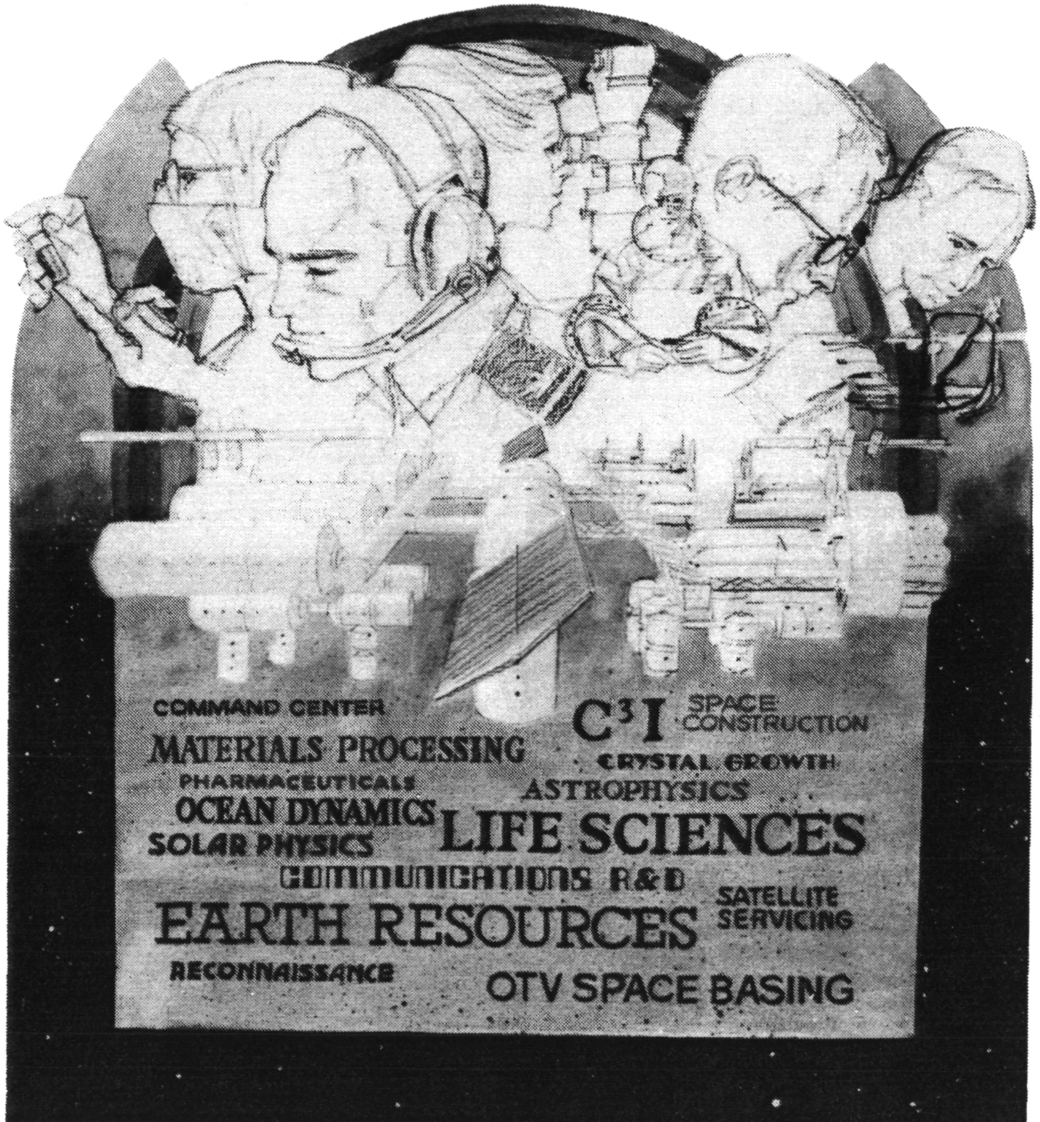
REPORT NO. GDC-ASP-83-002
CONTRACT NASW-3682

A STUDY OF SPACE STATION NEEDS, ATTRIBUTES & ARCHITECTURAL OPTIONS

N84-27804

FINAL REPORT

VOLUME II • TECHNICAL
BOOK 1 • MISSION REQUIREMENTS



GENERAL DYNAMICS
Convair Division

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A STUDY OF SPACE STATION NEEDS, ATTRIBUTES & ARCHITECTURAL OPTIONS

FINAL REPORT
VOLUME II • TECHNICAL
BOOK 1 • MISSION REQUIREMENTS

22 April 1983

Submitted to
National Aeronautics and Space Administration
Washington, D.C. 20546

Prepared by
GENERAL DYNAMICS CONVAIR DIVISION
P.O. Box 85357
San Diego, California 92138

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A STUDY OF SPACE STATION NEEDS, ATTRIBUTES, AND ARCHITECTURAL OPTIONS

FINAL REPORT

VOLUME I	Executive Summary
VOLUME II	Technical Report
Book 1	Mission Requirements
Appendix I	Mission Requirements Data Base
Appendix II	Space Station User Brochure and Fact Sheet
Book 2	Mission Implementation Options
Book 3	Economic Benefits, Costs, and Programmatics
Appendix I	Space Station Prospectus
Book 4	National Security Missions and Analysis

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PREFACE

The U.S. progress toward a complete space transportation system (STS) for the exploration and exploitation of space achieved an important milestone when the Space Shuttle became operational. Other elements of the system, such as the Payload Assist Modules, Inertial Upper Stage, Spacelab, Extra Vehicular Maneuvering System, and the Shuttle-Centaur Upper Stage are either in use or under development. However, there are other important STS elements that still require definition and development -- the major new element being a manned Space Station in low earth orbit. When available, a manned Space Station, plus the elements listed above, will provide the capability for a permanent manned presence in space.

The availability of a manned Space Station will:

a. Provide a versatile space system for an active space science program.

b. Stimulate development of advanced technologies.

c. Provide continuity to the civilian space program.

d. Stimulate commercial activities in space.

e. Enhance national security.

Through these, U.S. leadership in space will be maintained and our image abroad will be enhanced. The Space Station will provide:

a. A permanent manned presence.

b. Improved upper stage operations.

c. Maintenance of space systems through on-orbit checkout and repair.

d. Assembly and construction of large space elements.

It will also enhance Space Shuttle utilization as a transportation vehicle by releasing it from sortie missions that currently substitute for Space Station missions:

The Space Station will be a facility having the following general characteristics:

a. Support manned and unmanned elements.

b. User friendly.

c. Evolutionary in nature for size, capability, and technology.

d. High level of autonomous operations.

e. Shuttle compatible.

The primary purpose of this study was to further identify, collect, and analyze the science, applications, commercial, technology, U.S. national security, and space operations missions that require or that will be materially benefited by the availability of a permanent manned Space Station and to identify and characterize the Space Station attributes and capabilities that will be necessary to satisfy those mission requirements.

NASA intends to integrate these data, recommendations, and insights developed under this contracted effort with those developed from in-house activities and other sources and then synthesize from this information a set of mission objectives and corresponding Space Station requirements that will be used in future phases of study and Space Station definition.

The study objectives as defined in the Request for Proposal (RFP) are:

a. Identify, collect, and analyze missions that require, or will materially benefit from, the availability of a Space Station:

   - Science
   - Applications
   - Commercial
   - Technology
   - Space operations
   - U.S. national security

b. Identify and characterize the Space Station attributes and capabilities that are necessary to meet these requirements.

c. Recommend mission implementation approaches and architectural options.

d. Recommend time phasing of implementation concepts.

e. Define the rough order of magnitude programmatic/cost implications.

Book 1 will address the first objective and provide the realistic, time-phased set of mission requirements upon which the balance of the study was based. Accomplishments of objectives b, c, and d are documented in Book 2, and objective e is addressed in Book 3. Book 4 contains a definition and an analysis of national security missions (classified).

FOREWORD

This final report was prepared by General Dynamics Convair Division for NASA Headquarters under Contract Number NASW-3682.

The study was conducted from 20 August 1982 through 22 April 1983. A mid-term briefing was presented at NASA Headquarters on 17 November 1982; a final briefing was presented on 5 April 1983, also at NASA Headquarters.

The study was conducted within the Space Programs Organization at General Dynamics Convair Division, headed by W. F. Rector, III, Space Vice President and Program Director. D. E. Charhut, Director of Advanced Space Programs, was assigned specific responsibility for the study. The NASA COR is Brian Pritchard of the Space Station Task Force headed by John Hodge.

General Dynamics Convair Division personnel who significantly contributed to the study include:

Study Manager	Otto Steinbronn
Mission Requirements	Warren Hardy - Manager Jim Peterson Charlie Hyde
Mission Implementation	John Bodle - Manager Earl Davis Tom Kessler Norm Gray
Cost and Programmatics	Bob Bradley - Manager Michael Simon Sam Wagner
Nation Security Missions	Al Phillips Clint James

Subcontract support was obtained from Space Communiations Company (SPACECOM) in the area of communication spacecraft and related technologies, and from Advanced Technology, Inc. in the area of life science and life support systems.

For further information please contact:

Otto Steinbronn
General Dynamics
Convair Division
P.O. Box 85357
Mail Zone 21-9530
San Diego, CA 92138
(619) 277-8900, x6082

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ACRONYMS AND ABBREVIATIONS

AC	Acoustic Containerless
ACR	Active Cavity Radiometer
AEPI	Atmospheric Emission Photometric Imaging
AKM	Apogee Kick Motor
ALS	Advanced Limb Scanner
AM-0	Air Mass Zero
AMSU	Advanced Microwave Sounding Unit
AMTS	Advanced Moisture and Temperature Sounder
ASES	Advanced Solidification Experiment System
ASO	Advanced Solar Observatory
AST	Astronomy (Subdiscipline Code)
ATR	Atmospheric Research (Subdiscipline Code)
AVHRR	Advanced Very High Resolution Radiometer
AXAF	Advanced X-ray Astrophysics Facility
AXET	Advanced X-ray Telescope
BIO	Biological
BLS	Biological Science (Subdiscipline Code)
CELSS	Controlled Ecological Life Support System
CFE	Continuous Flow Electrophoresis
CHF	Control and Human Factors (Subdiscipline Code)
CLAES	Cryogenic Limb Array Etalon Spectrometer
COM	Communications (Subdiscipline Code)
COM'L	Commercial
CRM	Chemical Release Module
CRM	Crustal Motion (Subdiscipline Code)
CSE	Computer Science and Electronics (Subdiscipline Code)
DCS	Data Collection System
DEG	Degree(s)
DOD	Department of Defense

ACRONYMS AND ABBREVIATIONS, Contd

ECN	Energy Conversion (Subdiscipline Code)
EDY	Earth Dynamics (Subdiscipline Code)
EMC	Electromagnetic Containerless
EOO	Earth and Ocean Observations (Subdiscipline Code)
ERBE	Earth Radiation Budget Experiment
ERS	Earth Resources (Subdiscipline Code)
ESC	Electrostatic Containerless
ET	External Tank
EVA	Extra-Vehicular Activity
F/C	Fluids/Chemistry
FF	Free Flyer
FIREX	Free-Flying Imaging Radar Experiment
FOV	Field of View
FTP	Fluid and Thermal Physics (Subdiscipline Code)
FUSE	Far UV Spectroscopy Explorer
FZ	Floating Zone
GEO	Geostationary Earth Orbit
GOES	Geostationary Operational Environmental Satellite
GPF	Geopotential Fields (Subdiscipline Code)
GRO	Gamma Ray Observatory
HALOE	Halogen Occultation Experiment
HEIE	High Energy Isotope Experiment
HEN	High Energy (Subdiscipline Code)
HEO	High Earth Orbit
HF	High Frequency
HGDS	High Gradient Directional Solidification
HIRS-2	High Resolution Infrared Sounder
HRDI	High Resolution Doppler Imager
HTM	High Throughput Mission

ACRONYMS AND ABBREVIATIONS, Contd

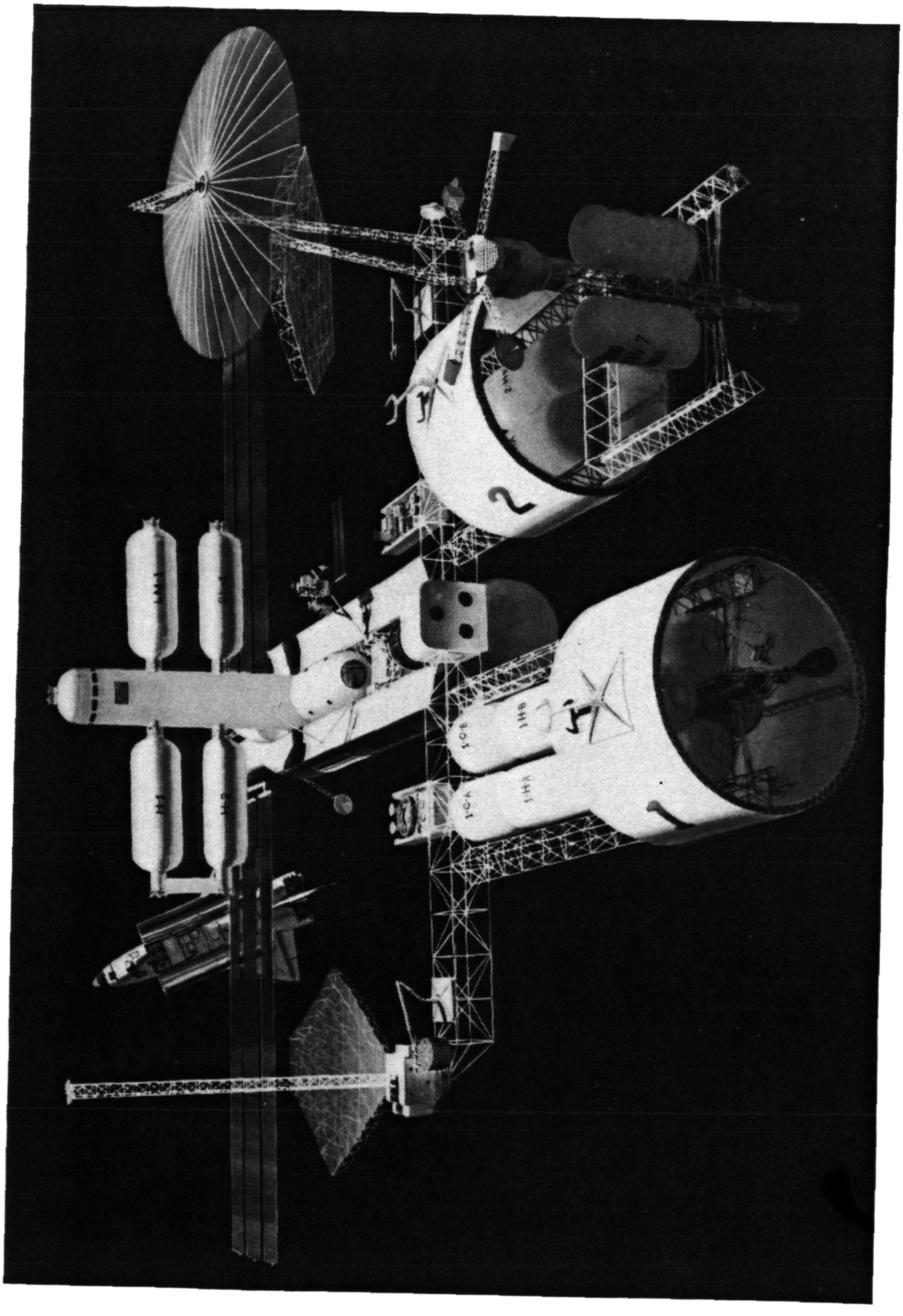
IEF	Isoelectric Focusing
INS	Industrial Services (Subdiscipline Code)
IOC	Initial Operational Capability
IR	Infrared
ISAMS	Improved Stratospheric and Mesospheric Sounder
ISO	Imaging Spectrometric Observatory
IUS	Inertial Upper Stage
IVA	Intra-Vehicular Activity
KPBS	Kilo Bits Per Second
LAMAR	Large Area Modular Array
LDR	Large Deployable Reflector
LEO	Low Earth Orbit
LFS	Life Support (Subdiscipline Code)
LIDAR	Light Detection and Ranging Facility
LM	Lightning Mapper
MAPS	Measurement of Air Pollution from Satellite
MHD	Magneto Hydrodynamics
MLA	Multispectral Linear Array
MLS	Microwave Limb Sounder
MMP	Magnetospheric Multiprobes
M-O	Man-Operated
MPC	Materials Processing - Com'l (Subdiscipline Code)
MPR	Materials Processing - S&S (Subdiscipline Code)
MPS	Materials Processing in Space
MPS	Microwave Pressure Sounder
MTN	Maintenance (Subdiscipline Code)
MTS	Materials and Structures (Subdiscipline Code)
MW	Microwave

ACRONYMS AND ABBREVIATIONS, Contd

OCI	Ocean Color Imager
OCN	Ocean (Subdiscipline Code)
OIP	Ocean Instrument Payload
OPM	Operational Medicine (Subdiscipline Code)
OTH	Other (Subdiscipline Code)
OTV	Orbital Transfer Vehicle
PACE	Physics and Chemistry Experiments
PLO	Planetary Observations (Subdiscipline Code)
POC	Proof of Concept
PPN	Propulsion (Subdiscipline Code)
RMS	Remote Manipulator System
RPDP	Recoverable Plasma Diagnostic Package
S&A	Science and Applications
SAR	Synthetic Aperature Radar
SAMEX-C	Shuttle Active Microwave Experiment
SBUV	Solar Backscatter Ultraviolet
SCAFEDS	Space Construction Automated Fabrication Experiment Definition Study
SCATT	Scatterometer (Wind)
SCDM	Solar Corona Diagnostics Mission
SCG	Solution Crystal Growth
SCRN	Spectra of Cosmic Ray Nucleus
SEC	Stationary Electrophoreses Column
SEPAC	Space Experiments with Particle Accelerators
SIDM	Solar Internal Dynamics Mission
SIFS	Space Isothermal Furnace System
SIRTF	Shuttle IR Telescope Facility
SPH	Solar Physics (Subdiscipline Code)

ACRONYMS AND ABBREVIATIONS, Contd

SPP	Space Plasma Physics
SSM	Solar System Mission (Subdiscipline Code)
SSS	Space Station Systems (Subdiscipline Code)
SSU	Stratospheric Sounding Unit
ST	Space Telescope
STO	Solar Terrestrial Observatory
STR	Solar/Terrestrial (Subdiscipline Code)
SUSIM	Solar Ultraviolet Spectral Irradiance Measurements
TDAS	Tracking and Data Acquisition System
TDM	Technology Development Mission
TDRSS	Tracking and Data Relay Satellite System
TMS	Teleoperator Maneuvering System
TOPEX	Ocean Topography Experiment
TRIC	Transition Radiation and Ionization Calorimeter
TWM	Temperature and Wind Measurement
UARS	Upper Atmosphere Research Satellite
USSIE	Ultraviolet Solar Spectral Irradiance Experiment
UV	Ultraviolet
VCG	Vapor Crystal Growth
VHF	Very High Frequency
VLBI	Very Long Baseline Interferometer
WCL	Weather/Climate (Subdiscipline Code)
WISP	Waves in Space Plasmas
XTE	X-ray Timing Explorer



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SECTION 1

INTRODUCTION AND SUMMARY

The overall objective of the Mission Requirements Analysis was to provide a time-phased set of mission requirements that could be used as a basis for the Space Station architectural option studies and related benefits, cost, and programmatic evaluations. The following types of missions -

Science

Applications

Commercial

Technology Development

Space Operations

National Security

were evaluated to determine those that require or will be materially benefited by a manned Space Station. General Dynamics Convair Division (GDC) placed particular emphasis on direct contacts with potential users to obtain valid definition of planned or proposed Space Station missions. Scientific, technology, and commercial mission requirements were compiled from a combination of NASA reports, personal visits to user facilities, telephone and personal interviews with industrial contacts, follow-up questionnaire responses, and information derived by subcontractors. Data for national security missions were obtained from DOD-supplied traffic model and reports and by personal visits to various commands. Space operations requirements were defined to provide necessary support and operation of all missions. In addition, data on missions proposed by potential foreign users were obtained by personal visits to European firms augmented by reports from MBB/ERNO and Dornier Systems.

With the exception of DOD mission requirements, which are discussed in Book 4, this book addresses the accomplishment of the above objective: the methodology used to identify, collect, and analyze mission data; a description of the user mission data; derivation of a baseline time-phased mission set; and the integrated requirements to be satisfied by the Space Station system elements.

1.1 APPROACH

The mission requirements analysis approach (Figure 1-1) provided a time-phased set of missions and their accommodation requirements.

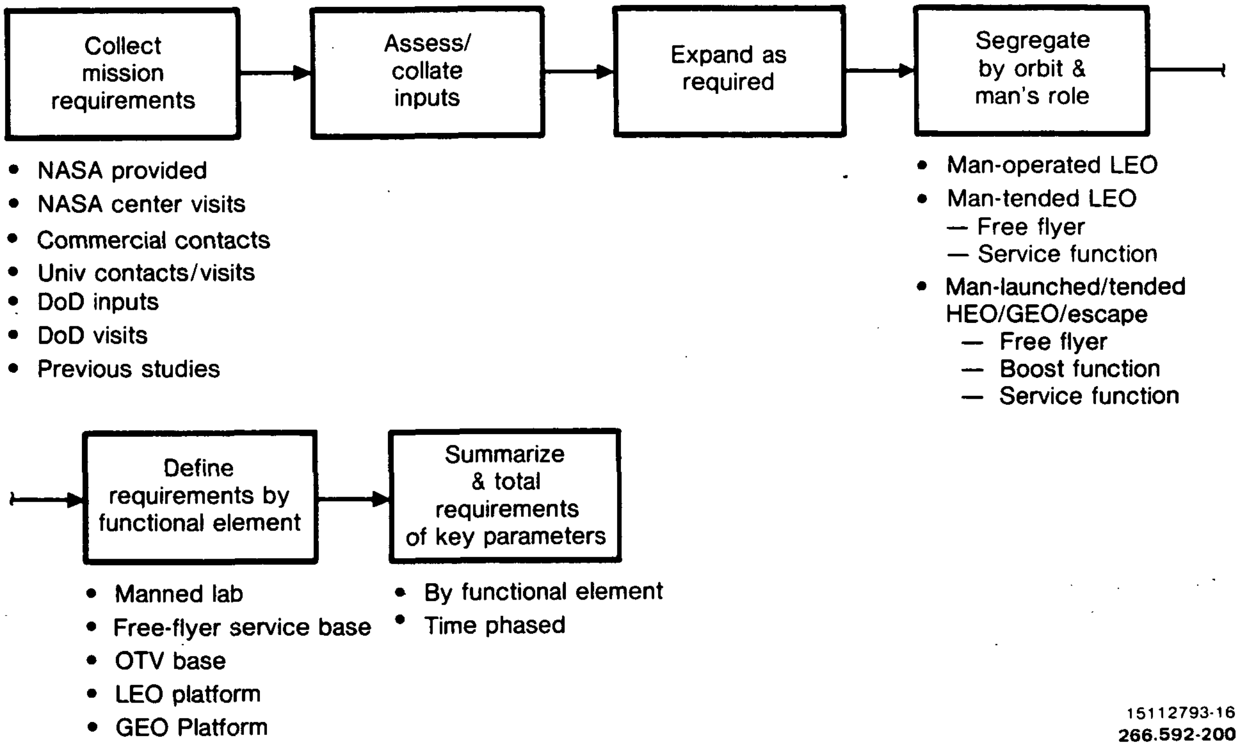

Figure 1-1. Mission Requirements Approach

The mission and payload requirements received from a variety of sources were documented using the LaRC-developed format (refer to Appendix I to Book 1). As these were collated and assessed for completeness, it became apparent that some technical parameters were missing and many -- especially those of science and applications -- had been structured without a manned Space Station in mind. The data were expanded and completed as necessary and the role of man appraised to determine where he could enhance or contribute to the mission.

The missions were then segregated by orbit inclination/altitude and into two basic functional categories:

a. Man-operated

b. Man-tended free flyers

From a requirements viewpoint, it was better to treat these as separate functions without regard to how they might be implemented by physical configurations. It was understood that man-operated implied a manned laboratory-type station with internally and externally mounted experiment/payload equipment. Also, that the free flyers were separate entities supported for service, maintenance, and possibly operations, such as data handling, from a manned facility. Other free-flyer missions that interfaced with the Space Station as a transportation node, such as GEO communication satellites and planetary probes, established a need for an OTV and support base. In effect, there are three functions: direct manned operations/support, free-flyer service, and OTV transportation.

The requirements for the three functions were collected and evaluated to determine the aggregate station resource requirements. No timelines were created due to the scope of the effort. It is apparent that considerable work remains to be done in this area. However, the range of values for the key parameters is reasonable and of sufficient accuracy for the architectural option studies and evaluation.

One directed output of the study was a "realistic" time-phased mission set. Several factors affect the definition of such a set. These include: technology readiness, technical risk, programmatic costs, station development requirements, and STS operations requirements. It was evident that the schedule for the mission set, which was based solely upon user requirements, was heavily front-end loaded. This is due in large measure to the fact that, in general, people tend to have a planning horizon that falls off in later years. This front-end loading drove the nonrecurring cost estimates for early years to be considerably larger than current NASA budget allocations.

The mission requirements schedules were reviewed as a function of technology readiness, risk, and mission need. Appropriate adjustments were then made that relieved some of the front-end loading and improved the costing curves.

1.2 SUMMARY

A number of conclusions can be drawn from the mission requirements analysis (Table 1-1). A manned Space Station will provide major performance and economic benefits to a wide range of missions planned for the 1990s. Most of these missions require, prefer, or will accept a 28.5-degree, 400-500 km orbit. Although preliminary studies indicate a need for separate station(s) for operational DOD missions, combined NASA and DOD RDT&E missions are feasible and desirable on a low earth orbit (LEO), 28.5-degree station.

There is sufficient traffic to support early implementation of an OTV and a space-based operations center. Development of this capability provides the most significant and the most quantifiable economic benefits, offering potential for rapid payback of the Space Station investment.

Free flyers, which do not lend themselves readily to a manned Space Station because of their particular requirements, will be operational throughout the decade. These occur at a variety of orbit altitudes and inclinations ranging from 28.5 to 100 degrees, but many fit the expected Space Station orbit. Providing periodic service to these free flyers will improve their performance output, enhance their cost effectiveness, and probably reduce total cost as well. A number of the free flyer missions are candidates for accommodation on an unmanned platform. The balance would be independent satellites.

Missions requiring higher inclinations, up to polar, have been identified that require or prefer accommodation on a Space Station. Those that require man occur in the last half of the decade. However, there may not be sufficient traffic to economically justify a second station in the 1990s.

Table 1-1. Mission Requirements Conclusions

- Large number of missions suitable for a 28.5 degree, 400-500 km station identified
- Sufficient OTV traffic exists to support early implementation
- Free-flyer emplacement, servicing, and retrieval required at low, mid, and high inclinations throughout 1990s
- Candidate missions for platform accommodation identified
- Man-operated mission requirements at polar inclination may not be sufficient to economically justify a second station in 1990s
- Baseline mission set is representative and provides rational basis for architectural solution and required capabilities of the station
- Commercial R&D and production markets need further development
- Joint station LEO is suitable for DOD R&D activities

The mission requirements derived during this study provide a rational basis for architectural option evaluations. They are sufficiently representative of activities that can be expected for the 1990s to permit the definition of an appropriate manned Space Station system.

The baseline time-phased mission set contains all the missions defined by potential users. An evaluation process to investigate the realism of the set resulted in a number of schedule changes that improved the distribution over the decade. However, the funding requirements for Science, Applications, and Technology missions exceed the estimated NASA budget for the early years. If the number of missions is too high, the station resource requirements sized during the study will be reduced somewhat. Crew and volume requirements appear to be very reasonable. Power requirements in the later years are quite high, driven principally by the commercial materials processing missions.

Man-operated facilities for commercial activities such as materials processing, communications, and earth/ocean observations have been defined. The highest interest is in launch services for commercial satellites. Other commercial interests in a Space Station do exist, but continued user interaction is necessary to develop it fully. An in-place facility (or firm availability date) will provide a major stimulant to potential commercial users. Special incentives may be required to stimulate commercial use of space to a significant level.

SECTION 2

REQUIREMENTS APPROACH AND DATA BASE

Scientific and commercial mission requirements for a manned Space Station were compiled from a combination of NASA reports, personal visits to many facilities, telephone contacts to industry with questionnaire follow-ups, and information compiled by subcontractors.

The mission analysis study orientation briefing of 15 September 1982 and supplements of November 1982 and January 1983 were used as the basis for many user requirements. A number of additional reports, such as those listed in Table 2-1, were used to expand the requirements definitions in specific areas.

Table 2-1. User Sources

- Space Platform Payload Data, MSFC, March 1982
- Space Operations Center Program Plan, November 1981
- Space Operations Center Study Extension, BAC, January 1982
- CELSS Program Plan, April 1982
- Astrophysics Near-term Program Project Concept Study, October 1980
- Nominal Mission Model, Revision 6, MSFC PS01 September 1982
- Science and Applications Requirements for Space Station, NASA HQ, November 1982
- Space Station & CELSS Concept Design, JSC, September 1982
- STS Mission Model 1983-2000, NASA-HQ, December 1982
- MEC Payloads Handbook, TRW, January 1981
- Spacelab Mission & Mission Definition, JSC, October 1982

Visits were made to various NASA Centers, universities, and other potential users to gather information on anticipated Space Station applications. We developed a Space Station User Brochure (Figure 2-1) to convey to potential users the opportunities and attributes of a manned Space Station. The brochure detailed the potential technological and economic benefits of such a station plus offering a concise summary of America's current and planned space activities.

USER BROCHURE
- STATION OPPORTUNITIES, ATTRIBUTES & STS FINANCIAL DATA

USER FACT SHEETS
- ECONOMIC & PLANNING FACTORS
- TECHNICAL FACTORS – E.G. ORBIT, CREW, POWER

NASA/AIAA CORPORATE ASSOCIATES PROGRAM LISTING (145) – AUGMENTED BY ADDITIONAL FIRMS FROM FORTUNE TOP 500
- METALS & NONMETALS
- CHEMICALS
- PHARMACEUTICALS
- EQUIPMENT
- PETROLEUM
- FOODS & FORESTRY
- COMMUNICATIONS
- AEROSPACE
- ELECTRONICS
- INSTRUMENTS
- UTILITIES

UNIVERSITIES
- LIFE SCIENCES
- EARTH OBSERVATIONS

NASA CENTERS/DEPT. OF AGRICULTURE
- LIFE SCIENCES
- MATERIALS PROCESSING
- EARTH OBSERVATIONS

SUBCONTRACTORS
- COMMUNICATIONS
- LIFE SCIENCES

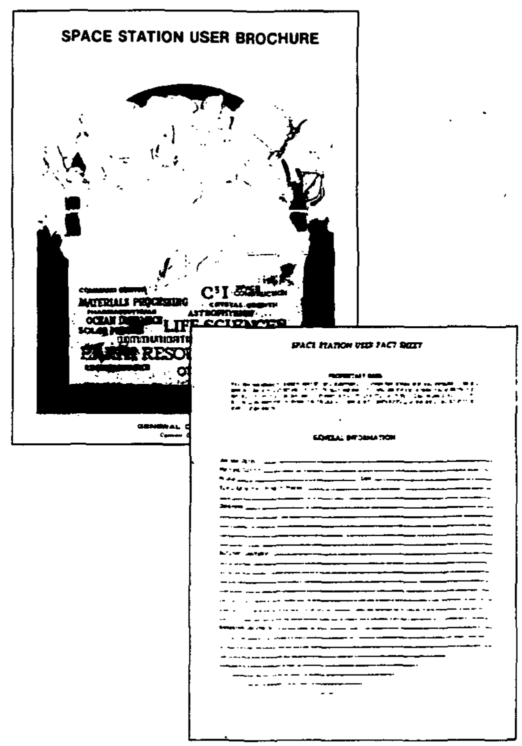

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Figure 2-1. User Contacts

Enclosed with the brochure is a "User Fact Sheet," designed so that the user can reply with an indication of economic interest, as well as a technical definition of potential needs in terms of size, weight, orbit, crew requirements, etc. The sheet was structured so that the recipient could respond by simply checking the applicable answers, with additional space provided for more detailed answers.

The brochures, which were offered after personal contacts were made with potential users, provided an excellent medium for increasing interest in a Space Station program. The discussions resulted in a number of mission descriptions. However, many potential users were not prepared to provide detailed technical payload element data such as NASA investigators are accustomed to seeing. Based on our contacts and discussions with commercial firms during this study, and the level of response to our user brochure, we conclude that considerable time, perhaps 2-3 years in some cases, will be required to develop the potential user market to a level commensurate with a mission definition and commitment existing today in scientific areas. The withdrawal of GTI from their commercial materials processing venture is further evidence of the status of today's commercial market for space use. A copy of the User Brochure and the accompanying Fact Sheet are included as Appendix II.

Astrophysics missions were validated by visits to MSFC and Los Alamos National Laboratory. Earth and Planetary Exploration missions were validated in the scientific area by visits to JPL and inputs from universities. Oil company contacts were used to validate the data for commercial applications of earth observations. Environmental observations missions were validated by visits to MSFC and a utility company for commercial use. Life Sciences missions were discussed with numerous NASA Centers, university visits, and a subcontract with Advanced Technology, Inc. Materials Processing missions were validated by visits to MSFC and a number of discussions with commercial firms. The subcontract with SAI was also used. SPACECOM conferred with a number of satellite users, such as American Satellite, to validate data for commercial communications missions.

Two basic classes of missions were established: man-operated, which are accommodated directly on the Space Station, i.e., attached, and free flyers, which are separate entities. Man's role in the mission was used as the basic evaluation criterion. Therefore, those cases where man's involvement was vital to the mission or would enhance the mission by a significant contribution on a continuing basis were classed as attached. Periodic servicing or reconfiguration is also required for many free flyers. A total of 149 missions were identified, and payload element data sheets were prepared for each. Of the 99 missions assigned to the man-operated facility, 18% could be accommodated as free flyers. Of the 50 free-flyer missions, 54% are compatible with a platform.

The following definitions were used during the study:

Payload element. An individual instrument or subsystem designed to conduct a specific type of observation or experiment.

Mission. The operation of one or more payload elements to achieve a specific objective or set of objectives.

Space Station. A spacecraft designed to provide a long-lived, man-habitable facility as a laboratory and payload element support facility for the accomplishment of a time-varying array of missions and as an on-orbit operational base for the provision of calibration, maintenance and repair, payload element changeout, recovery, refurbishment, staging, and assembly services for free flyers.

Free flyer. A generic term to describe unmanned spacecraft of either the satellite or platform class.

Satellite. A serviceable spacecraft designed to accomplish a specific mission without changes in its complement of mission elements. Servicing is limited to resupply of consumables and module replacement/repair.

Space platform. A serviceable spacecraft designed to be a long-lived facility for the accomplishment of either a number of missions or a single broad interdisciplinary mission involving potential future changes in its complement of payload elements.

Space Station system. The combination of the Space Station and companion free flyers designed to satisfy a broad spectrum of science applications, commercial technology development, and national security requirements in low earth orbit.

Additional analyses were made to determine preferred versus acceptable orbits, alternative accommodation modes, technology risk/status, and mission definition maturity. These, in conjunction with iterative feedback from the program costing and architectural accommodation activities, assisted in the determination of a realistic time-phased mission set, described in Section 4.4.

DOD RDT&E mission requirements were compared to the civilian man-operated missions and a determination made that similarities existed, which verified that joint usage was possible and DOD requirements could be satisfied within the envelope of capability derived from NASA/commercial missions. A traffic model for free flyers was derived based on the DOD-supplied mission model and MSFC mission model, Revision 6.

Reports we received from ERNO and Dornier Systems on European user studies document requirements that are similar to those we derived for U.S. usage. These represent materials processing, life sciences, earth observations, astrophysics, and communications. Thus, it can be concluded that the architecture derived from our data base will accommodate users from around the world. The key is to provide a flexible facility with modular growth capability.

2.1 GOVERNMENT AGENCIES SOURCES

In the civil sector, government agencies provided the sources for about 75% of the payload elements included in our data base. The most prominent was, of course, NASA.

The NASA Headquarters offices of Space Science and Applications (OSSA) and Aeronautics and Space Technology (OAST) provided the nucleus for our mission model for the disciplines within Science and Applications and Technology Development, respectively. Contacts with, and document obtained from, the NASA Field Centers provided the more detailed mission definition information required to compile the inputs to the NASA mission data base, and other data required for accommodation assessment and operations analysis. The NASA Field Centers and related discipline areas were:

• ARC	• Life Sciences • Earth & Planetary • Technology Development
• GSFC	• Technology Development
• JPL	• Earth & Planetary • Technology Development
• JSC	• Life Sciences • Operations • Technology Development
• LaRC	• Environmental Observations • Technology Development
• LeRC	• Technology Development
• MSFC	• Astrophysics • Environmental Observations • Earth & Planetary Exploration • Materials Processing • Technology Development

Civil meteorological and earth observation payload elements were, for the most part, extrapolated from the mission objectives and capabilities of existing NOAA spacecraft. From a technological standpoint, these spacecraft exhibit a trend to include more comprehensive and sophisticated sensors that possess wideband optical and RF active and passive sensors to provide multidisciplinary coverage. This increase in size and support requirements drives these spacecraft from the "Satellite" to "Space Platform" class in order to benefit from the economy of scale and lower operational costs that can accrue from this accommodation mode.

From a programmatic standpoint, the future involvement of the government in the development and/or operation of the U.S. family of civil remote sensing spacecraft is currently unclear. If this system is turned over to the private sector, as is currently being explored, this class of payloads would be reclassified from "Science and Applications" to "commercial."

Contact was made with the Department of Agriculture to explore future plans for the use of remote sensing instruments. This resulted in the identification of several valid contacts in the commercial sector for crop monitoring and forecasting.

In the National Security sector, the USAF was the prime contact for future mission needs. Mission information was obtained from various documents and through meetings at USAF Space Division and at the Pentagon. Additional details on some specific missions were obtained through visits to Los Alamos National Laboratory (LANL).

Because of security classification, all National Security Mission data is documented under separate cover.

2.2 COMMERCIAL/UNIVERSITY SOURCES

Requirements related to industrial/commercial and university sources were generated by making potential user contacts using a User Brochure and Fact Sheet developed expressly for this purpose by General Dynamics Convair Division (GDC).

The Space Station User Brochure was developed to convey to potential users the opportunities and attributes of a manned Space Station. The brochure detailed the potential technological and economic benefits of such a station plus offering a concise summary of America's current and planned space activities.

Enclosed with the brochure is a "User Fact Sheet," designed so that the user can reply with an indication of economic interest, as well as a technical definition of potential needs in terms of size, weight, orbit, crew requirements, etc. The sheet was structured so that the recipient could respond by simply checking the applicable answers, with additional space provided for more detailed answers.

The brochures were offered after personal contacts were made with potential users from industry, utilities, universities, research institutes, NASA centers, and foreign sources. More than 350 brochures were distributed, and more than 60 replies were received, (an overall 16% response) as summarized in Figure 2-2. Replies were acknowledged with a letter to the user thanking him for his time and effort. A sample User Brochure is contained in Book 1, Appendix II.

USER BROCHURE
- STATION OPPORTUNITIES, ATTRIBUTES & STS FINANCIAL DATA

USER FACT SHEETS
- ECONOMIC & PLANNING FACTORS
- TECHNICAL FACTORS – E.G. ORBIT, CREW, POWER

PERSONAL CONTACTS & MAILINGS
- 201 INDUSTRIAL/COMMERCIAL FIRMS
- 36 UNIVERSITIES
- 91 LIFE SCIENCES
  5 NASA CENTERS
  FOREIGN (BY ERNO-MBB)

REPLIES
- 40 INDUSTRIAL/COMMERCIAL FIRMS
- 8 UNIVERSITIES
- 13 LIFE SCIENCES

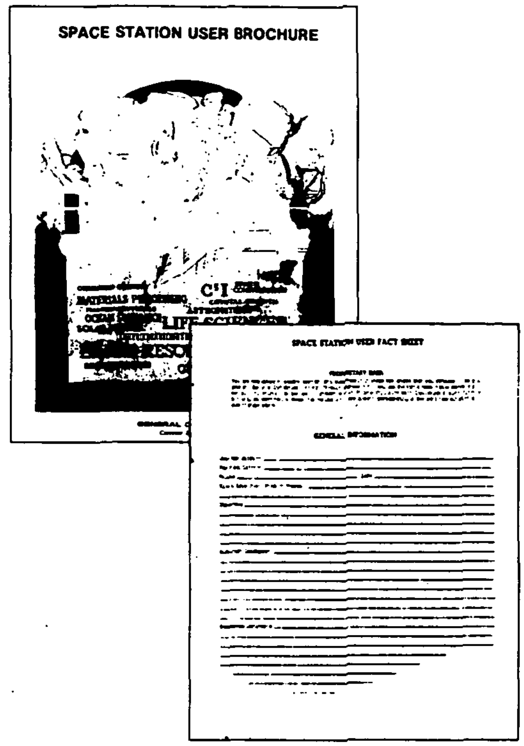

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Figure 2-2. User Contacts

The Space Station potential for commercial users includes both the user of station space or services, as well as the provider of equipment and operations. The list of candidates for participation started with those firms who had participated in the NASA/corporate associates program -- approximately 145 firms. This list was augmented by additional firms first listed in Fortune's top 500 with industry sales in metals and non-metals, chemicals, pharmaceuticals, equipment, petroleum, foods, mining and forestry, communications, aerospace, electronics, instruments, and utilities. The results of commercial user contacts are shown in Figure 2-3.

About 180 telephone contacts were made with key department personnel in the selected firms. Almost all of those contacted expressed an interest in receiving more information of the Space Station program. Of the approximately 200 commercial firms contacted, we estimated that fewer than one-fourth were likely candidates as Space Station users. The others were interested in drawing upon the technology to be developed. After the brochures were sent, 40 firms responded with either the fact sheet or by letter.

NASA/AIAA CORPORATE ASSOCIATES PROGRAM LISTING (145) – AUGMENTED BY ADDITIONAL FIRMS FROM FORTUNE TOP 500

- METALS & NONMETALS
- CHEMICALS
- PHARMACEUTICALS
- EQUIPMENT
- PETROLEUM
- FOODS & FORESTRY
- COMMUNICATIONS
- AEROSPACE
- ELECTRONICS
- INSTRUMENTS
- UTILITIES

CONTRACTS MADE	237
• COMMERCIAL	201
• UNIVERSITY	36
RESPONSES	48
• NO INTEREST	16
• LOW INTEREST	5
• MODERATE INTEREST	9
• HIGH INTEREST	18
CATEGORIES OF POSITIVE RESPONSES (TECHNICAL FACTORS ENTERED IN LARGE DATA SHEETS)	17
• EARTH & OCEAN OBSERVATION	4
• MATERIALS PROCESSING	8
• INDUSTRIAL SERVICES	5

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Figure 2-3. Commercial/University User Contacts

The categories where positive interest was shown included Earth and Ocean Observations, Material Processing, and Industrial Services missions. Most firms found the Space Station lead time beyond their present corporate planning timetable, and could respond only in generalities. It is also apparent that their interest will increase as the program comes closer to reality.

In addition to the payload elements identified by users, several commercial category elements were developed to ensure a full spectrum of communications and materials and processing payload elements. Nine communications payload elements were developed by SPACECOM through a subcontract to GDC. GDC developed two additional communications payload elements as well as seven materials processing payload elements.

All of the payload elements were documented on data sheets provided by NASA LaRC. In some cases, user provided data was augmented by GDC as necessary to provide requirements critical to development of Space Station attributes and architectural options. The total industrial/commercial/university data base encompasses 36 representative payload elements conducted over the 1990 to 2000 time period, distributed among the commercial disciplines as follows:

Commercial Disciplines	Number of Payload Elements
Earth and Ocean Observations	4
Communications	11
Materials Processing	15
Industrial Services	6*
TOTAL	36

*Includes one user response that identifies two payload elements

To ensure that our Life Sciences payload elements were representative of potential user requirements and concepts, we surveyed more than 90 individuals located at various universities and NASA centers. Thirteen responded with moderate to high interest levels. The responses were assessed to ensure the related Science and Applications Life Sciences discipline payload elements incorporated the needs of the community for the Space Station experimentation.

2.3 FOREIGN MISSIONS DATA

ESA has several Space Station studies in process. One objective is to "identify European payload candidates which can be beneficially supported by a Space Station." The areas of interest include:

- Material Science and Processing
- Life Science
- Space Science
- Earth Observation
- Space Technology and New Space Utilization Fields
- Operational Support

We have received reports from MBB/ERNO and Dornier Systems that provide insight into potential European Space Station missions. Dornier's work is concentrated in the life sciences and life support development areas. MBB/ERNO has identified missions in the materials processing, life science, earth observations, astronomy, communications, and space operations fields. Most of the missions are in the first two areas.

A comparison of the missions and their characteristics such as size, mass, pointing requirements, power levels, and data rates discloses that most are similar to those derived for U.S. missions. Some missions have similar objectives but are sized differently. The listing in Table 2-2 is typical of the European missions, which were compared in a general way to U.S. missions. We did not incorporate the European missions into our data base, nor is it profitable to document detailed comparisons of mission characteristics. Reviewing this data provided two principal pieces of information. First, insight into the views and plans of scientists outside the U.S. Second, substantiation of the premise that a worldwide cooperative effort will have positive results.

Table 2-2. European Space Station Missions

Astronomy

- Telescopes X-Ray, Gamma-Ray, IR
- Radio Interferometer
- High Resolution Spectrometer

Earth & Atmospheric Observations

- Geodesy Laser
- Imaging Microwave Radiometer
- Lidar
- Atmospherics and Cloud Physics

Life Science

- Human Physiology
- Gravity Biology
- Micro-g on Living Organism
- Ecological Life Support System

Materials Processing

- Crystal Growth
- Metal Alloys
- Low Convection Solidification
- Levitation Melting Facility
- Gradient Heating Facility

Communications

- Satellites
- Platforms

Operations

- Modular OTV
- Free-Flyer Support

SECTION 3

MISSION DESCRIPTION/REQUIREMENTS

Five basic steps were involved in deriving and documenting the user mission set (Figure 3-1).

a. Collect input data as described in Section 2.

b. Document derivation of data and mission operations requirements on GDC forms and document mission definition on LaRC payload element sheets (three-page set).

c. During the process of documenting mission requirements, determine missing information and augment as required.

d. Validate mission requirements.

e. Summarize mission requirements for NASA-defined disciplines on time-phasing charts and on mission requirement matrices.

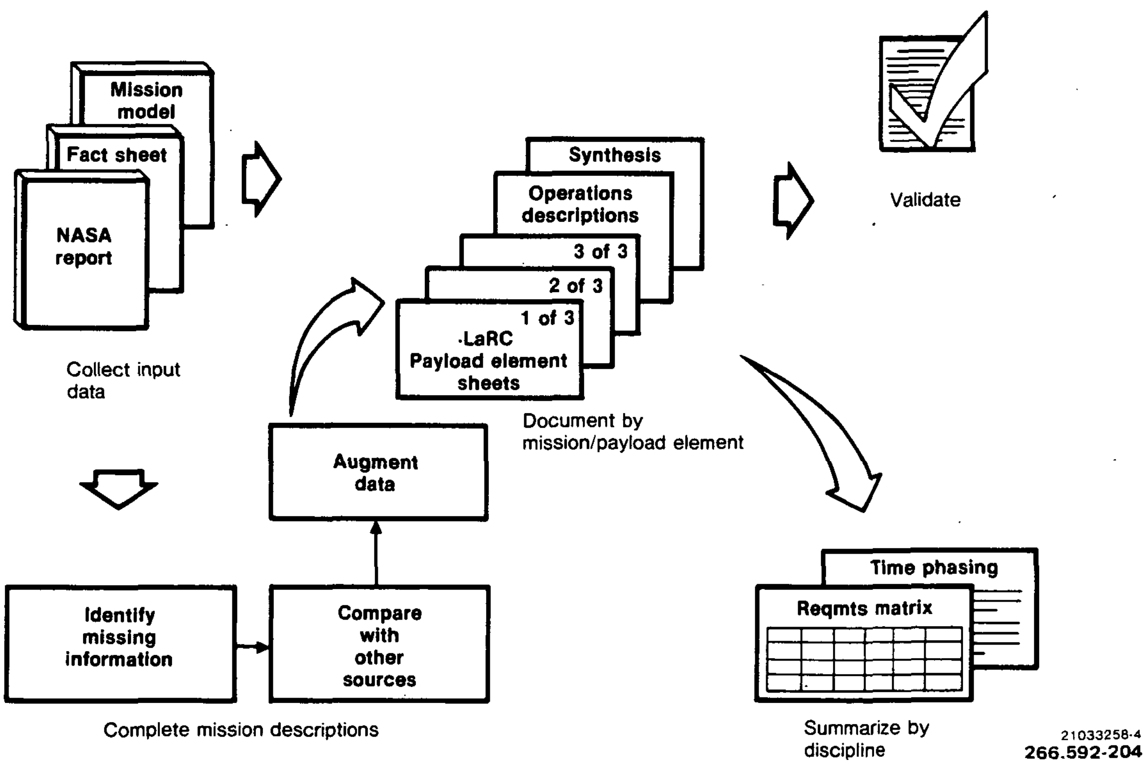

Figure 3-1. Mission Requirements Definition

Requirements for each of the identified 149 missions have been documented on the LaRC provided format. The three-page set of forms (Figure 3-2) contains a basic description of the payload element, its characteristics, and its demands upon Space Station resources. A definition of the content and format of the data is provided in the Introduction to Appendix I of this Book.

In the process of describing the missions, it was found to be useful to expand the definition of the operations requirements. A new form was created (Figure 3-2) that describes the crew activities for the basic functions of: assembly and checkout, continuous Station operational support, service, reconfiguration, and deactivation. Because this study did not address detailed Space Station operational timelining of missions, "operational crew time" represents an average over the life of the mission. Routine installation and checkout activities are included in this averaged time. Major assembly/construction/installation activities are defined separately.

Traceability of mission requirements is provided via a second GDC form called "Payload Element Synthesis" (Figure 3-2). This sheet(s) contains a list of reference sources and a narrative description of how the specific mission requirements were formulated.

The total data bank consisting of the LaRC payload element sheets and the two GDC forms for each of the 149 missions is provided in Appendix I.

In general, the primary source for any given mission did not provide all the necessary information to complete the mission requirements/description. Information from additional sources was compared with the primary source and used together with necessary synthesis and analysis to augment the initial data. Validation of mission requirements was accomplished by a variety of means as discussed in Section 2.

The missions were catalogued by the discipline breakdown provided in the Mission Description Document (Yellow Book) outline (Table 3-1). Disciplines are defined as the first level breakdown for Science & Applications, Commercial, Technology and Operations, e.g., Astrophysics, Life Sciences, Communications, Materials Processing, Propulsion. The next level of breakdown, e.g., Astronomy, High Energy & Solar Physics for Astrophysics, are defined as subdisciplines. Each payload element has an identifier that consists of "GDCD" followed by four digits for missions defined by GDC. The identifier number ranges were specified by LaRC. For simplicity, we refer to missions by the four digits only. To aid in identifying missions to disciplines or subdisciplines, we have also assigned three-letter codes (Table 3-1).

The statistics of the mission set broken down for discipline/subdiscipline and the accommodation mode is also provided in Table 3-1. The free flyers have also been subdivided into three groups: LEO/HEO, GEO, and ESCAPE (Planetary) missions.

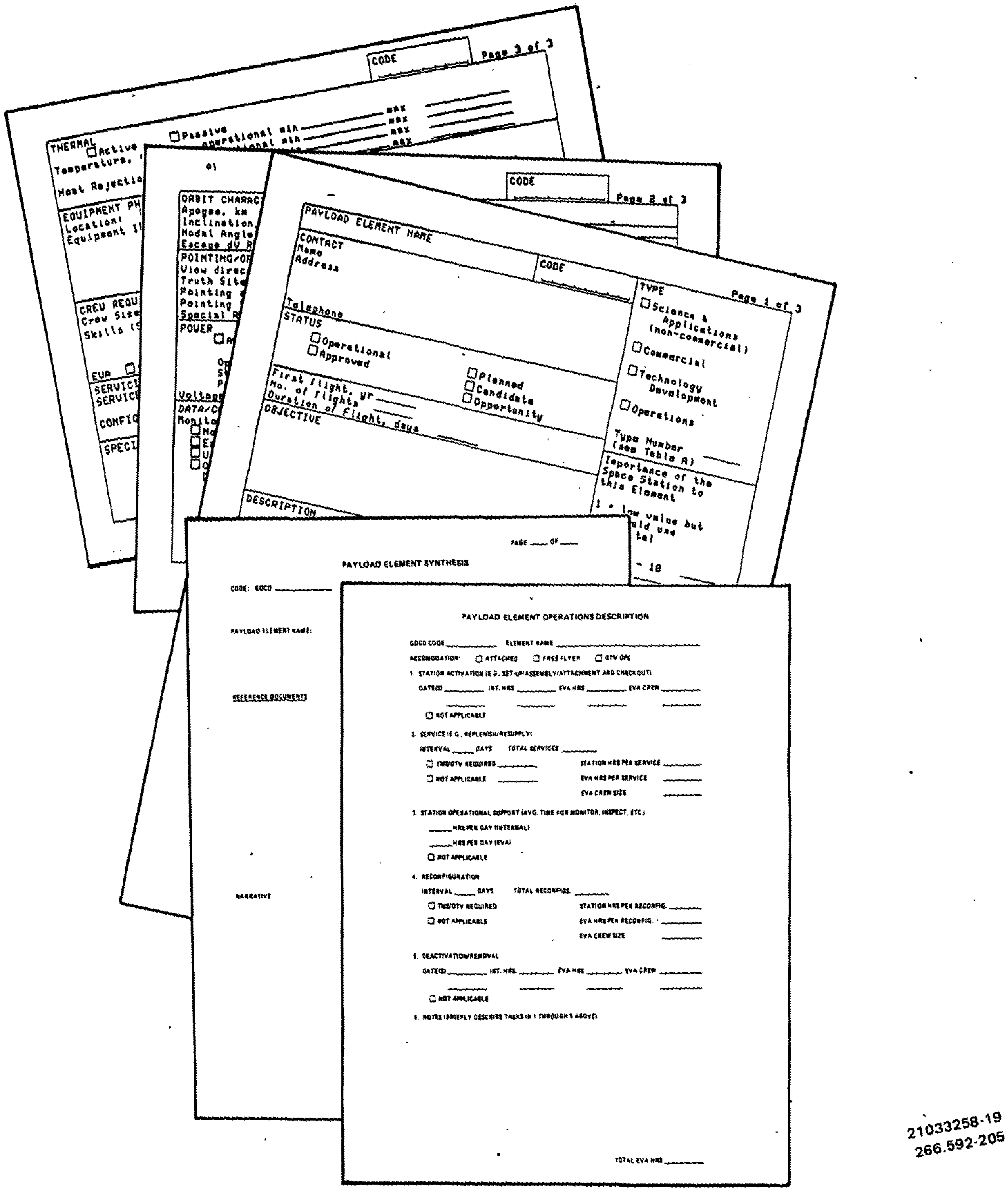

Figure 3-2. Payload Element Documentation

Table 3-1. Mission Identifiers and Statistics

MISSIONS	CODE	NUMBER RANGE FROM	NUMBER RANGE TO	MAN-OPER ATTACHED	FREE FLYERS LEO/HEO	FREE FLYERS GEO	FREE FLYERS ESCAPE	TOTAL
o SCIENCE AND APPLICATIONS MISSIONS	CODE	0000	0999	41	21	4	12	78
Astrophysics		(0000)	(0099)	(8)	(9)	(1)		(18)
Astronomy	AST	0000	0029	2	3	1		6
High Energy (Cosmic-Ray, Gamma-Ray, X-Ray)	HEN	0030	0059	6	3			9
Solar Physics	SPH	0060	0099		3			3
Earth and Planetary Exploration		(0100)	(0199)	(11)	(5)		(12)	(28)
Planetary Observations	PLO	0100	0119				8	
Solar System Missions	SSM	0120	0139				4	
Earth Dynamics	EDY	0140	0149					
Crustal Motion	CRM	0150	0159	2				
Geopotential Fields	GPF	0160	0169	1				
Earth Resources	ERS	0170	0199	8	5			
Environmental Observation		(0200)	(0299)	(13)	(7)	(3)		(23)
Weather/Climate	WCL	0200	0219	2	2	3		
Ocean	OCN	0220	0239		2			
Solar/Terrestrial	STR	0240	0259	6	1			
Atmospheric Research	ATR	0260	0279	5	2			
Life Sciences		(0300)	(0399)	(7)				(7)
Biological Science	BLS	0300	0319	2				
Operational Medicine	OPM	0320	0339	1				
Life Support	LFS	0340	0359	4				
Materials Processing	MPR	(0400)	(0499)	(2)				(2)
o COMMERCIAL MISSIONS		1000	1999	25	5	6		36
Earth and Ocean Observations	EOO	(1000)	(1099)		3	1		4
Communications	COM	(1100)	(1199)	6		5		11
Materials Processing	MPC	(1200)	(1299)	14	1			15
Industrial Services	INS	(1300)	(1399)	5	1			6
o TECHNOLOGY DEVELOPMENT		2000	1999	33				33
Materials & Structures	MTS	(2000)	(2099)	7				7
Energy Conversion	ECN	(2100)	(2199)	7				7
Computer Science & Electronics	CSE	(2200)	(2299)	4				4
Propulsion	PPN	(2300)	(2399)	2				2
Control & Human Factors	CHF	(2400)	(2499)	2				2
Space Station Systems/Ops	SSS	(2500)	(2599)	10				10
Fluid & Thermal Physics/PACE	FTP	(2600)	(2699)	1				1
o OPERATIONS		3000	4999			2		2
Maintenance	MTN	(3000)	(3999)					
Other	OTH	(4000)	(4999)			2		2
TOTAL				99	26	12	12	149

Payload requirements summary data sheets have been compiled and organized by discipline to display the data items most frequently needed for accommodation analyses (Figure 3-3). These summary data sheets are employed extensively throughout Sections 3 and 4. Most of the data item parameters and their units were taken directly from the NASA data base format. Several entries were added to assist in the accommodation analyses. The summary data entries are defined as follows:

a. Accommodation Mode, Attached or Freeflyer. Preferred (P) and (if applicable) acceptable (A) accommodation mode. The Station-attached (ATT) mode includes equipment installed within the pressurized volume of the manned Space Station as well as equipment installed on external mounting structure. Attached payloads are so defined because analysis of their requirements has identified a dependency on man-operation.

   The free-flyer (FF) mode includes both satellite and space platform accommodation of the payload elements. Free flyers that have long lifetimes will be man tended to provide servicing, repair, and updating.

b. Launch Date. Desired launch year(s). If more than one, each is entered or otherwise annotated.

c. Mission Duration. Mission duration is entered adjacent to the corresponding launch year(s).

d. Preferred Orbit. Preferred orbit altitude (km) and inclination (deg). If not critical, "ANY" is entered.

e. Acceptable Orbit. Acceptable range of orbit altitudes and inclinations that will permit the primary payload objectives to be accomplished. Some degradation in overall mission results may occur.

f. Viewing Direction. Desired viewing direction or orientation, i.e., inertial, solar, earth, or other appropriate explanation. Where no specific requirement applies, N/A is entered.

g. Pointing. Pointing requirements are expressed in terms of the maximum allowable magnitude of the line-of-sight angular pointing error envelope (accuracy) and the stability rate (jitter) of the line of sight. The relationship between the instrument line of sight, target, accuracy and jitter is illustrated in Figure 3-4.

   1. Pointing Accuracy - The required pointing accuracy at the interface between the instrument and its carrier. Where the payload definition includes a pointing mount, the accuracy required at the base of the mount is typically 30 to 60 arc minutes.

   2. Pointing Jitter - The maximum allowable angular rate of the line of sight.

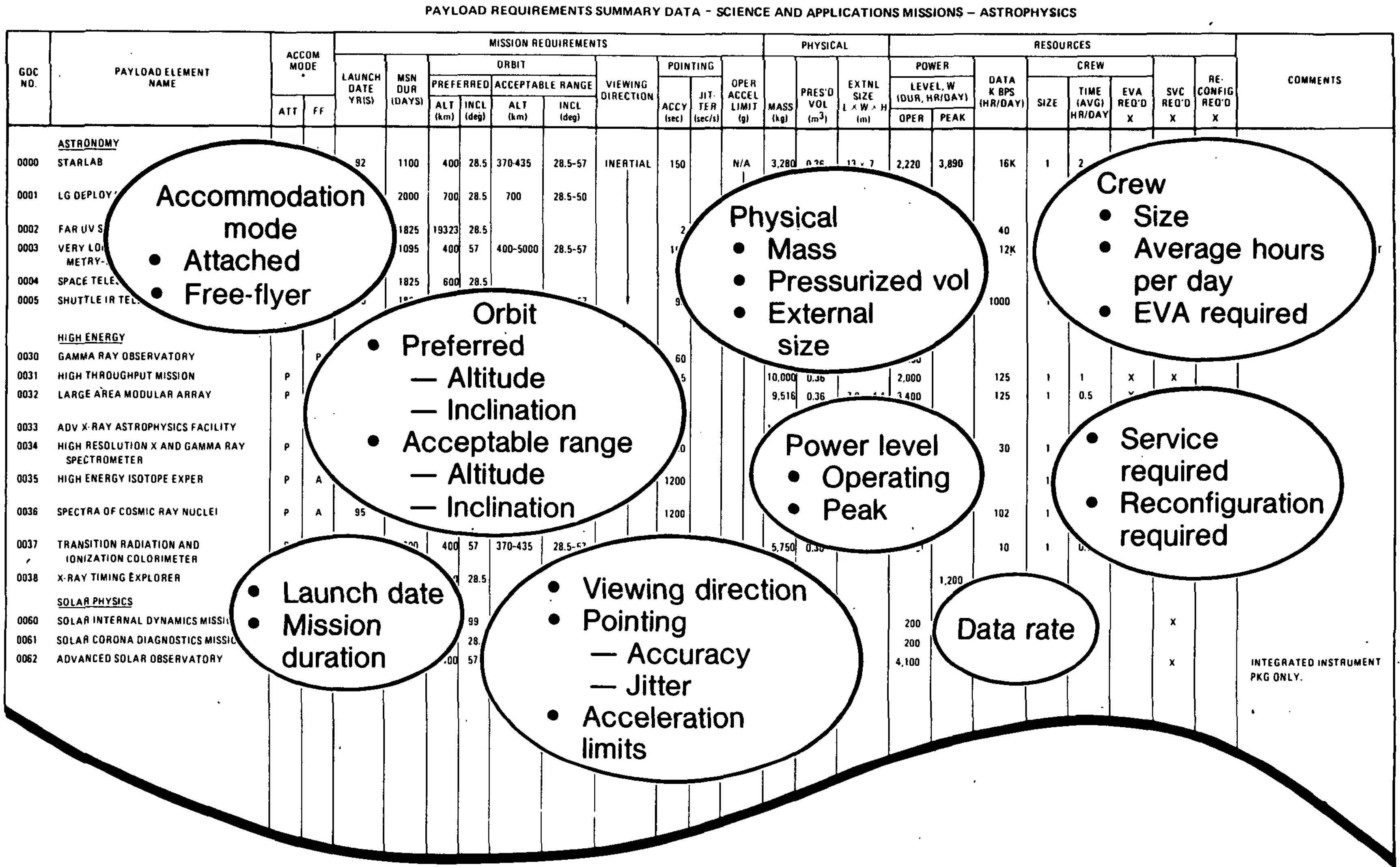

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Figure 3-3. Mission Requirements Matrix

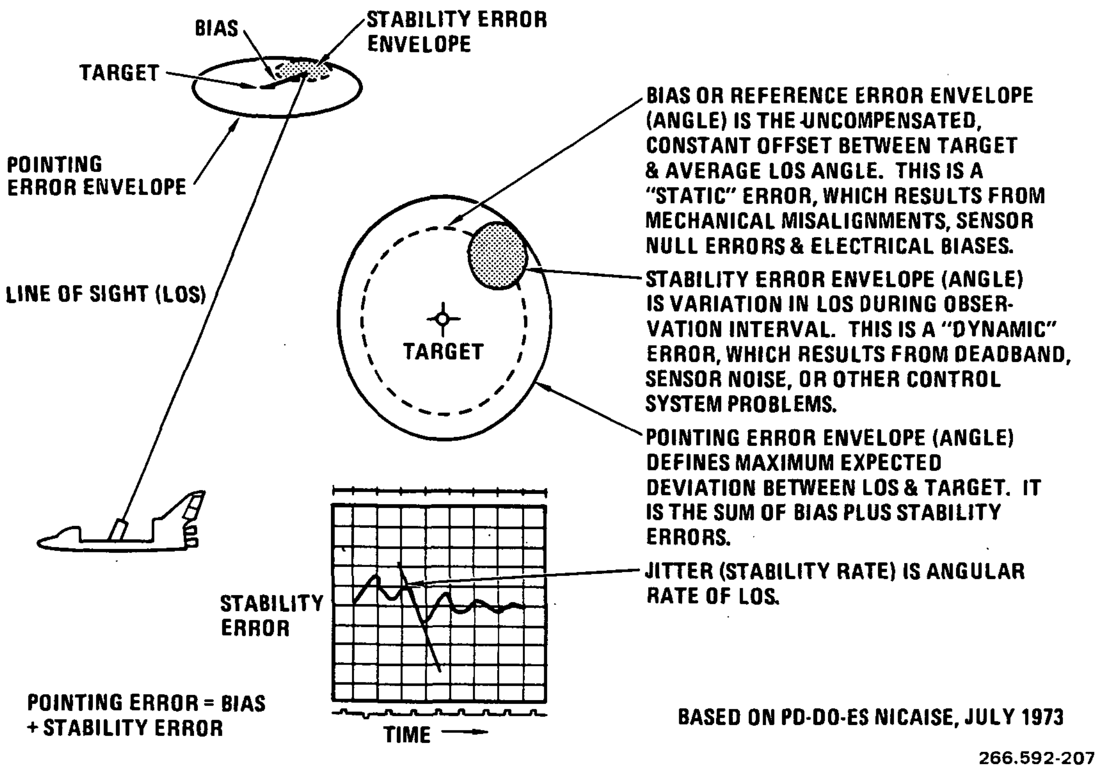


Figure 3-4. Line-of-Sight Error Definition

h. Operating Acceleration Limit. The highest permissible acceleration level during critical periods of experiment or processing operations. This is relatively long term, unidirectional acceleration as induced by atmospheric drag, stationkeeping or reboost thruster operation, or rotation for reorientation.

i. Physical. The physical characteristics listed are for the preferred accommodation mode. For station-attached payloads, these may be individual instruments or they may be integrated instrument groups that include a mounting structure, power and signal interface units, cold plates, and coolant pump packages. For free flyers, the descriptions are usually complete spacecraft with a few exceptions, which are integrated instrument packages only. These latter cases are annotated in the "comments" column. For detailed accommodations analyses, the data sheets must be consulted. If a payload is alternatively accommodated in an acceptable mode, the physical characteristics may change; e.g., a pointing mount that is part of an attached payload may be eliminated if the payload is alternatively accommodated on a free flyer that has the required pointing accuracy.

1. Mass - The mass of the payload equipment as described in the Payload Element Data Sheets.

2. Pressurized Volume - The total volume of equipment to be housed within pressurized modules or other areas within the Space Station. This volume includes payload equipment only, and does not include aisles, access space, and storage space -- with the exception of several of the Life Sciences modules. These exceptions are annotated in the "comments" column.

   Many of the payloads with externally mounted sensors or other types of experimental apparatus also require internally installed control and display (C&D) equipment. We have assumed that standardized "smart terminal" C&D units will be used for most of these applications. The number of C&D units used per payload will vary from one to several, depending upon the number of sensors controlled, the number of parameters monitored, and the number of crew persons required.

   By using standardized C&D units, costs can be reduced through the use of modular hardware and software elements.

   The C&D units will be rack mounted with a size of w = 0.48m by h = 1.0m by d = 0.75m, or a volume of $0.36m^3$. Mass and power for each unit are estimated at about 45 kg and 150 watts, respectively, although these values have not been added to the payload data entries because they are generally insignificant quantities compared to the overall payload requirements.

   The number of C&D units ranges from one to four. Further study may find that through timelining, several payloads could timeshare a C&D unit.

3. External Size - The envelope dimensions of payload equipment mounted externally to the station when the equipment is fully deployed, erected, or constructed.

j. Resources. The resource requirements listed are for the preferred accommodation mode. If a payload is alternatively accommodated in an acceptable mode, the physical characteristics may change.

k. Power. The power requirements are defined for average and peak levels.

1. Operational Power Level/Duration - The operational power input level and the corresponding time.

2. Peak Power Level/Duration - The peak power input level and the corresponding time.

l. Data. The digital data rate flowing from the payload (including both science and housekeeping data) and the number of hours per day that this data stream flows.

m. Crew. The crew requirements are defined for number of crew personnel and average hours per day.

   1. Crew Size - The minimum number of crew persons required simultaneously to support payload operations.

   2. Crew Time - The number of hours per day devoted to payload operations. This is an average over the mission duration and does not include EVA hours, which are accounted for separately.

   3. EVA Required - An "X" indicates that EVA is required to set up, operate, service, and/or reconfigure the payload. Consult data sheet for details.

   NOTE: Repair and tear-down are covered under Space Station operations for nominal activities.

n. Service Required. An "X" indicates that payload servicing is required. Consult data sheet for details.

o. Reconfiguration Required. An "X" indicates that reconfiguration of the payload is required. Consult data sheets for details.

p. Comments. Includes special requirements or other pertinent information about payload configuration, resources, multiple payloads, etc. Commercial payload requirements (included in brackets) are to be accommodated by the payload elements referenced in this column.

3.1 SCIENCE AND APPLICATIONS

The Science and Applications missions are primarily those that have been conceived and developed through the activities sponsored or carried out by NASA's Office of Space Science and Applications (OSSA). These comprise about 52% of the missions identified and defined in our data base.

The mission sets that were defined during the first half of the study and discussed at the study midterm review were based primarily upon the missions described in the briefing material presented at the 14 and 15 September 1982 Contractor Orientation Meetings. The mission sets were updated in the final half of the study based upon the draft document "Science and Applications Requirements for Space Station" that was received at the midterm review on 17 November 1982.

Our mission requirements data base includes 78 Science and Applications missions that could potentially have an interface with the Space Station system during the 1990-2000 time frame, either as attached payloads or payloads that could be launched from or serviced by the station or station-related facilities. Operational or planned missions that will be completed before the Space Station era or that have unique orbit requirements that dictate launch by Shuttle or expendable launch vehicle have not been included in the data base.

In the selection process to choose candidates that would require or whose utility would be enhanced by the Space Station, many possible payloads were eliminated because the proposed operational time frame was before the station would be ready for use. If, as these payloads become fact, the time frame moves into the station operational era, they too could benefit from Space Station support.

Science and Applications missions are categorized into five disciplines and 16 subdisciplines as illustrated in Table 3-2. Mission requirements for each of these disciplines are discussed in the following sections.

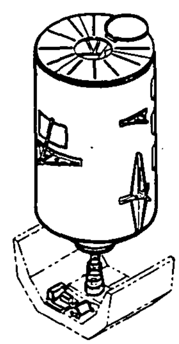
Table 3-2. Science and Applications Disciplines and Missions

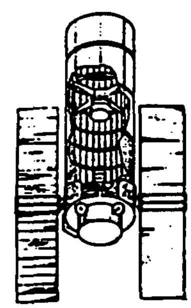
Discipline	No. of Missions	
Astrophysics		18
Astronomy	(6)	
High Energy (Cosmic Ray, Gamma Ray, X-Ray)	(9)	
Solar Physics	(3)	
Earth and Planetary Exploration		28
Planetary Observations	(8)	
Solar System Missions	(4)	
Earth Dynamics	(0)	
Crustal Motion	(2)	
Geopotential Fields	(1)	
Earth Resources	(13)	
Environmental Observations		23
Weather/Climate	(7)	
Ocean	(2)	
Solar/Terrestrial	(7)	
Atmospheric Research	(7)	
Life Sciences		7
Biological Science	(2)	
Operational Medicine	(1)	
Life Support	(4)	
Materials Processing		2
Total		78

3.1.1 ASTROPHYSICS. General characteristics of the Astrophysics missions are shown in Figure 3-5. The payload elements range in size from partial Space Shuttle loads to as many as three full Shuttle loads for the Large Deployable Reflector. The majority of the payloads can be accommodated at a low (28.5- degree) inclination orbit.

Six of the Astrophysics payload elements are long-lived facilities designed to accommodate a large number of sensors. These sensors will be periodically updated. Further, the system operation must be designed to take into account a myriad of guest investigators who will come to the appropriate NASA center to remotely operate their experiment. In some cases, it is even conceivable that the investigator could be transported to the Space Station to perform his experiment.

- Astronomy
- High energy
- Solar physics





Characteristics

- Wide range of sizes & types
  - —Very large, long-life observatories
  - —Single & multiple STS flights
  - —Smaller telescopes & sensor sets
  - —Partial STS loads
- Many service-dependent for long-term useful life
- Majority of missions — 28½ deg — station altitudes

Potential station role

- Man-tending free-flyers
  - —On-orbit assembly, checkout & calibration
  - —Update & servicing of sensors & subsystems
  - —Replenishment of consumables.
- Manned operation & resource provisioning of station-attached telescopes
- Develop assembly & checkout techniques

Driving requirements

- Size
- Contamination limits
- Pointing accuracy & stability

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Figure 3-5. Astrophysics Discipline Characteristics

The manned Space Station assumes several roles in the support and use of the Astrophysics payloads. For those that are suitable, the payloads can be housed and operated at the Station. For others that are not resident, the station becomes an assembly waypoint, wherein the Shuttle brings the payloads to the station for final operational orbit transfer via an Orbit Transfer Vehicle (OTV) or teleoperator. To extend the life of the payloads, service missions to refurbish and replenish with stores from the station can be performed via OTV and/or teleoperator. In some cases, later in the program, manned OTV support would significantly extend the life of a mission. At the end of the useful life, the payloads are recovered and returned to the station for storage, refurbishment, or return to Earth.

The Astrophysics mission model is shown in Figure 3-6. Some currently planned explorer-class payloads scheduled for the mid-to-late 1980s have not been included in the model because they will have no impact on the Space Station. The Far UV Spectroscopy Explorer (FUSE), currently planned for launch in 1989, also would not benefit from station support unless its launch schedule slips a few years.

The free-flying Space Telescope, first launched in 1985 and retrieved in 1990, is shown on its second mission after a 2-year ground refurbishment period. During this second mission, two Space Station-supported servicing and reconfiguration tasks are planned. Beyond 1997 it is likely that the facility will again be refurbished and relaunched. If possible, refurbishment may be performed on orbit.

The Shuttle IR Telescope Facility (SIRTF) is planned as a Space Shuttle payload in the late 1980s. With very little modification, it can be accommodated aboard the Space Station with a vast increase in available viewing time. Because the cryogenically cooled optics and detectors are sensitive to contaminants, timelining of SIRTF and other station activities will be required.

The Advanced X-Ray Astrophysics Facility (AXAF) is a large, free-flying observatory that is co-orbital with and supported by the station. Servicing and reconfiguration tasks are planned at two year intervals.

Starlab is a 1-meter, UV/Visible wide field telescope facility currently planned for its first flight aboard the Space Shuttle in 1989-1990. To accommodate Starlab aboard the Space Station, measures must be taken to control the optical contamination environment and to provide suitable pointing stability. The facility requires the use of an advanced pointing mount.

The Advanced Solar Observatory (ASO) is a large, multi-sensor facility with a long useful life through servicing and updating. It is currently configured as an integrated instrument group that is supported by a standardized spacecraft bus (e.g., a Leasecraft), or it may be berthed to a port on a large space platform. Alternatively, if future studies prove compatibility of the ASO with the Space Station environment, the instrument group could be a station-attached payload and thus benefit from a higher level of manned interaction for operation and servicing.

The Large Deployable Reflector is an advanced technology payload that will require multiple Shuttle logistics flights and on-orbit assembly, alignment, and checkout.

Table 3-3 lists a summary of mission requirements for the Astrophysics discipline. Of the 18 payload elements, eight require or prefer accommodation on the manned Space Station. Each of them could alternatively be accommodated as a man-tended free flyer, but only with a significant impact on the benefits that could be obtained from direct manned interaction.

