N83-28058

SOC-SE-03-01

Volume III	Mission Requirements	April 1983

SPACE STATION NEEDS, ATTRIBUTES, AND ARCHITECTURAL OPTIONS STUDY—FINAL REPORT

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This final report, submitted to National Aeronautics and Space Administration (NASA) Headquarters, Washington, DC 20546, presents the results of the Space Station Needs, Attributes and Architectural Options Study performed by the Space and Electronics Systems Division of the Martin Marietta Corporation under NASA Contract NASW-3686.

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1.0 INTRODUCTION

1.1 PURPOSE

The overall objectives of the Space Station study are to--identify missions that are enhanced or enabled by a permanent manned space station in low earth orbit; characterize the attributes and capabilities that will be necessary to satisfy mission requirements; recommend space station implementation approaches, architecture options, and evolutionary growth; and define the programmatic/cost implications.

The purpose of this volume is to--present the identification of user missions that are enabled or enhanced by a manned space station; delineate the mission capability requirements imposed on the space station by these users; identify the accommodation facilities, equipment, and functional requirements necessary to achieve these capabilities; and define the ecomomic, performance, and social benefits which accrue from the space station.

This section presents the introduction and background to the requirements volume, the study flow, and the groundrules and assumptions necessary to the completion of the task.

Section 2 is an abbreviated summary of this Mission Requirement volume and presents the task approach, methodology, and primary results of the requirements study. The remaining sections are an expansion of the individual items summarized in Section 2.

1.2 SCOPE

The primary purpose of this study was to identify, collect, and analyze the science, applications, commercial, U.S. national security and space operations missions that would require or be materially benefited by the availability of a permanent manned space station in low earth orbit and to identify and characterize the space station attributes and capabilities which will be necessary to satisfy these mission reqirements. Emphasis is placed on the identification and validation of potential users, their requirements, and the benefits accruing to them from the existence of a space station, and the programmatic and cost implications of a space station program. Less emphasis has been placed on detailed design beyond that necessary for the identification of system attributes, characteristies, implementation approaches and architecture options, and ROM costs.

The study results are presented in six volumes as follows:

Volume I presents an executive summary highlighting the specific results obtained during each phase of the study as described in Volumes II through VI (classified information excepted).

Volume II presents the results of our mission definition activities including the identification, modeling and validation of potential user missions, their requirements and the benefits that could accrue to the users from the existence of a space station.

Volume III presents the space station user requirements, their integration and time phasing, and the derivation of system and user accommodation requirements. The derivations of user requirements and space station accommodations encompassed a traceability analysis, parametric studies, and an analysis of economic, performance, and social benefits afforded by the existence of a space station.

Volume IV presents the results of our study efforts describing our analyses and defining our recommended space station implementation approaches, architecture options, and evolutionary growth.

Volume V presents the affordability analysis conducted to determine the affordable mission model, quantification of economic benefits, estimate of the ROM costs for each of the architectural options and their associated program and element schedules.

Volume VI presents the results (classified) of our analysis for the DOD National Security mission. This volume was published under a separate cover and is available through the DOD Task Manager at Space Division (SDXR), Los Angeles, California.

The scope of this Mission Requirements volume, Volume III, includes the presentation of space station user requirements, their integration and time phasing, and the derivation of system and user accommodation requirements. The derivations of user requirements and space station accommodations include traceability analysis, parametric studies, and an analysis of economic, performance, and social benefits afforded by the existence of a space station.

1.3 APPROACH AND METHODOLOGY

Figure 1.3-1 illustrates the Space Station program study flow. The shaded portions of this figure identify that part of the study reported on in this volume. There are four independent subtasks:

1) Define the Space Station system and user accommodation requirements,

2) Maintain traceability of all user requirements referenced to a specific user source,

3) Perform parametric mission studies and analyses, and

4) Determine the economic, performance, and social benefits that accrue from the Space Station.

Section 1 discusses the general approach and methodologies used to complete each subtask; more extensive discussions are presented in the detailed task presentations of Sections 3 through 7. It should be noted that the first task--the definition of the space station system and requirements is presented in two parts: definition of user requirements (Section 3) and definition of space station accommodation requirements (Section 4).

1.3.1 User Requirements Definition

As detailed in Volume II of this report, a Space Station Mission Model has been developed by applying mission capture and affordability criteria to the MMC, Composite Mission Model which was assembled from an integration of mission data provided by numerous government and industry sources. The resultant Space Station Mission Model was then analyzed to determine the user requirements and benefits afforded by the space station in the 1990-2000 time period. As shown in Figure 1.3.1-1a, the individual user requirements were assembled into a set of time-phased, integrated space station user requirements. The details and results of this subtask are presented in Section 3 of this volume. These results formed part of the input to the Space Station and User Accommodation Requirements subtask presented in Section 4, the Requirements Traceability subtask presented in Section 5, the Parametric Studies subtask presented in Section 6, and the Mission Alternatives and Benefits subtask presented in Section 7 of this volume.

1.3.2 Space Station and User Accommodation Requirements Definition

Figure 1.3.1-1a shows the task flow required to define space station operational and user accommodation requirements. Starting with the integrated, time phased user requirements, a series of scenarios were developed and subjected to functional analysis. From the functional analyses, ground rules, trades studies, and top level requirements were derived. Further analysis produced system and subsystem requirements for each scenario. These were then integrated to form a set of system, subsystem, and user accommodation requirements for the Space Station.

The details and results of this subtask are presented in Section 4 of this volume. These results formed part of the input to the Mission Implementation Concepts task reported on in Volume IV.

1.3.3 Traceability Analysis

Maintaining the traceability of space station design requirements back to the capabilities required by identified users was an important part of this study. The logic flow for this task is shown in Figure 1.3.1-1b. The key element of this task is the traceability matrix; its derivation, maintenance, and uses are fully described in Section 5 of this volume.

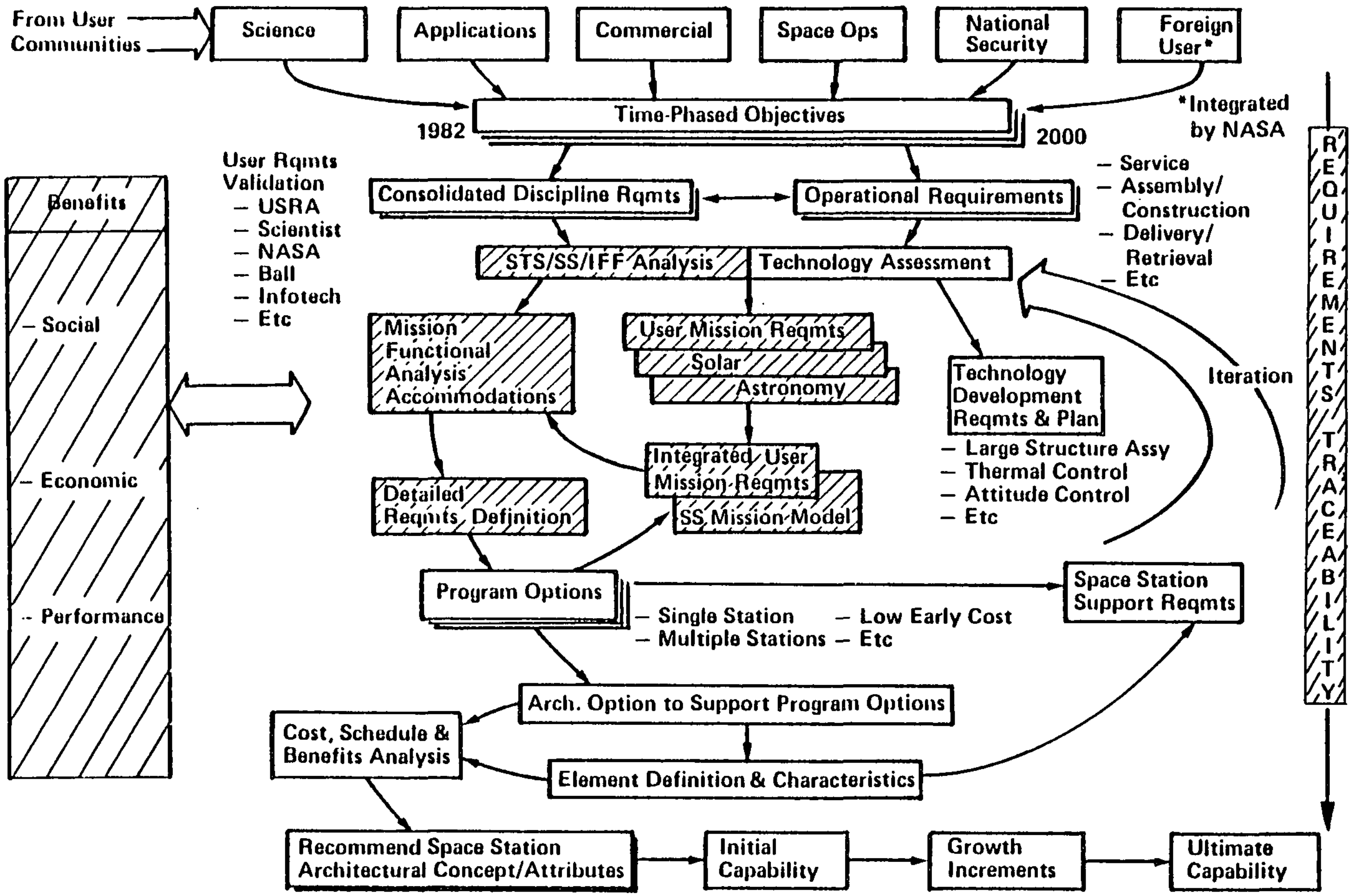
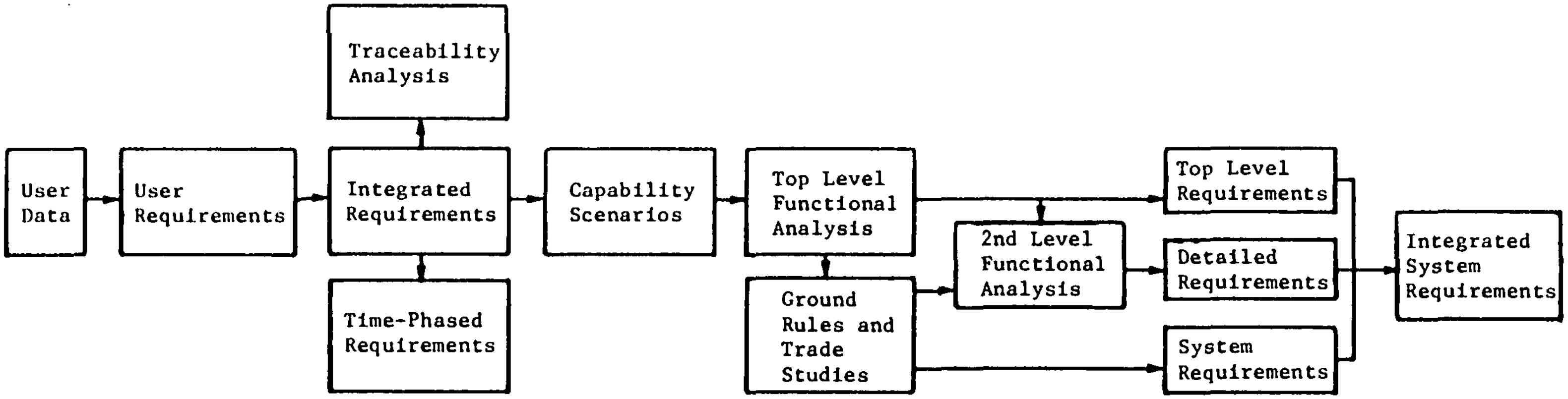
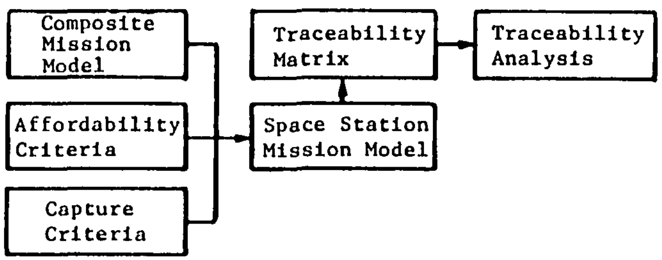


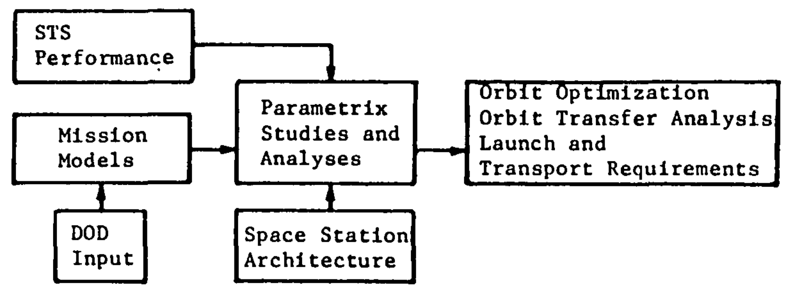
Figure 1.3-1 Space Station Study Flow—Mission Requirements



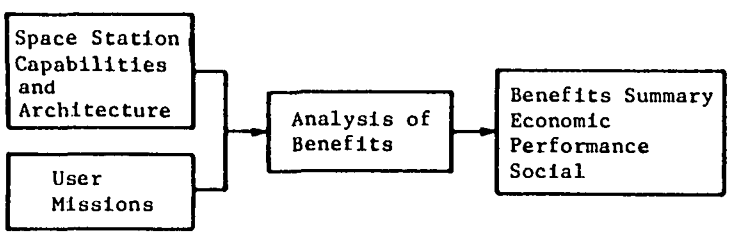
a. Definition of User and Integrated System Requirements



b. Traceability Analysis



c. Parametric Studies and Analyses



d. Benefits Analysis

Figure 1.3.1-1 Mission Requirements Task Flows

1.3.4 Mission Analysis and Parametric Studies

Section 6 of this volume presents the results of mission analysis and parametric studies performed in support of several activities during this study. As shown in the task flow diagram, Figure 1.3.1-1c, inputs to these analyses were the STS performance, a wide spectrum of mission models, and space station characteristics; outputs were optiminum orbits for the space station, orbit transfer analyses, and space and ground launch transport requirements. Detailed descriptions of these analyses, and discussions of the results obtained, can be found in Section 6. These results were input to the Mission Implementation Concepts task reported on in Volume IV of this report.

1.3.5 Mission Alternatives and Benefits Analysis

Section 7 is a mission by mission assessment of the benefits accruing to mission users from the presence of a space station. As shown in Figure 1.3.1-1d, the capabilities of the space station and the STS are compared with the requirements of each user mission to determine which best supports the mission in terms of economic, performance, and social benefits. These results are input to the cost, benefits, and programmatic analysis task reported on in Volume V of this report.

Appendix A is a list of symbols, acronyms, and abbreviations, common to each volume of this report; Appendix B is a list of cited references and bibliography materials applicable to the study.

1.4 GROUND RULES AND GUIDELINES

The statement of work to Contract NASW-3686 contains the following groundrules and guidelines (paraphrased and simplified):

- All facilities will be Shuttle launched and tended;
- Potential missions of interest will include domestic and foreign science, applications and commercial users as well as U.S. national security and space operations missions;
- All missions included in the study results will include the specific source of user input;
- Primary consideration should be given to the requirements for a permanent manned space station in low earth orbit;
- The Tracking Data Relay Satellite System (TDRSS) will be the primary space-to-ground communications interface for space station operations;
- Development of space station options should consider a single space station in the 1990 time frame while the evolutionary growth could require consideration of multiple stations or platforms;

- o Department of Defense (DOD) Task Assignment - Consider space station interaction with the total DOD space infrastructure envisioned to be in use in the later 1980s through the year 2000;

  (A mission model delineating the military space missions for the time period specified above was provided by DOD.)

- o The contractor has the responsibility to obtain all information and data necessary to conduct the study;

- o NASA will provide the results of appropriate in-house studies as a primary source of information on science and applications missions;

- o NASA will provide relevant results of mission analysis studies conducted in other countries.

1.5 DEFINITIONS

Appendix A contains a list of symbols, abbreviations, and acronyms used throughout this report. In addition, the following terms have acquired the specific meanings indicated:

<u>Free Flyer/Independent Free Flyer</u> - single-mission satellite in independent orbit.

<u>Platform</u> - unmanned, autonomous satellite carrying and providing subsystem support to several related/unrelated mission payloads.

<u>Space Station</u> - manned satellite in low earth orbit, serving as an operating base for scientific experiments and conducting satellite assembly, deployment, retrieval, and servicing operations.

<u>Internal Vehicular Activity (IVA)</u> - human activity performed in a shirtsleeve atmosphere. All other human activity is regarded as External Vehicular Activity (EVA). The Remote Manipulator System (RMS), Extravehicular Mobility Unit (EMU), Manned Maneuvering Unit (MMU), Teleoperator Maneuvering System (TMS), and Orbital Transfer Vehicle (OTV) are spacecraft handling and maneuvering devices of increasing capacity. All are similar to, but not necessarily identical to their currently operational or envisaged configurations.

<u>Servicer</u> - unpowered spacecraft designed to attach to an operational spacecraft for the purpose of replacing modules or replenishing propellants and other fluids, acting either autonomously or with the aid of a telepresence and remote control system. A servicer requires a TMS or other propulsion module for maneuvering and orbit-to-orbit transfer.

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2.0 EXECUTIVE SUMMARY

The overall objectives of the Space Station study are to identify missions that are enhanced by a permanent manned space station in low earth orbit, to characterize the attributes and capabilities that will be necessary to satisfy mission requirements, and to recommend space station implementation approaches, architecture options, and a plan for its evolutionary growth. The results of the mission identification task are reported in Volume II of this report, and this volume (Volume III) expands these missions and presents the attributes and capabilities required by the space station to satisfy both those specified and derived mission requirements.

2.1 INTEGRATED USER REQUIREMENTS

Derivation of space station capability requirements began with an assessment of the requirements imposed by individual missions. Initially, we considered some 327 missions; this number was reduced to 159 missions by applying affordability criteria, capture analysis, and combining missions with similar objectives. Individual requirements were then combined, integrated, and time-phased into a unified set of user requirements.

User requirements were divided into five broad classes of user support requirements:

- In-Space Assembly and Checkout
- Orbit Transfer and Retrieval
- Propellant and Consumables Resupply
- Maintenance and Repair
- Operational Support

We found that in-space assembly and operational support requirements were only a small fraction of the total requirements. Orbit transfer and retrieval accounted for 32% of the requirements, propellant and consumables resupply accounted for 36%, and maintenance and repair accounted for 26%. The mission category with the most requirements was commercial communications. This category, along with astronomy and earth observations accounted for two thirds of the total requirements in the time period between 1991 and 2000.

The time phasing of requirements shows a rapid buildup in the first two years, followed by a relatively level period, and then a gradual decline. However, the decline is more probably due to uncertainty in estimating the out-year requirements than to an actual reduction. Peak activity is 95 services per year, in 1997.

In the early years, the principal service required is orbit transfer and retrieval, while resupply requirements gradually increase to represent the majority of requirements in later years. Maintenance and repair requirements increase very gradually throughout the decade.

2.2 SPACE STATION USER ACCOMMODATION REQUIREMENTS

Space Station capability requirements originate from two sources: accommodation of users, and the operational capabilities required of the space station itself. User accommodation and space station operational requirements were derived from consideration of a series of eighteen operational scenarios representing space station and user support activities. These scenarios were subjected to functional analysis in order to identify the ground rules, functional capabilities, and support equipment required to accomplish each scenario. Subelements of the top-level functional flows were further analyzed where it was evident that additional capabilities and support equipment could be identified. Finally, all requirements were collected, collated, and categorized by subsystem into a set of integrated facility, hardware, and software requirements. Figure 2.2-1 illustrates a few of the important requirements that resulted from this task.

For the most part, numerical performance requirements have not yet been determined, because many of the underlying user support requirements, as well as the characteristics of the space station itself, are insufficiently defined. These requirements and characteristics should be subjects for additional study as the space station program matures.

2.3 REQUIREMENTS TRACEABILITY

During the course of this study, the basic mission model has evolved from a compilation of missions from several sources (MMC Composite Mission Model), through the application of affordability, capture criteria, and combination of related or redundant objectives, to a Space Station Mission Model. At each step, a unique identification code has been assigned to each mission so it can be traced to its original source for validation. In addition, the service and support capability requirements associated with each mission are indexed so each requirement can be traced to its user mission. In this way, space station capability requirements can be updated quickly to reflect mission model changes.

2.4 MISSION ANALYSIS AND PARAMETRIC STUDIES

The primary purpose of the parametric studies was to determine the optimum space station orbit altitude and inclination. Additional analyses were performed to determine orbit transfer vehicle performance requirements, launch window penalties, and concepts for station-keeping platforms. All orbit performance analyses were based on Hohmann transfer ellipses and impulsive velocity changes.

The recommended orbit altitude is nominally 250 nautical miles, based primarily on the requirement that the Space Station have at least a 90 day orbit lifetime without makeup of velocity lost due to drag decay. This altitude is also well above the traffic hazards posed by short-lifetime satellites and other low-altitude space debris.

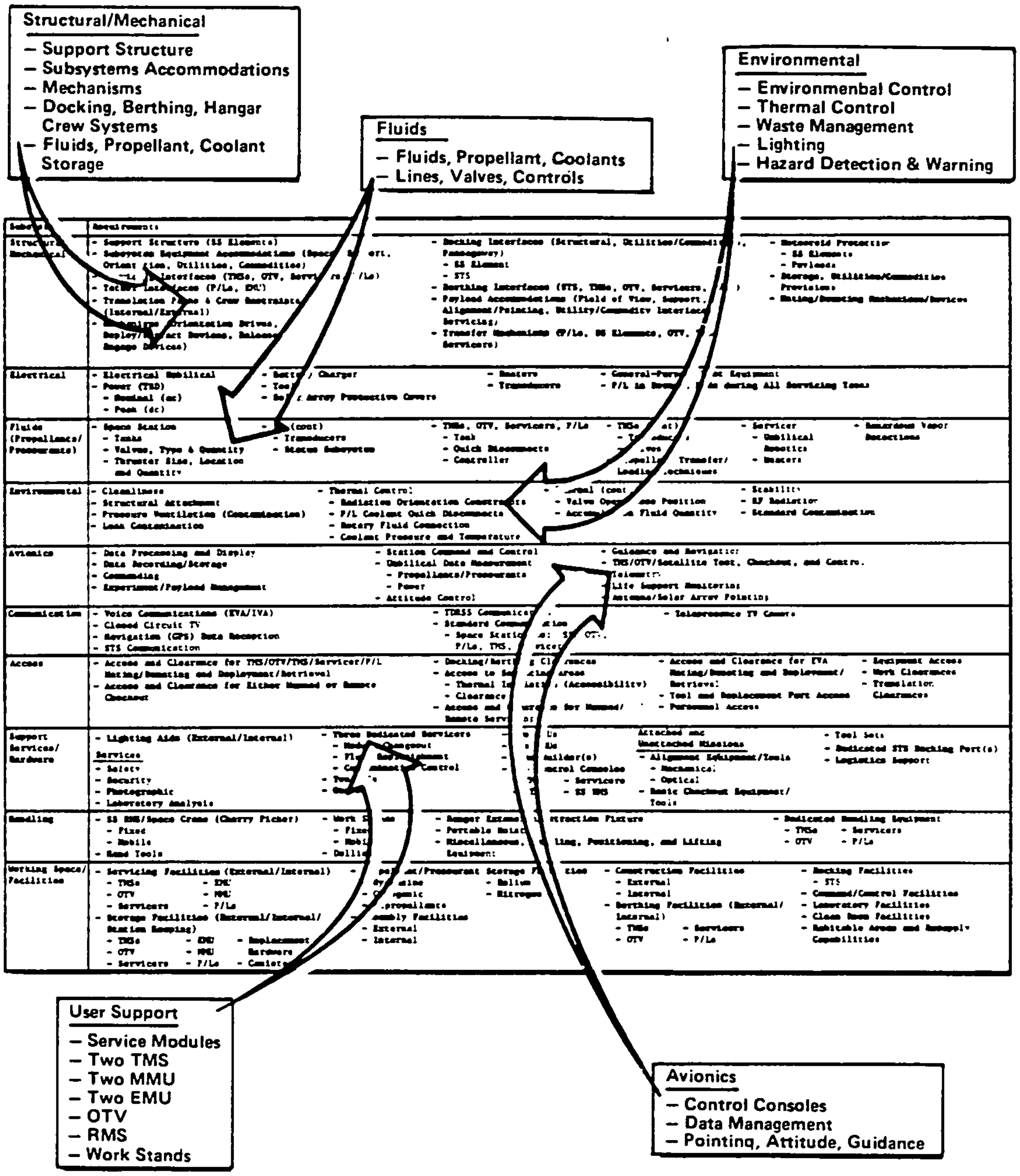

Figure 2.2-1 Space Station Capability Requirements

The optimum space station orbit inclination appears to be 28.5 degrees; this is optimum both from the standpoint of minimizing the number of STS flights and capturing the largest number of user missions. The space station reduces the number of STS flights for delivery by about one third. However, when additional STS flights required to support the space station are considered, the net benefit is about one flight in six.

A reusable, aerobraked, crogenic-fueled orbit transfer vehicle with a 16,000 kg propellant capacity captures approximately 80% of all missions considered; this size OTV can also be carried to the space station in a single STS flight.

For minimum propellant expenditure, an optimum time exists for orbit transfer involving a plane change; additional propellant is required for launch times before or after that optimum. The propellant requirements decrease as the target orbit altitude increases; however, the additional velocity capability required for a launch window enabling launch at any time exceeds two kilometers per second even for geosynchronous altitude, and is probably unacceptable except in extreme cases.

Unmanned platforms separated from the space station by a few tens of a kilometer confer significant benefits on the overall space station and mission user program. Several concepts have been identified for maintaining this separation so that regular visits between a platform and the space station can occur. Among these are station-keeping propulsion systems, utilization of drag-decay differences, and utilization of tethers between the vehicles. These concepts are still under study, and no recommendation can yet be made.

2.5 MISSION ALTERNATIVES AND BENEFITS

The purpose of this analysis was to identify the economic, performance, and social benefits accruing to science and commercial missions using the space station as an alternative to the STS for mission implementation and support. To accomplish this, we compared each mission in the Space Station Mission Model against a series of 26 potential benefits in the areas of operations, basing, servicing, assembly, and orbit transfer. For each potential benefit, we determined whether the mission was uniquely enabled by the space station, equally served by the space station or the STS, or favored by the STS alone. The analysis assumed the space station in orbit at 28.5 degrees and 250 nautical miles, with unmanned platforms at 28.5 degrees, 57 degrees, and 90^{o} degrees; note that this is an ultimate, not an initial, space station complex.

Of the 2065 benefit assessments made, 22% were uniquely enabled by the space station, and an additional 56% were favored by the space station; only 14% were more favorable to STS or STS-launched free flying satellites as an operational mode. These results were input to the Mission Implementation Concepts (Volume IV) and the Cost and Programmatic Analysis (Volume V) volumes of this report.

3.0 INTEGRATED USER REQUIREMENTS

3.1 REQUIREMENTS DEFINITION AND DERIVATION

The capability requirements are those logistical services and operations that--can be performed at the space station; can use the space station as a base to improve the capability duration and performance; or reduce the cost of a space mission or program. This section presents an outline of the derivation of these requirements, together with a summary of the results. Subsequent sections will amplify the points made here.

3.1.1 Input Data Sources

Determination of the capability requirements was based on an analyses of 327 missions derived from the twelve separate sources listed in Table 3.1.1-1. These missions were assimilated into the MMC Composite Mission Model (see Section 3.2.1). Each of these missions was individually analyzed to determine what logistical services or operations might be performed to enhance its capability or reduce its cost. The MMC Composite Mission Model was then studied to determine which missions and their indicated services might be captured by the space station, considering performance as well as NASA budget forecasts for each mission category to determine which missions were affordable in the time frame from late 1980's to the year 2000. The filtered results were assembled into a 159-mission Space Station Mission Model (Section 3.2.2); and each mission was again analyzed by scientists/engineers whose specialty included expertise in the respective mission categories. The resultant set of space station capability requirements for each mission was based on an in depth analysis incorporating both the objectives, and the equipment and methodology necessary to achieve these objectives.

3.1.2 Analysis and Classification

Fourteen services and operations have been identified as space station user requirements through the end of this century. These are classified as follows:

- Assembly:
  - Hardware Build-up
  - Construction
  - Payload Mating
- Resupply/Replenishment:
  - Fluid Transfer
    - Storable Propellants
    - Cryogenic and Other Coolants
  - Other Expendables
- Orbit Transfer:
  - Delivery
  - Retrieval
- Scheduled Servicing:
  - Preventive Maintenance
    - Remote
    - Space Station
  - Contamination Control
  - Refurbishment

Table 3.1.1-1 Mission Sources for User Requirements Analysis

Symbol	Source
L	Battelle's Outside Users P/L Low Model, '82
H	Battelle's Outside Users P/L High Model, '82
E	Battelle's Low Energy Model '80
T	Space Systems Technology, Model '80-'81 NASA, Vol. I
M	Space Systems Technology Model, '80-'81 NASA, Vol III
D	Space Station Program Definition, Attachment A, Candidate Technology Development Missions, '82
F	Flight Assignment Baseline, '80
N	National Space Club, '82
A	AIAA Assessment, '81
G	Gomersall Report, '82
B	NASA/Washington Bionetics Report, '82
U	Direct Contact with Outside Users

- o Random Failure Repair:
  - Remote
  - Space Station
- o Mission Operational Service:
  - Instrument Alignment
  - Instrument or Payload Changeout

Each of these logistical services and the rationale for their assumed service intervals (when applicable) is presented in Section 3.4.3.

3.1.3 Derivation Techniques

Each mission was individually scheduled for year of initial launch, desired mission duration, and its affordability. This schedule was analyzed together with the logistics requirements previously indicated for that specific mission. These requirements were then timelined consistent with the basing mode of the mission. While no attempt to optimize this timeline was made, the times of individual servicing operations were adjusted so as to minimize use of the OTV and TMS. For example, if a fluid transfer was scheduled near the time of an expected repair, these two services were assumed to be performed at the same time. A complete discussion and the results of this technique are given in Section 3.3.

3.1.4 Traceability

Table 3.1.4-1 presents the traceability from the mission model sources indicated in Table 3.1.1-1 through the Composite Mission Model (Section 3.2.1) to the Space Station Mission Model (Section 3.2.2) and the Langley Research Center Code developed by that organization. For example, the Cosmic Background Explorer (COBE) mission had as its source the Space System Technology Model, '80-'81, and a direct contact with the user. This mission was given the code DU in the Composite Mission Model and the code S4A in the Space Station Mission Model. Langley Research Center designated the COBE mission as MMCX-0001.

Table 3.1.4-1 Mission Traceability Guide

Source	CMM	SSMM	LaRC Code	Mission Title
				ASTRONOMY
TU	DU	S4A	MMCX-0001	COBE-Cosmic Background Explorer
MU	FA	S4B	-0002	FUSE-Far Ultraviolet Spectroscopy Explorer
ENTU	AM	S4C	-0003	XTE-X-Ray Timing Explorer
ENTU	AP	S4D	-0004	EUVE-Extreme Ultraviolet Explorer
MU	EY	S4E	-0005	GTE-Gamma Ray Transient Explorer
MU	EV	S4F	-0006	HNE-Heavy Nuclei Explorer
TU	AT	S4G	-0007	STARLAB
TU	AU	S4H	-0008	SIRTF-Shuttle Infrared Telescope Facility
TU	AL	S4J	-0009	LAMAR-large Area Modular Array of Reflectors
ETU	CF	S4K	-0010	OVLBI-Orbiting Very Long Baseline Inter ferometer
MU	EN	S4L	-0011	OIST-Orbiting Infrared Submillimeter Telescope
U	JF	S4M	-0012	FOT-Faint Object Telescope
ENTU	AK	S4N	-0013	ST-Space Telescope
ENTU	AN	S4P	-0014	AXAF-Advanced X-Ray Astrophysics Facility
TU	AJ	S4Q	-0015	LDR-large Deployable Reflector
ENTU	AR	S4R	-0016	GRO-Gamma Ray Observatory
MU	EQ	S4S	-0017	COSMIC-Coherent Optical System of Modular Imaging Collectors
MU	ER	S4T	-0018	TAT-Thinned Aperture Telescope
ETU	AX	S4U	-0019	CRO-Cosmic Ray Observatory
TU	AS	S4V	-0020	XRO-X-Ray Observatory
				PLANETARY
TU	DH	S1A	MMCX-0101	Venus Radar Mapper
TU	DI	S1B	-0102	Comet Rendezvous
MU	FR	S1C	-0103	Mars Geochemistry/Climatology Mapper
U	GV	S1D	-0104	Titan Probe
U	GW	S1E	-0105	Mars Probe Network
U	GX	S1F	-0106	Venus Atmospheric Probe
MU	FS	S1G	-0107	Lunar Orbiter
MU	FU	S1H	-0108	Comet Sample Return
TU	BY	S1I	-0109	Main-Belt Asteroid Multirendezvous
MU	FV	S1J	-0110	Earth Approaching Asteroid Rendezvous
TU	BU	S1K	-0111	Saturn Probe/Orbiter

Table 3.1.4-1 (Continued)

Source	CMM	SSMM	LaRC Code	Mission Title
				SOLAR PHYSICS
TU	BA	S5A	MMCX-0200	SOT-Solar Optical Telescope
TU	BB	S5B	-0201	SSXTF-Solar Soft X-Ray Telescope Facility
TU	DO	S5C	-0202	P/OF-Pinhole Occulter Facility
EU	AQ	S5E	-0203	ASO-Advanced Solar Observatory
U	JG	S5D	-0204	Solar Shuttle Facility
TU	BJ	S5G	-0205	SIS-Solar Interplanetary Satellite
TU	AO	S5H	-0206	SIDM-Solar Interior Dynamics Mission
TU	AV	S5J	-0207	SCE-Solar Corona Explorer
				SPACE PHYSICS
U	JE	S3A	MMCX-0400	Space Plasma Effects Upon Large Space-craft
U	GB	S3B	-0401	Large Spacecraft Impact Upon Proximate Space Plasma
TU	AZ	S3C	-0402	ISTO-Initial Solar Terrestrial Observatory
U	AZ	S3D	-0403	ASTO-Advanced Solar Terrestrial Observatory
U	AZ	S3E	-0404	GEOSTO-Geosynchronous Solar Terrestrial Observatory
U	JH	S3F	-0405	Very Large Radar
TU	BI	S3G	-0406	OPEN-Origin of Plasma in the Earth's Neighborhood
MU	EU	S3H	-0407	AIE-Advanced Interplanetary Explorer
TU	DR	S3J	-0408	Plasma Turbulence Explorer
TU	DP	S3K	-0409	Chemical Release Module Facility
				LIFE/BIOLOGICAL SCIENCES
TU	DJ		MMCX-0601	Operational Medicine
GBU	EA,GK, GL,GM	S6P,V, S6W,X	-0602	Cardiovascular Physiology
GU	ED,EE	S6S,T S6AJ	-0603	Vestibular/Neurophysiology
GU	BG	S6M	-0604	Osteology
GU	DN	S6N	-0605	Musculoskeletal Physiology
BU	GS,GT GU	S6U,AD AG,AH	-0606	Hematology/Immunology
GU	EB	S6Q	-0607	Fluid/Electrolytes

Table 3.1.4-1 (Continued)

Source	CMM	SSMM	LaRC Code	Mission Title
				LIFE/BIOLOGICAL SCIENCES (Cont)
GU	EC	S6R	-0608	Metabolism (Endocrinology, Ca++)
GU	EF,EJ EK	S6F,G, S6H	-0610	Embryology/Developmental Physiology
TU	CO		-0611	Psychology/Behavior
GU	GF,GG	S6L	-0612	Radiation Biology
TU	CP		-0614	Basic Space Biology
GU	GH,GI GJ	S6C,D S6E	-0615	CELSS-Controlled Environmental Life Support System
GU	GD,GE	S6J,K	-0616	Botany
				EARTH OBSERVATION
DU	EI		MMCX-0700	FILE-Feature Identification and Location Experiment
U				LAMMR-Large Antenna Multifrequency Microwave Radiometer
HU	BZ	S2E	-0702	Stereo Visual Imager
EFTU	AW	S2D	-0703	ERB-Earth Radiation Budget
U	FJ	S2O	-0704	CZCS-Coastal Zone Color Scanner
U	JL		-0705	Ocean Microwave Package
U	JM		-0706	Scatterometer
U	JC	S2L	-0707	THM-Tethered Magnetometer (Magnetic Gradiometer)
U	JD	S2M	-0708	GG-Gravity Gradiometer
TENU	BH	S2N	-0709	TOPEX-Ocean Topography Experiment
U	JB	S2H	-0710	Geosynchronous Satellite Intercalibration
ETU	BM,CZ	S2J	-0711	Thermal Infrared Imager
DU	DW,FI	S2I	-0712	WINDSAT (LIDAR)
U	FK	S2C	-0713	CLIR
ELHTDU	BL,CD CE,CY EG	S2B	-0714	Imaging Spectrometer
DU	DY	S2G	-0715	Microwave Radiometer
TU	CW,CX	S2A	-0716	Synthetic Aperture Radar
U	JA	S2F		Active Microwave
DU	DY	S2K		Passive Microwave, 100m

Table 3.1.4-1 (Continued)

Source	CMM	SSMM	LaRC Code	Mission Title
				MATERIALS PROCESSING
TDU	HH,HX	A1A	MMCX-0801	SS Materials Processing Lab
U	HS	A1B	-0802	Acoustic Containerless Furnace
U	HT	A1C	-0803	Electrostatic Containerless Furnace
U	JN	A1D	-0804	Electromagnetic Containerless Furnace
DU	HU	A1E	-0805	Vapor Crystal Growth Facility
DU	HU	A1F	-0806	Crystals From Solution Facility
U	JO	A1G	-0807	Electron Beam Furnace
DU	HU	A1H	-0808	Directional Solidification Furnace
U	JP	A1J	-0809	Fluids/Chemical Process Facility
U	JQ	A1K	-0810	Fluid Experiment System
U	JR	A1L	-0811	Gradient Furnace
U	JS	A1M	-0812	Isothermal Furnace
DU	HY	A1N	-0813	Electrophoresis Separation
DU	HZ	A1P	-0814	Bromine Phase Experiment
U	JJ	A1Q	-0815	Combustion Research
DU	HV	A1R	-0816	Molecular Beam Epitaxy
				COMMERCIAL COMMUNICATIONS
TU	LV	C2AH	MMCX-1001	XGP-Experimental Geostationary Platform
TU	LY	C2AJ	-1002	SARSAT-Search and Rescue Mission
MU	MD	C2AK	-1003	ODSRS-Orbiting Deep Space Relay Station
HU	NA-RJ	C2A-Z AA-AG	-1004	Commercial Communications Satellites (31 Missions)
				COMMERCIAL MATERIALS PROCESSING
HU	HO,HP HQ,HR	C1A	MMCX-1801	MDAC-Electrophoresis (EOS)
U	RK	C1B	-1802	Monodisperse Latex Reactor
U	JT		-1803	MPS Commercial Development Units
U	JU		-1804	MPS Commercial Production Units
				TECHNOLOGY DEVELOPMENT
	LB	011B	MMCX-2001	Thermal Shape Control Technology Development
DU	LC	08C	-2002	Large Antenna Development
DU	MA	09C	-2003	Large Solar Concentrator
DU	MB	09E	-2004	Solar Pumped Lasers
DU	LS	09F	-2005	Laser To Electric Energy Conversion

Table 3.1.4-1 (Concluded)

Source	CMM	SSMM	LaRC Code	Mission Title
			TECHNOLOGY DEVELOPMENT (Cont)	
DU	LQ	06B	-2006	Laser Propulsion Test
DU	LR	09D	-2007	Solar Sustained Plasmas
DU	LK	05A	-2008	OTV Servicing Technology
DU	LT	09A	-2009	Solar Panel Technology
DU	KI	03B	-2010	Fluid Management Technology
DU	KK	06A	-2011	Low Thrust Propulsion Technology
DU	KL	09B	-2012	Large Space Power System
DU	KM	09G	-2013	Solar Array Plasma Effects (Ion Thruster)
DU	KN	011A	-2014	Advanced Radiator Technology (Liquid Droplet Radiator)
DU	KP,KQ KR	07A,B 07C	-2015	Attitude Control System Development
DU	KS	08A	-2016	Antenna Range Facility
DU	KT	08B	-2017	Laser Comm, Track and Ranging
DU	KX	02A	-2018	Structural Strain Monitors
DU	KJ	010B	-2019	Fire Safety Technology
DU	KY	012A	-2020	Spacecraft Materials Technology
DU	LJ	01A	-2021	Satellite Servicing Technology
DU	KO	02B	-2022	Large Structure Technology
DU	LM	04A	-2023	Tether Dynamics Technology

3.1.5 Summation Techniques

The development of specific user requirements for individual missions assumed only minimal technology restrictions (i.e., the space station capabilities through the year 2000 are not a constraint on the users). For example, it was assumed that the OTV was large enough to make any orbital transfer indicated by the requirements. In addition it was assumed that any on-orbit service requirement such as fluid transfer or repair of random failure could be accomplished independent of the relative orbital inclinations and altitude of the space station and the satellite. The development of user requirements was also assumed to be independent of resource limitations (i.e., the space station has whatever number of OTV, TMS, and other support equipment necessary to perform the required tasks). The results in terms of absolute numbers can therefore be considered to be an upper limit. However, in terms of the relative proportion of the various requirements and the distribution of these requirements between mission categories the results are realistic. Figure 3.1.5-1 presents the relative distribution of the various types of logistic services. It can be seen that two-thirds of the service operations consist of resupply and orbital transfer; the addition of repair of random failures accounts for over 85% of the user requirements. Distributing these requirements among the various mission categories as shown in Figure 3.1.5-2 shows that three of these categories (Commercial Communications, Astronomy, and Earth Observation) account for almost two-thirds of the space station logistic capability requirements. Details of these results and further results can be found in Sections 3.3 and 3.4.

3.2 MISSION MODELS

The space station integrated user requirements were developed from the Space Station Mission Model (SSMM) which itself is a subset of the Composite Mission Model (CMM). These two mission models will be discussed in this section; and the development of the integrated user requirements will be discussed in the following two sections.

3.2.1 Composite Mission Model

The Composite Mission Model consists of 327 separate missions identified in one or more of the twelve sources described in Table 3.1.1-1. Of the 327 missions over half come from Battelle's Outside User P/L High Model, '82, and the NASA Space Systems Technology Model, '80-'81, Volume I. No restrictions were placed on incorporating a mission into the CMM; it was assumed that all desired missions, from any source whatsoever, could fly at the times indicated; and that any technology problems would also have been solved by those times.

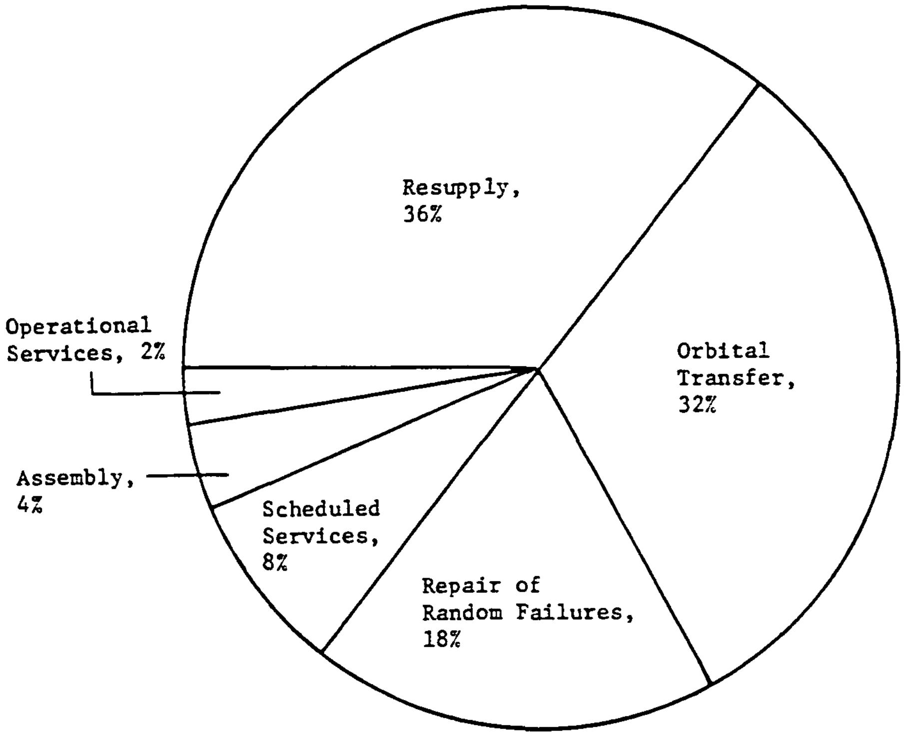

Figure 3.1.5-1 Distribution of Space Station Logistics Requirements

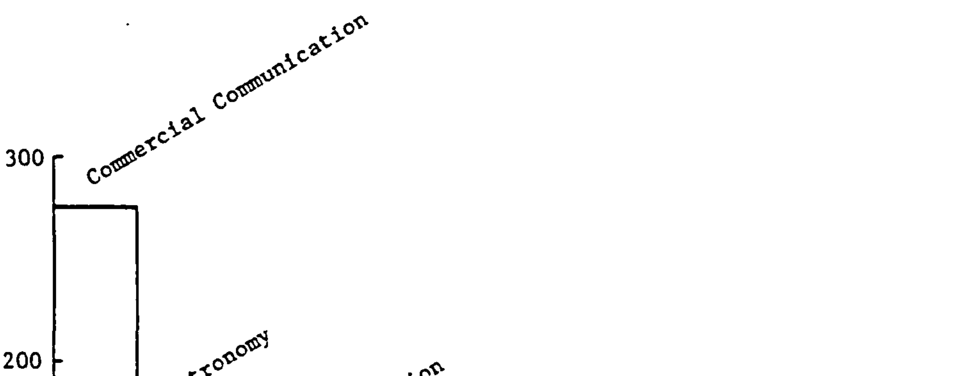

Figure 3.1.5-2 Logistics Service Requirements by Mission Category

Table 3.2.1-1 presents a page from the Composite Mission Model. Each mission in the CMM was given a unique two-letter identification symbol. The class or category (Table 3.2.1-2) within which the mission fell was also indicated. Launch site, orbital and physical parameters, and mission schedule data for each mission are included in the CMM. If the mission description in the original source included an indication that some type of service or that a retrieval was necessary this information was also included. Finally, a first estimate of the space station capability requirements is presented. The total CMM and a complete description of all the included data can be found in Volume II of this report.

3.2.2 Space Station Mission Model

The CMM contained no restrictions on which missions were to be included. User capability requirements developed from such a model would be unrealistic in that the results would require an exceptionally high budget and would assume upwards of 70 non DOD satellite launches in a single year, many with almost identical objectives. To bring the CMM to a realistic basis a Space Station Mission Model (SSMM) was developed using the following groundrules:

- Each mission in each category was prioritized according to scientific objectives.
- Missions with similar scientific objectives were combined.
- A "realistic" budget was developed for each discipline/ category and each mission was given a recommended "affordable" schedule (budget and spend plan).

The development of specific missions according to these groundrules is discussed in Volume II of this report; and the development of the budget and the determination of the mission schedules (launch dates) are covered in Volume V. Figure 3.1.5-2 presents the results of this analysis for the astronomy missions. While user requirements have been tentatively developed past the year 2000 it must be emphasized that the evaluations presented in Volumes II and V were intended to serve as a guide only to the year 2000; data for subsequent dates were beyond the scope of the current effort.

Table 3.2.2-1 presents a portion of the Space Station Mission Model (SSMM). This table identifies each mission's SSMM identification codes and the equivalent CMM identification code. Both the optimum and acceptable orbital parameters (inclination and altitude) are also given. Mission priorities and the desired and affordable launch dates are presented next. Included in Table 3.2.2-1a are the recommended basing requirements and an indication of possible logistic service requirements. Table 3.2.2-1b presents physical characteristics and operational requirements for each mission. These are discussed in depth in Volume II.

Table 3.2.1-1 MMC Composite Mission Model - Science Class

EXISTING PROGRAM PARAMETERS

PROGRAM ORG/NATION	STATUS --- ID	CLASS	LAUNCH: SITE	LAUNCH: VEHICLE	LAUNCH: OTS	ORBIT: INCLIN DEG	ORBIT: ALT KM/NM	PHYSICAL PARAMETERS: MASS KG/LB	PHYSICAL PARAMETERS: LENGTH M/FT	PHYSICAL PARAMETERS: DIAM M/FT	MISSION SUMMARY: DUR YRS	MISSION SUMMARY: NO. OF SATS	MISSION SUMMARY: LAUNCH YEAR	MISSION SUMMARY: LIFE YRS	SERVICE	RETRIEVE	CONFIDENCE	SOURCE
CXGT (X-Ray Telescope) NASDA, NASA, Joint	CA	S-4	KSC	STS							4	1 1	1993 1997	0			3	H
Very Long Baseline Interferometer (VLBI) MIT, NASA, JPL/U.S.	CF	S-4			OTS	45+	400-5000 / 216-2700			30.0/98.4	2+	1 1	1989 1990	1			2	ET
Gravity Probe-B (GP-B) NASA-MSFC, Stan. U./U.S.	DS	S-4	VAFB	STS	OMS KIT	90	520/281	1530/3366	4.2/13.8	4.2/13.8		1	1992	1			2	TA
Cosmic Background Explorer (COBE) NASA-GSFC/U.S.	DU	S-4	VAFB	STS		99 sun synch	900/486	1421/3126	4.8/15.7	4.4/14.4	1	1	1985	1			1	T
Active Optics Technology NASA-ARC/U.S.	EM	S-4		STS													3	D
Orbiting Infrared Submillimeter Telescope (OIST) JPL/U.S.	EN	S-4		STS			700/378	10000/22000						10			4	M
Infrafred Interferometer NASA-ARC/U.S.	EO	S-4	KSC	STS		28-50	400-700 / 216-378	22500/49500						5			4	M
Gravity Wave Interferometer NASA-GSFC/U.S.	EP	S-4		STS				16000/32500						1-5			4	M
Coherent Optical System of Modular Imaging Collectors (COSMIC) NASA-MSFC/U.S.	EQ	S-4	KSC	STS	HLLV OTV	28.5	500/270	67000/147400						10			4	M
100-Meter Thinned Aperture Telescope (TAT) NASA-MSFC/U.S.	ER	S-4	KSC	STS	HLV OTV IUS	28.5	500/270	85000/187000						10			4	M
Very Long Baseline UV/Optical/IR Interferometer NASA-MSFC/U.S.	ES	S-4	KSC	STS ETS		28.5	425/230	22850/50270									4	M
Very Large Space Telescope (VLST) NASA-MSFC/U.S.	ET	S-4	KSC	STS E.T.		28.5	425/230	22850/50270						10			4	M

PROJECTED SPACE STATION APPLICATIONS

PROGRAM ORG/NATION	LOD ENHANCE	DEL-RETRIEVE	SERVICING	SORTIE SUPPT	SPLY-STOW-FIX	OPS CNTL CNTR	LAB-TEST FAC	ASSEMBLY	STERILIZATION	COMM + DH	TETHERED SAT	SAFETY	FREE FLY PLAT	REMARKS
CXGT (X-Ray Telescope)		X	X											No backup designated
Very Long Baseline Interferometer (VLBI)		X	X					X		X				Ten year life desired.
Gravity Probe-B (GP-B)		X	X											
Cosmic Background Explorer (COBE)		X	X											DELTA is backup.
Active Optics Technology							X							Several year lifetime required.
Orbiting Infrared Submillimeter Telescope (OIST)		X	X							X				
Infrafred Interferometer		X	X					X		X				
Gravity Wave Interferometer			X				X			X				
Coherent Optical System of Modular Imaging Collectors (COSMIC)		X	X					X		X				Initially LEO. Eventually GEO.
100-Meter Thinned Aperture Telescope (TAT)			X					X		X				
Very Long Baseline UV/Optical/IR Interferometer		X	X					X		X				
Very Large Space Telescope (VLST)		X	X					X		X				

Table 3.2.1-2. Composite Mission Model Program Classes

Science	
S-1	Planetary Exploration
S-2	Earth Observation
S-3	Space Physics
S-4	Astronomy
S-5	Solar Physics
S-6	Life/Bio/Medical Sciences
S-7	Other
Applications (R&D)	
A-1	Materials Processing
A-2	Other
Operations (Technology Development)	
O-1	Satellite Servicing
O-2	Assembly of Space Structures
O-3	Fluid Transfer/Storage
O-4	Operating Platform
O-5	Launch Transfer
O-6	Propulsion
O-7	Spacecraft Control
O-8	Data Management & Communication
O-9	Electrical
O-10	Crew Systems
O-11	Thermal Control
O-12	Other
Commercial	
C-1	Space Processing
C-2	Communications Satellite
C-3	Other
DOD (Classified)	
D-1/D-4	Existing Programs
D-2/D-5	New Programs
D-3/D-6	Space Station Specific Applications

Table 3.2.2-1 Space Station Mission Model - Astronomy a. Mission Parameters

SCIENCE - ASTRONOMY

SPACE STATION MISSION MODEL

MISSION AGENCY OR SPONSOR LaRC CODE	SSMM REF	COMM REF	ORBIT PARAMETERS: INCLINATION OPTIMUM	INCLINATION USEFUL	ALTITUDE, km OPTIMUM	ALTITUDE, km USEFUL	COMPLIMENT MISSIONS	PRIORITY	SS PHASE LAUNCH YRS DESIRED AFFORDABLE	MISSION TYPE	MISSION DURATION (DAYS)	FREQUENCY	STATUS: EXIST	STATUS: NEW	SS SUPPORT FUNCTIONS: ON BOARD	ATTACHED	PLATFORM	FREE SAT	SERV. RETREV	SERV. REMOTE	RESUPPLY	LAUNCH	ASSEMBLY	CRITICAL INTEGRATION PARAMETERS AND OTHER CONSIDERATIONS
COBE-Cosmic Background Explorer NASA-GSFC MMCX-0001	S4A	DU	99 Sun Synch		900	800-1000	SIRTF LDR	High (Approved)	Initial 1985 Affordable 1989	Research	720	1	X					X	X	X	X			Design incorporates accessibility for servicing. 1500 kg
FUSE-Far Ultraviolet Spectroscopy Explorer NASA-GSFC MMCX-0002	S4B	FA	28.5		GEO		ST FOT	High (Opportunity)	Evol. 1992 Affordable 1993	Research	1800	1		X				X	X	X				" 1000kg
XTE-X-Ray Timing Explorer NASA-GSFC MMCX-0003	S4C	AM	28.5	28-57	300	300-400	LAMAR AXAF	High (Planned)	Initial 1989 Affordable 1989	Research	720	1		X				X	X	X				" 850 kg
EUVE-Extreme Ultraviolet Explorer NASA-GSFC MMCX-0004	S4D	AP	28.5	28-57	500	400-800	FUSE	High (Planned)	Initial 1987 Affordable 1989	Research	720	1	X					X	X	X				" 400 kg
GTE-Gamma Ray Transient Explorer NASA-GSFC MMCX-0005	S4E	EY	28.5	28-57	450	400-800	GRO	Med (Opportunity)	Evol. 1993 Affordable 1993	Research	720	1		X				X	X	X	X			" 3000 kg
HNE-Heavy Nuclei Explorer NASA-MSFC MMCX-0006	S4F	EV	57	28-57	400	400-800	CRO	Med (Opportunity)	Evol. 1995 Affordable 1997	Research	720	1		X		X								" 4000 kg
STARLAB NASA-GSFC MMCX-0007	S4G	AT	28.5	28-57	450	300-800	ST	Med (Planned)	Initial 1989 Affordable 1990	Research	3600	4 (14 days each)	X				X	X		X				" 2000 kg
SIRTF-Shuttle Infrared Telescope Facility NASA-ARC MMCX-0008	S4H	AU	28.5	28-57	400	300-800	COBE LDR	High (Planned)	Initial 1989 Affordable 1990	Research	1800	6 (14 days each)	X				X	X		X	X			" 10,000 kg

3-13

Table 3.2.2-1 Space Station Mission Model - Astronomy b. Mission Service & Support Requirements

SCIENCE - ASTRONOMY

SPACE STATION MISSION MODEL

MISSION / LaRC CODE	ACCEL. SENSITIVITY, g: SUST	ACCEL. SENSITIVITY, g: TRANS	POINTING: VIEW DIRC	POINTING: FOV DEG	POINTING: ACCUR ARC-SEC	POINTING: STABL ARC-SEC/SEC	POWER & DURATION: PEAK POWER ω / DURATION HRS	POWER & DURATION: OPER POWER ω / DURATION HRS	POWER & DURATION: STDBY POWER ω / DURATION HRS	DATA/COMM: COMMAND RATE KBPS UPLINK/DNLINK	DATA/COMM: RECORDING RATE KBPS / DURATION MIN	THERMAL: TEMP TOLER DEG C	PHYSICAL CHARACTERISTICS: LENGTH M	PHYSICAL CHARACTERISTICS: WIDTH M	PHYSICAL CHARACTERISTICS: HEIGHT M	PHYSICAL CHARACTERISTICS: MASS KG	MAINT/REPAIR CREW REQMTS: CREW SIZE	MAINT/REPAIR CREW REQMTS: SERV FREQ WKS	MAINT/REPAIR CREW REQMTS: MAN HRS PER SERVICE	SPECIAL CONSIDERATIONS
COBE-Cosmic Background Explorer MMCX-0001			Inertial	7	900	90		385				-268 ±3	4.8	4.8	4.4	1421	1	26	4	Contamination Sensitivity is extreme.
FUSE-Far Ultraviolet Spectroscopy Explorer MMCX-0002			Inertial	0.5	2	1.0	2000	1000				0±40	2	2	4	1000	1	52	4	Contamination Sensitivity is high.
XTE-X-Ray Timing Explorer MMCX-0003			Inertial	1.0	360	72	1000	300			61	0±20	2	2	4	850	1	52	4	
EUVE-Extreme Ultraviolet Explorer MMCX-0004			Inertial	5	10,500	1050	110	70			3.2	0±20	2.1	2.1	1	400	1	52	4	Contamination Sensitivity is high.
GTE-Gamma Ray Transient Explorer MMCX-0005			Inertial	1.0	360	72	2000	1500			61	0±20	2	2	2	3000	1	52	8	2X2X6 m deployed.
HNE-Heavy Nuclei Explorer MMCX-0006			Earth	30	120	12		500				0±20				4000	1	52	4	
STARLAB MMCX-0007			Inertial	0.5	2	0.02		1000				0±20	1.5	1.5	5	2000	2	52	16	Contamination Sensitivity is high.
SIRTF-Shuttle Infrared Telescope Facility MMCX-0008			Inertial	0.5	2	0.2		400		Spacelab Rate		-258 ±5	3.1	3.1	8.7	10,000	2	4	16	Contamination Sensitivity is extreme.

3.2.3 Space Station Mission Model Concept Data Sheets

The essential input to the SSMM are the concept data sheets for each mission. These sheets were developed in close coordination with the cognizant outside users, and include the mission objectives and description, orbital characteristics (including accuracy and tolerance if applicable), pointing requirements, and requirements for power, data/communication, and thermal considerations. The physical characteristics of the satellite are described in these sheets as well as operational and crew requirements and current servicing/maintenance concepts. Table 3.2.3-1 presents a typical concept data sheet for an astronomy mission (COBE). These sheets were used in the development of the user capability requirements.

3.3 MISSION TIMELINE AND USER REQUIREMENTS

This section describes the development of the mission timelines and the user requirement timelines for individual missions. Section 3.4 integrates and summarizes these requirements.

3.3.1 User Requirements Definition

The various services and operations consisting of the logistics capability requirements have been defined in Section 3.1. These requirements are assigned to each of the missions according to the requirements outlined in the mission models. To facilitate this assignment each of the applicable services and operations is given a code as indicated in Table 3.3.1-1. Also shown in this table are the normal service intervals discussed below.

The service interval is the expected time between successive applications of the same type of service. These times vary for each type of satellite. For the purposes of this study an average service interval for each type of service is assumed, applicable to all satellites.

Depending on usage, the service interval for storable propellants can range from two to as long as ten years. For this study a four to five year service interval for storable propellants was assumed for geosynchronous satellites, and a 30 month interval for other satellites.

It is assumed that for those missions where it is applicable, cryogen resupply is performed every 18 months. Present cryogen resupply is scheduled as often as every 6 months. The assumed service interval therefore appears to be near the upper bound of cryogen storage capability in the early 1990's.

Table 3.2.3-1 Concept Data Sheets

PAYLOAD ELEMENT NAME
COBE - Cosmic Background Explorer

CODE
M.M.C.X.0.0.0.1

CONTACT Dr. J. Mather
Name NASA/GSFC
Address Greenbelt, MD.

Telephone (303) 344-8720

STATUS

___ Operational
_X_ Approved

___ Planned
___ Candidate
___ Opportunity

First flight, yr 1985
No. of flights 1
Duration of Flight, days 365

OBJECTIVE Full Sky Survey to measure diffuse infrared and microwave cosmic background emission from one micron to thirteen mm.

TYPE

_X_ Science & Applications (non-commercial)

___ Commercial

___ Technology Development

___ Operations

Type Number (see Table A) 1

Importance of the Space Station to this Element

01 - low value but could use
10 - vital

Scale 1 - 10 4

DESCRIPTION Free-flyer explorer-class spacecraft which houses far IR absolute spectrophotometer, a diffuse IR background experiment, and a differential microwave radiometer, along with supporting subsystems.

Table 3.2.3-1 Concept Data Sheets (Cont.)

