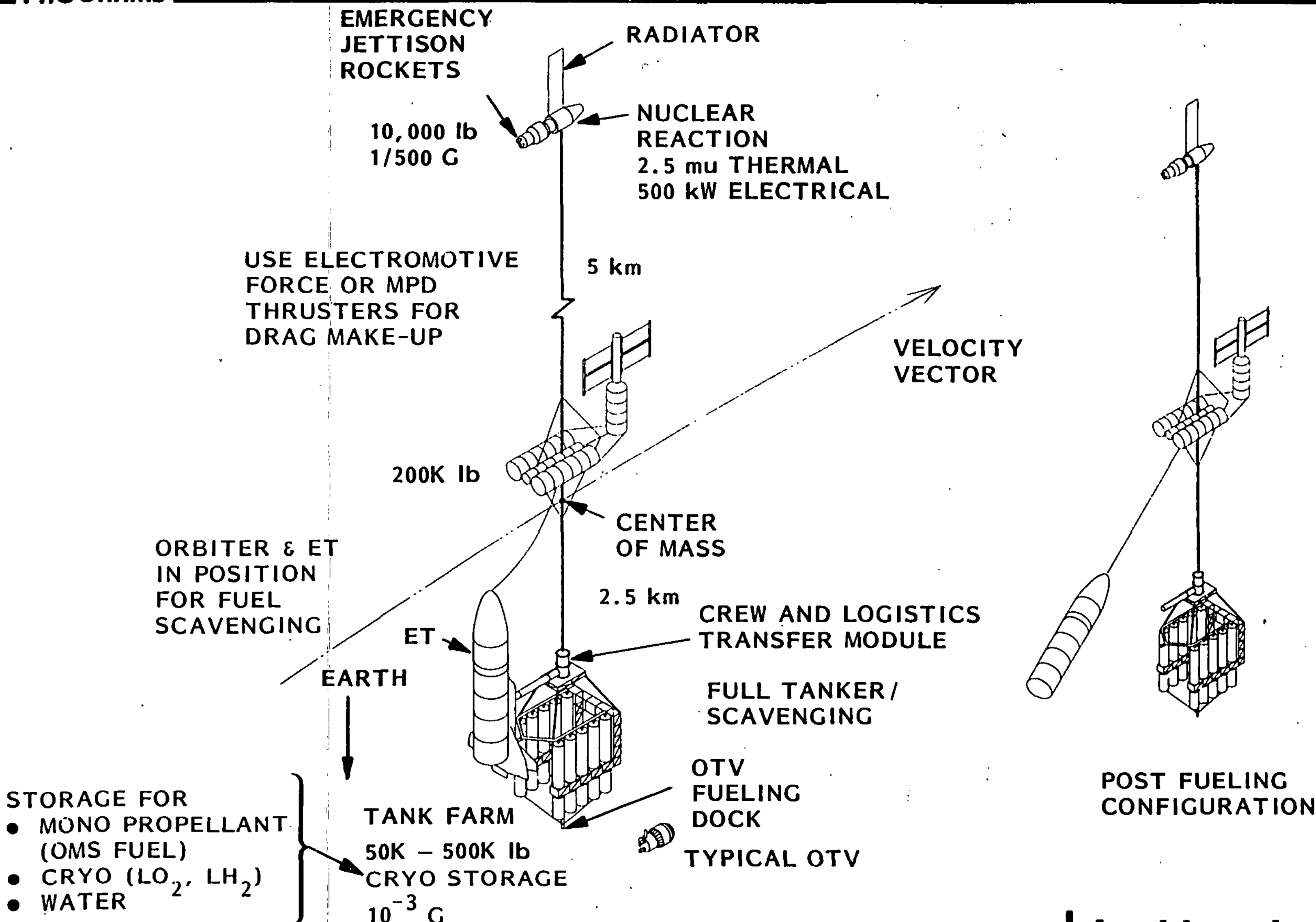
SPACE STATION TETHER CONCEPTS

Two important applications of the tether are shown in the figure on the facing page. One important application of a space station will be propellant storage for use in OTVs and for logistics support to satellites. A key challenge is orienting fluids in a zero g environment. The use of a tether to support a propellant farm provides a solution to this challenging technical issue. A 2.5 km tether will create 10^{-3}g, sufficient to orient propellants thus making the fluid transfer possible with a minimal difficulty. In our concept the space shuttle orbiter with the external tank attached could be docked to the propellant farm to allow scavenging of the residual propellant. The orbit mechanics of this berthing operation need to be studied from the point of view of orbiter safety since the tank farm is moving in a slightly different (slower) orbital speed than the orbiter at that altitude. The differences in velocity are small and should be accommodated with minimal difficulty. Payloads could be removed from the orbiter while berthed to the tank farm and tranferred to the space station by a tether. The propellant farm has been sized to 500 klb to accommodate 12 missions per year at 25klb per service mission.

Another application of tethers is to support a nuclear reactor. Initial station configurations will use solar arrays for power ranging up to 50 kw. Long term high power requirements will be required and a nuclear reactor is an ideal choice for that purpose. By placing the reactor on the end of a tether the shielding requirements are dramatically reduced and safety of the system is enhanced. Analysis has shown that for transmission of 100 kW, the tether, operating at 10 KV, will weigh less than 1000 lbs. For a 300 KW system, the tether weight for a 10km tether will be 6000 lbs. The reduction in shielding weight more than offsets the increase in tether weight as the reactor is moved away from the station.. The tether also provides the opportunity to use electromotive force induced by a current cutting the earths magnetic field as a means of providing for drag makeup and orbit change. Approximately 0.2 lbs thrust is obtained for 15 kw. Details and impact of the tether design on the overall system need to be assessed but it is clear that this concept offers some startling new opportunities for the space station configuraiton.

SPACE STATION PROGRAMS

TETHER CONCEPTS



TYPICAL STA. HDWR IMPACT FOR ARTIFICIAL G (STANDARD ROTATION)

Various impacts are encountered when designing a station which incorporates artificial gravity via the technique of rotation about a centerpoint. The impacts cover a range of interfaces, structural considerations, free swept volume constraints, etc. Several of these impacts are of highly significant nature and certainly would drive the overall station architecture. In particular, inertial reference or earth viewing requirements are substantially affected if those sensors are positioned on the rotational portion of the space station. It has been concluded by NASA that a rotational space station is a 'lesser desireable' architectural option based on studies conducted over the past 5 to 10 years. Industry has also given considerable study to the subject. In light of the extensive constraints evidenced by providing rotational capability when compared to the fairly 'limited' advantages gained in partial gravity, it has been concluded that minimum architectural effort be expended for a design concept embodying an artificial G approach through the medium of full station rotation.

TYPICAL STA. HARDWARE IMPACT FOR ARTIFICIAL G (STANDARD ROTATION)

A. STATIC SOLAR ARRAY MTG

OR

B. NON-USE OF SOLAR ARRAYS

C. SPIN-UP/SPIN DOWN RCS

D. INSTR./LAB POINTING/STABILITY
- STATIC MOUNT
- DECOUPLE

E. REDUCED FLEXIBILITY IN HABITAT L/O

F. REDUCED CREW WK.STA. LAYOUT ACCESS

G. ADDED HARDWARE SUBELEMENTS
- ROTATION HUB
- ROTATION SYSTEM
- INTERCONNECTING SPOKES OR
- INTERCONNECTING VOLS/AREAS
- MECHANISMS AND BACKUPS
- SLIPRINGS
- AIRLOCKS/HATCHES
- ETC.

H. STA. STABILIZATION MAINTENANCE

I. ORBITER & XPORT S/C VISIT CONSTRAINTS

J. SAFETY-RESCUE CONSTRAINTS

K. CONSTRUCTION/ASSEMBLY CONSTRAINTS

L. INTRINSIC STATION OPS CONSTRAINTS

M. ADDED STA. DELTA WT. FOR ROTATE CAPABILITY

N. ANTENNA POINTING CONSTRAINTS
- STATIC MOUNT
- MULTIPLE LOCATIONS
- STEERABLE
- DECOUPLE

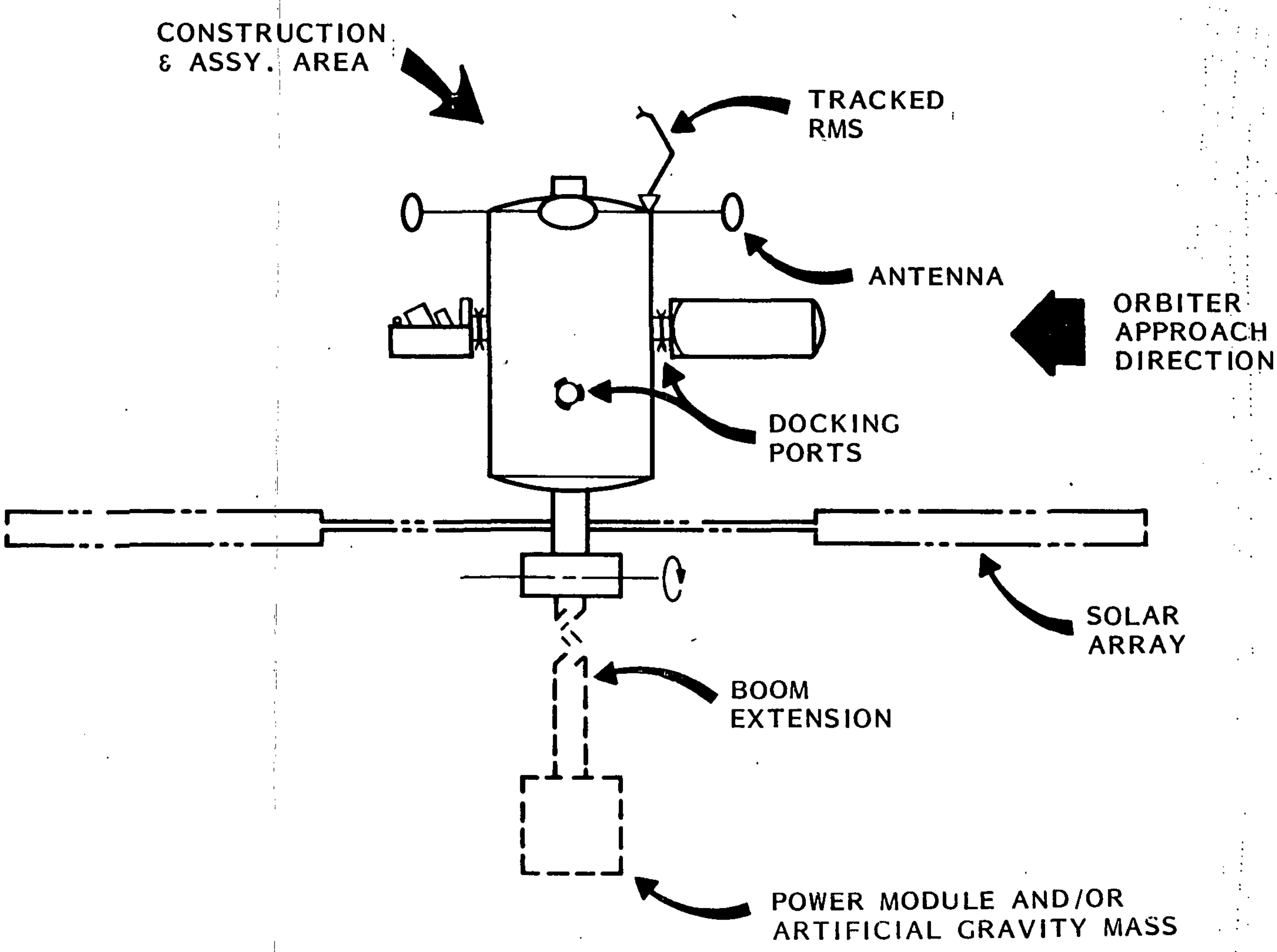
O. ADD-ON HDWR/LABS/HABITATS CONSTRAINTS
- LOCATION & MTG. I/Fs.
- STRUCTURAL STABILITY
- CENTER OF GRAVITY

STAY-OUT ENVELOPES (FREE SWEPT VOL.) (SCHEMATIC)

During the course of the user needs survey, requirements analysis effort, and the conceptual layout studies, one of the prime impact areas encountered was that associated with stay-out envelopes. The facing page indicates, schematically, the typical areas or volumetric zones wherein approaching Orbiters and/or spacecraft should not encroach. This factor is very impactful to the architectural analysis study and provides a substantially major criteria point for architectural station design. The diagram does not attempt to illustrate the stay-out area encountered when a major plume (pressure/temperature/contaminate) impinges upon the station and/or an extended appendage.

The stay out areas are further compounded if the station is in an artificial g spin mode. Further restrictions are very likely for this type of operation. Also to be considered is the post impact gyration encountered when a spacecraft docks to the station and docking/engagement dynamic motions are observed. These impact gyrations could, on a long spacecraft, exceed in diameter the allowable free swept volume.

STAY-OUT ENVELOPES (FREE SWEPT VOL) SCHEMATIC



SPACE STATION PROGRAMS

TASK 2—MISSION IMPLEMENTATION CONCEPTS

2.1 MISSION SCENARIO ANALYSIS AND ARCHITECTURAL CONCEPTS
2.2 ALTERNATIVE SYSTEMS CONCEPTS
2.3 MISSION OPERATIONS ARCHITECTURAL DEVELOPMENT
2.4 ARCHITECTURAL ANALYSIS TRADES
2.5 EVOLUTION
2.6 CONFIGURATION
2.7 TECHNOLOGY DEVELOPMENT
2.8 CONCLUSIONS

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BASIC ELEMENT HARDWARE CANDIDATES

Numerous existing, planned, and/or conceptual hardware candidates exist from which to select potential station sub-elements as a basis of constitutional make-up of the overall architecture. The facing page indicates, in schematic form, several potentially viable hardware concepts from which to select station sub-elements (or pieces). Assuming a parallel path development of either external tank or solid rocket booster elements, several sub-assemblies appear as potential candidates as follows:

- External tank barrel section = 27.5 ft. dia. by 26.5 ft. long; weight = Approx. 22,400 lbs.
- External tank forward skirt = 27.5 ft. dia. by 10.5 ft. long; weight = Approx. 8875 lbs.
- External tank dome = 27.5 dia. and approximate weight = 3400 lbs.
- Solid Rocket Booster forward skirt = 146 in. O.D. by 10.75 ft. long; weight = Approx. 6353 lbs.

The Aft Cargo Carrier (ACC) varies in diameter and length, however, it is anticipated that general dimension are approximately 27.5 ft. in diameter by 22.5 ft. in length. Internal volume is about 13,360 cu. ft. Other hardware candidates are illustrated and include tailored and unique designs.

BASIC ELEMENT HARDWARE CANDIDATES

A. SPACELAB ELEMENT

B. TAILORED HYBRID HABITAT/LAB ELEMENT

C. MODULAR HABITAT/LAB ELEMENT

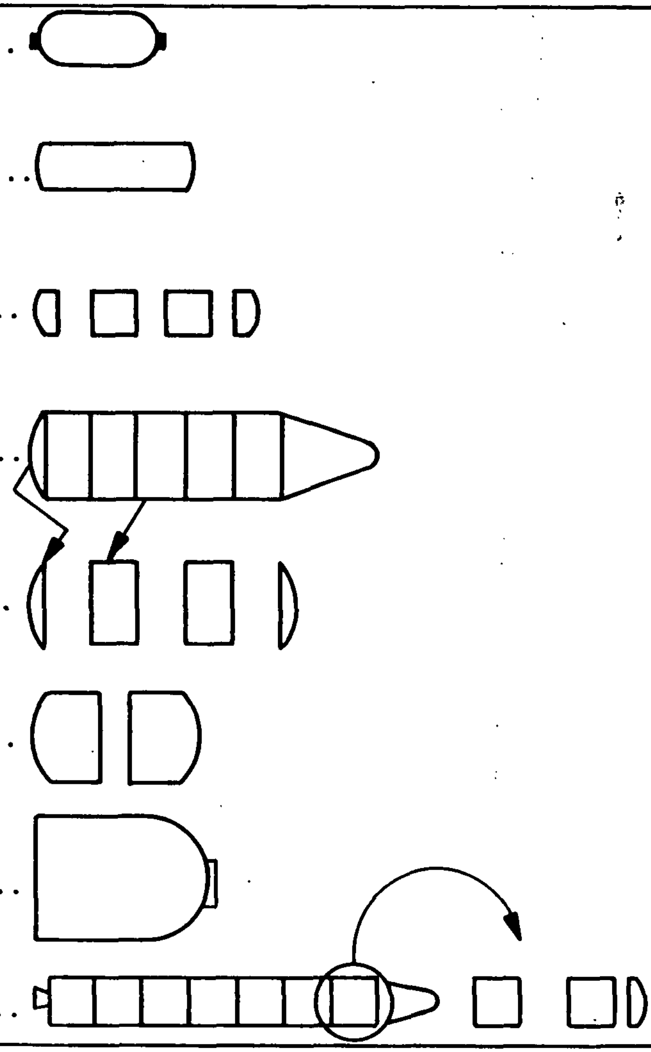
D. STS EXTERNAL TANK ELEMENT

E. STS EXT. TANK SUB-ELEMENT

F. AFT CARGO CARRIER

G. BASIC 'LARGE DIAMETER' MODULE ELEMENT

H. SOLID ROCKET BOOSTER SUB-ELEMENT



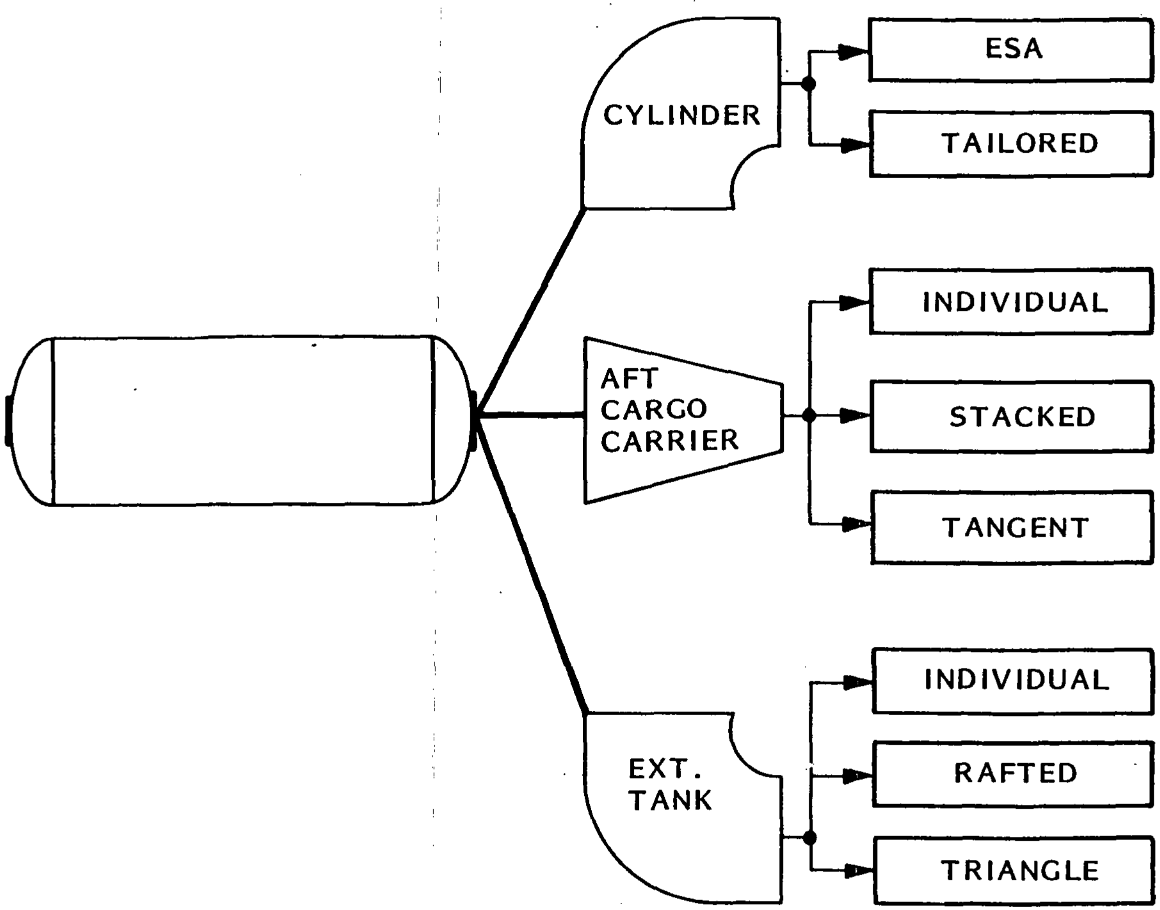
CANDIDATE MANNED HABITAT SOURCES (SELECTED)

A number of candidate sources exist from which habitable environments for the station could be selected and or evolved. The facing page illustrates several candidate sources. Tailored examples are simply those habitats which are designed from the 'ground-up'. The Aft Cargo Carrier (ACC) is still in the conceptual phase for any assembled configuration. The external tank (ET) would be a carried to orbit element which would require on-orbit passivation by an Orbiter based crew.

These candidates are for reference only, and provide a potential study inventory for development of station architectural concepts. Other design candidates are also viable for study and necessitate further examination and evaluation.

SPACE STATION PROGRAMS

CANDIDATE MANNED HABITAT SOURCES (SELECTED)



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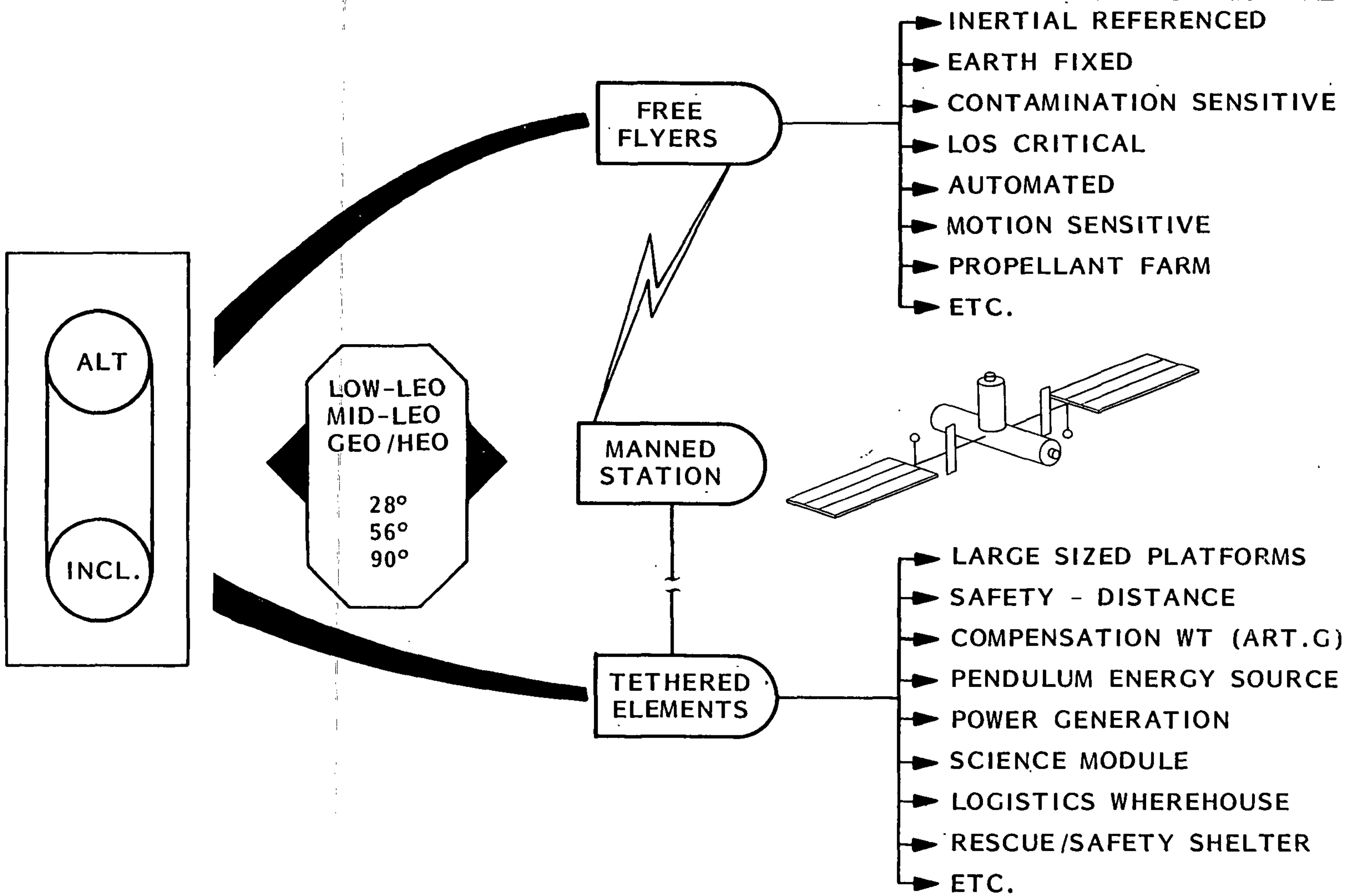
STATION ASSOCIATED FREE-FLYERS & TETHERED ITEMS

As indicated in the facing page, both altitude and inclination are of substantial concern when considering the option of providing either a free-flyer and/or tethered element. Typical free flyer operational uses are illustrated as are the tethered elements. Although the tether concept is not new (Ageni/Gemini flights 6/7), the concept of using this approach for the NASA stations has only recently been considered in any substantial depth. The use of the tethered satellite will occur in conjunction with the Orbiter and is planned for flight in the mid 1985 to 1990 timeframe.

Considerable interest has recently been generated in the tether concept and, initial reports indicate some potential. Implications for station architecture may be signficant particularly as they relate to attached mission payloads which may now be considered as tethered items. Station interface and resultant dynamics with the free flyers and/or tethered elements appears to require further investigation. Particularly attractive aspects include tethering nuclear power sources, logistics warehouse, rescue/safety shelters, etc.

