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SYSTEM ANALYSIS

STUDY EXTENSION

FINAL REPORT
VOLUME IV

SOC SYSTEM ANALYSIS REPORT
(BOOK 1 OF 2)

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THE BOEING COMPANY

HAMILTON STANDARD Division of UNITED TECHNOLOGIES

GRUMMAN

D180-26785-4

SPACE OPERATIONS CENTER
SYSTEM ANALYSIS
STUDY EXTENSION

Conducted for the NASA Johnson Space Center
Under Contract NAS9-16151, Exhibit B

FINAL REPORT
VOLUME IV

SYSTEM ANALYSIS REPORT
D180-26785-4
Book 1 of 2

January, 1982

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N82-20203 #

FOREWORD

The Space Operations Center System Analysis Study (Contract NAS9-16151) was initiated in June of 1980 and completed in May of 1981. A separately funded Technology Assessment and Advancement Plan study was conducted in parallel with the System Analysis Study. The study was conducted by the Boeing Aerospace Company with Hamilton Standard as the subcontractor. These studies were documented in 5 final reports:

D180-26495-1	Vol. I	-	Executive Summary
D180-26495-2	Vol. II	-	Requirements (NASA CR-160944)
D180-26495-3	Vol. III	-	SOC System Definition Report
D180-26495-4	Vol. IV	-	SOC System Analysis Report (2 volumes)
D180-26495-7		-	Space Operations Center Technology Identification Support Study, Final Report

The System Analysis Study was extended by a Study Extension contract (Contract NAS9-16151, Exhibit B) that was initated in August of 1981 and completed in January 1982. The study was conducted by the Boeing Aerospace Company with Hamilton Standard and Grumman Aerospace Company as subcontractors. The study extension results are reported in 6 final reports (eight books total):

D180-26785-1	Vol. I	-	Executive Summary
D180-26785-2	Vol. II	-	Programmatics
D180-26785-3	Vol. III	-	Final Briefing
D180-26785-4	Vol. IV	-	System Analysis Report (two books)
D180-26495-2A*	Vol. II	-	SOC System Requirements
D180-26495-3A*	Vol. III	-	SOC System Definition Report (two books)

*These documents are Revision A of the documents published at the end of the previous study. These revisions include requirements and configuration additions and modifications that resulted from the study extension analyses.

These studies were managed by the Lyndon B. Johnson Space Center. The Contracting Officer's Representative and Study Technical Manager is Sam Nassiff.

The Boeing study manager is Gordon R. Woodcock. The Hamilton Standard study manager is Harlan Brose. The Grumman study manager is Ron McCaffrey.

For convenience to the reader, a complete listing of all of the known Space Operations Center documentation is included in the Reference section of each document. This includes NASA, Boeing, and Rockwell documentation.

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KEY TEAM MEMBERS*

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LIST OF ACRONYMS AND ABBREVIATIONS

AAP	Airlock Adapter Plate
AC	Alternating Current
ADM	Adaptive Delta Modulation
AM	Airlock Module
APC	Adaptive Predictive Coders
APSM	Automated Power Systems Management
ACS	Attitude Control System
ARS	Air Revitalization System
ASE	Airborn Support Equipment
BIT	Built in Test
BITE	Built in Test Equipment
CAMS	Continuous Atmosphere Monitoring System
C&D	Controls and Displays
C&W	Caution and Warning
CCA	Communications Carrier Assembly
CCC	Contaminant Control Cartridge
CEI	Critical End Item
CER	Cost Estimating Relationships
CF	Construction Facility
CMG	Control Moment Gyro
CMD	Command
CMDS	Commands
CO_2	Carbon Dioxide
CPU	Computer Processor Units
CRT	Cathode Ray Tube
dB	Decibels
DC	Direct Current
DCM	Display and Control Module
DDT&E	Design, Development, Test, and Evaluation
DOD, DoD	Department of Defense
DT	Docking Tunnel
DM	Docking Module
DMS	Data Management System
DSCS	Defense Satellite Communications System

LIST OF ACRONYMS AND ABBREVIATIONS (Cont.)

ECLSS	Environmental Control/Life Support System
EDC	Electrochemical Depolarized CO_2 Concentrator
EEH	EMU Electrical Harness
EIRP	Effective Isotropic Radiated Power
EMI	Electromagnetic Interference
EMU	Extravehicular Mobility Unit
EPS	Electrical Power System
ET	External Tank
EVA	Extravehicular Activity
EVC	EVA Communications System
EVVA	EVA Visor Assembly
FM	Flow Meter
FMEA	Failure Mode and Effects Analysis
ftc	Foot candles
FSF	Flight Support Facility
FSS	Fluid Storage System
GN&C	Guidance, Navigation and Control
GEO	Geosynchronous Earth Orbit
GHZ	Gigahertz
GPS	Global Positioning System
GSE	Ground Support Equipment
GSTDN	Ground Satellite Tracking and Data Network
GFE	Government Furnished Equipment
GTV	Ground Test Vehicle
HLL	High Level Language
HLLV	Heavy Lift Launch Vehicle
HM	Habitat Module
HMF	Health Maintenance Facility
HPA	Handling and Positioning Aide
HUT	Hard Upper Torso
H_z	Hertz (cycles per second)
ICD	Interface Control Document
IDB	Insert Drink Bag
IOC	Initial Operating Capability

LIST OF ACRONYMS AND ABBREVIATIONS (Cont.)

IR	Infrared
IVA	Intravehicular Activity
JSC	Johnson Space Center
KBPS	Kilo Bits Per Second
KM, Km	Kilometers
KSC	Kennedy Space Center
lbm	Pounds Mass
LCD	Liquid Crystal Display
LCVG	Liquid Cooling and Ventilation Garment
LED	Light Emitting Diode
LEO	Low Earth Orbit
LiOH	Lithium Hydroxide
LM	Logistics Module
LPC	Linear Predictive Coders
LRU	Lowest Replaceable Unit
LSS	Life Support System
LTA	Lower Torso Assembly
LV	Launch Vehicle
lx	Lumens
MBA	Multibeam Antenna
mbps	Megabits per second
MHz	Megahertz
MMU	Manned Maneuvering Unit
MM-Wave	Millimeter wave
MOTV	Manned Orbit Transfer Vehicle
MRWS	Manned Remote Work Station
MSFN	Manned Space Flight Network
N/A	Not Applicable
NBS	National Bureau of Standards
NSA	National Security Agency
N	Newton
NiCd	Nickel Cadmium
NiH_2	Nickel Hydrogen
Nm, nm	Nautical miles

LIST OF ACRONYMS AND ABBREVIATIONS (Cont.)

N/m^2	Newtons per meter squared
OBS	Operational Bioinstrumentation System
OCS	Onboard Checkout System
OCP	Open Cherrypicker
OMS	Orbital Maneuvering System
OTV	Orbital Transfer Vehicle
PCM	Pulse Code Modulation
PCM	Parametric Cost Model
PEP	Power Extension Package
PIDA	Payload Installation and Deployment Apparatus
P/L	Payload
PLSS	Portable Life Support System
PM	Power Module
POM	Proximity Operations Module
ppm	Parts per Million
PRS	Personnel Rescue System
PSID	Pounds per Square Inch Differential
RCS	Reaction Control System
REM	Reoentgen Equivalent Man
RF	Radio Frequency
RFI	Radio Frequency Interference
RMS	Remote Manipulator System
RPM	Revolutions Per Minute
SAF	Systems Assembly Facility
SAWD	Solid Amine Water Desorbed
scfm	Standard Cubic Feet per Minute
SCS	Stability and Control System
SCU	Service and Cooling Umbilical
SDV	Shuttle - Derived Vehicle
SDHLV	Shuttle - Derived Heavy Lift Vehicle
SEPS	Solar Electric Propulsion System
SF	Storage Facility
SM	Service Module
SOC	Space Operations Center
SOP	Secondary Oxygen Pack
SSA	Space Suit Assembly

LIST OF ACRONYMS AND ABBREVIATIONS (Cont.)

SSTS	Space Shuttle Transportation System
SSP	Space Station Prototype
STAR	Shuttle Turnaround Analysis Report
STDN	Spaceflight Tracking and Data Network
STE	Standard Test Equipment
TBD	To Be Determined
TDRSS	Tracking and Data Relay Satellite System
TFU	Theoretical First Unit
TGA	Trace Gas Analyzer
TIMES	Thermoelectric Integrated Membrane Evaporation System
TLM	Telemetry
TM	Telemetry
TMS	Teleoperator Maneuvering System
TT	Turntable/Tilttable
TV	Television
UCD	Urine Collection Device
VCD	Vapor Compression Distillation
VDC	Volts Direct Current
VSS	Versatile Servicing Stage
WBS	Work Breakdown Structure
WMS	Waste Management System

1.0 INTRODUCTION

This volume of the SOC System Analysis Study Extension Final Project provides the documentation of the analyses conducted during this study.

Section 2.0 summarizes the study objectives and gives a cross-reference matrix showing where the study task outputs are documented in Sections 3.0 thru 9.0 of this document. Requirements and configuration updates that were products of this study were incorporated into the SOC Requirements Document (Boeing-18) and the SOC System Definition Document (Boeing-19) as Revision A to each of these books.

The programmatics and cost analyses conducted during this study have been documented in Vol. II of the Final Report (D180-26785-2).

2.0 SUMMARY OF STUDY EXTENSION TASKS

The study tasks are listed on the left axis of Figure 2.0-1. The location of the documentation and results of these task analyses are given by the matrix. Given below are capsule summaries of the key objectives of the various tasks. Complete descriptions of the task objectives will be found in the referenced subsection reports.

TASK 1.0 SATELLITE SERVICING, TEST, AND CHECKOUT

Subtask 1.1: Define Servicing Requirements and Approaches - Analyze the test and checkout requirements for attached and co-orbiting satellites to identify tasks, procedures, equipment, and timelines for accomplishing these functions from the SOC.

Subtask 1.2: Construction and Satellite Servicing Equipment Requirements - Analyze equipment requirements established for space construction and satellite servicing in the SOC system analysis study and the GAC and LMSC satellite servicing studies to identify common satellite servicing and construction requirements and equipment.

Subtask 1.3: Define Servicing Mission Needs and Benefits - Survey and analyze user mission needs for satellite servicing at LEO and GEO. Based on user inputs and historical and projected failure rate data, develop a forecast of servicing needs. Identify specific benefits derived by servicing satellites using SOC.

Subtask 1.4: Differential Drag Considerations of Co-orbiting Satellites - Analyze the effects of unequal ballistic coefficients on the relative orbital positions of the SOC and co-orbiting satellites.

Subtask 1.5: Transportation Considerations - Analyze the potential relative orbital positions of the SOC and serviceable satellites. Determine preferred transportation modes as a function of SOC - satellite separation and associated propellant requirements.

TASK DOCUMENTATION

CODE
● PRIMARY
X SECONDARY

STUDY TASKS

	SYSTEM ANALYSIS DOCUMENTS																																			
STUDY TASKS	1.0 INTRODUCTION	2.0 SUMMARY OF STUDY EXTENSION TASKS	3.0 MISSION MODELING AND MISSION NEEDS 3.1 Mission Analysis Overview	3.2 Telecommunications Missions	3.3 Space Science, Earth Sensing, and Space Testing Missions	3.4 Research and Applications Missions	3.5 DoD Missions	3.6 Satellite Servicing Missions	4.0 SATELLITE SERVICING 4.1 Introduction	4.2 Satellite Servicing Requirements and Approaches	4.3 Construction and Satellite Servicing Equipments Requirements	4.4 Satellite Servicing Mission Needs and Benefits	4.5 Differential Drag Characteristics of Co-Orbiting Satellites	4.6 Satellite Servicing Transportation Requirements	5.0 SOC/RESEARCH AND APPLICATIONS MISSIONS INTEGRATION 5.1 Introduction	5.2 Potential Research and Applications Missions and their Requirements	5.3 SOC Capabilities vs User Requirements	6.0 CREW REQUIREMENTS 6.1 Introduction	6.2 Integrated Crew Operations Requirements	6.3 Crew Labor Estimating relationships	7.0 FLIGHT SUPPORT OPERATIONS 7.1 Introduction	7.2 SOC/Shuttle Operations	7.3 SOC/Shuttle-Derived Vehicle Operations	7.4 SOC/OTV Operations	8.0 SOC ORBITAL OPERATIONS 8.1 Introduction	8.2 Low Mission Model Operations Analysis	8.3 Medium Mission Model Operations Analysis	8.4 High Mission Model Operations Analysis	9.0 SOC CONFIGURATIONS 9.1 Module Configuration and System Options	9.2 Summary of Crew and Systems Safety	9.3 SOC/External Tank Configurations	9.4 GEO SOC	EXECUTIVE SUMMARY DOCUMENT	PROGRAMMATICS AND COST DOCUMENT	SYSTEM DESCRIPTION DOCUMENT	SYSTEM REQUIREMENTS DOCUMENT
TASK 1.0 SATELLITE SERVICING, TEST AND CHECKOUT																																				
1.1 DEFINE SERVICING REQMTS																																			X	●
1.2 CONSTRUCTION AND SATELLITE SERVICING EQUIPMENT										●																									●	X
1.3 DEFINE SATELLITE SERVICING MISSIONS											●																							X		
1.4 DIFFERENTIAL DRAG CHARACT. OF CO-ORBITING SATELLITES								X				●																								
													●																							
1.5 SATELLITE SERVICING TRANSPORT. CONSIDERATIONS										X	X			●																						
TASK 2.0 SOC/RESEARCH AND APPLICATION																●																				
2.1 SOC R&D SUPPORT ANALYSIS						X																														
2.2 OPERATIONAL REQUIREMENTS																	●																			
2.3 ENVIRONMENTAL CAPABILITIES																●																			X	X
2.4 MATERIALS PROCESSING AND LIFE SCIENCES MISSIONS						X										●																	X			
TASK 3.0 CREW REQUIREMENTS INTEGRATION																																				
3.1 INTEGRATED CREW REQMNTS																			●																X	
3.2 CREW LABOR ESTIMATING RELATIONSHIPS																				●																
3.3 DEFINE RANGE OF REQMNTS																			●																	
TASK 4.0 SOC/EXTERNAL TANK																																				
4.1 PROPELLANT TANK OPTIONS																														●						
4.2 FLIGHT CONTROL																														●						
4.3 HANGAR OPTIONS																														●						
TASK 5.0 SOC ORBITAL OPS																																				
5.1 DEFINE OPERATIONAL SCENARIOS																										●	●	●								
5.2 IDENTIFY SPECIAL REQMNTS																										●	●	●								
5.3 ASSESS SOC CAPABILITY LIMITS																										●	●	●								
TASK 6.0 FLIGHT SUPPORT																																				
6.1 SOC–SHUTTLE OPS																						●													●	X
6.2 SOC–SHUTTLE-DERIVED VEHICLES OPS																							●													
6.3 SOC–OTV OPS																								●											●	X
TASK 7.0 SOC OPS TO GEO																																				
7.1 DEFINE REQUIREMENTS																																	●			
7.2 IDENTIFY DESIGN MODS																																	●			
TASK 8.0 MISSION NEEDS AND MODELING ANALYSIS																																				
8.1 MISSION MODEL FORECAST			●	●	●																													X	X	
8.2 DoD TRAFFIC MODEL						●																												X	X	
8.3 ECONOMIC AND BUDGET FORECAST			●																																●	
TASK 9.0 SOC REQUIREMENTS AND UPDATE CONFIGURATION																																				
9.1 UPDATE REQUIREMENTS DOC AND CONFIGURATION																																			●	●
9.2 ASSESS AND DOCUMENT RANGES OF REQUIREMENTS																										●	●	●					X			
TASK 10.0 PROGRAMMATICS																																				
10.1 UPDATE DEVELOPMENT PLAN			X																														X	●		
10.2 DEFINE PLANNING OPTIONS			X																														X	●		
10.3 DEVELOP USER CHARGE PLAN																																	X	●		

Figure 2.0-1 Study Tasks vs. Documentation Matrix

TASK 2.0: SOC/RESEARCH AND APPLICATIONS INTEGRATION

Subtask 2.1: SOC R&D Support Analysis - Analyze the potential of the basic SOC concept to support R&D through pilot plant operations leading to operational commercial, applications and scientific space systems.

Subtask 2.2: Operational Requirements for R&D and Applications Missions - Assess the changes in operating requirements for the operational phase of these systems, including any requirements for continuous manned presence or periodic manned presence. Determine whether the systems should be attached to the SOC, co-orbiting or completely independent in their operational phase.

Subtask 2.3: Environmental Capabilities Evaluations - Evaluate the requirements for the research and application activities against the capabilities and environment of an operational SOC. Identify areas of compatibility and incompatibility. Define any additional capabilities that a station configuration assembled from basic SOC modules and subsystem would need to support research, applications, and science objectives.

Subtask 2.4: Materials Processing and Life Sciences Research Capability Analysis Survey and analyze available plans for materials processing and life sciences research. Estimate the number and duration of experiments and the SOC accommodations required. Determine how the SOC could be used as a test bed and/or development facility for science/applications, materials processing, manufacturing, etc. Forecast the expected evolution to production facilities for materials processing, manufacturing, etc., and related SOC involvement.

TASK 3.0: CREW REQUIREMENTS

Subtask 3.1: Integrated Crew Operations Requirements - Summarize, on a yearly basis, the crew requirements, i.e., number of man-months and crew skills, to perform construction work, orbiter transfer vehicle (OTV) support, satellite servicing, science and applications, and SOC housekeeping and control duties.

__Subtask 3.2: Develop Crew Labor Estimating Relationships__ - This data should be presented in a format with suitable estimating relationships that allow the analysis of subsequent parametric variations of the mission model.

__Subtask 3.3: Define Range of Crew Requirements__ - Define the range of crew requirements corresponding to the range of mission models.

TASK 4.0 SOC/EXTERNAL TANK (ET) CONFIGURATION

__Subtask 4.1: Configuration Options__ - Assess the feasibility of operating the SOC with an ET attached and used as a propellant storage and propellant transfer depot.

__Subtask 4.2: Flight Control__ - Determine attitude stabilization and control, and orbit makeup requirements for the SOC with the ET attached.

__Subtask 4.3: Evaluate Other ET Uses__ - Evaluate ET use as a hangar for OTVs.

TASK 5.0 SOC ORBITAL OPERATIONS

__Subtask 5.1: Define Operations Scenario__ - Analyze the capability of the SOC to support multiple, simultaneous operations such as space construction, satellite servicing, test, and checkout, flight support for orbital transfer vehicles and operations with the Shuttle.

__Subtask 5.2: Identify Special Requirements__ - Identify special requirements and impacts on the SOC configuration and operations concepts to provide the capability to handle the simultaneous operations.

__Subtask 5.3: Assess SOC Operational Capability Limits__ - Assess the capability of the SOC to conduct the simulations operations required by the range of mission models.

TASK 6.0 FLIGHT SUPPORT

Subtask 6.1: Develop SOC-Shuttle Operational Interfaces - Analyze and further develop SOC operational interfaces with the Space Shuttle.

Subtask 6.2: Develop SOC/SDV Operational Interfaces - Analyze and further develop SOC operational interfaces with projected Shuttle-derived vehicles (SDVs).

Subtask 6.3: Develop SOC-OTV Operational Interfaces - Analyze and further develop SOC operational interfaces with OTVs to (1) assess the impact of OTV aerobraking, and, (2) compare SOC support provisions and launch operations required for reusable single-stage, two-stage, and one-and-a-half stage OTVs.

TASK 7.0 SOC OPERATIONS TO GEOSYNCHRONOUS ORBIT (GEO)

Subtask 7.1: Define Requirements - Determine the requirements and impacts on SOC elements for potential growth missions operating at GEO.

Subtask 7.2: Identify Design Modifications - Identify any hardware or software design modifications that are required to support a SOC growth mission operating at GEO.

TASK 8.0 CONDUCT MISSION NEEDS AND MODELING ANALYSIS

Subtask 8.1: Mission Model Forecasting - Survey and analyze existing mission models. Develop a range of forecasts for mission evolution in the following two functional area groups:

- Earth sensing, Earth and space sciences, space testing of developmental systems and subsystems.
- Communications, materials processing, life sciences.

Subtask 8.2: DoD Traffic Model Update - Update the DoD traffic model based on current available DoD information.

<u>**Subtask 8.3: Economic and Budget Forecasting**</u> - Employ economic and budget forecasting methods to rationalize mission model projections based on plausible growth patterns and budgetary limitations.

TASK 9.0: SOC REQUIREMENTS AND CONFIGURATION UPDATE

<u>**Subtask 9.1: Update Requirements Document and Configuration**</u> - The SOC requirements document and SOC configuration elements shall be updated to reflect results of the subcontract extension.

<u>**Subtask 9.2: Assess and Document Ranges of Requirements**</u> - Assess the impact of the variations in mission and traffic models on the SOC requirements and on the initial, operational and growth configurations. Develop an updated set of SOC growth options to reflect ranges of requirements derived from the mission and traffic models.

TASK 10: PROGRAMMATICS

<u>**Subtask 10.1: Update Development Plan**</u> - Update the development plan produced in the SOC Systems Analysis Study to incorporate schedule and cost revisions and any possible alternatives resulting from the task analyses of the contract extension. SOC modular approach, buildup, commonality of modules (primary and secondary structures, subsystems, etc.) and associated effects on DDT&E and manufacturing costs will be analyzed.

<u>**Subtask 10.2: Define Planning Options**</u> - Assess the impact of mission and traffic model variations on SOC development planning, buildup, evolution, and costs. Develop and describe a strategy for development that is adaptive to mission needs evolution.

<u>**Subtask 10.3: Develop User Charge Plan**</u> - Develop a rationale and plan for SOC user charges, based on amortization of SOC flight hardware, costs of facilities and services, operations costs, and resupply costs. Compare the projected user charges to estimated value of services and make any adjustments that would increase the utility of SOC services to the user community.

3.0 MISSION MODELING AND MISSION NEEDS

3.1 MISSION ANALYSIS OVERVIEW

3.0 MISSION MODELING AND MISSION NEEDS

This section of the report presents results of several related tasks in an integrated fashion. These tasks were concerned with SOC mission models, mission needs, satellite servicing, transportation interrelationships, orbital operations, and crew skills and manlevels. The presentation here is organized to present continuity from derivation of mission models through SOC utilization and crew size. The integrated discussion is followed by more detailed discussion of individual segments of the mission models.

3.1 MISSION ANALYSIS OVERVIEW

3.1.1 OBJECTIVES OF MISSION MODELING

One of the principal issues involved in design and program planning for a manned Space Operations Center is determination of mission needs, and the derivation of appropriate system requirements and program planning. Accordingly, as a major part of this Phase A study extension, a mission modeling and analysis task was conducted. A part of this task was to develop a fresh approach to mission modeling, one founded on economic principles rather than the survey methods that have been used in prior mission modeling activities. The objectives of this mission modeling activity are described in Table 3.1-1.

3.1.2 MISSION MODELING APPROACH

Past attempts at mission modeling have relied largely on survey methods. These have been historically unsuccessful. The reasons for lack of success differ in the different sectors of the space economy. (These sectors are discussed on subsequent pages.)

In the NASA Research and Application sector, past mission models have been generally based on lists of payloads for which some scientific or applications rationale exists, but lists that do not consider representative budget realities that will constrain the number of payloads developed and flown.

Table 3.1-1

OBJECTIVES OF MISSION MODELING

- Understand and characterize the fundamental determining forces that shape the future utilization of space systems

- Develop a range of specific mission event predictions encompassing the credible range of determining forces

- Provide a quantitative basis for evaluating the utility of manned space platforms and their relationships to space operations, research, and applications

- Create an overall future scenario within which the benefits of manned space platforms can be quantified and compared with costs.

If a permanently-manned station exists in low Earth orbit, this station can be used as a research facility for science and applications projects. Since no such facility presently exists, there is no well-organized user constituency to survey. The life sciences community is planning primarily Spacelab applications. There is some literature for utilization of a permanently-manned facility, and these were used in this study as a source. Materials processing science is presently considering mainly shuttle sortie flights and free fliers. The substantial opportunities that would exist with a manned platform have not been well represented in the available literature.

In the commercial sectors, the planning horizon is relatively short, commensurate with the emphasis on near-term profitability and cash flow that always exists in a commercial organization. Further, such long-term plans as may exist are generally treated as business secrets and are not revealed to anyone who surveys these organizations.

The defense sector exhibits some of the wish list syndrome but far less than the NASA sector, inasmuch as the planning process in DOD is more inclined to take into account budget realities. The defense sector also tends towards a planning horizon of about 10 years. Dealing with the defense sector in an unclassified study is confounded by classification of specific projects and the sensitivity of revealing potential evolutions of policy through forecasting of specific missions.

The first sector considered in our analysis was the NASA Research and Applications spacecraft sector. This sector represents institutionalized research and applications areas, including astrophysics and solar terrestrial physics, planetary exploration, etc. This sector is characterized by budget levels that have become generally institutionalized. These levels are subject to variation depending upon political trends and problems with Federal deficits. Presently, this sector is under considerable budget pressure, but a long-range forecast must presume that current budget pressure will not necessarily permanently reduce the institutionalized levels of research.

The second sector is represented by that category of research that would be carried out on a permanently-occupied manned platform, should one become available. A review of many potential lines of research indicated that the ones most likely to be implemented on a manned platform would be life sciences and materials processing, with some additional activity in space technology testing. There is no well-organized constituency for this kind of research on a manned platform since no research facility has been available. The constituency that existed in the early 1970s has generally dissolved.

This sector is characterized by latent demand. Budget levels for such research are not institutionalized and present levels of funding for life sciences and materials processing within NASA are quite small. It is plausible to anticipate some increase in budget levels in these areas with the availability of a manned platform, but because of continuing pressure on the Federal budget it is not expected that these areas will become funded to the same degree as existing research areas presently carrying out major flight projects. Private sector funding is available for materials research. The amount is not known, but is potentially large given the general economic character of the sectors of the economy that could benefit from breakthroughs in materials processing in the microgravity environment.

The commercial sector for space utilization exploits those operations using space that are profitable. Presently, this amounts to space communications, using communications satellites. A future potential exists for materials processing commercial production if suitable process candidates are developed. Commercial sectors are characterized by exponential growth. In the case of space communications, this growth has historically been quite rapid.

The final sector is the defense sector. This sector is driven by estimates of the military threat, and to some degree by perceived military opportunities. Historically, this sector has exhibited a continued gradual increase in budget. A projection of present trends would suggest a budget doubling by about the year 2000.

In accordance with the characteristics of the sectors presented above, the philosophy for construction of the mission model is presented in Table 3.1-2.

The present study has tended to be somewhat more conservative in satellite servicing than related studies. We have assumed that only high-value payloads

Table 3.1-2

MISSION MODEL PHILOSOPHY

Low Model—Highly Conservative Projections

NASA Research: Continued Gradual Decline in Real Budget Authority

Commercial: Less Growth Than Present

DoD: Cessation of Historical Growth Trends

Median Model –Most Likely Projections

NASA Research: Roughly Constant Real Budget Authority

Commercial: Continuation of Present Trends

DoD: Continuation of Present Trends

High Model –Optimistic Projections

NASA Research: Gradual Increase in Real Budget Authority

Commercial: Modest Increase in Present Growth Rate

DoD: Increase in Present Growth Rate

will be serviced inasmuch as low-cost payloads are of a nature not requiring service, and at any rate may not have sufficient value to warrant a servicing mission.

GEO servicing missions are deferred in this model until they are warranted by the total value of assets in geosynchronous orbit. We arrived at timing by taking an insurance approach: When the value of the GEO assets exceeds $10 billion, then the creation of a servicing capability is justified as insurance; if a high-value payload at GEO fails, the capability will exist to go there and restore it to service. This judgment was based on the premise that the basic upper-stage technology for a GEO servicing mission would exist in the form of orbit transfer vehicles for payload placement and that the added investment to create a manned orbit transfer vehicle capability for satellite servicing would be on the order of a billion dollars.

Servicing rates were estimated on the premise that a typical spacecraft has a 3% chance of failure in each year of service. This corresponds to a 20-year mean-time-between-failure for spacecraft. This is somewhat better than present experience, but trends in spacecraft life indicate that in the timeframe of interest a 20-year mean-time-between-failure is realistic. Finally, we assumed that the typical GEO servicing mission will service two to four spacecraft. Some failures at GEO will be so serious as to need immediate servicing. However, many will be of a nature that the spacecraft owner will elect to wait until he can cost-share with another owner needing service before he services his system.

3.1.3 SUMMARY OF MISSION MODEL DEVELOPMENT

The following discussion describes the development of the mission model, sector by sector.

3.1.3.1 NASA Research and Applications Spacecraft

The NASA Research and Applications sector mission model was rationalized beginning with the available models created by a survey approach. These available models were assumed to represent scientifically-justifiable missions. The principal premises and method of analysis are described in Figure 3.1-1.

- Mission projections based on living within historical budget trends
- High-Level Cost Model
  - Spacecraft Development $80,000/KG
  - Spacecraft Production $20,000/KG
  - Spacecraft Reuse after Recovery $10,000/KG
  - Spacecraft Revisit $5,000/KG

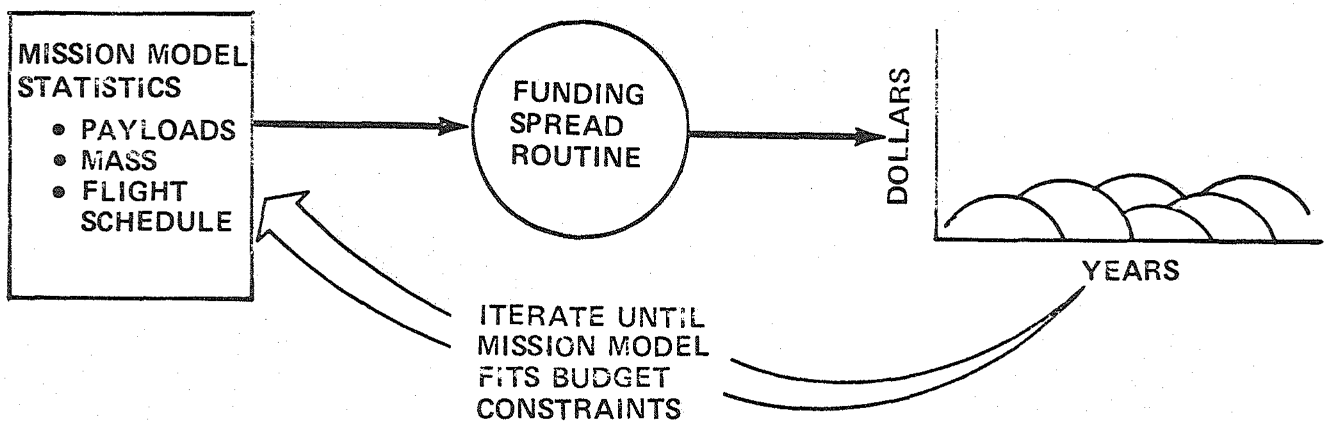


Figure 3.1-1. Budget Rationalization Approach

The basic premise was that each subsector of the NASA Research and Applications sector would have to live within historical budget levels. A high-level cost model was employed to derive budgetary estimates based on the cost of spacecraft development, production, reuse, and servicing. This high-level cost model was also derived from historical experience. It is presumed that the cost of spacecraft development and production will dominate the cost such that the simplification of ignoring launch services will not lead to major errors in the model. The iteration procedure presented in the figure was used to arrive at final models. The funding spread routine simply takes the costs estimated for spacecraft and spreads them over a reasonable development period for the development of the spacecraft, to present a funding projection for the subsectors.

The funding, spreading and plotting program utilized for this analysis accepts a maximum of 25 cost elements for each chart presented. The number of cost elements for the astrophysics program as presented in NASA planning documents was approximately 40. Consequently this program was divided into near-term and far-term programs. Figure 3.1-2 presents the estimated funding requirements for the near-term programs as presented in NASA planning documents. These programs were characterized by multiple simultaneous development of observatory class payloads, and generally resulted in budget level estimates that exceed the present budget level by factors approaching 10.

The funding estimates for the long range programs reached even higher total values than the near term program with a funding peak in the mid 1990s of roughly $1½ billion as shown in Figure 3.1-3. These models must be regarded as unrealistic inasmuch as the present level of funding for the astrophysics programs is on the order of $200 million. Consequently, the rationalization approach was used to eliminate or defer cost events until a program funding projection similar to historical budget trends was accomplished.

The astrophysics model, after being rationalized, exhibits the funding trend illustrated in Figure 3.1-4. This funding trend, although perhaps slightly ambitious, was used as the median traffic model. The low traffic model had fewer payloads and the high traffic model slightly more. In general for the NASA sector, the differences between the low and high models were not great inasmuch

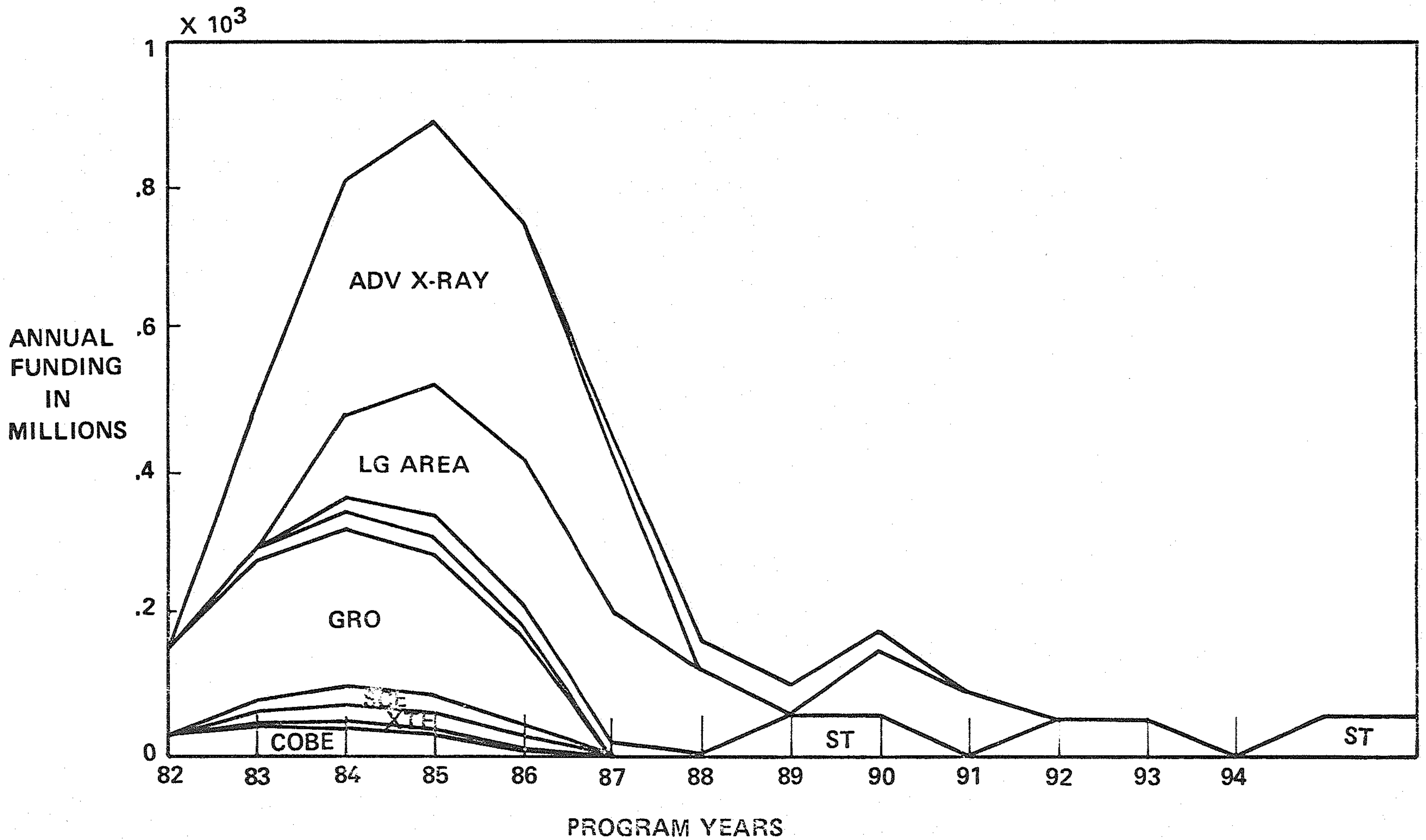


Figure 3.1-2. Astrophysics Funding Levels (Near-Term Programs as Presented in NASA Planning Documents)

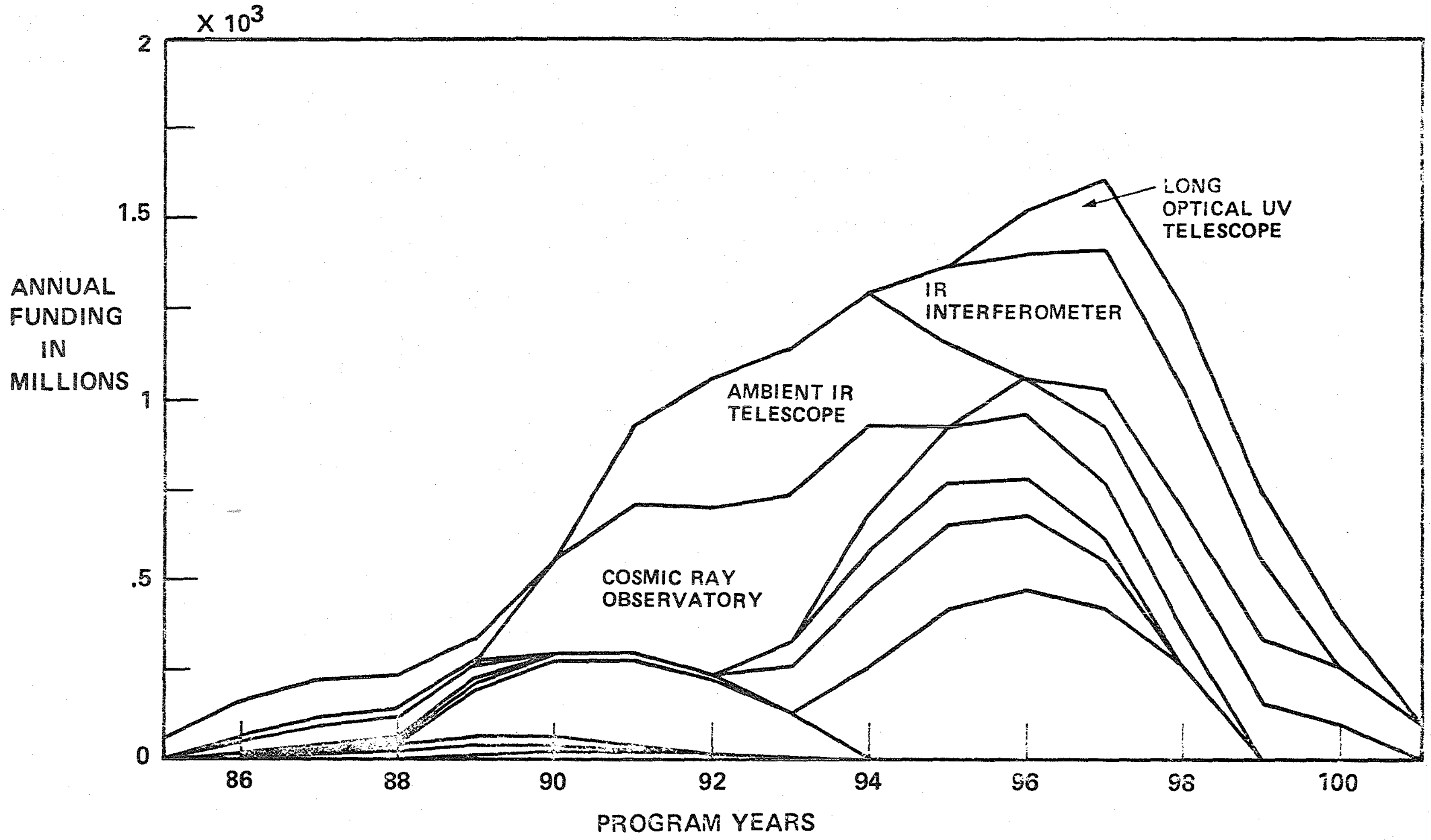


Figure 3.1-3. Astrophysics Funding (Long-Range Programs as Presented in NASA Planning Documents)

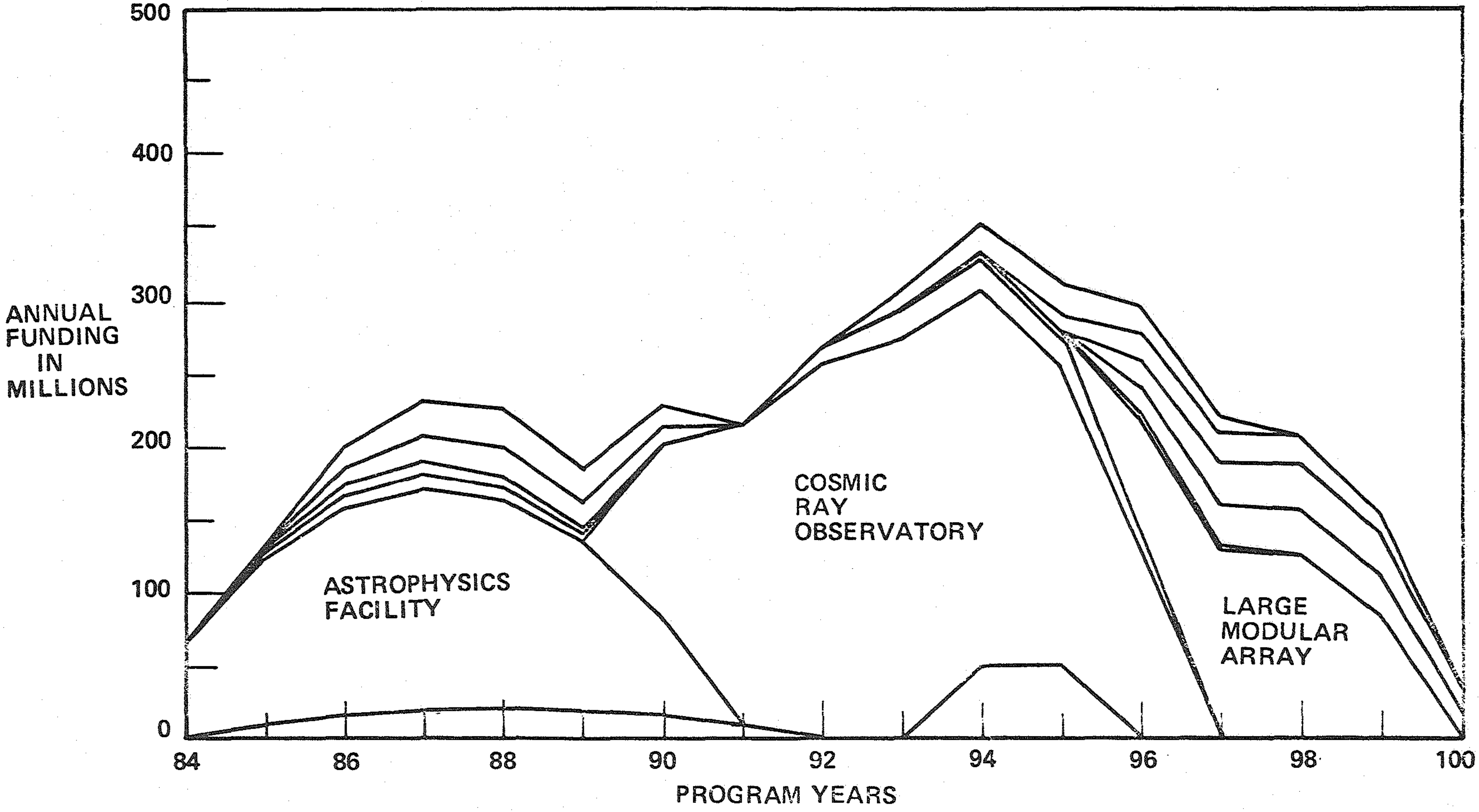


Figure 3.1-4. Rationalized Astrophysics Model (Based on Medium Traffic Model)

as the institutionalized nature of these sectors would suggest that large fluctuations in historical funding trends should not be expected.

Figure 3.1-5 presents a summary of the median traffic model for all of the NASA Research and Applications spacecraft payloads. Although there are a large number of individual payloads represented in this portion of the model, the total number of equivalent Shuttle flights is relatively small.

3.1.3.2 Research and Applications On Board SOC

Three representative mission categories were analyzed in this sector. These are life sciences, materials processing, and DoD and technology space testing of subsystems, instruments and technologies.

A review of the so-called "Blue Books" from the space station studies of the early 1970s suggested that mission activities in other areas such as space physics and communications would be relatively insignificant and not worth the investment of time and effort to create mission models. These kinds of activities can generally be aggregated under the DoD and technology category.

Only very limited life sciences research can be conducted on short duration space missions. The existence of a manned platform would permit research on the various long-term exposure effects for meaningful time periods. The flexibility of a permanently-occupied station would permit a diversity of research carried out over a long sustained period. It would also provide collection of medical data for 90 days or more on human beings. Operation in a laboratory mode would provide flexibility of in-situ modifications of experiment protocols and the introduction of new and varied experiments as the research was conducted. This would also provide the opportunity for fixing things if malfunctions occur and the experiment is put in jeopardy. The relative flexibility of timelines and operations in a permanently-manned station will allow the accomplishment of research at considerably less cost than would be required for operations in which detailed advanced plans must be prepared and followed meticulously.

Three models were created for life sciences research, as was the case for the other sectors. In life sciences, the low model was designed to satisfy those

	NAME	ORBIT		MASS (Kg)		MEDIUM TRAFFIC MODEL											
		ALT	INC	UP	DOWN	89	90	91	92	93	94	95	96	97	98	99	100
1	MP01 DEL SHORT EXP MODULE	370	28.5	5568	5568				1	2	2	2					
2	MP02 DEL FULL EXP MOD	370	28.5	8431	8431									1	2	2	2
3	MP03 DEL EXP PALLET	370	28.5	1437	1437				1	2	2	4	4	4	4	4	4
4	MP04 MPEXP MANLEVEL	0	0.0	0	0			1	5	5	5	10	10	10	10	10	10
5	MP05 DEL PROC DEV MOD	320	28.8	8431	8431					1	4	4	4	4	4	4	4
6	MP06 MPDEV MANLEVEL	0	0.0	0	0					10	20	20	20	20	20	20	20
7	MP07 RESUPPLY PROD	0	0.0	3000	0												
8	MP08 MPPROD MANLEVEL	0	0.0	0	0												
9	MP09 DEL PRODUC SC	370	28.5	10000	0												
10	LS01 DEL LS RSH MOD	370	28.5	10346	0							1					
11	LS02 DEL CELSS MOD	370	28.5	10346	0								1				
12	L503 DEL LS CENT MOD	370	28.5	5077	0								1				
13	LS04 LS CENT MANLEVEL	0	0.0	0	0								5	5	5	10	10
14	LS05 LSEXP MANLEVEL	0	0.0	0	0			7	12	12	20	20	30	30	30	30	30
15	DO01 DEL DOD SMPALLET	0	0.0	1450	1450	1	1	1	1	1	1	1	1	1	1	1	1
16	DO02 DEL DOD LGPALLET	370	28.5	6200	6200		1		1		2		2	1	2	1	2
17	DO03 DOD RES MANLEVEL	370	28.5	0	0	3	4	5	5	10	5	5	10	7	10	7	10
18	DO04 DEL 1-TON SPACFT	0	0.0	1000	0	3	2	2	1	1							
19	DO05 DEL 2-TON SPACFT	35786	0.0	2000	0	6	5	5	5	5	4	4	4	3	3	2	1
20	DO06 DEL 3-TON SPACFT	35786	0.0	3000	0	6	5	5	4	4	5	3	3	2	2	2	3
21	DO07 DEL 5-TON SPACFT	35786	0.0	5000	0	0	2	2	3	4	4	5	5	5	6	5	5
22	DO08 DEL 10-TON SPACFT	35786	0.0	10000	0									1	1	2	2
23	DO09 DEL MANNED STA	35786	0.0	20000	0												
24	MO10 RESUP MANNED STA	35786	0.0	6000	4000												
25	DT01 BASE HOUSE OPS	35786	0.0	0	0	10	10	10	10	10	10	10	10	10	10	10	10
26	DT02 SOC CREW ROT. AND RESUPPLY	0	0.0	17500	13000	4	4	4	4	4	4	4	4	4	4	4	4
27	CO01 1-TON COMSAT	370	28.5	1000	0												
28	CO02 2-TON COMSAT	35786	0.0	2000	0												
29	CO03 3-TON COMSAT	35786	0.0	3000	0	6	9	6	8	8	7	8	6	2	0	0	0
30	CO04 4-TON MINIPLAT	35786	0.0	4000	0			1	1	2	3	4	6	11	14	12	15
31	CO05 5-TON MINIPLAT	35786	0.0	5000	0												
32	CO06 7-TON PLATFORM	35786	0.0	7000	0								1	1	2	3	4
33	CO07 10-TON PLATFORM	35786	0.0	10000	0												
34	MO08 SV COMM PLATS	35786	0.0	6330	5330	0	0	0	0	0	2	3	3	4	4	5	6
35	AA01 DEL/RET SPACE TELESCOPE	35786	0.0	11000	0			1						1			
36	SS02 SV SPACE TELE	593	28.5	11000	0				1								
37	AA04 DEL/RET GAMMA RAY OBSERV	593	28.5	16000	16000												
38	SS05 SERVICE GAMMA RAY OBSERV	400	28.5	11000	0												
39	AA07 DEL/RET X-RAY ASTROPHYS FAC	400	28.5	10000	10000		1						1				
40	SS08 SERVICE X-RAY ASTROPHYS FAC	450	28.5	10000	10000			1							1		

Figure 3.1-5 Median NASA Payloads Mission Model

	NAME	ORBIT		MASS (Kg)		MEDIUM TRAFFIC MODEL											
		ALT	INC	UP	DOWN	89	90	91	92	93	94	95	96	97	98	99	100
41	AA10 DEL/RET COSMIC RAY OBS	400	56.0	18000	18000					1							
42	SS11 SV COS RAY OBS	400	56.0	6330	5330							1					
43	AA13 DEL VLBASE INTER	10000	45.0	1000	0								1	1			
44	AA16 DEL INT UVEXPL	35786	0.0	500	0	1											
45	AA25 DEL ADV INTER PLANETARY EX	0	0.0	1200	0											1	
46	AA26 DEL SOLAR PROBE	0	23.0	1500	0								1				
47	AA27 DEL/RET X-RAY OB	400	28.5	3550	3550												1
48	SS28 SV XRAY OBS	400	28.5	0	0												
49	PL01 DEL VENUS ORB IMAGE RADAR	0	0.0	1000	0												
50	PL02 DEL LUNAR POLAR ORB	0	0.0	1000	0									1			
51	FL03 MARS SAMPLE RET	0	0.0	7000	0						1						
52	FL04 ASTEROID MULT. RENDEZVOUS	0	0.0	3000	0								1				
53	FL05 SATURN ORB	0	0.0	3000	0			1									
54	PL06 URANUS NEP PLUT	0	0.0	1000	0				1		1				1		
55	EO01 DEL GEO ENV SAT	35786	0.0	720	0		1				1						
56	EO04 DEL STORM SAT	35786	0.0	1600	0				1					1			
57	EO07 DEL RES POLLUT	35786	0.0	700	0									1	1	1	
58	EO09 DEL GEO CROP MONITOR	35786	0.0	5000	0							1	1				
59	EO10 DEL INMET SAT	35786	0.0	943	0	1		1		1		1		1		1	
60	EO14 DEL SOIL MOIS	465	56.0	408	0										1		
61	PL07 DEL NR EAR ASTEROID	0	0.0	4000	0												
62	AA32 DEL SOLAR POL	0	0.0	683	0											1	
63	AA33 DEL GAM RAY TRANS EXPL	450	28.5	3000	0												
64	AA35 DEL MAG PARTICL EXPLORER	0	0.0	770	0												
65	AA36 DEL LARGE MOD ARRAY	400	28.5	5200	0							1					
66	SS37 SV LG MOD ARR	1400	28.5	260	260												
67	PL08 DEL GALILEO PROBE	0	0.0	450	0												
68	PL09 DEL GALILEO ORBITER	0	0.0	1800	0												

Figure 3.1-5 Median NASA Payloads Mission Model (Con't)

research objectives most essential to routine long-term manned space operations. These research objectives would be essential to a long-term program intended to eventually use manned systems for military purposes. These systems will require routine and highly effective operations with long crew stay times.

The median model included some additional research objectives of a more academic nature; objectives related to understanding the effects of micro-gravity, and other aspects of the space environment, on a variety of living organisms. These research objectives may also have a practical application inasmuch as the well being of other living organisms in space may eventually be of importance to permanent human settlements in space.

The high model was designed to satisfy all presently identified microgravity life sciences objectives, excepting those requiring a human centrifuge. (The human centrifuge was considered to be an unreasonable requirement to impose on a space station in the SOC class.) Note that even the high model does not address research objectives that might be identified in the future. It may be presumed that some such objectives of high priority would displace objectives presently recognized, but of lower priority.

Figure 3.1-6 presents the life sciences mission models that were developed as a result of the life sciences investigation.

The field of microgravity materials processing is presently in an early experi-mental research stage. This activity has been carried out on past space missions as well as in aircraft, drop towers and sounding rockets. A number of such experiments are planned for Shuttle and Spacelab flights in the 1980s. Figure 3.1-7 illustrates the evolution of this present phase of research into phases of process development toward commercially-viable processes, and finally commer-cial manufacturing of products for the free marketplace. The main character-istics of these phases of development are also indicated in the figure.

Process development represents a venture of commercial risk capital, to develop a proprietary process from which returns will be obtained when the process is fully developed, automated and commercialized. Accordingly, time is of the essence. It is very important that the process development be expected to reach

SOC-1394

	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
LOW MODEL																
MEDICAL RESEARCH	.1	.1	.1	.1	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5
SUITCASE EXPERIMENTS	.1	.1	.1	.1	.1	.1	.1									
SPACE AVAILABLE EXPER.								.2	.2	.2	.2					
DEDICATED LS MODULE	*.1	*.1	*.1	*.1								1	1	2	2	2
MEDIUM MODEL																
MEDICAL RESEARCH	.1	.1	.1	.1	.5	.5	.5	1	1	1	1	1	1	1	1	1
SUITCASE EXPERIMENTS	.1	.1	.1	.1	.1	.1										
SPACE AVAILABLE EXPER.							.2	.2	.2							
DEDICATED LS MODULE	*.1	*.1	*.1	*.1						1	1	2	2	2	2	2
RES. CENTRIFUGE MODULE												.5	.5	.5	1	1
HIGH MODEL																
MEDICAL RESEARCH	.1	.1	.1	.1	1	1	1.5	1.5	1.5	1.5	1.5	1.5	1	1	1	1
SUITCASE EXPERIMENTS	.1	.1	.1	.1	.1	.1										
SPACE AVAILABLE EXPER.																
DEDICATED LS MODULE	*.1	*.1	*.1	*.1			1	2	2	2	3	3	3	3	3	3
RES. CENTRIFUGE MODULE									1	1	1	1	1	1	1	1
DEDICATED CELSS MODULE																2

*CREW INVOLVEMENT BASED ON 1 SHUTTLE/LS SPACELAB MISSION PER YEAR.

Figure 3.1-6. Life Sciences Mission Model (Crew Involvement in Manyears/Year)

SOC-1367

EXPERIMENTAL RESEARCH	PROCESS DEVELOPMENT	COMMERCIAL MANUFACTURING
ON-BOARD SOC →	→	STATIONKEPT
SMALL "SUITCASE" EXPERIMENTS, MULTIPURPOSE RESEARCH MODULES AND PALLETS	DEDICATED-PURPOSE PROCESS DEVELOPMENT MODULE →	DEDICATED-PURPOSE COMMERCIAL MANUFACTURING FREE-FLYER
NASA-SPONSORED →	PROPRIETARY COMMERCIAL SYSTEMS	
PERIODIC ATTENTION BY SOC CREW →	FULL-TIME "COMPANY" RESEARCHERS →	PERIODIC ATTENTION BY THE SOC CREW IN SATELLITE SERVICING MODE

Figure 3.1-7. Materials Processing Evolution

a successful conclusion in relatively few years. Otherwise, the commercial return on investment will not be sufficiently attractive to merit a risk capital investment. The presence of a continuously-manned platform can be expected to reduce the process development time from one likely to be unattractive commercially to one probably attractive commercially. The process development time on a permanently manned platform would be not greatly more than a comparable process development on Earth.

The low model for materials processing is an extrapolation of Spacelab research plans presently in existence. It was estimated that a process development activity would begin in 1994, aimed at eventual commercialization.

The median model assumes that the existence of a permanently-manned platform would stimulate additional research activity over that planned for Spacelab, and that process development could begin in 1992.

The high model represents a moderately aggressive program to develop commercial processes. Process development begins in 1991, about as early as could be expected with a space station launched in 1989 or 1990. It assumes that four parallel process development activities are in progress by 1995, and that the first commercial production free-flyer is launched in 1998.

Figure 3.1-8 presents the principal statistics for the low, median and high models in terms of the number of processes and development, as well as the space station man level dedicated to research and to process development.

Figure 3.1-9 presents a summary of the DoD and technology space testing models. These represent continuations of present trends in space testing. It is assumed that the Space Operations Center would provide those services now provided by spacecraft busses or shuttle. Crew involvement would be primarily for experiment tending. These experiments would generally be mounted on pallets and berthed to a Space Operations Center berthing port. The required crew involvement is relatively minimal since most of the testing would simply be accomplished by relaying data to the ground.

		CALENDAR											
		89	90	91	92	93	94	95	96	97	98	99	00
LOW	NUMBER OF PROCESSES IN DEVELOPMENT						1	1	1	1	1	1	1
	RESEARCH MAN LEVEL	0.1	0.1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	DEVELOPMENT MAN LEVEL						2	2	2	2	2	2	2
MEDIAN	NUMBER OF PROCESSES IN DEVELOPMENT				1	1	2	2	2	2	2	2	2
	RESEARCH MAN LEVEL	0.1	0.1	0.1	0.5	0.5	0.5	1	1	1	1	1	1
	DEVELOPMENT MAN LEVEL				1	1	2	2	2	2	2	2	2
HIGH	NUMBER OF PROCESSES IN DEVELOPMENT			1	1	2	2	4	4	4	4	4	4
	RESEARCH MANLEVEL	0.25	0.25	1	1	2	2	2	2	2	2	2	2
	DEVELOPMENT MAN LEVEL			2	2	2	2	4	4	4	4	4	4
	PRODUCTION MAN LEVEL (FREE-FLYER TENDING)										0.5	0.5	0.5

Figure 3.1-8. Materials Processing Mission Model

- CONTINUATION OF PRESENT TRENDS IN SPACE TESTING
- SOC PROVIDES THOSE SERVICES NOW PROVIDED BY SPACECRAFT BUS OR SHUTTLE
- EXPERIMENT–TENDING OPERATIONS

	89	90	91	92	93	94	95	96	97	98	99	00
LOW MODEL MAN LEVEL	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
MEDIAN MODEL MAN LEVEL	0.2	0.2	0.7	0.3	0.7	0.7	0.7	1	1	1	1	1
HIGH MODEL MAN LEVEL	0.2	0.2	0.7	0.3	1	1	1	1	1	1	1	1

Figure 3.1-9. DoD and Technology Space Testing

3.1.3.3 Commercial Communications

The commercial communications sector model was derived from an economic-technical rationale based on historical experience and technological projections.

New technologies introduced to the marketplace often generate a very high rate of economic growth over a substantial number of years. Rapid economic growth occurs, as lower costs made possible by the new technology cause rapid acquisition of a significant market sector for whatever service or product is offered. Examination of historical data suggests that the process begins with an infancy period in which the growth is erratic and often at very high rates. Then an adolescent period occurs, in which the growth rate is more predictable but still quite rapid. This is followed by a period in which the new industry has reached maturity and its growth generally parallels the gross national product. Many industries eventually reach an old age period when growth subsides and decline takes place, even in some instances, entirely phasing out an industry. The trending concept illustrated in Figure 3.1-10 represents this rationale and is based on an examination of historical development of market sectors.

Figure 3.1-11 presents the space telecommunications model created as a part of this study. The economic trending concepts described earlier were used. This model presumes that space communications will acquire a larger and larger sector of the entire telecommunications marketplace until it reaches market saturation sometime in the future. In consonance with the idea of creating low, median and high models, three growth rate levels were presumed. The data on the chart represent the values actually used in the model.

The structure of the model projects economic developments in terms of investment in the industry, and technical trends in terms of technological improvements. These two sets of assumptions then allow derivation of the number and type of satellites launched. Information shown on the chart includes the following model elements: (1) Growth of total telecommunications, representing a ceiling for acquisition of market share by space telecommunications. (2) Growth rates for the space telecommunications sectors of the market. (3) The value of the space segment part of the space telecommunications system, this representing the actual value of assets placed in space. It is important to recognize that as the

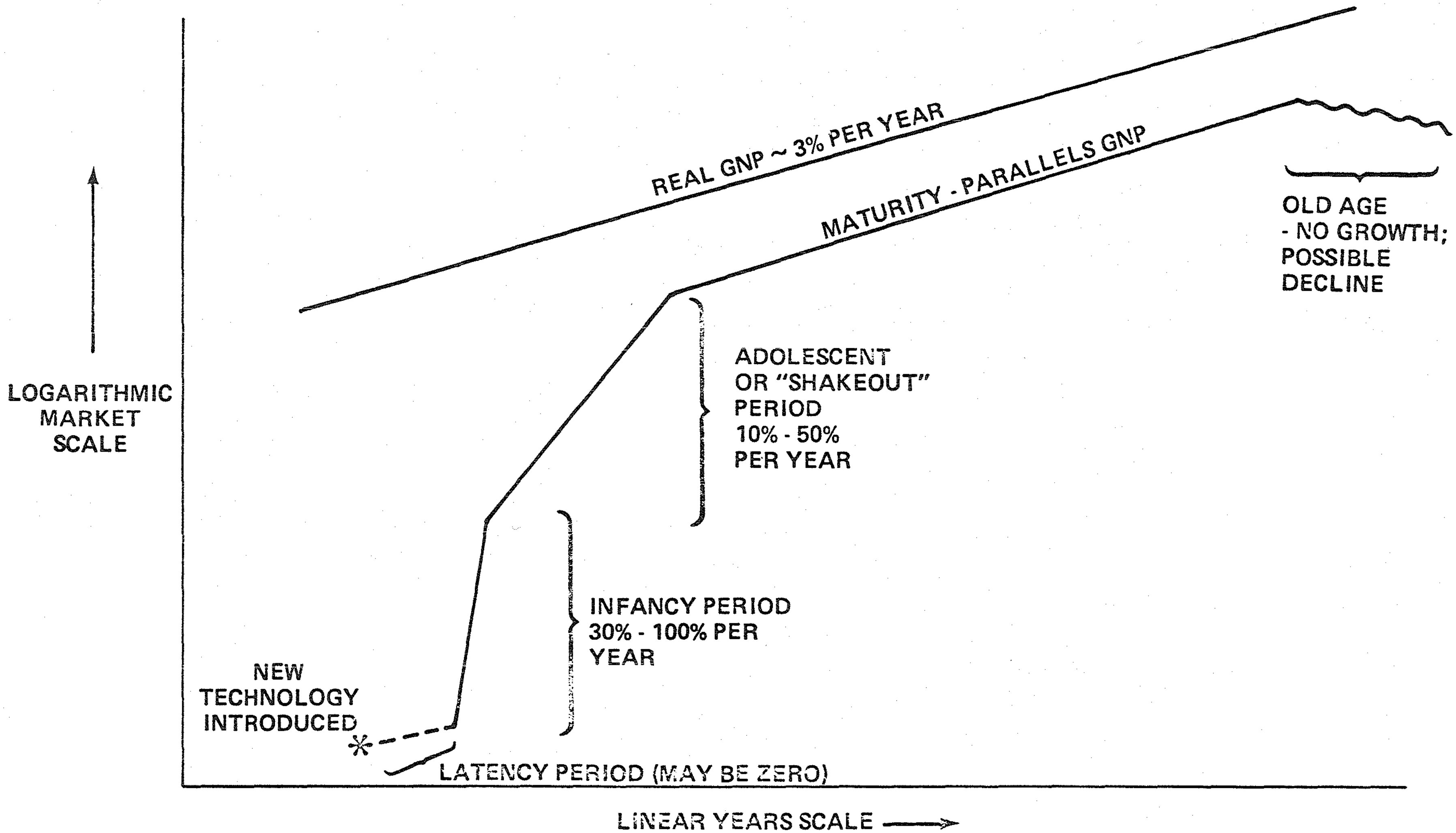
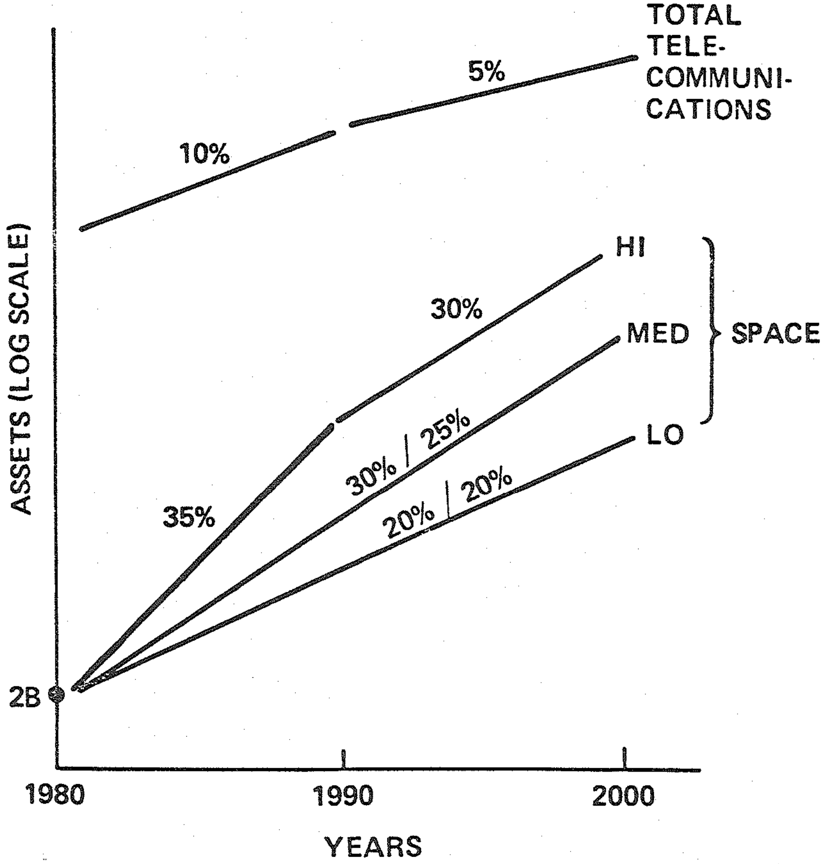


Figure 3.1-10. The Economic Trending Concept

ECONOMIC TRENDING



MODEL ELEMENTS

VALUE, 1980		VALUE, YR 2000 LOW	MED	HI
	VALUE OF SPACE SEGMENT, % OF TOTAL			
50%		20%	10%	10%
	SPACECRAFT COST, $/kg			
25000		14500	13500	10000
	SPACE TRANSPORTATION COST, $/kg			
20000		11000	7200	5000
	PAYLOAD MASS PER TRANSPONDER			
10 kg		3	3	3
	BUS/PAYLOAD RATIO			
3		2	2	2
	REPRESENTATIVE S/C MASS			
1000 kg		3000 Kg	4000 Kg	15000 Kg
	REPRESENTATIVE S/C LIFE			
7 YR		15 YR	15 YR	15 YR
100%	U.S. MARKET SHARE OR TOTAL TELECOM. LAUNCHES	50%	50%	50%

Figure 3.1-11. Space Telecommunications Model Concept

marketplace matures the fraction of the total investment in space telecommunication systems actually launched in space will decline. This is already taking place with the proliferation of ground receivers for television distribution. (4) The cost of spacecraft and space transportation, both expected to gradually decline on a unit mass basis over the next 20 years. The figures used for space transportation costs in the year 2000 are appropriate to a Shuttle with a reusable, aerobraked, high-energy orbit transfer vehicle. (Projections utilized in this study did not presume radical advances in space transportation such as fully reusable heavy lift systems or advanced technology propulsion.) (5) Payload mass per representative transponder based on results of the General Dynamics study of space platforms. (6) The spacecraft bus to payload ratio, also as estimated by the General Dynamics study, is expected to improve as size increases. (7) The representative spacecraft mass is expected to increase to the platform class by the year 2000. The size of the platform was varied as a function of the traffic models. (8) The representative spacecraft life is expected to gradually increase to 15 years. (9) Since this model is for U.S. space operations, a projection was made that the U.S. market share for total telecommunications launches would decrease from the present near 100% market share to about 50%.

The final telecommunications models shown in Figure 3.1-12 were completed by making the parametric economic model results specific in terms of numbers of spacecraft of different sizes to be launched every year. The progression to larger and larger spacecraft was forecast to be gradual with a new, larger size of spacecraft introduced every two to five years, such as has been true in the past. The high model is forecast to grow to bigger spacecraft than the median or low models. Overlap was forecast to occur with as many as three different classes of spacecraft being launched simultaneously in some years. This also is typical of present systems.

The number of communications satellites actually launched in 1981 will be eight, and about five of those will be one-ton class with the other somewhat smaller. Launches of a two-ton class will begin with the initial launches of TDRSS. Section 3.2 of this report presents additional details of the communications model.

CALENDAR YEAR

Model	MASS (TONNES)	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
HIGH MODEL	1	5	3	5	5	5	4														
	2		2	2	3	3	4	4	3												
	3					1	2	5	9	10	10	5									
	4									2	5	6	10	10	7	5					
	5											2	5	5	7	8	7	5			
	7													2	5	7	15	20	28	28	23
	10																	1	2	5	15
	TOTAL	5	5	7	8	9	10	9	12	12	15	13	15	17	19	20	22	26	30	33	38
MEDIAN MODEL	1	5	3	4	3	3	5	2	2												
	2		1	1	2	3	3	4	5	2											
	3							1	2	6	9	6	8	8	7	8	6	2			
	4											1	1	2	3	4	6	11	14	12	15
	7																1	1	2	3	4
	TOTAL	5	4	5	5	6	8	7	9	8	9	7	9	10	10	12	13	14	16	15	19
LOW MODEL	1	3	2	2	3	3	4	3	4	3	2										
	2		1	1	1	2	2	3	3	3	5	5	5	5	1						
	3									1	1	1	3	3	7	6	7	8	8	9	11
	5															1	2	2	3	3	4
	TOTAL	3	3	3	4	5	6	6	7	7	8	6	8	8	8	7	9	10	11	12	15

Figure 3.1-12. Telecommunications Models

3.1.3.4 Military Mission Model

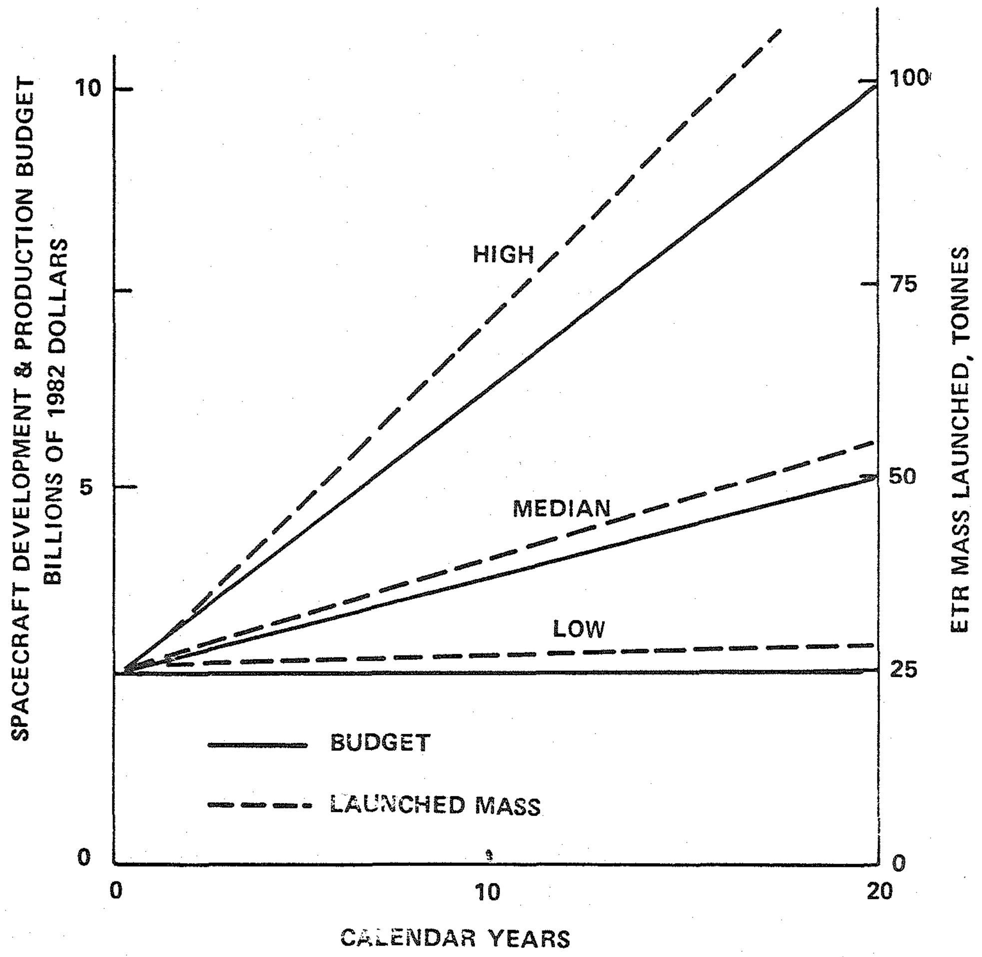
In the creation of an unclassified military mission model, the available DoD sources cannot be utilized because they are classified, with even some names of payloads classified. Almost all of the size and mass data necessary for a specific analysis were also classified. Finally, these plans do not generally predict far enough into the future to be very useful for a SOC mission model in which payload activity would begin about 1990. Unclassified sources permit projection of general types of missions.

Because we could not use classified models, we developed a budget-driven model that we feel is realistic. Again, three levels were developed: low, median and high.

We employed a simplification of not considering the WTR launches excepting in our projection of the total demand for space transportation. These launches are presumed to use 40% of the available launches and represent 70% of the launched spacecraft mass inasmuch as WTR launches generally are destined for relatively low Earth orbits, whereas ETR launches are typically destined for geosynchronous orbit; the spacecraft mass that can be launched with a Shuttle flight is substantially less than that for WTR. Finally, for purposes of analysis it was assumed that all ETR launches go to geosynchronous orbit. Even though some may go to other orbits, all of the high energy orbits represent approximately the same transportation challenge.

Figure 3.1-13 presents the budgetary assumptions used in the military model. The low model assumes a cessation of historical growth in military space spending, the median model projects a continuation of historical trends, and the high model presumes that space utilization increases with new classes of military missions.

The derived mission models for the three military model levels are presented in Figure 3.1-14. These models do not include WTR launches nor do they include space testing at SOC as the latter was included in an earlier sector. Section 3.5 of this report presents additional details of the military mission model.



- LOW MODEL
  - NO SIGNIFICANT CHANGE IN USES OF SPACE
  - GRADUAL GROWTH OF AVERAGE SPACECRAFT MASS TO 5000KG BY END OF CENTURY
- MEDIAN MODEL
  - ASAT THREAT LEADS TO BUDGET GROWTH FOR SPACE DEFENSE
  - SPACECRAFT MASS GROWTH SAME AS LOW MODEL
  - MANNED ACTIVITY ONLY FOR SPACE TESTING AT A NATIONAL SPACE STATION
- HIGH MODEL
  - SPACE EVOLVES TO THEATER OF CONFLICT
  - SPACECRAFT AVERAGE MASS GROWTH TO 10,000 KG
  - SMALL MILITARY MANNED

Figure 3.1-13. Military Mission Model Budgetary Assumptions

	CALENDAR YEAR											
LOW	89	90	91	92	93	94	95	96	97	98	99	200
1-TONNE CLASS	3	2	2	2	2	2						
2-TONNE CLASS	4	3	3	3	3	3	2	2	2	2	2	2
3-TONNE CLASS	3	3	3	3	3	3	3	3	3	3	3	3
MEDIAN												
1-TONNE CLASS	3	2	2	1	1							
2-TONNE CLASS	6	5	5	5	5	4	4	4	3	3	2	1
3-TONNE CLASS	6	5	5	4	4	5	3	3	2	2	2	3
5-TONNE CLASS		2	2	3	4	4	5	5	5	6	5	5
10-TONNE CLASS									1	1	2	2
HIGH												
1-TONNE CLASS	3	2	2	1	1							
2-TONNE CLASS	6	5	5	5	5	4	4	4	3	3	2	1
3-TONNE CLASS	6	5	5	4	4	5	3	3	2	2	2	3
5-TONNE CLASS		4	4	6	8	8	6	6	8	10	10	10
10-TONNE CLASS				1	1	1	2	2	2	3	4	4
MANNED STATION						1	1					
MANNED STATION RESUPPLY							2	4	4	4	4	4

NOTE: SPACE TESTING AT SOC NOT INCLUDED IN THESE PAYLOADS

Figure 3.1-14. Military Mission Models

3.1.4 SOC UTILIZATION ANALYSIS

3.1.4.1 Analysis Procedure

The mission models described above provide forecasts of mission events to be accomplished each year in a U.S. space program. Before the SOC operations analysis could be conducted, it was necessary to convert the mission models into traffic models. Since one of the functions of SOC is to serve as an element of space transportation systems, it is necessary to understand the space transportation requirements imposed by the mission models.

Traffic models were created by determining the space transportation traffic needed to accomplish each of the mission models. With the transportation traffic models created, the SOC operations analysis was then conducted to determine what SOC operations must take place, and what crew skills and man levels are required for a variety of mission models and transportation options. The general logic is shown in Figure 3.1-15.

Because the analysis is quite tedious and highly repetitive, an automated system was created to conduct the SOC utilization analysis. This automated system consists of four modular software units that communicate through data files, as diagrammed in Figure 3.1-16.

The first software element is a file-handling code which reads a sequential mission description file and converts this file into random-access format files for the transportation manifesting analysis and for the crew activities and facility utilization analysis.

The second element of the program is a manifesting code which organizes the payload and traffic model data for actual manifesting analysis. This code creates mission traffic listings and also has the capability to generate plots of payload mass versus calendar time.

The actual manifesting analysis is done by the third element of this modular system. It reads the files created by the other elements and provides a manifesting results listing. It also provides a year-by-year file that is the principal input to the crew activities and facility utilization analysis.

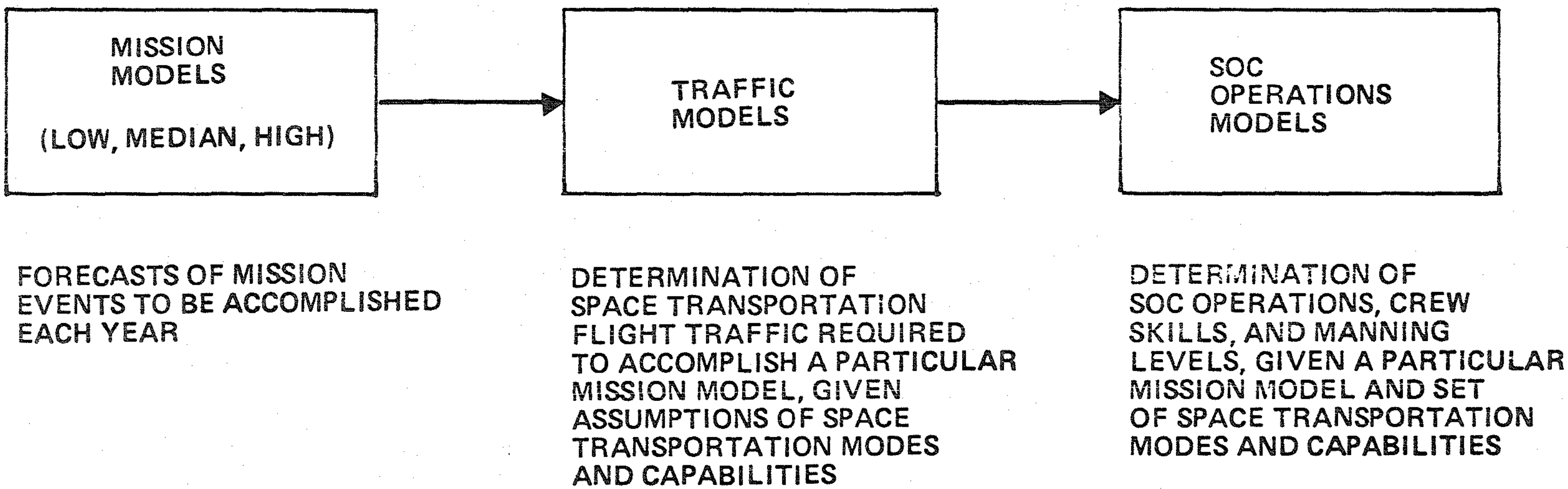


Figure 3.1-15. SOC Utilization Analysis Elements

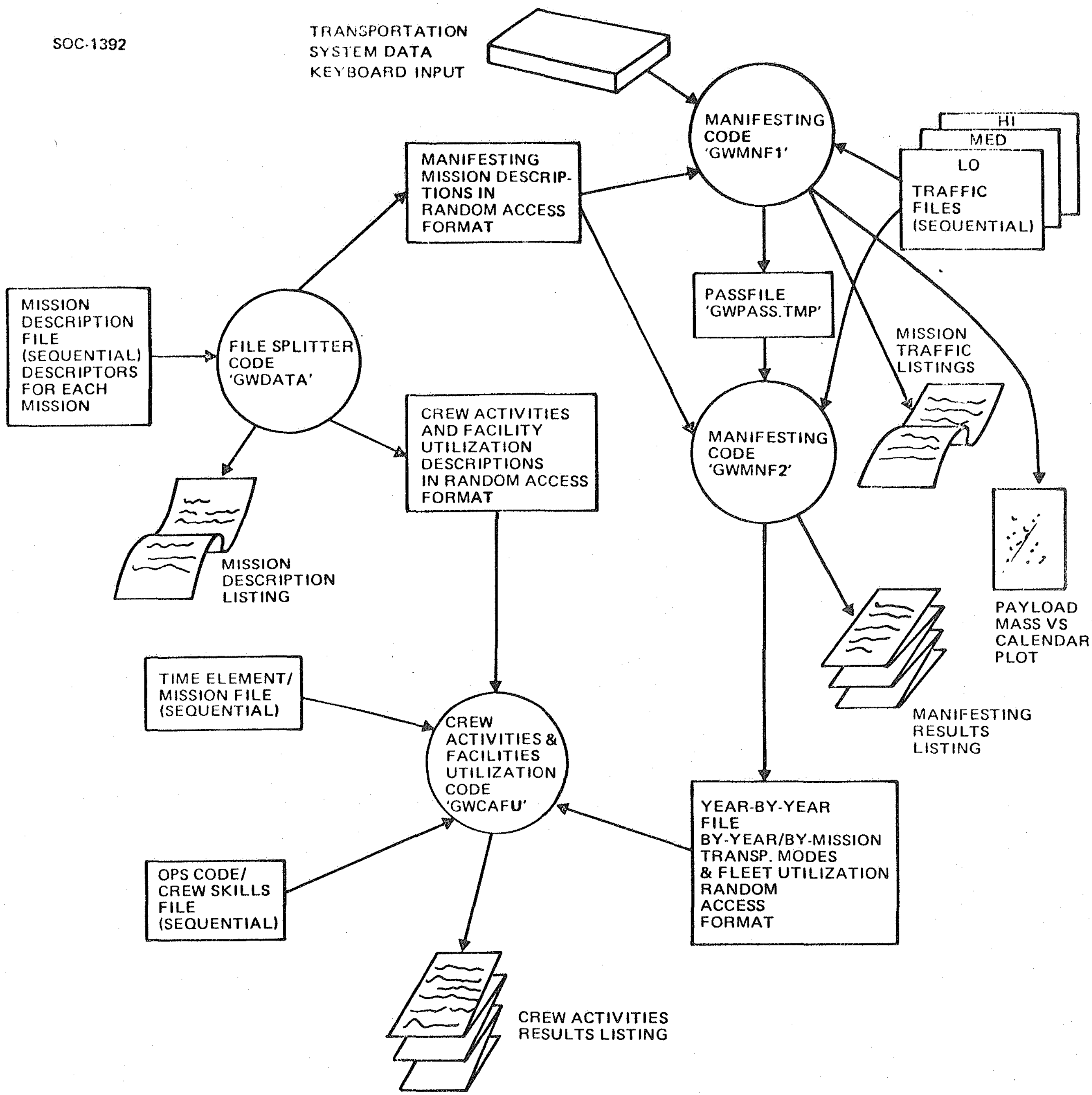


Figure 3.1-16. Automated SOC Utilization Analysis System

The fourth element of the software system determines SOC crew activities and facility utilization, based on the transportation operations descriptions created by the manifesting analysis.

Table 3.1-3 presents a sample of the payloads data used by these programs. This sample includes some payloads delivered to SOC as indicated by the delta v's being zeroes.

Research and applications man-level information is also listed in this file, and is flagged so that the transportation manifesting code recognizes this as a man-level pass-through to the crew activities code. No manifesting is conducted for these mission elements.

In addition to the payloads physical data, a variety of time information is provided in order to ascertain crew activities required for such missions as satellite servicing and space construction.

The mission model also includes traffic information. Illustrated in Table 3.1-4 is a sample of such information for the flight support part of the mission model. This segment of flight support information is for the low traffic model. As can be seen by the numbers on the left, many of the payloads have been skipped for this low traffic model. Also the man-level missions are not counted as flight support missions.

Complete listings of mission model and payloads information are presented in Sections 8.1 through 8.4 of this report.

3.1.4.2 Manifesting Analysis

The manifesting code analyzes each traffic model year-by-year and mission-by-mission. The logic is diagrammed in Figure 3.1-17. At user option, either ground- or space-basing of the OTV can be selected. In either case the first step is to select an appropriate OTV mode if an OTV is required. For the ground-based logic, if a payload and OTV cannot be integrated on a single Shuttle flight the payloads and OTVs are loaded into a holding array. Payloads not requiring an OTV

Table 3.1-3. Payloads Descriptions (Sample)

NO.	CODE	NAME	ORBIT ALT	ORBIT INCL	DELTA V'S UP	DELTA V'S DOWN	DELTA V'S A/B	MASSES SUPT	MASSES PAYLD	MASSES RET	LENGTHS SUPT	LENGTHS PAYLD	PAYLD DIA	MANIF RESTR	OPS CODE	TIMES UP/DN	TIMES ON ORB	TIMES MAINT DELTA	TIMES REP-AIR	TIMES RE-FURB	TIMES RE-SUPP	TIMES EXP-ERMT	LENGTH BEAM FAB	NO OF APP	NO OF MODULES
1	MP01	DEL SHORT EXP MODULE	370	28.5	0	0	0	0	5568	5568	0.00	4.27	4.06	0	MP	2.00	2.00	0.00	0.00	0.00	0.00	0.00	0	0	1
2	MP02	DEL FULL EXP MOD	370	28.5	0	0	0	0	8431	8431	0.00	6.97	4.06	0	MP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
3	MP03	DEL EXP PALLET	370	28.5	0	0	0	0	1437	1437	0.00	2.88	4.49	0	MP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
4	MP04	MPEXP MANLEVEL	0	0.0	0	0	0	0	0	0	0.00	0.00	0.00	0	MPO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
5	MP05	DEL PROC DEV MOD	320	28.8	0	0	0	0	8431	8431	0.00	6.97	4.06	0	MPP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
6	MP06	MPDEV MANLEVEL	0	0.0	0	0	0	0	0	0	0.00	0.00	0.00	0	MPO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
7	MP07	RESUPPLY PROD	0	0.0	0	0	0	0	3000	0	0.00	0.00	4.00	0	SIS	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0	0	0
8	MP08	MPPROD MANLEVEL	0	0.0	0	0	0	0	0	0	0.00	0.00	0.00	0	MPO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
9	MP09	DEL PRODUC SC	370	28.5	0	0	0	0	10000	0	0.00	12.00	4.49	0	MPP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
10	LS01	DEL LS RSH MOD	370	28.5	0	0	0	0	10346	0	0.00	6.97	4.06	0	LS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
11	LS02	DEL CELSS MOD	370	28.5	0	0	0	0	10346	0	0.00	6.97	4.06	0	LS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
12	LS03	DEL LS CENTMOD	370	28.5	0	0	0	0	5077	0	0.00	4.27	4.06	0	LS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
13	LS04	LS CENT MANLEVEL	0	0.0	0	0	0	0	0	0	0.00	0.00	0.00	0	LSO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
14	LS05	LSEXP MANLEVEL	0	0.0	0	0	0	0	0	0	0.00	0.00	0.00	0	LSO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
15	DO01	DEL DOD SMPALLET	370	28.5	0	0	0	0	1450	1450	0.00	2.00	2.00	0	DD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
16	DO02	DEL DOD LGPALLET	370	28.5	0	0	0	0	6200	6200	0.00	5.00	1.00	0	DD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
17	DO03	DOD RES MANLEVEL	0	0.0	0	0	0	0	0	0	0.00	0.00	0.00	0	DDO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
18	DO04	DEL 1-TON SPACFT	35786	0.0	4398	4412	2210	0	1000	0	0.00	2.80	3.00	0	NIL	2.00	1.00	0.00	0.00	0.00	0.00	0.00	0	0	0
19	DO05	DEL 2-TON SPACFT	35786	0.0	4398	4412	2210	0	2000	0	0.00	5.60	3.00	0	NIL	2.00	1.00	0.00	0.00	0.00	0.00	0.00	0	0	0
20	DO06	DEL 3-TON SPACFT	35786	0.0	4398	4412	2210	0	3000	0	0.00	4.77	4.00	0	NIL	2.00	1.00	0.00	0.00	0.00	0.00	0.00	0	0	0

Table 3.1-4. Low Traffic Model (Sample)

Flight Support Traffic Model

NO.	KEY	PAYLOAD DESCRIPTION	89	90	91	92	93	94	95	96	97	98	99	00
									TRAFFIC MODEL YEAR					
1	MP01	DEL SHORT EXP MODULE				1	1	1	1	1	1	1	1	1
3	MP03	DEL EXP PALLET			1	1	1	1	1	1	1	1	1	1
5	MP05	DEL PROC DEV MOD						2	4	4	4	4	4	4
10	LS01	DEL LS RSH MOD								1				
15	D001	DEL DOD SMPALLET		1		1		1		1		1		1
16	D002	DEL DOD LGPALLET	1		1		1		1		1		1	
18	D004	DEL 1-TON SPACFT	3	2	2	2	2	2						
19	D005	DEL 2-TON SPACFT	4	3	3	3	3	3	2	2	2	2	2	2
20	D006	DEL 3-TON SPACFT	3	3	3	3	3	3	3	3	3	3	3	3
21	D007	DEL 5-TON SPACFT		1	2	2	2	2	3	3	3	3	3	3
26	OT02	SOC CREW ROT. AND RESUPPLY	4	4	4	4	4	4	4	4	4	4	4	4
27	C001	1-TON COMSAT	3	2										
28	C002	2-TON COMSAT	3	5	5	5	5	1						
29	C003	3-TON COMSAT	1	1	1	3	3	7	6	7	8	8	9	11
31	C005	5-TON MINIPLAT							1	2	2	3	3	4
34	M008	SV COMM PLATS								2	2	3	3	4
35	AA01	DEL/RET SPACE TELESCOPE		1	1					1	1			
36	SS02	SV SPACE TELE					1						1	
37	AA04	DEL/RET GAMMA RAY OBSERV		1										
39	AA07	DEL/RET X-RAY ASTROPHYS FAC			1					1	1			
40	SS08	SERVICE X-RAY ASTROPHYS FAC					1						1	
41	AA10	DEL/RET COSMIC RAY OBS							1			1		
42	AA13	DEL VLBASE INTER											1	
44	AA16	DEL INT UVEXPL	1											
46	AA26	DEL SOLAR PROBE											1	
50	PL02	DEL LUNAR POLAR ORB												1
52	PL04	ASTEROID MULT. RENDEZVOUS												1

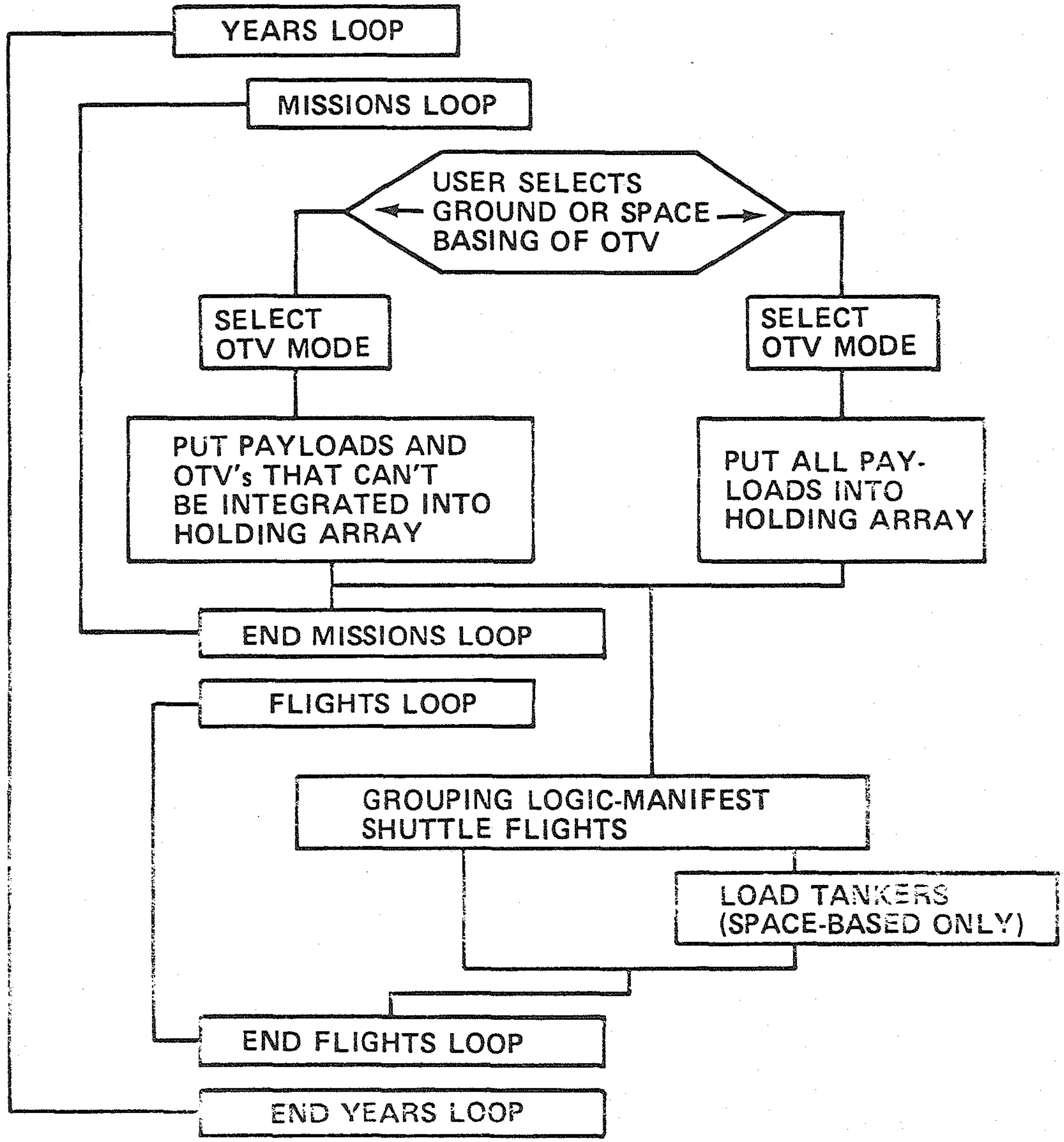


Figure 3.1-17. Manifesting Logic General Flow

are loaded into the same array. For the space-based option the OTV modes are selected, following which all payloads are loaded into the holding array.

These steps complete the missions loop. At this point a transition is made from analyzing the model mission-by-mission to analyzing it Shuttle-flight-by-Shuttle-flight. A payload grouping logic manifests Shuttle flights using all the payloads in the holding arrays. In addition, for the ground-based case, payloads that can be manifested with their own OTV are also manifested on Shuttles. In the space-based case, it is then necessary to manifest tanker flights in order to bring up enough propellant to accomplish the year's missions. This completes the flights loop. When all of the years of the traffic model have been completed, then the manifesting code prints the manifesting analysis results and generates the files required for the crew activities analysis.