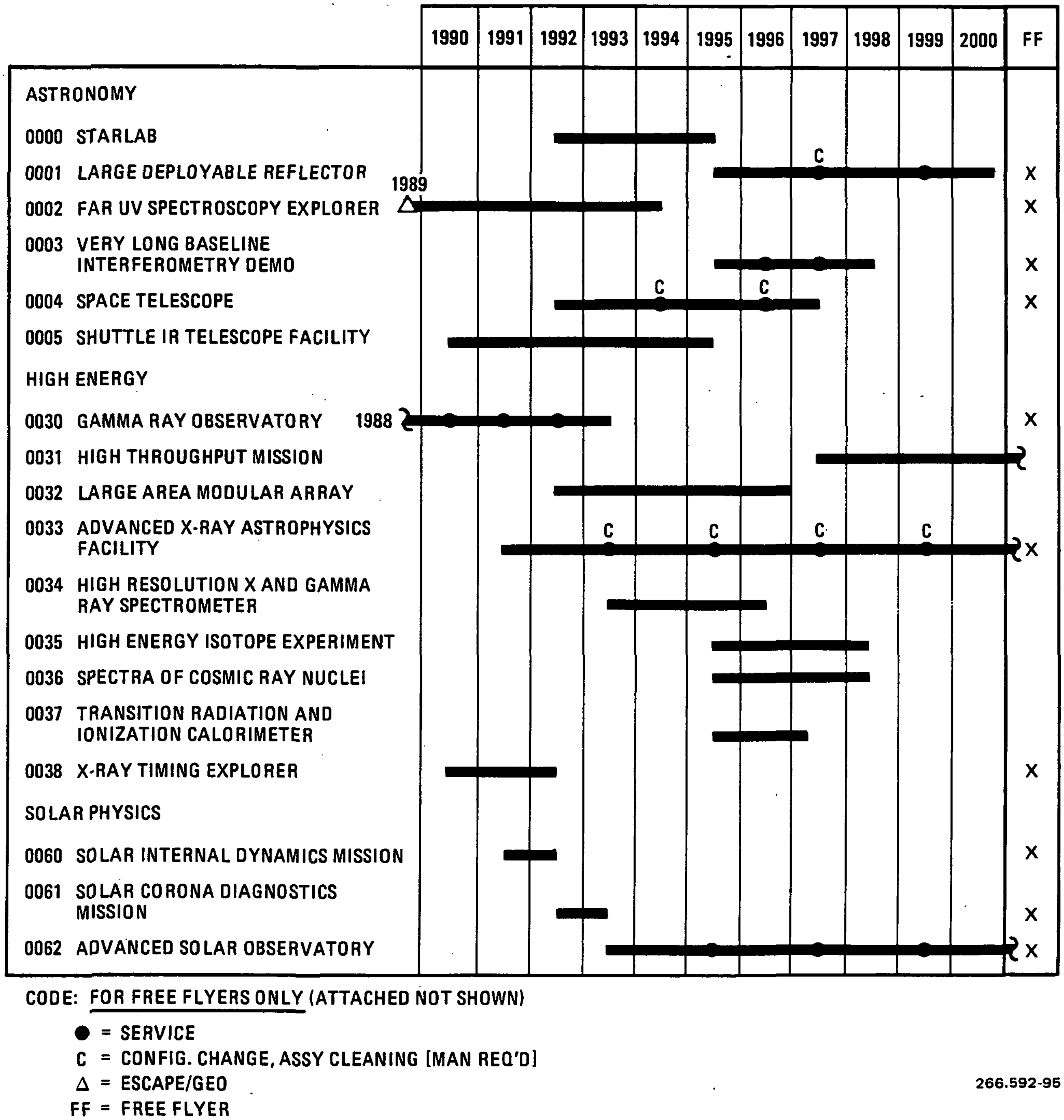

Figure 3-6. Astrophysics Time Phasing

Table 3-3. Payload Requirements Summary Data - Astrophysics

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE* ATT	ACCOM MODE* FF	LAUNCH DATE YR(S)	MSN DUR (DAYS)	MISSION REQUIREMENTS ORBIT PREFERRED ALT (km)	PREFERRED INCL (deg)	ACCEPTABLE RANGE ALT (km)	ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING ACCY (sec)	POINTING JIT-TER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L×W×H (m)	RESOURCES POWER LEVEL, W (DUR, HR/DAY) OPER	PEAK	DATA K BPS (HR/DAY)	CREW SIZE	CREW TIME (AVG) HR/DAY	EVA REQ'D X	SVC REQ'D X	RE-CONFIG REQ'D X	COMMENTS
	ASTRONOMY																								
0000	STARLAB	P	A	92	1100	400	28.5	370-435	28.5-57	INERTIAL	** 150		N/A	3,280	0.36	13 x 7 x 4.5	2,220 (18)	3,890	16K	1	2	X		X	
0001	LG DEPLOYABLE REFLECTOR		P	95	2000	700	28.5	700	28.5-50					55,000		30 x 20 x 20						X	X	X	
0002	FAR UV SPECTROSCOPY EXPL		P	89	1825	35,786	28.5				2			1,360				2,000	40						
0003	VERY LONG BASELINE INTERFERO-METRY-DEMONSTRATION		P	95	1095	400	57	400-5000	28.5-57		150			1,354		10 x 10 x 8	900	1,400	12K				X		INTEGRATED INSTRUMENT PKG ONLY.
0004	SPACE TELESCOPE		P	92	1825	600	28.5							11,600		13.1 X 4.26 X 4.26						X	X	X	
0005	SHUTTLE IR TELE. FACILITY	P	A	90	1825	400	28.5	300-400	28.5-57		** 96			7,018	0.36	11 x 4 x 4	1,300 (18)	2,735	1000	1	0.5	X	X		
	HIGH ENERGY																								
0030	GAMMA RAY OBSERVATORY		P	88	1825	400	0	350-450	0-28.5	INERTIAL	60			11,000			200					X	X		
0031	HIGH THROUGHPUT MISSION	P	A	97	1460	400	28.5				180			10,000	0.36		2,000 (20)		125	1	1	X	X		
0032	LARGE AREA MODULAR ARRAY	P	A	92	1640	400	28.5				180			9,516	0.36	7.8 x 4.4 x 4.4	3,400 (20)		125	1	0.5	X	X		
0033	ADV X-RAY ASTROPHYSICS FACILITY		P	91	3600	500	28.5				30			10,267		12.8 X 4.3 X 4.3						X	X	X	
0034	HIGH RESOLUTION X AND GAMMA RAY SPECTROMETER	P	A	93	1080	400	28.5				** 360			1,768	0.36	2.1 x 2.1 x 2.1	530 (18)	830 (6)	30	1	0.6	X	X		
0035	HIGH ENERGY ISOTOPE EXPERIMENT	P	A	95	1100	400	57	370-435	57	ANTI-EARTH	3600			3,000	0.36		300 (24)			1	0.5	X	X		
0036	SPECTRA OF COSMIC RAY NUCLEI	P	A	95	365	400	57	370-435	28.5-57		3600			3,082	0.36	3.3 x 4.8 x 3.8	731 (22)	785 (2)	102	1	0.2	X	X		
0037	TRANSITION RADIATION AND IONIZATION COLORIMETER	P	A	95	700	400	57	370-435	28.5-57		3600			5,750	0.36		550 (24)		10	1	0.5	X	X		
0038	X-RAY TIMING EXPLORER		P	90	720	400	28.5			INERTIAL	36			1,000		8 X 2 X 2		1,200	10						
	SOLAR PHYSICS																								
0060	SOLAR INTERNAL DYNAMICS MISSION		P	91	360	400	99			SOLAR	2			4,540			200		650						
0061	SOLAR CORONA DIAGNOSTICS MISSION		P	92	360	400	28.5				2			1,800			200		650						
0062	ADVANCED SOLAR OBSERVATORY		P	93	2900	400	57	370-435	28.5-57					12,500		8.2 X 3.8 X 3.8	4,100 (16)		42K				X		INTEGRATED INSTRUMENT PKG ONLY.

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE
**AT TELESCOPE INTERFACE WITH IPS

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All payloads except FUSE desire low earth orbit (LEO) altitudes. Fifteen of the 17 LEO payloads either require or will accept a 28.5-degree inclination orbit.

The optical, RF, and X-ray sensing instruments all require either an inertial (celestial) or solar pointing direction. Pointing accuracy requirements are very stringent, with the exception of the cosmic ray class of detectors, which are generally anti-earth oriented.

The Very Long Baseline Interferometry (VLBI) payload is a relatively small scale demonstration of the orbiting VLBI technique, using a 10-meter diameter receiving antenna. This is a precursor to a much larger facility (30-60 meter diameter) that is planned as a free flyer in the post-2000 time frame.

The physical and resources requirements shown for VLBI and ASO are for integrated instrument packages only and are dependent upon other support subsystems for orientation and pointing, power, thermal control, and data handling.

Power levels shown are those at the payload interface. For free flyers it represents the input to the scientific instrumentation package.

Data output rates are moderate-to-high. The ASO rate of 42M bps includes several channels of digitized TV.

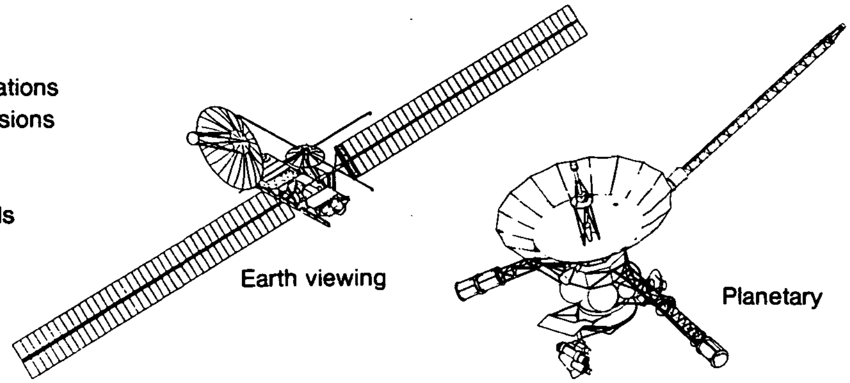
Routine operations of the station-attached payloads do not require more than one crewman for a small fraction of a day per payload.

The importance of payload servicing and reconfiguration to provide long useful life is evidenced by the high percentage of payloads that require these activities. A high percentage also require EVA for assembly, alignment, replacement of instrument and subsystem modules, and other tasks that require high dexterity.

3.1.2 EARTH AND PLANETARY EXPLORATION. The Earth and Planetary Exploration missions continue the exploration of the solar system both on Earth and the other bodies comprising the system. General characteristics of this discipline are shown in Figure 3-7. For earth study, the missions will explore earth dynamics, crustal motion, and potential fields to more fully understand interrelationships that will permit prediction of the environment. Earth resources study includes renewable resources such as crops, both land and ocean, and nonrenewable, such as minerals and petroleum.

The characteristics include planetary landings for in situ study, as well as remote viewing and other remote sensing. A wide range of orbits is required for these missions as will be discussed later. Some of the missions are for the development of instruments, sensors, and techniques for use on later operational missions.

- Planetary observations
- Solar system missions
- Earth dynamics
- Crustal motion
- Geopotential fields
- Earth resources



Characteristics

- Viewing systems & planetary landers
- Wide range of orbits
  —Planetary/escape
  —LEO low inclination
  —LEO high inclination, including sun-synch
- Broad spectrum of sensors, RF, optical, LIDAR
- Development & operational missions

Potential station role

- OTV basing for delivery to HEO — earth & planetary
- Man-tending free-flyers in LEO
  —Singular or grouped on platforms
- Man-conducted development of station-mounted sensors, analytical & automated techniques

Driving requirements

- Orbit range
- Orientation & pointing
- Data rates
- RF generation & susceptibility
- Power

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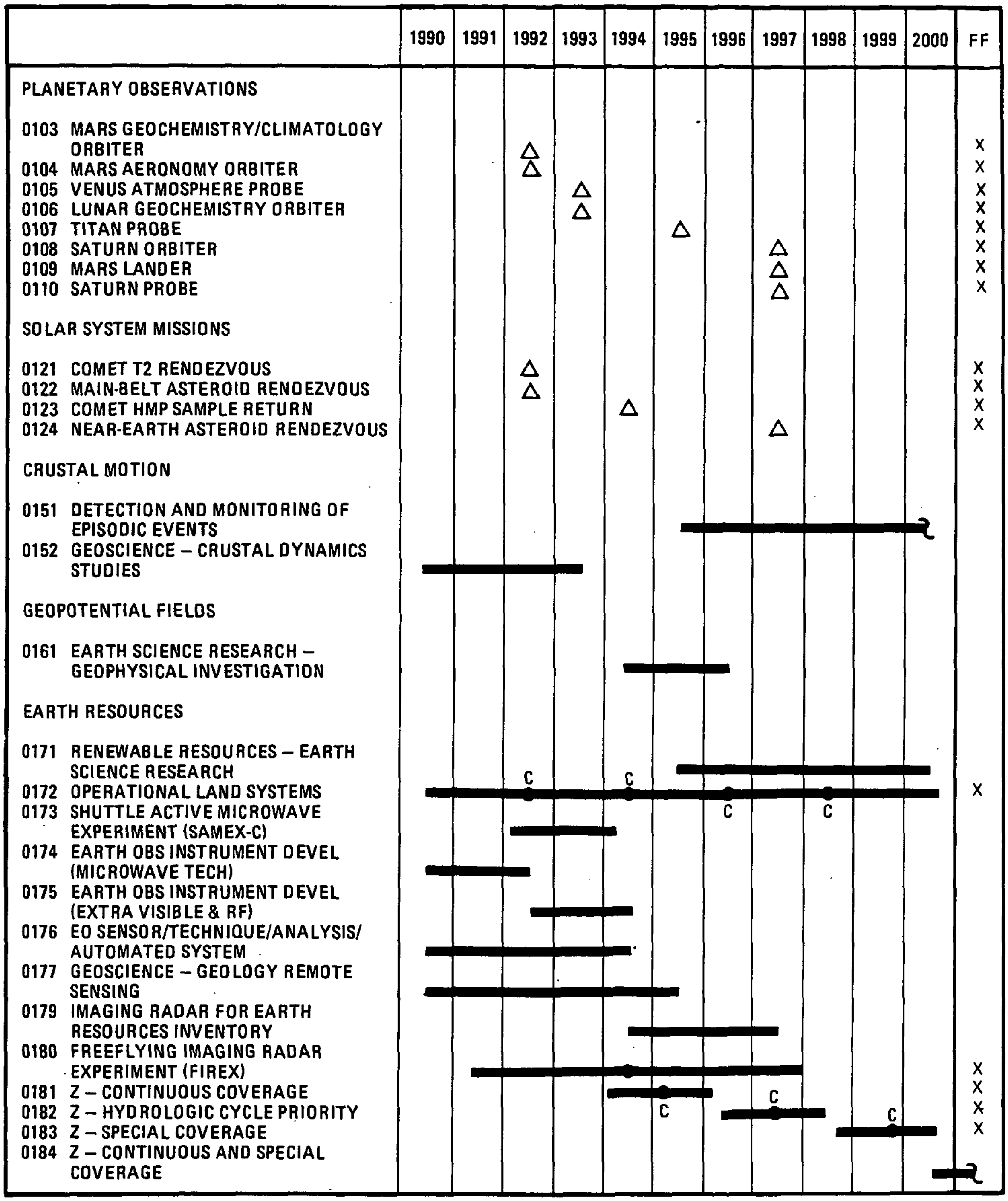
Figure 3-7. Earth and Planetary Exploration Discipline Characteristics

The support by the Space Station will include OTV basing for earth escape missions and support of man-tended LEO free flyers. For the development of sensors and automated techniques for use on free flyers, many of the missions will be conducted by man on the Station.

There are several driving requirements such as orbit, instrument pointing, data rates, RF noise susceptibility, and electrical power. The requirements for planetary missions are relatively easy to accommodate by the Space Station in a low inclined orbit in conjunction with the OTV. This same station can accommodate most of the development missions. However, for the earth dynamics and earth resources operational missions, which require near total global coverage, highly inclined orbits, up to polar, are required.

The Earth and Planetary Exploration mission model is shown in Figure 3-8. The 12 Planetary Observation and Solar System missions correspond to the core program recommendations of the Solar System Exploration Committee (SSEC). Only the launch dates from LEO to escape trajectory are shown. The descriptive material used as a data source for these missions was obtained through contacts with JPL in late 1982.



CODE: FOR FREE FLYERS ONLY (ATTACHED NOT SHOWN)

● = SERVICE
C = CONFIG. CHANGE, ASSY, CLEANING (MAN REQ'D)
Δ = ESCAPE/GEO
FF = FREE FLYER

266.592-96

Figure 3-8. Earth and Planetary Exploration Time Phasing

The Planetary Observation and Solar System missions are primarily "fire-and-forget" missions so far as the Space Station is concerned, with the exception of the sample return mission. This mission would employ the Space Station as a return way station, possibly including quarantine and preliminary analysis functions. The primary station support functions for the earth orbit escape missions would be as an OTV staging base and for the on-orbit assembly and checkout of the spacecraft prior to launch from LEO into their escape trajectory.

In the earth observations area, payload elements 0174, 0175, and 0176 are Technology Development missions for remote sensing instruments and their utilization techniques. These themes were expanded and quantitatively defined to develop Space Station support requirements.

The remainder of the mission descriptions are based primarily upon data furnished by OSSA in the draft mission description document. The Operational Land Systems mission is an advanced earth observation spacecraft that continues LANDSAT-type observations and data distribution services. Operation of this system may become a commercial venture in this time frame.

Payload elements 0181, 0182, and 0183 are large, polar orbiting, multidisciplinary remote sensing free flyers of the space platform class that will develop and verify sensing instruments, observation techniques, and data analysis and dissemination methods.

Payload element 0184 utilizes a complete and mature complement of the 0181 and 0183 instruments aboard a polar orbiting manned station. This multidisciplinary payload could then replace or reduce the number of Operational Land Systems and TIROS Follow-on Spacecraft.

Table 3-4 lists a summary of mission requirements for the Planetary Observation and Solar System missions. These mission descriptions are in the early formative stage, and little detail is available at this time. On-going work by NASA to descope mission objectives and reduce spacecraft complexity to lower costs may result in changes to spacecraft mass in the future.

Table 3-5 lists a summary of earth exploration mission requirements. All of these missions desire high (50-100 degree) orbit inclination for global coverage. However, some missions whose objectives are to develop instruments and utilization techniques, and who require direct manned interaction, can alternatively be accommodated in a low inclination orbit. Operational versions of the Earth Resources missions may be commercial endeavors.

Pointing accuracy requirements range from low to moderate. Many of these instruments incorporate built-in capabilities for fine pointing.

The mass range of these payloads varies from a fraction of a Shuttle load to several loads, noting that the Shuttle's launch capacity to polar orbit ranges from around 8000 to 12,000 kg. Several of these payloads will require on-orbit assembly and checkout.

Table 3-4. Payload Requirements Summary Data - Planetary Exploration

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE * ATT	ACCOM MODE * FF	LAUNCH DATE YR(S)	MSN DUR (DAYS)	MISSION REQUIREMENTS ORBIT PREFERRED ALT (km)	ORBIT PREFERRED INCL (deg)	ORBIT ACCEPTABLE RANGE ALT (km)	ORBIT ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING ACCY (sec)	POINTING JIT-TER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	RESOURCES POWER LEVEL, W (DUR, HR/DAY) OPER	POWER PEAK	DATA K BPS (HR/DAY)	CREW SIZE	CREW TIME (AVG) HR/DAY	EVA REQ'D X	SVC REQ'D X	RE-CONFIG REQ'D X	COMMENTS
	PLANETARY OBSERVATIONS																								
0103	MARS GEOCHEMISTRY/CLIMATOLOGY ORBITER		P	92	1	LEO (DEL ALT FOR ESC PAY-LDS)	28.5			N/A			N/A	5,600						2	8				
0104	MARS AERONOMY ORBITER		P	92	1									5,600											
0105	VENUS ATMOSPHERE PROBE		P	93	1									6,000											
0106	LUNAR GEOCHEMISTRY ORBITER		P	93	1									480											
0107	TITAL PROBE		P	95	1									960											
0108	SATURN ORBITER		P	97	1									1,800											
0109	MARS LANDER		P	97	1									1,700											
0110	SATURN PROBE		P	97	1									2,170											
	SOLAR SYSTEM MISSIONS																								
0121	COMET T2 RENDEZVOUS		P	92	1									2,200											
0122	MAIN-BELT ASTEROID RENDEZVOUS		P	92	1									2,700											
0123	COMET HMP SAMPLE RETURN		P	94	2									1,200											1 DAY LAUNCH; 1 DAY RETRIEVAL
0124	NEAR-EARTH ASTEROID RENDEZVOUS		P	97	1									1,170											

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

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Table 3-5. Payload Requirements Summary - Earth Exploration

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE* ATT	ACCOM MODE* FF	LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT PREFERRED ALT (km)	ORBIT PREFERRED INCL (deg)	ORBIT ACCEPTABLE RANGE ALT (km)	ORBIT ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING ACCY (sec)	POINTING JITTER (sec/s)	OPER ACCEL LIMIT (g)	MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L×W×H (m)	POWER LEVEL, W (DUR, HR/DAY) OPER	POWER LEVEL, W (DUR, HR/DAY) PEAK	DATA K BPS (HR/DAY)	CREW SIZE	CREW TIME (AVG) HR/DAY	EVA REQ'D X	SVC REQ'D X	RE-CONFIG REQ'D X	COMMENTS
	CRUSTAL MOTION																								
0151	DETECTION & MONITORING OF EPISODIC EVENTS	P		95	1825	450	90	400-500	80-100	EARTH	6		N/A	3,500	0.36	16 × 10 × 3	3,000		300K	2	1	X	X	X	
0152	GEOSCIENCE-CRUSTAL DYNAMICS STUDIES	P	A	90	1100	500	50	300-600	50-90	EARTH	60			185	0.36	2.5 × 1.5 × 1.5	500 (6)		10	1	0.2	X	X		
	GEOPOTENTIAL FIELDS																								
0161	GEOPHYSICAL INVESTIGATION	P		94	800	400	90	275-500	85-95	EARTH	1800			400	0.36	100 × 2 × 2	130 (24)	1200	30	1	0.5				
	EARTH RESOURCES																								
0171	RENEWABLE RESOURCES–EARTH SCIENCE RESEARCH	P	A	95	1825	400	90	300-500	57-90	EARTH	3600			2,000	0.72	40 × 30 × 3	5K	7K	100K	2	1	X	X	X	
0172	OPERATIONAL LAND SYSTEMS		P	90	3650	500	90	500-1000	80-100	EARTH	360			2,000		30 × 30 × 3	8K	10K	300K			X	X	X	
0173	SHUTTLE ACTIVE MICROWAVE EXPER (SAMEX-C)	P		92	730	400	90	275-500	28.5-90	EARTH	3600			2,000	0.36	15 × 3 × 2	5K(12)	7500	5	1	0.2	X		X	
0174	EARTH OBS INSTRU DEVEL (MICROWAVE TECH)	P		90	730	1000	90	400-1600	28.5-90	EARTH	360			200	0.36	1.5 × 1 × 1	200		1000	1	0.25			X	
0175	EARTH OBS INSTRU DEVEL (EXTRA VISIBLE & RF)	P		92	730	400	90	275-1000	28.5-90	EARTH	1800			1,000	0.36	8 × 4 × 2	500	700	1000	1	0.25	X	X	X	
0176	EO SENSOR/TECHNIQUE/ANAL/AUTO-MATED SYSTEM DEVEL	P		90	1460	500	90	275-825	28.5-90	EARTH	3600			2,000	0.72	40 × 30 × 3	6K(12)		80K	2	1	X	X	X	
0177	GEOSCIENCE-GEOLOGY REMOTE SENSING	P	A	90	1800	500	90	300-600	80-100	EARTH	6			2,000	0.36	30 × 30 × 3	10K		300K	1	0.2	X		X	
0178	RESERVED																								
0179	IMAGING RADAR FOR EARTH RESOURCES INVENTORY & MONITORING	P	A	94	1095	400	57	300-500	28.5-90	EARTH	360			2,000	0.36	15 × 3 × 2	5K	7.5K	20	1	0.2				
0180	FREE-FLYING IMAGING RADAR EXPERIMENT (FIREX)		P	91	2440	400	90	375-450	80-100	EARTH	3600			2,000		4 × 8 × 12	7K	10K	120K			X	X		
0181	Z – CONTINUOUS COVERAGE		P	94	720	1000	100	400-1000	96-100	EARTH				8,578		16 × 45 × 4.5	3160(24)		125K			X	X	X	
0182	Z – HYDROLOGIC CYCLE PRIORITY		P	96	720	1000	100	400-1000	96-100	EARTH				8,708		31 × 45 × 4.5	2370(24)	7970	300K			X	X	X	
0183	Z – SPECIAL COVERAGE		P	98	720	1000	100	400-1000	96-100	EARTH				8,821		33 × 45 × 4.5	10K		300K			X	X	X	
0184	Z – CONTINUOUS & SPECIAL COVERAGE	P		00	3650	500	97.5	400-1000	90-100	EARTH				14,260	1.08	38 × 22 × 4.5	30K	40K	300K	1	2	X	X	X	

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

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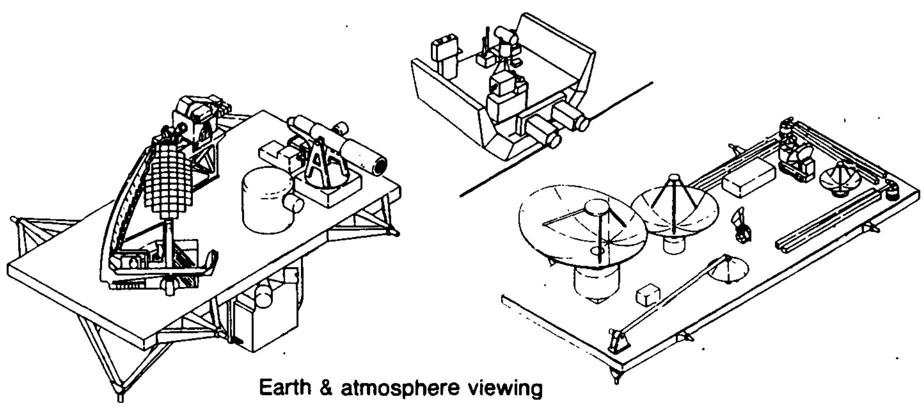
Many of these payloads require input power in the range of 5 to 10 kW, and 0184 requires 30 kW. Output data rates are in the very high category, with several payloads internally timelined to limit maximum data rates to 300M bps.

The majority of these payload elements require periodic instrument updating and servicing. Many employ cooled detectors that require periodic replenishment of cryogens.

3.1.3 ENVIRONMENTAL OBSERVATIONS. Environmental Observations Missions include investigations and data gathering in the subdisciplines of Weather and Climate, Ocean Observations, Solar/Terrestrial interactions, and Atmospheric Research. These missions employ both passive remote sensing of natural phenomena and also active stimulation using lasers, plasma wave injection facilities, electron beams, and powerful radars. General characteristics of this discipline are shown in Figure 3-9.

Early year missions for development of payload equipment and measurement techniques can make use of low inclination orbits and will benefit from man's presence for instrument adjustments and servicing. Later operational missions desire high inclination orbits to provide global coverage and access to the auroral zones. Man's presence for these operational missions would also be beneficial, although many of the observation functions can be automated.

- Weather/climate
- Ocean
- Solar/terrestrial
- Atmospheric research



Characteristics

- Viewing systems — broad spectrum RF & optical
- Orbit range
  GEO, HEO
  LEO — high inclination & sun-synch
- Large size sensors, including LIDAR
- Development & operational missions

Potential station role

- OTV basing for checkout & delivery to HEO & GEO
- Man-tending free-flyers —Singular or platform groupings
- Manned development of sensor systems

Driving requirements

- Orbit range
- Orientation & pointing
- Data rates
- Power (to 25 kW)

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Figure 3-9. Environmental Observations Discipline Characteristics

The LEO missions range from 28.5 to 98-degree inclinations, and several of the meteorological missions require GEO vantage points.

The Environmental Observations mission model is shown in Figure 3-10. Missions that require manned operation in the early period are for development of individual instruments and for the integration of multisensor groups that will later be operated simultaneously for broad spectrum (i.e., R.F., Optical, IR) measurements of earth, atmosphere, and solar emissions, and measurements of atmosphere constituents.

Free-flying LEO satellites and platforms will carry environmental observations sensors throughout the decade and beyond. These will present opportunities for a polar orbiting Space Station to provide support for servicing, updating, and repair late in the decade. Where sufficient changes in orbit altitude or inclination are required to emplace or retrieve satellites, a Space Station-based TMS or OTV could provide a significant economic benefit over dedicated Shuttle servicing missions.

In the later years, many of the missions involve the assembly, alignment, checkout, and use of physically large structures and antennas. High input power levels are also required.

The GEO meteorological mission requirements can potentially be satisfied by GEO platform accommodations in lieu of individual satellites.

Payload element 0202 is typical of a mission that would benefit from the availability of man during a 1-year developmental test period. In the following year, a free-flying version (0205) is placed in a high inclination orbit and collects data for the next 4 years. One use of this data will be as partial inputs to the global meteorological model.

Payload 0201 is a technology development mission for a large, high power meteorological radar that could become part of an operational meteorological remote sensing system in the post-2000 era. This operational system, as well as the GOES and TIROS Follow-on missions may be commercial ventures at this time.

Payload elements 0242 and 0243 are large radars that support multidisciplinary investigations in Solar Terrestrial interactions and also Atmospheric Research. The basis for these missions was conceived by Dr. Lewis M. Duncan of Los Alamos National Laboratories.

Payload 0266, WINDSAT, is a dedicated satellite that employs a scanning LIDAR to detect the motion of aerosols in the atmosphere and thereby compute wind speed and direction. Preliminary concept definition studies of the WINDSAT LIDAR and spacecraft have been conducted by LMSC and MSFC, respectively.

The 23 payload elements of the Environmental Observations discipline utilize 51 types of sensors. Many of the sensors are employed on two or more payloads. Table 3-6 lists the instrument complement of the payloads. The number of instruments carried by each payload ranges from 1 to 17.

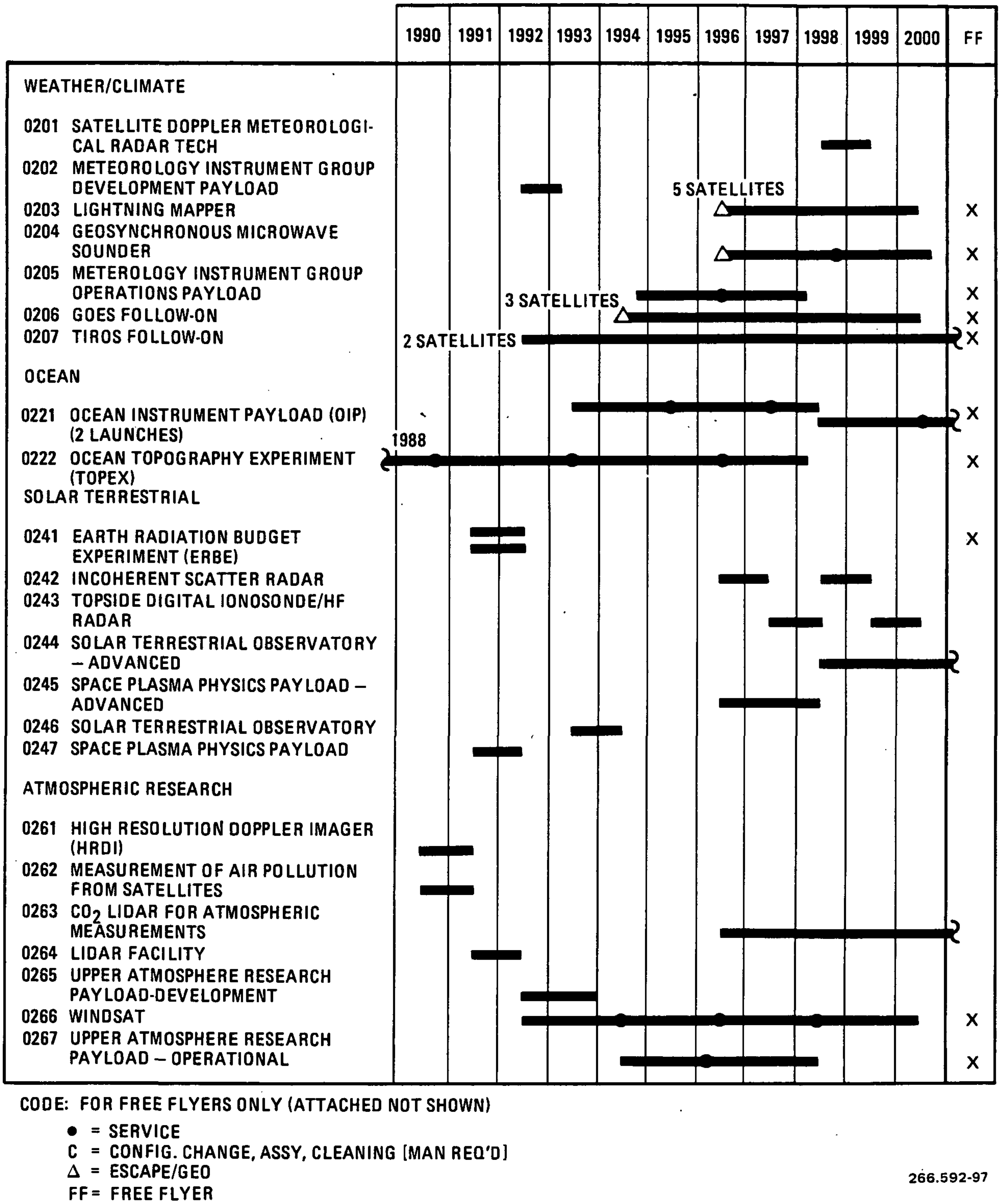

Figure 3-10. Environmental Observations Time Phasing

Table 3-6. Environmental Remote Sensing Instrument Utilization Summary

GDCD NO.	NAME (PAYLOAD ELEMENT)	HRDI	P.B. DOPPLER RADAR	AMSU	MPS	AMTS	LM TELESCOPE	M.W. RADIOMETER	VAS	MAGNETOMETER	SOLAR X-RAY MON.	ENERGETIC PART DET.	DCS	AVHRR	HIRS-2	MSU	SSU	SBUV	ERBE	SAR	VHF RADAR	HF RADAR	ACR	SUSIM	SOFT X-RAY TELESCOPE	L-α CORONAGRAPH	ATMOS-P	SEPAC	MMP	LIDAR FACIL	AEPI	ATMOS. X-RAY TELE.	ISO	ALS	WISP	CRM	RPDP SUBSAT	MAPS	CO_2 LIDAR	HALOE	TWM	CLAES	ISAMS	MLS	USSIE	DOPPLER LIDAR	SCATTEROMETER	OCEAN COLOR IMAGER	PASSIVE M.W. RADIOMETER	OWDS	MULTIBEAM ALTIMETER	GRAVITY GRADIOMETER
0201	Sat. Doppler Met. Radar		X																																																	
0202	Met. Instr. Gp. – Devel.			X	X	X																																														
0205	Met. Instr. Gp – Opnl.			X	X	X																																														
0206	GOES Follow-on								X	X	X	X	X																																							
0207	TIROS Follow-on										X	X	X	X	X	X	X	X	X	X																																
0221	Ocean Instr. P/L																			X																											X	X	X	X	X	
0222	TOPEX																																														X				X	X
0241	ERBE																		X																																	
0242	Incoherent Scatter Radar																				X																															
0243	Topside Digital Ionosonde																					X																														
0244	STO – Advanced	X																	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X															
0245	SPP – Advanced																											X			X				X																	
0246	STO	X																	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X															
0247	SPP																											X			X				X																	
0261	High Res. Doppler Imager (HRDI)	X																																																		
0262	MAPS																																					X														
0263	CO_2 LIDAR																																						X													
0264	LIDAR Facility																													X																						
0265	Upper Atmos. Research P/L – Devel.	X																						X																X	X	X	X	X	X							
0266	WINDSAT																																													X						
0267	UARS – Opnl.	X																						X																X	X	X	X	X	X							
0203	Lightning Mapper						X																																													
0204	Geosyn. MW Sounder							X																																												

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Table 3-7 lists a summary of Environmental Observations mission requirements. All of the LEO missions require or desire high (57-98 degree) inclination orbits. Missions whose primary mission requirements are for instrument development can alternatively be accommodated on low inclination facilities.

The Lightning Mapper mission employs sensors in geosynchronous orbit at five locations around the earth. These sensors are integrated with small subsystem modules that provide mission support.

The Geosynchronous Microwave Sounder is a passive microwave radiometer that utilizes a 33-meter diameter reflector. This large structure must be assembled and aligned in LEO and then boosted to GEO using a low thrust orbit transfer vehicle (OTV).

Payload 0241 (ERBE) comprises two instrument packages. Several sets of these instrument packages are used on multiple spacecraft in medium and high inclination orbits to provide global coverage with frequent temporal and spatial sampling.

Payload element 0243, the Topside Digital Ionosonde Sounder/High Frequency Radar, employs a large receiving antenna array that will require deployment, assembly, and installation of both transmitting and receiving antennas on the Space Station.

Payload 0246, the Solar Terrestrial Observatory (STO), and payload 0244, an advanced STO, are the largest of the Environmental Observations payloads, each having a mass of about 16,500 kg. These occupy the equivalent of four Spacelab pallets. Orientation of the instrument groups requires earth and solar pointing, and magnetic field line alignment. The STO instrument group is already well defined. Precursor instruments are scheduled to fly on the Shuttle in the mid and late 1980s. Considerable payload definition effort has been expended on integrating the STO on the MSFC Science and Applications Space Platform. The results of this planning effort should be directly applicable for accommodating the STO instruments on a Space Station in a suitable orbit (i.e., medium to high inclination).

Payload 0263, the CO_2 LIDAR, is a Technology Development Payload that employs a large CO_2 LIDAR to stimulate and measure atmospheric emissions to determine atmospheric constituents and to measure the transport of these constituents. It requires 25 kW input power and a high (TBD) level of active cooling.

The majority of the Environmental Observations payloads require periodic servicing and instrument updating. Many of the payloads require replenishment of cryogens for cooled detectors.

Table 3-7. Payload Requirements Summary Data - Environmental Observations (Sheet 1 of 2)

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE*		MISSION REQUIREMENTS										PHYSICAL			RESOURCES								COMMENTS
				LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT				VIEWING DIRECTION	POINTING		OPER ACCEL LIMIT (g)	MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	POWER		DATA K BPS (HR/DAY)	CREW			SVC REQ'D X	RE-CONFIG REQ'D X	
						PREFERRED		ACCEPTABLE RANGE									LEVEL, W (DUR, HR/DAY)			SIZE	TIME (AVG) HR/DAY	EVA REQ'D X			
		ATT	FF			ALT (km)	INCL (deg)	ALT (km)	INCL (deg)		ACCY (sec)	JIT-TER (sec/s)					OPER	PEAK							
	WEATHER/CLIMATE																								
0201	SATELLITE DOPPLER METEOROLOGICAL RADAR TECH DEVEL	P		98	365	400	57	300-500	28.5-90	EARTH	3600		N/A	2,600	0.36	50 x 5.2 x 5.2	6K		120K	2	0.4	X	X	X	
0202	METEOROLOGY INSTRU GROUP DEVEL PAYLOAD	P		92	365	400	57	300-500	28.5-90	EARTH	360			1,170	0.72	1.6 x 4.4 x 4.4	1140 (24)		3000	2	0.4	X	X	X	
0203	LIGHTNING MAPPER		P	96	1460	GEO	0			EARTH	2.0			900		6 x 5 x 5	200		2000						FIVE SATELLITES
0204	GEOSYNCHRONOUS MICROWAVE SOUNDER		P	96	1500	GEO	0			EARTH	20			5,850		40 x 60 x 33	200					X	X		
0205	METEROLOGY INSTRU GROUP OPERATIONS PAYLOAD		P	94	1200	400	57	300-500	57-90	EARTH	360			2,000		1.6 x 8 x 8	1140 (24)		3000				X		INTEGRATED INSTRUMENT PKG ONLY.
0206	GEOSTATIONARY OPNL ENV. SAT (GOES) FOLLOW-ON		P	94	2200	GEO	0			EARTH				500		3.6 x 2.2 x 2.2			28K						THREE SATELLITES
0207	TIROS FOLLOW-ON		P	92	2900	800	98			EARTH				2,000		15 x 12 x 4									TWO SATELLITES
	OCEAN																								
0221	OCEAN INSTRU PAYLOAD (OIP)		P	93 98	1825	500	98	300-800	57-98	(EARTH & SOLAR)	1080			1,600		16 x 10 x 2.5	1200 (18)		110K				X		
0222	OCEAN TOPOGRAPHY EXPERIMENT (TOPEX)		P	88	3650	1384	63.4			(EARTH & CELESTIAL)	1440			1,600		6 x 5 x 5	600 (18)		15				X		
	SOLAR TERRESTRIAL																								
0241	EARTH RADIATION BUDGET EXPERIMENT (ERBE)		P	91	365	(600) (800)	(46) (98)			EARTH, SOLAR				55		1 x 1 x 1	60 (24)		1.0						INSTRUMENTS ONLY.
0242	INCOHERENT SCATTER RADAR	P		96 98	365	400 400	0 90	400-500 400-500	0-28.5 80-100	EARTH, CELESTIAL	18000			1,000	0.36	25 x 25 x 15	1500			1	0.5	X			
0243	TOPSIDE DIGITAL IONOSONDE/HF RADAR	P		97 99	365	400 400	0 90	400-500 400-500	0-28.5 80-100	EARTH				500	0.36	200 X 200 X 3	1500			1	0.5	X			
0244	SOLAR TERRESTRIAL OBSERVATORY – ADVANCED	P		98	2190	400	57	300-500	57-90	SOLAR, EARTH	1800			16,500	1.44	13 x 300 x 10	10K (12)	21K (12)	42K	2	1.33	X	X	X	
0245	SPACE PLASMA PHYSICS PAYLOAD – ADVANCED	P		96	730	400	57	250-500	57-90	EARTH, SOLAR	3600			3,183	0.36	5 x 300 x 10	3225 (1)	12K (0.1)	12K	1	0.5		X		
0246	SOLAR TERRESTRIAL OBSERVATORY	P	A	93	365	400	57	300-500	57-90	EARTH, SOLAR	1800			16,500	1.44	13 x 300 x 10	10K (12)	21K (12)	42K	2	2	X	X		
0247	SPACE PLASMA PHYSICS PAYLOAD	P	A	91	365	400	57	250-500	57-90	EARTH, SOLAR	3600			3,183	0.36	5 x 300 x 10	3225 (1)	12K (0.1)	12K	1	0.25		X		

*ACCOM MODE: P = PREFERRED; A = ACCEPTABLE

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Table 3-7. Payload Requirements Summary Data - Environmental Observations (Sheet 2 of 2)

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE* ATT	ACCOM MODE* FF	MISSION REQUIREMENTS: LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT PREFERRED ALT (km)	ORBIT PREFERRED INCL (deg)	ORBIT ACCEPTABLE RANGE ALT (km)	ORBIT ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING ACCY (sec)	POINTING JIT-TER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL: MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	RESOURCES: POWER LEVEL, W (DUR, HR/DAY) OPER	POWER LEVEL, W (DUR, HR/DAY) PEAK	DATA K BPS (HR/DAY)	CREW SIZE	CREW TIME (AVG) HR/DAY	CREW EVA REQ'D X	SVC REQ'D X	RE-CONFIG REQ'D X	COMMENTS
	ATMOSPHERIC RESEARCH																								
0261	HIGH RESOLUTION DOPPLER IMAGER (HRDI)	P	A	90	365	400	57	300-600	57-90	EARTH	10800		N/A	78	0.36	2 x 2 x 2	82 (12)		4.0	1	0.1				
0262	MEASUREMENT OF AIR POLLUTION FROM SATELLITES (MAPS)	P		90	365	400	57	200-600	28.5-90	EARTH	7200			100	0.36	1 x 1 x 0.6	200		4600	1	0.2	X	X	X	
0263	CO_2 LIDAR FOR ATMOSPHERIC MEASUREMENTS	P		96	1825	400	57	300-500	28.5-90	EARTH	3600			4,000	0.36	9 x 4.5 x 4.5	25K		250	1	0.25	X	X	X	
0264	LIDAR FACILITY	P	A	91	365	400	57	300-500	57-90	EARTH	3600			1,900	0.36	4.5 x 4.5 x 4.5	4500		253	1	0.2	X	X	X	
0265	UPPER ATMOSPHERE RESEARCH PAYLOAD-DEVELOPMENT	P		92	550	400	57	400-600	28.5-90	EARTH, SOLAR	36			2,500	0.72	4.5 x 4.5 x 2	4K (4)		500	2	0.8	X	X	X	
0266	WINDSAT		P	92	3285	800	98			EARTH	1026			2,260		4.5 x 4.5 x 4.5	200						X		
0267	UPPER ATMOSPHERE RESEARCH PAYLOAD-OPERATIONAL		P	94	1460	400	57	400-600	57-90	EARTH, SOLAR	36			2,500		4.5 x 4.5 x 2	4K (12)		500				X		INTEGRATED INSTRUMENT PKG ONLY.

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

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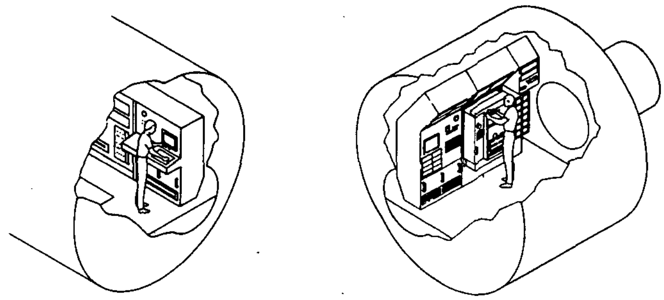
3.1.4 LIFE SCIENCES. Life Sciences missions will derive substantial benefit from a Space Station. Existing research opportunities in Spacelab are severely limited by the 7-10 day mission duration and tight budget for crew time and power. The Space Station will provide the capability for long duration missions, nominally 90 days for each crew, and continuous residency in space for animals and plants. The long mission duration allows investigation to proceed on the long term effects of microgravity, e.g., changes in bone, muscle, and blood, the long term effects of space radiation, and the effects of mission duration on human performance. These studies will be enhanced by the station's much larger budget of crew time and other resources to support a more complete investigative program with less scientific compromise and more room for contingency operations in the conduct of each experiment.

The general characteristics of this discipline are shown in Figure 3-11.

In a manned space mission, the first concern of Life Sciences is Operational Medicine. A manned Space Station will initially need to have a basic health maintenance capability and medical care equipment/supplies for routine and emergency care. Eventually, as crew size increases, additional onboard diagnostic and therapeutic capability and a dedicated health maintenance/medical clinic facility will be warranted. These capabilities will be an integral part of the station design.

- Biological science
- Operational medicine
- Life support



Characteristics
- Research labs & live specimen holding facilities in LEO
- Crew health care equipment
- Development payloads for self-sufficient life support & EVA

Potential station role
- Long-duration research —humans, animals, plants
- Food growth and air & water renewal
- Lifetime holding of plants & animals
- Measurement/improvement of crew performance — station & EVA

Driving requirements
- Man-conducted research —required time & skills
- Specimen care
- Disturbance g limits —for some plants
- Centrifuge accommodations
- Crew medical care for long duration

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Figure 3-11. Life Sciences Discipline Characteristics

Potential Space Station roles in Biological Science will include long duration research of human physiology and psychology, animal and plant physiology, and cellular and developmental biology. A broad spectrum of research into micro-gravity effects on human physiology and on basic biological systems is needed to address operational medical concerns and to elucidate basic mechanisms of adaptation to space.

The opportunity will also exist to perform zero-g verification tests of advanced Life Support Systems for H_2O reclamation, O_2 generation, N_2 generation, and CO_2 removal/reduction, and to test components of controlled ecological life support systems, such as organic waste processors and plant growth chambers for eventual onboard food production.

Life Sciences is divided into the three subdisciplines of Biological Science, Operational Medicine, and Life Support. These are each in turn organized into several experiment groups as illustrated in Figure 3-12. This figure summarizes physical accommodation and resource requirements for each of the Life Science experiment groups.

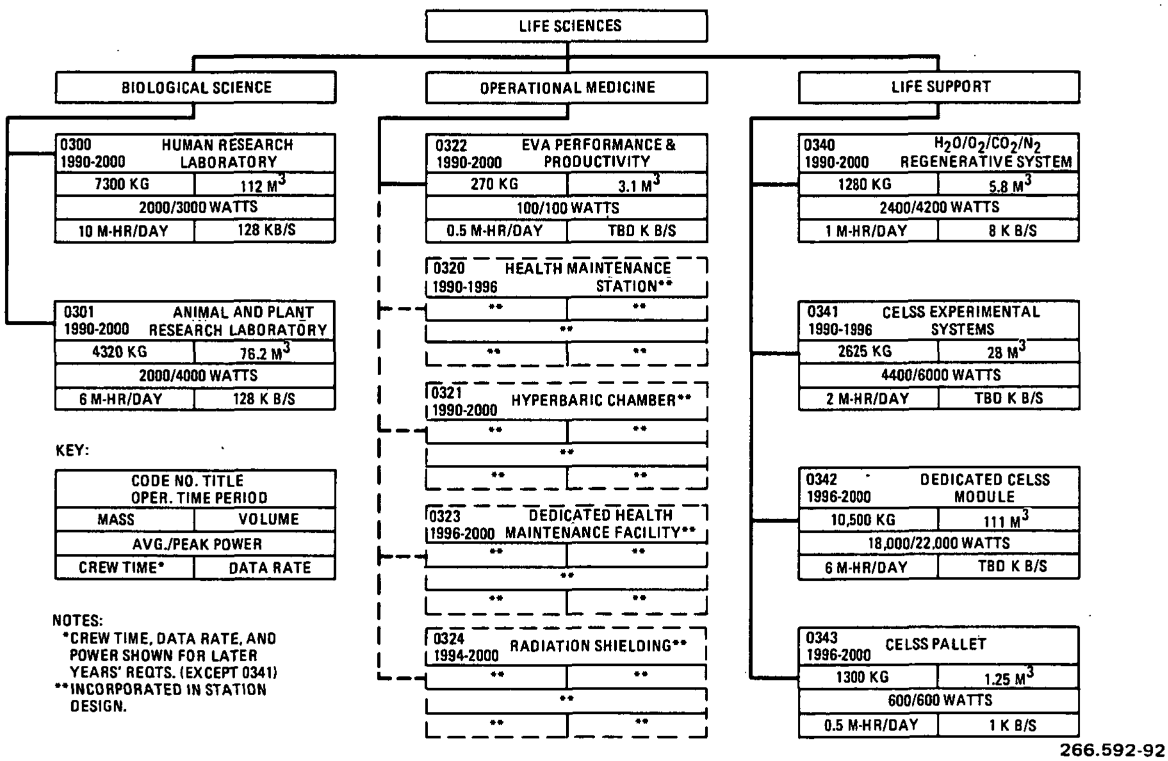

Figure 3-12. Space Station Era Life Sciences Payloads

3.1.4.1 Biological Science. The Biological Science subdiscipline comprises laboratory facilities for human research, and plant and animal research. A laboratory facility approach was taken to define life science payload elements. The two facilities provide a capability for conducting a myriad of experiments. Typical experiments have been identified and mission requirements derived accordingly, but no attempt was made to prepare payload element descriptions for each potential life science experiment as these are volatile over time. The Human Research Laboratory, 0300, will begin operation with basic capabilities at Station IOC. It will be improved with sequential buildup of capabilities during the decade as new and follow-on experiments are added and old equipment is replaced. Human research will span the areas of bone mineral and muscle metabolism, hematology, immunology, radiation effects, cardiovascular and pulmonary physiology, endocrinology, neurovestibular physiology, human performance, and medical care technology. The scope of experiments supported by the Human Research Laboratory is shown in Figure 3-13.

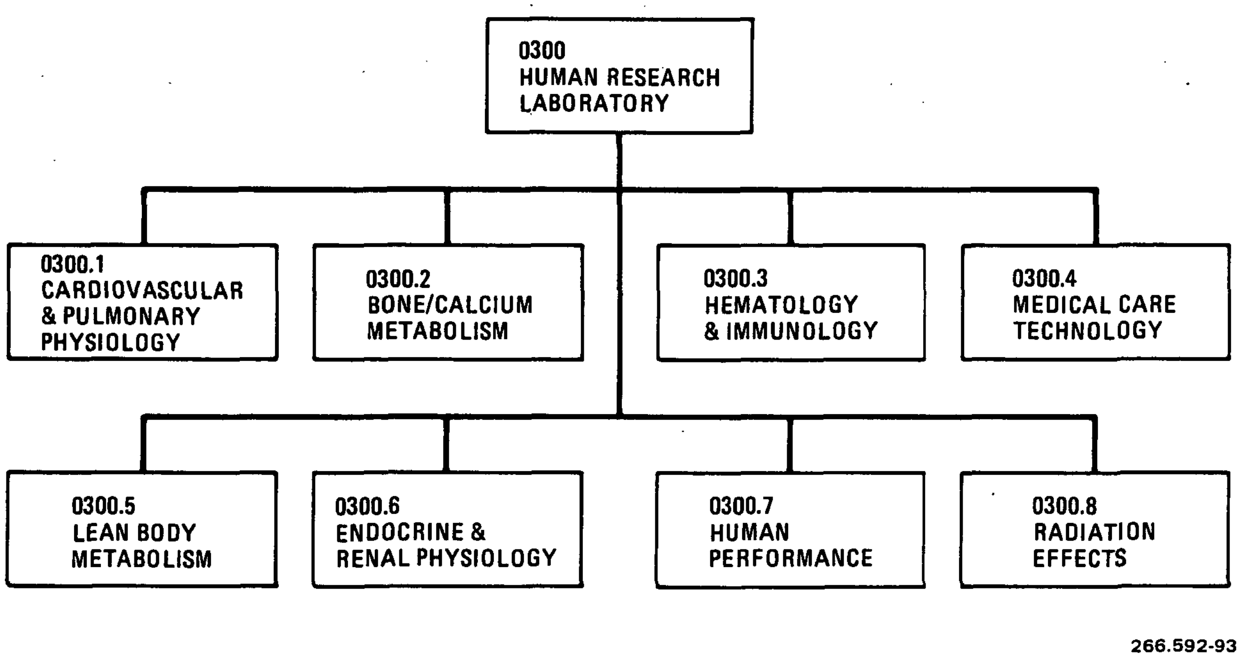

Figure 3-13. Human Research Experiment Activities

A dedicated Animal and Plant Research Laboratory, 0301, is planned starting in 1990 to provide an environmentally isolated home for animals (rats, mice, small primates) and plants, including a 1-g centrifuge for plants and small animals. The facility contains a work station for animal/plant manipulation, and instrumentation for monitoring/analysis. In later years, the animal facilities would be upgraded to accommodate larger primates. Figure 3-14 shows the research areas supported by the Animal and Plant Research Laboratory.

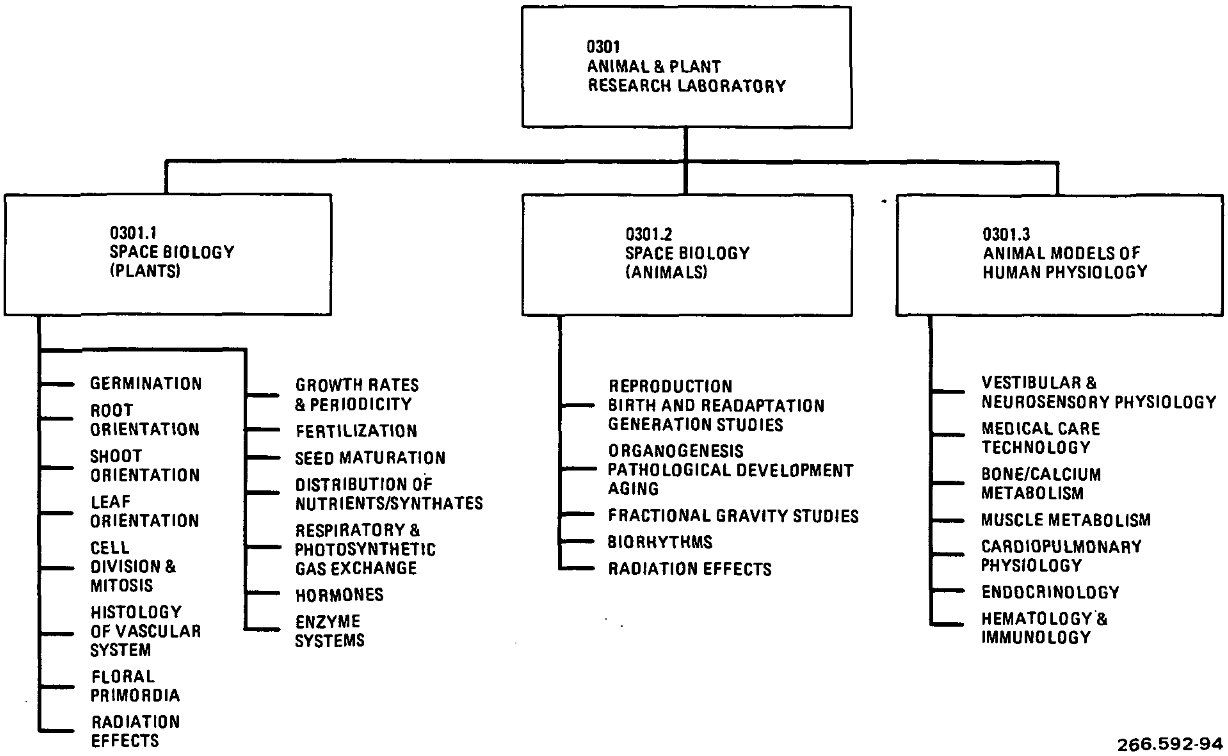

Figure 3-14. Animal and Plant Research Activities

3.1.4.2 Operational Medicine. Medical facilities for the crew will initially consist of the Shuttle Orbiter Medical System permitting on-board care of simple illnesses and injuries, means to stabilize serious medical conditions until return to Earth, and health maintenance capability providing for exercise, e.g., treadmill, and simple biomedical monitoring (heart rate, ECG). Early years upgrades will include items such as automated clinical biochemistry, microbiology, and medical imaging systems and rehydratable IV fluids capability. An extensive EVA workload is anticipated, thus increasing the chances for anomalies causing decompression sickness. Therefore, a hyperbaric chamber capable of providing 3 atmospheres pressure will be part of the initial Space Station. Regarding radiation shielding, the anticipated 1 gm/cm^2 aluminum wall density will provide adequate protection for the 28-1/2-degree LEO station. Radiation protection considerations for higher inclinations and orbits are addressed in Section 3.2.6.1.1.3, Book 2, Volume II.

In later years, a dedicated medical clinic is included to treat serious medical conditions in orbit. This clinic consists of rack, floor, and wall mounted equipment and supplies in a separate area, about 15 m^3 of a habitability module. It includes provision for bioisolation, quarantine and support of one crewman, creation of a sterile field for surgery, and two-way video communication (station/earth). This facility contains and exceeds all capabilities of the initial health maintenance station, including a more diversified exercise capability with about 10 different cardiovascular stress and coordination exercise devices.

The Operational Medicine subdiscipline is subdivided into five activity areas as shown in Figure 3-12. Of the five, the EVA Performance and Productivity mission, 0322, is classified as an experimental area. The other four missions are classified as Operations and are included in the Space Station subsystems design. Their accommodations requirements are discussed in Section 3.2.6.1.10, Book 2, Volume II.

3.1.4.3 Life Support. Station resources are required for zero-g verification tests of new life support systems components. Physical/chemical processes for H_2O reclamation, O_2 generation, CO_2 removal/reduction, N_2 generation, and trace contaminant removal, and biological processes for food and wastes will be tested starting in the early years, and new modules incorporated into the Station's operational systems in later years. Controlled Ecological Life Support Systems (CELSS) will grow food and process spent consumables for recycling into the food chain, as well as producing some air and water, appreciably reducing the need to import life sustaining supplies from Earth.

The Life Sciences mission model is shown in Figure 3-15. The Human Research, and Animal and Plant Research Laboratories will be in use throughout the decade, with periodic updating of equipment and capabilities. Experiments to develop new EVA tools and equipment, and testing of new regenerative life support system equipment will also span the decade.

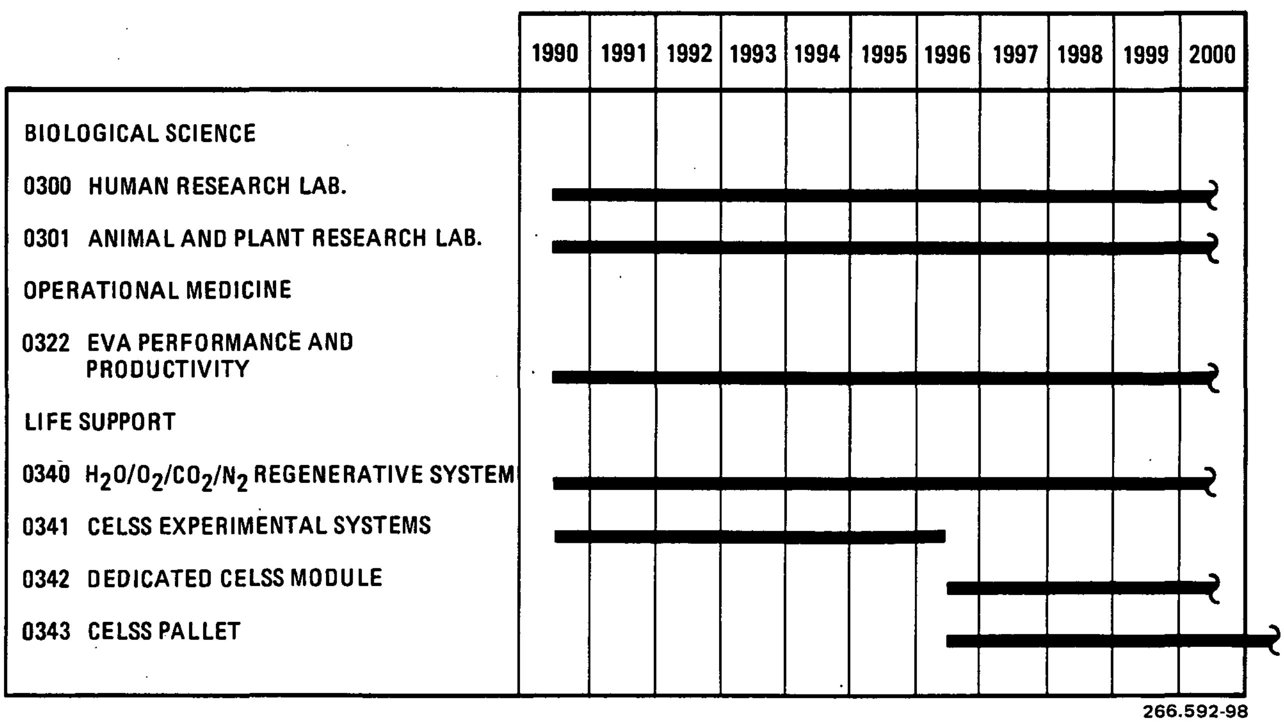

Figure 3-15. Life Sciences Time Phasing

Developmental work on closed environmental life support system hardware will be carried on through 1996, at which time an experimental CELSS subsystem capable of supporting four persons will be put into use for evaluation under realistic operational conditions.

Table 3-8 lists a summary of mission requirements for the Life Sciences discipline, excluding the four areas classified as Operations. Orbit altitude and inclination are not critical, so long as atmospheric drag-induced acceleration does not exceed 5×10^{-5} g.

The Human Research, and Animal and Plant Research Laboratories together are about equivalent to two Spacelab-type long modules. The power levels specified are for the experimental equipment only, and do not include the normal housekeeping functions.

The spectrum of Life Sciences and Life Support Development mission requirements defined by the European Life Sciences community have been reviewed and have been found to be very similar to the requirements defined for the planned U.S. program, with the addition of the ESA SLED for vestibular research. The range of mass, volume, power, crew size, etc., shown in Table 3-8 completely envelopes the requirements defined by ESA, and permits accommodation of specific items such as SLED, Anthrorack, and Botany Facility. (Refer to Dornier Report TN-SSS-DS-005, "Life Sciences and Life Support Development Experiment on a Space Station," 16 February 1982.)

3.1.5 MATERIALS PROCESSING. Materials Processing mission requirements are expressed in terms of an evolutionary complement of facilities that will be accommodated/supported by the Space Station. Figure 3-16 illustrates the total scope of projected 1990-2000 era Materials Processing activities, including both the Science and Applications and Commercial realms.

General purpose research facilities will be required from the outset, which will provide a continuation of Spacelab Materials Processing in Space (MPS) research capabilities for academic and industrial users. The initial facility (0400) will provide small scale experiment capabilities in all materials science areas and also fluid physics experiment capabilities. Analysis of the properties of the materials produced will be primarily ground-based. The research facility capabilities will expand with time to enable the production of larger and/or more complex products and will include equipment for some types of on-orbit analysis of material properties (0401).

When high potential for economically viable processes has been developed, specialized facilities for pilot production plants (1200, 1201, 1202) will be required to further develop equipment and to optimize the processes. Those processes/products that are proven in this phase will advance to full scale commercial production in dedicated facilities (1203, 1204, 1205).

Table 3-8. Payload Requirements Summary Data - Life Sciences

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE*		MISSION REQUIREMENTS										PHYSICAL			RESOURCES								COMMENTS
				LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT				VIEWING DIRECTION	POINTING		OPER ACCEL LIMIT (g)	MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L × W × H (m)	POWER LEVEL, W (DUR, HR/DAY)		DATA K BPS (HR/DAY)	CREW			SVC REQ'D X	RE-CONFIG REQ'D X	
						PREFERRED		ACCEPTABLE RANGE																	
		ATT	FF			ALT (km)	INCL (deg)	ALT (km)	INCL (deg)		ACCY (sec)	JIT-TER (sec/s)					OPER	PEAK		SIZE	TIME (AVG) HR/DAY	EVA REQ'D X			
	<u>BIOLOGICAL SCIENCE</u>																								
0300	HUMAN RESEARCH LAB	P		90	3600	ANY	ANY			N/A	N/A	N/A		7,300	112	N/A	2000 (8)	3000 (1)	128	2	10		X	X	VOLUME = TOTAL MODULE
0301	ANIMAL & PLANT RESEARCH LAB	P		90	3600								10^{-3} TO 5×10^{-5}	4,320	76.2	N/A	2000 (21)	4000 (3)	128	2	6		X	X	VOLUME = TOTAL MODULE CENTRIFUGE
	<u>OPERATIONAL MEDICINE</u>																								
0322	EVA PERF. & PRODUCTIVITY	P		90	3600									270	3.1	N/A	100 (0.3)			2	0.5	X	X	X	T.V. REQ'D
	<u>LIFE SUPPORT</u>																								
0340	$H_2O/O_2/CO_2/N_2$ REGENERATIVE SYSTEMS	P		90	3650									1,280	5.8	N/A	2400 (8)	4200 (16)	8	2	1			X	
0341	CELSS EXPERIMENTAL SYSTEMS	P		90	2190									2,625	28	N/A	4400 (23)	6000 (1)		2	2		X	X	
0342	DEDICATED CELSS MODULE	P		96	1460									10,500	111	N/A	18000 (23)	22000 (1)		2	6		X	X	VOLUME = TOTAL MODULE
0343	CELSS PALLET	P		96	2190									1,300		1 × 2.5 × 0.5	600 (24)		1	2	0.5		X		

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

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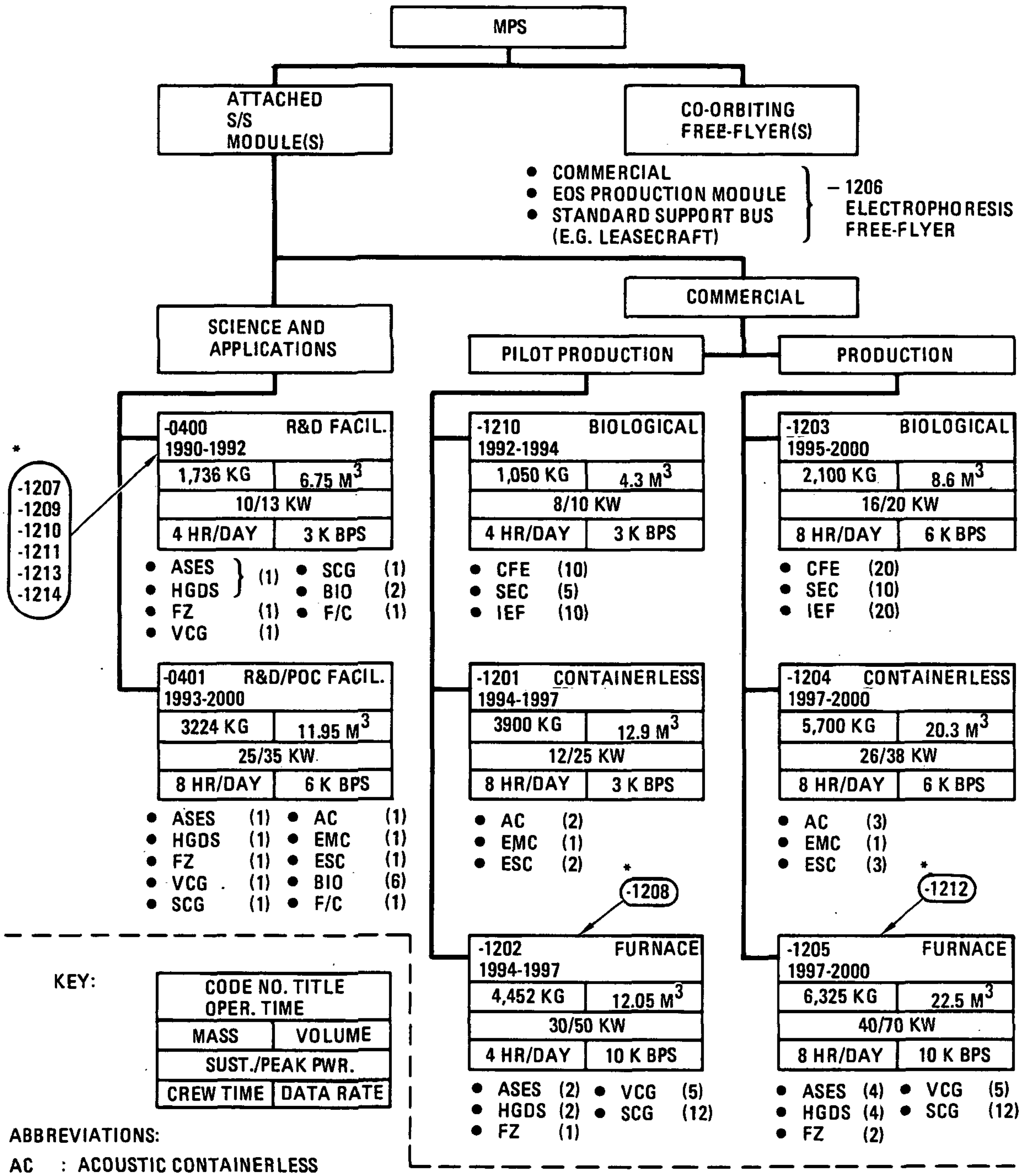

ABBREVIATIONS:

AC : ACOUSTIC CONTAINERLESS
ASES : ADVANCED SOLIDIFICATION EXPT. SYST.
BIO : BIOLOGICAL
CFE : CONTINUOUS FLOW ELECTROPHORESIS
EMC : ELECTROMAGNETIC CONTAINERLESS
ESC : ELECTROSTATIC CONTAINERLESS
FZ : FLOATING ZONE
F/C : FLUIDS/CHEMISTRY
HGDS : HIGH GRADIENT DIRECTIONAL SOLIDIFICATION
IEF : ISOELECTRIC FOCUSING
SCG : SOLUTION CRYSTAL GROWTH
SEC : STATIONARY ELECTROPHORESIS COLUMN
VCG : VAPOR CRYSTAL GROWTH
POC : PROOF OF CONCEPT
* = COMMERCIAL PAYLOADS ACCOMMODATED

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Figure 3-16. Scope of Space Station Era Materials Processing Activities

Research experiments and pilot production will be relatively labor intensive because of the high level of manned involvement in controlling test conditions and observing results. However, the production facilities will be automated for long-term production runs and man's role will be primarily for quality control, logistics, and maintenance.

The free-flying biologicals production spacecraft (1206) is currently planned to begin operation in 1986-1987 with servicing revisits by the Space Shuttle every 6 months. This servicing function could be assumed by the Space Station if economic benefits can be derived.

Throughout all phases of commercial experimentation and production, the facility arrangements, operational procedures, manning, logistics, data handling, and communications must ensure the protection of proprietary information.

For programmatic purposes, we have assumed that the two Research and Development (R&D) facilities (0040 and 0401) will be NASA-funded and will be utilized primarily by NASA-sponsored investigators for basic research. When utilized by industry for applied research, the facilities would be made available on a cost reimbursible basis.

The production facilities (1203, 1204, 1205) would be completely industry-funded, and the pilot production facilities (1200, 1201, 1202) would be jointly funded: one-third by NASA and two-thirds by industry.

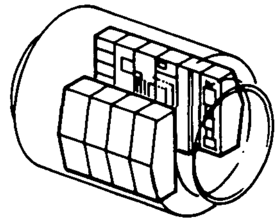
The rest of this section discusses only the materials processing research and development activities that are within the scope of OSSA. Commercial missions are discussed in Section 3.2.3.

The general characteristics of the Science and Applications Materials Processing missions are illustrated in Figure 3-17. The initial R&D facility (0400) provides four furnaces for solidification experiments, floating zone refining, and vapor and solution crystal growth; two electrophoresis columns for biologicals separation; and a chamber for fluids and chemistry experiments such as combustion, cloud physics, critical point investigations, and multiphase fluid flow and heat transfer. The four furnace experiment chambers time-share a common support equipment package to minimize payload mass, volume, power consumption, and cost. The support equipment package contains the power distribution, active cooling, control and data management, gas supplies, and vacuum venting lines.

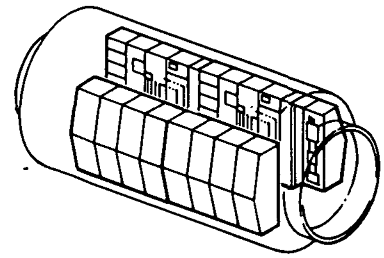
The advanced R&D/Proof-of-Concept facility (0401) adds an additional furnace for solidification experiments and three facilities for containerless processing. Also, on-orbit analysis of experiment products is expanded.

The microgravity requirements for these facilities range from 10^{-3} to 10^{-5} g for various time durations. Processing time for individual experiments can extend into the hundreds of hours and then many types of experiments require near-continuous support.

- Biologicals
- Furnace
- Containerless
- Fluids/Chemistry



Initial R&D
facilities



Advanced R&D/proof-of-
concept facilities

Characteristics

- Station-mounted equipment for R&D and proof-of-concept facilities
- General purpose facilities
- Limited on-orbit analysis capabilities

Potential station role

- Long-duration manned research activities
- Station resources

Driving requirements

- Man-conducted research
  —Required crew time
- Power levels
- Disturbance g limits

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Figure 3-17. Science and Applications Materials Processing Characteristics

All of the experimental processing facilities require vacuum vents, either for low pressure processing environments or for chamber cleaning and purging. The biological processing experiments require a vacuum vent for the freeze drying of experiment products. Special filtering means such as molecular sieves will be employed to minimize the uncontrolled escape of fluids and particulates. The controlled release of water vapor will be required and must be timelined with other Station operations.

The Science and Applications Materials Processing mission time phasing is shown in Figure 3-18. The initial Research and Development facility (0400) should be implemented at Station IOC or as soon as possible thereafter. This facility will provide vastly improved capabilities in experiment run time and power level over the Shuttle and Spacelab. The availability of these improved capabilities is a fundamental step required to encourage U.S. industry to enter into the space manufacturing field because these facilities will reduce both financial and technical risk to an acceptable level. Successful, economically viable products and processes developed in this early phase are a prerequisite for any further advancement into the space manufacturing industry. This is evidenced by the low level of commitment expressed by private industry in our user survey as well as other NASA and industry-sponsored surveys. The general purpose MPS R&D facilities must be utilized to produce useful and economical new products, or to produce enlightening information that provides great leverage in improving the value of ground-produced materials, for the MPS field to advance to a larger scale of operations.

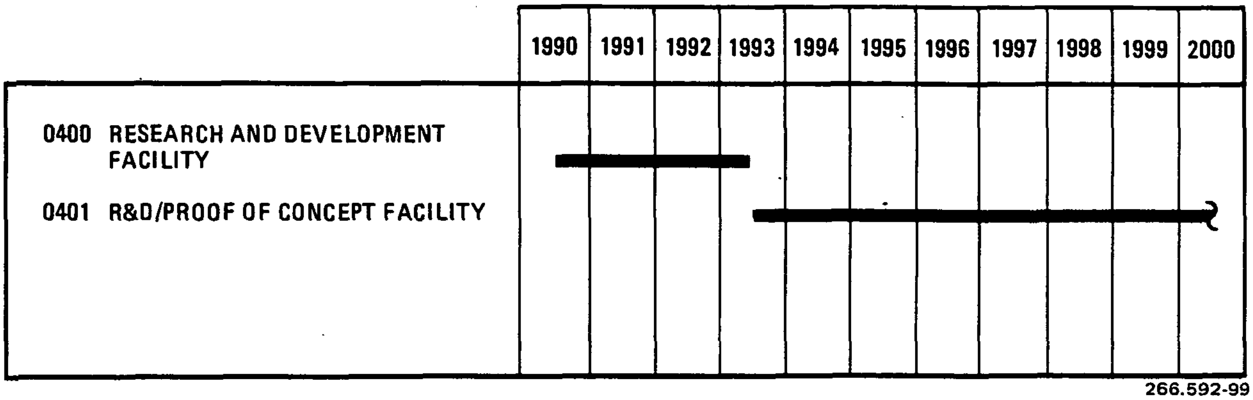

Figure 3-18. Science and Applications Materials Processing Time Phasing

The advanced R&D/Proof-of-Concept facility (0401) is shown beginning in 1993. This incremental change in research capabilities may take place in a gradual buildup commensurate with user demands. The projected MPS program schedule is success oriented and the time phasing of the introduction of expanding capabilities throughout the 1990s is assumed to occur in a logical, orderly progression as basic and applied research lead to new products and processes that reach commercial scale production as early as possible. Any impediments in this progress, such as schedule delays in basic and applied research or non-achievement of program milestones, would cause the projected schedule to stretch out to the right.

Table 3-9 lists a summary of Science and Applications Materials Processing mission requirements for the initial R&D facility (0400) and the advanced R&D/Proof-of-Concept facility (0401).

The initial facility (1990-1993) is a general purpose R&D facility for MPS research and physics and chemistry experiments in fluid behavior, chemical reactions, and combustion. Limited product analytical capabilities are included. The facility contains three sets of processing equipment packages and three corresponding support equipment packages. The facility would occupy the equivalent of about one-third of a Spacelab-type long module.

The advanced facility (1993-2000+) provides R&D capabilities in all MPS areas, and supports proof-of-concept experiments. It includes the same furnace and fluids/chemistry equipment as 0400, but expands the bioprocessing capabilities by a factor of three and adds containerless processing capabilities. Moderate product analysis capabilities are included. The facility contains four sets of processing equipment packages and four corresponding sets of support equipment packages and would occupy the equivalent of about one-half of a Spacelab-type long module.