MMCX 0001

ORBIT CHARACTERISTICS

Apogee, km 900 Perigee, km 900 Tolerance + ____ - ____

Inclination, deg 99 Tolerance + ____ - ____

Nodal Angle, deg ____ Emphemeris Accuracy, m 1000

Escape dV Required, m/s ____

POINTING/ORIENTATION

View direction X Interial ___ Solar ___ Earth

Truth Sites (if known) ____

Pointing accuracy, arc sec 900 Field of view, deg 7

Pointing Stability (Jitter) arc sec/sec ____

Special Restrictions (Avoidance) Sun, Earth, Moon

POWER

___ AC X DC

	Power, W	Duration, hrs/day
Operating	385	
Standby		
Peak		

X Continuous

Voltage, V 28 Frequency, Hz ____

DATA/COMMUNICATIONS

Monitoring Requirements:

___ None ___ Realtime X Offline ___ Other ____

___ Encryption/Decryption Required

___ Uplink Req.: Command Rate (KBS) ____ Frequency (MHZ) ____

X On-Board Data Processing Required

Description

Data Compression

Data Types: ___ Analog X Digital Hrs/Day ____

Film (Amount) ____ Voice (Hrs/Day) ____

Live TV (Hrs/Day) ____ Other ____

On-Board Storage (MBIT) ____

Data Dump Frequency (Per Orbit) ____

Recording Rate (KBPS) ____ Downlink Frequency (MHZ) ____

Table 3.2.3-1 Concept Data Sheets (Cont.)

MMCX 0001

THERMAL

___ Active   X Passive

		min	max
Temperature, deg C	operational	-271	-265
	non-operational		
Heat Rejection, w	operational		
	non-operational		

EQUIPMENT PHYSICAL CHARACTERISTICS

Location: ___ Internal   ___ External   X Remote

Equipment ID/Function   ___ Pressurized   X Unpressurized

L,m	W,m	H,m	
4.8	4.8	4.4	Stowed
			Deployed

Launch mass, kg 1421

Consumables Types LQ HE

Acceleration sensitivity, g   min ___   max ___

CREW REQUIREMENTS

Crew Size 1   Task Assignment Servicing

Skills (See Table B)

SKILL 7						
LEVEL 2						
Hrs/Day 4						

EVA   X YES   ___ NO   Reason Replace Cryogen   Hrs/EVA 4

SERVICING/MAINTENANCE

SERVICE: Interval, days 180   Consumables, kg 200

Returnables, kg 50   Man Hours 4

CONFIGURATION CHANGES: Interval, day ___   Man/hrs Req. ___

Deliverables, kg ___   Returnables, kg ___

SPECIAL CONSIDERATIONS/See Instructions

Extreme Sensitivity to comtaminants

Table 3.3.1-1 Space Station Capabilities Functional Requirements

Functional Requirement	Code	Normal Service Interval
Assembly		
Hardware Build-up	A1	NA
Construction	A2	NA
Payload Mating	A3	NA
Resupply/Replenishment		
Fluid Transfer		
Storable Propellant	P	30 months (4-5-Years at GEO)
Cryogenic and Other Coolants	Y	18 months
Other Expendables	E	Variable
Orbital Transfer		
Delivery	D	NA
Retrieval	R	NA
Scheduled Servicing		
Preventive Maintenance		
Remote	M1	Variable
Space Station	M2	Variable
Contamination Control	S	2-3 years
Refurbishment	B	3-5 years
Random Failure Repair		
Remote	F1	21 months
Space Station	F2	21 months
Mission Operational Services		
Instrument Alignment	I1	NA
Instrument/Payload Changeout	I2	3 years or user specified

The replenishment of expendables is mission peculiar, and their service intervals are discussed under specific missions in Volume II.

Preventive maintenance is normally scheduled to be accomplished in orbit. However if the spacecraft is to be returned to the space station for other purposes this service will be performed there.

Contamination control includes the cleaning or re-coating of optical parts to maintain performance. A 24-month service interval is assumed for this operation. It is also assumed that contamination control must be accomplished at the space station.

Reburbishment is the total restoration of an item to its original state, i.e., a complete overhaul of the spacecraft. Refurbishment is scheduled in the hangar of the space station every four to five years, or when indicated in the mission description (see Volume II).

No spacecraft has 100 percent reliability. Present designs of singly redundant spacecraft, extrapolated to the early 1990's, are expected to have a mean life of 36 months. It is assumed that repair/replacements of failed components will occur when the spacecraft is still operational. That is, when one of the redundant components fails it will be replaced before the backup also fails. If a combination of two redundant components has a mean life of 36 months, then one of them has a mean life in an excess of 20 months. This was rounded up to 21 months: the assumed mean time between repair/replacement of failed components.

3.3.2 Basing Modes

The support capabilities required by each mission are a function of its basing. The following basing options, listed in order of priority, are considered in this study:

Mounted in space station (onboard) - The mission payload is mounted to the interior of the space station.

Mounted to space station (attached) - A payload that is mounted to the exterior of the space station by whatever means. Includes platforms attached by a boom.

Tether - The payload is attached to the space station (or to a platform) by means of a flexible cable.

Platform - The payload is attached to an unmanned carrier which provides all subsystem support. The primary objective of the platform is to provide precise pointing, low contamination, a very low-g environment, subsystem support, and the unique opportunity to support servicing of multiple payloads at one time.

Free Flyer - Payload is detached from the space station during the operational phase and is capable of independent operation.

The particular basing option used for a given mission is that indicated in the Space Station Mission Model. If more than one option is indicated, the priority listed above was used, unless the mission user representative specified a different priority.

3.3.3 Operational Requirements Definition

In addition to the logistics capability requirements described above there are a set of operational requirements that must await further definition of the various missions and the space station itself prior to a detailed analysis. These potential operational requirements include:

- Manned operation of the payload.
- Real time monitoring of the payload from the space station.
- Downlink data interception and storage.
- Onboard space station data processing for various missions.
- Mission command/control including specifying targets of opportunity.

Also included in the operational requirements are those elements needed to size the space station to accommodate missions to be attached or placed onboard (e.g., operational power, maximum downlink data rates, and thermal control).

These operational requirements will be addressed in future studies.

3.3.4 Mission Support Requirements Definition Summary

Table 3.3.4-1 presents the user capabilities requirements summary for each of the missions in the Space Station Mission Model. This table includes the I.D. code referencing the mission back to the Composite Mission Model, and the preferred orbital inclination and altitude (in kilometers). Basing for each mission is indicated as selected (S), alternate (A), and unacceptable (U). (Some missions, such as the Heavy Nuclei Explorer, have more than one basing option. In these cases the mission description specified a change in basing mode from an initial deployment at the space station or on a free-flyer to a platform.) Specific user capability requirements are listed next for each mission. These were developed as discussed in Section 3.1. Finally, a mission timeline showing duration and year of launch from earth is given for each mission. In these timelines a dashed line indicates an uncertainty as to the desired mission duration. Such uncertainties will be resolved in future studies.

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Table 3.3.4-1 User Requirements Summary

Mission	Langley MMCX-ID	Orbit Inclination, deg	Altitude, km	Basing Options: Platform	Basing Options: Free Flyer	Basing Options: Tether	Basing Options: Attached to SS	Basing Options: Internal to SS	Assembly: H/W Build	Assembly: Construction	Assembly: Payload Mating	Resupply/Replenish: Propellants	Resupply/Replenish: Cryogens/Coolants	Resupply/Replenish: Other Expendables	Orbital Transfer	Scheduled Servicing: Prevent Maint Remote	Scheduled Servicing: Prevent Maint at SS	Scheduled Servicing: Contamination Control	Scheduled Servicing: Refurbishment	Random Failure/Repair: Remote	Random Failure/Repair: At SS	Mission Operational Constraints: Instrument Change	Mission Operational Constraints: Instrument Alignment	Timeline (∇ Space Station IOC; Year 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002)
ASTRONOMY																								
Cosmic Background Explorer (COBE)	0001	99	900	U	S	U	U	U				X	X		X			X	X		X			
Far UV Spectroscopy Explorer (FUSE)	0002	28	GEO	U	S	U	U	U							X	X		X			X			
X-Ray Timing Explorer (XTE)	0003	28	GEO	U	S	U	U	U								X				X				
Extreme UV Explorer (EUVE)	0004	28	500	U	S	U	U	U				X			X	X		X	X		X			
Gamma Ray Transient Explorer (GTE)	0005	28	450	U	S	U	U	U				X			X	X				X				
Heavy Nuclei Explorer (HNE)	0006	57	400	U	S	U	A	U							X					X				
Starlab	0007	28	450	S	A	U	S	U							X			X	X	X	X	X	X	
Shuttle IR Telescope (SIRTF)	0008	28	400	S	A	U	S	U					X		X			X	X	X	X	X		
Large Area Modular Array of Reflectors (LAMAR)	0009	0	300	S	U	U	A	U	X			X			X				X	X				
Orbiting Very Long Interferometer (OVLBI)	0010	45	800	S	S	U	U	U	X			X	X		X	X				X				
Orbiting IR Submillimeter Telescope (OIST)	0011	57	800	U	S	U	U	U				X	X		X	X				X		X	X	
Faint Object Telescope (FOT)	0012	28	800	U	S	U	U	U							X					X				← L 1985
Space Telescope (ST)	0013	28	450	U	S	U	U	U							X		X	X	X	X	X			← L 1986
Adv. X-Ray Astrophysics Facility (AXAF)	0014	28	400	U	S	U	U	U							X	X			X	X		X		
Large Deployable Reflector (LDR)	0015	57	750	A	S	U	U	U	X				X		X	X	X	X		X	X	X	X	
Gamma Ray Observatory (GRO)	0016	0	400	U	S	U	U	U								X				X		X	X	
Coherent Optical System of Mod. Imaging Coll. (COSMIC)	0017	28	450	A	S	U	U	U		X		X			X	X	X	X		X	X		X	
Thinned Aperature Telescope (TAT)	0018	28	450	A	S	U	U	U		X		X			X	X	X	X		X	X		X	L 2003 →
Cosmic Ray Observatory (CRO)	0019	0	400	U	S	U	A	U	X			X		X	X	X								
X-Ray Observatory (XRO)	0020	288	400	S	A	U	A	U			X				X					X				

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Table 3.3.4-1 User Requirements Summary (Cont.)

Mission	Langley ID MMCX-	Orbit Inclination, deg	Altitude, km	Basing Options: Platform	Free Flyer	Tether	Attached to SS	Internal to SS	Mission Capability Requirements: Assembly: H/W Build	Construction	Payload Mating	Resupply/ Replenish: Propellants	Cryogens/ Coolants	Other Expendables	Orbital Transfer	Scheduled Servicing: Prevent Maint Remote	Prevent Maint at SS	Contamination Control	Refurbishment	Random Failure/ Repair: Remote	At SS	Mission Operational Constraints: Instrument Change	Instrument Alignment	Timeline (∇ Space Station IOC; Year: 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002)
SOLAR PHYSICS																								
Solar Optical Telescope (SOT)	0200	57	460	A	S	U	U	A				X		X				X	X	X	X			←L 1988
Solar Soft X-Ray Telescope	0201	57	430	A	S	U	A	A				X		X				X			X	X		
Pinhole Oculter Facility	0202	97	450	S	A	U	A	U				X			X			X			X			
Advanced Solar Obs.	0203	57	370	S	U	U	U	U	X			X			X	X			X	X		X		
Solar Shuttle Facility	0204	57	450	S	A	U	A	A	X						X					X		X		
Solar Interplanetary Satellite	0205	80	1AU	U	S	U	U	U																
Solar Interior Dynamics Mission (SIDM)	0206	Sun Sync	Full Sun	A	S	U	A	A	X															
Solar Corona Explorer	0207	57	600	A	S	U	A	A	X			X		X	X			X			X			←L 1988

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Table 3.3.4-1 User Requirements Summary (Cont.)

Mission	Langley ID NMCX-	Orbit Inclination, deg	Altitude, km	Basing Options: Platform	Free Flyer	Tether	Attached to SS	Internal to SS	Mission Capability Requirements: Assembly: H/W Build	Construction	Payload Mating	Resupply/ Replenish: Propellants	Cryogens/ Coolants	Other Expendables	Orbital Transfer	Scheduled Servicing: Prevent Maint Remote	Prevent Maint at SS	Contamination Control	Refurbishment	Random Failure/ Repair: Remote	At SS	Mission Operational Constraints: Instrument Change	Instrument Alignment	Timeline (∇ Space Station IOC) Year: 1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
SPACE PHYSICS																																					
Space Plasma Effects on Large Spacecraft	0400	55	LEO	U	U	U	U	S						X							X																
Large Spacecraft Impact on Proximate Space Plasma	0401	55	LEO	U	S	U	U	U						X						X																	
Initial Solar Terrestrial Observatory (ISTO)	0402	57	400	S	A	A	U	A	X			X	X		X	X		X		X	X	X															
Advanced Solar Terrestrial Observatory (ASTO)	0403	90	250	S	A	A	U	A	X			X	X		X		X	X		X	X	X															
Geosynchronous Solar Terrestrial Obs (GEO-STO)	0404	0	GEO	S	S	U	U	U	X			X			X	X				X		X														L	2005
Very Large Radar	0405	0	GEO	A	S	U	U	U	X			X			X	X				X																L	
Origin of Plasma in the Earth's Neighborhood (OPEN)	0406	0-80	2-15 RE	U	S	U	U	U																													2006
Advanced Interplanetary Explorer (AIE)	0407	TBD		U	S	U	U	U							X																						
Plasma Trubulence Explorer	0408	TBD		U	S	U	U	U				X			X					X																	
Chemical Release Module Facility	0409	57	100/ 1200	U	A	U	U	U						X	X				X	X																	

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Table 3.3.4-1 User Requirements Summary (Cont.)

Mission	Langley ID MMCX-	Orbit Inclination, deg	Altitude, km	Basing Options: Platform	Free Flyer	Tether	Attached to SS	Internal to SS	Mission Capability Requirements: Assembly: H/W Build	Construction	Payload Mating	Resupply/ Replenish: Propellants	Cryogens/ Coolants	Other Expendables	Orbital Transfer	Scheduled Servicing: Prevent Maint Remote	Prevent Maint at SS	Contamination Control	Refurbishment	Random Failure/ Repair: Remote	At SS	Mission Operational Constraints: Instrument Change	Instrument Alignment
PLANETARY																							
Venus Radar Mapper	0101	NA	NA			NA									X								
Comet Rendezvous	0102	NA	NA			NA																	
Mars Geochemistry/ Climatology Mapper	0103	NA	NA			NA																	
Titan Probe	1004	NA	NA			NA																	
Mars Probe Network	0105	NA	NA			NA									X								
Venus Atmospheric Probe	0106	NA	NA			NA									X								
Lunar Orbiter	0107	NA	NA			NA									X								
Comet Sample Return	0108	NA	NA			NA									X								
Main-Belt Asteroid Multirendezvous	0109	NA	NA			NA									X								
Earth Approaching Asteroid Rendezvous	0110	NA	NA			NA									X								
Saturn Probe/ Orbiter	0111	NA	NA			NA																	

Timeline

∇ Space Station IOC

Year

1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002

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Table 3.3.4-1 User Requirements Summary (Cont.)

Mission	Langley ID MMCX-	Orbit Inclination, deg	Altitude, km	Basing Options: Platform	Free Flyer	Tether	Attached to SS	Internal to SS	Mission Capability Requirements: Assembly: H/W Build	Construction	Payload Mating	Resupply/Replenish: Propellants	Cryogens/Coolants	Other Expendables	Orbital Transfer	Scheduled Servicing: Prevent Maint Remote	Prevent Maint at SS	Contamination Control	Refurbishment	Random Failure/Repair: Remote	At SS	Mission Operational Constraints: Instrument Change	Instrument Alignment	Timeline (∇ Space Station IOC) Year: 1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
LIFE AND BIOLOGICAL SCIENCES																																					
Health Maintenance Lab	0617	NA	NA											X																							
Operational Medicine	0601	NA	NA	U	U	U	U	S						X																							
Life Science Lab and Vivarium	0618 0619	SS	SS	U	U	U	U	S		X				X																							
Cardiovascular Physiology	0602	NA	NA	U	U	U	U	S																													
Vestibular/ Neurophysiology	0603	NA	NA	U	U	U	U	S																													
Osteology	0604	NA	NA	U	U	U	U	S																													
Musculoskeletal Physiology	0605	NA	NA	U	U	U	U	S																													
Hematology/ Immunology	0606	NA	NA	U	U	U	U	S																													
Fluid/ Electrolyetes	0607	NA	NA	U	U	U	U	S						X		SAME AS RESUPPLY OF																					
Metabolism (Endrocinology)	0608	NA	NA	U	U	U	U	S								LIFE SCIENCE LABORATORY																					
Embryology/Developmental Physiology	0610	NA	NA	U	U	U	U	S																													
Psychology/ Behavior	0611	NA	NA	U	U	U	U	S																													
Radiation Biology	0612	NA	NA	U	U	U	U	S																													
Basic Space Biology	0614	NA	NA	U	U	U	U	S																													
CELESS-Controlled Environmental Life Support	0615	NA	NA	U	U	U	U	S																													
Botany	0616	NA	NA	S	U	U	U	U						X	X					X																	

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Table 3.3.4-1 User Requirements Summary (Cont.)

Mission	Langley ID MMCX-	Orbit Inclination, deg	Altitude, km	Basing Options: Platform	Free Flyer	Tether	Attached to SS	Internal to SS	Mission Capability Requirements — Assembly: H/W Build	Construction	Payload Mating	Resupply/Replenish: Propellants	Cryogens/Coolants	Other Expendables	Orbital Transfer	Scheduled Servicing: Prevent Maint Remote	Prevent Maint at SS	Contamination Control	Refurbishment	Random Failure/Repair: Remote	At SS	Mission Operational Constraints: Instrument Change	Instrument Alignment	Timeline (∇ Space Station IOC; Year 1989–2002)
EARTH OBSERVATION																								
Feature ID & Location Experiment (FILE)	0700			U	S	U	U	U																L 1982
Large Antenna Multi-frequency Microwave Radiometer	0701	57	700	U	S	U	U	U							X				X					
Stereo Visual Imager	0702	90	325	S	A	U	A	U			X				X				X					
Earth Radiation Budget	0703	94	450	S	A	U	A	U			X				X				X					
Costal Zone Color Scanner	0704	90	800	S	A	U	A	U			X	X			X	X			X					
Ocean Microwave Package	0705		200	S	U	U	U	U			X				X				X					
Scatterometer	0706			S	U	U	U	U			X				X				X					
Tethered Magnetometer	0707	90	100	A	U	U	U	U					X				X			X				
Gravity Gradiometer	0708	90	300	A	S	U	A	U					X		X	X			X					
Ocean Topography Experiment (TOPEX)	0709	63.43	1300	A	S	U	A	U				X			X	X			X					
Geosynchronous Satellite Intercalibration	0710	Any	Any	S	U	U	U	U			X				X									
Thermal IR Imager	0711	90	400	S	A	U	A	U			X		X		X			X			X			
Windsat (LIDAR)	0712	90	600	S	A	U	A	U			X		X	X	X					X				
CLIR	0713	90	500	A	S	U	U	U					X		X			X			X			
Imaging Spectrometer	0714	90	LEO	S	A	U	A	U			X	X			X	X				X				
Microwave Radiometers	0715	98	LEO	S	A	U	A	U				X				X				X				L 1988
Synthetic Aperture Radar	0716	90	LEO	S	A	U	A	U			X				X									L 1986
Active Microwave	0717	90	LEO	S	A	U	A	U			X	X			X	X								
Microwave, Passive 100m	0718	Equitorial		U	S	U	U	U	X						X					X				

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Table 3.3.4-1 User Requirements Summary (Cont.)

Mission	Langley ID MMCX-	Orbit Inclination, deg	Altitude, km	Basing Options: Platform	Basing Options: Free Flyer	Basing Options: Tether	Basing Options: Attached to SS	Basing Options: Internal to SS	Assembly: H/W Build	Assembly: Construction	Assembly: Payload Mating	Resupply/Replenish: Propellants	Resupply/Replenish: Cryogens/Coolants	Resupply/Replenish: Other Expendables	Orbital Transfer	Scheduled Servicing: Prevent Maint Remote	Scheduled Servicing: Prevent Maint at SS	Scheduled Servicing: Contamination Control	Scheduled Servicing: Refurbishment	Random Failure/Repair: Remote	Random Failure/Repair: At SS	Mission Operational Constraints: Instrument Change	Mission Operational Constraints: Instrument Alignment	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
MATERIALS PROCESSING APPLICATION																																					
SS Materials Processing Lab	0801	Any	Any	U	U	U	U	S		X				X																							
Acoustic Containerless Furnace	0802	Any	Any	U	U	U	U	S						X																							
Electrostatic Containerless Furnace	0803	Any	Any	U	U	U	U	S						X																							
Electromagnetic Containerless Furnace	0804	Any	Any	U	U	U	U	S						X																							
Vapor Crystal Growth Facility	0805	Any	Any	U	U	U	U	S						X																							
Crystals from Solution Facility	0806	Any	Any	U	U	U	U	S						X																							
Electron Beam Furnace	0807	Any	Any	U	U	U	U	S						X																							
Directional Solidification Furnace	0808	Any	Any	U	U	U	U	S						X																							
Fluids/Chemical Process Facility	0809	Any	Any	U	U	U	U	S						X																							
Fluid Experiment System	0810	Any	Any	U	U	U	U	S						X																							
Gradient Furnace	0811	Any	Any	U	U	U	U	S						X																							
Isothermal Furnace	0812	Any	Any	U	U	U	U	S						X																							
Electrophoresis Separation	0813	Any	Any	U	U	U	U	S						X																							
Bromine Phase Experiment	0814	Any	Any	U	U	U	U	S						X																							
Combustion Research	0815	Any	Any	U	U	U	U	S						X																							
Molecular Beam Epitaxy	0816	Any	Any	U	U	U	U	S						X																							

SAME AS RESUPPLY OF SS MATERIALS LABORATORY

Timeline: ∇ Space Station IOC

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Table 3.3.4-1 User Requirements Summary (Cont.)

Mission	Langley ID MMCX-	Orbit Inclination, deg	Altitude, km	Basing Options: Platform	Free Flyer	Tether	Attached to SS	Internal to SS	Mission Capability Requirements: Assembly: H/W Build	Construction	Payload Mating	Resupply/Replenish: Propellants	Cryogens/Coolants	Other Expendables	Orbital Transfer	Scheduled Servicing: Prevent Maint Remote	Prevent Maint at SS	Contamination Control	Refurbishment	Random Failure/Repair: Remote	At SS	Mission Operational Constraints: Instrument Change	Instrument Alignment
COMMERCIAL COMMUNICATIONS																							
Experimental Geostationary Platform	1001	0	GEO	U	S	U	U	U				X			X								
Search and Rescue	1002	90	926	S	A	U	U	S			X				X					X			
Orbiting Deep Space Relay Station	1003	0	GEO	U	S	U	U	U	X			X			X					X			
Intelsat VII	1004	0	GEO	U	S	U	U	U				X			X					X			
Telesat-K-N	1004	0	GEO	U	S	U	U	U							X								
Telesat F/O	1004	0	GEO	U	S	U	U	U				X			X					X			
SBS F/O	1004	0	GEO	U	S	U	U	U				X			X					X			
Satcom F/O	1004	0	GEO	U	S	U	U	U							X								
Telstar-3	1004	0	GEO	U	S	U	U	U			X				X					X			
Westar F/O	1004	0	GEO	U	S	U	U	U			X				X					X			

Timeline — ∇ Space Station IOC — Year: 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002

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Table 3.3.4-1 User Requirements Summary (Cont.)

Mission	Langley ID MMCX-	Orbit Inclination, deg	Altitude, km	Basing Options					Mission Capability Requirements: Assembly			Resupply/ Replenish				Scheduled Servicing				Random Failure/ Repair		Mission Operational Constraints		Timeline ∇ Space Station IOC Year													
				Platform	Free Flyer	Tether	Attached to SS	Internal to SS	H/W Build	Construction	Payload Mating	Propellants	Cryogens/ Coolants	Other Expendables	Orbital Transfer	Prevent Maint Remote	Prevent Maint at SS	Contamination Control	Refurbishment	Remote	At SS	Instrument Change	Instrument Alignment	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
COMMERCIAL COMMUNICATIONS																																					
Advanced Westar-2	1004	0	GEO	U	S	U	U	U			X				X					X																	
Tracking and Data Requisition System (TDAS)	1004	0	GEO	U	S	U	U	U			X				X					X																	
Galaxy F/O	1004	0	GEO	U	S	U	U	U							X																						
Syncom F/O	1004	0	GEO	U	S	U	U	U							X																						
G-Star F/O	1004	0	GEO	U	S	U	U	U			X				X					X																	
SPC F/O	1004	0	GEO	U	S	U	U	U							X																						
MSat	1004	0	GEO	U	S	U	U	U			X				X					X																	
SBTS F/O	1004	0	GEO	U	A	U	U	U							X																						
Mexsat F/O	1004	0	GEO	U	S	U	U	U							X																						
Satcol F/O	1004	0	GEO	U	S	U	U	U							X																						

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Table 3.3.4-1 User Requirements Summary (Cont.)

Mission	Langley ID MMCX-	Orbit Inclination, deg	Altitude, km	Basing Options					Mission Capability Requirements															Timeline ▽ Space Station IOC													
									Assembly			Resupply/ Replenish				Scheduled Servicing				Random Failure/ Repair		Mission Operational Constraints		Year													
				Platform	Free Flyer	Tether	Attached to SS	Internal to SS	H/W Build	Construction	Payload Mating	Propellants	Cryogens/ Coolants	Other Expendables	Orbital Transfer	Prevent Maint Remote	Prevent Maint at SS	Contamination Control	Refurbishment	Remote	At SS	Instrument Change	Instrument Alignment	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
COMMERCIAL COMMUNICATIONS																																					
Aussat	1004	0	GEO	U	S	U	U	U				X			X					X																	
Italsat F/O	1004	0	GEO	U	S	U	U	U							X																						
Nordsat F/O	1004	0	GEO	U	S	U	U	U				X			X					X																	
Arabsat F/O	1004	0	GEO	U	S	U	U	U							X																						
Palapa F/O	1004	0	GEO	U	S	U	U	U							X																						
Chicomsat	1004	0	GEO	U	S	U	U	U							X																						
Regional Communications Satellites	1004	0	GEO	U	S	U	U	U							X																						
Data Transmission Satellites F/O	1004	0	GEO	U	S	U	U	U				X			X					X																	
Banking	1004	0	GEO	U	S	U	U	U							X																						

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Table 3.3.4-1 User Requirements Summary (Cont.)

Mission	Langley ID MMCX-	Orbit Inclination, deg	Altitude, km	Basing Options: Platform	Free Flyer	Tether	Attached to SS	Internal to SS	Mission Capability Requirements: Assembly: H/W Build	Construction	Payload Mating	Resupply/ Replenish: Propellants	Cryogens/ Coolants	Other Expendables	Orbital Transfer	Scheduled Servicing: Prevent Maint Remote	Prevent Maint at SS	Contamination Control	Refurbishment	Random Failure/ Repair: Remote	At SS	Mission Operational Constraints: Instrument Change	Instrument Alignment	Timeline ∇ Space Station IOC Year: 1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
COMMERCIAL COMMUNICATIONS																																					
Mail F/O	1004	0	GEO	U	S	U	U	U				X			X					X																	
STC/FO	1004	0	GEO	U	S	U	U	U				X			X					X																	
DBS F/O	1004	0	GEO	U	S	U	U	U							X																						
China DBTV	1004	0	GEO	U	S	U	U	U							X																						
Canada DBTV Fo	1004	0	GEO	U	S	U	U	U				X			X					X																	

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Table 3.3.4-1 User Requirements Summary (Cont.)

Mission	Langley ID MMCX-	Orbit Inclination, deg	Altitude, km	Basing Options: Platform	Basing Options: Free Flyer	Basing Options: Tether	Basing Options: Attached to SS	Basing Options: Internal to SS	Assembly: H/W Build	Assembly: Construction	Assembly: Payload Mating	Resupply/Replenish: Propellants	Resupply/Replenish: Cryogens/Coolants	Resupply/Replenish: Other Expendables	Orbital Transfer	Scheduled Servicing: Prevent Maint Remote	Scheduled Servicing: Prevent Maint at SS	Scheduled Servicing: Contamination Control	Scheduled Servicing: Refurbishment	Random Failure/Repair: Remote	Random Failure/Repair: At SS	Mission Operational Constraints: Instrument Change	Mission Operational Constraints: Instrument Alignment	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
COMMERCIAL MATERIALS PROCESSING																																					
Electrophoresis (EOS)	1801	Any	Any	U	S	U	U	U												X				L 1988 L 1988													
				U	U	U	U	S													X																
				S	U	U	U	U			X				X					X																	
Monodisperse Latex Reactor	1802	Any	Any	U	U	U	U	S						X							X																
MPS Commercial Development	1803	Any	Any	U	U	U	U	S						X																							
MPS Commercial Production	1804	Any	Any	S	U	U	U	U			X			X	X																						

Timeline: ∇ Space Station IOC

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Table 3.3.4-1 User Requirements Summary (Cont.)

Mission	Langley ID MMCX-	Orbit Inclination, deg	Altitude, km	Basing Options: Platform	Free Flyer	Tether	Attached to SS	Internal to SS	Mission Capability Requirements — Assembly: H/W Build	Construction	Payload Mating	Resupply/ Replenish: Propellants	Cryogens/ Coolants	Other Expendables	Orbital Transfer	Scheduled Servicing: Prevent Maint Remote	Prevent Maint at SS	Contamination Control	Refurbishment	Random Failure/ Repair: Remote	At SS	Mission Operational Constraints: Instrument Change	Instrument Alignment	Timeline (∇ Space Station IOC) Year: 1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
TECHNOLOGY DEVELOPMENT																																					
Thermal Shape Control Technology Development	2001			A	U	U	S	U																							▬						
Large Antennae Development	2002			A	U	U	U	S																					▬								
Large Solar Concentrator	2003			A	U	U	S	U																							▬						
Solar Pumped Lasers	2004			U	U	U	U	S						X																		▬					
Laser to Electricity Energy Conversion	2001			U	U	U	U	S						X																		▬					
Laser Propulsion Test	2006			U	U	U	U	S																									▬				
Solar Sustained Plasmas	2007			A	U	U	S	U																										▬			
OTV Servicing Technology	2008			A	U	U	S	U																			▬										
Solar Panel Technology	2009			U	U	U	S	U						X														▬									
Fluid Management Technology	2010			A	U	U	S	U				X	X													▬											
Low Thrust Propulsion	2011			A	A	U	U	S				X																	▬	▬							
Large Space Power System	2012			A	U	U	A	S	X																				▬	▬	▬						
Solar Array Plasma Effects (Ion Thruster)	2013			A	U	U	S	U			X				X													▬									
Advanced Radiator Technology	2014			A	U	U	U	S																						▬							
Attitude Control System Development	2015			A	U	U	S	U																			▬										
Antenna Range Facility	2016			U	U	A	U	S																					▬	▬	▬						
Laser Comm. Track, Range	2017			U	U	U	U	S						X																▬							
Structural Srain Monitors	2018			A	U	U	S	U																			▬										
Fire Safety Tech	2019			A	U	U	A	S						X												▬											
SC Materials Tech	2020			A	U	U	S	U																				▬									

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Table 3.3.4-1 User Requirements Summary (Concl.)

Mission	Langley ID MMCX-	Orbit Inclination, deg	Altitude, km	Basing Options					Mission Capability Requirements															Timeline													
									Assembly			Resupply/ Replenish				Scheduled Servicing				Random Failure/ Repair		Mission Operational Constraints		∇ Space Station IOC													
																								Year													
				Platform	Free Flyer	Tether	Attached to SS	Internal to SS	H/W Build	Construction	Payload Mating	Propellants	Cryogens/ Coolants	Other Expendables	Orbital Transfer	Prevent Maint Remote	Prevent Maint at SS	Contamination Control	Refurbishment	Remote	At SS	Instrument Change	Instrument Alignment	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
TECHNOLOGY DEVELOPMENT																																					
Satellite Servicing	2021			U	U	U	S	U									X				X							■									
Large Structure Tech	2022			A	U	S	U	U																							■						
Tether Dynamics Tech	2023			U	U	S	U	U																							■						

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3.4 INTEGRATED USER TIMELINES

3.4.1 Integrated User Mission Sets

Table 3.2.1-2 above lists 24 mission categories that were used to develop the CMM. For the purposes of the SSMM and the integrated user requirements these were reduced to the ten mission sets listed below:

- Astronomy - 20 missions
- Planetary - 10 missions
- Solar Physics - 8 missions
- Space Physics - 10 missions
- Life and Biological Sciences - 15 missions
- Earth Observation - 19 missions
- Materials Processing Applications - 16 missions
- Commercial Communications - 34 missions
- Commercial Materials Processing - 4 missions
- Technology Development - 23 missions

3.4.2 Capability Requirements Prioritization

Table 3.3.1-1 lists 16 separate user requirements. It is expected that the space station will not be able to perform all these services at IOC. Each of these services will require unique capabilities and equipment that must be developed and thoroughly tested prior to becoming operational. Table 3.4.2-1 lists a recommended priority for developing the logistics capability requirements. Each of the services have been placed in one of the four priority classes shown in Table 3.4.2-1. No attempt has been made to prioritize services within these classes. However, the development of services performed at the space station should probably take precedence over those that are remote. Also, services requiring higher amounts of EVA or more complex equipment to perform should be developed later than others.

3.4.3 Capability Requirements Timeline

Based on the data presented in Table 3.3.4-1 a timelines of user requirements were developed (Table 3.4.3-1). This table assumes that all the services indicated in Table 3.3.1-1 are operational at space station IOC in 1991. As mentioned above this will likely not be the case. These timelines must therefore be considered to reflect what is desired to be done, rather than that which can actually be accomplished. As IOC dates for each of the space station capability requirements are determined the timelines will be changed to reflect this.

The following examples indicate how the user requirements timelines were developed.

Table 3.4.2-1 User Capability Requirements Priority

Class I - Immediate
- Delivery to Orbit
- Payload Mating

Class II - High
- Retrieval to SS
- Resupply/Replenishment
- Preventive Maintenance
- Random Failure Repair
- Instrument/Payload Changeout

Class III - Medium
- Contamination Control
- Refurbishment
- Instrument Alignment
- Hardware Buildup

Class IV - Deferred
- Construction

Table 3.4.3-1 Space Station Logistics Requirement Timeline

Mission	Langley ID MMCX-	Year														
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Astronomy																
Cosmic Background Explorer (COBE)	0001	RY S P PF2D		RY S PB D												
Far UV Spectroscopy Explorer (FUSE)	0002			D		R F2 S D	M1	RSD								
X-Ray Timing Explorer (XTE)	0003		F1		M1		F1									
Extremely UV Explorer (EUVE)	0004		RS P M2 D		RO S D		RS F2 D									
Gamma Ray Transient Explorer (GTE)	0005			D			P F1	M1		P F1						
Heavy Nuclei Explorer (HNE)	0006							D1		F1						
Starlab	0007			SB I1 D		R F2 S D		RB I2 S D		RS I2 D	F1					
Shuttle IR Telescope Facility (SIRTF)	0008			SB Y D		RY F2 SD	I2 Y	RB Y SD		R SY I2 F2 D						
Large Area Modular Array of Reflectors (LAMAR)	0009						A1 D		F1	R B P D			F1 P			
Orbiting Very Long Baseline Interferometer (OVLBI)	0010			A1 D	Y	F1 P	M1 Y	Y	F1 P	Y	F1 YP		Y	F1 P	Y	
Orbiting IR Submillimeter Telescope (OIST)	0011										I1 D	Y	F1 P	Y M1 I2	Y	F1 P
Faint Object Telescope (FOT)	0012	F1														
Space Telescope (ST)	0013		RB S D		F1	RS D		RB SD			RS M2 D		F1			
Adv X-Ray Astrophysics Facility (AXAF)	0014					D		F1 I2		RB I2 D		M1		F1		
Large Deployable Reflectors (LDR)	0015												A1 D	Y	RS F2 D	Y
Gamma Ray Observatory (GRO)	0016		F1		F1		F1 I2	M1		F1	F1	I2		F1	M1	

Table 3.4.3-1 Space Station Logistics Requirement Timeline (Cont.)

Mission	Langley ID MMCX-	Year 1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Astronomy (concl)																
Coherent Optical System of Modular Imaging Collectors (COSMIC)	0017												A2 I1 D		RS F2 D	P
Thinned Aperture Telescope (TAT)	0018															A2 I1 D
Cosmic Ray Observatory (CRO)	0019											A1 D			P	
X-Ray Observatory (XRO)	0020									A3 D		F1				

Table 3.4.3-1 Space Station Logistics Requirement Timeline (Cont.)

Mission	Langley ID MMCX-	Year														
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Solar Physics																
Solar Optical Telescope (JOT)	0200	F1		RB SP D	F1	P	R F2 S D									
Solar Soft X-Ray Telescope	0201		R1 E F2 s p d													
Pinhole Oculter Facility	0202	D			R F2 S P D		R F2 SP D									
Adv Solar Observatory	0203					A1 D		F1 P	F1		RB P I2 D		F1	P	F1	
Solar Shuttle Facility	0204		A1 D		F1 I2											
Solar Interplanetar Satellite	0205															
Solar Interior Dynamics Mission (SIDM)	0206															
Solar Coronal Diagnostics Facility	0207	RE F2 SP D		F1	P											

Table 3.4.3-1 Space Station Logistics Requirement Timeline (Cont.)

Mission	Langley ID MMCX-	Year														
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Space Physics																
Space Plasma Effects on Large S/C	0400		F2		F2		F2									
Large S/C Impact on Proximate Space Plasma	0401		F1		F1		F1									
Initial Solar Terrestial Obs (ISTO)	0403					A1 D	Y	R YS P F2 D	F1	R I2 YS D	Y P F1	RY S D	M1 P	RY SD	Y	RY S P F2 D
Geosynchronous Solar Terrestial Observatory (Geo-STO)	0404											A1 D	Y	RS YP F2 D	F1	RY I2 Y D
Very Large Radar	0405														A1 D	
Origin of Plasma in the Earth Neighborhood (OPEN)	0406															
Adv Interplanetary Explorer (AIE)	0407								D							
Plasma Turbulence Explorer	0408												D		F1 P	
Chemical Release Module Facility	0409	F1		R B E D		F1		F1								

Table 3.4.3-1 Space Station Logistics Requirement Timeline (Cont.)

Mission	Langley ID MMCX-	Year														
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Planetary																
Venus Radar Mapper	0101															
Comet Rendezvous	0102		D													
Mars Geochemistry/Climatology	0103															
Titan Probe	0104															
Mars Probe Network	0105											D				
Venus Atmospheric Probe	0106									D						
Lunar Orbiter	0107						D									
Comet Sample Return	0108							DR								
Main-Belt Asteroid Multirendezvous	0109										D					
Earth Approaching Asteroid Rendezvous	0110											D				
Saturn Probe/Orbiter	0111															

Table 3.4.3-1 Space Station Logistics Requirement Timeline (Cont.)

Mission	Langley ID MMCX-	Year 1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Life and Biological Sciences																
Health Maintenance Laboratory	0617	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Botany	0616					D	E	E R1	E	E						
Vivarium and Life Science Lab	0618 0619					A2	4E	4E	4E	4E	4E	4E	4E	4E	4E	4E
Various Life/Biological Science Experiments		Same Services Indicated for Health Maintenance Laboratory, Vivarium, and Life Sciences Laboratory														

Table 3.4.3-1 Space Station Logistics Requirement Timeline (Cont.)

Mission	Langley ID MMCX-	Year 1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Earth Observation																
Feature ID & Location Exp (FILE)	0700															
Large Antenna Multifrequency Microwave Radiometer	0701	D A3		F1	F1											
Stereo Visual Imager	0702					A3 D		F1		F1						
Earth Radiation Budget	0703	A3 D		F1		F1		F1		F1						
Coastal Zone Color Scanner	0704	D A3		M1 P	F1											
Ocean Microwave Package	0705				A3 D		F1	F1								
Scatterometer	0706				A3 D		F1	F1								
Tethered Magnetometer	0707											Y	M2	Y	F2 Y	
Gravity Gradiometer	0708										D	Y	M1	Y	F1 Y	
Ocean Topography Exp (TOPEX)	0709			D		M1 P		P	F1	P	M1		P			
Geosynchrounous Satellite Intercalibration	0710	A3 D	R		D	R		D	R							
Thermal Imager	0711								A3 D	Y	R F2 S D	Y F1	R YS D			
WINDSAT (LIDAR)	0712				A3 D 2E	4E Y	4E F1	4E Y	4E F1 Y							
CLIR	0713	R F2 S Y D		R F2 S Y D												
Imaging Spectrometer	0714	F1 P	M1													

Table 3.4.3-1 Space Station Logistics Requirement Timeline (Cont.)

Mission	Langley ID MMCX-	Year														
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Earth Observation (concl)																
Microwave Radiometer	0715	F1 P	M1	P	F1		P F1									
Synthetic Aperture Radar	0716															
Active Microwave	0717								A3 D		F1	M1			F1	
Microwave, Passive, 100m	0718								A1 D	F1		M1			F1	

Table 3.4.3-1 Space Station Logistics Requirement Timeline (Cont.)

Mission	Langley ID MMCX-	Year														
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Material Processing Application																
SS Materials Processing Lab	0801		6E	6E	6E	6E	6E	6E	6E	6E	6E	6E	6E	6E	6E	6E
Various Missions		Same Service as SS Materials Processing Laboratory														

Table 3.4.3-1 Space Station Logistics Requirement Timeline (Cont.)

Mission	Langley ID MMCX-	Year 1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Commercial Communications																
Experiments Geostationary Platform	1001		D				P F1				P F1					
Search and Rescue	1002					P F1				P F1				P F1		
Orbiting Deep-Space Relay Station	1003								A1 D				P F1			
Intelsat VII	1004			DD	DD	DD	PP F1 DD F1	PP DD F1 F1	PP DD F1 F1	PP D F1 F1	PP F1 F1	PP F1 F1	P F1			
Telestat-K-N	1004	D														

Table 3.4.3-1 Space Station Logistics Requirement Timeline (Cont.)

Mission	Langley ID MMCX-	Year 1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Commercial Communication Satellites																
Telesat F/O	1004						D	D			P F1	P F1				
SBS F/O	1004				D	D	D	D	P F1	P F1	P F1	P F1				
SATCOM F/O	1004	D	D	D	D											
Telstar 3 F/O	1004			D	D	D		P F1	P F1	P F1						
Wester F/O	1004			DD	DD											
Advanced Wester-2	1004				D	D	D	D	P F1	P F1	P F1	P F1				
Tracking & Data Acquisition System (TDAS)	1004			D	D	D	D	P F1	P F1	P F1	P F1					
Galaxy F/O	1004		D	D	D	D	D									
Syncom F/O	1004				DD	DD										
G-Star F/O	1004				D	D	D	D	P F1	P F1	P F1	P F1				
SPC F/O	1004	D	D	D	D	D	D									
MSat	1004			D		D		P F1		P F1						
SBTS F/O	1004		D	D	D	D										
Mexsat F/O	1004		D	D												
Satcol F/O	1004			D		D		D		D						
Aussat F/O	1004			D	D	D	D	P F1	P F1	P F1	P F1					
Italsat F/O	1004		D	D												

Table 3.4.3-1 Space Station Logistics Requirement Timeline (Cont.)

Mission	Langley ID MMCX-	Year														
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Commercial Communication Satellites (concl)																
Nordsat F/O	1004					D	D	D				P F1	P F1	P F1		
Arabsat F/O	1004		D		D											
Palapa F/O	1004	D	D													
Chicomsat F/O	1004	D	D	D	D	D	D	D	D							
Regional Comm Sats	1004	D	D	D	D	D	D	D								
Data Transmission Sets F/O	1004			D	D	D	D	P F1	P F1	P F1	P F1					
Banking	1004		D		D											
Mail F/O	1004					D	D	D				P F1	P F1	P F1		
STC F/O	1004			DDD	DDD			P P P F1 F1 F1	P P P F1 F1 F1							
DBS F/O	1004		DDD	D D D	DDD	DDD	DDD									
China DBTV	1004	D	D	D	D	D	D	D	D							
Canada DBTV	1004					D	D	D	D	P F1	P F1	P F1	P F1			

Table 3.4.3-1 Space Station Logistics Requirement Timeline (Cont.)

Mission	Langley ID MMCX-	Year 1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Commercial Materials Processing																
Electrophoresis (EOS)	1801	F1 F1	F2 F2	4 A3 4D F2 F2	3 A3 3D 4 F1	2 A3 2D 3 F1	F1 F1									
Monodisperse Latex Reactor	1802			2E F2	2E	2E F2										
MPS Commercial Development	1803					2E	2E									
MPS Commercial Production	1804					A3 D	2E	2E	2E	2E						

Table 3.4.3-1 Space Station Logistics Requirement Timeline (Concl.)

Mission	Langley ID MMCX-	Year														
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Technology Development																
Low-Thrust Propulsion Tech	2011				P	P P										
Large Space Power System	2012				A1											
Solar Array Plasma Effects	2013			A3 D R												
Solar Pumped Lasers	2004						E	E								
Laser to Electric Energy Conversion	2005						E	2E								
Solar Panel Technology	2009			E												
Fluid Management Technology	2010	PY	P Y													
Antenna Range Facility	2016						E	E								
Laser Comm, Track, Range	2017				E	E										
Fire Safety Technology	2019	E														
Satellite Servicing Tech	2021		M2 F2													

An early astronomy mission, Cosmic Background Explorer (COBE), is scheduled to be launched from earth in 1989 (Table 3.3.4-1). This is two years before space station IOC, and its scheduled mission duration is only one year. However it is assumed that it is desired to keep this program operational for several more years (dashed line, Table 3.3.4-1). Therefore, when the space station achieves IOC in 1991, COBE should be retrieved and attached or placed in close proximity to the space station. Cryogen and propellants will be replenished and contamination control accomplished. After over two years on station it is probable that at least one of COBE's redundant systems will have failed. Any such system will be replaced, and COBE will be redelivered to its operational orbit. Eighteen months later COBE will require more cryogen. This could be accomplished on-orbit. However, it is probable that once again the satellite will be retrieved and a complete refurbishment, including replenishment of propellants and contamination removal, will be accomplished. By accomplishing all services at one time the satellite may then be redeployed, and no further services would be required unless the duration of the program requires additional cryogen.

The Far Ultraviolet Spectroscopy Explorer (FUSE) mission will be launched from the earth in 1993, and brought to the space station by the shuttle where it will be mated to a TMS and deployed to its operational orbit. Sometime within the next two years a failure in one of its redundant systems is likely. Rather than repair the satellite on orbit it will be retrieved to the space station where contamination control can also be done. A year to 18-months after it is redeployed, a servicer will be sent to the satellite where on-orbit preventive maintenance can be accomplished to keep the satellite in satisfactory operating condition for the duration of its mission. In 1997, the satellite will be retrieved again for contamination control, and redeployed to its operational orbit.

The user capability requirements timelines for the other missions were developed in a like manner.

3.5 INTEGRATED REQUIREMENTS SUMMARY

3.5.1 User Requirements

The user requirements in Table 3.4.3-1 are summarized in Figures 3.5.1-1 and 3.5.1-2. Figure 3.5.1-1 shows the distribution of the major user servicing requirements over time. The drop in orbit transfers after 1995 is due principally to a lack of definition of new missions after that time. Realistically, it can be expected that as we approach the 1990's and obtain a better knowledge of future programs, such requirements will stay constant or rise. This same reduction in indicated requirements in the late 1990's can be seen in Figure 3.5.1-2 depicting total services by mission set. In this instance most of the

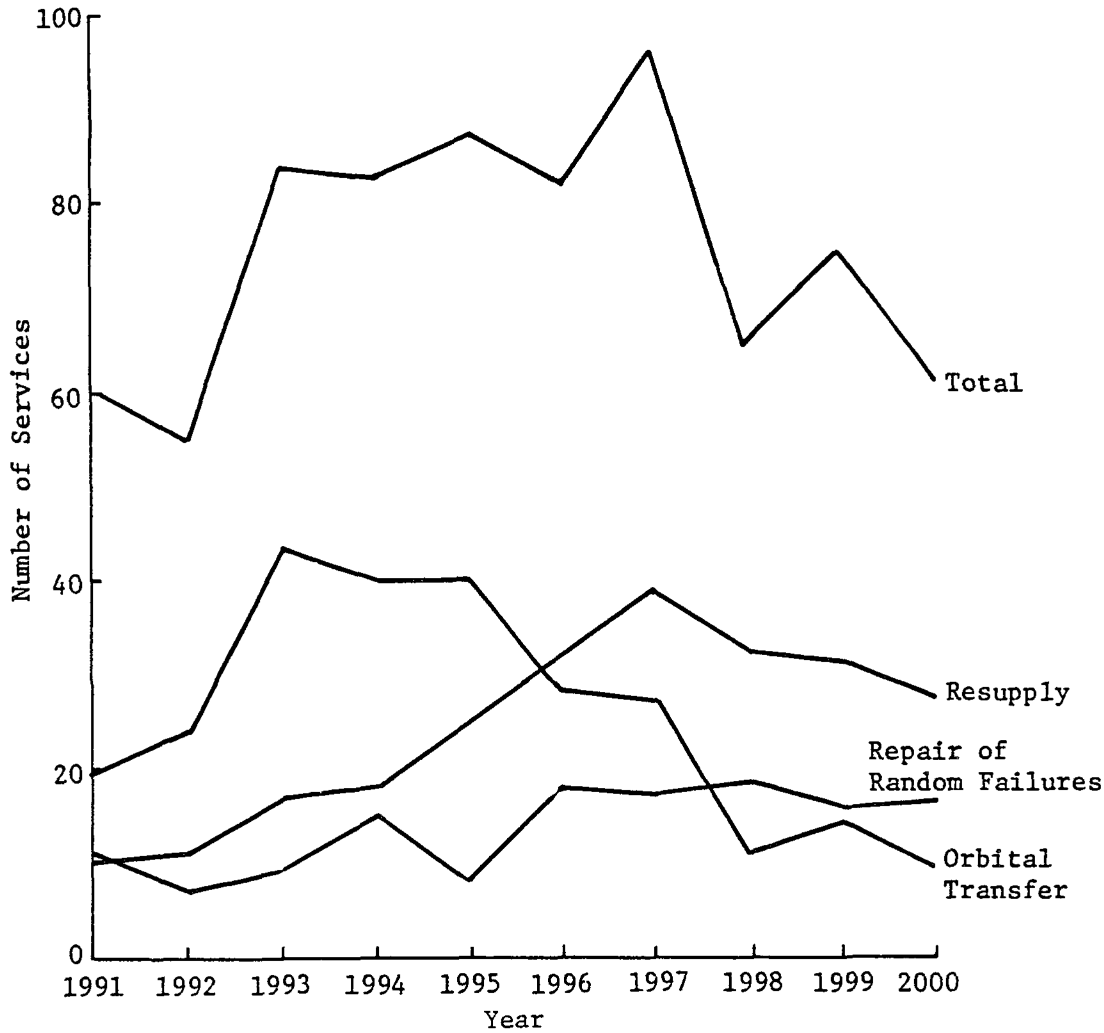


Figure 3.5.1-1 User Requirements Timeline Distribution by Type

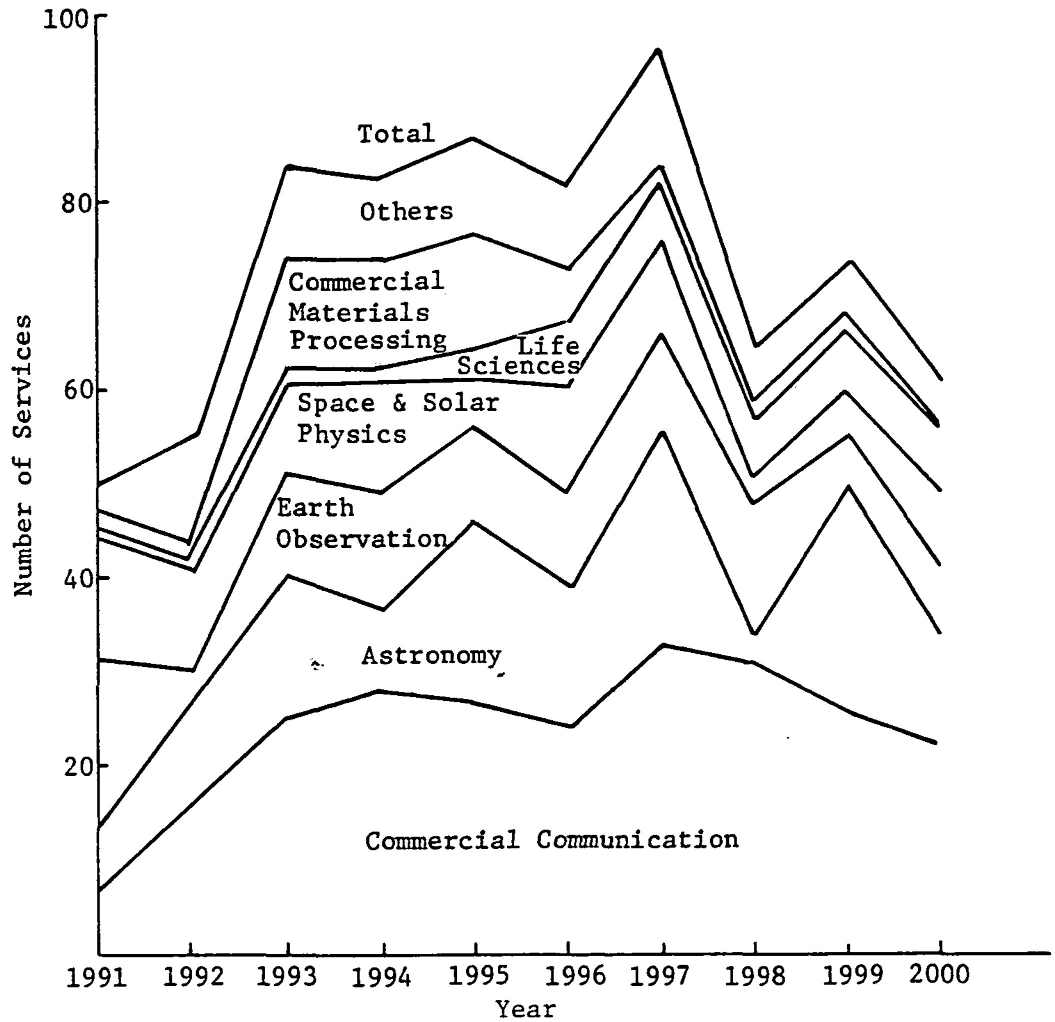


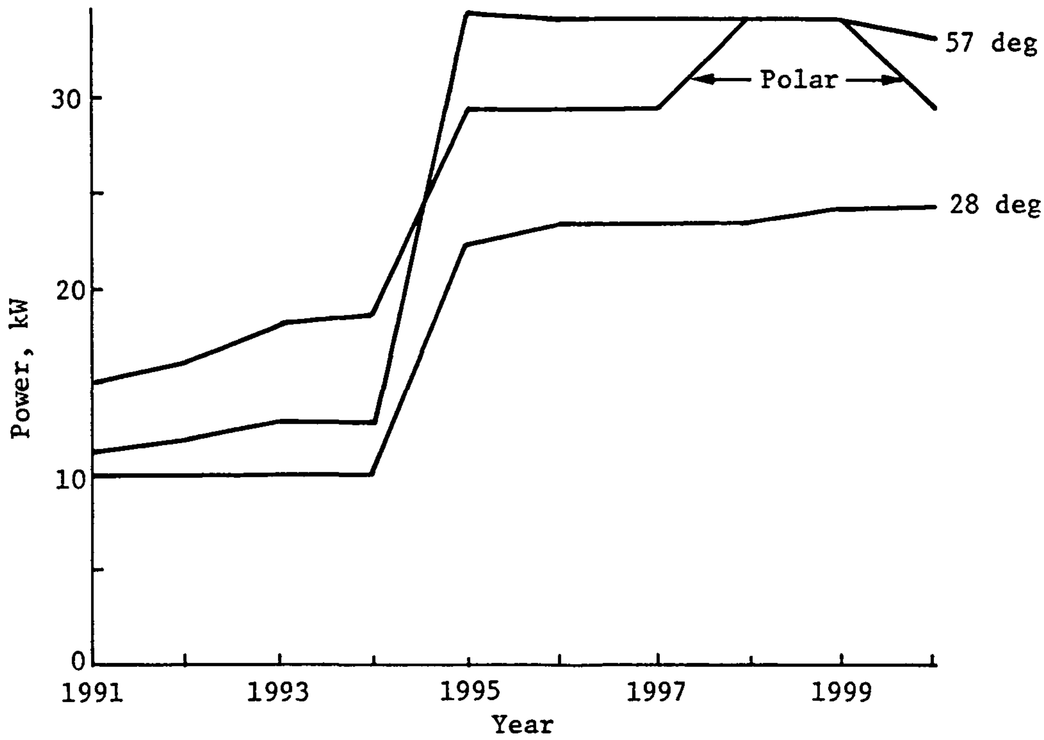
Figure 3.5.1-2 User Requirements Timeline Distribution by Mission Category

drop can be attributed to astronomy and space and solar physics which show a drop-off of satellites in orbit after 1997 (Table 3.8). Here again, as the knowledge of future programs in these areas becomes clearer it can be expected that user capability requirements will not exhibit such behavior.

3.5.2 Operational Requirements

As mentioned in Section 3.3.3 a definitive analysis of integrated operational requirements must await a further definition of the various missions. In particular the sizing of the space station to accommodate those missions to be placed onboard or attached requires detailed knowledge of the subsystem, e.g., power and maximum downlink data rate, for each mission. These data are not presently available in sufficient detail for definitive analysis. However Figure 3.5.2-1 present a rough estimate of these requirements, assuming that all missions that are a candidate for placement on the space station are actually located there. These results are a function of the orbit inclination of the space station. For example, if the space station were placed in a polar orbit then many Earth Observation missions could also be placed aboard, significantly increasing the requirements for operating power and downlink data rate over that of a space station placed in an orbit which precluded captive earth observation missions.

(a) Operating Power by Year



(b) Maximum Data Rate by Year

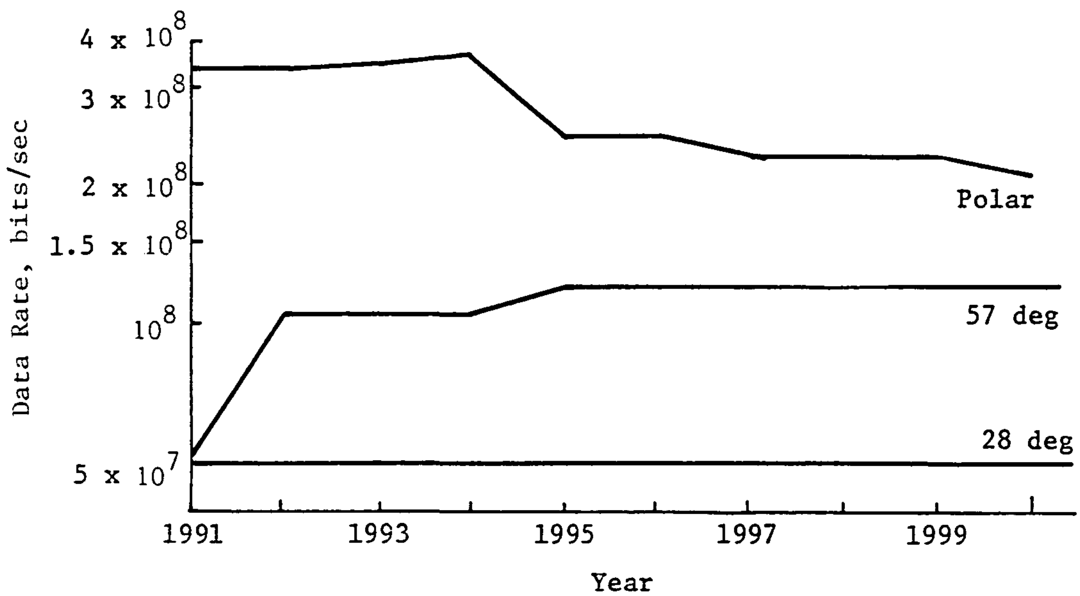


Figure 3.5.2-1 Integrated Operational Requirements for Three Space Station Orbit Inclinations

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4.0 SPACE STATION USER ACCOMMODATION REQUIREMENTS

4.1 INTRODUCTION

The purpose of this section is to derive accommodation requirements that satisfy the user mission needs from the late 1980's through the year 2000. These user mission needs were identified in section 3 of this document. In order to satisfy those needs the following integrated Space Station capabilities were identified: assembly, propellant resupply/replenishment, orbit transfer, scheduled servicing, random failure repair, and mission operation constraints. Also identified were the following basing modes: platform, free-flyer, tether, attached to and/or mounted in SS.

Accommodation requirements were those elements required for the space station to support a user's mission needs from start to finish of that mission. For our purposes these requirements have been broken down into five major categories: (1) Mission System, (2) Facility Requirements, (3) Operational Requirements, (4) SS Configuration Elements & Interfaces, and (5) Support Module Requirements. These requirements were considered independent of time, cost, benefit and user/space station constraints.

We derived these requirements through evaluation of previous studies performed by NASA, Martin Marietta Corporation, other contractors, the scientific community and our own in-house functional capability analyses in support of this study.