SPACE STATION PROGRAMS

STATION ASSOCIATED FREE-FLYERS & TETHERED ITEMS



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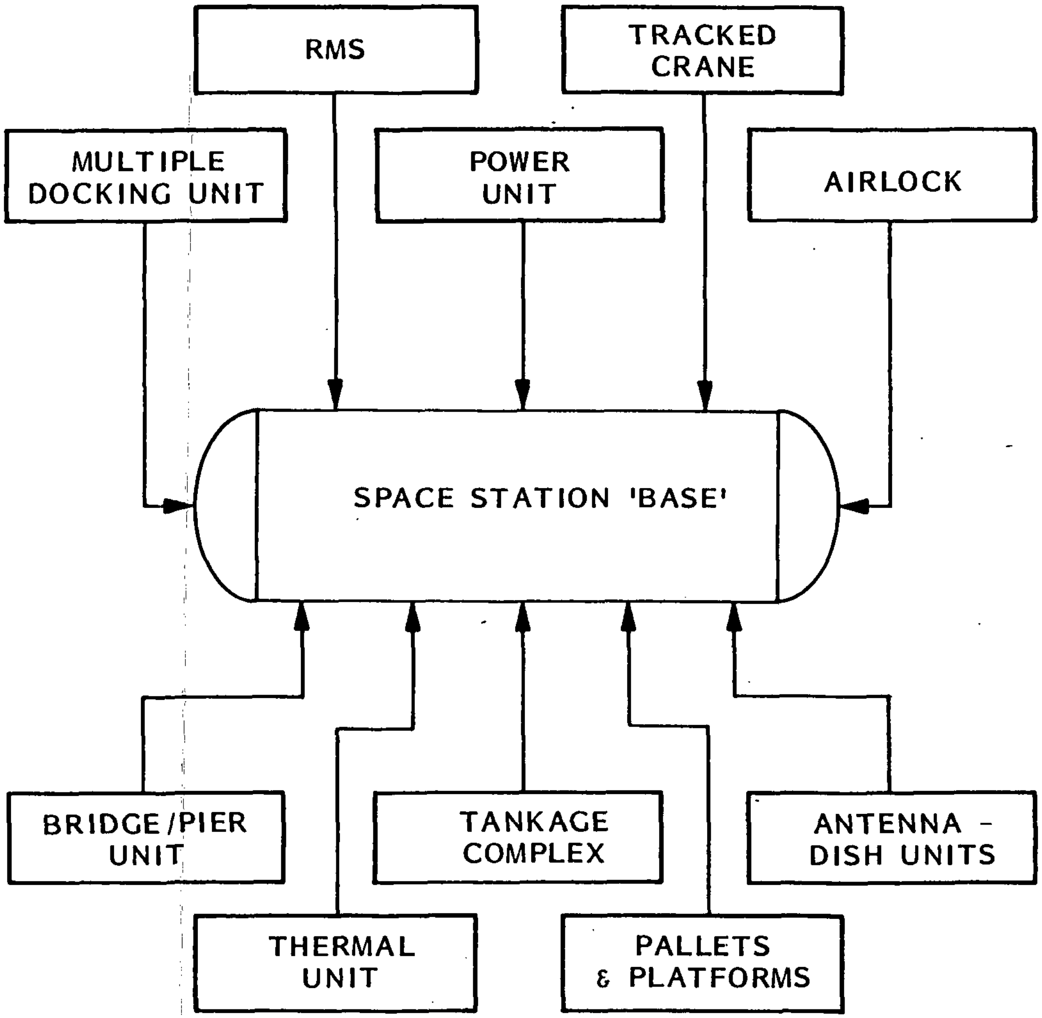
TYPICAL STATION MODULES

A number of station 'modules' will be developed to support basic station opertions and mission support functions. As schematically represented on the opposite page, there is a compliment which can be considered almost as a standard cadre from which to select. Certain modules may be attached directly to the station element being delivered to orbit while others, e.g., RMS's, Cranes, bridge/pier units, palles/platforms, etc., may be delivered on scheduled launches for attachment to the already existing station. The degree of modularity vs built-in capability requires further examination prior to formal design integration. Each affects the architectural development concept, evolution sequence, launch cargo allocation, cost phasing, etc., and, accordingly, must be considered in the overall aggregate of the architectural composite.

SPACE STATION PROGRAMS

TYPICAL STATION MODULES



RATIONALE FOR STATION EVOLUTION

Complete and fully justified station evolution rationale is beyond the scope, and current state of mission/user need definition at this time. Nonetheless, several important and pivotal issues can be identified which bear upon the evolution consideration. Presently, six basic categories have been defined wherein the rationale has been allocated and are:

- Programatics
- Expand Capabilities
- Operational Enhancement
- User Needs
- Research & Development
- Demonstrations/Technology

Nearly 60 discrete rational items have been identified and many have sub-factors which further expand the list. The following pages address the currently envisioned rationale per each category. They are, in general, self explanatory and need little further amplification as to meaning. Subsequent future studies could logically be addressed as to the substantive impact of each and the associated relative merit. Of all the rationale presented, that category associated with the sub-category (under Programmatics) entitled 'Intangables' proves to be the most difficult to deal with in terms of methods of substantiation, dollar or instrinsic value, benefit, and importance. Certainly, NASA budget forecasts are difficult to portray at this time, thus, the budgetary picture is also elusive.

The general composite of rationale for evolution were submitted to and applied in the generic studies of conceptual station architectural definition and 'build-up'. As the concepts were narrowed, the rationale became more important, particularly as to the evolutionary stepped build-up sequence and the associated costing implications.

SPACE STATION PROGRAMS

RATIONALE FOR STATION EVOLUTION

PROGRAMMATICS

1. PLANNED & ORCHESTRATED STAGED BUDGETARY ALLOCATIONS
2. POSSIBLE FINANCIAL PARTICIPATION BY FOREIGN NATIONALS
3. ENABLE GREATER SENSITIVITY TO FUTURE OUT-YEAR FUNDING PLANNING
4. PRECLUDE MUTUALLY EXCLUSIVE DEAD-END DEVELOPMENT EFFORTS
5. GREATER UTILIZATION OF STS RESIDUALS (E.G., EXTERNAL TANK)
6. PROVIDE FOR AND/OR ENHANCE INTANGIBLES
   - NATIONAL PRESTIGE
   - NATIONAL SECURITY
   - TECHNOLOGY TRANSFER
   - SUPPORT TO FOREIGN POLICY
   - SUPPORT TO PRIVATE/EDUCATION SECTOR

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RATIONALE FOR STATION EVOLUTION

EXPANDED CAPABILITIES

1. INCREASE IN OTV BASING/OPS
2. ADDED S/C SERVICING ATTACHED/REMOTE
3. RESOURCES TO CONDUCT FULL ON-ORBIT M&R
4. INCREASED CAPABILITY TO DOCK ATTACHED P/Ls (E.G., LABS) FOR 6-12 MONTH ORBIT STAY
5. INCREASED LOGISTICS STORAGE TO REDUCE ORBITER LOGISTICS LAUNCHES OR SHARED RIDES
6. INCREASED VOL. FOR INTEGRAL OR ATTACHED P/L SYSTEM UPGRADE/ADDITION
7. INCREASED PIER/COLUMN (OR SUPPORT) CAPABILITY FOR FIXED (AND/OR MOBILE) RMS(S)/CRANE(S)

EXPANDED CAPABILITIES

8. ADDED STA. PIERS/BEAMS TO PROVIDE SUPPLEMENTAL SUPPORT STRUCT. STRENGTHENING
9. INCREASED NO. OF HABITATS/LABS OR VOLUME TO FACILITATE ADDED FUNCTIONS
10. EXPAND 'HANGAR' FACILITIES
11. INCREASE IN RADIATOR AREA TO ACCOMMODATE ADDED CYCLIC OPERATIONS
12. ACCOMMODATE LARGER EQUIPMENT SUBSYSTEMS
13. INCREASED POWER TO FACILITATE SUPPLEMENTED AND/OR ADDED FUNCTIONS/SUPPORT
14. PROVIDE BASE FOR ADVANCED EVA AND 'ENCLOSED' CREW DETACHED WORK SYSTEMS

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SPACE STATION PROGRAMS

RATIONALE FOR STATION EVOLUTION

OPERATIONAL ENHANCEMENT

1. SYNERGISTIC USE OF MAN
2. INNOVATIVE & SERENDIPITOUS USE OF MAN, PARTICULARLY FOR R&D AND TECHNOL. DEMANDS
3. INCREASED ORBITAL CAPABILITY TO SUPPORT MAN'S RESIDENCE TO SET UP/ASSEMBLE, C/O, & VERIFY, E.G.:
   - LARGE STRUCTURES/PLATFORMS
   - LARGE ANTENNAS/REFLECTORS,
   - MULTISTAGE ASSY.
   - REMOTE SERVICING
   - HEO/GEO SUPPORT
   - SPACE PROCESSING
4. CENTRALIZED BASING OF MULTI-ORBIT OPS
5. ADDED STATION, E.G., 57-58°

OPERATIONAL ENHANCEMENT

6. MULTI-SIMULTANEOUS OPS
7. INTERACTION WITH LARGER LAUNCH VEHICLE
8. ADDED CAPABILITY FOR MULTI-ORBITER 'VISITS'
9. INCREASED ON-ORBIT DATA HANDLING/ PROCESSING/SORTING/STORAGE TO ACHIEVE SIGNIFICANT REDUCTION IN GROUND STATION INTERACTION
10. INCREASED HABITABILITY PROVISIONS AND FREE VOL. FOR 'EXISTING' AND EXPANDED CREWS
11. HABITABILITY VOL. GROWTH FROM 'ACCEPTABLE' TO 'HIGHLY DESIRABLE'
12. TO ALLEVIATE PROBLEM OF 'TOO MANY OPS-P/L ACTIVITIES' IN THE SAME VOL. AS CREW QUARTERS
13. ADDED SAFETY/RESCUE RESOURCES FOR LARGER MULTISHIFT CREWS

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RATIONALE FOR STATION EVOLUTION

USER NEEDS

1. INCREASE CREW SIZE & FULL 24-HR SHIFT OPS
2. EXPERIMENT ALLOCATION FLEXIBILITY NEEDS
3. ADDED DOD EXPER/TECHNOLOGY PROFILE
4. EXTENDED MATERIALS PROCESSING (WT/VOL/PWR)
5. INTERNATIONAL PARTICIPATION
6. COMMERCIAL PARTICIPATION AND INVESTMENT
7. LONGER FLIGHTS REQUIRING MANNED INTERACTION
8. LONGER TERM ON-ORBIT RESIDENCE (& SUPPORT) TO PARTICIPATE IN INTERMITTENT/INFREQUENT SPACE PHENOMENA, E.G.:
   - OCEANOGRAPHIC
   - SOLAR TERRESTRIAL
9. ADDED CAPABILITY TO TEND LONG-TERM CONTINUALLY-MONITORED/ PERIODICALLY-TENDED SPACE PROCESSING EXP/PROJECTS
10. ABILITY TO ACCOMMODATE (AS YET) UNDEFINED REQTS. AND ULTIMATE USER NEEDS

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SPACE STATION PROGRAMS

RATIONALE FOR STATION EVOLUTION

(CONTINUED)

OPERATIONAL ENHANCEMENT

14. ADDED CAPABILITY TO SUPPORT 'NEAR PLANETARY' MANNED EXPLORATION
15. DEDICATION OF STATION TO ACHIEVE CONTINUOUS 24-HR CREW INTERACTION WITH STATION INTEGRAL, ATTACHED AND FREE-FLY SYS. OPS.
16. TO MEET INCREASED DEMAND FOR SPACE SUPPORT NOT ACHIEVABLE BY STS FLEET SIZE VS ORBIT STAY-TIME

OPERATIONAL ENHANCEMENT

17. ACCOMMODATE MORE SIMPLIFIED AND SAFE S/C SERVICING WITHIN 'ENCLOSED/ PROTECTED AREAS'
18. PROVIDE RESOURCES FOR DETACHED (FREE-FLY) P/Ls, E.G.:
    - SERVICING BASE
    - DATA/HANDLING MGMT.
    - POWER XMIT
    - LOGISTICS RESUPPLY
19. CAPABILITY FOR 'BREAKAWAY' ELEMENT THAT IS MANEUVERABLE

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RATIONALE FOR STATION EVOLUTION

R&D

1. ADDED SCOPE OF R&D ACTIVITIES
   - INCREASED NUMBER
   - INCREASED CAPABILITY (WT/PWR/VOL)
   - ADDED SUPPORT PERSONNEL & FULL SHIFT OPS
   - ADDED ON-ORBIT TIME INCREMENTS (EQUIP. TIE-UP)
   - EXPANDED SUPPORT NEEDS
   - INCREASED LOGISTICS
   - POTENTIAL REMOTE OPS
2. INCREASED STRUCTURE AND HDWR TO FACILITATE ARTIFICIAL GRAVITY
3. ADDED CAPABILITY TO EXAMINE LONG-TERM EFFECTS ON BIOLOGICAL/ PLANT/ANIMAL SPECIMENS
   - NON-HUMAN MODELS
   - RESEARCH ON IN-FLT GROWN SUSTENANCE
   - CONTINUED-DIRECT P.I. INTERACTION
   - SERENDIPITY INTERACTION
4. EVALUATION OF LONG-TERM CREW RESIDENCY

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RATIONALE FOR STATION EVOLUTION

DEMONSTRATIONS

1. ADDED CAPABILITY FOR LONGER TERM TECHNOLOGY DEMONSTRATIONS, E.G.:
   - OTV TECHNOLOGY
   - SPACECRAFT SERVICING (REMOTE/ATTACHED)
   - RENDEZVOUS/DOCKING/REENTRY TECHNOLOGY
   - ECLSS TECHNOLOGY
   - LARGE STRUCTURE BUILDUP/ASSY TECHNOLOGY
   - FLUIDS HANDLING/TRANSFER-LARGER SCALE
   - ON-ORBIT LARGE STRUCT. ALIGNMENT
2. LARGE EXPERIMENTS, STRUCTURES, AND DEVICES REQUIRING O-G FOR DEMONSTRATION AND VERIFICATION
3. FACILITATE DoD/DARPA/ET AL. R&D/DEMO ACTIVITIES
4. 'INCREMENTAL' LARGE STRUCT. ASSY BUILDUP
5. ACCOMMODATE DMS ENHANCEMENTS AS ENABLING TECHNOLOGY ADVANCES

FUNCTIONS

The reference station will provide as a minimum, the following functions at the dates shown to ensure effective use of the various systems as they develop and mature.

- HABITATION
- LABORATORY - DEVELOPMENT
  - GENERAL
- PROPELLANT STORAGE
- PROPELLANT TRANSFER
- SPACECRAFT/SATELLITE SERVICING
- LOGISTICS
- STAGE ASSEMBLY/INTEGRATION
- DOCKING
- TRANSPORTATION SYSTEM SUPPORT
- CONSTRUCTION/ASSEMBLY (LARGE)
- MISSIONS CONTROL
- RESCUE/EMERGENCY
- ATTACHED PLATFORM
- FREE FLYING PLATFORM

IDENTIFIED FUNCTIONS NEED DATE

FUNCTION	DATE 1990		1992		1994		1996		1998		2000
HABITATION	X										
LABORATORY	X										
PROPELLANT - STORAGE			X								
- TRANSFER			X								
SPACECRAFT SERVICING				X							
LOGISTICS (MODULE)		X									
STAGE (S/C) ASSY			X								
DOCKING		X									
TRANSPORTATION SYS. SUPPORT			X								
LARGE STRUCT. ASSY					X						
MISSIONS CONTROL		X							M		
RESCUE							X				
PLATFORM - ATTACHED		X									
- FF			X								
COMMAND POST									X		

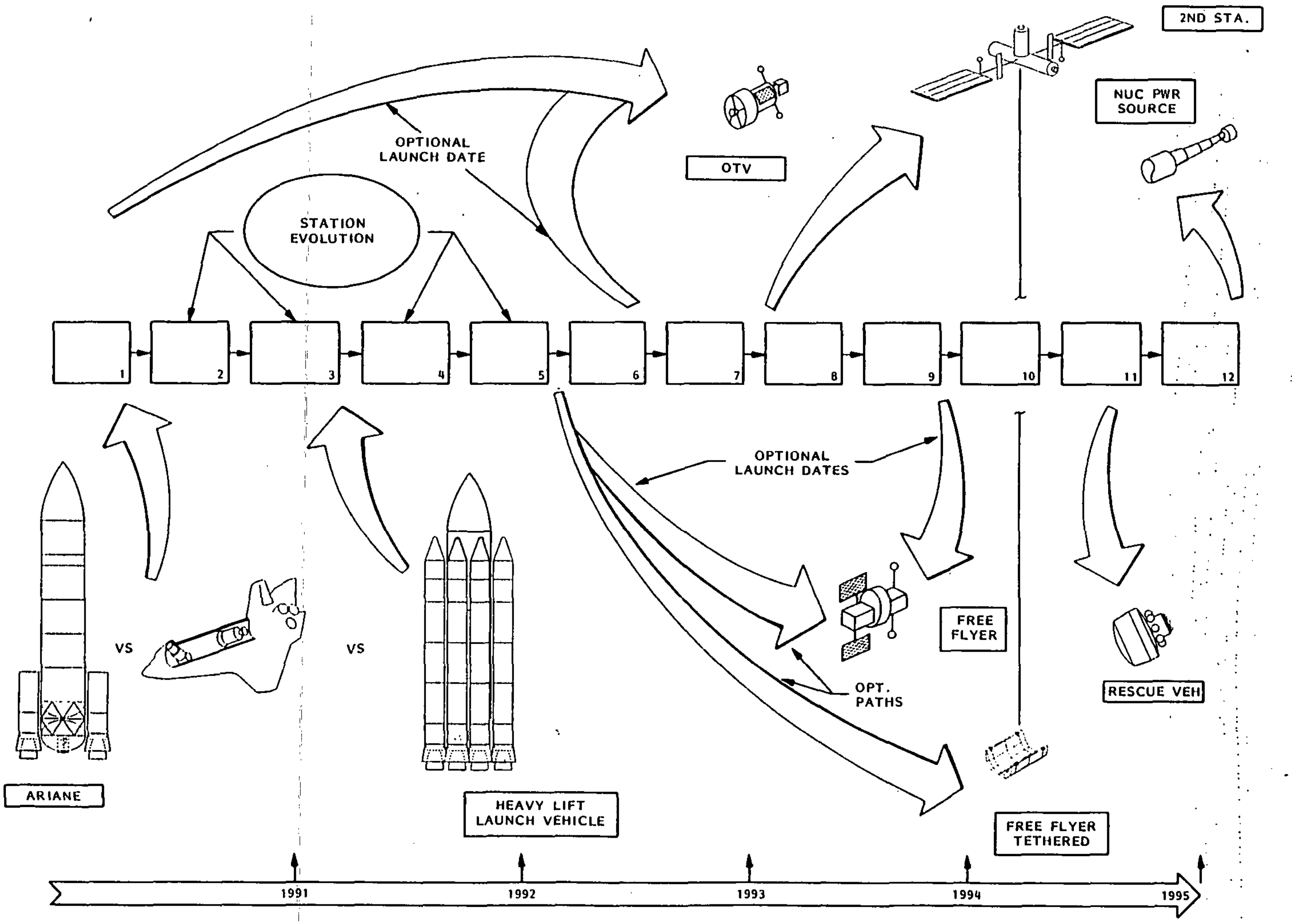
OPTIONS IN STATION SUPPORT/DEVELOPMENT

The station growth and evolution sequence has been defined in a series of 12 discrete steps (discussed in subsequent pages). A myriad of alternative support and development options are currently being addressed, however, a selected few are presented on the facing page to illustrate their significance. Although this study used the Orbiter as the primary launch vehicle, options such as the Ariane and Heavy Launch Vehicle (or similar vehicles) have been suggested as potential station support elements. Availability of the HLV is problematical whereas the Ariane is an existing program with solid plans for uprating, thus, possible future consideration of the Ariane as an unmanned launch vehicle for station sub-elements and/or logistics may be worthy of examination particularly if European participation is desired.

The need for an orbital transport vehicle is highly viable, however, the RDT&E date for station application support has not been formally established (e.g., 1990 to 1993 time frame). Similarly, the numbers, types, and capabilities of the free flyers anticipated for the 1990 to 2000 time frame are somewhat soft at this time, however, every indication tends to support the potential of their availability beginning late 1991 and continuing thereafter. The potential application of certain of these free flyers to more simplified payloads exists relative to the possiblility of tethering these from the station itself.

A second (or 3rd) station potential exists and could be implemented as early as 1994/5. In association with the station(s) will be the need for a rescue vehicle (with multi-purpose applications) which could come on line in the mid-1990's. A nuclear power source may be required for the Command Post Module (DoD mission/program), thus, it may launched as early as 1995. This power source may also have application to station tethered uses for supplemental power.

OPTIONS IN STATION EVOLUTION



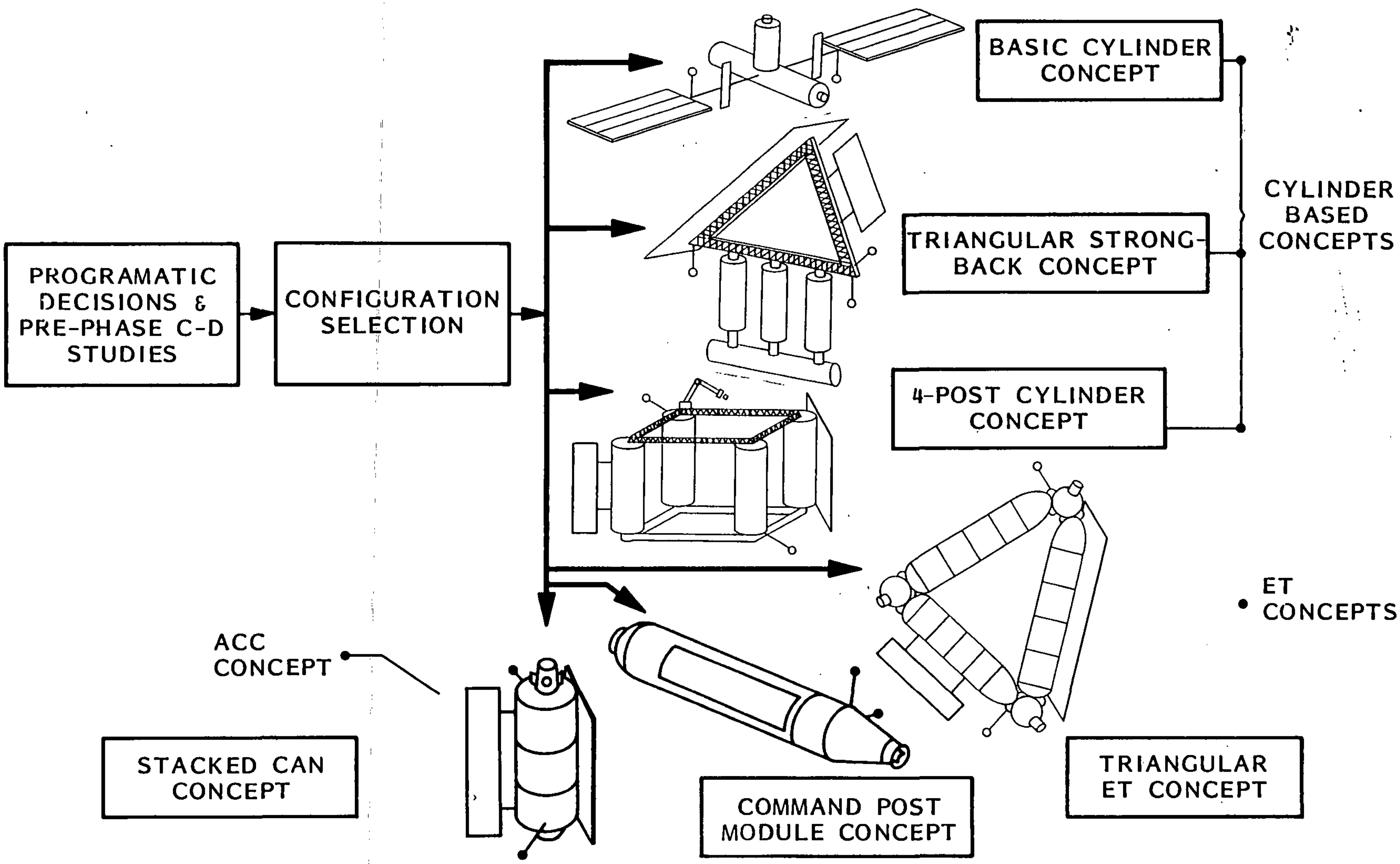
ALTERNATE STATION DEVELOPMENT PATHS (CONCEPTUAL)

A number of alternate space station configuration paths are currently under consideration. The facing page indicates a selected sample of the candidates which are presently being examined. Other configurations are also being addressed such as the triangular 'pup-tent', clustered tanks, clustered aft cargo carriers, etc. A previously set of assessment and evaluation criteria is being applied to each configuration to determine the feasibility of initial development and the ultimate growth and evolution.

It is planned to consider specific NASA sub-elements, e.g., habitats, airlocks, docking modules, the external tank itself, etc., as integral US National Defense hardware which can be allocated to the Command Post Module. Thus, a parallel path approach has been established for the combined development effort anticipated for the development of the NASA station and the DoD Command Post Module.

Viability of the alternatives in terms of specific design and cost data would require further study and design effort. However, for purposes of study and costing, the basic cylinder concept has been used as the reference baseline. Furthermore, this configuration holds up well relative to criteria and assessment examination. Accordingly, the basic cylindrical approach maintains the opportunity to further study similar alternatives yet maintaining the basis for the Command Post Module.

ALTERNATE STATION DEVELOPMENT PATHS (CONCEPTUAL)



SPACE STATION PROGRAMS

TASK 2—MISSION IMPLEMENTATION CONCEPTS

2.1 MISSION SCENARIO ANALYSIS AND ARCHITECTURAL CONCEPTS

2.2 ALTERNATIVE SYSTEMS CONCEPTS

2.3 MISSION OPERATIONS ARCHITECTURAL DEVELOPMENT

2.4 ARCHITECTURAL ANALYSIS TRADES

2.5 EVOLUTION

2.6 CONFIGURATION

2.7 TECHNOLOGY DEVELOPMENT

2.8 CONCLUSIONS

Lockheed

SPACE STATION ARCHITECTURE - CONFIGURATION

The five major configuration alternatives for the space station are symbolized on this chart and discussed in this section.