The manifesting logic selects from among nine ground-based OTV modes or five space-based modes. These modes are listed in Table 3.1-5. The mode for each mission is selected to provide the least cost, considering Shuttle and OTV costs. In the event a mission cannot be accomplished by the most capable OTV mode available, the software flags the mission as not achievable, but it charges the space transportation system with the most difficult applicable mode so that faulty comparisons do not arise from not manifesting missions in one case that are manifested in another.

Aerobraking operations are simulated by adjusting the delta v and the inert weight of the OTV to represent the delta v savings of the aerobraking pass and the increased inert weight of the aerobraking equipment.

On the left of Figure 3.1-18 is shown the ground-based OTV manifesting logic. Whenever possible, a payload is manifested with its own OTV in a Shuttle flight. In such an instance, SOC operations are not required unless the payload requires some sort of servicing from a SOC (such as construction). If necessary, the OTVs and payloads are manifested separately, in which case these OTVs and payloads go through the grouping logic to improve transportation manifesting whenever possible.

GROUND-BASED MODES

1 — SINGLE-STAGE, MATCHED WITH PAYLOAD & REUSED

2 — SINGLE-STAGE, MATCHED WITH PAYLOAD & EXPENDED

3 — SINGLE-STAGE, NOT MATCHED WITH PAYLOAD BUT REUSED

4 — SINGLE-STAGE, NOT MATCHED WITH PAYLOAD, EXPENDED

5 — TANDEM-STAGE, UPPER MATCHED WITH PAYLOAD, ALL REUSED

6 — TANDEM-STAGE, UPPER MATCHED WITH PAYLOAD, UPPER EXPENDED

7 — TANDEM-STAGE, NOT MATCHED WITH PAYLOAD, ALL REUSED

8 — TANDEM-STAGE, NOT MATCHED WITH PAYLOAD, UPPER EXPENDED

9 — CAN'T DO MISSION

SPACE-BASED MODES

1 — SINGLE-STAGE, REUSED

2 — SINGLE-STAGE, EXPENDED

3 — TANDEM-STAGE, REUSED

4 — TANDEM-STAGE, UPPER EXPENDED

5 — CAN'T DO MISSION

- AEROBRAKING SIMULATED BY ADJUSTING DELTA V AND INERT WEIGHT
- SELECT LEAST-COST MODE THAT CAN DO MISSION, CONSIDERING SHUTTLE AND OTV COST

Table 3.1-5. OTV Mode Selection

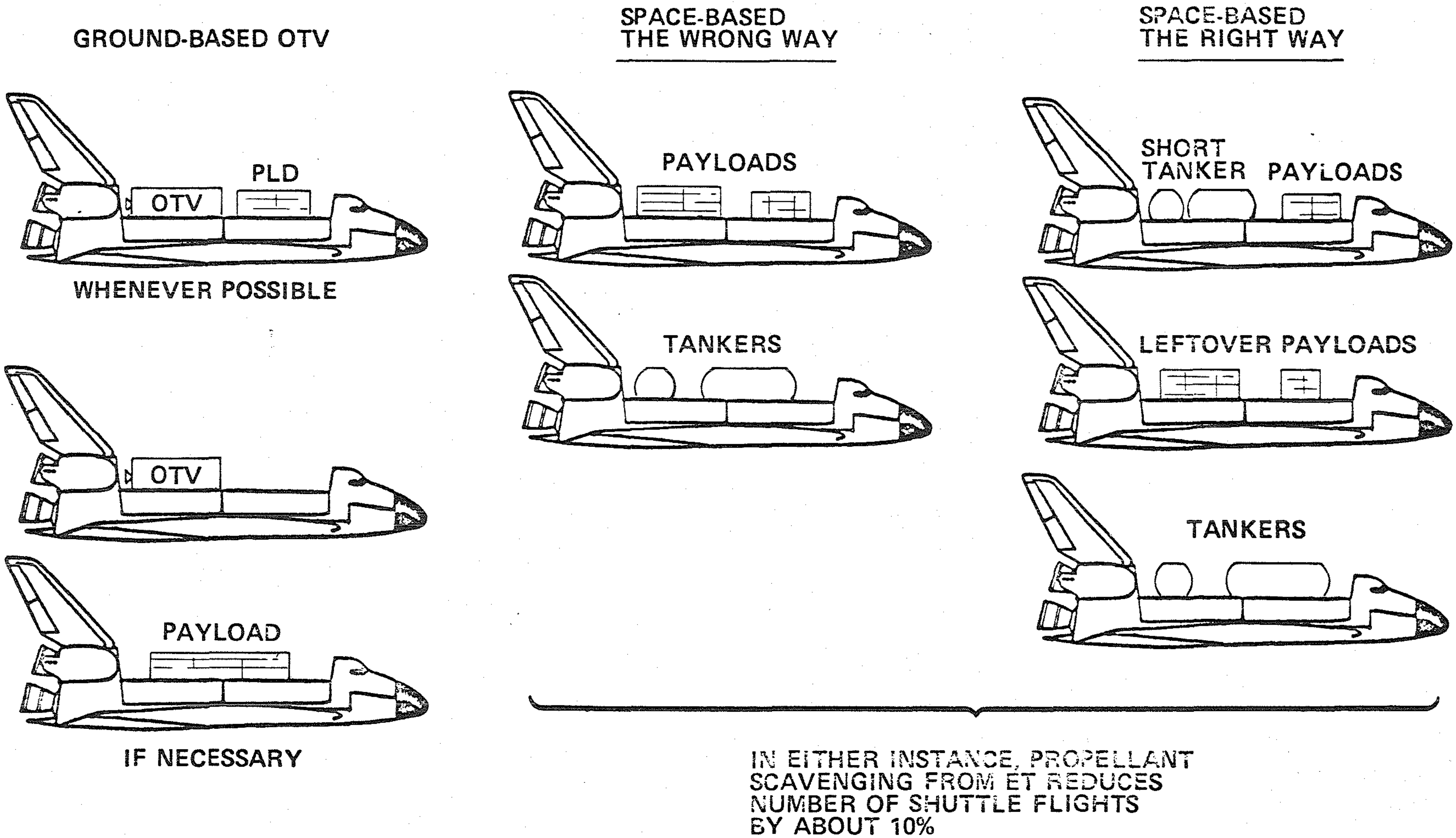


Figure 3.1-18. Space Shuttle Manifesting Options

The center diagram shows the space-based manifesting logic that was used earlier in the SOC study. This logic loaded all payloads into the holding array, manifested payloads together whenever possible, and then completed the year's flights by loading enough tankers to provide the propellant required for the year's missions. This manifesting mode turned out to be relatively inefficient inasmuch as the manifesting of payloads together ordinarily resulted in volume-limited rather than mass-limited flights.

On the right hand we show an improved space-based manifesting logic. Shuttle center of gravity constraints will allow approximately 20,000 pounds of payload to be loaded in the front of the Shuttle payload bay if a reduced-capacity tanker is placed in the back of the payload bay. Approximately the same payload is allowable whether the tanker is full or empty. Accordingly, a short tanker was designed with a propellant capacity of about 40,000 pounds. The manifesting logic manifests as many payloads with this short tanker as can be so manifested within the payload bay length and mass limits available. Those payloads that cannot be so manifested are then grouped together for additional Shuttle flights. Finally, any full-capacity tankers that may be necessary to bring up the balance of propellant required are manifested.

In either of the space-based cases, propellant scavenging from the ET reduces the number of Shuttle flights by about 10%. Propellant scavenging can be used to increase the mass loading of either the short tanker or the full tanker. In addition, when payloads manifested together have space available in the back of the payload bay for a small catch tank set, additional propellant can be brought up on payload flights.

Five OTV operating modes were analyzed in this study. These are compared in Figure 3.1-19. The results presented are for the median mission model, for ETR launches only.

A space transportation cost indicator was used, this being the number of Shuttle flights required plus the number of OTVs expended. Although neither the cost of an OTV nor the cost of a Shuttle flight are accurately known, it is presently thought that these costs are roughly comparable.

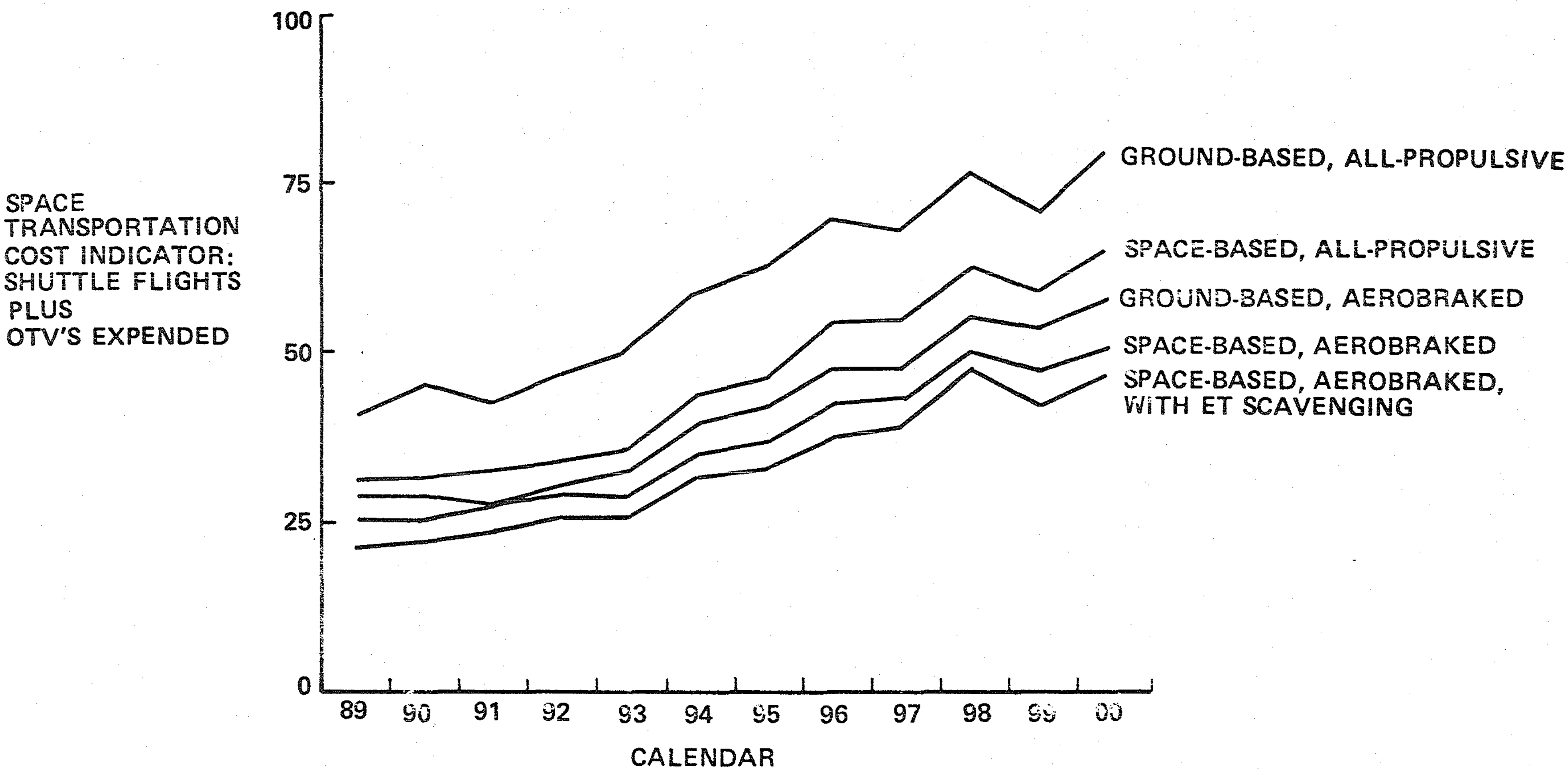


Figure 3.1-19. Comparison of OTV Operating Modes Median Mission Model ETR Only

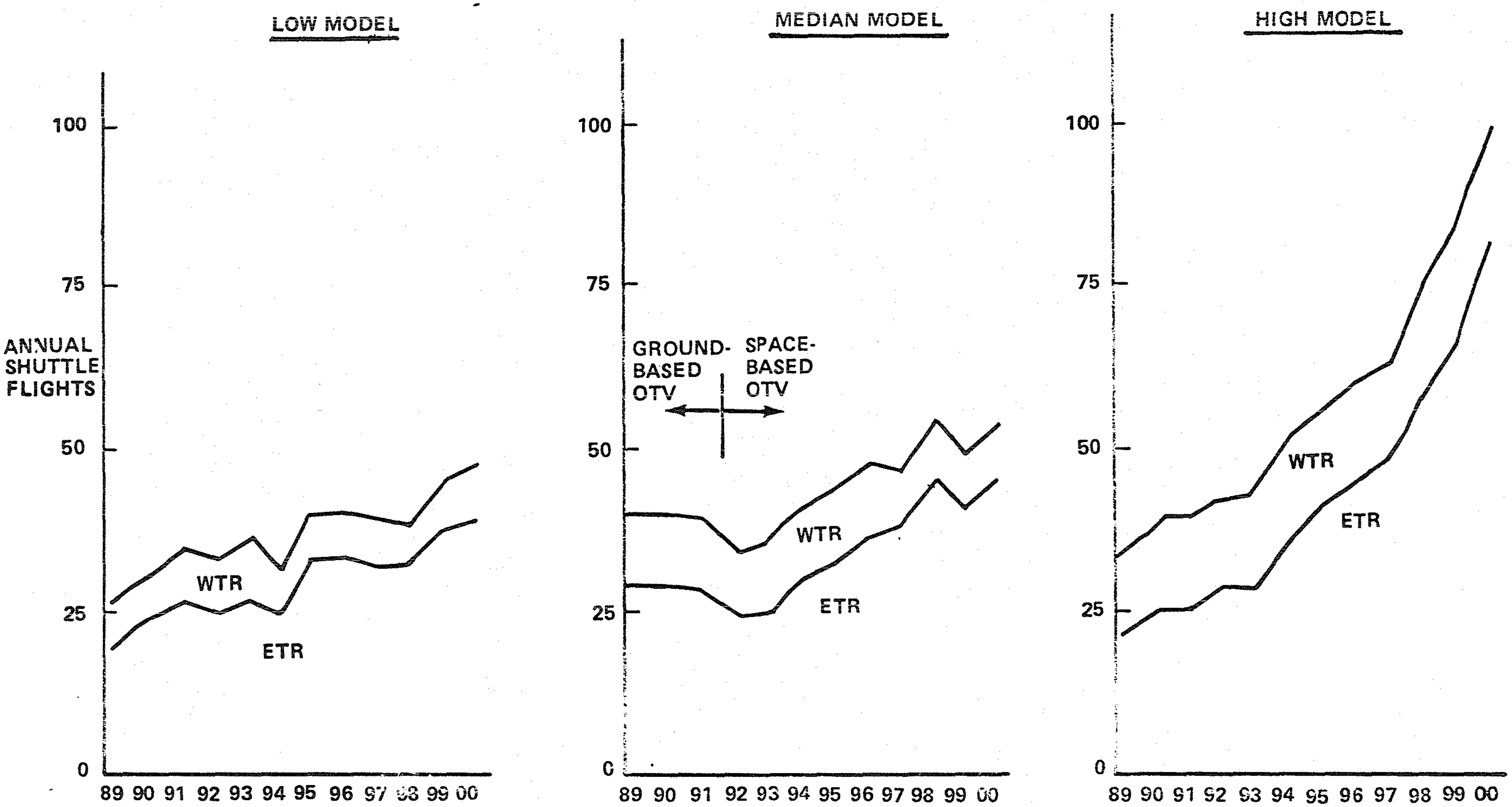
The comparison shows that the greatest leverage in reducing space transportation costs arises from the use of aerobraking in either the ground- or space-based case. The comparison also shows that space-basing offers an advantage of about 10% over ground-basing in the aerobraking case. Finally, the addition of ET scavenging adds about another 10%. The difference between the least effective OTV mode, ground-based or propulsive, and the most effective mode represents approximately a 40% reduction in the number of Shuttle flights required to accomplish the median traffic model.

The automated analysis did not process WTR-launched payloads and certain small payloads inasmuch as it is presently not expected that these would be involved in SOC operations. To complete the picture for the space transportation analysis, the WTR launches were included in a total space transportation demand forecast. The demand forecast for the three models is presented in Figure 3.1-20. This forecast assumes that space-based aerobraked OTVs are employed and that ET scavenging is implemented.

The total demand forecast for the low and median models is quite similar because the space transportation systems are used somewhat more effectively in the median models. There are more opportunities for payload grouping; on the average, the payloads are somewhat larger. The high model reflects a rapid growth in space transportation demand approaching 100 Shuttle flights per year by the year 2000.

The high model represents a scenario in which extensive commercial investments in space activities would occur along with a significant level of military operations. An assumption consistent with the high model scenario is one that would presume a development of a second generation space transportation system by the mid-1990s.

Table 3.1-6 lists the payloads that were deleted from the SOC mission model as they do not involve the SOC for one reason or another.



NOTE: THIS DEMAND FORECAST ASSUMES:

1) TRANSITION TO SPACE-BASED OTV IN 1992
2) ALL OTV's ARE AEROBRAKED
3) ET SCAVENGING IS IMPLEMENTED FOR SPACE-BASING

Figure 3.1-20. Total Space Transportation Demand Forecast (Aerobraked OTV)

Table 3.1-6. Additional Payloads (Excluded from Automated Processing Model)*

MISSION	Length (M)	Dia. (M)	Weight (KG)	High Traffic Model: 9	0	1	2	3	4	5	6	7	8	9	0
Cosmic Background Explorer	4.8	4.4	1421	R											
Extreme UV Explorer	4.5	2	400	R											
X-ray Timing Explorer	4	2	1000	R						D		R			
Solar Corona Explorer	3.5	3	1000	D				R							
Gravity Probe B	4.2	4.2	1270			R									
X-ray Spectroscopy	3	2	1500									D			R
Soft X-ray Survey	4	3	1600									D			R
Submillimeter Telescope	12	4.5	1000												D
Molecular Line Survey	3	3.5	1000									D			S
Extreme UV Spectroscope	4	3	1000							D					R
Landsat D	3	2	1597	D	R	D		R		D					
Magsat B	.9	.9	272							D	R				
Gravsat	4	1.2	4000					D	D						
Water Quality Monitor	3.5	2.5	1000						D				R		
Landsat E	4.3	2.2	1700							D	D	D	R	R	R

MISSION	Med. Traffic Model: 9	0	1	2	3	4	5	6	7	8	9	0
Cosmic Background Explorer		R										
Extreme UV Explorer		R										
X-ray Timing Explorer		R							D		R	
Solar Corona Explorer		D				R						
Gravity Probe B		D			R							
X-ray Spectroscopy												D
Soft X-ray Survey												D
Submillimeter Telescope												
Molecular Line Survey												D
Extreme UV Spectroscope									D			
Landsat D	D	R			D/R				R			
Magsat B												
Gravsat						D		D				
Water Quality Monitor							D				R	
Landsat E									D		D	D/R

MISSION	Low Traffic Model: 9	0	1	2	3	4	5	6	7	8	9	0
Cosmic Background Explorer		R										
Extreme UV Explorer		R										
X-ray Timing Explorer	D		R									
Solar Corona Explorer		D				R						
Gravity Probe B		D			R							
X-ray Spectroscopy												
Soft X-ray Survey												
Submillimeter Telescope												
Molecular Line Survey												
Extreme UV Spectroscope												
Landsat D												
Magsat B												
Gravsat							D				D	
Water Quality Monitor												D
Landsat E												

* Excluded because not considered missions involving potential [illegible] involvement.

D = Delivery
R - Retrieve

Table 3.1-6. *Additional Payloads (Excluded from Automated Processing Model*)*

MISSION	Length (M)	Dia. (M)	Weight (KG)	High Traffic Model												Med. Traffic Model												Low Traffic Model											
				9	0	1	2	3	4	5	6	7	8	9	0	9	0	1	2	3	4	5	6	7	8	9	0	9	0	1	2	3	4	5	6	7	8	9	0
Thermal Mapping	2.5	2	1450									D															D												
Adv Geology Satellite	4	3	2000										D												D														
Private Earth Resource	4.3	2.2	1700				D/R								R				D/R								R				D/R								R
Magnetic Field Survey	3.5	2.5	800											D																									
National Ocean Satellite	10.7	4.5	4500	R	D		R			D				D/R					D				R										D				R		
Earth Radiation Budget	4	2.1	1134			D											R	D		R								D		R		D		R					
Upper Atmosphere Research	4	2	3700				D					R								D				R										D			R		
NOAA – H&I	8	3.7	4173	R					D				R			R						D				R		R										D	
Topex	4	3	1000							R											D			R											D			R	
Operational Meteor Sat	10	4.5	4500	D				R								D				R								D				R							
Global Atm. Monitor	8.5	3.4	2381												D																								
Ocean Research	6	4	3000										D																										
Chem Rel Module	2	3	2700																																				
Origin of Plasma	3.5	3	1000																									T3											
Solar Cycle & Dynamics	4.6	2.4	2600						D	R					D							D		R														D	
Subsat Facility	1.5	1	500	D/S R	[illegible]	D/S R	D/S R	D/S R								D/S R	D/S R	D/S R	D/S R	D/S R	D/S R							D/S R	D/S R	D/S R	D/S R	D/S R	D/S R						
Heavy Nuclei Explorer	4	4	4000							D					R									D															
Solar Terr Observatory	15	4.5	20000												D																								

3.1.4.3 SOC Crew Activities Analysis

The crew activities analysis operated on the results of the manifesting analysis and employed additional input data as noted on an earlier chart. The crew activities analysis operates on a year-by-year basis and examines each Shuttle flight as manifested in sequence.

Figure 3.1-21 illustrates the Shuttle functions analysis in more detail than the other functions. Since a Shuttle may carry two payloads in addition to a tanker, the Shuttle functions for the first payload are identified. Those functions required are marked by setting flags. Then these functions are manloaded using a function-versus-skills matrix. Secondly, the Shuttle functions required for the second payload are then identified. A flag flip-flop routine is used to avoid double counting of Shuttle functions. In other words, if an Orbiter arrival operation is required for the first payload, the flag flip-flop prevents that arrival operation from being counted again for the second payload. The functions for the second payload are then manloaded using the functions skills matrix. In a similar manner, OTV functions, construction functions, satellite servicing functions and onboard science and applications functions are analyzed. These are then summed up and printed for each flight. Following the analysis of all the flights in each year, they are summed up and printed for the year.

Table 3.1-7 is an example of the crew skills matrix used to compute SOC crew skills requirements and manloading requirements. On the left-hand side are indicated five Orbiter functions that may occur for any particular payload delivery. The analysis logic selects those functions that are applicable to a particular flight. The time estimates in the second column represent the number of days required to accomplish a particular function. These represent days of continuous work. An Orbiter offloading activity is estimated to require 6/10ths of a day, representing 14.4 hours of continuous manned operations. As indicated in the body of the matrix, three skills would be required full time during this 14.4 hours of activity for Shuttle offloading.

Continuous hours of work are adjusted for actual shift operations and days off to determine calendar time required to accomplish a particular set of functions for a particular mission.

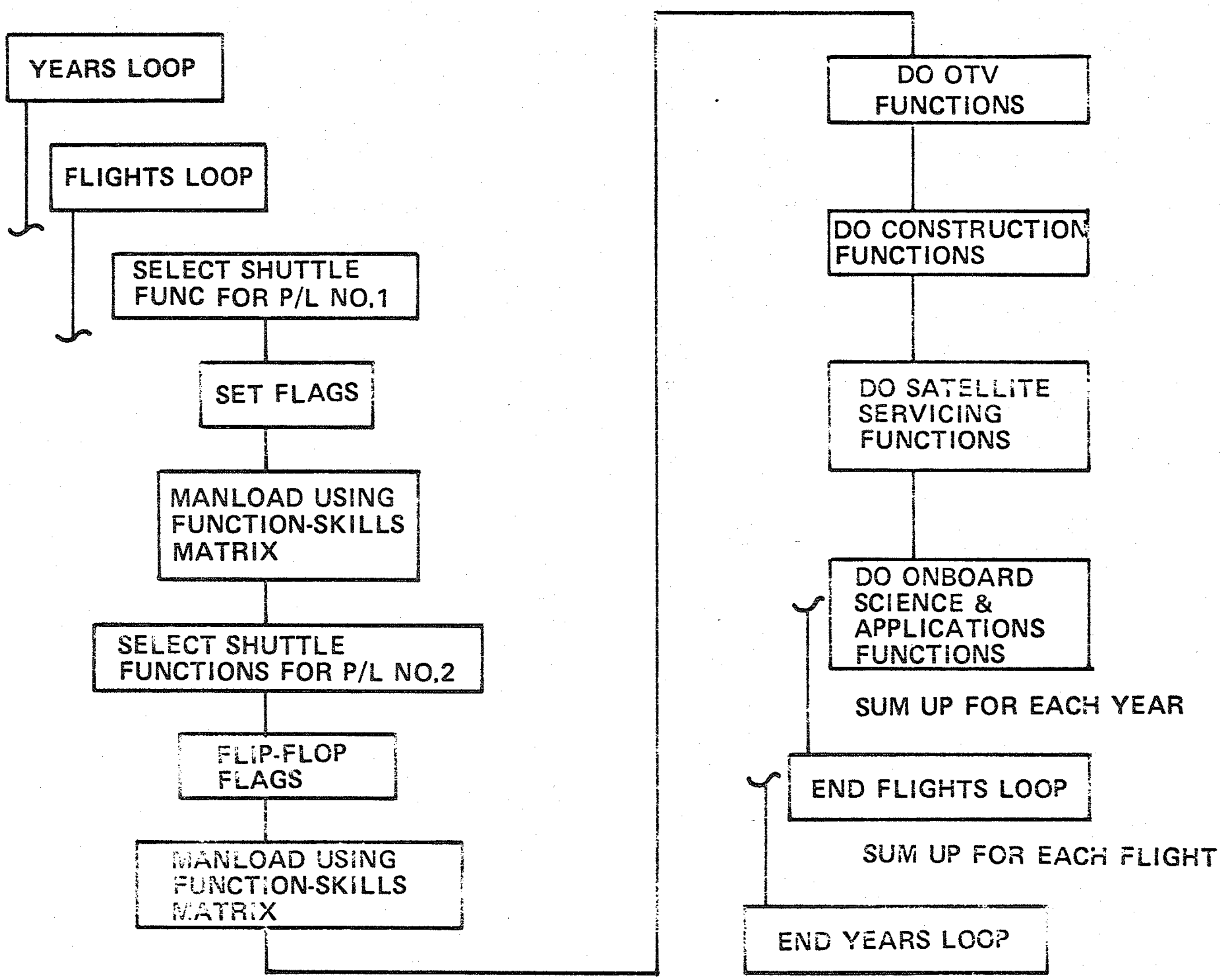


Figure 3.1-21. Crew Activities Analysis Overall Logic

Table 3.1-7. Shuttle SOC Crew Skills Matrix

SOC-1398

NO.	ITEM	TIME	IVA OPERATOR	EVA C/P OPERATOR	EVA WORKER	TEST & C/O ENGR	ELEC/MECH ENGR	PROP/FLUIDS SPCLST	FLT CONTR/SYS ENGR	PILOT	MATLS SPCLST	VISITING RESEARCHER	LIFE SCI SPCLST/DR	GENERAL
1	ORBITER ARRIVE	0.0416	100						50					
2	ORBITER OFFLOAD	0.60	100	100	100									
3	ORBITER RELOAD	0.60	100	100	100									
4	ORBITER DEPART	0.021	100						100					
5	ORBITER PROP. X-ER	.5417	100				25	100						
	ORBITER WAIT													
	RESERVED													
	RESERVED													

Similar matrices were used for the OTV construction and satellite servicing functions. A slightly different mechanism was used to estimate the required science and applications functions inasmuch as the research manlevels were passed through from the traffic model.

3.1.5 CONCLUSIONS

Consideration of whether to base OTVs in space or on the ground requires evaluation of the SOC requirements as well as evaluation of the transportation requirements. Shown on the left of Figure 3.1-22 are the annual Shuttle flights plus OTVs expended for three cases all with aerobraking of the OTV. Space-basing saves on the average about four Shuttle flights per year. However, it requires on the average about three-and-a-half extra SOC crew members.

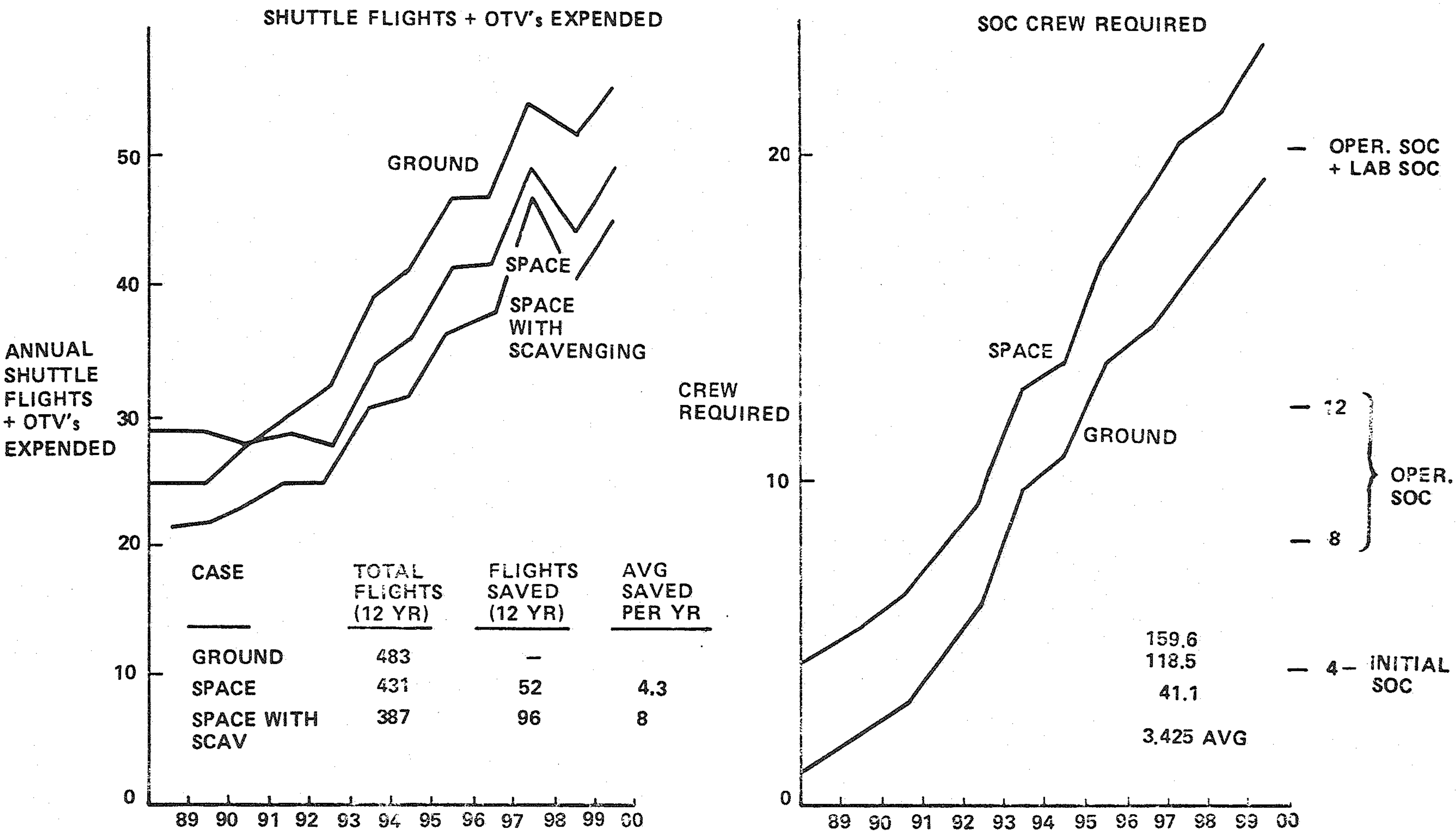
Based on a cost estimate for SOC crew labor, to be described in Section 6.0, the costs of space-basing for the crew labor are approximately \$1.67 billion over a 12-year mission model, and the savings are somewhat greater, approximately \$2 billion over the same period based on a \$40 million average Shuttle flight cost.

Several conclusions were drawn from this analysis. First, the mission model is dominated by the commercial and defense sectors as shown in Figure 3.1-23. This is an expected result inasmuch as these sectors represent important national priorities.

We found a definite need for a Space Operations Center. A manned space station pays off both for operations and for research and applications. In fact, the SOC utility divides roughly evenly between the operations functions and on-board science and applications.

The science and applications activities in this mission model were confined to those that have significance to either long-term manned space operations or potential commercial applications.

Because we project an increase in the SOC crew requirements with time, an evolutionary program is the best fit to mission needs. It would be logical to begin SOC operations with a ground-based OTV for the first two or three years. The



CASE	TOTAL FLIGHTS (12 YR)	FLIGHTS SAVED (12 YR)	AVG SAVED PER YR
GROUND	483	–	
SPACE	431	52	4.3
SPACE WITH SCAV	387	96	8

SPACE-BASING SAVES 52 @ $40M = $2.081B

SPACE-BASING COSTS:
3.425 AVG EXTRA CREW X 12 YR X 312 WORK-DAYS/YR X $130K/MANDAY = $1.67B

Figure 3.1-22. OTV Basing: Space vs Ground (Median Traffic Model)

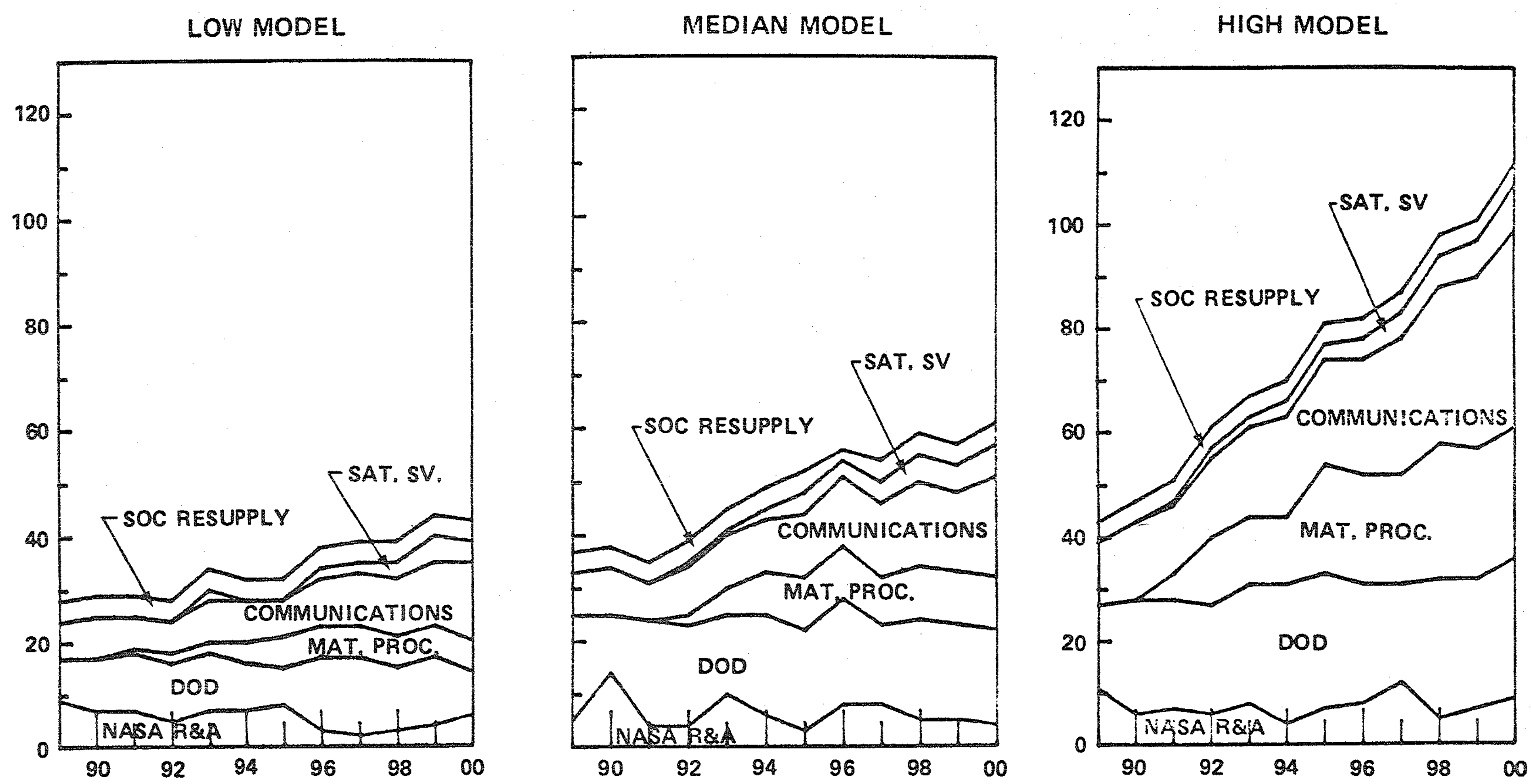


Figure 3.1-23. Summary of the Mission Models: Delivery or Servicing Events

SOC crew will initially be largely occupied with smoothing out station operations. Further, it would be most practical to ground-base the OTV until some operating experience with the vehicle is obtained. It appears logical to begin with a four-man SOC and eventually grow to 8 to 12 people. Towards the end of the 1990s, it may be desirable to set up a separate station for research and application missions.

We found that OTV aerobraking is essential to reduce the demands on space transportation. It does not appear to make sense to develop an OTV without aerobraking. Finally, space-basing pays off as does ET external tank scavenging. It appears that the OTV should be designed for space-basing even though it will probably be initially operated in a ground-based mode.

The low and median mission models developed by this study represent moderate demands on space transportation. They do not appear to exceed the capabilities of a five-Orbiter fleet even by the year 2000, assuming that all five Orbiters are in the turnaround cycle. Only the high model exceeds this demand level. The high model represents an economic scenario in which commercial investment in space transportation fleet equipment could probably provide the additional capacity.

3.2 TELECOMMUNICATIONS MISSION MODEL

3.2 TELECOMMUNICATIONS MISSION MODEL

3.2.1 APPROACH AND RATIONALE

The commercial communications sector model was derived from an economic-technical rationale based on historical experience and technological projections.

New technologies introduced to the marketplace often generate a very high rate of economic growth over a substantial number of years. Rapid economic growth occurs, as lower costs made possible by the new technology cause rapid acquisition of a significant market sector for whatever service or product is offered. Examination of historical data suggests that the process begins with an infancy period in which the growth is erratic and often at very high rates. Then an adolescent period occurs, in which the growth rate is more predictable but still quite rapid. This is followed by a period in which the new industry has reached maturity and its growth generally parallels the gross national product. Many industries eventually reach an old age period when growth subsides and decline takes place, even in some instances, entirely phasing out an industry. The trending concept illustrated in Figure 3.2-1 represents this rationale and is based on an examination of historical development of market sectors.

A few years ago the Boeing Commercial Aircraft Company performed a study of historical growth and development in the transportation sector. Four principal industries were examined dating all the way back to clipper ships. The data presented in the figure are on a semi-logarithmic scale. In each instance, as in Figure 3.2-2, the transportation sector exhibited a period of rapid growth, followed by a leveling-off paralleling the gross national product. In all instances, these rapid growth periods represented the adolescent or shakeout period; very early history was not presented. The annual growth rates for the motor car and airline operations are on the order of 50% per year for 20 to 30 years. The items plotted represent delivered services or products. The growth rates presented are for growth in market quantity. Inasmuch as costs per unit were being reduced over this period the growth rates in actual market value would be less.

Illustrated in Figure 3.2-3 is the number of installed telephones versus time for the U.S. telephone industry. The infant and adolescent rapid growth periods are

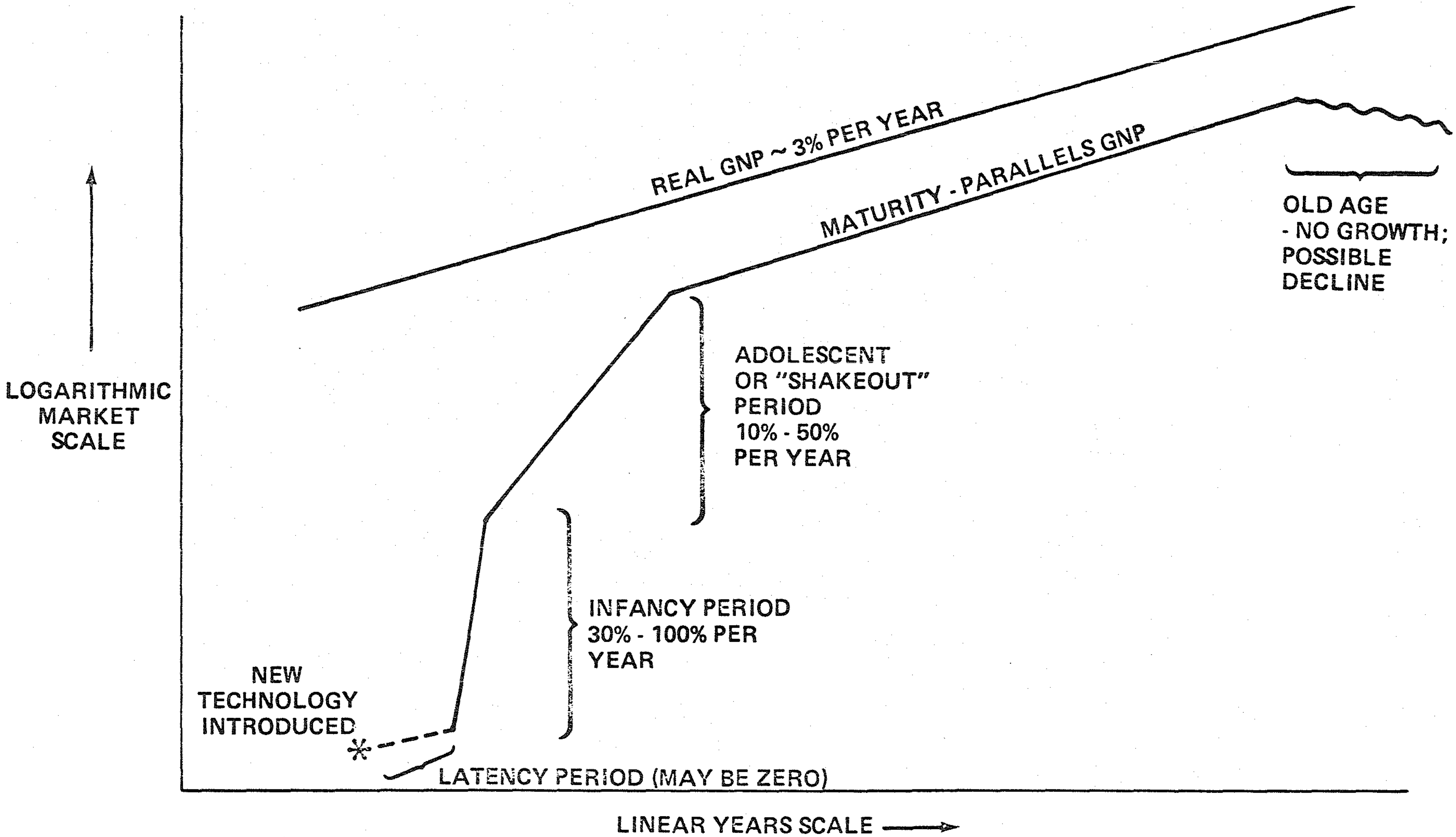
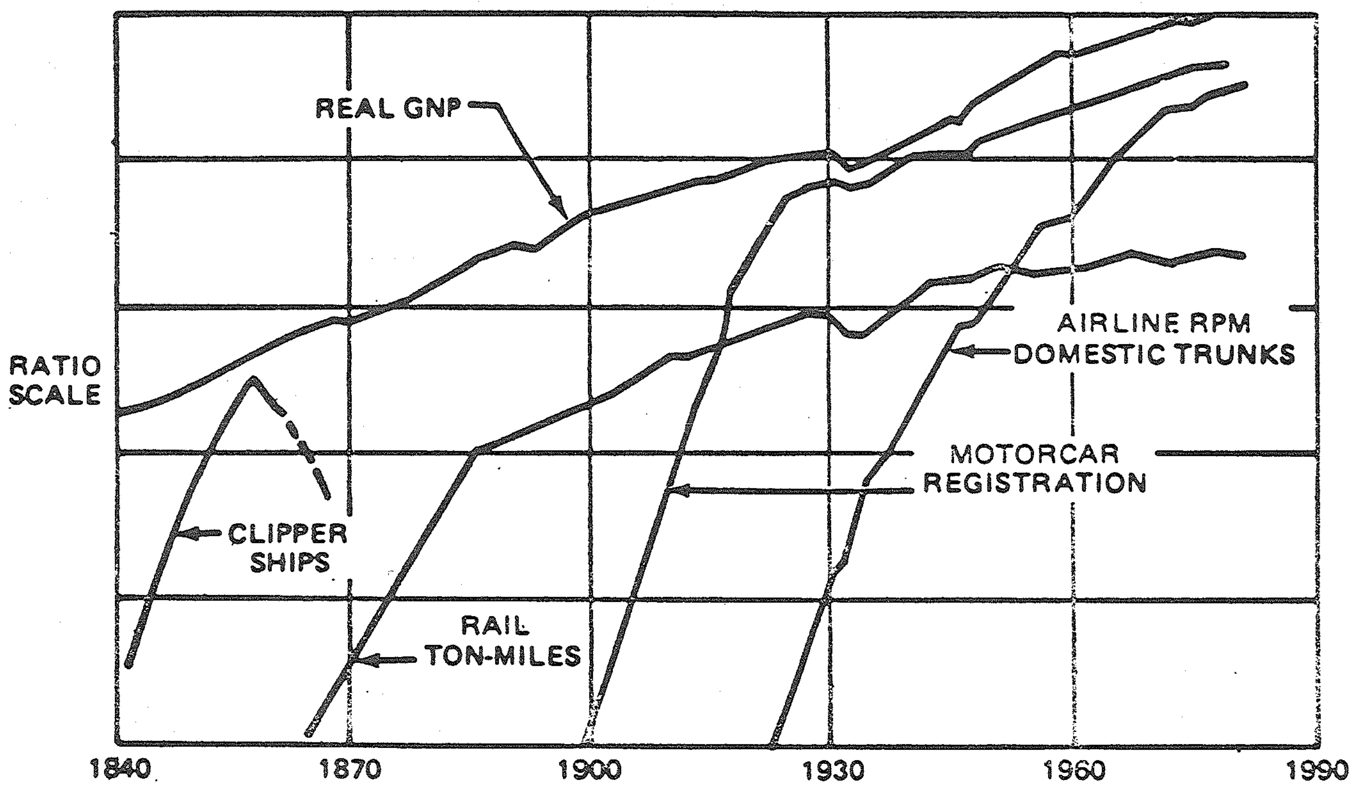


Figure 3.2-1. The Economic Trending Concept

1840-1978



Sources: Historical Statistics of the U.S., Colonial Times to 1970
U.S. Dept. of Commerce

Figure 3.2-2. Growth and Maturing in the U.S. Economy

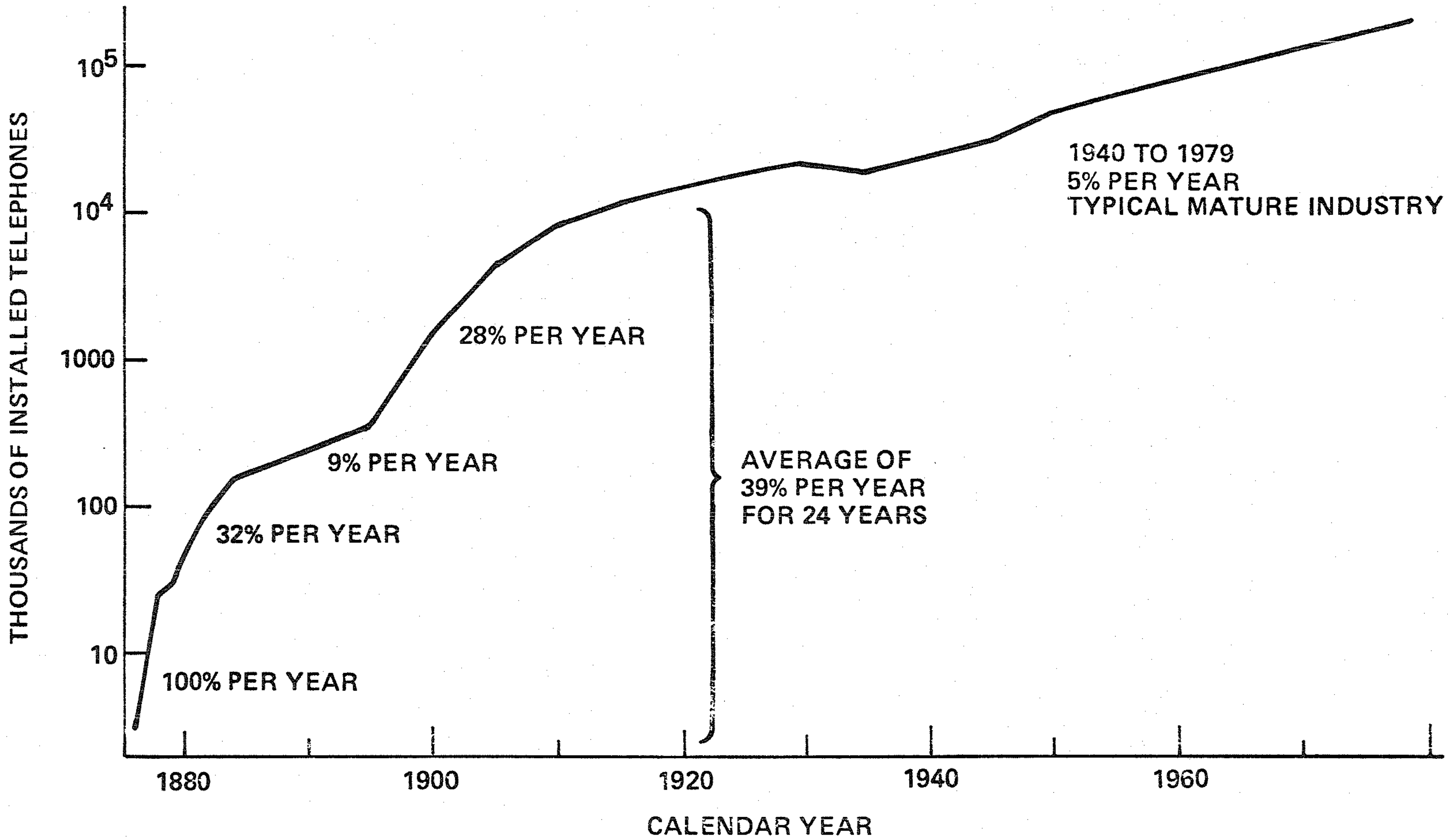


Figure 3.2-3. Telecommunications Growth

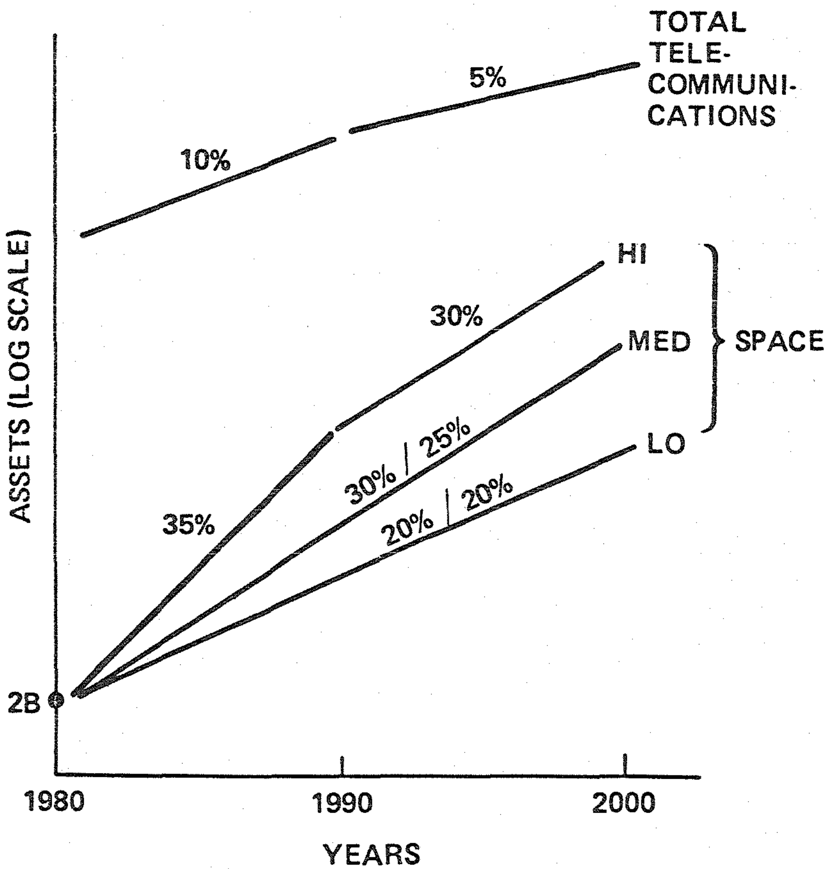
clearly discernible. Since 1940 the growth has been nearly parallel to the gross national product. However, it is worthy of note that for 24 years the average growth rate was 39% per year. What began as a novelty in the late 19th century grew into one of the principal economic sectors in the U.S. economy today, with over 200 million telephones installed across the United States.

3.2.2 PARAMETRIC RESULTS

Figure 3.2-4 presents the space telecommunications model created as a part of this study. The economic trending concepts described earlier were used. This model presumes that space communications will acquire a larger and larger sector of the entire telecommunications marketplace until it reaches market saturation sometime in the future. In consonance with the idea of creating low, median and high models, three growth rate levels were presumed. The data on the chart represent the values actually used in the model.

The structure of the model projects economic developments in terms of investment in the industry, and technical trends in terms of technological improvements. These two sets of assumptions then allow derivation of the number and type of satellites launched. Information shown on the chart includes the following model elements: (1) Growth of total telecommunications, representing a ceiling for acquisition of market share by space telecommunications. (2) Growth rates for the space telecommunications sectors of the market. (3) The value of the space segment part of the space telecommunications system, this representing the actual value of assets placed in space. It is important to recognize that as the marketplace matures the fraction of the total investment in space telecommunication systems actually launched in space will decline. This is already taking place with the proliferation of ground receivers for television distribution. (4) The cost of spacecraft and space transportation, both expected to gradually decline on a unit mass basis over the next 20 years. The figures used for space transportation costs in the year 2000 are appropriate to a Shuttle with a reusable, aerobraked, high-energy orbit transfer vehicle. (Projections utilized in this study did not presume radical advances in space transportation such as fully-reusable heavy lift systems or advanced technology propulsion.) (5) Payload mass per representative transponder based on results of the General Dynamics study of space platforms. (6) The spacecraft bus to payload ratio, also as estimated by the

ECONOMIC TRENDING



MODEL ELEMENTS

VALUE, 1980	VALUE, YR 2000 LOW	MED	HI
VALUE OF SPACE SEGMENT, % OF TOTAL			
50%	20%	10%	10%
SPACECRAFT COST, $/kg			
25000	14500	13500	10000
SPACE TRANSPORTATION COST, $/kg			
20000	11000	7200	5000
PAYLOAD MASS PER TRANSPONDER			
10 kg	3	3	3
BUS/PAYLOAD RATIO			
3	2	2	2
REPRESENTATIVE S/C MASS			
1000 kg	3000 Kg	4000 Kg	15000 Kg
REPRESENTATIVE S/C LIFE			
7 YR	15 YR	15 YR	15 YR
100% U.S. MARKET SHARE OR TOTAL TELECOM. LAUNCHES	50%	50%	50%

Figure 3.2-4. Space Telecommunications Model Concept

General Dynamics study, is expected to improve as size increases. (7) The representative spacecraft mass is expected to increase to the platform class by the year 2000. The size of the platform was varied as a function of the traffic models. (8) The representative spacecraft life is expected to gradually increase to 15 years. (9) Since this model is for U.S. space operations, a projection was made that the U.S. market share for total telecommunications launches would decrease from the present near 100% to about 50%.

One of the significant trends in this model is a decrease in the cost per transponder-year for spacecraft. This decrease results from a decrease in the payload mass per transponder, a decrease in the bus to payload ratio, a decrease in spacecraft plus space transportation cost, and finally a decrease in the annual capital charge as the spacecraft life increases. Sample calculations as illustrated in Figure 3.2-5 indicate that the cost per transponder-year may decline from a present figure of roughly $400,000 to something on the order of $30,000 by the year 2000. This result closely parallels the results presented in the General Dynamics platform studies.

The parametric graph presented in Figure 3.2-6 was taken from the General Dynamics platform study. It illustrates the decrease in space segment cost per transponder-year, both historical and projected, for a variety of platforms. The noted circles on the chart represent the results of our parametric trending models. The circles are about a factor of two above the General Dynamics curve because our cost per transponder-year included capital charges, whereas the General Dynamics data did not.

Tab runs from the final economics model are presented in Tables 3.2-1 through 3.2-4. Table 3.2-1 includes the inputs to the model and the remaining tables present model outputs for the high, median, and low cases. The model is implemented in a small software package on a timeshare minicomputer.

Figures 3.2-7 through 3.2-9 present a graphical summary of the results from the three telecommunications forecast models. The principal results are plotted on the chart. The result of primary significance to the modeling activity is the annual number of U.S. launches and the value of assets in space. The annual number of U.S. launches represents a potential demand for launch and SOC

$$\text{COST PER XP-YR} = \left(\begin{array}{l}\text{P/L MASS}\\ \text{PER XP}\end{array}\right)(1 + \text{BUS-P/L RATIO})\ (\text{S/C} + \text{S/T COST})\quad(\text{CCF FOR LIFE})$$

WITH A 15% RETURN, CCF = 0.24 FOR 7 YEARS

= 0.17 FOR 15 YEARS

IN 1980, C = 10 x 4 x 45,000 x .24 = $432,000 12½% PER YEAR

IN 2000, C = 3 x 3 x 19,500 x . 171 = $30,000 DECLINE

Figure 3.2-5. Sample Calculations:

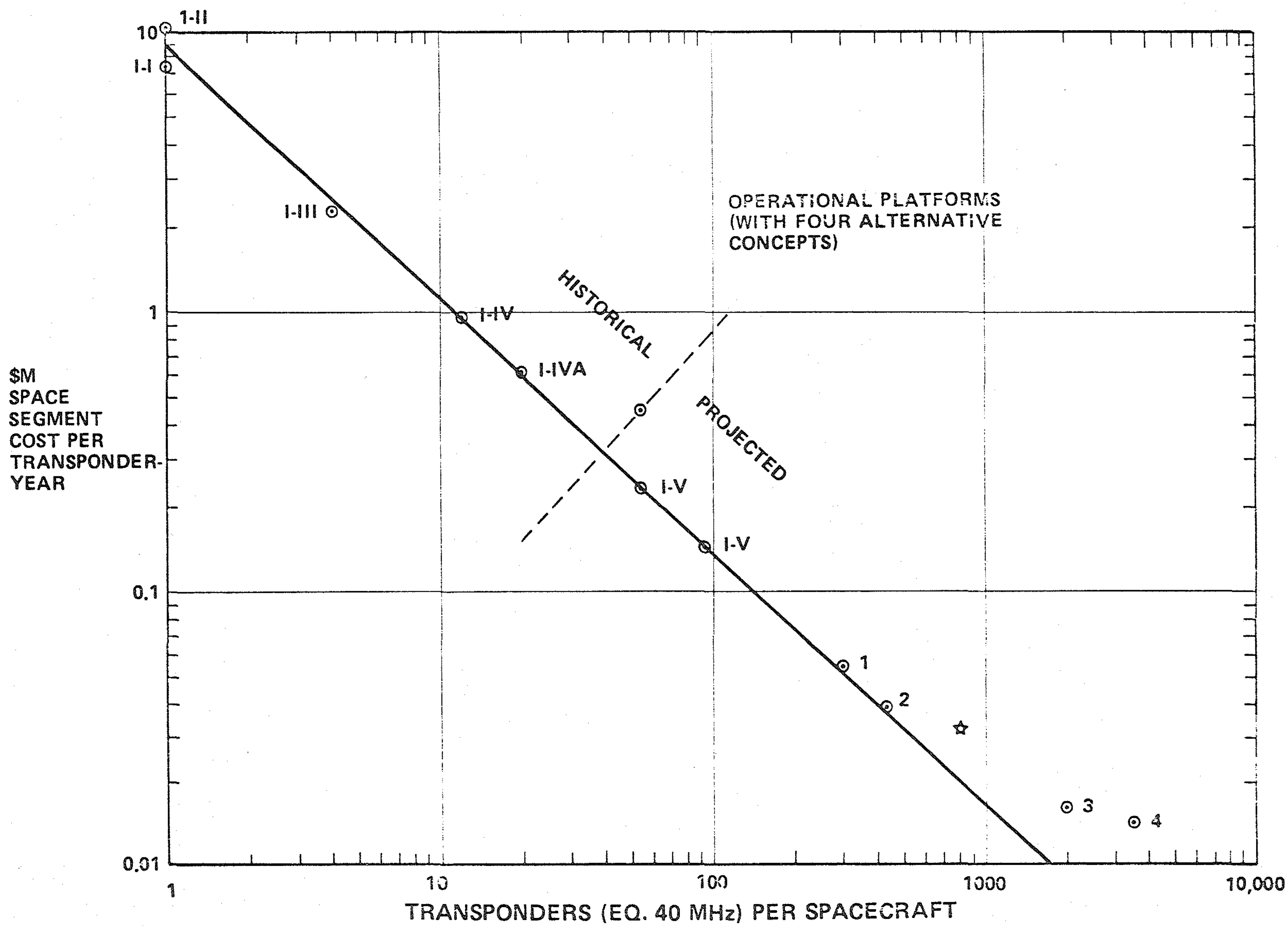


Figure 3.2-6. Intelsat Series Demonstrates Economy of Scale in Communications Spacecraft

Initial Total Telecom Assets in Billions	200
Telecom Assets Growth Rates: First and Second Ten Years	10, 5
Initial Space Telecom Assets Value in Billions	2
Space Telecom Growth Rates for Three Traffic Scenarios:	
High Model, First & Second Ten Years	35, 30
Median Model, First & Second Ten Years	30, 25
Low Model, First & Second Ten Years	20, 20
Initial Value of Space Segment, % of Space Telecom Assets	50
Decrease Rate (%/Yr) of Space Segment Percentage for High, Median and Low Models	7.73, 7.73, 3.675
Initial Cost of Spacecraft Hardware, $/Kg	25,000
Initial Cost of Space Transportation to GEO, $/Kg	20,000
Decrease Rate (%/Yr) for S/T Cost for High, Median, and Low Models	7, 5, 3
Initial U.S. Share of Launch Traffic, %	100
Decrease Rate (%/Yr) of U.S. Share	3.5
Initial Payload Mass Per Transponder, Kg	10
Decrease Rate (%/Yr) of Mass/Transponder	5.84
Initial Bus-to-Payload Ratio	3
Decrease Rate (%/Yr) of Bus-to-Payload Ratio	2
Initial Representative Spacecraft Mass, Tonnes	1
Increase Rate (%/Yr) of Spacecraft Mass for High, Median, and Low Models	12, 7, 6
Initial Spacecraft Life, Yr	7
Increase Rate (%/Yr) in Spacecraft Life	3.88
Spacecraft Cost Learning Curve	95

Table 3.2-1 - Communications Mission Model Inputs

Table 3.2-2

RESULTS FOR LOW MODEL

Year	Total Telcom Assets	Space Telcom Assets	Space Seg Value	Space Cost/ Xpond ($K)	No. Xpond Launched	S/C Mass, 1000KG	S/C+S/T Cost $/KG	No. of S/C In Orbit	No. of U.S. Launches	Total U.S. Launch Mass, T
Initial Values (Not Plotted)										
0	200.0	2.0	1.0	1800	556	1.00	45000	22.2	22.2	0.0
Model Results										
1981	220.0	2.4	1.2	1647	650	1.06	44400	25.5	3.2	3.4
1982	242.0	2.9	1.3	1488	771	1.12	43242	29.2	3.5	3.9
1983	266.2	3.5	1.5	1344	926	1.19	42092	33.4	3.7	4.4
1984	292.8	4.1	1.8	1213	1125	1.26	40951	38.1	4.0	5.1
1985	322.1	5.0	2.1	1094	1379	1.34	39822	43.3	4.4	5.8
1986	354.3	6.0	2.4	987	1705	1.42	38709	49.1	4.7	6.7
1987	389.7	7.2	2.8	890	2123	1.50	37615	55.7	5.1	7.7
1988	428.7	8.6	3.2	802	2659	1.59	36540	64.4	6.5	10.4
1989	471.6	10.3	3.7	723	3346	1.69	35487	74.1	7.1	11.9
1990	518.7	12.4	4.3	652	4228	1.79	34458	85.1	7.7	13.7
1991	544.7	14.9	4.9	587	5358	1.90	33453	95.5	7.1	13.4
1992	571.9	17.8	5.7	529	6809	2.01	32473	108.9	8.7	17.5
1993	600.5	21.4	6.6	477	8669	2.13	31518	123.9	9.4	20.1
1994	630.5	25.7	7.6	430	11056	2.26	30589	140.7	10.2	23.1
1995	662.1	30.8	8.8	387	14117	2.40	29685	157.4	9.8	23.4
1996	695.2	37.0	10.2	349	18044	2.54	28807	178.1	11.7	29.8
1997	729.9	44.4	11.7	314	23081	2.69	27953	201.8	12.9	34.8
1998	766.4	53.2	13.6	283	29541	2.85	27123	228.4	14.0	40.0
1999	804.7	63.9	15.7	255	37826	3.03	26318	254.9	13.5	40.8
2000	845.0	76.7	18.1	230	48451	3.21	25536	287.7	16.1	51.5

Table 3.2-3

RESULTS FOR MEDIAN MODEL

Year	Total Telcom Assets	Space Telcom Assets	Space Seg Value	Space Cost/ Xpond ($K)	No. Xpond Launched	S/C Mass, 1000KG	S/C+S/T Cost $/KG	No. of S/C In Orbit	No. of U.S. Launches	Total U.S. Launch Mass, T
Initial Values (Not Plotted)										
0	200.0	2.0	1.0	1800	556	1.00	45000	22.2	22.2	0.0
Model Results										
1981	220.0	2.6	1.2	1632	678	1.07	44000	26.5	4.1	4.4
1982	242.0	3.4	1.4	1457	842	1.14	42354	31.4	4.6	5.3
1983	266.2	4.4	1.7	1301	1063	1.23	40743	37.1	5.2	6.3
1984	292.8	5.7	2.1	1160	1360	1.31	39171	43.9	5.8	7.6
1985	322.1	7.4	2.5	1034	1759	1.40	37641	51.7	6.5	9.2
1986	354.3	9.7	3.0	922	2297	1.50	36156	60.8	7.4	11.1
1987	389.7	12.5	3.6	821	3020	1.61	34719	71.5	8.3	13.3
1988	428.7	16.3	4.3	732	3994	1.72	33331	85.5	10.5	18.1
1989	471.6	21.2	5.1	652	5306	1.84	31993	101.8	11.9	21.8
1990	518.7	27.6	6.2	581	7073	1.97	30704	120.9	13.4	26.3
1991	544.7	34.5	7.1	517	8902	2.10	29465	136.2	10.3	21.7
1992	571.9	43.1	8.2	462	11264	2.25	28352	155.4	12.5	28.2
1993	600.5	53.9	9.5	413	14313	2.41	27277	177.1	13.6	32.8
1994	630.5	67.3	10.9	368	18251	2.58	26240	201.4	14.8	38.2
1995	662.1	84.1	12.6	329	23336	2.76	25241	225.5	14.1	38.9
1996	695.2	105.2	14.5	294	29902	2.95	24279	255.4	16.9	49.9
1997	729.9	131.5	16.7	263	38380	3.16	23353	289.5	18.6	58.8
1998	766.4	164.3	19.3	235	49325	3.38	22463	327.8	20.2	68.3
1999	804.7	205.4	22.3	210	63454	3.62	21607	365.7	19.3	69.7
2000	845.0	256.8	25.7	187	81690	3.87	20784	412.8	23.1	89.4

Table 3.2-4

RESULTS FOR HIGH MODEL

Year	Total Telcom Assets	Space Telcom Assets	Space Seg Value	Space Cost/ Xpond ($K)	No. Xpond Launched	S/C Mass, 1000KG	S/C+S/T Cost $/KG	No. of S/C In Orbit	No. of U.S. Launches	Total U.S. Launch Mass, T
Initial Values (Not Plotted)										
0	200.0	2.0	1.0	1800	556	1.00	45000	22.2	22.2	0.0
Model Results										
1981	220.0	2.7	1.2	1618	707	1.12	43600	27.3	4.9	5.4
1982	242.0	3.6	1.6	1421	923	1.25	41305	33.2	5.5	6.9
1983	266.2	4.9	1.9	1248	1228	1.40	39099	40.1	6.2	8.8
1984	292.8	6.6	2.4	1095	1662	1.57	36986	48.3	7.1	11.1
1985	322.1	9.0	3.0	961	2277	1.76	34969	57.9	8.0	14.2
1986	354.3	12.1	3.7	842	3152	1.97	33049	69.1	9.1	18.0
1987	389.7	16.3	4.7	739	4394	2.21	31225	82.4	10.4	22.9
1988	428.7	22.1	5.8	647	6160	2.48	29497	99.4	12.8	31.6
1989	471.6	29.8	7.2	568	8668	2.77	27861	119.4	14.5	40.3
1990	518.7	40.2	9.0	498	12233	3.11	26316	143.0	16.5	51.2
1991	544.7	52.3	10.8	436	16346	3.48	24856	163.8	14.0	48.8
1992	571.9	68.0	12.9	384	21958	3.90	23542	189.0	16.5	64.2
1993	600.5	88.3	15.5	337	29614	4.36	22295	217.7	18.0	78.7
1994	630.5	114.9	18.6	297	40058	4.89	21115	250.2	19.8	96.5
1995	662.1	149.3	22.3	261	54303	5.47	19997	284.2	19.9	108.9
1996	695.2	194.1	26.8	229	73732	6.13	18940	325.0	23.1	141.6
1997	729.9	252.3	32.1	202	100224	6.87	17940	371.5	25.4	174.4
1998	766.4	328.0	38.5	178	136342	7.69	16995	424.3	27.8	213.6
1999	804.7	426.4	46.2	156	185570	8.61	16101	479.7	28.2	242.7
2000	845.0	554.4	55.5	138	252655	9.65	15257	546.0	32.5	313.6

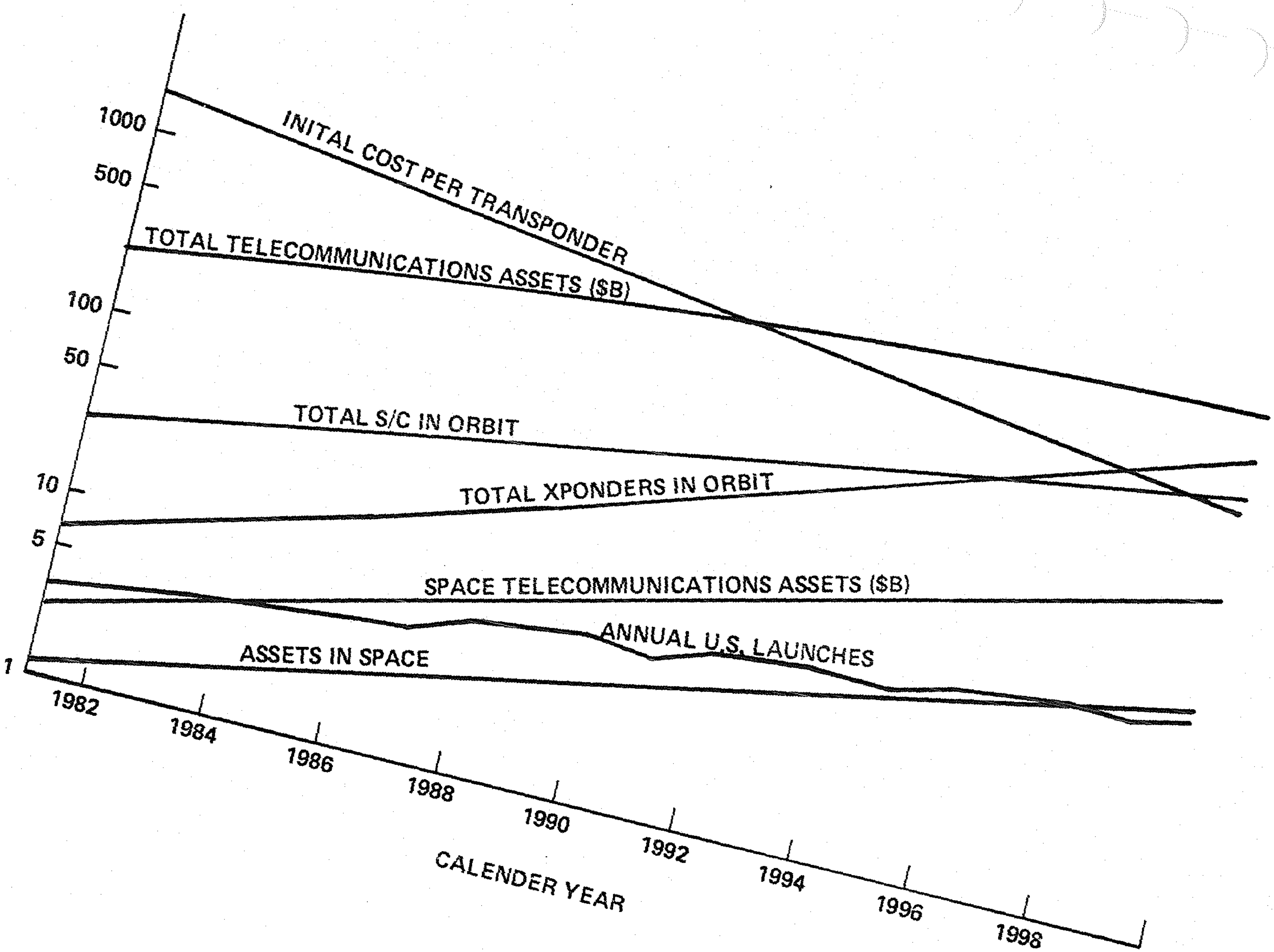


Figure 3.2-7. Telecommunications Low Model

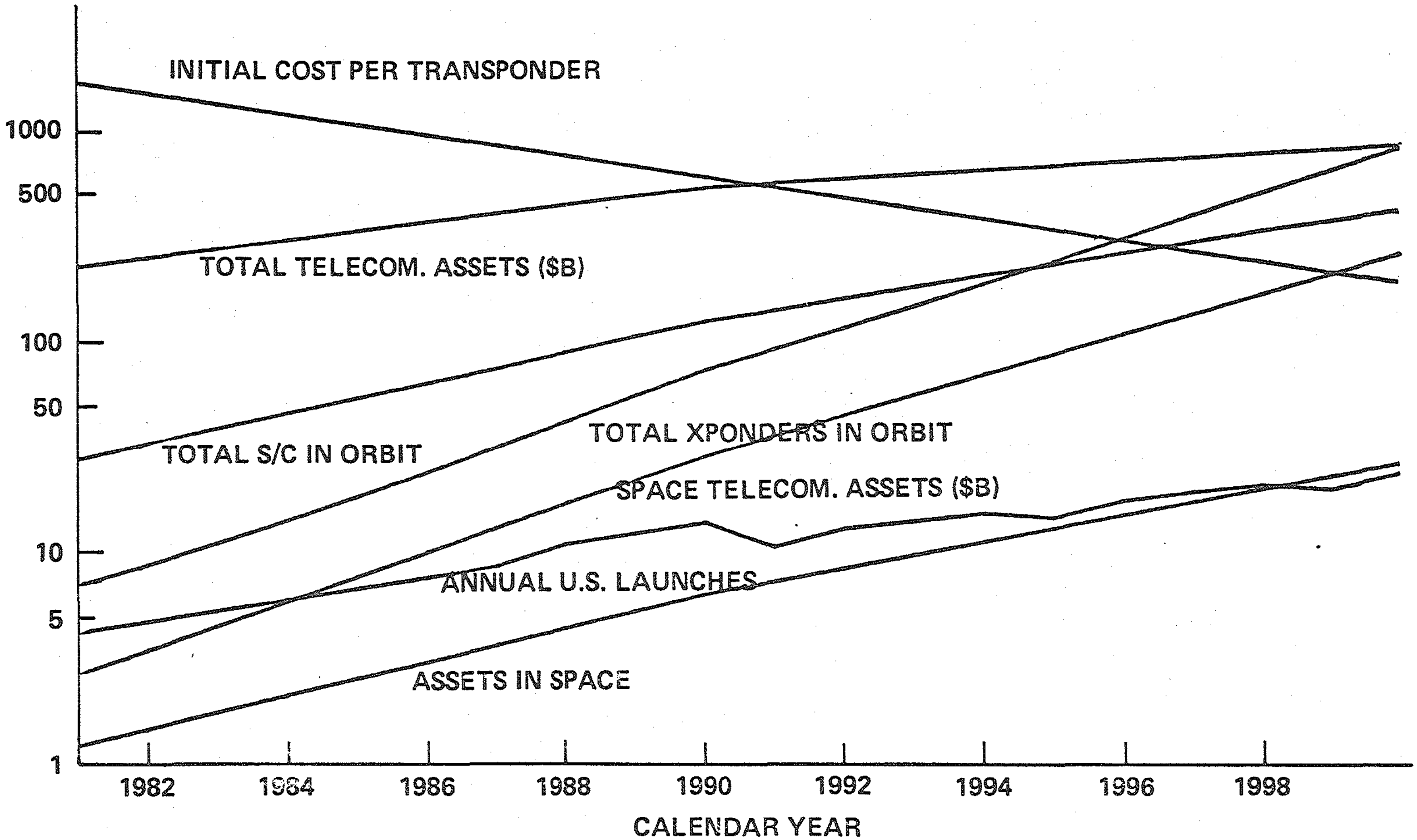


Figure 3.2-8. Telecommunications Medium Model

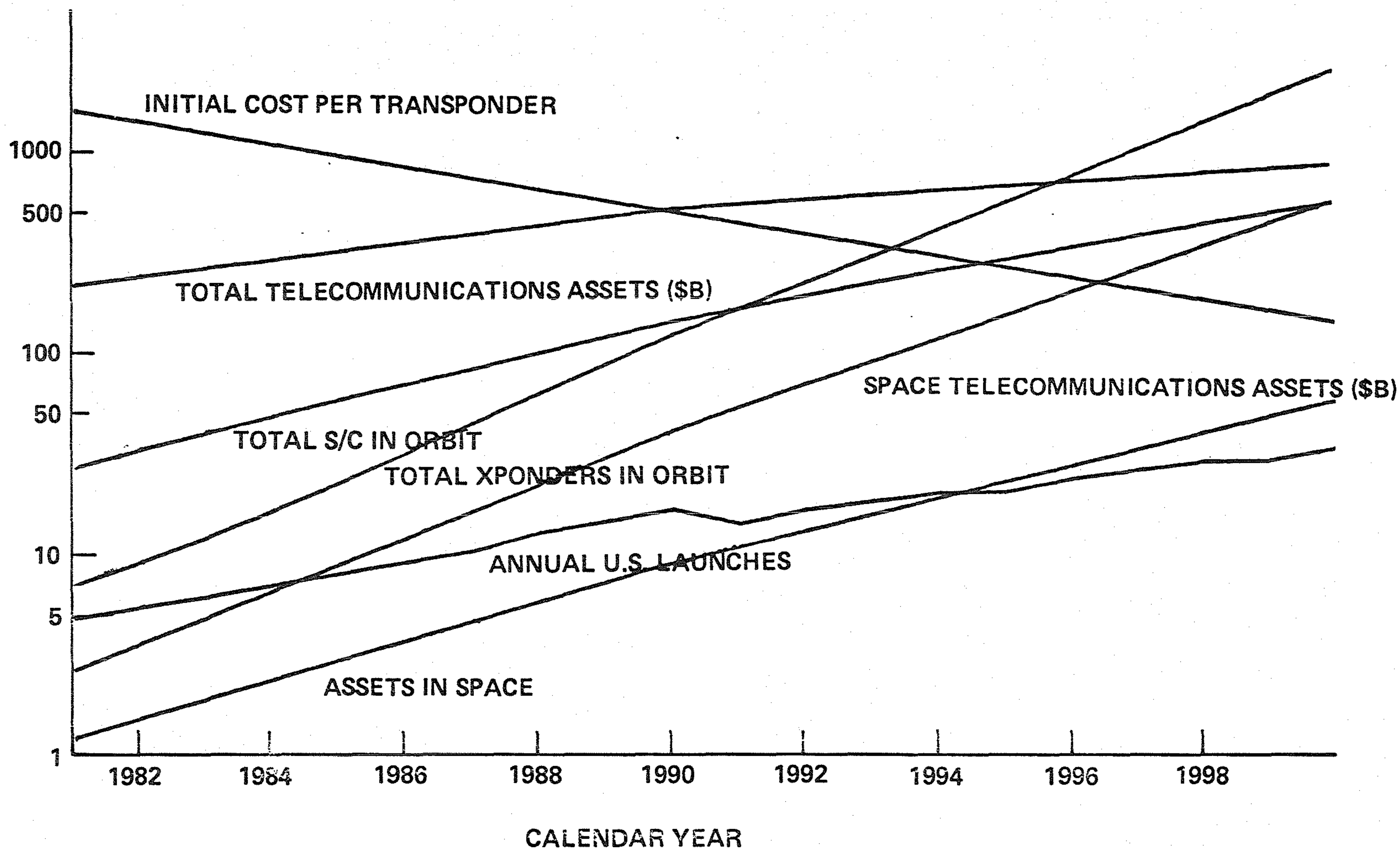


Figure 3.2-9. Telecommunications High Model

service. The accumulation of value and assets in space is a determining factor for the development of geosynchronous satellite servicing capability.

3.2.3 THE FINAL MODELS

In order to finalize the payloads launch forecast the parametric results from the model were made specific by projecting a range of satellite sizes that might be launched in the next 20 years. Figure 3.2-10 presents the assumed characteristics of the satellites including estimates of the type of service and the sizes and lengths needed as inputs for the analyses to be described on later pages.

The final telecommunications models were completed by making the parametric economic model results specific in terms of numbers of spacecraft of different sizes to be launched every year. The progression to larger and larger spacecraft was forecast to be gradual with a new, larger size of spacecraft introduced every two to five years, much as has been true in the past. The high model is forecast to grow to bigger spacecraft than the median or low models. Overlap was forecast to occur with as many as three different classes of spacecraft being launched simultaneously in some years. This also is typical of present systems. The models are presented in Figure 3.2-11.

The number of communications satellites actually launched in 1981 will be eight, and about five of those will be one-ton class with the other somewhat smaller. Launches of a two-ton class will begin with the initial launches of TDRSS.

A traffic model for space communications was developed in the earlier SOC study. The annual mass delivered in this earlier model is represented by the squares in Figure 3.2-12. The new models are also presented on the same chart.

3.2.4 EVALUATION OF MODELS

Table 3.2-5 presents a comparison of total cumulative equivalent transponders launched for the three mission models of the present study, and for a mission model created by Econ for the United States only, including video teleconferencing. In the Econ data, the term "equivalent transponders" includes only bandwidth considerations. In the present model, the term "equivalent transponders" includes

MASS (TONNES)	MODEL	UPPER STAGE	SERVICE CLASSES	DIA.	LENGTH	SOC SERVICE
1	INTELSAT V; LEASAT	SSUS	POINT-TO-POINT TRUNKING	3	2.8	NONE
2	TDRSS	IUS	POINT-TO-POINT; DATA RELAY; DIR BC	3	5.6	NONE
3	GROWTH TDRSS	UPRATED IUS; IOTV	(SAME)	4	5	TEST
4	MINI-PLATFORM	IOTV	(SAME)	4.4	5	DEPLOY & TEST; STORE; MATE
5	MINI-PLATFORM	A/B OTV	SAME PLUS USER-PREMISES SERVICES	4.4	6.6	SAME
7	PLATFORM	A/B OTV	ADD MOBILE SERVICE	4.4	9.2	ASSEMBLE & TEST; MATE
10	PLATFORM	A/B OTV	SAME	4.4	13.2	SAME

Figure 3.2-10. Assumed Characteristics of Communications Satellites

CALENDAR YEAR

Model	Mass (Tonnes)	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
HIGH MODEL	1	5	3	5	5	5	4														
	2		2	2	3	3	4	4	3												
	3					1	2	5	9	10	10	5									
	4									2	5	6	10	10	7	5					
	5											2	5	5	7	8	7	5			
	7													2	5	7	15	20	28	28	23
	10																	1	2	5	15
	TOTAL	5	5	7	8	9	10	9	12	12	15	13	15	17	19	20	22	26	30	33	38
MEDIAN MODEL	1	5	3	4	3	3	5	2	2												
	2		1	1	2	3	3	4	5	2											
	3							1	2	6	9	6	8	8	7	8	6	2			
	4											1	1	2	3	4	6	11	14	12	15
	7																1	1	2	3	4
	TOTAL	5	4	5	5	6	8	7	9	8	9	7	9	10	10	12	13	14	16	15	19
LOW MODEL	1	3	2	2	3	3	4	3	4	3	2										
	2		1	1	1	2	2	3	3	3	5	5	5	5	1						
	3									1	1	1	3	3	7	6	7	8	8	9	11
	5															1	2	2	3	3	4
	TOTAL	3	3	3	4	5	6	6	7	7	8	6	8	8	8	7	9	10	11	12	15

Figure 3.2-11. Telecommunications Models

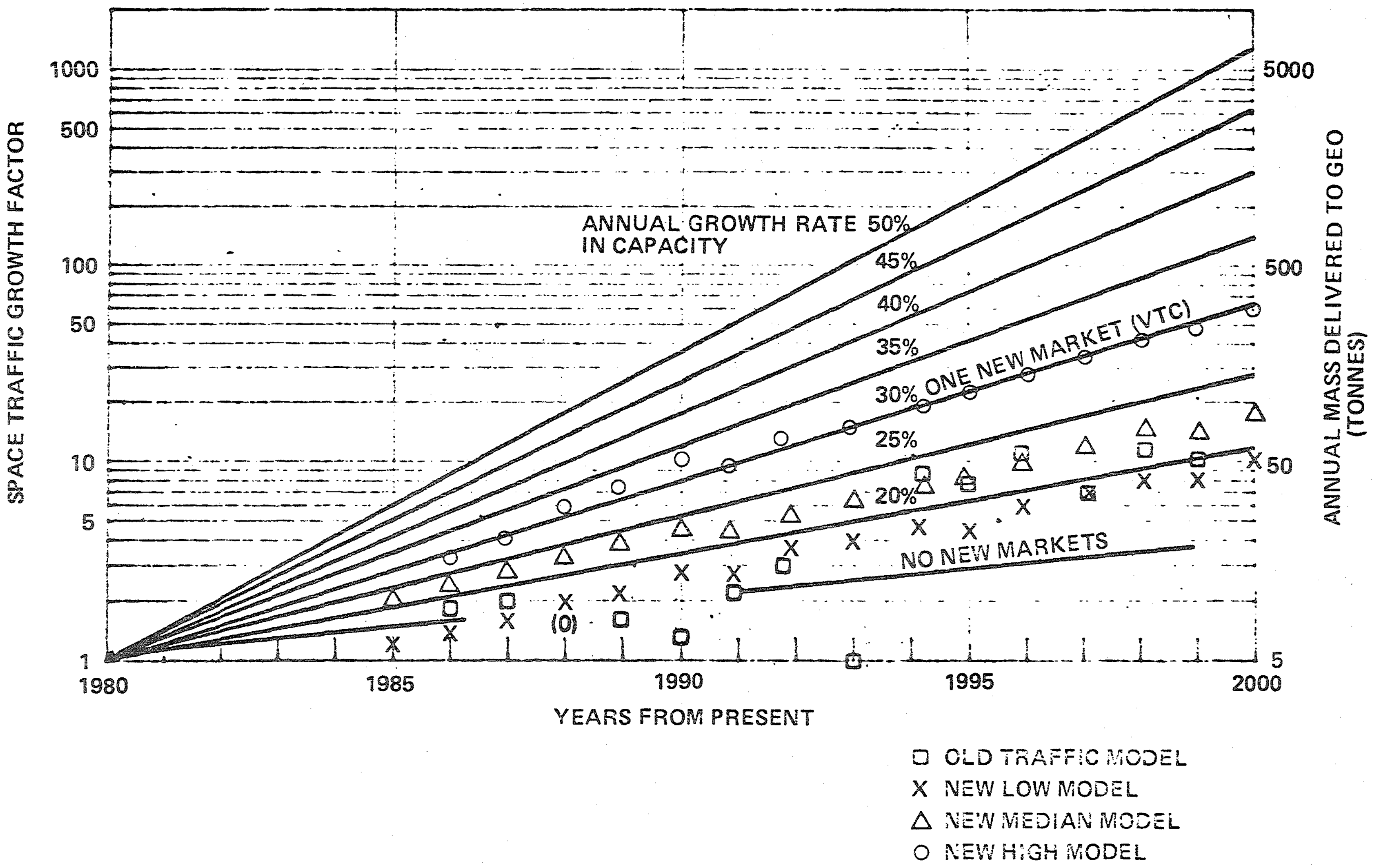


Figure 3.2-12. Communications Traffic Model

Table 3.2-5. "Equivalent Transponders" Comparison

"EQUIVALENT TRANSPONDERS" INCLUDES BANDWIDTH, POWER, AND COMPLEXITY FACTORS

MISSION MODEL		1980	1985	1990	1995	2000
LOW	WORLD-WIDE	550	1380	4200	14000	48000
MEDIAN	WORLD-WIDE	550	1760	7000	23000	82000
HIGH	WORLD-WIDE	550	2300	12000	54000	250000
ECON (U.S. ONLY, INCLUDING VIDEO TELECONF.		200	500	5000	10000	NO FORECAST

SERVICES NOT INCLUDED IN ECON FORECAST

- DIRECT BROADCAST TV
  - STANDARD
  - WIDEBAND
- USER-PREMISES ON-REQUEST SERVICES
  - DATA & INFORMATION
  - ENTERTAINMENT

bandwidth, power, and complexity factors, inasmuch as some future services may require additional mass per transponder for high gain multi-beam antennas, more complex switching systems, more power as for direct broadcast TV, or higher complexity associated with dividing a given transponder bandwidth into a large number of individual user-premises communication links.

The present traffic models trend higher than the Econ forecast. However, the Econ forecast included only one new demand segment, that of video teleconferencing. Historically, a new application of space communications has arisen every two to four years. Some services not included in the Econ forecast but now either on the horizon or technically feasible include direct broadcast TV. Direct broadcast TV with standard bandwidth is now in the planning stage with filings for over 20 satellite slots presently before the Federal Communications Commission. The Japanese are working on a wideband TV system using 3,000 or so scan lines instead of the 525-line U.S. standard. It is reported that this wideband TV provides a picture comparable in quality to technicolor movies. The bandwidth requirement would be something like 10 to 20 times that for standard TV broadcast. This very great bandwidth per channel would be probably feasible only with an advanced satellite direct broadcast system.

A wide variety of user-premises on-request services are technically feasible. Based on projected cost trends, direct satellite linking for home and small business computers could be less costly than installing a second telephone line to provide the same service. The communications cost for such services would be small compared to the charges normally accrued for the data services themselves. Even such applications as on-request stereo music broadcast or TV entertainment broadcast should be technically and economically feasible before the year 2000.

Satellite direct TV broadcasting is a representative new application not represented or under-represented in earlier forecasts. Table 3.2-6 summarizes the more significant proposals for direct broadcast satellites presently before the FCC. (This information comes from Barron's Magazine.) The total is 14, but some of the filings were regarded by this source as not likely to result in a satellite launch even if a slot were granted. The number of satellites in the proposals listed on the table totals 24.

Table 3.2-6. Orbital Slots Major U.S. Direct Satellite Broadcasting Proposals

COMPANY	SATEL-LITES	CHANNELS PER SATELLITE	DISH SIZE	SYSTEM COST	
CBS	4	3	39"	N.A.	ADVERTISING & PAY
DIRECT BROADCAST SATELLITE CORP.	3	14	35"	$725 MIL.	COMMON CARRIER
FOCUS BROADCAST	1	1	29" - 59"	$53 MIL. YR. (LEASE)	PAY & ADVERTISING
GRAPHIC SCANNING	2	4	23" - 39"	$136 MIL. (1 SAT)	PAY - $24.95/MO.
RCA	4	6	23" - 39"	$775 MIL.	COMMON CARRIER
SATELLITE TV CORP.	4	3	23" - 35"	$683 MIL.	PAY
HUBBARD BROAD-CASTING	2	4	35"	$234 MIL.	ADVERTISING
WESTERN UNION	4	4	15" - 35"	$516 MIL.	COMMON CARRIER

SUBSECTION 3.3 TABLE OF CONTENTS

3.3 SPACE SCIENCE, EARTH SENSING & SPACE TESTING MISSIONS

Grumman's mission needs and modeling analysis task on SOC are keyed to the Satellite/Service User Model (S/SUM) developed for its recent study of satellite services near the orbiter (Reference 3.3-1). The S/SUM contains 210 satellites and payloads, which were derived from the NASA 5-Year Plan (1981 - 85), (Reference 3.3-15), STS Flight Assignment, (Reference 3.3-5), OAST Space Systems Technology model (Reference 3.3-3) and other unclassified data sources. This model spans the years 1981 to 2000 and includes LEO service events for launch, on-orbit servicing revisits, and retrieval for earth return. In addition to Orbiter direct delivery satellites, it covers LEO selfpropelled satellites, GEO satellites, upper stages, planetary spacecraft, sortie payloads and DOD missions.

As shown in Figure 3.3-1 Grumman's SOC mission modeling effort was focused on Space Science, Earth Sensing and Space Testing missions. Information on current NASA programs was used to update the S/SUM data base for these mission areas in the 1985 to 2000 year period. Thi mission forecast was then analyzed with respect to related budget projections and estimated satellite program costs. As a result of this analysis three mission models (High, Medium and Low) are defined for each area of interest.

3.3.1 MISSION MODEL DEVELOPMENT

In selecting a data base for carrying out the SOC Mission Modeling, Grumman initially revised the S/SUM model developed for the Satellite Service Systems study as reported in Reference 3.3-2. Inputs to this model were primarily from the 1980 NASA Space Systems Technology Model (Reference 3.3-3), The 1979 Low Energy Payload Model (Reference 3.3-4), The June 1980 NASA Flight Assignment Manifest (Reference 3.3-5) and the Mission Data Catalogue (Reference 3.3-6). Other data for completeness of the data file were drawn from References 3.3-7 through 3.3-11. This allowed compilation of a Shuttle use model containing the spectrum of missions covering Civil and DOD satellites and sorties as well as servicing and satellite recovery

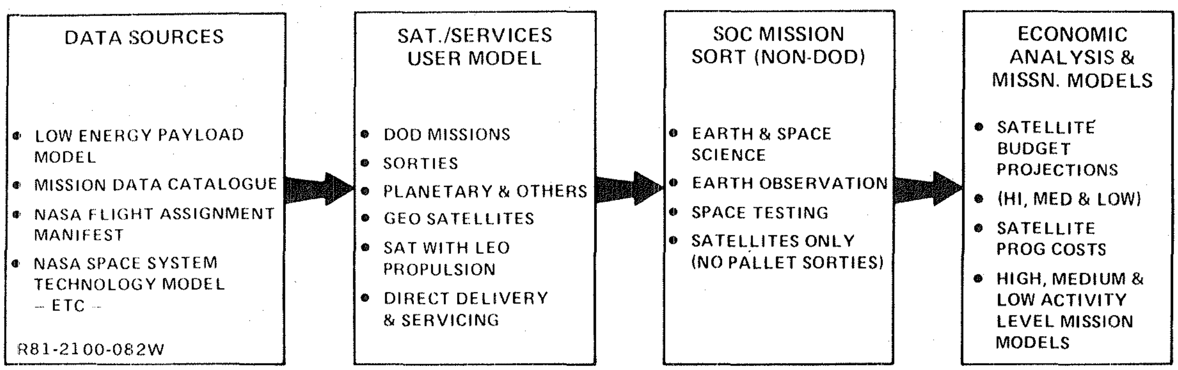


Fig. 3.3-1 Grumman SOC Mission Model Development

operations. Comparison of this data base with the 1981 NASA Space Systems Technology Model (Reference 3.3-12), as shown in Figure 3.3-1, indicated limited program changes. Because of the preliminary nature of Reference 3.3-12, the choice was made to retain 1980 mission nomenclature as the primary baseline for mission modeling.

The contents of the S/SUM model and the development of SOC data base covering NASA's Space Science, Earth Sensing and Space Testing mission categories are discussed in the subparagraphs below.