4.2 ANALYSIS PLAN

Our approach to this section was accomplished in two parts. The first was to develop a data base using the previously mentioned data sources to identify the associated user/space station requirements. Secondly, we derived our own requirements through an in-house study. Our approach for the in-house study has been identified in Figure 4.2-1. As shown in this diagram we first took the fifteen identified capability requirements from Section 3 and developed space station scenarios capable of supporting their needs. Of the eighteen scenarios generated, fifteen accommodated the user and the rest supported the space station itself. Next we looked across all the scenarios and establish ground rules (mainly hardware) and trade studies that were common to all of them. Then function definitions (top level requirements) were generated for each of the eighteen scenarios and associated ground rules. These functional definitions were analyzed and broken down into two areas: standard functions, that occured in more than one top level requirement, and unique functions that applied to individual definitions. These standard and unique functional definitions were then taken to the next level to derive detailed functional requirements. During this process additional ground rules and trades were identified that were common to each scenario. Once this was accomplished, facility, hardware and software requirements were derived, by subsystem, for each of the scenarios and their functional requirements. Next we studied all of the generated requirements and integrated them into one set of requirements that support the user needs.

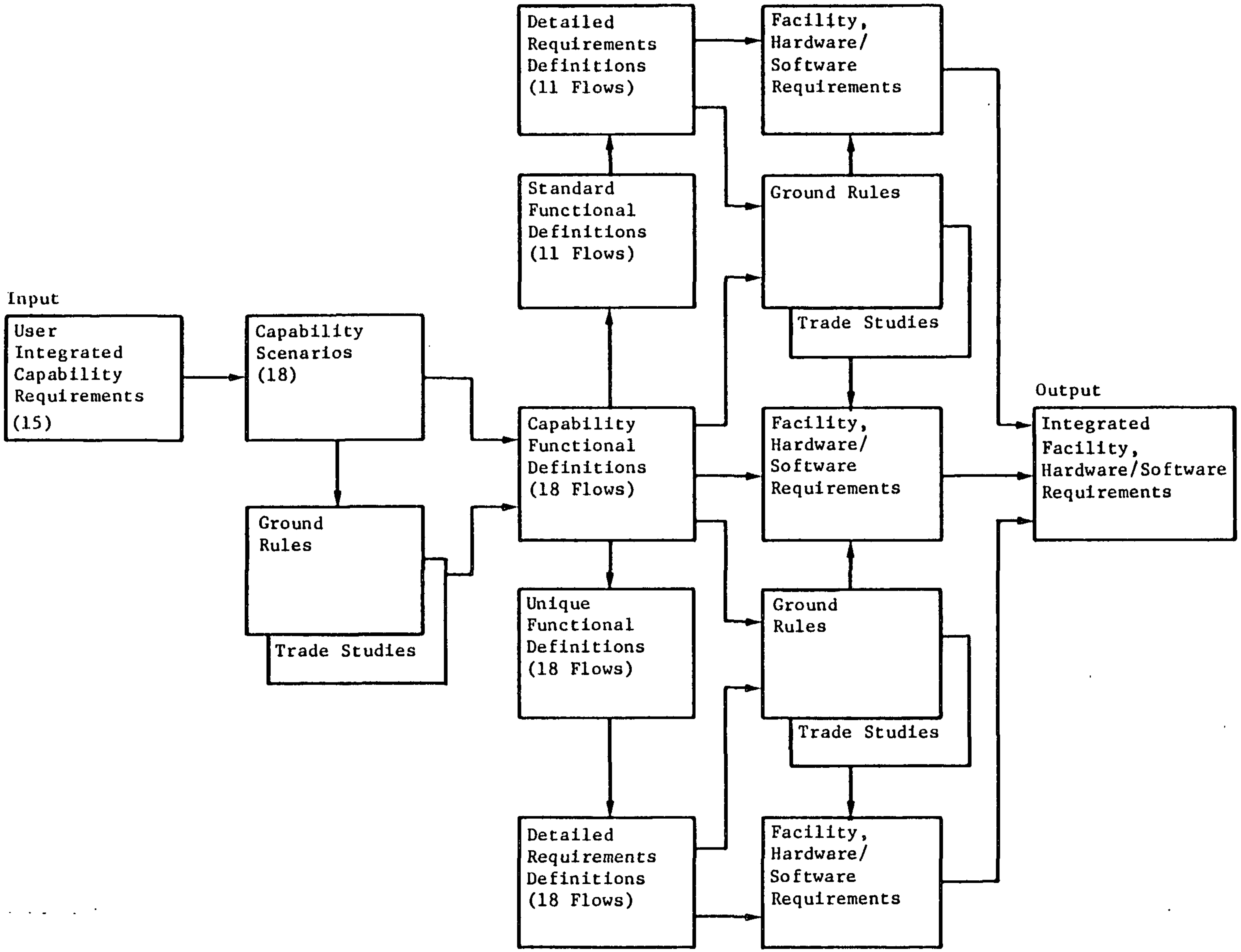

Figure 4.2-1 User Accommodations Work Flow Diagram

4.3 INTEGRATED REQUIREMENTS

User and space station system requirements were initially derived from the functional flows in Section 4.4. Those requirements that were identified from the various functional flows (top level, standard and unique) were then integrated together, categorized by subsystem and listed in Table 4.3-1. These integrated requirements do not include physical parameters/characteristics, and were independent of costing, benefit and timeline impacts.

After reviewing the requirements in Table 4.3-1, our data base (Appendix B), and NASA requirements, we established a series of top level requirements for the development of the space station concept. These were again derived independent of cost, benefit, timeline, and physical parameters/characteristics. These requirements have been broken down into five categories (Figure 4.3-1): (1) Mission System, (2) Facility Requirements, (3) SS Configuration Elements and Interfaces, (4) Operational Requirements, and (5) Support Module Requirements.

The Mission System requirements were identified from three mission classes derived from the SS mission model; SS assembly/support, platform operations/support, and satellite operations/support. These requirements have been described in Section 4.3.1. The Facility Requirements cover safety, maintainability, reliability and systems design and have been identified in Section 4.3.2. Basic core element requirements for the SS were defined under SS configuration elements and Interfaces (Section 4.3.3) and include the command module, habitability module and the logistics module. These in turn led to the formulation of operational and support module requirements that have been discussed in Section 4.3.4 and 4.3.5, respectively. In the support module requirements section, two areas were identified: crew systems and individual subsystem requirements.

The summation of the above top level requirements and Table 4.3-1 satisfied the user needs and defined the basic space station concepts.

The DOD mission considerations and related studies have not been identified in this section, but are identified in Volume VI, which is a classified document.

4.3.1 Mission System Requirements

The following are SS top level design drivers:

- o The SS will provide permanent manned presence.
- o The SS will maintain a minimum operating altitude such that it will have approximately: (1) 180 days of station keeping propellant and life support commodities for a nominal 90 day stay time plus 90 days for contingencies and (2) 90 additional days of orbit lifetime without station keeping capability, including life support commodities, during a maximum drag period of the 11 year solar cycle.

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Table 4.3-1 Integrated Facility, Hardware, and Software Requirements (Top Level)

Subsystem	Requirements

Structural/ Mechanical	- Support Structure (SS Elements)
	- Subsystem Equipment Accommodations (Space, Support, Orientation, Utilities, Commodities)
	- Servicing Interfaces (TMSs, OTV, Servicers, P/Ls)
	- Tether Interfaces (P/Ls, EMU)
	- Translation Paths & Crew Restraints (Internal/External)
	- Mechanisms (Orientation Drives, Deploy/Retract Devices, Release/Engage Devices)
	- Docking Interfaces (Structural, Utilities/Commodities, Passageway)
	  - SS Element
	  - STS
	- Berthing Interfaces (STS, TMSs, OTV, Servicers, P/Ls)
	- Payload Accommodations (Field of View, Support, Alignment/Pointing, Utility/Commodity Interfaces, Servicing)
	- Transfer Mechanisms (P/Ls, SS Elements, OTV, TMSs, Servicers)
	- Meteoroid Protection
	  - SS Elements
	  - Payloads
	- Storage, Utilities/Commodities Provisions
	- Mating/Demating Mechanisms/Devices

Electrical	- Electrical Umbilical
	- Power (TBD)
	  - Nominal (ac)
	  - Peak (dc)
	- Battery Charger
	- Tools
	- Solar Array Protective Covers
	- Heaters
	- Transducers
	- General-Purpose Test Equipment
	- P/L in Dormant Mode during All Servicing Tasks

Fluids (Propellants/ Pressurants)	- Space Station
	  - Tanks
	  - Valves, Type & Quantity
	  - Thruster Size, Location and Quantity
	- SS (cont)
	  - Transducers
	  - Status Subsystem
	- TMSs, OTV, Servicers, P/Ls
	  - Tank
	  - Quick Disconnects
	  - Controller
	- TMSs (cont)
	  - Transducers
	  - Valves
	- Propellant Transfer/ Loading Techniques
	- Servicer
	  - Umbilical Robotics
	  - Heaters
	- Hazardous Vapor Detections

Environmental	- Cleanliness
	- Structural Attachment
	- Pressure Ventilation (Contamination)
	- Leak Contamination
	- Thermal Control
	  - Radiation Orientation Constraints
	  - P/L Coolant Quick Disconnects
	  - Rotary Fluid Connection
	  - Coolant Pressure and Temperature
	- Thermal (cont)
	  - Valve Open/Close Position
	  - Accumulation Fluid Quantity
	- Stability
	- RF Radiation
	- Standard Contamination

Avionics	- Data Processing and Display
	- Data Recording/Storage
	- Commanding
	- Experiment/Payload Management
	- Station Command and Control
	- Umbilical Data Measurement
	  - Propellants/Pressurants
	  - Power
	- Attitude Control
	- Guidance and Navigation
	- TMS/OTV/Satellite Test, Checkout, and Control
	- Telemetry
	- Life Support Monitoring
	- Antenna/Solar Array Pointing

Communication	- Voice Communications (EVA/IVA) - Closed Circuit TV - Navigation (GPS) Data Reception - STS Communication - TDRSS Communication - Standard Communication - Space Station to: SS, OTV, P/Ls, TMS, Servicers - Telepresence TV Camera

Access	- Access and Clearance for TMS/OTV/TMS/Servicer/P/L Mating/Demating and Deployment/Retrieval
	- Access and Clearance for Either Manned or Remote Checkout
	- Docking/Berthing Clearances
	- Access to Servicing Areas
	  - Thermal Insulation (Accessibility)
	  - Clearance
	- Access and Clearance for Manned/ Remote Servicing
	- Access and Clearance for EVA Mating/Demating and Deployment/ Retrieval
	- Tool and Replacement Part Access
	- Personnel Access
	- Equipment Access
	- Work Clearances
	- Translation Clearances

Support Services/ Hardware	- Lighting Aids (External/Internal)
	Services
	- Safety
	- Security
	- Photographic
	- Laboratory Analysis
	- Three Dedicated Servicers
	  - Module Changeout
	  - Fluid Replenishment
	  - Contamination Control
	- Two TMSs
	- One OTV
	- Two EMUs
	- Two MMUs
	- Beam Builder(s)
	- Two Control Consoles
	  - TMS
	  - OTV
	  - Servicers
	  - SS RMS
	Attached and Unattached Missions
	- Alignment Equipment/Tools
	  - Mechanical
	  - Optical
	- Basic Checkout Equipment/ Tools
	- Tool Sets
	- Dedicated STS Docking Port(s)
	- Logistics Support

Handling	- SS RMS/Space Crane (Cherry Picker)
	  - Fixed
	  - Mobile
	- Hand Tools
	- Work Stands
	  - Fixed
	  - Mobile
	- Dollies
	- Hanger Extension/Retraction Fixture
	- Portable Hoists
	- Miscellaneous, Handling, Positioning, and Lifting Equipment
	- Dedicated Handling Equipment
	  - TMSs
	  - OTV
	  - Servicers
	  - P/Ls

Working Space/ Facilities	- Servicing Facilities (External/Internal)
	  - TMSs
	  - OTV
	  - Servicers
	  - EMU
	  - MMU
	  - P/Ls
	- Storage Facilities (External/Internal/ Station Keeping)
	  - TMSs
	  - OTV
	  - Servicers
	  - EMU
	  - MMU
	  - P/Ls
	  - Replacement Hardware
	  - Canisters
	- Propellant/Pressurant Storage Facilities
	  - Hydrazine
	  - Cryogenic
	  - Bipropellants
	  - Helium
	  - Nitrogen
	- Assembly Facilities
	  - External
	  - Internal
	- Construction Facilities
	  - External
	  - Internal
	- Berthing Facilities (External/ Internal)
	  - TMSs
	  - OTV
	  - Servicers
	  - P/Ls
	- Docking Facilities
	  - STS
	- Command/Control Facilities
	- Laboratory Facilities
	- Clean Room Facilities
	- Habitable Areas and Resupply Capabilities

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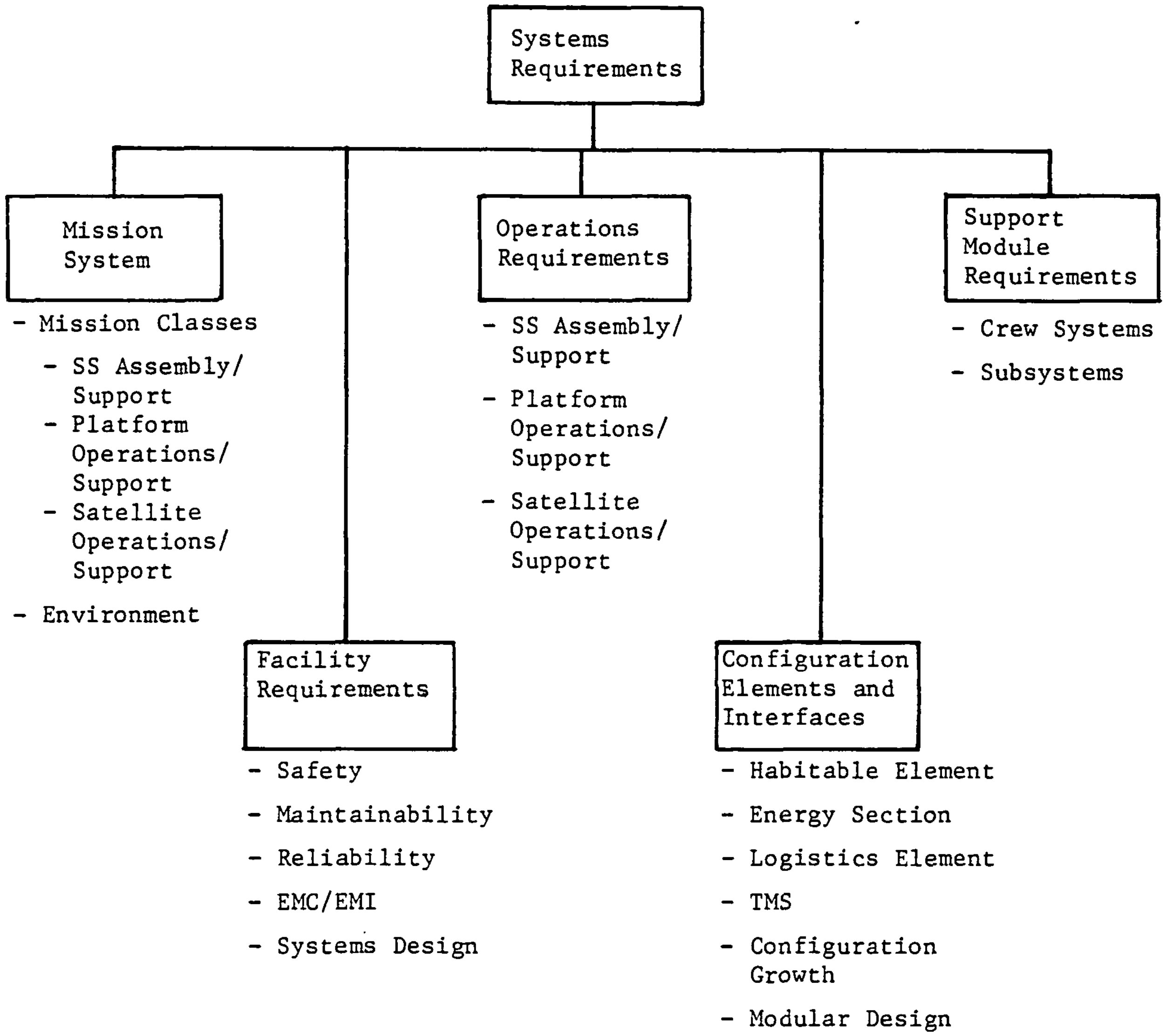

Figure 4.3-1 Top-Level System Requirements Breakdown

- The SS will have an operating life of at least 10 years with the capability of extended life by using a system/subsystem modular changeout concept for maintenance and upgrades.

- During initial operation, a safe haven for the crew will be provided. Under consideration are the habitat module which could be divided into two independent elements by a pressure bulkhead or the EPS module which is accessible from the remaining modules.

- The SS configuration will be designed for gravity gradient stabilization.

- During orbiter docking, the SS will not perform attitude maneuvers.

- Attitude disturbances will be corrected by the orbit adjust/attitude control subsystem.

- One primary control station and several strategically located back-up stations will be provided onboard the SS.

- Following initial SS build-up, the addition of modules will provide crew members with more than one path for exiting any habitable module.

- The orbiter will deliver SS elements during build-up and will resupply the SS during initial operations.

- The initial SS will consist of an energy section, habitat module, logistics module, airlock, and TMS.

- The SS will be designed to accommodate the following types of growth: (1) Scheduled Growth such as a materials lab, scientific packages, a second energy section, expansion of existing solar arrays, a second and potentially a third habitat module, SS RMS, propellant storage tank, OTV, IVA hangar, EVA airlock, a second TMS, space crane, three dedicated servicers and stowage, servicing, assembly/construction facilities, and (2) Unscheduled Growth.

- In an emergency situation the SS end of life will be a controlled de-orbit.

- The SS elements will be designed to withstand launch loads.

- The SS elements will be designed so that they can be removed and replaced by another module.

- IOC and SS growth will be compatible with the orbiter, aft cargo carrier and shuttle derived vehicles.

- Ease of maintenance will be a major consideration in the SS design.

- The SS design will take into consideration technological advancements throughout the life of the station.

- To keep costs down and reliability up, proven state of the art technology will be used wherever possible.

In analyzing our mission model the following mission classes were identified: SS Assembly/Support, Platform Operations/Support, and Satellite Operations/Support.

A series of top level requirements have been generated for each of these mission classes.

4.3.1.1 <u>SS Assembly/Support</u> - Requirements associated with this mission class are:

- For the SS build-up sequence refer to Figure 4.4.3-6 & 6a.

- The elements of the SS will be delivered to their designated assembly site by the orbiter or a shuttle derived vehicle.

- The orbiter's remote manipulator system (RMS) or payload installation and deployment aid (PIDA) will be capable of removing SS elements from the orbiter cargo bay.

- The orbiter RMS will be capable of joining the SS elements together.

- The SS elements will be connected together with a SS module docking mechanism designed into each element.

- The TMS will be capable of transferring, but not docking with SS elements after they have been removed from the orbiter cargo bay.

- During build-up of the SS the TMS will be controlled by a ground station. Once the SS is operational, the TMS will be controlled by SS when in line of sight.

- Additional assembly aids and mobility devices are yet to be defined.

- Checkout of the SS will be performed by one or more of the following: Orbiter, SS, and/or ground link.

- Initial SS repair will be accomplished by the orbiter crew. After IOC, repairs will be handled by the SS crew.

- After the SS is operational, the orbiter will periodically resupply it with required consumables and materials.

- The SS will provide docking facilities for the orbiter during all phases of the its evolution.

- The SS will provide storage, servicing and berthing facilities for the TMS, OTV, servicer and other various satellites.

- The SS will provide (TBD) orbiter airlocks for internal transfer of personnel/supplies and (TBD) EVA airlocks for external transfer.

- The SS RMS, EMU/MMU, and beam builder will be used during construction of the SS.

- Additional mobility devices and construction aids are not yet defined.

4.3.1.2 Platform Operations/Support - The SS will be capable of supporting the following experiments: Astronomy, solar physics, planetary studies, earth observations, earth atmospheric research, life sciences, and space environment.

Requirements for SS to function as a space platform are:

- Subsystem support will be provided for attached experiments.

- Compatible interfaces are required for both the SS and experiments. (e.g., structural, electrical).

- Experiments that impose a potential risk to crew safety or SS sub-systems operation will be mounted a safe distance away from the SS.

- Storage facilities will be provided for experiment spare parts, handling and support equipment, and new experiments waiting to be mounted.

- Mounting facilities will be required for experiments attached external and internal to the SS.

- Experiments will be modular in design for easy installation, removal, and handling.

- Data processing/display and data recording/storage capabilities will be provided for experiments.

- Human resource experiments will be performed by SS's medical personnel.

- All other early experiments, requiring man in the loop, will be performed by SS personnel only if these experiments are of the type that are task trainable.

- As experiments become more complicated a dedicated specialist, who is not part of the SS crew, will be required.

- Maintenance and repair of experiments mounted on the outside of the SS will be accomplished by either the SS RMS/Servicer, TMS/Servicer, EVA, and/or other mobile manipulator devices.

- Contamination levels will be kept to a minimal. Experiments might have to be isolated from the SS because of contamination by incorporating a boom or tether concept.

- Maintenance and repair of experiments will be accomplished by SS personnel.

- The SS attitude control system will provide stability and attitude adjustments to meet required experiment levels, when possible.

- Payloads needing fine pointing will be required to supply their own pointing system that is compatible with the SS.

- The SS will have limited calibration and testing capabilities.

- Experiments requiring unique checkout equipment will have to be checked out by a communications link to a ground station.

- Basic checkout equipment will be provided by the SS for compatible experiments.

4.3.1.3 Satellite Operations/Support - In order to simplify our analysis for this last mission class we chose to trisect it into the following areas: servicing, orbit transfer, and assembly. In each of these areas the satellites will be stored, serviced, repaired, refurbished, refueled, assembled, constructed, and checked out at or onboard the SS.

A. Satellite Servicing - Servicing has been broken down further into: remote mechanism servicing for satellites either remotely serviced at the SS using a SS RMS and servicer units or remotely serviced in their operational orbits using a TMS, servicer, and when needed, an OTV combination; and, EVA and IVA servicing when the satellite is berthed to the SS. These servicing tasks will consist of; module replacement, fluid replenishment, preventive maintenance, refurbishment, and contamination control.

   1. Remote Mechanism Servicing - refer to Figure 4.4.3-1 for functional explanations .

      - The SS will have either a non-pressurized hangar or an external storage facility to accommodate an OTV, two TMSs, three servicers, satellite components, and will:

- Provide passive thermal control and micro-meteoroid protection.

- Provide several berthing mechanisms capable of handling the above hardware.

- Provide deployment/retraction devices for handling hardware within the storage facility.

- All operations within this facility will be monitored by closed circuit TV and controlled by SS crew in the command center.

- Propellants (cryogenic and mono) will be stored in an external storage modules.

a. <u>On-Orbit Servicing</u>

o The following vehicles are required for a more complex on-orbit servicing missions: (the servicing configuration will vary depending upon the complexity of the missions).

  - One TMS to deliver/retrieve the OTV/TMS/Servicer to/from a designated launch stand-off position.

  - An OTV that will deliver the TMS/servicer to the satellites orbit and then return to spent vehicles to the SS launch stand-off-site.

  - A second TMS that will maneuver and dock the servicer to the satellite.

  - One servicer that is capable of docking to a satellite and replacing a bad module.

  - A second servicer that also will dock to a satellite, and replenish spent propellant tanks.

o For the above hardware requirements refer to Table 4.4.1-1.

o The SS will be capable of servicing satellites or platforms that are within the TMS's or OTV's performance range.

o Servicing operations will be monitored by a telepresence TV camera(s) mounted on the vehicles used.

o Servicing operations will be monitored by a ground control station when they are not in line-of-site with SS.

- o Orbit transfer operations will be monitored and controlled the same as above.

- o Two separate missions are required for both module changeout and fluid replenishment.

- o Servicers, satellites, and platforms will require compatible interfaces.

- o Universal docking mechanisms will be required for on-orbit docking.

- o Each servicer will be equipped with telepresence TV camera for visual monitoring.

- o On-orbit vehicles that require servicing will be designed to be serviced remotely.

b. <u>Servicing at SS.</u>

- o The following vehicles are required for more complicated mission that cannot be serviced on-orbit: (the less complicated servicing missions will require different servicing configurations).

  - One TMS to deliver the OTV/TMS to a designated launch stand-off-site and then to retrieve the returning OTV/TMS/P/L to SS.

  - An OTV that will deliver TMS to the satellite orbit and return the TMS/P/L to the SS launch stand-off-site.

  - A second TMS that will separate from the OTV, maneuver and dock to the P/L, maneuver back and dock to the OTV.

  - One servicer with robotics to changeout modules.

  - A second servicer with fluid transfer capabilities.

  - A third servicer capable of performing contamination control tasks.

- o The SS will be capable of retrieving satellites that are within TMS's and OTV's performance range.

- o Orbit transfer operations will be monitored and controlled as previously mentioned.

- A designated servicing facility will be provided.
- All servicing operations being accomplished at the SS will be monitored by closed circuit TV and telemetry/command links to the SS command centers.
- Payloads must be designed to be serviced by a remote mechanism system.
- The servicing facility will have mating/demating mechanisms.
- The SS RMS and all the above vehicles will have compatible interfaces via a universal docking mechanism.
- For payloads requiring protection, the servicing facility will provide thermal control and micro-meteoroid protection.
- The SS RMS can be used with the servicer during servicing operations.
- The SS will provide basic checkout of the serviced payload.
- Further check out will be performed through a data link from the satellite to the ground.
- Payload contamination will be kept to a minimum.

2. <u>EVA Servicing</u> - Refer to Figure 4.4.3-2 for functional explanation.

    - Storage facility requirements will be the same as remote mechanism servicing except for the following:
        - A second storage facility for EVA equipment (EMU's and MMU's) will be provided in a pressurized module just before an EVA airlock.
    - Retrieval hardware and servicing facility requirements are the same as remote mechanism servicing at the SS.
    - Payload contamination will be kept to a minimum.
    - The MMU can be equipped with a work restraint unit to aid in performing module changeout when the satellite is attached to the SS or when station keeping.
    - For MMU and EVA hardware requirements refer to Table 4.4.1-1.

- Servicing tasks will be monitored by closed circuit TV's and through direct voice communication from the EVA crew to the SS command center.

- Equipment and procedures will be provided for extensive EMU and MMU maintenance.

- A space crane will be provided that is capable of transporting an EVA crewmember to a servicing site and aid in servicing the P/L.

- EVA servicing will consist of module changeout and observation.

- Propellant transfer and contamination control will still be performed by the servicer.

- Payloads will be designed for easy access and module changeout by man or servicer.

- Servicing areas will be properly illuminated.

- Subsystem support will be provided when required.

3. <u>IVA Servicing</u> - Refer to Figure 4.4.3-3 for functional explanation.

    - Storage requirements will be the same as EVA servicing.

    - Retrieval hardware and servicing facility requirements are the same as EVA servicing.

    - IVA servicing will consist of servicing satellite components small enough to fit inside the SS. The servicing will consist of repair, refurbishment, contamination control, preventative maintenance and experiment resupply.

    - The IVA facility will provide:

        - A "shirt sleeve" environment.

        - Lighting aids.

        - Hand tools.

        - Contamination free environment.

        - Miscellaneous handling tools.

    - Basic checkout of the components will be performed by the SS personnel.

- o Further checkout will be performed by ground facilities through SS.

- o Trouble shooting capabilities will be provided by the SS and/or ground facilities.

B. Orbit Transfer - Orbit transfer consists of payload delivery, that includes initial delivery or delivery after a servicing or assembly task has been completed and payload retrieval.

- o Refer to Figure 4.4.3-4 for functional explanation.

- o Storage facility requirements will be the same as remote mechanism servicing.

- o The following vehicles are required for a more complicated satellite delivery and retrieval mission: (the vehicle configuration will vary for less complicated missions.)

  - One TMS to deliver the OTV/P/L to a designated launch stand-off-site and then to retrieve and return vehicles to the SS.

  - An OTV that will deliver a P/L to its desired orbit or return the TMS/P/L to the SS launch stand-off-site.

  - A second TMS that docks to a P/L and returns to mate with the OTV.

- o Payload retrieval will be accomplished by a single TMS or a TMS/OTV/TMS configuration.

- o Payload delivery will be accomplished by a single TMS or TMS/OTV configuration.

- o The ground station will checkout the satellite thru a command link after delivery to orbit.

- o The SS will checkout OTV/P/L configuration prior to launch from the launch stand-off-site.

- o The launch stand-off-site will be at a location where the exhaust from an OTV will not impact the surrounding SS environment.

- o Retrieval and delivery operations will be monitored and controlled by the telemetry/command links, directly to SS when within line-of-sight and through a ground control station when not within line-of-sight.

- All vehicles will use the compatible mating/demating mechanisms.

- Payloads and all transfer vehicles will have compatible interfaces.

C. Payload Assembly - This will consist of payload assembly from module level, payload mating, and payload construction including large structures.

- An assembly facility will include:

  - A berthing systems equipped with mating/demating mechanisms.

  - A SS RMS to transfer and handle components.

  - Lighting aids for construction activities and visual monitoring.

  - Closed circuit TV for visual monitoring.

  - Access for visual inspection of all components to be assembled.

  - Checkout and initial verification equipment.

  - Subsystem support when required.

- The Assembly facility will be capable of handling a variety of P/L's.

- Payload build-up and mating will normally be performed by SS RMS.

- Payload mating operations will be performed in either the servicing or assembly facilities.

- Payloads will have compatible interfaces with delivery vehicles.

- Payloads will be designed for robotic mating.

- Payloads will be equipped with a universal docking mechanism.

- Mating operations will be aided by alignment equipment.

- Payload construction will be done remotely with EVA supervision.

- The SS RMS will accomplish the remote operations.
- An MMU, space crane or work restraint unit will be used during EVA operations.
- A construction area will be designated.
- All construction and assembly operations will be monitored by closed circuit TV.
- Subsystem support will be provided, when required, for all construction and assembly operations.
- Calibration, alignment, and checkout equipment will be provided to support construction and assembly tasks.

4.3.1.4 Environments - The SS will be compatible with the natural and induced environments required during assembly, platform operations and satellite operations.

The SS will be required to keep induced contamination levels to a minimum while supporting user mission needs. If contamination levels cannot be met, the SS will then use alternate means of satisfying user mission requirements (i.e., tether, boom, free-flyer).

4.3.2 Facility Requirements

A series of top level facility requirements have been generated for the following: (1) safety, (2) maintainability, (3) reliability, (4) EMC/EMI, and (5) systems design requirements.

4.3.2.1 Safety - There will be no compromise for crew safety:

- In the event of an emergency there will be at least 60 days of life support for each SS crew member.
- Orbiter rescue of SS crew members will be accomplished within 30 days after an emergency situation has been identified.
- During the IOC phase, crew members will be rescued from a designated safe haven area in the event their normal living quarters become unlivable and/or cannot be repaired.
- Each module will be designed so that all exists are sealable for containment of hazardous elements.
- All pressurized modules will be designed to leak before rupturing.
- All pressure bulkheads, seals, walls, and docking mechanisms will be accessable for inspection.

- All major subsystems will have back-up modes to minimize crew injury or loss due to a critical subsystem failure.

- The SS will provide adequate crew warnings of subsystem failures, hazardous conditions such as depressurization, toxic contamination, fires, structural damages, uncontrollable mechanisms, and be capable of isolating and controlling such malfunctions or failures.

- During initial build-up and premanning operations the SS will be capable of being manned for performance of maintenance and component failure detection and changeout by either IVA or EVA.

- The "buddy" system will be used for all EVA operations.

- Comprehensive accident procedures will exist for the safe return and treatment of an injured/incapacitated EVA astronaut to the SS.

- Potentially explosive containers will be isolated and protected to insure no crew injuries or loss of life.

- Operations considered potentially dangerous will be performed remotely and a safe distance from SS. (ie boom deployment).

- Radiation exposure rates will be controlled to acceptable levels onboard SS.

- Hazardous materials/fluids will be contained/confined away from habitable areas and monitored at all times.

- Provisions will be made for the containment and/or disposal of all toxic materials.

- All subsystems will be designed to assure crew safety.

- All servicing, assembly, and construction operations will be provided with adequate access/clearance to assure crew safety.

- One entry/egress path for initial operational SS and two or more entry/egress paths for full operations will be provided to and from every pressure vessel. These paths will be separated by airtight partitions and shall lead to an area in which crew members can survive until orbiter rescue.

4.3.2.2 Maintainability - As a design goal, most failures or damages (including structural) will be repairable or replaceable. The following are maintainability requirements for SS.

- Checkout, monitoring, warning, and trouble shooting capabilities will be provided for onboard systems.

- o Critical subsystems will have a primary and separate back-up system.

- o Non critical subsystems will be designed to be repairable within an allotted time span.

- o The data management system will be designed to monitor and isolate problems within subsystems.

- o Handling tools and aids will be provided for subsystem/replacement or repair.

- o By-pass capabilities will exist so that overall SS operations will not be affected during subsystem repair.

- o All subsystems will be of modular design.

- o Critical life support subsystems will be designed for easy inspection/monitoring.

- o The crew will have adequate time to react to subsystem failures through a set of caution and warning equipment as part of the command and data handling system.

- o Caution and warning systems will be installed throughout the SS.

- o All critical and non-critical components and subsystems will be designed to allow ground and on-orbit monitoring systems to assess and predict possible failures.

4.2.3.2 Reliability - SS system and subsystem reliability will be high enough so that: (1) crew safety and maintenance activities do not place excessive demands on crew time, and (2) equipment failures, spares storage, and resupply do not impose significant penalties on SS operations.

Requirements for reliability include:

- o Critical systems and subsystems will have alternate or redundant systems that are physically separated and protected from the primary system so a lose of the primary system will not effect the secondary system.

- o All critical systems and subsystems will be designed fail-operational, fail-safe and require back-up systems to guarantee reliability.

- o Primary structures and habitable modules are designed to leak before bursting.

- o Onboard spares/fluids will meet the reliability, maintenance, and repair requirements.

- o Designed-in reliability of system and subsystem hardware will be such that SS operations will not be greatly affected if equipment outages, spare shortages occur.

4.3.2.4 EMC/EMI - EMC/EMI will be kept to a minimum.

4.3.2.5 Systems Design Requirements - Top level general systems design requirements fall into the following categories:

A. The SS will provide or be a multipurpose, versatile platform to support a variety of user needs.

- o The SS will be designed to accommodate planned growth.
- o Commonality will be used wherever practical when designing various modules.
- o During SS assembly, all modules will be compatible with the orbiter, aft cargo carrier and shuttle derived vehicles.
- o The SS elements will be designed so that they can be removed and replaced at any time during the SS's life.
- o To reduce SS costs, standard fabrication techniques, components, and off the self hardware will be used where possible.
- o The SS elements will be interchangeable so the initial configuration can be modified to accommodate multiple operations.
- o Subsystem support will be available to accommodate various user needs.
- o The SS elements and user hardware will be designed to accommodate maintenance and servicing techniques.

B. The goal of the SS is to reduce dependency on ground support:

- o The SS will accommodate onboard guidance and navigation.
- o Where possible, the SS crew will do most of its on-orbit mission and activity planning.
- o The SS crew responsibilities will gradually increase with increased usage.
- o The SS will have data processing/display and data recording/storage capabilities to support multi-mission operations.

- During growth of the SS, system and subsystem monitoring, fault detection, and trouble shooting capabilities will be increased.

- Upgrades to initial SS system and subsystem components will be made as often as feasible to increase reliability and capability.

- Dependency on the STS for delivery of SS commodoties will be reduced.

- The SS crew rotation time will be expanded when feasible.

- A new communications system that will allow the SS to maintain control of a TMS, OTV, and/or servicer after they have gone beyond line-of-sight will be required.

C. The goal of the SS is to reduce dependency on ground resupply:

- Critical subsystems will have alternate and redundant modes.

- Fail-safe subsystems will be repairable or replacable by SS crew members.

- Contingency modes will be available to avoid premature termination of missions.

- Critical systems/subsystems will have redundant capabilities that are separate from the primary systems/subsystems.

- A long life power generation system will be provided that can be expanded for future growth.

- The SS will eventually have a life support recycling system for air and water.

- The SS crew duration will be expanded when feasible.

- Subsystem reliability will be increased by hardware upgrades as often as feasible.

4.3.3 SS Configuration Elements and Interface Requirements

The initial SS will consist of basic building blocks. The energy section will be the first module to be deployed and activated in space which will serve as the nucleus of the SS. The second orbiter flight will deliver, deploy, and mate the habitability module to the energy section. Finally, the third orbiter flight will deliver, deploy, and mate a logistics module to the energy section, an airlock to the habitat module, and a first generation TMS to the logistic module. All modules will be pressurized, activated, and after extensive checkout manned by a crew of four. At this point the SS is now operational and man's presence will be permanent. Having established an initial operating capability the space station will grow by the addition of modules as required to support various mission classes. Refer to Figure 4.4.3-6 for elements being added to SS during its growth period.

The following are required for the initial SS elements and further growth.

4.3.3.1 Energy Module - The requirements are:

- o This module will have solar arrays mounted to the core section. These solar arrays will be designed to accommodate expansion for future growth.
- o The core section will consist of regulators, batteries, power conditioning units, power switching units, a thermal control subsystem, an attitude control subsystem, propulsion system, reaction control subsystem, data management subsystem and communication subsystem.
- o Sun sensors will be located on the solar arrays.
- o The solar array booms will incorporate drive mechanism and provisions for a thermal radiator.
- o The core section will be designed to allow passage of crew members between modules and also allow IVA inspection and maintenance of subsystem equipment.
- o The core section is being will be considered for a safe haven.

4.3.3.2 Habitability Module - The habitat module will be a pressurized vessel with life support systems to accommodate a four man crew during IOC. The requirements are:

- o The module design will provide for crew health, safety, personal comfort, and assist with crew task performance.
- o This module is also being considered as a safe haven.
- o Living areas will include provisions for sleeping, dining, personal hygiene, recreation, waste management and health maintenance.
- o Lighting levels will be adequate for manned operations.
- o The SS design will effectively utilize the available space onboard.
- o The module will provide a command and control center for data display/processing, data storage/recording, crew monitoring and subsystem/instrumentation control.

- Hand and foot restraints will be stratigically placed throughout the module for crew mobility.

- The module will be designed to keep noise attenuation down to an acceptable level.

- An air lock facility will be provided for Orbiter docking.

- The module will have an auxiliary storage facility for clothing, food, water, rescue equipment and other miscellaneous items.

- Several external attachments will be provided for commodities and handling fixtures.

- There will be mounting and subsystem provisions for experiments on a space-available basis.

4.3.3.3 Logistics Module - This module will be the storage facility for the SS. The requirements are:

- Designed to store 270 days worth of life support commodities.

- Be capable of storing 180 days of station keeping propellants (including 90 days reserves).

- Will provide storaged for the following: frozen food, canned food, personal gear, clothing, ECLSS supplies, EVA supplies, maintenance and housekeeping supplies, SS spares, user spares, water, and propellants.

- This module will consist of a pressurized section for easy crew access to supplies and an unpressurized section containing hydrazine, oxygen, and water.

- Docking provisions for a TMS will be provided.

- Umbilical provisions for transferring hydrazine into the TMS will be provided.

- A second set of umbilicals will be provided to transfer water and hydrazine to other SS elements.

- Fluid transferring mechanism/devices will be provided.

4.3.3.4 Remotely Controlled Teleoperator Maneuvering System - The SS will have a remotely controlled TMS to assist in the SS buildup and support operations. Refer to Table 4.4.1-1 for TMS hardware requirements.

- A berthing port on the logistics module will be provided, for storage of the TMS when not in use.

- The habitat module will have controls for the crew to operate the vehicle.

- The SS will provide required subsystem support/interfaces for the TMS.

- The SS will be capable of servicing the TMS with hydrazine and hardware replacement.

- Both the TMS and SS berthing ports will be a compatible with the universal docking mechanism.

- The TMS will be designed for ease of servicing.

4.3.3.5 Future Growth - Having established an initial SS, the capability will exist to attach more modules and expand the capabilities of the SS system to deal with simultaneous multiple operations such as vehicle assembly, satellite servicing and large space structure construction.

Key requirements will be:

- Commonality between the various modules will be a prime consideration. Structural interfaces for mating modules, subsystems, components, and mission hardware will be compatible with each other where possible.

- The SS design will accommodate modification in the SS configuration as multiple operations are conducted simultaneously.

- The SS Elements will be interchangeable.

- The SS design will accommodate the addition of:

  - A second or third habitat module.

  - A second TMS.

  - A propellant transfer and storage facility.

  - A dedicated command and control module.

  - An OTV.

  - A Hangar.

  - A dedicated servicing facility.

  - A dedicated assembly/construction facility.

  - Three dedicated servicers.

- A dedicated research module or modules.
- One or more mobile SS RMS's.
- A dedicated mating facility.
- Hardware storage facilities.
- A dedicated orbiter docking port(s).
- One or two EVA airlocks.

o For future SS growth the following systems would be required:

- Larger solar arrays.
- A second energy module.
- A more complex attitude control subsystem.
- On orbit maintenance implications on the propulsion system.
- Increased data management capability.
- Increased communications capability.

4.3.4 Operations Requirements

SS operations requirements were derived from the basic core element requirements from which second order requirements were defined and supporting simulation activities were identified. The SS operations requirements were established by identifying three major operational mission classes: (1) SS assembly/support, (2) platform operations/support, and (3) satellite operations/support. These requirements were based on the assumptions that first, an orbiting operations center will be assembled and its operational capability demonstrated; second, a mature operating capability for supporting user experiments and activities will follow; and finally, an increase in operational capability to perform the control, monitoring, and servicing of satellites that are either earth-orbiting or deep-space missions must exist.

4.3.4.1 Assembly/Support - The driving requirement here is that SS will be placed in an orbit that can operationally support missions in the 1980 time frame. The SS will be designed so that initial operational capability can be achieved with a minimum of orbiter support. The following requirements have been identified to provide a basis for operations analysis.

A. SS Build-up - The following operational considerations have been identified and are currently being evaluated.

o Module size/operational capability.

- Module mating.
  - Mating/demating mechanisms and devices.
  - Latching mechanisms and devices.
  - Connectors (consumables, power, life support).
  - Fluid transfer mechanisms.
  - Remote docking mechanisms and devices.
  - Remotely controlled Teleoperator Maneuvering System (TMS).
  - Servicing interfaces between SS and TMS.
  - Berthing interfaces between SS, Orbiter, and TMS.
  - SS meteoroid protection.

B. SS Supply/Logistics - Operational logistics support consideration include:

- Self-contained (per module).
- Crew rotation every 90 days.
- Logistic module replacement every 90 days.
- A 90 day supply of consumables for normal operations.
- A 180 day supply of consumables for contingency mode except for propellants. There will only be 90 additional days of SS propellants for emergency modes.
- Propellant and water transfer mechanism from non-pressurized vessels to supply the rest of SS elements.

C. Initial Operational Capability (IOC) - Operational considerations for IOC are:

- The SS will have systems monitoring stations.
- Command and control station for SS and support for user experiments and attached payloads.
- The SS is capable of being habitable for normal mission durations of 90 days.
- The SS is capable of being habitable for an additional 180 days for contingency operations.

- The SS will be equipped for emergency medical support.
- The SS will be equipped for an emergency EVA capability (i.e. rescue sphere).
- The SS will provide subsystem support for user experiments and payloads.
- Servicing capabilities to support user experiments and payloads will be provided.
- In emergency situations the minimum orbiter turn around time will be 30 days.
- A minimum of 270 days crew survivability will be provided.

4.3.4.2 SS Platform Operations/Support - This type of operation will begin when the SS has developed mature operation capabilities and is capable of providing the full time mission support required by attached experiments. This operational capability is the next phase of evolution after IOC. This includes SS system and subsystem growth as the user experiment support requirements expand.

The following requirements have been defined for mature operations.

A. SS Support Systems - Support systems operations requirements are:

- Continuous habitable modules.
- Continuous operational command/control station.
- Spares/expendables and replacements.
- On-orbit crew activity planning.
- Emergency and routine medical support.
- Expandable subsystem support.
- Additional logistic modules.

B. SS Based Experiment Support Systems - SS based experiment support systems operational requirements are:

- Materials/manufacturing processing:
  - Controlled laboratory facilities.
- Medical/pharmaceuticals processing:
  - Environmentally controlled laboratory.

- o Basic orbit maintenance and platform attitude control for "observation" experiments.

C. SS Logistics and Maintenance - The operational considerations are:

- o The Logistic module will be designed to accommodate:
  - Total module changeout.
  - Module growth.
  - Consumable and fluid replacements.
- o Maintenance considerations imposed on the Logistics module will be:
  - Spare storage and replacement capabilities.
  - Systems/subsystems can be removed, replaced, and stored.
  - Systems/subsystem handling equipment storage and removal.
  - Capable of normal/contingency operations.

4.3.4.3 Satellite Operations/supports - This mission class is the next evolutionary phase of the SS. Its capability to function as an operations platform expands to a space-based flight control and servicing center. The following four areas have been defined.

A. Satellite Build-up and Construction - Satellite Build-up and construction requirements include:

- o Satellite build-up:
  - Mating facility.
  - Mating/demating mechanisms/devices.
  - Alignment aids.
  - Basic checkout and verification equipment will be available.
  - Mating fixture.
  - Universal docking mechanism.
  - System and subsystem support when required.
- o Experiment module attachment/replacement requirements are:

- Alignment aids.
- Each module will have a compatible mating interface.
- Experiments will be designed for ease of replacement.
- Systems/subsystem support when required.
- Basic checkout and verification equipment will be available.
- Mating tools for EVA crew will be provided.

o The large space structure construction requirements are:

- A construction facility.
- Construction equipment and aids.
- EVA capabilities.
- Systems/subsystem support when required.
- State of the art construction and assembly.

B. Satellite Staging and Placement - Satellite servicing/maintenance operations at the SS and remote operations at satellite orbit. Operations requirement will include:

o Servicing/maintenance at SS:

- A servicing facility.
- A berthing system.
- Mating/demating mechanisms/devices.
- Servicing aids (SS RMS, space crane, MMU, and a work restraint unit).
- Servicing mechanisms (three satellite servicers, space crane, SS RMS).
- Hangar facility.
- Servicing interfaces.
- Fluid transfer mechanisms.
- Visual and voice communications.
- Alignment equipment and aids.

- Checkout and verification equipment.
- System and subsystem support when required.
- Servicing capabilities include:
  * Module change out.
  * Fluid replenishment.
  * Contamination control.
  * Repair.
  * Refurbishment.
  * Preventive maintenance.
- Refurbishment facility.
- Environmental control systems.
- Consumable transfer system.

o Remote servicing at satellite orbit:
- SS command/control station.
- SS ground command/control station.
- TDRSS.
- Two satellite servicers.
- One or two TMSs
- One OTV (reusable).
- Spares/consumables storage at SS.
- Servicing capabilities:
  * Module change out.
  * Fluid replenishment.
- Visual communications.
- Universal docking mechanisms.
- Compatible interfaces.

C. Satellite Servicing and Maintenance - Satellite Servicing/maintenance must be assessed based on operations at the SS and remote operations at the satellite orbit. These requirements include:

1. Servicing at the SS.

   - Mating Fixture(s).

   - Servicing mechanisms (ss RMS, space crane, satellite servicer(s), MMU).

   - Environmental control systems.

   - Consumables transfer systems including cryogenics and propulsion.

2. Remote servicing.

   - Maneuvering servicing system(s).

   - SS control station.

   - Spare/consumables storage at SS end transport to satellite orbit.

D. Satellite Mission and Flight Control - A number of missions will require a manned control station to provide the maneuvering/control inputs to a satellite such as a TMS, satellite servicer, remote RMS, etc. The following requirements that apply these systems are:

- o Telepresence TV system.

- o Rotational, Translational Hand controllers.

- o Control Console.

  - Visual displays.

  - Audio displays.

  - Caution and warning systems.

- o Satellite systems health and status monitoring.

- o Command/control key board.

- o Software state of the art technology.

- o Hardware state of the art technology (compact consoles).

4.3.5 Support Module Requirements

The support module requirements have been broken down into two main subsections. These are crew support and subsystem requirements. Requirements will be categorized as either Initial Operating Capability (IOC) or Final Operating Capability (FOC).

The initial SS configuration is one that will provide the basic habitation requirements and satellite servicing capabilities using TMS. For this phase, crews will be delivered to the SS via orbiter, spend 90 days in orbit performing various tasks, and then be returned to earth via the orbiter.

The fully operational configuration will have the ability to accommodate any of the mission classes associated with this program. For this phase, crews would be rotated through the SS via orbiter, permitting permanent manned operations. Mission and logistics support would be supplied by shuttle visits at 90 day intervals.

4.3.5.1 Crew Systems - The SS crew system requirements are broken down into the six major areas shown in Figure 4.3.5.1-1. Each of these address a specific aspect of manned space operations.

A. Operational Control Interface - The initial SS design will provide the following operational interface requirements between crew and the control system.

- o The operation and repair of SS equipment will be compatible with the standardized space tool kit. Specialized tools will be kept to a minimum.
- o All SS equipment will have concise lables that can be easily seen by crew member.
- o Lighting levels will be adequate for manned operations.
- o Human factors will be applied when designing the video and audio equipment, the control consoles, and the servicing procedures.
- o Control consoles will be designed to utilize available space efficiently.
- o Foot and hand restraints will be designed for maximum ease of crew operations and mobility.

The fully operational SS will refine and expand the above requirements to accommodate permanent habitation.

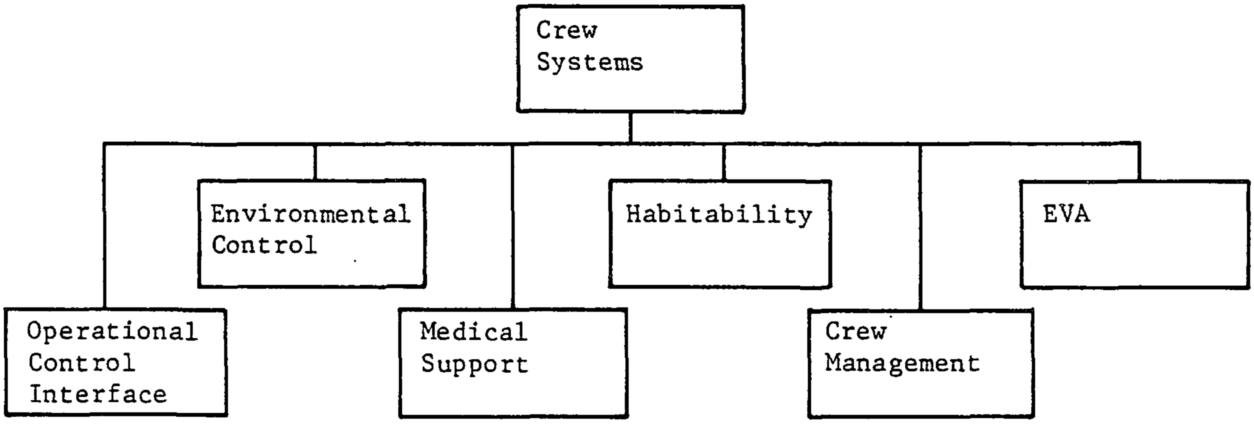

Figure 4.3.5.1-1 Support Module Requirements—Crew Systems

B. Environment Control - The initial SS design must provide and maintain a suitable life support environment.

- o The gas composition will be maintained to provide sea-level-equivalent ambient conditions.

- o The pressure in the living volumes will be set to minimize the interface procedures during EVA operations and orbiter docking.

- o Temperature and humidity will be kept within a comfort range to maximize crew comfort and work output.

- o Air flow for ventilation will be sent to optimize crew comfort.

- o To insure crew safety, a caution and warning systems, that monitor the environment, will be provided throughout the habitable area.

With the fully operational SS, the above requirements will be expanded to accommodate larger crews for longer periods of time.

C. Medical Support - The initial SS will provide medical support, medical monitoring, and emergency services.

- o The SS will have a MD, medicine and drugs, and appropriate equipment to provide routine medical care to crew members.

- o Physical fitness equipment will be provided.

- o Emergency surgery equipment will be provided.

- o The SS MD will be able to consult with medical ground facilities.

- o The SS MD will also provide minor dental care.

- o All crew members will have emergency medical training.

The fully operational SS will provide a more extensive medical program to accommodate the increase in crew size and longer stay-times.

- o A second crew member will have extensive medical training to assist the MD.

- o Besides crew care, the MD will support user life science experiments.

- o Expanded surgical capability and facilities will be provided.

- o The SS will incorporate medical facilities capable of supporting crew quarantine and observation.

D. Habitability - The initial SS will provide a habitation facility with task performance, health, safety, and personnel comfort considerations:

- Living areas will include provisions for sleeping, dining, personnel hygiene, recreation, waste management and health maintenance.
- Lighting levels will be adequate for manned operations.
- Hand and foot restraints will be sized for maximum ease of crew mobility.
- Attenuation of noise levels will be provided.

The fully operational SS will refine and expand the above requirement to accommodate permanent habitation.

E. Crew Management - During IOC, SS will be responsible for preparing, organizing and managing crew activities:

- Short term activity planning will be done by SS crew members.
- The SS crew positions and specialties will be established by the ground control center prior to manning the SS.
- The SS crew members will perform all SS systems and attached user experiment monitoring and data management.
- The SS crew members will modify and/or update SS flight data files.
- The SS crew members will be responsible for all scheduled maintenance and repairable unscheduled maintenance.

The fully operational SS program will expand the use of on-orbit manpower and minimize management problems associated with permanent habitation.

- Long-term activity planning will be accomplished by ground facilities and SS crew members when applicable.
- Training programs for scheduled tasks will be performed onboard SS to better utilize manpower. Unscheduled tasks will be assisted by the ground facilities.
- Human factors concepts, that apply, will be incorporated into SS's design.

F. EVA - Basic EVA opertaions by SS crew members will be provided at IOC:

- o SS systems/subsystem support will be provided for EVA activities.
- o Procedures will be provided for limited EVA opertions.
- o Two or more EMU's will be provided for crew members to perform EVA tasks.
- o MMU's will be provided to assist man for EVA tasks.
- o One EVA airlock will be provided.
- o The orbit docking port can only be used as an EVA airlock when orbiter is docked to it.
- o EVA activities will be monitored at all times by SS closed circuit TV and voice communication with the EVA crewman.
- o Emergency EVA equipment such as rescue spheres will be provided for contingency modes.
- o The SS will be able to refurbish the EMU, MMU, and replenish personal life support system (PLSS) consumables.

The fully operational SS will provide more complex and expanded EVA operations.

- o Extensive EMU servicing capabilities will be provided.
- o One or two additional EVA airlocks will be provided.
- o Additional EMU's and MMU's will be provided.
- o One or two work restraint units will be provided.
- o A space crane will be provided.
- o Expanded SS systems/subsystem support will be provided for increased EVA activities.

4.3.5.2 SS Subsystems - The SS subsystems have been broken down into the eight areas shown in Figure 4.3.5.2-1. Each of these subsystems addresses a specific aspect of SS operations.

A. Command and Data Handling - The subsystem has been divided into processing, commanding, caution/warning, and subsystems monitoring. Each of these four areas will have their own requirements.

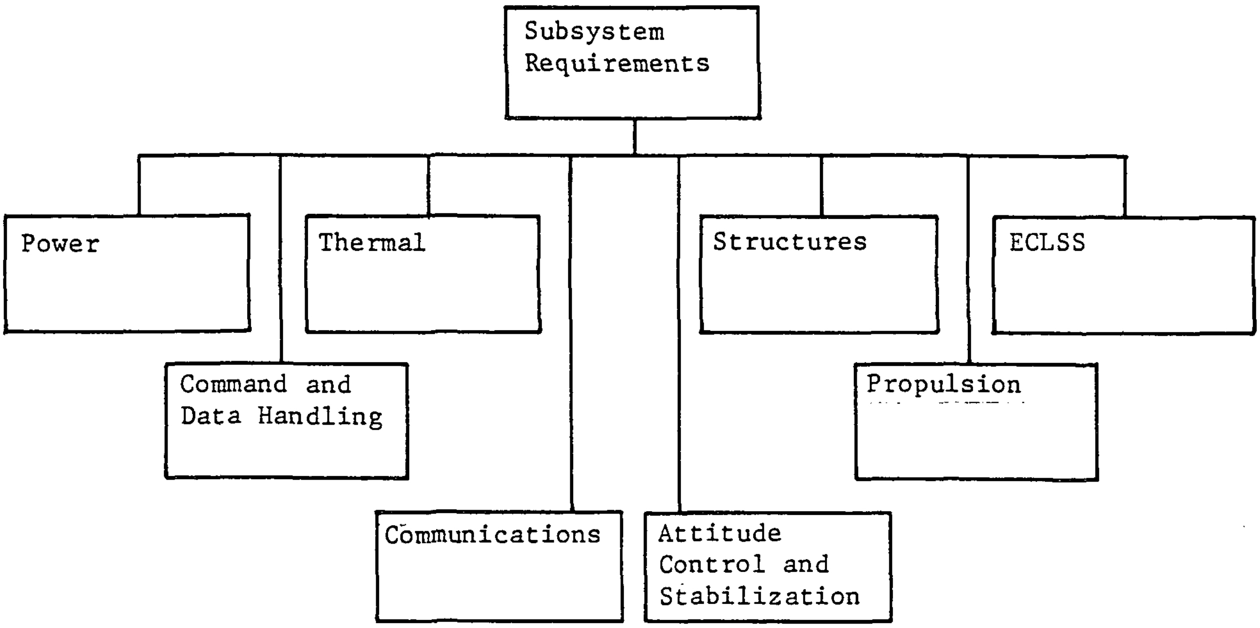

Figure 4.3.5.2-1 Support Module Requirements—Subsystem

1. Data Processing/Data Storage - The SS will provide equipment to process/display commands and information:

   - A processing architecture will be provided.

   - SS will provide storing and multiplexing equipment.

   - A data bus system for command and data transfer through SS will be provided.

   - A mass data storage capability to support crew activity and planning will be provided.

2. Commanding - The SS will provide equipment for commanding SS subsystems.

   - Control of SS functional subsystems will be provided.

   - Control of TMS's will be provided for all maintenance and servicing operations.

   - There will be a primary command/control center and back-up centers stratigically located.

   - The SS RMS controls will be provided for mission support.

   The SS will provide additional equipment for command and control as needed:

   - Control and checkout of OTV, a second TMS, three servicers, and various payloads will be provided to support user requirements.

   - Man-machine control of various facilities such as RMS, TV cameras, and support equipment required to service space station payloads.

3. Experiment Operation and Control - The SS will provide support equipment for control, data aquisition, and onboard display of experiment operation and data acquisition. Equipment will be provided to:

   - Interface with each experiment such that SS auxillary data is available to the experiment;

   - Process data for onboard storage or transmission to the ground;

   - Display data on standard SS equipment.

4. Subsystems Monitoring - The SS will provide equipment to monitor subsystem status and identify failure conditions.

   - ECLSS and consumables will be monitored.
   - Power and thermal systems will be monitored.
   - Propellant monitoring will be provided.
   - External closed circuit TV will be provided.
   - Monitoring of the TMS while either berthed or detached will be provided.

   The SS will expand subsystem monitoring to accommodate more complex operations:

   - As additional elements are added to the SS's configurations, more monitoring will be provided.
   - Monitoring of the OTV, a second TMS, three services, and various payloads when either berthed or detached will be provided.
   - Monitoring of the SS RMS and space cranes will be provided.

   These monitor functions will be selectively interconnected to a caution and waring system which will provide for:

   - Limit sensing.
   - Warning annunciation equipment.
   - Manual/automated emergency control equipment.

B. Communications - The communications subsystem has been broken down into four basic sets of requirements (see Table 4.3-1).

1. Ground Communication - The SS will provide voice and data exchange between SS and earth.

   - A voice and data link will be provided for through TDRSS.

2. On-Orbit Communication With Other Systems - The SS design will provide a communications interface between the SS and other systems only when they are within line-of-sight.

- SS will provide voice and data links to the orbiter.
- Command and video link will be available for the TMS from the SS when with in line-of-sight of the SS and from the ground control station when out of line-of-sight.
- A system for radar ranging compatible with SS and other systems will be provided.
- Command and video link will be available for OTV, a second TMS and three servicers from the SS and grand station as described above.
- A communication and command link will be available between SS and on-orbit payloads when within line-of-sight.
- Hard copies of uplink messages will be available to the crew.

3. Internal Communications - The initial SS will provide voice and video communications within and around the SS.

    - All habitable areas will have voice communications between them.
    - Closed circuit TV and monitoring systems will be provided throughout SS.
    - All habitable areas will be capable of being monitored in the primary and back-up command/control stations.
    - Closed circuit TV and monitoring will be provided for all remote mechanism operations around the SS.

4. EVA Communications - The SS will provide voice and data exchange between the SS and EVA crew members.

    - Voice and data links between SS and EVA crew will be provided.
    - Video monitoring will be provided for all EVA operations that occur around SS.

C. Attitude Control & Stabilization - The attitude control and stabilization subsystem has been broken down into four sets of requirements:

1. Sensing - The SS design will provide information collection on SS status:

    o Equipment will be provided to determine SS attitude, position and rate status.

    o Equipment will be provided to determine unattached platform attitude, position and rate status.

2. Stability - The initial SS will provide processing to accommodate dynamic perturbations.

    o Processing equipment will be provided to adequately accommodate perturbations of stability caused by orbiter docking, and TMS berthing operations.

    o Processing equipment will adequately accommodate perturbations of stability caused by the presence of flexible appendages on SS. (SS RMS).

    The fully operational SS will provide processing equipment to adequately accommodate pertubations of stability caused by the berthing, docking, or transferring of other vehicles and payloads.

3. Control Computing - Initial SS design will provide processing for attitude control functions.

    o Processing equipment will be provide to allow adequate guidance and navigation as well as generating an adequate empemeris using GPS.

    o Processing equipment will be provided to generate targeting parameters for SS.

    The full operating SS will provide expanded processing to accommodate attitude control function growth on SS and platform.