The principal system design drivers for all of these configurations are listed below:

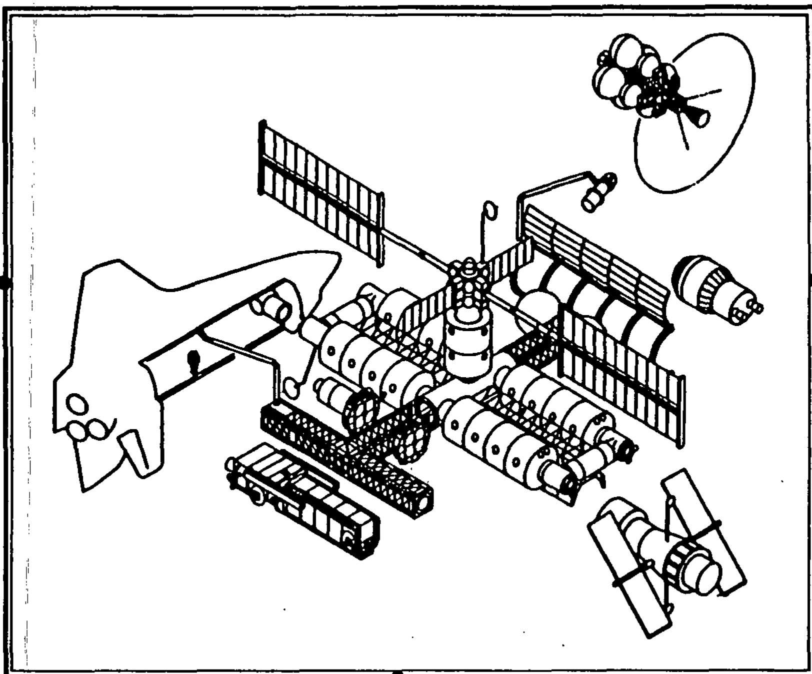
- CONTROL, STABILITY, POINTING
- ORIENTATION; EARTH FIXED/INERTIAL/COMBINATIONS
- SAFETY
- CREW SIZE
- DOCKING CAPABILITY
- PAYLOAD ACCOMODATION AND FOV
- ANTENNAE FOV
- MASS PROPERTIES, M OF I + CG EXCURSIONS
- POWER SUPPLY TYPE + ORIENTATION
- RCS PLUME INPINGEMENT/CONTAMINATION
- OTV + VISITING SPACECRAFT OPERATIONS
- SERVICING
- MODULARITY, EVOLUTIONARY
- THERMAL CONTROL
- LAUNCH CONFIGURATION
- EVA

The shuttle is always used as the basic transportation verhicle with a capability of 63,000 lbs to 150 NM orbit at 28.5° inclination, this is conservative as some projections suggest that by 1985, with all SRB, ET + shuttle improvements included, the capability could be as high as 80,000 lbs.

The probability of funding being available for the heavy lift shuttle configurations is considered low at this time. Therefore, heavy lift launch vehicles are not considered in this study.

In addition to the command post concept the military space station could be developed in the same way as the LMSC reference station; or it could be a series of free flyers operating around a basic core command system. These are numerous possibilities.

SPACE STATION ARCHITECTURE



INTEGRAL

DETACHED

ATTACHED

MOUNTED

TETHERED

SELECTED SCENARIO RELATED EQUIPMENT REQUIREMENTS

REFERENCE SPACE STATION

Fifteen of the selected scenarios referred to in Task 1, Mission Requirements, have been surveyed to see what types of equipment and experiments each requires.

The attached table summarizes these requirements and indicates that the space station must be a very versatile facility, with the ability to service all manner of payloads, spacecraft OTV's, etc., along with providing workspace (and equipment) and habitation for visiting scientific, engineering and military personnel.

SELECTED SCENARIO RELATED EQUIPMENT REQUIREMENTS

SCENARIO #	LIFETIME RESUPPLY	ALTITUDE	TOTAL MASS	POWER	INITIAL OP. DATE	EQUIPMENT	COMMENTS	DIMENSIONS	CREW SIZE	TRANSFER VEHICLE	POINTING REQUIREMENTS		FREE FLYER
12 COMMAND POST	10 YEAR	INC 28.5° 350 800 KM	90,000KG	15-50KW	1995				20 MAN CREW				
11 OCEAN DEV. LAB	3 6 MO/EXP. 10 YEAR	300 700KM INC. 60%	14,000KG	5KW	1988 1990	ESS OR PALLET	TO SUPT. EXPERIMENTAL HDWE & SENSORS	9.1x4.3M DIA. 9.1M ANT(SORTIE) 91M-FREE FLYER	2 EXPERIMENTORS 10 MAN CREW	(TMS)	—	COMM WITH MILSTAR-	
10 SPACE OBSERVATION	"	300 700KM 28.5°	"	4KW	"	"	"	" "	"	(TMS)	—		
6 EARTH HABITABILITY OBSERVATION LAB	10 YEAR	300KM	"	7KW	1990	"	ON BOARD STORAGE PROC. & SNAL. CONTINUOUS OPER.	9.1x4.3M DIA.	4-6	—	—		
3 CELESTIAL OBSERVATORY	"	300 400KM		1.4KW 5KW PEAK	1989-90	PALLET STARLAB 1,M UV WF TEL	CONTINUOUS SLEW RATE 180°/5 MIN. CONTAM-CONTROL	1.5M DIAx5M	?	?	10-30 SEC		YES
4 SPACE ENVIRONMENT FACILITY		400KM 57°	1500KG	10KW	1990	4 PALLETS	CONTINUOUS	7.6Mx4.3 (X) 3x4.3 + 3x4.3 -	?	—	—	LIMB THRU SOLAR OCCULT RADAR & MAGNETIC FIELD POINTING	
5 EARTH OBSERVATION FACILITY		400-600 57° 28.57	5000KG	6KW	1990	4 PALLETS	CONTINUOUS	7.6x4.3 DIA. 10.6M ANT. (SAR) 11M2.1M P.P.A.A.		(TMS)	—	TELESCOPE MOUNT FOR 3M TEL	
8 MAT. PROC. RESEARCH	3 6 YEARS	ANY	15,000KG	5-10KW	1990	SPACELAB SHIRTSLEEVE LAB	FIREWALL TO EXPERIMENT SECTION	10.5x4.3M	2-4	—	—		
9 MAT. PROC. FACILITY	10 20 YRS.	"	20,000KG 25,000K	10KW 15KW	1995	SUPPT 1 MAN FOR 2 DAY AT TIME FREE FLYER TENDED BY SPACE STATION		15.2x4.3M 50x14 FT.	?	—	—		YES
2 NON HUMAN RESEARCH LAB	10 3 6 MO.	28.5° +?	10,000KG	8KW	1990	EQ. TO SPACE LAB		7.6x4.3M	?	—	—		
1 HUMAN RESEARCH LAB	10 3 6 MO.	"	5000KG	4KW	1990	PART OF SPACE STATION		5 MAN	?	—	—		
7 METEOROLOGY FACILITY	NO LIMIT	400KM	1170KG	2KW		SCANNING MIRRORS		1.6x4.0x2.7M	?	—	POINT 6 MIN STAB. 6 SEC		YES
13 SPACE OBJECTS I. SYS.													
14 ON ORBIT SAT. SERV IN LEO	10	SAT # VARIOUS LOCATIONS 23.5°	NO MASS GIVEN	—		FUEL/OX STORAGE & TRANSFER			10	OTV MANNED & UNMANNED	—		
15 LARGE SAT. ASSY (SBR)	5 10	LEO TO HEO	15,000KG	—	1988 1993	60M (REFLECTOR) 225M ANT. 57A CONSTRUCTED WITH		—	?	PROP. MODULE LEO TO GEO TMS ?	PLATFORM STABILITY 1/10 OF ANT. BEAM WIDTH		

SPACE STATION HARDWARE ELEMENTS

A listing of the many hardware elements which in one way or another influence a space staion configuration is shown on the right. Envelope drawings and system mass properties of most of these are now entered into our Cadam data base and were used extensively during this study. Data sheets detailing design functions, performance, FOV, envelope geometry, weight, etc., have also been prepared to simplify and provide a common data base, in the configuration study process. Much of the data was obtained, and is referenced to, existing NASA and industry reports. It is recommended that NASA produce a similar data base for future space station study efforts, see Attachment 2, Volume II.

SPACE STATION PROGRAMS

SPACE STATION HARDWARE ELEMENTS

BASIC MODULES

HABITATION
AIRLOCK
DOCKING
COMMAND

STRUCTURAL MODULES

CYLINDERS
END BULKHEADS
ATTACHMENT FLANGES
VIEW PORTS

STATION & PAYLOAD HANDLING

RMS FIXED, TRAVELING
RMS MANNED
PIDA
HPA
F35
TILT TABLES
TURNTABLES
ROBOTICS
SMALL MANIPULATORS
GRAPPLE FITTINGS
SPECIAL END EFFECTORS
CHERRY PICKERS (OPEN CLOSED)
ROSS DEXTEROUS MANIPULATOR
SPMS
ITSS
POM

UMBILICALS

POWER
DATA TRANSMITTAL
FLUIDS

ENERGY MODULES

SOLAR ARRAYS
FUEL CELL MODULES
NUCLEAR SYSTEMS
SOLAR ARRAY MAGAZINES
25 kW POWER SYSTEM

SUBSYSTEM MODULES

ECLSS
POWER DISTRIBUTION
THERMAL CONTROL
RCS
ATTITUDE DETERMINATION
TRACKING COMMUNICATION
ANTENNA
WASTE MANAGEMENT
CREW SYSTEMS
MECHANISMS
DATA MANAGEMENT

CONSUMABLES, RESUPPLY

FOOD MODULES
H_2O MODULES
CRYOGENS
STORABLE PROPELLANTS

SHUTTLE ELEMENTS

ORBITER
EXTERNAL TANK
EXTERNAL TANK ACC
SRBs
INTERNAL/EXTERNAL AIRLOCKS
OMS KITS

GENERAL PURPOSE EQUIPMENT

SURROGATE SHUTTLE
BRIDGE MODULES
WORKSTATIONS

MOBILITY SYSTEMS

MMU
MTV

EXISTING SPACE STATION CONCEPTS

SKYLAB
SPACELAB
JSC SOC
MSFC PLATFORMS
SALYUT 6+7

SPECIAL PURPOSE MODULES

MATERIAL PROCESSING DEVELOPMENT
MATERIAL MANUFACTURING SYSTEMS
BEAM BUILDERS
MBB ELECTRO
OSS 1
TDRSS
MMM (MMS)

LARGE SPACE STUCTURES

30 to 300 m ANTENNA
MANY MANY CONCEPTS

TANK FARM

CRYO TANKAGE
STORABLE TANKAGE
PRESSURE SUPPLY TANKS
TRANSFER SYSTEMS
LOADING BOOMS

POTENTIAL VISITING SPACECRAFT TYPES

SPACE TELESCOPE
SOLAR MAX
LANDSAT
INTELSAT
GRAVITY PROBE B
LDEF
FLTSATCOM
DSCS
GPS
MANY FREE FLYERS

ORBIT TRANSFER VEHICLES

W/B CENTAUR
IUS
TMS MANNED
TMS UNMANNED
SCS (LMSC)
SPACE-BASED CONCEPTS
MANY STORABLE CONCEPTS
PAMs

PAYLOAD SUPPORT CRADLES

ESA
ESS 2
MBB
GE
LMSC FLATBED

RESCUE VEHICLES

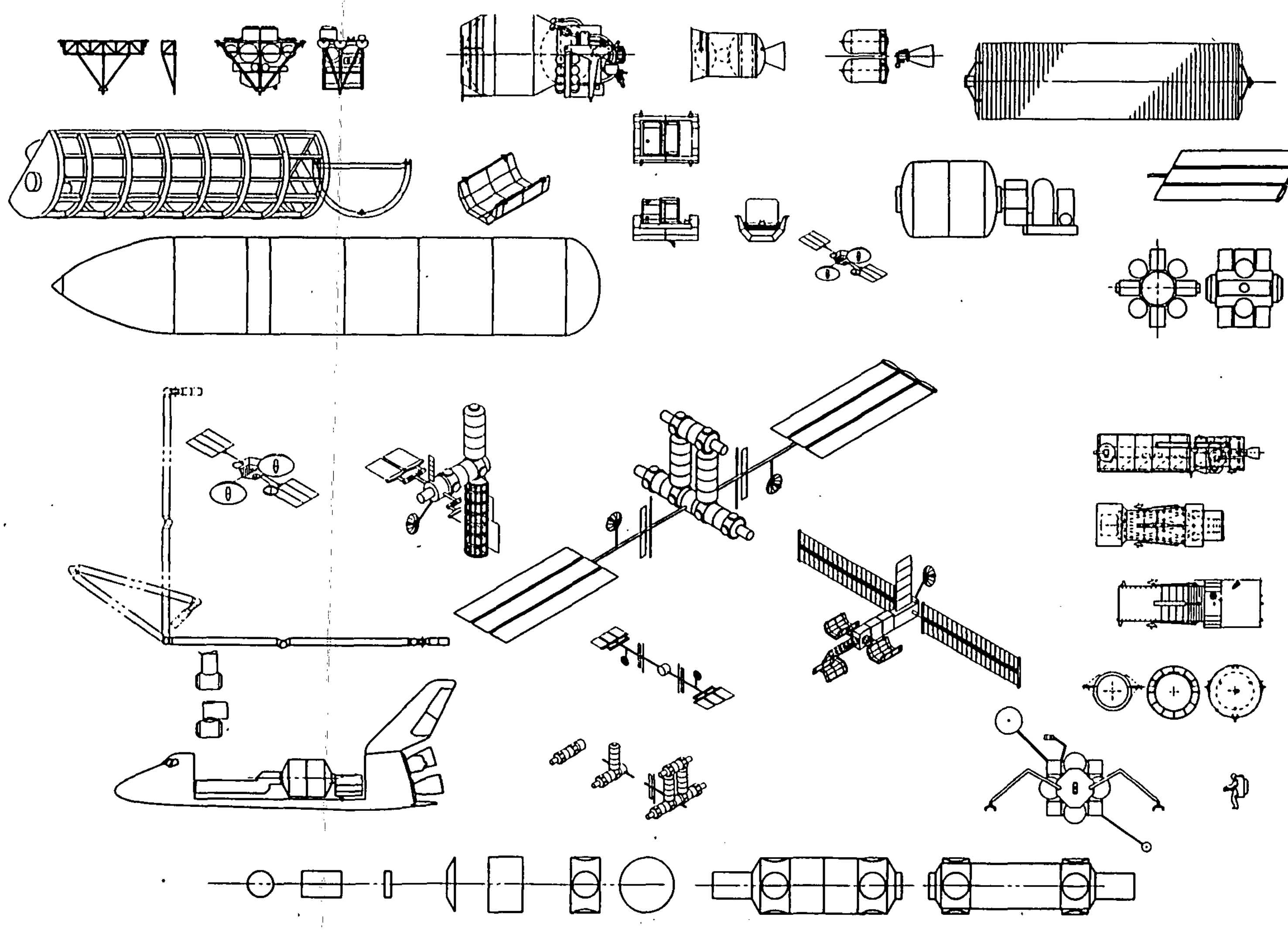
APOLLO CM
4 MAN APOLLO
10 MAN
DYNASOAR TYPE

TYPICAL SPACE STATION HARDWARE ELEMENTS

The opposite page illustrates some of the candidate hardware elements referred to on the previous page.

SPACE STATION PROGRAMS

TYPICAL HARDWARE SPACE STATION ELEMENTS



ALTERNATE CONFIGURATIONS

Eight very different approaches to a space station configuration are illustrated on the following two charts:

The tent and triangular concepts are loosely based on some JSC ideas whereby the solar arrays are not always sun oriented; but the concepts aim for very high stiffness thereby simplifying control and stability; attitude being maintained by large CMG's located at each corner.

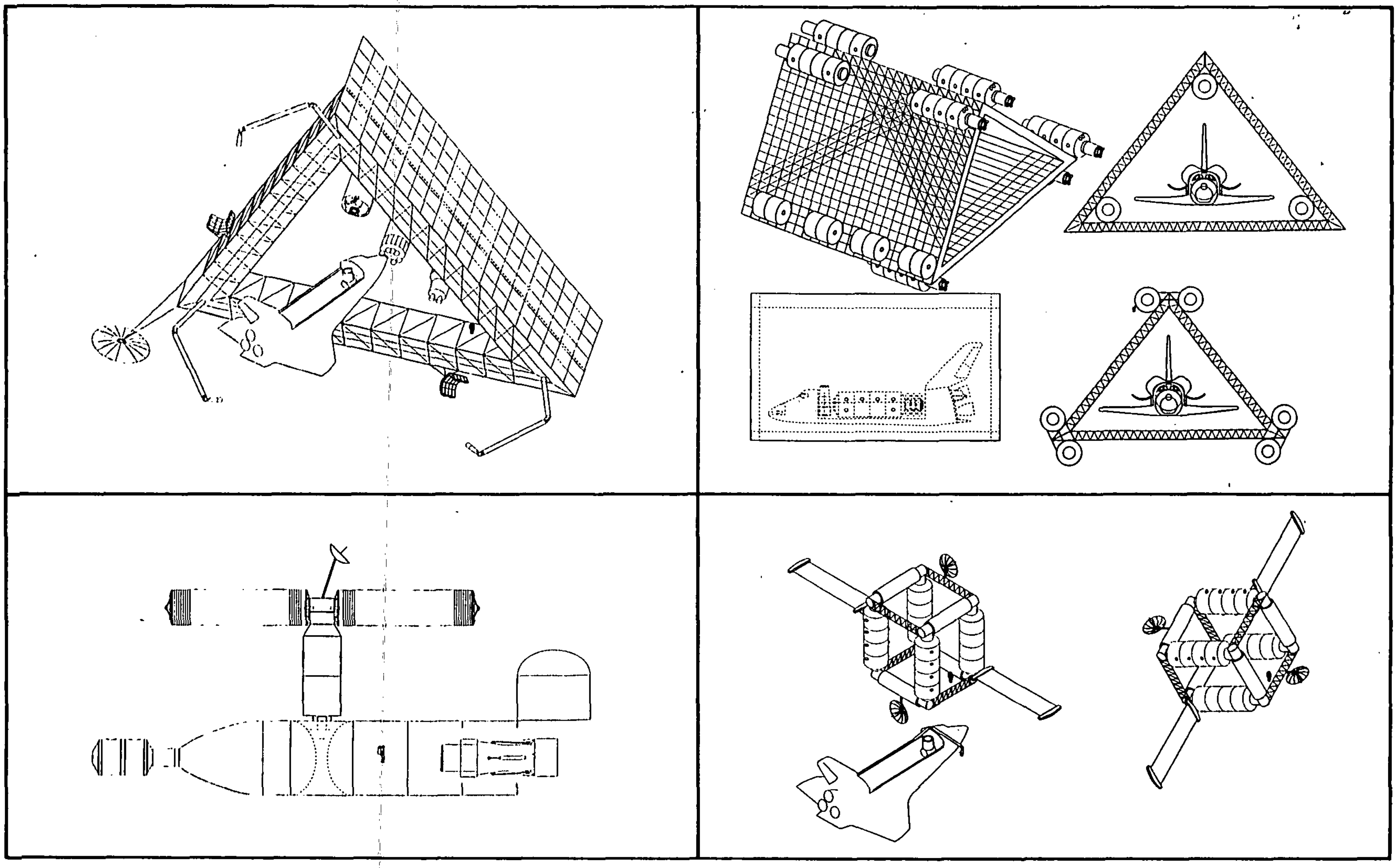
In the lower left concept maximum use is made of the converted external tank both as a hangar and experiment areas, habitation, power, and control module support.

The Stonehenge arrangement shown at lower right has four interconnected habitable modules with areas inside and out for spacecraft and assembly operations.

The following concepts are on sheet 2:

> The rigid raft concept shown on the upper right of this chart has major working/assembly areas on a grid type structure above and/or below the main pressurized habitation and laboratory modules.
>
> Lower right shows a typical 'tuna can' approach with access to an experiment pallet.
>
> Bottom left is a variation of the MSFC vertical assembly complex.
>
> Upper right is the LMSC reference station used in the cost analysis of this study.

ALTERNATE CONFIGURATIONS (SHEET 1)

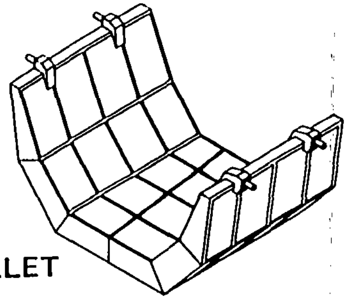


EXPERIMENT SUPPORT CRADLES

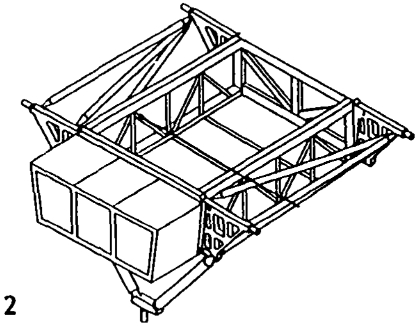
This sketch shows the wide variety of experiment carriers, existing and proposed, available for mission planners, all of these could be used either as free-flyers in a distributed space station system or be permanently attached to the station itself.

No doubt many other platforms will be developed during the next few years, probably dedicated to specific scientific needs, therefore it is important to establish early the various interface and integration requirements for use with the space station, e.g., data management, data rates, control, communication, structural, mechanical, thermal, etc.

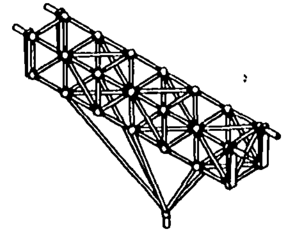
EXPERIMENT SUPPORT CRADLES



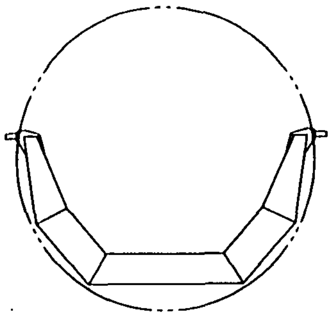
ESA PALLET
IN PRODUCTION

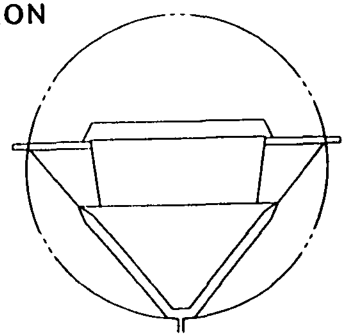


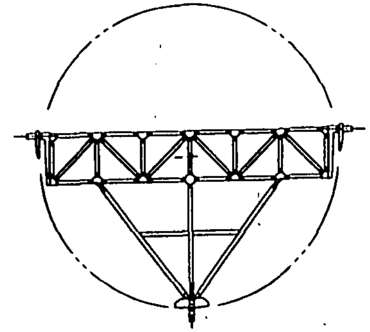
LMSC ESS-2
IN PRODUCTION

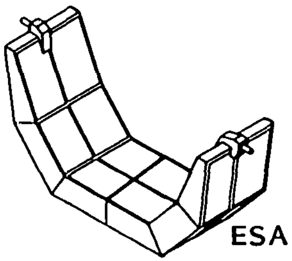


ESA/SPAS
MODULAR
STRUCTURE
IN PRODUCTION

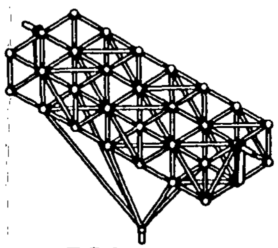






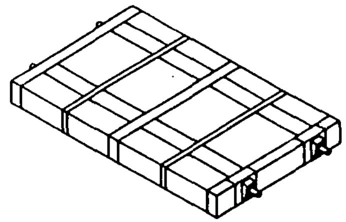


BAE 1/2 PALLET

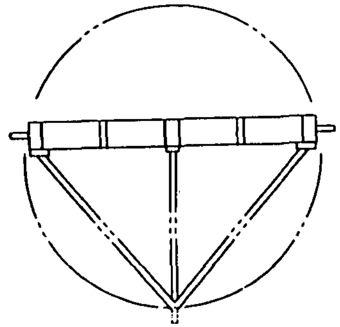


ESA EUREKA
CONCEPTS

MBB TWO-BAY TRUSS



LMSC FLATBED
CONCEPT



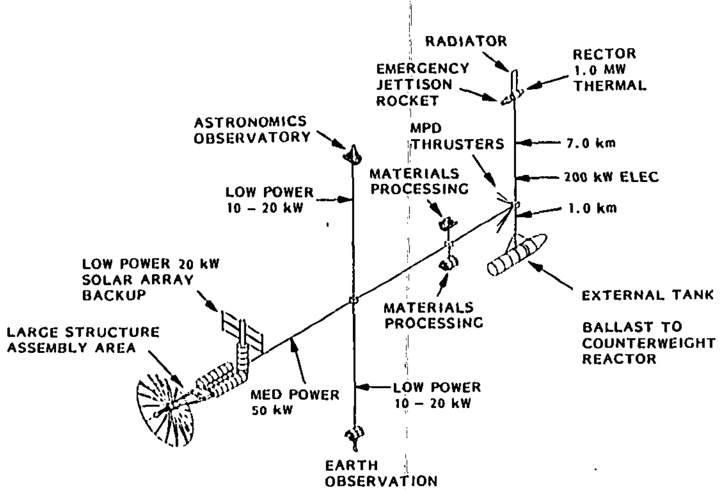
TETHERED SATELLITE CONCEPTS

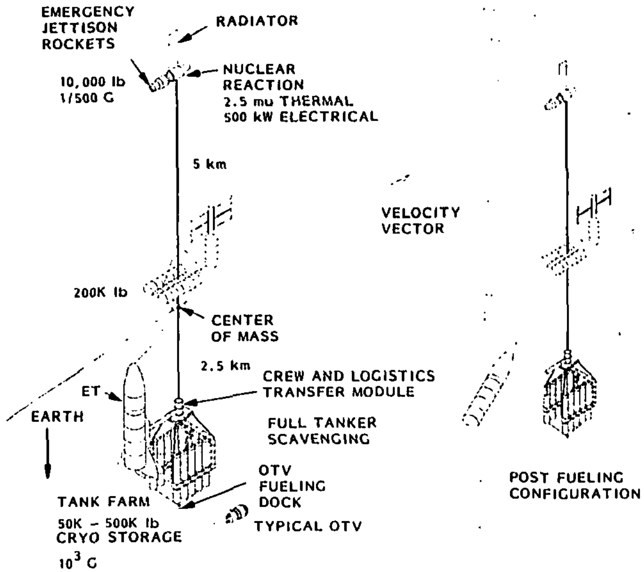
The possibility of developing the tethered satellite concept has been briefly addressed and some interesting concepts have evolved and are discussed in some detail, primarily in the orbit mechanics field, in Task 1.