Table 3-9. Payload Requirements Summary Data - Materials Processing

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE*		MISSION REQUIREMENTS										PHYSICAL			RESOURCES								COMMENTS
						ORBIT					POINTING						POWER			CREW					
				LAUNCH DATE YR(S)	MSN DUR (DAYS)	PREFERRED		ACCEPTABLE RANGE		VIEWING DIRECTION			OPER ACCEL LIMIT (g)	MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	LEVEL, W (DUR, HR/DAY)		DATA K BPS (HR/DAY)	SIZE	TIME (AVG) HR/DAY	EVA REQ'D X	SVC REQ'D X	RE-CONFIG REQ'D X	
		ATT	FF			ALT (km)	INCL (deg)	ALT (km)	INCL (deg)		ACCY (sec)	JIT-TER (sec/s)					OPER	PEAK							
0400	RESEARCH & DEVELOPMENT FACILITY	P		90	1095	>400	ANY			N/A	N/A	N/A	10^{-5}	1,736	6.75	N/A	10K (22)	13K (2)	3 (24)	1	4				VACUUM VENT REQ'D
0401	R & D/PROOF OF CONCEPT FACILITY	P		93	2600	-400	ANY			N/A	N/A	N/A	10^{-5}	3,224	11.95	N/A	25K (22)	35K (2)	6 (24)	1	8				

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

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For all materials processing missions, the orbit parameters are not critical so long as the atmospheric drag-induced acceleration is less than about 10^{-5} to 10^{-6} g. Operating acceleration limits specified are for the worst case experiment in each processing area; many can tolerate higher levels during experiment or processing operations. Also, some processes can be put into a standby mode if advanced warning of an unacceptable disturbance can be given.

Input power requirements for materials processing are inherently high compared to most other experiments. The fact that a Space Station can meet these high demands is one of the important attributes of the Station. Shuttle-supported MPS experiments in the 1980s are severely hampered by the 7 kW power level available in the cargo bay and 1.2 kW available within the Spacelab. The high power level available from the Space Station will be one of the factors that open the frontier to space manufacturing.

The basic data source used for the quantified descriptions of materials processing equipment and support requirements was TRW Report MPS.6-80-286, Volume II, "Materials Experiment Carrier Payloads Handbook," 30 January 1981, prepared under contract NAS8-33688 for Marshall Space Flight Center.

The results of the European Space Station Participation study of the Material Sciences and Processing disciplines were reviewed (refer to MBB/ERNO Report MSS-RP-ER-001-82, 11 February 1983). These were compared to the requirements derived by GDC for U.S. Science and Applications and commercial users. The envelope of European MPS user requirements is summarized below:

Parameter	Range of Requirements
Mission Duration	4 to 360 days
Payload Mass (single experiment)	30 to 1000 kg
Electrical Power (single experiment)	0.1 to 10 kW
Crew Time	0.5 to 8 hours per day
Gravity Level	10^{-4} to 10^{-7} g
Logistics resupply interval	3 to 12 months

These requirements are well within the range of payload element characteristics defined by GDC for the Space Station materials processing facilities, and have no impact on the integrated time-phased mission requirements that were defined.

3.2 COMMERCIAL MISSIONS

Commercial missions could be some of the most important because of their unique characteristic to provide benefits of cost sharing and potential sources of revenue to NASA through private sector involvement in the Space Station program. Thirty-six representative payload elements were developed in the four LaRC defined commercial disciplines (see Table 3-10). The missions were time phased for the 1990-2000 time period. The details of each of these payload elements are contained in Book 1, Appendix I.

Table 3-10. Commercial Missions

• COMMERCIAL DISCIPLINES & PAYLOAD ELEMENTS	No. P/L Elements	User Fact Sheets	Sub-Contract
Earth and Ocean Observations	4		
1000 Geological Reconnaissance		X	
1001 Remote Atmospheric Sensing		X	
1002 Worldwide Cotton Acreage and Production		X	
1003 Petroleum and Mineral Location		X	
Communications	11		
1100 Small Communication Satellite			X
1101 Medium Communication Satellite			X
1102 Large Communication Satellite			X
1103 Experimental Geo Platform			
1104 Operational Geo Platform			
1105 Reserved			
1106 Large Deployable Antenna			X
1107 RFI Measurements			X
1108 Laser Communications			X
1109 Open Envelope Tube			X
1110 Spaceborne Interferometer			X
1111 Millimeter Wave Propagation			X
Materials Processing	15		
1200 Pilot - Biological Processing Facility			
1201 Pilot - Containerless Processing Facility			
1202 Pilot - Furnace Processing Facility			
1203 Commercial - Biological Processing Facility			
1204 Commercial - Containerless Processing Facility			
1205 Commercial - Furnace Processing Facility			
1206 Electrophoresis Free-Flyer			
1207 Electrophoretic Separation		X	
1208 Crystal Growth		X	
1209 Metal Clusters and Crystal Growth		X	
1210 Enzyme Production and Separation		X	
1211 Silicon Crystals		X	
1212 Heat Resistant Alloys		X	
1213 Chemical Reactions		X	
1214 Space Isothermal Furnace System (SIFS)		X	

Table 3-10. Commercial Missions, Contd

o COMMERCIAL DISCIPLINES & PAYLOAD ELEMENTS	No. P/L Elements	User Fact Sheets	Sub-Contract
Industrial Services	6		
1300 Radiation Hardened Computer		X	
1301 Full-Body Teleoperator		X	
1302 Gamma Ray Astronomy		X	
1303 Plant in Controlled Env Life Support Systems*		X	
1304 Controlled Environment Life Support Systems*			
1305 Communication Satellite Service/Handling		X	
Subtotal		(17)	(9)
*From one fact sheet — Total	36		

Of the 36 listed payload elements, a subset of 17 was identified by commercial organizations (including two universities) through the mechanism of the User Fact Sheets (described in Section 2.2), while the remainder were developed by GDC and by SPACECOM as a GDC subcontractor.

The commercial organizations providing positive responses to the User Fact Sheet are identified in Table 3-11. The missions were assigned to the commercial disciplines and numbered as shown. Industrial services missions were identified as those elements that could be classed primarily as "Providers" of Space Station resources as differentiated from potential users. The commercial payload elements defined in the User Fact Sheets were assessed for compatibility with other representative payload elements. The assessment revealed that, except for two discussed in Section 3.2.4, all of the payload elements so defined could be accommodated by payload elements in related Science and Applications or Technology Development subdisciplines and by commercial Materials Processing payload elements. This assessment tends to validate the adequacy of the representative mission requirements set in reflecting the requirements of potential Space Station users.

Not all firms who responded provided specifics on potential commercial missions. The defined missions cover a range from research-type such as chemical reaction effects in microgravity to MPS production and monitoring the earth's atmosphere for pollution. Johnson and Johnson indicated their well-known efforts in electrophoresis but declined to provide detailed information because of their affiliation with McDonnell Douglas. Because the Johnson and Johnson payload elements is an important space mission, it is identified as a payload in the mission set but is not counted as a positive response because no specific data were provided.

Table 3-11. Positive Commercial Fact Sheet Responses

Item	GDCD No.	Data Source	Payload Element	Commercial Discipline	Similar Accommodation* GDCD No./Category
1	1000	Mobil	Geological Reconnaissance	Earth & Ocean Obs	0174/0175 S&A - Earth Exploration
2	1001	S. Calif. Edison	Pollutant Mapping	Earth & Ocean Obs	0262/0206 S&A - Environ Observations
3	1002	Cotton Industries	Cotton Acreage and Production	Earth & Ocean Obs	0172 S&A - Earth Exploration
4	1003	Amoco Production Co.	Petroleum & Mineral Location	Earth & Ocean Obs	0172 S&A - Earth Exploration
5	1207	U. of Arizona	Electrophoretic Separation	Mtls Processing	0400/S&A - Mtls Processing
6	1208	Microgravity Research Associates	Crystal Growth	Mtls Processing	1202/Commercial - Mtls Processing
7	1209	3M	Metal Clusters and Crystal	Mtls Processing	0400/S&A - Mtls Processing
8	1210	A. E. Staley	Enzyme Production of Separation	Mtls Processing	0400/S&A - Mtls Processing
9	1211	Monsanto	Silicon Crystals	Mtls Processing	0400/S&A - Mtls Processing
10	1212	INCO	Heat Resistant Alloys	Mtls Processing	1205/Commercial - Mtls Processing
11	1213	E. I. duPont	Chemical Reactions	Mtls Processing	0400/S&A Mtls Processing
12	1214	GTI	Space Isothermal Furnace	Mtls Processing	0400/S&A Mtls Processing
13	1300	Control Data	Radiation Hardened Computer	Industrial Services	-

Table 3-11. Positive Commercial Fact Sheet Responses, Contd

Item	GDCD No.	Data Source	Payload Element	Commercial Discipline	Similar Accommodation* GDCD No./Category
14	1301	Glob Enterprises	Full-Body Teleoperator	Industrial Services	-
15	1302	Bell Labs	Gamma Ray Astronomy	Industrial Services	0030/S&A - Astrophysics
16	1303	Texas A&M	Plants in CELSS	Industrial Services	0341/S&A - Life Science
	1304	Texas A&M	CELSS	Industrial Services	0342/S&A - Life Science/ Technology
17	1305	RCA	Comm Satellite Service/Handling	Industrial Services	2504, 2505/ Technology Space Sta Syst & Opns 1106/Commercial - Communications

*S&A = Science and Applications

(Note: Does not include Johnson & Johnson due to affiliation with MDAC)

The industry responses to economic factors inquiries in the Fact Sheets are particularly important and are unique to commercial missions. They are summarized in Figure 3-19 for the 18 Fact Sheet questions. Perhaps the most significant response (Figure 3-19) was the broad interest expressed in potential for entering into JEAs with NASA. The responding firms estimated investment horizon for Space Station related ventures are principally in the range up to 10 years. Risk associated with such ventures is characterized as fairly great. Estimated investment potential varied widely; however, some firms showed significant expectations.

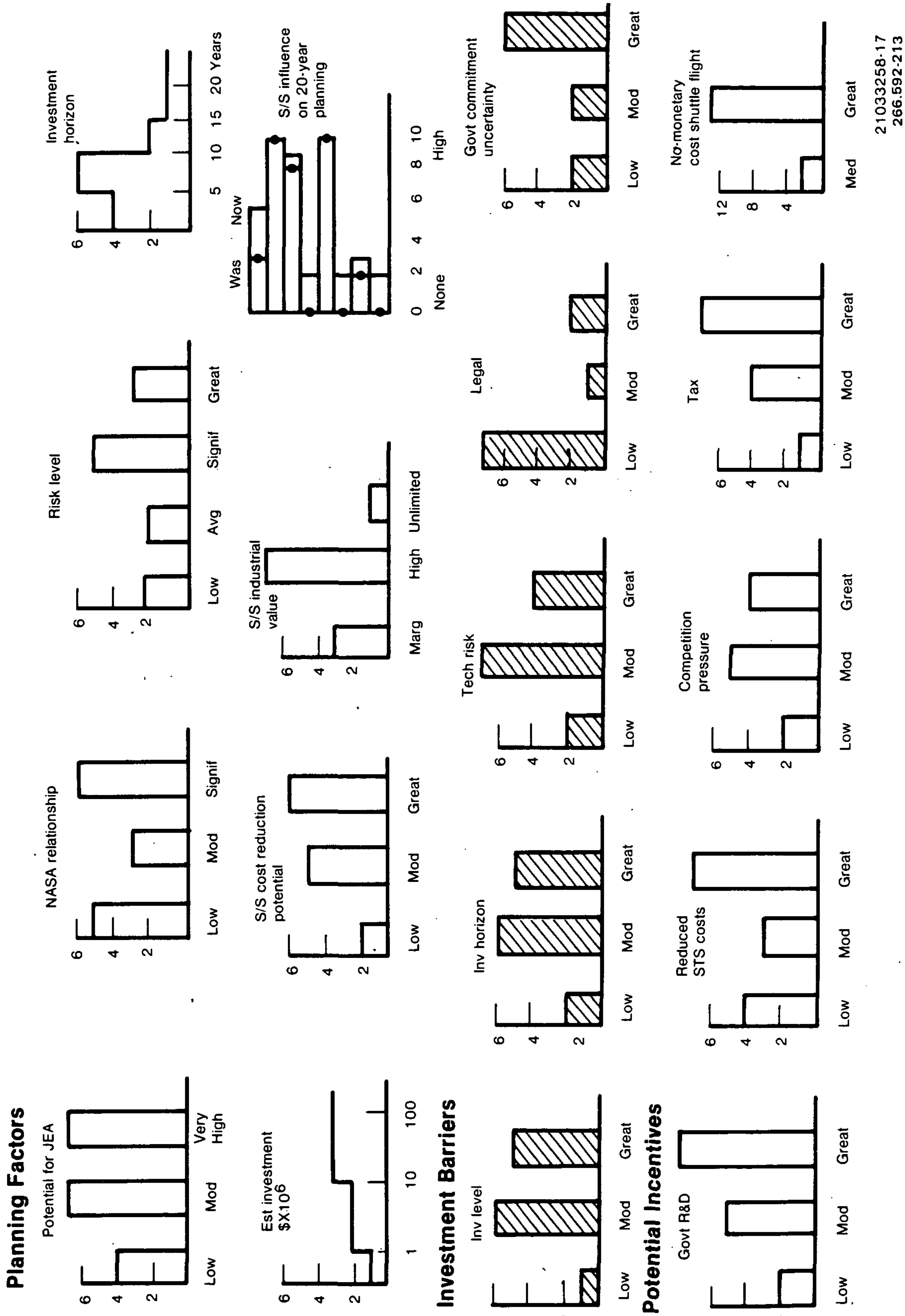

Figure 3-19. Commercial User Fact Sheet Responses

The most significant investment barriers identified are investment levels, investment horizons, and industrial firms' perception of uncertainty in the government commitment to the Space Station. Factors such as these reflect the concerns of potential commercial users and must be addressed in developing user involvement.

Overwhelmingly, the non-monetary cost of Shuttle flights was the most important investment incentive identified. Government-sponsored R&D was identified as an important investment incentive for potential commercial users, as well as tax incentives and reduced overall STS costs.

Of interest were the responses to the question, to what degree has the possible availability of a manned Space Station influenced the company's planning for the next 20 years. The answers were heavily "no or low influence." The second question asked how this would change after receiving our User Brochure. The indications were generally a moderate increase in influence.

Although the sample is small, these responses were from firms who had sufficient interest to fill out and return part or all of our User Fact Sheets.

Initially, there was concern about the potentially proprietary nature of user space operations. Therefore, a question was asked if sharing of a general purpose facility would be an acceptable accommodation considering proprietary processes, security, etc. Except for one, potential users responding to this question indicated maybe or yes as a response.

Conclusions that may be drawn from an overview of the commercial discipline missions are summarized in Figure 3-20. The data is very positive from the communications satellite sector. There are strong signs of interest in MPS and more limited in the earth/ocean observations sectors and for "Providers" of Space Station industrial services. We feel that although present planning is somewhat inhibited by the perceived barriers, a stronger reason for the limited interests may be due to the basic nature of businesses. For example, if one had conducted a similar study in 1885 or even 1903 about the planned uses for the new transportation system called airplanes, a similar result would have been obtained.

The potential market exists and can be developed, but it will take additional time and innovative approaches that address the unique needs of the users and their perceived barriers to involvement. Furthermore, once a Space Station is in being, the activities therein will generate uses and users that are not or cannot be foreseen at this time.

3.2.1 COMMERCIAL EARTH AND OCEAN OBSERVATIONS MISSIONS. Business opportunities for use of a Space Station to provide earth and ocean observations data are expected to occur in four basic categories:

- Geological surveys and petroleum exploration
- Earth Resource Management for Agriculture and Forestry
- Ocean Resource Management
- Atmospheric Monitoring, e.g., pollution

COMMERCIAL SATELLITE PLACEMENT MARKET EXISTS
- OTV AN ECONOMIC ALTERNATIVE TO CURRENT LAUNCH SYSTEMS

COMMERCIAL COMMUNICATIONS SATELLITE DEPLOYMENT AND STORAGE ARE VIABLE SS SUPPORT OPERATIONS

MPS & EARTH OBSERVATION MARKETS EXIST BUT NEED DEVELOPMENT
- PLANNING SOMEWHAT INHIBITED BY PERCEIVED BARRIERS
  - RELATIVELY LONG ROI HORIZONS
  - SPACE STATION SOME DISTANCE IN FUTURE
  - SPACE OPERATIONS ARE COSTLY

INTEREST IN SPACE STATION INDUSTRIAL SERVICE "PROVIDERS" EXISTS

MARKET POTENTIAL & INTERESTS EXIST
- ADDITIONAL TIME & DETAILED DISCUSSIONS REQUIRED TO EXPAND BEYOND CURRENTLY IDENTIFIED LEVEL
- AN IN-PLACE FACILITY WILL GENERATE USES THAT MAY NOT SURFACE DURING ADVANCED APPRAISALS

SPECIAL INCENTIVES MAY BE REQUIRED TO INDUCE COMMERCIAL FIRMS TO INCREASE RESEARCH INVESTMENTS
- REDUCE STS COSTS, TAX INCENTIVES, NO-MONETARY COST SHUTTLE FLIGHTS

266.592-245

Figure 3-20. Commercial Applications - Conclusions

These in turn are supported by missions such as instrument development, surveys and data collection, and monitoring and reporting conditions.

In making contacts within the business community, GDC found firms who expressed specific interest in three areas: petroleum and mineral exploration, cotton acreage and production, and pollution monitoring. These missions are time phased in Figure 3-21 to consider both the user desires and the planned schedule for the similar missions that accommodate them.

All of these missions are accommodated by free flyers, operating in LEO and HEO orbits and in geosynchronous orbit.

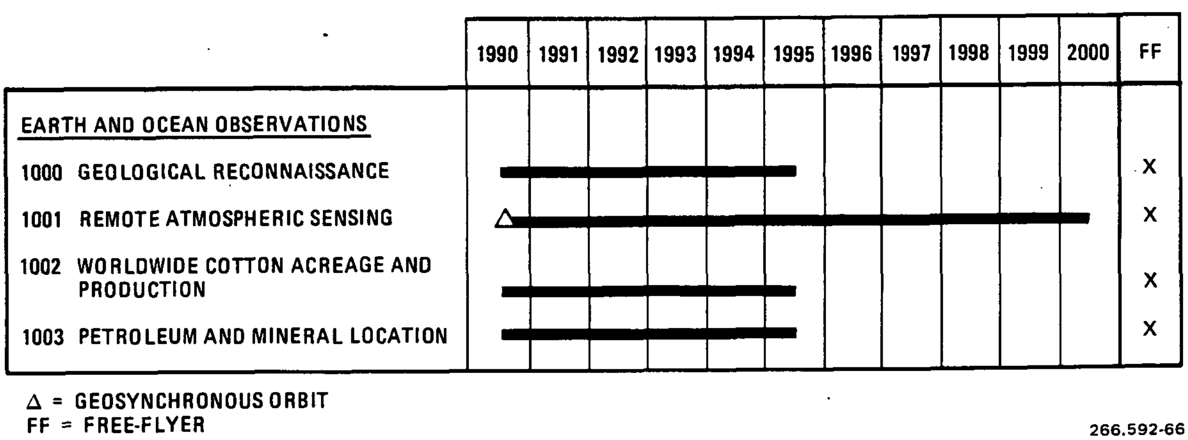

Figure 3-21. Earth and Ocean Observations Time Phasing

The requirements for commercial Earth and Ocean Observations missions are summarized in Table 3-12. The weights and power levels shown reflect estimates of typical ranges as identified by the user; however, they should not be considered additive to the referenced mission weights because the referenced accommodation provides an adequate instrument complement to accomplish the identified objectives. The remote atmospheric sensing mission (1001) requires real-time pollution monitoring to optimize adjustment of loads for all the facilities owned by the power utility company. Operationally a payload element such as GOES Follow-On (0206) could provide the required capabilities. Instrument development to support the operational mission could be accommodated by a low earth orbit, man-operated payload, such as Measurement of Air Pollution from Satellites (MAPS), 0261. Sufficient schedule time between missions is provided for development feedback.

Economic factors for commercial Earth and Ocean Observations (Figure 3-22) generally followed the trends of the other commercial payload elements described in Section 3.2. For this subset, however, all of the respondents perceived an investment level barrier.

3.2.2 COMMERCIAL COMMUNICATIONS MISSIONS. The communications discipline includes two separate and distinct mission roles as shown in Figure 3-23. 1) the Space Station/OTV support of communication satellites and platforms for boost to GEO, and 2) the technology development that will be performed at the Space Station for advanced communications technology.

Conclusions reached from the SPACECOM analysis of historical trends in spacecraft reliability, failure data, and the spacecraft insurance industry shows that a Space Station in a low earth orbit will provide a positive impact on two areas of the communication satellite industry.

The primary benefit derived from a manned Space Station will be the ability to deploy and test a satellite after it has been launched from earth and before being placed into a geosynchronous orbit. The financial impact will manifest itself in insurance savings, pre-launch testing, hardware redundancy considerations, and many other areas designed to ensure launch survival and appendage deployment. The scope of spacecraft insurance coverage is outlined in Table 3-13. Communications satellites are typically insured against revenue loss from operating failure, at a premium cost of about 1-2% of stated value per year. For a 24-channel satellite that rents for $6-8 million per month, the insurance premium could be as high as $120-160 thousand per month, or $1.4-1.9 million per year.

Table 3-12. Payload Requirements Summary Data - Earth and Ocean Observations

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE* ATT	ACCOM MODE* FF	MISSION REQUIREMENTS: LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT PREFERRED ALT (km)	ORBIT PREFERRED INCL (deg)	ORBIT ACCEPTABLE RANGE ALT (km)	ORBIT ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING ACCY (sec)	POINTING JITTER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL: MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	RESOURCES: POWER LEVEL, W (DUR, HR/DAY) OPER	POWER PEAK	DATA K BPS (HR/DAY)	CREW SIZE	CREW TIME (AVG) HR/DAY	CREW EVA REQ'D X	SVC REQ'D X	RE-CONFIG REQ'D X	COMMENTS
1000	GEOLOGICAL RECONNAISSANCE		P	90	1825	500	90	300–600	80–100	EARTH	<1.0		N/A	[300-1000]											REF. 0172, 0174, 0175
1001	REMOTE ATMOSPHERIC SENSING		P	90	3650	GEO	0							[300-1000]			[500-1000]								REF. 0262, 0206
1002	WORLDWIDE COTTON ACERAGE AND PRODUCTION		P	90	1825	500	45	500-1000	45-90																REF. 0172
1003	PETROLEUM AND MINERAL LOCATION		P	90	1825	920	99.2	880–930	99-99.9		0.1			[30]											REF. 0172

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

[ ] = ACCOMMODATED BY REFERENCED PAYLOAD ELEMENT(S)

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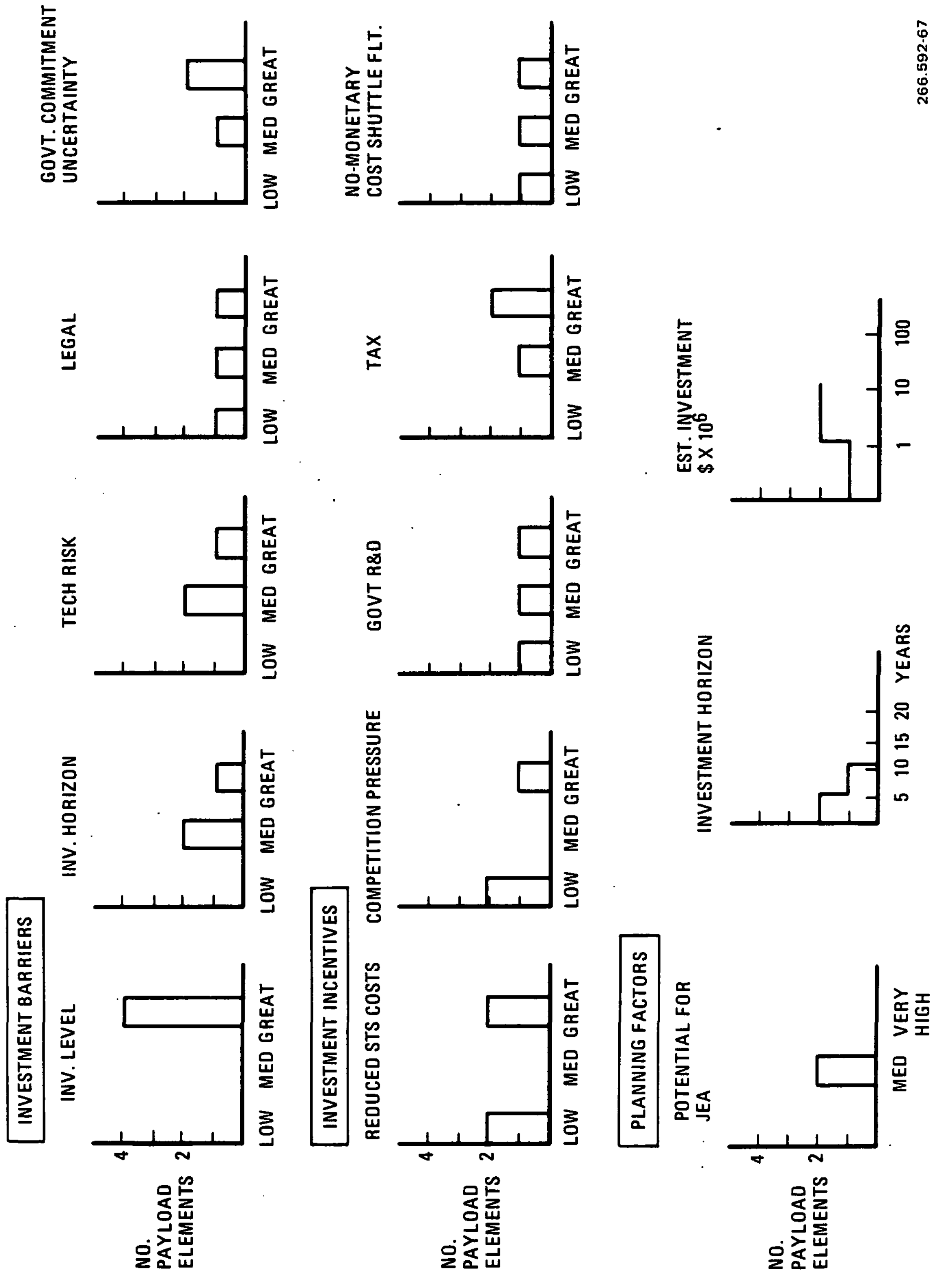

Figure 3-22. Economic Factors - Commercial, Earth and Ocean Observations

Characteristics

- Operational satellites & platforms at GEO
- Advanced communications technology development in LEO

Potential station role

- OTV basing for delivery to GEO
- LEO assembly & checkout/repair
- Servicing — Retrieval to LEO
  — In-situ by OTV
- Manned development of station-attached advanced systems

Driving requirements

- Operating orbit — OTV base for boost to GEO
- Size

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Figure 3-23. Communications Discipline Characteristics

The second impact area is derived from the ability to store comsats in space, in a protected environment versus on-orbit storage where no environmental protection is afforded. This benefit will enhance spacecraft life expectancy and improve the ability of a common carrier to provide backup capacity in the event of failure. After analyses of technology (present and projected), satellite communication economics, communications demand, and outage impact on subscribers, SPACECOM determined that there is no reason either in the present or in the future to invest in comsat repair or consumables replenishment.

Communications traffic to GEO represents an existing and growing potential for Space Station operation as an OTV base. Shuttle delivered satellites can be grouped on an OTV without separate boost stages for GEO deployment. Future large satellites can be assembled, checked out, and repaired at the Space Station. Eventually, multiple modules and antennas can be assembled at LEO and boosted to GEO at low (0.1 - 0.2) g levels.

Table 3-13. Spacecraft Insurance Coverages

Prelaunch Coverage

- All risk physical damage during manufacture, transit, and launch site assembly
- Terminates at launch vehicle ignition

Launch Coverage

- Begins at launch and terminates 180 days later
- Coverage includes costs of:
  - -- Replacement spacecraft
  - -- Re-launch services
  - -- Delay expenses

"Life" Insurance

- Begins 181st day and terminates 3 years after launch
- Covers costs of:
  - -- Replacement S/C
  - -- Re-launch services
  - -- Delay expenses
  - -- Partial loss of S/C subsystems

Liability Coverage

- Extends from launch to end of satellite in-orbit life
- Covers all 3rd party claims

Transmission Interruption Insurance

- Covers users of satellite capacity against losses incurred due to partial or total S/C capacity

Ground Support Coverage

- All risk property damage and business interruption on both transmit and receive earth stations, transmission toners, and headquarters

Small, medium, and large communications satellites, Payload Elements 1100, 1101, and 1102, respectively, will be launched continuously over the period of 1990 through 2000 and beyond. Upper stages and the OTV, when available, will be used in the boost of these satellites to GEO. Therefore, the 1990-2000 era comsats are defined without apogee kick motors. The traffic model for missions was developed by SPACECOM and includes 81 small satellites, 40 medium satellites, and 114 large satellites. The model is based on the factors identified in Table 3-14 and analyses of the source documents shown in Table 3-15.

Table 3-14. Basis of Launch Predictions

- Planned launches based on FCC filings
- Historical trends with modest growth for a high or nominal mission model and no-growth or reduction of present trends for a low mission model
- Technological projections - new technologies introduced to the marketplace often stimulate a high rate of growth over one to three decades
- Military satellite forecasts are driven by increases or decreases in budgetary trends of military space spending
- Projections of worldwide satellite communications demand
- Projections of future GNP and population growth in the countries or world regions under study
- Demand projections for new services such as teleconferencing, direct broadcast, electronic mail, mobile communications, etc.
- NASA studies
- Increasing life and reliability of communications satellites reduces replacement launches
- Future demographics and international political factors

Table 3-15. Communications Satellites Traffic Model Reference Sources

1. Space Station Study, Commercial Communications Satellites, SPACECOM, Feb. 83, (GDC subcontract)
2. Task II Report Planning Assistance for the 30/20 GHz Program - Worldwide Market Demand Forecast, Western Union Report Sponsored by NASA, June 1981
3. STS Mission Model 1983-2000, Advanced Planning Division, NASA Headquarters, Dec. 10, 1982
4. Mission Requirements and Network Support Forecast, (STDN No. 803), Goddard Space Flight Center, Dec/Jan 1982/1983
5. The Satellite Communications Market in North America, 1982-1991, Frost and Sullivan, July 1981
6. The Market, SPACECOM Study, 4-5/1982 Presentation
7. Space Operations Center Systems Analysis Study Extension, Final Report, Volume I Executive Summary, By Boeing Aerospace, January 1982.
8. Growth and Status of Commercial Communications Satellites, NASA/LeRC, Oct. 15, 1982
9. A 25-Year Forecast for Commercial COMSATS and the Congestion of the Geostationary Arc, Future Systems Inc., Nov. 1977
10. Future of Communications Satellites, STS Users Conference, Sept. 1982, By Goddard Space Flight Center
11. National Space Outlook, National Space Club, June 22-23, 1982
12. Nominal Mission Model, Rev. 6, PS01 MSFC, 30 Sept. 1982

The method used to estimate commercial communication satellite traffic is documented in Reference 1. References 2-11 contain projections made in various studies and were used as primary sources. The results of seven principal traffic projections were compared (Figure 3-24) and found to have considerable variation. However, there is also considerable overlap in these projections. Next, a comparison was made of the average of the projections, the maximum and the minimum curves (Figure 3-25). Because not all of these data distinguished between satellite sizes, a second analysis was made using a subset of three projections that did make this distinction (Table 3-16) and an average calculated for each size. When the total traffic of the two analyses is compared on a year-by-year basis, very close agreement is found. The results of the second analysis became our traffic model (Figure 3-26) because of greater information content. Reference 12 of Table 3-15 was used in conjunction with internal analyses to validate satellite weights. Lengths were derived based on a modest improvement in density from current satellites. A more optimum packaging design could be forecast, which would reduce transportation costs.

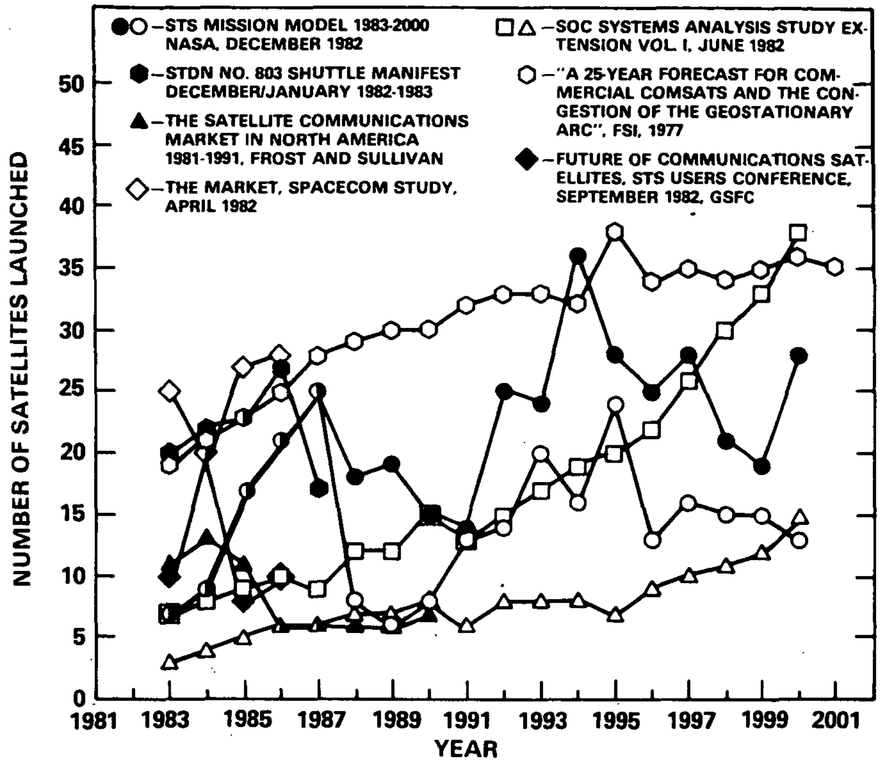

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Figure 3-24. Geosynchronous Launches Reference Summary

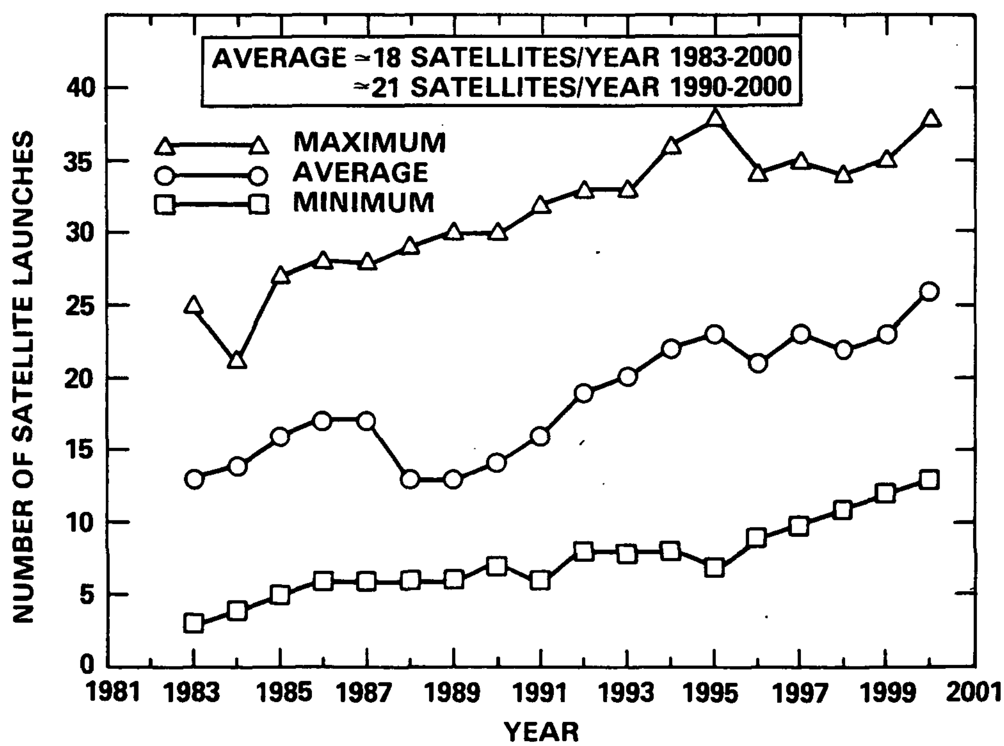

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Figure 3-25. Total Geosynchronous Launches

Table 3-16. Satellite Launch Prediction by Mass

YEAR	MODEL A			MODEL B			MODEL C			AVG.		
	SMALL	MEDIUM	LARGE	SMALL	MEDIUM	LARGE	SMALL	MEDIUM	LARGE	SMALL	MEDIUM	LARGE
81	—	—	—	5/3*	0	0	—	—	—	4	0	0
82	9	8	0	3/2	0	0	—	—	—	5	4	0
83	10	8	1	5/2	2/1	0	5	0	2	5.5	3	1
84	10	9	2	5/3	3/1	0	7	0	2	6	3	1
85	14	8	1	5/3	3/2	1	17	0	0	10	3	1
86	9	12	4	4/4	4/2	2/0	17	2	2	8.5	5	2
87	12	10	6	0/3	4/3	5/0	21	4	0	9	5	2
88	11	12	6	0/4	3/3	9/0	12/7	3/0	3/1	7	4	4
89	14	10	6	0/3	0/3	12/1	10/6	5/0	4/0	7	4	6
90	11	12	7	0/2	0/5	15/1	10/5	3/2	2/1	6	4	5
91	11	12	9	0	0/5	13/1	9/9	3/1	2/3	6	4	6
92	10	13	10	0	0/5	15/3	20/10	3/2	2/2	8	6	6
93	13	11	9	0	0/5	17/3	22/13	1/4	1/3	10	4	7
94	11	10	11	0	0/1	19/7	26/14	0	10/2	10	3	10
95	11	16	11	0	0	20/7	17/21	3/0	8/3	10	4	10
96	8	13	13	0	0	22/9	12/6	3/0	10/7	5	3	12
97	9	13	13	0	0	26/10	17/11	0	11/5	7	3	13
98	11	11	12	0	0	30/11	12/9	0	9/6	6	3	14
99	8	13	14	0	0	33/12	14/10	0	5/6	6	3	14
00	6	13	17	0	0	38/15	17/10	0	11/3	7	3	17
01	8	13	14	—	—	—	—	—	—	8	13	14
02	7	12	18	—	—	—	—	—	—	7	12	18

SMALL UP TO 1800 lbs. (RCA SATCOM/HUGHES 376 CLASS)
MEDIUM 1900-4500 lbs. (FORD INTELSAT V CLASS)
LARGE 5100 lbs.+ (TDRSS CLASS)

*HIGH/LOW MODEL

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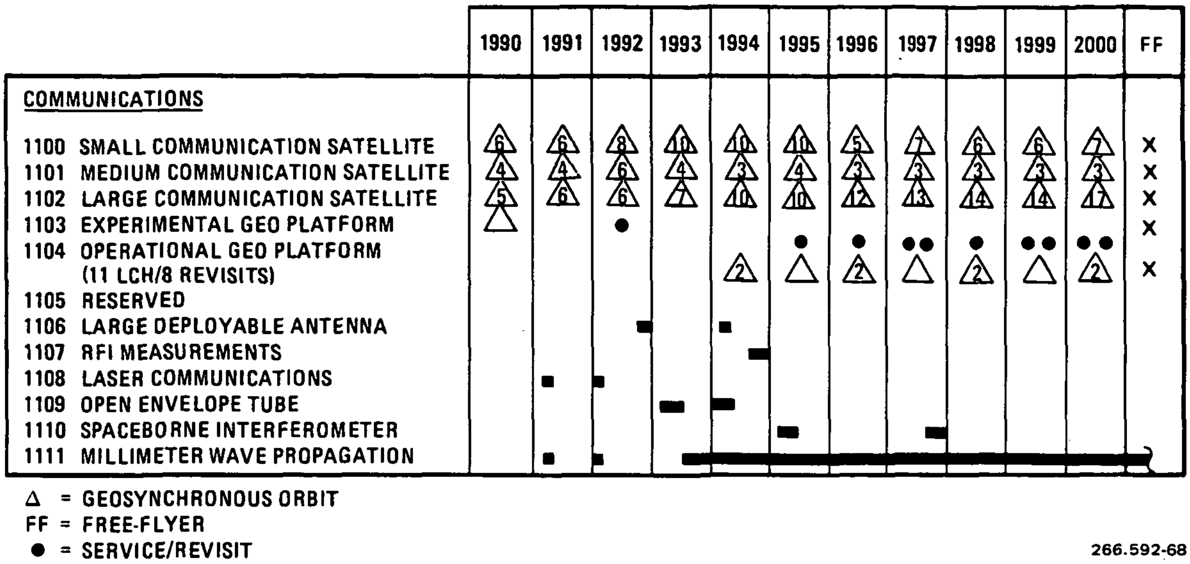

Figure 3-26. Commercial Communications Time Phasing

Part of the geosynchronous orbit traffic involves another type of GEO mission; namely, the GEO platform. The MSFC Nominal Mission Model, Rev. 6, identifies the launch of an experimental GEO platform, with service in 2 years, and several subsequent operational GEO platform modules launches. After review of related GDC studies, the schedule for the experimental platform (1103) was adjusted to reflect a more realistic schedule 1 year later than suggested by the Nominal Missions Model (Figure 3-26). There are significant benefits for the geostationary platforms, and specific candidate payload elements for accommodation on these platforms in the late 1990s are further described in Section 4.3.

The second major communications objective is to advance the development of communication satellite technology. The Space Station can be employed to promote this objective. Its large size; high prime power supply; availability of man to observe, photograph, and assist; and capability for recovery of the hardware makes it ideal for the communication satellite developers to employ as an <u>in situ</u> laboratory. The Space Station will provide the base for technological development of new communication opportunities such as land/mobile communications employing advanced equipment and very large antennas. Six representative communications development missions are identified at Space Station compatible orbits (Payload Elements 1106 through 1111).

The time phasing for communication technology development missions places most of the experimentation in the first half of the decade (Figure 3-26). They are generally conducted at least twice with sufficient time between operations for data feedback. The missions are planned early because commercial applications for this advanced technology already exist, and advanced satellites will be incorporating these advancements as soon as possible. Some of these experiments are conducted only once or twice, although continuing experimentation on similar items is entirely possible. Other experiments, such as millimeter wave propagation, will be carried out over long time periods, after short initial experimentation periods.

Construction of a large deployable antenna is key to many new areas of communication such as land mobile satellite service, direct broadcasting to homes, tracking and data acquisition, search, and rescue. Laser communications, open envelope tube, and millimeter wave propagation are candidates for immediate commercial exploitation. Objectives of each of these development missions are discussed in the following sections.

3.2.2.1 <u>GDCD 1106 -- Large Deployable Antennas</u>. One of the prime objectives in satellite communications technology developments is to provide an increase in services and a decrease in cost to prospective users. One method is to provide an increase in EIRP from the satellite to permit the users to employ smaller antennas and/or lower powered RF equipments for the same communications service. The 9.2-meter diameter ATS-6 antenna was the largest, non-military communications antenna deployed in space. But antennas of greater than 15m diameter have future potentials for comsats. A number of large antenna deployment concepts have been proposed by industry -- the Maypole of Harris, the wrapped rib of LMSC, the deployable truss of General Dynamics, the umbrella of Grumman. Tests of these antennas on the ground are not completely valid because the zero-gravity effects cannot be taken into account. In orbit and attached to the Space Station, antenna deployment would simulate as close as practical to the actual operating environment. Mechanical tests would provide data on the stresses in the antenna ribs, the degree of hysteresis, the surface accuracy as a function of time in orbit, and the effects of the space environment on the antenna structure and performance.

3.2.2.2 <u>GDCD 1107 -- Radio Frequency Interference Measurements</u>. A need exists to be able to detect and measure the signal strength of terrestrial-based radio emissions operating out of band or transmitting higher than permitted signal levels. The FCC attempts to monitor these emissions by ground-based vehicles. A low-altitude satellite containing a sensitive receiver and high G/T antenna should be capable of detecting sources of terrestrial transmissions in frequency bands of interest, determine their spectral signatures and antenna patterns, and locate the sources (to a few kilometers). To accomplish this experimental test, a large antenna having a "zoom" capability to narrow its beam coverage will be required, plus a low noise receiver and a spectrum analyzer. The antenna should have a capability to operate within a frequency range from 100 MHz to 30 GHz.

A scientist-astronaut on the Space Station can aid this experiment by setting up the antenna, changing feeds when required, operating the zoom feature of the antenna, observing the spectral data, and verifying the interfering source's location on the earth.

3.2.2.3 <u>GDCD 1108 -- Laser Communications</u>. Space Station offers a unique opportunity to develop the technology for space-to-space, very high data rate communications employing lasers. Competing laser technologies, such as CO_2 and NdYAG, can be tested and results compared for signal/noise, bit error rate, sensitivity to jitter, and capability to lock-on to a receiver or transmitter.

The applications of high data rate communications apply to NASA, DOD, and commercial missions. Future TDRSS missions may have to handle giga-bits of data, and the use of laser transmitters and receivers at the White Sands Ground Terminal may prove practical. DOD space missions of the future may desire intersatellite linking of many intelligence and communications satellites to avoid the use of overseas ground stations. The narrow bandwidth of lasers offers a low probability of signal jamming. The commercial comsat community has interests in intersatellite links to eliminate the need for a "double hop" for communicating with stations on the other side of the earth.

The approach to the conduct of a laser intersatellite test requires that an optical receiving system be located some distance from the Space Station-based laser transmitter. This can be accomplished by the deployment of a suitably equipped subsatellite from the Space Shuttle, use of a Shuttle-based pallet, or cooperation with some other laser receiver equipped satellite, U.S. or international. The Space Station will house an instrument pointing system for the laser transmitter, which should have an accuracy of better than 0.5 degree.

The astronaut-scientist on the Station will be responsible for attaching the laser package to the pointing system and power supply, seeing that the equipment is operating, assist in calibrating the instrument, point it in the correct direction, and observe that lock-up has occurred and that data is flowing.

3.2.2.4 GDCD 1109 -- Open Envelope Tube. A major technical problem to the development of long life, high performance space communications electronic tubes is the deterioration of the vacuum inside the tube envelope caused by outgassing, overheating, barium deposition, or insulators and output window cracking due to thermal stresses. One concept to maintain vacuum is to utilize the infinite pumping capacity of space by opening the tube to the space vacuum. Such a tube could be redesigned for simpler fabrication by eliminating the ion pump employed to maintain vacuum and the removal of output waveguide windows.

Space Station affords the communications engineer the opportunity to test a number of competing techniques for tube envelope removal in space. The tube should be placed on an extendable boom and deployed at a distance from the Station to avoid any contamination. An electrical command from the astronaut will "blow" the cover. Tube operating characteristics and temperature distribution in the collector will be measured and transmitted to earth.

3.2.2.5 GDCD 1110 -- Spaceborne Interferometer. In the 1960s, NASA's minitrack system employed widely spaced interferometric antennas on the ground to position locate earth orbiting satellites. This concept has been studied by NASA for the tracking of aircraft, ships, balloons, and buoys, and for search and rescue applications. It affords the opportunity for a single GEO comsat to communicate and position locate various moving platforms. This feature could provide an air traffic control or ship coordination application.

The technology for space based interferometers needs to be developed and demonstrated. Potential technical problems of boom deflection and spacecraft jitter and stabilization on the location accuracy must be tested. Space Station affords the opportunity to develop the techniques and demonstrate the position determination accuracy of interferometers.

Booms of varying length and antennas with different RF feeds could be housed on Space Station to demonstrate different applications. Aircraft and ship positioning should use the 1.5 GHz band, while search and rescue and data collection would install the antenna and feed booms at the ends of Space Station elements to form a long, cross-baseline interferometer. They would inspect periodically the antenna and electronics for proper operations.

3.2.2.6 GDCD 1111 -- Millimeter Wave Propagation. The 1979 World Administrative Radio Conference (WARC) assigned new frequency bands for future comsat applications and research needs in the millimeter wave band (30-300 GHz). Prior to use of these bands for space applications and communications, the basic characteristics of the frequency band is required, such as: effects on the signal due to fog, rain, snow, elevation angle, and terrain. The performance data of the various new RF components, antenna, and antenna feeds are also to be obtained. Some of the bands of interest to comsat developers and users are: Broadcast - 41.5 and 48.5 GHz; Mobile - 40 and 51 GHz; and Fixed Service - 43/49 GHz. Space Station affords the opportunity to place various laboratory developed receivers, transmitters, antennas, feeds, and associated components in space to conduct propagation and performance (S/N, EIRP, G/T) tests.

The Space Station will provide the platform to house the different antennas and associated RF equipments and conduct the propagation tests. The astronauts will be required to connect power lines to the equipments, assure that the antenna is properly stabilized, and observe instruments that indicate that a proper RF signal is being transmitted. Installation of a new feed system may also be required.

The requirements for the commercial communications discipline missions are summarized in Table 3-17. The requirements of Large Deployable Antenna (1106), Laser Communications (1108), and Spaceborne Interferometer (1110), while listed in the commercial discipline, encompass the requirements of similar technology demonstration missions. The driving requirements on the Space Station and STS for the commercial payloads in geosynchronous orbit are the traffic flow and the satellite physical characteristics that influence transportation costs for both Shuttle manifesting and the number of satellites deliverable by the upper stage in a single flight. Weights are based on SPACECOM-developed characteristics for satellites without kick stages and grouped as follows: small satellites up to 816 kg (RCA SATCOM/Hughes 376 class), medium satellites in the range of 816 to 2014 kg (Ford INTELSAT V class), and large satellites greater than 2313 kg (TDRSS class). Satellite lengths are based on modest improvement to current satellite packaging. The driving Space Station requirement for the attached communications technology development missions is accommodation of the 50-meter deployed antenna defined as the Large Deployable Antenna (1106).

3.2.3 COMMERCIAL MATERIALS PROCESSING MISSIONS. Materials Processing mission requirements are expressed in terms of an evolutionary complement of facilities that will be accommodated/supported by the Space Station, as shown in Figure 3-27.

Table 3-17. Payload Requirements Summary Data - Commercial Communications

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE* ATT	ACCOM MODE* FF	MISSION REQUIREMENTS LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT PREFERRED ALT (km)	ORBIT PREFERRED INCL (deg)	ORBIT ACCEPTABLE RANGE ALT (km)	ORBIT ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING ACCY (sec)	POINTING JITTER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	RESOURCES POWER LEVEL, W (DUR, HR/DAY) OPER	POWER LEVEL, W (DUR, HR/DAY) PEAK	DATA K BPS (HR/DAY)	CREW SIZE	CREW TIME (AVG) HR/DAY	EVA REQ'D X	SVC REQ'D X	RE-CONFIG REQ'D X	COMMENTS
1100	SMALL COMMUNICATIONS SAT		P	90(1)	1	GEO	0			N/A	N/A		N/A	816		2 x 4.5 x 4.5				2	8				81 SATELLITES
1101	MEDIUM COMMUNICATIONS SAT		P	90(1)	1									2,041		4 x 4.5 x 4.5				2	8				40 SATELLITES
1102	LARGE COMMUNICATIONS SAT		P	90(1)	1									2,313		5 x 4.5 x 4.5				3	12				114 SATELLITES
1103	EXPERIMENTAL GEO PLATFORM		P	90	5									5,450		10 x 4.5 x 4.5				2	8	X	X		UNMANNED SERVICING AT GEO
1104	OPERATIONAL GEO PLATFORM		P	94(1)(3)	5									5,450		10 x 4.5 x 4.5				1	4	X	X		UNMANNED SERVICING AT GEO
1105	RESERVED																								
1106	LARGE DEPLOYABLE ANTENNA(2)	P		92 94	14 14	ANY	ANY			EARTH	360			500	0.36	50 x 20 x 50	200	300	400	1	0.5	X			
1107	RFI MEASUREMENTS	P		94	21					EARTH	3600			50	0.36	15 x 15 x 15	100	300	1K	1	0.5	X		X	
1108	LASER COMMUNICATIONS(2)	P		91 92	5 5					INERTIAL	360			140	0.36	2 x 1 x 1	200 (3)	500 (20.5)	100K	1	0.5	X			
1109	OPEN ENVELOPE TUBE	P		93 94	7 7					INERTIAL				157	0.36	0.2 x 0.2 x 6	500	2000	100	1	0.25	X			
1110	SPACEBORNE INTERFEROMETER(2)	P		95 97	15 15					EARTH	360			60	0.36	30 x .2 x .2	100 (2)	150 (0.5)	500	1	0.5	X			
1111	MILLIMETER WAVE PROPAGATION	P		91 92 93	5 5 2920					EARTH	3600			40	0.36	3 x .5 x 3	25	100		1	0.25	X		X	

NOTES:

(1) INITIAL LAUNCH DATE. THERE WILL BE MULTIPLE LAUNCHES THROUGHOUT THE DECADE. SEE MISSION MODEL.

(2) ENCOMPASSES TECHNOLOGY DEVELOPMENT MISSION OBJECTIVES.

(3) ELEVEN FLIGHTS

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

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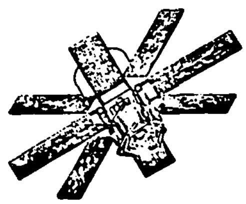
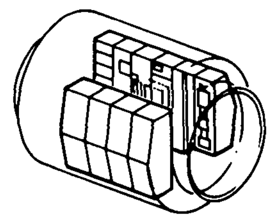
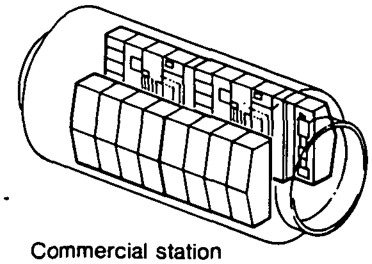


Commercial free-flyer facility



Station R&D facilities (NASA provided)



Commercial station production facilities

Characteristics

- Station-mounted equipment for commercial use & man-conducted R&D
- Commercial facilities in free-flyer in LEO

Potential station role

- Long-duration manned research activities
- Station resources
- Service & update free-flyers

Driving requirements

- Man-conducted research
  —Required crew time
- Power levels
- Disturbance g limits
- Logistics
  —Materials weight, volume & thermal control

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Figure 3-27. Materials Processing

General purpose research facilities will be required from the outset that will provide a continuation of Spacelab MPS research capabilities for academic and industrial users. These NASA facilities are further described in Section 3.1.5. The initial facility will provide small scale experiment capabilities in all materials science areas and also fluid physics experiment capabilities. Analysis of the properties of the materials produced will be primarily ground-based. The research facility capabilities will expand with time to enable the production of larger and/or more complex products and will include equipment for some types of on-orbit analysis of material properties.

When high potential for economically viable processes has been developed, specialized facilities for pilot production plants will be required to further develop equipment and to optimize the processes. Those processes/products that are proven in the preceding phase will advance to full-scale commercial production in dedicated facilities.

Research experiments and pilot production will be relatively labor intensive because of the high level of manned involvement in controlling test conditions and observing results. However, the commercial production facilities will be automated for long term production runs.

The free-flying biologicals production spacecraft is currently planned to begin operation in 1986-1987 with servicing revisits by the Space Shuttle every 6 months. This servicing function could be assumed by the Space Station if economic benefits can be derived.

Throughout all phases of commercial experimentation and production, the facility arrangements, operational procedures, manning, logistics, data handling, and communications must ensure the protection of proprietary information.

The facilities shown in Figure 3-28 and identified as payload elements 1200 through 1206 represent the spectrum of MPS facilities envisioned through the year 2000. General purpose research facilities, shared by all types of users, will be required throughout the entire period, with both experimental and analytical capabilities increasing with time. These facilities are described as part of the Science and Applications Materials Processing discipline in Section 3.1.5 and are identified as payload elements 0400 and 0401.

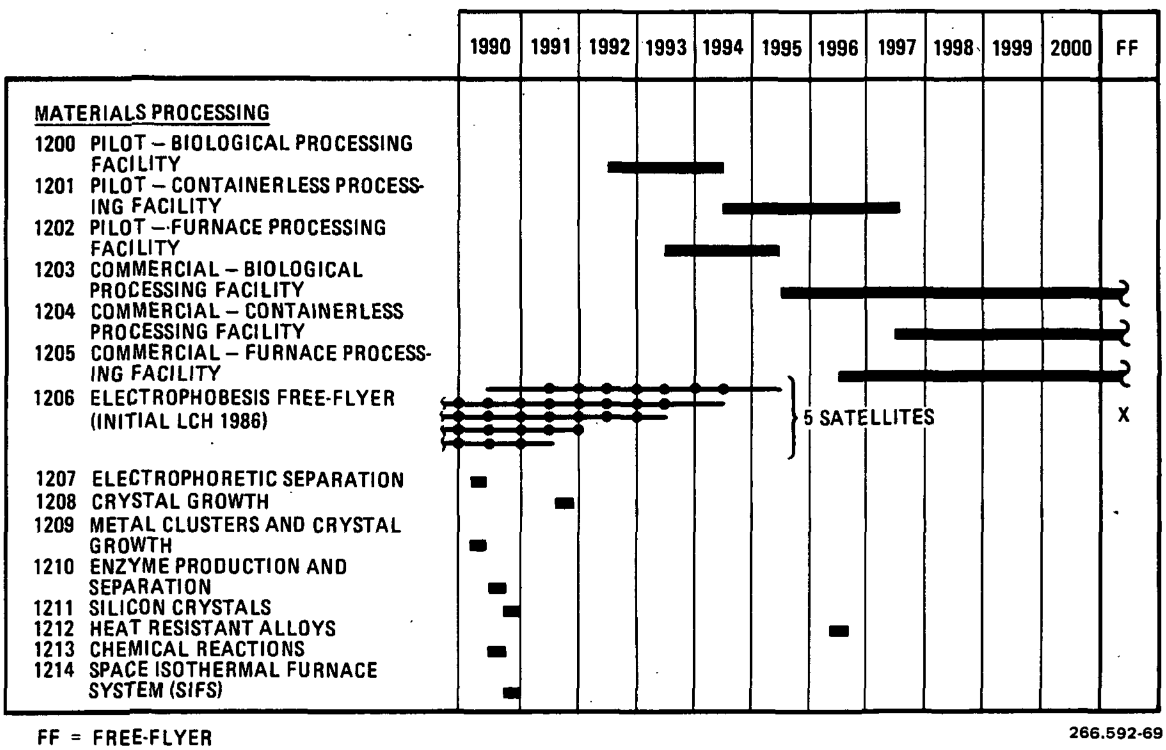

Figure 3-28. Commercial Materials Processing Time Phasing

Time phasing shown for the pilot production and production commercial processing facilities follows a logical progression from Spacelab and early Space Station MPS research. However, no schedule commitments from potential commercial users have been obtained at this early date, primarily because commercial processing in space is perceived to be beyond the nominal 10-year investment horizon. Time phasing for the user identified missions based on fact sheet data (1207 through 1214) is scheduled to be in synch with the user requirements and the accommodating Science and Applications and Commercial MPS missions. Figure 3-16 depicts the Space Station era materials processing discipline in terms of a hierarchy of missions with their associated technical characteristics and materials processing functions. Specific interrelationships with other user missions are also shown. Section 3.1.5 describes methods of funding these missions. R&D facilities will be available for commercial users on a cost-reimbursable basis or other beneficial economic relationships. This could be particularly attractive for quick turnaround investigations desired by users to cut long development lead times. The commercial facilities could be operated under various schemes; for example, the facility could be owned by a commercial organization and facility services leased to users, or other ownership/operations arrangements. Schedules for the commercial facilities are the earliest expected and are based on a success-oriented R&D program and anticipated market development and should be considered flexible.

It is assumed that by 1990, MPS free flyers may already be in operation, such as for commercial-scale electrophoretic separation of pharmaceuticals. Payload element 1206, the representative free flying mission, first flies in 1986 with a mission duration of 5 years, and is serviced at 6-month intevals for change-out of the resupply module. Five of these free flyers are scheduled. Tail-off of this type of facility assumes transition of Commercial Biological operations to the Space Station.

Requirements for the commercial MPS discipline are summarized in Table 3-18. MPS missions are characterized by high average and peak electrical power levels. The microgravity requirements for the MPS facilities range from 10^{-3} to 10^{-5} g for various time durations. All of the facilities require vacuum ports.

It should be noted that one user, INCO, (refer to mission GDCD 1212) estimated a potential power level of 100 kW -- which exceeds the capability of the largest accommodating payload element. Projections of this level, however, are not expected to occur until after the year 2000. Should such power levels become a reality, the modular architecture would make it possible to satisfy requirements.

Table 3-18. Payload Requirements Summary Data - Commercial Materials Processing

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE* ATT	ACCOM MODE* FF	MISSION REQUIREMENTS: LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT PREFERRED ALT (km)	ORBIT PREFERRED INCL (deg)	ORBIT ACCEPTABLE RANGE ALT (km)	ORBIT ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING ACCY (sec)	POINTING JIT-TER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL: MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	RESOURCES: POWER LEVEL, W (DUR, HR/DAY) OPER	POWER LEVEL, W (DUR, HR/DAY) PEAK	DATA K BPS (HR/DAY)	CREW SIZE	CREW TIME (AVG) HR/DAY	EVA REQ'D X	SVC REQ'D X	RE-CONFIG REQ'D X	COMMENTS
1200	PILOT – BIOLOGICAL PROCESSING FACILITY	P		92	730	>400	ANY			N/A	N/A	N/A	10^{-3}	1,050	4.3	N/A	8K (2)	10K (22)	3 (24)	1	4				VACUUM VENT REQ'D.
1201	PILOT – CONTAINERLESS PROCESSING FACILITY	P		94	1095								10^{-3}	3,900	12.9		12K (4)	25K (4)	3 (8)	1	8				
1202	PILOT – FURNACE PROCESSING FACILITY	P		93	1095								10^{-5}	4,452	12.05		30K (12)	50K (12)	10 (24)	1	4				
1203	COMMERCIAL – BIOLOGICAL PROCESSING FACILITY	P		95	1825								10^{-3}	2,100	8.6		16K (4)	20K (20)	6 (24)	1	8				
1204	COMMERCIAL – CONTAINERLESS PROCESSING FACILITY	P		97	1095								10^{-3}	5,700	20.3		26K (20)	38K (4)	6 (24)	1	8				
1205	COMMERCIAL – FURNACE PROCESSING FACILITY	P		96	1500								10^{-5}	6,325	22.5		40K (20)	70K (4)	10 (24)	1	8				
1206	ELECTROPHORESIS FREE FLYER		P	86(1)	1865								10^{-3}	9,987	N/A	5.5 x 4.3 x 4.3							X		FIVE SPACECRAFT
1207	ELECTROPHORESIS SEPARATION	P		90	7	ANY	ANY			N/A	N/A	N/A	10^{-4}	[300]	[2.7]	N/A	[500]			[1]	[0.5]				REF. – 0400
1208	CRYSTAL GROWTH	P		92	6.5																				REF. – 0400
1209	METAL CLUSTERS & CRYSTAL GROWTH	P		90	15								10^{-4}	[100]	[0.5]		[1000]			[1]	[1]				REF. – 0400
1210	ENZYME PRODUCTION & SEPARATION	P		90	4															[1]	[2]				REF. – 0400
1211	SILICON CRYSTALS	P		90	30								10^{-4}	[300]	[1.2]		[5000] (8)			[1]	[8]				REF. – 0400 FOR 30 SAMPLES
1212	HEAT RESISTANT ALLOYS	P		96	30									[5000]			[100K] (6)			[1]	[8]				REF. – 1205 FOR 30 SAMPLES
1213	CHEMICAL REACTIONS	P		90	7															[1]	[0.5]				REF. – 0400
1214	SPACE ISOTHERMAL FURNACE SYSTEM (SIFS)	P		90	4	>250														[1]	[0.5]				REF. – 0400

NOTE:
(1) INITIAL LAUNCH DATE. FOUR ADDITIONAL LAUNCHES AT A RATE OF ONE PER YEAR.

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

[ ] = ACCOMMODATED BY REFERENCED PAYLOAD ELEMENT(S)

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The processing of materials in space represents a relatively new and expanding frontier for commercial applications. A number of business opportunities were confirmed through personal and telephone contacts. In particular, a potential for future space business was identified in the area of investigation of new alloys under zero-g conditions, the growth of high purity crystals, the manufacture of pharmaceuticals, and the formation of glass and ceramics in space. Payload element 1207 from the University of Arizona proposes the purification of biomaterials using electrophoretic methods complementary to those developed by MDAC. Micrograving Research Associates mission 1208 has the objective to provide very high quality gallium arsenide and other electronic crystals in space. Performance of metal cluster chemistry and growth of organic and inorganic crystals in a convection-free environment was suggested by 3M Company (1209). A. E. Staley Manufacturing Company proposed involvement with fermentation of microorganisms, producing a useful enzyme and/or separation of enzyme constituents from broth (1210). Monsanto, in payload element 1211, proposed production of 25 to 50 millimeter dislocation free silicon crystal ingots with uniform homogeneous properties both with respect to dopant distributions and to microdefect incorporation. The growth method would be floating zone -- possibly in a mirror furnace. INCO desires to explore ways of using zero gravity to improve thermal and corrosion resistance properties of alloys (1212), while E. I. duPont suggested a mission objective to determine the influence, if any, of microgravity on chemical reactions (1213). At one time GTI was developing a multi-module furnace for isothermal processing of up to 220 separate samples at several temperatures (1214).

Economic factors for MPS fact sheet respondents are summarized in Figure 3-29. Investment level, investment horizon, and technical risk are identified as the most influential perceived investment barriers. Tax incentive appears as a driving investment incentive for this discipline. All respondents indicated an interest in establishing a JEA with NASA -- of the three indicating very high interest levels, one (GTI) had already developed a JEA with NASA.

3.2.4 COMMERCIAL INDUSTRIAL SERVICES MISSIONS. The industrial services discipline has been identified in the draft NASA "Yellow Book" as one of the commercial disciplines. Most of the missions identified for this discipline are considered as "Providers" of Space Station or OTV base resources. One mission, identified by Bell Laboratories, is oriented toward acquisition of high energy astrophysics data as a follow-on to current company research activities conducted on balloon flights. This free flying mission was hosted by GDC on the NASA-approved Gamma Ray Observatory, 0030, based on similarity of the objectives and requirements. This mission could be representative of a class of potential users that could provide various beneficial economic arrangements such as additional research at no cost to NASA.

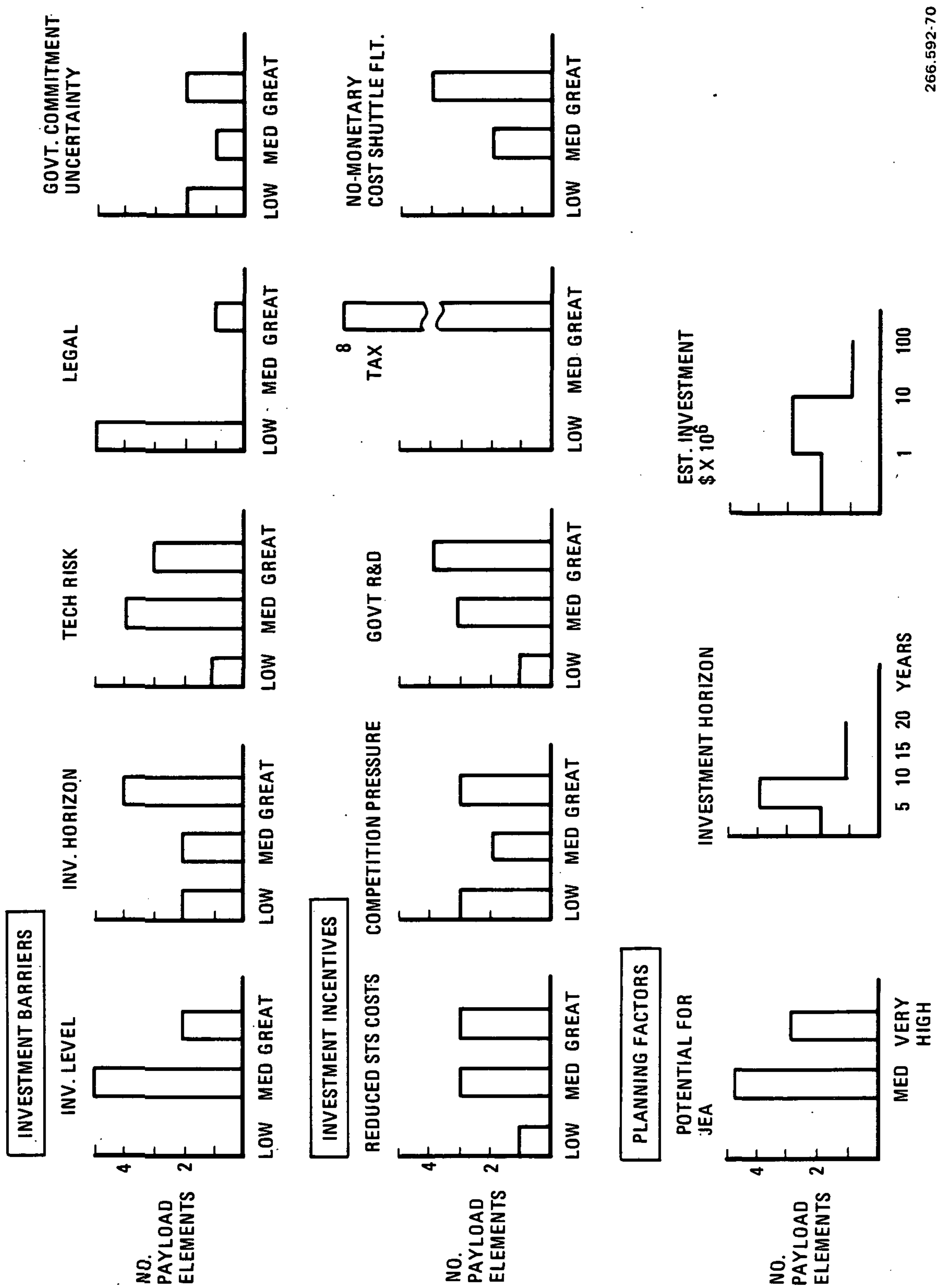

Figure 3-29. Economic Factors - Commercial MPS

The payload elements for the industrial services discipline are identified and time-phased in Figure 3-30. Time phasing is based on both user desires and compatibility with accommodating missions. The requirements for this discipline are summarized in Table 3-19 and are further described in Book 1, Appendix I. The radiation hardened computer experiment was identified by Control Data with the physical and resource requirements and accommodation derived by GDC. Early scheduling of this mission permits tie-in with the Space Component Lifetime Technology Mission, 2503, should the need to assess long term exposure effects be identified. Accommodation of the computer at polar inclination would accelerate radiation exposure.

A User Fact Sheet was received from an entrepreneur proposing to provide a full-bodied teleoperator for use on the Space Station. The full-bodied teleoperator would provide the Space Station with a substantial fraction of EVA functions without crew members leaving the pressurized volume. Movement sensors attached to the IVA crewman's limbs, head, and fingers control a jointed robot located outside. The full-body teleoperator would follow the Manipulator Controls Technology mission, 2401, and would be supported by ongoing activities conducted on Advanced EVA Technology and EVA Performance and Productivity missions (2402 and 0322, respectively).

The CELSS-related missions, an experimental and a commercial venture, are compatible with similar NASA Science and Applications CELSS missions (0341 and 0342). In another fact sheet response, RCA provided user interest in both a communication development mission and a satellite handling and servicing mission that could typically be accommodated by an OTV base. Similar and compatible missions are identified as 1106, which is oriented toward large deployable antenna technology, and 2504 and 2505, which relate to OTV payload handling and payload servicing repair for future satellites.

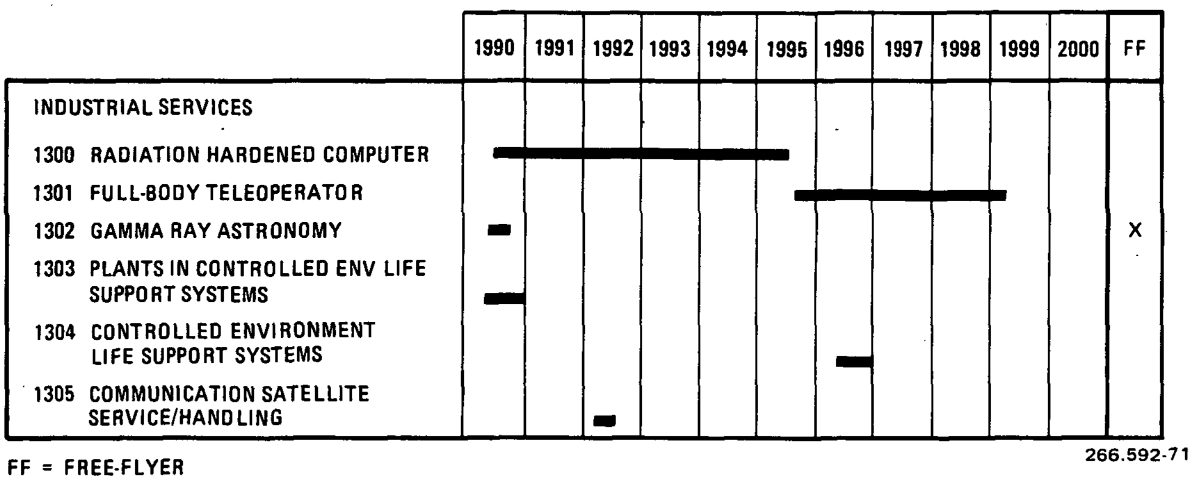

Figure 3-30. Commercial Industrial Services Missions

Table 3-19. Payload Requirements Summary Data - Industrial Services

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE* ATT	ACCOM MODE* FF	MISSION REQUIREMENTS: LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT PREFERRED ALT (km)	ORBIT PREFERRED INCL (deg)	ORBIT ACCEPTABLE RANGE ALT (km)	ORBIT ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING ACCY (sec)	POINTING JIT-TER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL: MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	RESOURCES: POWER LEVEL, W (DUR, HR/DAY) OPER	POWER PEAK	DATA K BPS (HR/DAY)	CREW SIZE	CREW TIME (AVG) HR/DAY	CREW EVA REQ'D X	SVC REQ'D X	RE-CONFIG REQ'D X	COMMENTS
1300	RADIATION HARDENED COMPUTER	P	A	90	1825	ANY	ANY			N/A			N/A	50	0.36	.6 x .5 x .4	200 (24)		1,000			X			
1301	FULL-BODY TELEOPERATOR	P		95	1460	ANY	ANY			N/A				300	1.5		500-1000								
1302	GAMMA RAY ASTRONOMY		P	90	60	400	0	350-450	0-28.5	INERTIAL	360			[1000-3000]		[3 x 3 x 3]	[200] (10)								REF. 0030
1303	PLANTS IN CONTROLLED ENV LIFE SUPPORT SYS (CELSS)	P		90	180	ANY	ANY			N/A										1	0.2				REF. 0341, 1304
1304	CONTROLLED ENVIRONMENT LIFE SUPPORT SYSTEMS (CELSS)	P		96	180									[1500]	[9.3]		[300]	[1000-2500]		1	0.2				REF. 0342
1305	COMMUNICATION SATELLITE SERVICE/HANDLING	P		92	30																				REF. 1106, 2504, 2505.

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

[ ] = ACCOMMODATED BY REFERENCED PAYLOAD ELEMENT(S)

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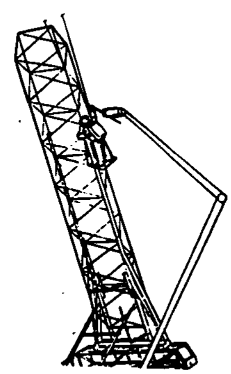
Responses to questions pertaining to economic factors varied widely for this discipline and exhibit no significant trends, except that three of the five respondents indicated a very high interest in exploring a JEA with NASA.

3.3 TECHNOLOGY DEVELOPMENT MISSIONS

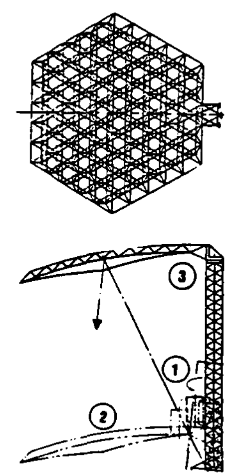
The technology missions cover a broad range of disciplines and take place throughout the 1990s. Seven disciplines have been identified by NASA as shown in Figure 3-31. Some missions call for very long exposure to the space environment, covering most of the decade. These are generally the investigations relating to long term effects on properties and performance, as exemplified by the experiments in materials and coatings, special sensors and space component lifetimes. Other experiments such as those in advanced energy conversion and controls technology have span times in the order of 1 year. All of the missions identified in this discipline prefer station attached accommodations. The station provides the necessary characteristics of low gravity, availability of power, man/experiment interaction, data processing, and long-term presence in the space environment to facilitate the technology development missions. These missions benefit all other categories of users and enhance capabilities for advanced missions that will have greater capabilities.

Disciplines
- Materials & structures
- Energy conversion
- Computer science & electronics
- Propulsion
- Control & human factors
- Space station systems/ops
- Fluid & thermal physics/PACE

Characteristics
- Wide size & mass range of attached structures, panels & packaged system experiments
- Stable platform required for testing of integral & attached spacecraft systems & components
- Experiment durations from one week to 20 years
- Frequent changeout of test systems & components



Potential Station Roles
- Crew activity for
  - Structures assembly
  - Hardware changeout
  - Systems operation
  - TMS/OTV operations
  - Test observation/ evaluation
- Constant use of data acquisition & analysis facility



Driving requirements
- Accommodation of large structures
- Platform stability
- Data acquisition & analysis
- TMS/OTV control center
- EVA

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Figure 3-31. Technology Development

A representative set of 33 technology development missions (covering 7 disciplines) have been defined for the 1990 time frame, and are identified in Table 3-20 and further defined in Book 1, Appendix I. GDC missions augment the NASA concepts in several areas.

3.3.1 TECHNOLOGY DEVELOPMENT -- MATERIALS AND STRUCTURES MISSIONS. This group of missions establishes a representative data base for the deployment of structures in space. Long term tests are performed on advanced materials and coatings, as well as specialized sensors for nondestructive evaluation, extending through the decade. The investigation into dynamics of lightly loaded structures tests the premise that for structures erected in zero gravity, flimsy components may be perfectly adequate. Thermal shape technology is a mission in which heaters are applied to a flexible panel for control of its shape by varying the local temperature distribution. Active optics technology involves assembly of mirror segments and structure and mirror positional actuators and instruments and evaluating long term effects and mirror surface accuracy. Large structures technology experiments will establish both techniques and a data base for erecting future large structures in space.