3.3.1.1 Total Satellite Model from S/SUM Data Base

The histogram in Figure 3.3-2 provides the projected launch rate per year from 1981 through 2000 for the updated SAT/SUM data base of 11/2/81, including both military launches of Shuttle and the non-DOD payloads. During the post-1987 time period, this data base nominally covers 5 unclassified DOD launches per year: whereas, the non-DOD satellite launches per year range from 50 to 60 in the early 1990s and then approach 80 in the late 1990s. Since the data base covers a broad range of satellite orbital inclinations (i.e., 0 to 100 degrees), all of these satellites are not compatible with SOC. The non-DOD launches are divided into the overall mission areas being addressed by Boeing and Grumman. Grumman's assigned NASA mission areas covering Earth and Space Sciences, Earth Sensing, and Space Testing is depicted at the bottom of the chart. Boeing addressed the other mission areas, independently.

3.3.1.2 Earth and Space Science Satellite Model

A historgram of the satellite launch traffic from S/SUM for the Earth and Space Sciences mission category is presented in Figure 3.3-3. Earth and Space Sciences missions encompass Astrophysics, Solar Terrestrial Physics and Planetary satellites. Satellites launched in each of these three satellite categories are totaled each year for 1983 through the year 2000 inclusive, and range from a single launch in 1983 to 14 in 1989. Some 100 launches are included in the historgram with Astrophysics missions averaging about four launches per

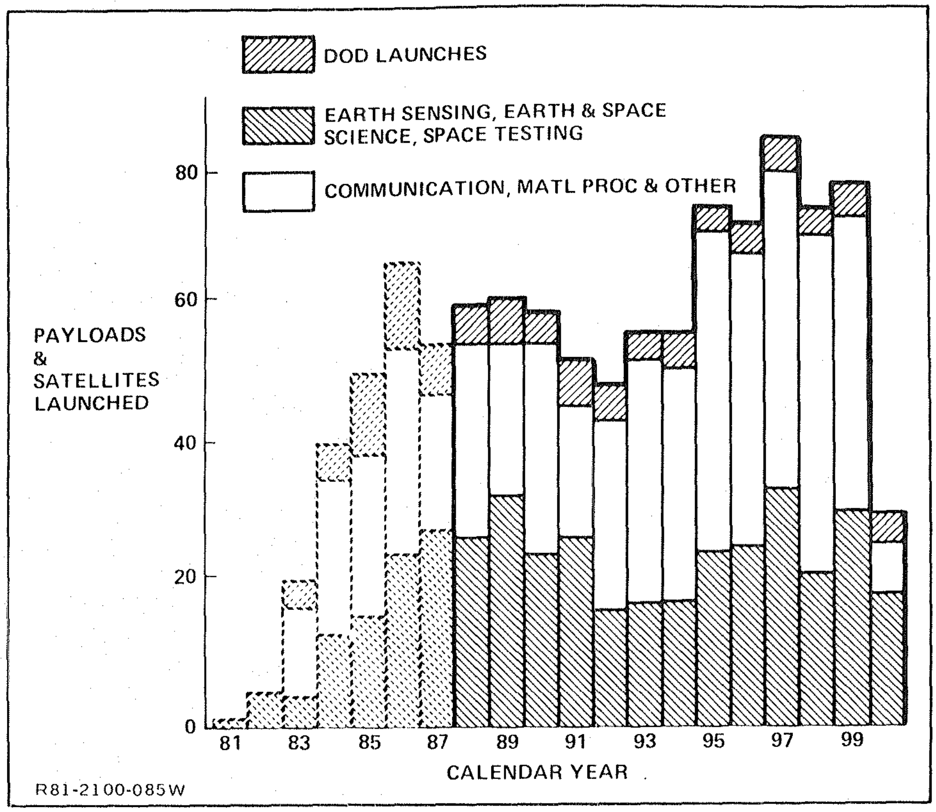


Fig. 3.3-2 Total Satellite Model From S/SUM Data Base

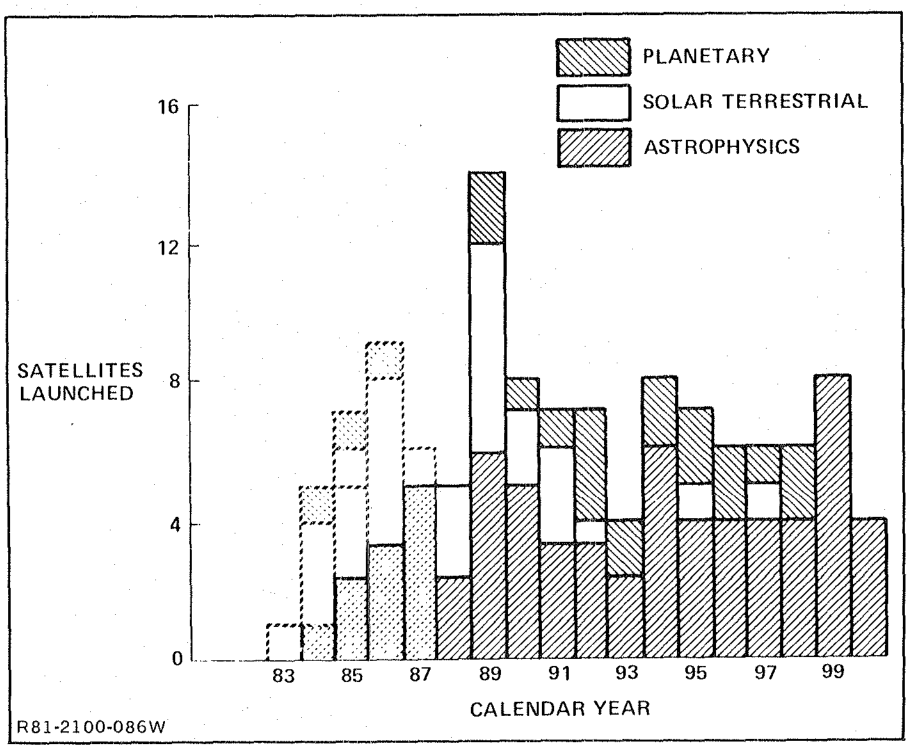


Fig. 3.3-3 Earth and Space Sciences

year and Solar Terrestial two per year. The Solar Terrestrial annual count is seen to be concentrated in the 1980s with only two launches after 1982. Although Planetary averaged slightly more than one launch per year, the traffic load is larger during the 1990s when SOC is operational, at nearly two launches per year. A significant number of solar terrestrial launches in the S/SUM are pallet missions, and are not included herein because they are short duration missions.

Satellite characteristics, their orbits and mission traffic schedule are provided for the three satellite categories in Tables 3.3-1 through 3.3-3. The satellite missions are listed chronologically within each category. These missions are identified in accordance with the nomenclature defined in the 1980 NASA Space Systems Technology Model (i.e., A-3, S-2, etc). The correlation between these designators and the revised listing in the 1981 NASA Space Systems Technology Model is shown parenthetically under the name of the satellite. Satellite service mission events for deployment (D), on orbit support service(S) and satellite return/retrieval (R), are scheduled on different lines. The Space Telescope (Table 3.3-1) for example, is planned to be launched in 1984. This satellite will be serviced on-orbit at least once (1986) during its 5 year mission. Potential service events for contingency situations are shown as dots. The Space Telescope is retrieved in 1989 for ground refurbishment and then relaunched in 1990 for another 5-year mission. This retrieval and relaunch cycle is repeated again in 1995 and 1996. Similar data are provided for other satellite missions included within the 1985 through 2000 time frame. Twenty six satellite programs are included in Table 3.3-1, seven are flagged for deployment and recovery directly by Orbiter because they are beyond SOC retrieval. Satellite count is much higher due to multiple satellites required in some programs as indicated by the numbers in the table.

Table 3.3-2 lists 15 Solar Terrestrial mission programs, 3 are flagged for deployment and recovery directly by Orbiter Programs, such as the International Solar Polar Mission (SS) and the X-Ray Observatory (S27) are included in the table.

TABLE 3.3-1 SATELLITE/SERVICE USER MODEL FOR ASTROPHYSICS MISSIONS
SHEET 1 OF 3

ID NO.	NAME	MISSION FUNCTION*	ORBIT H	ORBIT I	MASS KG UP	MASS KG DN	LENGTH M	DIA M	TRAFFIC (1) 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A3	SPACE TELESCOPE (S3)	D S R	593 KM	28.5	11000 11000 --	 11000 11000	13.6	4.3	●	1	●	●	1	1	●	1	●	●	1	1	●	1	●	●
A7	GAMMA RAY OBSERVATORY (S9)	D S R	400	28.5	11000 11000 --	-- 11000 11000	6.0	4.5	1	●	1													
A4	COSMIC BKGND EXPL. (2) (S7)	D R	900	99	1421 --	-- 1421	4.8	4.4	1		1													
A5	EXTREME UV EXPLORER (S10)	D R	550	28.5	400 —	— 400	4.5	2.0		1	1													
A10	X-RAY TIME EXPLORER (S11)	D S R	400	28.5	1000 1000 —	-- 1000 1000	4.0	2.0		1	●	1	1	●	1									
A61	SOLAR CORONA EXPLORER (2) (S13)	D S R	600	33	1000 1000 —	— 1000 1000	3.5	3.0		1		●		1										
A8	GRAVITY PROBE B (2) (S14)	D R	520	90	1270	— 1270	4.2	4.2			1	●	●	1										
A9	ADV X-RAY ASTROPHY FAC. (S17)	D S R	450	28.5	10000 10000	 10000 10000	11.5	3.1			1	●	1	●	●	1	1	●	1	●	●			

(1) NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

(2) DIRECT ORBITER LAUNCH AND RECOVERY

*D – DEPLOY
S – SERVICE
R – RETRIEVE

R81-2100-134B

TABLE 3.3-1 SATELLITE/SERVICE USER MODEL FOR ASTROPHYSICS MISSIONS SHEET 2 OF 3

ID NO.	NAME	MISSION FUNCTION*	ORBIT		MASS KG		LENGTH	DIA	TRAFFIC 1															
			H	I	UP	DN	M	M	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A13	COSMIC RAY OBSERVATORY 2 (S23)	D S R	400 KM	56°	18000 18000	– 18000 18000	15	4.5			1	●	●	1	1	●	●	●	●	1				
A14	LARGE AREA MODULAR ARRAY (S28)	D S R	400	28.5	5200 5200 –	– 5200 5200	6.0	4.0				1	●	●	●	●	1				1			
A15	VERY LONG BASELINE INTERFACE (S29) 2 3	D S R	1000	45	NA			4.5				1	●	●	1									
A52	UV PHOTO/POLAR-METRIC EXP	D R	400	28.5	545 –	– 545		3					1		1									
A53	INTERNATIONAL UV EXPLORER (FOREIGN)	D R	35786	0	500	– 500	4	3					1					1						
A59	SIMULTANEOUS ASTRO MISSION (S42)	D R	35786	0	2075 –	– 2075	4	3					1					1						
A54	EXTREME UV SPECTRO-SCOPE (S44)	D R	35786	0	1000 –	1000	4	3					1					1						
A55	X-RAY SPECTROSCOPY (S39)	D S R	400	28.5	1500 1500 –	– 1500 1500	3	2						1	●	1								
A56	SOFT X-RAY SURVEY (S40)	D R	400	28.5	1600 –	– 1600	4	3						1		1								

1 NUMERALS DENOTE SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

2 DIRECT ORBITER LAUNCH AND RECOVERY

3 SOC SERVICE OPTION TO BACK UP ORBITER AVAILABILITY

*D – DEPLOY
S – SERVICE
R – RETRIEVE

R81-2100-135B

TABLE 3.3-1 SATELLITE/SERVICE USER MODEL FOR ASTROPHYSICS MISSIONS SHEET 3 OF 3

ID NO.	NAME	MISSION FUNCTION*	ORBIT		MASS KG		LENGTH	DIA	TRAFFIC 1															
			H	I	UP	DN	M	M	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A57	MOLECULAR LINE SURVEY (S45)	D R	600 KM	28.5	1000	1000		3.5						1			1							
A58	ADVANCED RELATIVITY 2	D R	520	90	901	901	3.6	2.2							2						?			
A16	SUBMILLIMETER TELESCOPE 2 (S30)	D S R	1000	98	1000 1000	1000 1000	12.0	4.5								1		●		●		●		1
A17	AMBIENT DEPLOY IR TELESCOPE (S25)	D S R	500	28.5	18000 18000 -	18000 18000		4.5								2	1	1	1	1	1			
A18	IR INTERFEROMETER (S31)	D S R	400	28.5	22500	22500	100										1	1	1	1	1	1		
A19	GRAVITY WAVE INTER-FEROMETER (S32)	D R	35786	0	11250	–	1000 TOTAL											4	4			1		
A20	COSMIC-COHERENT OPT SYS (S33)	D	35786	0	11500		12 100 TOTAL	4												3	3		3	3
A21	LONG OPTICAL UV TELESCOPE (S36)	D	450	28.5	22800		28.5	8.4													1	1	1	1
A22	100M THIN APERTURE TELESCOPE (S34)	D	35876	0	10600			100														4	4	

1 NUMERALS DENOTE SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

2 DIRECT ORBITER LAUNCH AND RECOVERY

*D – DEPLOY
S – SERVICE
R – RETRIEVE

R81-2100-136B

TABLE 3.3-2 SATELLITE/SERVICE USER MODEL FOR SOLAR TERRESTRIAL MISSIONS SHEET 1 OF 2

ID NO.	NAME	MISSION FUNCTION*	ORBIT H	ORBIT I	MASS KG UP	MASS KG DN	LENGTH M	DIA M	TRAFFIC [1] 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
S3	ISPM-SOLAR POLAR (S5)	D	5.2AU	23°	683		2.0	3.2	1															
S5	CHEM REL MODULE [2] (S4)	D R	1200	57	2700	2700	2.0	3.0	1	1														
S7	ORIGIN OF PLASMA (S12)	D	240ER	23	1000		3.5	3.0		4														
S9	SUBSAT FACILITY (S22)	D R	400	28.5	500	500	1.5	1.0		1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1									
S11	SOLAR PROBE (S20)	D	4RS	23	1500		4.4	3.8				1												
S13	SOLAR CYCLE & DYN MISSION (S21)	D S R	575	28.5	2600	2600	4.6	2.4				1	●	1	1	●	●	●	●	●	1			
S51	ASTRONOMY	D S R	5000	28.5	950		1.0	2.4					1		●		●		●		1			
S52	GAMMA RAY TRANS EXPLOR (S41)	D R	450	28.5	3000 –	– 3000	2	3					1		1									
S53	X-RAY OBSERVATORY (S27)	D S R	400	28.5	3550		8	3					1	●	●	1 ●	● 1	●	●	1				
S54	ADV INTERPLANETARY EXPLOR (S37)	D	LI		1200		1						1											
S6	ACT. MAG PART EXPLOR (S-8)	D	300KM 7RE	28.5	770		1.1	3	1															

[1] NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

[2] DIRECT ORBITER LAUNCH AND RECOVERY

*D – DEPLOY
S – SERVICE
R – RETRIEVE

R81-2100-137B

TABLE 3.3-2 SATELLITE/SERVICE USER MODEL FOR SOLAR TERRESTRIAL MISSIONS SHEET 2 OF 2

ID NO.	NAME	MISSION FUNCTION*	ORBIT		MASS KG		LENGTH	DIA	TRAFFIC ▷1															
			H	I	UP	DN	M	M	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
S55	HEAVY NUCLEI EXPLORER (S38) ▷2	D S R	400 KM	56°	4000	4000	8.8						1	●	●	●	1							
S56	LARGE SOLAR OBSERVATORY	D S R	350	28.5	9800		16.2	4.6						1	●	●	●	●	1					
S12	SOLAR TERR OBSERVATORY (S24) ▷2	D S R	400	57			80								1	1	1	1	1	1				
S15	CLOSE SOLAR ORBITER	D	.1AU	23															1					

▷1 NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

▷2 DIRECT ORBITER LAUNCH AND RECOVERY

*D – DEPLOY
S – SERVICE
R – RETRIEVE

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TABLE 3.3-3 SATELLITE/SERVICE USER MODEL FOR PLANETARY MISSIONS
SHEET 1 OF 2

ID NO.	NAME	MISSION FUNCTION*	ORBIT H	ORBIT I	MASS KG UP	MASS KG DN	LENGTH M	DIA M	TRAFFIC [1] 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
P2	VENUS ORB. IMAGE RADAR (P2)	D	.72AU		1000		6	6		1														
P4	SATURN ORBITER (P7)	D	9.5AU		3000	--	70	5					2											
P6	URANUS NEPTUNE PLUTO (P6)	D	40AU		1000	--									1	1								
P7	ASTEROID MULTI RENDZ (P5)	D	3AU		2000		35	8									1							
P8	LUNAR POLAR ORBITER (P10)	D	400K		300	--	6.0	4.5									1							
P5	MARS SAMPLE RETURN (P8)	D	1.5AU		7000	--	70	5.0										1		1				
P11	NR EARTH ASTEROID SAMPLE (P13)	D	3AU		4000		70	5.0									1			1				
P15	LUNAR BACKSIDE SAMPLE (P17)	D																1						
P14	AUTO PLANETARY STATION (P16)	D	400	28.5	25000		80	15											1					
P16	GANYMEDE LANDER (P18)	D	5.2AU		80			1											1					
P10	COMET SAMPLE RETURN (P12)	D	N.A.		3500		70	5.0													1			

[1] NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

*D – DEPLOY

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TABLE 3.3-3 SATELLITE/SERVICE USER MODEL FOR PLANETARY MISSIONS SHEET 2 OF 2

ID NO.	NAME	MISSION FUNCTION*	ORBIT		MASS		LENGTH	DIA	TRAFFIC 1															
			H	I	UP	DN	M	M	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
P12	VENUS LANDER (P14)	D	.72AU		550		2.0	1.0														1		
P13	AUTO MOBILE LUNAR SURVEY (P15)	D	400K		500		1.5	1.0														1		
P16	GALILEO ORBITER	D	5.2AU		1800		5.1	4.4																
P16	GALILEO PROBE	D	5.2AU		450		--	1.3																

*D – DEPLOY

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Fifteen Planetary programs are listed in Table 3.3-3 including Saturn Orbiter (P7) which involves deployment of two satellites in 1989. The Galileo Orbiter and Probe deployments are not shown on the Table since they occur prior to 1985. These satellites are listed because if they experience considerable delay in launch, possibly due to budget constraints, they could be deployed during the SOC era.

3.3.1.3 Earth Sensing Satellite Model

The data for Earth Sensing missions from S/SUM are presented in the Figure 3.3-4 histogram. Resource Observation and Global Environment mission categories are included in the Earth Sensing Model. The Resource Observation mission component for this category is seen to reach an average of nearly eight missions per year during the late 1980s but then slacks off to four or five launches per year during the 1990s.

The other component of the Earth Sensing mission category, Global Environment, is depicted in the upper portion of the histogram presented in Figure 3.3-4. During the potential SOC availability time period after 1987-88 the Global Environment mission launch rate holds at an average of over five per year until the 1997 where the increased totals reflect the build up of the postulated Department of Energy (DOE) nuclear waste disposal launches.

Tables 3.3-4 and -5 contains the satellite characteristics, orbits, and mission traffic scheduled for the Earth Sensing category. Resource Observation (Table 3.3-4) contains 16 satellite programs, which include 2 commercial programs. Landsat D (R1) and Magsat B (R2) are two of the better known NASA satellites in this category.

Global Environment (Table 3.3-5) contains 13 programs, which include a foreign satellite (Inmetsat), 3 commercial satellites, and the DOE Nuclear Waste Disposal. The high number of Waste Disposal Missions in the late 1990s drives the Earth Sensing Model.

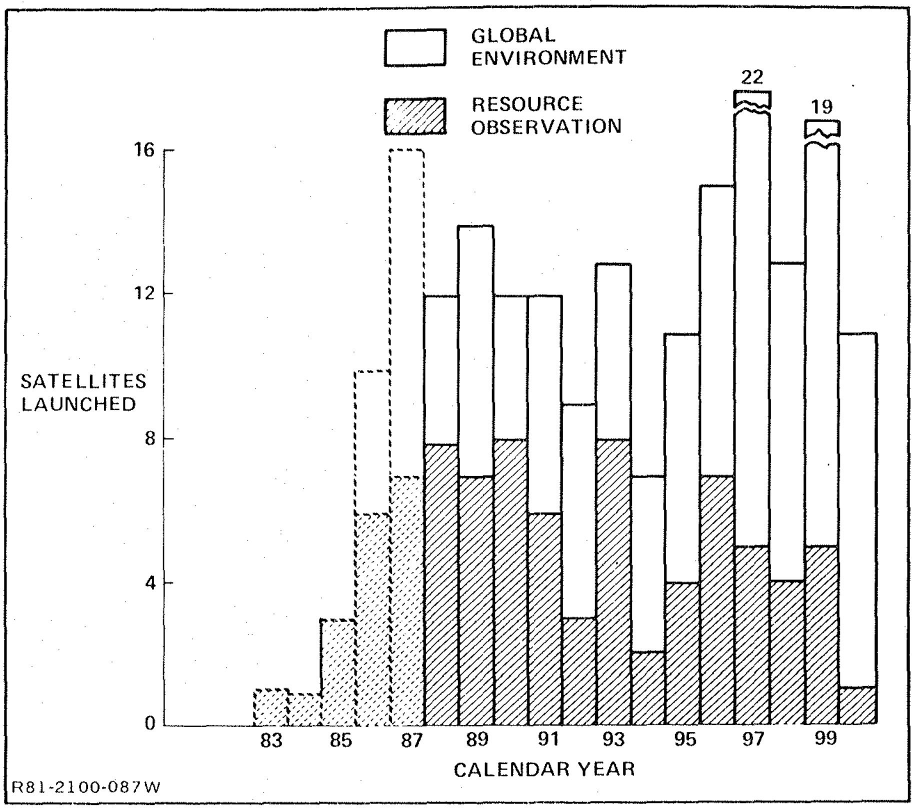

Fig. 3.3-4 Earth Sensing Satellite Model

TABLE 3.3-4 SATELLITE/SERVICE USER MODEL FOR RESOURCE OBSERVATION MISSIONS SHEET 1 OF 2

ID NO.	NAME	MISSION FUNCTION*	ORBIT H	ORBIT I	MASS UP	MASS DN	LENGTH M	DIA M	TRAFFIC 1 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
R2	LAND SAT D (R1) 2	D S R	705	98	1597 1597	· 1597 1597	3 0	2.0	1		●		1											
R1	MAGSAT B (R2) 2	D R	550	99	272	272	.9	.9		1	1													
R4	GRAVSAT 2 (R3 & R8)	D	170	90	4000		4.0	1.2	2					2										
R50	ICE & CLIMATE EXPLORER 2	D S R	700	87	5000 5000	· 5000 5000	18.	4.		1	●	1	1	●	● 1									
R51	REGION H_2O QUAL MONITOR (R13) 2	D S R	700	58	1000 3600 –	· 3600 1000	3.5	2.5		1		●		1										
R53	EARTH OBSERVATION/ COMM	D S R	35786	0	943 2040	–	4.0	3.1		1	2	1	2 ●	1 ● ●	●	1 ● ●	2 ●	1	●	3 ● ● 1	● 2	1	● ● ● 2	1
R54	RESOURCES/POLLUTION (R12)	D S R	35786	0	615 998	–	1.6	1.2		1	1	2	2 ●	2 ●	3 ● ●	● ●	3 ● ●	1 ● ● ●	2	2 ● ● ● 1	3 ● 1	● ● 2	3 ● ● 2	● ● ● 3
R55	EARTH SURVEY 2	D S R	910	99	772	–	3.0	1.5			1		1 ●		1 ● ●		1 ● ● ●		1 ● ● ● 1		1 ● ● ● 1		1 ● ● ● 1	
R56	COASTAL SATELLITE 2	D S R	296	100	4173 –	– 4173	8.0	3.7			1	●	●	●	●	1								

1 NUMERALS DENOTE SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

2 DIRECT ORBITER LAUNCH & RECOVERY

*D – DEPLOY
S – SERVICE
R – RETRIEVE

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TABLE 3.3-4 SATELLITE/SERVICE USER MODEL FOR RESOURCE OBSERVATION MISSIONS SHEET 2 OF 2

ID NO.	NAME	MISSION FUNCTION*	ORBIT H	ORBIT I	MASS UP	MASS DN	LENGTH M	DIA M	TRAFFIC ▷1 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
R8	SOIL MOISTURE (R10) ▷2	D	465	56	408		3.5	4.6			1			1			1			1			1	
		R											1			1			1			1		
R5	OPERATIONAL LAND OBSERVATION SYSTEM (R6) ▷2	D	700	98	1700	–	4.3	2.2		1	1	1		1	1	1			1	1	1			1
		S			1700	1700						●	●	●		●	●	●			●	●	●	
		R			–	1700							1	1	1		1	1	1			1	1	1
R58	ADV GEOLOGY SATELLITE (R5) ▷2	D	700	98	2000	-	4.0	3.0				1					1							
		S			2000	2000								●					●					
		R														1					1			
R59	PRIVATE EARTH RESOURCE (COMMERCIAL) ▷2	D	700	98	1700	–	4.3	2.2				1				1								
		S			1700	1700								●				●	●	●				
		R			–	1700										1								1
R6	ADV THERMAL MAPPING (R7) ▷2	D	700	98	1450	–	2.5	2.0				1		1										
		S			1450	1450								●		●		●						
		R			–	1450										●		1		1				
R7	MAGNETIC FIELD SURVEY (R9) ▷2	D	300	97	800	–	3.5	2.5				1												
		S			800	800							●	●										
		R			–	800									1									
R60	ENVIRONMENTAL MONITOR ▷2	D	700	57	1000	–	3.5	3.5					1		1									
		S			1000	1000									●		●		●					
		R			–	1000											●		1		1			

▷1 NUMERAL DENOTE SCHEDULE EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

▷2 DIRECT ORBITER LAUNCH & RECOVERY

*D – DEPLOY
S – SERVICE
R – RETRIEVE

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TABLE 3.3-5 SATELLITE/SERVICE USER MODEL FOR GLOBAL ENVIRONMENT MISSIONS SHEET 1 OF 2

ID NO.	NAME	MISSION FUNCTION*	ORBIT		MASS		LENGTH	DIA	TRAFFIC ▷1															
			H	I	UP	DN	M	M	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
E2	GEO OPER. ENVIR. SAT (E1)	D	35786	0	720		3.5	2.0		1	1					1					1			
		S																	●				●	
		R													1	1					1			
E6	NAT'L OCEAN SAT (E4) ▷2	D	787	87	4500		10.7	4.5		1	1	1	1			1	1							
		S									●	●		●	●			●	●	●	●			
		R										1	1			1	1				1	1		
E7	UPPER RES SAT ATMOS (E5) ▷2	D	500	56	3700	–	4.0	2.0		1	1													
		S			3700	3700						●	●	●	●	●	●	●	●	●	●			
		R½			–	3700															1	1		
E5	NOAA-H&I (E7) ▷2	D	830	99	4173	–	8.0	3.7		1	1													
		S			4173	4173						●	●											
		R			–	4173								1	1									
E4	EARTH RADIATION (E3) ▷2 ▷3	D	600	46	1134	–	4.0	2.1			1				1									
		S			3600	3600							●				●							
		R			–	1134									1				1					
E50	INMET SAT (FOREIGN)	D	35786	0	943 –	– 943	3.0	2.5			1	2	4	3	4	2	4	3	4	3	4	3	4	
E52	STORM SAT (COMMERCIAL)	D	35786	0	1600		6.0	3.7			1					1					1			
		S			3600	3600													●			●		●
		R			–	1600										1								
E53	MAP GRAVITY FIELD/ COMM	D	35786	0	615	–	1.0	1.4			1				1			1			1			
		R			–	615										1				1			1	
E9	TOPEX (E6) ▷2	D	700	87	1000	–	4.0	3.0			1													
		R			–	1000								1										

▷1 NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

▷2 DIRECT ORBITER LAUNCH AND RECOVERY

▷3 SOC SERVICE OPTION TO BACK UP ORBITER AVAILABILITY

*D – DEPLOY
S – SERVICE
R – RETRIEVE

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TABLE 3.3-5 SATELLITE/SERVICE USER MODEL FOR GLOBAL ENVIRONMENT MISSIONS SHEET 2 OF 2

ID NO.	NAME	MISSION FUNCTION*	ORBIT H	ORBIT I	MASS UP	MASS DN	LENGTH M	DIA M	TRAFFIC 1 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
E10	OPERATIONAL METEROLOGY (COMMERCIAL) 2	D	800	87	4500	–	10.0	4.5					1											
		S			4500	4500									●									
		R			–	4500											1							
E11	OCEAN RESEARCH	D	300	56									1											
		S																						
	(E8) (FIREX) 2	R												●	●	●	●							
																		1						
E54	GLOBAL REG ATMOS MONIT	D	700	98	2381	–	8.5	3.4				1				1								
		S																						
	(E9) (LARS) 2	R			2381	2381								●				●		●		●		
					–	2381										1								1
E57	NUCLEAR WASTE DISPOSAL (DOE)	D	.85AU	28.5	10430	–												1	3	5	10	10	10	10

1 NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

2 DIRECT ORBITER LAUNCH AND RECOVERY

*D – DEPLOY
S – SERVICE
R – RETRIEVE

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3.3.1.4 Space Testing Modeling

A representative set of space test flight programs was developed for the 1981-2000 time period. These missions, which include approximately 22 launches, focus on experiments related to the SOC induced environment: long duration space exposure, micro gravity fluid mechanics, large space structure technology, and scientific instrument development.

The S/SUM launch activity for this mission category is presented in Figure 3.3-5. The activity profile shown indicates a maximum of two missions in a given year.

The following payloads/satellites are included in this mission category:

- Long Duration Exposure Facility (LDEF) - the LDEF is a reusable, gravity-gradient stabilized, free-flying structure. It has no propulsive capability and can accommodate many technology, science, and applications experiments, both passive and active, that require extended exposure to space. Experiments are mounted on 72 periphery trays and on 2 trays at each end. These trays could be removed and replaced with new experiments in SOC. The LDEF could even remain attached or tethered to SOC to facilitate periodic experiment examination.
- Induced Environment Contamination Monitor (IECM) - An IECM similar to the one used during the Orbiter flight tests, will also be used on SOC to measure gaseous and particulate contaminants during various orbital operations (i.e., Orbiter cargo removal, satellite servicing, etc). The IECM will be positioned at different locations around SOC, with the manipulator to measure contamination levels.
- Space Deployable Antenna Experiment - An antenna system of approximately 50-m diameter would be deployed on the SOC for a flight test. The antenna would contain a multibeam feed system that would be excited for RF transmission and beam pattern tests. The antenna would also be instrumented to measure

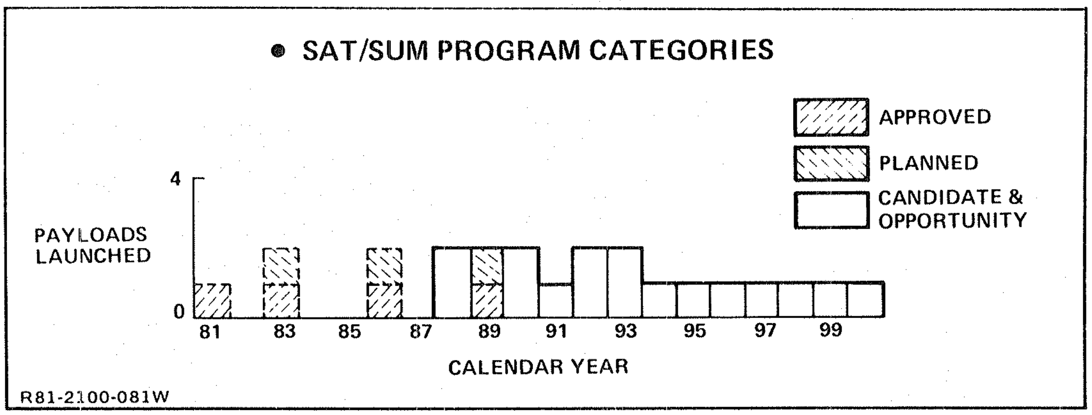

Fig. 3.3-5 Space Testing Modeling

dynamic response to environmental inputs, control system commands, and surface and structural distortions encountered. At the conclusion of testing, the antenna system would be restowed and returned to Earth where it would be studied and refurbished for a subsequent flight if required.

- Structural Assembly Demonstration Experiment (SADE) - the SADE will establish a quantitative correlation between earth-based assembly simulations and on-orbit operations. Space-based assembly will occur through a coordinated activity between the RMS and EVA crewman. Once assembly has been completed, a structural dynamics experiment will be performed to obtain correlation with ground testing and analytical predictions and to assess the effects of SOC Coupling. A large space structure mission will demonstrate on-orbit fabrication, assembly and integration of a large structure, and also provide a user-oriented satellite platform in the process.

- Deployable Platform Experiment (DPE) - The objective of the DPE is to validate the characteristics of large space system platform technology. Ground support programs will be initiated to study various aspects of platforms prior to flight experiments. Subsystem verification will also be done in flight testing.

- Two Phase Fluid Mechanics and Heat Transfer Facility - Specific objectives are to develop an understanding of, and mathematical models for, reduced-gravity physical phenomena such as two-phase flow, forced convection boiling, reorientation fluid dynamics, bubble dynamics, pool boiling, and sloshing dynamics.

Table 3.3-6 presents the descriptive data and traffic schedules on these Space Testing programs. The Long Duration Exposure Facility (LDEF) program at the top of Table 3.3-6 was launched prior to 1985 with its first retrieval scheduled for 1985. The 1986 launch for a longer mission offers the potential for servicing and change-out of experiments in 1987, with a retrieval schedule for 1988.

TABLE 3.3-6 SATELLITE/SERVICE USER MODEL FOR SOC SPACE TESTING MISSIONS

ID NO.	NAME	MISSION FUNCTION*	ORBIT H	ORBIT I	MASS UP	MASS DN	LENGTH M	DIA M	TRAFFIC [1] 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
O110	LONG DURATION EXPOSURE FACILITY (OI-17)	D S R	509	28.5	4500 4500 –	– 4500 4500			1	1	●	1	1	●	●	1	1	●	●	●	1	1	●	●
O12	INDUCED ENVIRO CONTAMINATION (OI-11)	D			338	–								1										
O157	LARGE DEPLOY ANTENNA DEMO (OI-22+)	D			4700	–		50		1					1									
O159	STRUCTURAL ASSY (OI-21+)	D			19000		70						1											
O160	DEPLOYABLE PLATFORM EXPERIMENT (OI-23+)	D			15000		50					1					1							
O161	FLUID MECH & HEAT XFER FACILITY (OI-25)	D			580		1	1						1										
O162	PACE EXMPTS (OI-26/27)	D			100													1				1		
O163	SCIENCE INSTRUMENT DEMO	D														1			1	1			1	1

*D – DEPLOY
S – SERVICE
R – RETRIEVE

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3.3.2 ECONOMIC ANALYSIS

Alternate mission models (High, Medium and Low) were derived from the S/SUM-SOC data by assessing the cost of projected satellite programs with future NASA budgets. In the budget projection process, it was recognized that both national policy and national economic growth could influence the funding available to the various space mission categories. In the cost assessment, it was necessary to define simple cost estimating relationships to apply to the satellite within each mission area. Finally, it was necessary to test cumulative costs against budget funds available to define compatible programs schedules. The major ground rules and assumptions used in this analysis are shown in Figure 3.3-6.

This process, covered the 1983 through 2000 time frame for six NASA mission areas (Planetary, Astrophysics, Solar Terrestrial, Global Environment, Resource Observations and Space Testing). In projecting alternative budgets, baseline budgets were established based upon data from recent NASA 5-year plans and FY 82 budget estimates using satellite program costs only, excluding Research and Analysis, sub-orbital testing, Spacelab and other non-satellite programs.

Estimates of the cost per unit mass of a spectrum of types of satellites were developed using data derived from informal contacts with NASA centers and from in-house cost evaluation file data. Three rather distinct categories or types of satellites tended to emerge, suggesting three cost factors rather than a single one. Cumulative program costs for each mission area could then be developed assuming the S/SUM launch sequence with satellite costs assigned at launch date. By referencing the cumulative cost history from S/SUM against the three alternative budgets for each mission area, corresponding alternative budget-limited launch schedules were developed. Reflights within a given satellite program and non-NASA satellite missions were then inserted on the budget limited schedules based upon

APPROACH

- DEVELOP HIGH, MEDIUM AND LOW BUDGETS
- COST S/SUM SOC SATELLITE LAUNCH PLAN
- MATCH LAUNCH SCHEDULES TO GUM BUDGETS AVAIL.

COVERAGE

- MAJOR NASA OFFICES (OSTA, OSS, ETC) ONLY
- TIME FRAME – 1983 THRU 2000

BUDGET PROJECTION

- BASELINE SAT PROG BUDGETS - 5 YR PLANS & BUDGET EST
- SAT. PROG ONLY; EXCLUDES R & A, SUB ORB, SPACELAB & OTHER

SATELLITE PROGRAM COST ASSESSMENT

- PROG COSTS & MASS FROM NASA & GAC DATA
- COST PER UNIT MASS - THREE SAT. CLASSES

CUM PROG COSTS & BUDGET LIMITED LAUNCH SCHED

- S/SUM LAUNCH SEQUENCE
- SAT. COSTS ASSIGNED AT LAUNCH DATE
- LAUNCH DATE KEYED TO AVAIL BUDGETS
- RE-FLIGHTS & NON-NASA SCHEDULED PER S/SUM

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Fig. 3.3-6 Economic Analysis Ground Rules & Assumptions the S/SUM intervals between follow-on missions, and upon S/SUM schedules for non-NASA programs.

3.3.2.1 Budget Trending Alternatives

From the baseline budget available on the six mission areas, covering a maximum of 6 years, it was necessary to project future alternative budgets covering a span of the next 18 years. Figure 3.3-7 illustrates three conceptual approaches for developing alternate budgets.

The first, Continued Trend, illustrates projecting the present trend of growth along with a High and Low budget based on a growth or shrinkage of this annual budget trend by an arbitrary percent each year. A second approach, Current Base, using FY-82 as an annual base budget level and projecting zero, and positive and negative annual percentage growth rates of 2.5% is illustrated second. This 2.5% real annual growth and its mirror shrinkage rate are keyed to the Autumn 1981 U.S. Long-Term Review assessment by Data Resources, Inc. of 2.5% real GNP growth rate through 2006. The third conceptual chart illustrates a choice of a constant (baseline) annual budget and then a constant delta above and below that level for the high and low projection.

The Continued Trend approach with varying growth rates above and below the trend offers the potential advantages of capturing the trend of budgeting for each mission area, and looks at growth potentials relative to trends in real Gross National Product. This approach has the weaknesses of a short trend base causing unrealistic swings of the annual budget on an 18-year projection. Study of NASA budgets over the last 15 years also indicates that the annual budgets in constant dollars fluctuate significantly, representing policy changes in contrast with national economic growth trends.

The Current Base approach establishes a recent budget as a base and looks at long term growth on an annual average basis comparable to real GNP changes. Although two weaknesses of this approach, potential

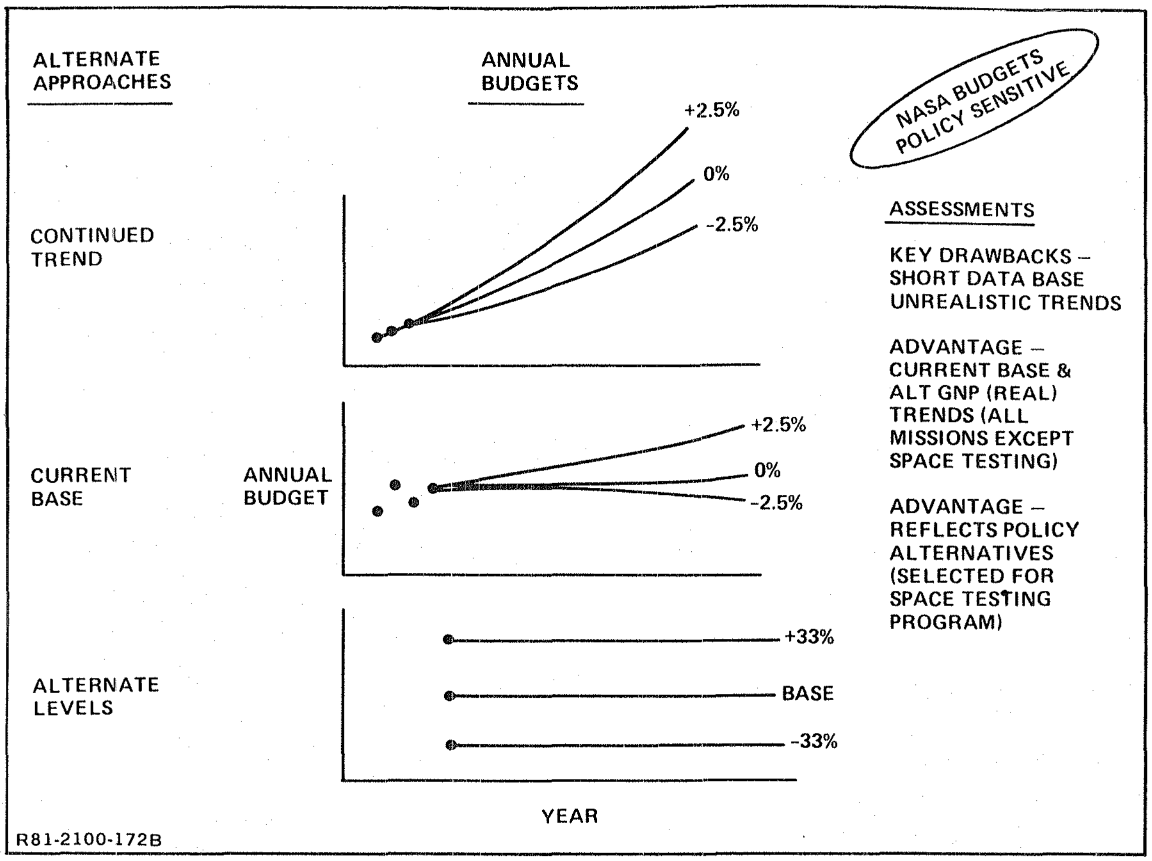

Fig. 3.3-7 Budget Trending Alternatives

bias in the chosen base and the policy nature of NASA funding are recognized, the Current Base approach offered near term policy guidance and use of reasonable real GNP trends. Projections of future High, Medium and Low budgets for five of the six NASA mission areas were carried out using this approach.

The Alternate Levels approach primarily reflects government policy alternatives and was used for the Space Testing mission area, with plus and minus 33% shifts around the small constant baseline budget.

3.3.2.2 Recent Budgets for NASA Satellite Programs

Table 3.3-7 presents recent satellite program budget histories for five traditional NASA mission areas. Data are provided in 1981 dollars with the dollar base of the data sources and the required adjustment factor for conversion to 1981 dollars presented to the upper portion of the chart. Data covering satellite total program costs, without Research and Analysis were, obtained from NASA 5-Year Plans, References 3.3-13, 3.3-14 and 3.3-15 and the FY-82 Budget Request (Reference 3.3-16).

The Astrophysics and Solar Terrestrial mission budgets are combined in the last 3 fiscal years. These combined budgets were therefore used as the budget history, which represents a generally rising trend of about 6% per year from FY-78 through FY-82. Planetary, Global Environment and Resource observation presented less obvious trends.

Because of the sensitivity of NASA budgets to policy changes and the shortness of the budget data base for trending, the FY-82 column of data was chosen as the baseline for these NASA mission areas.

Since definitive budget histories for Space Testing were not readily defined, a budget base for this mission area was derived out of recent OSTS and OAST programs and average Space Testing annual program costs through the late 1990s.

TABLE 3.3-7 ASSESSMENT OF NASA SATELLITE BUDGET HISTORIES BY TECHNICAL PROGRAM AREA

YEAR	FY-'77	FY-'78	FY-'79	FY-'80	FY-'81	FY-'82
$ YR/BASE ADJUST FACTOR	'78/'81 0.77	'79/'81 0.84	'80/'81 0.92	'80/'81 0.92	'81/'81 1.00	'82/'81 1.09
PROGRAM ELEMENTS		ANNUAL BUDGET, $M				
ASTROPHYSICS	68	147	157	256*	250*	295*
SOLAR TERRESTR	65	79	71			
PLANETARY	147	151	145	190	125	183
GLOBAL ENVIRON	—	—	30	55	60	122
RESOURCE OBS.	—	—	130	131	115	119

* COMBINED ASTROPHYSICS & SOLAR TERRESTRIAL

DATA BASE: – NASA 5YR PLANS FY'78, '79 & '80 & FY'82 NASA BUDGET REQUEST
– SATELLITE PROGRAMS ONLY, EXCLUDES SUPPORT R&A
– CONST '81$ USING JUNE '80 ESCALATION FACTORS

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3.3.2.3 NASA Satellite Mission Alternative Budget Projections

Budget history data were used in combination with the Current Base concepts in Figure 3.3-7 for annual budget projection to establish alternative budgets for the six NASA mission areas. Data base and High, Medium and Low annual and cumulative budgets for the 1983 through 2000 time frame were used as discussed in the following sections.

3.3.2.3.1 Alternate Budgets for Planetary Satellite Programs - Three alternate budget projections in 1981 dollars for the Planetary satellite program through the year 2000 are shown in Figure 3.3-8 as projections from the Current Base (FY-82 Estimate) from Table 3.3-7. Annual Budget alternatives are seen as: (1) constant at $185 M; (2) $185 M at the start of 1983 growing at 2.5% per year, and (3) this $185 M baseline shrinking at 2.5% per year. Thus the High annual budget has grown to nearly $290 M by the end of the year 2000, while the Low annual budget is seen to drop from $185 M in 1983 to under $120 M at the end of the year 2000.

This chart also provides these three budgets in cumulative form in the curves which slope upward to the right from the start of 1983. The baseline constant budget projection cumulates to over $3.25 B over this 18 year period. The High Budget projection cumulates to nearly $4.4 B while the Low Budget accrues a total of about $2.6 B. Although the differences between the high and low budgets is small during the 1980s the cumulative effects are significant by the mid 1990s.

3.3.2.3.2 Alternate Budgets for Combined Solar Terrestrial and Astrophysics Satellite Programs - Annual and cumulative alternate budgets are presented for these combined mission areas in Figure 3.3-9. It is seen that the combined budget history showed an annual increase of approximately 6% per year, resulting in nearly a threefold annual growth by the end of this century.

Basic zero growth, and plus and minus 2.5% per year projections from the 1983 baseline of $295 M are shown as the assumed annual

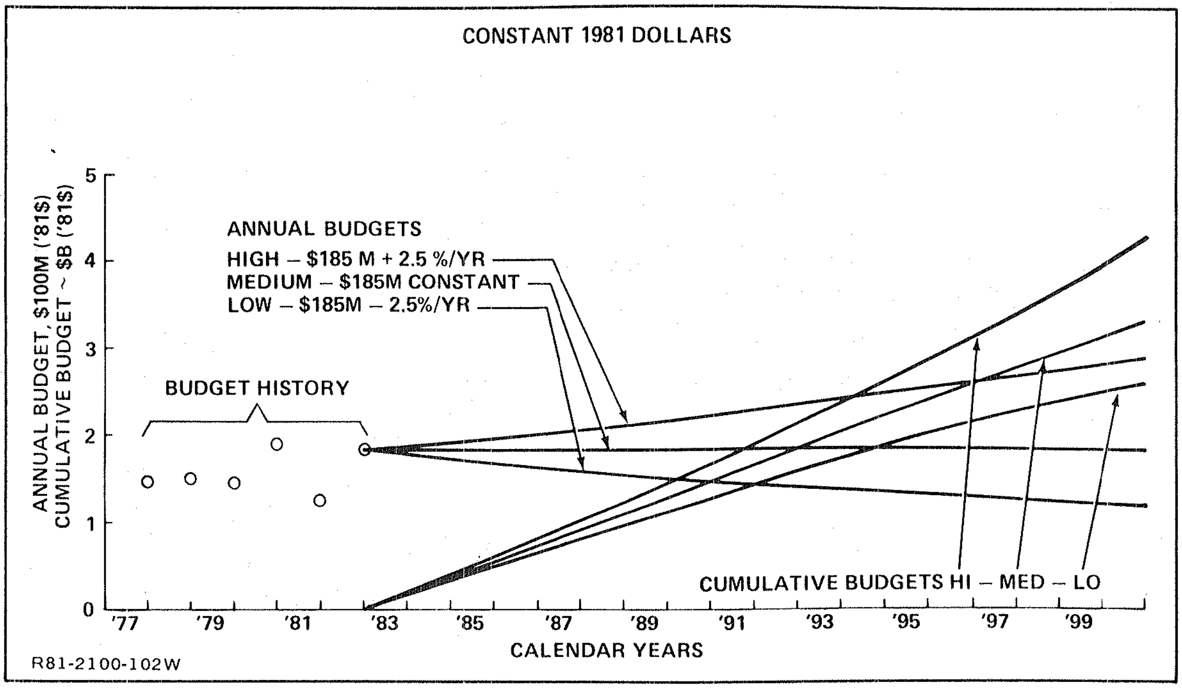

Fig. 3.3-8 Satellite Program Alternative Budgets for Planetary Missions

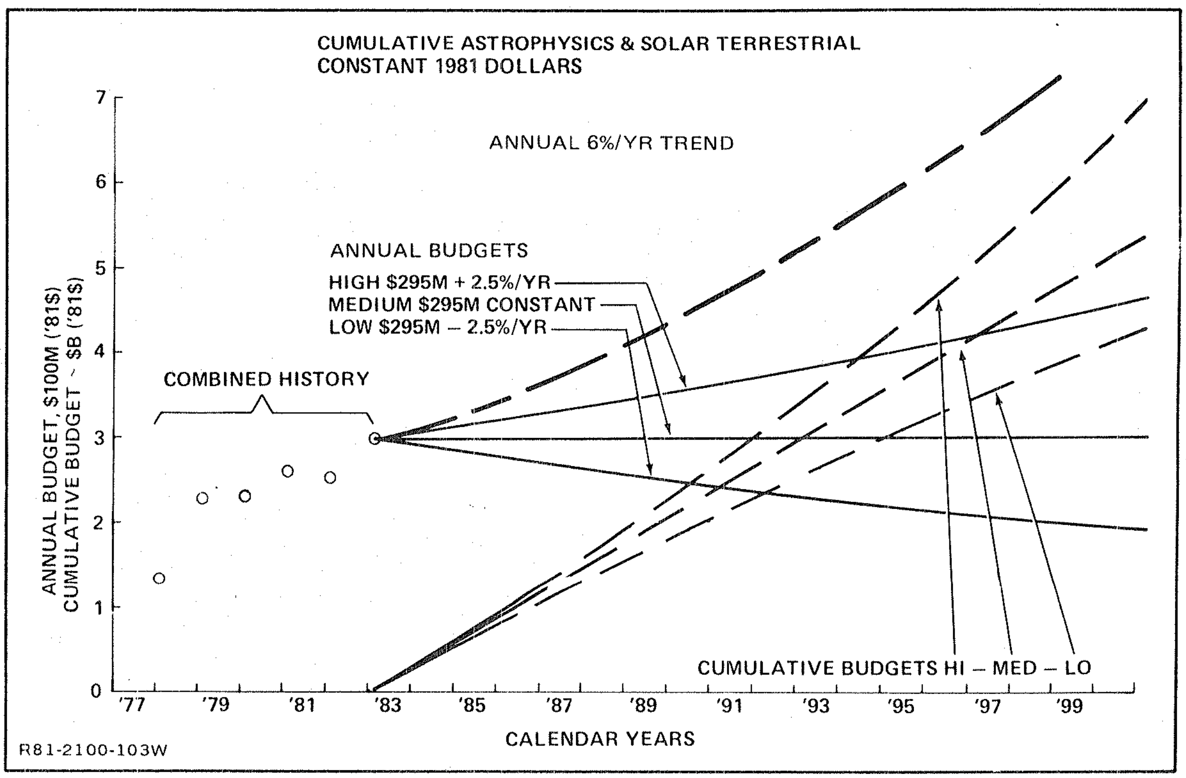

Fig. 3.3-9 Satellite Program Alternative Budgets for Combined Solar Terrestrial & Astrophysics Missions

budgets. The cumulative High budget makes nearly $7 B available for these combined satellite programs compared to just over $4 B for the cumulative Low budget over the 18 year period.

3.3.2.3.3 Alternate Budgets for Resource Observation Satellite Program - Budget history, and annual and cumulative projections at three levels are presented in Figure 3.3-10 for the Resource Observation mission, in constant 1981 dollars.

The limited budget history data are relatively constant and close to the $120 M baseline from the FY-82 budget estimate. Annual growth rates of zero and plus and minus 2.5% per year were again assumed. The resulting cumulative budgets over the 18 year period show a spread of nearly $1.25 B between the high and low projections.

3.3.2.3.4 Alternative Budgets for Global Environment Satellite Program - The budget history along with annual and cumulative alternate projections are presented in Figure 3.3-11 for NASA's Global Environment satellite program. Rapid increases in the annual budget history from 1979 through 1982 are thought to reflect policy changes in this mission area funding which can not be considered as a trend. Thus the FY-82 budget estimate of approximately $120 M was chosen as the baseline, and zero and plus and minus 2.5% growth per year projections were assumed.

The projected budgets for this Global Environment satellite program are identical to those used for the Resource Observation program.

3.3.2.3.5 Alternative Budgets for Space Testing Program - Budget histories for this mission area were derived out of advanced programs at OSTS and space systems technology at OAST. Assessments of the cost of Space Testing articles in the S/SUM/SOC model indicated an annual expenditure comparable to the average Space Testing budgets of OAST and OSTS at about $9 M/year. This constant value was selected as the medium budget projection shown in Figure 3.3-12. Because of the small

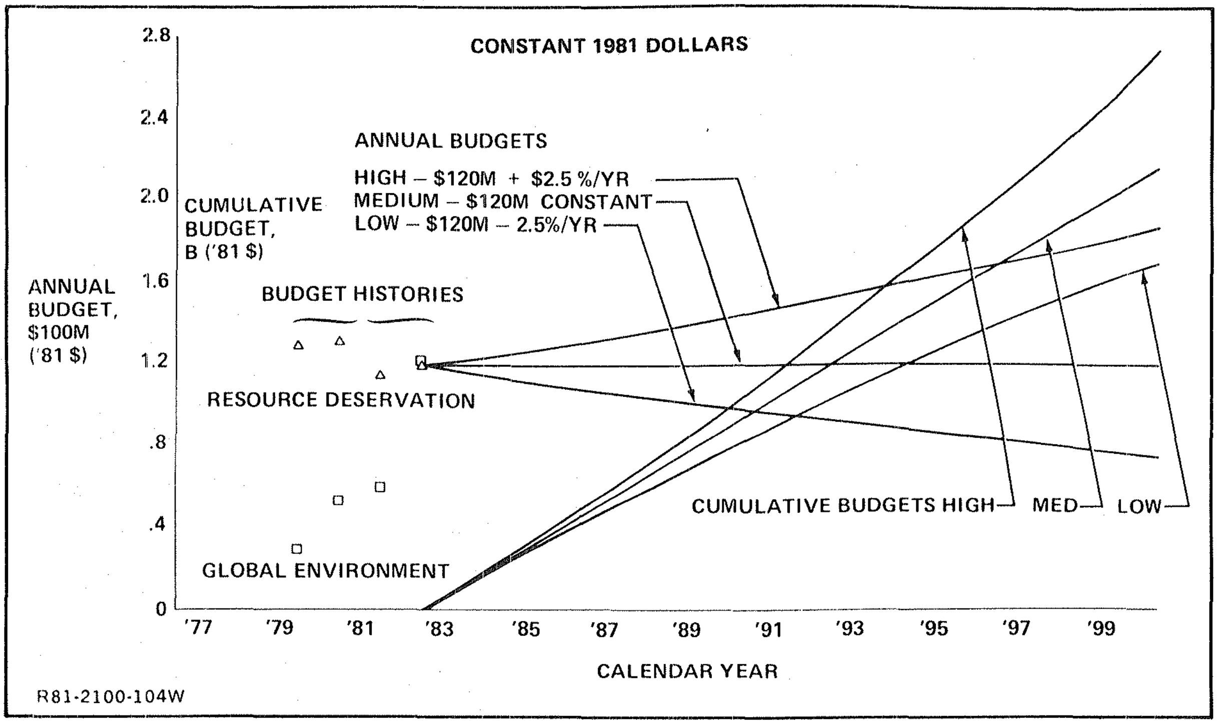

Fig. 3.3-10 Satellite Program Alternative Budgets For Global Environment & Earth Resources

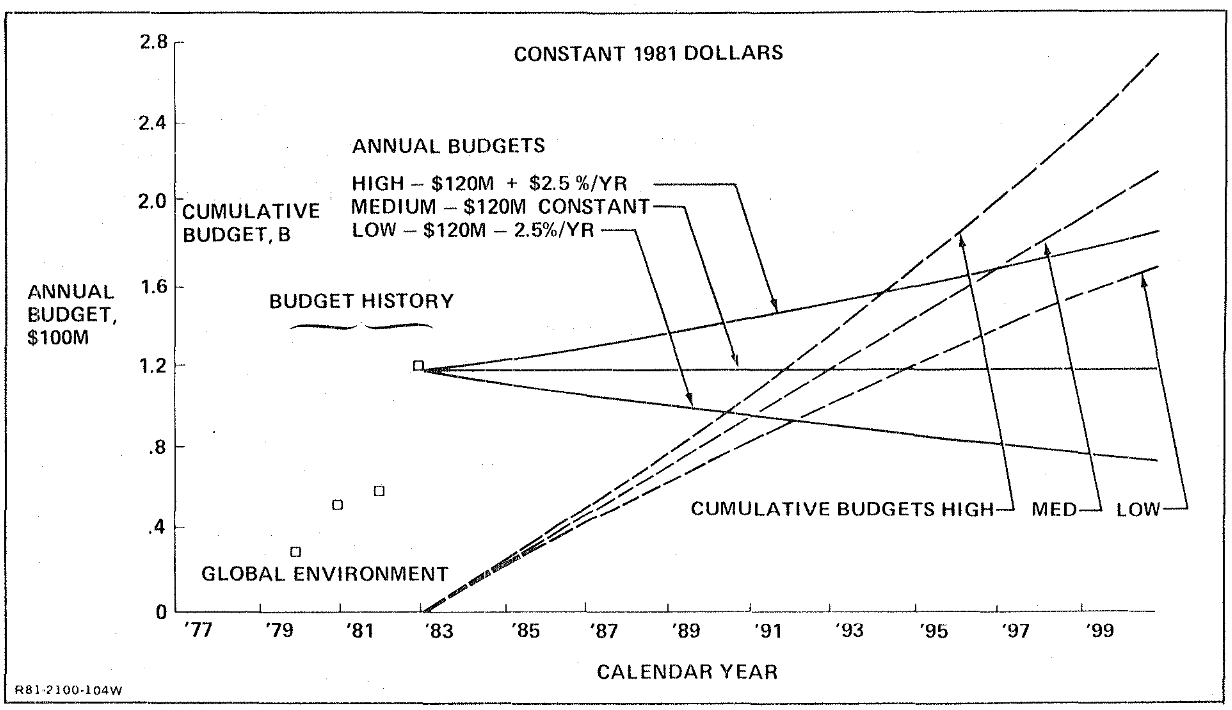

Fig. 3.3-11 Alternative Budgets for Global Environment Satellite Program

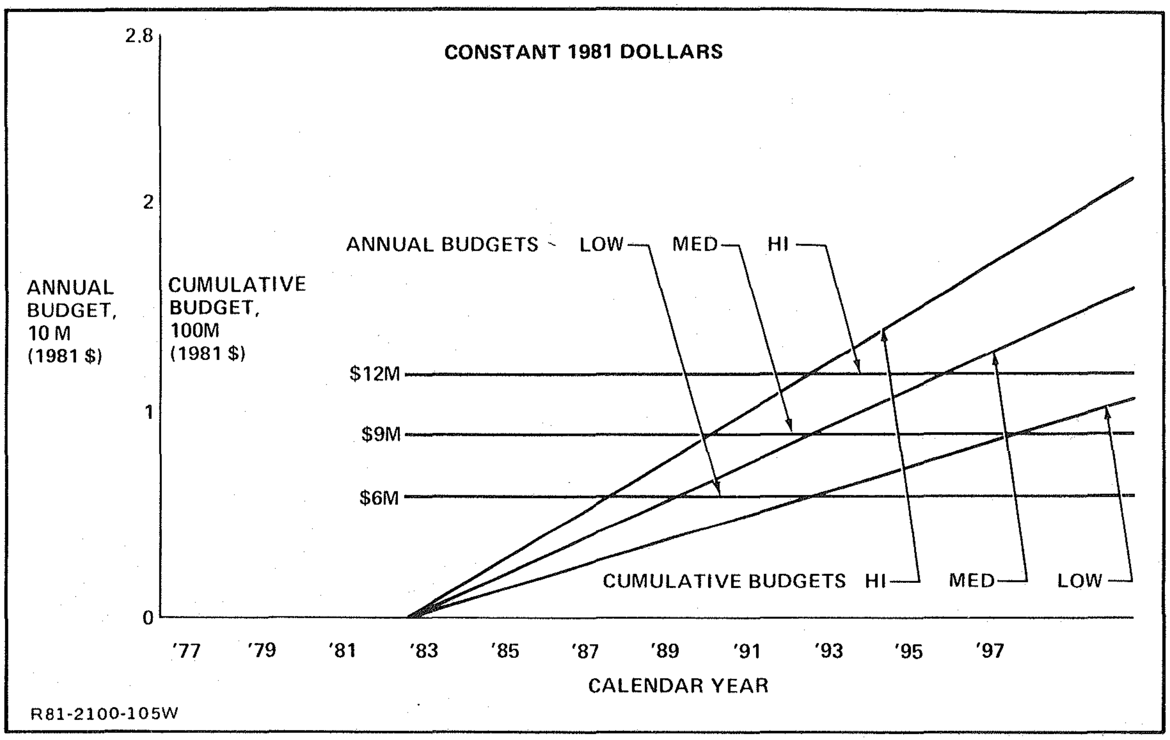

Fig. 3.3-12 Satellite Program Alternative Budgets For Space Testing Missions

overall budget level involved, it appeared appropriate to treat the high and low budgets as alternate policies parallel to the constant medium projection. A delta of 33% ($3 M) above and below the medium annual budget was chosen to reflect significant policy differences for the three budget projections.

Cumulative budgets corresponding to these three constant annual budget projections in Figure 3.3-12 show a significant spread by the end of the study time period.

3.3.2.4 Typical Satellite Program Costs vs Mass

As discussed previously in reviewing ground rules and assumptions for this economic analysis, simple cost estimating relationship (CERs) were needed to develop estimates of total mission area costs. The plot in Figure 3.3-13 of satellite total program cost versus total payload to operating orbit presents this simple CER development.

Program Costs in 1981 dollars and the on-orbit mass of a number of different classes of satellites were defined from informal NASA contacts and from Grumman internal studies. Data appeared to fall into three distinct bands of cost per unit mass.

Planetary programs and high technology programs involving advanced state-of-the-art sensors and/or guidance and control formed one band at the upper left of the chart. A CER of $250,000 per kilogram as indicated by the heavy line labeled Planetary/Landsat appeared to adequately represent this group.

A second band, shown through the center of the chart is based on several rather "conventional" high technology satellites not requiring major breakthroughs in technology. NOAA, HEAO and Solar Max define a slope of approximately $50,000 per kilogram shown for the Conventional LEO and GEO line.

A third type of satellite involving primarily structural elements was found to be again significantly less expensive per unit mass. A

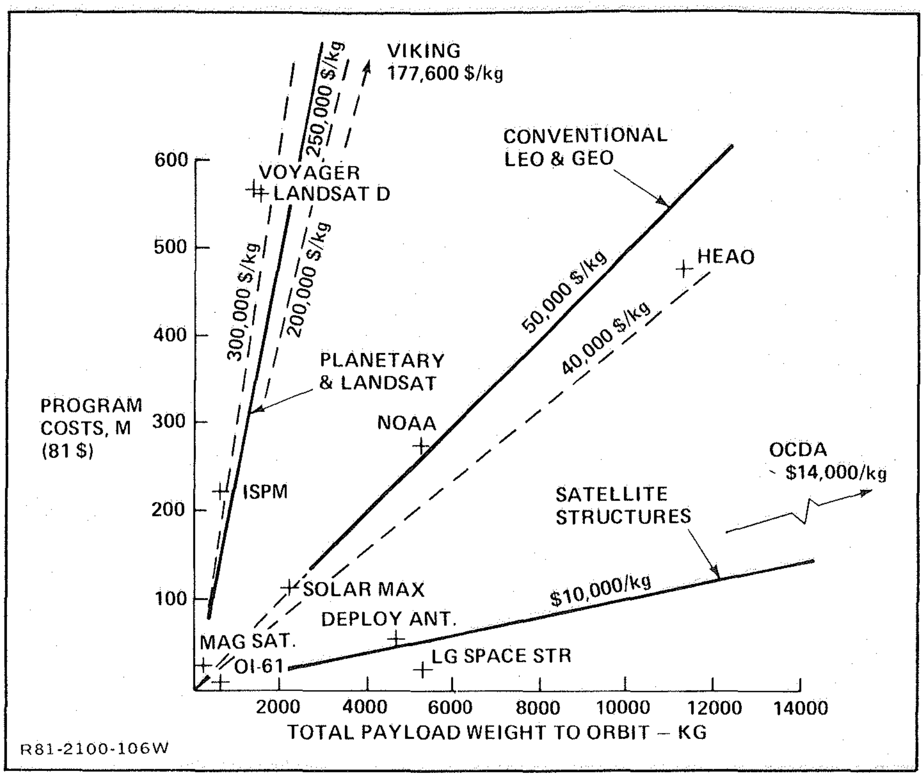

Fig. 3.3-13 Typical Satellite Program Costs vs Mass, 1981 $

total of four of these type articles was used to define the $10,000 per kilogram CER line at the lower right of the chart.

3.3.2.5 Cumulative Costs and Budget Limited Schedules

In this section the costs based on the preceding CER development are consolidated for each mission area and launch schedules are keyed to available budget to establish budget limited launch schedules.

3.3.2.5.1 Alternative Cumulative Budgets and Cumulative Program Costs - Planetary Satellites - The relationship between cumulative budgets and cumulative Planetary satellite program costs is shown in Figure 3.3-14. Cumulative costs were generated by summing costs based on the planetary CER applied to the satellite weights on the traffic schedule from the S/SUM/SOC planetary mission model in Table 3.3-3.

The cumulative cost progression, with each satellite identification number called out in Figure 3.3-14, indicates that out through 1991 the S/SUM/SOC schedule is generally close to the high cumulative budget (+2.5%/Yr) line. From 1993 on, the cumulative costs line rapidly diverges from the high budget line alternate. Cumulative budget lines of 5 to 10% per year are shown to illustrate general level of growth involved. The data point at the upper right labeled P-5 with an arrow denoting $14.2 B indicates that even a 10% annual real growth accrues only about two-thirds of the budget required to fund the complete S/SUM in the same time frame.

Figure 3.3-14 is also useful for defining satellite launch schedules for the three chosen projected budget levels of zero and plus and minus 2.5% annual growth. The horizontal, constant cost line drawn through the P-7 data point intercepts the High, Medium and Low cumulative budget curves. These points of intersection correspond to the schedule on which the budgets would be available to launch Planetary satellite P-7, Asteroid Multiple Rendezvous. Thus where S/SUM/SOC calls for a mid 1993 launch of P-7, the High budget allows Fall of 1994 launch, the Medium budget in late 1996 and the Low projection not until the first half of 2000.

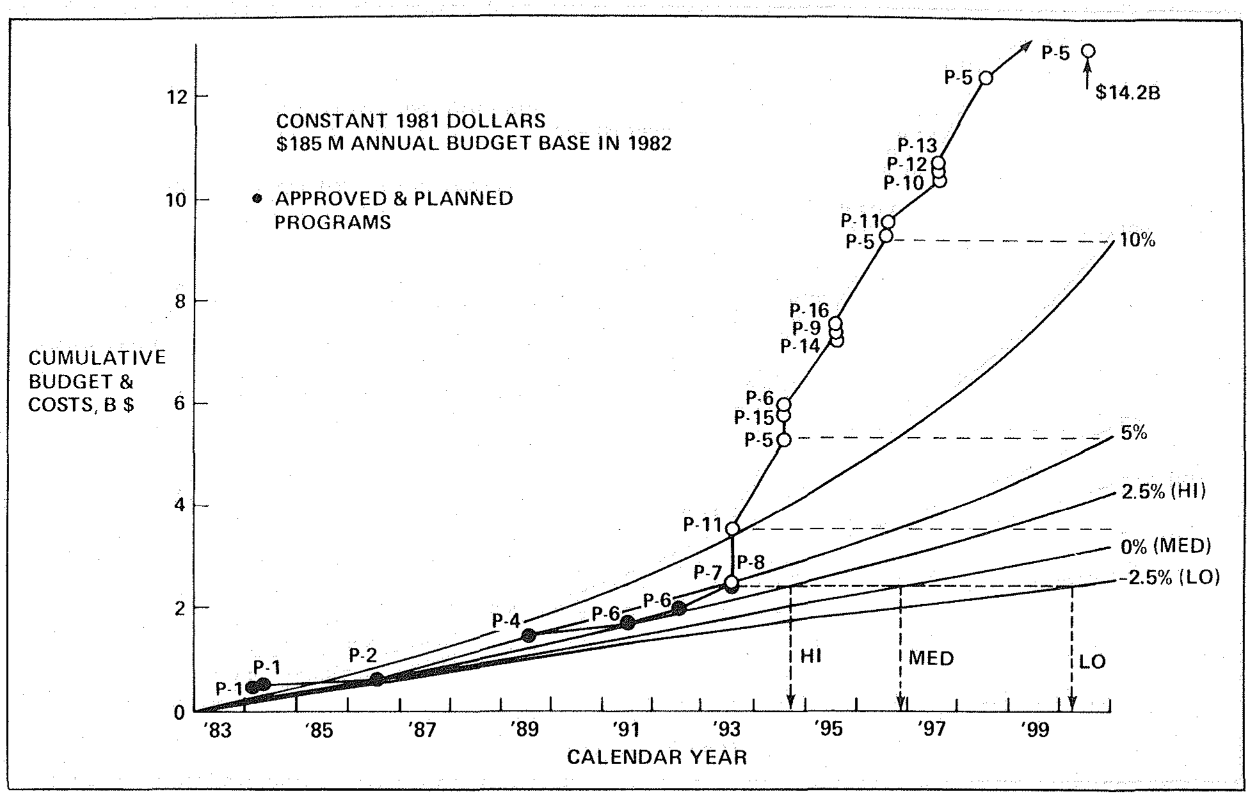

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Fig. 3.3-14 Alternate Cumulative Budgets and Cumulative Program Costs —Planetary Satellites

Dashed horizontal lines drawn through P-11, Near Earth Asteroid Sample and the first and second launches of P-5, Mars Sampler Return, inidcates the potential extension of the Planetary satellite program through real annual budget growth rates fo 5 and 10% per year.

3.3.2.5.2 <u>Alternative Cumulative Budgets and Cumulative Costs for Combined Solar Terrestrial and Astrophysics Satellites</u> - Cumulative projected budgets and cumulative program costs are shown in constant 1981 dollars in Figure 3.3-15 for the combined Solar Terrestrial and Astrophysics programs. The basic zero, plus and minus 2.5% annual growth rate curves are augmented by a 5% growth line for added growth rate insight. Projection of a constant $295 M annual budget through the year 2000 would make a total of over $5 B available, whereas the high (+2.5% per year) budget would provide nearly $6.5 B.

The cumulative costs of these two mission areas, versus years within the S/SUM/SOC model, are seen as the series of data points coded with satellite identification numbers (ID numbers) across the center of the chart. Note that the sequence of cost cumulation arbitrarily "launches" the Astorphysics satellites first in each year. Again the cost curve moves out above the projectied budgets including the added curve for 5% annual growth.

The costs of the S/SUM/SOC mission model clearly outstrip normal growth or even priority redistributions within the Earth Sensing, Earth and Space Science and Space Testing mission categories. The end data point of $26.1 B in the upper right corner is a factor of five larger than the cumulative constant budget (Medium) projection. Changes in priorities within the combined Solar Terrestrial and Astrophysics programs as relative to other mission areas within the three mission categories will serve to prevent the excessive delays of most programs as implied by maintaining the S/SUM/SOC launch sequence and the individual budget ceilings.

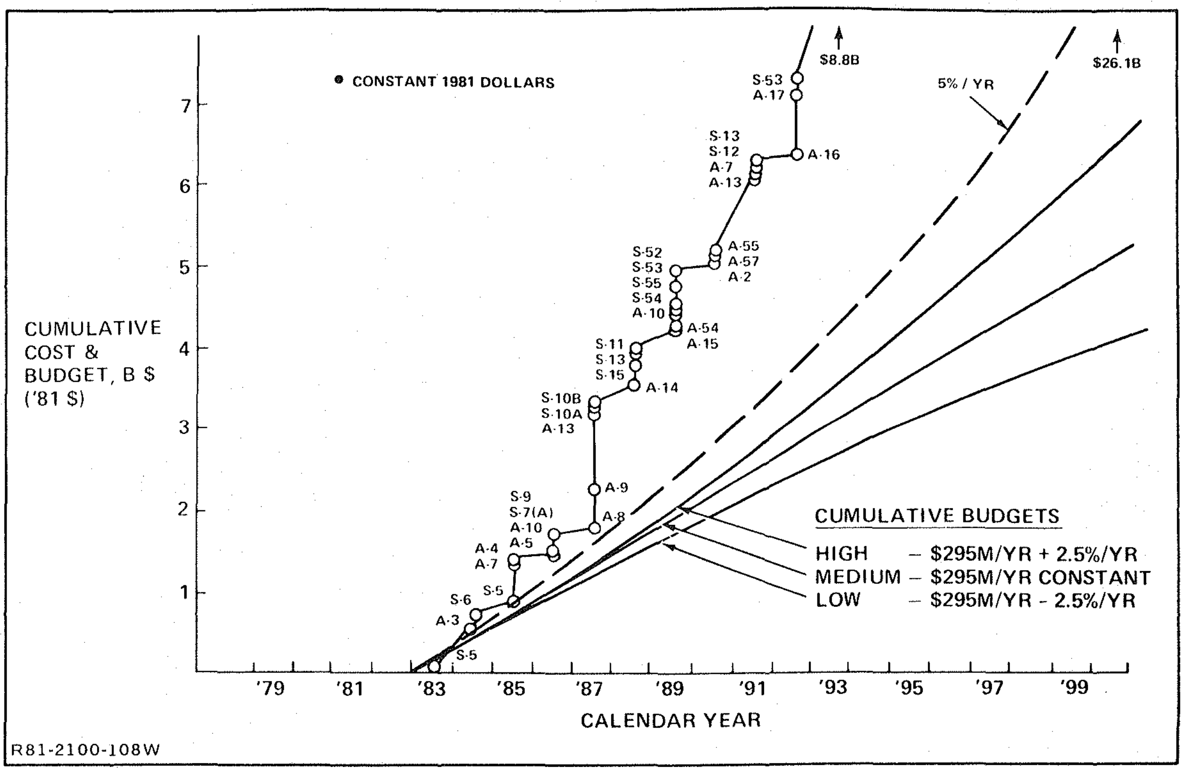

Fig. 3.3-15 Alternative Cumulative Budgets and Cumulative Program Costs — Combined Solar Terrestrial and Astrophysics Satellites

3.3.2.5.3 Alternative Cumulative Budgets and Cumulative Program Costs - Global Environment Satellites - The budget projections and satellite program cost cumulations for Global Environment satellites are presented in constant 1981 dollars in Figure 3.3-16 showing a similar trend of costs exceeding budget projections. This trend is again particularly strong in the 5-year period from 1988 through 1992. After the mid-1990s the S/SUM/SOC model shows limited numbers of satellites programmed, providing a closer match between budgets and program costs in the late 1990s.

Satellite E-9 (TOPEX), seen in this chart to be scheduled for late 1987 within S/SUM/SOC, would be delayed until early 1993, mid 1994 or late 1996 within the High, Medium and Low budgets, respectively. The Approved and Planned status programs, except for the last two E-2 (GOES) launches, are compatible with launch prior to 2000 within the High budget.

3.3.2.5.4 Alternative Cumulative Budgets and Cumulative Program Costs - Resource Observation Satellites - The Resource Observation cumulative program costs are seen in Figure 3.3-17 to start above budget in the early 1980s and never approach the trends of projected budget.

In the beginning of 1991 the cost of satellites launches on the S/SUM/SOC schedule exceeds \$3.2 B while at the time that the High cumulative budget is less than \$1.2 B. Due to the apparent high cost of the early satellite program within this mission area only five launches in the sequence of S/SUM could occur before the year 1999 within the Low budget projection. Even on the High budget projection this fifth launch (R-4 second launch) would be delayed until mid 1994.

3.3.2.5.5 Alternative Cumulative Budgets and Cumulative Program Costs - Space Testing Articles - Cumulative S/SUM/SOC program costs are presented in comparison with the three projected cumulative budgets in Figure 3.3-18. Costs in the early '90s exceed the high budget cumulative line by about 25% but fall back within this projection before the year 2000.

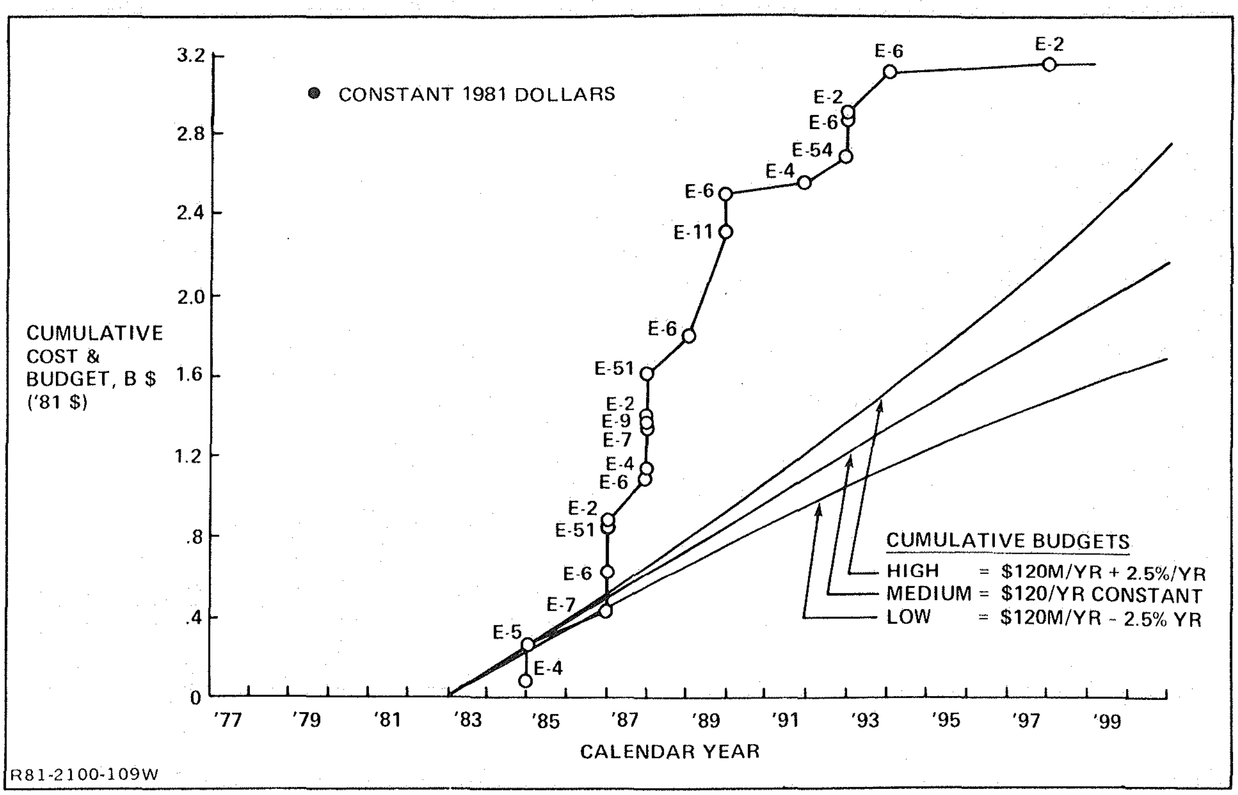

Fig. 3.3-16 Alternative Cumulative Budgets and Cumulative Program Costs — Global Environment Satellites

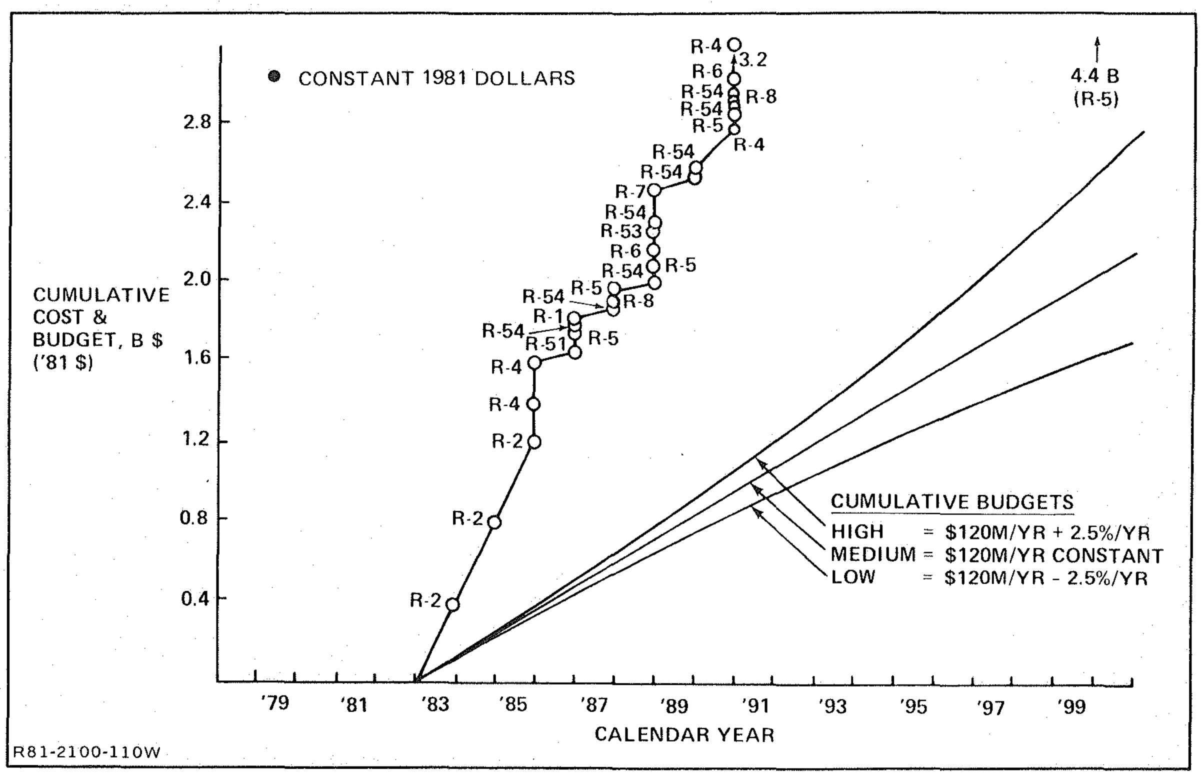

Fig. 3.3-17 Alternative Cumulative Budgets and Cumulative Program Costs — Resource Observation Satellites

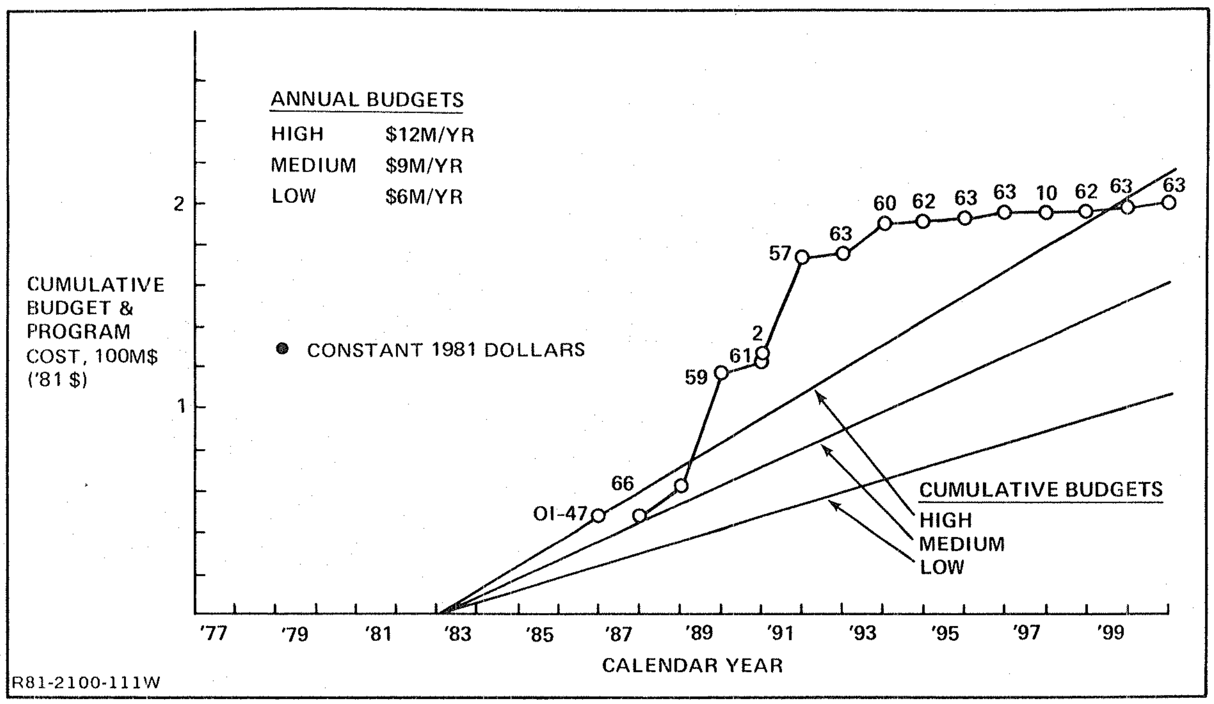

Fig. 3.3-18 Alternative Cumulative Budgets and Cumulative Program Costs — Space Testing Articles

The relationship between cumulative mission program costs and the projected cumulative budgets should show close correspondence. As discussed in conjunction with the Space Testing budget projection chart, the budget levels selected were guided partially by average annual estimated costs within the S/SUM/SOC mission module.

3.3.2.6 Economic Based Mission Activity Summaries

The budget impact upon satellite launch frequency in the 1988 through 2000 time frame is summarized in Table 3.3-8 for Earth and Space Science satellite programs. High, Medium and Low budget-constrained annual launch frequency is shown for the combined Solar Terrestrial and Astrophysics mission area and for the Planetary mission.

Annual totals launched for the three budget levels show the effects of low budgets, particularly in the 1990s. The total impact of the decreasing budget level is most apparent in cumulating the total annual launches over the 18-year model period. A total of 44 launches were available within the High budget, 39 under the Medium model and 31 launches when constrained by the Low budget model.

The annual mission rate for the Earth Sensing mission category satellite flights is presented in Table 3.3-9. In this mission category, significant numbers of satellite flights are financed by foreign organizations, commercial interests and other U.S. Government agencies, and are therefore independent of NASA budget projection levels. These annual flight rates are summarized separately at the bottom of the chart.

Launch rates for the three budget level models for Global Environment and Resource Observation are shown in the three data groups above. Total annual NASA funded launches may be seen to drop significantly as the constraints are increased from the High to Medium to Low model. These decreases in annual flight rates reflect in the 18-year flight totals which drop from 32 launches under the High budget to only 14 under the Low budget constraints.

TABLE 3.3-8 Earth & Space Science Satellite Flights – Economic Missions Models

FY	'88		'90		'92		'94		'96		'98		'00
HIGH MODEL (AT 2.5%/YR)													
SOLAR TERR & ASTRO	6	3	2	2	2	2	2	3	4	3	5	–	4
PLANETARY	–	–	1	1	1	2	1	–	–	–	–	1	–
TOTAL	6	3	3	3	3	4	3	3	4	3	5	1	4
MEDIUM MODEL (AT 0%/YR)													
SOLAR TERR & ASTRO	6	3	4	2	1	1	1	–	4	4	2	2	3
PLANETARY	–	–	–	1	1	–	1	1	–	1	1	–	–
TOTAL	6	3	4	3	2	1	2	1	4	5	3	2	3
LOW MODEL (AT -2.5%/YR)													
SOLAR TERR & ASTRO	3	7	3	3	1	1	1	1	–	3	–	3	–
PLANETARY	–	–	–	–	1	–	1	–	1	–	–	–	2
TOTAL	3	7	3	3	2	1	2	1	1	3	–	3	2

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TABLE 3.3-9 EARTH SENSING SATELLITE FLIGHTS – ECONOMIC MISSION MODELS

FY	'88		'90		'92		'94		'96		'98		'00
HIGH MODEL (AT +25%/YR)													
GLOBAL ENVIRON	–	2	1	1	2	1	1	1	–	–	1	1	2
RESOURCE OBSER	–	1	–	1	–	1	2	3	4	2	2	2	1
TOTAL	–	3	1	2	2	2	3	4	4	2	3	3	3
MEDIUM MODEL (AT 0%/YR)													
GLOBAL ENVIRON	1	–	2	–	2	1	2	–	1	–	1	–	–
RESOURCE OBSER	–	–	1	–	1	–	1	–	2	2	3	2	2
TOTAL	1	–	3	–	3	1	3	–	3	2	4	2	2
LOW MODEL (AT -2.5%/YR)													
GLOBAL ENVIRON	1	–	–	2	–	1	1	–	2	1	–	1	–
RESOURCE OBSER	–	–	1	–	–	–	1	–	1	–	–	1	1
TOTAL	1	–	1	2	–	1	2	–	3	1	–	2	1
FOREIGN, COMML & DUE	3	4	3	4	4	4	4	7	8	15	13	14	10

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The non-NASA Earth Sensing missions (foreign, commercial and DOE) are seen to increase significantly in the late 1990s. These added missions are the projected DOE Nuclear Waste Disposal missions at 10 per year after 1987.

The flight activity levels for the three budget levels projected for the Space Testing mission category are summarized in Table 3.3-10. The drop in numbers of missions per year is obvious as the High budget of $12 M/yr drops to $9 M/yr in the Medium model and to $6 M/yr at the projected Low level.

Total missions for the 18 year period drop successively from 15 to 8 to 7 for the High, Medium and Low budget models, respectively.

3.3.2.7 Comparison of Launch and Service Models

The economic based satellite launch schedules developed from the Cumulative Cost and Budget projections data in Figures 3.3-14 through 3.3-18 and summarized in Tables 3.3-8 through 3.3-10 are related back to the contents in the S/SUM model in the following traffic comparison tables. The comparison format places the traffic tables from the Satellite/Services User Model for SOC alongside the traffic tables generated for the High, Medium and Low economic projections. Sheet 1 of 3 of the Astrophysics mission listings Table 3.3-11, can be used to illustrate the re-incorporation of on-orbit servicing in the economic based models, and the waterfall effect of decreasing funding on mission schedules.

A simple case of re-incorporation of servicing and retrieval into the launch model is illustrated in the second Table 3.3-11 listing, A-7, Gamma Ray Observatory (GRO). In the S/SUM/SOC model, the traffic listing in Table 3.3-11 showed a launch in 1985, an unscheduled potential servicing in space in 1986, and a retrieval from space in 1987. For the High and the Medium Traffic Models on the right in Table 3.3-11, the launch schedule shifts to 1987 and the servicing and retrievals are then scheduled in the following two years as in the S/SUM/SOC model. For the Low Astrophysics budget model, cumulative

TABLE 3.3-10 SPACE TESTING SATELLITE FLIGHTS ECONOMIC MISSION MODEL

CY	'88		'90		'92		'94		'96		'98		'00
HIGH MODEL ($12M/YR)													
SPACE TESTING	—	1	1	—	1	2	—	—	2	2	4	1	1
MEDIUM MODEL ($9M/YR)													
SPACE TESTING	1	2	1	—	—	1	—	—	2	—	1	—	—
LOW MODEL ($6M/YR)													
SPACE TESTING	—	1	2	—	—	2	—	—	—	—	1	—	1

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TABLE 3.3-11 ASTROPHYSICS MISSIONS, SHEET 1 OF 3

ASTROPHYSICS MISSIONS

ID NO.	NAME	S/SUM TRAFFIC [1] 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A3	SPACE TELESCOPE (S3)	●	1	●	●	1	1	●	1	●	●	1	1	●	1	●	●
A7	GAMMA RAY OBSERVATORY (S9)	1	●	1													
A4	COSMIC BKGND EXPL. [2] (S7)	1		1													
A5	EXTREME UV EXPLORER (S10)		1	1													
A10	X-RAY TIME EXPLORER (S11)		1	●	1	1	●	1									
A61	SOLAR CORONA EXPLORER [2] (S13)		1		●		1										
A8	GRAVITY PROBE B [2] (S14)			1	●	●	1										
A9	ADV X-RAY ASTROPHY FAC. (S17)			1	●	1	●	●	1	1	●	1	●	●			

ID NO.	NAME	HIGH TRAFFIC MODEL 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A3	SPACE TELESCOPE (S3)	1	●	1	●	●	1	1	●	1	●	●	1	1	●	1	●
A7	GAMMA RAY OBSERVATORY (S9)			1	●	1											1
A4	COSMIC BKGND EXPL. [2] (S7)			1		1											
A5	EXTREME UV EXPLORER (S10)				1	1											
A10	X-RAY TIME EXPLORER (S11)			1	●	1						1	●	1			
A61	SOLAR CORONA EXPLORER [2] (S13)					1		●		1							
A8	GRAVITY PROBE B [2] (S14)				1	●	●	1									
A9	ADV X-RAY ASTROPHY FAC. (S17)						1	●	1	●	●	1	1	●	1	●	●

ID NO.	NAME	MEDIUM TRAFFIC MODEL 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A3	SPACE TELESCOPE (S3)	1	●	1	●	●	1	1	●	1	●	●	1	1	●	1	●
A7	GAMMA RAY OBSERVATORY (S9)			1	●	1											
A4	COSMIC BKGND EXPL. [2] (S7)				1		1										
A5	EXTREME UV EXPLORER (S10)					1	1										
A10	X-RAY TIME EXPLORER (S11)				1	●	1							1	●	1	
A61	SOLAR CORONA EXPLORER [2] (S13)						1		●		1						
A8	GRAVITY PROBE B [2] (S14)						1	●	●	1							
A9	ADV X-RAY ASTROPHY FAC. (S17)						1	●	1	●	●	1	1	●	1	●	●

ID NO.	NAME	LOW TRAFFIC MODEL 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A3	SPACE TELESCOPE (S3)	1	●	1	●	●	1	1	●	1	●	●	1	1	●	1	●
A7	GAMMA RAY OBSERVATORY (S9)				1	●	1										
A4	COSMIC BKGND EXPL. [2] (S7)				1		1										
A5	EXTREME UV EXPLORER (S10)					1	1										
A10	X-RAY TIME EXPLORER (S11)					1	●	1									
A61	SOLAR CORONA EXPLORER [2] (S13)						1		●		1						
A8	GRAVITY PROBE B [2] (S14)						1	●	●	1							
A9	ADV X-RAY ASTROPHY FAC. (S17)							1	●	1	●	●	1	1	●	1	●

[1] NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

[2] DIRECT ORBITER LAUNCH AND RECOVERY

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TABLE 3.3-11 ASTROPHYSICS MISSIONS, SHEET 2 OF 3

ASTROPHYSICS MISSIONS (CONT'D)

S/SUM TRAFFIC [1]

ID. NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A13	COSMIC RAY OBSERVATORY [2] (S23)			1	•	•	1	1	•	•	•	•	1				
A14	LARGE AREA MODULAR ARRAY (S28)				1	•	•	•	•	1				1			
A15	VERY LONG BASELINE INTERFACE (S29) [2] [3]				1	•	•	1									
A52	UV PHOTO/ POLARMETRIC EXP					1		1									
A53	INTERNATIONAL UV EXPLORER (FOREIGN)					1					1						
A59	SIMULTANEOUS ASTRO MISSION (S42)					1					1						
A54	EXTREME UV SPECTROSCOPE (S44)					1					1						
A55	X-RAY SPECTROSCOPY (S39)						1	•	1								
A56	SOFT X-RAY SURVEY (S40)						1		1								

HIGH TRAFFIC MODEL

ID. NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A13	COSMIC RAY OBSERVATORY [2] (S23)								1	•	•	1					1
A14	LARGE AREA MODULAR ARRAY (S28)									1	•	•	•	•	1		
A15	VERY LONG BASELINE INTERFACE (S29) [2] [3]										1	1 •	•	• 1	1		
A52	UV PHOTO/ POLARMETRIC EXP																
A53	INTERNATIONAL UV EXPLORER (FOREIGN)					1					1						
A59	SIMULTANEOUS ASTRO MISSION (S42)																
A54	EXTREME UV SPECTROSCOPE (S44)											1					1
A55	X-RAY SPECTROSCOPY (S39)													1	•	1	
A56	SOFT X-RAY SURVEY (S40)													1		1	

MEDIUM TRAFFIC MODEL

ID. NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A13	COSMIC RAY OBSERVATORY [2] (S23)									1	•	•	1				
A14	LARGE AREA MODULAR ARRAY (S28)											1	•	•	•	•	1
A15	VERY LONG BASELINE INTERFACE (S29) [2] [3]												1	1 •	•	• 1	1
A52	UV PHOTO/ POLARMETRIC EXP																
A53	INTERNATIONAL UV EXPLORER (FOREIGN)					1					1						
A59	SIMULTANEOUS ASTRO MISSION (S42)																
A54	EXTREME UV SPECTROSCOPE (S44)													1			
A55	X-RAY SPECTROSCOPY (S39)																1
A56	SOFT X-RAY SURVEY (S40)																1

LOW TRAFFIC MODEL

ID. NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A13	COSMIC RAY OBSERVATORY [2] (S23)											1	•	•	1		
A14	LARGE AREA MODULAR ARRAY (S28)													1	•	•	•
A15	VERY LONG BASELINE INTERFACE (S29) [2] [3]															1	•
A52	UV PHOTO/ POLARMETRIC EXP																
A53	INTERNATIONAL UV EXPLORER (FOREIGN)					1					1						
A59	SIMULTANEOUS ASTRO MISSION (S42)																
A54	EXTREME UV SPECTROSCOPE (S44)																
A55	X-RAY SPECTROSCOPY (S39)																
A56	SOFT X-RAY SURVEY (S40)																

[1] NUMERALS DENOTE SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

[2] DIRECT ORBITER LAUNCH AND RECOVERY

[3] SOC SERVICE OPTION TO BACK UP ORBITER AVAILABILITY

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TABLE 3.3-11 ASTROPHYSICS MISSIONS, SHEET 3 OF 3

ASTRO PHYSICS MISSIONS (CONT'D)

ID NO.	NAME	S/SUM TRAFFIC 1															
		5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A57	MOLECULAR LINE SURVEY (S45)						1			1							
A58	ADVANCED RELATIVITY 2							2						2			
A16	SUBMILLIMETER TELESCOPE 2 (S30)								1		•		•		•		1
A17	AMBIENT DEPLOY IR TELESCOPE (S25)								2	1	1	1	1	1			
A18	IR INTERFEROMETER (S31)									1	1	1	1	1	1		
A19	GRAVITY WAVE INTERFEROMETER (S32)										1	4			1		
A20	COSMIC-COHERENT OPT SYS (S33)												3	3		3	3
A21	LONG OPTICAL UV TELESCOPE (S36)													1	1	1	1
A22	100M THIN APERTURE TELESCOPE (S34)														4	4	

ID NO.	NAME	HIGH TRAFFIC MODEL																MEDIUM TRAFFIC MODEL																LOW TRAFFIC MODEL															
		5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A57	MOLECULAR LINE SURVEY (S45)													1			1																1																
A58	ADVANCED RELATIVITY 2																																																
A16	SUBMILLIMETER TELESCOPE 2 (S30)																1																																
A17	AMBIENT DEPLOY IR TELESCOPE (S25)																																																
A18	IR INTERFEROMETER (S31)																																																
A19	GRAVITY WAVE INTERFEROMETER (S32)																																																
A20	COSMIC-COHERENT OPT SYS (S33)																																																
A21	LONG OPTICAL UV TELESCOPE (S36)																																																
A22	100M THIN APERTURE TELESCOPE (S34)																																																

1 NUMERALS DENOTE SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

2 DIRECT ORBITER LAUNCH AND RECOVERY

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funding does not allow launch of GRO until 1988. The follow-on potential servicing and retrieval remain on the same one-year intervals after launch on the assumption that total satellite costs are assigned at launch, and other events for that satellite do not effect budget scheduling.