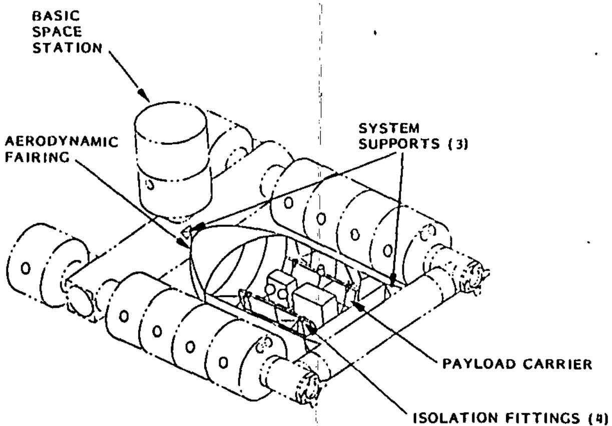
The sketches opposite show typical configurations for true tether concepts above, using vertical or horizontal complex's while below is shown the close-in 'tether' system whereby the modules requiring physical isolation from the main space station are suspended in special devices but remain close-hauled to it.

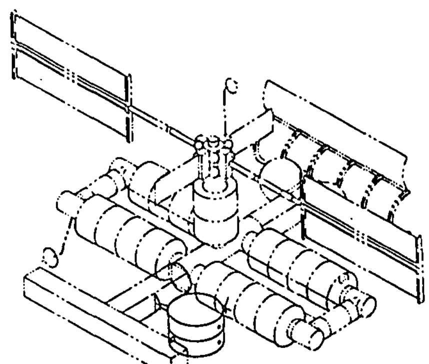
SPACE STATION PROGRAMS

TETHERED SATELLITE CONCEPTS









22 ft diam LABORATORY
SUSPENDED IN THE LMSC
REFERENCE SPACE STATION

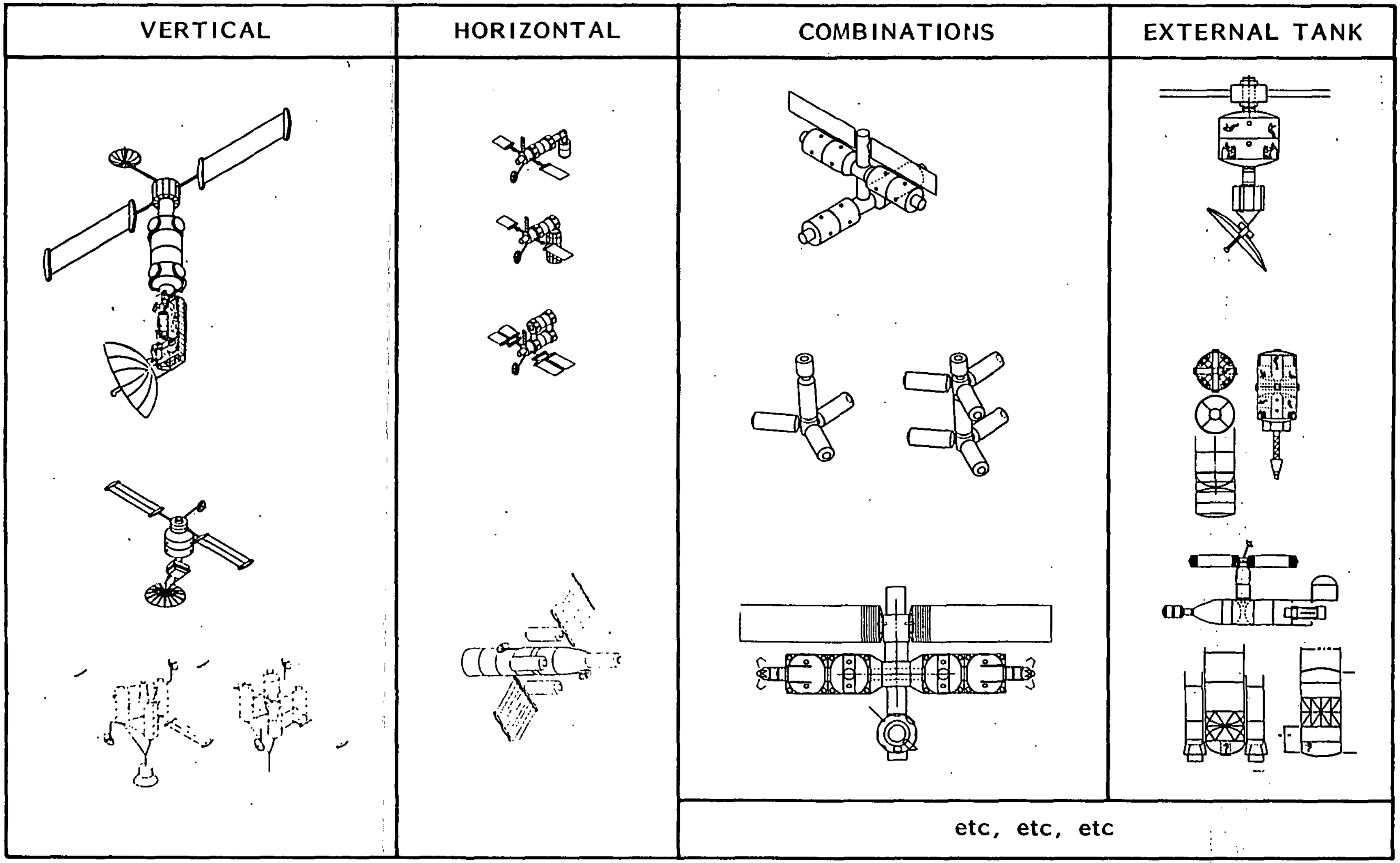
CONFIGURATION EVALUATION

From the previous operations/functions analysis efforts, 5 major station configurations were evolved which met the basic operational and mission criteria. Examination of these 5 configuration concepts resulted in the preparation of eight (8) discrete station layouts considered worthy of further examination, analysis, and subsequent evaluation. The 8 layouts are indicated on the opposite page. Examination of the layouts (previously pictorally represented) will reveal that the major types of structural design are fairly well represented, e.g., rigid/flexible body, strongback, integral, rigid assembly, and pier/cylindical assembly.

The 8 layouts were broadly examined relative to top-tier assessment criteria for purposes of determining candidates which should be further studied. A KTA type of assessment approach was used and numerical scores given to each layout within the 14 criteria categories. Although substantively judgemental in nature, the assessment attempted to discover major swings in the scoring, thereby, indicating that certain of the layouts were, at this time, not fruitful relative to further architectural study. As shown on the facing page, the scores of the 8 layouts are presented and the rank order indicated. This effort tentaviely indicated that other previously conducted criteria assessments and evaluations were substantiated with the simplified effort, particularly with respect to the fact that the reference configuration layout again rated number one. It is patently obvious that this assessment/evaluation is only a quick-look overview, however, the intent is to summarize the many examinations and evaluations conducted during the course of the architectural development effort. Future effort should be expended in developing more detailed evaluation and assessment criteria and, in particular, inclusion of the total sub-system aggregate of the station.

SPACE STATION PROGRAMS

SPACE STATION CONFIGURATION — AN OPEN BOOK



SPACE STATION CONFIGURATION - AN OPEN BOOK

Selection of a preferred configuration is not attempted since its requirements will not be known for some time; however, to help make the costing task simpler, a reference SS has been developed and is discussed on the following pages.

A wide variety of configurations have been examined, some are summarized on the opposite page and many more are possible. Since we need a prebuilt (on earth) pressure vessel for habitation and laboratory use, a longitudinal cylinder approximately 14 ft in diameter and 45 ft long, capable of being launched by the shuttle, makes sense as the primary modular building block around which various special-purpose modules and structures for experiments and equipment can be attached.

If earth transporation via C5 aircraft becomes a requirement (attractive for military SS elements), the cylinder diameter would be reduced to approximately 12.5 ft.

Arranging the cylinders vertically gives a fragmented interior arrangement and provides less opportunity for earth or outward (to space) viewing experiments. Therefore, a horizontal arrangement is selected.

Should a very large-diameter module become necessary, then the aft cargo compartment of the external tank, or a section within the ET itself, could be used as depicted on the facing page.

The message of this chart is to encourage an open-minded approach to design until firm requirements are set. (See Attachment 2, Volume II for additional configuration studies).

CONFIGURATION EVALUATION *

SPACE STATION CONCEPT \ CRITERIA	MULTI-MISSION SUITABILITY	OPERATIONAL FLEXIBILITY	GROWTH POTENTIAL	TECHNOLOGICALLY FEASIBLE	COMPAT. WITH LARGE SPACE STRUCT. CONST/ASSY	OPS COMPATIBILITY	DoD COMPATIBLE	EASE OF ASSY	ORBIT CHARCT. (ALT/INCL.)	OVERALL SAFETY	LOGISTICS COMPATIBILITY	COST SENSITIVITY	COST BASIC	MAX USE OF EXIST. HDWR.		TOTAL	RANK
TRIANGULAR	8	9	8	4	6	7	5	5	5	8	8	9	6	3		91	4/3
TENT	7	7	5	3	6	6	4	4	4	8	7	6	4	2		73	7
EXTERNAL TANK	6	6	3	6	7	7	9	4	8	6	6	5	9	9		91	3/4
STONEHENGE	7	8	2	6	7	8	3	4	4	6	9	6	4	3		77	5/6
REFERENCE STATION	9	9	8	7	8	8	5	6	9	7	8	8	6	4		102	1
RAFT	8	8	7	8	7	7	5	9	7	6	7	8	5	4		96	2
VERTICAL COMPLEX	7	5	6	5	7	6	4	6	5	5	7	6	5	3		77	6/5
TUNA CAN	7	6	1	5	6	7	5	8	6	6	6	3	4	1		71	8

*SINCE NO ENGINEERING OR SUB-SYSTEM ANALYSIS WAS ATTEMPTED IN THIS STUDY THE ABOVE EVALUATION IS BEST ENGINEERING JUDGEMENT ONLY

A SELECTED REFERENCE SPACE STATION CONFIGURATION

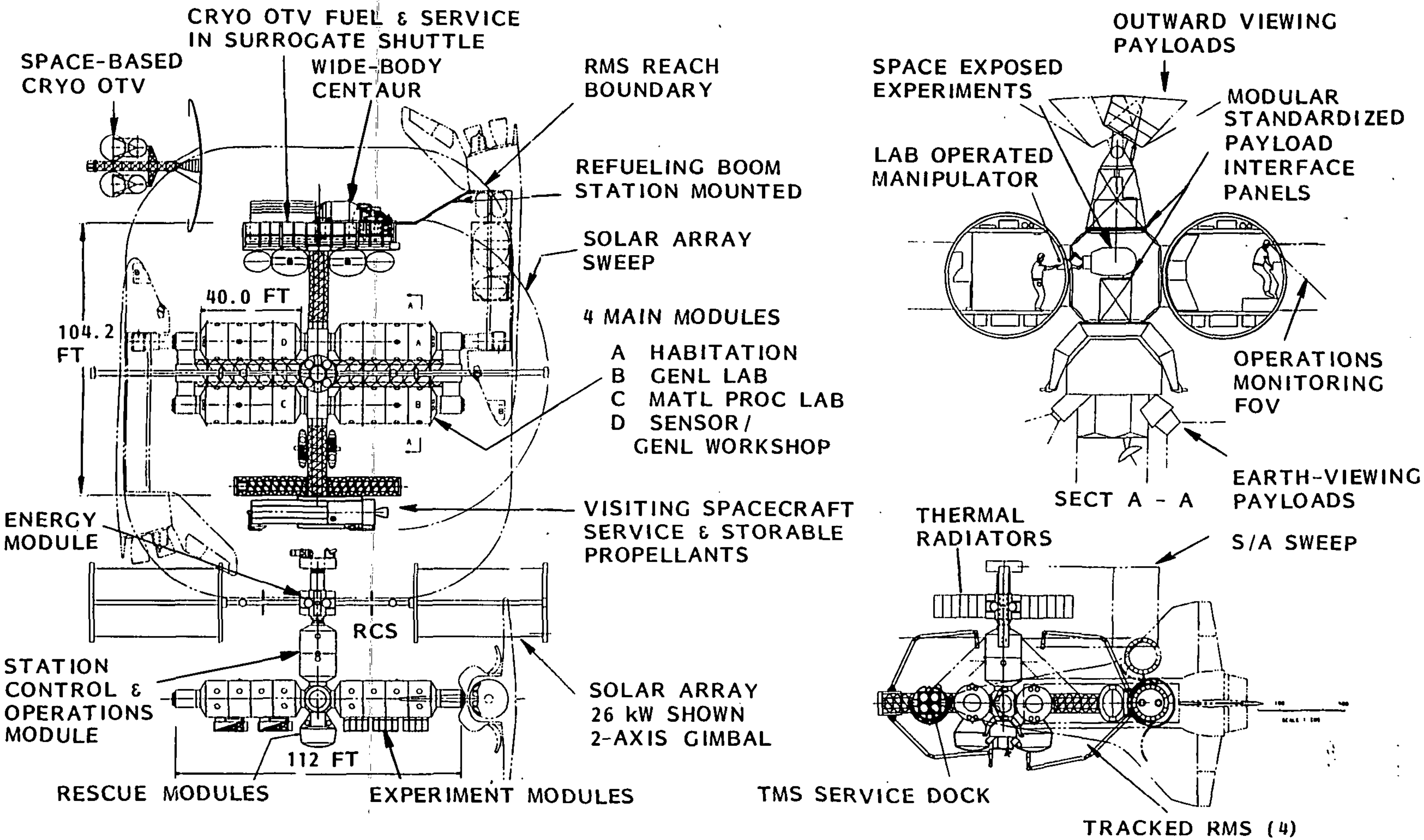
Primarily for the purposes of costing, a reference space station was configured as shown on the oppostie page. The principal considerations in determining the concept were based on the following arbitrary assumptions:

Modular Approach	Early initial capability; growth provisions
Experiment Integration	Provide work areas and platforms, internal and external
Crew Size	3 initially, growing to 6
Power	Solar array 13 kW growing to 26 kW
Safety	2 independent living cells and rescue capability
Type of Control	Earth oriented, active RCS thrusters
Habitation & Lab Module Size	14 ft dia x 40 ft long
Servicing	Provide for OTV, visiting spacecraft, TMS, etc.
Communications	Primarily provide FOV for dish to ground and TDRSS (there will be many other antennae).
Resupply	Crew and consumables every 90 days
EVA	Provide volume and equipment to support EVA

A determined effort was made to make the station as compact as possible, not only to provide good FOV for solar arrays, radiators, payloads and antennae but to simplify attitude control + CG + MOI excursions, and also to provide maximum visibility for crew members during external operations.

SPACE STATION PROGRAMS

A SELECTED REFERENCE SPACE STATION CONFIGURATION



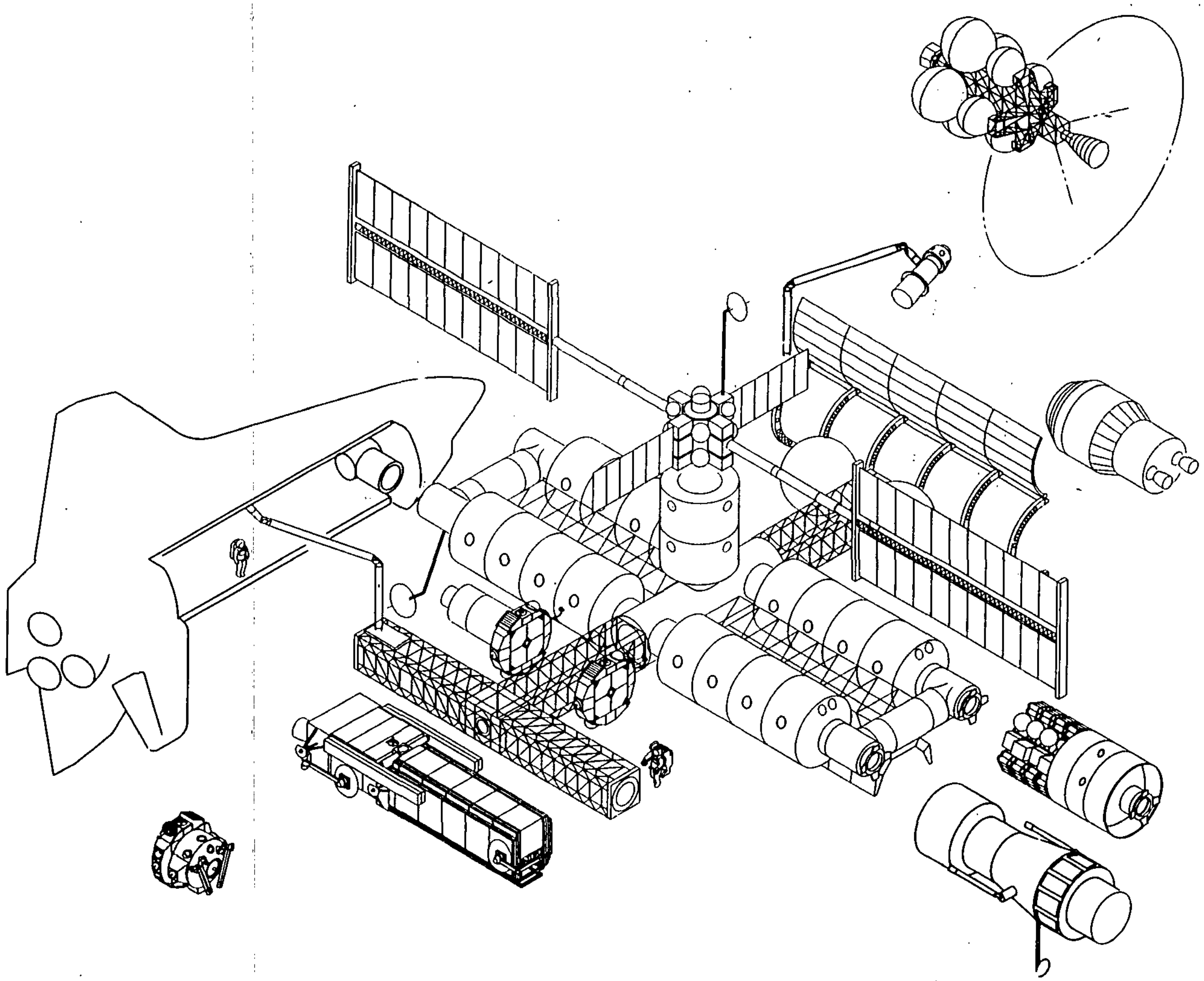
REFERENCE SPACE STATION - ISOMETRIC

The reference configuration is shown here with representative visiting spacecraft, and EVA astronaut, manned maneuvering unit and two teleoperating maneuvering units.

In the upper right corner is a General Dynamics space based (and assembled) cryogenic OTV concept; a wide body Centaur is stationed close by the OTV shelter and refuelling pier (surrogate shuttle).

To the lower right can be seen an AXAF spacecraft and a typical logistics module along with a manned TMS concept.

REFERENCE SPACE STATION ISOMETRIC

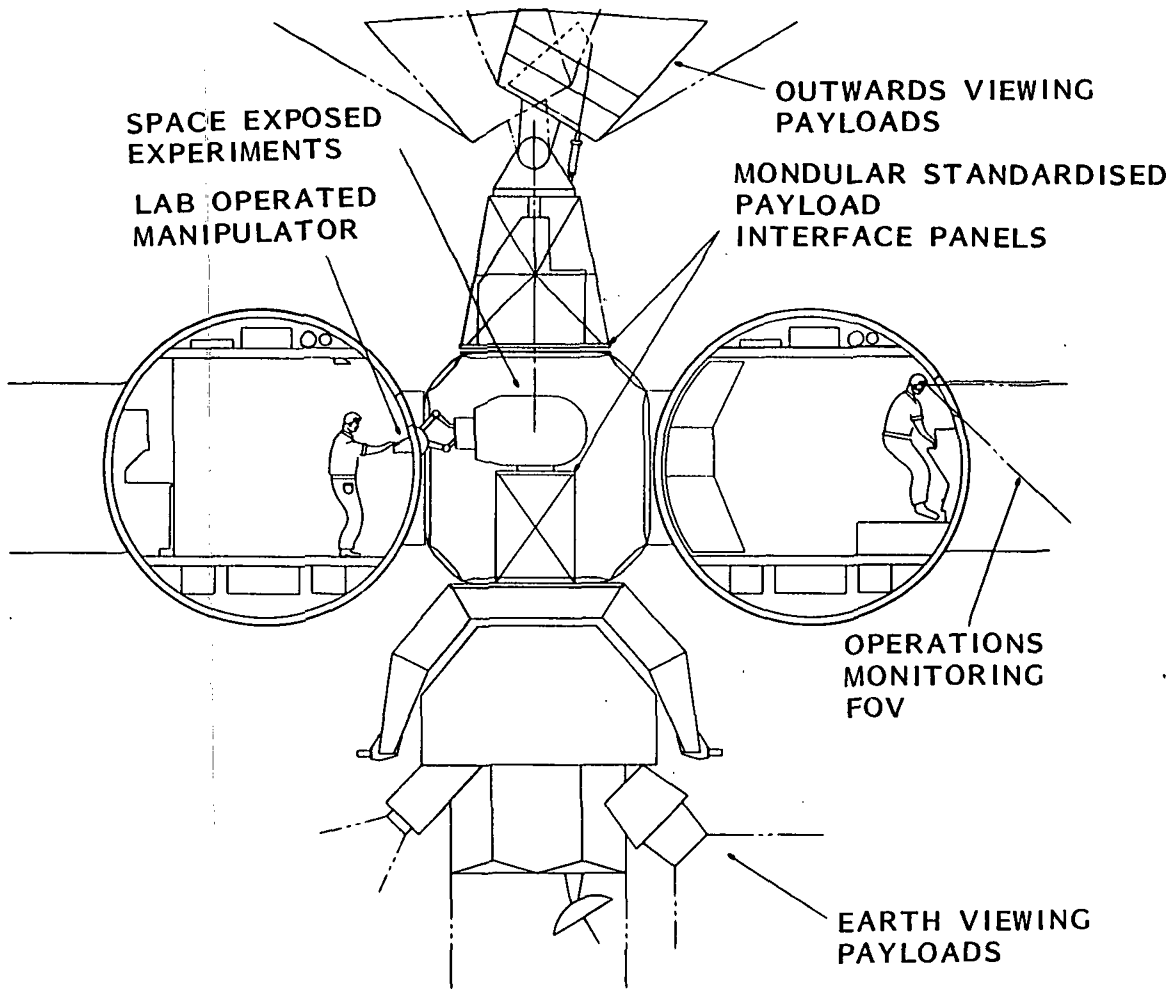


REFERENCE CONFIGURATION - CROSS SECTION

The disposition of the various types of payloads both within and outside the habitation and laboratory modules is shown on this chart.

SPACE STATION PROGRAMS

CROSS SECTION THROUGH REFERENCE STATION



Lockheed

OTV SERVICING CONCEPT

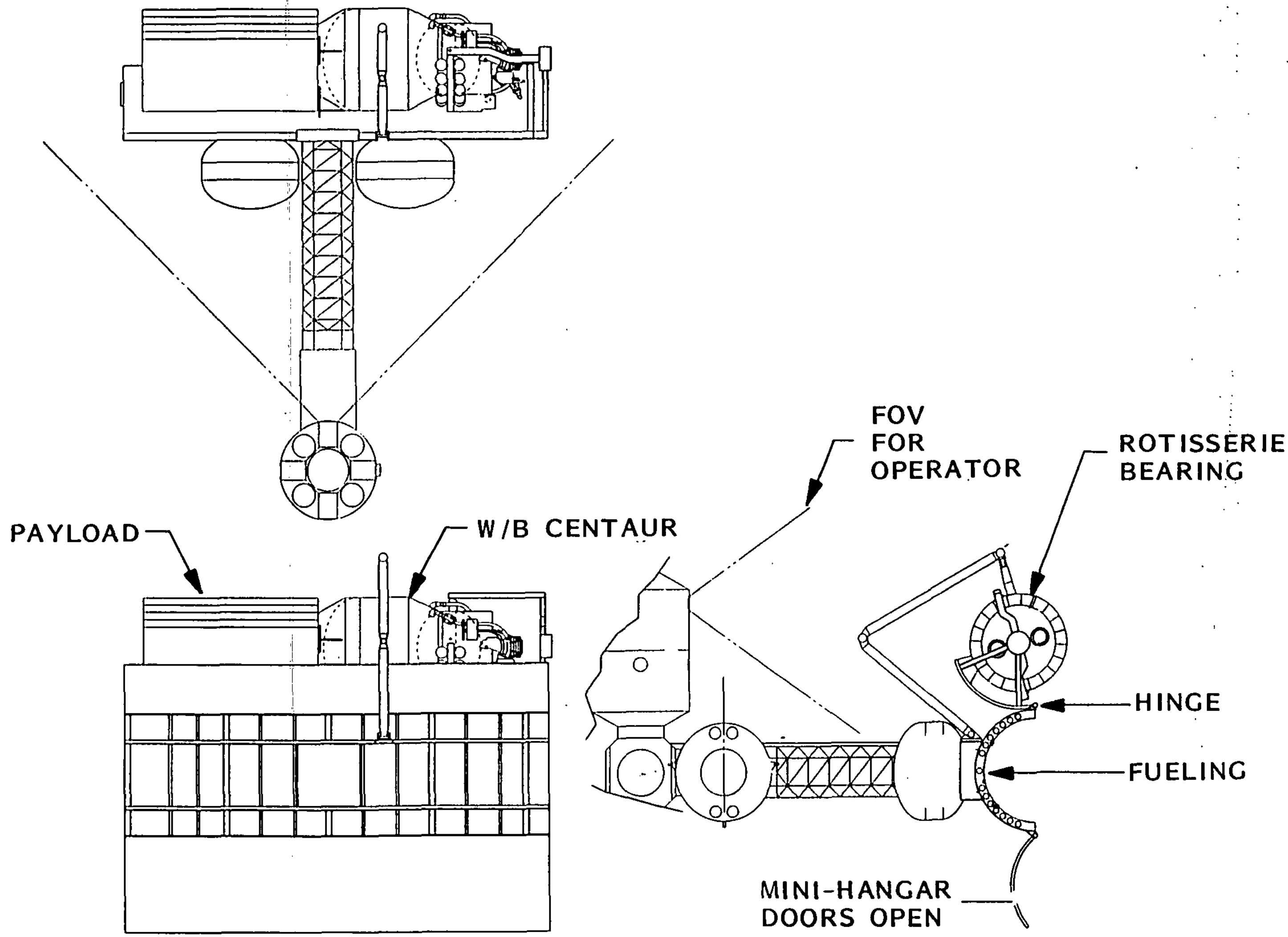
This concept is a minimum type protective structure based on the geometry of the wide body Centaur. The backbone is essentially a surrogate shuttle bay containing all of the cryogenic plumbing, umbilicals, flow control equipment and safety features developed for the installation and fueling of the W/B centaur in the real shuttle.

