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MDAC

Ford IBM RCA

SPACE STATION DATA SYSTEM ANALYSIS/ARCHITECTURE STUDY

Task 1 – Functional Requirements Definition, DR-5

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MCDONNELL DOUGLAS CORPORATION

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MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-HUNTINGTON BEACH

5301 Bolsa Avenue Huntington Beach, California 92647 (714) 896-3311

PREFACE

The McDonnell Douglas Astronautics Company has been engaged in a Space Station Data System Analysis/Architecture Study for the National Aeronautics and Space Administration, Goddard Space Flight Center. This study, which emphasized a system engineering design for a complete, end-to-end data system, was divided into six tasks:

Task 1. Functional Requirements Definition
Task 2. Options Development
Task 3. Trade Studies
Task 4. System Definitions
Task 5. Program Plan
Task 6. Study Maintenance

McDonnell Douglas was assisted by the Ford Aerospace and Communications Corporation, IBM Federal Systems Division and RCA in these Tasks. The Task inter-relationship and documentation flow are shown in Figure 1.

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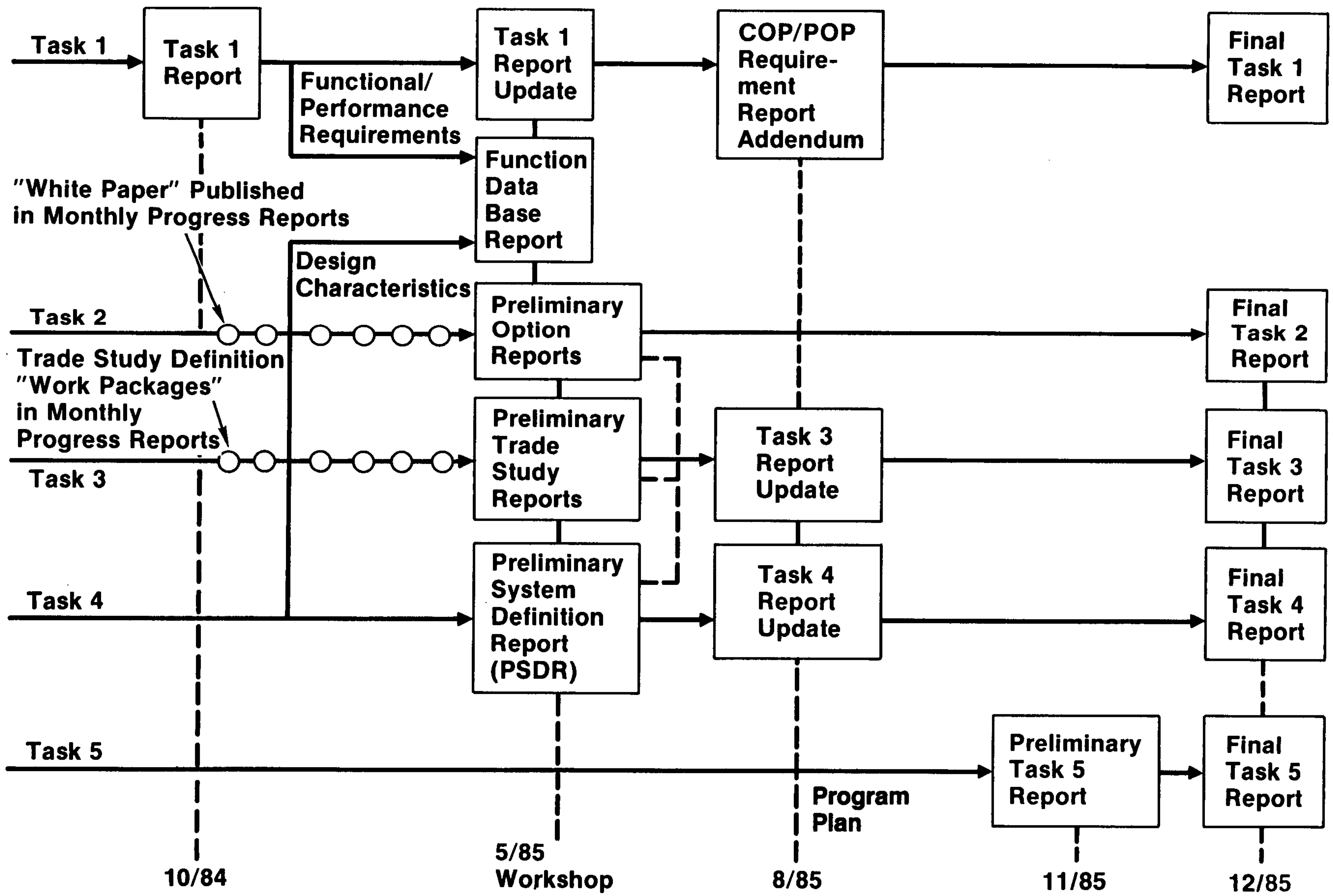
Questions regarding this report should be directed to:

Glen P. Love
Study Manager
McDonnell Douglas Astronautics Company
Huntington Beach, CA 92647
(714) 896-2292

Figure 1

VHG598

SSDS A/A DOCUMENTATION SCHEDULE



CONTENTS

GLOSSARY

A	Automatic
A&R	Automation and Robotics
A/A	Analysis/Architecture
A/D	Advanced Development
A/L	Airlock
A/N	Alphanumeric
AC&S	Attitude Control System
ACA	Attitude Control Assembly
ACO	Administrative Contracting Officer
ACS	Attitude Control and Stabilization
ACS/COM	Attitude Control System/Communications
ACTS	Advanced Communications Technology Satellite
AD	Ancillary Data
AD	Advanced Development
ADOP	Advanced Distributed Onboard Processor
ADP	Advanced Development Plan
AFOSR	Air Force Office of Scientific Research
AFP	Advanced Flexible Processor
AFRPL	Air Force Rocket Propulsion Laboratory
AGC	Automatic Gain Control
AGE	Attempt to Generalize
AI	Artificial Intelligence
AIE	Ada Integrated Environment
AIPS	Advanced Information Processing System
AL1	Air Lock One
ALS	Alternate Landing Site
ALS/N	Ada Language System/Navy
AMIC	Automated Management Information Center
ANSI	American National Standards Institute
AOS	Acquisition of Signal
AP	Automatic Programming
APD	Avalanche Photo Diode
APSE	Ada Programming Support Environment
ARC	Ames Research Center

ART	Automated Reasoning Tool
ASCII	American Standard Code for Information Exchange
ASE	Airborne Support Equipment
ASTROS	Advanced Star/Target Reference Optical Sensor
ATAC	Advanced Technology Advisory Committee
ATC	Air Traffic Control
ATP	Authority to Proceed
ATPS	Advanced Telemetry Processing System
ATS	Assembly Truss and Structure
AVMI	Automated Visual Maintenance Information
AWSI	Adoptive Wafer Scale Integration
B	Bridge
BARC	Block Adaptive Rate Controlled
BB	Breadboard
BER	Bit Error Rate
BIT	Built-in Test
BITE	Built-in Test Equipment
BIU	Buffer Interface Unit
BIU	Bus Interface Unit
BIU	Built-in Unit
BMD	Ballistic Missile Defense
BTU	British Thermal Unit
BW	Bandwidth
C	Constrained
C^2	Command and Control
C^3	Command, Control, and Communication
C^3I	Command, Control, Communication, and Intelligence
C&DH	Communications and Data Handling
C&T	Communication and Tracking Subsystem
C&T	Communications and Tracking
C&W	Control and Warning
C/L	Checklist
CA	Customer Accommodation
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CAIS	Common APSE Interface Set
CAM	Computer-Aided Manufacturing

CAMAC	Computer Automatic Measurement and Control
CAP	Crew Activities Plan
CASB	Cost Accounting Standard Board
CASE	Common Application Service Elements
CATL	Controlled Aceptance Test Library
CBD	Commerce Business Daily
CBEMA	Computer and Business Equipment Manufacturing Association
CCA	Cluster Coding Algorithm
CCB	Contractor Control Board
CCB	Configuration Control Board
CCC	Change and Configuration Control
CCD	Charge-Coupled Device
CCITT	Consultive Committee for International Telegraph and Telephone
CCITT	Coordinating Committee for International Telephony and Telegraphy
CCMS	Checkout Control and Monitor System
CCR	Configuration Change Request
CCSDS	Consultative Committee for Space Data System
CCTV	Closed-Circuit Television
cd/M^2	Candelas per square Meter
CDG	Concept Development Group
CDMA	Code Division Multiple Access
CDOS	Customer Data Operations System
CDR	Critical Design Review
CDS	Control Data Subsystem
CE	Conducted Emission
CEI	Contract End-Item
CER	Cost Estimating Relationship
CFR	Code of Federal Regulations
CFS	Cambridge File Server
CG	Center of Gravity
CIE	Customer Interface Element
CIL	Critical Item List
CIU	Customer Interface Unit
CLAN	Core Local Area Network
CM	Configuration Management
CM	Center of Mass
CMDB	Configuration Management Data Base

CMG	Control Moment Gyro
CMOS	Complementary Metal-Oxide Semiconductor
CMS	Customer Mission Specialist
CMU	Carnegie-Mellon University
CO	Contracting Officer
COF	Component Origination Form
COL	Controlled Operations Library
COMM	Commercial Missions
COP	Co-orbital Platform
COPCC	Coorbit Platform Control Center
COPOCC	COP Operations Control Center
COTS	Commercial Off-the-Shelf Software
CPCI	Computer Program Configuration Item
CPU	Central Processing Unit
CQL	Channel Queue Limit
CR	Compression Ratio
CR	Change Request
CR&D	Contract Research and Development
CRC	Cyclic Redundancy Checks
CRF	Change Request Form
CRSS	Customer Requirements for Standard Services
CRT	Cathode Ray Tube
CS	Conducted Susceptibility
CSD	Contract Start Date
CSDL	Charles Stark Draper Laboratory
CSMA/CD/TS	Carrier-Sense Multiple with Access/Collision Detection and Time Slots
CSTL	Controlled System Test Library
CTA	Computer Technology Associates
CTE	Coefficient of Thermal Expansion
CUI	Common Usage Item
CVSD	Code Variable Slope Delta (Modulation)
CWG	Commonality Working Group
D&B	Docking and Berthing
DADS	Digital Audio Distribution System
DAIS	Digital Avionics Integration System
DAR	Defense Acquisition Regulation

DARPA	Defense Advanced Research Projects Agency
DB	Data Base
DBA	Data Base Administrator
DBML	Data Base Manipulation Language
DBMS	Data Base Management System
DCAS	Defense Contract Administrative Services
DCDS	Distributed Computer Design System
DCR	Data Change Request
DDBM	Distributed Data Base Management
DDC	Discipline Data Center
DDT&E	Design, Development, Testing, and Engineering
DEC	Digital Equipment Corp.
DES	Data Encryption Standard
DFD	Data Flow Diagram
DGE	Display Generation Equipment
DHC	Data Handling Center
DID	Data Item Description
DIF	Data Interchange Format
DMA	Direct Memory Access
DMS	Data Management System
DoD	Department of Defense
DOMSAT	Domestic Communications Satellite System
DOS	Distributed Operating System
DOT	Department of Transportation
DPCM	Differential Pulse Code Modulation
DPS	Data Processing System
DR	Discrepancy Report
DR	Data Requirement
DRAM	Dynamic Random-Access Memory
DRD	Design Requirement Document
DS&T	Development Simulation and Training
DSDB	Distributed System Data Base
DSDL	Data Storage Description Language
DSDS	Data System Dynamic Simulation
DSIT	Development, Simulation, Integration and Training
DSN	Deep-Space Network
DTC	Design to Cost

DTC/LCC	Design to Cost/Life Cycle Cost
DTG	Design To Grow
E/R	Entity/Relationship
EADI	Electronic Attitude Direction Indicator
ECC	Error Correction Codes
ECLSS	Environmental Control and Life-Support System
ECMA	European Computers Manufacturing Assoc.
ECP	Engineering Change Proposals
ECS	Environmental Control System
EDF	Engineering Data Function
EEE	Electrical, Electronic, and Electromechanical
EHF	Extremely High Frequency
EHSI	Electronic Horizontal Situation Indicator
EIA	Electronic Industry Association
EL	Electroluminescent
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EMCFA	Electromagnetic Compatibility Frequency Analysis
EME	Earth Mean Equator
EMI	Electromagnetic Interference
EMR	Executive Management Review
EMS	Engineering Master Schedule
EMU	Extravehicular Mobility Unit
EMUDS	Extravehicular Maneuvering Unit Decontamination System
EO	Electro-optic
EOL	End of Life
EOS	Earth Observing System
EPA	Environmental Protection Agency
EPS	Electrical Power System
ERBE	Earth Radiation Budget Experiment
ERRP	Equipment Replacement and Refurbishing Plan
ESR	Engineering Support Request
ESTL	Electronic Systems Test Laboratory
EVA	Extravehicular Activity
F/T	Fault Tolerant
FACC	Ford Aerospace and Communications Corporation
FADS	Functionally Automated Database System

FAR	Federal Acquisition Regulation
FCA	Functional Configuration Audit
FCOS	Flight Computer Operating System
FCR	Flight Control Rooms
FDDI	Fiber Distributed Data Interface
FDF	Flight Dynamics Facility
FDMA	Frequency-Division Multiple Access
FEID	Flight Equipment Interface Device
FETMOS	Floating Gate Election Tunneling Metal Oxide Semiconductor
FF	Free Flier
FFT	Fast Fourier Transform
FIFO	First in First Out
FIPS	Federal Information Processing Standards
fl	foot lambert - Unit of Illumination
FM	Facility Management
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Mode Effects and Criticality Analysis
FO	Fiber-Optics
FO/FS/R	Fail-Operational/Fail Safe/Restorable
FOC	Fiber-Optic Cable
FODB	Fiber-Optic Data Bus
FODS	Fiber Optic Demonstration System
FPR	Federal Procurement Regulation
FQR	Formal Qualification Review
FSD	Full-Scale Development
FSE	Flight Support Equipment
FSED	Full Scale Engineering Development
FSIM	Functional Simulator
FSW	Flight Software
FTA	Fault Tree Analysis
FTMP	Fault Tolerant Multi-Processor
FTSC	Fault Tolerant Space Computer
GaAs	Gallium Arsenide
GaAsP	Gallium Arsenic Phosphorus
GaInP	Gallium Indium Phosphorus
GaP	Gallium Phosphorous
GAPP	Geometric Arithmetic Parallel Processor

Gbps	Gigabits Per Second
GBSS	Ground Based Support System
GEO	Geosynchronous Earth Orbit
GEP	Gas Election Phosphor
GFC	Ground Forward Commands
GFE	Government-Furnished Equipment
GFP	Government-Furnished Property
GFY	Government Fiscal Year
GIDEP	Government/Industry Data Exchange Program
GMM	Geometric Math Model
GMS	Geostationary Meteorological Satellite
GMT	Greenwich Mean Time
GMW	Generic Maintenance Work Station
GN&C	Guidance, Navigation, and Control
GPC	General-Purpose Computer
GPP	General-Purpose Processor
GPS	Global Positioning System
GRO	Gamma Ray Observatory
GSC	Ground Service Center
GSE	ground Support Equipment
GSFC	(Robert H.) Goddard Space Flight Center
GTOSS	Generalized Tethered Object System Simulation
H/W	Hardware
HAL	High-Order Algorithmic Language
HDDR	Help Desk Discrepancy Report
HDDR	High Density Digital Recording
HEP	Heterogeneous Element Processor
HFE	Human Factors Engineering
HIPO	Hierarchical Input Process Output
HIRIS	High Resolution Imaging Spectrometer
HM1	Habitation Module One
HM	Habitation Module
HOL	High Order Language
HOS	High Order Systems
HPP	High Performance Processors
HRIS	High Resolution Imaging Spectrometer
I	Interactive

I/F	Interface
I/O	Input/Output
IBM	IBM Corporation
IC	Intercomputer
ICAM	Integrated Computer-Aided Manufacturing
ICB	Internal Contractor Board
ICD	Interface Control Document
ICOT	Institute (for new generation) Computer Technology
ICS	Interpretive Computer Simulation
ID	Interface Diagram
ID	Identification
IDM	Intelligent Database Machine
IDMS	Information and Data Management System
IEEE	Institute of Electrical and Electronic Engineers
IEMU	Integrated Extravehicular Mobility Unit
IF	Intermediate Frequency
IFIPS	International Federation of Industrial Processes Society
ILD	Injector Laser Diode
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
IOC	Initial Operating Capability
IOP	Input/Output Processor
IPCF	Interprocess Communications Facility
IPC	Interprocesses Communication
IPL	Initial Program Load
IPR	Internal Problem Report
IPS	Instrument Pointing System
IR	Infrared
IR&D	Independent Research and Development
IRN	Interface Revision Notices
ISA	Inertial Sensor Assembly
ISA	Instruction Set Architecture
ISDN	Integration Services Digital Network
ISO	International Standards Organization
ITAC-O	Integration Trades and Analysis-Cycle 0
ITT	International Telegraph and Telephone
IV&V	Independent Validation and Verification

IVA	Intravehicular Activity
IWS	Intelligent Work Station
JPL	Jet Propulsion Laboratory
JSC	(Lyndon B.) Johnson Space Center
KAPSE	Kernal APSE
KEE	Knowledge Engineering Environment
KIPS	Knowledge Information Processing System
KOPS	Thousands of Operations Per Second
KSA	Ku-band, Single Access
KSC	(John F.) Kennedy Space Center
Kbps	Kilobits per second
Kipc	Thousand instructions per cycle
LAN	Local-Area Network
LaRC	Langley Research Center
LCC	Life-Cycle Cost
LCD	Liquid Crystal Display
LDEF	Long-Duration Exposure Facility
LDR	Large Deployable Reflector
LED	Light-Emitting Diode
LEO	Low Earth Orbit
LeRC	Lewis Research Center
LIDAR	Laser-Instrument Distance and Range
LIFO	Last In First Out
LIPS	Logical Inferences Per Second
LISP	List Processor
LisP	List Processor
LLC	Logical Link Control
LMI	LISP Machine Inc.
LN_2	Liquid Nitrogen
LNA	Low-noise Amplifier
LOE	Level of Effort
LOE	Low-earth Orbit Environments
LOS	Loss of Signal
LPC	Linear Predictive Coding
LPS	Launch Processing System
LRU	Line-Replaceable unit
LSA	Logistic Support Analysis

LSAR	Logistic Support Analysis Report
LSE	Language Sensity Editors
LSI	Large-scale Integration
LTV	LTV Aerospace and Defense Company, Vought Missiles Advanced Programs Division
LZPF	Level 0 Processing Facility
M	Manual
µP	Microprocessor
MA	Multiple Access
MA	Managing Activity
MAPSE	Minimum APSE
Mbps	Million Bits Per Second
MBPS	Million Bits Per Second
MCAIR	McDonnell Aircraft Company
MCC	Mission Control Center
MCC	Microelectronics and Computer Technology Corp.
MCDS	Management Communications and Data System
MCM	Military Computer Modules
MCNIU	Multi-compatible Network Interface Unit
MDAC-HB	McDonnell Douglas Astronautics Company-Huntington Beach
MDAC-STL	McDonnell Douglas Astronautics Company-St. Louis
MDB	Master Data Base
MDC	McDonnell Douglas Corporation
MDMC	McDonnell Douglas Microelectronics Center
MDRL	McDonnell Douglas Research Laboratory
MFLOP	Million Floating Point Operations
MHz	Million Hertz
MIMO	Multiple-Input Multiple-Output
MIPS	Million (machine) Instructions Per Second
MIT	Massachusetts Institute of Technology
MITT	Ministry of International Trade and Industry
MLA	Multispectral Linear Array
MMI	Man Machine Interface
MMPF	Microgravity and Materials Process Facility
MMS	Module Management System
MMS	Momentum Management System
MMU	Mass Memory Unit

MMU	Manned Maneuvering Unit
MNOS	Metal-Nitride Oxide Semiconductor
MOC	Mission Operations Center
MOI	Moment of Inertia
MOL	Manned Orbiting Laboratory
MOS	Metal Oxide Semiconductor
MPAC	Multipurpose Application Console
MPS	Materials, Processing in Space
MPSR	Multi-purpose Support Rooms
MRMS	Mobile Remote Manipulator System
MRWG	Mission Requirements Working Group
MSFC	(George C.) Marshall Space Flight Center
MSI	Medium-Scale Integration
MSS	Multispectral Scanner
MTA	Man-Tended Approach
MTBF	Mean Time Between Failures
MTTR	Mean Time to Repair
MTU	Master Timing Unit
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NASPR	NASA Procurement Regulation
NBO	NASA Baseline
NBS	National Bureau of Standards
NCC	Network Control Center
NFSD	NASA FAR Supplement Directive
NGT	NASA Ground Terminals
NHB	NASA Handbook
NISDN	NASA Integrated System Data Network
NIU	Network Interface Unit
NL	National Language
NLPQ	National Language for Queuing Simulation
NMI	NASA Management Instruction
NMOS	N-Channel Metal-Oxide Semiconductor
NMR	N-Modular Redundant
NOS	Network Operating System
NS	Nassi-Schneidermann
NSA	National Security Administration

NSF	National Science Foundation
NSTS	National Space Transportation System
NTDS	Navy Tactical Data System
NTE	Not To Exceed
NTRL	NASA Technology Readiness Level
NTSC	National Television Standards Committee
Nd:YAG	Neodynium Yttrium Aluminum Garnet (laser type)
O&M	Operations and Maintenance
O/B	Onboard
OASCB	Orbiter Avionics Software Control Board
OCN	Operations and Control Network, Operational Control Networks
ODB	Operational Data Base
ODBMS	Onboard Data Base Management System
OEL	Operating Events List
OES	Operating Events Schedule
OID	Operations Instrumentation Data
OLTP	On Line Transaction Processing
OMCC	Operations Management and Control Center
OMV	Orbital Maneuvering Vehicle
ONR	Office of Naval Research
ORU	Orbital Replacement Unit
OS	Operating System
OSE	Orbit Support Equipment
OSI	Open Systems Interconnect
OSM	Orbital Service Module
OSSA	Office of Space Science and Applications
OSTA	Office of Space and Terrestrial Application
OSTDS	Office of Space Tracking and Data Systems
OTV	Orbital Transfer Vehicle
P&SA	Payload and Servicing Accommodations
P/L	Payload
PA	Product Assurance
PAM	Payload Assist Module
PASS	Primary Avionics Shuttle Software
PBX	Private Branch Exchange
PC	Personal Computer
PCA	Physical Configuration Audit

PCA	Program Change Authorization
PCM	Pulse Code Modulation
PCR	Program Change Request
PDP	Plazma Display Panel
PDR	Preliminary Design Review
PDRD	Program Definition and Requirements Document
PDRSS	Payload Deployment and Retrieval System Simulation
PILS	Payload Integration Library System
PIN	Personal Identification Number
PLA	Programmable Logic Array
PLAN	Payload Local Area Network
PLSS	Payload Support Structure
PMAD	Power Management and Distribution
PMC	Permanently Manned Configuration
PN	Pseudonoise
POCC	Payload Operations Control Center
POP	Polar Orbiter Platform
POPCC	Polar Orbit Platform Control Center
POPOCC	POP Operations Control Center
PRISM	Prototype Inference System
PSA	Problem Statement Analyzer
PSA	Preliminary Safety Analysis
PSCN	Program Support Communications Network
PSL	Problem Statement Language
PTR	Problem Trouble Report
QA	Quality Assurance
R	Restricted
R&D	Research and Development
R&QA	Reliability and Quality Assurance
R/M/A	Reliability/Maintainability/Availability
R/T	Real Time
RAD	Unit of Radiation
RAM	Random Access Memory
RAP	Relational Associative Processor
RC	Ring Concentrator
RCA	RCA Corporation
RCS	Reaction Control System

RDB	relational Data Base
RDC	Regional Data Center
REM	Roentgen Equivalent (man)
RF	Radio Frequency
RFC	Regenerative Fuel Cell
RFI	Radio Frequency Interference
RFP	Request for Proposal
RGB	Red-Green-Blue
RID	Review Item Disposition
RID	Revision Item Description
RISC	Reduced Instruction Set Computer
RMS	Remote Manipulator System
RMSE	Root Mean Square Error
RNET	Reconfiguration Network
ROM	Read Only Memory
ROTV	Reuseable Orbit Transfer Vehicle
RPMS	Resource Planning and Management System
RS	Reed-Solomon
RSA	Rivest, Skamir and Adleman (encryption method)
RTX	Real Time Execution
S&E	Sensor and Effector
S/C	Spacecraft
S/W	Software
SA	Single Access
SA	Structured Analysis
SAAX	Science and Technology Mission
SAE	Society of Automotive Engineers
SAIL	Shuttle Avionics Integration Laboratory
SAIS	Science and Applications Information System
SAR	Synthetic Aperture Radar
SAS	Software Approval Sheet
SASE	Specific Application Service Elements
SATS	Station Accommodations Test Set
SBC	Single Board Computer
SC	Simulation Center
SCR	Software Change Request
SCR	Solar Cosmic Ray

SCS	Standard Customer Services
SDC	Systems Development Corporation
SDP	Subsystem Data Processor
SDR	System Design Review
SDTN	Space and Data Tracking Network
SE&I	Systems Engineering and Integration
SEI	Software Engineering Institute
SESAC	Space and Earth Scientific Advisory Committee
SESR	Sustaining Engineering System Improvement Request
SESS	Software Engineering Standard Subcommittee
SEU	Single Event Upset
SFDU	Standard Format Data Unit
SI	International System of Units
SIB	Simulation Interface Buffer
SIFT	Software Implemented Fault Tolerance
SIMP	Single Instruction Multi-Processor
SIRTF	Shuttle Infrared Telescope Facility
SLOC	Source Lines of Code
SMC	Standards Management Committee
SMT	Station Management
SNA	System Network Architecture
SNOS	Silicon Nitride Oxide Semiconductor
SNR	Signal to Noise Ratio
SOA	State Of Art
SOPC	Shuttle Operations and Planning Complex
SOS	Silicon On Saphire
SOW	Statement of Work
SPC	Stored Payload Commands
SPF	Software Production Facility
SPF	Single-Point Failure
SPR	Spacelab Problem Reports
SPR	Software Problem Report
SQA	Software Quality Assurance
SQAM	Software Quality Assessment and Measurement
SQL/DS	SEQUEL Data System
SRA	Support Requirements Analysis
SRAM	Static Random Access Memory

SRB	Software Review Board
SRC	Specimen Research Centrifuge
SREM	Software Requirements Engineering Methodology
SRI	Stanford Research Institute
SRM&QA	Safety, Reliability, Maintainability, and Quality Assurance
SRMS	Shuttle Remote Manipulator System
SRR	System Requirements Review
SS	Space Station
SSA	Structural Systems Analysis
SSA	S-band Single Access
SSCB	Space Station Control Board
SSCC	Station Station Communication Center
SSCR	Support Software Change Request
SSCS	Space Station communication system
SSCTS	Space Station communications and tracking system
SSDMS	Space Station data management system
SSDR	Support Software Discrepancy Report
SSDS	Space Station data system
SSE	Software Support Environment
SSEF	Software Support Environment Facility
SSIS	Space Station Information System
SSME	Space Shuttle Main Engine
SSO	Source Selection Official
SSOCC	Space Station Operations Control System
SSOCC	Space Station Operations Control Center
SSOL	Space Station Operation Language
SSON	Spacelab Software Operational Notes
SSOS	Space Station Operating System
SSP	Space Station Program
SSPE	Space Station Program Element
SSPO	Space Station Program Office
SSSC	Space Station Standard Computer
SSST	Space Station System Trainer
STAR	Self Test and Recovery (repair)
STARS	Software Technology for Adaptable and Reliable Software
STDN	Standard Number
STI	Standard Technical Institute

STO	Solar Terrestrial Observatory
STS	Space Transportation System
SUSS	Shuttle Upper Stage Systems
SYSREM	System Requirements Engineering Methodology
Si	Silicon
SubACS	Submarine Advanced Combat System
TAI	International Atomic Time
TBD	To Be Determined
TBU	Telemetry Buffer Unit
TC	Telecommand
TCP	Transmissions Control Protocols
TCS	Thermal Control System
TDASS	Tracking and Data Acquisition Satellite System
TDM	Technology Development Mission
TDMA	Time-Division Multiple Access
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TFEL	Thin Film Electrolumenescent
THURIS	The Human Role in Space (study)
TI	Texas Instruments
TM	Technical Manual
TM	Thematic Mapper
TMDE	Test, Measurement, and Diagnostic Equipment
TMIS	Technical and Management Information System
TMP	Triple Multi-Processor
TMR	Triple Modular Redundancy
TMS	Thermal Management System
TPWG	Test Planning Working Group
TR	Technical Requirement
TRAC	Texas Reconfigurable Array Computer
TRIC	Transition Radiation and Ionization Calorimeter
TSC	Trade Study Control
TSIP	Technical Study Implementation Plan
TSP	Twisted Shielded Pair
TSS	Tethered Satellite System
TT&C	Telemetry, Tracking, and Communications
TTC	Telemetry Traffic Control

TTR	Timed Token Ring
TWT	Traveling-Wave Tube
U	Non-restrictive
UCC	Uniform Commercial Code
UDRE	User Design Review and Exercise
UIL	User Interface Language
UON	Unique Object Names
UPS	Uninterrupted Power Source
URN	Unique Record Name
UTBUN	Unique Telemetry Buffer Unit Name
UTC	Universal Coordinated Time
V&V	Validation and Verification
VAFB	Vandenberg Air Force Base
VAX	Virtual Address Exchange
VHSIC	Very High-Speed Integrated Circuit
VLSI	Very Large-Scale Integration
VLSIC	Very Large-Scale Integrated Circuit
VV&T	Validation, Verification and Testing
WAN	Wide Area Network
WBS	Work Breakdown Structure
WBSP	Wideband Signal Processor
WDM	Wavelength Division Multiplexing
WP	Work Package
WRO	Work Release Order
WS	Workstation
WSGT	White Sands Ground Terminal
WTR	Western Test Range
XDFS	XEROX Distributed File System
YAPS	Yet Another Production System
ZOE	Zone Of Exclusion
ZONC	Zone Of Non-Contact
ZnS	Zinc Sulfide

Section 1
EXECUTIVE SUMMARY

The initial task in the Space Station Data System (SSDS) Analysis/Architecture Study is the definition of the functional and key performance requirements for the SSDS. The SSDS is the set of hardware and software, both on the ground and in space, that provides the basic data management services for Space Station customers and systems. The primary purpose of the requirements development activity is to provide a coordinated, documented requirements set as a basis for the system definition of the SSDS and for other subsequent study activities. These requirements should also prove useful to other Space Station activities in that they provide an indication of the scope of the information services and systems that will be needed in the Space Station program. Key objectives of the requirements development task are as follows:

1. Identify a conceptual topology and architecture for the end-to-end Space Station Information Systems SSIS.

2. Develop a complete set of functional requirements and design drivers for the SSIS.

3. Develop functional requirements and key performance requirements for the Space Station Data System (SSDS).

4. Define an operating concept for the Space Station Information Systems SSIS.

The operating concept was developed both from a Space Station payload customer and operator perspective in order to allow a requirements practicality assessment.

1.1 METHODOLOGY

The SSDS requirements task methodology emphasized the use of higher level requirements that were developed in other Space Station activities. The requirements methodology flow is shown in Figure 1-1. The primary sources of higher level requirements were; (1) the mission, operations, and system requirements from the Space Station definition and preliminary design RFP, (2) the Customer Requirements for Standard Services from the SSIS document prepared by GSFC, and (3) the Mission Requirements Working Group mission data base. In addition, other Space Station documents, requirements developed on other space programs, and industry study reports were used to identify potential requirements. It should be noted that the RFP and the customer requirements document were not available until late in the study task. The requirements imposed by these documents were superimposed on a basic set of requirements that had been developed earlier from the previous NASA studies, industry studies, and functional analysis.

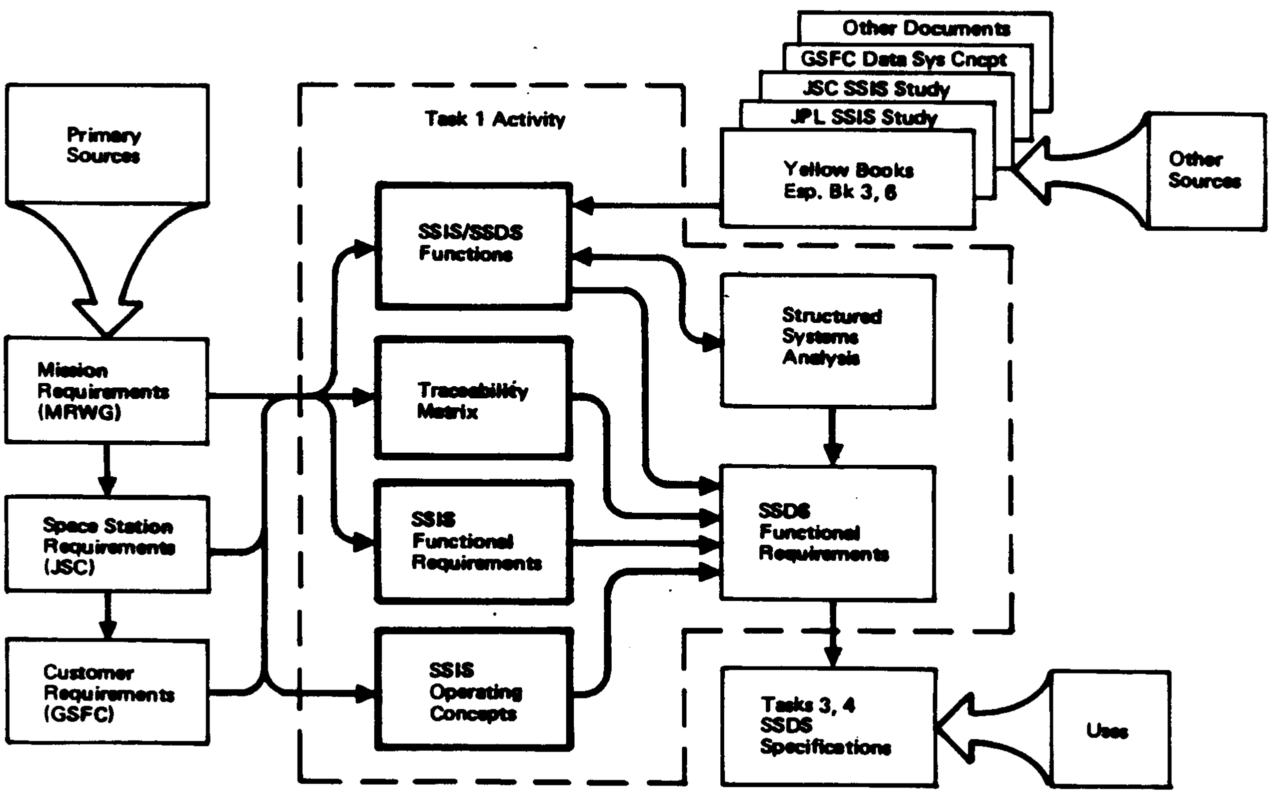


Figure 1-1. Requirements Development Methodology Flow

To establish a context for defining and testing requirements, a concept for the SSDS, and for a more encompassing Space Station Information System (SSIS), was defined. The definition includes a description of the system topology, its architecture, and an operational concept. The SSIS "topology" is a description of the SSIS showing its elements and their interconnections, i.e., what the system looks like. The "architecture" describes the form of the system as viewed by the customer/user, i.e., how the system works. The operational concept describes scenarios for customer and system operator interaction with the SSIS. The concepts that have been defined provide a context for requirements generation and should not be taken as a representation of the final architecture of the SSDS. However, certain themes have been established in the concept that have been used to influence the requirements and will be carried into the system definition task. These themes include standardization of interfaces, elements, and procedures, an end-to-end view of the system, a continual emphasis on customer accommodations, and a cost versus benefit approach to autonomy and automation.

Given the SSIS topology, and the higher level requirements contained in the RFP, the GSFC Customer Requirements for Standard Services document, and the mission requirements data base, a detailed set of SSIS and SSDS functions was identified and the associated requirements defined. A system analysis technique called Structured System Analysis (SSA) was used to decompose high level functions into lower level functions and to test the completeness of the function set. SSA creates data flow diagrams that describe the information flow and identify processes that affect information as it flows through the system. The top-level data flow diagrams for the SSDS are included in Section 6.2. The functions list and the associated requirements are contained in Section 5 and in Appendix A. The operations concept was used as a cross check on the practicality, completeness and adequacy of the requirements.

Functional requirements are presented in a hierarchical manner for clarity. For the lower level functional requirements, requirements data sheets were completed that defined, for that function, its meaning, criticality, interfaces, and key performance requirement(s). This data is entered in a computer data base and is presented in Appendix A.

Traceability of the SSDS requirements has been developed to show both "top-down" and "bottom-up" traceability. The top-down traceability shows, for each applicable requirement in the higher level documents, what SSDS function defines and implements the corresponding SSDS requirement. Bottom-up traceability defines, for each SSDS requirement that we defined, what its higher level source(s) is.

1.2 SSIS/SSDS CONCEPTS

A model was established for the SSIS in the form of a topology of the end-to-end information system for Space Station customer and operators, encompassing both space and ground elements. The space elements in the SSIS were defined to include the Space Station (base), the platforms, OMV, OTV, and co-orbiting free-flyers. Ground elements were identified to operate the system and support the major end-to-end functions. These elements (or functions) include Space Station control, platform control, OMV control, OTV control, data handling, and customer data centers (regional data centers and customer remote facilities). Added to this were data distribution elements and support elements to complete the end-to-end nature of the SSIS. Primary information interfaces were identified to complete the functional topology.

The SSDS is defined as a subset of the SSIS. A set of criteria was defined to determine the placement of SSIS elements inside or outside the SSDS. The intent of the criteria was to refine the study statement of work definition of SSIS/SSDS boundaries, including consideration of NASA funding and organizational patterns, and to exclude unique customer applications and core systems functions from the SSDS. These SSIS/SSDS boundary definitions apply to both space and ground functions. The primary criteria used were (1) the perception of the SSIS element or function as a user standard service, and (2) the perception of the element or function as a core service. In general, elements or functions that met either of these criteria were placed in the SSDS. Figure 1-2 shows the SSIS/SSDS model resulting from the use of the boundary criteria. A more detailed discussion of the criteria and the SSDS/SSIS division is contained in Section 4.

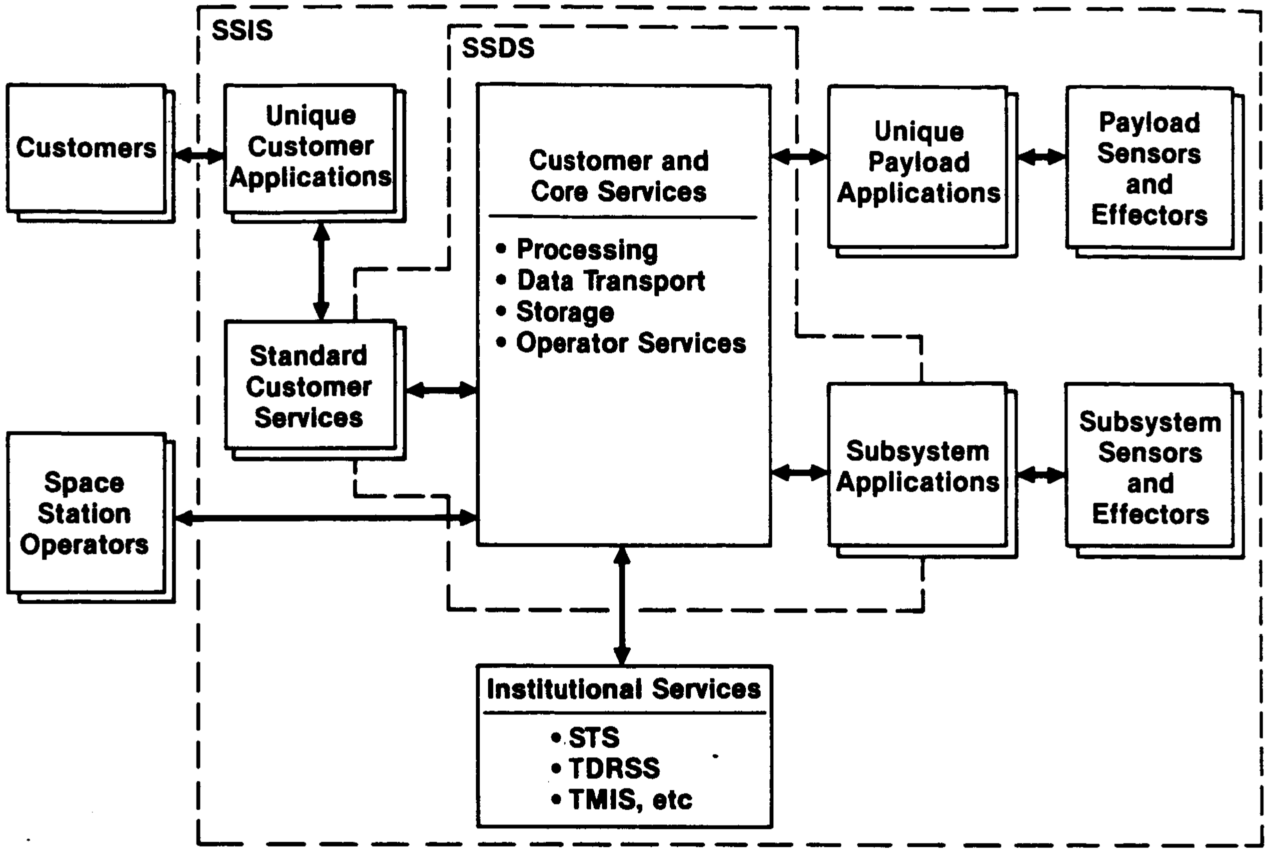


Figure 1-2. SSIS/SSDS Model

A key interface for the SSDS is with the planned Space Station Technical and Management Information System (TMIS). While the TMIS fits at least partially within our concept of the SSIS, we have defined the SSDS to be mutually exclusive of the TMIS. The TMIS is expected to be the primary repository of Space Station program management and engineering data, and certain types of operational data. SSDS functions use and access the TMIS data bases and, in turn, provide data to the TMIS. Onboard crew, mission controller, and customer access to the TMIS data bases may be provided through the SSIS.

The architecture concept for the SSIS is an explanation of how the SSIS works in moving, processing, and storing data. The architecture description provides a top level view of how the system manages commands, manages customer and operator data, supports system scheduling and control, manages core systems and resources, supports simulation, integration, and training, and provides (limited) programmatic support. This top-level "how-it-works" description gives an integrated overview of the major SSDS functions.

A concept of command management was developed that provides validation, conflict checking to avoid undesirable payload interaction, and feedback to ensure system integrity and safety while providing a high degree of autonomy to the customer. In fact, customers should be unaware of the command management process unless a real conflict is detected which precludes or delays the execution of a command.

A more detailed view of the SSIS is provided in the discussion of operational concepts, which is provided both from customer and operator perspectives. The operations concept provides a view of the primary customer information system needs and an operational approach that is responsive to those needs. These needs encompass system transparency, customer operational autonomy, data integrity, system friendliness, and flexibility. An SSIS which has these attributes can contribute greatly to the ability of the customer to maximize return on his space mission investment. The SSIS must also support the overall program needs for crew safety, system integrity, and overall system management, including a capability to resolve competing demands for system resources. The operations concept described in Section 4 addresses these customer and system needs for information services. A key feature of the operations concept from the customer's perspective is the plan to allow a customer to interact with the SSIS on his terms to the maximum extent feasible. In other words, the customer can interact using nonspecialized hardware and software, with minimal specialized training, from a location and at a time of his choosing, and with minimal operational constraints.

The operator's perspective of SSIS operations describes a view of how onboard crew members, ground controllers, planners, and system developers interact with the SSIS, and how the SSIS supports their operations.

Autonomy and automation are important top-level themes that influenced our operations concept. Autonomy and automation are intended to improve cost effectiveness, crew productivity, system performance, and reliability. These techniques will be applied to our future architecture definition where they produce clear advantages.

The SSIS provides resources to support long- and short-term planning and scheduling. The TMIS provides supporting analyses and data bases in the area of mission manifests and accommodation analysis. The short-term functions will be shared between the space and ground elements with a capability to do the daily activity scheduling and rescheduling onboard the station. As the system matures, a higher percentage of the planning and scheduling activity will be performed on board.

The importance of standardization to the operating and architectural concepts is apparent. The multiplicity and complexity of customer needs could drive system costs and customer costs out of reasonable bounds if a standards discipline is not imposed on the system. Selection of appropriate standards can significantly help control system and customer costs for development, integration, training, operations, and maintenance. Our theme for selecting standards will be to use widely accepted commercial and international standards in areas where they are available and to recommend the use of new or evolving standards in other areas.

1.3 SSIS/SSDS FUNCTIONAL AND PERFORMANCE REQUIREMENTS

The key functional requirements for the broadly defined SSIS have been defined and an assumed allocation made to Space Station Program Elements (SSPEs). Drivers on the SSDS related to these requirements are identified. Functional requirements for the SSDS were defined at a greater level of detail and key SSDS performance drivers were identified. A traceability matrix was developed to show the source of SSDS requirements in higher level documents and to show the allocation of higher level requirements to SSDS functions.

The functional requirements allocated to the SSPEs, that are not in the SSDS, are complementary to the functions assigned to the SSDS. The identification of these requirements provides an indication of the functional interfaces between the SSDS and other program elements. The SSDS drivers that have been identified are primarily related to (1) data rates, and (2) activity scheduling. Mission aggregate data rates are clearly going to be a major influence on the SSDS system design, affecting onboard acquisition and storage, onboard communication processing, TDRSS utilization, ground data distribution, ground data processing, and data archiving provisions.

The complexity and simultaneous nature of mission tasks and the need to consider several interrelated resource constraints will make activity scheduling a challenge. SSDS provisions to support the activity scheduling will be driven by these considerations.

Several customer standard services have been identified and have been allocated to the SSIS (external to the SSDS). This allocation was made on the basis that, (1) it was determined that the service will most likely be implemented as a multiprogram (institutional) NASA service, i.e., not dedicated to the Space Station program, or (2) it was determined that the service should be offered as a customer option (extended service) because it may not be universally needed. These customer services include ground processing of customer data beyond GSFC-defined Level 0 (time-ordered raw data, separated by customer, with essential ancillary data), long-term data archiving, customer-to-customer data exchange, customer facility work stations, and certain long-term planning and programmatic data that is assumed to be in the TMIS.

The SSDS functional requirements are organized into a hierarchical set of functions under seven top-level functions as shown in Figure 1-3. This organization of functions is carried down to the third and fourth levels in the SSDS functions list and is consistent with our data flow diagrams.

Function 1.0, Manage Customer/Operator Delivered Data, contains those requirements related to payload and core data acquisition, time-tagging, distribution, buffering, temporary storage, and display, including the processing necessary to support these activities. Data accounting requirements are included. Requirements for real-time and delayable data for customers are addressed. Level 0 data processing is available as a standard customer service.

Function 2.0, Manage Customer/Operator Supplied Data, encompasses the requirements associated with commands and other data that originate at the customer or operator. These include command distribution and validation, and ancillary data acquisition, formatting, and distribution. Also included are customer support requirements related to payload pointing, payload control processing, payload monitoring, and quick-look data processing. OTV, OMV, and payload checkout operation support requirements are defined.

SSDS FUNCTIONS

1.0 MANAGE CUSTOMER/ OPERATOR DELIVERED DATA (37)	2.0 MANAGE CUSTOMER/ OPERATOR SUPPLIED DATA (23)	3.0 SCHEDULE AND EXECUTE OPERATIONS(5)	4.0 OPERATE CORE SYSTEMS(1)	5.0 MANAGE SSDS FACILITIES(2)	6.0 DEVELOP SIMULATE INTEGRATE AND TRAIN(5)	7.0 SUPPORT SPACE STATION PROGRAM(0)
-1.1 MANAGE REAL TIME DATA RETURN (11)	-2.1 VALIDATE PAYLOAD COMMANDS/ DATA (18)	-3.1 DEVELOP RECURRING OPS MASTERS (8)	-4.1 OPERATE GN&C SYSTEMS (67)	-5.1 MANAGE FLIGHT FACILITIES (16)	-6.1 INTERPRET MODEL REQUESTS (2)	-7.1 MAINTAIN INTEGRATED LOGISTICS PLAN (4)
-1.2 MANAGE DELAYABLE DATA RETURN (6)	-2.2 CHECK PAY-LOAD COMMANDS/ DATA (13)	-3.2 DEVELOP SHORT TERM SCHEDULE (20)	-4.2 OPERATE NON-GN&C CORE SYSTEMS (103)	-5.2 MANAGE GROUND SYSTEM FACILITIES (4)	-6.2 DEVELOP COMM. MODEL CONFIG. (2)	-7.2 LOG CUST. SYSTEM USAGE (4)
-1.3 DATA DISTRIBUTION (5)	-2.3 VALIDATE CORE COMMANDS/ DATA (2)	-3.3 DEVELOP OPERATING EVENT SCHEDULE (10)	-4.3 CREW SUPPORT (77)		-6.3 SIMULATE COMM (7)	-7.3 MAINTAIN TECHNICAL DOCUMENTS (2)
-1.4 MANAGE DELIVERABLE CUSTOMER DATA (45)	-2.4 PROVIDE ANCILLARY DATA (13)	-3.4 SEQUENCE OPERATIONS (6)	-4.4 SPECIAL CUST. AVIONICS SERVICES (16)		-6.4 DEVELOP HDW CONFIG. (10)	-7.4 CONTROL INVENTORIES (2)
-1.5 MANAGE DELIVERABLE CORE DATA (3)	-2.5 SUPPORT CUSTOMER SYSTEM OPERATION (68)		-4.5 MONITOR AND STATUS SYSTEM (30)		-6.5 SIMULATE GS SYSTEM (13)	-7.5MANAGEMENT CONFIGURATION (1)
	-2.6 SSPE CHECKOUT & SERVICING (7)				-6.6 DEVELOP S/W CONFIG (12)	
					-6.7 SIMULATE PROCESSORS (10)	
					-6.8 CONDUCT TRAINING (14)	
					-6.9 DEVELOP SOFTWARE (14)	

ADDITIONAL REQUIREMENTS
NOT ALLOCATED TO FUNCTIONS

GENERAL PERFORMANCE	(1)
GENERAL DESIGN	(51)
SSIS/SCS, NOT SSDS	(48)
TMIS	(26)

* Numbers in parenthesis refer to the number of requirements traced to the function at the level indicated.

NOTE: Requirements listed at a higher level are generally applicable to all lower level functions.

Figure 1-3. Top Level SSDS Function Tree

Function 3.0, Schedule and Execute Operations, contains those functional requirements related to developing generic and specific schedules, command conflict checking, and the control of command sequences. Specific scheduling products have been identified, including a typical day schedule, a short-term schedule, and an operating event schedule.

Function 4.0, Operate Core Systems, contains the SSDS requirements which have been collected to support core system operations, to provide crew support in areas such as health maintenance, recreation, EVA, training, and safety, to provide special onboard customer services, and to monitor both core and customer systems. The special customer services include: monitoring of contamination, venting, and the general payload environment; providing relative alignment reference; providing current and projected ground track information; and providing current and projected magnetic field information. The system monitor and status functional requirements include caution and warning and mass properties status.

Function 5.0, Manage Facilities and Resources, contains the SSDS functional requirements for managing space and ground data processing facilities of the Space Station Program. The ground facilities include control centers, data handling facilities, and support facilities. As part of this functional area the SSDS is required to monitor customer usage of Space Station resources for potential billing purposes. This function also includes SSDS requirements to reconfigure facilities in response to operations or maintenance timelines or system failures.

Function 6.0, Develop, Simulate, Integrate, and Train, contains the SSDS functional requirements to support development, simulation, integration, and training. This very broad set of requirements are interrelated in their extensive use of simulation models. They are also related in that they are primarily off-line from the mission operations. These requirements are intended to meet the majority of core system and customer needs for integrated system simulations.

Function 7.0, Support Space Station Program, includes SSDS requirements for support of programmatic activities such as logistic planning, operating manual maintenance, inventory control, and configuration management. The SSDS will be closely coupled to the Technical and Management Information System (TMIS) in this functional area. The exact allocation of functions between the SSDS and the TMIS will need to be refined as the two systems become better defined.

In reviewing the SSDS requirements that have been defined, several areas appear to contain the most critical drivers to the SSDS design. These areas are related to (1) overall data rates, (2) real-time payload operation, (3) automation and autonomy, (4) development, training, and simulation support, 5) level of physical distribution, and (6) scheduling. In these areas, the magnitude or complexity suggested by the requirements indicate that particular attention should be paid to these areas in future study tasks.

1.4 CONCLUSIONS AND RECOMMENDATIONS

An overall concept has been defined for an end-to-end SSIS that includes all major SSIS elements and functions. The concept, and the accompanying operational concept for the SSIS, served as a context for validating the completeness and correctness of the set of functional requirements.

Within the SSIS, the SSDS was defined by developing a set of boundary criteria. The functional requirements for the SSDS were developed in detail by identifying requirements in higher level documents, decomposing the requirements through functional analysis, and allocating the requirements to SSDS by use of the boundary criteria. This set of functional requirements are soundly derived and are adequate to support the subsequent tasks of the study.

Key performance requirements were derived from the higher level source requirements. SSDS design drivers have been identified in the requirements set and can be used to properly focus the trade studies and system definition activities.

Recommendations resulting from this task are as follows:

1. The operating and architectural concepts developed in this task should be presented to Space Station operators and potential customers for comment and feedback.

2. The Mission Requirements Working Group data base should be refined and expanded to provide more definitive customer requirements in areas such as live television, remote real-time operations, ancillary data type and quality, and data delivery.

3. A special emphasis study should be conducted to define customer classes and a NASA interface scenario with the classes.

Results from these activities will enable requirements refinement and SSIS operating concepts completeness.

Section 2
TASK 1 DESCRIPTION

The MDAC Team has completed the Functional Requirements Definition (Task 1) for the Space Station Information System (SSIS) design. The major products of Task 1 are:

1. Top level end-to-end SSIS overall concept, including:
   a. SSIS operational concept from both customer and operator perspectives
   b. Functional topology
   c. Functional architecture
2. SSIS functional requirements
3. SSDS interface definition
4. SSDS functions identification
5. SSDS functional requirements
6. SSDS requirements drivers
7. Computer-based requirements traceability matrix

In addition, a relational data base has been created which includes design characteristics of the functions, and will be extended during the remainder of the study to include function assignment to end item and physical location. This data base is reported in a separate document entitled "SSDS Functional Requirements and Design Characteristics". An example of the data contained in this document is shown in Figure 2.1. The electronic data base contains the output in four screens. These screens are merged into two pages in the report. One page presents requirements and the other characteristics.

2.1 PURPOSE

Task 1 has been conducted to develop a top level, end-to-end SSIS overall concept and to provide a coordinated, documented set of requirements to serve

DESCRIPTION

Prepared By: T.F. Gallo
Revision: New
Function No: 4.2.4.1
Function Type: C

Revised By:
Revision Date: 01/09/1985
Name: Ctrl Press and ATM Comp
Program Phase: I,G,B3

Description:
Controls Cabin Press and Atmos O_2N_2 and CO_2, Provides Independent Detection and Control of Hazardous Gases and Vapors, Provides Warning of Hazardous Atmospheric Contamination.

Function Sources: RFP Para: C-4-2.1.3.3, C-4-2.1.11.1.A1, C-4-2.2.9.1.A, C-4-2.2.10.1J.1.C,

Criticality — Recovery Time: 3 **Impact** 1

Data Privacy Code: L

Alarms/Annunciations — Required; Y **Number:** 5

Function and Performance Requirements

Function No: 4.2.4.1 **Name:** Cntrl Press and ATM Comp

Requirements:

Doc.	Paragraph No.	Descriptor
RFP	C-3-2.2.A	Independent Emergency Detection and Cntrl
RFP	C-4-2.1.3.3	Internal/External Contamination Monitor
RFP	C-4-2.1.11.2	Independent Emergency Detect and Cntrl
RFP	C-4-2.1.9.1.A	Monitor and Regulate Module Atmos. Gases
RFP	C422.10.1J.1A	Detect and Cntrl of Internal Atmos. Contam
RFP	C422.10.1J.1C	Detection, Correction, and Warning for SS Atmos Contamination
RFP	C-4-2.1.11.2E	Detect, Monitor, Control Hazardous Fluids
MRWG	SAAX0302(24)	Control Pressurized Module ATM Comp

Input/Output

Function No.: 4.2.4.1 **Name:** Ctrl Press and ATM Comp

Type	Trigger	Source/Destination Type	Source/Destination Code	Input/Output Code	Input/Output Rate	Data Amount
I	Y	E	ATCOMP	C	60	.01
I	Y	E	CABNPRES	C	1	.01
I	Y	E	AIRTEMP	C	60	.01
I	Y	E	AIRTOX	C	60	.01
I	Y	E	O2LEVEL	C	60	.01
I	Y	F	4.2.4.2	C	60	.01
O	Y	E	OPERATOR	C	60	0.1
O	Y	E	AIRMAKE	C	60	.01
O	Y	E	AIRREV	C	60	.01
O	Y	F	4.2.4.2	C	60	.01
O	N	D	CORESTAT	C	60	0.1

Design Characteristics

Function No: 4.2.4.1 **Name:** Ctrl Press and ATM Comp

Data Sources: RFP
Methodology: RFP Plus Background Experience

Response Time: I/O Delay Allowable: 1.0E3 msec
Command/Control: Level: A Location: 0 Rate: 0.05 kbps

Data Quality: Maximum Bit Error Rate: 1.0E-3
Synchronization With: N/A
System Dependency Code: S Physical Location Code: M

Diagnostics/Self Test: Required: Y	Number: 11	Interval = 29E3 sec
Data Processing Instruction Per Cycle:	IOC = 1.0 kipc	Growth = 1.0 kipc
Repetition Rate:	IOC = 1/min	Growth = 1/min
Processor Memory: Program Size	IOC = 4 kbytes	Growth = 4 kbytes
Data Requirement:	IOC = 5 kbytes	Growth = 5 kbytes
Data Storage: Secondary:	IOC = 0 kbytes	Growth = 0 kbytes
Perishability:	IOC = 0% in 0 hrs	Growth = 0% in 0 hrs
Archival:	IOC = 0 kbytes	Growth = 0 kbytes
No. of Displays:	IOC = 11	Growth = 11

Figure 2-1. Function Data Base Presentation Format

as a basis for the development of the Space Station Data System (SSDS) preliminary design. Results are documented in this report, principally in Sections 4 and 5 and Appendix A.

2.2 SCOPE

This report presents the results of Task 1 - Functional Requirements Definition, including:

- The SSIS Functional Topology (Section 4.2) - Topology is defined as the structure and interrelationship of the subsections of the SSIS. The topology discussion identifies the physical elements comprising the SSIS and how they interconnect. The role of each element is defined, and top level functions are identified.

- The SSIS Functional Architecture (Section 4.3) - Architecture describes the functional form of the SSIS as viewed by the customers and operators. The architecture shows how the SSIS works. The architecture from Task 1 is preliminary and was developed to provide a basis for further system analysis. Details of the architecture are to be developed in Task 4.

- The SSIS Operating Concepts (Section 4.4) - The operating concepts supplement the architecture by describing how the customers and operators use the system.

- Functional Requirements (Section 5) - The SSIS and SSDS functional requirements define, by SSIS element and SSDS function, what must be done to meet the Space Station requirements (Reference 1), the customer requirements for standard services (Reference 2), mission requirements compiled by the Mission Requirements Working Group (Reference 3), and the requirements implied by the topology, architecture, and operating concepts.

- SSDS Requirements Drivers (Section 5.4) identifies those functional and performance drivers that are expected to have a major impact on the SSDS designs.

- The Requirements Traceability Matrix (Section 5.5) provides sources for all functional requirements and top-down traceability of all Space Station and customer requirements to responsive functions. This allows functions to be related to system requirements, establishing the scope of the functional requirements.

- The complete functions list (Appendix A-4) and functional data sheets (Reference 14) characterize the functions and define key design and performance characteristics.

- The functions list (Appendix A-4) contains indications of functions solely in the Space Station and its associated ground elements, common to both Space Station and platform systems, and replicated among the Space Station, platforms, and associated ground elements.

Section 3
STUDY METHODOLOGY

The Task 1 study methodology is illustrated by the diagram of Figure 3-1. There are three principal sources of SSIS requirements indicated:

- The Space Station Phase B RFP Statement of Work, Attachments C-2, C-3, and C-4 (Reference 1) - The final draft, issued September 15, 1984, was used to indicate the Space Station Program (SSP) scope and Space Station mission, operation, and system requirements.

- The Customer Requirements for Standard Services from the SSIS (Reference 2) - Revision 1, dated September 19, 1984, was used to indicate customer requirements for the SSIS.

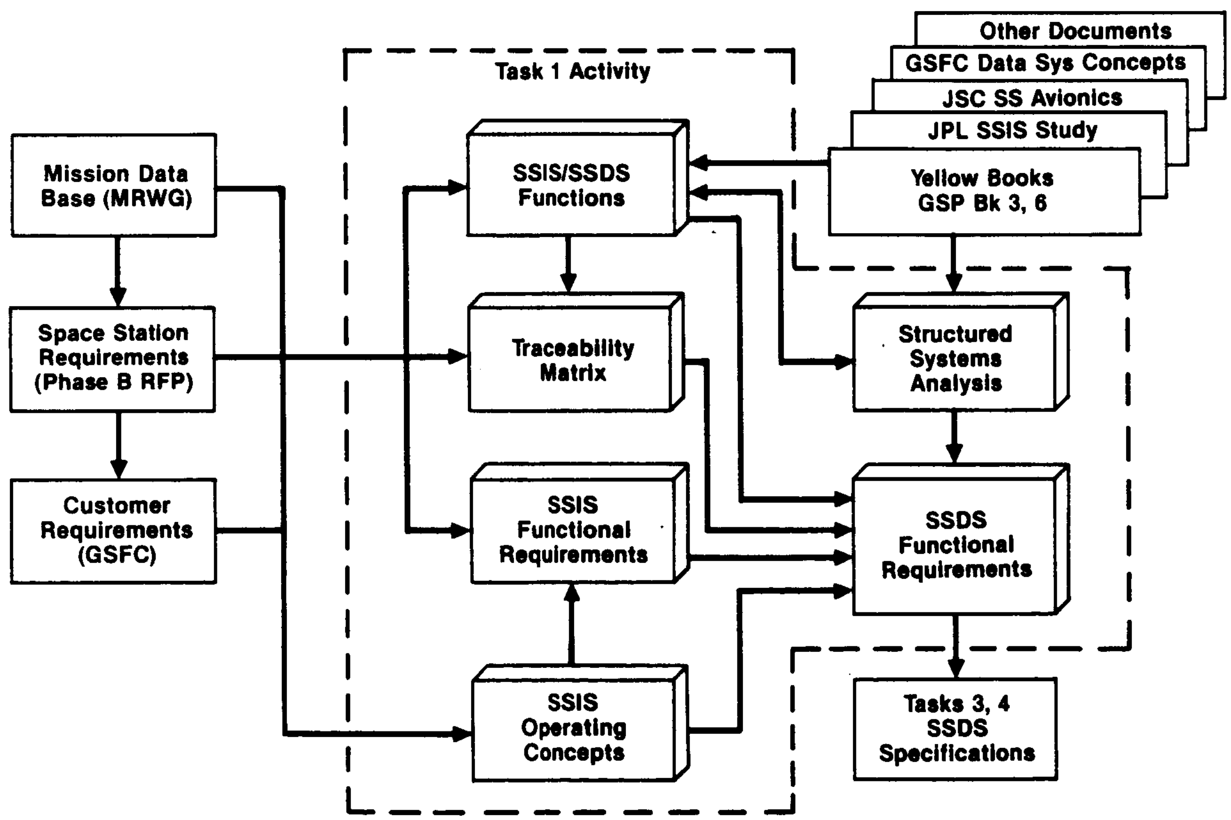


Figure 3-1. Requirements Definition Methodology

- Space Station Program Mission Requirements (Reference 3) - The Mission Requirements Working Group (MRWG) compilation of mission requirements, dated March 15, 1984, was used to indicate typical mission support requirements and key performance requirements to meet mission demands.

The explicit and implicit SSIS functional requirements from these documents have been combined with requirements resulting from the Task 1 analyses to form functional requirements (Section 5.2). The development of these requirements was facilitated by two principal analyses:

- The development of a top level, end-to-end SSIS concept, including topology, architecture, and operation.

- Structured system analysis, identifying the logical functions of the system and their interrelationship (Section 6.2).

The next step was to develop SSDS functional requirements (Section 5.3). Development of a complete set of performance requirements and an SSDS specification was deemed to be a part of the Task 3 and 4 effort. However, much of the groundwork for the SSDS specifications was laid in Task 1. Specifically, the team has

1. Developed a complete list of SSDS functions which meet the functional requirements of the SSIS and References 1, 2, and 3.

2. Performed complete Level 1 and limited Level 2 and 3 structured systems analyses to define and scope these functions.

3. Mapped requirements from references 1, 2, and 3 to the functions list and developed a complete traceability matrix showing this mapping.

4. Developed functional and key performance requirements for each function at the appropriate level from References 1, 2, and 3, other NASA documents, and the team data base.

5. Identified additional source documents supporting the need for and requirements on each function.

6. Performed engineering analyses of mission requirements to derive key SSDS performance requirements.

The results of these analyses are collected in the data base in Appendix A and Reference 14. The complete data base is available in the VAX computer at MDAC Huntington Beach in the Smartstar data management system. In Smartstar, the data base can be updated, supplemented by performance and design data from Tasks 3 and 4, manipulated to generate key parameter reports, and accessed by NASA and team members.

The above work was greatly aided by prior and concurrent studies conducted or sponsored by the NASA. Table 3-1 shows some of the more frequently used documents and the portions of the Task 1 activity to which they were most applicable. The scope and depth of this prior work helps assure the completeness and correctness of the Task 1 products.

Table 3-1. Prinicipal Documents Used in Task 1

Document	Usage							
	Reference	Developing SSIS concept	Structured systems analysis	SSIS requirements	SSIS/SSDS functions	Traceability matrix	SSDS functional requirements	SSDS performance requirements
Space station RFP	1	√		√	√	√	√	√
Customer requirements for standard services	2	√		√	√	√	√	√
Mission requirements	3	√	√			√	√	√
SSDS RFP	5	√			√			
Yellow book 3, 6	6	√	√		√			√
JSC 18740	7	√	√		√			
GSFC data system concepts	8	√	√		√			
JPL D1737	9	√	√		√			
Space telescope	10	√				√		
Global positioning system	11	√			√		√	√
TDRSS	12	√			√		√	√
EOS status review	13							√

Section 4
SSIS/SSDS CONCEPTS

A top level, end-to-end SSIS overall concept was developed in Task 1. This concept is described from five perspectives:

1) Functional topology (what the system looks like)
2) Functional architecture (how the system works)
3) Operations from customer perspective
4) Operations from a system operator perspective.
5) Operations from buildup and growth perspectives.

Each of these concept descriptions emphasizes the complete, end-to-end data flow. Identification of all of these data flows and all of the interactions customers and operators will have with the system ensures adequate breadth for the requirements. Decomposition of functional requirements can then be performed with confidence in the completeness of the scope.

4.1 SSIS CONCEPT ASSUMPTIONS

The key assumptions that guided the development of the SSIS concept are discussed below.

4.1.1 Controlling Documents

References 1, 2, and 3 were selected as controlling the scope, function, performance, and design of the SSIS and SSDS.

4.1.2 Customer Service Assumptions

Customers include all authorized users of Space Station program, engineering and payload data or products for scientific, commercial, or technological purpose. Potential Space Station customer operating requirements affecting customer service functions of the SSIS include:

- Customers will want to access SSIS services from onboard the Space Station or any of several ground locations, including the customer's own facility and facilities provided by the program and NASA.

- Customers will want to operate their payloads interactively in real time. This operation may include coordination between onboard and ground operations.

- Customers will want to choose from a variety of data return means to satisfy operational and economic constraints.

- Customers will require quick-look payload data to ensure proper payload functioning.

- Customers will desire interactive involvement in system schedule development, including real-time adjustments to accommodate targets of opportunity.

- Customers will require system support throughout the phases of their programs from inception through development integration, activation, operation, and closeout.

- Customers will have a variety of technical backgrounds. The system must be user friendly in order to accommodate all customers. It must facilitate their use of the system, minimize the need for special training, and maximize Space Station program productivity.

4.1.3 Program Operating Assumptions

The Space Station Program includes multiple ground and orbital elements operating together. Key operating assumptions affecting the function of the SSIS include:

- The Space Station navigates using GPS. TDRSS provides backup navigation.

- Space and ground elements communicate primarily through the Tracking and Data Relay Satellite System (TDRSS). One, two or three Ku-band Single Access (KSA) and S-band Single Access (SSA) channels must be shared at least among Space Station Program Elements (SSPEs). A Task 3 trade study will examine these alternatives.
- The Space Station is normally operated onboard, with capability for at least limited operation from the ground.
- The Space Station will provide data relay and navigation and control services for constellation elements.
- The ground system will handle data for all SSPEs.
- The system will support SSPE growth, expansion, and upgrade.

4.1.4 Program Phase Assumptions

The Space Station Program requirements on the SSIS will vary during the program phases. The following assumptions characterize the relationship during the development, buildup, and growth phases:

- Development - The SSIS/SSDS will be developed in parallel with the modules, subsystems, ground facilities, and space elements. Portions of the SSIS may be available to support SSPE prelaunch verification, but the complete SSIS will not be operational until IOC. Simulation and integration test software and hardware developed for the integration tasks are assumed to be useable in the ongoing "Develop, Simulate, Integrate, and Train" function, especially the Software Support Environment (SSE).

- Buildup - The SSIS capability to support remote operation of the Space Station and platforms must be in place at the beginning of the buildup phase. The initial Space Station module(s) transported to orbit is assumed to be unable to support continuous occupancy. The start of continuous operation will follow an on orbit integrated system test. IOC and continuous occupation are assumed to be coincident.

- Operation - The SSIS will fully support the continuing operation of the Space Station Program (SSP). The SSDS will support operation of the Space Station and its ground facilities, and coordinate multiprogram support services. The SSDS will support customer payload command and operation and deliver customer payload data. The SSIS will provide additional Standard Customer Services in support of customers throughout their involvement with the SSP.
- Growth and Evolution - The SSIS will fully support the growth and evolution of the program and its associated elements. Growth and evolution includes adding new Space Station modules, adding new SSPE's, automating functions, relocating functions, expanding services, and improving system operation. The SSIS will support the development and verification of hardware and software to achieve growth and evolution, in addition to supporting operation of the system.

4.2 FUNCTIONAL TOPOLOGY OF THE SSIS

The functional topology of the SSIS shows the functional elements of the SSIS and their relationship. The topology was developed by first identifying the SSPEs, determining their roles, and identifying relationships. This functional topology represents a baseline to be used to develop SSDS requirements. Allocation of specific functions to systems, subsystems and facilities will be developed in Tasks 3 and 4.

4.2.1 SSPE Identification

SSPEs were identified from References 1 and 2, the assumptions of Section 4.1, other prior Space Station and Data System Studies, and system analyses of the SSIS. Table 4-1 shows the SSPEs identified and their sources. The SSPEs and roles thus identified provide a context for the SSIS. These SSPEs are used to develop the SSIS topology and their roles are used to aid definition of the SSDS element functions.