4. Command - The SS will provide output commands to the ACS actuators on itself or platforms.

    o Equipment will be provided to transfer ACS commands to drive propulsion systems.

    o Equipment will be provided to transfer ACS commands to drive pointing systems on relay data to autonomous pointing systems on individual payloads.

D. Propulsion - The propulsion subsystem has been broken down into four basic sets of requirements.

1. ACS Maneuvering - The SS design will provide actuation of ACS pertubation control.

   - Adequate control over SS pitch, yaw, roll rotations and translation will be provided with considerations made for SS band widths.

   - Following ACS commands, adequate thrust level and rates will be available.

   - ACS propulsion design will provide adequate avoidance of plume impingement and contamination.

   - Interaction of propulsion and structural coupling will be considered in designing ACS.

2. Orbital Maintenance - The SS will provide periodic SS orbital maintenance.

   - Adequate total impulse and thrust to maintain the SS in its proper orbit for a maximum of 90 days (nominal) between propellant resupply by the orbiter during periods of maximum solar activity.

   - For reboost activities, effective thrust vector/C.G. alignment will be provided.

   - Reboost propulsion design will provide adequate avoidance of plume impingement and contamination.

   - Thrust levels will be compatible with SS dynamic response.

3. SS Propellant Resupply - the initial SS program will provide a system for resupply of propellant to the SS storage facilities.

   - Storage and transportation of earth storable propellants will be compatible with the orbiter and SS system.

   - Transfer mechanisms/devices for transfer of earth storable propellants from orbiter to SS, SS to subsystems, and from SS to TMS will be compatible.

     The fully operational SS will provide systems for the transportation and resupply of SS cryogenic propellants.

- Transfer mechanisms/devices for transfer of earth storable propellants from SS to OTV, SS to a second TMS, and SS to servicer tanks will be compatible.

4. SS Propellant Storage and Transfer - The initial SS design will provide onboard propellant storage and management.

    - Spacecraft propellant servicing systems will be compatible with the SS transfer mechanisms/devices.

    The fully operational SS will provide systems for the storage and spacecraft servicing of cryogenic propellants.

    - Spacecraft on-orbit propellant capability. (servicer)

    - Servicer propellant transfer mechanism/devices compatible with spacecraft.

    - Cryogenic storage facilities and onboard SS, attached to SS, and satellite on-orbit transfer mechanisms/devices.

E. Electrical Power - The electrical power subsystem has been broken down into the following requirements:

- The power system for the initial SS will generate 14.8 KW of power for day time loads, 9.7 KW for eclipse period loads, and will accommodate (TBD) peak power loads.

- The fully operational SS will generate adequate additional power to accommodate 77.5 KW daytime loads, 6.2.5 KW eclipse loads, and (TBD) peak loads.

- During emergency situation for both IOC and FOC, the power system will generate 13.6 KW for day time loads, 8.6 KW eclipse loads, and (TBD) peak loads.

- Power system equipment will be provided for additional free-flying platforms.

- The SS design will provide adequate power distribution and control throughout SS.

- A high voltage power bus system will be used to distribute power throughout SS to minimize power losses.

- Power services, other voltages and frequencies will be regulated in each individual area where it is required.

- Circuit protection will be integrated throughout the power system.

- Power interfaces will be capable of expansion without major SS configuration changes.

- Power will be provided to a berthed TMS, OTV, servicer or a payload for battery recharging and dormant mode support.

- The fully operational SS will provide power service to additional SS operations and support of simultaneous user operations.

- The SS design will provide continuous power under failure conditions to critical SS operational subsystems for a minimum of 270 days.

- In emergency conditions continuous power will be provided to critical habitation subsystems for 270 days.

- The power system design will minimize ground crew and flight crew monitoring envolvement.

F. Thermal - The initial SS design will provide a system that include all the functions associated with:

- The acquisition of waste heat from heat sources or the addition of heat energy at rates which maintain the sources at acceptable temperature levels.

- The transport of the waste heat from the source to the heat rejection system.

- The rejection of waste heat to the space environment.

- The decoupling of the SS from the space thermal environmental extremes.

- The judicious use of waste heat by making it readily available to subsystems and payloads.

- Non-toxic and non-flammable coolants will be used in pressurized areas.

G. Structures & Mechanisms

1. Structures - The initial SS will provide structural support and subsystem accommodations for all phases of the SS operation.

    - The SS subsystem structure will withstand all launch and, in some cases, return (abort) dynamic and steady state loads.

- The fully assembled SS will withstand all attitude control and stabilization, docking, and reboost dynamic and steady state loading conditions.
- The SS structure will provide dynamic isolation of rotating and moving assemblies as required.
- The SS structure will provide support for all pressurized habitable areas.
- The SS structure will provide adequate meteoroid and debris protection.
- Structural center of mass management will be provided through configuration control.
- External viewing will be provided through structural geometry considerations.
- The SS structure will withstand thermal load cycling.
- The SS structure will accommodate other subsystem elements/components and payloads.
- Passive structural design will minimize crew related hazards, e.g., from sharp surfaces and crevices.
- Support for; an on-board RMS, space crane, and related activities.

The fully operational SS will provide structural support for the above requirements in addition to the SS configurations listed below:

- Support for additional docking and berthing operations.
- Additional growth in the various subsystem and payload elements.

2. <u>Mechanisms</u> - The initial SS design will incorporate individual subsystems mechanisms to support SS operations.

    - SS will provide solar array drives and arrays as necessary for SS and user operations.
    - Antenna drives will be provided when required.
    - Docking and berthing ports will be provided.
    - IVA and EVA airlock hatch mechanisms will be provided.

- ASE will be provided, as needed, to support build-up and operation.
- Experiment servicing equipment will be provided.

The fully operational SS will incorporate additional individual subsystems mechanisms to support more complex SS operation. An RMS, space crane, advanced manipulator, and supporting equipment will be provided to enhance or replace EVA servicing.

H. Environmental Control and Life Support - The initial SS design will provide and maintain a suitable environment for life support.

- Storage provisions and supplies of necessary atmosphere constituents will be provided.
- For adequate air quality, CO_2 contaminants, debris, and odors will be removed from living areas.
- Humidity and temperature maintained with optimum comfort limits.
- Adequate ventilation will be provided.
- Adequately pressurized vessels will be provided.
- EVA life support equipment and supplies will be provided.
- For crew safety, fire suppression an emergency life support equipment will be provided.
- Radiation monitoring and protection will be provided.
- For crew safety, over pressure monitoring, protection, and dumping will be provided.
- Potable and non-potable water will be supplied.
- Living areas will include provisions for sleeping, dining, personal hygiene, recreation, waste management and health maintenance.
- Noise attenuation levels will be maintained for crew comfort.
- Adequate lighting will be provided.

The fully operational SS will eventually provided a system for recycling of materials to maximize on-orbit time without resupply.

4.4 FUNCTIONAL CAPABILITY ANALYSIS

Functional capability analysis is the means used to identify and analyze the operations required of personnel and equipment to perform a task or a mission within the system requirement constraints. The purpose of this analysis is to analyze and expand the system requirements in sufficient detail such that a system configuration can be developed. The analysis of the functions required to accomplish the mission is performed first. These functions resulted in the eighteen scenarios and are represented in Figures 4.4.3-1 thru 4.4.3-6. Functional capability analysis is a tool that is used primarily during early design definition phase activities to help develop the detail requirements to be included in configuration item specifications and program plans.

The functional analysis was conducted based on the established set of hardware ground rules as given in Table 4.4.1-1. Each function required to develop, acquire, use, and support the system in the specified or anticipated environments is analyzed including no go, emergency, and consequent alternative functions. The analysis consists of identifying the functions, establishing their relative sequences and defining the requirements for each function, including the beginning and end conditions, inputs, outputs, and interface requirements both from intra- and inter-system view point. The requirements of each function must be developed in sufficient detail that, if met, the function will be performed adequately to meet the system objectives.

As a result of our initial analysis, Table 4.4-1, scenarios were identified that support a majority of capability categories and basing modes that directly satisfy the user mission needs. In addition, a number of scenarios have been identified that would require slight modification to satisfy more capability categories. Also, identified are some scenarios that are (TBD) and will be developed at a later date. As seen in Table 4.4-1, a number of capability categories are not applicable to certain scenarios and are, therefore, left blank.

In order to perform the functional capability analysis it was necessary to examine the Derived Integrated User Requirements identified in Section 3.0. These baseline requirements were grouped according to the capabilities that are necessary in order to accomplish the objectives of the user missions. The grouping of these requirements into "Mission Capability Requirements" resulted in the following categories; assembly, resupply/replenishment, orbital transfer, scheduled servicing, unscheduled servicing, and mission operational constraints.

In order to accomplish the missions bound by the above categories certain basing modes have also been identified and include the following; platform, free flyer, tether, mounted to SS, and mounted in SS.

The objectives was to take the mission capabilities and basing modes and develop scenarios required to accommodate the user missions. We have identified 15 scenarios that were directly applicable to user requirements and three scenarios that were related to the assembly, construction and servicing of the space station. These have been identified in Table 4.4-1, Integrated Capability Definitions.

4.4.1 Top Level Ground Rules for Space Station

Are those ground rules and assumptions that have been established after reviewing the eighteen scenarios generated to meet user needs. These ground rules (see Table 4.4.1-1) describe hardware elements and have several characteristic requirements for each.

4.4.2 Top Level Required Trade Studies

Are trade studies that were derived from the top level ground rules established in Table 4.4.1-1. These studies are shown in Table 4.4.2-1 and will be evaluated at a later date. Through trade studies, further hardware characteristics are defined and design concepts established.

4.4.3 Capabilities Definition

The eighteen capability definition scenarios that we have identified thus far have been grouped according to the type of service that is provided. The grouping resulted in six task areas and are as follows; (1) Remote Mechanism Servicing, (2) EVA Servicing, (3) IVA Servicing, (4) Orbit Transfer, (5) Payload Assembly, Mating and Construction, and Space Assembly, Evolution, and Construction (Figures 4.4.3-1 thru 4.4.3-6).

1. Remote Mechanism Servicing - The Remote Mechanism scenarios consist of providing a service for the user payload, either attached or unattached to the space station. Depending on the objectives and complexity of a mission, the vehicle combination will vary. The following scenarios are an example of two types of servicing missions. Additional remote servicing scenarios exist for the space station itself and user platforms.

a. Attached Servicing - can be accomplished remotely by using a servicer connected to the SS RMS after the payload has been retrieved and berthed to the space station. The objective of the attached remote mechanism servicing is to satisfy the following requirements; fluid transfer/replenishment, large module replacement/repair, contamination control, and/or preventative maintenance. As shown in Figure 4.4.3-1 we have the mating of the OTV TO TMS_1 and TMS_2 to OTV. TMS_1 deploys the stack

Table 4.4-1 Integrated Capability Definitions

- Flow Directly Applicable
- Modified Flow Applicable
- Flow TBD
- Not Applicable

Tasks	Scenarios	Assembly: Hardware Buildup	Assembly: Mating	Assembly: Construction	Resupply/ Replenish: Storable	Resupply/ Replenish: Cryogen	Resupply/ Replenish: Other	Orbit Transfer	Scheduled Servicing: Prevent. Maint	Scheduled Servicing: Sterilization	Scheduled Servicing: Contamination	Scheduled Servicing: Refurbishment	Random Failure Repair: Remote	Random Failure Repair: SS	Mission Ops Constraint: Inst Align.	Mission Ops Constraint: Inst Changeout	Basing Modes: Platform	Basing Modes: Free Flyer	Basing Modes: Tether	Basing Modes: Mounted to SS	Basing Modes: Mounted in SS
Remote Servicing	Remote Attached Servicing				D	D	D	D	D	M	D	D	D		TBD	M		D			
	Remote Unattached Servicing				D	D	D	D	D	M	D	D	D		TBD	M		D			
	Remote Servicing for SS				D	D	D		D	M	D	D		D	TBD	M				D	
	Remote Platform Servicing				D	D	D		D	M	D	D	D		TBD	M	D	D	M		
EVA Servicing	EVA Servicing for SS								D		M	D		D	TBD	M				D	
	EVA Free Flyer Servicing								D		M	D	D		TBD	M		D			
	EVA Platform Servicing								D		M	D	D		TBD	M	D		M		
	EVA Attached Servicing							D	D		M	D	D		TBD	M		D			
IVA Servicing	IVA Servicing for SS								D		M	D		D	TBD	M					D
	IVA Attached Servicing							D	D		M	D	D		TBD	M		D			
Orbit Transfer	Payload Delivery				D	D	D	D	D	M	D	D	D		TBD	M		D			
	Payload Retrieval				D	D	D	D	D	M	D	D	D			M		D			
Payload Assembly Mating Const	Payload Assembly at SS	D															D		D	D	
	Payload Mating at SS		D														D		D	D	
	Payload Construction			D													D		D	D	
SS Assembly Evolution Const	Initial SS Assembly	D	D																	D	
	Space Station Evolution	D	D		D	D	D													D	
	Space Station Construction			D													D		D	D	

Table 4.4.1-1 Top-Level Ground Rules for Space Station

Hardware	Requirements
(T)eleoperator (M)aneuvering (S)ystem	- Is used to transfer an OTV to a launch standoff position before OTV engine firing. - Is based at and serviced by SS (module changeout and fluid replenishment. - Has a compatible interface with an OTV, servicer and payloads. - Is used to rendezvous, maneuver, and dock to an OTV and/or payload and return them to Space Station. - Is capable of transferring user and Space Station components around Space Station. (See trade #1.) - Has no robotic servicing capabilities without a servicer attached to it. - Is monitored and controlled by Space Station when in line-of-sight. - Is monitored and controlled by ground control through TDRSS when not in line-of-sight. (See trade #4.) - Will not dock itself directly to Space Station. (See trade #2.) - Is delivered to Space Station by the Orbiter, aft cargo carrier, or Shuttle-derived vehicle. (See trade #3.) - Is used for the transferring of a servicer (IOSS or ROSS) to a payload, platform, or Space Station attached free flyer to assist in servicing functions.
(O)rbital (T)ransfer (V)ehicle	- Has rendezvous and maneuvering capabilities. - Can dock to other vehicles. - Is based at and serviced by SS (module changeout/fluid replenishment). - Has compatible interface with TMSs and payloads. - Has delivery and return to Space Station capabilities. - Has stationkeeping capabilities. - Is monitored and controlled by Space Station when in line-of-sight. - Is monitored and controlled by ground control through TDRSS when not in line-of-sight of Space Station. (See trade #5.) - Design and performance requirements will be influenced by the servicing tasks. - Is delivered to Space Station by the Orbiter, aft cargo carrier or Shuttle-derived vehicle. (See trade #6.) - Will not fire its engines until it is a safe distance away from Space Station. (See trade #7.)

Table 4.4.1-1 (continued)

Hardware	Requirements
(M)anned (M)aneuvering (U)nit	- Will be stored on and serviced by Space Station (module changeout/fluid replenishment). - Is used to transfer man for servicing tasks. - Operational performance is not limited to existing cold gas system.
Remote Mechanism Servicer	- Will provide all robotic capabilities for servicing tasks unattached from Space Station. (See trade #10.) - Is a dedicated vehicle with either module changeout, fluid replenishment, or contamination control capabilities. - Has a compatible interface with TMS, SS RMS, and payloads. (See trade #9.) - Cannot perform an unassisted rendezvous and docking mission without TMS. - Will be used with SS RMS or hard mounted to SS to provide robotic capabilities for servicing tasks attached to and outside Space Station. (See trade #8.) - Is delivered to Space Station by the Orbiter, aft cargo carrier, or Shuttle-derived vehicle. (See trade #11.) - Is based at and serviced by Space Station (module changeout/fluid replenishment). - Is monitored and controlled by Space Station through TMS when unattached from Space Station and SS RMS when attached to Space Station. (See trade #12.)
Orbiter	- Used for delivering SS modules, resupplying SS with crews, consumables, and SS and user replacement hardware (includes OTV, TMSs, servicers, and payloads). - Will soft dock directly to Space Station. (See trade #13.)
(S)pace (S)tation	- Is considered our logistics base for all servicing and operations missions. - Is used to house replacement parts and fluids before mission usage. - Is an operational station.
(R)emote (M)anipulator (S)ystem	- Is used to initially deploy/retrieve TMS or TMS plus stack. (See trades #14 and #15.) - Is used to transfer user and Space Station hardware from one point to another during normal operations on Space Station. (See trade #14.) - Has no servicing capabilities without the servicer. - Will be used in the assembly of Space Station. - Performance capabilities are not limited to those of the Orbiter RMS.

Table 4.4.1-1 (concluded)

Hardware	Requirements
(R)emote (M)anipulator (S)ystem (concl)	- Has a compatible interface with TMS, OTV, servicer, payloads, and containerized cargo. - Will assist the servicer in all servicing tasks attached to Space Station.
(E)xtra (V)ehicular (A)ctivity	- EVA crew members are equipped with noncontaminating Portable Life Support System (PLSS) for use on contamination-sensitive payloads.
(I)ntra (V)ehicular (A)ctivity	- The gas to pressurize the shirt sleeve environment (hangar) will be an O_2N_2 mixture to provide a breathable environment for the crew. (See trade #16.) - Suitable ventilation and heat will be provided.

Table 4.4.2-1 Top-Level Required Trade Studies

Hardware	Trade Questions
TMS	1. What is a safe distance away from Space Station for TMS operation? (Must consider safety, contamination and plume impingement requirements.) 2. Compared to the Orbiter RCS contamination during docking operations with the Space Station, how much contamination would a TMS RCS contribute during docking to Space Station? (Our desire is to dock directly to Space Station if safety, contamination, and plume impingement levels are acceptable.) 3. What are the geometry, transfer, and storage envelope requirements involved in the delivery of TMS to Space Station via Orbiter cargo bay, aft cargo carrier, or Shuttle-derived vehicle? 4. Should all servicing missions be completely controlled by Space Station or partially by Space Station and partially by ground control?
OTV	5. Same as Trade Study 4. 6. Same as Trade Study 3. 7. Same as Trade Study 1.
Servicer	8. Cost and performance of robotic servicing (servicer) versus cost and performance of EVA/IVA servicing. 9. What techniques and mechanisms would a servicer require for docking operations during servicing tasks? 10. What are the capability boundaries of the servicer? 11. Same as Trade Study 6. 12. Same as Trade Study 4.
Orbiter	13. Where would the best location be for the Orbiter docking port to minimize contamination, SS mass properties changes, and impingement impacts?
SS RMS	14. What is the RMS's reach, envelope, and initial ΔV (deployment) capabilities? 15. What other methods of initial deployment besides RMS can be used (i.e., spin mechanism)?
IVA	16. Do we want the hangar to have a "shirt sleeve" environment (i.e., ventilation, heat, and breathable air provided) or an environment where each crew member is supplied his own ventilation, air, and heat in an EVA-type suit except for meteoroid/thermal protection or some compromise solution.

(OTV/TMS_2) to the launch stand-off-site separates, and then returns to the SS. The OTV is then ignited, changes orbits, and rendezvous with the payload. The TMS_2 separates from the OTV, captures the payload, then returns and docks to the OTV. The stack (Payload, TMS_2 and OTV) is then returned to the launch stand-off-site. Again TMS_1 leaves the SS and rendezvous and docks with the stack at the stand-off-site. The stack (Payload/TMS_2/OTV) is returned to the SS by TMS_1 and berthed at the mating facility by the SS RMS. The vehicles are separated from each other and the payload moved to the servicing area. A dedicated servicer is then employed using the SS RMS, and the required servicing mission is performed. All or any items of the stack, TMS's or OTV can be removed from the stack and serviced at the space station. The delivery is illustrated in Figure 4.4.3-4. All TMS's and OTV's are stored onboard the SS and will be available to support a remote mechanism servicing mission.This flow could be modified to where a single TMS would be necessary to retrieve and deliver a payload for a remote mechanism servicing mission provided TMS's performance limits are not exceeded.

b. Unattached Remote Mechanism Servicing - The objective here is to satisfy one of the following user requirements; fluid transfer/replenishment, module replacement/repair, or preventative maintenance. As shown in Figure 4.4.3-1, the servicer designated to perform one of these requirements is mated to a stack consisting of two TMS's and an OTV. To minimize contamination near the SS, the SS RMS imparts a delta-velocity to the stack so it drifts away to a safe distance. At this point TMS, maneuvers the stack to a designated launch stand-off-site position for the OTV engine firing. TMS_1 then separates from the stack and returns to the SS. The OTV then is commanded by SS to transfer the TMS_2/Servicer to the desired orbit.

   Once in the orbit, the TMS_2/Servicer separates from the OTV and maneuvers to the payload. The OTV remains in a station keeping mode awaiting the return of the TMS_2/Servicer once their servicing task is complete to return them back to the designated stand-off-site. At the SS, the TMS_1 is deployed by SS RMS, rendezvous, docks to the stack, and returns it to the SS. Variations of this mission may not require an OTV or a second TMS.

c. Space Station Remote Mechanism Servicing - This is accomplished remotely using a SS RMS internally controlled by the SS. In this scenario a dedicated servicer would be used in conjunction with the SS RMS or hard mounted to the SS in order to perform repairs on the space station itself, and provide fluid transfer/replenishment, module replacement/repair, or preventative maintenance service.

d. Unattached Platform Remote Servicing - In this task the servicing is accomplished using a TMS and Servicer. It is presumed that the platform is in a similar orbit to that of the space station so the TMS performance limits are not exceeded. Once again the repairs consists of fluid transfer/replenishment, module replacement/repair and or preventative maintenance.

2. EVA Servicing - The EVA servicing scenario consists of providing EVA service for the space station itself, free-flyer, platform or attached servicing.

a. EVA Space Station Servicing - This can be accomplished thru the use of the MMU or MMU and space crane combination. This servicing consists of replacement of a failed component and/or repair and preventative maintenance (reference Figure 4.4.3-2). This type of mission is restricted by the time limit imposed by the astronauts portable life support system (PLSS), and by the delta-velocity capability of the MMU.

b. EVA Unattached Free-Flyer Servicing - The servicing here is accomplished thru the use of the MMU. This type of service is the same as that for EVA space station servicing. Again this type of mission is restricted by the time limit imposed by the PLSS and by the delta-velocity capability of the MMU. The MMU delta-velocity limitation are due to teh problem caused by the differences of regression of similar orbits and the ability of the MMU to maneuver between these orbits. However, a second generation, higher performance MMU could be developed as the result of a trade study. A possible outcome of this analysis could be that the MMU should be used for inspection missions only.

c. EVA Unattached Platform Servicing - This is an identical mission to EVA unattached free-flyer.

d. EVA Attached Servicing - This is similar to remote mechanism attached servicing. Again two TMS's and an OTV are employed to capture the payload from other orbit and return it to the space station. Upon return of the stack (TMS_1/OTV/TMS_2/P/L) to the space station the servicing function is performed by an EVA servicer. This type of servicing consists of a men on a space crane and or a men with a MMU to perform the necessary repair either due to the complexity of the repair or the non-modularity of the payload being repaired. Once again servicing will be performed on the OTV and TMS's in preparation for delivery of the repaired payload to its proper orbit.

3. IVA Servicing - The IVA servicing scenario consists of providing IVA service for the space station itself or an attached payloads.

a. IVA Space Station Servicing - IVA servicing is the repair and maintenance of any item that is internal to the space station (reference Figure 4.4.3-3). All IVA repair and maintenance will be accomplished in a shirt sleeve environment. This scenario satisfies any housekeeping type of repair and maintenance work necessary to keep the space station in proper operation.

b. IVA Servicing of an Attached Payload - This task requires that the payload to be returned to the space station from another orbit using the TMS's and an OTV. Once returned a component of the payload is transferred to the EVA airlock and brought inside the SS. The advantage of IVA is the shirt sleeve working environment which is a valuable aid when replacing a delicate portion of the component. The end result of this IVA servicing is the delivery of the repaired payload to its original orbit (reference Figure 4.4.3-4).

4. Orbit Transfer - Orbit transfer consists of two scenarios; payload delivery and payload retrieval.

a. Payload Delivery - This task is integral to many of the scenarios and consists of the mating of an OTV to a TMS and a payload to that OTV. The stack is then deployed from the space station using the SS RMS. The TMS maneuvers the stack to the launch stand-off-site and then separates and returns to the space station as shown in Figure 4.4.3-4. The OTV then delivers the payload and returns to the launch stand-off-site where it is recovered by a TMS and returned to the space station. Once returned to the space station the stack is demated, inspected, serviced and stored for future mission.

b. Payload Mating - This task is also integral to many of the scenarios. It consists of the mating of an OTV to TMS_1, and TMS_2, to that OTV. The stack is deployed from the space station using the SS RMS. The TMS again maneuvers the stack to the launch stand-off-site, separates, and returns to the space station. The OTV delivers TMS_2 to the payload orbit where it separates from the OTV and rendezvous and docks to the payload. The TMS/payload combination returns and docks to the OTV which transfers the stack to the launch stand-off-site. Here the stack is retrieved by the first TMS and returned to the SS RMS. The stack is once again demated, inspected, serviced, and stored for future missions.

5. Payload Assembly, Mating, and Construction - Payload assembly, mating, and construction from the fifth group of tasks is illustrated in Figure 4.4.3-5.

a. Payload Assembly - The assembly scenario consists of the fastening of pre-manufactured components into a (payload) configuration. This is accomplished at the space station using EVA crew members or remote manipulators.

b. Payload Construction - The mating of a payload consists of the build-up of a stack (i.e. a payload mated to an OTV and an OTV to a TMS). The interfaces between each component are checked after the mating to insure proper functioning.

c. Payload Construction - The construction of a payload consists of the assembly of parts that are manufactured at the space station. For example a beam builder will be employed to construct beams of a required dimensions that otherwise would not fit in the Orbiter cargo bay.

6. SS Initial Assembly, Evolution, and Construction - The last group of tasks consists of the initial assembly, the evolution, and construction of the SS. The illustrations and functional flows in Figure 4.4.3-6 addresses only one of the concepts under consideation. In this concept a crew of four will be brought up on flight three thus beginning IOC.

a. SS Initial Assembly - This scenario depicts the sequence of build-up of the various space stations modules.

b. SS Evolution - During this phase the SS and crew will grow to accommodate simultaneous multiple user missions.

c. SS Construction - This scenario was generated in order to accommodate any growth of the space station that could not be accomplished by assembly. For this scenario a beam builder is invisioned as being a basic tool needed to provide support members for any of the following; solar arrays, experiment platforms, SS RMS, and materials processing facilities.

After reviewing the eighteen scenarios, one observes a number of standard tasks that are common to more than one scenario. In order to simplify the analysis these standard tasks are further expanded in section 4.4.4, Standard Functional Definitions. This section contains eleven of the Standard Flows that will be used to support the six task areas as identified above (Figures 4.4.4-1 thru 4.4.4-4). Additionally, in the breakdown of the eighteen capabilities definitions, unique functions were identified as definitions (referenced in Figure 4.2-1).

In summary we have a top level functional analysis for the eighteen Capability Definitions, and a second level functional analysis for the eleven standard functions, plus a second level functional analysis for the eighteen unique functional definitions. The following top level capability definitions also use the top level delivery and retrieval capability definitions; remote mechanism servicing attached, EVA servicing attached, IVA servicing unattached and payload construction. For these cases the delivery and retrieval becomes a second level functional analysis and the normal 2nd level standard functions that support delivery and retrieval become a 3rd level functions.

As a result of the functional analysis performed on the eighteen scenarios we have been able to identify groundrules and requirements that pertain to each of these scenarios. These groundrules and requirements are identified on Figures 4.4.3-1 thru 4.4.3-6 and Figures 4.4.3-1a thru 4.4.3-6a.

As an example we have illustrated the breakdown of remote mechanism servicing attached, into a retrieval, servicing and delivery mission. This scenario is the most complex of the scenarios. As shown in Figure 4.4.3 the pictoral scenario can be broken down into retrieval consisting of functional designators A, B1, B2, B3, B4, B5, B6 and B7, servicing consists of functional designators of C, D, E and F, and delivery consists of G1, G2, G3, G4 and G5 with the corresponding functions listed. All of those functions have been identified in the top level, stand and unique functional definitions on page that follows.

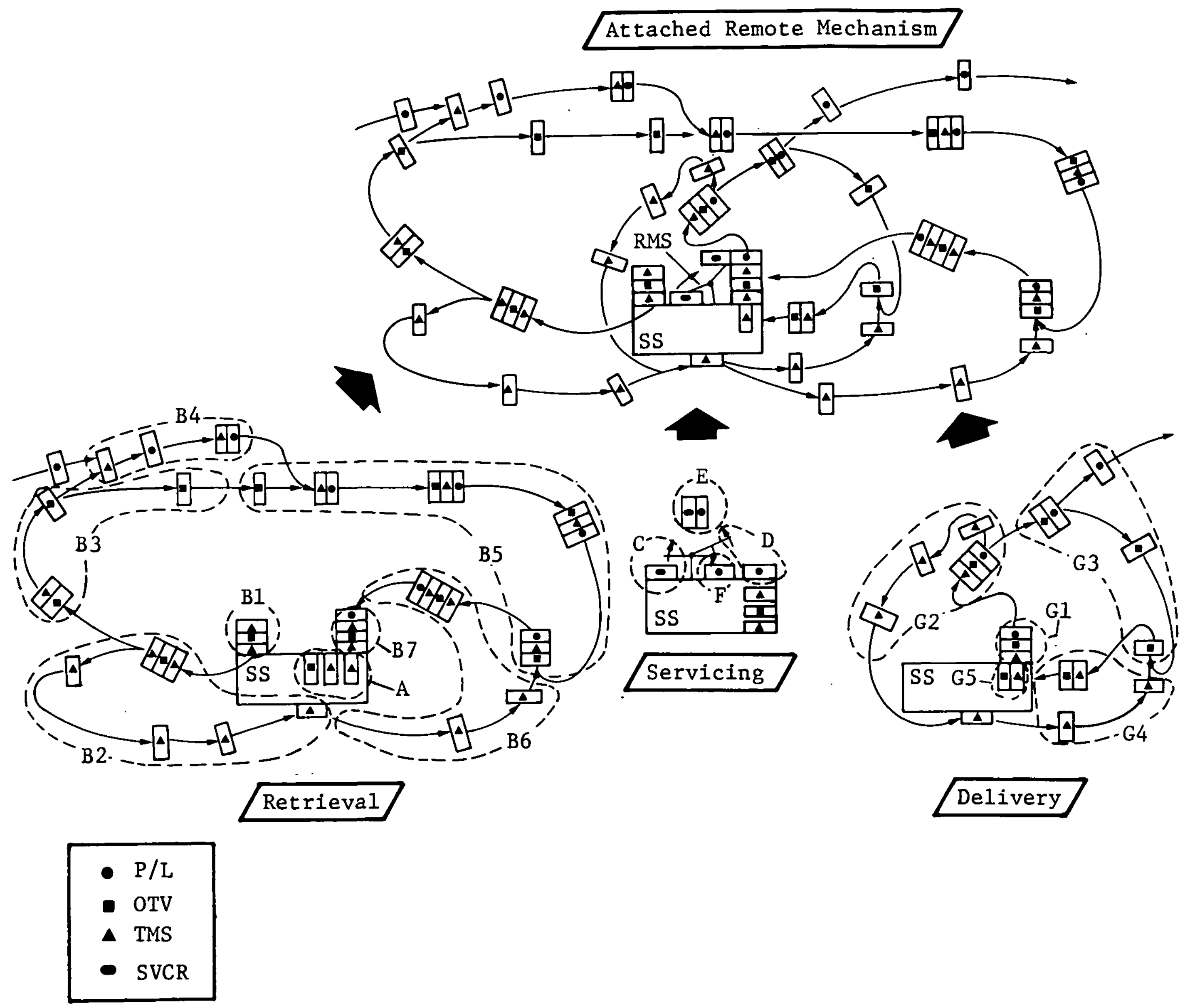

Figure 4.4.3
Remote Mechanism Servicing Scenario and Functional Definitions for Tasks Accomplished at Space Station

Designator (Top Level / 2nd Level / 3rd Level Function)	Retrieval
A	Cargo Transfer and Stowage (Cargo Delivered to SS)(Fig. 4.4.4-1)
A1	Cargo Delivery by Orbiter
A2	Cargo Removed from Orbiter
A3	Cargo Transferred to Storage Facility
A4	Cargo Berthed at Storage Facility
A5	Cargo Transferred to (TBD) Facility
B	Payload Retrieval (Fig. 4.4.3-4)
B1	TMS_1/OTV/TMS_2 Mating (Fig. 4.4.4-1)
B1.1	TMS_1 and Mating Fixture I/Fs Prepared for Mating
B1.2	TMS_1 Mounted to Mating Fixture
B1.3	TMS_1/OTV I/Fs Prepared for Mating
B1.4	OTV Mated to TMS_1
B1.5	OTV/TMS_2 I/Fs Prepared for Mating
B1.6	TMS_2 Mated to OTV
B1.7	System Functional Check
B2	Initial Deployment from Space Station (Fig. 4.4.4-2)
B2.1	SS RMS Attaches to Vehicle(s)
B2.2	SS RMS Transfers Vehicle(s) to Deployment Site
B2.3	SS RMS Deploys Vehicle(s) from SS
B2.4	TMS_1 Maneuvers Vehicle(s) to Launch Stand Offsite
B2.5	TMS_1 Separates from Vehicle(s)
B2.6	TMS_1 Returns to SS
B2.7	SS RMS Attaches to TMS_1
B2.8	SS RMS Transfers TMS_1 to Servicing Facility
B2.9	TMS_1/Berthing Fixture I/Fs Prepared for Mating
B2.10	TMS_1 Is Mounted to Berthing Fixture
B2.11	TMS_1 Is Serviced (Maintenance and Fluids)
B3	TMS_2 Delivery by OTV (Fig. 4.4.4-2)
B3.1	Final System Functional Check of Vehicles
B3.2	OTV Launches/Delivers Vehicle(s) to Desired Orbit
B3.3	Vehicle(s) Separates from OTV
B3.4	OTV Continues a Parallel Orbit
B4	TMS_2 Docks to P/L (Fig. 4.4.3-4a)
B4.1	TMS_2 Maneuvers to Rendezvous with Payload
B4.2	TMS_2 Rendezvous with Payload
B4.3	TMS_2 Docks to Payload
B4.4	TMS_2/Payload Prepare for Rendezvous with OTV
B5	Retrieval by OTV (Fig. 4.4.4-2)
B5.1	OTV Maintains a Parallel Orbit with Vehicle(s)
B5.2	OTV Maneuvers to Rendezvous with Vehicle(s)
B5.3	OTV Rendezvous with Vehicle(s)
B5.4	Vehicle(s) Dock to OTV
B5.5	OTV (Vehicles(s)) Prepare for Deorbit
B5.6	OTV Starts Deorbit
B5.7	OTV/Vehicle(s) Return to Launch Stand Offsite
B6	Final TMS_1/SS RMS Retrieval (Fig. 4.4.4-3)

Designator (Top Level / 2nd Level / 3rd Level Function)	Retrieval
B6.1	TMS_1 Functional Check
B6.2	SS RMS Attaches to TMS_1
B6.3	TMS_1 Demating from Berthing Fixture
B6.4	SS RMS Transfers TMS_1 to Deployment Site
B6.5	SS RMS Deploys TMS_1 from SS
B6.6	TMS_1 Maneuvers to Rendezvous Site
B6.7	TMS_1 Docks to Vehicle(s)
B6.8	TMS_1/Vehicle(s) Return to SS
B6.9	SS RMS Attaches to TMS_1/Vehicle(s)
B6.10	SS RMS Transfers Stack to TBD Facility
B7	TMS_1/OTV/TMS_2/P/L Demating (Fig. 4.4.4-3)
B7.1	TMS_1 and Mating Fixture I/Fs Prepared for Mating
B7.2	TMS_1/OTV/TMS_2/P/L Mounted to Mating Fixture
B7.3	P/L Demated from TMS_2
B7.4	Hardware Inspected
B7.5	Hardware Serviced (Maintenance/Fluid)
B7.6	Hardware Functional Check
B7.7	TMS_2 Demated from OTV
B7.8	Hardware Inspected
B7.9	Hardware Serviced (Maintenance/Fluid)
B7.10	Hardware Functional Check
B7.11	OTV Demated from TMS_1
B7.12	Hardware Inspected
B7.13	Hardware Serviced (Maintenance/Fluid)
B7.14	Hardware Functional Check
B7.15	TMS_1 Demated from Mating Fixture
B7.16	Hardware Inspected
B7.17	Hardware Serviced (Maintenance/Fluid)
B7.18	Hardware Functional Check
B7.19	Mating Fixture Inspected
B7.20	Mating Fixture Serviced
B7.21	Mating Fixture Secured

	Servicing
C	Servicer Servicing (Fig. 4.4.4-1)
C1	Servicer Arrives at Servicing Facility
C2	Servicer Mated to Servicing Fixture
C3	Operational Check of Remote Manipulator System
C4	Replacement Component Installed on Servicer
C5	or Servicer Umbilical Extends and Attaches to Servicing Tank
C6	Fluid Transferred into Servicer
C7	Transfer Verified
C8	Fluid Transfer Operational Check
C9	Servicer Tank Topped Off
C10	Servicer Umbilical Disconnected and Retracted
C11	Leak Check
C12	and Servicer Demated from Servicing Fixture
C13	Servicer Transferred to Servicing Site
D	P/L Transferred to Servicing Facility (Fig. 4.4.4-3)
D1	P/L Prepared for Transfer
D2	SS RMS Grapples P/L
D3	P/L Is Released from Holding Fixture
D4	P/L Is Transferred to Servicing Site
D5	P/L Aligned with Servicing Fixture

Designator (Top Level / 2nd Level / 3rd Level Function)	Servicing
D5	P/L Aligned with Servicing Fixture
D6	P/L Attached to Servicing Fixture
D7	SS RMS Releases P/L
E	P/L Servicing (Fig. 4.4.3-1a)
E1	SS RMS Moves Servicer Over to P/L
E2	SS RMS Mates Servicer to P/L
	Module Changeout
E3	SS RMS System Operation Check
E4	Bad Component Removed
E5	Bad Component Stored on Servicer
E6	Replacement Component Removed from Servicer
E7	Replacement Component Installed
E8	Replacement Component Functional Check
	or Fluid Replenishment
E9	Servicer Umbilical Extends and Attaches to P/L
E10	Fluid Transfer Begins
E11	Fluid Transfer Verified
E12	Fluid Transfer Ends
E13	Leak Check Inspection
E14	System Functional Check
	or Contamination Control
E15	Analyze Surface for Degradation
E16	Clean Surface
E17	Prepare Surface Coating
E18	Treat/Apply New Surface Protection
E19	Final Inspection of Surface
E20	SS RMS Separates Servicer from P/L
E21	SS RMS Returns Servicer to SS
F	P/L Transferred to Mating Facility (Fig. 4.4.4-3)
F1	P/L Prepared for Transfer
F2	SS RMS Grapples P/L
F3	P/L Is Released from Servicing Fixture
F4	P/L Is Transferred to Mating Site
F5	P/L Aligned with Mating Fixture
F6	P/L Attached to Mating Fixture
F7	SS RMS Releases P/L

	Delivery
G	Payload Delivery (Fig. 4.4.3-4)
G1	TMS_1/OTV/P/L Mating (Fig. 4.4.4-1)
G1.1	TMS_1 and Mating Fixture I/Fs Prepared for Mating
G1.2	TMS_1 Mounted to Mating Fixture
G1.3	TMS_1/OTV I/Fs Prepared for Mating
G1.4	OTV Mated to TMS_1
G1.5	OTV/P/L I/Fs Prepared for Mating
G1.6	P/L Mated to OTV
G1.7	System Functional Check
G2	Initial Deployment from Space Station (Fig. 4.4.4-2)
G2.1	SS RMS Attaches to Vehicle(s)
G2.2	SS RMS Transfers Vehicle(s) to Deployment Site
G2.3	SS RMS Deploys Vehicle(s) from SS
G2.4	TMS_1 Maneuvers Vehicle(s) to Launch Stand Offsite
G2.5	TMS_1 Separates from Vehicle(s)
G2.6	TMS_1 Returns to SS
G2.7	SS RMS Attaches to TMS_1

Designator (Top Level / 2nd Level / 3rd Level Function)	Delivery
G2.8	SS RMS Transfers TMS_1 to Servicing Facility
G2.9	TMS_1/Berthing Fixture I/Fs Prepared for Mating
G2.10	TMS_1 Is Mounted to Berthing Fixture
G2.11	TMS_1 Is Serviced (Maintenance and Fluids)
G3	P/L Delivery by OTV (Fig. 4.4.4-2)
G3.1	Final System Functional Check of Vehicle(s)
G3.2	OTV Launches/Delivers Vehicle(s) to Desired Orbit
G3.3	Vehicle(s) Separates from OTV
G3.4	OTV Prepares for Deorbit
G3.5	OTV Starts Deorbit
G3.6	OTV Returns to Launch Stand Offsite
G4	Final TMS_1/SS RMS Retrieval (Fig. 4.4.4-3)
G4.1	TMS_1 Functional Check
G4.2	SS RMS Attaches to TMS_1
G4.3	TMS_1 Demating from Berthing Fixture
G4.4	SS RMS Transfers TMS_1 to Deployment Site
G4.5	SS RMS Deploys TMS_1 from SS
G4.6	TMS_1 Maneuvers to Rendezvous Site
G4.7	TMS_1 Docks to OTV
G4.8	TMS_1/OTV Return to SS
G4.9	SS RMS Attaches to TMS_1/OTV
G4.10	SS RMS Transfers Stack to TBD Facility
G5	TMS_1/OTV Demating (Fig. 4.4.4-3)
G5.1	TMS_1 and Mating Fixture I/Fs Prepared for Mating
G5.2	TMS_1/OTV Mounted to Mating Fixture
G5.3	OTV Demated from TMS_1
G5.4	Hardware Inspected
G5.5	Hardware Serviced (Maintenance/Fluid)
G5.6	Hardware Functional Check
G5.7	TMS_1 Demated from Mating Fixture
G5.8	Hardware Inspected
G5.9	Hardware Serviced (Maintenance/Fluid)
G5.10	Hardware Functional Check
G5.11	Mating Fixture Inspected
G5.12	Mating Fixture Serviced
G5.13	Mating Fixture Secured

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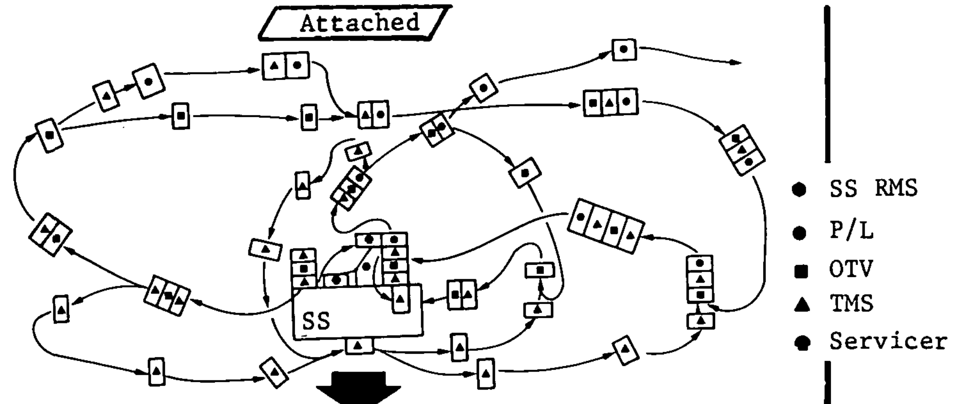

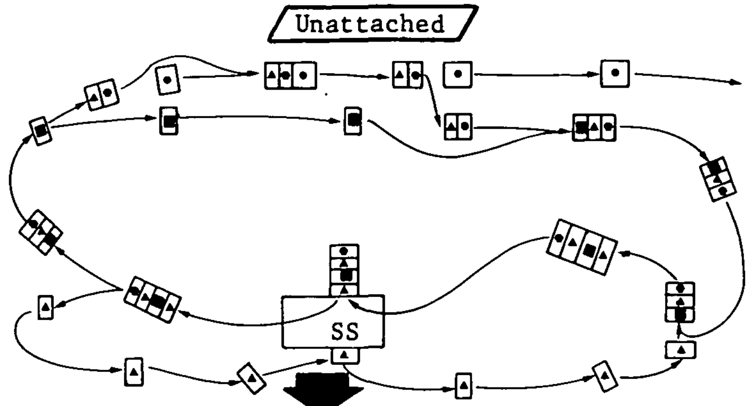

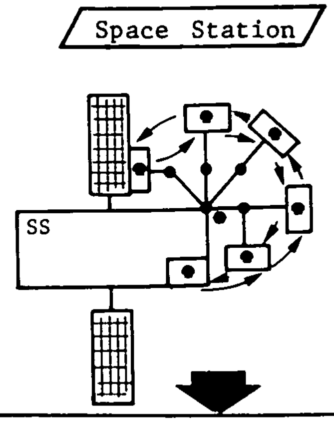

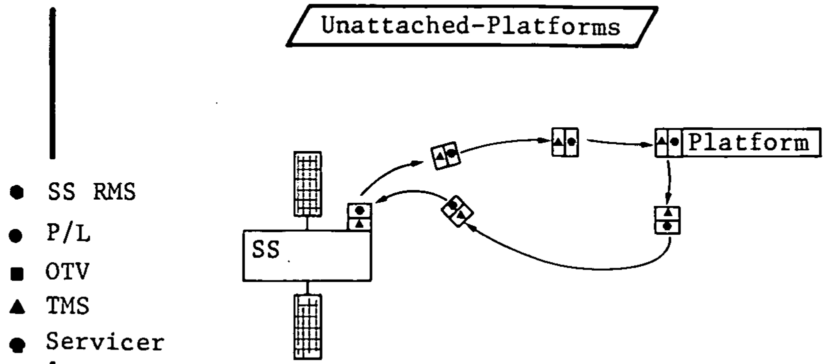

Ground Rules (Attached)
- TMS
- OTV
- SS RMS
- Servicer
- Man
- P/L
- SS

Ground Rules (Unattached)
- TMS's
- OTV
- Servicer
- Man
- SS RMS
- P/L
- SS

Ground Rules (Space Station)
- SS RMS
- Servicer
- Man
- SS

Ground Rules (Unattached-Platforms)
- TMS
- Servicer
- Man
- SS RMS
- SS
- Platform

Cargo Transfer & Stowage (Fig. 4.4.4-1) → Servicer Servicing (Fig. 4.4.4-1) →

Attached: P/L Retrieval (Fig. 4.4.3-4) → Servicer Servicing (Figure 4.4.4-1) → P/L Transferred to Servicing Facility (Fig. 4.4.4-3) → P/L Servicing (Fig. 4.4.3-1a) → P/L Transferred to Mating Facility (Fig. 4.4.4-3) → P/L Delivery (Fig. 4.4.3-4)

Unattached: $TMS_1/OTV/TMS_2/$ (Servicer) Mating (Fig. 4.4.4-1) → Initial Deployment from SS (Fig. 4.4.4-2) → (TMS_2/Servicer) Delivery by OTV (Fig. 4.4.4-2) → P/L Servicing (Fig. 4.4.3-1a) → Retrieval by OTV (Fig. 4.4.4-2) → Final $TMS_1/$ SS RMS Retrieval (Fig. 4.4.4-3) → $TMS_1/OTV/TMS_2/$ (Servicer) Demating (Fig. 4.4.4-3)

Space Station: SS RMS Deployment (Fig. 4.4.3-1a) → SS Hardware Servicing (Fig. 4.4.3-1a) → SS RMS Retrieval (TBD) → Servicer/ SS RMS Demating (TBD)

Unattached-Platform: $TMS_1/$ (Servicer) Mating (Fig. 4.4.4-1) → Initial Deployment from SS (Fig. 4.4.4-2) → (Servicer) Delivery by TMS_1 (TBD) → Platform Servicing (Fig. 4.4.3-1a) → TMS_1 Returns Servicer to SS (N/A) → Final SS RMS Retrieval (N/A) → $TMS_1/$ (Servicer) Demating (Fig. 4.4.4-3)

Requirements (Attached)
- Universal Docking Sys
- Logistics Support
- Berthing Sys
- Control Station
- Mating Facility
- Transfer Mechanism (SS RMS)
- Servicing Facility
- Storage Facility

Requirements (Unattached)
- Universal Docking Sys
- Logistics Support
- Berthing Sys
- Control Station
- Mating Facility
- Transfer Mechanism (SS RMS)
- Servicing Facility
- Storage Facility

Requirements (Space Station)
- Universal Docking Sys
- Logistics Support
- Control Station
- Transfer Mechanism (SS RMS)
- Storage Facility

Requirements (Unattached-Platforms)
- Universal Docking Sys
- Logistics Support
- Control Station
- Transfer Mechanism (SS RMS)
- Mating Facility
- Berthing Sys
- Servicing Facility
- Storage Facility

Figure 4.4.3-1 Remote Mechanism Servicing Capability Scenarios and Functional Definitions

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Table 4.4.3-1 Ground Rules for Remote Mechanism Servicing

Hardware	Requirements

TMS	- Two TMSs are required:
	  - One for deployment and retrieval of a stack (e.g., OTV/Servicer);
	  - One for maneuvering and docking servicer to payload or maneuvering and docking to payload (see trade #1).
	- Both TMSs are interchangeable.

Servicer	- Three servicers are required:
	  - One for module and hardware changeout;
	  - One for fluid transfer and replenishment;
	  - One for contamination control.
	- Each of the above servicers is dedicated and is not interchangeable.

Payload	- Has been designed to be serviced via a remote mechanism system (Servicer) (see trade #3).
Orbiter	- Involvement is minimal after initial delivery of hardware. (Once delivered, the OTV, TMS, and Servicers are permanent parts of Space Station.) User hardware will require Orbiter involvement.

Mating Operation	- Will be completely accomplished remotely using:
	  - Universal Docking System;
	  - SS RMS;
	  - Closed circuit TV.

Table 4.4.3-2 Required Trade Studies for Remote Mechanism Servicing

Hardware	Trade Questions
TMS/OTV	1. Which would be the best (economical/performance) configuration: - To use TMS as the second stage for OTV; - To design a completely new OTV with a separable second stage capable of rendezvous, maneuvering, and docking operations?
TMS/OTV, TMS, Servicer and Payload	2. What would be the best interface between TMS and OTV; OTV and TMS, TMS and servicer; or OTV, TMS, servicer, and payload?
SS RMS	3. Can a payload be serviced via an intelligent manipulator system (e.g., module changeout, fluid transfer and replenishment, and contamination control)?
Servicer	4. Examine current and future fluid transfer techniques and determine the probability of leakage for various fluid transfer setups, including amount of leakage that could result in contamination.
Space Station	5. Should Space Station have one dedicated deployment site or several, and where should it (they) be located?
Servicer	6. What size modules will the servicer be capable of removing and replacing?

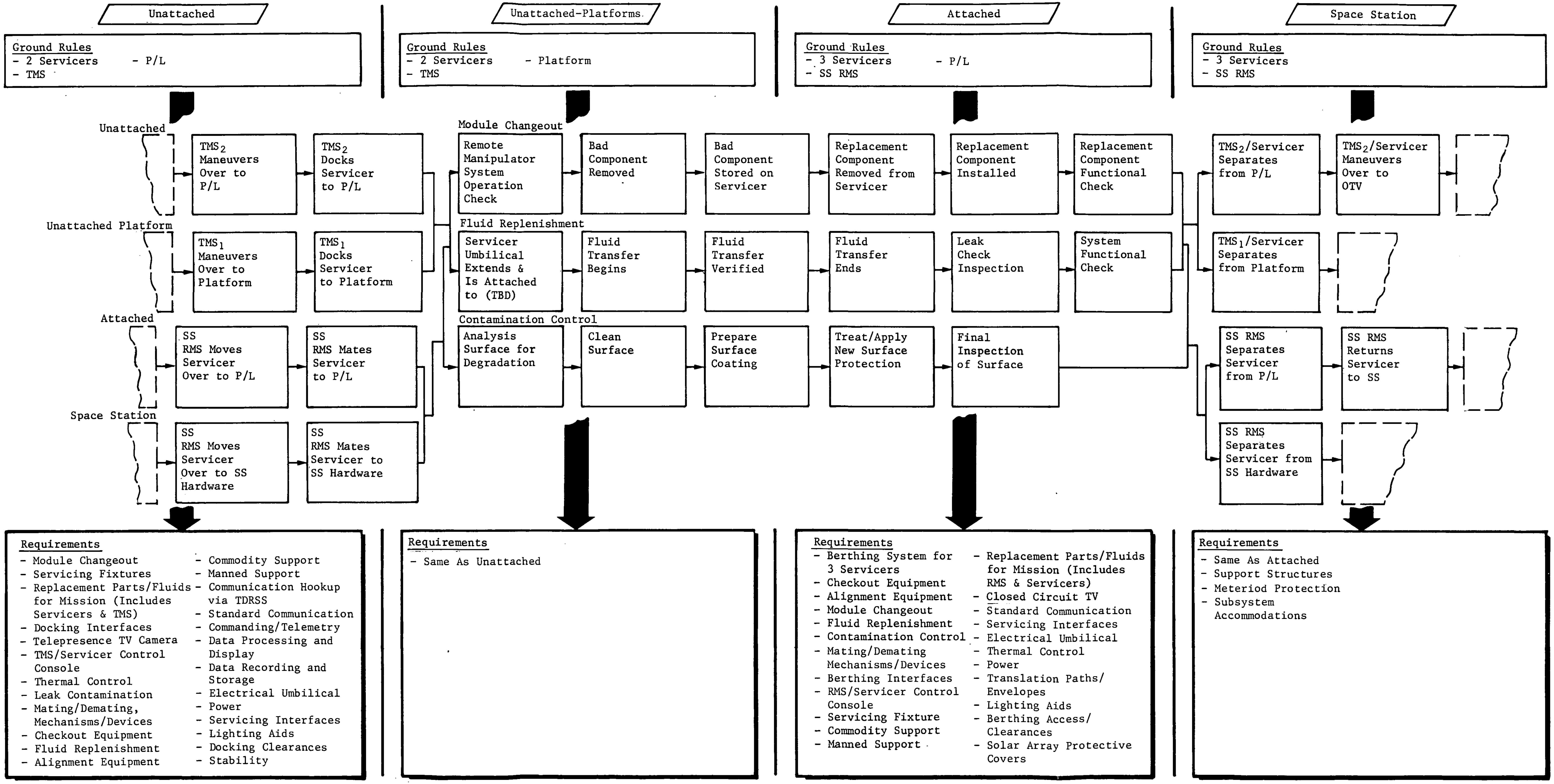

Figure 4.4.3-1a Remote Mechanism Servicing Detailed Requirements Definitions

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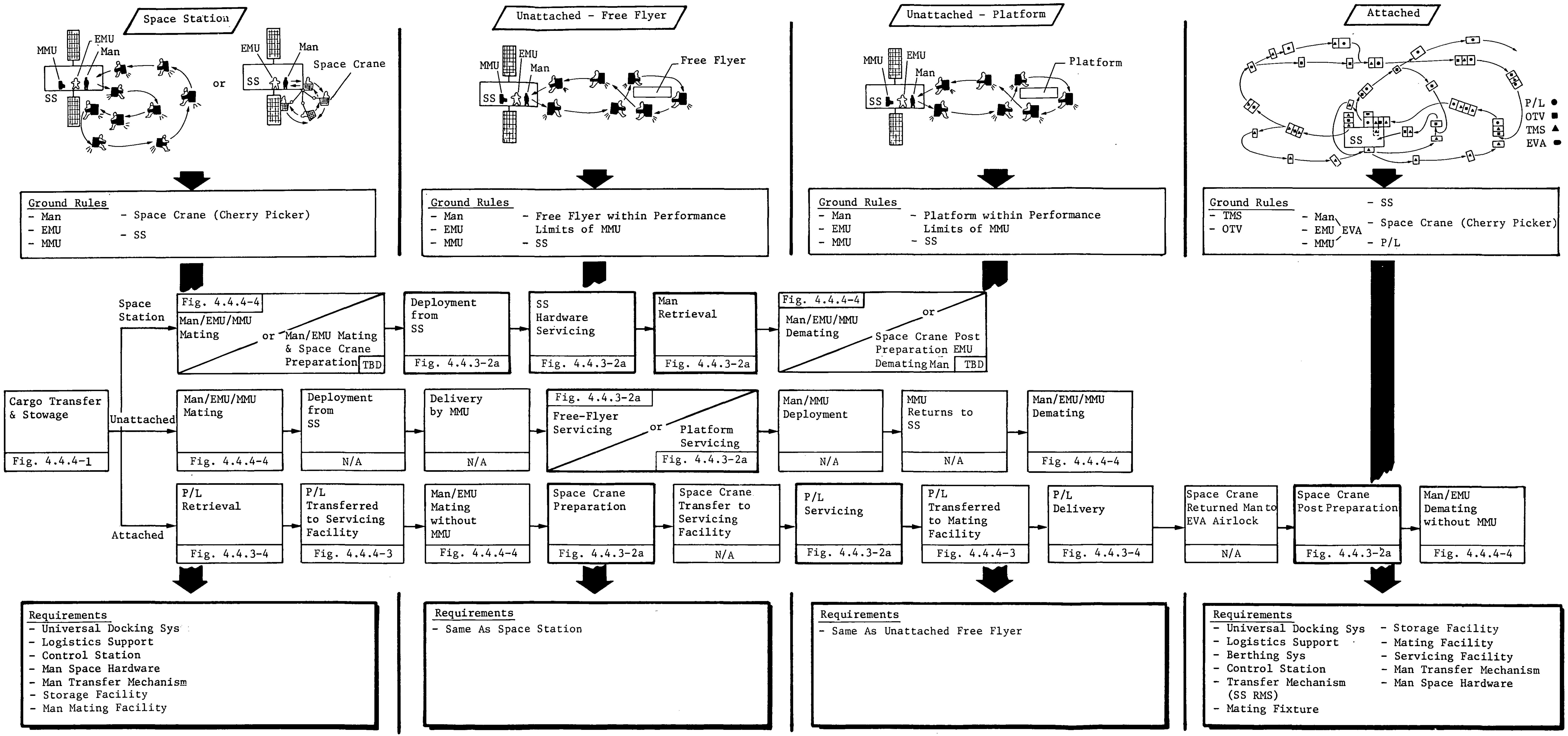

Figure 4.4.3-2 EVA Servicing Capability Scenarios and Functional Definitions

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Table 4.4.3-3 Ground Rules for EVA Servicing

Hardware	Requirements

MMU	- (TBD) MMUs, depending on requirements, will be part of the SS once delivered.
	- Will transfer man (TBD) distance from the SS for:
	  - Stabilization of tumbling spacecraft;
	  - Inspection of spacecraft and platforms;
	  - Small module changeout and contingency repairs of spacecraft and platforms (see trades #1 and #2).
	- Equipped with a work restraint unit that contains provisions for:
	  - Attachment of a universal docking mechanism;
	  - Small module storage capability.

Free Flyer - Spacecraft - Platform	- Will be compatible with universal docking system. - Will be powered down into a passive mode for safety considerations prior to MMU servicing. - Appendages will be retracted when required for safety considerations prior to MMU servicing.
Orbiter	- Involvement will be minimal after the initial delivery of the EVA servicing hardware.
Space Station	- (TBD) EVA airlocks will be required depending on initial and final SS configuration. - Decontamination provisions are required. - Will provide adequate lighting at frequently used work sites. - Will provide adequate working volumes at known work sites.
EMU	- Pressure differential between the SS and the EMU will be small to prevent the need for prebreathing by the crew before going EVA. - Crew will have available a non-contaminating PLSS when servicing sensitive P/L.
MAN	- Servicing operations that involve the crew on EVA will be kept to a minimum to reduce the consumption of consumables, loss of crew time during pre- and post-EVA operations, and potential dangers associated with EVA.

Table 4.4.3-4 Required Trade Studies for EVA Servicing

Hardware	Trade Questions
MMU	1. Study a concept for a higher performance, hot gas propulsion MMU and compare to the existing cold gas MMU in terms of ΔV capability, contamination, control harmony, and docking capability. 2. What is the maximum distance and mission duration for an MMU mission given a specific ΔV?