The outer portion are hinged doors, the upper one containing a rotation system such that the OTV and it's payload may be inspected and serviced remotely within full view of the station command center. The upper door would also contain the deployment mechansism.

Propellant tanks and feed system are adjacent on the inner face of the OTV pier. RMS tracks are located on the upper and lower faces of the pier.

SPACE STATION PROGRAMS

OTV SERVICING CONCEPT



Lockheed

REFERENCE SPACE STATION MODULAR ELEMENTS

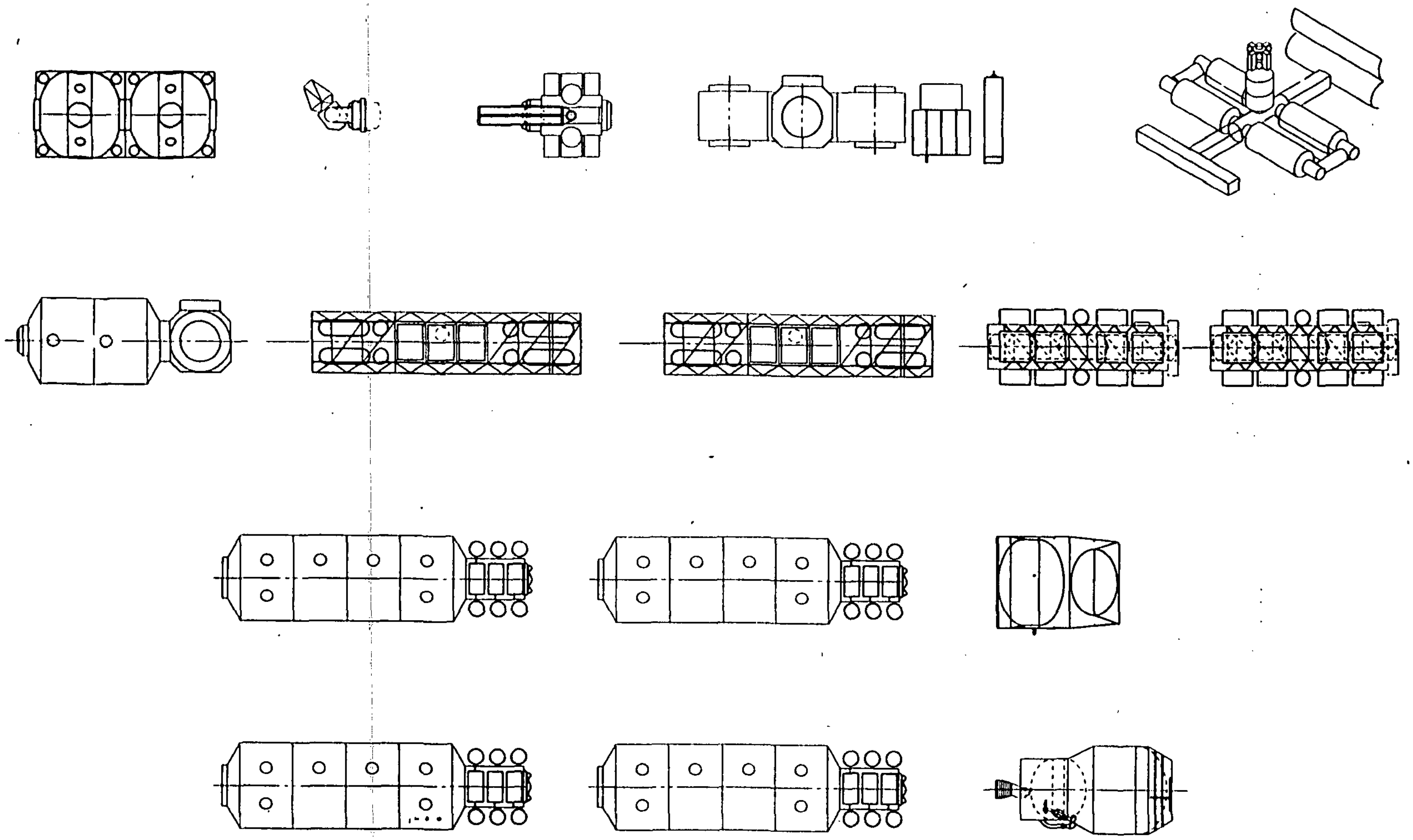
The major elements used in the reference configuration study are depicted here, all to the same scale.

The initial modules for habitation, payload sensor, electrical power, interconnect module, pallet and TMS are shown on the upper row, while below it are shown an alternate Spacelab type habitation module, rigid support structures with integral consumables and equipment modules.

The main laboratory and habitation modules along with typical OTV tankages and the wide-body Centaur are standardized interface rings located at strategic positions on the various structures; handling of the modules will be via grapple fixtures with RMS and TMS interface connectors.

All modules are sized for the shuttle payload bay.

LMSC REFERENCE STATION ELEMENTS



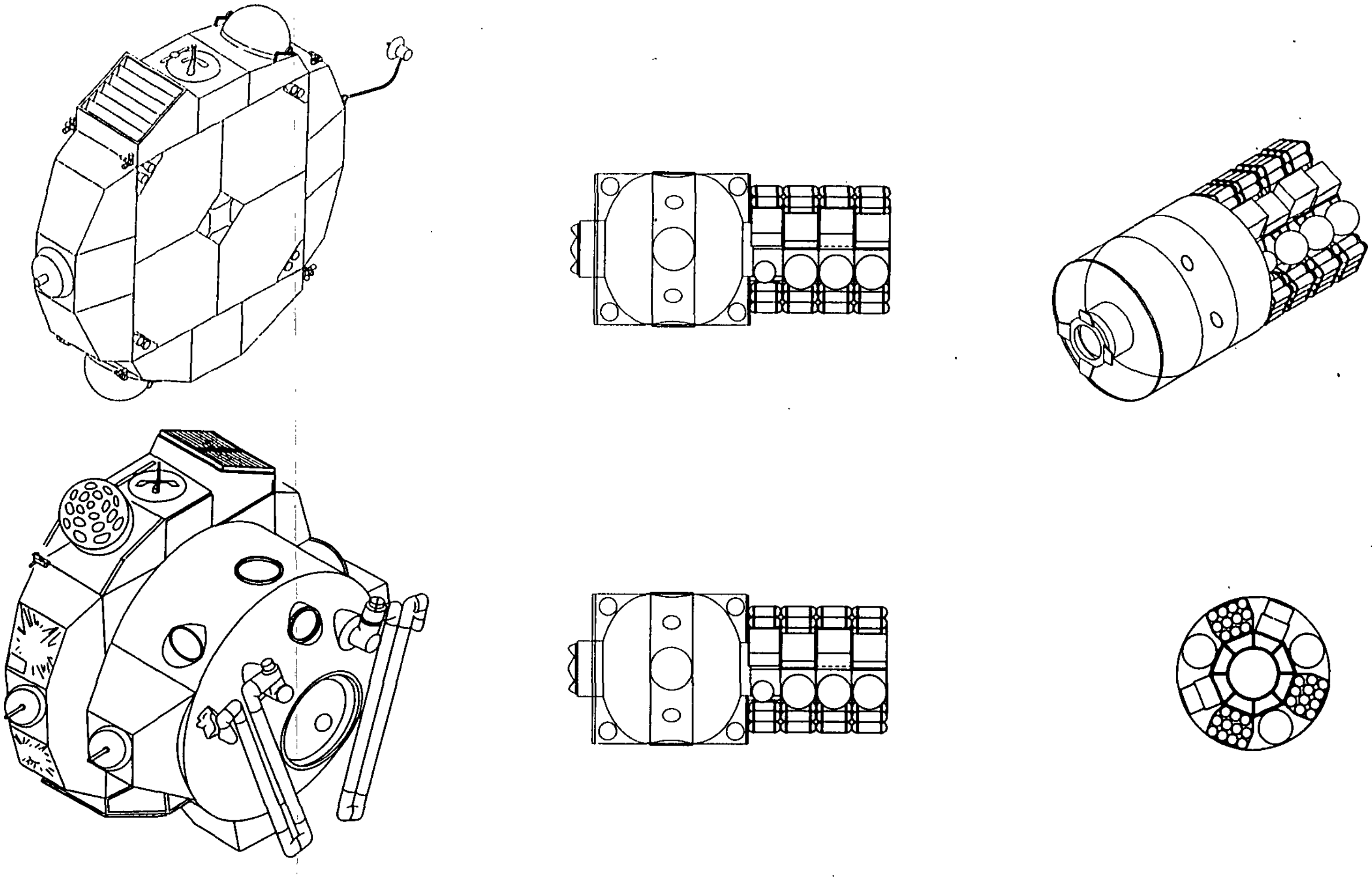
LOGISTICS MODULE AND TELEOPERATOR MANEUVERING SYSTEM

Shown here are probably, along with tracked RMS's, the most important utility modules to be used around the space station.

The logistics module will in itself have standardized modular elements to simplify both earth and space handling. One compartment is a controlled pressurized environment while the other compartment is not. Each compartment could be a modular element itself depending on the requirements of a particular logistics launch.

Also shown are the manned and unmanned TMS concepts, harbor tugs for a multitude of station duties.

LOGISTICS MODULE AND TELEOPERATOR MANEUVERING SYSTEM



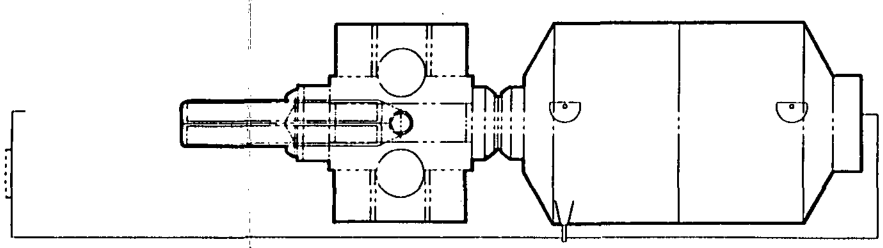
ORBITER INTERFACES

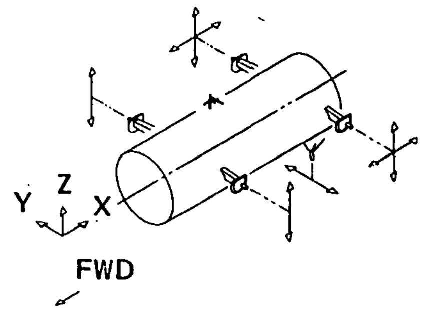
All shuttle payloads are designed such that structural loading and center of gravity constraints are not exceeded. This chart approximates the current loads and CG envelope being used for payload mass distribution.

The relationship between the reference space station (shown by heavy outline) and orbiter stations is shown here, along with a diagram of a typical 5 point payload retention system.

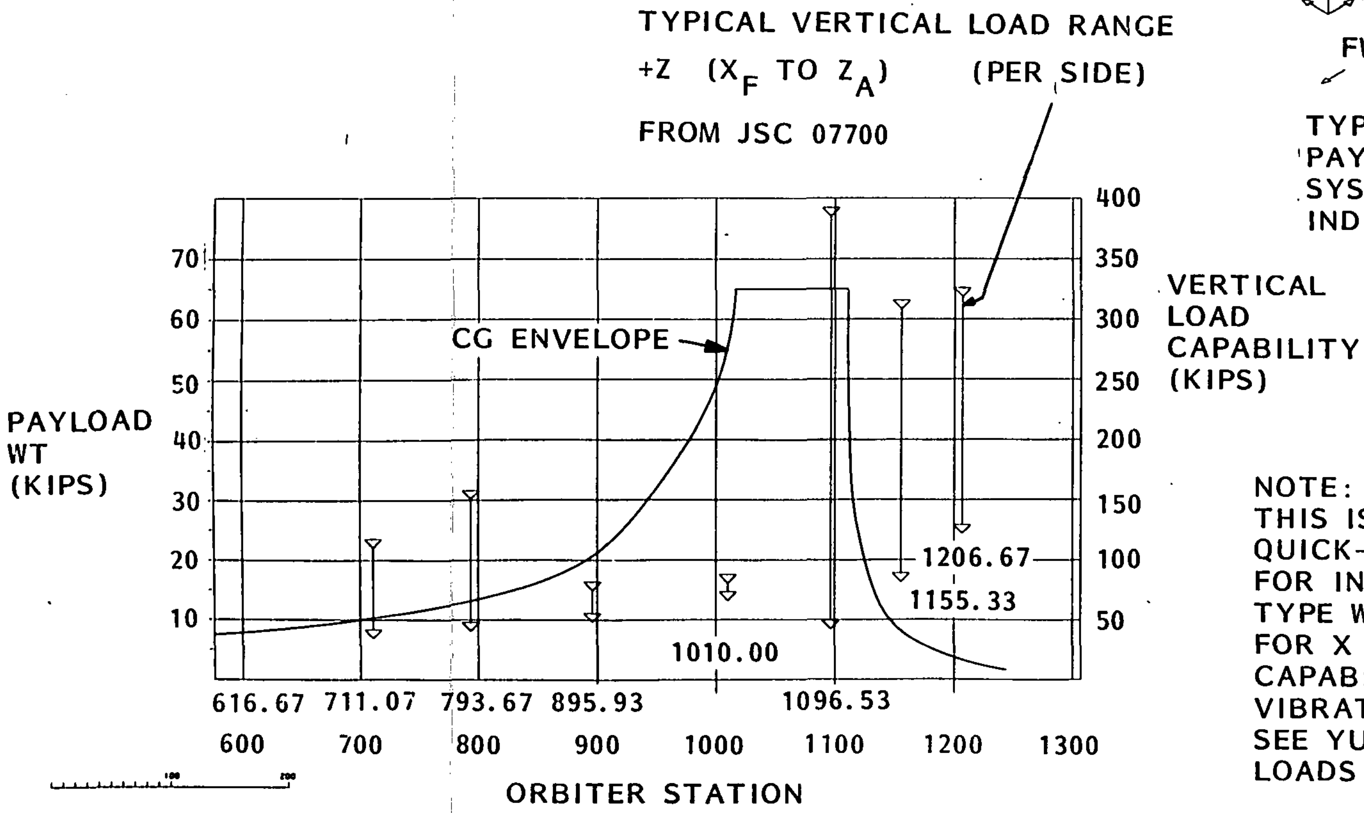
SPACE STATION PROGRAMS

ORBITER INTERFACES





TYPICAL 5-POINT PAYLOAD RETENTION SYSTEM INDETERMINATE



NOTE:
THIS IS TO PROVIDE QUICK-LOOK CAPABILITY FOR INITIAL CONCEPT TYPE WORK ONLY.
FOR X $ Y LOAD CAPABILITY, MODIFIERS, VIBRATION STUFF, ETC., SEE YUOR FAVORITE LOADS MAN & JSC 07700.

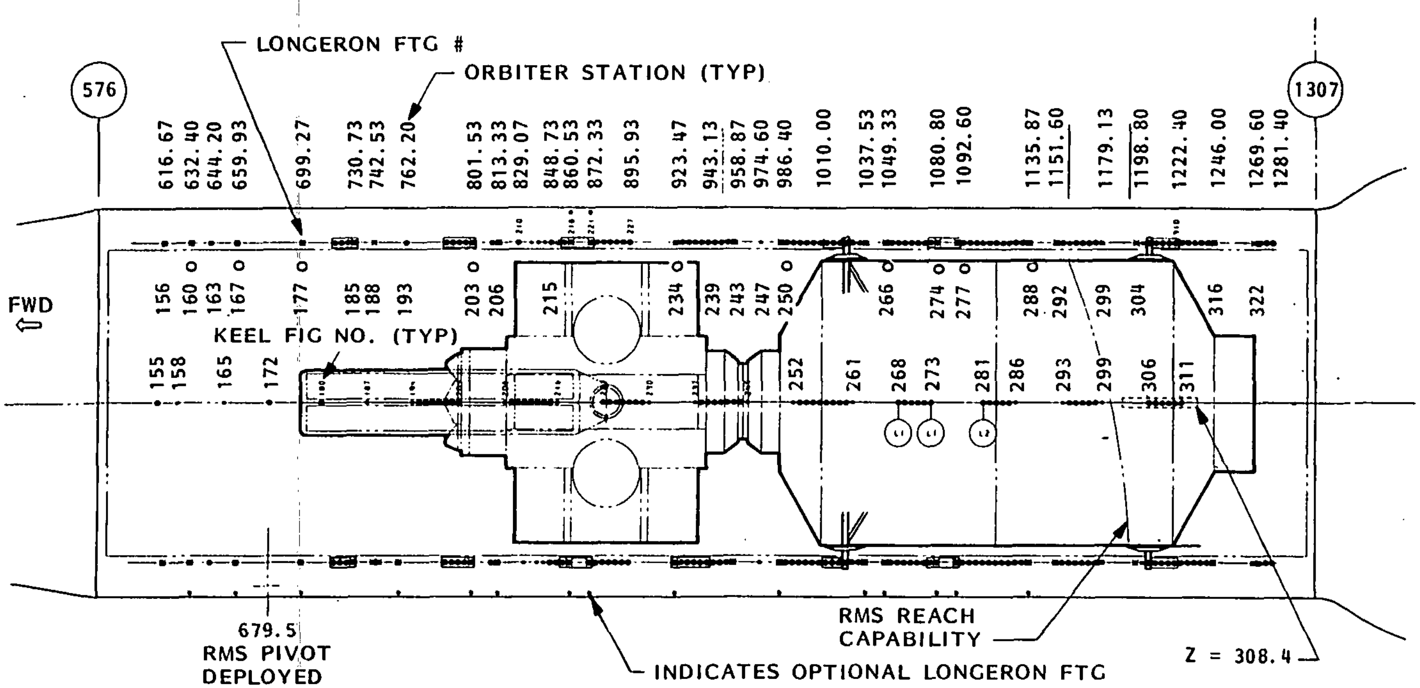
ORBITER INTERFACES

This picture shows a plan view of the reference station with its energy section, folded solar arrays etc., installed in the shuttle cargo bay.

The many available payload attachment points of various types are shown along with the maximum reach envelope of the remote manipulator system.

SPACE STATION PROGRAMS

ORBITER INTERFACES



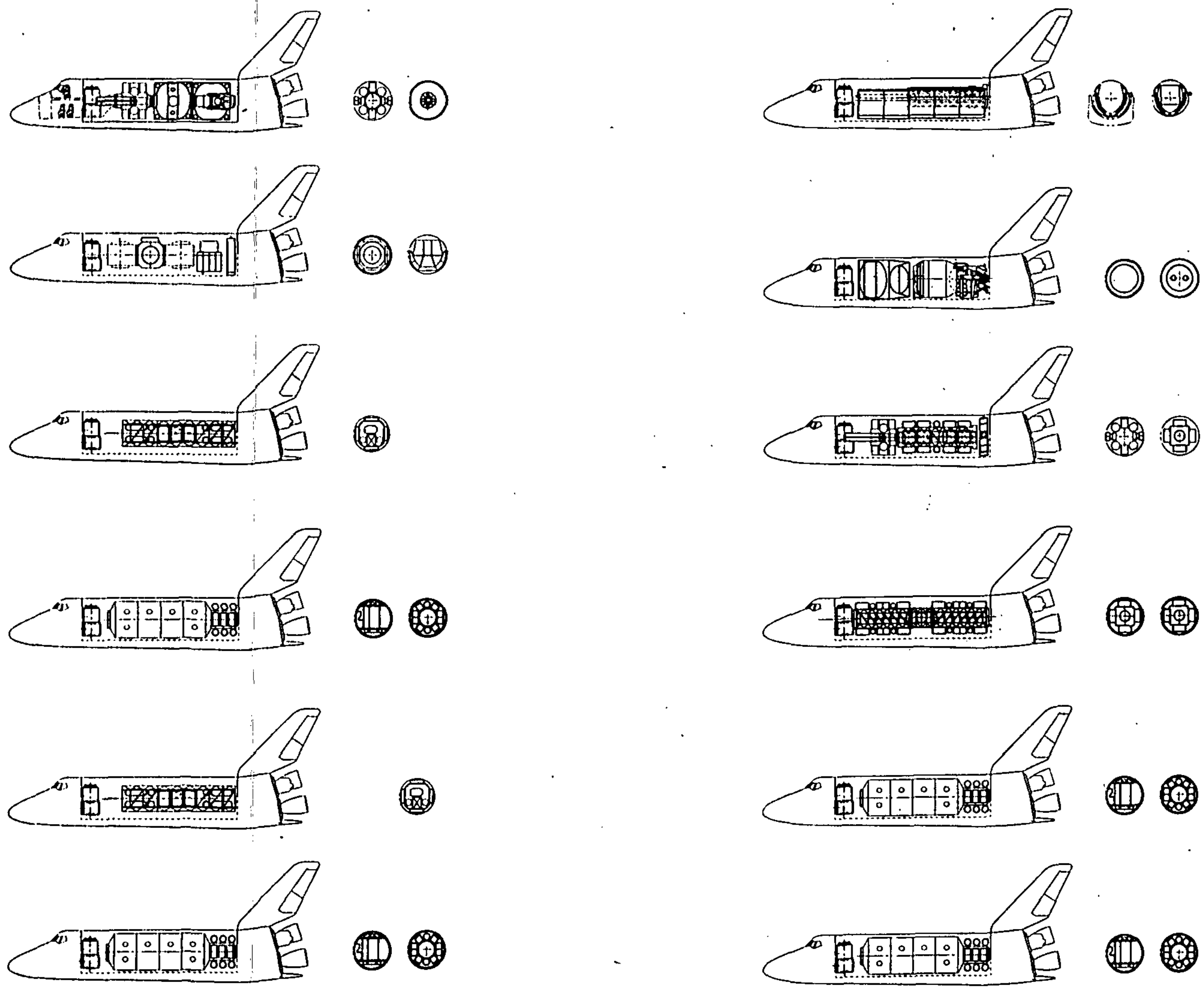
LEGEND · NON-DEPLOYABLE, FIXED OR SLIDING
• DEPLOYABLE, FIXED OR SLIDING
X NON-DPLOYABLE, FIXED ONLY
X DEPLOYABLE, FIXED ONLY
▭ SMALL RETRIEVAL TRUNNION GUIDE (8 IN) ONLY

NOTES:
1. (L1) INDICATES LIMITATIONS TO RETRIEVAL CAPABITY CAPABILITY LONGERON FTG SPACING > OR = 100 IN.
2. (L2) INDICATES LIMITATIONS TO RETRIEVAL CAPABILITY LONGERON FTG SPACING > OR = 70 IN.
3. ORBITER STATION = $\frac{\text{FTG NO. X 59}}{15} + 3.07$

REFERENCE STATION LAUNCH CONFIGURATIONS

The shuttle payload bay is fully occupied for almost all twelve build-up launches as can be seen from this drawing, however, although the available volume is effectively used, the total weight capability is not as can be seen on the preceding chart. This excess capability could be used, of course, for experiments, consumables, contingency etc.

REFERENCE SPACE STATION — LAUNCH CONFIGURATIONS

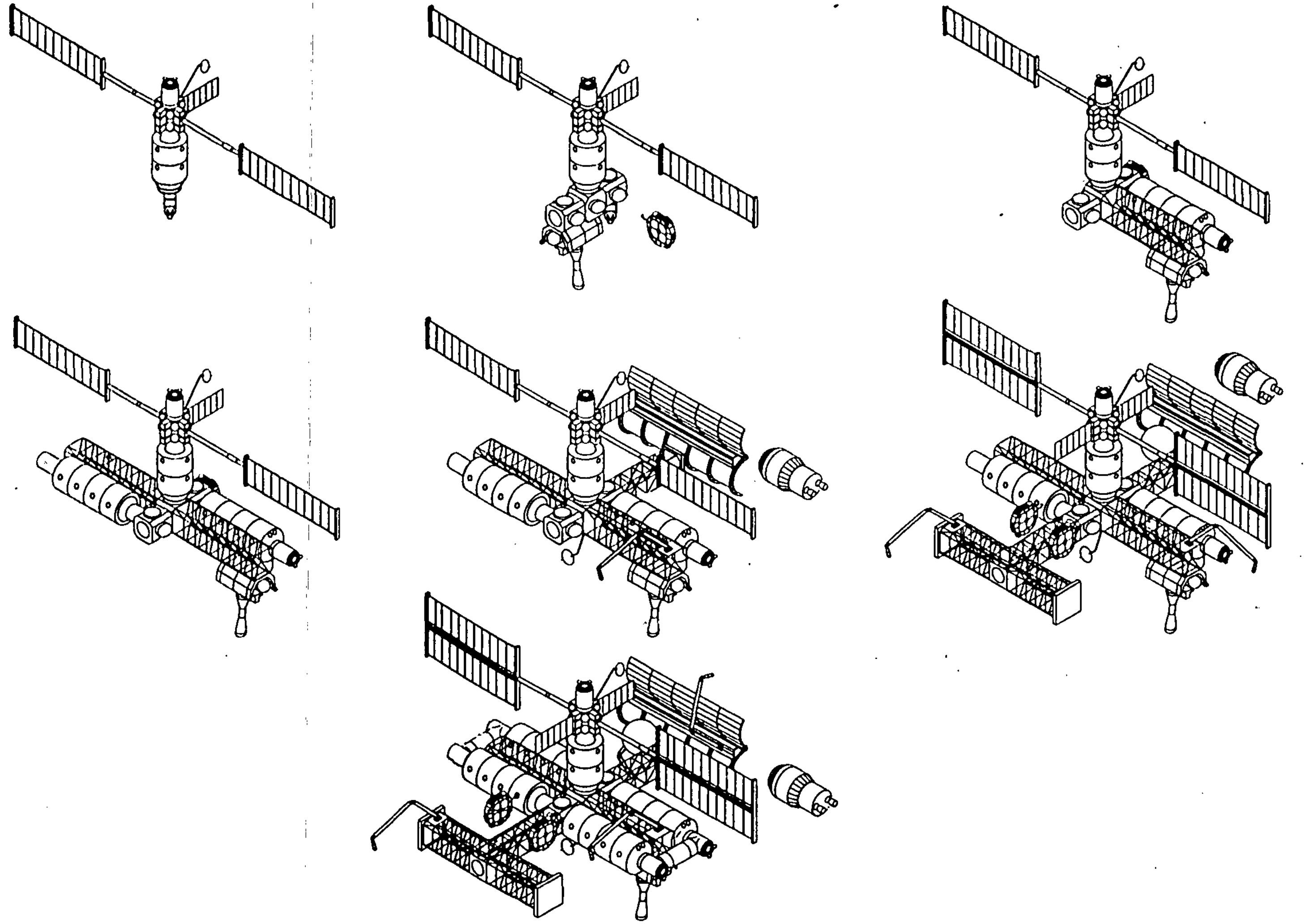


REFERENCE SPACE STATION BUILD UP

The attached sketches depict the evolutionary build up, through seven distinct phases, from a small 3 man/single module station to a 6 man all-embracing configuration. The build-up is arranged such that the evolution could be stopped at any phase and a useful facility remain operational. Twelve launches are required to place the facility on station not including approximately two resupply launches per year.