Table 4-1. Space Station Program Elements, Sources, and Roles

Space station program element	Sources	Paragraph number	Roles
GPS	RFP[1] RFP	C-4- 2.2.5.3f C-4- 2.2.6.2k	Stable time and frequency reference Navigation signals
Polar platform (POP)	RFP	C-2- 2.3	Base for multiple payloads
POP control	RFP	C-3- 2.4g	Routine platform planning and operations
Coorbiting platforms (COP)	RFP	C-2- 2.2	Base for multiple payloads
COP control	RFP	C-3- 2.4g	Routine platform planning and operations
Free fliers	RFP	B- 2.12d	SSPE's
Free flier control	Analogy to RFP	C-3- 2.4g	Routine free flier planning and operations
Space station	RFP RFP RFP CRSS[2]	C-2- 2.1 C-4- 1.2 C-3- 2.1c 6.1.2[2]	Base for multiple payloads Laboratory and crew habitation provisions Service/maintain OMV Operate customer payloads
Space station control	RFP RFP	C-3- 2.4g C-3- 2.4j	Coordinate SSP operations, planning and support Provide essential ground operations capability to space station
TDRSS	RFP CRSS	C-4- 2.2.6.2g 0.1	Space station – ground communications Platform – ground communications
Network control	CRSS	0.1	Coordinate uplink/downlink service requests
Data distribution network	CRSS	2.2.3.4, 3.1.2.1	Provide transparent data link between customer and onboard equipment
Data handling center	Engineering Analysis	N/A	Required to separate/merge and buffer customer and core data steams
OMV	RFP	C-3-1.1c	Orbit maneuvers for satellite/platform servicing
OMV control	RFP	C-3-2.4g	Onboard and ground locations are required to control OMV operations
OTV	RFP	C-3-2.1d	High energy orbit payload transfer
OTV control	RFP	C-3-2.4g	Ground location is prepared to control high energy orbit injection and return
Space station payloads	RFP	C-2-2.1	Perform science and applications, commercial and technology Development missions
Customer, subcontractor Discipline data centers	RFP CRSS CRSS	C-3-2.4g 3.3.2 3.4	Routine payload planning and operations Routine customer data processing Maintain customer data archives
Remote customer facilities	CRSS	6.1.2	Command customer payload operation and data handling
Space station engineering data center	RFP CRSS	C-4-2.2.5.3e 4.1.1	Archival storage of core system data Provide stored and processed data to customers
NSTS orbiter	RFP RFP	B-2.12a C-3-2.1f	Primary means for launch, access and resupply Tend initial and growth space station
NSTS mission control	CRSS	0.1, 7.1.2	Long term rendezvous service planning, support
Deep space network	RFP	C-4-2.2.6.2g	Provide contingency command and telemetry link
Launch integration site	RFP	C-3-2.3a	Provide launch readiness verification
Contractor facilities	Engineering analysis	N A	Provide pre-delivery verification and integration test
Development, simulation and training	RFP RFP RFP CRSS	C-3-2.3b C-3-2.3d C-3-2.5 1.1.4	Use flight system to reduce GSE for testing Insure modifications and upgrades interface and function correctly Provide ground and onboard crew training Provide focal point for customer payload integration and test
Other communications links	RFP CRSS	C-4-2.2.6.2f 1.1.10	Provide customer payload-ground communication independent of TDRS/TDAS
Technical management information system	RFP	C-6	Provide program management services Provide SSP, engineering, operations, administrative and descriptive information Bill customer for services rendered
EVA (MMU, EMU)	RFP	C-4-2.2.11	Assembly, maintenance, servicing, repair of SS, platforms, structures, satellites, and vehicles

1) Space station definition and preliminary design, RFP, September 15, 1984.
2) Customer Requirements for Standard Services from the SSIS, revision 1, September 19, 1984

4.2.2 Space Station System Element Connection

The SSPEs and their interconnection are shown in Figure 4-1. The SSPEs are derived from those of Table 4-1. Their relationships to the SSIS are discussed below:

- Global Positioning System (GPS) - The GPS is a system of satellites emitting signals which allow accurate determination of position and velocity. The Space Station, platforms, free-flyers, and the OMV and OTV are presumed to be able to navigate using GPS. GPS also provides an accurate time and frequency reference.

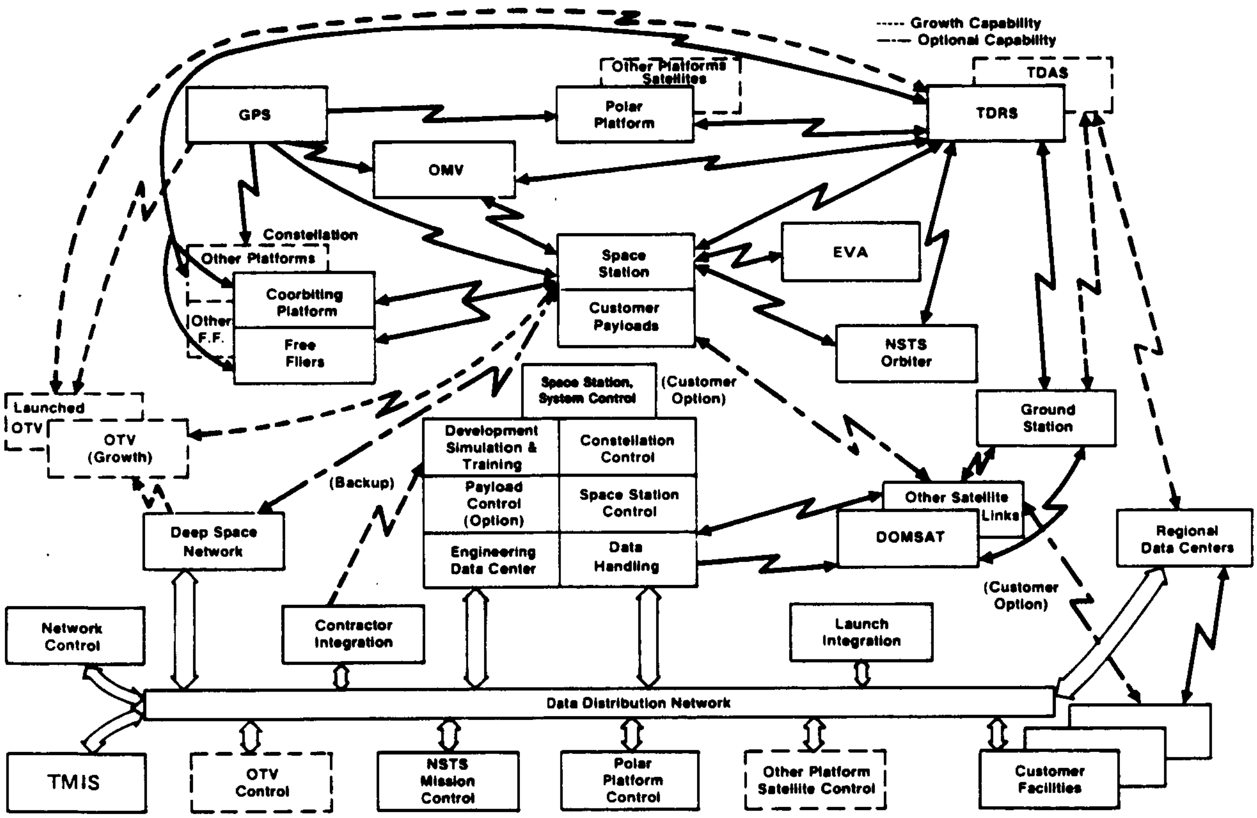


Figure 4-1. Space Station Program Element Interconnection

- Polar Platform (POP) and Control - The POP is a polar platform in sun-synchronous orbit which will be used primarily for earth and atmospheric observation. POP has no direct orbital communication with the Space Station, but will coordinate some observations and share some ground data handling facilities. Both will relay data to the ground through TDRSS KSA channels. Since the Space Station and

POP need not transmit simultaneously, a single ground Data Handling Center and network sized to handle 300 Mbps could distribute data for both systems. The POP will be joined by other satellites which may similarly share the ground Data Handling Center. POP and these additional satellites will be controlled from their own ground control centers.

- Co-orbiting Platform (COP) and Control - The COP is a platform in low inclination, low earth orbit. Early payloads are primarily astronomical and solar observatories. Other platforms, providing bases for multiple payloads, may be added. When in line of sight, the platform(s) may use the Space Station to relay data to and from ground stations and customer facilities. The Space Station provides tracking, traffic control, and support services. It may also provide remote platform and/or payload operation. Platforms at different orbital altitudes will not be able to maintain line-of-sight communications to the Space Station. These platforms must provide their own communication links, but may use Space Station ground facilities in the same manner as the POP.

- Free-Flyers and Control - Free-Flyers are single payload satellites. When in orbits accessable from the Space Station, Free-Flyers may be serviced and maintained from the Space Station. The Space Station will provide communications, tracking, traffic control and support services to coorbiting free-flyers, including spacecraft and payload control options.

- Space Station and Control - The Space Station is the permanently manned vehicle which provides a base for multiple payloads, habitation for the crew, and operating control for payloads, the Space Station, and constellation elements. The Space Station receives data from the payloads and constellation elements, and relays the data to the ground, together with core systems data, through TDRSS. Customer payload commands and data, together with ground operator commands and data are relayed to the Space Station through TDRSS. The Space Station routes the commands and data to payloads, core systems, and constellation elements. The Space Station must support real-time transmission of operating data and commands, near real-time transmission of quick-look data, and delayed transmission of bulk commands and data. Real-time operations of the payloads require limited two-way data relay, including audio and video links. Delayed data will be packetized and transferred at rates consistent with the TDRSS KSA band. In addition, the Space Station must support onboard operation of the Station, its payloads, constellation elements, the OMV, and the OTV. The Space Station operation and control is supported from the Space Station Control Center.

- Space Station's System Control - The Space Station System Control Center provides overall SSP coordination, including services such as scheduling and resource planning, coordination among SSPES, ground facilities management, portions of command management, and customer information coordination and dissemination. Their service will be defined during Task 4.

- Tracking and Data Relay Satellite System (TDRSS), Network, and Control - The TDRSS satellites will be the primary means for communication between the Space Station and the ground. TDRSS provides Ku and S-band single access channels (KSA and SSA) and multiple access (MA) S-band channels for communication. The equivalent of one KSA will be available to the program for bulk data uplink and downlink. The equivalent of one SSA channel will be available for command and monitoring. An MA channel will be available for voice communication. The Tracking and Data Acquisition Satellite (TDAS), as a growth capability, will provide multiple beam antennas. This capability will allow direct data relay to multiple customer and SSDS centers, or even remote customer facilities. The TDRSS ground station at White Sands, New Mexico is a relay station. It provides for channel separation and retransmission through DOMSAT and other satellite and ground links. It is assumed that the aggregate of these links, comprising the Space Station Data Distribution Network, will be able to handle simultaneous KSA and SSA transmissions at the full TDRSS bandwidth capability. The Network Control Center regulates and allocates network operation.

- Data Handling Center - The Data Handling Center receives, buffers, and retransmits uplink and downlink data. Data from TDRSS are captured and pre-processed (if desired by the customer), separated according to destination, and retransmitted according to negotiated schedules. The records are purged when satisfactory receipt at the destination is confirmed. Uplink data are received, buffered, merged, and transmitted to TDRSS according to a negotiated schedule. Again, recorded data are purged when satisfactory transmission is confirmed.

- Orbital Maneuvering Vehicle (OMV) and Control - The OMV provides for the deployment and retrieval of payloads in low inclination, low earth orbit. The vehicle is reusable and based on the Space Station. OMV will have manipulators and grapplers which allow it to retrieve and service satellites on orbit. The Space Station provides maintenance, resupply, and primary control. The OMV has a video camera which provides an image of the work to the operator for interactive control. The operator may be located on the ground for operations out of direct Space Station-OMV communications. The OMV will also be used to maneuver traffic through the constellation.

- Orbit Transfer Vehicle (OTV) and Control - A reuseable OTV, or ROTV, is classified as a Space Station growth element. There may be interim, expendable stage OTVs as well. Both reuseable and non-reuseable vehicles will be referred to as OTVs in this report. The OTV is used to launch payloads to geostationary and other high energy orbits and return or to launch interplanetary missions. It is also possible that OTVs will be used to place or service payloads in intermediate inclination orbits, in the absence of suitable National Space Transportation System (NSTS) flights. Payloads in geostationary orbit may also be serviced on orbit, using the robotics of an OMV. The OTV is based on the Space Station for maintenance, payload mating, and resupply. The OMV may be used to maneuver the OTV into and out of the constellation. Once at the orbital launch point, control is handed over to the OTV ground control center for launch and return. The OTV may use TDRSS, DSN, and Space Station communications links.

- Regional Data Centers (RDC) - The regional data centers are multipurpose facilities or facility complexes providing payload operation, data processing, and data archiving services for a class of related payloads. Instrument specialists and principal investigators may use regional data center facilities to validate, access, and analyze data. The centers may also provide instrument monitoring and payload operations control center (POCC) services, including real-time payload operation and quick-look monitoring of engineering and scientific data. Alternatively, the POCC function may be accommodated in separate facilities.

- Remote Customer Facilities - Commercial customers, as well as some others, will have their own facilities for payload operation and control and data reception, archiving, and analysis. A remote customer facility may be connected directly to the data distribution network or to a regional data center. When tied to the RDC, the customer facility can utilize the support services available at the RDC.

- Engineering Data Center - The Engineering Data Center(s) provides archival storage of Space Station and platform engineering data. This center will support program and customer requests for Space Station Program historical data.

- Optional Payload Control Center - A payload control center may be provided at the Space Station Control Center to provide short term support, additional support for payload checkout and special or short term mission operations, such as some technology development missions.

- NSTS Orbiter and Control - The orbiter is the means of Space Station deployment, construction, and resupply. All ground-to-orbit transportation is assumed to be handled via Shuttle orbiter. Two way communication is required to facilitate maneuvering through the constellation and docking to the Space Station. The NSTS orbiter is controlled from its existing Mission Control Center, as well as by the onboard crew.

- Deep Space Network (DSN) - This network is the primary means for communication between the OTV control center and the OTV from orbital launch through geostationary orbit operations and return to rendezvous with the Space Station. It also provides a contingency command and telemetry link for Space Station communications. The DSN will handle only spacecraft data in this backup role. Command and telemetry data will be transferred directly with the SSCC.

- Launch Integration Facilities - These ground facilities provide verification of launch readiness for payloads and SSPEs. Launch integration facilities are assumed to be remote from the SSDS ground element. The relationships may include both software and simulation support, as well as interface control.

- Contractor Facilities - The contractor facilities at which Space Station modules and upgrades are being manufactured will be supported in their validation and integration tests. The primary support to the facility is expected to be in the development and delivery of simulation models, and in software development and integration.

- Development, Simulation, Integration, and Training - Support functions anticipated include the development and integration of new and modified software, software uplink, integration of customer payloads, end-to-end communications checkout, use of flight equipment in lieu of GSE, crew training, and construction of simulation models for use at remote sites.

- Other Communications Links - Provisions to allow customers to communicate with their payloads outside of TDRSS/TDAS are to be supplied by the customers. These include direct space-ground links and other satellite relays. These links are most likely to be used by foreign customers desiring little delay in transmitting commands and receiving data and by customers requiring complete security of their data.

- Technical and Management Information System (TMIS) - The TMIS will be used to support the management of the SSP and engineering development and integration of the Space Station elements. This program element will be involved in establishing schedules, monitoring and controlling resources, managing budgets, maintaining manuals and procedures, developing NSTS manifests, controlling inventories, and developing and managing the Space Station configuration. The SSDS provides the TMIS with station operating data, and the TMIS provides the SSDS with configuration, planning, and programmatic data. Frequent data interchange between the SSDS and the TMIS will be required. Details of these interchanges will be developed during the SSP preliminary design.

- EVA (MMU, EMU) - EVA support systems, including the MMU and EMU will be monitored by the SSDS and may be automatically maintained on the Space Station using SSDS support services. The SSDS will also maintain EVA communications, including ground links and operations and procedure support.

4.2.3 SSIS/SSDS Functional Boundaries

With the many SSPEs and functions performed by these elements, it becomes necessary to establish criteria for inclusion in or exclusion from the SSIS and the SSDS. These criteria are discussed below and applied to determining SSIS and SSDS boundaries.

<u>Criteria For Inclusion in SSIS</u>

An SSP element or function is to be included in the SSIS if

1. <u>The element or function is in the end-to-end data flow</u>. The end-to-end data flow extends from the customer's facility to his payload, from the engineering data center to the Space Station hardware elements, and from the platform or free-flyer control centers to the platforms or free-flyers.

2. <u>The element or function is a Space Station or Platform Core or Customer Unique Application</u>. Space Station and platform core systems and customer-unique applications, both onboard and on the ground, are considered to be part of the SSIS, as they are end points for data.

Core systems maintain the environment in which those using Space Station Program services operate. Customer-unique applications are performed by customer supplied subsystems implementing functions unique to their applications. Customer-unique applications may be supported as SSIS customer services, but only to the extent negotiated between the customer and the Space Station Program. This criterion incorporates requirements of Reference 5.

3. The function or element performs services dedicated to the SSIS, which the SSIS must have to operate. This criterion becomes a catchall for elements or functions which may be unclear or omitted under criteria 1 and 2. No new elements or functions were included in the SSIS under this criterion, but it does serve to confirm several elements and functions as being a part of the SSIS.

4. The function or element is in the SSDS. The SSDS is defined to be a wholly contained subset of the SSIS. Therefore, any element or function found to be in the SSDS must also be in the SSIS.

Criteria for Inclusion in the SSDS

An element or function is included in the SSDS if

5. The element or function provides a core service. All data processing and data management services provided to the Space Station and platform facility subsystems are included in the SSDS. These services may be implemented in space or on the ground. This criterion incorporates requirements of Reference 5.

6. The element or function provides a standard customer service. The standard customer services are understood to include those services available to any customers, whether in space or on the ground. Standard services should be defined in response to requests from multiple customers. Some standard customer services will be included in the SSIS, but not in the SSDS, per Table 4-2. This criterion incorporates requirements of References 2 and 5.

Table 4-2. Customer Standard Services in SSIS, Not in SSDS

Standard customer services not in SSDS	Rationale: Extended service	Rationale: Multi program	Rationale: TMIS service	Applicable paragraph from Ref. 2
• Payload data processing beyond level 0	X			3.1.1, 3.1.3, 3.3.1
• Data archiving beyond that necessary to ensure satisfactory delivery to the customer's designated facility	X	X		3.1.6, 3.4.1 3.4.1.1 3.4.1.3
• Facilitate routine data analysis services	X			3.3.3
• Access to Space Station programmatic, administrative and descriptive information (Note: engineering and some operations information are provided by SSDS)			X	4.2.1
• Data exchange among customers	X	X		3.1.7 5.4.1
• Audio and video recording and playback between elements		X[1]		5.2.3, 5.2.6, 5.3.3
• Long term mission planning (not including mission operations)			X	7.1.2
• Remote Work Stations at customers home institution	X			6.1.5.2.3

[1]Onboard record and playback services for both audio and video are in SSDS

7. The element or function manages data inboard of sensors and effectors. This criterion is a clarification of criteria 5 and 6, in that it excludes the hardware elements (sensors and effectors) from the SSDS.

8. The element or function manages data prior to delivery to or after receipt from customers or operators. This criterion clarifies the customer and operator ends of the SSIS/SSDS boundary. The end-to-end data flow includes institutional facilities, such as TDRSS, that cannot be a part of the SSDS. However, the associated data management functions provided by the SSP are tested by this criterion for inclusion.

Criteria for Exclusion from the SSDS

9. The element is a unique sensor/effector/special purpose processor embedded in a system. This criterion compliments criterion 7 by excluding elements which are more appropriately part of nominally autonomous systems. These systems may still contribute status data to the SSDS and receive operating commands such as mode and configuration changes.

10. Element or function is a multiprogram facility or service used by but not dedicated to the SSP. This criterion adds a restriction on the SSDS scope to exclude institutional facilities and systems.

The elements and functions included in the SSIS and in the SSDS are shown in Table 4-3. The criteria by which the decision was made are indicated.

Table 4-3. Development of SSIS and SSDS Boundaries

	SSIS criteria				SSDS criteria				Exclusions		Disposition		
Space station program element/funtion	1 End to end data	2 RFP def	3 Ded SSIS serv	4 In SSDS	5 Core serv	6 User std serv	7 Mng inbd data	8 Mng data before trans	9 Embed proc	10 Multi prog serv	In SSP	In SSIS	In SSDS
GPS										✓	No	No	No[2]
Polar platform (POP)	✓										Yes	Yes	Yes
POP ground data handling	✓			✓		✓		✓			Yes	Yes	Yes
POP control	✓										Yes	Yes	Yes
Co-orbiting platform (COP)	✓		✓	✓		✓	✓	✓			Yes	Yes	Yes
COP control	✓	✓	✓								Yes	Yes	Yes
Free fliers	✓		✓	✓							Yes	Yes	No
Free flier control	✓	✓	✓								Yes	Yes	Yes[3]
Space station	✓	✓	✓	✓	✓	✓	✓	✓			Yes	Yes	Yes
Space station control	✓	✓	✓	✓	✓						Yes	Yes	Yes
TDRSS	✓							✓		✓	Yes	Yes	No
Network control	✓					✓				✓	Yes	Yes	Yes[1]
Data distribution network	✓					✓		✓		✓	Yes	Yes	Yes[1]
Data handling center	✓	✓	✓	✓		✓	✓	✓			Yes	Yes	Yes
OMV services	✓	✓	✓	✓		✓	✓	✓			Yes	Yes	Yes
OMV control	✓	✓	✓	✓		✓	✓	✓			Yes	Yes	Yes
OTV services	✓	✓	✓	✓				✓			Yes	Yes	Yes
OTV control	✓	✓	✓	✓		✓	✓	✓			Yes	Yes	Yes
Core systems	✓	✓	✓	✓							Yes	Yes	Yes[3]
S.S. payloads	✓	✓									Yes	Yes	No
Regional data centers	✓	✓		✓				✓		✓	Yes	Yes	Yes[1]
Engineering data center	✓					✓		✓			Yes	Yes	Yes
Customer facilities	✓										Yes	Yes	No
Customer payload control	✓	✓		✓				✓			Yes	Yes	Yes
NSTS orbiter	✓										Yes	Yes	No
NSTS mission control	✓										Yes	Yes	No
Deep space network	✓									✓	Yes	Yes	No
Launch integration site	?	✓									Yes	Yes	No
Contractor facilities	?	✓									Yes	Yes	No
Development, simulation and training facility	✓	✓	✓	✓		✓	✓	✓			Yes	Yes	Yes
Alt. communications links	✓	✓									Yes	Yes	Yes[3]
Technical management information system				✓		✓					Yes	Yes	No[2]

1) Portions are institutional and not in the SSDS. 2) See text for explanation of exclusions
3) Included to define interfaces

Free flyer control, Network control Data Distribution and Alternative Communications link are included in the SSDS for the purpose of defining interfaces and potential additional requirements placed on these elements. These interfaces are discussed in Section 5.2.1.

The GPS broadcasts signals that are received and processed by the SSPEs. However, GPS neither responds to the Space Station nor has knowledge of its presence. Hence, GPS meets the requirements for exclusion.

The Technical and Management Information System (TMIS) serves program-wide technical and management information distribution functions for both the SSP and for customer services. The customer services provided are more properly considered to be part of the SSP than of the Space Station Data System in the context of this study. Therefore, the TMIS is considered to be part of the SSIS, but not part of the SSDS.

There are, in addition, some customer standard services in the SSIS, but not in the TMIS or the SSDS. These services are excluded from the SSDS because the services are considered to be beyond those appropriate for SSDS (extended services), or meet criterion 10. Table 4-2 shows the customer standard services in the SSIS, including those within TMIS.

The entries in Table 4-2 require some explanation. "Applicable Paragraph" shows the specific paragraphs in Reference 2 which define the required standard service. Only those portions of the paragraph implicit in the listed Standard Customer Service are intended to apply. Some paragraphs will also contain services which are included in the SSDS.

- Payload Data Processing Beyond Level Zero (raw data) includes all processing producing physical units and parameters (Reference 2, Appendix B), but excludes unique processing or handling (paragraph 3.1-3) unless specifically negotiated between the customer and Space Station Program.

- Data Archiving ranges from short term (¨ 1 week) to long term (up to two years). The short-term archiving (paragraph 3.4.1.2) is included in the SSDS to ensure delivery of acceptable quality data to the customer. This archiving includes only level 0 data. All longer term archiving is an SSIS standard customer service.

- Facilitate Routine Data Analysis Services provides facilities and off-the-shelf software routines to support routine customer data analyses.

- Access to Space Station Programmatic, Administrative, and Descriptive Data is expected to be supported by the TMIS. The engineering and operations data also mentioned in paragraph 4.2.1 should be accessed through the SSDS. These boundaries should be either transparent to the customer or delineated through user friendly prompts and interaction, such that customers can easily access all types of information.

- Data Exchanges Among Customers will often involve archival or planning data. To keep the system uniform, all data exchange among customers is allocated to SSIS standard customer services.

- Audio and Video follows the same rules as data exchange, above.

- Long-Term Mission Planning, in the context of paragraph 7.1.2, includes SSPE support services (NSTS, OMV, OTV, etc). Customer payload accommodations is also a part of long-term mission planning. SSDS will provide all phases of mission operations planning.

- Remote Work Stations are an extended service to promote standardization.

4.2.4 SSDS/TMIS Boundaries

There are potential areas of overlap between the SSDS and the TMIS in programmatics. The functions involved were examined in light of the stated TMIS objectives (Reference 1, section C-6) and the Customer Requirements for Standard Services, (Reference 2). The distinguishing features of the TMIS and SSDS identified are discussed below.

The TMIS features are:

- Deals primarily with management, development, and long range planning for the Space Station.
- Deals primarily with program managers, designers, and contractors.
- Deals primarily with engineering development data and programmatic data.
- Development contractors are the primary data sources.
- Customer interactions are primarily program information and coordination of multiprogram services.

The contrasting SSDS features are:

- Deals primarily with operation of the Space Station and payloads and handling of customer data and commands.
- Deals primarily with core operator and customer operators.
- Deals with both real-time and non-real-time operational data and commands.
- Customer interactions are primarily operational and data processing.

Based on these distinguishing features, the SSDS/TMIS boundaries are drawn in the areas of potential overlap as defined in Table 4-4.

4.2.5 SSDS - Subsystem Interface Diagrams

The onboard portion of the SSDS includes both core and customer services. This scope is understood to include all those standard data services appropriate for implementation in general purpose processors. The charts that follow are a first step in defining a detailed boundary betwen the SSDS and the onboard subsystem equipment. This boundary will be further clarified by the SSDS Functional Interface Specifications that are to follow in Task 4.

Figure 4.4.4.1-1 from the Reference System Configuration has been copied and annotated as Figure 4-2 to show a top level view of the SSDS-subsystem boundary on the Space Station. The boundary is shown by the bold, dashed lines. Note that the Information and Data Management Subsystem (IDMS) is fully contained within the SSDS. The Subsystem Data Processors (SDP) for the subsystems are also shown a within the SSDS.

Table 4-4. SSDS/TMIS Boundary Definition

Function	SSDS responsibility	TMIS responsibility
Logistics Planning	• Customer and core resupply needs • Payload, space station, platform, Satellite, OMV and ROTV maintenance needs • LRU's on orbit	• New payloads • New modules • Major upgrades • STS scheduling and manifest requests
Program budgeting and scheduling	• Input requests and status	• Integrated development, monitor and statusing of budgets and schedules
Customer Billing	• Input data services rendered	• Prepare billing for all services and post payments
Manuals and procedures reporting	• Payload operations procedures • Payload maintenance manuals • Facility operating procedures • Space station system maintenance manuals • Emergency procedures	• Equipment specifications • Equipment operating procedures • Other facility and equipment maintenance manuals • Payload interface specifications • System specifications
Configuration management	• Real time mass and area properties • Core system equipment status • Facility configurations • LRU status • Real time operational data base • Measurement, monitor and test current configuration	• Configurational properties • Equipment lists, serial nos. • Equipment histories, failure mechanisms • Planning for changes • Instrumentation lists • List of possible system tests
Inventory Control	• Spares on board • Spares at facilities	• Spares in pipeline • Location of payloads • Location of payload spares • Location of repair parts
Planning/scheduling	• Operating schedules	• Programmatic schedules • Master Plan • Accommodation plan
Customer interfaces	• Receipt and delivery of payload commands • Receipt and delivery of payload data • Acquisition and delivery of ancillary data • Development and use of simulation for payload integration and customer training • Customer authentication • Command dictionary maintenance	• Customer handbook • Customer accommodation plan • Customer billing • Customer priorities • Prior designation of specific commands as restricted or constrained by the SSP • Manifesting customer payloads and supplies

The numbers 1 through 7 appear next to the subsystems and indicate the figure number in which the subsystem interfaces are further defined. The Propulsion System electronics (RCS electronics) are shown to be included within the GN&C subsystem (page 416 of the reference configuration). Therefore, no separate figure is provided for the RCS. Similarly, the electronics support of payloads is included in the SSDS, and no separate diagram is shown for the payload and servicing accommodations subsystems. The remaining seven subsystems are shown in the interface diagrams of Figures 4-3 through 4-9.

The Subsystem Interface Diagrams show the subsystem "sensors and effectors" on the left hand side. Typical data flows between the SSDS and the sensors and effectors are indicated. Subsystem functions performed by the SSDS are

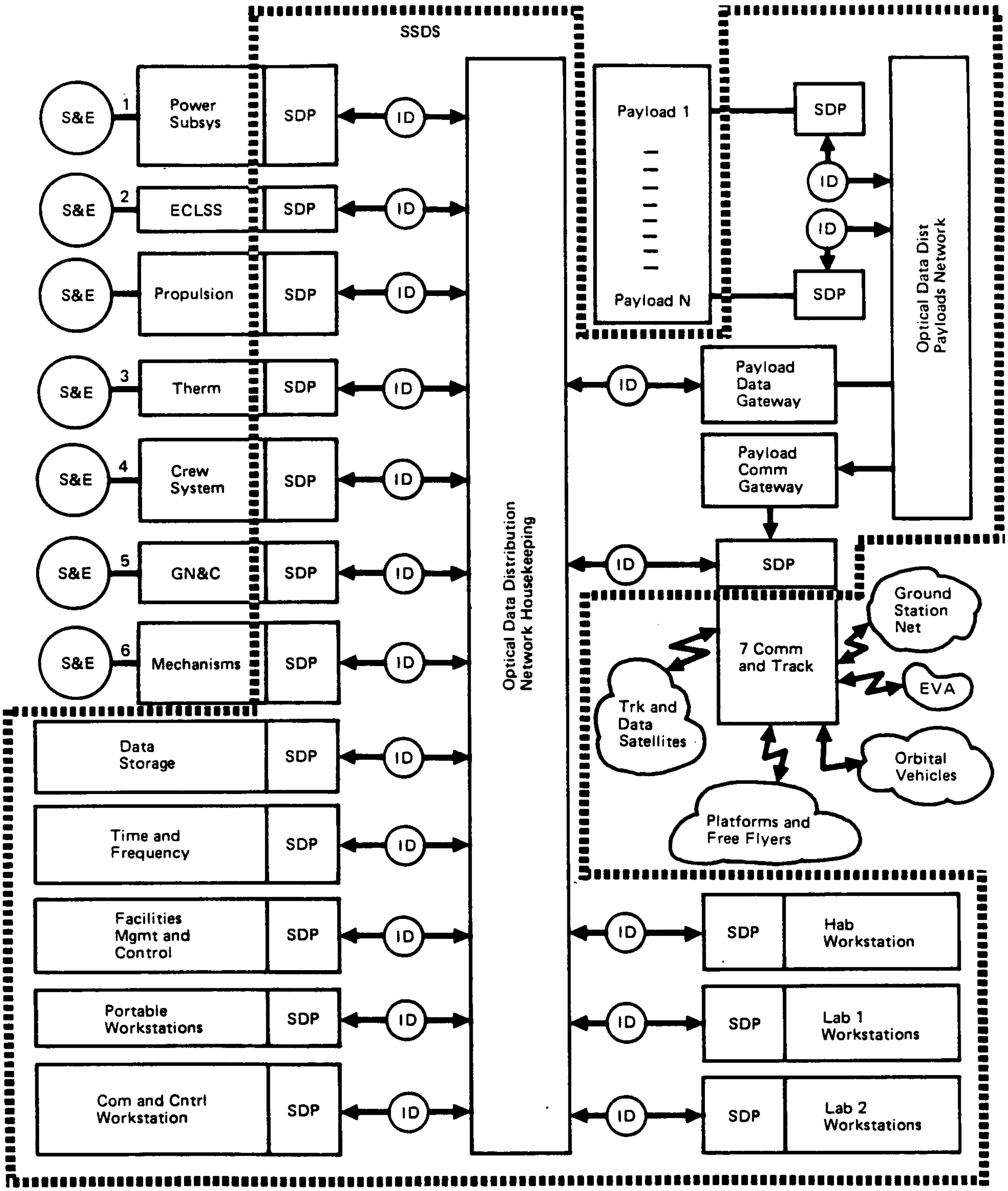


Figure 4-2. Information and Management Subsystem Space Station

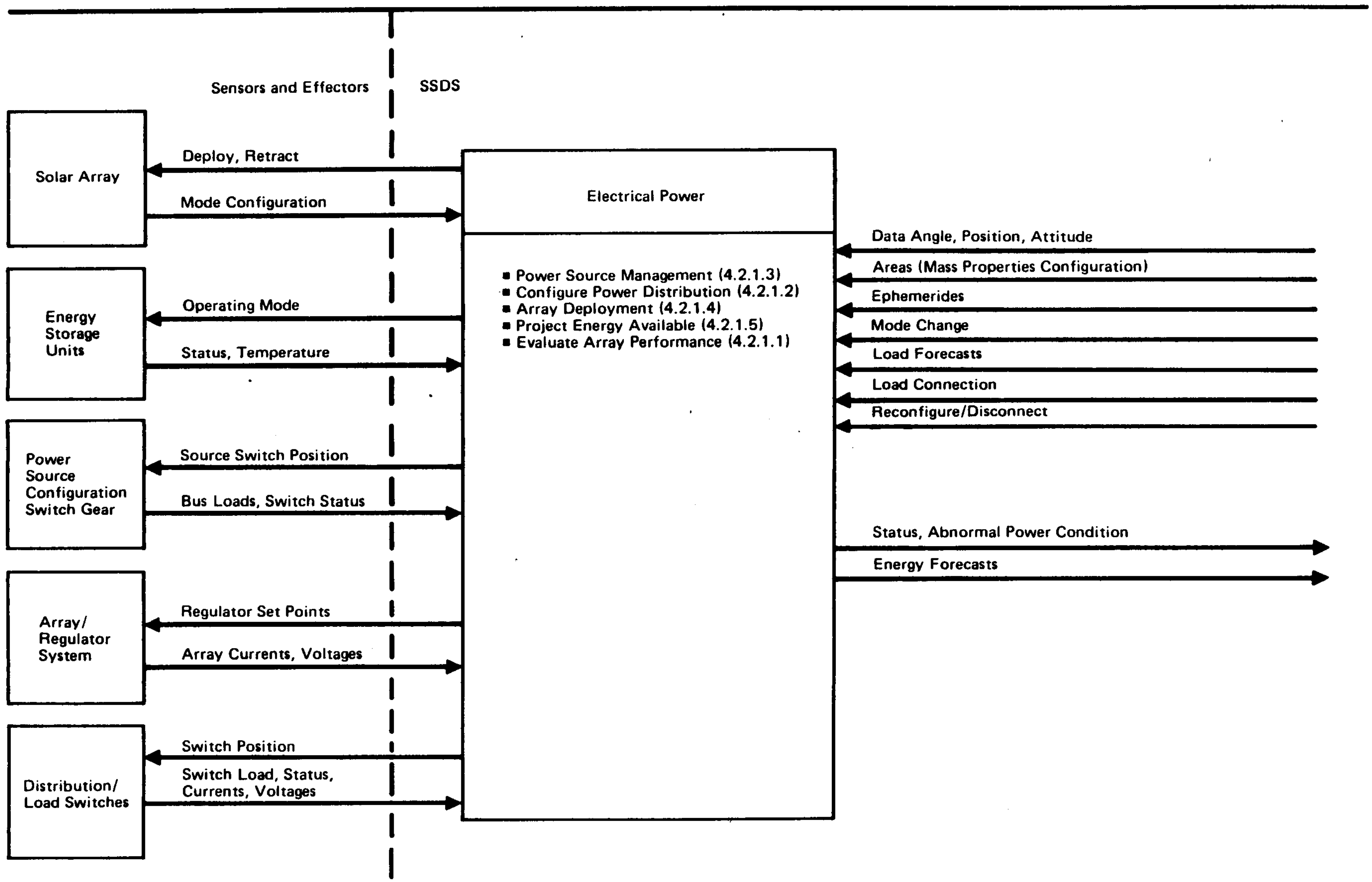


Figure 4-3. Electrical Power SSDS Interfaces, Space Station and Platform

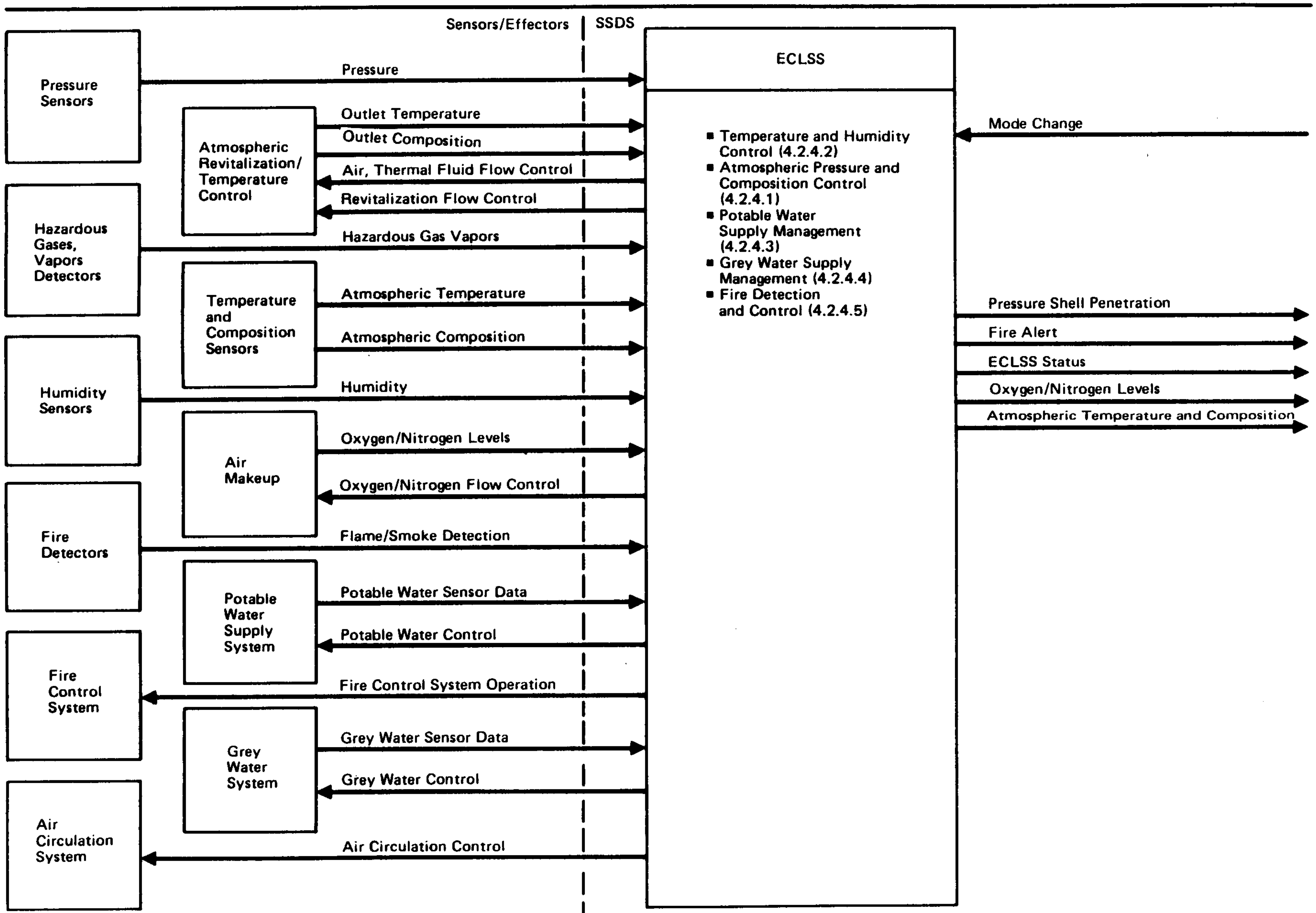


Figure 4-4. ECLSS SSDS Interfaces – Space Station, Only

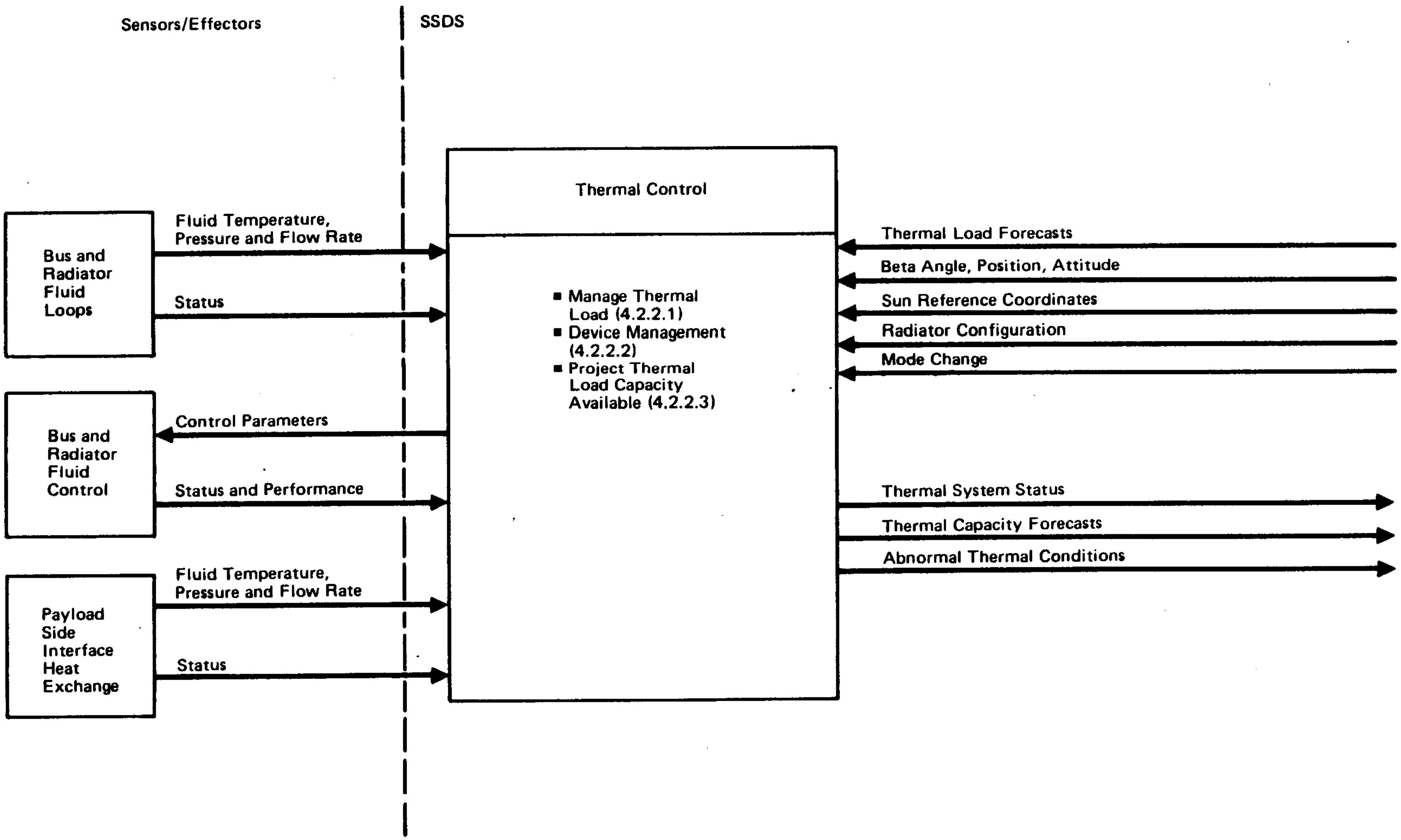


Figure 4-5. Thermal Control SSDS Interface, Space Station and Platforms

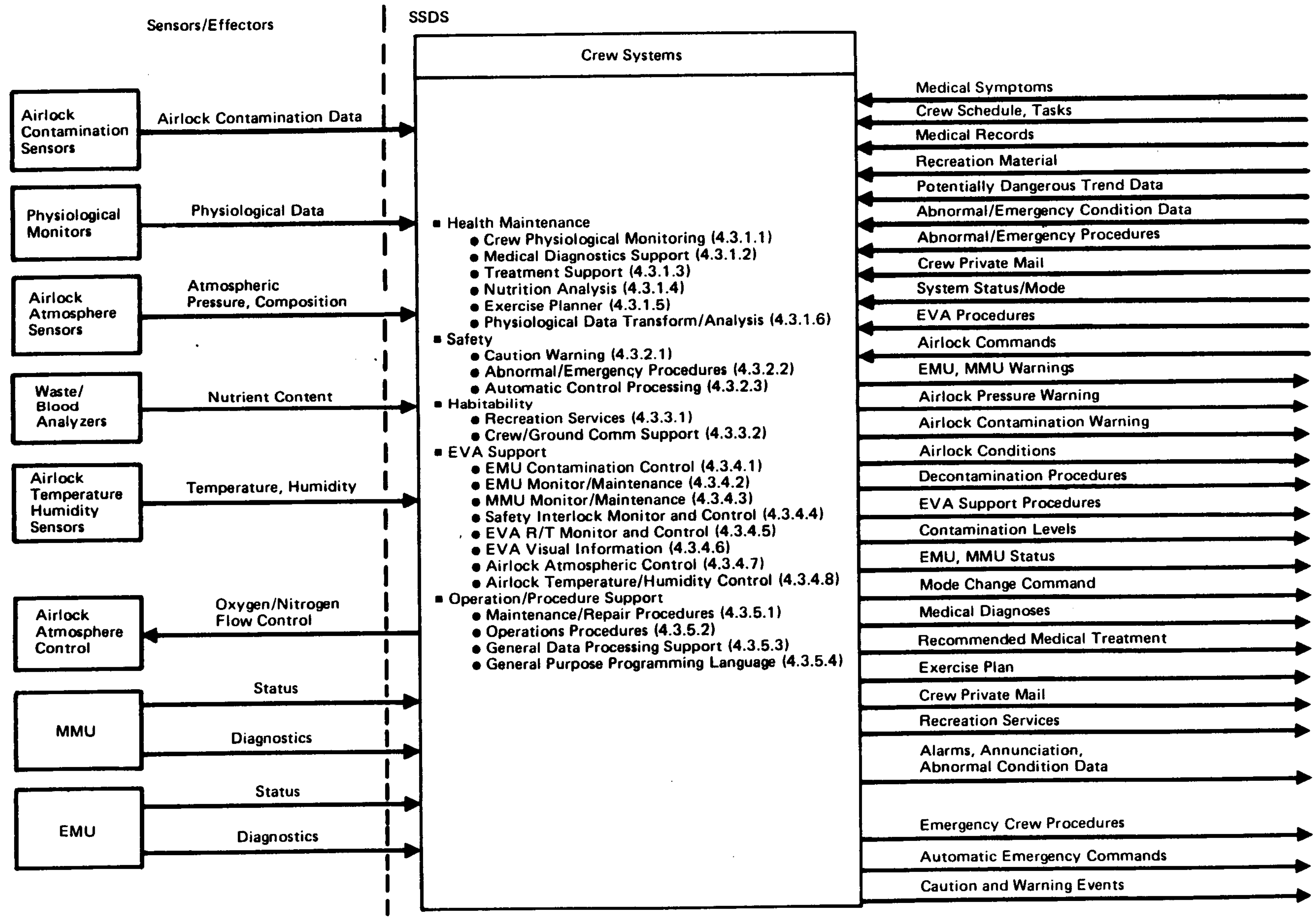


Figure 4-6. Crew Systems SSDS Interfaces, Space Station, Only

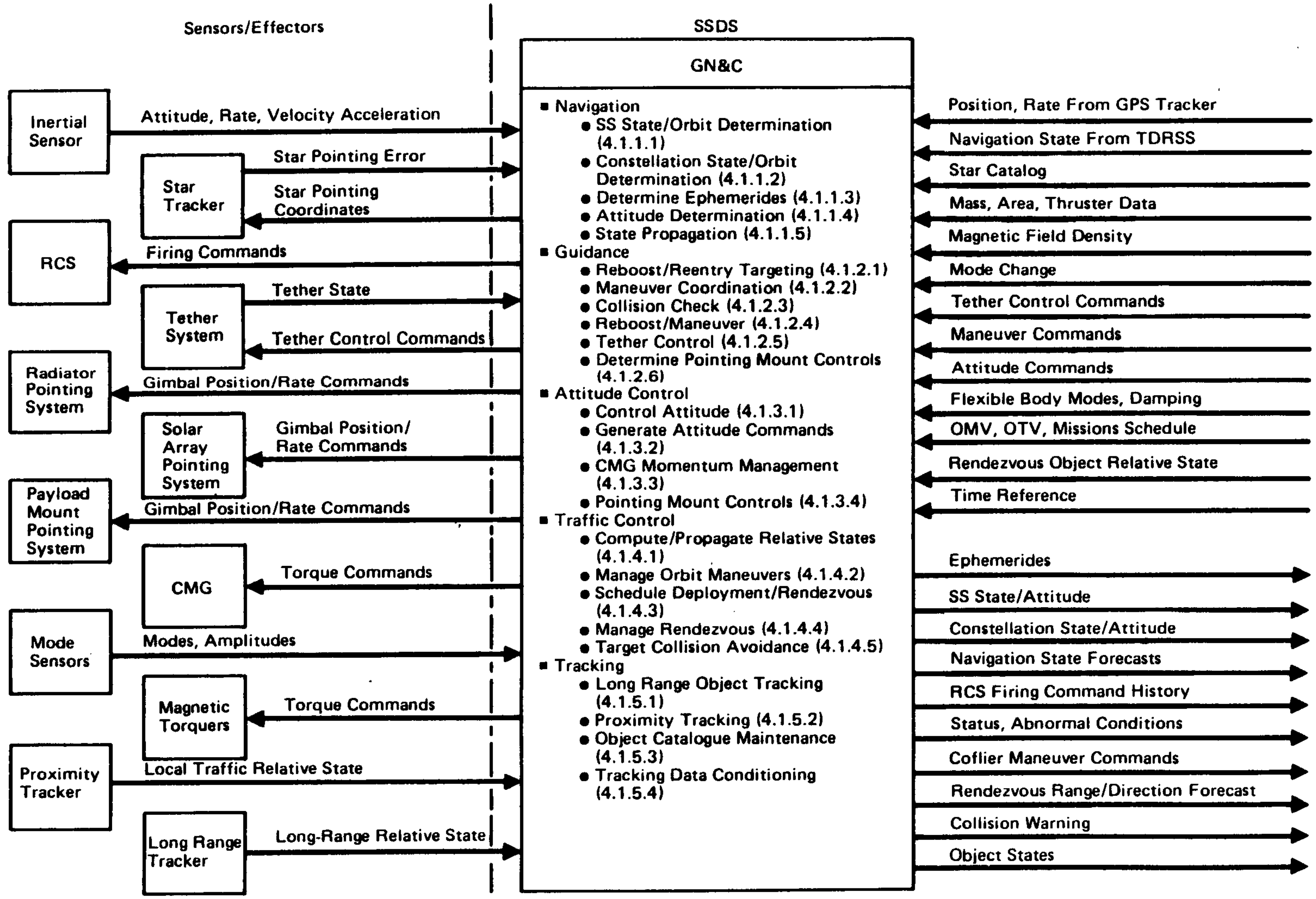


Figure 4-7. GN&C SSDS Interfaces, Space Station and Platforms

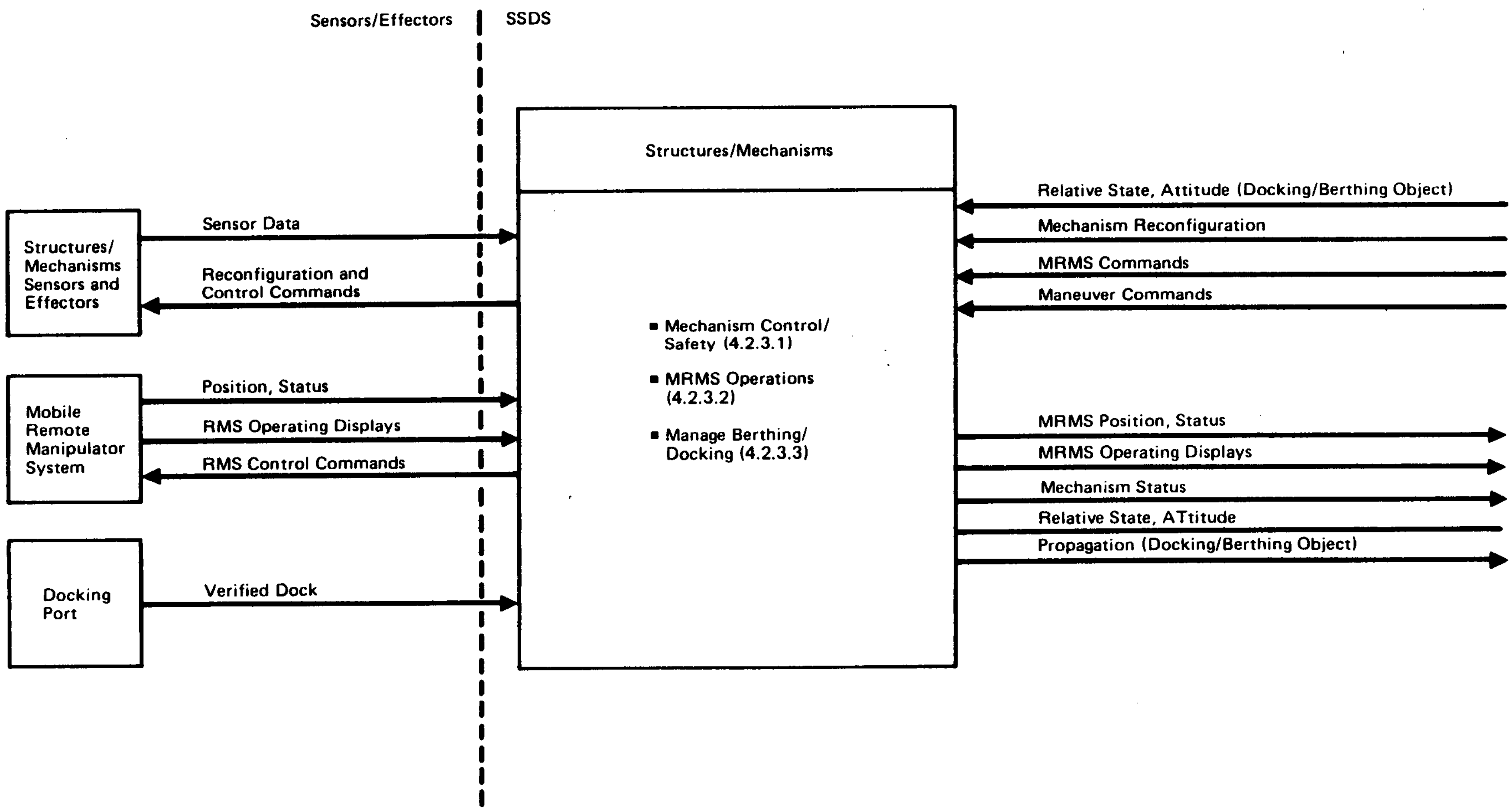


Figure 4-8. Structures and Mechanisms SSDS Interfaces, Space Station, Only

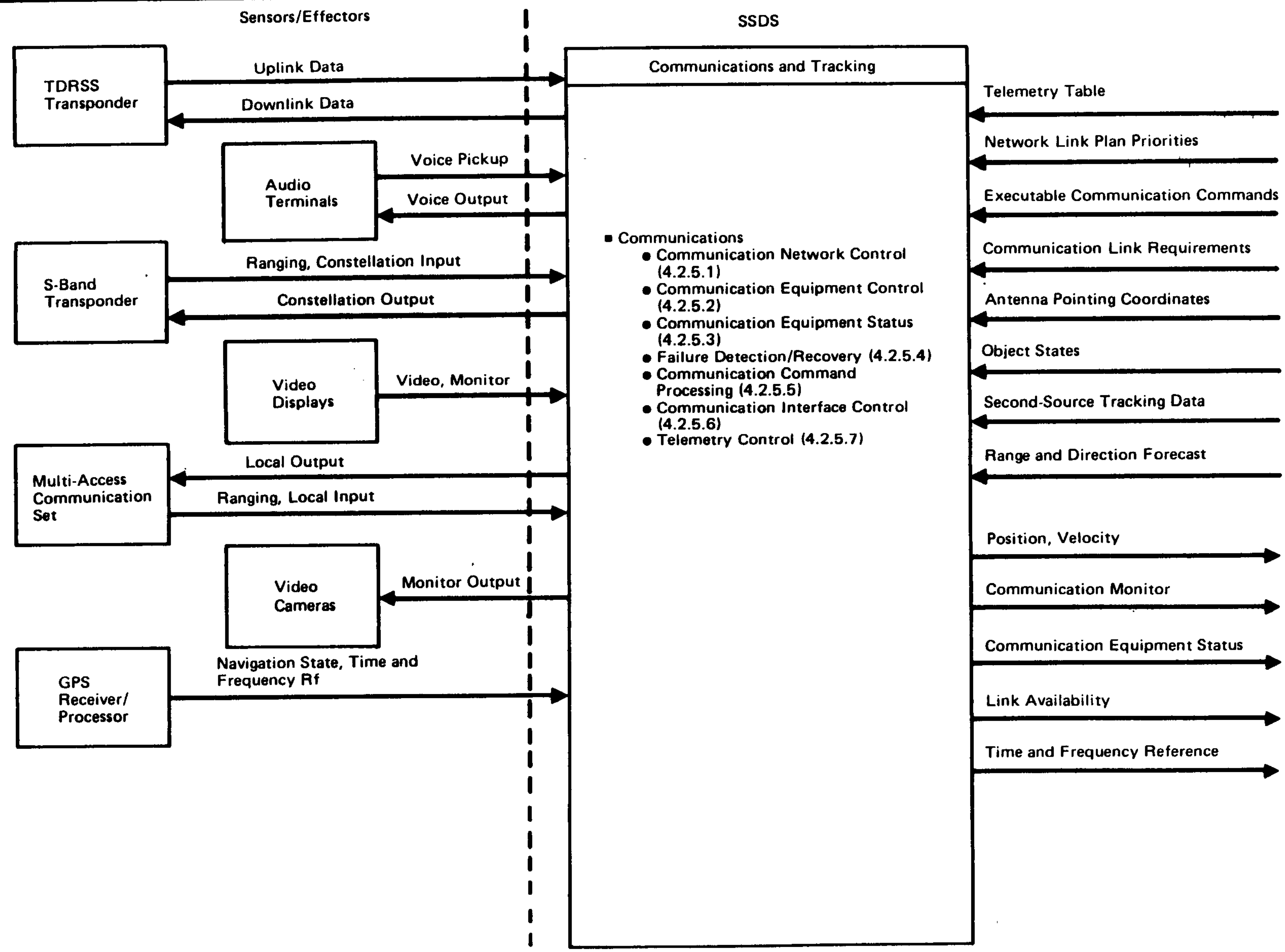


Figure 4-9. Communications and Tracking SSDS Interfaces, Space Station , Only

indicated in the center boxes on the diagrams. Data flows to and from other SSDS functions are also indicated.

A similar set of diagrams define the platform SSDS - subsystem interfaces. ECLS and crew systems are not present on the platforms. Structures and mechanisms and Communications are modified as shown in Figures 4-10 and 4-11.

4.3 FUNCTIONAL ARCHITECTURE OF SSIS

System architecture is closely related to system design. Only the top level of architecture can be presented without specifying the design to a significant degree. This section is, therefore, constrained to a very top level discussion. Some additional design-independent detail will be provided in Section 4.4 in the discussion of SSIS operation.

The architecture will be presented in a top level data flow diagram, showing how the system works from a logical perspective. A more detailed discussion will follow on the two major end-to-end data flows, command management, and customer data handling.

4.3.1 Data Flow Diagram Conventions

Structured Systems Analysis (SSA), Reference 4, has been used extensively in Task 1 to develop the logical operation of the system. Data flow diagrams (DFD) are used to provide a graphic presentation of the results of SSA, and to show the overall working of the system being analyzed. There are four conventions used in data flow diagrams, as illustrated in Figure 4-12, etc.

- External agencies enter data into the system and receive data from the system. They do not otherwise interact with the system. External agencies are designated by squares with a double line at the top and left. For simplicity of the diagram, an external agency may be duplicated on the diagram. A diagonal line across the bottom right corner indicates a duplication.

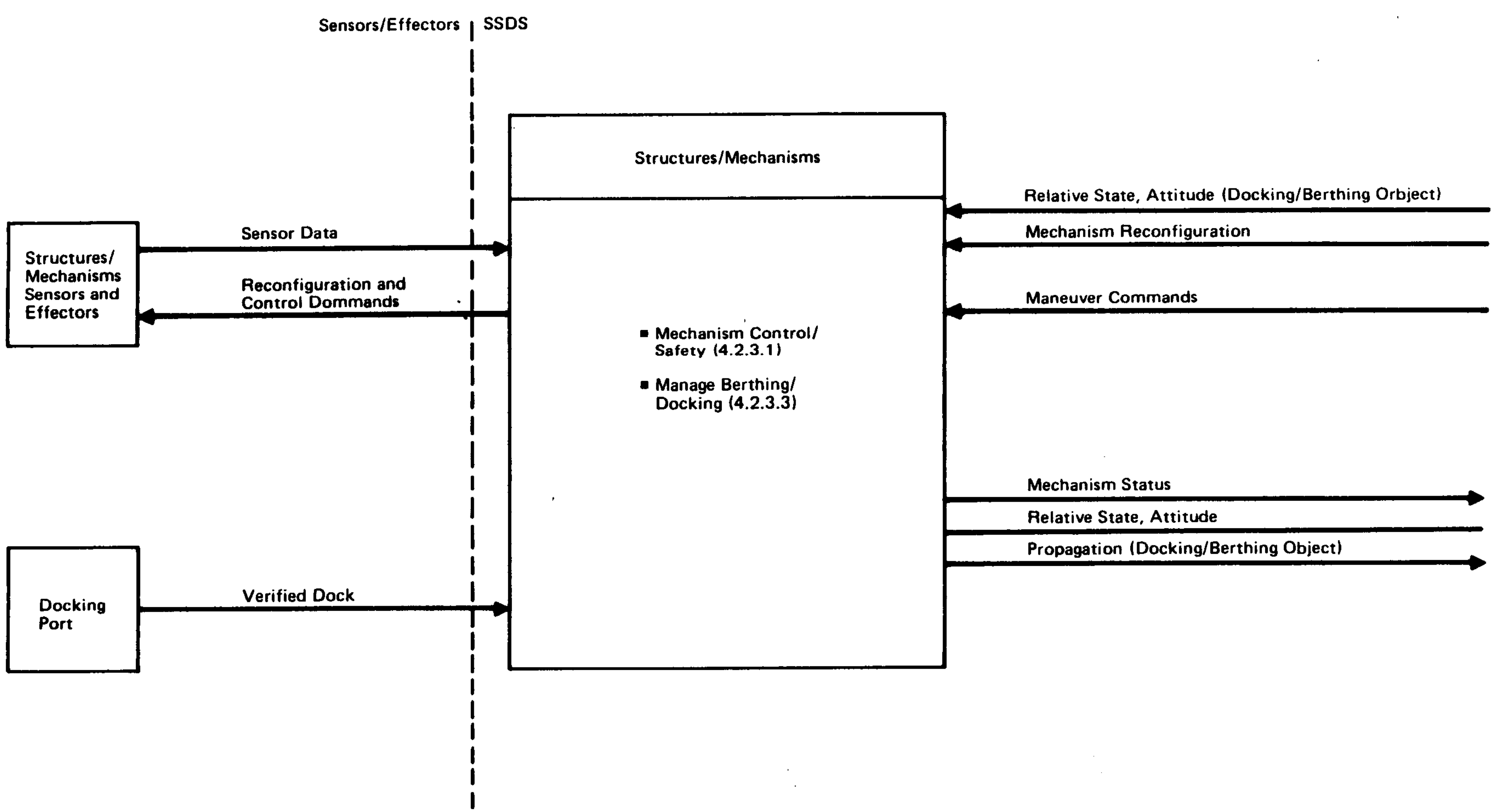


Figure 4-10. Structures and Mechanisms SSDS Interfaces, Platform, Only

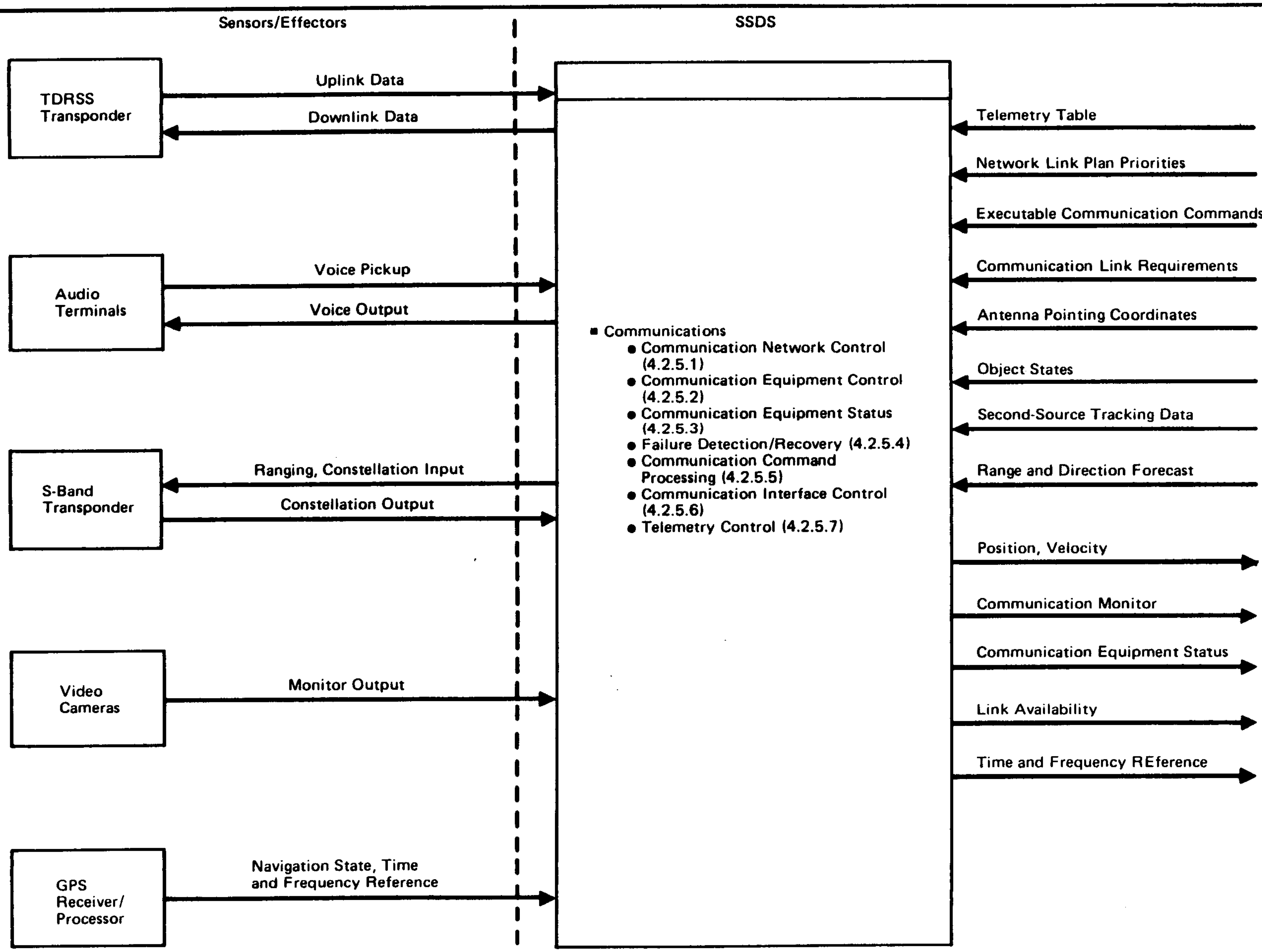


Figure 4-11. Communications and Tracking SSDS Interfaces, Platform, Only

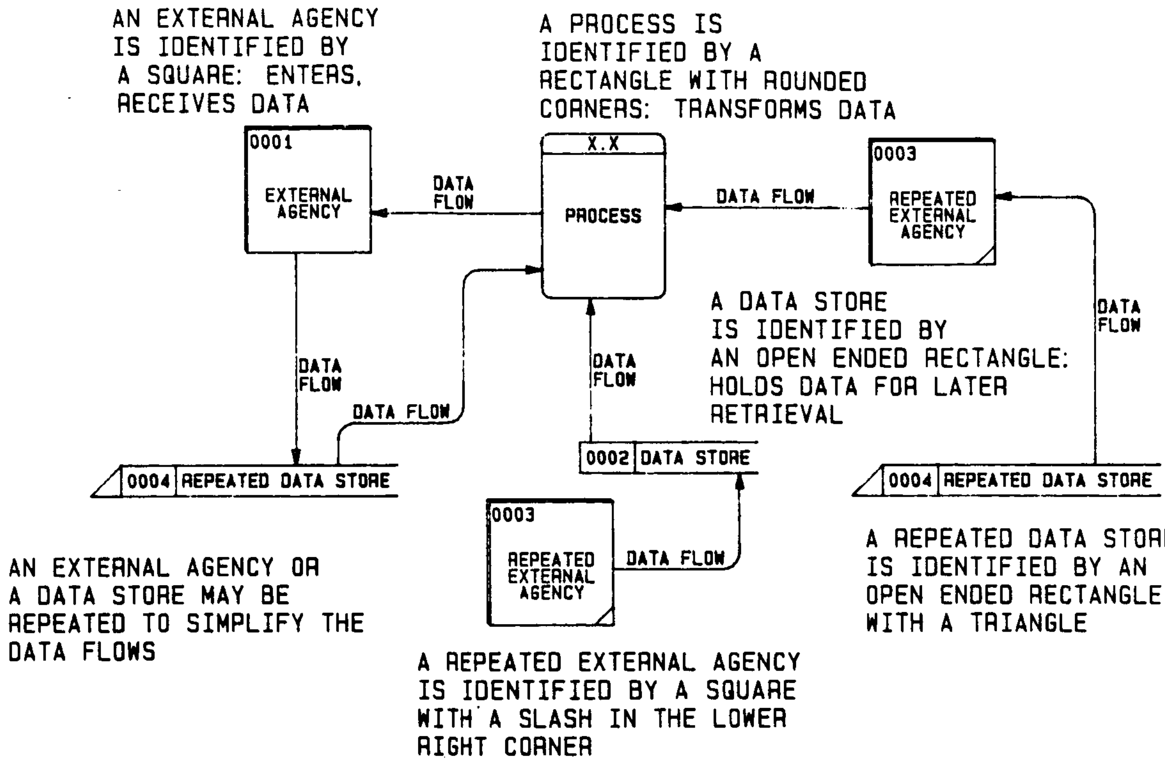


Figure 4-12. DFD Symbol Conventions

- Processes transform flows of data, usually in some fundamental way that alters its form and content. A process is designated by a rounded corner rectangle.

- Data Stores contain data to be made available to other processes when the processes do not necessarily take place in immediate sequence. Therefore, the data in a data store should have a significant lifetime. Data stores are designated by extended, open sided rectangles. Data stores may also be duplicated to simplify the diagram.

- Data Flows identify the data moving among processes, data stores and external agencies. The data flows are designated by labeled arrows.

Structured systems analysis is used to develop multiple levels of detail to describe what the system does. The top level (Level 0 DFD) shows the entire system in its simplest form. The level 0 analysis concentrates on the end-to-end paths connecting external agencies. It becomes an outwardly focused description, focusing on the questions, "Who will be using the system?", "What do they want the system to do?", and "What are the major data input to the system?." The processes depicted are very top level and generic. Subsequent levels of DFDs will add progressively more detail.

4.3.2 Characterization of the SSIS

The first step in an SSA is to ascertain the answers to the above questions. These responses, in appropriate detail for an SSIS Level 0 DFD, are:

a. Customers will use the system to develop payloads, develop software and command sequences, command payloads and receive data.

b. Operators will use the system to command the Space Station and associated flight and ground SSPEs and receive the data required to operate these systems.

c. Contractors will use the system to develop software and verify SSPEs.

d. Payloads will interface with the system, receiving required commands and ancillary data and generating data to be returned to the customer and/or operator.

e. SSPEs, including core systems, facilities, and constellation elements, will interface with the system, receiving required control and generating operating and status data.

f. TMIS will interface with the system, providing program management control and requiring programmatic and technical information.

4.3.3 Operation of the SSIS - How the System Works

The team used SSA to develop the data flow diagram of Figure 4-13. Key definitions for the data flow diagrams are provided, and the major functions of the SSIS identified in the analysis are described in the following paragraphs.