The Space Telescope, listed at the top of Table 3.3-11 illustrates one of the three cases where it was assumed that the satellite would be refurbished after retrieval. Here it was assumed that the total Space Telescope (ST) costs were expended at initial launch, and re-trievals, re-furbishing and re-launch costs were included in the original costs. This then established the total sequence of the ST program to be identical to that presented in the S/SUM/SOC Traffic Schedule. The budget restrictions would only shift the year of initial launch. The other two satellites assumed re-furbished are A-9, the Advanced X-Ray Astrophysics Facility listed at the bottom of Sheet 1 of Table 3.3-11 and S-9, Subsatellite Facility, the fourth entry in Table 3.3-12, Sheet 1.

The comparisons of traffic schedules for S/SUM, and High, Medium and Low budgets for the six mission areas are provided in this visual data base in Tables 3.3-11 through 3.3-16. The updating of the data base during the study to reflect input from the most recent NASA Systems Technology Model Reference 3.3-12 is illustrated in Table 3.3-12, Sheet 1, for entry S-51, Astronomy. Since this mission did not appear specifically in Reference 3.3-12, it was not considered in the costing and was dropped from the economic models as indicated by the blank traffic modeling under High, Medium and Low traffic scheduling.

It may also be noted in Table 3.3-12 that the new 1981 identity numbers from Reference 3.3-12 are included in parentheses under the satellite name in Tables 3.3-1 through 3.3-6 and Tables 3.3-11 through 3.3-16.

TABLE 3.3-12 SOLAR TERRESTRIAL MISSIONS, SHEET 1 OF 2

SOLAR TERRESTRIAL MISSIONS

S/SUM TRAFFIC [1]

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
S3	ISPM-SOLAR POLAR (S5)	1															
S5	CHEM REL MODULE [2] (S4)	1	1														
S7	ORIGIN OF PLASMA (S12)		4														
S9	SUBSAT FACILITY (S22)		1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1									
S11	SOLAR PROBE (S20)				1												
S13	SOLAR CYCLE & DYN MISSION (S21)				1	●	1	1	●	●	●	●	●	1			
S51	ASTRONOMY					1		●		●		●		1			
S52	GAMMA RAY TRANS EXPLOR (S41)					1		1									
S53	X-RAY OBSERVATORY (S27)					1	●	●	1 ●	● 1	●	●	1				
S54	ADV INTERPLANETARY EXPLOR (S37)					1											
S-6	ACT. MAG PART EXPLOR	1															

HIGH TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
S3	ISPM-SOLAR POLAR (S5)	1															
S5	CHEM REL MODULE [2] (S4)	1	1														
S7	ORIGIN OF PLASMA (S12)			1	3												
S9	SUBSAT FACILITY (S22)				1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1							
S11	SOLAR PROBE (S20)										1						
S13	SOLAR CYCLE & DYN MISSION (S21)										1	●	1				1
S51	ASTRONOMY																
S52	GAMMA RAY TRANS EXPLOR (S41)													1		1	
S53	X-RAY OBSERVATORY (S27)												1	●	●	●	1
S54	ADV INTERPLANETARY EXPLOR (S37)											1					
S-6	ACT. MAG PART EXPLOR	1															

MEDIUM TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
S3	ISPM-SOLAR POLAR (S5)	1															
S5	CHEM REL MODULE [2] (S4)	1	1														
S7	ORIGIN OF PLASMA (S12)				4												
S9	SUBSAT FACILITY (S22)					1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1						
S11	SOLAR PROBE (S20)												1				
S13	SOLAR CYCLE & DYN MISSION (S21)												1	●	1		
S51	ASTRONOMY																
S52	GAMMA RAY TRANS EXPLOR (S41)															1	
S53	X-RAY OBSERVATORY (S27)															1	●
S54	ADV INTERPLANETARY EXPLOR (S37)														1		
S-6	ACT. MAG PART EXPLOR	1															

LOW TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
S3	ISPM-SOLAR POLAR (S5)	1															
S5	CHEM REL MODULE [2] (S4)	1	1														
S7	ORIGIN OF PLASMA (S12)				1	3											
S9	SUBSAT FACILITY (S22)					1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1						
S11	SOLAR PROBE (S20)															1	
S13	SOLAR CYCLE & DYN MISSION (S21)															1	●
S51	ASTRONOMY																
S52	GAMMA RAY TRANS EXPLOR (S41)																
S53	X-RAY OBSERVATORY (S27)																
S54	ADV INTERPLANETARY EXPLOR (S37)																
S-6	ACT. MAG PART EXPLOR	1															

[1] NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

[2] DIRECT ORBITER LAUNCH AND RECOVERY

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TABLE 3.3-12 SOLAR TERRESTRIAL MISSIONS, SHEET 2 OF 2

SOLAR TERRESTRIAL MISSIONS (CONT'D)

S/SUM TRAFFIC 1

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
S55	HEAVY NUCLEI EXPLORER (S38) 2					1	●	●	●	1							
S56	LARGE SOLAR OBSERVATOR						1	●	●	●	●	1					
S12	SOLAR TERR OBSERVATORY (S24) 2							1	1	1	1	1	1				
S15	CLOSE SOLAR ORBITER											1					

HIGH TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
S55	HEAVY NUCLEI EXPLORER (S38) 2												1	●	●	●	1
S56	LARGE SOLAR OBSERVATOR																
S12	SOLAR TERR OBSERVATORY (S24) 2																1
S15	CLOSE SOLAR ORBITER																

MEDIUM TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
S55	HEAVY NUCLEI EXPLORER (S38) 2														1	●	●
S56	LARGE SOLAR OBSERVATOR																
S12	SOLAR TERR OBSERVATORY (S24) 2																
S15	CLOSE SOLAR ORBITER																

LOW TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
S55	HEAVY NUCLEI EXPLORER (S38) 2																
S56	LARGE SOLAR OBSERVATOR																
S12	SOLAR TERR OBSERVATORY (S24) 2																
S15	CLOSE SOLAR ORBITER																

1 NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

2 DIRECT ORBITER LAUNCH AND RECOVERY

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TABLE 3.3-13 PLANETARY MISSIONS, SHEET 1 OF 2

PLANETARY MISSIONS

S/SUM TRAFFIC (see note 1)

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
P2	VENUS ORB. IMAGE RADAR (P2)		1														
P4	SATURN ORBITER (P7)					2											
P6	URANUS NEPTUNE PLUTO (P6)							1	1								
P7	ASTEROID MULTI RENDZ (P5)									1							
P8	LUNAR POLAR ORBITER (P10)									1							
P5	MARS SAMPLE RETURN (P8)										1		1				
P11	NR EARTH ASTEROID SAMPLE (P13)									1			1				
P15	LUNAR BACKSIDE SAMPLE (P17)										1						
P14	AUTO PLANETARY STATION (P16)											1					
P16	GANYMEDE LANDER (P18)											1					
P10	COMET SAMPLE RETURN (P12)													1			

HIGH TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
P2	VENUS ORB. IMAGE RADAR (P2)		1														
P4	SATURN ORBITER (P7)						1										
P6	URANUS NEPTUNE PLUTO (P6)							1	1			1					
P7	ASTEROID MULTI RENDZ (P5)										1						
P8	LUNAR POLAR ORBITER (P10)										1						
P5	MARS SAMPLE RETURN (P8)																
P11	NR EARTH ASTEROID SAMPLE (P13)															1	
P15	LUNAR BACKSIDE SAMPLE (P17)																
P14	AUTO PLANETARY STATION (P16)																
P16	GANYMEDE LANDER (P18)																
P10	COMET SAMPLE RETURN (P12)																

MEDIUM TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
P2	VENUS ORB. IMAGE RADAR (P2)			1													
P4	SATURN ORBITER (P7)							1									
P6	URANUS NEPTUNE PLUTO (P6)								1		1				1		
P7	ASTEROID MULTI RENDZ (P5)												1				
P8	LUNAR POLAR ORBITER (P10)													1			
P5	MARS SAMPLE RETURN (P8)																
P11	NR EARTH ASTEROID SAMPLE (P13)																
P15	LUNAR BACKSIDE SAMPLE (P17)																
P14	AUTO PLANETARY STATION (P16)																
P16	GANYMEDE LANDER (P18)																
P10	COMET SAMPLE RETURN (P12)																

LOW TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
P2	VENUS ORB. IMAGE RADAR (P2)			1													
P4	SATURN ORBITER (P7)								1								
P6	URANUS NEPTUNE PLUTO (P6)										1		1				1
P7	ASTEROID MULTI RENDZ (P5)																1
P8	LUNAR POLAR ORBITER (P10)																1
P5	MARS SAMPLE RETURN (P8)																
P11	NR EARTH ASTEROID SAMPLE (P13)																
P15	LUNAR BACKSIDE SAMPLE (P17)																
P14	AUTO PLANETARY STATION (P16)																
P16	GANYMEDE LANDER (P18)																
P10	COMET SAMPLE RETURN (P12)																

1 NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

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TABLE 3.3-13 PLANETARY MISSIONS, SHEET 2 OF 2

PLANETARY MISSIONS (CONTD)

S/SUM TRAFFIC

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
P12	VENUS LANDER (P14)														1		
P13	AUTO MOBILE LUNAR SURVEY (P15)														1		
P1A	GALILEO ORBITER																
P1B	GALILEO PROBE																

HIGH TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
P12	VENUS LANDER (P14)																
P13	AUTO MOBILE LUNAR SURVEY (P15)																
P1A	GALILEO ORBITER	1															
P1B	GALILEO PROBE	1															

MEDIUM TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
P12	VENUS LANDER (P14)																
P13	AUTO MOBILE LUNAR SURVEY (P15)																
P1A	GALILEO ORBITER	1															
P1B	GALILEO PROBE	1															

LOW TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
P12	VENUS LANDER (P14)																
P13	AUTO MOBILE LUNAR SURVEY (P15)																
P1A	GALILEO ORBITER	1															
P1B	GALILEO PROBE		1														

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TABLE 3.3-14 GLOBAL ENVIRONMENT MISSIONS, SHEET 1 OF 2

GLOBAL ENVIRONMENT MISSIONS

S/SUM TRAFFIC (1)

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
E2	GEO OPER. ENVIR. SAT (E1)		1	1				1	1 1			●		1 1		●	
E6	NAT'L OCEAN SAT (E4) (2)		1	1 ●	1 ● 1	1 1	●	●	1 1	1 1	●	●	●	● 1	1		
E7	UPPER RES SAT ATMOS (E5) (2)		1	1	●	●	●	●	●	●	●	●	●	● 1	1		
E5	NOAA-H&I (E7) (2)		1	1	●	●	1	1									
E4	EARTH RADIATION BUDGET (E2) (2) (3)			1		●		1 1		●		1					
E50	INMET SAT (FOREIGN)			1	2	4	3	4	2	4	3	4	3	4	3	4	
E52	STORM SAT (COMMERCIAL)			1					1 1			●		1	●		●
E53	MAP GRAVITY FIELD/COMM			1				1	1		1		1	1		1	
E9	TOPEX (E6) (2)						1			1							

HIGH TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
E2	GEO OPER. ENVIR. SAT (E1)					1				1	1				1		
E6	NAT'L OCEAN SAT (E4) (2)			1	●	1	1	●	1			1		●		1 1	
E7	UPPER RES SAT ATMOS (E5) (2)		1		●		●		1 ●		● ●		●	1	●		●
E5	NOAA-H&I (E7) (2)	1		●		1					1		●		1		
E4	EARTH RADIATION BUDGET (E2) (2) (3)							1		●		1					
E50	INMET SAT (FOREIGN)			1	2	4	3	4	2	4	3	4	3	4	3	4	
E52	STORM SAT (COMMERCIAL)			1					1 1			●		1	●		●
E53	MAP GRAVITY FIELD/COMM																
E9	TOPEX (E6) (2)								1			1					

MEDIUM TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
E2	GEO OPER. ENVIR. SAT (E1)						1				1 1					1	
E6	NAT'L OCEAN SAT (E4) (2)				1	●	1	1	●	1							
E7	UPPER RES SAT ATMOS (E5) (2)		1		●		●		●	1	●	●	●	● 1		●	
E5	NOAA-H&I (E7) (2)	1		●		1						1		●		1	
E4	EARTH RADIATION BUDGET (E2) (2) (3)								1		●		1				
E50	INMET SAT (FOREIGN)			1	2	4	3	4	2	4	3	4	3	4	3	4	
E52	STORM SAT (COMMERCIAL)			1					1 1			●		1	●		●
E53	MAP GRAVITY FIELD/COMM																
E9	TOPEX (E6) (2)										1			1			

LOW TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
E2	GEO OPER. ENVIR. SAT (E1)							1					1	1			
E6	NAT'L OCEAN SAT (E4) (2)					1	●	1		1	●	1					
E7	UPPER RES SAT ATMOS (E5) (2)			1		●		●		●		●	1	●	● 1		●
E5	NOAA-H&I (E7) (2)	1		●		1										1	
E4	EARTH RADIATION BUDGET (E2) (2) (3)										1		●		1		
E50	INMET SAT (FOREIGN)			1	2	4	3	4	2	4	3	4	3	4	3	4	
E52	STORM SAT (COMMERCIAL)			1					1 1			●		1	●		●
E53	MAP GRAVITY FIELD/COMM																
E9	TOPEX (E6) (2)												1			1	

(1) NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

(2) DIRECT.ORBITER LAUNCH AND RECOFERY

(3) SOC SERVICE OPTION TO BACK UP ORBITER AVAILABILITY

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TABLE 3.3-14 GLOBAL ENVIRONMENT MISSIONS, SHEET 2 OF 2

GLOBAL ENVIRONMENT MISSIONS – (CONTD)

S/SUM TRAFFIC [1]

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
E10	OPERATIONAL METEROLOGY (COMMERCIAL) [2]					1		•		1							
E11	OCEAN RESEARCH (E8) (FIREX) [2]					1	•	•	•	•	1						
E54	GLOBAL REG ATMOS MONIT (E9) (LARS) [2]				1		•		1 1		•		•		•		1
E57	NUCLEAR WASTE DISPOSAL (DOE)										1	3	5	10	10	10	10

HIGH TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
E10	OPERATIONAL METEROLOGY (COMMERCIAL) [2]					1		•		1							
E11	OCEAN RESEARCH (E8) (FIREX) [2]														1	•	•
E54	GLOBAL REG ATMOS MONIT (E9) (LARS) [2]																1
E57	NUCLEAR WASTE DISPOSAL (DOE)										1	3	5	10	10	10	10

MEDIUM TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
E10	OPERATIONAL METEROLOGY (COMMERCIAL) [2]					1		•		1							
E11	OCEAN RESEARCH (E8) (FIREX) [2]																
E54	GLOBAL REG ATMOS MONIT (E9) (LARS) [2]																
E57	NUCLEAR WASTE DISPOSAL (DOE)										1	3	5	10	10	10	10

LOW TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
E10	OPERATIONAL METEROLOGY (COMMERCIAL) [2]					1		•		1							
E11	OCEAN RESEARCH (E8) (FIREX) [2]																
E54	GLOBAL REG ATMOS MONIT (E9) (LARS) [2]																
E57	NUCLEAR WASTE DISPOSAL (DOE)										1	3	5	10	10	10	10

[1] NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

[2] DIRECT ORBITER LAUNCH AND RECOVERY

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TABLE 3.3-15 RESOURCE OBSERVATION MISSIONS, SHEET 1 OF 2

RESOURCE OBSERVATION MISSIONS

ID NO.	NAME	S/SUM TRAFFIC ▷1															
		5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
R2	LAND SAT D (R1) ▷2	1		●		1											
R1	MAGSAT B (R2) ▷2		1	1													
R4	GRAVSAT (R3-8) ▷2	2					2										
R50	ICE & CLIMATE EXPLORER ▷2		1	●	1	1	●	● 1									
R51	REGION H_2O QUAL MONITOR (R13) ▷2		1		●		1		1								
R53	EARTH OBSER OBSERVATION/ COMM		1	2	1	2 ●	1 ● ●	●	1 ● ●	2 ●	1	●	3 ● ● 1	● 2	1	● ● ● 2	1
R54	RESOURCES/ POLLUTION (R12)		1	1	2	2 ●	2 ●	3 ● ●	● ●	3 ● ●	1 ● ● ●	2	2 ● ● ● 1	3 ● 1	● ● 2	3 ● ● 2	● ● ● 3
R55	EARTH SURVEY ▷2			1		1 ●		1 ● ●		1 ● ● ●		1 ● ● ● 1		1 ● ● ● 1		1 ● ● ● 1	
R55	COASTAL SATELLITE ▷2			1	●	●	●	●	1								

ID NO.	NAME	HIGH TRAFFIC MODEL															
		5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
R2	LAND SAT D (R1) ▷2		1		●	1	1	1 ●		● 1		1					
R1	MAGSAT B (R2) ▷2											1	1				
R4	GRAVSAT (R3-8) ▷2									1	1						
R50	ICE & CLIMATE EXPLORER ▷2																
R51	REGION H_2O QUAL MONITOR (R13) ▷2										1		●		1		
R53	EARTH OBSER OBSERVATION/ COMM																
R54	RESOURCES/ POLLUTION (R12)												1	2	●	2 ● ●	1 ● ●
R55	EARTH SURVEY ▷2																
R55	COASTAL SATELLITE ▷2																

ID NO.	NAME	MEDIUM TRAFFIC MODEL															
		5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
R2	LAND SAT D (R1) ▷2		1		●	1	1	●		1 1		●		1			
R1	MAGSAT B (R2) ▷2																
R4	GRAVSAT (R3-8) ▷2										1		1				
R50	ICE & CLIMATE EXPLORER ▷2																
R51	REGION H_2O QUAL MONITOR (R13) ▷2											1		●		1	
R53	EARTH OBSER OBSERVATION/ COMM																
R54	RESOURCES/ POLLUTION (R12)													1	1	1 ●	●
R55	EARTH SURVEY ▷2																
R55	COASTAL SATELLITE ▷2																

ID NO.	NAME	LOW TRAFFIC MODEL															
		5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
R2	LAND SAT D (R1) ▷2		1		●		1 1		●		1 1		●		1		
R1	MAGSAT B (R2) ▷2																
R4	GRAVSAT (R3-8) ▷2											1				1	
R50	ICE & CLIMATE EXPLORER ▷2																
R51	REGION H_2O QUAL MONITOR (R13) ▷2																1
R53	EARTH OBSER OBSERVATION/ COMM																
R54	RESOURCES/ POLLUTION (R12)																
R55	EARTH SURVEY ▷2																
R55	COASTAL SATELLITE ▷2																

▷1 NUMERALS DENOTE SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

▷2 DIRECT ORBITER LAUNCH & RECOVERY

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TABLE 3.3-15 RESOURCE OBSERVATION MISSIONS, SHEET 2 OF 2

SPACE TESTING MISSIONS

ID NO.	NAME	S/SUM TRAFFIC															
		5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
O110	LONG DURATION EXPOSURE FACILITY (OI-17)	1	1	●	1	1	●	●	1	1	●	●	●	1	1	●	●
O12	INDUCED ENVIRO CONTAM-INATION (OI-11)						1										
O157	LARGE DEPLOY ANTENNA DEMO (OI-22+)		1					1									
O159	STRUCTURAL ASSY DEMO (OI-21+)					1											
O160	DEPLOYABLE PLATFORM EXPERIMENT (OI-23+)				1					1							
O161	FLUID MECH & HEAT XFER FACILITY (OI-25)						1										
O162	PACE EXMPTS (OI-26/27)										1				1		
O163	SCIENCE INSTRUMENT DEMO								1			1	1			1	1

ID NO.	NAME	HIGH TRAFFIC MODEL															
		5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
O110	LONG DURATION EXPOSURE FACILITY (OI-17)	1	1	●	1	1	●	●	1	1	●	●	●	1	1	●	●
O12	INDUCED ENVIRO CONTAM-INATION (OI-11)						1										
O157	LARGE DEPLOY ANTENNA DEMO (OI-22+)		1										1				
O159	STRUCTURAL ASSY DEMO (OI-21+)								1								
O160	DEPLOYABLE PLATFORM EXPERIMENT (OI-23+)			1										1			
O161	FLUID MECH & HEAT XFER FACILITY (OI-25)									1							
O162	PACE EXMPTS (OI-26/27)												1			1	
O163	SCIENCE INSTRUMENT DEMO													1	3		1

ID NO.	NAME	MEDIUM TRAFFIC MODEL															
		5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
O110	LONG DURATION EXPOSURE FACILITY (OI-17)	1	1	●	1	1	●	●	1	1	●	●	●	1	1	●	●
O12	INDUCED ENVIRO CONTAM-INATION (OI-11)						1										
O157	LARGE DEPLOY ANTENNA DEMO (OI-22+)				1												
O159	STRUCTURAL ASSY DEMO (OI-21+)												1				
O160	DEPLOYABLE PLATFORM EXPERIMENT (OI-23+)					1											
O161	FLUID MECH & HEAT XFER FACILITY (OI-25)												1				
O162	PACE EXMPTS (OI-26/27)																
O163	SCIENCE INSTRUMENT DEMO																

ID NO.	NAME	LOW TRAFFIC MODEL															
		5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
O110	LONG DURATION EXPOSURE FACILITY (OI-17)	1	1	●	1	1	●	●	1	1	●	●	●	1	1	●	●
O12	INDUCED ENVIRO CONTAM-INATION (OI-11)						1										
O157	LARGE DEPLOY ANTENNA DEMO (OI-22+)						1										
O159	STRUCTURAL ASSY DEMO (OI-21+)																1
O160	DEPLOYABLE PLATFORM EXPERIMENT (OI-23+)									1							
O161	FLUID MECH & HEAT XFER FACILITY (OI-25)																
O162	PACE EXMPTS (OI-26/27)																
O163	SCIENCE INSTRUMENT DEMO																

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TABLE 3.3-16 SPACE TESTING MISSIONS

RESOURCE OBSERVATION MISSIONS (CONT'D)

S/SUM TRAFFIC 1

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
R8	SOIL MOISTURE (R10) 2			1		1	1		1	1		1	1		1	1	
R5	OPERATIONAL LAND OBSERVATION SYSTEM (R6) 2		1	1	1 ●	● 1	1 ● 1	1 1	1 ●	● 1	● 1	1 1	1	1 ●	● 1	● 1	1 1
R58	ADV GEOLOGY SATELLITE (R5) 2				1		●		1	1		●		1			
R59	PRIVATE EARTH RESOURCE (COMMERCIAL) 2				1		●		1 1		●	●	●				1
R6	ADV THERMAL MAPPING (R7) 2				1		1 ●		● ●		● 1		1				
R7	MAGNETIC FIELD SURVEY (R9) 2				1	●	●	1									
R60	ENVIRONMENTAL MONITOR 2					1		1 ●		● ●		● 1		1			

HIGH TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
R8	SOIL MOISTURE (R10) 2												1		1		
R5	OPERATIONAL LAND OBSERVATION SYSTEM (R6) 2											1	1	1 ●	● 1	● 1	1
R58	ADV GEOLOGY SATELLITE (R5) 2														1		●
R59	PRIVATE EARTH RESOURCE (COMMERCIAL) 2				1		●		1 1		●		●		●		1
R6	ADV THERMAL MAPPING (R7) 2													1		●	
R7	MAGNETIC FIELD SURVEY (R9) 2															1	●
R60	ENVIRONMENTAL MONITOR 2																

MEDIUM TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
R8	SOIL MOISTURE (R10) 2														1		1
R5	OPERATIONAL LAND OBSERVATION SYSTEM (R6) 2													1		1 ●	1 ● 1
R58	ADV GEOLOGY SATELLITE (R5) 2														1		●
R59	PRIVATE EARTH RESOURCE (COMMERCIAL) 2				1		●		1 1		●		●		●		1
R6	ADV THERMAL MAPPING (R7) 2																1
R7	MAGNETIC FIELD SURVEY (R9) 2																
R60	ENVIRONMENTAL MONITOR 2																

LOW TRAFFIC MODEL

ID NO.	NAME	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
R8	SOIL MOISTURE (R10) 2																
R5	OPERATIONAL LAND OBSERVATION SYSTEM (R6) 2																
R58	ADV GEOLOGY SATELLITE (R5) 2																
R59	PRIVATE EARTH RESOURCE (COMMERCIAL) 2				1		●		1 1		●		●		●		1
R6	ADV THERMAL MAPPING (R7) 2																
R7	MAGNETIC FIELD SURVEY (R9) 2																
R60	ENVIRONMENTAL MONITOR 2																

1 NUMERAL DENOTE SCHEDULE EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

2 DIRECT ORBITER LAUNCH & RECOVERY

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3.3.2.8 Typcial Waterfall Effects of Budget Limits

The effects of budget constraints on program schedules is cumulative both from the standpoint of depth of budget constraint and length of time the constraint is in effect. These effects on the NASA missions schedules are illustrated in Figure 3.3-19. Schedules on two Astrophysics satellite programs, Gamma Ray Observatory (GRO) and Very Long Base Line Radio Interferometer (VLBI) are presented for the S/SUM/SOC (full funding), and the High economic and Low economic models are shown.

Astrophysics program A-7 (GRO) is planned for early launch in S/SUM/SOC (1985) and therefore should be least affected by cumulative budget constraints. It is seen at the middle of the chart the High budget model (with growth at 2.5% per year above the FY-82 baseline) still allows launch of A-7 in 1985. At the Low budget level, corresponding to shrinkage at 2.5% per year below the FY-82 baseline, A-7 launch is delayed until 1988.

The VLBI satellite program, A-15, comes later in the S/SUM/SOC schedule with the initial launch shown for 1988 in the upper portion of the chart. At the High economic model budget level, cumulative funds to support launch of A-15 (and all of those prior to it in the S/SUM/SOC model sequence) are not accrued until 1994. The combined effects of lower annual budget and this budget constraint over a longer time is seen for A-15 in the Low economic model section of the chart, indicating delay of first launch until 1999.

Thus a moderate budget constraint has small impact on launch schedules in the mid 1980s, a moderate effect in the late 1980s and significant stretch-out impact on programs scheduled in the early 1990s in S/SUM/SOC.

S/SUM/SOC																		
		MISS	TRAFFIC BY YEAR															
IDENT	SAT NAME	FUNCT	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A-7	GAMMA RAY OBSERVATORY	D	1															
		S		●														
		R			1													
A-15	VERY LONG BASE INTERF	D				1	1											
		S						●	●	●	●							
		R										1	1					
HIGH ECONOMIC MODEL																		
A-7	GAMMA RAY OBSERVATORY	D	1															
		S		●														
		R			1													
A-15	VERY LONG BASE INTERF	D										1	1					
		S												●	●	●	●	
		R																1
LOW ECONOMIC MODEL																		
A-7	GAMMA RAY OBSERVATORY	D				1												
		S					●											
		R						1										
A-15	VERY LONG BASE INTERF	D															1	1
		S																
		R																
D – DEPLOY, S – SERVICE, R – RETRIEVE																		

Fig. 3.3-19 Typical Waterfall Effects of Budget Limits

SUBSECTION 3.3 REFERENCES

3.3-1 GAC Satellite Services System Study, Vol II, System Requirements, Grumman Aerospace Corporation Report CSS-SSS-RP009, August 1981

3.3-2 Satellite/Services User Model (S/SUM) ENCL (1), Satellite Service System Analysis Study, Seventh Progress Report, Mar 1981

3.3-3 NASA Space Systems Technology Model, Volume I and II, June 1980

3.3-4 1981 - 1992 Low Energy Payload Model, NASA KSC Missions, Low Energy Deployment and Retrieval Analysis Progress Review, Sept 1979, Batelle, Columbus Labs

3.3-5 STS Flight Assignment Manifest, 13000-3 November 1980

3.3-6 Mission Data Catalogue Advanced Spacecraft Deployment Systems Martin Marietta Aerospace, L.A-5-80-1 Oct 1979

3.3-7 NASA Program Plan Fiscal Years 1981 through 1985

3.3-8 Goddard Space Flight Center Reports Series, July 1980

3.3-9 Department of Defense STS Utilization Plan, July 1980

3.3-10 Goddard Space Flight Center Multi-Mission Spacecraft Listing

3.3-11 International Astronautics Federation 81-125, September 12, 1981

3.3-12 1981 NASA Space Systems Technology Model, (Second Draft)

3.3-13 NASA Fiscal Year 1978 Five year Plan

3.3-14 NASA Fiscal Year 1979 Five year Plan

3.3-15 NASA Fiscal Year 1980 Five year Plan

3.3-16 NASA Fiscal Year 1982 Budget Estimate

3.4 RESEARCH AND APPLICATIONS MISSIONS

The research and applications missions include life sciences research, materials processing research and development, and advanced military technology testing. The definition of these missions was one of the primary tasks for the study extension. The complete reports on these three research and applications missions are found in Sections 5.2.2, 5.2.3, and 5.2.4 of this document.

The integrated SOC Research Mission Models (the Low, Medium, and High) are given in Tables 3.4-1 through -3. Table 3.4-4 summarizes the involvement of SOC in these missions.

Table 3.4-1. SOC Low-Research Mission Model

SOC-1387

CODE NO.	MISSION NAME	YEAR 90	91	92	93	94	95	96	97	98	99	00
MP01	SHORT EXPM'T MODULE DEL.			1	1	1	1	1	1	1	1	1
MP02	FULL EXPM'T MODULE DEL.											
MP03	EXPM'T PALLET DELIV.	1	1	1	1	1	1	1	1	1	1	1
MP04	MP EXPM'T MAN-LEVEL	.1	.1	.25	.25	.25	.25	.25	.25	.25	.25	.25
MP05	PROC DEV MODULE DEL.					2	4	4	4	4	4	4
MP06	PROC DEV MAN-LEVEL					2	2	2	2	2	2	2
MP07	PRODUCTION RESUPPLY											
MP08	PRODUCTION MAN-LEVEL											
MP09	PRODUCTION SPACECRAFT DEL.											
MP10	SHORT MODULE RETURN			1	1	1	1	1	1	1	1	1
MP11	FULL MODULE RETURN	1	1	1	1	1	1	1	1	1	1	1
MP12	PALLET RETURN					2	4	4	4	4	4	4
MP13	PROC DEV MOD RETURN											
MP14	PROD SPACECRAFT RETURN											
LS01	LS RESEARCH MOD DEL							1				
LS02	CELSS RESEARCH MOD DEL											
LS03	CENTRIFUGE RES MOD DEL											
LS04	CENTRIFUGE RES MAN-LEVEL											
LS05	LS EXPM'T MAN-LEVEL	.6	.6	.7	.7	.7	.7	1.5	1.5	2.5	2.5	2.5
DO01	DoD SMALL PALLET DEL.	1	1	1	2	1	2	1	2	1	2	1
DO02	DoD SMALL PALLET RETURN	1	1	1	2	1	2	1	2	1	2	1
DO03	DoD LARGE PALLET DEL.											
DO04	DoD LARGE PALLET RETURN											
DO05	DoD RESEARCH MAN-LEVELS	.1	.1	.1	.2	.1	.2	.1	.2	.1	.2	.1
	TOTAL NO. OF DELIVERIES	2	2	3	4	5	8	8	8	7	8	7
	TOTAL NO. OF RETURNS	2	2	3	4	5	8	7	8	7	8	7
	TOTAL MAN-LEVEL	.8	.8	1.05	1.15	3.05	3.15	3.85	3.85	4.85	4.85	4.85

Table 3.4-2. SOC Medium-Research Mission Model

SOC-1388

CODE NO.	MISSION NAME	YEAR 80	81	82	83	84	85	86	87	88	89	00
MP01	SHORT EXPM'T MODULE DEL.			1	2	2	2	2				
MP02	FULL EXPM'T MODULE DEL.								1	2	2	2
MP03	EXPM'T PALLET DELIV.	1	1	1	2	2	4	4	4	4	4	4
MP04	MP EXPM'T MAN-LEVEL	.1	.1	.1	.5	.5	.5	1	1	1	1	1
MP05	PROC DEV MODULE DEL.			1	1	4	4	4	4	4	4	4
MP06	PROC DEV MAN-LEVEL			1	1	2	2	2	2	2	2	2
MP07	PRODUCTION RESUPPLY											
MP08	PRODUCTION MAN-LEVEL											
MP09	PRODUCTION SPACECRAFT DEL.											
MP10	SHORT MODULE RETURN			1	2	2	2	2				
MP11	FULL MODULE RETURN								1	2	2	2
MP12	PALLET RETURN	1	1	1	2	2	4	4	4	4	4	4
MP13	PROC DEV MOD RETURN			1	1	4	4	4	4	4	4	4
MP14	PROD SPACECRAFT RETURN											
LS01	LS RESEARCH MOD DEL					1						
LS02	CELSS RESEARCH MOD DEL											
LS03	CENTRIFUGE RES MOD DEL							1				
LS04	CENTRIFUGE RES MAN-LEVEL							.5	.5	.5	1	1
LS05	LS EXPM'T MAN-LEVEL	.6	.7	1.2	1.2	2	2	3	3	3	3	3
DO01	DoD SMALL PALLET DEL.	2	2	2	2	2	3	3	3	3	3	3
DO02	DoD SMALL PALLET RETURN	2	2	2	2	2	3	3	3	3	3	3
DO03	DoD LARGE PALLET DEL.		1		1	1	1	1	1	1	1	1
DO04	DoD LARGE PALLET RETURN		1		1	1	1	1	1	1	1	1
DO05	DoD RESEARCH MAN-LEVELS	.2	.7	.3	.7	.7	.7	1	1	1	1	1
	TOTAL NO. OF DELIVERIES	3	4	5	8	12	14	15	12	14	14	14
	TOTAL NO. OF RETURNS	3	4	5	8	11	14	14	12	15	14	14
	TOTAL MAN-LEVEL	.9	1.5	1.6	3.4	5.2	5.2	7.5	7.5	7.5	8	8

Table 3.4-3. SOC High-Research Mission Model

SOC-1380

CODE NO.	MISSION NAME	YEAR 90	91	92	93	94	95	96	97	98	99	00
MP01	SHORT EXPM'T MODULE DEL.											
MP02	FULL EXPM'T MODULE DEL.		1	1	1	1	1	1	1	1	1	1
MP03	EXPM'T PALLET DELIV.	2	2	4	8	8	8	8	8	8	8	8
MP04	MP EXPM'T MAN-LEVEL	.25	.25	1	1	2	2	2	2	2	2	2
MP05	PROC DEV MODULE DEL.		2	2	4	4	12	12	12	12	12	12
MP06	PROC DEV MAN-LEVEL		2	2	2	2	4	4	4	4	4	4
MP07	PRODUCTION RESUPPLY									4	4	4
MP08	PRODUCTION MAN-LEVEL									.5	.5	.5
MP09	PRODUCTION SPACECRAFT DEL.									1		
MP10	SHORT MODULE RETURN											
MP11	FULL MODULE RETURN		1	1	1	1	1	1	1	1	1	1
MP12	PALLET RETURN	2	2	4	8	8	8	8	8	8	8	8
MP13	PROC DEV MOD RETURN		2	2	4	4	12	12	12	12	12	12
MP14	PROD SPACECRAFT RETURN											
LS01	LS RESEARCH MOD DEL		1									
LS02	CELSS RESEARCH MOD DEL											1
LS03	CENTRIFUGE RES MOD DEL				1							
LS04	CENTRIFUGE RES MAN-LEVEL				1	1	1	1	1	1	1	1
LS05	LS EXPM'T MAN-LEVEL	1.1	2.5	3.5	3.5	3.5	4.5	4.5	4	4	4	6
DO01	DoD SMALL PALLET DEL.	2	2	3	3	3	4	4	4	5	5	5
DO02	DoD SMALL PALLET RETURN	2	2	3	3	3	4	4	4	5	5	5
DO03	DoD LARGE PALLET DEL.	1	1	1	1	2	2	2	2	2	2	2
DO04	DoD LARGE PALLET RETURN	1	1	1	1	2	2	2	2	2	2	2
DO05	DoD RESEARCH MAN-LEVELS				1	1	1	1	1	1	1	1
	TOTAL NO. OF DELIVERIES	5	9	11	18	18	27	27	27	29	28	29
	TOTAL NO. OF RETURNS	5	8	11	17	18	27	27	27	28	28	28
	TOTAL MAN-LEVEL	1.35	2.75	6.5	7.5	9.5	12.5	12.5	12	12.5	12.5	14.5

Table 3.4-4. *Summary of SOC Involvement in Research/Applications Missions*

SOC-1330

RESEARCH/ APPLICATIONS SYSTEM	SOC INVOLVEMENT	BENEFITS OF SOC INVOLVEMENT
"SUITCASE" EXPERIMENTS	• PROVIDE INTERNAL STOWAGE LOCATION • PROVIDE POWER • PROVIDE CREW TIME TO INSTALL PACKAGE, INFREQUENTLY ATTEND	• CONTINUOUS LONG DURATION EXPERIMENTAL TIME
"SPACE AVAILABLE" EXPERIMENTS	• PROVIDE INTERNAL LOCATION • PROVIDE POWER, THERMAL CONTROL, DATA MANAGEMENT, ECLS, ETC. • PROVIDE CREW TIME (FRACTIONAL MAN-YEAR PER YEAR) TO INSTALL EQUIPMENT, CONDUCT EXPERIMENTS, MODIFY EXPERIMENTAL SETUPS, INTERPRET DATA	• CONTINUOUS LONG-DURATION EXPERIMENTAL TIME • EXPERIMENTERS DO NOT HAVE TO INCUR THE EXPENSE OF DESIGNING, MANUFACTURING, TESTING, AND DELIVERY OF A HABITABLE MODULE FOR INSTALLATION OF THEIR EXPERIMENTAL EQUIPMENT
RESEARCH MODULES	• PROVIDE BERTHING PORTS • PROVIDE POWER, DATA BUS, COMMUNICATIONS, AND PARTIAL ECLS SUPPORT • PROVIDE CREW TIME (UP TO SEVERAL MAN-YEARS PER YEAR) TO CONDUCT FULL TIME RESEARCH/PROCESS DEVELOPMENT OPERATIONS. SOME OF THE CREW MAY BE COMMERCIAL CUSTOMER EMPLOYEES.	• CONTINUOUS, LONG-DURATION EXPERIMENT TIME • SOC WILL PROVIDE SOME OF THE SUBSYSTEMS, THEREFORE, THE RESEARCH MODULE BUYER DOES NOT HAVE TO PAY FOR THE DEVELOPMENT OF THESE. • SOC WILL PROVIDE THE CREW SUPPORT PROVISIONS (SLEEPING QUARTERS, DINING, ETC.)
COMMERCIAL MANUFACTURING STATION (FREE-FLYER)	• PROVIDE PERIODIC IN-SITU SERVICING OF STATION TO PROVIDE RESUPPLY, MAINTENANCE, REFURBISHMENT	• THIS WILL BE A ROUTINE SERVICE PROVIDED BY SOC SO THE COMMERCIAL CUSTOMER WILL NOT HAVE TO PAY FOR THE DEVELOPMENT OF DEDICATED EQUIPMENT OR OPERATIONS

3.5 DoD MISSION MODEL

3.5 DoD MISSION MODEL

3.5.1 Introduction

Military mission models were discussed with Dr. Robert Davis of Aerospace Corporation. There are a number of classified sources for military mission models such as the STS Utilization Plan, but these cannot be used as source material for unclassified models because of their classification. The discussion with Dr. Davis concluded that it is not possible to "sanitize" these sources and retain sufficient information to permit a mission analysis.

Further problems with the available sources are that they do not project far enough into the future, and when subjected to a rough budget analysis, the resulting funding profile does not follow the expected trends.

Because of these problems it was decided to create an unclassified mission model for the SOC mission analysis. This model, based entirely on unclassified sources, on speculation, and on budget projects, suffers from a lack of "authenticity" in not being derived from official sources, but is probably at least as realistic as one which might be derived from those sources. Figure 3.5-1 presents the main considerations used in deriving the models.

3.5.2 Economic Basis of DoD Mission Models

In order to develop budget-driven models, one must employ some sort of cost model to derive spacecraft cost as a first step in estimating the number of launches. Figure 3.5-2 presents the high-level model used. On the left of the figure, we present historical experience for simple and complex spacecraft, in terms of 1980 dollars versus weight. On the right, we have converted this to 1982 dollars per pound. Development of a spacecraft is estimated as five times the unit cost. The representative military program is estimated to include ten product units. This assumption yields the typical program aggregate shown on the curve.

Figure 3.5-1

Military Mission Model
Considerations and Assumptions

- Can't Use STS Utiliziation Plan
  - Classified Data
  - Does Not Project Far Enough Into Future
- Budget - Driven Mission Model Most Realistic
  - Three levels: low, medium, high
- Unclassified Sources Permit Projection of General Classes of Missions
- Simplifications:
  - WTR launches not included but presumed to consume 40% of available launches; 70% of launched spacecraft mass
  - All ETR launches to high-energy orbits go to GEO

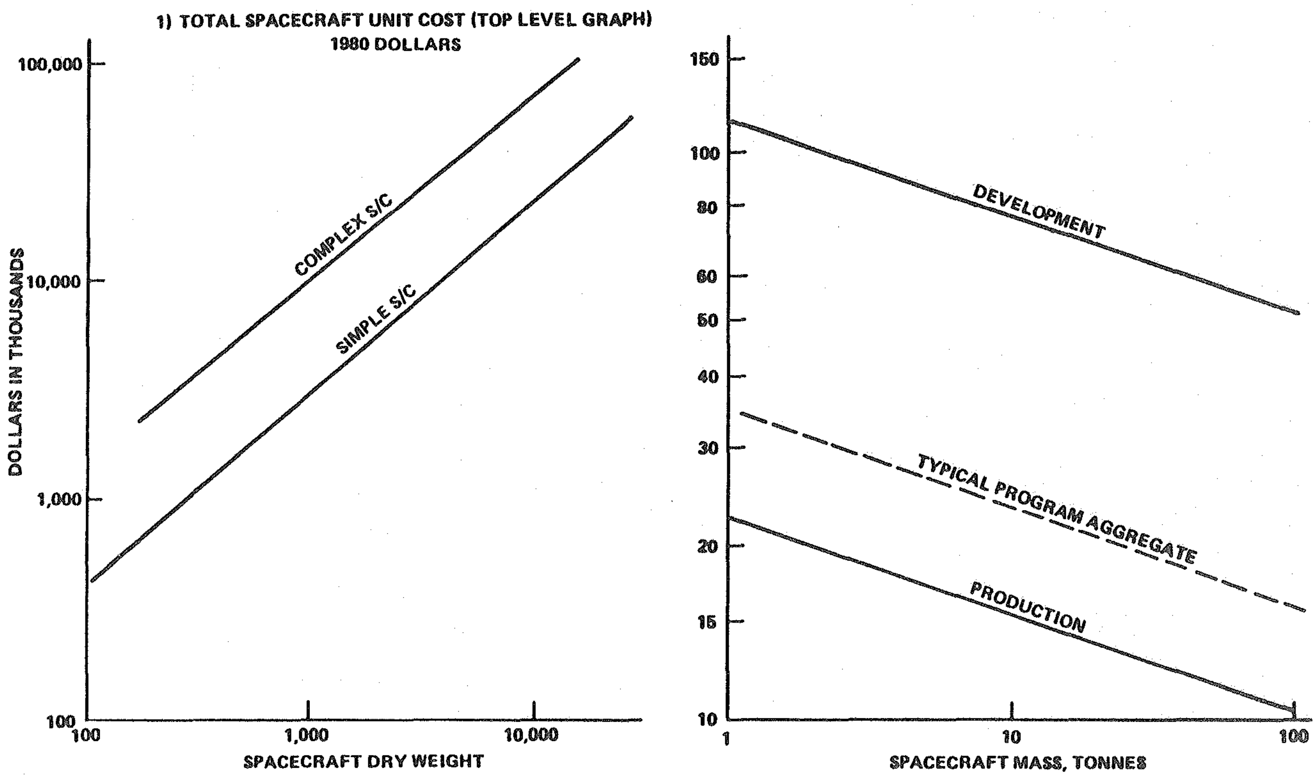
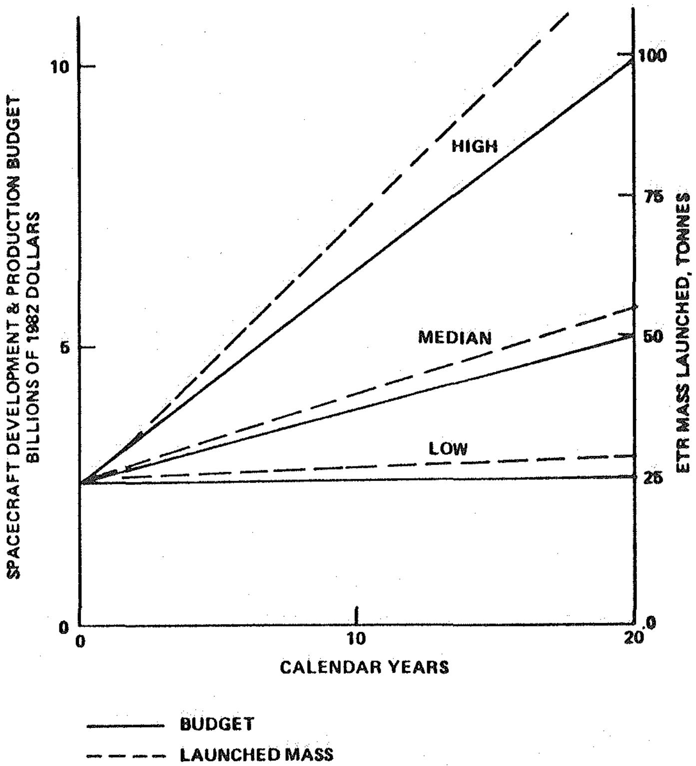


Figure 3.5-2. High-Level Cost Model

Budgetary assumptions are presented in Figure 3.5-3. Three models are considered, with themes, budgets, and annual launches as presented in the figure. The launched mass is based on that proportion of the military budget allocated to ETR activities. WTR activities were not considered as they would not involve the use of a Space Operations Center.

3.5.3 DoD Mission Models

In order to predict the number of launches, it is also necessary to know something about spacecraft characteristics. The assumptions used are presented in Table 3.5-1. These were used with the launch mass estimates from the previous figure to derive the specific mission models presented in Table 3.5-2. Additional estimates of system characteristics, needed to conduct the specific SOC utilization analyses, are being developed.



- LOW MODEL
  - NO SIGNIFICANT CHANGE IN USES OF SPACE
  - GRADUAL GROWTH OF AVERAGE SPACECRAFT MASS TO 500 kg BY END OF CENTURY
- MEDIAN MODEL
  - ASAT THREAT LEADS TO BUDGET GROWTH FOR SPACE DEFENSE
  - SPACECRAFT MASS GROWTH SAME AS LOW MODEL
  - MANNED ACTIVITY ONLY FOR SPACE TESTING AT A NATIONAL SPACE STATION
- HIGH MODEL
  - SPACE EVOLVES TO THEATER OF CONFLICT
  - SPACECRAFT AVERAGE MASS GROWTH TO 10,000 kg
  - SMALL MILITARY MANNED STATION IN HIGH ORBIT

Figure 3.5-3. Military Mission Model Budgetary Assumptions

Table 3.5-1

Assumed Spacecraft Characteristics

ASSUMED MILITARY SPACECRAFT	MASS KG	LENGTH, M	DIA, M (BASED ON 50 kg/m^2 AVERAGE DENSITY)	
1-Tonne Class	1000	2.8	3	Compatible With T-IV
2-Tonne Class	2000	5.6	3	Compatible With T-IV
3-Tonne Class	3000	4.77	4	
5-Tonne Class	5000	6.58	4.4	
10-Tonne/Class	10,000	13.16	4.4	
Manned Station	20,000	15	4.4	Single Shuttle Launch for Delivery to LEO
Manned Station Resupply	6000 up 4000 down	6	4.4	

Table 3.5-2
Military Mission Models

	Calendar Year											
LOW	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**200**
1-tonne class	3	2	2	2	2	2						
2-tonne class	4	3	3	3	3	3	2	2	2	2	2	2
3-tonne class	3	3	3	3	3	3	3	3	3	3	3	3
5-tonne class		1	2	2	2	2	3	3	3	3	3	3
MEDIAN												
1-tonne class	3	2	2	1	1							
2-tonne class	6	5	5	5	5	4	4	4	3	3	2	1
3-tonne class	6	5	5	4	4	5	3	3	2	2	2	3
5-tonne class		2	2	3	4	4	5	5	5	6	5	5
10-tonne class									1	1	2	2
HIGH												
1-tonne class	3	2	2	1	1							
2-tonne class	6	5	5	5	5	4	4	4	3	3	2	1
3-tonne class	6	5	5	4	4	5	3	3	2	2	2	3
5-tonne class		4	4	6	8	8	6	6	8	10	10	10
10-tonne class				1	1	1	2	2	2	3	4	4
Manned Station						1	1					
Manned Station Resupply							2	4	4	4	4	4

Note: Space Testing at SOC Not Included in These Payloads

3.6 SATELLITE SERVICING MISSIONS

Satellite servicing missions are an extension of the Space Transportation System which provides on-orbit services and operational capabilities that exploit the unique capabilities of the Shuttle (vis-a-vis expendable launch vehicles) with the advantages of manned presence in orbit. The Space Operations Center (SOC) will add a new dimension to these services which are decoupled from Shuttle launch delays (i.e., weather, strikes, accidents, etc), Orbiter mission duration constraints, and Orbiter availability. Because of its continuous manned operation in low earth orbit, the SOC offers greater flexibility for dealing with extended contingency situations than the Orbiter (such as satellite deployment hang-ups or difficult repairs). As discussed in Section 4, the SOC provides more economical services than the Orbiter and facilitates the assembly of very large systems in orbit.

Section 4 provides further discussion on the requirements and approaches for servicing attached and co-orbiting satellites on SOC. It also identifies commonality of requirements and equipment for space construction and satellite servicing operations; defines servicing mission needs and benefits; determines differential decay characteristics of co-orbiting satellites, and provides information on satellite servicing transportation considerations.

SECTION 4 TABLE OF CONTENTS

4.0 SATELLITE SERVICING TEST AND CHECKOUT

4.1 INTRODUCTION

Satellite services is an extension of the Space Transportation System which provides on-orbit services and operational capabilities that exploit the unique capabilities of the shuttle (vis-a-vis expendable launch vehicles) with the advantages of manned presence in orbit. The Space Operations Center (SOC) will add a new dimension to these services which are decoupled from Shuttle launch delays (i.e., weather, strikes, accidents, etc), Orbiter mission duration constraints, and Orbiter availability. Because of its continuous manned operation in low earth orbit, the SOC offers greater flexibility than the Orbiter for dealing with extended contingency situations (such as satellite deployment hangups or difficult repairs). As discussed below, the SOC provides more economical services than the Orbiter and facilitates the assembly of very large systems in orbit.

Satellite servicing covers the full mission cycle from initial checkout and orbital deployment to subsequent in-orbit support, and finally, removal of the spacecraft from orbit. In-orbit support includes examination, maintenance/repair of basic subsystems and mission peculiar equipment, resupply of consumables, and reconfiguration of experiments. End of mission retrieval and temporary on-orbit storage of satellites awaiting repair, earth return or controlled re-entry disposal are also part of satellite servicing.

The objectives of this task were to define requirements and approaches for servicing attached and coorbiting satellites on SOC, identify commonality of requirements and equipment for space construction and satellite servicing operations, define servicing mission needs and benefits, determine differential decay characteristics of co-orbiting satellites, and analyze satellite servicing transportation considerations. The first three tasks were performed by Grumman and the two remaining tasks were performed by Boeing.

SUBSECTION 4.2 TABLE OF CONTENTS

4.2 SERVICING REQUIREMENTS AND APPROACHES

Satellite servicing covers the full mission cycle from initial checkout and orbital deployment to subsequent in-orbit support and finally, removal of the spacecraft from orbit. In-orbit support includes examination, maintenance/repair of basic subsystems and mission peculiar equipment, resupply of consumables, and reconfiguration of experiments. End of mission retrieval and temporary on-orbit storage of satellites awaiting repair, earth return, or controlled re-entry disposal are also part of satellite servicing.

Servicing requirements were analyzed for the Advanced X-ray Astrophysics Facility (AXAF) and the GEO Communications Platform missions. Functional analysis, procedures, crew tasks, operational timelines and equipment for accomplishing these functions were determined when operating from SOC and from Orbiter.

Specifically the following orbital servicing operations were analyzed in detail:

- AXAF and communications platform maintenance
- AXAF checkout before and after mating to a versatile service stage
- Communication platform checkout after unfolding/assembly and after mating to an orbital transfer vehicle.

Comparison was made of SOC and Orbiter operations, servicing the AXAF and the Communication Platform with respect to Orbiter flights, crew requirements, and costs of operations.

4.2.1 FUNCTIONAL ANALYSIS OF SERVICING OPERATIONS

Satellite servicing operations are subdivided into two main categories, those that are accomplished on SOC and those that are conducted remotely from SOC (see Figure 4.2-1). Satellite servicing operations are designated Block 5, as established by the Boeing top level functions.

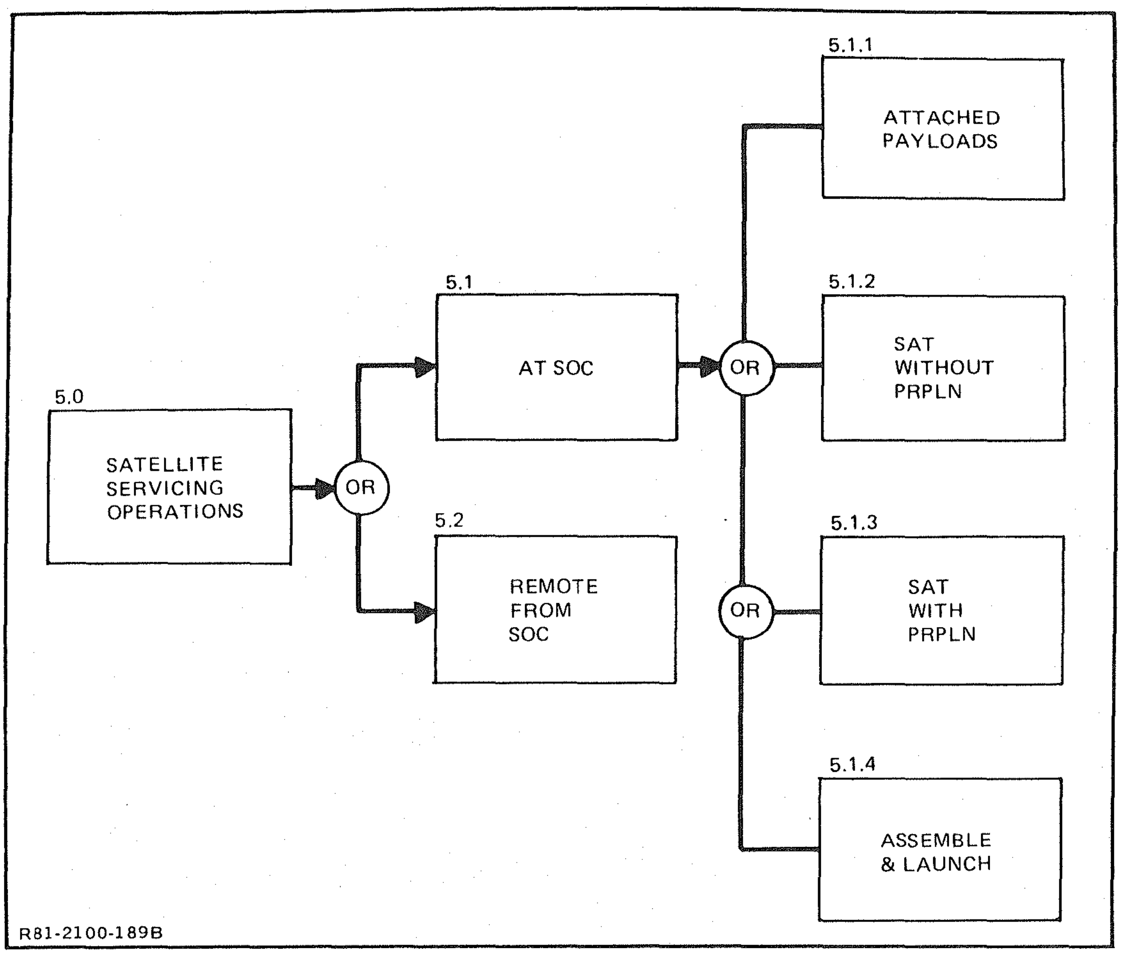


Fig. 4.2-1 Satellite Servicing Operations

Remote in situ operations would be performed on LEO satellites that are too large to be brought to SOC or would impose prohibitive propulsion requirements to transport them to SOC. Remote satellites are serviced in the same way as those serviced on SOC.

In later years, the availability of a manned OTV will greatly extend the range of access for LEO SOC satellite servicing. Satellites in orbits of significantly different inclination and altitude than SOC will be accessible for service, even to GEO orbit. Staging OTV service operations from the SOC with a manned OTV will reduce the number and complexity of Shuttle flights required. This is especially true where multiple-flight missions would otherwise be needed; space-basing decouples OTV operations from Shuttle operations.

Figure 4.2-1 shows the following functional modes of satellite servicing at SOC:

- Payloads that are attached and operated on SOC
- On-orbit satellites without propulsion
- On-orbit satellites with propulsion
- Satellites that are prepared/assembled at SOC and launched for co-orbiting flight or transfer to another operating orbit.

4.2.1.1 SOC Attached Payloads

The item to be serviced is attached to the SOC. This would be the case for Spacelab-derived missions or instruments. The SOC would provide services such as power and communications in addition to crew attention for maintenance or instrument changes. This mode of operations would "extend" certain Spacelab missions to arbitrarily long duration and could be quite beneficial in improving Shuttle fleet utilization by performing long-duration missions to avoid long on-orbit stay times by Shuttle.

SOC-based science missions will include life sciences and materials processing research. Materials processing research, as opposed to process development and prototyping, should be carried out onboard SOC because of the relatively short duration of most experiments, the need for crew involvement to avoid high automation costs for one-of-a-kind tests, and the benefits of crew participation in a research-oriented activity where dealing with the unexpected is much more likely than in development and prototyping.

These experiment programs will initially be carried out on a time and equipment available basis, but to reach full potential will probably require a dedicated mission module.

4.2.1.2 Satellites Without Propulsion

SOC Proximity Operated Satellites - Proximity operated spacecraft could be intentionally station-kept with the SOC. This would allow convenient access at frequent intervals. It could be the preferred operational mode for missions that require frequent service but are separated from the SOC to avoid contamination of the mission environment. A good example is a space processing facility that needs a high-purity zero-g environment. Certain optical instrument missions will also be best flown in this mode because of outgassing and similar contamination problems.

Remotely Operated Satellites - Satellites that are operated remotely from SOC and do not have orbit transfer capability, either due to propulsion fuel depletion or have no propulsion system, must be transported to SOC for service. In this case, the SOC will dispatch a vehicle such as the Proximity Operations Module, Versatile Service Stage, or Orbit Transfer Vehicle, depending on propulsion needs, to fetch the satellite. Figure 4.2-2 contains the primary servicing functions. After the satellite is berthed to SOC, the propulsion stage requires servicing in addition to SOC meeting the needs of the satellite. The satellite could be repaired, resupplied, and reconfigured then checked out and returned to operational orbit.

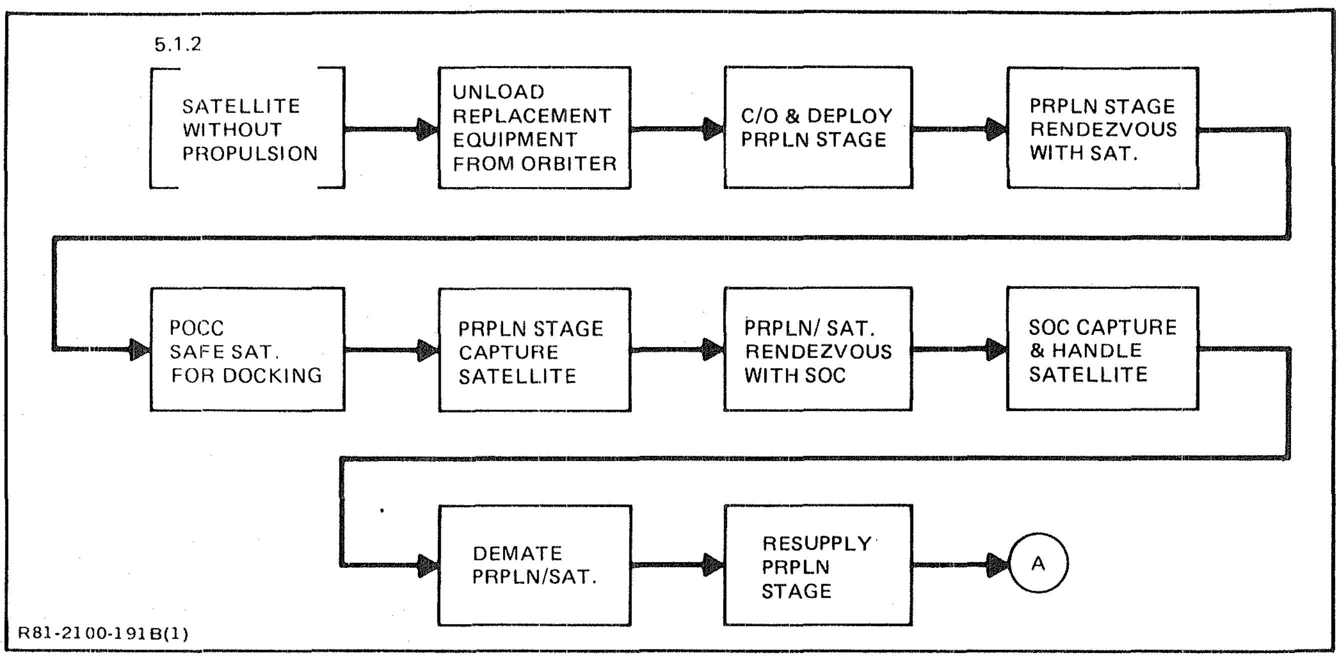


Fig. 4.2-2 Satellites Without Propulsion (Sheet 1 of 2)

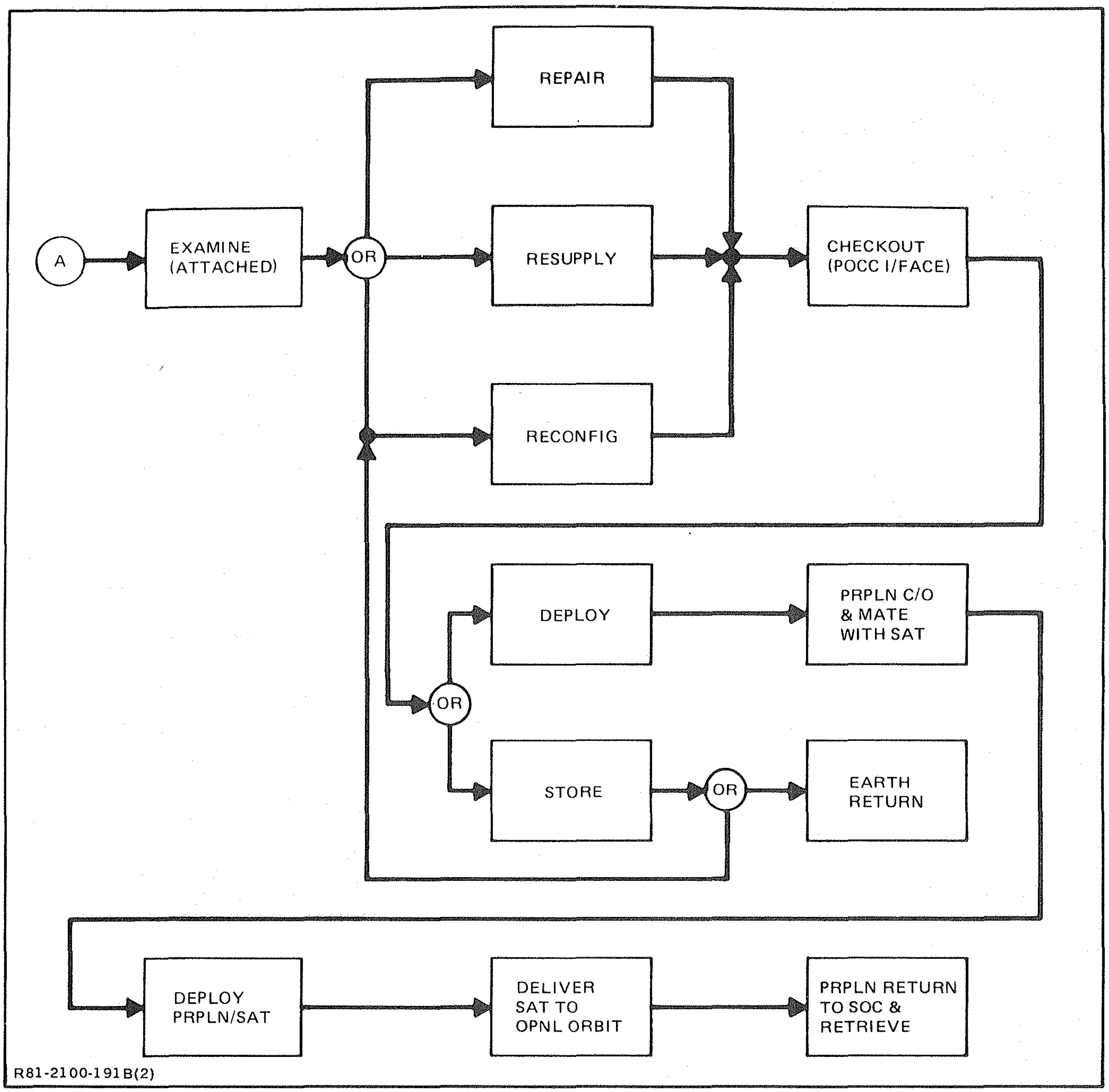


Fig. 4.2-2 Satellites Without Propulsion (Sheet 2 of 2)

Scientific satellites such as the Space Telescope, Long Duration Exposure Facility, Advanced X-Ray Astrophysics Facility, and materials processing free flyers are likely candidates.

4.2.1.3 Satellites with Propulsion

Satellites with propulsion are manuevered to the vicinity of SOC when servicing is required, being controlled by their respective Payload Operations Control Center, so that SOC operations can implement retrieval using a Proximity Operation Module (POM). The same types of services would be provided as those satellites fetched by SOC based vehicles. An additional item is servicing of the onboard propulsion system. Scientific satellites, such as the X-Ray Observatory, are expected to require about one visit every 2 years. The most practical mode of operation will be for these satellites to rendezvous with the SOC and be berthed for the service interval.

4.2.1.4 SOC Assembled & Launched Satellites

The assembly and launch mode (Figure 4.2-3) consists of satellites such as the GEO Communications Platform that are delivered to SOC by Orbiter for subsequent launch. Satellites could be launched at the appropriate time into a near SOC co-orbiting operational location or launched with a propulsion stage to transport them to operational location. Therefore, an appropriate propulsion stage would be checked out and attached to the satellite prior to launching operations.

4.2.2 SOC SATELLITE SERVICE REQUIREMENTS

SOC satellite servicing requirements are keyed to the major ground rules in Table 4.2-1. The analysis of satellite services for the Space Operations Center is focused on the operational configuration defined for SOC during the previous Boeing study. Satellite service concepts for SOC shall be common with the Orbiter, wherever possible. Maximum use of existing equipment (or those under development, such as the Open Cherry Picker) shall also be a goal in order to achieve low development costs. Candidate satellite service equipment concepts have been recently defined by Grumman and Lockheed (Reference 4.2-6 and 4.2-7).

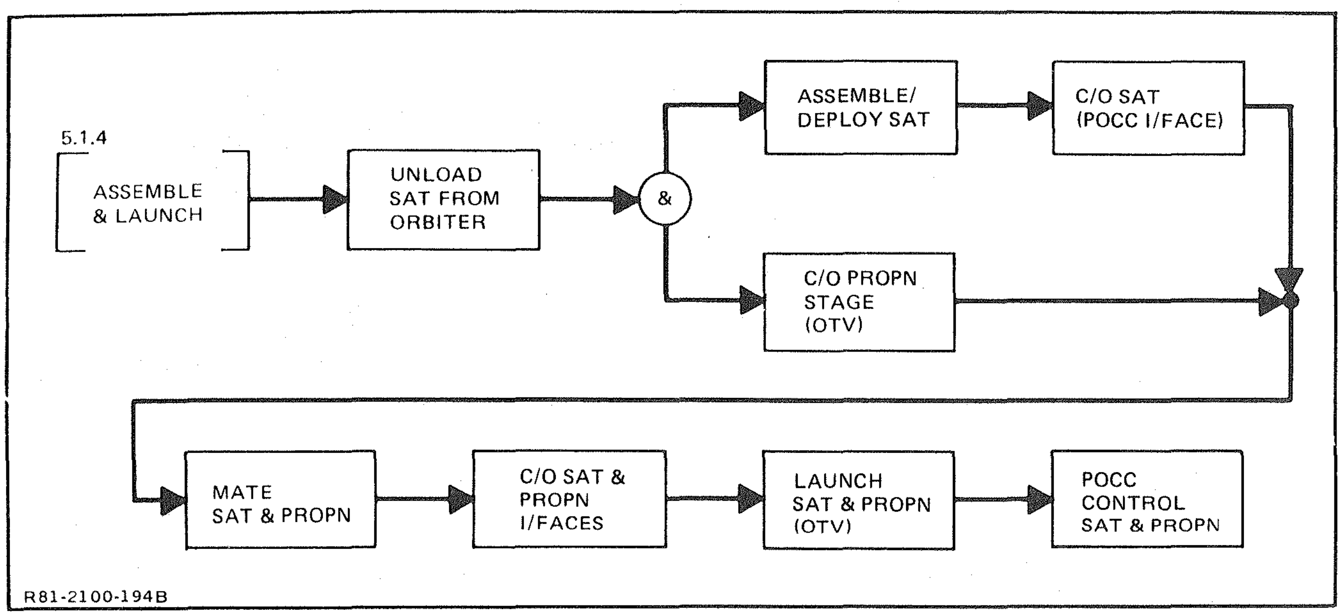


Fig. 4.2-3 Satellite Assembly & Launch Services

TABLE 4.2-1 SOC SATELLITE SERVICES GROUND RULES

- SOC CONFIG DEFINED IN BOEING FINAL REPORT D180 – 26495-4, 7/81, NAS 9 – 16151
- STANDARDIZE ON-ORBIT SERVICE OPS WITH ORBITER
- MAXIMIZE USE OF EXISTING EQUIP OR THOSE UNDER NEW
- STS SAT SERVICES CONCEPTS
  - GAC FINAL REPORT LSS-SSS-RP009, 7/81, NAS 9 – 16120
  - LMSC FINAL REPORT LMSC D764514, 7/81, NAS 9 – 16121

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TABLE 4.2-2 SOC SATELLITE SERVICE MISSIONS

	TEND			SAT. LAUNCH	
SERVICE OPERATIONS	ATTACHED PAYLOADS	CO-ORBITING SATELLITES	REMOTE ACCESSIBLE SATELLITES	LOW ENERGY ORBIT	HIGH ENERGY ORBIT
EXAMINATION	•	•	•		
RETRIEVAL		•			
MAINTENANCE/REPAIR	•	•	•		
RESUPPLY	•	•	•		
RE CONFIGURATION	•	•	•		
ON-ORBIT ASSEMBLY				•	•
MATE UPPER STAGES					•
TEST & CHECKOUT	•	•	•	•	•
ON-ORBIT STORAGE		•		•	•
DEPLOY		•		•	•

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TABLE 4.2-3 SATELLITE ORBITAL PARAMETERS

SATELLITE	OPS ALT (km)	OPS INC (DEGREES)	LENGTH (m)	DEPLOYED DIA (m)	MASS (km)
AXAF	500	28.5	13.1	12	10 - 12,000
LAMAR	400	28.5	6.5	14	5,200
X-RAY OBSERVATORY	400	28.5	6	16	3,550
LDEF	556	28.5 & 57	19.1	4.3	4,500
GEO COMM PLAT	35786	0	20.7	66	6,100

The satellite service missions for the Space Operations Center includes those satellites which are in orbit and require periodic tending for continued operations as well as those satellites which are ready for initial launch into orbit (see Table 4.2-2). Tended satellites encompass attached payloads, co-orbiting, and remote accessible satellites. Co-orbiting satellites station keep with SOC, those that are initially in the same orbital plane and similar altitude (within $\approx$100 km) and those that are transferred to SOC by a propulsion stage. Remote accessible satellites are remote to SOC but accessible by in-situ remote servicing from a manned/remote teleoperated service stage.

The launched satellites are subdivided into two energy orbit categories (i.e., low energy orbits up to 2000 km and high energy orbits above 2000 km)

The types of service operations that can be performed on SOC are listed in Table 4.2-2 and keyed to the respective missions. Many of the co-orbiting satellite services are the same as those required for attached payloads. Much of the equipment required to perform these service operations have been previously identified in Satellite Service Studies and some are already under development. While most of these service operations can be performed with the Shuttle Orbiter the SOC can also offer other services. These services include on-orbit assembly of large systems, mating of large upper stages and the option for on-orbit storage of satellite hardware if predeployment test and checkout fails.

Several of the satellites that are in compatible orbits for servicing by SOC (370 km, 28.5 degrees inclination) are shown in Figure 4.2-4 and pertinent operational data is listed in Table 4.2-3 (Reference 4.2-1).

The Advanced X-ray Astrophysics Facility (AXAF) configuration (Reference 4.2-2, 3, 4 and 5) is similar in many respects to the Space Telescope. It will be designed for space maintenance and the instruments are located at the opposite end to the aperture and accessible through an external door. The instruments are mounted in quadrants of

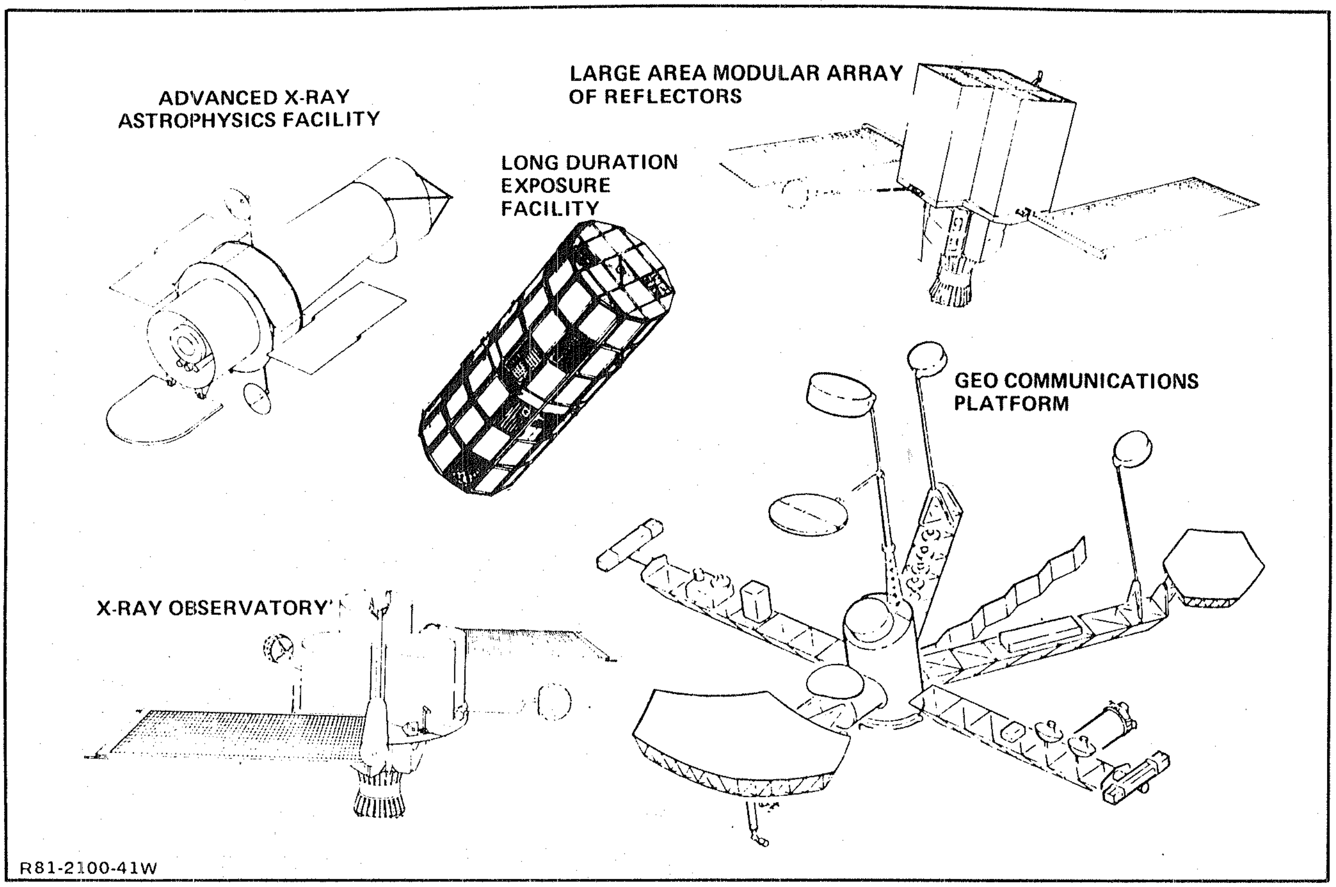

Fig. 4.2-4 Typical Satellites Launched or Tended From SOC

a carousel that rotates the instrument to the focal plane and also makes the instruments accessible at the door opening. The subsystems are contained in a donut-configured structure that has many access doors. Approximately 80 to 100 components are replaceable on the AXAF. The AXAF has no on-board capability to change its orbital location.

The Large Area Module Array of Reflectors (LAMAR) is mounted on a Multimission Modular Spacecraft (MMS) bus including a propulsion module. The MMS is designed for maintenance but the instrument's capability for space maintenance is yet to be determined.

The X-ray Observatory is similar in configuration to th LAMAR as can be seen in the figure.

The Long Duration Exposure Facility (LDEF) is a reusable, gravity-gradient-stabilized, free flying structure. It has no propulsive capability and can accommodate many technology, science, and applications experiments, both passive and active, that require exposure to space. Experiments are mounted on 72 periphery trays and on 2 trays at each end. At present, the trays are not designed for replacement in space.

The GEO Communications Platform is a large structure that unfolds like an umbrella in low earth orbit and is attached to an orbital transfer vehicle, then boosted to geosynchronous orbit.

4.2.2.1 Maneuverable Television - (MTV)

The MTV, an equipment expected to have a high utilization rate in satellite service operations, is shown in Figure 4.2-5. Currently under development, the MTV is used to remotely examine satellites prior to retrieval, observe attached satellite operation, view or record satellite upper stage firing, and support numerous experiments in a free-flying mode.

The system is flown remotely from the Orbiter and SOC via translational and rotational hand controllers. Video and telemetry data recorded by the MTV are transmitted back to the SOC.

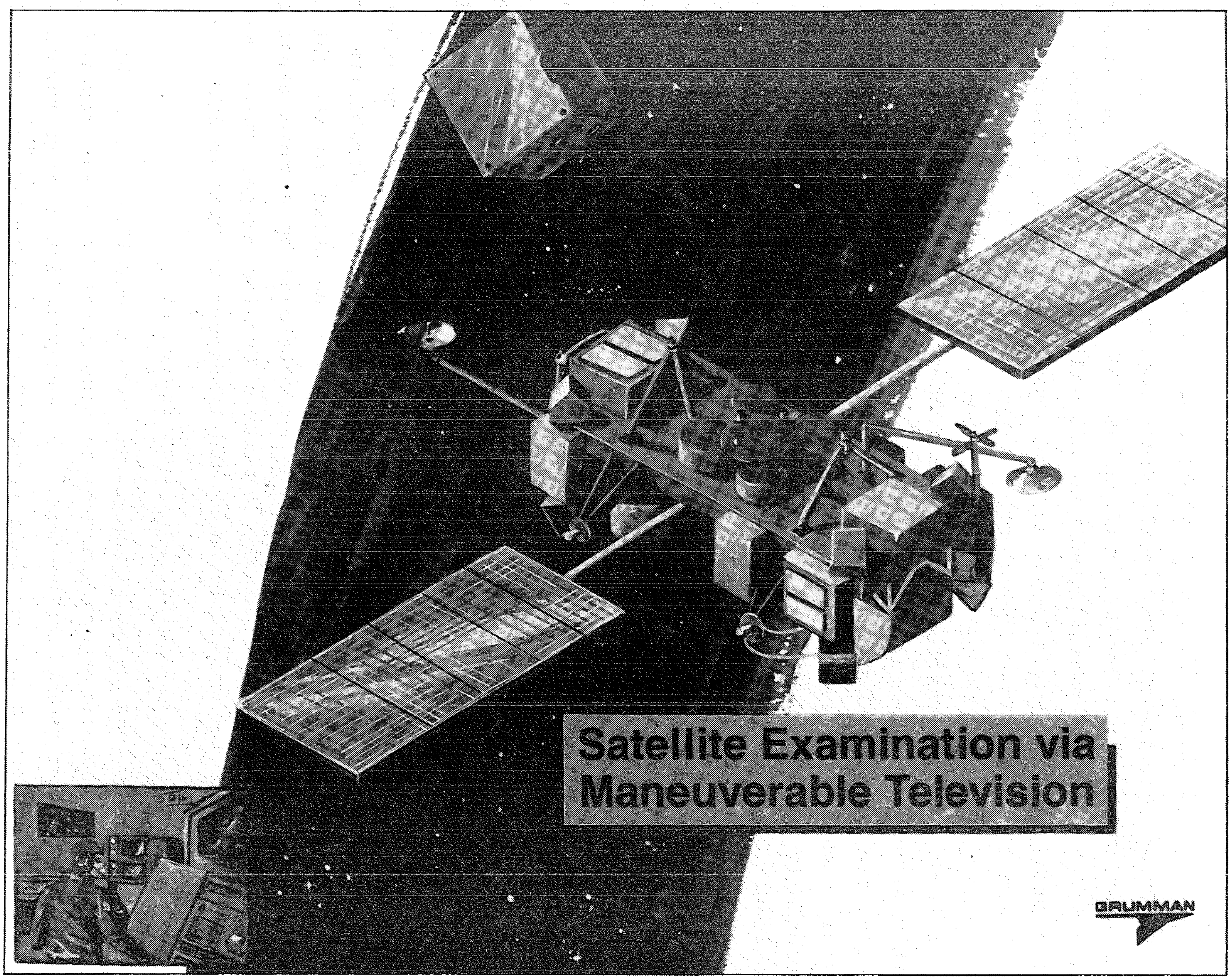

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Fig. 4.2-5 Satellite Examination via Maneuverable Television

4.2.2.2 Strategies for Retrieving Co-orbiting Satellites

Three strategies for retrieving co-orbiting satellites, for maintenance/resupply/reconfiguration at SOC, are shown in Figure 4.2-6. The requirements imposed on SOC will vary in accordance with the proximity or relative position of each co-orbiting satellite to SOC and the satellite's orbit adjust capabilities. In the first retrieval scenario, the satellite is shown to be in the same orbit (altitude and inclination) and station keep with respect to SOC; in this situation, the satellite could be either a free flyer which can be controlled by SOC or any satellite which operates under ground control. When free flying vehicles return to SOC, operating in close proximity and berthing, they will be controlled by the SOC. For on-orbit safety, ground controlled satellites would not be flown all the way to dock at SOC. Nor is it practical to maneuver the SOC toward the satellite for terminal acquisition. Final satellite retrieval, instead, is accomplished by a Proximity Operation Module (POM) which can be readily deployed and controlled from the SOC.

Many satellites will not actively station keep with SOC but will be allowed to decay in altitude and drift out of plane. If the satellite has an orbital maneuvering system, as shown in the second scenario, it could be used to adjust its altitude so that it will drift back toward SOC when it is time for maintenance. A SOC controlled POM can then retrieve these satellites as before; on the other hand, if the satellite does not have an orbital adjust capability it will continue to drift out of plane from SOC as shown in the third scenario. The latter satellite must be retrieved by a more capable SOC based vehicle, such as the Versatile Service Stage, which must rendezvous with the satellite, dock and transport it back to SOC.

4.2.2.3 Alternate Proximity Operations Equipment

The Orbiter can readily rendezvous with a satellite to within a 1000-ft distance. However, concerns by some satellite users regarding Orbiter thruster plume impingements or contamination during terminal closure maneuvers could preclude direct Orbiter rendezvous/retrieval

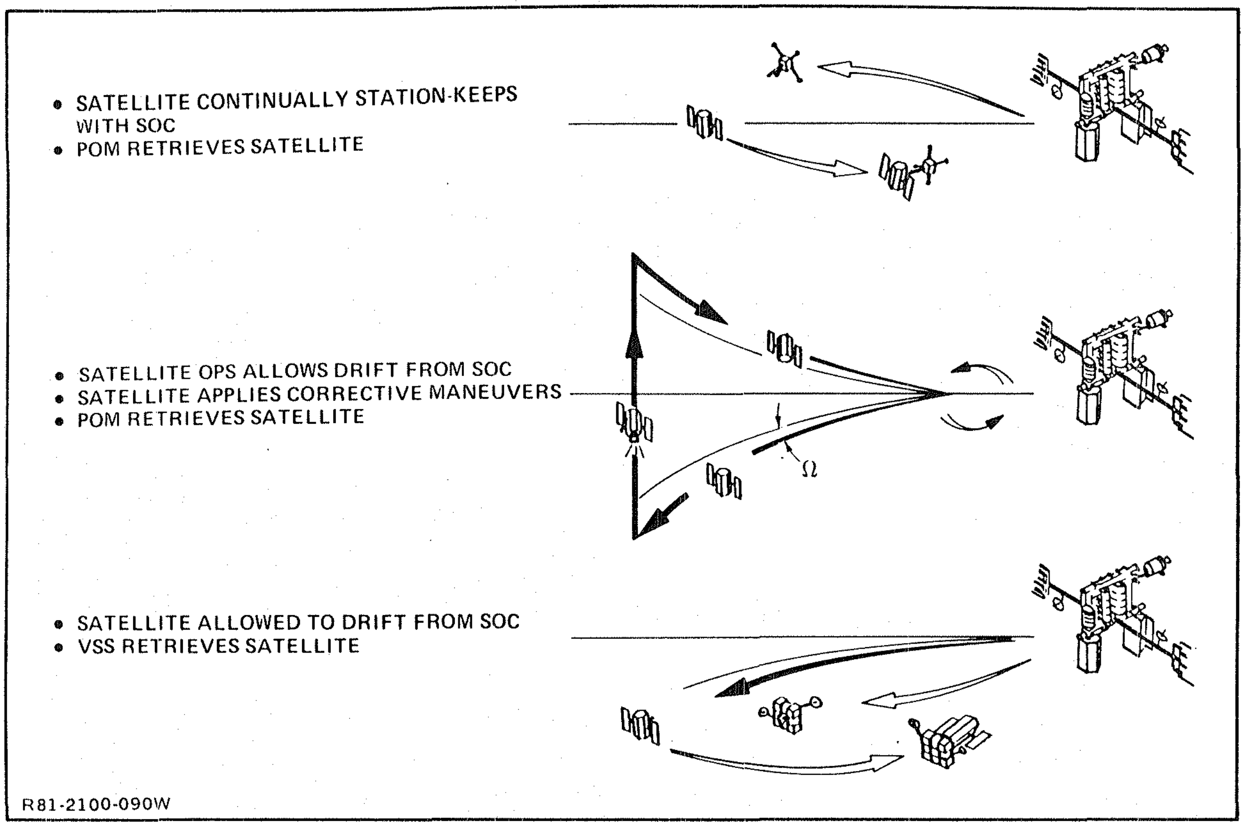

Fig. 4.2-6 Strategies for Retrieving Co-Orbiting Satellites

of a spacecraft. Retrieval of satellites within a 1000-ft range can be accomplished by a manned or unmanned Proximity Operations Module (POM).

The manned POM concept (Figures 4.2-7 and 8) is an adaptation of the Work Restraint Unit (WRU) and can be used in conjunction with an Manned Maneuvering Unit (MMU) to retrieve moderate size satellites of the Multimission Modular Spacecraft class. The WRU is equipped with an extendible mast and an RMS end-effector mounted to a support structure to allow the astronaut to fly with the snare end-effector in a forward position during satellite engagement and in an aft position during satellite towing operations. An astronaut would fly the manned POM to the satellite, capture it via the satellite's RMS-compatible grapple fixture, and tow the satellite to within reach distance of the RMS. The WRU was developed by Grumman to support a potential on-orbit Orbiter tile repair mission. During the development program, neutral buoyancy testing was performed in the NASA Johnson Space Center's Water Immersion Facility to validate the WRU design. The mission requirement has since been cancelled, but the WRU hardware is presently in storage at NASA Johnson Space Center.

Unmanned retrieval of satellites within $\approx$1 km of the Orbiter or SOC can be accomplished by a POM (Figure 4.2-9 and 10) that is an adaptation (or outgrowth) of the MTV. Controlled by the crew in the SOC, the POM would be dispatched to capture the satellite and return it to within the reach distance of the RMS. The POM would be flown via TV (using essentially MTV equipment) to effect satellite capture by an RMS end- effector on an extendible boom mating to a compatible grapple fitting. TV visibility is needed only during the satellite capture phase; return to the SOC is via remote command/control from the SOC crew station. The POM could be designed to retrieve satellites of varying size/mass. It used a non-contaminating cold gas propulsion system that provides three axes of translation and rotation during free- flight and towing operations.