SPACE STATION PROGRAMS

REFERENCE SPACE STATION BUILD UP



REFERENCE SPACE STATION BUILD-UP LAUNCHES

A time phased evolutionary build-up of the all-up complex is shown here, the weights associated with each launch, the major elements being deployed, and launch date are included.

A detailed weight estimate for each launch is included in the programmatics study, Attachment 1, Volume IV.

REFERENCE STATION BUILD UP LAUNCHES

	STEP 1	STEP 2	STEP 3		STEP 4		STEP 5		STEP 6		STEP 7	
LAUNCH DATE	JAN '90	JAN '91	JULY '91	OCT '91	JAN '92	APR '92	JAN '93	MAR '93	JAN '94	APR '94	JAN '95	APR '95
LAUNCH NO.	1	2	3	4	5	6	7	8	9	10	11	12
PRIMARY ELEMENTS												
3 MAN HAB	28.15											
ENERGY MODULE	17.80											
SENSOR MODULE	4.90											
INTERCONNECT MODULE		18.35										
TMS		7.83										
CENTER STRUCT #1			26.4									
HABITATION MODULE				30.4								
AIR LOCK				4.0								
CENTER STRUCT #2					21.4							
SENSOR LAB						32.55						
AIRLOCK MODULE						4.00						
CRYO OTV SUPPT.							20.2					
CRYO HANGAR							15.9					
RMS							1.2					
OTV TANKAGE								7.0				
OTV VEHICLE								53.2				
COMM ANT.								.4				
25 Kw PWR.									17.8			
TMS SUPT.MOD									22.9			
TMS									7.8			
SPACECRAFT SERVICE										20.1		
RMS										1.2		
STORABLE PROPS.										10.0		
ATT.CONT.MODULES										2.0		
G.P.RESEARCH											39.8	
RMS											1.2	
MATL.PROC.MOD.												44.4
RMS (2)												2.4
SHUTTLE ITEMS	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.0	4.0	3.0	3.0	3.0
TOTAL LAUNCH V/H	54.85	30.18	30.4	38.4	25.4	40.55	41.3	62.6	52.5	36.3	44.0	49.8

REFERENCE SPACE STATION EVOLUTIONARY SEQUENCE

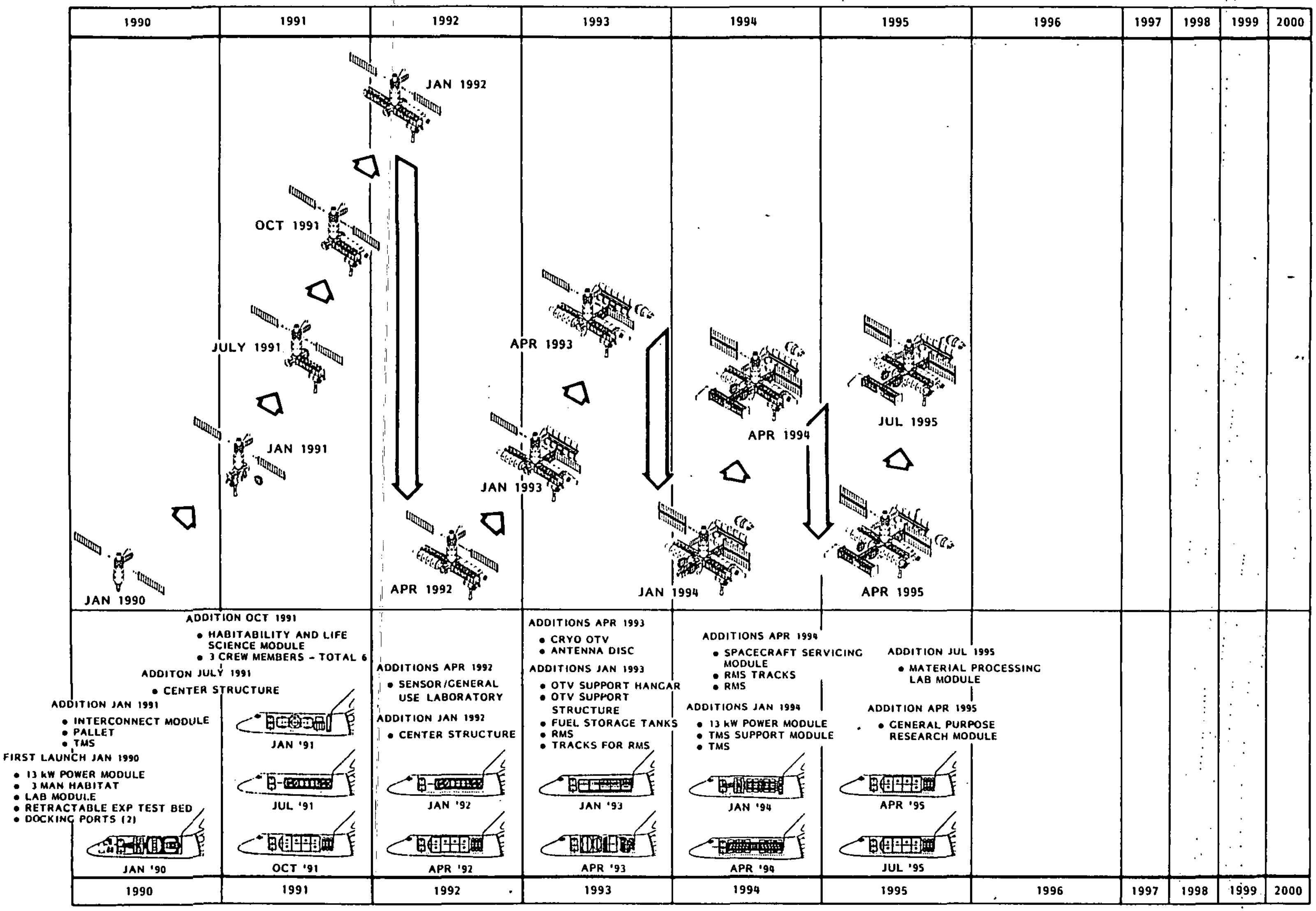
The reference station evolves in form and functional capability as shown on the facing page. A basic capability is established in 1990 with the single shuttle launch at a 3 man habitation module combined with a permanently attached electrical power module, and a retractable sensor experiment test bed. This initial station is maintained, with shuttle resupply visits, for a full twelve months during which time all of the subsystems, controls, communication, power, thermal control, etc.,would be thoroughly flight tested prior to delivery of the remaining station elements.

The station build up is phased over a six year period and averages two shuttle launches per year for transport of station elements to orbit. Incremental capability is added in successive launches such that the station is always operational from the first launch and is flexible ecnough to accomodate changes in launch make and mission requirements. It is assumed that some resupply of the station (personnel and supplies) can be accomplished during the placement launches. In addition up to two resupply visits will be required each year to maintain the station.

The addition to find capability configuration is accomplished in 1996 by addition of an enclosed research module laboratory and a specialized materials processing laboratory. At this time (1996) the station is effectively functioning as an operational space transportation node and full capability research facility.

The estimated funding for the sequence is included in Task 3, Attachment 1, Volume IV.

SPACE STATION EVOLUTION



SPACE STATION PROGRAMS

TASK 2—MISSION IMPLEMENTATION CONCEPTS

2.1 MISSION SCENARIO ANALYSIS AND ARCHITECTURAL CONCEPTS
2.2 ALTERNATIVE SYSTEMS CONCEPTS
2.3 MISSION OPERATIONS ARCHITECTURAL DEVELOPMENT
2.4 ARCHITECTURAL ANALYSIS TRADES
2.5 EVOLUTION
2.6 CONFIGURATION
2.7 TECHNOLOGY DEVELOPMENT
2.8 CONCLUSIONS

Lockheed

TECHNOLOGY DEVELOPMENT APPROACH

In the course of defining and identifying technologies that need to be developed further to support the feasibility of a Space Station, LMSC identified technology issues, TDMs, and technologies needing development.

The TDMs selected need to have a mix of analysis and trade-offs with an emphasis on key subsystem technologies that are drivers in the total system selected technologies must be congruent with the need to develop capabilities for an evolutionary Space Station - growth in habitats, larger structural assembly, propellant transfer, distributed data processing, etc.

TECHNOLOGY DEVELOPMENT APPROACH

- TECHNOLOGY DEVELOPMENT ISSUES
- TECHNOLOGY DEVELOPMENT MISSIONS
- TECHNOLOGIES NEEDING DEVELOPMENT

TECHNOLOGY DEVELOPMENT ISSUES

The next ten charts present lists of technology issues that must be addressed in the development of a Space Station whether it be a modest limited capability station or a fully evolved station. Alternative approaches reflecting additional or viable alternatives and possible solutions to the issues are identified as are systems or subsystems that will be impacted.

Technology issues are summarized in the following nine categories:

- Structures and Mechanisms
- Propulsion/Propellant Management
- Attitude Control and Stabilization
- Electrical Power
- Thermal Management
- Crew and Life Support
- Data Management
- Communication and Tracking
- Space Operations

TECHNOLOGY DEVELOPMENT ISSUES
STRUCTURES & MECHANISMS

TECHNOLOGY ISSUES

DESIGN/FAB LARGE SPACE STRUCTURES

CONTROL DYNAMICS OF LARGE, FLEX STRUCT

JOINTS/JOINT EFFICIENCY/MECHANISMS

PLATFORM STRUCTURES
- PRESSURIZED
- UNPRESSURIZED

LARGE ANTENNA STRUCTURES

INTERACTION WITH ACTIVE CONTROLS

MANIPULATOR SYSTEM

ASSEMBLE/DEPLOY LGE STRUCT. & ANTENNAS

ALTERNATIVE APPROACHES

STRUCTURAL DESIGN OPTIMIZATION

DOCKING/BERTHING DEVICES

MODULAR DESIGNS

ASSEMBLY ON ORBIT STRUCTURE/CONTROL/ INTERACTIONS

SYSTEM/SUBSYSTEM/IMPACTS

CONTROL SYSTEMS & ALIGNMENT

CONSTRUCTION/ASSY

MANUFACTURING PROCESSES

THERMAL MANAGEMENT

ORBITAL OPERATIONS

STRUCTURAL COATINGS

MAINTAINABILITY

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TECHNOLOGY DEVELOPMENT ISSUES
PROPULSION/PROPELLANT MANAGEMENT

TECHNOLOGY ISSUES

- LONG TERM PROPELLANT STORAGE (ZERO-G)
- PROPELLANT LOADING & TRANSFER (CRYOGEN & FLUID)
- PROPELLANT MGMT DEVICES (ORIENTATION)
- ON-ORBIT MAINTENANCE
- GASEOUS LIQUIFICATION VERIFICATION
- ADVANCED PROPULSION SYSTEMS

ALTERNATIVE APPROACHES

- CRYOGENS VS. BIPROPELLANTS
- PRESSURIZED VS. PUMPED
- GASEOUS VS. LIQUID STORAGE
- LOW LEVEL THRUSTERS
- HIGH PERFORMANCE STORABLES
- REMOTE CONNECT/DISCONNECT

SYSTEM/SUBSYSTEM/IMPACTS

- POWER SYSTEMS
- ECLSS
- THERMAL MANAGEMENT
- SENSORS
- MECHANISMS
- AUXILIARY PROPULSION

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TECHNOLOGY DEVELOPMENT ISSUES
ATTITUDE CONTROL & STABILIZATION

TECHNOLOGY ISSUES

- DISTRIBUTED & ADAPTIVE CONTROL
- AUTONOMOUS POINTING & NAVIGATION
- CONTROL FUNCTION INTEGRATION
- MODAL DETERM CONTROL FOR FLEXIBLE MULTIBODY DYNAMICS
- LARGE VARYING MASS & DYNAMICS
- PRECISION POINT SYST.
- PAYLOAD ISOLATION FROM SS DYNAMICS

ALTERNATIVE APPROACHES

- STIFFEN STRUCTURE
  - MAT'L IMPROVE.
  - DESIGN TECHNIQUE
- REDUCE THERMAL DISTORTION
- DISTRIBUTED CONTROL & SENSING
- ACTIVE SURFACE/SHAPE CONTROL
- CMG VS. THRUSTERS
- LOW BANDWIDTH CONTROL SYSTEMS
- COMMAND/CONTROL FOR PROXIMITY FLYERS
- STRUCTURE/CONTROL INTERACTIONS

SYSTEM/SUBSYSTEM/IMPACTS

- STRUCTURES DESIGN
- MATERIALS
- COMPUTER/SOFTWARE
- THERMAL MANAGEMENT

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TECHNOLOGY DEVELOPMENT ISSUES
ELECTRICAL POWER SYSTEMS

TECHNOLOGY ISSUES

- SOLAR ARRAY
  - LARGE ARRAY DYNAMICS
  - IMPROVED SOLAR CELL TECHNOLOGY
- POWER DISTRIBUTION SYSTEM
  - HIGH VOLTAGE DISTRIB
  - AC/DC DISTRIBUTION
  - AUTOMATED POWER MGMT
- MULTI HUNDRED KW SYS.
- REGENERATIVE FUEL CELLS
- NUCLEAR POWER
  - REACTOR TECHNOLOGY
  - HEAT REJECTION
  - NUCLEAR SHIELDING
  - THERMAL/ELECT CONVERSION

ALTERNATIVE APPROACHES

- SOLAR VS. NUCLEAR
- THIN, HIGH PERFORM CELLS
- CONCENTRATOR ARRAY
- AC VS. DC POWER
- MICROPROCESSOR CONTROL SYS
- IMPROVED ARRAY STRUCTURE
- WELDED SOLAR CELL INTERCONNECT
- MODULARITY
- MOMENTUM DEVICES (POWER STORAGE)

SYSTEM/SUBSYSTEM/IMPACTS

- ELECT POWER
- STRUCTURES
- ATTITUDE CONTROL SYSTEM
- POWER COND & DISTRIBUTION
- THERMAL MANAGEMENT
- DATA MANAGEMENT
- ORBITAL REPLACEMENT
- OPER CONSTRAINTS TO SERVICE VEHICLE
- ENVIRON INTERACTION - PLASMA/RADIATION
- POWER PLATFORM

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TECHNOLOGY DEVELOPMENT ISSUES
THERMAL MANAGEMENT

TECHNOLOGY ISSUES

- LARGE DEPLOYED RADIATORS
- CONCENTRATED HEAT LOADS/HEAT REJECTION
- LONG LIFE SYSTEMS
- MAINTAINABLE COATINGS

ALTERNATIVE APPROACHES

- LARGE CENTRALIZED RADIATORS
- THERMAL BUS
  - PUMPED FLUIDS
  - HEAT PIPES
  - PUMP ASSIST
  - HEAT PIPE
- PASSIVE CONTROL SURFACES

SYSTEM/SUBSYSTEM/IMPACTS

- STRUCTURES
- ELECTRICAL POWER
- CONTROL SYSTEMS
- MATERIALS
- STRUCTURES & MECHANISMS
- ENVIRONMENTAL INTERACTION

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TECHNOLOGY DEVELOPMENT ISSUES
CREW & LIFE SUPPORT

TECHNOLOGY ISSUES

- REGENERABLE VS. EXPENDABLE
- LONG TERM ZERO-G EFFECTS
- TWO PHASE FLOW SYSTEMS
- CHEMICAL PROCESSES SYSTEMS
- TRACE CONTAMINATION CONTROL SYSTEM (TOC, AMMONIA, ETC)
- MAN'S ROLE & CAPABILITIES IN SPACE

ALTERNATIVE APPROACHES

- THERMOELECTRIC DISTILLATION
- MULTIFILTRATION
- AIR/WATER VAPOR ELECTROLYSIS
- O_2 RECOVERY
- WATER RECOVERY

SYSTEM/SUBSYSTEM/IMPACTS

- ELECTRICAL POWER
- THERMAL MANAGEMENT
- CREW SYSTEMS
- RESUPPLY LOGISTICS
- DATA MANAGEMENT
- SAFETY

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TECHNOLOGY DEVELOPMENT ISSUES
DATA MANAGEMENT

TECHNOLOGY ISSUES	ALTERNATIVE APPROACHES	SYSTEM/SUBSYSTEM/IMPACTS
HIGH DATA RATE SYSTEMS	REAL TIME INTERACTIVE DISPLAYS	COMMUNICATIONS
ON-ORBIT PROCESSING	CENTRALIZED COMPUTER ON SS VS. AUTONOMOUS FREE FLYER CAPABILITY	ELECTRICAL POWER
DATA STORAGE	TRANSPORTABILITY OF FUNCTIONS BETWEEN COMPUTERS	EMI/EMC
ADVANCED SOFTWARE/ LANGUAGE	ON-BOARD SOFTWARE VS. SUPPORT SOFTWARE	THERMAL MANAGEMENT
FUNCTIONAL SOFTWARE PARTITIONING	DISTRIBUTED FLIGHT PROCESSING	GUIDANCE & NAVIGATION
DIRECT USER ACCESS	STANDARD PROCESSOR	DISPLAYS & CONTROLS
CONTROLS & DISPLAYS	STANDARD SOFTWARE ARCHITECTURE	
HIGH SPEED, MULTIPLEXED DATA BUS		
GLOBAL DATA BUS NETWORK		

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TECHNOLOGY DEVELOPMENT ISSUES
COMMUNICATION & TRACKING

TECHNOLOGY ISSUES	ALTERNATIVE APPROACHES	SYSTEM/SUBSYSTEM/IMPACTS
INTEGRATED TELECOMMUNICATIONS SYSTEM	OPTICAL DATA LINKS	DATA MANAGEMENT
AUTOMATED COMMAND & CONTROL	ANTENNA SHARING	DISPLAYS & CONTROLS
HIGH DATA RATE INTERFACING	DISTRIBUTED PHASED ARRAY ANTENNAS	ANTENNAS
ANTENNA CONFIGURATIONS	HIGHER DATA RATES	SPACE OPERATIONS
LASER COMMUNICATIONS & TRACKING	NARROW BEAM TRANSMISSION	RF RADIATION
MULTIPLE COMMUNICATON LINKS		PRECISION TRACKING
		PROXIMITY OPERATIONS

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TECHNOLOGY DEVELOPMENT ISSUES
SPACE OPERATIONS

TECHNOLOGY ISSUES

- MOBILE MANIPULATOR
- SATELLITE ASSY & TEST
- LARGE STRUCTURE ASSY & TEST
- SATELLITE RETRIEVAL/ HANDLING/SERVICING
- AUTONOMOUS RENDEZVOUS
- CHECKOUT CONCEPTS
- MATERIAL PROCESSING CHANGEOUT
- PAYLOAD MATING
- SERVICE OTV/TMS
- COMMAND/CONTROL FREE FLYING PLATFORMS
- AEROBRAKING

ALTERNATIVE APPROACHES

- SS AUTONOMY
- SATELLITE SERVICING ON SS VS. IN SITU
- EVA VS. REMOTE MANIPULATION
- ORU REPLACEMENT (CHANGEOUT VS. REPAIR LEVEL)
- INFLATABLE HANGERS
- OTV STABIL & CONTROL DURING SERVICING/DOCKING/ BERTHING
- ASSY/DISASSY OF SPACECRAFT
- AEROBRAKING VS. NON-AEROBRAKING
- PRESSURIZED HANGER
- REMOTE PROPELL HANDLING PLATFORM

SYSTEM/SUBSYSTEM/IMPACTS

- STRUCTURES
- MECHANISMS
- CONSTRUCTION/ASSEMBLY
- ORBIT REPLACEMENT
- PROPELL MANAGEMENT
- CONTROL SYSTEM
- EVA ACTIVITY & DYNAMICS
- OPER. CONSTRAINTS TO SERVICE VEHICLE
- TMS/OTV

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SPACE STATION PROGRAMS

TECHNOLOGY DEVELOPMENT ISSUES
SPACE OPERATIONS (CONT)

TECHNOLOGY ISSUES	ALTERNATIVE APPROACHES	SYSTEM/SUBSYSTEM/IMPACTS
MAINTENANCE/CLEANING REFLECTING SURFACES	ROBOTICS	
TETHER OPERATIONS	ADVANCED PROPULSION SYSTEMS	
RESCUE	OTV PAYLOAD OPERATIONS	
SATELLITE RETRIEVAL FRON NON CO-ORBIT	RESCUE VEHICLE VS. SAFE HAVEN	
PAYLOAD CHANGEOUT		
REFUELING		
SATELLITE LAUNCH		

TECHNOLOGY DEVELOPMENT MISSIONS

The following pages list technologies requiring development and demonstration in a space environment. These technologies are all oriented toward the capabilities required for a large (evolved) Space Station in the mid 1990's. Time phasing of the TDMs has not been done. The TDMs have been identified as to whether they are of critical need to the Space Station or whether they have a high potential pay-off through performance, cost or weight.

SPACE STATION PROGRAMS

TECHNOLOGY DEVELOPMENT MISSIONS

SUBSYSTEM	TECHNOLOGY DEVELOPMENT MISSION	CRITICAL NEED	HIGH POTENTIAL PAYOFF
STRUCTURES & MECHANISMS	LARGE STRUCTURES CONSTRUCTION	X	
	PRECISION STRUCTURE ASSY	X	
	LARGE ANTENNA ASSEMBLY & DEPLOYMENT		X
	LARGE STRUCTURE INTERACTION WITH ACTIVE CONTROL SYSTEM	X	
	REMOTE MANIPULATOR ARM & USE IN ASSY/SERVICING	X	
PROPULSION/ PROPELLANT MANAGEMENT	DEMONSTRATE LONG TERM SPACE CRYOGENIC STORAGE	X	
	RELIQUIFICATION VERIFICATION	X	
	PROPELLANT TRANSFER DEMONSTRATION - CRYO/BIPROPELLANT	X	
	DEMONSTRATE REMOTE PROPELL LINE CONNECT/DISCONNECT		
ATTITUDE CONTROL	VERIFY ADAPTIVE CONTROL OF LARGE FLEXIBLE STRUCTURE	X	
	DEMONSTRATE AUTONOMOUS CONTROL OF OTV	X	

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TECHNOLOGY DEVELOPMENT MISSIONS (CONT)

SUBSYSTEM	TECHNOLOGY DEVELOPMENT MISSION	CRITICAL NEED	HIGH POTENTIAL PAYOFF
	DEMONSTRATE COMMAND/CONTROL FOR PROXIMITY FLYERS		X
ELECTRICAL POWER	DEMONSTRATE DEPLOYMENT OF LARGE SOLAR ARRAYS	X	
	VERIFY LIGHTWEIGHT SOLAR ARRAY PERFORMANCE AND LIFE	X	
	SPACE DEMONSTRATION OF CONCENTRATOR CELL SOLAR ARRAY		X
	DEMONSTRATE AUTOMATED POWER MANAGEMENT IN SPACE	X	
	HIGH VOLTAGE POWER TRANSFER OVER LONG LINES		X
THERMAL MANAGEMENT	DEMONSTRATE ASSEMBLY AND PERFORMANCE OF LARGE DEPLOYED RADIATORS	X	
	VERIFY LIFE OF SYSTEM CONCENTRATED HEAT REJECTION/ COATINGS/JOINTS	X	

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TECHNOLOGY DEVELOPMENT MISSIONS (CONT)

SUBSYSTEM	TECHNOLOGY DEVELOPMENT MISSION	CRITICAL NEED	HIGH POTENTIAL PAYOFF
CREW & LIFE SUPPORT	DEMONSTRATE REGENERATIVE ECLSS	X	
	TWO PHASE FLOW SYSTEM VERIFICATION		X
	IMPROVE TRACE CONTAMINENT CONTROL SYSTEM RELIABILITY	X	
	DEMONSTRATE CREW EVA ASSEMBLY OPERATIONS		X
DATA MANAGEMENT	DEMONSTRATE DISTRIBUTED FLIGHT DATA PROCESSING SYSTEM		X
	ADVANCED SOFTWARE LANGUAGE		X
	HIGH SPEED, MULTIPLEXED DATA BUS		X
	GLOBAL DATA BUS NETWORK		X
COMMUNICATION & TRACKING	DEMONSTRATE PRECISION NARROW BEAM ANTENNA POINTING		X
	DISTRIBUTED PHASED ARRAY ANTENNAS		X
	BROAD BAND DATA TRANSMISSION		X

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TECHNOLOGY DEVELOPMENT MISSIONS (CONT)

SUBSYSTEM	TECHNOLOGY DEVELOPMENT MISSION	CRITICAL NEED	HIGH POTENTIAL PAYOFF
	LASER COMMUNICATIONS SYSTEM		X
OPERATIONS	OTV ON-ORBIT CHECKOUT	X	
	OTV/TMS SERVICING	X	
	BERTHING/DOCKING MECHANISM	X	
	FLUID TRANSFER	X	
	AUTONOMOUS FREE FLYER RENDEZVOUS	X	
	SATELLITE RETRIEVAL/HANDLING/ SERVICING		X
	MAINTENANCE & CLEANING REFLECTIVE/ OPTICAL SURFACES	X	
	TETHER OPERATIONS		X
	PAYLOAD CHANGEOUT		X
	ORU REPLACEMENT		X
	REMOTE PROPELLANT HANDLING PLATFORM		X
	ASSEMBLY/DISASSEMBLY OF SPACECRAFT		
	ROBOTICS DEMONSTRATION IN SPACE		X

TDM SELECTION CRITERIA

Nine criteria or selection factors are listed which were used as a guide to the selection of technologies that need to be developed. These criteria were used to select TDM candidates presented in the previous charts as well as to recommend specific technologies to be developed. Those technologies follow in the next 3 charts.