4.3.3.1 Level 0 DFD Definitions. The following definitions will aid in the understanding of the Level 0 Data Flow Diagram:

- Payloads are the customer supplied packages mounted in or on the Space Station. Some payloads will utilize Space Station data processing and/or operator services.

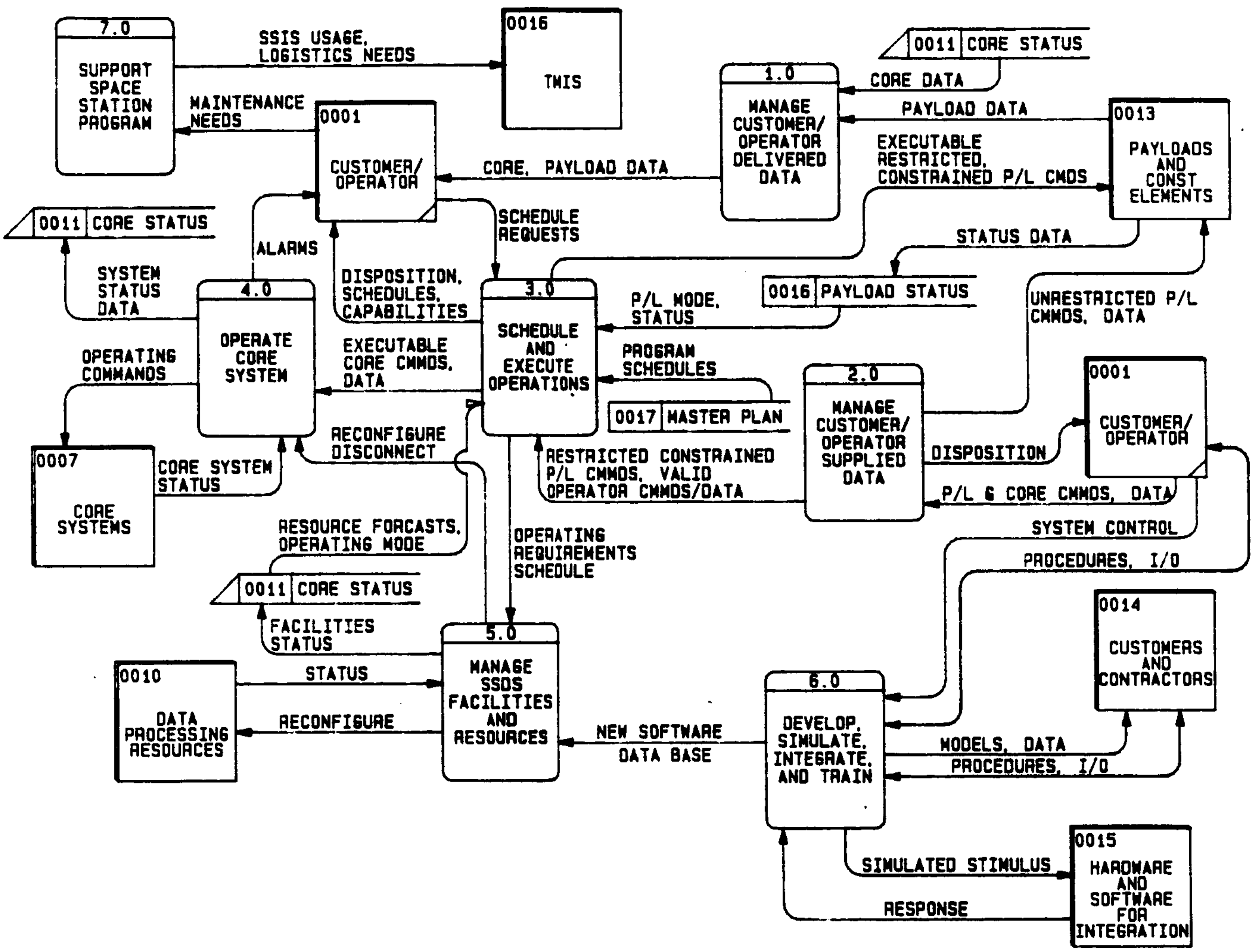


Figure 4-13. SSDS Level 0 DFD

- Constellation Elements include those spacecraft and their payloads flying in the proximity of the Space Station. Most constellation elements will use the Space Station as a communications node. The Space Station will also control the maneuvers of these vehicles.

- Polar and Coorbiting Platforms are unmanned, multimission spacecraft. The Polar platform(s) will operate independent of the Space Station using their own communication links through TDRSS. The coorbiting platform may use the Space Station as a communications node, if it remains in line or sight of the Space Station, or it may operate independently.

- Customers are those utilizing Space Station services, primarily commanding payloads and receiving data. Customers may be either onboard or on the ground.

- Operators are Space Station Program employees, both onboard and on the ground.

- Contractors are designers and developers of Space Station equipment and software.

- Data Processing Resources include the computers, storage devices and networks supporting the SSDS facilities.

- Core Systems are the systems that maintain the environment in which the customers and operators perform their functions.

- TMIS is the Technical and Management Information System. The TMIS supports the SSDS by providing information and coordinating multiprogram resources.

- Core Status is a data store containing the status and monitoring data for all core systems and SSDS facilities.

- Payload Status contains the status and monitoring data for all payloads.

- Master Plan is provided by TMIS and contains program schedules.

- Restricted Commands are those payload and core commands which could endanger the health and safety of the Space Station, or its payloads, and constellation elements.

- Constrained Commands are those payloads which require coordination with other customers and core systems to ensure that customers do not interfere with each other and to coordinate Space Station Systems support of customer requests for services.

- Unrestricted Commands are those that are neither restricted nor constrained.

- Executable Commands are restricted or constrained, but cleared for execution on a specific schedule.

4.3.3.2 Level 0 Data Flow Diagram

Manage Customer/Operator Supplied Data (1.0) - This function receives both real-time and bulk payload and core systems data and transmits these data to the customer's and operators.

Manage Customer/Operator Supplied Data (2.0) - This function receives payload and core commands and data from the customers and operators. Operators will always provide the core commands and data. Both customers and operators may command payloads and enter data destined for the payloads. The function will pass unrestricted payload and core commands and all payload data on to the Space Station, Constellation and platforms and their payloads. Restricted and constrained commands are sent to the Scheduling function to be checked for execution. The customer or operator entering the command is notified of its disposition.

Schedule and Execute Operations (3.0) - This function provides an environment for customers and operators to develop the Space Station, platform, payload, and supporting facility operating schedules. The schedules are developed to maximize the value of payload output within the constraints of SSP resources. The execute operations portion of the function dispatches commands to execute operations according to the schedule. Restricted and constrained commands are checked to determine whether they are executable under the conditions at the requested execution time. Those which are executable are passed on to the payloads or core system. Those not executable are arbitrated with the operator and customers involved and scheduled for execution, if possible.

Operate Core Systems (4.0) - Evaluates and processes core system sensor data and generates system operating commands. Many of these commands are generated autonomously within this process. Commands which can be generated and executed by the process are governed by system operating mode.

Manage Core Facilities (5.0) - Performs any necessary reconfiguration of the facilities. The data processing facilities are notified of scheduled events affecting their operation. Limitations have been taken into consideration as SSP constraints in the scheduling process. The function will also notify Operate Core Systems (4.0) to disconnect operating power from payloads showing evidence of serious malfunction or exceeding prescribed operating power limits. Standby power will not be disconnected unless the Space Station crew's health or safety are endangered.

Develop, Simulate, Integrate and Train (6.0) - This function serves customers, operators and SSP contractors by configuring and executing simulations to

- Develop new software
- Verify and integrate new software
- Verify and integrate new hardware
- Deliver simulation models to customers and contractor facilities
- Train operators to operate the Space Station, platforms, and selected payloads
- Train customers in the use of the system
- Verify end-to-end communications links.

Support Space Station Program (7.0) - This function provides logistic requirements and SSIS resource usage to the TMIS. It also provides maintenance of SSDS facility and payload manuals and procedures, facility spare and repair parts inventory control, and operating configuration management.

4.3.4 End-to-End Command Management and Data Handling/Delivery

These two major, end-to-end functions of the SSDS were selected for further elaboration due to their importance.

4.3.4.1 Command Management. The SSDS command management problem represents a demanding set of requirements unique to the Space Station program. As described in the operations concepts and requirements, there is a desire to meet the following needs:

- The value of the Space Station and platform payload and mission operations should be maximized within constraints of limited resources and safety.

- It should be possible for customers to command their payloads in real time or with stored commands, from space or ground, for non-restricted, and restricted and constrained commands.

- Non-restricted commands should receive no further checking beyond the address of the payload. Ideally, restricted and constrained commands should be allowed in real time also, as long as the customer is operating within the resources and constraints that have been negotiated.

- Autonomy and customer operations and commanding should be supported to the maximum extent possible, with minimum delays and schedule constraints. This implies less reliance than in the past on the use of integrated timelines and schedules which must be developed long in advance for all customer operations.

- Customer privacy should be supported, with commands from some customers being encrypted.

- The personnel operations activity and customer specific development required to perform command management should be minimized.

- Space Station health and safety must be protected, and customers must be inhibited from interfering with each other.

In summary, the steps in implementing the command management data flow to be described in Section 6 (figures 6-3 and 6-4) are:

- The sender is authenticated, and the command and its destination is validated as being authorized for the issuer (customer or operator) for the time the command is sent.

- Data and commands destined for the core system may be subject to checking depending on the authorization of the operator issuing the command (e.g., not all operators will be allowed to issue all commands).

- Customer commands are checked for their classification as restricted, non-restricted, or constrained.

- Non-restricted commands and data other than commands are passed directly to the core or payload with no further checking beyond the address of the destination.

- Restricted and constrained commands receive command management, with conditions for executability of the commands checked by one of several alternative processes.

- Some restricted and constrained commands may be processed for immediate execution, while others are processed for later execution. Those commands accepted for later execution may become not executable before their scheduled time because of unforecasted system or payload status changes.

- Those restricted or constrained commands which can be executed immediately are routed directly to their destination without further delay.

- Those restricted or constrained commands which are entered by the customer for execution at a later time are checked for executability under the conditions scheduled for the time of execution. Commands executable at their scheduled time are held until the time for their release and routed to the payload. Changes to the schedule resulting from equipemnt failure, loss of capability, or preemption by higher priority may cause commands being held for later execution to become not executable. These commands so affected will be treated as any other "not executable" command.

- Commands which are not executable are referred to the customer and/or operator for scheduling.

- Disposition is reported back to the customer or operator at several points:
  - upon acceptance or denial of the command
  - upon scheduling of the command for later execution
  - upon delivery of the command to the customer built-in unit (BIU) port
  - perhaps at intermediate points
- All disposition is reported to the customer/operator entering the command.

- All processing is consistent with customer real-time payload operation from space or ground, except for disposition of not executable commands.

The following discusses some of the options and issues related to meeting the above requirements. Options are classified by each of the following steps:

- Options for the off-line analysis of customer command operations and classification as to whether they are non-restricted, constrained, or restricted.

- Options for the on-line process of classifying a command when it is issued by the customer and received by the SSDS.

- Options for checking restricted and constrained commands to determine whether they are executable.

The final design for command management will be developed in Tasks 2, 3 and 4. Some of the activities for which options will be developed and trade studies conducted are discussed below, together with one or more of the possible options.

First, the customer command operations must be classified as restricted, constrained, or non-restricted. This classification must be done no matter how the command management is implemented.

One option for this classification and command development process involves building a command dictionary as illustrated in Figure 4-4. The dictionary would contain command identification information, "command keys" which initiate execution of the operation, and command restrictions and constraints. (Note that the end-to-end command flow is shown in the data flow diagrams in section 6. Figure 4-14 illustrates the command classification and command dictionary development process which is normally performed offline to support the command management flows.)

The proposed operation is analyzed against 1) a preselected list of Space Station resources which may limit operations (e.g., power), 2) potential interferences with sensitive Space Station systems and payloads, and 3)

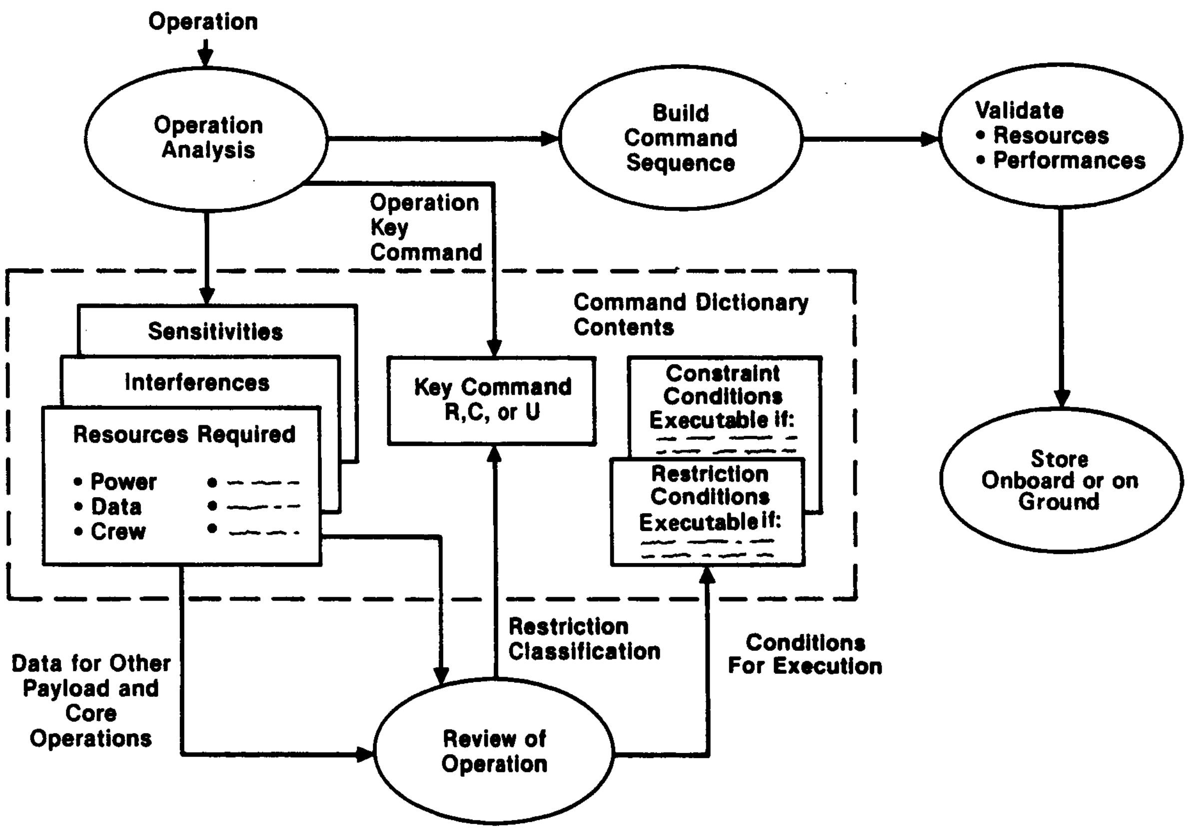


Figure 4-14. Customer Operation Commands Sequence Development

potential sensitivity to interference from projected payload and Space Station operations. The command operation is classified according to restricted, constrained, or non-restricted. If restricted or constrained, the specific conditions for execution are defined.

Customers may use combinations of operations contained in the command dictionary to construct operational sequences for real-time or scheduled control of their payloads. The classification of the set and of the conditions for execution may be carried to higher and lower levels to allow customer flexibility in building commands without repeated review. However, each operational sequence must bear the highest classification of the constituent command sets.

The second area for options development relates the results of the off-line analysis of customer command operations to implementation of the on-line command management functions (see Figure 6-3). There are several options for implementing this command management function. All will likely utilize some form of the command header, and thus some background is needed to explain this concept.

Customer command messages will likely be in the form of "messages" or "packets" (though this need not imply packet switching). Such command packets will have a header (and trailer) which wrap around the customer command, with information to be supplied in a standard format (which is to be determined in this study). This header information must have the destination address (the payload) so that it may be routed over the ground and/or on-board transport networks, but the header may be used for command management as well. For example, the command headler could specify the command classification (restricted, constrained, or non-restricted). In fact, the addressing scheme might itself be used for command classification as noted below.

If this header were customer supplied and not checked, it would imply trusting the customer to not intentionally or unintentionally mis-identify the command (e.g., labeling a constrained command as non-restricted). Checking might also be necessary to prevent customers from sending commands to the wrong payload, or a saboteur from sending commands to a payload. If SSDS supplied, it implies maintenance of a database for all customer commands so that the SSDS can perform the classification, which will require significant effort.

When a customer issues a command (real time or stored), the SSDS must first verify that the command is coming from a valid customer authorized to send commands to the specified payload. The command must then be managed as restricted, constrained, or non-restricted. Two options to performing this management are:

- In one option, the results of the analysis of the customer command operation could be reflected in the command header and the data transport network and affect how commands are routed. Commands with addresses which imply that they are not restricted would be routed directly to the payload -- in effect having their own logical path. Restricted or constrained commands would be routed to intermediate destinations for further checking.

This option implies trusting the customer to identify the command correctly, and also implies an SSDS ability to read and check restricted or constrained commands. However, the command distribution capability (e.g., the data network) would automatically route non-restricted commands in real time, and no separate unrestricted command databases would need to be employed other than the network routing tables. However, the database for reading and resolving restricted and constrained commands may be extensive. Customer payload software could further be required to ignore unresolved, restricted and constrained commands and this would have to be verified in testing.

- Another option would be to require the customer to pre-define concatenated versions of all restricted or constrained commands for use in a command dictionary maintained by SSDS. The customer would issue "command keys". Command keys would have address headers so they could be routed to the right payload. The SSDS would use the command dictionary to check the condition for execution of the commands and accept commands whose requirements are met at the time indicated for execution. Resolution of restricted and constrained commands would be simplified at the expense of an extensive SSDS database maintenance task. Non-restricted commands may be passed directly through to the payload or may be required to be recognizable by the SSDS.

Validated command sequences triggered by the key commands could be stored on the ground or on-board the Space Station, either in the customer's processor or in an SSDS processor utilized by the customer as a standard service. This processor would translate all key commands into the pre-stored sequences. Non-restricted commands would be forwarded directly to the payload, while restricted or constrained commands would be subject to checking conditions for execution. The command dictionary would be required to keep a list of at least all customer restricted and constrained operations and their command keys, as well as information on constraint and restriction conditions.

In both options, a mechanism must be provided to merge or otherwise issue the core commands (e.g., connect power) necessary to implement the payload commands. Knowledge of Space Station and payload status is required at the location where this command management is performed.

The final area for options development is resolution of the commands which exceed constraints or violate restrictions. This condition may result from circumstances such as:

- Customers attempting to operate their equipment in a manner not anticipated in the schedule.
- Station equipment failure or other loss of capability.
- Schedule preemption by a higher priority operation.
- Error conditions.

The SSDS should attempt to resolve these commands. Resolution could be determined by an operator, automatically by the SSDS software, or interactively, with or without customer involvement. An interactive procedure with customer involvement is currently preferred.

If the command cannot be scheduled for execution at a time satisfactory to the customer it must be rejected. The customer must then replan the operation. In order to replan the operation, the customer must be informed of the reasons for rejection, and may require assistance in replanning. The SSDS will be required to supply the reasons for rejection, and the Space Station Program should be prepared to assist in replanning.

One implementation of the command management process is illustrated in Figure 4-15. When a customer or operator enters a command key, the SSDS will perform the following functions:

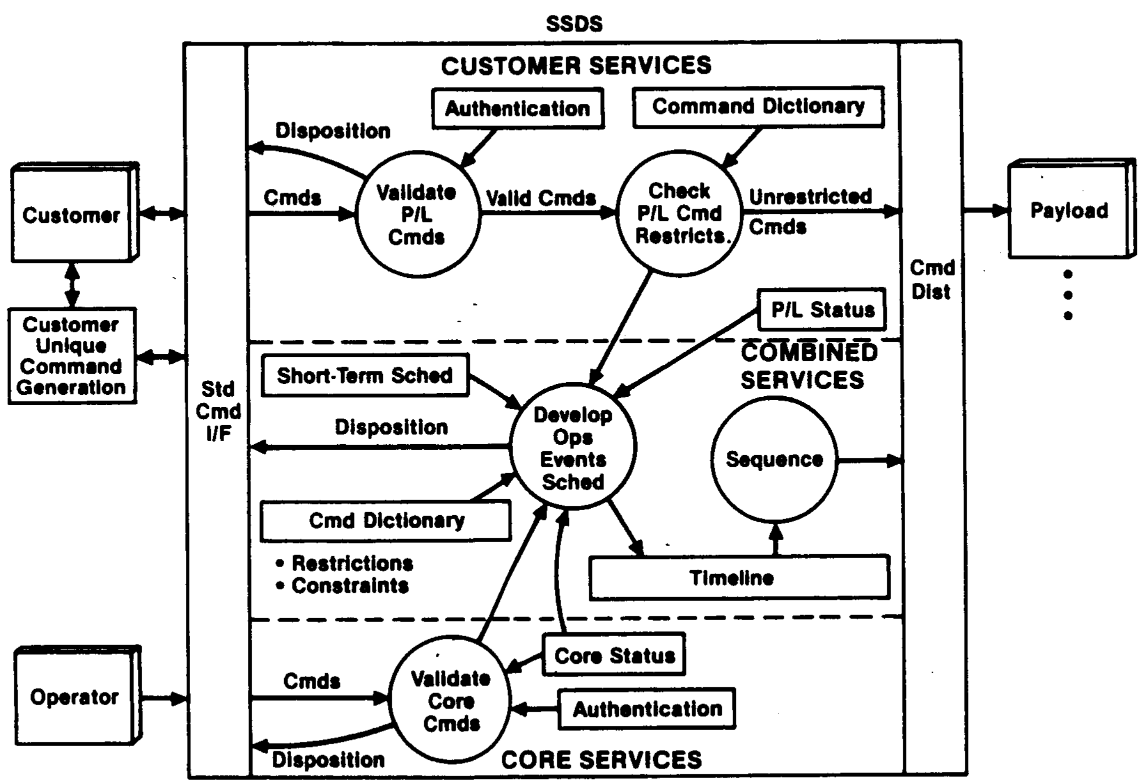


Figure 4-15. End-to-End Command Management

a. Validate P/L commands

- The Customer/Operator is validated as one who is authorized to use the system.

- The address for the input is validated as authorized for the customer or operator.

- Data other than commands destined for the core system, payloads and constellation elements are passed directly to their addressed destination.

b. Check P/L Command Restrictions/Constraints

- Payload commands are checked against the command dictionary and confirmed as restricted, constrained, or non-restricted.

- Non-restricted commands are sent directly to the payload, core system, or constellation elements.

- Restricted and constrained commands are sent to the scheduling process for disposition.

c. Develop Ops Events Schedule

- Disposition is reported back to the customer or operator.

- Conditions for executability of restricted or constrained commands are checked. Those commands which can be executed immediately are passed on to their destination. Other executable commands are time tagged and loaded into the Operating Events Schedule to be delivered at their scheduled time.

- Commands which are not executable are referred to customer and operator for scheduling.

- All disposition is reported to the customer/operator entering the command.

- All processing is consistent with customer real-time payload operation, except disposition of not executable commands.

4.3.4.2 End-to-End Customer Data Handling/Delivery

This second major end-to-end data flow is illustrated in Figure 4-16. The customer payload receives real-time ancillary data from the SSDS and merges the data into the payload data stream. Payload data required by the customer in real-time are designated by the payload for real-time delivery. These data are kept separate from bulk data in order to expedite delivery. Bulk data are accumulated onboard for scheduled, high data rate downlink. Once per orbit downlink of bulk data will accommodate all requests from Reference 3. However, optimum link usage and onboard storage may require other schedules.

The data downlink and distribution is governed by priorities developed interactively among customers and operators.

Downlink data are captured, and delivered to a handling process for standard processing. The data are sorted according to customers, processed to level 0,

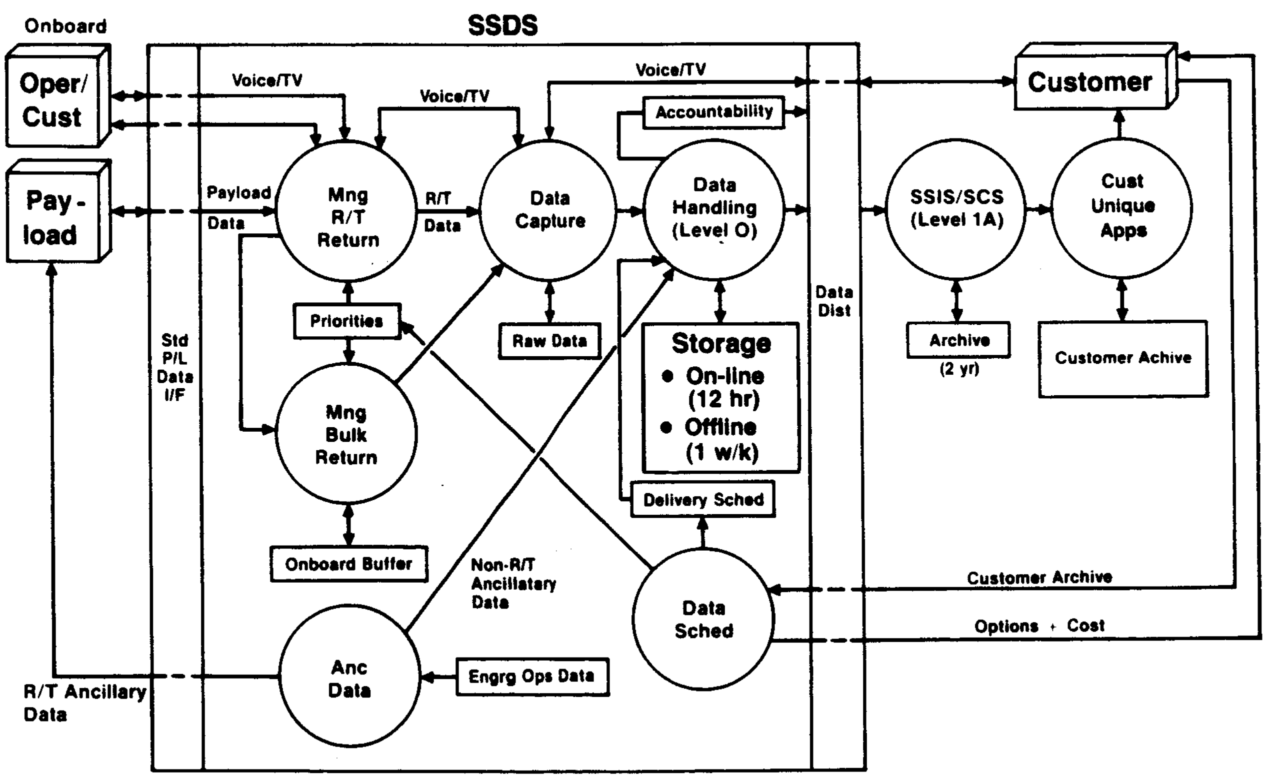


Figure 4-16. End-to-End Customer Data Delivery

and delivered. Online storage is maintained for 12 hours to support quick-look monitoring by the customer and to ensure delivery. Offline storage is maintained for one week after receipt of satisfactory quality data by the customer. Data accounting is provided to the customers, showing the status of all payload data.

Archival storage for up to two years, as well as level 1A processing, are SSIS standard customer services. Additional archival storage and customer unique processing are beyond the scope of the SSIS.

4.4 OPERATIONS CONCEPTS FOR THE SSIS

An operations concept for the SSIS was developed to describe how customers and system operators would use the SSIS in support of their missions. The purpose of this operations concept is to describe the ways in which people will use the SSIS to accomplish all phases and modes of their operation. The operation concept also serves as a preliminary description for potential customers and operators of the way the SSIS works so that they may provide inputs to the system requirements refinement and design.

Two views of SSIS operations are provided; the customer's perspective (paragraph 4.4.1) and the operator's perspective (paragraph 4.4.2). The customer's perspective describes how a Space Station or Platform customer uses the SSIS to plan missions, develop and integrate payloads and support systems, perform mission operations, and acquire and use the mission data. The key goals driving this operations concept have been (1) to provide maximum operational autonomy for the customer, (2) to make the integration of customer systems with the Space Station and Platforms simple, straightforward, and relatively inexpensive, and (3) to provide the customer with a reasonably broad set of options for planning and implementing his Space Station and/or Platform mission(s).

The operator's perspective describes the SSIS operations concept from the viewpoint of the Space Station operations manager. Space Station and Platform resources scheduling, crew scheduling, overall mission integration, core system maintenance, training, and system upgrades are key concerns.

The above perspectives deal with the operation of the Space Station and platforms after IOC and between growth cycles. A buildup scenario has also been provided (paragraph 4.4.3) to identify the capabilities required during buildup and the SSDS functional requirements. Growth cycles are examined in paragraph 4.4.4.

From the above, the operational design drivers are identified (paragraph 4.4.5) to provide guidance to the remainder of the study.

4.4.1 SSIS Life Cycle Operations - Customer Perspective

This section describes a chronological sequence of operations related to the customer. For the purpose of this discussion, a customer is defined as an individual or organization with an objective related to the Space Station Program and has primary responsibility for a payload and for the use and interpretation of data provided by that payload. The customer will receive support from the SSIS to accomplish the mission objectives. Inherent in this description is the philosophy that each customer will differ in the degree and type of services that he will use; customer costs vary accordingly. This concept implies the need to clearly inform the customer of the methodology for getting an experiment on the Space Station or the Platform, and of these optional services and related costs available with each option to support his activities.

Basic to the customer perspective is that most operations are transparent and, with few exceptions, all interfaces standard.

Some of the operations described in this section may become part of the TMIS as its definition becomes firm. Since those portions of the TMIS needed for customer operations are contained within the SSIS, no distinction is made between the SSIS and TMIS in discussing operations from the customer's perspective.

4.4.1.1 Familiarity and Agreements. Many prospective customers will know the Space Station Program well enough to initiate inquiries into becoming a customer and to promote their own missions. However, it is to NASA's interest to agressively seek customers by supplying program information on capabilities and services offered. Workshops, seminars and public releases can be used as information dissemination vehicles. NASA may consider assigning prospective customer relations to a specific organization as an option.

In the age of personal computers, it is desirable that NASA maintain a menu driven, publicly accessible data base that describes the Space Station Program details as selected by the viewer. This will be enhanced to enable an easy transition from the general public to a Space Station Program (SSP) customer. It is envisioned that SSP customers will vary from college graduate students working on theses to highly competitive commercial customers similar to the STS electrophoresis experiments which may yield production of life saving pharmaceuticals. Figure 4-17 is an example of a menu provided to the public simply by dialing an 800 number or some equally inexpensive access. The content of this information and procedural data base will evolve with the Space Station Program.

The NASA will maintain a customer handbook available in either printed form or by electronic transmission. This handbook would be available in different levels of detail depending on the customers level of interest and negotiation. The sincere customer will obtain a thorough description of the services that could be provided as well as the actions expected of a customer. Example topics covered will include:

- Space Station Program general description
- Management procedures
- Available resources
- User interface
- Scheduling
- Security
- Space platforms
- Space Station Attached facilities
- Space Station Laboratory Facilities
- Crew services
- Flight preparation
- Launch and landing operation
- Orbital operations

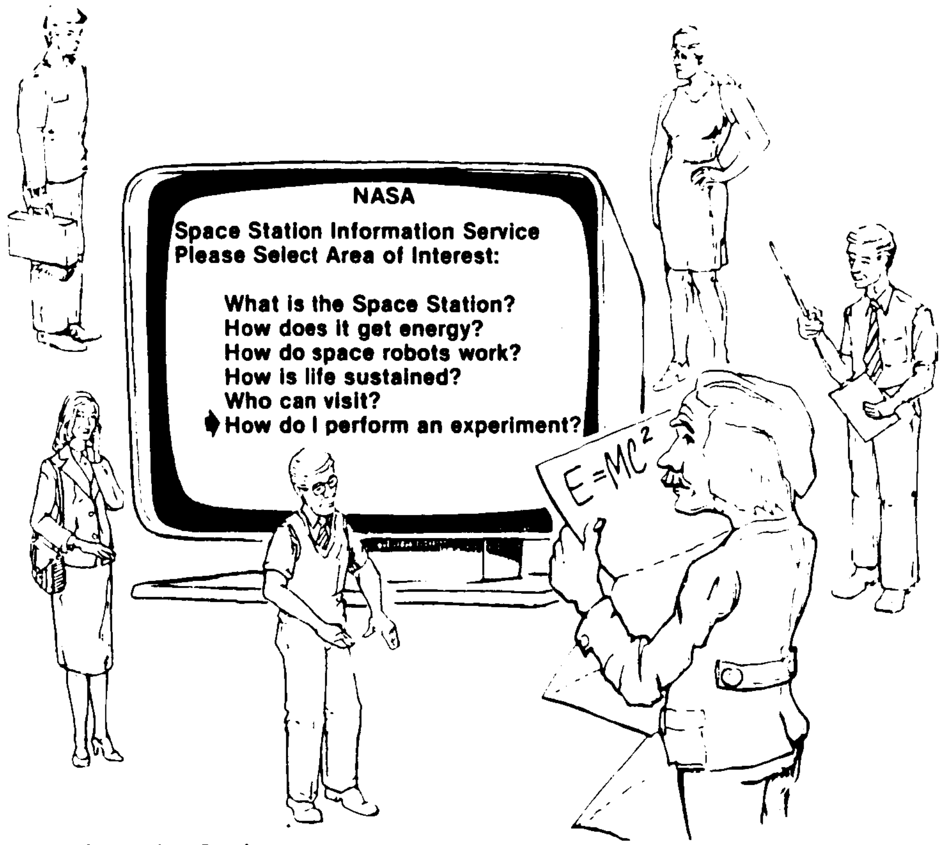


Figure 4-17. Space Station Information Service

- Customer responsibilities
- Cost estimating procedures and data base.
- Current & Projected Nonproprietary Payloads & Missions

This handbook would be supplemented by meetings with cognizant NASA personnel as well as workshops.

Historically the programmatics of having an experiment accepted on a NASA program involves lengthy, time engaging, very formal interface meetings and a mountain of paper. To a large extent, this process will be codified and reduced to an interactive dialog through terminals. This trend is exemplified in Figure 4-18.

One electronic process would be explanation of available, measurable resources and services versus cost; it would be a NASA policy decision to provide a schedule of cost. Figure 4-19 shows examples of measurable items.

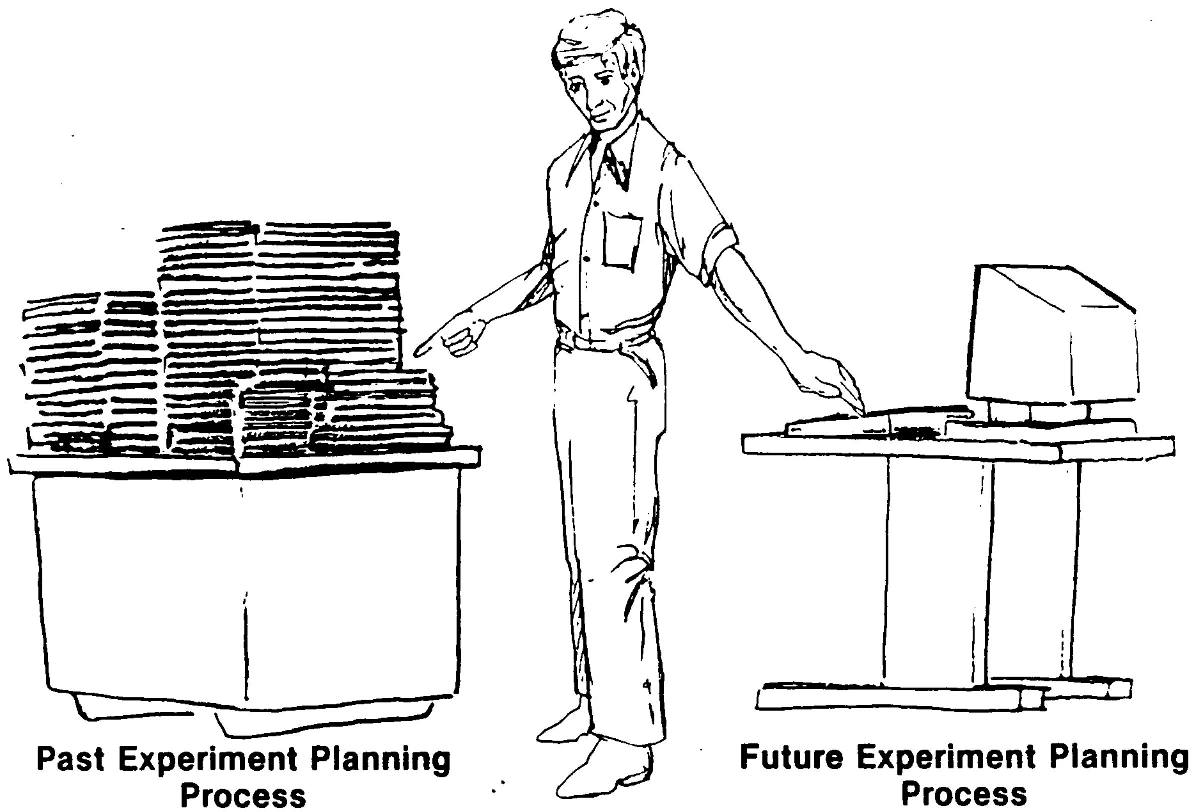


Figure 4-18. Trends in Experiment Planning

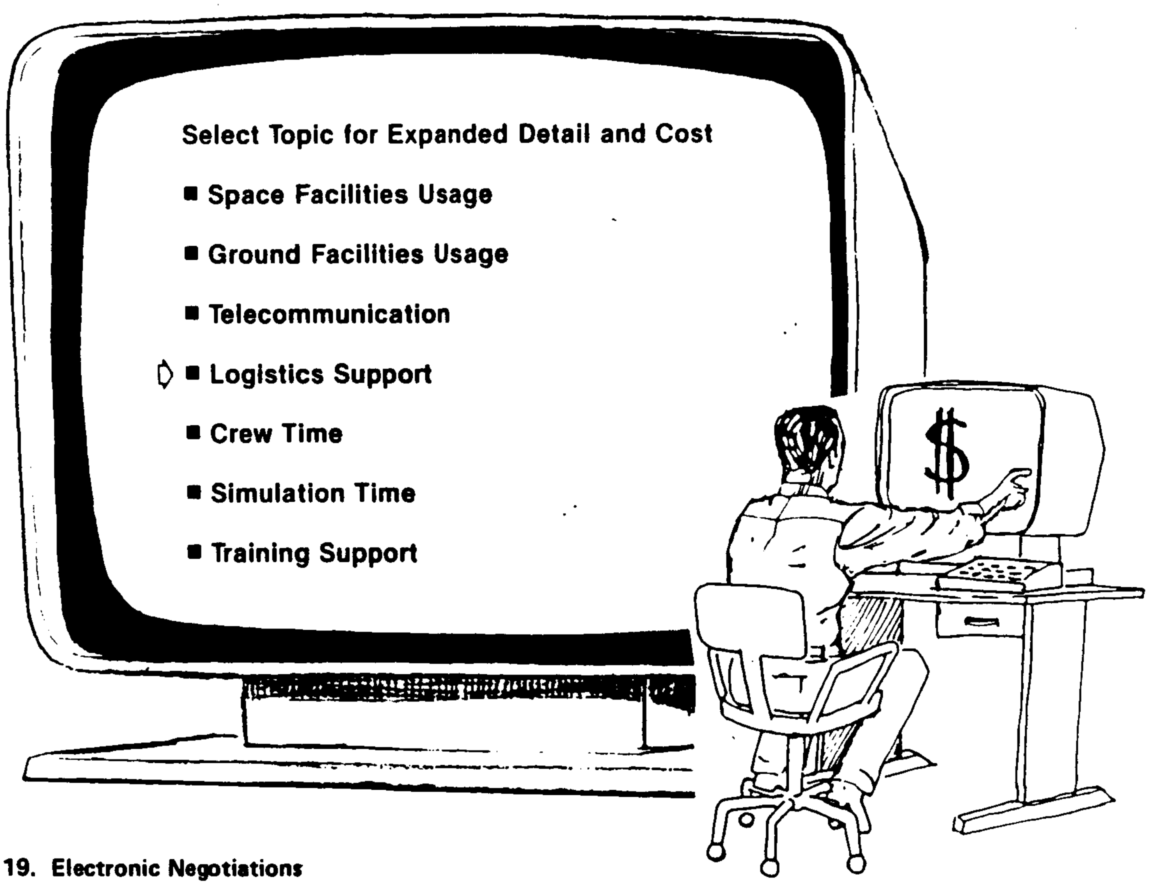


Figure 4-19. Electronic Negotiations

Other measureables include:

- Integration and training
- Storage by duration and media type
- Communication links and local bus bandwidth
- Priority servicing
- Launch and deorbit (by weight and volume)
- Power
- Operator time
- Special facilities.
- Security/privacy

Given detailed knowledge of the Space Station Program and costs of service from either an electronic data base or a written handbook, the potential customer can then prepare and submit a proposal to NASA. The customer's proposal could be prepared electronically by providing responses to a standard set of queries.

Successful review and subsequent negotiations would necessarily be performed in face-to-face meetings; each customer would then enter into a contractual agreement with NASA which specifically describes the services to be provided and the associated costs. In many cases, these costs would represent fund transfers between NASA offices or reimbursable funds between other government agencies and NASA. The extent that these procedures can be made uniform will aid in the development of a commercial customer base.

4.4.1.2 Long Term Planning. A traditional source of consternation between an experimenter and the Program Office is the lack of synchronization between their respective schedules. For example, experimenters must realize that a high fidelity simulation of a major payload requires precise definition of all interfaces as much as a year prior to the simulation.

An explicit planning process would synchronize deliverables by all parties. This process would be accessible from interactive terminals. The planning system would be sufficiently programmed to prompt for delinquent entries or inadequate responses. This intelligence would include the ability to suggest adequate work-around during contingencies. Figure 4-20 gives examples of issues to be addressed by long-term planning.

The consequence of interactive sessions associated with this long-term planning process would be the definition of specific dates agreeable to both parties for milestones associated with the activities typified in Figure 4-20. Naturally this procedure would be interactive and, when required, supplemented with face-to-face negotiations. However, the long-term planning process could easily be designed to provide prompting comments to either party that would indicate, among other things, time to fulfillment of the next milestone and the status of past milestones fulfillment.

A major function during this phase will be customer familiarization with the required standards. In addition, contingency management planning would be initiated in order to establish respective roles in the event of payload malfunction. This planning would continue to be updated as the project progresses, perhaps even supported by a customer failure modes and effects analysis.

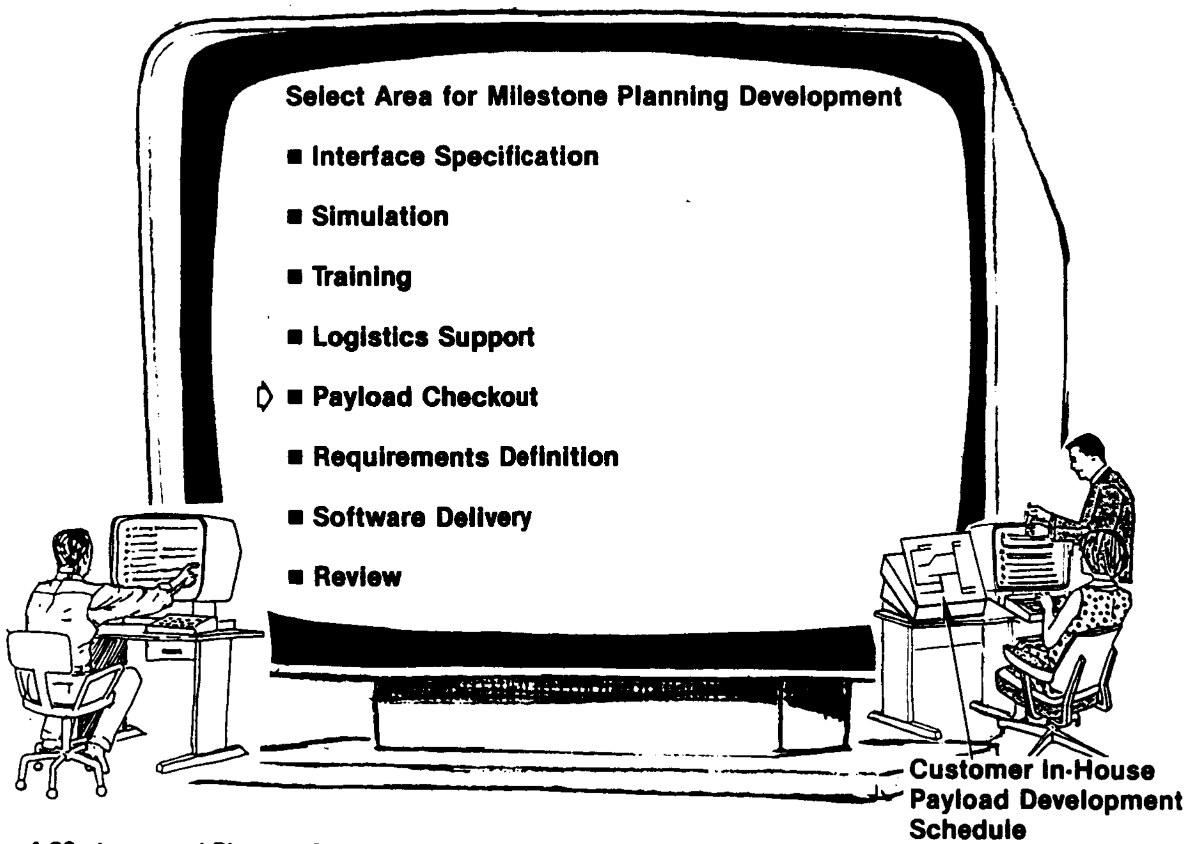


Figure 4-20. Integrated Planning Process

4.4.1.3 Development and Training. As development progresses, details, specifically Interface Control Documents (ICDs) must be agreed upon. In general, standards will exist. Even so, each customer will have certain options and related design decisions such as:

- Encryption/decryption
- Higher level protocols
- Data capture parameters
- Display page definitions
- Processing algorithms
- Command philosophy
- Command specifications
- Telemetry measureables
- Operational constraints
- Standard core services.

The standard core services requested by the customer will include avionics support (orbit and attitude determination), core resources monitoring (power, core data and communications services, ECLSS usage (on Space Station), sensor monitoring, etc.), configuration management, generic resource scheduling, etc.

Payload operations could be simulated on NASA premises or through telecommunication from NASA to customer premises. NASA supported simulation would include mechanical, electrical, logical, and format test for compatibility with the Space Station or Platform data system.

Higher fidelity simulations may be required for payload operations which have complex interfaces to the Space Station or Platform Systems and/or which impose risk on the health and safety of the Space Station/Platform. In these cases, their operation cannot be made autonomous, and coordinated operational scenarios will be required.

Dependent upon the nature of the payload and the fidelity of the simulation chosen by the customer or required for Space Station or NSTS crew training, the customer will have to provide varying amounts of information, characterizing the payload. Figure 4-21 gives example items.

C-2

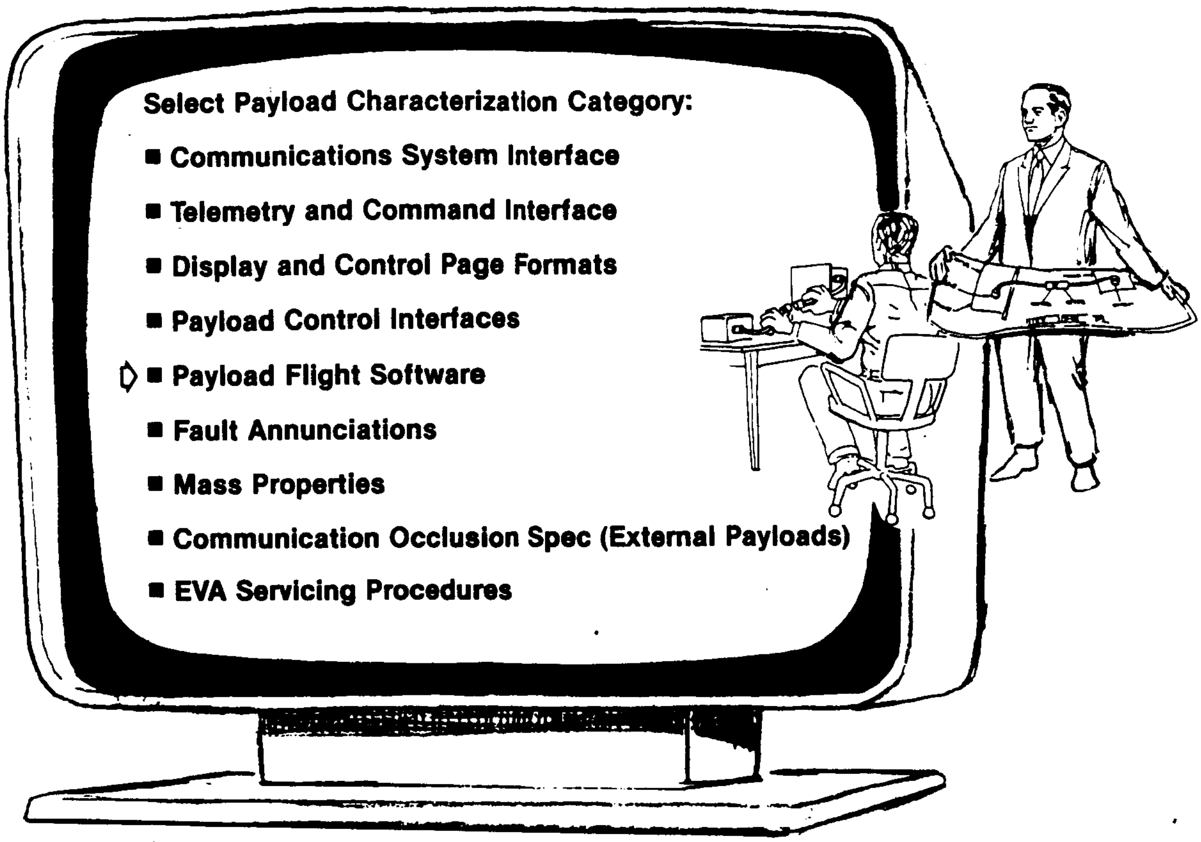


Figure 4-21. Payload Definition Requirements

Definition of other payload characteristics may include:

- Payload design documentation
- Workstation/payload interfacing software (for Space Station operation)
- Payload models
- Malfunction and anomaly procedures
- Environmental contamination -- outputs and sensitivities
- Power and thermal requirements
- Fluid dynamics
- Graphics information; information required for visual modeling
- Berthed payload dynamics (includes RMS-type operations)
- Payload retention and deployment specifications
- Payload tracking (deployed and co-orbiting payloads)
- Carrier (OMV and OTV)/payload interface specifications and switchover procedures for deployment (e.g., hardwire to Space Station vs. RF link tracking, telemetry, and command interfaces)

To ensure that the customer's payload can be integrated into the Space Station or Platform in a straightforward manner, and in order to ensure data availability, the customer will have to provide information for simulations. This information will vary in detail depending on the complexity of payload operations and required coordination with Space Station or Platform systems. Discussions will probably begin several years before the detailed simulation is required. Initially, only general instrument parameters will be required. These will then be refined up to the time that the complete simulations is available. At this time customer provided models, or an actual payload simulator developed by the customer will be used for simulations and training on complex payload operations.

Training would be mostly applicable when a Customer Mission Specialist (CMS) is required. If the Mission Specialist is trained by NASA, this training could include all adjustments, installation, tear down and rebuild with any or all specific parts of the customer's payload. Further, a ground operator instructor could be co-trained by means of closed circuit television with appropriate time delay.

Other typical training choices for the customer include:

- SSPE training -- OMV and OTV (for co-orbiting platforms), platform operations, etc. or subsystems which are subject to customer interaction.
- Instrument control -- cameras, thematic mappers, multi-spectral scanners, telescopes, sensor pointing.
- Platform Operations control center capabilities, interfaces, and operating procedures.
- POCC operations training for customers purchasing POCC services.
- Services training -- TMIS (or its equivalent for customers), scheduling services.
- Voice communication protocol

- Archival data retrieval and analysis.
- Space Station and Program capabilities and operations.

It should be noted that no science or payload training will be available on the Space Station Program. Thus, such training, as is required may be minimized in customer ground facilities.

4.4.1.4 Launch Support and Payload Integration. The customer will be actively involved in all integration and in all of the integration and test phases of his payload. This section discusses the program support provided to the customer during predelivery testing, launch support, transport to orbit, and during final integration and test onboard the Space Station or Platform.

Predelivery testing would principally consist of some levels of simulation, as discussed in Section 4.4.1.3. The level of complexity of this testing will vary from customer to customer. Tests could be as simple as a mere physical and functional electrical verification up through a rather complex, high fidelity simulation. The location of these tests would, in turn, also vary depending on complexity; they could be performed at the customer's facility or at a NASA facility.

Launch support would include a variety of customer support operations such as calibration, flight readiness checkout, environmental control, interface verification, and other functions that could be performed prior to launch. These functions that would be so tested are dependent on the type of payload.

The final integration and test of the payload would then be performed by the crew or the CMS possibly in conjunction with the ground based customers. The Mission Specialists will need to perform instrument checks, operational checks, and data handling checks. These might include:

Instrument Checks

Damage Inspection
Alignment and clearance checks
Pressure test

Power connection checks
Basic start-up test (a go, no-go type assessment)
Thermal checks

Operation Checks

Functional Checks
Communication interface checks
Temperature
Cleanliness
Humidity compatibilities
Safety constraints (hazardous material handling, etc.)
Emergency procedures
Maintenance procedures

Data Handling Checks

Instrument calibration and baseline operational checks
Data capture
Data reduction algorithm verification
End-to-end data transmission and verification test
Software and data hardware verification
Command verification

The customer-developed test and verification procedures will be performed for assurance that the customer apparatus is performing properly, that no unexpected interface problems have occurred, that no transit damage has resulted during the launch and transport to the spacecraft, and that the crew or CMS has set up the payload to operate as expected. This procedure execution phase is shown in Figure 4-22.

4.4.1.5 Operations Phase.

4.4.1.5.1 Status. Customers could maintain knowledge of the current Space Station operation by means of remote terminals. Information obtained would include that shown in Figure 4-23.

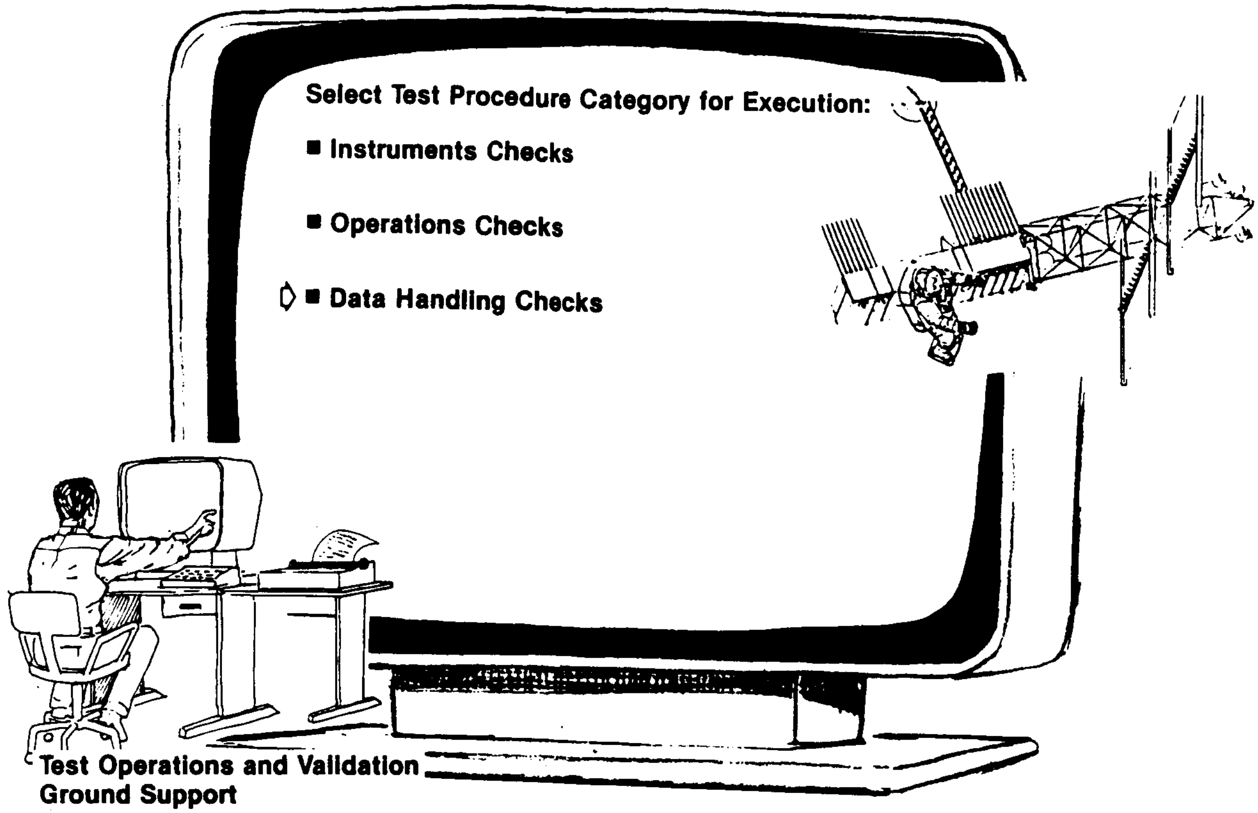


Figure 4-22. On-Orbit Test and Validation

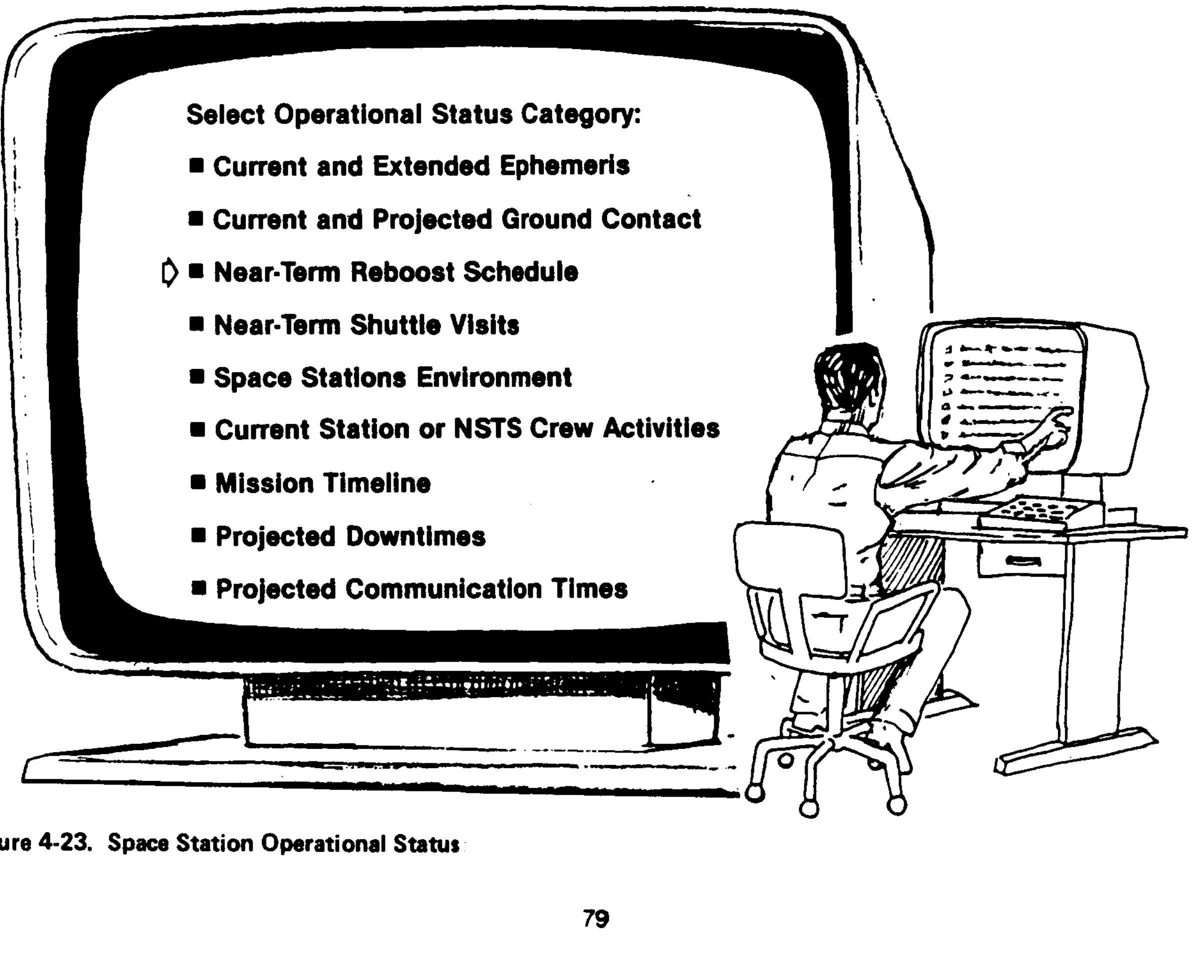


Figure 4-23. Space Station Operational Status

As protected by an access code, the customer would also be able to obtain specific status information relative to his payload operations such as:

Current operating schedule

Projected operating schedule, especially where required resources may be impacted

Current health and safety

Logistics status (consumer resupply schedule)

Archival data status (location, amount, accessibility)

Maintenance schedule

Status of payload instrument interfaces.

4.4.1.5.2 Scheduling. In the context of this section, scheduling refers to the prearranged timeline execution of payload commands in context with operational status. This is in contrast to the planning function which takes place over a period of time prior to command execution. Scheduling which takes place closer to the time of execution frequently involves conflict resolution between requests for limited Space Station or Platform resources. The scheduling function must take into account changing priorities and payload compliment.

Principal Investigators or Payload Managers clearly prefer that their payload schedules be autonomous; certain payload operations, unfortunately, result in potential conflicts between payloads and between any given payload and the Space Station or Platform operations. Therefore, scheduling must consider the interrelationships between these elements. Constrained and restricted commands will be subject to scheduling and timetagging based on numerous criteria such as the Space Station or Platform attitude, orbital position, interaction between payloads, etc. Unrestricted commands may bypass the scheduling function of the customer's discretion, and be delivered directly to the payload.

There may be more payloads on board the Space Station than can be operated at their maximum desired duty cycle because of limited resources. Principal Investigators will need to interact with the scheduling function to help optimize the output of their payloads within the constraints imposed by the limiting resources.

Outside events, such as emergencies or even transient observational events may dictate the desire for short-term schedule modification. The Space Station Program must support different time levels of schedule change as, for example, monthly inputs (astrophysics), daily inputs (earth observations), hourly changes (atmospheric observations). In all cases the SSDS must support short term schedule revisions down to the last minute to accommodate changes in observations and targets of opportunity.

4.4.1.5.3 Payload Control. Customer control over payloads will be exercised primarily through commands; commands may be entered either from the customer facility, the Payload Operational Control Center, from the Space Station (includes the co-orbiting platform), or from commands stored or generated by the payload.

Figure 4-24 illustrates the SSIS top level role in payload operations of which payload control is one. Not shown here is the aspect that many customer commands are not subject to scheduling and pass unrestricted directly to the payload, while others will be checked prior to transmission to the payload.

During the development stage, the customer will provide NASA with a list of expected commands and associated results from these commands; this list will be updated through operations. All commands will be categorized by the Space Station Program according to whether they are unrestricted, constrained, or restricted. Unrestricted commands may be exercised by the customer at any time without review by the SSP, subject to the limitation that such conditions as emergencies or safing modes could prevent the delivery of unrestricted commands. Typical unrestricted commands might include:

- Iris adjustments
- Filter wheel location
- Change in focal length

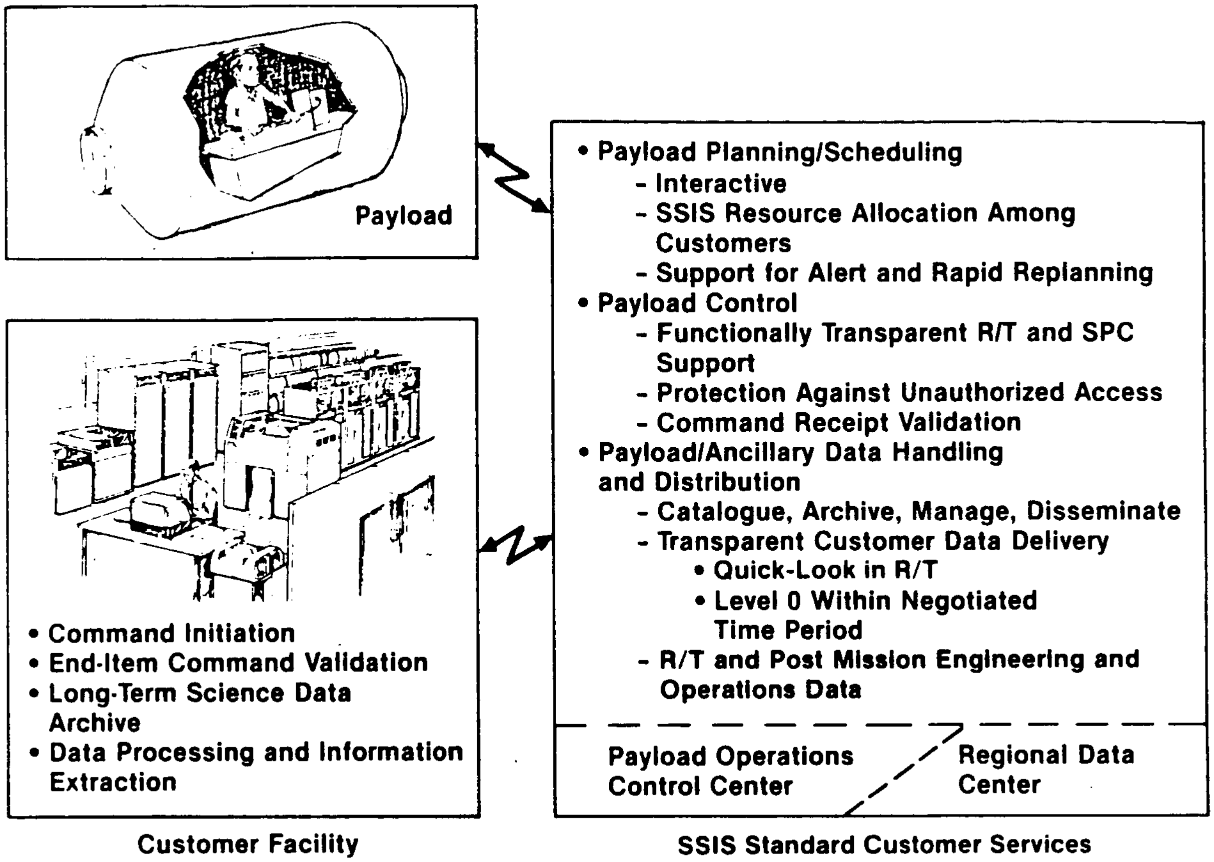


Figure 4-24. Payload Operations

- Contained gas flow rate
- Request for video information
- Shutoff of equipment (no large power surge)
- Temperature sensing.

Restricted commands are, by definition, those commands that might involve the health and safety of the Space Station or Platform or any habitable portion of the Space Station. Typical restrictive commands might be:

- Power on (significant power surge)
- Attitude related maneuvers
- Toxic material control
- Spacecraft data base modifications
- Pyrotechnic initiation
- Component rotation
- EVA navigational control.

Constrained commands are, by definition, those commands that may affect other payloads and/or commands that require certain Space Station or platform support requiring associated engineering commands. The list of constrained commands will vary in time due to a changing payload manifest and an evolving spacecraft configuration. Typical constrained commands which may affect other payloads are:

- Gas emission
- Electromagnetic wave generation
- Demand for spacecraft resources
- Communications demands
- Large thermal changes.

Typical of the payload commands affecting the spacecraft might be:

- Observations requiring large scale attitude maneuvers
- Power bus reconfiguration
- Module atmosphere pressure changes

Stored program commands can fall into any of the above categories. In general, the customer will have unencumbered control of software embedded in a payload. However, restricted and constrained commands must be checked for execution.

One basic requirement of the SSDS is that the customer be granted privacy of command and data. Privacy of the command channel can be effected by ensuring adequate authentication of the customer identification code prior to transmission and permitting encryption. Similarly, the customer's command data base and the nature, type and results of his commands must be protected by adequate code words. In addition, the NASA will design to ensure that a customer command sequence cannot be encroached upon. Security, however, shall be the responsibility of the customer, as for example, by providing his own encryption/decryption devices as desired.

In addition to digital commands, the customer may exercise a command process through either audio and/or video communication with Mission Specialists.

Again, during such operations, these links can be kept private. For certain operations including the co-orbiting platform and/or the Orbital Maneuvering Vehicle (OMV), the customer could be permitted, within the limits of safety to control selected operations by direct interaction. This would require the customer's presence at the appropriate control center.

The customer may incorporate validation into the payload command, either by telemetry measurables or by end-item verification. In addition, the customer may request the SSDS to provide status throughout the command process, e.g., RF lockon, command receipt, and command transfer to the payload. The Space Station Program may also provide full duplex verification of command delivery to ensure no undetected transmission errors.

4.4.1.5.4 Customer Data. The customer may receive data at several locations:

- Space Station (for customer Mission Specialists)
- Orbiter
- POCC
- Discipline-oriented regional center
- Customer premises.

Data may come from several sources: Payload (real time and delayed), ancillary (real time and delayed), payload archives and engineering/core archives. The data may be transmitted through TDRSS, or by alternative means supplied by the customer.

Operational aspects of SSIS support for data flow to the customer are shown in Figure 4-24.

With the exception of data received at the Space Station or NSTS, real time data will actually be subject to a variety of delays; these delays will not necessarily be constant for any given customer or type of data. The transmission delay is predictable but may vary for any given task. Even though dedicated TDRSS links may be used, transmission and buffering delays will still occur. It is, as yet, uncertain whether there will be competition for TDRSS links among the Space Station, POP(s) and the COP. To the extent that channels are shares, real time data will be restricted. Given the high data rates now projected for some payloads, further buffering may be necessary at TDRSS White Sands recieving station in order to match the rate of incoming data with the available link capacity leaving White Sands. If the data are to be distributed from a POCC to the customer's premises, then further buffering is likely, in order to accommodate POCC to customers data link rates. Under the foregoing conditions, it appears that there are major potential differences in system impact between data delivery with only transmission delays and data delivery with relatively short delays resulting from in transit buffering. Although operations with the SSDS and even the SSIS should be transparent to the customer, significant data delays are likely to occur unless a single access (SA) link has been scheduled. A design driver will be the requirement to minimize these delays and restrictions for the delivery of payload and engineering/ancillary data for real-time operations.

Data received at any site from any source may be processed at a variety of levels. Data will be provided by the SSDS as raw data or at Level 0 at the customer option, or at level 1A by the SSIS with processing performed at the customer's option. At the Space Station and POCC sites the customer can perform routine analyses on his data using SSIS standard customer services and can perform quick look and routine analyses using SSIS facilities and his own software resources.

One example of customer processing above Level 0 is quick-look data processing. The SSDS will provide the customer any selected Level 0 data from his payload data stream to allow for quick-look processing in space, at a POCC, or at the customer's premises. This data will include the necessary ancillary data to support the processing to the desired level.

Required ancillary data will be selected by the customer during the development phase. These data will be provided to the customer coincident with his relevant data. Examples of ancillary data are:

Time
Configuration changes
Attitude
Orbit position
Water dump status.

Pointing/orientation
Power flux/usage
EMI map of station
Thruster firings
Internal pressure
Atmosphere composition
Relative humidity
Radioactivity exposure
Chemical contaminants
Optical environment contaminants
Crew/operations activity
Accelerometer data
OMV berthings/status
EVA activity
Internal temperature
External temperature
Particulate count
Particulate types.

The SSDS also provides the customer with the capability to request ancillary data not on his original list. In this case, the data would be retrieved from the core data base, whether in space or on the ground. The customer may also retrieve data from the core engineering archived data base during its retention time of at least two years.

The customer's ability to process data shall be protected by several mechanisms. To begin with, the customer shall have the option to peruse quick-look data at the level he selects. Further, upon receipt of customer data, should anomalies become apparent, the customer may request repeat transmission of data from an SSDS archive for up to 12 hours. Further, this same capability exists for data up to one week of relative age with a slightly greater time lag for delivery. All of this data will contain a priori designated ancillary data. Should the customer desire engineering or ancillary data other than a priori designated ancillary data of one week in relative age, it may be obtained from short-term archives. Such data would also be available for a period of up to 2 years from longer term archives.