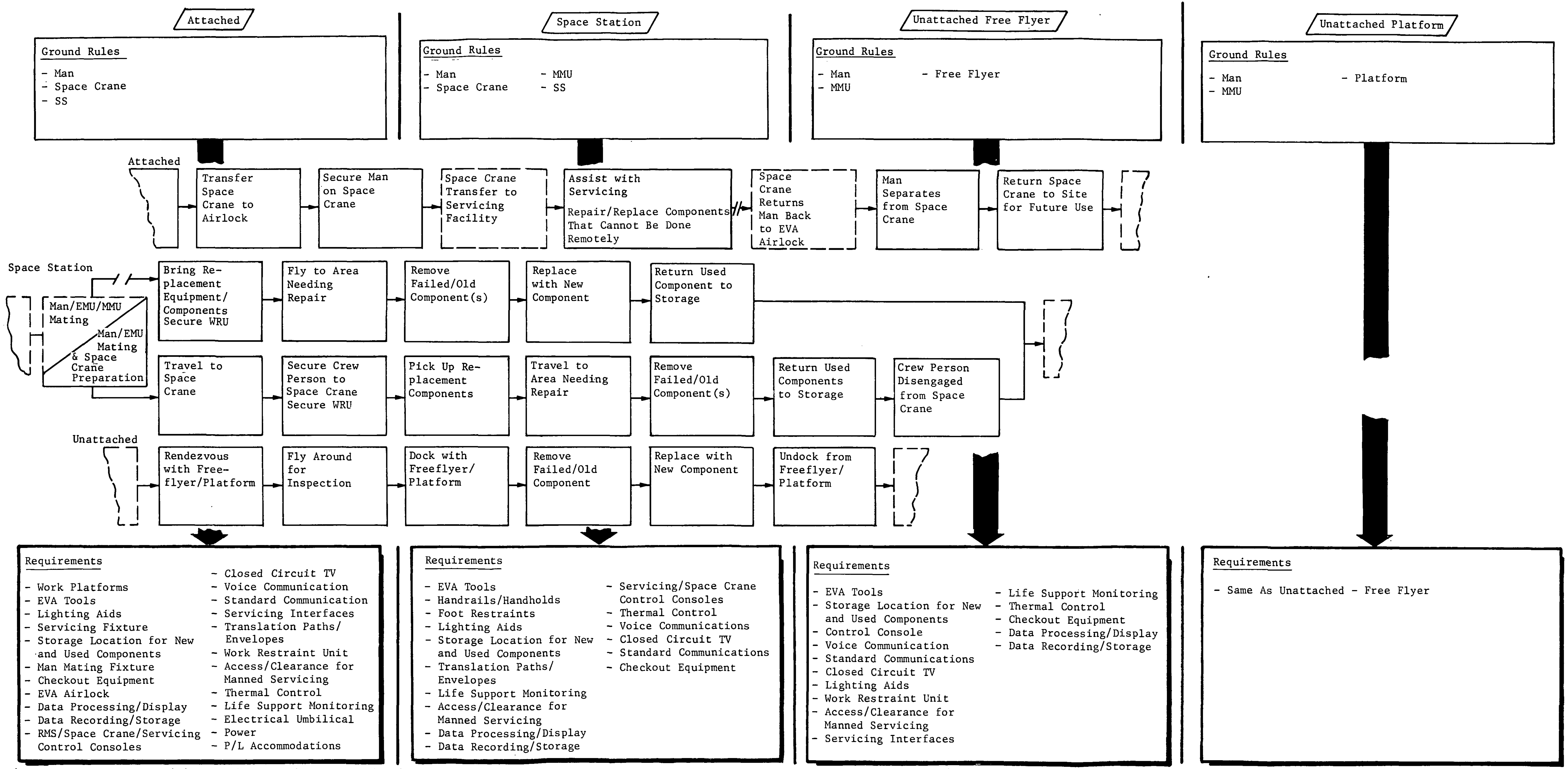

Figure 4.4.3-2a EVA Servicing Detailed Requirements Definitions

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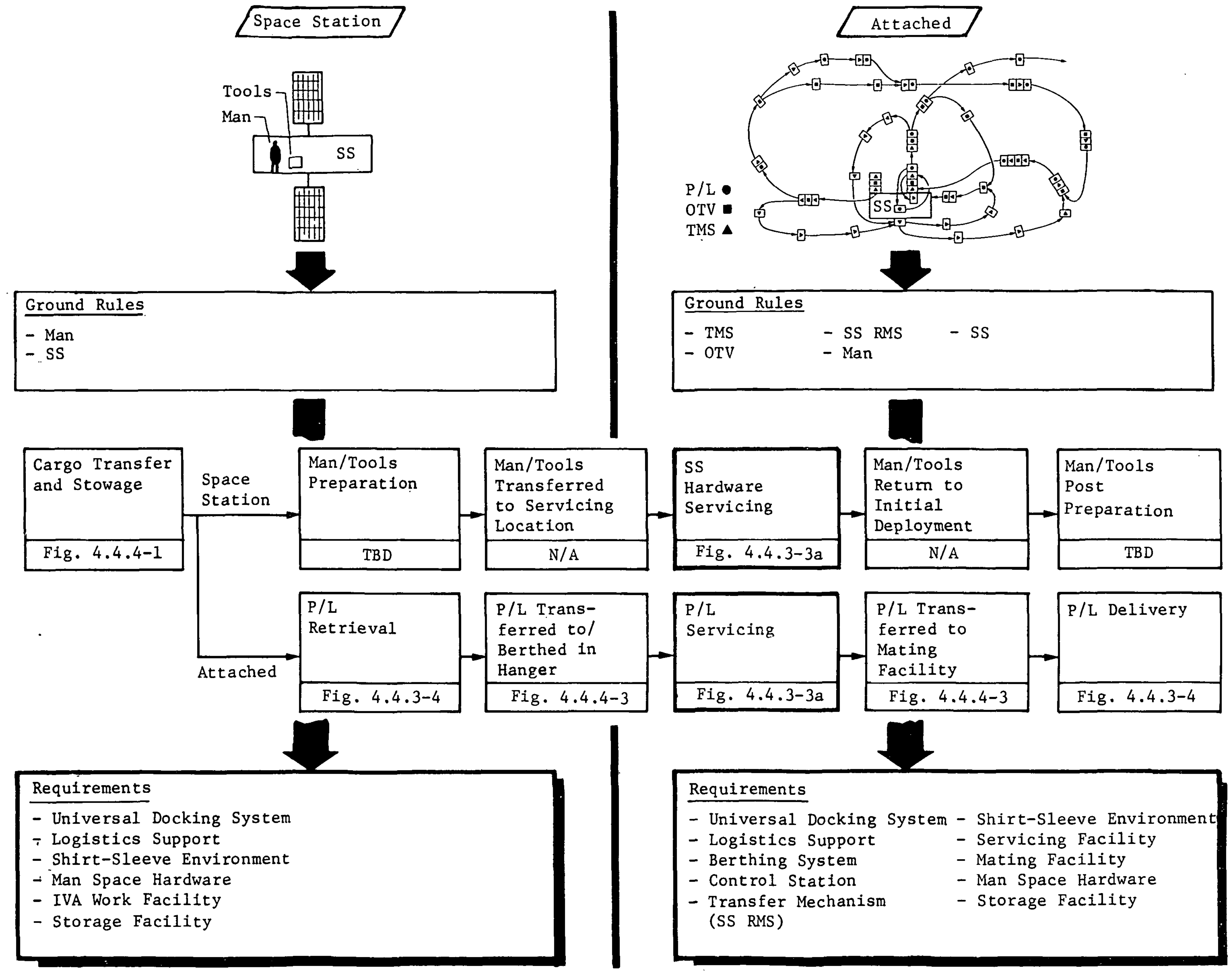

Figure 4.4.3-3 IVA Servicing Capability Scenarios and Functional Definitions

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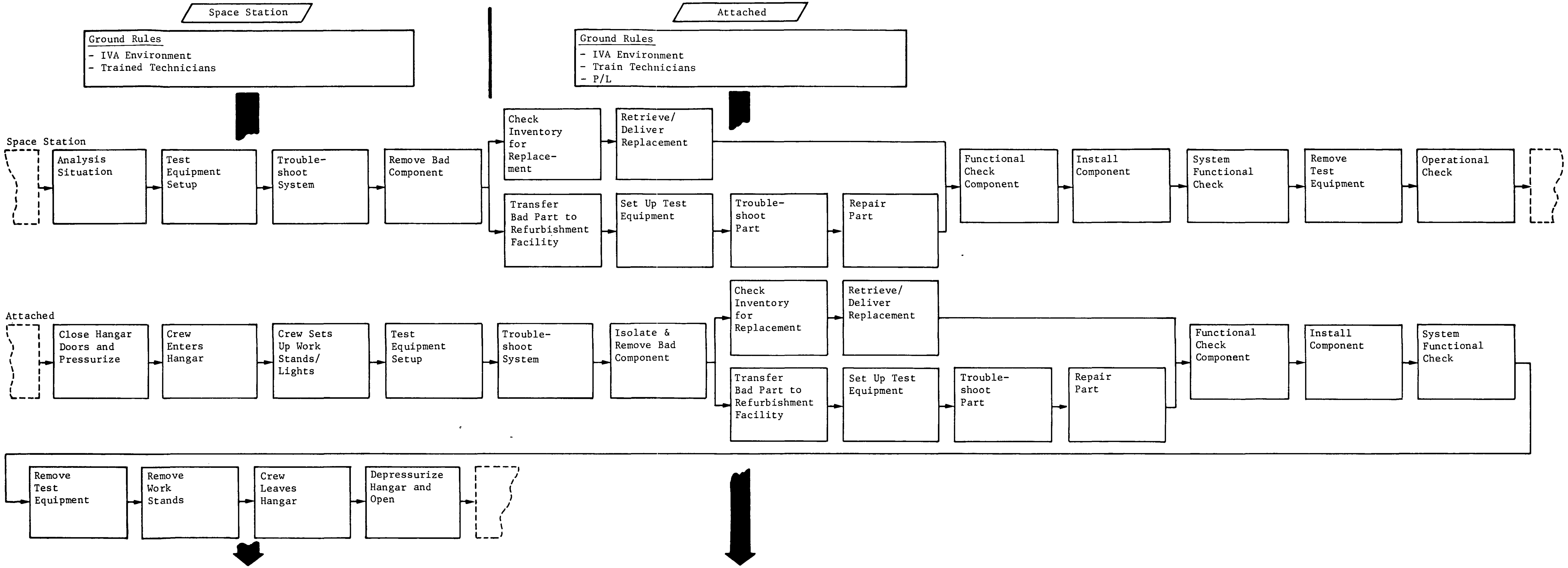
Table 4.4.3-5 Ground Rules for IVA Servicing

Hardware	Requirements
Space Station	- Since many 1-g control and display requirements are applicable in the 0-g environment, MIL-STD-1472C, paragraphs 5.2 - 5.4 will be used initially as a requirements source. - Atmospheric conditions, gas composition and pressure, temperature, humidity, and ventilation will be controlled to maximize crew comfort and work output (see trade #1). - Working volumes will be designed to align crew members to perform their tasks safely and with ease. - The lighting system must provide the servicing crew with at least minimum illumination levels specified in Table XXI in MIL-STD-1472C.

Table 4.4.3-6 Required Trade Studies for IVA Servicing

Hardware	Trade Questions
Space Station	1. The atmospheric pressure of the Space Station will be set to minimize special interfaces with the orbiter and EVA operations (e.g., prebreathing, additional airlocks). 2. What servicing tasks could be completed in less time and/or minimize the use of expendables in a pressurized hangar as opposed to an EVA environment?



Requirements

- Checkout Equipment
- Alignment Equipment
- Test Equipment
- Voice Communication
- Replacement Parts
- Refurnishment Facility
- Translation Paths/ Envelopes
- Portable Hoist
- Dollies
- Lighting Aids
- Cleanliness
- Data Processing/Display
- Tool Sets
- Personnel/Tool Access
- Data Recording/Storage
- Access/Clearance for Manned Servicing

Requirements

- Mating Fixture
  - Rotation/Reposition
- Voice Communications
- Alignment Tools
- Checkout Equipment
- Replacement Parts
- Work Stands
  - Restraints
- Closed Circuit TV
- Zero-g Crane
- Lighting Aids
- Refurbishment Facility
- Tool Sets
- Test Equipment
- Data Recording/Storage
- Dollies
- Data Processing/Display
- Cleanliness
- Thermal Control
- Structural Attachment
- Personnel Access
- Hangar
- Access/Clearance for Manned Servicing
- Translation Paths/ Envelopes
- P/L Accommodations

Figure 4.4.3-3a IVA Servicing Detailed Requirements Definitions

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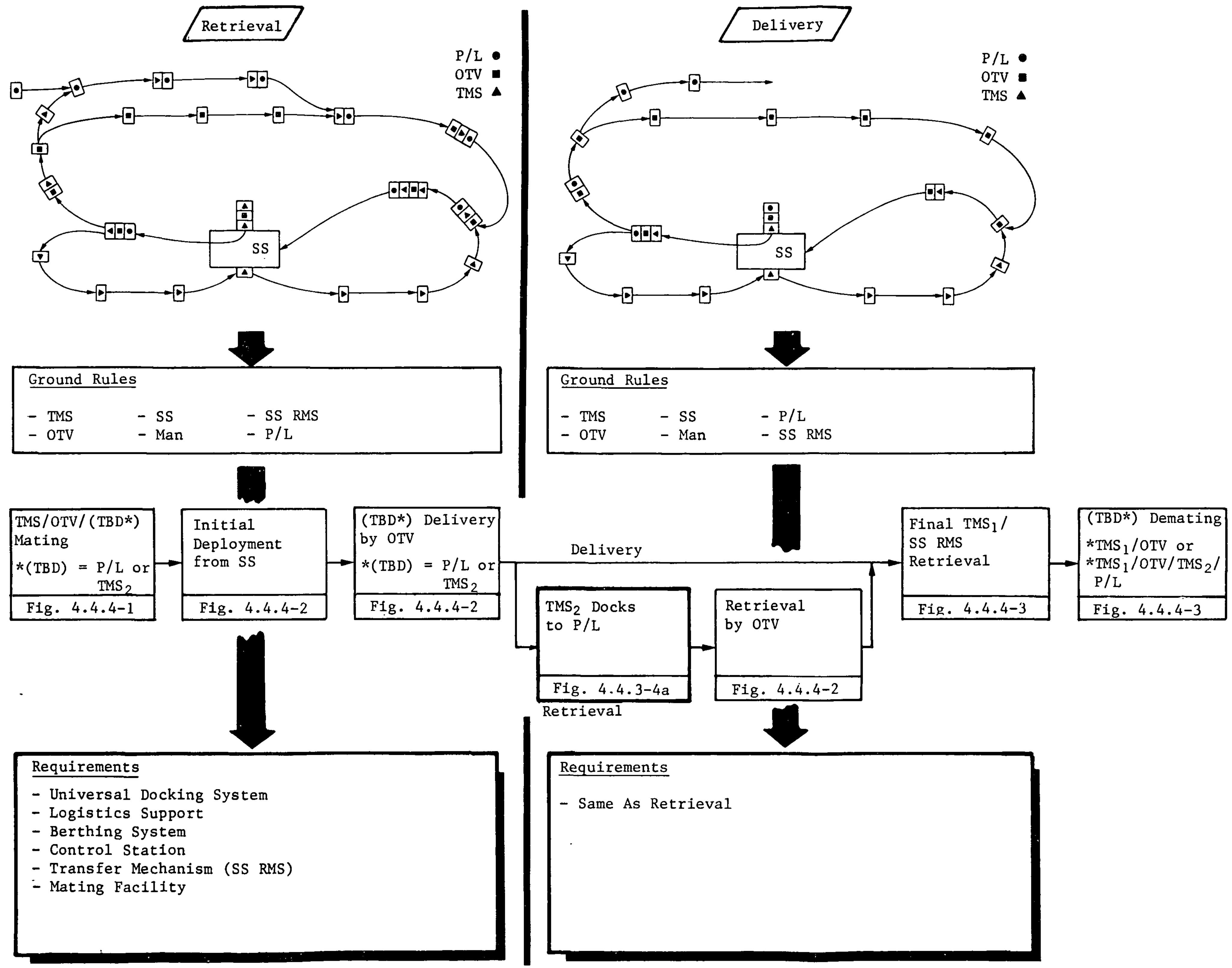

Figure 4.4.3-4 Payload Delivery and Retrieval Capability Scenarios and Functional Definitions

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Table 4.4.3-7 Ground Rules for Payload Delivery and Retrieval

Hardware	Requirements
All Spacecraft/ Satellites	- All spacecraft/satellites will have the same mechanical docking/berthing interfaces (i.e., a universal docking/berthing system). This simplifies berthing procedures and allows for a greater flexibility in the mating of spacecraft and payloads (see trade #1).
TMS	- Will have the capability to dock backwards to the front of an OTV. - With a special interface structure, the TMS can dock with the back end of an OTV.

Table 4.4.3-8 Required Trade Studies for Payload Delivery and Retrieval

Hardware	Trade Questions
All Spacecraft/ Satellites	1. Evaluate various types of mechanical docking/ berthing interfaces and study the potential uses of other types of interfaces (e.g., power, data, video).

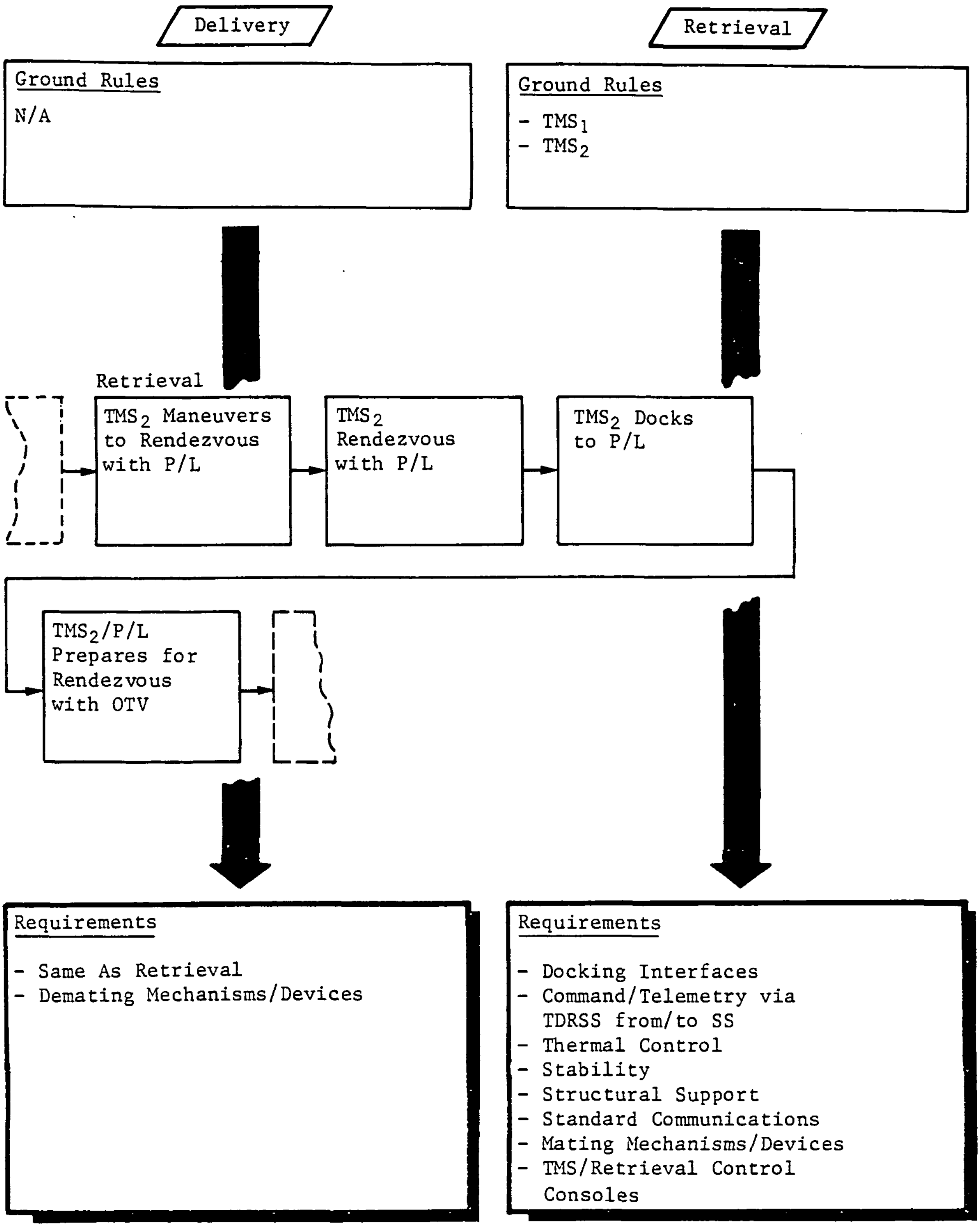

Figure 4.4.3-4a Payload Delivery and Retrieval Detailed Requirements Definitions

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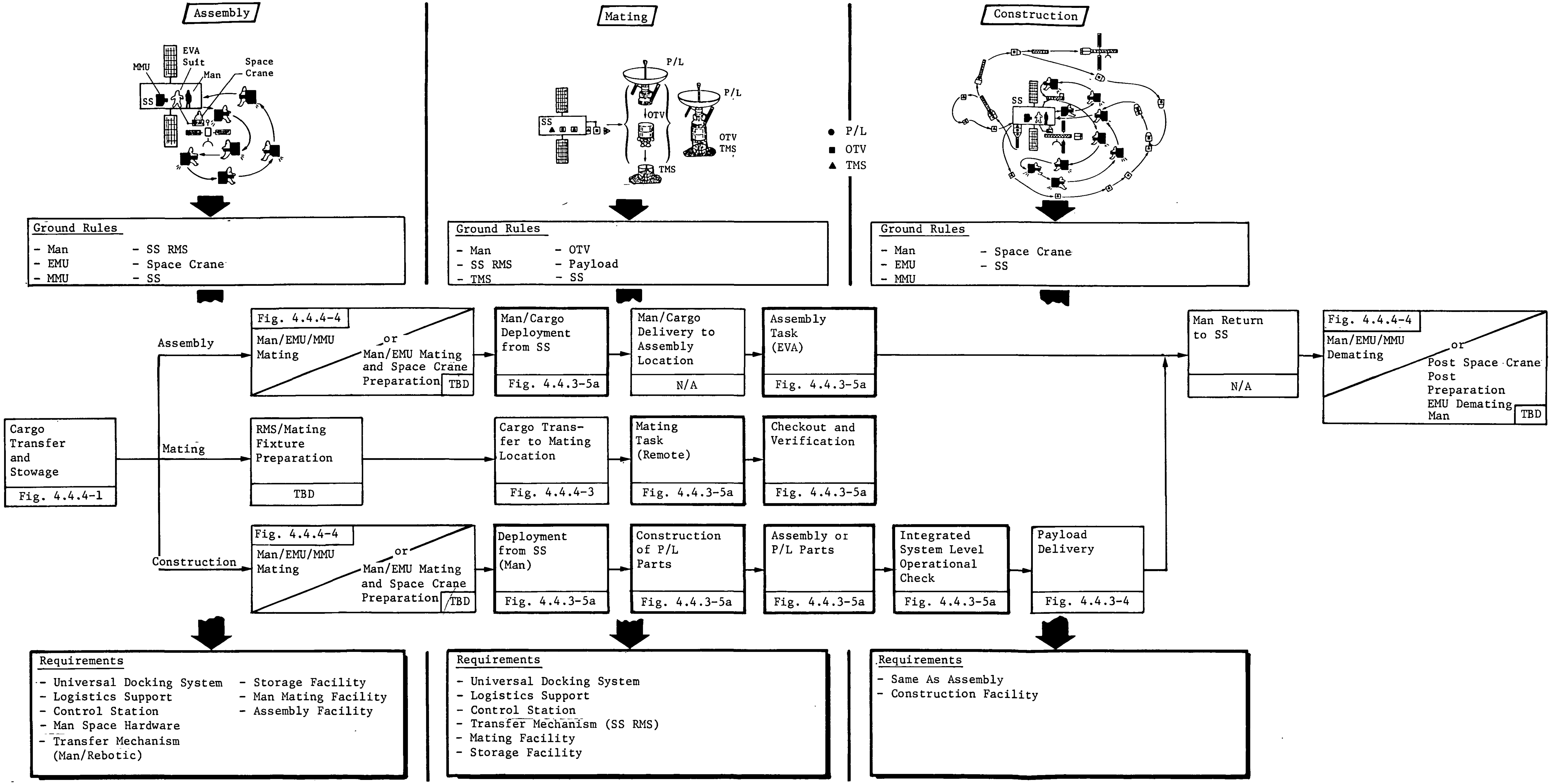

Figure 4.4.3-5 Payload Assembly, Mating, and Construction Capability Scenarios and Functional Definitions

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Table 4.4.3-9 Ground Rules for Payload Assembly, Mating, and Construction

Hardware	Requirements
Payload	- All payload components will be at the SS prior to the assembly, mating, or construction operation. This will reduce the additional loads induced to the payload by an orbiter docking. (See trade #1 and #2.)
Space Station	- Will provide a designated facility for handling and assembling/mating/constructing the payloads.

Table 4.4.3-10 Required Trade Studies for Payload Assembly, Mating, and Construction

Hardware	Trade Questions
Payload	1. Depending on the configuration of the SS, how large can a payload become while attached to the SS before it begins to perturb the stability of the SS or shadows the solar arrays? 2. Study the best way to attach two components together (remote vs. man).

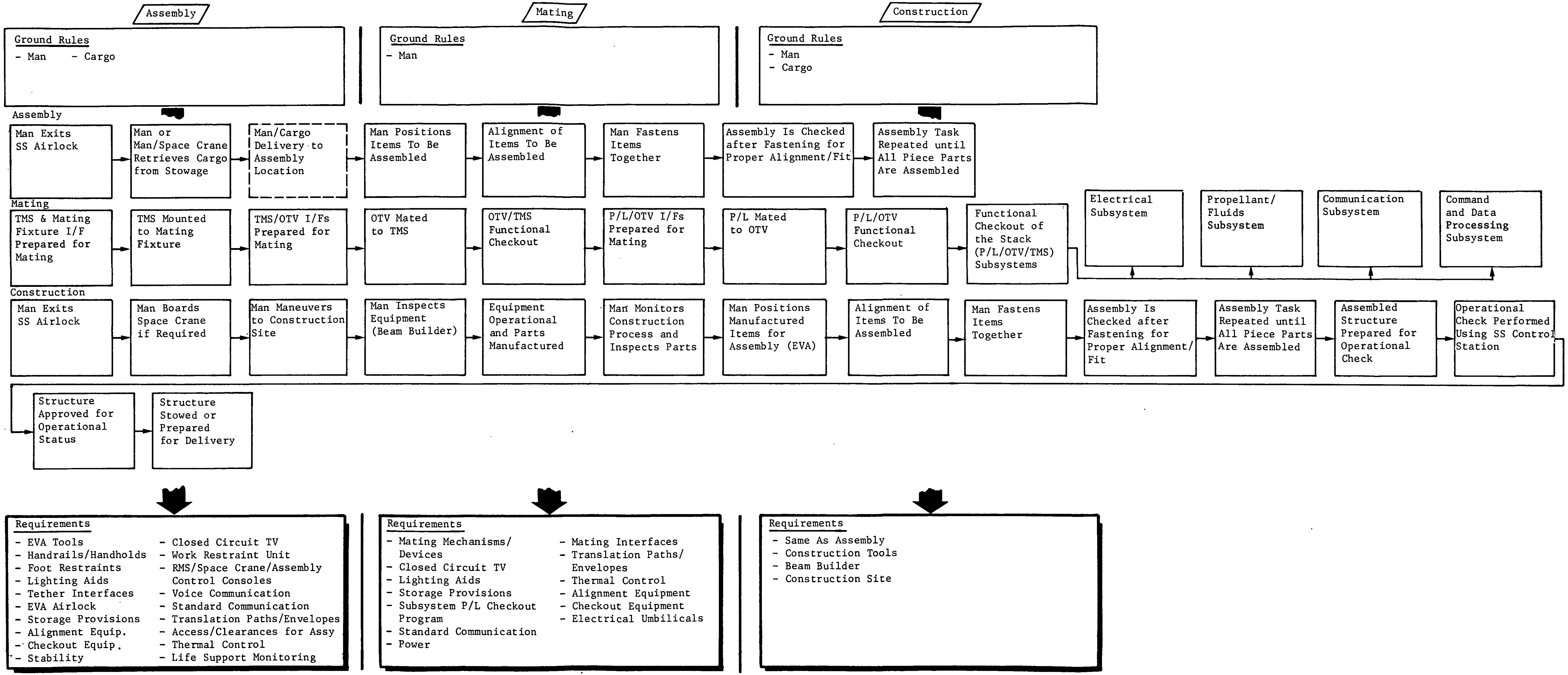

Figure 4.4.3-5a Payload Assembly, Mating and Construction Detailed Requirements Definitions

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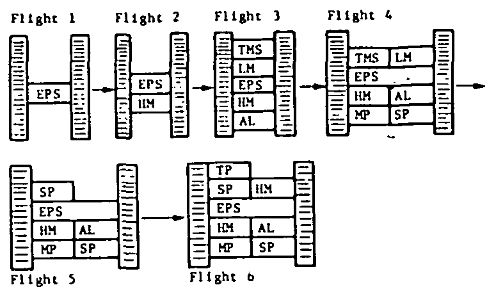
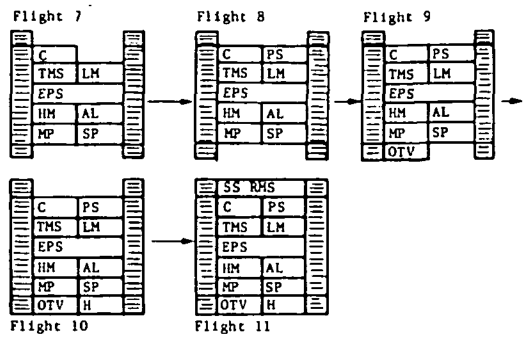
Initial Assembly

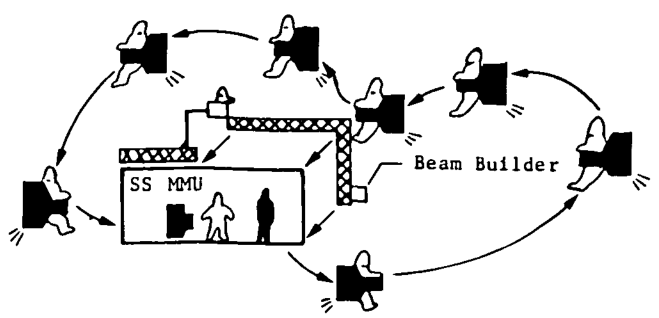


LM - Logistics Module
HM - Habitation Module
EPS - Electrical Power System (Plus Core)
AL - Airlock
SP - Scientific Payload
MP - Materials Processing
TP - Thermal Panels
C - Core
PS - Propellant Storage
H - Hangar

Evolution



Construction



Ground Rules (Initial Assembly)
- Orbiter
- Ground Control
- TMS

Ground Rules (Evolution)
- Orbiter
- Ground Control
- TMS

Ground Rules (Construction)
- Man
- EMU
- MMU
- Space Crane

Initial Assembly

- Flight 1: Deploy EPS Module/Core from Orbiter — Fig. 4.4.3-6a
- Flight 2: STS Dock Deploy/Berth Habitat Module 1 to Core — Fig. 4.4.3-6a
- Flight 3: STS Dock Deploy/Berth Airlock to Habitat Module — Fig. 4.4.3-6a
- Flight 3: Deploy/Berth Logistics Module to Core — Fig. 4.4.3-6a
- Flight 3: Deploy/ Berth TMS to Logistics Module — Fig. 4.4.3-6a
- Flight 4: STS Dock Deploy/Berth Materials Process to Core — Fig. 4.4.3-6a
- Flight 4: Deploy/Berth 1st Scientific Payload to Core — Fig. 4.4.3-6a
- Flight 5: STS Dock Deploy/Berth 2nd Scientific Payload to Core — Fig. 4.4.3-6a
- Flight 6: STS Dock Deploy/Berth Habitat Module to Core — Fig. 4.4.3-6a
- Flight 6: Install Additional Thermal Panels — Fig. 4.4.3-6a → (A)

Flight 3 2- to 4-Man Crew
Flights 4, 5, 6 4-Man Crew

Evolution

- (A) → Flight 7: STS Deploy/ Berth 2nd Core to Airlock — Fig. 4.4.3-6a
- Flight 7: 2nd Core/ Airlock Reberthed to Habitat Modules — Fig. 4.4.3-6a
- Flight 7: Install Additional EPS Panels — Fig. 4.4.3-6a
- Flight 7: Reberth Logistics Module/TMS to Upper Core — Fig. 4.4.3-6a
- Flight 8: STS Dock Deploy/Berth Prop. Storage Tank to Lower Core — Fig. 4.4.3-6a
- Flight 8: Reberth Materials Processing from Lower Core to Upper Core — Fig. 4.4.3-6a
- Flight 9: Transfer Material Processing Payloads to Boom — Fig. 4.4.3-6a
- Flight 9: Deploy/Berth OTV to Lower Core — Fig. 4.4.4-6a
- Flight 10: - LM Resupply - Crew Xfer - Hangar Assemble to Lower Core — Fig. 4.4.3-6a
- Flight 11: SS RMS Attached to Hangar — Fig. 4.4.3-6a

Flights 7, 8, 9, 10, 11 8-Man Crew

Construction

- Cargo Transfer and Storage — Fig. 4.4.4-1
- Man/EMU/MMU Mating — Fig. 4.4.4-4 or Man/EMU Mating and Space Crane Preparation — TBD
- Deployment from SS (Man) — Fig. 4.4.3-6a
- Construction of SS Structure — Fig. 4.4.3-6a
- Assembly of SS Structure — Fig. 4.4.3-6a
- Integrated System Check — Fig. 4.4.3-6a
- Assembly of Structure to SS — Fig. 4.4.3-6a
- Integrated System Check — Fig. 4.4.3-6a
- Retrieval (Man) — N/A
- Man/EMU/MMU Demating — Fig. 4.4.4-4 or Space Crane Post Prep Man/EMU Demating — TBD

Requirements (Initial Assembly)
- Universal Docking Sys
- Logistics Support
- Control Station
- Berthing Sys
- Transfer Mechanism (Orbiter RMS/TMS)

Requirements (Evolution)
- Same As Initial Assembly
- Transfer Mechanism (Orbiter RMS/TMS/SS RMS)

Requirements (Construction)
- Universal Docking System
- Logistics Support
- Control Station
- Man Space Hardware
- Transfer Mechanism
- Transfer Mechanism (Man/Robotic)
- Construction Facility

Figure 4.4.3-6
Space Station Initial Assembly, Evolution, and Construction Capability Scenarios and Functional Definitions

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Table 4.4.3-11 Ground Rules for Space Station Initial Assembly, Evolution, and Construction

Hardware	Requirements
Space Station	- The initial SS will be manned when shuttle tended. - The initial SS will be ground controlled, gradually phasing into SS control as the SS evolves.
STS	- The STS will be the launch vehicle used to bring up the SS elements.

Table 4.4.3-12 Required Trade Studies for SS Initial Assembly, Evolution, and Construction

Hardware	Trade Questions
	None Identified

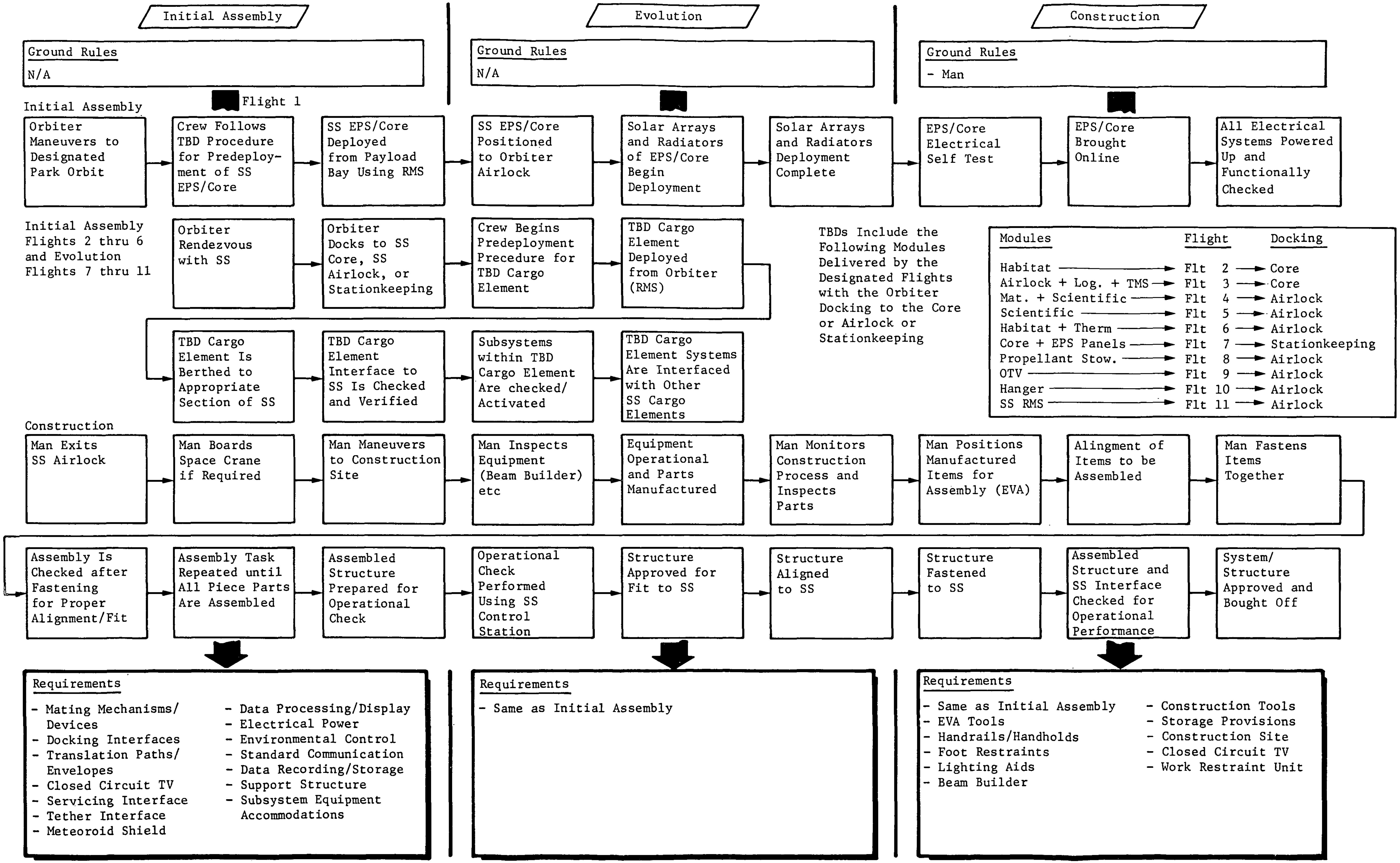

Figure 4.4.3-6a Space Station Initial Assembly, Evolution, and Construction Detailed Requirements Definitions

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4.4.4 Standard Functional Definitions

After a thorough examination of the previously mentioned capability scenarios and functional definitions a pattern was identified. This pattern was the repetition of certain capability definitions that occurred across most of the scenarios. To simplify the analysis process, these repetitive definitions have been grouped here and are individually broken down into the next level of detailed functional requirements. Also included are the facility, hardware and software requirements that were derived from each definition while keeping in mind all of the scenarios they appear in. The following paragraphs consists of a brief description of each of the standard function definitions.

1. Cargo Transfer and Storage (see Figure 4.4.4-1) - The functional requirements for this analysis have been split into two separate flows. The first is cargo delivered to the space station by the Orbiter, Aft Cargo Carrier or shuttle derived vehicle and the second is cargo returned to earth from space station via the Orbiter. The cargo mentioned can be space station and/or user hardware. While the cargo is waiting to be used for a mission or to be returned to earth, it will be stored in an enclosed stowage facility for thermal protection. This facility is either internal or external to the space station. The cargo will be removed from or installed in the Orbiter by the SS RMS or if small enough it will be transferred by the crew through the Orbiter cabin directly to the space station. The transferring of cargo external to the space station will be accomplished by the SS RMS.

2. Servicer Servicing (see Figure 4.4.4-1) - This analysis describes the functions required for servicing a dedicated servicer. Depending on the nature of the mission there will be a dedicated servicer for module changeout, fluid replenishment or contamination control. These services will require servicing prior to departing on their assigned missions. The flow illustrated shows preparation of a servicer for either module changeout or fluid replenishment. Contamination control has not been shown because the preparation functional requirements are (TBD). In order to service a servicer, we will need a servicing facility equipped to transfer fluids and install replacement hardware on the servicer. The SS RMS will be used for all equipment transferring and robotic tasks.

3. TMS_1/OTV/TMS_2/(TBD) Mating (see Figure 4.4.4-1) - In this analysis each vehicle's interface is prepared for mating after it has been transferred by the SS RMS to the mating site. The mating fixture itself is also readied for the mating tasks. After the preparations are completed, TMS_1 is mounted in the mating fixture first. The OTV is then mated to TMS_1, TMS_2 is mated to the OTV, and soon. Once the mating task has been completed, a system function check is performed for each mating operation and then for the total stack. This mating flow can be altered depending upon which vehicles are to be stacked together. (i.e., TMS_1/Servicer or TMS/OTV/P/L).

4. Initial Deployment from SS (see Figure 4.4.4-2) - To deploy a spacecraft and propulsion device(s) from the space station to a launch stand-off-site the SS RMS grapples the stack and transfers it to a designated deployment site. Once there, the RMS imparts a ΔV on the stack so that it can drift a safe distance away from the SS. TMS_1 then transfers the stack to the launch stand-off-site with its RCS. Then TMS_1 separates from the OTV and returns to the SS where it is berthed with the aid of the RMS and serviced (module changeout/fluid replenishment) for future use. The TMS_1 will shut down its RCS engines prior to arrival at space station and drift to an assigned position to be grappled by the SS RMS. TMS_1 will be controlled directly by space station controls.

5. (TBD) Delivery by OTV (see Figure 4.4.4-2) - Once the OTV and attached vehicle(s) are delivered to the launch stand-off-site a final systems check is performed by the SS. Once the check is completed the SS starts the sequence of commands required to start the OTV on its task of transferring the vehicle(s) to their desired orbit. Once there the vehicle(s) separate from the OTV and OTV will then perform one of two operations depending on the assigned mission. The OTV will either station keep in its present orbit while waiting for the return of the spent vehicle(s) or return to the designated launch stand-off-site for rendezvous and docking with TMS_1. TMS_1 does all the final maneuvering and docking operations. Space station ground control will monitor and command these operations through TDRSS when not in line-of-sight from the SS.

6. Retrieval by OTV (see Figure 4.4.4-2) - In this flow the OTV is either station keeping or transferring from the designated launch stand off site (see previous paragraph). The OTV will rendezvous with the waiting vehicle(s). Once in position the vehicle(s) will dock to the OTV which will then transfer the stack back to the launch stand-off-site and await TMS_1. Space station ground control will monitor and command this operation through a data link with TDRSS when not in line-of-sight from the SS.

7. Final TMS_1/SS RMS Retrieval (see Figure 4.4.4-3) - A function check is performed on TMS_1 prior to SS RMS grappling to it. The RMS then transfers and deploys TMS_1 similar to the operations mentioned in paragraph 4. Once deployed its thrusters fire and maneuver TMS_1 to the stand-off launch stand-off-site for rendezvous and docking to the OTV or OTV/stack. After docking is completed, TMS_1 then returns the stack to the SS where the RMS attaches to the stack and transfers it to the mating site. TMS_1 will shut down its thrusters prior to arrival at space station and drift inti the RMS's each. TMS_1 is controlled and monitored by space station directly.

8. TMS_1/OTV/TMS_2/(TBD) Demating (see Figure 4.4.4-3) - In this flow prior to the arrival of the stack to be demated, the mating fixture and associated facilities are prepared. The vehicle(s) are then transported to the mating site where TMS_1 interface is prepared for mating to the fixture. Once this is done, TMS_1 is then berthed to the mating fixture. The last vehicle mated to the stack in paragraph 3 is now the first vehicle demated and so on for the rest of the stack. Once a vehicle is demated, it is then inspected, serviced and transferred to and berthed in its designated facility. The mating fixture is the last to be inspected, serviced and secured for the next mission. The SS RMS is the hardware used for demating, transferring and berthing all vehicles. This demating flow can be altered depending upon which vehicles have been stacked in paragraph 3.

9. Transfer P/L to (TBD) Facility (see Figure 4.4.4-3) - All payload transferring on space station is accomplished with SS RMS. The RMS attaches to a payload through the use of a universal grappling mechanism/fixture. Once the payload has been grappled, it will then be released from the mating fixture. A load will be applied and the RMS/payload attachment verified. Once verified the RMS lifts the payload off of the mating fixture and transfers it to a designated facility. Once at the designated facility the P/L's and mating fixture's interfaces are prepared for mating. Then the RMS positions the P/L over the fixture and any alignment tools are attached to the fixture P/L. Now the RMS begins to lower the P/L slowly while closed circuit TV monitors all operations. Once P/L contact has been made and verified the mating fixture is attached to the P/L by a universal docking mechanism. The RMS then releases the P/L and is stowed away from the P/L awaiting future use. This transferring task can be modified for any hardware, not just a P/L.

10. Crew/EMU/MMU Mating (see Figure 4.4.4-4) - This flow is self-explanatory and does not need to be explained any further.

11. Man/EMU/MMU Demating (see Figure 4.4.4-4) - This flow also is self-explanatory and does not require to be explained any further except for the post EVA servicing tasks. For both the EMU and MMU the servicing requirements are similar. Both components are visually and mechanically inspected and then serviced by either replacing faulty parts or replenishment of their tanks with the appropriate fluids.

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Table 4.4.4-1 Ground Rules for Cargo Transfer/Stowage, Servicer Servicing, and TMS_1/OTV/TMS_2/(TBD) Mating

Hardware	Requirements
Storage	- Will provide environmental control for payloads. - Will be located on the SS such that the varying mass would not disturb the stability of the SS. (See trade #1.)
STS	- The STS will be the launch vehicle that provides the SS with supplies and payloads.
SS	- Vehicle mating will be done remotely, commanded from the SS control station.

Table 4.4.4-2 Required Trade Studies for Cargo Transfer/Stowage, Servicer Servicing, and TMS_1/OTV/TMS_2/(TBD) Mating

Hardware	Trade Questions
Storage Facility	1. Could cargo that is very large be stored away from the SS in a station keeping mode and be accessed to quickly and easily?

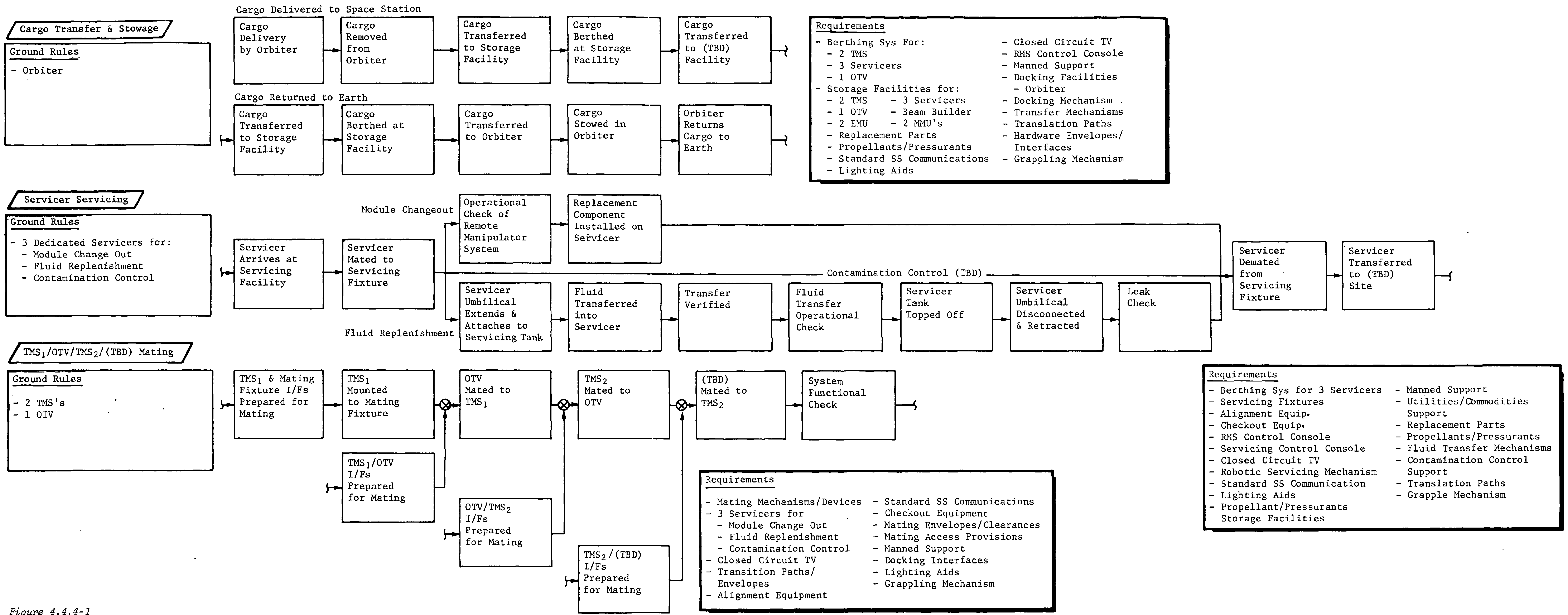

Figure 4.4.4-1
Cargo Transfer and Stowage, Servicer Servicing and TMS_1/OTV/TMS_2/(TBD) Mating Detailed Requirement Definitions

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Table 4.4.4-3 Ground Rules for Initial Deployment from SS, TBD Delivery and Retrieval by an OTV

Hardware	Requirements
Space Station	- Will be a dedicated deployment/retrieval site on board the SS. - The OTV will be ignited at a standoff launch site to prevent SS contamination from the OTV exhaust (see trade #1).

Table 4.4.4-4 Required Trade Studies for Initial Deployment from SS, TBD Delivery and Retrieval by an OTV

Hardware	Trade Questions
Space Station	1. Determine what a safe distance is between the SS and OTV during launch.

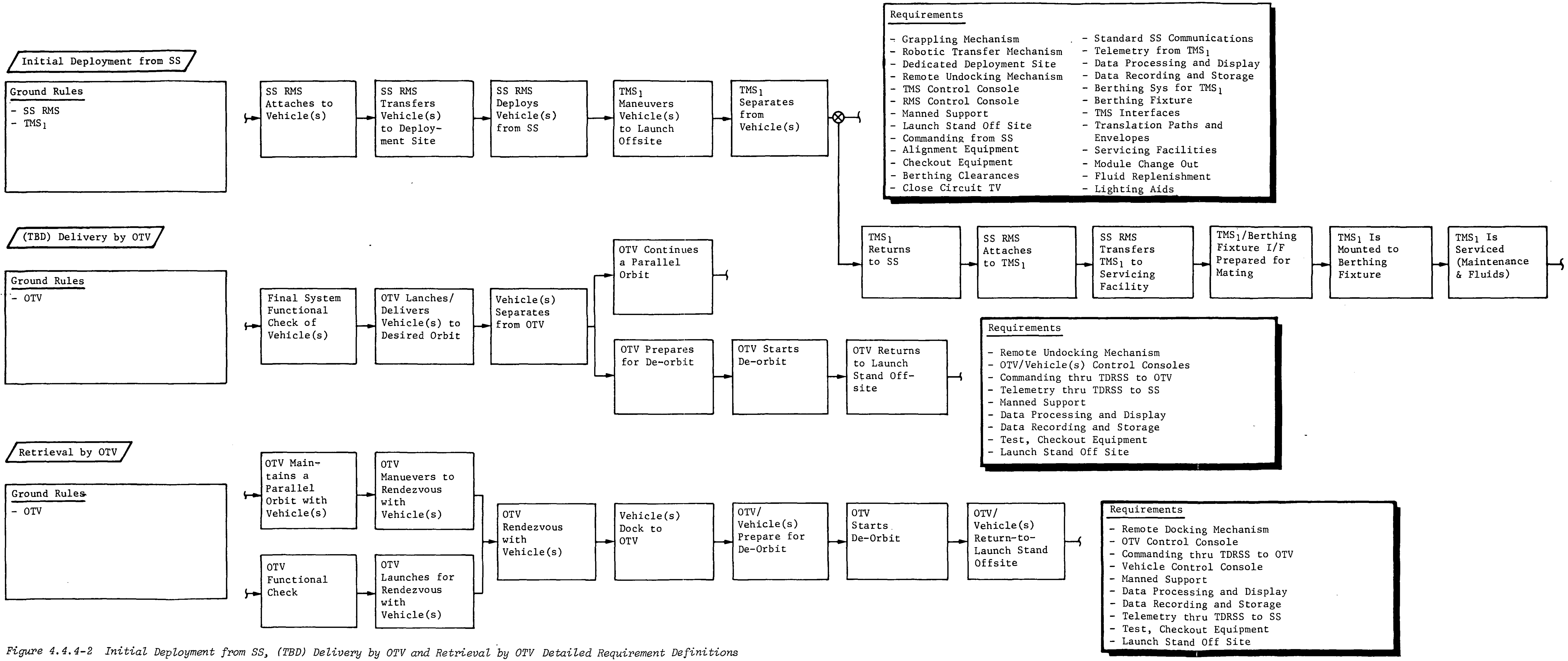

Figure 4.4.4-2 Initial Deployment from SS, (TBD) Delivery by OTV and Retrieval by OTV Detailed Requirement Definitions

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Table 4.4.4-5 Ground Rules for Final TMS_1/SS RMS Retrieval, TMS_1/OTV/TMS_2/TBD Demating and Payload Transfer

Hardware	Requirements
Space Station	- Will be a dedicated deployment/retrieval site on board the SS. - The TMS will return the OTV and attached vehicles (servicer, P/L) to the SS from a designated rendezvous position. - Demating and vehicle transfer to berthing sites will be done remotely, commanded from the SS control station.

Table 4.4.4-6 Required Trade Studies for Final TMS_1/SS RMS Retrieval, TMS_1/OTV/TMS_2/TBD Demating, and P/L Transfer

Hardware	Trade Questions
	None Identified

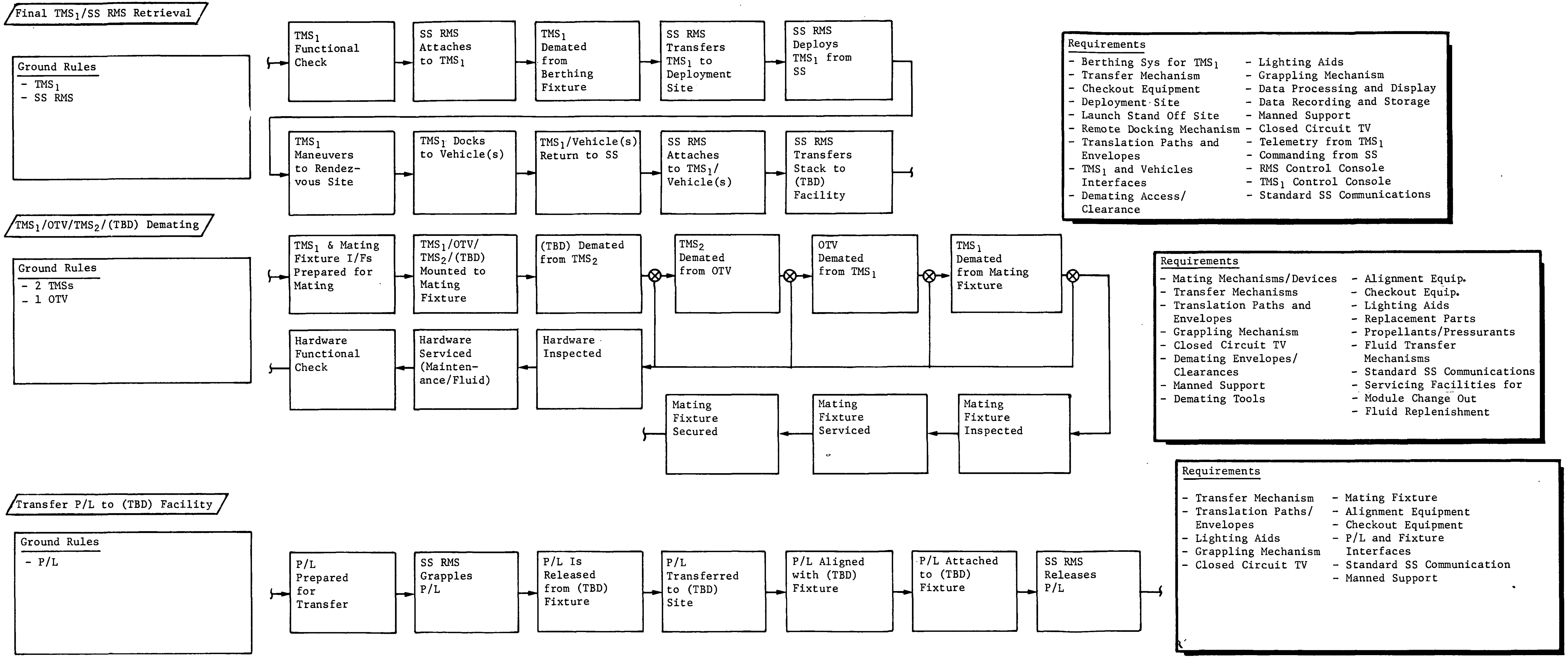

Figure 4.4.4-3 Final TMS_1/SS RMS Retrieval, TMS_1/OTV/TMS_2/(TBD) Demating and Transfer P/L to (TBD) Facility Detailed Requirement Definitions

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Table 4.4.4-7 Ground Rules for Crew/EMU/MMU Mating and Demating

Hardware	Requirements
EMU	- Pressure differential between the SS and the EMU will be small to prevent the need for prebreathing by the crew before going EVA.
MMU and EMU	- Post-EVA refurbishment procedures will be established to prepare the equipment for the next EVA.

Table 4.4.4-8 Required Trade Studies for Crew/EMU/MMU Mating and Demating

Hardware	Trade Questions
Space Station	1. Determine where EVA equipment should be stored,in the EVA airlock or in the habitability module just before the airlock. The smaller the airlock the less atmosphere is lost to space.

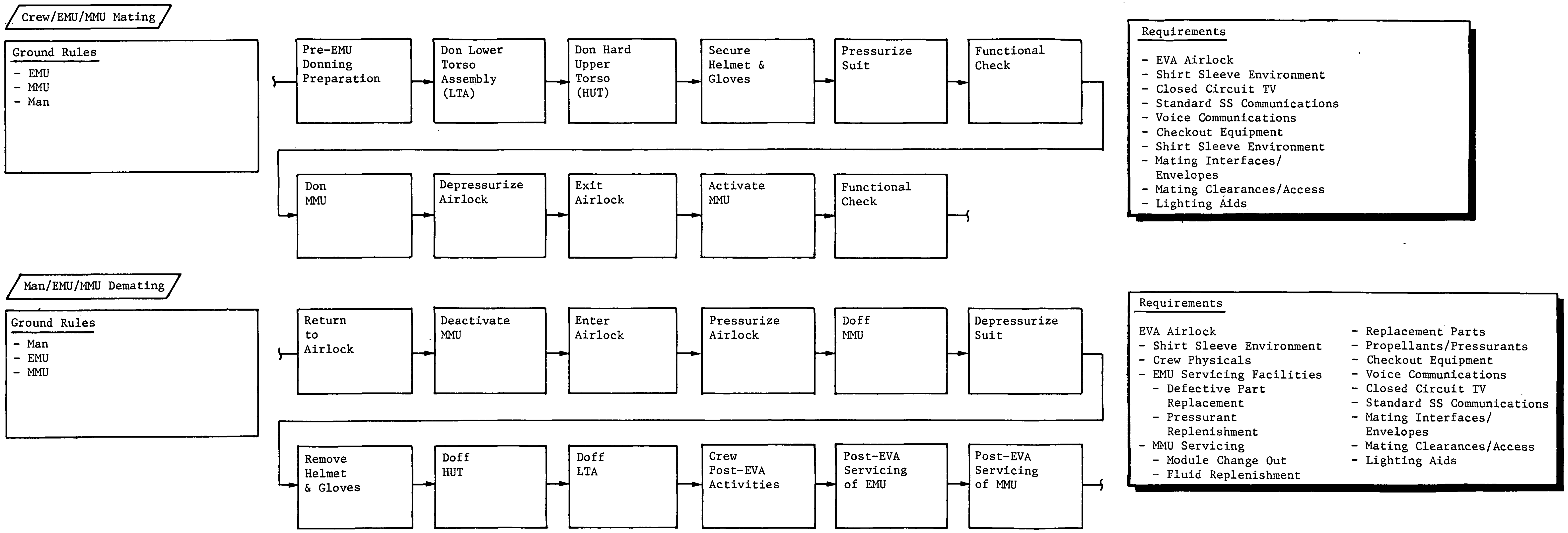

Figure 4.4.4-4 Crew/EMU/MMU Mating and Man/EMU/MMU Demating Detailed Requirement Definitions

5.0 TRACEABILITY ANALYSIS

The validity of the missions and requirements developed for the space station are strongly dependent on the traceability of the user data to specific, identified sources. This is the principal objective of the traceability system. User validity is maintained by regular visits and contacts with the user community through mission specialists as described in Volume II of this report.

As each mission was identified through the user community and the various mission models, it was assigned a unique two-letter identification code; this code was also used as an identifying subscript for each of the mission characteristics, so that as mission characteristics were transformed into space station requirements, those requirements could be traced to a specific mission source.

During the course of the study, the basic mission model has evolved from an unrestricted compilation of missions from several sources (the MMC Composite Mission Model) through the application of affordability, capture criteria, and combination of related or redundant objectives, to the present Space Station Mission Model. The Space Station Mission Model has been coded into the NASA Langely Research Center format and entered into the NASA LaRC system. Figure 5-1 is a traceability matrix showing the correspondence between missions identified by two-letter MMC Composite Mission Model codes, across the top, and the eight-place alphanumeric LaRC codes for the Space Station Mission Model, classified by mission category. This matrix graphically shows how certain missions have been combined, and the tabular data below each category identify those MMC Composite Mission Model missions that were eliminated or superseded by other missions. Table 3.1.4-1, presented in Section 3, is a tabular presentation of mission identifiers from the MMC Composite Mission Model, the Space Station Mission Model, and the LaRC data base.