TDM SELECTION CRITERIA

THE SELECTED TDM CANDIDATE:

- IS REQUIRED TECHNICALLY TO PROVIDE MISSION CAPABILITY
- INVOLVES SIGNIFICANT NEW TECHNOLOGY/DESIGN/SPACE OPERATION
- HAS EVOLUTIONARY GROWTH POTENTIAL
- COMBINES SEVERAL TECHNOLOGY DEVELOPMENT OBJECTIVES
- REQUIRES MORE SPACE CAPABILITY THAN THE SHUTTLE CAN PROVIDE
- SATISFIES SEVERAL SPACE STATION PROGRAM OBJECTIVES
- SUPPORTS MULTIPLE SPACE OPERATIONS/MISSIONS/EXPERIMENTS
- DEMONSTRATES ENHANCED OPERATIONAL CAPABILITY
- UTILIZES THE CREW EFFICIENTLY

TECHNOLOGIES THAT NEED DEVELOPMENT

Technologies were grouped on the basis of the nine categories for which issues were identified. The issues and alternative approaches were analyzed as to their impact on our Space Station concepts if such technologies were not available. The key factor was the degraded capability of the station concepts in meeting functional requirements were the technologies not ready in time.

The intent here is not to identify a specific solution to a technology issue but to summarize the areas requiring development. No attempt was made either to differentiate between a technology currently under development or successfully working in a laboratory environment, i.e., regenerative ECLSS.

SPACE STATION PROGRAMS

TECHNOLOGIES THAT NEED DEVELOPMENT

- LARGE SPACE STRUCTURE ASSEMBLY CONCEPTS
- PRECISION STRUCTURES ASSEMBLY IN SPACE
- METAL MATRIX FOR LARGE STRUCTURES
- REMOTE MANIPULATOR/ ROBOTICS APPLICATIONS
- CRYOGENIC STORAGE/ TRANSFER/RELIQUIFICATION
- MONO/BIPROPELLANT TRANSFER
- PROPELLANT MANAGEMENT DEVICES (ORIENTATION)
- REMOTE PROPELLANT CONNECT/DISCONNECT
- ADVANCED PROPULSION
  - MPD
  - ION
  - LOW THRUST CHEMICALS
  - HIGH PERFORMANCE STORABLES
- ADAPTIVE CONTROL SYSTEM FOR LARGE, FLEXIBLE STRUCTURE
- AUTONOMOUS CONTROL FOR PROXIMITY FREE FLYERS
  - PLATFORMS
  - OTV
- LARGE SOLAR ARRAYS
  - DEPLOYMENT
  - PERFORMANCE
  - LIFE
  - MAINTENANCE
  - SOLAR CELL IMPROVEMENTS
- NUCLEAR TECHNOLOGY
  - REACTOR
  - SHIELDING
  - THERMOELECTRIC CONVERSION
  - HEAT REJECTION

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TECHNOLOGIES THAT NEED DEVELOPMENT

- AUTOMATED POWER MANAGEMENT
- HIGH VOLTAGE POWER TRANSFER
- RADIATOR MATERIALS
  - LONG LIFE/HIGH HEAT RATE
  - COATINGS
  - FLEXIBLE JOINTS
- REGENERATIVE ECLSS
- TRACE CONTAMINATION CONTROL SYSTEM
- DISTRIBUTED FLIGHT DATA PROCESSING SYSTEM
- HIGH SPEED MULTIPLEXED DATA BUS
- ADVANCED SOFTWARE LANGUAGE
- LASER COMMUNICATIONS
  - HIGHER RATES
  - NARROW BEAM
- LARGE ANTENNA SYSTEMS
  - NARROW BEAM
  - BROAD BEAM
  - DISTRIBUTED PHASED ARRAY
- AUTONOMOUS RENDEZVOUS
- REUSABLE OTV/TMS
- OPERATIONAL TECHNIQUES
  - EVA
  - REMOTE CONTROL
  - ROBOTICS
  - SATELLITE RETRIEVAL
  - SATELLITE SERVICING
  - CHECKOUT
  - ORU REPLACEMENT
  - BERTHING
  - PAYLOAD CHANGEOUT

SPACE STATION CONCEPTS TO DEVELOP TECHNOLOGIES

From the technologies tabulated in the previous charts and the Alternative Space Station Systems concepts developed earlier in Task 2, a compatibility analysis was performed to define which Space Station Concept(s) can be used to verify or develop the needed technologies. The grouping often indicates the importance of a technology to the viability of station concept to be able meet its functional requirements.

Analysis results indicate that no single Space Station Concept can be used to satisfy the verification or development of these identified technologies.

SPACE STATION CONCEPTS TO DEVELOP TECHNOLOGIES

TECHNOLOGIES THAT NEED DEVELOPMENT	SPACE STATION MISSION CONCEPTS				
	A – ATTACHED LAB, 57 DEG	B – ATTACHED LAB, 28-1/2 DEG	C – DETACHED FACILITIES, 28-1/2 DEG	D – LEO, SERVICING, 28-1/2 DEG	E – DOD, 28-1/2 DEG
• LARGE SPACE STRUCTURE ASSEMBLY CONCEPTS		X	X	X	
• PRECISION STRUCTURES ASSEMBLY IN SPACE			X	X	
• METAL MATRIX FOR LARGE STRUCTURES	X	X	X	X	X
• REMOTE MANIPULATOR/ ROBOTICS APPLICATIONS			X	X	
• CRYOGENIC STORAGE/ TRANSFER/RELIQUIFICATION			X	X	X
• MONO/BIPROPELLANT TRANSFER			X	X	
• PROPELLANT MANAGEMENT DEVICES (ORIENTATION)	X	X	X	X	X
• REMOTE PROPELLANT CONNECT/DISCONNECT			X	X	

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SPACE STATION CONCEPTS TO DEVELOP TECHNOLOGIES

TECHNOLOGIES THAT NEED DEVELOPMENT	SPACE STATION MISSION CONCEPTS				
	A – ATTACHED LAB, 57 DEG	B – ATTACHED LAB, 28-1/2 DEG	C – DETACHED FACILITIES, 28-1/2 DEG	D – LEO, SERVICING, 28-1/2 DEG	E – DOD, 28-1/2 DEG
• ADVANCED PROPULSION					
– MPD	X	X	X	X	X
– ION			X		
– LOW THRUST CHEMICALS			X	X	
– HIGH PERFORMANCE STORABLES	X	X	X	X	X
• ADAPTIVE CONTROL SYSTEM FOR LARGE, FLEXIBLE STRUCTURE	X	X	X	X	
• AUTONOMOUS CONTROL FOR PROXIMITY FREE FLYERS					
– PLATFORMS			X	X	
– OTV	X	X	X	X	
• LARGE SOLAR ARRAYS – DEPLOYMENT – PERFORMANCE – LIFE – MAINTENANCE – SOLAR CELL IMPROVEMENTS	X	X	X	X	
• NUCLEAR TECHNOLOGY – REACTOR – SHIELDING – THERMOELECTRIC CONVERSION – HEAT REJECTION		X	X		X

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SPACE STATION CONCEPTS TO DEVELOP TECHNOLOGIES

TECHNOLOGIES THAT NEED DEVELOPMENT	SPACE STATION MISSION CONCEPTS: A – ATTACHED LAB, 57 DEG	B – ATTACHED LAB, 28-1/2 DEG	C – DETACHED FACILITIES, 28-1/2 DEG	D – LEO, SERVICING, 28-1/2 DEG	E – DOD, 28-1/2 DEG
• AUTOMATED POWER MANAGEMENT	X	X		X	X
• HIGH VOLTAGE POWER TRANSFER	X	X	X		X
• RADIATOR MATERIALS – LONG LIFE/HIGH HEAT RATE – COATINGS – FLEXIBLE JOINTS	X	X	X		X
• REGENERATIVE ECLSS	X	X		X	X
• TRACE CONTAMINATION CONTROL SYSTEM	X	X		X	X
• DISTRIBUTED FLIGHT DATA PROCESSING SYSTEM	X	X	X		
• HIGH SPEED MULTIPLEXED DATA BUS	X	X			X
• ADVANCED SOFTWARE LANGUAGE	X	X			

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SPACE STATION CONCEPTS TO DEVELOP TECHNOLOGIES

TECHNOLOGIES THAT NEED DEVELOPMENT	SPACE STATION MISSION CONCEPTS: A – ATTACHED LAB, 57 DEG	B – ATTACHED LAB, 28-1/2 DEG	C – DETACHED FACILITIES, 28-1/2 DEG	D – LEO, SERVICING, 28-1/2 DEG	E – DOD, 28-1/2 DEG
• LASER COMMUNICATIONS – HIGHER RATES – NARROW BEAM	X	X			X
• LARGE ANTENNA SYSTEMS – NARROW BEAM – BROAD BEAM – DISTRIBUTED PHASED ARRAY	X	X			
• AUTONOMOUS RENDEZVOUS	X	X	X	X	X
• REUSABLE OTV/TMS			X	X	
• OPERATIONAL TECHNIQUES					
– EVA	X				
– REMOTE CONTROL			X	X	
– ROBOTICS			X	X	
– SATELLITE RETRIEVAL				X	
– SATELLITE SERVICING			X	X	
– CHECKOUT				X	
– ORU REPLACEMENT	X	X	X	X	
– BERTHING	X	X	X	X	
– PAYLOAD CHANGEOUT	X	X		X	

SPACE STATION PROGRAMS

TASK 2—MISSION IMPLEMENTATION CONCEPTS

2.1 MISSION SCENARIO ANALYSIS AND ARCHITECTURAL CONCEPTS
2.2 ALTERNATIVE SYSTEMS CONCEPTS
2.3 MISSION OPERATIONS ARCHITECTURAL DEVELOPMENT
2.4 ARCHITECTURAL ANALYSIS TRADES
2.5 EVOLUTION
2.6 CONFIGURATION
2.7 TECHNOLOGY DEVELOPMENT
2.8 CONCLUSIONS

Lockheed

CONCLUSIONS
TASK 2

Our analysis of mission support requirements and development of station architectural concepts, system implementation concepts, configuration alternatives, and technology considerations leading to selection of a reference space station configuration and evolutionary plan, resulted in the conclusions shown on the facing page.

We feel that our reference configuration is a reasonable concept and in accordance with the depth to which we performed analyses of optional condidates represents the best selection.

We concluded that the station configuration is an "open book" at this stage of investigation and that more extensive subsystem performance requirements must be developed in order to provide the basis ultimately for a design selection.

A major conclusion we have reached is that the station should be designed and operated as a true "space facility" resource that can satisfy the needs of multiple users and can also have the flexibility to meet unique user needs without interfering with the basic station capability. We conclude as a follow on to this that Logistics to support the station and the use of a ground based transportation system as well as station based transport vehicles will play a dominant role in the design and operation of the space station.

SPACE STATION PROGRAMS

CONCLUSIONS TASK 2

- DERIVED STATION MAJOR FUNCTIONAL ATTRIBUTES ARE COMMON TO THE MAJORITY OF MISSIONS EVALUATED
- USER REQUIREMENTS CAN BE MET BY APPLICATION OF BASIC INHERENT SPACE STATION CAPABILITIES PLUS MISSION UNIQUE SUPPORT EQUIPMENT AND PROCEDURES
- SPACE OPERATIONS CATEGORY MISSIONS ARE THE MAJOR DRIVER FOR SYSTEMS ARCHITECTURE
- THE STATION MUST RELY ON BOTH ATTACHED SUPPORT ELEMENTS AND FREE FLYER SATELLITES TO ACCOMODATE THE SPECTRUM OF MISSIONS EVALUATED
- DoD RESEARCH AND DEVELOPMENT MISSIONS CAN EFFECTIVELY USE CAPABILITY OF A SPACE STATION
- OPERATIONAL MISSIONS ARE BEST IMPLEMENTED BY DETACHED MISSION UNIQUE FREE FLYERS
- USE OF TETHER CONCEPTS APPEARS FEASIBLE AND FURTHER STUDIES OF THIS APPLICATION ARE NEEDED
- THE STS MUST PLAY A DOMINANT ROLE IN SUPPORT OF THE SPACE STATION
- EXTERNAL TANKS (ETS) ARE VIABLE HARDWARE CANDIDATES FOR MULTIPLE USES BY THE STATION
- STATION CONFIGURATION IS AN "OPEN BOOK" AT THIS TIME - EXTENSIVE SUBSYSTEM PERFORMANCE REQUIREMENTS NEED TO BE DEVELOPED
- A REASONABLE EVOLUTIONARY GROWTH FROM AN INITIAL LOW CAPABILITY TO A FINAL HIGH CAPABILITY SPACE STATION CAN BE ACHIEVED IN SIX YEARS

Lockheed

SPACE STATION PROGRAMS

TASK 3 - COST AND PROGRAMMATIC ANALYSIS

3.1 BENEFITS

3.2 COST, SCHEDULE AND FUNDING

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SPACE STATION PROGRAMS

TASK 3 - COST AND PROGRAMMATIC ANALYSIS

3.1 BENEFITS

3.2 COST, SCHEDULE AND FUNDING

Lockheed

THE LANGUAGE OF BENEFIT ASSESSMENT

Orderly discussion of Space Station benefits requires a common linguistic framework. A useful beginning is the definition of a benefit from Webster's New International Dictionary (Second Edition):

"Whatever promotes welfare; advantage; profit."

This definition suggest three convenient classifications for benefits. Each class benefits a different group and each is assessed in a different way. 'Welfare' benefits accrue to the populace at large, either nationally or internationally. They are factors that motivate decisions, yet are not used to justify these decisions analytically. This is because welfare benefits are the least tangible of all three classes and hence are difficult to quantify.

'Advantage' benefits accrue to the users of a system such as Space Station who have a job to be done and have alternative ways to do this job. The alternatives may be either of two types, i.e., 'equal capability' or 'unequal capability'. In the first case, the mission capability of alternatives (payload capability, data return, etc.) is approximately equal andlife cycle cost becomes the discriminator between approaches. In the unequal-capability case, the mission performance of alternative approaches is significantly different and cost is just one factor in selection of a preferred approach. For both of these advantage-type benefits, the techniques of cost-benefit analysis apply.

'Profit" type benefits, as defined here, accrue to a commercial firm. These are the competitive margins that can be realized with a new venture. They are quantified using profitability analysis, and such measures as return on investment and cash flow. Such benefits are not the focus of this analysis.

SPACE STATION PROGRAMS

THE LANGUAGE OF BENEFIT ASSESSMENT

DEFINITION OF A BENEFIT:
"WHATEVER PROMOTES WELFARE, ADVANTAGE, PROFIT."

WELFARE
- TO POPULACE

- NATIONAL SECURITY
- NATIONAL PRESTIGE
- TECHNO ECONOMIC STABILITY
- INT'L COOPERATION

ADVANTAGE
- TO USERS

EQUAL CAPABILITY
- REDUCED LOGISTICS (TRANSPORTATION, MAINTENANCE) COSTS
- REDUCED ACQUISITION COSTS

UNEQUAL CAPABILITY
- UNIQUE TECHNOLOGY
- UNIQUE MISSION CAPABILITY

PROFIT
- TO PRIVATE FIRMS

- COMPETITIVE MARGIN IN EXISTING PRODUCT LINE
- NEW PRODUCT LINE

BENEFIT ASSESSMENT (QUALITATIVE) → WELFARE

BENEFIT/COST ANALYSIS → EQUAL CAPABILITY; UNEQUAL CAPABILITY

PROFITABILITY ANALYSIS → PROFIT

SOME QUALITATIVE BENEFITS

The benefits categorized as 'welfare' type in the preceding figure are qualitative rather than quantitative. This figure lists some of the qualitative Space Station benefits that have emerged in this study.

One category of these benefits arises from the fact that the Space Station is the largest open program likely to occur in the next decade. The sheer size of the Space Station program makes possible:

Commercialization of space on a large scale, even to the point of contemplating space 'industrial parks'.

International cooperation in which participants can develop elements of significant size (e.g., whole modules) rather than subsystems or assemblies.

The establishment of a technology and manpower base large enough to buffer uncertainties in national policy.

Another category of non-quantifiable benefits arises from the national security advantages of a manned presence in space. The U.S. has recognized that a presence in otherwise uninhabitable places such as Antarctica adds an intangible sense of cognizance in areas where national sovereignty cannot be claimed. And if, in such a relatively inaccessible area a national command authority can survive better than on earth, then the assured continuation of our defense can be made more visible.

The list of qualitative benefits on this figure is representative but not comprehensive. This effort must continue until a policy on Space Station development is established.

SPACE STATION PROGRAMS

SOME QUALITATIVE BENEFITS

BENEFITS DUE TO STATION 'CRITICAL MASS'

- UNIQUE FRAMEWORK FOR SPACE INDUSTRIAL PARK
- 'FLYWHEEL' TO PRESERVE TECHNOLOGICAL & INDUSTRIAL BASE
- LARGE ENOUGH FOR SIGNIFICANT INTERNATIONAL PARTICIPATION
- UNFORESEEN SPINOFFS TO CIVILIAN ECONOMY

BENEFITS TO NATIONAL SECURITY

- U.S. CONTINUING PRESENCE IN SPACE (ANTARCTICA ANALOGY)
- SURVIVABLE NATIONAL AUTHORITY
- 'HIGH-GROUND' OBSERVER

SAFETY BENEFITS

- 'SAFE HAVEN' FOR STS CREWS

SOME QUANTIFIABLE SPACE STATION BENEFITS

The next two figures summarize certain specific areas in which it is possible, at least in principle, to quantify Space Station benefits. The work of quantification was begun in this study and will be the subject of a planned follow-on effort.

The benefit categories listed on these figures cover the following general areas:

Bringing the Space Transportation System to the full level of capability that was originally planned but never realized

Allowing man to substitute for, and improve upon, the mechanical and interpretative functions now assigned to hardware and software

Providing a low-cost test bed for technology development

Lockheed has used the case-study method to quantify benefits in key areas, as is discussed subsequently.

SPACE STATION PROGRAMS

SOME QUANTIFIABLE SPACE STATION BENEFITS

BENEFIT CATEGORY	APPLICABILITY ALL MSNS	APPLICABILITY SELECTED MSNS	MECHANISMS FOR QUANTIFYING BENEFITS
SPACE STATION AS ORBITAL DEPOT & MAINTENANCE BASE	X		IMPROVED LOGISTICS: • POTENTIALLY FEWER STS FLIGHTS • POTENTIALLY SMALLER ORBITER FLEETS
		X	RAPID RESPONSE MAINTENANCE: • SHORTER DOWN TIME PER OUTAGE • LONGER MISSION LIFE
MAN-IN-LOOP DATA		X	REDUCED DATA STREAM TO GROUND: • LESS TRANSMISSION HARDWARE/SOFTWARE • REDUCED GROUND DATA REDUCTION HARDWARE/SOFTWARE
SPACE-STATION-BASED OTV		X	IMPROVED OTV MASS FRACTION: • GREATER PERFORMANCE LOGISTICS ADVANTAGES: • FULL SHUTTLES • POSSIBLE ET SCAVENGING

SOME QUANTIFIABLE SPACE STATION BENEFITS (CONT'D)

In addition to the quantifiable benefits listed here, there are potential macroeconomic advantages to government spending in high technology areas. These are expected to be the focus of a forthcoming study.

SPACE STATION PROGRAMS

SOME QUANTIFIABLE SPACE STATION BENEFITS (CONT'D)

BENEFIT CATEGORY	APPLICABILITY: ALL MSNS	APPLICABILITY: SELECTED MSNS	MECHANISMS FOR QUANTIFYING BENEFITS
TEST BED CAPABILITY	X		BRASSBOARD EXPERIMENTS FLIGHT OPTION: REDUCED ANALYSIS/DESIGN; REDUCED TEST
MAN-TENDED EXPERIMENTS		X	REDUCED AUTOMATION, REDUCED DATA HANDLING: HARDWARE ACQUISITION; SOFTWARE DEVELOPMENT
TECHNOLOGY BASE FOR MANNED MISSIONS		X	REDUCED DDT&E FOR: MANNED PLANETARY MISSIONS; OTHER ADVANCED MISSIONS
LONG DURATION MANNED MISSION CAPABILITY		X	REDUCED DEMAND ON STS: POTENTIALLY SMALLER ORBITER FLEET

CASE STUDY OF LOGISTICS ADVANTAGES

The next three figures summarize a case study in benefits quantification that centered on the relative logistics efficiency of spacecraft servicing with an Orbital Transfer Vehicle (OTV). The specific program selected for analysis was the Integrated Tactical Surveillance System (ITSS), a program that has been analyzed in depth by Lockheed. The ITSS comprises orbital constellations of surveillance satellites. The procurement of these satellites can be reduced by extending their lifetime through scheduled servicing over the operational life of the program. In previous sections of this report, it was established that energy requirements for orbital transfer from a Space Station to a satellite are reasonable at nodal coincidence. Consequently the analysis was limited to scheduled servicing rather than unscheduled maintenance.

The alternative servicing modes considered in this case study span a range of options available with the OTV, as follows:

Servicing the ITSS satellites in place using a ground-based OTV

Servicing the ITSS satellites in place using a space-based OTV that operates from a Space Station

Using the space-based OTV to ferry the ITSS satellites to/from the Space Station for servicing

Conclusions of the analysis may be considered conservative because of the following assumptions:

Scavenging of External Tank propellants was not assumed for the space-based OTV. Such scavenging, if feasible, would magnify the cost advantage of the space-based system by providing essentially 'free' propellants with each STS resupply flight

The space-based OTV was not credited with potential improvements in mass fraction that might be realized through orbital basing of an OTV. This would affect the payload capability of the various OTV concepts

The ground-based OTV was not charged with the cost of a retrieval flight, i.e., it was assumed that the same shuttle used to deliver the OTV could wait on orbit until ITSS servicing was completed, then return to earth.

CASE STUDY OF LOGISTICS ADVANTAGES

CASE SELECTED FOR STUDY:

- ITSS PROGRAM
- CONSTELLATION OF 24,000 LB. SATELLITES
- 1400 NM ALTITUDE

GROUNDRULES:

- NO ET PROPELLANT SCAVENGING FOR SPACE-BASED OTV
- SCHEDULED ITSS SERVICING
- SPACE-BASED OTV FLIES ONLY AT NODAL COINCIDENCE

ALTERNATIVES EVALUATED:

- ITSS SATELLITES SERVICED AT 1400 NM BY GROUND-BASED OTV
- ITSS SATELLITES SERVICED AT 1400 NM BY SPACE-BASED OTV
- ITSS SATELLITES CARRIED TO/FROM STATION BY SPACE-BASED OTV

SAVINGS WITH SPACE-BASED OTV

SCHEDULED SERVICE MISSIONS

In scheduled servicing of an ITSS orbital constellation, the advantage of a space-based OTV over a ground-based OTV lies in fully-efficient use of the Space Transportation System. For each ITSS service mission, the ground-based OTV and its servicing payload must be launched from the earth; in so doing, the reusable OTV and payload could easily occupy 75 percent of Orbiter cargo bay length, thereby incurring a dedicated flight charge. (Expendable OTV concepts, while shorter, cost a significant fraction of the Shuttle price per flight.) Moreover, if the ITSS servicing takes longer than the nominal Orbiter staytime, extra charges could be incurred for the extra stay or for a dedicated retrieval flight.

By contrast, the space-based OTV operates with a Space Station propellant depot which is at the end of an efficient logistics pipeline. The depot is resupplied using nondedicated Shuttle flights that are fully loaded. The OTV then draws from this store only enough propellants to perform ITSS servicing and return to the Station (15,500 lb for 1400 nautical mile orbit). This is less than one third of an equivalent shuttle flight per servicing mission.