Table 3-20. Technology Development Missions

TECHNOLOGY DISCIPLINES & PAYLOAD ELEMENTS	No. P/L Elements	Mission NASA*	Concept GDC
MATERIALS & STRUCTURES	7		
2001 Strain and Acoustic Sensors		X	
2002 Spacecraft Materials Technology		X	
2003 Materials and Coatings		X	
2004 Thermal Shape Control		X	
2005 Dynamics of Flimsy Structures		X	
2006 Active Optics Technology		X	
2007 Large Structures Technology		X	
ENERGY CONVERSION	7		
2101 Low-Cost Modular Solar Panels		X	
2102 Reserved			
2103 Ion Effects on LEO Power Systems		X	
2104 Large Solar Concentrator		X	
2105 Solar Pumped Lasers		X	
2106 Laser/Electric Energy Conversion		X	
2107 Solar Sustained Plasmas		X	
2108 Space Nuclear Reactor			X

Table 3-20. Technology Development Missions, Contd

TECHNOLOGY DISCIPLINES & PAYLOAD ELEMENTS	No. P/L Elements	Mission NASA*	Concept GDC
COMPUTER SCIENCE & ELECTRONICS	4		
2201 Attitude Control - System Ident. Exper.		X	
2202 Attitude Control - Adaptive Cont. Exper.		X	
2203 Attitude Control - Distributed Cont. Exper.		X	
2204 Advanced Adaptive Control Technology Demo		X	
PROPULSION	2		
2301 Controlled Accel. Propulsion Technology		X	
2302 Laser Propulsion Test		X	
CONTROL & HUMAN FACTORS	2		
2401 Manipulator Controls Technology		X	
2402 Advanced EVA Technology			X
SPACE STATION SYSTEMS & OPERATIONS	10		
2501 Liquid Droplet Radiator		X	
2502 Advanced Control Device		X	
2503 Space Component Lifetime Technology		X	
2504 OTV Payload Handling		X	(Augment)
SPACE STATION SYSTEMS & OPERATIONS, Contd.			
2505 Payload Servicing and Repair		X	(Augment)
2506 OTV Propellant Transfer & Storage		X	(Augment)
2507 OTV Propellant Liquefaction		X	(Augment)
2508 OTV Docking and Berthing		X	(Augment)
2509 OTV Maintenance		X	(Augment)
2510 Tether Dynamics Technology		X	(Augment)
FLUID & THERMAL PHYSICS, PHYSICS AND CHEMISTRY	1		
2601 Lightweight Cryo Heat Pipes		X	
Subtotal		(31)	(2)
Total	33		

*Orientation meeting handout, 14-15 September 1982

The materials and structures missions are sequenced in Figure 3-32. Since technology developed by these payload elements will be used for later elements of the Space Station, it is desirable to conduct them as early as possible. The Active Optics Technology, 2006, mission schedule, for example, supports the Large Deployable Reflector, payload element 0001, and also some of the planetary missions. Although experiment periods are shown to extend over long periods, actual operations will be characterized by periods of intensive manned participation to set up and activate a new set of test conditions -- followed by periods of data taking, analysis, and then reconfiguration for a new test series.

The requirements of materials and structures missions are summarized in Table 3-21. Driving characteristics of these missions are large size (up to 1000m by 200m), weight (requiring multiple Shuttle launches), and extensive EVA requirements (see Book 1, Appendix I) needed to support space construction. SCAFEDS technology was assumed as the baseline for development of requirements for the driving payload element (2007).

3.3.2 <u>TECHNOLOGY DEVELOPMENT -- ENERGY CONVERSION MISSIONS</u>. The energy conversion missions focus both on low cost and advanced technology approaches. The missions are time-phased in Figure 3-33. The low cost solar panels are deployed for the entire decade to provide data on long term endurance characteristics in the space environment. In the space power experiment, a solar array is assembled in modular form, capable of generating power at various high voltages, which is converted to alternating current for efficient transmission. It is tested first in the natural space environment and then in the proximity of an ion engine. A series of tests on a large solar concentrator establishes the optical characteristics of the mirror then utilizes the concentrated solar energy for experiments with solar pumped lasers and solar sustained plasmas. A space nuclear reactor is delivered and deployed using manned assistance, toward the end of the decade.

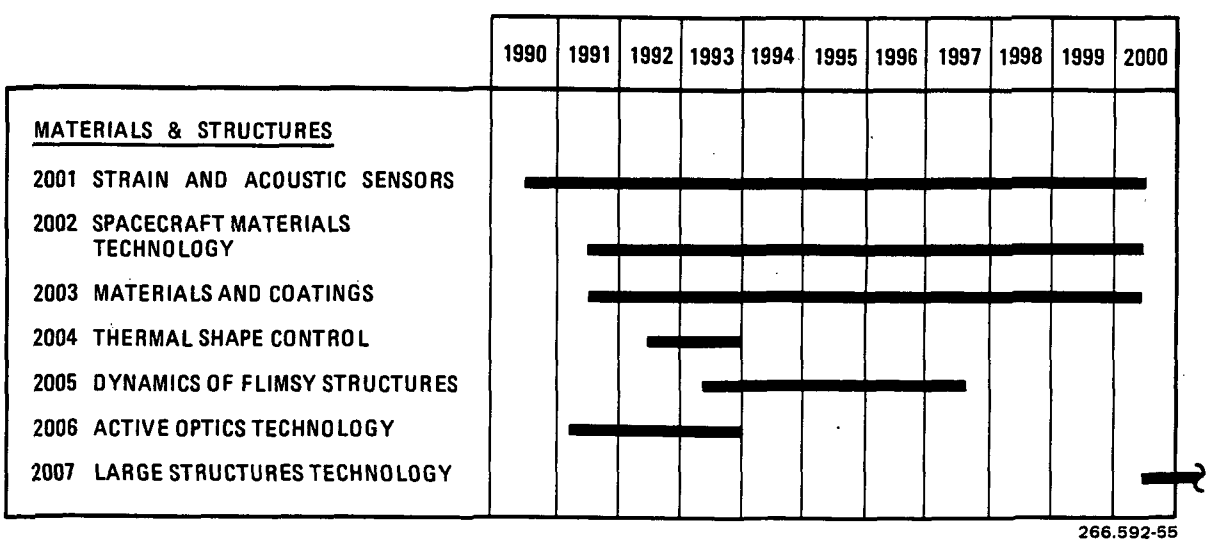

Figure 3-32. Materials and Structures Time Phasing

Table 3-21. Payload Requirements Summary Data - Materials and Structures

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE*		MISSION REQUIREMENTS										PHYSICAL			RESOURCES									COMMENTS
				LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT				VIEWING DIRECTION	POINTING		OPER ACCEL LIMIT (g)	MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	POWER LEVEL, W (DUR, HR/DAY)		DATA K BPS (HR/DAY)	CREW			SVC REQ'D X	RE-CONFIG REQ'D X	
						PREFERRED		ACCEPTABLE RANGE																	
		ATT	FF			ALT (km)	INCL (deg)	ALT (km)	INCL (deg)		ACCY (sec)	JIT-TER (sec/s)					OPER	PEAK		SIZE	TIME (AVG) HR/DAY	EVA REQ'D X			
2001	STRAIN & ACOUSTIC SENSORS	P		90	3650	LEO	ANY			N/A			N/A	50	0.36		100 (4)		1.0	1	0.1	X	X	X	
2002	SPACECRAFT MATERIALS TECH	P		91	3300									150	0	5 x 1 x 0.1				1	0.1	X	X	X	
2003	MATERIALS AND COATINGS	P		91	3300									250	0	10 x 5 x 0.2				1	0.1	X	X	X	
2004	THERMAL SHAPE CONTROL	P		92	550									1,000	0.36	20 x 10 x .2	3000	6000	1.0	1	0.1	X			
2005	DYNAMICS OF FLIMSY STRUCT	P		93	1460									1,000	0.72	100 x 20 x 2.5	1000 (24)		1.0	1	0.1	X			
2006	ACTIVE OPTICS TECHNOLOGY	P		91	1000					INERTIAL				10,000	0.36	16 x 12 x 16	1000			1	0.2	X	X		
2007	LARGE STRUCTURES TECH	P		00	1100					N/A				100K	0.36	1000 x 200 x 5	1000		1.0	2	0.4	X			

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

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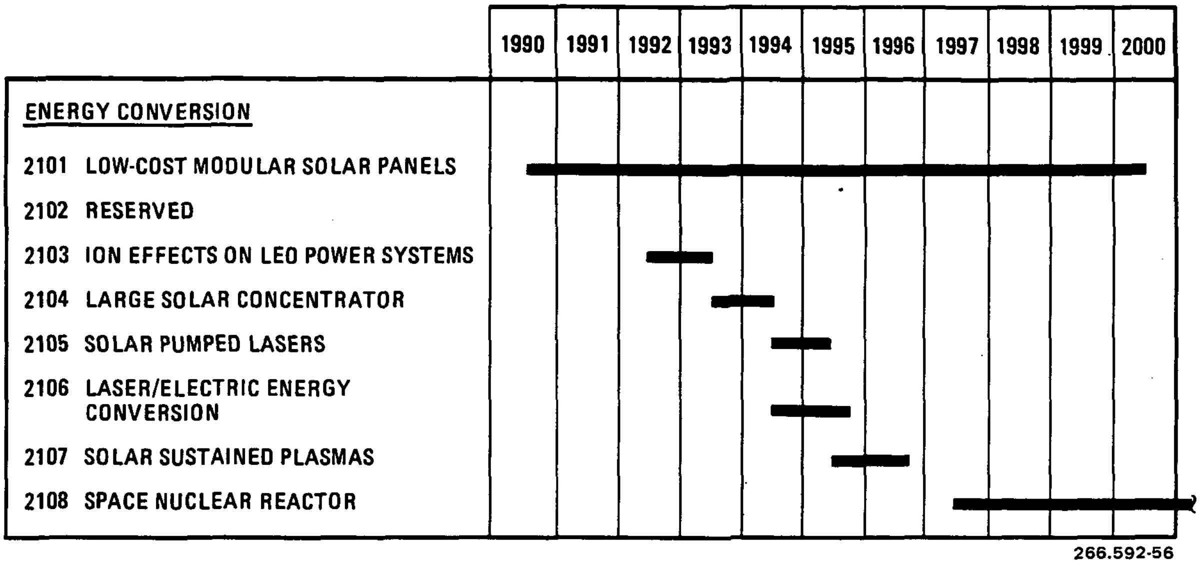

Figure 3-33. Energy Conversion Missons Time Phasing

Many of the missions are linked together to reduce hardware costs and take advantage of prior development activities. For example, laser and plasma payload elements 2105, 2106 and 2107 utilize the solar concentrator hardware from 2104. The solar panels used to assess ion engine effects (2103) can use similar solar panel modules developed for tests conducted in 2101. The heat pipe technology advancements needed for the Space Nuclear Reactor, 2108, will benefit from a Technology Development mission on heat pipes (2601) planned for 1991.

The requirements for the energy conversion discipline missions are summarized in Table 3-22. The driving requirements are the accommodation of the relatively large structures generally used in this discipline and the 100m long deployment boom for the nuclear reactor. It is expected that NASA could share the cost of the Space Nuclear Reactor (payload element 2108) with DOE and DOD, on the basis of one-third for each participating agency. The payload element sizes shown for the Laser and Plasma missions (2105, 2106, and 2107) are envelopes that include the large solar concentrator hardware initially used in 2104. The weights shown, however, are the delta weights for the experiment pecular apparatus and are additive to the 5000 kg solar concentrator. The solar concentrator is assumed to be a parabolic trough design with a geometrical concentration ratio of 20. It uses galium arsenide solar cells with an aluminum combination mirror/radiator and composite structure.

Table 3-22. Payload Requirements Summary Data - Energy Conversion

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE* ATT	ACCOM MODE* FF	MISSION REQUIREMENTS: LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT PREFERRED ALT (km)	ORBIT PREFERRED INCL (deg)	ORBIT ACCEPTABLE RANGE ALT (km)	ORBIT ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING ACCY (sec)	POINTING JITTER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL: MASS (kg)	PRES'D VOL (m³)	EXTNL SIZE L×W×H (m)	RESOURCES: POWER LEVEL, W (DUR, HR/DAY) OPER	POWER PEAK	DATA K BPS (HR/DAY)	CREW SIZE	CREW TIME (AVG) HR/DAY	EVA REQ'D X	SVC REQ'D X	RE-CONFIG REQ'D X	COMMENTS
2101	LOW-COST MODULAR SOLAR PANELS	P		90	3650	LEO	ANY			SOLAR	10000		0.1	30	0	5 × 6 × 0.1				1	0.1	X			
2102	RESERVED																								
2103	ION EFFECTS ON LEO POWER SYSTEMS	P		92	365					SOLAR	7,200		N/A	150	0.36	5 × 6 × 0.1				1	0.1	X		X	
2104	LARGE SOLAR CONCENTRATOR	P		93	365					SOLAR	900			5,000	0.36	10 × 10 × 10				1	0.2	X			
2105	SOLAR PUMPED LASERS	P		94	270					SOLAR	900			200	0	10 × 10 × 10*				1	0.2	X		X	*USES – 2104 COLLECTOR
2106	LASER/ELECTRIC ENERGY CONVERSION	P		94	450					SOLAR	900			500	0	10 × 10 × 10*				1	0.2	X		X	*
2107	SOLAR SUSTAINED PLASMAS	P		95	450					SOLAR	900			2,000	0	10 × 10 × 10*				1	0.2	X		X	*
2108	SPACE NUCLEAR REACTOR	P	A	97	2560					N/A				2,500	0.36	100 × 4 × 4				1	0.1	X			NASA COST SHARE IS 1/3.

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

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3.3.3 TECHNOLOGY DEVELOPMENT -- COMPUTER SCIENCE AND ELECTRONICS. Missions in the Computer Science discipline focus on validating hardware, algorithms, and systems for attitude control of Space Station and flexible structure.

To reduce costs, the missions are linked sequentially as shown in Figure 3-34, and use the structure provided by another Technology Demonstration payload related to flimsy structures (2205). In addition, control hardware elements from the earlier experiments in this discipline will probably be useful in determining dynamic characteristics in later altitude control experiments.

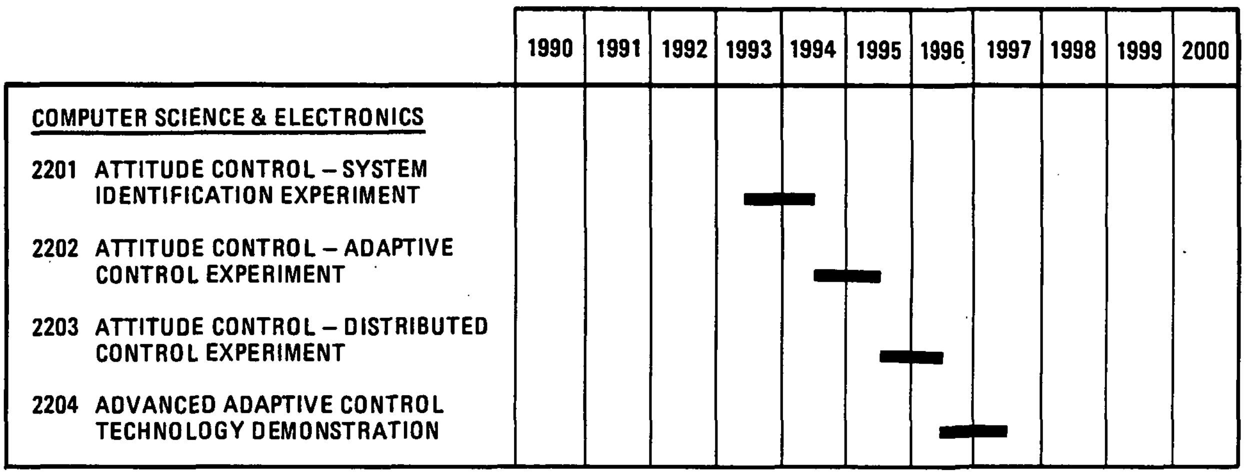

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Figure 3-34. Computer Science and Electronics Time Phasing

The requirements of Computer Sciences and Electronics payload elements are summarized in Table 3-23. The driving characteristics of this discipline are station accommodation of the large (100m by 20m) structural elements and control of vibration perturbations during periods when the experiment is active. The mass shown in Figure 3-35 includes the payload unique equipment only and excludes the structure weight. It is assumed that data resulting from these missions would be analyzed on the ground. However, quick-look data monitoring would be accomplished at the station.

3.3.4 TECHNOLOGY DEVELOPMENT -- PROPULSION. One of the propulsion missions is intended to evaluate low thrust system characteristics and the ability of candidate low thrust systems such as resistojets to control Space Station accelerations. In the Laser Propulsion Test, advanced laser propulsion system-level characteristics will be evaluated for potential use on future OTVs. These propulsion missions are time phased in Figure 3-35. Since the laser propulsion test requires a high power source, a cost effective approach uses the solar concentrator and solar pumped laser initially developed for 2104 and 2105.

Table 3-23. Payload Requirements Summary Data - Computer Science and Electronics

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE*		MISSION REQUIREMENTS										PHYSICAL			RESOURCES									COMMENTS
						ORBIT					POINTING						POWER			CREW					
						PREFERRED		ACCEPTABLE RANGE									LEVEL, W (DUR, HR/DAY)								
		ATT	FF	LAUNCH DATE YR(S)	MSN DUR (DAYS)	ALT (km)	INCL (deg)	ALT (km)	INCL (deg)	VIEWING DIRECTION	ACCY (sec)	JIT-TER (sec/s)	OPER ACCEL LIMIT (g)	MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	OPER	PEAK	DATA K BPS (HR/DAY)	SIZE	TIME (AVG) HR/DAY	EVA REQ'D X	SVC REQ'D X	RE-CONFIG REQ'D X	
2201	ATTITUDE CONTROL – SYSTEM IDENTIFICATION EXPER	P		93	365	LEO	ANY			N/A			N/A	100	0.36	100 x 20 x 2.5**	1000		1.0	2	0.2	X		X	**USES STRUCTURE FROM -2005
2202	ATTITUDE CONTROL – ADAPTIVE CONTROL EXPERIMENT	P		94	365									100	0.36		1000		1.0	2	0.2	X		X	**
2203	ATTITUDE CONTROL – DISTRIBUTED CONTROL EXPER	P		95	365									100	0.36		1000		1.0	2	0.2	X		X	**
2204	ADVANCED ADAPTIVE CONTROL TECHNOLOGY DEMO	P		96	365									100	0.36		1000		1.0	2	0.2	X		X	**

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

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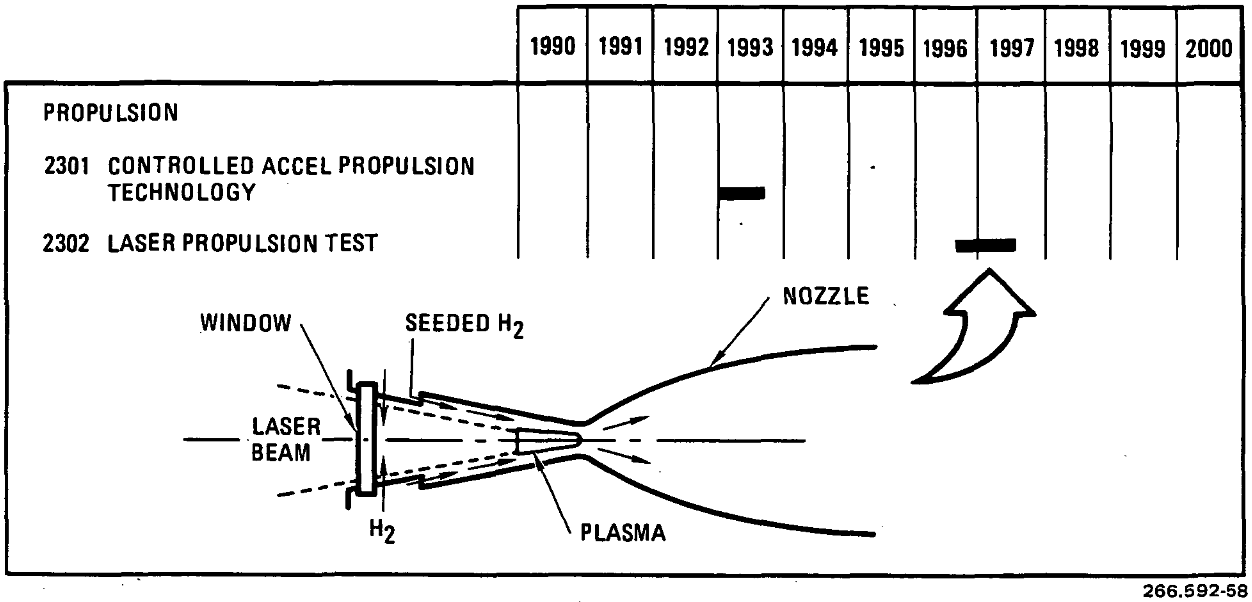

Figure 3-35. Propulsion Missions Time Phasing

Summary requirements are shown in Table 3-24. The weight, size, and power for the Laser Propulsion mission (2302) are for the unique payload elements only (e.g., hydrogen propellants), and do not include the large solar concentrator and the laser. Depending on thrust level being tested, an opposed engine may also be required.

3.3.5 TECHNOLOGY DEVELOPMENT -- CONTROL AND HUMAN FACTORS. The Manipulator Controls Technology experiment will determine the characteristics and limitations of control technology applied to space teleoperator systems. Advanced EVA technology will develop advanced EVA tools and equipment for assembly and construction of large space structures. The missions in this discipline are sequenced as shown in Figure 3-36 to provide early design data and validations as well as interactive support for other missions throughout the decade. The Advanced EVA Technology mission (2402) is linked to the physiological aspects of EVA, which are being concurrently studied under the Science and Applications operational medicine discipline (refer to mission 0322).

Summary requirements for this discipline are shown in Table 3-25. The driving requirement is the large pressurized volume needed as an operating envelope to exercise the dual 3m-long manipulator arms used by payload element 2402.

Table 3-24. Payload Requirements Summary Data - Propulsion

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE * ATT	ACCOM MODE * FF	MISSION REQUIREMENTS: LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT PREFERRED ALT (km)	ORBIT PREFERRED INCL (deg)	ORBIT ACCEPTABLE RANGE ALT (km)	ORBIT ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING ACCY (sec)	POINTING JIT-TER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL: MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L × W × H (m)	RESOURCES: POWER LEVEL, W (DUR, HR/DAY) OPER	POWER LEVEL, W (DUR, HR/DAY) PEAK	DATA K BPS (HR/DAY)	CREW SIZE	CREW TIME (AVG) HR/DAY	CREW EVA REQ'D X	SVC REQ'D X	RE-CONFIG REQ'D X	COMMENTS
2301	CONTROLLED ACCELERATION PROPULSION TECH	P		93	180	LEO	ANY			N/A			N/A	45	0.36	.6 x .4 x .4	1500			1	0.2	X	X		PROPELLANT REQ'D.
2302	LASER PROPULSION TEST	P		96	180	LEO	ANY			SOLAR			N/A	100	0.36	1.5 x .5 x .5	200		5	1	0.25	X	X		COLLECTOR & LASER FROM 2104 & 2105. GH_2 REQ'D.

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

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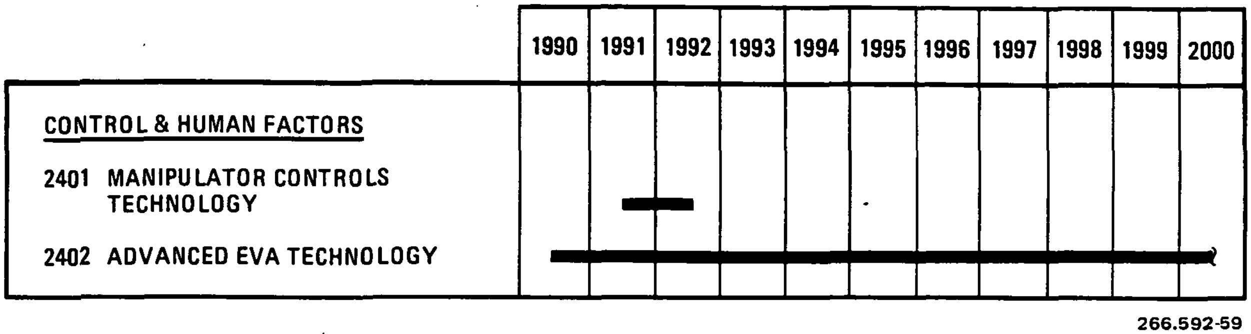

Figure 3-36. Control and Human Factors Missions Time Phasing

3.3.6 TECHNOLOGY DEVELOPMENT -- SPACE STATION SYSTEMS AND OPERATIONS/FLUID AND THERMAL PHYSICS. The Space Station Systems and Operations discipline covers a variety of missions (Figure 3-37); one provides technical verification of a liquid droplet radiator and another conducts life demonstrations of various systems, such as spaceborne power units, propulsion systems and, navigational devices. To reduce cost, the Advanced Control Device mission, 2502, uses the large structure hardware from an earlier mission (2005). Several missions are needed to develop payload-related operations as well as OTV propellant, docking, and maintenance operations, prior to introduction of the OTV -- which is assumed to be available in 1994. A tether maneuvering experiment provides small scale operations validation prior to operations involving costly Shuttle Orbiters and external tanks.

The fluid and thermal physics discipline involves a mission to charge and test the performance of cryogenic heat pipes in space. These lightweight, 15.2m long heat pipes would be fabricated and meticulously cleaned on earth prior to delivery to LEO by the Shuttle.

Requirements for both of the technology demonstration disciplines are incorporated into Table 3-26. Driving requirements for this group are accommodation of the liquid droplet radiator collector in optimum relation to other large deployed systems, as well as accommodating the large structures for the group of payload and OTV-related payload elements. Payload elements in these disciplines are generally labor intensive for rather short durations, involve EVA, and need access to the Station-provided RMS or equivalent equipment. The weights shown for payload and OTV-related missions (2504-2509) are for the unique payload structure, tankage service enclosure, etc., and assume the Space Station provides the interfacing resources (power, data, etc.). An example of the unique payload equipment needed for the Propellant Transfer and Storage mission (2506) is shown in Figure 3-38.

Table 3-25. Payload Requirements Summary Data - Control and Human Factors

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE*		MISSION REQUIREMENTS										PHYSICAL			RESOURCES								COMMENTS
						ORBIT					POINTING						POWER			CREW					
				LAUNCH DATE YR(S)	MSN DUR (DAYS)	PREFERRED		ACCEPTABLE RANGE		VIEWING DIRECTION			OPER ACCEL LIMIT (g)		PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	LEVEL, W (DUR, HR/DAY)		DATA K BPS (HR/DAY)				SVC REQ'D X	RE-CONFIG REQ'D X	
		ATT	FF			ALT (km)	INCL (deg)	ALT (km)	INCL (deg)		ACCY (sec)	JIT-TER (sec/s)		MASS (kg)			OPER	PEAK		SIZE	TIME (AVG) HR/DAY	EVA REQ'D X			
2401	MANIPULATOR CONTROLS TECH	P		91	365	LEO	ANY			N/A	N/A	N/A	N/A	600	12		3150		1.0	2	0.4	X			
2402	ADVANCED EVA TECHNOLOGY	P		90	3600	LEO	ANY			N/A	N/A	N/A	N/A	500	2.2		100			1	0.02	X			

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

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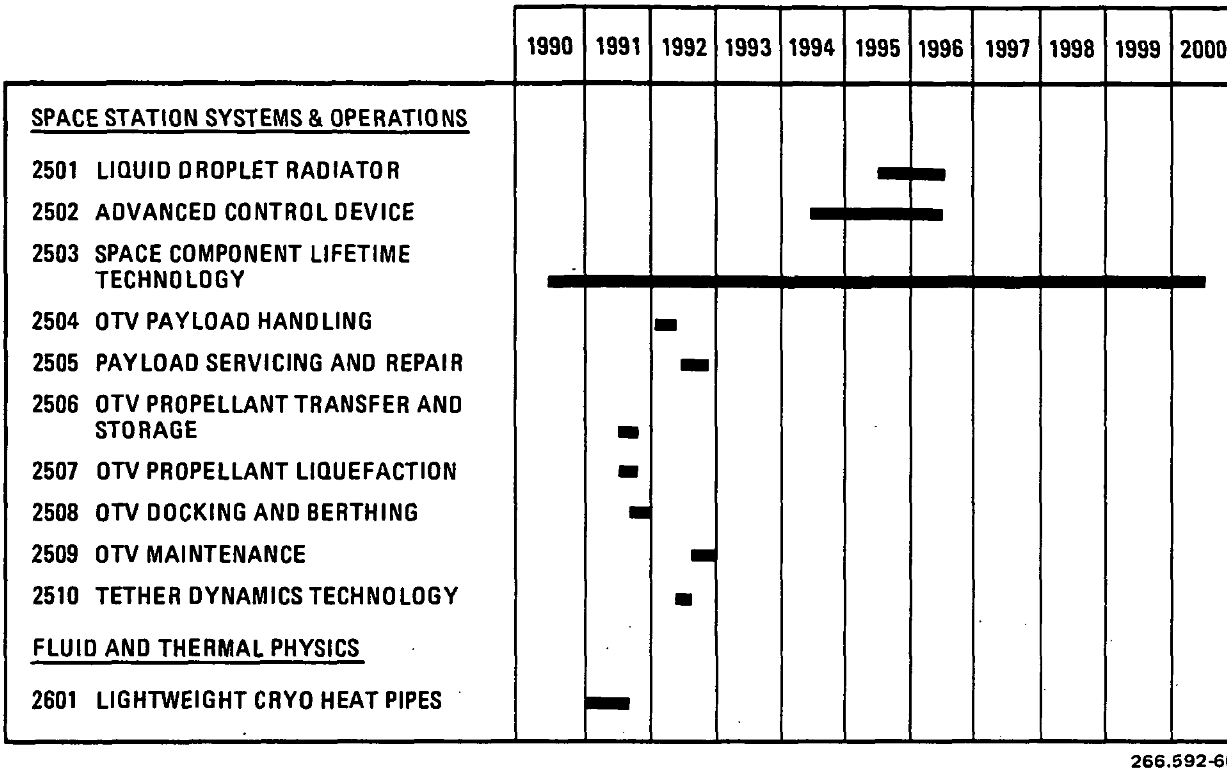

Figure 3-37. Space Station Systems and Operations/Fluid and Thermal Physics Missions

EQUIPMENT
RECEIVER TANK
RECEIVER TANK ACQUISITION SYSTEM
RECEIVER TANK MLI
SUPPLY TANK
SUPPLY TANK ACQUISITION SYSTEM
SUPPLY TANK MLI
TRANSFER LINES
DATA CONTROL & INTERFACE ELECTRONICS
HELIUM STORAGE
SHUTTLE INTERFACE LINES
SUPPORTING TRUSS STRUCTURE
LH_2
HYDRAZINE SUPPLY SYSTEM
FOR ACS MODULE
TOTAL EQUIPMENT WEIGHT (Kg) 2000

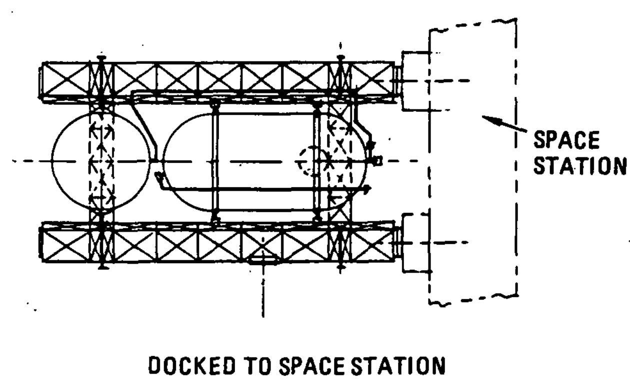

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Figure 3-38. Propellant Transfer and Storage Mission Concept

Table 3-26. Payload Requirements Summary Data - Space Station Systems and Operations/Fluid and Thermal Physics Missions

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE*		MISSION REQUIREMENTS										PHYSICAL			RESOURCES								COMMENTS
				LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT				VIEWING DIRECTION	POINTING		OPER ACCEL LIMIT (g)	MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	POWER LEVEL, W (DUR, HR/DAY)		DATA K BPS (HR/DAY)	CREW			SVC REQ'D X	RE-CONFIG REQ'D X	
						PREFERRED		ACCEPTABLE RANGE																	
		ATT	FF			ALT (km)	INCL (deg)	ALT (km)	INCL (deg)		ACCY (sec)	JIT-TER (sec/s)					OPER	PEAK		SIZE	TIME (AVG) HR/DAY	EVA REQ'D X			
2501	LIQUID DROPLET RADIATOR	P		95	365	LEO	ANY			N/A			N/A	1,000	0.36		1000		1.0	1	0.1	X			
2502	ADVANCED CONTROL DEVICE	P		94	730									400	0.36	100 x 20 x 2.5**	1000		1.0	2	0.2	X		X	**USES STRUCTURE FROM -2005
2503	SPACE COMPONENT LIFETIME TECH	P		90	3650									300		.2 x .2 x .2 (EACH OF SIX)				1	0.2	X		X	SIX COMPONENTS
2504	OTV PAYLOAD HANDLING	P		92	30									2,000		4 x 4.5 x 4.5	300 (2)			2	8	X			TV REQ'D'
2505	PAYLOAD SERVICING & REPAIR	P		92	90									500		9 x 4.5 x 4.5				1	1	X			TV REQ'D.
2506	OTV PROPELLANT TRANSFER & STORAGE	P		91	30									2,000		8.5 x 4.6 x 3.6	500 (2)			1	1				
2507	OTV PROPELLANT LIQUEFACTION	P		91	30									1,000		3.5 x 2 x 2	350 (24)			1	1				
2508	OTV DOCKING & BERTHING	P		91	30									5,900		10 x 4.5 x 4.5	500 (2)			1	2				TV REQ'D.
2509	OTV MAINTENANCE	P		92	30									3,000		8.5 x 7.5 x 7.5	500 (4)		4.0	4	13	X			TV REQ'D.
2510	TETHER DYNAMICS TECH	P		92	3									3,000	0.36	4 X 4 X 2				1	3				
2601	LIGHTWEIGHT CRYO HEATPIPES	P		91	250	LEO	ANY							1,000	0.36	15 X 1 X 1	200	5K**	2.0	1	1.6	X	X		**5 MINUTES TWELVE TIMES DURING THE MISSION.

*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

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3.4 NATIONAL SECURITY MISSIONS

The details of the DOD portion of the study are reported in Book 4. The interface of national security missions with the science and commercial Space Station is discussed in this section.

The DOD study (Figure 3-39) examined the DOD Space Station needs and interaction with the DOD space infrastructure. A top down approach was used to synthesize requirements in the basic categories of RDT&E, operational, and logistic missions. Security and survivability issues were addressed as a special consideration.

Several facts emerge from an evaluation of generic operational mission requirements. They generally require GEO or high inclination orbits and often higher than LEO altitudes. Security and survivability requirements are key and often drivers. A basic conclusion is that dedicated, i.e., not joint with scientific/foreign users, facilities are required.

DOD RDT&E missions are derived from operational missions and directly support their evolvement. When considered as two sets, R&D and T&E, logical differences are evident. Verification T&E for operational missions either require or benefit from performance in the operational environment, in this case -- orbit. On the other hand, R&D missions can usually be performed under different though comparable conditions and are candidates for a low inclination LEO orbit such as that required for most S&A and commercial missions. Furthermore, the survivability requirements become progressively lower -- progressing from operational to R&D. Security is less demanding also but still of concern. The conclusions are, therefore, that R&D activities are suitable for a LEO low inclination orbit, and a joint station offers many advantages. Some T&E missions may also be suitable for a joint Space Station, but others will require operational mission orbits.

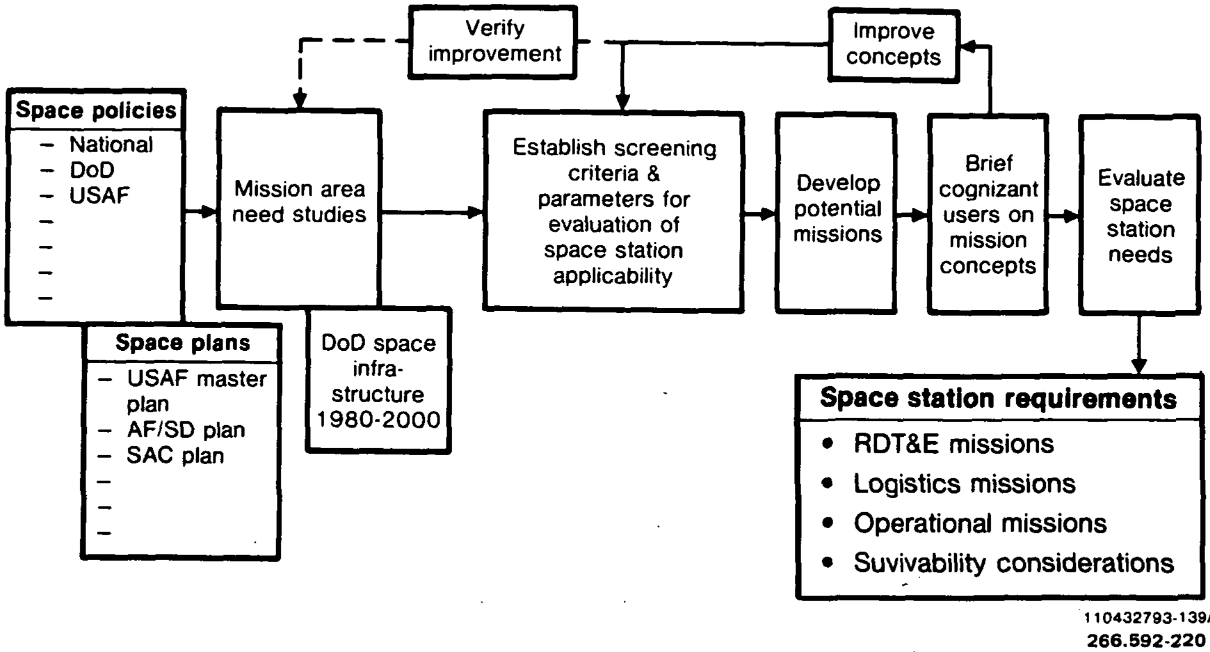

Figure 3-39. DOD Study Flow

The high payoff technology areas for DOD missions were compared to the NASA and commercial missions and a high level of correlation was observed (Table 3-27). However, this is not to infer that the parameters currently defined for DOD and NASA technology objectives are of equal magnitude. In some cases, NASA objectives are more demanding and in others, DOD. The station resource levels derived for the integrated mission requirements will support both. We can draw the conclusion that DOD R&D can be accomplished in the man-operated research and development facility. In fact, many of the objectives may be achieved jointly. Furthermore, the level of station resources required for national security missions are already accounted for in the station architecture defined for Science, Application, and Commercial Missions. How these are applied becomes a function of how the Space Station is operated. For example, missions peculiar to DOD will have special security requirements. This will require either temporal or spatial separation from non-military operations. If temporal separation is chosen, the Space Station will be supporting either military or non-military research and development activities at any given time and the resource levels previously identified for NASA and commercial activities will suffice. If spatial separation is chosen and both types of activities are underway simultaneously in different parts of the Space Station, a higher level of resource may be required depending upon the mission schedule and timeline selected. This is always the case, even for a Space Station devoted only to non-military missions.

Table 3-27. DOD High Payoff Technologies

TECHNOLOGY	SYSTEM PAYOFF	SIMILAR/RELATED NASA/COMMERCIAL MISSIONS
PROPULSION		
LOW-THRUST CHEMICAL	INCREASED PAYLOAD	OTV DEVELOPMENT
HEAVY LIFT CHEMICAL	MILITARY ACCESS TO SPACE	–
ADVANCED PROPULSION SYSTEMS	LARGE STRUCTURES, OTV	2302
ELECTRIC PROPULSION	MANEUVER CAPABILITY	2301
POWER		
LONG-LIFE BATTERIES	IMPROVED SPECIFIC POWER	–
ADVANCED POWER PROCESSING	IMPROVED SURVIVABILITY	2104 THRU 2107
HIGH VOLTAGE DISTRIBUTION	INCREASED SYSTEM CAPABILITY	TECHNOLOGY AVAILABLE BY 1990
NUCLEAR REACTORS	REDUCED WEIGHT	2108
	ENABLE ADVANCED CONCEPTS	
MATERIALS		
ADVANCED COMPOSITES	INCREASED STIFFNESS	
IMPROVED MATERIAL CAPABILITY	REDUCED WEIGHTS	2002, 2003
	SURVIVABILITY	
STRUCTURES		
LARGE DEPLOYABLE ANTENNAS	SPACE RADARS	1106, 2004, 2005, 2007
SPACE BASED FABRICATION, ASSEMBLY, DEPLOYMENT		
LIGHTWEIGHT OPTICS	MILITARY ACCESS TO SPACE	2006
HOT STRUCTURES		–
TELEMETRY AND COMMUNICATIONS		
DATA RATES TOO SMALL, MOBILE EARTH TERMINALS		
K-BAND TECHNOLOGY FOR TELECOMMUNICATIONS	HIGH ACCURACY WIDEBAND LINKS	1111
60 GHz TECHNOLOGY FOR TELECOMMUNICATIONS	ANTI-JAM, LPI SERVICE	
HIGH DATA RATE CROSSLINKS	NULLING	
• MICROWAVE TECHNOLOGY		1111
• LASER COMMUNICATIONS	MULTI-USER CAPABILITY	1108
HIGH PERFORMANCE MULTI-BEAM ANTENNAS	SURVIVABLE MISSION DATA	1106
HIGH POWER, HIGH EFFICIENCY TRAVELING WAVE TUBE AMPLIFIERS		
SENSORS		
LARGE DIAMETER MIRRORS		0001, 2006, 2104
FOCAL PLANE DETECTORS	HIGH RESOLUTION, SCAN RATE	0005, 0175, 0176
• NUMBER OF DETECTORS	HIGH RESOLUTION, LIGHTWEIGHT	
• CCD TECHNOLOGY	SPATIAL/TEMPORAL DATA	
• LOW TEMPERATURE OPERATION	DETECTION/TRACK INFORMATION	
CONTAMINATION CONTROL FOR SYSTEMS	SMALL TARGET DETECTION	0004, 0005
LOW NOISE POWER AMPLIFIERS FOR RADAR APPLICATIONS		0173, 0174, 0179, 0180, 0182, 0183
NAVIGATION, GUIDANCE, AND CONTROL		
POINTING CONTROL SYSTEMS	MANEUVERING CAPABILITY	
• ACCURACY, STABILITY	TARGETING CAPABILITY	2202 THRU 2204
GYRO LIFE	INCREASED LIFE	2502, 2503
INFORMATION PROCESSING		
SPACECRAFT PROCESSORS		
• VERY HIGH SPEED		
• LOW POWER REQUIREMENTS		
ON-BOARD DATA PROCESSING	FLEXIBLE, SURVIVABLE SYSTEMS	
ADVANCED SIGNAL PROCESSORS	AUTONOMOUS SPACECRAFT	
• BANDWIDTH	MULTIMISSION, HIGH DATA CAPACITY	0181 THRU 0184
• A/J MARGIN		
SIGNATURE MODEL PREDICTION ACCURACY	ON-BOARD PROCESSING	
IMAGE PROCESSING SYSTEM IMPROVEMENTS		
HARDENED COMPONENTS		
CRYOGENICS/THERMAL CONTROL		
ACTIVE CRYOGENIC REFRIGERATORS		2503
• LIFETIME	INCREASED ORBITAL LIFE	2507
• THERMAL LOAD	LWIR CAPABILITY	
PASSIVE CRYOGENIC COOLERS		2503
• LIFETIME		
DEPLOYABLE RADIATORS		2501
• SPECIFIC MASS		

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In addition to the operational missions (which are expected to occur in the post year 2000 time frame) and the RDT&E missions that are compatible with the man-operated Space Station as a laboratory, there are two other aspects of importance. The first is for logistics and the second is the interaction with the currently planned DOD space infrastructure.

Logistics missions are similar to the service and maintenance functions defined for non-military free flyers. The details depend upon the degree to which current space system elements can be serviced and to which future free-flyer elements are designed for maintenance and resupply, the orbits in which they function, and the relationship of that orbit to the manned station. These specifics were not accounted for in this study so far as the OTV/TMS servicing functions are concerned for two reasons. First, orbit and functional details of DOD missions are classified and the results could not be incorporated into the civilian missions traffic model. Second, the level of effort for the study did not permit detailed definition of future DOD free flyers. The negative aspects of not having done this analysis are minimal. The impact will be some increase in the defined servicing traffic model.

Interaction with the DOD infrastructure as it is defined today for the 1990s was taken into account. In this case, the Space Station operates as a transportation node. The requirements for transportation from earth to LEO in equivalent Shuttle flights and from LEO to HEO/GEO in equivalent OTV flights (Table 3-28) was used in summary form as part of our traffic model. The data are unclassified at this level of definition and were derived from information in the DOD mission model, Rev 12, and the MSFC nominal mission model, Rev 6.

Table 3-28. DOD Traffic Model

Launch		1990	91	92	93	94	95	96	97	98	99	2000
Earth to LEO (Equivalent STS Flights)	ETR	5	7	6	9	10	10	9	8	14	5	9
	WTR	9	7	6	7	7	3	4	7	6	7	7
LEO to HEO/GEO (Equivalent OTV Flights)	ETR	4	4	4	5	6	7	5	5	8	9	9
	WTR	5	4	3	4	4	2	3	4	3	4	4

3.5 SPACE OPERATIONS

Space operations missions are of two distinct categories: 1) those that are conducted in support of, or are an integral part of, an overall mission, and 2) those that are separate specific missions having operational characteristics. Examples of the first category are: assembly and construction, servicing, and high energy staging of free flyers. An example of the second category is a manned GEO sortie mission. The first mission category is discussed in Section 3.5.1 and the second in 3.5.2.

3.5.1 SUPPORT OPERATIONS. Requirements for operational support of the Science, Applications, Commercial, and Technology Missions were derived during the definition process. These were first identified on a Payload Element Operations Description (Figure 3-40) sheet for each mission/payload. Five main activities were considered: activation, which includes assembly and checkout; service, which covers resupply and replenishment; station operational support, i.e., on a continuous or on a periodic basis of short interval; reconfiguration; and deactivation or removal for return to Earth. These descriptions are included in Appendix I for each payload. The output of this analysis is incorporated into LaRC payload element data sheets.

For payload elements attached to the station, the activation and removal operations times are included along with the operation support times and averaged over the mission period to determine average crew hours per day unless they are of a major nature, in which case they are accounted for separately.

GOCD CODE ________ ELEMENT NAME ____________________

ACCOMODATION: ☐ ATTACHED ☐ FREE FLYER ☐ OTV OPS

1. STATION ACTIVATION (E.G., SET-UP/ASSEMBLY/ATTACHMENT AND CHECKOUT)

DATE(S) ________ INT. HRS ________ EVA HRS ________ EVA CREW ________

☐ NOT APPLICABLE

2. SERVICE (E.G., REPLENISH/RESUPPLY)

INTERVAL _____ DAYS TOTAL SERVICES ________

☐ TMS/OTV REQUIRED ________ STATION HRS PER SERVICE ________

☐ NOT APPLICABLE ________ EVA HRS PER SERVICE ________

EVA CREW SIZE ________

3. STATION OPERATIONAL SUPPORT (AVG. TIME FOR MONITOR, INSPECT, ETC.)

_____ HRS PER DAY (INTERNAL)

_____ HRS PER DAY (EVA)

☐ NOT APPLICABLE

4. RECONFIGURATION

INTERVAL _____ DAYS TOTAL RECONFIGS. ________

☐ TMS/OTV REQUIRED STATION HRS PER RECONFIG. ________

☐ NOT APPLICABLE EVA HRS PER RECONFIG. ________

EVA CREW SIZE ________

5. DEACTIVATION/REMOVAL

DATE(S) ________ INT. HRS. ________ EVA HRS ________ EVA CREW ________

☐ NOT APPLICABLE

6. NOTES (BRIEFLY DESCRIBE TASKS IN 1 THROUGH 5 ABOVE)

TOTAL EVA HRS ________

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Figure 3-40. Payload Element Operations Description

For free flyers, the results are summarized as: emplacements, servicing, reconfigurations, and retrievals. The free flyers have been divided into the three categories of: LEO/HEO (Table 3-29), GEO (Table 3-30), and Planetary or escape missions (Table 3-31) because of the similarities within the categories and differences between them. Separate payload element sheets were not prepared for each of these operational missions because that did not appear to be necessary and tended to confuse the data set.

Table 3-29. LEO/HEO Payload Model

GDCD NO.	PAYLOAD ELEMENT NAME	ORBIT ALTITUDE (KM)	INCLINATION (DEG)	UNIT WT (KG)	UNIT LENGTH (M)	P/L ELEMENT DEFINITION: INTEG. INST. PKG. (1)	P/L ELEMENT DEFINITION: SPACECRAFT	SPACECRAFT INCL. ORBIT XFER PROPUL.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	ASTROPHYSICS																		
	• ASTRONOMY																		
0001	LARGE DEPLOYABLE REFLECTOR	700	28.5	55,000			X							E		S/C		S/C	R
0003	VERY LONG BASE-LINE INTERFEROMETER	400	57	1,354	5	X								E	S	S	R		
0004	SPACE TELESCOPE	600	28.5	11,600	13.1		X				E		S/C		S/C	R			
	• HIGH ENERGY (COSMIC, γ, X-RAY)																		
0030	GAMMA RAY OBSERVATORY (1988 LAUNCH)	400	28.5	11,000			X	X	S	S	S	R							
0033	ADV X-RAY ASTROPHYSICS FACILITY	500	28.5	10,267	12.8		X			E		S/C		S/C		S/C		S/C	
0038	X-RAY TIMING EXPLORER	400	28.5	1,000	2		X	X	E		R								
	• SOLAR PHYSICS																		
0060	SOLAR INTERNAL DYNAMICS MISSION	400	99	4,540						E	R								
0061	SOLAR CORONA DIAGNOSTIC MISSION	400	28.5	1,800			X	X			E	R							
0062	ADVANCED SOLAR OBSERVATORY	400	57	12,500	8.2	X						E		S		S		S	
	EARTH EXPLORATION																		
	• EARTH RESOURCES																		
0172	OPERATIONAL LAND SYSTEMS	500	90	2,000	4		X	X	E		S/C		S/C		S/C		S/C		R
0180	FREE-FLYING IMAGING RADAR EXP (FIREX)	400	90	2,000	4	X				E			S				R		
0181	Z-CONTINUOUS COVERAGE	1,000	100	8,578	16		X	X					E	S/C	R				
0182	Z-HYDROLOGIC CYCLE PRIORITY	1,000	100	8,708	16		X	X							E	S/C	R		
0183	Z-SPECIAL COVERAGE	1,000	100	18,821	17		X	X									E	S/C	R
	ENVIRONMENTAL OBSERVATIONS																		
	• WEATHER/CLIMATE, OCEAN, SOLAR/ TERRESTRIAL, ATMOS RESEARCH																		
0205	METEORLOGY INST GRP OPS P/L	400	57	2,000	4.4	X							E		S		R		
0207	TIROS FOLLOW-ON (2)	800	98	2,000	9		X				E								
0221	OCEAN INSTRUMENT PAYLOAD	500	98	1,600	10	X						E		S			E R		S
0222	OCEAN TOPOGRAPHY EXP. (TOPEX) (1988 LCH)	1,384	63.4	1,600	6		X		S			S			S		R		
0241	EARTH RADIATION BUDGET EXP (ERBE)	600	46	55	1	X (PIGGY BACK P/L)				E	R								
		800	98	55	1					E	R								
0266	WINDSAT	800	98	2,260	4.5		X				E		S		S		S		R
0267	UPPER ATMOSPHERE RESEARCH P/L	400	57	2,500	4.5	X							E		S		R		
	COMMERCIAL																		
1206	ELECTROPHORESIS F/F – BIOLOGICALS (INITIAL LCH 1986)	≥400	ANY	9,987	5.5		X	X	E 9S	8S R	6S R	4S R	2S R	R					
1000	GEOLOGICAL RECONNAISSANCE	500	90						E	[ACCOMMODATED BY GDCD 0172; 0174; 0175 FOR DEVELOPMENT]									
1002	WORLDWIDE COTTON ACREAGE & PROD	500	45						E	[ACCOMMODATED BY GDCD 0172]									
1003	PETROLEUM AND MINERAL LOCATION	920	99.2						E	[ACCOMMODATED BY GDCD 0172]									
1302	GAMMA RAY ASTRONOMY	400	28.5						E	[ACCOMMODATED BY GDCD 0030]									

NOTES: TMS AVAILABLE IN 1990; OTV AVAILABLE IN 1994
E = EMPLACE, S = SERVICE, C = CONFIGURATION CHANGE,
R = RETRIEVE

(1) THESE P/L ELEMENTS ASSUME ACCOMMODATION ON A PLATFORM OR LEASECRAFT – TYPE SPACECRAFT WHICH HAS ORBIT TRANSFER PROPULSION.

(2) TWO SATELLITES

266.592-12.1

Table 3-30. Geosynchronous and DOD Payload Model

GDCD NO.	PAYLOAD ELEMENT NAME	ORBIT ALTITUDE (KM)	INCLINATION (DEG)	UNIT WT (KG)	UNIT LENGTH (M)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	ASTROPHYSICS															
	• ASTRONOMY															
0002	FAR UV SPECTROSCOPY EXPLORER (LAUNCH IN 1989)	GEO	28.5	1360 (INCL AKM)												
	ENVIRONMENTAL OBSERVATIONS															
	• WEATHER/CLIMATE															
0203	LIGHTNING MAPPER	GEO	0	900(1)	6							E				
0204	GEOSYNC MICROWAVE SOUNDER	GEO	0	5850	10							E		S		R
0206	GOES FOLLOW-ON	GEO	0	500(2)	3.6					E						R
	(1) 5-EACH AT 900KG/SPACECRAFT															
	(2) 3-EACH AT 500KG/SPACECRAFT															
	COMMERCIAL MISSIONS															
	• COMMUNICATIONS															
1001	REMOTE ATMOSPHERIC SENSING	GEO	0			E	(ACCOMMODATED BY GDCD 0206 AND BY GDCD 0262 FOR DEVELOPMENT)									
1100	SMALL COMMUNICATIONS SATELLITES	GEO	0	<816	2	6	6	8	10	10	10	5	7	6	6	7
1101	MEDIUM COMMUNICATIONS SATELLITES	GEO	0	<2041	4	4	4	6	4	3	4	3	3	3	3	3
1102	LARGE COMMUNICATIONS SATELLITES	GEO	0	>2313	5	5	6	6	7	10	10	12	13	14	14	17
	• PLATFORMS															
1103	EXPERIMENTAL GEO PLATFORM	GEO	0	5450	<10	E		S								
1104	OPERATIONAL GEO PLATFORM	GEO	0	5450(3)	<10					2E	E S	2E S	E 2S	2E S	E S	2E 2S
	(3) 11 EMPLACEMENT FLIGHTS OF 5450KG EACH (6 FOR ONE PLATFORM & 5 FOR SECOND PLATFORM) PLUS 8 REVISIT FLIGHTS															
	OPERATIONAL															
	• OTHER MISSIONS															
4000	MANNED GEO SORTIE CAPSULE	GEO	0	4535	4.4						E	E	E	E	E	E
4001	MANNED GEO SUPPORT MODULE	GEO	0	8160	6.8											E
	DOD SCENARIO – DERIVED FROM NOMINAL MISSION MODEL, REV 6, MSFC PS01, 9/30/82 AND DOD MSN MODEL REV 12, SUMMARY LEVEL.															
	{EQUIVALENT OTV FLIGHTS} →		ETR			4	4	4	5	6	7	5	5	8	9	9
	{BOTH GEO & HEO MISSIONS} →		WTR			5	4	3	4	4	2	3	4	3	4	4

NOTES: E = EMPLACE, S = SERVICE, C = CONFIGURATION CHANGE, R = RETRIEVE
TMS AVAILABLE IN 1990; OTV AVAILABLE IN 1994

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Table 3-31. Escape Missions Payload Model

GDCD NO.	PAYLOAD ELEMENT NAME	ORBIT ALTITUDE (KM)	INCLINATION (DEG)	UNIT WT (KG)	ESCAPE ΔV FROM LEO (M/S)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	PLANETARY EXPLORATION	SPACECRAFT TO ESCAPE FROM 370-400 CIRCULAR ORBIT														
	• PLANETARY OBSERVATIONS															
0103	MARS GEOCHEM/CLIMATOLOGY ORBITER		28.5	5,600	3,380			E								
0104	MARS ARONOMY ORBITER			5,600	3,380			E								
0105	VENUS ATMOSPHERIC PROBE								E							
0106	LUNAR GEOCHEMISTRY PROBE			480					E							
0107	TITAN PROBE			960	7,390						E					
0108	SATURN ORBITER (TITAN FLY-BY)			1,800									E			
0109	MARS SURFACE NETWORK (LANDER)												E			
0110	SATURN PROBE												E			
	• SOLAR SYSTEM MISSIONS															
0121	COMET RENDEZVOUS			2,200				E								
0122	MAIN BELT ASTEROID RENDEZVOUS			2,700				E								
0123	COMET SAMPLE RETURN (HMP)			1,200						E						
0124	NEAR EARTH ASTEROID RENDEZVOUS		28.5	1,170	4,120								E			

NOTES: TMS AVAILABLE IN 1990; OTV AVAILABLE IN 1994
E = EMPLACE, S = SERVICE, C = CONFIGURATION CHANGE, R = RETRIEVE

266.592-12.2

From these requirements, an analysis was made, as part of the mission implementation task, to determine the OTV and TMS operations activities for free flyers. As an aid in performing this analysis, those individual missions having on-orbit propulsion capability were also identified.

In reviewing the traffic level over the decade, we felt the "planning horizon" problem was again influencing the data. There is a higher level of activity early in the decade than there is later. One would, in general, expect the opposite. Part of this is due to the twice a year servicing of five free-flyer MPS (electrophoresis) missions. These are all conceived as being in operation prior to the advent of the Space Station. We felt that had this timing not been the case, these missions could have been station attached and the free-flyer servicing traffic in the early years reduced significantly. Without these missions, the traffic model still increases for a period of time and then dwindles almost to zero, which is an indication that users see more clearly needs within the near term than in the far term. We feel that as techniques and capabilities are proven in the early years, planning and provisions for the use of servicing will increase in the out years. The upcoming Solar Max Repair Mission should do much to improve confidence in on-orbit repair and servicing. Also, the data reflects planned servicing actions only. Necessary unplanned maintenance actions will increase the traffic, especially in the out years, which are expected to have a larger accumulation of on-orbit free flyers. For this reason, we chose to make a projection of needs in the out years as a basis for the servicing implementation analysis.

The projection analysis is difficult because no clear patterns emerge. Examining the emplacement/servicing/retrieval requirements separately for the low, mid, and high inclination gives a general impression of essentially constant traffic levels. Yet there are a few more per year in the mid years than in the early years. However, calculating growth rates over short term periods can be very misleading as widely different values can be obtained depending on the years chosen. Furthermore, the base values are so small (3) that a small growth rate would be difficult to observe in a 5 year period or less. The communication satellite traffic was examined and found to have a long term growth rate of approximately 7.5%. This rate applied to the LEO/HEO missions would cause a beginning level of 3 to grow to 5 in 7 years, which is similar to the low and high inclination traffic levels when examined separately. In the aggregate, there are 9 missions in 1990 and 12 in 1995 (again without the electrophoresis experiment). This is a 7.5% growth rate. Everything considered, this modest growth rate is believed to be conservative and was used for the out year traffic projections (Figure 3-41).

If a discount factor of 50% is applied to the commercial electrophoresis free-flyer traffic, the 1990 total for low inclination becomes 8. The 7.5% growth factor applied to this will make the 1993 total 10 (compared to a data base of 11), the year 1995 total 11, and the year 2000 total 16.

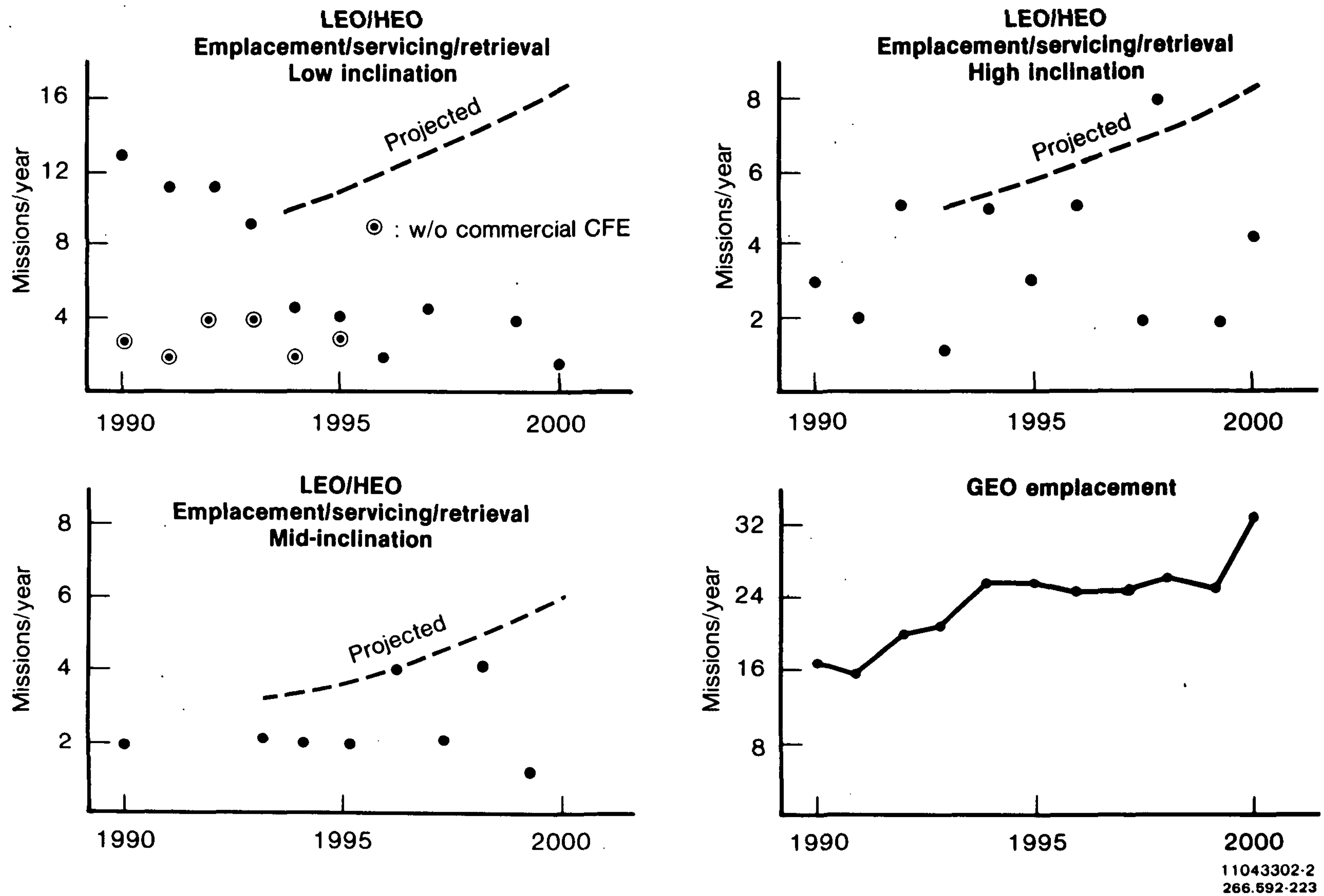

Figure 3-41. Free-Flyer Traffic Model

3.5.2 SPACE OPERATIONS MISSIONS. Two specific missions have been identified by GDC as space operations candidate missions. (Within the NASA LaRC type numbering system, Type 18 "other" best fits these missions.) Both missions involve development activity related to placing and supporting a manned presence at geosynchronous orbit altitude. Both missions are intimately linked together and can be described in terms of operations concepts. (Further descriptions may be found in Book 1, Appendix A.)

The first mission is the Manned Geosynchronous Sortie Capsule and is designed as payload element 4000. It is launched initially in 1995 and yearly thereafter through the year 2000. The Manned Geosynchronous Sortie Capsule is delivered by the Shuttle to the Space Station where systems are checked out and the capsule is manned. The capsule could be mated to the upper stage at LEO prior to departure, or the capsule/upper stage could be delivered simultaneously. The upper stage delivers the capsule to GEO where it remains attached to the upper stage for a short time period, e.g., 1-2 days, while manned operations are conducted. The upper stage injects the capsule into return transfer orbit. The capsule uses aerodynamic braking to assist in returning to LEO. Alternatively, the capsule could remain attached and the OTV could provide aero braking for both elements. Routine capsule refurbishment could be accomplished at LEO, or the sortie capsule could be returned to the ground for refurbishment. Figure 3-42 shows an operations concept for this mission and the relationship to the Manned Geosynchronous Support Module mission, payload element 4001.

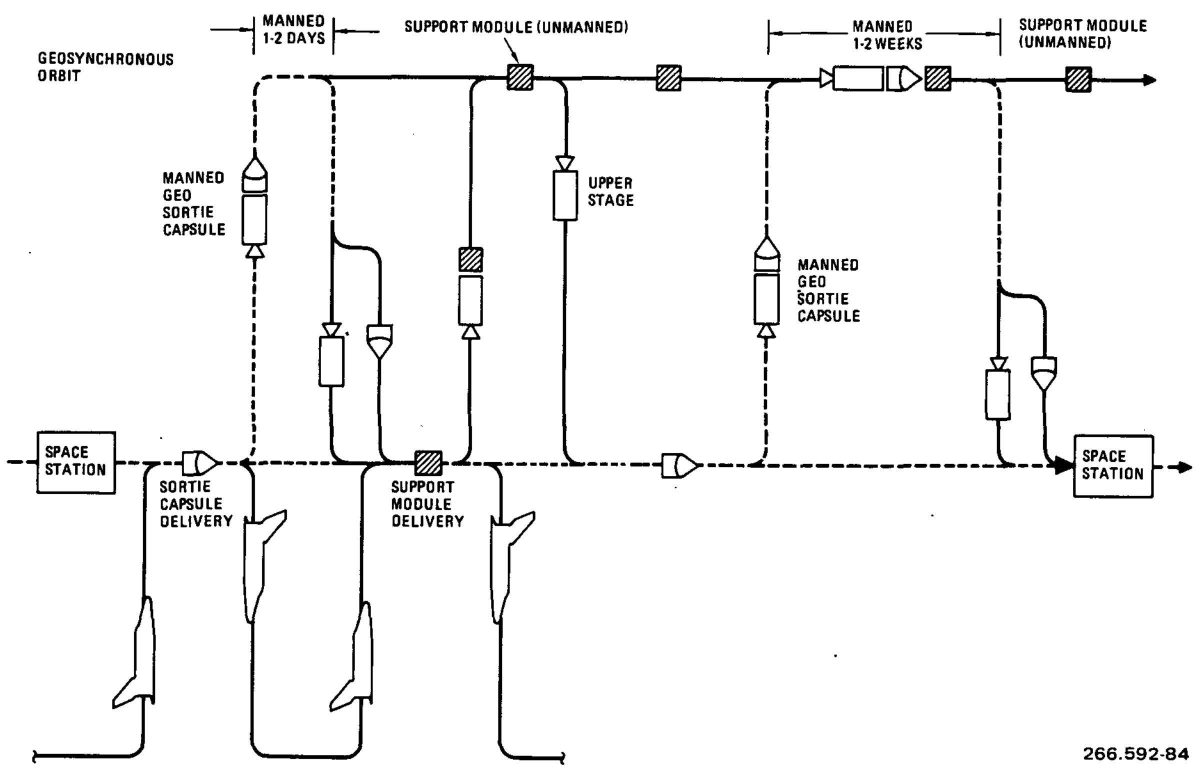

Figure 3-42. Manned Geosynchronous Missions Operations Concept

The Manned Support Module mission is launched in the year 2000 and uses the Shuttle to deliver the support module/upper stage to low earth orbit, or the module could be mated to upper stage at LEO prior to departure. The upper stage delivers the support module in an unmanned status to GEO for later rendezvous with a manned sortie capsule (refer to payload element 4000). The support module provides crew accommodations for periods of 1-2 weeks, and also reliquifies the cryogenic upper stage boil-off. The sortie capsule is used to return the crew to the Space Station or Shuttle at LEO. The support module remains on-orbit (probably in a quiescent mode) awaiting the next manned sortie missions. Requirements for the manned geosynchronous missions are summarized in Table 3-32. The driving requirements on the Space Station are support of on-orbit checkout of a man-rated OTV and manned sortie capsule and the operations involved in orbital recovery of the capsule.

Table 3-32. Payload Requirements Summary Data - Operations

GDC NO.	PAYLOAD ELEMENT NAME	ACCOM MODE *		MISSION REQUIREMENTS										PHYSICAL			RESOURCES								* COMMENTS
				LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT				VIEWING DIRECTION	POINTING		OPER ACCEL LIMIT (g)	MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	POWER LEVEL, W (DUR, HR/DAY)		DATA K BPS (HR/DAY)	CREW			SVC REQ'D X	RE-CONFIG REQ'D X	
						PREFERRED		ACCEPTABLE RANGE																	
		ATT	FF			ALT (km)	INCL (deg)	ALT (km)	INCL (deg)		ACCY (sec)	JIT-TER (sec/s)					OPER	PEAK		SIZE	TIME (AVG) HR/DAY	EVA REQ'D X			
	MANNED GEOSYN MISSIONS																								
4000	MANNED GEO SORTIE		P	95 (1)	1	GEO	0							4,535		4.4 X 3.3 X 3.3				2	12				
4001	MANNED GEO SUPPORT MODULE		P	00	1	GEO	0							8,160		6.8 X 4.5 X 4.5				2	12				UNMANNED WHEN LAUNCHED.

NOTE
(1) INITIAL LAUNCH DATE. ADDITIONAL LAUNCHES AT A RATE OF ONE PER YEAR. SEE MISSION MODEL.
*ACCOM. MODE: P = PREFERRED; A = ACCEPTABLE

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SECTION 4

INTEGRATED MISSION REQUIREMENTS

During the Mission Definition activity it was necessary to make an initial appraisal of whether the mission would be operated in a manned or a free-flyer mode to be able to define the physical aspects of the mission. This was iterated during the Integration activity along with several other mission analyses. The results were fed back into the mission descriptions. The first, and most important part of the integration analysis was to divide the mission set into the two basic types, attached and free flying (Figure 4-1). From that point on they are treated differently because of the differences in Space Station roles.

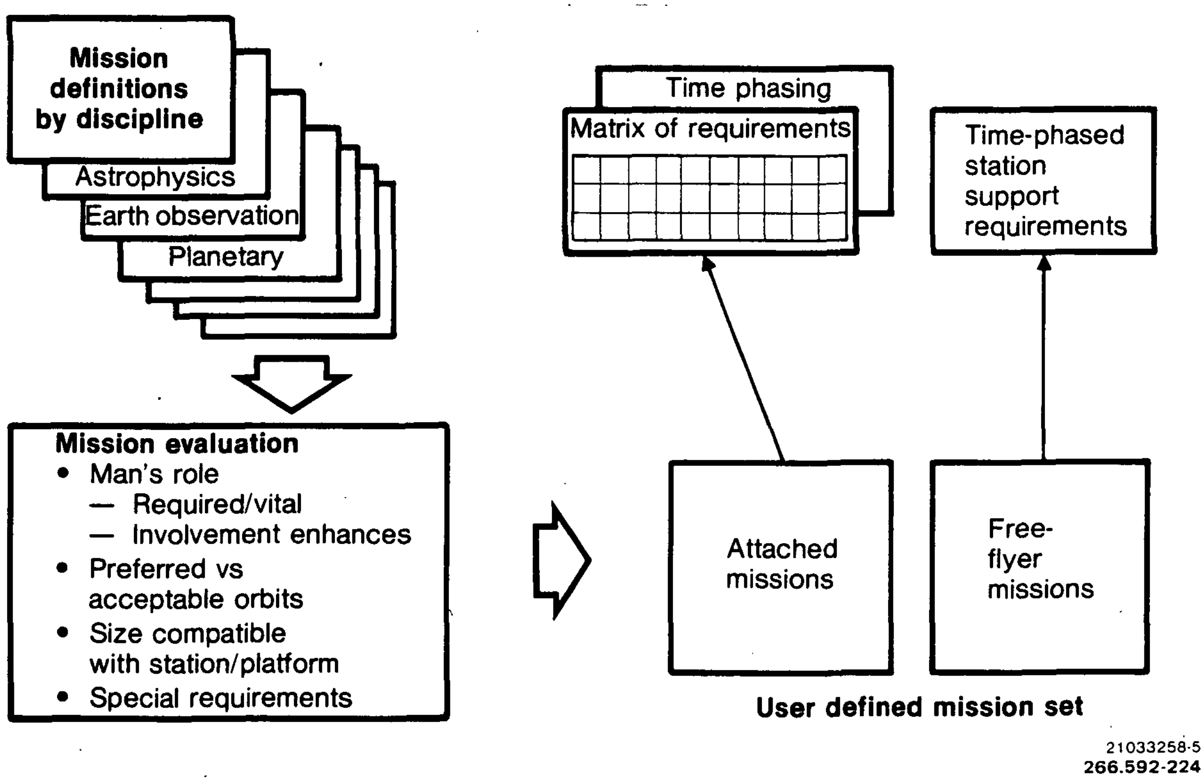

Figure 4-1. Integration of Requirements

The distinction between the first mission type and the second is the requirement for continuous crew tending of the mission experimental apparatus or interaction during mission operations. This type includes experiments in life sciences, materials science, and the operation of observational facilities usually of an experimental nature. These missions are too intensely observer-interactive for the use of automated systems, require configuration changes that are too data-dependent to be predictable *a priori*, are judged to be too developmental to operate reliably without attention or adjustment for periods of time consistent with periodic revisits, or have some other special requirements that dictate constant attention.

The second type are either downward-looking or outward-looking, devoted to a wide range of earth-observing and astrophysics payloads, respectively. Their principal characteristic is the ability they provide for making a number of mutually supportive observations using an array of high-capability instruments over long observational periods. They require man tending for instrument calibration, repair and replacement, and consumable replenishment.

For attached or Station accommodated missions, the most important need is to determine time-phased station resource requirements. The principal requirements are power levels, crew size and hours per day, pressurized volume, and data rates.

The determination for attached versus free-flyer accommodation is straightforward for most missions but in some cases it is not so obvious. This is especially true in the Astrophysics discipline where considerable technology exists for unmanned, untended free-flyer satellites. Some of them are very large with stringent pointing requirements and often severe contamination limits. On the other hand, based upon similar activities in earth observatories, the missions can be enhanced by man's direct access to focal plane instruments. Top level tradeoffs were made to determine the accommodation assignments. Although some missions were originally conceived as free flyers, the overall utility of the mission was judged to be significantly enhanced by direct man support and they were assigned to the Station. Some of these trade studies were concerned with the operation of the mission versus the operation of the Station and their compatibility. Another was evaluating the ability to design the payload element equipment for greater utility and cost effectiveness by performing assembly at the Station, for later installation in the Station or as a free flyer, while considering the problems concerned with space assembly and checkout. Another was to examine manual versus automated operation of the mission to provide the greatest experimental value to the scientist. Evaluation of EVA activities during assembly and later to support the vehicle were made.

Pressurized volumes along with the number and size of externally mounted equipment are also important. Pointing requirements for direction and accuracy/stability as they reflect onto the Station as interface requirements must be accounted for. Those missions with severe pointing accuracy/stability requirements must provide their own pointing equipment, as the Station's capabilities are limited by the realities of a large platform.

It is not meaningful to sum or integrate requirements for power, data, or equipment sizes for free flyers. The important considerations are those related to mission support by the Station in terms of: assembly/construction, emplacement, service, reconfiguration, and retrieval.

The purpose of these data is to provide a basis for architectural options studies to determine the type, location, and general size of Space Station elements.

A positive response to the following is required for man-operated Station attached missions and payloads:

a. Launch/operational date within 1990-2000 time period.

b. LEO altitude, i.e., 400-500 km, circular.

c. Inclination compatible, i.e., not unusual/peculiar. 28.5 degrees, 57 degrees and polar orbit cases segregated but considered candidates. Preferred and acceptable orbits defined.

d. Man's presence/involvement required, e.g., to handle/process live specimens.

e. Man's direct involvement can enhance the mission through:

   1. Continuous/periodic interaction

   2. Frequent, periodic adjustment/calibration

   3. Frequent, periodic sample replacement, product removal, or configuration change

   4. Perception, recognition, comprehension, or deduction

f. Shock/disturbance and contamination compatible with continuous manned operations and Station resupply operations at approximately 90-day intervals.

g. Pointing/stability compatible with manned operations.

h. Size compatible with a Station.

Missions that require man-tending at longer intervals and for lower levels of involvement are classified as free flyers. Long term, i.e., 1-3 year, periodic servicing for the following is suitable for the free-flyer mode:

a. Product removal/raw material supply, sample replacement, and configuration change.

b. Adjustment/calibration

c. Consumables resupply

All free flyers are candidates for unscheduled maintenance and repair.

Free-flyer missions can be divided into two classes: those suitable for separate satellites and those suitable for integration with other similar/compatible missions on a larger, unmanned platform. For requirements definition purposes, we have treated all of them as separate entities and identified those that are suitable for installation on a platform. Two exceptions are the experimental GEO Platform (1103) and Operational GEO Platform (1104) missions under Commercial Communications, which are platforms by definition.

Some missions designated for Station operations have lower levels of manned involvement and have the potential for accommodation as free flyers. In these cases, we have always carried them in the preferred, i.e., attached mode, group with the alternative being identified to provide some flexibility during the implementation analysis task. The baseline time-phased mission set described in Section 4.4 reflects those instances where the flexibility was utilized and re-assignments made.

The results of the accommodation analysis showing the preferred, i.e. selected, accommodation mode and alternative mode are presented in Table 4-1. By showing the incompatibility with an alternate accommodation, it is possible to indicate the reason also. This table also presents the preferred and acceptable orbit data.

Some missions have a development phase, which requires or is enhanced by man's direct involvement, and then evolve into an operational phase that can well be accommodated as a free flyer. The two phases generally have different acceptable orbits. In these cases, the two phases have been treated as two separate missions. An example of this pairing is Meteorology Instrument Group Development Payload (0202) and Meteorological Instrument Group Operations Payload (0206). Here the mission payload element descriptions are the same. The free-flyer mission could be accommodated as a separate satellite or on a platform. We did not undertake the design definition of the spacecraft portion of such satellites during this study. The payloads were identified as being suitable for support by a Leasecraft-type spacecraft if flown as separate satellites. Certain other S&A missions such as Advanced Solar Observatory (0062) had definition data available for the instrument package only. Here also we did not undertake a spacecraft design as part of the study because it did not appear to be appropriate. They too have been identified as being suitable for support by a Leasecraft-type spacecraft or on a platform.