The mission identifier subscript is attached to each of the mission support requirements identified in Tables 3.3.4-1 and 3.4.3-1 of this volume. These subscripts are used to determine the user sources from which the integrated user support requirements were derived. For example, the five satellite retrieval missions required in 1993 come from the following users: DU, BA, DP, DM and FK. Similarly, the 10 Kw experiment support power requirement at the space station in 1993 comes from the following users: AT, AV, HX, GS, GT, GM, GL, GP, GQ. In this way, space station user support requirements can be modified and updated in near real time as the Space Station Mission Model evolves.

a. Astronomy Missions

SPACE STATION MISSION MODEL	LRD Code	Composite Mission Model																			
Astronomy Missions		DU	FA	AM	AP	EZ	EV	AT	AU	AL	CF	EN	JF	AK	AN	AJ	AR	EQ	ER	AX	AS
Cosmic Background Explorer (COBE)	0001	X																			
Far Ultraviolet Spectroscopy Explorer	0002		X																		
X-Ray Timing Explorer	0003			X																	
Extreme Ultraviolet Explorer	0004				X																
Gamma Ray Transient Explorer	0005					X															
Heavy Nuclei Explorer	0006						X														
Starlab	0007							X													
Shuttle Infrared Telescope Facility	0008								X												
Large Area Modular Array of Reflectors	0009									X											
Orbiting Very Long Baseline Interferometer	0010										X										
Orbiting Infrared Submillimeter Telescope	0011											X									
Faint Object Telescope	0012												X								
Space Telescope	0013													X							
Advanced X-Ray Astrophysics Facility	0014														X						
Large Deployable Reflector	0015															X					
Gamma Ray Observatory	0016																X				
Coherent Optical System (COSMIC)	0017																	X			
Thinned Aperture Telescope	0018																		X		
Cosmic Ray Observatory	0019																			X	
X-Ray Observatory	0020																				X

Not Included in SSMM:

CA	EO	ET	EY	FO	FG
DS	EP	EW	FB	FE	FH
EM	ES	EX	FC	FF	

Figure 5-1 Mission Traceability Matrix

b. Planetary Exploration Missions

SPACE STATION MISSION MODEL Planetary Exploration Missions	LRC Code	Composite Mission Model										
		DH	DI	FR	GV	GW	GX	FJ	FU	BY	FV	BU
Venus Radar Mapper	0101	X										
Comet Rendezvous	0102		X									
Mars Geochemistry/Climatology Map	0103			X								
Titan Probe	0104				X							
Mars Probe Network	0105					X						
Venus Atmospheric Probe	0106						X					
Lunar Orbiter	0107							X				
Comet Sample Return	0108								X			
Main-Belt Asteroid Multirendezvous	0109									X		
Earth Approaching Asteroid Rendezvous	0110										X	
Saturn Probe/Orbiter	0111											X

Not Inluded in SSMM:

BJ	FW	FZ
DG	FX	GA
FT	FY	GC

Figure 5-1 Mission Traceability Matrix (Cont.)

c. Solar Physics Missions

SPACE STATION MISSION MODEL Solar Physics Missions	LRC Code	Composite Mission Model							
		BA	BB	DO	AQ	JG	BJ	AO	AV
Solar Optical Telescope	0200	X							
Solar Soft X-Ray Telescope Facility	0201		X						
Pinhole Occulter Facility	0202			X					
Advanced Solar Observatory	0203				X				
Solar Shuttle Facility	0204					X			
Solar Interplanetary Satellite	0205						X		
Solar Interior Dynamics Mission	0206							X	
Solar Corona Explorer	0207								X

Not Included in SSMM:
BC
EC
FL

Figure 5-1 Mission Traceability Matrix (Cont.)

d. Space Physics Missions

SPACE STATION MISSION MODEL Space Physics Missions	LRC Code	Composite Mission Model							
		JE	GB	AZ	JH	BI	EU	DN	DP
Space Plasma Effects Upon Large Spacecraft	0400	X							
Large SC Impact Upon Proximate Space Plasma	0401		X						
Initial Solar Terrestrial Observatory (ISTO)	0402			X					
Advanced Solar Terrestrial Observatory (ASTO)	0403			X					
Geosynchronous Solar Terrestrial Observatory (GEOSTO)	0404			X					
Very Large Radar	0405				X				
OPEN	0406					X			
Advanced Interplanetary Explorer	0407						X		
Plasma Turbulence Explorer	0408							X	
Chemical Release Module Facility	0409								X

Not Included in SSMM:
BX
DQ

Figure 5-1 Mission Traceability Matrix (Cont.)

e. Life Sciences Missions

SPACE STATION MISSION MODEL Life Sciences Mission	LRC Code	Composite Mission Model																									
		DJ	EA	GK	GL	GM	ED	EE	BG	DN	GS	GT	GU	EB	EC	EF	EJ	EK	CO	GF	GC	CP	GH	GI	GJ	GD	GE
Operational Medicine	0601	X																									
Cardiovascular Physiology	0602		X	X	X	X																					
Vestibular/Neurophysiology	0603						X	X																			
Osteology	0604								X																		
Musculoskeletal Physiology	0605									X																	
Hematology/Immunology	0606										X	X	X														
Fluid/Electrolytes	0607													X													
Metabolism (Endocrinology, Ca^{++})	0608														X												
Embryology/Developmental Physiology	0610															X	X	X									
Psychology/Behavior	0611																		X								
Radiation Biology	0612																			X	X						
Basic Space Biology	0614																					X					
CELSS	0615																						X	X	X		
Botany	0616																									X	X

Not Included in SSMM:

CM	CR	DL	FN	GP
CN	CS	DM	GN	GR
CQ	DK	FM	GO	

Figure 5-1 Mission Traceability Matrix (Cont.)

f. Earth Observations Missions

SPACE STATION MISSION MODEL Earth Observation Missions	LRC Code	Composite Mission Model																								
		EI	JK	BZ	AW	FJ	JL	JM	JC	JD	BH	JB	BM	CZ	DW	FI	FK	BL	CD	CE	CY	EG	DY	CW	CX	JA
Feature I.D. End Location Experiment	0700	X																								
LAMMR	0701		X																							
Stero Visual Imager	0702			X																						
Earth Radiation Budget	0703				X																					
Coastal Zone Scanner	0704					X																				
Ocean Microwave Package	0705						X																			
Scatterometer	0706							X																		
Tethered Magnetometer	0707								X																	
Gravity Gradiometer	0708									X																
Ocean Topography Experiment	0709										X															
Geosynchronous Satellite Intercalibration	0710											X														
Thermal Infrared Imager	0711												X	X												
WINDSAT	0712														X	X										
CLIR	0713																X									
Imaging Spectrometer	0714																	X	X	X	X	X				
Microwave Radiometer	0715																						X			
Synthetic Aperture Radar	0716																							X	X	
Active Microwave	0717																									X
Microwave Passive 100	0718																						X			

Not Included in SSMM:

AA	BN	CH,CI	DB	DX
AB	BO	CJ	DL	DZ
AC,AD	BP	CK	DC	EH
AE,AF	BQ	CL	DD	FO
AG,AH	BR	CT	DE	FP
AY	BV	CU	DF	FQ
BD	BW	CV	DT	AI
BK	CB,CC	DA	DV	BE,BF
				CG

Figure 5-1 Mission Traceability Matrix (Cont.)

g. Materials Processing Missions

SPACE STATION MISSION MODEL Materials Processing Missions	LRC Code	Composite Mission Model														
		HH	HX	HS	HT	JN	HU	JO	JP	JQ	JA	JS	HY	HZ	JJ	HV
SS Materials Processing Lab	0801	X	X													
Acoustic Containerless Furnace	0802			X												
Electrostatic Containerless Furnace	0803				X											
Electromagnetic Containerless Furnace	0804					X										
Vapor Crystal Growth Facility	0805						X									
Crystals From Solution Facility	0806						X									
Electron Beam Furnace	0807							X								
Directional Solidifcation Furnace	0808						X									
Fluids/Chemical Process Facility	0809								X							
Fluid Experiment System	0810									X						
Gradient Furnace	0811										X					
Isothermal Furnace	0812											X				
Electrophoresis Separation	0813												X			
Bromine Phase Experiment	0814													X		
Combustion Research	0815														X	
Molecular Beam Epitaxy	0816															X

Not Included in SSMM:

HG	HM,HN	HE,HG
HI,HJ	HA,HB	
HK,HL	HC,HD	

Figure 5-1 Mission Traceability Matrix (Cont.)

h. Commercial Materials Processing Missions

SPACE STATION MISSION MODEL Commercial Materials Processing Missions	LRC Code	Composite Mission Model						
		HO	HP	HQ	HA	RK	JT	JU
MDAC - Electrophoresis	1801	X	X	X	X			
Monodisperse Latex Reactor	1802					X		
MPS Commercial Development Units	1803						X	
MPS Commercial Production Units	1804							X

Not Included in SSMM:
RB,RC

Figure 5-1 Mission Traceability Matrix (Cont.)

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i. Commercial Communications Missions

SPACE STATION MISSION MODEL Commercial Communications Missions	LRC Code	LV	MY	MD	NI	NJ	PG	PH	PI	PJ	OA	OB	NY	NZ	NM	NN	NQ	NR	NS	NT	NU	NV	OO	OP	OE	OF	OG	OH	QG	QH	QF	QI	QJ	PY	PC	PD	QM	QN	QZ	RA	QB	PK	PL	PO	PP	PQ	PR	OS	OT	OU	OV	PX	OK	OL	PV	PW	QD	QO	QP
Experimental Geostationary Platform	1001	X																																																									
Search and Rescue Mission	1002		X																																																								
Orbiting Deep Space Platform	1003			X																																																							
Intelsat VII	1004				X	X																																																					
Telesat-K-N	1004						X	X																																																			
Telesat F/O	1004								X	X																																																	
SBS F/O	1004										X	X																																															
Satcom F/O	1004												X	X																																													
Telstar-3 F/O	1004														X	X																																											
Westar F/O	1004																X	X																																									
Advanced Westar-2	1004																		X	X																																								
TDAS	1004																				X	X																																						
Galaxy F/O	1004																						X	X																																				
Syncom F/O	1004																								X	X																																		
G-Star F/O	1004																										X	X																															
SPC F/O	1004																												X	X																													
Msat	1004																														X																												
SBTS F/O	1004																															X	X																										
Mexsat F/O	1004																																	X																									
Satsol F/O	1004																																		X	X																							
Aussat F/O	1004																																				X	X																					
Italsat F/O	1004																																						X																				
Nordsat F/O	1004																																							X																			
Arabsat F/O	1004																																								X																		
Palapa F/O	1004																																									X	X																
Chicomsat	1004																																											X	X														
Regional Communications Satellites	1004																																													X	X												
Data Transmission Satellites F/O	1004																																															X	X										
Banking	1004																																																	X	X								
Mail F/O	1004																																																			X							
STC F/O	1004																																																				X	X					
DBS F/O	1004																							X	X																														X	X			
China DBTV	1004																																																								X		
Canada DBTV F/O	1004																																																									X	X

Not Included in SSMM: NA, NE,NF, NG,NH; NK,NL, NO,NP, NW,NX; OC,OD, OI,OJ, OM,ON; OQ,OR, OW,OX, OY,OZ; PA,PB, PE,PF, PM,PN; PS,PT, PV, QC; QK,QL, QQ,QR, QS,QT; QU,QV, QW,QX, QS,QT; QU,QV, QW,QX, QY; RJ, RD,RE, RF,RG; RA

Figure 5-1 Mission Traceability Matrix (concl)

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j. Technology Development Missions

SPACE STATION MISSION MODEL	LRC Code	Composite Mission Model																								
Technology Development Missions		LB	LC	MA	MB	LS	LQ	LR	LK	LT	KI	KK	KL	KM	KN	KP	KQ	KA	KS	KT	KX	KJ	KY	LJ	KO	LM
Thermal Shape Control Tech Dev	2001	X																								
Large Antenna Development	2002		X																							
Large Solar Concentrator	2003			X																						
Solar Pumped Lasers	2004				X																					
Laser-to-Electric Energy Conversion	2005					X																				
Laser Propulsion Test	2006						X																			
Solar Sustained Plasmas	2007							X																		
OTV Servicing Technology	2008								X																	
Solar Panel Technology	2009									X																
Fluid Management Technology	2010										X															
Low Thrust Propulsion Technology	2011											X														
Large Space Power System	2012												X													
Solar Array Plasma Effects	2013													X												
Advanced Radiator Technology	2014														X											
Attitude Control System Development	2015															X	X	X								
Antenna Range Facility	2016																		X							
Laser Comm Track and Range	2017																			X						
Structural Strain Monitors	2018																				X					
Fire Safety Technology	2019																					X				
Spacecraft Materials Technology	2020																						X			
Satellite Servicing Technology	2021																							X		
Large Structure Technology	2022																								X	
Tether Dynamics Technology	2023																									X

Not Included in SSMM:

KA	LI	LH	KE	KD	KV	ME	KU	LD
LO	LN	KB	LP	KZ	LU	KF	LE	LL
KW	KH	KC	MC	LA	LW	KG	LF	LZ

Figure 5-1 Mission Traceability Matrix (Cont.)

6.0 MISSION ANALYSIS AND PARAMETRIC STUDIES

6.1 DEFINITION

The purpose of the mission analysis and parametric studies is primarily to recommend a space station orbit (altitude and inclination) that would provide the greatest benefit in terms of reduced STS launches for a specific set of missions. The main parametric study effort is involved with the orbit inclination tradeoff of launching OTVs from the space station for various orbit inclinations as opposed to using the STS as the launching platform. This effort ties in directly with the costing of the various options and also provides a guideline for OTV sizing. Additional mission analysis considerations include launch window penalties, platforms, tethered body considerations, and OTV launch variations.

6.2 STS PERFORMANCE CONSIDERATIONS

The primary source for the STS performance was the data furnished by JSC (Ref 6-1) in the Space Station contract orientation meeting of September 1982. Additional information on extending the direct insertion capability from 28.5 deg inclination to 57 deg inclination was provided by Mr. C. Teixeira of JSC in October 1982 and is shown in Figure 6.2-1 and Table 6.2-1. The projected weight capabilities apply to the late 1980's and consider such improvements as the filament wound cases.

The infomation provided for WLS launches reflected data for an orbital inclination of 90 degrees. These data show a normal injected payload capability up to approximately 170 nmi, with Orbital Maneuvering System (OMS) kits required for higher altitudes and no currently available STS performance data on direct insertion capability at the high orbit inclinations.

Since one of the main uses for the STS performance data is in the inclination tradeoff analysis affecting cost, and since the OMS kits are not currently planned, Martin Marietta estimates were made to provide comparable direct insertion performance data at WLS. As shown in Figure 6.2-1, the direct insertion payload performance to 250 nmi altitude at 90 degrees was estimated to be 25,000 lb with a payload variation of -515 lb/deg at all altitudes for inclinations from 70 to 90 degrees.

Notice also that a projected maximum payload capability of 65,000 lb was assumed, corresponding to the original design landing abort limit. This compares with the current 43,000 lb to 48,000 lb range for a landing abort limit which is expected to improve by the late 1980s.

In addition to the cargo weight capability shown in Figure 6.2-1, nominal propellant scavenging from the external tank is utilized for STS flights going to the space station, as is discussed in section 6.4.

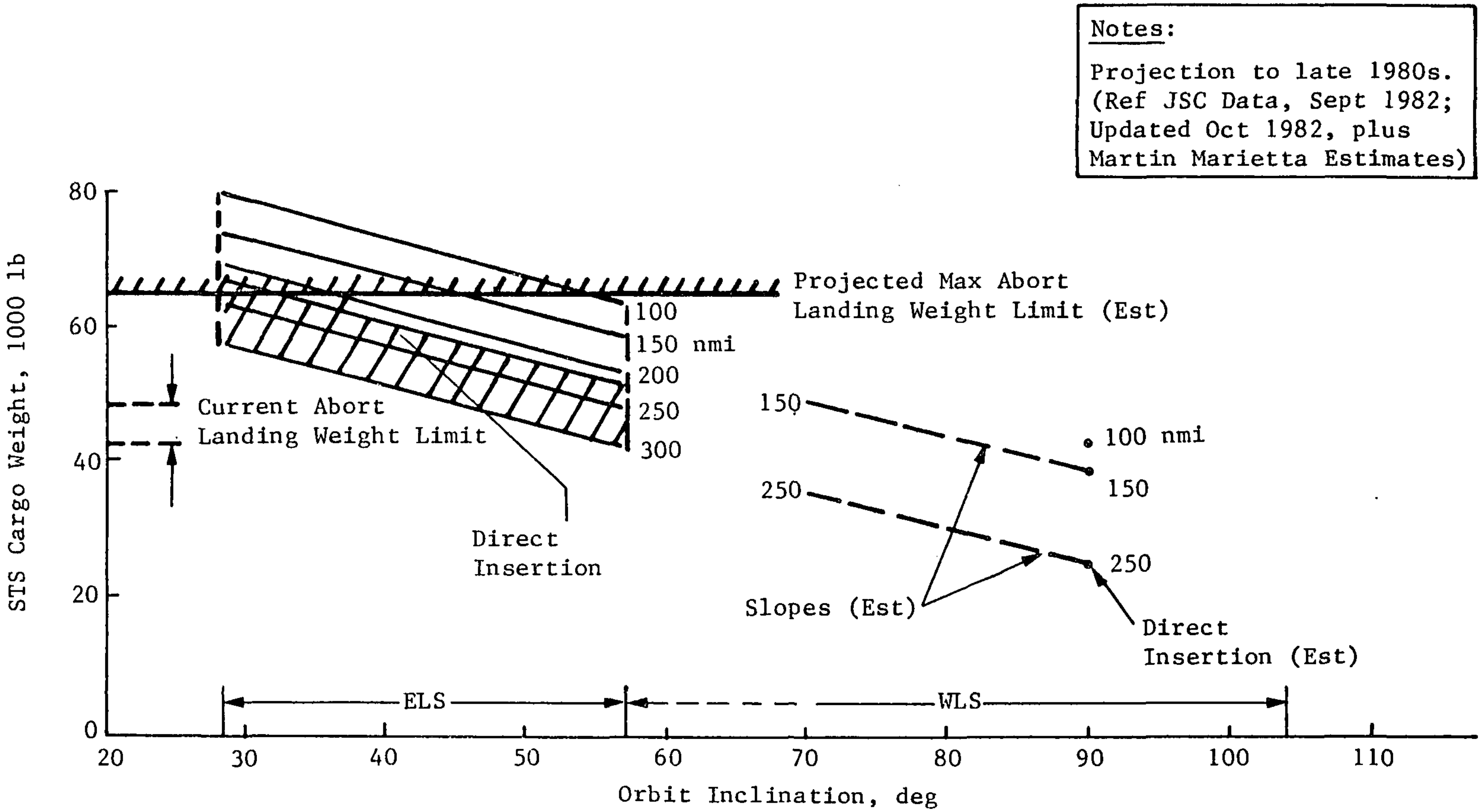


Figure 6.2-1 Projected Shuttle Cargo Weight Capability

Table 6.2-1 Summary of STS Performance Assumptions

Source	Item
JSC-Sept 82 Updated-Oct 82	Standard ascent cargo wt. capability to 210-220 nmi altitude at ELS (28.5 deg. incl. to 57 deg. incl.)
"	Standard ascent cargo wt. capability to 170 nmi altitude at WLS for 90 deg. incl.
"	Direct insertion cargo wt. capability from 210-220 nmi altitude to approximately 325 nmi altitude for ELS inclinations.
"	Current abort landing wt. limit of 43 to 48 klb with the prospect of improving by late 1980's.
MMC estimates Nov 82	Projected maximum abort landing wt. limit will improve to the original specified cargo wt. capability of STS (ie. 65 klb) by the late 1980's.
"	The direct insertion cargo wt. capability should equal approximately 25 klb for 250 nmi altitude at 90 deg. incl. at WLS.
"	A sensitivity of -515 lb/deg is assumed between 70 deg. and 90 deg. incl. at WLS.

6.3 SPACE STATION ALTITUDE SELECTION STUDIES

Selection of space station altitude is important to the overall space station study since cost tradeoffs are involved in STS performance and orbit propellant stationkeeping to overcome drag during the life of the station.

Atmospheric density profiles were selected to reflect the changing solar activity during the 11 year solar cycle and are presented in Figure 6.3-1. The extreme curves 1 and 3, from Reference 6-2, correspond to the highest and lowest densities that can normally be expected (durations of hours to a few days) and are useful for attitude control calculations.

Since the space station was assumed to have a 90 day lifetime (without orbit stationkeeping), a high solar activity density profile (curve 2) was selected from Ref 6-3 which corresponds to the maximum density expected for the worst 90-day period and was used for drag calculations. For comparison purposes the best 90-day period (minimum density curve 4) was selected from Ref 6-4 and shows an order of magnitude reduction in density during the solar cycle.

Propellant requirements were calculated for the design density condition previously selected, using a typical average space station area of 19,220 sq ft, a drag coefficient of 2.4 and assuming monomethyl hydrazine with a specific impulse of 230 sec. As shown in Figure 6.3-2, drag makeup propellant requirements vary from 600 lb per day at 160 nmi to under 30 lb per day at 280 nmi.

An altitude of 250 nmi is recommended since it provides approximately a 90 day lifetime with no drag makeup (under the worst density conditions) and would require about 46 lb/day of hydrazine or 4200 lb (5000 lb with margin) for a 90 day resupply period. For the low solar activity period, only one-tenth as much propellant is required (Figure 6.3-2). If a storable bi-propellant (N_2O_4/MMH) or cryogenic (LO_2/LH_2) system were used, propellant requirements would be reduced respectively to 74 and 49% of the values shown.

The major reasons for recommending a circular orbit altitude of 250 nmi are summarized in Table 6.3-1. In the addition to the above points concerning natural orbit lifetime and reasonable stationkeeping propellant requirements, the STS performance achievable by direct insertion (47,000 to 63,000 lb at ELS and 25,000 lb to 35,000 lb estimated at WLS) is quite significant.

An additional consideration is safety. By keeping the space station at 250 nmi, it is well above most of the traffic hazards including short orbit lifetime satellites and large debris caused by failures in the high traffic parking orbit region.

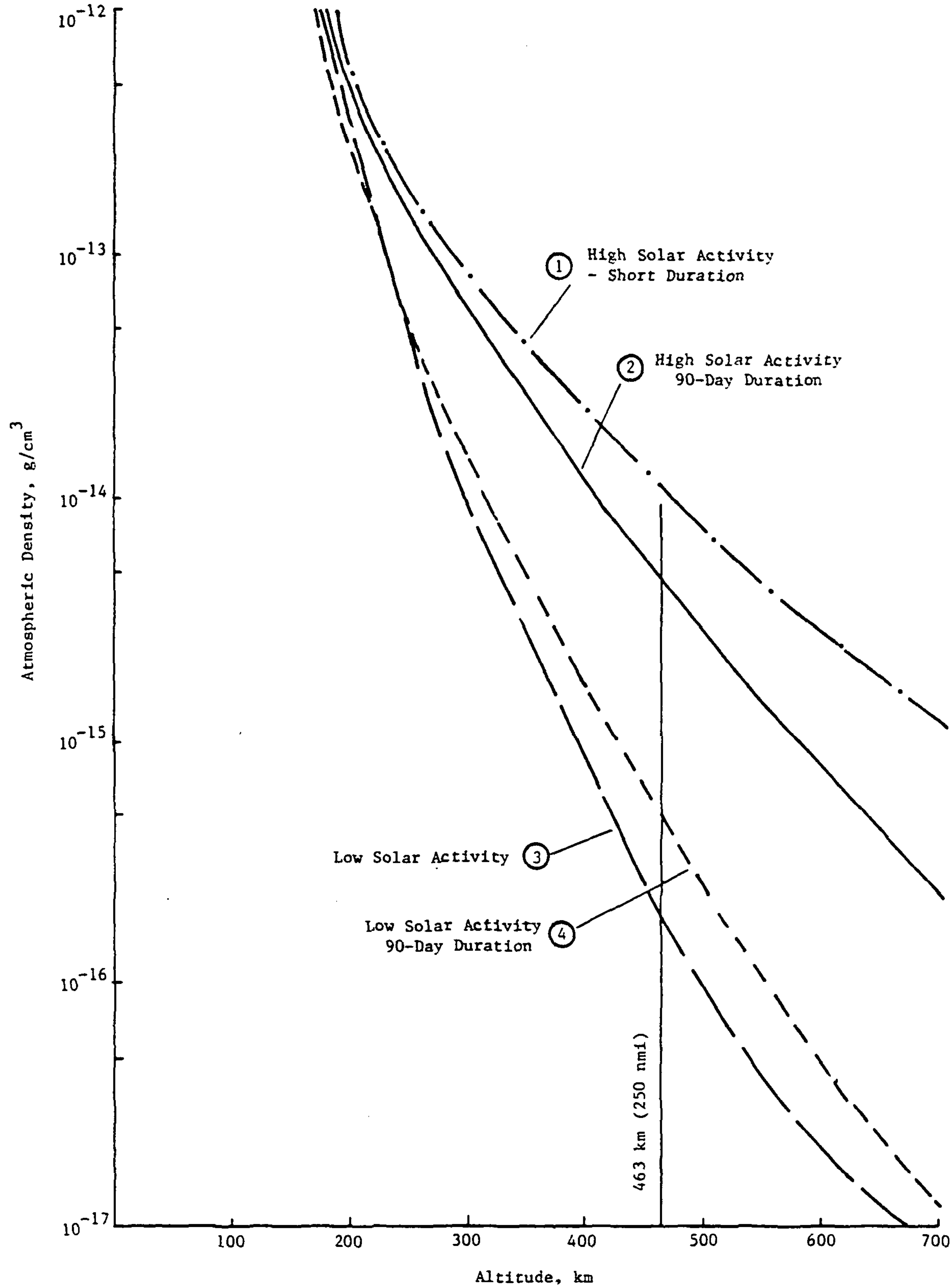


Figure 6.3-1 Selected Atmospheric Density Profiles for Space Station Studies

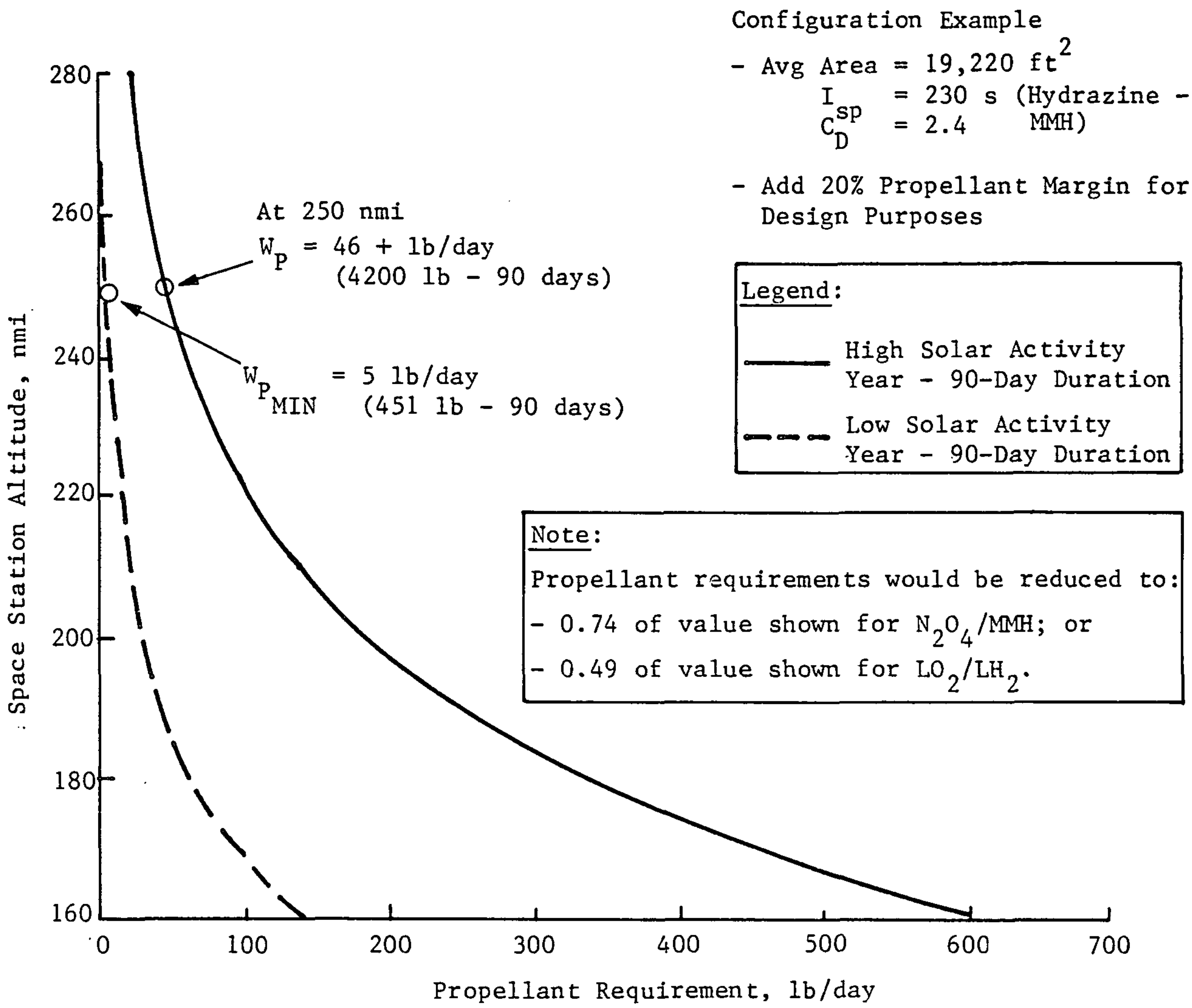


Figure 6.3-2 Orbit Stationkeeping Drag Makeup Propellant Requirements

Table 6.3-1 Space Station Orbit Altitude Selection Criteria

- Recommended Orbit Altitude - 250 nmi.
  - Above most of the low altitude traffic hazards (large debris, etc.)
  - Station keeping propellant reasonable (46 lb/day plus margin at max. drag condition of solar cycle for hydrazine).
  - Permits approximately a 90 day lifetime for the space station if the propellant is depleted (under the worst condition).
  - 47-63 klb cargo wt. capability can be achieved by direct insertion launches at ELS (57 deg to 28.5 deg. inclinations). A predicted cargo weight capability of 25-35 klb should be achieveable for WLS launches at 70-90 deg inclinations.

6.4 SPACE STATION ORBIT INCLINATION OPTIMIZATION ANALYSIS

6.4.1 Parametric Approach

One of the primary purposes for a manned space station is to have the capability of launching payloads with economical reusable stages that normally return to the space station after each mission. A parametric study was therefore undertaken to determine the varying launch requirements (OTV propellant and STS launches) with SS orbit inclination and to recommend an orbit inclination that would minimize these requirements.

A dual parametric approach was undertaken to maximize results in a short period of time and to have an independent check on the conclusions leading to the selection of the optimum inclination.

The first approach, which led to the recommended OTV stage sizes, consisted of an indepth investigation of three SS orbit inclination candidates (28.5, 57, and 70 deg) using the composite mission model (Ref 6-5), including DOD missions. With this approach, the object was to select only those missions that normally had an OTV launch requirement at the varying inclinations and exclude those missions going to the space station or a nearby platform, regardless of inclination. Using this technique, OTV stage sizing requirements could be determined over the full spectrum of missions and the efficiency of launching from the space station as compared to launching from the STS could be assessed.

The second approach used the SS Mission Model (representing fewer missions than the composite mission model), but determined the total STS transportation requirement for all types of missions including those going to the SS or a nearby platform (see Section 3.2). With this approach, all inclinations from 28.5 to 57 degrees were considered, but estimates of stage sizing and other factors were simplified to speed the calculations, as will be discussed later. STS launch requirements were then compared at all inclinations over the range studied to determine at which inclinations the SS reduced the STS traffic compared to using the STS alone.

In the following subsections, only the first approach will be detailed, but assumptions and results for the two approaches will be compared in 6.4.4.

6.4.2 Space Station Delivery Launch Requirements

Using the composite mission model (including DOD) for the years 1989-2000, a total of 492 missions were noted. Of this total, 407 missions were possible OTV candidates and were examined parametrically by energy requirements.

To simplify the parametric process, the 407 individual mission flight candidates were divided into 30 classes as shown in Table 6.4.2-1. The number of missions in a class varies from 1 to a maximum of 96 missions and are generally ordered by average orbit inclination, average altitude, and average payload weight. With the tabulated mission class data, launch delta velocity requirements could be determined for the SS at the various inclinations and also for the competing STS OTV launches.

The following basic mission assumptions (for both SS or STS OTV launches) were used throughout the study:

1) All missions were considered as delivery missions (i.e., deliver the payload to another orbit, release it, and return the empty stage).

2) Plane change requirements were minimized by assuming that the ascending nodes of the launch orbit (STS or SS) and the target orbit were coincident.

3) For low energy orbit transfers (near-plane and/or near altitude) two impulse transfers were considered for both the outboard and return legs (Fig. 6.4.2-1a).

4) For moderate energy transfers (intermediate to larger plane changes, generally) three impulse transfers are used with most of the plane change made at a high altitude, where velocity is low (Fig 6.4.2-1b).

5) For high energy transfers (large plane changes and/or altitude changes, including geostationary orbits) aerobraking of the stage alone on the return leg greatly reduces delta V requirements and may involve either a two impulse or three-impulse transfer (Fig 6.4.2-1d).

6) For very high energy transfers (e.g., 40 deg or more plane change at low altitude) aerobraking on the outbound (Fig. 6.4.2-1c) also significantly reduced velocity requirements, but the maneuver was found to be impractical due to the large weight penalty for the aerobraking system (60 to 100% increase in the empty stage weight) which offset the velocity gain for reasonable sized OTV stages.

7) All delta V maneuvers were considered to be impulsive.

8) Transfer orbits were chosen for three impulse transfers such that transfer time did not exceed 1 day.

OTV maneuver delta V requirements were determined using the parametric data generated in the recent JSC maneuver strategies report (Ref 6-6).

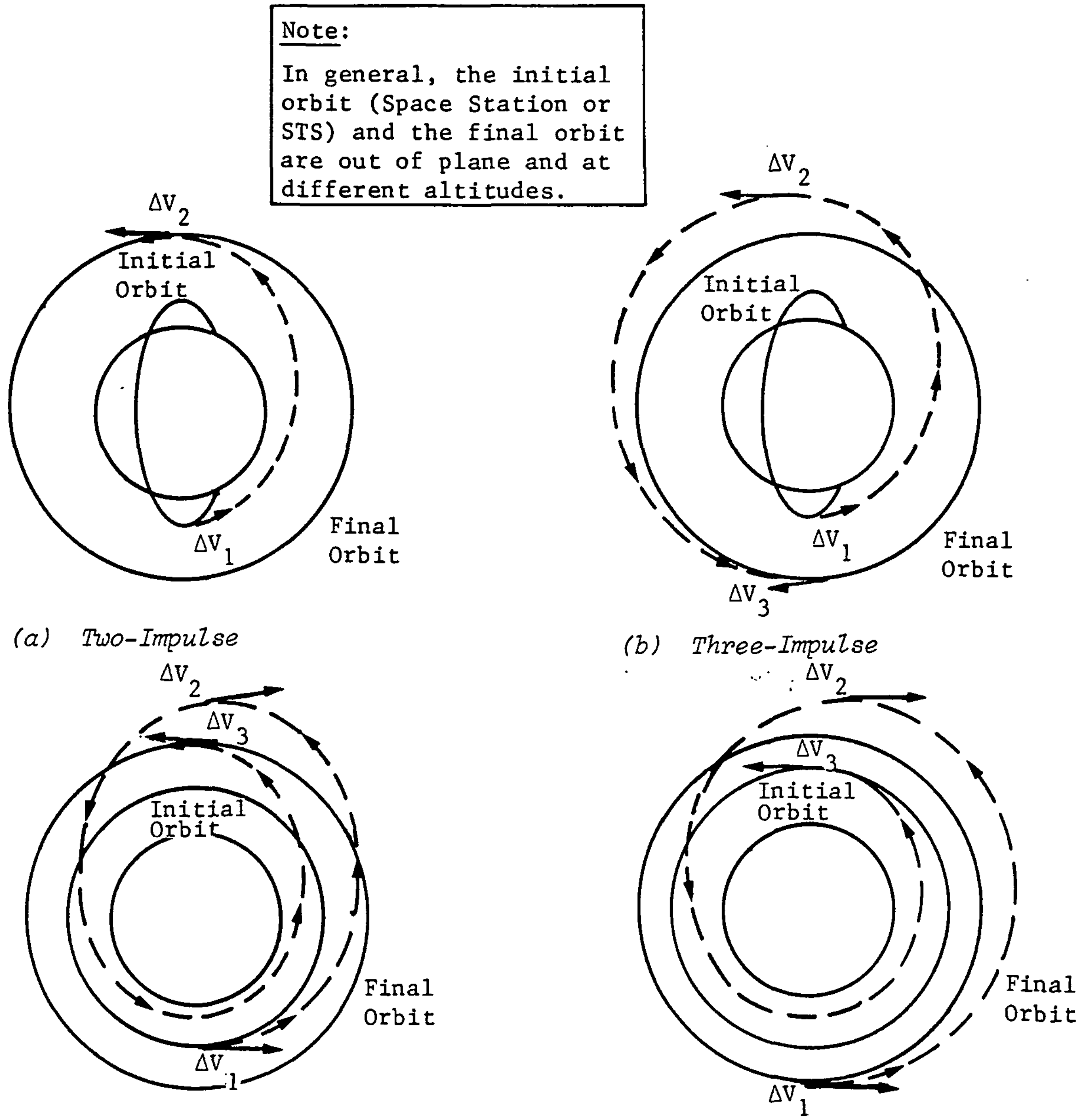
6.4.3 OTV Stage Sizing Analysis

As delta V requirements (outbound and inbound) were determined for the various mission classes from the selected inclinations and from the competing STS launches, reusable stage sizes were determined for each mission class with the aid of Figure 6.4.3-1.

*Table 6.4.2-1 Classification of Candidate OTV Missions (1989-2000)**

Class No.	Average Inclination (Deg.)	Average Altitude (nmi)	Average Payload (klb)	No. of Flights
1	0	19323	16.0	2
2	0	19323	8.0	42
3	0	19323	4.5	37
4	0	19323	2.5	96
5	0	19323	1.8	29
6	28.5	19323	6.7	6
7	28.5	1700	7.5	3
8	28.5	300	3.5	10
9	28.5	300	21.0	14
10	44	1100	9.2	7
11	55	10900	2.2	51
12	55.5	3200	14.1	12
13	56	325	8.1	4
14	56	270	40.0	1
15	57	19323	9.0	4
16	57	1600	7.5	2
17	57	250	7.6	4
18	57	200	32.0	1
19	57	200	110.0	2
20	60	10900	5.0	5
21	60	550	3.1	8
22	65	500	2.2	1
23	74	1100	7.5	3
24	90	325	7.1	8
25	92	1100	7.5	3
26	97.5	400	6.5	13
27	97.5	200	22.0	1
28	98.9	450	0.4	7
29	98.9	470	3.7	28
30	110	1100	7.5	3

* 407 out of the total of 492 missions (including DOD) have been included. The remaining 85 missions are not OTV candidates since they are going to the space station or nearby platform.



(a) Two-Impulse

(b) Three-Impulse

(c) Aerobraking Outbound

(d) Aerobraking Return

Figure 6.4.2-1 OTV Maneuvering Techniques Used for Delivery Missions

It was assumed that a small reusable mono-propellant stage (5500 lb of monomethyl hydrazine of the TMS type (Ref 6-7) would be available for transferring and servicing payloads for low energy missions near the space station or from STS. This stage (specific impulse of 228 sec) was included in the OTV study for nearby missions of opportunity, and off-loaded as required (Fig. 6.4.3-1).

A typical mass fraction curve is also shown in Figure 6.4.3-1 for reusable storable bi-propellant stages (N_2O_4/MMH) from approximately 8000 lb of propellant to more than 90,000 lb of propellant. The curve for no aerobraking is presented and approaches stage mass fractions of 0.90 at the higher propellant weights. Specific impulse is 310 sec.

Mass fraction curves are also shown in Figure 6.4.3-1 for hydrogen cryogenic stages for propellant weights from 30,000 to above 90,000 lb with mass fractions slightly higher than 0.90 at the higher propellant weights for no aerobraking. The specific impulse assumed was 465 sec. The following assumptions were used in deriving the cryogenic mass fraction curves presented:

1) A typical curve for no aerobraking was generated from available data and projections.

2) Since the wide body Centaur versions currently under development for STS have propellant weights of approximately 28,000 and 45,000 lb, a 30,000 lb likely lower propellant weight limit was selected for the parametric studies.

3) Based upon recent studies of reusable aerobraked stages (Ref 6-8) a typical aerobraking system weight penalty was assumed to equal approximately 12 percent of the weight being braked by aerodynamic drag. Accordingly, the following formulas were derived to generate the mass fraction curves with aerobraking:

   a) Aerobraked return

   $$\lambda = \frac{1}{1+1.12B}$$

   where B = stage burnout weight to propellant weight ratio

   b) Aerobraking outbound

   $$\lambda(\text{upper}) = \frac{1}{1+1.6B}$$

   $$\lambda(\text{lower}) = \frac{1}{1+2B}$$

It was actually found in the parametric study that the propellant requirements were always higher for a storable bi-propellant stage than the cryogenic stage and was therefore not recommended, based upon this preliminary orbit inclination trade study.

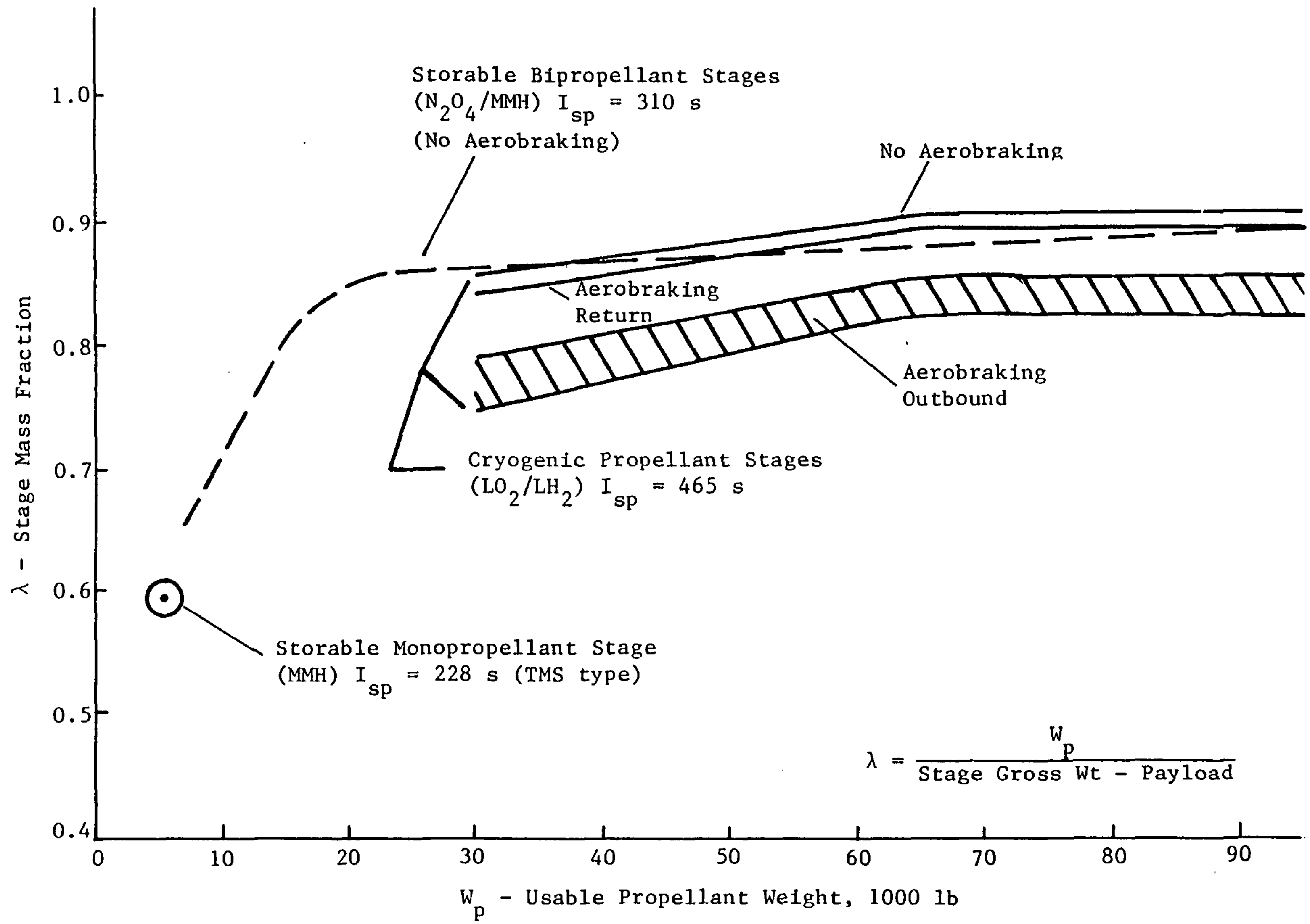


Figure 6.4.3-1 Propellant Mass Fractions for OTV Stage Candidates

Typical results of the propellant requirement calculations for both the SS launched missions and competing STS missions are shown in Figures 6.4.3-2 and 6.4.3-3, respectively, for a space station at 28.5 degrees inclination. The procedure used at each SS orbit inclination was to determine the mission flights that were candidates for the SS and then attempt to fly these same missions with the STS and a properly sized OTV.

Figure 6.4.3-2 shows how the recommended missions and OTV stage size were determined for the 28.5 deg inclination case. Notice that of the 407 total SS candidate flights, 383 flights require a cryogenic OTV and 24 flights can be accomplished with the TMS. Of the 383 cryo flights, 81% (310 flights) can be accomplished with a 35,000 lb propellant weight stage. The 35,000 lb stage was therefore selected and would be off-loaded as required. Total flights captured were 334 (including TMS flights).

Figure 6.4.3-3 summarizes the propellant requirements for recommended OTV stage sizes assuming launch from the STS and competing specifically for the 334 mission flights selected for the SS at 28.5 deg. In this case, 294 flights could be captured with a minimum sized cryogenic stage (30,000 lb propellant), 8 TMS flights, and 32 flights launched directly with the STS. Reusable stage sizes are generally smaller for STS launched OTVs since the STS generally puts the stage in an orbit close to the desired plane and plane change requirements are usually lower. However, as will be shown later, the total propellant used for STS and OTV is less when space station is used as a base than when only the STS is used.

Table 6.4.3-1 summarizes the OTV stage sizing analysis results for the three selected space station inclinations of 28.5 deg, 57 deg, and 70 deg. In all cases, over 80% of the 407 candidate OTV launched delivery missions were captured with a single cryogenic stage of 30,000 to 35,000 lb propellant for the SS and 30,000 lb propellant for the competing STS launched OTV, including a small number of TMS and STS direct flights.

All recommended stages are reusable, would normally be off-loaded for the mission, and are designed to utilize aerobraking on the return leg (to SS or STS), as required.

6.4.4 Space Station Orbit Inclination Trade Study

6.4.4.1 Overall SS Traffic Analysis Approach - As previously discussed, the second parametric approach used was the overall analysis approach using the SS mission model covering the 10-year period from 1991-2000. This model considered 315 missions, including SS or platform missions and was used for an independent check on the SS inclination optimization selection. Basic assumptions and ground rules used for this analysis are summarized in Table 6.4.4-1 and are discussed in the following paragraphs.

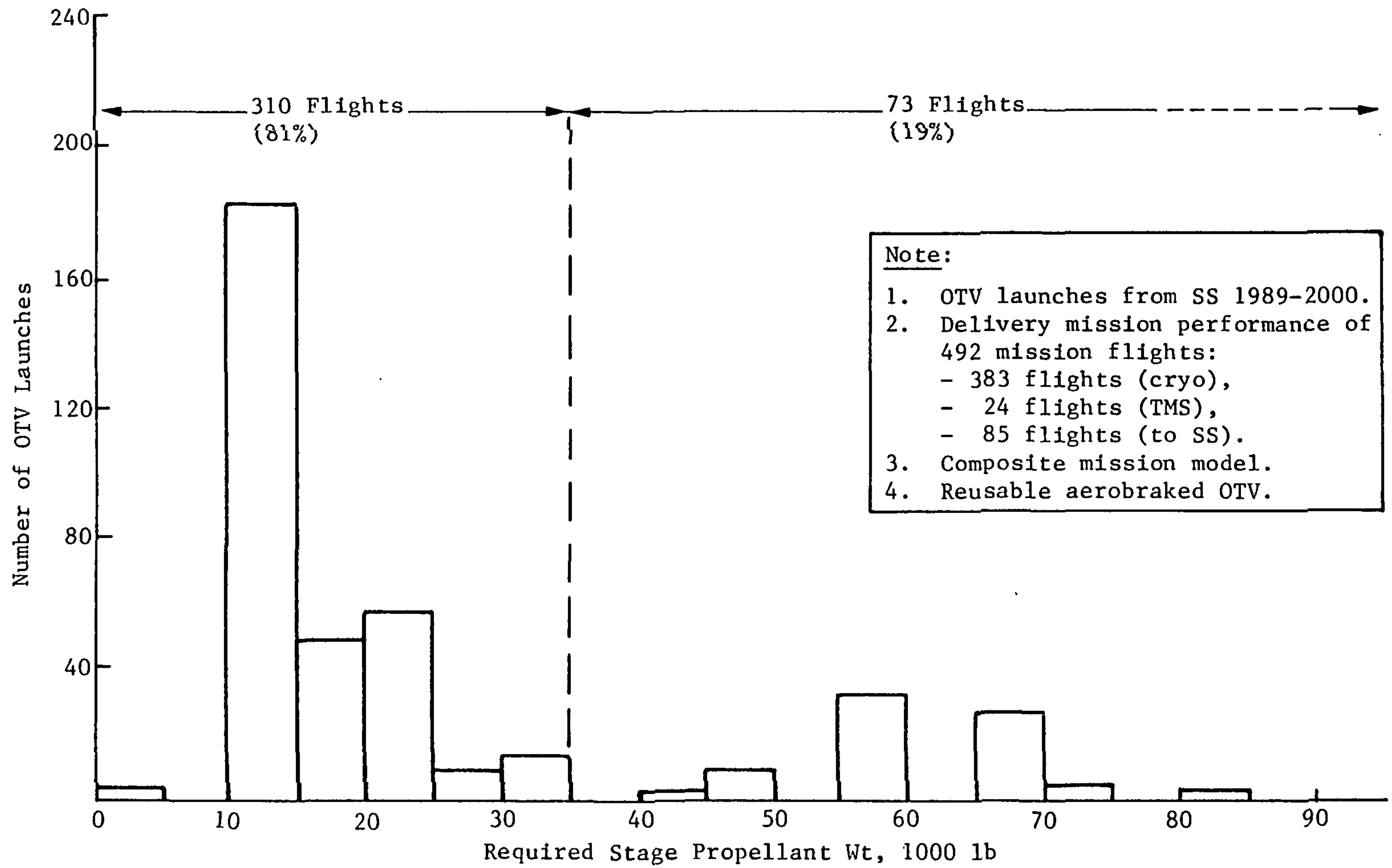


Figure 6.4.3-2 SS Cryogenic OTV Sizing Distribution (SS at 28.5 degrees)

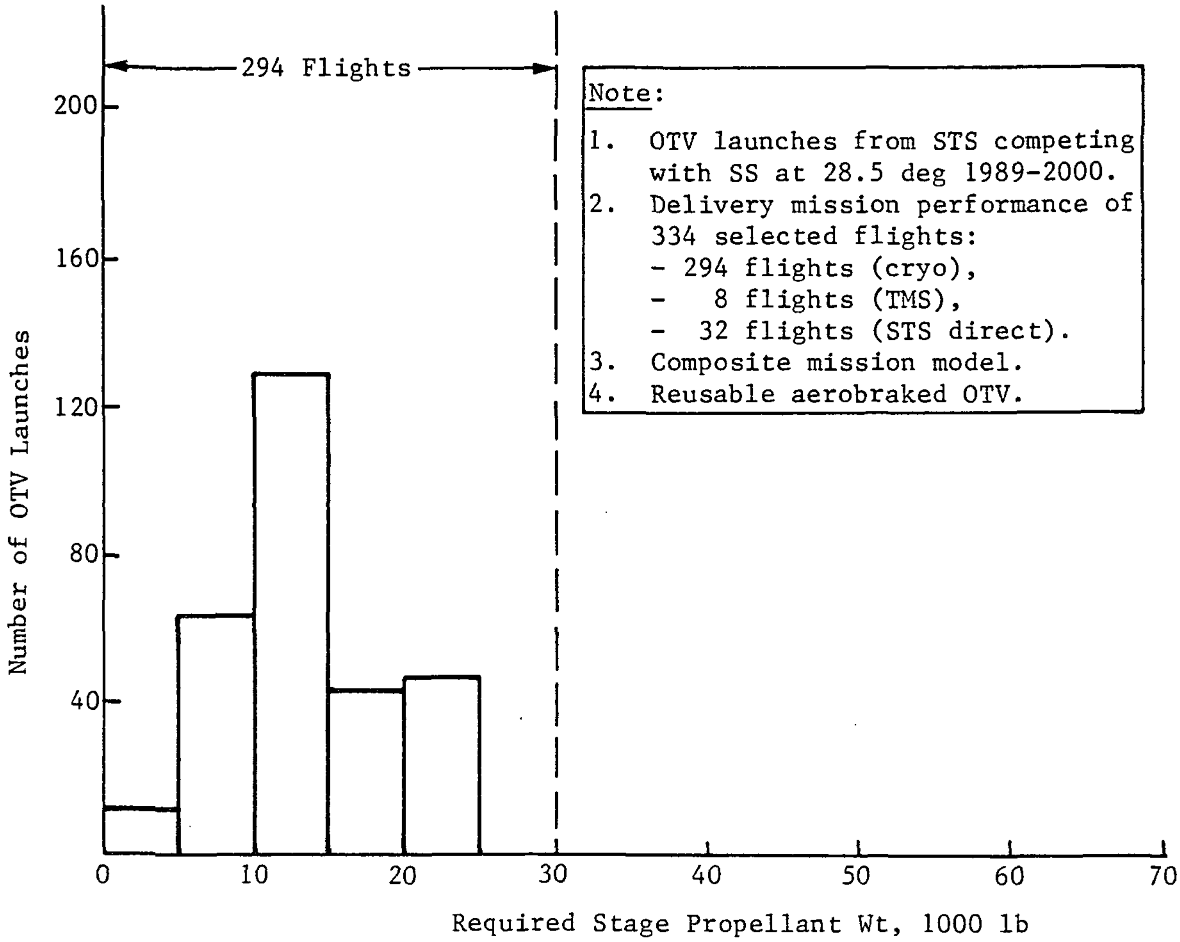


Figure 6.4.3-3 STS Cryogenic OTV Sizing Distribution

*Table 6.4.3-1 Recommended Cryogenic OTV Stage Sizes vs SS Inclination**

SS Inclination (Deg.)	No. of Flts** Captured (Out of 407)	OTV Size SS Launches (klb prop.)	OTV Size STS Launches (klb prop.)
28.5	334	35	30
57.0	328	35	30
70	330	30	30

*All stages are reusable and include aerobraking for return to the space station or to STS.

**Numbers include some TMS Flights and STS direct flights.

Table 6.4.4-1 Assumptions for SS Orbit Inclination Trade Study Overall Analysis Approach

Mission Model	Space Station Mission Model, 10-yr Period (1991-2000), 315 missions considered (32 per yr. avg.)
SS Orbit Inclinations	28.5 to 57.0 deg considered.
STS Performance	Maximum cargo wt. capability 65 KLB without scavenging (see fig. 6-1). For ELS launches (28.5 deg to 57.0 deg. inclinations), the orbiter was presumed to deliver payloads directly to their desired orbit when under 270 nmi altitude. For WLS launches (inclinations greater than 70 deg), the orbiter altitude limit used was 162 nmi. (STS only, flts.)
Upper Stage Performance	Similar to that described in subsection 6.4.2 (maneuver techniques) and 6.4.3 (OTV stage sizing analysis), except constant mass fractions and rubber stages were used.
STS Operations	Cargo wt. load factors (manifesting) 68% (STS only, flt.) 92% (STS to SS.) Net cargo wt. factor (ASE and tankage 86% of cargo wt. (STS only, flt) 89% of cargo wt. (STS to SS) Scavenging (flights to SS, only). 10,000 lb of propellant scavenged per STS flight for storage at SS.
Space Station Resupply	51 additional STS flights were alloted for reg. resupply, crew rotation, stage refurbishment, & misc.

Since the higher inclinations (WLS launches) did not appear promising midway into the contract, SS orbit inclinations studied were limited to the 28.5 deg to 57 deg range (a 70-deg inclination was also covered in the first approach to confirm this view). A maximum cargo weight carrying capability of 65,000 lb (without scavenging) was also assumed and the orbiter was presumed to deliver payloads directly to desired orbits up to 270 nmi for ELS launches and up to 162 nmi for WLS launches (for STS-only flights).

OTV stage performance was calculated similarly to that described previously in subsection 6.4.2 (Maneuvering Techniques) and 6.4.3 (OTV Stage Sizing Analysis), except that constant mass fractions were used and a different stage was designed for every mission and fully loaded (i.e., "rubber stages").

To determine the total number of STS flights required to support the mission model with and without a space station, assumptions were made concerning STS average manifesting and airborne support equipment (ASE) to determine the average net cargo weight that could be carried to a particular orbit altitude and inclination.

Based on studies at the Michoud Division (Ref 6-9) and consultations with the study team, an average weight load factor of 68% was assumed for STS-only flights and 92% for STS flights going to the SS. A net cargo weight factor of 86%, allowing for average ASE weight, was assumed for STS-only flights and 89%, including propellant tankage weight, was assumed for STS flights going to the SS.

Examples of how the these factors were used are shown as follows for the maximum cargo weight to SS at 28.5 deg case:

1) STS only flight to 250 nmi (not to SS) net cargo weight (1000 lb) = 63 x 0.68 x 0.86 = 36.8.

2) STS to SS (at 250 nmi) net cargo weight (1000 lb) = 63 x 0.92 x 0.89 = 51.6.

It should be noted that there is an added weight efficiency for delivering cargo to the SS. This is due in part to the fact that the STS-only flights are carrying stages most of the time with payloads cantilevered from them, giving poorer volumetric efficiency and higher ASE weights. In addition, the nominal residual weight of 10,000 lb of propellant is assumed to be scavenged from the external tank into a small cargo bay holding tank on mostly all flights going to the space station, whereas scavenging is not considered for STS only flights.

In addition to the flights to the SS to support the mission model, 51 STS flights were allotted (over 10 yr) for regular resupply and crew rotation (40 flights), stage refurbishment (every 20 OTV or TMS flights), and miscellaneous resupply flights.

Figure 6.4.4-1 summarizes the results of the overall analysis approach in terms of the total number of STS flights, normalized (where 234 STS flights over 10 years corresponds to an indicator of 1.00) versus space station orbit inclination with or without a space station. The chart conclusively shows the reduction in STS transportation flights by having a space station at 28.5 deg (fewer than 84% of STS flights, compared to doing all missions with the STS/reusable stage combinations).

As SS orbit inclination is increased to approximately 40 degrees (with SS losing geosynchronous missions to the STS), the advantage of having the SS is eliminated, with higher SS inclinations showing that missions should be accomplished with the STS.

The jump in STS flights that occurs near 40 degrees orbit inclination for the SS is caused by the constant mass fraction assumption. Since mass fraction would actually improve for larger stages the curve should more closely follow the dashed line, with crossover at 48 degrees inclination, if this effect were included. The major conclusion would still remain that a significant advantage in terms of reducing flights to support the SS mission model can be achieved by locating a space station at 28.5 degrees.

6.4.4.2 <u>OTV Launch Support Traffic Analysis Approach</u> - As previously mentioned, the first parametric approach used was the OTV launch support analysis approach using the Composite Mission Model (including DOD flights) covering the 12-year period from 1989 to 2000, considering a total of 407 OTV delivery missions of which 328 to 334 missions (depending upon inclination) were captured. Basic assumptions and groundrules used for this analysis are summarized in Table 6.4.4-2 and are discussed in the following paragraphs.

Two SS inclinations (28.5 degree and 57 degrees) representing the minimum and maximum STS orbit inclinations at ELS were chosen for this study. In addition, an inclination of 70 degrees was chosen for a comparison at WLS, since it represented the maximum payload capability (minimum orbit inclination for range safety) and also had a finite nodal regression rate to allow a nodal lineup with other orbit planes over a period of time to minimize plane change requirements.

STS performance assumptions were similar to those used in the previous subsection, except that the direct insertion capability was considered up to a maximum altitude of 325 nmi at ELS and to 250 nmi at WLS, as already shown in Table 6.2-1.

OTV stage performance was calculated as previously discussed in Subsections 6.4.2 and 6.4.3 for the propellant requirements of fully loaded "rubber stages" for the various missions. Once the stages were selected, propellant requirements were then recalculated for off-loaded stages, typically increasing propellant requirements by 20-25 percent.