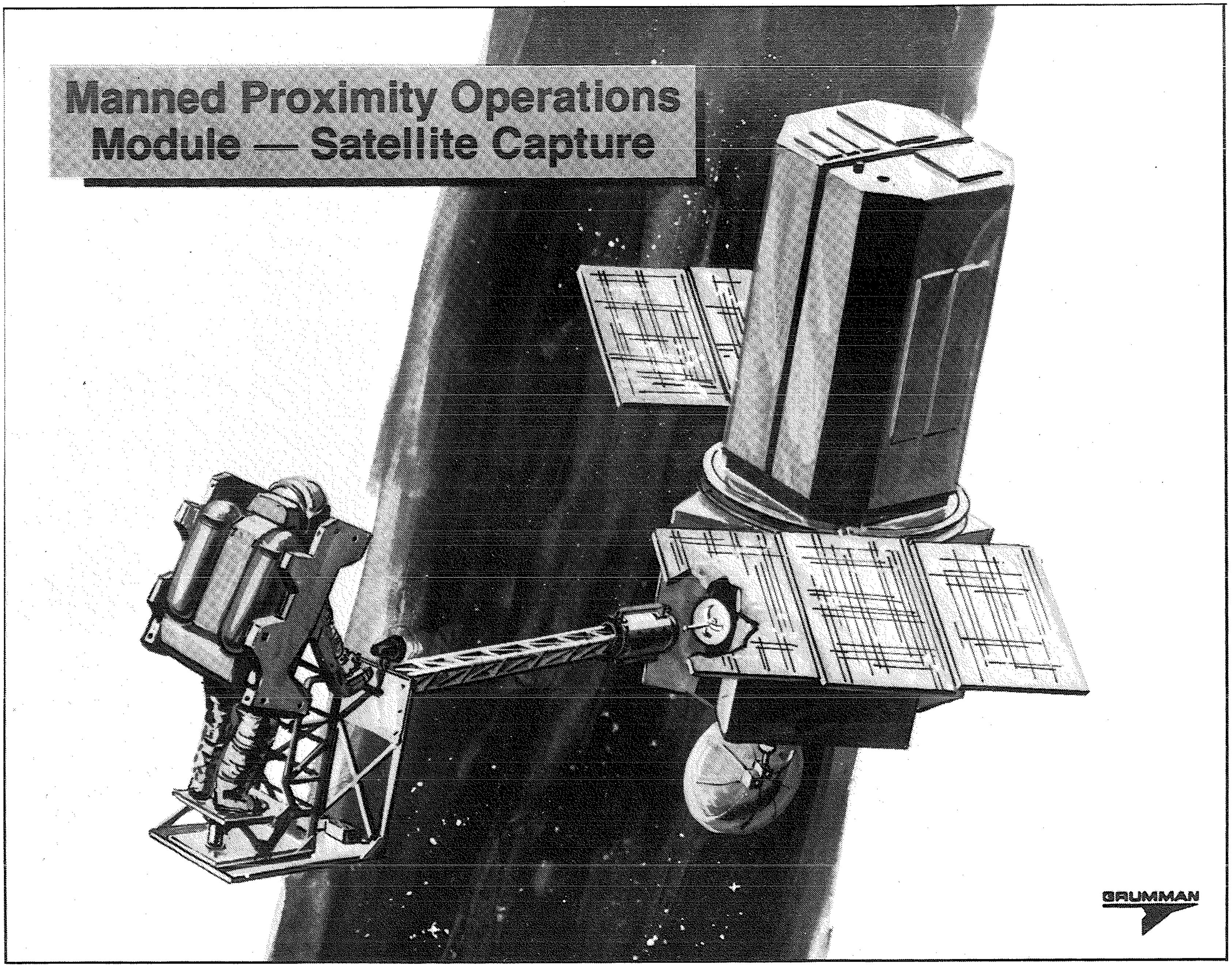

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Fig. 4.2-7 Manned Proximity Operations Module — Satellite Capture

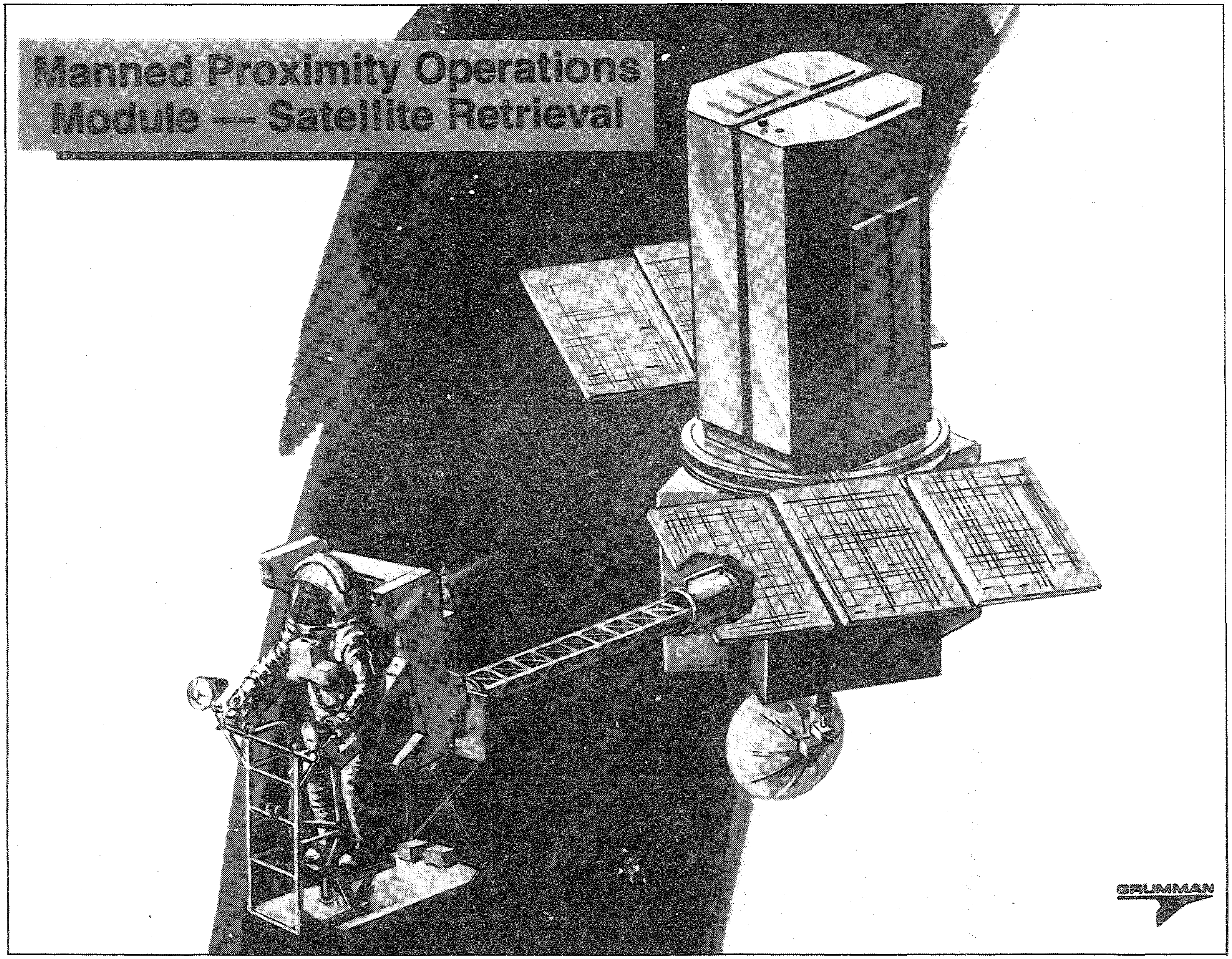

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Fig. 4.2-8 Manned Proximity Operations Module – Satellite Retrieval

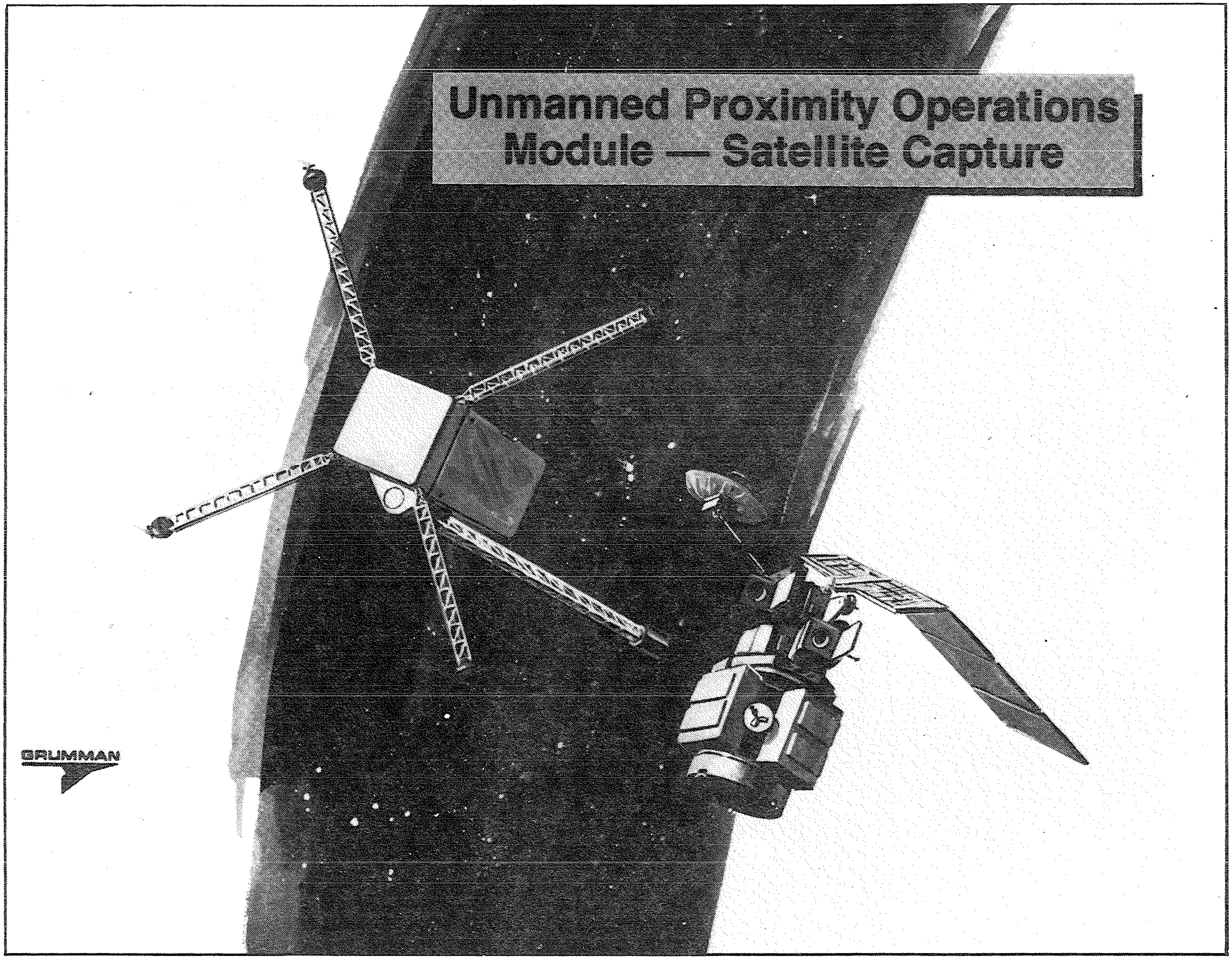

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Fig. 4.2-9 Unmanned Proximity Operations Module — Satellite Capture

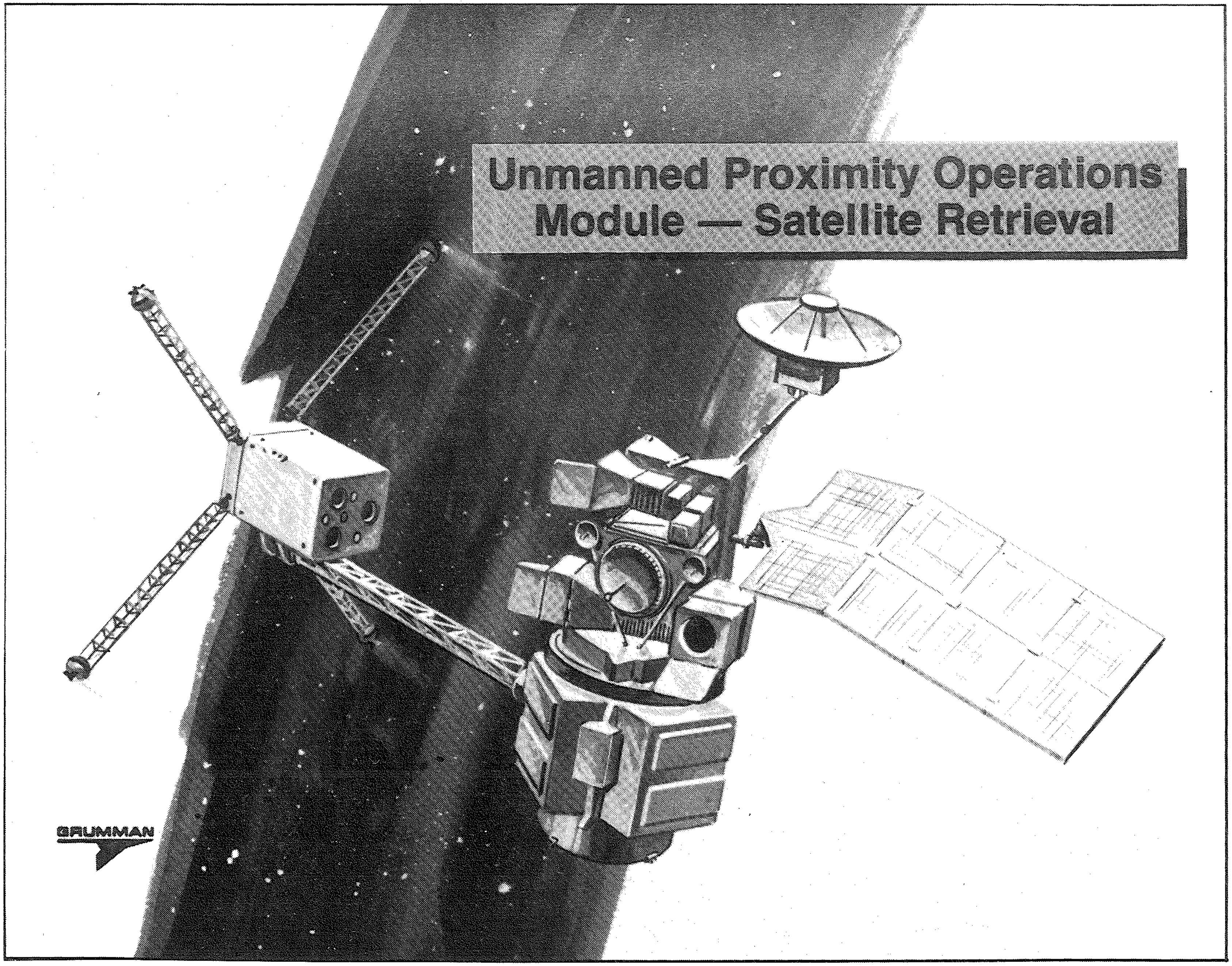

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Fig. 4.2-10 Unmanned Proximity Operations Module – Satellite Retrieval

4.2.2.4 Versatile Service Stage (VSS)

A versatile service stage which is needed primarily for the transfer and return of satellites to/from higher-energy LEO orbits is illustrated in Figure 4.2-11.

The VSS is designed to operate with several front-end attachments to satisfy a wide assortment of mission needs. Included are a snare end effector on an extendible mast for grappling satellites rotating at higher rates than that accomplishable for docking, a docking/berthing system for attaching to compatible spacecraft, and manipulators that provide berthing to uncooperative or tumbling satellites and debris.

It is equipped with a high performance propulsion system for performing large delta-V maneuvers and a clean-firing cold gas propulsion system for satellite and SOC close proximity operations. An on-orbit refueling capability is also provided. The VSS is also equipped with TV systems for satellite examination.

4.2.2.5 VSS & MOTV Plane Change Capability

Figure 4.2-12 is a nomograph which shows the payload capability of the MOTV core stage, and the Versatile Service Stage (VSS) in terms of its ΔV capability to perform a given plane change from SOC and then return to SOC. Two cases are illustrated; one where the payload out and back are equal (i.e., round trip), and the other where the stage goes out alone to retrieve a satellite and then return with it to SOC. If an MOTV crew capsule, plus general purpose mission equipment and one MMS module weighing around 8000 kg were brought round trip to a service site away from SOC, then that site may not be more than 18 degrees from SOC. If SOC is nominally at 28.5 degrees, then the MOTV core stage can perform plane change transfer to inclinations up to 46.5 degrees and still return to SOC with its payload.

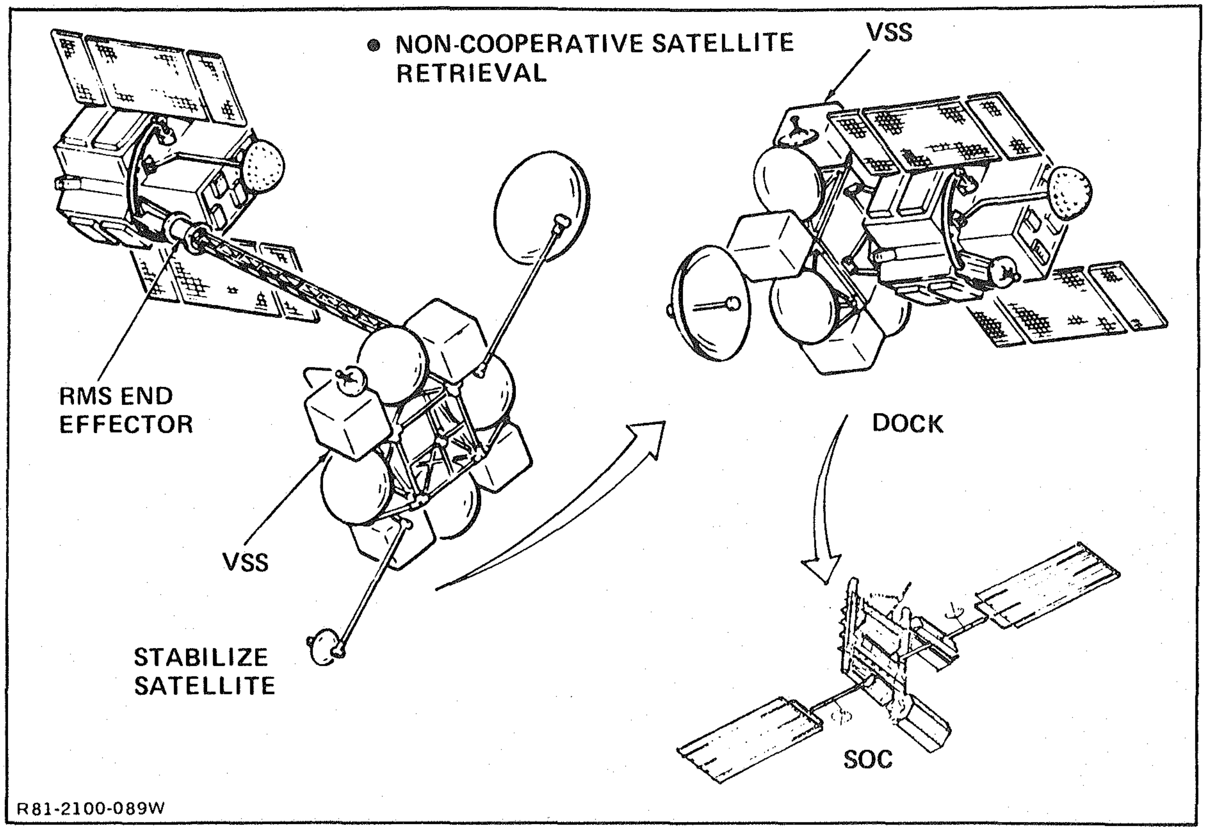

Fig. 4.2-11 Versatile Service Stage (VSS)

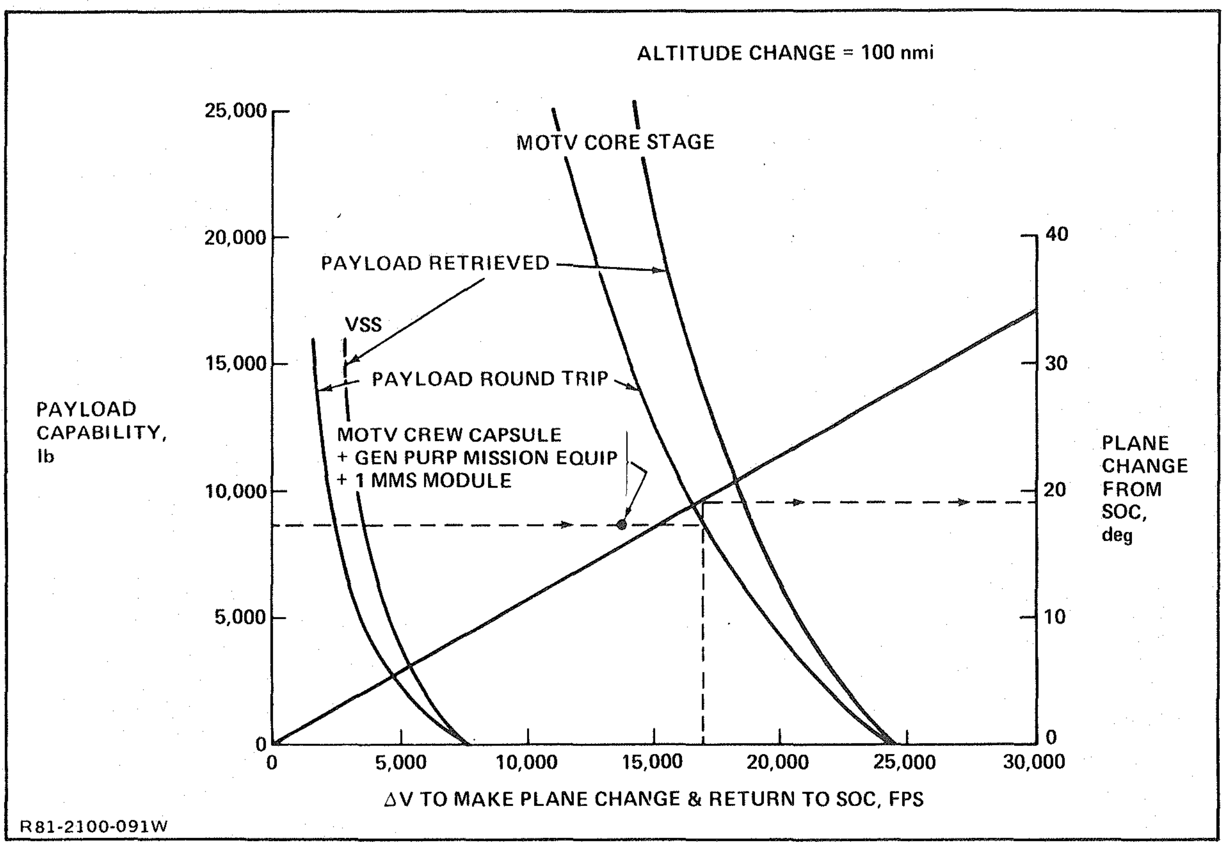

Fig. 4.2-12 VSS & MOTV Plane Change Capability from SOC with Return

4.2.3 REPRESENTATIVE SATELLITE SERVICE OPERATIONS

Candidate service missions in Figure 4.2-13 imposed the requirements on SOC to provide the service operations listed previously (Reference Table 4.2-1). From the candidate list, two representative satellites, the Advanced X-ray Astrophysics Facility (AXAF) and a GEO Communication Platform, were selected for further analysis.

The AXAF has a planned lifetime of 10 to 15 years. It will be maintained in orbit and returned to earth for major improvements. The following SOC provided service operations are needed: examination of external configuration, retrieval, maintenance, resupply, reconfiguration, mating of propulsion stage, test and checkout, potential on orbit storage, and deployment.

The GEO Communications Platform requires unfolding/assembly and checkout in low earth orbit on SOC. It will be mated to on orbital transfer vehicle propulsion stage (which will normally be based at SOC), then released for subsequent transportation to geosynchronous orbit.

4.2.3.1 Servicing Scenario Assumptions

The servicing scenario assumptions (Figure 4.2-14) were based on those formulated for the Satellite Services Systems Analysis Study. Satellites with propulsion systems will be controlled via their normal operational ground station and rendezvous with SOC. When they are in the vicinity of SOC, control will be turned over to SOC for terminal guidance or for docking and retrieval by POM or manipulator grappling and berthing. Deployment will be done by SOC and when a safe separation distance is achieved, the ground Payload Operations Control Center (POCC) will control subsequent operations.

4.2.3.2 Description of SOC Satellite Service Facility

Operational SOC configuration was used as the baseline configuration for satellite servicing operations (Figure 4.2-15). The tracks

SERVICE MISSIONS	SAT. TEST & C/O — SERVICING	MATE STAGE	ORBIT ASSY
• TEND ATTACHED PAYLOAD			
– NATIONAL MATERIAL LABORATORY PAYLOADS	√		
• TEND CO-ORBITING SATELLITES			
– ADVANCED X-RAY ASTORPHYSICS FACILITY (AXAF)	√	√	
• LAUNCH CO-ORBITING SATELLITES			
– SCIENCE & APPLICATIONS SPACE PLATFORM PAYLOADS (SASP)			√
• LAUNCH LOW ENERGY ORBIT SATELLITES			
– GAMMA RAY OBSERVATORY (GRO)			
• LAUNCH HIGH ENERGY ORBIT SATELLITES			
– COMMUNICATIONS PLATFORM		√	√
– PLANETARY PROBE		√	√

REPRESENTATIVE SATELLITES

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Fig. 4.2-13 Candidate Service Missions

- GO-NO-GO FOR DEPLOYMENT, SERVICING VERIFICATION/ EFFECTIVENESS IS SAT USER DECISION
- SAT DEPLOYMENT VIA SOC COMMAND
- SAT SEPARATION ΔV DURING DEPLOYMENT IMPARTED BY SOC EQUIPMENT WHERE PRACTICAL
- SOC SAFETY CONSIDERATIONS
  - – SAT HOT RCS FIRINGS.................. > 200 FT SEPARATION
  - – LIQUID ROCKET ENGINE FIRINGS....... > 2700 FT SEPARATION
  - – SOLID ROCKET ENGINE FIRINGS .... ADEQUATE SEPARATION REQUIRED TO ASSURE SOC EXIT OF HAZARD ENVELOPE
- CLOSE PROXIMITY OPERATIONS
  - – TERMINAL ACQUISITION OF S/C WILL BE CONTROLLED BY SOC
  - – "CLEAN" VEHICLE PROVIDES CLOSURE ΔV
- STATUS MONITORING, CHECKOUT, ACTIVATION/DEACTIVATION OF SATS IS USER-CONTROLLED (SAT COMM VIA SOC S-BAND OR SAT'S SYSTEM VIA TDRS)
- MINIMIZE SOC STATUS/CHECKOUT INVOLVEMENT
  - – POWER (AS REQUIRED)
  - – OVERALL HEALTH (EXTENT TBD, STANDARDIZED FOR ALL SATELLITES)
- EVA IS ACCEPTABLE SERVICE MODE

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Fig. 4.2-14 Assumptions — Servicing Scenarios

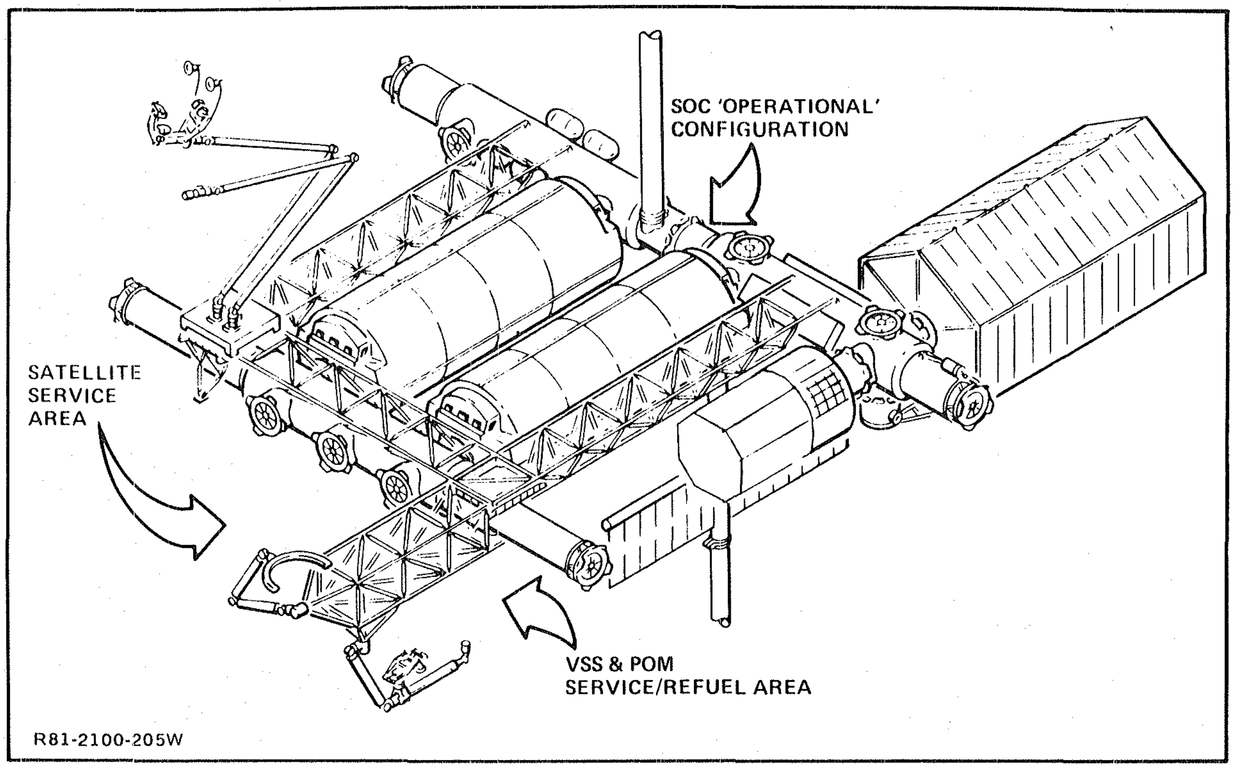

Fig. 4.2.15 Operational SOC with Satellite Servicing Facilities

running around three sides of the two habitat modules are part of the basic configuration, as is the service modules with docking ports.

For satellite servicing operations, a 7.5-m extension pier is added to one arm of the SOC track system in the direction outboard of the docking module (Figure 4.2-16). A Handling and Positioning Aid (HPA) is mounted on a truss structure at the tip of the pier. An end effector, suitable for the particular mission, attaches to the HPA tip. An OCP to hold an EVA crewman can be mounted on a track running along the HPA arm for a two-man satellite service operation. A mobile platform runs around the existing track system, as well as along the extension pier, to locate a twin manipulator system where required for the particular service mission. These manipulators are based on the RMS and one of them mounts on Open Cherry Picker (OCP) at its tip, while the other mounts a standard mount snare end effector. The EVA crewman on the OCP controls both manipulator arms and the HPA, each in selective sequence. These facilities can also be controlled from a station in the SOC habitation module.

Unless self-propelled, free-flying satellites must be brought to SOC by a propulsion stage. It is necessary to service and refuel these propulsion stages. OTV/MOTV have their own service hangar but smaller propulsion stages, such as Versatile Service Stage (VSS) and Proximity Operations Module (POM), require another facility which is located on the "underside" of the extension pier, as illustrated. A second HPA is mounted on a truss structure to handle VSS and POM. An OCP mounts to a track on the HPA arm and holds an EVA crewman who controls the HPA and thus, the servicing and refueling operations.

4.2.3.3 AXAF Servicing by SOC

The AXAF normally operates at 450 km altitude at 28.5 degrees inclination. The scenario illustrated in Figure 4.2-17 shows its retrieval by a Versatile Service Stage (VSS), which originates from SOC, rendezvous with AXAF and brings it to SOC for scheduled on-orbit

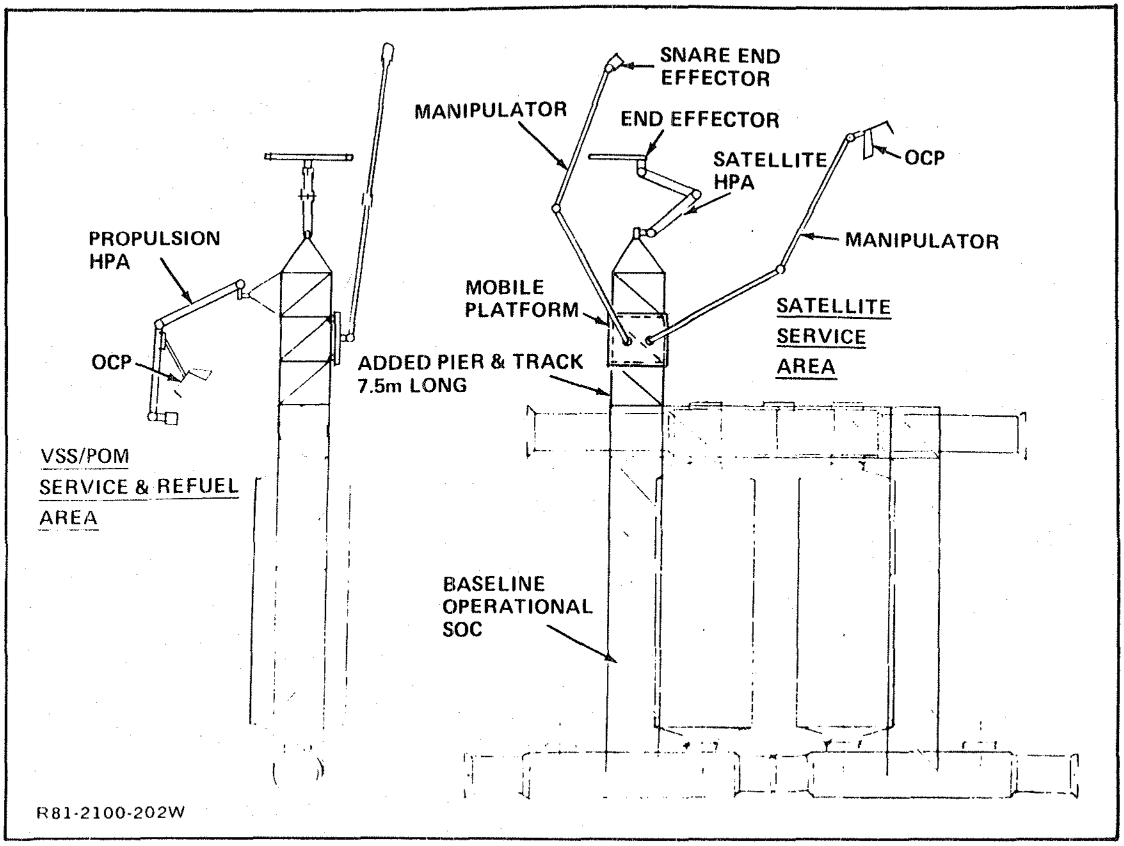

Fig. 4.2-16 SOC Modified for Satellite Servicing

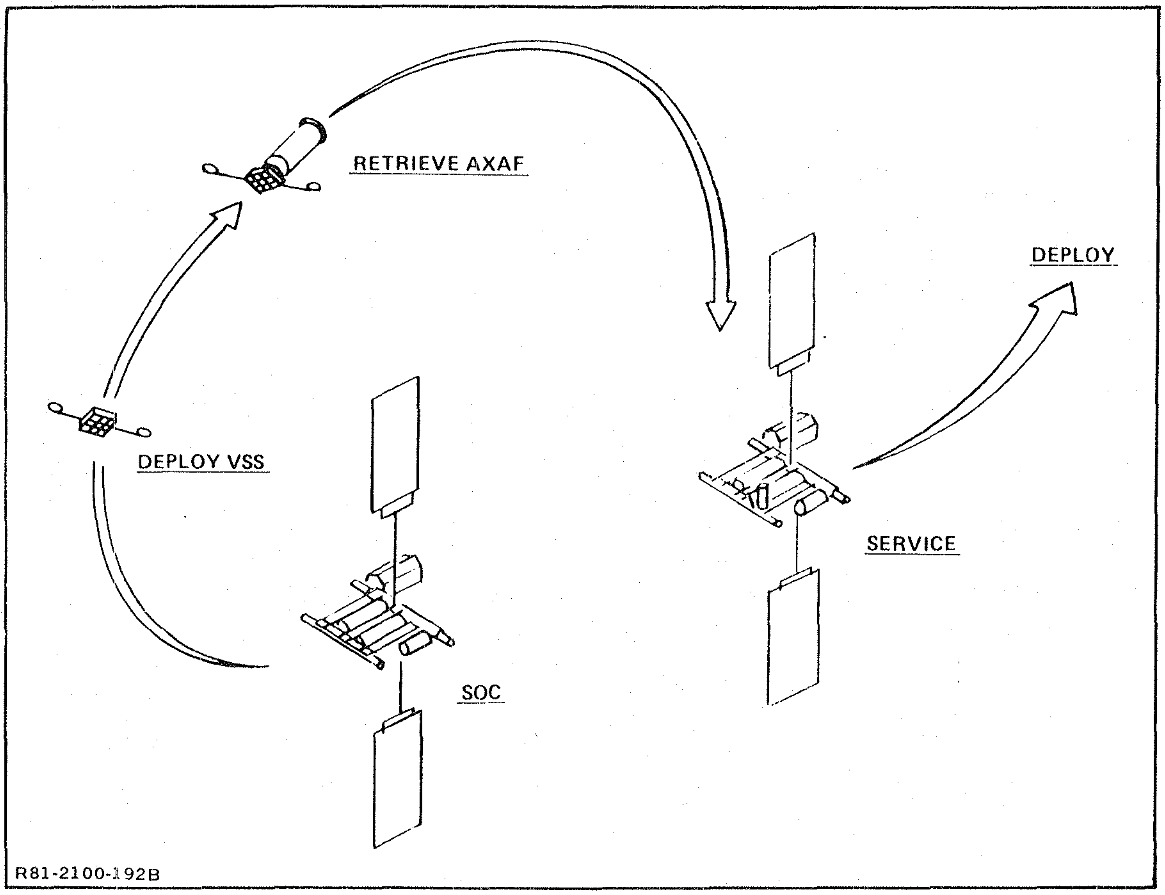

Fig. 4.2-17 AXAF Service Mission Scenario

service. After service and check out, the VSS returns the AXAF satellite to its operational orbit.

The operational SOC configuration is shown in Figure 4.2-18. The AXAF is berthed to an HPA and is being maintained by astronauts on OCPs. The HPA can position the AXAF as shown, or alternatively swing it 90 degrees so that it is parallel with the SOC service modules, depending on accessibility requirements. AXAF subsystems are being serviced by a manipulator-mounted OCP while the instruments are serviced at the same time from an OCP mounted on an HPA extension boom. An MTV is shown inspecting the far side of the AXAF, by transmitting TV to SOC. The VSS is also berthed to an HPA and components are being replaced by EVA OCP operations. In the background a POM has grappled a satellite and its transporting it to SOC for subsequent service operations. Note that the HPAs are mounted on a servicing pier and two logistic pallets with satellite replacement equipment conveniently positioned to support the servicing operations.

4.2.3.3.1 <u>AXAF Service Mission Timeline</u> - SOC operations associated with servicing the AXAF are shown in Figure 4.2-19. Replacement parts and consumables are delivered to SOC by Orbiter logistic flights. These flights would occur on a regularly scheduled basis, meeting anticipated demands for satellite servicing operations and, therefore, would not impact plans for maintenance on any particular satellite.

The VSS is checked out, then sent to fetch the AXAF under control of the VSS POCC and bring it to SOC for maintenance. Twenty-four hour rendezvous time has been allowed each way since phasing could take considerable time. Three EVAs were judged sufficient to replace malfunctioning equipment. After the AXAF has been buttoned up, three and one-half hours are allocated for remote check out from the SOC operations room in conjunction with the AXAF POCC. Then the AXAF is mated to a VSS for subsequent redeployment. Time for redeployment is approximately one-quarter of that for retrieval because phasing is not a factor. The time for nominal AXAF maintenance support operations is six and one-half days. This could easily be extended if problems

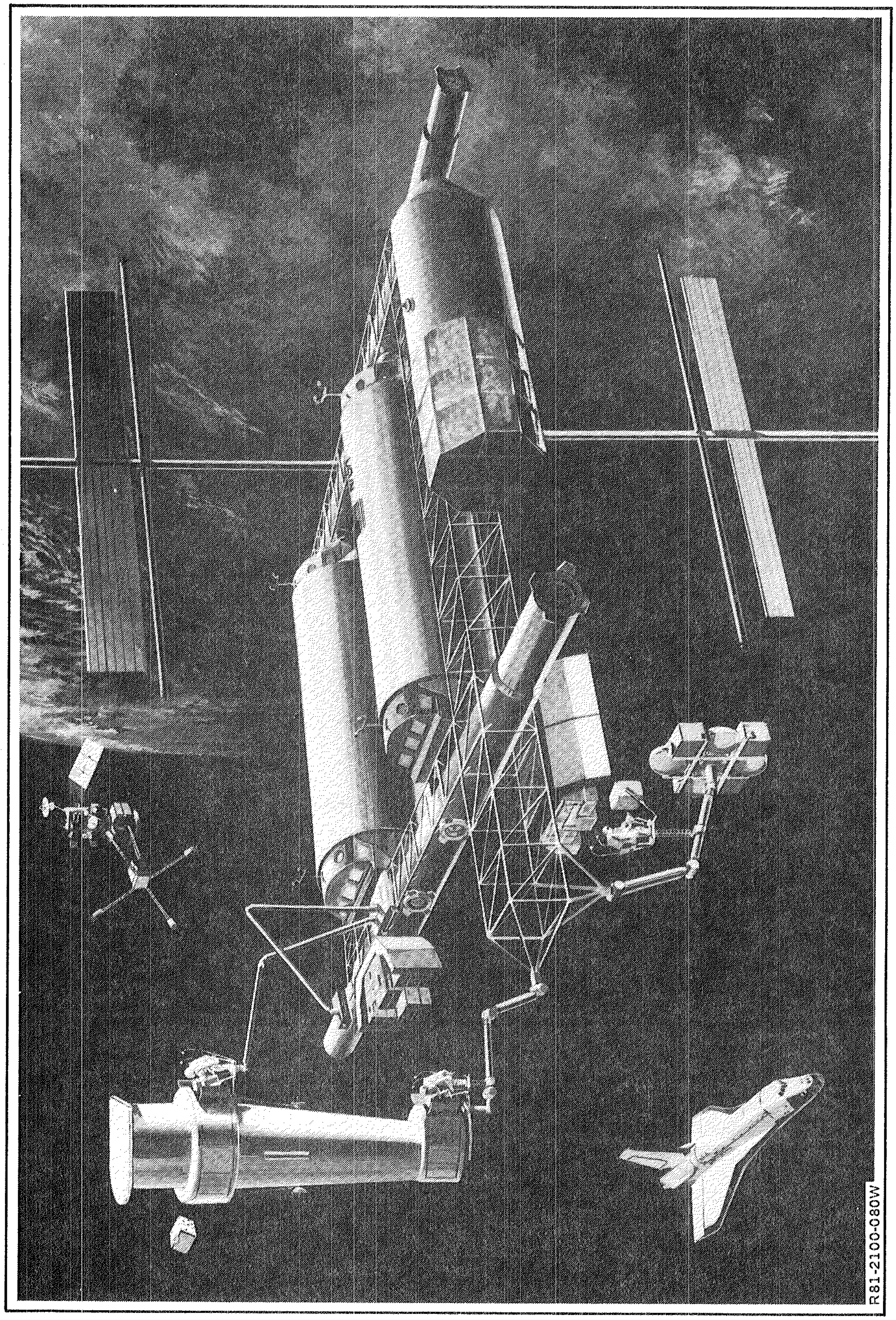

Fig. 4.2-18 Servicing Operations at SOC

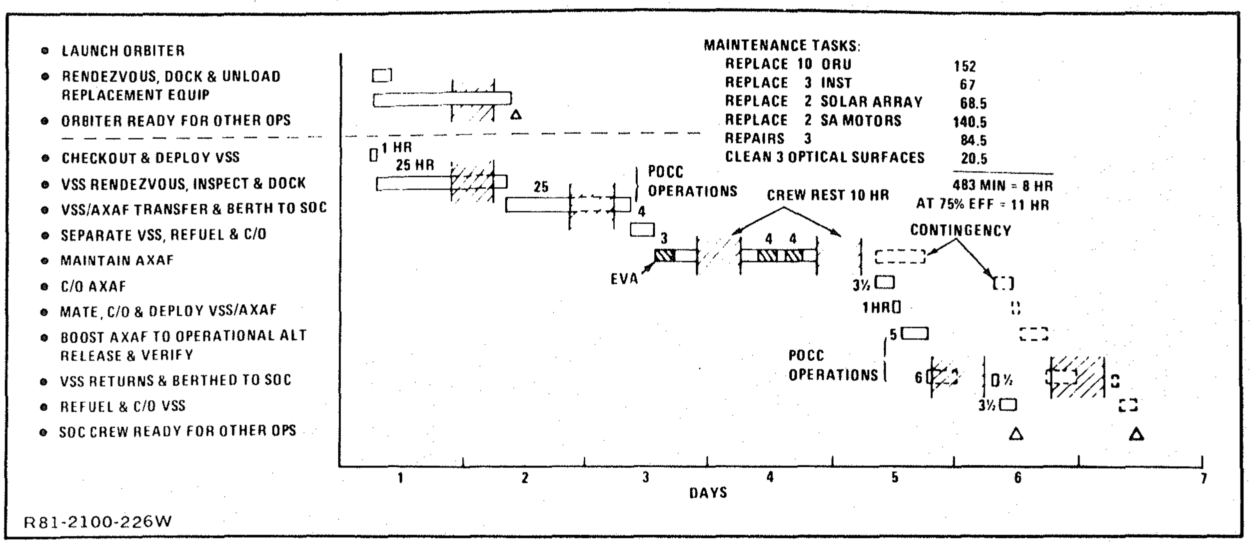

Fig. 4.2-19 Timeline – AXAF Servicing from SOC

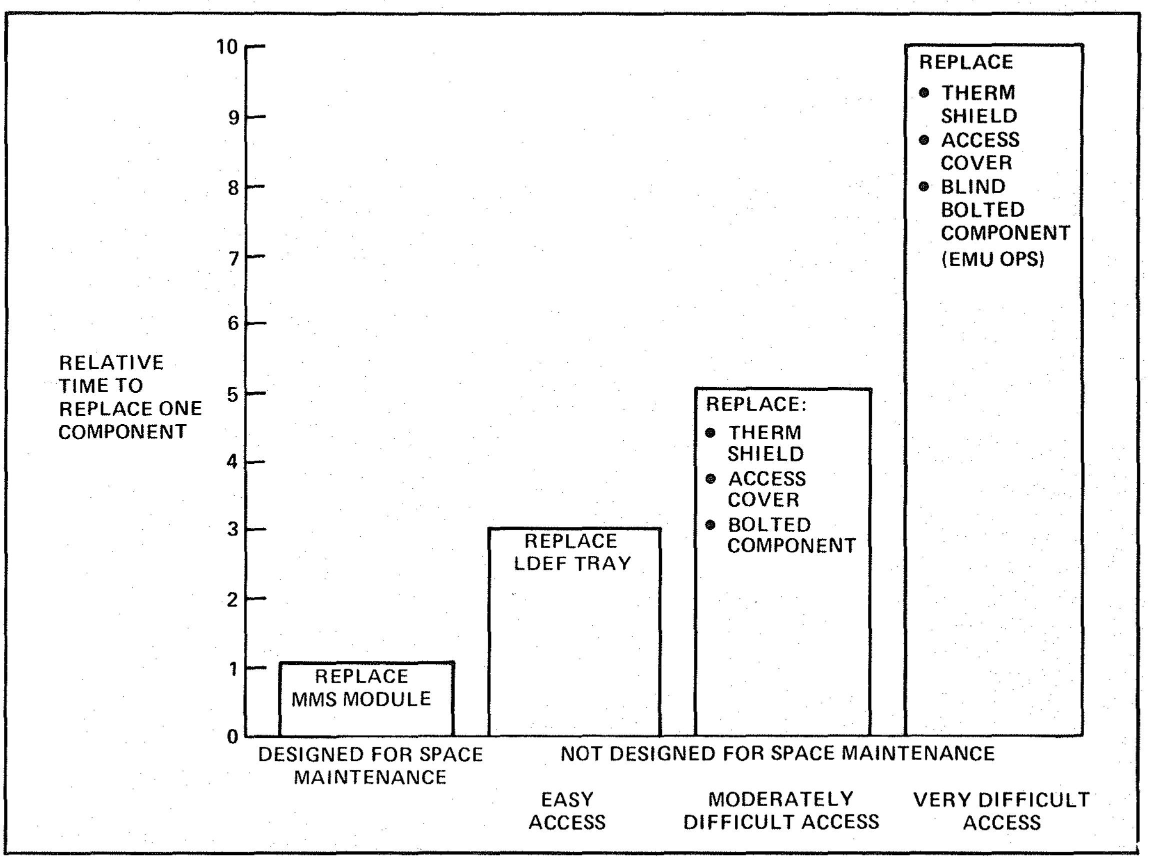

Fig. 4.2-20 Time to Replace Component vs Task Difficulty

developed during servicing. A contingency time of one day has been allocated.

Contingency time allowance adequate for satellites designed for space repair may be inadequate for satellites not designed for in-flight maintenance. Figure 4.2-20 shows the likely increase in time required to change-out a component in an spacecraft not designed for maintenance. Ground simulation tests with a suited astronaut established the time to change one MMS module (Reference 4.2-8). Time to remove an LDEF tray was similarly estimated from ground tests. Although the LDEF trays were not designed for in-flight maintenance, the bolts are accessible for removal. The next task time that was evaluated consists of replaceing a component which is behind a ground service access panel. The task here is to cut away a thermal shield, then remove the panel bolts to provide access to the malfunctioning component. This component is attached with four accessible bolts and has one electrical connector to be removed. The time to replace this component, including taping the thermal shield in place, is five times that required to replace an MMS module. The most difficult task shown in the figure repeats the work just described but two of the four bolts are in a blind location to the suited astronaut. While this task would be easy for ground operations (the EMU helmet limits access and visibility) it would be very difficult for space suit operations even with ground simulation training. The astronaut would have to rely on feel to remove and re-install two bolts. Consequently, this task is estimated to take 10 times as long as the MMS module replacement.

4.2.3.3.2 AXAF Service Operations - The operations for servicing an AXAF at SOC starts with delivery of supplies by an Orbiter. These supplies are mounted on pallets which are transferred from a docked Orbiter, as shown in Figure 4.2-21. These operations are performed by a mobile platform manipulator which berths the supplies pallet to a berthing port on the SOC docking module. The pallets for servicing and refueling the VSS and the POM are transferred to mountings on the extension pier. Both operations are controlled by an EVA crewman on the OCP.

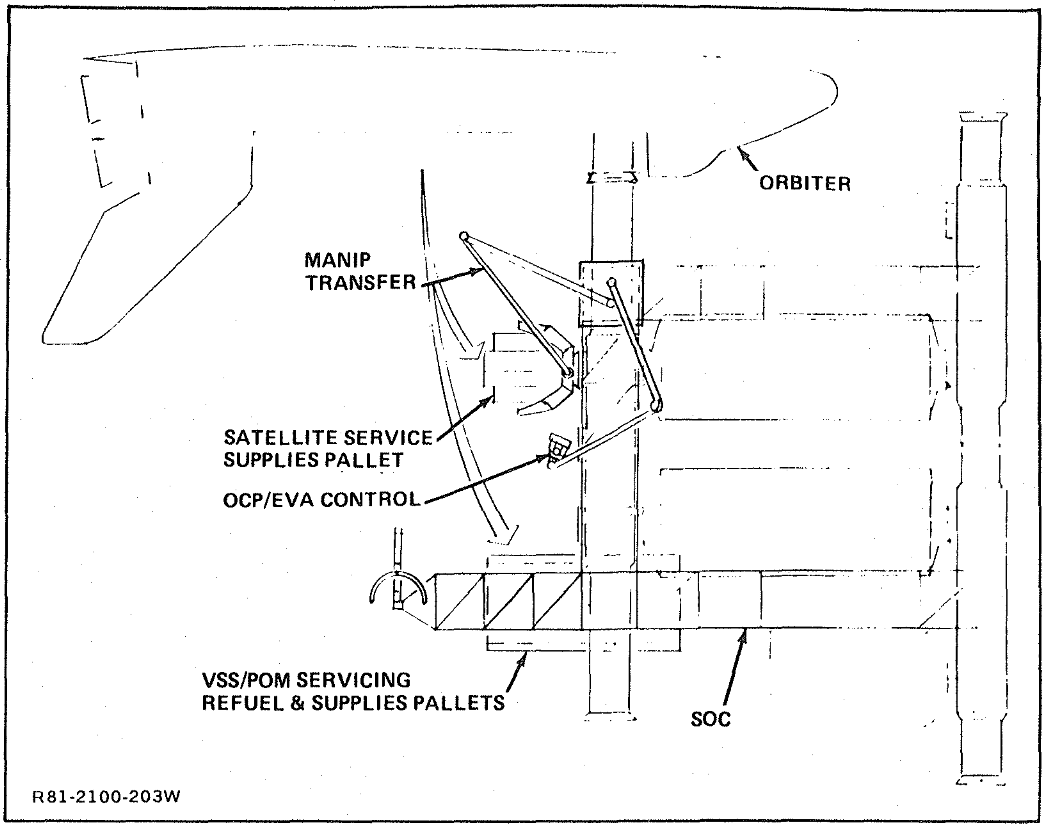

Fig. 4.2-21 AXAF Service Mission – Transfer of Supplies

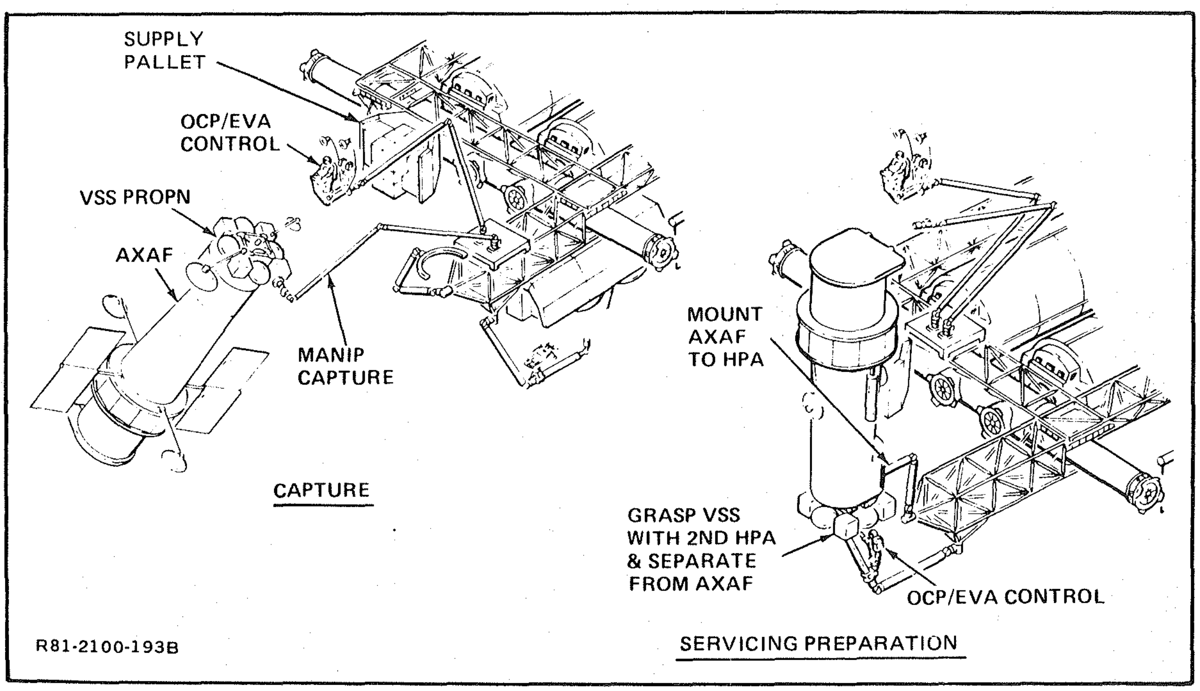

Fig. 4.2-22 AXAF Satellite Service – Satellite Capture & Preparation for Service

The AXAF is a free flyer with no transfer propulsion of its own. A small SOC based propulsion stage, in this case a VSS, is sent to dock to the AXAF and bring it to SOC. The mobile platform is moved along the tracks to the tip of the extension pier. Then, controlled by the OCP/EVA crewman, the platform manipulator is maneuvered to capture the VSS/AXAF (Figure 4.2-22 and 23). The manipulator then transfers the VSS/AXAF to berth it to the end effector on the satellite service HPA. For this mission, the end effector has a yoke which holds the base of the AXAF. The propulsion service HPA is then moved to grasp the VSS with its end effector (Figure 4.2-24). This operation is controlled by an EVA crewman operating the OCP mounted to that HPA. The AXAF and VSS are now separated at their docking interface. The VSS is transferred, on its HPA mount, to the propulsion service area. There it is serviced by the EVA crewman operating the OCP which has module handling arms. After servicing, the HPA transfers VSS to the refueling pallet where it mates to the fuel transfer umbilical (Figure 4.2-25).

While VSS servicing and refueling is proceeding the AXAF can be serviced in its capture attitude, or rotated by the satellite service HPA to the "horizontal" position for servicing. Figures 4.2-26 and 27 show the operations. The mobile platform has been moved along the SOC track from its satellite capture location at the tip of the extension pier to the location shown here. Considering a one man AXAF service operation, the EVA crewman locates his OCP so that he can service the subsystems area of the satellite. He also controls the second manipulator to fetch and carry change-out modules from the services pallet. Having serviced the subsystems, the mobile platform is relocated so that the crewman can service the scientific instrument area in a similar manner. This last operation is not shown in either figure. Instead, a second crewman is shown as an alternate for servicing the instrument area from an OCP mounted to the HPA arm, much as the propulsion stage servicing is performed.

After servicing, the AXAF and VSS, are remated and prepared for final checkout. In this operation, the VSS is located as shown in

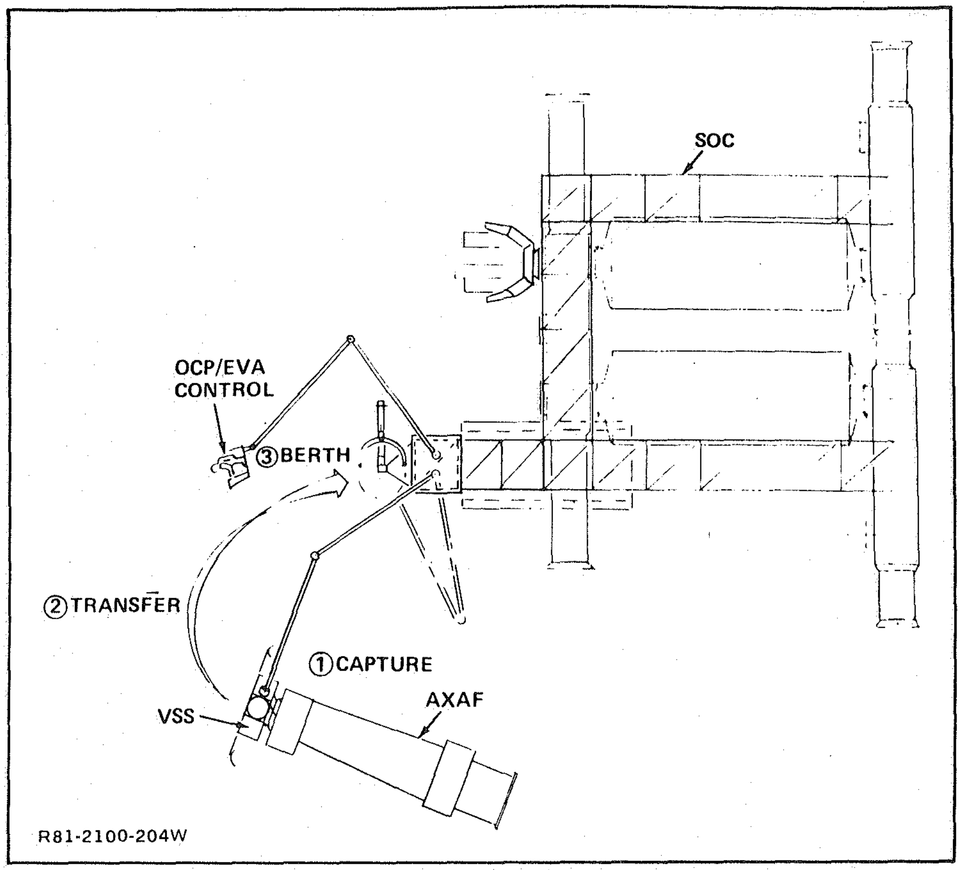

Fig. 4.2-23 AXAF Service Mission – Satellite Capture

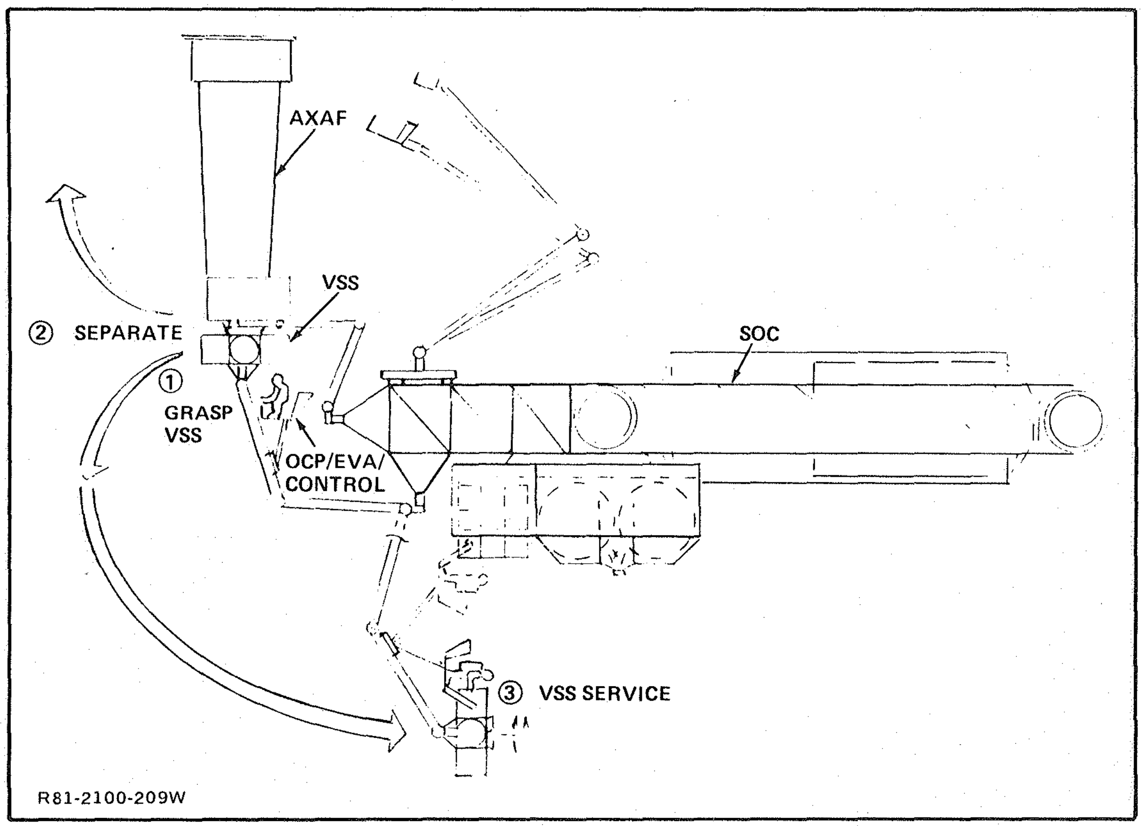

Fig. 4.2-24 AXAF Service Mission – Satellite Handling & VSS Service

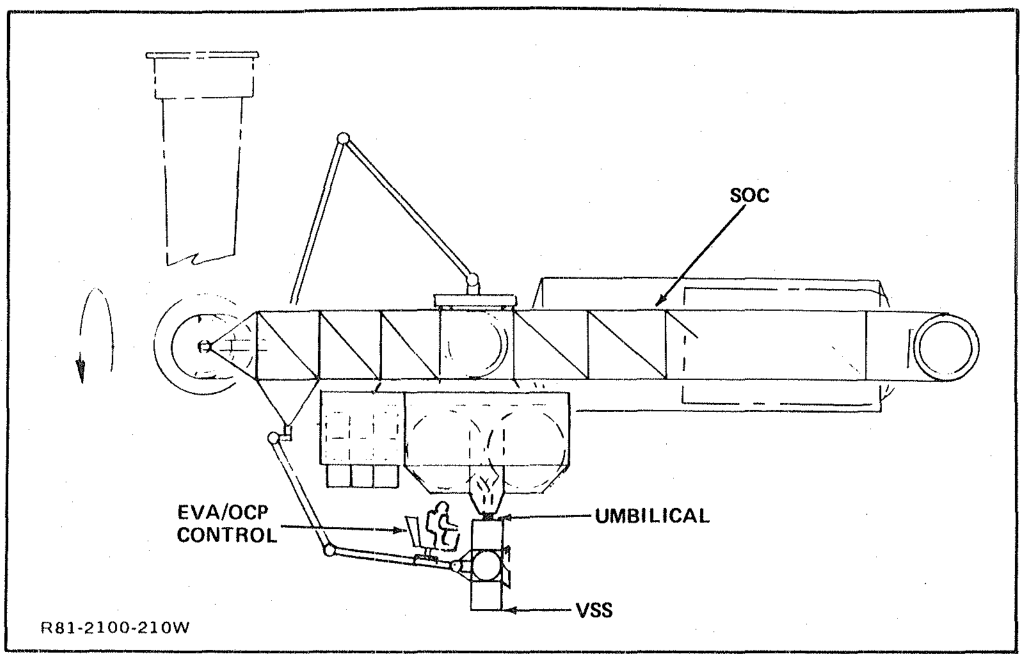

Fig. 4.2-25 AXAF Service Mission – VSS Refueling

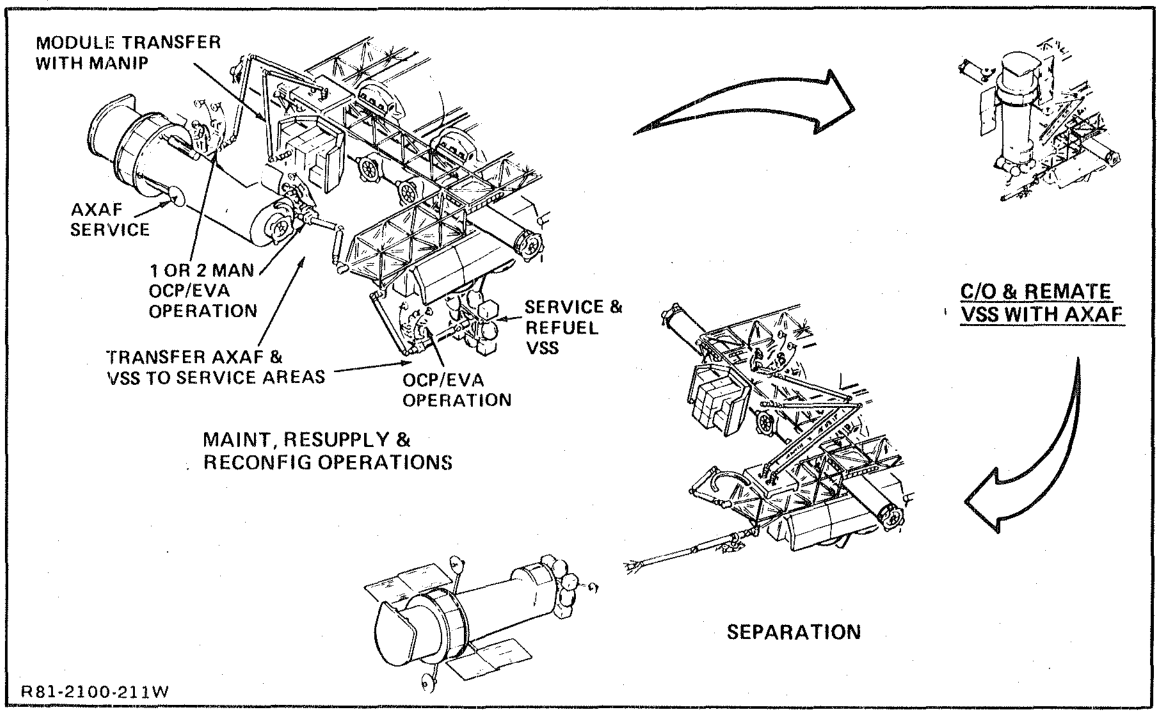

Fig. 4.2-26 AXAF Satellite Service, Checkout & Separation

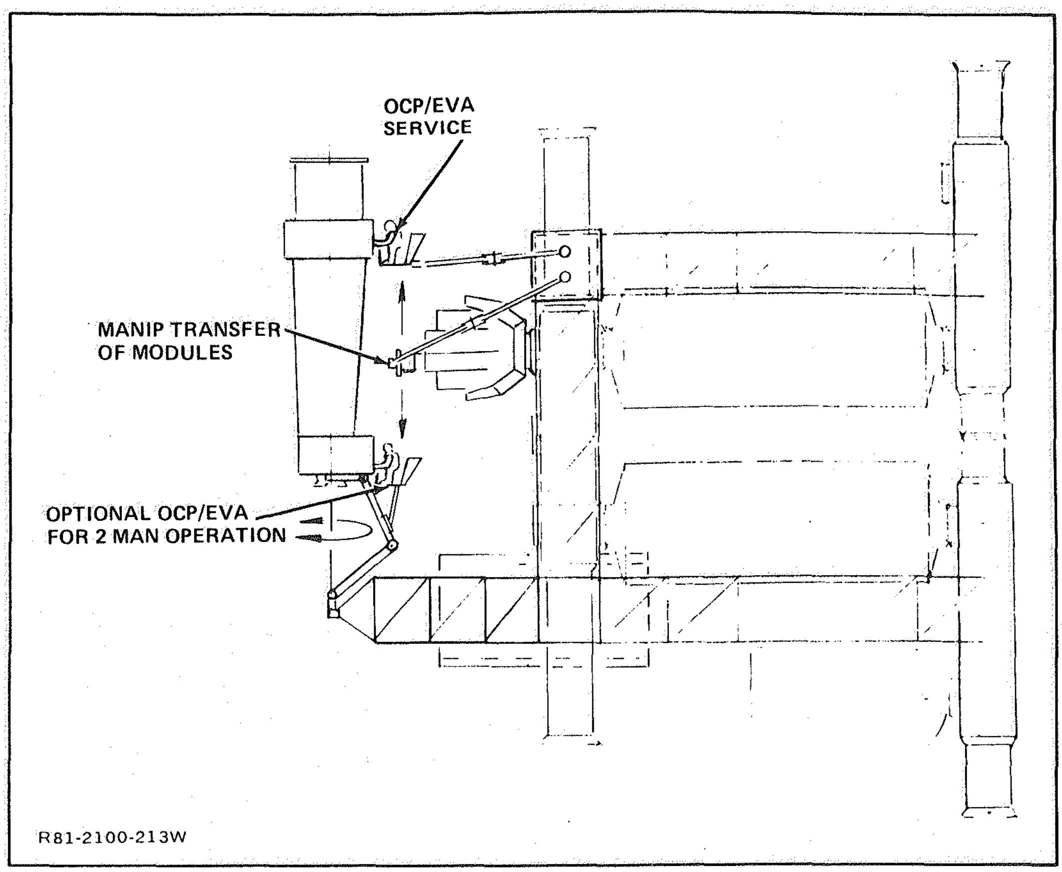

Fig. 4.2-27 AXAF Service Mission – AXAF Service

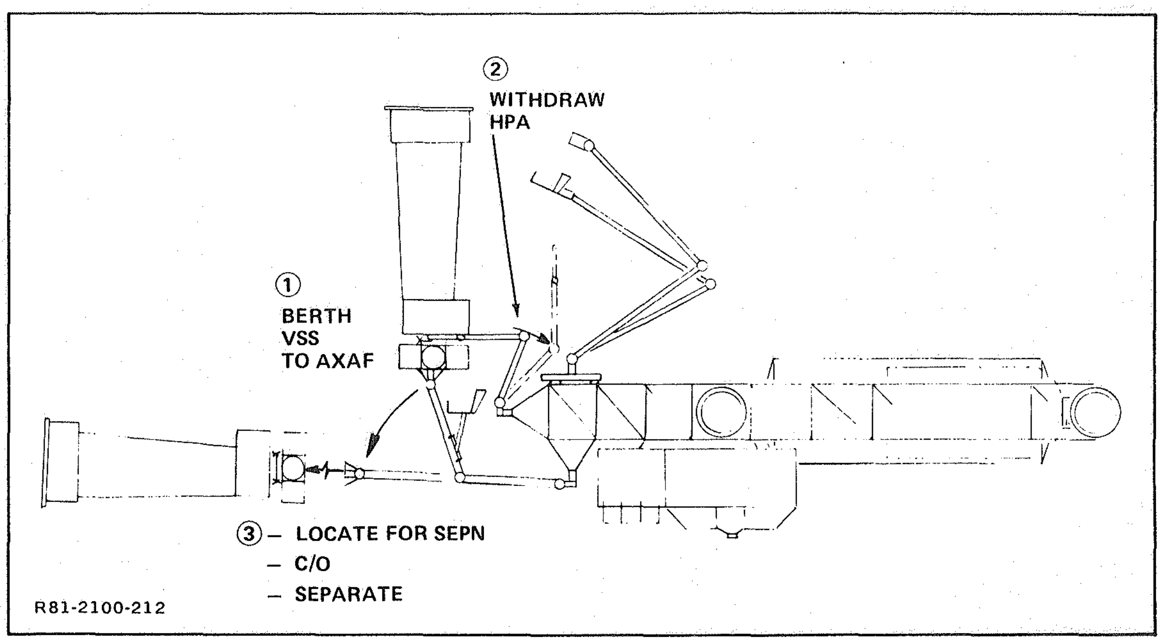

Fig. 4.2-28 AXAF Service Mission – Satellite Preparation & Deployment

step 1 of Figure 4.2-28. The AXAF is then berthed to VSS by its HPA, controlled from the Mobile Platform OCP. This HPA is now withdrawn, leaving the mated VSS/AXAF mounted on the other HPA which now locates the satellite for separation. Final checkout is performed, then separated from SOC as illustrated in Figure 4.2-28.

4.2.3.3.3 AXAF Maintenance Operations Assumptions - Maintenance of the AXAF (see Table 4.2-4 for maintenance assumptions) is planned to be accomplished by crew EVAs to replace subsystem and instrument components. With adequate crew restraint, good suit mobility, and simple EVA compatible equipment interfaces, time to complete space operations are comparable with simulated ground operations. Our simulation experience utilizing the Open Cherry Picker (OCP) found that pressure suit operations took 60% longer than unsuited work.

The single shift crew work days in 11 hours. This is the time remaining after allowance has been made for 10 hours rest and 3 hours for meals.

EVA assumptions are:

- No prebreathing required
- Two EVA/day of 4 hours each
- RMS operator serves as EVA monitor
- Single person EVA permissible.

The OCP is currently under development at Grumman. Its initial configuration, the manned foot restraint, is being considered for the Solar Maximum Mission retrieval and repair in 1983.

Equipment to be replaced will be determined prior to maintenance operations by down link data to the POCC.

It is postulated that orbital replacement and units (subsystem electronic boxes and components) will be mounted in racks that are attached to a logistic pallet (standard Spacelab pallet). An effective way of transferring this equipment is to move the entire rack to

TABLE 4.2-4 AXAF MAINTENANCE ASSUMPTIONS

- MAINTENANCE ACCOMPLISHED BY EVA UTILIZING OCP
- REPLACEMENT ORUs & INSTRUMENTS MOUNTED ON RACKS/MODULES FOR HANDLING AT SOC
- SECOND RMS AVAILABLE TO TRANSPORT EQUIPMENT
- INSTRUMENT FLUID REPLENISHMENT ACCOMPLISHED BY REPLACEMENT OF TANK OR INSTRUMENT
- ORUs DESIGNED WITH ONE OR TWO LATCHES FOR MECHANICAL ATTACHMENT. ELECTRICAL CONNECTION MATES/DEMATES AUTOMATICALLY WITH MECHANICAL OPERATION
- SOLAR ARRAYS & ANTENNAS DESIGNED FOR ON-ORBIT REPLACEMENT
- ACCESS PROVIDED FOR REPLACEMENT OF DRIVE MOTORS
- NO EVA PREBREATHING REQUIRED

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the AXAF within reach of the astronaut to exchange failed units. Transportation of the rack could be accomplished by the OCP payload handling device or the second RMS. Instruments could be handled in a similar manner to the ORUs. Either inidividual instruments could be changed-out in each segment of the instrument carousel, or each segment module containing its complement of instruments could be exchanged as a unit. When fluids (xenon, propane, carbon dioxide, and argon) require replenishment, the impact on support equipment is reduced by exchanging instrument tanks or the instrument. The alternate is to provide dewars and fluid transfer equipment. Fluid replenishment would be required if there were a leak in the system, and in that event the instrument and/or tank plumbing would probably be replaced anyway.

4.2.3.3.4 Maintenance Operations Functions - Functional analysis of on orbit maintenance operations associated with the following tasks was performed:

- Replace subsystem orbital replacement units (ORU) (Figure 4.2-29)
- Replace instruments (Figure 4.2-30)
- Replace solar array or antenna (Figure 4.2-31)
- Repair damage/replace equipment (Figure 4.2-32)
- Clean optical surface (Figure 4.2-33).

Subfunctions of the operational functions shown in the figure were determined and task times were assigned to each of the subfunctions, then summed, to establish the time listed to perform each maintenance function.

4.2.3.3.5 AXAF Checkout - After the AXAF has been maintained, its operability will be verified. The checkout functions are shown in Figure 4.2-34 with extimated time to perform each function. Time for

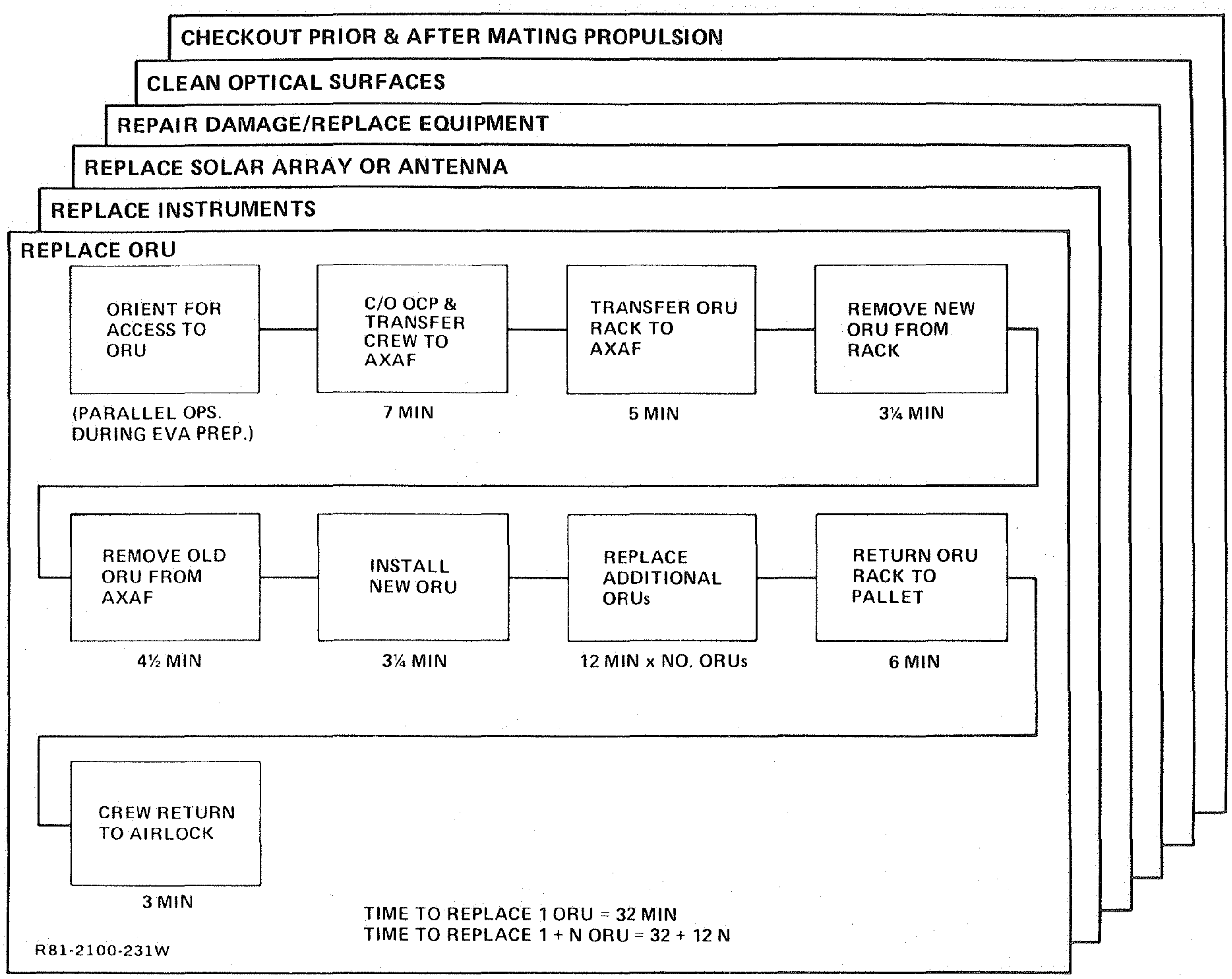


Fig. 4.2-29 AXAF Maintenance — Replace ORU

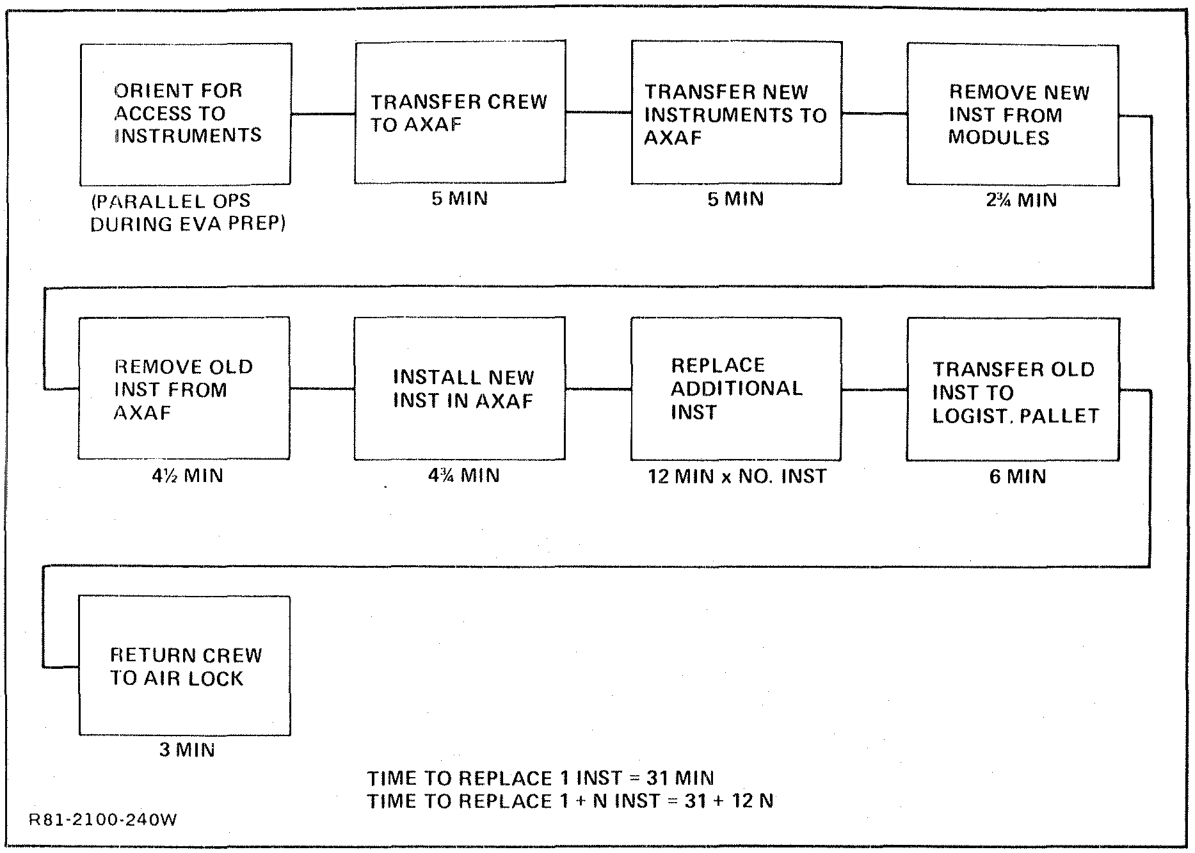


Fig. 4.2-30 AXAF Maintenance – Replace Instruments

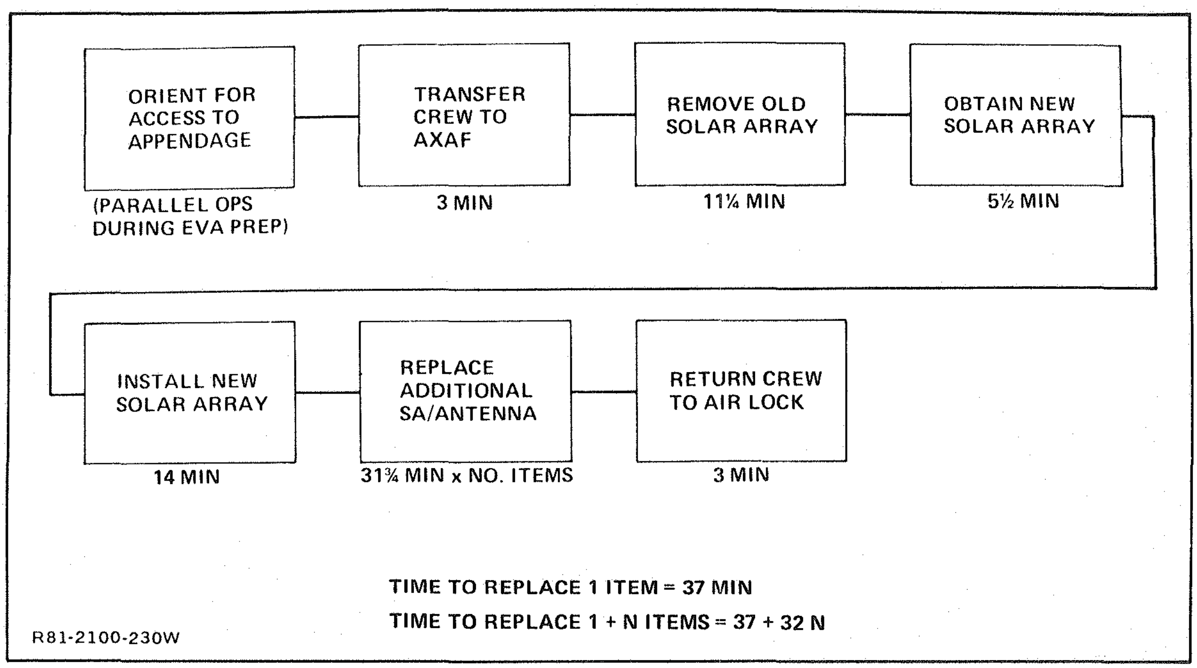


Fig. 4.2-31 AXAF Maintenance — Replace Solar Array or Antenna

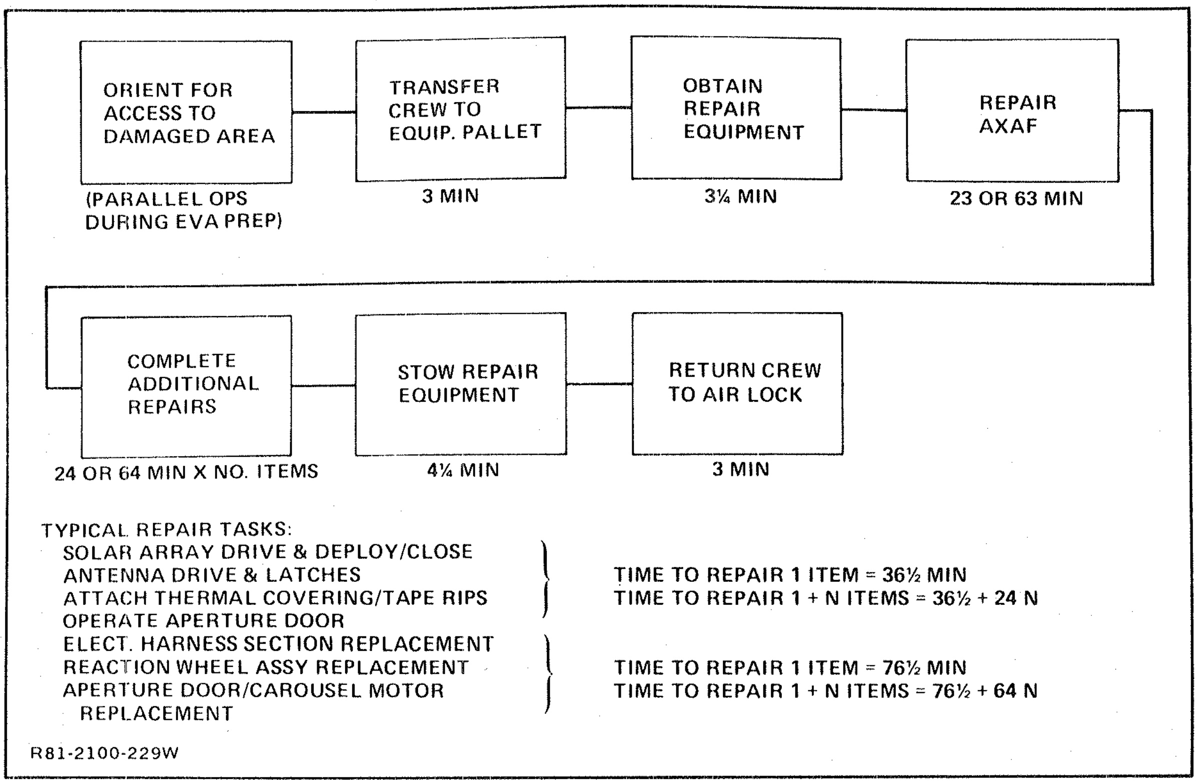


Fig. 4.2-32 AXAF Maintenance – Repair Damage/Replace Equipment

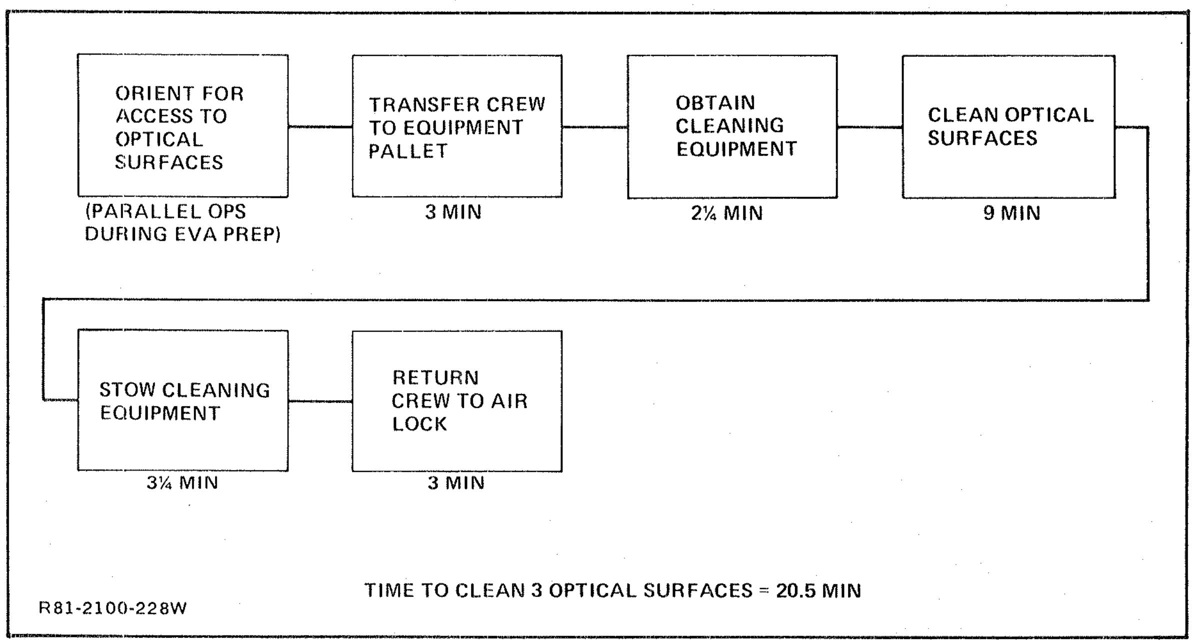


Fig. 4.2-33 AXAF Maintenance – Clean Optical Surfaces

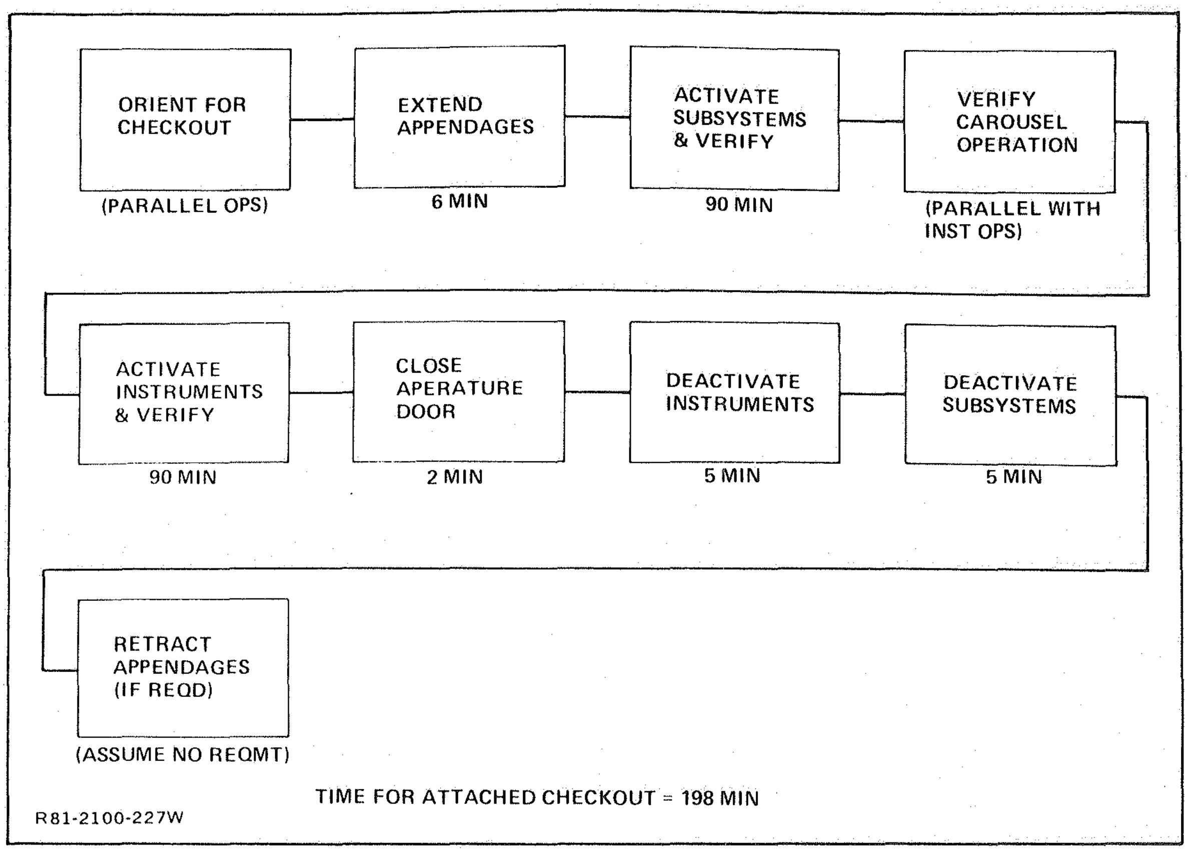


Fig. 4.2-34 AXAF Checkout Prior Mating Propulsion

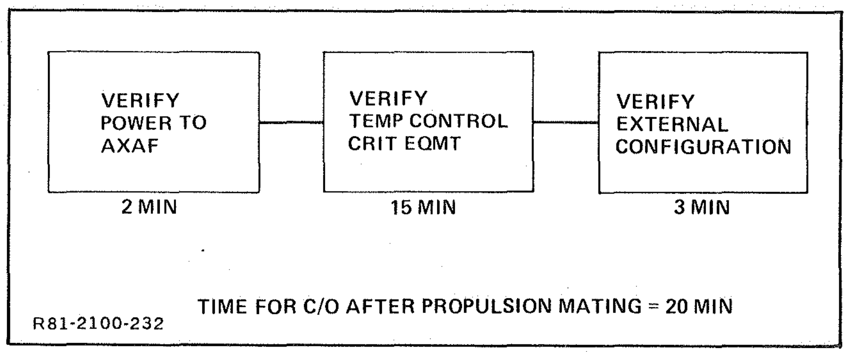


Fig. 4.2-35 AXAF Checkout After Mating Propulsion

subsystem checkout and instruments is estimated at 90 minutes each. At the end of the checkout, the equipment is turned off or put in a standby mode. The solar arrays and TDRS antennas remain deployed.

Next, a propulsion stage, the versatile service stage (VSS), is attached to the AXAF to boost it to operating altitude. Only the interface between the AXAF and VSS requires verification as shown in Figure 4.2-35, and this consists of power/control of communication equipment and monitoring temperature of critical equipment.

4.2.3.4 GEO Communication Platform Launched by SOC

The folded GEO Communicaiton Platform completely fills the Orbiter payload bay and may require a dedicated flight to deliver it to SOC (Reference 4.2-10). It is unloaded from the Orbiter cargo bay and supported by an HPA during unfolding operations, (see Figure 4.2-36). After checkout, an orbital transportation vehicle (OTV) that is based on SOC is mated to the GEO Platform, interfaces verified, and then released for transfer to geostationary orbit.

4.2.3.4.1 GEO Communications Platform Launch Mission Time Line - Figure 4.2-37 shows 27 hours for Orbiter rendezvous with SOC and unloading of the GEO platform. After emptying the cargo bay, the Orbiter is ready for other operations. The Orbiter could be loaded with debris or a satellite that requires earth refurbishment. Next, the platform is unfolded and a calibration MTV launched for determining antenna patterns. The major portion of the 44.5 hours shown in the figure is required to obtain the antenna patterns. The antenna pattern data is obtained during around the clock operations for 40 hours. Two crew members alternate 12 hours on and 12 hours off to control test operations. Only 3 additional hours are required to mate the Platform to the OTV, check interfaces, and deploy it. If the OTV was based on earth, then another orbiter logistics flight would be required.