4.1 INTEGRATION OF REQUIREMENTS

Missions with operational (launch) dates prior to 1990, which was groundruled as the Space Station IOC date in the Study RFP, would be automatically classified as free flyers. Also, those with HEO, i.e., greater than 400-500 km altitude, or peculiar orbit inclination requirement such as 46 degrees or 63.4 degrees would become free flyers. Beyond these basic criteria, the role of man in performing the mission is the key criterion. The description of man's role in space has been studied by NASA and others. It is summarized in Table 4-2.

Table 4-1. Missions Accommodations Summary (Sheet 1 of 9)

	MISSIONS	DATE	PREFERRED ALTITUDE (km)	PREFERRED INCLINATION (deg)	ACCEPTABLE ALTITUDE (km)	ACCEPTABLE INCLINATION (deg)	NOT FREE FLYER COMPATIBLE	SELECT'D ACCOM-MODAT'N: ATTACHED	SELECT'D ACCOM-MODAT'N: FREE FLYER	NOT PLATFORM COMPATIBLE	REMARKS
•	SCIENCE AND APPLICATIONS MISSIONS										
	<u>ASTROPHYSICS</u>										
	ASTRONOMY										
0000	STARLAB	1992	400	28.5	370-435	28-57		X			
0001	LARGE DEPLOYABLE REFLECTOR	1995	700	28.5	700	28-50			X	X	OPERATIONAL CONSIDERATION
0002	FAR UV SPECTROSCOPY EXPLORER	1989	GEO	28.5					X	X	OPERATIONAL CONSIDERATION
0003	VERY LONG BASELINE INTERFEROMETRY DEMO	1995	400	57	400-5000	28-57			X		
0004	SPACE TELESCOPE	1992	600	28.5					X	X	OPERATIONAL, PROGRAMMATICS
0005	SHUTTLE IR TELESCOPE FACILITY	1990	400	28.5	300-400	28-57		X			
	HIGH ENERGY										
0030	GAMMA RAY OBSERVATORY	1988	400	0	350-450	0-28			X	X	PROGRAMMATICS
0031	HIGH THROUGHPUT MISSION	1997	400	28.5				X			
0032	LARGE AREA MODULAR ARRAY	1992	400	28.5				X			
0033	ADVANCED X-RAY ASTROPHYSICS FACILITY	1991	500	28.5					X	X	OPERATIONAL, PROGRAMMATICS
0034	HIGH RESOLUTION X AND GAMMA RAY SPECTROMETER	1993	400	28.5				X			
0035	HIGH ENERGY ISOTOPE EXPERIMENT	1995	400	57	370-435	57		X			
0036	SPECTRA OF COSMIC RAY NUCLEI	1995	400	57	370-435	28-57		X			
0037	TRANSITION RADIATION AND IONIZATION COLORIMETER	1995	400	57	370-435	28-57		X			
0038	X-RAY TIMING EXPLORER	1990	400	28.5					X	X	PROGRAMMATICS
	SOLAR PHYSICS										
0060	SOLAR INTERNAL DYNAMICS MISSION	1991	400	99					X		
0061	SOLAR CORONA DIAGNOSTICS MISSION	1992	400	28.5					X		
0062	ADVANCED SOLAR OBSERVATORY	1993	400	57	370-435	28-57			X		

266.592-16.1

Table 4-1. Missions Accommodations Summary (Sheet 2 of 9)

MISSIONS	DATE	PREFERRED ALTITUDE (km)	PREFERRED INCLINATION (deg)	ACCEPTABLE ALTITUDE (km)	ACCEPTABLE INCLINATION (deg)	NOT FREE FLYER COMPATIBLE	SELECT'D ACCOMMODAT'N ATTACHED	SELECT'D ACCOMMODAT'N FREE FLYER	NOT PLATFORM COMPATIBLE	REMARKS
• SCIENCE AND APPLICATIONS MISSIONS (Cont.)										
EARTH AND PLANETARY EXPLORATION										
PLANETARY OBSERVATIONS										
0103 MARS GEOCHEMISTRY/CLIMATOLOGY ORBITER	1992	LEO	28.5					X	X	
0104 MARS AERONOMY ORBITER	1992	(DELIVERY ALT. FOR ESCAPE PAYLOADS)	↓					X	X	
0105 VENUS ATMOSPHERE PROBE	1993	↓	↓					X	X	
0106 LUNAR GEOCHEMISTRY ORBITER	1993	↓	↓					X	X	
0107 TITAN PROBE	1995	↓	↓					X	X	
0108 SATURN ORBITER	1997	↓	↓					X	X	
0109 MARS LANDER	1997	↓	↓					X	X	
0110 SATURN PROBE	1997	↓	↓					X	X	
SOLAR SYSTEM MISSIONS										
0121 COMET T2 RENDEZVOUS	1992	LEO	28.5					X	X	
0122 MAIN-BELT ASTEROID RENDEZVOUS	1992	LEO	28.5					X	X	
0123 COMET HMP SAMPLE RETURN	1994	↓	↓					X	X	
0124 NEAR-EARTH ASTEROID RENDEZVOUS	1997	↓	↓					X	X	
EARTH DYNAMICS										
NO PAYLOAD ELEMENTS IDENTIFIED IN THIS DISCIPLINE										
CRUSTAL MOTION										
0151 DETECTION AND MONITORING OF EPISODIC EVENTS	1995	450	90	400-500	80-100	X	X			OPERATIONAL CONSIDERATIONS
0152 GEOSCIENCE–CRUSTAL DYNAMICS STUDIES	1990	500	50	300-600	50-90		X			
GEOPOTENTIAL FIELDS										
0161 EARTH SCIENCE RESEARCH–GEOPHYSICAL INVESTIGATION	1994	400	90	275-500	85-95	X	X			MANNED RESEARCH

266.592-16.2

Table 4-1. Missions Accommodations Summary (Sheet 3 of 9)

	MISSIONS	DATE	PREFERRED ALTITUDE (km)	PREFERRED INCLINATION (deg)	ACCEPTABLE ALTITUDE (km)	ACCEPTABLE INCLINATION (deg)	NOT FREE FLYER COMPATIBLE	SELECT'D ACCOM-MODAT'N ATTACHED	SELECT'D ACCOM-MODAT'N FREE FLYER	NOT PLATFORM COMPATIBLE	REMARKS
	• SCIENCE AND APPLICATIONS MISSIONS (Cont.)										
	EARTH RESOURCES										
0171	RENEWABLE RESOURCES–EARTH SCIENCE RESEARCH	1995	400	90	300-500	57-90		X			
0172	OPERATIONAL LAND SYSTEMS	1990	500	90	500-1000	80-100			X		
0173	SHUTTLE ACTIVE MICROWAVE EXPERIMENT (SAMEX-C)	1992	400	90	275-500	28-90	X	X			OPERATIONAL CONSIDERATIONS
0174	EARTH OBS INSTRUMENT DEVEL (MICROWAVE TECH)	1990	1000	90	400-1600	28-90	X	X			MANNED RESEARCH
0175	EARTH OBS INSTRUMENT DEVEL (EXTRA VISIBLE & RF)	1992	400	90	275-1000	28-90	X	X			MANNED RESEARCH
0176	EO SENSOR/TECHNIQUE/ANALYSIS/AUTOMATED SYSTEM DEVEL	1990	500	90	275-925	28-90	X	X			MANNED RESEARCH
0177	GEOSCIENCE–GEOLOGY REMOTE SENSING	1990	500	90	300-600	80-100		X			
0179	IMAGING RADAR FOR EARTH RESOURCES INVENTORY & MONITORING	1994	400	57	300-500	28½-90		X			
0180	FREEFLYING IMAGING RADAR EXPERIMENT (FIREX)	1991	400	90	375-450	80-100			X		
0181	Z – CONTINUOUS COVERAGE	1994	1000	100	400-1000	96-100			X		
0182	Z – HYDROLOGIC CYCLE PRIORITY	1996	1000	100	400-1000	96-100			X		
0183	Z – SPECIAL COVERAGE	1998	1000	100	400-1000	96-100			X		
0184	Z – CONTINUOUS AND SPECIAL COVERAGE	2000	500	97.5	400-1000	90-100	X	X			OPERATIONAL CONSIDERATIONS
	ENVIRONMENTAL OBSERVATIONS										
	WEATHER/CLIMATE										
0201	SATELLITE DOPPLER METEOROLOGICAL RADAR TECH DEVEL	1998	400	57	300-500	28-90	X	X			MANNED RESEARCH
0202	METEOROLOGY INSTRUMENT GROUP DEVELOPMENT PAYLOAD	1992	400	57	300-500	28-90	X	X			MANNED RESEARCH
0203	LIGHTNING MAPPER	1996	GEO	0					X		
0204	GEOSYNCHRONOUS MICROWAVE SOUNDER	1996	GEO	0					X		
0205	METEOROLOGY INSTRUMENT GROUP OPERATIONS PAYLOAD	1994	400	57	300-500	57-90			X		
0206	GEOSTATIONARY OPNL. ENV. SATELLITE (GOES) FOLLOW-ON	1994	GEO	0					X		
0207	TIROS FOLLOW-ON	1992	800	98					X		

266.592-16.3

Table 4-1. Missions Accommodations Summary (Sheet 4 of 9)

	MISSIONS	DATE	PREFERRED ALTITUDE (km)	PREFERRED INCLINATION (deg)	ACCEPTABLE ALTITUDE (km)	ACCEPTABLE INCLINATION (deg)	NOT FREE FLYER COMPATIBLE	SELECT'D ACCOM-MODAT'N ATTACHED	SELECT'D ACCOM-MODAT'N FREE FLYER	NOT PLATFORM COMPATIBLE	REMARKS
•	SCIENCE AND APPLICATIONS MISSIONS (Cont.)										
	OCEAN										
0221	OCEAN INSTRUMENT PAYLOAD (OIP)	1993	500	98	300-800	57-98			X		
0222	OCEAN TOPOGRAPHY EXPERIMENT (TOPEX)	1988	1384	63.4					X		
	SOLAR TERRESTRIAL										
0241	EARTH RADIATION BUDGET EXPERIMENT (ERBE)	1991	{600 800 &	46 98}					X		VARIOUS ORBITS
0242	INCOHERENT SCATTER RADAR	1996 & 1998	400	0 & 90	400-500	0-28 +	X	X			OPERATIONAL CONSIDERATIONS
0243	TOPSIDE DIGITAL IONOSONDE/HF RADAR	1997 & 1999	400	0 & 90	400-500	80-100	X	X			OPERATIONAL CONSIDERATIONS
0244	SOLAR TERRESTRIAL OBSERVATORY – ADVANCED	1998	400	57	300-500	57-90	X	X			OPERATIONAL CONSIDERATIONS
0245	SPACE PLASMA PHYSICS PAYLOAD – ADVANCED	1996	400	57	250-500	57-90	X	X			OPERATIONAL CONSIDERATIONS
0246	SOLAR TERRESTRIAL OBSERVATORY	1993	400	57	300-500	57-90		X			
0247	SPACE PLASMA PHYSICS PAYLOAD	1991	400	57	250-500	57-90		X			
	ATMOSPHERIC RESEARCH										
0261	HIGH RESOLUTION DOPPLER IMAGER (HRDI)	1990	400	57	300-600	57-90		X			*
0262	MEASUREMENT OF AIR POLLUTION FROM SATELLITES (MAPS)	1990	400	57	200-600	28-90	X	X			MANNED RESEARCH
0263	CO_2 LIDAR FOR ATMOSPHERIC MEASUREMENTS	1996	400	57	300-500	28-90	X	X			MANNED RESEARCH
0264	LIDAR FACILITY	1991	400	57	300-500	57-90		X			
0265	UPPER ATMOSPHERE RESEARCH PAYLOAD – DEVELOPMENT	1992	400	57	400-600	28-90	X	X			MANNED RESEARCH
0266	WINDSAT	1992	800	98					X		
0267	UPPER ATMOSPHERE RESEARCH PAYLOAD – OPERATIONAL	1994	400	57	400-600	57-90			X		

*SINGLE INSTRUMENT – COMBINES ON MANY MISSIONS

266.592-16.4

Table 4-1. Missions Accommodations Summary (Sheet 5 of 9)

MISSIONS	DATE	PREFERRED ALTITUDE (km)	PREFERRED INCLINATION (deg)	ACCEPTABLE ALTITUDE (km)	ACCEPTABLE INCLINATION (deg)	NOT FREE FLYER COMPATIBLE	SELECT'D ACCOM-MODAT'N ATTACHED	SELECT'D ACCOM-MODAT'N FREE FLYER	NOT PLATFORM COMPATIBLE	REMARKS
• SCIENCE AND APPLICATIONS MISSIONS (Cont.)										
LIFE SCIENCES										
BIOLOGICAL SCIENCE										
0300 HUMAN RESEARCH LAB.	1990	ANY	ANY			X	X			MANNED RESEARCH
0301 ANIMAL AND PLANT RESEARCH LAB.	1990	ANY	ANY			X	X			MANNED RESEARCH
OPERATIONAL MEDICINE										
0322 EVA PERFORMANCE AND PRODUCTIVITY	1990	ANY	ANY			X	X			MANNED RESEARCH
LIFE SUPPORT										
0340 $H_2O/O_2/CO_2/N_2$ REGENERATIVE SYSTEMS	1990	ANY	ANY			X	X			MANNED RESEARCH
0341 CELSS EXPERIMENTAL SYSTEMS	1990					X	X			
0342 DEDICATED CELSS MODULE	1996					X	X			
0343 CELSS PALLET	1996					X	X			
MATERIALS PROCESSING										
0400 RESEARCH AND DEVELOPMENT FACILITY	1990	>400	ANY			X	X			MANNED RESEARCH
0401 R&D/PROOF OF CONCEPT FACILITY	1993	>400	ANY			X	X			MANNED RESEARCH
• COMMERCIAL MISSIONS										
EARTH AND OCEAN OBSERVATIONS										
1000 GEOLOGICAL RECONNAISSANCE	1990	500	90	300-600	80-100			X		
1001 REMOTE ATMOSPHERIC SENSING	1990	GEO	0					X		
1002 WORLDWIDE COTTON ACREAGE AND PRODUCTION	1990	500	45	500-1000	45-90			X		
1003 PETROLEUM AND MINERAL LOCATION	1990	920	99.2	880-930	99-99.9			X		

266.592-16.5

Table 4-1. Missions Accommodations Summary (Sheet 6 of 9)

MISSIONS	DATE	PREFERRED ALTITUDE (km)	PREFERRED INCLINATION (deg)	ACCEPTABLE ALTITUDE (km)	ACCEPTABLE INCLINATION (deg)	NOT FREE FLYER COMPATIBLE	SELECT'D ACCOM-MODAT'N ATTACHED	SELECT'D ACCOM-MODAT'N FREE FLYER	NOT PLATFORM COMPATIBLE	REMARKS
• COMMERCIAL MISSIONS (Cont.)										
COMMUNICATIONS										
1100 SMALL COMMUNICATION SATELLITE	1990	GEO	0					X	X	PROGRAMMATIC
1101 MEDIUM COMMUNICATION SATELLITE	1990							X	X	PROGRAMMATIC
1102 LARGE COMMUNICATION SATELLITE	1990							X	X	PROGRAMMATIC
1103 EXPERIMENTAL GEO PLATFORM	1990							X		
1104 OPERATIONAL GEO PLATFORM	1994							X		
1105 RESERVED										
1106 LARGE DEPLOYABLE ANTENNA	1992	ANY	ANY			X	X			MANNED RESEARCH
1107 RFI MEASUREMENTS	1994									
1108 LASER COMMUNICATIONS	1991									
1109 OPEN ENVELOPE TUBE	1993									
1110 SPACEBORNE INTERFEROMETER	1995									
1111 MILLIMETER WAVE PROPAGATION	1991					X	X			MANNED RESEARCH
MATERIALS PROCESSING										
1200 PILOT – BIOLOGICAL PROCESSING FACILITY	1992	>400	ANY			X	X			OPERATIONAL CONSIDERATIONS
1201 PILOT – CONTAINERLESS PROCESSING FACILITY	1994									
1202 PILOT – FURNANCE PROCESSING FACILITY	1993									
1203 COMMERCIAL – BIOLOGICAL PROCESSING FACILITY	1995									
1204 COMMERCIAL – CONTAINERLESS PROCESSING FACILITY	1997									
1205 COMMERCIAL – FURNACE PROCESSING FACILITY	1996					X	X			OPERATIONAL CONSIDERATIONS
1206 ELECTROPHORESIS FREE-FLYER	1986							X		*
1207 ELECTROPHORETIC SEPARATION	1990					X	X			OPERATIONAL CONSIDERATIONS
1208 CRYSTAL GROWTH	1992									
1209 METAL CLUSTERS AND CRYSTAL GROWTH	1990									
1210 ENZYME PRODUCTION AND SEPARATION	1990									
1211 SILICON CRYSTALS	1990					X	X			OPERATIONAL CONSIDERATIONS

*COULD BE CONVERTED TO ATTACHED IN 1990's (1980's PAYLOAD)

266.592-16.6

Table 4-1. Missions Accommodations Summary (Sheet 7 of 9)

MISSIONS	DATE	PREFERRED ALTITUDE (km)	PREFERRED INCLINATION (deg)	ACCEPTABLE ALTITUDE (km)	ACCEPTABLE INCLINATION (deg)	NOT FREE FLYER COMPATIBLE	SELECT'D ACCOM-MODAT'N ATTACHED	SELECT'D ACCOM-MODAT'N FREE FLYER	NOT PLATFORM COMPATIBLE	REMARKS
• COMMERCIAL MISSIONS (Cont.)										
MATERIALS PROCESSING (Cont.)										
1212 HEAT RESISTANT ALLOYS	1996	>400	ANY			X	X			OPERATIONAL CONSIDERATIONS
1213 CHEMICAL REACTIONS	1990	>400				X	X			OPERATIONAL CONSIDERATIONS
1214 SPACE ISOTHERMAL FURNACE SYSTEM (SIFS)	1990	>250				X	X			OPERATIONAL CONSIDERATIONS
INDUSTRIAL SERVICES										
1300 RADIATION HARDENED COMPUTER	1990	ANY	ANY				X			
1301 FULL-BODY TELEOPERATOR	1995	ANY	ANY			X	X			
1302 GAMMA RAY ASTRONOMY	1990	400	0	350-450	0-28			X	X	SEE GDCD 0030
1303 PLANTS IN CONTROLLED ENV. LIFE SUPPORT SYSTEMS (CELSS)	1990	ANY	ANY			X	X			OPERATIONAL CONSIDERATIONS
1304 CONTROLLED ENVIRONMENT LIFE SUPPORT SYSTEMS (CELSS)	1990	ANY	ANY			X	X			OPERATIONAL CONSIDERATIONS
1305 COMMUNICATION SATELLITE SERVICE/HANDLING	1992	ANY	ANY			X	X			OPERATIONAL CONSIDERATIONS
• TECHNOLOGY DEVELOPMENT										
MATERIALS & STRUCTURES										
2001 STRAIN AND ACOUSTIC SENSORS	1990	LEO	ANY			X	X			MANNED RESEARCH
2002 SPACECRAFT MATERIALS TECHNOLOGY	1991									
2003 MATERIALS AND COATINGS	1991									
2004 THERMAL SHAPE CONTROL	1992									
2005 DYNAMICS OF FLIMSY STRUCTURES	1993									
2006 ACTIVE OPTICS TECHNOLOGY	1991									
2007 LARGE STRUCTURES TECHNOLOGY	2000					X	X			MANNED RESEARCH

266.592-16.7

Table 4-1. Missions Accommodations Summary (Sheet 8 of 9)

MISSIONS	DATE	PREFERRED		ACCEPTABLE		NOT FREE FLYER COMPATIBLE	SELECT'D ACCOM-MODAT'N		NOT PLATFORM COMPATIBLE	REMARKS
		ALTITUDE (km)	INCLINATION (deg)	ALTITUDE (km)	INCLINATION (deg)		ATTACHED	FREE FLYER		
• TECHNOLOGY DEVELOPMENT (Cont.)										
ENERGY CONVERSION										
2101 LOW-COST MODULAR SOLAR PANELS	1990	LEO	ANY			X	X			MANNED RESEARCH
2102 RESERVED	–									
2103 ION EFFECTS ON LEO POWER SYSTEMS	1992									
2104 LARGE SOLAR CONCENTRATOR	1993									
2105 SOLAR PUMPED LASERS	1994									
2106 LASER/ELECTRIC ENERGY CONVERSION	1994									
2107 SOLAR SUSTAINED PLASMAS	1995					X				MANNED RESEARCH*
2108 SPACE NUCLEAR REACTOR	1997						X			
COMPUTER SCIENCE & ELECTRONICS										
2201 ATTITUDE CONTROL – SYSTEM IDENTIFICATION EXPERIMENT	1993	LEO	ANY			X	X			MANNED RESEARCH
2202 ATTITUDE CONTROL – ADAPTIVE CONTROL EXPERIMENT	1994					X	X			
2203 ATTITUDE CONTROL – DISTRIBUTED CONTROL EXPERIMENT	1995					X	X			
2204 ADVANCED ADAPTIVE CONTROL TECHNOLOGY DEMONSTRATION	1996					X	X			MANNED RESEARCH
PROPULSION										
2301 CONTROLLED ACCELERATION PROPULSION TECHNOLOGY	1993	LEO	ANY			X	X			MANNED RESEARCH
2302 LASER PROPULSION TEST	1996	LEO	ANY			X	X			MANNED RESEARCH
CONTROL & HUMAN FACTORS										
2401 MANIPULATOR CONTROLS TECHNOLOGY	1991	LEO	ANY			X	X			MANNED RESEARCH
2402 ADVANCED EVA TECHNOLOGY	1990	LEO	ANY			X	X			MANNED RESEARCH

*NEEDS TO BE ASSOCIATED WITH HIGH POWER LOADS

266.592-16.8

Table 4-1. Missions Accommodations Summary (Sheet 9 of 9)

MISSIONS	DATE	PREFERRED ALTITUDE (km)	PREFERRED INCLINATION (deg)	ACCEPTABLE ALTITUDE (km)	ACCEPTABLE INCLINATION (deg)	NOT FREE FLYER COMPATIBLE	SELECT'D ACCOM-MODAT'N: ATTACHED	SELECT'D ACCOM-MODAT'N: FREE FLYER	NOT PLATFORM COMPATIBLE	REMARKS
• TECHNOLOGY DEVELOPMENT (Cont.)										
SPACE STATION SYSTEMS & OPERATIONS										
2501 LIQUID DROPLET RADIATOR	1995	LEO	ANY			X	X			MANNED RESEARCH
2502 ADVANCED CONTROL DEVICE	1994									
2503 SPACE COMPONENT LIFETIME TECHNOLOGY	1990									
2504 OTV PAYLOAD HANDLING	1992									
2505 PAYLOAD SERVICING AND REPAIR	1992									
2506 OTV PROPELLANT TRANSFER AND STORAGE	1991					X	X			MANNED RESEARCH
2507 OTV PROPELLANT LIQUIFACTION	1991					X	X			MANNED RESEARCH
2508 OTV DOCKING AND BERTHING	1991					X	X			MANNED RESEARCH
2509 OTV MAINTENANCE	1992					X	X			MANNED RESEARCH
2510 TETHER DYNAMICS TECHNOLOGY	1992					X	X			MANNED RESEARCH
FLUID & THERMAL PHYSICS, PHYSICS AND CHEMISTRY										
2601 LIGHTWEIGHT CRYO HEAT PIPES	1991	LEO	ANY			X	X			MANNED RESEARCH
• OPERATIONS										
OTHER										
4000 MANNED GEOSYNCHRONOUS SORTIE CAPSULE	1995	GEO	0					X	X	OPERATIONAL CONSIDERATIONS
4001 MANNED GEOSYNCHRONOUS SUPPORT MODULE	2000	GEO	0					X		

266.592-16.9

Table 4-2. Summary of Task Categorization*

MAN	MAN/MACHINE
NORMAL ACTIVITIES/OPERATION:	Deploy payloads/spacecraft
Replace spares	Rendezvous
Replace expendables	Docking/berthing
Equipment calibration	Capture W/RMS
Exp monitor/supervision	Inst orb repl units
Data interpretation	Insp & maintenance
Specimen handling	Expendable replenish
Routine checkout, service	EVA repair
Assembly	Assembly
CONTINGENCY ACTIVITIES:	Checkout
Trouble shoot	MACHINE
Repair	Orbit reboost
Modify protocol	Orbit transfer
Resource allocation	Inspection
Work around solutions	Remote repair
Deploy, retract, jettison appendages	Remote replacement
	Hazardous operations
	Assembly

*Source: NASA TM-82482 "The Human Role in Space," MSFC, April 1982.

The classification of GEO and Escape type, i.e., planetary and solar system missions as free flyers, needs no further explanation. The rationale for classification for each LEO/HEO free flyers is presented in Table 4-3 along with related information on platform compatibility and spacecraft capability.

The following definitions for mission classes were extracted from a draft of the Space Station Program Description Document, Book 1:

Class 1. Missions best accomplished using the manned element of the system (Space Station).

Class 2. Missions best accomplished using large, man-tended platforms (space platform).

Class 3. Missions best accomplished using narrowly focused, relatively small satellites (free flyers).

Table 4-3. LEO/HEO Free Flyer Classification Rationale (Sheet 1 of 2)

MISSION/PAYLOAD	PLATFORM COMPATIBLE	RATIONALE FOR ACCOMMODATION AS A FREE FLYER	P/L ELEMENT DEFINITION		SPACECRAFT INCLUDES ORBIT TRANSFER PROPULSION
			INTEG'D INSTRU PKG*	SPACE-CRAFT	
ASTROPHYSICS					
0001 LDR		SIZE; ORBIT ALTITUDE		X	
0003 VLBI DEMO	X	POINTING & SIZE COMBINATION	X		
0004 SPACE TELESCOPE		POINTING & CONTAMINATION REQ		X	
0030 GRO		PAYLOAD IS DESIGNED FOR 1988 LAUNCH		X	X
0033 AXAF		SIZE; POINTING & CONTAMIN REQ		X	
0038 X-RAY TIMING XPLORER		POINTING ACCURACY FOR LONG TERM		X	X
0060 SIDM	X	HIGH INCLIN IN EARLY TIME FRAME; POINTING ACCURACY		X	X
0061 SCDM	X	POINTING ACCURACY		X	
0062 ASO	X	SIZE; CONTAMINATION REQS	X		
EARTH & PLANETARY					
0172 OPERL LAND SYS	X	HIGH INCLIN IN EARLY TIME FRAME; CONTAMINATION REQ		X	X
0180 FIREX	X	HIGH INCLIN IN EARLY TIME FRAME	X		
0181 Z – CONTIN COVERAGE	X	CONCEPT PROVIDED BY NASA		X	X
0182 Z – HYDROLOGIC CYCLE	X	CONCEPT PROVIDED BY NASA		X	X
0183 Z – SPECIAL COVERAGE	X	CONCEPT PROVIDED BY NASA		X	X
ENVIRON. OBS					
0205 METEOROLOGY INSTRU. GR	X	HIGH INCLIN IN EARLY TIME FRAME	X		
0207 TIROS FOLLOW-ON	X	ORBIT ALTITUDE & INCLINATION		X	
0221 OIP	X	HIGH INCLIN IN EARLY TIME FRAME	X		

*THESE PAYLOAD ELEMENTS ASSUME ACCOMMODATION ON A PLATFORM OR LEASECRAFT TYPE SPACECRAFT WHICH HAS ORBIT TRANSFER PROPULSION.

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Table 4-3. LEO/HEO Free Flyer Classification Rationale (Sheet 2 of 2)

MISSION/PAYLOAD	PLATFORM COMPATIBLE	RATIONALE FOR ACCOMMODATION AS A FREE FLYER	P/L ELEMENT DEFINITION		SPACECRAFT INCLUDES ORBIT TRANSFER PROPULSION
			INTEG'D INSTRU PKG*	SPACE-CRAFT	
ENVIRON. OBS (Cont'd)					
0222 TOPEX	X	ORBIT ALT & INCLIN; PAYLOAD IS DESIGNED FOR 1988 LAUNCH		X	
0241 ERBE	X	FLYS ON 0206, 0207 (PIGGY BACK)	X		
0266 WINDSAT	X	ORBIT ALTITUDE & INCLIN		X	
0267 UARS – OPERL	X	OPTICS CONTAMIN SENSITIVITY; HIGH INCLIN IN EARLY TIME FRAME	X		
COMMERCIAL					
1000 GEOLOG RECONN	X	PROVIDED BY 0172 (0174 & 0175 FOR DEVELOPMENT)			
1002 WORLDWIDE COTTON PROD	X	PROVIDED BY 0172			
1003 PETROL & MINERAL LOCAT	X	PROVIDED BY 0172			
1206 ELECTROPHORESIS FF	X	CURRENTLY PLANNED PAYLOAD FOR 1986 LAUNCH		X	X
1302 GAMMA RAY OBSERV		PROVIDED BY 0030			

*THESE PAYLOAD ELEMENTS ASSUME ACCOMMODATION ON A PLATFORM OR LEASECRAFT TYPE SPACECRAFT WHICH HAS ORBIT TRANSFER PROPULSION.

266.592-14.2

Summary statistics for the three mission classes by Space Station System Element (Figure 4-2) provide an overview of the mission set used during the study for the Mission Implementation task.

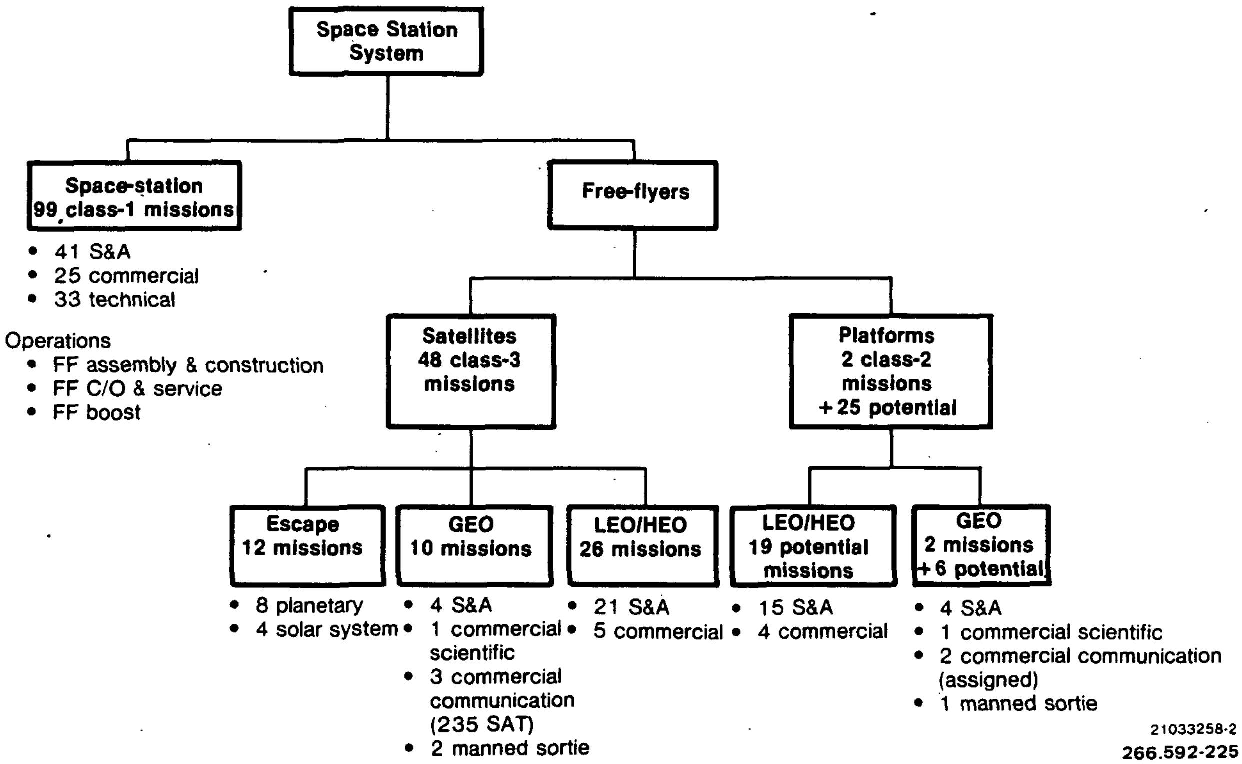

Figure 4-2. Space Station System Elements and Mission Classes

4.2 MAN-OPERATED MISSIONS

Man-operated missions are those meeting the selection criteria defined in Section 4.1. Of the 149 representative missions defined within all disciplines, two-thirds (99 out of 149) were found to possess the characteristics that make good Station-attached candidates. The set of attached missions break down further into 81 that require attached accommodations primarily for long term man-involvement, and 18 that would accept free-flying accommodation either on a platform or on a satellite as listed in Table 4-4. This man-operated attached mission data base is assessed from the viewpoint of both programmatic and technical requirements in Sections 4.2.1 and 4.2.2, respectively. The NASA Orientation Meeting provided the primary data inputs for attached payload elements.

Table 4-4. Man's Role in Man-Operated Attached Missions (Sheet 1 of 5)

	MAN'S ROLE			FREE-FLYER ACCEPTABLE
	VITAL	SIGNIFICANT BENEFIT	CONTRIB	
• SCIENCE AND APPLICATIONS MISSION				
ASTROPHYSICS				
ASTRONOMY				
0000 Starlab		✓		✓
0005 Shuttle IR Telescope Facility		✓		✓
HIGH ENERGY				
0031 High Throughput Mission			✓	✓
0032 Large Area Modular Array		✓		✓
0034 High Resolution X and Gamma Ray Spectrometer		✓		✓
0035 High Energy Isotope Experiment		✓		✓
0036 Spectra of Cosmic Ray Nuclei			✓	✓
0037 Transition Radiation and Ionization Colorimeter		✓		✓
EARTH AND PLANETARY EXPLORATION				
CRUSTAL MOTION				
0151 Detection and Monitoring of Episodic Events	✓			
0152 Geoscience – Crustal Dynamic Studies			✓	✓
GEOPOTENTIAL FIELDS				
0161 Earth Science Research – Geophysical Investigation	✓			
EARTH RESOURCES				
0171 Renewable Resources – Earth Science Research		✓		✓
0173 Shuttle Active Microwave Experiment (SAMEX-C)	✓			
0174 Earth Obs Instrument Devel (Microwave Tech)	✓			
0175 Earth Obs Instrument Devel (Extra Visible & RF)	✓			
0176 EO Sensor/Technique/Analysis/Automated System	✓			
0177 Geoscience-Geology Remote Sensing			✓	✓
0179 Imaging Radar for Earth Resources Inventory			✓	✓
0184 Z – Continuous and Special Coverage		✓		

266.592-72.1

Table 4-4. Man's Role in Man-Operated Attached Missions (Sheet 2 of 5)

	MAN'S ROLE			
	VITAL	SIGNIFICANT BENEFIT	CONTRIB	FREE-FLYER ACCEPTABLE
ENVIRONMENTAL OBSERVATIONS				
WEATHER/CLIMATE				
0201 Satellite Doppler Meteorological Radar Tech	✓			
0202 Meteorology Instrument Group Development Payload	✓			
SOLAR TERRESTRIAL				
0242 Incoherent Scatter Radar	✓			
0243 Topside Digital Ionosonde/ HF Radar	✓			
0244 Solar Terrestrial Observatory — Advanced	✓			
0245 Space Plasma Physics Payload — Advanced	✓			
0246 Solar Terrestrial Observatory		✓		✓
0247 Space Plasma Physics Payload		✓		✓
ATMOSPHERIC RESEARCH				
0261 High Resolution Doppler Imager (HRDI)			✓	✓
0262 Measurement of Air Pollution from Satellites	✓			
0263 CO_2 LIDAR for Atmospheric Measurements	✓			
0264 LIDAR Facility			✓	✓
0265 Upper Atmosphere Research Payload — Development	✓			
LIFE SCIENCES				
BIOLOGICAL SCIENCE				
0300 Human Research Lab.	✓			
0301 Animal and Plant Research Lab.	✓			
OPERATIONAL MEDICINE				
0322 EVA Performance and Productivity	✓			
LIFE SUPPORT				
0340 $H_2O/O_2/CO_2/N_2$ Regenerative Systems	✓			
0341 CELSS Experimental Systems	✓			
0342 Dedicated CELSS Module	✓			
0343 CELSS Pallet	✓			

266.592-72.2

Table 4-4. Man's Role in Man-Operated Attached Missions (Sheet 3 of 5)

		MAN'S ROLE		
	VITAL	SIGNIFICANT BENEFIT	CONTRIB	FREE-FLYER ACCEPTABLE
MATERIALS PROCESSING				
0400 Research and Development Facility	✓			
0401 R&D/Proof of Concept Facility	✓			
• COMMERCIAL MISSIONS				
COMMUNICATIONS				
1106 Large Deployable Antenna		✓		
1107 RFI Measurements		✓		
1108 Laser Communications		✓		
1109 Open Envelope Tube		✓		
1110 Spaceborne Interferometer		✓		
1111 Millimeter Wave Propagation		✓		
MATERIALS PROCESSING				
1200 Pilot — Biological Processing Facility	✓			
1201 Pilot — Containerless Processing Facility	✓			
1202 Pilot — Furance Processing Facility	✓			
1203 Commercial — Biological Processing Facility		✓		
1204 Commercial — Containerless Processing Facility		✓		
1205 Commercial — Furnace Processing Facility		✓		
1207 Electrophoretic Separation	✓			
1208 Crystal Growth	✓			
1209 Metal Clusters and Crystal Growth	✓			
1210 Enzyme Production and Separation	✓			
1211 Silicon Crystals	✓			
1212 Heat Resistant Alloys	✓			
1213 Chemical Reactions	✓			
1214 Space Isothermal Furnace System (SIFS)	✓			
INDUSTRIAL SERVICES				
1300 Radiation Hardened Computer			✓	✓
1301 Full-Body Teleoperator	✓			
1303 Plants in Controlled Env Life Support Systems	✓			
1304 Controlled Environment Life Support Systems	✓			

266.592-72.3

Table 4-4. Man's Role in Man-Operated Attached Missions (Sheet 4 of 5)

	MAN'S ROLE			
	VITAL	SIGNIFICANT BENEFIT	CONTRIB	FREE-FLYER ACCEPTABLE
1305 Communication Satellite Service/Handling	✓			
• TECHNOLOGY DEVELOPMENT				
MATERIALS & STRUCTURES				
2001 Strain and Acoustic Sensors	✓			
2002 Spacecraft Materials Technology			✓	
2003 Materials and Coatings			✓	
2004 Thermal Shape Control	✓			
2005 Dynamics of Flimsy Structures	✓			
2006 Active Optics Technology	✓			
2007 Large Structures Technology	✓			
ENERGY CONVERSION				
2101 Low-Cost Modular Solar Panels	✓			
2103 Ion Effects on LEO Power Systems	✓			
2104 Large Solar Concentrator	✓			
2105 Solar Pumped Lasers	✓			
2106 Laser/Electric Energy Conversion	✓			
2107 Solar Sustained Plasmas	✓			
2108 Space Nuclear Reactor			✓	✓
COMPUTER SCIENCE & ELECTRONICS				
2201 Attitude Control — System Identification Experiment	✓			
2202 Attitude Control — Adaptive Control Experiment	✓			
2203 Attitude Control — Distributed Control Experiment	✓			
2204 Advanced Adaptive Control Technology Demonstration	✓			
PROPULSION				
2301 Controlled Accel Propulsion Technology	✓			
2302 Laser Propulsion Test	✓			
CONTROL & HUMAN FACTORS				
2401 Manipulator Controls Technology	✓			
2402 Advanced EVA Technology	✓			

266.592-72.4

Table 4-4. Man's Role in Man-Operated Attached Missions (Sheet 5 of 5)

		MAN'S ROLE			FREE-FLYER ACCEPTABLE
		VITAL	SIGNIFICANT BENEFIT	CONTRIB	
SPACE STATION SYSTEMS & OPERATIONS					
2501	Liquid Droplet Radiator	✓			
2502	Advanced Control Device	✓			
2503	Space Component Lifetime Technology	✓			
2504	OTV Payload Handling	✓			
2505	Payload Servicing and Repair	✓			
2506	OTV Propellant Transfer and Storage	✓			
2507	OTV Propellant Liquefaction	✓			
2508	OTV Docking and Berthing	✓			
2509	OTV Maintenance	✓			
2510	Tether Dynamics Technology	✓			
FLUID & THERMAL PHYSICS, PHYSICS AND CHEMISTRY					
2601	Light Weight Cryo Heat Pipes	✓			

255.592-72.5

4.2.1 MAN-OPERATED MISSIONS TIME PHASING. The 99 missions selected as preferring the attached accommodation are identified and arranged in a time-sequenced waterfall chart (Figure 4-3). Within each year, they are arranged in ascending order by discipline. Missions are seen to spread over the 1990-2000 time frame. Missions at the end of the decade fall into three classes: those ending in the year 2000; those with a mission duration extending beyond 2000; and those by their nature will probably continue but are not specifically defined for continuation in the data sheets identified in Appendix I. The requirements differentiation is useful in performing later crew analyses that take into account not only activation and routine operations time, but also time to deactivate applicable payload elements and prepare equipment for return to earth.

Missions for the man-operated facility comprise activities in all of the disciplines concerned with Space Station activities. These include research and technology development in the low-g environment of LEO, "outward" looking observations from above the filtering of the earth's atmosphere, and observations of the earth's surface and atmosphere from the vantage point of LEO.

The schedule data of Figure 4-3 has been summarized in two forms: as a histogram of the first launch date requirements (IOC) and as a profile of the number of missions in operation in each year (Figure 4-4). The number of starts represents the number of new payload elements added in each year for Space Station accommodation. By examining the number of initial launches over the

GDCD NO.	PAYLOAD ELEMENT NAME	DISCI-PLINE	90	91	92	93	94	95	96	97	98	99	00
0005	Shuttle IR Tele. Facility	AST											
0152	Geoscience-Crustal Dynamics Studies	CRN											
0174	Earth Obs Instru Devel (Microwave Tech)	ERS											
1076	EO Sensor/Technique/Anal/ Automated System Devel	ERS											
0177	Geoscience-Geology Remote Sensing	ERS											
0261	High Resolution Doppler Imager (HRDI)	ATR											
0262	Measurement of Air Pollution from Satellites (MAPS)	ATR											
0300	Human Research Lab	BLS											
0301	Animal & Plant Research Lab	BLS											
0322	EVA Perf. & Productivity	OPM											
0340	$H_2O/O_2/CO_2/N_2$ Regenerative Systems	LFS											
0341	CELSS Experimental Systems	LFS											
0400	Research & Development Facility	MPR											
1207	Electrophoresis Separation	MPC											
1209	Metal Clusters & Crystal Growth	MPC											
1210	Enzyme Production & Separation	MPC											
1211	Silicon Crystals	MPC											
1213	Chemical Reactions	MPC											
1214	Space Isothermal Furnace System (SIFS)	MPC											
1300	Radiation Hardened Computer	INS											
1303	Plants in Controlled Env Life Support Sys (CELSS)	INS											
2001	Strain & Acoustic Sensors	MTS											
2101	Low-Cost Modular Solar Panels	ECN											
2402	Advanced EVA Technology	CHF											
2503	Space Component Lifetime Tech	SSS											
0247	Space Plasma Physics Payload	STR											
0264	LIDAR Facility	ATR											
1108	Laser Communications	COM											
1111	Millimeter Wave Propagation	COM											
2002	Spacecraft Materials Tech	MTS											
2003	Materials and Coatings	MTS											
2006	Active Optics Technology	MTS											
2401	Manipulator Controls Tech	CHF											
2506	OTV Propellant Transfer Storage	SSS											
2507	OTV Propellant Liquefaction	SSS											

266.592-17.1

Figure 4-3. Man-Operated Missions Time Phasing (Sheet 1 of 4)

GDCD NO.	PAYLOAD ELEMENT NAME	DISCIPLINE	90	91	92	93	94	95	96	97	98	99	00
2508	OTV Docking & Berthing	SSS											
2601	Light Weight Cryo Heat Pipes	FTP											
0000	Starlab	AST											
0032	Large Area Modular Array	HEN											
0173	Shuttle Active Microwave Exper (SAMEX-C)	ERS											
0175	Earth Obs Instru Devel (Extra Visible & RF)	ERS											
0202	Meteorology Instru Group Devel Payload	WCL											
0265	Upper Atmosphere Research Payload-Development	ATR											
1106	Large Deployable Antenna	COM											
1200	Pilot – Biological Processing Facility	MPC											
1208	Crystal Growth	MPC											
1305	Communication Satellite	INS											
2004	Thermal Shape Control	MTS											
2103	Ion Effects on LEO Power Systems	ECN											
2504	OTV Payload Handling	SSS											
2505	Payload Servicing & Repair	SSS											
2509	OTV Maintenance	SSS											
2510	Tether Dynamics Tech	SSS											
0034	High Resolution X and Gamma Ray Spectrometer	HEN											
0246	Solar Terrestrial Observatory	STR											
0401	R&D/Proof of Concept Facility	MPR											
1109	Open Envelope Tube	COM											
1202	Pilot-Furnace Processing	MPC											
2005	Dynamics of Flimsy Struct	MTS											
2104	Large Solar Concentrator	ECN											
2201	Attitude Control – System Identification Exper	CSE											
2301	Controlled Acceleration Propulsion Tech	PPN											
0161	Earth Science Research – Geophysical Investigation	GPF											
0179	Imaging Radar for Earth Resources Inventory & Monitoring	ERS											
1107	RFI Measurements	COM											
1201	Pilot – Containerless Processing Facility	MPC											

266.592-17.2

Figure 4-3. Man-Operated Missions Time Phasing (Sheet 2 of 4)

GDCD NO.	PAYLOAD ELEMENT NAME	DISCI-PLINE	90	91	92	93	94	95	96	97	98	99	00
2105	Solar Pumped Lasers	ECN											
2106	Laser/Electric Energy Conversion	ECN											
2202	Attitude Control – Adaptive Control Experiment	CSE											
2502	Advanced Control Device	SSS											
0035	High Energy Isotope Exper	HEN											
0036	Spectra of Cosmic Ray Nuclei	HEN											
0037	Transition Radiation and Ionization Colorimeter	HEN											
0151	Detection & Monitoring of Episodic Events	CRM											
0171	Renewable Resources-Earth Science Research	ERS											
1110	Spaceborne Interferometer	COM											
1203	Commercial-Biological Processing Facility	MPC											
1301	Full-Body Teleoperator	INS											
2107	Solar Sustained Plasmas	ECN											
2203	Attitude Control – Distributed Control Exper	CSE											
2501	Liquid Droplet Radiator	SSS											
0242	Incoherent Scatter Radar	STR											
0245	Space Plasma Physics Payload-Advanced	STR											
0263	CO_2 LIDAR for Atmospheric Measurements	ATR											
0342	Dedicated CELSS Module	LFS											
0343	CELSS Pallet	LFS											
1205	Commercial-Furnace Processing Facility	MPC											
1212	Heat Resistant Alloys	MPC											
1304	Controlled Environment Life Support Systems (CELSS)	INS											
2204	Advance Adaptive Control Technology Demo	CSE											
2302	Laser Propulsion Test	PPN											
0031	High Throughput Mission	HEN											
0243	Topside Digital Ionosonde HF Radar	STR											
1204	Commercial-Containerless Processing Facility	MPC											
2108	Space Nuclear Reactor	ECN											

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Figure 4-3. Man-Operated Missions Time Phasing (Sheet 3 of 4)

GDCD NO.	PAYLOAD ELEMENT NAME	DISCI-PLINE	90	91	92	93	94	95	96	97	98	99	00
0201	Satellite Doppler Meteorological Radar Tech Devel	WCL											
0244	Solar Terrestrial Observatory – Advanced	STR											
0184	Z – Continuous & Special Coverage	ERS											
2007	Large Structures Tech	MTS											

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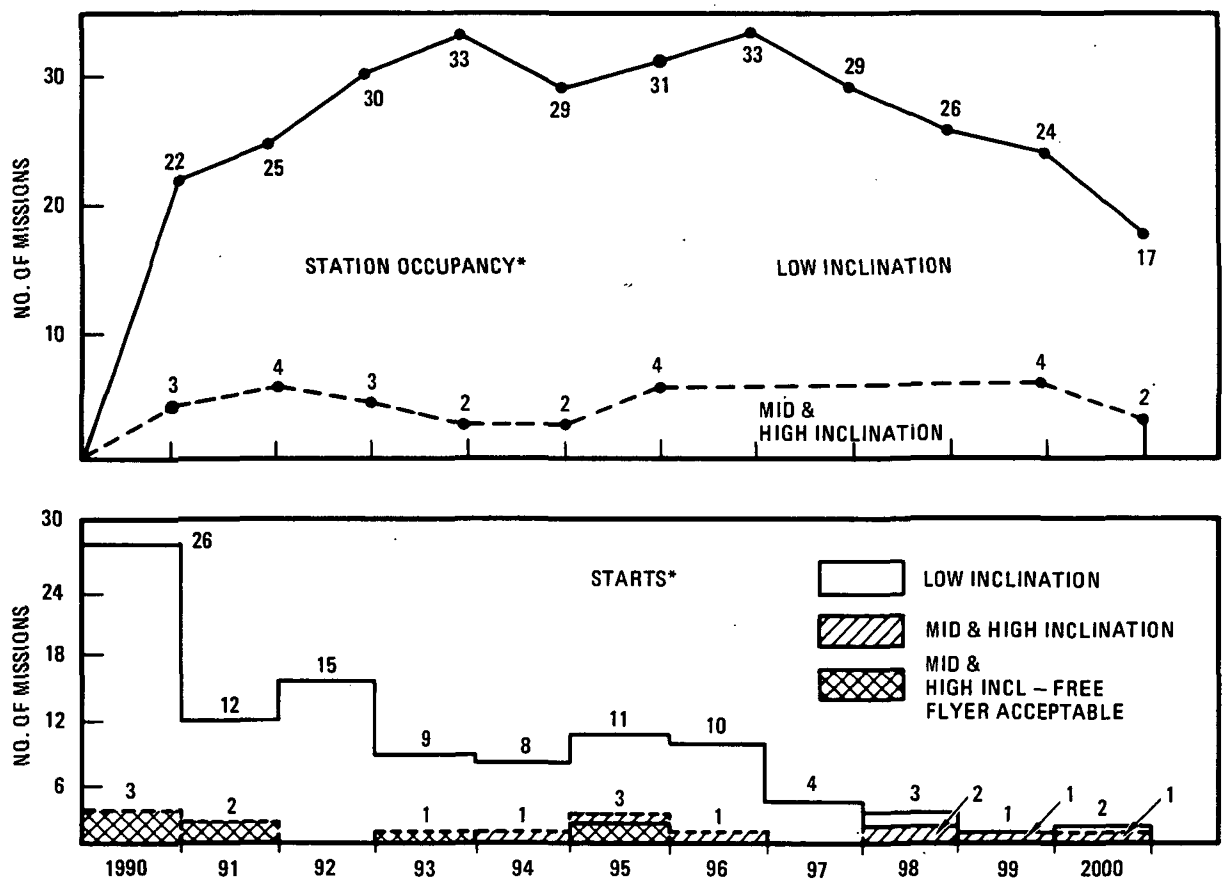
Figure 4-3. Man-Operated Missions Time Phasing (Sheet 4 of 4)



*101 MISSIONS INCLUDES TWO MISSIONS WITH 2 INCLINATIONS EACH

266.592-105

Figure 4-4. Attached Missions/Payloads

decade (1990-2000) of man-operated missions, it becomes evident that the planning and definition of missions and payload elements is better in early years than in later years. This tendency results in planning horizon effects that reflect in a distorted funding profile and a reduction in traffic forecasting accuracy for later years. During the analyses that we made to put more realism in the mission set (Section 4.4), a number of missions were rescheduled and this resulted in an improvement of the mission density over time.

Occupancy for Station-attached payload elements is shown to peak at a level of 33 and maintain a level of about 30 for a 5-6 year period. During this time some of the shorter duration missions become operational and are completed, while others are added. The distribution of missions by duration, which also accounts for multiple missions flown by five of the payload elements, discloses a range from less than a week to more than 8 years (Figure 4-5). Twelve percent of the missions have Shuttle-compatible mission durations and could be candidates for continued Shuttle support, although in themselves they do not constitute complete Spacelab missions. They are carried in the Space Station era as representative of typical quick turnaround missions that could be decoupled from time-constrained Shuttle transportation operations.

The mission start dates and duration data provide a basis for estimating the time-phased mission development and operations costs. These cost analyses were used to evaluate program variations and during the evaluation of the mission set for realism as discussed in Section 4.4.

4.2.2 MAN-OPERATED MISSION REQUIREMENTS. The requirements for man-operated attached missions are displayed in a matrix format useful for accommodation analyses (Table 4-5). The definition of terms used in the matrix is contained in Section 3, which also defines the three-digit discipline codes. Missions are arranged by year of first flight and ordered by discipline using the ascending order of GDCD Code numbers assigned and documented in Book 1, Appendix I. Key parameters from Table 4-5 are discussed in the following sections, primarily in terms of requirements envelopes and "tall poles" related to individual missions. Analysis of integrated requirements of mission sets is, in general, reserved until after programmatic and technology assessments permit the selection of a baseline mission set (Section 4.4).

4.2.2.1 Orbit Requirements. Orbit inclination requirements for Station-attached missions range from equatorial to polar (Figure 4-6). All are satisfied by a LEO altitude of 400 to 500 km. The orbital inclination requirements generally fall into one of three groups, dependent on mission objectives:

a. Missions conducting R&D in low-g or viewing above the earth's atmosphere, are not sensitive to orbit inclination and can be satisfied by the 28.5-degree inclination most efficient for Shuttle launching.

b. Earth viewing missions desiring a high latitude either to provide adequate coverage of the earth or to operate in a preferred position relative to the Van Allen belts can be satisfied in most cases by the maximum 57-degree inclination orbit possible from KSC, with most missions having a preference for a polar orbit when possible.

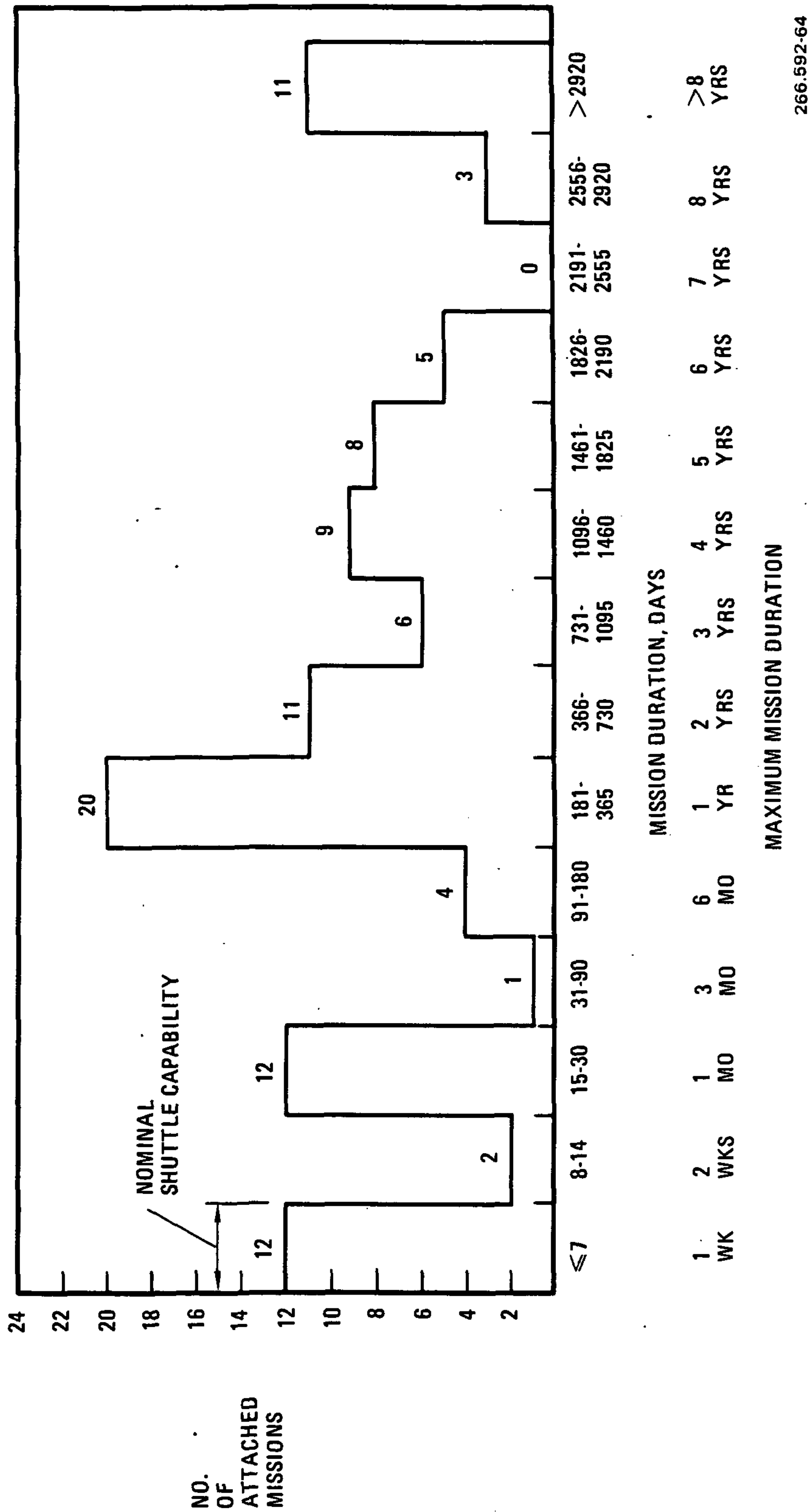


Figure 4-5. Attached Mission Duration

Table 4-5. Payload Requirements Summary Data - Man-Operated Accommodation Mode (Sheet 1 of 6)

GDC NO.	PAYLOAD ELEMENT NAME	DISCIPLINE	MISSION REQUIREMENTS: LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT: PREFERRED ALT (km)	PREFERRED INCL (deg)	ACCEPTABLE RANGE ALT (km)	ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING: ACCY (sec)	JITTER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL: MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	RESOURCES: POWER LEVEL, W (DUR, HR/DAY) OPER	PEAK	DATA K BPS (HR/DAY)	CREW: SIZE	TIME (AVG) HR/DAY	EVA REQ'D √	SVC REQ'D √	RE-CONFIG REQ'D √	COMMENTS
0005	Shuttle IR Tele. Facility	AST	90	1825	400	28.5	300-400	28.5-57	Inertial	96*		N/A	7,018	0.36	11x4x4	1300 (18)	2735	1000	1	0.5	✓	✓		
0152	Geoscience-Crustal Dynamics Studies	CRN	90	1100	500	50	300-600	50-90	Earth	60		N/A	185	0.36	2.5x1.5 x1.5	500 (6)		10	1	0.2	✓	✓		
0.174	Earth Obs Instru Devel (Microwave Tech)	ERS	90	730	1000	90	400-1600	28.5-90	Earth	360		N/A	200	0.36	1.5x1.x1.	200		1000	1	0.25			✓	
0176	EO Sensor/Technique/Anal/ Automated System Devel	ERS	90	1460	500	90	275-925	28.5-90	Earth	3600		N/A	2,000	0.72	40x30x3	6K (12)		80K	2	1	✓	✓	✓	
0177	Geoscience-Geology Remote Sensing	ERS	90	1800	500	90	300-600	80-100	Earth	6		N/A	2,000	0.36	30x30x3	10K		300K	1	0.2	✓		✓	
0261	High Resolution Doppler Imager (HRDI)	ATR	90	365	400	57	300-600	57-90	Earth	10800		N/A	76	0.36	2x2x2	82 (12)		4.0	1	0.1	✓	✓	✓	
0262	Measurement of Air Pollution from Satellites (MAPS)	ATR	90	365	400	57	200-600	28.5-90	Earth	7200		N/A	100	0.36	1x1x0.6	200		4600	1	0.2		✓	✓	
0300	Human Research Lab	BLS	90	3600	ANY	ANY			N/A	N/A	N/A		7,300	112.	N/A	2000 (8)	3000 (1)	128.	2	10		✓	✓	Volume = Total Module
0301	Animal & Plant Research Lab	BLS	90	3600	ANY	ANY			N/A	N/A	N/A	10^{-3} to $5x10^{-5}$	4,320	76.2	N/A	2000 (21)	4000 (3)	128	2	6		✓	✓	Volume = Total Module
0322	EVA Perf. & Productivity	OPM	90	3600	ANY	ANY			N/A	N/A	N/A	N/A	270	3.1	N/A	100 (0.3)			2	0.5	✓	✓	✓	TV Required
0340	$H_2O/O_2/CO_2/N_2$ Regenerative Systems	LFS	90	3650	ANY	ANY			N/A	N/A	N/A		1280	5.8	N/A	2400 (8)	4200 (16)	8	2	1			✓	
0341	CELSS Experimental Systems	LFS	90	2190	ANY	ANY			N/A	N/A	N/A		2,625	28.0	N/A	4400 (23)	6000 (1)		2	2		✓	✓	
0400	Research & Development Facility	MPR	90	1095	>400	ANY	N/A	N/A	N/A	N/A	N/A	10^{-5}	1736	6.75	N/A	10K (22)	13K (2)	3 (24)	1	4				Vacuum Vent Required
1207	Electrophoresis Separation	MPC	90	7	ANY	ANY	N/A	N/A	N/A	N/A	N/A	10^{-4}	[300]	[2.7]	N/A	[500]			[1]	[0.5]				Ref. – 0400
1209	Metal Clusters & Crystal Growth	MPC	90	15	ANY	ANY	N/A	N/A	N/A	N/A	N/A	10^{-4}	[100]	[0.5]	N/A	[1000]			[1]	[1]				Ref. – 0400
1210	Enzyme Production & Separation	MPC	90	4	ANY	ANY	N/A	N/A	N/A	N/A	N/A				N/A				[1]	[2]				Ref. – 0400
1211	Silicon Crystals	MPC	90	30	ANY	ANY	N/A	N/A	N/A	N/A	N/A	10^{-4}	[300]	[1.2]	N/A	[5000] (8)			[1]	[8]				Ref. – 0400 For 30 Samples

*At telescope interface with IPS.
[ ] = Accommodated by Referenced Payload Element(s)

266.592-48.1

Table 4-5. Payload Requirements Summary Data - Man-Operated Accommodation Mode (Sheet 2 of 6)

GDC NO.	PAYLOAD ELEMENT NAME	DISCI-PLINE	MISSION REQUIREMENTS										PHYSICAL			RESOURCES								COMMENTS
			LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT				VIEWING DIRECTION	POINTING		OPER ACCEL LIMIT (g)	MASS (kg)	PRES'D VOL (m³)	EXTNL SIZE L X W X H (m)	POWER LEVEL, W (DUR, HR/DAY)		DATA K BPS (HR/DAY)	CREW		EVA REQ'D √	SVC REQ'D √	RE-CONFIG REQ'D √	
					PREFERRED		ACCEPTABLE RANGE																	
					ALT (km)	INCL (deg)	ALT (km)	INCL (deg)		ACCY (sec)	JIT-TER (sec/s)					OPER	PEAK		SIZE	TIME (AVG) HR/DAY				
1213	Chemical Reactions	MPC	90	7	ANY	ANY			N/A	N/A	N/A								(1)	(0.5)				Ref. – 0400
1214	Space Isothermal Furnance System (SIFS)	MPC	90	4	>250	ANY			N/A	N/A	N/A				N/A				(1)	(0.5)				Ref. – 0400
1300	Radiation Hardened Computer	INS	90	1825	ANY	ANY			N/A		N/A	N/A	50	0.36	.6x.5x.4	200 (24)		1000			✓			
1303	Plants in Controlled Env Life Support Sys (CELSS)	INS	90	180	ANY	ANY			N/A										1	0.2				Ref. – 0341, 1304
2001	Strain & Acoustic Sensors	MTS	90	3650	LEO	ANY			N/A				50	0.36		100		1.0	1	0.1	✓	✓	✓	
2101	Low-Cost Modular Solar Panels	ECN	90	3650	LEO	ANY			Solar	10000		0.1	30	0	5x6x0.1				1	0.1	✓			
2402	Advanced EVA Technology	CHF	90	3600	LEO	ANY			N/A	N/A	N/A	N/A	500	2.2		100			1	0.02	✓			
2503	Space Component Lifetime Tech	SSS	90	3650	LEO	ANY			N/A				300	0	.2x.2x.2 (ea of 6)				1	0.2	✓		✓	Six Components
0247	Space Plasma Physics Payload	STR	91	365	400	57	250-500	57-90	Earth, Solar	3600			3183	0.36	5x300x10	3225 (1)	12K (0.1)	12K		0.25		✓		
0264	LIDAR Facility	ATR	91	365	400	57	300-500	57-90	Earth	3600			1900	0.36	4.5x4.5 x4.5	4500		253	1	0.2	✓	✓	✓	
1108	Laser Communications	COM	91 92	5 5	ANY	ANY			Inertial	360			140	0.36	2x1x1	200 (3)	500 (20.5)	100K	1	0.5	✓			
1111	Millimeter Wave Propagation	COM	91 92 93	5 5 2920	ANY	ANY			Earth	3600			40	0.36	3x.5x3	25	100		1	0.25	✓		✓	
2002	Spacecraft Materials Tech	MTS	91	3300	LEO	ANY			N/A				150	0	5x1x0.1				1	0.1	✓	✓	✓	
2003	Materials and Coatings	MTS	91	3300	LEO	ANY			N/A				250	0	10x5x0.2				1	0.1	✓	✓	✓	
2006	Active Optics Technology	MTS	91	1000	LEO	ANY			Inertial				10000	0.36	16x12x16	1000			1	0.2	✓	✓		
2401	Manipulator Controls Tech	CHF	91	365	LEO	ANY			N/A	N/A	N/A		600	12.		3150		1.0	2	0.4	✓			
2506	OTV Propellant Transfer and Storage	SSS	91	30	LEO	ANY			N/A				2000	0	8.5x4.6 x3.6	500 (2)			1	1				
2507	OTV Propellant Liquefaction	SSS	91	30	LEO	ANY			N/A				1000	0	3.5x2x2	350 (24)			1	1				

*At telescope interface with IPS.

266.592-48.2

Table 4-5. Payload Requirements Summary Data - Man-Operated Accommodation Mode (Sheet 3 of 6)

GDC NO.	PAYLOAD ELEMENT NAME	DISCIPLINE	LAUNCH DATE YR(S)	MSN DUR (DAYS)	MISSION REQUIREMENTS: ORBIT PREFERRED ALT (km)	ORBIT PREFERRED INCL (deg)	ORBIT ACCEPTABLE RANGE ALT (km)	ORBIT ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING ACCY (sec)	POINTING JITTER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL: MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	RESOURCES: POWER LEVEL, W (DUR, HR/DAY) OPER	POWER PEAK	DATA K BPS (HR/DAY)	CREW SIZE	CREW TIME (AVG) HR/DAY	EVA REQ'D √	SVC REQ'D √	RE-CONFIG REQ'D √	COMMENTS
2508	OTV Docking & Berthing	SSS	91	30	LEO	ANY			N/A			N/A	5900	0	10x4.5 x4.5	500 (2)			1	2				TV Required
2601	Light Weight Cryo Heat Pipes	FTP	91	250	LEO	ANY			N/A				1000	0.36	15x1.0 x1.0	200	**	2.0	1	1.6	✓	✓		**5000W Reqd 12 Times/ Mission for 5 Min each
0000	Starlab	AST	92	1100	400	28.5	370-435	28.5-57	Inertial	150*			3280	0.36	13x7x4.5	2220 (18)	3890	16K	1	2	✓		✓	
0032	Large Area Modular Array	HEN	92	1640	400	28.5			Interial	180			9516	0.36	7.8x4.4 x4.4	3400 (20)		125	1	0.5	✓	✓		
0173	Shuttle Active Microwave Exper (SAMEX-C)	ERS	92	730	400	90	275-500	28.5-90	Earth	3600			2000	0.36	15x3x2	5K (12)	7500	5	1	0.2	✓		✓	
0175	Earth Obs Instru Devel (Extra Visible & RF)	ERS	92	730	400	90	275-1000	28.5-90	Earth	1800			1000	0.36	8x4x2	500	700	1000	1	0.25	✓	✓	✓	
0202	Meteorology Instru Group Devel Payload	WCL	92	365	400	57	300-500	28.5-90	Earth	360			1170	0.72	1.6x4.4 x4.4	1140 (24)		3000	2	0.4	✓	✓	✓	
0265	Upper Atmosphere Research Payload-Development	ATR	92	550	400	57	400-600	28.5-90	Earth/ Solar	36			2500	0.72	4.5x4.5x2	4K (4)		500	2	0.8	✓	✓	✓	
1106	Large Deployable Antenna	COM	92 94	14 14	ANY ANY	ANY ANY			Earth	360			500	0.36	50x20x50	200	300	400	1	0.5	✓			
1200	Pilot – Biological Processing Facility	MPC	92	730	>400	N/A			N/A	N/A		10^{-3}	1050	4.3	N/A	8K (2)	10K (22)	3 (24)	1	4				Vacuum Vent Required
1208	Crystal Growth	MPC	92	6.5	ANY	ANY			N/A	N/A		N/A			N/A									Ref. – 0400
1305	Communication Satellite Service/Handling	INS	92	30	ANY	ANY			N/A															Ref. – 1106, 2504, 2505
2004	Thermal Shape Control	MTS	92	550	LEO	ANY			N/A				1000	0.36	20x10x.2	3000	6000	1.0	1	0.1	✓			
2103	Ion Effects on LEO Power Systems	ECN	92	365	LEO	ANY			Solar	7200			150	0.36	5x6x0.1				1	0.1	✓		✓	
2504	OTV Payload Handling	SSS	92	30	LEO	ANY			N/A				2000	0	4x4.5 x4.5	300 (2)			2	8	✓			TV Required
2505	Payload Servicing & Repair	SSS	92	90	LEO	ANY			N/A				500	0	9x4.5 x4.5				1	1	✓			TV Required
2509	OTV Maintenance	SSS	92	30	LEO	ANY			N/A				3000	0	8.5x7.5 x7.5	500 (4)		4.0	4	13	✓			TV Required

*At telescope interface with IPS.

266.592-48.3

Table 4-5. Payload Requirements Summary Data - Man-Operated Accommodation Mode (Sheet 4 of 6)

GDC NO.	PAYLOAD ELEMENT NAME	DISCIPLINE	MISSION REQUIREMENTS										PHYSICAL			RESOURCES								COMMENTS
			LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT				VIEWING DIRECTION	POINTING		OPER ACCEL LIMIT (g)	MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	POWER LEVEL, W (DUR, HR/DAY)		DATA K BPS (HR/DAY)	CREW			SVC REQ'D √	RE-CONFIG REQ'D √	
					PREFERRED		ACCEPTABLE RANGE																	
					ALT (km)	INCL (deg)	ALT (km)	INCL (deg)		ACCY (sec)	JITTER (sec/s)					OPER	PEAK		SIZE	TIME (AVG) HR/DAY	EVA REQ'D √			
2510	Tether Dynamics Tech	SSS	92	3	LEO	ANY			N/A			N/A	3000	0.36	4x4x2				1	3				
0034	High Resolution X and Gamma Ray Spectrometer	HEN	93	1080	400	28.5			Inertial	360*			1768	0.36	2.1x2.1 x2.1	530 (18)	830 (6)	30	1	0.5	✓	✓		
0246	Solar Terrestrial Observatory	STR	93	365	400	57	300-500	57-90	Earth/ Solar	1800			16500	1.44	13x300 x10	10K (12)	21K (12)	42K	2	2	✓	✓		
0401	R&D/Proof of Concept Facility	MPR	93	2600	>400	ANY			N/A	N/A	N/A	10^{-5}	3224	11.95	N/A	25K (22)	35K (2)	6 (24)	1	8				Vacuum Vent Required
1109	Open Envelope Tube	COM	93 94	7 7	ANY	ANY			Inertial			N/A	157	0.36	0.2x0.2 x6	500	2000	100	1	0.25	✓			
1202	Pilot-Furnace Processing	MPC	93	1095	>400	ANY			N/A	N/A	N/A	10^{-5}	4452	12.05	N/A	30K (12)	50K (12)	10 (24)	1	4				Vacuum Vent Required
2005	Dynamics of Flimsy Struct	MTS	93	1460	LEO	ANY	N/A	N/A	N/A			N/A	1000	0.72	100x20 x2.5	1000 (24)		1.0	1	0.1	✓			
2104	Large Solar Concentrator	ECN	93	365	LEO	ANY			Solar	900			5000	0.36	10x10x10				1	0.2	✓			
2201	Attitude Control – System Identification Exper	CSE	93	365	LEO	ANY			N/A				100	0.36	100x20 x2.5**	1000		1.0	2	0.2	✓		✓	**Uses Structure from 2005
2301	Controlled Acceleration Propulsion Tech	PPN	93	180	LEO	ANY			N/A				45	0.36	0.6x0.4 x0.4	1500			1	0.2	✓	✓		Propellant Required
0161	Earth Science Research – Geophysical Investigation	GPF	94	800	400	90	275-500	85-95	Earth	1800			400	0.36	100x2x2	130 (24)	1200	30	1	0.5				
0179	Imaging Radar for Earth Resources Inventory & Monitoring	ERS	94	1095	400	57	300-500	28.5-90	Earth	360			2000	0.36	15x3x2	5K	7.5K	20	1	0.2				
1107	RFI Measurements	COM	94	21	ANY	ANY			Earth	3600			50	0.36	15x15x15	100	300	1K	1	0.5	✓		✓	
1201	Pilot – Containerless Processing Facility	MPC	94	1095	>400	ANY			N/A	N/A	N/A	10^{-3}	3900	12.9	N/A	12K (4)	25K (4)	3 (8)	1	8				Vacuum Vent Required
2105	Solar Pumped Lasers	ECN	94	270	LEO	ANY			Solar	900		N/A	200	0	10x10 x10**					0.2	✓		✓	**Uses – 2104 Collector
2106	Laser/Electric Energy Conversion	ECN	94	450	LEO	ANY			Solar	900		N/A	500	0	10x10 x10**				1	0.2	✓		✓	**Uses – 2104 Collector

*At telescope interface with IPS.

266.592-48.4

Table 4-5. Payload Requirements Summary Data - Man-Operated Accommodation Mode (Sheet 5 of 6)

GDC NO.	PAYLOAD ELEMENT NAME	DISCIPLINE	MISSION REQUIREMENTS: LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT: PREFERRED ALT (km)	PREFERRED INCL (deg)	ACCEPTABLE RANGE ALT (km)	ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING: ACCY (sec)	JITTER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL: MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L×W×H (m)	RESOURCES: POWER LEVEL, W (DUR, HR/DAY) OPER	PEAK	DATA K BPS (HR/DAY)	CREW SIZE	CREW TIME (AVG) HR/DAY	EVA REQ'D √	SVC REQ'D √	RE-CONFIG REQ'D √	COMMENTS
2202	Attitude Control – Adaptive Control Experiment	CSE	94	365	LEO	ANY			N/A			N/A	100	0.36	100x20 x2.5**	1000		1.0	2	0.2	✓		✓	**Uses Structure From – 2005
2502	Advanced Control Device	SSS	94	730	LEO	ANY			N/A				400	0.36	100x20 x2.5**	1000		1.0	2	0.2	✓		✓	**Uses Structure From – 2005
0035	High Energy Isotop Exper	HEN	95	1100	400	57	370-435	57	Anti-Earth	3600			3000	0.36		300 (24)			1	0.5	✓	✓		
0036	Spectra of Cosmic Ray Nuclei	HEN	95	365	400	57	370-435	28.5-57	Anti-Earth	3600			3082	0.36	3.3x4.8 x3.8	731 (22)	785 (2)	102	1	0.2	✓	✓		
0037	Transition Radiation and Ionization Colorimeter	HEN	95	700	400	57	370-435	28.5-57	Anti-Earth	3600			5750	0.36		550 (24)		10	1	0.5	✓	✓		
0151	Detection & Monitoring of Episodic Events	CRM	95	1825	450	90	400-500	80-100	Earth	6			3500	0.36	16x10x3	3000		300K	2	1	✓	✓	✓	
0171	Renewable Resources – Earth Science Research	ERS	95	1825	400	90	300-500	57-90	Earth	3600			2000	0.72	40x30x3	5K	7K	100K	2	1	✓	✓	✓	
1110	Spaceborne Interferometer	COM	95 97	15 15	ANY	ANY			Earth	360			60	0.36	30x.2x.2	100 (2)	150 (0.5)	500	1	0.5	✓			
1203	Commercial-Biological Processing Facility	MPC	95	1825	>400	ANY			N/A	N/A		10^{-3}	2100	8.6	N/A	16K (4)	20K (20)	6 (24)	1	8				Vacuum Vent Required
1301	Full-Body Teleoperator	INS	95	1460	ANY	ANY			N/A			N/A	300	1.5		500-1000								
2107	Solar Sustained Plasmas	ECN	95	450	LEO	ANY			Solar	900		N/A	2000	0	10x10 x10**				1	0.2	✓		✓	**Uses -- 2104 Collector
2203	Attitude Control – Distributed Control Exper	CSE	95	365	LEO	ANY			N/A				100	0.36	100x20 x2.5**	1000		1.0	2	0.2	✓		✓	**Uses Structure From – 2005
2501	Liquid Droplet Radiator	SSS	95	365	LEO	ANY			N/A				1000	0.36		1000		1.0	1	0.1	✓			
0242	Incoherent Scatter Radar	STR	96 98	365	400 400	0 90	400-500 400-500	0-28.5 80-100	Earth, Celestial	18000			1000	0.36	25x25 x15	1500			1	0.5	✓			
0245	Space Plasma Physics Payload – Advanced	STR	96	730	400	57	250-500	57-90	Earth, Solar	3600			3183	0.36	5x300 x10	3225 (1)	12K (0.1)	12K	1	0.5		✓		
0263	CO_2 LIDAR for ATmospheric Measurements	ATR	96	1825	400	57	300-500	2.85-90	Earth	3600			4000	0.36	9x4.5 x4.5	25K		250	1	0.25	✓	✓	✓	

*At telescope interface with IPS.