The customer shall be able to either restrict or authorize access to payload data. A standard level of SSDS data privacy will be available to the customer. In addition, the customer may elect to implement his own higher level of security.

4.4.1.5.5 Teleconferencing. Customers may elect video and/or voice teleconferencing among several sites on earth and the Space Station and NSTS. This teleconferencing capability may be required when missions involve different experimenters located at different sites or where experts are available at different sites.

Video teleconferencing would be possible between NASA facilities and the Space Station and NSTS using NASA's private telecommunication networks currently under development (e.g., NASCOM, Program Support Communication Network) and a link to space through White Sands. Optionally customers may tie into the video conferencing network by leasing transmission facilities which interconnect with the NASA facilities. The number of customers allowed this type of direct connection will be severely limited. Further, this type of function is limited to standard physical (transmission) and logical (compression algorithms) interfaces. Such customers must also provide their own equipment.

Customers will arrange a video conference in advance by calling a central NASA point of contact. Since the conference resources are shared among many customers, and might be shared with Space Station core operations, delay may vary depending upon the degree of contention. It is likely that only one duplex, two party conference may be in progress at any given time. However, many parties may have "monitor only" capability.

To schedule a conference, each customer must specify the time, date, duration and the location of the "chairman" in control of the conference proceedings. The "chairman location" must be at a NASA facility.

Each conference will be in "near" full motion as NASA's networks employ video compression down to 1.544 Mbps; the customer will notice some degree of degradation.

The transmission among the NASA facilities (including the Space Station) will be encrypted (in response to the general requirement placed by Presidential Directive on all such transmission). However, encryption to the customer premises is the responsibility of the customer.

Voice teleconferencing, in contrast to video teleconferencing, may be arranged on relatively short notice. Customers will see few delays in scheduling. Urgent requests, particularly in support of an active mission, may be scheduled on the same day.

Voice teleconferencing may be implemented through existing NASA facilities with a link to the Space Station through White Sands. However customers can tie into the conferencing network by leasing transmission facilities which interconnect with NASA facilities. Customers who do so must provide their own equipment. Conferees may also be added using "dial-up" connections over the telephone network, though the customer will likely see severe degradation of quality in this case. Orbiter teleconferencing capabilities for Polar Platform missions are described in SG07700. Capabilities can be scheduled through the Platform Operations Control Center.

Privacy for all links may be provided by virtue of having point-to-point transmission facilities. This privacy will apply to the Space Station by providing an appropriate receiver.

4.4.1.5.6 Customer Mission Specialist (CMS). Some customers may desire that their own Mission Specialist perform their payload on-orbit operations, as was the case with the recent electrophoresis experiment where MDAC supplied a CMS as part of the NSTS crew. Feedback from these experiences are providing valuable data as to how the SSIS can better serve customer provided CMS personnel. The Customer Mission Specialist will operate under the authority of the Station Director or NSTS commander, as appropriate, and will perform associated payload operations and housekeeping tasks.

Two aspects of the SSIS functions to support this level of customer participation are the need for high fidelity simulations, and the need to provide a flexible and efficient near-term scheduling environment allowing a high degree of autonomy for onboard crew personnel. This aspect is also addressed in the operator's view of this operating concept. Other items, one of which is standard service requirements, are: ready access to a ground data base with pertinent experiment and systems data; point-to-point audio and high resolution video; and real-time access onboard to Space Station engineering and payload data.

NASA documentation will be provided that describes the requirements for selection and qualification of these Mission Specialists. Given selection, Customer Mission Specialists will receive training on general Space Station operations for approximately two to three months. Examples of training areas include:

- Zero-g orientation
- Habitability equipment and procedures
- Activity planning
- Communications procedures
- Emergency and safety procedures
- Exercise and health maintenance routines
- Housekeeping
- Information and data management system.

Naturally, the CMS would prove useful in the event of a contingency involving the customer's payload by providing fault isolation support, limited repair and modification and part replacement.

4.4.1.6 Post Mission Operations.

The customer may receive some services after mission completion. This would include return of the payload, availability of archived data and data based files, analysis of space affects on the physical payload, and analysis of the payload data. The analyses, both scientific and engineering, would be based on NASA's experience and would include correlation of spacecraft operations and status with the particular payload operations involved. Engineering data will be archived by the Space Station Program for at least two years. Customers can negotiate for longer term storage of engineering data as well as long term storage of payload data. The customer will have knowledge, by means of an interactive terminal, of the contents of all archived data and the means to retrieve it with the exception of data that is protected for privacy purposes. In this regard, any customer may designate the level of privacy associated with the data, and through mutual agreement, allow other persons access to the data. Again, the level of post-mission support would be cost-dependent.

4.4.2 Operator's Perspective of SSIS Operations

SSIS operation is described in this section from the perspective of ground and onboard Space Station Program (SSP) operators. Operator is defined as either NASA or contractor personnel who manage, coordinate, and effect SSP operations and assist customers in accomplishing mission objectives. The operator's perspective is described through a set of operator tasks. These tasks range from system development to real-time operations. Section 5 provides additional information.

Figure 4-25 provides an overview of operator's perspective discussed herein.

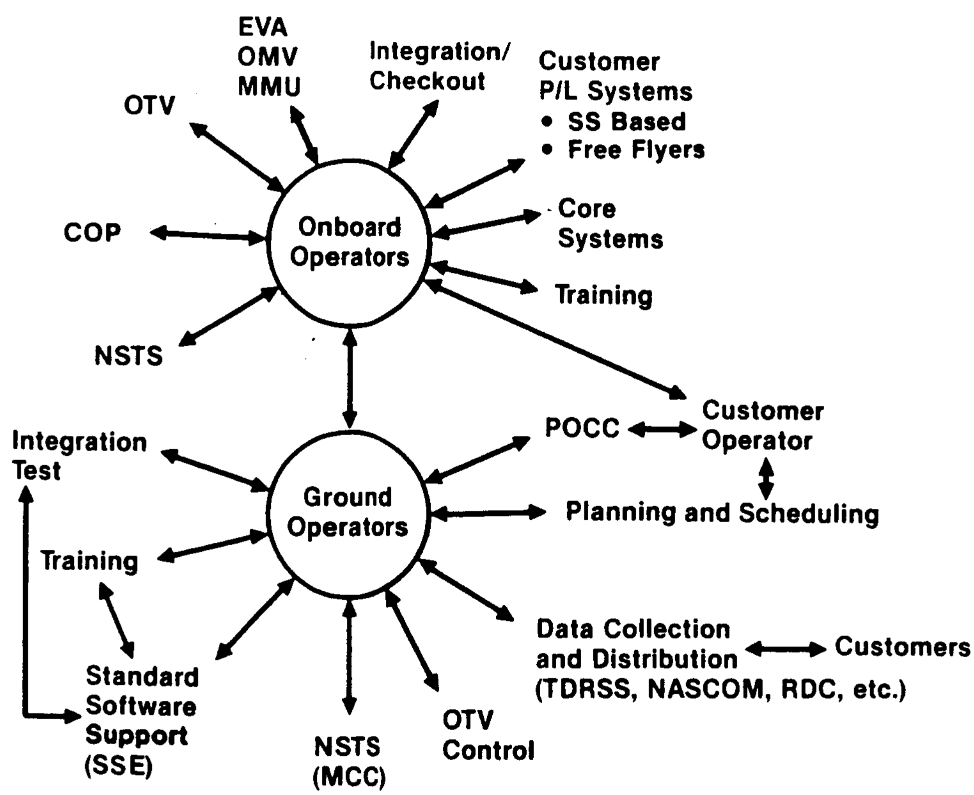


Figure 4-25. Overview of Operator's Perspective

4.4.2.1 Operator Background. Before the individual operator tasks are presented, the assumptions made for the operators' perspectives and a description of generic material that applies to all the operators is presented. These descriptions provide background material that may apply to one or more of the operator tasks and can influence the operator perspective.

The generic material provides viewpoints or perspectives of what an operator should know about these subjects. None of the descriptions are specific tasks but concepts that influence operators' perspectives. This information enables the operator to understand the overall ground or onboard operational environment and/or scope of responsibility. At times, these descriptions touch on customer perspectives to give a clearer picture of the operator environment. The five areas cover

1. Automation
2. Work stations
3. Redundancy/failure management
4. Privacy/security
5. Standardization/commonality.

The fifteen operator tasks are

1. Hardware maintenance
2. Software development and maintenance
3. OMV, OTV, MMU, COP, and free-flyer control
4. Docking/berthing
5. EVA
6. Avionics management
7. Non-avionics core system management
8. Logistics
9. Unmanned operations
10. Safe-haven/contingency
11. Facilities management
12. Training and simulation
13. Planning/scheduling
14. Onboard mission support
15. Customer coordination

4.4.2.2 Assumptions for Operator's Perspective

The following assumptions augment those of Section 4.1 for the descriptions in 4.4.2.

- Operator data provided by standard communication services
- Spacecraft hardware maintenance is primarily replacement.
- COP is serviced from the Space Station
- POP is serviced from the NSTS
- Prime software development languages for the SSP will be a minimum set of standard High Order Languages (HOL's). Included will be a
    - "User Interface Language" for commands, displays, system test.
- Space Station controls all operations within its control zone.
- Constellation Operations:
    - Station remote manipulator for berthing/docking, deployment, station servicing.
    - OMV can grapple, maneuver OTV, COP, free-flyers
    - EVA's for COP, OMV, free-flyer servicing
- SSCC provides global interfacility coordination
- COP and POP control centers control platform operation
- Planning and scheduling integrates core and customer requirements; all data/plans for flight and flight support operators contained in flight data file.

4.4.2.3 Generic Concepts. The six generic support considerations and concepts described in this section apply to all of the specific tasks performed by the operators.

4.4.2.3.1 Automation. The first viewpoint of any operator is to ask: what job or role must I fulfill? One major factor impacting the answer is the degree of automation of the system that will support the operator. The spectrum of automation ranges from a labor intensive, step-by-step manual control to attending to a system only when alerted by the system of a problem or need for interaction. The operator does not have to monitor a display unless there is a specific reason. Casual monitoring is possible but not required. Certain safety aspects may require close-at-hand monitoring for specific operations to reduce the time for manual takeover, but this is a planned event.

Table 4-5 presents a view of core and customer weekly manpower derived from data in the Phase B RFP (reference 1). The data shows the limited number of hours available per week for all operation activities, particularly for core operations. These data clearly show a limitation of onboard operator time availability. The automation and autonomy trade studies must consider this limitation for the autonomous, non-automated Space Station option in addition to other factors such as cost effectiveness and total program cost.

The burden of onboard operator monitoring and management of core and customer systems can greatly be reduced by tutorial and prompting aids. Figure 4-26 gives a view of an operator managing three displays. The cursor on the operators Daily Summary is positioned and the "enter" key is depressed to activate the Payload SAA XXX Plan display. After, "events" 1 and 2 are completed ("C" under status), the cursor is positioned to Event-3 and the Event-3 detailed display is activated. This display shows the operating status as active ("A") at Step-2 whose duration is 50 minutes. The

Table 4-5. On-Orbit Manpower Availability in Man-Hours Per Week

Activity	Core Support	Customer Support
Scheduled	48 (Note 1)	264 (Note 2)
Training	6 (Note 3)	18 (Notes 3,4)
Replanning	6 (Note 3)	18 (Notes 3, 4)
Unscheduled	6 (Note 3)	18 (Notes 3, 4)
Total	66 Hours	318 Hours

Notes:

(1) 2 Space Station Operators × 4 Hrs/Operator × 6 Days = 48

(2) Note (1) + 4 Mission Operators × 9 Hrs/Operator × 6 Days = 264

(3) Space Station Specialist Time for These Activities Divided Evenly Between Core and Mission OPS

(4) Nominal Mission Specialist Time Spent Only on Missions

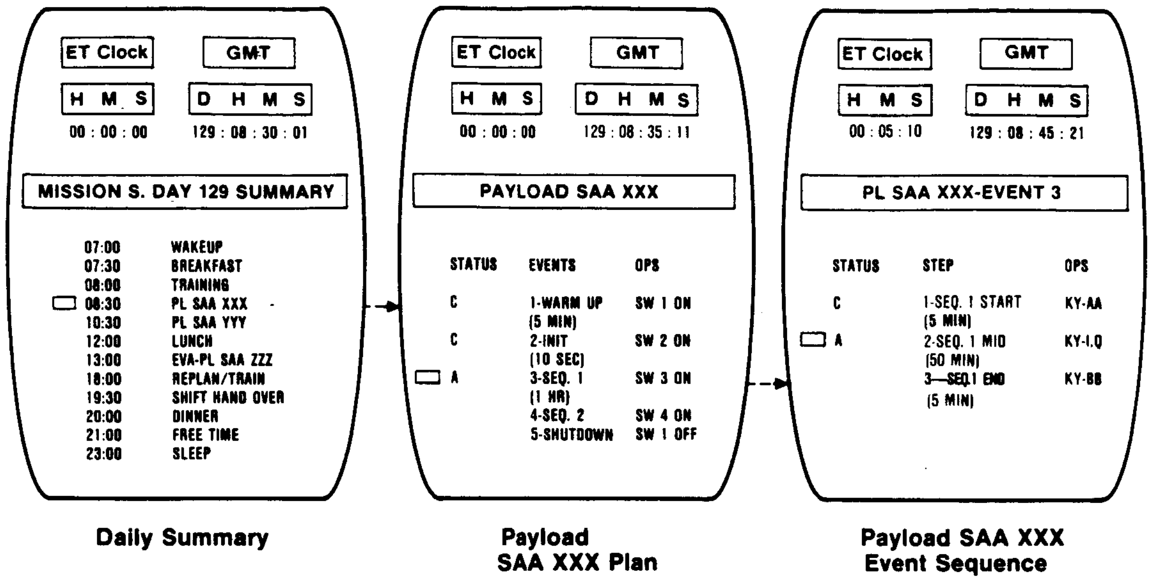


Figure 4-26. Prompts for Operator

elapsed-time clock indicates 5 minutes and 10 seconds of activity into the Step-2 sequence. These types of aids are necessary to maximize efficient onboard operations and to minimize training time.

In an effort to relieve the Space Station ground and flight operators of as many duties as possible, the promising potential of artificial intelligence (AI) will be considered. In addition to the more traditional automation techniques, full use will be made of the emerging capabilities of AI systems that perform such functions as: problem diagnosis, planning and scheduling, computer-aided instruction and training, data base storage and retrieval, voice recognition, natural language understanding, visual pattern recognition and robotics. IOC versions of these systems will generally tend to take the form of operator "assistants" rather than operator "substitutes". As confidence grows in the reliability of these systems, they will evolve toward more autonomous operation.

The area of artificial intelligence with the most near-term promise is in the area of "expert systems". Very significant gains in operator productivity can be expected early in the program through the utilization of this technology. Potential SSP applications for expert systems are numerous and varied, and the production of these systems will yield a great deal of terrestrial benefit, as well as Space Station benefit. Some of the more obvious applications are:

diagnosis of problems in on-board systems, medical diagnosis, activity planning and scheduling, intelligent computer-aided instruction and training, and intelligent data storage and retrieval assistance.

Figure 4-27 provides a brief summary of operators perspectives towards automation.

DRIVERS

- Full-Time Operation
- Limited On-Orbit Resources
- Minimize Ground Army

OPERATOR'S VIEW OF AUTOMATED OPERATION

- Normal Operations Are Automated
- Operator Notification When Action Required
- Prompts Operator
    - Level Choosen by Operator
    - Supports Training

ARTIFICIAL INTELLIGENCE TECHNOLOGY

- Expert Systems Now Emerging
- Other Technologies for Growth
    - Voice Recognition

Figure 4-27. Automation Is the Key to Effective Use of Operators

4.4.2.3.2 Workstation. Workstations are generally viewed as multipurpose applications consoles (MPAC). These provide ground and onboard operators the necessary means to control and monitor the status of all SSIS functions. A portable MPAC is also available for flight operations at locations away from fixed MPACs.

The basic characteristics performed by the MPAC are:

1. Command and control (interactive)
2. Multifunction (not dedicated to a specific task)
3. Visibility into all SSIS functions
4. Annunciation (alarms, caution, and warning).

The operations tasks are all accomplished by configuring a MPAC. A second MPAC can be configured as a backup to the prime MPAC.

Workstations will also take other forms. Onboard windows will be used to monitor EVAs, exterior station operations (docking/berthing, vehicle relative motion, mechanism movements, and earth/celestial observations). Television monitors will be used extensively for IVA and EVA operations. OMV and RMS end-effectors and docking operations are some examples. Also, joystick control of the Space Station Mobile Remote Manipulator System (MRMS) is a special feature not part of the MPAC. Other special mechanisms for specific operations at various Space Station locations will be used.

4.4.2.3.3 Redundancy/Failure Modes. The Space Station and platforms will have a wide variety of redundancy management methods employed in the implementation of the ground and on-board systems. Those ground parts of the data system which do not provide real-time support are expected to be simplex, with repair as the failure recovery technique. Any ground data system components which support real-time operations may, in addition, include redundancy in the form of on-line (hot backup) equipment ready to take over immediately, or in the form of off-line (cold backup) equipment that can be reconfigured in a short time for real-time support. In both cases, the current configuration will be available as a checkpoint from which to restart, without the need to manually respecify the entire system configuration.

The onboard subsystems may require a wider variety of redundancy options, due to more limited repair and replacement capability. Those portions of onboard data critical to the operation of the spacecraft and to the well-being of the crew (Space Station) will employ redundant on-line subsystems, executing in a fail-operational/fail-safe (FOFS) configuration. Those portions of the data system requiring recovery in a few seconds may utilize an on-line, reconfigurable spare in a failure mode. Less critical portions that allow a few minutes of down time, may be implemented as one on-line unit with an alternate unit connected to the system but with power removed. This cold backup technique allows recovery by manually or automatically turning off the faulty unit and turning the replacement unit on. The faulty unit may then be repaired or replaced from the spares. For subsystems which allow extensive periods of down time, ranging from a few minutes to several hours or days (or until the next NSTS visit, in the case of the POP(s)), there may be a single unit connected to the system. In case of failure, this unit would be repaired or replaced from the spares before being restored to normal operation. Finally, for the least critical subsystems, where loss is very unlikely and is not critical to safety or to the mission, there may be no spare or repair capability on-board.

The operator may be involved in implementing portions of any of these redundancy methods. The operator will be especially involved in directing system fault down when system capability must be shed because of failures, in fault isolation and recovery, and in repair. The exact technique to be used will depend on the subsystems which are defined as the system design is developed. Key considerations in arriving at the redundancy levels will be the criticality of the subsystem, the likelihood of subsystem failure (including the probability of multiple failures between the NSTS revisit points), the sparing level (subsystem, units, components, etc., including online spares on the platforms), the ease of replacement or repair (especially if EVA is necessary), and the storage space available for spare parts.

4.4.2.3.4 Privacy/Security

Privacy and security (definitions) of data and communications will be needed within the data system to prevent unauthorized access to customer's data bases, payloads and operations procedures. Security requirements may include the resource utilization profiles of some payloads. These needs must be balanced with the need for safety of the vehicle and crew and for the control of interaction among the vehicle and several payloads.

The three basic parts of privacy provided by the data system are the ability to command a payload or core function, the ability to passively listen to communications, and the ability to read out stored data and procedures. Commands to the payloads must be checked for authorization of the operator to command that payload. Further measures must be provided to assure a high degree of security and privacy of data, such as that contained in on-board or ground data bases and of data transmissions. The data system will include normal commercial protection techniques such as password protection for access to data bases. All transmissions of data will be encrypted. In addition, the individual customers may apply their own data encryption within the data itself for further security and protection against "tapping" the communication links. The data required for interactive planning and scheduling must also be protected from general access to avoid inadvertent compromising of proprietary processes. The only constraint imposed by the data system on individual data encryption is that any information needed for routing data within the data system must be in the clear. For example, the identification of the destination of the communication, the identification of the sender, and adequate information to distinguish restricted and constrained commands must be in the clear.

4.4.2.3.5 Standardization/Commonality. Standardization can lead to increased human productivity and reduced program life-cycle costs and therefore will be used extensively on the Space Station Program. The concept of standardization can have different meanings. Standardization can mean a common element used widely within a program, but this element may not be common with any other program. It can mean commercial or military standard specifications or discipline organization standard specifications for communications interfaces, network protocols, processor instruction architectures, etc. Standardization will be incorporated into the Space Stations program in some or all of the following forms:

1. Space Station program defined standards
2. Commercial standards
3. Military standards
4. Discipline organization (e.g., IEEE, SAE).

These standardization issues will be the subset of a Task 3 trade study to determine the level and vigor with which standards will be employed. Commonality on the Space Station Program (SSP) means use of the same equipment and software across Space Station Program Elements (SSPEs). That is the use of standard or common hardware and software systems for Space Station, Co-orbiting Platform, Polar Orbiting Platform, OMV, OTV, etc. As such, commonality could be considered a higher level of standardization applied at the program level.

Standardization will be used extensively for application in the SSP and in SSDS. Standardization will be implemented for:

1. Data Distribution
   - network protocols
   - network operating systems
   - inter-networking

2. Software languages
   - user interface language
   - applications language

3. Operating Systems

4. Data Base Management Systems
   - query language
   - data organization

5. Packet telemetry and telecommands

6. Processors
   - embedded microprocessors
   - general purpose processors
   - network interface units

7. Multi-purpose Application Consoles (MPAC)

8. Software development approaches/tools.

All of these areas are transparent to the operator except the various languages (user interface, applications, DBM query), the MPAC and the software development approaches/tools.

The International Standards Organization (ISO) seven layer reference model for Open Systems Interconnect (OSI) is not a fully accepted standard, but current and future implementations will greatly influence future standards.

The following operator interface scenario describes the standardization level that will be realized on the SSP. The operator interfaces to the SSDS through a standard MPAC. The fixed and portable MPAC are functionally the same. The operator has worked on a standard MPAC during ground training and simulation and knows the Logon procedures and how to select options from menus. Standard aids are available which present "help" displays which the operator has seen before and during training.

Changing or creating software in the space environment is the same process as the operator uses on the ground. The applications language and user interface language are the same and the software editor is the same. All the procedures for changing or creating software are the same. The onboard operator will be able to address software created off-line and make desired corrections. Simulation support to validate and integrate new software will be available. Protection will be provided to inhibit inadvertent or unintentional changes to flight critical software. The flight-critical software development is a ground process. The standard user interface language allows any operator to create and execute test control sequences. However, coordination is required if test control sequences cross some core subsystem and customer payload interface boundaries.

The technique for requesting hard copy of displayed data is the same on all MPACs. Each display panel used for subsystem control presents a unique layout, but typically items such as the keyboard layout and touch screen control will be standard.

The operator has a standard data base query language. The query language is the same as that used on the ground for inventories, manuals, schedules, maintenance, etc. The physical location of the data is transparent to the operator.

Growth and technology insertion are both very strongly tied to standardization. For example, growth in data processing can be achieved by: (1) adding more processors to a system to provide additional capability, or (2) replacing the entire subsystem with new technology. In either case, the interface standards between the new change (processor, software, sensors, devices) and the existing systems must meet established standards.

Software improvements can be particularly expensive in an embedded system unless pre-planned improvements were accounted for in the initial designs. Again, interface standards must be met.

Operator perspectives for these improvements could range from no impact to a direct impact. Direct operator impacts are those that involve: (1) defining the change, (2) implementing the change, or (3) new training because of the change.

Figure 4-28 provides a summary of standardization/commonality with respect to simplification of operations.

- **Ground to Onboard**
  - **Training to Operations**
  - **Maintenance**
- **Throughout Space Station Program**
  - **Core Systems**
  - **Customer Systems**
  - **Standard Customer Services**
- **Operations Transparency**
  - **Growth**
  - **Technology Insertion**
  - **Changing Mission Set**
  - **Data Handling**

Figure 4-28. Standardization/Commonality Will Simplify Operations

4.4.2.4 Operator Task Descriptions. The following sections describe fifteen operator tasks that encompass the onboard and ground SSIS functions. This approach allows an across the SSIS functions view to provide a perspective of the SSIS through the separate operator tasks. The viewpoints generally represent mature operations. NSTS operations in support of the Space Station Program are not emphasized.

The individual operator tasks may provide views that range beyond the boundaries of SSIS. As such, the task scenarios were developed for completeness and general understanding of task activities.

4.4.2.4.1 Hardware Maintenance. This operator task consists of maintaining hardware associated with the Space Station and co-orbiting platform payload and core systems. The hardware is the set of data management equipment and subsystem devices. The hardware is distributed among the ground, the platform and the Space Station. Therefore, the operators are physically located in space and on the ground.

The hardware operator task involves the following

- Observation of equipment performance degradation or failure
- Isolation of the problem
- Determination of what action, if any, is necessary
- Scheduling the maintenance
- Performing the maintenance and retesting.

This operator task is accomplished by using the functions of device management and monitor and status. Device management is a generic function that enables the operator to manage and control the hardware and devices associated with a specific function group. For example, device management covers the devices associated with navigation. These devices could include star trackers, rate gyros, and alignment sensors. Device management allows the operator direct control via an MPAC over typical subfunctions for each device such as

- performance monitor
- redundancy management
- configuration management
- power distribution.

The performance monitor subfunction is intended for a detailed health and status of the device. Monitor and status system is a global view of the health and status of the subsystems.

Generally, monitor and status system provides the operator with the first indication of a problem in a subsystem. System status provides this global service. This function would indicate which subsystem is affected and how to access the subsystem device management display for more detail. "Caution" and "Warning" may actually provide the first indication of a failure if the failure warrents an audio and/or visual alarm. Diagnostics support will be used by onboard and ground operators to provide more detailed support in determining the exact cause of the failure or isolating the failure to an Orbital Replaceable Unit (ORU). Schematic presentation, expert systems and trend analysis support will be available to the operators. Command interface processing will be a software process that implements the operator MPAC input commands to control any function group.

In summary, the device management functions in conjunction with the monitor and status system function allow onboard and ground operator capability to perform the overall hardware maintenance task for ground and Space Station equipment.

4.4.2.4.2 Software Development and Maintenance. The perspective of this task depends on the specific type of software to be developed. Software development will be performed for

1. Onboard operating system and network operating system

2. Onboard application software

3. SSPE software: OMV, OTV, Core

4. Optional support for customer software development

5. Ground operations support sites: SSCC, COP-CC, POP-CC, DHC, RDC, SSE

6. System test and control - generic

7. User displays.

Another aspect of the problem is the specification of the language or languages a software developer would expect to use.

Figure 4-29 illustrates the software development operator's viewpoint of the SSE.

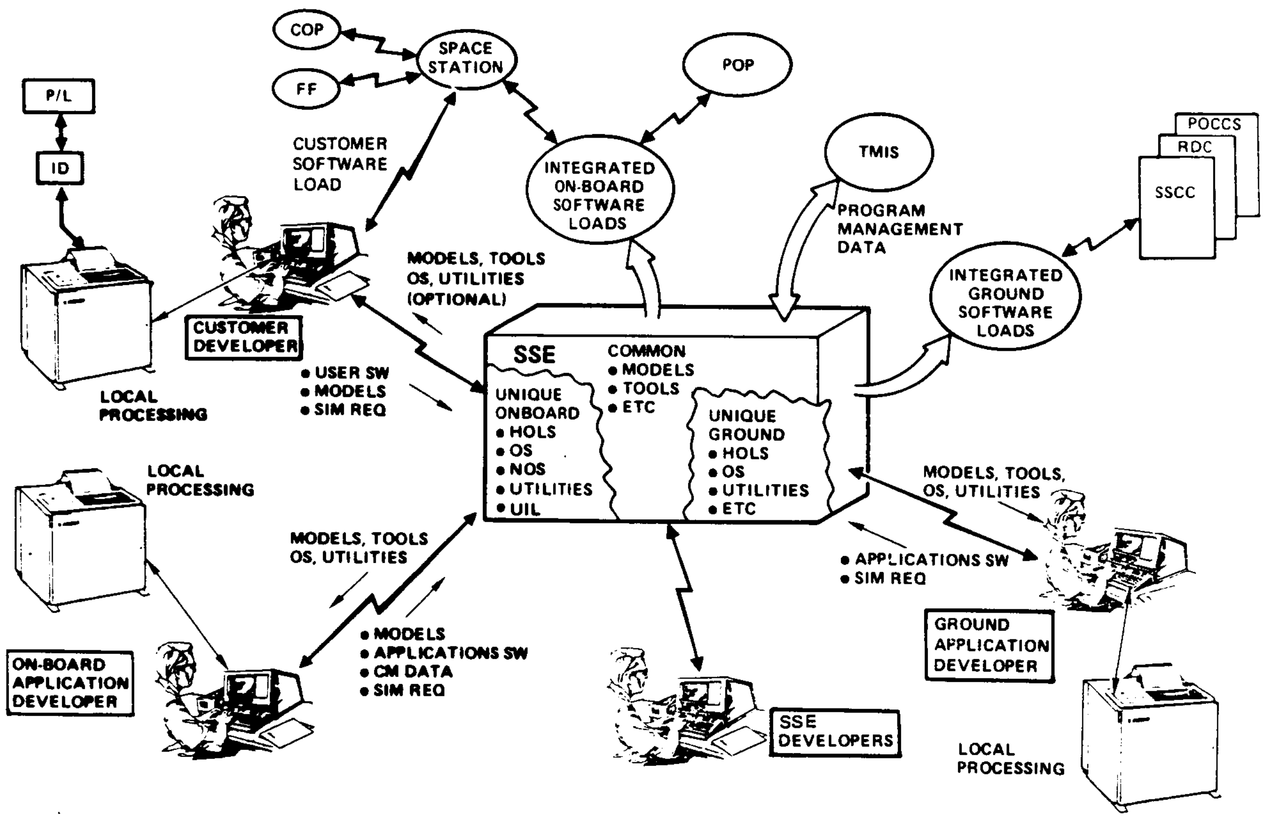


Figure 4-29. Centralized Coordination Is Required for Distributed Software Development

The Software Support Environment (SSE) presents a perspective that is essentially the same for all software developers. The Phase B RFP goal is to use the SSE for all onboard and ground software development and maintenance for each flight Space Station Program Element (SSPEs) and for their ground support functions. Another Space Station program objective is to maximize commonality of hardware, software and systems among the SSPEs. "The SSE is defined as the common software required for the development of application software for the flight and ground systems." The exact SSE will be under study during the Phase B period. The SSE provides capabilities which supports the development facility discussed in 4.4.2.4.11. The following is a summary of the SSE scope.

a) Language processors -- compilers, interpreters, preprocessors, assemblers and link editors.
b) Simulators -- for design, development, test, validation and secondary training.
c) Data Base Management Systems -- storage and access of large set of data.
d) Requirements and Design Tools -- requirements development and program design languages.
e) Test and Analysis Tools -- simulation aids and data reduction
f) Build and Delivery -- integration of software components into program-end-items.
g) Operating Systems -- standard network operating system and standard subsystem processor operating system for onboard SSDS.
h) User Interface Language -- a standard language for core and payload operators.
i) Software Quality Assurance and Configuration Control Standards -- follow NMI 2410.6 for all software development.
j) Business Support Systems -- all support tools must be consistent with the TMIS.

The above SSE scope is today's best perspective for Space Station Program software development. However, all program elements may not be compatible with these concepts. For ground facilities, we must consider that NASA institutions currently contain millions of lines of development and operational software that support various space programs. The potential to recover much of the existing software base for Space Station Program utilization will be traded against developing and integrating new software based on program standards. It is anticipated that the ground systems will continue to reflect a mixture of commercially available program product software, NASA and DoD space program developed software and uniquely developed software for Space Station Program.

A language utilization perspective for the various Space Station Program software users is presented in Table 4-6 The table is based on several assumptions, one of which is that a standard "higher order language" (HOL) will be adopted as the primary method for software implementation. This does not preclude the customer from using non-HOL source language as an embedded element in the payloads but it will not be supported by the SSE. The payload software must then only satisfy the required, standard interfaces to the subject SSPE.

Table 4-6. Software Development Language Development

Software development type	Languages		
	Standard HOL	User interface language	Other language(s)
Onboard operating system (SS, COP, POP)	X		
Network operating system	X		
Core applications	X	X	
Payload applications	X	X	X
OMV and OTV	X	X	X (Note)
SSCC, DHC, RDC, SDE	X	X	X
System test and control		X	
User displays		X	

Note: Allows for the potential use of existing flight-qualified embedded processor hardware and software.

The User Interface Language (UIL) is viewed as the prime operator language to perform system testing and control. This applies to all SSPEs including the Space Station Program ground and onboard elements. As indicated in the table, UIL is viewed as the language that is utilized by all operators to build all system displays and by any operator to build special displays for viewing desired data. Also, UIL is used by all operators to build commands to acquire data and to send commands to Space Station systems, ground and onboard, and for customer payloads. Again, this does not preclude the payload operator from embedding pre-stored commands that are envoked by onboard operators or by standard customer interfaces.

The need for other languages is indicated in the table. These cover the discussions presented above with respect to the payloads, the OMV and OTV, and special ground operating systems, and existing institutional software programs.

The SSE, the above language view, and NASA controlled software development procedures provide a perspective of software development. Operator developed procedures must follow NMI 2410.6 for all software development.

4.4.2.4.3 OMV, OTV, MMU, COP and Free-Flyer Control. A background overview for the constellation elements operations described in this and the next section allows the Space Station to be used as an effective base of operations. In summary, it allows: (1) a variety of environments, (2) extend the range of man's operation, (3) extends system life, and (4) provides a base for higher energy missions.

The general operator tasks associated with these five vehicles in association with the Space Station are:

1. Maintain and service
2. Deploy
3. Control within Space Station control zone
4. Control outside Space Station control zone
5. Retrieve.

Task 1 is performed by onboard or ground operators. Tasks 2, 3, and 5 are the responsibility of onboard operators. Task 4 is a ground responsibility and is not in the SSDS. The preceding applies to the OMV, OTV, and COP. The MMU is controlled only by onboard operators. All operators can utilize an MPAC to achieve these tasks. All five tasks are achieved by managing operator input commands/data and basic operation of the core systems.

Task 1 Maintenance and Service, is accomplished by using the functions which support customer system operations, operate Core subsystems and basic crew support. The OTV, OMV, and MMU maintenance operations are performed jointly by onboard and ground operators. The service and maintenance of the COP and free-flyers are both treated as payloads and are achieved by operator interaction with functions which support customer payload checkout/service.

Any vehicle, while attached to the Space Station, can receive standard services. These are: power, thermal control, structures and mechanical support, communication, and external interface management. The platform is serviced by EVA or robotic operations, either on site or retrieved and attached to the Space Station. EVA may be based on the Space Station or the Shuttle Orbiter, while robotic operations may be controlled from the ground, the Shuttle Orbiter, or the Space Station.

Task 2, vehicle deployment from the Space Station, is achieved by onboard operators. The Space Station MRMS is likely to be used for deployment of most vehicles from the Space Station. The MMU is deployed by EVA operators. The MRMS operator would impart sufficient relative velocity to avoid recontact. The onboard operators could deploy the OMV by directly controlling its translational capability. This depends on safety and environment contamination considerations. The same could apply to the OTV. Another option is, once the OMV is free it could be controlled by the onboard operators to grapple and then deploy the vehicle (OTV, free-flyers). Automatic deployment by the MRMS may be a possible operator selected option.

For task 3, control within the Space Station zone, the onboard operators will generally control the attitude and positioning of all vehicles. This will be accomplished by transmitting relative position and attitude commands to constellation members. Those vehicles without guidance, navigation and control functions (free-flyers) will be placed and repositioned by operators controlling the OMV. Vehicles in the constellation will be maintained in a basically coplanar orbit with the Space Station. Position monitoring and traffic control will be highly automated functions. Approach and departure corridors will be kept clear to allow access to the control zone.

Vehicles such as the OTV, OMV, and COP may leave the control zone and thus require ground operator control. These vehicles are returned to the zone by rendezvous sequences controlled by ground operation centers (Task 4). The desired return point for entry to the proximity sphere is defined by the Space Station traffic control function. Control handoff after rendezvous completion is accomplished automatically by traffic control command to the cooperating vehicles (OTV, OMV, COP). One transfer option is for traffic control to command the cooperating vehicle to maneuver to a zone reachable by the Station MRMS (except COP). Another is to have the OMV maneuver the vehicle to the MRMS reachable zone. When the MRMS has grappled the vehicle, traffic control discontinues active control.

Task 4, control of vehicles outside the Space Station control zone are the ground operator's responsibility. These are not discussed in detail. Operations include: (1) maneuvering the OTV, OMV, and COP to and from the Space Station control zone, (2) platform operations, (3) OTV missions, and (4) free-flyer operations.

Task 5, the retrieval of a vehicle in the Space Station control zone, is achieved by onboard operators. The OMV is maneuvered to the docking/berthing position along a safe return path. The safe return path is determined by using traffic control for all approach trajectories. The OTV may be maneuvered to the Station by onboard operators, or the OMV may be used to retrieve the OTV. The MMU can be maneuvered by the EVA operator to the Station MMU attach point. The COP is brought near the Station by the OMV for EVA servicing.

4.4.2.4.4 Docking/Berthing. Docking/berthing is likely accomplished with the use of the Station MRMS. It is basically the reverse of deployment. Video cameras are used to monitor and an MPAC is used to manually control the operation. The RMS operation could be highly automated; automatic deployment, storage and way point maneuver sequences, collision avoidance from known configuration, video on end-effector, automated grappling and rigidizing sequences. The operator could invoke these automated sequences and supplement them with manual RMS control to berth the COP, OMV or free-flyer. Final alignment, retraction, capture latching, and rigidizing may be done by automated sequences, monitored and controlled by the operator. The MMU is attached by the EVA operator. The free-flyers are attached to a maintenance position by the RMS or EVA operator.

The NSTS can dock to an unmanned Space Station or be berthed at a manned Space Station. If the Space Station is manned then there is audio contact between the NSTS and Space Station operators. The NSTS crew also has visual contact with the docking port during final approach. The Space Station operator requests the NSTS to be placed in a free drift manual mode before the RMS grapples the NSTS for berthing. If the Space Station is unmanned, then the docking is controlled by the NSTS.

4.4.2.4.5 EVA. The operator monitors EVA using video support and audio communications to MMU or EMU. An MPAC is configured to monitor and control airlock activity. Automated sequences (with manual override) are used for environmental conditioning of the airlock and control of airlock access (opening, closing, latching). Manual overrides are provided for all these automated functions. Monitoring and control of the MMU is performed autonomously by the EVA operator and station operators. The RMS can be used to position the EVA operator for Station and vehicle service operations. The platform will be serviced by EVAs. The OMV can maneuver the COP platform within the MMU/EVA range for serving. The platform itself may be maneuvered within servicing range. POP EVA activities and capabilities are described in JSC 07700.

4.4.2.4.6 GN&C Management. The avionics systems are highly automated and are designed to require minimal attention by operators to continue proper operation. The avionics systems include navigation, guidance, attitude control, traffic control, tracking and time management. These systems are self-managing and perform automatic reconfiguration to recover from failures. Manual override is provided.

The operator interfaces with each of these systems by configuring an MPAC by selection from system menus. The operator is aided with prompts. Systems performance and status is displayed at the MPAC. Graphics is used as much as possible to present data. When failed ORUs are replaced and demonstrated to be operational by self-test, the operator uses the MPAC to inform the avionics system of this restoration. The avionics system then automatically reconfigures the redundancy management level.

The operator has the capability to override or inhibit automated functions using the MPAC.

Many avionics systems are automatic with minimal operator interaction. The operator interacts with mission planning to coordinate reboost. Momentum management is automated. The nominal Space Station attitude is an earth reference local vertical. The operator can select and effect various attitude orientations from the nominal. Any attitude maneuvering is performed automatically after the attitude reference is established.

The navigation functions of attitude and state vector determination are performed automatically. This includes filtering, sensor source selection and source editing. The operator has override capability. The operator interacts with traffic control to coordinate OMV activities required to reposition free-flyers in the constellation. The operator also manages collision avoidance option selection. Time and frequency management is automated using GPS signals.

4.4.2.4.7 Non-GN&C Core System Management. The operator manages the core facility subsystems using automated sequences supported by the MPAC. The core facility subsystems include: power, thermal control, structures and mechanisms support, ECLSS, communications, and external interface management. All core facilities operate automatically with minimal operator attention. The operator monitors and controls the core facilities subsystem in a similar fashion to the avionics systems. The main operator interactions are to monitor status and performance and to restore redundancy following replacement of failed ORUs.

The operator interacts with the communication subsystem to establish voice and video contact internal to the Space Station and with external vehicles. The operator also configures the communications subsystem to establish voice and video contact with the MMU for EVA.

4.4.2.4.8 Logistics. The primary onboard operator interface with the logistics system will be to update the status of inventory items not monitored automatically. These data are input to the integrated logistics function for resupply and inventory management, using methods similar or the same as commercial inventory managers and resupply. While some spare parts and supplies will be monitored automatically, most will require the onboard operator involvement in entering identification of failed parts and spares and supplied used.

The ground operator may have a much wider involvement, in that some aspects of inventory control and transportation may be cost effective as manual or interactive operations.

4.4.2.4.9 Unmanned Operations. The Space Station is intended to be a manned operation after initial build-up, except in unforeseen circumstances that may require removal of the crew. In such a case, the vehicle will be made quiescent, with only safety critical core and/or payloads operating. There will, of course, be no onboard operator. The ground operators will assume responsibility for all operations during unmanned phases. Nominally, the operator should need no special functions beyond his normal monitoring functions, since the onboard subsystems are automated and operate autonomously. In the event of a failure or the need to activate or deactivate a subsystem, the ground operator will use the normal telecommunications to perform the needed actions to monitor and control the onboard systems.

4.4.2.4.10 Safe Haven/Contingency. This operator task involves those functions of the data system needed to operate the safe haven in contingency conditions, such as loss of pressurization or damage to a module. The basic assumption is that there will be the need for an orderly shutdown of non-critical core and payload functions, and for a more frequent monitoring of remaining levels of resources, such as food, water, and other supplies.

The safe haven/contingency operator tasks include the following:

1. Monitoring supply levels in the safe haven.
2. Safing or orderly shutdown of non-essential subsystems and payloads.
3. Correction of the malfunction, if possible.
4. Resumption of normal operations after correction.
5. Docking and rescue from the safe haven, if appropriate.

These operator tasks make use of several functions. The generic function of device management, necessary for safing and orderly shutdown, is exercised from the workstations in the safe haven by the onboard operator, or from the telecommunication link by the ground operator.

At any time, the ground operators can take over onboard operator's systems management tasks, if necessary, during contingencies.

4.4.2.4.11 Facilities Management. This core operator perspective covers several viewpoints:

1. A physical location and means to accomplish an operator task.

2. A location to status all high level aspects of a facility.

3. A location to access detailed data from distributed facility sources.

4. A location to command and control distributed facility functions.

5. A location for coordination of separate operational requirements into an integrated operational plan.

These five tasks can be grouped in two basic sets. The first set is task 1 by itself. The second set is the rest of tasks 2 to 5. Task 1 is the view that facility management is the means to do the job. The second set is a view for the operator whose job is basically to either directly support the operators under task 1 or manage/control the specific facility so that the operators under task 1 are successful. The "facilities" in this report are:

- Space Station Flight Facility
- Space Station Control Center (SSCC)
- Regional Data Center (RDC)
- Data Handling Center (DHC)
- Development Facilities (includes SSE).

The subfunctions under "Manage SSDS Facilities", describe the activities associated with these five facilities. All of these facilities are used by both core and customer operators. This section provides a core operator viewpoint.

Table 4-7 provides a perspective of facilities management for each individual operator task in 4.4.2.4. This table is a task 1 viewpoint of what each facility provides as a means to accomplish each operator job.

Tasks 2 through 5 are partially described in the table. However, these tasks are much more detailed at each facility level. They cover the day-to-day and long term management of each facility.

The flight facility is managed by both ground and onboard operators when it is manned. Onboard, the generic device management and operate core systems function, are used to achieve detailed reviews of system performance, individual device performance, and subsystem performance and status. Most of these tasks will be automated in the mature operations phase. More hands-on monitoring and control will be needed prior to this time. Global management of all onboard systems and necessary customer systems management (basic operations and safety information) will be achieved by interfacing with the "Monitor and Status System" function set. The SSCC provides basic onboard operator support and will manage separately, specific onboard elements. The ground also provides basic "second source" data and commands for element failures and contingency needs. For extreme contingencies, the ground operators at the SSCC, may take over most of the Space System system management. For normal operations prior to the "mature operations phase", the ground will receive more telemetry to monitor and control the planned operations. Much less telemetry will be needed for the mature operations because of increased onboard automation onboard reports if system status and operation will be prepared and downlinked. In addition, the capability to increase the detailed view of any onboard system through increased telemetry will be available and easily invoked by ground operators. The unmanned operation by SSCC operators may require less telemetry for habitable systems, but again, for special needs the ability to acquire any system and control that system will be easily implemented.

The SSCC operators must also manage SSCC ground operations and also provide global interfacility coordination and planning. These detailed operations are not detailed herein. Tasks 1 through 5 and the "views" in Table 4-8 provide some insight. In general, the parallels between the flight facility management and the SSCC management are very strong. Both must manage: (1) distributed functions in physically separated systems, and (2) personnel assignments and coordination in widely separated locations.

The RDC and DHC management needs are indicated by their functions and in Table 4-7. The management needs of these facilities again parallel the SSCC general needs.

Table 4-7. Operator Facility Perspective

Operator task	Facility applicability				
	Space Station	Space Station control center (SSCC)	Regional data center (RDC)	Data handling center (DHC)	Development facility
H/W maintenance	• Hands-on • Performance • Inventory • Self test • Replace • Short term trend	• Performance • Inventory • Diagnostic • Schematics • Expert system • Long term trend • Contractors	Same as SSCC for RDC functions	Same as SSCC for RDC functions	• H/W sim • System test (H/W, S/W) • Trouble analysis • Training
S/W development and maintenance	• Display gen. • Develop some test scripts (test lang) • No source language S/W dev	• Test scripts (test lang) • S/W dev • Display gen	Same as SSCC for RDC functions	Same as SSCC for DHC functions	SDE for all application S/W dev
OMV, OTV, COP free-flyer control	• Hands-on • S.S. control zone • OMV control • OTV control • COP control • S.S. RMS	• Outside • S.S. control zone • OTV control • Coordination (COP, OTV, OMV) • SSST training	N/A	Vehicle data TLM handling	• Simulation • Secondary training
Docking/ berthing	• Hands-on • All vehicles • Monitor/control • S.S. RMS • Cooperative NSTS docking	• Monitor • Support • SSST training	N/A	Vehicle data TLM handling	• Simulation • Secondary training
EVA	• Hands-on • Monitor • S.S./Vehicle servicing	• Monitor • Support • SSST training	N/A	TLM handling	N/A
Avionics management	• Hands-on • Monitor • Control	• Monitor/Perform. • SSST training • Control support • Diagnostics • Expert system	N/A	TLM handling	• Simulation • Secondary training • S/W dev
Non-avionics core system	Same as above	Same as above	N/A	Same as above	Same as above
Logistics	• Sparing • Logistics module	• Inventory • Center logistics • S.S. support	N/A	N/A	N/A

Table 4-7. Operator Facility Perspective (Continued)

	Facility management				
Operator task	Space Station	Space Station control center (SSCC)	Regional data center (RDC)	Data handling center (DHC)	Development facility
Unmanned operations	N/A	• Management of all core systems • Reduced SSCC ops	N/A	Reduced TLM	Continue normal functions
Safe-haven	• Occupy area • Reduced ops • Contingency train. • Contingency flight data file	• Contingency support • More onboard ops mgmt	N/A	• Normal TLM • Special TLM needs	• Contingency support • Continue normal functions
Training and simulation	• Station specialist • Mission specialist • Health and habitat • Infrequent events • Contingency	• SSST training • SSCC ops • Global mgmt • Contingency	• RDC training • RDC simulation	• DHC training • DHC simulation	• Normal ops • All operators • Contingency • Sim support
Planning and scheduling	• Near term updates • Long term access coordination • Flight data file access • Contingency	• Near term coord • Long term dev. • Intercenter coordination • Flight data file mgmt • Contingency	• Plan • RDC train and sim	• Plan • DHC train and sim	• Normal ops • Contingency ops
Onboard mission support	• Prime support to customers • Station specialist backup • Multi-tasked among customers	• Normal ops • Customer support • Global mgmt	• POCC role • Customer control options • Customer/mission specialist coordination	• Normal ops • Special customer needs	• Normal ops • Sim support • SW dev (optional)
Customer coordination	N/A (ground)	• Normal ops • Customer/mission specialist coordination • Global mgmt	• POCC • Customer control options • Customer/mission specialist coordination	• Normal ops • Customer/specialist needs coordination	• Normal ops • SW dev coordination • Sim support

4.4.2.4.12 Training and Simulation. This section covers the training and simulation needs of COP operators in the Space Station and ground operators for the POP and COP. It does not cover those same needs at the Data Handling Center (DHC) and at the Regional Data Center (RDC). The discussions do cover the needs of the Space Station Control Center (SSCC), the SSE, the customer facilities and the flight facilities. Training is defined as all the information and interactions necessary for an individual to perform a task.

This can include "built-in simulations" that are envoked by the operator interactions. Other simulations are controlled by operators that are examining detailed data to determine system element correctness or performance. These latter simulations are typically performed by software development and system testing personnel and are not considered operator training herein. Lesser training fidelity is required for the Space Station than in past programs because of increased system automation.

Figure 4-30 provides a view that training and simulation maximizes SSP operational capabilities.

Training of flight operators is achieved by interaction with onboard and ground facilities. The ground training elements of the SSCC are:

- Space Station Systems Trainer (SSST)
- Proximity and manipulator operations trainer
- One-g trainer
- Flight environment trainer
- Training terminals.

Operator training is achieved through "part-task" training and "full-task" training. The part-task training is focused on smaller tasks. Full-tasking training joins part-task elements into a higher-level of fidelity necessary for integrated training.

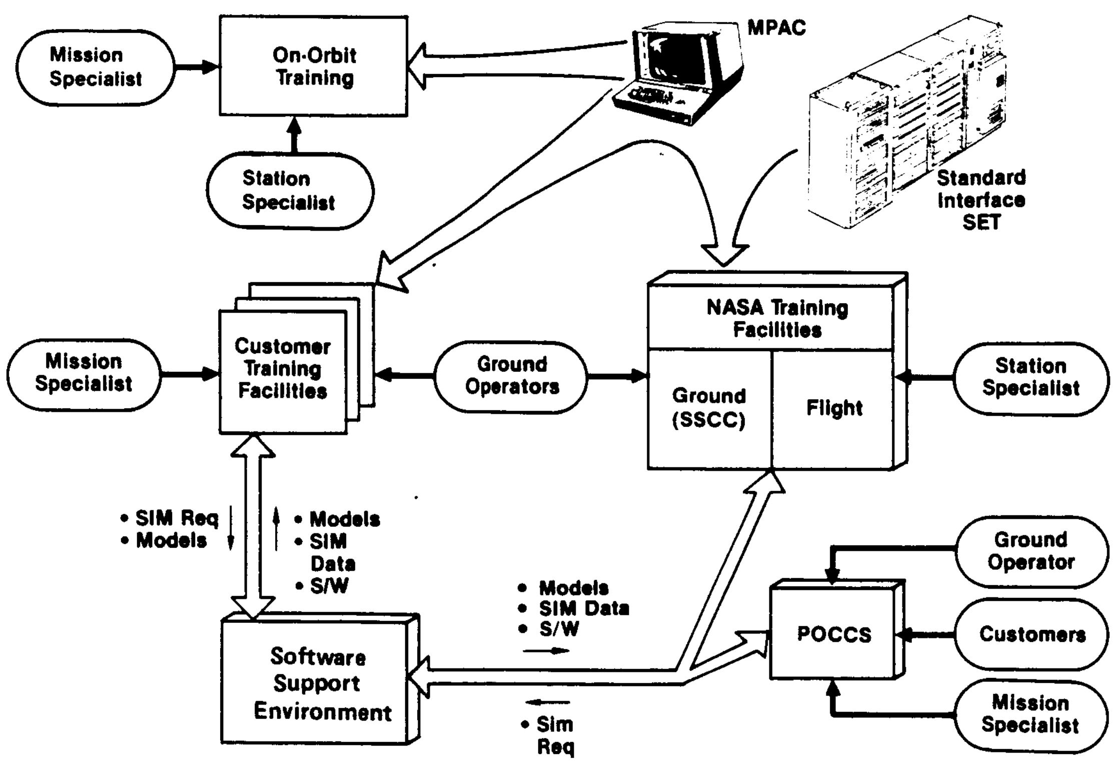


Figure 4-30. Training and Simulation Maximizes Use of Program Operational Capabilities

The SSST provides both part-task and full-time task training. This includes system management (avionics and non-avionics), system management ground support, activity planning, logistics, communications usage and contingencies. It provides a representation of the operating environment of the manned modules. The SSST will be networked to the other ground training elements as needed.

The proximity and manipulator operation trainer provides part-task operator training to develop hand and eye coordination and precise control. The manipulator is used for berthing/docking, grappling structures, and payload deployment. This high-fidelity training contains controls, displays, visual cues and dynamics. The trainer can be interfaced with the SSST and NSTS crew simulator as necessary. The trainer also contains a high-fidelity OMV simulator of its maneuver capabilities and it manipulator operation.

The one-g trainer will be kept in the same configuration as the Space Station and provides training for habitability, maintenance/service and EVA preparation.

The flight environment trainers provide a neutral buoyancy trainer, hardware mockups and tools for activities in a weightless environment.

Training terminals will be available (MPACs) that are the same as those in the SSST that provide tutorial walk through training. These relieve the training load on the SSST.

Preflight training for Mission Specialists and customers is a ground reponsibility. These ground operators are tasked with the training of these two sets of people to operate in the Space Station environment. POCC training is provided at the POCCs. The customer facilities are used extensively for onboard (Mission Specialists) and ground operator/customer payload training.

Training on the Space Station will essentially take place on the job. Experienced crew members will train new crew members. The Space Station, obviously, contains the highest training fidelity. The operators will have interfaces to onboard data bases that contain information on schedules, activity plans, maintenance and operations. All these data are available via an MPAC. Tutorial information on basic and detailed operations for onboard training and refresher training needs are available.

The above are the prime training viewpoints. The Software Support Environment (SSE) is considered a secondary training facility and a prime specific simulation facility. The SSE training aspect may provide more fidelity in some cases than the ground facilities. These will be used as needed.

The SSE presents to the operator not only a software development facility but a facility to perform simulations and secondary training. The operator controls simulations and training sessions from a standard MPAC, the same MPAC used for software development and for the onboard SSDS interface. The SSE simulation capability has several major modes: flight simulation mode and flight computer mode. These modes are selectable by the operator. The flight computer mode is supported by hardware elements. These hardware elements are used to support the prototype concept. Customer supplied hardware can also be integrated into the simulation in the flight computer mode. The SSE always contains a full-up flight computer mode (network, processors, interface devices, secondary memory, etc.). The SSE has a network connection to the NASA Advanced Development DMS test bed for exchange of application software and models.

The use of the SSE for simulation and training is supported by documentation in the form of user guides. These user guides are available on the MPAC or in manuals. Remote ground and onboard workstations (MPACs) are supported. The user guides contain various MPAC capabilities for selecting options in the simulation or training session. The operator is aided with "help" displays, prompts and illustrative examples. The test scripts developed for a session may be saved and used in subsequent sessions. The operator language for test script development contains as a subset a user interface language. The user interface language is used during operations to construct test sequences and can be used for the same purpose during simulation or training.

The SSE will support real-time training sessions and training in either the flight simulation or flight computer mode. Simulation runs will normally be submitted by the operator for batch execution. These runs can be submitted remotely. Interactive simulation can be performed by the operator by uploading the simulation configuration to their remote workstation. Remote site training is supported but not in real time. Real-time remote site training can be accomplished by uploading the simulation configuration to the remote workstation or by the remote workstation interacting with the SSE.

Simulation hardware models are selectable by the SSE operator. Model selections are made on panels presented on the MPAC. The operator can control the insertion of hardware model errors and model failures. The simulation defaults to idealized models in case the operator does not select an option on the panel. Customer supplied hardware models are supported.

SSE software versions (developed or operational) are selected in much the same manner as the selection of hardware models.

SSE simulation results are presented to the operator in the form of plots reports, etc. The operator developed test script controls the post processing of results. The results can be delivered to the operator on the MPAC display. The operator can select formats for hardcopy or display presentation.

The SSE maintains parameter simulation files which contain software names and labels. Software parameters can be sampled at various locations during execution. The operator specified these locations and parameters in the test scripts.

SSE aids are provided to isolate on-line errors (i.e., program exceptions). Errors are logged and traces are provided to aid the operator. Various monitoring devices are available to allow monitoring of the onboard Operating System (OS) and onboard Network Operating System (NOS) execution and performance during software development and testing.

System tests are performed in the SSE by the operators. The flight computer mode, highest fidelity mode of hardware, will be used for system test. A high fidelity simulation occurs at this time and all the major hardware components are available. Some hardware interfaces are still simulated. The simulation fidelity level will be specified by the operators.

The operator training task at <u>any</u> facility involves those functions of the data system needed to train the onboard and ground personnel to operate: the Space Station, the constellation elements, the ground facilities, and payloads. There are three primary personnel groups:

1. Onboard operators
2. Ground facility operators
3. Customer/operators.

Onboard and ground facility operators will require periodic training of off-nominal conditions that are not encountered in the day-to-day operation of the Space Station, and in operation of payloads that will not be directly controlled and monitored by the payload's owners. These conditions would typically be emergency procedures that require more rapid response than is available from textual reference to fault recovery procedures, or infrequent procedures.

4.4.2.4.13 Planning and Scheduling. These operator tasks are among the most important and difficult to achieve in order to produce effective coordination of requirements and resources. Without well understood objectives and timely plans to achieve them, an inordinate amount of operator time will be wasted in support of system operation and customer objectives.

Planning and scheduling applies in some degree to all operator tasks. A starting point is to begin with customer requirements and basic core system requirements. A view of the overall process is illustrated in Figure 4-31. The basic core and customer requirement inputs and established SSP program objectives and priorities are utilized by the SSP community as a whole to develop operational plans. For clear objectives, a programmatic plan is established which becomes the skeleton for specific mission plans. From the mission plans, long-term plans are developed which are utilized by operators to develop near term plans which are then used to control the operations of the various SSPEs. The status of the SSPEs provide feedback in this process that can cause changes in the various multilevel plans to accommodate the real environment operations. The entire set of information or plans is called the Flight Data File.

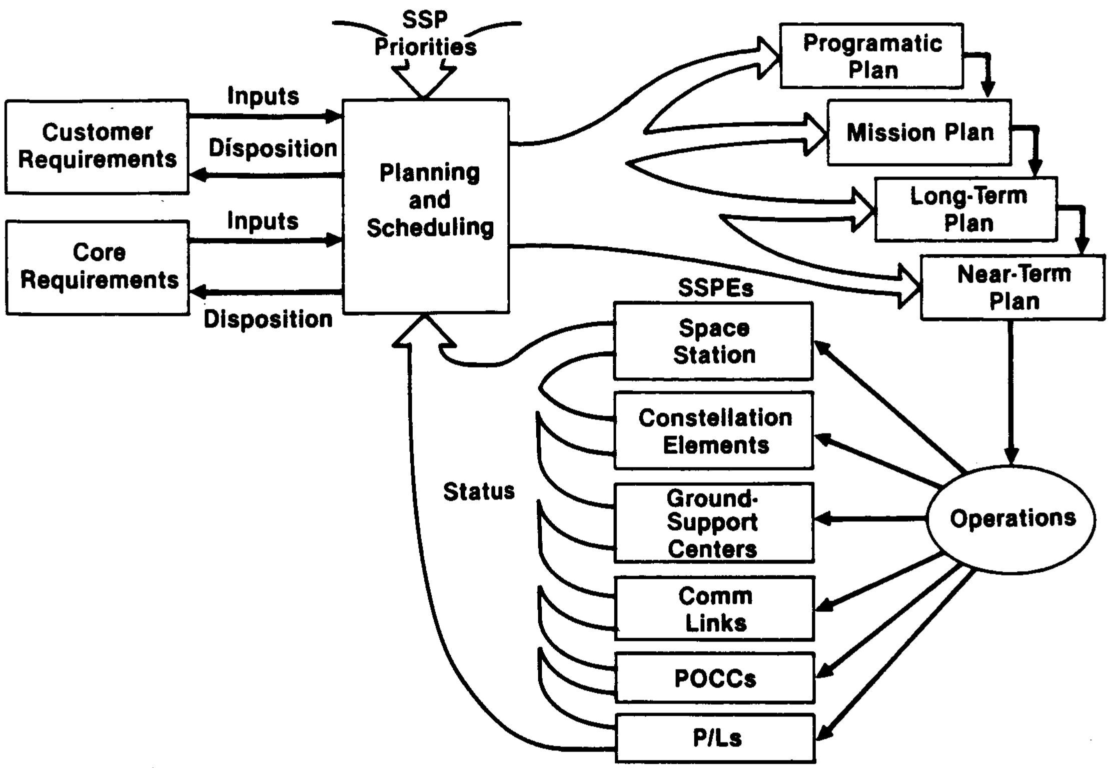


Figure 4-31. Planning and Scheduling Provides Coordination of Requirements and Resources

The above process generally describes planning and scheduling for onboard and ground operators performing station core tasks and operators supporting customer payloads. The view presented herein is that the planning and scheduling process for onboard and ground operator directly performing core and customer tasks and those operators supporting these operations will be merged together into a uniform plan.

Generally, all plans are electronically available to any operator. Special security needs are accommodated. The process begins with premission (i.e., preoperations) activities that must accommodate basic SSP goals and requirements. Mission manifests are utilized to determine the desired habitat and customer needs and resources. The premission plan baselines ground and onboard personnel support levels and skills required. Ground resources are established to provide basic support from the (1) NSTS, (2) SSCC, (3) DHC, (4) RDC. Onboard system resource needs are similarly established: (1) avionics services, (2) subsystems, (3) OMV, OTV, and EVA, and (4) data management services and storage. Next, an integrated communications and network utilization baseline is established. Iteration of these early premission/preoperations requirements evolve into the accepted mission plan.

The next step is the development of a long-term plan. This is defined by ground operators and customers for on-orbit operators to follow. Plans are blocked out by operator and task for approximately a two week period. This integrated plan coordinates all known ground and flight systems status (core and payload). This plan is uplinked to the on-orbit operators. It becomes the skeleton of the near-term crew activity plan (CAP) developed by the on-orbit operators.

The on-orbit operators use the skeleton long-term CAP, onboard data and status, and communications with ground operators and customers to create the near-term CAP. This covers a one-to-two day period. The on-orbit operator can best develop the detailed plan and schedule based on their station environment knowledge and crew skills and status.

4.4.2.4.14 On-orbit Mission Support. The on-orbit operator task functions are:

1. Coordinate operations with ground customer.

2. Operate necessary customer payload/experiment equipment.

3. Maintain/service customer equipment (reference 4.4.2.4.1, Hardware Maintenance, for viewpoint).

4. Perform EVAs as required.

5. Execute training for specific customer related tasks.

Both the Mission Specialists and Station Specialists share their scheduled work time supporting, as necessary, all the Space Station and COP payloads and experiments. They are, in general, not experts in all the payloads. The customers or principal investigators are, in general, on the ground. This does not preclude a customer or expert operator from becoming an on-orbit crew member for a long duration need.

The preceeding includes autonomous operation of a payload by the customer with only occasional support by on-orbit operators.

The customer coordination needs may be very extensive. Voice and video are utilized between the customer and onboard operators. Common data base access for both is the prime means for recording/updating experiment operations procedures. These data are contained in the Flight Data File. Customers are expected to provide their equivalent of a Flight Data File to Space Station specifications.

4.4.2.4.15 Customer Coordination. This ground operator task directly supports the customer by providing the following:

1. Point of contact for customer to assist them in general SSP policy and procedures.

2. Specifically includes:
   - Front-end negotiation for customer experiment integration into planned profiles
   - Training of customer and a Mission Specialist will address Space Station environment and procedures, and standard customer services -- voice, video, data processing, and problem reporting.
   - Handling and transportation of payload.
   - Arrange/contract data links and processing to acquire data and move it to customer.
   - Training of customer and Mission Specialist(s) to acquire data.

3. Negotiation of NASA provided services beyond the standard services.

These ground customer specialists share their time among several customers. The time spent is proportional to prenegotiated services. Telemetry service and data rates will be based on the amount of data captured, stored and delivered.

4.4.3 Space Station Data System Build-Up Scenario

The current NASA plans call for an operational Space Station during the early 1990's. One of the challenging aspects associated with this goal, is that of "Station build-up", defined as the set of activities that transform the fully developed Space Station elements into the deployed, operational, IOC system. This scenario is intended to provide some insight into the Space Station Program (SSP) build up activities while focusing on its Data System (SSDS) operations. The objective is not to develop a comprehensive description of the build-up procedure but to insure that Station requirements imposed on the SSDS by the Station configuration at each step of the build-up can be satisfied by the SSDS capabilities provided at the corresponding step. These requirements must also include those uniquely associated with build-up.

There is a tendency to think of "build-up" only in terms of the space segment because of the associated unique accessibility/environmental issues; however, ground segment support is such an integral part of the over-all operation that, in the general case, the ground elements must also be addressed. Conceptually, the ground segment will be initially emplaced and activated in order to provide maximum support for the space segment preparations, and activation. The actual station hardware must itself be segmented into launch packages for NSTS transport to the defined low earth orbit and integrated in an orderly sequence into the defined IOC configuration. Specifically, then, the build-up activities will include:

1) installation/activation of the program ground segments,
2) space segment launch preparations and launch operations
3) launch package on orbit deployment and assembly to existing structure
4) activation and checkout of added Station equipment and capabilities
5) full verification of SSDS operation and performance at final assembly
6) full crew manning of Station
7) installation/deployment and activation (as required) of experiments/payloads

Clearly, the build-up planning effort must generate a comprehensive task sequence with sufficient definition early in the acquisition phase to effectively interface with the design/development activities.

A distributed networking approach is anticipated for the Station SSDS since

- the Station itself has physically distributed modules and sub-systems
- processing loads may be too large to be efficiently supported by a centralized configuration
- network technologies with adedquate data rates to support SSP applications are currently being defined/developed and will be available for IOC
- this approach provides the modularity that supports
    a) commonality/standardization
    b) technology insertion
  and, c) orderly growth

Technology/design details of the SSDS have been minimized in an attempt to maintain generic concepts; however it has been necessary to generate a ground/space allocation of SSDS functions and to provide a distribution of sub-system equipment across the Station structure and modules to support those functions. The intent of these assumptions and allocations is only to provide a target final configuration to be achieved within the scenario, not to espouse any particular design features.

With respect to the space segment Build-up, the distributed approach also supports the derived requirement to maintain a stable, self-powered, ground controllable configuration at each stage of the operation as subsequently discussed.

An initial task of the scenario development was an assessment, provided in Table 4-8, of SSDS functional requirements at each stage of the build-up sequence. This assessment led to a distribution of SSDS functions across the Station, i.e., launch packages as shown in Figure 4-32 and an insight into the SSDS equipment requirements within each package. These requirements are integrated into Table 4-9 which summarizes the over-all scenario in terms of

Table 4-8. Build-Up Functional Allocation

BUILD-UP FUNCTIONAL ALLOCATION

FLIGHTS / ALLOCATED DMS FUNCTIONS	FLIGHT 1 TRANSVERSE BOOM	FLIGHT 2: KEEL/BERTH STRUCT RAD PNLS/RCS	FLIGHT 3: HM1/AL1 & 2	FLIGHT 4: HM2/ANTENNAS BOOM/KEEL STRUCT	FLIGHT 5: LOG1/SOL ARRY R&L BOOM STRUCT.	FLIGHT 6: LAB1/SPARES EXT EXPMTS	FLIGHT 7: LAB2/SPARES EXT EXPMTS	IOC: ON-BOARD CREW
•MANAGE CUST/OPER DELIV'D DATA								
MANAGE REAL TIME DATA RTN	YES	YES	YES	YES	YES	YES	YES	YES
MANAGE DELAYABLE DATA RTN	NO	NO	NO	NO	YES	YES	YES	YES
•MANAGE CUST/OPER SUPPL'D DATA								
VALIDATE P/L CMNDS	NO	NO	NO	NO	NO	YES	YES	YES
CHECK CMND RESTR/CONSTRAINTS	YES(1)	YES(1)	YES(1)	YES(1)	YES(1)	YES	YES	YES
VALIDATE CORE CMNDS/DATA	YES(1)	YES(1)	YES(1)	YES(1)	YES(1)	YES(1)	YES(1)	YES
PROVIDE ANC. DATA	NO	NO	NO	NO	NO	YES	YES	YES
SUPPORT CUST. OPS	NO	NO	NO	NO	NO	YES	YES	YES
SSPE C/O & SERVICE	NO	NO	NO	NO	NO	YES(1)	YES(1)	YES
•SCHEDULE/EXECUTE OPS								
DEVELOP OP SCHED	NO	NO	NO	YES	YES(1)	YES(1)	YES(1)	YES
SEQUENCE OPS	NO	NO	NO	YES	YES	YES	YES	YES
•OPERATE CORE S/S								
OPERATE AVIONICS S/S	YES(2)	YES(2)	YES(2)	YES(2)	YES(2)	YES(2)	YES(2)	YES
OPERATE NON-AV CORE S/S	YES(2)	YES(2)	YES(2)	YES(2)	YES(2)	YES(2)	YES(2)	YES
SUPPORT CREW ACTIV.	NO	NO	NO	NO	NO	NO	YES	YES
PROVIDE CUST AVIONICS SERV	NO	NO	NO	NO	YES	YES	YES	YES
CONTROL & MONITOR	YES	YES	YES	YES	YES	YES	YES	YES
•MANAGE FACILS & RESOURCES								
MANAGE FL SYST FACIL	YES(2)	YES(2)	YES(2)	YES(2)	YES(2)	YES(2)	YES(2)	YES

1) CAPABILITY SHOULD BE IN PLACE - CAN BE DEFEATED BY GROUND. I.E. ALL OPTIONS AVAILBLE TO GROUND CMND AND CONTROL

2) CAPABILITY SHOULD BE IN PLACE - BUT CAN BE DISBLED OR SELECTIVELY OVER-RIDDEN BY GROUND CMND.

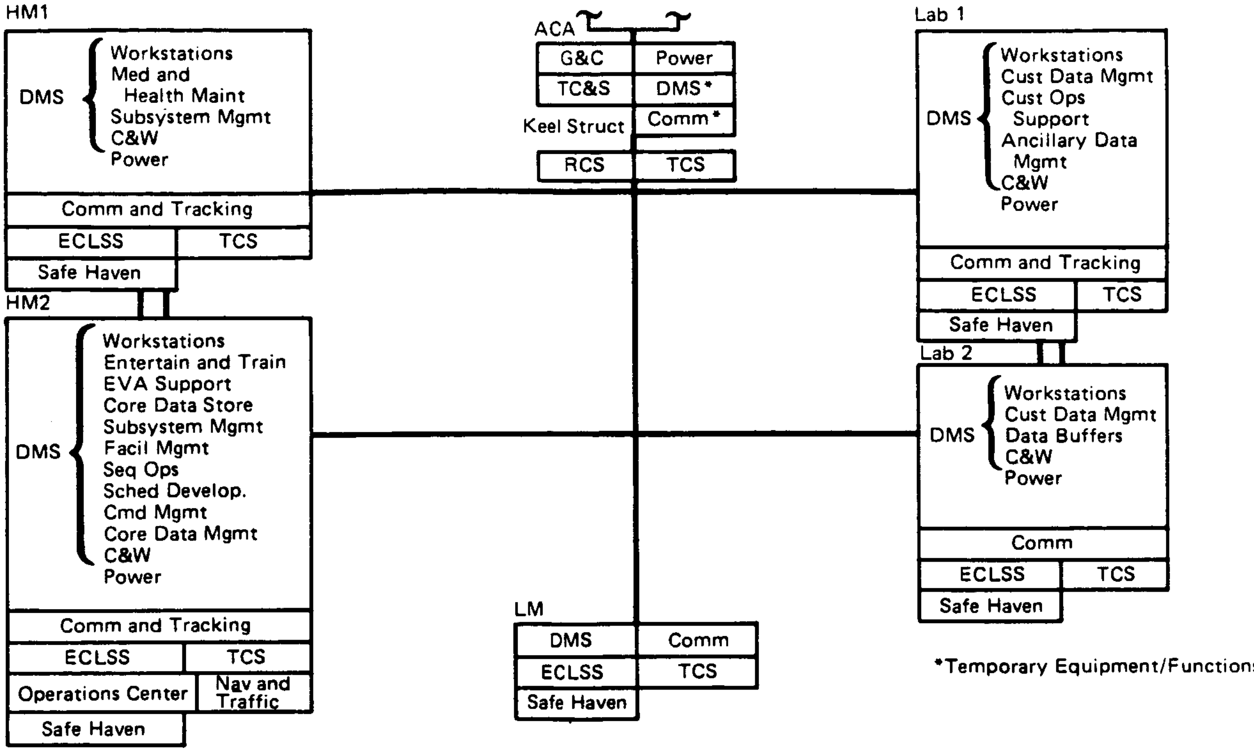


Figure 4-32. Preliminary Space Station Functional Distribution

1) the sequence of launch packages, 2) derived Station operational requirements (at each stage), 3) the SSDS functions to satisfy the Station requirements, and finally, 4) the equipment added to perform the SSDS functions.