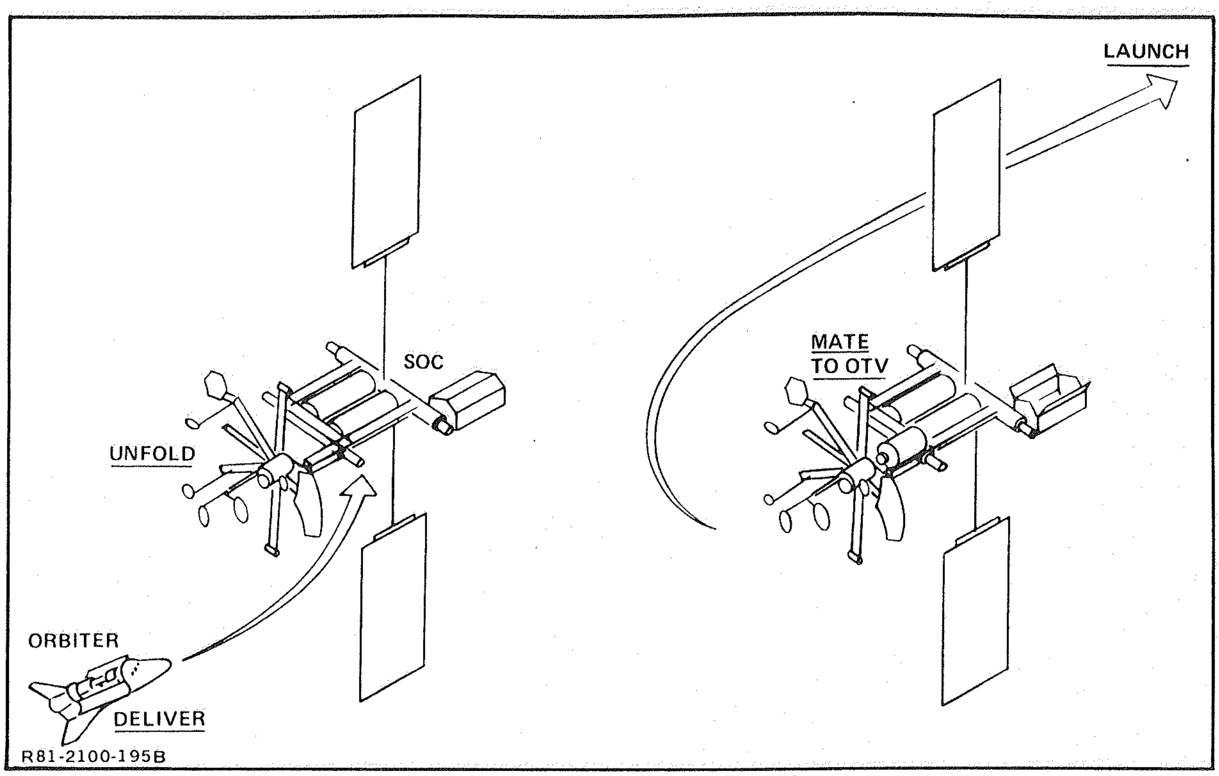


Fig. 4.2-36 GEO Communications Platform Launch Mission Scenario

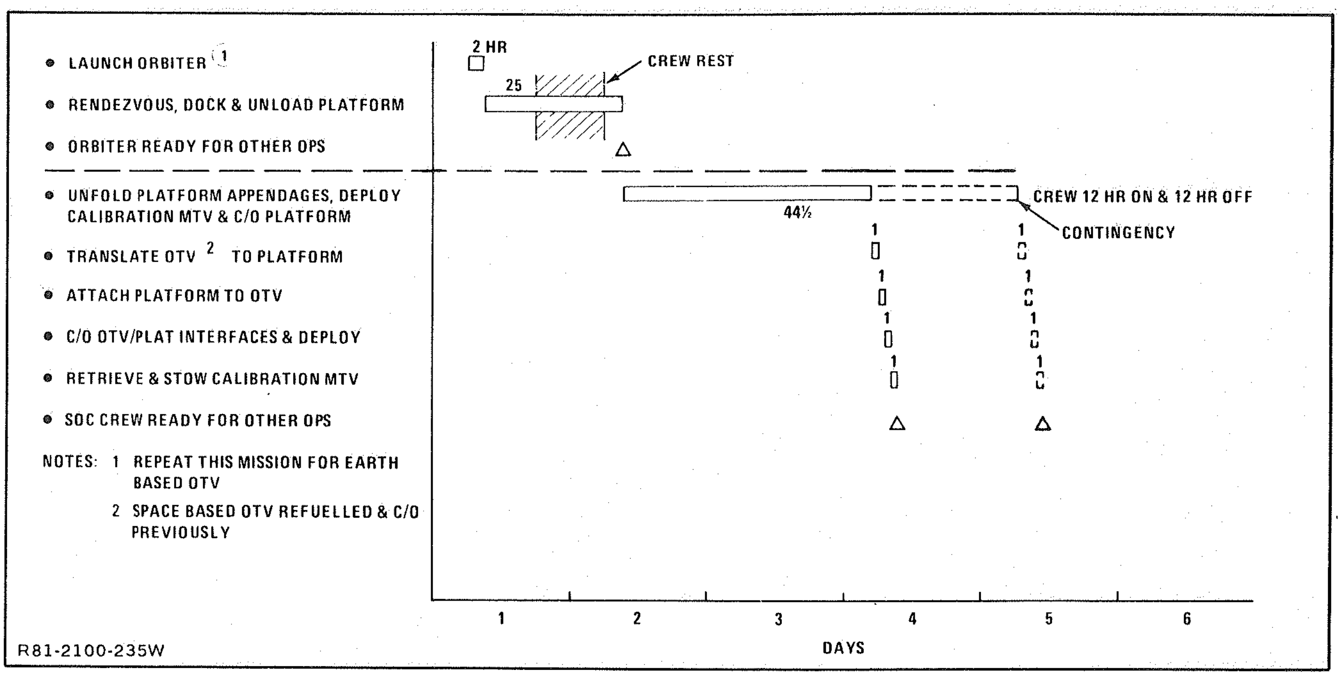


Fig. 4.2-37 Timeline – GEO Communication Platform Deployed from SOC

4.2.3.4.2 GEO Communication Platform Launch Operations - Two assumptions were used during the compilation of launch operations:

(1) The nominal plan for unfolding the platform is to control the operations remotely from the SOC control room. If appendages get hang-up, EVA operations, if warranted, will be used to solve the problem.

(2) The fuel for the SOC based OTV is assumed to be scavenged from Orbiter external tanks during previous delivery flights.

Launch of a communication platform to geosynchronous orbit from SOC starts with delivery of the platform by an Orbiter which docks to SOC (Figure 4.2-38 and 39). The platform, folded for stowage in the Orbiter cargo bay, is transferred by the mobile platform manipulator to be berthed to the satellite servicing HPA on SOC. The HPA then articulates to move the platform to its preferred location for deployment of appendages.

Figure 4.2-40 shows deployment of the appendages which mount antennas, reflectors, experiments, solar arrays and radiators. Most are deployed automatically, others may need assistance by the OCP mounted EVA crewman as shown in Figure 4.2-41. The platform can be rotated on the HPA, as indicated, to bring a radial appendage arm within reach of the OCP.

There maybe a hangup in an automatic deployment sequence. To illustrate the proposed handling of this problem, Figure 4.2-42 assumes that the forward point 10-m antenna receive feed mast is deployed automatically. Should there be a problem with this feed mast requiring direct attention by the EVA crew, the crewman can go out on an MMU, or a tether, to deal with it. A preferred way of reaching the mast is shown in this figure, which is with the HPA extended and tilted to bring the problem area within reach of the OCP and its supportive capabilities. Between the degrees of freedom and reach of the HPA and the capabilities of the mobile platform with its manipulators, any part of this large platform can be reached. This is shown in

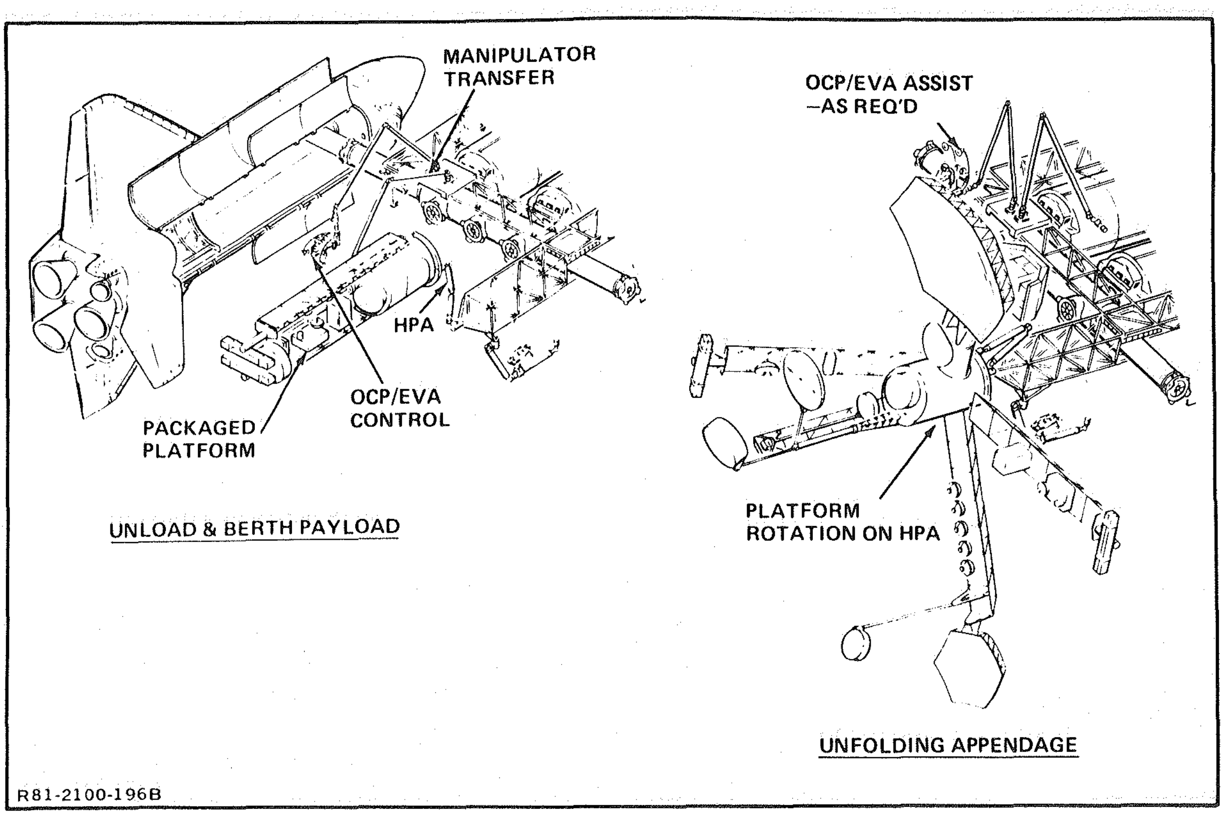


Fig. 4.2-38 GEO Comm Platform Launch – Unload & Unfold Payload

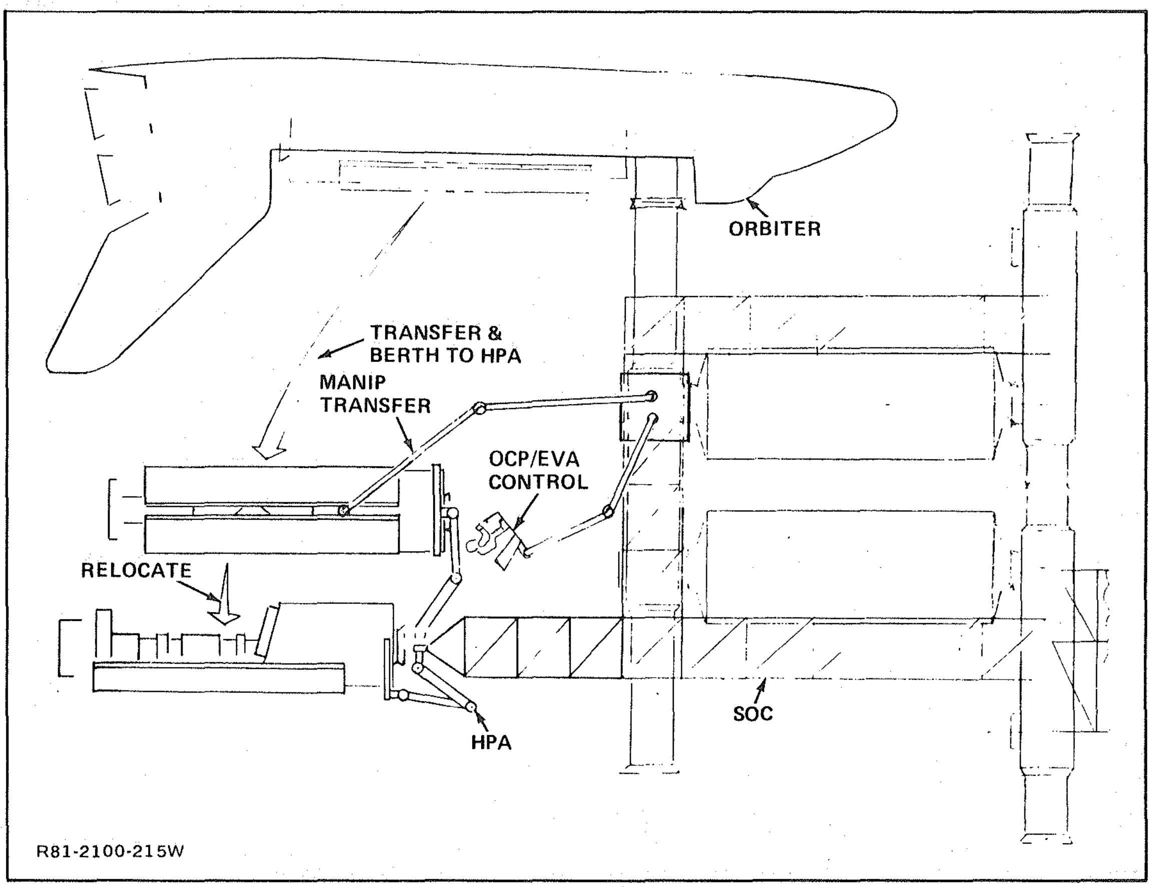


Fig. 4.2-39 GEO Comm Platform Initial Launch – Transfer to SOC From Orbiter

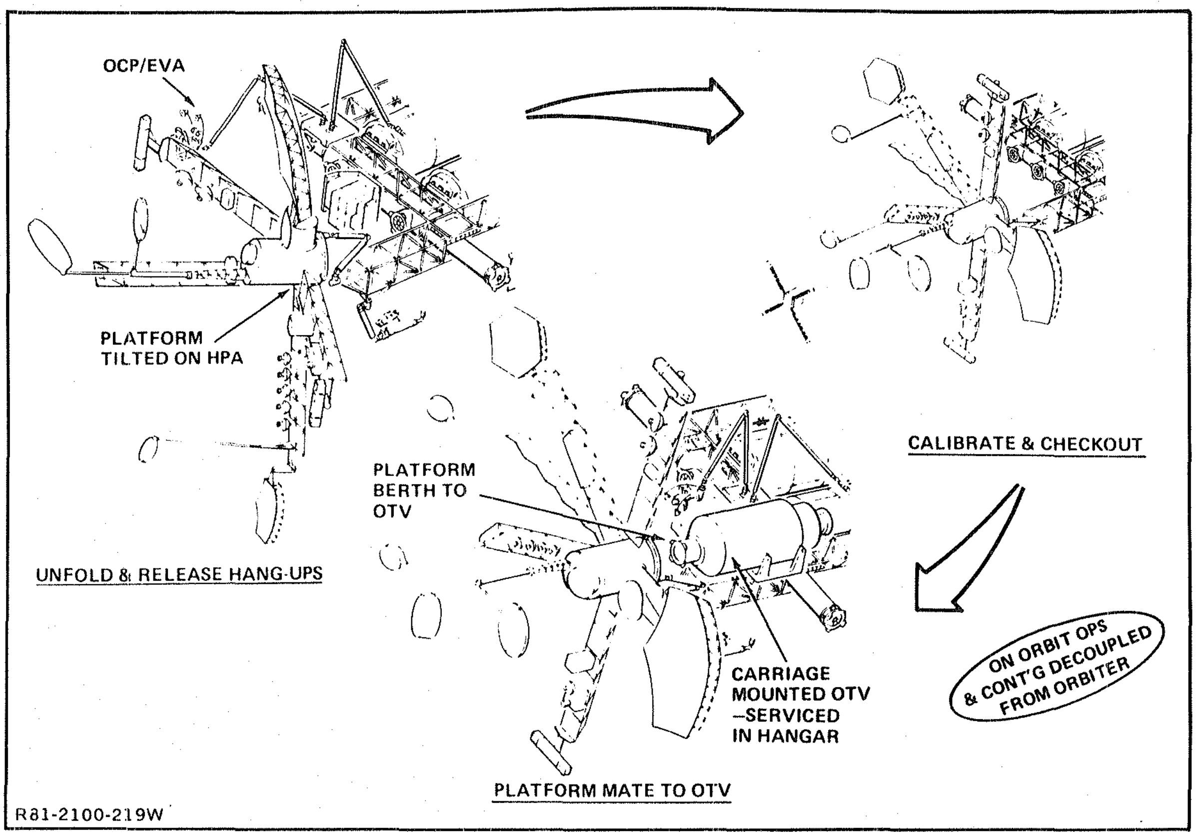


Fig. 4.2-40 GEO Comm Platform Launch Checkout, Mate to OTV

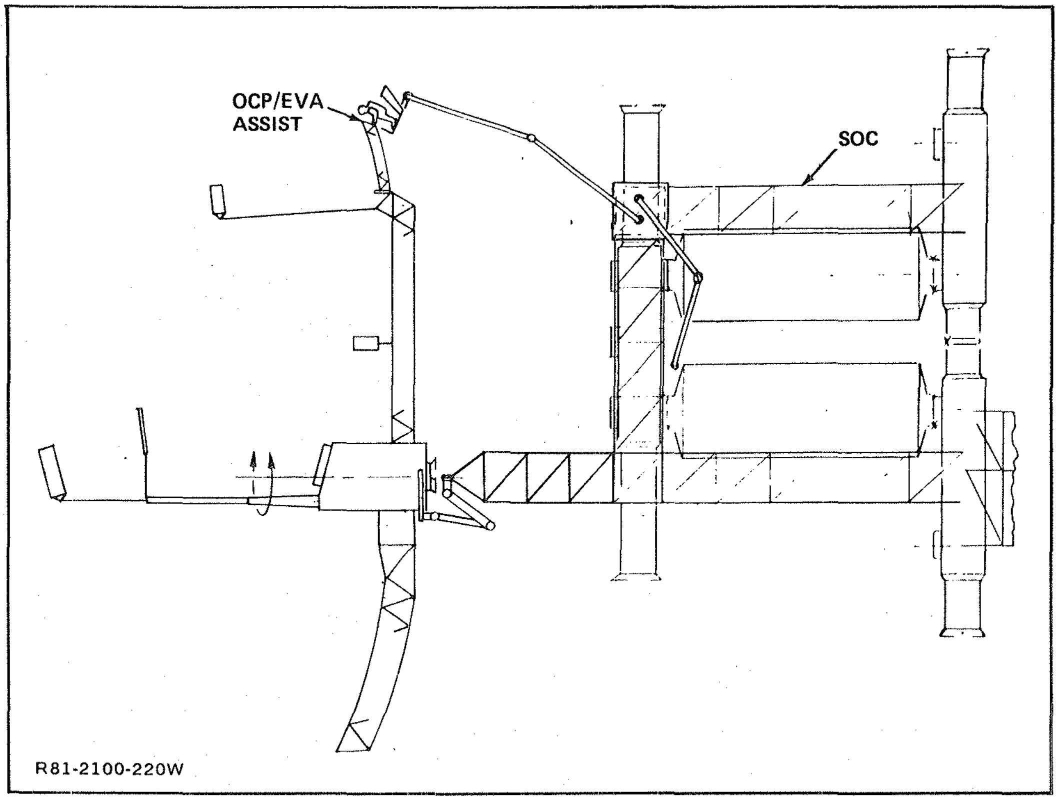


Fig. 4.2-41 GEO Comm Platform Initial Launch – Appendage Deployment

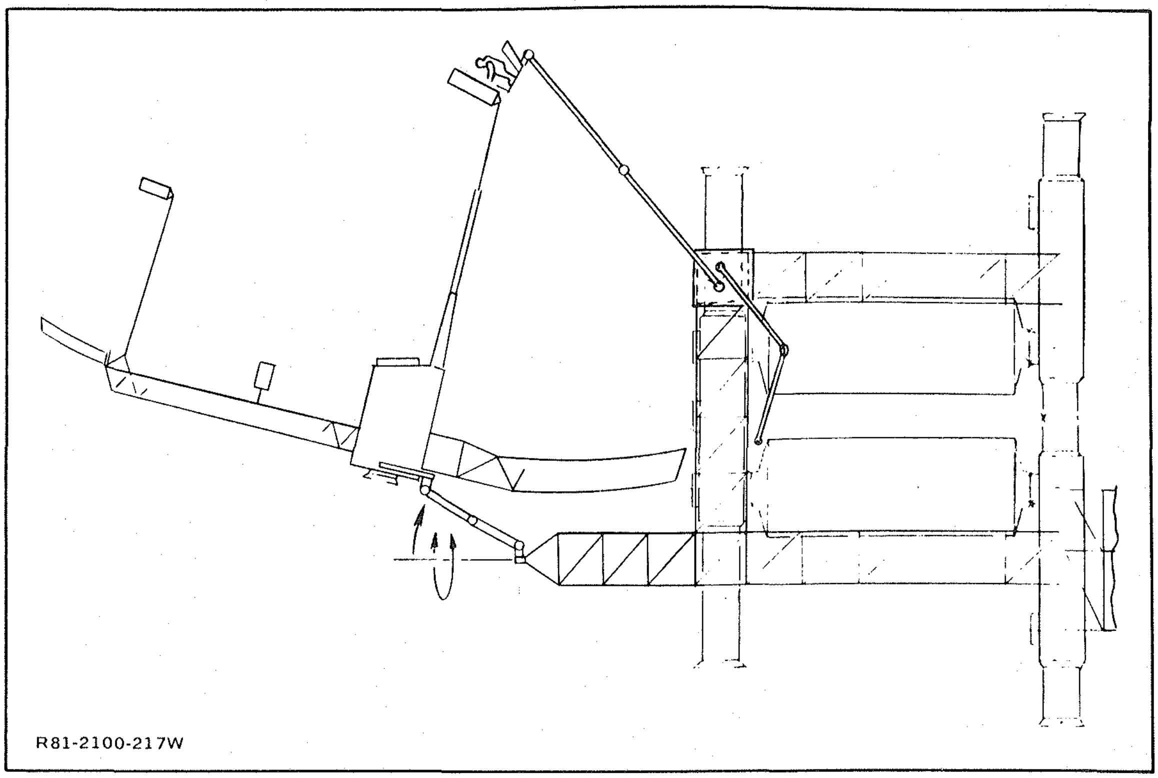


Fig. 4.2-42 GEO Comm Platform Initial Launch – Typical Access to Remote Area

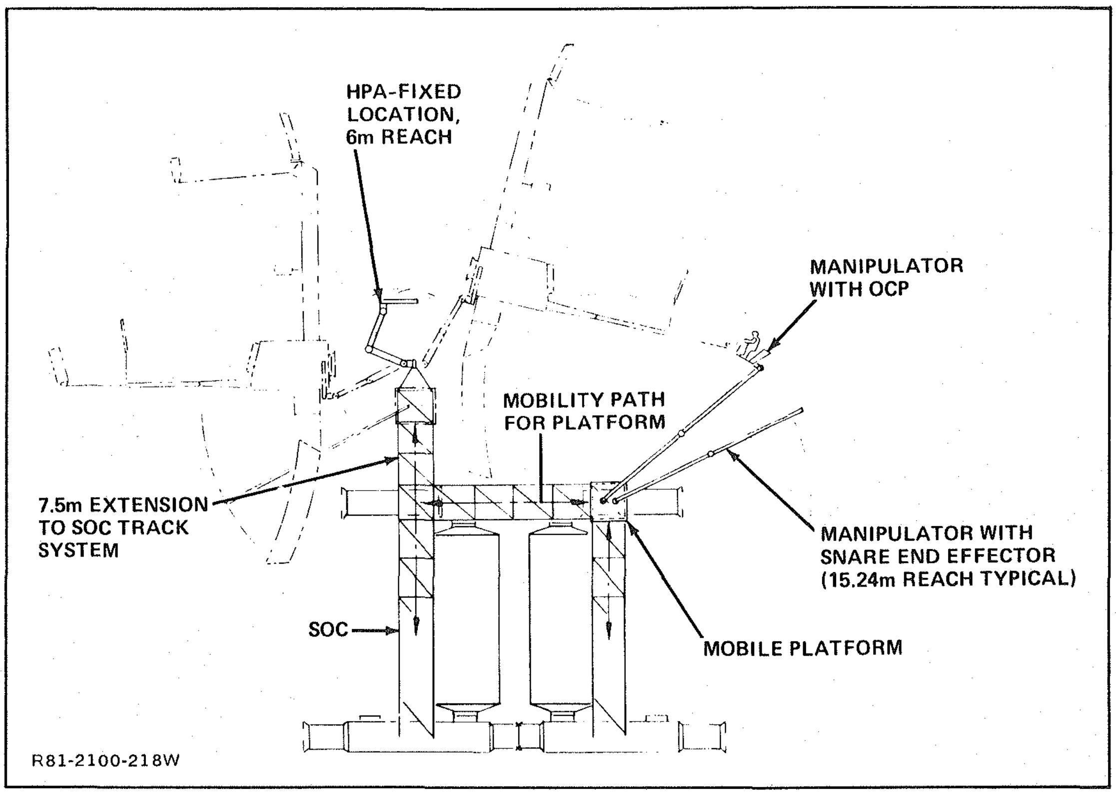


Fig. 4.2-43 Sketch Illustrating Reach Capabilities of Satellite Service Equipment

Figure 4.2-43 which uses the communications platform to illustrate the reach capabilities of satellite servicing equipments. One attitude of the platform (Figure 4.2-43) shows access to the feed mast; the other attitude illustrates a possible location for the platform when calibrating antennas from a free flying signal source.

After deployment of the platform appendages, the checkout of the systems and subsystems and the calibration of antenna patterns, the platform is mated, (Figure 4.2-40 and 44) to an OTV which will transfer it to geosynchronous orbit. The carriage-mounted OTV has been serviced in its hangar and refueled. It is then translated out of the hangar, put on the track system and run along to the tip of the SOC extension pier. The satellite servicing HPA, controlled by the OCP/EVA crew, then berths the platform to the OTV. After final check out, the platform/OTV is separated from SOC. The method of separation will be determined when groundrules governing the burning of "dirty" RCS, separation and approach corridors, etc have been established.

4.2.3.4.3 GEO Communication Platform Checkout Functions - The functions required to assemble the communications platform to the OTV are shown in Figure 4.2-45. A major portion of the time required for checkout is measuring the antenna patterns to calculate gain. The MTV will separate incrementally from SOC, e.g. at 25 and 50 km, and a signal generator on the MTV will radiate energy to the communication platform. The antenna will be rotated incrementally about its boresight 360 degrees. At each position, the antenna will be pitched one or two degrees each side of its boresight while received signal level is recorded. Several other items of equipment such as the DMSP data relay, tactical satcom, lightning mapper and magnetic substorm monitor also require verification of operability. After checkout, the platform will be assembled to the OTV and interfaces verified prior release from SOC. Should a malfunction be uncovered during checkout then additional time and EVA operations are available to resolve the problem.

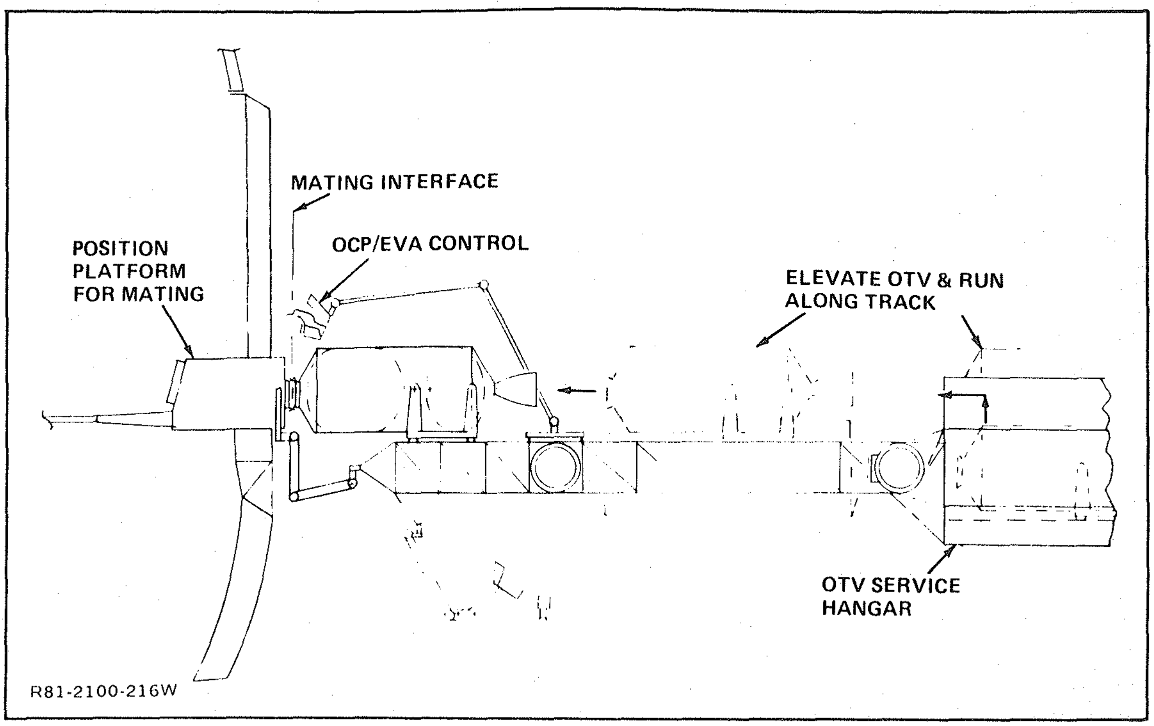


Fig. 4.2-44 GEO Comm Platform Initial Launch – Mating To OTV

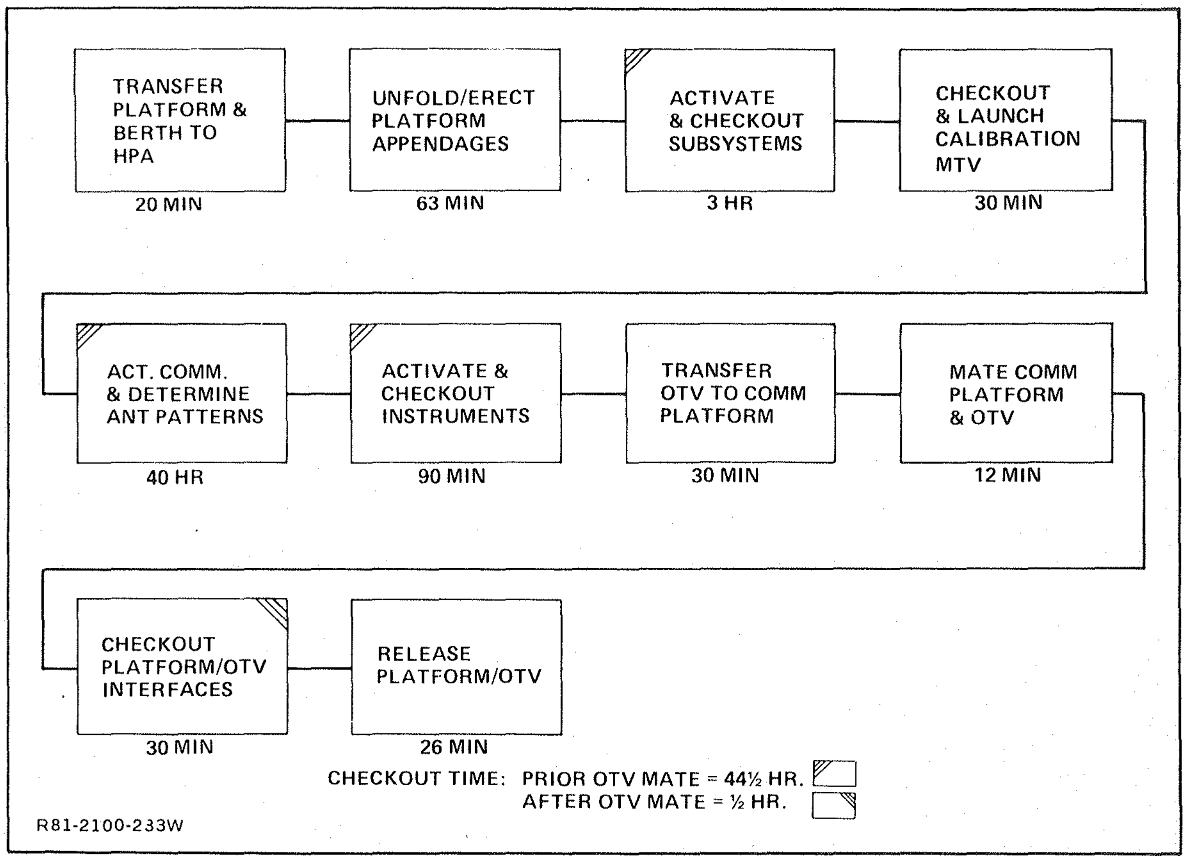


Fig. 4.2-45 Communications Platform SOC Assembly and Checkout

4.2.3.5 Comparison of SOC & Orbiter Servicing

Representative satellite service operations that were analyzed for SOC were also analyzed for operations from Orbiter. This data is compared for number of Orbiter flights, orbital time to perform servicing operations, crew operations time and costs.

4.2.2.5.1 AXAF Servicing by Orbiter - After the Orbiter is inserted into orbit, it immediately commences rendezvous with the AXAF which will have decayed from its initial operational orbit of 500 km. When the Orbiter is in close proximity to the AXAF, the POM will be launched from Orbiter, maneuvered to the AXAF, grapple it, and then transfer the AXAF to the Orbiter for berthing on the HPA. The POM will maneuver the AXAF to the HPA berthing mechanism where the HPA completes the operation by latching onto the AXAF. Figure 4.2-46 shows a time allowance of 30 hours for these operations and Figure 4.2-47 illustrates this sequence of events. One and one-half days have been allowed for maintaining the AXAF which includes 3 EVAs. The nominal approach is to work serially at two levels. To shorten the operations time, Figure 4.2-48 depicts parallel maintenance operations being performed on the instruments by an OCP mounted on an HPA extension and at the subsystem donut at the same time. After completing AXAF maintenance, the Orbiter transfers to 500 km, checks out the AXAF and deploys it as illustrated in Figure 4.2-49. This AXAF servicing operation from Orbiter is completed in 4 days. Contingency time of one or two days could be accommodated if needed, within the Orbiter flight time of 7 days.

4.2.3.5.2 GEO Communications Platform Launched by Orbiter - The GEO communications platform is placed in low earth orbit, and attitude stablized for later retrieval. The attitude could be gravity gradient stablized by a simple mechanical boom or cable and mass. See Figure 4.2-50 for the operations timeline.

The second Orbiter transports the OTV to orbit and rendezvous with the communications platform; see Figure 4.2-51 for the sequence of events. Next the RMS grapples the platform and berths it to the HPA.

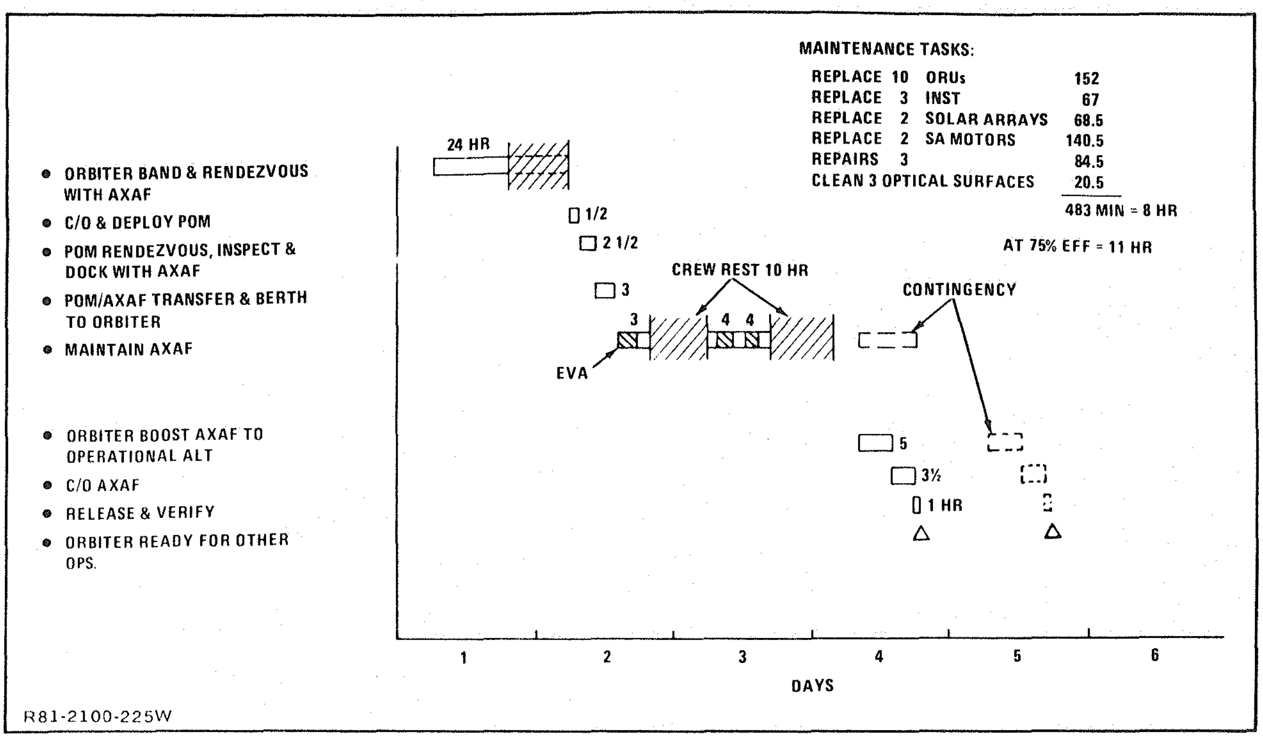


Fig. 4.2-46 Timeline – AXAF Servicing from Orbiter

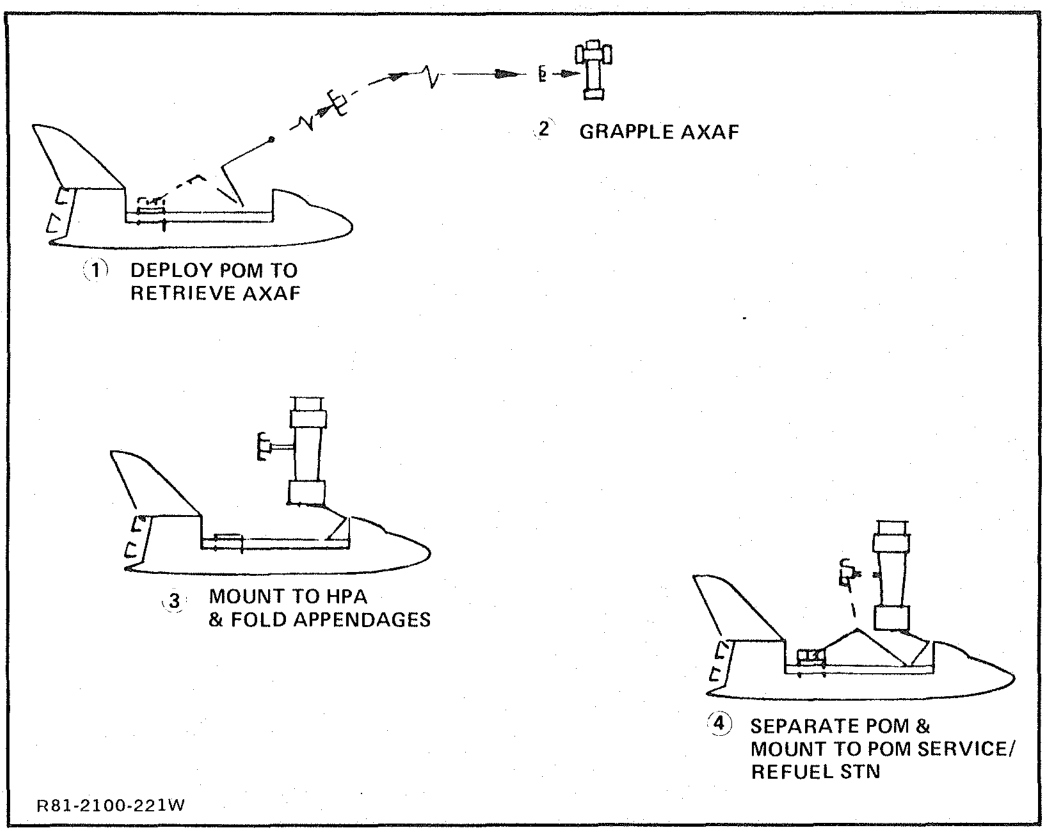
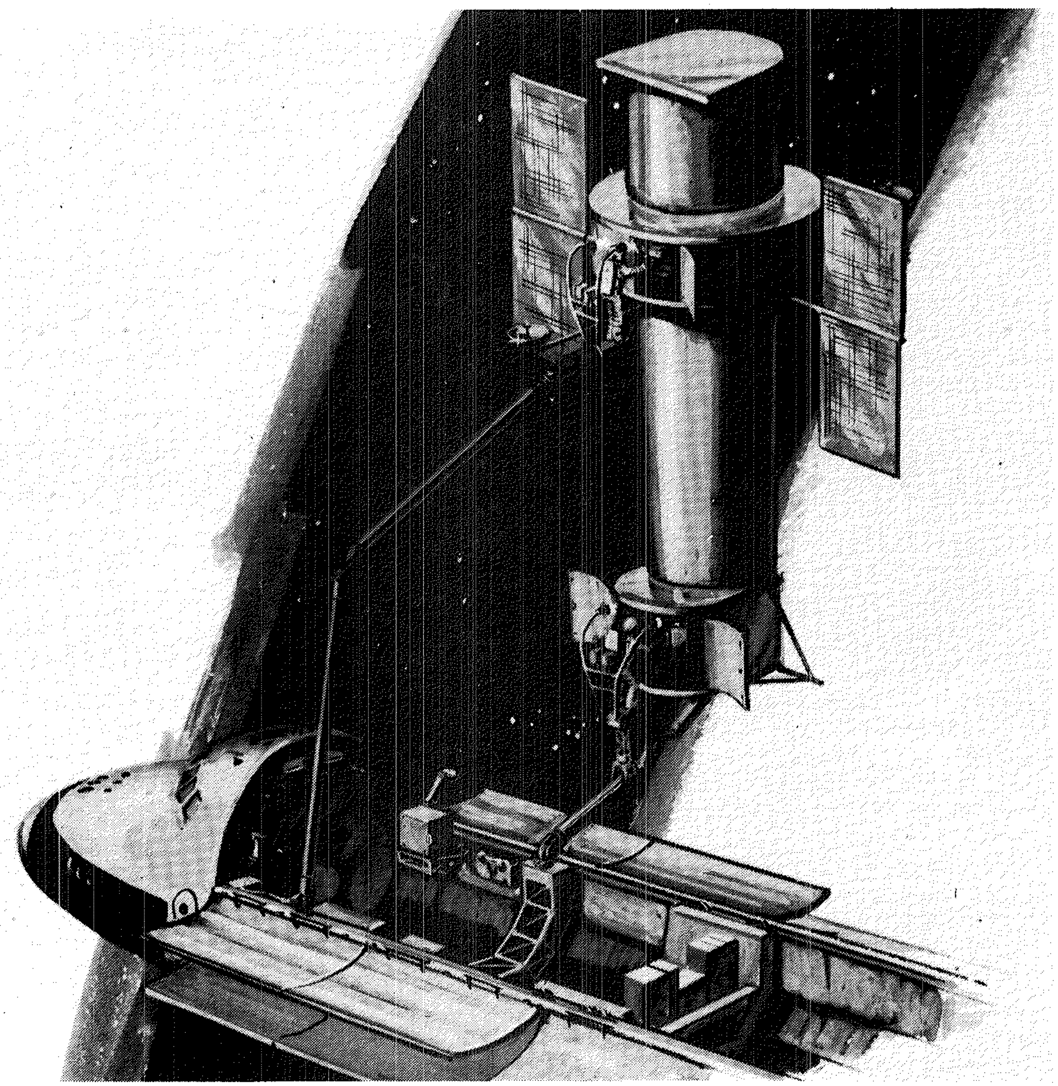


Fig. 4.2-47 AXAF Servicing Sequence



Dual Servicing Capabilities

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Fig. 4.2-48 AXAF Servicing By Orbiter

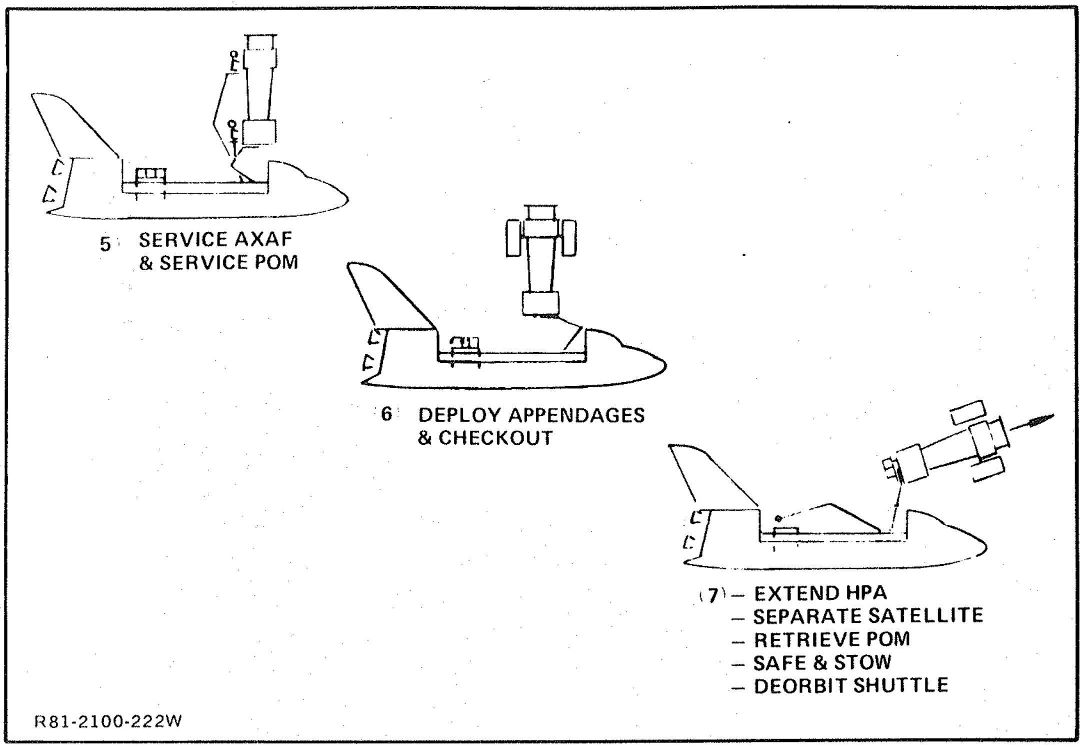

Fig. 4.2-49 AXAF Servicing Sequence (continued)

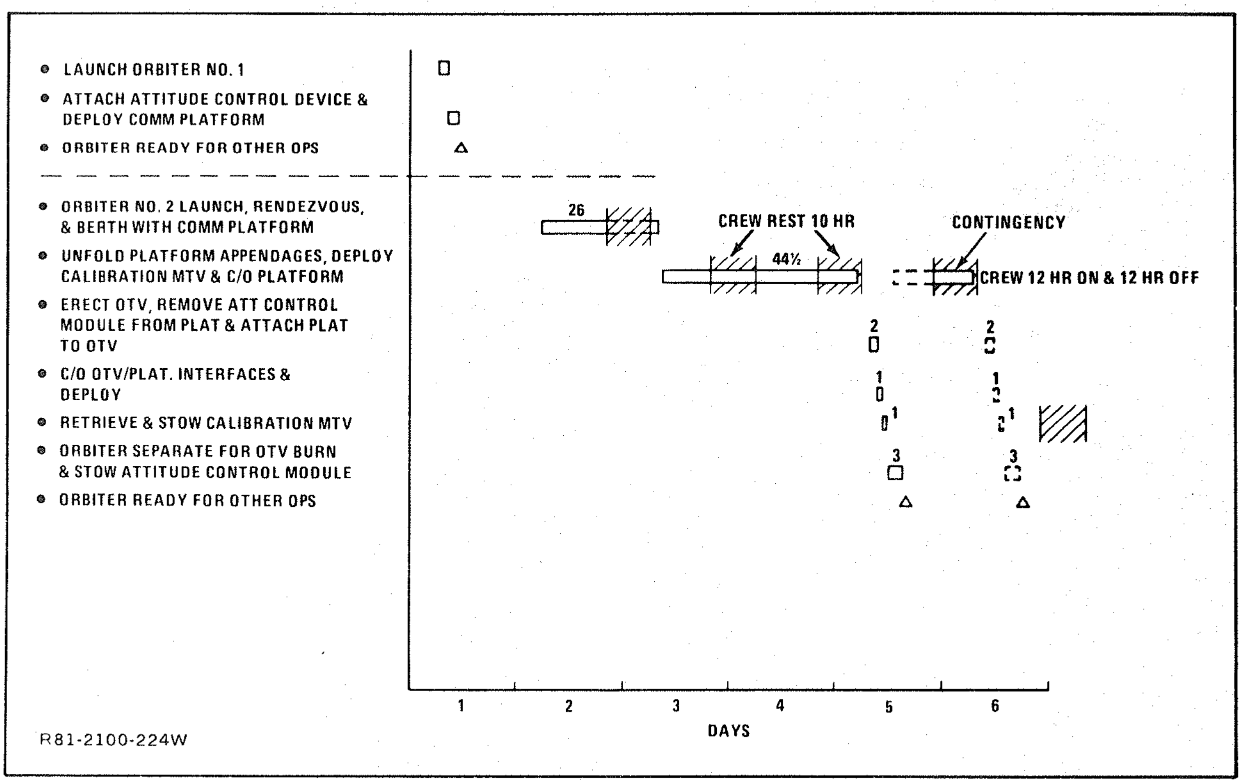

Fig. 4.2-50 Timeline – GEO Communication Platform Deployed From Orbiter

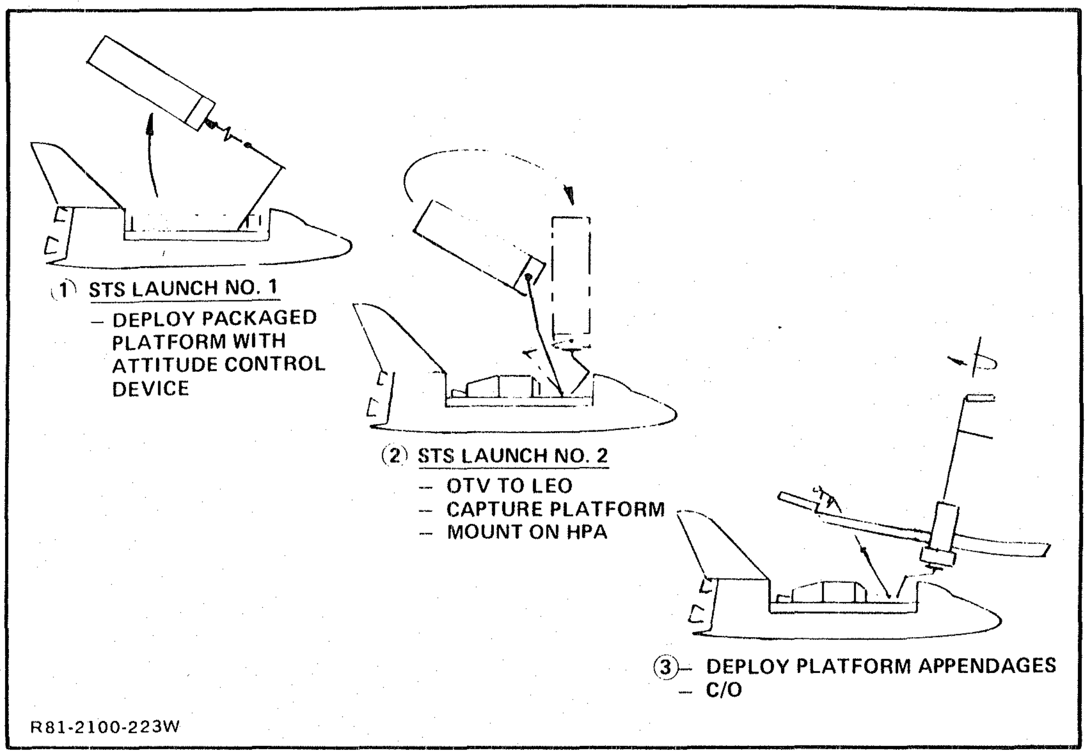

Fig. 4.2-51 GEO Comm Platform – Initial Launch From Orbiter

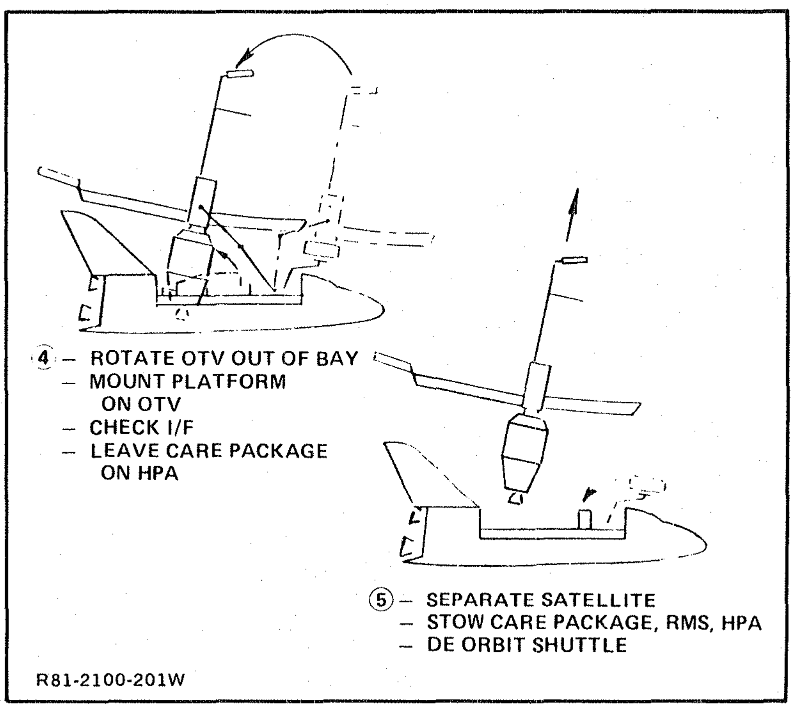

Fig. 4.2-52 GEO Comm Platform–Initial Launch from Orbiter (continued)

Now the communication platform unfolding is controlled from the Orbiter aft flight deck. In the event that appendages do not deploy completely, EVA operation will rectify the situation. Platform check-out operations are similar to those described for SOC, i.e., the calibration MTV is released and antennae patterns determined. Figure 4.2-52 shows the OTV erected out of the cargo bay so that the platform can be assembled to it. After interfaces are verified and the OTV checkout out, the OTV is released for subsequent transfer to geosynchronous orbit. The last event to be accomplished prior to Orbiter departure is the retrieval and stowage of the calibration MTV.

Figure 4.2-53 contains the functions required for orbiter assembly and checkout of the platform/OTV and includes the block time allocated for each operation.

4.2.3.5.3 Comparative Data - Comparative data of AXAF servicing from the SOC and Orbiter is shown in Figure 4.2-54. All parameters compared are quite similar, except costs (Reference 4.2-11) for the planned operations and cost allowance for contingencies. Increased costs when servicing the AXAF from Orbiter and launching the Communication platform, without utilizing SOC, are illustrated in Figure 4.2-56. The reason the Orbiter transportation costs associated with the AXAF (13.5 + 5.6 = $19.1 million 1981 constant dollars) are high is that the HPA, AXAF replaceable equipment, POM, and OMS kit require a payload bay length factor of 0.67.

A similar comparison of the Communications Platform costs are shown in Figures 4.2-55 and 4.2-56. The Orbiter transportation costs of $57.7 million (1981 constant dollars) includes two flights, with full cargo bays on each flight. The SOC transportation cost of $29.8 million (1981 constant dollars) (Reference 4.2-11 and 12) is the Orbiter flight that transports the communications platform to SOC.

4.2.4 MISSION MODEL IMPACT ON SATELLITE SERVICE FACILITY

This task assessed the impact of mission and traffic models on equipment requirements and on the initial, operational, and growth SOC configurations.

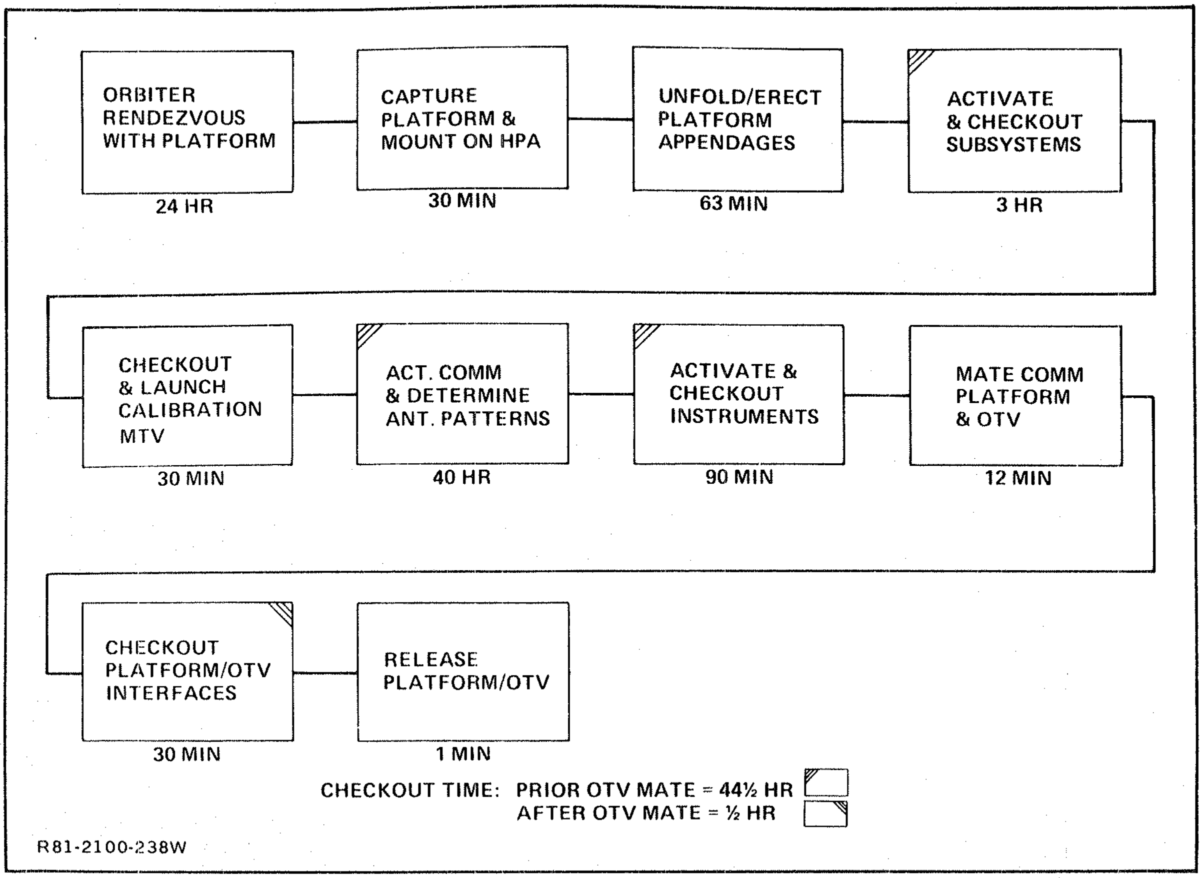

Fig. 4.2-53 Communications Platform Orbiter Assembly and Checkout

MISSION PARAMETER	SOC	ORBITER	COMMENTS
NUMBER OF ORBITER FLIGHTS	1	1	AXAF REPLACEMENT EQUIP. & VSS PROP. DELIVERED TO SOC BY SHARED LOGISTIC FLIGHT
MISSION TIME IN DAYS	5½	4	AXAF/SOC OPERATIONS (ORBITER SHARED LOGISTICS FLIGHT NOT INCLUDED)
NO. CREW (AXAF WORKERS)	2	2	SINGLE SHIFT
CREW WORK TIME (HR) (AXAF RELATED)	18	21	INCLUDES ORBITER BOOST OF AXAF TO OPERATING ALTITUDE
EVA TIME (HR)	11	11	
COSTS MILLION (1981 DOLLARS)	$7.4	$24.7	ORBITER RESUPPLY FLT TO SOC COSTS INCLUDED
CONTINGENCY $ MILLION (1981 DOLLARS)	$0.03	$ 0.7	ONE DAY WITH 2 EVAs

Fig. 4.2-54 Comparison of AXAF Servicing From SOC and Orbiter

MISSION PARAMETER	SOC	ORBITER	COMMENTS
NUMBER OF ORBITER FLIGHTS	1	2	SOC FUEL FOR OTV SCAVENGED FROM ET ON PREVIOUS ORBITER FLIGHTS
MISSION TIME IN DAYS	2½	4	
NO. CREW (PLATFORM WORKERS)	2	2	ONE PERSON/SHIFT
CREW WORK TIME (HR) (PLATFORM RELATED)	49½	54½	SOC UNLOADING PLATFORM FROM ORBITER INCLUDED
EVA TIME (HR)	0	0	ALL OPERATIONS PERFORMED REMOTELY
COSTS MILLION (1981 DOLLARS)	$31.4	$61.5	
CONTINGENCY MILLION (1981 DOLLARS)	$ 0.01	$ 0.4	ONE DAY OPERATIONS

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Fig. 4.2-55 Comparison of Communication Platform Assembly and Checkout from SOC and Orbiter

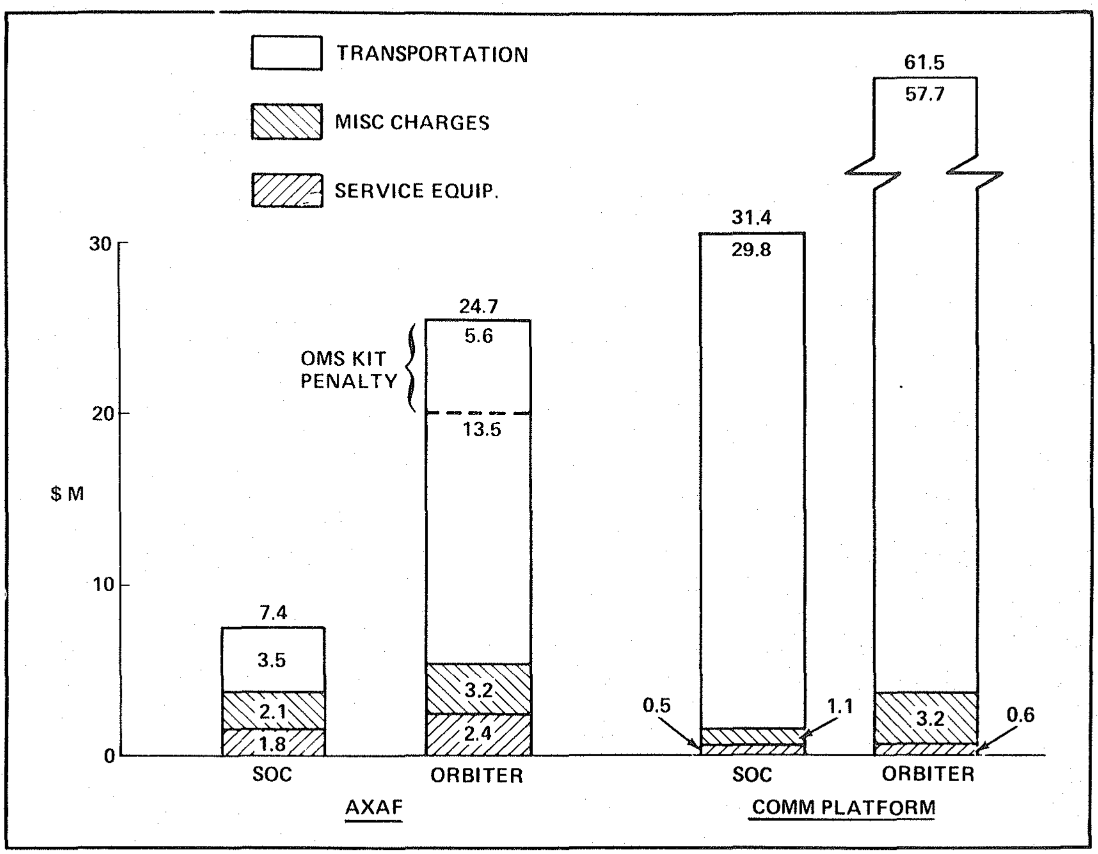

Fig. 4.2-56 Representative Mission Service Costs (1981 Constant $)

Figure 4.2-57 illustrates satellite servicing at the initial SOC. The main equipment added to the baseline configuration is a handling and positioning aid (HPA) to handle the satellite and an OCP to mount to the tip of the standard manipulator. A service supplies pallet, delivered by the Orbiter, is berthed to a standard port on the Service Module (SM). This pallet provides supplies for maintenance/ resupply operations of co-orbiting satellites and the Proximity Operations Module (POM) which retrieves these satellites. A grappling point is also provided on the pallet to hold a POM for service. When a satellite has been captured and returned to SOC, the POM propulsion unit berths the satellite to the HPA. The POM is demated from the satellite and transferred to the grapple point on the service supplies pallet where it is serviced and refueled by the EVA crewman on the OCP. The satellite is also serviced, in turn, by the EVA crew who obtains change-out modules, etc from the supplies pallet.

Satellite servicing from the operational SOC was discussed previously in detail. Considering the impact of traffic model variation, it has been established that with the current models, no increase in equipments will be required before 1995, after the proposed IOC for growth SOC.

Figure 4.2-58 shows a concept for satellite servicing on growth SOC. It utilizes the same equipments as proposed for operational SOC. However, introduction of the construction facility forces the pier, which supports the HPAs, to another location. It is shown here as extending out from the underside, i.e., the side opposite to that mounting the standard track system. A cross track is also added to this side to provide mobility for the carriage platform which mounts the two manipulators. Servicing operations follow those described for the operational SOC.

The reason for the operational SOC not having its satellite service facility located where shown for growth SOC, thus avoiding rework, is that it is believed that the operational SOC concept will

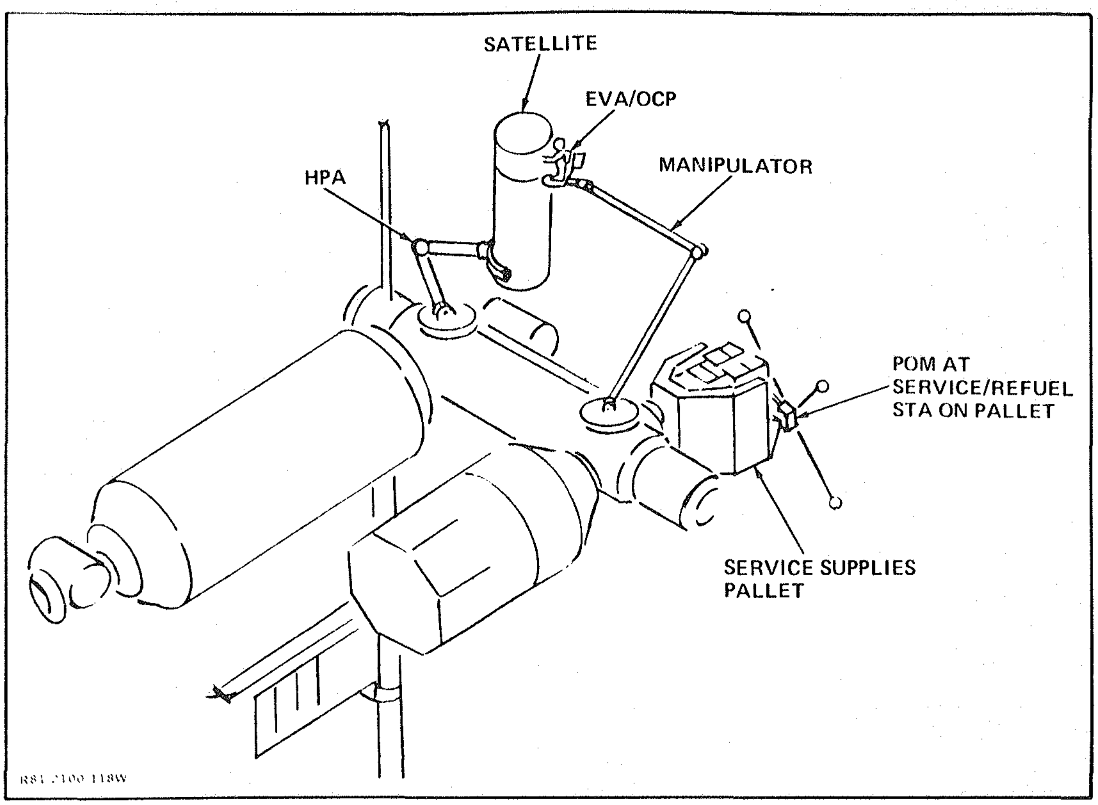

Fig. 4.2-57 Satellite Service at "Initial" SOC

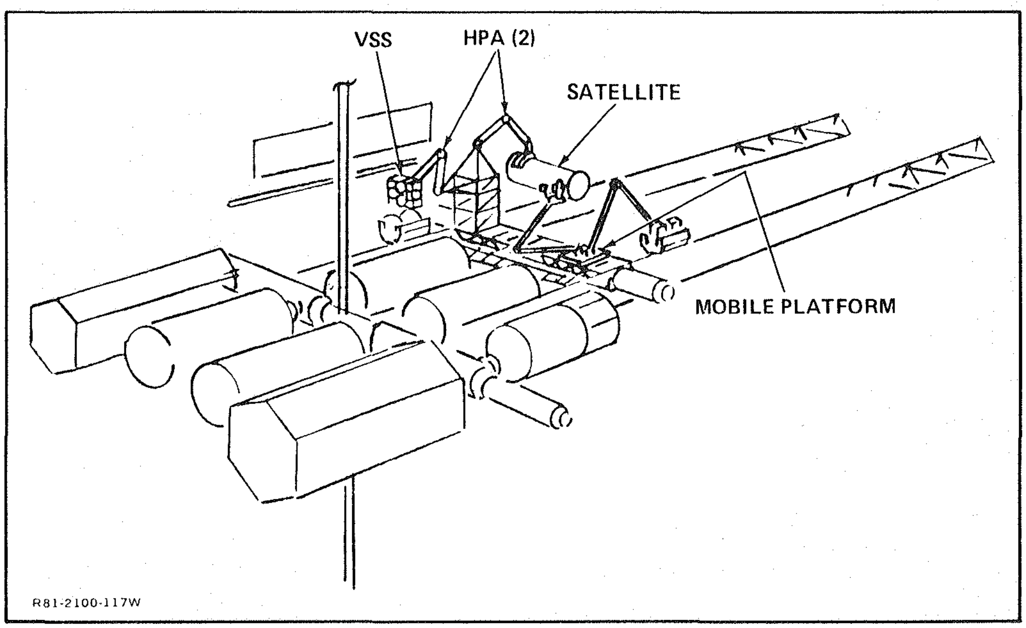

Fig. 4.2-58 Satellite Service at "Growth" SOC

be utilized for a long period of time. Facility location on operational SOC is more convenient since it gives more flexibility in reach for the manipulators and HPAs. The locations shown here for growth SOC satellite servicing is just one of many alternates which require further study. Additional servicing equipment will be required after 1995 if parallel servicing is necessary to meet scheduled events.

SUBSECTION 4.2 REFERENCES

4.2-1 Space Systems Technology Model, Second Draft, July 1981, NASA

4.2-2 Advanced X-Ray Astrophysics Facility (AXAF) Science Working Group Report, NASA TM-78285, May 1980, MSFC

4.2-3 Space Telescope Support System Module Phase B Definition Study, March 1976, LMSC-D 495154, Lockheed Missiles & Space Co.

4.2-4 Space Telescope Space Support Equipment, P-Wear Presentation, May 1979, LMSC-D710766, Lockheed Missiles & Space Co.

4.2-5 Space Telescope Mission Operations Requirements, November 1980, LMSC 4171847F, Lockheed Missiles & Space Co.

4.2-6 Satellite Services System Analysis Study, CSS-SSS-RP009, August 1981, Grumman Aerospace Corp.

4.2-7 Satellite Services System Analysis Study, February 1981, LMSC-D792242, Lockheed Missiles & Space Co.

4.2-8 Manned Remote Work Station Development Test Article, October 1981, SA-MR-RP049, Grumman Aerospace Corp.

4.2-9 STS Work Day Handbook, February 1980, NASA

4.2-10 Geostationary Platform Systems Concepts Definition Study, GDC-GPP-79-006, June 1980, General Dynamics.

4.2-11 STS Reimbursement Guide, JSC-11802, May 1980, NASA

4.2-12 Man-Hour Cost Estimate for SOC-Based OTV Servicing LR-15-1622, Oct. 15 1980, NASA JSC Memorandum

SUBSECTION 4.3 TABLE OF CONTENTS

4.3 ANALYSIS OF CONSTRUCTION AND SERVICE EQUIPMENT REQUIREMENTS

There were four main objectives to this task:

- To identify common requirements and equipments for implementing satellite service missions and construction missions on SOC. Candidate equipment concepts are based on the findings of three earlier studies and on the servicing requirements established in the preceding task. The earlier studies include the orbiter based Satellite Servicing Systems Analysis Studies by Lockheed and Grumman (Ref 4.3-1 and 4.3-2), and Boeing's previous SOC Systems Analysis Study (Ref. 4.3-3)
- To analyze these requirements and equipments for maximum commonality and utility
- To provide updated equipment lists, and
- To define the evolutionary growth of servicing and
- construction capabilities through the first 10 years of SOC operations.

4.3.1 IDENTIFICATION OF SIMILAR EQUIPMENTS

The initial list of satellite servicing equipments for SOC was derived from the reference mission scenarios defined in the preceding task. Additional equipments defined in the three earlier studies for servicing satellites and constructing large space systems were also incorporated into the listing. The entire list was then categorized into five areas:

- Required satellite service equipment for SOC
- Required flight support equipment for SOC based servicing
- Potential use satellite service equipment group
- Potential use flight support equipment group
- Other equipments.

Satellite service equipment required for SOC is listed in Table 4.3-1. This list includes the major equipment needed to perform the two reference missions (e.g., open cherry pickers, manipulators and handling/positioning aids). Some of these equipments were also identified in the earlier studies and are so indicated. The technology status of each equipment item is also listed. Required flight support equipment for SOC based satellite servicing is provided in Table 4.3-2, which covers the propulsion equipments and their service requirements neccessary to perform the reference missions. Limited resources for this short study extension did not permit an in-depth analysis of all equipment concepts identified to date. Thus, it is possible that further analysis will identify additional equipment which will also be required for use on SOC. Tables 4.3-3 through 4.3-5 list those remaining equipments defined in the earlier studies for satellite servicing which were not derived from the reference missions. The satellite service equipment group shown in Table 4.3-3, and the flight support equipment group, Table 4.3-4, are not considered necessary for the reference missions but are considered to have potential use as general purpose equipments for servicing satellites.

The remainder of the earlier equipments were considered to have no obvious use for SOC based servicing since they are unique to orbiter based servicing. These items are listed under "other equipments", as shown in Table 4.3-5.

Turning to construction equipment, 21 pieces were identified in the SOC main study, (Ref. 4.3-3) and are listed in Table 4.3-6. They were compared to the "required equipments" and the "potential use equipments" listed for satellite servicing. Some construction equipments had no equivalent requirement in satellite servicing and were identified as such. Others were identical or similar to equipments required for satellite servicing. For each of the "similar equipments" in this category, the comparable piece of satellite service equipment was identified. Also identified in this table is construction equipment which also appears as "potential use" equipment on the satellite servicing listing.

TABLE 4.3-1 REQUIRED SATELLITE SERVICE EQUIPMENT – REFERENCE SATELLITE SERVICE MISSIONS

EQUIPMENT	WHERE IDENTIFIED				TECH STATUS
	SOC EXTN STUDY	SOC MAIN STUDY	LOCKH'D SAT. SERV	GRUMMAN SAT. SERV	
• MOBILE PLATFORM ASSY					
– PLATFORM CARRIAGE	√				NEW
– STS MANIPULATORS	√		√	√	EXISTING
– END EFFECTORS	√	√	√		DEVLT/NEW
– OPEN CHERRY PICKER (OCP)	√	√	√	√	DEVLT
• AIRLOCK	√		√		SOC STD EQMT
• EMU	√	√	√		EXISTING
• HANDLING & POSITIONING AID (HPA) ASSY					
– HPA STRUCT/MECHMS	√			√	DEVLT
– END EFFECTORS	√			√	NEW
– OCP SUPPORT BOOM	√			√	NEW
– UMBILICALS	√				NEW
• HAND TOOLS	√	√	√		EXISTING/DEVLT/NEW
• SATELLITE/PAYLOAD CHECK OUT	√				DEVLT/NEW
• SERVICE SUPPLIES PALLETS	√				EXISTING (SPACELAB)
• FAULT DIAGNOSIS	√	√			NEW
• TOOL/AID STORAGE ON SOC	√	√	√		SOC STD EQMT
• HANDHOLDS	√	√	√		SOC STD EQMT
• HANDRAILS	√	√	√		SOC STD EQMT
• GROUNDING STRAP	√	√	√		NEW
• OPTICAL SURFACE CLEANING KIT	√	√			NEW
• TELEMETRY & COMMAND SYS	√	√			SOC STD EQMT

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TABLE 4.3-2 REQUIRED FLIGHT SUPPORT EQUIPMENT – REFERENCE SATELLITE SERVICE MISSIONS

EQUIPMENT	WHERE IDENTIFIED				TECH STATUS
	SOC EXTN STUDY	SOC MAIN STUDY	LOCKH'D SAT. SERV	GRUMMAN SAT. SERV	
• OTV	√				NEW
• HANGAR	√	√			SOC STD EQUIPT
• OTV ELEVATOR	√				NEW
• OTV UMBILICAL	√				NEW
• OTV DOLLY	√	√			NEW (SEE MOBILE PLTFM CARRIAGE)
• OTV SERVICE EQMT	√				NEW
• OTV REFUEL EQMT	√				NEW
• OTV CHECKOUT EQMT	√				NEW
• VERSATILE SERVICE STAGE (VSS)	√			√	NEW (TMS ADAPTION)
• VSS SERVICE EQMT	√				NEW
• VSS REFUEL EQMT	√				NEW
• VSS CHECKOUT EQMT	√				NEW
• MANEUVERABLE TELEVISION (MTV)	√		√	√	DEVLT
• PROPN ARMING/SAFING	√				NEW
• FLUID LINE REPAIR KIT	√	√			NEW

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TABLE 4.3-3 'POTENTIAL USE' SATELLITE SERVICE EQUIPMENT – IDENTIFIED IN PREVIOUS STUDIES

EQUIPMENT	WHERE IDENTIFIED: SOC EXTN STUDY	SOC MAIN STUDY	LOCKH'D SAT. SERV	GRUMMAN SAT. SERV	TECH STATUS
• EMU HELMET LIGHTS			√	√	NEW (LOCAL ILLUMINATION)
• PORTABLE EVA WORK STN		√	√	√	NEW (BEYOND OCP REACH)
• TOOL/BOND KIT		√	√		NEW
• PORTABLE TV CAMERA		√	√		NEW
• TETHERS & RINGS		√	√		EXISTING
• SHARP CORNER/EDGE PADDING KIT		√	√		NEW
• ILLUMINATION KIT FLOOD LIGHTS		√	√		NEW
• TEMPORARY ATTACH DEVICE		√	√		NEW
• SUN SHIELD		√		√	NEW
• DEXTROUS MANIPULATOR				√	DEVLT (FUTURE IVA OPN)
• PHOTOGRAPHY EQMT		√			EXISTING/DEVLT/NEW
• COATING APPLICATOR		√			NEW
• WIRE SPLICER		√			NEW
• TAPE DISPENSER		√			NEW
• THERMAL COVER ATTACH KIT		√			NEW
• CORROSION CONTROL KIT		√			NEW
• ALIGNMENT INSTRUMENT		√			NEW
• SPIN TABLE				√	DEVLT (SPIN STABILIZED PROPN)

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TABLE 4.3-4 POTENTIAL USE' FLIGHT SUPPORT SYS EQUIPMENT – IDENTIFIED IN PREVIOUS STUDIES

EQUIPMENT	WHERE IDENTIFIED				TECH STATUS
	SOC EXTN STUDY	SOC MAIN STUDY	LOCKH'D SAT. SERV	GRUMMAN SAT. SERV	
• UNMANNED PROXIMITY OPS MODULE (POM) PROPN					
– MTV	√		√	√	DEVLT
– PROPN STAGE				√	NEW
• MANNED POM					
– MMU				√	EXISTING
– WORK RESTRAINT UNIT (WRU)				√	PARTIALLY DEVELOPED

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TABLE 4.3-5 OTHER EQUIPMENT PREVIOUSLY IDENTIFIED

EQUIPMENT	WHERE IDENTIFIED SOC EXTN STUDY	SOC MAIN STUDY	LOCKH'D SAT. SERV	GRUMMAN SAT. SERV	REMARKS
• FOOT RESTRAINT & RECEPTACLE		√	√	√	FUNCTIONS REQUIRING THESE EQMTS ARE PROVIDED BY EVA/OCP/MANIPULATOR SYSTEM
• MINI WORK STN			√		
• TOOL CADDY		√	√		
• PORTABLE LIGHTS		√	√		
• MODULE EXCHANGE MECHM.			√		
• SLIDE WIRES			√		
• CLOTHES LINE			√		
• UMBILICAL		√	√		FUNCTIONS REQUIRING THESE EQMTS ARE PROVIDED BY HPA SYSTEM
• EXTRACT/INSERT TABLE			√		
• PIVOT/ROTATE TABLE		√	√	√	
• NASA TOOLS		√	√		THESE ARE CONSIDERED 'HANDTOOLS' – LISTED AS 'REQD EQMT'
• POWER WRENCH		√	√		
• ENERGIZED DRILL WRENCH		√	√		
• MANUAL OVERRIDE TOOL		√			
• ATTACH/REMOVE GRAPPLE FXTRS			√		THESE ARE CONSIDERED 'END EFFECTORS' – LISTED AS 'REQD EQMT
• GRAPPLE ASSY STANDOFF			√		
• SPARES RACK/ENCLOSURE		√	√	√	SEE 'SERVICE SUPPLIES PALLETS'
• DESPIN PACKAGE		√	√		PERFORMED BY VSS OR POM
• FLUID CONNECTOR		√	√		PART OF OTV/VSS/POM REFUEL EQMT
• FLUID MANIFOLD		√	√		
• FLUID TRANSFER KIT		√	√	√	

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TABLE 4.3-5 OTHER EQUIPMENTS PREVIOUSLY IDENTIFIED (CONTD)

EQUIPMENT	WHERE IDENTIFIED: SOC EXTN STUDY	SOC MAIN STUDY	LOCKH'D SAT. SERV	GRUMMAN SAT. SERV	REMARKS
• MESA KIT			√		THESE ITEMS ARE REQUD FOR SATELLITE SERVICE FROM THE ORBITER – NOT APPLICABLE TO SOL OPNS
• ORBITER LIGHTS			√		
• FSS			√	√	
• DOCKING MODULE			√		
• OMS KIT MOD			√		
• RMS NET			√		
• RETENTION STRUCTURES				√	
• PIDA				√	
• NON CONTAMINATING ACS				√	
• ATTITUDE TRANFSER				√	
• LATCH MECHANISM		√	√		NO KNOWN REQUT
• DE ORBIT KIT		√	√		NO KNOWN REQUT

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TABLE 4.3-6 CONSTR EQUIPMENT - COMMONALITY WITH SAT. SERVICE EQUIPMENT

CONSTR EQUIPMENT - DEFINED IN MAIN STUDY	NO. SAT SERVICE EQUIV IDENTIFIED	REQUIRED FOR SAT. SERVICE		IDENTIFIED AS 'POTENTIAL USE' FOR SAT. SERVICE	COMPARABLE SAT. SERVICE EQMT – WHERE APPLICABLE
		IDENTICAL EQMT	SIMILAR EQMT		
• MOBILE CHERRY PICKER			√		MOBILE PLATFORM
• HANDLING TOOLS			√		END EFFECTORS
• PORTABLE EVA WORK STN				√	
• EMU		√			
• STD HAND TOOLS		√			
• MANIPULATOR SYS			√		MOBILE PLATFORM FUNCTION
• ARTICULATED CONSTR FIXTURE			√		HPA
• MODULAR CONSTR FIXTURE	√				
• TURNTABLE/TILTTABLE			√		HPA FUNCTION
• CONSTR UMBILICAL SYS			√		HPA FUNCTION
• BEAM BUILDER SYS	√				
• STRUT ASSY AIDE	√				
• TAPE DISPENSER				√	
• LIGHT LEAK SENSOR INSTR	√				
• CONTOUR MEASURING INSTR	√				
• DATA RECORDER		√			C/O EQMT
• TETHERS		√			
• DATA BUS TEST MODULE		√			C/O EQMT
• ELECTRICAL CONTINUITY TESTER		√			C/O EQMT
• MEASURING TAPES	√				
• OTV + NECESSARY SERVICE & REFUEL EQMT		√			

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In summary, 21 pieces of construction equipment were identified in the SOC main study, 15 of which had comparable satellite servicing functions. Considering these 15 pieces of comparable equipment, 9 of them were identical to satellite servicing equipments, either as "required" or as "potential use", and could be used directly. The remaining 6 comparable equipments had functions similar to satellite servicing and were, therefore, investigated further to assess the impacts of using common equipments.

4.3.2 COMPARISON OF SIMILAR EQUIPMENTS

The six construction equipments, with their similar function satellite servicing equipments, are shown in Figures 4.3-1 thru 4.3-5.

Figure 4.3-1 shows the Mobile Cherry Picker, a new piece of construction equipment with 18 m total reach. At its tip it can mount on open cherry picker (OCP) which, in turn, can mount a payload handling tool. The whole is mounted on a carriage to run along the SOC track.

For satellite servicing, two STS manipulators are mounted on a carriage to provide a mobile platform. One manipulator mounts an OCP at its tip while the other manipulator mounts an appropriate end effector. Two manipulator arms are provided which allows the crewman on the OCP to control both arms, yet position himself to watch and control the handling of the payload by the other arm from a suitable, safe location. This is of particular significance when, for example, capturing a free flying satellite prior to berthing. There is also operational flexibility in the two-arm system when, for example, the second manipulator arm can fetch and carry change out modules for the crewman working from the OCP. Questions of reach, degrees of freedom and load handling capabilities are considered elsewhere in this report.

Payload handling tools require a "small object" and "large object" tool for construction work. If proven to be suitable, these tools can be adapted to attach to the STS manipulator snare end effector for satellite servicing.

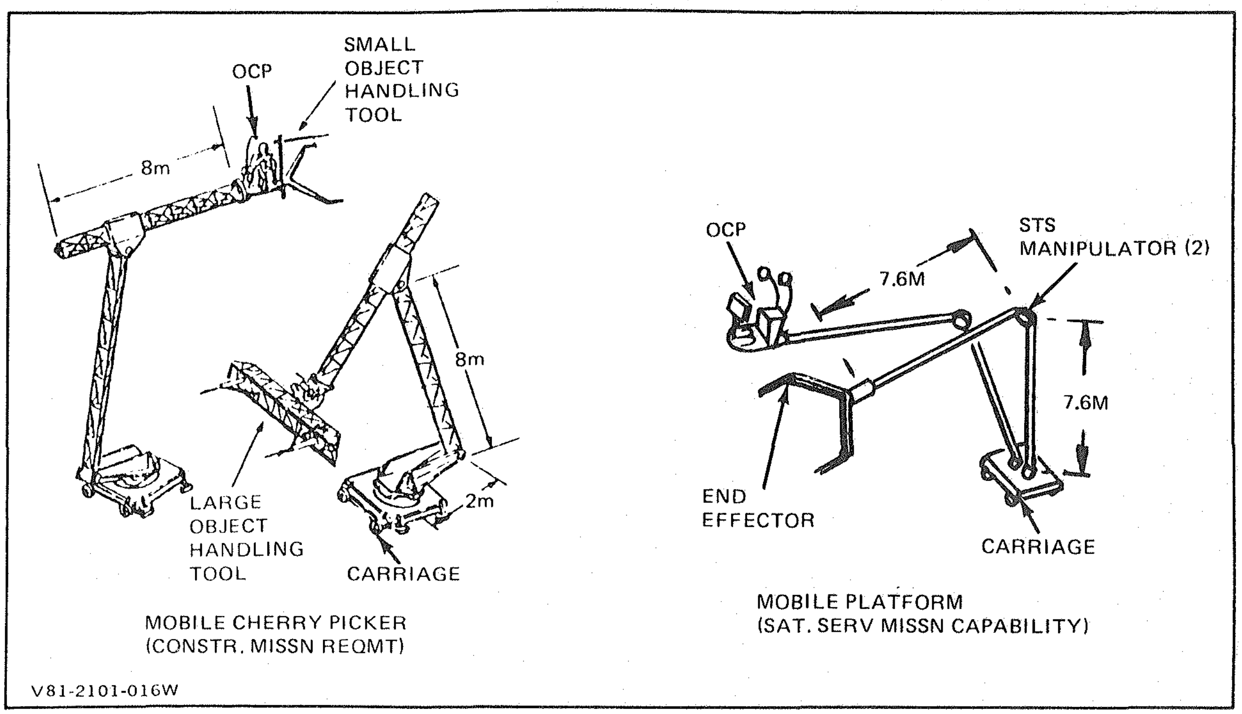

Fig. 4.3-1 Similar Equipments – Mobile Cherry Picker and Mobile Platform

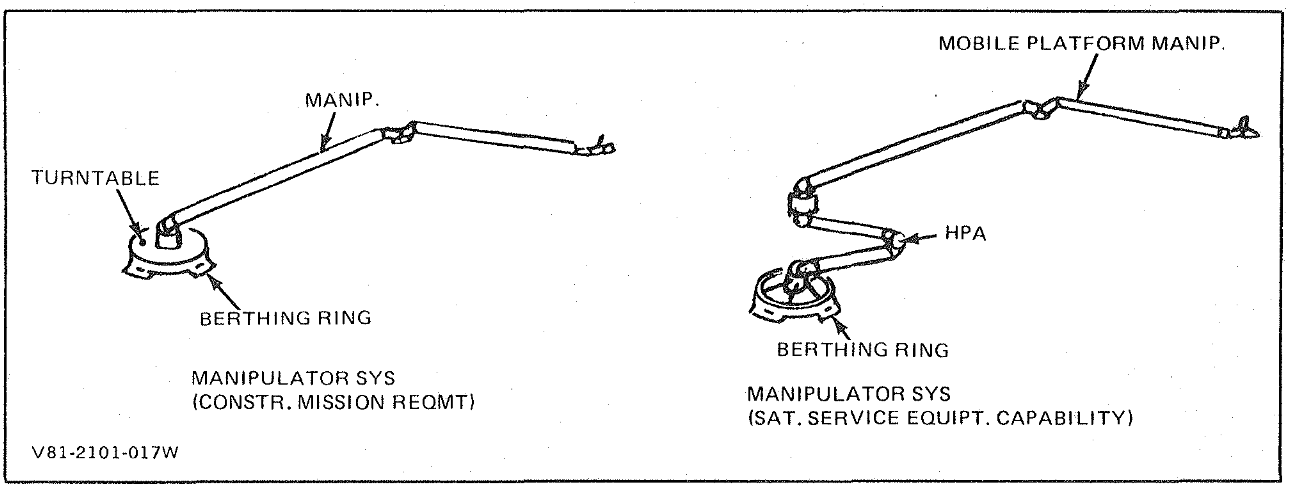

Fig. 4.3-2 Similar Equipments – Manipulator Systems

The Manipulator System for construction missions, shown in Figure 4.3-2, is used for build up and operations of the Initial SOC. It comprises a manipulator mounted to a turntable, which is mounted in turn to a berthing ring. The manipulator is defined as being based on the Orbiter RMS configuration.

Since the manipulators for the satellite servicing mobile platform are also based on the Orbiter RMS, this piece of equipment can be used directly. The handling and positioning aid (HPA) has the capability of turning and, although elaborate for the function, it could be used as a turntable. The berthing ring is standard. Therefore, a manipulator system, which is assembled from satellite servicing equipment, can be provided for construction activities.

The primary objective of the Turntable/Tilt Table (Figure 4.3-3) is to reorient a workpiece of accessibility by a cherrypicker or an EVA crewman. The HPA, presently being developed for orbiter operations and used for satellite servicing, has the same objectives and provides similar degrees of freedom.

Figure 4.3-4 shows the articulated construction fixture necessary to provide the support and positioning interface between the workpiece and the SOC. It has an articulating arm mounted to the turntable/tilt table and has a payload attachment grapple fixture at its tip. The HPA offers similar articulations and can, with suitable interface, mount the same grapple fitting at its tip. Questions of reach, degrees of freedom, and load handling capabilites are considered elsewhere in this report.