266.592-48.5

Table 4-5. Payload Requirements Summary Data - Man-Operated Accommodation Mode (Sheet 6 of 6)

GDC NO.	PAYLOAD ELEMENT NAME	DISCI-PLINE	MISSION REQUIREMENTS: LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT: PREFERRED ALT (km)	PREFERRED INCL (deg)	ACCEPTABLE RANGE ALT (km)	ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING: ACCY (sec)	JIT-TER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL: MASS (kg)	PRES'D VOL (m³)	EXTNL SIZE L X W X H (m)	RESOURCES: POWER LEVEL, W (DUR, HR/DAY) OPER	PEAK	DATA K BPS (HR/DAY)	CREW: SIZE	TIME (AVG) HR/DAY	EVA REQ'D √	SVC REQ'D √	RE-CONFIG REQ'D √	COMMENTS
0342	Dedicated CELSS Module	LFS	96	1460	ANY	ANY			N/A	N/A	N/A		10500	111	N/A	18000 (23)	22000 (1)		2	6		✓	✓	Volume = Total Module
0343	CELSS Pallet	LFS	96	2190	ANY	ANY			N/A	N/A	N/A		1300		1x2.5 0.5	600 (24)		1	2	0.5		✓		
1205	Commercial-Furnace Processing Facility	MPC	96	1500	>400	ANY			N/A	N/A	N/A	10^{-5}	6325	22.5	N/A	40K (20)	70K (4)	10 (24)	1	8				Vacuum Vent Required
1212	Heat Resistant Alloys	MPC	96	30	ANY	ANY			N/A	N/A	N/A		[5000]			[100K] [(6)]			[1]	[8]				Ref. – 1205 for 30 Samples
1304	Controlled Environment Life Support Systems (CELSS)	INS	96	180	ANY	ANY			N/A			N/A	[1500]	[9.3]		[300]	[1000-2500]		1	0.2				Ref. 0342
2204	Advance Adaptive Control Technology Demo	CSE	96	365	LEO	ANY			N/A				100	0.36	100x20 x2.5**	1000		1.0	2	0.2	✓		✓	**Uses Structure From – 2005
2302	Laser Propulsion Test	PPN	96	180	LEO	ANY			Solar				100	0.36	1.5x.5 x.5	200		5	1	0.25	✓	✓		Collector & Laser From 2104 & 2105. GH_2 Required
0031	High Throughput Mission	HEN	97	1460	400	28.5			Intertial	180			10000	0.36		2000 (20)		125	1	1	✓	✓		
0243	Topside Digital Ionosonde HF Radar	STR	97 99	365	400 400	0 90	400-500 400-500	0-28.5 80-100	Earth				500	0.36	200x200 x3	1500			1	0.5	✓			
1204	Commercial-Containerless Processing Facility	MPC	97	1095	>400	ANY			N/A	N/A	N/A	10^{-3}	5700	20.3	N/A	26K (20)	38K (4)	6 (24)	1	8				Vacuum Vent Required
2108	Space Nuclear Reactor	ECN	97	2560	LEO	ANY			N/A			N/A	2500	0.36	100x4x4				1	0.1	✓			NASA Cost Share is 1/3
0201	Satellite Doppler Meteorological Radar Tech Devel	WCL	98	365	400	57	300-500	28.5-90	Earth	3600			2600	0.36	50x5.2 x5.2	6K		120K	2	0.4	✓	✓	✓	
0244	Solar Terrestrial Observatory – Advanced	STR	98	2190	400	57	300-500	57-90	Solar, Earth	1800			16500	1.44	13x300 x10	10K (12)	21K (12)	42K	2	1.33	✓	✓	✓	
0184	Z – Continuous & Special Coverage	ERS	00	3650	500	97.5	400-1000	90-100	Earth				14260	1.08	38x22 x4.5	30K	40K	***300K	1	2	✓	✓	✓	*** +1 Gbps Direct
2007	Large Structures Tech	MTS	00	1100	LEO	ANY			N/A				$1x10^5$	0.36	1000x200 x5	1000		1.0	2	0.4	✓			

*At telescope interface with IPS.
[ ] = Accommodated by Referenced Payload Element(s)

266.592-48.6

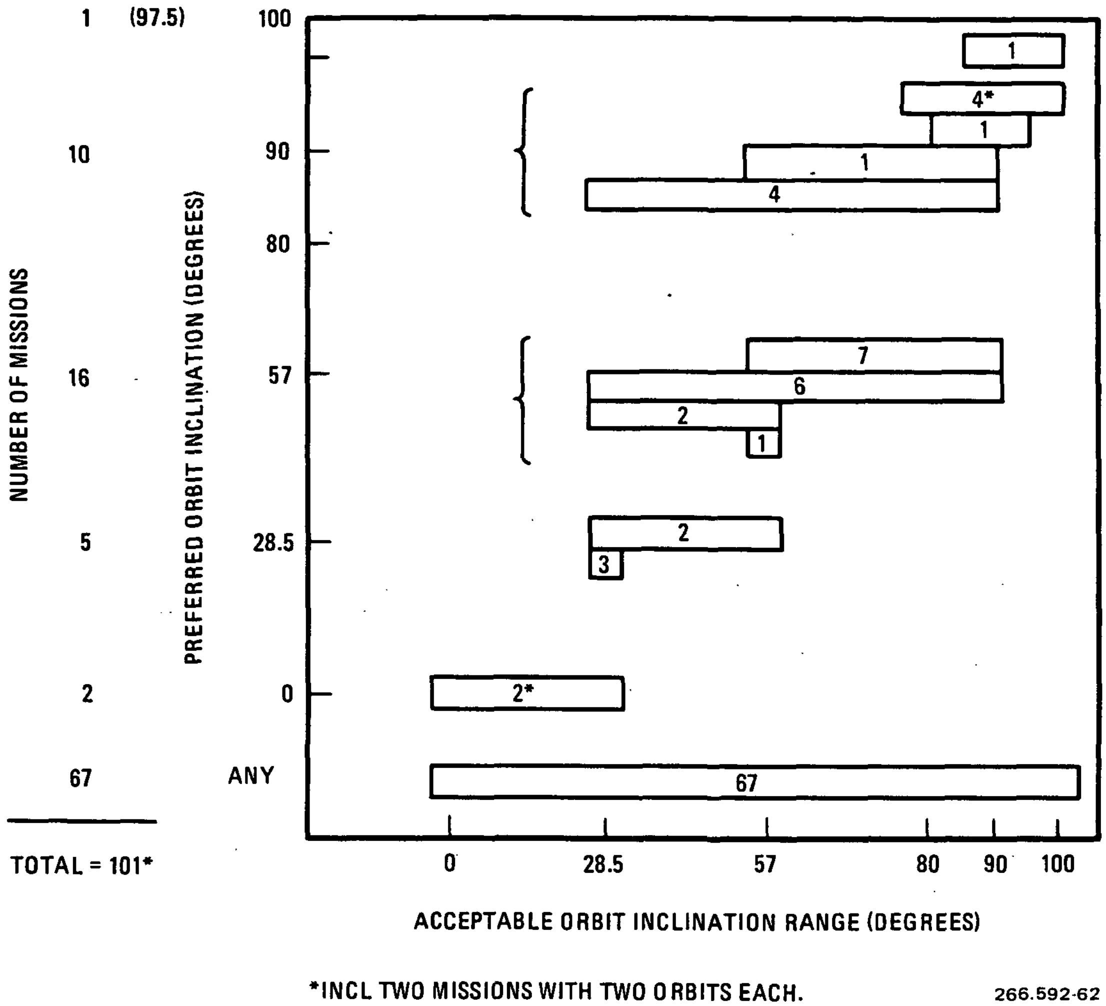


Figure 4-6. Orbit Inclination Requirements - Attached Missions/Payloads

c. Viewing missions requiring global coverage by operating in a 90-degree polar orbit or in a sun-synchronous orbit.

For example, in the Astrophysics discipline the principal driving requirement is a low altitude, low inclined orbit that provides a low radiation environment for the sensors.

On the other hand, the Earth and Planetary Exploration missions have more flexibility because their primary mission in the man-operated facility is to develop sensors and techniques for later use on free flyers in specific higher inclined orbits that provide global coverage. This flexibility is also generally true for Environmental Observations. Two missions were identified that have more than one discrete preferred or required orbit (0242 and 0243).

For Life Sciences and Materials Processing, the orbits are not critical so long as the acceleration level is within acceptable limits. The Communications development missions (i.e., LEO experiments), Industrial Services missions, and most of the Technology Development missions are insensitive to orbit parameters.

In summary, the orbit requirements for the man-operated Station facility must be selected to be compatible with discipline requirements.

The orbit inclination preferences and acceptable ranges for attached missions are summarized in Figure 4-6, which accounts for the 99 missions, including missions 0242 and 0243, each of which has a requirement for two different orbits.

Location of a single Space Station at 28.5 degrees will accommodate 85% of the payloads at their preferred location or at acceptable limits. A Station located at 57 degrees accommodates 89%, while a Station at 90 degrees captures 92% of the total missions. Clearly, a decision as to orbit selection must be made on the basis of other considerations, which include the lift capability of the Shuttle for logistics support, and the needs of the Station to support emplacement, service, and retrieval operations of free flyers.

The time-phased requirements for man-operated missions to a large degree are related to orbit inclination as depicted in Figure 4-7. The earliest requirements are missions that are satisfied with a 28.5-degree inclination orbit. These comprise research and development missions in low-g, and viewing from above the earth's atmosphere. Only one (1995) mission requires a specific 57-degree inclination; however, there are seven missions that prefer a 57-degree inclination but will accept polar orbits. If a 1990 operation was postulated for a 28.5-degree Station, then these missions would be candidates for other accommodations (free flyer or Shuttle support) or rescheduling until a suitable accommodation becomes available. The polar orbit requirement, which would likely satisfy most or all 57-degree missions, is seen to be required no earlier than the mid-90s, except for one mission desiring only polar orbit in 1990. The polar orbit missions would be candidates for reschedule or use of other supporting accommodations. Two of the polar orbit missions also have earlier missions at 28.5-degree inclination. The user has identified a single mission for each as an acceptable accommodation.

Again, the choice to use the 57-degree or polar orbits lies with consideration of ETR versus WTR launch availability, the comparative payload delivery capability of the Shuttle from these two locations, and the need to support free flyers (which include co-orbiting satellites/observatories, high-energy launches, and free-flying platforms).

4.2.2.2 Mass Requirements. The mass of most of the individual missions is well within the nominal capability of the Space Shuttle element of the STS. At least two of the missions will require more than one Shuttle flight. The estimated structure mass of the Large Structures Technology mission (2007) is about 100,000 kg and will require a minimum of four flights. This mass is envisioned to be delivered as reels that dispense graphite thermoplastic composite tape to supply an on-orbit beam-builder concept. Tape reels could be packaged in logistic modules aboard many Shuttle flights, along with the

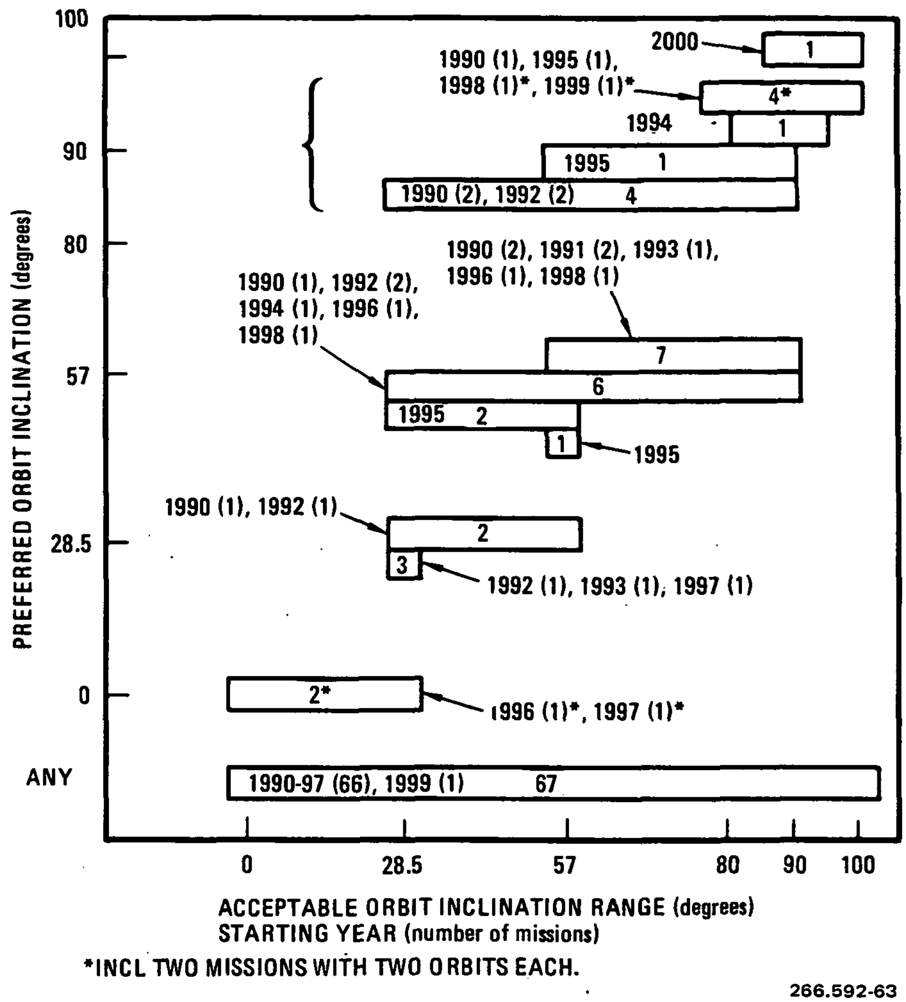


Figure 4-7. Time Phased Orbit Inclination Requirements - Attached Missions/Payloads

delivery of one (or more) beam-builder machines and assembly jigs, which are considered as part of Space Station operations support equipment and therefore are not included in the payload element weight.

The Z-Continuous Coverage and Special coverage mission (0184) will require at least two Shuttle flights to deliver the payload element to polar orbit. The payload element concept uses a modular approach that will permit multiple deliveries. Another mission, the Solar Terrestrial Observatory (0246), will nearly load a Shuttle to its delivery capability. More detailed analysis is required, however, before Shuttle manifesting is attempted. Additional analyses are also required to determine any needed support equipment, e.g., pallets and logistic modules, which are required to transport payload elements defined as integrated instrument packages.

4.2.2.3 Size and Pressurized Volume Requirements. Size for each mission is characterized in terms of a "maximum external dimension." This term applies to the experiment-unique equipment as deployed in space and varies from a fraction of a meter to a kilometer for the Large Structure Technology mission (2007) flown in the year 2000. The larger sizes represent extensive structures, assembled and deployed in orbit, employing components delivered by one or more Shuttle flights. The driving requirements on the Space Station appear to be the number of concurrent payload equipment items to be accommodated and their resource requirements, location and interaction with Space Station solar panels or other appen- dages and with each other.

Pressurized volume is indicative of the controlled-environment space and mounting demands of the various experiments on-board the Station, and is useful in preliminary sizing of the Space Station. In addition to experiment equipment volume, an allocation for control and display has been provided for those payload elements that do not otherwise contain C&D provisions as discussed in the introduction to Section 3. The maximum individual payload element pressurized volume of 112 cubic meters is found in the Life Sciences discipline (0300) as early as 1990. This payload and two other large volume payloads, i.e., the Animal Research Laboratory (0301) and the Dedicated CELSS module (0342) are defined to include crew access volume and do not require a packaging factor correction to be applied for accommodation. Minimum volumetric requirements are a fraction of a cubic meter, which in many cases represents the allocated control and display module. Eventually, timelining will permit some of these C&D units to be identified for time sharing or provisioning by the Space Station as a resource, with resultant reductions in pressurized-volume requirements.

4.2.2.4 Power Requirements. Approximately 60% of the individual missions require less than 5 kW average electrical power to operate. However, Material Processing Commercial missions (1202 and 1205) operate continuously and require significantly more power, e.g., 30 kW in 1993 and 40 kW in 1996. Average power requirements for the driving MPS discipline are timelined in Figure 4-8. If all missions were operating simultaneously, the maximum power level would reach 107 kW near the end of the decade. Peak power levels for payload elements 1202 and 1205 are 50 kW and 70 kW, respectively. A LIDAR mission (0263) also scheduled in 1996 requires 25 kW average power when operating.

4.2.2.5 Data Requirements. The data generation rates for three of the Earth Exploration Payload elements range up to 300 megabits per second, and will require some type of processing on the Space Station. The first occurs in 1990 and is a geoscience payload element (0177). The second, Detection and Monitoring of Episodic Events (0151) occurs in 1984 and the Z-Continuous and Special Coverage mission (0184) does not occur until 2000. The summary of the highest mission data rates is shown in Table 4-6.

Many missions have identified requirements for real-time communications and TDRSS access, and some require film (movies and photos) and TV up to 4 hours per day as well as digital data recording.

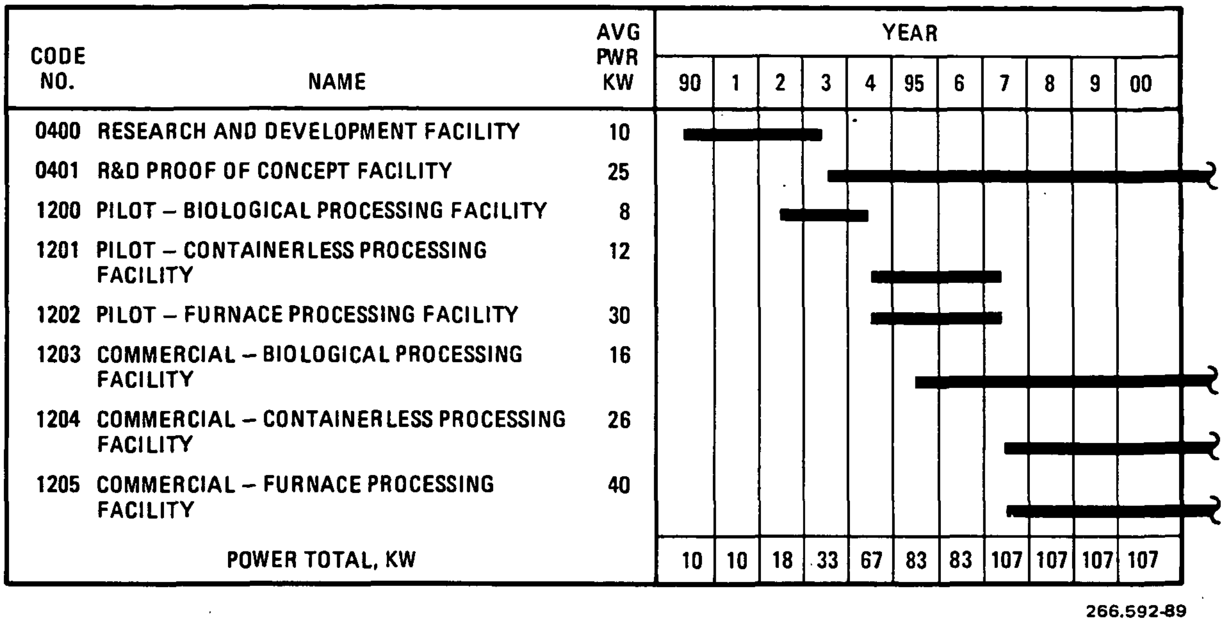


Figure 4-8. Materials Processing Power Requirements

4.2.2.6 Crew Requirements. Most of the missions have requirements for crew utilization of less than 1 manhour per day. In a few cases, the requirements reach 4 to 8 manhours per day for Material Processing missions in 1993, and up to 10 manhours per day for Life Sciences missions in 1990. In the Technology Development discipline, one of the 1992 Payload Handling missions (2507) requires up to 8 manhours per day, but only for a 30-day duration. Maximum crew size required for an individual mission is four men by Technology mission OTV Maintenance (2509), which includes EVA. A two-man crew is required by some Life Sciences missions such as the Human Research Laboratory (0300) in 1990, an early (1990) Earth Resources mission (0176) in 1990, and later (1995) Geoscience and Earth Explorations missions 0151 and 0171. Two-man crews are also estimated for some of the Technology Development missions. Cross-training at various levels of task complexity will be required to maintain reasonable crew levels. Approximately half of the payload elements require EVA support. Both one- and two-man EVA tasks have been identified.

4.2.2.7 Special Requirements. Special mission requirements place constraints on Station accommodations and operations when viewed separately and, when viewed in total, represent conflicting or compounded requirements. Some of the Astrophysics experiments scheduled throughout the decade require a contamination-free environment. Engine effluents, for example, could contaminate a telescope lens. Operations countermeasures and experiment-supplied covers will be required. Some of the payload element sensors, e.g., telescopes, require a high pointing accuracy and pointing stability that could not be reasonably achieved on a manned platform without provisions for pointing mounts, which may augment experiment-supplied image motion compensation.

Table 4-6. Attached Mission Data Rates Summary

MISSION TYPES	HIGHEST DATA RATE (bps)
• Science & Applications	
Astronomy	42M
Earth & Planetary Exploration	300M
Environmental Observations	120M
Life Sciences	128k
Materials Processing	6k
• Commercial Missions	
Communications	100M
Materials Processing	10k
Industrial Services	-
• Technology Development	
Materials & Structures	1k
Energy Conversion	-
Computer Science & Electronics	1k
Propulsion	-
Control & Human Factors	-
Space Station Systems/Operations	1k
Fluid & Thermal Physics	4k

Pointing accuracy required by the attached payload elements is shown in Figure 4-9. A nominal station pointing capability of 1 degree would accommodate more than 80%. The remaining payloads would require IPS or equivalent mounts or payload-provided mounts. The mass and power requirements given for STARLAB, SIRTF, and HRS all include pointing mounts that provide fine pointing. The Station mounting accommodation must permit required payload orientations, which include earth, anti-earth, solar, and inertial, and must accommodate the dynamic pointing envelope.

Requirements for Life Sciences Missions include accommodation of plants and animals. A 0-1g centrifuge must be provided for some experiments (accomplished in 0301) while near continuous low-g conditions ($\leq 10^{-3}$ to $\leq 5 \times 10^{-5}$ g) are required for plant experiments in the same payload. Near continuous low-g conditions are also required for some Material Processing in space ($\leq 10^{-3}$ to $\leq 10^{-5}$ g); for example, crystal growth processes.

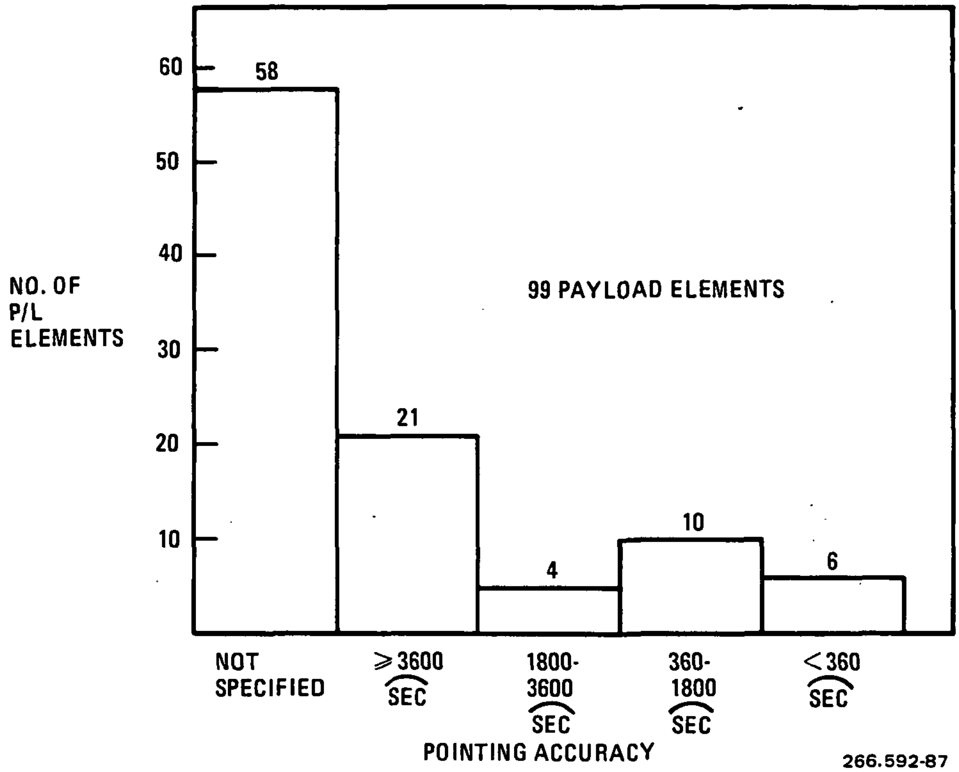


Figure 4-9. Pointing Requirements

Some of the payload elements such as Communications Development missions are sensitive to RFI and will be a source of RFI to other missions during operation. Other missions require deployment, control, and retrieval of subsatellites. Materials Processing missions require vacuum vent access. Many payloads have logistic (up/down) requirements for raw materials, cryogens, and specimens/products.

4.2.2.8 Summary. In summary, the Space Station must provide users with satisfactory orbits and with pressurized modules with space and mounting for research laboratory equipment and commercial equipment, as well as control and data handling systems. External mounting provisions with the proper orientation are required for very large sensors, antennas, and structural elements. Crew and electrical power resources are required as well as basic platform accuracy and stability. Provisions for special mission requirements are also needed.

The major sensitivities of attached missions to Space Station operations are:

a. The sensitivity of low-g research activities to local disturbances from crew activities, transportation elements activities (docking, etc.).

b. The sensitivity of many viewing sensors to contamination, such as from local atmosphere cabin leakage or other sources that could cause deposition on sensitive surfaces or interrupted viewing for optical, IR, and X-ray Earth Observations and Astrophysics missions.

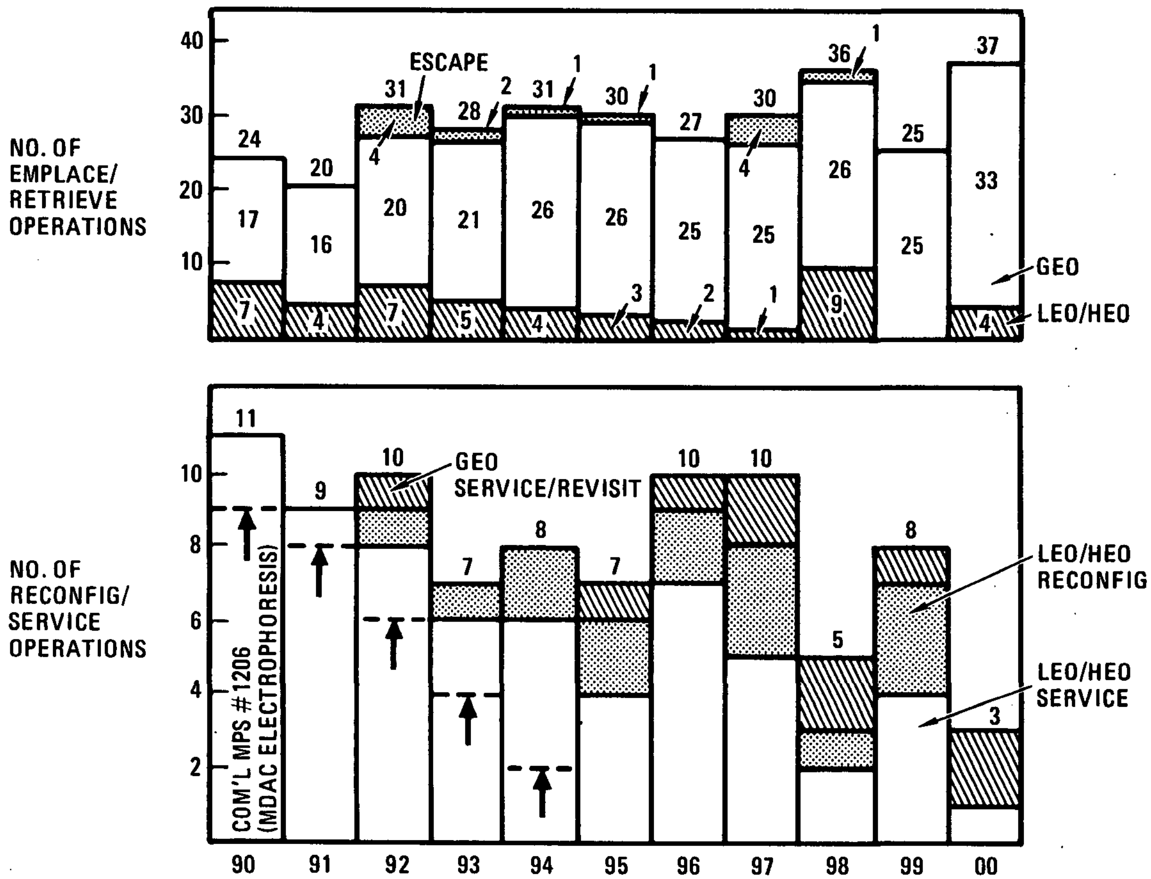
4.3 FREE-FLYING MISSIONS

The free-flying (FF) mode includes both individual satellites and space platform accommodation of the payload elements.

The basic criteria for selection of free-flying missions is described in the introduction to this section. A set of 50 representative missions has been identified as potential user requirements for free flyers. The primary involvement of the Space Station with free flyers is through support operations, which include assembly/construction, emplacement, service, reconfiguration, and retrieval. Large free flyers that are delivered to LEO in modular form can be assembled and checked out prior to being placed on station. Free flyers that have long lifetimes will be man-tended to provide servicing, repair, and updating. Due to unique orbit characteristics, free flyers have been subdivided into three groups: low earth orbit/high earth orbit (LEO/HEO), Geosynchronous orbit (GEO) and Escape (planetary) missions. These mission groups are discussed in Sections 4.3.1, 4.3.2, and 4.3.3, respectively, in terms of mission time-phasing and mission requirements and characteristics. Individual missions are further described in Book 1, Appendix I.

The Station support operations traffic flow for all orbit altitude groups is summarized in Figure 4-10, which excludes DOD requirements. The predominant emplacement traffic throughout the decade is seen to be the geosynchronous orbit communication satellites. Planetary missions include 12 deliveries to high-energy escape trajectories as well as a sample return mission. LEO/HEO emplacement/retrieval missions are spread at three inclinations -- 28.5 degrees, 57 degrees, and polar, with the majority preferring near-equatorial (low) and high (polar) inclinations. The bulk of service/reconfiguration missions are at low altitude/inclination; however, several geosynchronous revisits to large platforms are planned, mostly in the latter half of the decade. A significant portion of the potential traffic for early service missions is attributed to a single mission: the commercial MPS electrophoresis free flyer. This function is accommodated in later years by commercial Station-attached missions. Service/reconfiguration traffic appears to suffer a decline due to limited planning horizons, an effect seen throughout other requirements analyses. Further discussions of traffic projections for free-flying missions station-supported operations are contained in Section 4.4.

For planning purposes, it is assumed that the TMS will be available to support free-flyer operations traffic in 1990. The OTV is assumed to have an IOC of 1994 and to be fully operational in 1-3 years. Until then, traffic requiring OTV energy capabilities will be provided by Shuttle/upper stage support or other launch vehicles.



TOTAL MISSION TRAFFIC

	EMPLACE	RETRIEVE
• LEO/HEO	24	22
LOW INCL.	(8)	11
MID INCL.	(5)	(4)
POLAR INCL.	(11)	(7)
• GEO	258	2
• ESCAPE	12	1
	294	25
TOTAL	319	

TOTAL MISSION TRAFFIC

	RECONFIG	SERVICE/ REVISIT
• LEO/HEO	15	63
LOW INCL.	(8)	(40)
MID INCL.	(0)	(10)
POLAR INCL.	(7)	(13)
• GEO	0	10
• ESCAPE	0	0
	15	73
TOTAL	88	

*EXCLUDES DOD

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Figure 4-10. Station Support Operations Traffic Flow

4.3.1 LEO/HEO FREE-FLYING MISSIONS. This section discusses the 26 representative LEO/HEO free-flying missions in subsections that address time-phasing and mission requirements including potential platform accommodations. The terms LEO and HEO denote a spectrum of orbit altitudes, and are divided somewhat arbitrarily for discussion purposes: LEO being assumed to include altitudes at or near anticipated Space Station altitude (400-500 km), which are suitable for co-orbital operations, and HEO encompassing locations above this altitude but less than GEO. As a matter of interest, a concept for more precisely defining near and distant orbits in terms of a self-contained payload/rocket system mass ratio (near orbit has a mass ratio not greater than 2:1) has been suggested by S. J. Paddack, NASA GSFC, AAS 83-061.

4.3.1.1 LEO/HEO Free-Flying Missions Time Phasing. The LEO/HEO traffic model (Table 3-29) was derived from several inputs including the NASA Orientation meeting handouts as well as later supplements; various data sheet inputs (see Book 1, Appendix I); Nominal Mission Model, Rev 6 MSFC PS01, dated 30 September 1982; and User Fact Sheets.

Three of the free flyers included in the model are already planned for flight prior to the advent of the Space Station era and are assumed to transition from Shuttle-supported to Station-supported after 1990. These missions are: the Gamma Ray Observatory (0030), the Ocean Topography Experiment TOPEX (0222), and the Commercial Electrophoresis Biological Free Flyer (1206), which is a group of five satellites. The first of the five is launched in 1986 and the others are launched yearly thereafter. For this model, service operations for any applicable missions are scheduled whenever reconfigurations are scheduled, thereby conserving trips and mission downtime.

One of the Weather/Climate missions is implemented by multiple satellites, i.e., the TIROS follow-on (0207). It requires a pair of satellites operating simultaneously and staged in the same orbit. Table 3-29 shows unit weights and dimensions for each of the two TIROS follow-on payload elements. The Earth Radiation Budget Experiment (ERBE 0241) is an integrated instrument package not counted in traffic statistical analyses because it is flown as a piggy-back payload. Likewise, the four commercial missions shown in Table 3-29 (1000, 1002, 1003, 1302) are accommodated by other missions and therefore are shown for schedule purposes but are not counted as separate emplacements.

4.3.1.2 LEO/HEO Free-Flying Missions Requirements. Low earth orbit and high earth orbit (LEO/HEO) free-flyer missions generally fall into the same groupings of orbit inclination as the man-operated missions discussed in Section 4.2 and for much the same reasons:

a. 28.5-degree inclination for conduct of automated low-g processes or viewing from above the earth's atmosphere.

b. 57-degree inclination for adequate coverage of the earth's surface or consideration of Van Allen belt latitudes for plasma and high energy missions. Two special orbit inclinations, at 46 and 63.4 degrees, are included in the 57-degree category.

c. Polar orbits for global coverage of the earth's surface or atmosphere.

The man-tended free flyers include those that can be serviced from the Space Station or the Shuttle Orbiter, facilitated by TMS as required or with the OTV when it becomes available.

The free flyers include a wide span of physical sizes, which affects the servicing requirements and methods applicable to this group of spacecraft.

Free flyers operating at 28.5-degree inclination are primarily Astrophysics observatories. Many of these are very large observatories. One of these, the Large Deployable Reflector (0001), will require multiple Shuttle flights and assembly on orbit. This large size also suggests the likelihood of servicing by visiting the observatory in situ using TMS or Shuttle, while smaller spacecraft could potentially be retrieved to the Space Station for servicing.

Free flyers at the 57-degree and polar inclinations are primarily Earth and Planetary Research and Environmental Observation satellites of moderate size and, therefore, are potentially serviceable from either the Shuttle or a co-orbital Station, using TMS or possibly OTV.

An analysis of mission requirements indicates that there are 13 free-flying missions that prefer a low earth orbit (LEO) altitude of 400-500 km. There are eight missions that prefer higher orbits. The LEO/HEO designation is somewhat arbitrary and is intended to provide a gross indication of which free flyers might be considered as co-orbital with Space Station orbits. An altitude versus inclination plot of these payloads is shown in Figure 4-11. Grouped at an inclination of 28.5 degrees and an altitude of 400-500 km are one Materials Processing free flyer and four Astrophysics missions. Two additional Astrophysics missions are grouped at 28.5 degrees, but at altitudes of 600 and 700 km.

Four free flyers are grouped at an inclination of 57 degrees at 400-500 km. These include two Astrophysics experiments and two associated with Environmental Observations. One payload desires a special orbit of 63.4-degree inclination at an altitude of 1384 km.

Two Earth and Planetary Research missions are grouped at 90-degree inclination, 400 to 500 km altitude. These highly inclined orbits provide for the required global coverage.

One Astrophysics mission is scheduled for a 98-degree inclination at 400 km, and one Environmental Observations mission is also at 98 degrees but at 500 km. Two other Environmental Observations experiments operate at an inclination of 98 degrees and an altitude of 800 km. Of these, TIROS Follow-On (0207) is configured as a pair of satellites orbiting at a fixed spacing from each other. Three other system Z payloads in the Earth Resources discipline need 100-degree, 1000-km orbits to obtain the desired global coverage. If the altitude of one of these missions was reduced to 500 km to increase its man-tending accessibility, then a second "daughter" satellite would be required for each mission so adjusted as to retain the desired global coverage.

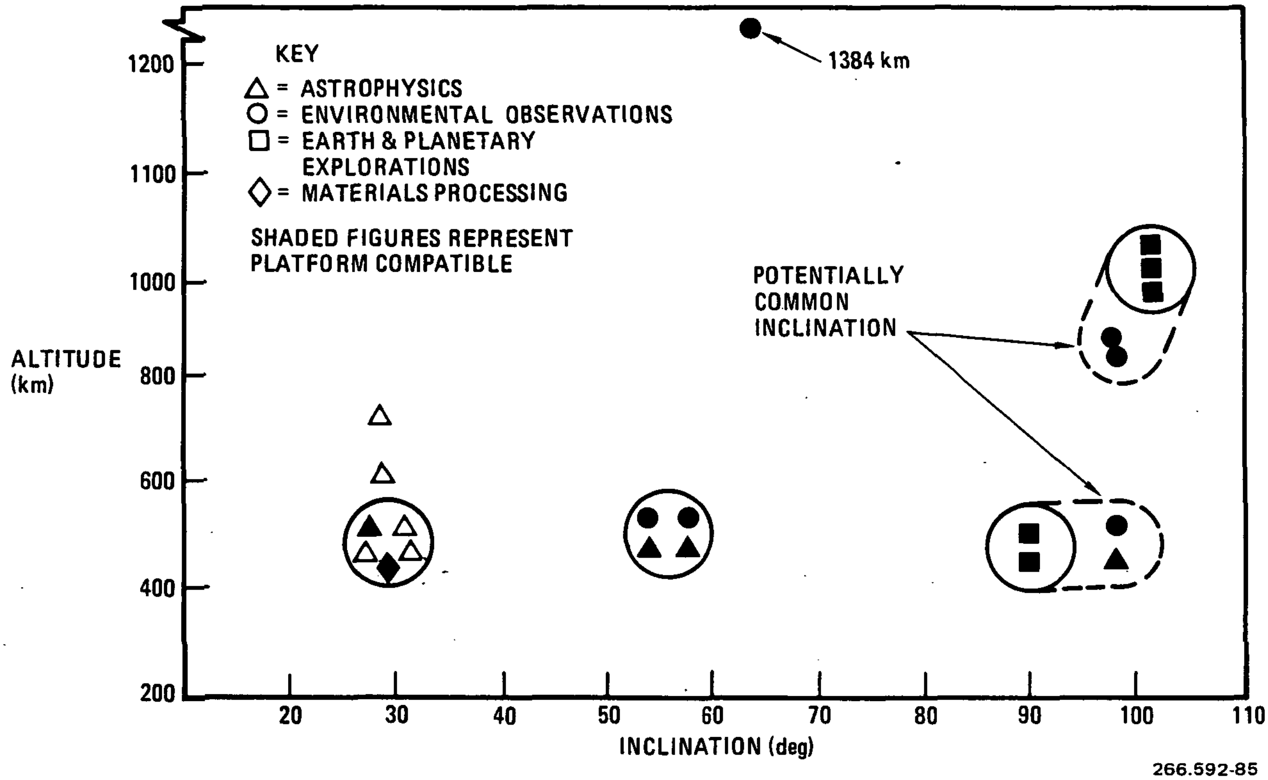

Figure 4-11. LEO/HEO Free Flyers

The tentative grouping shown in Figure 4-11 permits Space Station architecture planning to support free-flyer missions using the minimum number of Station elements or support items. Not shown in Figure 4-11 are four commercial missions that can be accommodated by other missions and the Earth Radiation Budget Experiment (ERBE, identified as 0241), which flies piggyback onboard other missions.

Further analyses of acceptable orbits for free-flying missions (Table 4-7) suggests an even greater flexibility for mission grouping to permit optimization of servicing/reconfiguration operations or for possible candidates for platform accommodations. The characteristics and capabilities of the LEO/HEO spacecraft are also important in determining the best methods of performing the service and reconfiguration functions. Most of the payload elements identified in Table 4-7 are seen to include not only the payload instruments but also a basic spacecraft that provides needed power, data handling, and attitude control resources.

Some payload elements have orbit transfer propulsion included as an integral part of the spacecraft. However, six payloads are shown with an orbit mass that includes only the integrated instrument package. These payloads are adaptable to accommodation by either a platform or a Leasecraft-type spacecraft that provides orbit transfer propulsion. Due to its extreme weight, the Large Deployable Reflector (0001) must be delivered to LEO by the Shuttle in

Table 4-7. LEO/HEO Free-Flyer Characteristics

GDCD NO.	PAYLOAD ELEMENT NAME	PREFERRED ORBIT		ACCEPTABLE ORBIT		UNIT WT (KG)	UNIT LENGTH (M)	P/L ELEMENT DEFINITION		SPACE-CRAFT INCLUDES ORBIT XFER PROPUL	NOT COMPATIBLE WITH PLATFORM ACCOMMODATION	REQUIRED ON-ORBIT OPERATIONS			
		ALTITUDE (KM)	INCLINATION (DEG)	ALTITUDE (KM)	INCLINATION (DEG)			INTEG. INST. PKG. (1)	SPACE-CRAFT			ASSY	STA SUPPORTED CHECKOUT	SERVICE	RE-CONFIG
	ASTROPHYSICS														
	• **ASTRONOMY**														
0001	Large Deployable Reflector	700	28.5	700	25-50	55,000			✓		✓	✓	✓	✓	✓
0003	Very Long Base-Line Interferometer Demo	400	57	400-5000	28-57	1,354	5	✓						✓	
0004	Space Telescope	600	28.5			11,600	13.1		✓		✓			✓	✓
	• **HIGH ENERGY (Cosmic, γ, X-Ray)**														
0030	Gamma Ray Observatory (1988 Launch)	400	28.5	350-450	0-28	11,000			✓	✓	✓			✓	
0033	Adv X-Ray Astrophysics Facility	500	28.5			10,267	12.8		✓		✓			✓	✓
0038	X-Ray Timing Explorer	400	28.5			1,000	2		✓	✓	✓				
	• **SOLAR PHYSICS**														
0060	Solar Internal Dynamic Mission	400	99			4,540			✓	✓				✓	
0061	Solar Corona Diagnostic Mission	400	28.5			1,800			✓						
0062	Advanced Solar Observatory	400	57	370-435	28-57	12,500	8.2	✓						✓	
	EARTH EXPLORATION														
	• **EARTH RESOURCES**														
0172	Operational Land Systems	500	90	500-1000	80-100	2,000	4		✓	✓				✓	✓
0180	Free-flying Imaging Radar Exp (FIREX)	400	90	375-450	80-100	2,000	4	✓						✓	
0181	Z-Continuous Coverage	1000	100	400-1000	96-100	8,578	16		✓	✓				✓	
0182	Z-Hydrologic Cycle Priority	1000	100	400-1000	96-100	8,708	16		✓	✓				✓	
0183	Z-Special Coverage	1000	100	400-1000	96-100	18,821	17		✓	✓				✓	
	ENVIRONMENTAL OBSERVATIONS														
	• **WEATHER/CLIMATE, OCEAN, SOLAR/TERRESTRIAL ATMOS. RESEARCH**														
0205	Meteorology Inst Grp Ops P/L	400	57	300-500	57-90	2,000	4.4	✓						✓	
0207	TIROS Follow-on (2)	800	98			2,000	9		✓					✓	
0221	Ocean Instrument Payload	500	98	300-800	57-98	1,600	10	✓							
0222	Ocean Topography Exp. (TOPEX)	1384	63.4			1,600	6		✓					✓	
0241	Earth Radiation Budget Exp. (ERBE)	600	46			55	1	✓							
	(1988 Launch)	800	98			55	1	(Piggy Back P/L)							
0266	WINDSAT	800	98			2,260	4.5		✓					✓	
0267	Upper Atmosphere Research P/L	400	57	400-600	57-90	2,500	4.5	✓						✓	
	COMMERCIAL • MAT PROCESSING														
1206	Electrophoresis F/F – Biologicals (Initial Lch 1986)	>400	Any			9,987	5.5		✓	✓				✓	
1000	Geological Reconnaissance	500	90												
1002	Worldwide Cotton Acreage & Production	500	45												
1003	Petroleum and Mineral Location	920	99.2												
1302	Gamma Ray Astronomy	400	28.5												

(1) These P/L Elements assume accommodation on a platform or leasecraft-type spacecraft which has orbit transfer propulsion.

(2) Two satellites required

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more than one module. The large reflector is assembled and subsequently checked out at the Station. Specific checkout requirements for other payloads have not been identified, but checkout conducted to verify reconfiguration and installation could be considered as a potential Station interface.

Free-flyer servicing operations may be performed at the Space Station or in the free-flyer orbit by the use of TMS/RMS or OTV/TMS. In either case, the TMS or Space Station must be able to command the free flyer to deactivate/activate systems, and for any spin stabilized satellites, to command them to despin. During the despin period and subsequent servicing, the free-flyer solar arrays must be protected from heat and cold.

The free flyers and TMS/RMS must both be designed for automatic servicing to include: checkout/diagnostics, consumable resupply, and planned maintenance. Unplanned maintenance or planned maintenance on free flyers not designed for automatic servicing will be performed at the Space Station by use of RMS or EVA. TMS must also be designed to capture free flyers designed and operating in the pre-Space Station era. An example is the Gamma Ray Observatory (0030), which is launched in 1988.

Servicing of free-flyers co-orbital with the Space Station may be performed either in situ by TMS or at the Space Station by TMS/RMS as shown in Figure 4-12. Servicing of free flyers not co-orbital with the Space Station may be performed either in situ by OTV/TMS by the Shuttle with TMS, or by waiting for orbital conjunction with the Space Station and using OTV/TMS (Figure 4-13). The option selected will be based on factors such as the following:

Factor	Co-Orbital Free Flyer	Not-Co-Orbital Free Flyer
• Orbital parameters/communication links		X
• Degree of automatic servicing free flyer is designed for	X	X
• Economic tradeoff-time/cost for preparation	X	X
• Time available for servicing	X	X
• Number of times servicing is required	X	X
• Planned versus unplanned maintenance	X	X
• Capability of spacecraft orbit transfer propulsion	X	X

The servicing task may be performed by automatic means or by man-in-the-loop, dependent upon the degree of automatic servicing designed into the free flyer.

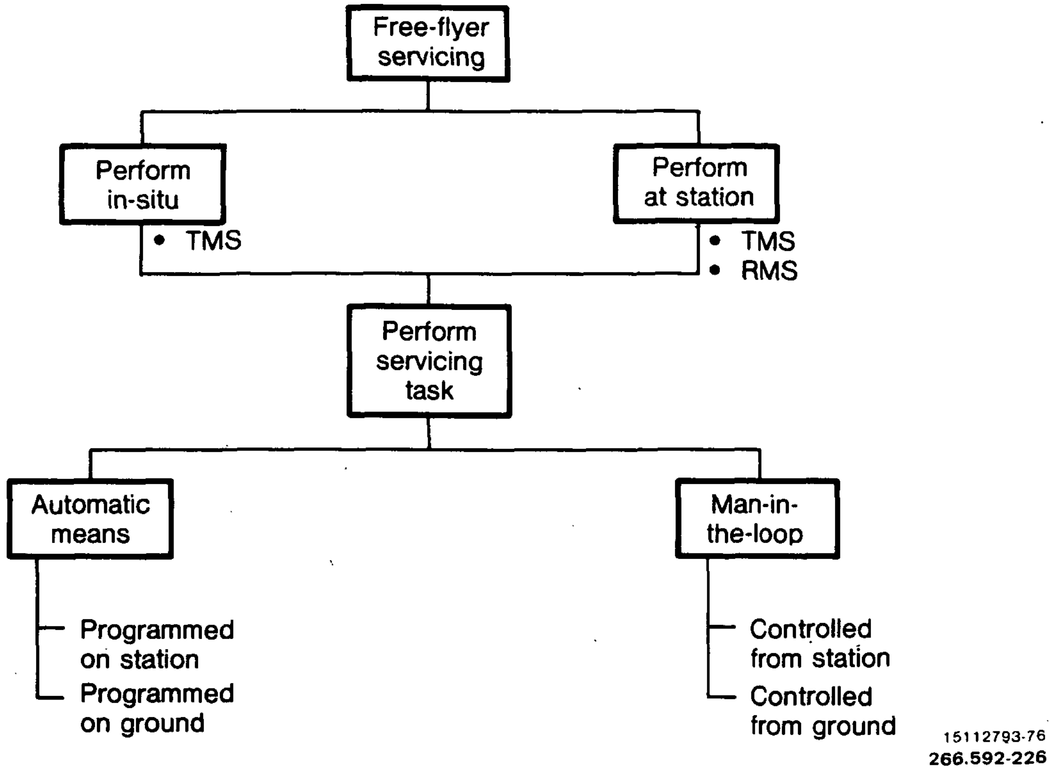


Figure 4-12. Free-Flyer Servicing Options - Free-Flyer Co-Orbital with Station

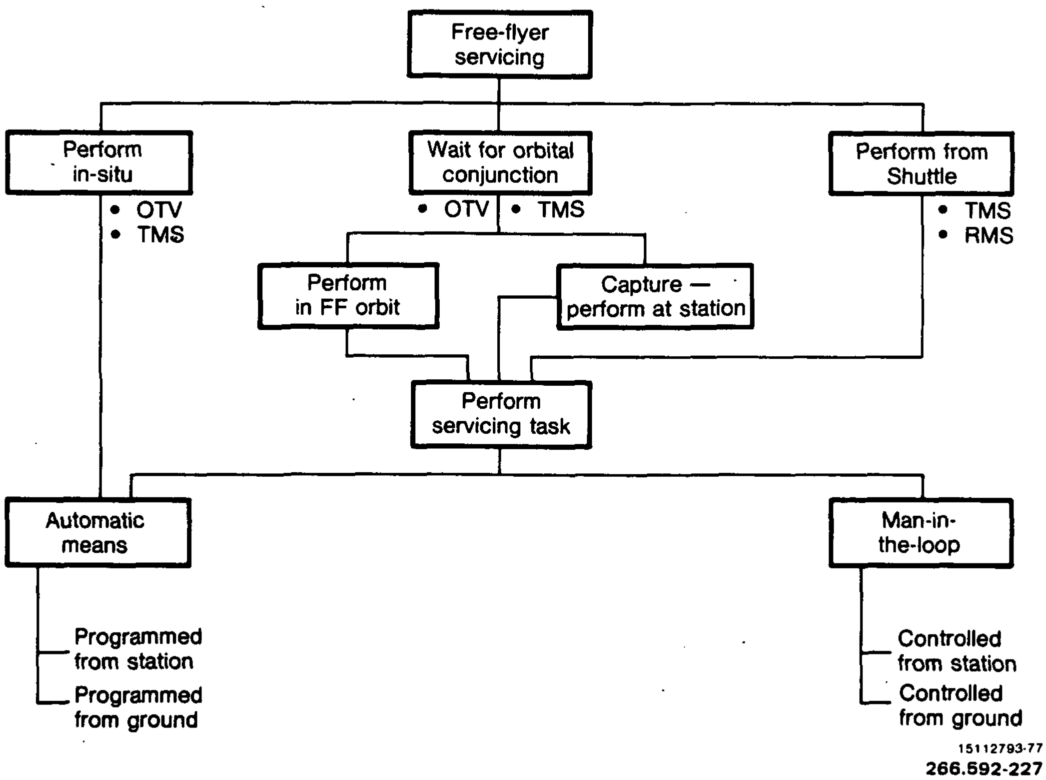


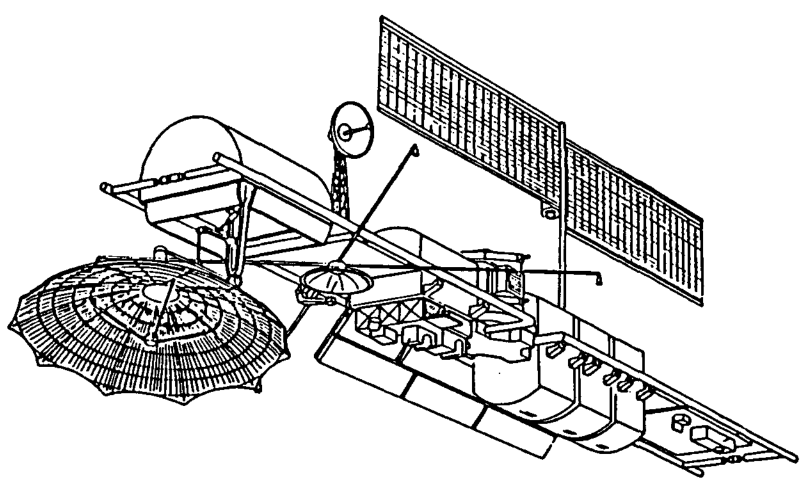
Figure 4-13. Free-Flyer Servicing Options - Free-Flyer Not Co-Orbital with Station

If servicing is to be performed by automatic means, the servicing task may be programmed on the Space Station or the ground based on cost, crew loading, computer capability, checkout simulation, controls and displays, and overall timelines.

If servicing is to be performed with the man-in-the-loop, the servicing task may be controlled from the Space Station or the ground, dependent upon relative orbits, communication links, crew loading, station autonomy, and controls/displays.

Reconfiguration tasks are considered to be unique man or man-machine tasks, and each payload will require EVA support wherever reconfiguration is accomplished (refer to Section 3 for task criteria).

4.3.1.3 LEO/HEO Free-Flying Platforms. Grouping of compatible missions on a single platform permits sharing of platform services, such as stabilization/pointing, electrical power, and data and communications, thereby reducing spacecraft cost and weight, with resultant reduction in launch costs for the spacecraft (Figure 4-14).



Services provided by platform

- Mounting provisions for sensors
- Orientation & pointing
- Electrical power
- Data collection, handling & distribution
- Docking provisions for Orbiter or TMS

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Figure 4-14. LEO/HEO Platform Example

Where two or more integrated instrument packages are mounted on the platform at the same time, servicing missions can be combined and the cost shared for further reduction in operating costs.

Many of the free flyers operating in LEO/HEO have similar orbital altitude and inclination requirements, which offers the potential for grouping these spacecraft on platforms. Such sharing can be in parallel timewise, or could be shared sequentially by time-separated spacecraft.

Of the five free flyers at 28.5 degrees and 400-500 km, four are Astrophysics missions as shown in Table 3-29. However, three of these -- namely Gamma Ray Observatory (0030), AXAF (0033), and X-Ray Timing Explorer (0038) -- are currently planned as individual satellites and would not be considered as platform candidates.

The Materials Processing Mission for 28.5 degrees, 400-500 km flown continuously starting in 1986 is a candidate for either Station or platform accommodation because multiple servicing trips, performed by either the onboard Leasecraft-type propulsion system or the TMS, could be eliminated.

From a schedule standpoint, the remaining Astrophysics mission flies later than most of the materials processing missions, and therefore dual discipline occupancy of a low inclination platform would occur for a limited time period.

A group of environmental observation and astrophysics missions at 57 degrees and 400-500 km are suitable candidates for a LEO platform. From a scheduling standpoint and a design compatibility standpoint, the occupancy of a 57-degree LEO platform could be up to four platform compatible payload elements simultaneously. These elements are identified as the VLBI Demonstration (0003), the Advanced Solar Observatory (0062), the Meteorology Instrument Group (0205), and the Upper Atmosphere Research payload (0267). In addition to "standardized" platform resources, the VLBI Demonstration mission requires the platform to supply a freon loop for thermal control.

Similar mission groupings occur at polar and sun-synchronous orbits and are potential candidates for platforms. It is recognized that the 98-degree orbit is needed to accomplish mission objectives, but the 90-degree Earth Resources missions are probably amenable to 98 degrees because they are interested primarily in global coverage. It appears that up to four missions could be accommodated simultaneously on a polar LEO platform, and two missions on a HEO platform. The three remaining Earth Observations missions in polar HEO orbit are the system Z set of sequentially growth-phased multidiscipline missions, which are free-flying platforms in their basic concept. Of particular value would be a small number of rather large platforms at near-polar orbit where the weight savings made possible by platform sharing and servicing helps to compensate for the lesser payload capability of the Shuttle at this inclination. Also, the capability to economically extend the useful life of spacecraft by shared service visits could result in an increase in the projected number in operation.

4.3.1.4 Summary. In summary, missions accomplished by spacecraft operating as free flyers in LEO/HEO, and that require or would significantly benefit from manned service on-orbit, are included as man-tended free flyers. Requirements envelopes for LEO/HEO missions are outlined in Table 4-8. These servicing operations are aimed at extending the useful life of the spacecraft, while minimizing the onboard provisions for consumables storage, provisions for redundant elements, or automatic replacement of sensors.

Table 4-8. LEO/HEO Man-Tended Free-Flyer Summary

REQUIREMENT	28½ DEG	57 DEG	90 DEG
No. in operation Typical mass (kg)	1-8 1000 to 55,000	1-4 1350 to 12,500	1-7 1600 to 19,000
Service/Reconfig. Interval Access means	1-3 years Visit – TMS – Option-Shuttle, or Self Propulsion	1-3 years Visit – shuttle or OTV/TMS	1-3 years Visit – shuttle or TMS/self propulsion when station avail.
Crew – per service Crew Time EVA	1 to 2 men 1-4 days required	1 to 2 men 1-2 days required	1 to 2 men 1-2 days required
Power-service (avg kW)	<1	<1	<1

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The free flyers operate in orbits with altitude and inclination limits that make some of them accessible for servicing from a co-orbital manned Space Station, while the others could be serviced from the Space Shuttle Orbiter. Servicing from a co-orbital Space Station offers the greatest potential for cost savings since Shuttle service launch costs are minimized. This method also has potential for the most performance benefits, since the servicing operation is not constrained to be completed within the limited on-orbit stay time of the Orbiter.

A potential for grouping free flyers onto 57-degree and near polar platforms has been identified as an attractive means of optimizing costs and resource requirements as well as service and reconfiguration operations.

4.3.2 GEOSYNCHRONOUS ORBIT MISSIONS. In the typical Space Station era GEO mission scenario, the Orbiter delivers the spacecraft to a Space Station/OTV operations base in LEO, where the spacecraft is mated to an OTV or other upper stage, as required, and transferred to its operating orbit.

In early years, however, GEO spacecraft would be delivered by planned upper stage, i.e., PAM, IUS, or Centaur, operating from the Shuttle Orbiter.

During later years after transition to Station/OTV basing operations, the satellites could be grouped for launch by the Orbiter, and subsequently by the OTV, where weights allow. A further growth is possible by grouping the spacecraft on a platform similar to the LEO platform for sharing of platform services, thus reducing spacecraft construction, launch, and servicing costs.

A growth is foreseen where certain high value satellites could be retrieved from their operating orbits by the OTV, and returned to the Station/OTV base for servicing or repair, or possibly repaired *in situ* by an OTV/TMS vehicle.

4.3.2.1 Geosynchronous Orbit Missions Time Phasing. The geosynchronous payload model (Table 3-30) was derived from a number of data sources which include 1) the NASA Orientation Meeting handouts and supplements, 2) the Nominal Mission Model, Rev. 6, MSFC PS01, dated 30 September 1982 for geosynchronous platforms, 3) SPACECOM derived requirements for the COMSAT traffic, 4) User Fact Sheets, and 5) JSC/GDC operational missions discussed in more detail in Section 3.5. The DOD scenario was derived from MSFC and DOD mission models and is further described in Section 3.4. The COMSAT traffic predominates the geosynchronous missions and was derived from extensive analysis by SPACECOM and documented in Section 3.2.2.

The number of payloads launched in any year and the unit weight/length are shown in Table 3-30; however, this should not be construed as either the number of Shuttle delivery flights or the number of OTV launches. The Shuttle is assumed to be manifested with as many satellites as permitted by length and weight constraints. Likewise, the OTV will deliver multiple satellites within its capability.

A specific requirement for the geosynchronous spacecraft retrieval has been identified for the middle of the decade; namely, the Manned GEO Sortie Capsule (4000). In this mission, the capsule remains integral with the OTV while at geosynchronous orbit and then returns in 1-2 days to the Station at LEO. However, the future utilization of the OTV capability for retrieval of high-value spacecraft is foreseen. The GEO retrieval missions shown in Table 3-30 are considered as debris removal missions and could be accomplished by reboost or treated as demonstration missions to verify the OTV/TMS capture and return capabilities.

4.3.2.2 Geosynchronous Orbit Mission Requirements. The basic spacecraft support requirements derive from the on-orbit spacecraft preparation and checkout for launch to GEO missions.

In the initial years, these requirements are seen as limited to storage of the spacecraft prior to mating with the OTV as well as the spacecraft handling, OTV mating, and mating verification. The spacecraft checkout is conducted by RF link to a ground control center for closed-loop verification of spacecraft command and data nets, requiring high data rates in some cases. Observation of the spacecraft during this process may be desirable, especially to monitor appendage deployment. An analysis by SPACECOM of the advantages and disadvantages of modifying deployment subsystems based on the availability of a manned Space Station as an intermediate launch platform for spacecraft launches yielded the following conclusions:

- Manufacturing cost savings of 5-8% of a total spacecraft's production cost is a reasonable assumption.

- All spacecraft, regardless of their orbit or use of the OTV or projected life expectancy, would benefit both structurally and economically from simplified deployment mechanisms.

- Launch reliability would increase tremendously with the availability of snap-together appendages that were verifiable on orbit.

- Deployment problems and thus launch insurance would decrease appreciably.

Resource requirements for these operations are dependent on spacecraft design and the launch rates. Unplanned maintenance and repair of geosynchronous payload elements will provide performance and economic benefits.

During later years, the requirement for EVA is anticipated to permit assembly of very large antennas and to perform or assist in the deployment of solar panels and other large structures. Further growth in Space Station/OTV basing function requirements is foreseen with the beginning of in situ servicing of GEO spacecraft, and by capture/retrieval of high value spacecraft and return to LEO.

The 1990-2000 decade will probably see the advent of manned geosynchronous missions such as the sortie capsule and module operations missions (4000 and 4001) described in Section 3.5. these missions could herald a new era of Space Station involvement -- countdown and launch of manned vehicles to other orbits. Transitioning from large earth-based crews to a few Station personnel performing prelaunch operations with man-rated spacecraft/OTV will require extensive spacecraft design provisions, such as built-in test, to permit the development of safe and routine space-based operations. Capture, storage, and refurbishment of satellites and aerobraked stages returning from GEO will be required.

A preliminary review of the GEO mission spacecraft, together with consideration of the projected GEO population, indicates that in the 1990s there is a high potential for large support platforms carrying communications receivers, switches, transmitters, and antenna systems to replace the smaller communications satellites. Our mission plan currently projects the launch of an experimental GEO platform in the early 1990s (1103), followed by an operational platform by the middle of the decade. Requirements for the platforms are similar to the COMSAT's except for more extensive Space Station involvement in LEO preparations to include deployment and checkout operations prior to geosynchronous orbit delivery. These same platforms could also provide support services to some of the meteorological sensors, and some of the passive earth resources sensors. A GEO platform concept is shown in Figure 4-15. Some of the current payload elements comprise one or several sensors integrated with a support spacecraft. If geostationary platforms become a reality, these sensors could be configured as modular sensor packages that could be delivered to GEO by an OTV and remotely docked and interconnected to the platform.

Candidate payload elements that should be considered for accommodation on geostationary platforms are:

- 0203 Lightning Mapper
- 0204 Geosynchronous Microwave Sounder
- 0206 GOES Follow-On

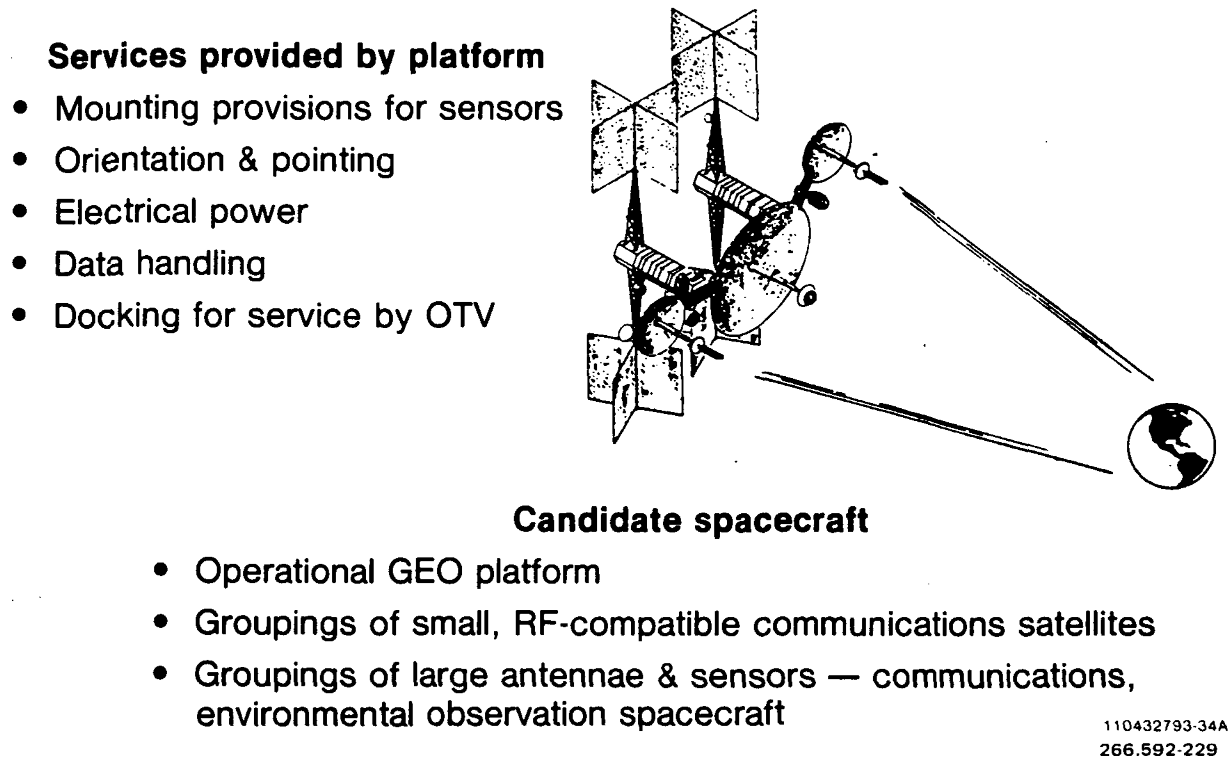

Figure 4-15. GEO Platform Example

Of primary concern in any grouping is the need for RF compatibility between emissions/receptions of the grouped spacecraft.

4.3.2.3 Summary. In summary, the composite Station/OTV base requirements of all the GEO missions are listed in Table 4-9. Requirements on the OTV/TMS, which are described in Section 4.3.1, such as for spinning satellites, will also be required for applicable geosynchronous missions.

As part of the study tasks, SPACECOM performed an assessment of the COMSAT community to test the reaction to the Space Station concept. Since this segment of the geosynchronous mission model has the greatest potential for development, the results are particularly interesting and informative.

To develop the interest and involvement of members of the communications satellite community in the potential of a Space Station, SPACECOM made contacts with representative companies and a questionnaire was sent to others. Contacts were builders (Fairchild Industries), owners (COMSAT General, COMSAT Laboratories, Satellite Business Systems, INTELSAT), and customers (American Satellite Company, Continental Telecom). The consensus is as follows:

a. Space Station has a role in developing COMSAT-related technology. Large antenna development has the most interest.

Table 4-9. Spacecraft Operations/Resource Requirements

	Initial Years	Final Years
• LAUNCH FREQUENCY PER YEAR	15-20	20-30
• SPACECRAFT HANDLING		
-- Transfer and Storage Facilities	X	X
-- Mating Provisions	X	X
-- Crew and Controls	X	X
-- Power	X	X
• SPACECRAFT SERVICING		
-- Antenna and Panel Extension Provisions		X
-- Consumables Storage and Loading Equipment		X
-- Repair Facility	X	X
-- Crew - Including EVA Provisions		X
-- Power		X
• SPACECRAFT ACTIVATION CHECKOUT/LAUNCH		
-- Manual Appendage Deployment/Assembly	X	X
-- Interface Connections - Control, Data		X
-- Data Processing		X
-- RF Link to Ground/POCC		X
-- Crew, Countdown/Mission Control		X
-- Power		X
• SPACECRAFT RETRIEVAL		
-- Handling and Storage		X
-- Maintenance		X

b. Visual examination of a COMSAT by Space Station personnel is desirable, but not necessary.

c. Storage of a "spare" COMSAT at the Space Station would seem to have many merits. Further study is required.

d. An in-orbit booster stage, which is docked to the Space Station (orbital transfer vehicle) and having the characteristics of reuse and a low "g-level" ride, would have utility for the COMSAT community. Cost savings of such a stage for the various applications will determine its use.

e. Launch of a fully deployed COMSAT that has been checked out at LEO via Space Station prior to boost to GEO by a "low-g" stage (OTV-type) is attractive. Cost for such a service must be compared with an expendable, high performance booster.

f. Space Station storage of spare replacement parts used in the repair of COMSATs is not practical. Too many types exist, testing would be required in orbit before use, shelf life limits are encountered, environmentally controlled storage would be required, and many other facts point toward storage of a full spare, not spare components.

4.3.3 ESCAPE MISSIONS. The availability of the Space Station will enhance exploratory missions to the planets and other solar system bodies in the 1990s time frame. The main contribution will come in the area of preparation and launch of the spacecraft to escape trajectory. For specific missions, the Sta- tion will also be involved in retrieval of a returning spacecraft elements carrying comet samples.

4.3.3.1 Escape Missions Time Phasing. Twelve planetary (escape) missions have been identified for the 1990-2000 time frame. These missions were identified in Table 3-31. Data sources used for derivation of advanced escape missions that could be launched from an orbital base are as shown in Table 4-10.

4.3.3.2 Escape Mission Requirements. Launching of a spacecraft for planetary rendezvous must occur within a known window, of a few days duration, for a given mission opportunity. Without the Space Station, this function would require scheduling of Shuttle flights to carry the spacecraft to LEO during launch windows. The availability of a Space Station permits the spacecraft to board a convenient Shuttle flight before the launch window, without disturbing the Shuttle schedule established for other users. Upon rendezvous with the Space Station, the crew will transfer the payload from Shuttle to Station, mate it to the OTV, and observe deployment of antenna (and of solar panels if applicable). Checkout of spacecraft systems functional capability would be conducted from the ground. The spacecraft will then be launched into escape trajectory at the optimum time.

The comet HMP surface sample return mission will return modules containing the samples for return to earth. These will enter low earth orbit in the proximity of the Space Station with retrieval by TMS or OTV. The sample may then be transferred to an appropriate laboratory on the Station for preliminary analysis and temporary storage prior to earth return.

Characteristics of several of the advanced missions were shown in Table 3-31. The Δv shown is from a 370-400 km circular orbit altitude.

4.4 BASELINE TIME-PHASED MISSION SET

The work done throughout the study to identify users and their requirements produced the mission set described earlier. This "Users Set" provides a menu of representative missions whose requirements have been validated to the degree that they can be used to establish a basis for architectural option

Table 4-10. Escape Missions Data Sources

GDCD No.	Title	Source Code
	• Planetary Observations	
0103	Mars Geochem/Climatology Orbiter	1
0104	Mars Aronomy Orbiter	1
0105	Venus Atmospheric Probe	
0106	Lunar Geochemistry Probe	2
0107	Titan Probe	1
0108	Saturn Orbiter (Titan Fly-By)	3
0109	Mars Surface Network (Lander)	1
0110	Saturn Probe	4
	• Solar Systems Missions	
0121	Comet Rendezvous	3
0122	Main Belt Asteroid Rendezvous	3
0123	Comet Sample Return (HMP)	3
0124	Near Earth Asteroid Rendezvous	1

Source Code:

1. SAI Report SAI 1-120-340-T19, Sep 1982; Telecon J. Niehoff, Oct 1982
2. MSFC Solar System Exploration Scenario, 30 Sep 1982; GDC visit Oct 1982
3. JPL Memo, 18 Nov 1982
4. Jesse W. Moore (NASA), Astronautics and Aeronautics Journal, "Effective Planetary Exploration at Low Cost", Oct 1982

studies (Figure 4-16). The missions are more concentrated in the early timeframe because people tend to concentrate more on near term than long term planning (Figure 4-17). Some of these may also be optimistic in terms of technology readiness for this timeframe.

The study mid-term redirection called for the definition of "Validated and realistic mission sets and associated requirements" as a study output. The definition of "realistic" is left open. Some questions to be addressed in this determination are listed in Table 4-11.

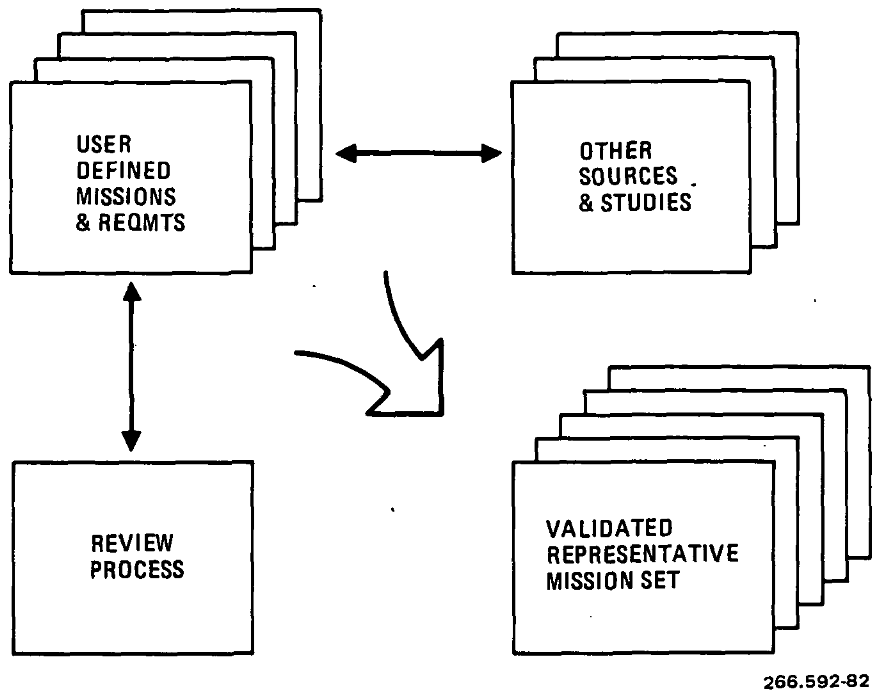

Figure 4-16. Validated User Requirements Defined

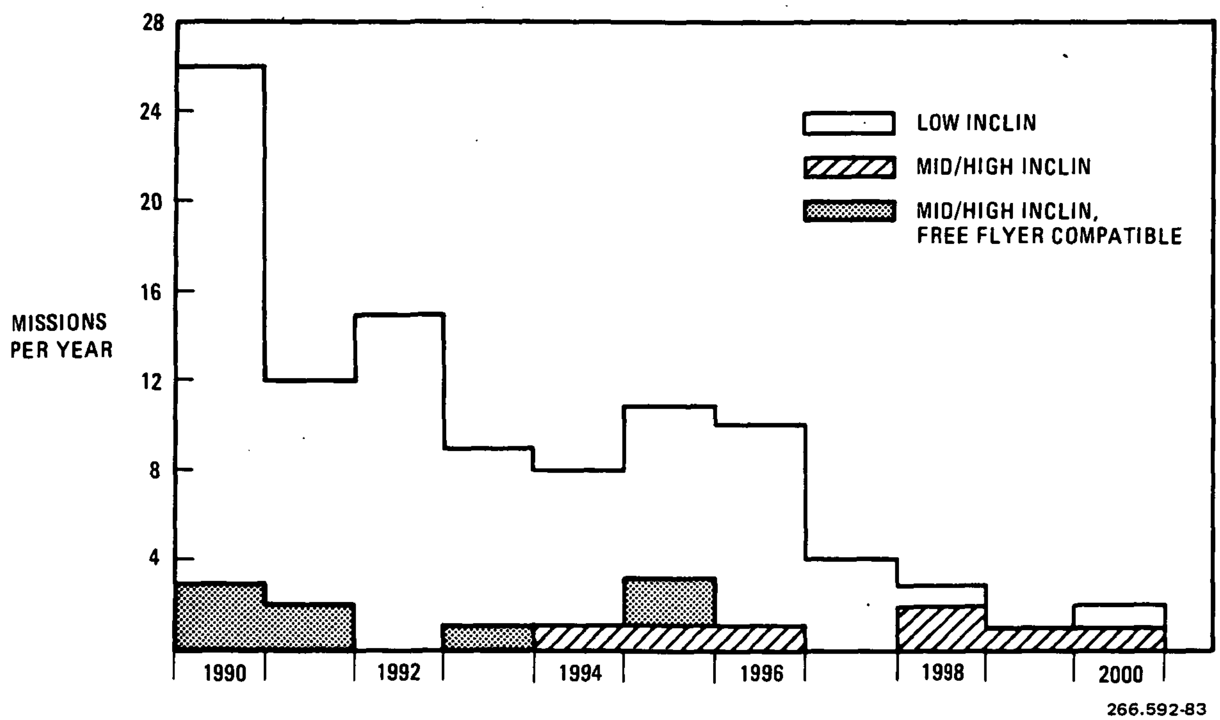

Figure 4-17. Mission IOC Dates

Table 4-11. Determination of a "Realistic" Mission Set

- Are the mission requirements valid?
- Are missions' requirements adequate for architectural studies?
- Do needs/benefits exist?
- Are the number of missions reasonable?
- Is the schedule reasonable?
- Will technology development support the mission schedule?
- Is the technical risk of the mission acceptable?
- Is there budget available for the number of missions?