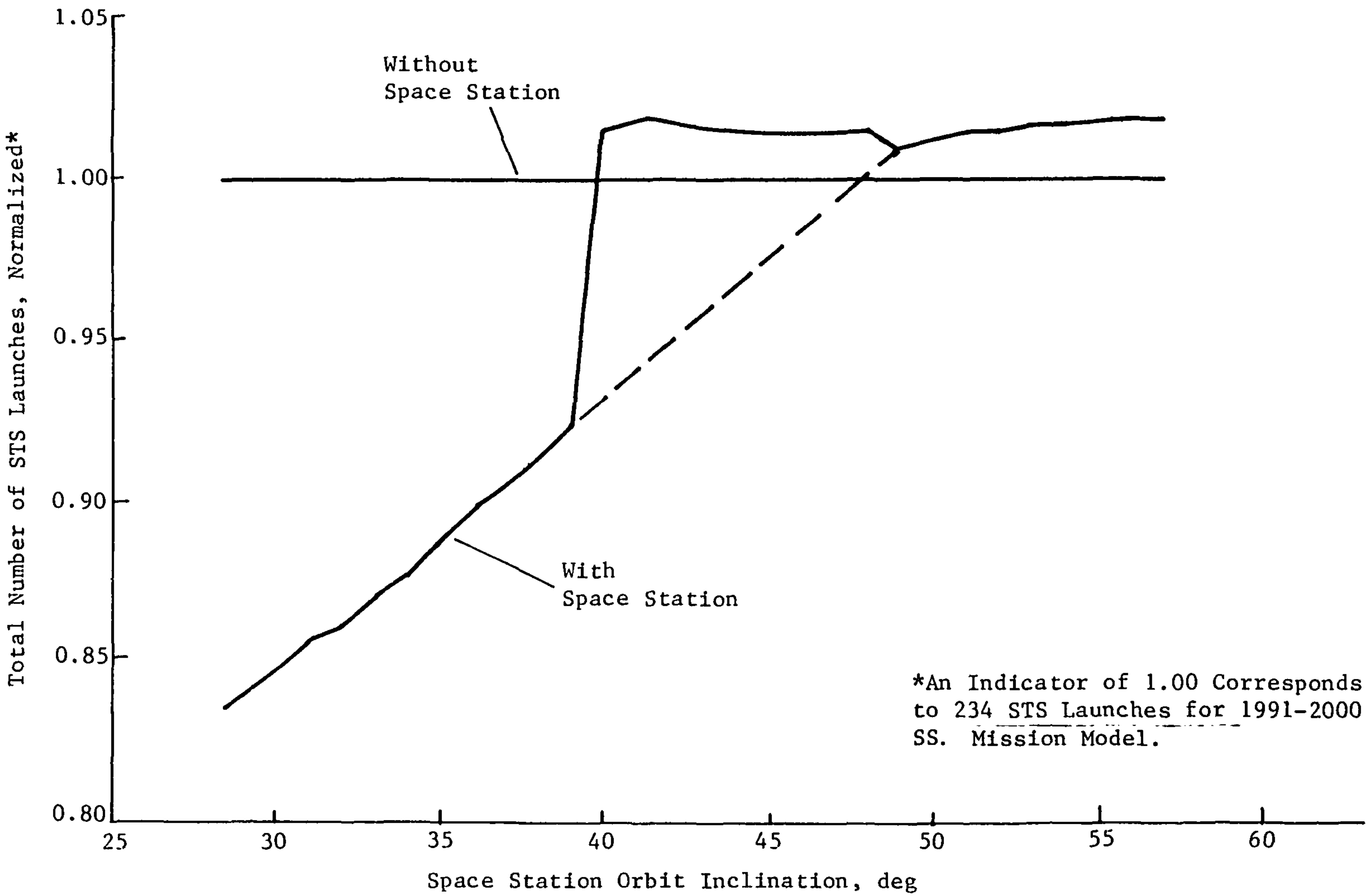


Figure 6.4.4-1 Sensitivity of STS Launch Requirements to SS Orbit Inclination

Table 6.4.4-2 Assumptions for SS Orbit Inclination Trade Study OTV Launch Support Analysis Approach

Mission Model	Composite Mission Model (Including DOD flts.) 12 Yr period (1989-2000) 407 missions considered (34 per yr, avg.)
SS Orbit Inclinations	28.5, 57.0 and 70.0 deg. considered
STS Performance	Maximum cargo wt. capability 65 klb without scavenging (see Fig. 6-1). Direct insertion capability at ELS to 325 nmi and to 250 nmi at WLS as discussed in Table 6-1.
Upper Stage Performance	Similar to that described in subsection 6.4.2 (maneuver techniques) and 6.4.3 (OTV stage sizing analysis). Fixed stages selected and off-loaded as required after missions to be captured were chosen.
STS Operations	Cargo wt. load factors and net cargo wt. factors as in Table 6-5 Nominal scavenging (10 klb) assumed in all fully loaded flts to SS. For flts not fully loaded, additional propellant could be loaded equal to the reduction in payload from maximum capability at the particular SS inclination.
Space Station Resupply	54-55 additional STS flights are required for reg. resupply, crew rotation, and stage refurbishment.

The method and factors used for determining the total number of STS flights (STS only or STS to SS) was identical to that used in Subsection 6.4.4.1. As in the previous analysis, STS flights to the SS could be made up of a cargo of payloads, OTV or TMS propellant in tanks, stages to be refurbished, or any combination thereof to best utilize the cargo bay, with nominal scavenging always used.

In addition, 54-55 additional STS flights are required (over 12 years) for regular resupply and crew rotation (48 flights) and 6-7 flights for OTV and TMS refurbishment (every 20 missions).

Table 6.4.4-3 summarizes the results of the OTV launch support analysis approach in terms of the direct benefit of having a SS versus doing the same OTV/TMS missions with the STS only. The refurbishment flights are included in the comparison, but not the regular SS resupply/crew rotation flights (48) since part of those would be allocated to support OTV launches and part would be allocated to support missions going directly to the SS or nearby platforms.

Comparing launch from the SS for selected missions (328-334) as opposed to launching the same missions from the STS, a clear advantage exists at 28.5 degrees inclination for the SS (i.e., 151 STS launches compared to 231 STS launches for STS only) or 80 flights. At 57 degrees the gross benefit is cut in half (38 flights) and at 70 degrees the SS is at a disadvantage of 16 flights. (This confirms the conclusion reached in Subsection 6.4.4.1.)

6.4.4.3 Recommended SS Orbit Inclination/OTV - Based upon the two parametric approaches the following conclusions can be reached:

1) The launch site for the initial space station is ELS.

2) The best SS orbit inclination from the standpoint of minimizing transportation costs (STS flights) is 28.5 degrees.

3) A reusable 35,000 lb (propellant) cryogenic stage designed for aerobraking on the return leg appears to be a good first choice for OTV sizing purposes for delivery missions.

4) Both parametric approaches indicate a net savings of 3-4 STS flights per year for a SS located at 28.5 degrees. (This considers regular resupply, crew rotation, and stage refurbishment flights to the SS.)

6.5 ADDITIONAL MISSION ANALYSIS CONSIDERATIONS

6.5.1 Launch Window Considerations

To minimize plane change requirements for OTV launches from the SS the ascending node of the SS orbit and the target orbit were considered to be coincident for the parametric studies as discussed in Section 6.4.2. For many delivery missions this is not a consideration since target orbit nodal location is not that important. Other delivery missions and servicing or retrieval missions, however, would

Table 6.4.4-3 STS Launch Requirements Comparison for Selected SS Orbit Inclinations (1989-2000)

SS Orbit Inclination (Deg)	No. of SS Launches Captured*	No. of STS Launches** SS Launched OTVS	STS Launched OTVS	SS Advantage
28.5	334	151	231	80
57.0	328	196	234	38
70.0	330	232	216	-16

* Using 35 klb propellant (maximum) sized stage

** Not considering required SS resupply FLTS.
(Does consider STS flights for OTV/TMS refurbishment)

be concerned with nodal location and near co-nodal launches would be desired. This would be particularly true when most of the performance capability of the OTV is being utilized.

Figure 6.5.1-1 presents the maximum OTV launch delay required as a function of target orbit inclination and altitude for a space station located at 250 nmi altitude and 28.5 degrees inclination. The maximum delay occurs when the target orbit ascending node is 180 degrees away from that of the SS orbit and actual times are a function of the difference between the spatial nodal regression rate of the target orbit and the SS orbit.

Notice that above a 7500 nmi target orbit altitude, the delay time approaches a constant of just under 27 days for all inclinations above zero. This is due to the fact that all orbits above this altitude have a nearly zero orbit regression rate and all motion is caused by the SS orbit regression rate of about 6.8 degrees per day in a westerly direction. This maximum delay period would also be valid for a delivery mission to any orbit inclination and altitude since relative regression rates are not involved. Note that for an equatorial orbit there is no delay since minimum plane change opportunities occur at all equatorial crossings.

For posigrade target orbits and lower altitudes, the value of the regression rate approaches that of the space station regression rate so that the maximum launch delay continues to increase at an increasing rate (infinite delay for identical altitude and inclination). Target orbit altitudes above 3500 nmi would require a maximum of one month delay and target orbit altitudes above 1000 nmi would require a maximum of two months of launch delay.

At a target orbit altitude approaching that of the SS, the launch delay is a strong function of inclination. Below 55 degrees target orbit inclination, the maximum delay can be many months (75 days at 55 degrees). As the target orbit inclination approaches 90 degrees (zero regression rate), the maximum launch delay is reduced to under 27 days. For retrograde target orbits (easterly nodal progression rate) the launch delay is reduced further, as indicated in Figure 6-9.

Figure 6.5.1-2 shows the launch window penalties, in terms of OTV plane change and delta V requirements, for launching early or late from the co-nodal launch condition. An example of a 28.5 degree target orbit (two altitudes) is shown, since penalties are generally maximized at this condition. Note that plane change and delta V penalties are symmetrical for a given early or late launch condition.

The two target orbit altitudes shown on Figure 6.5.1-2 are a high altitude (15,000 nmi) and a medium altitude (1000 nmi). Plane changes are nearly linear with time on either side of the co-nodal condition and are a function of the relative regression rates discussed previously, becoming more non linear away from the co-nodal point.

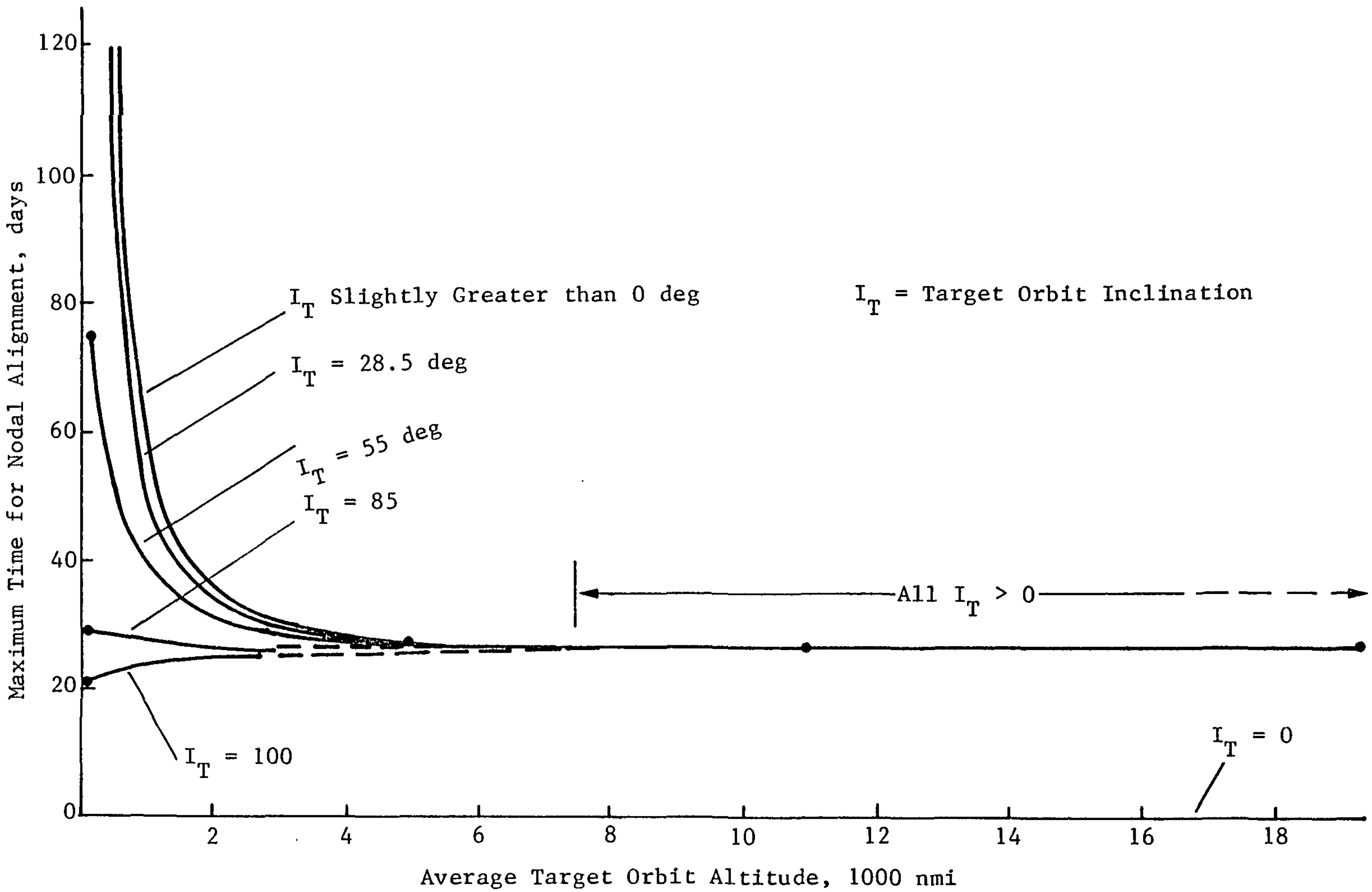


Figure 6.5.1-1 Maximum OTV Launch Delay for Co-Nodal Launch

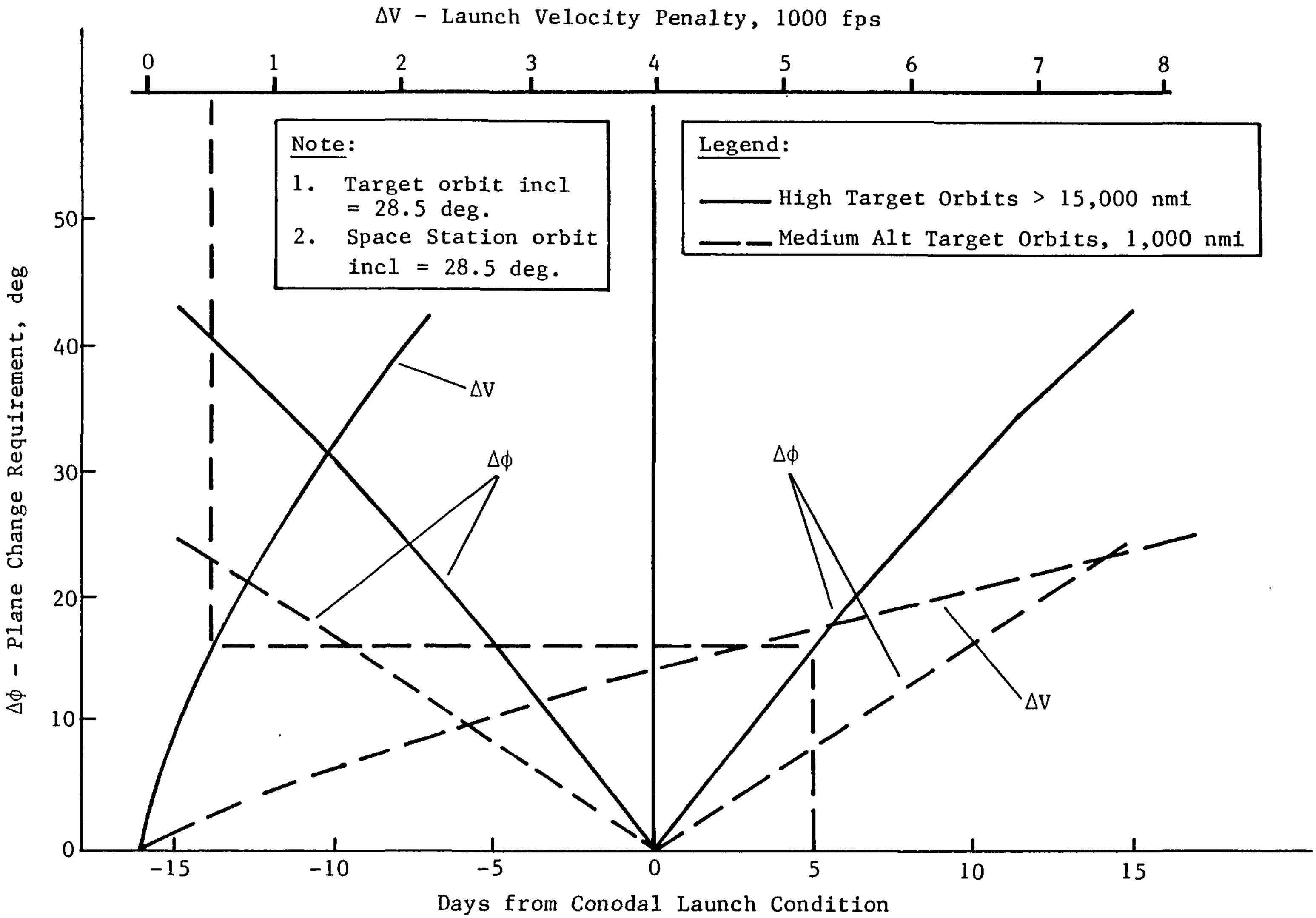


Figure 6.5.1-2 Launch Window Penalties Near a Co-Nodal Launch

A 5-day early (or late) launch is illustrated for the high altitude case and requires a 16 degree plane change. Note that this corresponds to a delta V penalty of only 550 fps. The reason for a value this low is that the OTV is already going to a high apogee (15,000 nmi) and a plane change costs little at this point. In contrast a 5-day early launch for the 1000 nmi case required a plane change of only 8 degrees but increases the delta V penalty to over 2000 fps. In this case, the velocity is comparatively high at apogee and the penalty is much higher.

In actual practice, node-sensitive launches from the SS would have a delta V budget allocation for a launch window, depending upon the target orbit and anticipated launch holds. This delta V budget would allow a launch window that would be initiated days or hours before the co-nodal point and exist for the same period after the co-nodal condition, as indicated for the 10-day launch window example in Figure 6.5.1-2.

6.5.2 Platforms and Tethering Aspects

6.5.2.1 Free Flying Platforms - For some missions and experiments, a platform which can be serviced from the SS has been shown to be desirable from the standpoint of having an isolated environment. Some platforms would be in greatly differing orbit planes or altitudes, would require an OTV for servicing, and would be similar to OTV satellite servicing from the SS.

Of special interest are nearby or co-orbiting platforms that could be serviced or visited by a TMS at regular intervals. Studies (Ref 6-10) have suggested that by proper timing, a platform or platforms could be located within some miles of the SS (down range, at a different altitude, and/or out of plane) in such a manner that for a delta V requirement within TMS capability the platform could be visited at regular intervals (monthly or every several months). From an orbital mechanics standpoint, this could certainly be done.

As pointed out in reference 6-11, differences in drag decay between the platform and the SS can also be utilized in the revisit planning. Although platforms are not currently under study (from a mission analysis standpoint), it is recommended that active orbit stationkeeping be considered in the design of platforms, due to differing drag and orbit earth oblateness effects.

6.5.2.2 Tethering Aspects - Another interesting concept which has been suggested for space station use is the tethering concept. Martin Marietta has been conducting in-house studies in this area (ref 6-12), in addition to its Tethered Satellite System contract (contract number NAS 8-3600).

One suggested use of tethering is in the area of space platforms. In place of or in addition to co-orbiting platforms, it would be possible to have space platforms above and/or below these up to tens of miles away with some of the same advantages (e.g., low gravity and isolated environment) that the free flying platforms have. In addition, a direct communication and/or power link may be possible through the tether, and the platform could be reeled in for local servicing and changeout.

Other suggested uses include storing supplies in remote storage containers (e.g., modified external tanks) and also tethering the orbiter for a momentum exchange when the tether is cut, which can cause the SS altitude to increase (drag makeup replacement) and simultaneously reduce the orbiter re-entry propellant requirement (lower perigee). Some of these and other tethering applications are discussed in Reference 6-13.

6.5.3 OTV Launch Variations

During the parametric studies described in Section 6.4 single payload launches were assumed for all OTV mission flights. In most of the flights, the OTV is launched with a partial propellant load (typically 65% of the full 35,000 lb propellant load). Although many missions may be required to be launched singly (target orbit location, incompatibility with payload sharing and timeliness requirements), a significant number of missions may still exist where OTV launch sharing may be possible. These should be investigated in future studies since they would have an impact on cost and STS transportation requirements.

Another area where performance improvement is possible is in the area of the 3-impulse transfer for launch plane changes as discussed in Section 6.5.2. The transfer orbit was limited to one day to keep the duration of the OTV delivery mission to within a few days. For some missions, OTV mission duration may not be a consideration. In these cases (with proper OTV design) the transfer orbit time might be increased to 4 to 8 days, resulting in a reduction in transfer delta V up to several thousand fps for large plane change missions.

6.5.4 Space Station Deorbit Considerations

At the end of the useful life of the SS a fairly precise deorbit with impact control will be required for safety purposes (e.g., to specify a time interval when impact will occur and the size and location of the impact footprint). A remote ocean location would probably be selected with by ships, planes, etc would be warned out of the area during the reentry period.

Since the mature space station will probably be quite large, with a number of appendages, causing the space station to tumble before reentry, it does not appear feasible to maintain drag control. A more reasonable approach would be to actively control the attitude of the space station as long as possible into and after reentry until initial breakup occurs.

A suggested preliminary procedure for SS deorbit preparation through deorbit is as follows:

1) While the SS is still at normal altitude, maintain its altitude during the deorbit preparation phase.

2) The last several STS flights would bring up and attach a deorbit propulsion system to apply a retro delta V of at least 150-200 fps and make any necessary SS modifications for deorbit attitude control. These flights would also return equipment salvaged from the SS to the ground.

3) During the deorbit preparation any external stores that would break off early or affect attitude control during reentry would be stowed or returned via the STS.

4) After the last STS flight, the SS orbit would be allowed to decay to approximately 150 nmi under active attitude control.

5) The deorbit burn (approximately 10 minutes) would cause reentry at a specified time and location shortly after reaching 150 nmi and the desired orbit pass.

6) During the coast period to reentry the SS would be placed in the most desirable attitude to delay breakup as long as possible (probably a low drag attitude).

7) Active attitude control would then be maintained until breakup occurred.

7.0 MISSION ALTERNATIVES AND BENEFITS

The objective of the alternatives and benefits analysis is to identify benefits to be derived by or from the user missions for the various mission alternatives. The relationship of the benefits analysis to the other tasks in the space station is shown in Figure 7-1.

7.1 TASK FLOW

Figure 7.1-1 represents the task flow for the space station study and the relationship of the other study tasks to the benefits and alternatives analysis. The inputs to the analysis are in the form of integrated user requirements, STS/SS/FF relationship data, and the Space Station Mission Model. These inputs are used to define the benefits and alternatives for each mission. The identified benefits are then input to the Mission Implementation Concepts (Volume IV), and the Cost and Programmatic Analysis (Volume V).

7.2 APPROACH AND SCOPE

The approach to identifying mission alternatives and benefits is twofold. For each user mission, the most desirable way in which the mission is to be performed must be identified, based on the user requirements and space station program option capabilities. The three approaches to performing the mission are: (1) the space station (including unmanned platforms), (2) the shuttle orbiter, or (3) an independent free flyer. These alternatives are assessed against the appropriate user benefits in terms of the space station functions and the alternative which provides the best results is selected. Figure 7.2-1 shows the approach flow for benefits assessment. Benefits are divided into three classes: (1) economic, (2) performance, and (3) social.

Each mission is assessed for benefits against the space station functions identified in Section 7.3. For each of the benefits an assessment is made as to whether the benefit is: (1) unique to the space station, (2) the benefit would favor doing the mission with the space station (3) there is no significant difference between doing the mission with the space station or with the STS, or (4) the benefit favors doing the mission with the STS only.

7.3 ASSESSMENT

The space station program option selected for analysis consists of a permanently manned space station facility in an orbit inclined 28.5 degrees and an altitude of 250 nautical miles. The space station is supported by the STS and is operational from 1991 to 2000. Several platforms in orbits removed from the space station are considered to be part of the space station complex; note that this is the final and not the initial space station operational capability.

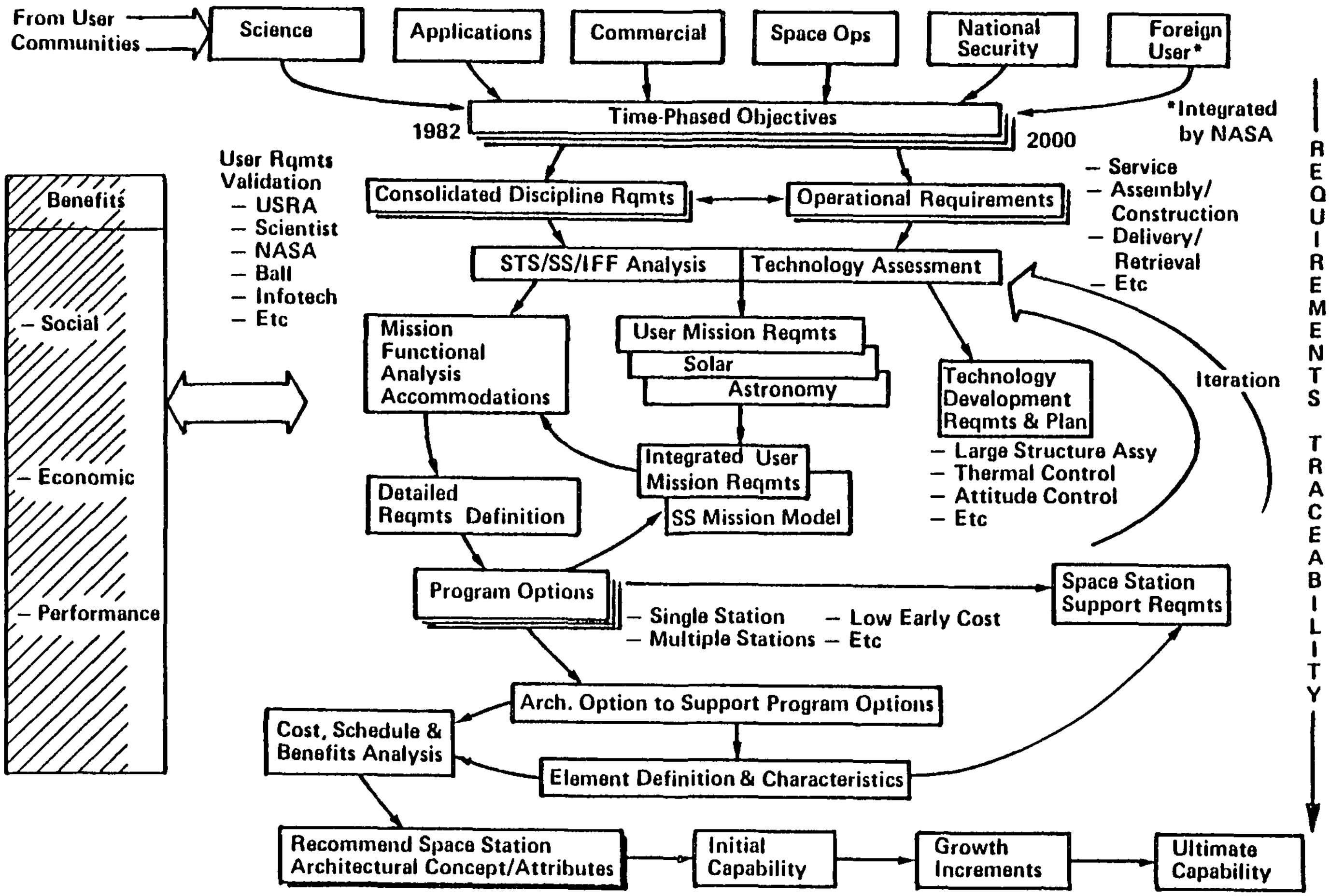


Figure 7-1 Space Station Study Flow

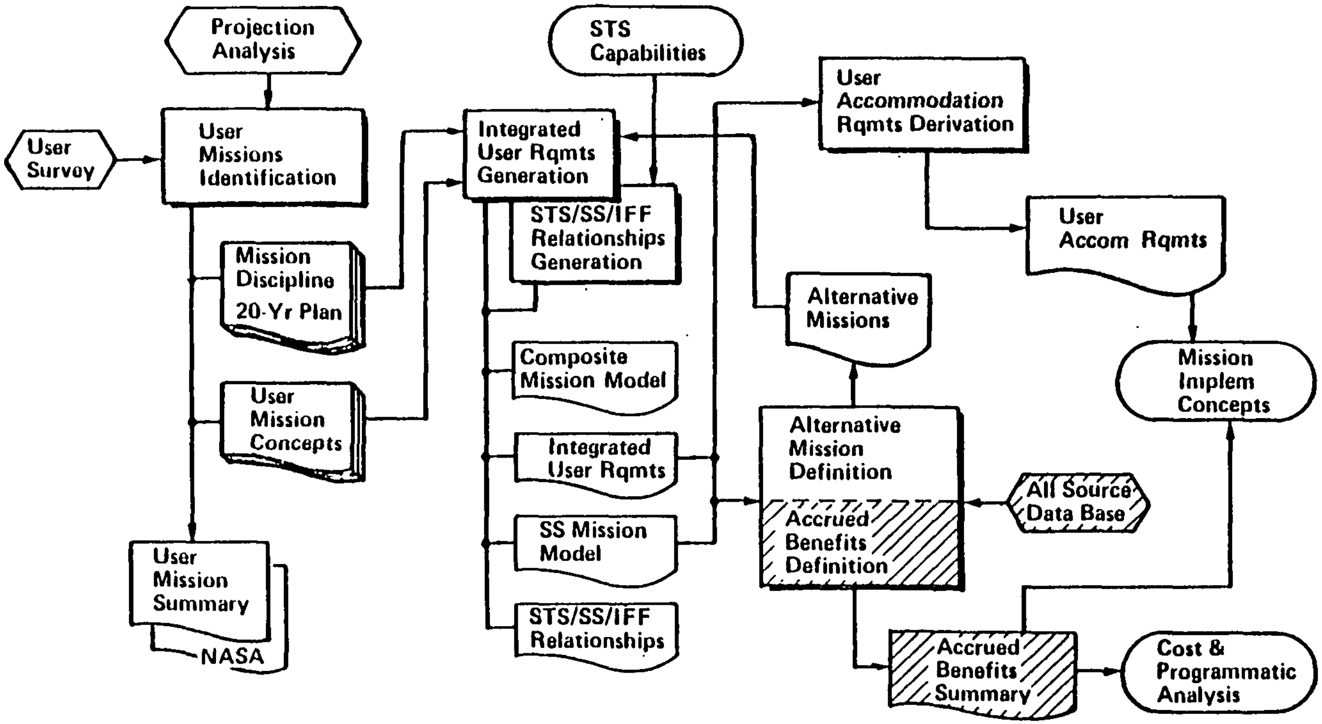


Figure 7.1-1 Benefits Analysis Task Flow

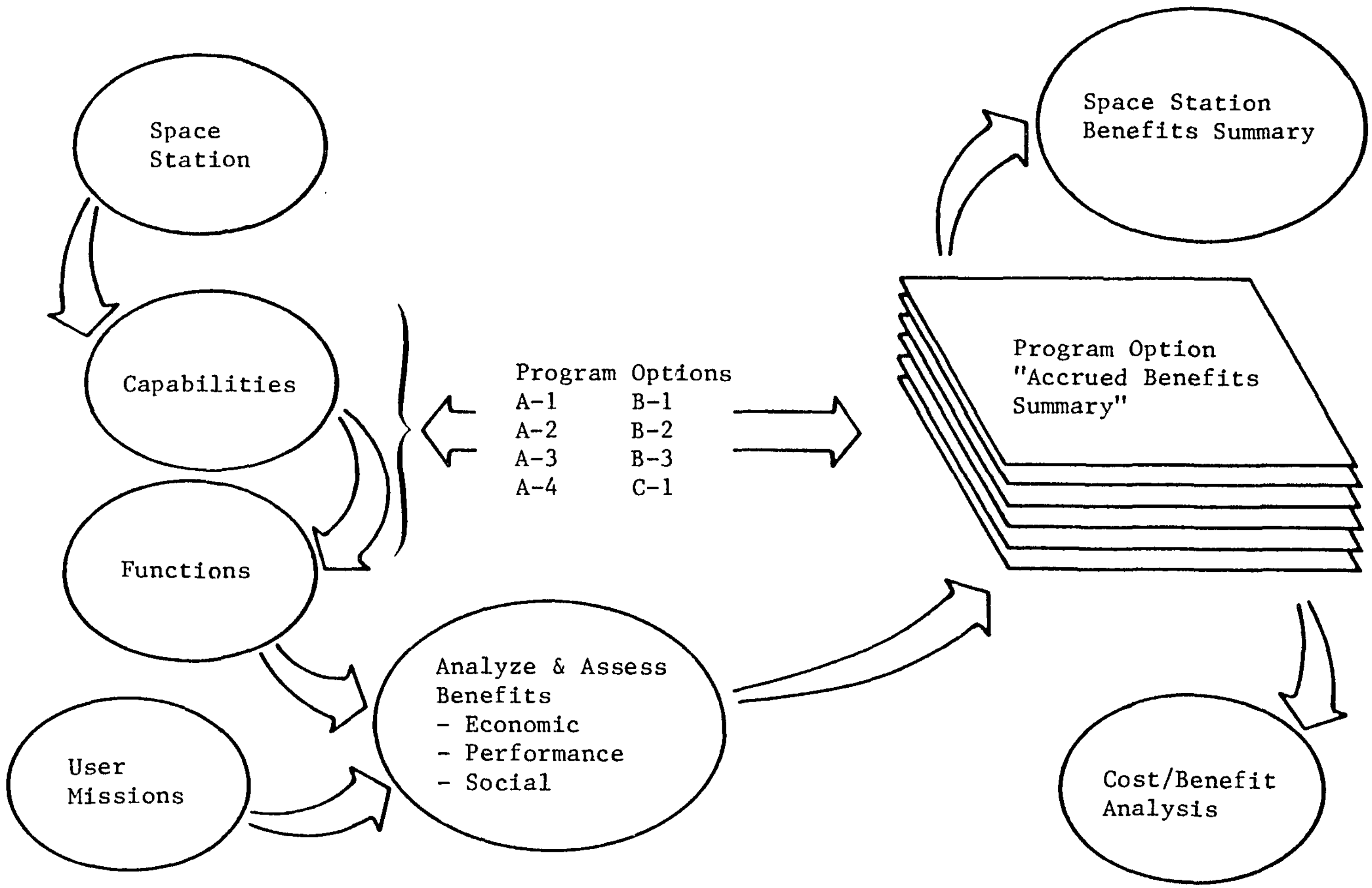


Figure 7.2-1 Benefits Analysis Approach

The mission model used to assess user requirements against SS benefits is the Space Station Mission Model described in Volume II and the preceeding sections 6.3 and 6.4 of this report.

The user missions evaluated for the Full Operating Capability (FOC) space station benefit areas and specific capabilities are shown in Table 7.3-1.

For the benefits assessment each user mission was assigned an operational basing mode through discussions with the appropriate user representatives. Compromises were made when significant benefits could be derived from them. Five primary basing modes were defined for the benefits assessment, and are identified in Table 7.3-2. Missions assigned to each mode are identified in Tables 7.3-3 through 7.3-7.

Benefits are identified as economic, performance, or social benefits. Economic and performance benefits are readily identified and quantified. Social benefits are more difficult to define because of their primarily subjective nature, and because they tend to be quantified as economic benefits. For the purposes of this study, a positive social benefit is assumed if the factor under consideration results in one or more of the following:

- Advancement in general knowledge,
- Potential technology spinoff,
- Provides a focusing purpose for technology development,
- Improves social awareness between diverse elements of society,
- Improves national security, and
- Provides national prestige.

Most benefit areas show both economic and performance aspects because increased performance at constant cost can generally be traded for reduced cost at constant performance. Generally, a performance or economic benefit also has socially beneficial aspects, though this is not always true.

Table 7.3-1 Space Station Benefit Areas

Capabilities/Functions	Benefits
Operations	Adaptive Control Labs/Data Analysis Targets of Opportunity Long Term Observations Calibration/Alignment/Checkout Subsytem Support Multiple Instrument Correlation Propellant Scavenging
Basing	In/At Space Station Platform Free Flyer Tether
Servicing	Repair Refurbishment Instrument Change-Out Contamination Control Preventive Maintenance
Resupply	Cryogenics Storables Others
Assembly	Mating Hardware Build-Up Construction
Orbit Transfer	Delivery Retrieval Launch on Demand

Table 7.3-2 Basing Modes

I	-	Attached/Onboard/Platform at Space Station	28.5° x 463 km
II	-	Platform At Low Inclination	28.5° x 463 km
III	-	Platform At Moderate Inclination	57° x 350 km
IV	-	Platform At High Inclination	90° x 500 km
V	-	Free Flyers	

Table 7.3-3 Basing Mode I - Attached to or in SS, 28.5° X 463 km

Class	User Mission	Desired Location	
Astronomy	HNE	28.5°-57°	400-800 km
	STARLAB	28.5°-57°	300-800 km
	CRO	0°-28.5°	400-600 km
Space Physics	SPELS	@ SS	
	LSEPS	@ SS	
Life Sciences	*ALL*	@ SS	
Materials Processing	*ALL*	@ SS	
Commercial Materials Processing	*ALL*	@ SS	
Technology Development	*ALL*	@ SS	

Table 7.3-4 Basing Mode II - Platform at 28.5° X 463 km

Class	User Mission	Desired Location	
Astronomy	XTE	28.5°-57°	300-400 km
	EUVE	28.5°-57°	400-800 km
	GTE	28.5°-57°	400-800 km
	FOT	28.5°-57°	400-800 km
	LDR	28.5°-57°	400-800 km
	GRO	0°-28.5°	400-600 km
	XRO	28.5°-57°	400-600 km

Table 7.3-5 Basing Mode III - Platform at 57° X 350 km

Class	User Mission	Desired Location	
Space Physics	ISTO/ASTO (57°)	57°-70°	300-400km
Solar Physics	SOT		
	SSXTF SSF P/OF ASO	57°	350 km

Table 7.3-6 Basing Mode IV - Platform at 90° X 500 km

Class	User Mission	Desired Location	
Earth Observation	SVI	90°	200-450 km
	GSSI	90°	LEO
	LIDAR	90°	400-800 km
	CLIR	90°	500-600 km
	IS	90°	LEO
	AMIMS	90°	LEO
	SAR	90°	LEO
	Radar	90°	LEO
	LAMMR	90°	LEO
	SSR	90°	LEO
	TIMI	90°	LEO
	OMP	90°	LEO
	Scatterometer	90°	LEO
Commercial Communications	SARSAT	90°	926 km

Table 7.3-7 Basing Mode V - Free Flyers

Class	User Mission	Desired Location	
Astronomy	COBE	99°	900 km
	FUSE	28.5°	Geosync
	SIRTF	28.5°-57°	300-400 km
	LAMAR	28.5°	300-400 km
	OVLBI	40°-57°	400-1500 km
	OIST	28.5°-57°	400-1500 km
	ST	28.5°-57°	400-800 km
	AXAF	28.5°-57°	400-800 km
	COSMIC	28.5°-57°	400-800 km
	TAT	28.5°-57°	400-800 km
Planetary	*ALL*	Earth-Escape	
Solar Astronomy	SIDM	Sun-Sync	
	SCE	Sun-Sync	
	SIS	Earth-Escape	
Space Physics	ASTO (Polar)	90°	200-250 km
	GEOSTO	Geostationary	
	VLR	Geostationary	
	OPEN	0°-80°	VHEO
	AIE	15°-50°	L1
	PTE	VHEO	
	CRMF	Many	
Earth Observatory	THM	90°	200 km
	TOPEX	65°	1300 km
	Microwave Sounder	Geostationary	
	GG	90°	LEO
Commercial Communications	XGP	Geostationary	
	ODSRS	Geostationary	
	Comsats	Geostationary	

7.4 RESULTS

Figures 7.4-1 through 7.4-10 present the results of the benefits analysis. In summary, 465 of the 2065 assessments are benefits that are uniquely enabled by the space station, 1151 additional benefits favor the space station over the STS, and only 297 benefits are more favorably presented by the STS. The following discussion presents the benefits assessment for each of the nine user categories.

7.4.1 Astronomy

Primary areas where the space station can provide significant benefits to the astronomy user missions are in the operations, servicing and orbit transfer areas. In the operations area the most significant benefit is in the multiple instrument correlation area. By transmitting all data to one central location (the SS), coordinated real time analysis of transient phenomena can be conducted. In the other operations areas significant performance benefits can probably be obtained by conducting operations in a coordinated manner at the space station although in practice this may not be economically feasible.

The servicing benefits primarily consist of all the functions involved in servicing as outlined in Table 7.3-1. For orbit transfer, delivery and retrieval are significant benefits to the user missions that the space station can provide.

All astronomy missions except the COBE mission benefit from the presence of the space station. Because COBE is in a 99 degree orbit, it is considered more economical to deploy and service this experiment from the STS.

7.4.2 Planetary

Planetary missions by their very nature are long term, relatively independent missions and as such the space station acts as little more than a way station for them.

The principal benefit to planetary missions provided by the space station is the ability to scavenge propellant from the STS ET on regular flights to the SS. This propellant then need not be carried on the flight that carries up the planetary mission, thus lowering the weight to be lifted to the space station on any one payload flight. Also some benefits are identified in the areas of mating spacecraft to their launch vehicles in orbit and the actual launching of those payloads.

For the Comet Sample Return mission the SS could provide retrieval capability and some contamination control (isolation). A drawback is that the relative orientation of the sample return orbit and the SS orbit may be such that retrieval could be accomplished more efficiently by the STS; this tradeoff can be performed when the Comet Sample Return mission is defined more precisely.

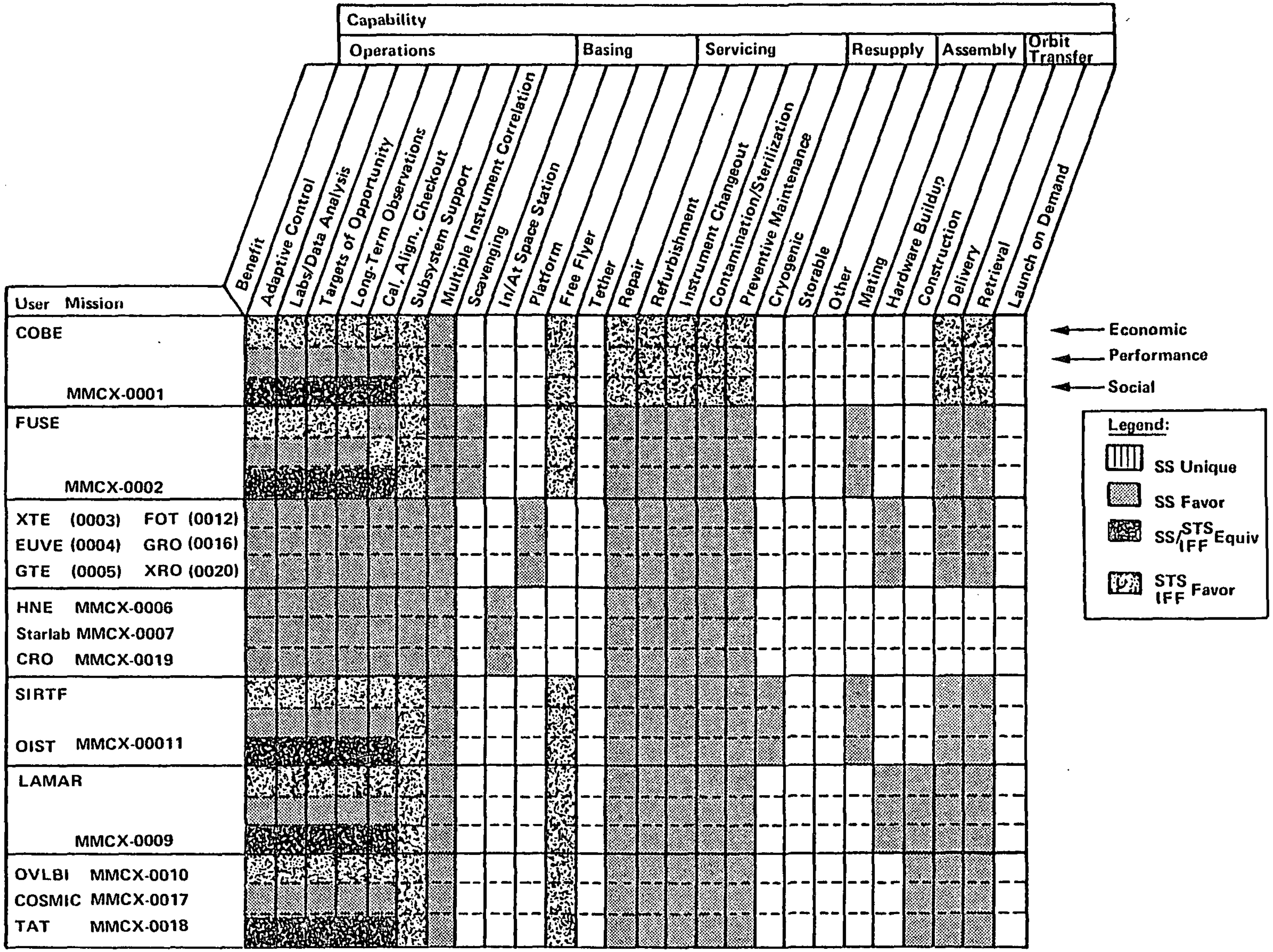


Figure 7.4-1 Benefits Assessment - Astronomy

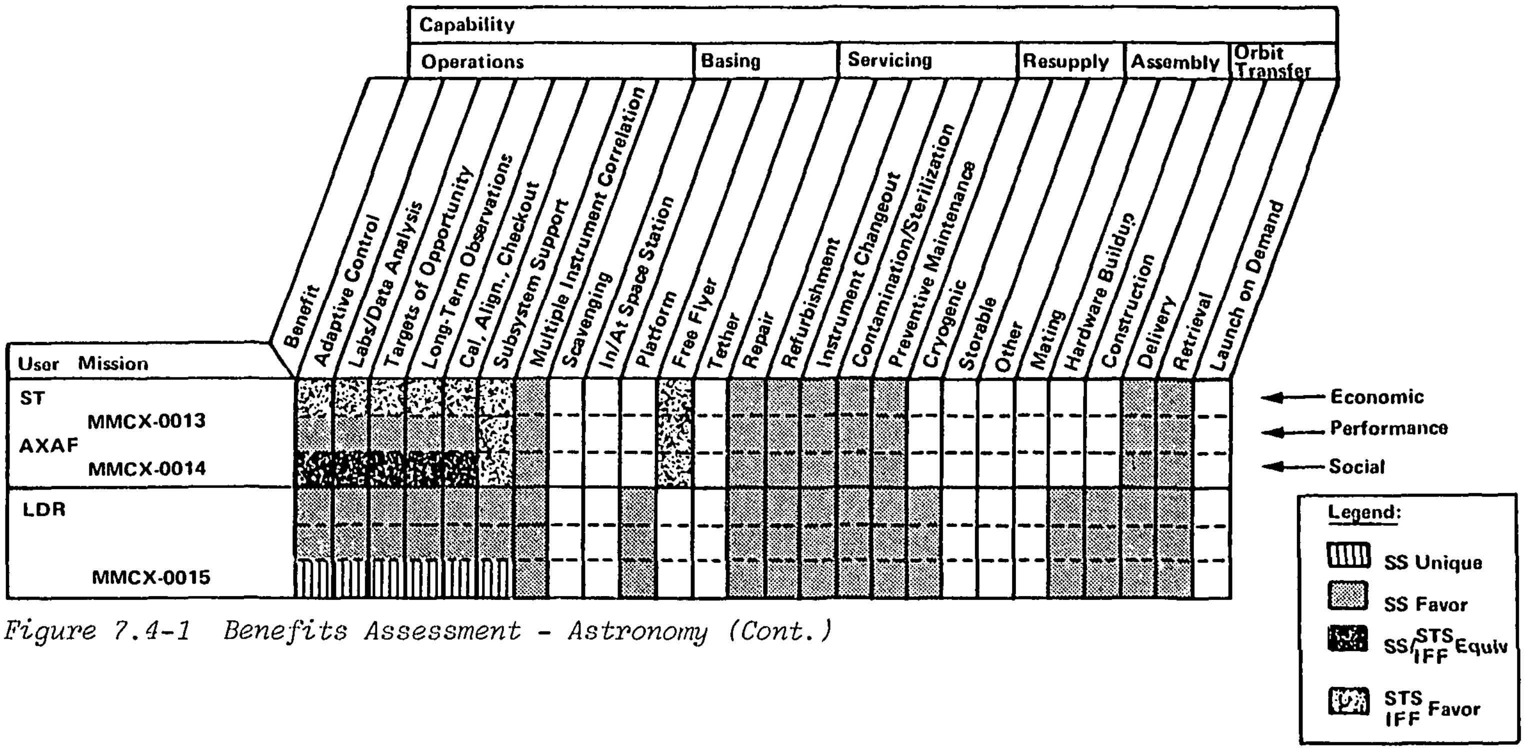
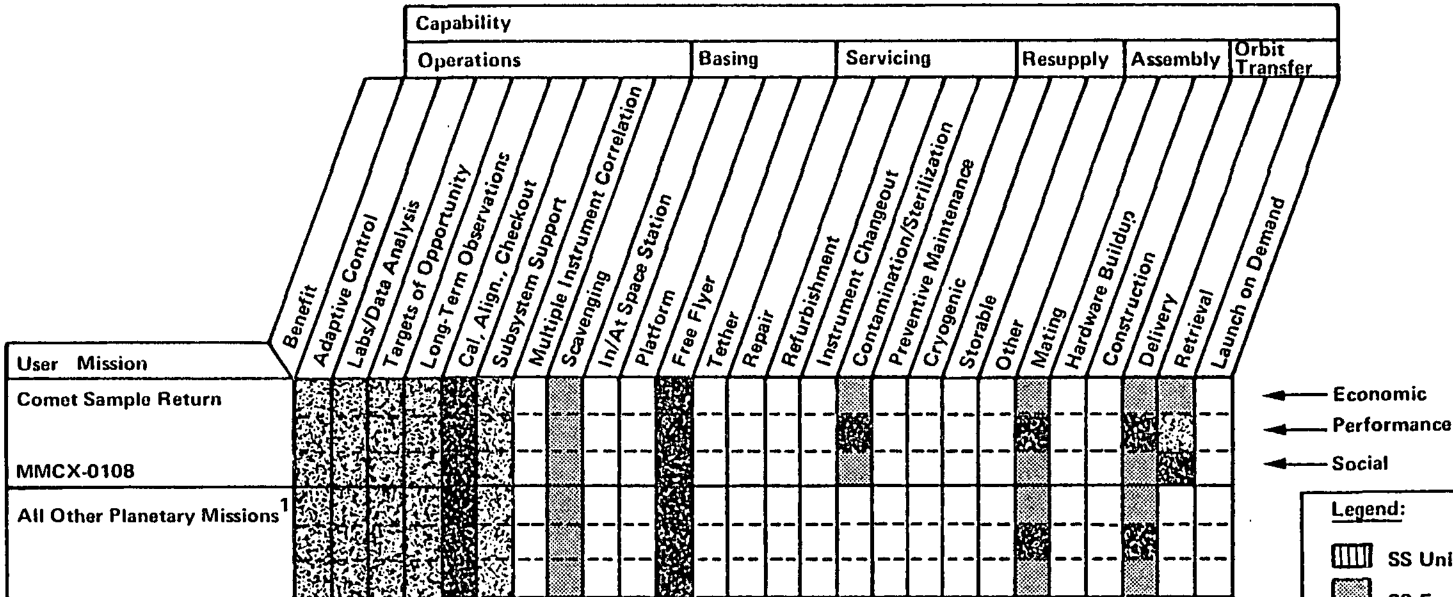
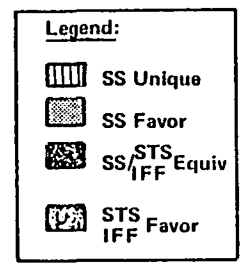


Figure 7.4-1 Benefits Assessment - Astronomy (Cont.)





Note:

1. MMCX-0101 Venus Radar Mapper
   MMCX-0102 Comet Rendezvous
   MMCX-0103 Mars Geochemistry/Climatology Mapper
   MMCX-0104 Titan Probe
   MMCX-0105 Mars Probe Network
   MMCX-0106 Venus Atmospheric Probe
   MMCX-0107 Lunar Orbiter
   MMCX-0109 Main-Belt Asteroid Multirendezvous
   MMCX-0110 Earth Approaching Asteroid Rendezvous
   MMCX-0111 Saturn Probe/Orbiter

Figure 7.4-2 Benefits Assessment - Planetary Exploration

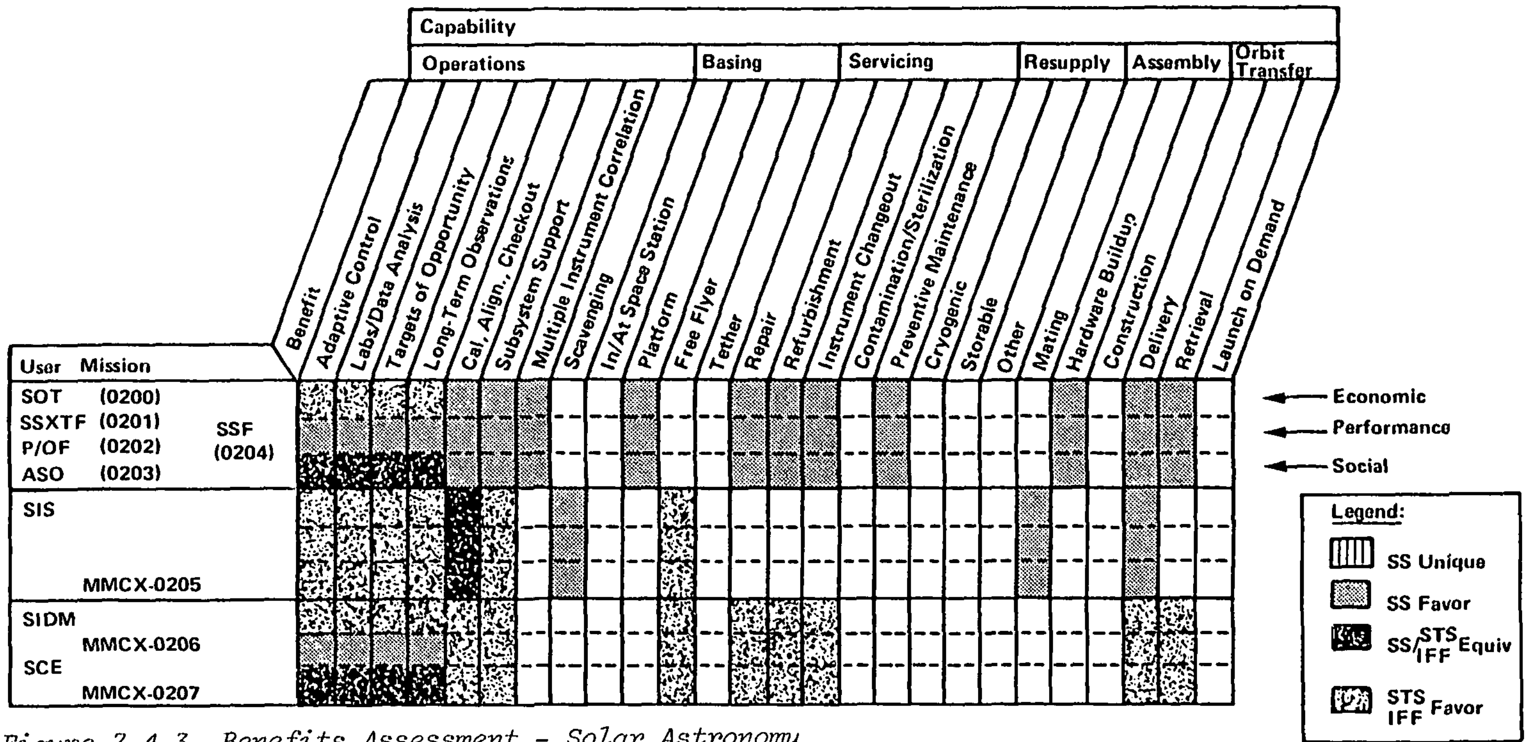


Figure 7.4-3 Benefits Assessment - Solar Astronomy

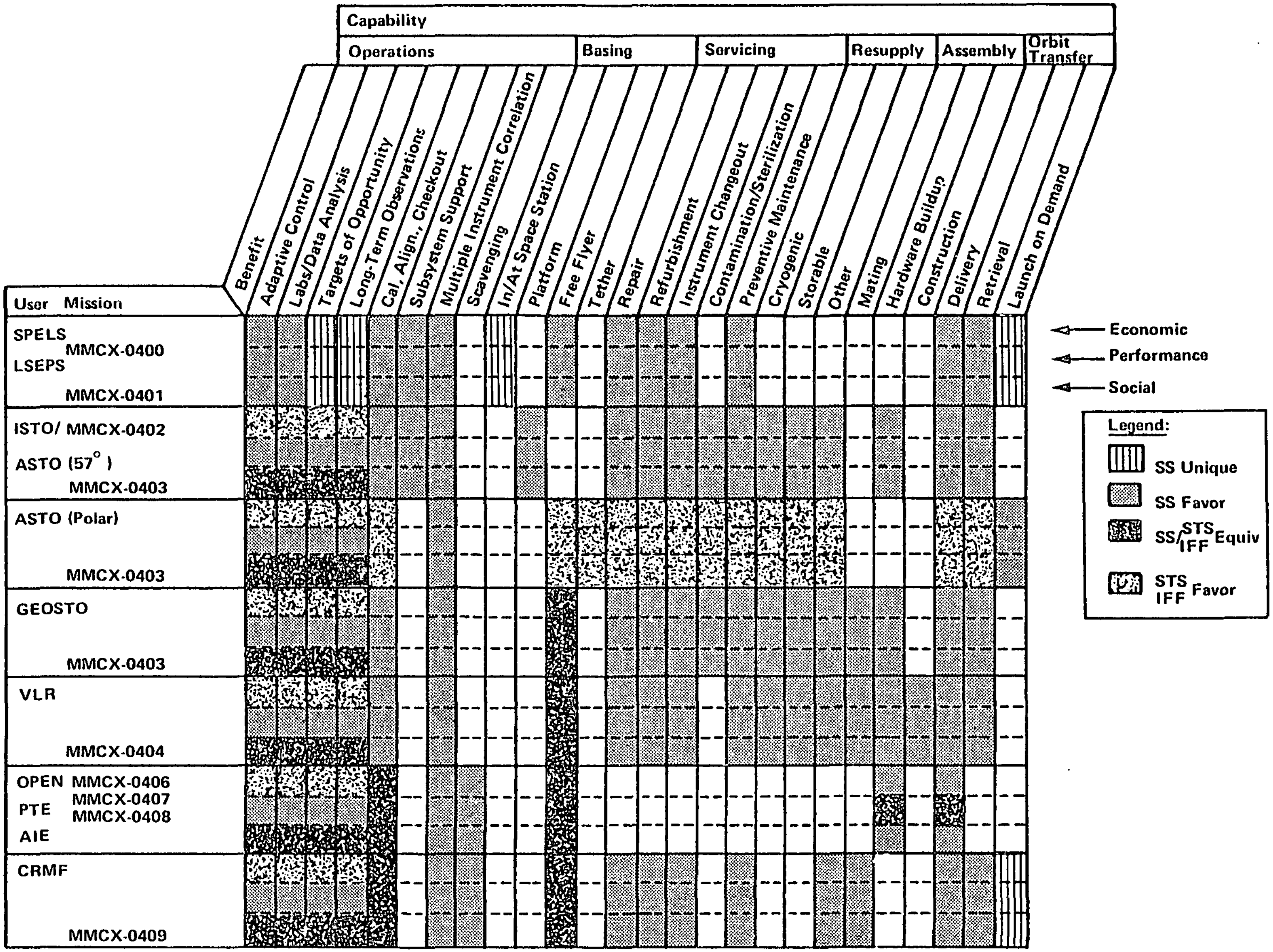
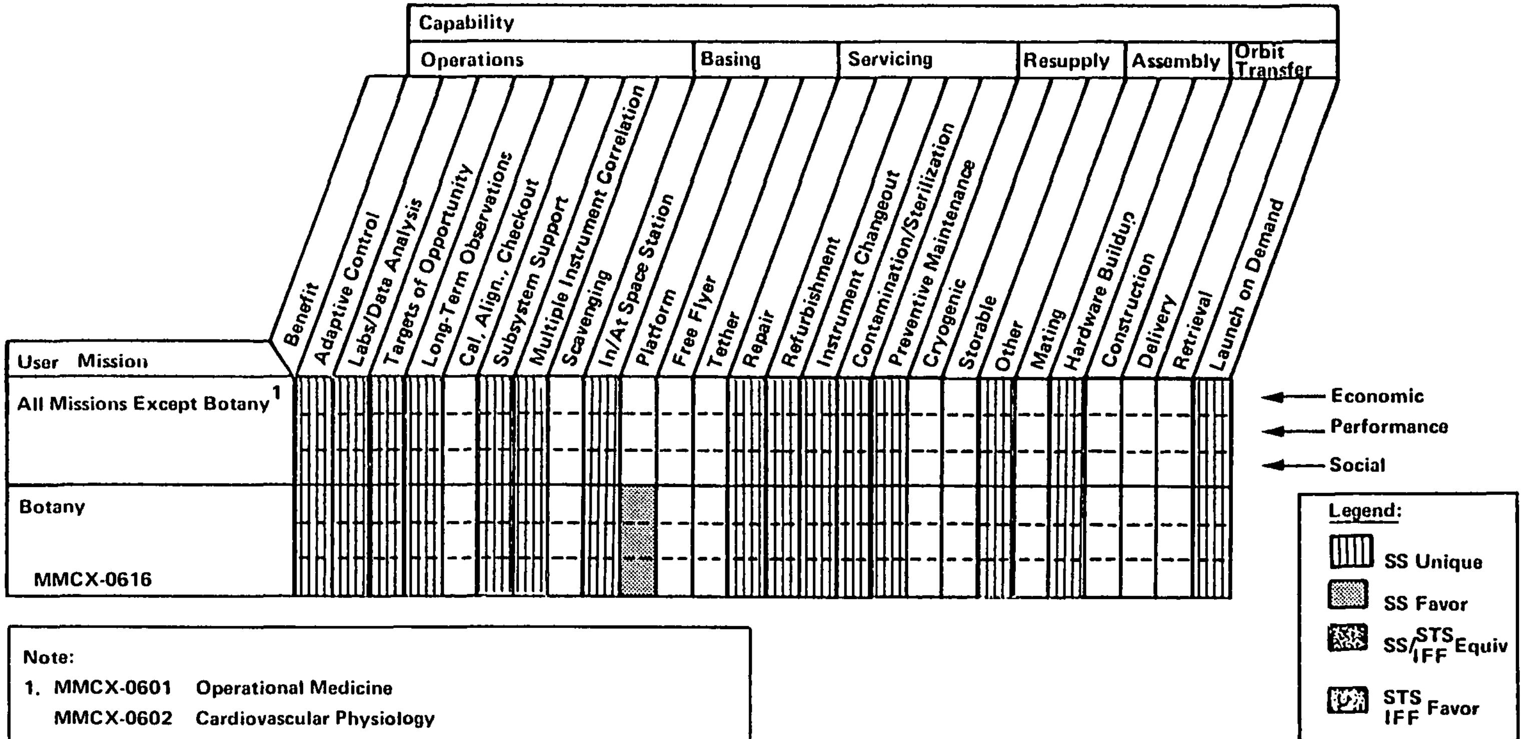


Figure 7.4-4 Benefits Assessment - Space Physics



Note:

1. MMCX-0601 Operational Medicine
   MMCX-0602 Cardiovascular Physiology
   MMCX-0603 Vestibular/Neurophysiology
   MMCX-0604 Osteology
   MMCX-0605 Musculoskeletal Physiology
   MMCX-0606 Hematology/Immunology
   MMCX-0607 Fluid/Electrolytes
   MMCX-0608 Metabolism (Endocrinology, Ca^{3+})
   MMCX-0610 Embryology/Developmental Physiology
   MMCX-0611 Psychology/Behavior
   MMCX-0612 Radiation Biology
   MMCX-0614 Basic Space Biology
   MMCX-0615 CELSS-Controlled Environmental Life Support System

Figure 7.4-5 Benefits Assessment - Life Sciences

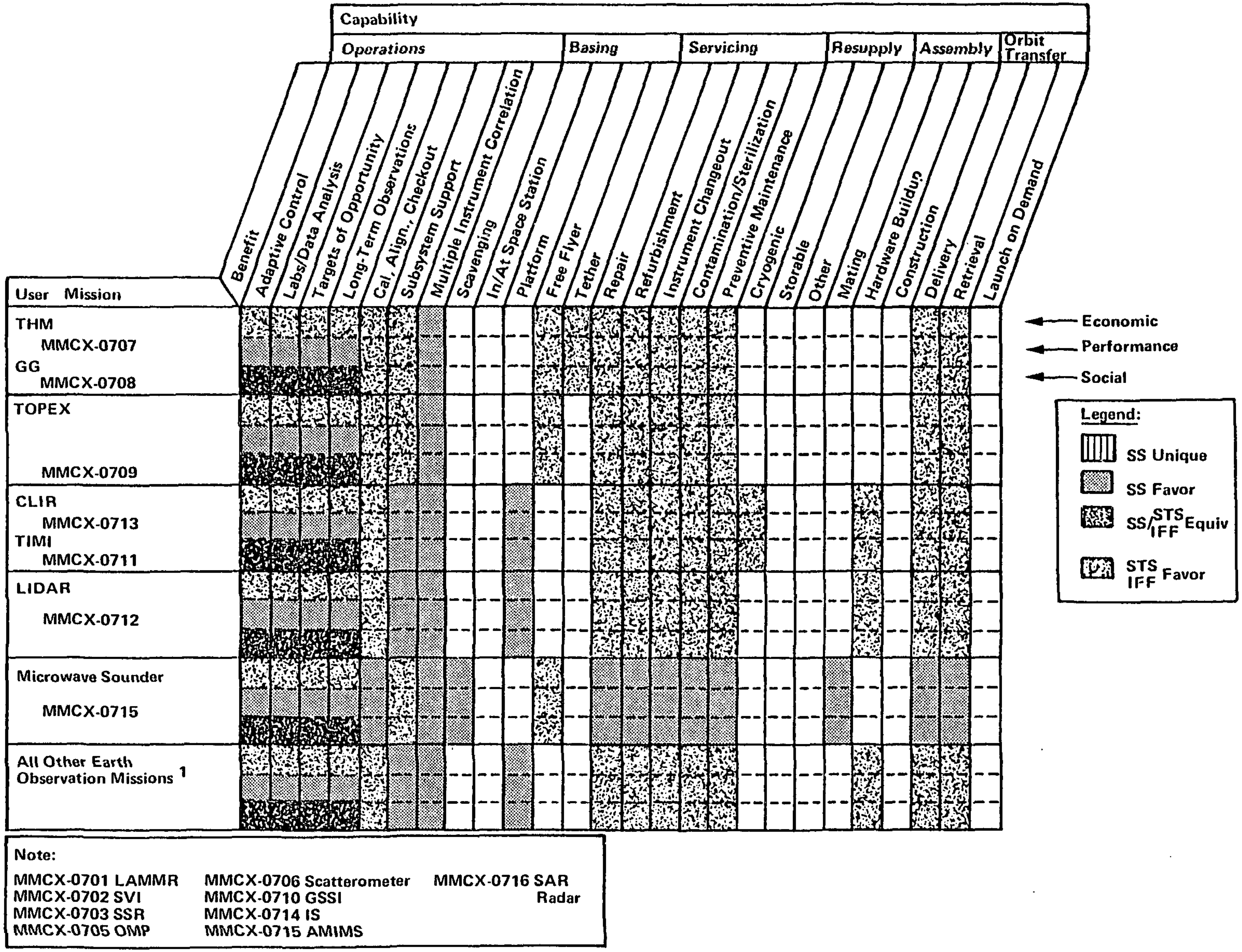
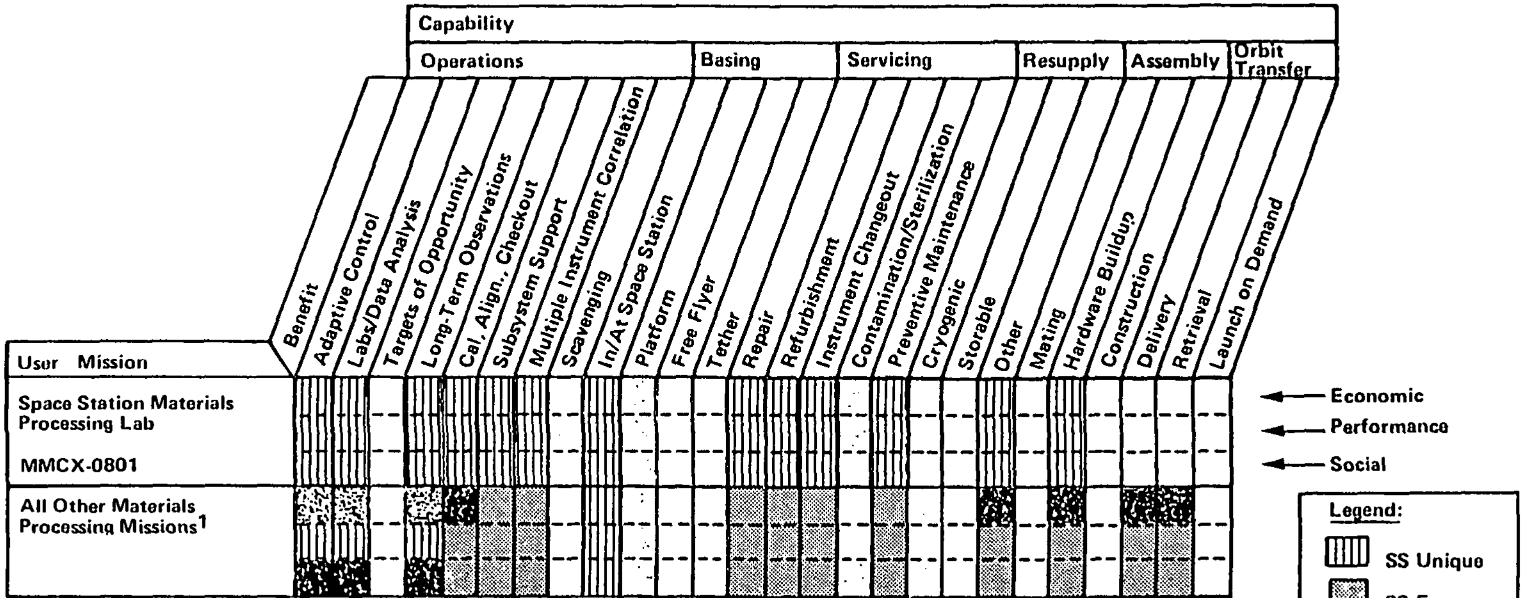
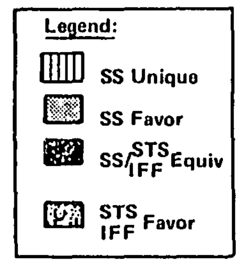


Figure 7.4-6 Benefits Assessment - Earth Observations





Note:

1.