An umbilical system is necessary to carry power, data, and (in the growth SOC) fluids to the work piece. The system, shown in Figure 4.3-5 for construction missions, has an articulated arm which mounts the utilities at its tip. These umbilicals will be located at fixed locations on the SOC. Although not presently incorporated in the HPA, since it is still in the early development stage, it is envisaged that an umbilical system will be incorporated into the flight version. A

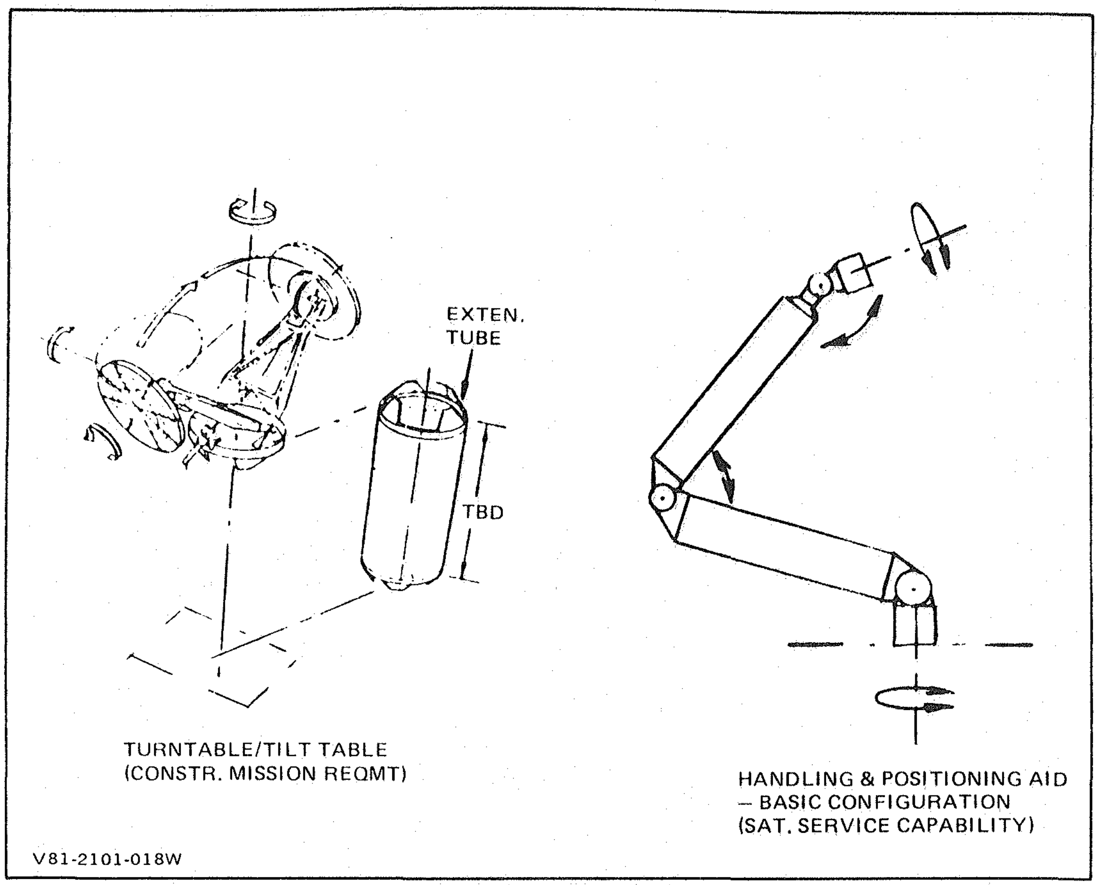

Fig. 4.3-3 Similar Equipments – Turntable/Tilttable and HPA

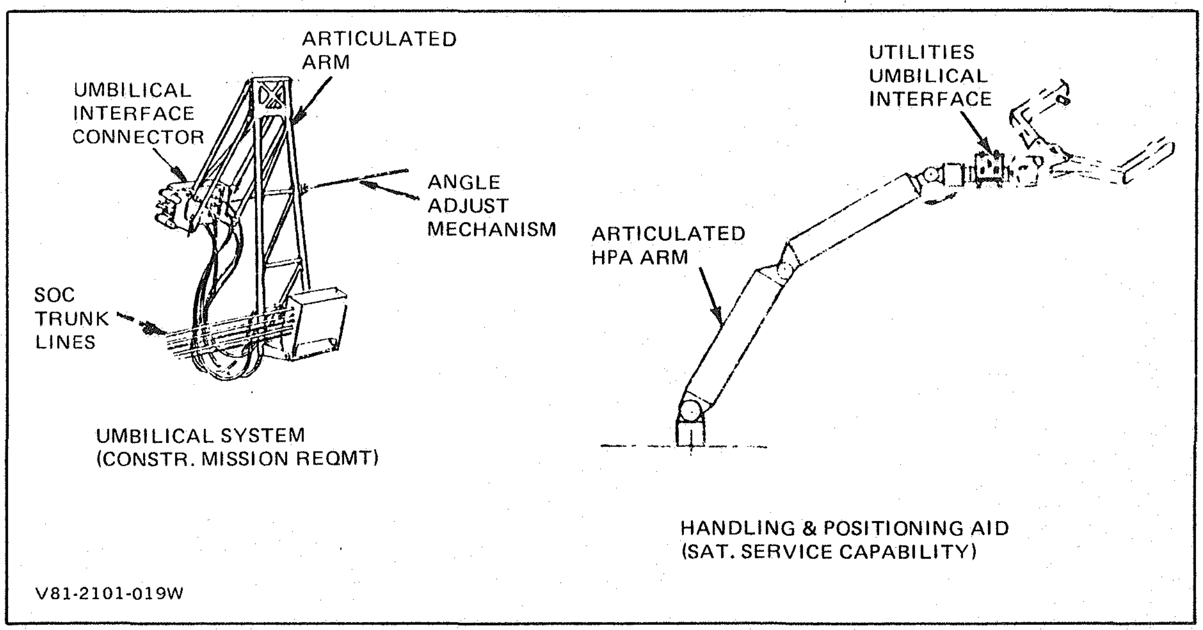

Fig. 4.3-4 Similar Equipments – Construction Umbilical System and HPA Umbilical System

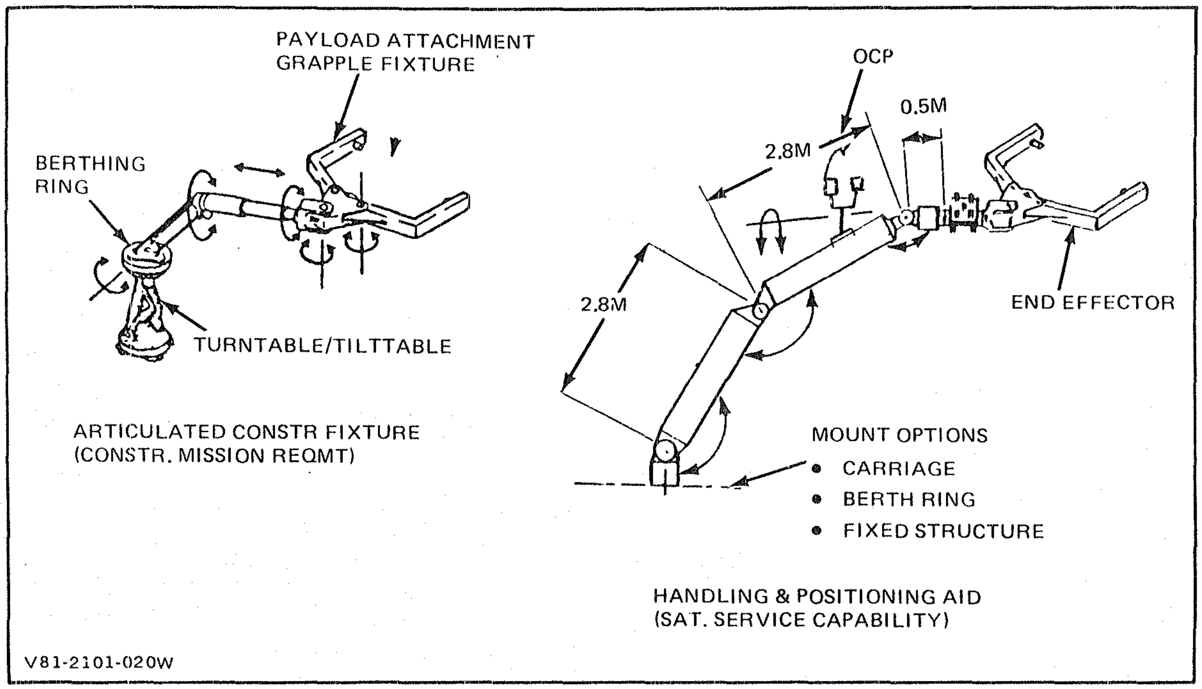

Fig. 4.3-5 Similar Equipments – Articulated Construction Fixture and HPA

panel carrying the utilities will probably be located near the tip and the lines run up the arm. Direct mating for the workpiece to the umbilical panel will probably prove to be too restricting on design and may, therefore, be flying leads to be connected to a workpiece panel by the EVA crewman. Thus, the utilities would be readily available on the piece of equipment which supports the workpiece. However, in locations where the HPA is not required, the provision of utilites at an interface may require development of the construction umbilical system. To compare these equipments, requirements for the six construction equipments were taken from the main study and listed, as shown in Table 4.3-7. Capabilities of the comparable pieces of satellite service equipment were then listed and compared, item for item, with the requirements.

Table 4.3-8 summarizes the results of this comparison and shows that most of the requirements could be satisfied directly. Some requirements were TBD and will require further study when they are known. This table considered those requirements which cannot be satisfied directly by the capabilites and offers candidate solutions.

Considering the Mobile Cherry Picker, its reach is required to be 18 m to place an OTV in its service hangar. There is, however, an elevator proposed to lift the OTV and its carriage out of the hangar and put it in line with the track system. Alternately, the latest SOC configuration shows a hangar which is located so that an OTV can be moved directly onto the track system. Either of these proposals would, presumably, reduce the required 18-m reach. The satellite service mobile platform arms offer a tip reach of 15.24 m, excluding added handling tools. Regarding maintenance, the satellite service mobile platform arm is an STS manipulator, which is designed to be maintained on the ground, whereas te requirement is for EVA space maintenance. It is proposed that spare arms be kept at the SOC to replace an operating arm for regular maintenance or for repair. This arm would then be transported to ground by the Orbiter in its unused starboard RMS location, serviced, then returned to SOC. Alternatively, the arm could be modified for EVA maintenace. The last

TABLE 4.3-7 EQUIPMENTS COMPARISON – CONSTRUCTION REQUIREMENTS vs SAT. SERVICE CAPABILITIES

CONSTRUCTION EQMT REQMT	SAT. SERVICE EQMT CAPABILITY
MOBILE CHERRY PICKER MAXIMUM LOAD – THE LARGEST AND THE HEAVIEST LOAD TO BE MOVED IS A FULLY FUELED OTV (APPROX 40,000 kg) PLUS ITS HEAVIEST PAYLOAD (APPROX 15,000 kg), FOR A TOTAL OF 55,000 kg. THIS REQUIREMENT COMES FROM THE CONTINGENCY CONDITION WHERE A JUST-LAUNCHED OTV MALFUNCTIONS AND MUST BE RECAPTURED.	**MOBILE PLATFORM** – SPAR SIMULATION RUNS SHOW THAT IT IS FEASIBLE TO BERTH ORBITER (90,000 kg) TO SOC USING ORBITER MANIPULATORS, IF SOFTWARE IS MODIFIED [RMS 2ND USERS CONFERENCE]
MAXIMUM SPEED – TBD.	– MANIPULATOR TIP SPEED IS 0.2 FT/SEC WITH 14,500 kg.
REACH ENVELOPE – 18-m TIP RADIUS TO PLACE OTV IN HANGAR.	– MANIPULATOR TIP RADIUS IS 15.24 m
MAXIMUM SIZE PAYLOAD – 4.2 m DIAMETER X TBD m LONG (DEPENDS ON SPACECRAFT GEOMETRY WHEN ATTACHED TO AN OTV).	– MANIPULATOR HANDLES AT LEAST 4.2 m DIA X 17.5 m PAYLOAD. CONTRIBUTION TO INERTIA IS THE RESTRICTION.
TRANSLATION CAPABILITY – PROVIDE CAPABILITY TO MOVE ALONG THE FACILITY TRACK NETWORK. THIS REQUIREMENT IS BASED ON THE FACT THAT THE SOC OPERATIONAL AREAS (CONSTRUCTION AND FLIGHT SUPPORT) WERE SEPARATED TO ALLOW PLENTY OF WORKING ROOM. IN ADDITION, PROVIDING TRANSLATION CAPABILITY PROVIDES AN ADDITIONAL DEGREE OF FREEDOM IN MOVING PAYLOADS.	– CAN UTILIZE SAME CARRIAGE AS DEFINED FOR MOBILE CHERRY PICKER.
MANNED REMOTE WORK STATION – A MANNED WORK STATION TO BE LOCATED AT THE END OF THE CHERRY PICKER BOOM ASSEMBLY. THIS WORK STATION TO PROVIDE FOOT RESTRAINTS, LIGHTING, AND A CONTROL CONSOLE.	– OPEN CHERRY PICKER (OCP) HAS CAPABILITY.
END EFFECTOR GRAPPLE SYSTEM – PROVIDE A GRAPPLE SYSTEM FOR EASILY CHANGING THE END EFFECTORS TO BE ATTACHED TO THE WORK STATION. TWO TYPES OF END EFFECTORS HAVE BEEN DEFINED – A SMALL OBJECT HANDLING TOOL AND A LARGE OBJECT HANDLING TOOL.	– MANIPULATOR CAN GRAPPLE SPECIAL PURPOSE END EFFECTORS.
CONTROL MODES – THE CHERRYPICKER MUST BE CONTROLLABLE FROM THE MANNED REMOTE WORK STATION AND REMOTELY FROM THE HABITAT MODULE COMMAND CENTER. THE NUMBER AND TYPES OF CONTROL MODES HAVE NOT BEEN DEFINED.	– MOBILE PLATFORM SYSTEM WILL PROVIDE THESE CAPABILITIES.
MAN-RATED – THE MOBILE CHERRYPICKER MUST INCORPORATE FEATURES WHICH MAKE IT A MAN-RATED SYSTEM.	– ORBITER MANIPULATOR IS MAN RATED.
MAINTAINABILITY – DESIGN THE CHERRYPICKER TO BE MAINTAINABLE VIA EVA.	– ORBITER MANIPULATOR IS GROUND MAINTAINED.
RELIABILITY – THE MOBILE CHERRYPICKER IS USED IN ALMOST ALL OF THE SOC OPERATIONS. IT MUST, THEREFORE, BE A HIGHLY RELIABLE SYSTEM SO THAT DOWN TIME IS MINIMIZED. THE EXACT RELIABILITY REQUIREMENTS ARE TBD.	– MANIPULATOR CAPABILITIES WILL BE EVALUATED WHEN REQUIREMENTS ARE KNOWN.
FAIL OPERATIONAL/FAIL SAFE – THE MANIPULATOR SHALL BE DESIGNED FOR FAIL OPERATIONAL/FAIL SAFE PERFORMANCE.	– MANIPULATOR IS FAIL SAFE.
STOPPING DISTANCE – THE MAXIMUM STOPPING DISTANCE OF THE MANIPULATOR, AS MEASURED AT THE WRIST TO MRWS INTERFACE, SHALL BE LIMITED TO 2 FT IRRESPECTIVE OF ITS LOADING CONDITIONS (UP TO 55,000 kg PAYLOAD). V81-2101-014(1)W	– MANIPULATOR STOPS IN 2 FT AT 0.2 FT/S WITH 14,500 kg. PAYLOAD. CAPABILITY WITH 55,000 kg STOPPED IN 2 FT IS A FUNCTION OF RATE.

TABLE 4.3-7 EQUIPMENTS COMPARISON – CONSTRUCTION REQUIREMENTS vs SAT. SERVICE CAPABILITIES (contd)

CONSTRUCTION EQMT REQMT	SAT. SERVICE EQMT CAPABILITY
MOBILE CHERRY PICKER	**MOBILE PLATFORM**
TRACK AND CAPTURE – THE MANIPULATOR SHALL HAVE THE CAPABILITY TO TRACK AND CAPTURE INCOMING SPACECRAFT UP TO 55,000 kg MASS WITH SPACECRAFT VELOCITIES RELATIVE TO SOC OF UP TO TBD FT/S AND RATES OF TBD DEGREES/S.	– MANIPULATOR CAPTURES 14,500 kg MOVING AT 0.1 FT/S. CAPABILITY WITH 55,000 kg TO BE EVALUATED WHEN REQUIREMENTS ARE KNOWN.
POWER – POWER SHALL BE SUPPLIED TO THE MANIPULATOR BY RECHARGEABLE BATTERIES MOUNTED ON THE CARRIAGE. VOLTAGE AND POWER LEVELS TBD.	– THIS SYSTEM WILL PROVIDE
DUTY CYCLE – THE CHERRYPICKER SHALL BE CAPABLE OF OPERATING FOR 16 HOURS IN ANY 24-HOUR PERIOD.	– REQUIRES FUTHER STUDY
CCTV'S AND LIGHTING – SHALL BE PROVIDED AT TBD LOCATIONS ON THE MANIPULATOR. VIDEO DATA SHALL BE TRANSMITTED TO THE D&C PANELS IN THE HABITAT MODULE. PROVISION SHALL BE MADE FOR TWO PARALLEL VIDEO CHANNELS TO THE MRWS SUCH THAT THE MRWS OPERATOR MAY SELECT ANY TWO CAMERA COMBINATIONS FROM THOSE MOUNTED ON THE MANIPULATOR AND ANYWHERE ELSE ON SOC (SUCH AS THE OTV HANGAR).	– MANIPULATOR PROVIDES CCTV & LIGHTING. THE REQUIREMENTS CAN BE INCORPORATED INTO THE SYSTEM
PAYLOAD HANDLING TOOLS A SMALL OBJECT HANDLING TOOL IS AFFIXED TO THE MOBILE CHERRYPICKER'S MANNED WORKSTATION END-EFFECTOR VIA A QUICK-DISCONNECT GRAPPLE FITTING. THIS TOOL IS OPERATED FROM THE WORKSTATION CONTROL PANEL. THE TOOL HAS ADJUSTABLE ARMS AND INTERCHANGEABLE TIPS SO THAT IT CAN BE CONFIGURED TO HANDLE A VARIETY OF OBJECTS. A LARGE-OBJECT HANDLING TOOL IS AFFIXED TO THE MOBILE CHERRYPICKER'S MANNED WORKSTATION END-EFFECTOR VIA A QUICK-DISCONNECT GRAPPLE FITTING. THIS TOOL IS OPERATED FROM A CONTROL STAND THAT IS WITHIN REACH OF THE OPERATOR AFTER THE TOOL IS ATTACHED TO THE MOBILE CHERRYPICKER. THE TOOL HAS ADJUSTABLE ARMS AND TIPS THAT CAN BE CONFIGURED TO HANDLE A VARIETY OF LARGE OBJECTS.	**END EFFECTORS** – MANIPULATOR PROVIDES A STANDARD END EFFECTOR WHICH CAN QUICK-DISCONNECT OTHER END EFFECTORS SUCH AS HANDLING TOOLS – CONSTRUCTION HANDLING TOOLS MAY BE OF USE IN SATELLITE SERVICING
MANIPULATOR SYSTEM	**MOBILE PLATFORM MANIPULATOR + HPA**
MAXIMUM LOAD – THE LARGEST AND HEAVIEST LOAD TO BE HANDLED BY THE MANIPULATOR IS THE HABITAT MODULE NO. 2 (21,740 kg) WHICH IS PUT INTO PLACE DURING THE SOC BUILD-UP OPERATIONS.	– MANIPULATOR CAN HANDLE & BERTH 90,000 kg IF CONTROL SOFTWARE IS MODIFIED.
MAXIMUM SPEED – TBD.	– TIP SPEED 0.2 FT/S FOR 14,500 kg. EVALUATE WHEN REQUIREMENTS KNOWN.
MAXIMUM REACH – APPROXIMATELY 50 FT. THIS REACH DISTANCE IS ESTABLISHED BY THE REQUIREMENTS FOR INSTALLING HM2 ONTO SM2.	– 15.24 m (50 FT)
END EFFECTOR – USE THE STANDARD ORBITER RMS END EFFECTOR.	– USECS STANDARD END EFFECTOR
CONTROL – THIS MANIPULATOR IS REMOTELY CONTROLLED FROM THE HM1 COMMAND CENTER VIA THE OPERATIONS CONTROL PANEL. V81-2101-014(2)W	– MOBILE PLATFORM SYSTEM CONTROLLABLE FROM HM1

TABLE 4.3-7 EQUIPMENTS COMPARISON – CONSTRUCTION REQUIREMENTS vs SAT. SERVICE CAPABILITIES (contd)

CONSTRUCTION EQMT REQMT	SAT. SERVICE EQMT CAPABILITY
MANIPULATOR SYSTEM (CONTD) ARTICULATIONS – THE FOLLOWING DEGREES OF FREEDOM ARE REQUIRED: – SHOULDER YAW (±360°) – SHOULDER PITCH (-2° TO +145°) – ELBOW PITCH (+2° TO -160°) – WRIST PITCH (+120° TO -120°) – WRIST YAW (+120° TO -120°) – WRIST ROLL (±447°)	**MOBILE PLATFORM MANIPULATOR + HPA (CONTD)** – MEETS ALL REQUIREMENTS EXCEPT SHOULDER YAW WHICH IS ±180°
TURNTABLE ROTATION – ±360°	– HPA PROVIDES
DATA AND POWER – PROVIDED VIA THE STANDARD UTILITY INTERFACES CONTAINED IN THE STANDARD SOC BERTHING PORT.	– WILL UTILIZE STANDARD BERTHING RING CARRYING DATA & POWER
INTERFACES – TURNTABLE MATES TO SM1 BERTHING PORT NO. 2 VIA A STANDARD BERTHING FIXTURE AND TO THE BOOM'S SHOULDER JOINT.	– HPA REQUIRES MOUNTING STRUCTURE TO MATE WITH BERTHING RING
TURNTABLE/TILTTABLE DEGREES OF FREEDOM – THE FIGURE SHOWS THE VARIOUS DEGREES OF FREEDOM THAT ARE REQUIRED (4 DOF SHOWN)	**HANDLING & POSITIONING AID** – DTA HAS 5 DOF
DIMENSIONS – THE DIMENSIONS OF THE TURNTABLE/TILTTABLE ARE TBD.	– 6 m REACH. EVALUATE WHEN REQUIREMENTS KNOWN
INTERFACES – INITIAL AND OPERATIONAL SOC – BERTHED TO ONE OF THE BERTHING PORTS. MECHANICAL ELECTRICAL POWER, AND CONTROL SIGNAL INTERFACES ARE MADE THROUGH THE BERTHING RING. GROWTH SOC – MOUNTED ON A CARRIAGE THAT IS, IN TURN, MOUNTED ON THE CONSTRUCTION FACILITY PIER. MECHANICAL INTERFACE IS THE WHEELS AND TRACKS. ELECTRICAL POWER AND CONTROL SIGNALS INTERFACES ARE TBD. NOTE – THIS CARRIAGE SHOULD BE IDENTICAL TO THE CARRIAGE USED BY THE MOBILE CHERRYPICKER.	 – MOUNT TO BERTHING RING USING A DEDICATED MOUNTING STRUCTURE – MOUNT TO CARRIAGE, USE SAME STRUCTURE AS FOR BERTH RING MOUNT
TURNTABLE INTERFACE – THE PLATEN OF THE TURNTABLE SHOULD BE CONFIGURED SO THAT A WIDE VARIETY OF MECHANICAL ATTACHMENTS COULD BE MADE. A PATTERN OF THREADED HOLES SHOULD SUFFICE.	– HPA TIP WILL PROVIDE STANDARD INTERFACE TO MOUNT END EFFECTORS & ATTACHMENTS
CONTROL – THE VARIOUS MECHANISMS SHOULD BE CONTROLLABLE VIA THE SOC DATA BUS INTERFACE.	– CAN BE INCORPORATED
EXTENSION STRUCTURE – A SEPARATE TBD LONG EXTENSION STRUCTURE SHOULD BE PROVIDED SO THAT THE TURNTABLE CAN BE OFFSET FROM THE SOC STRUCTURES.	– HPA CAN OFFSET TIP 6 m. EVALUATE WHEN REQUIREMENTS KNOWN
MASS AND SIZE OF ARTICLE TO BE REORIENTED – ARTICLES RANGE IN SIZE FROM 1 m DIAMETER TO 100 m DIAMETER; MASS RANGE IS 1000 kg TO 100,000 kg. V81-2101-014(3)W	– SIZE CAN BE ACCOMMODATED – MASS & INERTIA DEPENDS ON CONTROL SYSTEM. REQUIRES FURTHER STUDY WHEN FLIGHT HPA CAPABILITIES ARE KNOWN.

TABLE 4.3-7 EQUIPMENTS COMPARISON – CONSTRUCTION REQUIREMENTS vs SAT. SERVICE CAPABILITIES (contd)

CONSTRUCTION EQMT REQMT	SAT. SERVICE EQMT CAPABILITY
ARTICULATED CONSTRUCTION FIXTURE	**HANDLING & POSITIONING AID (HPA)**
THE FIXTURE SHALL BE DESIGNED PRIMARILY FOR THE POTENTIAL "CONSTRUCTABLE" SPACECRAFT OF THE 1988 TO 1993 TIME SPAN. THIS DOES NOT PRECLUDE ITS BEING USED FOR POST-1993 SPACECRAFT.	– IOC FOR HPA IS 1986
THE FIXTURE PROVIDES THE SUPPORT AND POSITIONING INTERFACE BETWEEN THE SPACECRAFT AND THE SOC.	– HPA PROVIDES
THE FIXTURE SHOULD ATTACH TO THE TURNTABLE/TILTTABLE.	– PROVIDES TURNTABLE/TILTTABLE FUNCTION
THE FIXTURE MUST BE CAPABLE OF ALIGNING THE CENTERLINE OF THE SPACECRAFT WITH THE CENTERLINE OF THE OTV TO FACILITATE MATING OF THE VEHICLE TO THE SPACECRAFT.	– HPA IS CAPABLE
THE FIXTURE MUST BE CONFIGURED SO THAT IT CAN BE RETRACTED OUT OF THE WAY AFTER THE SPACECRAFT AND OTV ARE MATED (I.E., AFTER THE SPACECRAFT IS SUPPORTED BY THE OTV).	– IS CAPABLE
THE FIXTURE DESIGN SHOULD IMPOSE A MINIMAL DESIGN IMPACT ON THE SPACECRAFT.	– ONLY REQUIRES MATING FITTING FOR END EFFECTOR
WHEREVER FEASIBLE, FIXTURE ATTACHMENT DEVICES ON THE SPACECRAFT SHOULD SERVE MULTIPLE PURPOSES (E.G., THE HARDPOINTS USED TO ATTACH THE SPACECRAFT TO THE TRANSPORTATION PALLET SHOULD ALSO BE USED AS THE HARDPOINTS FOR ATTACHING THE FIXTURE, IF FEASIBLE).	– FUNCTION OF THE END EFFECTOR
THE DIMENSIONS OF THE FIXTURE ARE TBD.	– HPA HAS 6 m REACH. EVALUATE WHEN REQUIREMENTS KNOWN
THE DEGREES OF FREEDOM PROVIDED BY THE FIXTURE ARE TBD.	– HPA DTA PROVIDES 5 DOF. EVALUATE WHEN REQUIREMENTS ARE KNOWN
CONSTRUCTION UMBILICAL SYS	**UMBILICAL I/F ON HPA**
THE UMBILICAL SYSTEM CONNECTS THE SOC UTILITIES TO THE SPACECRAFT. THESE UTILITIES INCLUDE POWER, DATA BUS, AND (IN THE GROWTH CONFIGURATION ONLY) FLUIDS.	– HPA UMBILICAL WILL PROVIDE THESE UTILITIES
THE UMBILICAL SERVICES SHOULD BE REMOTELY CONTROLLED FROM THE SOC COMMAND CENTERS VIA DATA BUS SIGNALS TO A MICROPROCESSOR VALVE/SWITCH CONTROLLER LOCATED ON THE UMBILICAL STATION.	– SYSTEM CAN INCORPORATE

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TABLE 4.3-8 SIMILAR EQUIPMENTS COMPARISON SUMMARY

CONSTR. EQMT REQMTS	SAT. SERVICE EQMT CAPABILITY	CANDIATE RESOLUTIONS
MOBILE CHERRY PICKER	**MOBILE PLATFORM**	
• 17 REQMTS DEFINED	• 10 REQMTS SATISFIED	
	• 3 REQMTS ARE TBD	
	• 1 REQMT FOR DUTY CYCLE REQUIRES FURTHER STUDY	– FURTHER STUDY WHEN INFO AVAILABLE
• UNSATISFIED REQMTS		
– REACH 18 m AT TIP (TO PUT OTV IN HANGER)	– 15.24 m TIP RADIUS	– INCORPORATE PROPOSED HANGAR ELEVATOR. RE-EVALUATE REQMT
– EVA MAINTENANCE	– STS MANIP GROUND MAINTAINED	– FREE RIDE MANIP TO GROUND IN ORBITER STBD RMS LOCATION
– FAIL OP/FAIL SAFE	– STS MANIP IS FAIL SAFE	– 2ND MANIP ALLOWS WORK AROUND WHILE FAILED MANIP REPAIRED/ REPLACED
HANDLING TOOLS	**END EFFECTORS**	
– SMALL OBJECT HANDLING – LARGE OBJECT HANDLING	– SIMILAR TOOLS REQD	– DESIGN THE TOOL MOUNT TO MATE WITH MANIP SNARE END EFFECTOR
– QUICK DISCONNECT MOUNT	– STS MANIP STANDARD END EFFECTOR PROVIDES THIS	
MANIPULATOR SYSTEM	**MOBILE PLTFM ARM + HPA + BERTH RING**	
• 9 REQMTS DEFINED	• 6 REQMTS SATISFIED	
	• 1 REQMT IS TBD	– FURTHER STUDY WHEN DEFINED
• UNSATISFIED REQMTS		
– ARM ARTICULATION FOR SHOULDER YAW IS ± 360°	– STS MANIP PROVIDES ± 180° FOR SHOULDER YAW	– ACCEPT, SINCE 360° IS COVERED
– MOUNT MANIP TURNTABLE ON STD BERTHING FIXTURE	– HPA DOES NOT MOUNT DIRECTLY TO BERTHING FIXTURE	– PROVIDE INTERFACE STRUCTURE
TURNTABLE/TILTTABLE	**HANDLING & POSITIONING AID**	
• 8 REQMTS DEFINED	• 4 REQMTS SATISFIED	
	• 2 REQMTS TBD	– FURTHER STUDY WHEN DEFINED
• UNSATISFIED REQMTS		
– MOUNT ON STD BERTHING FIXTURE FOR INITIAL & OPNL SOC	– DOES NOT MOUNT DIRECTLY TO BERTHING FIXTURE	– PROVIDE INTERFACE STRUCTURE
– MOUNT ON CARRIAGE FOR GROWTH SOC	– DOES NOT MOUNT DIRECTLY TO CARRIAGE	– PROVIDE INTERFACE STRUCTURE
ARTICULATED CONSTR FIXTURE	**HANDLING & POSITIONING AID**	
• 9 REQMTS DEFINED	• 7 REQMTS SATISFIED	
	• 2 REQMTS ARE TBD	– FURTHER STUDY WHEN DEFINED
UMBILICAL SYS	**HPA UMBILICAL**	
• 5 REQMTS DEFINED	• REQMTS SATISFIED	
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concern with the Cherry Picker is that it is required to be fail operation/fail safe, but the STS manipulator is fail safe. It is considered that the two manipulator system of the mobile platform allows the second manipulator to continue a task or, at the least, to hold the workpiece while the failed manipulator is replaced.

Handling tools present no problem since they are general purpose equipment and of use for construction and servicing. They can be mounted to the tip of the mobile platform manipulator if the interface is designed to be compatible with the manipulator standard snare end effector.

The Manipulator System, required for operations and build-up of the Initial SOC, bases its manipulator requirements on those of the STS manipulator, which provides ±180 degrees of shoulder yaw movement. However, the requirement is at variance with this since it calls for ±360 degrees of shoulder yaw. It is suggested that ±180 degrees be accepted, since it covers 360 degrees in total. If an HPA it used as the system turntable, then an interface structure is necessary to mount the system on a berthing ring.

Use of an HPA as a turn/tilt table requires that it be mounted on a standard berthing ring for use on initial and operational SOC and that it be mounted on a carriage for the growth SOC. Here again, interface structures are necessary to mount the HPA.

The articulated construction fixture and the umbilical system have their requirements satisfied by an HPA.

It is considerd that the only significant issues are those concerning the mobile cherry picker/mobile platform and that they are capable of resolution, as suggested.

4.3.3 EVOLUTIONARY GROWTH OF COMMON EQUIPMENTS

Much of these common usage equipments are used directly, or developed, from Orbiter hardware. Figure 4.3-6 shows how the RMS, OCP, and HPA lead into initial, operational, and growth SOC equipments and the inter-relationships of those equipments over the early SOC years of operation.

4.3.4 IMPACT OF VARIATIONS IN SATELLITE SERVICE TRAFFIC MODEL

Results of the preceding tasks answer, in general, the requirements for this task. Analysis of the current mission model shows that the facilities and equipments defined for satellite servicing at operational growth SOC's will support the missions until 1995, after the planned introduction of growth SOC. Subsequent to that date, projected traffic may require parallel satellite service operations which may demand additional equipments. These will be duplications of the equipments then existing.

Variations in the traffic model may introduce satellite servicing at the initial SOC. A configuration to provide this capability was shown in Figure 4.2-57 which shows the addition of an HPA to the equipment requirements.

Figure 4.3-7 shows the impact that these increases in traffic may have on the introduction of satellite service equipments.

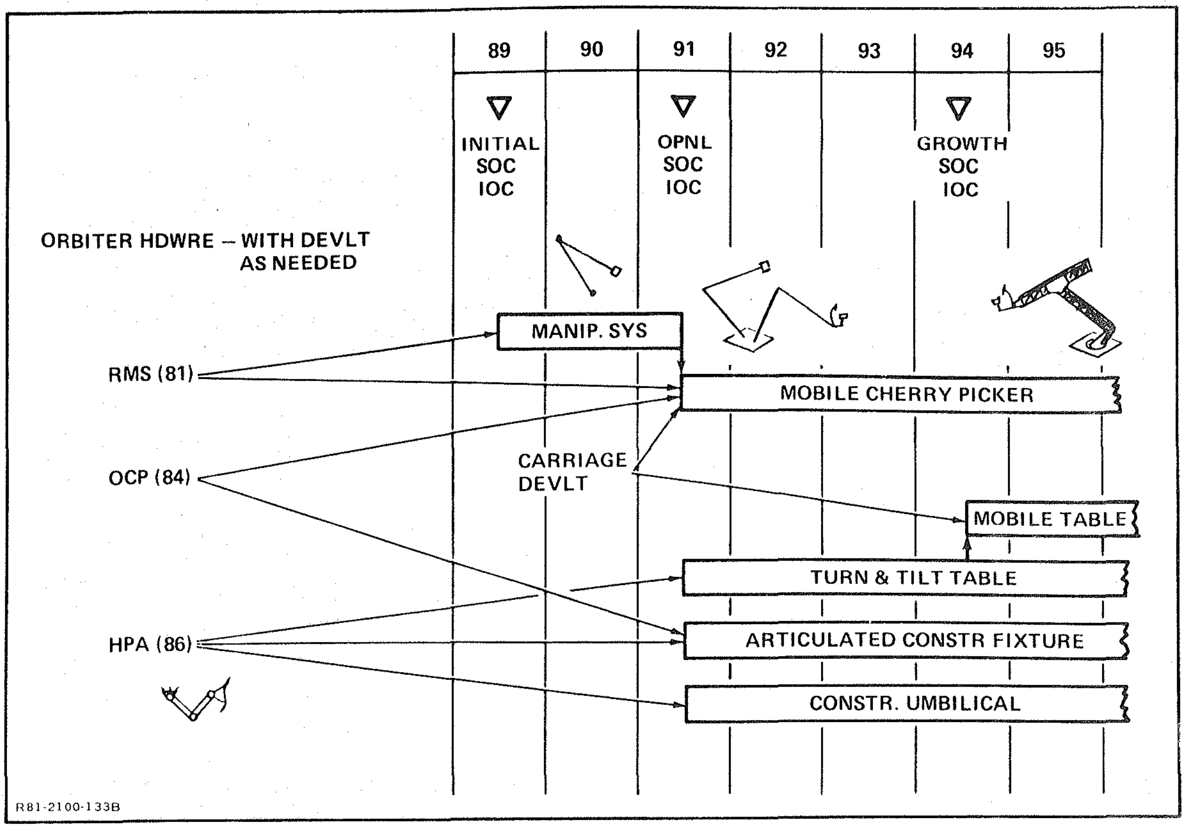

Fig. 4.3-6 Evolutionary Growth of Common Sat. Service & Construction Equipments

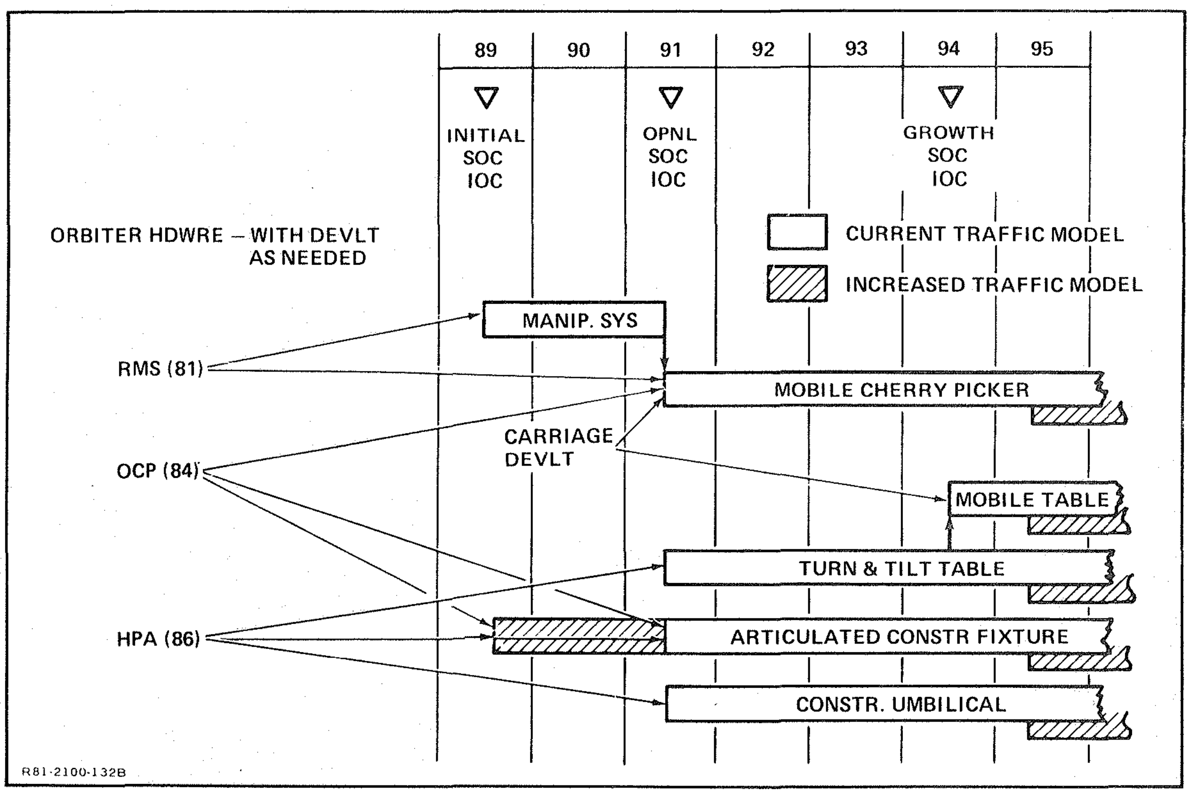

Fig. 4.3-7 Impact on Equipments IOC of Increased Satellite Service Traffic

SUBSECTION 4.3 REFERENCES

4.3-1 Satellite Services System Analysis Study, Feb 1981 LMSC-D792242, Lockheed Missiles & Space Co.

4.3-2 Satellite Services System Analysis Study, Aug 1981 CSS-SSS-RP009, Grumman Aerospace Corp.

4.3-3 Space Operations Center System Analysis, Final Report, D180-26495-4, July 1981, The Boeing Company

SUBSECTION 4.4 TABLE OF CONTENTS

4.4 SERVICING MISSION NEEDS AND BENEFITS

The objective of this task was to survey and analyze the user mission needs for servicing satellites in low earth orbit and geosynchronous orbit. Particular attention was given to the user mission requirements as they relate to SOC. Alternate satellite services have been identified together with the benefits that SOC could provide to the user. In addition, satellite servicing needs have been forecast for the period between 1985 and 2000. Co-orbiting satellite missions, which can be serviced at SOC, and remote satellites, which can be reached from SOC for servicing in situ, have also been identified. Potential savings have been defined for using SOC to service satellites in LEO and GEO. Finally the benefits of using the SOC to service satellites, in lieu of the Orbiter, are identified.

4.4.1 SATELLITE SERVICING NEEDS FORECAST

4.4.1.1 User Mission Requirements

The overall mission model includes a broad array of satellites and payloads which are deployed into various orbits. The satellites in low altitude orbits and higher energy orbits can be classified with respect to the Space Operations Center in the manner shown in Figure 4.4-1. Some payloads will be attached directly to the SOC, while others will co-orbit as free flying satellites that can be reached from SOC. At higher altitudes, the satellites will be deployed with either a low energy or high energy upper stage that will deliver it to its proper orbit as depicted by the LEO propulsion, geosynchronous and planetary satellite classes. Each of these satellites can be supported by the Space Operations Center for in-orbit verification testing, checkout and launch into final orbit. Satellites at very high inclination orbits are beyond normal reach from the SOC and must rely upon services provided by the Orbiter.

The mission model encompasses both satellites and payloads for scientific mission, space applications missions, and DOD missions.

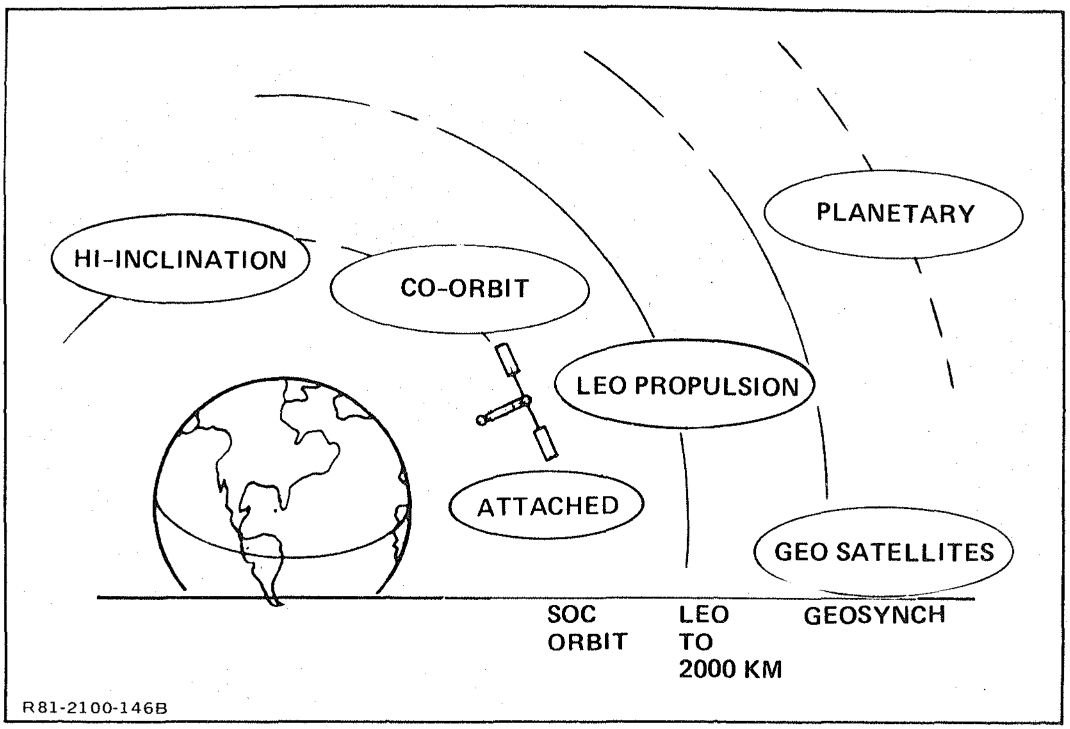

Figure 4.4-1 SOC Satellite Classes

Potential commerical and foreign missions for the shuttle orbiter are also included.

As shown in Figures 4.4-2 through 4.4-4 most space science satellites for astrophysics and solar terrestrial physics are assemble from the low orbital altitude and low inclination of the SOC. Hence the SOC could be quite useful in supporting their initial deployment and providing in-orbit maintenance. At the end of the satellite mission, the SOC could also aid in the final operations to remove the satellite from orbit.

Planetary spacecraft, of course, can only be supported for their initial launch. The Space Operation Center could support on-orbit assembly of the unmanned planetary spacecraft with a reusable upper stage or faciltitate on-orbit buildup of a large planetary exploration vehicle. All planetary spacecraft launches from SOC must be timed to occur when the line of nodes coincide with the plane of the ecliptic. While this situation occurs at least seven times each year with a 400-km altitude, 28.5 degree orbit, it may not be at the optimal time to perform certain minimum energy planetary missions. However multiple impulse departure maneuvers can broaden the on-orbit launch window while using less propellant than a single departure burn.

In contrast to the space science missions, very few of the earth sensing missions on resource observations or global environment are accessible in 28.5 degree Orbit to LEO SOC. These missions generally operate in highly inclined polar and sun synchronous orbits or are deployed into geostationary orbits as shown in Figures 4.4-5 through 4.4-7. The high oribtal inclination missions must rely upon the Shuttle or expendible launch vehicles for initial deployment. Retrieval for in-orbit maintenance/repair or final removal from orbit can only be provided by the Shuttle. The SOC, however, can support in-orbit checkout and launch of the geosynchronous satellites. In-situ maintenance/repair of these geosynchronous satellites could be performed with the use of Manned Orbital Transfer Vehicles (MOTV) operating from SOC.

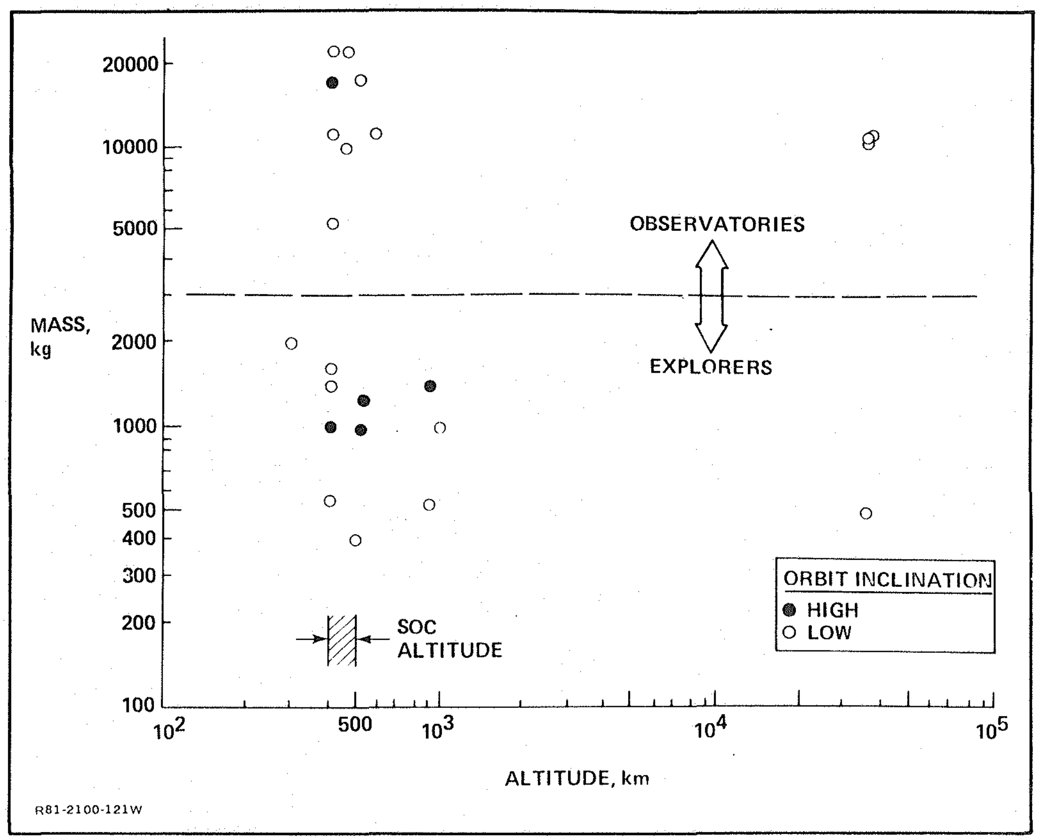

Figure 4.4-2 Astrophysics Satellite Altitudes

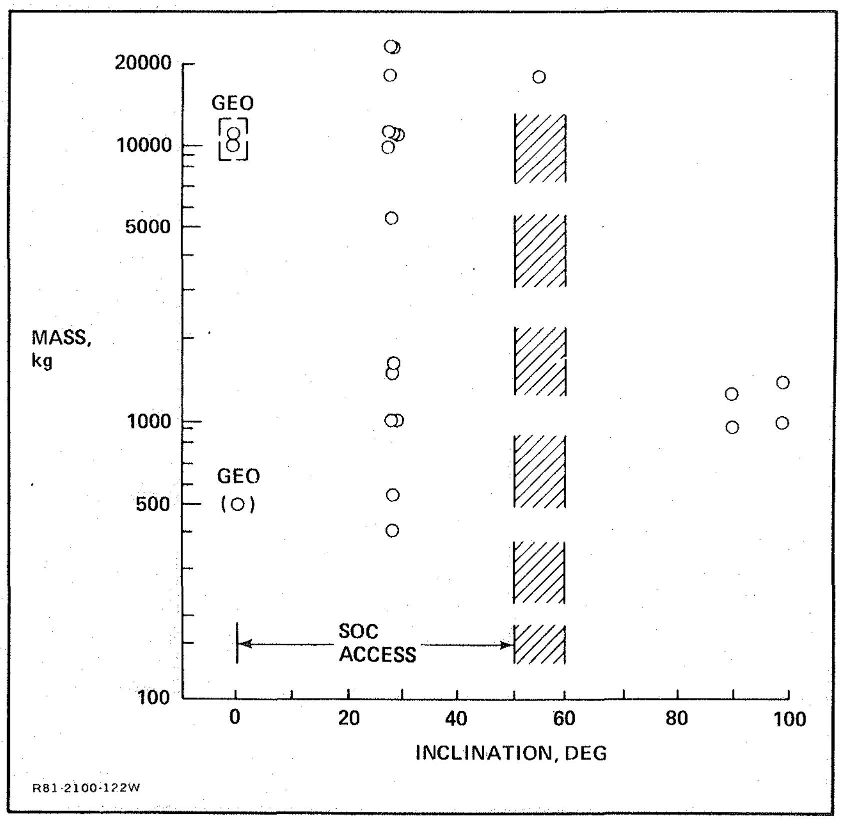

Figure 4.4-3 Astrophysics Satellite - Orbital Inclinations

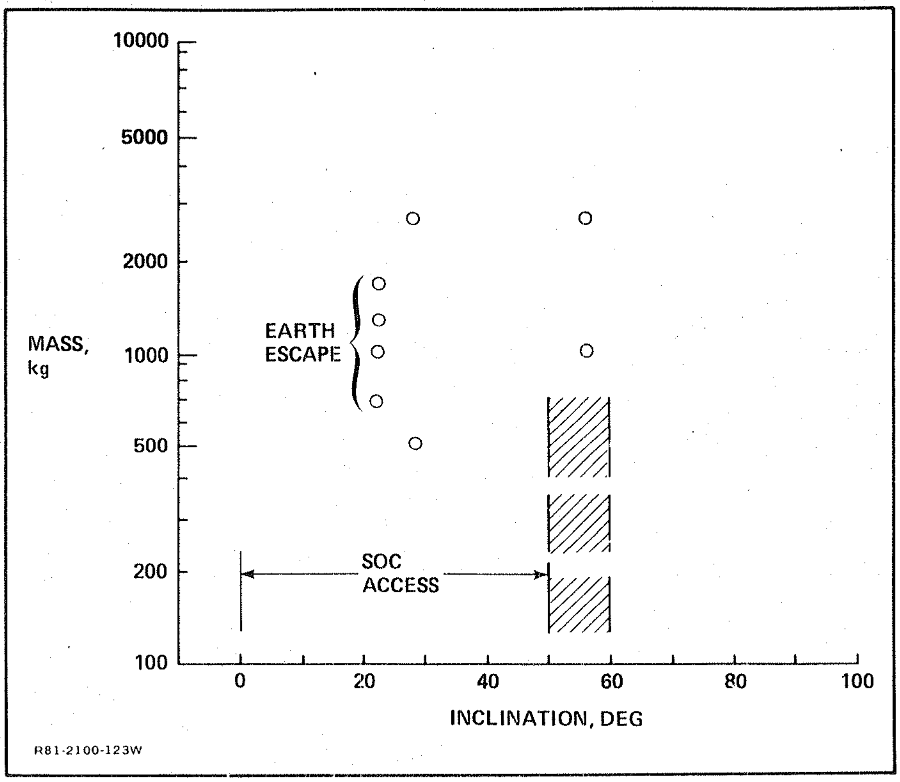

Figure 4.4-4 Solar Terrestrial Satellites - Orbital Inclination

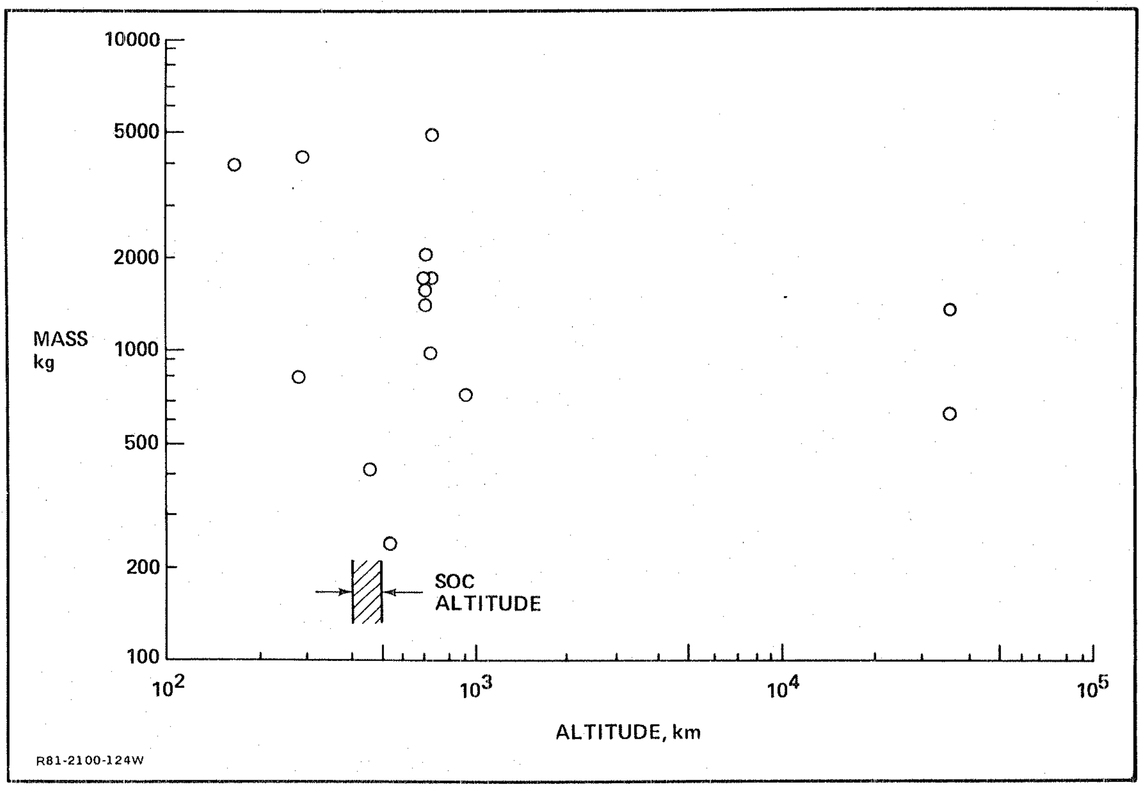

Figure 4.4-5 Resource Observation Satellites - Orbital Altitude

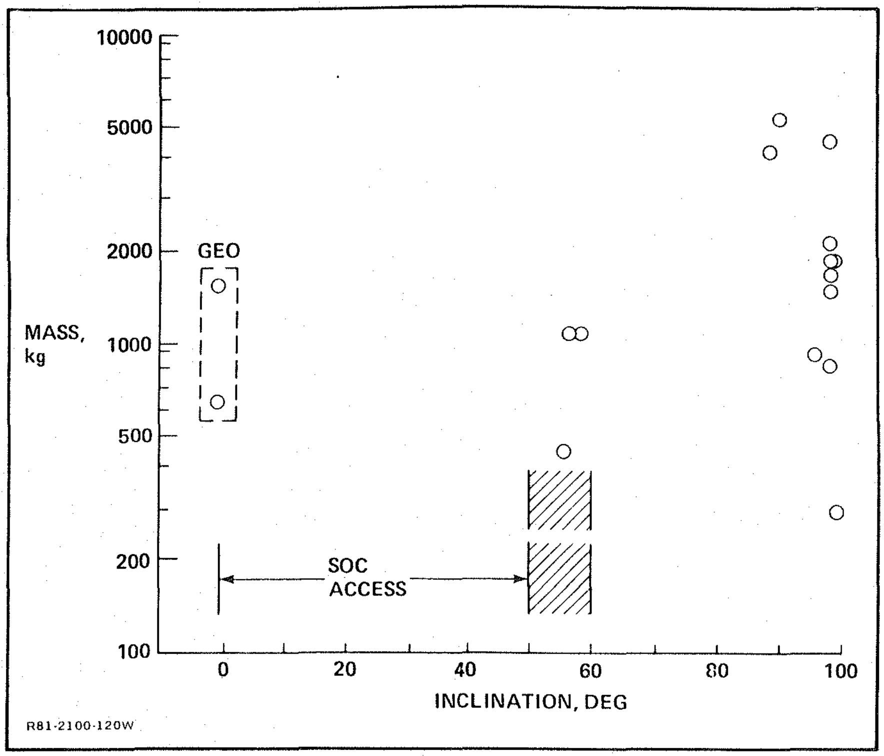

Figure 4.4-6 Resource Observation Satellites - Orbital Inclination

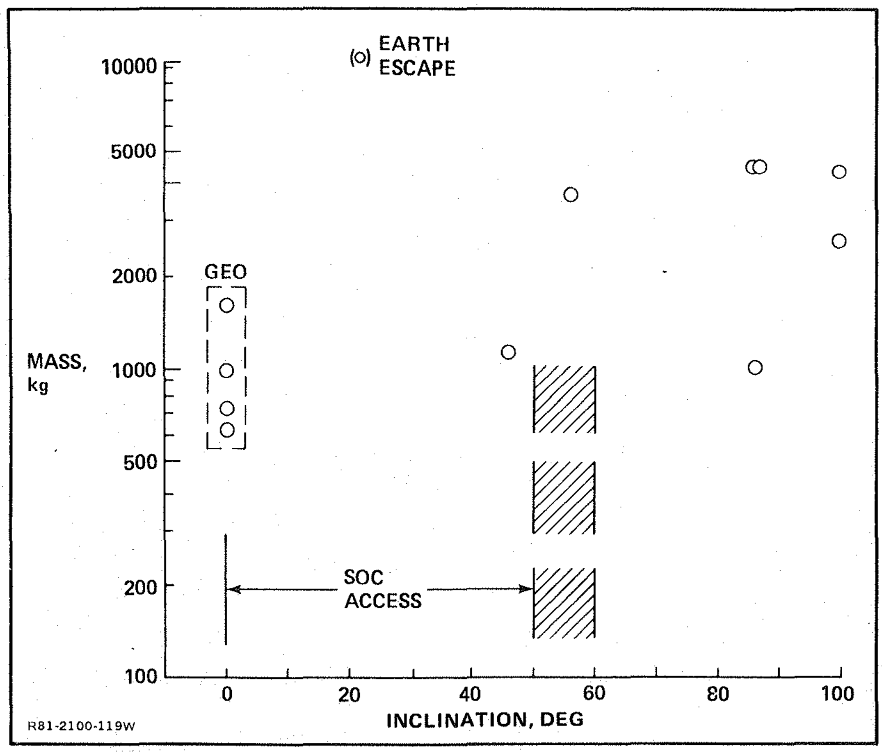

Figure 4.4-7 Global Environment Satellites - Orbital Inclination

Other space application missions include telecommunications satellites and material processing payloads. All telecommunication satellites operate in geosynchronous and can be supported for initial deployment and subsequent on-orbit maintenance and resupply as described above. The materials processing payloads require periodic tending and may either be attached to the SOC or deployed as a free flyer, which can be retrieved, as needed, to remove and reload throughput materials.

Space testing missions are also viewed as attached or free-flying payloads such as the Long Duration Experiment Facility (LDEF), which can be supported directly from the SOC.

Finally the DOD missions are generally operated in either high energy orbits or low energy orbits. Depending upon the specific orbital parameters, these missions can also be supported for initial deployment, on-orbit resupply/maintenance, and finally, retrieval by one or more of the systems discussed above.

Figure 4.4-8 summarizes the orbital distribution of each program category within the total mission model. SOC can support those missions which operate in low inclination oribt, nominally for 0 to 5 degrees, and can initiate planetary and escape missions. In all but two categories, the majority of programs can utilize SOC. With resource observation programs, most missions require polar orbits and are therefore not accessible from SOC. Similarly, about half of the global environment missions require polar orbits.

4.4.1.2 Satellite Services Available

Recent studies on satellite servicing from the Shuttle Orbiter (References 4.4-2 and 4.4-14) have identified a broad range of services which could be made available to the satellite user community. The Space Operations Center (SOC) will be able to provide many of the same services as the Space Transportation System (STS), and thereby release the orbiter for other mission assignments. Figure 4.4-9 denotes which services can be provided by either the STS or SOC and identifies the potential benefits which may be derived by the satellite user community.

PROGRAM CATEGORIES	ORBITAL DISTRIBUTION			
	HI INCL	LOW INCL		
	LEO	LEO	GEO	ESCAPE
ASTROPHYSICS	23%	63%	14%	–
SOLAR TERRESTRIAL	25%	25%	–	50%
PLANETARY	–	–	–	100%
LIFE SCIENCES	–	100%	–	–
RESOURCE OBS	88%	–	12%	–
GLOBAL ENVIRON.	50%	8%	34%	8%
MATL PROCESS	–	100%	–	–
COMMUNICATIONS	–	–	100%	–
SPACE TESTING	–	100%	–	–
DOD	?	?	?	–

SOC SUPPORT

Figure 4.4-8 SOC Support of Satellite/Payload Mission Needs

SERVICES	STS	SOC	BENEFITS
• DEPLOYMENT	√	√	ENHANCED MISSION SUCCESS
• EXAMINATION • RETRIEVAL	√	√	NEEDED FOR ON-ORBIT SUPPORT AND EARTH RETURN SERVICES
• ON-ORBIT SUPPORT	√	√	COST EFFECTIVE FOR LONG DURATION MISSIONS OR EMERGENCY REPAIR
• ON-ORBIT STORAGE		√	COST EFFECTIVE FOR UNPLANNED REPAIR
• EARTH RETURN	√		COST EFFECTIVE FOR HIGH DEVELOPMENT COST SATELLITES; SCIENTIFIC OBSERVATION

SOC SERVICING INDEPENDENT OF STS SCHED, MISSION TIME & AVAILABILITY

Figure 4.4-9 Satellite Services and Potential Benefits to Satellite User Community

Both systems, of course, can provide on orbit checkout and back-up support during initial satellite deployment. Subsequent revists for in-orbit examination and/or retrieval can also be performed with similar proximity equipment operating from either system. In addition, both systems can provide on-orbit support to maintain, resupply, and reconfigure appropriate satellites, as needed. However, since the SOC is continuously manned in low earth orbit, it can provide more flexibility to deal with contingency situations than the Orbiter. Once the satellite supplies and servicing equipment is delivered to orbit, the SOC can perform satellite servicing operations completely independent of STS schedule, mission time constraints and availability. Of course, only the Orbiter is able to return high value satellites to earth. The SOC, in turn, can more readily provide on-orbit storage for satellites awaiting: emergency repair instructions/equipment, return to earth or reentry disposal as unwanted debris.

Manned presence on SOC during satellite deployment can provide users with a higher prospect of mission success than can be expected from expendable launch vehicles. Unstowing satellite appendages, providing on-the-spot examination to deal with hangups and other contingencies during predeployment checkout will significantly reduce infant mortality. Previous studies (References 4.4-14 and 4.4-15) have indicated that payload failures can be reduced by approximately one half by Orbiter support through the infant mortality phase (see Figure 4.4-10). Similar benefits are expected from the SOC which can "nurse" a newly launch spacecraft free of STS mission duration constraints.

On-orbit maintenance, resupply, and reconfiguration of satellites is another avenue for user program cost reduction which can be used either to achieve long mission life times, to reduce requirements for on-orbit stand by spacecraft, or to fix random failures that threaten mission continuation. Studies have been conducted (Reference 4.4-16 and 4.4-17) which show that once the satellite mission exceeds one year, it is cheaper to double satellite design life through maintenance and resupply than through overly redundant design techniques.

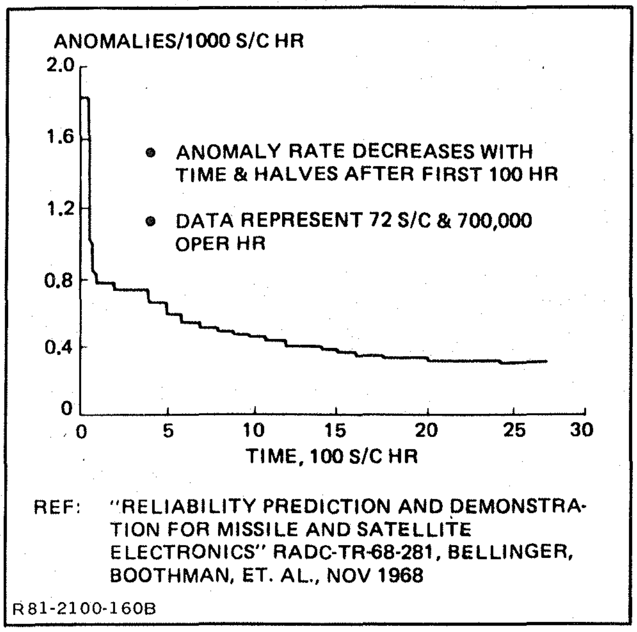

Figure 4.4-10 Payload Failure Rate After Launch Conventional Launch Vehicles

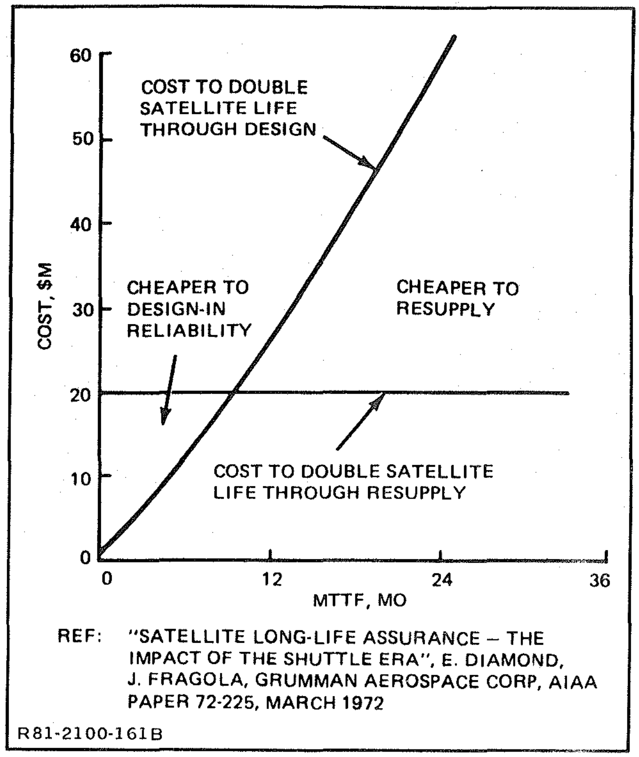

Figure 4.4-11 Resupply/Design Tradeoff

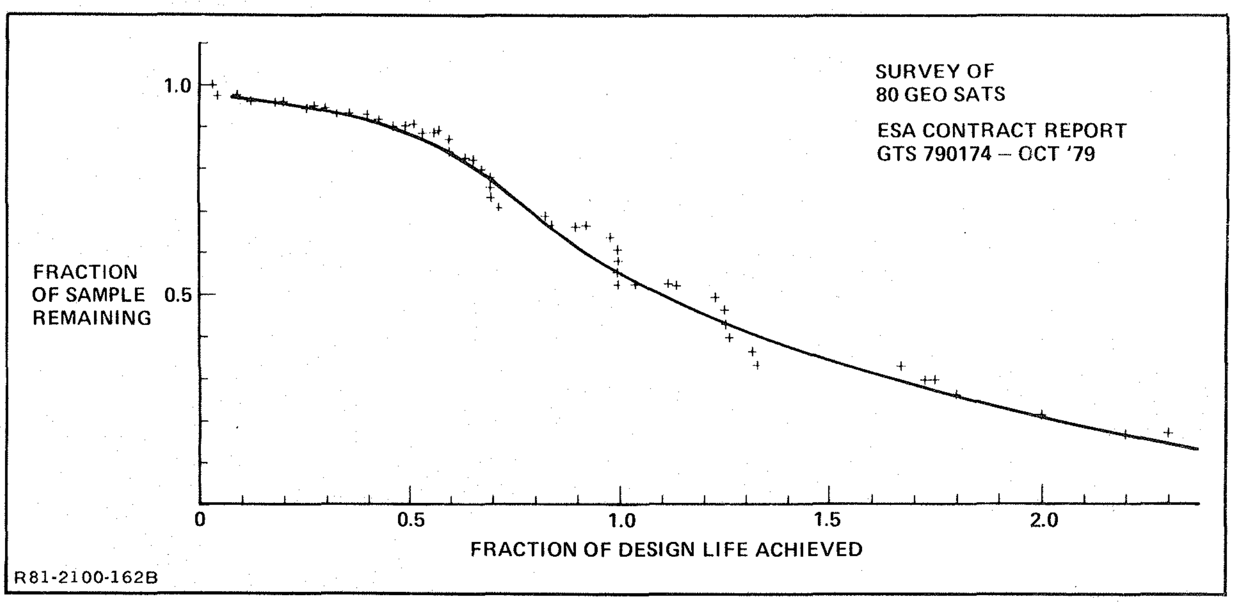

Figure 4.4-12 Demonstrated Communications Spacecraft Lifetimes Achieved

Figure 4.4-11 shows a tradeoff performed for GSFC which ultimately led to the present Multimission Spacecraft design for on-orbit servicing. The cost data provided in the figure are based on 1972 dollars. The tradeoff is just as valid today except that the 12-month MTTF cross-over will occur at $50 M in 1981 dollars.

Early GEO communication satellites, for example, have demonstrated very poor lifetime performance. A recent survey of 80 satellites in geosynchronous orbit showed that at least half of the satellites failed before they reached their design life. The satellites included in Figure 4.4-12 are visualized as test articles in a 100% sample. Each is activated at time zero and deactivated when it fails or reaches the end of its test period. Satellite deactivation times were plotted as a fraction of design life to provide the normalized reliability curve shown for communication satellites. The convex appearance of the upper portion of the curve is characteristic of a design employing extensive redundancy - usually the case in a modern communications satellite. The use of high-reliability parts, together with extensive redundance, have been the only options available to date. During the SOC era, the introduction of space based Manned Orbital Transfer Vehicles will allow GEO satellites and LEO satellites remote from SOC to be serviced in situ.

SOC satellite service modes are illustrated in Figure 4.4-13. The SOC is used as a transportation node for: assembly and deployment of satellites; on orbit support of attached and retrieval payloads; and as a base of in-situ servicing of remote satellites in LEO and GEO. Since the SOC is decoupled from ground launch constraints, it can provide on-demand service to examine and repair satellite random failure situations. The probability of random failure prior to end of mission or scheduled maintenance for observatory class satellites could be as high as 20%. The SOC can also support the buildup of large systems in orbit such as an IR Interferometer in LEO, a Cosmic Coherent Optical System for GEO or perhaps a new large interplanetary spacecraft.

Whenever practical, all co-orbiting satellites in need of maintenance/resupply should be returned to the SOC for that purpose. Out-

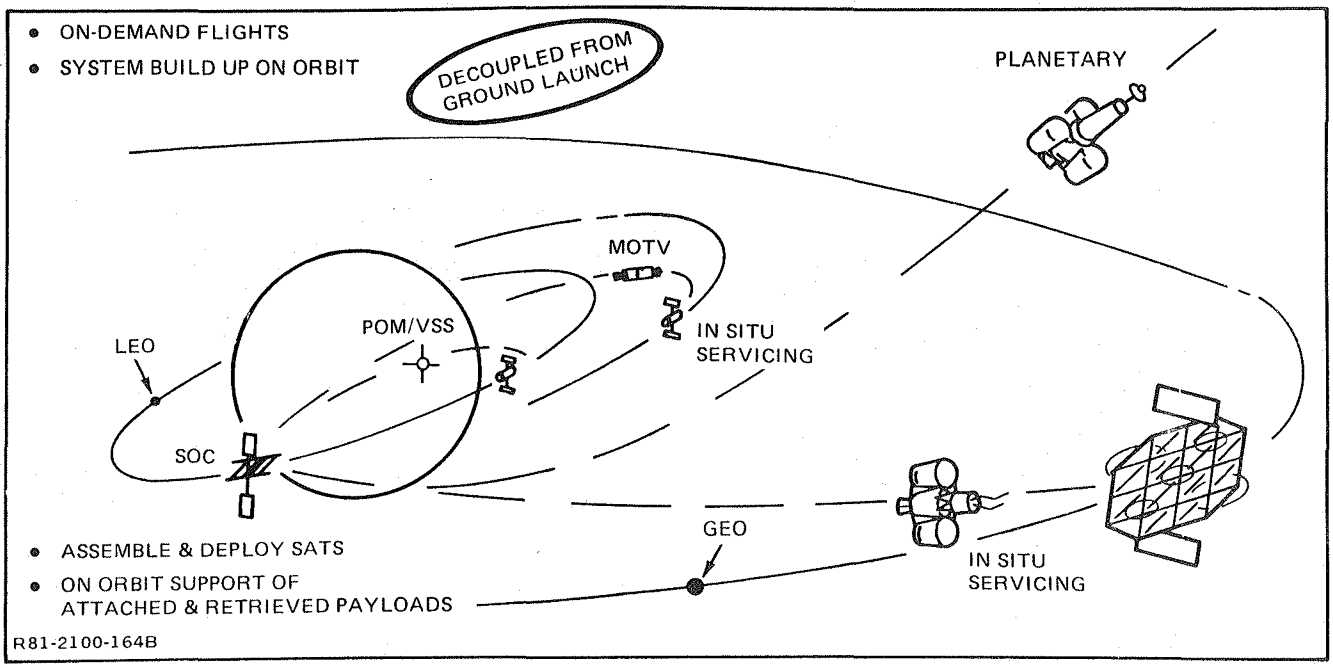

Figure 4.4-13 Satellite Service Modes

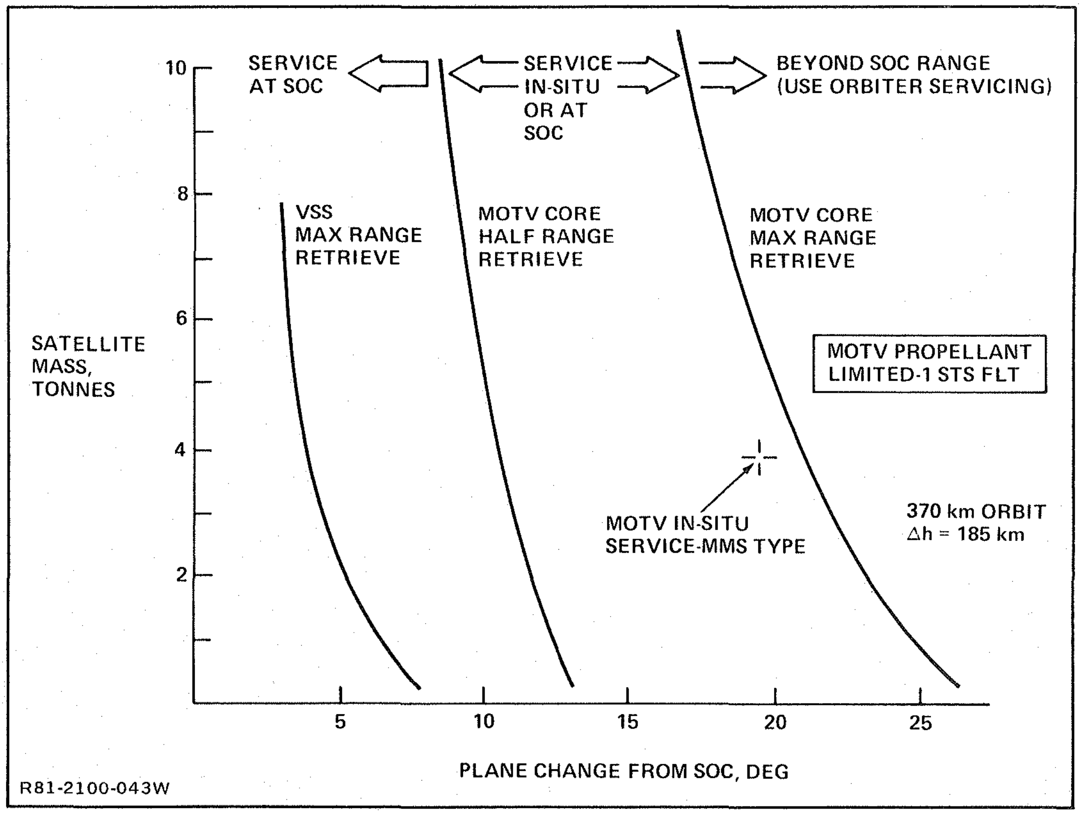

Fig. 4.4-14 LEO Satellite Servicing Regions for SOC Based Vehicles

sized platforms of comparable size to SOC should, of course, be serviced in situ. Cost efective satellite servicing regions in LEO are shown in Figure 4.4-14 for SOC based vehicles. The region identified for service at SOC versus service in situ are bounded by MOTV core stage capabilities for half range and maximum range payload retrieval performance, when limited to one STS propellant delivery flight. For example, the MOTV half-range retrieval capability defines the maximum plane change maneuver for bringing a satellite back to SOC for servicing and to then return the satellite to its original orbit. Satellites beyond the MOTV half range capability can also be returned to SOC for servicing if needed. However, it would be more economical if they were serviced in situ. As shown in the figure, an MOTV can provide in-situ service to an MMS class satellite in a 185 km higher oribt which is almost 20 degrees out of plane with respect to the SOC. The maximum payload retrieval range of the Versatile Service Stage (VSS) is also shown for comparison.

4.4.1.3 Satellite Servicing Missions

Grumman's Satellite Services User Model (S/SUM) was used to identify potential service missions for the period between 1985 and 2000. Emphasis was placed on those satellite missions which could be supported by SOC in the areas of space science, space applications and space testing. The following ground rules were used to define on-orbit support and retrieval requirements for satellites deployed in LEO and GEO:

- All satellites built after 1988 shall be capable of being serviced on orbit
- Satellites greater than 500 kg are candidates for on-orbit servicing and retrieval.
- Scheduled servicing revisits for LEO Observatory class satellites shall occur at 2 to 3 year intervals after deployment or as needed

- GEO satellites shall be serviced on 3- to 5- year intervals
- Foreign satellites shall be excluded from post deployment servicing and retrieval analysis
- All satellites shall be removed from orbit at the end of their mission
- Small scientific satellites and larger space application satellites in GEO shall be removed from their orbital slots after 5 years and 10 years, respectively.

Tables 4.4-1 through 4.4-12 provide mission information for servicing satellites with the SOC or the STS as appropriate. These data cover projected missions for astrophysics, solar terrestrial, planetary, resource observation, global environment, and the space testing categories. The satellite missions are listed chronologically within each category. These missions are identified in accordance with the nomenclature defined in the 1980 NASA Space Systems Technology Model (i.e., A-3, S-2, etc). The correlation between these designators and the revised listing in the 1981 NASA Space Systems Technology Model is shown parenthetically on the first part of these data sheets. Satellite sevice mission events for deployment, on-orbit support, and satellite return are identified with the following codes for operations and transportations.

FL - Self-propelled satellite

FTU - Versatile Service Stage Operations

POU - Unmanned Proximity Operations Module Support

FSSML - SOC Based Manned Orbit Transfer Vehicle Core Stage/LEO support capability

FSSMG - SOC Based Manned Orbit Transfer Vehicle/GEO support capability

TABLE 4.4-1 ASTROPHYSICS MISSIONS PART I SHT 1 OF 3

ID NO.	NAME	OPERATIONS CODE	TRANSP CODE	ORBIT H	ORBIT I	TRIP TIME DAYS	DELTA VKM/S UP	DELTA VKM/S DN	DELTA VKM/S XB	MISSION FUNCT*	MASS KG UP	MASS KG DN	LENGTH M	DIA M	TRAFFIC [1] 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A3	SPACE TELESCOPE	FTU	–	593 km	28.5°	0.03	0.1	–		D	11,000	–	13.6	4.3						1						1				
	(S3)	SOC	FTU			0.03	0.1	0.1		S	11,000	11,000			•	1	•	•			•	1	•	•			•	1	•	•
		FTU	–			0.03	–	0.1		R	–	11,000							1						1					
A7	GAMMA RAY OBSERVATORY	FTU	–	400	28.5	0.03	<0.1	–		D	11,000	–	6.0	4.5	1															
	(S9)	SOC	FTU			0.03	<0.1	<0.1		S	11,000	11,000				•														
		FTU	–			0.03	–	<0.1		R	–	11,000					1													
A4	COSMIC BKGND EXPL	FL	–	900	99	0.03				D	1,421	–	4.8	4.4	1															
	[2] (S7)	FL	–			0.03				R	–	1,421					1													
A5	EXTREME UV EXPLORER	FL	–	550	28.5	0.03		–		D	400	–	4.5	2.0		1														
	(S10)	FTU	–			0.03	–	0.1		R	–	400					1													
A10	X-RAY TIME EXPLORER	FL	–	400	28.5	–				D	1,000	–	4.0	2 0		1			1											
	(S11)	SOC	FTU			0.03				S	1,000	1,000					•			•										
		FL	–			–				R	–	1,000						1			1									
A61	SOLAR CORONA EXPLORER	FL		600	33	0.03	<0.1	–		D	1,000	–	3 5	3.0		1														
	[2] (S-13)	SOC	FTU			0.03	1.5	1.5		S	1,000	1,000						•												
		FL				0.03	–	<0.1		R	–	1,000								1										
A8	GRAVITY PROBE B			520	90					D	1,270	–	4 2	4 2			1													
	[2] (S-14)	SIO	POU			0.03	<0.1	<0.1		S								•	•											
										R		1,270								1										
A9	ADV X-RAY ASTROPHY FAC	FTU		450	28.5	0.03	<0.1	–		D	10,000		11 5	3.1			1						1							
	(S17)	SOC	FTU			0.03	<0.1	<0.1		S	10,000	10,000						•	1	•	•			•	1	•	•			
		FTU				0.03	–	<0.1		R		10,000										1						1		

[1] NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

[2] DIRECT ORBITER LAUNCH AND RECOVERY

( ) NASA 1981 SYSTEMS TECHNOLOGY MODEL ID No.

* D – DEPLOY
S – SERVICE
R – RETRIEVE

R81-2100-057W

TABLE 4.4-1 ASTROPHYSICS MISSIONS PART I SHT 2 OF 3

ID NO.	NAME	OPERATIONS CODE	TRANSP CODE	ORBIT		TRIP TIME	DELTA VKM/S			MISSION FUNCT*	MASS KG		LENGTH M	DIA M	TRAFFIC [1]															
				H	I		UP	DN	XB		UP	DN			5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A13	COSMIC RAY OBSERVATORY [2] (S23)	POU SIO POU	POU	400 km	56°	0.03 DAYS 0.03 0.03	<0.1 <0.1 –	– <0.1 <0.1		D S R	18,000 18,000	– 18,000 18,000	15	4.5			1	•	•	1	1	•	•	•	•	1				
A14	LARGE AREA MODULAR ARRAY (S28)	FL SOC FL	FTU	400	28.5	0.03 0.03 0.03	<0.1 0.1 –	– 0.1 <0.1		D S R	5,200 5,200 –	– 5,200 5,200	6.0	4.0				1	•	•	•	•	1				1			
A15	VERY LONG BASELINE INTERFACE (S29) [2] [3]	FL SIC FL	FSSML	1,000	45	0.03 0.05 0.03	0.34 2.5 –	– 2.5 .34		D S R	NA			4.5				1	•	•	1									
A52	UV PHOTO/POLARMETRIC EXP	FL FL		400	28.5	0.03 0.03	<0.1 –	– <0.1		D R	545 –	– 545		3					1		1									
A53	INTERNATIONAL UV EXPLORER (FOREIGN)			35,786	0	0.25	3.9			D R	500	– 500	4	3					1					1						
A59	SIMULTANEOUS ASTRO MISSION (S42)			35,786	0	0.25	3.9			D R	2,075 –	– 2,075	4	3					1					1						
A54	EXTREME UV SPECTRO- SCOPE (S44)			35,786	0	0.25	3.9			D R	1,000 –	1,000	4	3					1					1						
A55	X-RAY SPECTROSCOPY (S39)	FL SOC FL	FTU	400	28.5	0.03 0.03 0.03	<0.1 0.1	0.1 <0.1		D S R	1,500 1,500 –	– 1,500 1,500	3	2						1	•	1								
A56	SOFT X-RAY SURVEY (S40)	FL FL		400	28.5	0.03 0.03	<0.1	<0.1		D R	1,600 –	– 1,600	4	3						1		1								

[1] NUMERALS DENOTE SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

[2] DIRECT ORBITER LAUNCH AND RECOVERY

[3] SOC SERVICE OPTION TO BACK UP ORBITER AVAILABILITY

* D – DEPLOY
S – SERVICE
R – RETRIEVE

( ) NASA 1981 SYSTEMS TECHNOLOGY MODEL ID NO.

R81-2100-058

TABLE 4.4-1 ASTROPHYSICS MISSIONS PART I SHT 3 OF 3

ID NO.	NAME	OPERATIONS CODE	TRANSP CODE	ORBIT H	ORBIT I	TRIP TIME	DELTA VKM/S UP	DELTA VKM/S DN	DELTA VKM/S XB	MISSION FUNCT*	MASS KG UP	MASS KG DN	LENGTH M	DIA M	TRAFFIC [1] 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
A57	MOLECULAR LINE SURVEY	FL		600	28.5	0.03 DAYS	0.1			D	1,000	–		3.5						1										
	(S45)	FL		km		0.03		0.1		R	–	1,000											1							
A58	ADVANCED RELATIVITY	FTU		520	90	0.03	<0.1			D	901	–	3.6	2.2							2									
	[2]	FTU				0.03		<0.1		R	–	901															2			
A16	SUBMILLIMETER TELE-	FL		1,000	98	0.03	0.34	–		D	1,000		12.0	4.5								1								
	SCOPE [2] (S30)	S!O	FTU			0.03	0.34	0.34		S	1,000	1,000												•		•		•		
		FL				0.03	–	0.34		R		1,000																		1
A17	AMBIENT DEPLOY IR					0.03				D																				
	TELESCOPE (S25)	FTU		500	28.5	0.03	<0.1			S	18,000	–		4.5								2								
		SOC	FTU			0.03	0.1	0.1		R	18,000	18,000											1	1	1	1				
		FTU						<0.1			–	18,000															1			
A18	IR INTERFEROMETER	CGM	FTU	400	28.5	0.03	<0.1	–		D	22,500		100										1							
	(S31)	SIC	FSSML			0.03	0.1	0.1		S														1	1	1	1			
		FTU				0.03	–	0.1		R		22,500																1		
A19	GRAVITY WAVE INTER-	CFM	FSSMG	35,786	0	0.25	3.9	–		D	11,250	–	1 000											4	4					
	FEROMETER (S32)	SIC	FSSMG				3.9	3.9		R			TOTAL															1		
A20	COSMIC-COHERENT OPT	CAM	FL	35,786	0	0.25	3.9	–		D	11,500		12	4												3	3		3	3
	SYS (S33)												100																	
													TOTAL																	
A21	LONG OPTICAL UV TELE-	CGH	FTU	450	28.5	0.03	<0.1	–		D	22,800		28.5	8.4													1			
	SCOPE (S36)	SOC	FTU							S																		1	1	1
A22	100 M THIN APERTURE	CFH	FL	35,876	0	0.25	3.9	–		D	10,600			100														4	4	
	TELESCOPE (S34)																													

[1] NUMERALS DENOTE SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED
[2] DIRECT ORBITER LAUNCH AND RECOVERY

*D – DEPLOY
S – SERVICE
R – RETRIEVE

( ) NASA 1981 SYSTEMS TECHNOLOGY MODEL ID NO.

R81-2100-059

TABLE 4.4-2 ASTRO PHYSICS MISSIONS PART 2

ID NO.	ON-ORBIT OPS TIME	NO. OF APPENDAGES	NO. OF MODULES	FAB TIME	MAINTENANCE & REPAIR/RECONFIGURE/ RESUPPLY TIME
A3	*	4	–	–	***
A7	*	3	–	–	***
A4	*	1	–	–	–
A5	*	1	–	–	–
A10	*	3	–	–	**
A56	*	2	–	–	**
A8	*	4	–	–	**
A9	*	4	–	–	***
A13	*	2	–	–	***
A14	*	3	–	–	***
A15	*	2	–	–	***
A52	*	3	–	–	–
A53	*	2	–	–	–
A59	*	3	–	–	–
A60	*	3	–	–	–
A55	*	3	–	–	**
A56	*	1	–	–	–
A57	*	3	–	–	–
A58	*	2	–	–	–
A16	*	3	–	–	**
A17	*	1	–	–	***
A18	*	6	2	0.1 DAYS	***
A19	*	2	–	–	***
A20	*	2	6	0.5 DAYS	***
A21	*	2	–	–	***
A22	*	2	–	–	***

* LAPSED TIME FOR POST DELIVERY, SEPARATION, AND CHECKOUT – ASSUME 0.12 DAY
** LAPSED TIME FOR ON ORBIT SERVICE AND CHECKOUT OF SATELLITES < 3000 kg ASSUME 0.3 DAY TOTAL OR 1 WORK SHIFT
*** LAPSED TIME FOR ON ORBIT SERVICE AND CHECKOUT OF SATELLITES > 3000 kg ASSUME 0.9 DAY TOTAL OR 2 WORK SHIFTS

R81-2100-060W

TABLE 4.4-3 SOLAR TERRESTRIAL MISSIONS PART 1

ID NO.	NAME	OPERATIONS CODE	TRANSP CODE	ORBIT		TRIP TIME	DELTA VKM/S			MISSION FUNCT*	MASS KG		LENGTH M	DIA M	TRAFFIC [1]															
				H	I		UP	DN	XB		UP	DN			5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
S3	ISPM-SOLAR POLAR (S5)	FGTUG		5.2 AU km	23°		5.0			D	683		2.0	3.2	1															
S5	CHEM REL MODULE [2] (S4)	FL FTU		1200 km	57	0.04 DAYS	.45 –	– .45		D R	2700	 2700	2.0	3.0	1	 1														
S7	ORIGIN OF PLASMA (S12)	FSSUG		240 ER	23		3.2			D	1000		3.5	3.0		4														
S9	SUBSAT FACILITY (S22)	FL SOC FL	 FL	400 km	28.5	0.03	<.1 –	– <.1		D S R	500	 500	1.5	1.0		1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1									
S11	SOLAR PROBE (S20)	FSSUG		4 RS	23		10			D	1500		4.4	3.8				1												
S13	SOLAR CYCLE & DYN MISSION (S21)	FL SOC FL	 FTU	575 km	28.5	0.03	<.1 .1 –	– .1 <.1		D S R	2600	 2600	4.6	2.4				1	 •	 1	1	 •	 •	 •	 •	 •	 1			
S51	ASTRONOMY	FL SOC FL	 FTU	5000 km	28.5	0.06 0.06 0.06	1.7 1.7 –	– 1.7 1.7		D S R	950		1.0	2.4					1		 •		 •		 •		 1			
S52	GAMMA RAY TRANS EXPLOR (S41)	FL FL		450 km	28.5	0.03	<.1 –	– <.1		D R	3000 –	– 3000	2	3					1		 1									
S53	X-RAY OBSERVATORY (S27)	FL SOC FL	 POU	400 km	28.5	0.03	<.1 <.1 –	– <.1 <.1		D S R	3550		8	3					1	 •	 •	1 •	 • 1	 •	 •	 1				
S54	ADV INTERPLANETARY EXPLOR (S37)	FSSUG		LI			3.1			D	1200		1						1											
S6	ACT. MAG PART EXPLOR			300 km x7RE	28.5	0.3	~4.0			D	770		1.1	3																
S55	HEAVY NUCLEI EXPLORER (S38) [2]	POU SIO POU	 FTU	400 km	56°	0.03 DAYS	<.1 –	– <.1		D S R	4000	 4000	8.8						1	 •	 •	 •	 1							
S56	LARGE SOLAR OBSERVATOR	FTU SOC FTU	 FTU	350 km	28.5	0.03	<.1 <.1 –	– <.1 <.1		D S R	9800		16.2	4.6						1	 •	 •	 •	 •	 1					
S12	SOLAR TERR OBSERVATORY (S24) [2]	CAM SIO		400	57	0.03				D S R			80								1	 1	 1	 1	 1	 1				
S15	CLOSE SOLAR ORBITER	FSSUG		0.1 AU	23		>15			D															1					

[1] NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

[2] DIRECT ORBITER LAUNCH AND RECOVERY

( ) NASA 1981 SYSTEMS TECHNOLOGY MODEL ID NO.

* D – DEPLOY
S – SERVICE
R – RETRIEVE

R81-2100-062W

TABLE 4.4-4 SOLAR TERRESTRIAL MISSIONS PART 2

ID NO.	ON-ORBIT OPS TIME	NO. OF APPENDAGES	NO. OF MODULES	FAB TIME	MAINTENANCE & REPAIR/RECONFIGURE/ RESUPPLY TIME
S3	*	2	–	–	–
S5	*	0	–	–	–
S7	*	3	–	–	–
S9	*	2	–	–	**
S10	*	2	–	–	–
S11	*	2	–	–	**
S13	*	3	–	–	**
S51	*	2	–	–	–
S52	*	4	–	–	–
S53	*	3	–	–	***
S54	*	6	–	–	–
S55	*	2	–	–	***
S56	*	3	–	–	***
S12	*	3	9	0.8 DAYS	***
S15	*	2	–	–	–

* LAPSED TIME FOR POST DELIVERY, SEPARATION, AND CHECKOUT – ASSUME 0.12 DAY
** LAPSED TIME FOR ON ORBIT SERVICE AND CHECKOUT OF SATELLITES $<$ 3000 kg ASSUME 0.3 DAY TOTAL OR 1 WORK SHIFT
***LAPSED TIME FOR ON ORBIT SERVICE AND CHECKOUT OF SATELLITES $>$ 3000 kg ASSUME 0.9 DAYS TOTAL OR 2 WORK SHIFTS

R81-2100-064W

TABLE 4.4-5 PLANETARY MISSIONS PART 1

ID NO.	NAME	OPERATIONS CODE	TRANSP CODE	ORBIT		TRIP TIME	DELTA VKM/S			MISSION FUNCT*	MASS		LENGTH M	DIA M	TRAFFIC 1															
				H	I		UP	DN	XB		UP	DN			5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
P2	VENUS ORB. IMAGE RADAR (P2)			0.72 AU			3.5			D	1,000	–	6	6		1														
P4	SATURN ORBITER (P7)			9.5 AU			7			D	3,000	–	70	5					2											
P6	URANUS NEPTUNE PULTO (P6)			40 AU			8			D	1,000	–									1	1								
P7	ASTEROID MULTI RENDZ (P5)			3 AU			4.0			D	2,000	–	35	8									1							
P8	LUNAR POLAR ORBITER (P10)			400 K			3.1			D	300	–	6.0	4.5									1							
P5	MARS SAMPLE RETURN (P8)			1.5 AU			3.5			D	7,000	–	70	5.0										1		1				
P11	NR EARTH ASTEROID SAMPLE (P13)			3 AU			4.0			D	4,000		70	5.0									1			1				
P15	LUNAR BACKSIDE SAMPLE (P17)						3.0			D														1						
P14	Auto Planetary Station (P16)			400	28.5		<.1			D	25,000		80	15											1					
P16	GANYMEDE LANDER (P18)			5.2 AU			5.5			D	80			1											1					
P10	COMET SAMPLE RETURN (P12)			NA			NA			D	3,500		70	5.0													1			
P12	VENUS LANDER (P14)			0.72 AU			>7.5			D	550		2.0	1.0														1		
P13	AUTO MOBILE LUNAR SURVEY (P15)			400 K						D	500		1.5	1.0														1		
P1A	GALILEO ORBITER			5.2 AU			5.5			D	1,800		5.1	4.4																
P1B	GALILEO PROBE			5.2 AU			5.5			D	450		–	1.3																

* D – DEPLOY

1 NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED ( ) NASA 1981 SYSTEMS TECHNOLOGY MODEL ID NOS.

R81-2100-065W

TABLE 4.4-6 PLANETARY MISSIONS PART 2

ID NO.	ON-ORBIT OPS TIME	NO. OF APPENDAGES	NO. OF MODULES	FAB TIME	MAINTENANCE & REPAIR/RECONFIGURE/ RESUPPLY TIME
P2	< 0.1 DAY	4	–	–	–
P4	↓	NA	–	–	–
P6	↓	NA	–	–	–
P7	↓	NA	–	–	–
P8	↓	5	–	–	–
P5	↓	3	–	–	–
P11	↓	NA	–	–	–
P15	↓	NA	–	–	–
P14	↓	NA	–	–	–
P16	↓	1	–	–	–
P10	↓	NA	–	–	–
P12	↓	NA	–	–	–
P13	↓	NA	–	–	–

NA – NOT AVAILABLE

R81-2100-067W

TABLE 4.4-7 GLOBAL ENVIRONMENT MISSIONS PART I SHT 1 OF 2

ID NO.	NAME	OPERATIONS CODE	TRANSP CODE	ORBIT		TRIP TIME	DELTA VKM/S			MISSION FUNCT*	MASS		LENGTH M	DIA M	TRAFFIC ▷1															
				H	I		UP	DN	XB		UP	DN			5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
E2	GEO OPER ENVIR SAT (E1)			35,786	0	0.25 DAYS	3.9	–		D	720		3.5	2.0		1	1					1					1			
		SIC	FSSMG			0.25	3.9	3.9		S															•				•	
										R											1	1					1			
E6	NAT'L OCEAN SAT (E4) ▷2	FL		787	87	0.04	0.2	–		D	4500		10.7	4.5		1	1	1	1			1	1							
		SIO	FTU			0.04	0.2	0.2		S							•	•		•	•			•	•	•	•			
		FL				0.04	–	0.2		R								1	1			1	1				1	1		
E7	UPPER RES SAT ATMOS (E5) ▷2	FL		500	56	0.02	<0.1	–		D	3700	–	4.0	2.0		1	1													
		SIO	FTU			0.04	0.1	0.1		S	3700	3700						•	•	•	•	•	•	•	•	•	•			
		FL				0.02	–	<0.1		R	–	3700															1	1		
E5	NOAA-H&I (E7) ▷2	FL		830	99	0.04	>0.3	–		D	4173	–	8.0	3.7		1	1													
		SIO	FTU			0.04	>0.3	>0.3		S	4173	4173						•	•											
		FL				0.04	–	>0.3		R	–	4173								1	1									
E4	EARTH RADIATION BUDGET (E2) ▷2 ▷3	FL		600	46	0.03	0.1	–		D	1134	–	4.0	2.1			1				1									
		SIC	FSSML			0.03	2.7	2.7		S	3600	3600							•				•							
		FL				0.03	–	0.1		R	–	1134									1				1					
E50	INMET SAT (FOREIGN)			35,786	0	0.25	3.9	–		D	943	–	3.0	2.5			1	2	4	3	4	2	4	3	4	3	4	3	4	
										R	–	943																		
E52	STORM SAT (COMMERCIAL)			35,786	0	0.25	3.9	–		D	1600	–	6.0	3.7			1					1					1			
		SIC	FSSMC			0.25	3.9	3.9		R	3600	3600													•			•		•
											–	1600										1								
E53	MAP GRAVITY FIELD/COMM			35,786	0	0.25	3.9	–		D	615	–	1.0	1.4			1				1			1			1			
										R	–	615										1				1			1	
E9	TOPEX (E6) ▷2	FL		700	87	0.04	0.2	–		D	1000	–	4.0	3.0			1													
		FL				0.04	–	0.2		R	–	1000								1										

▷1 NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

▷2 DIRECT ORBITER LAUNCH AND RECOVERY

▷3 SOC SERVICE OPTION TO BACK UP ORBITER AVAILABILITY

* D – DEPLOY
S – SERVICE
R – RETRIEVE

( ) NASA 1981 SYSTEMS TECHNOLOGY MODEL ID No.