In addressing these questions, a number of observations were made. Because the missions and their requirements were based, for the most part, upon user supplied data independently validated by reference to other sources and through a review cycle, we believe they are representative of missions that will be performed in the 1990s. Thus, they are adequate for the purpose of this study, which is primarily to define a Space Station architecture.

A second question revolves around the number and timing of the missions. This questions is important because the number of missions in a given time period sizes the Station resources. In this regard, we believe that the early years traffic is probably high (Figure 4-17). There are also several missions that require inclinations greater than 28.5 degrees. All of these in the early years are capable of alternative accommodation as a free flyer. All the missions requiring higher inclinations that occur in the out years also require man's presence. Those scheduled in the mid-years are a mixed group. Two messages are present. First, using this distribution, which is based upon the user-defined missions and schedules, the initial Station could be driven to provide rather high levels of resources in terms of power, crew size, etc. However, when the resource levels were calculated, they did not indicate any unusual requirements except for the power levels in the out years. Crew size varied from approximately four in the early years to eight later. Pressurized volume was about 300 cubic meters early and 600 later. Average power was around 30 KW early and 150 later. This high power requirement was driven by commercial materials processing production, which was 90 kW. Second, an additional station is required at polar inclinations fairly early in the decade. The planning horizon effect mentioned earlier is also obvious.

With respect to mission needs and benefits, the answer is more difficult to quantify on a mission-by-mission basis. Man's presence is vital to the Life Sciences and Technology Development missions. Very little can be accomplished with automated payload elements. Materials processing research will be strongly enhanced by man's involvement; production requires less direct participation. The principal contribution of man to viewing missions such as Astrophysics, Earth Exploration, and Environmental Observations is for sensor/equipment development and, of course, for free-flyer service. A number of performance benefits can be described for individual missions. Each of the user defined missions has some specific benefit. There are those who also feel that a significant contribution can be made by man in the data collection process for viewing missions. This is reflected in the high inclination mission definitions. Certainly a case can be made for the fact that science will benefit from a manned Space Station. Therefore, there are social benefits. To attempt to rank or rate individual missions, however, does not appear to be valuable. Economic benefits are readily derived for high energy staging using a space-based OTV. In addition, there are launch cost savings and on-orbit operations cost savings for man-operated missions. Free flyers will reap economic benefits from the ability to provide service and maintenance actions.

A cost analysis was made of the Science, Applications, and Technology missions, and a comparison made to anticipated NASA budget levels. Commercial missions were not examined in the same manner because it is assumed that if the commercial missions are economically viable, they will be financed. The results indicate serious budget implications, especially in the early years. Because the involvement of the Space Station with the planetary missions is minimal, it was decided to examine them separately and the sum of the other missions as a subset (Figure 4-18). A discipline level evaluation disclosed considerable variation between disciplines and irregular funding profiles within disciplines. The details of this analysis are in Book 3.

Included in the mission set are two very expensive missions. The first is Large Structures Technology, 2007, which is scheduled at the end of the decade. This mission is a major contributor to the total cost for the decade, but because of its IOC date, does not affect the peak, which occurs early in the decade.

The second is the pair of Manned Geosynchronous Missions -- Sortie and Support Module (4000 and 4001), which occur in the last half of the decade. This is actually a major new program and probably should not have been aggregated with the rest of the user requirements. However, because they were used as part of the STS infrastructure to determine Space Station requirements, we treated them the same as other user missions. Because of the scheduled launch dates, there is some increase in peak funding requirements caused by these two missions. They appear separate from all other missions in the discipline level analysis.

The conclusion was that we needed to do another evaluation of the mission set. The mission status and importance of the Space Station to each payload element were determined in accordance with the LaRC codes (Figure 4-19). As can be seen, only a few Astrophysics missions are in the approved status and only the commercial communication satellites are operational. Of those that are in the planning stage, most are free flyers. These results would be expected because of the current program status of the Space Station program.

Although most of the missions are in the candidate status today, they are representative of what will ultimately be approved and assigned to the Space Station program. Therefore, they provide a base for establishing program requirements and the Station architecture, including resource levels.

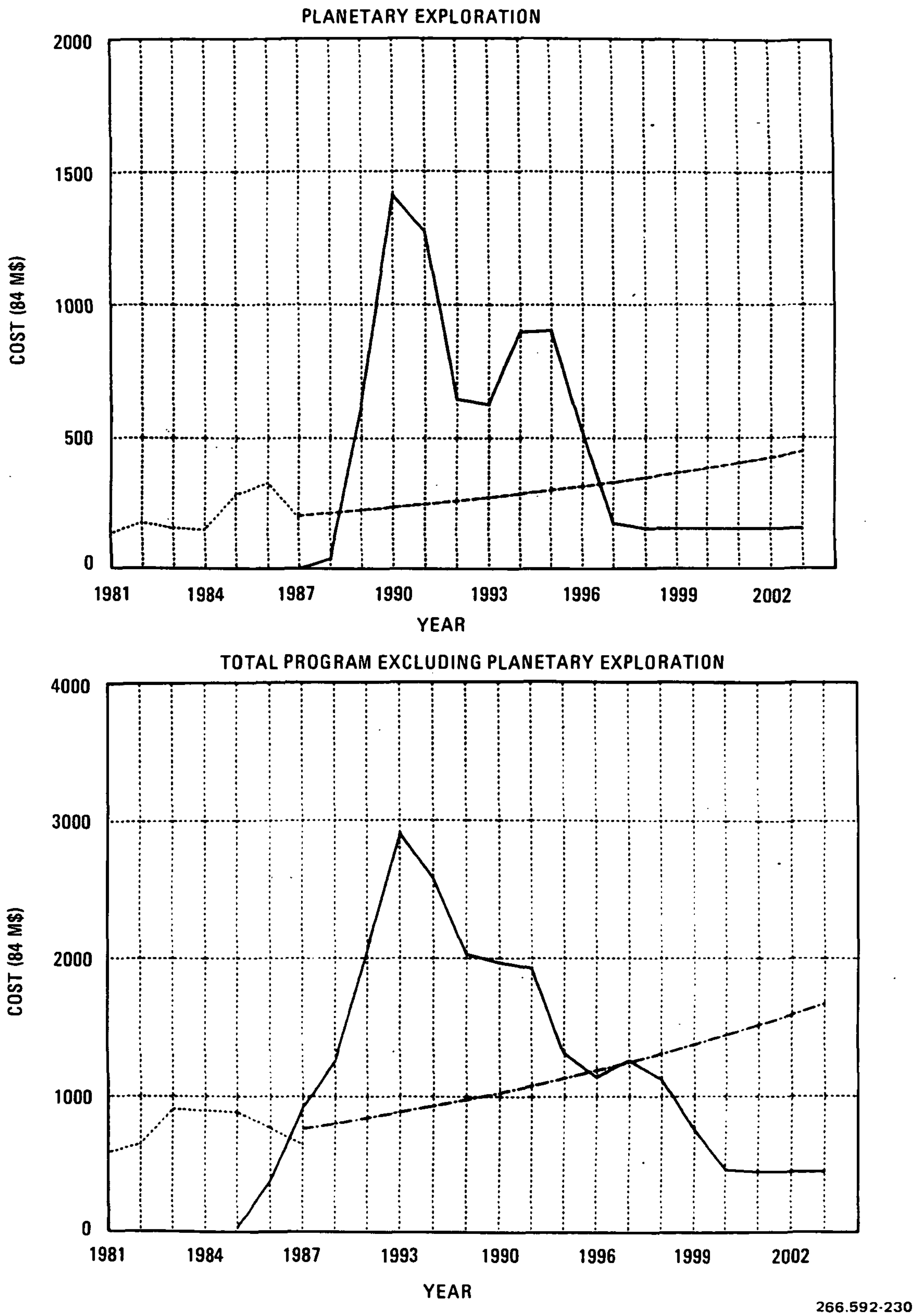

Figure 4-18. User Information Mission Set Funding Requirements

MISSION STATUS	10 VITAL	9	8	7	6	5	4	3	2	1 BENEFIT	TOTAL
CANDIDATE	24 ATTACHED	21 ATTACHED 2 FREE-FLYER	20 ATTACHED 1 FREE-FLYER	4 ATTACHED 2 FREE-FLYER	10 ATTACHED 1 FREE-FLIER	7 ATTACHED 10 FREE-FLYER	2 ATTACHED	6 FREE-FLYER	1 ATTACHED 8 FREE-FLYER		89 ATTACHED 30 FREE-FLYERS
PLANNED	6 ATTACHED		3 ATTACHED 2 FREE-FLYERS	2 FREE-FLYERS	1 ATTACHED 1 FREE-FLYERS	6 FREE-FLYERS	4 FREE-FLYERS	1 FREE-FLYERS			10 ATTACHED 16 FREE-FLYERS
AP-PROVED					1 FREE-FLYERS		1 FREE-FLYERS				2 FREE-FLYERS
OPERA-TIONAL						2 FREE-FLYERS					2 FREE-FLYERS

VALUE OF STATION TO PAYLOAD ELEMENT

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Figure 4-19. Mission Status and Value Comparison

The second conclusion one can draw from this analysis is that there is a large number of missions to which a Space Station has a high value. If one needed to reduce the number of missions based upon the benefit evaluation criterion, he would logically delay or delete those candidate missions that are low on the value scale. Figure 4-16 was constructed with benefits decreasing left to right to make this evaluation easier. However, we did not delete any missions on this basis or on the basis of cost versus value to the Station.

4.4.1 MISSIONS SET EVALUATION PROCESS. A set of criteria was established (Table 4-12) and a process defined (Figure 4-20) for evaluating the user-defined mission set to determine its realism. Other than planetary, no missions were excluded from the analysis or dropped from the set on an a priori basis. Even though the projected NASA budget would not fund the entire set, it did not appear incumbent upon us to make the decisions necessary to size the set to an estimated 1990s budget level. As discussed earlier, the mission set of user requirements had already proven useful in architectural option studies.

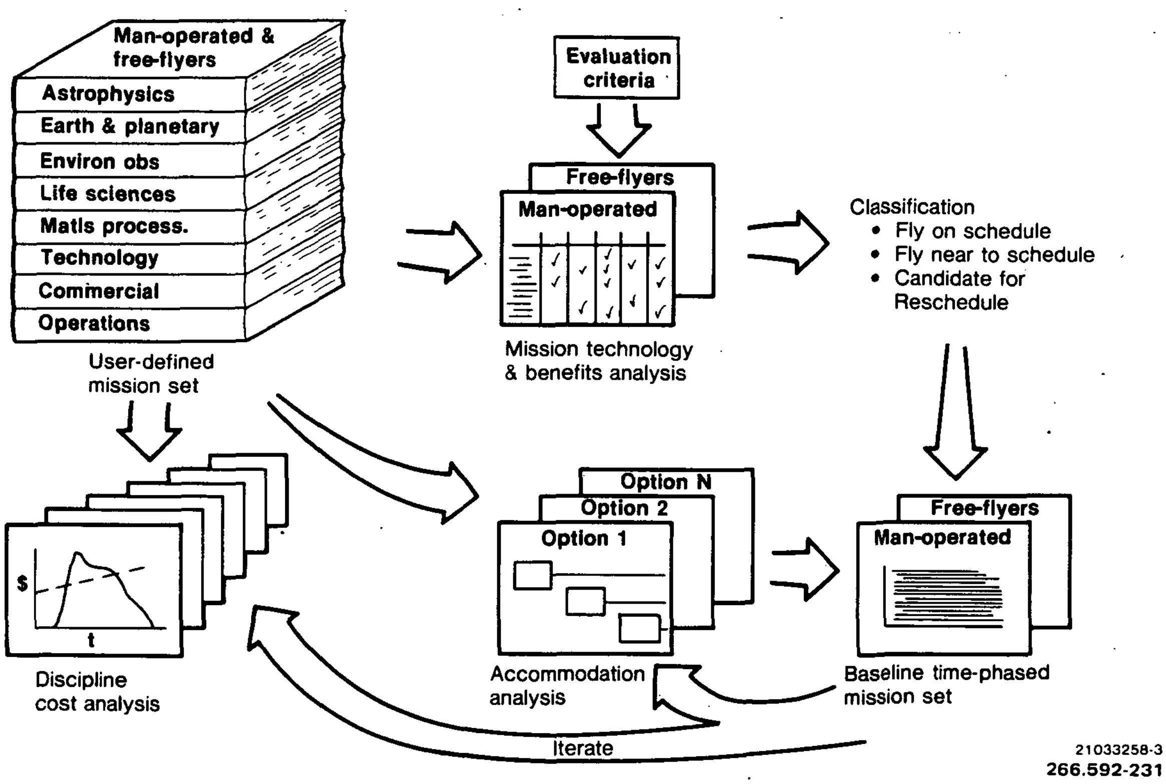

Figure 4-20. Mission Set Evaluation Process

The planetary missions were excluded from the analysis because of their limited involvement with the Space Station program. They are part of the high energy staging traffic model but represent only 12 missions in the decade. Half of these are planned before the OTV is expected to come on-line in 1994.

Table 4-12. Evaluation Criteria

- NASA Approved and Planned Missions
- Commercial Planned and Projected Missions
- Benefit to Future Space Activities
- Technology Readiness
- Technical Risk
- Mission Definition Maturity

If the set becomes reduced or schedules change, the impact on currently estimated OTV traffic will be minimal. Because methods of reducing planetary mission costs are already in discussion and the mission set described herein is known to be in accordance with current planning, no changes were made in this discipline.

The analysis was conducted separately for the two subsets: man-operated missions and free-flyer missions. The recommendations were to be one of the following: delete, maintain time phasing with another mission, fly on schedule, or permit rescheduling at the discretion of the accommodation analysis activity. The reschedule options were: fly on/near schedule, fly near to schedule, and candidate for rescheduling; which meant, in general terms: 0-1, 1-2, and 2-4 years, respectively. Specific evaluation factors were:

- Technology progression
  - Predecessor event/mission
  - Advancement as a major or moderate step
- Technical Risk
  - High
  - Medium
  - Low
  - Area of risk for medium and high categories
- Maturity of the mission definition

For man-operated missions, notations on the degree of man's role in the mission and acceptability of alternative accommodation modes were included for reference. For free-flyer missions, notations of the required on-orbit operations of assembly, checkout, service, and reconfiguration were included for reference. On-orbit checkout at the station was noted only if it was a firm requirement. It is assumed that many missions can benefit from checkout, but this is less significant as an evaluation factors.

The man-operated mission set analysis results (Table 4-13) are summarized as follows:

Classification	S&A	Technology	Commercial	Total
Delete	*			*
Schedule Tied to Other Mission	2		11	13
Fly On Schedule	12	11	3	26
Fly On/Near to Schedule	6	5	7	18
Fly Near to Schedule	6	6	2	14
Candidate for Rescheduling	14	11	2	27

*1 mission was identified as being less mandatory than a second (GDCD 0242 over 0243) but because of its low cost, it was retained.

The accommodations analyses had previously determined that several missions would be accommodated as free flyers even though the preferred mode was man-operated (Table 4-14). Each of these required inclinations of 57 degrees or higher, all were scheduled early in the decade and all indicated that accommodation as a free flyer was an acceptable alternative. The alternative mode was selected because the architectural options studies showed 1) that a 28.5-degree orbit was preferred ovr a 57-degree orbit for the station located in a lower inclination, and 2) a polar orbit Station was not viable until late in the decade.

A second decision out of the architectural option studies was that 1998 would be the earliest IOC for a polar inclination Station. Therefore, those missions later in the decade that required man operation and high inclination were rescheduled to match that date.

The free-flyer mission set analysis results (Table 4-15) are summarized as follows:

	LEO/HEO			GEO			
Classification	S&A	Com'l	Total	S&A	Com'l	Manned	Total
Delete							
Schedule Tied to Other Missions	4	4	8		1		1
Fly on Schedule	5	1	6	1	5		6
Fly On/Near Schedule	9		9	1			1
Fly Near to Schedule	1		1				
Candid. for Rescheduling	2		2	2		2	4

Table 4-13. Technology Readiness and Mission Needs, Man-Operated Payloads (Sheet 1 of 7)

	FREE-FLYER ACCOMMODATION ACCEPTABLE	PROGRESSION			MAN'S ROLE			MISSION DEFINITION MATURITY	TECHNICAL RISK				RECOMMENDATION, DISPOSITION, & RATIONALE
		PREDECESSOR EVENT	ADVANCEMENT										
			MAJ	MOD	VITAL	SIGNIF BENEFIT	CONTRIB		HI	MED	LO	RISK AREA	
• SCIENCE AND APPLICATIONS MISSIONS													
ASTROPHYSICS													
ASTRONOMY													
0000 Starlab	✓	Shuttle P/L		✓		✓		High			✓		Fly on sched. (in NASA appl cycle)
0005 Shuttle IR Telescope Facility	✓	Shuttle P/L		✓		✓		High			✓		Fly on sched. (in NASA appl cycle)
HIGH ENERGY													
0031 High Throughput Mission	✓	0032		✓			✓	Low			✓		Timing based on 0032
0032 Large Area Modular Array	✓		✓	✓		✓		Med		✓			Candidate for resched
0034 High Resolution X and Gamma Ray Spectrometer	✓	Possible Shuttle P/L		✓		✓		Med			✓		Fly on schedule
0035 High Energy Isotope Experiment	✓			✓		✓		Low			✓		Candidate for resched
0036 Spectra of Cosmic Ray Nuclei	✓	Possible Shuttle P/L		✓			✓	Med			✓		Fly near to sched
0037 Transition Radiation and Ionization Colorimeter	✓	Possible Shuttle P/L		✓		✓		Med			✓		Fly near to sched
EARTH AND PLANETARY EXPLORATION													
CRUSTAL MOTION													
0151 Detection and Monitoring of Episodai Events		0176, 0152		✓	✓			Low			✓		Candidate for resched
0152 Geoscience – Crustal Dynamics Studies	✓			✓			✓	Low			✓		Fly on sched – supports later missions

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Table 4-13. Technology Readiness and Mission Needs, Man-Operated Payloads (Sheet 2 of 7)

		FREE-FLYER ACCOMMODATION ACCEPTABLE	PROGRESSION			MAN'S ROLE			MISSION DEFINITION MATURITY	TECHNICAL RISK				RECOMMENDATION, DISPOSITION, & RATIONALE
			PREDECESSOR EVENT	ADVANCEMENT MAJ	ADVANCEMENT MOD	VITAL	SIGNIF BENEFIT	CONTRIB		HI	MED	LO	RISK AREA	
	GEOPOTENTIAL FIELDS													
0161	Earth Science Research – Geophysical Investigation		0176, 0177		✓	✓			Med			✓		Fly on/near sched
	EARTH RESOURCES													
0171	Renewable Resources – Earth Science Research	✓	0172		✓		✓		Low			✓		Fly near to sched
0173	Shuttle Active Microwave Experiment (SAMEX-C)				✓	✓			Med			✓		Fly on sched
0174	Earth Obs Instrument Devel (Microwave Tech)				✓	✓			Low			✓		Fly near to sched
0175	Earth Obs Instrument Devel (Extra Visible & RF)				✓	✓			Low		✓			Candidate for resched
0176	EO Sensor/Technique/Analysis/ Automated System				✓	✓			Low		✓		New Instru & Techniq.	Fly near sched – supp later msns
0177	Geoscience – Geology Remote Sensing	✓			✓			✓	Med			✓		Fly on schedule
0179	Imaging Radar for Earth Resources Inventory	✓	0173		✓			✓	Med		✓		New Instru	Candidate for resched
0184	Z – Continuous and Special Coverage		0171, 0181, 0182, 0183		✓		✓		Med			✓		Candidate for resched – Complex mission
	<u>ENVIRONMENTAL OBSERVATIONS</u>													
	WEATHER/CLIMATE													
0201	Satellite Doppler Meteorological Radar Tech			✓		✓			Low	✓			New Instru Development	Candidate for resched
0202	Meteorology Instrument Group Development Payload				✓	✓			High			✓		Fly on/near sched
	SOLAR TERRESTRIAL													
0242	Incoherent Scatter Radar				✓	✓			Med		✓		Size	Preferred over 0243, 1 P/L accept
0243	Topside Digital Ionosonde/HF Radar				✓	✓			Med		✓		Size	1 P/L of 2 planned is accept
0244	Solar Terrestrial Observatory – Advanced		0246		✓	✓			Med			✓		Candid. for resched

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Table 4-13. Technology Readiness and Mission Needs, Man-Operated Payloads (Sheet 3 of 7)

No.	Payload	Free-Flyer Accommodation Acceptable	Progression: Predecessor Event	Progression: Advancement MAJ	Progression: Advancement MOD	Man's Role: Vital	Man's Role: Signif Benefit	Man's Role: Contrib	Mission Definition Maturity	Technical Risk: HI	Technical Risk: MED	Technical Risk: LO	Technical Risk: Risk Area	Recommendation, Disposition, & Rationale
0245	Space Plasma Physics Payload – Advanced		0247		✓	✓			Med			✓		Candid. for resched
0246	Solar Terrestrial Observatory	✓	0241, 0247, 0261, 0264		✓		✓		Med			✓		Fly on/near sched – Supp later msn
0247	Space Plasma Physics Payload	✓	Space Lab Exp		✓		✓		High			✓		Fly on/near sched
	ATMOSPHERIC RESEARCH													
0261	High Resolution Doppler Imager (HRDI)	✓	Space Lab Exp		✓			✓	High			✓		Fly on sched
0262	Measurement of Air Pollution from Satellites		Space Lab Exp		✓	✓			High			✓		Fly on sched
0263	CO_2 LIDAR for Atmospheric Measurements			✓		✓			Low	✓			Size, New Eq	Candid. for resched
0264	LIDAR Facility	✓	Space Lab Exp		✓			✓	High			✓		Fly on/near sched
0265	Upper Atmosphere Research Payload – Development		0261		✓	✓			Med		✓		Adv. Instru	Fly near sched
	LIFE SCIENCES													
	BIOLOGICAL SCIENCE													
0300	Human Research Lab.				✓	✓			High			✓		Fly on sched
0301	Animal and Plant Research Lab.				✓	✓			High			✓		Fly on sched
	OPERATIONAL MEDICINE													
0322	EVA Performance and Productivity				✓	✓			High			✓		Fly on sched – Continual develop, supports many technology missions
	LIFE SUPPORT													
0340	$H_2O/O_2/CO_2/N_2$ Regenerative Systems				✓	✓			High			✓		Fly on/near sched
0341	CELSS Experimental Systems			✓		✓			Mod		✓		New/Adv Tech	Cand for resched
0342	Dedicated CELSS Module		0341	✓		✓			Low			✓	New Tech/Eq	Cand for resched
0343	CELSS Pallet		0341, 0342		✓	✓			Low			✓	New Tech/ Equip	Cand for resched

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Table 4-13. Technology Readiness and Mission Needs, Man-Operated Payloads (Sheet 4 of 7)

		FREE-FLYER ACCOMMODATION ACCEPTABLE	PROGRESSION			MAN'S ROLE			MISSION DEFINITION MATURITY	TECHNICAL RISK				RECOMMENDATION, DISPOSITION, & RATIONALE
			PREDECESSOR EVENT	ADVANCEMENT										
				MAJ	MOD	VITAL	SIGNIF BENEFIT	CONTRIB		HI	MED	LO	RISK AREA	
MATERIALS PROCESSING														
0400	Research and Development Facility		Space Lab Exp		✓	✓			High			✓		Fly on schedule
0401	R&D/Proof of Concept Facility		0400		✓	✓			High			✓	Containerless processing	Candid. for resched – Market dependent
• COMMERCIAL MISSIONS														
COMMUNICATIONS														
1106	Large Deployable Antenna			✓			✓		Med		✓		Size	Fly near to sched
1107	RFI Measurements				✓		✓		Med			✓		Fly on sched
1108	Laser Communications				✓		✓		Med			✓		Fly on/near sched
1109	Open Envelope Tube				✓		✓		Med			✓		Fly on/near sched
1110	Spaceborne Interferometer				✓		✓		Med			✓		Fly on/near sched
1111	Millimeter Wave Propagation				✓		✓		Med			✓		Fly near to sched
MATERIALS PROCESSING														
1200	Pilot – Biological Processing Facility		Space Lab, 0401		✓	✓			Med			✓		Fly on/near sched
1201	Pilot – Containerless Processing Facility		Space Lab, 0401		✓	✓			Low		✓		Adv Technol	Cand for resched
1202	Pilot – Furnace Processing Facility		Space Lab, 0401		✓	✓			Med			✓		Fly on/near sched
1203	Commercial – Biological Processing Facility		1200		✓		✓		Low			✓		Fly on/near sched
1204	Commercial – Containerless Processing Facility		1201		✓		✓		Low		✓		Adv Technol	Cand for resched
1205	Commercial – Furnace Processing Facility		1202		✓		✓		Low			✓		Fly on/near sched
1207	Electrophoretic Separation		On 0400			✓			Low					
1208	Crystal Growth		On 0400			✓			Low					
1209	Metal Clusters and Crystal Growth		On 0400			✓			Low					
1210	Enzyme Production and Separation		On 0400			✓			Low					

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Table 4-13. Technology Readiness and Mission Needs, Man-Operated Payloads (Sheet 5 of 7)

No.	Payload	Free-Flyer Accommodation Acceptable	Progression: Predecessor Event	Progression: Advancement MAJ	Progression: Advancement MOD	Man's Role: Vital	Man's Role: Signif Benefit	Man's Role: Contrib	Mission Definition Maturity	Technical Risk: HI	Technical Risk: MED	Technical Risk: LO	Technical Risk: Risk Area	Recommendation, Disposition, & Rationale
1211	Silicon Crystals		On 0400			✓			Low					
1212	Heat Resistant Alloys		On 1205			✓			Low					
1213	Chemical Reactions		On 0400			✓			Low					
1214	Space Isothermal Furnace System (SIFS)		On 0400			✓			Low					
	INDUSTRIAL SERVICES													
1300	Radiation Hardened Computer	✓			✓			✓	Low			✓		Fly on sched
1301	Full-Body Teleoperator		2401		✓	✓			Med		✓		New Tech/Eq	Fly on sched – Later Applic
1303	Plants in Controlled Env Life Support Systems		On 0341			✓			Low					
1304	Controlled Environment Life Support Systems		On 0342			✓			Low					
1305	Communication Satellite Service/Handling		On 1106, 2504, 2505			✓			Low					
	• TECHNOLOGY DEVELOPMENT													
	MATERIALS & STRUCTURES													
2001	Strain and Acoustic Sensors				✓	✓			High			✓		Fly on sched
2002	Spacecraft Materials Technology		LDEF		✓			✓	High			✓		Fly on/near sched
2003	Materials and Coatings		LDEF		✓			✓	High			✓		Fly on/near sched
2004	Thermal Shape Control			✓		✓			Low		✓		Concept/Size	Candid. for resched
2005	Dynamics of Flimsy Structures			✓		✓			Med	✓			Size	Candid. for resched
2006	Active Optics Technology			✓		✓			Low		✓		Assy, Accuracy	Candid. for resched
2007	Large Structures Technology			✓		✓			Low	✓			Extreme Size	Cand for resched – low priority as future applic uncertain
	ENERGY CONVERSION													
2101	Low-Cost Modular Solar Panels				✓	✓			High			✓		Fly on/near sched
2103	Ion Effects on LEO Power Systems		2101		✓	✓			Med			✓		Fly on/near sched

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Table 4-13. Technology Readiness and Mission Needs, Man-Operated Payloads (Sheet 6 of 7)

	FREE-FLYER ACCOMMODATION ACCEPTABLE	PROGRESSION			MAN'S ROLE			MISSION DEFINITION MATURITY	TECHNICAL RISK				RECOMMENDATION, DISPOSITION, & RATIONALE
		PREDECESSOR EVENT	ADVANCEMENT MAJ	ADVANCEMENT MOD	VITAL	SIGNIF BENEFIT	CONTRIB		HI	MED	LO	RISK AREA	
2104 Large Solar Concentrator			✓		✓			Low		✓		Size	Candid. for resched
2105 Solar Pumped Lasers		2104		✓	✓			Low		✓		Size	Candid. for resched
2106 Laser/Electric Energy Conversion		2104, 2105	✓		✓			High	✓			Size, Boiler Temp	Candid. for resched
2107 Solar Sustained Plasmas		2104	✓		✓			Low	✓			Size, Technol Base	Candid. for resched
2108 Space Nuclear Reactor	✓			✓			✓	Med		✓		Size, Power Level	Fly near sched (some sources show earlier date)
COMPUTER SCIENCE & ELECTRONICS													
2201 Attitude Control – System Identification Experiment		2005		✓	✓			Low			✓		Fly near to sched
2202 Attitude Control – Adaptive Control Experiment		2005, 2201		✓	✓			Low		✓		New Tech'y Applic	Fly near to sched
2203 Attitude Control – Distributed Control Experiment		2005, 2201, 2202		✓	✓			Low			✓		Fly near to sched
2204 Advanced Adaptive Control Technology Demonstration		2005, 2201, 2202, 2203		✓	✓			Low			✓		Fly near to sched
PROPULSION													
2301 Controlled Accel Propulsion Technology				✓	✓			Low		✓		New Technol	Fly near to sched – Later applic.
2302 Laser Propulsion Test		2104, 2105	✓		✓			Low	✓			New Technol	Candid. for resched
CONTROL & HUMAN FACTORS													
2401 Manipulator Controls Technology				✓	✓			Low			✓		Fly on sched – Later use
2402 Advanced EVA Technology				✓	✓			Low			✓		Fly on sched – Later use
SPACE STATION SYSTEMS & OPERATIONS													
2501 Liquid Droplet Radiator			✓		✓			Low	✓			Complexity & Concept	Candid. for resched

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Table 4-13. Technology Readiness and Mission Needs, Man-Operated Payloads (Sheet 7 of 7)

		FREE-FLYER ACCOMMODATION ACCEPTABLE	PROGRESSION			MAN'S ROLE			MISSION DEFINITION MATURITY	TECHNICAL RISK				RECOMMENDATION, DISPOSITION, & RATIONALE
			PREDECESSOR EVENT	ADVANCEMENT										
				MAJ	MOD	VITAL	SIGNIF BENEFIT	CONTRIB		HI	MED	LO	RISK AREA	
2502	Advanced Control Device		2005		✓	✓			Low			✓		Fly on sched
2503	Space Component Lifetime Technology		LDEF (Partial)		✓	✓			Low			✓		Fly on sched
2504	OTV Payload Handling		Various STS Prgms		✓	✓			Low			✓		Fly on sched
2505	Payload Servicing and Repair		Various STS Prgms		✓	✓			Low			✓		Fly on sched
2506	OTV Propellant Transfer and Storage		Shuttle Exper		✓	✓			Low		✓		Technology	Fly on sched – Later Use
2507	OTV Propellant Liquefaction			✓		✓			Low		✓		Technology	Fly on sched – Later use
2508	OTV Docking and Berthing				✓	✓			Low			✓		Fly on sched
2509	OTV Maintenance				✓	✓			Med		✓		Opers Complex	Fly on sched – Later use
2510	Tether Dynamics Technology		Shuttle Exper	✓		✓			Med		✓		Concept	Candid. for resched
<u>FLUID & THERMAL PHYSICS, PHYSICS AND CHEMISTRY</u>														
2601	Light Weight Cryo Heat Pipes				✓	✓			Low		✓		Opers & Technology	Fly on/near sched

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Table 4-14. Man-Operated Missions Reassigned as Free Flyers

GDCD 0035	High Energy Isotope Experiment
GDCD 0152	Geoscience-Crustal Dynamics Studies
GDCD 0171	Renewable Resources-Earth Science Research
GDCD 0177	Geoscience-Geology Remote Sensing
GDCD 0246	Solar Terrestrial Observatory
GDCD 0247	Space Plasma Physics Payload
GDCD 0261	High Resolution Doppler Imager (HRDI)
GDCD 0264	LIDAR Facility

The accommodation analysis was iterated with these recommendations in hand. In most cases, full advantage was taken of the opportunity to reschedule missions to a later date. Two missions (0184, Z-Continuous and Special Coverage and 2007, Large Structures Technology) were moved to the year 2002 from 2000. These are man-operated at 28.5 degrees and polar orbits, respectively. The revised mission set was defined as the Baseline Set. The early year distribution of man-operated mission IOC dates was considerably improved and the profile of Station occupancy improved as well.

The cost analysis was iterated based upon the Baseline Mission set, which is considered to be more realistic than the set based solely upon user requirements. The results (Figure 4-21) are a lower peak ($2B versus $3B) and a flatter profile. The total expenditures in the 1990-2000 time period are reduced also but still exceed the estimated NASA budget.

As noted earlier, a review of the discipline level reveals features unique to each discipline. The funding requirements curves are, in general, improved with lower peaks and more reasonable profiles. Astrophysics Requirements (Figure 4-22) still exceed the expected budget in the early years but could be rescheduled to fit under the curve for the total period. The excess is due to currently planned missions, such as AXAF, FUSE, SIRTF, and GRO, most of which are fairly expensive.

The Earth Observations part of Earth and Planetary exceed the total budget for essentially all the decade (Figure 4-23). The NASA budget in this area is questionable based upon current trends to transfer missions of this type to commercial firms. The good news is that should this occur, the missions currently defined would still fly but would be paid for out of private versus public funds. Candidate missions for transfer out of Science and Applications are shown in Table 4-16.

Table 4-15. Technology Readiness and Mission Needs - Free Flyers (Sheet 1 of 4)

	PROGRESSION			REQUIRED ON-ORBIT OPERATIONS					TECHNICAL RISK				
	PREDECESSOR EVENT	ADVANCEMENT MAJ	ADVANCEMENT MOD	ASS'Y	AT STA. C/O	SERV.	RE-CONFIG.	MISSION DEFINITION MATURITY	HI	MED	LO	RISK AREA	RECOMMENDATION, DISPOSITION, & RATIONALE
• SCIENCE AND APPLICATIONS MISSIONS													
ASTROPHYSICS													
ASTRONOMY													
0001 Large Deployable Reflector		✓		✓	✓	✓	✓	Low	✓			Size, Assy OPS	Candidate for reschedule
0002 Far UV Spectroscopy Explorer													Shuttle Launch 1989
0003 Very Long Baseline Interferometry	Shuttle Exper		✓			✓		Low			✓		Fly on/near schedule
0004 Space Telescope	Shuttle P/L Initially		✓			✓	✓	High			✓		Fly on schedule
HIGH ENERGY													
0030 Gamma Ray Observatory						✓							Shuttle launched 1988
0033 Advanced X-ray Astrophysics Facility			✓			✓	✓	High			✓		Fly on sched – (in NASA approval cycle)
0038 X-ray Timing Explorer			✓					High			✓		Fly on schedule
SOLAR PHYSICS													
0060 Solar Internal Dynamics Mission			✓			✓		Low			✓		Fly on/near schedule
0061 Solar Corona Diagnostics Mission			✓					Low			✓		Fly on/near schedule
0062 Advanced Solar Observatory	Solar Optic Tele (SOT)		✓			✓		High		✓		Size, Complexity	Fly on/near schedule
EARTH AND PLANETARY EXPLORATION													
PLANETARY OBSERVATIONS													
0103 Mars Geochemistry/Climatology Orbiter													The principal space station involvement is as a transportation mode Mission sched/selection is a NASA policy matter. This program may be descoped in cost or qty. Examine effects of a smaller program.
0104 Mars Aeronomy Orbiter													
0105 Venus Atmosphere Probe													
0106 Lunar Geochemistry Orbiter													
0107 Titan Probe													
0108 Saturn Orbiter													
0109 Mars Lander													
0110 Saturn Probe													

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Table 4-15. Technology Readiness and Mission Needs - Free Flyers (Sheet 2 of 4)

	Progression: Predecessor Event	Progression: Advancement: MAJ	Progression: Advancement: MOD	Required On-Orbit Operations: ASS'Y	Required On-Orbit Operations: At Sta. C/O	Required On-Orbit Operations: SERV.	Required On-Orbit Operations: RE-CONFIG.	Mission Definition Maturity	Technical Risk: HI	Technical Risk: MED	Technical Risk: LO	Technical Risk: Risk Area	Recommendation, Disposition, & Rationale
SOLAR SYSTEM MISSIONS													The principal space station involvement is as a transportation mode Mission sched/selection is a NASA policy matter. This program may be descoped in cost or quantity. Examine effects of a smaller program.
0121 Comet T2 Rendezvous													
0122 Main-Belt Asteroid Rendezvous													
0123 Comet HMP Sample Return													
0124 Near-Earth Asteroid Rendezvous													
EARTH RESOURCES													
0172 Operational Land Systems	Landsat		✓			✓	✓	Low			✓		Fly on/near schedule
0180 Freeflying Imaging Radar Experiment (FIREX)	Shuttle SLR					✓		Med			✓		Fly on/near schedule
0181 Z – Continuous Coverage	0172, 0174, 0175, 0176, 0202	✓				✓		Med		✓		Data Sys.	Fly near to schedule
0182 Z – Hydrologic Cycle Priority	0181		✓			✓		Med			✓		Sched sequence to 0181
0183 Z – Special Coverage	0182	✓				✓		Med		✓		New Instru. Hi Data Rates	Sched sequence to 0182
ENVIRONMENTAL OBSERVATIONS													
WEATHER/CLIMATE													
0203 Lightning Mapper	Shuttle Exp		✓					Low			✓		Cand for reschedule
0204 Geosynchronous Microwave Sounder		✓			✓	✓		Low	✓			Antenna Size/ Precision	Cand for reschedule
0205 Meterology Instrument Group Operations Payload	0202		✓			✓		Med			✓		Fly on/near schedule
0206 Geostationary Opnl. Env. Satellite (GOES) Follow-on	GOES, 0207, 0262		✓					Low			✓		Fly on/near schedule
0207 TIROS Follow-on	TIROS		✓					Low			✓		Fly on/near schedule
OCEAN													
0221 Ocean Instrument Payload (OIP)	Shuttle Exp		✓			✓		Med			✓		Fly on/near schedule
0222 Ocean Topography Experiment (TOPEX)						✓							Shuttle launched in 1988

266.592-26.2

Table 4-15. Technology Readiness and Mission Needs - Free Flyers (Sheet 3 of 4)

	PROGRESSION: PREDECESSOR EVENT	PROGRESSION: ADVANCEMENT MAJ	PROGRESSION: ADVANCEMENT MOD	REQUIRED ON-ORBIT OPERATIONS: ASS'Y	REQUIRED ON-ORBIT OPERATIONS: AT STA. C/O	REQUIRED ON-ORBIT OPERATIONS: SERV.	REQUIRED ON-ORBIT OPERATIONS: RE-CONFIG.	MISSION DEFINITION MATURITY	TECHNICAL RISK: HI	TECHNICAL RISK: MED	TECHNICAL RISK: LO	TECHNICAL RISK: RISK AREA	RECOMMENDATION, DISPOSITION, & RATIONALE
SOLAR TERRESTRIAL													
0241 Earth Radiation Budget Experiment (ERBE)	Shuttle Exp		✓					High			✓		Instrum pkg. Fly on other missions incl. 0206, 0207
ATMOSPHERIC RESEARCH													
0266 WINDSAT		✓				✓		Low	✓			New Instru.	Candid. for resched.
0267 Upper Atmosphere Research Payload – Operational	0265		✓			✓		Med			✓		Sched in seq w/0265
• COMMERCIAL MISSIONS													
EARTH AND OCEAN OBSERVATIONS													
1000 Geological Reconnaissance	On 0172, 0174, 0175												
1001 Remote Atmospheric Sensing	On 0206, 0262												
1002 Worldwide Cotton Acreage and Production	On 0172												
1003 Petroleum and Mineral Location	On 0172												
COMMUNICATIONS													
1100 Small Communication Satellite			✓					High			✓		Fly on sched. Principal station involvement is as x'portn mode. Strong com'l support for these msns. (1100–1102)
1101 Medium Communication Satellite			✓					High			✓		
1102 Large Communication Satellite			✓					High			✓		
1103 Experimental Geo Platform			✓	✓	✓	✓		Med		✓		Assy Opers & Antenna	Fly on sched. 1103 & 2 of 1104 P/L are NASA w/anticipated payback. Bal are com'l payloads. Good commercial backing for these P/L. Principal station involvement is as transportation mode. (1103–1104)
1104 Operational Geo Platform			✓	✓	✓	✓		Med			✓		

266.592-26.3

Table 4-15. Technology Readiness and Mission Needs - Free Flyers (Sheet 4 of 4)

	PROGRESSION			REQUIRED ON-ORBIT OPERATIONS					TECHNICAL RISK				
	PREDECESSOR EVENT	ADVANCEMENT: MAJ	ADVANCEMENT: MOD	ASS'Y	AT STA. C/O	SERV.	RE-CONFIG.	MISSION DEFINITION MATURITY	HI	MED	LO	RISK AREA	RECOMMENDATION, DISPOSITION, & RATIONALE
MATERIALS PROCESSING													
1206 Electrophoresis Free-Flyer	Shuttle launches from 1986 on		✓			✓		High			✓		Fly on sched.
INDUSTRIAL SERVICES													
1302 Gamma Ray Astronomy	On 0030												
MANNED GEOSYNCHRONOUS MISSIONS													
4000 Manned Geosynchronous Sortie Capsule		✓			✓			Low		✓		Msn Operations	Candidates for resched. The only space station involvement is as a transportation mode. Missions dependent upon NASA policy-decisions. Timing is optimistic.
4001 Manned Geosynchronous Support Module	2507, 4000	✓						Low			✓		

266.592-26.4

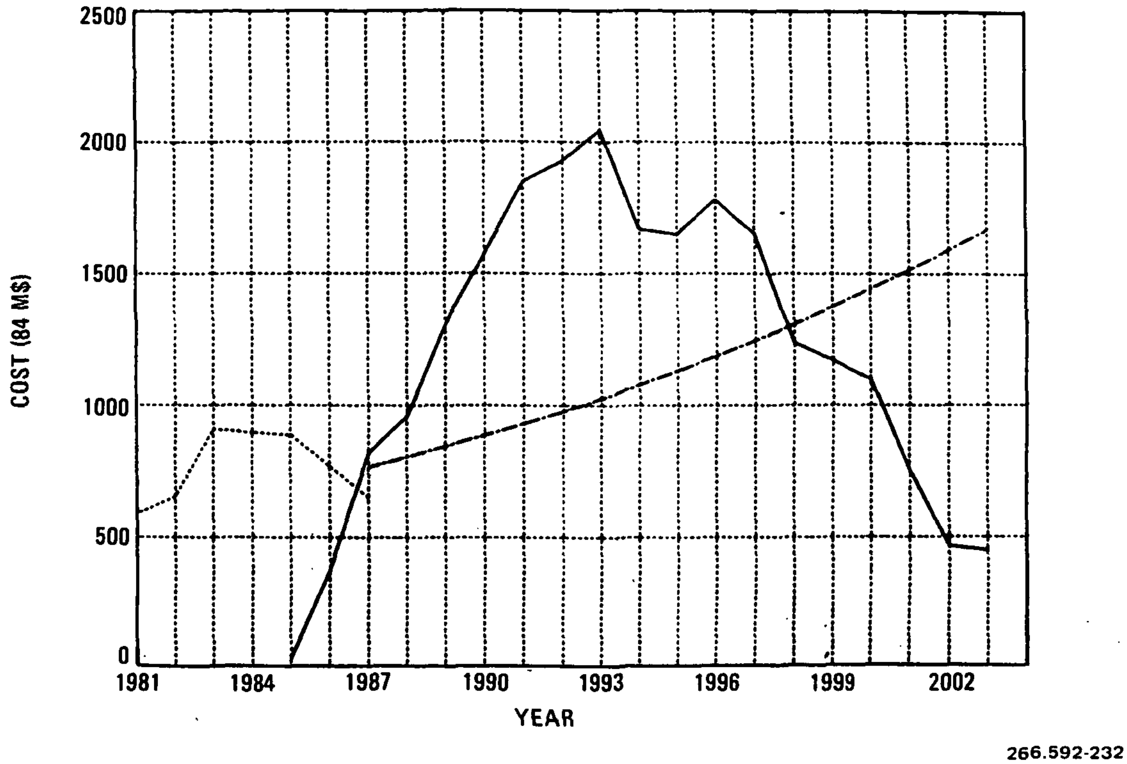

Figure 4-21. Baseline Mission Set Funding Requirements - Excluding Planetary Exploration

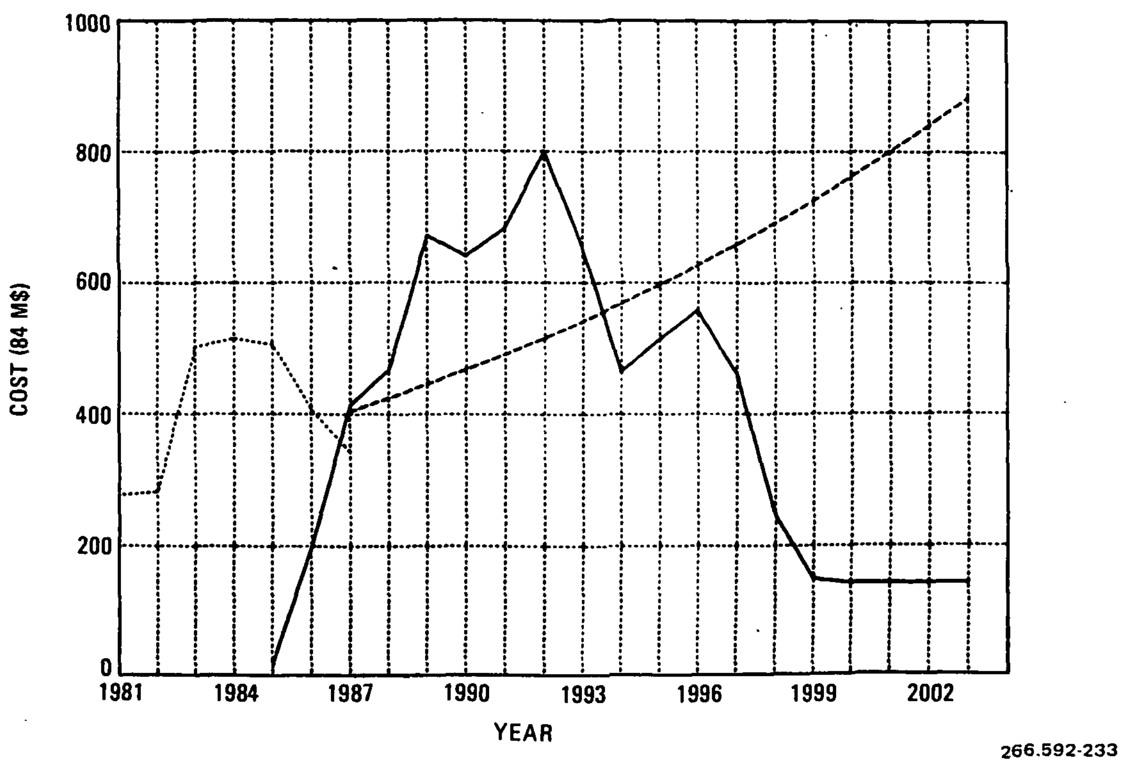

Figure 4-22. Baseline Mission Set Funding Requirements - Astrophysics

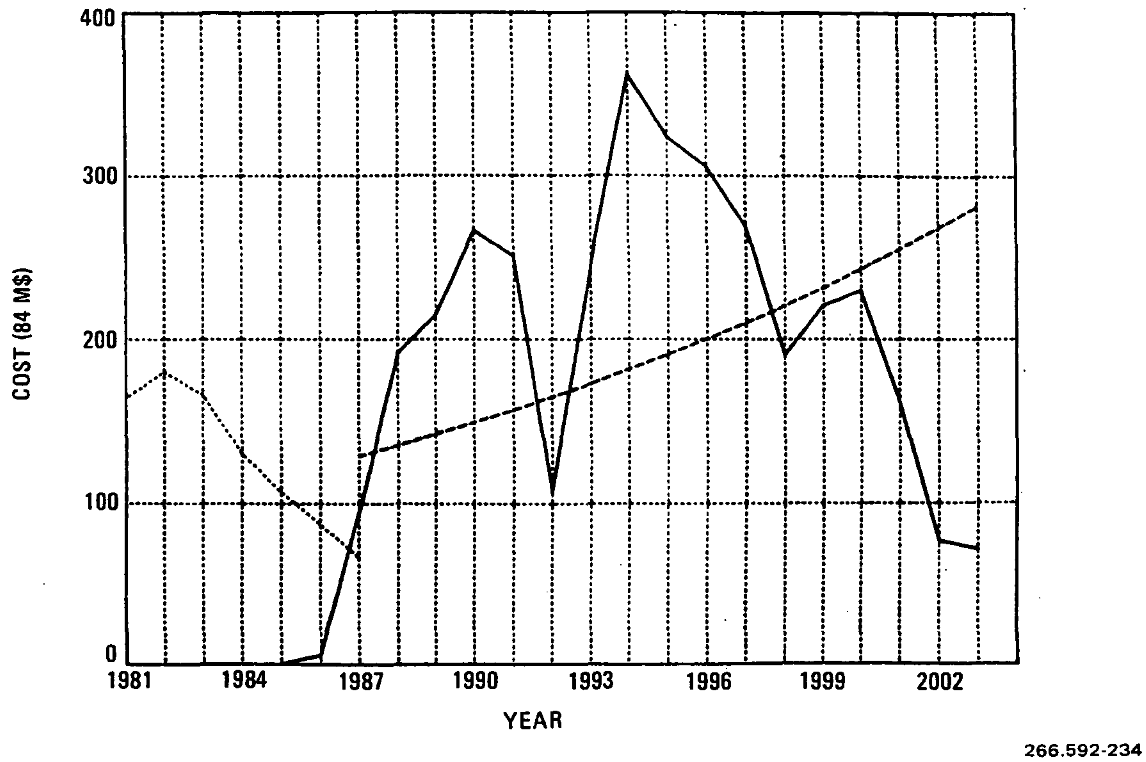

Figure 4-23. Baseline Mission Set Funding Requirements - Solid Earth Observations

Table 4-16. Candidate Commercial Payloads

GDCD 0172	Operational Land Systems
GDCD 0184	Z-Continuous and Special Coverage
GDCD 0206	Geostationary Operational Environmental Satellite (GOES) Follow-On
GDCD 0207	TIROS Follow-On
GDCD 0267	Upper Atmosphere Research Payload (Operational)

Environmental Observations (Figure 4-24) has similar problems to that of Earth Exploration. It would appear that some prioritizing of missions will be necesssary.

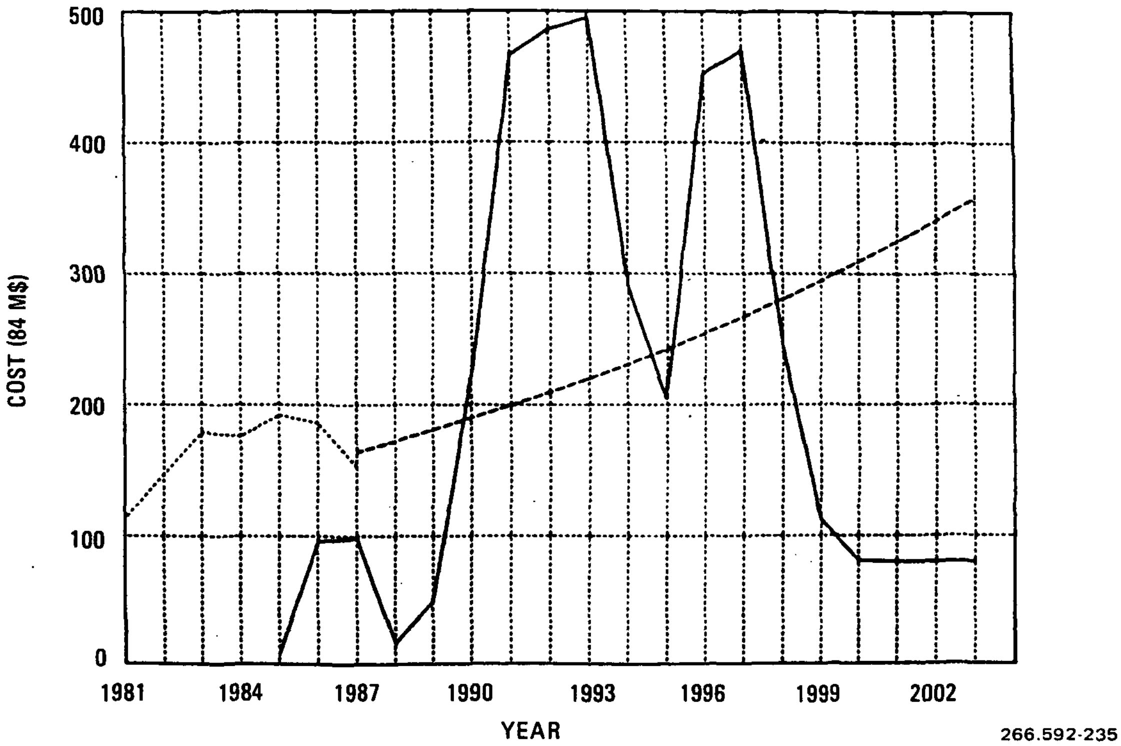

Figure 4-24. Baseline Mission Set Funding Requirements - Environmental Observations

Life Sciences (Figure 4-25) exceeds the budget estimate based upon current allocations by a large factor. This is expected because of the relatively low level of activity in manned space research currently. With approval of a manned Space Station, it is expected that this would change. The peak funding requirements are due to the early needs in Biological Science and to move out with regenerative life support systems.

Materials Processing requirements (Figure 4-26) reflect a shift to commercial firms for pilot and production level activities. The peak is due to an initial funding by NASA of R&D, proof of concept and pilot facilities. We anticipate that most of this would be recovered from commercial firms as markets develop during the 1990s.

Technology Development missions include some high cost items and the current budget projections are very low (Figure 4-27). Like Life Sciences, this should change with the approval of a manned Space Station. One of these (2007, Large Structures Technology) is very expensive and is seen as a separate peak in the funding requirements.

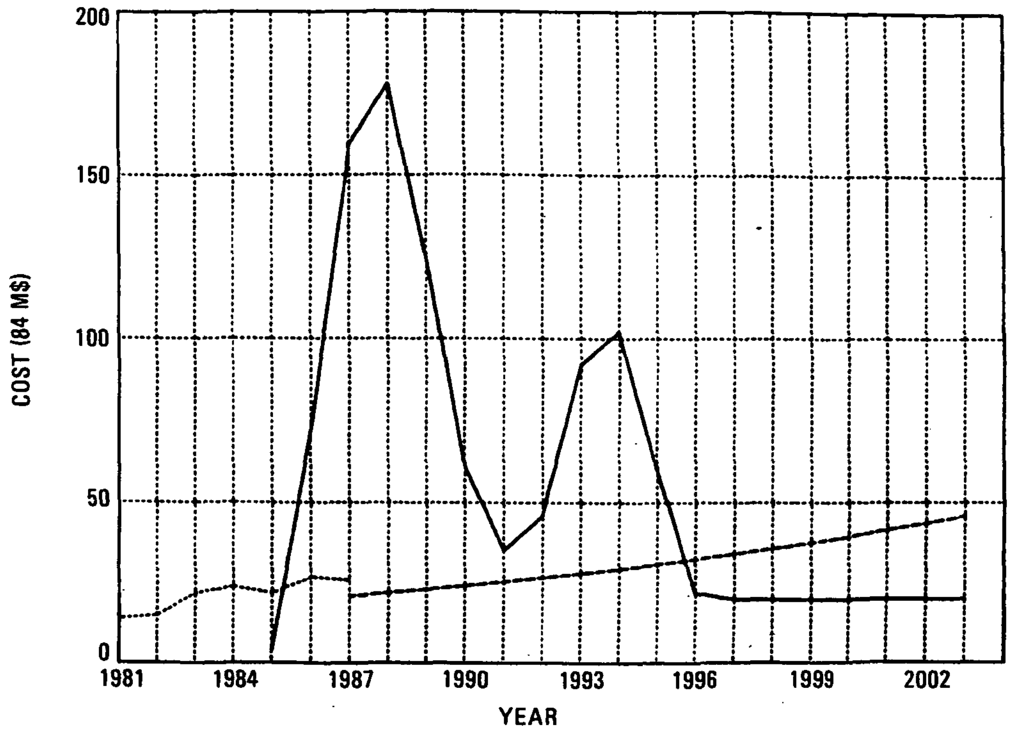

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Figure 4-25. Baseline Mission Set Funding Requirements - Life Sciences

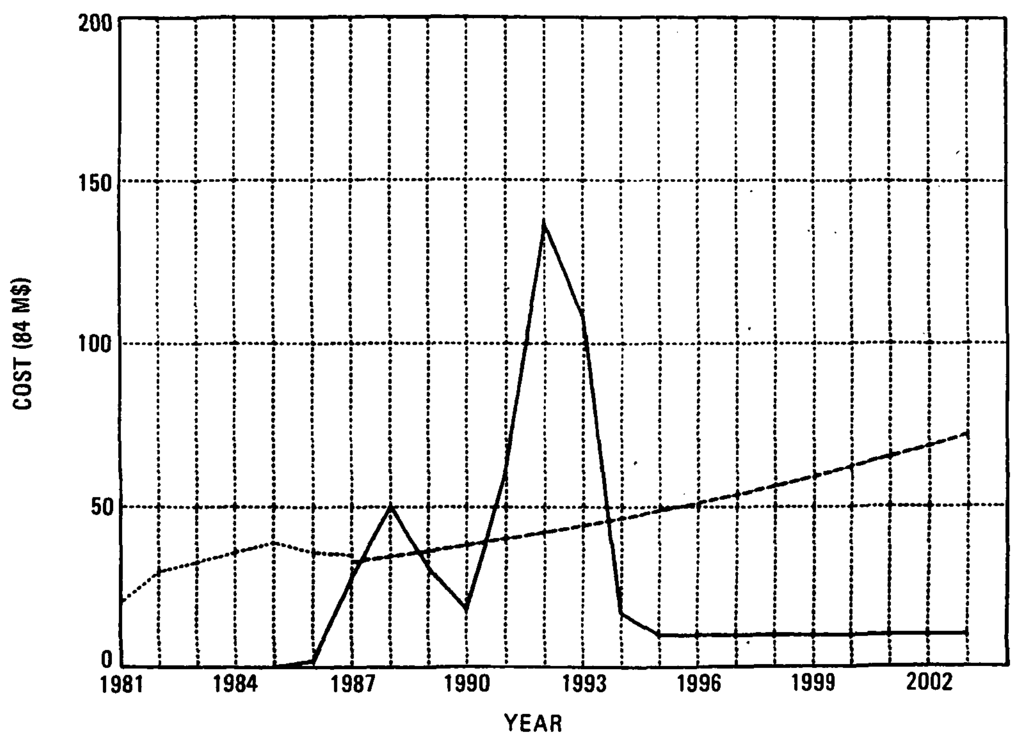

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Figure 4-26. Baseline Mission Set Funding Requirements - Materials Processing

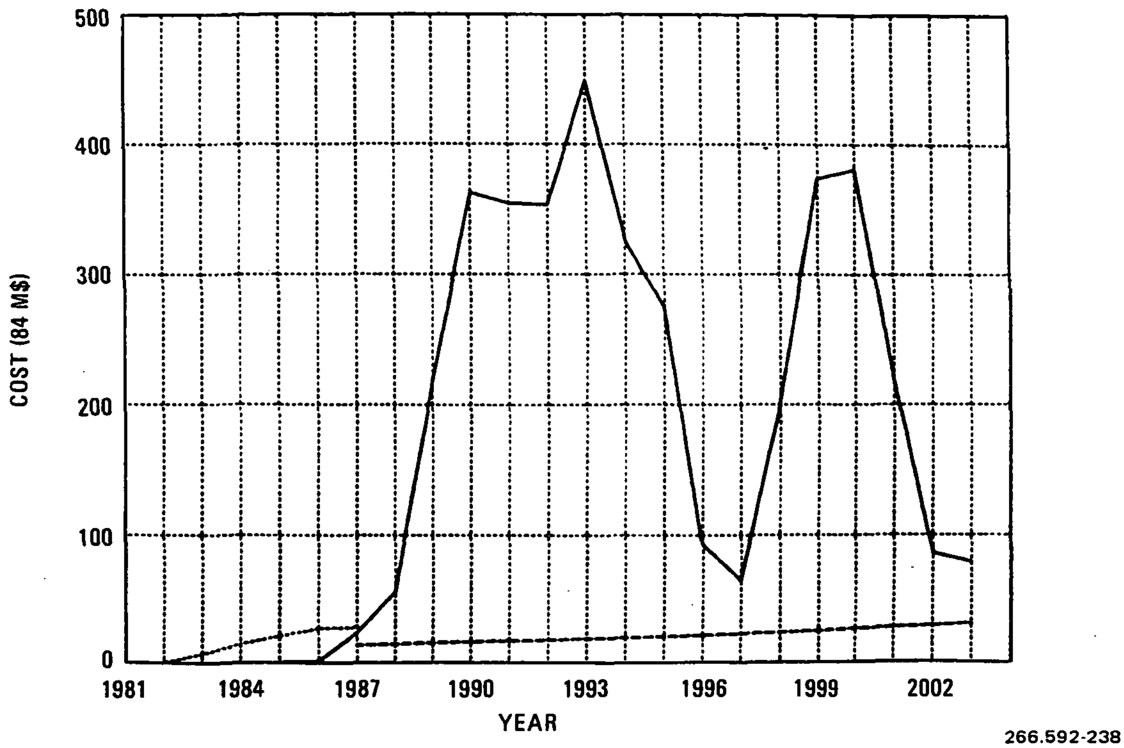

Figure 4-27. Baseline Mission Set Funding Requirements - Technology Development

The Manned Geo missions were delayed to the end of the decade. No specific budget allocations were forecast for this area (Figure 4-28). These are very costly missions and represent a major program start.

4.4.2 BASELINE MAN-OPERATED MISSIONS. The original set of candidate man-operated missions was evaluated in accordance with the criteria discussed in Section 4.4.1 and a revised mission set, defined as the Baseline Set, was established. None of the 99 candidate missions was deleted, but some changes were made in schedules, and alternate accommodation modes were employed where required.

Thirty-six missions were rescheduled to have their initial launch date occur 1 to 4 years later than originally planned. The distribution of the schedule changes is as follows:

No. Years Slippage	No. of Missions
1	16
2	16
3	3
4	1

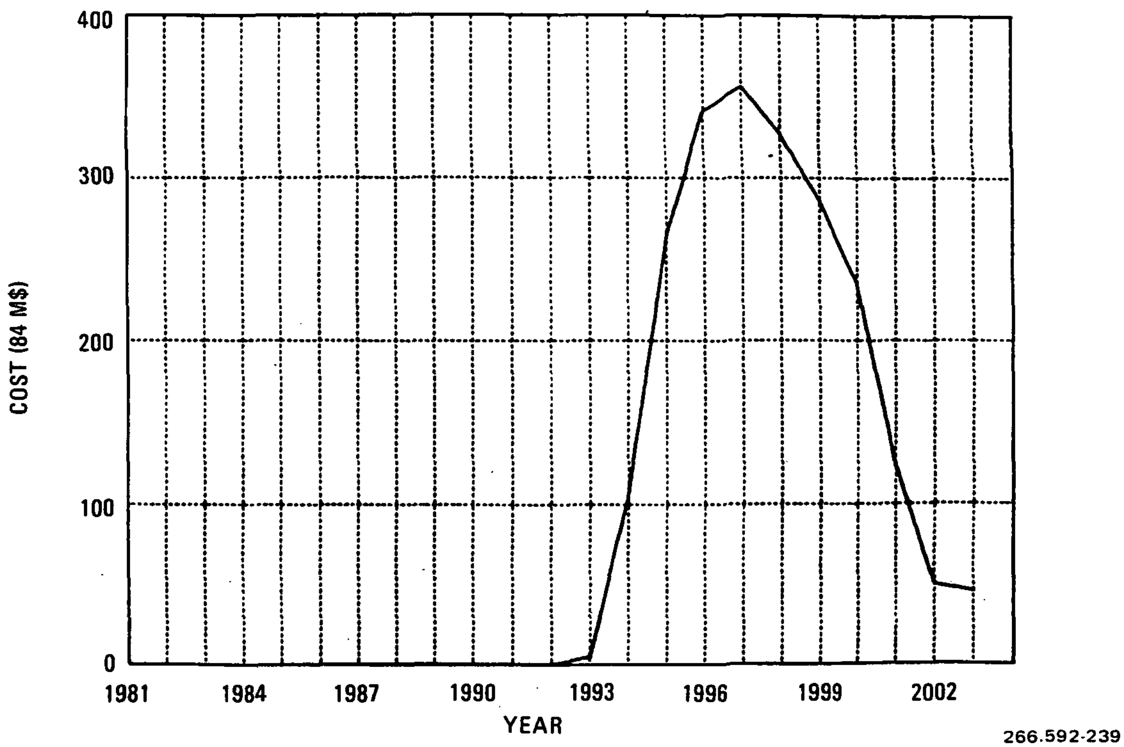

Figure 4-28. Baseline Mission Set Funding Requirements - Space Operations - Manned GEO Missions

The average slippage in schedule is 1.7 years, including two missions rescheduled beyond the year 2000, i.e., 0184, Z-Continuous and Special Coverage and 2007, Large Structures Technology.

Eight of the missions were changed from the Station-attached to the free-flying accommodation mode, primarily because these missions require high inclination orbits (57-100 degrees) in the first half of the decade. The analysis described in Section 4.4.1 indicated that a manned Station would not be programmatically viable in this era. The reassigned missions are listed in Table 4-17. Five of these missions were changed in both accommodation mode and schedule.

The revised or baseline mission set of 89 man-operated missions for the years 1990-2000 is reflected in the Payload Element Data Sheets that are included in Appendix I.

4.4.2.1 Man-Operated Missions Time Phasing. The 89 baseline missions selected for accommodation in the attached mode are identified in the revised time-sequenced waterfall chart in Figure 4-29.

Table 4-17. Man-Operated Missions Reassigned as Free Flyers

		Orbit Incl. (deg) Desired/Acceptable	Original Schedule	Re-Schedule
GDCD 0035	High Energy Isotope Experiment	57 / 57	1995	1997
GDCD 0152	Geoscience-Crustal Dynamics Studies	50 / 50-90	1990	--
GDCD 0171	Renewable-Resources-Earth Science Research	90 / 57-90	1995	1996
GDCD 0177	Geoscience-Geology Remote Sensing	90 / 80-100	1990	--
GDCD 0246	Solar Terrestrial Observatory	57 / 57-90	1993	1994
GDCD 0247	Space Plasma Physics Payload	57 / 57-90	1991	1992
GDCD 0261	High Resolution Doppler Imager (HRDI)	57 / 57-90	1990	--
GDCD 0264	LIDAR Facility	57 / 57-90	1991	1992

Missions for the man-operated facility comprise activities in all of the disciplines concerned with Space Station activities. These include research and technology development in the low-g environment of LEO, "outward" looking observations from above the filtering of the earth's atmosphere, in-situ measurements, and observations of the earth's surface and atmosphere from the vantage point of LEO.

The distribution of man-operated attached missions is shown in Figure 4-30. The upper half of the figure shows a profile of the number of simultaneous missions in operation over the decade, while the lower half is a histogram of the planned first launches. A station at 28.5-degree inclination captures 92% of the man-operated missions. Stated occupancy, in terms of number of missions on board, is essentially constant in the mid years. Two missions (0242 and 0243) each have low and high inclination payload elements.

This distribution of payload elements provided a basis for estimating time-phased mission development and operations costs by discipline. Costs developed to revised mission start dates and mission durations were used in the analysis of program variations. The number of starts shown in Figure 4-30

GDCD NO.	PAYLOAD ELEMENT NAME	DISCI-PLINE	90	91	92	93	94	95	96	97	98	99	00
0005	Shuttle IR Tele. Facility	AST											
0262	Measurement of Air Pollution from Satellites (MAPS)	ATR											
0300	Human Research Lab	BLS											
0301	Animal & Plant Research Lab	BLS											
0322	EVA Perf. & Productivity	OPM											
0400	Research & Development Facility	MPR											
1207	Electrophoresis Separation	MPC											
1209	Metal Clusters & Crystal Growth	MPC											
1210	Enzyme Production & Separation	MPC											
1211	Silicon Crystals	MPC											
1213	Chemical Reactions	MPC											
1214	Space Isothermal Furnace System (SIFS)	MPC											
1300	Radiation Hardened Computer	INS											
1303	Plants in Controlled Env Life Support Sys (CELSS)	INS											
2001	Strain & Acoustic Sensors	MTS											
2402	Advanced EVA Technology	CHF											
2503	Space Component Lifetime Tech	SSS											
0174	Earth Obs Instru Devel (Microwave Tech)	ERS											
0340	$H_2/O_2/CO_2/N_2$ Regenerative Systems	LFS											
1108	Laser Communications	COM											
1111	Millimeter Wave Propagation	COM											
2002	Spacecraft Materials Tech	MTS											
2003	Materials and Coatings	MTS											
2101	Low-Cost Modular Solar Panels	ECN											
2401	Manipulator Controls Tech	CHF											
2506	OTV Propellant Transfer Storage	SSS											
2507	OTV Propellant Liquefaction	SSS											
2508	OTV Docking & Berthing	SSS											
0000	Starlab	AST											
0173	Shuttle Active Microwave Exper (SAMEX-C)	ERS											
0176	EO Sensor/Technique/Anal/ Automated System Devel	ERS											
0341	CELSS Experimental System	LFS											
1106	Large Deployable Antenna	COM											
1200	Pilot – Biological Processing Facility	MPC											

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Figure 4-29. Baseline Man-Operated Missions Time Phasing (Sheet 1 of 3)

GDCD NO.	PAYLOAD ELEMENT NAME	DISCI-PLINE	90	91	92	93	94	95	96	97	98	99	00
1208	Crystal Growth	MPC											
1305	Communication Satellite	INS											
2103	Ion Effects on LEO Power Systems	ECN											
2504	OTV Payload Handling	SSS											
2505	Payload Servicing & Repair	SSS											
2509	OTV Maintenance	SSS											
1109	Open Envelope Tube	COM											
2601	Light Weight Cryo Heat Pipes	FTP											
0034	High Resolution X and Gamma Ray Spectrometer	HEN											
0202	Meteorology Instru Group Devel Payload	WCL											
2004	Thermal Shape Control	MTS											
0032	Large Area Modular Array	HEN											
0175	Earth Obs Instru Devel (Extra Visible & RF)	ERS											
0265	Upper Atmosphere Research Payload-Development	ATR											
0401	R&D/Proof of Concept Facility	MPF											
1107	RFI Measurements	COM											
1201	Pilot – Containerless Processing Facility	MPC											
1202	Pilot-Furnace Processing	MPC											
2005	Dynamics of Flimsy Struct	MTS											
2006	Active Optics Technology	MTS											
2201	Attitude Control – System Identification Exper	CSE											
2202	Attitude Control – Adaptive Control Experiment	CSE											
2301	Controlled Acceleration Propulsion Tech	PPN											
2502	Advanced Control Device	SSS											
1110	Spaceborne Interferometer	COM											
1203	Commercial-Biological Processing Facility	MPC											
1301	Full-Body Teleoperator	INS											
2104	Large Solar Concentrator	ECN											
2203	Attitude Control – Distributed Control Exper	CSE											
2510	Tether Dynamics Tech	SSS											

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Figure 4-29. Baseline Man-Operated Missions Time Phasing (Sheet 2 of 3)

GOCD NO.	PAYLOAD ELEMENT NAME	DISCI-PLINE	90	91	92	93	94	95	96	97	98	99	00
0036	Spectra of Cosmic Ray Nuclei	HEN											
0037	Transition Radiation and Ionization Calorimeter	HEN											
0242	Incoherent Scatter Radar	STR											
0342	Dedicated CELSS Module	LFS											
0343	CELSS Pallet	LFS											
0179	Imaging Radar for Earth Resources Inventory & Monitoring	ERS											
1304	Controlled Environment Life Support Systems (CELSS)	INS											
2105	Solar Pumped Lasers	ECN											
2106	Laser/Electric Energy Conversion	ECN											
2204	Advanced Adaptive Control Technology Demo	CSE											
2302	Laser Propulsion Test	PPN											
2501	Liquid Droplet Radiator	SSS											
0243	Topside Digital Ionosonde HF Radar	STR											
1204	Commercial-Containerless Processing Facility	MPC											
1205	Commercial-Furnace Processing Facility	MPC											
1212	Heat Resistant Alloys	MPC											
2107	Solar Sustained Plasmas	ECN											
2108	Space Nuclear Reactor	ECN											
0151	Detection & Monitoring of Episodic Events	CRM											
0161	Earth Science Research-Geophysical Investigation	GPE											
0245	Space Plasma Physics Payload-Advanced	STR											
0263	CO_2 LIDAR for Atmospheric Measurements	ATR											
0031	High Throughput Mission	HEN											
0201	Satellite Doppler Meteorological Radar Tech Devel	WCL											
0244	Solar Terrestrial Observatory — Advanced	STR											

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Figure 4-29. Baseline Man-Operated Missions Time Phasing (Sheet 3 of 3)

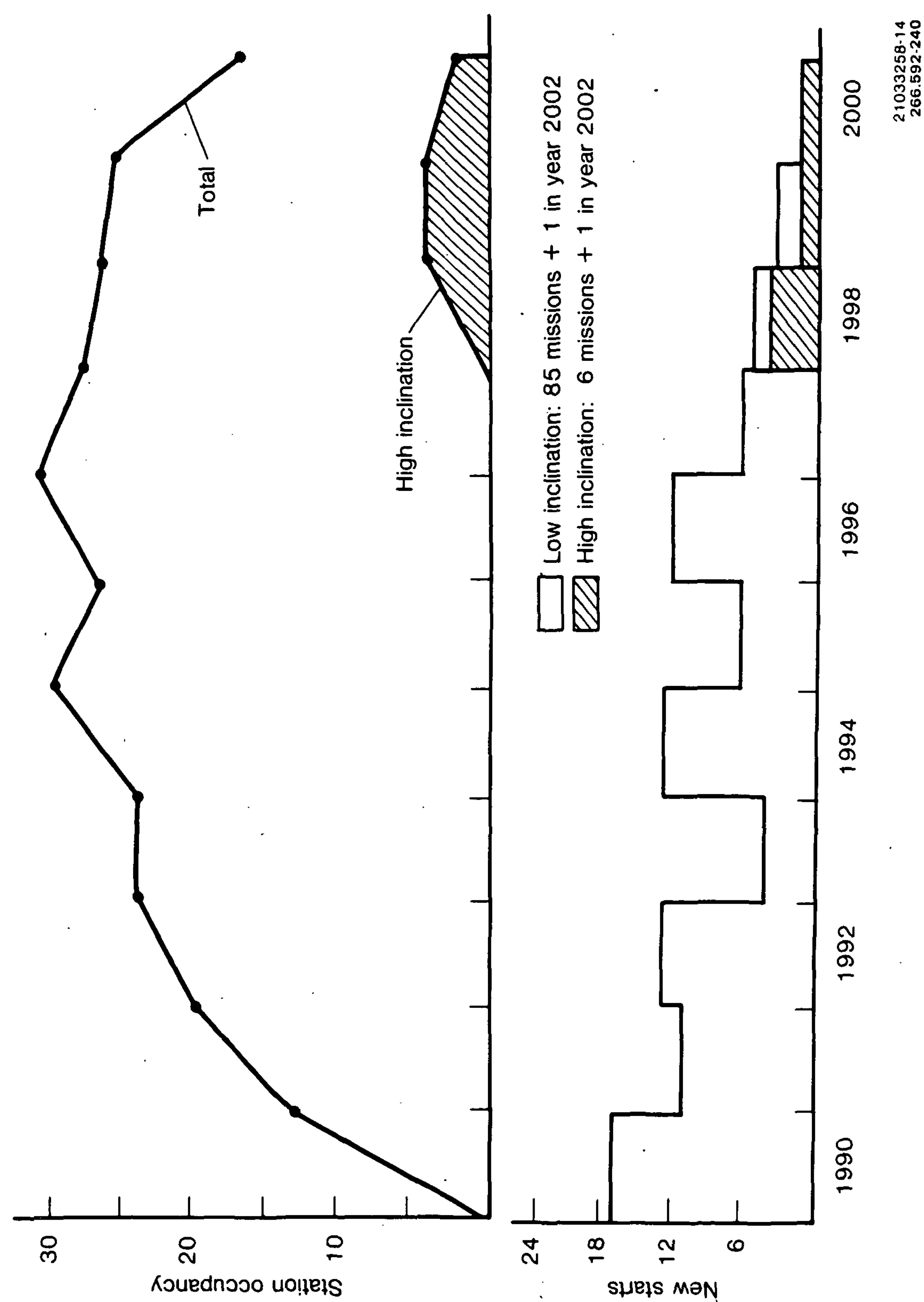

Figure 4-30. Baseline Time-Phased Mission Set - Man-Operated Missions

represents the number of new payload elements added in each year for Space Station accommodation. By examining the number of initial launches of man-operated missions over the decade (1990-2000), it becomes evident that the planning and definition of missions and payload elements is better in early years than in later years. This tendency results in planning horizon effects that reflect in a reduced funding profile and a reduction in forecast traffic for later years.

Occupancy for Station-attached payload elements is shown to peak at a level of 31 and maintain an average level of about 28 for the last half of the decade. During this time some of the shorter duration missions drop out of the set, while others are added.

Using curve fit techniques from the year 1992 to 1997, a growth rate of approximately 5% can be projected. Using the average mission duration of approximately 3 years (derived from Figure 4-5), a new start rate of about 12 missions per year results versus the declining rate shown for the baseline mission set data in the last 4-year period. The result of the 5% annual growth projection would be a station occupancy of 35-36 missions at the end of the decade versus that derived from the baseline mission set, which is about half of this amount.

4.4.2.2 Man-Operated Mission Requirements. Requirements for the man-operated attached missions are displayed in Table 4-18. Missions are arranged by discipline using the ascending order of GDCD Code numbers assigned and documented in Book 1, Appendix I. The definition of terms used in Table 4-18 is contained in the introduction to Section 3.

The individual mission requirements are the same as presented in Section 4.2.2 (Table 4-5). The discussions of driving requirements for key parameters of orbit, mass, power, size/volume, crew, and data requirements are still applicable, with the possible exception of some of the eight payloads reassigned as free flyers. These are further discussed in Section 4.4.3 for the baseline free-flyer mission set.

4.4.2.3 Integrated Mission Requirements. The major resource requirements that affect the architectural options for a 28.5-degree inclination Space Station are summarized in Figure 4-31. This figure illustrates time-phased requirements for power, crew size, and pressurized volume, and the overall spectrum of pointing accuracy requirements.