SPACE STATION PROGRAMS

SAVINGS WITH STATION-BASED OTV

SCHEDULED SERVICE MISSIONS

	GROUND-BASED OTV	STATION-BASED OTV
SHUTTLE UTILIZATION	DEDICATED DELIVERY MODE: • ONE FLIGHT SCHEDULED PER SERVICE MISSION • LOAD FACTOR VARIABLE RETURN MODE: • DEDICATED RETRIEVAL FLIGHT • OR FLIGHT OF OPPORTUNITY • OR SHUTTLE STAYTIME EQUAL TO MISSION DURATION	DEPOT RESUPPLY MODE: • FLUIDS, EQUIPMENT RE-SUPPLIED ON SPACE-AVAILABLE BASIS • LOAD FACTOR 100%
OTV UTILIZATION	NOMINAL PROPELLANT LOADING	'TAILORED' PROPELLANT LOADING FOR EACH MISSION

GROUND-BASED VS STATION-BASED OTV SERVICING

COST OF RECURRING TRANSPORTATION

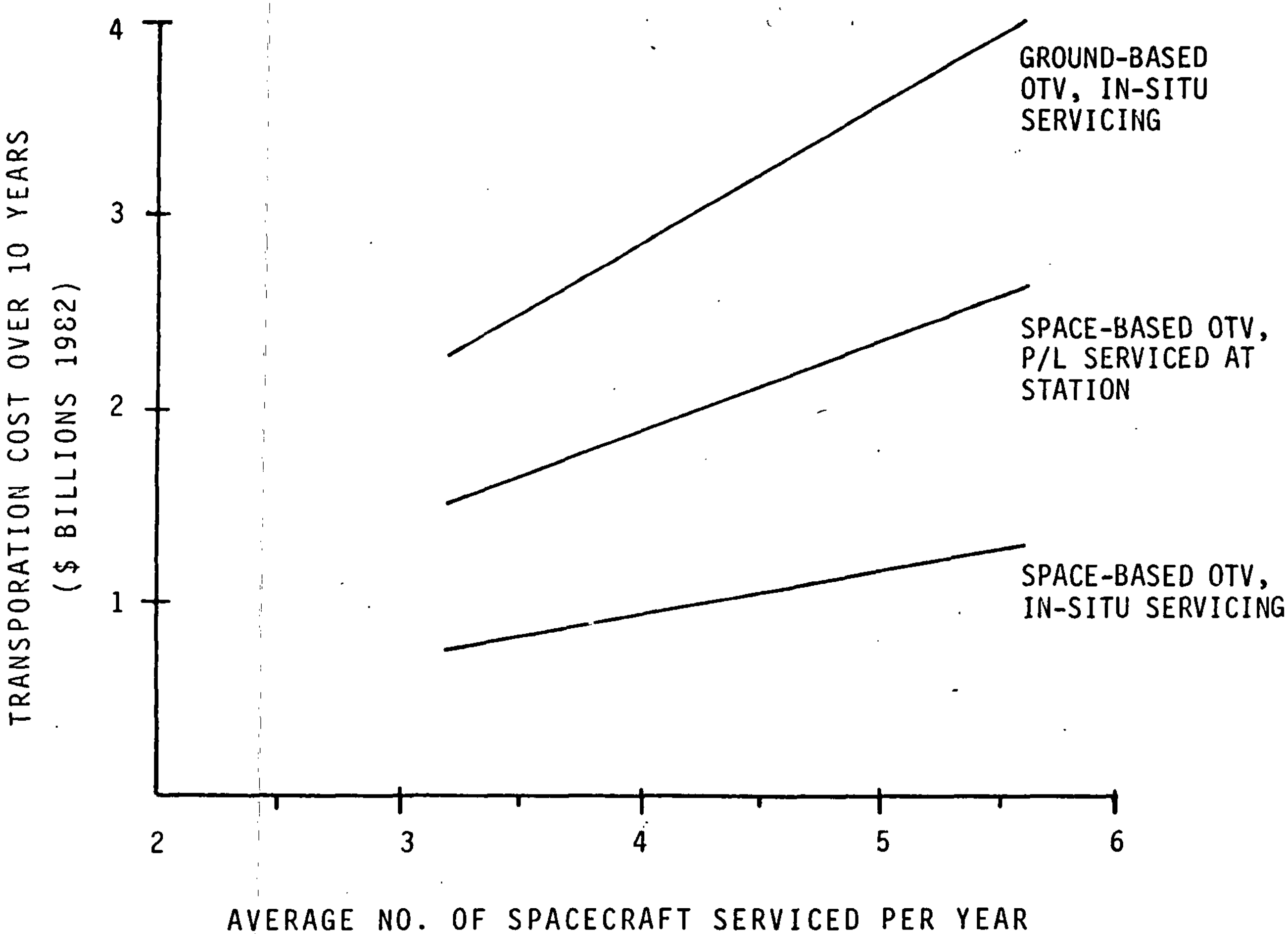
A parametric approach was used in analyzing the relative costs of ground-based and Space-Station-based servicing systems. The measure of cost was total recurring Space Transportation outlay over ten years. Concept-to-concept differences between OTV flight operations costs were judged to be small; hence, these costs were omitted. The independent variable was chosen as the average number of ITSS spacecraft serviced in a year; this figure combines the total number of spacecraft with the average frequency of servicing.

Results of this analysis show that both of the space-based OTV systems are signficantly lower in cost for ITSS servicing than the ground-based system. Moreover, these savings are of a magnitude for this one mission (roughly $2.6 billion at the high end) to offset an appreciable amount of Space Station acquisition costs.

SPACE STATION PROGRAMS

GROUND-BASED VS. STATION-BASED OTV SERVICING

(COST OF RECURRING TRANSPORTATION)



PAYLOAD EFFECTS REVISITED

Development of the Space Transportation System was justified in part by so-called 'payload effects'. These were projected cost savings in spacecraft and payloads that appeared feasible with a fully developed STS. The three categories of savings shown in this figure were the expected means by which these savings would be achieved.

As of 1983, all three factors have influenced STS payloads, but the exact way in which some of the changes have occurred differs from the 1971 perspective. Some of these differences arise because the fully-implemented STS was to have incorporated a reusable OTV capable of deploying and servicing large spacecraft. For example, only low-earth-orbit (LEO) payloads such as Space Telescope are being designed for on-orbit servicing. High-earth-orbit (HEO) payloads not only are not designed for servicing, some are paying a premium in development costs to miniaturize their electronics (with hybrids, etc.). A full capability OTV operating with the Space Station could recapture some of these payload effects.

PAYLOAD EFFECTS REVISITED

CATEGORY OF PAYLOAD SAVINGS WITH STS

	WEIGHT/VOLUME RELAXATION	SPACECRAFT SERVICING	INTACT ABORT CAPABILITY
PROJECTED MECHANISMS FOR SAVINGS	1) AVOIDING MINIATURIZATION AND/OR 2) 'HEAVY, CHEAP' PAYLOADS	1) LONGER LIFE, FEWER SATELLITES 2) EXPERIMENT CHANGEOUT 3) REDUCED TESTING	1) FEWER SATELLITES FEWER LAUNCHES
WHAT IS HAPPENING	LEO PAYLOADS INCORPORATING 1) BUT NOT HEO; NOBODY OPTING FOR 2)	LEO PAYLOADS SLOWLY INCORPORATING 1) AND 2); NOBODY OPTING FOR 3)	STS INSURANCE RATES LOWER THAN ELV
IMPLICATIONS TO SPACE STATION	HIGH PERFORMANCE OTV WILL DECREASE P/L MINIATURIZATION	SPACE STATION CAN SERVE AS DEPOT	(NOT APPLICABLE)

OBSERVATIONS ON BENEFITS

In benefit studies performed to date, the area of STS and OTV enhancement is emerging as a source of quantifiable support for the Space Station. Moreover, these results are decoupled from feasibility issues (such as ET scavenging) that have diverted attention from the justification of a Space Station.

The case study method continues to emerge as a key to realistic and traceable quantification of Station benefits. In this method, realistic mission scenarios are formulated, and alternative systems are defined both with and without Space Station support. The acquisition, operation and transportation costs of each alternative are compared and any net savings for the Space Station supported alternative are counted as benefits. The case study method is too detailed for quantifying total Space Station benefits, but should instead be used to establish the trends in cost/benefit analysis.

OBSERVATIONS ON BENEFITS

STATION-BASED OTV REALIZES TANGIBLE BENEFITS:

- SCENARIO IS FOR SCHEDULED SERVICING OF SATELLITE NETWORK
- SAVINGS INDEPENDENT OF ET SCAVENGING

ADDITIONAL BENEFITS ARE STILL TO BE EXPLORED:

- PAYLOAD EFFECTS
- ONBOARD DATA EVALUATION
- TEST BED HARDWARE DEVELOPMENT

CASE STUDY IS METHOD FOR BENEFIT QUANTIFICATION:

- DEFINE OPTIONS
- COST EACH AND MEASURE SAVINGS

SPACE STATION PROGRAMS

TASK 3 - COST AND PROGRAMMATIC ANALYSIS

3.1 BENEFITS

3.2 COST, SCHEDULE AND FUNDING

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COSTING GROUNDRULES/ASSUMPTIONS

Emphasis in the cost analysis was on identifying cost drivers, uncertainties, and evolutionary trends. The estimates presented here cover development, production, operation and deployment of the reference Lockheed Space Station evolutionary architecture. The estimates exclude costs for development and support of Station payload costs. Likewise, costs for acquisition and operation of the OTV and Teleoperator Maneuvering System were omitted from the cost tabulations in this section even though they were used in the benefits analysis.

The reference costs presented here incorporate the $83 million per flight STS user charge, while the $117 million per flight upper bound was used to explore uncertainty effects. The derivation of these numbers is explained subsequently.

COSTING GROUNDRULES/ASSUMPTIONS

ALL COSTS IN CONSTANT 1984 DOLLARS

ONE EQUIVALENT SET OF FLIGHT HARDWARE FOR GROUND TEST

STS COSTS ESTABLISHED AS UNCERTAINTY BAND:

- LOWER BOUND = CURRENT USER CHARGE OF $71M (1982) = $83M (1984)
- UPPER BOUND = EST. 1983-2000 CUM. AVG. COSTS = $117M (1984)

ONLY SPACE STATION MODULES ESTIMATED:

- NO OTV COSTS
- NO TMS COSTS
- NO PAYLOAD TRANSPORTATION/OPERATIONS

WORK BREAKDOWN STRUCTURE

The Work Breakdown Structure (WBS) used in formulating Space Station cost estimates is tailored to track evolutionary growth of Station architecture. The general arrangement is by evolutionary steps within the overall Space Station program. A standardized breakdown of hardware, software and services is replicated for every step; this conforms with the philosophy of the standard WBS promulgated by the Space Systems Cost Analysis Group. Building-block modules peculiar to each step are identified, and their subordinate subsystems are broken out. All hardware estimates were generated at subsystem level.

NOTE: For more information on the evolutionary space station growth steps refer to Attachment 2, Volume I, Task 3 Cost and Programmatic Concepts.

SPACE STATION PROGRAMS

WORK BREAKDOWN STRUCTURE

- SPACE STATION PROGRAM
  - STEP 1
    - HARDWARE
      - HABITATION MODULE
        - STRUCTURES/MECHANISMS
        - THERMAL CONTROL
        - ECLSS/CREW
        - ELECTRICAL POWER
        - STABILIZATION & CONTROL
        - DATA MANAGEMENT/INSTRUMENTATION
        - COMMUNICATIONS
        - MODULE INTEG/ASSY/TEST
      - ENERGY MODULE
        - (SUBSYSTEMS)
      - PAYLOAD MODULE
        - (SUBSYSTEMS)
    - SOFTWARE
    - SERVICES
      - LAUNCH OPS
      - FLIGHT OPS
      - STS SERVICES
      - STATION INTEGRATION
        - OVERALL STATION DEFINITION
        - SYSTEM/PROGRAM MANAGEMENT
        - GROUND EQUIPMENT
        - TEST OPERATIONS
        - INTEGRATION/ASSEMBLY/CHECKOUT
  - STEP 2
    - (SIMILAR BREAKDOWN)
  - STEP 'N'
    - (SIMILAR BREAKDOWN)

Econon — Lockheed

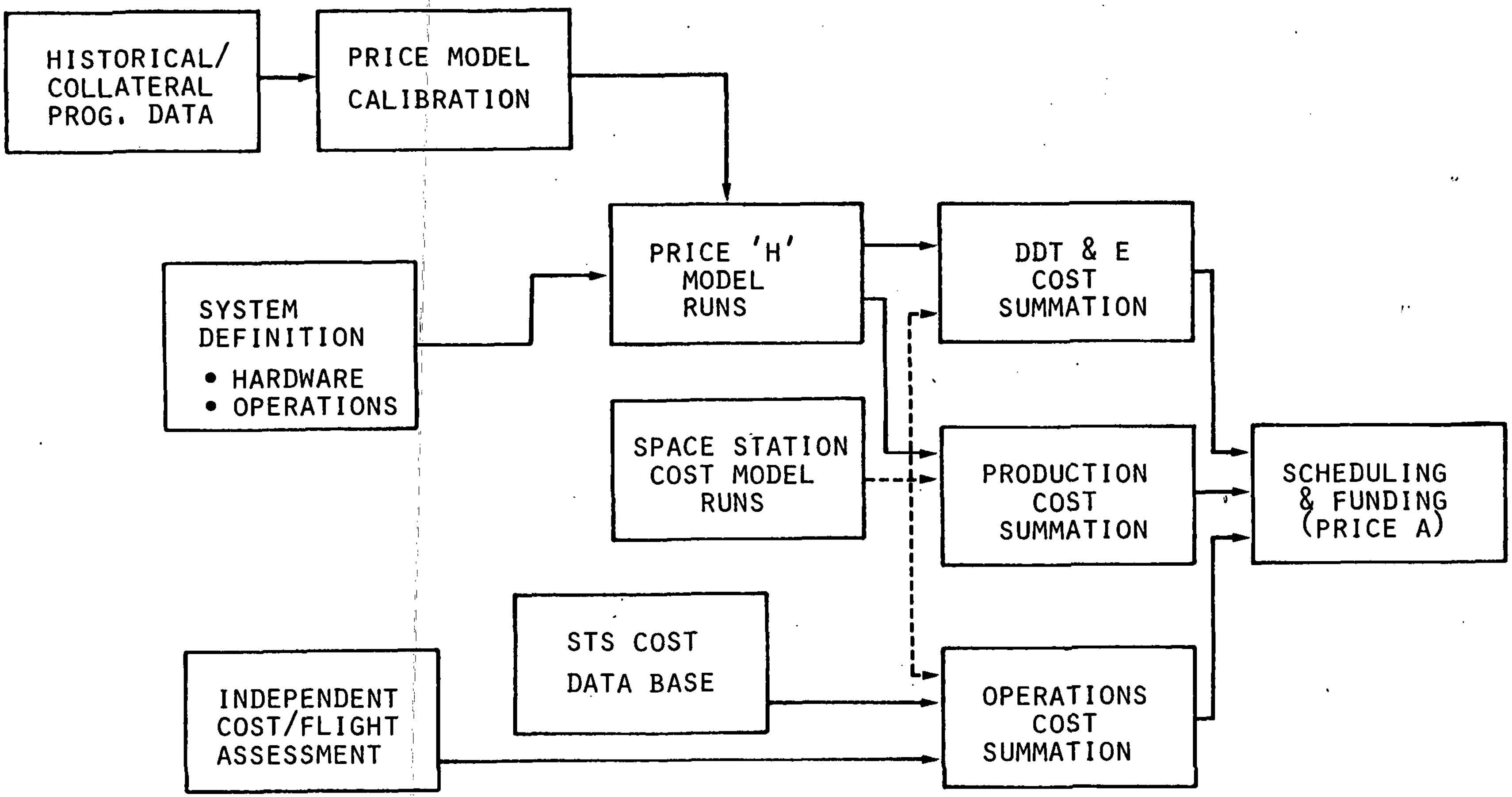
In keeping with the definition level of Space Station architecture, parametric and analogy type cost estimating techniques were used. The RCA PRICE family of models was used to estimate evolutionary module costs. Hardware costs were estimated at subsystem level using typical manned-spacecraft complexity factors; these factors were calibrated in PRICE from historical data, from collateral Space Station studies, and special complexity equations. PRICE was selected over a special-purpose Space Station cost model because: 1) It can analyze costs at any indenture level, making possible estimates at the individual module level, 2) It can be tailored to the specific end-item configuration rather than to the design concepts frozen into a historical data base, 3) It accounts for design inheritance (a critical factor in evolutionary growth) for technology state of te art and for the number of test articles, 4) It separates analysis of hardware and software.

Operations costs were estimated by analogy to the operational support costs for the Space Transportation System. ECON has modeled typical STS operations costs as part of its Shuttle Cost and Price (SCP) model; the equations in this model separately account for Mission Control Center operations, crew training and operations, spares, simulators, launch operations, and logistics. Each of these elements was reviewed, modified as needed for Space Station operations, and incorporated into the operations cost algorithms. Separate cost equations were generated for operations performed during Station evolution as distinct from steady-state operation.

The PRICE 'A' model was used to perform funding analysis. Expenditures for each major cost element of each evolutionary Space Station step were entered in PRICE A, schedules were incorporated based on evolutionary program milestones, and spread factors were applied to each cost. The result was a funding profile for each step which was then summed into an overall Space Station program profile. These profiles can be varied parametrically to account for alternative scenarios.

SPACE STATION PROGRAMS

TECHNICAL APPROACH



STS COST/ACTIVITY SENSITIVITIES

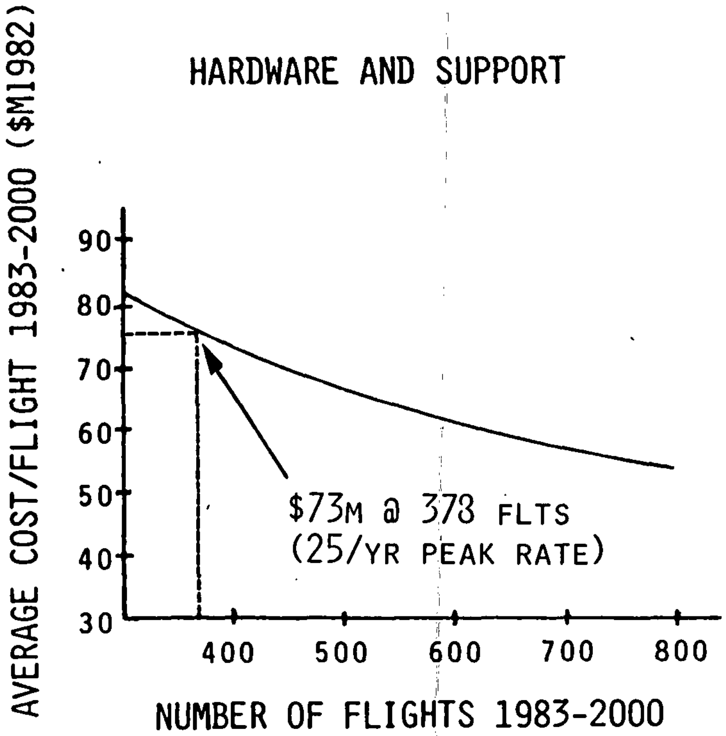
As noted earlier, two values of STS price per flight were used to span the uncertainty range in the Space Station time frame. The lower value was the current $71 million per flight (1982 dollars) changed to foreign and commercial users 1986-1988, as updated to 1984 dollars. Using an estimated escalation rate of 17 percent from 1982 to 1984 dollars (PRICE model reference values) the resulting price per flight is 83 million in 1984 dollars.

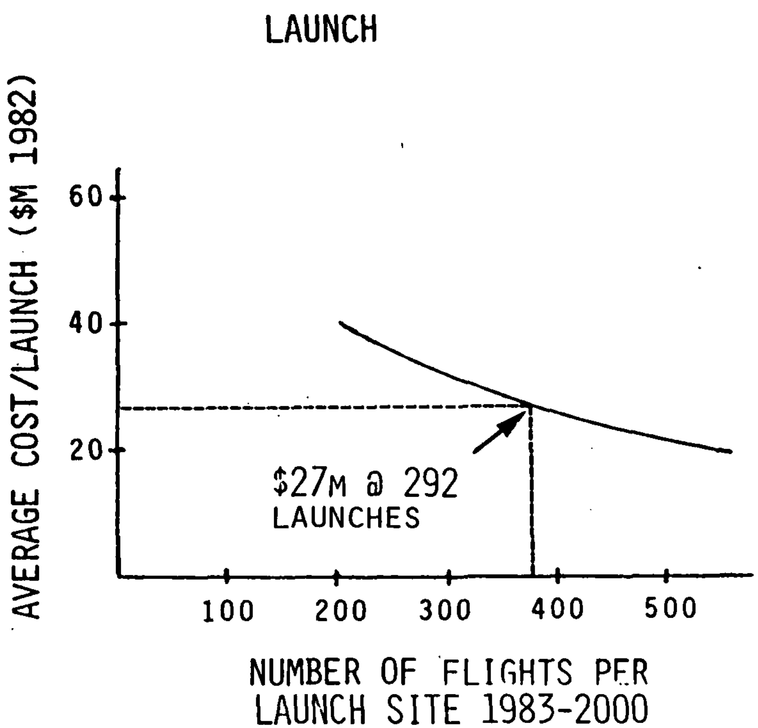
The figure opposite shows how the upper bound value was derived. First, a conservative activity level of 378 STS flights for the years 1983-2000 was selected; this assumes that the combined effect of Space Station building (4 launches per year exclusive of payloads) is matched by a modest level of other STS activity and that the peak rate does not exceed 25 flights per year. A conservative activity level drives price per flight upward. The 378 flight level was then entered into the ECON-derived cost/activity graph for hardware and support (left hand chart); comparable ETR launch activity levels were entered into the graph for launch and launch support (right hand chart). The resulting cost per flight is 73 million for hardware plus $27 million for launch, which totals $100 million in 1982 dollars, or $117 million in 1984 dollars. If these costs, which represent cumulative average cost 1983-2000, were applied as a price per flight (also a conservative assumption) then a safe upper bound for STS charges has been derived.

SPACE STATION PROGRAMS

STS COST/ACTIVITY SENSITIVITIES

ESTIMATED CUMULATIVE AVERAGE COSTS





SPACE STATION PROGRAM COSTS

This figure summarizes the incremental buildup of costs needed to implement each step of the reference Lockheed Space Station architecture. Step 1 deploys a Station that represents an initial operational capability at a cost of $2.8 billion. Steps 2 through 4 augment this capability in increments for an added cost of $2.8 billion ($5.6 billion cumulative). Step 5 adds OTV servicing capability for an added cost of $1.4 billion ($7.0 billion cumulative). Step 6 adds spacecraft servicing capability at an added cost of $1.3 billion ($8.3 billion cumulative). Step 7 completes the configuration and adds materials processing capability for an added $1.6 billion ($9.9 billion cumulative).

Acquisition cost drivers for the Space Station include test article philosophy (photoflight versus one or more dedicated test vehicles); relative state of the art; and inheritance (for both hardware and software). Operational cost drivers include STS resupply intervals and STS price per flight. For example, applying the upper-bound STS price per flight of $117 million would increse the operations costs shown here by $850 million, an increase of more than 25 percent.

The influence of Space Station autonomy on life cycle cost is not completely clear. The most likely area for savings due to autonomy is in the operational cost for NCC operations, which is estimated at $50.2 million per year. However, any savings must be traded against the added acquisition costs needed to achieve autonomy.

SPACE STATION PROGRAMS

SPACE STATION PROGRAM COSTS

($ MILLION, 1984)

	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6	STEP 7	TOTAL
DDT & E	1938	129	556	392	631	321	534	4501
PRODUCTION	392	60	289	316	276	327	564	2224
OPERATIONS	511	255	255	511	511	639	456	3138
TOTAL	2841	444	1100	1219	1418	1287	1554	9863

PROGRAM FUNDING PROFILE

This figure shows the funding levels for development, and operation of the Lockheed reference Space Station architecture. Costs are in millions of constant 1984 dollars. This is a composite chart that sums the funding levels for each of the seven evolutionary steps, plus one year of steady-state operations for the all-up configurations. The one year of operations (ending December 1996) is funded at $580 million.

The assumed start of the program is October 1984 (the beginning of fiscal year 1985). This date has no significance other than in terms of the arbitrary January 1990 first-launch data shown in the LMSC evolutionary scenario. All spans and funding should be thought of as 'time zero' i.e., years from program start. In these terms, the peak funding of just under $1.5 billion occurs in the sixth and seventh years after go-ahead.

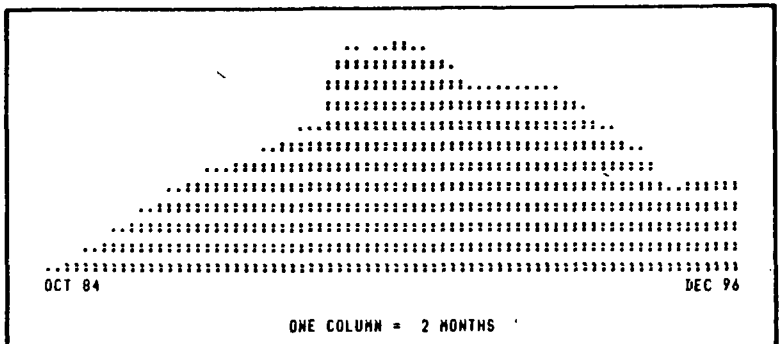
SPACE STATION PROGRAMS

PROGRAM FUNDING PROFILE

YEARLY EXPENDITURE SUMMARY

COSTS IN DOLLARS — 1 JAN 84 UNITS

PERIOD ENDING	PER CENT COMPLETE	EXPENDITURES FOR PERIOD TOTAL	EXPENDITURES FOR PERIOD %	CUMULATIVE EXPENDITURES TOTAL	CUMULATIVE EXPENDITURES %
DEC 84	0.0	1.0	0.0	1.0	0.0
DEC 85	1.0	102.7	1.0	103.7	1.0
DEC 86	4.5	369.6	3.5	473.3	4.5
DEC 87	10.3	605.6	5.8	1078.9	10.3
DEC 88	17.6	752.9	7.2	1831.7	17.6
DEC 89	27.1	999.8	9.6	2831.5	27.1
DEC 90	41.1	1455.7	14.0	4287.3	41.1
DEC 91	54.9	1445.9	13.9	5733.2	54.9
DEC 92	66.7	1226.2	11.8	6959.4	66.7
DEC 93	78.1	1187.8	11.4	8147.2	78.1
DEC 94	87.8	1015.4	9.7	9162.6	87.8
DEC 95	94.4	691.7	6.6	9854.2	94.4
DEC 96	100.0	580.2	5.6	10434.4	100.0



OBSERVATIONS ON COST AND SCHEDULE

The LMSC evolutionary architecture defined in this study provides an early operational capability yet grows to provide services that bring the national Space Transporation to its full original promise. Moreover, this capability is added in increments that keep annual outlay within reasonable bounds.

SPACE STATION PROGRAMS

OBSERVATIONS ON COST AND SCHEDULE

FOR THE REFERENCE LMSC SPACE STATION EVOLUTION:

- AN INITIAL CAPABILITY (STEP 1) CAN BE IMPLEMENTED FOR LESS THAN $4 BILLION (1984)
- FULL CAPABILITY (STEPS 1-7) CAN BE ATTAINED FOR LESS THAN $10 BILLION

FOR A FY1985 START, THE FUNDING LEVELS ARE:

- PEAK FUNDING LESS THAN $1.5 BILLION
- PEAK IN 1990-1991

DESIGN-TO-LIFE-CYCLE-COST CONSIDERATIONS:

- BEST PAYOFF IS IN REDUCING RESUPPLY COSTS ($83M - 117M/FLIGHT)
- THESE SAVINGS CAN OFFSET HIGHER SUBSYSTEM DEVELOPMENT COSTS

SSD

Lockheed Missiles & Space Company, Inc.