The basic approach to the space segment build-up scenario is the deployment of each launch package outfitted with its full IOC. A policy established for the scenario was the activation of these added capabilities as soon as possible in order to provide early exposure of problems and to maximize crew familiarity with the Station operating characteristics. When a module is added to the Station, for example, its equipment will be powered up in a predefined sequence, excercised through its Built-In-Test (BIT) diagnostics, configured with its appropriate software and brought on-line to allow NSTS and ground crews to perform incremental system verification tests. Operational realities cannot be pre-defined however it is anticipated that much of the Station autonomy will be initially over-ridden by ground control; responsibilities will migrate from ground to space as the Station develops and ground crew confidence increases.

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Table 4-9. Scenario Summary (Page 1 of 2)

LAUNCH NO.	LAUNCH PACKAGE DESCRIPTION	ADDED DERIVED STATION REQUIREMENTS	ADDED SSDS FUNCTIONS	ADDED SSDS HARDWARE
1.	o TRANSVERSE BOOM ASSEMBLY o INITIAL SOLAR ARRAYS o ELEC POWER GEN EQUIP o GUID, NAV, & CONT EQUIP o INERTIAL SENSORS o CMG's o MAG TORQUERS o THERMAL RADIATORS o COMM EQUIP o ANTENNAS, MODULATORS, DEMODS, XCVRS (temporary?) o GPS RCVRS o MOBILE REMOTE MNVR SYSTEM	o BOOM ATTITUDE CONTROL o ARRAY POINTING o PWR GEN & DISTRIBUTION o NSTS/GND COMMUNICATIONS o MRMS CONTROL/ASSY SUPPORT	o MONITOR/CONTROL SUBSYSTEMS o MANAGE REAL TIME RTN LINK DATA o MANAGE FWD LINK CMDS/DATA o CHECK CMD RESTRAINT/CONSTRAINT o DISTRIBUTE DATA o TIME & FREQUENCY MGMT o PERFORM FACILITY MGMT o REDUNDANCY/CONFIG MGMT	o PROCESSORS, NETWORK INTERFACE UNITS, MASS STORAGE (SOME POTENTIAL SHARING WITH GN&C SUBSYSTEM EQUIPMENT)
2.	o LOWER KEEL ASSEMBLY o THERMAL CONTR SUB-SYSTEM EQUI o REACT CONTR SUB-SYSTEM EQUIP o LOWER KEEL EXTENSION o INTERCONNECT BAY STRUCTURE	o BOOM/KEEL ATT CONTROL o RCS FOR ORBIT ADJUST/COLLISION AVOIDANCE	o MONITOR/CONTROL TCS & RCS (added function of Boom Equip)	o INTERCONNECTS TO TCS, RCS o N/W INTERFACE UNITS, CABLING
3.	o HABITATION MODULE (HM1) o AIR-LOCK #1 & #2	o SUBSYSTEM MGMT (note 1) o HM1 COMM I/F, VOICE, VIDEO o HM1 THERM CONTROL EQUIP o HM1 ECLSS (deferred - note 2) o CREW SUPPORT (deferred - note 2) o CREW HYGIENE, GALLEY, HEALTH MAINTENANCE o HM1 SAFE HAVEN	o SUPPORT MPAC ACESS TO SSDS o CREW MEDICAL AND HEALTH MAINTENANCE (note 1) o SUB-SYSTEM MGMT (note 1) o MONITOR/CONTROL o REDUNDANCY/CONFIG MGMT o CAUTION & WARNING	o FIXED & PORTABLE MPACS o PROCESSORS, MEMORY, MASS STORAGE N/W INTERFACE UNITS o S/S INTERFACE DEVICES o INTERCONNECTING (SERVICE) TRUSS/MODULE CABLES.
4.	o HABITATION MODULE #2 (HM2) o UPPER KEEL STRUCTURE o UPPER BOOM ANTENNAS	o SUBSYSTEM MGMT (note 1) o HM2 COMM I/F, VOICE, VIDEO o OPERATIONS CENTER o EVA SUPPORT o HM2 THERM CONTROL o HMW ECLSS (deferred . note 1) o SCHEDULING, SEQUENCE OPERATIONS o ENTERTAIN, TRAIN CREW (deferred note 1) o HM2 SAFE HAVEN	o SUPPORT MPAC ACCESS TO SSDS o DELIVERED (RTN LINK) DATA MGMT o REAL TIME, DELAYED DATA o SUPPLIED (FWD LINK) DATA MGMT o CMD MGMT o DATA DISTRIBUTION o CORE DATA STORAGE o MONITOR/CONTROL SUBSYSTEMS o CREW ENTERTAINMENT/TRAINING o TIME & FREQUENCY MGMT o TRAFF CONTR/RDVS/COLL AVOID o SCHEDULING & OPS EXECUTION o FACILITY MGMT o REDUNDANCY/CONFIG MGMT o CAUTION & WARNING	o FIXED & PORTABLE MPACS o PROCESSORS, MEMORY, MASS STORAGE N/W INTERFACE DEVICES o S/S INTERFACE DEVICES o INTERCONNECTING (SERVICE) TRUSS/MODULE CABLES

Table 4-9. Scenario Summary (Page 2 of 2)

LAUNCH NO.	LAUNCH PACKAGE DESCRIPTION	ADDED DERIVED STATION REQUIREMENTS	ADDED SSDS FUNCTIONS	ADDED SSDS HARDWARE
5.	o LOGISTICS MODULE o TRANSVERSE BOOM EXTENSIONS o 2ND SOLAR ARRAY SET	o FULL HM1/HM2 ECLSS CAPABILITY o LOG MODULE THERMAL CONTROL o LOG MODULE COMM o LOG MODULE ECLSS o FULL 75KW PWR GEN CAPABILITY o LOG MODULE SAFE HAVEN o RESOURCE/SPARES MONITORING	o LOG MODULE FACILITY MGMT o RESOURCE/SPARES MONITORING	o SUBSYSTEM INTERFACE DEVICES o CONNECTING (SERVICE) TRUSS/MODUL CABLES
6.	o LABORATORY 1 o LIFE SCIENCES LAB	o WORKSTATION ACCESS TO SSDS o EXPERIMENT/PAYLOAD SUPPORT o HIGH RATE DATA MGMT o ANCILLARY DATA AVAILABILITY o LAB SAFE HAVEN o CONSTELLATION TRACKING o LAB1 ECLSS o LAB1 THERMAL CONTROL SYSTEM o CAUTION & WARNING o LAB1 SAFE HAVEN	o WORKSTATION ACCESS TO SSDS o CUSTOMER DATA/CMD MGMT o REAL TIME & DELAYED DATA MGMT o CMD RESTRAINT/CONSTRAINT CHEC o TRAFF CONTR/RENDEZVOUS (CONST'N) o CONTAMINATION CONTROL o CUSTOMER OPS SUPPORT o GN&C SERVICES o ANCILLARY DATA MGMT o CAUTION & WARNING o SAFE HAVEN SUPPORT	o SUB-SYSTEM INTERFACE DEVICES o DATA, SIGNAL PROCESSORS, MULTIPLEXERS, N/W INTERFACES MEMORY, MASS STORAGE
7.	o LABORATORY 2 o MATERIALS PROCESSING LAB	o WORK STATION ACCESS TO SSDS o COMMUNICATION, VOICE, VIDEO o EXPERIMENT/PAYLOAD SUPPORT o HIGH RATE DATA MGMT o CUSTOMER DATA BUFFERS o CAUTION & WARNING o LAB2 ECLSS o LAB2 THERMAL CONTROL SYSTEM o LAB2 SAFE HAVEN	o WORK STATION ACCES TO SSDS o CUSTOMER DATA/CMD MGMT o REAL TIME & DELAYED DATA MGMT o CMD RESTRAINT/CONSTRAINT MGMT o CUSTOMER DATA STORAGE o CAUTION & WARNING o SAFE HAVEN SUPPORT	o SUBSYSTEM INTERFACE DEVICES o DATA, SIGNAL PROCESSORS, MULTIPLEXERS, N/W INTERFACES MEMORY, MASS STORAGE

NOTE 1. FUNCTIONS TRANSFERRED FROM TRANSVERSE BOOM EQUIPMENT AT FLIGHT 5.
NOTE 2. ECLSS & CREW HYGIENE NOT AVAILABLE UNTIL LOGISTICS MODULE INSTALLED AND ACTIVATED.

Platform and free flyer deployment/activation are not separately discussed in this paper since build-up operations for these spacecraft is expected to closely resemble those of the Space Station build-up operations. There will be some interaction between these elements (during their build-up phase) and the Space Station, however, these interactions should not differ from the servicing and data support activities that are adequately documented elsewhere. The ground elements for these platforms and free-flyers are part of the SSDS ground segment and will not be separately addressed.

Also, the man tended Station option has not been specifically addressed since it is concluded that this option would consist of build-up operations provided in following scenario, however an interim configuration would be maintained for the unmanned period, then upgraded to the manned configuration discussed in the following sections.

The space segment build-up sequence provided in these discussions has been adapted from the reference 1 NASA Reference Configuration. The scenario presented here is an expansion of that NASA effort.

4.4.3.1 Data System Ground Segment

The SSDS ground segment will consist of those elements (functions) required to:

- monitor and control the SS, COP, POP, and free-flyers
- distribute uplinked data/commands and downlinked core and mission telemetry
- capture, process, archive and distribute the core and mission telemetry data
- develop software and hardware and provide system simulation and training
- manage (scheduling, config. control, etc.) the above.

These ground elements will include but not be limited to SS, COP, POP and free flyer Control Centers, POCC's, Engineering Data Center, Data Handling Center, Regional Data Centers, Development, Simulation & Training (DS&T) System, and Data Distribution Network and Network Control, plus the appropriate interfaces to the NASA Technical, Management and Information System (TMIS). The TMIS is expected to support the ongoing configuration management, scheduling, and readiness status functions required during the build-up.

Clearly, the build-up phase represents a period of uncertainty since it may represent the first 'all systems' integration effort. The ground elements associated with 'core' operations must, therefore, be in place with sufficient operational maturity to support monitoring and control of the first space segment elements. These capabilities must include effective sub-system monitoring and commanding, plus the ability to simulate system phenomena/anomalies, diagnose the cause(s), and design and validate solutions prior to effecting appropriate changes on the flight system. The Data Handling Center, and other Network and Data Distribution elements must also be ready to support the initial data format and rate requirements.

In reviewing the operations of ground system emplacement and activation, no specific technical or operational issues have been identified that necessitate particular strategies or sequencing except, as indicated earlier, the need to have an operational system of sufficient capability to support the deployment, assembly and activation of the space segment. The high IOC data rate capabilities associated with capture, distribution, archiving etc. need not actually be operational until late in the Station build up sequence; however, any options excercised in this area must not impact the over-all build-up schedule. The ground segment elements will incorporate the standardization/commonality policies of the over-all program (SSP) such that individually verified equipment can be 'installed and activated' within each respective facility with minimal problems. The degree of pre-launch ground/space segment integration will depend on the particular strategies selected, however the DS&T System, utilized heavily during DDT&E of the ground and space elements, will continue to support the build-up and activation operations in any case. TDRS/distribution links will be simulated at least initially and full end-to-end data checks may be deferred until the Space Segment is in place.

The ground SSDS/TMIS combination will support the planning, scheduling, configuration management, and mission readiness, including pre-launch integration and checkout. The NASA/Contractor team will update the associated status data bases such that comprehensive, real-time visibility of build-up operations will be available via this 'paperless' system to perform effective program planning/scheduling.

4.4.3.2 Data System Space Segment

One of the goals of the on orbit space segment build-up task is to maintain a stable, self-powered and ground controllable configuration at each step of the operation. This goal, coupled with the constraints of NSTS payload limits, has led to the development of the plan presented in the NASA Reference [1] in which a specific sequence of structural and module packages are boosted into near earth orbit for incremental assembly into the IOC configuration. The plan requirements drive the Station configuration and design in order to develop packages compatible with the NSTS cargo envelope, weight, c.g., etc., and allow subsequent deployment and assembly within the projected on-orbit resources.

Preliminary NASA planning accomplishes the build-up with 7 such packages, shown in Figure 4-33; a schedule of 6 - 12 months is anticipated for the effort, driven primarily by the launch preparations (NSTS refurbishment, launch package integration, and pre-launch checkout) and other impacting flight commitments. As indicated earlier, it is the intent of this scenario to insure that this build-up sequence can provide, at the conclusion of each mission, an appropriate complement of SSDS hardware and software to meet the projected interim requirements of the Station.

Ground operations between the initial build-up missions will focus on monitoring, controlling, and correcting the developing station, becoming thoroughly familiar with the station operations and operating characteristics at each stage of development. It is possible that perturbations to this scenario may result from equipment failures, incompatibilities or deficiencies detected during the build-up however, in the work case the resultant activities would merely be re-iterations (launch package removal and replacement) of the activities and operations presented. Such perturbations are therefore not specifically addressed.

4.4.3.3 Build-Up Preparations

In the anticipated sequence of build-up preparation, the flight segments of the SSDS, will first be integrated and verified within their parent elements of the Station. These elements will then be assembled for Station system

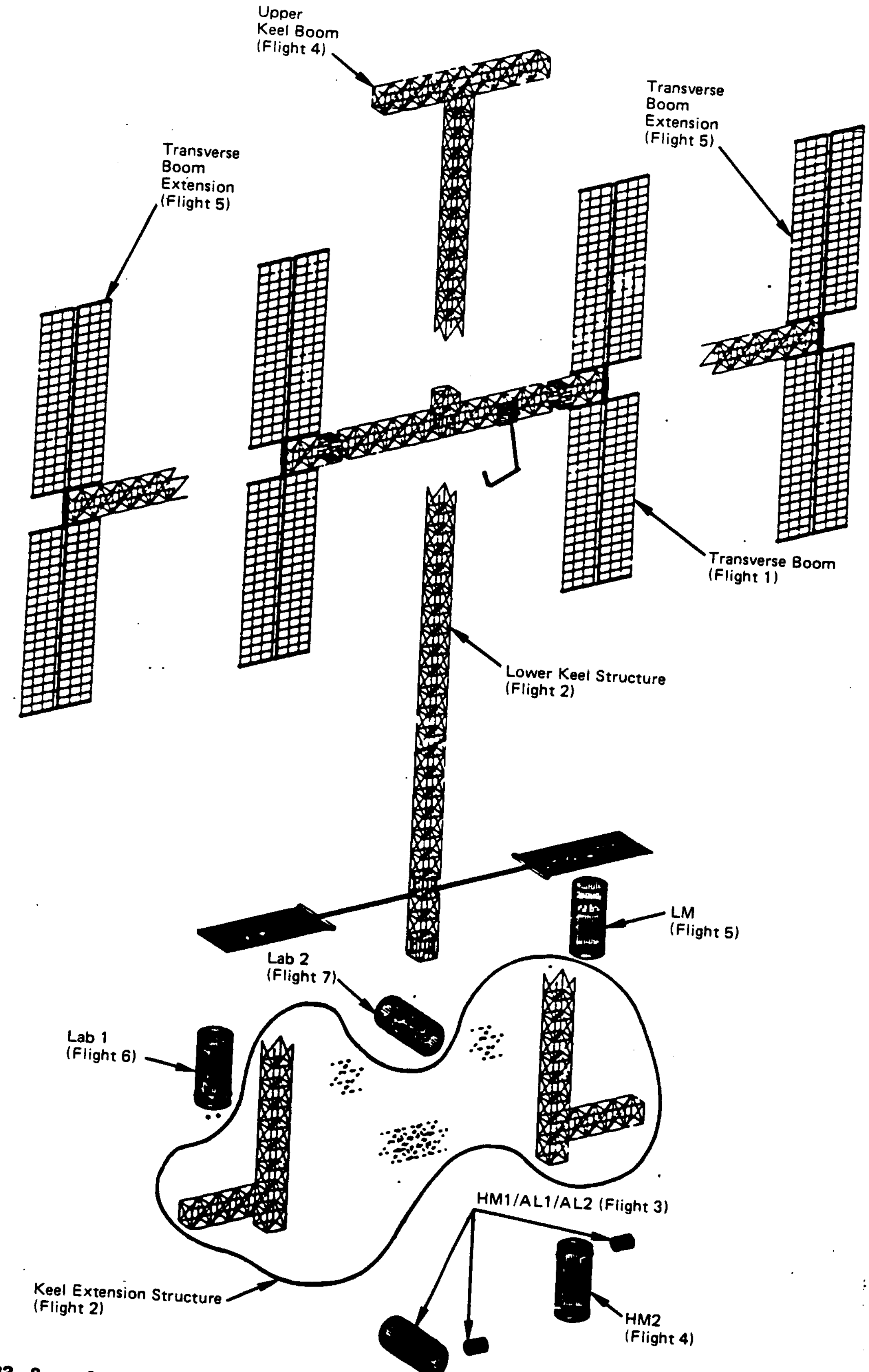


Figure 4-33. Space Station Build Up Packages

integration and verification prior to launch according to the selected integration strategy. Finally, system elements will be assembled into assigned launch packages for Orbiter integration, pre-launch checkout, and launch. Orbiter integration will require special preparation and attachment of structural members however, the SSDS equipment located within module or structural housings should not be impacted.

During pre-launch operations some SSDS checkout is anticipated with the packages in the Orbiter bay. Several options are available to accommodate this checkout, depending on the required depth. This scenario, however, has shown a need for an interface between the Orbiter and the SSDS to allow the orbiter crew to perform on orbit monitor and control functions on the Station sub-systems. DMS common equipment, (MPAC, BIU, and processors), may therefore be installed within the Orbiter to support this function; the network interface(s) will most likely be provided through the docking port. This interface could be harnessed to the launch package within the cargo bay to perform at least confidence level diagnostics. If required, more comprehensive system level checkout could be performed prior to Orbiter integration using a combination of specific GSE at the launch site plus remote system simulation support provided by the Software Support Facility. It is anticipated, however, that some checkout of the launch package will be required prior to its removal from the Orbiter bay to establish that no significant damage has occurred. Power will be provided from an auxillary on the Orbiter for this operation and the SSDS interface will be utilized (through the special harnessing above) to perform this checkout.

For the actual launch and orbital boost, it is assumed that there is no continuous power requirement for any of the station equipment, sensors, or experiments, and each package will be 'cold started' on orbit.

4.4.3.4 Build-Up Operations

The following discussions provide general descriptions and features of each launch package, an overview of each mission with the identified issues, and a discussion of the SSDS operations and issues.

For all orbital construction tasks, the Orbiter will be rigidly attached to the developing Station in order to reduce dynamics complexities and minimize collision risk. The Shuttle Remote Manipulator System (SRMS) grappling capability will be used to maneuver the Orbiter and/or Station into coupling position with temporary or permanent docking ports utilizing engagement mechanisms and some aids for range, range rate and attitude will be utilized. For the remainder of the discussions, these attachment operations will merely be referred to as berthing. Impact dynamics during berthing, SRMS/MRMS loading/unloading operations, and resultant attitude control requirements are acknowledged to be significant issues but will be appropriately left to others for comprehensive analysis and discussion.

Communications will play a major role in developing the Station configuration and a number of associated issues must be resolved. Of particular concern are the Station/Orbiter communication interfaces. It is not intended to provide solutions or even options to such issues within this document. Instead, communications functions will only be generically addressed with the assumption that appropriate conversions and/or compatible transponders can be utilized.

4.4.3.4.1 Flight #1

4.4.3.4.1.1 Package Definition

The initial build-up mission will deply the Station Transverse Boom shown as a folded launch package in Figure 4-34 and unfolded in Figure 4-33. The preliminary configuration provided in reference [1], locates hardware for the Electrical Power System (EPS), Thermal Control (TCS), and Guidance, Navigation and Control (GN&C) sub-systems across the Boom a shown in the figure. The 9 foot cube at the center of the structure, identified as the Attitude Control Assembly (ACA) compartment will house the Inertial Sensor Assemblies (ISA)'s, CMG's of the GN&C sub-system, and regulators/distribution equipment of the electrical power system (EPS); solar arrays and regenerative fuel cells will

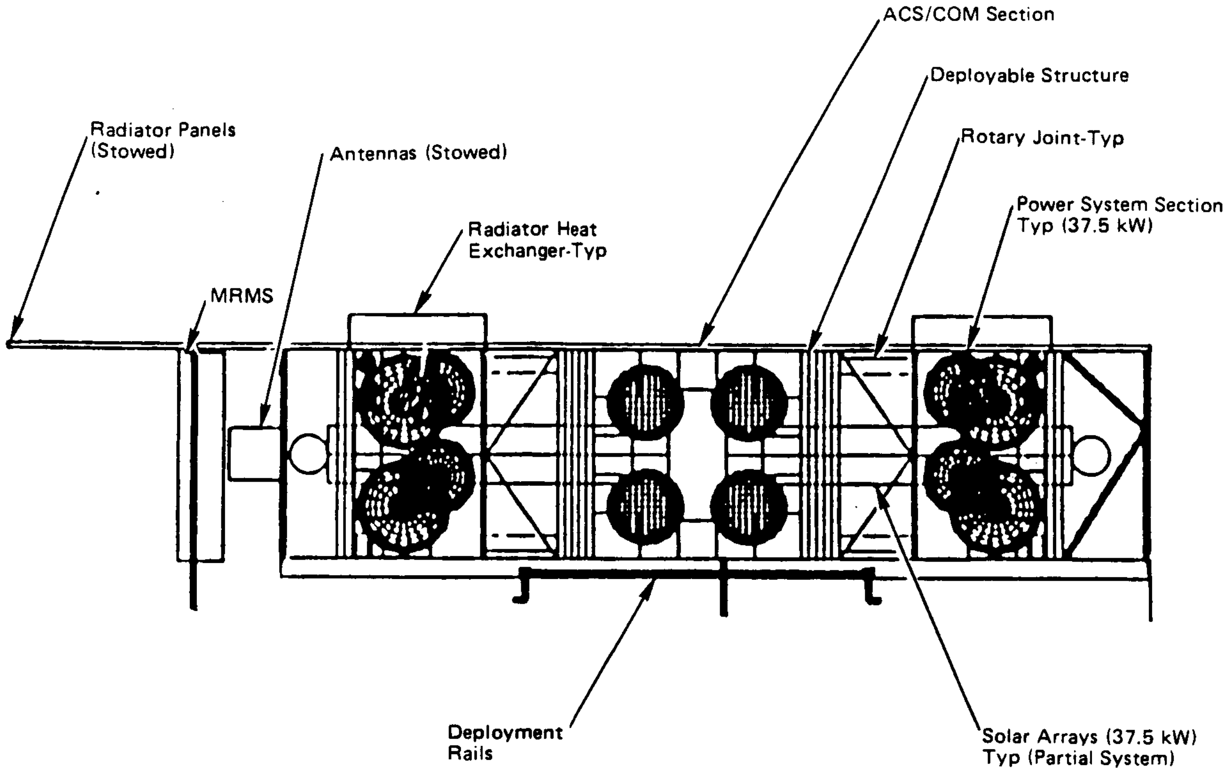


Figure 4-34. Transverse Boom Launch Package

be located further out on the boom structure as may be the Magnetic Torquers of the GN&C.

Addition of communications and some SSDS capabilities, will allow the Boom to be deployed as the initial stable element around which the Space Station can be assembled.

The SSDS capability will require a set (or sets) of processors, memories, mass storage devices, etc. but is expected to be temporary in that its functions will be transferred when the permanent equipment is integrated into the Station. However the equipment may remain in place as a spares resource and also for contingency purposes. Other options include use of a 'throw away' unit or permanently locating some function in the ACA. Networks/busses will be provided to permanently interface this equipment to the sub-systems NIU's and to the DMS of the final IOC configuration.

The communications equipment must include both a NSTS and TDRS S-Band capability. One option for the TDRS link would be to provide the full IOC capability within the boom structure then relocate the antennas, amplifiers, and recievers etc. to the upper boom when installed. The alternative, proposed in reference [1], utilizes low gain S-Band equipment for all communications on the initial configurations. This latter approach is basically compatible with the requirements and has therefore been adopted. GPS receivers will be included in the preliminary configuration to provide position, velocity and time reference to the GN&C sub-system.

Thermal control equipment, radiator panels, etc., provided on the Boom for Power Sub-system equipment cooling will also accommodate the added DMS and Communications equipment.

The initial SSDS will have an autonomous capacity to perform the Station data and command management functions plus subsystem supervision and redundancy management. Consistent with IOC design requirements, the ground crew will have the ability to over-ride all operations.

4.4.3.4.1.2 <u>Mission Overview</u>

The first mission will remove the Boom structure from the Orbiter cargo bay using the Orbiter SRMS, and fully 'construct'/deploy the boom with its first set of solar arrays. Typical of most build-up operations, this activity will be EVA intensive. Communication between EVA and NSTS crew will be relayed to ground as usual.

For the start-up/checkout operation, the Orbiter will be attached to the Boom at its temporary docking port utilizing the Orbiter attitude control system to sun orient the boom solar panels for the activation of the Electrical Power Generation System. An alternate possibility, however, is to allow the Fuel Cell system to provide the start up power and allow the station to autonomously orient the solar arrays when the DMS and GN&C subsystems are operational. The Power Management and Distribution equipment will be activated and configured followed in sequence by the DMS, Comm, and GN&C subsystems.

The last major operation will be to checkout the Mobile Remote Manipulator System (MRMS). It will be positioned at its designated servicing station which will supply power for manipulator operations and recharge its batteries for mobile operations. The MRMS will be excercised both from its local control panel and via its S-Band RF link.

4.4.3.4.1.3 SSDS Operations

The SSDS equipment will be powered and software configured via an automatic ROM bootstrap/memory load technique typical of all the equipment, power up BIT/diagnostics will also be performed. The SSDS will perform its 'manage delivered data' function by accumulating the sub-system data, formating the data packets with appropriate header/trailer data and issuing the resulting data stream to the Comm system. This low rate data will not require any substantial DMS or Comm buffering and will be compatible with the S-Band links provided. The Comm system will begin transmitting the Station sub-system 'operation and health' (house keeping) data stream to the ground via the Orbiter for evaluation. The SSDS ground system will perform functions of data capture, data handling, and processing to support real time displays and trend analyses for ground crew evaluation. The raw data will also be archived within the Engineering Data Center for available access and additional processing by ground personnel. As previously indicated, the Orbiter will have access to the DMS via its onboard workstation (MPAC) interconnected through the docking port. This access will allow any special sub-system diagnostics or verification tests to be performed or any operating mode to be established. The GN&C equipment (ISA's, CMG's, star-trackers, processors and BIU, etc.) will be powered up and its associated processors (dedicated or assigned) initialized and brought on line under DMS control. Some time (perhaps hours) will be required for the GN&C equipment, i.e. CMG's to reach operational status.

During this period, the GN&C will be placed in an 'attitude hold' mode to disable all control command outputs, however the sub-system will begin its initial attitude determination/update utilizing the sub-system star trackers, then begin to navigate based on incoming GPS data. Ephemeris data will be provided in secondary storage for DMS/GN&C to propagate orbit parameters and begin control and pointing command generation. GN&C command and data products will be interrogated/monitored by NSTS (via Orbiter MPAC) and ground crews with updates/adjustments provided as required. When operation is judged acceptable, command outputs will be selectively enabled and the GN&C will slew and maintain the solar arrays to appropriate pointing angles.

At some point in the mission the Station/TDRSS S-Band link capability will be exercised with the ground crew monitoring the Station and exercising the repertoire of commands required to control the DMS and other subsystems. The DMS will receive the uplinked commands and data provided by the Comm system, perform validation and authentication checks, then issue the commands and data to the appropriate subsystem.

The final SSDS capabilities will be that of subsystem monitoring and configuration management. The 'operation and health' data of each subsystem will be monitored and appropriate action taken depending on the fault tolerance techniques employed. Typically, each subsystem processor will reconfigure its own sensors and effectors as required, however, the initial DMS may have the capability to reconfigure and initialize the sub-system processors.

When NSTS and ground crews are satisfied with the station operation, the attitude control operation will be verified by disabling the Orbiter control system and allowing some low level of control by the Station. With normal indications, the Orbiter will disengage to a safe distance and ground crews will fully enable the attitude control. Autonomous momentum management will also be provided by the SSDS utilizing the magnetic torquers however this function may be initially assumed by ground crews.

4.4.3.4.2 Flight #2

4.4.3.4.2.1 Package Description

The second flight package will consist of the Keel structure plus lower assembly support bays shown in Figure 4-33. IOC equipment on the structure will include Reaction Control System (RCS) and Thermal Control Sub-system (TCS) hardware.

4.4.3.4.2.2 Mission Overview

For this mission the Orbiter will berth at the port on the Transverse Boom; the ground crew will command the GN&C into the 'attitude hold' mode as the Orbiter approaches. When docked, the Orbiter will establish an optimum, stable attitude to support the assembly operations.

The initial build-up operation will checkout and position the MRMS which will be used in conjunction with the SRMS to remove the upper keel structure from the Orbiter bay. When the main body of the keel is assembled to the boom, the MRMS will be 'walked' down the keel to support construction of the lower keel assemblies. Redundant service lines (DMS networks, TCS & RCS ducts and power distribution cables) will be connected/attached to their respective sub-systems. These service lines may be pre-integrated or may be carried separately; in either case they will require routing and securing within the previously packaged structure.

The RCS equipment (thruster nozzles, drivers, instrumentation, etc.) mounted on the keel will be used for orbit adjustments, collision avoidance and for back-up momentum management. The TCS equipment (fluid pressure vessels, flow control devices system processor(s), instrumentation, etc.) will provide and control heat exchange with the Station main thermal radiator panels to maintain appropriate temperature sinks for the Station equipment.

Both systems will be activated, and checked out. Reserve propellant tanks attached to the lower keel structure will support the RCS checkout. Instrumentation packages within the Keel structure will monitor vibration/flexure modes and structural misalignment. At the conclusion of the mission the Orbiter will disengage. Ground personnel will establish a favorable gravity gradient station orientation.

4.4.3.4.2.3 SSDS Operations

No additional SSDS functions are provided by this mission however the existing SSDS capabilities will support the routing of commands from the GN&C subsystem to test fire the RCS jets under ground crew control. The structural instrumentation will be treated as a set of isolated sensors. The resulting data will be monitored by the appropriate 'caution & warning' function of the SSDS and will be included within the downlinked engineering data.

4.4.3.4.3 Flight #3

4.4.3.4.3.1 Package Definition

The third mission will include the first habitation module, HM1, with the two Station Airlocks AL1 & AL2 shown in Figure 4-33. AL2 will be subsequently removed and permanently attached to HM2. As indicated in Figure 4-33, HM1 contains DMS, Comm, ECLSS, TCS equipment plus crew facilities and "Safe Haven" capability.

4.4.3.4.3.2 Mission Overview

The Orbiter will dock/berth to the temporary docking port at the starboard keel extension. This port will include the DMS/C&T interface. For this and subsequent missions, the Station attitude control system will remain operational and the Orbiter ACS will be inhibited prior to berthing contact and securing. The MRMS will be relocated to support SRMS removal of the module and its attachment to the lower keel structure. Module utility lines (electrical power, SSDS/C&T links, and TCS/ECLSS ducting) will then be attached. Finally, AL1 and AL2 will be attached to the module. Following module attachment, the Orbiter will berth at the HM1 docking port.

The module equipment will be activated and checked out as much as possible prior to Orbiter departure. However, two issues must be addressed in order to speculate on the immediate utility of the HM1 capabilities. First, it is not clear that the stand-alone module can initiate and maintain its 'shirt sleeve' environment for effective use as a work/rest station. Secondly, it is not clear whether the electrical/electronic equipment can be activated and checked out within the unpressurized module due to thermal considerations.

This scenario will assume that the module ECLSS will not have the stand-alone capability, therefore, the crew will remain suited for all flight #3 and #4 module activities. This will not only limit the utility of the module but will delay the detailed module checkout of the man/machine interfaces until flight #5. On the second issue, it will be assumed that the module electrical equipment can be operated in the unpressurized environment with the available Thermal Control equipment and cold plates in each module.

Suited crewmembers will enter the module via the docking port to configure and perform a limited module checkout. Following module checkout, the crew will establish a predefined module configuration, and depart with the Orbiter.

4.4.3.4.3.3 SSDS Operations

The HM1 checkout effort will complete the normal power up and self test operations then proceed with a communications verification, including voice/video to the Orbiter and communication via TDRS to the ground. 'Safe haven' direct to ground communications will be excercised at appropriate orbit positions. The HM-1 SSDS equipment will be initialized with its appropriate memory load and brought "on-line". Appropriate operational diagnostics will be performed with both local operation utilizing the MPAC and by the ground crew.

The SSDS equipment in this module will provide crew support functions, i.e medical, health maintenance, EVA support together with some general data storage and buffer capability. The HM-1 communications equipment signal processors will support the K and S-Band communication with TDRS.

4.4.3.4.4 Flight #4

4.4.3.4.4.1 Package Definition

The fourth NSTS package, shown in Figure 4-33, will consist of the second Habitation Module, HM2, plus the upper keel structure with its high performance (IOC) TDRSS communication equipment.

4.4.3.4.4.2 Mission Overview

The mission will begin with the Orbiter berthing at HM1. The MRMS will remove the HM2 module from the Orbiter bay in conjunction with the SRMS and position it for attachment to the keel structure. These attachment operations differ in that HM2 will also attach to HM1 to form one half of the module "race track". Airlock AL2 will be relocated from HM1 to HM2 and the HM2 service links will be connected. The upper keel and boom structure will be transported via the MRMS under EVA control and assembled to the keel. The 9 foot TDRS antennas, power amplifiers, low noise amplifiers (LNA)'s and receivers will be located onto the upper keel structure to support the IOC ground link capability.

Suited crewmembers will then enter HM2 and perform a checkout sequence similar to that employed on HM1.

4.4.3.4.4.3 SSDS Operations

The DMS equipment within HM2 will include fixed and portable work stations (MPAC's) plus the processors, BIU's and mass storage to provide the functions of sub-system monitor and control, scheduling, operations sequencing, command management, traffic control, Facility Management, and Caution & Warning. Once the equipment is brought on line with an appropriate software load, the limited functions of the ACA SSDS equipment will be assumed by the HM1 and HM2 equipment and the ACA equipment will be taken off line. Appropriate Command/control diagnostic checks will be performed from the ground.
The added SSDS functions of scheduling, operations sequencing, along with enhanced Caution & Warning, and Facility Management functions, when operationally mature will reduce the ground crew requirements during and between Orbiter missions. The remaining functions within the module will be checked within the inherent limitations of the suited crewmen; however, the GN&C, Comm and DMS will be configured, through ground and Orbiter crew commands, to activate the high gain direct TDRS link.

4.4.3.4.5 Flight #5

4.4.3.4.5.1 Package Definition

The fifth package as shown in Figure 4-33 will consist of the Logistics Module (LM), along with port and starboard extensions for the Transverse Boom to support the second set of solar arrays.

4.4.3.4.5.2 Mission Overview

As usual, the Orbiter will dock at the HM1 docking port. The MRMS will remove the Logistics Module from the cargo bay and position the module for positive mate to HM2 and attachment to the keel structure. The normal connection of utilities, power, and thermal control will occur.

A major activity of this mission will be the activation of the LM, HM1 and HM2 ECLSS system to provide module habitability and a second base for EVA support.

The Transverse boom extensions will be deployed utilizing the MRMS under EVA control followed by attachment of the set of solar arrays.

4.4.3.4.5.3 SSDS Functions

Suited crewmen will enter HM1 through the docking port and cross into the Logistics Module to configure its ECLSS equipment, pressure sources and regulators and sinks. HM-2 first and then HM1 will be configured to accept the LM supply pressures of gas, water etc. and their ECLS systems will be set to normal design conditions.

Once monitoring on ground and within the module indicate an acceptable crew environment, the crewmen will de-suit and begin the comprehensive checkout of each habitation module. This checkout will verify the full workstation/DMS capabilities and voice/video comm capabilities between modules and Orbiter and ground. The EVA servicing and support functions will also be checked, in addition to other crew support functions not previously excercised. All discrepancies and anomalies will be worked with ground crew utilizing full audio/visual (TV, text, and graphics) communication capabilities. Effective troubleshooting can be performed to isolate faulty equipment and return it with the Orbiter.

At this point, the program has the option of leaving a 2-3 man crew at the Station to support the on-orbit integration operations. The decision would be based on factors of overall utility and the demonstrated station safety and reliability.

4.4.3.4.6 Flight #6

4.4.3.4.6.1 Flight Package

The Flight No. 6 will consist of laboratory module, LAB 1. This module, as shown in Figure 4-33, contains a major portion of the C&T control and processing equipment associated with traffic control, the DMS payload collection and distribution equipment, and the standard communication (voice/video) access, ECLSS, and "Safe-Haven" equipment.

4.4.3.4.6.2 Mission Overview

For this mission, the Orbiter will dock at HM1 and the MRMS will be translated down the keel for access to the Orbiter and the LAB 1 attach point. LAB 1 will be removed and positioned using the combination of SRMS, MRMS and EVA support. Following mechanical securing of the module and attachment of its utility lines, the crew will checkout and configure the module to establish a habitable environment for subsequent checkout.

This mission provides a second opportunity to leave a 2-3 man crew on-orbit to support continuing station checkout operations . Experiments housed within the Lab 1 module could also be activated at the conclusion of the mission, depending on their support requirements.

Any defective equipment identified during this or earlier checkout could be removed by the crew for onboard repair or return to earth, since the orbiter will have available cargo space to deliver repaired/replacement equipment on both the 6th and 7th flights.

The LAB 1 module will be configured for either a 'manned' or 'man-tended' operation depending on whether a partial crew remains within the Station.

It should be noted that the SSDS functional distribution provided in Figure 4-32 dictates a deviation from the Reference Configuration in that LAB 1, with its customer data management, mission support, and ancillary data management functions, has been deployed first to provide a more operationally continuous build-up sequence. There has been no consideration for any structural difficulties that this deviation might cause.

4.4.3.4.6.3 SSDS Operations

Once the LAB 1 module has been powered and is habitable, its communication equipment will be checked out followed by activation of the DMS and Comm & Tracking equipment. It is also anticipated that some payloads/experiments within this module will be activated to satisfy associated 'user' agencies and also to support some limited system checkout. The added SSDS functions within this module are those of 'customer data management', customer operations support' and 'ancillary data management'. The Comm & Tracking equipment includes signal and data processors for constellation tracking functions and to support video/data formatting associated with the TDRSS forward and return links.

System level checks will be initiated from the HM1 workstation in conjunction with ground crews to fully exercise the payload oriented capabilities. These exercises will include command and monitor sequences by ground and on-board crews to: 1) verify command management functions, 2) verify payload sequencing operations, 3) verify the distribution of ancillary data for payload access, and 4) verify the end-to-end, multi-experiment (and core) data flow including ground archiving and distribution to user.

4.4.3.4.7 Flight #7

4.4.3.4.7.1 Package Description

The last station build-up package will consist of the LAB 2 module plus any replacement/returned equipment.

4.4.3.4.7.2 Mission Overview

This mission will berth to HM1 and utilize the MRMS and SRMS with EVA support to emplace the LAB 2 module.

This module, as shown in Figure 4-32, will house the normal ECLSS, TCS, communication access, Power, and "safe haven" equipment plus DMS equipment in the form of work stations, data processors, and mass storage equipment, to support functions of customer data management and customer operations support. The module activation/checkout sequence will follow the previous flow and finish with system integration of its functions via HM1 and HM2 operations.

4.4.3.4.7.3 SSDS Operations

When the module has been powered up, and is habitable, the normal checkout will proceed with verification of communications (voice/video) and its workstation. Then, as with the LAB 1 checkout, some payload/experiments within the module will be activated and end to end checkout performed. This module, as indicated in Figure 4-33, will house the large mass storage equipment utilized during zone of exclusion (ZOE) period and for general (load relief) data buffering as required.

4.4.3.5 Initial Operational Capability

At the conclusion of the 7 mission sequence, the SSDS will be fully in place, performing or ready to perform all defined functions. Additional flights will be required, however, to transport the OMV, additional payloads/experiments/ free flyers, and personnel required to supplement the Station crew and thus achieve the IOC station configuration illustrated in Figure 4-35. Also, there will be some transitional, start-up period to bring the Station up to a routine working status. There will be a heavy reliance on the robustness, i.e. flexibility and tolerance of the SSDS during this period since its background tasks must be continued while supporting ground/Station crew real time tasks and adapting to the growing payload/experiment mission support requirements. Equipment problems will inevitably occur during this period as will human errors; the systems must discriminate faulty conditions and command sequence errors while continually prompting the crews for appropriate actions. This will not only test the dynamic and static fault tolerance features of the subsystems but will also be a challenge to the short term scheduling and operations sequencing capability of the SSDS.

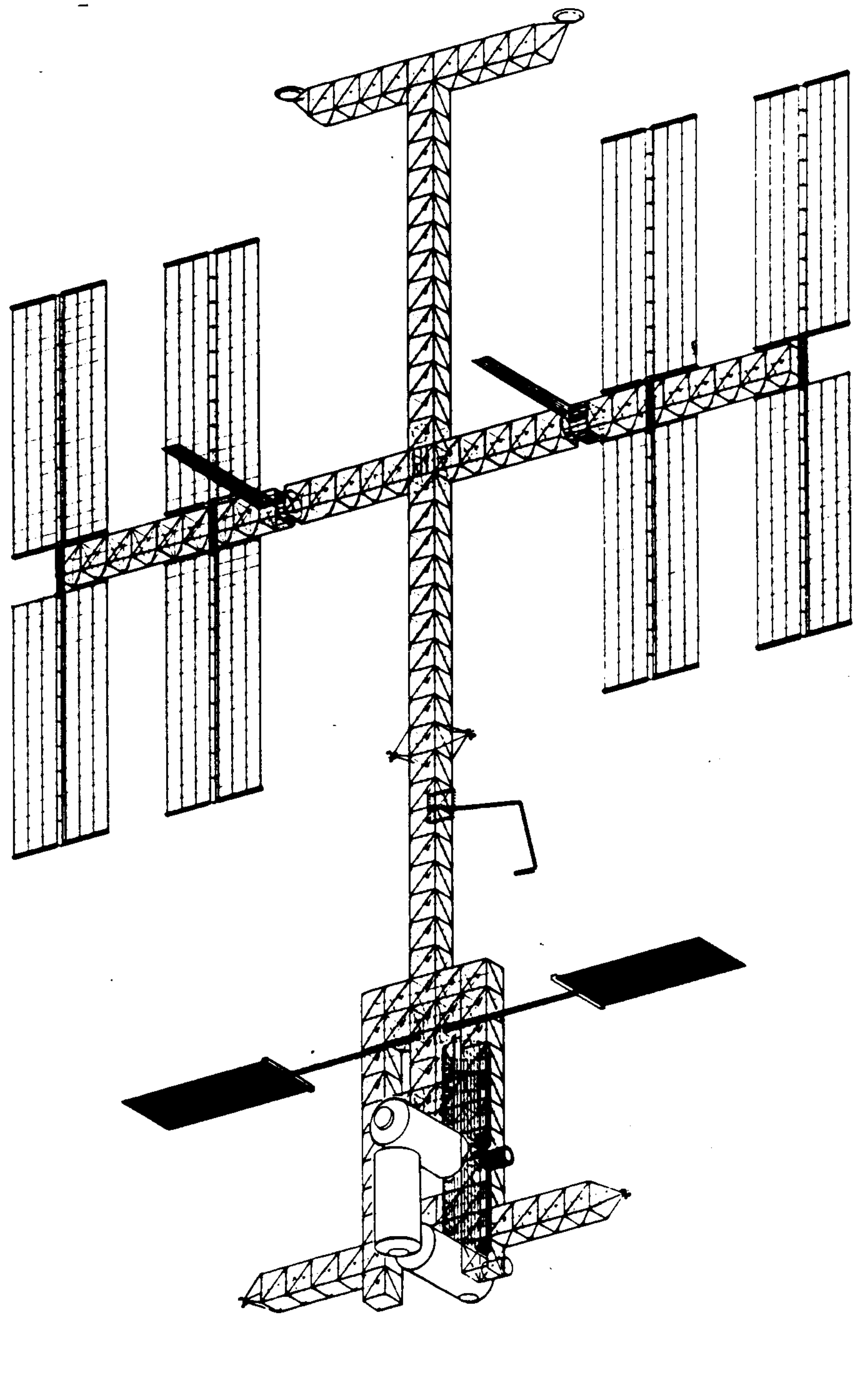


Figure 4-35. IOC Configuration

The activities required to emplace and activate payloads and experiments should not present any particular difficulties after the 7th mission. Internal (pressurized) payloads/experiments will be carried through from the Orbiter, through the habitation modules to the Laboratory Modules. Size limitations must be imposed to insure appropriate clearance through this path. In the Laboratory modules, the payloads/experiments will be placed on standardized racks with 'standardized' interfaces for power, SSDS functions, and thermal control as required. The checkout will be initiated with a power up, built in testing (BIT) operations. Scheduling of this testing and the monitoring of its results will be performed locally on the Laboratory work station. Voice and video communication will be available directly to the associated user agency for use as required. Once this checkout is complete, then the SSDS will be configurated to schedule the Payload/Experiments operations with respect to Space Station resources, and data management.

Externally mounted payloads, particularly the larger volume variety will be transported from the Orbiter bay, most likely under EVA control, to their structural mount. The payloads will be mounted at prepared locations with the standard interfaces to electrical power, thermal control, and the SSDS. Rotating mounts will be available as required. Portable MPACs will be utilized by the EVA personnel to support the initial checkout and appropriate configuration of the payload. Voice communication will be transmitted to the associated user along with video provided by remote cameras. Provisions must be made to support this local operation of the MPAC and video camera. Once the payload has been judged operational, its schedule will be established via command through the MPAC to the SSDS scheduling function.

The scenario proposed for this initial build up provides a key advantage in that on-orbit integration and verification is performed incrementally, allowing early and continuous evaluation of each subsystem as deployed. Thus adjustments and corrections can be applied in a more timely manner. This approach is, of course, heavily dependent on, and strengthens the arguments for a distributed subsystem architecture. The alternative, centralized approach would necessitate deferment of any significant system verification until the major elements of the Station had been assembled and presents a somewhat higher risk to the over-all program.

4.4.4 Space Station Growth Scenario

A growth phase for the Space Station is predicated on currently projected mission manifests and foreign (international) Station involvement plus addition of the Orbital Transfer Vehicle (OTV) with its mission operation and servicing requirements. It is also anticipated, however, that the reality of an operational Space Station will stimulate unscheduled demands for payload/experiment support in both high and low earth orbits. This support will translate into additional laboratory modules and payload truss mounts, additional habitation modules, additional structure, and additional capacities in all sub-systems as diagrammed in Figure 4-36. While some elements and options of growth can be formulated to a reasonable degree, the actual growth path cannot be defined because of the mission demand uncertainties and to a lesser extent, the unpredictability of technological advances.

With respect to the SSDS, the key growth drivers will be: 1) increased volumes of data to be handled at higher data rates, 2) increased free flyer (and tethered) traffic, and 3) increased space/space and space/ground communications requirements. More processing power, more mass memory, and higher data transfer capacities will clearly be required, coupled with improved space/ground communication paths, i.e. TDAS and direct broadcast. Growth activities are expected to occur in discrete and potentially independent steps. The distributed SSDS topology anticipated for IOC appears, therefore, to provide an optimum baseline for the growth scenario, but must incorporate flexibilities for growth that have been planned from the inception of the program. 'Scarring' (built-in growth accomodation), will be provided wherever practical within the space elements, to absorb or anchor the additional capacitities and resources.

The growth activities provide the opportunity not only to increase mission support capabilities, but also to reduce operational costs through technology

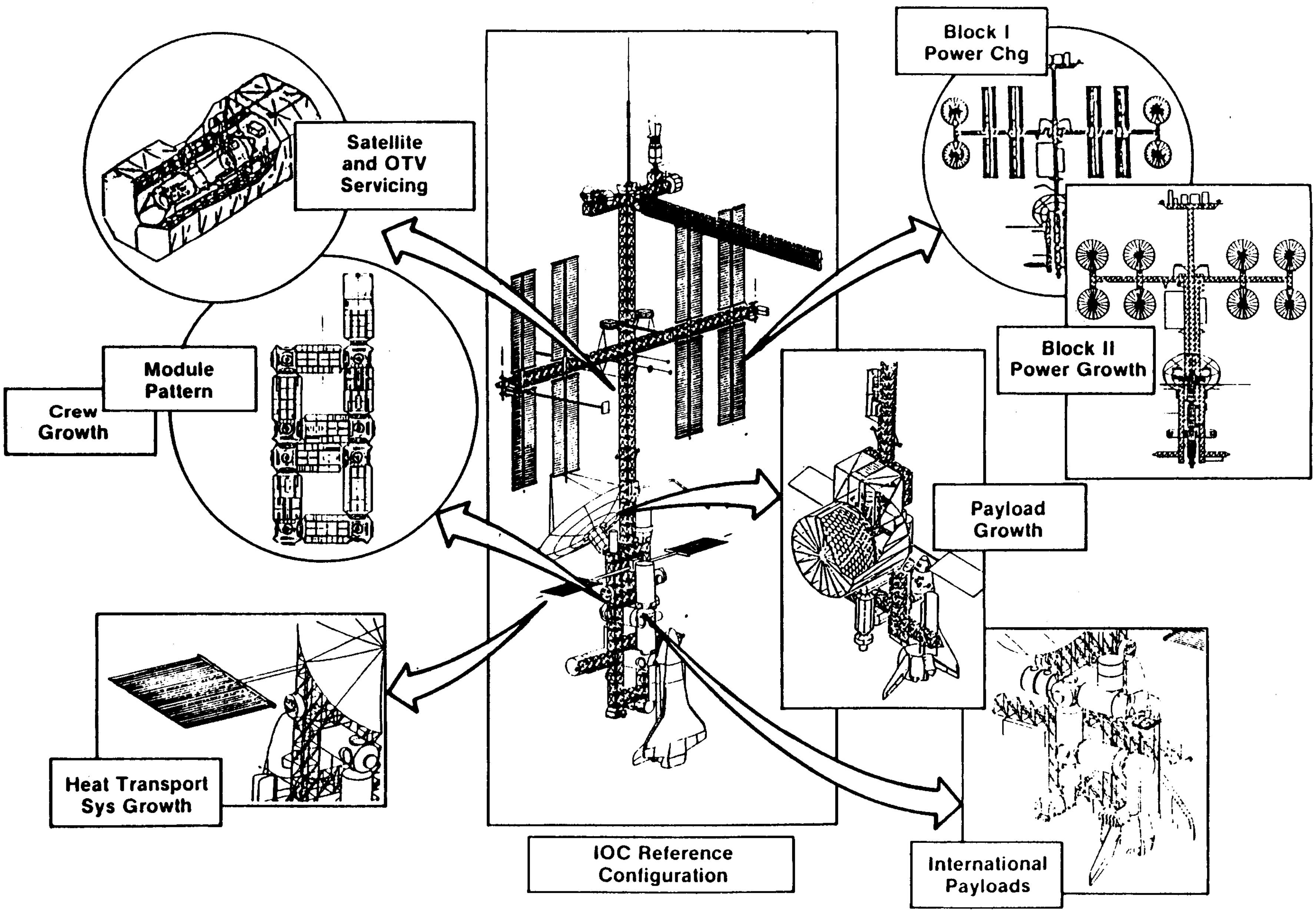


Figure 4-36. Growth Issues

upgrades, and to reduce ground support requirements through implementation of more Station automation and autonomy. Technology upgrading (or insertion) will be supported through continued use of standardized hardware such that higher performance, higher reliability products of reduced size, weight, power and cost can be 'dropped in' with minimal impact. Greater automation and autonomy will require more use of artificial intelligence and robotics, both of which are expected to proliferate in the growth time frame.
The specific drivers and impacts of growth are discussed in the following paragraphs.

4.4.4.1 <u>Ground Segment</u>

The growth of the ground segment and its drivers cannot be specifically tracked since significant changes in the configuration of the space/ground link are expected within the growth period. Thus, although the projected mission set may generate higher aggregate data rates and volumes, addition of improved beam switched communication satellites and/or direct broadcast will relieve much of the ground data handling/distribution demands through use of more distributed approaches.

There will be a continuing effort to reduce operational costs of the SSDS ground system by reducing ground crew requirements through the use of enhanced automation and 'expert systems', and through the use of more reliable, more fault tolerant hardware to reduce down time and maintenance requirements.

Software upgrades will be an implicit part of growth to correct identified deficiencies and enhance user (customer and ground crew) utility. This is likely to be a significant program cost driver beyond initial development costs. Provisions for cost effectively accommodating software upgrades must be a major consideration in early definition and planning.

No significant technical drivers can be identified in these 'growth' modifications since the ground elements are not impacted by volume, weight, power constraints or accessibility limitations. Addition of ground terminals within regional data enters or remote customer facilities to accommodate direct broadcase will be accomplished with no particular difficulty. In summary then, the SSP ground segment 'growth' can be characterized as:

1) enhancements to the space/ground communication and data distribution, supported at least in part by direct broadcast from Station or through advanced communication satellites

2) enhancements in data handling, resource planning/scheduling, etc. utilizing 'expert systems'.

and 3) software upgrades to correct identified deficiencies and improve user utility of the SSDS with a relatively unconfined environment.

The issue to be resolved is that of location and capability of the Data Handling Center (DHC). Current planning, co-locates the DHC at the White Sands Ground Terminal. When direct broadcast to the Regional Data Centers (e.g., TDAS) is implemented the DHC functions that are duplicated with the Regional Data Centers will disappear. The majority of the remaining functions will migrate to orbit. The IOC location of the DHC should consider the smooth transition to the growth phase.

4.4.4.2 Space Segment

The Space segment, in contrast, will be continually constrained by volume, power, weight, and accessibility. In addition, sub-system capabilities cannot be significantly impaired during growth rework.

As indicated in the Background section, the demand for additional payload/experiment support translates to additional structure, additional laboratory and habitability modules, and additional sub-system capabilities. The laboratory modules will house the added payloads/experiments along with additional Comm & Tracking and DMS hardware/software for their support. The habitability modules will house additional DMS equipment including normal MPAC's, and will support additional crew personnel, including mission specialists as required. The additional structure will be required for the attachment of these modules and any for additional external payload/experiment support.

Sub-system expansion must occur across the board to provide the increased capacities in the areas of power generation, thermal dissipation, attitude control etc. The primary impact on the SSDS, however, is from the growth requirements of data handling, data base management, and communications although the distributed topologies postulated in the Build-Up scenario should adequately support expansions of the data/data base management capacities. Growth of the SSDS functions will be facilitated by spare capabilities built in to the IOC configuration. Spare network nodes, for example, and even spare networking can be provided in the IOC configuration along with the required additional sub-system associated cables and ducts. Local area networks (LAN's) within each added module can therefore be readily linked to existing backbone networks or to new backbones which are bridged to those existing. The data/data base management equipment within those modules will provide the horizontal growth required.

Clearly, some vertical growth can be implemented through technology insertion, the replacement of existing ORU's or perhaps single card's to provide more faster, lower power, or (for the Polar Platform(s)) more radiation tolerant hardware.

Continued utilization of standards will be mandatory in the growth phase to insure compatibility of physical and logical interfaces such that replacement hardware and software will essentially be a 'drop-in' operation, transparent to the system operation.

Foreign involvement is anticipated in the Space Station and may take the form of additional modules with potentially differing LAN topologies. Interfacing these modules to the SSDS can be effected through imposed standards or through the use of internetwork gateways.

Some growth will have more of an impact, particularly if specialized solutions are implemented for functions previously performed by general purpose hardware. A primary example of this is the area of artificial intelligence. A.I. machines and software will be further exploited during growth phases of the SSP. Functions such as scheduling, operations sequencing, configuration and resource management, crew support i.e. physiological, biological, training are all strong candidates for A.I. expert system solutions. An implementation option, in such cases would be to house these new solutions in the added habitation modules. The function would then merely be with minimal disruption to function operation.

The most significant driver to SSDS growth will be the management of the data that is collected from the additional experiments/payloads and free-flyers and delivered to the communication port(s) for transfer to the ground. This volume of data may require new solutions perhaps beyond the capabilities of the TDRSS link(s), particularly in a multiple COP and POP scenario. Improved and multiple communications ports may be required to implement direct transmission to ground or use of multiple satellites with advanced technologies.

The space segment growth scenario therefore consists of the following tasks.

- replacement of ORU's and/or component cards to provide an expansion of capabilities.
- expansion of sub-systems to provide more additional resources and support capabilities.
- addition of structural elements and associated monitoring instrumentation.
- addition of the OTV to support high energy orbit transfer and servicing of payload.
- addition of lab and habitation modules
- addition of back-bone networks/bridges/gateways for the additional modules/nodes
- addition of data management/communication equipment to transfer the increased volumes and rates of data to the ground/users.

Verification of these additional/modified resources will be performed in the same fashion as described in the original build-up, i.e. no specific additional growth implementation issues are identified.

4.4.5 Operational Design Drivers

One of the purposes of the operational concept definition was to identify key SSIS and SSDS design drivers that result from the operational concept. A key design driver is an operational, functional, or performance requirement that is expected to have significant impact on the performance, complexity, risk, or cost of the system. The following key operational design drivers have been identified:

a. The need for system transparency as viewed by the customer will impact system complexity by causing special provisions to be implemented to minimize data transport delays and to minimize system interactions that might constrain or interfere with customer independence. Certain delays are inevitable because of communication path propagation times and link outages. Additional delays, such as those caused by processing, reformatting, conflicts, or capacity limitations, need to be minimized in the design in order to provide good functional transparency.

b. The quantity of data archiving requested by customers and the need to provide wide, easy-to-use, access to the archived data will influence the capacity and complexity of the system.

c. The amount of customer data processing beyond Level 0 will drive the capacity of the processing resources in the SSIS.

d. The amount, type, and quality (accuracy, precision, etc.) of ancillary data requested by the customer will influence the SSIS processing resources significantly.

e. The level and implementation plan for autonomy/automation provisions will have a profound effect on system processing resource requirements. The need for autonomy and automation also will influence the basic system architecture and the design implementation of subsystems.

f. The number and physical distribution of customers will impact the networking, complexity of interactive scheduling, and the difficulty of dealing with restricted and constrained commands.

g. The degree to which customers are involved in payload operation, especially real time command and monitor and short term schedule changes, will drive operations approaches and affect the complexity of the scheduling, command management and data handling functions.

h. The number of customers competing for limiting system resources will also impact the complexity of scheduling and system operation.

i. The Space Station is expected to undergo extensive growth modification and upgrade during its lifetime. New technology must be accommodated, providing ready means for its integration.

Section 5
SSIS/SSDS FUNCTIONAL REQUIREMENTS

This section contains the functional and performance requirements developed in Task 1. The SSIS functional requirements are given in Section 5.2, together with the performance drivers. The SSDS functional requirements are given in Section 5.3. Section 5.4 provides a summary of SSDS functional and performance requirements which will have a major effect on the SSDS design.

The discussion of requirements is divided between the SSIS and the SSDS. Discussions of the SSIS, because of its broader scope, will be centered on the SSPEs. The SSPEs and their roles have already been identified in Section 4.2. In Section 5.2, the discussion will cover the functions and key performance drivers. Discussions of the SSDS will be centered on functions and their decomposition to lower-level functional requirements.

5.1 REQUIREMENTS ANALYSIS METHODOLOGY

The functional requirements have been developed from previously published documents, from the team data base, and from engineering analysis. Functional requirements from the controlling documents (References 1, 2, and 3) were identified and entered into the traceability matrix. Details of this process are given in Section 5.5, and the complete traceability matrix is given in Appendix A.

In addition, two top-down analyses were conducted in parallel to develop SSDS functions. A function tree was developed from prior analyses and logical decomposition of functions to successive levels. In parallel, data flow diagrams were developed to level 1 for all functions, and to levels 2 and 3 selectively for some of the complex or critical functions. These parallel analyses provided an extremely valuable cross check of the completeness of the functions required of the SSDS.

The function tree and data flow diagrams were merged to form an integrated, hierarchical set of SSDS functions. The function set was checked for completeness against the SSIS and SSDS requirements. Each of the requirements was mapped to an appropriate function. Where no appropriate function was found, a function was added to provide for the SSIS requirement.

The result is a validated, integrated set of SSDS functions, traceable to the requirements and/or analyses that were used to identify the functions. The functions are fully responsive to the requirements, and are sufficient to perform all identified SSDS operations.

The final function list is contained in Appendix A, Section A-4. Figure 5-1 shows the top three levels of the function tree. The number of SSIS requirements mapping to each function is shown in parentheses after each entry. Most of the functions are supported at this third level by multiple requirements. Some of the broader or more generic requirements were mapped only to the second level. These requirements also support the lower level functions. There are, therefore, many requirements supporting each function at the third level, considering the flow down of the requirements from the higher level.

Space Station Program Elements (SSPEs) were identified and allocated to SSDS or to the non-SSDS portions of the SSIS in Section 4.2. Requirements pertaining to non-SSDS elements and their interfaces were collected by SSPE. These requirements are delineated in Section 5.2. Requirements pertaining to SSDS elements were collected by SSDS function in the hierarchical structure of Figure 5-1. These requirements are delineated in Section 5.3.

An SSIS Functional Requirements Data Sheet, Figure 5-2, was prepared for the functions in the function tree at a level which will support definition of design requirements. The functional requirements from these data sheets have been entered into a computer-based requirements data base. Output reports are found in Reference 14. Key performance requirements identified for those functions are collected as SSDS performance requirements in Section 5.4. Only those requirements affecting the overall SSDS performance were considered. Hence, the performance requirements relate to quantities of data, rates of throughput, and timeliness of operation. Wherever possible, representative

SSDS FUNCTIONS

1.0 MANAGE CUSTOMER/ OPERATOR DELIVERED DATA (37)	2.0 MANAGE CUSTOMER/ OPERATOR SUPPLIED DATA (23)	3.0 SCHEDULE AND EXECUTE OPERATIONS(5)	4.0 OPERATE CORE SYSTEMS(1)	5.0 MANAGE SSDS FACILITIES(2)	6.0 DEVELOP SIMULATE INTEGRATE AND TRAIN(5)	7.0 SUPPORT SPACE STATION PROGRAM(0)
-1.1 MANAGE REAL TIME DATA RETURN (11)	-2.1 VALIDATE PAYLOAD COMMANDS/ DATA (18)	-3.1 DEVELOP RECURRING OPS MASTERS (8)	-4.1 OPERATE GN&C SYSTEMS (67)	-5.1 MANAGE FLIGHT FACILITIES (16)	-6.1 INTERPRET MODEL REQUESTS (2)	-7.1 MAINTAIN INTEGRATED LOGISTICS PLAN (4)
-1.2 MANAGE DELAYABLE DATA RETURN. (6)	-2.2 CHECK PAY-LOAD COMMANDS/ DATA (13)	-3.2 DEVELOP SHORT TERM SCHEDULE (20)	-4.2 OPERATE NON-GN&C CORE SYSTEMS (103)	-5.2 MANAGE GROUND SYSTEM FACILITIES (4)	-6.2 DEVELOP COMM. MODEL CONFIG. (2)	-7.2 LOG CUST. SYSTEM USAGE (4)
-1.3 DATA DISTRIBUTION (5)	-2.3 VALIDATE CORE COMMANDS/ DATA (2)	-3.3 DEVELOP OPERATING EVENT SCHEDULE (10)	-4.3 CREW SUPPORT (77)		-6.3 SIMULATE COMM (7)	-7.3 MAINTAIN TECHNICAL DOCUMENTS (2)
-1.4 MANAGE DELIVERABLE CUSTOMER DATA (45)	-2.4 PROVIDE ANCILLARY DATA (13)	-3.4 SEQUENCE OPERATIONS (6)	-4.4 SPECIAL CUST. AVIONICS SERVICES (16)		-6.4 DEVELOP HDW CONFIG. (10)	-7.4 CONTROL INVENTORIES (2)
-1.5 MANAGE DELIVERABLE CORE DATA (3)	-2.5 SUPPORT CUSTOMER SYSTEM OPERATION (68)		-4.5 MONITOR AND STATUS SYSTEM (30)		-6.5 SIMULATE GS SYSTEM (13)	-7.5MANAGEMENT CONFIGURATION (1)
	-2.6 SSPE CHECKOUT & SERVICING (7)				-6.6 DEVELOP S/W CONFIG (12)	
					-6.7 SIMULATE PROCESSORS (10)	
					-6.8 CONDUCT TRAINING (14)	
					-6.9 DEVELOP SOFTWARE (14)	

ADDITIONAL REQUIREMENTS NOT ALLOCATED TO FUNCTIONS

GENERAL PERFORMANCE	(1)
GENERAL DESIGN	(51)
SSIS/SCS, NOT SSDS	(48)
TMIS	(26)

* Numbers in parenthesis refer to the number of requirements traced to the function at the level indicated.

NOTE: Requirements listed at a higher level are generally applicable to all lower level functions.

Figure 5-1. Top Level SSDS Function Tree

SSDS FUNCTIONAL REQUIREMENTS DATA SHEET

Prepared by: ____________ Revised by: ____________ No. ____ Date: ____________

Function Number, Name: ____________

Function Type: ____________ Program Phase: Initial ____ Growth ____

Description: ____________

Function Sources: ____________

Criticality: Recovery Time ____________ Impact ____________

Data Privacy Code: ____________

Alarms/Annunciations: Required? ____________ Number ____________

Input:	#1	#2	#3	#4	#5
Type, Trigger					
Source					
Rate					
Amt					
Output:					
Type, Trigger					
Destination					
Rate					
Amt					

ADDITIONAL REQUIREMENTS:

DESIGN CHARACTERISTICS:

Data Sources: ____________

Methodology: ____________

Response Time: I/O Delay Allowable ____________ msec

Command/Control: Level ________ Location ________ Rate ________ kbps

Data Quality: Maximum Bit Error Rate ________

Synchronization With: ____________ ____________

System Dependency Code: ____________

Physical Location Code: ____________

Diagnostics/Self Test: Required? ____________ Number ____________ Interval ____________

IOC CAPABILITY

Data Processing: Instructions Per Cycle ____________ Repetition Rate ____________

Processor Memory: Program Size ________ Data Reqmt ________

Data Storage: Secondary ____________ kBytes Perishability ______ % in ______ hrs

Archival ____________ kBytes No. of Displays ____________

GROWTH CAPABILITY

Data Processing: Instructions Per Cycle ____________ Repetition Rate ____________

Processor Memory: Program Size ________ Data Reqmt ________

Data Storage: Secondary ____________ kBytes Perishability ______ % in ______ hrs

Archival ____________ kBytes No. of Displays ____________

Figure 5-2. Functional Requirements Data Sheet

data are drawn from the Woods Hole Mission Requirements (workshop). Engineering estimates are used where no applicable data are found.

Areas of major design impact which will be noted in the following sections are:

1. Peak data rates, especially for Space Station and POP payloads, will drive data throughput, onboard processing, and recording rates.

2. The combined data rate of the Space Station, COP and POP(s), including payload data, are to be transmitted to the ground via TDRSS. A single Ku-band channel is limited to about 300 Mbps. The combined average data rates of these facilities is approaching 300 Mbps. Hence, these data rates drive the system.

3. The requirement for real time, interactive control of payloads from a remote location will affect primarily the scheduling of data and command handling resources and communication links.

4. The data rates and requirements for on-line and short-term archival storage combine to drive the design of data storage systems. Onboard storage is driven by the scheduling of TDRSS downlinks. In-process storage at the Data Handling Center is driven by the requirement for 12 hours of in-process storage to ensure data delivery. Short-term archival storage is driven by the requirement for storage for one week after receiving data of satisfactory quality at the customer's facility.

5. The Network Control capability (NCC) must be expanded to accommodate the increased TDRSS traffic and to operate the Data Distribution Network. Implications to he NCC will be developed in Task 3 and 4.

5.2 SSIS FUNCTIONAL REQUIREMENTS AND DESIGN DRIVERS

This section defines functional requirements for the Space Station Information System (SSIS) and interfacing Space Station Program Elements (SSPEs). Section 5.2.1 provides the functional requirements related to the SSPEs and their interfaces with SSIS, together with the key requirements driving the SSIS/SSDS design. Section 5.2.2 defines customer requirements for standard services from the SSIS for those SSIS functions that were determined to be outside the SSDS by the criteria in Section 4.2. Customer requirements for the SSDS will be addressed in Section 5.3.

5.2.1 SSPE Functional Requirements

Each of the Space Station Program Elements (SSPEs) identified in Section 4.2 are either in the SSIS or interface with the SSIS/SSDS. Functional requirements allocated among the SSPEs, SSIS and SSDS, and key performance drivers are presented by SSPE in this section. The discussion is restricted to those elements identified in Table 4-3 as being in the SSIS, but not in the SSDS.

5.2.1.1 Space Station Payload Requirements

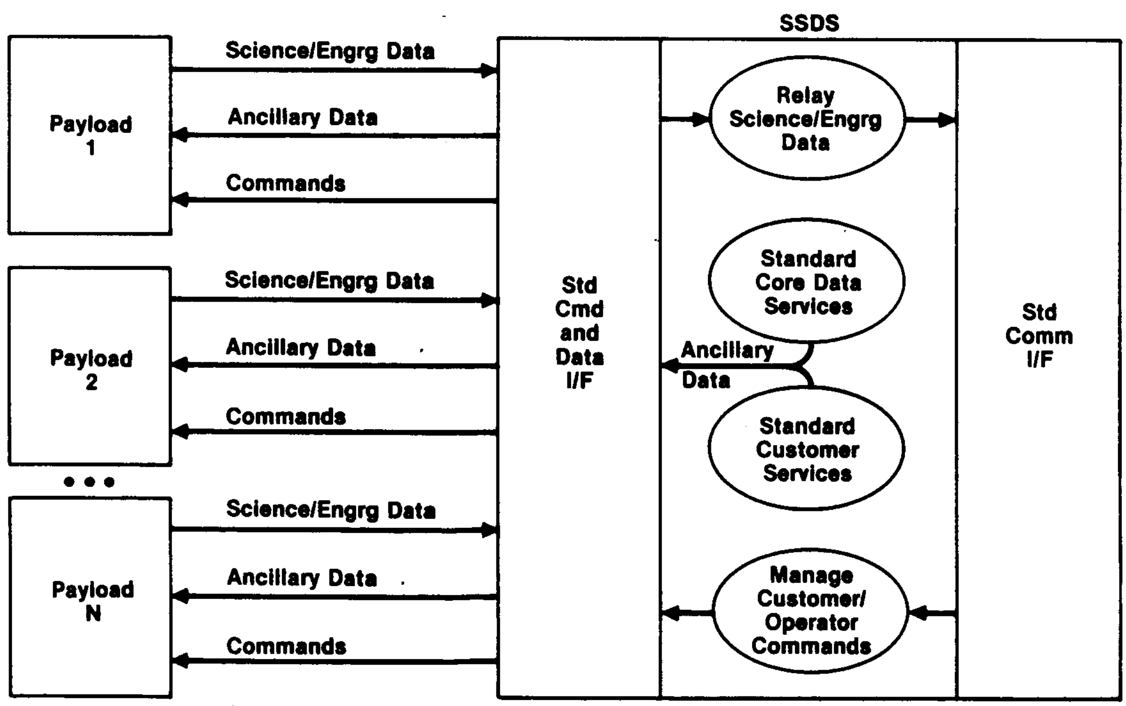
A) Payload Functional Requirements

The Space Station payload interfaces with the SSDS are illustrated in Figure 5-3. The payloads shall perform the following functions:

1. Receive customer/operator data and commands from the SSDS.
   a. Decode/de-encrypt data and commands protected by customer
   b. Execute prestored sequences of commands

2. Receive time and frequency references

3. Receive from SSDS standard core and customer data services, for example,
   - State vector
   - Ephemerides
   - Pointing angles, etc.