R81-2100-067W

TABLE 4.4-7 GLOBAL ENVIRONMENT MISSIONS PART I SHT 2 OF 2

ID NO.	NAME	OPERATIONS CODE	TRANSP CODE	ORBIT H	ORBIT I	TRIP TIME	DELTA VKM/S UP	DELTA VKM/S DN	DELTA VKM/S XB	MISSION FUNCT*	MASS KG UP	MASS KG DN	LENGTH M	DIA M	TRAFFIC ▷1 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
E10	OPERATIONAL METEROLOGY (COMMERCIAL) ▷2	FL SIO FL	FTU	800	87	0.04 DAYS 0.04 0.04	>0.3 >0.3 –	– >0.3 >0.3		D S R	4,500 4,500 –	– 4,500 4,500	10.0	4.5					1		•		1							
E11	OCEAN RESEARCH (E8) (FIREX) ▷2	SIO	POU	300	56	0.02 0.02	>0.1 0.1 –	– 0.1 >0.1		D S R									1	•	•	•	•	1						
E54	GLOBAL REG ATMOS MONIT (E9) (LARS) ▷2	FL SIO FL	FTU	700	98	0.04 0.04 0.04	0.2 0.2 –	– 0.2 0.2		D S R	2,381 2,381 –	– 2,381 2,381	8.5	3.4				1		•		1 1		•		•		•		1
E57	NUCLEAR WASTE DISPOSAL (DOE)	FSSUG		0.85 AU	28.5		4.	–		D	10,430	–												1	3	5	10	10	10	10

▷1 NUMERALS DENOTED SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

▷2 DIRECT ORBITER LAUNCH AND RECOVERY

( ) NASA 1981 SYSTEMS TECHNOLOGY MODEL ID NO.

*D – DEPLOY
S – SERVICE
R – RETRIEVE

R81-2100-069W

TABLE 4.4-8 GLOBAL ENVIRONMENT MISSIONS (PART 2)

ID NO.	ON-ORBIT OPS TIME	NO. OF APPENDAGES	NO. OF MODULES	FAB TIME	MAINTENANCE & REPAIR/RECONFIGURE/ RESUPPLY TIME
E2	*	3	–	–	**
E6	*	5	–	–	***
E7	*	3	–	–	***
E5	*	1	–	–	***
E4	*	4	–	–	***
E50	*	2	–	–	–
E52	*	2	–	–	***
E53	*	2	–	–	–
E9	*	2	–	–	–
E10	*	2	–	–	***
E11	*	2	–	–	***
E54	*	2	–	–	**
E57	*	2	–	–	–

* LAPSED TIME FOR POST DELIVERY, SEPARATION, AND CHECKOUT – ASSUME 0.12 DAY
** LAPSED TIME FOR ON ORBIT SERVICE AND CHECKOUT OF SATELLITES < 3000 kg ASSUME 0.3 DAY TOTAL OR 1 WORK SHIFT
***LAPSED TIME FOR ON ORBIT SERVICE AND CHECKOUT OF SATELLITES > 3000 kg ASSUME 0.9 DAY TOTAL OR 2 WORK SHIFTS

R81-2100-070W

TABLE 4.4-9 RESOURCE OBSERVATION MISSIONS PART I SHT 1 OF 2

ID NO.	NAME	OPERATIONS CODE	TRANSP CODE	ORBIT H	ORBIT I	TRIP TIME	DELTA VKM/S UP	DELTA VKM/S DN	DELTA VKM/S XB	MISSION FUNCT*	MASS UP	MASS DN	LENGTH M	DIA M	TRAFFIC ▷1 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
R2	LAND SAT D (R1) ▷2	FL SIO FL	FTU	705	98	0.04 DAYS 0.04 0.04	0.2 0.2 –	– 0.2 0.2		D S R	1,597 1,597 –	– 1,597 1,597	3.0	2.0	1		•		1											
R1	MAGSAT B (R2) ▷2	FL FL		550	99	0.03 0.03	<0.1 –	– <0.1		D R	272 –	– 272	.9	.9		1	1													
R4	GRAVSAT (R3-8) ▷2			170	90					D	4,000	–	4.0	1.2	2					2										
R50	ICE & CLIMATE EXPLORER ▷2	FL SIO FL	FTU	700	87	0.04 0.04 0.04	0.2 0.2 –	– 0.2 0.2		D S R	5,000 5,000 –	– 5,000 5,000	18.	4.		1	•	1	1	•	• 1									
R51	REGION H_2O QUAL MONITOR (R13) ▷2	FL SIO FL	FTU	700	58	0.04 0.04 0.04	0.2 0.2 –	– 0.2 0.2		D S R	1,000 3,600 –	– 3,600 1,000	3.5	2.5		1		•		1										
R53	EARTH OBSERVATION/COMM	SIC	FSSMG	35,786	0	0.25 0.25	3.9 3.9	– 3.9		D S R	943- 2,040	–	4.0	3.1		1	2	1	2 •	1 • •	•	1 • •	2 •	1	•	3 • • • 1	• 2	1	• • • 2	1
R54	RESOURCES/POLLUTION (R12)	SIC	FSSMG	35,786	0	0.25 0.25	3.9 3.9	3.9		D S R	615- 998	–	1.6	1.2		1	1	2	2 •	2 •	3 • •	• •	3 • •	1 • • •	2	2 • • • 1	3 • 1	• • 2	3 • • 2	• • • 3
R55	EARTH SURVEY ▷2	FL SIO FL	FTU	910	99	0.04 0.04 0.04	0.3 0.3	– 0.3 0.3		D S R	772	–	3.0	1.5			1		1 •		1 • •		1 • • •		1 • • • 1		1 • • • 1		1 • • • 1	
R56	COASTAL SATELLITE ▷2	SIO		296	100	0.02	– –	– –		D S R	4,173 –	– 4,173	8.0	3.7			1	•	•	•	•	1								

▷1 NUMERALS DENOTE SCHEDULED EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

▷2 DIRECT ORBITER LAUNCH & RECOVERY

( ) NASA 1981 SYSTEMS TECHNOLOGY MODEL ID NO.

* D – DEPLOY
S – SERVICE
R – RETRIEVE

R81-2100-071W

TABLE 4.4-9 RESOURCE OBSERVATION MISSIONS PART I SHT 2 OF 2

ID NO.	NAME	OPERATIONS CODE	TRANSP CODE	ORBIT H	ORBIT I	TRIP TIME	DELTA VKM/S UP	DELTA VKM/S DN	DELTA VKM/S XB	MISSION FUNCT*	MASS UP	MASS DN	LENGTH M	DIA M	TRAFFIC [1] 5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
R8	SOIL MOISTURE (R10) [2]	FL FL		456	56	0.02 DAYS 0.02	0.1 –	– 0.1		D R	408		3.5	4.6			1		1	1		1	1		1	1		1	1	
R5	OPERATIONAL LAND OBSERVATION SYSTEM (R6) [2]	FL SIO FL	 FTU	700	98	0.04 0.04 0.04	0.2 0.2 –	– 0.2 0.2		D S R	1,700 1,700 –	– 1,700 1,700	4.3	2.2		1	1	1 •	• 1	1 • 1	1 1	1 •	• 1	• 1	1 1	1	1 •	• 1	• 1	1 1
R58	ADV GEOLOGY SATELLITE (R5) [2]	FL SIO FL	 FTU	700	98	0.04 0.04 0.04	0.2 0.2 –	– 0.2 0.2		D S R	2,000 2,000	– 2,000	4.0	3.0				1		•		1	1		•		1			
R59	PRIVATE EARTH RESOURCE (COMMERCIAL) [2]	FL SIO FL	 FTU	700	98	0.04 0.04 0.04	0.2 0.2 –	– 0.2 0.2		D S R	1,700 1,700 –	– 1,700 1,700	4.3	2.2				1		•		1 1		•	•	•				1
R6	ADV THERMAL MAPPING (R7) [2]	FL		700	98	0.04 0.04 0.04	0.2 0.2 –	– 0.2 0.2		D S R	1,450 1,450 –	– 1,450 1,450	2.5	2.0				1		1 •		• •		• 1		1				
R7	MAGNETIC FIELD SURVEY (R9) [2]	SIO	POU	300	97	0.02 0.02 0.02	0.1 0.1 –	– 0.1 0.1		D S R	800 800 –	– 800 800	3.5	2.5				1	•	•	1									
R60	ENVIRONMENTAL MONITOR [2]	FL SIO FL	FTU	700	57	0.04 0.04 0.04	0.2 0.2 0.2	– 0.2 0.2		D S R	1,000 1,000 –	– 1,000 1,000	3.5	3.5					1		1 •		• •		• 1		1			

[1] NUMERAL DENOTE SCHEDULE EVENTS – DOTS DENOTE POTENTIAL SERVICE EVENTS – UNSCHEDULED

[2] DIRECT ORBITER LAUNCH & RECOVERY

( ) NASA 1981 SYSTEMS TECHNOLOGY MODEL ID NO.

* D – DEPLOY
S – SERVICE
R – RETRIEVE

R81-2100-072W

TABLE 4.4-10 RESOURCE OBSERVATION MISSIONS (PART 2)

ID NO.	ON-ORBIT OPS TIME	NO. OF APPENDAGES	NO. OF MODULES	FAB TIME	MAINTENANCE & REPAIR/RECONFIGURE/ RESUPPLY TIME
R2	*	3	–	–	**
R1	*	3	–	–	–
R4	*	3	–	–	–
R50	*	2	–	–	***
R51	*	2	–	–	***
R53	*	2	–	–	**
R54	*	2	–	–	**
R55	*	2	–	–	**
R56	*	2	–	–	***
R8	*	4	–	–	–
R5	*	2	–	–	**
R58	*	2	–	–	**
R59	*	2	–	–	**
R6	*	2	–	–	**
R7	*	2	–	–	**
R60	*	2	–	–	**

* LAPSED TIME FOR POST DELIVERY, SEPARATION, AND CHECKOUT – ASSUME 0.12 DAYS
** LAPSED TIME FOR ON ORBIT SERVICE AND CHECKOUT OF SATELLITES < kg ASSUME 0.3 DAY TOTAL OR 1 WORK SHIFT
***LAPSED TIME FOR ON ORBIT SERVICE AND CHECKOUT OF SATELLITES > kg ASSUME 0.9 DAY TOTAL OR 2 WORK SHIFTS

R81-2100-073W

TABLE 4.4-11 SPACE TESTING MISSIONS PART 1

ID NO.	NAME	OPERATIONS CODE	TRANSP CODE	ORBIT		TIME	DELTA V $_{KM/S}$			MISSION FUNCT*	MASS		LENGTH M	DIA M	TRAFFIC															
				H	I		UP	DN	XB		UP	DN			5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
O110	LONG DURATION EXPOSURE FACILITY (OI-17)	FTU SOC FTU	FTU	509	28.5	0.03 DAYS	.1 .1 –	– .1 .1		D S R	4,500 4,500 –	– 4,500 4,500			1	1	•	1	1	•	•	1	1	•	•	•	1	1	•	•
O12	INDUCED ENVIRO CONTAMINATION (OI-11)	SOE-T SOC								D	338	–								1										
O157	LARGE DEPLOY ANTENNA DEMO (IO-22+)	SOE-T SOC								D	4,700	–		50		1					1									
O159	STRUCTURAL ASSY DEMO (OI-21+)	SOE-T SOC								D	19,000		70						1											
O160	DEPLOYABLE PLATFORM EXPERIMENT (OI-23+)	SOE-T SOC								D	1,500		50					1					1							
O161	FLUID MECH & HEAT XFER FACILITY (OI-25)	SOE-T SOC								D	580		1	1						1										
O162	PACE EXMPTS (OI-26&27)	SOE-T SOC								D	100													1				1		
O163	SCIENCE INSTRUMENT DEMO	SOE-T								D												1			1	1			1	1

( ) NASA 1981 SYSTEMS TECHNOLOGY MODEL ID NO.

* D – DEPLOY
S – SERVICE
R – RETRIEVE

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TABLE 4.4-12 SPACE TESTING MISSIONS (PART 2)

ID NO.	ON-ORBIT OPS TIME	NO. OF APPENDAGES	NO. OF MODULES	FAB TIME	MAINTENANCE & REPAIR/RECONFIGURE/ RESUPPLY TIME
OI-10	<.1 DAYS	–	–	–	***
OI-2	~30 DAYS	–	–	–	**
OI-57	7-20 DAYS	2	–	–	**
OI-59	7-20 DAYS	> 1	–	–	***
OI-60	7-20 DAYS	> 1	–	–	**
OI-61	5-20 DAYS	–	–	–	**
OI-62	7 DAYS	–	–	–	**
OI-63	10-20 DAYS	NA	–	–	**

**LAPSED TIME FOR ON ORBIT SERVICE AND CHECKOUT OF SATELLITES < 3000 kg ASSUME 0.3 DAY TOTAL OR 1 WORK SHIFT
***LAPSED TIME FOR ON ORBIT SERVICE AND CHECKOUT OF SATELLITES > 3000 kg ASSUME 0.9 DAY TOTAL OR 2 WORK SHIFTS
NA NOT AVAILABLE

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FSSUG - Space Based Unmanned Orbit Transfer Vehicle/GEO plus support capability

FGTUG - Ground Based Unmanned Orbit Transfer Vehicle/GEO plus support capability

SOC - Satellite maintenance/repair, reconfigure and resupply on SOC

SIC - SOC based satellite servicing in situ

SIO - Orbiter based satellite servicing in situ

SOE - On board SOC space tests

CAM - On orbit assembly - medium complexity

CGM - On orbit deploy and assembly - medium complexity

CGH - On orbit deploy and assembly - high complexity

CFM - On orbit deploy assembly and fabricate - medium complexity

CFH - On orbit deploy assembly and fabricate - high complexity

A capsule description is provided for each mission. Part 1 data (Tables 4.4-1, -3, -5, -7, -9, and -11) also characterizes each mission with its target orbit, estimated transfer time from a 400 km orbit, required delta vee, mass, size, and scheduled service events. The Part 2 sheets (Tables 4.4-2, -4, -6, -8, -10, and -12) provided additional information on the characteristics of each satellite and the estimated times for implementing on-orbit operations, on-orbit servicing and fabrication.

4.4.1.4 Co-orbiting Satellite Service Missions

Candidate services for satellites co-orbiting with the SOC are provided in Figure 4.4-15. These satellites, which are derived from the S/SUM data base, are nominally at 28.5 degrees inclination and orbital altitudes between 300 and 600 km. A few out-of-plane satellites within range of the MOTV core stage are also included. The

Fig. 4.4-15 Co-Orbiting Satellites — Candidate Services for Space Operations Center — S/Sum Data

SHEET 1 OF 2

	SATELLITE	SPONSOR	ORBIT ALT-km	ORBIT INC-DEG	MASS-kg	CY – EVENTS '86 '88 '90 '92 '94 '96 '98 '00	IN-ORBIT MAINTENANCE SUPPORT	REF
A-3	ST – SPACE TELESCOPE	OSS	593	28.5	11,000		REPLACE S/S ORUs, SCI INSTR, GUID SENSOR, ANTENNA, RATE GYROS, STAR TRACKERS, SOLAR ARRAYS, ETC	1, 2, 3
OI-10	LDEF – LONG DURATION EXPOSURE FACILITY	OAST	509	28.5	4,500		CHANGE EXPERIMENT TRAYS	1, 2
S-9	SUBSATELLITE FACILITY	OSS	296	28.5	500		RECONFIG INSTRUMENTS, MAINTAIN SUB/SYS, RESUPPLY PROP & GASSES	1, 2
A-9	AXAF – ADVANCED X-RAY ASTROPHYSICS FACILITY	OSS	450	28.5	10,000		REPLACE SUBSYS ORUs, SCI INSTR, GUID SENSOR, ANTENNA, ETC, RESUPPLY RADIATION DETECTOR GAS	1, 2, 4
A-61	SOLAR CORONA EXPLORER	OSS	600	33.	1,000		REPLACE SUBSYS ORUs RESUPPLY RCS PROPELLANT	1, 2
S-56	LARGE SOLAR OBSERVATORY	OSS	350	28.5	9,800		CHANGE SUBSYS UNITS	.2
A-17	LARGE AMBIENT DEPLOYABLE IR TELESCOPE	OSS	500	28.5	16,000		CHANGE OUT SUBSYS UNITS, SCI INSTRUMENTS, ANTENNA – RESUPPLY RCS PROP & INSTRUMENT CRYOGENS	1
A-18	IR INTERFEROMETER	OSS	400	28.5	22,500		CHANGE SUBSYS UNITS, SCI INSTR, ANTENNAS & ARRAYS RESUPPLY RCS PROP & INSTRUMENT CRYOGENS	1, 2
P-14	AUTOMATED PLANETARY STATION	OSS	400	28.5	25,000		CHANGE SUBSYS UNITS/ASSYS SCI INSTRUMENTS, RESUPPLY CRYOGENS & FLUIDS	1,2
A-21	LARGE OPTICAL/UV TELESCOPE	OSS	450	28.5	22,800		CHANGE SUBSYS UNITS/ASSYS, & SCI INSTRUMENTS	
A-5	EUVE-EXTREME UV EXPLORER	OSS	550	28.5	400		NOT DESIGNED FOR IN-ORBIT SERVICE	2, 8
A-62	HI-ENERGY EXPLORER	OSS	463	28.5	2,268		REPLACE SCIENTIFIC INSTRUMENTS & SUB-SYS UNITS	2,
A-10	X-RAY TIMING EXPLORER	OSS	400	28.5	1,000		REPLACE FAILED SUBSYS MODULES – PWR, COMM/DATA & ATT CTL	1, 2, 5
S-13	SCADM – SOLAR CYCLE & DYNAMICS MISSION	OSS	575	28.5	2,600		REPLACE FAILED SUBSYS MODULES, PWR, COMM/DATA & ATT CTL	1, 2
A-14	LAMAR – LARGE AREA MODULAR ARRAY REFLECTOR	OSS	400	28.5	5,200		REPLACE FAILED SUBSYS MODULES, PWR, COMM/DATA & ATT CTL	1, 2, 6
S-52	GTE – GAMMA-RAY TRANSIENT EXPLORER	OSS	450	28.5	3,000		NOT DESIGNED FOR IN-ORBIT SERVICE	1, 2, 7
A-52	UV PHOTOMETRIC/POLARMETRIC	OSS	400	28.5	545		NOT DESIGNED FOR IN-ORBIT SERVICE	2, 9

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Fig. 4.4-15 Co-Orbiting Satellites – Candidate Services for Space Operations Center

SHEET 2 OF 2

	SATELLITE	SPONSOR	ORBIT ALT-km	ORBIT INC-DEG	MASS-kg	CY – EVENTS '86 '88 '90 '92 '94 '96 '98 '00	IN-ORBIT MAINTENANCE SUPPORT	REF
S-55	XRO – X-RAY OBSERVATORY	OSS	400	28.5	3,550	A ▲-○-○-○-▼	REPLACE FAILED SUBSYS MODULES PWR, COMM OR ATT CTL	1, 2, 10
						B ▲-○-○-○-▼	SAME AS ABOVE	
A-56	SXS – SOFT X-RAY SURVEY	OSS	400	28.5	1,600	▲—▼	NOT DESIGNED FOR IN-ORBIT SERVICING	2, 11
A-57	MLS – MOLECULAR LINE SURVEY	OSS	600	28.5	1,000	▲—▼	NOT DESIGNED FOR IN-ORBIT SERVICING	2, 12
A-55	XSM – X-RAY SPECTROSCOPY MISSION	OSS	400	28.5	1,500	▲-○-▼	REPLACE FAILED SUBSYS MODULES PWR, COMM & ATT CTL	2, 13
E-4	ERBS – EARTH RADIATION BUDGET SATELLITE	OSTA	600	46	1,150	△—○—▽△—○—▽	REPAIR IN-SITU – REPLACE FAILED SUB-SYS MODULES, ETC	2,
A-15	VERY LONG BASELINE RADIO INTERFEROMETER	OSS	1000	45		α △—○—○—▽	REPAIR IN SITU – REPLACE FAILED SUBSYS MODULES, ETC	2
						β △—○—○—▽		

LEGEND

▲▼ SCHEDULED LAUNCH & RETURN
△▽ ASSUMED LAUNCH & RETURN
● SCHEDULED SERVICE EVENT
○ ASSUMED SERVICE EVENT

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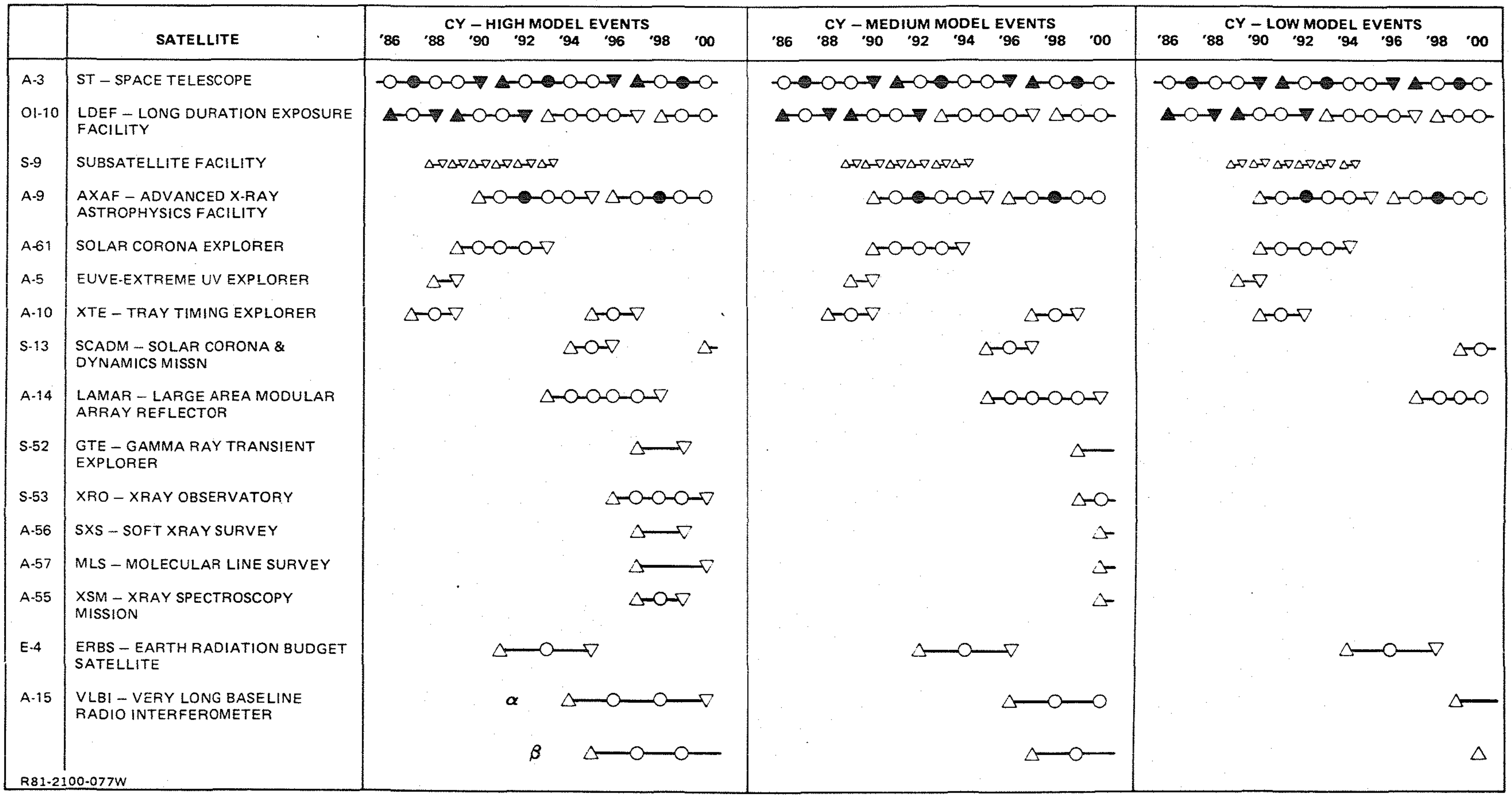
first 10 satellites, which have no self-propulsion capability, are listed in chronological order. The remaining satellites include a low energy propulsion system and are also listed in chronological order. Servicing events for launch and return are annotated to follow the approved/planned schedule and the assumed opportunity schedule described by Grumman's S/SUM data (Reference 4.4-2). The scheduled and assumed events for in-orbit maintenance resupply and reconfiguration are annotated in a like manner. Some satellites are not designed for in-orbit maintenance, such as the Gamma Ray Transient Explorer. Other satellites require periodic, resupply of cryogens (i.e., IR Interferometer) or changeout of scientific instruments (i.e., Space Telescope and AXAF). There are yet other satellites of short mission duration, such as the X-Ray Spectroscope Mission, which will only be serviced if needed.

Economic analysis of the co-orbiting satellites included in the S/SUM data has resulted in fewer programs in LEO which in turn has a moderate impact on SOC required service events. Figure 4.4-16 defines alternate service event schedules for these satellites from the high, medium and low economic models. The reference S/SUM service events are compared in Figure 4.4-17 with respect to the results of the high and low economic models. The in-orbit service events are denoted as scheduled maintenance and potential revisits. For LEO satellites "potential revisits" cover the possible need for more frequent on-orbit support and possible random failure situations which add to the schedule maintenance requirements. Both the high and low models include launch support for at least two co-orbiting satellites per year. The models also indicate that potential exists for on-orbit maintenance/resupply on three to four satellites per year. In addition, the SOC would have to support the retrieval of one or two satellites per year which are to be removed from orbit.

4.4.1.5 Satellite Service Missions In situ

Candidate satellites which can be serviced in situ, by SOC based vehicles, are identified in Figure 4.4-18. This includes satellites

Figure 4.4-16 Co-Orbiting Satellites for Servicing By Space Operations Center — Economic Mission Model



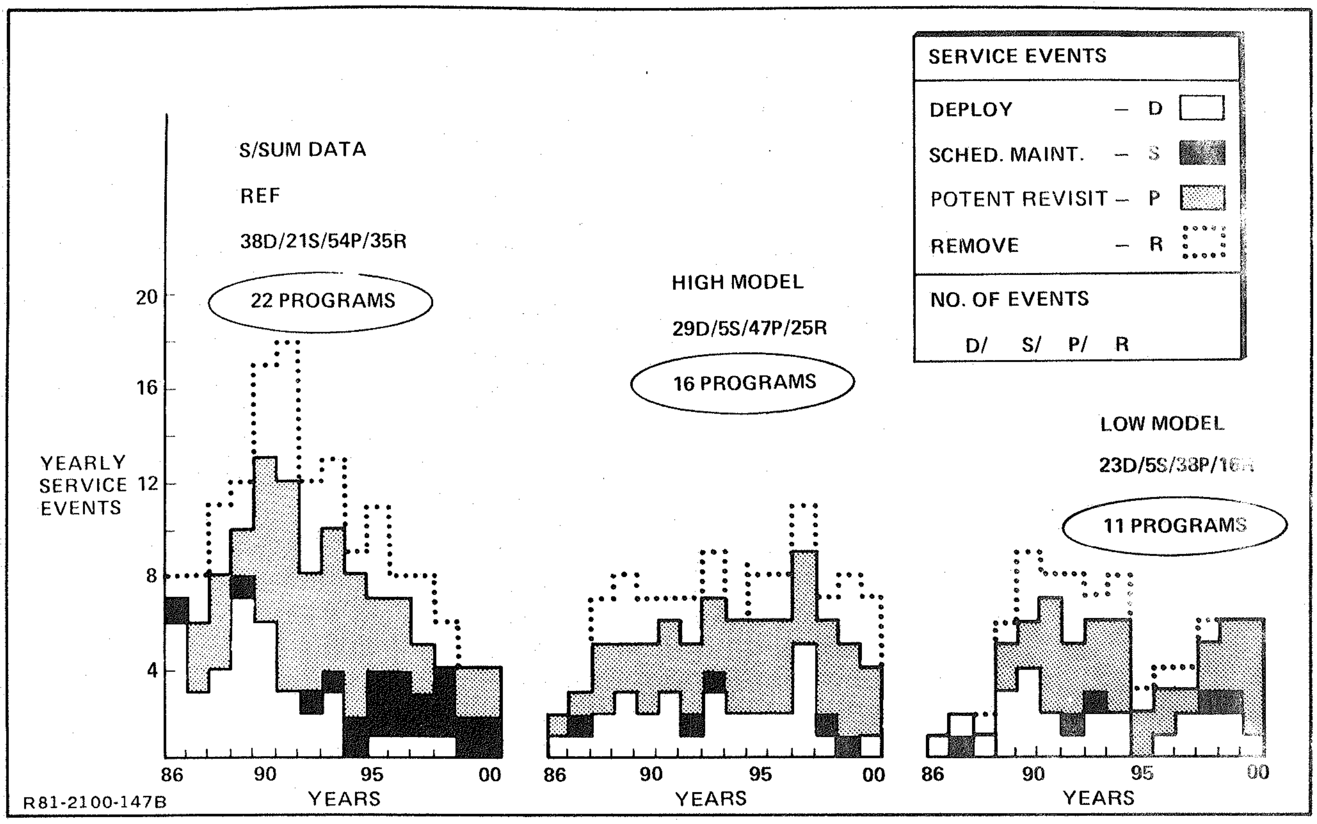


Figure 4.4-17 LEO Co-Oribiting Satellite Service Mission Models for SOC – Non Dod & Non Foreign

Fig. 4.4-18 Satellites for Servicing In-Situ By Vehicles Based at Space Operations Center

SHEET 1 OF 2

	SATELLITE	SPONSOR	ORBIT ALT-km	ORBIT INC-DEG	MASS-kg	CY – EVENTS – S/SUM DATA '86 '88 '90 '92 '94 '96 '98 '00	CY – HIGH MODEL EVENTS '86 '88 '90 '92 '94 '96 '98 '00
A-15	VERY LONG BASELINE INTERFEROMETER	OSS	1,000	45	ND	A	
						B	
A-53	INTERNATIONAL UV EXPLORER	FOREIGN	GEO	0	500		
A-59	SIMULTANEOUS ASTRONOMY MISSION	OSS	GEO	0	2,080		
A-54	EXTREME UV SPECTROSCOPE	OSS	GEO	0	1,000		
A-18	IR INTERFEROMETER	OSS	400	28.5	22,500		
A-19	GRAVITY WAVE INTERFEROMETER	OSS	GEO	0	11,250		
A-20	COSMIC COHERENT OPTICAL SYSTEM	OSS	GEO	0	11,500		
A-22	100 M THIN APERTURE TELESCOPE	OSS	GEO	0	10,600		
S-51	ASTRONOMY	OSS	5,000	28.5	950		
E-2	GEO OPERATING ENVIRONMENT SATELLITE	OSTA	GEO		720		
E-4	ERBS – EARTH RADIATION BUDGET SAT	OSTA	600	46	1,150		
E-52	STORM SAT	NOAA	GEO		1,600		

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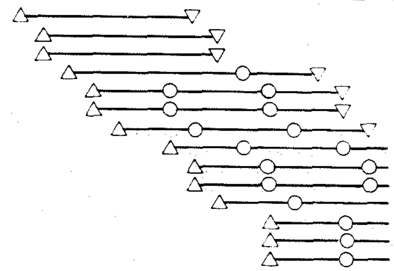
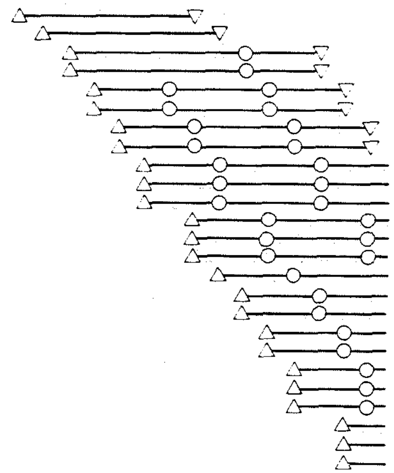
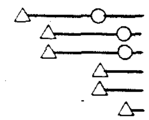
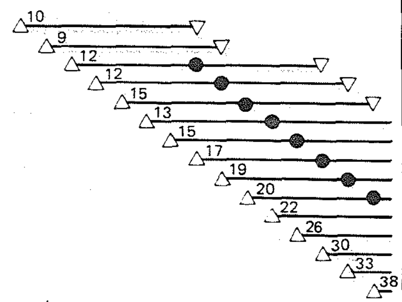
Fig. 4.4-18 Satellites for Servicing In-Situ By Vehicles Based at SOC

SHEET 2 OF 2

	SATELLITE	SPONSOR	ORBIT ALT-km	ORBIT INC-DEG	MASS-kg	CY – EVENTS S/SUM DATA '86 '88 '90 '92 '94 '96 '98 '00	CY – HIGH MODEL EVENTS '86 '88 '90 '92 '94 '96 '98 '00
R-53	EARTH OBSERVATION/COMM	OSTA	GEO	0	943-2040		
R-54	RESOURCES/POLLUTION	OSTA	GEO	0	615-998		
	TELECOMMUNICATIONS (BOEING DATA)	COMM'L	GEO	0	1000-10,000		

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in remote orbits (e.g., 46 degree inclination or at GEO) and a few co-orbiting satellites in LEO which are too large to return for servicing at SOC (i.e, IR Interferometer). Scheduled service events are shwon for both the reference S/SUM data and the results of the high economic model analysis. The high model and the other economic model are dominated by the commercial telecommunication missions at GEO, which Boeing analyzed and defined. Telecommunication satellites are presently being designed for about 7 years. As stated above, it is assumed that all satellites will be designed for on-orbit maintenance after 1988. At that time, all communication satellites are assumed to be designed for a 10-year mission life, which is achieved by in-orbit maintenance and resupply after five years.

Cummulative yearly service events are shown in Figure 4.4-19 for these GEO satellites, which exclude DOD and foreign satellites, with respect to the three economic mission models (high, medium, and low). The progressive buildup of LEO SOC supported launch events is shown for each model. During the SOC era a large number of satellites will accumulate in GEO due to these launches alone. There will be more than 100 to 200 satellites, depending upon the model used, which will be repairable and operating in GEO at the same time. From this population alone, a sizeable number of satellites can be expected to have random failures before their end-of-mission or scheduled maintenance time. These failures are identified as part of the scheduled revisits for GEO satellite periodic maintenance. Between the low and the high model there are 8 to 18 scheduled revisits needed every year if each telecommunication satellite is serviced at least once after deployment. Otherwise 3 to 6 random failures per year, which may occur regardless, can be expected to occur. During this period 7 to 12 satellites per year will reach the end of their mission and should be removed from their orbital slots.

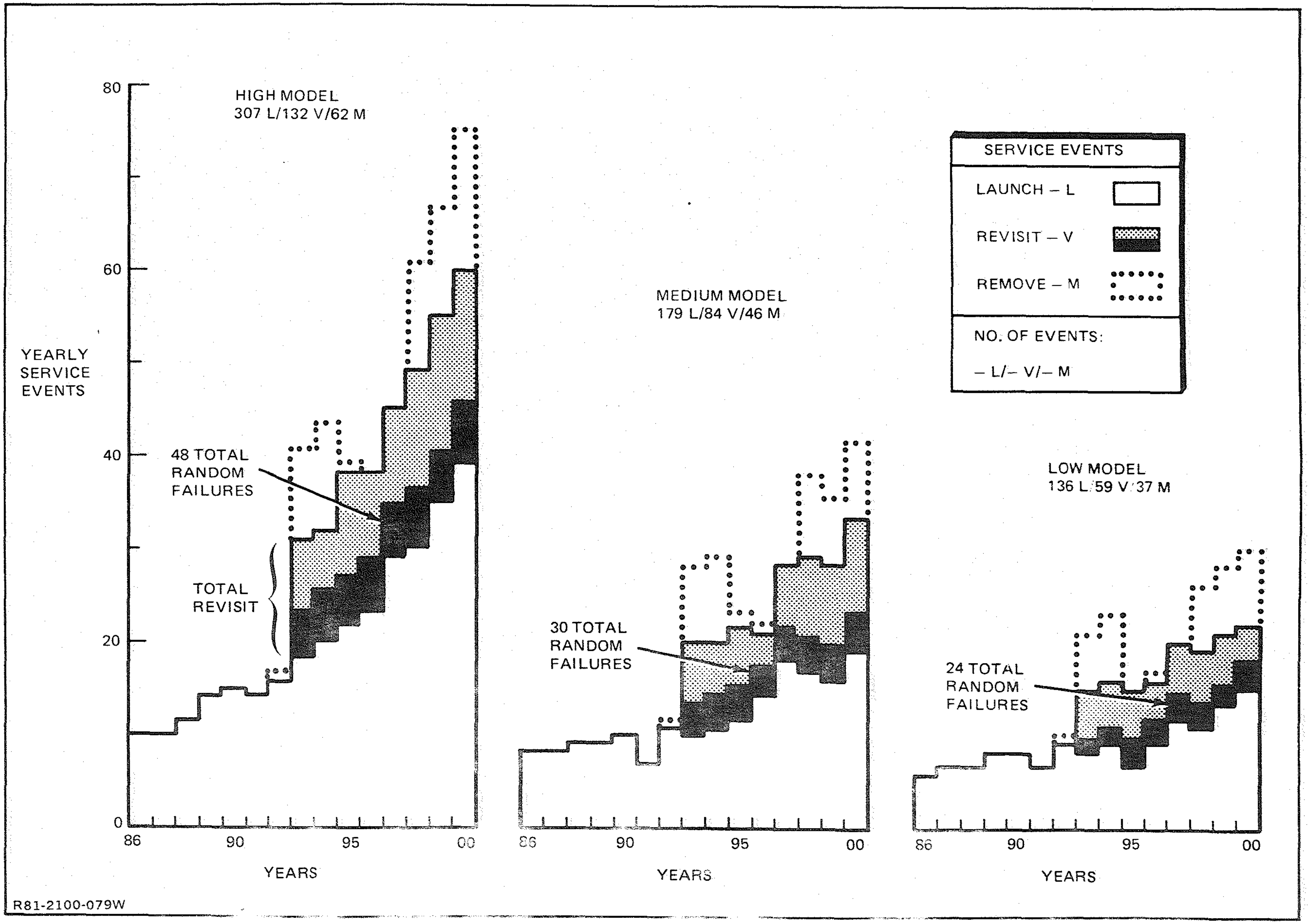

Figure 4.4-19 Geo Satellite Service Mission Models for SOC – Non Dod & Non-Foreign

4.4.2 BENEFITS OF USING SOC TO SERVICE SATELLITES

4.4.2.1 Potential Savings for LEO Satellite Users

Representative mission service costs are shown in Figure 4.4-20 for a large scientific observatory such as the Advanced X-ray Astrophysics Facility and a smaller MMS type satellite such as the Large Area Modular Array of Reflectors (LAMAR) spacecraft. The cost of replacing these spacecraft in event that they fail prematurely has been estimated at between $150 and 200 M. The direct charge to the user to repair these satellites with the Orbiter is estimated to be $16 to 19 M, or even higher if an OMS kit is required to reach the satellite. Nevertheless, to the user these costs are only 10% of the total replacement costs for a new satellite. The largest part of the Shuttle revisit cost results from the charge to carry the required service equipment (i.e., proximity operations, modules, handling/positioning aid, etc) to and from orbit. The SOC achieves its major cost advantage of $6 to 7 M, since these equipments are always left in orbit.

4.4.2.2 Potential Savings for GEO Communication Satellites

The telecommunication satellite community can derive considerable savings by using SOC based vehicles to maintain and support their satellites in GEO. Figure 4.4-21 shows the range of potential savings that can be accured by either servicing all satellites once or only repairing those as needed.

Both strategies deal with communication satellites that are designed for a 10-year mission life with in-orbit servicing provisions. The full traffic model includes all the scheduled maintenance revisits as defined by the three GEO satellite service mission models shown in Figure 4.4-19. The partial traffic model only considers random failure situations which could have a 15% to 20% probability of occurrence. In both instances the total savings, which exceed $1 B by 2000, reflects the user's costs of transporting a new satellite to GEO, less the cost of satellite repair. Satellite replacement costs are based upon $50 M/tonne and $35 M was used to cover

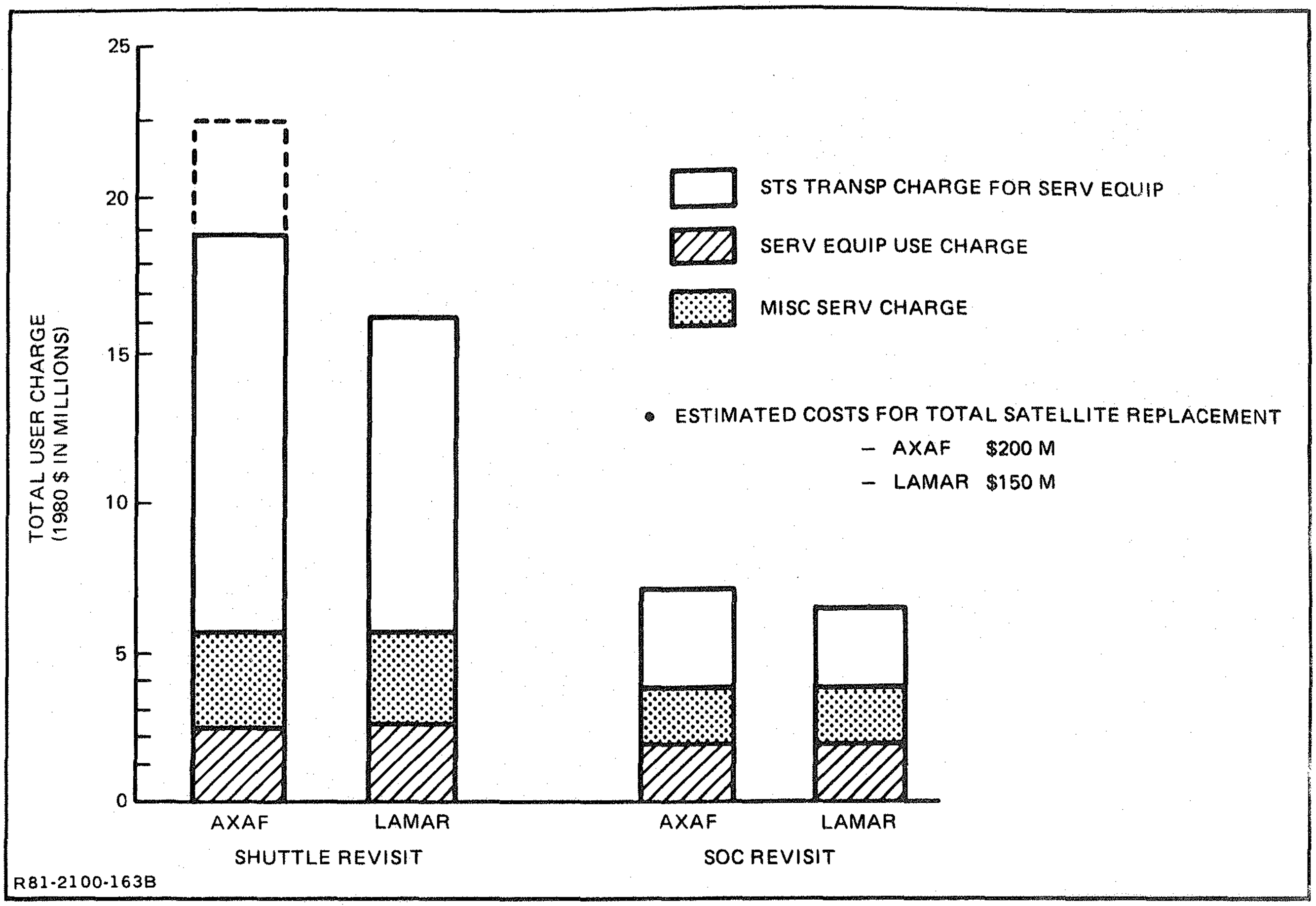

Figure 4.4-20 Representative Missions – Service Costs

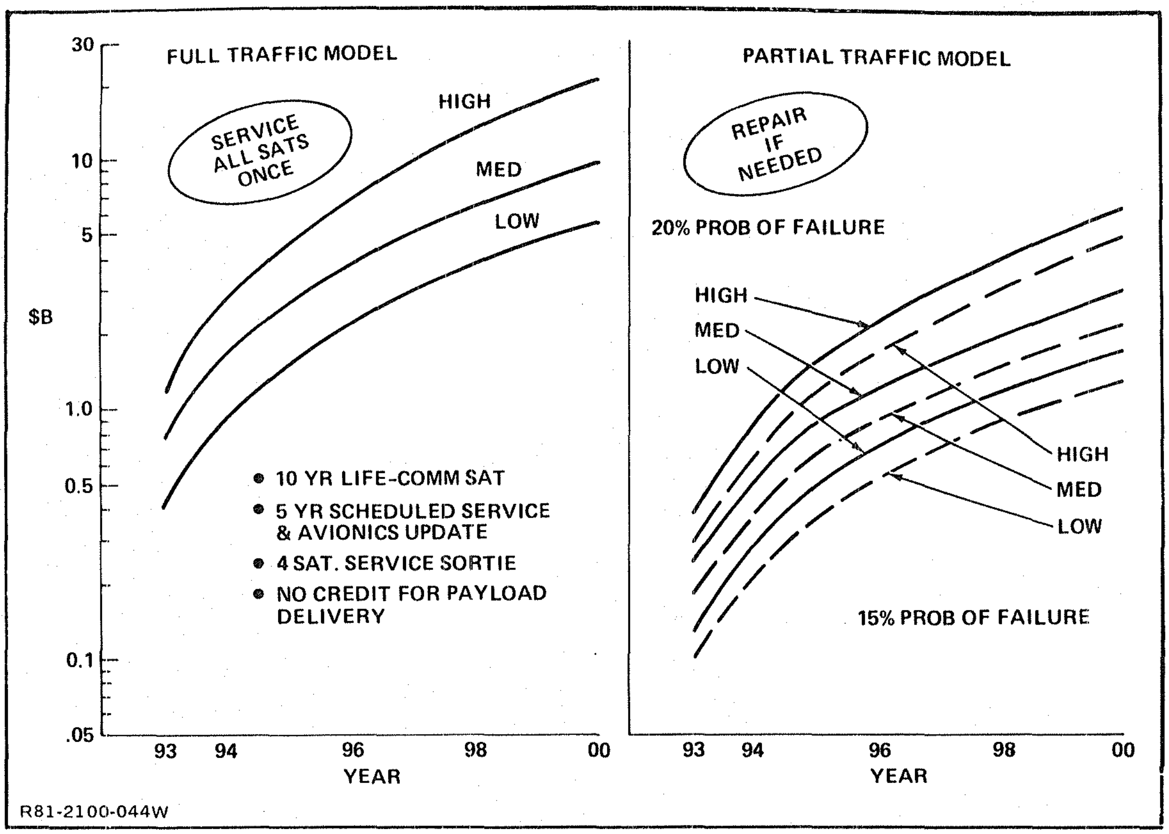

Fig. 4.4-21 Potential Savings from Servicing Satellites in GEO With LEO-Based MOTV

the cost of transporting each satellite to orbit. Satellite servicing costs, in turn, are based upon a four satellite service sortie mission where each user shares the cost at $30 M per satellite. The total satellite servicing cost also includes an allowance to cover satellite related repair costs (i.e., 10% of new satellite cost).

4.4.2.3 Summary of Benefits

The major benefits of using SOC to service satellites in LEO & GEO are that it provides a continuously manned transportation node, which is decoupled from potential ground launch problems and/or mission constraints of the Space Shuttle. Figure 4.4-22 summarizes the major advantages of using SOC to supplement the Orbiter for satellite servicing. By basing orbital service vehicles on the SOC it will be able to provide a broad range of services (including launch, on-orbit support, and removal from orbit) to the satellite users when they are needed. With advanced mission planning and early provisioning of satellite replaceable items and supplies onboard, the SOC should be immune to STS launch delays and vehicle availability problems. The SOC, of course, is not constrained by the Orbiter mission duration limits. By using the SOC to support satellite deployment and on-orbit maintenance in LEO, the Orbiter will be free to support other mission operations which are beyond its range. SOC accessible orbits extend from LEO to GEO and include an out-of-plane sector at LEO which can be ± 3 degrees with a Versatile Service Stage, or even ± 20 degrees or more with the core stage from a Manned Orbital Transfer Vehicle (MOTV). Since it is continuously in orbit, the SOC offer greater flexibility to deal with satellite deployment situations which may require extended test and checkout operations with the Payload Operations Control Center (POCC), extended calibration operations or other contingencies that might arise. The SOC has the inherent capability for on-orbit storage, which can be used to deal with delays in maintenance and repair, to maintain a cache for common modules/equipment, or even as a depot for earth return spacecraft. By operating in a 28.5 degree orbit the SOC will be able to service 50% of the satellites in LEO, launch all GEO and planetary spacecraft, and support MOTV satellite service at GEO.

- DECOUPLED FROM STS LAUNCH DELAYS, MISSION LIMITS AND VEHICLE AVAILABILITY
- ON-DEMAND SERVICE TO SOC ACCESSIBLE ORBITS
  - LEO OUT OF PLANE SECTOR: ± 3° VSS (TMS) / ± 20° MOTV CORE — WITH 5 MT RETURN PAYLOAD
  - GEO ALTITUDES AND HIGHER
- FLEXIBILITY IN SATELLITE DEPLOYMENT
  - EXTEND TEST AND CHECKOUT WITH POCC
  - EXTEND CALIBRATION OPERATIONS
  - CONTINGENCIES
- ON-ORBIT STORAGE CAPABILITY:
  - HANDLE OPERATIONAL DELAYS (MAINT/REPAIR & DEPLOY)
  - MAINTAIN COMMON MODULE/EQUIPMENT CACHE
  - RETURN TO EARTH DEPOT
- 28.5° SOC SERVES 50% LEO AT SAT PROGRAMS, ALL GEO AND PLANETARY LAUNCHES, AND ALL SERVICES IN GEO
  - FREES ORBITER TO SUPPORT HIGH INCL LEO PROGRAMS
- MAINTAIN/REPAIR LEO SATS AT SOC $7M/USE VS STS $19-25M
- INSITU MAINTAIN/REPAIR 20% GEO COMM SAT SAVES $200M/YR (FY-'95 LOW MODEL)

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Fig. 4.4-22 Major Advantages of Using SOC vs Orbiter for Satellite Servicing

It is estimated that servicing LEO satellites on SOC will save $12-18 M of related orbiter transportation costs for performing the same function.

Potential savings from the maintenance and repair of GEO communication satellites with a SOC based MOTV can also be quite substantial ($200 M/year for the low model if 20% are repaired due to random failures).

SUBSECTION 4.4 REFERENCES

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4.4-3 Space Support Equipment, P-Wear Presentation, Lockheed Missiles and Space Coporation, CM-04, 24-25 May 1981

4.4-4 Advanced X-Ray Astrophysics Facility (AXAF) - Science Working Group Report NASA TM-78285 May 1980

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4.4-6 Large Area Modular Array of Reflectors, NASA/GSFC White Paper, July 1980

4.4-7 Gamma-Ray Transient Explorer, NASA/GSFC White Paper, July 1980

4.4-8 Extreme Ultraviolet Explorer, NASA/GSFC White Paper, July 1980

4.4-9 Ultraviolet Photometric/Polarmetric Explorer, NASA/GSFC White Paper, July 1980

4.4-10 X-Ray Observatory, GSFC White Paper, July 1980

4.4-11 Soft X-Ray Survey, GSFC White Paper, July 1980

4.4-12 Molecular Line Survey, GSFC White Paper, July 1980

4.4-13 X-Ray Spectoscopy Mission, GSFC White Paper, July 1980

4.4-14 "Satellite Servicing from the Shuttle Orbiter", by R. L. Kline and R. J. Adornato-Grumman Aerospace Corporation, IAF XXXII Congress, Rome, Italy, September 1981 Preprint IAF 81-43

4.4-15 "Reliability Prediction and Demonstration for Missile and Satellite Electronic" Bellinger Boothman, et al RADC-TR-68281, November 1968

4.4-16 An Analytical Technique to Assess the Economic Impact of the Shuttle on Satellite Payloads. A. Salee, Grumman Aerospace Corporation, AIAA paper No. 71-807 July 1971

4.4-17 "Satellite Long Life Assurance - The Impact of the Shuttle Era" E. Diamond & J. Fragola, Grumman Aerospace Corporation, AIAA paper 72-775 March 1972

4.5 DIFFERENTIAL DRAG CONSIDERATIONS OF CO-ORBITING SATELLITES

4.5 DIFFERENTIAL DRAG CONSIDERATIONS OF CO-ORBITING SATELLITES

4.5.1 Introduction

Satellites co-orbiting with a Space Operations Center, so located for servicing reasons, will in general have different drag characteristics other than the SOC. At the flight altitude selected for the SOC (370 km), orbit decay rates due to differential drag are appreciable, 0.25 km/day being a typical figure for the SOC itself. Co-orbiting satellites will have drag characteristics ranging from greater decay rates than the SOC to no decay at all, in the case of a satellite that employs continuous orbit makeup.

Differential drag, and the changes in relative orbit location it causes, must be considered in (1) the selection of an orbit makeup strategy for SOC, (2) the selection of an orbit makeup strategy for co-orbiting satellites, and (3) the selection of propulsive means for accomplishing servicing.

If two spacecraft, initially co-orbital, experience differential drag, and do not compensate for it, they will become separated: (1) in altitude by the difference in orbit decay; (2) along the orbit track because the satellite at lower altitude will move faster; and (3) in plane, because of differential nodal regression resulting from the difference in altitude.

4.5.2 Analytical Models

To study this phenomena, an orbital simulation was employed using three different satellites. This simulation model contained a Jacchia dynamic atmospheric density model, effects due to the sun and moon, and harmonics of the Earth's gravitational field through the fourth order degree. The Science and Applications Space Platform (SASP) and the Advanced X-Ray Astronomy Facility (AXAF) were used as the SOC co-orbiting satellite models. These satellites were chosen on the basis that they represented a fairly wide range of ballistic coefficients (approximately 21 to 190 Kg/M^2). An operational SOC configuration was used for comparing the different orbit decay rates. It was assumed that SOC maintained its initial altitude by employing continuous orbit makeup since this will be quite likely. Two Jacchia models were used: the NASA Neutral Model with a value of

230 for the 10.7 near solar flux (F10.7) and a value of 20.3 for the geomagnetic index (Ap), and a Minimum Model using a F10.7 of 73.3 with an Ap of 10.9.

The results of these simulations are shown in Figures 4.5-1 and 4.5-2.

4.5.3 Results

As seen in these figures, the along-track separation develops more rapidly than the other separations. The "sinusodial" effects in the along-track separation are due to the fact that once the two satellites become 180 degrees out of phase, they begin to approach each other (i.e., one satellite "laps" the other).

If the same average altitude is maintained, the plane differences will approximately cancel out. A representative relative maneuver strategy for a co-orbiting satellite needing periodic service is illustrated in Figure 4.5-3. The orbit of the satellite experiencing the greatest decay rate is reboosted once per service interval. The reboost occurs halfway between intervals so that as the service time approaches, the satellite approaches the SOC with a low closing velocity. Terminal maneuvering can then be used to effect rendezvous and capture. The means of orbit makeup and maneuver are the subject of an investigation into satellite servicing transportation considerations.

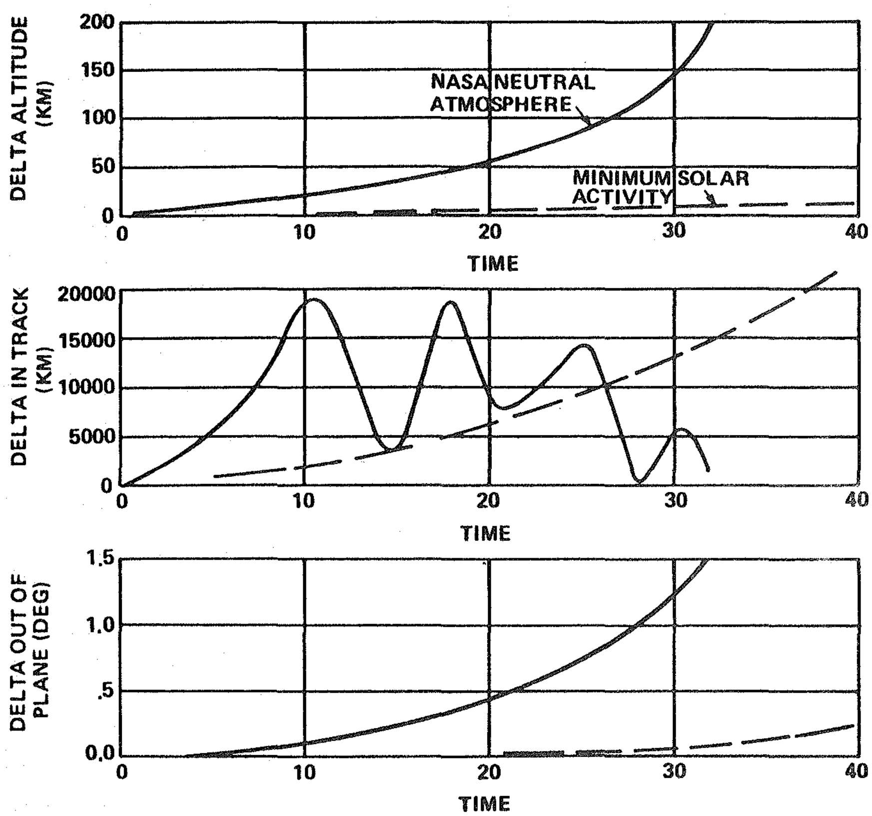

Figure 4.5-1 Differential Drag Between Operational SOC (No Drag) and SASP (C_D-3.0)

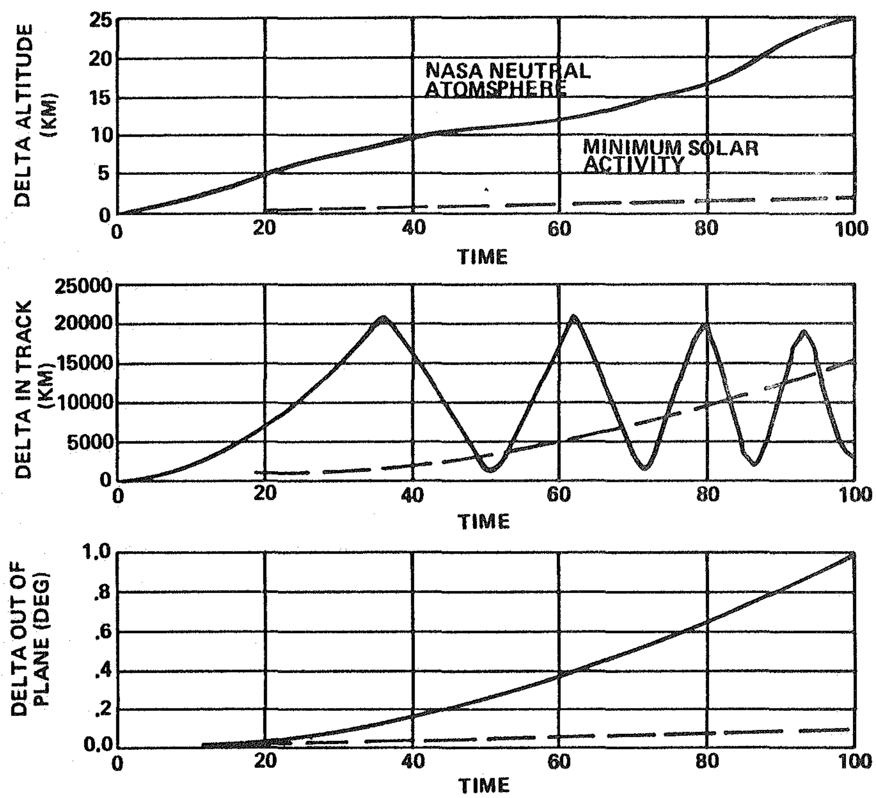

Figure 4.5-2 Differential Drag Between Operational SOC (No Drag) and UXAF (C_D-3.0)

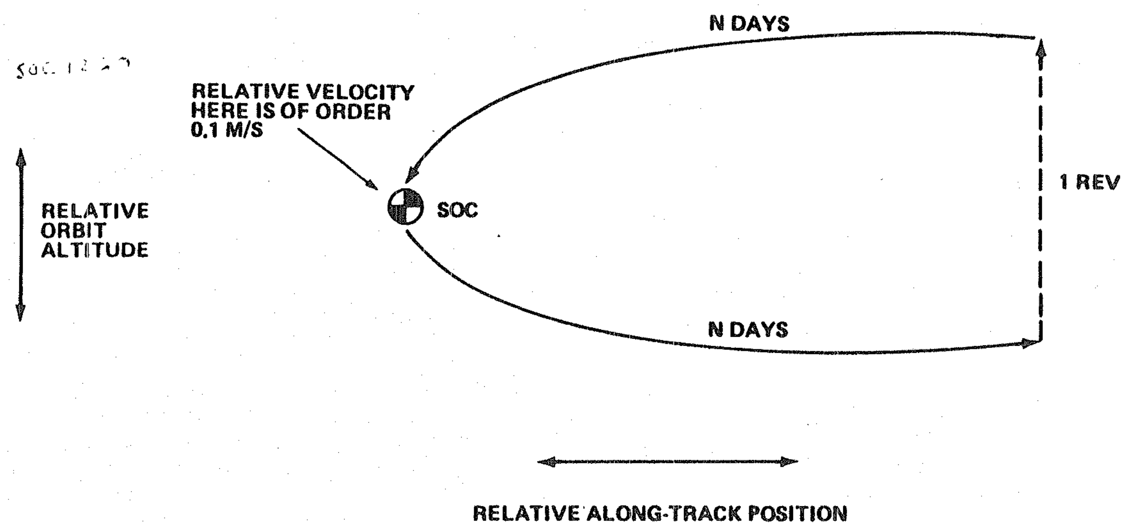

Figure 4.5-3 Differential Drag Orbit Makeup Strategy

4.6 SATELLITE SERVICING TRANSPORTATION CONSIDERATIONS

4.6 SATELLITE SERVICING TRANSPORTATION CONSIDERATIONS

4.6.1 Performance Capability Analysis

Performance capabilities have been established for a space-based Orbital Transfer Vehicle (OTV) and a Teleoperator Maneuvering System (TMS). Assumptions used in the analysis are as follows:

1) All vehicle missions begin and end at the Space Operations Center (SOC), which is in circular orbit at 370 km.

2) Vehicle performance characteristics reflect all propulsive maneuvers up through plane changes of 28.5 degrees and altitude changes up to 7800 km for delivery, and a lower altitude for retrieval or round trip. The altitude for the latter types of missions depends on the payload weight inserted into LEO. Aeroassist below these altitudes is not beneficial on a cost basis.

3) OTV (normal growth technology) system characteristics as per the Future Orbital Transfer Vehicle Study (NAS1-16088). TMS system characteristics per Vought TMS book for NASA MSFC, 29-30 May 1980.

4) Vehicle Characteristics:

		FOTV	TMS
Vehicle Burnout Mass	kg	4,342	1,282
Propellant Mass	kg	33,043	2,268
Total Vehicle Mass	kg	37,385	3,550
Specific Impulse	seconds	485	230

The performance capabilities that have been defined include mission envelopes for three types of missions for each vehicle. The missions are:

a) Delivery. The vehicle takes a payload from the SOC and returns (empty).

b) Retrieval. The vehicle brings a payload to the SOC.

c) Round Trip. The vehicle takes a payload from the SOC and brings it back.

FOTV performance capability is presented in Figures 4.5-1 through -4 and TMS performance in Figures 4.5-5 through 4.5-9. The TMS data includes capability provided when using the standard propellant tank set as well as that available with dual and triple tank sets.

4.6.2 Results

The key obervations resulting from this analysis are as follows:

- o The FOTV is limited to less than 40 degrees plane change for altitude up to 2000 km above SOC
- o The TMS is limited to less than 4 degrees plane change
- o The TMS cannot perform any mission above 2800 km altitude
- o For coplanar orbits with small (less than 100 km) altitude changes, neither vehicle is likely to be limited by the payload mass

SOC-1344

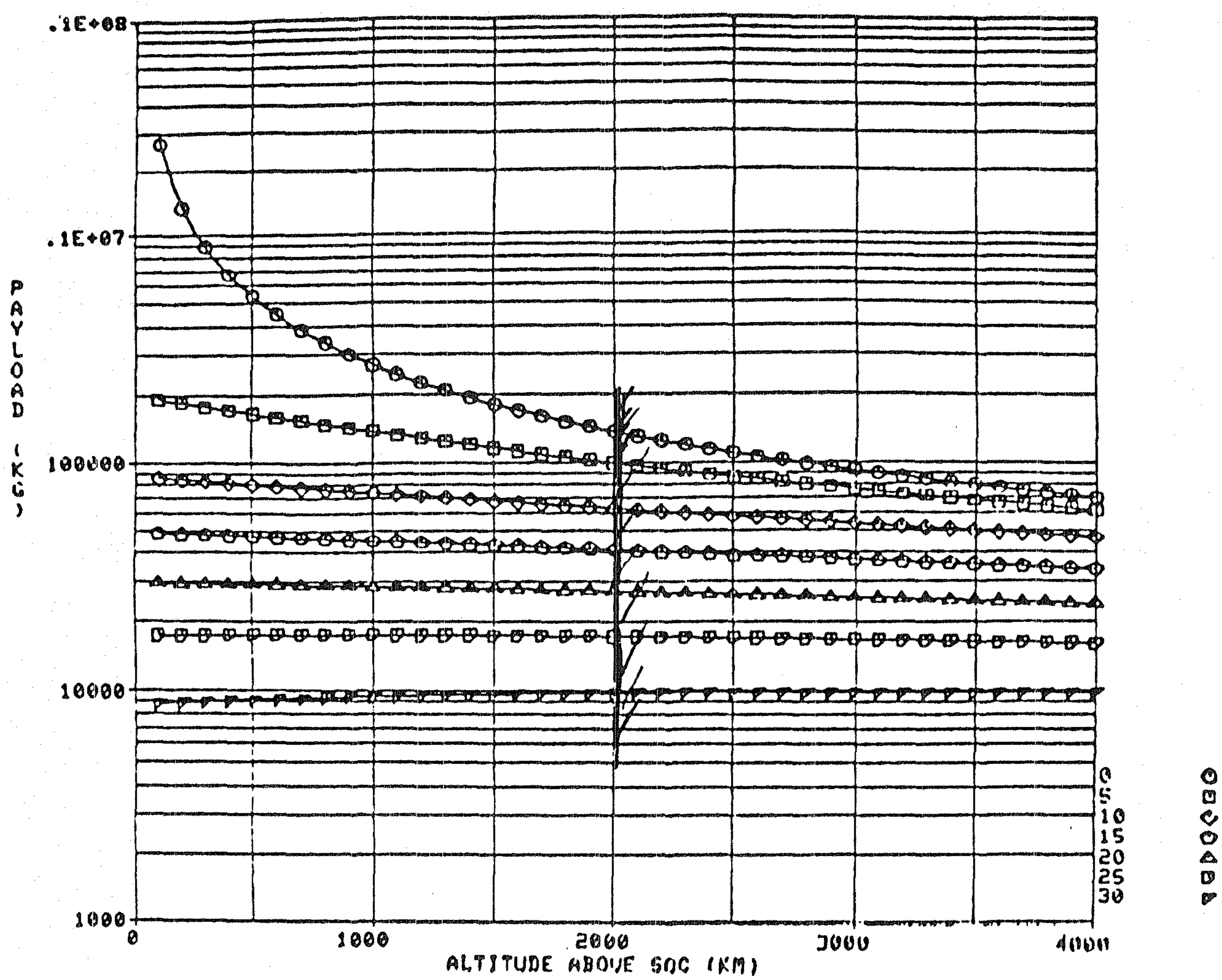

Figure 4.5-1. FOTU Payload Delivery Capability—Low Altitudes

SOC-1345

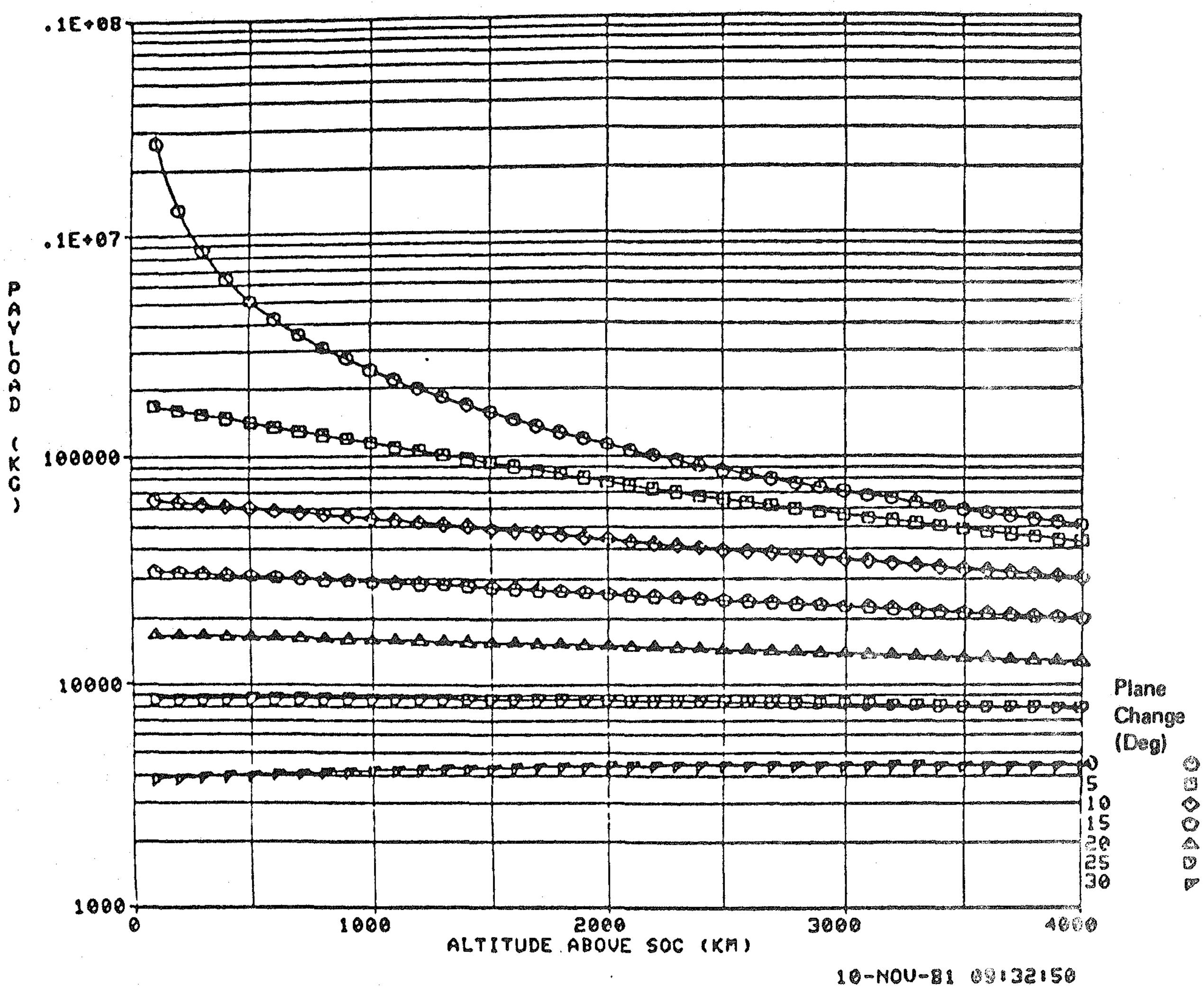

Figure 4.5-2. FOTU Payload Retrieval Capability—Low Altitudes

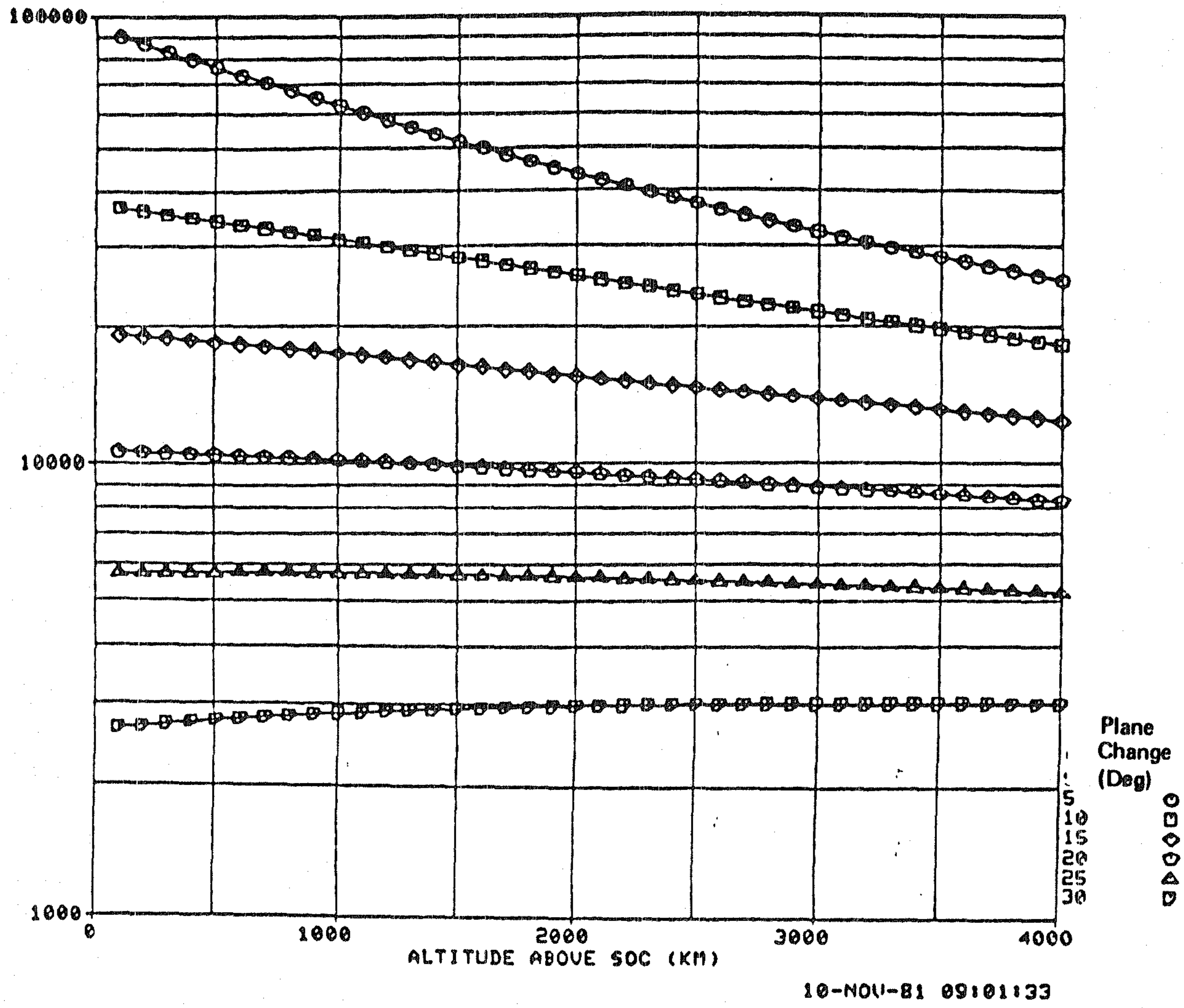

Figure 4.5-3. FOTU Round Trip Payload Capability—Low Altitudes

SOC-1347

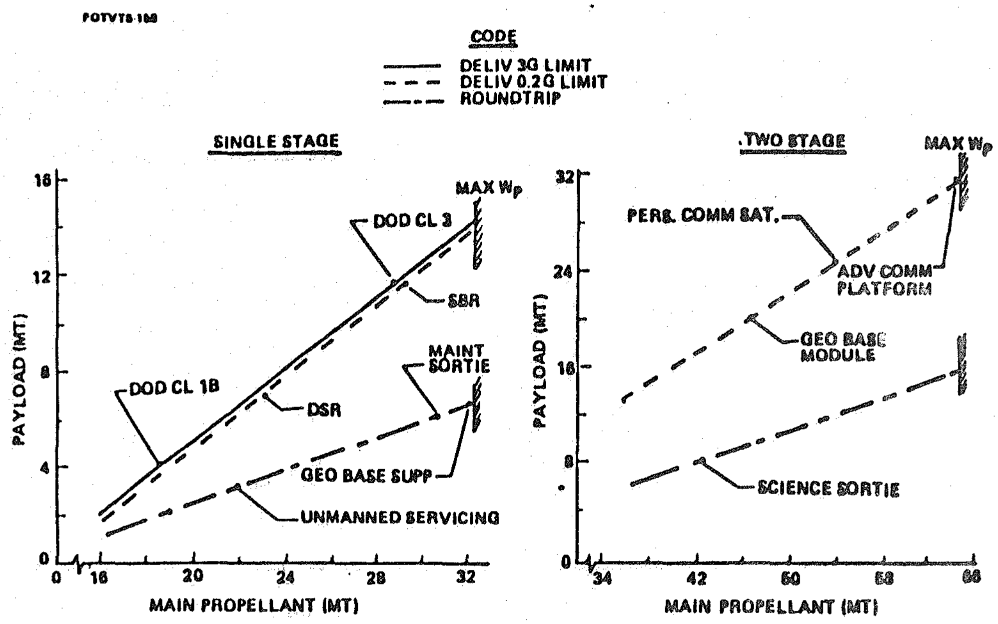

Figure 4.5-4. Performance—Off-Loaded Space Based LO_2/LH_2 OTV

SOC-1348

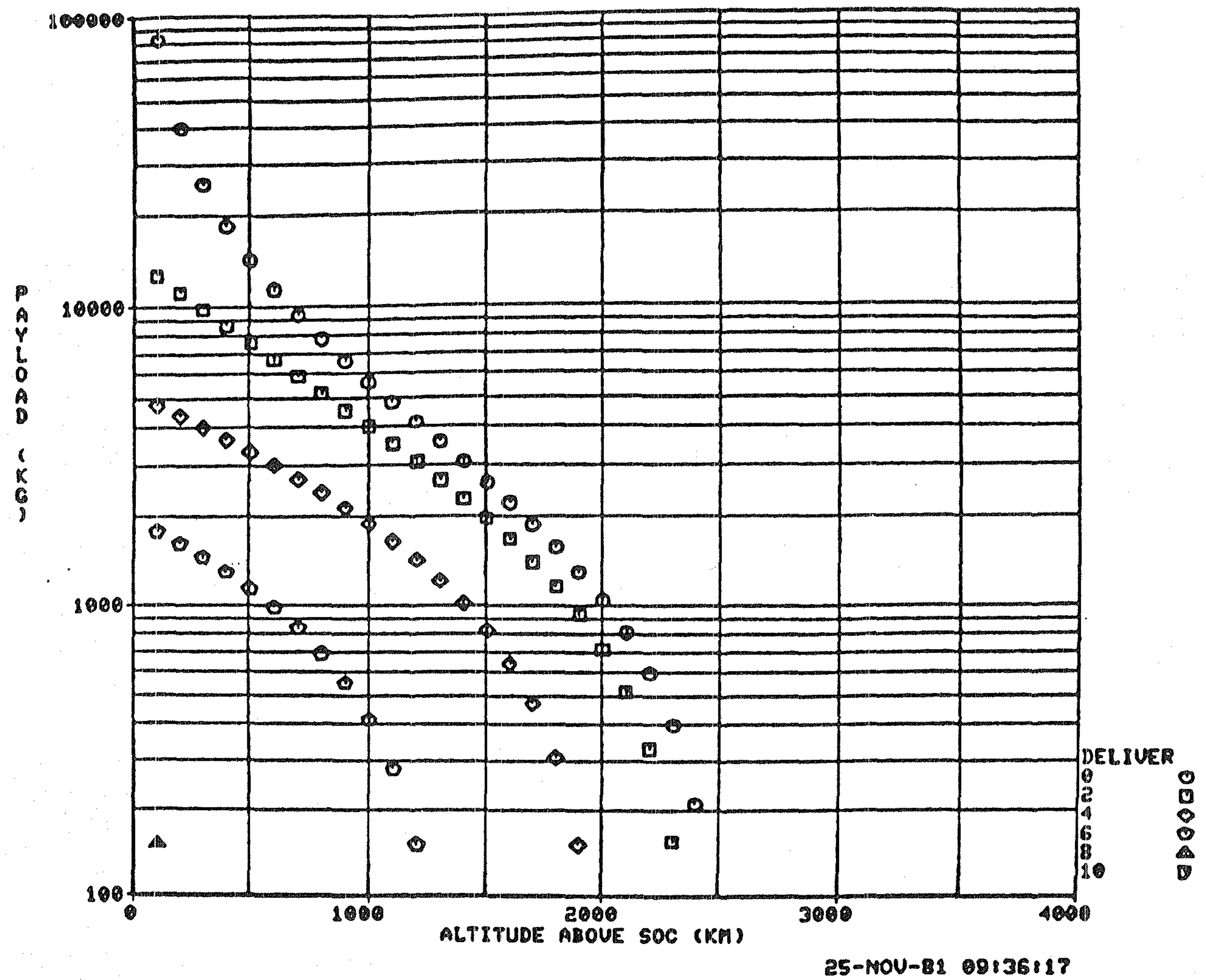

Figure 4.5-5. TMS Payload Delivery Capability From SOC

SOC-1349

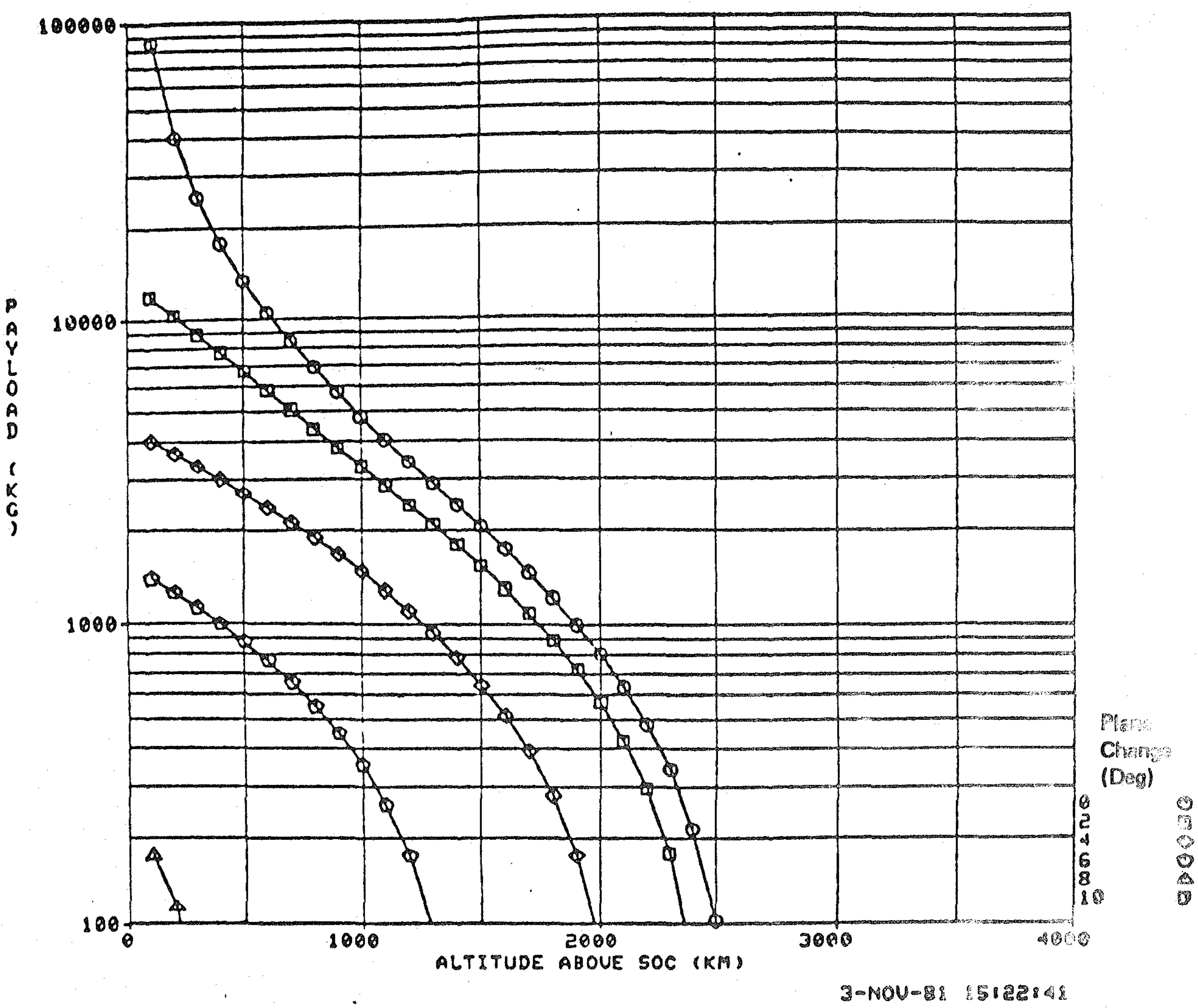

Figure 4.5-6. TMS Payload Retrieval Capability To SOC

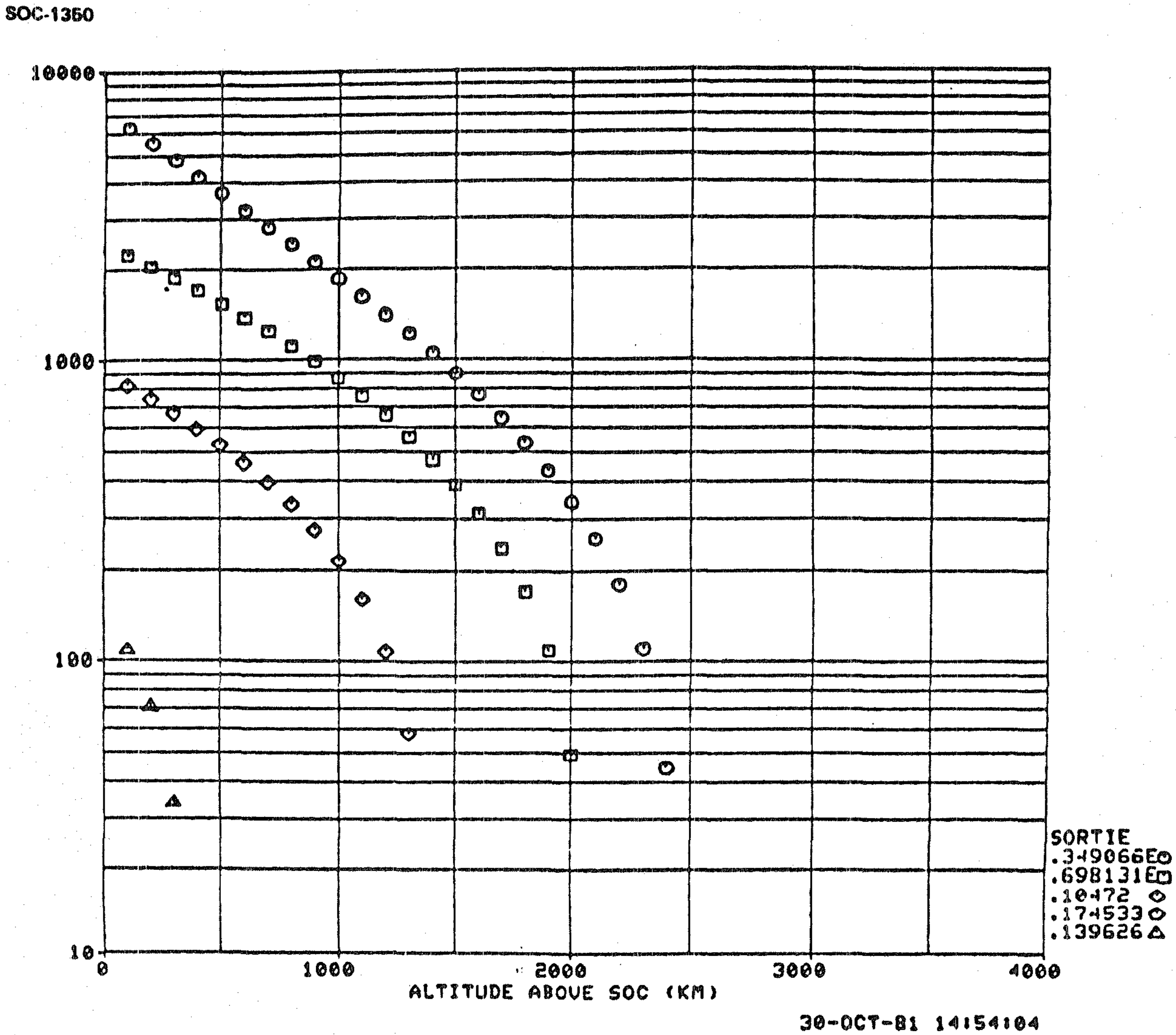

Figure 4.5-7. TMS Roundtrip Payload Capacities

SOC-1351

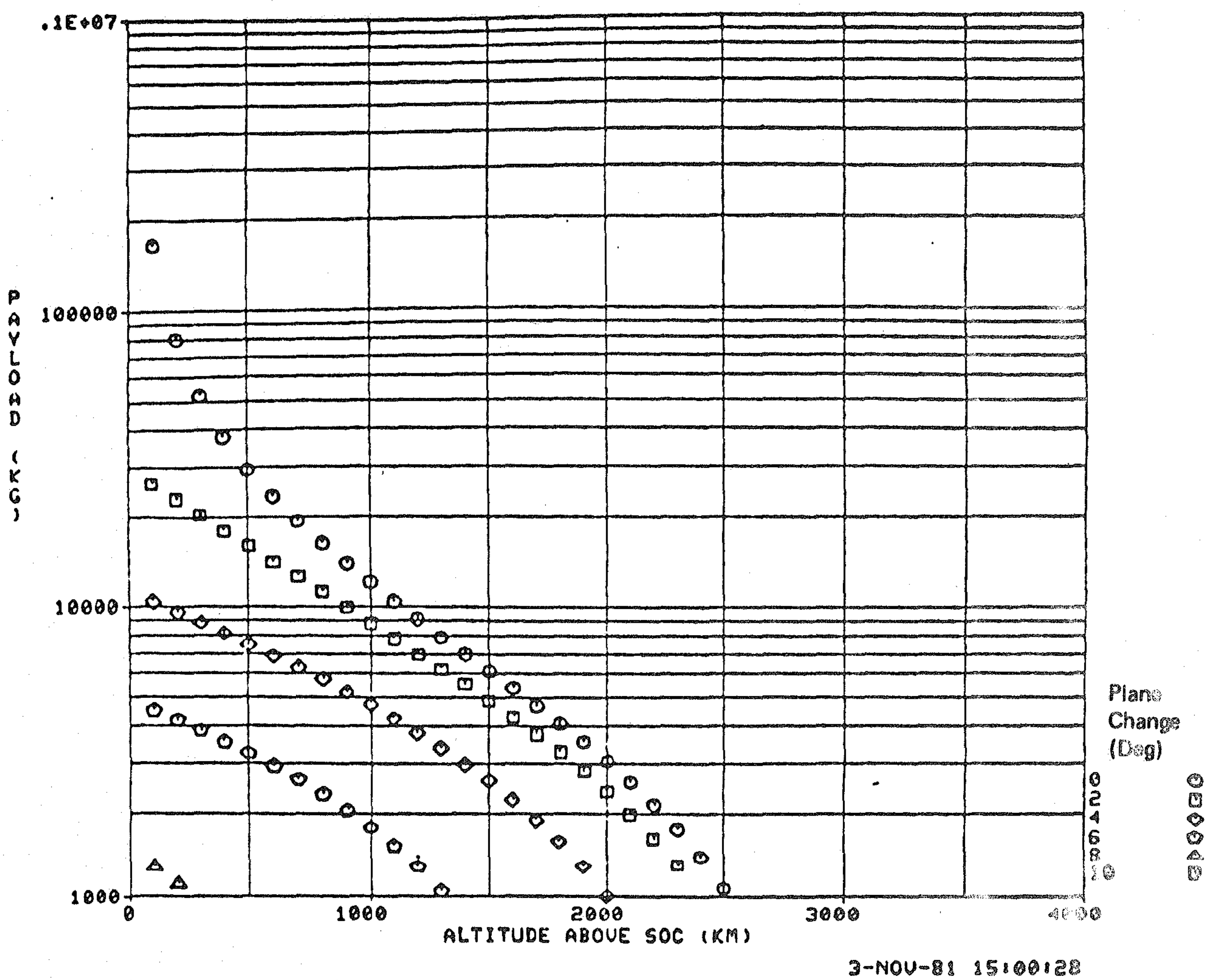

Figure 4.5-8. Dual TMS Payload Delivery Capability From SOC

SOC-1352

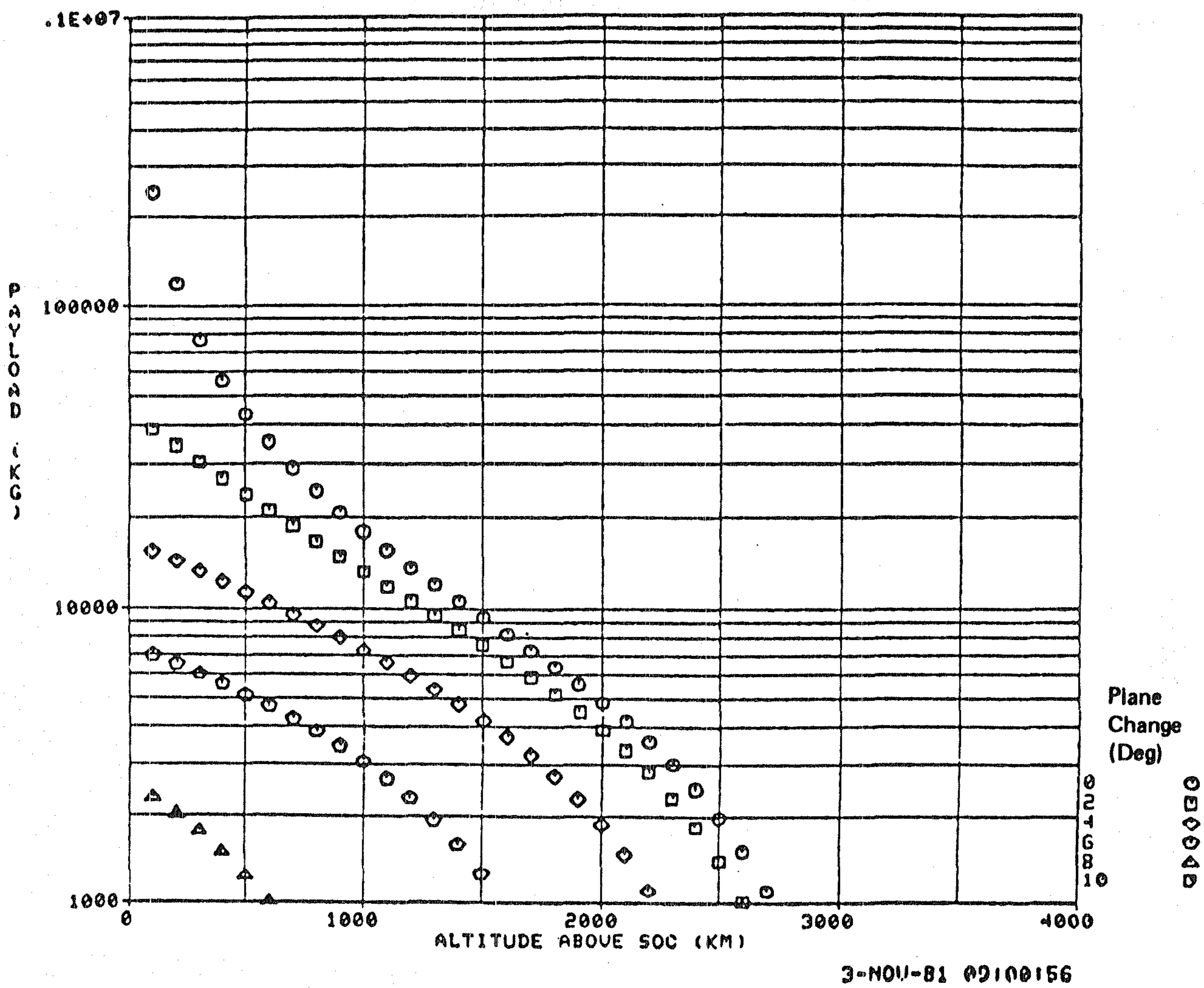

Figure 4.5-9. Triple TMS Payload Delivery Capability From SOC

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