The power required by the baseline mission set (Figure 4-31A) reaches about 40 kW in the first third of the decade, rises rapidly to about 190 kW in 1996, and then stabilizes at around 180 kW for the rest of the decade. Slightly more than half of the power is required for commercial materials processing missions (paying customers) in the latter half of the decade.

The time-phased crew requirements are shown in Figure 4-31B. The crew size required for the baseline mission set starts at the three to four level early in the decade, rises to eight in the mid term and then remains constant for the last few years. Again, the commercial MPS missions require a significant portion of the crew resource, in this case 25% to 35% in the later years.

Table 4-18. Baseline Payload Requirements Summary Data - Man-Operated Accommodation Mode (Sheet 1 of 6)

GDC NO.	PAYLOAD ELEMENT NAME	DISCIPLINE	MISSION REQUIREMENTS: LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT PREFERRED ALT (km)	ORBIT PREFERRED INCL (deg)	ORBIT ACCEPTABLE RANGE ALT (km)	ORBIT ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING ACCY (sec)	POINTING JITTER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL: MASS (kg)	PRES'D VOL (m³)	EXTNL SIZE L×W×H (m)	RESOURCES: POWER LEVEL, W (DUR, HR/DAY) OPER	POWER PEAK	DATA K BPS (HR/DAY)	CREW SIZE	CREW TIME (AVG) HR/DAY	EVA REQ'D √	SVC REQ'D √	RECONFIG REQ'D √	COMMENTS
0005	Shuttle IR Tele. Facility	AST	90	1825	400	28.5	300-400	28.5-57	Inertial	96*		N/A	7018	0.36	11x4x4	1300 (18)	2735	1000	1	0.5	✓	✓		
0262	Measurement of Air Pollution from Satellites (MAPS)	ATR	90	365	400	57	200-600	28.5-90	Earth	7200		N/A	100	0.36	1x1x0.6	200		4600	1	0.2	✓	✓	✓	
0300	Human Research Lab	BLS	90	3600	ANY	ANY			N/A	N/A	N/A		7300	112.	N/A	2000 (8)	3080 (1)	128.	2	10		✓	✓	Volume = Total Module
0301	Animal & Plant Research Lab	BLS	90	3600	ANY	ANY			N/A	N/A	N/A	10^{-3} to 5×10^{-5}	4320	76.2	N/A	2000 (21)	4000 (3)	128	2	6		✓	✓	Volume = Total Module
0322	EVA Perf. & Productivity	OPM	90	3600	ANY	ANY			N/A	N/A	N/A		270	3.1	N/A	100 (0.3)			2	0.5	✓	✓	✓	TV Required
0400	Research & Development Facility	MPR	90	1460	>400	ANY	N/A	N/A	N/A	N/A	N/A	10^{-5}	1736	6.75	N/A	10K (22)	13K (2)	3 (24)	1	4				Vacuum Vent Required
1207	Electrophoresis Separation	MPC	90	7	ANY	ANY	N/A	N/A	N/A	N/A	N/A	10^{-4}	(300)	(2.7)	N/A	(500)			(1)	(0.5)				Ref. – 0400
1209	Metal Clusters & Crystal Growth	MPC	90	15	ANY	ANY	N/A	N/A	N/A	N/A	N/A	10^{-4}	(100)	(0.5)	N/A	(1000)			(1)	(1)				Ref. – 0400
1210	Enzyme Production & Separation	MPC	90	4	ANY	ANY	N/A	N/A	N/A	N/A	N/A	N/A			N/A				(1)	(2)				Ref. – 0400
1211	Silicon Crystals	MPC	90	30	ANY	ANY	N/A	N/A	N/A	N/A	N/A	10^{-4}	(300)	(1.2)	N/A	(5000) (8)			(1)	(8)				Ref. – 0400 For 30 Samples
1213	Chemical Reactions	MPC	90	7	ANY	ANY	N/A	N/A	N/A	N/A	N/A								(1)	(0.5)				Ref. – 0400
1214	Space Isothermal Furnace System (SIFS)	MPC	90	4	>250	ANY	N/A	N/A	N/A	N/A	N/A				N/A				(1)	(0.5)				Ref. – 0400
1300	Radiation Hardened Computer	INS	90	1825	ANY	ANY			N/A			N/A	50	0.36	.6x.5x.4	200 (24)		1000			✓			
1303	Plants in Controlled Env Life Support Sys (CELSS)	INS	90	180	ANY	ANY			N/A										1	0.2				Ref. –0341
2001	Strain & Acoustic Sensors	MTS	90	3650	LEO	ANY			N/A			N/A	50	0.36		100		1.0	1	0.1	✓	✓	✓	
2402	Advanced EVA Technology	CHF	90	3600	LEO	ANY			N/A	N/A	N/A	N/A	500	2.2		100			1	0.02	✓			

*At telescope interface with IPS.

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Table 4-18. Baseline Payload Requirements Summary Data - Man-Operated Accommodation Mode (Sheet 2 of 6)

GDC NO.	PAYLOAD ELEMENT NAME	DISCIPLINE	MISSION REQUIREMENTS										PHYSICAL			RESOURCES								COMMENTS
			LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT				VIEWING DIRECTION	POINTING		OPER ACCEL LIMIT (g)	MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	POWER LEVEL, W (DUR, HR/DAY)		DATA K BPS (HR/DAY)	CREW		EVA REQ'D √	SVC REQ'D √	RE-CONFIG REQ'D √	
					PREFERRED		ACCEPTABLE RANGE																	
					ALT (km)	INCL (deg)	ALT (km)	INCL (deg)		ACCY (sec)	JITTER (sec/s)					OPER	PEAK		SIZE	TIME (AVG) HR/DAY				
2503	Space Component Lifetime Tech	SSS	90	3650	LEO	ANY			N/A			N/A	300	0	.2x.2x.2 (ea of 6)				1	0.2	✓		✓	Six Components
0174	Earth Obs Instru Devel (Microwave Tech)	ERS	91	730	1000	90	400-1600	28.5-90	Earth	360		N/A	200	0.36	1.5x1.x1.	200		1000	1	0.25			✓	
0340	$H_2O/O_2/CO_2/N_2$ Regenerative Systems	LFS	91	3650	ANY	ANY			N/A	N/A	N/A		1280	5.8	N/A	2400 (8)	4200 (16)	8	2	1			✓	
1108	Laser Communications	COM	91 92	5 5	ANY	ANY			Inertial	360		N/A	140	0.36	2x1x1	200 (3)	500 (20.5)	100K	1	0.5	✓			
1111	Millimeter Wave Propagation	COM	91 92 93	5 5 2920	ANY	ANY			Earth	3600		N/A	40	0.36	3x.5x3	25	100		1	0.25	✓		✓	
2002	Spacecraft Materials Tech	MTS	91	3300	LEO	ANY			N/A			N/A	150	0	5x1x0.1				1	0.1	✓	✓	✓	
2003	Materials and Coatings	MTS	91	3300	LEO	ANY			N/A			N/A	250	0	10x5x0.2				1	0.1	✓	✓	✓	
2101	Low-Cost Modular Solar Panels	ECN	91	3650	LEO	ANY			Solar	10000		0.1	30	0	5x6x 0.1				1	0.1	✓			
2401	Manipulator Controls Tech	CHF	91	365	LEO	ANY			N/A	N/A	N/A	N/A	600	12.		3150		1.0	2	0.4	✓			
2506	OTV Propellant Transfer and Storage	SSS	91	30	LEO	ANY			N/A			N/A	2000	0	8.5x4.6 x3.6	500 (2)			1	1.0				
2507	OTV Propellant Liquefaction	SSS	91	30	LEO	ANY			N/A			N/A	1000	0	3.5x2x2	350 (24)			1	1.0				
2508	OTV Docking & Berthing	SSS	91	30	LEO	ANY			N/A			N/A	5900	0	10x4.5 x4.5	500 (2)			1	2.0				TV Required
0000	Starlab	AST	92	1100	400	28.5	370-435	28.5-57	Inertial	150*		N/A	3280	0.36	13x7x4.5	2220 (18)	3890	16K	1	2	✓		✓	
0173	Shuttle Active Microwave Exper (SAMEX-C)	ERS	92	730	400	90	275-500	28.5-90	Earth	3600		N/A	2000	0.36	15x3x2	5K (12)	7500	5	1	0.2	✓		✓	
0176	EO Sensor/Technique/Anal/ Automated System Devel	ERS	92	1460	500	90	275-925	28.5-90	Earth	3600		N/A	2000	0.72	40x30x3	6K (12)		80K	2	1	✓	✓	✓	
0341	CELSS Experimental Systems	LFS	92	2190	ANY	ANY			N/A	N/A	N/A		2625	28	N/A	4400 (23)	6000 (1)		2	2		✓	✓	

*At telescope interface with IPS.

266.592-49.2

Table 4-18. Baseline Payload Requirements Summary Data - Man-Operated Accommodation Mode (Sheet 3 of 6)

GDC NO.	PAYLOAD ELEMENT NAME	DISCIPLINE	MISSION REQUIREMENTS: LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT: PREFERRED ALT (km)	PREFERRED INCL (deg)	ACCEPTABLE RANGE ALT (km)	ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING: ACCY (sec)	JITTER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL: MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	RESOURCES: POWER LEVEL, W (DUR, HR/DAY) OPER	PEAK	DATA K BPS (HR/DAY)	CREW SIZE	CREW TIME (AVG) HR/DAY	EVA REQ'D √	SVC REQ'D √	RE-CONFIG REQ'D √	COMMENTS
1106	Large Deployable Antenna	COM	92 94	14 14	ANY ANY	ANY ANY			Earth	360		N/A	500	0.36	50x20x50	200	300	400	1	0.5	✓			
1200	Pilot – Biological Processing Facility	MPC	92	730	>400	N/A			N/A	N/A		10^{-3}	1050	4.3	N/A	8K (2)	10K (22)	3 (24)	1	4				Vacuum Vent Required
1208	Crystal Growth	MPC	92	6.5	ANY	ANY			N/A	N/A	N/A				N/A									Ref. – 0400
1305	Communication Satellite Service/Handling	INS	92	30	ANY	ANY			N/A			N/A												Ref. – 1106, 2504, 2505
2103	Ion Effects on LEO Power Systems	ECN	92	365	LEO	ANY			Solar	7200		N/A	150	0.36	5x6x0.1				1	0.1	✓		✓	
2504	OTV Payload Handling	SSS	92	30	LEO	ANY			N/A			N/A	2000	0	4x4.5 x4.5	300 (2)			2	8				TV Required
2505	Payload Servicing & Repair	SSS	92	90	LEO	ANY			N/A			N/A	500	0	9x4.5 x4.5				1	1	✓			TV Required
2509	OTV Maintenance	SSS	92	30	LEO	ANY			N/A			N/A	3000	0	8.5x7.5 x7.5	500 (4)		4.0	4	13	✓			TV Required
2601	Light Weight Cryo Heat Pipes	FTP	92	250	LEO	ANY			N/A			N/A	1000	0.36	15x1.0 x1.0	200	**	2	1	1.6	✓	✓		**5000W Reqd 12 Times/ Mission for 5 Min Each
1109	Open Envelope Tube	COM	93 94	7 7	ANY	ANY			Inertial				157	0.36	0.2x0.2 x6	500	2000	100	1	0.25	✓			
0034	High Resolution X and Gamma Ray Spectrometer	HEN	93	1080	400	28.5			Inertial	360*		N/A	1768	0.36	2.1x2.1 x2.1	530 (18)	830 (6)	30	1	0.5	✓	✓		
0202	Meteorology Instru Group Devel Payload	WCL	93	365	400	57	300-500	28.5-90	Earth	360		N/A	1170	0.72	1.6x4.4 x4.4	1140 (24)		3000	2	0.4	✓	✓	✓	
2004	Thermal Shape Control	MTS	93	550	LEO	ANY			N/A			N/A	1000	0.36	20x10x.2	3000	6000	1.0	1	0.1	✓			
0032	Large Area Modular Array	HEN	94	1640	400	28.5			Interial	180		N/A	9516	0.36	7.8x4.4 x4.4	3400 (20)		125	1	0.5	✓	✓		
0175	Earth Obs Instru Devel (Extra Visible & RF)	ERS	94	730	400	90	275-1000	28.5-90	Earth	1800		N/A	1000	0.36	8x4x2	500	700	1000	1	0.25	✓	✓	✓	
0265	Upper Atmosphere Research Payload-Development	ATR	94	550	400	57	400-600	28.5-90	Earth-Solar	36		N/A	2500	0.72	4.5x4.5x2	4K (4)		500	2	0.8	✓	✓	✓	

*At telescope interface with IPS.

266.592-49.3

Table 4-18. Baseline Payload Requirements Summary Data - Man-Operated Accommodation Mode (Sheet 4 of 6)

GDC NO.	PAYLOAD ELEMENT NAME	DISCIPLINE	MISSION REQUIREMENTS: LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT: PREFERRED ALT (km)	PREFERRED INCL (deg)	ACCEPTABLE RANGE ALT (km)	ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING: ACCY (sec)	JITTER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL: MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L×W×H (m)	RESOURCES: POWER LEVEL, W (DUR, HR/DAY) OPER	PEAK	DATA K BPS (HR/DAY)	CREW SIZE	TIME (AVG) HR/DAY	EVA REQ'D √	SVC REQ'D √	RE-CONFIG REQ'D √	COMMENTS
0401	R&D/Proof of Concept Facility	MPR	94	2600	>400	ANY			N/A	N/A	N/A	10^{-5}	3224	11.95	N/A	25K (22)	35K (2)	6 (24)	1	8				Vacuum Vent Required
1107	RFI Measurements	COM	94	21	ANY	ANY			Earth	3600		N/A	50	0.36	15x15x15	100	300	1K	1	0.5	✓		✓	
1201	Pilot – Containerless Processing Facility	MPC	94	1095	>400	ANY			N/A	N/A	N/A	10^{-3}	3900	12.9	N/A	12K (4)	25K (4)	3 (8)	1	8				Vacuum Vent Required
1202	Pilot-Furnace Processing Facility	MPC	94	1095	>400	ANY			N/A	N/A	N/A	10^{-5}	4452	12.05	N/A	30K (12)	50K (12)	10 (24)	1	4				Vacuum Vent Required
2005	Dynamics of Flimsy Struct	MTS	94	1460	LEO	ANY			N/A			N/A	1000	0.72	100x20 x2.5	1000 (24)		1.0	1	0.1	✓			
2006	Active Optics Technology	MTS	94	1000	LEO	ANY			Inertial			N/A	10000	0.36	16x12x16	1000			1	0.2	✓	✓		
2201	Attitude Control – System Identification Exper	CSE	94	365	LEO	ANY			N/A			N/A	100	0.36	100x20 x2.5**	1000		1.0	2	0.2	✓		✓	**Uses Structure From 2005
2202	Attitude Control – Adaptive Control Experiment	CSE	94	365	LEO	ANY			N/A			N/A	100	0.36	100x20 x2.5**	1000		1.0	2	0.2	✓		✓	**Uses Structure From - 2005
2301	Controlled Acceleration Propulsion Tech	PPN	94	180	LEO	ANY			N/A			N/A	45	0.36	0.6x0.4 x0.4	1500			1	0.2	✓	✓		Propellant Required
2502	Advanced Control Device	SSS	94	730	LEO	ANY			N/A			N/A	400	0.36	100x20 x2.5**	1000		1.0	2	0.2	✓		✓	**Uses Structure From - 2005
1110	Spaceborne Interferometer	COM	95 97	15 15	ANY	ANY			Earth	360		N/A	60	0.36	30x.2x.2	100 (2)	150 (0.5)	500	1	0.5	✓			
1203	Commercial-Biological Processing Facility	MPC	95	1825	>400	ANY			N/A	N/A	N/A	10^{-3}	2100	8.6	N/A	16K (4)	20K (20)	6 (24)	1	8				Vacuum Vent Required
1301	Full-Body Teleoperator	INS	95	1460	ANY	ANY			N/A			N/A	300	1.5		500-1000								
2104	Large Solar Concentrator	ECN	95	365	LEO	ANY			Solar	900		N/A	5000	0.36	10x10x10				1	0.2	✓			
2203	Attitude Control – Distributed Control Exper	CSE	95	365	LEO	ANY			N/A			N/A	100	0.36	100x20 x2.5**	1000		1.0	2	0.2	✓		✓	**Uses Structure From -- 2005
2510	Tether Dynamics Tech	SSS	95	3	LEO	ANY			N/A			N/A	3000	0.36	4x4x2				1	3				

*At telescope interface with IPS.

266.592-49.4

Table 4-18. Baseline Payload Requirements Summary Data - Man-Operated Accommodation Mode (Sheet 5 of 6)

GDC NO.	PAYLOAD ELEMENT NAME	DISCIPLINE	MISSION REQUIREMENTS: LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT PREFERRED ALT (km)	ORBIT PREFERRED INCL (deg)	ORBIT ACCEPTABLE RANGE ALT (km)	ORBIT ACCEPTABLE RANGE INCL (deg)	VIEWING DIRECTION	POINTING ACCY (sec)	POINTING JIT-TER (sec/s)	OPER ACCEL LIMIT (g)	PHYSICAL: MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L×W×H (m)	RESOURCES: POWER LEVEL, W (DUR, HR/DAY) OPER	POWER PEAK	DATA K BPS (HR/DAY)	CREW SIZE	CREW TIME (AVG) HR/DAY	EVA REQ'D √	SVC REQ'D √	RE-CONFIG REQ'D √	COMMENTS
0036	Spectra of Cosmic Ray Nuclei	HEN	96	365	400	57	370-435	28.5-57	Anti-Earth	3600		N/A	3082	0.36	3.3x4.8 x3.8	731 (22)	785 (2)	102	1	0.2	✓	✓		
0037	Transition Radiation and Ionization Colorimeter	HEN	96	700	400	57	370-435	28.5-57	Anti-Earth	3600		N/A	5750	0.36		550 (24)		10	1	0.5	✓	✓		
0242	Incoherent Scatter Radar	STR	96 98	365	400 400	0 90	400-500 400-500	0-28.5 80-100	Earth, Celestial	18000		N/A	1000	0.36	25x25x15	1500			1	0.5	✓			
0342	Dedicated CELSS Module	LFS	96	1460	ANY	ANY			N/A	N/A	N/A		10500	111	N/A	18000 (23)	22000 (1)		2	6		✓	✓	Volume = Total Module
0343	CELSS Pallets	LFS	96	2190	ANY	ANY			N/A	N/A	N/A		1300		1x2.5 x0.5	600 (24)			2	0.5		✓		
0179	Imaging Radar for Earth Resources Inventory & Monitoring	ERS	96	1095	400	57	300-500	28.5-90	Earth	360		N/A	2000	0.36	15x3x2	5K	7.5K	20	1	0.2				
1304	Controlled Environment Life Support Systems (CELSS)	INS	96	180	ANY	ANY			N/A			N/A	(1500)	(9.3)		(300)	(1000-2500)		1	0.2				Ref. 0342
2105	Solar Pumped Lasers	ECN	96	270	LEO	ANY			Solar	900		N/A	200	0	10x10 x10**				1	0.2	✓		✓	**Uses – 2104 Collector
2106	Laser/Electric Energy Conversion	ECN	96	450	LEO	ANY			Solar	900		N/A	500	0	10x10 x10**				1	0.2	✓		✓	**Uses – 2104 Collector
2204	Advance Adaptive Control Technology Demo	CSE	96	365	LEO	ANY			N/A			N/A	100	0.36	100x20 x2.5**	1000		1.0	2	0.2	✓		✓	**Uses Structure From – 2005
2302	Laser Propulsion Test	PPN	96	180	LEO	ANY			Solar			N/A	100	0.36	1.5x.5 x.5	200		5	1	0.25	✓	✓		Collector & Laser From 2104 & 2105. GH_2 Required
2501	Liquid Droplet Radiator	SSS	96	365	LEO	ANY			N/A			N/A	1000	0.36		1000		1.0	1	0.1	✓			
0243	Topside Digital Ionosonde HF Radar	STR	97 99	365	400 400	0 90	400-500 400-500	0-28.5 80-100	Earth			N/A	500	0.36	200 x200x3	1500			1	0.5	✓			
1204	Commercial-Containerless Processing Facility	MPC	97	1095	>400	ANY			N/A	N/A	N/A	10^{-3}	5700	20.3	N/A	26K (20)	38K (4)	6 (24)	1	8				Vacuum Vent Required

*At telescope interface with IPS.

266.592-49.5

Table 4-18. Baseline Payload Requirements Summary Data - Man-Operated Accommodation Mode (Sheet 6 of 6)

GDC NO.	PAYLOAD ELEMENT NAME	DISCI-PLINE	MISSION REQUIREMENTS										PHYSICAL			RESOURCES								COMMENTS
			LAUNCH DATE YR(S)	MSN DUR (DAYS)	ORBIT				VIEWING DIRECTION	POINTING		OPER ACCEL LIMIT (g)	MASS (kg)	PRES'D VOL (m^3)	EXTNL SIZE L X W X H (m)	POWER		DATA K BPS (HR/DAY)	CREW		EVA REQ'D √	SVC REQ'D √	RE-CONFIG REQ'D √	
					PREFERRED		ACCEPTABLE RANGE			ACCY (sec)	JIT-TER (sec/s)					LEVEL, W (DUR, HR/DAY)			SIZE	TIME (AVG) HR/DAY				
					ALT (km)	INCL (deg)	ALT (km)	INCL (deg)								OPER	PEAK							
1205	Commercial-Furnace Processing Facility	MPC	97	1500	>400	ANY			N/A	N/A	N/A	10^{-5}	6325	22.5	N/A	40K (20)	70K (4)	10 (24)	1	8				Vacuum Vent Required
1212	Heat Resistant Alloys	MPC	97	30	ANY	ANY			N/A	N/A	N/A		[5000]			[100K] [(6)]			[1]	[8]				Ref. – 1205 for 30 Samples
2107	Solar Sustained Plasmas	ECN	97	450	LEO	ANY			Solar	900		N/A	2000	0	10x10 x10**				1	0.2	✓		✓	**Uses – 2104 Collector
2108	Space Nuclear Reactor	ECN	97	2560	LEO	ANY			N/A			N/A	2500	0.36	100x4x4				1	0.1	✓			NASA Cost Share is 1/3
0151	Detection & Monitoring of Episodic Events	CRM	98	1825	450	90	400-500	80-100	Earth	6		N/A	3500	0.36	16x10x3	3000		300K	2	1	✓	✓	✓	
0161	Earth Science Research-Geophysical Investigation	GPF	98	800	400	90	275-500	85-95	Earth	1800		N/A	400	0.36	100x2x2	130 (24)	1200	30	1	0.5				
0245	Space Plasma Physics Payload-Advanced	STR	98	730	400	57	250-500	57-90	Earth, Solar	3600		N/A	3183	0.36	5x300 x10	3225 (1)	12K (0.1)	12K	1	0.5		✓		
0263	CO_2 LIDAR for Atmospheric Measurements	ATR	98	1825	400	57	300-500	285-90	Earth	3600		N/A	4000	0.36	9x4.5 x4.5	25K		250	1	0.25	✓	✓	✓	
0031	High Throughput Mission	HEN	99	1460	400	28.5			Inertial	180		N/A	10000	0.36		2000 (20)		125	1	1	✓	✓		
0201	Satellite Doppler Meteorological Radar Tech Devel	WCL	99	365	400	57	300-500	28.5-90	Earth	3600		N/A	2600	0.36	50x5.2 x5.2	6K		120K	2	0.4	✓	✓	✓	
0244	Solar Terrestrial Observatory – Advanced	STR	00	2190	400	57	300-500	57-90	Solar, Earth	1800		N/A	16500	1.44	13x300 x10	10K (12)	21K (12)	42K	2	1.33	✓	✓	✓	

*At telescope interface with IPS.

266.592-49.6

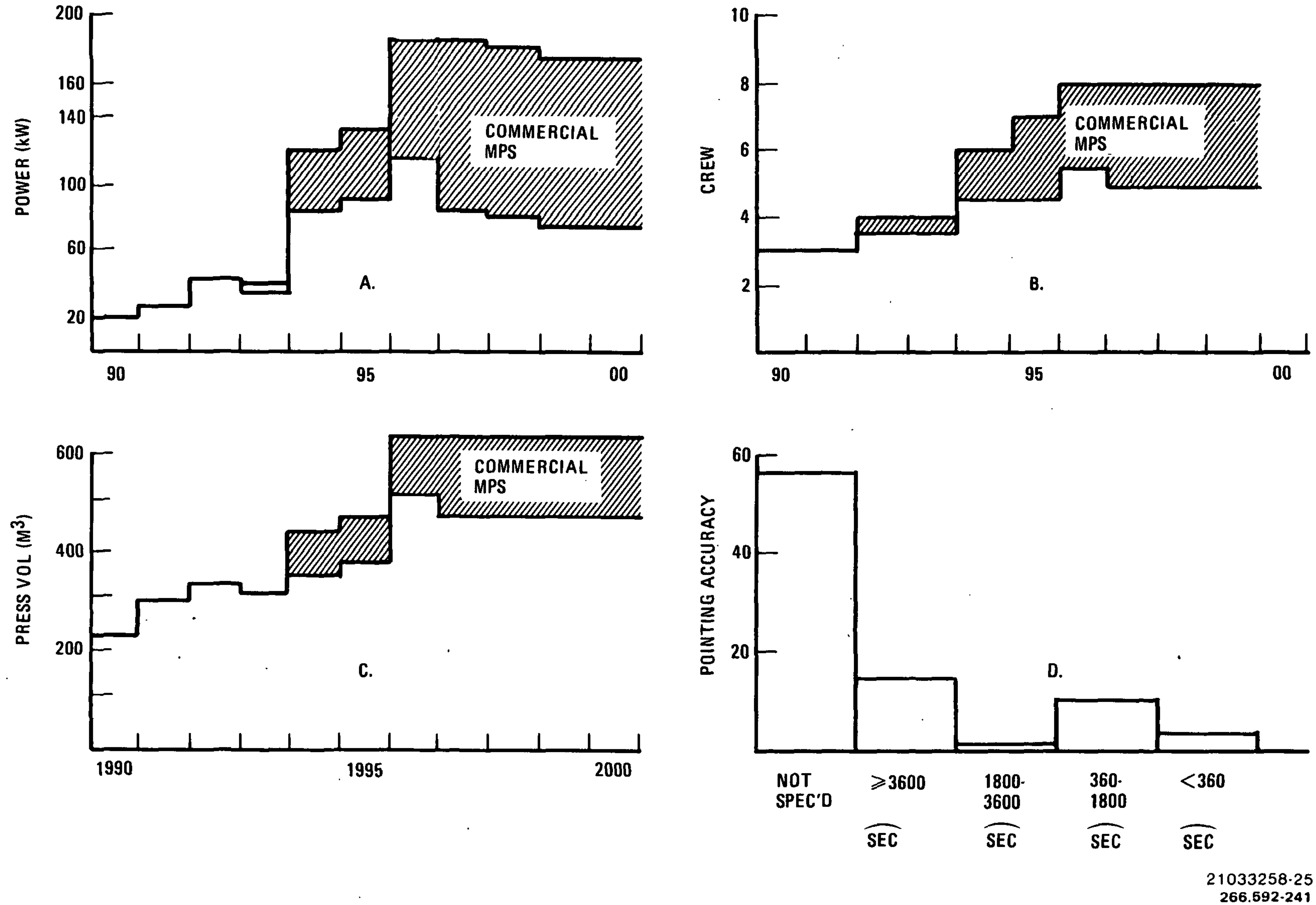

Figure 4-31. Man-Operated Missions - 28.5-Degree Station Resource Requirements

The pressurized, i.e., man-inhabitable, volume required to conduct the man-operated missions is plotted versus time in Figure 4-34C. The initial volume required is about 230 m^3; this grows at a rate of about 100 m^3 per year to a requirement of about 600 m^3 in 1996. This level is sustained through the end of the decade.

The distribution of payload pointing accuracy requirements is provided in Figure 4-31D. About 84% of the payloads' pointing accuracy requirements can be satisfied by an accuracy of 1 degree. Fourteen payloads require higher accuracy, and must therefore be equipped with additional pointing means. Three of the payload elements that are in the less than 3600 sec category are defined to incorporate fine pointing mounts already. Mass, size, and power for the pointing systems are included in the payload element descriptions.

A top level assessment of the requirements for external attachments was made (see Table 4-18). Of the 89 man-operated payloads in the baseline mission model, 66, or 74%, employ some external elements. These all require some type of mounting structure and 94% require support resources as well.

The mounting structures are in three categories: dedicated pallet, shared pallet, and unique structures. The pallets are envisioned to be similar to Spacelab pallets, and are equipped with trunnions and keel fittings that mate with the Orbiter attachment fittings for delivery to LEO and return to earth. The same fittings could be used for Station installation. They are also equipped with RMS grappling fittings and interface connections for resources such as power. Standard berthing adapters may be provided to permit easy installation at berthing ports on the Space Station or Space Platform. Pallets are especially suited for large and/or complex payloads that can be most efficiently assembled and checked out on the ground, and then delivered to LEO as an integrated payload.

Payload elements requiring mounting provisions classified as unique structure cover a wide range of sizes and weights. In some cases, the hardware is distributed over a large area. The mission times vary over a wide range. Some are installed for periods of months or years; others, e.g., EVA technology development missions, have much shorter lifetimes, and individual test runs may require only several hours. As the payload hardware and its accommodation requirements become better defined, some of these missions may be found to be more compatible with pallet mounting.

Resource requirements include electrical power, data transfer, and active thermal control (fluid loop). The entries in the right hand column are coded to indicate which of these resources are required. Sixty-two, or 94%, of the external elements require resources support.

Time-phased requirements for pallet mounting of payload elements on the 28 1/2 degree station were derived for the baseline mission model (Figure 4-32). The requirements for dedicated pallets build up to six during the mid years and increase to nine in the latter part of the decade. Multiple shared-pallet payloads require the equivalent of one pallet maximum early in the decade. This assumes compatibility in viewing orientation, stability, and contamination considerations.

Table 4-19. External Attachments (Sheet 1 of 3)

GDCD NO.	PAYLOAD ELEMENT NAME	DISCIPLINE	90	91	92	93	94	95	96	97	98	99	00	EXTERNAL ELEMENTS USED: NO	EXTERNAL ELEMENTS USED: YES	MOUNTING PROVISIONS: DEDICATED PALLET	MOUNTING PROVISIONS: SHARED PALLET	MOUNTING PROVISIONS: UNIQUE STRUCTURE	MOUNTING PROVISIONS: RESOURCES REQ'D
0005	Shuttle IR Tele. Facility	AST													X	1			E, D, T
0262	Measurement of Air Pollution from Satellites (MAPS)	ATR													X		1/4		E, D
0300	Human Research Lab	BLS												X					
0301	Animal & Plant Research Lab	BLS												X					
0322	EVA Perf. & Productivity	OPM													X			X	
0400	Research & Development Facility	MPR												X					
1207	Electrophoresis Separation	MPC												X					
1209	Metal Clusters & Crystal Growth	MPC												X					
1210	Enzyme Production & Separation	MPC												X					
1211	Silicon Crystals	MPC												X					
1213	Chemical Reactions	MPC												X					
1214	Space Isothermal Furnace System (SIFS)	MPC												X					
1300	Radiation Hardened Computer	INS													X			X	E, D
1303	Plants in Controlled Env Life Support Sys (CELSS)	INS												X					
2001	Strain & Acoustic Sensors	MTS													X			X	E, D
2402	Advanced EVA Technology	CHF													X			X	E, D
2503	Space Component Lifetime Tech	SSS													X			X	E, D
0174	Earth Obs Instru Devel (Microwave Tech)	ERS													X		1/2		E, D
0340	$H_2O/O_2/CO_2/N_2$ Regenerative Systems	LFS												X					
1108	Laser Communications	COM													X		1/2		E, D
1111	Millimeter Wave Propagation	COM													X	1			E, D
2002	Spacecraft Materials Tech	MTS													X			X	
2003	Materials and Coatings	MTS													X			X	
2101	Low-Cost Modular Solar Panels	ECN													X			X	D
2401	Manipulator Controls Tech	CHF													X		1/2		E, D
2506	OTV Propellant Transfer Storage	SSS													X			X	E, D
2507	OTV Propellant Liquefaction	SSS													X	1			E, D
2508	OTV Docking & Berthing	SSS													X			X	E, D
0000	Starlab	AST													X	1			E, D, T
0173	Shuttle Active Microwave Exper (SAMEX-C)	ERS													X	1			E, D, T
0176	EO Sensor/Technique/Anal/ Automated System Devel	ERS													X			X	E, D, T
0341	CELSS Experimental System	LFS												X					
1106	Large Deployable Antenna	COM													X			X	E, D
1200	Pilot – Biological Processing Facility	MPC												X					

E = ELECTRICAL; D = DATA TRANSFER; T = THERMAL

266.592-242.1

Table 4-19. External Attachments (Sheet 2 of 3)

GDCD NO.	PAYLOAD ELEMENT NAME	DISCIPLINE	90	91	92	93	94	95	96	97	98	99	00	EXTERNAL ELEMENTS USED: NO	EXTERNAL ELEMENTS USED: YES	MOUNTING PROVISIONS: DEDICATED PALLET	MOUNTING PROVISIONS: SHARED PALLET	MOUNTING PROVISIONS: UNIQUE STRUCTURE	MOUNTING PROVISIONS: RESOURCES REQ'D
1208	Crystal Growth	MPC												X					
1305	Communication Satellite	INS													X			X	E, D
2103	Ion Effects on LEO Power Systems	ECN													X			X	E, D
2504	OTV Payload Handling	SSS													X			X	E, D
2505	Payload Servicing & Repair	SSS													X			X	E, D
2509	OTV Maintenance	SSS													X			X	E, D
1109	Open Envelope Tube	COM													X			X	E, D
2601	Light Weight Cryo Heat Pipes	FTP													X			X	E, D
0034	High Resolution X and Gamma Ray Spectrometer	HEN													X		1/4		E, D
0202	Meteorology Instru Group Devel Payload	WCL													X			X	E, D, T
2004	Thermal Shape Control	MTS													X			X	E, D
0032	Large Area Modular Array	HEN													X	1			E, D
0175	Earth Obs Instru Devel (Extra Visible & RF)	ERS													X	1			E, D
0265	Upper Atmosphere Research Payload-Development	ATR													X			X	E, D, T
0401	R&D/Proof of Concept Facility	MPF												X					
1107	RFI Measurements	COM													X			X	E, D
1201	Pilot – Containerless Processing Facility	MPC												X					
1202	Pilot-Furnace Processing	MPC												X					
2005	Dynamics of Flimsy Struct	MTS													X			X	E, D
2006	Active Optics Technology	MTS													X			X	E, D
2201	Attitude Control – System Identification Exper	CSE													X			X	E, D
2202	Attitude Control – Adaptive Control Experiment	CSE													X			X	E, D
2301	Controlled Acceleration Propulsion Tech	PPN													X			X	E, D
2502	Advanced Control Device	SSS													X			X	E, D
1110	Spaceborne Interferometer	COM													X			X	E, D
1203	Commercial-Biological Processing Facility	MPC												X					
1301	Full-Body Teleoperator	INS													X			X	E, D
2104	Large Solar Concentrator	ECN													X			X	E, D
2203	Attitude Control – Distributed Control Exper	CSE													X			X	E, D
2510	Tether Dynamics Tech	SSS													X			X	E, D

E = ELECTRICAL; D = DATA; T = THERMAL

266.592-242.2

Table 4-19. External Attachments (Sheet 3 of 3)

GDCD NO.	PAYLOAD ELEMENT NAME	DISCI-PLINE	90	91	92	93	94	95	96	97	98	99	00	EXTERNAL ELEMENTS USED NO	EXTERNAL ELEMENTS USED YES	MOUNTING PROVISIONS DEDICATED PALLET	MOUNTING PROVISIONS SHARED PALLET	MOUNTING PROVISIONS UNIQUE STRUCTURE	MOUNTING PROVISIONS RESOURCES REQ'D
0036	Spectra of Cosmic Ray Nuclei	HEN													X			X	E, D, T
0037	Transition Radiation and Ionization Calorimeter	HEN													X			X	E, D
0242	Incoherent Scatter Radar	STR													X			X	E, D, T
0342	Dedicated CELSS Module	LFS												X					
0343	CELSS Pallet	LFS													X			X	E, D, T
0179	Imaging Radar for Earth Resources Inventory & Monitoring	ERS													X	1			E, D, T
1304	Controlled Environment Life Support Systems (CELSS)	INS												X					
2105	Solar Pumped Lasers	ECN													X			X	E, D
2106	Laser/Electric Energy Conversion	ECN													X			X	E, D
2204	Advanced Adaptive Control Technology Demo	CSE													X			X	E, D
2302	Laser Propulsion Test	PPN													X			X	E, D
2501	Liquid Droplet Radiator	SSS													X			X	E, D, T
0243	Topside Digital Ionosonde HF Radar	STR													X			X	E, D, T
1204	Commercial-Containerless Processing Facility	MPC												X					
1205	Commercial-Furnace Processing Facility	MPC												X					
1212	Heat Resistant Alloys	MPC												X					
2107	Solar Sustained Plasmas	ECN													X			X	E, D
2108	Space Nuclear Reactor	ECN													X			X	E, D
0151	Detection & Monitoring of Episodic Events	CRM													X			X	E, D, T
0161	Earth Science Research-Geophysical Investigation	GPE													X	1			E, D
0245	Space Plasma Physics Payload-Advanced	STR													X	1			E, D, T
0263	CO_2 LIDAR for Atmospheric Measurements	ATR													X	3			E, D, T
0031	High Throughput Mission	HEN													X	1			E, D
0201	Satellite Doppler Meteorological Radar Tech Devel	WCL													X	1			E, D, T
0244	Solar Terrestrial Observatory — Advanced	STR													X	2,1,1			E, D, T

E = ELECTRICAL; D = DATA; T = THERMAL

266.592-242.3

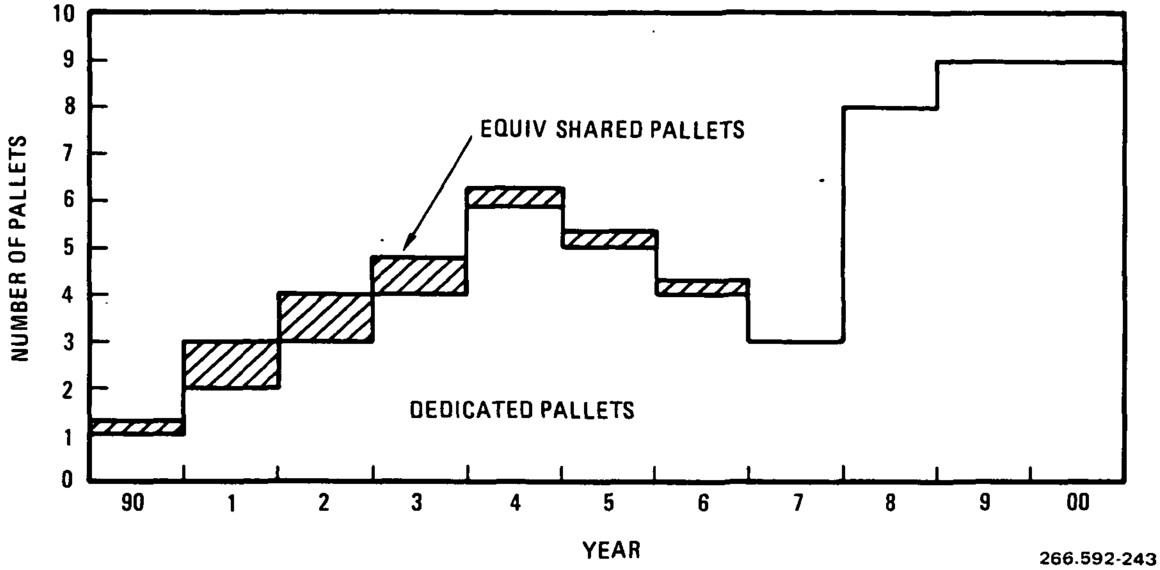

Figure 4-32. Time-Phased Pallet Mounting Requirements, 28.5 Degree Station

4.4.3 BASELINE FREE-FLYING MISSIONS. The baseline set of free-flying missions was selected from the representative set of user mission requirements by the iterative evaluation process described in Section 4.4.1. The resulting baseline missions differ from the user missions in three ways:

a. Delay in schedule from desired date to a later acceptable date, while observing predecessor-successor relationships between related missions.

b. Change attached missions to free-flying missions where permitted by mission objectives and requirements.

c. Combination of a and b.

Table 4-20 presents the results and shows the current baseline schedule deltas from the initial schedule and the added free-flying missions with their associated schedules and schedule delays, where applicable. For purposes of completeness, the missions that were unchanged are also shown. The baseline mission set contains 57 free-flying missions for the years 1990-2000 versus the set of 50 missions described in Section 4.3. The changes can be summarized as follows for each mission group:

LEO/HEO	-	Added 8 missions and rescheduled 15
GEO	-	Rescheduled 4 missions (includes 1 mission rescheduled to year 2002, i.e., 4001, Manned GEO Support Module)
Escape	-	No change

Table 4-20. Baseline Free-Flying Missions (Sheet 1 of 2)

	BASELINE SCHEDULE START DATE	SCHEDULE SLIP* (YRS)	REASSIGNED FROM ATTACHED MISSION
SCIENCE AND APPLICATIONS MISSIONS			
ASTROPHYSICS			
ASTRONOMY			
0001 LARGE DEPLOYABLE REFLECTOR	1998	3	
0002 FAR UV SPECTROSCOPY EXPLORER	1989	–	
0003 VERY LONG BASELINE INTERFEROMETRY	1995	–	
0004 SPACE TELESCOPE	1992	–	
HIGH ENERGY			
0030 GAMMA RAY OBSERVATORY	1988	–	
0033 ADVANCED X-RAY ASTROPHYSICS FACILITY	1991	–	
0035 HIGH ENERGY ISOTOPE EXPERIMENT	1997	2	X
0038 X-RAY TIMING EXPLORER	1990	–	
SOLAR PHYSICS			
0060 SOLAR INTERNAL DYNAMICS MISSION	1991	–	
0061 SOLAR CORONA DIAGNOSTICS MISSION	1993	1	
0062 ADVANCED SOLAR OBSERVATORY	1995	2	
EARTH AND PLANETARY EXPLORATION			
PLANETARY OBSERVATIONS			
0103 MARS GEOCHEMISTRY/CLIMATOLOGY ORBITER	1992	–	
0104 MARS AERONOMY ORBITER	1992	–	
0105 VENUS ATMOSPHERE PROBE	1993	–	
0106 LUNAR GEOCHEMISTRY ORBITER	1993	–	
0107 TITAN PROBE	1995	–	
0108 SATURN ORBITER	1997	–	
0109 MARS LANDER	1997	–	
0110 SATURN PROBE	1997	–	
SOLAR SYSTEM MISSIONS			
0121 COMET T2 RENDEZVOUS	1992	–	
0122 MAIN-BELT ASTEROID RENDEZVOUS	1992	–	
0123 COMET HMP SAMPLE RETURN	1994	–	
0124 NEAR-EARTH ASTEROID RENDEZVOUS	1997	–	
CRUSTAL MOTION			
0152 GEOSCIENCE – CRUSTAL DYNAMICS STUDIES	1992	2	X
EARTH RESOURCES			
0171 RENEWABLE RESOURCES – EARTH SCIENCE RESEARCH	1996	1	X
0172 OPERATIONAL LAND SYSTEMS	1990	–	
0177 GEOSCIENCE – GEOLOGY REMOTE SENSING	1990	–	X
0180 FREEFLYING IMAGING EXPERIMENT (FIREX)	1992	–	
0181 Z – CONTINUOUS COVERAGE	1996	2	
0182 Z – HYDROLOGIC CYCLE PRIORITY	1998	2	
0183 Z – SPECIAL COVERAGE	2000	2	

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*FROM INITIAL SCHEDULE

Table 4-20. Baseline Free-Flying Missions (Sheet 2 of 2)

	BASELINE SCHEDULE START DATE	SCHEDULE SLIP* (YRS)	REASSIGNED FROM ATTACHED MISSION
SCIENCE AND APPLICATIONS MISSIONS (Continued)			
ENVIRONMENTAL OBSERVATIONS			
WEATHER/CLIMATE			
0203 LIGHTNING MAPPER	1998	2	
0204 GEOSYNCHRONOUS MICROWAVE SOUNDER	1999	3	
0205 METEROLOGY INSTRUMENT GROUP OPERATIONS PAYLOAD	1995	1	
0206 GEOSTATIONARY OPNL. ENV. SATELLITE (GOES) FOLLOW-ON	1994	–	
0207 TIROS FOLLOW-ON	1992	–	
OCEAN			
0221 OCEAN INSTRUMENT PAYLOAD (OIP)	1994	1	
0222 OCEAN TOPOGRAPHY EXPERIMENT (TOPEX)	1988	–	
SOLAR TERRESTRIAL			
0241 EARTH RADIATION BUDGET EXPERIMENT (ERBE)	1991	–	
0246 SOLAR TERRESTRIAL OBSERVATORY	1994	1	X
0247 SPACE PLASMA PHYSICS PAYLOAD ATMOSPHERIC RESEARCH	1992	1	X
0261 HIGH RESOLUTION DOPPLER IMAGER	1990	–	X
0264 LIDAR FACILITY	1992	1	X
ATMOSPHERIC RESEARCH			
0266 WINDSAT	1995	3	
0267 UPPER ATMOSPHERE RESEARCH PAYLOAD-OPERATIONAL	1994	–	
COMMERCIAL MISSIONS			
EARTH AND OCEAN OBSERVATIONS			
1000 GEOLOGICAL RECONNAISSANCE	1990	–	
1001 REMOTE ATMOSPHERIC SENSING	1990	–	
1002 WORLDWIDE COTTON ACREAGE AND PRODUCTION	1990	–	
1003 PETROLEUM AND MINERAL LOCATION	1990	–	
COMMUNICATIONS			
1100 SMALL COMMUNICATION SATELLITE	1990-2000	–	
1101 MEDIUM COMMUNICATION SATELLITE	1990-2000	–	
1102 LARGE COMMUNICATION SATELLITE	1990-2000	–	
1103 EXPERIMENTAL GEO PLATFORM	1990/1992	–	
1104 OPERATIONAL GEO PLATFORM	1994-2000	–	
MATERIALS PROCESSING			
1206 ELECTROPHORESIS FREE-FLYER	1986	–	
INDUSTRIAL SERVICES			
1302 GAMMA RAY ASTRONOMY	1990	–	
OTHER MISSIONS			
MANNED GEOSYNCHRONOUS MISSIONS			
4000 MANNED GEOSYNCHRONOUS SORTIE	1999	4	

266.592-104-2

*FROM INITIAL SCHEDULE

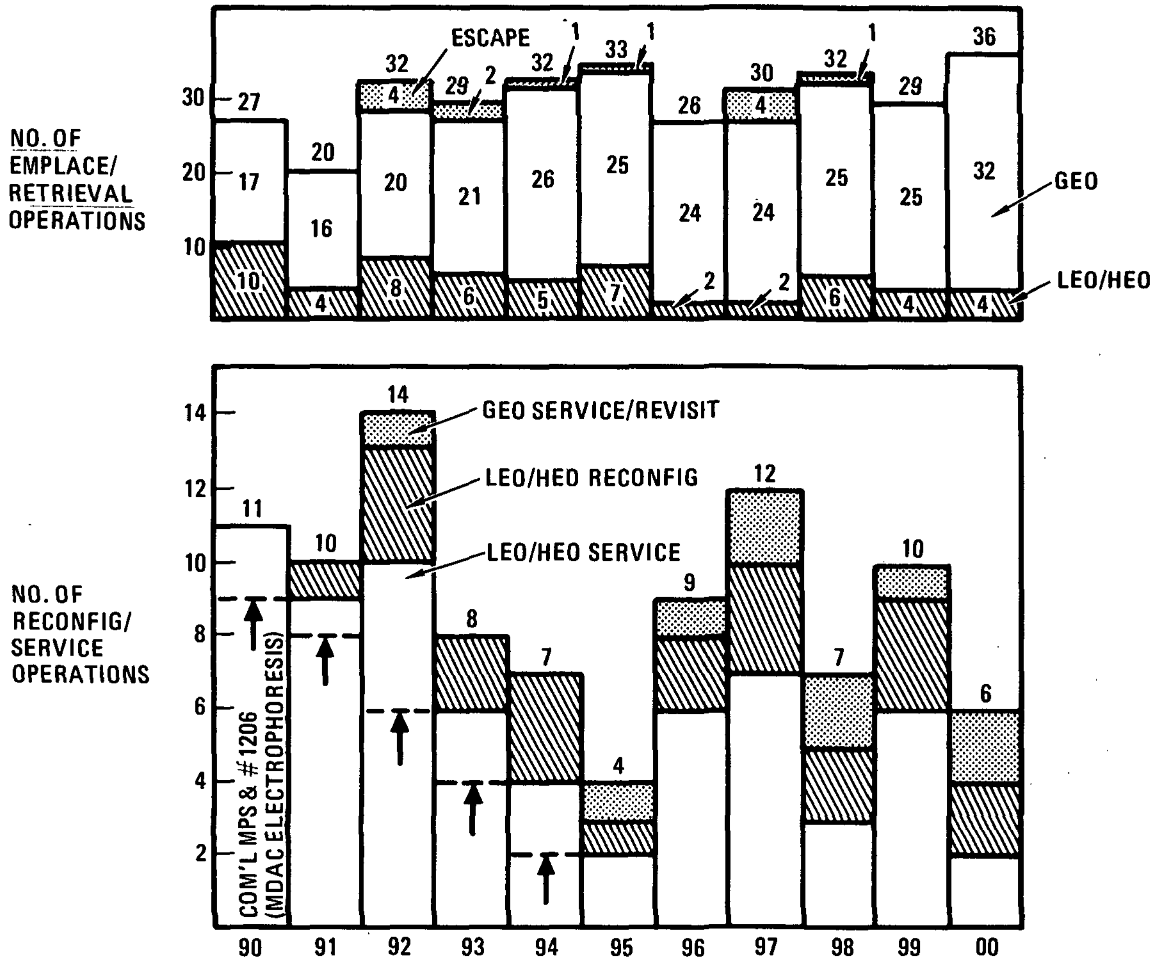
The payload element data sheets, documented in Book 1, Appendix I, reflect the baseline mission launch date. The remaining data sheet requirements are for the preferred accommodation mode and remain unchanged. In the data sheets, the parameters that would typically be impacted by a change from attached to free-flying mode are: 1) crew time, which is not required in free flyers on a routine basis and therefore should be deleted; 2) service/reconfiguration interval, which should be extended for a free flyer by payload redesign (e.g., larger storage tanks) to reflect that the payload has relatively less accessibility when accommodated as a free flyer; and 3) data rates, which should increase for a free flyer due to the absence of man-in-the-loop to perform some of the data processing functions.

The baseline Station support operations traffic flow for all three mission groups (LEO/HEO, GEO, Escape) is summarized in Figure 4-33, which excludes DOD requirements. Comparison of the initial user requirements with the baseline shows that there are changes in some of the peak traffic levels (notably in 1992 with 14 baseline reconfiguration/service operations versus 10), and in total traffic, which is increased due to the added missions. However, trends and conclusions remain the same -- there is sufficient OTV/TMS traffic to warrant early implementation.

4.4.3.1 LEO/HEO Baseline Missions. The LEO/HEO free-flying mission group was significantly impacted in deriving baseline requirements because eight 57-degree and polar missions were added, bringing the total to 34. Five of these formerly attached missions were also rescheduled 1-2 years. In addition, 10 of the initial 26 missions were slipped 1-3 years. The results are depicted in Table 4-21. The primary benefits of these rearrangements were to tend to level funding peaks in the Astrophysics, Earth Exploration, and Earth Observations disciplines, and to permit mission accomplishment within acceptable orbit/operations limits, but without requiring a mid-inclination station. Accommodation of these payload elements could be as individual satellites using a Leasecraft-type bus, or as platform candidates. The altitude versus inclination plot of the baseline LEO/HEO free flyers (Figure 4-34) shows the opportunities for platforms. No change occurred to missions located at 28.5 degrees; however, significant change is seen in the potentially compatible grouping at 57-degree inclination, which now contains 10 payloads versus four. Schedule wise, maximum concurrent occupancy of a 57-degree platform increases from four to five. Astrophysics and Earth Observations payloads (platform candidates) appear to be mutually compatible. However, detailed assessment of payload operations and constraints would be necessary to confirm compatibility issues.

At 90-degree inclination, the addition of two Earth Resources missions further enhances the potential benefits of a platform and increases the maximum concurrent occupancy from three to four payload elements.

A conclusion resulting from the rearrangement in the LEO/HEO missions to form the baseline set is that 57- and 90-degree inclination platforms look even more attractive as an accommodation for compatible free-flyer missions.



TOTAL MISSION TRAFFIC

	EMPLACE	RETRIEVE
• LEO/HEO	32	26
LOW INCL.	(7)	(9)
MID INCL.	(11)	(10)
POLAR INCL.	(14)	(7)
• GEO	254	1
• ESCAPE	12	1
	298	28
TOTAL	326	

TOTAL MISSION TRAFFIC

	RECONFIG.	SERVICE/ REVISIT
• LEO/HEO	22	66
LOW INCL.	(7)	(39)
MID INCL	(1)	(13)
POLAR INCL.	(14)	(14)
• GEO	0	10
• ESCAPE	0	0
	22	76
TOTAL	98	

*EXCLUDES DOD

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Figure 4-33. Baseline Space Station Support Operations Traffic

Table 4-21. Baseline LEO/HEO Free-Flyer Payload Mode (Sheet 1 of 2)

GDCD NO.	PAYLOAD ELEMENT NAME	ORBIT ALTITUDE (KM)	INCLINATION (DEG)	UNIT WT (KG)	LENGTH (M)	P/L ELEMENT DEFINITION: INTEG. INST. PKG. ①	P/L ELEMENT DEFINITION: SPACECRAFT	SPACECRAFT INCL. ORBIT XFER PROPUL.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	RESCHEDULED? YES (NO. YRS)	RESCHEDULED? NO
	ASTROPHYSICS																				
	● Astronomy																				
0001	Large Deployable Reflector	700	28.5	55,000			✓										E		S/C	✓(3)	
0003	Very Long Base-Line Interferometer Demo	400	57	1,354	5	✓								E	S	S	R				✓
0004	Space Telescope	600	28.5	11,600	13.1		✓				E		S/C		S/C	R					✓
	● High Energy (Cosmic, γ, X-Ray)																				
0030	Gamma Ray Observatory (1988 Launch)	400	28.5	11,000			✓	✓	S	S	S	R									✓
0033	Adv X-Ray Astrophysics Facility	500	28.5	10,267	12.8		✓			E		S/C		S/C		S/C		S/C			✓
0038	X-Ray Timing Explorer	400	28.5	1,000	2		✓	✓	E		R										✓
	● Solar Physics																				
0060	Solar Internal Dynamic Mission	400	99	4,540			✓	✓		E	R										✓
0061	Solar Corona Diagnostic Mission	400	28.5	1,800			✓					E	R							✓(1)	
0062	Advanced Solar Observatory	400	57	12,500	8.2	✓								E		S		S		✓(2)	
	EARTH EXPLORATION																				
	● Earth Resources																				
0172	Operational Land Systems	500	90	2,000	4		✓	✓	E		S/C		S/C		S/C		S/C		R		✓
0180	Freeflying Imaging Radar Exp (FIREX)	400	90	2,000	4	✓					E			S				R		✓(1)	
0181	Z-Continuous Coverage	1000	100	8,578	16		✓	✓							E	S/C	R			✓(2)	
0182	Z-Hydrologic Cycle Priority	1000	100	8,708	16		✓	✓									E	S/C	R	✓(2)	
0183	Z-Special Coverage	1000	100	18,821	17		✓	✓											E	✓(2)	
	ENVIRONMENTAL OBSERVATIONS																				
	● Weather/Climate, Ocean, Solar/Terrestrial, Atmos Research																				
0205	Meteorology Inst Grp Ops P/L	400	57	2,000	4.4	✓								E		S		R		✓(1)	
0207	Tiros Follow-on ③	800	98	2,000	9		✓				E										✓
0221	Ocean Instrument Payload	500	98	1,600	10	✓							E		S			E R		✓(1)	
0222	Ocean Topography Exp. (TOPEX)	1384	63.4	1,600	6		✓		S			S			S		R				✓
0241	Earth Radiation Budget Exp. (ERBE) (1988 Lch)	600 800	46 98	55 55	1 1	✓ (Piggy Back P/L)				E	R										✓
0266	WINDSAT	800	98	2,260	4.5		✓							E		S		S		✓(3)	
0267	Upper Atmosphere Research P/L	400	57	2,500	4.5	✓							E		S		R				✓

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Table 4-21. Baseline LEO/HEO Free-Flyer Payload Mode (Sheet 2 of 2)

GDCD NO.	PAYLOAD ELEMENT NAME	ORBIT ALTITUDE (KM)	INCLINATION (DEG)	UNIT WT (KG)	LENGTH (M)	P/L ELEMENT DEFINITION: INTEG. INST. PKG. (1)	P/L ELEMENT DEFINITION: SPACECRAFT	SPACECRAFT INCL. ORBIT XFER PROPUL.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	RESCHEDULED? YES (NO. YRS)	RESCHEDULED? NO
	COMMERCIAL																				
	• Mat Processing																				
1206	Electrophoresis F/F – Biologicals (Initial Lch 1986)	>400	Any	9,987	5.5		✓	✓	E 9S	8S R	6S R	4S R	2S R	R							✓
1000	Geological Reconnaissance	500	90						E	[Accommodated by GDCD 0172; 0174; 0175 for development]											✓
1002	Worldwide Cotton Acreage & Prod	500	45						E	[Accommodated by GDCD 0172]											✓
1003	Petroleum and Mineral Location	920	99.2						E	[Accommodated by GDCD 0172]											✓
1302	Gamma Ray Astronomy	400	28.5						E	[Accommodated by GDCD 0030]											✓
	<u>P/L REASSIGNED FROM ATTACHED MODE</u>																				
	ASTROPHYSICS																				
0035	High Energy Isotope Experiment	400	57	3,000		✓(2)										E	S	S	R	✓(2)	
	EARTH EXPLORATION																				
0152	Geoscience – Crustal Dynamics Studies	500	50	185		✓			E		S	R									✓
1071	Renewable Resources – Earth Sci	400	90	2,000		✓(2)									E	S/C	S/C	S/C	S/C	✓(1)	
0177	Geoscience – Geology Rem. Sensing	500	90	2,000		✓			E	C	C	C	C	R							✓
	ENVIRONMENTAL OBSERVATIONS																				
0246	Solar Terrestrial Observatory	400	57	16,000		✓(2)							E	R						✓(1)	
0247	Space Plasma Physics P/L	400	57	3,183		✓(2)					E	R								✓(1)	
0261	High Res. Doppler Imager	400	57	10,800		✓			E	R											✓
0264	LIDAR Facility	400	57	1,900		✓					E S/C	R								✓(1)	

NOTES: TMS available in 1990; OTV available in 1994.
E = Emplace, S = Service, C = Configuration Change, R = Retrieve

(1) These P/L elements assume accommodation on a platform or leasecraft-type spacecraft which has orbit transfer propulsion.

(2) Originally defined as attach payload element with servicing at 180 day intervals. Redefinition as free flyer would require redesign for 360 day service interval.

(3) Two satellites required.

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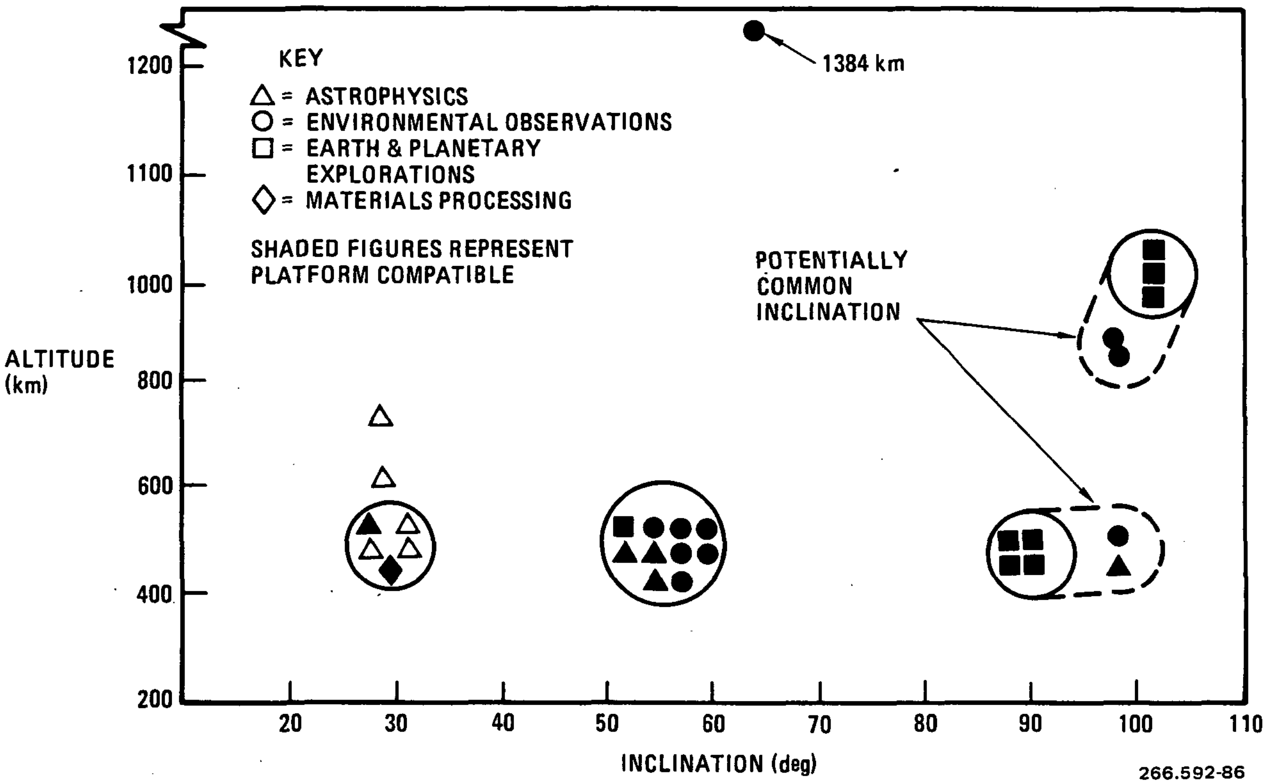

Figure 4-34. Baseline LEO/HEO Free Flyers

4.4.3.2 GEO Baseline Missions. Geosynchronous baseline missions can be subdivided into three groups by discipline: Environmental Observations, Commercial, and Operations missions. None of the commercial user missions was rescheduled in the process of deriving the baseline set. As shown in Table 4-22, the Lightning Mapper mission (payload element 0203) and the Geosynchronous Microwave Sounder (0204), both Environmental Observations missions, were rescheduled 2 and 3 years, respectively, in accordance with the criteria discussed in Section 4.4.1. Manned geosynchronous missions were also slipped 2-4 years with a result that, to retain the desired development sequence between related missions, the GEO Support Module (4001) moved to year 2002 and no longer appears on the schedule. However, due to the predominance of the commercial segment within the mission model, there is still evidence of sufficient traffic to support early implementation of the OTV. Likewise, the requirement for the OTV to support missions that involve delivery and return of manned geosynchronous sortie capsules still exists within the decade.

4.4.3.3 Baseline Escape Missions. The baseline escape missions are identical to the user defined missions since escape missions are energy-sensitive to launch date. The baseline escape mission schedule is shown in Table 3-31.

Table 4-22. Baseline GEO Payload Model

GDCD NO.	PAYLOAD ELEMENT NAME	ORBIT ALTITUDE (KM)	INCLINATION (DEG)	UNIT WT (KG)	LENGTH (M)	P/L ELEMENT DEFINITION: INTEG. INST. PKG. (1)	P/L ELEMENT DEFINITION: SPACECRAFT	SPACECRAFT INCL. ORBIT XFER PROPUL.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	RESCHEDULED? YES (NO. YRS)	RESCHEDULED? NO
	ASTROPHYSICS																				
	• Astronomy																				
0002	Far UV Spectroscopy Explorer (Lch in 1989)	Geo	28.5	1,360	(Incl AKM)																
	ENVIRONMENTAL OBSERVATIONS																				
	• Weather/Climate																				
0203	Lightning Mapper	Geo	0	900(1)	6												E			✓(2)	
0204	Geosync Microwave Sounder	Geo	0	5,850	10														E	✓(3)	
0206	Goes Follow-On (1) 5-each at 900 Kg/flight (2) 3-each at 500 Kg/flight	Geo	0	500(2)	3.6								E						R		✓
	COMMERCIAL MISSIONS																				
	• Communications																				
1001	Remote Atmospheric Sensing	Geo	0	[300-1000]					E	[Accommodated by GDCD 0206 and for development GDCD 0262]											✓
1100	Small Communications Satellites	Geo	0	<816	2				6	6	8	10	10	10	5	7	6	6	7		✓
1101	Medium Communications Satellite	Geo	0	<2,041	4				4	4	6	4	3	4	3	3	3	3	3		✓
1102	Large Communication Satellite	Geo	0	>2,313	5				5	6	6	7	10	10	12	13	14	14	17		✓
	• Platforms																				
1103	Experimental Geo Platform	Geo	0	5,450	<10				E		S										✓
1104	Operational Geo Platform (4)	Geo	0	5,450	<10								2E	E S	2ES	E2S	2ES	E S	2E 2S		✓
	OPERATIONAL																				
	• Other Missions																				
4000	Manned Geo Sortie Capsule	Geo	0	4,535	4.4													E	E	✓(4)	
4001	Manned Geo Support Module	Geo	0	8,160	6.8															✓(2)	
	DOD SCENARIO – Derived from Nominal Mission Model, Rev. 6, MSFC PS01, 9/30/82 and DoD MSN Model Rev. 12, Summary Level (Equivalent Qty Flights Both Geo & Heo Missions)		ETR						4	4	4	5	6	7	5	5	8	9	9		✓
			WTR						5	4	3	4	4	2	3	4	3	4	4		✓

NOTES: TMS available in 1990; OTV available in 1994.
E = Emplace, S = Service, C = Configuration Change, R = Retrieve

(1) These P/L elements assume accommodation on a platform or leasecraft-type spacecraft which has orbit transfer propulsion.

(2) Originally defined as attach payload element with servicing at 180 day intervals. Redefinition as free flyer would require redesign for 360 day service interval.

(3) Two satellites required.

(4) 11 Emplacement flights of 5450 Kg each (6 for one platform and 5 for second platform) plus 8 Revisit Flights.

4.4.3.4 <u>Time-Phased Mission Set</u>. The baseline time-phased mission set shown in Figure 4-35 summarizes the free-flyer traffic for 58 missions (57 plus 1 in year 2002) by low, mid, and high LEO/HEO missions and for geosynchronous placement. The impact of the planning horizon on the spread of data points for the LEO/HEO missions is such that the addition of new free-flying payload elements and the mission rescheduling did not affect the 7.5% growth projections discussed in Section 3.5. Since the geosynchronous communications satellite traffic was not adjusted, the long term growth rate projection of 7.5% is still applicable for the baseline set.

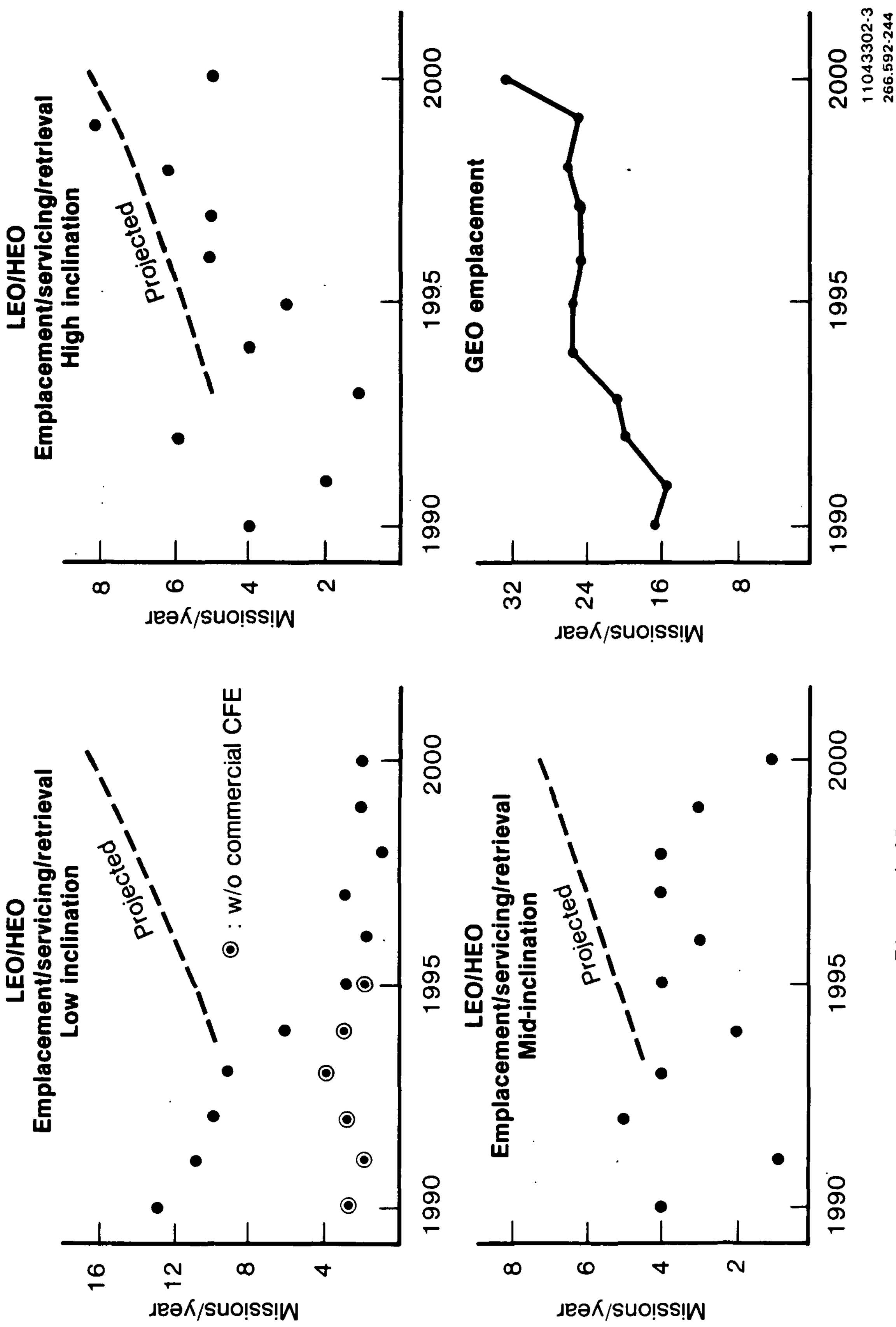

Figure 4-35. Baseline Free-Flyer Traffic Model

SECTION 5

BENEFITS

A Space Station would enable the scientific and commercial communities to expand and improve upon their exploitation of space. As a part of the Space Transportation System, it would extend the ability to test and verify operational capabilities of space system elements beyond that available with the Shuttle Orbiter and automated satellites. The advancements in technology to be gained during such a program will also reflect back into non-space areas in the same manner experienced in the Apollo and Space Shuttle programs. The benefits can be classified as economic, performance, and social.

5.1 ECONOMIC BENEFITS

Space Station economic benefits derive from three primary sources: research and production, satellite servicing, and OTV operations.

Research and production conducted on the manned Station are substantially lower in cost than equivalent Spacelab missions. Launch cost savings are achieved by having a permanent on-orbit laboratory versus multiple Spacelab missions. In addition, manned laboratory equipment with capability for adjustment, repair, and modification as needed will be lower in cost than fully automated equipment. One measure of system accomplishment is the product of kilograms of mission equipment in operation and the hours of mission operation. When divided into operational cost, this becomes a figure of merit in dollars per kilogram-hour ($/kg-hr). On this basis, the Space Station provides an order of magnitude reduction from Spacelab for space science and MPS. Because the Space Station will provide significantly greater numbers of manned mission hours per year than any alternative, it will reduce the time for commercialization of experimental processes. Earlier returns are expected from technology development missions with reduced risk for incorporation of results into operational space systems. As described in Book 3, the total annual benefit from research, development, and production is estimated at nearly $300M per year, excluding benefits in commercialization of processes.

Satellite servicing is the second area from which economic benefits will be derived. Reduced payload launch costs are possible because less spacecraft mass and volume will be allocated to storage of consumables and perhaps by reduced system redundancy. Spacecraft life extension will be made possible by maintenance and repair capability in orbit. The Space Station makes satellite servicing cost effective for many missions that could not be done economically from the Shuttle. A factor of four reduction in the cost of servicing satellites from Shuttle has been estimated. A reduction in spacecraft fabrication, launch, and servicing costs can be achieved by grouping mission sensors on a platform. As described in Book 3, the expected benefit per servicing mission is $12M. Based upon current trends in satellite values, the benefit could be much higher.

The greatest quantifiable economic benefit from Space Station is for OTV operations. Reduced launch costs are achieved with a reusable OTV based in LEO. The launch costs to LEO from earth will be reduced due to improved Shuttle manifesting to the Station as a waypoint. The OTV maximizes the economic efficiency of the Shuttle for geosynchronous missions. The benefit is not sensitive to most OTV cost factors. The most critical factor is the loading efficiency of Shuttle-delivered payloads to LEO. The second most critical factor is propellant delivery cost. A benefit will be returned to other Shuttle users in terms of lowered launch costs because of the value of scavenged propellants or profit on external-tank tanker operations. As explained in Book 3, launch costs per satellite could become as low as $10M with an OTV. The expected benefit is $63M per OTV mission and up to $1.08B annually.

5.2 PERFORMANCE BENEFITS

Performance benefits for a continuously manned Space Station over alternative methods of accomplishing the same or similar objectives stem from two principal sources. The first relates to improved ability to perform tasks and to an increase in quantity of output. The second relates to improved output quality. The increase in quantity also leads to cost benefits.

The capability for long term manned presence will permit scientific research for periods exceeding that available in Spacelab, which are limited to a week or two and a maximum of 1 month. Many life science missions require minimum periods on the order of 2 to 6 months. The objectives of these missions cannot be accomplished in full using the current STS. Some planning is underway by the Europeans for automated free-flyer missions on Eureca to approximate the mission objectives that could be accomplished on Space Station. Some of the life science missions require not only long durations but also manned interaction to the degree that there is no viable alternative to the Station.

A similar comment can be made about materials processing research missions. However, in this case it is more a matter of efficiency rather than inability to perform the mission. If accommodated on Orbiter or Spacelab, there is limited manned interaction regarding sample exchange and process modification because of the shorter mission duration. There is also a long turnaround time between flights. Both of these limitations are overcome with the Space Station -- thus shortening the development time and increasing the research output per unit time. If SPAR rockets are used for accommodation, the turnaround time can be reduced but the time spent in microgravity is in minutes per flight. Again, the Space Station clearly offers increased performance benefits.

The advanced technology development missions that require man's presence over extended mission times either have no viable alternative accommodation means or would require considerable revision of the mission objectives to fit them into current STS capabilities. This is true for technology missions conducted to improve or develop advanced space systems, sensors for earth and environmental observations, and communications systems such as large antennas.

The Space Station will enhance man's ability to assemble large structures. The continuous time on orbit will permit larger construction projects. The availability of a permanent stable platform will also make the process more efficient over one supported only by shorter term Orbiter missions.

With respect to providing support to free-flyer satellites and platforms, the Space Station provides a base for maintenance and repair on an as-needed basis as well as for scheduled activities. Thus the useful life of observation type spacecraft can be extended by replenishment of consumables and changeout of sensors on a planned basis as well as by repair, as necessary. On-orbit checkout prior to initiating the mission can ensure proper performance and the quality of observation data can also be improved through sensor updating. Increased technical capability can be achieved by on-orbit assembly techniques to create larger spacecraft elements such as antennas and reflectors.

Satellites in geosynchronous orbit occasionally need replacement due to equipment failures. This causes a loss of system capability for observation missions such as LANDSAT and GOES. Providing replacement satellites with current launch systems requires either an on-orbit spare, which is exposed to the space environment awaiting activation, or scheduling additional launch services, which can seldom be done on an expedited basis. By maintaining a spare satellite in storage on the Space Station, both of these disadvantages can be overcome. The satellite is protected from the environment, and scheduling an additional OTV mission from LEO to GEO is simpler and easier than scheduling an additional launch from earth to GEO.

5.3 SOCIAL BENEFITS

Scientific and social benefits are closely interlocked. As man gains greater scientific knowledge, he is able to enhance the quality of life available to all. Strides made in basic research provide the needed background and information to push forward in applied research where the social benefits are more visible. Research in fields such as astrophysics, solar/terrestrial, geopotential fields, and earth dynamics will be advanced by providing an improved access to space for manned or man-supported systems.

Earth resources, weather/climate, ocean, and atmosphere research missions are important for improving man's capability to manage renewable resources, locate new sources for non-renewable resources, and control his environment. The enhancement of the quality of life for mankind requires improvement in each of these areas.

Life science studies are necessary to understand the effects on humans of long term presence in the space environment and to provide more efficient crew support. These missions are fundamental to the very existence of a Space Station with continuous manned presence, but for the true social benefits we must look beyond this. In addition, these studies will complement earth laboratory investigations into life processes, the combating of diseases, and the counteracting of debilitating conditions. New pharmaceuticals made possible by access to the space environment for materials processing can have far-reaching effects.

Materials processing research activities will increase man's capability to use the space environment to produce new/improved materials that will lead to either better or lower cost products to benefit society. In addition to pharmaceuticals, there are anticipated advancements in metallurgy, semi-conductors, and ceramics. There may even be new material combinations just over the horizon that we cannot even imagine. Although exploitation of such improved or new products would be a commercial venture, both public and private research efforts are anticipated. It may be that research in space will lead to production on earth where mass production is less costly.

Technology development missions are important to the improvement of space systems. These include improvement of man's ability to use the space environment, reduction in the cost of space systems, and improvements of space systems' performance. In addition to the accrued benefits to missions mentioned earlier, space technology advancements have historically yielded benefits for everyday life and systems/equipment that may be considered more mundane than space systems but certainly effect people because of their close interactions. Today's video, computer, and transporation systems would be considered anything but mundane to a nineteenth century man.