- Peak Science/Engineering Data Rate = 300 Mbps
- Average Science/Engineering Data Rate = 6.9 Mbps, 1994
  = 54.1 Mbps, 1997
- Average Command Data Rate = 2.8 kbps, 1994
  = 3.4 kbps, 1997

Figure 5-3. SSDS/Payload Data Interfaces

4. Generate and issue scientific/engineering data stream to the SSDS. The payload shall:
   a. Accept and merge Space Station ancillary data
   b. Provide error protection enhancement coding and security
   c. Encrypt as required
   d. Issue payload data stream in appropriate format
   e. Issue payload health and safety status monitors.

5. Utilize subsystem-protected, reconfigurable resources:
   - Electrical power
   - Thermal control
   - Fluids.

6. Provide fine pointing, as required by the payload, to supplement coarse pointing provided by the Space Station articulating payload mount. The customer shall be responsible for developing the coarse-pointing reference and delivering pointing requirements to the SSDS in the commands from the payload.

B) <u>Key Drivers</u>

1. Return Data Rates and Storage.

The IOC Space Station payload complement may provide an aggragate peak data rate of up to 302 Mbps. An estimated IOC (1994 reference date) onboard storage requirement of about 10^{10} to 10^{11} bits is based on the scenario of a single downlink data burst of about 5 minutes per orbit with data collected at the 14.9 Mbps (6.4 payload data plus 8 voice/video and core) average rate indicated in Table 6-9, during a nominal 90-minute orbit. The average data rate peak is 56 Mbps in 1996. Note that these rates include a 1.8 "scheduling factor" applied to missions with data rates less than 50 Mbps and apply to short term averages. See Section 6.4 for further discussion of average data rates. The corresponding onboard storage requirement is about 10^{10} bits for IOC and $3X10^{11}$ bits in 1997. These figures include Space Station core data and voice/video link requirements, and represent a significant impact on the return portion of the SSDS data management and communication subsystems.

2. Forward Data Rates.

The aggregate IOC forward link command rate is estimated at 3-4 kbps average for IOC and growth payloads. The rate does not include voice/video or Space Station core requirements. The total potential forward rate requirements represent an impact on the forward portions of the SSDS data management and communication subsystems.

3. Scheduling of Resources.

Mission model analysis yields an average IOC payload power consumption on the Space Station of 54 kw, neglecting possible redundancy between Comm 1201 and SAAX0401. The target IOC power system delivery is 75 kw of which 25 kw is allocated for SS housekeeping. Thus a power resource allocation/scheduling impact on the payload complement is indicated.

A crew of two station specialists and four mission specialists is forecast for the IOC Space Station. The crew resource matches the estimated payload support requirements on an averaged allocation; however, some impact is anticipated on day-to-day operations which will require scheduling flexibility.

5.2.1.2 Core System Requirements

A) Core System Functional Requirements

The Space Station core systems interfaces with the SSDS are illustrated in Figure 5-4. The core systems shall perform the following typical functions:

1. Maintain Space Station environment and communications links.

2. Accept and execute SSDS commands for
   a. Orbit maintenance

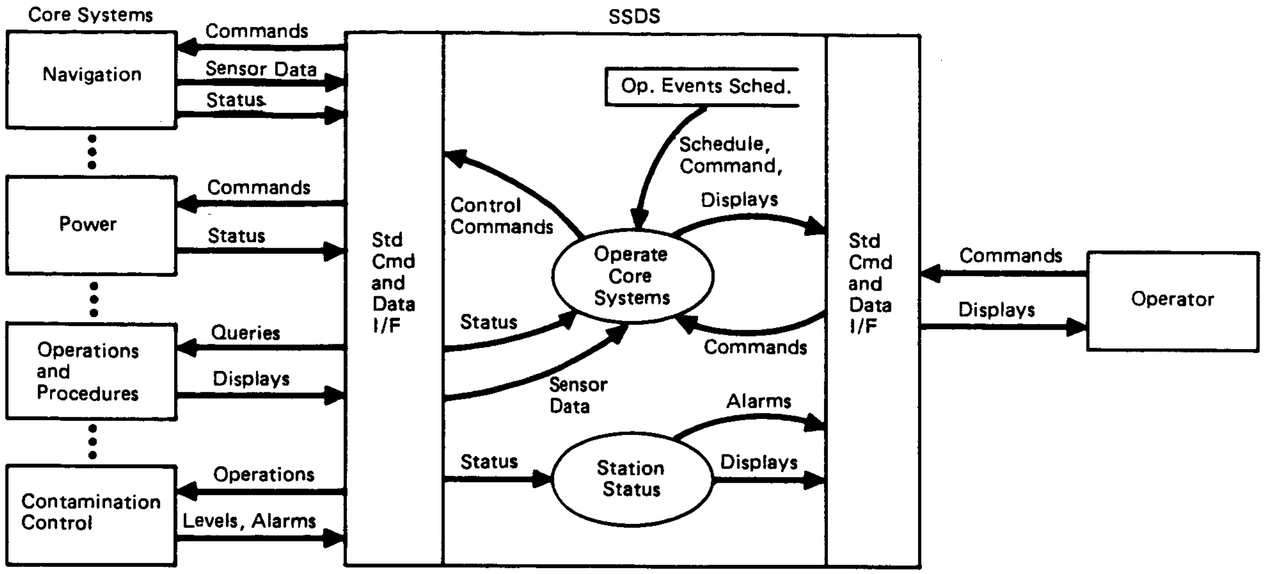


Figure 5-4. SSDS – Core Systems Data Interface

b. Collision avoidance

c. Attitude maintenance

d. Attitude changes to accommodate payloads

e. Crew health maintenance, recreation, and training

f. ECLSS reconfiguration

g. Thermal control subsystem reconfiguration

h. Power subsystem reconfiguration

i. Communication subsystem reconfiguration

j. Resource management

k. Redundancy management

l. Maintenance/repair/growth operations.

3. Generate engineering and status data

   a. Subsystem status

   b. Consumables status.

4. Generate caution and warning information on equipment operating limits and hazards to personnel and vehicle safety, and alert operators to unsafe conditions

B) Key Drivers

1. Data Rates and Buffering.

The high payload data rates will have a significant impact on the SSDS/communications subsystem design to provide

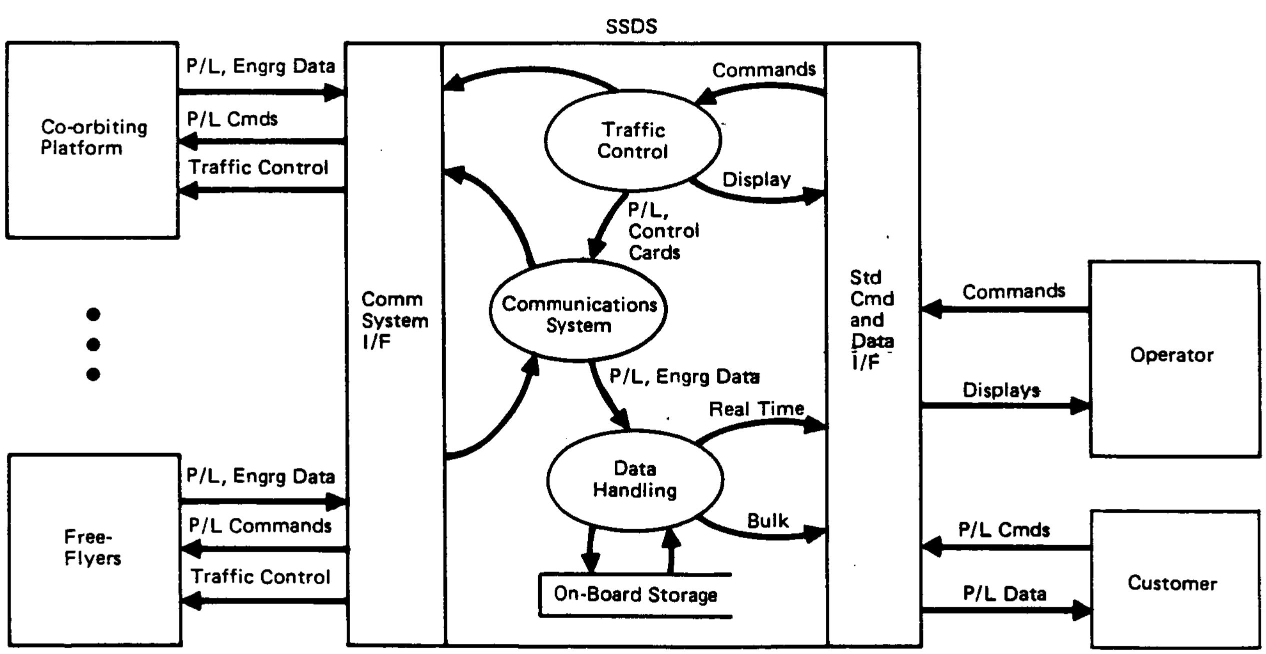
a. adequate data distribution and growth capability,
b. adequate data buffering and growth capability,
c. rapid reconfigurability to accommodate operations schedule changes

5.2.1.3 Co-Orbiting Platform Requirements

A) COP Functional Requirements

The co-orbiting platform(s) (COP) interfaces with the Space Station communications system are shown in Figure 5-5. Alternatively, the COP may interface directly with TDRSS. The COP shall perform the following functions:

1. Maintain orbit and attitude per performance requirements



Peak Science/Engineering Data Rate = 1 Mbps
Average Science/Engineering Data Rate = 1 Mbps
Average Command Data Rate = 1 kbps

Figure 5-5. COP, Free-Flyer — SSIS Data Interfaces

2. Receive commands and data via TDRS or Space Station relay and
   a. Error check data
   b. Validate data and command sources and destinations
   c. Distribute data and commands to individual payloads
   d. Execute orbit, attitude, and resource adjustment commands.

3. Provide scientific/engineering data stream to co-orbiting platform control and customers via TDRSS or Space Station relay, and
   a. Collect scientific/engineering data and merge to data stream
   b. Encode, modulate, and transmit return link data via TDRS.

   NOTE: Platform ancillary data are provided to payloads for their own merging.

4. Receive and execute traffic control and proximity operations commands from Space Station while in Constellation area.

5. Receive and execute COP Control Center orbit and attitude commands when remote from the Space Station.

B) <u>Key Drivers</u>

1. Return Data Rates and Storage Requirements.

   The IOC Co-Orbiting Platform payload data rate varies with mission assignment from 1 to 16 Mbps, with growth to about 100 Mbps in some mission models. Reference 15 seems to show 1 Mbps peak and average with no growth. The onboard storage requirement is estimated to be about $5X10^9$ bits based on the 1 Mbps average data rate of Reference 15, and of a single downlink burst during each 90-minute orbit. The onboard storage requirement may apply either to the Space Station, the platform, or both, depending on whether the platform transmits directly to TDRS or uses the Space Station to relay data.

5.2.1.4 Co-Orbiting Platform and Free Flyer Control Center Requirements

A) COP and Free Flyer Control Center Functional Requirements

The COP and Free Flyer control center interfaces with the Space Station Control Center are illustrated in Figure 5-6. Both control centers shall also interface with the TDRSS ground station (optional) and the Data Handling Center. The COP and Free Flyer Control Centers shall perform the following functions:

1. Plan and schedule Spacecraft operations
   a. Maneuvers
   b. Data links.

2. Provide mission control data to the SSCC or TDRSS ground station for relay to the Spacecraft
   a. Attitude and orbital adjustments for nonproximity operations
   b. Core system data and commands.

3. Receive engineering data from the Data Handling Center.

4. Coordinate with the SSCC for rendezvous with the Space Station or OMU for payload or Spacecraft servicing and maintenance.

B) Key Drivers

None identified.

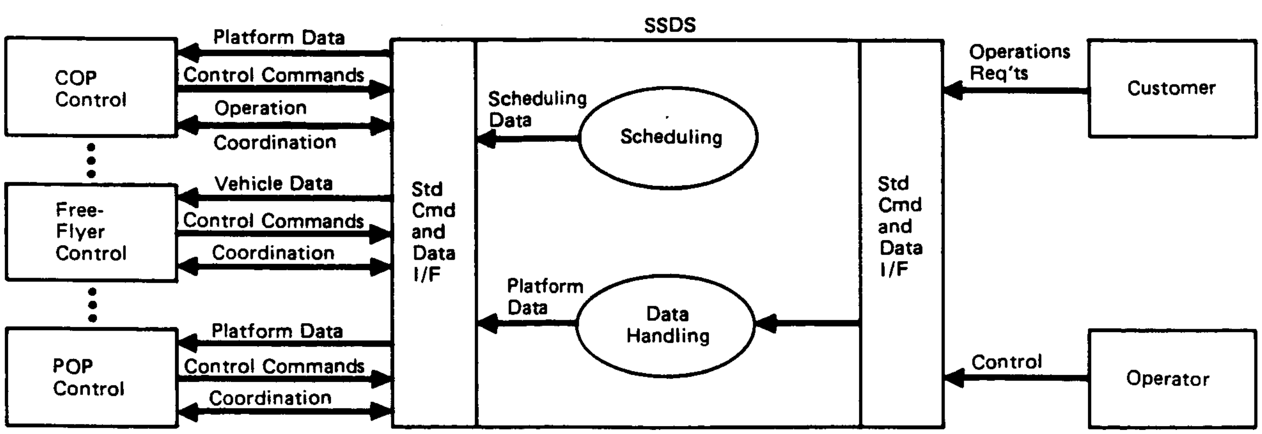


Figure 5-6. COP, POP, Free-Flyer Control — SSDS Data Interfaces

C-3

5.2.1.5 Polar Platform

A) POP Functional Requirements

The Polar Platform (POP) shall have no direct orbital interfaces with the Space Station. The POP shall perform the following functions:

1. Maintain orbit and attitude to performance and mission requirements.

2. Receive commands data from Polar Platform Control via TDRS distribution network and
   a. Error check data
   b. Validate data and command sources and destinations
   c. Distribute data and commands to individual payloads
   d. Execute orbit, attitude, and resource adjustment commands.

3. Provide scientific and engineering data stream to Polar Platform Control Center and customers via TDRSS and the Data Handling Center.
   a. Collect data from the commercial and scientific, and merge to data stream
   b. Encode, modulate, and transmit downlink data to TDRSS.

   NOTE: Platform ancillary data are provided to payloads for merging prior to downlink.

The mission model of Reference 15 indicates three POPs, designated POP-1, POP-2 and POP-3.

B) Key Drivers

1. Return Data Rates and Data Storage Requirements

   The proposed complement of POP payloads has an aggregate peak data rate of 393 Mbps for POP-1, 300 Mbps for POP-2 and 76 Mbps for POP-3 at IOC for each POP. POP-1 data rates grow to 669 in 1995. An estimated storage requirement of about 0.5×10^{12} bits for POP-1 and 10^{11} bits for POP-2 and -3 derives primarily from buttering high rate missions through the exclusion zone. It was assumed that only the highest rate mission would operate through the exclusion zone on any single pass. These figures represent a significant potential impact on the POP data management and communication subsystem design.

5.2.1.6 Polar Platform Control Center

A) POP Control Center Function Requirements

The POP Control Center shall interface with the Space Station Control Center, the TDRSS ground station, and the Data Handling Center. Interfaces with the SSCC were shown in Figure 5-6. The POP Control Center shall perform the following functions:

1. Provide scheduling, and operations control for Polar Platform.

2. Coordinate scheduling requirements for data links with Network control center.

3. Provide scheduling and command management for coordinated payload operation between the Space Station and POP.

4. Receive POP engineering data from the Data Handling Center.

B) Key Drivers

None identified.

5.2.1.7 Tracking and Data Relay Satellite (TDRS)

A) TDRS Functional Requirements

The TDRS shall be the primary data link for the Space Station and platforms. The TDRS shall

1. Receive reconfiguration commands from White Sands Ground Terminal (WSGT) for antenna pointing, frequency, and modulation, etc., to transmit and receive payload data.

2. Receive and forward link signals from TDRS ground station.

3. Retransmit forward link data to the Space Station Communications Subsystem, COP Communications Systems (optional), Polar Platform Communications System, and other SSPEs such as OMV and OTV when these SSPEs are not using other links for communication with the ground (users are discriminated by frequencies, polarization, PN code, and communication beam pointing).

4. Receive return link signals from Space Station Communications Subsystem, COP Communications Systems (optional), and Polar Platform Communications System (users are discriminated by freqencies, polarization, PN code, and communication beam pointing).

5. Retransmit return link signals to TDRS ground station.

B) <u>Key Drivers</u>

1. <u>Return Data Rates</u>.

The current planning is to effectively dedicate one to three SA channels to the Space Station program (SSP). This limits the SSP return link data rate to 300, 600 or 900 Mbps total data rate. These rates will place some new requirements or limitations on the SSP or TDRSS. A single channel limits return data operations of SS, COP, and POP and may translate to schedule constraints for payload operations. Two or three channels will require new and extensive equipment at the ground stations. In addition, the TDRSS is designed to operate at steady data rates, necessitating buttering and scheduling operation. These impacts will be more severe with the implementation of the proposed uplink and downlink video, real-time remote payload operation, and audio communicaions.

5.2.1.8 TDRSS Ground Station Requirements

A) TDRSS Ground Station Functional Requirements

The TDRSS ground station shall interface with the Space Station Control Center, platform control center(s) and the Data Distribution Center. The TDRSS ground station shall:

1. Provide forward link data and commands to TDRS:
   a. Receive packetized, framed data from the data distribution network
   b. Error check
   c. Provide data accounting
   d. Format and transmit data to TDRS per scheduled time, frequency, channel, and modulation.

2. Provide return link data to the Data Distribution Center
   a. Receive and capture TDRS data
   b. Transmit framed data.

3. Provide second source tracking data for SSPE navigation.

B) Key Drivers

1. Data Rates.

   The high payload data rates will significantly impact the current configuration of TDRSS Ground Station operation. Average data rates, including Space Station and platform engineering data and audio/video links, will approach 300 Mbps, while peak rates could exceed 600 Mbps.

5.2.1.9 Space Station Data Distribution Network Requirements

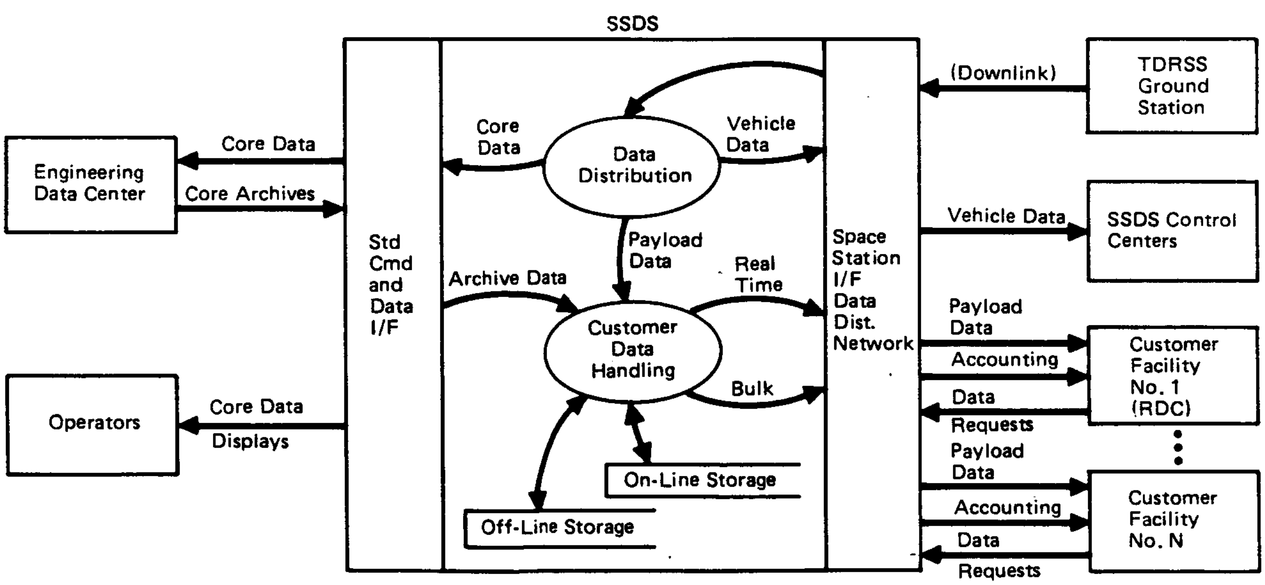
A) Data Distribution Network Functional Requirements

The Data Distribution Network interfaces with the TDRSS Ground Station, the Data Handling Center, customer facilities, RDCs, and SSPE control centers are illustrated in Figure 5-7. The network shall:

1. Relay forward link commands and data from SSPE and payload control centers to the TDRSS Ground Station.

2. Relay return link data from the TDRSS Ground Station to the Data Handling Center.

3. Distribute return link data to customers, data centers and control centers.



Average TDRSS Downlink Data Rate { = 108 Mbps, IOC; = 263 Mbps, 1999
On-Line Storage = 10^{13} Bits
Off-Line Storage = 2×10^{14} Bits

Customer Peak Individual Data Rate = 300 Mbps

Figure 5-7. Data Network — SSDS Data Interfaces

B) Key Drivers

1. Data Rates

The high data rates will require a major increase in the capacities of the current configuration distribution network. The average data rate between the TDRSS Ground Station and the Data Handling Center will approach 300 Mbps, while peak rates may exceed 600 Mbps. The aggregate rate from the Data Handling Center to customer and program facilities will also approach 300 Mbps.

5.2.1.10 National Space Transportation System (NSTS) Requirements

A) NSTS Functional Requirements

The NSTS shall support the Space Station program by providing transportation services, including

1. Coordinate rendezvous and berthing with the Space Station.

B) Key Drivers

None Identified.

5.2.1.11 NSTS Mission Control Requirements

A) NSTS Mission Control Functional Requirements

The NSTS Mission Control Center shall coordinate operations with the Space Station, including

1. Participate in and support scheduling for NSTS operations to transport payloads, SSPEs, crew and logistics supplies between the ground and the Space Station.

2. Support customer payload/NSTS integration, launch and space deployment.
3. Support SSPE/NSTS integration, launch, and space deployment operations.

B) Key Drivers

None identified.

5.2.1.12 Contractor Site Integration Facility Requirements

A) Contractor Site Functional Requirements

Contractor facilities shall interface with the software development environment and the integration facilities to coordinate the development and verification of applications software and the integration of hardware and software into the Space Station system, including the following:

1. Link to the SDE to utilize the software development and integration tools discussed in Section 4.4.2.4.2.

2. Link to the Development, Simulation, and Training Facility for system electrical and communications interface compatibility.

B) Key Drivers

None identified.

5.2.1.13 Network Control Requirements

A) Network Control Functional Requirements

The Network Control Center shall support scheduling of links, including the following:

1. Plan and schedule network operations, maintenance, and growth.

2. Provide routing, ID, TDRS channel, frequency, PN modulation assignments per SSP and other customer requests.

3. Provide rapid rescheduling of links in support of customer window of opportunity or operating requests.

B) <u>Key Drivers</u>

1. Data Scheduling

   The high data rates represent a major increase in network performance requirements which will necessitate additional communications channels and intensive scheduling for data handling, buffering, temporary storage and distribution.

2. Operation/Configuration Scheduling

   An impact is anticipated in responding to SSDS schedule change requests to accommodate customer "windows of opportunity". Policies must be established supported by realistic reconfiguration capabilities.

3. Customer Real-Time, Remote Operation Complete

   Complete, two-way links between the customer and payload must be kept open continuously during real-time operation. Typical command rates range up to 100 Kbps, while data rates for most real-time, remote operation are under 1 Mbps.

5.2.1.14 OTV Requirements

A. OTV Functional Requirements

The Orbital Transfer Vehicle (OTV) shall interface with the Space Station. It shall be controlled from the Space Station during prelaunch deployment and postrendezvous retrieval. The OTV shall perform the following functions:

1. Communicate with the Space Station
   a. Vehicle status
   b. Payload status
   c. Responses in support of deployment and retrieval operations.

2. Respond to Space Station control commands.

3. Berth to the Space Station for checkout and servicing.
   a. Provide diagnostics on OTV system status.

B) Key Drivers

None identified.

5.2.1.15 Customer Regional Data Centers (RDC) Requirements

A) SSIS Functional Requirements

The RDCs shall interface with the Data Distribution Network, and shall perform the following functions:

1. Receive, process, and archive payload return data.

2. Generate catalogs and indexes for archived data and provide query/accessibility.

3. Receive requested core ancillary data and process with payload data.

4. Provide SSDS entry point for uplink payload data and commands.

5. Provide SSDS entry point for schedule, configuration, and core ancillary data requests.

6. Receive dispositions to customer requests.

7. Provide alternative POCC services to customers.

8. Support customer data processing at all levels.

B) Key Drivers

None Identified. Data rates to be developed in Task 4.

5.2.1.16 Individual Customer Facility

A) SSIS Functions

Customers may use the support facilities provided by the RDCs or the payload operations center for all of their payload operations and data processing. Customers may also have their own individual facilities. Those not connected to an RDC must provide the RDC resources desired themselves. Those utilizing RDC support shall interface with the RDC and shall

1. Provide SSDS entry point for payload commands and data.

2. Provide delivery point for payload data (raw, pre-, or fully processed).

3. Provide SSDS entry point for schedule transactions
   a. Existing schedule examination
   b. Schedule requests/dispositions.

4. Provide SSDS entry point for core data requests
   a. Core data and processing level.

5. Process amd archive payload return data.

6. Generate catalogs and indexes for archived data.

B) Key Drivers

None identified.

5.2.1.18 Deep Space Network Requirements

A) SSIS Functional Requirements

The Deep Space Network shall

1. Provide communication link to OTV, when outside Space Station and TDRSS communications zones.

2. Provide backup, limited capability communications link for Space Station.

B) Key Drivers

1. Data Rates

In the event that DSN is used as a backup communications link, the downlink data sourced by SS, COP and POP must be configured to meet the capability (~85 Mbps) of this network, without causing unacceptable impacts on other DSN-dependent space vehicles.

2. Reduced Coverage

Use of DSN will impose severe constraints on orbital coverage of space elements, limiting communication traffic to the Space Station to an average of (TBD).

5.2.1.19 Space Station Integration Facilities at Launch Site

A) SSIS Functions

The Launch Site integration facilities shall interface with the SSIS for requirements and simulations, and shall

1. Support integration activity of payloads and SSPEs.

2. Support prelaunch checkout of payloads and SSPEs.

B) Key Drivers

None identified.

5.2.1.20 Alternative Communications Links

A) SSIS Functions

The customer may provide alternative communication links from his payload to his ground station, either by non-TDRSS satellite link or by direct broadcast. The SSDS shall be involved in this transmission only to the extent that interference with other SSP communication links is precluded. No independent customer command links are anticipated.

5.2.2 Customer Requirements for Standard Services From the SSIS.

The SSIS shall provide the following customer standard services exclusive of SSDS:

5.2.2.1 Data Processing Beyond Level 0. The SSIS shall provide or provide for the following standard customer data processing services:

a. Payload data processing to level 1A at a negotiated cost to the customer.

b. Support of production of level 1B data.

c. Facilities and software routines to support routine analysis of payload data for customers.

5.2.2.2 Data Archiving. The SSIS shall provide, as a standard service, data archiving beyond that necessary to ensure the satisfactory delivery of payload data to the customer's designated facility. The SSIS shall provide the following standard archiving services:

a. Maintain customer data archives including both level 0 and level 1A data as required.

b. Provide a data search and retrieval system for archived level 0 and 1A data.

c. Support long term archiving of level 0 and level 1A data for up to two years at a negotiated cost to the customer.

d. Provide a catalogue of archive data and support interactive customer access to the catalogue.

e. Provide an inventory of level 0 and level 1A data available from the archive, the characteristics of the data and sensor system, the level of processing and quality of data, associated ancillary data, where the data reside, and how to obtain the data.

f. Maintain a log of customer data transfer requests and their disposition, cataloging access information for file transfer and producing management reports on the transfer activity.

5.2.2.3 Provide Access to Space Station Programmatic Data. The SSIS shall provide a standard customer service to assist customers in obtaining standard programmatic data sets including

a. Space Station programmatic data, such as the master plan and customer payload inventory control.

b. Space Station administrative data, such as requirements for SSP-customer interfacing, resource utilization reports and billing for services rendered.

c. Space Station program descriptive data, such as the customer handbook and experiment long term planning support.

5.2.2.4 Data Exchange Among Customers. The SSIS shall provide, as a standard service, support for data exchange among customers. This support shall be provided at RDC's and other facilities, as appropriate.

5.2.2.5 Audio and Video Recording and Playback Between Elements. The SSIS shall provide, as a standard service, support for the capability for video recording and playback between any two elements of the Space Station program which are capable of exchanging video recording information.

5.2.2.6 Long-Term Mission Planning. The SSIS shall provide standard support service to customers to assist them in their long-term mission planning. These services shall include

a. Trajectory and rendezvous planning service relating to the Space Station.

b. Space Shuttle rendezvous with the Space Station and projected Space Shuttle manifests.

c. OMV and OTV planned launches and trajectory and rendezvous planning.

d. Platform trajectory and rendezvous planning services.

e. Trajectory and rendezvous planning services for other free-flyers.

5.2.2.7 Remote Workstations at Customer's Facility. The SSIS shall also provide, as a standard customer service, a portable remote workstation which may be located at the customer's home institution.

5.3 SSDS FUNCTIONAL REQUIREMENTS

This section presents the SSDS functional requirements, as derived from References 1, 2, and 3 and the systems analyses of Task 1. The SSDS must continue to perform many of these functions in the presence of various faults. Specifics are given in the criticality entries of Appendix A, Section 9. The requirements are organized according to the logical, end-to-end data flow structure of SSDS Level 0 data flow diagrams (Figure 4-3) and the complete functions list of Appendix A, section 4.

5.3.1 Functional Requirements to Manage Customer/Operator Delivered Data (Function 1.0)

The SSDS shall provide end-to-end handling of data originating in customer payloads and core systems. Specifically, the SSDS shall

a. Accept customer data from attached, platform, and free-flyer payloads and deliver the data to the customer's designated location. Customer data includes payload instrument data, engineering data, SSPE ancillary data delivered to the payload, processor dumps, and any other data available in or to the payload and required by the customer.

b. Accept core systems data and deliver to the Space Station Control Center, Platform Control Centers and Engineering Data Center.

c. Manage customer payload data.

d. Manage Space Station and Platform core systems data.

e. Provide data privacy (definition).

f. Time tag customer delivered data.

g. Manage Space Station Program engineering archival data retrieval and delivery to customers.

h. Perform data quality analysis at appropriate points throughout the system.

5.3.1.1 Additional Functional Requirement to Manage Real Time Data Return (Function 1.1). The SSDS shall provide for the capture, prioritizing, routing, dispatch, and packetizing of real-time and near-real-time data to customers and station operators, within the constraints of available data link schedules. Specifically, the SSDS shall support real-time and near-real-time data return by the following services:

a. Provide real-time, raw payload data to customer.

b. Relay level-0 payload and monitor data to customers in near real time for "quick look" monitoring.

c. Deliver core system monitor data to ground operators in real time or near real time.

d. Provide real time core data and critical payload data to ground operators to enable ground control of critical systems.

e. Account for real-time and near-real-time data until delivered.

5.3.1.2 Additional Functional Requirements to Manage Delayable Data Return (Function 1.2). The SSDS shall provide for the capture, prioritizing, routing, dispatch, and prompt delivery of bulk data from payload and core systems to customers and ground operators. Specifically, the SSDS shall

a. Accumulate bulk data from all payload sources and core systems.

b. Relay all data to the ground at least once per orbit, consistent with scheduling of available data links.

c. Account for all accumulated payload data until satisfactorily received at the customer's designated location.

d. Account for all accumulated core data until satisfactorily received at the program designated facility.

5.3.1.3 Additional Functional Requirement for Data Distribution (Function 1.3). The SSDS shall provide for general preprocessing, capture, routing and retransmission of real time, near real time, and delayable data to the designated end points. Specifically, the SSDS shall

a. Provide real-time distribution of real time and near-real-time data, including level 0 processing, demultiplexing, buffering, routing, and retransmission.

b. Provide for real-time reallocation of data distribution resources to support customer target of opportunity operation.

c. Provide prompt distribution of delayable data.

d. Provide temporary storage for data until confirmation of receipt.

5.3.1.4 Additional Functional Requirements to Manage Customer Data (Function 1.4). The SSDS shall manage the delivery of requested data to the customer, including data interface management, capture, handling, standard processing, and accounting of payload and ancillary data. Specifically, the SSDS shall

a. Acquire core ancillary data, in addition to the ancillary data merged into the customer payload data telemetry stream, including:
   (1) Space Station engineering and operations data
   (2) Space Station programmatic, descriptive, and administrative data
   (3) Related SSPE data
   (4) Related payload data.

b. Distribute data to local customers, including audio, video, and digital data.

c. Provide routine customer Level 0 data processing, i.e., data as output from the payload with reconstructed sensor formats, time ordering, full resolution, and merged ancillary data.

d. Provide temporary customer data archives to ensure satisfactory data delivery.

e. Provide customer data accounting until confirmation of satisfactory receipt:
   (1) Search, access, and retrieval
   (2) Catalog and inventory Level 0 and 1A data
   (3) Customer data tracking.

5.3.1.5 <u>Additional Functional Requirements to Manage Deliverable Core Data</u>. The SSDS shall manage the delivery of core data, including interface management, capture, data processing, and data display. Specifically, the SSDS shall

a. Support retrieval of archived core data.

b. Distribute core data to SSPE elements, including:
   (1) Space Station control center
   (2) Platform control centers
   (3) Free-flyer control center
   (4) OTV control center
   (5) OMV control center
   (6) Engineering data center.

c. Support delivery of core ancillary data to customers requesting specific data.

d. Provide core data archival storage.

e. Process and display data for Space Station operators according to standard, operator-selected formats.

5.3.2 Functional Requirements to Manage Customer/Operator Supplied Data (Function 2.0)

The SSDS shall provide end-to-end handling of commands and data originated by customers and operators. Specifically, the SSDS shall

a. Provide command, control, and data handling for all customer payloads on the Space Station, free-flyers or platforms.

b. Support remote operation of customer payloads, including real time entry of non-restricted commands, executable restricted and constrained commands, as processed in functions 3.2 and 3.3.

c. Support payload operation from the Space Station, ground control centers, and customer remote facilities.

d. Support transmission, reception, and distribution of customer audio, video, and digital data.

e. Support loading of customer provided on-board computers.

f. Provide the capability for crew or ground to modify, and/or delete software within the operating system consistent with operational safeguards to prevent impact to station operations.

g. Permit, with proper authorization, the ground or the payload specialists to generate or change, in a real-time mode, payload stored, automated command sequences for future execution on board platforms or the Space Station.

h. Provide distribution of commands and serial data loads to subsystems.

i. Log all commands and maintain a record of command disposition.

j. Report command and data disposition to the command source.

k. Verify that all transmitted commands, including those scheduled for later execution, are delivered to the customer interface and retransmit as required.

5.3.2.1 Additional Functional Requirements to Validate Payload Commands/Data (Function 2.1). The SSDS shall provide for authorization of commands and uplinked data flow to payloads and subsystems. Specifically, the SSDS shall

a. Provide a check of operator/customer identification to ensure that commands and data are being issued by an authorized customer/operator.

b. Perform simple syntax checks on the command data header.

c. Include provisions which prevent unauthorized access to all communication links.

d. Ensure that the operator is authorized to send commands or data to the address in the header.

e. Provide customer command and data entry accountability.

5.3.2.2 Additional Functional Requirements to Check Payload Command Restriction/Constraint (Function 2.2). The SSDS shall check each payload command, real time or deferred execution, to determine whether the command is restricted or constrained. Non-restricted commands and all data shall be passed directly to the addressed payload or to the Space Station processor scheduling operation of that payload. Restricted and constrained commands shall be checked against the appropriate restriction/constraint parameters, as outlined in Section 5.3.3. If found to be allowable at their scheduled execution time, the restricted/constrained commands will be executed as outlined in Section 5.3.3. If commands are not executable, an unacceptibility disposition report shall be promptly issued to the command source.

Specifically, the SSDS shall

a. Maintain a list of all customer commands indicating which are restricted, constrained, and non-restricted.

b. Provide for identification/differentiation of restricted, non-restricted and constrained commands and transmit or route to scheduling as appropriate.

c. Provide disposition of commands and data status to the customer.

d. Pass non-restricted commands directly to the customer payload with no further checking beyond that of the address of the payload.

e. Provide command management to protect the system from executing inadvertent and unauthorized (and restricted) payload commands that may affect crew safety and/or damage the station.

5.3.2.3 Additional Functional Requirements for Vehicle Core Commands/Data (Function 2.3). The SSDS shall provide for commands and data entered by the core system operators. Specifically, the SSDS shall

a. Verify that the operator is authorized to enter commands or data.

b. Verify that the operator is authorized to command the system addressed.

c. Check command or data header syntax.

d. Check commands for restriction or constraints.

e. Deliver non-restricted, real-time commands and data to their destination.

f. Process restricted or constrained commands as provided in Section 5.3.3.

5.3.2.4 Additional Functional Requirements to Provide Ancillary Data (Function 2.4). The SSDS shall make available and provide to customers a standard package of Space Station avionics, housekeeping, and special event data for inclusion in the payload data stream. The SSDS shall also make Space Station ancillary data to customers upon request. Specifically, the SSDS shall

a. Provide ancillary avionics and housekeeping data (timing, state vector, RF communication, System Status, Acquisition of Signal/Loss of Signal, moding, pointing, etc.) to attached payloads and customers.

b. Provide state vector data, attitude, attitude rate, and other special purpose information to support individual customer payload functions on the Space Station, Space Platforms, satellites, and free-flyers.

c. Provide ancillary data, when appropriate, to the customer's own equipment either on the ground or onboard, and in calibrated (engineering) units.

d. Routinely provide a time reference to an accuracy of 1 millisecond.

e. Provide orbit position data of a selected reference point for each Space Station system element to an accuracy of TBD meters.

f. Provide attitude data for each Space Station system element to an accuracy of TBD degrees.

5.3.2.5 Additional Functional Requirements to Support Customer System Operation (Function 2.5). The SSDS shall provide standard support functions to Space Station, platform and free-flyer payloads. These services shall range from data processing to payload checkout, servicing, and operation, as described in the ensuing sections. The SSDS shall provide general payload support in the following areas:

a. Provide moderate accuracy pointing of rotating payload mounts, as required for attached payloads to meet nominal pointing requirements. (High accuracy pointing shall be funded and provided by the customer.)

b. Support cooperative operation with co-orbiting platforms and their attached instruments, experiments and payloads.

5.3.2.5.1 Additional Functional Requirements for Customer Data Processing (Function 2.5.1). The end-to-end data support is primarily transparent such that as a basic service, the delivered data has the same form and content as that issued from the payload. However, some options will be available.

Specifically, the SSDS shall provide customers with options for

a. Payload data storage and processing facilities to support payload operation. Access to the services shall be provided through standard network interface nodes and attached work stations.

b. Monitoring payload housekeeping data.

c. A negotiated quick-look capability for level 0 data.

All customer unique software must be provided by the customer and must be compatible with SSP programming standards. All data processing and handling within the SSIS must be according to standard service practices.

5.3.2.5.2 Additional Functional Requirements for Customer Payload Operation (Function 2.5.2). The SSDS shall provide general support functions for customer payloads. Specifically, the SSDS shall

a. Provide for capability for independent customer operation and monitoring of payloads, including ground-to-payload command and monitor, consistent with safety and compatible with SSP operational constraints.

b. Provide for activation of payload stored command sequences by 1) time comparison with the space element onboard clock (to a resolution of 1.0 milliseconds), 2) initiation of a payload real-time command, 3) another stored command, or 4) event-driven sequences.

c. Provide health and safety monitoring of payload at customer request.

d. Provide, as an optional service, customer payload or process control.

e. Provide customer payload activation/safing services.

5.3.2.5.3 Additional Requirements to Support OTV Operations (Function 2.5.3). As part of the Space Station growth capability, the Orbital Transfer Vehicle (OTV) will be a key element in the transfer of platforms and/or free-flying payloads between the Space Station and high-energy orbits. The SSDS functional requirements include support of OTV operations, maintenance and servicing. Specifically the SSDS shall

a. Support the integration, checkout and launch of payloads and satellites with OTVs prior to transfer to high energy orbits.

b. Provide for maintenance, servicing, refueling and logistical resupply for OTVs.

c. Support deployment, launch planning, rendezvous planning, and retrieval of OTVs.

d. Relay OTV status to OTV control and customer.

e. Support handoff of OTV operation to OTV control center.

5.3.2.5.4 Additional Functional Requirements to Support OMV Operations (Function 2.5.4). The Orbital Maneuvering Vehicle will be operated and based at the Space Station and supported by the Space Station. Specifically, the SSDS shall

a. Provide support for the OMV to checkout, maintain, and service payloads, satellites, and platforms in low inclination, low earth orbits.

b. Provide support for the OMV to transport co-orbiting satellites and platforms between their orbits and the Space Station for servicing.

c. Provide for storage, maintenance, servicing, and refueling of OMV.

d. Support deployment, targeting, rendezvous, and retrieval of the OMV.

e. Support remote OMV operations for onsite maintenance and servicing of satellites and platforms.

5.3.2.5.5 Additional Functional Requirements for Customer Payload Checkout and Servicing (Function 2.5.5). The SSDS shall support all phases of customer payload checkout and servicing. Specifically, the SSDS shall

a. Support checkout of payloads and satellites after receipt from NSTS.

b. Provide a standard servicing interface, servicing equipment and EVA support equipment.

c. Provide for maintenance (instrument replacement, etc.), servicing (consumables resupply, battery recharge/replacement and checkout of remotely located payloads capable of maneuvering themselves to within the range of OMV or OTV.

d. Support the integration, checkout, and launch of payloads and satellites with transfer stages for deployment to other orbits.

e. Provide the resources to support fault detection and isolation to customer's payload.

f. Provide optional payload activation/safing services.

5.3.2.6 Additional Functional Requirements for SSPE Checkout and Servicing (Function 2.6). The SSDS shall support all phases of SSPE checkout, and servicing. Specifically, the SSDS shall

a. Support/interface with SSPEs and customer elements during assembly, growth, and servicing.

b. Support maintenance and servicing of OMVs and platform as an initial capability and OTVs as a growth capability including logistical resupply.

c. Support on site servicing within the capabilities of the OMV and OTV. Support servicing of the co-orbiting platform at the Space Station.

d. Support real-time operations, trend analysis, maintenance, and checkout of all SSPEs.

e. Support automatic servicing and performance checkout of the EMUs, MMUs and general EVA equipment.

f. Retain service data and performance trend data for use in defining the need for maintenance of all Space Station systems and equipment.

g. Provide the resources and services to differentiate between payload and SSIS faults.

5.3.3 Functional Requirements to Schedule and Execute Operations (Function 3.0)

The SSDS shall provide for the short term (estimated to be one to two weeks) scheduling and executing all operations required by the Space Station operators and all commands that are either restricted or constrained and entered by payload operators. The SSDS schedules shall be based on the master plan maintained by the SSDS with inputs from the Space Station Program and transmitted through the TMIS. Disposition of all commands entered will be shown to the operator or customer entering the command.

5.3.3.1 Functional Requirements to Develop Recurring Operations Masters (Function 3.1). The SSDS shall support customer and operator interactive development of normal day and major event operations masters. Both shall be used as baselines for developing the short term operating schedule for the Space Station program elements.

The SSDS shall support the development of recurring operations masters by

a. Supporting interactive payload planning and scheduling.

b. Integrating customer payload operating requests with Space Station resource availability.

c. Supporting customer requests for non-SSIS resources.

d. Providing projected data on Space Station resources

e. Interactively developing payload and Space Station operations schedules.

5.3.3.2 Functional Requirements to Develop Short Term Schedules (Function 3.2). The SSDS shall support the interactive development of short term Space Station schedules by Space Station system operators and customers. Specifically, the SSDS shall

a. Allow near-term planning entries by the onboard crew.

b. Coordinate communications allocations for all SSPEs with the network control center. Resolve all SSP requirements conflicts. Provide type of service, data rates, desired times, and allocations to SSPEs.

c. Support interactive planning by payload and core system operators, including significant orbital parameters, such as time, orbital position, and object ephemerides, which may influence payload and Space Station operations scheduling.

d. Provide indications of Space Station and Platform resource capabilities and availability to support payload output optimization.

e. Optimize utilization of Space Station and Payload resources and maximization of payload output.

f. Support rapid replanning to allow customers to take advantage of payload opportunities.

g. Support clearing of restricted and constrained payload commands to assist in real-time payload operation.

h. Support customer requests for non-SSIS resources.

i. Develop integrated Space Station Program operations schedules.

j. Provide accounting of the disposition of restricted and constrained commands.

k. Schedule use of Space Station resources by other SSPE's (e.g., platform, Space Station communications, crew time, etc.) and resolve conflicting requests.

l. Support interactive schedule development with appropriate data processing, input/output, and displays.

5.3.3.3 <u>Functional Requirements to Develop Operating Event Schedule (Function 3.3)</u>. The SSDS shall prepare an operating event schedule containing the time sequenced operating events in the short term schedule, together with the commands necessary to initiate these operations. Specifically, the SSDS shall

a. Check restricted commands and constrained commands for execution within the existing short term schedule.

b. Deliver immediately or incorporate into the operating event schedule, as appropriate, those restricted and constrained payload and core commands which are executable.

c. Alert the customer and operator to those restricted and constrained payload commands which are not executable in the current short terms schedule. Transfer these commands to Function 3.2 for disposition.

d. Support real-time reallocation of data distribution resources to help meet customer priorities. Coordinate communications requirements with Network Control.

e. Store customer payload commands for execution according to a schedule, sequence of events, or another stored command.

f. Provide accounting of commands incorporated into the operating event schedule.

5.3.3.4 Additional Functional Requirements to Sequence Operations (Function 3.4). The SSDS shall provide for the execution of the scheduled operations. Specifically, the SSDS shall

a. Activate stored payload command sequences based on time, sequence of events, or other stored command prompts.

b. Provide for the execution of core commands according to locally stored command sequences.

c. Provide accounting of commands issued.

5.3.4 Functional Requirements to Operate Core Systems (Function 4.0)

Core system include both the space and ground elements that are necessary to operate the Space Station, Platforms and their associated control and data handling program elements.

5.3.4.1 Functional Requirements to Operate GN&C Systems (Function 4.1). The SSDS shall provide the capability to operate the Space Station and Platform GN&C systems. The SSDS shall also support the control of proximity operations with other vehicles.

5.3.4.1.1 Functional Requirements for Navigation (Function 4.1.1). The SSDS shall perform navigation functions including:

a. Calculation of the Space Station and Platform navigation state vector.

b. Calculation of navigation state vectors for Space Station program elements. (Space Station only)

c. Incorporation of navigation state vector information from second sources.

d. Developing approach and departure trajectories for SSPEs. (Space Station only)

e. Delivery of navigation attitude and attitude rate information to customers.

f. Delivery of navigation information to payloads, including position to an accuracy of TBD meters.

g. Delivery of empherides data to assist in pointing of payloads, pointing mounts, and Space Station and platform appendages (solar arrays, radiators, antennas, etc.).

h. Determination of Space Station and Platform attitudes.

i. Providing the attitude to customers and payloads to an accuracy of TBD degrees.

j Providing an appropriate time tagging for all navigations state data to an accuracy of TBD msec.

k. Propagating the Spacecraft navigation state vector to specific states.

l. Propagating constellation navigation state vectors to specific states. (Space Station only)

m. Maintaining Space Station, Platform and constellation drag and gravity models.

n. Initiation of scheduling attitude and translation manuevers. (Note: these may also be operator initiated.)

5.3.4.1.2 Functional Requirements for Guidance (Function 4.1.2). The SSDS shall provide or support the guidance and orbit control of the Space Station and constellation elements. Specifically, the SSDS shall

a. Provide guidance for SSPE traffic control.

b. Provide guidance for approach and departure for SSPEs.

c. Support SSPE planned operations.

d. Coordinate reboost maneuvers among payloads and SSPEs.

e. Manage Space Station and Platform reboost, translation and attitude maneuvers.

f. Plan orbital maneuvers to avoid collisions with orbital SSPEs and debris.

g. Provide orbital re-entry targeting for disposal of SSPEs.

h. Provide Space Station and tether control when in tethered operations.

i. Totally or selectively inhibit RCS operation during periods of EVA and sensitive payload operations.

j. Command gimbal position and rate for Spacecraft controlled pointing mounts, radiations, solar arrays and communications antennas.

5.3.4.1.3 Functional Requirements for Attitude Control (Function 4.1.3). The SSDS shall support attitude control for the Space Station and selected SSPEs. Specifically, the SSDS shall

a. Establish and command the maintaining of the Spacecraft attitude.

b. Establish and maintain SSPE relative attitudes.

c. Provide planning informaion for SSPE operations.

d. Provide active Spacecraft momentum management.

e. Coordinate attitude maneuvers with SSPEs and payloads.

f. Provide dynamic stabilization between flexible body modes and attitude control.

5.3.4.1.4 Functional Requirements for Traffic Control (Function 4.1.4). The SSDS shall support local traffic control in the vicinity of the Space Station. Specifically, the Space Station SSDS shall:

a. Establish and maintain SSPE relative state vectors.

b. Accept second source relative state vector information.

c. Propagate constellation relative state vectors.

d. Monitor SSPE approach and departure trajectories.

e. Warn operators of unsafe traffic conditions.

f. Support development of collision avoidance commands.

g. Execute collision avoidance maneuvers.

h. Support berthing, docking, and separation operations.

i. Control OMV operations within the constellation.

j. Control OTV operations within the constellation.

k. Schedule rendezvous with satellites and free-flyers.

l. Control satellite and free-flyer maneuvers during proximity operations, via OMV or direct Space Station control of free flyer.

m. Provide powered guidance support to satellites and free-flyers.

5.3.4.1.5 Functional Requirements for Tracking (Function 4.1.5). The SSDS shall support tracking of objects in the vicinity of the Space Station and platforms. Specifically, the SSDS shall

a. Provide tracking and acquisition for detached vehicles.

b. Track all objects near or approaching the Space Station and platforms.

c. Provide target identification/discrimination and maintain accounting for all objects in the tracking zone based on propagated state vectors and tracking data. Use state vectors to account for objects not resolved because of proximity or obscuration.

5.3.4.1.6 Functional Requirements for Time and Frequency Management (Function 4.1.6). The SSDS shall support the maintenance of time and frequency standards for Space Station and payloads. Specifically, the SSDS shall

a. Provide a time reference to an accuracy of at least 1 millisecond.

b. Provide a frequency reference to at least TBD.

c. Support the generation of a more accurate time reference for payloads which require greater time accuracy.

5.3.4.2 Functional Requirements to Operate Non-GN&C Core Systems (Function 4.2). The SSDS shall support the operation of non-GN&C core systems. The support shall include system command and control, data handling, resource distribution and control, and monitoring and fault isolation of orbital replaceable units.

5.3.4.2.1 Functional Requirements to Operate Power System (Function 4.2.1). The SSDS shall support the operation of the Space Station and platform power systems. Specifically, the SSDS shall support

a. Automatic reconfiguration of electrical resources, loads and busses to optimize the collection of energy and to distribute electrical power to payloads and core systems according to the scheduled demands.

b. Automatic shedding of loads to control power consumption during periods of lower than planned energy, including various system faults.

c. Notification to operators of abnormal power conditions.

d. Reduction or shedding of power to payloads exceeding prescribed limits.

e. Evaluation of array and projection of energy available.

f. Array deployment and retraction.

g. Maintain power to critical systems during all system faults and emergencies. (Note: this requirement may be met autonomously by the power system.)

5.3.4.2.2 Functional Requirements to Operate Thermal Control System (Functions 4.2.2). The SSDS shall support operation of the thermal control system. Specifically, the SSDS shall support

a. Control of temperatures in electronic equipment and habitable units of the Space Station.

b. Management of customer payload thermal loads.

c. Management of Spacecraft thermal loads.

d. Monitoring and protection of payload thermal interfaces.

5.3.4.2.3 Functional Requirements for Structures and Mechanisms Support (Function 4.2.3). The SSDS shall provide support for structures and mechanism monitoring on the Space Station. Specifically, the SSDS shall support:

a. Berthing, docking and separation operations for OMV, OTV, NSTS, platforms, MMU, and free flyers.

b. OMV berthing.

c. OTV berthing.

d. MRMS operations for construction, berthing and EVA.

e. Mechanism control.

5.3.4.2.4 Functional Requirements for ECLSS Operation (Function 4.2.4). The SSDS shall support the operation of the environmental and life support systems on the Space Station. Specifically, the SSDS shall support

a. The monitoring and regulation of the atmospheric composition in habitable modules.

b. The control of temperature and humidity in habitable modules.

c. The management of potable and grey water quality.

d. The detection and control of contaminates and toxic fluids.

e. The detection of emergency conditions, such as fire, unsafe environment, excessive pressure shell leakage, and critical equipment failures.

5.3.4.2.5 Functional Requirements for Communication (Function 4.2.5). The SSDS shall support communications between the Space Station and ground elements, between the Space station and constellation elements, between the platforms and ground elements and within the Space Station both inside the vehicle and during EVA. Specifically, the SSDS shall provide or support

a. Near continuous ground to Space Station communication by voice and video, and data for real-time monitor and control.

b. Cooperative operations with constellation elements and payloads.

c. Intrastation and extrastation person to person audio and video communication.

d. Support of remote operations by manipulators and OMV.

e. Private crew communications between the Space Station and the ground.

f. Control of OTV and OMV operations.

g. Control of free-flyers and satellites during proximity operations, via OMV or direct Space Station control of free flyer.

h. Control of space platforms and platform payloads.

i. Payload data return from platforms, free-flyers, and other satellites in the constellation.

j. Management of communication links and antennas.

k. Coordination and sequencing of transmissions.

In addition to support of payload data return, the SSDS shall not preclude independent customer communication for return through satellite links other than TDRS or direct broadcast to the ground. The Space Station shall communicate primarily through the TDRSS satellite system. The communications systems shall also provide a contingency link between the Space Station and the ground. The SSDS shall provide privacy of all communications to and from Space Station and SSPEs.

5.3.4.3 Functional Requirements to Support Flight Crew Activities (Function 4.3). The SSDS shall support the normal operations of the Space Station crew, including such activities as health maintenance, recreation, operation of Space Station equipment servicing and maintenance of Space Station and payload equipment, and servicing and maintenance of satellites and SSPEs.

5.3.4.3.1 Functional Requirements for Health Maintenance (Function 4.3.1). The SSDS shall support the operation of the Space Station health maintenance facilities. Specifically, the SSDS shall support

a. The maintenance of crew medical data base and health records.

b. The downlink of diagnostics for crew health maintenance.

c. The physiological monitoring and analysis of crew physiological data.

d. Support of medical diagnostics for the crew.

e. The analysis of crew nutrition requirements.

f. Planning of crew exercise programs to accommodate varying levels of strenuous crew activities in operating the Space Station and payloads.

5.3.4.3.2 Functional Requirements for Space Station Safety (Function 4.3.2). The SSDS shall support the maintenance of safe conditions on board the Space Station. Specifically, the SSDS shall

a. Provide for independent detection and control of emergency conditions.

b. Notify operators of the failing of critical systems.

c. Provide for detection and suppression of fires.

d. Detect and correct unsafe buildup of toxic or undesirable elements in the Space Station atmosphere.

e. Provide alarm to warn Space Station crewmen of the buildup of toxic elements in the Space Station atmosphere.

f. Monitor all Space Station payloads, systems and coorbiting spacecraft status data. The SSDS shall analyze the status data and determine unsafe and out of tolerance conditions. The SSDS shall identify failed equipment and automatically execute reconfiguration. The caution and warning system shall provide alarms and warnings to the Space Station crew and present appropriate diagnostic displays.

5.3.4.3.3 Functional Requirements to Support Habitability (Function 4.3.3). The SSDS shall support the habitability of the Space Station by providing commercial video and audio-visual entertainment. The SSDS shall also support private crew/ground audio communications.

5.3.4.3.4 Functional Requirements for EVA Support (Function 4.3.4). The SSDS shall support the safe EVA activities of the Space Station crew by:

a. Inhibiting RCS firings during EVA activities.

b. Controlling manipulator arm movement during EVA activity to avoid hazzards to the EVA crew.

c. Providing O&M procedure support to crewmen during EVA.

d. Providing support for automatic and semiautomatic servicing and checkout of MMU and EMU equipment.

e. Supporting airlock control.

f. Supporting EVA monitoring and control.

5.3.4.3.5 Functional Requirements for Operations and Procedure Support (Function 4.3.5). The SSDS shall provide operations and procedure support to the Space Station crew and ground crews in Space Station facilities. Specifically, the SSDS shall provide:

a. Onboard training of crewmen in critical and emergency operations.

b. Onboard training of crewmen in various maintenance and operating procedures for core and payload systems.

c. Maintenance and troubleshooting procedures support.

d. Critical or contingency procedures support.

e. Documentation of IVA and EVA operations data.

f. Maintenance information recording and retrieval.

5.3.4.4 <u>Functional Requirements to Provide Customer Avionics Services (Function 4.4)</u>. The SSDS shall provide avionics data to meet specific customer needs. The support shall include the recording of anomalous events taking place aboard the Space Station and platforms which may affect the operation or the quality of the data collected by Space Station payloads. These reports shall automatically be available to customers whose payloads or payload data may be affected.

5.3.4.4.1 Functional Requirements for Special GN&C Services (Function 4.4.1). The SSDS shall provide special GN&C support services for customer payloads, including:

a. Pointing coordinates for articulating mounts and payloads.

b. Relative alignment attitude references to payloads.

c. Ground track determination and forecast to payloads and customers.

d. Magnetic field and field forecasts to payloads and customers.

e. Provide range, range rate and attitude of platforms and free fliers relative to space station.

5.3.4.4.2 Functional Requirements for Contamination Control (Function 4.4.2). The SSDS shall monitor the contamination environment in and about the Space Station or platform and provide contamination data to customers who payloads or payload data may be affected by contamination events. Specifically, the SSDS shall

a. Monitor internal and external contamination sensors and other induced environment sensors including electromagnetic vibration, acoustics, shock, linear acceleration, temperature, reduced atmosphere, contamination, and radiation.

b. Determine the potential effects of venting, RCS and other burns, and water dumps on external payloads.

c. Monitor the external environment including return flux, number column density of IR and other molecules, and discernable particles in the field of view of optical instruments.

d. Determine the potential effects of venting, burns, and water dumps by any object in the constellation on all objects in the constellation.

e. Determine the effects of performing EVA activities on all objects in the constellation.

5.3.4.4.3 Functional Requirements for Tracking Services (Function 4.4.3). The SSDS shall provide customers and their payloads basic data on the relative range and range rate to SSPEs of interest to the customers.

5.3.4.5 <u>Function Requirements to Monitor and Status System (Function 4.5)</u>. The SSDS shall provide general monitoring and status of both core and customer systems.

5.3.4.5.1 Functional Requirements to Monitor Core System Status (Function 4.5.1). The SSDS shall provide general capability to monitor the status of core systems, including:

a. Monitoring of orbital replaceable units, notifying crew of failed units and supporting fault isolation and repair. (Space Station only)

b. Monitoring and control of fluids and fluids status.

c. Monitoring of Space Station, platform and ground station system performance.

5.3.4.5.2 <u>Functional Requirements to Monitor Customer System Status (Function 4.5.2)</u>. The SSDS shall provide general customer system monitoring support, including

a. Monitoring of fluids status.

b. Monitoring of payload status indicators such as voltage and current.

c. Monitoring of customer and customer support ground systems such as data links, data processing equipment and data storage equipment.

5.3.4.5.3 <u>Functional Requirements for Mass Properties Configuration Updates (Function 4.5.4)</u>. The SSDS shall provide up-to-date data on mass properties and related configuration information for the Space Station. Data to be provided includes:

a. Mass
b. Moments of inertia
c. Area and area distribution
d. Location of payloads
e. Location of other key equipment.

5.3.4.5.4 Functional Requirements for Diagnostic Support (Function 4.5.5). The SSDS shall provide general diagnostic support for the Space Station operators. Support categories include

a. Schematic presentations showing key status and performance data of various Space Station equipment.

b. Expert system analysis to support the operation and control of the Space Station.

c. Trend analysis to indicate the probable performance of various Space Station systems and potential for failures or less than satisfactory performance.

5.3.4.5.5 Functional Requirements for System Test and Evaluation (Function 4.5.6). The SSDS shall support the test and evaluation of both payload and Space Station systems. This support shall include both prelaunch and on-orbit procedures. Payload test data shall be delivered to the customer. System test data shall be delivered to the Space Station operators and to the affected contractors. Operators shall be supported by procedures and by indications of satisfactory system performance.

5.3.5 Functional Requirements to Manage Facilities and Resources (Function 5.0)

The SSDS shall provide for the management of facilities identified as being in the SSDS. This management shall include the protection of proprietary information, the management and distribution of data bases, the support of access to subsystems status, and the management of facility data processing equipment.

5.3.5.1 Functional Requirements to Manage Flight System Facilities (Function 5.1). The SSDS shall provide the facilities necessary to manage the flight system data base, manage the flight system data processing equipment, and prepare displays and controls for operator interfacing. Specifically, the SSDS shall provide for

a. Command and control and data handling from all habitable Space Station modules.

b. Management and delivery of core data files to appropriate data processors and to operators.

c. Monitor and control data processing equipment.

d. Management of facilities supporting payload data processing.

e. Rate buffering for customer delivered data.

f. Support of fault detection and isolation for data processing equipment.

g. Reconfiguration of data processing equipment to meet changing demands and to recover from equipment failures.

h. Monitoring and protecting of data system interfaces.

i. Measurement and control of available data resources.

j. Monitoring of payload consumption of critical Space Station resources and issuance of reconfiguration or disconnect commands to the core subsystems.

k. Support for onboard separation of customer stored command sequences.

l. Storage of customer command sequences.

5.3.5.2 Functional Requirements to Manage Ground System Facilities (Function 5.2). The SSDS shall provide for the management of the Space Station Program Ground System facilities, including SSDS data base management, Ground System schedule managment, management of displays and controls for ground operators, and global facilities management coordination for all SSDS data processing facilities. Specifically, the SSDS shall provide for

a. SSDS data base file management and delivery.

b. Status inset end-to-end communications system.

c. Status at ground data processing equipment.

d. Reconfiguration of ground system data processing equipment to meet changing demands or to recover from equipment failure.

e. Monitoring and protection of ground data system interfaces.

f. Customer systems statusing.

g. Real-time reallocation of data distribution resources to meet real-time changes in customer requirements.

h. Support uplink of developed software for both customer systems and core systems, including customer stored command sequences. (Note: Customer command sequences may also originate from the customer's facility and be transmitted as payload data or may be originated by an onboard mission specialist.)

5.3.6 Functional Requirements to Develop, Simulate, Integrate, and Train (Function 6.0)

The SSDS shall provide a robust environment for development and integration of hardware and software and the training of crew, operators, and customers. Not the least of this environment will be simulations of sufficient fidelity to support verification of 1) physical and logical interfaces, 2) software performance, and 3) end-to-end data transfer. The SSDS shall

a. Provide the capability to ensure that all modifications and upgrades function properly and are compatible with interfacing hardware and software components.

b. Provide to the customer those common tools necessary to permit adequate verification and validation of customer hardware and software with the standardized SSDS interfaces. All tools necessary for payload performance verification, over and above interface verification, will be the responsibility of the customer.

5.3.6.1 <u>Additional Functional Requirements To Interpret Model Requests (Function 6.1)</u>. The SSDS will provide a configurable integration system of sufficient breadth to support all standard customer, crew, and contractor requirements. A primary task of the system mechanization will be the processing of system requests to determine and issue the reconfiguration requirements to the overall hardware and software elements of the system. The system will operate interactively with the using agency to support these requests. Specifically, the SSDS shall

a. Provide user-friendly remote access using menu-driven prompts to set up the simulation for use by the customer.

b. Provide a choice of subsystem models ranging from static models to highly dynamic models subject to customer provided boundary conditions. Models of SSIS subsystems, ancillary data blocks, and operational constraints are some of the required models.

c. Accept characteristics of equipment and/or software to be supplied by the user.

d. Display resource availability.

e. Display current system interconnection.

f. Display system schedules.

5.3.6.2 Additional Functional Requirements To Develop Communication Model Configuration (Function 6.2). The integration system communication links to the operational system will operate in conjunction with a configurable communications element simulator. Specifically, the SSDS shall support integration testing to:

a. Verify customer payload to communication system interfaces.

b. Provide for external interfaces to verify end-to-end customer data throughput. The data shall be verified from the payload through delivery as a completed data set. The customer shall provide the source of the payload data.

c. Select system simulations to be used, including data entry and reception models.

5.3.6.3 Additional Functional Requirements To Simulate Space Station Communication Elements (Function 6.3). The communications simulation shall include communication links to the operational system. Specifically the SSDS shall

a. Provide for maximum use of flight system capability to reduce the requirements for ground support equipment and other support during ground testing.

b. Accept payload test data from the Space Station or the customer payload in the simulator and deliver to the customer for verification of communication links.

c. Accept payload commands from the customer and deliver to the Space Station payload in the simulator for verification of command link.

d. Provide the interfaces to allow a verification of (segmented as necessary) end-to-end customer data throughput.

e. Configure the communications simulation.

f. Perform simulations of communications system elements.

g. Interface with other simulations, as required to incorporate communications interfaces and simulations.

5.3.6.4 <u>Additional Functional Requirements To Develop Hardware Integration Configuration. (Function 6.4)</u>. This funtion derives and issues the hardware simulation configuration requirements. The SSDS shall

a. Select a standard data interface for payload or contractor hardware connection.

b. Select simulation models of the SSDS interaction with the hardware to verify hardware functions.

5.3.6.5 <u>Additional Functional Requirements To Simulate Space Station Elements (Function 6.5)</u>. The SSDS shall provide the resources to support customer and contractor hardware integration. Specifically, the SSDS shall

a. Provide standard data interfaces for mounting customer payloads and contractor hardware at the simulator.

b. Provide for remote hardware data interfaces at the customer or contractor facility.

c. Provide the facilities and resources to support Space Station equipment verification testing to ensure that all elements and payloads are launch ready.

d. Accept test data from the customer payload and return to the customer for verification.

e. Support verification and compatibility testing of standard ancillary data formats and information content.

f. Provide simulation functions to enable the validation of operational procedures and software to the limits of expected flight constraints.

g. Support software development for the customer testing and execution of customer analysis programs.

h. Develop simulation models and deliver to contractor to support Space Station hardware integration at the contractor's facility.

i. Develop simulating models and deliver to customer to support payload integration at the customer's facility.

j. Verify that interfacing hardware meets data interface standards.

5.3.6.6 Additional Functional Requirements To Develop Software Integration Configuration (Function 6.6). The SSDS shall provide the facilities and resources to support customer and contractor software integration. Specifically, the SSDS shall

a. Provide a remotely accessible, real-time simulation of SSIS software services to the extent necessary to verify the SSIS to Payload software interfaces at the customer's facility.

b. Provide user-friendly remote access using menu-driven prompts to set up software integration simulations for use by the customer.

c. Provide simulation functions to enable the validation of operational procedures and software to the limits of expected flight constraints.

5.3.6.7 Additional Functional Requirements To Simulate Space Station Processors (Function 6.7). The SSDS shall provide Space Station software simulation and processor emulation in support of software development, integration, and performance simulations. Specifically, the SSDS shall

a. Support the capability for customer payload specialists to develop and verify payload stored command sequences for future execution onboard the platforms or the Space Station, especially those requiring core system interaction.

b. Provide a remotely accessible real-time simulation of SSIS software services to the extent necessary to verify the following SSIS-to-payload software interfaces at the customer's facility:

   1) Protocols at all software layers

   2) Full breadth of customer command capability

   3) Standard ancillary data formats and information content

   4) SSIS/DBMS interaction with flight and ground customer application software.

c. Configure system data processing simulations.

d. Simulate command and data management.

e. Simulate system operation.

f. Verify that software packages meet interface standards.

5.3.6.8 Additional Functional Requirements to Conduct Training Exercise (Function 6.8). The SSDS shall interpret training requests and provide the appropriate training operation configuration. Specifically, the SSDS shall

a. Provide capability to receive new or revised training material transmitted from the ground.

b. Provide preflight training on systems management, trajectory and navigation support, activity planning, logistics, communications, emergencies, proximity and manipulator operations, and the onboard training system. Extensive preflight training will be limited to critical systems functions with an emphasis on part-task training.

c. Configure on-orbit training to support crew special and emergency operations.

d. Configure ground based training to support all aspects of crew training.

e. Select procedures, simulations, and interfaces to be used.

f. Provide on-board accessible training capabilities to maintain critical crew skills, to maintain crew quick reaction capability for emergency procedures and contingencies, and to support in-flight operation and maintenance tasks, both IVA and EVA, for payloads and core system operation.

g. Provide preflight training which is limited to critical system functions with emphasis on part-task training.

h. Optimize crew interfaces and establish training commonality, providing common training software packages and video tapes for ground training facilities and on-board training utilizing Station training capability, using new or revised training lessons transmitted from the ground.

i. Provide CCTV for crew training.

j. Provide mission and payload independent customer training facilities necessary to adequately train the customers in operation of the SSIS.

k. Provide high fidelity simulation of payload work stations.

l. Provide for training in the integrated operation of multiple payloads.

m. Configure training simulations.

n. Simulate system operation.

5.3.6.9 Additional Functional Requirements to Develop Software (Function 6.9. The development function shall include services to assist both contractors and customers in software development. The software support environment shall primarily support contractor applications software development and integration. The SSDS shall also support the development of software for customer payloads and for use in the simulator. The SSDS shall

a. Provide software programming language support.

b. Maintain a library of standard routines for use by customers, contractors, and simulation software developers.

c. Provide simulation functions to validate customer and contractor software.

d. Support onboard or customer facility generation of customer stored command sequences.

e. Support onboard software development for modification by the Space Station crew.

5.3.7 Functional Requirements to Support Space Station Program (Function 7.0).

The SSDS shall interface with the SSIS and TMIS to provide SSP programmatic support.

5.3.7.1 Functional Requirements to Maintain Integrated Logistics Plan (Function 7.1). The SSDS shall monitor payload and core systems consumables, repair parts and spare parts. The logistics planning shall develop requirements for timely resupply. Logistics support requirements shall be delivered to TMIS for incorporation into the SSP plans.

5.3.7.2 Functional Requirements to Log Customer Usage of the System (Function 7.2). The SSDS shall be responsible for logging all customer usage of SSIS services. Reports shall be presented to the customers, and chargeable service data shall be delivered to the TMIS.

5.3.7.3 Functional Requirements to Maintain Technical Documents (Function 7.3). The SSDS shall be responsible for maintaining Space Station, SSDS facilities, and payload operations and maintenance manuals. Satellite service procedures shall be supplied by the SSP, with updates based on servicing experience supplied through the SSDS. Manuals required onboard shall be available to customer guest operators and crew via CRT display.

5.3.7.4 Functional Requirements to Control Inventories (Function 7.4). The SSDS shall be responsible to status inventories of materials, repair parts and spares for SSDS facilities, the Space Station, and payloads. The primary responsibility for inventory control will rest with the SSP. Inventory status will be communicated through the TMIS.

5.3.7.5 Functional Requirements for Configuration Management (Function 7.5). The SSDS shall be responsible for monitoring the mass properties data required to perform avionics calculations. Basic data are provided through the TMIS. The SSDS will keep the mass properties data base current, including effects of docked vehicles and tethers.

5.3.8 General Design Requirements

5.3.8.1 SSDS Operational Lifetime. (RFP C-4-2.1.4.1) The SSDS shall have the ability to remain operational indefinitely through periodic inspection, maintenance, and replacement of components. Servicing intervals for the platforms shall be as specified in paragraph 3.4 of attachment C-3.

5.3.8.2 SSDS Modular design commonality growth. (RFP C-4-2.1.5) The SSDS shall be designed to facilitate system growth through use of modular and subsystem design. The SSDS shall employ common hardware, software, and standard interfaces which optimize benefit to the SSP.

The SSIS/SCS shall be designed to be modularly expandable/replaceable. It shall permit customer and system technology upgrades, capability upgrades, and function migration between ground and space. (CRSS-1.1.6)

5.3.8.3 SSDS Technology accommodations. (RFP C-4-2.1.6) The SSDs shall be designed to accommodate the incorporation of new technology as appropriate to optimize benefits to the program.