MMCX-0802	Acoustic Containerless Furnace	MMCX-0810	Fluid Experiment System
MMCX-0803	Electrostatic Containerless Furnace	MMCX-0811	Gradient Furnace
MMCX-0804	Electromagnetic Containerless Furnace	MMCX-0812	Isothermal Furnace
MMCX-0805	Vapor Crystal Growth Facility	MMCX-0813	Electrophoresis Separation
MMCX-0806	Crystals From Solution Facility	MMCX-0814	Bromine Phase Experiment
MMCX-0807	Electron Beam Furnace	MMCX-0815	Combustion Research
MMCX-0808	Directional Solidification Furnace	MMCX-0816	Molecular Beam Epitaxy
MMCX-0809	Fluids/Chemical Process Facility		

Figure 7.4-7 Benefits Assessment - Materials Processing

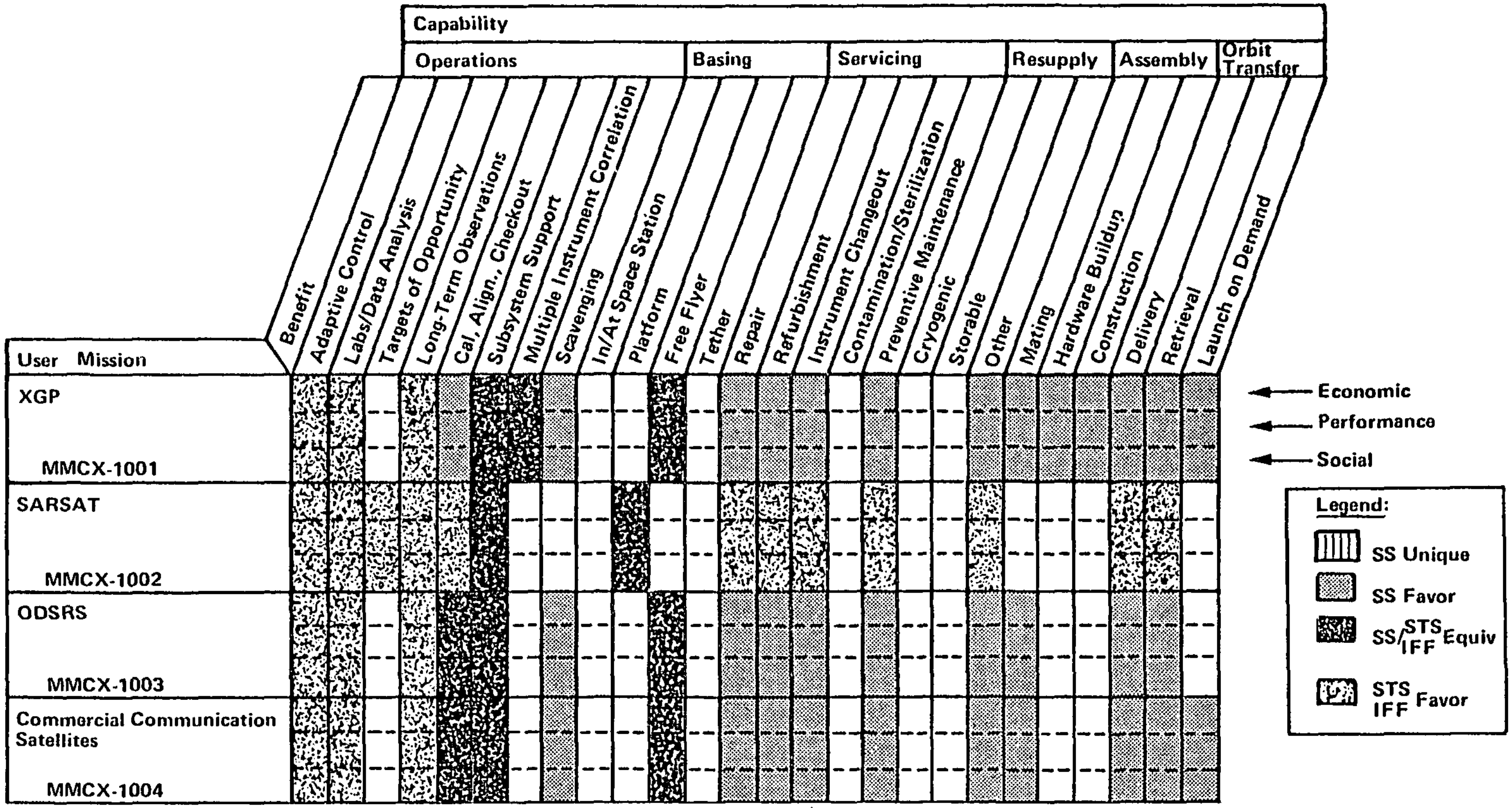


Figure 7.4-8 Benefits Assessment - Commercial Communications

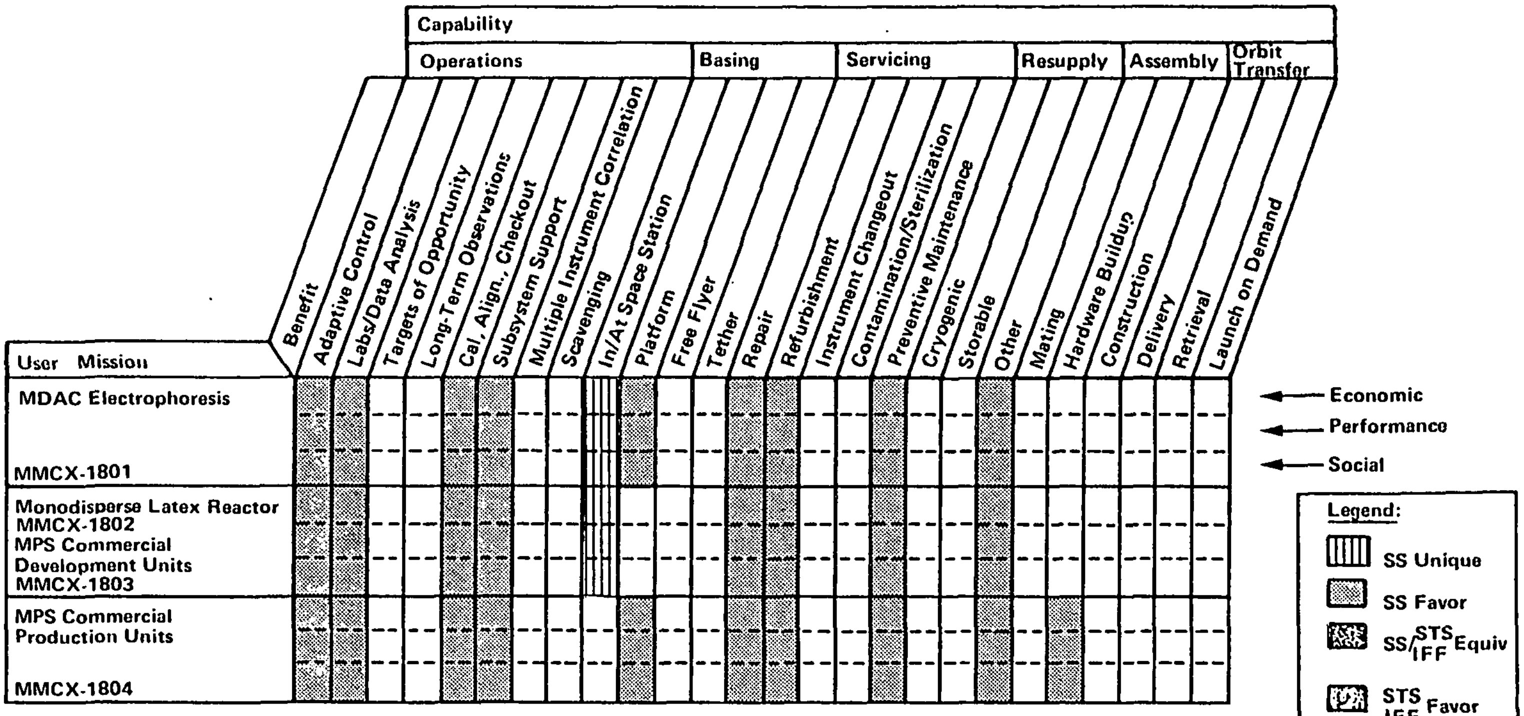


Figure 7.4-9 Benefits Assessment - Commercial Materials Processing

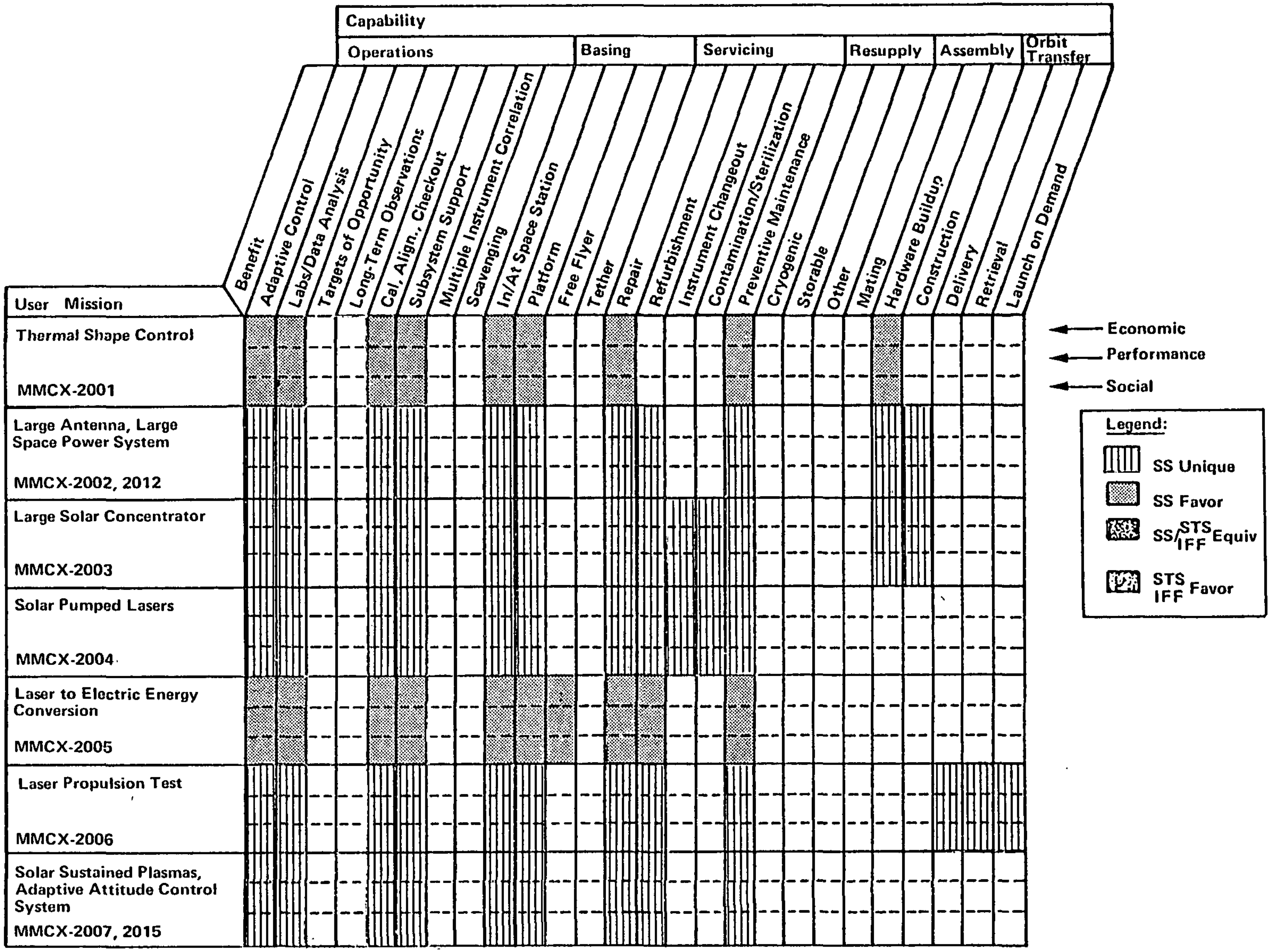


Figure 7.4-10 Benefits Assessment - Technology Development

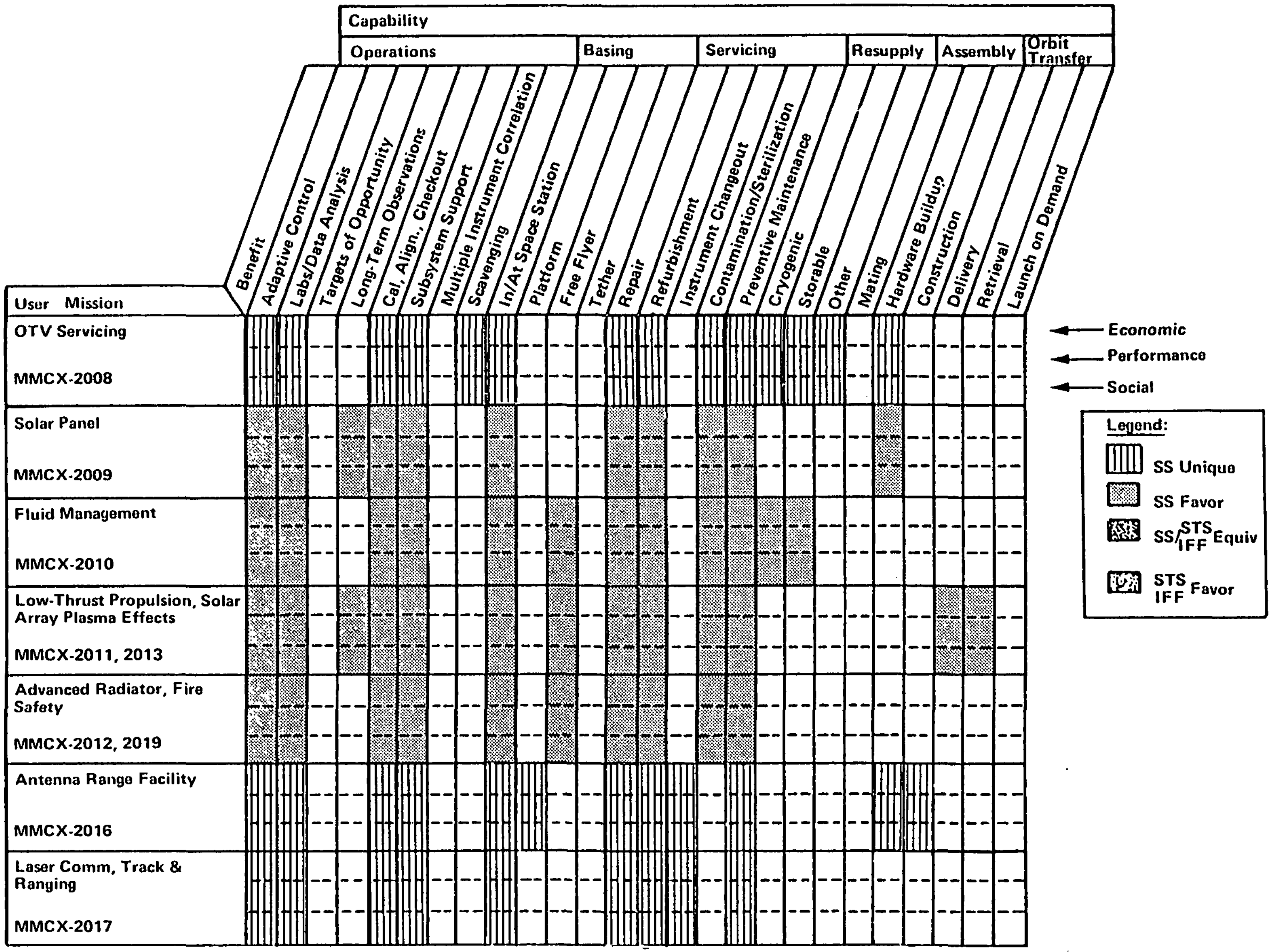


Figure 7.4-10 Benefits Assessment - Technology Development (Cont.)

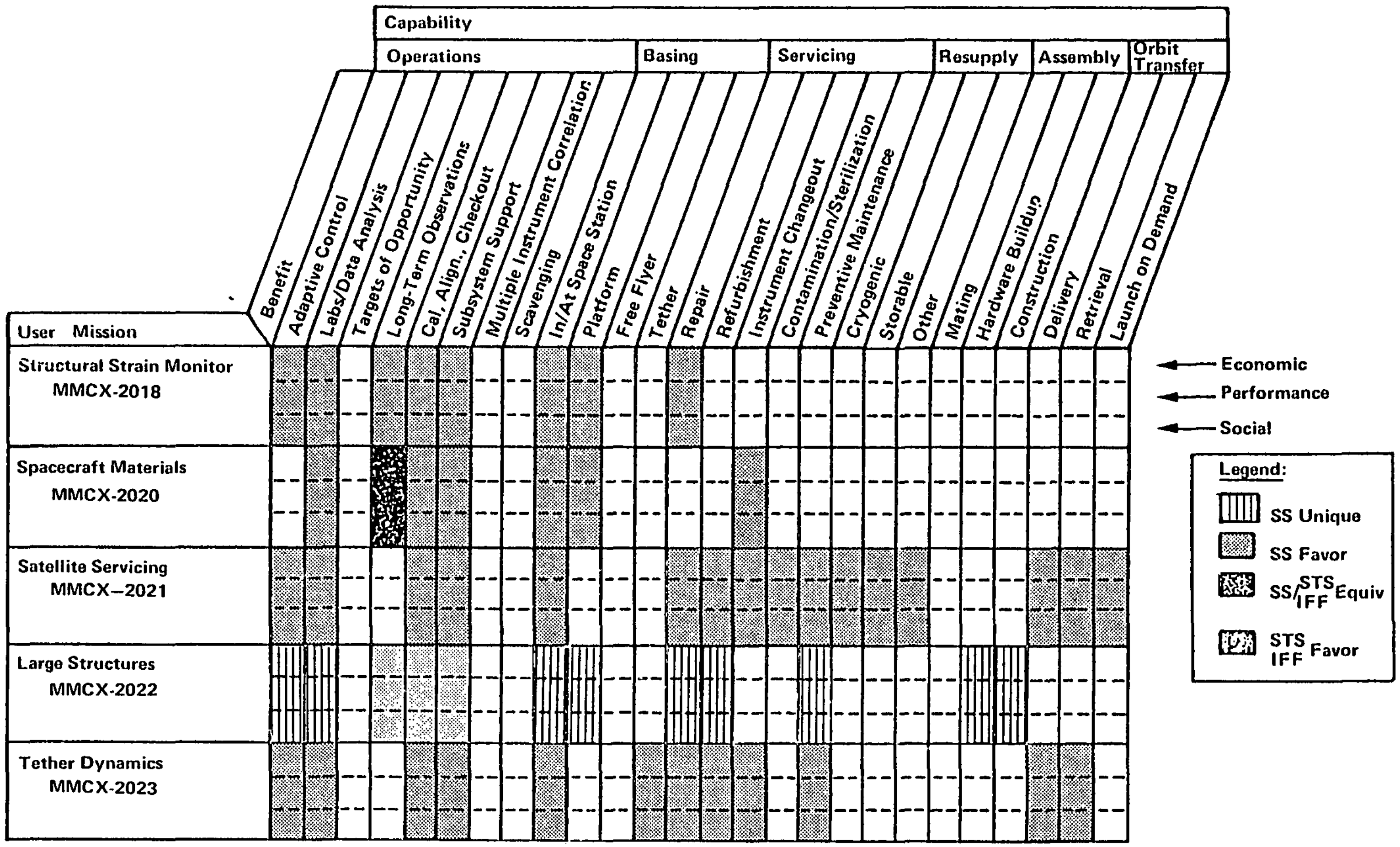


Figure 7.4-10 Benefits Assessment - Technology Development (Cont.)

7.4.3 Solar Astronomy

All missions in the solar physics area are directed toward one purpose: understanding the sun as a star. To that end, and because some solar events are of such short duration, real time control and correlation of all instruments and data collection is highly desirable.

Because such correlation and control is desirable, conducting the research from the space station or a platform can provide significant performance improvements.

Additional areas of benefit to solar physics payloads are in operations, servicing and orbit transfer. For operations involving platform missions, checkout, subsystem support (provided by the platform) and instrument correlation are the significant beneficial areas. Servicing (i.e., repairs, refurbishment, maintenance, and instrument changeout) are areas where payloads benefit, together with the advantage of being delivered to the platform from the SS.

The missions which benefit most from the space station are those on the moderate inclination platforms (Table 7.3-5). These payloads benefit primarily in the operations, basing, servicing and transfer areas. The missions in synchronous orbit benefit from the space station only in the data correlation and control functions. The SIS is an interplanetary spacecraft and benefits only if the space station can aid in its initial delivery.

7.4.4 Space Physics

The space physics area, like the solar physics area, is a collection of instruments designed to be operated primarily on a synergistic group. The instruments are based: (1) at the space station, for large structure/space plasma interaction studies, (2) on the moderate inclination platform (Table 7.3-5), for the solar/terrestrial observatories, and (3) on free flyers at various locations. The benefits assessment is presented in Figure 7.4-4.

The primary areas for benefits to the space physics mission are in operations, servicing, resupply, assembly and orbit transfer. The opportunity to conduct long term observations and observations of transient phenomena in the area of structure/space plasma interaction is a unique benefit of operations at the space station, as is the ability to launch the Chemical Release Module Facility (CRMF) on demand.

Space physics missions which benefit most from the space station are the Space Plasma Effects on Large Spacecraft (SPELS)/Large Spacecraft Effects on Primate Space (LSEPS) and those on the moderate inclination platform. (Table 7.3-5).

The GEO free flyers Geosynchronous Solar Terrestrial Observatory (GEOSTO) and Very Large Radar (VLR) also benefit from the servicing and construction capability of the SS. The CRMF, as mentioned above, benefits from the flexibility of launch provided by the SS. Finally, as with solar physics, the ability to correlate data from all instruments in real time and to respond to targets of opportunity (i.e., transient phenomena) in an efficient manner is a principal benefit of the space station.

7.4.5 Life Sciences

The only life sciences mission included in the space station mission model were those that could not be accomplished by the STS/Spacelab combination. All of these missions are based in the Life Sciences Laboratories on the space station. A summary of significant benefits to the life sciences effort is shown in Figure 7.4-5. As with previous categories, most of these missions are part of a larger effort to understand the "big picture" of life sciences, both in space and on the ground.

Unique benefits to life sciences occur in all SS capability areas. Adaptive control of both long term and short term experiments are provided together with the support systems provided by the space station through the life sciences laboratory. Servicing/resupply of the life sciences experiments is easily provided in all areas because of the centralized basing at the space station itself. Hardware build-up in the labs can proceed on an as required basis by taking advantage of space available on regularly scheduled STS flights to the SS.

One additional benefit to the botany experiment would be the possibility of launching a self-contained experiment from the space station, either as a free flyer or as a package to a platform to provide a completely isolated, zero-g environment.

7.4.6 Earth Observation

The earth observation program is another coordinated effort involving a number of separate missions. This effort is aimed at understanding the earth as a system. Most of the earth observations experiments are mounted on the high inclination platform; others are free flyers.

For the most part the space station plays a data collection/correlation role. Because the earth observations platform is at a high orbit inclination, servicing is better done from the orbiter. Ocean Topography Experiment (TOPEX) is at an inclination better reached with a Shuttle/OTV combination.

The two primary missions where the space station can provide benefits to the earth observations program are the delivery and servicing of the geosync microwave sounder, and the real time collection, correlation and control of the earth observations platform.

Thus, benefits provided to the earth observations program by the space station are in the area of instrument/data correlation and control with secondary benefits in the area of servicing and delivery for the geosynchronous mission.

7.4.7 Materials Processing

All materials processing experiments are conducted either on board the space station in the SS materials processing laboratory or on a nearby materials processing platform. Figure 7.4-7 is a summary of the materials processing benefits.

The SS materials processing laboratory provides a unique benefit to the materials processing program by providing one location where all materials processing activity can take place. This allows all experiments and hardware to share data correlation and subsystems support. In some cases the space station is the only way of providing long term adaptive experiment control and real time data analysis, while at the same time permitting continuous monitoring and rapid response to malfunctions.

7.4.8 Commercial Communications

The commercial communications missions are all basically free flyers in geosynchronous orbit with the exception of the Search and Rescue Satellite - Aided Tracking (SARSAT) which shares the earth observations platform in polar orbit. A summary of the benefits assessment is shown on Figure 7.4-8.

Servicing, resupply, assembly and orbit transfer are the significant SS capabilities that provide benefits to the commercial communications user missions. Other minor benefits are cryogenic scavenging, for missions that require cryogenic OTV delivery or retrieval, and in calibration, checkout, and alignment of target structures (i.e., Experimental Geostationary Platform (XGP)).

7.4.9 Commercial Materials Processing

All commercial materials processing missions take place at the space station or on a platform nearby. Figure 7.4-9 is a summary of the benefits assessment for the commercial materials processing missions.

Areas where the SS provides benefits to the effort are in the ability to adaptively control and analyze those processes together with calibration, checkout, subsystems support, and servicing (repair, refurbishment and maintenance of the materials processing units).

Benefits to the commercial materials processing missions are virtually the same across all missions, the only significant difference being the ability to provide hardware build-up capability for the commercial production units.

7.4.10 Technology Development

All technology development missions take place on or near the space station or are free flyers based at the space station. Figure 7.4-10 presents the benefits assessment for the technology development area.

Areas where the SS provides benefits are in adaptive control, laboratories and data analysis, checkout/calibration/alignment, subsystems support, servicing, and assembly or construction in space. Almost all of the missions make use of the servicing capability of the SS. The space station provides a unique capability for construction of hardware buildup in space, and finally, the space station can act as a delivery and retrieval orbit transfer base.

APPENDIX A ACRONYMS AND ABREVIATIONS

A	Angstrom
AC&S	Attitude Control and Stabilization
ACC	Aft Cargo Carrier
ACS	Attitude Control Subsystem
ACTS	Advanced Communications Satellite Corporation
AFB	Air Force Base
AHUT	Animal Holder and Unit Tester
AIAA	American Institute of Aeronautics and Astronautics
AIE	Advanced Interplanetary Explorer
AL	Airlock
ALCOA	Aluminum Company of America
AMIMS	Advanced Meteorological Infrared & Microwave Soander
AMPTE	Active Magnetosphere Particle Tracer Experiment
AO	Announcement Opportunity
AP	Action Potential
ARC	Arnold Research Center
ASE	Airborne Support Equipment
ASO	Advanced Solar Observatory
ASTO	Advanced Solar Terrestrial Observatory
ATP	Authority to Proceed
AXAF	Advanced X-Ray Astrophysics Facility
B	Billion
BASD	Ball Aerospace Division
BCK	Blood Collection Kit
BIT	Built-In Test

APPENDIX A ACRONYMS AND ABREVIATIONS

BITE	Built-In-Test-Equipment
BIU	Bus Interface Unit
BOL	Beginning of Life
BTS	Biotelemetry System
BYU	Brigham Young University
C	Core
c	Centigrade
Ca	Calcium
CB	Cargo Bay
C&DH	Command and Data Handling Subsystem
CDP	Coronal Diagnostic Package
CDR	Critical Design Review
CELSS	Controlled Environment Life Support System
CER	Cost Estimating Relationship
CF	Construction Facility
CG	Center of Gravity
CIT	California Institute of Technology
Cl	Chloride
CLIR	Cryogenics Limb Scanning Interferometer & Radiometer
CM	Command Module
CMD	Command
CMG	Control Moment Gryo
CMM	Composite Mission Model
CO_2	Carbon Dioxide
COBE	Cosmic Background Explorer

APPENDIX A ACRONYMS AND ABREVIATIONS

COMPMM	Composite Mission Model
COMSAT	Communications Satellite Corporation
COSMIC	Coherent Optical System Modular Imaging Collector
CR	Comet Rendezvous
CRM	Chemical Release Module
CRMF	Chemical Release Module Facility
CRO	Cosmic Ray Observatory
CRT	Cathode-Ray Tube
CSR	Comet Sample Return
CU	Colorado University
CZCS	Coastal Zone Color Scanner
DBS	Direct Broadcast Satellite
DBV	Derived Boost Vehicle
DDT&E	Design Development, Test and Evaluation
DEMS	Dynamic Environment Monitoring System
DMPS	Data Management and Processing System
DOD	Department of Defense
DRM	Design Reference Mission
DSN	Deep Space Network
DVM	Doctor of Veterinarian Medicine
EAAR	Earth Approaching Asteroid Rendezvous
ECG	Electrocardiograph
ECLS	Environmental Control Pipe Support
ECLSS	Environmental Control/Life Support Systems

APPENDIX A ACRONYMS AND ABREVIATIONS

ECS	Environmental Control System
EEG	Electroencephalogram
e.g.	Example
EKG	Electromyogram
ELS	Eastern Launch Site
EMC	Electromagnetic Compatibility
EMG	Electromyogram
EMI	Electromagnetic Interference
EMU	Extravehicular Mobility Unit
ENG	Electonystagnogram
EOL	End of Life
EOS	Electrophoresis Operations In Space
EOTV	Expendable Orbital Transfer Vehicle
EPS	Electrical Power
EPDS	Electrical Power and Distribution System
ERB	Earth Radiation Budget
ET	External Tank
ETCLS	Environmental and Thermal Control and Life Support
EUVE	Extreme Ultraviolet Explorer
EVA	Extra-Vehicular Activity
Exper	Experimeter
Expmt	Experimeter
fps	Feet per Second
FCC	Federal Communications Commission
FDMA	Frequency-Division Multiple Access

APPENDIX A ACRONYMS AND ABREVIATIONS

FF	Free Flyer
FILE	Feature Identification and Location Experiment
FLOPS	Floating Point Operations Per Second
FOC	Full Operating Capability
FOCC	Flight Operations Control Center
FOT	Faint Object Telescope
FSF	First Static Firing
FUSE	Far Ultraviolet Spectroscopy Explorer
FY	Fiscal Year
g	Gravity
GG	Gravity Gradient
G_Z	Vertical Gravity Acceleration Component
GaAs	Galium Arsemide
GEO	Geosynchronous Earth Orbit
GEOSTO	Geosynchronous Solar Terrestrial Observatory
GFP	Government-Furnished Property
GG	Gravity Gradiometer
GHZ	Gigadertz
GND	Ground
GPS	Global Positioning System
GPWS	General Purpose Work Station
GRIST	Grazing Incidence Solar Telescope
GRO	Gamma Ray Observatory
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center

APPENDIX A ACRONYMS AND ABREVIATIONS

GSS	Ground Support System
GSSI	Geosynchronous Satellite Sensor Intercalibration
GTE	Gamma Ray Timing Explorer
H	Hangar
H_2O	Water
H/W	Hardware
HM	Habitation Module
HMF	Health Maintenance Facility
HNE	Heavy Nuclei Explorer
HOL	Higher Order Language
I&C	Installation and Checkout
I/F	Interface
ID	Identification
INCO	International Nickel Company
INTELSAT	International Telecommunications Satellite Organization
IOC	Initial Operating Capability
IPS	Instrument Pointing System
IR	Infrared
IRAS	Infrared Astronomy Satellite
IRD	Instrument Research Division
IS	Imaging Spectrometer
ISP	Initial Specific Impulse
ISPM	International Solar Polar Mission
ISTO	Initial Solar Terrestrial Observatory
IUE	International Ultra Violet Explorer
IVA	Intravehicular Activity

APPENDIX A ACRONYMS AND ABREVIATIONS

J&J	Johnson and Johnson
JEA	Joint Endeavor Agreement
JHU	John Hopkins University
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
K	Potassium
Kbps	Kilobits Per Second
KG, kg	Kilogram
KSC	Kennedy Space Center
KW, kw	Kilowatt
lbm	Pounds
LAMAR	Large Area Modular Array Reflectors
LAMMR	Large Antenna Multifrequency Microwave Radiometer
LaRC	Langley Research Center
LBNP	Lower Body Negative Pressure
LBNPD	Lower Body Negative Pressure Device
LDR	Large Deployable Reflector
LEO	Low Earth Orbit
LeRC	Lewis Research Center
LIDAR	Light Detection and Ranging
LiOH	Lithium Hydroxide
LM	Logistics Module
LMMI	Large Mass Measurement Instrument
LSEPS	Large Spacecraft Effects on Proximate Space

LSLE	Life Sciences Laboratory Equipment
LSLF	Life Sciences Laboratory Facility
LSM	Life Support Module
LSRF	Life Sciences Research Facility
LSRM	Life Sciences Research Module
LSS	Life Support Systems
LRU	Line Replaceable Unit
LWA	Long Wavelength Antenna
mV	Millivolt
M	Million
MAM	Main Belt Asteroid Multirendezvous
Mbps	Megabits Per Second
MD	Medical Doctor
MDAC	McDonnell Douglas Astronautics Company
MeV	Million Electron Volts
MGCM	Mars Geochemistry/Climatology Mapper
MIT	Massachusetts Institute of Technology
MMC	Martin Marietta Corporation
MML	Martin Marietta Laboratories
MMS	Multimission Modular Spacecraft
MMU	Manned Maneuvering Unit
MOHM	Megaohms
MOTV	Manned Orbital Transfer Vehicle
MP	Materials Processing
MPN	Mars Probe Network

APPENDIX A ACRONYMS AND ABREVIATIONS

MPS	Materials Processing in Space
MR	Microwave Radiometer
MRICD	Medical Research Institute for Chemical Defense
MRWS	Mobile Remote Work Station
M-SAT	Mobile Satellite
MSFC	Marshall Space Flight Center
MWPC	Multi-Wire Proportional Counter
MWS	Microwave Sounder
N/A	Not Applicable
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NiH_2	Nichel Hydrogen
NM	Nautical Miles
NMR	Nuclear Magnetic Resonance
NOAA	National Oceanic and Atmospheric Administration
NRL	Naval Research Laboratory
ODSRS	Orbiting Deep Space Relay Station
OIST	Orbiting Infrared Submillimeter Telescope
OMP	Ocean Microwave Package
OMS	Orbital Maneuvering Systems
O_2	Oxygen
O_2/N_2	Oxygen/Nitrogen
OPEN	Origin of Plasma in the Earth Neighborhood
OSA	Optical Society of America
OTV	Orbital Transfer Vehicle
OVLBI	Orbital Very Long Baseline Interferometer

APPENDIX A ACRONYMS AND ABREVIATIONS

P	Phosphorous
PDR	Preliminary Design Review
PET	Position Emission Tomography
PhD	Doctorate of Philosophy
PH	Level of Acidity
PI	Principal Investigator
PIDA	Payload Installation and Deployment Aid
P/L	Payload
PLSS	Portable Life Support Systems/Personal Life Support System
PMD	Propellant Management Device
PMS	Physiological Monitoring System
P/OF	Pinhole/Occulter Facility
PS	Payload Specialist
psi	Pounds per Square Inch
psia	Pounds per Square Inch Absolute
PTE	Plasma Turbulence Explorer
QD	Quick Disconnect
R&D	Research and Development
R&T	Research and Technology
RAHF	Research Animal Holding Facility
RBC	Red Blood Cell
RCA	Radio Corporation of America
RCS	Reaction Control System
REM	Roentgen Equivalent, Mass

RF	Radio Frequency
RFP	Request for Proposal
RMS	Remote Manipulator System
ROM	Rough Order of Magnitude
ROSS	Remote Orbital Servicing System
ROTV	Reusable Orbital Transfer Vehicle
SAO	Smithsonian Astronomical Observeratory
SAR	Synthetic Aperture Radar
SARSAT	Search and Rescue Satellite - Aided Tracking
SAT	Satellite
S/C	Spacecraft
SCADM	Solar Cycle and Dynamics Mission
SCDM	Solar Coronal Diagnostic Mission
SCE	Solar Corona Explorer
SDCV	Shuttle Derived Cargo Vehicle
SDV	Shuttle Derived Vehicle
SERV	Servicing
SEXTF	Solar EUV/XUV Telescope Facility
SHEF	Solar High Energy Facility
SIDM	Solar Interior Dynamics Mission
SIDF	Solar Interior Dynamics Facility
SIRTF	Shuttle Infrared Telescope Facility
SIS	Solar Interplanetary Satellite
SL	Spacelab
SLFRF	Solar Low Frequency Radio Facility

SMMI	Small Mass Measurement Instrument
SOMS	Shuttle Orbiter Medical Systems
SO/P	Saturn Orbiter/Probe
SOT	Solar Optical Telescope
SP	Scientific Payload
SPELS	Space Plasma Effects on Large Spacecraft
SPIE	Society Photo-Optics Instrument Engineers
SRB	Solid Rocket Booster
SRR	Systems Requirements Review
SS	Space Station
SSCAG	Space System Cost Analysis Group
SSEC	Solar Systems Exploration Committee
SSF	Solar Shuttle Facility
SSL	Space Sciences Laboratory
SSMM	Space Station Mission Model
SSR	Solar Spectrometer/Radiometer
SSRMS	Space Station Remote Manipulator System
SSXTF	Solar Soft X-Ray Telescope Facility
ST	Space Telescope
STDN	Space Tracking and Data Network
STO	Solar Terrestrial Observatory
STS	Space Transportation System
SVI	Stereo Visual Image
TAT	Thinned Aperture Telescope
TBD	To Be Determined
TBR	To Be Required

APPENDIX A ACRONYMS AND ABREVIATIONS

TBS	To Be Supplied
TCS	Thermal Control Subsystem
TDAS	Tracking and Data Acquisition System
TDM	Technology Development Mission
TDMA	Time-Division Multiple Access
TDRS	Tracking and Data Relay Satellite
TDRSS	TDRS System
TEM	Transmission Electron Microscopy
THM	Tethered Magnetometer
TIMI	Thermal Infrared Multispectral Imager
TM	Technical Memorandum
TMS	Teleoperator Maneuvering System
TOPEX	Ocean Topography Experiment
TP	Thermal Panels
TPS	Thermal Protection System
TSS	Time Sharing System
TV	Television
um	Micrometer = micron
usec	Microsecond
uvolt	Microvolt
UARS	Upper Atmosphere Research Satellite
UC	University of California
UCSF	University of California, San Francisco
UHF	Ultra High Frequency

Ult	Ultimate
UM	University of Maryland
UM	University of Michigan
UMS	Urine Monitoring System
U.S./USA	United States/United States of America
US	Upper Stage
USRA	University Space Research Association
UT	University of Texas
UV	Ultraviolet
V	Velocity
VAP	Venus Atmospheric Probe
VAFB	Vandenberg Air Force Base
VCU	Virginia Commonwealth University
Vdc	Volts Direct Current
VFR	Vestibular Function Research
VHEO	Very High Earth Orbit
VHSIC	Very High Speed Integrated Circuit
VLR	Very Large Radar
VLST	Very Large Space Telescope
VRF	Vestibular Research Facility
VRM	Venus Radar Mapper
WARC	World Administration Radio Conference
WBS	Work Breakdown Structure
WLS	Western Launch Site
WRU	Work Restraint Unit

XGP	Experimental Geostationary Platform
XRO	X-Ray Observatory
XTE	X-Ray Timing Explorer
Zero g	Zero Gravity
β angle	Angle Between Orbit Plane and Solar Vector
α_s	Coating Solar Absorptance
ε	Coating Emmitance
ω	Watts

I. SPACE OPERATIONS CENTER

A. Boeing Aerospace (NAS9-16151)

Monthly Progress Report #1	June 1980
Monthly Progress Report #2	July 1980
" " " #4	Sept 1980
" " " #6	Oct 1980
" " " #7&8	Jan 1981
" " " #9	Feb 1981
" " " #10	Mar 1981
First Quarter Briefing	Sept 1980
Mid Term Review	Dec 1980
Final Briefing	June 1981
Executive Summary	June 1981
Final Report, Vol I - Executive Summary	July 1981
Final Report, Vol III - System Definition	July 1981
Final Report, Vol IV (1 of 2) - System Analysis	July 1981
Final Report, Vol IV (2 of 2) - System Analysis	July 1981
Progress Systems Requirements Document	July 1981
Monthly Progress, Study Extension #1	Oct 1981
Mid Term Review, " " #2	Oct 1981
Final Briefing " "	Jan 1982
Executive Summary " "	Jan 1982
Final Report, Vol IV - Addendum I	Apr 1982

B. Rockwell International (NAS9-16153)

Monthly Progress Report #1	Aug 1980
" " " #2	Sept 1980
" " " #3	Oct 1980
" " " #5	Dec 1980
" " " #6	Jan 1981
" " " #7	Feb 1981
First Quarter Review	Aug 1980
Mid Term Review	Dec 1980
Final Briefing	April 1981
Mid Term Review, Study Extension #3	Oct 1981
Monthly Progress Report #4, Study Extension	Nov 1981
Mid-Term Review, " "	Oct 1982
Final Review, " "	Feb 1981
Executive Summary, " "	Feb 1982
Final Report, Vol I " "	Feb 1982
Final Report, Vol II " "	Feb 1982

C. Martin Marietta Denver Aerospace

Year End IRAD Report	Dec 1982
Denver/Michoud Technical Interchange	Jan 1982

Space Station Needs, Attributes, and Architectural Options Study (NASW-3686)

(Cont)	C.	Monthly Progress Report #1	Oct 1982
		" " " #2	Nov 1982
		" " " #3	Dec 1982
		" " " #4	Jan 1983
		" " " #5	Feb 1983
		Mid Term Review	Nov 1982
	D.	Johnson Space Center	
		Concept Analysis I	Nov 1979
		Concept Analysis II	Nov 1979
		Conference	Nov 1979
		SOC Status Review	Sept 1981
		Requirements Document	Nov 1981
		Program Plan	Nov 1981
		Technology Plan	Oct 1981
		Mission Plan	Apr 1982
		Mission Model Addendum	Nov 1981
		Boeing Program Plan	Nov 1981
		Advanced Mission Studies	Feb 1982
		STS Capabilities for Supporting the Space Station Program	Sep 1982
	E.	Marshall Space Flight Center	
		Use of External Tank for SOC	Dec 1981
		25 KW Power System	Sept 1979

F. International Data

Status of Space Station Study in Canada	Dec 1982
ESA; Space Station: Status of Planning Activities	Dec 1982
German Presentation for Space Station Conference	Dec 1982
Italian Presentation: Potential Application of the Tethered Satellite System Concept to the Space Station	Nov 1982
Japanese Study Status on Space Station	Dec 1982
European Utilization Aspects of a U.S. Manned Space Station	Dec 1982

II. GEOSTATIONARY PLATFORM

A. General Dynamics - Convair (NAS8-33527)

System Concept Definition	July 1981

III. SCIENCE AND APPLICATIONS SPACE PLATFORM

A. McDonnel Douglas (NAS8-33592)

First Interim Briefing	(DR-3)	Aug 1981
Second Interim Briefing		Nov 1981
Final Briefing		Feb 1982

B. NASA

Science and Applications Requirements 30th Space Station, Draft Reports, NASA/GSFC.	Nov 1982
Space Science Platform: Panel Reports from UAH/NASA Workshop. NASA/MSFC.	Dec 1978

IV. TELEOPERATOR MANEUVERING SYSTEM (TMS)

A. Martin Marietta Denver Aerospace (NAS8-34581)

Mark II Concept	Dec 1979
" " Summary	
" " AIAA Study	July 1981
Technical Proposal	Mar 1980
Reference Missions	Oct 1981
Monthly Progress Report #1	Nov 1981
" " " #2	Dec 1981
" " " #3	Jan 1982
" " " #4	Jan 1982
" " " #5	Mar 1982
" " " #6	Mar 1982
" " " #7	May 1982
Requirements Review	Nov 1981
Executive Overview	Dec 1981
Mid Term Review	Feb 1982

(Cont) A.

Executive Summary	Apr 1982
Final Review	May 1982
Final Report	June 1982

B. Vought Corporation

TMS Study	April 1981
Interim Review	Dec 1980

Final Review	July 1981
Executive Summary	July 1981
Technical Summary	July 1981
System Definition Study	
Vought/MMC TMS Comparisons	July 1978
Low Energy Stage Study	Oct 1978
Mission Requirements Systems Definition-Tech Report	May 1982
Mission Requirements System Definition-Final Review	May 1982

C. Marshall Space Flight Center

Modular Propulsion concept	June 1981

V. SHUTTLE DERIVED VEHICLES

A. Martin Marietta Denver Aerospace (NAS8-341B3)

Final Report	July 1981

VI. ORBITAL TRANSFER VEHICLE

A. Grumman Aerospace Corporation

System Analysis Study Extension	Feb 1981

B. Boeing Aerospace (NAS8-33532)

Concept Definition Study	1980

C. General Dynamics - Convair (NASI-33533)

Concept Definition Study	Feb 1981

VII. SPACE CONSTRUCTION

A. General Dynamics Convair (NAS9-16120)

Space Construction Experimentation

Definition Study — July 1981

B. Rockwell International (NAS9-15718)

Space Construction System Analysis — Mar 1981

Cost and Program — Apr 1980

C. Grumman Aerospace (NAS9-16120)

Orbiter-Based Construction Equipment Study (OBCES) — Apr 1981

VIII. SATELLITE SERVICING

A. Grumman Aerospace (NAS9-16120)

Final Briefing (Part II) — July 1981

Executive Summary — July 1981

Mid Term Briefing — Dec 1981

B. Lockheed Missiles and Space (NAS9-16121)

Final Review — July 1981

Executive Summary — July 1981

Mid Term Review — Dec 1981

C. Martin Marietta Denver Aerospace

Rendezvous and Docking System — June 1981

Integrated Orbital Servicer Vol I — April 1978

" " " Vol II — April 1978

D.	Lincom Corporation Automated Rendezvous	(NAS9-16130)	Oct 1981

IX. DEFINITION OF TECHNOLOGY DEVELOPMENT MISSIONS FOR EARLY SPACE STATION

-Satellite Servicing

A.	Martin Marietta Denver Aerospace	(NAS8-35042)	
	Monthly Progress Report #1		Nov 1982
	" " " #2		Dec 1982
	" " " #3		Jan 1983
	" " " #4		Feb 1983
	Mid Term Review		Oct 1982
	Environmental Analysis		Jan 1983
B.	TRW	(NAS8-35081)	
	Mid Term Review		Oct 1982

-Orbital Transfer Vehicle

A.	General Dynamics Convair	(NAS8-35039)	
	Mid Term Review		Oct 1982
-	Large Space Structures	(NAS8-35043)	
	Mid Term Review		Oct 1982

X. MISSION MODELS

A. NASA

Space Systems Technology Model	May 1980
Space Systems Technology Model	Sept 1981
STS Flight Assignment Baseline	Dec 1980

B. Martin Marietta Denver Aerospace

National Mission Model	Sept 1981
TMS Mission Model	Oct 1981
Space Station Composite Mission Model	Nov 1982

C. Eagle Engineering

National Mission Model	June 1981

D. Battelle Columbus Laboratories

Low Energy Model	Oct 1980

E. National Academy of Sciences

Astronomy and Astrophysics for the 1980's	1982
A Strategy for Space Astronomy and Astrophysics for the 1980's	1979

F. American Institute of Aeronautics and Astronautics

Space Transportation Services Through 2000	Jan 1981

G. Technology for Space Astrophysics: The next 30 years — Oct 1982

XI. ENVIRONMENT

A. AIAA

Bluth, B. J., Social and Psychological Problems of Extended Space — May 1980

B. NASA

Terrestrial Environment (Climatic) Criteria Guidelines for use in Aerospace Vehicle Development Technical Memorandum 78118 — 1977

Space and Planetary Environment Criteria Guidelines for use in Aerospace Vehicle Design Development Technical Memorandum 78119 — 1977

Space Vehicle Design Criteria (Environment) Model of Earths Atmosphere (90-2500 km) Sp-8021 — Mar 1973

The NASA/MSFC Global Reference Atmospheric Model MOD-3 (With Spherical Harmonic Wind Model) CR-3256 — Mar 1980

Tables of Atmospheric Temperature, Density, and Composition Derived from Satellite and Ground Based Measurements Vol 1, 2 — Jan 1979

Four Dimensional World Wide Atmospheric Models Allied Research Associates, INC — July 1972

Roth, Emaneul Compenduim of Human Responses to the Aerospace Environment, Report CR-1205 — 1968

XII. LIFE SCIENCES

A. NASA

Life Sciences Considerations for Space Station, NASA/HQ&Bionetics, Inc. — Sept 1982

Life Sciences Research and the Science and Applications Space Platform, NASA/ARC. — Jan 1982

Medical Operations and Life Sciences Activities on Space Station NASA/JSC TM 58248. — Oct 1982

D.L. DeVincenez;, J.R. Bagby
Orbiting Quarantine Facility: The Antaeus Report
NAS SP-454 — 1981

Fabricant, J.D., "Life Sciences Experiments for a Space Platform/Station," Society of Automotive Engineers, Inc., (MSFC SAE-TP82834). 1982

T. Bannister, Man Tended - Life Sciences Research Facility: A Conceptual Design and Analysis Study, (MSFC-PD-A5555) Jan 1982

T.W. Halstead, D.R. Beam, P.L. Russell, Descriptions of Current Research Projects on the NASA Space Biology Program, NASA/HQ 1983

Johnston, R.S., Dietlein, L.F., Berry, C.A., Biomedical Results of Apolls, NASA/JSC 1975

Johnston, R.S. Dietlein, L.F., Biomedical Results from Skylab, NASA/JSC 1977

Spacelab 4: Mission Science Requirements Document, NASA/JSC June 1982

Space Motion Sickness Symposium Proceedings, GE; POT-1830G; NASA/JSC Nov 1978

Space Lab 1: Mission Operations Recurements Dcoument, NASA/TSC, LS 2000 8-4 May 1980

Simmonds, R.C., Bournc, G.H., The Use of Non-human Primates in Space, NASA Conference Publication 005 Dec 1974

B. Richard S. Johnston & Associates

Review of Present and Future Trends of Materials Science and Life Sciences Flight Experiments: Part I Life Sciences. Feb 1981

C. Other

CELSS Principle Investigators Workshop Abstracts. Dec 1982

National Research Council Space Science Board, Life Beyond the Earth's Environment: The Biology of Living Organisms in Space (The Bricker Report) 1979

Furukawa, S., Operational Medicine Support in Long-Duration Manned Space Missions - Low Earth Orbit and Beyond, McDonnel Douglas Technical Services Company - KSC, Feb 1982

T.W. Halstead, "The NASA Space Biology Program," The Physiologist, Vol 25, No. 6, Suppl. 1982

XIII. HUMAN FACTORS

A. NASA

Man/System Requirement for Weightless Environments

MSEC-STD-512 Rev A Dec 1976

B. Department of Defense

Human Engineering and Facilities.

MIL-STD-1472 Rev C May 1981

XIV. MISSION ANALYSIS

A. Johnsom Space Center, STS Capabilities for Supporting the Space Station Program, Spetember 1982.

Johnson Space Center, Mission Planning and analysis Division, Maneuver Strategies and Performance Requirements for Sphere of Influence Determination, March 1982.

Johnson Space Center, Joseph P. Loftus, Jr., Advanced Missions Discussions, Martin-Marietta Denver, November 16, 1982.

Johnson Space Center, L. E. Livingston, Co-Orbiting Mechanics, June 22, 1982.

B. Marshall Space Flight Center, Space and Planetary Environment Criteria Guidelines for Use in Space Vehicle Development, 1977 Revision, PP 2-4.

C. Goddard Space Flight Center, A. E. Hedin, Tables of Atmospheric Temperature, Density and Comp]osition Derived from Satellite and Ground Based Measuremetns, Volume 2 of 3 (AP=20), January 1979, P-608.

XIV. MISSION ANALYSIS

Goddard Space Flight Center, A. e. Hedin, Tables of Atmospheric Temperture, Density and Composition Derived from Satellite and Ground Based Measurements, Volume 1 of 3 (AP+4), January 1979, P-108.

D Martin Marietta Corporation, Composite Mission Model (including DOD flts), Space Station Needs, Attributes, and Architectural Optios Study, Initial Release, November 1982.

Martin Marietta Corporation, Tethered Satellite Advanced Mission Development, Project No. D-29D (Proprietary Studies), 1 November 1982.

Martin Marietta Aerospace, Teleoperator Maneuvering System/Mark II Propulsion Module Study, Final Report, June 1982.

Martin Marietta Aerospace, System Technology Analysis of Aero Assisted Orbital Transfer Vehicles: Low Lift/Drage (0-0.75), Folder 1, Technical Proposal, July 1982.

XIV. MISSION ANALYSIS

Martin Marietta Corporation, SDV Technology Requirements Study, Phase 1, Final Report Contract NAS8-24183, MMC-SDV-DR-6-1, July 1981.

D. California Space Institute, Utilization of the External Tanks of the Space Transportation System, Draft Report, October 8, 1982.

XV. TETHERED SATELLITE

A. Martin Marietta Denver Aerospace
Advanced Mission Development (Proprietary Studies) Nov 1982

XVI. COST MODELS

A. Unmanned Spacecraft Cost Model, U. S. Air Force, Space Division, Fifth Edition, June 1981.