Technology accommodation. The SSDS shall accommodate new technology without requiring major redesign or reevaluation or disruption of services of the system to the extent practical. (RFP C-4-2.5.1.c)

5.3.8.4 SSDS Autonomy/Automation (RFP C-4-2.1.7,2.1.8) A phase degree of on-orbit autonomy shall be provided consistent with evolving systems and operations requirements, cost, and applicable evolving technologies. Platform design shall facilitate autonomous operations between scheduled servicing period but shall not preclude ground intervention.

A phased progressive automation of both flight and ground elements shall be accommodated consistent with evolving system requirements, cost, applicable technologies, and the NASA Automation and Robotics Plan (to be supplied at CSD, April 1985).

5.3.8.5 SSDS Maintainability. (RFP C-4-2.1.9) SSDS hardware and software shall be designed:

To facilitate on-orbit and ground maintenance, inspection, and repair with maintenance performed on-orbit to the Orbital Replaceable unit (ORU) level. (RFP C-4-2.1.9.a)

Such that all reasonable failures or damage is restorable or repairable. (RFP 4-2-1.9.b)

To be capable of undergoing maintenance without the interruption of critical services and with minimum interference with other SSDS operations. (RFP C-4-2.1.9.d)

Such that preventive and corrective maintenance activities for the Space Station system minimize the use of available crew time. (RFP C-4-2.1.9.h)

5.3.8.6 <u>SSDS Reliability. (RFP C-4-2.1.10)</u> Reliability programmatic requirement shall be as specified in SSP J8400001, "Product Assurance Requirements for the Space Station Program." Reliability design requirements for the SSP are as follows:

Failure tolerance. (RFP C-4-2.1.10.1) Safety critical and mission critical subsystems are those whose function, if lost, would produce a condition endangering on-board personnel or prevent the accomplishment of a critical mission objective. Safety and mission-critical subsystems shall be designed to be fail-operational/fail-safe/restorable, as a minimum (except primary structure and pressure vessels in rupture mode and premature firing of pyrotechnics). This criteria applies during all operational phases except initial assembly and maintenance. For applicable subsystems, some degraded performance following the first failure is not precluded by the fail-operational/fail-safe requirement. During assembly and maintenance, critical SSDS subsystems shall be fail-safe as a minimum. Other SSDS subsystems and ground support hardware shall be designed to be fail-safe/restorable. Subsystems in pressurized modules shall be able to return to normal operation after the module has lost pressure on-orbit and been repressurized.

Redundancy (RFP C-4-2.1.10.2) Redundancy verification. Redundant functional paths of subsystems shall be designed to permit verification of their operational status in flight without removal of ORUs. (RFP C-4-2.1.10.2.a)

Failure propagation. (RFP C-4-2-1.10.3) Subsystem design shall be such that one failure does not cause additional failures.

Separation of redundant paths. (RFP C-4-2.1.10.4) Alternate or redundant functional paths shall be separated or protected such that any event which causes the loss of one functional path will not result in the loss of the alternate or redundant functional path(s).

5.3.8.7 <u>SSDS Safety. (RFP C-4-2.1.11)</u> The safety programmatic requirements shall be as specified in "Product Assurance Requirements for the Space Station Program", J4800001. The SSDS and ground systems shall meet the safety design requirements specified herein.

The following safety requirements are applicable to all SSP systems, subsystems, and operations. These requirements apply under worst-case natural and induced environments.

Override capability. The crew must be able to override any automated safing or switchover capability of functional paths. All overrides shall be two-step operations with positive feedback to the initiator that reports the impending results of the override command prior to the acceptance of an execute command. Separable functional paths shall be used to prevent single failures from causing both an unintended auto switchover and the inability to override it. (RFP C-4-2.1.11.4.a)

Command/control redundancy. Redundant accommodations for complete command and control of the Space Station shall be provided in separate pressurized volumes. Functions to reestablish pressure in a module shall be operable by pressure-suited crewmembers. (RFP C-4-2.1.11.4.b)

5.3.8.8 SSDS Privacy/Security Information privacy. The SSDS shall provide data partitioning and protection to assure mission success and accommodate data privacy, commercial proprietary data, and security measures. (RFP C-4-2.2.2.5.1.b)

The SSDS design shall provide for crew members to communicate privately with the ground. This private communication link shall include both audio and video data. (RFP C-4-2.2.6.2.j)

The SSIS/SCS shall permit the customer to perform private operations covering commanding, data transmission, and in Site hands-on operations. (CRSS-1.1.7)

5.3.8.9 SSDS Standards Standardized language, protocol, format, and transmission rates for all SSDS and all SSDS subsystems. (RFP C-4-2.2.5.3.g)

As a first preference, customer interface standards shall be defined in accordance with the International Standards Organization (ISO) seven layer model for Open System Interconnect (OSI). (CRSS02.1.1)

The SSIS/SCS shall use, for each of the seven layers, existing internationally accepted standards as first priority followed by new standards development (within the OSI model framework). (CRSS-2.1.1.1)

The customer interfaces defined within the first three layers of the OSI model shall conform to standards defined and controlled by sources such as:

NBS, National Bureau of Standards

ANSI, American National Standards Institute

ECMA, European Computer Manufacturing Association

CCIUTT, Consultative Committee for International Telegraph and Telephone

EIA, Electronic Industry Association

CCSDS, Consultive Committee for Space Data Systems

IEEE, Institute of Electrical Electronics Engineers

(CRSS-2.1.1)

When practical, appropriate standards from these sources shall be used at higher layers of the OSI model. (CRSS-2.1.2.1)

The SSIS/SCS shall obtain and/or develop standards for customer interfaces in candidate areas such as software, critical/limited payload health and safety monitoring, man-machine interfaces, uniform system control and operational language for Payload test/checkout and operations, command generation, time code, attitude and position data, pointing coordinate systems, data base management systems, graphics displays, data handling/archiving/distribution, documentation, configuration control, cost accounting, data system requirements definition, operation audit trail, etc. When new customer standards are proposed, the SSIS/SCS shall present these standards on behalf of all customers. (CRSS-2.2.1)

5.3.8.10 <u>SSDS Customer/Operations Support</u> The SSDS shall support a user-friendly language for the man/machine interface. The language shall be capable of interfacing between man and machine for communications, display generation, monitoring, checkout and control during all phases of development and operations. (RFP C-4-2.2.5.2.c)

The SSIS/SCS shall be designed to provide simultaneous premission, mission, and postmission customer support. (CRSS-1.1.2)

The SSIS/SCS shall be designed to reduce requirements placed upon customers by minimizing the complexity of interfaces, avoiding duplication of payload options, and by providing a user friendly environment for the customer during the payload life cycle. (CRSS-1.1.4)

The SSIS/SCS shall maximize the use of standard interfaces throughout the system. (CRSS-1.1.5)

The SSIS/SCS system design and operation shall be user friendly.

Examples of "user friendly" features are:

- Interactive SSIS user terminals
- "Prompts" user through an operation
- Informs user of errors made and where they were made
- Provides a "help" function to assist user when necessary
- Protects against customer deduced system crashes
- Continually informs user of what operation is taking place (never displays a blank screen)
- Allows a skilled user to bypass menus, etc. for more rapid operation (CRSS-1.1.8)

The SSIS/SCS shall enable a customer to control his payload in functionally the same manner as if the payload were in his laboratory. (CRSS-6.1.3,1.1.3)

The SSIS/SCS shall make payload information available to the flight crew or payload specialists via computer terminal equipment with keyboard entry/display and generation of text/graphics display. A hard copy generation capability shall be provided. (CRSS-6.4.1)

This equipment shall be functionally equivalent to commercially available equipment to the maximum extent reasonable. (CRSS-6.1.4.2)

The SSIS/SCS shall be designed to support customer payload operations 24 hours/day, 7 days/week. (CRSS-1.1.1)

5.3.8.11 SSDS Communications TDRSS shall be the primary means of Orbital Maneuvering Vehicle (OMV), platform and Space Station payloads space to ground communications. All payload (requiring TDRSS services) downlink/uplink communication rates shall be consistent with the TDRSS limitations, as defined in the latest users guide, ["TRDSS User's Guide", Revision 5, March 1984, (J8400026)]. The Space Station and platform(s) shall be capable of transmitting/receiving customer data to/from the ground through TDRSS consistent with requirements in Reference 19, Appendix A. All customer requests for uplink/downlink support will be managed by the SSIS in coordination with the TDRSS Network Control Center (NCC). (CRSS-0.1)

Communications between the ground and the Space Station and Space Platforms shall be through the Tracking and Data Relay Satellite System (TDRSS) or its replacement system. The use of the maximum TDRSS transmitted and received data rates over both the Ku-band single access link and the S-band single access link shall be provided for. Data rates in excess of the maximum shall be transmitted as individual data streams to the ground independent of TDRSS and TDAS using payload providing systems. Provisions shall be made for a contingency command and telemetry link to the ground from the Space Station and Space Platforms. (RFP C-4-2.2.6.2.g)

The SSIS/SCS shall permit an alternate communication link consistent with Space Station Program policies, implemented by the customer independent of TRDSS/TDAS. (CRSS-1.1.10)

The SSIS/SCS shall support the customer requirements for communication rates up to those overall design constraints described in Reference 19, Appendix A. (CRSS-5.1.3)

The SSIS/SCS shall permit customer provided direct Space Station System-to-Ground transmission links subject to Space Station System constraints and restrictions. (CRSS-5.1.5)

Standard telecommunications interfaces shall be provided enabling customers to receive and transmit video, voice, data, and commands via customer supplied equipment. (CRSS-5.1.8)

The SSIS/SCS shall provide sufficient video channel(s) (uplink and downlink) to the Station for use by all customers on a scheduled basis. (CRSS-5.2.9)

The uplink and downlink shall support transmission of command and data information between customer's ground and onboard equipment in a transparent manner. Restricted and constrained commands shall be identified and transmitted or inhibited by the SSIS. (CRSS-6.1.3.1)

5.3.8.12 <u>SSDS Workstation</u> The SSIS/SCS shall provide these work stations at three locations as follows:

A work station in the customer control facility which will be available to individual customers. (CRSS-6.1.5.2.1)

A flight station which will be used by the onboard Space Station crew or the onboard payload specialists. This station shall provide for onboard time shared use of text and graphics type keyboard display terminals for use by crew or customer's onboard representative in controlling the operations of the customer's onboard hardware. This terminal shall be functionally identical to a commercially available text and graphics terminal and shall interface to the customer's payload via a transparent data link. (CRSS-6.1.5.2.2)

The SSIS/SCS shall provide onboard workstations capable of supporting mission planning, scheduling, and system resource allocation as stated Paragraphs 7.2.1 and 7.2.2 of reference #2. (CRSS-7.2.3)

Operational interfaces. The onboard operational interface to the DMS shall be through Multipurpose Applications Consoles (MPAC) and the distributed computer processing system. (RFP C-4-2.2.5.1.a)

5.4 REQUIREMENTS DRIVERS

The team has reviewed the functional and performance requirements generated in Task 1 and identified those functional and performance requirements which are expected to have a major impact on the design of the SSDS. These requirements and their expected impacts will be discussed in the subsections of 5.4.

5.4.1 Impacts of Overall Data Rates

Data rates for the primary SSPEs are developed in Section 6.4. Data rates are shown in Figure 5-8. The aggregate average payload data rate of the Space Station, COP and POP begins in 1992 at about 100 Mbps. There is an additional estimated overhead of about 8.6 Mbps for voice, video, and spacecraft engineering data. As the number of payloads on orbit increases, the aggregate data rate increases to a peak of 253 Mbps in 1999. With voice, video, and engineering data, the average data rate is about 263 Mbps. These data rates do not include the additional transmission requirements necessary to achieve the bit error rates of 10^{-6} required by the Space Station program. The current KSA channel capability for TDRSS is 276 Mbps. With current coding,

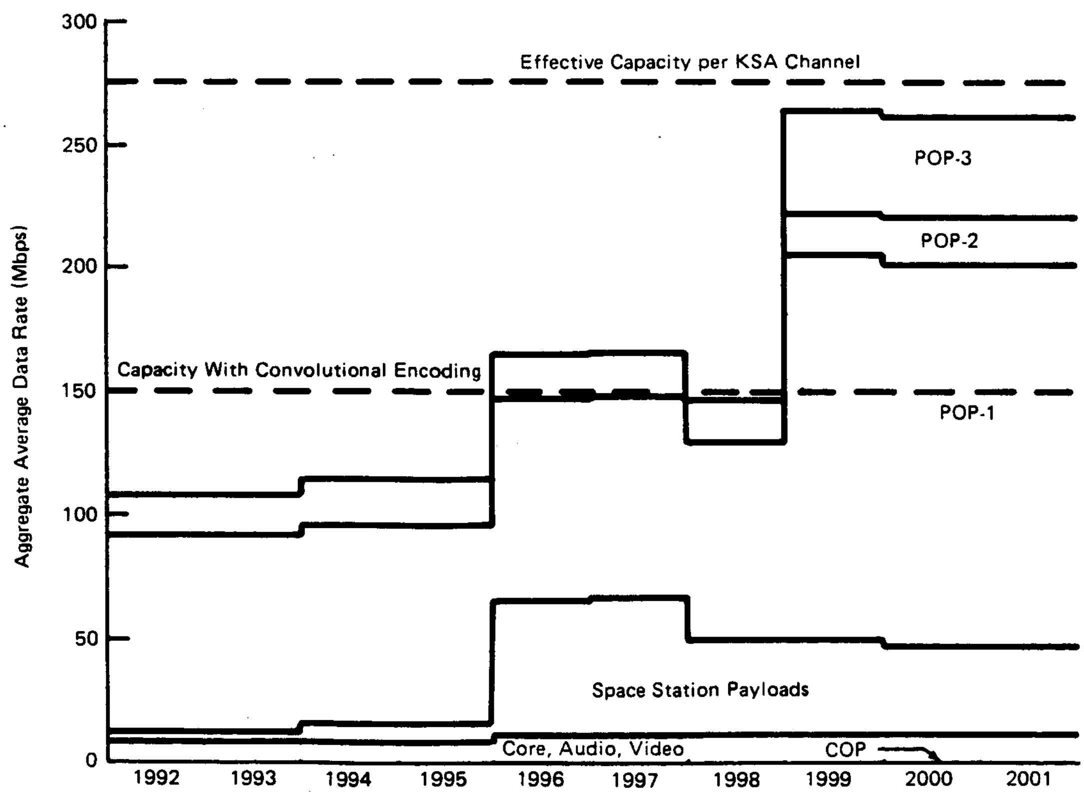


Figure 5-8. TDRSS KSA Channel Requirements Versus Capacity

the effective capacity is 150 Mbps. Hence, lower coding overheads, lower data rates and/or multiple TDRSS channels are required for the combined transmission, especially after 1999. The level of coding and overhead to be incorporated will be developed in Task 4.

It is conceivable that the peak payload data transmission for the combined Space Station, COP and POP could be scheduled so that there is no simultaneous transmission of information on two KSA channels. There is some evidence supporting a probable lower average data rate for some of the highest data rate instruments in the Space Station program, especially those of POP-1. With these caveats, it seems possible that the combined data rates of the Space Station program will be consistent with the use of an equivalent single KSA channel. If this is indeed the direction that the program takes, data rates will become design drivers in the following areas:

- Scheduling of facilities and communication links from the space vehicles through the TDRSS to the Data Handling Center.

- Providing adequate onboard storage for data to buffer the data collection and transmission according to the combined transmission schedule to TDRS.

- Performing level 0 data processing in real time at 300 Mbps with data recording and error detection.

- Supporting real-time error correction processing on the raw data.

- On-line storage of up to 10^{13} bits of data to support the 12 hour on-line storage requirement.

- Sorting, repackaging, routing, and transmission of individual customer data packages.

- Distribution of data rapidly enough to receive confirmation of satisfactory transmission within the 12 hours on-line storage duration.

If the program chooses instead to go to simultaneous use of parallel TDRS channels, the impact on the design will be felt primarily at the TDRS ground station and in the communication from the ground station to the Data Handling Center. The TDRS ground stations will have to be upgraded to receive 600 Mbps transmission rates. The ground station must later buffer these transmission rates over the entire period of transmission overlap, or it must upgrade its retransmission facility to route the full 600 Mbps transmission rate. In either case, it will be necessary to have at least four and perhaps eight equivalent DOMSAT links connecting the TDRS ground station or the Data Handling Center to the next communication nodes. Design impacts to the Data Handling Center would be dependent upon which method for relay of data is selected. If the TDRSS ground station does not provide data buffering, the Data Handling Center must. Otherwise, the Data Handling Center impact is probably not substantially dependent on the transmission scenario selected.

A trade study will be conducted in Task 3 to determine the program impact of using 1, 2, or 3 single access channels.

5.4.2 Real Time Operation of Payloads.

There is a requirement for customers to be able to operate their payloads interactively in real time from remote operations centers. Real-time operation implies the real time entry of commands, the real-time processing of those commands and delivery of the command to the payload, the real-time return of payload monitor data from the payload to the customer, and some amount of real-time processing of the payload monitor data to enable the customer to determine the next operation. Intermingling of the real-time data throughput with the bulk data discussed in Section 5.4.1 would create very serious operating problems. However, many of the payloads can be operated in real time using a dedicated or shared MA channel. Most payloads can be operated using only the data capabilities of a single SSA TDRS channel. Depending on the specific payloads, it may be possible to operate several payloads simultaneously on a single SSA channel, and some may be operated simultaneously on an MA channel. Since the SSA and MA channels can be kept separate from the KSA channel, this would facilitate real-time data movement for a single customer. It appears that the SSDS can provide for the real-time operation needs of most customers in this manner. The allowable reaction time or performance delay for various payloads will also bear on this problem. MDAC will develop representative delays allowable.

A second implication of real-time operation is involved in the designation of commands as being unrestricted, restricted, or constrained. Real-time operation must be conducted using only allowable commands. The Space Station and all of its payloads must be in operating modes that will permit all of the operations that are to be performed in real-time payload operation. This creates a potential for a severe scheduling problem for real-time payload operations.

Real-time operation may also be conducted by a Space Station guest investigator or mission specialist onboard the Space Station. This mode of operation relieves the data communication problems between the Space Station and the customers facility. The operation may need to be supported by a two-way audio or video return and two-way audio link between the Space Station and the customer's facility. Including video return and frame rates in excess of those which can be transmitted by a TDRS SSA band would again impose difficult data separation problems. Real-time operation on board will also require that all of the constraint and restriction checking for commands be accomplished on board.

5.4.3 Automation

The degree to which SSDS functions are automated will have a major impact on the design of the SSDS. Functions which can be automated can be located either on board or on the ground according to results of relatively simple trade studies. Functions which are not completely automated impose requirements on the operators. Since operators are a limited resource on board the Space Station, the opportunity for onboard manned involvement in the operation of the Space Station functions is limited. Therefore, functions which are not automated will tend to be driven to locations on the ground. There will certainly be effects on the Space Station engineering data rates. There may also be effects on the operation and performance of Space Station systems which are not fully automated.

5.4.4 Scheduling

In the preceding paragraphs several references to scheduling problems have been raised. Automation of many of the scheduling functions appears to be important in reducing program operating costs. However, both operators and customers will require that they be allowed to interact the scheduling function. Scheduling appears to be driven toward a responsive, interactive tool. The concept developed for scheduling functions in Task 1 appears to be amenable to this form of schedule development. However, other alternatives should be considered in selecting the concept to be used in scheduling. Some of the requirements placing additional burdens on scheduling function include

- Customer and operator interactive scheduling.
- Flight crew involvement in selecting tasks to be performed on orbit and the sequence and timing of these tasks.
- The customer requirement for rapid rescheduling to meet "windows of opportunity" for his payload.
- The desire of many customers for real-time payload operation, which involves the real-time processing of commands through the scheduling function and the rapid arbitration of restricted or constrained commands not executable in the current schedule.
- The major impact on day-to-day schedules caused by the scheduling of major events such as satellite servicing, vehicle mating and launching, and major maintenance for buildup activities on the Space Station or payloads.

These requirements all drive scheduling toward a high degree of automation. The degree of difficulty embodied in automating scheduling will be very strongly affected by the degree to which the systems resources are to be optimized. Scheduling a function to 80% of a limiting or constraining capacity is far easier than scheduling a function to 90% or 100% of that capacity. Scheduling automation will be greatly facilitated by working to the 80% capacity level for all but the most critical functions. The three resources identified as most critical are: Space Station power, Space Station crew time, and communications data rate. Communications data rates are buffered by onboard storage of data. Power generation is buffered by onboard energy storage. Limiting of payloads and their duty cycles, especially during the early years of Space Station operation, to something significantly less than the limits of these constraining resources will greatly simplify the automation of Space Station program scheduling. Hence, there is a trade between the cost and time required to develop varying degrees of schedule automation with varying degrees of sophistication and the ability to fully utilize limiting Space Station resources. However, automated scheduling is mandatory to meet Space Station customer requirements.

5.4.5 Level of Physical Distribution

The SSDS functions will be physically distributed among many geographic and space locations. Some locations will be divided into two or more facilities. Within facilities, functions may be allocated to multiple processors and storage units.

The level of distribution, including both the numbers of locations and facilities and the functions assigned to the locations and facilities, and the types and quantities of data traffic among functions will drive the selection of network concepts to be used. The problems of distribution and networking must be worked together to produce the optimum system design.

Distribution, and the associated potential for functional autonomy, can also benefit SSDS development and maintenance. Functional partitioning with well selected interfaces allows corrections, extensions, and upgrades to be incorporated in one function substantially independent of other functions. This capability will be required in the development and anticipated growth and evolution of the Space Station. Functional distribution should be planned to facilitate system developmental and operational autonomy, as it affects this flexibility.

These benefits must be traded against the inherent design problems of highly distributed systems, e.g., data base management, resource control, and network communications.

5.5 REQUIREMENTS TRACEABILITY

The credibility of SSIS functions evolved by the Task 1 activities is maintained by full traceability to the requirement that each function was derived to meet. The need to understand the system drivers is the first of three major benefits that traceability provides. By having traceability between the top level requirements and the functions, changes in requirements are made simpler. If the design of a system to implement a function is found to be too complex or expensive, the driving requirement may be traced and altered. Any alterations to a requirement may also affett other functions. With a traceability system the affected functions can be traced and modified as required.

Requirement/function traceability supports function justification. With a traceability system each function can be traced to its key driving requirement, thus each function is justified.

The visibility of the completeness of the functions list is also provided by assuring traceability. Mapping all the SSDS related requirements insures that the functions list accommodates all requirements, thus the functions list is validated and checked for completeness.

5.5.1 Requirement Sources

The Space Station Definition and Preliminary Design RFP (Reference 1), and the Customer Requirements for Standard Services from the SSIS (Reference 2) are the primary control documents for use in the traceability matrix. Additionally, engineering analyses were performed on the data base derived by the Langley Mission Requirements Working Group (reference 3) to extract mission requirements that affect the SSDS.

5.5.2 Traceability Implementation

An analysis of the requirements documents was performed to extract the functional requirements that pertained to the SSDS. After this analysis was completed, each of the resulting requirements were mapped to specific functions that were derived to meet each requirement. The results from the mapping process were entered into a computerized traceability matrix that was developed using the ACCENT R data management system.

The automated traceability matrix provides complete top down/bottom up traceability. A requirement can be traced to the functions that satisfy the requirement. In addition, functions can be traced to the requirements that gave rise to each function; thus, the traceability matrix gives complete top-down/bottom-up traceability as shown in Figure 5-9.

Additional bottom-up traceability exists within the requirements data base. Many functions were derived from other requirements documents such as Yellow Books and CDG briefing material (before References 1 and 2 were available). To accommodate this, space was provided on a functional data sheet to give the document name and paragraph number of the requirement that needed the function.

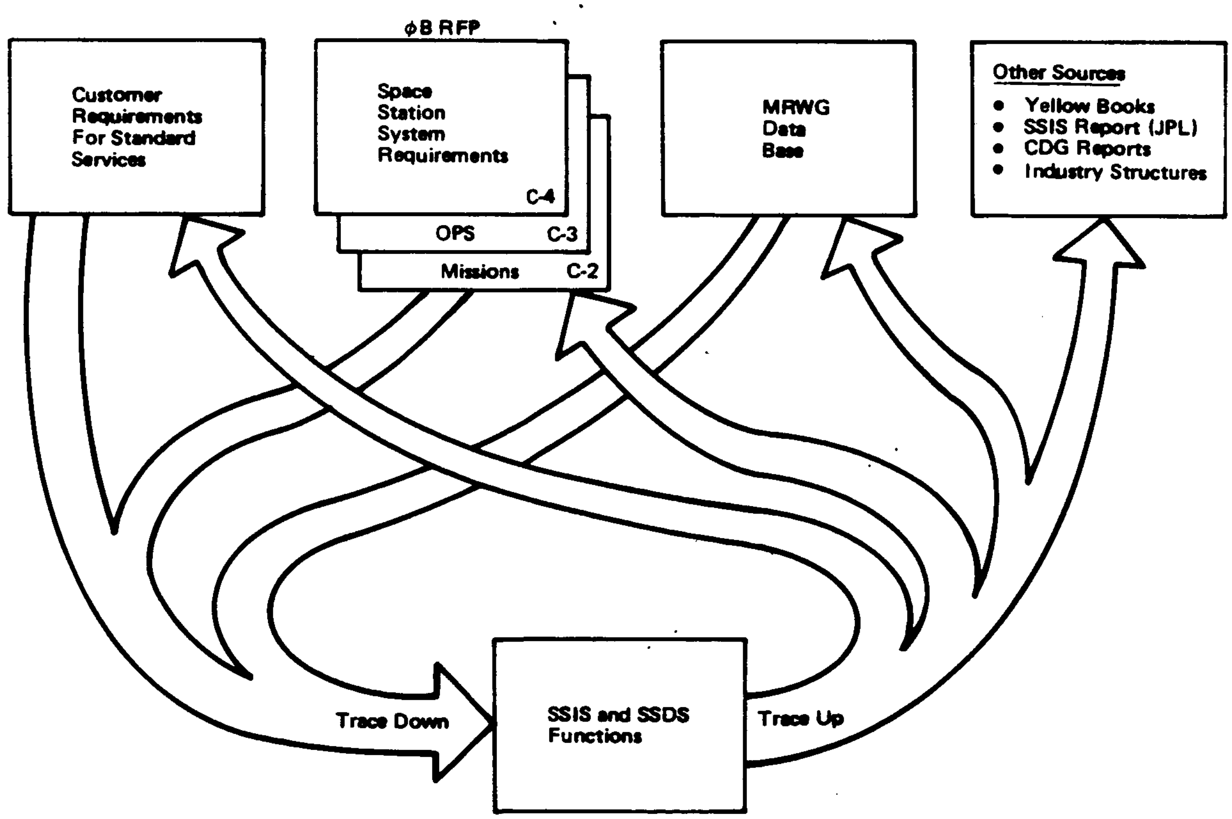


Figure 5-9. Traceability

5.5.3 Traceability Report Examples

The top-down traceability report maps each requirement to the function derived to meet the requirement. The requirement is identified by its unique requirement number, document abbreviation from where the requirement was extracted, and the paragraph number of the requirement. Each requirement is also given a brief descriptor to help further identify the requirement. Requirements extracted from Reference 3 are identified by the major mission number, then the count of other missions that need the function is given in parentheses. Next, the list of functions that map to the requirement are given. The functions are identified by their derived function number and abbreviated function title. Example output from the top-down report can be seen in Figure 5-10. The full report is in Appendix A-5.

The bottom-up traceability report maps each function to the requirements that gave rise to the function. The function is identified by function number and abbreviated function title. The requirements are identified by their paragraph number from the document from which they were extracted. The document can be identified from the requirement number field. Requirements numbered from 1000-1999 come from Reference 1, requirements numbered from 2000-2999 come from Reference 2, and requirements numbered from 3000-3999 come from the analysis of Reference 3. The requirement is further identified by a brief descriptor. Example output from the report can be seen in Figure 5-11. The complete bottom-up report is in Appendix A-6.

REQUIREMENT #	DOCUMENT	PARAGRAPH #
1105	RFP	C-4-2.2.8

DESCRIPTOR

ATTITUDE CTRL & VELOCITY ADJUSTMENT

DERIVED FUNCTION NUMBER	FUNCTION TITLE
4.1.2	GUIDANCE
4.1.3	ATTITUDE CONTROL

REQUIREMENT #	DOCUMENT	PARAGRAPH #
2012	CRSS	3.2.2

DESCRIPTOR

PROVIDE CUSTOMER DATA ACCOUNTABILITY

DERIVED FUNCTION NUMBER	FUNCTION TITLE
1.4.6	CUSTOMER DATA ACCOUNTING
2.1	VALIDATE P/L CMMDS/DATA
2.2	CHECK P/L CMMDS/DATA
3.3	DEVELOP OP EVENT SCHEDULE

REQUIREMENT #	DOCUMENT	PARAGRAPH #
3023	MRWG	SAAX0303(8)

DESCRIPTOR

CREW PHYSIOLOGICAL MONITORING

DERIVED FUNCTION NUMBER	FUNCTION TITLE
4.3.1	HEALTH MAINTENANCE

Figure 5-10. Output from Top-Down Traceability Report

FUNCTION NUMBER	FUNCTION NAME
2.5.2	COST P/L OPS

PARAGRAPH NUMBER	REQ #	DESCRIPTOR
C-2-3.1.3	1005	INDEPENDENT CUST. OPERATION & MONITOR OF P/L
C-3-3.1.G	1034	INDEPENDENT CUST. OPERATION AND MONITOR
6.3.1.1	2046	ACTIVATE STORED COMMAND SEQUENCES
6.3.2	2047	STORED P/L CMMD ACTIVATED BY ANOTHER STORED CMMD
7.1.3	2053	PAYLOAD HOUSEKEEPING DATA MONITOR
SAAX0305(32)	3040	CUSTOMER PROCESS CONTROL
COMM1117(37)	3044	PAYLOAD ACTIVATION/SAFING

Figure 5-11. Output from Bottom-Up Traceability Report

Section 6
Substantiating Analyses/Technical Justification

This section contains a description of additional analyses which were performed in the development of the SSDS and SSIS functional requirements. The section also contains the technical justification for some of the key performance requirements. This section is not intended to be a complete discourse on the analyses undertaken. Rather, it is a supplement to the other sections of this report wherein many of the appropriate analyses are described.

6.1 REVIEW OF ANALYSES PERFORMED

The methodology followed in developing the SSDS and SSIS requirements was described in Section 3 of this report. Three parallel paths were followed in developing the SSIS and SSDS requirements. One path involved the review of then available literature and extraction from the literature functions which were appropriate for the SSIS and SSDS. A second path used structured systems analysis to define the logical steps required to process data during end-to-end movement through the system. The third path used requirements from the Mission Requirements Working Group, the Space Station Phase B RFP, and the customer's requirements for standard services from the SSIS, produced by GSFC. Functional and performance requirements were identified from these three documents and traced through to the SSIS functional requirements and the SSDS requirements.

The structured systems analysis was described at a top level in section 4.3. Section 6.2 will present the Level 1 data flow diagrams and the analyses represented in the indicated flows. Lower level data flow diagrams and the accompanying data dictionary will be developed as a part of task 4.

The development of the function requirements was covered in Section 5.1. The analysis of available literature and development of SSIS and SSDS functions is shown in Appendix A-4.

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Section 6.3 shows the development of functional requirements from the mission requirements working group output. Section 6.4 shows a compilation of performance requirements as generated by the Mission Requirements Working Group.

6.2 STRUCTURED SYSTEMS ANALYSIS - LEVEL 1 DATA FLOW DIAGRAMS

There are two accepted approaches in structured systems analysis to developing Level 1 data flow diagrams from a level 0 data flow diagram. In one approach the level 1 data flow diagram covers the entire system, but contains significantly more detail than the level 0 diagram. In the other approach each function in the level 0 diagram is expanded at Level 1. Because of the complexity of the system and the significant degree of independence of functions at level 0, the latter course has been chosen.

The Level 0 data flow diagram was shown as Figure 4-3. This diagram is reproduced here as Figure 6-1 for convenience. The diagram contains seven functions, each of which will be expanded as Level 1 data flow diagrams. Figure 6-2 shows the expansion of Function 1, Manage Customer/Operator Delivered Data. This function receives data generated by the payloads and core systems and delivers the data to its appropriate destination. The external agency in the upper left hand corner of the diagram, labelled OMV, OTV, and constellation interfaces represents the communication interfaces on the Space Station to elements in the constellation. These elements may be transferring to the Space Station both data to be relayed to a destination in real time and data which may be held for bulk transfer at a frequency of approximately once per orbit. Real-time data are delivered to Function 1.1, Manage Real-Time Return. Bulk data are delivered to a data store labeled "Delayed Payload Data." Similarly core systems, at the top of the figure, also generate real-time data for monitoring. The bulk core systems data to be returned has previously been stored by the core system functions in a data store labeled Core Status. The real time core system data are also delivered to Function 1.1. At the far left, Space Station payload data to be delivered in real time are routed to Function 1.1 while delayable payload data are routed to a data store, and held for the once per orbit bulk data return.

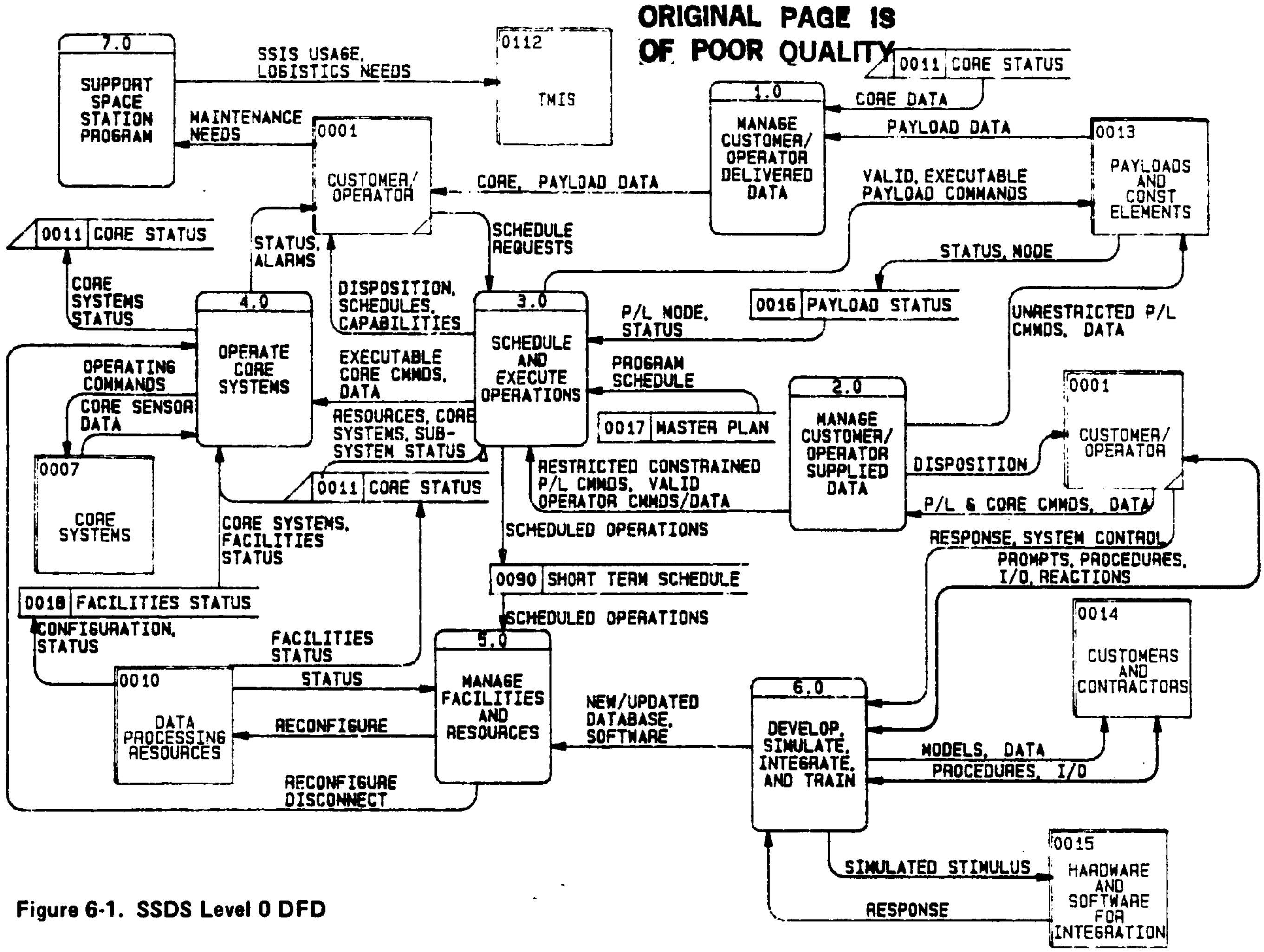

Figure 6-1. SSDS Level 0 DFD

The onboard customer or operator represents one of the end points of the data. Both real-time and delayed data are shown as delivered to the onboard customer/operator. Note that the box representing this external agency has been duplicated and it appears at the top center and the bottom left of the figure. The onboard customer or operator use these data to monitor the performance of payloads and to interact with payloads or core systems in real time. A two-way voice and video communication link between the onboard customer or operator and the ground customer or operator is provided by this function.

Bulk data from both the core and the payloads is delivered to Function 1.2, Manage Delayed Data Return. Both data return links are governed by previously established priorities. Both deliver data to a data distribution function, Function 1.3. The data distribution function will read the data header, select the appropriate routing of the data, and deliver the data to the designated end point. The data are shown as divided into two streams. One

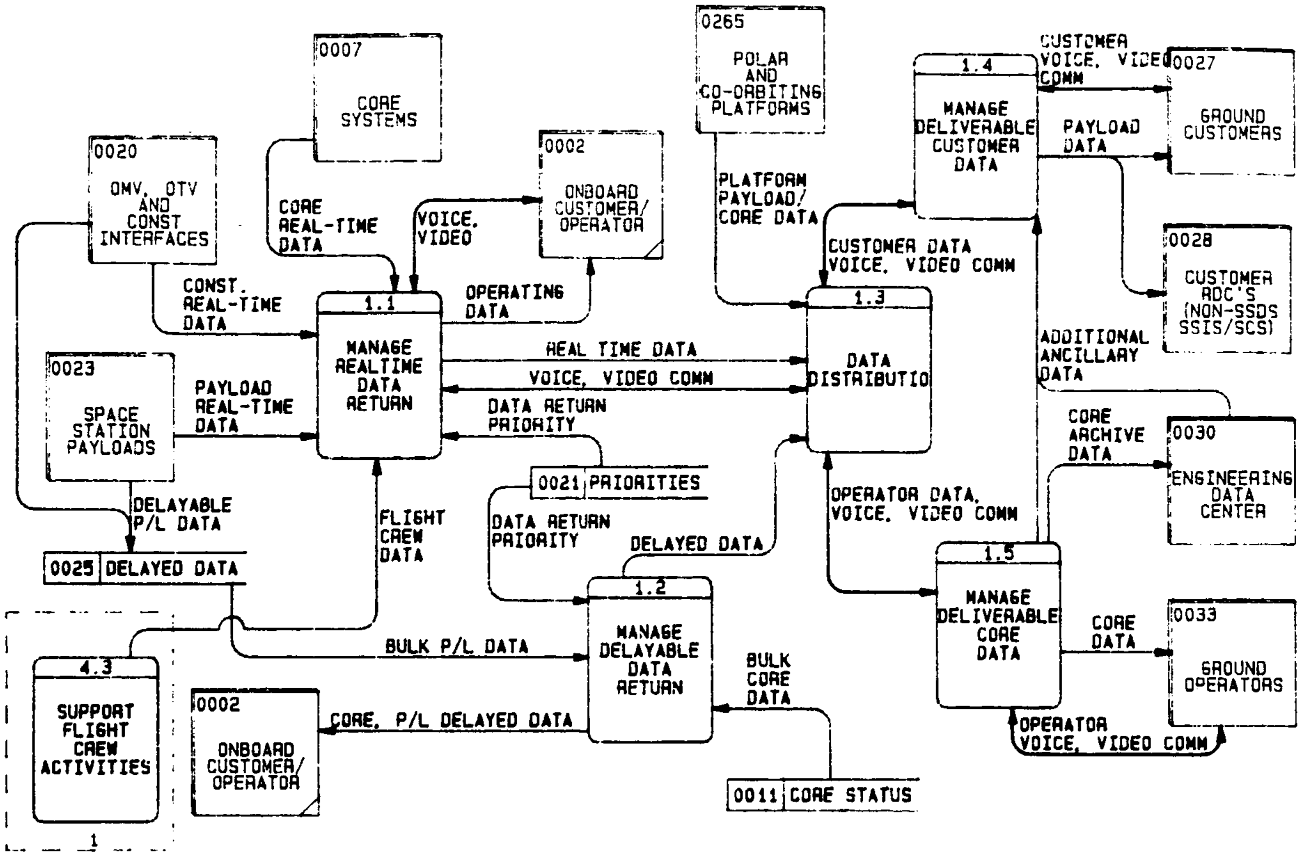

Figure 6-2. SSDS Level 1 DFD 1.0 Manage Customer/Operator Delivered Data

stream includes all customer data while the other stream includes all core data. The recipients are the ground customers at their own facilities, customers regional data centers, the engineering data center, and ground operators. The customer payload data will be delivered either to the customer's own facility or to the customer's regional data facility, depending upon the customer's selection. Core data are either delivered to ground operators or to the core data center for archiving.

Most of the customer's ancillary data requirements are expected to be met by delivering ancillary data in real time to the customer's payload on the Space Station. Additional ancillary data are provided either from the Space Station control center or the engineering data center upon customer request.

Figure 6-3 shows the management of customer or operator supplied data. This function manages the commands and data supplied by the customer or by the core system operator. Payload commands and data are received from the customer/operator in the upper right hand corner of the figure while core commands are received from the core operator at the right center of the figure. Commands and data destined for the payload or for vehicles in the constellation are sent to function 2.1, Validate Payload Commands/Data. In this function the customer or operator is first authenticated as being one who is able to enter commands. The address of the command is then checked against those that the customer or operator is authorized to command.

The commands and data meeting these tests are termed valid payload data and valid payload commands. Valid payload data are delivered directly to the payloads or to the OMV, OTV, or constellation interface with no further checking. Valid payload commands are checked against the list of constrained

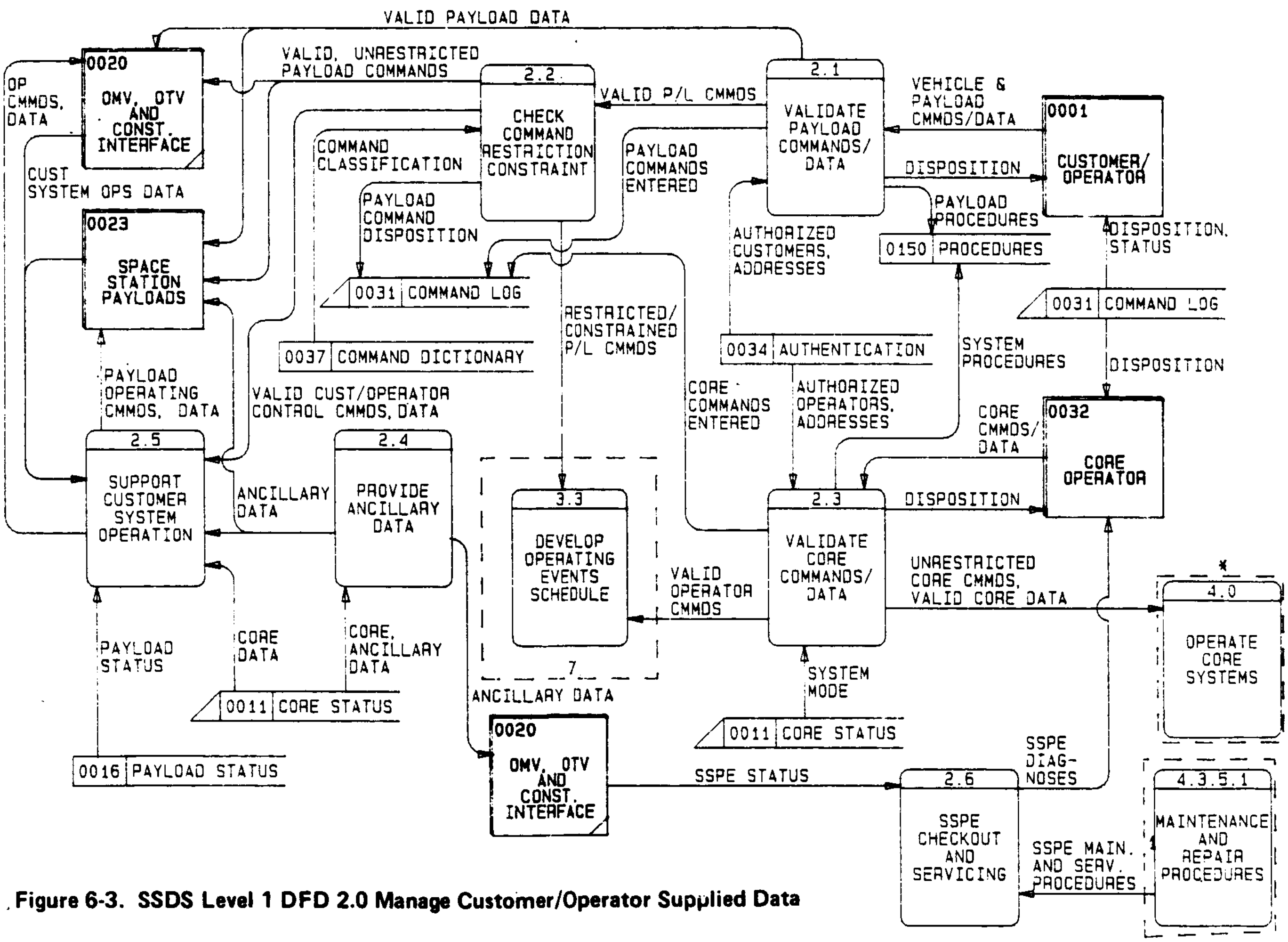

Figure 6-3. SSDS Level 1 DFD 2.0 Manage Customer/Operator Supplied Data

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and restricted commands contained in the command dictionary. Those commmands found to be unrestricted are delivered directly to the constellation interface or payload. Those found to be restricted or constrained are sent to Function 3.3 to determine whether the command can be executed. A command log is kept to record the disposition of all commands. Disposition is reported back to the operator who entered the command.

Commands and data entered by the core system operator follow a similar chain of processes. The commands are validated in Function 2.3. However, valid core commands are all checked for restriction in Function 3.3. As with the payloads, valid core data are sent directly to the appropriate core system.

Ancillary data required by payloads and by constellation elements is provided through Function 2.4. Function 2.5 provides support for the operation of customer systems, including the operation of customer payloads, the provision of data processing resources in support of customer payload operation, the operation of the OMV and the OTV, and support of customer payload checkout.

Function 2.6, SSPE Checkout/Service, which would normally appear at this level, is not included because the data flow paths are many and varied. It was felt that their inclusion would not significantly improve understanding of the system operation.

Function 3.0, Schedule and Execute Operations is shown in the Figure 6-4. The scheduling of Space Station operations begins with a master plan generated by the TMIS. This input is seen in the center left hand side of the figure. The master plan contains major events such as the STS visits to the Space Station, OMV and OTV launches, major maintenance actions and buildup of the Space Station, addition and removal of payloads, major construction activities, and major payload maintenance actions. The accommodation portion of the master plan shows what payloads will be onboard the Space Station at what times and the characteristics of the payload operations.

Typical day schedules are developed for both a normal day and for days on which major events occur. Normal days are defined as those days when no major events take place. These days are expected to comprise approximately 60% to

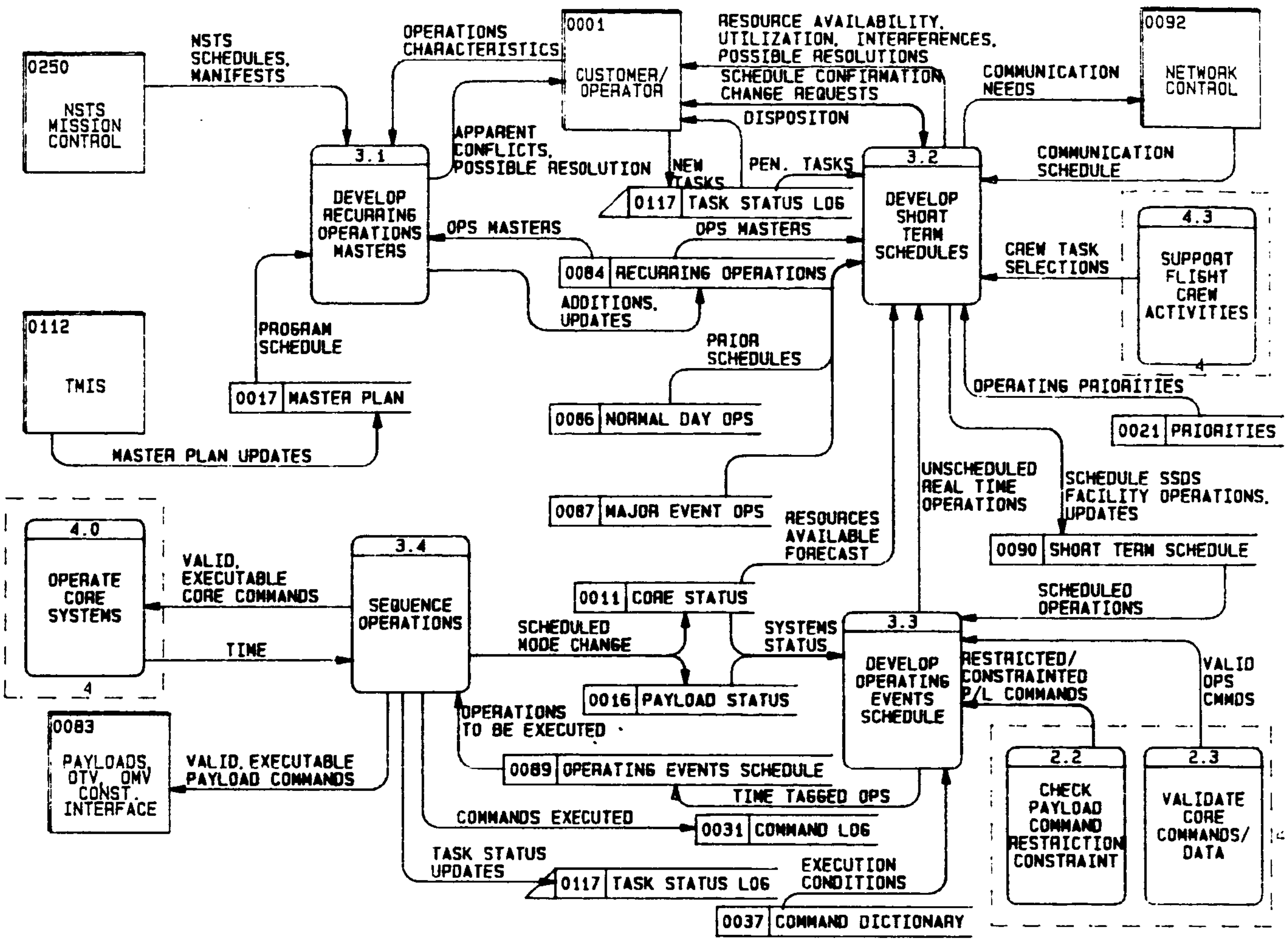

Figure 6-4. SSDS Level 1 DFD 3.0 Schedule and Execute Operations

80% of the total operating days of the Space Station. A normal day schedule is used as a baseline for developing a schedule for a major event day. Payload operation may be discontinued on major event days in accordance with constraints imposed by the major event taking place and with any limitations that may be required for critical Space Station resources. Operating priorities are used to allocate any impacted Space Station resources.

Customers and operators input their desired operations with sufficient descriptive information to develop timelines, assess impacts on Space Station resources, and determine interferences between operations of core and payload systems. Any conflicts in the schedule are examined in the scheduling function and possible resolution is reported back to the customers and operators. Again, operating priorities are used to arbitrate between competing requirements for critical resources and interferences or conflicts between the operation and characteristics of the payloads and core systems.

Shuttle manifests and schedules have previously been established in the master plan. Additional interaction is allowed to provide space on the Shuttle for repair parts and resupply of consumables. A file of recurring operations is kept to show resource requirements timelines and interferences for each of the recurring core and payload operations. This file is periodically updated by the information coming into the development of typical day schedules or the development of short term schedules.

Short term schedules are developed beginning with a baseline of a normal day or a major event day. The events in the normal operating day are confirmed with the customers and operators. Any change requests from the customers or operators are entered into the short term schedule. Resource availability and utilization, interferences, and possible resolutions of conflicts are relayed back to the customers and operators. The customers and operators interactively develop the short term schedule to optimize the output of payloads during specific days.

Communications needs are arbitrated with network control for each individual day. Communication allocations are returned from the network control showing the time slots that can be reserved for the major communication links to be used.

The flight crew is involved in the development of the short term schedule through their task selections. Again, conflicts are resolved by operating priorities.

The output of the short term schedule is held in the data store. The short term schedule will typically be developed, beginning approximately one week before the date of operation. The schedule may be updated or revised to accommodate targets of opportunity by individual customers.

The operating event schedule is the actual detailed timeline on which the Space Station will operate for a particular day. Function 3.3 develops the operating event schedule based on the short term schedule for that day. The real-time commands for the payloads and for the core system are checked against the restrictions or constraints for those commands. Those commands which are found to be provided for within the short term scheduled are time tagged and loaded into the operating events schedule. Those restricted or constrained commands which are inconsistent with the short term schedule are returned to the short term schedule development function for arbitration between the customers and operators.

Any change to the payload or core which has not been scheduled will automatically trigger a review of the operating events schedule to ensure that all of the commands that have been stored in that file are executable.

The operations to be executed are selected from the operating events schedule in accordance with their time tag by the sequence operations function. Payload commands are sent on to the payloads on the constellation interfaces. Core commands are sent to Function 4, Operating Core Systems. The timing for the execution of the commands in the operating events schedule can be controlled to approximately 1 msec. The time input comes from Function 4.1.6, Time and Frequence Management.

The commands stored in the operating events schedule are not envisioned to be the detailed instructions set that is executed by the payload or core system. These commands are envisioned to be keys that trigger the execution of a command sequence which has been prestored in the payload or the core system processor.

The operation of the Space Station and ground core systems is shown in Figure 6-5. The core systems are split into avionics core systems and non-avionics core systems, following approximately along the lines of predominantly software systems and predominantly hardware systems. Operator control inputs enter into the system via the validated core commands and sequence operations functions in the upper right hand corner. These commands have been previously checked for restrictions and constraints and are found to be executable at the time the commands are issued by these functions.

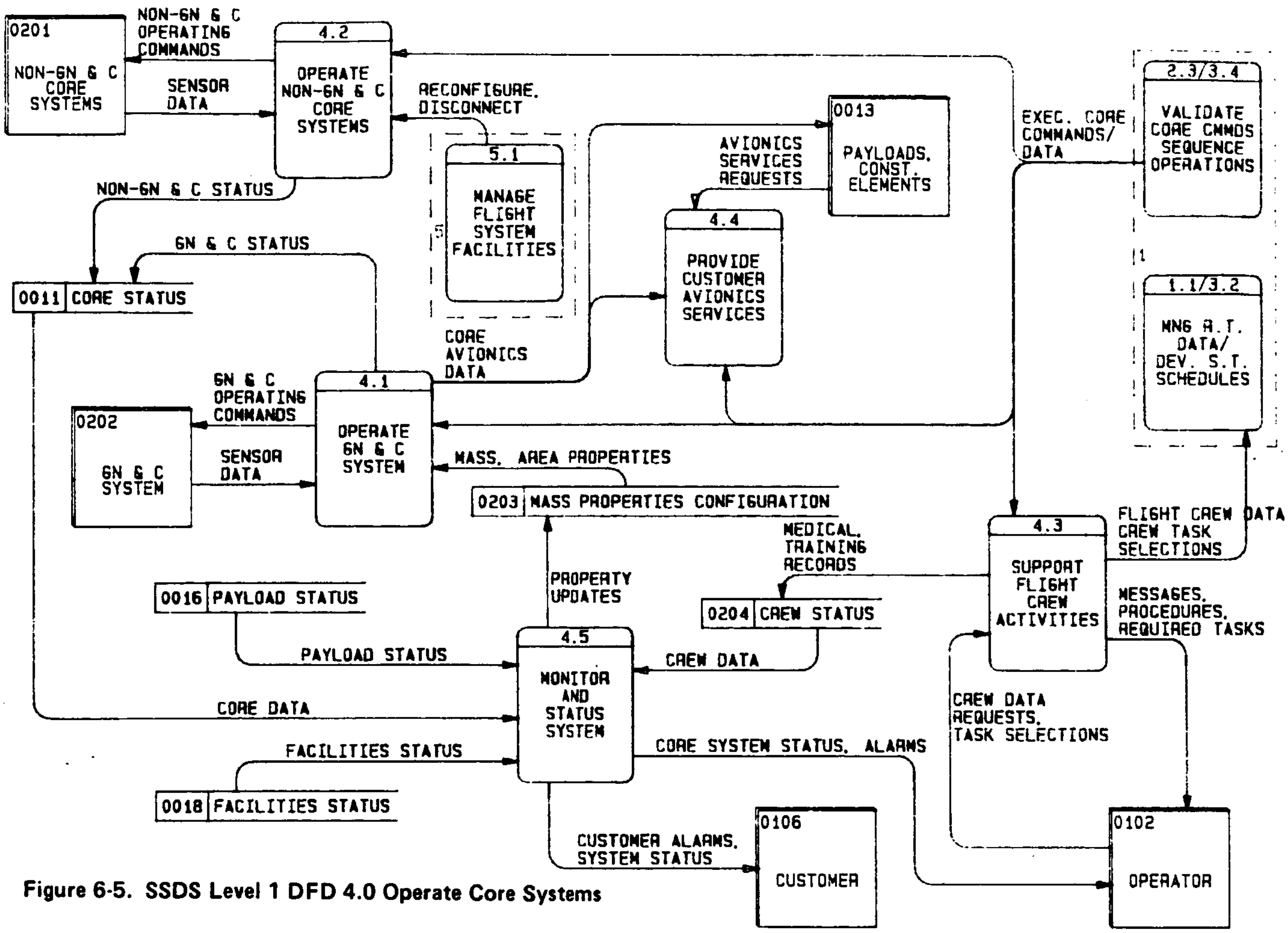

Figure 6-5. SSDS Level 1 DFD 4.0 Operate Core Systems

The two functions operate non-avionics core systems and operate avionic systems are still high level functions. There are two additional levels of subdivision, shown in Appendix A-4, before the detailed operation of these functions is defined. At the level illustrated, these functions enter commands and control into the systems and receive back sensor data. The sensor data are processed to provide the status of the core systems. Each of the functions must have both ground and onboard sections in order to provide for the autonomous operation of the Space Station onboard as well as the operation of the Space Station by ground crews during periods of emergency or periods when the Space Station is not inhabited.

Function 5.1, Manage Flight System Facilities, monitors the voltage and current draw of the payloads as well as other potentially critical indicators of payload status. When a payload is determined to be drawing more power than allocated to that payload or when evidence of serious payload malfunction is detected the reconfigure or disconnect command is sent to the non-avionics core systems. The function will then disconnect operating power from the payload which appears to be malfunctioning.

Function 4.3 in the lower right hand corner, provides support for the flight crew activities. This function prepares the necessary displays of core data to the flight crew to enable them to monitor and operate the core systems. The function also displays procedures to the crew to instruct the crew in Space Station and payload operations and maintenance procedures. The function assists in displaying required tasks to the crew and entering their task selections into the scheduling function.

Function 4.4 provides special avionics services to payloads and to customers. This function will provide such avionics type information as is not normally generated by the core avionics systems. This function includes such avionics services as providing pointing coordinates to payloads, determining and forecasting ground track and monitoring Space Station contamination environment.

Function 4.5 provides a general monitor and statusing of both the core and the payload systems. This function monitors core payload facilities and crew status and prepares appropriate display data for operators and customers. This function also prepares the mass properties configuration data necessary for the avionics systems to determine orbit and attitude and propagate the navigation state vector.

The management of SSDS facilities is illustrated in Figure 6-6. Each of the functions manages the data processing equipment in its facility. The functions include the evaluation of the data processing requirements for the facility and determination of the utilization of the available data processing equipment. The functions monitor the status of their respected facilities and determine facility capability.

Function 5.2, Manage Space Station Control Center Facilities, also includes a global facilities management function. This function includes the

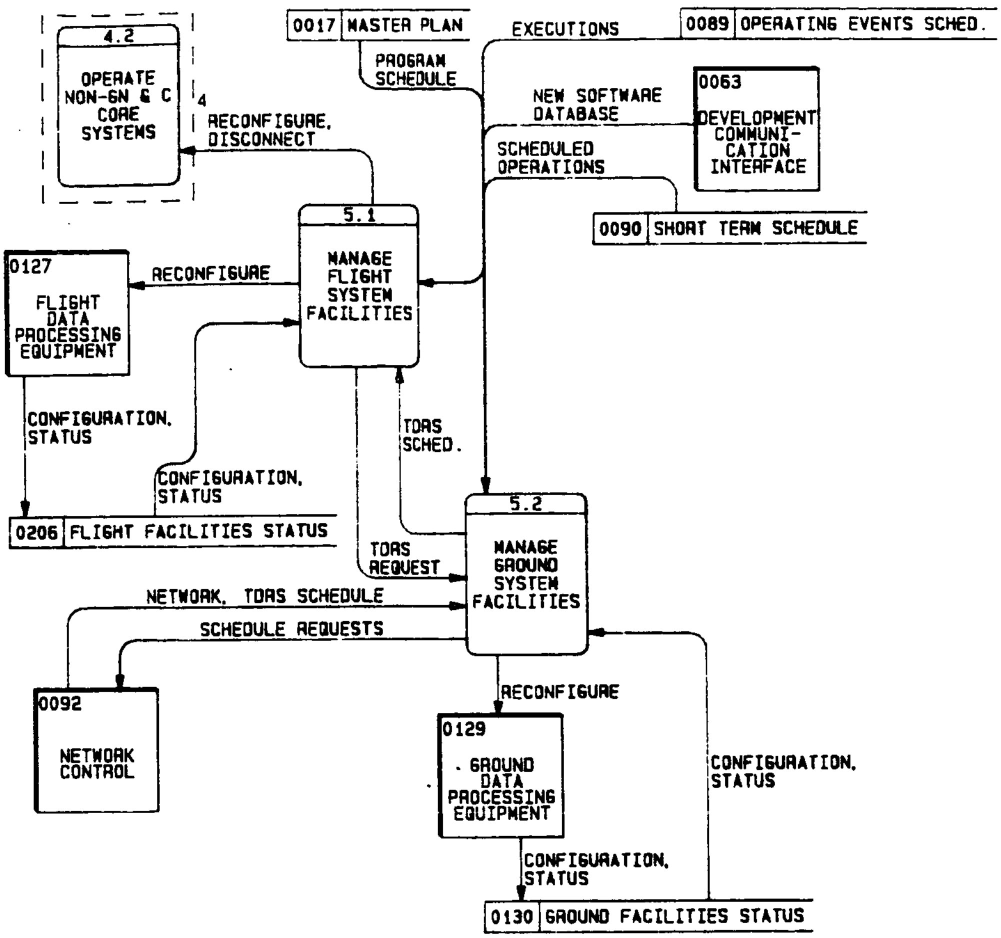

Figure 6-6. SSDS Level 1 DFD 5.0 Manage Facilities and Resources

coordination of the configuration of data processing equipment for all facilities in order to provide for the prompt movement of data through the system. This function also arranges the network and TDRS satellite schedules.

As previously mentioned, monitoring of payload status indicators and core system indicators in Function 5.1 may lead to a requirement to reconfigure the non-avionic core systems or to disconnect various payloads. This function also controls the systematic shedding of load under conditions of loss of power system capability in order to protect the Space Station and its crew.

The development, simulation, integration, and training function operation is illustrated in Figure 6-7. This function provides a development and simulation environment for general purpose use by contractors, customers and system operators. NASA is considering multiple facilities to support this function, including a software development environment, core and payload

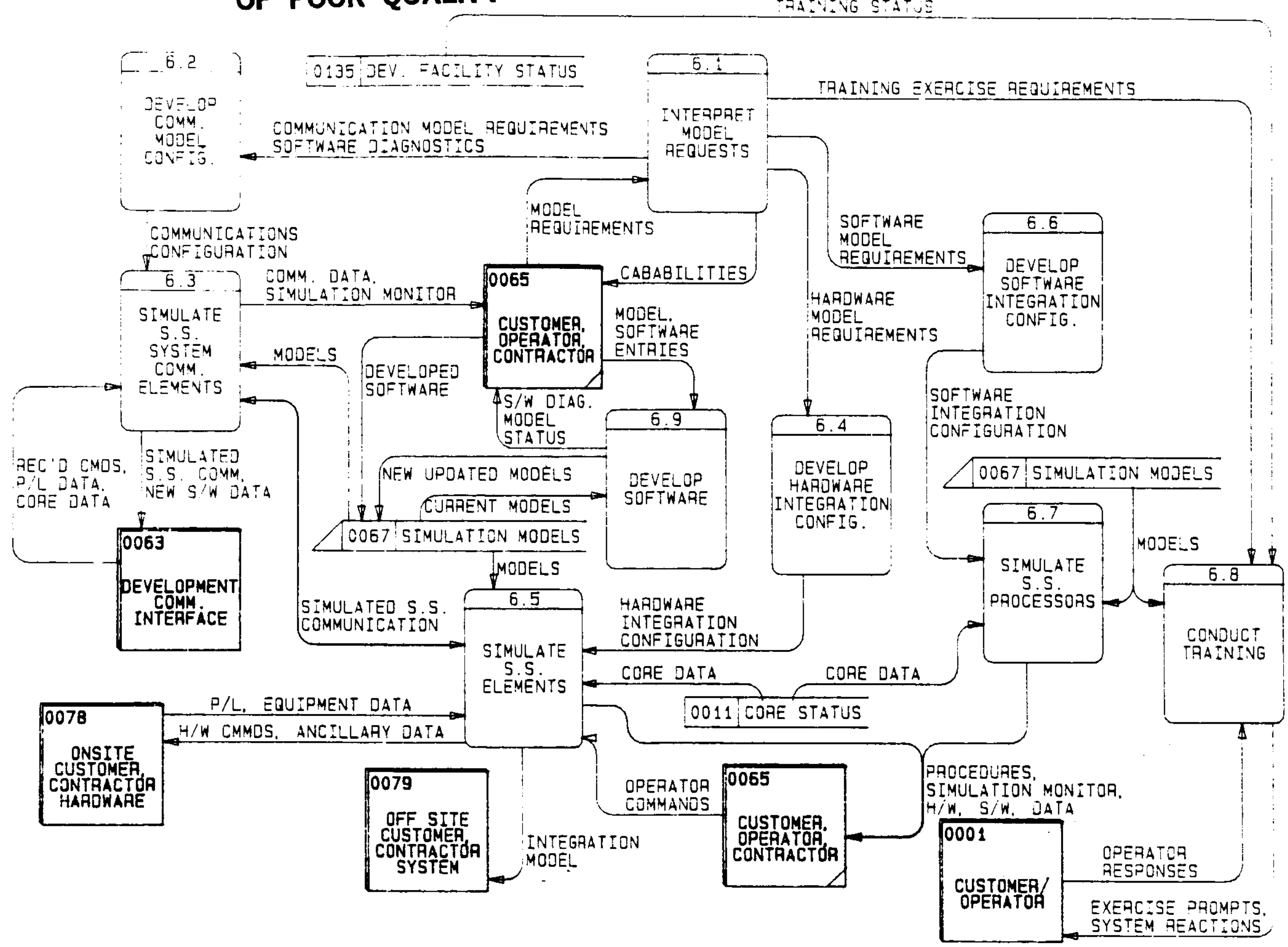

Figure 6-7. SSDS Level 1 DFD 6.0 Develop, Simulate, Integrate and Train

integration facilities, and a Space Station simulator and training facility. This section discusses those SSDS functions performed by the aggregate of all of these facilities. The data flow diagram has five major branches:

a. Communication simulation models which enable the function to interface with Space Station elements through communication interfaces.

b. Hardware integration interfaces which enable the function to validate the performance of payload and contractor hardware for onsite and off-site.

c. Software integration capability which allows the function to verify the functioning and operation of software packages in the simulated environment of the Space Station system.

d. Customer and operator training capability which conducts training exercises and simulates the response of the Space Station system to customer or operator input.

e. Software development environment for both operational software and software simulations built into the simulation models.

These five areas all allow cross coupling between areas to share capabilities among the simulations. A single function provides an operator interface to enter into each of the branches of the system. Function 6.1, Interpret Model Requests, provides a user friendly environment to assist the facility user in establishing the model requirements and developing the software simulation that will best suit the needs of the user.

Each branch is separated into functions which develop the model configuration and functions which actually perform the simulation. Thus 6.2 develops communication model configurations while 6.3 simulates the Space Station communications elements. Function 6.3 interfaces with an external communications interface that allows any portion of the communication links of the Space Station system to be accessed in the simulation. Data are provided directly back to the user. It is anticipated that this branch will be used primarily in verifying the customer end-to-end data links.

Function 6.4 develops the hardware integration configuration while Function 6.5 simulates the Space Station elements, allowing both payload and Space Station hardware to be verified. The facilities include external interfaces for both customer payloads and contractor hardware to be validated on site. The communication interface can also be used to validate off-site hardware. The integration simulation model may also be exported to a customer or contractor off-site location to allow the customer or contractor to perform his own integration tests at his own facility.

The software integration configuration is developed in Function 6.6. Function 6.7 simulates the operation of the Space Station Program processors with their software. The customer operator or contractor inserts his software into the Simulation Models data store from the external agency box in the top center in the figure. This model then is available to insert into the software simulation from the duplicated simulation data store in the right center of the figure.

Function 6.10 supports the development of software for both simulation and use in operational equipment. Validated models may be transported directly to the Space Station or payloads through the communications interface provided in this function.

Training exercises are configured in Function 6.8 and performed in Function 6.9. The simulator prompts the operator to execute the training exercise, accepts the operator responses and displays back the system reaction to the operator response. Actual or simulated core data are made availabe to the simulation to support the use of authentic data in the simulations.
The programmatic support is illustrated in Figure 6-8. It is envisioned that the majority of the programmatics for the Space Station program will be provided through the TMIS. A limited logistics plan covering payload and station resupply and maintenance needs will be delivered to the TMIS from the SSDS. Logistics support requirements are coordinated by the TMIS.

A majority of the manuals are also envisioned to be prepared by Space Station program contractors, and available through TMIS. However, the actual operating procedures for various core systems are expected to be prepared and maintained in the SSDS. Payloads procedures for both operations and maintenance are also expected to be provided by the customer. The procedures in these manuals are expected to be made available to the customers and facility operators, primarily via CRT display.

Inventory control is also limited to the inventories of material and equipment in the various SSDS facilities. The TMIS and SSDS will cooperate in this inventory control.

Configuration management is predominantly a TMIS function. The only role of configuration management in the SSDS is to maintain the specific data required to operate and control the Space Station.

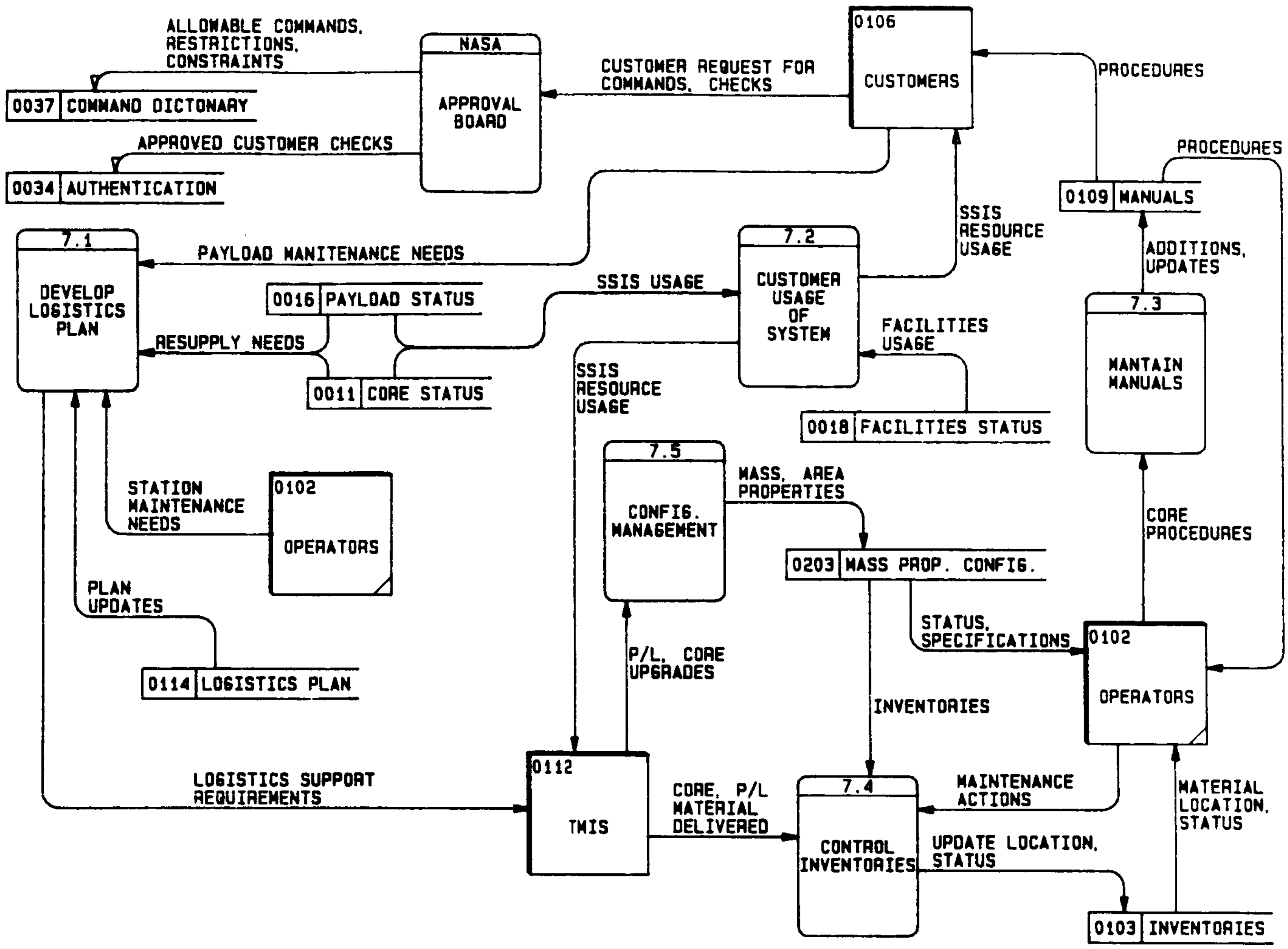

Figure 6-8. SSDS Level 1 DFD 7.0 Support Space Station Program

Customers are expected to provide their own command authentication data. Customers, in addition to using the identification provided through the TMIS, may also incorporate such passwords as they wish to protect the transmission of data to and from their payloads. Customers are expected to provide a complete list of their commands including the restrictions and constraints on any commands. Those commands to be restricted or constrained are negotiated with the Space Station Program through the TMIS. The command dictionary will contain not only the complete list of commands and the commands that are constrained or restricted, but will also contain the circumstances under which these constrained or restricted commands are executable.

The above data flow diagrams contain the logical structure required for the platforms, also. However, there are many non-platform functions, external agencies, and data flows also presented. Figures 6-9 through 6-11 show the diagrams significantly altered for the platforms, i.e., Functions 1.0, 2.0 and 4.0. The logic of each is the same as for the Space Station, with the exception of the elements removed. The remaining data flow diagrams are substantially the same and show replicated and common or shared functions.

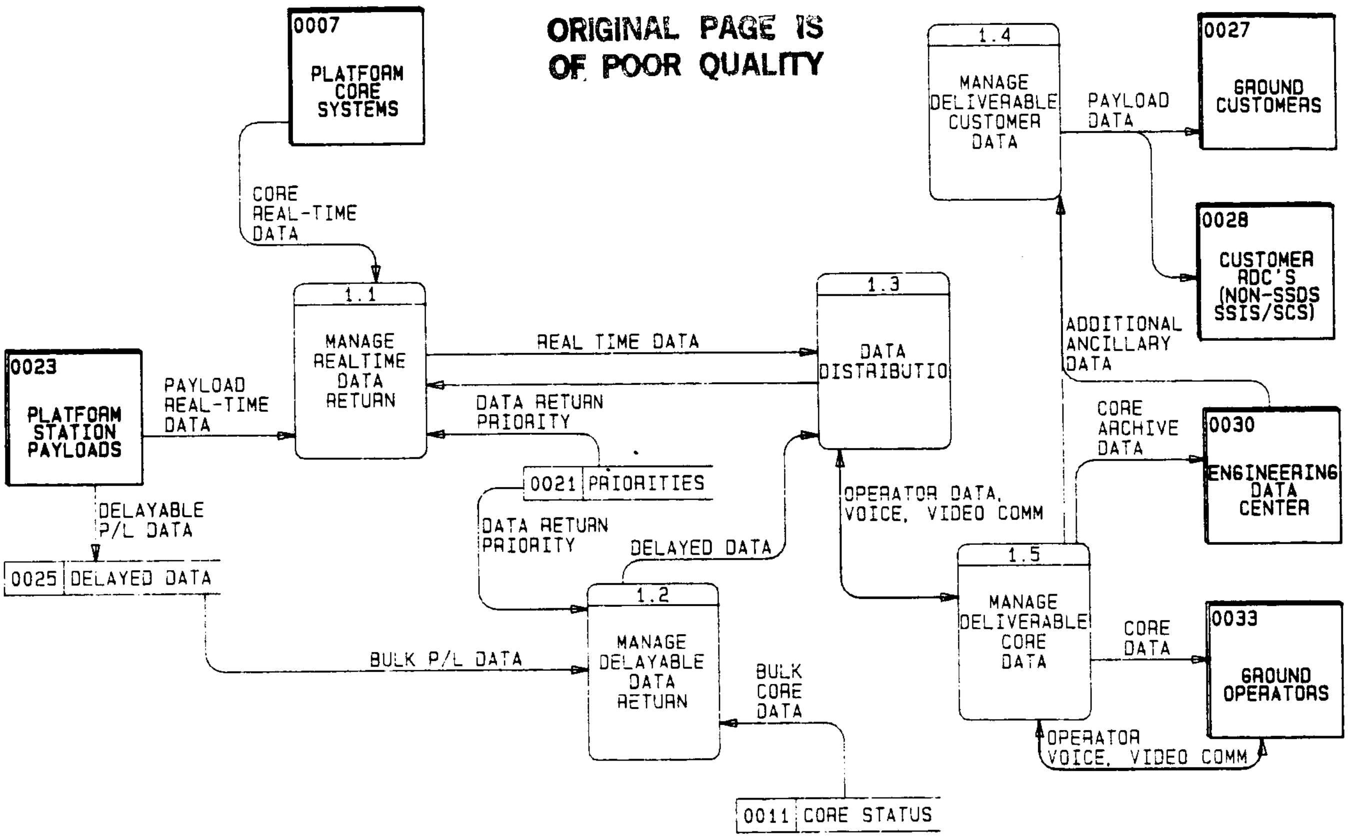

Figure 6-9. SSDS Level 1 DFD — Platforms, 1.0 Manage Customer/Operator Delivered Data

6.3 MRWG FUNCTIONAL REQUIREMENTS ANALYSIS

The Mission Requirements Working Group (MRWG) of the Space Station task force prepared a mission model for the Space Station comprised of 111 missions. These requirements and the mission model were subsequently updated by the Woods Hole Mission Requirements Workshop. Requirements for Space Station program services for each of the missions were identified in the mission model. These requirements include power, thermal control, data processing, data rate, data storage, crew activities, mass, and volume. There are well over 100 such requirements tabulated in the electronic data base maintained by Langley Research Center. In addition, there are textual descriptions of each mission and its operation. This data base was reviewed to determine the standard customer services being requested from the mission data base.

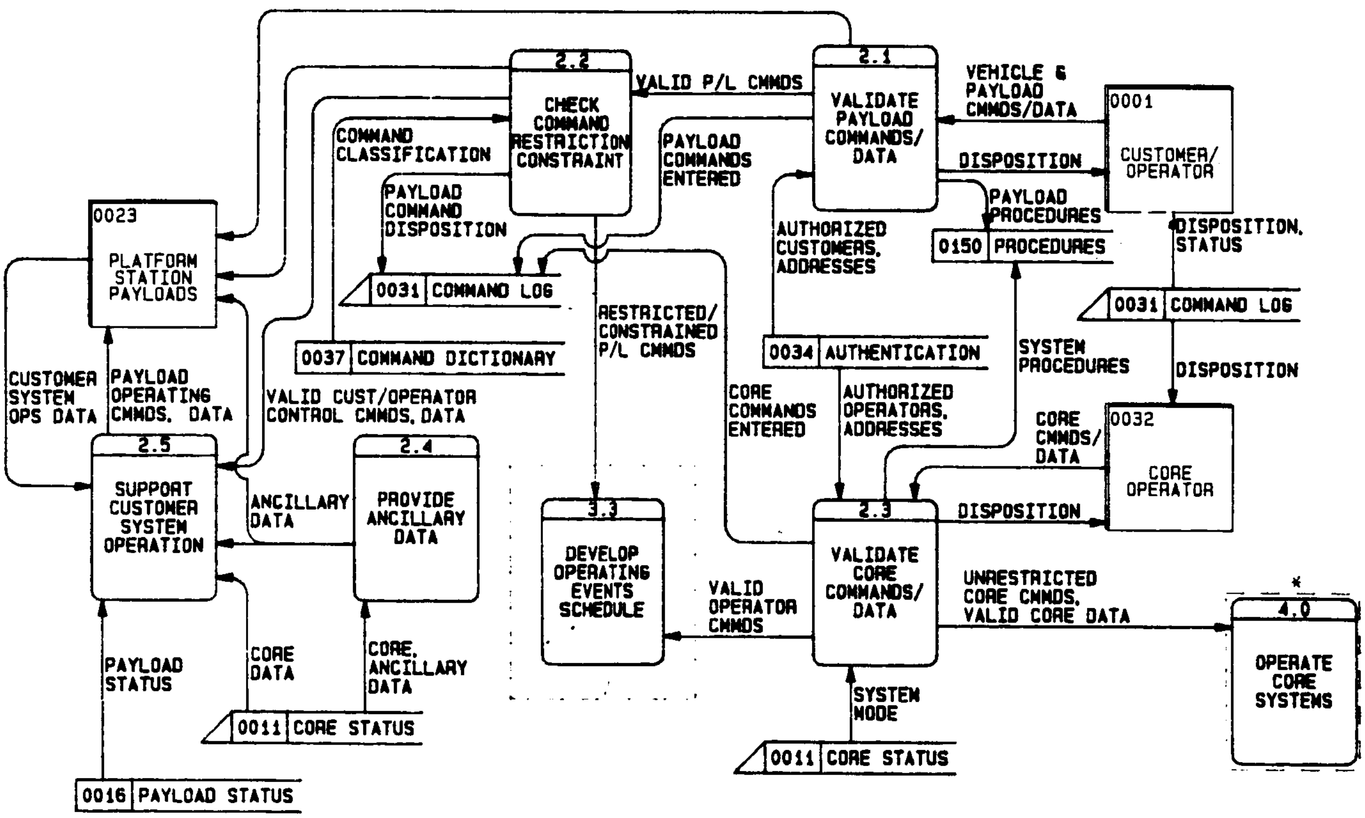

Figure 6-10. SSDS Level 1 DFD – Platforms, 2.0 Manage Customer/Operator Supplied Data

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In this review, 57 standard customer services for the SSDS were identified. Thirty of the services involved the providing of data either already available in the core systems or readily providable by core systems software. Twenty-seven of these services require functions which are not presently envisioned to be required to operate the core systems. Customer core and service functions were developed for each of the missions in the MRWG mission model (111 missions). This tabulation has not been updated for the "Woods Hole" model, as the conclusions regarding SSDS mission support services would not be materially altered. These are recorded in Tables 6-1 thru 6-8. The missions are divided according to payloads in or on the Space Station, payloads on platforms, payload integration and launch services, and satellite

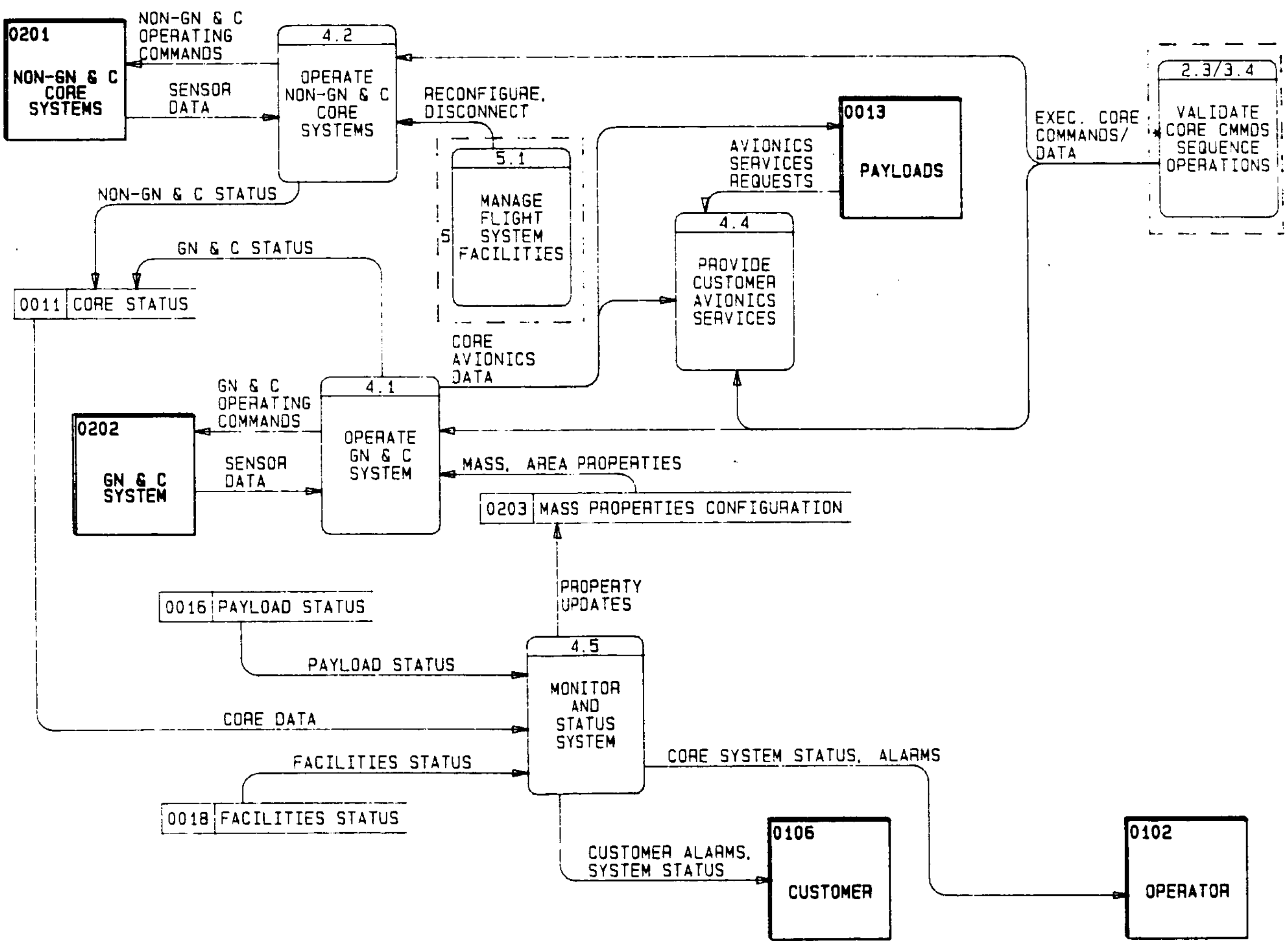

Figure 6-11. SSDS Level 1 DFD — Platforms, 4.0 Operate Core Systems

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servicing missions. Tables 6-1 thru 6-4 show the standard core service functional requirements of the mission model. Tables 6-5 thru 6-8 show the payload requirements for customer services which are not normally provided by the core systems.

Each of the functional requirements which were identified for the Space Station payloads has been recorded in the requirements traceability matrix. The requirements are also assigned to functions in the Space Station functions list and are incorporated into the SSDS functional requirements in section 5.3.

Table 6-1. Space Station Mission Requirements for Standard Core Services

Y - MISSION REQUIRES THIS SERVICE

CODE NO	MISSION TITLE	SS STATE/ORBIT DET	CONST STATE/ORBIT DET	EPHEMERIDES DET	ATTITUDE DET	SS STATE PROP	CONST STATE PROP	REBOOST COORDINATION	ATTITUDE MANEUVER	TARGET CO FLYER MANEUVER	SCHEDULE RENDEZVOUS	CONTROL TEMPERATURE	MANAGE THERMAL LOAD	TIME UPDATE	MESSAGE TIME TAGGING	IN ORBIT TRAINING	GROUND BASED TRAINING	CUSTOMER TRAINING SUPPORT	INTEGRATED SS SCHEDULING	SYS/SUBSYS CONFIGURATION STATUSING	INTEGRATED SS OPS SCHEDULING	COMMAND ENTRY	FLUIDS DATA STATUS	CREW PHYS MONITORING	MED DIAG SUPPORT	HEALTH RECORD MAINTENANCE	NUTRITION ANALYSES	RMS OPERATIONS	DOCKING OPERATIONS	LOGISTICS SCHEDULING	CONTROL PRESS MOD ATM COMP
SAAX0001	SPECTRA OF COSMIC RAY NUCLEI	Y		Y	Y				Y			Y	Y	Y	Y	Y			Y		Y	Y	Y					Y		Y	
SAAX0005	TRANSITION RADIATION AND IONIZATION CAL.	Y		Y	Y				Y			Y	Y	Y	Y	Y			Y		Y	Y	Y					Y		Y	
SAAX0008	HIGH ENERGY ISOTOPE EXPERIMENT	Y		Y	Y				Y			Y	Y	Y	Y	Y			Y		Y	Y	Y					Y		Y	
SAAX0010	SOLAR CORONA DIAGNOSTICS MISSION				Y									Y	Y	Y	Y	Y	Y		Y	Y								Y	
SAAX0201	LIDAR FACILITY	Y			Y	Y		Y	Y			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y									
SAAX0207	SOLAR TERRESTRIAL OBSERVATORY	Y			Y	Y		Y				Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y					Y	Y		
SAAX0301	HEALTH MAINTENANCE/CLINICAL RES											Y	Y		Y		Y	Y	Y		Y	Y		Y	Y	Y	Y				Y
SAAX0302	ANIMAL AND PLANT VIVARIUM AND LAB											Y	Y		Y	Y	Y	Y	Y		Y	Y			Y	Y	Y			Y	Y
SAAX0303	HUMAN RESEARCH LABORATORY											Y	Y		Y	Y	Y	Y	Y		Y	Y		Y	Y	Y	Y			Y	Y
SAAX0304	CELSS EXPERIMENTAL SYSTEMS											Y	Y		Y	Y	Y	Y	Y		Y	Y					Y			Y	Y
SAAX0305	DEDICATED CELSS MODULE											Y	Y		Y	Y	Y	Y	Y		Y	Y	Y				Y			Y	Y
SAAX0306	CELSS PALLET											Y	Y		Y	Y	Y	Y	Y		Y	Y	Y				Y			Y	Y
SAAX0307	LIFE SCIENCES LAB											Y	Y		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y			Y	Y
SAAX0401	MICROGRAVITY AND MAT PROCESS FAC NO. 1	Y						Y				Y	Y		Y	Y	Y	Y	Y		Y	Y	Y							Y	Y
SAAX0403	MICROGRAVITY AND MAT PROCESS FAC NO. 2	Y						Y				Y	Y		Y	Y	Y	Y	Y		Y	Y	Y							Y	Y
SAAX0404	MICROGRAVITY AND MAT PROCESS FAC NO. 3	Y						Y				Y	Y		Y	Y	Y	Y	Y		Y	Y	Y							Y	Y
COMM1014	REMOTE SENSING TEST, DEV AND VERIF	Y				Y		Y	Y					Y	Y	Y			Y		Y	Y									
COMM1105	COMMUNICATIONS TEST LAB	Y	Y			Y	Y	Y		Y					Y	Y			Y		Y		Y	Y					Y		
COMM1201	MPS PROCESSING LAB 1	Y						Y				Y	Y		Y	Y	Y	Y	Y		Y	Y	Y							Y	Y
COMM1202	EOS PRODUCTION UNITS	Y						Y				Y	Y		Y	Y	Y	Y	Y		Y	Y	Y							Y	Y
COMM1203	ECG PRODUCTION UNITS	Y						Y				Y	Y		Y	Y	Y	Y	Y		Y	Y	Y							Y	Y
COMM1204	MPS PROCESSING LAB 2	Y						Y				Y	Y		Y	Y	Y	Y	Y		Y	Y	Y							Y	Y
COMM1205	ECG PRODUCTION UNITS †2	Y						Y				Y	Y		Y	Y	Y	Y	Y		Y	Y	Y							Y	Y
COMM1206	BIOLOGICAL PRODUCTION UNITS	Y						Y				Y	Y		Y	Y	Y	Y	Y		Y	Y	Y							Y	Y
COMM1208	CRYSTAL PRODUCTION UNITS	Y						Y				Y	Y		Y	Y	Y	Y	Y		Y	Y	Y							Y	Y
COMM1213	CONTAINERLESS PROCESS PROD. UNIT	Y						Y				Y	Y		Y	Y	Y	Y	Y		Y	Y	Y							Y	Y
TDMX2010	MATERIALS PERFORMANCE TECH			Y				Y							Y	Y			Y		Y									Y	
TDMX2020	MATERIALS PROCESSING TECHNOLOGY	Y						Y				Y	Y		Y	Y	Y	Y	Y		Y	Y	Y							Y	Y
TDMX2060	DEPLOYMENT ASSEMBLY AND CONSTRUCTION	Y	Y					Y						Y	Y	Y	Y	Y	Y		Y	Y		Y				Y			
TDMX2070	STRUCTURAL DYNAMICS	Y						Y						Y	Y	Y	Y	Y	Y		Y									Y	
TDMX2080	DESIGN VERIFICATION TECHNOLOGY							Y						Y	Y	Y	Y	Y	Y		Y							Y		Y	
TDMX2110	LARGE SOLAR CONCENTRATOR TECHNOLOGY	Y		Y	Y									Y	Y	Y	Y	Y	Y		Y							Y			
TDMX2120	LASER POWER TRANSMISSION/RECEPT	Y	Y	Y	Y			Y	Y	Y	Y			Y	Y	Y			Y		Y										
TDMX2130	WASTE HEAT REJECTION TECHNOLOGY	Y			Y										Y	Y			Y		Y										
TDMX2150	POWER SYSTEM TECHNOLOGY EXP	Y			Y										Y	Y			Y		Y										
TDMX2210	LARGE SPACE ANTENNA TECHNOLOGY	Y	Y			Y	Y	Y		Y				Y	Y	Y			Y		Y							Y		Y	
TDMX2220	TELECOM SYSTEMS TECHNOLOGY	Y	Y			Y	Y	Y		Y				Y	Y	Y			Y		Y										
TDMX2230	SPACE INTERFEROMETER SYST TECH	Y	Y		Y	Y	Y	Y		Y				Y	Y	Y			Y		Y										
TDMX2260	EARTH OBSERVATION INSTRUMENT TECH	Y			Y	Y		Y						Y	Y	Y			Y		Y							Y			
TDMX2310	FLUID MANAGEMENT TECHNOLOGY	Y						Y							Y	Y			Y		Y							Y			
TDMX2320	LOW THRUST PROPULSION	Y			Y	Y		Y		Y				Y	Y	Y			Y		Y	Y	Y								
TDMX2410	ATTITUDE CONTROL TECHNOLOGY	Y			Y	Y		Y		Y				Y	Y	Y			Y		Y										
TDMX2420	FIGURE CONTROL TECHNOLOGY	Y			Y	Y		Y		Y				Y	Y	Y			Y		Y	Y	Y								
TDMX2430	ADVANCED CONTROL DEVICE TECHNOL	Y			Y	Y		Y		Y					Y	Y			Y		Y	Y	Y								
TDMX2460	TELEPRESENCE TECHNOLOGY	Y						Y							Y	Y	Y	Y	Y		Y							Y			
TDMX2470	INTERACTIVE HUMAN FACTORS											Y	Y		Y	Y	Y	Y	Y		Y	Y		Y		Y		Y			Y
TDMX2510	ENVIRONMENTAL EFFECTS TECHNOL	Y						Y							Y	Y			Y		Y			Y		Y					Y
TDMX2520	HABITATION TECHNOLOGY											Y	Y		Y	Y			Y		Y			Y		Y					Y
TDMX2530	MEDICAL TECHNOLOGY											Y	Y		Y	Y			Y		Y			Y	Y	Y	Y				Y
TDMX2570	OTV SERVICING TECHNOLOGY	Y	Y			Y	Y	Y		Y	Y	Y	Y		Y	Y	Y	Y	Y		Y	Y	Y					Y	Y	Y	

Table 6-2. Platform Requirements for Standard Core Services

Y – MISSION REQUIRES THIS SERVICE

CODE NO.	MISSION TITLE	SS STATE/ORBIT DET	CONST STATE/ORBIT DET	EPHEMERIDES DET	ATTITUDE DET	SS STATE PROP.	CONST STATE PROP.	REBOOST COORDINATION	ATTITUDE MANEUVER	TARGET CO-FLYER MANEUVER	SCHEDULE RENDEZVOUS	CONTROL TEMPERATURE	MANAGE THERMAL LOAD	TIME UPDATE	MESSAGE TIME TAGGING	IN-ORBIT TRAINING	GROUND-BASED TRAINING	CUSTOMER TRAINING SUPPORT	INTEGRATED SS SCHEDULING	SYS/SUBSYS CONFIGURATION STATUSING	INTEGRATED SS OPS SCHEDULING	COMMAND ENTRY	FLUIDS DATA STATUS	CREW PHYS MONITORING	MED DIAG SUPPORT	HEALTH RECORD MAINTENANCE	NUTRITION ANALYSES	RMS OPERATIONS	DOCKING OPERATIONS	LOGISTICS SCHEDULING	CONTROL PRESS. MOD ATM COMP
	COORBITING PLATFORM																														
SAAX0004	SHUTTLE INFRARED TELESCOPE FACILITY		Y	Y		Y	Y	Y		Y	Y			Y	Y	Y	Y		Y		Y	Y	Y						Y	Y	
SAAX0006	STARLAB		Y	Y		Y	Y	Y		Y	Y			Y	Y	Y	Y	Y	Y		Y	Y	Y						Y	Y	
SAAX0007	HIGH THROUGHPUT MISSION		Y	Y		Y	Y	Y		Y	Y			Y	Y	Y			Y	Y	Y	Y	Y						Y	Y	
SAAX0009	PINHOLE/OCCULTER FACILITY		Y	Y		Y	Y	Y	Y	Y	Y			Y	Y	Y	Y	Y	Y		Y	Y	Y							Y	
SAAX0011	ADVANCED SOLAR OBSERVATORY (ASO)		Y			Y	Y	Y		Y	Y			Y	Y	Y	Y	Y	Y										Y		
	POLAR PLATFORM																														
SAAX0202	EARTH OBSERVING SYSTEM (EOS)	Y		Y		Y		Y																							
SAAX0208	MOD RES IMAGING SPECTROMETER																														
SAAX0209	HIGH RES IMAGING SPECT (HIRIS)																														
SAAX0210	HIGH RES MULTIFREQ MW RADIOMETER																														
SAAX0211	LASER ATMOSPHERIC SOUNDER (LASA)																														
SAAX0212	SYNTHETIC APERTURE RADAR																														
SAAX0213	RADAR ALTIMETER (ALT)																														
SAAX0214	SCATTEROMETER (SCATT)																														
SAAX0215	TROPOSPHERIC COMPOSITION MONITOR																														
SAAX0216	DIRECT TROPOSHPERIC WIND SENSING																														
SAAX0217	UPPER ATMOSPHERIC COMPOSITION																														
SAAX0218	UPPER ATMOSPHERIC WIND SOUNDING																														
SAAX0219	ENVIRONMENTAL MONITORS																														
SAAX0220	AUTOMATED DATA COLLECT./LOC SYS																														
COMM1023	STEREO SAR AND MLA AND CZCS																														
COMM1019	MULTI LINEAR ARRAY STEREO																														

Table 6-3. Payload Integration Mission Requirements for Standard Core Services

Y – MISSION REQUIRES THIS SERVICE

CODE NO.	MISSION TITLE	SS STATE/ORBIT DET	CONST STATE/ORBIT DET	EPHEMERIDES DET	ATTITUDE DET	SS STATE PROP.	CONST STATE PROP.	REBOOST COORDINATION	ATTITUDE MANEUVER	TARGET CO-FLYER MANEUVER	SCHEDULE RENDEZVOUS	CONTROL TEMPERATURE	MANAGE THERMAL LOAD	TIME UPDATE	MESSAGE TIME TAGGING	IN-ORBIT TRAINING	GROUND-BASED TRAINING	CUSTOMER TRAINING SUPPORT	INTEGRATED SS SCHEDULING	SYS/SUBSYS CONFIGURATION STATUSING	INTEGRATED SS OPS SCHEDULING	COMMAND ENTRY	FLUIDS DATA STATUS	CREW PHYS MONITORING	MED DIAG SUPPORT	HEALTH RECORD MAINTENANCE	NUTRITION ANALYSES	RMS OPERATIONS	DOCKING OPERATIONS	LOGISTICS SCHEDULING	CONTROL PRESS. MOD ATM COMP
SAAX0020	LARGE DEPLOYABLE REFLECTOR	Y	Y			Y	Y	Y		Y	Y					Y			Y		Y		Y					Y	Y		
SAAX0101	MARS GEOSCIEN/CLIMATOL ORBITER	Y	Y					Y		Y									Y		Y		Y					Y	Y		
SAAX0102	LUNAR GEOSCIENCES ORBITER	Y	Y					Y		Y									Y		Y		Y					Y	Y		
SAAX0103	COMET RENDEZVOUS/ASTEROID FLYBY	Y	Y					Y		Y									Y		Y		Y					Y	Y		
SAAX0104	VENUS ATMOSPHERE PROBE	Y	Y					Y		Y									Y		Y		Y					Y	Y		
SAAX0105	SATURN ORBITER/TITAN PROBE	Y	Y					Y		Y									Y		Y		Y					Y	Y		
SAAX0106	SATURN FLYBY/SATURN PROBE	Y	Y					Y		Y									Y		Y		Y					Y	Y		
SAAX0107	MAIN BELT ASTEROID RENDEZVOUS	Y	Y					Y		Y									Y		Y		Y					Y	Y		
SAAX0109	NEAR EARTH ASTEROID RENDEZVOUS	Y	Y					Y		Y									Y		Y		Y					Y	Y		
SAAX0110	MARS SAMPLE RETURN LAUNCH	Y	Y			Y	Y	Y		Y	Y					Y			Y		Y		Y					Y	Y		
SAAX0221	LARGE MICROWAVE ANTENNA	Y	Y			Y	Y	Y			Y			Y	Y	Y			Y		Y	Y	Y					Y			
COMM1110	CLASS IV COMM SAT. DELIVERY	Y	Y			Y	Y	Y		Y	Y					Y	Y	Y	Y		Y	Y	Y					Y	Y		
COMM1115	CLASS III SAT. DELIVERY	Y	Y			Y	Y	Y		Y	Y					Y	Y	Y	Y		Y	Y	Y					Y	Y		
COMM1116	CLASS II COMM SAT DELIVERY	Y	Y			Y	Y	Y		Y	Y					Y	Y	Y	Y		Y	Y	Y					Y	Y		
COMM1117	CLASS I COMM SAT DELIVERY	Y	Y			Y	Y	Y		Y	Y					Y	Y	Y	Y		Y	Y	Y					Y	Y		
COMM1124	CLASS IV COMM SAT. SERVICING	Y	Y			Y	Y	Y		Y	Y					Y	Y	Y	Y		Y	Y	Y					Y	Y		
COMM1125	CLASS III COMM SAT SERVICING	Y	Y			Y	Y	Y		Y	Y					Y	Y	Y	Y		Y	Y	Y					Y	Y		
COMM1126	CLASS II COMM SAT SERVICING	Y	Y			Y	Y	Y		Y	Y					Y	Y	Y	Y		Y	Y	Y					Y	Y		
COMM1304	OMV/TMS	Y	Y	Y		Y	Y	Y		Y	Y			Y	Y	Y			Y		Y	Y	Y					Y	Y	Y	
COMM1309	SPACE BASED OTV	Y	Y	Y		Y	Y	Y		Y	Y			Y	Y	Y			Y		Y	Y	Y					Y	Y	Y	
COMM1312	SATELLITE SERVICING	Y	Y			Y	Y	Y		Y	Y					Y	Y	Y	Y		Y	Y	Y					Y	Y	Y	
COMM1318	MULTIUSE PLATFORM	Y	Y			Y	Y	Y		Y	Y			Y	Y	Y			Y		Y	Y	Y					Y		Y	
TDMX2560	SATELLITE SERVICING TECH	Y	Y		Y	Y	Y	Y		Y	Y				Y	Y	Y	Y	Y		Y							Y			Y

Table 6-4. Free Flyer Servicing Mission Requirements for Standard Core Services

Y – MISSION REQUIRES THIS SERVICE

CODE NO.	MISSION TITLE	SS STATE/ORBIT DET	CONST STATE/ORBIT DET	EPHEMERIDES DET	ATTITUDE DET	SS STATE PROP	CONST STATE PROP	REBOOST COORDINATION	ATTITUDE MANEUVER	TARGET CO-FLYER MANEUVER	SCHEDULE RENDEZVOUS	CONTROL TEMPERATURE	MANAGE THERMAL LOAD	TIME UPDATE	MESSAGE TIME TAGGING	IN-ORBIT TRAINING	GROUND BASED TRAINING	CUSTOMER TRAINING SUPPORT	INTEGRATED SS SCHEDULING	SYS/SUBSYS CONFIGURATION STATUSINC	INTEGRATED SS OPS SCHEDULING	COMMAND ENTRY	FLUIDS DATA STATUS	CREW PHYS MONITORING	MED DIAG SUPPORT	HEALTH RECORD MAINTENANCE	NUTRITION ANALYSES	RMS OPERATIONS	DOCKING OPERATIONS	LOGISTICS SCHEDULING	CONTROL PRESS MOD ATM COMP
SAAX0012	HUBBLE SPACE TELESCOPE	Y	Y		Y	Y	Y	Y	Y	Y	Y					Y	Y	Y	Y		Y		Y					Y	Y		
SAAX0013	GAMMA RAY OBSERVATORY	Y	Y		Y	Y	Y	Y	Y	Y	Y					Y	Y	Y	Y		Y		Y					Y	Y		
SAAX0014	X-RAY TIMING EXPLORER	Y	Y		Y	Y	Y	Y	Y	Y	Y					Y			Y		Y		Y					Y	Y		
SAAX0015	INTERNAT SOLAR TERRESTRIAL PROGRAM																														
SAAX0016	SOLAR MAX MISSION	Y	Y		Y	Y	Y	Y	Y	Y	Y					Y			Y		Y		Y					Y	Y		
SAAX0017	ADVANCED X-RAY ASTROPHYSICS FACILITY	Y	Y		Y	Y	Y	Y	Y	Y	Y					Y			Y		Y		Y					Y	Y		
SAAX0018	UV LONG BASELINE INTERFER							Y			Y					Y			Y		Y										
SAAX0019	FAR UV SPECTROSCOPY EXPLORER	Y	Y		Y	Y	Y	Y	Y	Y	Y					Y			Y		Y		Y						Y		
SAAX0022	SOLAR SEISMOLOGY MISSION	Y	Y			Y	Y	Y		Y	Y					Y			Y		Y		Y					Y	Y		
SAAX0203	OCEAN TOPOGRAPHY EXP (TOPEX)																														
SAAX0204	GEOPOTENTIAL RESEARCH MISSION																														
SAAX0205	GEOSYNCHRONOUS PLATFORM																														
SAAX0206	UPPER ATMOSPHERE RESEARCH SAT.																														
SAAX0222	INFRARED SOUNDING	Y	Y			Y	Y	Y			Y			Y	Y	Y			Y		Y	Y	Y					Y			
SAAX0223	LARGE IMAGER	Y	Y			Y	Y	Y			Y								Y				Y					Y	Y		
SAAX0402	MICRO G VARIABLE 'G' FREE FLYER	Y	Y			Y	Y	Y		Y	Y				Y	Y			Y		Y		Y					Y	Y		
SAAX0501	EXPERIMENTAL GEO PLATFORM (XGP)																														

6.4 MRWG PERFORMANCE REQUIREMENTS ANALYSIS

The various panels at the Woods Hole Requirements Workshop tabulated performance requirements for each of the 111 missions in the mission set. These requirements include performance requirements applicable to the SSDS, such as:

- Data rate from the payloads
- Payload operating hours per cycle
- Payload operating cycles per day
- Delta delivery time
- Command rate to the payloads
- Command generation hours per cycle
- Command generation cycles per day
- Command delivery time
- Voice channel time
- Video channel time.

In addition, an upper limit for onboard data storage for the Space Station and platforms can be inferred by assuming a once per orbit data dump to the

Table 6-5. Space Station Mission Requirements for Customer Services

Y – MISSION REQUIRES THIS SERVICE

CODE NO.	MISSION TITLE	GROUND TRACK DET	VENTING EFFECTS DET	MAG FIELD DET	POWERED GUIDANCE	SS USER SYS STATUS	GROUND USER SYS STATUS	RELAY USER COMMUNICATIONS	USER DATA PROCESSING	USER PROCESS CONTROL	USER SOFTWARE DEVELOPMENT SUPPORT	USER PACKAGE VERIFICATION	PAYLOAD CHECKOUT SERVICES	PAYLOAD ACTIVATION/SAFING	PAYLOAD OPS SCHEDULING	OTV RECHARGE	OTV CHECKOUT/DIAGNOSTICS	OTV DEPLOYMENT	OMV RECHARGE	OMV REFUEL	OMV CHECKOUT/DIAGNOSTICS	OMV DEPLOYMENT	OMV REMOTE OPS CONTROL	REL RANGE, RATE AND ATTITUDE DET	MISSION PLANNING	ENVIRONMENTAL MONITOR	VOLTAGE/CURRENT MONITOR	REALTIME/QUICK LOOK DATA
SAAX0001	SPECTRA OF COSMIC RAY NUCLEI		Y	Y				Y	Y			Y	Y		Y											Y	Y	
SAAX0005	TRANSITION RADIATION AND IONIZATION CAL.		Y	Y				Y	Y			Y	Y		Y											Y	Y	
SAAX0008	HIGH ENERGY ISOTOPE EXPERIMENT		Y	Y				Y	Y			Y	Y		Y											Y	Y	
SAAX0010	SOLAR CORONA DIAGNOSTICS MISSION		Y			Y		Y	Y	Y	Y	Y	Y	Y	Y										Y		Y	
SAAX0201	LIDAR FACILITY	Y				Y		Y	Y	Y		Y	Y	Y	Y									Y	Y	Y	Y	
SAAX0207	SOLAR TERRESTRIAL OBSERVATORY										Y	Y			Y										Y	Y	Y	
SAAX0301	HEALTH MAINTENANCE/CLINICAL RES					Y	Y	Y	Y	Y	Y	Y													Y		Y	
SAAX0302	ANIMAL AND PLANT VIVARIUM AND LAB					Y	Y	Y	Y	Y	Y	Y	Y	Y	Y										Y		Y	
SAAX0303	HUMAN RESEARCH LABORATORY					Y	Y	Y	Y	Y	Y	Y	Y	Y	Y										Y		Y	
SAAX0304	CELSS EXPERIMENTAL SYSTEMS					Y	Y	Y	Y	Y	Y	Y	Y	Y	Y										Y		Y	
SAAX0305	DEDICATED CELSS MODULE					Y	Y	Y	Y	Y	Y	Y	Y	Y	Y										Y		Y	
SAAX0306	CELSS PALLET					Y	Y	Y	Y	Y	Y	Y	Y	Y	Y										Y		Y	
SAAX0307	LIFE SCIENCES LAB					Y	Y	Y	Y	Y	Y	Y	Y	Y	Y										Y		Y	
SAAX0401	MICROGRAVITY AND MAT. PROCESS FAC NO. 1					Y	Y	Y	Y	Y	Y	Y	Y	Y	Y										Y	Y	Y	Y
SAAX0403	MICROGRAVITY AND MAT. PROCESS FAC NO. 2					Y	Y	Y	Y	Y	Y	Y	Y	Y	Y										Y	Y	Y	Y
SAAX0404	MICROGRAVITY AND MAT. PROCESS FAC NO. 3					Y	Y	Y	Y	Y	Y	Y	Y	Y	Y										Y	Y	Y	Y
COMM1014	REMOTE SENSING TEST, DEV AND VERIF	Y						Y		Y															Y		Y	Y
COMM1105	COMMUNICATIONS TEST LAB	Y				Y		Y	Y		Y								Y	Y	Y	Y	Y	Y	Y		Y	Y
COMM1201	MPS PROCESSING LAB 1					Y		Y	Y	Y	Y	Y	Y	Y	Y										Y	Y	Y	Y
COMM1202	EOS PRODUCTION UNITS					Y		Y	Y	Y	Y	Y	Y	Y	Y										Y	Y	Y	Y
COMM1203	ECG PRODUCTION UNITS					Y		Y	Y	Y	Y	Y	Y	Y	Y										Y	Y	Y	Y
COMM1204	MPS PROCESSING LAB 2					Y		Y	Y	Y	Y	Y	Y	Y	Y										Y	Y	Y	Y
COMM1205	ECT PRODUCTION UNITS †2					Y		Y	Y	Y	Y	Y	Y	Y	Y										Y	Y	Y	Y
COMM1206	BIOLOGICAL PRODUCTION UNITS					Y		Y	Y	Y	Y	Y	Y	Y	Y										Y	Y	Y	Y
COMM120C	CRYSTAL PRODUCTION UNITS					Y		Y	Y	Y	Y	Y	Y	Y	Y										Y	Y	Y	Y
COMM1213	CONTAINERLESS PROCESS PROD. UNIT					Y		Y	Y	Y	Y	Y	Y	Y	Y										Y	Y	Y	Y
TDMX2010	MATERIALS PERFORMANCE TECH		Y												Y										Y	Y	Y	
TDMX2020	MATERIALS PROCESSING TECHNOLOGY							Y	Y	Y	Y	Y	Y	Y	Y										Y	Y	Y	Y
TDMX2060	DEPLOYMENT, ASSEMBLY AND CONSTRUCTION							Y	Y	Y	Y	Y	Y	Y	Y				Y	Y	Y	Y	Y	Y	Y			Y
TDMX2070	STRUCTURAL DYNAMICS		Y			Y		Y	Y	Y	Y														Y		Y	Y
TDMX2080	DESIGN VERIFICATION TECHNOLOGY		Y			Y		Y	Y																Y		Y	Y
TDMX2110	LARGE SOLAR CONCENTRATOR TECHNOLOGY		Y					Y	Y										Y	Y	Y	Y	Y	Y	Y		Y	Y
TDMX2120	LASER/POWER TRANSMISSION/RECEPT							Y	Y																Y		Y	Y
TDMX2130	WASTE HEAT REJECTION TECHNOLOGY							Y																	Y		Y	Y
TDMX2150	POWER SYSTEM TECHNOLOGY EXP							Y																	Y		Y	Y
TDMX2210	LARGE SPACE ANTENNA TECHNOLOGY							Y	Y										Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
TDMX2220	TELECOM SYSTEMS TECHNOLOGY							Y	Y										Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
TDMX2230	SPACE INTERFEROMETER SYST TECH	Y						Y	Y										Y	Y	Y	Y	Y	Y	Y		Y	Y
TDMX2260	EARTH OBSERVATION INSTRUMENT TECH	Y						Y																	Y		Y	Y
TDMX2310	FLUID MANAGEMENT TECHNOLOGY							Y																	Y	Y	Y	Y
TDMX2320	LOW THRUST PROPULSION	Y						Y																	Y	Y	Y	Y
TDMX2410	ATTITUDE CONTROL TECHNOLOGY							Y	Y																Y	Y	Y	Y
TDMX2420	FIGURE CONTROL TECHNOLOGY	Y						Y	Y																Y	Y	Y	Y
TDMX2430	ADVANCED CONTROL DEVICE TECHNOL	Y						Y																	Y		Y	Y
TDMX2460	TELEPRESENCE TECHNOLOGY							Y	Y										Y	Y	Y	Y	Y	Y	Y		Y	Y
TDMX2478	INTERACTIVE HUMAN FACTORS							Y																	Y		Y	Y
TDMX2510	ENVIRONMENTAL EFFECTS TECHNOL							Y																	Y	Y	Y	Y
TDMX2520	HABITATION TECHNOLOGY							Y																	Y		Y	Y
TDMX2530	MEDICAL TECHNOLOGY							Y																	Y		Y	Y
TDMX2570	OTV SERVICING TECHNOLOGY							Y	Y							Y	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y

ground. These requirements are summarized for the Space Station and for the platforms in Tables 6-9 thru 6-13. The peak data rates shown in the tables represent the sum of the peak data rates of the individual payloads which are on board the vehicles for each of the years shown. Two average data rates are shown, one for all missions, and one excluding the very high rate missions likely to be downlinked by "bent-pipe" relay. The average data rates for the low rate missions includes a scheduling factor of 1.8 for data rates less than 50 Mbps to accommodate peak data recording rates. The peak and average command

Table 6-6. Platform Requirements for Customer Services

Y - MISSION REQUIRES THIS SERVICE

CODE NO.	MISSION TITLE	GROUND TRACK DET	VENTING EFFECTS DET	MAG FIELD DET	POWERED GUIDANCE	SS USER SYS STATUS	GROUND USER SYS STATUS	RELAY USER COMMUNICATIONS	USER DATA PROCESSING	USER PROCESS CONTROL	USER SOFTWARE DEVELOPMENT SUPPORT	USER PACKAGE VERIFICATION	PAYLOAD CHECKOUT SERVICES	PAYLOAD ACTIVATION/SAFING	PAYLOAD OPS SCHEDULING	OTV RECHARGE	OTV CHECKOUT/DIAGNOSTICS	OTV DEPLOYMENT	OMV RECHARGE	OMV REFUEL	OMV CHECKOUT/DIAGNOSTICS	OMV DEPLOYMENT	OMV REMOTE OPS CONTROL	REL RANGE, RATE AND ATTITUDE DET	MISSION PLANNING	ENVIRONMENTAL MONITOR	VOLTAGE/CURRENT MONITOR	REALTIME/QUICK LOOK DATA
	COORBITING PLATFORM																											
SAAX0004	SHUTTLE INFRARED TELESCOPE FACILITY		Y			Y		Y		Y			Y		Y				Y	Y	Y	Y	Y		Y	Y		Y
SAAX0006	STARLAB		Y					Y	Y	Y	Y	Y	Y		Y				Y	Y	Y	Y	Y		Y	Y		Y
SAAX0007	HIGH THROUGHPUT MISSION					Y		Y	Y			Y	Y		Y				Y	Y	Y	Y	Y		Y	Y		Y
SAAX0009	PINHOLE/OCCULTER FACILITY		Y			Y		Y	Y	Y	Y	Y	Y	Y	Y										Y			
SAAX0011	ADVANCED SOLAR OBSERVATORY (ASO)		Y			Y		Y	Y	Y	Y	Y	Y	Y	Y				Y	Y	Y	Y	Y	Y	Y	Y		
	POLAR PLATFORM																											
SAAX0202	EARTH OBSERVING SYSTEM (EOS)										Y	Y			Y										Y			
SAAX0208	MOD RES IMAGING SPECTROMETER										Y	Y			Y										Y			
SAAX0209	HIGH RES IMAGING SPECT (HIRIS)										Y	Y			Y										Y			
SAAX0210	HIGH RES MULTIFREQ MW RADIOMETER										Y	Y			Y										Y			
SAAX0211	LASER ATMOSPHERIC SOUNDER (LASA)										Y	Y			Y										Y			
SAAX0212	SYNTHETIC APERTURE RADAR										Y	Y			Y										Y			
SAAX0213	RADAR ALTIMETER (ALT)										Y	Y			Y										Y			
SAAX0214	SCATTEROMETER (SCATT)										Y	Y			Y										Y			
SAAX0215	TROPOSPHERIC COMPOSITION MONITOR										Y	Y			Y										Y			
SAAX0216	DIRECT TROPOSHPERIC WIND SENSING										Y	Y			Y										Y			
SAAX0217	UPPER ATMOSPHERIC COMPOSITION										Y	Y			Y										Y			
SAAX0218	UPPER ATMOSPHERIC WIND SOUNDING										Y	Y			Y										Y			
SAAX0219	ENVIRONMENTAL MONITORS										Y	Y			Y										Y			
SAAX0220	AUTOMATED DATA COLLECT./LOC SYS										Y	Y			Y										Y			
COMM1023	STEREO SAR AND MLA AND CZCS										Y	Y			Y										Y			
COMM1019	MULTI LINEAR ARRAY STEREO										Y	Y			Y										Y			

Table 6-7. Payload Integration Mission Requirements for Customer Services

Y - MISSION REQUIRES THIS SERVICE

CODE NO.	MISSION TITLE	GROUND TRACK DET	VENTING EFFECTS DET	MAG FIELD DET	POWERED GUIDANCE	SS USER SYS STATUS	GROUND USER SYS STATUS	RELAY USER COMMUNICATIONS	USER DATA PROCESSING	USER PROCESS CONTROL	USER SOFTWARE DEVELOPMENT SUPPORT	USER PACKAGE VERIFICATION	PAYLOAD CHECKOUT SERVICES	PAYLOAD ACTIVATION/SAFING	PAYLOAD OPS SCHEDULING	OTV RECHARGE	OTV CHECKOUT/DIAGNOSTICS	OTV DEPLOYMENT	OMV RECHARGE	OMV REFUEL	OMV CHECKOUT/DIAGNOSTICS	OMV DEPLOYMENT	OMV REMOTE OPS CONTROL	REL RANGE, RATE AND ATTITUDE DET	MISSION PLANNING	ENVIRONMENTAL MONITOR	VOLTAGE/CURRENT MONITOR	REALTIME/QUICK LOOK DATA
SAAX0020	LARGE DEPLOYABLE REFLECTOR				Y								Y						Y	Y	Y	Y	Y	Y				
SAAX0101	MARS GEOSCIEN-CLIMATOL ORBITER							Y					Y						Y	Y	Y	Y	Y	Y				
SAAX0102	LUNAR GEOSCIENCES ORBITER							Y					Y						Y	Y	Y	Y	Y	Y				
SAAX0103	COMET RENDEZVOUS/ASTEROID FLYBY							Y					Y						Y	Y	Y	Y	Y	Y				
SAAX0104	VENUS ATMOSPHERE PROBE							Y					Y						Y	Y	Y	Y	Y	Y				
SAAX0105	SATURN ORBITER/TITAN PROBE							Y					Y						Y	Y	Y	Y	Y	Y				
SAAX0106	SATURN FLYBY/SATURN PROBE							Y					Y						Y	Y	Y	Y	Y	Y				
SAAX0107	MAIN BELT ASTEROID RENDEZVOUS							Y					Y						Y	Y	Y	Y	Y	Y				
SAAX0109	NEAR EARTH ASTEROID RENDEZVOUS							Y					Y						Y	Y	Y	Y	Y	Y				
SAAX0110	MARS SAMPLE RETURN LAUNCH							Y					Y						Y	Y	Y	Y	Y	Y				
SAAX0221	LARGE MICROWAVE ANTENNA	Y				Y		Y	Y	Y	Y	Y	Y	Y	Y				Y	Y	Y	Y	Y	Y				
COMM1110	CLASS IV COMM SAT DELIVERY					Y	Y	Y				Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y				
COMM1115	CLASS III SAT DELIVERY					Y	Y	Y				Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y				
COMM1116	CLASS II COMM SAT DELIVERY					Y	Y	Y				Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y				
COMM1117	CLASS I COMM SAT DELIVERY					Y	Y	Y				Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y				
COMM1124	CLASS IV COMM SAT SERVICING					Y	Y	Y				Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y				
COMM1125	CLASS III COMM SAT SERVICING					Y	Y	Y				Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y				
COMM1126	CLASS II COMM SAT SERVICING					Y	Y	Y				Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y				
COMM1304	OMV TMS	Y			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y				Y	Y	Y	Y	Y	Y	Y			Y
COMM1309	SPACE BASED OTV	Y			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y			Y
COMM1312	SATELLITE SERVICING					Y	Y	Y				Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y			Y
COMM1318	MULTIUSE PLATFORM					Y		Y											Y	Y	Y	Y	Y	Y				
TDMX2560	SATELLITE SERVICING TECH							Y											Y	Y	Y	Y	Y	Y	Y		Y	Y

Table 6-8. Free Flyer Servicing Mission Requirements for Customer Services

Y – MISSION REQUIRES THIS SERVICE

CODE NO.	MISSION TITLE	GROUND TRACK DET	VENTING EFFECTS DET	MAG FIELD DET	POWERED GUIDANCE	SS USER SYS STATUS	GROUND USER SYS STATUS	RELAY USER COMMUNICATIONS	USER DATA PROCESSING	USER PROCESS CONTROL	USER SOFTWARE DEVELOPMENT SUPPORT	USER PACKAGE VERIFICATION	PAYLOAD CHECKOUT SERVICES	PAYLOAD ACTIVATION/SAFING	PAYLOAD OPS SCHEDULING	OTV RECHARGE	OTV CHECKOUT/DIAGNOSTICS	OTV DEPLOYMENT	OMV RECHARGE	OMV REFUEL	OMV CHECKOUT/DIAGNOSTICS	OMV DEPLOYMENT	OMV REMOTE OPS CONTROL	REL RANGE, RATE AND ATTITUDE DET	MISSION PLANNING	ENVIRONMENTAL MONITOR	VOLTAGE/CURRENT MONITOR	REALTIME/QUICK LOOK DATA
SAAX0012	HUBBLE SPACE TELESCOPE		Y		Y								Y						Y	Y	Y	Y	Y	Y		Y		
SAAX0013	GAMMA RAY OBSERVATORY		Y		Y								Y						Y	Y	Y	Y	Y	Y		Y		
SAAX0014	X-RAY TIMING EXPLORER				Y								Y						Y	Y	Y	Y	Y	Y		Y		
SAAX0015	INTERNAT SOLAR TERRESTRIAL PROGRAM																											
SAAX0016	SOLAR MAX MISSION				Y								Y						Y	Y	Y	Y	Y	Y		Y		
SAAX0017	ADVANCED X-RAY ASTROPHYSICS FACILITY				Y								Y						Y	Y	Y	Y	Y	Y		Y		
SAAX0018	UV LONG BASELINE INTERFER				Y								Y						Y	Y	Y	Y	Y	Y				
SAAX0019	FAR UV SPECTROSCOPY EXPLORER				Y								Y						Y	Y	Y	Y	Y	Y				
SAAX0022	SOLAR SEISMOLOGY MISSION				Y								Y						Y	Y	Y	Y	Y	Y				
SAAX0203	OCEAN TOPOGRAPHY EXP (TOPEX)																											
SAAX0204	GEOPOTENTIAL RESEARCH MISSION																											
SAAX0205	GEOSYNCHRONOUS PLATFORM	Y																										
SAAX0206	UPPER ATMOSPHERE RESEARCH SAT.																											
SAAX0222	INFRARED SOUNDING	Y				Y		Y	Y	Y	Y	Y	Y	Y	Y				Y	Y	Y	Y	Y	Y				
SAAX0223	LARGE IMAGER							Y											Y	Y	Y	Y	Y	Y				
SAAX0402	MICRO G VARIABLE 'G' FREE FLYER							Y											Y	Y	Y	Y	Y	Y				
SAAX0501	EXPERIMENTAL GEO PLATFORM (XGP)															Y	Y	Y	Y	Y	Y	Y	Y	Y				

Table 6-9. Space Station Attached and Internal Payloads Mission Data Requirements Summary

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Peak Data Rate (Mbps)	2.4	2.4	312	312	403	403	353	353	53	53
Scheduled Data Rate, Low Rate[1] Missions (Mbps) (Ref 15)	4.3	4.3		7.1	52.9	54.1	39.4	39.4	39.4	39.4
Average Data Rate[2] (Mbps)	2.4	2.4	6.3	6.4	55.0	55.7	38.1	38.1	35.6	35.6
Onboard Data Storage (Gbits)	13	13	34	35	297	301	206	206	192	192
Peak Command Rate (kbps)	79	78	79	82	81	77	67	67	67	67
Average Command Rate (kbps)	1.6	1.6	2.8	3.3	3.4	3.4	3.0	3.5	3.5	3.5
Voice/Video Channel Time (hr/day)	19.4	21.1	45.8	47.6	71.6	71.3	71.3	71.4	71.4	71.4

1. Contains Missions With Data Rates Less Than 200 Mbps, Uses a 1.8 Schedule Factor for Missions With Data Rates Below 50 Mbps
2. Rate for All Missions Without 1.8 Schedule Factor Applies to Long Term Averages
3. Based on Storage at Scheduled Data Rate for the Low Data Rate Missions for One Orbit

Table 6-10. Coorbiting Platform Mission Data Requirements Summary

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Peak Data Rate (Mbps)	1	1	1	1	1	1	1	1	1	1
Scheduled Data Rate (Ref 15) (Mbps)	1	1	1	1	1	1	1	1	1	1
Avg Data Rate (Mbps)	1	1	1	1	1	1	1	1	1	1
Onboard Storage (Gbits)	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Peak Command Rate (kbps)	10	10	10	10	10	10	10	10	10	10
Average Command Rate (kbps)	0.625[1*]	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625

1. Based on Space Station Relay of All COP Data Once per Orbit

Table 6-11. Polar Platform 1 Mission Data Requirements Summary

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Peak Data Rate (Mbps)	393	393	393	393	395	395	393	669	669	669
Scheduled Data[1] Rate, Low Rate Missions (Mbps) (Ref 15)	28.4	28.4	28.4	28.4	30.7	30.7	28.4	28.4	28.4	28.4
Average Data Rate[2] (Mbps)	79.6	79.6	79.6	79.6	80.9	80.9	79.6	154.4	154.4	154.4
Onboard Storage (Gbits)[3]	347	347	347	347	353	353	347	450	450	450
Peak Command Rate (kbps)	4.6	4.6	4.6	4.6	24.6	24.6	4.6	5.6	5.6	5.6
Average Command Rate (kbps)	0.05	0.05	0.05	0.05	0.21	0.21	0.05	0.05	0.05	0.05

1. Contains Missions With Data Rates Less Than 200 Mbps, Uses a 1.8 Schedule Factor for Missions Below 50 Mbps
2. Rate for Missions Without 1.8 Schedule Factor
3. Assumes Bent Pipe Relay of Missions Over 200 Mbps, Except Exclusion Zone, Twice per Orbit Downlink of Remainder

data rates to the payloads are the sum of the command rates to each individual payload. Voice and live TV channel time also represent the summation of requirements for individual payloads on the Space Station.

An aggregate allocation for voice, video, and core data is required to complete the downlink data rates. MDAC has used an allocation based on the following assumptions:

- An initial combined voice/video allocation is made to the Space Station and payloads providing one high rate channel of video at 25

Table 6-12. Polar Platform 2 Mission Data Requirements Summary

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Peak Data Rate (Mbps)	300	300	302	302	302	302	302	302	302	302
Scheduled Data[1] Rate, Low Rate Missions (Mbps) (Ref 15)	0.1	0.1	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Average Data Rate[2] (Mbps)	16.3	16.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3
Onboard Storage (Gbits)	108.2	108.2	118.3	118.3	118.3	118.3	118.3	118.3	118.3	118.3
Peak Command Rate (kbps)	6.1	6.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1
Average Command Rate (kbps)	0.36	0.36	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41

1. Contains Missions With Data Rates Less Than 200 Mbps, Uses a 1.8 Schedule Factor for Missions Below 50 Mbps
2. Rate for Missions Without 1.8 Schedule Factor
3. Assumes Bent Pipe Relay of Missions Over 200 Mbps, Except Exclusion Zone, Twice per Orbit Downlink of Remainder

Table 6-13. Polar Platform 3 Mission Data Requirements Summary

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Peak Data Rate (Mbps)					0.043	0.043	0.043	76	76	76
Scheduled Data[1] Rate, Low Rate Missions (Mbps) (Ref 15)					0.034	0.034	0.034	41.2	41.2	41.2
Average Data Rate[2] (Mbps)					0.019	0.019	0.019	41.2	41.2	41.2
Onboard Storage (Gbits)[3]					0.09	0.09	0.09	103	103	103
Peak Command Rate (kbps)					3	3	3	4	4	4
Average Command Rate (kbps)					0.02	0.02	0.02	0.03	0.03	0.03

1. Contains Missions With Data Rates Less Than 200 Mbps, Uses a 1.8 Schedule Factor for Missions Below 50 Mbps
2. Rate for Missions Without 1.8 Schedule Factor
3. Assumes Bent Pipe Relay of Missions Over 200 Mbps, Except Exclusion Zone, Twice per Orbit Downlink of Remainder

Mbps for 6 hours per day and one low rate channel at 1.544 Mbps continuously. Since most payload and surveillance requirements can use freeze frame, it is assumed that all of the sources can be multiplexed into a single low rate channel.

- Two additional low rate channels are assumed for the growth Space Station, beginning in 1996.

- Space Station core data are assumed to be 160 Kbps for bulk downlink. An allocation of 16 Kbps is provided for real time downlink under normal operation.

- Platforms are assumed to have freeze frame surveillance video in a 150 Kbps allocation. Note that data are taken continuously, and may be monitored by an expert system which can automatically increase the data rate to full band width in the event of a sudden change in the region surveyed.

- Platforms are allocated an additional 50 Kbps for core data.

The combined audio, video and core data rates are 8.55 Mbps through 1995 and 10.30 from 1996 on. These values may be refined by later analyses, but will be used in this report to provide an allocation for data beyond payload digital data.

The aggregate ground data handling requirements for the Data Handling Center (DHC) are developed in Table 6-14, assuming that a single center will handle data for the Space Station COP and POP. The average data rates from each facility, as given in Reference 1, are shown at the top of the table. The scheduling factor of 1.8 applied to the averages is used to size the onboard storage, but tends to be levelized during the transmission and data handling steps. Therefore, the DHC rates have been redeveloped to use actual instrument averages with the 1.8 scheduling factor removed. The average DHC rates range from 32 Mbps at IOC to a peak of 242 Mbps in 1995.

There are few storage duration requirements given in Reference 2:

1) Online storage of customer data for 12 hours.

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Table 6-14. SSIS/SSDS Data Handling Rates and Storage Capacities

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
SS Data Rate (Avg)	2.4	2.4	6.3	6.4	55.0	55.7	38.1	38.1	35.6	35.6
COP Data Rate (Avg)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
POP 1	79.6	79.6	79.6	79.6	82.9	82.9	79.6	154.4	154.4	154.4
POP 2 Data Rate (Avg)	16.3	16.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3
POP 3	—	—	—	—	0.02	0.02	0.02	41.2	41.2	41.2
Audio, Video and Core Data Allocation (Mbps)	8.6	8.6	8.6	8.6	10.3	10.3	10.3	10.3	10.3	10.3
Combined Long-Term Average Data Rate SS + COP + POP 1, 2, 3 (Mbps)	108	108	114	114	166	166	147	263	261	261
12-Hour On-Line Storage Capacity (10^{12} bits)	4.7	4.7	4.9	4.9	7.2	7.2	6.4	11.4	11.3	11.3
1-week Short-Term Archive Capacity (10^{12} bits)	65	65	69	69	100	100	89	159	158	158
2-year Long-Term Archive Capacity (10^{15} bits)	6.8	6.8	7.2	7.2	10.4	10.4	9.3	16.6	16.4	16.4

2) Rapid recall storage for up to one week, pending verification of receipt of each data set by the customer.

3) Short term archival storage maintained for one week after verification of acceptable data quality by the customer.

4) Long term archiving for up to 2 years.

There is a potential for the short term archive to be open ended in duration. If the data quality check by the customer is immediate, durations 2 and 3 are the same. Table 6-14 indicates the total storage requirements for customer data storage capacity to meet each of these three storage requirements.

Reference 13 indicates that the science requirements for the two high rate instruments on the POP (HRIS and SAR) may be met with a lower average data rate than indicated in Table 6-14. It will therefore be assumed that:

1) The equivalent of a single TDRS KSA channel can support the combined bulk data transmission requirements of the Space Station, COP, and POP.

2) The transmissions can be scheduled such that no simultaneous transmission is required.

Section 7
TASK MAINTENANCE

The functional and performance requirements for the SSIS and the SSDS are based on mission definitions, customer requirements, operational requirements, and system configuration plans and assumptions. These requirements, plans, and assumptions are continually evolving as the total Space Station program moves forward. As part of the ongoing SSDS Analysis/Architecture Study the requirements defined in this study will be updated to reflect overall program evolution as well as reflect inputs from government reviews and to meet specific requirements definition needs of later tasks in the study contract. A specific study task (Task 6) has been defined to manage the maintenance of this requirements task product and other study products.

The management of requirements updating will be facilitated by our electronic data base system. Requirement changes can be entered at a terminal and will be immediately available to NASA and to the study team by electronic access means. This ability to easily modify the requirements set must be tempered by the need to keep the requirements relatively stable during the critical phases of other study tasks, such as the system definition tasks.

Our plans for managing and implementing requirements updates is to (1) accumulate a list of external changes and customer comments that potentially cause changes to the SSDS requirements, (2) assess each of these changes and comments for impact and timeliness, (3) coördinate the need for a requirements change and its timing with the NASA Technical Officer, (4) develop the revised requirements, and (5) update the requirements data base. Requirements data base changes will be made in blocks to provide a degree of stability. As a minimum, major requirements updates will be included in the study iterations that are planned for month 19 and month 24 of the study. It is anticipated that several earlier requirements updates will be made to support the trade study and system definition tasks.

Section 8
CONCLUSIONS AND RECOMMENDATIONS

Conclusions resulting from the Task 1 analyses and generation of SSIS/SSDS requirements include:

1) An end-to-end, overall SSIS concept has been defined. This concept includes identification of all SSIS elements and their interrelationship. The major SSIS elements are:

   - Orbital elements interfacing with the Space Station for communications, traffic control and on orbit servicing (COP, Free-Flyers)

   - Orbital elements sharing ground facilities and services (POP, high altitude COP)

   - Space Station core systems and payloads

   - Communications links (TDRSS, DOMSAT, other satellite and ground links, DSN, Network Control)

   - Data handling and distribution elements

   - Customer support elements providing POCC, archival and data processing services

   - Customer facilities

   - Space Station ground elements (Space Station Control Center, platform control centers, other vehicle control centers, Space Station archives, and development, integration, and training elements).

2) Clear boundaries were defined for the SSDS and the SSIS. These boundaries were codified in a set of criteria that will allow continued, consistent evaluation at lower levels. The boundaries identify elements in the SSIS, and divide SSIS functions among SSDS, TMIS, and SSIS Standard Customer Services. Principal boundary elements interfacing with the SSDS include:

- Customers interface with the SSDS at a point(s) where data are delivered to the customer's designated end point as raw data with level 0 processing and where commands and data are entered by the customer

- Payload physical interfaces generally coincide with their SSDS interfaces. Exceptions may exist where the SSDS provides on orbit data processing support for the payloads

- Space Station core systems interface at the sensors and effectors, or at embedded, dedicated subsystem processors

- Multiprogram or institutional services, such as TDRSS, may interface with either the SSDS or the SSIS

- Services in the SSIS, such as data archiving and customer data processing support, as well as TMIS interface with the SSDS to transfer information

3) The functioning of the SSIS was defined through Structured Systems Analysis. Major end-to-end data paths for command management and customer data delivery were defined in more detail.

4) SSIS operating concepts were defined for both the total life cycle of customer involvement, and for the tasks performed by ground and onboard operations.

5) The team was able to develop a complete set of SSIS and SSDS functional requirements. The functional requirements are adequate to support Tasks 2 through 5.

6) The primary SSDS design drivers identified are:

- Aggregate average data rates for the Space Station, COP and POP and their payloads approach 300 Mbps. It will be difficult to schedule transmissions using only one TDRSS KSA channel at a time. In addition, ground data handling and relay facilities must be designed to meet a nearly continuous 300 Mbps data rate.

- There are at least four points where data storage amounts and rates will drive system design:

  - onboard storage on the Space Station (0.5×10^{12} bits) and POP (10^{12} bits)
  - online, 12 hour storage on the ground (10^{13} bits)
  - short term (1 week) archival storage (10^{14} to 10^{15} bits)
  - two year archival storage (10^{16} bits).

- The total video requirements of 54 hours per day peak in 1996 will tax the communications channels. Frame rates should be minimized, and expert systems utilized to compress the video to a single equivalent, part time channel.

- System transparency and user friendliness for customers will drive some design concepts and most customer interfaces with the system.

- Planning and scheduling is a major design driver for all multiple customer systems. The scheduling function must be automated to the degree that customers and onboard crew may interactively develop schedules.

- Development, integration, and training is also a major design driver. The Space Station will grow and evolve throughout its indefinite lifetime, and new customers and payloads will join the program. The Space Station and customers will require continuing support for software development, hardware and software integration, system test, and training for both ground and onboard operators.

- The level of physical distribution of functions, both geographic and local, will drive the selection of networking concepts. Physical distribution must be designed to enhance developmental and operational autonomy, especially to facilitate the anticipated Space Station growth and evolution.

- Processing and interpreting payload data, while not an SSDS function, will require a major expansion of current capability.

Recommendations from Task 1 include:

1) Structured system analysis has proved to be a very useful tool for developing system concepts and functions. This approach should continue to be used for the design of the SSDS preliminary.

2) The concepts from Task 1 should be presented to potential Space Station customers for comment and feedback.

3) The Mission Requirements data base should be extended and refined to provide more definitive requirements, such as:

   - Live TV frame rates

   - Remote, real-time, interactive operating time

   - Ancillary data requirements

   - Data delivery time, performance, and form requirements.

4) A special emphasis study is needed to identify and characterize customer classes and to develop operating concepts and requirements for each customer class.

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DICTIONARY OF ACRONYMS AND TERMS

CMS	Customer Mission Specialist
COP	Co-orbiting Platform
CPU	Central Processor Unit
DFD	Data Flow Diagram
DHC	Data Handling Center
DMS	Data Management System (see Definition)
DSN	Deep Space Network
ECLSS	Environmental Control and Life Support System
EMU	Extravehicular Mobility Unit (Space Suit)
EVA	Extravehicular Activity
GPS	Global Positioning System
GSE	Ground Support Equipment (used especially here to refer to integration test support)
ICD	Interface Control Document
IOC	Initial Operating Capability
IVA	Intravehicular Activity
KSA	Ku-band, Single Access
MA	Multiple Access (S-band)
MDAC	McDonnell Douglas Astronautics Company
MMU	Manned Maneuvering Unit
MPAC	Multipurpose Applications Console
MRWG	Mission Requirements Working Group
NSTS	National Space Transportation System
OMV	Orbital Maneuvering Vehicle (formerly TMS)
ORU	Orbital Replaceable Unit
OTV	Orbit Transfer Vehicle
POCC	Payload Operations Control Center
POP	Polar Orbiting Platform
RDC	Regional Data Center
RMS	Remote Manipulator System
R/T	Real-Time
SDE	Software Development Environment
SPC	Stored Program Commands
SS	Space Station
SSA	S-band, Single Access
SSCC	Space Station Control Center
SSDS	Space Station Data System
SSIS	Space Station Information System
SSP	Space Station Program
SSPE	Space Station Program Element
TDAS	Tracking and Data Acquisition Satellite
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TMIS	Technical and Management Information System

DEFINITIONS

Level 0 Data Processing - Raw data with reconstructed sensor formats, time ordering, full resolution, and ancillary data.

Level 1A Data Processing - Reversibly calibrated in physical units (level 0 can be reconstructed).

Level 1B Data Processing - Irreversibly calibrated in physical units.

Constellation - Spacecraft in the same orbit and within communications range of the Space Station.

Core - That portion of the Space Station system which maintains the environment in which the customer operates.

Customer - Individual/organization with Space Station payload responsibility; cradle to grave.

Data Management System (DMS) - Onboard system that provides the processing, storage, and handling of digital data.

Function - A single duty which is implemented, controlled, sensed, computed, monitored, or aided by electronic devices.

Operator - NASA or contractor personnel who manage, coordinate and affect Space Station program operations and assist customers in accomplishing mission objectives.

User - Any person or organization who requires the transitory use of the services provided by the Space Station and who is authorized to use those services.

Data Privacy - Limited access to information to some level short of a complete guarantee of security.

Security - The protection of resources from damages and the protection of data against accidental or intentional disclosure to unauthorized persons or unauthorized modification or destruction.